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The New Psychology of Love

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The Drive to Love: The Neural Mechanism for Mate Selection

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"Since the heaven and earth were created, you were made for me and I was made for you and I will not let you go," declared Chang Po to his beloved Meilan (Yutang, 1954, p. 73). The Chinese still cry over this twelfth-century Chinese fable, "The Jade Goddess," their version of Romeo and Juliet. "My beloved, the delight of my eyes," exclaimed Inanna of her beloved Dumuzi in a Sumerian poem recorded some four thousand years ago (Wolkstein, 1991, p. 51). An anonymous Kwakiutl Indian of southern Alaska recited these words in 1896: "Fires run through my body—the pain of loving you" (Hamill, 1996).

Paris and Helen, Orpheus and Eurydice, Abelard and Eloise, Troilus and Cressida, Tristan and Iseult, Shiva and Sati, Layla and Majnun: thousands of romantic poems, songs, and stories come across the centuries from Europe, the Middle East, Japan, China, India, and every other society that has left written or oral records. In a survey of 166 varied cultures, anthropologists found evidence of romantic love in 147 (Jankowiak and Fischer, 1992). There were no negative data; in the remaining nineteen societies, scholars had simply failed to examine this aspect of people's lives.

"What 'tis to Love?" Shakespeare asked in *As You Like It.* From the ancient Greeks to contemporary scholars, hundreds have offered theories about the components of love and styles of loving (Lee, 1988; Fehr, 1988;

Aron and Westbay, 1996; Hatfield and Sprecher, 1986; Critelli, Myers, and Loos, 1986; Hendrick and Hendrick, 1986; Zick, 1970; Hazan and Shaver, 1987; Sternberg, 1986). And for good reason: love has myriad variations. Nevertheless, neuroscientists believe that the basic human emotions and motivations arise from distinct systems of neural activity, networks that derive from mammalian precursors (Davidson, 1994; Panksepp, 1998). This article takes the neurological approach. It does not attempt to define one's idiosyncratic ways of loving that develop in childhood, nor why an individual chooses one person rather than another. Instead, it explores the underlying neural mechanisms associated with love, specifically romantic love.

Psychological studies indicate that romantic love is associated with a discrete constellation of emotions, motivations, and behaviors (Liebowitz, 1983; Hatfield and Sprecher, 1986; Tennov, 1979; Harris, 1995). Romantic love begins as an individual comes to regard another as special, even unique. The lover then intensely focuses his or her attention on this preferred individual, aggrandizing the beloved's better traits and overlooking or minimizing his or her flaws. Lovers experience extreme energy, hyperactivity, sleeplessness, impulsivity, euphoria, and mood swings. They are goal-oriented and strongly motivated to win the beloved. Adversity heightens their passion, in what is known as the Romeo and Juliet effect or "frustration attraction" (Fisher, 2004). Lovers become emotionally dependent on the relationship. They reorder their daily priorities to remain in contact with their sweetheart, and experience separation anxiety when apart. And most feel powerful empathy for their amour; many report they would die for their beloved.

A striking property of romantic love is "intrusive thinking." The lover thinks obsessively about the beloved. And, perhaps most central to this experience, the lover craves emotional union with his or her sweetheart. Plato wrote of this in *The Symposium* some twenty-five hundred years ago, saying the God of Love "lives in a state of need." Love-smitten individuals feel intense sexual desire, as well as extreme possessiveness of the beloved. Yet their craving for emotional union supersedes their longing for sexual contact. As a result, rejected lovers often go to extraordinary, inappropriate, even dangerous efforts to win back their sweetheart. Many spurned lovers suffer "abandonment rage" and depression as well, culminating in feelings of hopelessness, lethargy, resignation, and despair (Fisher, 2004). Last, romantic love is involuntary, difficult to control, and impermanent (Tennov, 1979; Hatfield and Sprecher, 1986; Harris, 1995). As Violetta sings in *La Traviata*, Verdi's tragic opera, "Let's live for pleasure alone, since love, like flowers, swiftly fades."

To further establish that the above assemblage of characteristics is accurate, I used these traits as domains in a questionnaire on romantic passion; 437 Americans and 402 Japanese filled out my questionnaire. The results indicate that romantic love does not vary considerably with age, gender, sexual orientiation, or ethnic group. For example, people over age forty-five and those under age twenty-five showed no significant statistical differences on 82 percent of the statements. On 87 percent of the queries, American men and women responded virtually alike. Heterosexuals and homosexuals gave statistically similar responses on 86 percent of the questions. American "whites" and "others" responded similarily on 82 percent of the questions. And where the above groups showed statistically significant differences in their responses, one group was usually just a little more passionate than the other. The greatest differences were between the Americans and the Japanese. On most of the forty-three questions where they showed statistically significant variations, these differences were small, however. And the twelve queries showing dramatic variance appeared to have cultural explanations (Fisher, 2004).

World poetry, myths and legends, many anthropological and psychological reports, and this questionnaire suggest that romantic love is a human universal (Jankowiak and Fischer, 1992; Fisher, 1998; Hatfield and Rapson, 1996). In fact, I have come to believe that romantic love is one of three discrete, interrelated emotion/motivation systems that all birds and mammals have evolved to direct courtship, mating, reproduction, and parenting. The other two are the sex drive and attachment. Each brain system is associated with different feelings and behaviors; each is associated with a different (and dynamic) constellation of neural correlates; each evolved to direct a different aspect of reproduction; and each interacts with the other two in myriad combinations to produce the range of emotions, motivations, and behaviors associated with all types of love (Fisher, 2004).

Lust, Attraction, Attachment: Three Brain Systems for Love

The sex drive (libido or lust) is characterized by the craving for sexual gratification; it is often directed toward many partners. In mammals, the sex drive is associated primarily with the estrogens and androgens; in humans, the androgens, particularly testosterone, are central to sexual desire in both men and women (Sherwin, 1994; Van Goozen, Wiegant, Endert, Helmond, and Van de Poll, 1997). Studies (fMRI) of human sexual arousal show that specific networks of brain activation are associated with the sex drive (Arnow, Desmond, Banner, Glover, Solomon, Polan, Lue, and Atlas, 2002;

Beauregard, Levesque, and Bourgouin, 2001; Karama, Lecours, Leroux, Bourgouin, Joubert, and Beauregard, 2002; Tiihonen et al., 1994). These vary; but among them are the hypothalamus (Arnow et al., 2002; Beauregard et al., 2001; Karama et al., 2002) and the amygdala (Beauregard et al., 2001; Karama et al., 2002).

Attraction (the mammalian/avian counterpart to human romantic love) is characterized by increased energy, focused attention on a specific mate, obsessive following, affiliative gestures, possessive mate-guarding, and motivation to win a *preferred* mating partner (Fisher, Aron, Mashek, Strong, Li, and Brown, 2002, 2002a; Fisher, 2004). In humans, the developed form of animal attraction is known as romantic love, obsessive love, passionate love, or being in love. Recent data suggest this brain system is primarily associated with elevated activity of dopamine in the reward pathways of the brain. Most likely it is also associated with elevated activity of central norepinephrine and suppressed activity of central serotonin, as well as other brain systems acting together to produce the range of emotions, motivations, cognitions, and behaviors common to romantic love (Fisher, 1998, 2004; Fisher et al., 2002, 2002a).

Attachment is characterized in birds and mammals by mutual territory defense and/or nest-building, mutual feeding and grooming, maintenance of close proximity, separation anxiety, shared parental chores, and affiliative behaviors (Carter, DeVries, Taymans, Roberts, Williams, and Getz, 1997; Lim, Murphy, and Young, 2004; Lim and Young, 2004). In humans, partner attachment is known as companionate love (Hatfield, 1988, p. 191). Human attachment is associated with the above mammalian traits, as well as feelings of calm, security, social comfort, and emotional union with a long-term mate. Animal studies suggest this brain system is associated primarily with oxytocin and vasopressin in the nucleus accumbens and ventral pallidum, respectively (Lim et al., 2004; Lim and Young, 2004).

Each of these primary brain systems evolved to play a different role in courtship, mating, reproduction, and parenting (Fisher, 1998, 2004; Fisher et al., 2002, 2002a). The sex drive evolved to motivate our ancestors to seek coitus with a *range* of appropriate partners. Attraction (and its developed human form, romantic love) evolved to motivate individuals to select among potential mates, *prefer* a particular individual, and *focus* courtship attention on this favored mating partner, thereby conserving courtship time and energy. Attachment evolved primarily to motivate individuals to sustain an affiliative connection with this reproductive partner at least long enough to complete species-specific parental duties. Moreover, these three brain systems interact in myriad ways to direct many behaviors, emotions, and motivations associated with human reproduction.

fMRI Studies of Romantic Love

To investigate the biology of romantic love in humans, I and my colleagues Lucy L. Brown of the Albert Einstein College of Medicine, Arthur Aron of SUNY Stony Brook, and Stony Brook graduate students Greg Strong and Debra Mashek embarked on a neuroimaging study of men and women who had "just fallen madly in love" (Fisher et al., 2003; Aron, Fisher, Mashek, Strong, Li, and Brown, 2005). My hypothesis was that this phenomenon was associated with elevated activity of central dopamine and/or norepinephrine and low activity of central serotonin (Fisher, 1998).

Using functional magnetic resonance imaging (fMRI), we collected data on ten women and seven men who reported being in love an average of 7.4 months (median 7; range 1–17 months); they ranged in age from eighteen to twenty-six. Each subject looked at a photograph of his or her beloved as well as a photograph of an emotionally neutral acquaintance, each viewing followed by a distraction task to cleanse the mind of strong emotion. This distraction task consisted of mentally counting backward from a large number, such as 9,471, in increments of seven. The protocol consisted of (1) positive stimulus (thirty seconds); (2) counting task (forty seconds); (3) neutral stimulus (thirty seconds); (4) counting task (twenty seconds). This process (or its reverse) was repeated six times; the experiment lasted about twelve minutes.

Group activation specific to the beloved occurred in several regions. Most significant was activity in the right ventral tegmental area (VTA) and right postero-dorsal body and dorsal tail of the caudate nucleus (Fisher, Aron, Mashek, Strong, Li, and Brown, 2003; Aron et al., 2005). The region activated in the VTA is rich in cells that produce and distribute dopamine to many brain regions, including the caudate nucleus. Moreover, the VTA is central to the brain's "reward system" (Schultz, 2000; Martin-Soelch, Leenders, Chevalley, Missimer, Kunig, Magyar, Mino, and Schultz, 2001; Breiter, Gollub, Weisskoff, Kennedy, Makris, Berke, Goodman, Kantor, Gastfriend, Riorden, Mathew, Rosen, and Hyman, 1997), the neural network associated with sensations of pleasure, general arousal, focused attention, and motivation to pursue and acquire rewards (Schultz, 2000; Delgado, Nystrom, Fissel, Noll, and Fiez, 2000; Elliott, Newman, Longe, and Deakin, 2003). The caudate nucleus is also associated with motivation and goal-oriented behaviors; it, too, is central to the dopaminergic reward system (Martin-Soelch et al., 2001; Schultz, 2000).

Using fMRI, Bartels and Zeki also investigated brain activity in seventeen men and women who reported being "truly, deeply, and madly in love" (2000, p. 3829). However, in this study, individuals reported being in love an average of 28.8 months, considerably longer. These subjects were less intensely in love. This was established (serendipitously) because both our participants and Bartels and Zeki's participants were administered the same questionnaire, the Passionate Love Scale (Hatfield and Sprecher, 1986), prior to scanning. Bartels and Zeki (2000, 2004) also found activation in a region of the dorsal caudate nucleus and the ventral tegmental area.

The above data suggest that the focused attention, motivation, and goal-oriented behaviors characteristic of romantic love are associated with elevated activity of central dopamine. Because specific activities of dopamine are also associated with ecstasy, intense energy, sleeplessness, mood swings, emotional dependence, and craving (see Fisher, 1998), dopamine most likely also contributes to these aspects of romantic love.

Elevated activity of norepinephrine and *low* activity of central serotonin may also be involved, although I have only corollary evidence at present. Norepinephrine is associated with a pounding heart, elevated blood pressure, and other physiological responses of the sympathetic nervous system, phenomena common to romantic love (Fisher, 1998, 2004). And scientists have recently studied concentrations of serotonin transporter in blood platelets of sixty individuals: twenty had fallen in love in the previous six months; twenty suffered from unmedicated obsessive-compulsive disorder (OCD); twenty normal (control) individuals were not in love (Marazziti, Akiskal, Rossi, and Cassano, 1999). Both the in-love participants and those suffering from OCD showed significantly lower concentations of the platelet serotonin transporter. Thus decreased activity of bodily (and perhaps also brain) serotonin most likely contributes to the lover's obsessive thinking and impulsivity.

The Drive to Love

Psychologists distinguish between emotions and motivations, which are brain systems oriented around planning and pursuit of a specific want or need. 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 and Aron, 1991; Aron et al., 1995). Because the above-mentioned experiments indicate that this passion is associated with activity in the VTA and caudate nucleus, Aron's hypothesis is most likely correct: motivation and goal-oriented behaviors form the core of romantic love. These findings then suggested to me that romantic love is a *primary* motivation system—a fundamental mating drive (Fisher, 2004).

Donald Pfaff defines 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). Romantic love shares many traits with basic drives: (1) Like all drives, romantic attraction is tenacious; emotions dissipate or change far more rapidly. (2) Romantic love is focused on a specific reward (the beloved); emotions, such as joy and disgust, are focused on a range of phenomena instead. (3) This passion is not associated with any particular facial expression, while all of the primary emotions have characteristic facial poses. (4) Like all drives, romantic love is exceedingly difficult to control; it is harder to curb thirst, for example, than anger. (5) And, like all of the basic drives (Pfaff, 1999), romantic love is associated with elevated activity of central dopamine.

Drives lie along a continuum (Fisher, 2004). Some, such as thirst and the need for warmth, can rarely be extinguished until satisfied, while the sex drive and the maternal instinct can often be redirected. Falling in love appears to be near the base of this continuum. For example, romantic love is considerably stronger than the sex drive. Few people whose sexual advances are rejected proceed to kill themselves or someone else, whereas rejected lovers in cultures around the world commit suicide or homicide; many more become depressed. In a study of 114 Americans who had been romantically rejected in the past eight weeks, 40 percent were clinically depressed; 12 percent suffered moderate to severe depression (Mearns, 1991). Since romantic love is a universal and powerful human mating drive, it must have evolved.

Evolution of Romantic Love: The Brain Network for "Mate Choice"

Ever since Darwin (1859, 1871) proposed the concept of sexual selection to explain patterns of sexual dimorphism in birds and mammals, scientists have been describing physical and behavioral traits that birds and mammals have evolved to *attract* potential mates (Andersson, 1994; Miller, 2000). The peacock's tail feathers are the standard example. But the corresponding brain mechanism by which the display chooser responds to these traits, comes to prefer a specific individual, and focuses his or her courtship time and energy on this *particular* conspecific has not been defined (Fisher et al., 2002, 2002a; Fisher, 2004).

Yet all birds and mammals express mate preferences; none copulate indiscriminately. The phenomenon of mate choice is so common in nature that the ethological literature regularly uses several terms to describe it, including "individual preference," "favoritism," "female choice," "sexual choice," "selective proceptivity," and "attraction." In most mammalian and avian species this mate preference is brief. In rats, for example, courtship attraction often lasts seconds; among elephants, it lasts three to five days; among foxes, it lasts about two weeks (Fisher, 2004). But all species display similar characteristics of attraction. Among these traits, attracted individuals focus their attention on a preferred mating partner and express heightened energy, obsessive following, sleeplessness, loss of appetite, possessive mate-guarding, affiliative courtship gestures such as patting, stroking, and nuzzling, goal-oriented courtship behaviors, and intense motivation to win this *particular* individual (see Fisher, 2004). All these traits are also characteristic of human romantic love. Moreover, many creatures express this attraction instantly, what may be the forerunner of human "love at first sight."

Animal studies indicate that this mate preference (or attraction) is associated with elevated activities of central dopamine, another similarity with human romantic love. When a female lab-raised prairie vole is mated with a male, she forms a distinct preference for him associated with a 50 percent increase of dopamine in the nucleus accumbens, a region of the brain's reward system (Gingrich, Liu, Cascio, Wang, and Insel, 2000). 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, Yu, Cascio, Liu, Gingrich, and Insel, 1999). An increase in central dopamine is also associated with mate attraction in female sheep (Fabre-Nys, 1998).

This mammalian (and avian) attraction system most likely evolved for the same adaptive reason it evolved in humans: to enable individuals to *prefer* specific mating partners, thereby conserving valuable courtship time and energy (Fisher, 1998, 2004; Fisher et al., 2002, 2002a). Then, at some point in hominid evolution, this mammalian neural mechanism for mate preference developed into human romantic love. Perhaps this process initially began as early as 3.5 million years ago, along with the evolution of hominid pair-bonding (Fisher, 1992; Reno, Meindl, McCollum, and Lovejoy, 2003), then started to take its developed human form some two million years ago as the brain began to exhibit some characteristically human traits (Fisher, 2004).

Biology of Romantic Rejection

To understand the range of emotions, motivations, and behaviors associated with human romantic love, my colleagues and I conducted a second fMRI study, this one of romantic rejection. We used functional magnetic resonance imaging (fMRI) to study ten women and five men who were still very much in love but had recently been rejected by their romantic partner (Fisher et al., 2005). We employed the same protocol as with our happily in love subjects. Rejected participants alternately viewed a photograph of their abandoning beloved and a photograph of a familiar, emotionally neutral individual, interspersed with a distraction attention task.

Preliminary analysis of the positive-neutral contrast showed significant group effects in the right nucleus accumbens/ventral putamen/pallidum, lateral orbitofrontal cortex, and anterior insular/operculum cortex (Fisher et al., 2005).

Other studies have shown that the nucleus accumbens/ventral pallidum/putamen region where we found activity becomes more active as an individual chooses a high-risk investment associated with big gains or big losses (Kuhnen and Knutson, 2005) or anticipates a monetary reward (Zald, Boileau, El-Dearedy, Gunn, McGlone, Dichter, and Dagher, 2004). This region is also part of the dopaminergic reward system (Gingrich, Liu, Cascio, Wang, and Insel, 2000). The region of the anterior insula/operculum cortex where we found activity has been associated with skin and muscle pain and anxiety (Schreckenberger, Siessmeier, Viertmann, Landvogt, Buchholz, Rolke, Treede, and Bartenstein, 2005). The region of the orbitofrontal cortex where we found activity hasbeen associated with "theory of mind" (Vollm, Taylor, Richardson, Corcoran, Stirling, McKie, Deakin, and Elliott, 2006), the human ability to muse on the thoughts and intentions of others; this brain region is also associated with evaluating punishers (Kringelbach and Rolls, 2004), implementing appropriate adjustments in behavior (Ridderinkhof, Van den Wildenberg, Segalowitz, and Carter, 2004), obsessive/compulsive behaviors (Evans, Lewis, and Iobst, 2004), and controlling anger (Goldstein, Alai-Klein, Leskovjan, Fowler, Wang, Gur, Hitzemann, and Volkow, 2005).

These results suggest that the dopaminergic reward system remains active in recently romantically rejected men and women, but the precise location of activity differs. These preliminary results also suggest that neural regions associated with taking risks for big gains or losses, physical pain, obsessive/compulsive behaviors, ruminating on the intentions and actions of the rejecter, evaluating options, and emotion regulation increase their activity when someone is rejected by a beloved.

Ours is the second investigation of romantic rejection. Najib and colleagues (2004) studied nine women who were "actively grieving" a recent romantic breakup. Preliminary comparisons uncovered no commonalities; in fact, in several regions where we found activations, they found deactivations. Because our subjects regularly reported anger and hope for reconciliation, while the subjects in the Najib et al. study more regularly reported acceptance of the situation, I suspect that our participants were in the initial stage of romantic rejection, the protest phase, while their participants were in the subsequent resignation/despair phase.

Protest: The Initial Stage of Romantic Rejection

Lewis, Amini, and Lannon divide romantic rejection into two general phases: protest and resignation/despair (2000). During the protest phase, abandoned lovers express intense energy, heightened alertness, and extreme motivation to win back their beloved. These psychiatrists theorize that this "protest response" evolved from a basic mammalian reaction to the rupture of *any* social tie. Moreover, they suggest that this protest response is associated with elevated activity of dopamine and norepinephrine, reasoning that these neurotransmitters most likely produce the heightened alertness, energy, and motivation that abandoned creatures exhibit as they call for help and search for their abandoner, generally their mother.

Our data on rejected lovers is preliminary evidence that the hypothesis of Lewis, Amini, and Lannon is correct: elevated activity in dopaminergic reward pathways are likely to be involved in the initial protest phase of romantic rejection. Our results may also help explain "frustration attraction"—why disappointed lovers begin to love their rejecting partner even more passionately (Fisher 2004). When a reward is delayed in coming, reward-expecting neurons *prolong* their activity (Schultz, 2000) and activity of the dopaminergic reward system is associated with feelings of intense romantic love. This phenomenon of frustration attraction appears to be maladaptive, but the intense energy, focused attention, extreme motivation, and goal-oriented behaviors that dopamine produce are useful biological tools for regaining a beloved (Fisher, 2004).

During the protest stage, rejected lovers often also experience "abandonment rage" (Meloy, 1998, 1999), another trait that may be linked to the dopaminergic reward system. The primary rage system has pathways to regions in the prefrontal cortex that anticipate rewards (Panksepp, 1998), and animal studies indicate that these reward and rage circuits are closely connected. For example, when you pet a cat, it expresses pleasure; when you withdraw the stimulation, it often bites (Panksepp, 1998), a response to unfulfilled expectations known as "frustration aggression." The data on our rejected lovers suggests one of the neural regions linked to this rage response, a region of the lateral orbitofrontal cortex associated with controlling anger.

These fMRI data on romantic rejection also suggest that the brain mechanisms for abandonment rage and romantic love can operate in tandem, biological data that corroborates current behavioral research. Ellis and Malamuth (2000) report that rejected men and women can be furious at a rejecting partner, while still being very much in love with him or her. Moreover, love and hate/rage have several behavioral similarities, including focused attention, obsessive thinking, heightened energy, and intense emotion, motivation, and craving (Fisher, 2004). So these data indicate that the opposite of love is not hate; more likely it is indifference. Like frustration attraction, abandonment rage appears to be maladaptive. It stresses the heart, raises blood pressure, and suppresses the immune system (Dozier, 2002). But it probably evolved to enable jilted lovers to depart a dead-end relationship faster; this way they could renew courtship sooner, a reproductive advantage (Fisher, 2004). Abandonment rage also motivates people to fight for the welfare of their offspring, as seen so often during divorce proceedings (Fisher, 2004).

Resignation/Despair: The Second Stage of Romantic Rejection

The second general phase of romantic rejection, resignation/despair, may be associated with *reduced* activity in subcortical dopaminergic pathways. I hypothesize this for three reasons. First, a primate study indicates that when a monkey realizes an expected reward will *never* come, dopamine-making cells in the midbrain *decrease* their activity (Schultz, 2000). Second, the other recent fMRI investigation, of women suffering from a recent romantic breakup (Najib et al., 2004, p. 2253), reports decreased activity in parts of the dorsal caudate, a brain region rich in receptor sites for dopamine. Last, long-term stress suppresses the activity of dopamine and other monoamines, producing lethargy, despondency, and depression (Panksepp, 1998), which are traits of resigned and despondent lovers.

This despair response also seems counterproductive. But scientists argue that the high metabolic costs of depression are actually its benefits. They reason that depression is an honest, believable signal that something is desperately wrong, so it galvanizes friends and relatives to support the rejected person during his or her time of intense need (Hagen, Watson, and Thomson, in press). Depression also stimulates insight (Watson and Andrews, 2002), mental clarity that may spur the rejected lover to make difficult decisions that promote reproductive success (Nesse, 1991).

Love hurts. A recent neuroimaging study indicates that emotional pain induced by social exclusion affects some of the same brain regions that become active during physical pain (Eisenberger, Lieberman, and Williams, 2003). Some broken-hearted lovers even die from a heart attack or stroke caused by their depression (Rosenthal, 2002). Not everyone suffers from romantic rejection to the same degree, of course. Across the life course, individuals develop different feelings of competence or incompetence, different expectations of love, different sensitivities to rejection, and different coping strategies that predispose them to romantic rejection in different ways (Downey and Feldman 1996; Downey, Freitas, Michaelis, and Khouri, 1998; Leary, 2001). Moreover, some have more mating opportunities, options that mitigate feelings of protest, rage, and despair.

Men and women tend to express some differences in how they handle rejection, too (Baumeister, Wotman, and Stillwell, 1993; Buss, 1994; Hatfield and Rapson, 1996). Men are three to four times more likely to commit suicide after being rejected (Hatfield and Rapson, 1996) and are more likely to stalk a rejecting partner, as well as batter or kill her (Meloy, 2001; Meloy and Fisher, 2005). Rejected women report more severe feelings of depression (Mearns, 1991; Hatfield and Rapson, 1996), and more chronic strain and rumination after being rejected (Nolen-Hoeksema, Larson, and Grayson, 1999). Women are more likely to talk about their trauma as well, sometimes inadvertently retraumatizing themselves in the process (Hatfield and Rapson, 1996).

But few people avoid the pain of romantic rejection. In one college community, 93 percent of both sexes queried reported that they had been spurned by someone they passionately loved; and 95 percent reported they had rejected someone who was deeply in love with them (Baumeister et al., 1993). These rejected lovers suffer for important evolutionary reasons. Discarded sweethearts have wasted precious courtship time and metabolic energy; and their reproductive future has been jeopardized, along with their social alliances, self-esteem, and happiness.

Romantic Love: A Combination of Brain Systems

The above data suggest that central dopamine, norepinephrine, and serotonin, in various changing ratios and in conjunction with other neural systems, contribute to multiple aspects of romantic love. But these neurotransmitters also contribute to many other emotions and motivations; they are not specific to romantic love. This is to be expected. Pfaff (1999) proposes that all drives have two components: a *generalized* arousal system in the brain produces the energy and motivation to acquire any biological need; and a specific constellation of brain systems produces the feelings, thoughts, and behaviors associated with each *particular* biological need. The general arousal component of all drives, Pfaff reports, is associated with the actions of dopamine, norepinephrine, and serotonin, as well as several other brain chemicals. The specific constellation of brain systems associated with *each* particular drive varies. Our fMRI study may have uncovered only the "general arousal" component of romantic love.

We found activations and deactivations in many other brain regions and pathways, however, and some particular combination of these is probably specific to romantic love. Among them may be a region of the right anteromedial caudate body (Aron et al., 2005), because our happily in love subjects who scored higher on one of the questionnaires we administered prior to scanning, the Passionate Love Scale (Hatfield and Sprecher, 1986), also showed more activity in this brain region. Deactivation of the amygdala may also be central to the experience of being in love (Aron et al., 2005; Bartels and Zeki, 2000), as well as activations and deactivations in other limbic and cortical regions. But the thoughts, emotions, and motivations associated with romantic love may be so varied across individuals, as well as across time within each individual, that the full set of dynamic, parallel neural systems involved may be impossible to record by group analysis.

Can Love Last?

Nevertheless, these fMRI experiments indicate some of the primary neurotransmitter systems involved in romantic love. They also suggest some things about the duration of intense, early stage romantic love.

Nisa, a !Kung woman of the Kalahari Desert of Botswana, summed up love's trajectory succinctly: "When two people are first together, their hearts are on fire and their passion is very great. After a while, the fire cools and that's how it stays. They continue to love each other, but it's in a different way—warm and dependable" (Shostak, 1981, p. 268). Romantic love can be sustained in a long-term relationship, but it generally becomes less intense (Traupmann and Hatfield, 1981; Wallerstein and Blakeslee, 1995). And the characteristic impermanence of early-stage, intense romantic love is most likely an adaptive mechanism. Romantic love is metabolically expensive. So this brain system probably evolved primarily to enable our forebears to focus their courtship and mating energy on a preferred individual only long enough to conceive a child. Then this intense passion gradually subsided as most couples shifted into feelings of attachment so they could more calmly rear their child through infancy together (Fisher, 2004).

Two studies have explored the trajectory of intense, early stage romantic love. One investigation of blood platelet density of serotonin transporter indicates that intense romantic love lasts between twelve and eighteen months (Marazziti et al., 1999). And our between-subject analysis of happily in love individuals in longer relationships (eight to seventeen months) suggests how this passion changes across time. We initiated this secondary investigation because our group of happily in love subjects showed some different patterns of brain activation than did those of the Bartels and Zeki study. But, as mentioned earlier, our subjects were in love an average duration of 7.4 months, while those in the Bartels and Zeki study were in love an average duration of 28.8 months. So we separately analyzed only our happily in love participants who were in longer relationships. The results showed that these men and women exhibited brain activation patterns more closely resembling those of the subjects in the Bartels and Zeki study (Aron et al., 2005), specifically, activity in the anterior cingulate cortex and insular cortex. These data indicate that changes in cognition and emotion occur as love proceeds.

Romantic Love: An Addiction?

These fMRI studies of human romantic love have several implications for the medical and legal communities, as well as for individuals. Among them, romantic love is most likely highly addictive. Indeed, because romantic love is associated with focused attention, euphoria, craving, obsession, compulsion, distortion of reality, personality changes, emotional and physical dependence, inappropriate (even dangerous) behaviors, tolerance, withdrawal symptoms, relapse, and loss of self-control, psychologists have long regarded it as an addiction (Peele, 1975; Carnes, 1983; Halpern, 1982; Tennov, 1979; Hunter, Nitschke, and Hogan, 1981; Mellody, Miller, and Miller, 1992; Griffin-Shelley, 1991; Schaef, 1989; Findling, 1999). The above fMRI data on romantic love support this hypothesis. Those who are happily in love express neural activity in a region associated with the "rush" of cocaine, and those who are rejected in love appear to have neural activity in common with those who gamble for money, risking big gains and big losses.

Other studies also support the possible parallel between romantic love and addiction. When Bartels and Zeki compared the brain scans of their happily in love subjects with those of men and women who had injected cocaine or opioids, they found that some of the same brain regions became active (Bartels and Zeki, 2000). In addition, studies of cocaine addiction in animals (David, Segu, Buhot, Ichaye, and Cazala, 2004; Kalivas and Duffy, 1998; Wise and Hoffman, 1992) and humans (fMRI) (Breiter et al., 1997) indicate that the VTA is involved in addiction, as it is in romantic love. Last, the decreasing desire for more chocolate (aversion) is associated with decreasing activity in the VTA (Small, Zatorre, Dagher, Evans, and Jones-Gotman, 2001). Laymen generally consider that there are five major physiological addictions: food, alcohol, drugs, gambling, and nicotine. Romantic love may be another.

Individual Variations in Romantic Love

These fMRI data also suggest why some people fall in love more regularly and/or more passionately than others. Childhood, adolescent, and adult experiences unquestionably play a role. But baseline levels of dopamine and serotonin are directed by specific genes, and these genes are polymorphic; they produce individual variations in these neurotransmitter systems (Gibbons, 2004; Lesch, Bengel, Heils, Sabol, Greenberg, Petri, Benjamin, Muller, Hamer, and Murphy, 1996). Hence some men and women can potentially inherit the biological proclivity to fall in love more often and/or more intensely than others.

One's habits and diseases can also affect one's biological susceptibility to romantic love. For example, daily drug use can alter the structure and function of the brain's reward system for weeks, months, or years (Nestler, 2001). Moreover, schizophrenia, Parkinson's disease, and other ailments alter dopaminergic pathways. Even environmental and social circumstances potentially contribute to one's romantic receptiveness. Novel situations, for example, can stimulate romantic feelings (Norman and Aron, 1995; Aron and Aron, 1996; Dutton and Aron, 1974), most likely because novelty (and danger) raise the activity of central dopamine (Fisher, 2004).

But the above fMRI studies can contribute nothing to the question of why we fall in love with one person rather than another. *Who* triggers this brain system is a different issue, directed largely by environmental and social forces. Timing plays a role; people tend to fall in love when they are ready (Hatfield, 1988). Proximity can spark this rapture (Pines, 1999). As the poet Ezra Pound wrote of this, "Ah, I have picked up magic in her nearness." Most men and women fall in love with individuals of the same ethnic, social, religious, educational, and economic background, those of similar physical attractiveness, a comparable intelligence, similar attitudes, expectations, values, interests, and those with similar social and communication skills (Rushton, 1989; Laumann, Gagnon, Michael, and Michaels, 1994; Pines, 1999; Buston and Emlen, 2003). People also gravitate toward those who fit within what I refer to as their love template or love map (Fisher, 2004) and Zentner (2005) refers to as an individual's ideal mate personality concept. This love template is an unconscious list of traits that an individual is looking for in an ideal partner; it develops as he or she grows up and then becomes refined as the person moves through life.

Biology also plays a role in whom we find attractive. People fall in love with individuals who are somewhat mysterious, perhaps in part because novelty elevates the activity of dopamine and norepinephrine. Women are more attracted to men with a different immune system (Wedekind et al., 1995), an evolutionary mechanism that may have evolved to rear more varied young. Like many creatures, humans also tend to be attracted to those who are symmetrical (Gangestad and Thornhill, 1997). When scientists recorded the brain activity of heterosexual men ages twenty-one to thirty-five as they looked at women with symmetrical faces, the ventral tegmental area became active (Aharon et al., 2001). I suspect that scientists will find many more biological mechanisms that contribute to attraction to a specific individual.

But whether all these environmental and biological stimuli trigger the brain circuitry associated with romance, or the brain circuitry of romance somehow sparks one's interest in a particular individual, is undetermined. The above fMRI data cannot solve the metaphysical issue of cause and effect between brain and mind.

Lust, Romance, and Attachment: Interactions

However, data collected from these fMRI studies can help to explain some of the psychobiological interactions among the three basic mating drives: lust, romantic love, and attachment. And they suggest at least one of the dangers of tampering with these three delicately balanced systems.

People who have fallen madly in love generally begin to find their beloved enormously sexually attractive, and biological interactions between romantic love and the sex drive may contribute. Increasing dopamine associated with romantic love can stimulate a cascade of reactions, including the release of testosterone, the hormone of sexual desire (Wenkstern, Pfaus, and Fibiger, 1993; Wersinger and Rissman, 2000; Szezypka, Zhou, and Palmiter, 1998; Hull, Du, Lorrain, and Matuszewick, 1997). In fact, elevated activity of dopamine generally increases sex drive, sexual arousal, and sexual performance in humans (Clayton, McGarvey, Warnock, et al., 2000; Heaton, 2000; Walker, Cole, Gardner, Hughes, et al., 1993; Coleman, Cunningham, Foster, Batey, Donahue, Houser, and Ascher, 1999; Ascher, Cole, Colin, Feighner, Ferris, Fibiger, Golden, Martin, Potter, Richelson, and Sulser, 1995). This chemical connection between romantic love and lust makes evolutionary sense: if romantic love evolved to stimulate courtship with a preferred individual, it should also trigger the drive for sex, in order to start the mating process.

But can casual sex trigger feelings of romantic love? Most liberated adults have had sex with a friend or acquaintance and never fallen in love with him or her. But it can happen. The natives of rural Nepal say of this, "Naso pasyo, maya basyo," or "the penis entered and love arrived" (Ahearn, 2001). Perhaps this occurs because sexual activity increases the activities of dopamine in the brain (Damsma, Pfaus, Wenkstern, Phillips, and Fibiger, 1992; Pleim, Matochik, Barfield, and Auerbach, 1990; Yang, Pau, Hess, and Spies, 1996). In fact, women may be particularly vulnerable to falling in love with a casual sex partner because seminal fluid contains dopamine and tyrosine, a building block of dopamine (Burch and Gallup, in press). Sexual activity can also stimulate feelings of attachment via orgasm. Orgasm produces a flood of oxytocin and vasopressin, the neuropeptides associated with attachment in women and men (Carmichael, Humbert, Dixen, Palmisano, Greenleaf, and Davidson, 1987).

Because of the complex interactions among these three primary mating drives, the psychiatrist J. Anderson Thomson and I have proposed that serotonin-enhancing antidepressants (SSRIs) can jeopardize one's ability to feel romantic passion for a new partner or a deep attachment for a long-term mate (Fisher, 2004; Fisher and Thomson, in press). These medications *suppress* dopaminergic pathways; they also dull the emotions and curb obsessive thinking: All are associated with early-stage, intense romantic love. As many as 70 percent of patients taking these medications experience a decline in sexual desire, sexual arousal, and orgasm (anorgasmia). This anorgasmia may jeopardize the lover's feelings of attachment to a long-term partner too.

The negative biological effects of serotonin-enhancing antidepressants on feelings of romantic love and attachment were reported by a patient, who wrote: "After two bouts of depression in ten years, my therapist recommended I stay on serotonin-enhancing antidepressants indefinitely. As appreciative as I was to have regained my health, I found that my usual enthusiasm for life was replaced with blandness. My romantic feelings for my wife declined drastically. With the approval of my therapist, I gradually discontinued my medication. My enthusiasm returned and our romance is now as strong as ever. I am prepared to deal with another bout of depression if need be, but in my case the long-term side effects of antidepressants render them off limits" (Frankel, 2004).

The complex and dynamic interactions among these three brain systems suggest that *any medication* that changes their chemical checks and balances is likely to alter an individual's courting, mating, and parenting tactics, ultimately affecting fertility and one's genetic future.

Biological Underpinnings of Serial Monogamy and Adultery

The above fMRI data also bring understanding to the human tendency for serial monogamy and clandestine adultery. But to discuss the significance of these data, it is necessary to review the central elements of the human reproductive strategy.

Only 3 percent of mammals pair up to rear their young. *Homo sapiens* is among them. Today some 90 percent of women and men marry by age fifty in all but a few countries (Bruce et al., 1995), and cross-cultural data confirm that humans primarily practice social monogamy, forming a socially recognized pair-bond with a single mate at a time (Fisher, 1992). Although polygyny is permitted in 84 percent of human societies, in the vast majority of these cultures only about 10 percent of men actually maintain two or more wives simultaneously (Fisher, 1992). Moreover, because polygyny in humans is regularly associated with rank and wealth, Daly and Wilson propose that monogamy was even more prevalent in prehorticultural, unstratified societies (1983). In fact, anthropologists recently remeasured *Australopithecus afarensis* fossils for skeletal size, and reported that by 3.5 million years ago men and women exhibited roughly the same degree of sexual dimporphism as the sexes do today. Thus they propose that hominids lived in the same sorts of social units as modern *Homo sapiens*; these ancestral men and women were "principally monogamous" (Reno et al., 2003, p. 1073).

Humans are also adulterous. The National Opinion Research Center in Chicago reports that approximately 25 percent of men and 15 percent of women cheat at some point during marriage (Laumann et al., 1994). Other studies indicate that from 30 percent to 50 percent of married men and women philander (Gangestad and Thornhill, 1997). Scholars may never establish the true frequency of adultery in either sex, due to reporting bias. Nevertheless, studies of American adultery from the 1920s through the 1990s report its occurrence (Fisher, 1992). Extra-pair copulations occur frequently in every other society for which data are available (Frayser, 1985), as well as in many other socially monogamous species (Fisher, 1992, 1999). And human testes size, which varies according to a species' predominant reproductive strategy, suggests that adultery by both sexes was common in hominid prehistory (Miller, 2000).

Human divorce and remarriage, as well, and biological (as well as cultural) forces may be involved. Data on fifty-eight human societies, taken from the *Demographic Yearbook of the United Nations* between 1947 and 1989, indicate a worldwide divorce peak during and around the fourth year of marriage (Fisher, 1992). Because four years is the characteristic duration of birth spacing in hunting/gathering societies, and because many other socially monogamous avian and mammalian species form pair-bonds that last only long enough to rear the young through infancy, I have hypothesized that this human cross-cultural divorce peak represents the remains of a specific ancestral hominid reproductive strategy to remain together at least long enough to raise a single child through infancy (Fisher, 1992).

Children in hunting/gathering societies join a multiage play group soon after being weaned, becoming the responsibility of older siblings and other relatives in the band. So the ecological pressure on couples to remain pair-bonded was reduced after the weaning of a child, unless they had conceived another. Moreover, divorce most likely had an adaptive payoff in ancestral times: those who practiced serial monogamy in association with offspring weaning would have created healthy genetic variety in their lineages (Fisher, 1992).

Evolutionary hypotheses such as this are often regarded with skepticism by those unfamiliar with human ethology. I find this attitude shortsighted. Anthropologists, psychologists, sociologists, economists, primatologists, zoologists, and many other scholars have painstakingly accumulated a wealth of data on aspects of human behavior and its counterparts in many other species. Integrating these disparate facts with logical, scientific reasoning can add understanding, stimulate discourse, and initiate new inquiry into this difficult puzzle: human nature.

But regardless of the reasons for the evolution of human serial monogamy, or the myriad biological and social forces that contribute to human divorce

(Fisher, 1992), everywhere in the world that men and women have the economic resources to divorce, divorce and remarriage are common.

So clandestine adultery and serial monogamy are primary aspects of this "dual" human reproductive strategy. And the above MRI data on romantic love add insight to these human patterns.

Foremost, these fMRI data show that the brain circuitry for romantic love is distinct from that of the sex drive and that of attachment. Anecdotal data support this finding: one can feel deep attachment for one individual *while* feeling romantic passion for someone else *while* feeling the sex drive for a range of others. The relative biological independence of these three mating drives may have evolved to enable ancestral men and women to opportunistically engage in monogamy and adultery simultaneously and/or sequentially (Fisher, 2004). But the relative neurological *independence* of these three mating drives helps to explain contemporary cross-cultural patterns of philandering, sexual jealousy, stalking, spousal abuse, love homicide, love suicide, and the clinical depression associated with unstable and disbanded partnerships.

Love's Fickle but Eternal Nature

Wild is love. This passion can trigger the reward system in the brain at almost any time of life; even four-year-old children and senior citizens report this craving (Hatfield, Schmitz, Cornelius, and Rapson, 1988; Hatfield and Rapson, 1987; Purdy, 1995, Fisher 2004). Perhaps romantic love in children evolved to motivate them to practice at life's most essential task, choosing an appropriate mating partner. And romance in one's elder years keeps the body toned and the mind alert, and provides lovers with companionship, optimism, and energy.

As fMRI and other research techniques become more sophisticated, scientists will establish more about romantic love in children and the aging. Future research may also establish specifically how serotonin-enhancing antidepressants affect the brain activity of romantic passion; how diseases such as schizophrenia, Parkinson's disease, and various addictions affect this circuitry; why certain personality types fall in love more regularly than others; why some people suffer less from romantic rejection; how "talking therapies" or "twelve-step" programs affect brain circuitry in disappointed lovers; how the brain mechanisms for romantic love change across time; how this passion transforms into feelings of attachment for a long-term partner; how some couples sustain romantic love in long-term partnerships; and how novel situations, vacations, adultery, divorce, and childhood experiences and other life circumstances interact with brain mechanisms to affect whom we love, when we love, and how we express love. Future investigations may even help to explain the prevalence of some modern diseases that appear to be unrelated to romantic passion. For example, as the brain system for intense romantic love evolved, it may have contributed to the development of several obsessive-compulsive disorders and addictions as well.

The ancient Greeks called romantic love the "madness of the gods." It is important to investigate the biology of this passion in all its variations—because this madness is central to our lives. In a study of thirty-seven societies, men and women ranked love, or mutual attraction, as the first criterion for choosing a spouse (Buss, 1994). Everywhere people sing for love, pray for love, work for love, live for love, kill for love, and die for love. Even where marriages are arranged, spouses often fall in love. Nothing will extinguish the human drive to love.

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