13

Love and the Social Bond

The Sources of Nurturance and Maternal Behavior

Love comes quietly . . .
but you know when it is there,
because, suddenly . . .
you are not alone any more . . .
and there is no sadness
inside you.

J. W. Anglund, "Love Is a Special Way of Feeling" (1960)

CENTRAL THEME

Although there are many bad forms of parenting, there are also good and nurturant forms. An age-old concern of pregnant women is the doubt they feel about their ability to nurture and love their first baby. However, nature tends to spontaneously take care of such concerns, at least in lower animals, as the sequence of biological events leading up to the delivery of the baby unfolds. The ongoing physiological changes that prepare the body for birth also prepare the mother's brain for nurturance. In most animals this includes her role as the primary caregiver. Males can be trained to exhibit a high level of nurturance, but their care is rarely as natural or as intense a motive as it is for the mother. Only in species where male participation is absolutely essential for offspring survival, as in some birds and perhaps in humans, where the child is helpless for longer than any other animal, can nurturant behavior be as vigorous in males as it is in females. On the other hand, in many species of fish where external fertilization is the norm, the fathers typically remain to tend and protect the eggs while females depart to entice another receptive male. Nurturance may have emerged independently several times in the evolution of different species, but in mammals the basic urge probably comes from homologous brain circuits, even though the specific behaviors that constitute parenting can vary markedly from species to species. Humans obviously exhibit more behavioral complexity in child care endeavors than other species, but our behavior is still motivated, in part, by primitive emotional systems we share with the other mammals.

When did nurturant motivation emerge in mammalian brain evolution? Momentous evolutionary changes must have occurred when animals with an urge to take care of their offspring emerged on the face of the earth. Presumably this was achieved because parental care provided a decisive competitive edge for the survival of certain species. But how could nurturance have evolved from a state of nonnurturance? We cannot go back in evolutionary history, but we know that part of the script was written with the same ancient chemistries that generate sexual urges. In mammals, brain oxytocin circuits lie at the neural core of the incipient maternal intent that follows the first birth. As we saw in the previous chapter, this chemistry is important for regulating both male and female sexuality. The nurturant circuits in the mother's brain and care-soliciting circuits in infants are closely intermeshed with those that control sexuality in limbic areas of the brain. This confluence lends modest support to controversial and widely debated Freudian notions of infantile sexuality and the possible relations between maternal love and female sexuality. Nurturance circuits can lead to the rapid learning of maternal behaviors, which then become permanent parts of a mother's behavioral repertoire. Males can also learn nurturant behaviors, and it is intriguing that sexual activity can strengthen anti-aggressive, caregiving substrates in male brains. We are finally deciphering the ancient neurosymbolic processes that first led to nurturance and social attachments in the mammalian brain. This work has important implications for the biological sources of friendship and love, as well as for sociopathy and psychiatric disturbances of affective contact such as autism. Although as yet there is little information about the operation of these systems in the human brain, our understanding of these issues in the animal brain is impressive. In this chapter, I will again entertain the working assumption that the information obtained from animals will apply reasonably well to understanding basic emotional tendencies in humans. Of course, the emotional feelings that accompany nurturance are subtle, warm, and soft, and in the complex, cortically mediated politics of human societies, such social feelings can easily be overridden by other concerns. Also, in humans, where child care is accompanied by various unpleasant chores like changing diapers, it is sometimes difficult to view the emotional pleasures of nurturance with a completely unjaundiced eye.

An Overview of Human Nurturance

Human societies have seen many forms of parenting down through the ages. At present, we live in a child-oriented era, whereas in many previous ages, child care was more harsh, producing emotional harm that may have had untold effects on the course of human history. As Robert Burton wrote in his classic, *The Anatomy of Melancholy*: "If a man escape a bad nurse, he may be undone by evil bringing up. . . . Parents . . . offend many times in that they are too stern, always threatening, chiding, brawling, whipping, or striking; by means of which their poor children are so disheartened and cowed, that they never after have . . . a merry hour in their lives."[1] It is generally believed that harsh early experiences can modify emotional traits for a lifetime. Could the many wars and other human tragedies caused by the megalomaniac tendencies of certain individuals and groups throughout history have been avoided if the leaders had been more warmly parented as children?

Parenting styles still vary enormously from culture to culture, depending on existing traditions and ecological necessities confronted by various societies. For instance, not too long ago in certain arctic aboriginal groups, such as the Netsilik Eskimo of northern Canada, long-term social concerns often overrode short-term emotional ones. Female babies who had little hope of finding an appropriate mate, because no male babies of comparable age had been born in the tribe, would be left to die in the snow, with little outward distress or remorse exhibited by the parents.[2] In our culture, such behavior is deemed criminal. This indicates once again that among humans, biology is not necessarily destiny, because we have the ability to make cognitive choices.

For humans, the rearing of a child is as much an economic question as an emotional one, and economic concerns often prevail. Antecedents of this are evident even in some lower species, where mothers kill some of their weaker pups. When environmental resources are scarce, this practice can increase the probability of success for the surviving offspring. Thus, the amount of investment made in offspring is only partly an emotional issue. This is one of the reasons there is so much confusion and variety in child care practices, in human cultures as well as across species.

While we presently accept a long period of childhood dependence, certain African tribes have encouraged levels of early independence unheard of in our culture. In the Digo tribe of East Africa, most babies are toilet trained by 1 year of age, and soon thereafter they are encouraged to behave as relatively independent members of their tightly knit, extended-family group. In our nuclear-family culture, parents of 1-year-olds are just beginning to think about toilet training. Much older children are still closely supervised and are afforded little opportunity for independent action within the larger community. Obviously, Digo types of nurturance can occur only in social situations where the whole village cares for children. As the African proverb says: It only takes one woman to bear a child, but it takes a whole village to raise it.[3]

The variety of parenting in other species is also vast, ranging from frequent, highly attentive parenting, as in rats, which feed their offspring every few hours and exhibit intense search and retrieval behaviors if infants are lost or dispersed, to very brief and infrequent parenting, as in rabbits, which feed their sequestered litters only once a day and seem not to possess the motivational or neurobehavioral equipment to retrieve little bunnies that are dispersed from the nest.

It is widely believed in our culture that children who come from loving and supportive families, and who are given progressive age-appropriate educational challenges, have the best chance of growing to a vigorous and independent adulthood. Put another way, many experts agree that a "secure base" is essential for optimal personality development in children.[4] Chronic insecurity is likely to yield adults who have difficulties with intimacy and trust and are more likely to act out their lack of confidence by burdening others with their insecurities. But what is the nature of this loving and supportive "secure base" that psychologists speak of? Obviously, it is partly a matter of how parents behave toward their children, but it also runs deeper into our affective nature as biological creatures.

The Physiology of Nurturant Behavior

Although child-rearing practices vary greatly, the emotional dimensions of social bonds are probably controlled by highly conserved biological processes that guide expressions of both parental and infantile behavior and the consequent feelings that parents and children develop for each other. Before the birth of their first child, women commonly worry about their future adequacy as mothers, but such doubts typically vanish, as if by magic, soon after the birth of the baby.

Recent brain investigations suggest that social bonding is rooted in various brain chemistries that are normally activated by friendly and supportive forms of social interaction. As will be elaborated in this and the ensuing two chapters, such urges are controlled by neuropeptides such as oxytocin and prolactin, as well as endogenous opioids such as endorphins (*endo-* meaning produced inside the body rather than coming from outside, and *-orphins* meaning like morphine).[5] For instance, opioids mimic the action of heroin in the brain and have powerful influences over our feelings, especially our negative responses to social isolation. Animal research indicates that both brain opioid and oxytocin circuits are activated by various pleasurable pro-social activities, such as grooming, play, and sexual interchange. Accordingly, such neurochemical changes in the brain may promote feelings of security in children, as well as nurturant and sexual behaviors and related social emotions, perhaps even love, in adults.

Of course, because of our cognitive abilities, humans begin to prepare for the baby months before its arrival, but there still seems to be a special time just preceding delivery where strong biologically based motivations take hold. This is probably because of the many hormonal changes, such as those summarized in Figure 13.1, that herald birth. Although such data are from the rat, the general patterns are quite similar across all mammals, and these changes, artificially produced, are known to promote nurturance.[6] In other words, evolution has not left the important events of birthing and the ensuing nurturance and bonding either to chance or to the vagaries of individual learning.

All mammals have neuronal operating systems that evolved to help prepare them to take care of infants, even though some, such as the Netsilik mentioned previously, do not exercise the option of warm social acceptance in circumstances they believe compromise the long-term stability of their culture. Presumably the Netsilik, as well as other parents who abandon their infants, do so before the bonding process has progressed too far. Some species, such as rats and humans, have a bonding window that remains open for a long time, while for others, including herbivores such as sheep and many avian species, the entry window is closed within a few hours of birth. This variability appears to reflect the motoric maturity of the young when they are born. Prey species are typically born rather mobile, so they can run away from predatory dangers soon after birth. They also tend to live in herds where the young can easily get separated from parents. Thus, out of sheer necessity, mothers and infants must bond rapidly. Predators, on the other hand, are typically born relatively immature, and the bonding process, at least from viewpoint of the offspring, can be extended across longer periods without compromising their chances of survival.

Some animals, such as infant rats, bond as much to their nest sites as to their mothers.[7] Likewise, rat mothers readily accept strange pups into their nests and begin to provide care without much fussing or aggression. Sheep and other ungulates, on the other hand, will re-

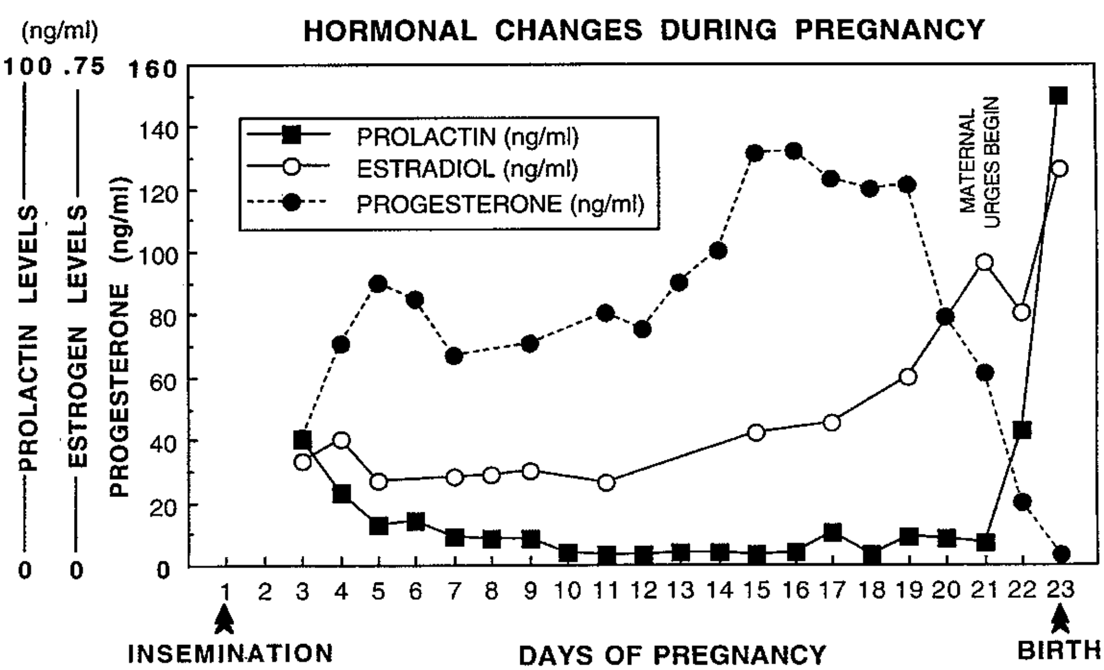

Figure 13.1. Circulating levels of progesterone, estradiol, and prolactin during pregnancy in the rat. (Adapted from Rosenblatt, 1990; see n. 6).

ject others' young. Despite these outward differences among species, it presently seems likely that their bonding chemistries are quite similar. They simply operate in different time frames and within different ecological constraints. These fascinating species differences shall receive little additional attention here, for my aim will be to summarize underlying physiological principles that may have substantial cross-species generality, extending hopefully even to the human level.

We now know a great deal about the nurturance systems of the mammalian brain, and this chapter covers some recent information that now needs to be integrated into modern psychological thought. Some remarkable neurochemical systems, which promote both sexual and maternal behaviors and even more subtle social processes, have been revealed within the subcortical reaches of the visceral nervous system, including areas like the cingulate cortex, septal area, bed nucleus of the stria terminalis, and preoptic and medial areas of the hypothalamus, along with their respective mesencephalic projection areas. At present, brain oxytocin, opioids, and prolactin systems appear to be the key participants in these subtle feelings that we humans call acceptance, nurturance, and love—the feelings of social solidarity and warmth.[8] Although many human interactions and cognitive experiences also contribute to maternal states, without the underlying mood- and behavior-altering neuropeptides, those experiences would probably remain shallow and without emotional intensity.

When humans have imbalances in these chemical systems, they experience emotional problems, which, if sufficiently severe, can be deemed psychiatrically significant bonding disorders. For instance, postpartum depression and psychosis, which have been correlated with high levels of a circulating ß-casomorphin (an opioid peptide derived from milk), are not uncommon in humans.[9] Perhaps tendencies toward sociopathy, characterized by the inability to share the emotions of others, are also accompanied by abnormalities in these social chemistries. The same may apply to psychiatric conditions characterized by social and emotional deficiencies, such as early childhood autism.[10] Both of these problems are much more common in males than in females, suggesting striking gender-related differences in the underlying brain circuits. Unfortunately, our understanding of these systems in the human brain is meager, but knowledge concerning such systems in animal models is growing rapidly.

Sex Differences in Nurturance Circuits

I use the term CARE circuits to acknowledge the existence of intrinsic brain systems that promote nurturant behaviors of mothers, and occasionally fathers, toward their offspring. In rats, full maternal behavior consists of building nests, gathering all dispersed pups together, hovering over them to provide warmth, and, in the presence of lactation, sustaining pups through nursing. In most species, mothers are more adept at these behaviors than fathers, presumably because of the more vigorous CARE systems in their brains, but this is not to suggest that males cannot exhibit nurturance. As we will see, even male rats, especially if they are young, will exhibit maternal-type care under the right conditions.

Obviously, humans, contrary to most other animals, can consciously appreciate the importance of child care, but despite such cognitive assistance, fathers probably provide child care more instrumentally than mothers. Mothers are more prone to get intensely involved with babies than fathers, and they exhibit a more natural persistence, warmth, and desire to communicate affectively with the baby. They typically get more concerned when babies are in distress; this is also evident in animals.[11]

Thus, the biggest differences in human nurturance probably exist at the emotional level—with most mothers generally having stronger and more positive emotional responses in nurturant situations than fathers. Of course, there are bound to be exceptions to this rule, depending upon one's early brain organization (see previous chapter), early rearing experiences, prevailing cultural rules, and individual philosophical perspectives. However, because of evident sex differences at the biological level, I will occasionally call nurturant CARE circuits maternal behavior circuits, in the context of the present discussion.

Because of our ability to conceptualize social rules, human mothers and fathers can care for a child equally well, but only a mother can provide sustenance from her breasts. She is also more likely to offer affective engagement from emotional depths unfamiliar to most men. We now know that among all mammals that have been closely studied, the female brain is more prepared than the typical male brain to care for infants. Indeed, it may have been the evolution of the maternal circuits that initially led creatures down the mammalian path that now makes us humans the sophisticated social creatures that we are. Not surprisingly, if we dwell on the matter, maternal urges probably emerged (i.e., were *exaptations*) from a subset of subcortical systems that initially governed female sexual urges. It would also have been reasonable to couple parental emotions to the preexisting psychobehavioral systems that encourage individuals to come together for mating. Thus, maternal nurturance and social bonding may have emerged from evolutionary tinkering with preexisting processes, rather than through totally new forms of brain "engineering." As François Jacob, the Nobel Prize–winning molecular biologist, put it: "Natural selection . . . works like a tinkerer . . . who does not know exactly what he is going to produce but uses whatever he finds around him . . . to produce some kind of workable object. . . . Evolution makes a wing from a leg or a part of an ear from a piece of jaw. . . . Natural selection . . . does not produce novelties from scratch. It works on what already exists."[12]

This is the essential meaning of an *exaptation*—the utilization of an existing function for some other purpose. Indeed, modern neuroscience highlights the possibility that the neural dictates of the sexually passionate parts of the limbic system set the stage for parental nurturance. The evolution of such systems also led females to be especially sensitive and responsive to calls of distress from infants (see Chapter 14) and to interact with them more intimately, and probably more playfully, throughout childhood (see Chapter 15).

Although we have no firm data for humans, on the assumption that similar neural dictates still govern our deepest social feelings, I will devote the next two chapters to a detailed discussion of the relevant animal brain issues. Because of the reciprocity between maternal behavior and infant need systems, and the importance of these systems for understanding normal human behavior and its pathologies, there will be some overlap of materials. The premise will be that when we nurture our children well, they have a secure base because their brain chemicals evoke the comfortable feeling that "everything is all right." When children are neglected, other chemical patterns prevail in their brains. The latter patterns do not promote confidence and social efficacy but rather motivate behaviors based on persistent feelings of resentment and emotional distress. If these feelings prevail for too long, depression emerges, personality changes may occur, and the most sensitive individuals may be psychologically scarred for life.[13]

Let us first pause to consider how the new forms of mammalian social behavior could have emerged from preexisting solutions in the brains of ancestral vertebrates that did not care for their offspring. After all, parental care evolved from a mode of life that was nonparental, a mode that still predominates in the reptilian world. Most reptiles produce their young and leave them to fend for themselves. Although a number of species—for instance, crocodiles—do exhibit some parental care, it is meager by mammalian standards. If we simply consider that all infants enter the world through a well-regulated birth process, it would be reasonable to suppose that the initial impulse for nurturance might have been closely linked to the biological mechanisms that already existed to deliver the young into the world. Indeed, as we shall see, nurturance probably initially arose from neurochemical processes that controlled mating and egg laying in reptiles.

The Evolutionary and Sexual Sources of Maternal Intent: Pituitary Peptides and Parental Behavior

As mentioned in the previous chapter, vasotocin is an ancient brain molecule that controls sexual urges in reptiles. This same molecule, the precursor of mammalian oxytocin, also helps deliver reptilian young into the world. When a sea turtle, after thousands of miles of migration, lands on its ancestral beach and begins to dig its nest, an ancient birthing system comes into action.[14] The hormone vasotocin is secreted from the posterior pituitary to facilitate the delivery of the young. Vasotocin levels in the mother turtle's blood begin to increase as she lands on the beach, rise further as she digs a pit large enough to receive scores of eggs, and reach even higher levels as she deposits one egg after the other. With her labors finished, she covers the eggs, while circulating vasotocin diminishes to insignificant levels (Figure 13.2). Her maternal responsibilities fulfilled, she departs on another long sea journey. Weeks later, the newly hatched turtles enter the world and scurry independently to the sea without the watchful, caring eyes of mother to guide or protect them.

In mammals, the ancient molecules that control reptilian sexuality and egg laying evolved into the oxytocin and arginine-vasopressin (AVP) social circuits of the brain (see Figures 6.7 and 12.2). As discussed in the previous chapter, oxytocin came to prevail in female sexual behavior, and AVP prevails in that of males. Now we also know that oxytocin—the hormone that helps deliver mammalian babies by promoting uterine contractions and helps feed them by triggering milk letdown from mammary tissues—also serves to facilitate maternal moods and related action tendencies in the brains of new mothers. However, these psychobehavioral effects can emerge only if a variety of physiological and hormonal changes related to parturition have first occurred in the brain and body of the mother.

The initial clue that there is an intrinsic bodily signal to promote maternal behavior was the fact that transfusion of blood from a female rat that had just given birth could instigate maternal behaviors in a virgin female.[15] It is not yet known exactly what the blood-borne signals are, since oxytocin alone cannot perform this function. It may be the full symphony of hormonal changes that precede birth. As summarized in Figure 13.1, estrogen, which has remained at modest levels throughout pregnancy, rapidly increases as parturition nears. Progesterone, which has been high throughout pregnancy, begins to plummet. And, of course, there is a precipitous rise in prolactin, which induces the mother's acinar glandular tissues to manufacture milk.

These hormonal changes heralding imminent birth also prepare the mother to exhibit maternal urges before the actual arrival of the infant(s). Human mothers commonly exhibit a compulsive flurry of house preparation several days before the baby is due, and rat mothers begin to build nests and become substantially more eager to interact with baby rats. Such tendencies are common in many species and are especially clear if the mother has given birth before. This heightened maternal desire corresponds to the peak of the three previously mentioned hormonal changes, reaching an apex several hours before birth in rats. As mentioned earlier, if one produces this pattern of hormone change via injection, one can also instigate expressions of maternal

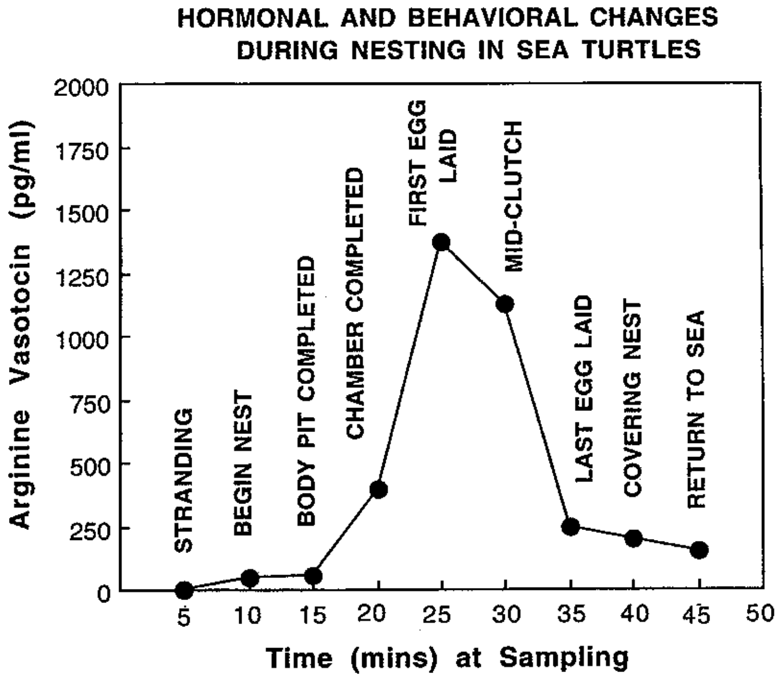

Figure 13.2. Mean serum vasotocin levels in loggerheads and ridley olive sea turtles. (Adapted from Figler et al., 1989; see n. 14.)

care in virgin rats.[16] Prolactin may be the critical ingredient in sustaining the natural behavior sequence, not only because brain injections of prolactin promote nurturance,[17] but females who are nonmaternal because they have been surgically deprived of their pituitary glands do gradually become maternal when replacement injections of prolactin are provided.[18] But what are the relevant changes in the brain that result from these hormonal manipulations?

Although many neural changes result from such peripheral hormonal fluctuations, the increased responsivity and sensitivity of brain oxytocin circuits is a major event. During the last few days of pregnancy and the first few days of lactation, there are remarkable increases in oxytocin receptors in several brain areas, as well as increases in the number of hypothalamic neurons that begin to manufacture this neuropeptide. Both of these effects are controlled by the elevations of estrogen at the end of pregnancy, and the induction occurs in circuits that promote nurturance.[19] These estrogenic effects on the genetic expression of oxytocin synthesis and receptor expression may be further reinforced by the stimulating effects of the newborn pups, as well as other hormonal shifts in the body.

These changes are accompanied by additional adjustments in oxytocin circuitry. During lactation, oxytocin cells begin to communicate with each other directly via the development of *gap junctions* between adjacent oxytocinergic neurons, allowing them to synchronize their neural messages precisely.[20] This helps suckling stimuli from nursing babies to more effectively trigger oxytocin secretion in the brain of the mother, presumably to sustain a maternal mood, as well as release from the pituitary gland, which is essential for milk to be released from the breasts (Figure 13.3).[21]

Brain Oxytocin and Maternal Competence

A critical question is whether and to what extent these brain changes do, in fact, mediate the affective and behavioral components of maternal urges. For a long time it was believed that oxytocin was not essential for mothering, since elimination of peripheral oxytocin (by removing the posterior pituitary in nursing mothers) did not eliminate subsequent maternal behavior.[22] It was only when distinct oxytocinergic neural systems were discovered in the brain (see Chapter 6) that a role for oxytocin was entertained once more. Most of the pertinent work to date has been done in rats and sheep, and hence substantive conclusions must be restricted to those species; but considering the ways of evolution, the probability that the results do not apply to others, including humans, is remote.

The initial studies that evaluated the ability of oxytocin to mediate maternal behavior found strikingly rapid onset of maternal tendencies in female rats when this peptide was administered directly into the brain's ventricular system.[23] Similar effects were obtained in sheep.[24] However, the evidence rapidly became confusing and contradictory. While a few investigators were

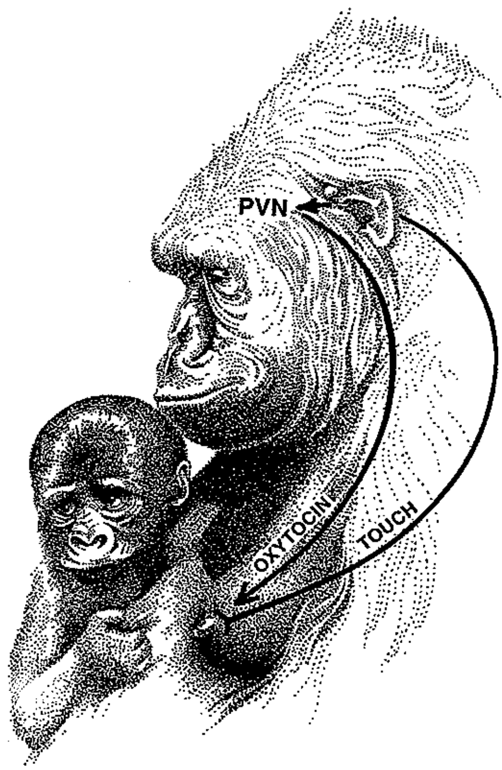

Figure 13.3. Depiction of suckling reflex. The infant's suckling stimulation of the nipple sends messages to the paraventricular nucleus of the hypothalamus (PVN), which instigates the release of oxytocin from the posterior pituitary into the circulation, leading to the contraction of smooth muscles of mammary tissues, which pumps milk from the breast. This reflex becomes easily conditioned to various behavioral cues from the infant.

able to trigger full maternal behavior (nest building, retrieving, and attempts to nurse) in virgin female rats, others had no success.[25] Such failures to replicate were very troublesome, but more recent work has revealed that many of the problems were methodological.

Normally, virgin female rats tend to find the odors of newborn pups aversive, perhaps to dissuade them from wasting time interacting with strange babies.[26] Thus, even if such animals were in a maternal mood, they might not exhibit nurturant behaviors if the aversion outweighs the maternal urges. Oxytocin alone is apparently not able to overcome this olfactory "disgust," even though the complex of physiological changes that accompany birth accomplishes that quite well—changing the olfactory aversion to an attraction.[27] In other words, oxytocin triggers rapid maternal behavior in virgin female rats only if they are first prevented from smelling the pups.[28]

In addition, to get a robust maternal effect from oxytocin infusions into the brain, virgin females need to be primed with injections of estrogen so that the appropriate oxytocinergic receptor fields have a chance to proliferate (natural mothers, of course, provide their own estrogen, as described earlier). Finally, and quite perplexingly, oxytocin is effective only if animals have been habituated to test chambers for a few hours but not if they have been fully habituated for a day or more.[29] This may mean that if animals already have a reasonably well-established place attachment, they have difficulty forming new social attachments. Perhaps test animals that are just becoming familiar with a situation are in a transient neuropsychological state that enhances their motivation to start a new family and to modify their environment appropriately. In any event, the likelihood that endogenous oxytocin does in fact normally promote such behavioral tendencies is affirmed by the ability of oxytocin receptor antagonists to reduce the onset of maternal behavior following the first delivery.[30] Surprisingly, this manipulation does not disrupt maternal behavior that has already been fully developed.[31]

Thus, if all the conditions are right, oxytocin administered directly into the brain can provoke maternal behavior, but it is certainly not the only ingredient that can do this. As mentioned, administration of prolactin into the brain also facilitates maternal tendencies. In fact, we now know that there are prolactin-based neural systems in the brain, and, as indicated, there is active uptake of this rather large peptide hormone into the brain from the circulation.[32]

As will be discussed more fully in the next chapter, maternal competence can also be increased by mild facilitation of opioid activity, even though high levels of opioids diminish maternal interest, as well as gregariousness in general.[33] It presently seems likely that part of the gratification derived from the primal act of nursing emerges from the concurrent release of oxytocin and opioids within the limbic system, as well as other chemistries that remain to be identified. While oxytocin may be especially important in the initial triggering of maternal behavior, prolactin, opioids, and social learning are important in sustaining it once the behavior pattern has developed.

Experience-Induced Solidification of Maternal Behavior

It should be emphasized that well-established maternal behavior no longer requires brain oxytocin arousal; oxytocin blockade impairs maternal behavior only if administered to mothers during the birth of their first litter of pups. In animals that have been allowed to exhibit maternal behavior for several days, oxytocin antagonists have no outward effect on maternal competence. In other words, they cannot block previous social learning.

The ability of several days of normal maternal experience to solidify maternal competence is also evident in studies that have focused on nurturance after lesions of one of the primary sources of brain oxytocin, the paraventricular nucleus (PVN). PVN lesions administered prior to parturition weaken subsequent maternal behavior, but those administered after several days of normal maternal functioning do not.[34] It seems that learning that transpires from the spontaneous use of this intrinsic brain operating system rapidly becomes functionally autonomous, at least in the short run. In other words, once the habit has solidified, maternal behavior can proceed independently of the original initiating processes.

Analysis of this learning mechanism deserves more experimental attention than it has yet received. Similar to the pattern seen with other emotions, a great deal of learning is probably controlled in the higher reaches of CARE circuits such as the anterior cingulate cortex and bed nucleus of the stria terminalis. It is still an open question whether ongoing brain oxytocin activity is essential for continuation of efficient maternal behavior in the long term. Although there are no relevant human data on such issues, perhaps the oxytocin secretion during each successful nursing episode continues to reinforce the affective experience of a satisfying social interaction. Temporary absence of such satisfaction (as might occur with centrally administered oxytocin antagonists) is apparently not sufficient to dissuade the mother from carrying out her maternal responsibilities, once she has established the social bond and can cognitively mediate social commitments.

However, it would come as no surprise if maternal vigor diminished gradually without the reinforcement provided by periodic oxytocin release within the brain. If that is the case, *long-term* sustained oxytocin blockade may lead to the gradual deterioration of maternal care. It might also be expected that chronic oxytocin blockade would reduce the experience-induced maternal behavior that can be normally evoked in nonmaternal animals by long-term exposure to young pups. As will be discussed later in this chapter, social experience itself, without the physiological act of parturition, is sufficient to arouse nurturant motives in virgin rats, both male and female.[35] However, the role of oxytocin in such processes remains to be evaluated empirically.

It also remains to be determined whether the absence of oxytocinergic transmission in the brain makes the maternal experience less satisfying. This could be tested by allowing mothers to nurse in one environment while their brain oxytocin systems are blocked with an appropriate receptor antagonist and in an adjacent distinct environment without blockade. At present, most investigators would predict that such animals would exhibit a place preference only for the environment in which they fully experienced their brain oxytocin systems in action, but we do not yet know that to be the case. Indeed, in our lab, we have tried repeatedly to obtain a robust conditioned place preference with centrally administered oxytocin, but we have not been successful. Oxytocin only works when supplemented with other social stimuli. By comparison, it is easy to obtain simple reward effects with opiates and psychostimulants.

In sum, it seems that maternal behavior is initially aroused by changing responsivity and synaptic sensitivity in brain oxytocin systems. This sensitivity is due, to a substantial extent, to the proliferation of oxytocin receptors, a change resembling that which occurs in the uterus just before the onset of labor.[36] In the brain, the greatest oxytocin receptor proliferation is observed in the bed nucleus of the stria terminalis (BNST); when that area is damaged, maternal behavior is severely impaired.[37] These kinds of studies are beginning to clarify the details of maternal CARE circuits in the mammalian brain.

The Neural Circuitry for Maternal Behavior

The actual brain circuits that control the various components of full maternal behavior extend far and wide in subcortical regions of the brain (Figure 13.4). Part of the circuitry descends from the preoptic area along a dorsal route through the habenula to the brain stem, and part through a hypothalamic route to ventral tegmental area (VTA) dopamine systems and beyond.[38] The VTA component may facilitate general foraging tendencies that are essential in retrieval and nest building, while the other routes may be more important in up-close nurturance and nursing. For instance, a distinct neural circuit that controls milk letdown descends from the lateral midbrain area down to segments of the spinal cord that innervate the nipples.[39]

It is especially noteworthy that neural circuitry for maternal behavior (and estrogen-responsive populations of oxytocin cells) are situated within the dorsal preoptic area (POA) just above the brain areas that elaborate male sexuality. These cells probably control nurturance in both males and females, but there are more of them in females, partly because of the inductive effect of estrogen.[40] The specific ventromedial hypothalamic zones that control female lordosis behavior (where oxytocin systems also proliferate under the influence of estrogen and progesterone) do not appear to be essential for maternal behavior. However, lesions of the BNST and the nearby POA can eliminate essentially all aspects of maternal behavior.[41] As mentioned, the relevant neural pathways exit from the POA laterally and descend in the medial forebrain bundle, with key terminals being in the VTA.[42]

It has been established that the oxytocinergic synapses that terminate on dopamine cells of the VTA do, in fact, promote maternal behavior. Oxytocin injections into the VTA can induce maternal behavior, whereas comparable injections are not effective in amygdala, septum, or POA.[43] Damage to these ascending dopam-

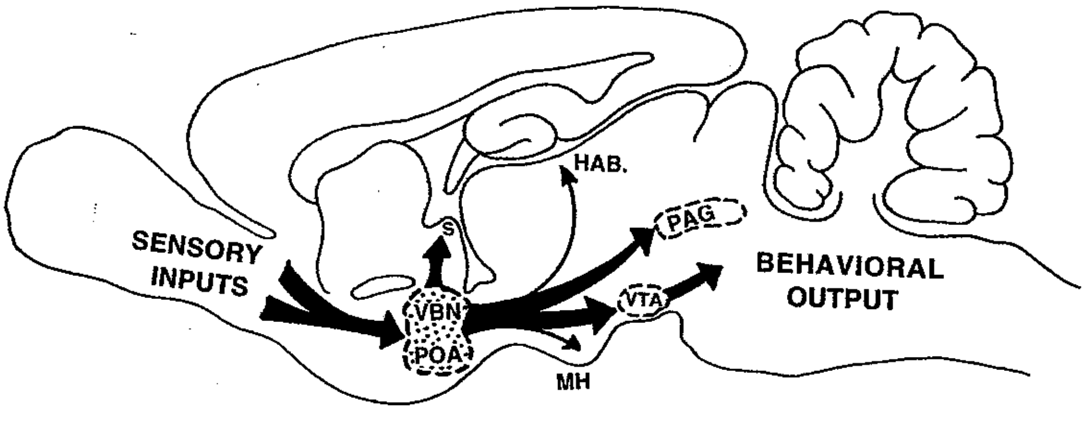

Figure 13.4. General overview of maternal behavior circuits in rodents. The central integrator is in the dorsal preoptic area (POA) and the ventral bed nucleus of the stria terminalis (VBN), which receives various sensory cues for maternal behavior and distributes controls into widespread brain areas, including the medial hypothalamus (MH), the ventral tegmental area (VTA), the periaqueductal gray (PAG), the habenula (HAB), and the septal area (S). The precise functions of these various areas remain to be identified.

ine systems can also severely impair maternal behavior, including dopamine-selective neurotoxic lesions of the VTA, as well as the lateral hypothalamic and dopamine target zones in the nucleus accumbens.[44] Of course, these forms of damage compromise many other sorts of appetitive behavior. As discussed in Chapter 8, the VTA-centered SEEKING system is a nonspecific appetitive system that can mediate many goal-directed behaviors. If this oxytocin-VTA interface is relatively nonspecific, the additional oxytocin influences, perhaps lower in the brain stem, may be essential for engaging specific motivational circuits for maternal behavior, such as sensitization of affective responses to specific forms of somatosensory stimulation such as suckling. We do not yet know where those circuits are situated, although there are some clues.[45] Alternatively, it is possible that oxytocin input to the VTA can intrinsically code a subtype of appetitive eagerness that is specifically directed toward expressions of nurturant behaviors.

To what extent are the brain circuits for social bonds coextensive with those that mediate maternal behavior? It is reasonable to suppose that the neurochemical satisfactions of giving birth and the natural urges of motherhood would prepare the brain for the formation of social attachment to the infant. However, we also need to look at the social bond from the infant's side, and the mechanisms there may be slightly different (see the next chapter for a fuller discussion of this distinction). Work on such questions is just beginning, but there appears to be a substantial overlap between the two processes, at least at the neurochemical level, even though we do not know yet exactly where in the brain the bonding process transpires. The prime neurochemical candidates at present are the endogenous opioids, oxytocin, and AVP. Neuroanatomically, the best candidate areas are the higher brain zones, where damage can disturb maternal competence: the amygdala,[46] the septal area,[47] and the cingulate cortex.[48] What these specific brain areas contribute to maternal competence will have to be solved by more sophisticated psychobiological research than has yet been conducted. We will certainly have to pay more attention to issues such as which brain mechanisms mediate social attachments, friendly interactions, gregariousness, and various social memories, in addition to specific perceptual and behavioral abilities.

Brain Systems for Social Bonds

Social bonding is of enormous psychiatric importance, for if it is inadequately established, the organism can suffer severe consequences for the rest of its life. A solid social bond appears to give the child sufficient confidence to explore the world and face a variety of life challenges as they emerge. As John Bowlby poignantly documented in a series of books,[49] a child that never had a secure base during childhood may spend the rest of its life with insecurities and emotional difficulties.

Until recently, we knew nothing about the neurochemical nature of social bonds. Even though all humans feel the personal intensity of their friendships, family attachments, and romantic relationships, there was practically no way of studying how these feelings might be constructed from specific brain activities. In the past score of years there have been several breakthroughs: the discovery that neural circuits mediating separation distress are under the control of brain opioids,[50] and, as already discussed, the developing understanding of the neurochemical basis of maternal and sexual behaviors.[51] In addition, several groups of investigators have started to decode how filial imprinting and sexual bonding are neurochemically mediated within the brain.[52] These lines of inquiry proceeded separately for some time, but they are coming together now in quite interesting ways.

The first neurochemical system that was found to exert a powerful inhibitory effect on separation distress was the brain opioid system. This provided a powerful new way to understand social attachments.[53] There are strong similarities between the dynamics of opiate addiction and social dependence (see Figure 13.5), and it is now clear that positive social interactions derive part of their pleasure from the release of opioids in the brain. For instance, the opioid systems of young animals are quite active in the midst of rough-and-tumble play, and when older animals share friendly time grooming each other, their brain opioid systems are activated (see Chapters 14 and 15). Finally, sexual gratification is due, at least in part, to opioid release within the brain.[54] From all this, it is tempting to hypothesize that one reason certain people become addicted to external opiates (i.e., alkaloids, such as morphine and heroin, that can bind to opiate receptors) is because they are able to artificially induce feelings of gratification similar to that normally achieved by the socially induced release of endogenous opioids such as endorphins and enkephalins. In doing this, individuals are able to pharmacologically induce the positive feeling of connectedness that others derive from social interactions.[55] Is it any wonder that these people even become intensely attached (classically conditioned) to the paraphernalia associated with their drug experiences, or that addicts tend to become socially isolated, except when they are approaching withdrawal and seeking more drugs? Indeed, opiate addiction in humans is most common in environments where social isolation and alienation are endemic. Investigators have been able to increase opiate consumption in experimental animals simply by separating them from companionship.[56] These social problems are more understandable in light of the fact that positive social emotions and social bonds are, to some extent, mediated by opioid-based, naturally occurring addictive processes within the brain (see Figure 13.5 and Chapter 14).

One of the methodological difficulties in studying social-bonding in mammals has been the lack of efficient laboratory models. By comparison, excellent models exist in birds. Konrad Lorenz originally described the powerful form of social learning that can occur in infancy, whereby young animals strongly "imprint" upon available social stimuli.[57] Newborn birds of species that are born relatively mature (i.e., precocious species such as chicks, ducks, and geese) will typically learn to follow the first moving object they encounter. In this way, young animals normally come to follow eagerly after their mothers, and Lorenz easily trained young greylag geese to treat him as their surrogate parent. In other words, newborn geese that

SIMILARITIES BETWEEN

OPIATE ADDICTION & SOCIAL DEPENDENCE

OPIATE ADDICTION	SOCIAL DEPENDENCE
1) Drug Dependence	1) Social Bonding
2) Drug Tolerance	2) Estrangement
3) Drug Withdrawal	3) Separation Distress
a) PSYCHIC PAIN →	a) LONELINESS
b) LACRIMATION →	b) CRYING
c) ANOREXIA →	c) LOSS OF APPETITE
d) DESPONDENCY →	d) DEPRESSION
e) INSOMNIA →	e) SLEEPLESSNESS
f) AGGRESSIVENESS →	f) IRRITABILITY

Figure 13.5. Summary of the major similarities between the dynamics of opioid dependence and key features of social attachments.

were separated from other geese and allowed to spend a lot of quality time with Lorenz developed a special fondness for him and would persistently follow him about as if he were the matriarch of the group. In adulthood, sexual desires could also be guided by these early imprints to take a cross-species course that seemed comical from a human, albeit not an evolutionary, perspective. For instance, Lorenz vividly described how he was courted by a blackbird he had hand-reared from infancy. A great deal of neuroscientific information is available on imprinting, including the demonstration of specific brain changes (see next chapter), but we still do not satisfactorily understand the neuroanatomical pathways and the neurochemical factors that mediate these effects. Many researchers believe vasotocin in birds and oxytocin in mammals are key factors, but pertinent evidence is scarce.

However, due to the recent development of an efficient mammalian model for studying bonding, compelling evidence from laboratory rats indicates that central oxytocin may mediate the attachment of an infant to the mother. Basically, the experimental design was to separate pups from their mother for several hours and then reunite them for half an hour. Just before each reunion, the mother's ventral surface was sprayed with a distinct odor (either lemon or orange), which imparted a distinct sensory quality to the reunion episodes. In contrast, control animals were simply reunited with a cotton wad permeated with those same odors. This was done for three successive reunion trials, all occurring during a single day. The following day, the attraction of the pups to the conditioned odor and other odors was evaluated using various measures, including approach in runways and place preference tasks. Clearly, only the pups that had been reunited with mom exhibited a selective approach and an attraction to the odor associated with maternal reunion. This attraction was blocked completely in animals that had been given oxytocin antagonists. However, giving animals oxytocin when they were "reunited" with the cotton wad was not sufficient to induce such an attraction.[58]

Considering the importance of oxytocin for maternal behavior, it has also been of great interest to determine whether the molecule modulates negative emotions that arise from separation. Indeed, as discussed in detail in Chapter 14 oxytocin and vasotocin have turned out to be extremely powerful inhibitors of the separation call in various species, affirming that social comfort is produced by the same brain chemistries that help mediate maternal and sexual behaviors.[59]

Moreover, it is noteworthy that the oxytocin molecule has special properties to increase the sensitivity of brain opioid systems. Organisms typically exhibit tolerance to opiates, as in the case of addicts who must administer ever-increasing amounts to obtain the same psychological response. Oxytocin can inhibit the development of this tolerance.[60] Perhaps the secretion of oxytocin in nursing mothers blocks tolerance to opioid reward, and thus provides a dual way for the maternal experience to sustain social pleasures: not only by directly activating oxytocin-based social reward processes but also by sustaining high affective arousal in the brain's opioid experiences. It would be disastrous if mothers lost their ability to feel intense social gratification from nurturance when children were still quite young. Parenthetically, it should be emphasized that the male sex factor, AVP, has little ability to reduce separation distress, but as we will see later, it can facilitate social memories. Recent work in males also suggests that AVP is an important ingredient in sexual bonding, as demonstrated in the tendency of field mice to defend and prefer the company of certain female partners. Male *prairie voles*, an especially gregarious mouse strain, will choose to spend time with those females in whose company they have experienced elevated levels of AVP.[61]

At the present time, AVP, oxytocin, and opioid systems appear to be prime movers in the construction and maintenance of social bonds in mammals. Vasotocin, which is the homologous peptide in birds, may also be important in guiding social preferences, but this has not been demonstrated yet. Animals also prefer to spend more time with other animals in whose presence they have experienced high brain oxytocin and opioid activities.[62] Thus, it seems as if friendships are cemented by the same chemical systems that mediate maternal and sexual urges. Perhaps this is one of the primitive emotional reasons we are more likely to help family and friends than strangers (a phenomenon called *kin selection* by sociobiologists). Not only do we simply feel better about those we already know than we do about strangers, but even their faces, voices, and ways of being are engraving more powerful affective imprints in our memories. How does this engraving process occur?

Oxytocin, AVP, and Social Memories

How do we come to recognize and value friends above strangers? Although the answer to this question remains complex and poorly understood, we can assume a central role for brain chemistries that help strengthen and consolidate memories made up of positive social experiences. Emotionally, there are bound to be connections to the mother-infant type bonding processes discussed here, as well as the emotional systems that mediate separation distress (see Chapter 14) and social play (see Chapter 15). However, these affective issues interact with various special-purpose cognitive mechanisms.

While humans recognize each other very well by sight and sound, with the aid of special-purpose face and voice recognition networks situated in specialized areas of the temporal lobes, rats generally accomplish this by smell. This mode of social recognition has been used to develop an effective animal model for the analysis of social memories, relying on the fact that rats get acquainted through mutual investigation, especially of the ano-genital region (as do dogs). If animals already know each other well, they spend considerably less time investigating each other than if they are strangers.[63]

The decrease in social investigation as familiarity increases reflects social memories, and provides a simple way to analyze neurochemistries of the underlying brain processes. It has been found that administration of AVP soon after a social encounter strengthens social memories (at least in males; again, females remain to be tested!). Conversely, administration of AVP antagonists (various molecules that prevent communication at AVP synapses) can obliterate the memories.[64] While data indicated that oxytocin also impairs the consolidation of such memories, more recent work has demonstrated that only very high doses produce such effects. In fact, low doses of oxytocin, which are more likely to be in the natural physiological range, also strengthen social memories.[65] Thus, the same brain chemistries that facilitate various friendly social and sexual behaviors also help solidify the memories that emerge from those experiences.

It remains a mystery exactly where and how memories promoted by oxytocin are solidified in the brain. Interestingly, however, the hippocampus, which is a key brain area for the consolidation of memories, has high oxytocin and AVP sensitivity. It is also noteworthy that the ability of oxytocin to promote erections in male rats is especially easily obtained by infusion of the neuropeptide into the hippocampus.[66] This is perplexing, since the hippocampus is not generally thought to control sexuality. However, the dilemma may be easily resolved if one is willing to entertain the possibility that the manipulation can evoke sexually arousing memories in the rat's "mind."

Oxytocin and Peaceful Coexistence ("Make Love Not War!")

Additional research on oxytocin provides yet another intriguing piece to the neurosocial puzzle. The chemistries that promote pleasure and family values are also able to dramatically reduce irritability and aggressiveness. It has long been known that human societies that encourage physical closeness, touching, and the free flow of intimacy tend to be the least aggressive in the world. For instance, it has been documented that societies that exhibit high levels of physical affection toward infants and children and permit premarital sex are generally low in adult physical violence, while those that are low in physical affection and punish premarital sex tend to be more violent.[67] This, of course, makes a great deal of evolutionary sense: If one is socially well satisfied, there is little reason to fight. However trite this may sound, the principle is profound and supported by brain research. Both opioids and oxytocin (but not AVP!) are powerful antiaggressive molecules,[68] and they also have a powerful inhibitory effect on separation distress. For the present purposes, let us focus on the oxytocin part of the story.

Oxytocin administration reduces all forms of aggression that have been studied. Perhaps the most intriguing one is infanticide—the tendency of animals, especially strange males, to kill the young in a territory they have successfully invaded;[69] this is an especially common (mis)behavior in male rats. Oxytocin, whether given peripherally or centrally, dramatically diminishes this tendency.[70] Since it has been found that sexual experiences promote oxytocin synthesis in the male brain, we might expect that access to sexual contact would also make males less aggressive. Indeed, as mentioned in Chapter 10, it has recently been discovered that sexual activity diminishes the tendency of male rats to exhibit infanticide. This peaceful tendency grows as a function of the number of weeks that have followed copulation, peaking at three weeks after the sexual encounter.[71]

This curious fact makes good evolutionary sense: The male rat has a mechanism in its brain that decreases the likelihood that it will kill its own young. In rats, it typically takes three weeks from the time of successful fertilization to the time of birth. Thus, it would behoove a male rat to restrict its pup-killing ways maximally at about 21 days following sexual activity. As mentioned in Chapter 10 (see Figure 10.7), this is exactly what happens.[72] Although it has not yet been demonstrated that this effect is directly attributable to the lingering effect of brain oxytocin dynamics, it is certainly a reasonable place for investigators to search for a physiological explanation. In rodents, however, it has been shown that free access to sexual gratification can lead to an enormous threefold elevation in oxytocin levels in some parts of the male brain. Apparently, sex promotes the synthesis of nurturant and antiaggressive neurochemistries in the male. Of course, the female is already endowed with abundant activity in this system. Perhaps this brain change, which brings male chemistries closer to those of the female, is one that coaxes males to become supportive and nurturant fathers. This is a socially attractive idea, but only future research will tell us to what extent it can subvert the strong positive linkage that also exists between sexual desire and the arousal of male jealousies and ensuing tendencies toward aggression (see Chapter 10).

Experience-Induced Maternal Behavior

It makes good evolutionary sense for an animal not to "waste" much effort taking care of another animal's offspring—time that would be better spent looking after the welfare of one's own genes. Thus it is perplexing that the mere exposure to young infants can induce nurturant behaviors in some animals, a phenomenon that has been studied extensively in rats.

Since work on this question can only be conducted in animals that normally do not exhibit infanticide, only certain individuals can be tested for the induction of nurturance. Those laboratory rats that do not exhibit infanticide can be induced to gradually exhibit maternal behavior by the simple maneuver of repeatedly exposing them to infant rats. Although they are not attracted by this opportunity at the outset (due, in part, to the smell aversion discussed earlier), the animals gradually begin to show interest in the pups, and eventually most will exhibit well-organized maternal behaviors.

This artificial induction of maternal behavior has been termed *concaveation* or *sensitization* by different authors.[73] It should come as little surprise that mature virgin female rats typically exhibit the behavior more rapidly (about four to seven days) than males (about six to eight days).[74] This finding indicates that adult female brains can be sensitized more readily, but we do not yet know how or where in the brain this phenomenon is elaborated. It does seem to correspond to an increase in prolactin and oxytocin output of the pituitary. One reasonable hypothesis is that the experience with the pups gradually leads to increased genetic expression of these neuropeptides within the relevant brain circuits, but that remains to be empirically demonstrated. It is noteworthy, however, that among juvenile rats, which normally exhibit a brief natural period of great interest in small pups (maybe the rat analog, or even homolog, of playing with dolls), sensitization progresses very rapidly, and slightly more rapidly in young males than in females.[75] However, this period of heightened "intrigue" with infants is short-lived, and throughout most of adolence, juvenile rats are not as strongly attracted to baby rats.

The tendency of young male rats to sensitize more rapidly than females suggests that the organizational effects of early hormones that lay down a male brain do not inhibit the sensitization process. Indeed, the faster sensitization may be an adaptive way for males to obtain early experience with nurturant behaviors that they may need later in life. In this context, it is worth reemphasizing that males from prenatally stressed mothers (i.e., those with homosexual tendencies described in the previous chapter) exhibit sensitization faster than their "normal" nonstressed counterparts. On the contrary, females from these same stressed mothers show the opposite trend; their acquisition of maternal tendencies is impaired.[76]

Whether these effects are present in other species, such as humans, and whether they are caused by changes in the responsivity of brain oxytocin systems remain unknown. However, the potential implications of such findings for understanding the learning processes that contribute to human social bonding, as well as problems in nurturant motivation, deserve wider attention. Might such processes explain the emotional difficulties and temperamental differences that exist among human mothers? Can difficulties in human bonding be explained by the disruption of such neural dynamics? Do human mothers have a special window of opportunity when they would bond most effectively with their infants? Do mothers who exhibit bonding problems have difficulties in recruiting the relevant brain chemistries? Can medical assistance be provided in such cases? And, perhaps most important, can fathers, who seem to be instinctively less nurturant than mothers, be induced to be more nurturant by facilitating certain neurochemical processes? We simply do not know at the present time, but we can begin to entertain such questions. The probability that simple administration of oxytocin (in a brain-accessible form) would promote social tendencies seems remote. Many of the dynamic changes in sensitivity within this system reside in the proliferation and location of oxytocin-receptive fields, which vary widely as a function of species and a host of physiological variables.[77]

Species also differ widely in the temporal dynamics of the social bonding processes. To some extent this is related to how mature the offspring are at birth. As already indicated, animals that have very altricial (i.e., immature) offspring, like rats and humans, generally exhibit a wider "window of opportunity" for social acceptance than precocious species, like sheep, whose young are born very mature.[78] Generally, rat mothers sequester their offspring in nests and exhibit a great deal of tolerance if their babies are replaced with strangers. They appear to be satisfied as long as some young remain in the nest, for they seem to be attached more to the general concept of having babies in their nests than to their own specific babies, presumably because the appearance of strangers has been a rare event in their evolutionary history. On the other hand, in most herbivores, babies are born motorically precocious, and the mothers must rapidly establish discriminating bonds. Sheep are an interesting species in this regard. Mothers typically tolerate and feed only their own lambs, or only those lambs with which they have developed social bonds within the first hour or two after birth. This is based primarily on olfactory recognition processes. If ewe and lamb are separated for several hours after birth, the window of bonding opportunity passes, and mothers will then reject the care-soliciting overtures of their own lambs, butting them and refusing them opportunities to nurse.[79]

However, as previously indicated, once the window of opportunity has closed, it can be opened once more by two manipulations. First, "reminding" mother sheep of the birthing experience, via artificial vaginocervical stimulation, puts the mother in a mood to accept lambs once more for another hour or two.[80] They become bonded and exhibit full maternal care. As we know from sex research summarized in the previous chapter, this type of stimulation activates oxytocin systems in the female brain, and perhaps that is the key. Indeed, the other method of reinducing bonding is to simply administer oxytocin into the mother's brain; this will reopen the window of maternal acceptance.[81] Parenthetically, it should be noted that in sheep, opioids do not promote active acceptance of lambs, but they do reduce the tendency of female sheep to actively reject strange lambs.[82] Thus, it is likely that oxytocin is more important than endogenous opioids in the mediation of maternal responsivity at least in sheep.

Considering the importance of oxytocin in sexual behavior and the mediation of mother-infant bonds, we must suspect that sexual interactions among consenting adults may neurophysiologically facilitate the consolidation of social attachments, thereby promoting the more nurturant forms of human love. However, before the final story is told, we will have to work through many complex empirical details, including issues related to the nature of altruism and emotions such as possessiveness and jealousy.[83]

Thoughts on Altruism

Since there are circuits and neurochemistries for nurturance in the mammalian brain, and since social bonding in mammals is largely a learned phenomenon, the possibility arises that humans may be able to sincerely extend love and altruism toward strangers. Indeed, we were all impressed recently when Binti the gorilla, of the Brookfield Zoo on the outskirts of Chicago, saved a young boy who fell into her "home." This act of concern impressed many, and it surely emerged from the types of CARE circuits that we share as mammals. To help commemorate such events, and to highlight the very nature of maternal instincts and the social bond, the portrait of motherhood depicted in Figure 13.3 was commissioned. The existence of maternal care should broaden our thinking about altruism.

However, sociobiologists have advised us that "true altruism" cannot exist in any animal, for to sacrifice one's good for the sake of others would be a self-defeating genetic strategy. Self-sacrifice typically occurs only in relation to kin, when it helps one's own gene pool. Although all this is true, we should remember that in mammals the social bonding mechanisms are based on learning and are certainly more pervasive than the *innate* mechanisms for "kin recognition."[84] We can learn to love other animals. It is especially important to emphasize that the experience of motherhood is a powerful force in promoting future nurturance. Thus, while a virgin female rat's nurturant urges require many days to become sensitized, those of a female who has once been a mother are engaged rapidly, usually in less than a day. Similar processes exist in humans.[85]

The acquisition of nurturant behavior leaves a seemingly indelible imprint on a creature's way of being in the world. Although learning is most likely to operate in the presence of genetic kin (for simple geographic reasons), in a cosmopolitan human world, bonding can become broader. Mass communication can potentially promote wider networks of bonding than is common in nature, assuming, of course, that a long-term "bonding window" remains partially open for humans as they mature. This broad albeit frail window of opportunity may be the best hope for the future of humankind.

In any event pro-social affiliative and bonding tendencies should be cultivated and accorded a value on a par with testosterone-driven power-urges. Indeed, the two can sometimes be productively joined, as they are in international efforts such as the Olympic Games. How this might be achieved in other arenas of human life deserves more attention from sociologists and political scientists (see "Afterthought," Chapter 16). Whether and how we shall choose to promote or hinder nurturance across cultural and geographic borders remain societal and political questions of momentous proportions.

AFTERTHOUGHT: The "Mere-Exposure" Effect

One of the most intriguing general psychological phenomena related to those discussed here is called the "mere-exposure" effect. If one simply exposes animals to various stimuli, they begin to develop a preference for those stimuli, especially if they have been paired with positive affective experiences.[86] This effect is pervasive and applies to all species and most objects that have been studied.[87] If one has been exposed to certain foods, one begins to prefer those foods.[88] If one has been exposed to certain objects and places, one begins to prefer those objects and places.[89] Indeed, place attachment arises from mere exposure, which may have been one of the antecedent processes for social bonding. Much of the mere-exposure effect operates at a subconscious level and may be related to other preconscious evaluative effects of emotional stimuli. For instance, it has been demonstrated that if one simply exposes American students to written Chinese characters they do not understand, some of which are preceded by a brief subliminal presentation of a smiling face, subjects will later prefer those characters as opposed to ones that were shown without affective priming.[90]

The attraction of familiar experiences may have far-reaching consequences: Humans who have been exposed to certain ideas often begin to prefer those ideas. Perhaps the most poignant example of this is the ease with which people can defend ideas they have held dear since childhood or even a short while, and how easy and natural it is to contradict the new ideas of others. Although one can readily conjure up exceptions to this pattern (e.g., as encapsulated in the phrase "familiarity breeds contempt"), the mere-exposure effect is a remarkably robust experimental finding. Indeed, some have suggested that social bonding or imprinting may simply reflect this type of process.[91]

The effect has also been used to focus investigators' attention on the possibility that unconscious evaluative processes may be important in the generation of emotional states and judgments.[92] Indeed, it is possible that this phenomenon may be reflected in the many psychobehavioral processes described in this chapter. If so, it would be important to clarify the neurobiological underpinnings of the mere-exposure effect, but relevant research is scarce.

It might be worthwhile to consider whether some of the chemistries that participate in the elaboration of social processes may also play a role in the generation of this interesting phenomenon.[93] Might opioids and oxytocin, as well as other bonding chemistries, be important in molding and modulating the mere-exposure effect? Conversely, what might be the role of other affectively positive neurochemistries such as dopamine, which do not appear to be important for bonding? If we begin to understand the mere-exposure effect, we may also shed light on what it means to feel relaxed and comfortable in a given situation. The mere-exposure effect may be a major affective process that allows animals to become accustomed to new situations efficiently. Is the feeling of déjà vu generated by the release of such chemistries? The mere-exposure effect may be an especially beneficial adaptation for animals that migrate, as well as for ones that are exposed to a variety of social stimuli.

Indeed, social tolerance may be promoted by mere exposure. Recall the young cats that were brought up with rats (see Chapter 2); they did not attack rats when they became adults. This speaks strongly for the benefits of exposing children to a diversity of other individuals and cultures when they are young. The more they have experienced of the world, the more accepting they will be of diversity. Wise governments will promote the use of mass media for such purposes, rather than undermining support for public broadcasting, educational endeavors, and endowments for the humanities, as is popular in some reactionary quarters.

In sum, specific brain systems lie at the heart of complex neuroevolutionary programs that generate the deeply social nature of mammals. Psychobiologists have started to recognize and untangle the neural underpinnings that control social motivation within the old mammalian brain. Nurturant behaviors can become a habit, at least partly independent of the basic brain substrates from which they were initially constructed. The potential implications of such lines of investigation are profound.

Suggested Readings

Alexander, R. D. (1987). *The biology of moral systems.* Hawthorne, N.Y.: Aldine de Gruyter.

Bowlby, J. (1972). *Attachment and loss.* Vol. 1, *Attachment.* New York: Basic Books.

Emde, R., & Harmon, R. (eds.) (1982). *The development of attachment and affiliative systems.* New York: Plenum Press.

Fletcher, D. J. C., & Michener, C. D. (eds.) (1987). *Kin recognition in animals.* London: Wiley.

Harlow, H. F. (1971). *Learning to love.* San Francisco: Albion.

Klaus, M. H., & Kennell, J. H. (1976). *Maternal-infant bonding.* St. Louis, Mo.: Mosby.

Knobil, E., & Neill, J. D. (eds.) (1988). *The physiology of reproduction.* New York: Raven Press.

Krasnegor, N. A., & Bridges, R. S. (eds.) (1990). *Mammalian parenting: Biochemical, neurobiological, and behavioral determinants.* New York: Oxford Univ. Press.

Petersen, C. A., Caldwell, J. D., Jirikowski, G. F., & Insel, T. R. (eds.) (1992). *Oxytocin in maternal, sexual and behaviors.* Special issue of *Annals of New York Academy of Sciences,* Vol. 652. New York: New York Academy of Sciences.

Winberg, J., & Kjellmer, I. (eds.) (1994). *The neurobiology of infant-parent interaction in the newborn period. Acta Paediatrica,* Vol. 83, Suppl. 397. Oslo: Scandinavian Univ. Press.