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Lust, Attraction, Attachment: Biology and Evolution of the Three Primary Emotion Systems for Mating, Reproduction, and Parenting

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Humans and other mammals have evolved three primary emotion systems for mating, reproduction, and parenting: the sex drive, or lust, characterized by the craving for sexual gratification; attraction, characterized by increased energy and focused attention on one or more potential mates, accompanied in humans by exhilaration, intrusive thinking, and craving for emotional union; and attachment, characterized by close social contact and feelings of calm, comfort, and emotional union. Each emotion system is associated with a discrete constellation of brain circuits, and each evolved to direct a specific aspect of mating and reproduction. The psychophysiological properties of romantic attraction suggest that this emotion system is associated with increased levels of dopamine and norepinephrine and decreased levels of serotonin in the brain; a study using functional magnetic resonance imaging (fMRI) is in progress to investigate the neural architecture of this primary emotion system. During the course of hominid evolution these three emotion systems became increasingly independent of one another, contributing to modern patterns of marriage, adultery, and divorce as well as to the worldwide incidence of stalking, homicide, suicide, and clinical depression associated with rejection in love.

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It is hypothesized that mammals and birds have evolved three primary, discrete, and interrelated emotion systems in the brain for mating, reproduction, and parenting: lust, attraction, and attachment. Each emotion system is associated with a specific constellation of neural correlates. Each is associated with a distinct behavioral repertoire. And each evolved to direct a specific aspect of reproduction (Fisher, 1998, 1999).

The sex drive (the *libido* or *lust*) is characterized by a craving for sexual gratification; it is associated primarily with the estrogens and androgens. The sex drive evolved principally to motivate individuals to seek sexual union with any appropriate member of the species.

The attraction system (termed *passionate love, obsessive love,* or *infatuation* in humans) is characterized by increased energy and focused attention on a preferred mating partner. In humans, attraction is also characterized by feelings of exhilaration, intrusive thinking about the love object, and a craving for emotional union with this partner or potential partner. Attraction is associated primarily with high levels of the catecholamines, dopamine and norepinephrine, and low levels of the indoleamine, serotonin, in the brain. This emotion system evolved primarily to facilitate mate choice, enabling individuals to select between potential mating partners, conserve their mating energy, and focus their attention on genetically superior individuals.

The attachment system (usually termed *companionate love* in humans) is characterized in birds and mammals by mutual territory defense and/or nest building, mutual feeding and grooming, the maintenance of close proximity, separation anxiety, shared parental chores, and other affiliative behaviors. In humans, attachment is also characterized by feelings of calm, security, social comfort, and emotional union. Attachment is associated primarily with the neuropeptides, oxytocin and vasopressin. This emotion system evolved to motivate individuals to engage in positive social behaviors and/or sustain their affiliative connections long enough to complete species-specific parental duties.

The neural circuits for each of these three emotion systems can be expected to vary from one species to the next, according to the specific mating strategy of each. For example, seasonal breeders such as rabbits and deer express the sex drive and attraction seasonally; and monogamous creatures express more attachment behaviors than those that are semi-solitary. The biology associated with this species variation has been established among voles. Among prairie voles, a monogamous species (*Microtus ochrogaster*), the distribution of limbic system receptor sites for oxytocin

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varies from that of montane voles (*Microtus montanus*), an asocial species (Insel et al., 1993).

The neural mechanisms governing these emotion systems can also be expected to vary among individuals within a species. For examples, humans vary in the frequency and duration of their sex drive (Laumann et al., 1994) and feelings of attraction (Tennov, 1979); humans also vary in the frequency and degree to which they attach to a mate (Fisher, 1989, 1992, 1994). These emotion systems can also be expected to vary across the life course of any single individual.

These emotion systems regularly act in concert with one another and with other bodily systems. In mammals, for example, testosterone can facilitate the production of vasopressin; oxytocin can alter dopaminergic activity; and serotonin can alter the synthesis, release, and function of several neuropeptides (see Fisher, 1998). This interaction between emotion systems is evident in humans. A person may begin a sexual liaison merely for sexual pleasure, then become romantically involved with that sexual partner. Some become deeply attached to the partner as well. This attachment to a sexual partner can be explained biologically. After orgasm, levels of vasopressin rise in men; after orgasm, levels of oxytocin rise in women (see Damasio, 1994).

These three emotion systems can also act independently, however. In approximately 90% of avian species, individuals form seasonal or lifelong pair-bonds. Yet in 90% of some 180 species of socially monogamous songbirds, individuals engage in "extra-pair" copulations as well (Morell, 1998; Black, 1996). Men and women can also express attachment for a long-term spouse or mate while they simultaneously express attraction for someone in their social circle, and/or while they simultaneously feel the sex drive in response to visual, verbal, or mental stimuli that are unrelated to either partner.

Psychologists distinguish between the sex drive, attraction, and attachment (Hatfield and Rapson, 1996; Hatfield & Sprecher, 1986; Hatfield, 1988; Shaver, Hazan & Bradshaw, 1988). But they have not discussed the neural correlates of these emotion systems, the biological interrelationships between these three emotion systems, the specific role that attraction plays in mammalian reproduction, the evolution of these emotion systems in *Homo sapiens*, or how the brain architecture associated with these systems contributes to contemporary human patterns of mating, reproduction, and parenting.

Neuroscientists currently believe that different emotions are produced by different brain-body circuits (Damasio, 1999; Davidson, 1994; Lazarus, 1991; Panksepp, 1998). And they have begun to explore the biochemistry of fear, depression, anxiety, and affiliation. But they have not delineated the above-mentioned three categories of emotion associated with mammalian reproduction. So this paper defines these three emotion systems for mating, reproduction, and parenting; it reports on the primary hormones and/or neurotransmitters associated with each emotion system; and it illustrates ways in which these three emotion systems interact in humans. It proposes that the attraction system evolved to conserve mating energy and facilitate mate choice in birds and mammals and it briefly discusses the functional magnetic resonance imaging (fMRI) brain scanning project currently being conducted to investigate the neural circuitry of this emotion system. It hypothesizes how and why the attachment system evolved in *Homo sapiens*. It concludes that during the course of hominid evolution, these three emotion circuits—lust, attraction, and attachment—became increasingly independent from one another, and that this brain architecture contributes to worldwide patterns of marriage, adultery, divorce, and remarriage, as well as to the worldwide prevalence of sexual jealousy, stalking, homicide, suicide, and clinical depression associated with rejection by a mate or potential mate.

Lust

The sex drive, otherwise known as lust, the libido, or the urge for sexual consummation, is a multidimensional phenomenon that is triggered by myriad ecological, social, psychological, and physiological stimuli. But scientists have long regarded the sex drive as a distinct emotion system that is innate, common to all birds and mammals, and associated with specific hormones and primary neural structures in the avian and mammalian brain (Beach, 1976; see Komisaruk, Siegel, Cheng & Feder, 1986). Moreover, they agree that the sex drive is predominantly associated with the androgens in both men and women (Sherwin, 1994).

The biological relationship between the sex drive and the attraction system has not been defined in most mammals. But there is evidence that these brain circuits interact in prairie voles. When female prairie voles are exposed to a drop of male urine on the upper lip, norepinephrine is released in specific areas of the olfactory bulb of the brain, stimulating the release of estrogen and concomitant proceptive sexual behavior (Dluzen, Ramirez, Carter & Getz, 1981). But the sex drive and attraction can also act independently in animals. All mammals express the sex drive, yet all prefer to mate with certain individuals and avoid others. Evidence that lust and attraction are distinct emotion systems is clearer in humans. When middle-aged men and women are administered injections of testosterone, their sex drive is enhanced—but they do not fall in love.

In mammals, the brain circuitry for the sex drive is clearly independent of the neural correlates for long-term attachment. All engage in sexual activity, yet only 3% of mammalian species form a long-term attachment to a mating partner (Kleiman, 1977). Moreover, humans can express sexual desire toward individuals to whom they are not emotionally attached, and they can feel deeply attached to a mate or spouse for whom they have no sexual desire.

In fact, the sex drive can have a negative impact on expressions of attachment. When scientists surgically injected testosterone into mated male sparrows, all abandoned their partners to pursue other females (Wingfield, 1994). Men with high baseline levels of testosterone marry less frequently, they are more abusive during marriage, and they divorce more often (Booth & Dabbs, 1993). And as a man's marriage becomes unstable, his levels of testosterone rise (Booth & Dabbs, 1993). The reverse is seen in expectant fathers: concentrations of testosterone plunge when their infants are born (see Blum, 1997).

This negative relationship between high levels of testosterone and expressions of attachment may help to explain why individuals in long marriages tend to express less sexual desire for one another. In these marriages, high levels of vasopressin and/or oxytocin may decrease levels of testosterone. This negative relationship between the brain circuitry for lust and attachment may also help to explain why some new mothers report a decline in their sex drive after parturition. Prior to childbirth, levels of oxytocin increase—perhaps decreasing levels of testosterone.

A host of different ecological, cultural, and psychological stimuli trigger the sex drive. But regardless of how this feeling is triggered, to whom it is directed, or how it is expressed, the libido is associated with a specific constellation of correlates in the brain—an emotion circuit that evolved to initiate the mating process. Attraction, I propose, is a different emotion system designed for a different but related function.

Attraction

In 1991, anthropologists surveyed studies of 166 varied societies and found evidence of romantic attraction in 147 of them (Jankowiak & Fischer, 1992). People sang love songs, composed romantic verse, performed love magic, carried love charms, or brewed love potions; some eloped; some committed suicide or homicide because of unrequited love. And in many cultures, myths and fables portrayed romantic entanglements. The researchers found no negative evidence; in the other 19 societies, the scientists had failed to examine this aspect of daily living. So anthropologists currently conclude that romantic attraction is a universal or near-universal experience in humans (Jankowiak & Fischer, 1992).

I will go farther and contend that attraction—also called romantic love, obsessive love, passionate love, infatuation, or *limerence* (Tennov, 1979) in humans—constitutes a discrete emotion system common to all birds and mammals; that this emotion system is associated with a specific constellation of neural correlates; and that this neural circuitry evolved to enable individuals to conserve their mating energy, choose between potential mates, focus their attention on the best available mating partners, and pursue these potential mates at least until insemination has been completed.

Scientists have intuitively acknowledged the existence of this emotion system for over a century. Darwin discussed animal attraction when he wrote about the evolution of the secondary sexual characteristics (Darwin, 1859, 1871). He reasoned that birds and mammals evolved these seemingly-unnecessary bodily decorations for one of two reasons: to fight or intimidate members of the same sex and win breeding opportunities, or to attract members of the opposite sex. Implicit in Darwin's model is the understanding that these physical traits trigger some type of physiological attraction response in the viewer.

Today this animal attraction is termed *favoritism, selective proceptivity, sexual preference, sexual choice,* or *mate choice;* and many scientists have discussed aspects of this mate preference in birds and mammals (see Andersson, 1994; Campbell, 1972). Yet no one has examined the biological process by which the viewer arrives at his or her mate preferences. So I propose that many of the secondary sexual characteristics of any species, such as the peacock's elaborate tail feathers, evolved to trigger a specific "attraction circuit" in the brain of the viewer—a brain system that humans have come to call romantic love.

To begin my investigation of the biology of this neural emotion system, I canvassed the psychological literature on romantic passion and compiled a list of 13 psychophysiological properties associated with this excitatory state (see Tennov, 1979; Hatfield & Sprecher, 1986; Fisher, 1998).

Second, with Rutgers University graduate student Michelle Christiani, I designed a 72-item questionnaire based on these common properties of romantic love. To date, 420 American and 430 Japanese men and women have completed this questionnaire (M. Hasegawa and T. Hasegawa, personal communication, June 15, 1996). And with colleague MacGregor Suzuki, I have made a preliminary tabulation of the results.

Third, with Lucy L. Brown, a neuroscientist from Albert Einstein College of Medicine, Yeshiva University; Arthur Aron, a psychologist at State University of

New York (SUNY)—Stony Brook; and Debra Mashek, graduate student in psychology at SUNY—Stony Brook, I have begun to put infatuated subjects through an fMRI machine to scan the brain. Data on four subjects have been collected; these data are currently being analyzed. My hypothesis is that the feeling of romantic attraction is associated with high levels of dopamine and norepinephrine and low levels of serotonin. I arrived at this premise after I compared the primary psychophysiological characteristics of romantic attraction with the primary properties of dopamine, norepinephrine, and serotonin.

The Biology of Romantic Attraction

When someone falls in love, they begin to feel that their beloved is unique; their "love object" takes on "special meaning" (Tennov, 1979). This phenomenon is coupled with the inability to feel romantic passion for more than one person at a time. Increased concentrations of dopamine in the central nervous system (CNS) are associated with exposure to a novel environment (Tassin, Herve, Blanc & Glowinski, 1980) as well as with heightened attention, motivation, and goal-directed behaviors (Kiyatkin, 1995; Salamone, 1996; Scatton, D'Angio, Driscoll & Serrano, 1988). These parallels suggest that levels of CNS dopamine are rising in the infatuated individual as their beloved takes on special meaning.

The love-possessed tend to focus their attention on the positive qualities of the loved one, and overlook or falsely appraise his/her negative traits. Infatuated men and women also focus on specific events, objects, and other phenomena they have come to associate with the beloved. Seventy-two percent of men and 84% of women who answered our questionnaire remembered trivial things that the beloved said and did. Moreover, 82% of men and 90% of women said they replayed these precious moments as they mused.

This tendency to focus on, remember, and cherish specific traits of the beloved, as well as the tendency to focus on specific moments associated with the beloved, are additional indications that dopamine is involved in the feeling of romantic attraction. As mentioned above, increased levels of dopamine are associated with focused attention (Kiyatkin, 1995; Salamone, 1996; Scatton et al., 1988). Increased levels of CNS norepinephrine are most likely also involved, because elevated levels of CNS norepinephrine are associated with increased memory for new stimuli (Griffin & Taylor, 1995).

Increased levels of CNS norepinephrine have also been associated with imprinting (Davies, Horn & McCabe, 1985). *Imprinting* is an ethological term originally used to define the instinctive "following behaviors" of just-hatched geese toward the first moving creature that they see; generally this is the mother. The focused attention of the infatuated man or women is similar to imprinting, further suggesting that elevated levels of norepinephrine are associated with this aspect of romantic attraction.

The infatuated individual begins to think about the beloved obsessively, what is known as *intrusive thinking*. Many informants report that they muse about their love object more than 85% of their waking hours (Tennov, 1979). As intrusive thinking is a form of obsessive behavior, and as serotonin-reuptake inhibitors are currently the agents of choice in treating most forms of obsessive-compulsive disorder, I have speculated for some time that low levels of serotonin are responsible for the intrusive thinking associated with romantic attraction (Fisher, 1998). Now neuroscientist Donatella Marazziti of Pisa University in Tuscany and her colleagues have confirmed that low levels of serotonin are indeed associated with romantic attraction (Marazziti, Akiskal, Rossi & Cassano, 1999).

The love-possessed also experience a host of labile psychophysiological responses including exhilaration, euphoria, increased energy, sleeplessness, loss of appetite, trembling, a pounding heart, and accelerated breathing. Many also report feeling anxiety, panic, and/or fear in the presence of the beloved. The love-possessed are subject to abrupt mood swings, too. If the relationship suffers a setback, the attracted individual may fall into listlessness, brooding, and feelings of despair.

Increased concentrations of dopamine in the brain are associated with euphoria (Wise, 1988), loss of appetite (Colle & Wise, 1988), hyperactivity (Post, Wise & Pert, 1988), increased mental activity, a delay of the onset of fatigue, and decreased need for sleep (Kruk & Pycock, 1991), as well as a "hyperreactive fearlike state" (Lee, Ellinwood & Nishita, 1988) and anxiety and panic (Post et al., 1988). Hence dopamine is a likely agent for the exhilaration, heightened energy, sleeplessness, reduced appetite, and fear and anxiety associated with passionate attraction in humans. When scientists block the activity of dopamine in courting rats, these creatures do less hopping and darting prior to copulation (Herbert, 1996). Dopamine gives these animals energy during courtship as well.

The remaining psychophysiological properties of obsessive romantic attraction do not appear to have any direct correlation with dopamine, norepinephrine, and/or serotonin. But they may be associated with these neurochemicals in as yet undefined ways.

Infatuated individuals regularly report feelings of emotional dependency on the relationship with the beloved. Specific feelings include possessiveness, jealousy, fear of rejection, and separation anxiety. Those

who are infatuated yearn for emotional reciprocity and emotional union with the beloved. Smitten men and women feel a powerful sense of empathy toward the loved one and a willingness to sacrifice for him or her. The love-possessed tend to reorder their daily priorities and/or change their clothing, mannerisms, habits, or values to become available to the loved one. And infatuated individuals experience an intensification of passionate feelings in times of adversity.

Most people in the throes of romantic love experience sexual desire for the beloved, coupled with the drive for sexual exclusivity and feelings of jealousy if they suspect infidelity in their romantic partner. This desire for sexual exclusivity probably evolved for an important purpose: to drive partners to exclude other suitors, thereby insuring that courtship is not interrupted until insemination has been completed. Yet for those who are "in love," the craving for emotional union often takes precedence over the desire for sexual union with the beloved. Fifty-eight percent of men and 72% of women in our study disagreed with the statement, "The best thing about love is sex." And 64% of both sexes disagreed with the statement, "Sex is the most important part of my relationship with —." The love-possessed also commonly report that this passion is involuntary and uncontrollable.

Last, romantic attraction is almost always impermanent, unless a physical or social barrier inhibits partners from seeing one another regularly. Scientists have recently gained some understanding of the duration of attraction. When scientists retested serotonin levels in 20 infatuated men and women some 12 to 18 months after the individuals had started their romances, levels of serotonin had risen—becoming indistinguishable from the subjects of the control group (Marazziti et al., 1999). The researchers surmised that passionate romantic love generally lasts between 6 and 18 months.

Dosage effects of the above-mentioned monoamines, interactions between these monoamines, and interactions between these monoamines and other CNS and peripheral emotion systems make analysis of the attraction system complex. Yet similarities between the above-mentioned psychophysiological properties of romantic attraction and the properties of dopamine, norepinephrine, and serotonin suggest that increased concentrations of CNS dopamine and norepinephrine and decreased concentrations of CNS serotonin play roles in romantic attraction in humans.

Observational data from nonhuman mammals include many incidences in which courting individuals display increased energy, focused attention, and goal-directed behavior. And several studies conclude that the catecholamines play a crucial role in the preparatory phase of sexual behavior, specifically motivation and sexual arousal (Melis & Argiolas, 1995). But in humans, passionate attraction takes a variety of graded forms—from reciprocated love, associated with fulfillment and ecstacy, to unrequited love, associated with emptiness, anxiety, and despair (Hatfield & Walster, 1978). In other species, attraction also varies in frequency and duration. So it is expected that the proportions of these neurotransmitters in the brain and body will fluctuate in association with gradations of attraction.

Scanning the Brains of Infatuated People

To try to pinpoint the brain circuitry associated with passionate romantic attraction, I, with colleagues Lucy L. Brown, Arthur Aron, and Debra Mashek, have launched a research study of individuals experiencing feelings of romantic attraction. By word of mouth we found four individuals in the New York area, two men and two women, all of whom reported to one of us that they had "just fallen madly in love." I conducted formal interviews with each potential participant to establish that he or she exhibited heightened levels of energy, feelings of elation, intrusive thinking about the beloved, and other psychophysiological traits associated with romantic attraction. Then we put these subjects into a fMRI machine to scan the brain under three conditions: while the subject was looking at a photograph of his or her romantic partner; while he or she mentally counted backwards from a large number (such as 8,421) in increments of 7; and while the participant looked at a neutral photograph designed to produce no positive or negative emotional response. This project is still in progress. I hypothesize that the regions of the brain most likely to be involved in romantic attraction will be found to include the ventromedial prefrontal cortex, sectors of the anterior cingulate region, the amygdala, the hippocampus, the nucleus accumbens, the hypothalamus, and regions of the brain stem.

Undoubtedly many ecological, cultural, and psychological factors activate the attraction system in the brain (see Hatfield & Rapson, 1996; Shaver et al., 1988; Sternberg & Barnes, 1988). But I suspect that childhood experiences are the primary factors that trigger obsessive romantic attraction. Psychologist John Money of Johns Hopkins University theorizes that somewhere between the ages of 5 and 8, individuals develop a *love map*—an unconscious mosaic of traits they will later look for in a mate (Money, 1997). So when you fall in love, whom you fall in love with, where you fall in love, what you find attractive in a partner, and how you court a potential mate will vary from one society and one individual to the next. But once you find that special person, the actual physical

feeling you have as you experience this passion is lodged in the architecture of the brain. It evolved to enable individuals to select between potential mates and focus their mating energy on preferred partners.

Attachment

Psychologists have recognized attachment as a specific emotion since John Bowlby began to record attachment behaviors in humans and other mammals in the 1950s. In mammals, attachment behaviors include maintaining proximity and displaying separation anxiety when apart (Bowlby, 1969; Mendoza & Mason, 1997). In pair-bonding species, the male often defends the territory and helps to build the nest; partners also feed one another, groom one another, and share parental chores (see Carter, Lederhendler & Kirkpatrick, 1997; Pedersen, Caldwell, Jirikewski & Insel, 1992). Securely attached men and women also report feelings of closeness, security, peace, social comfort, and mild euphoria when in contact with a partner, and separation anxiety when apart for a length of time (Liebowitz, 1983).

Several neuropeptides are associated with male-female bonding, group bonding, and mother-infant bonding (see Carter et al., 1997; Insel, 1992; Pedersen et al., 1992). But recent data indicate that vasopressin and oxytocin released in the CNS are the hormones primarily involved in the production of attachment behaviors in monogamous prairie voles and other mammals (Carter, 1992; Carter, DeVries & Getz, 1995; Insel et al., 1993; also see Pedersen et al., 1992; Winslow et al., 1993).

Moreover, neuroscientists have recently studied a gene associated with the receptor binding of vasopressin. When this gene is transferred from monogamous prairie voles to non-monogamous laboratory mice, and these mice are injected with vasopressin, the mice express increased affiliative behaviors (Young, Nilsen, Waymire, MacGregor & Insel, 1999). Because the gene family that includes vasopressin and oxytocin is found in all mammals and birds, and because humans share variations of these substances with other mammals, it seems probable that vasopressin and oxytocin are associated with the feelings of attachment in people as well.

Evolution of Human Serial Attachment

Marital attachment is a hallmark of humanity (see Fisher, 1989, 1992, 1994, 1995, 1998, 1999). In 97 societies canvassed by the United Nations, 93% of women and 92% of men married by age 49 (Fisher, 1989, 1992). Currently 91% of Americans marry by age 49 (Fisher, 1999). Almost all men and women in traditional societies wed. Some 83% of these cultures permit a man to take more than one wife at once, a practice known as *polygyny* (van den Berghe, 1979). But in about two-thirds of these polygynous societies, fewer than 20% of men actually take two or more wives simultaneously; in the balance, around 20% of men engage in polygyny at some point during their lives (Lancaster & Kaplan, 1994). Approximately 0.5% of cultures permit a woman to take more than one husband simultaneously; this practice, *polyandry*, is rare (van den Berghe, 1979). Hence the vast majority of human beings around the world marry one person at a time (Fisher, 1989, 1992, 1994).

I have hypothesized elsewhere that the brain circuitry for human monogamous attachment evolved soon after our ancestors descended from the fast-disappearing trees of East Africa some 4 million years ago (Fisher, 1989, 1992, 1994). With the evolution of the upright bipedal stride, ancestral females became obliged to carry their infants in their arms instead of on their backs. Ancestral females began to need a mate to protect and provision them—at least while they carried and nursed an infant. As pair-bonding became critical to females, it became suitable to males. A male would have had difficulty protecting and providing for a harem of females as he wandered the African plains, but he could provide for and defend a single female and her infant. So with time, natural selection favored females and males with the genetic propensity to form pair-bonds; their young disproportionately survived; and the brain circuitry for attachment evolved.

But almost all societies permit divorce; moreover, divorce is common in cultures around the world. Several patterns to human divorce have purely cultural explanations (see Fisher, 1989, 1992, 1994). But data taken from the Demographic Yearbooks of the United Nations on 62 societies for all obtainable years between 1947 and 1989 indicate several worldwide patterns of divorce that do not correlate with divorce rates (Fisher, 1989, 1992, 1994). Among those patterns are the findings that marriages tend to dissolve during and around the fourth year of marriage, and that most divorced individuals of reproductive age remarry (Fisher, 1989, 1992, 1994). Serial monogamy is common in cultures worldwide.

A look at attachment behaviors in other species suggests that these patterns have a biological component. Males and females in over 90% of some 9,000 species of birds form a pair-bond at the beginning of the mating season. But in more than 50% of these avian species, partners go their separate ways at the end of the breeding period; most join with a new partner in the next mating season. Only 3% of mammals form pair-bonds to rear their young. Nevertheless, the

same habit of serial pairing in conjunction with a breeding season prevails in many of these species.

The modal duration of human marriage that ends in divorce, around 4 years, conforms to the traditional period between human successive births, 4 years. So I have proposed that the worldwide human tendency to pair and remain together for about 4 years reflects an ancestral hominid reproductive strategy to pair and remain together at least through the breast-feeding and infancy of a single child. Once an ancestral youngster was able to join a multi-age play group at about age 4, the older siblings, aunts, grandmothers, and other members of the hunting-gathering band could take up much of the burden of parenting. So if a couple did not conceive a second child together, both were free to disband, find new partners, and breed again—creating genetic variety in their respective lineages. Worldwide serial monogamy is probably the remnant of an ancestral breeding season.

This human tendency to divorce probably has a physiological correlate in the brain. Perhaps the receptor sites for the attachment chemicals become overstimulated or the brain produces less of these compounds, leaving one physiologically susceptible to separation. Then with time, the brain systems for the sex drive and attraction predominate and one begins to court, fall in love, mate, and attach again.

Conclusion

Human beings exhibit three interrelated, yet distinct, emotion systems for mating, reproduction, and parenting: the sex drive, attraction, and attachment. It is hypothesized that the independence of these emotion systems evolved to enable our hominid forebears to attach to a mate while they simultaneously took advantage of extra-pair mating opportunities. Males who were adulterous acquired additional chances to bear young; females who were adulterous procured friendships with additional males who could provide valuable food, protection, and connections to other bands. Extra-pair copulations could also provide females with different, perhaps superior genes for their forthcoming young. The independence of these brain systems also enabled our ancestors to practice serial monogamy as well as take advantage of a wide mix of secondary reproductive strategies, including polygyny and polyandry.

With the concomitant evolution of the human prefrontal cortex and its brain and bodily connections, our ancestors also evolved the neural architecture to make decisions and oversee, often even override, the forces of lust, attraction, attachment, and detachment. In fact, some 75% of American men and 85% of American women report that they are not adulterous; some 50% of Americans marry for life.

But men and women do not always control these primal emotions. At least 25% of homicides in the United States involve spouses, sexual partners, or sexual rivals. In any given year, some 1 million American women are stalked by rejected lovers; some 370,000 men are stalked by former partners; and approximately 1.8 million wives in the United States are beaten by their husbands (see Meloy, 1998). In fact, male jealousy is the most common cause of wife battering in cultures around the world. Husbands also receive physical abuse from wives. Moreover, demographers estimate that the divorce rate in the United States will soon reach 67%; high divorce and remarriage rates are seen in many other cultures (Fisher, 1999). Inappropriate sexual advances, sexual jealousy, spousal battering, and adultery are also common in cultures around the world. And an untold number of men and women commit suicide or experience clinical depression when a love relationship fails.

So further exploration of the brain circuitry of romantic attraction and investigation of the interactions among these three primary emotion systems may contribute to the understanding of some contemporary patterns of criminality, social deviance, and mental illness.

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