The Neurobiology of Love

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Falling in love and attempting to stay in love is a time honored human tradition. Why we are driven to be in love, and how we behave during the process has been the subject of endless poems, songs and stories. The advent of modern brain imaging technology and continuing research regarding the functioning of the human body has laid the ground work for this paper; a theoretical model of how we fall in love, stay in love, parent children, and lose a close partner though divorce or death. The Neurobiological Model of Love (NBML) focuses on biological processes that drive our intimate behavior.

The Neurobiological Model of Love draws from the author's own research focused on couples in committed relationships and the work of other researchers, particularly Helen Fisher and Jaak Panksepp. Helen Fisher (Fisher, 1996; Fisher, 2016; Fisher, Aron, & Brown, 2005) has described three stages couples go through as they begin and establish a relationship: Lust, Attraction, and Attachment. Jaak Panksepp (2011) has identified seven basic emotional circuits common to mammalian brains. The author's ongoing research has attempted to link these circuits to Fisher's stages of falling in love. The NBML goes beyond Fisher's work to include additional stages of love focused on parenting and partner loss. In sum, the model attempts to describe the neurobiology of love throughout the life span.

What motivates humans to spend so much time and energy pursuing relationships with other people? To answer this question we must examine how our brains work. Panksepp (2012) and other affective neuroscientists have identified primary emotional systems that underlie and motivate all human behavior. These systems are outlined in Table 1.

Table 1: Primal Emotions and Associated Feelings

Primary Emotional Systems	Associated Feeling
• **SEEKING/EXPECTANCY**	**Enthusiastic**
• **RAGE/ANGER**	**Pissed Off**
• **FEAR/ANXIETY**	**Anxious**
• **LUST/SEXUALITY**	**Horny**
• **CARE/NUTURANCE**	**Tender & Loving**
• **PANIC/GRIEF**	**Lonely & Sad**
• **PLAY/JOY**	**Joyous**

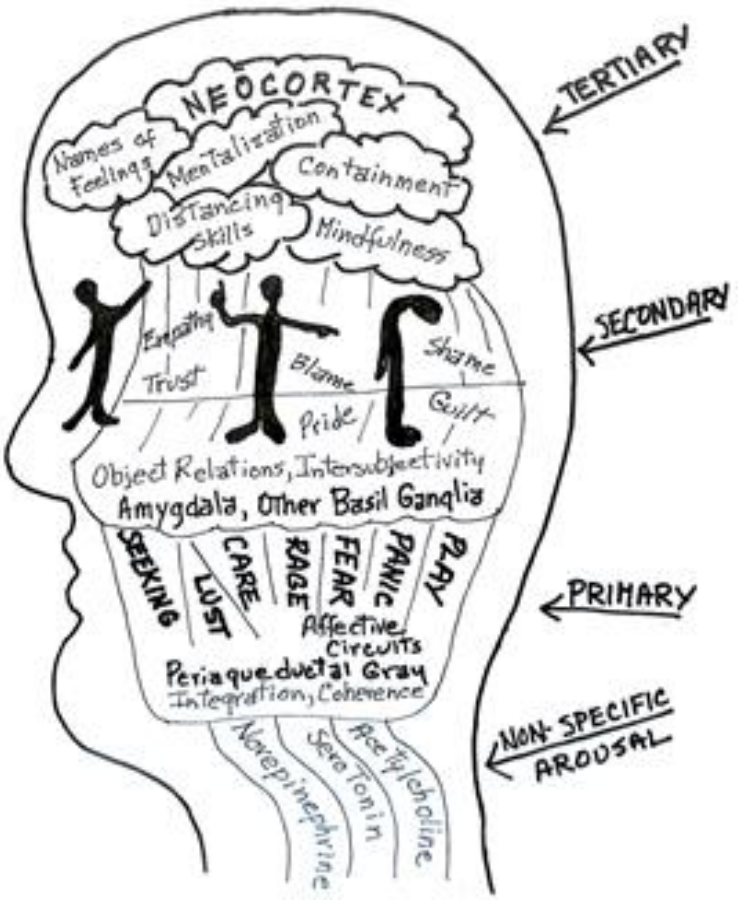
The names of primary emotional systems are all capital letters to distinguish these neurological systems from the everyday language used by humans to describe how they are feeling. These primary emotional systems have very specific biological characteristics and promote specific behaviors. Our everyday use of these terms is much more variable.

These primary emotional systems are buried deep in the brain, are ancient from an evolutionary perspective and are highly connected to the limbic system and the neocortex, more recently evolved regions of the brain. Affective neuropsychologists argue that our emotional experiences in everyday life stem from these primary emotional systems and are modified by learning and our ability to think about our experiences. For many years neuroscientists believed

that our "thinking brain", the neocortext, generated emotions; but that view is being challenged by recent research. Animals and humans are capable of experiencing emotions even when the cortex has been damaged or removed. For purposes of this paper and the NBML, we will assume that emotions emerge from these primary systems.

Each of these emotional systems controls distinct but specific types of behavior associated with many overlapping physiological changes; stimulating intense emotional feelings, memories, and thoughts about what is happening in our lives. Figure 1 (Adapted from Panksepp, 2012) illustrates these primary emotional systems (affective circuits) and the secondary feelings and tertiary processes that emerge in higher regions of the brain. These basic affective circuits are ancient and give rise to "higher feelings", second order processing of primary emotions within the limbic system. Primary emotions are driven by hormones that arise within our bodies as we respond to environmental stimuli. These primary emotions in turn stimulate our limbic system to produce "Secondary" feelings such as pride, blame, shame, confidence, trust, disgust, dominance, empathy and guilt. They are the result of the limbic system interacting with the environment in which we live and interact. Tertiary processes are what we typically think of as "mind" and occur in the neocortext; that is, how we think about primary emotions that have been converted into feelings within the environment context in which the person is living. These Secondary feelings and Tertiary processes are influenced by the cultural and immediate interpersonal context as we live our lives, and are at least in part learned.

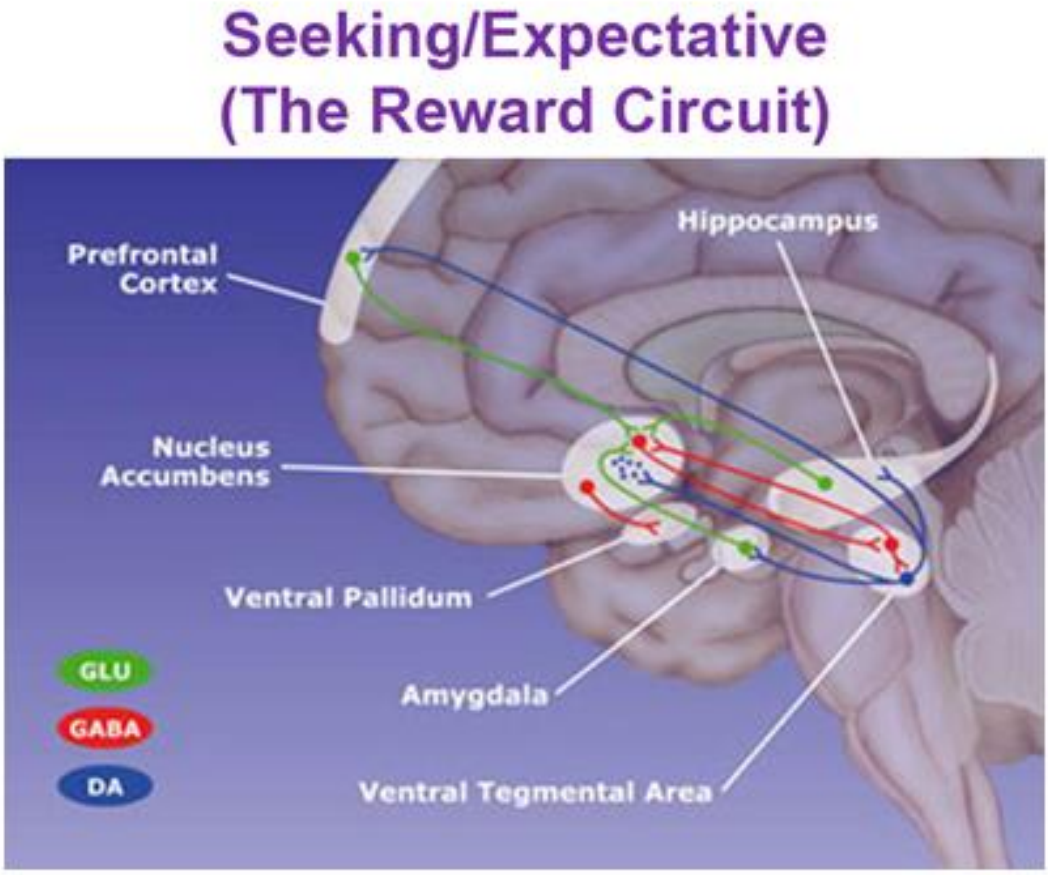
Figure 1



Often emotions are not under willful control of our higher mind (neocortext) but rather are programmed by our lower mind (primary emotional systems) in conjunction with our early learning (Narvaez, D., Panksepp, J., Schore, A., & Gleason, T., 2012). In sum, our daily experience of life is instinct (lower brain) moderated by life experience (higher brain). As our higher brain thinks and reflects on our day to day experiences, our lower brain influences our thoughts although we are not consciously aware of those influences. Primary process emotional

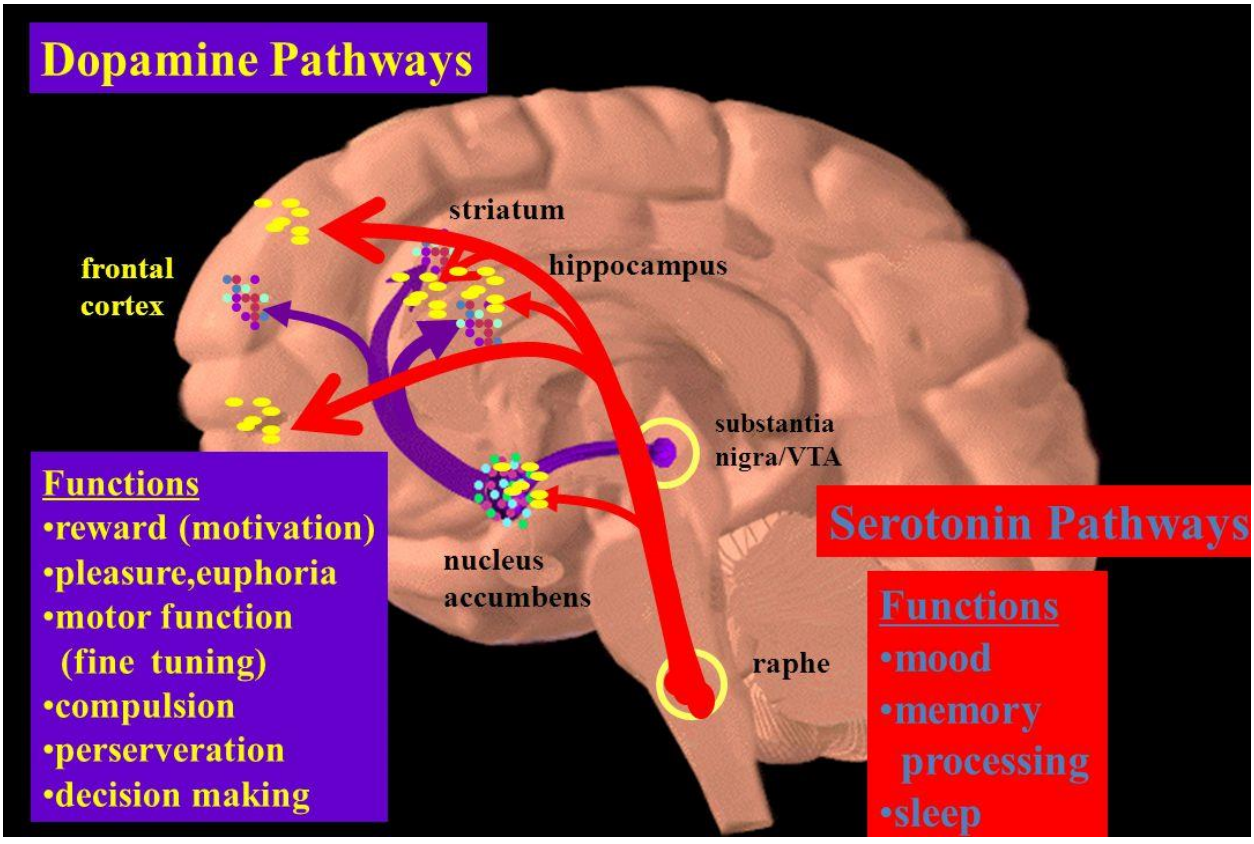
systems are raw affects that automatically make important decisions for us. Our conscious processes create a narrative to explain what is happening. At times that narrative interprets our raw affects in irrational ways because we are not consciously aware of our primary emotions but need to invent a story that helps us make sense of the world in which we are living. Partners in close relationships at times disagree because their individual interpretations of shared life experiences differ; that is, their individual primary emotional processes interact with their past learning to produce personal narratives that disagree. Couples seen by marital therapists and those involved in our study demonstrate this phenomenon regularly.

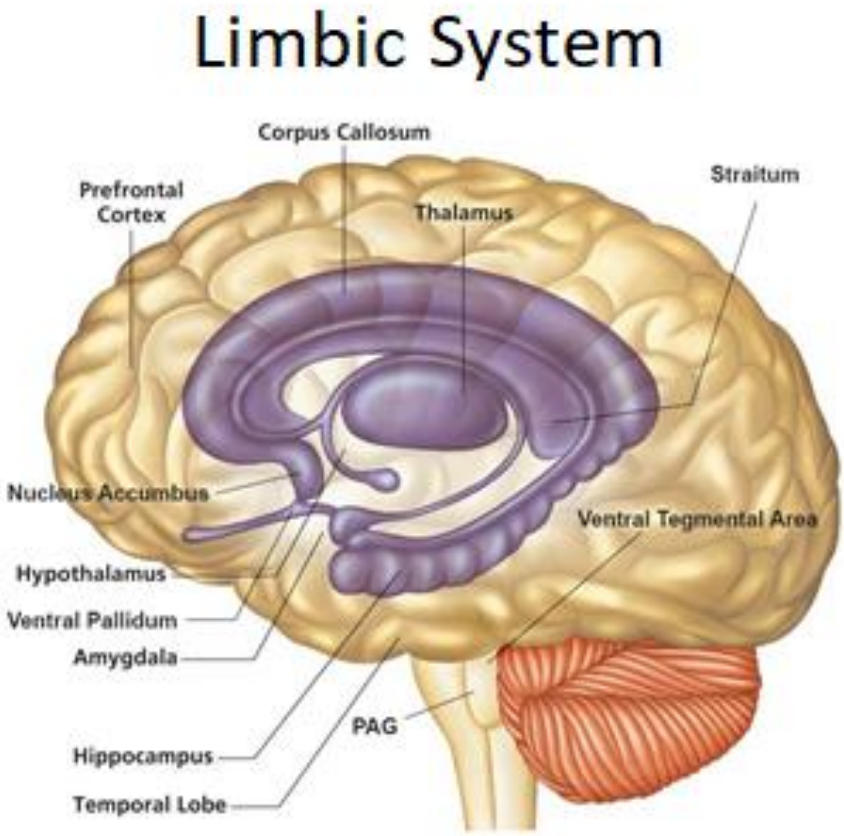
Of the seven primary emotional systems, SEEKING/EXPECTANCY is the most pervasive and plays a supportive role for all other emotions. Its activation is necessary to motivate any mammal including humans to want to do anything. If this system is not functioning well, a person may appear, and may indeed be, depressed. If this system is activated, the person is motivated to enthusiastically explore, seek out resources, and euphorically anticipate a reward. In fact, anticipation of a reward is the primary motivation that drives us to do something. Actually receiving the reward: food, water, sex is pleasurable because it returns our body to homeostasis (satiation), but anticipating the reward is the true motivation. Consequently calling the SEEKING/EXPECTANCY system the "reward system" is misleading. Unfortunately reward system is still often used by individuals who are not aware of recent research.



The SEEKING/EXPECTATION circuit runs from the ventral tegmental area (VTA) to three destinations: the medial forebrain bundle and lateral hypothalamus (MFB-LH), nucleus accumbens, and medial prefrontal cortex following the mesolimbic and mesocortical dopamine pathways. In sum, the VTA receives messages from other parts of the brain as to how efficiently basic human needs (e.g., sex, companionship) are being met. If needs are being satisfied, dopamine neurons alert the nucleus accumbens; dopamine levels increase, enhancing pleasurable feelings and thereby "rewarding" the behaviors through which the basic needs are met. The medial frontal cortex and MFB-LH help devise strategies to get what we want out of life and avoid problems. Raw emotions connect to pleasure producing portions of the brain that are informed by our “thinking” brain so we follow the most productive course of action. We

humans become motivated to seek a relationship with other people when the SEEKING/EXPECTANCY system, the PANIC/GRIEF and the LUST/SEXUALITY systems are all activated. This occurs when we desire to have other people in our lives to keep our bodies in a state of homeostasis. To feel comfortable we need other people to fulfill our desires for love and attachment. When we have been without food or water for a long period we feel hungry and thirsty. When we do not have someone to fill our social needs we become lonely. When we do not have a sexual partner, we become sexually aroused. Consequently when we are lonely or anxious because we don't have a loved one or partner close, several of our primary emotional systems become activated to reestablish homeostasis; that is, feel comfortable.

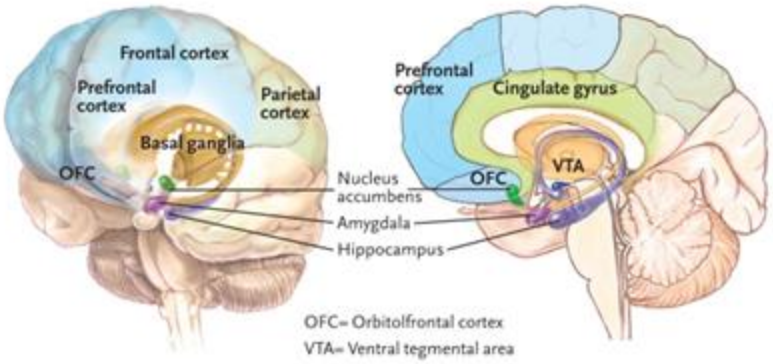




Lust

Fisher's first stage of love, the Lust or Sex Drive is characterized by a craving for sexual gratification. This should come as no surprise because humans, like all mammals, are driven to reproduce. Panksepp's LUST/SEXUALITY system and PANIC/GRIEF systems are activated as humans initially approach each other seeking a mate. Our SEEKING/EXPECTANCY system motivates us to seek another person to fulfill this desire.

Brain Regions Key to Love



Humans, like other animals, display a rich assortment of "courting" behavior. We flirt in a particular sequence. She smiles and lifts her eyebrows, raises her shoulders, arches her back, tosses her hair. He walks up to her, arches his back, and thrusts his upper body in her direction (Fisher, 2016). Such instinctive behaviors are common among mammals (Sapolsky, 2017). The author's observations of human mating behavior in 27 different cultures and baboons in Kenya have shown similar recurring tendencies. All these behaviors are generated by the primary emotional systems described by Panksepp; largely outside of our conscious behavior. Trained actors, anthropologists, and relationship therapists are aware of these behavioral tendencies and use them in their professional work.

We are usually unaware that such behavior is due to our genes, hormones, and nervous system driving us to reproduce. We may find someone attractive, interesting, and find ourselves pursuing them. When we interact with a potential love interest, phenyl ethylamine (PEA) in the ventral tegmental area (VTA) of our brain stimulates dopamine neurons that in turn increase

dopamine levels in the nucleus accumbens (NA); an important brain area in forming memories involving salient environmental stimuli, both positive and negative. In sum, the rise of dopamine levels in the nucleus accumbens helps us remember what environmental stimuli increase pleasure and what stimuli cause discomfort. Consequently, we seek a mate who we perceive to be a source of pleasure and avoid individuals who we perceive as causing pain. The same person can be seen as a source of pleasure (when courting) and a source of pain (when considering a divorce).

Phenyl ethylamine also helps to stimulate the production of beta-endorphins (endogenous opioids), which are our brain's 'feel-good' hormones. This process acts like amphetamine. Some scientists believe that PEA is responsible for the giddy, intoxicating feeling we experience when falling in love (Fisher, 2016).

We are not aware of the activation of our lust brain circuit, the flow of testosterone and estrogen through our blood stream and glands, or of the increase of dopamine in the SEEKING/EXPECTANCY, reward circuit of our brain. None the less, our bodies are aware in the sense that the "feeling" center of our brain, the limbic system, is strongly activated and pushing us to engage in behavior that the rational part of our brain, the prefrontal cortex, may not perceive as rational. We all smile when we see lovers engaging in behavior that may seem charming, provocative, or silly to an observer. We engage in such behavior because our bodies are designed to do what is needed to reproduce. An amusing example of these behaviors is the television show, The Orville, a quirky science fiction parody of the Star Trek series in which the captain, a man, is attempting to deal with his first officer, a woman who happens to be his ex-wife. They are sexually attracted to one another so struggle to overcome their history as a couple.

When the lust system is activated, it produces feelings of sexual arousal; thoughts oriented toward sexual fulfillment, and urge us to engage in sexual activity. The evolutionary advantage of having a lust system is to motivate organisms to reproduce.

Lust stems predominantly from the hypothalamus, a region of the brain that also controls basic desires such as hunger and thirst. The hypothalamus is closely tied to the autonomic nervous system that controls our heart rate and how fast we breathe. When we fall in love with someone our initial lustful feelings are enhanced by dopamine, a neurohormone produced by several areas of the brain including the ventral tegmental area and the hypothalamus. Once in our bloodstream, dopamine triggers the release of testosterone from our gonads, the hormone that drives sexual desire. Specific receptors on the hypothalamus for testosterone result in a strong drive for reproduction in both men and women. In effect, dopamine feeds back to the hypothalamus in the form of testosterone which in turn stimulates more dopamine release. As we fall in love we experience a highly sexual urge that is very pleasurable if we find the right partner. The lust system "jump starts" our relationship and sets the stage for the activation of other brain systems important to relationship development.

Men and women have somewhat different sexual neuro-circuitry that helps explain differences in sexual behavior. Our sexual interests and behavior as adults is the result of different experiences in our mother's womb. All fetuses start as anatomically female but boy babies change structurally because of greater influence by testosterone during fetal development. Male fetuses have more testosterone receptors especially in the hypothalamus (specifically the anterior, front part, the preoptic area). This makes males very susceptible to surges of testosterone during fetal development and again during puberty. Testosterone also activates vasopressin and nitric oxide. Vasopressin promotes sexual ardor, sexual bonding, inter-male

aggression, and possibly jealousy; tends to make males more "pushy and competitive" (Taylor et. al., 2000). Males have twice as much vasopressin as females. Nitric oxide heightens sexual eagerness and "offensive" aggression. This hormonal cocktail also promotes social dominance. Testosterone also sensitizes the RAGE/ANGER circuit. No wonder adolescent males at times engage in fierce competition for female attention.

Female fetuses are more influenced by estrogen which enhances oxytocin neural systems in the female brain while testosterone increases vasopressin in males. Oxytocin calms the brain and appears to facilitate positive social bonding in both men and women. Women have far more estrogen than males. From an evolutionary perspective, greater estrogen production in females leading to social bonding with children and other women makes sense. When estrogen is combined with oxytocin, female typical nurturing attitudes are enhanced, the tendency "to trend and befriend" (Taylor et.al. 2000). For hundreds of thousands of years proto-humans and modern humans survived in migrating small bands or clans with the woman and children staying close to one another while men at times hunted. Not until the rise of agriculture approximately 11,000 years ago did that pattern change, a small period time from an evolutionary standpoint. Women are neurologically wired to work together to raise children.

Like males female sexual receptivity is governed by the hypothalamus, specifically the ventromedial hypothalamus (upper middle area). Human females do not produce much testosterone so their hypothalamus is more influenced by estrogen and progesterone. Female testosterone is produced by the adrenal gland and has some influence on sexual receptivity especially when estrogen and progesterone levels are high during ovulation. The greater influence of estrogen and progesterone is governed by the pituitary gland, an extension under the hypothalamus that secretes gonadotropin releasing hormone (GnRH) during the menstrual cycle.

GnRH causes the ovaries to ripen and release eggs as well as produce more estrogen and progesterone. These hormones in turn promote the release of oxytocin and make females' hypothalamus more receptive to oxytocin. This hormonal mix in turn makes females more trusting of and emotionally receptive to suitors.

At a primary emotional level attractiveness between the sexes is also neurologically programed. Men respond to a 0.73 waist to hip ratio, the classic hourglass figure, a sign of fertility recognized by wiring in the male visual system. At a primal level human females like other primates are attracted to confident, dominant males with resources. Dominant, resource rich males increase the likelihood that a female's children will be protected and have enough to eat. At times human females can also be affected by testosterone as evidenced by mothers' fierce protection of their children and anger with other women who attempt to seduce their mates. Social context and learning can modify our primal tendencies at a secondary (feeling) and tertiary (thought) level. Men may learn to treat women respectfully at a behavioral level and think of them as their equal even though their primal urge may push them to be sexually dominant. Human females tend to exhibit more discernment than other primates so may choose to not enter a relationship with a socially dominant, powerful, self-centered male even though he may offer social status and wealth. To paraphrase Edgar Rice Boroughs, the author of the Tarzan series of books, men and women are restrained by a "thin veil of civilization."

Sexually driven courting behavior is especially pronounced during adolescence because of the flood of sex hormones invading the bodies of young humans. Although the intensity of the lust circuit's influence on our behavior diminishes with age, it never goes away. Even the "elderly" couples we have studied show activation of the lust circuit especially if they are

beginning a relationship. Their bodies still want to reproduce even though they are not physically capable of doing so.

Attempting to suppress the sex drive of adolescents is usually a futile effort because the lust circuit is activated much of the time. The best we can hope for is to channel their sex drive in a productive direction by providing age appropriate sex education including training regarding relationship development; sexual activity when appropriate as a relationship develops rather than an end in itself.

The LUST/SEXUALITY circuit stimulates sexual activity and social bonding because a bonded pair has each other to gratify sexual desire and to provide social support, which in turn stimulates beta-endorphin and oxytocin production. This process makes us feel calm and loved. However, oxytocin may not act alone but in a context of pleasant social interaction that enhances endogenous opioids (endorphins), the comfort and joy hormones. Feeling calm, loved, and comfortable with our partner leads to a satisfying sex life. A satisfying sex life promotes a competent immune system and increases our life span just like exercise; in fact, a satisfying sexual encounter is exercise. Well bonded, loving couples live longer because their bodies remain healthy longer. Sexual enrichment programs that emphasize couple closeness and sexually satisfying interaction enhance this effect (Joanning, H. & Keoughan, P., 2005; Nathan, E. & Joanning, H., 1985).

Limbic System The stages of love and the brain systems involved with love are moderated by the limbic system, a part of the brain that evolved after the primary emotional systems identified by Panksepp and before the neocortex.

The limbic system affects mood, memory and hormone production. A primary part of the limbic system, the hypothalamus, controls the endocrine system and regulates temperature, hunger, thirst, sexual arousal, stress, and the sleep/wake cycle.

Another part of the limbic system, the amygdala senses ambiguity in environment and is the source of curiosity. If ambiguity is perceived as dangerous, the amygdala signals the hypothalamus to trigger the fight/anger or flight/fear response. These responses are involved with two of the brain systems identified by Panksepp, RAGE/ANGER and FEAR/ANXIETY that will be described in more detail when we discuss stress responses during relationships, especially when couples move toward divorce or have a spouse die. If the amygdala compares new stimuli being perceived from the environment and senses no danger, it can lead us to become curious; an experience we will explore in more detail when we examine the Attraction Stage of love.

The amygdala attempts to make emotional experience (feelings) congruent with and appropriate to the context of the event experienced. Ambiguity takes away our sense of security and predictability. Ambiguity is perceived as fearful so the amygdala calls for more information by "turning up the volume" of hearing and increasing sensitivity of all senses; it compares new stimuli to memories stored in the brain. If the ambiguity is resolved, we remember similar events that were not dangerous, the amygdala stays calm. If the ambiguity is not resolved, the amygdala alerts the hypothalamus to take action to protect us from danger. The amygdala's default reaction is fear. For love to emerge, danger must not be sensed.

The amygdala is the "watchdog" of our brain and nervous system. It reacts to the external and internal environment before our neocortex ("thinking brain") has time to react. A

primary function of the amygdala is to keep us alive until we can "think through" what is happening to us.

An additional part of the limbic system that is involved in love is the hippocampus, a brain structure that influences memory formation, spatial memory, navigation and remembers prior sexual arousal especially in males. This is the first part of the brain to be damaged by Alzheimer's disease causing the victim to be unable to form new memories. The hippocampus processes our experience of dealing with our partner and is critically involved in helping us "learn" how to relate to our partner. When an organism is highly stressed, this brain structure does not function properly making it difficult to process relationship issues. Relationship problems can be sufficiently stressful to lessen hippocampus functioning; at times causing one spouse to complain that the other is not remembering important relationship issues.

The hypothalamus controls the endocrine system; ductless glands that release hormones that direct our body to respond to changes in our bodies and the environment. When we fall in love, the hypothalamus is actively influencing our thoughts and behavior by releasing dopamine that enhances testosterone from testes, ovaries, and adrenal glands and promotes basic reproduction drive in both sexes.

Attraction Fisher's second stage of love, Attraction, begins shortly after or concurrent with the Lust stage. Attraction is characterized by increased energy, intrusive thinking about and craving for emotional union with a mate. In sum, our body is involved in an addiction like process that takes over the SEEKING/EXPECTANCY system in the brain and occurs concurrently with activation of Panksepp's PLAY/JOY circuits.

As we continue to fall in love and the dopamine rush subsides, our love is maintained by oxytocin and vasopressin, the same bonding, calming hormones that are secreted by the hypothalamus to promote lust. Some scientists point to a progression in a relationship. First lust (he or she is cute or sexy), then romance (I'll profess my love), then marriage (calmer and cozier). Sex, romance, and affection may dwindle but continue to interact.

If the amygdala compares what we are experiencing in the here and now to memories stored in our brain and no ambiguity (danger) is sensed, it remains calm. The hypothalamus proceeds to instruct our endocrine glands to release hormones that produce pleasure (endorphins), bonding (oxytocin), and sexual desire (testosterone) in response to our interaction with a potential lover.

During attraction, we become curious about our new partner and want to learn more about them. This curiosity is handled by Panksepp's SEEKING/EXPECTANCY system. When this system is active, people experience curiosity, interest, anticipation, craving, expectancy, engagement, excitement, eagerness, and directed purpose. It leads people to energetically explore their world and seek resources. It produces an invigorated feeling of anticipation we experience when actively seeking accomplishments and rewards. The SEEKING/EXPECTANCY system is driven by dopamine, a hormone that causes a pleasurable feeling. From an evolutionary perspective this system motivates us to learn, to give us effective agency in the world. While falling in love, we use this system to learn all we can about our partner and we feel vigorously motivated to do so. We experience a "love high."

At the same time the SEEKING/EXPECTANCY system is activated, another system important to developing a love relationship is activated, the PLAY/JOY System. This system triggers the urge to vigorously and spontaneously interact with others. The accompanying

emotions can be characterized by joy or delight, and associated thoughts are generally positive. From an evolutionary perspective, the play systems triggers the release of hormones (oxytocin and vasopressin) that promote social belonging; in combination with the SEEKING/EXPECTANCY system, the PLAY/JOY system motivates creativity and experimentation; and releases intrinsic healing properties of hormones (endorphins) that make us feel better.

During the attraction stage of love, we experience intense positive feelings within our bodies and are drawn toward our partner because our relationship with him or her is the stimulus triggering our bodies to have these emotions that in turn stimulate feelings such as joy and enthusiasm. We seek our new partner like a drug addict seeks their desired drug. Fortunately our bodies are designed to have a "love high" and we do not do physical damage to ourselves like we do when using street drugs to get high.

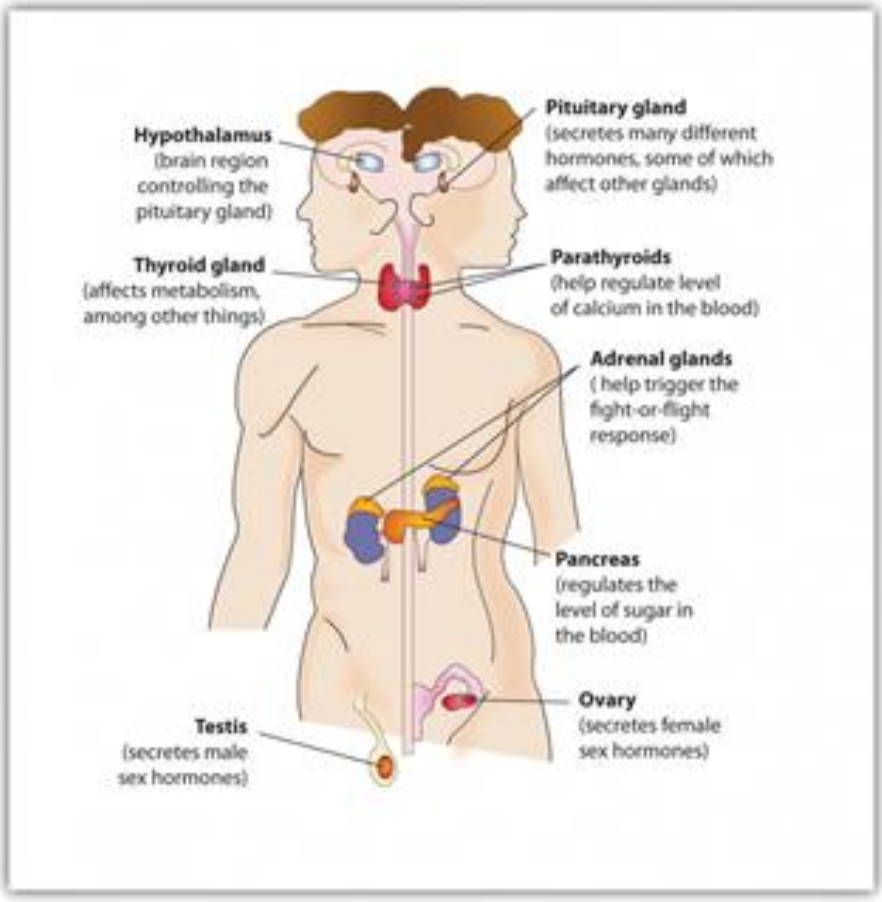
Hormones Before moving to the Attachment stage of love it will be helpful to describe the role of hormones in relationship development. Hormones are crucial to the function of brain systems and our bodies in general. Hormones come in a variety of flavors and functions. The following is a brief summary of the hormones already mentioned that are involved in sexual functioning, the key component of the Lust (Romance) stage of love and some additional hormones that are also important to the maintenance of relationships during the later stages of love.

Testosterone contributes to motivation to action and sexual urges (libido) so is critical to the sex drive of men and women although men have much more of it than women; thus the perception that men are more interested in having sex. However, interest in sexual expression is

also moderated by age, health, quality of the relationship, stress levels, and attitudes about sexuality. The popular notion that men are more sexual than women is not supported by scientific studies. Although young men may have a strong desire to have sex, that does not make them more sexual than women, simply more aroused in part due to high levels of testosterone in their systems. The picture changes as men and women age (Joanning & Keoughan, 2005).

Estrogen regulates reproduction cycles, menstruation, promotes wellbeing, keeps female genital tissues healthy, and promotes sperm production in males. Consequently, it is essential to keeping women's bodies sexually functional and able to become pregnant before menopause. Estrogen supplementation may be necessary to maintain that functionality later in life. Although some concern exists regarding estrogen supplementation increasing the risk of breast cancer, recent research has modified that concern. Progesterone along with estrogen is needed to keep women's bodies fertile and facilitates enjoyment of sex.

Oxytocin is a hormone secreted by the pituitary gland to reinforce attachment and trust, as well as to promote breastfeeding and child birth. Oxytocin is referred to as the "cuddle hormone" because it strongly promotes bonding. It is expressed during nursing and surges during orgasm. It makes us feel bonded to our babies or to the person with whom we are having sex. It also is expressed if we hold or are held by a lover, parent, or caregiver. A German study, (Scheele, et. al., 2013) found that male volunteers shown pictures of their female partner while being scanned by an fMRI after intranasal oxytocin was administered showed preference for their partner over other women friends and women they did not know as indicated by VTA and nucleus accumbens activation (award regions of the brain). It was hypothesized that oxytocin contributes to romantic bonds by enhancing partner attractiveness and reward value compared to other women.



Vasopressin is a hormone similar to oxytocin that facilitates and coordinates reward circuits crucial for bonding. This hormone helps coordinate the closeness felt due to oxytocin with the good feelings generated by dopamine and endorphins.

Oxytocin and vasopressin are synthesized in the hypothalamus and secreted into the blood by the pituitary gland, a gland attached to the hypothalamus. These hormones are exclusive to monogamous pair bonded species as an evolutionary adaption for the long-term care of helpless infants. In short, we fall in love because our children need us! We will explore this notion when we describe parenting.

Endorphins are endogenous opioids that reduce pain sensation, increase feelings of pleasure and surge with exercise, orgasm, and love. Non-endogenous opioids (street drugs) attach to the same receptor cites in the SEEING/EXPECTANCY, reward circuit of the brain associated with pleasure and cause addiction and physical damage over time. As mentioned earlier, endorphins make us feel good while doing no damage because our brain is designed to be simulated by this hormone. An increase in endorphins is also part of the placebo effect that needs to be controlled for in experiments. The placebo effect is real. If we take a pill or receive a treatment while being attended to by a person we respect and have them tell us the pill or their interaction with us will be helpful, endorphins are released into our bodies and make us feel better, at least for the short term. Having a lover who attends to us and tells us they love us also releases endorphins.

Dopamine is released by the hypothalamus to promote motivation and reward seeking behavior involved in promoting love. Dopamine also acts like endogenous opioids by attaching to receptor cites in the SEEKING/EXPECANCY, reward circuit. Again, the first stage of romantic love is similar to being high. Dopamine is coupled with a decrease in serotonin similar to individuals with obsessive compulsive disorders. We literally become obsessed with our beloved. Dopamine drives lust and triggers release of testosterone. Also, dopamine is vital for voluntary movement, attentiveness, motivation, & pleasure. Consequently dopamine is a key player in addiction, ecstasy, and love.

Serotonin is a hormone that levels mood and is involved in regulating memory, emotion, sleep, appetite, and mood; too little leads to depression, too much lowers sexual desire. Antidepressant drugs affect serotonin levels by adding more of it or inhibiting it from being reabsorbed by our neurons. In sum, falling in love alters our balance of dopamine and serotonin

in a positive way. When we examine the effects of divorce or death of a spouse, we will see the opposite.

These hormones are expressed in the SEEKING/EXPECTANCY and PLAY/JOY brain systems, the so called anticipation- reward circuit of the brain, and in turn help to drive the Attraction and Attachment stages of love. All these hormones work collectively to move relationships from the reproductive Lust stage of love through the Attraction stage, the bridge to long term bonded commitment that emerges in the Attachment stage.

Attachment Fisher's third stage of love is characterized by forming close social contact with another person and experiencing feelings of calm, comfort, and emotional union with a mate. The brain systems already activated during the Lust (Romance) and Attraction stages of love continue to operate, but are moderated by another brain system that begins to be activated during the Attraction stage and becomes dominate during the Attachment stage. This CARE/NUTURANCE system is crucial to the long term survival of a relationship and is also critical to parenting. In sum, this circuit is major component of all types of love.

The CARE/NUTURANCE system produces spontaneous feelings of warmth, tenderness and concern for others, thoughts about the welfare of others, and urges to act in nurturing ways toward others. The evolutionary advantage of this system is the protection of important relationships with others.

All the hormones described earlier continue to be present in our bodies if we maintain a close, loving relationship with our partner. Oxytocin insures a feeling of closeness, dopamine a feeling of pleasure, serotonin a feeling of calmness, testosterone a feeling of sexual desire, and endorphins accentuate all these feelings. In sum, by the time the Attachment stage of love is

fully achieved, the relationship becomes self-reinforcing cognitively and emotionally. Couples are motivated to do what is necessary to keep these positive feelings flowing.

Emotions and Feelings We often use these terms interchangeable in our daily lives. For the theory described in this paper, it is important to draw a clear distinction between the two. Primary Emotions are lower level physical responses occurring in the Panksepp's Seven Executive Operating Systems of the brain. These Primary Emotions create biochemical reactions in our neurons and endocrine system. Primary Emotions are physical changes in our bodies; neurological reactions to a stimuli in our environment.

Primary Emotions (Figure 1) are bodily reactions activated by hormones generated within our body as it reacts to our environment. Feelings (Secondary processes, Figure 1) emerge in our limbic system; specifically the amygdala and hippocampus described earlier. Thoughts (Tertiary processes, Figure 1) arise in the ventromedial prefrontal cortices, (which deal with conscious thoughts, reasoning, and decision making). Thoughts originate in the neocortical regions of our brain (the outer layer of the brain that evolved most recently, thus the "neo" prefix) and grow out of our personal experiences, beliefs, memories, and thoughts linked to particular feelings and primary emotions. A feeling is our brain perceiving a Primary Emotion and assigning a meaning or label to it. The same emotion can generate different feelings depending on the context in which the emotion is experienced. Antonio Damasio (1999, 2010) has described feelings as mental experiences of a body state; the way in which our brain interprets emotions that are physical states arising from the body's responses to external stimuli. For example: we are threatened (a man pointing a gun at us); we have a Primary Emotional reaction named FEAR/ANXIETY, and we cognitively label it as horror (because it is an appropriate label given the context of a gun pointed at us).

Primary Emotions are raw physical reactions common to mammals. Feelings are interpretive labels used by humans to describe their experience of an emotion. FEAR/ANXIETY is a basic emotion. We might label the feeling emerging from FEAR/ANXIETY as exhilaration (when we are voluntarily sky diving), or horror (if we are pushed out of an airplane against our will). The Primary Emotion stays the same, our body reacts to an environment stimulus as designed, but our feeling label changes as the context changes. In close relationships, a basic emotion such as LUST/SEXUALITY could evoke a different feeling such as ecstasy if we are having sex with our lover or guilt if we are masturbating while thinking of someone other than our lover.

Biologists disagree as to what are the basic human emotions. For purposes of this theory, we use Panksepp's Seven Executive Operating Systems as the Primary Emotions driving close relationships. We have chosen Panksepp's systems as Primary Emotions because he has been able to demonstrate brain regions activated in humans and other animals when these emotions are experienced. For those interested in what parts of the brain are responsible for which primary emotions, we refer you to Panksepp's paper: The basic emotional circuits of mammalian brains: Do animals have affective lives? (Panksepp, 2011). Also, for purposes of this paper, we are using Panksepp's Seven Executive Operating Systems, as Primary Emotions not feelings, although people commonly use them as feeling labels. Many feeling words are used to describe meanings individuals attach to their experience of Primary Emotions. We will continue to distinguish feeling labels from Primary Emotions as we discuss other stages of close relationships.

Parenting and Children

Women have a strong nurturance urge that is driven by the CARE/NURTURANCE primary emotional system. Men also have this urge although it is usually latent until it is stimulated as men interact with their infant children. The CARE/NURTURANCE system probably arises from the SEEKING/EXPECTANCY system that underlies all the primary emotional systems. The CARE/NURTURANCE system is driven by oxytocin and dopamine. Oxytocin stimulates and maintains the desire to care and dopamine "rewards" caring behavior when infants and children respond favorable to their parents' attention.

Consistency and quality of parental attention have a major impact on oxytocin production in the parent and the child. Oxytocin stimulates caring while vasopressin stimulates parental bonding with their child. This infant bond with a parent, their first primary caregiver (and first lover), determines how well a child will relate to others during his or her lifetime. Oxytocin and vasopressin affect parents' ability to attend to and bond with their children. The type of bond formed between parents and their child is the basis of type of attachment that is formed.

Parents' brains change while interacting with their children. Mom's reward processing center is activated by seeing her baby's face. Mom's SEEKING/EXPECTANCY system (anticipation-reward center) mirrors the emotions she sees in her baby. Abusive and neglectful mothers show less empathy and aversion than nurturing moms. Empathy is a product of the CARE/NURTURANCE system interacting with the PANIC/GRIEF primary emotional system. The PANIC/GRIEF in each parent is stimulated when their child cries. This leads the parents to protect the child in a caring manner which is necessary for survival. Most mothers can distinguish the cry of their baby from those of strangers.

Adult brains, even elderly adults, show more brain activity when viewing pictures of their parents, especially their moms, than any other pictures of humans. During stressful situations, adults touched by a woman in a supportive manner show brain reactions similar to babies touched by their mothers. Mom's touch becomes hard wired.

As pregnancy progresses, moms become better at recognizing emotions on faces of others, especially fear, disgust, and anger. Animal studies with mice and primates show that fathers who interact with their offspring display brain changes similar to females, greater sensitivity to oxytocin and vasopressin, and bond long term with their children. Oxytocin stimulates contractions during labor and triggers letdown of milk when nipples are suckled. Oxytocin keeps the CARE/NURTURANCE emotional system active following delivery. Being cared for long term gives infants and children a competitive edge in the battle for survival. The CARE/NURTURANCE system interacts with the LUST/SEXUALITY system to ensure reproduction and ultimately social attachments. Long term bonding such as marriage increases the probability that parents will reproduce, continue their relationship and help their children mature.

The CARE/NURTURANCE system is connected through the hypothalamus to the Ventral Tegmental Area (VTA), a dopamine producing area of the brain. This connection stimulates the SEEING/EXPECTANCY system and in turn makes parenting rewarding. This connection also promotes goal-oriented maternal tendencies. If a baby cries, the PANIC/GRIEF system is activated and parents protect their children which also reinforces a sense of reward in parents when the baby's distress is diminished. Oxytocin enhances learning by the CARE/NURTURANCE system that improves parenting skills. Oxytocin also enhances the effects of endogenous opioids, again leading the parents to feel rewarded by parenting.

Parents' brains become focused on the care and wellbeing of their offspring. Neurons in the part of the brain that regulate maternal behavior (medial preoptic area) grow impressively during late pregnancy preparing mom to respond to a baby with appropriate and sensitized impulses. Estrogen and progesterone help mom focus on cues and cries of her infant.

In sum, our experiences of parenting and our children's experience of being parented are driven by hormones generated within our bodies. The specific hormones released are in turn governed by the brain systems operating while we are parenting. To complete the cycle, hormones feed back to our brains to continue the neuronal/hormonal process driving our parenting. Nature has designed our bodies to ensure that the joys of parenting will outweigh the burdens. We have some conscious control of this process but much of what we do is driven by the emotions our interaction with our children generates. We can attempt to consciously reframe the feelings we experience in response to our body's emotional reaction to our children's behavior in an attempt to moderate or change the emotions we feel, but it is a difficult process, as any family therapist will testify. The effects of hormones such as oxytocin on relational and parenting behavior is an important future direction for mental health professionals, especially couple and family therapists to attend to.

Psychotherapy with Children and Adult Survivors of Childhood Trauma How children develop emotionally, cognitively, and behaviorally is much dependent on how they are raised. Table 2 describes parenting styles and Table 3 how children react in terms of how they bond to parents or other caregivers.

Table 2

Parenting Style	Jellyfish (Permissive Parents)	Dolphin (Authoritative Parenting)	Tiger (Authoritarian)
Drive in childhood	Drive dominated by child's demands.	Parent-guided drive of nurturing the child's nature.	Parent-driven pushing and/or hovering.
Autonomy	Too much autonomy too early.	Gradual increasing of autonomy with age.	Expectation of autonomy but it is unintentionally impeded by pushing and hovering.
Role-modeling	Non-purposeful	Purposeful use of role modeling for collaboration, balanced lifestyle, and core character values.	Non-purposeful or dominated by a narrow definition of success (financial or status oriented).
Instruction	Not enough or absent	Instruction when needed but focus is guidance including learning from trial and error.	Too much adult instruction leading to lack of opportunity for independent problem-solving.
Discipline	Avoidance of confrontation and few rules and consequences.	Collaborative discussion of rules and consequences. Parents maintain authority.	Parent-determined rules and consequences.
Goals	Not clear	Long term 21st century skills = creativity, collaboration, critical thinking, and communication (CQ)	Short-term performance or achievement.
Expectations	Not clear	Living a life of health, balance, meaning, and purpose.	Early performance and achievement with assumption this will lead to wealth, status, and thus happiness later in life.
Drive in adulthood	Not clear or random	Healthy, internal drive that is sustainable	Diminished and/ or dependent on external reward or pressure.

Table 3

Attachment styles	% of sample (also generalized to represent U.S. population)	The child's general state of being	Mother's responsiveness to her child's signals and needs	Fulfillment of the child's needs (why the child acts the way it does)
Secure Attachment	65%	Secure, explorative, happy	Quick, sensitive, consistent	Believes and trusts that his/her needs will be met
Avoidant Attachment	20%	Not very explorative, emotionally distant	Distant, disengaged	Subconsciously believes that his/her needs probably won't be met
Ambivalent Attachment	10-15%	Anxious, insecure, angry	Inconsistent; sometimes sensitive, sometimes neglectful	Cannot rely on his/her needs being met
Disorganized Attachment	10-15%	Depressed, angry, completely passive, nonresponsive	Extreme, erratic: Frightened or frightening, passive or intrusive	Severely confused with no strategy to have his/her needs met

Loving, caring parents tend to produce children who are securely attached to their parents. Parents who begin with high structure and low autonomy for their children when they are infants but gradually reduce structure and encourage autonomy as their children grow to adulthood provide society with well-adjusted adults who can contribute to the good of society. Unfortunately one third of children are treated harshly or raised by one or more anxious individuals who rear children to become less than optimally functioning adults. Such adults often develop psychological disorders that can cause themselves or others distress. If the distress is severe enough, these individuals may seek or be referred for mental health treatment.

Throughout the rest of this paper, suggestions will be given for treating these problems based on what affective neuroscience is learning about how our bodies produce these effects.

If children are raised in a harsh or anxiety producing environment, their lives may give them limited opportunity for their PLAY/JOY primary emotional systems to be activated, an important component of learning to interact with their social environment,. If this is the case, children and adults may benefit from activation of this circuit, and in turn their SEEKING/EXPECTANCY circuit by play. For children, play therapy or access to children of a similar age in a safe environment can activate these systems and stimulate positive emotional growth. Play increases social learning and promotes a sense of fun and humor. Such an approach may be particularly help for attention deficit hyperactivity oriented children or those with autistic tendencies. For adults, activities that are joyful can activate these circuits and possibly counter antisocial tendencies such as personality disorder or stress disorders resulting from childhood trauma. Therapies designed to engage adults in playful interactions and direct body work (e.g., family sculpting) may counter chronically activated RAGE/ANGER, FEAR/ANXIETY, OR PANIC/GRIEF circuits by stimulating hormone production (endorphins, dopamine) that suppress these circuits. It is important that therapists guide patients toward positive emotional states so that at a primary emotional level hormones begin to flow that allow individuals begin to dampen negative primary emotional systems and enhance positive emotional states along with positive feelings at a secondary level and thoughts at a tertiary level. This approach is in contrast to "top-down" approaches such as cognitive-behavioral therapy and mindfulness training. These approaches can still be used but in conjunction with affect based approaches. Allowing clients to experience negative emotions in a context that also incorporates positive emotional experiences increases the range of emotional states available. Emotional arousal modifies how we think and

modifying how we think can modify emotional arousal. It is important to remember that emotions are primal and automatic while cognitions are learned. Therapists are advised to work from the "bottom up and top down" simultaneously.

The importance of early intervention must also be emphasized. Young children are particularly sensitive to environmental stressors because their brains are still developing and their neurons are differentiating. If the environment is harsh, young brains adapt to cope with the harshness, and can produce lifelong negative results. However, young brains are also very resilient because their young neurons are looking for something to do. If positive influences replace negative environmental stimuli, young brains can adapt in a positive manner. Just like young brains can learn multiple languages more easily than adult brains, young brains can overcome early harsh experiences if given the opportunity.

Teen Brains Yes, they do have one. Adults are often frustrated by their teenage children's behavior. There is a reason for their behavior; they think more slowly than adults.

Myelination is the formation of a fatty sheath on the axon of neurons during adolescence. This process turns much of the brain from gray to white. Myelination speeds up the conduction of nerve impulses up to 100 times faster than the unmyelinated gray matter of childhood (Gield, 2015).

Myelination also accelerates axon recovery time between nerve impulses thus increasing information processing. Quicker recovery time allows up to a 30 fold increase in information transmission. Combining faster neuronal transmission with shorter recovery time provides a 3000 fold increase in computational power from childhood to adulthood.

Increased speed and computational power increases the ability to learn. Inputs from nearby and distant neurons become able to arrive simultaneously at a given neuron allowing different parts of the brain to coordinate. Greater speed and coordination leads to better decision making.

Frequently used neural connections are strengthened and unused or maladaptive neurons are pruned. Gray matter decreases while white matter increases. Neurotransmitter receptor sites on neurons increase so dopamine; serotonin and glutamate have more effect and modulate communication among neurons.

The combination of greater processing speed and specialization of brain function allows the prefrontal cortex to better organize, make decisions, plan, and regulate emotion. As the brain matures individuals are able to make more accurate simulations of what will happen in the future if they behave and think in a particular way today. It is no wonder adults get frustrated with teens. While teenagers are planning to do something that is potentially dangerous, adults already know what might happen. But try telling that to a teen (Strauch, 2003).

The limbic system, the center for emotion and impulsive behavior, matures faster than the prefrontal cortex, the center for careful planning and decision making. Consequently, for at least ten years teens engage in novelty seeking, risk taking behavior and are more in tune with their peers than adults, unless the adults act appropriately. Adults need to "stand in" where the teen brain cannot yet function.

In sum, a teenager's emotional brain is functioning pretty well by the beginning of adolescence. Unfortunately, their prefrontal cortex, the planning, reasoning brain, is not well

connected to the rest of their brain; thus emotionally impulsive behavior emerges. Fortunately by age 23-25, teen brains catch up with adults (Strauch, 2010).

Adults need to understand teen brain development. Respectful conversation between adults and teens led by adult example is crucial for monitoring and guiding teen behavior. Treat your teenage child like your best friend's child and you are more likely to get the desired response.

Relationships over the Long Term Over time couples tend to bond or move apart depending on processes they develop to regulate their relationship. The brains of couples change over time. Loving couples bond and develop styles of interaction that support continued bonding (Henrich, 1987). If a couple does not bond, they tend to develop interaction styles that negate love (Joanning & Keoughan, 2006). Their brains change to negate bonding.

As couples continue in their relationship, the "real" self emerges. If the couple has developed a pattern of mutual respect, caring, communication, and problem solving, they can continue to enjoy the warm feelings that emerge as the LUST/SEXUALITY, PLAY/JOY, SEEKING/EXPECTANCY, and CARE/NURTURANCE systems function. Unfortunately, not all couples develop functional patterns of interaction (Gottman, 1999). Arguments become more frequent. Negative verbalizations take a huge toll on the couple (five times more potent than positive verbalization). Partner support is not always well received. Sexual problems emerge if the CARE/NURTURANCE system is not functioning well. Difficulty with emotional regulation and hypersensitivity to negative emotions emerge. Gender differences become pronounced because men and women are socialized differently and have some differences in brain wiring. These changes are accompanied by stress responses that can become extreme.

"Sometimes I wonder if men and women really suit each other. Perhaps they should live next door and just visit now and then." -Katherine Hepburn

Human Stress Response Certain stimuli representing ambiguity or danger (e.g., your spouse's facial expression, tone of voice, or comments) feed directly into the amygdala. In humans the amygdala depends on perceptions of ambiguity or danger to be transmitted to the neocortex for help in resolving ambiguity and to determine if danger really exists (Kurzweil, 2012).

In response to ambiguous or threatening environmental or internal stimulus, the amygdala stimulates an increase in our sensitivity to stimuli; literally "turning up the volume" on auditory stimuli and making us more aware of visual, tactile, and olfactory stimuli. In short the amygdala makes us more alert if ambiguous or threatening stimuli are sensed.

Once the amygdala does decide that ambiguity or danger is present, it signals the hypothalamus which in turn signals the pituitary or "master hormone" gland to release a hormone, ACTH (adrenocorticotropin). This in turn triggers the stress hormone cortisol from the adrenal glands (on kidneys) which results in more energy being provided to your muscles and nervous system.

The adrenal glands also produce adrenaline (epinephrine) and noradrenaline (norepinephrine), which suppress your digestion, immune, and reproductive systems because they are of low priority in an emergency. Levels of blood pressure, blood sugar, cholesterol, and fibrinogen (speeds clotting) all rise. Heart rate and respiration increase. Pupils dilate so you can see your enemy (e.g., angry spouse) and your escape route better (e.g., a way out of the room). In humans the "escape route" might become an excuse or a lie designed to placate a significant

other. Our “old brain”, limbic system and “new brain”, neocortext, both come on-line and process Primary Emotions and produce feelings.

Our old brain attempts to reduce fear and increase pleasure while our new brain attempts to determine whether fear or pleasure are appropriate given the circumstances. The new brain tries to control the old brain. The amygdala (old brain) cannot evaluate ambiguity or danger on its own so relies on the neocortex to decide.

When individuals are in contact with other individuals with whom they have an intimate relationship (e.g., spouses; parent and child) the amygdala is stimulated and seeks assistance from the neocortex, where memories are stored and processed, to determine if ambiguity or danger exists. Behaviorally, this process leads the individuals involved to attend very carefully to verbal and nonverbal cues consciously and unconsciously.

Whether the individuals involved fight, flee, freeze, or “talk about it”, their emotional cascade continues throughout their bodies. If a fight or attempt to flee occurs, hormonal levels and physiological changes can escalate making it increasingly difficult for the neocortext to control the lymbic system so the “old brain” goes into full “survival mode.” To avoid defaulting to survival mode (e.g., bitter arguments or “stonewalling”), the people involved must slow down the cascade process by bringing the neocortext more fully on-line. Typically this is done by “talking about it” slowly and deliberately (Joanning, 1982).

Males TEND to become “emotionally flooded” and try to escape. Females TEND to “push for emotional connection” and attack. These stereotypic responses are both biologically based and learned. Women are socialized to bond to support child-rearing while men are

socialized to hunt silently with their pack to avoid detection by game or the enemy. These are ancient patterns.

During conflict men TEND to be more reactive (high heart rate, tension) due to their evolutionary history as hunters leading them to shut down or stonewall. During conflict women TEND to be better able to soothe themselves during and following stress due to their evolutionary history as mothers.

When humans are stressed, one or more of brain executive operating systems Panksepp has identified are activated. These include the RAGE/ANGER, FEAR/ANXIETY, AND PANIC/SEPARATION systems.

Activation of the RAGE/ANGER executive operating system produces feelings ranging from frustration to intense anger (RAGE); thoughts that overflow with blame, scorn memories of past transgressions, and urge us to strike at the offending agent. Nature evolved this system to enable us to protect ourselves. When dealing with a parent perceived as being unfair, children will become frustrated and express RAGE if their demands are not met; teenagers might rebel and run away from home. When a spouse learns that their partner has been unfaithful, they may become angry and consult a divorce attorney. In extreme cases one partner in an unhappy marriage may become so enraged that they harm the other partner physically. When activated, this system can lead to child or spouse abuse.

RAGE/ANGER is a primary emotional process that does not need an object. Jealousy and blame are examples of secondary feelings that emerge as the limbic system processes Primary Emotions within an environmental context. Secondary feelings have an object that grows out of our life experiences; e.g., our spouse if she or he has an affair, our enemy if they kill a friend.

RAGE/ANGER can be particularly intense if someone "robs us" of someone we love. Divorce attorneys can attest to the venomousness of someone shunned. Humans may experience love as a limited resource and fight to protect it. In doing so we can experience secondary feelings such as blame as our limbic system interacts with our neocortext to process what should be done; tertiary thoughts such as revenge and hatred. These tertiary thoughts arise as we think about (neocortex) who or what is responsible for the ire we feel (a secondary feeling generated by the limbic system) when our bodies generate the primary emotion of RAGE/ANGER.

When our SEEKING/EXPECTANCY system is looking for a lover and someone competes with us for this prize, our RAGE/ANGER system can drive us to behave in ways that may be unproductive and not socially sanctioned such as challenging or fighting with the competition. Any high school principal can tell stories of adolescents acting out when feelings of jealously emerge. Raw RAGE/ANGER is not cognitive; however, secondary and tertiary feelings have a cognitive component and emerge as we think about our body's reaction to our environment.

The neuro-circuitry of RAGE/ANGER runs from the periaqueductal gray (PAG) to the amygdala and hypothalamus (See Limbic System plate).

The PAG, located at the top of the spinal column, acts as an interface between the lower brainstem, the limbic system and ultimately the forebrain (prefrontal cortex). The PAG helps integrate behavioral responses to external (e.g., threat) and internal (e.g., pain) stressors. It sends impulses such as sexual desire, fatigue, and hunger to the hypothalamus and amygdala (limbic system). The amygdala in turn senses something in the environment that could be a threat such as another man talking to my girlfriend, and cooperates with the hypothalamus to prepare our body to react to the threat; turn our body, focus on the other man, and signal for stress hormones.

The PAG is the source of primary emotion that is then processed by the hypothalamus and amygdala. The amygdala and hypothalamus are also connected to the neocortext where memories of past experiences can be accessed to assist in determining if a threat exists and what should be done about it. The prefrontal cortex can also become involved to plain an appropriate course of action.

A number of hormones can promote activation of the RAGE/ANGER system, notably testosterone that in turn promotes social dominance. This is no surprise to anyone who has witnessed the response of young, sexually aroused male mammals (teenage boys) who are competing for a sexually available (provocatively dressed) female. Unfortunately when primary emotional systems such as the RAGE/ANGER and LUST/SEXUALITY circuits are fully aroused, many areas of the neocortext shut down. No wonder adolescents may need an adult to monitor their behavior and intervene to limit problematic behavior.

Activation of the FEAR/ANXIETY operating system produces feelings ranging from anxiety to intense fright, thoughts on a continuum from worried to catastrophic, and motivation to escape existing circumstances. From an evolutionary perspective this system motivates organisms to escape danger. Without this system we would be helpless when confronted with life threatening circumstances. When dealing with our spouse, parent, or child, this system can become activated when we feel threatened by something they are doing; an angry spouse yelling at us, a child doing something dangerous, a parent beating us.

Although some triggers of FEAR/ANXIETY are instinctive (e.g. fear of falling, loud noises, pain, human infants feeling insecure when not being held), many are learned. Fear states promote learning because fear events could cause us physical harm; events such as car crashes

and being assaulted; other events we can imagine that could cause use psychological distress, job loses or contracting a fatal disease.

The FEAR/ANXIETY circuit runs from the PAG to the amygdala and back again. The amygdala is connected to the hypothalamus that it alerts if a threat is perceived. The hypothalamus triggers hormones that cause our heart to beat rapidly, our palms to sweat, and our bodies to freeze in place or try to run away. When the frightening stimulus is far away (an overbearing aunt who we will visit at Christmas) the higher cognitive parts of the brain such as the frontal cortex interact with the amygdala to keep us calm or cause us to freeze (hide, not return auntie's phone calls). If the frightful stimulus is close (a mugger coming toward us with a knife), the PAG takes over and pushes us to take flight, or turn and fight; e.g., if we are trapped and protecting our child. Finally, animals and people can experience free floating anxiety states because we have an inherent, biologically hard wired capacity to FEAR; that is; we have intrinsic emotional systems that cause us to experience FEAR/ANXIETY.

Paradoxically, pain (also processed by the PAG) can reduce our fear response by delaying pain so we can escape a dangerous situation. Pain stimuli enter the PAG directly triggering the release of endogenous opioids, endorphins, hormones that reduce the pain response. Consequently, someone hits us but we run away before we realize that the assailant has broken our arm. We say "Alright" when our girlfriend says "our relationship is over", we feel numb until we can seek our best male friend to commiserate about how cruel women can be. We tolerate pain until we can seek a safe hiding place. These responses are hard wired so we can survive the vicissitudes of life.

Sometimes events are so fearful or anxiety producing that we may escape the immediate threat, a firefight in combat, only to haunted by the memory of the event. Our body continues to react to the threat; Post Traumatic Adjustment Disorder (PTSD). The response continues automatically because the amygdala becomes more responsive and enlarges while the medial prefrontal cortex becomes smaller and less responsive. The medial prefrontal cortex processes stimuli from the external environment and our body and in turn interacts with our limbic system and PAG to generate appropriate emotions and feelings. In sum, FEAR/ANXIETY is more intensely stimulated by the amygdala and the medial prefrontal cortex is less able to calm the amygdala. Treatment of PTST requires shutting down this habitual reaction when no environmental stimulus is present. Simply the memory of the event or the occurrence of a similar event can set off the intense FEAR/ANXIETY survival reaction. Treatment strategies such as cognitive behavioral therapy attempt to calm the amygdala's habitual reaction to environmental stimuli reminiscent of the feared event. Vigorous exercise and laughter stimulates the medial prefrontal cortex to release beta-endorphins, neuropeptides that suppress pain and also calm the amygdala and hippocampus which in turn diminishes the FEAR/ANXIETY response at a primary emotional level. Consequently, psychotherapies and/or physical and social activities that help us think differently and change our body's response while interacting with our environment can relieve stress and counter PTSD.

Medications can be used to suppress the FEAR/ANXIETY response in the short term. Benzodiazepines and brain norepinephrine inhibitors (beta blockers such as propranolol) can be used until psychotherapy can help clients establish emotion and cognition based methods to replace FEAR/ANXIETY with arousal of more positive primary emotional states.

The PANIC/GRIEF operating system is located in the anterior cingulate gyrus, dorsomedial thalamus, and the periaqueductal gray (PAG), (Damasio, et.al. 2000) and generates sadness, grief, and the urge to cry. It appears to have evolved from brain systems that mediate the intensity of pain and responds to social isolation. This system reacts to Corticotrophin Releasing Factor, a stress hormone released when mammals are isolated, and is calmed by brain opioids (endorphins), oxytocin, and prolactin produced when mammals are engaged in positive social activity. Prolonged intense activation of the system can in turn shut down the SEEKING/EXPECTANCY system and lead to depression as endorphin and serotonin levels fall. This system is more sensitive in women when activated by separation and loss of attachment leading to more depression than in men. Some early studies suggest that buprenorphine; a relatively safe opiate receptor agonist/antagonist can be used to counter depressive symptoms by boosting endorphin levels rather than using standard anti-depressants. Other studies suggest that extreme arousal of the PANIC/GRIEF system may trigger panic attacks. Still other studies suggest over exposure of this system to endorphins may lead to autism as children become addicted to their own self-released opioids making them socially aloof. Much more research is needed to study the function and emotional/behavioral effects of this brain system.

PANIC/GRIEF is usually activated by separation from important persons or circumstances. Feelings associated with this neural command system include variations of loneliness, sadness, and disappointment. When the PANIC/GRIEF system is activated, it produces thoughts centering on the obtainment of social contact and urges us to move toward possible sources of comfort. This system evolved to motivate organisms to affiliate with and seek support from others. When a small child in a store is separated from her mother, she may wail and cry to try to find her parent. When a couple is divorcing and has physically separated, the spouses often

experience “separation shock”, especially the partner less desirous of the divorce. He or she may feel so alone and abandoned that they panic and pursue their partner, begging them to try again. Both partners need emotional support and can benefit from divorce adjustment therapy (Joanning & Keoughan, 2006). Social support during times of crisis that stimulate the PANIC/GRIEF can help calm this circuit by raising endorphin and dopamine levels. Having close friends interact with a person feeling distressed due to loss of a loved one stimulates medial prefrontal cortex to release beta-endorphins that in turn calm the amygdala and hippocampus, leaving the person feel more connected. This response is similar to that described for the treatment of PTSD. Children raised by parents who have a good relationship tend to have better mental health in part because this brain system is rarely activated. Finally, affective support of individuals grieving the loss of a loved one boosts endorphin production and allows them to pass through the stages of grief without sinking into depression. Traditional cultures with close supportive communities have institutionalized this process. Sadly, modern cultures have moved away from long term close support of grieving individuals making grief more stressful. Therapists can provide grief support by allowing clients to repeatedly talk about their lost loved one until they have externalized the lost individual without pushing them to achieve closure. Being an empathic listener provides a context that stimulates the production of endogenous opioids (endorphins) in the brain of the client.

Couple Communication Couple therapists frequently hear client couples complain that they don’t communicate. Each person thinks their partner doesn’t respect or care enough about their concerns to really listen and respond in a manner that pleases the speaker; “I say the same thing over and over again but it doesn’t get through.” On the other hand, couples in satisfying relationships report feeling respected by understood by their partner. Couples can be taught to

communicate in manner that improves relationship satisfaction (Brock &Joanning, 1983) and the effects of such training or the lack of it can be measured (Joanning, Brewster, and Koval, 1984). Couples can be taught specific skills that change the primary emotional responses their bodies generate and in turn the feelings they experience at secondary level and the thoughts they have about their relationship at a tertiary level.

Specific skills that couples can learn that improve communication (Joanning, Brewster, and Koval, 1984) include listening to their partner and paraphrasing what they have heard before responding, ensuring that what is communicated is perceived as intended. Orienting their bodies to face their partner with hands in front, extended toward their partner, perhaps holding hands if the topic is important or intense, and leaning toward their partner. Staying with an issue and discussing it until the issue is explored and understood by both partners. Each partner modulates their tone of voice to sound interested in their partner's point of view. Understanding that agreement may not always be possible but that creative alternatives or compromise may be achieved. Couples in long term happy marriages display these behaviors (Henrich, 1987). Couples experiencing relationship difficulties tend to talk over one another, use a harsh or patronizing tone of voice, cross their arms or wave their arms in front of their bodies while talking, lean back away from their partner, change the topic or focus to defend their point of view, and make judgements about their partner's intent.

Couples who are in good relationships who communicate well report feeling calm, content, respected, understood by, and bonded with their partner. Descriptions of their thoughts and feelings indicate that their SEEKING/EXPECTANCY AND CARE/NURTURING circuits are up and running most of the time they are together. Evidence of these circuits being engaged can be measured use EEG, EKG, and other biometric readouts and by observing how they interact

while talking with one another about important issues in their relationship (Joanning, Shelly-Tremblay, Meyers & Overstreet, 2018). Couples in poor relationships display behaviors and report thoughts and feelings that indicate their RAGE/ANGER, FEAR/ANXIETY, and/or PANIC/SEPARATION circuits at times or frequently override their SEEKING/EXPECTANCY and CARING/NURTURANCE circuits.

Good communication appears to be a necessary condition to establish and maintain a good relationship. However, couples also need to be able to express affection, be physically and emotionally intimate as well as communicate to maintain a healthy, loving relationship. It would be interesting to give couples intranasal oxytocin as part of relationship therapy in an attempt to "jump start" the SEEKING/EXPECTATION and CARE/NURTURANCE systems. In a similar vein, it is probably important for therapists to exercise the "mirror neurons" of their sensory system so their bodies can empathize with the emotional state of their clients.

Divorce or Death of a Spouse When relationships deteriorate, the stress response described above sets in and couples go through a series of changes in their relationship (Joanning and Keoughan, 2006). The first change is "emotional erosion"; that is, positive feelings toward one's partner are replaced by negative feelings. The SEEKING/EXPECTANCY, LUST/SEXUALITY, PLAY/JOY, AND CARE/NUTURANCE circuits dissipate and the RAGE/ANGER, FEAR/ANXIETY and/or PANIC/SEPARATION circuits become dominant. The intensity of feelings generated by one or more of the later three circuits raise the stress hormone levels of one or both partners to the point that staying in the relationship becomes intolerable. Eventually the couple reaches the stage of "emotional divorce" and distance themselves emotionally. As this stage continues, the couple finally separates physically. This can set off "separation shock" mentioned above as their bodies adjust to absence of their partner.

Even couples who mutually decide to separate can experience this "shock". After living together, sleeping together, being sexually intimate, couples have habituated to one another physically and emotionally. Severing that tie can produce unexpected effects such as arousal of the PANIC/SEPARATION circuit, especially for a partner who does not want the divorce to occur. Any therapist who has done divorce counseling has seen this phenomena display itself as one or both divorcing partners engage in inappropriate behavior such as sexual promiscuity or exhausting their friends with complaints about their spouse. Some individuals contemplate suicide or causing harm to their partner. Fortunately, divorce adjustment training can moderate these severe reactions and help individuals adjust more appropriately (Joanning, 1985).

Fortunately, divorce can eventually remove stress as the RAGE/ANGER, FEAR/ANXIETY and PANIC/SEPARATION circuits dissipate and the SEEKING/EXPECTANCY, LUST/SEXUALITY, PLAY/JOY, AND CARE/NUTURANCE circuits are reactivated. Hopefully these changes occur as the partners go through the rebuilding and reestablishment stages of divorce; that is, they receive support from friends, establish a new intimate relationship, evaluate and change their behaviors (Fisher and Alberti, 2016).

Individuals who lose a partner to death also experience extreme stress especially if they had a close loving relationship with their spouse. The PANIC/SEPARATION circuit can become activated as they lose the close physical and emotional connection with their partner. This circuit is activated most severely if the partner dies suddenly because the surviving spouse does not have time to prepare emotionally. Widows and widowers also experience intense stress because of the loss of activation of the SEEKING/EXPECTANCY, LUST/SEXUALITY, PLAY/JOY, AND CARE/NUTURANCE circuits stimulated by their partner. Grief counselors can help these individuals mourn the loss and take steps to reactivate these circuits by encouraging their clients

to turn to friends and family for support and perhaps establish a new intimate relationship. Unfortunately for elderly women this can be difficult because of the limited number of same aged men. Some widows turn to female friends to fill the emotional support void.

Suggestions for Mental Health Workers Enabling people to better understand how their brain systems operate may be therapeutic. For example, treating Tinnitus (ringing in the ears) is best accomplished by first explaining what causes the tinnitus and how the brain's emotional reaction to phantom sound triggers a distress response. This basic understanding of the process is an important step toward helping individuals learn to cope. Explaining the unknown by describing how emotional responses arise from deep in the brain can reduce the fear factor; change the primary emotional reaction, especially when coupled with behavioral and emotionally focused therapy.

Further development of psychotherapeutic interventions may be facilitated by findings emerging from affective neuroscience. These interventions include direct brain stimulation such as transcranial magnetic stimulation, deep brain stimulation (of the subgenual anterior cingulate for treatment resistant depression), and the development of pharmaceuticals that more accurately target specific brain structures, neurotransmitters, and hormones.

Inducing emotionally based feelings at a secondary level can be rapidly achieved by directly stimulating primary emotional reactions. Examples include simply getting people to laugh, cry, or experience intense curiosity (primary emotional responses) by the use of jokes, playing with a child or a dog, mental imagery, music, or engaging entertainment. Highly focused emotional experiences like those used during the "human potential movement" of the 1970's can also stimulate primary emotional responses. Daily practice of positive emotional exercises can

habituate individuals to gradually replace the negative effects of past stress and trauma. Stage directors use such exercises to teach or assist actors to generate emotional responses needed to enhance the performance.

The personal characteristics of therapists are crucial to successful treatment. "Attention-Expectancy Effect", the impact of attunement to a client's emotional state while offering hope for improving that state is well known to researchers evaluating psychotherapeutic effectiveness. Therapists must be perceived as caring and able to offer helpful interventions. If a person is feeling bad and another person interacts with us in a caring, concerned manner we feel better. Such attention stimulates endorphin production and "eases the pain". Such caring attention to a client's emotional state can help change the primary emotional process that has "enslaved" the person's perceived feelings and higher cognitive functions. Creative caring, interventions that reframe a client's feeling and cognitive reaction to primary emotional processes can assist in changing those processes by reconsolidating memories in less troublesome forms. These emotion focused approaches to therapy access feelings emerging from primary emotional processes and change client reactions. Therapists tend to be a combination of social (helpers) and artistic (creative) personality types according to John Holland's Theory of Career Typologies. Who better to work with individuals wanting to change their emotional reaction to the vicissitudes of life?

Conclusion: The Neurobiological Model of Love outlined here is an attempt to provide a conceptual schema to understand how complex patterns of behavior, feelings, and cognitions of love are driven by our biology. Although we may "think" we understand how we fall in love and maintain love, it is our contention that much of this lifelong process is outside our conscious awareness.

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