

1

BROKEN HEARTS: THE NATURE AND RISKS OF ROMANTIC REJECTION

Helen Fisher
Rutgers University

“Oh, tell me the truth about love,” poet W. H. Auden wrote. Poems, dramas, novels, songs, stories, myths, legends, and men and women around the world have attempted to describe love. The earliest love poems come from ancient Sumeria some 4,000 years ago (Wolkstein, 1991). But our forebears probably mused about love since they evolved the rudiments of language and spoke across their campfires over a million years ago. Love means many different things to many different people. But this multi-faceted experience is becoming understood.

Neuroscientists currently believe that the basic human emotions and motivations arise from distinct circuits or systems of neural activity (Davidson, 1994; Panksepp, 1998). Among these neural systems, humanity has evolved three distinctly different yet interrelated brain systems for courtship, mating, reproduction, and parenting (Fisher, 1998). These are lust, romantic love, and male/female attachment.

Lust, characterized by the craving for sexual gratification, is associated primarily with the androgens in both men and women (Edwards & Booth, 1994; Sherwin, 1994; Van Goozen et al., 1997). Studies of human sexual arousal that use functional magnetic resonance imaging (fMRI) show that specific networks of brain activation are associated with the sex drive (Arnow et al., 2002; Beauregard, Levesque, & Bourgouin, 2001; Karama et al., 2002).

Romantic love, characterized by elation, heightened energy, mood swings, focused attention, obsessive thinking, craving for emotional union with a beloved, goal-oriented behaviors, and intense motivation to win a preferred mating partner, is associated primarily with dopaminergic pathways in the reward system of the brain (Aron et al., 2004; Bartels & Zeki, 2000, 2004; Fisher et al., 2003).

Male/female attachment (or companionate love), characterized by the maintenance of proximity, affiliative gestures, and expressions of calm and contentment when in social contact with a long-term mating partner and “separation anxiety” when apart, is associated with the neuropeptides, oxytocin and vasopressin, and related brain systems (Carter, 1992; Carter et al., 1997; Lim, Murphy, & Young, 2004; Lim & Young, 2004; Pitkow et al., 2001; Young, Wang, & Insel, 1998; Young et al., 1999).

Each primary brain system for loving—lust, romantic love and attachment—produces a different constellation of thoughts, feelings, and behaviors. Each evolved to play a different role in courtship, mating, reproduction, and parenting (Fisher,

1998; Fisher et al., 2002a; Fisher et al., 2002b; Fisher, 2004). The sex drive evolved to motivate our ancestors to seek coitus with a *range* of partners. Romantic love evolved to motivate individuals to select among potential mates, prefer a *particular* individual, and focus their courtship attention on this favored mating partner, thereby conserving precious courtship time and energy. The brain system for male/female attachment evolved primarily to enable our forebears to sustain this affiliative connection long enough to rear a single child through infancy together (Fisher, 1992).

In this chapter I discuss the most powerful of these three neural systems—romantic love. I illustrate some of the ways in which romantic love interacts with feelings of lust and attachment, and explore the biology, feelings, adaptive functions, and risks of a broken heart.

Almost no one in the world escapes the craving, depression, fear, and rage that rejection can create (Baumeister & Dhavale, 2001). Among college students at Case Western Reserve, 93% of both sexes reported having been spurned by someone they adored. Moreover, 95% said they had rejected someone who was deeply in love with them (Baumeister, Wotman, & Stillwell, 1993). Through an understanding of the biology of romantic love, the range of psychophysiological feelings associated with romantic rejection and the possible ways to alleviate the pain of spurned passion, educators, parents, and friends can help teenagers and young adults cope with this painful and dangerous experience—lost love.

Romantic Love: Psychophysiological Properties

Intense attraction, commonly known as romantic love, is recorded in all human societies for which data are available (Jankowiak & Fischer, 1992). This experience is associated with a specific constellation of emotions and motivations (Fisher 1998, 2004; Harris, 1995; Hatfield & Sprecher, 1986; Tennov, 1979).

Romantic love begins as an individual comes to regard another as special, even unique. As a love-stricken American man remarked, “The world has a new center and that center is Maryanne.” The lover then intensely focuses his/her attention on this preferred individual, aggrandizing and adoring the beloved’s good traits and overlooking or minimizing their flaws. Characteristically, the lover also experiences extreme energy, hyperactivity, sleeplessness, euphoria, mood swings, goal-oriented behaviors, and a strong motivation to win the beloved. Adversity heightens their passion. This is known as the “Romeo and Juliet Effect” or “frustration attraction” (Fisher, 2004). Lovers become emotionally dependent on the relationship; many experience separation anxiety; many reorder their daily priorities to remain in contact with their sweetheart; most feel a powerful sense of empathy for their amour; and many report that they would even die for their beloved. A striking property of romantic love is “intrusive thinking”—the smitten lover thinks obsessively about the beloved. Most important, the lover craves

emotional union with his/her sweetheart. And although the love-stricken individual feels intense sexual desire for their special other, as well as intense possessiveness of him or her, the lover's craving for emotional union takes precedence over their longing for sexual contact. Last, romantic passion is involuntary and difficult, even impossible, to control.

This constellation of psychophysiological traits suggests that romantic love is associated with many brain systems. However, two neurotransmitters may be primary contributors—elevated activity of dopamine and decreased activity of serotonin—largely because these monoamines, in particular concentrations, produce many of the above traits associated with romantic love (Fisher, 1998).

Elevated activity of central dopamine has been associated with focused attention, extreme energy, hyperactivity, sleeplessness, elation, mood swings, craving, emotional dependence, goal-oriented behaviors, and strong motivation to pursue and win a preferred reward (Abbott, 2002; Colle & Wise, 1988; Kiyatkin, 1995; Post, Weiss, & Pert, 1988; Robbins & Everitt, 1996; Salamone, 1996; Schultz, Dayan, & Montague, 1997; Wise, 1988, 1996). All of these traits are characteristic of romantic love.

Low activity of central serotonin is most likely also involved, because obsessive thinking is central to the experience of being in love and obsessive thinking is currently thought to be due to decreased activity of this neurotransmitter (Flament, Rapoport, & Berg, 1985; Hollander et al., 1988; Thoren, Asberg, & Bertilsson, 1980).

So I have hypothesized that romantic love is associated with elevated activities of central dopamine and decreased activity of central serotonin (Fisher, 1998). "Being in love" takes a variety of graded forms, however, ranging from romantic love that is returned to unrequited love. These gradations of romantic attraction are most likely associated with varying ratios of dopamine and serotonin, as well as many other brain systems (Fisher, 1998, 2004; Fisher et al., 2002).

Brain Scanning Studies of Romantic Love

Recent data indicate that at least one of these neurotransmitters, dopamine, is involved in romantic love.

Using functional magnetic resonance imaging (fMRI), Fisher and colleagues Lucy Brown, a neuroscientist at the Albert Einstein College of Medicine; Arthur Aron, a research psychologist at State University of New York at Stony Brook; and others studied the brain activity of seven men and ten women who had "just fallen madly in love" (Aron et al., in preparation; Fisher et al., 2003). Participants reported being in love an average of 7.4 months (median = 7; range 1–17 months); they ranged in age from 18 to 26.

The experiment consisted of four tasks. Each subject looked at a photograph of his/her beloved, as well as the photograph of an emotionally-neutral acquaintance, inter-spersed with a "distraction task". The distraction task consisted of looking at a large number, such as 8,241, and (beginning with this number) counting backwards in increments of seven. This task was designed to wash the mind clean of all emotion between looking at the positive and neutral stimuli. Hence the protocol consisted of (1) positive stimulus (30 seconds); (2) distraction task (40 seconds); (3) neutral stimulus (30 seconds); and (4) distraction task (20 seconds). This process (or its reverse) was repeated six times; the experiment lasted about 12 minutes.

The results indicated that central dopamine is associated with feelings of romantic passion.

When looking at the positive image (the beloved), subjects showed increased activity in many brain regions. Most pertinent, however, was activity in the right ventral tegmental area (VTA) of the midbrain and several regions of the caudate nucleus. The VTA is rich in cells that produce and distribute dopamine to many brain areas, including the caudate nucleus. Moreover, the VTA is part of the brain's "reward system" (Breiter et al., 2001; Fiorillo, Tobler, & Schultz, 2003; Martin-Soelch et al., 2001; Schultz, 2000; Schultz et al., 1997; Volkow et al., 1997; Wise, 1996), the network that controls general arousal, sensations of pleasure, focused attention and motivation to pursue and acquire rewards (Delgado et al., 2000; Elliot et al., 2003; Gold, 2003; Schultz, 2000).

The caudate nucleus is also associated with motivation and goal-oriented behaviors and is central to the reward system. The caudate plays a role in reward detection and expectation, the representation of goals, and the integration of sensory inputs to prepare for action to win a reward (Martin-Soelch et al., 2001; Schultz, 2000). Some 80% of receptor sites for dopamine reside in the caudate nucleus.

Using functional magnetic resonance imaging (fMRI), Bartels and Zeki also investigated brain activity in seventeen young men and women who reported being "truly, deeply, and madly in love" (Bartels & Zeki, 2000, p. 3829). Eleven were women; all looked at a photograph of their beloved and photos of three friends of similar age, sex, and length of friendship. In this study, individuals were in love an average of 2.3 years, however. Thus, the love relationships of these individuals were considerably longer than the love relationships in the study by Fisher and colleagues. These individuals were also less intensely in love (Aron et al., in preparation). This was established because both groups of subjects were administered the same questionnaire prior to scanning, the Passionate Love Scale (Hatfield & Sprecher, 1986).

In spite of these differences in protocol, Bartels and Zeki (2000, 2004) also found that feelings of romantic love were associated with a region of the caudate nucleus and the ventral tegmental area (as well as several other brain regions).

These data support the hypothesis that mesolimbic dopamine pathways in the reward system of the brain play a central role in the euphoria, mood swings, energy, sleeplessness, focused attention, emotional dependence, craving, motivation, and goal-oriented behaviors associated with romantic love (Fisher, 1998).

A recent study also supports the hypothesis that decreased activity of central serotonin is associated with the obsessive thinking so characteristic of romantic love. In this experiment 20 men and women who had fallen in love in the previous six months, 20 who suffered from unmedicated obsessive-compulsive disorder (OCD), and 20 normal (control) individuals who were not in love were tested for concentrations of serotonin transporters in blood platelets (Marazziti et al., 1999). Both the in-love participants and those suffering from OCD had significantly lower concentrations of platelet serotonin transporters than did the controls. Thus, it is likely that decreased activity of central serotonin contributes to the lover's obsessive thinking. Decreased activity of central serotonin is also associated with impulsivity, another trait of romantic love.

The Drive to Love

Psychologists distinguish between emotions and motivations—brain systems oriented around planning and pursuit of a specific want or need. Our colleague, Arthur Aron, had proposed that romantic love is not an emotion but a motivation system designed to enable suitors to build and maintain an intimate relationship with a preferred mating partner (Aron & Aron, 1991; Aron, Paris, & Aron, 1995). Because the above-mentioned experiments indicate that this passion emanates from the VTA and caudate nucleus, Aron's hypothesis was proven correct: motivation and goal-oriented behaviors are involved in romantic love. These findings then suggested to me that romantic love is a *primary* motivation system—a fundamental human mating drive (Fisher, 2004).

Neuroscientist Donald Pfaff defined a drive as a neural state that energizes and directs behavior to acquire a particular biological *need* to survive or reproduce (Pfaff, 1999, pp. 7, 40). Like drives, romantic attraction is tenacious; emotions come and go (you can be happy in the morning and angry in the afternoon). Like drives, romantic love is focused on a specific reward, the beloved, in the same way that hunger is focused on food. Emotions, such as disgust, pin themselves instead to an immense variety of objects and ideas. Like drives, romantic love is not associated with any particular facial expression; all of the primary emotions (such as anger, fear, joy, surprise, and disgust) have stereotypic facial poses. Like drives, romantic love is exceedingly difficult to control. It is harder to curb thirst, for example, than to control anger. And like all of the basic drives (Pfaff, 1999), romantic love is associated with the elevated activity of central dopamine.

Drives lie along a continuum (Fisher, 2004). Some, like thirst and the need for warmth, cannot be extinguished until satisfied. The sex drive, hunger, and the maternal instinct can often be redirected, even quelled. Falling in love is evidently stronger than the sex drive because when one's sexual advances are rejected, people do not tend to kill themselves or someone else. Rejected lovers, on the contrary, sometimes commit suicide or homicide.

Romantic love exhibits all of the primary traits associated with drives (Fisher, 2004). Moreover, on the continuum of drives, it appears to be basic. So I have hypothesized that romantic love is a primary mating drive.

Animal Attraction

This drive appears to be ubiquitous among avian and mammalian species (Fisher, 2002a; Fisher, 2004). No bird or mammal will copulate with any conspecific; they all have preferences. In fact, this drive to pursue *specific* mating partners is so common that the ethological literature regularly uses several terms to describe it, including "mate choice," "female choice," "individual preference," "favoritism," "sexual choice," and "selective perceptivity." This mate preference is associated with many of the same characteristics associated with romantic love, including heightened energy, focused attention on a preferred mating partner, obsessive following, sleeplessness, loss of appetite, possessive "mate guarding," affiliative gestures, goal-oriented courtship behaviors, and intense motivation to court and win a specific individual (Fisher, 2004).

Moreover, data from animal studies indicate that, similar to humans, elevated activities of central dopamine play a primary role in mammalian mate preference. In rats, blocking the activities of dopamine diminishes specific proceptive behaviors, including hopping and darting (Herbert, 1996). An increase in central dopamine is associated with mate attraction in female sheep (Fabre-Nys et al., 1998). When a female lab-raised prairie vole is mated with a male, she forms a distinct preference for him, a preference associated with a 50% increase of dopamine in the nucleus accumbens, a region of the brain's reward system (Gingrich, Liu, Cascio, Wang, & Insel, 2000). In fact, when a dopamine antagonist is injected into the accumbens, the female no longer prefers this partner; and when a female is injected with a dopamine agonist, she begins to prefer the conspecific who is present at the time of infusion, even if she has not mated with this male (Gingrich et al., 2000; Wang et al., 1999).

Hence the brain system associated with mate preference is associated with the same catecholamine in several mammalian species, including human beings. This brain system for "animal attraction" unquestionably operates in tandem with myriad other neural networks, including the sex drive and specific sensory circuits for mate discrimination, as it does in *Homo sapiens*. But it is parsimonious to suggest that animal attraction evolved for the same adaptive reason that romantic love evolved in humans: to enable individuals to *prefer* potential mating partners

who advertise superior genes, better resources and/or more parental investment and motivate them to focus their courtship attention on these individuals, thereby conserving courtship time and energy (Fisher, 1998, 2004; Fisher et al., 2002b).

In most species of mammals, this excitatory state is brief. In fact, the human phenomenon of "love at first sight" probably stems from instant attraction among mammals. This expression of attraction most likely lasts only minutes in rats, days among elephants, and weeks among foxes (Fisher, 2004). In humans, the neural mechanism for attraction is more developed, forming the physiological basis of what is commonly known as romantic love.

Nevertheless, the considerable data on mate *preference* in mammalian and avian species, including humans, and the association of this mate preference with subcortical dopaminergic pathways in other mammals as well as humans suggests that attraction is a specific brain system; this neural system is associated primarily with central pathways for dopamine and serotonin; romantic love is best characterized as a drive; and this mating drive evolved to facilitate pursuit of preferred mating partners.

The brain system for human romantic love most likely evolved from the neural mechanism for animal attraction along with the general development of the hominid brain some two million years ago (Fisher, 2004). *Hence all teens and young adults have inherited this powerful biological network for reproduction.* And just about all of these young people are susceptible to being emotionally (and physically) swept away by romantic love at times that are incompatible with their school, social, and family responsibilities.

Moreover, the biological system for romantic love is integrally connected with a range of other neural systems, including the brain system for the sex drive and the neural circuitry for attachment. These interactions can cause additional psychological, social, and familial problems for teens and young adults (as well as for the rest of us).

Romance Triggers Lust

Few people in Western societies confuse the ecstasy, obsession, and longing of romantic love with the mere appetite for sexual gratification (Hatfield & Rapson, 1996; Tennov, 1979). Evidence indicates that this distinction is also easily made in an array of traditional societies (Bell, 1995; Harris, 1995; Jankowiak, 1995; Rebhun, 1995). Nevertheless, people who fall in love generally begin to find their beloved enormously sexually attractive.

This positive association between romance and lust may be due, in part, to the biological link between these two brain systems. Dopamine, associated with romance, can stimulate a cascade of reactions, including the release of testosterone, the hormone of sexual desire (Hull et al., 1995; Hull, Lorrain, & Matuszewick, 1997; Kawashima & Takagi, 1994; Szezycka, Zhou, & Palmiter, 1998; Wenkstern, Pfaus,

& Fibiger, 1993; Wersinger & Rissman, 2000). In fact, data indicate that elevated activity of dopamine generally elevates the sex drive, sexual arousal, and sexual performance in humans (Clayton et al., 2000; Fabre-Nys, 1998; Heaton, 2000), even in men and women who are depressed. When depressed people take antidepressant drugs that elevate the activity of central dopamine, their sex drive and sexual performance improve (Ascher et al., 1995; Coleman et al., 1999; Walker et al., 1993).

So when teens and young adults fall in love, they can also become biologically motivated to seek sexual activity with their beloved.

important to the discussion in this chapter, a teenage romantic “crush” can lead to sexual activity, creating psychological and social complications as well as risks to health.

Lust Brings Romance?

But is the reverse true; can lust stimulate amour? Can a young man or woman climb in bed with “just a friend” or stranger and then suddenly fall in love with him or her?

Many teens and young adults have copulated with “just a friend” and never fallen in love. But it can happen, perhaps because increasing activity of testosterone associated with the sex drive can elevate the activity of dopamine (Hull et al., 1999), one of the neurotransmitters associated with romance. This positive correlation also occurs in other animals: sexual activity can increase the brain activity of dopamine (Damsma et al., 1992; Pleim et al., 1990; Yang et al., 1996). Even without sexual activity, however, the increasing activity of testosterone can elevate levels of dopamine (Hull et al., 1999), as well as suppress the activity of serotonin (Gonzalez et al., 1994; Netter et al., 1998; Sundblad & Eriksson, 1997). In short, the hormone of sexual desire can produce the combination of brain chemicals associated with romantic passion: elevated activity of central dopamine and lower activity of central serotonin. Hence teens and young adults who copulate with “just a friend” are biologically susceptible to falling in love.

Women may be particularly vulnerable to falling in love with a casual sex partner because seminal fluid also contains dopamine and tyrosine, a building block of dopamine (Burch & Gallup, in press). Although these chemicals do not pass across the blood-brain barrier, elevated activities of dopamine and tyrosine may affect brain physiology through other complex interactions. In fact, people report that sex can lead to romantic love. The natives of rural Nepal even use an off-color term for this phenomenon, saying “Naso pasyo, maya basyo,” or “the penis entered and love arrived” (Ahearn, 1998).

Once again, this biological link between lust and romantic love is not direct or simple. Athletes who inject synthetic androgens to build muscle do not fall in love. When middle-aged men and women inject androgens or apply testosterone cream to stimulate their sex drive, their sexual thoughts and fantasies increase (Sherwin & Gelfand, 1987; Sherwin, Gelfand, & Brender, 1985). But neither do these individuals become enamored.

Nevertheless, the chemical interactions between testosterone and dopamine and the chemical changes that accompany sexual arousal suggest that those who engage in sexual intercourse are more likely to fall in love; their threshold for this passion is lowered. And women who engage in sex without a condom may be even more susceptible to romantic passion. Hence teens and young adults who pursue “casual sex” with a friend or stranger can become enamored with their sexual partner even when they have no intention of beginning a romance.

Lust Can Trigger Attachment

Sexual activity can also trigger the brain system for attachment. In humans, orgasm elevates the activity of oxytocin and vasopressin (Carmichael et al., 1987; Young et al., 1998); and these neuropeptides are associated with attachment in people and other animals (Wang, Ferris, & DeVries, 1994; Williams et al., 1994; Young et al., 1998).

Hence, teenagers who engage in casual sex can trigger the brain system for attachment (as well as that for romantic love), leading to complex, unanticipated emotional entanglements with psychologically and socially unsuitable mating partners.

Lust, Romance, and Attachment

Despite the interactions between these three brain systems—lust, romantic love, and attachment—these mating drives can also act independently. You can feel profound attachment for a long-term partner *while* you feel romantic passion for someone else *while* you feel the sex drive for a range of other individuals.

The independence of these three motivation/emotion systems most likely evolved to enable ancestral men and women to opportunistically engage in several reproductive relationships simultaneously. Perhaps a million years ago many formed a socially sanctioned partnership with one mate at a time, along with one or more clandestine “extra-pair” relationships, as is characteristic of men and women cross-culturally today (Fisher, 1992, 2004).

But the neural independence of these three motivation/emotion systems almost surely contributes to our contemporary worldwide patterns of adultery and divorce, the high incidence of sexual jealousy, and the prevalence of homicide, suicide, and clinical depression associated with naïve expectations and disappointments in love.

Teens and young adults are just as vulnerable to these conflicting appetites as everybody else. And because regions of the prefrontal cortex associated with decision making do not mature until the mid-teens, young men and women may have less impulse control as well. Thus for teens and young adults, the complex interactions between these three basic brain systems can contribute to unrealistic expectations of romance and sexual activity, unstable and inappropriate romances and attachments, philandering, and broken hearts.

And a broken heart is a far more serious condition than many scientists, educators, and parents realize. As Emily Dickinson wrote, “Parting is all we need to know of hell.”

Protest: The First Stage of Rejection

In 2001 I and my colleagues used functional Magnetic Resonance Imaging (fMRI) to investigate the brain activity associated with rejection in love. We used the same protocol that had been followed among our subjects who were happily in love, but this time we collected data on those who had recently been “dumped.” Each participant looked at a photograph of his/her rejecting partner, as well as a photo of an emotionally neutral individual, interspersed with the same distraction task, mentally counting backwards from a large number in increments of seven.

This study is in progress. But we anticipate we will once again find activity in the ventral tegmental area and associated regions of the caudate nucleus because lovers generally remain “in love” for weeks, months, or years after they have been rejected. We may find activity in many other brain regions as well, because romantic rejection is a complex experience.

Psychiatrists divide romantic rejection into two phases: “protest” and “resignation/ despair” (Lewis, Amini, & Iannon, 2000). During the protest phase, abandoned lovers are generally dedicated to winning their sweetheart back. They obsessively dissect the relationship, trying to establish what went wrong; and they doggedly strategize about how to rekindle the romance. Disappointed lovers often make dramatic, humiliating, even dangerous entrances into a beloved’s home or place of work, then storm out, only to return to berate or plead anew. They visit mutual haunts and shared friends. And they phone, e-mail, and write letters, pleading, accusing, and/or trying to seduce their abandoner.

Psychiatrists Lewis, Amini, and Iannon (2000) argued that this “protest response” is a basic mammalian reaction to the rupture of any social tie. Moreover, they hypothesized that this protest response is associated with the elevated activity of dopamine and its close chemical relative, norepinephrine. Elevated activities of these chemicals, they argued, produce heightened alertness and stimulate the abandoned animal to call for help and search for its abandoner, generally its mother.

The biology of this “protest response” lends some insight into why romantically rejected teens and young adults can engage in dangerous, even humiliating behaviors as they attempt to win their beloved back.

Frustration Attraction

Associated with abandonment and protest is a related biological phenomenon: as adversity intensifies, so does romantic passion. As the Roman poet Terence wrote, “The less my hope, the hotter my love.” This phenomenon is so common in the psychological literature that I refer to it as “frustration attraction” (Fisher, 2004). When romantic love is thwarted, the lover just loves harder.

Frustration attraction may be a direct result of the protest response: As abandonment elevates the activity of central dopamine during protest, this rising catecholamine simply intensifies one’s passion. Another brain mechanism may

contribute to frustration attraction: the stress system. As stress increases, it triggers the production of dopamine (and norepinephrine) and suppresses serotonin activity (Kapit, Macey, & Meisami, 2000; Nemeroff, 1998), the cocktail of neurotransmitters associated with romantic love.

Frustration attraction may also be due, in part, to another brain response associated with abandonment: the neural reaction to a delayed reward. When an expected reward is delayed in coming, reward-expecting neurons prolong their activities (Schultz, 2000). These neurons are central components of the brain's dopaminergic reward system, the pathways associated with romantic love.

Hence the teenager or young adult who has been rejected is susceptible to a host of socially compromising and psychologically debilitating feelings, behaviors, and desires, including impulsive and inappropriate show-downs and intense craving for a departed beloved. The protest phase of rejection may also trigger activity in the brain's panic system, the network associated with "separation anxiety" (Panksepp, 1998). So the youngster may panic, too.

How each individual copes with these reactions of protest, frustration-attraction, stress, and panic will vary with his/her idiosyncratic biological make-up, experiences, and cultural milieu. Nevertheless, rejected lovers (of any age) suffer a complex array of intense emotions and motivations. And young adults may be particularly vulnerable due to their inexperience and lack of impulse control.

Abandonment Rage

Yet another brain system often becomes active as the rejected lover protests the departure of a beloved: rage. Even when the departing individual severs the partnership with honesty and compassion and honors his/her social obligations to the relationship, many rejected lovers swing violently from heartbreak to fury. Psychologist Reid Meloy called this reaction "abandonment rage" (Meloy 1998, 1999). I use the term "love hatred" as well. Abandonment rage is a curious reaction. Unlike protest and frustration attraction, hate and rage are not likely to entice an abandoning mate to return to the partnership. Why does love turn to hate and rage?

Love and hate/rage are linked in the brain (Fisher, 2004). The primary rage system is closely connected to centers in the prefrontal cortex that anticipate rewards (Panksepp, 1998). Animal studies have shown how intimately these reward and rage circuits are intertwined. Stimulate a cat's reward circuits and it feels intense pleasure; withdraw the stimulation and it bites (Panksepp, 1998). This common response to unfulfilled expectations is known as "frustration-aggression" (Panksepp, 1998). Thus, romantic love and love-hatred are well linked in the brain. And when the drive to love is thwarted, the brain can rapidly turn this passion into fury.

Rage elevates blood pressure, stresses the heart, and suppresses the immune system (Dozier, 2002; Panksepp, 1998). So this response must have evolved to solve some crucial reproductive problem. Perhaps abandonment rage emerged to enable jilted lovers to extricate themselves more swiftly from a dead-end relationship so they could renew the vital courting process sooner (Fisher, 2004). Abandonment rage most likely also motivates people to fight for the welfare of their offspring (Fisher, 2004). This occurs in divorce proceedings: otherwise well-adjusted men and women become diabolical to acquire custody of and resources for their children.

But abandonment rage does not extinguish romantic love. In a study of 124 dating couples, psychologists Bruce Ellis and Neil Malamuth found that romantic love and feelings of hate/rage can operate simultaneously (Ellis & Malamuth, 2000). Hence, you can be terribly angry at a rejecting sweetheart but still very much in love. In fact, the opposite of love is not hate but indifference.

The mixture of violent emotions and motivations associated with rejection in love, including feelings of protest, frustration attraction, stress, panic, and abandonment rage, as well as a host of social emotions (not discussed in this paper) such as embarrassment, shame, and jealousy can unquestionably produce a psychobiological upheaval in almost anyone, and certainly in teens and young adults.

Resignation/Despair: Phase Two of Rejection

The rejected lover's problems can get worse. With time the spurned individual gives up pursuit of the abandoning partner. Then he or she must deal with intensified feelings of helplessness, resignation, and despair. Drugged by sorrow, most cry, lie in bed, stare into space, drink too much, or hole up and watch TV. Feelings of protest and anger resurface intermittently; but rejected lovers mostly just feel profound melancholy. In 1991, sociologists assessed 114 people who had been rejected by a sweetheart within the past eight weeks. More than 40% were clinically depressed; of these, 12% were suffering moderate to severe depression (Mearns, 1991). Some people in the despair phase of rejection kill themselves. Some die of a broken heart. Broken-hearted lovers expire from heart attacks or strokes caused by their depression (Nemeroff, 1998; Rosenthal, 2002). Resignation and despair are well documented in other mammalian species. When infant mammals are abandoned by their mother, first they protest and panic. Later they exhibit the "despair response" (Panksepp, 1998).

In humans, the despair response has been associated with several different networks in the brain—among them, the reward system. As the abandoned partner realizes that the expected reward will never come, dopamine-making cells in the midbrain decrease their activity (Schultz, 2000). Diminishing levels of dopamine produce lethargy, despondency, and depression (Panksepp, 1998). The stress

system also plays a role. As stress wears on, it suppresses the activity of dopamine and other monoamines, contributing to feelings of depression (Kapit et al., 2000; Nemeroff, 1998).

Like abandonment rage, the despair response seems counterproductive. Why waste time and energy moping? But depression may have evolved as a coping mechanism. Several scientists have proposed theories regarding depression as an adaptive mechanism (see Fisher, 2004). Among them, anthropologist Edward Hagen, biologists Paul Watson and Paul Andrews, and psychiatrist Andy Thomson argue that the high metabolic and social costs of depression are actually its benefits: depression is an honest, believable signal to others that something is desperately wrong (Hagen, Watson, & Thomson, in preparation). Depression is a cry for help in a time of intense need that compels friends and relatives to provide aid.

Depression may be adaptive for another reason: it provokes insight. Depression enables individuals to make more honest assessments of themselves and others (Watson & Andrews, 2002). Even severe depression can push a person to face unpalatable truths and make difficult decisions that ultimately promote their survival and reproductive success (Nesse, 1991; Rosenthal, 2002). So the intense depression that many rejected teens and young adults suffer is most likely deeply embedded in the brain.

Not everyone suffers from romantic rejection to the same degree, of course. Some make secure attachments as children and have the self-esteem and resilience to overcome a romantic setback relatively quickly. Others grow up in loveless homes fraught with tension, chaos, or rejection, leaving them “clingy” or defenseless in other ways (Ainsworth et al., 1978; Bowlby, 1969; Chisholm, 1995; Hazan & Shaver, 1987). Then as boys and girls mature, each develops new feelings of competence or incompetence, different sorts of romantic expectations, different sensitivities to rejection, and different coping mechanisms that affect how they will weather lost love (Downey & Feldman, 1996; Downey et al., 1998; Leary, 2001).

Moreover, some people have more mating opportunities so they easily replace an abandoning lover with amorous distractions that mitigate their feelings of protest and despair. And different people have different basic biological response patterns; some are less angry, less depressed, more self-confident, and more relaxed about life’s traumas in general or about romantic rejection in particular. Myriad biological, psychological, and social circumstances surrounding one’s romantic disappointment contribute to his/her ability to withstand the trauma of rejected love.

On average, men and women express some differences in how they handle rejection, too. Men are often more dependent on their romantic partners (Baumeister et al., 1993; Buss, 1994), probably because men have fewer ties to relatives and friends. Perhaps as a result, men are more likely to turn to alcohol, drugs, or reckless driving than to pals and kin when they have been dumped (Hatfield & Rapson, 1996). Men are also less likely to reveal their pain (Taffel, 1990; Tavris, 1992). There are exceptions: men are three to four times more likely than women to

commit suicide after being rejected (Hatfield & Rapson, 1993). And men are far more likely to stalk a rejecting partner, as well as to batter or kill her (Dozier, 2002; Fremouw, Westrup, & Pennypacker, 1997; Gugliotta, 1997; Meloy, 1998; Meloy & Gothard, 1995; Meloy, 2001; Wilson & Daly, 1992).

Rejected women report more severe feelings of depression, particularly hopelessness (Mearns, 1991). They are more likely than men to cry, lose weight, sleep too much or not at all, lose interest in sex, become unable to concentrate, forget things, and contemplate suicide (Hatfield & Rapson, 1996). Women are more verbally expressive, too. Many write about their feelings of loss; many more talk for hours with friends, reviewing their disappointments. These lengthy discussions are not always healing. As a woman dwells on the dead relationship, she can inadvertently retraumatize herself (Hatfield & Rapson, 1996).

Many biological, psychological, and social forces contribute to the degree and duration of a rejected lover's grief. But all human beings appear to be intricately wired to suffer when they have been spurned, for good evolutionary reasons. Rejected men and women have often wasted significant courtship time and metabolic energy. For many, their reproductive future has been jeopardized, along with their social alliances, personal happiness, self-esteem, and reputation as well.

Adolescents may be particularly vulnerable because these men and women are at a crucial phase in their development, attempting to make social and breeding relationships that will ensure their genetic future. In fact, the direct link between romantic rejection and the loss of significant social benefits and reproductive opportunities may partially account for the high rate of suicide among teens and young adults today.

Addicted to Love

Because of the central role of romantic love in pair formation, reproduction, and parenting, teens and young adults may be particularly susceptible to becoming addicted to a sweetheart, too.

Romantic love has all of the primary characteristics of an addictive substance (Fisher, 2004). Like drug addicts, the lover craves contact with the beloved. Like drug addicts, the lover also expresses increasing tolerance to the sweetheart. In the beginning of the relationship, the lover is often content to see the beloved irregularly; with time, however, the lover seeks to interact with the beloved more and more. Like drug addicts, the lover displays inappropriate, even dangerous behaviors when s/he senses physical or emotional barriers to the relationship. They are inclined to skip school or work, alienate teachers, employers, family, or friends to be near their sweetheart, spend money on things they cannot afford, even risk their lives to impress or see their beloved.

Moreover, if the beloved breaks off the relationship, the lover also shows the common signs of drug withdrawal, including depression, crying spells, lethargy, anxiety, insomnia or hypersomnia, loss of appetite or binge eating, irritability, and

chronic loneliness (Panksepp, 1998; Rosenthal, 2002). Indeed, a recent neuroimaging study indicates that emotional pain induced by social exclusion affects some of the same primary brain regions as does physical pain (Eisenberger, Lieberman, & Williams, 2003). So the physical pain that many rejected lovers report is real.

Rejected lovers also relapse the way drug addicts do. Long after the romantic relationship has ended, events, people, places, even songs associated with the beloved can trigger the lover's craving and initiate obsessive thinking and/or compulsive calling or writing to achieve contact with the beloved.

Even the primary brain chemical and brain region associated with romantic love are similar among drug addicts. Directly or indirectly, all "drugs of abuse" affect a single pathway in the brain, the mesolimbic reward system, associated with dopamine (Abbott, 2002; Leshner, 1997; Robbins & Everitt, 1996; Rosenthal, 2002; Schultz et al., 1997; Wise, 1989, 1996, 1998). Romantic love stimulates the same pathways with the same neurotransmitter (Aron et al., in preparation; Bartels & Zeki, 2000; Fisher et al., 2003). In fact, when neuroscientists Andreas Bartels and Semir Zeki compared the brain scans of their lover-stricken subjects with those of men and women who had injected cocaine or opioids, they found that many of the same brain regions become active (Bartels & Zeki, 2000). And animal studies of cocaine addiction (David et al., 2004; Kalivas & Duffy, 1998; McBride, Murphy, & Ikemoto, 1999; Wise & Hoffman, 1992), as well as fMRI studies involving cocaine injection in humans, indicate that activity in the VTA is associated with addiction (Breiter et al., 1997) as well as with romantic love.

Because romantic love is regularly associated with intensely focused attention, euphoria, craving, obsession, compulsion, distortion of reality, emotional and physical dependence, personality changes, and loss of self-control, psychologists regard romantic love as an addiction (Carnes, 1983; Findling, 1999; Griffin-Shelley, 1991; Halpern, 1982; Hunter, Nitscheke, & Hogan, 1981; Liebowitz, 1983; Melody, Miller, & Miller, 1992; Peele, 1975; Schaef, 1989; Tennov, 1979). This passion is a positive addiction when the lover's adoration is returned and a horribly negative fixation when the lover's passion is spurned.

In short, among adolescents (and the rest of us), romantic rejection is an addictive state with high risks to the sufferer, including severe psychobiological distress, social problems in school, work and family life, and potential physical and emotional harm to one's self and/or others.

Controlling Love

Because of the biological and behavioral affinities between romantic addiction and drug addiction, it might be prudent to employ some of the basic tenets of the "12-step" approach (used in Alcoholics Anonymous) to relieve some of the symptoms of romantic rejection.

Most important, avoid all possible contact with the rejecting partner. Sunlight, exercise, and a balanced diet can help stabilize brain physiology (Rosenthal, 2002). Dopamine neurons innervating the prefrontal cortex are stimulated during exposure to a novel environment (Tassin et al., 1980). New activities with family and friends can raise dopamine activity and potentially alleviate some of the pain of romantic withdrawal. "Talking therapy" and/or short-term use of antidepressant medications may be suitable for some disappointed lovers. Long-term use of serotonin-enhancing medications may jeopardize the individual's potential to fall in love again, however, because of their negative effects on neural dopaminergic pathways (Fisher, 2004; Fisher & Thomson, in preparation). Therefore, it is not advised that teens or young adults use this drug over the long term.

Most important, parents, siblings, teachers, and friends should regard romantic rejection as a serious, even life-threatening emotional and physical condition, and help the teen or young adult by listening, expressing concern, engaging the suffering individual in mind-absorbing activities, and excusing some of the rejected lover's inappropriate behaviors as they weather this utterly painful, although temporary, mental and physical malaise.

Future Research

Being in love is perhaps the most powerful psychobiological constellation of feelings experienced by a human being. Moreover, "cupid's fiery shaft" as Shakespeare called romantic love, can trigger the reward system in the brain at any time of life. Children aged five and seniors in their 70s report this passion (Hatfield & Rapson, 1987; Purdy, 1995). But this panoply of emotions and motivations may be particularly significant among young men and women because their romantic passion can play a central role in their reproductive future. In fact, in a study of 37 societies, men and women ranked love, or mutual attraction, as the primary criterion for choosing a spouse (Buss, 1994).

Even when romantic love is not linked with reproduction, this passion can provide a teen or young adult with some exceptional personal and social benefits, including exhilarating joy, increased energy and optimism, feelings of intimacy, self-esteem, inclusion in health-giving social groups, exercise, social and personal support, and crucial practice in the skills of building a long-term partnership—skills they will need to make the most important social contract of their reproductive lives. And when a love affair is ruptured, romantic rejection can lead to one of humanity's most dangerous sorrows—a broken heart.

Love matters. Yet little is currently known about the specific health benefits and risks of this primary mating drive, how and why people vary in their ability to fall in love, how the brain system for romantic love interacts with other neural