The Biology of Human Behavior

Also by the author:

Exercise and Children's Health

Children's Exercise Physiology

Pediatric Exercise Medicine (with Oded Bar-Or)

The Athlete's Clock

Biological Regulation of Physical Activity

Tennisology

A Philosophy of Tennis, or You Kant Be Serious

Controversies in Exercise Science

The Fatigue Chronicles. Searching for the Limits of Human Physical Performance

The Biology of Human Behavior:

A Brief Inquiry

By

Thomas Rowland

Cambridge
Scholars
Publishing

The Biology of Human Behavior: A Brief Inquiry

By Thomas Rowland

This book first published 2020

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Cover: *Hercules, revealed* by Thomas Rowland

ISBN (10): 1-5275-4476-1
ISBN (13): 978-1-5275-4476-5

We are so small in every way compared with what there is,
and so ignorant.
Mystery surrounds us on every side.
—Bryan Magee

TABLE OF CONTENTS

PICTURE CREDITS

Figure 2.1. Personal collection of the author
Figure 3.1. Wikimedia Commons/ Public domain
Figure 5.1. Personal collection of the author
Figure 8.1. Personal collection of the author
Figure 10.1. Rembrandt
Figure 11.1 Andrew Schmidt/ public domain

PREFACE

Biological science. And human behavior. Hardly expected to be close travelling companions, these two. The first describes the quest for understanding the objective reality in the living world around us (including *Homo sapiens)*, while the second involves a confusion of emotions and experiences shared by the human psyche as we act out our lives, uncertain and subjective to say the least. The series of chapters that follow, however, will examine how evidence is gradually emerging that the two might surprisingly interface, and that much of what we experience and drives our behavior in our daily lives is controlled—at least to some extent—by objective biological processes. That's what this book is all about—what science can tell us about the ways we behave and relate to our fellow humans. A spoiler alert: on reaching the final chapter, the reader should not expect to have discovered any facile solutions or definitive insights to such "inquiries," but, rather, the author hopes, an awakening to lines of thinking that may ultimately provide us with such understandings.

Of course, it would demand an inappropriate expenditure of ink and paper to consider all the means that science and its applications through technology have impacted our modern lives. Science has brought us the ability to communicate instantaneously with all our friends, back up our car in a tight parking lot without risk of collision, permit a denizen of Miami to demand a restaurant reservation for tomorrow night in Vancouver just by making an oral command. We no longer worry about contracting poliomyelitis, going blind from cataracts, or suffering gnawing heartburn from over-indulgences. One can be transported from Boston to any of the major capitals of Europe in not much more time than it takes to cook a 25-pound Thanksgiving turkey. The list could go on and on.

Without doubt, science and technology have served us well in making our lives easier, safer, and more efficient. At the same time, one hesitates to be convinced that such advances have provided any advances in the more meaningful—and often challenging—aspects of the human experience. Here we can make a different list: establishing satisfying relationships with other persons, forming a loving, supportive family, working at a fulfilling occupation, behaving in an ethical manner, providing for the common good, finding a true meaning for one's life. Again, the list could go on. But here, on these more substantial aspects of human existence, little appreciation

exists for the input of science.[1] And that's it, the point of this book: in this more elevated and meaningful atmosphere of scholarly inquiry, evidence grows that biological science is beginning to shed light on the complexity of human behavior.

Before embarking on this "brief inquiry," let's be certain we know what we're talking about. *Science* is essentially a method, a means by which the reality of the natural world can be logically and accurately examined. The *scientific method* is a step-wise approach which assesses a *hypothesis (*a conjecture based on previous experience, observation, or studies) by a careful structured and controlled experiment. This method, then, is based on inductive empiricism rather than assuming that truths of the natural world can be revealed by reason alone. The assumption here is that there exists in any field of inquiry an objective truth, and that the scientific method is the means for discovering it.

Despite its time-tested validity, a number of issues swirl about this conclusion. To start with, does an ultimate truth actually exist? Is the human brain—or even, by extension, a computer—capable of understanding this truth? Does use of the scientific method to examine a hypothesis imply that truth can be assumed only when there exists a test to determine if it is "falsifiable"? Is there a "real" objective universe that surrounds us? Or, does reality only exist in light of how we human beings observe it?[2]

The link of science and what constitutes the "real world" has undergone a series of serious upheavals, beginning with the teachings of Euclid, which held that the universe conformed to rules set forth by geometrical principles, then Newton, who described a deterministic, mechanistic universe based on physical laws of motion, which was superseded by Einstein's theories of relativity, by which reality depends on the condition and motion of the observer, to, most recently the bizarre subatomic world of quantum mechanics, where uncertainty rules, and chance replaces cause and effect.[3] Even within the realm of deterministic behavior, chaos theory indicates that minor differences in initial conditions can be manifest as random and unpredictable outcomes (such as weather forecasting).

Each of these approaches truly describes an aspect of the "real world." But they reflect a reality only in a certain perspective, and these domains are often mutually exclusive. The conclusion therefore is that the goal of *science* as an endeavor to describe the natural world must be appreciated only within certain restrictions of the form of "reality" being addressed.

Living beings share functions that obey the laws of physics and chemistry, yet there exists the obvious observation that "something" sets apart living systems, or biological truths, from those of other scientific disciplines. Whether such biological "laws" exist (most would think so),

and of what these consist (no one yet knows) remain issues that have drawn controversy for centuries. Particularly, for the discussion at hand, one can reasonably ask (without expecting an answer) whether such unique biological determinants are responsible for human behavior, or, on the other hand, how we act is simply an outcome of the cerebral interaction of molecular attractions, biochemical neurotransmitters, and ion-derived electrical charges—all conforming to traditional physical and chemical laws.

Defining *human behavior* proves to be even more problematic. Perhaps one could start by thinking how one would respond to an alien visitor from outer space who asks "What is it like to be a human being?" You might start by answering "Well, I am a biological machine, although it remains a mystery as to precisely how, as a living being, I differ from non-living matter. This machine that I am has evolved through many millions of years by a process of natural selection so that my working parts are in fine harmony with each other and resist perturbations of environmental disturbances. For the most part, this machine operates beyond my awareness, automatically responding to my physiological needs. I have a brain inside my head, though, that *thinks*, and since I can in this way "talk" within myself (gratefully in my native language) I feel like I am the captain of a ship, providing orders of where I should go and what I should or should not do. It seems, though, that I am often deceived by this sense of free will and self-determination by my thinking brain, because it is now understood that a large part of how I behave is dictated by subconscious actions deep within its gray matter that, in fact, often direct what I mistakenly feel are my own thinking decisions and behaviors."

You could continue: The relationship of my sense as an individual and that of a member of an organized group, or society, is a complex one. For example, although "civilized," I still possess the instincts and drives of my animal ancestors. So, I must channel my appetites, aggression, sexual desires, and so on into socially acceptable ways. I have certain desires, or goals, in my life, and I direct many actions towards satisfying these—finding a love partner, raising a family, finding a satisfying life's work, financial security, seeking pleasure and courage in facing the challenges in life's ups and downs, and so forth. To accomplish this my behaviors must satisfy the requirements of the culture in which I live. And this sometimes requires that I sacrifice my desires as an individual for the collective good of that society. At the same time, it is clear that I need a surrounding society to provide me with an infrastructure—food, clothing, shelter, protection, health care—that allows me to survive. So, the relationship between myself as an individual and that of a constraining but nourishing society is a highly

complex one which must be satisfactorily negotiated to reach one's goals in life. The drive for individualism must be balanced against the demands of society, and my will for personal freedom must also be tempered by my requirements to find security and personal identity as part of a human group.

In fact, this "escape from freedom" has been considered as an essential aspect of my psyche, paradoxically contradicting the will toward my nature to exist as an individual. That we should seek "freedom or death" is everywhere from historical accounts to New Hampshire license plates, but the meaning here (one supposes) is freedom against tyranny of society (or more precisely, society's government). Yet, in fact, freedom from acting as a member of a society would be intolerable. Edward Wilson wrote insightfully about this:

> "An hereditary peculiarity of human behavior is the overpowering instinctual urge to belong to groups in the first place. To be kept in solitude is to be kept in pain and put on the road to madness. A person's membership in his group—his tribe—is a large part of his identity. It also confers upon him to some degree or other a sense of superiority….All thing being equal (fortunately things are seldom equal, not exactly), people prefer to be with others who look like them, speak the same dialect and hold the same beliefs."[4]

All of these multi-directional arrows of that link me with my society influence the human experience. The ultimate human condition that looms over my daily existence, though, is that my time here on Earth is a limited one. We human beings are, in fact, the only living beings who are aware of their own mortality. How to face this inevitable reality is perhaps the most confounding of my difficulties in defining a meaning for my short stay. For many a certain fatalism can thus haunt their lives, the resigned acceptance that any of our actions and behaviors are of temporary consequence; others, particularly those with a belief in God and the reward of an after-life, find this faith to be a more accepting resolution.

"It probably strikes you," you say to your Martian visitor, "that each morning a human being awakes with a blank slate of behaviors, unlimited options, which can be freely adopted to satisfy one's need for pleasure and happiness in life." "Yes," he replies. "Then why don't you just do that?" "It just doesn't work like that," you say. "There is a line in popular song by the Eagles which says 'we are just prisoners here of our own device,' which says it all. We are obligated to elect certain behaviors (some would insist that these are pre-determined instead of subject to free will) for not only our benefit but also for the good of living in a nurturing society as well."

It has not been lost on dramatists (including the Bard himself) that in our daily lives we behave as if we are acting roles—father, boss, rock star, spouse, best friend, and so on—in a giant play, which we adopt to satisfy the complicated arrangements we have with personal goals and ego-supportive activities consistent with our part in organized society. Think about a list of what governs how we learn to behave, or act out our roles. You might include:

- Parents and family members
- Behavior of peers
- School teachers
- Religious leaders, athletic coaches as role models
- Imitation of behaviors in films, plays, literature, television shows
- Legal constraints

Looking at this compilation, one might easily conclude that the determinants of human behavior are all culturally-derived—that the script of our lives that we play out reflects the influence of family, community, and society in general. That is, we adopt behaviors according to what is expected of us by the culture in which we live. At least theoretically, one could cognitively decide to do or not to do this (or at least some of this). We have, it could be argued, a choice.

However, this perspective ignores the central role of emotions in triggering human behavior as well—sadness from personal loss, jealousy, euphoria, the pain of rejection, anger at being cut off in traffic, etc. A good many would argue that these reactions which guide behavior are biological, being evolutionary-derived (as witnessed even in animals). And, in accepting this concept, one is left with a more deterministic outlook on human behavior. Controlling emotions is difficult, although the behavioral reactions to such emotions may be managed.

Just *why* biological determinants should underlie human emotions is, of course, a fabulous mystery. What would be the evolutionary value of all the sentiments that flood our minds on a daily basis? How do they fit into a general picture of an advantageous reproductive capability? Now we're getting down to what this book is about. Again, no answers will be provided, but food for thought will be gratuitous.

Now that we have a general sense of the meanings of biological science and human behavior, we can proceed with a description of the focus of this book--an examination of how the former might impact the latter. What follows is a series of factual discussions of just how different aspect of

human behavior and experience—love, travel, aging, jealousy, and so on—can be placed in the context of the growing awareness of both philosophical and scientific inquiry. Thrown in, too, are a pair of fictional pieces, a short story and a play, as well as two brief discussions to fill up the intermissions (*Les Entr'actes*) provided for those readers wishing a break for refreshments or other human needs. As much of this material transgresses on rather combative grounds of opinion, each chapter is replete with quotations from those who have weighed in on these issues. The references provided will offer the reader whose imagination is stimulated by these discussions the availability of further resource material.

Hopefully not necessary to say, but still important to emphasize, the author asks that the reader approach each of the issues in this book with an open and receptive mind. Much of this subject material has previously been trivialized and strait-jacketed into opinions which should be popular or "correct." One of the purposes of writing this book is to offer the reader the opportunity to free oneself from the shackles of these conventions and strike out on unexplored intellectual and behavioral territory. In the course of this exploration one is presented with the possibility of gaining greater insights into the nature of this extraordinary complex creature we call *Homo sapiens.* Bonne route!

Notes

1. Rothman T, Sudarshan G. *Doubt and Certainty.* Reading MA: Perseus Books, 1998.
2. See Lewens T. *The Meaning of Science. An Introduction to the Philosophy of Science.* New York: Basic Books, 2016; Holt J. *When Einstein Walked with Gödel. Excursions to the Edge of Thought.* New York: Farrar, Straus and Giroux, 2018.
3. Davies P, Gribbin J. *The Matter Myth.* New York: Simon & Schuster, 1992.
4. Wilson EO. Evolution and our inner conflict. In: Catapano P, Critchley S. *The Stone Reader.* New York: Liveright Publishing, 2016, pp. 270-274.

1. LOVE

Love, unrequited love, robs me of my rest:
Love, hopeless love, my ardent soul encumbers:
Love, night-mare like, lies heavy on my chest,
And weaves itself into my midnight slumbers!
—*From* Iolanthe (Gilbert & Sullivan)

The French, as usual, have a better way of saying it: *un coup de foudre.* To English speakers it's "love at first sight;" for les Parisiens it's a "bolt of lightning." Which is just what it is. Flash! Boom! Crash! It doesn't much matter if it's "across a crowded room," or "strangers in the night, exchanging glances," or just that you "saw her standing there." It ranks among the most supreme feelings of emotional euphoria that a human being can experience.

Of course, romantic love often comes more gradually, too, in a sense "sneaking up" on one unexpectedly. (In the standard cinematic fare this is predictable by two oil-and-water protagonists at the beginning of the film, who initially detest each other but then…) Thus one, in this more restrained process, "falls in love," so that "on est tombé amoureux." It's interesting here that in both languages this process is considered in terms of "falling," perhaps a bit of insight that will be dealt with later in this chapter.

The reader will no doubt agree that the subject of romantic love has always taken on a rather frivolous flavor. Not serious, somewhat amusing, thanks to Cupid and shooting arrows, tunnels of love, puppy love, love boats, lyrics of popular music, and so on. Add to this the fact that falling in love is often first experienced in the pubertal throes of adolescence, with its naivety, immaturity, and social awkwardness. The past several decades, however, have brought a realization on the part of researchers, psychologists, psychiatrists, and the like, that romantic love is, to the contrary, a very serious business. Falling in love is attended by a suspension of normal social and moral judgements, while rejection and/or termination of a romantic relationship can be emotionally devastating and accompanied by very real risks of non-frivolous matters such as severe depression, stalking, suicide, and homicide. Indeed, in these features—ecstatic pleasure and insupportable nightmare of withdrawal—the entire process of falling in and out of love is not dissimilar to that of narcotic addiction, an affliction considered to be of

much greater import and significance than that of "simply" falling in love with the girl or guy next door.

This chapter will examine what this new research attention has revealed regarding the nature of romantic love. Much of this scientific information has served to simply confirm centuries-old ideas of what it means to fall in love. But some fascinating new concepts have arisen as well, such as the neurochemical basis of romantic love, its similarity to addictive behaviors, why breaking up with a love object is, indeed, "hard to do," and relationships that may exist between emotions of love and hate. All of this is witness, then, to the growing role of science in understanding human behavior. The reader is forewarned, however, that the essential question once posed by the young singer Frankie Lymon—"Why Do Fools Fall in Love?"—will not be likely resolved in any satisfying manner.[1]

(The psychological and philosophical implications of this question presumably were not appreciated by Mr. Lymon when he recorded this song with The Teenagers in 1956. What causes one person to fall in love with another? Does one, in fact, possess free will to *choose* or *not to choose* to fall in love? Based on much of the evidence outlined in the discussions that follow, perhaps the answer to the latter question is "probably not.")

Defining Romantic Love

So what exactly are we talking about here? One could probably devote a full chapter to the various interpretations of the meaning of the word "love." The discussion in this chapter is restricted to that *coup de foudre* kind of falling in love that we'll call *romantic love,* an intensely passionate yearning for another person. The exhilaration on seeing or thinking of the other person can be overwhelming. Sleep is troubled by a constant thinking of the beloved. "Besotted lovers may also compulsively call, write, or unexpectedly appear, all in an effort to be with their beloved day and night. Paramount to this experience is intense motivation to win him or her."[2] In contrast to other forms of love, romantic love is both irrational and unrealistic. The positive features of one's obsession becomes all-consuming, to the exclusion of all negative else. When this torrent of emotional focus is reciprocated, the ecstasy is further compounded.[3]

Two other forms of love have often been considered associated with this kind of romantic love—*sexual attraction* (lust), and the emotion that links married couples, which we'll label *spousal love.* The former is goal-directed with or without emotional attachment, while the latter is a rational bond based on trust and respect that grows from shared emotional, experiential, and physical intimacy. Throughout history many have felt that some

common ground, either simultaneously or, more likely, in temporal succession (i.e. one leading to the other), exists between these three, but, at the same time, it is not difficult to claim certain differences. It would not be expected, for instance, that falling in love at a tenth-grade sock hop would by necessity include a desire for sexual union;[4] certainly a sexually desirable person might be courted with the goal of physical intimacy in mind without the emotional accoutrements of romantic love. Too, these same volcanic emotional features of falling in love, one might confidently suggest, don't exist in the majority of long-term marital love relationships. (To draw parallels to other used terms, spousal love (or its companions, *filial and maternal love*) here is considered as *mature love,* while romantic love—the topic at hand—is *immature love.)* As will be addressed below, recent neuro-imaging studies have substantiated such proposed relationships between the three—overlapping but with distinct anatomic functions.

A number of other features characterize romantic love:

- Experiencing the emotional trauma of a romantic breakup or an unrequited love is common, particularly among teenagers. In a study of 910 Canadian adolescents, Connolly and McIsaac found that 23% had experienced a breakup in the past six months.[5] In somewhat older young adults the number is higher. Baumeister reported that 93% described having been rejected by a passionately-loved other. (Of interest to those who would insist that turn-around is fair play, 95% reported they had served as the rejecting person of someone who was in love with them.)[5]
- While euphoria and happiness are considered the "reward" that transports one into a state of romantic love, such experiences are often marked by periods of emotional distress as well.[6] Similar to manic-depressive (bipolar) behavior, the love-stricken person not infrequently experiences swings in emotional state, with anxiety, depression, and insecurity balancing times of overwhelming ecstasy.
- The emotional forces that put a person "in love" have a limited lifespan. Ultimately, the neurochemical reactions outlined below which drive romantic love run down. For most, relationships built only on romantic love in the end, quite literally, run out of gas. Some have suggested 12 to 16 months as an average.
- Romantic love is a universal phenomenon, recognized in all societies when appropriate investigational methods have been utilized, and is independent of sex. These observations support the conclusion that

falling in love represents a biological rather than a culturally-derived phenomenon.

The Science of Love

An understanding of the nature of love, once confined to the realm of folklore, has been provided a scientific foundation by advances in neuroimaging techniques and insights into cerebral neurochemical pathways. These have revealed that 1) the centers in the brain responsible for the euphoria and other exhilarating features of romantic love are discrete and distinct, but still some cross-over and overlapping functions are observed with centers responsible for sexual attraction and spousal love, 2) when falling in love, separate neurologic pathways act to inhibit rational decision-making and even challenge moral limits, confirming that, in fact, "love is blind," and 3) the neurochemical functions underling the emotional experiences of falling in and out of love mimic directly those of other established addictions (such as narcotics, sex, gambling, etc.).

Neurophysiological Localization

The advent of neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET scan) has for the first time permitted key insights into brain function. Particularly, these methodologies have identified links between subjective mental processes (i.e., emotions) and anatomic localization. Both of these diagnostic methods work by identifying areas of the brain demonstrating increased metabolic rate, which is associated with neuronal activity. In a typical investigation, then, the act of an individual falling in love is reflected in a "lighting up" on a scan of a responsible brain regions by these techniques.

A number of such imaging studies have been performed in an attempt to link the activity of specific brain regions to the act of falling or being in love. These have quite consistently revealed that one particular area—the ventral tegmental area (VTA)—is activated in individuals involved in a passionate love affair, with close connections to the nucleus accumbens and regions of the cerebral cortex that include the medial insula, anterior cingulate, and hippocampus.[7] The study of Aron et al. is typical.[8] These authors reported fMRI findings in 10 women and 7 men who reportedly had recently fallen intensely (and happily) in love. (As proof of the appropriateness of this cohort, all the subjects reported that they spent at least 85% of their waking hours thinking of the object of their affection.) When viewing a photo of their loved one, augmented activity was observed

in the VTA and caudal nucleus, "regions associated with pleasure, general arousal, focused attention and motivation to pursue and acquire rewards."

Importantly, such scanning studies indicate that areas associated with other forms of love (including sexual arousal and maternal love) may overlap regions associated with romantic love but remain distinct from them. In 2010, Ortigue et al. reviewed the published literature which has described fMRI studies indicating brain regions that are linked to different forms of love (J Sex Med. 2010;7:3541-52). Although all types of love were associated with activity of brain reward systems, this review "demonstrated that different types of love involve distinct cerebral networks, including those for higher cognitive functions such as social cognition and bodily self-representation."

The finding of similar but distinct areas of brain function for different forms of love coincides with observations from common experience. That is, one would not confuse the behaviors surrounding a mother's love or that of a couple on their 50th wedding anniversary with that of a college sophomore experiencing a c*oup de foudre* with his chemistry lab partner. This does raise some interesting thoughts, though, regarding the possible connection of romantic love, spousal love, and arousal of sexual drive, which, again, are emotions which demonstrate distinctly separate, though overlapping, areas of cerebral activity. Specifically, does the former lead to the latter? And, by extension, if so, can we then ascribe an evolutionary basis for romantic love as a kind of "jump start" to more mature, sustained love, sexual activity, and reproductive preservation of the species? Here is what S. Zeki had to say on the matter (FEBS Letters 2007;581:2575-2579):

> "It is noteworthy that sexual arousal activates regions adjacent to—and in the case of the hypothalamus overlapping with—the areas activated by romantic love……This intimacy in terms of geographical location between brain areas engaged during romantic love on one hand and sexual arousal on the other is of more than passing interest. Judged by the world literature of love, romantic love has at its basis a concept—that of unity, a state in which, at the height of passion, the desire of lovers is to be united with one another and to dissolve all distance between them. Sexual union is as close as humans can get to achieving that unity. It is perhaps not surprising to find, therefore, that the areas engaged during these two separate but highly linked states are juxtaposed."

Besides activation of brain areas associated with pleasure-seeking reward systems (see below), falling in love has been observed to trigger a *decrease* in activity in areas of the cerebral cortex which are normally responsible for controlling judgements one uses to assess other persons. This effect accounts for what is typically observed in persons who are head-

over-heels in love—a failure to objectively consider the qualities of the object of their passion. "Here, then, is a neural basis for saying that love is blind. It is not surprising that we are often surprised by the choice of partner that someone makes, asking futilely whether they have taken leave of their senses. In fact, they have. Love is often irrational because rational judgments are suspended or no longer applied with the same rigour." Falling in love, then, is a two-pronged neurological process—"euphoria and suspension of judgement [which] can lead to states others might interpret as madness" (Zeki S. 2007;581:2575-2579).[9]

A Biochemical Basis

Readers owning a pet hamster will be quick to confirm the compulsive wheel-running that these small animals exhibit in their cages, often for hours at a time throughout the night. Why do they do that? The answer is that they are motivated by a "reward" system within certain specific areas of the brain, fueled by the neurotransmitter dopamine and other biochemical agents, which provides a strong sense of "pleasure" (assumed but not reported by the animal).[10] (A similar explanation has been suggested for humans who engage in obsessive distance running.)

Dopamine, an agent chemically related to adrenaline, has received a good deal of popular attention for its reputation as a conveyor of sensory pleasure—the "rush" from your morning coffee, the joy of sexual union, the euphoria of falling in love. This chemical does, in fact, participate in a wide variety of disparate physiological functions, including lactation, vasoactivity of arteriolar walls, cellular immune responses, gastrointestinal motility, and the salt content and volume of urine output (Figure 1.1).

In the central nervous system, dopamine serves to connects signals from one nerve cell (neuron) to the next across a synaptic space. Dopamine-secreting neurons are grouped within the brain in specific areas related to a particular function, although a wide network of connections to other portions of the central nervous system is typically evident. In the ventral tegmental area (VTA), the nucleus accumbens, and other areas of the brain dopamine participates in a "reward system" whereby certain behaviors are reinforced and thereby motivated by providing positive feelings of pleasure.

Some researchers have contended, however, that dopamine does not actually serve as a "pleasure chemical" in this regard but instead is "necessary for 'wanting' incentives".[11] That this differentiation between "wanting" a romantic partner and "liking" an attractive face (or sunset, or Monet canvas) may have a neurophysiological basis was indicated in the fMRI study of Aron et al. noted above. These investigators found that when

viewing an attractive face, study participants activated the left VTA, while when looking at a photo of a love partner, the right VTA became activated.

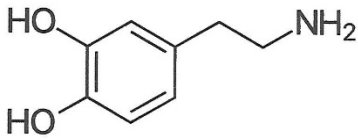

Figure 1.1. So this is love? (Or rather cupid disguised in the molecular structure of the neurotransmitter dopamine?)

This action of dopamine-based reward circuits in the central nervous system has been well-documented as the driving factor in compulsive wheel-running in rodents. Evidence indicates that the same reward system is in play during courting and coupling of animals as well. One faces a difficulty, of course, in interpreting such behaviors in animals as parallels to the different forms of love defined in human beings. Do animals experience the same kind of reward-system euphoria as do humans in the throes of passionate romantic love? One witnesses certain characteristics of courtship in animals, but do these reflect the same behaviors of humans afflicted with a *coup de foudre* (as opposed to sexual or spousal love)? Some authors have thought so. As Fisher et al. have contended:

> "Like humans, all birds and mammals exhibit mate preferences; they focus their courtship energy on favored potential mates and disregard or avoid others. Moreover, most of the basic traits associated with human romantic love are also characteristic of mammalian courtship attraction, including increased energy, focused attention, obsessive following, affiliative gestures, possessive mate guarding, goal-oriented behaviors and motivation to win and keep a preferred mating partner for the duration of one's species-specific reproductive and parenting needs."[12]

A number of studies have examined neurochemical correlates to mating and coupling behavior in animals. The role of dopamine systems has been particularly substantiated. For example, in one study a 50% increase in dopamine content of the nucleus accumbens was observed during expression of mating preference of prairie voles. Subsequent injection of a dopamine antagonist resulted in dissolution of the attraction. Increased dopamine activity in the central nervous system in association with courtship attraction has also been observed in sheep and rats.[13]

In addition, other neurochemical agents appear to be involved in aspects of animal courtship. Mating behavior has been closely linked to oxytocin,

produced by the hypothalamus, and vasopressin. Yong and Wan have suggested that these two agents "facilitate the process of social cues necessary for partner recognition while dopamine plays a reinforcing role by signaling reward."[14]

That the same anatomical areas of the brains of human beings falling in love are activated on fMRI as those associated with the dopamine reward system in animals is strong evidence that these same neurochemical processes account for romantic love in humans. This conclusion is supported by some experimental evidence. Particularly convincing is the study of Takahashi et al. who demonstrated increase in dopamine release within human brains by administration of a dopamine receptor antagonist with PET scanning when subjects were viewing pictures of romantic partners.[15]

Other neurochemicals are involved in inter-personal attraction and coupling in humans that mimic those observed in animals. Falling in love has been associated with depressed brain levels of *serotonin.* Limited research information suggests that oxytocin and vasopressin play important roles in long-term love relationships in the same manner that they trigger animal coupling behavior.[16] It appears likely, then, that the actions of these agents effect coupling and connectiveness, and in humans are probably related more to long-term commitments which reflect mature spousal love with a secure, reality-based emotional union than romantic love. Sexual drive, on the other hand, is linked to a different chemical basis—the actions of the sex hormones, testosterone and estrogen. The combination of neuroimaging and neurochemical findings suggest, then, that the three types of human love—romantic, sexual, and spousal—are distinct in terms of functional brain structures and biochemical pathways responsible for each. How each evolves over time in a relationship, and the extent that these individual forms of love interact and might follow each other "in tandem" remains to be clarified.

All of this discussion of brain chemistry, then, leads to the somewhat discomforting conclusion that falling in love is perhaps nothing more than straightforward chemical reactions within the brain.[17] When you exchanged glances with that stranger in the night standing there across a crowded room your brain became inundated with a tsunamic wave of dopamine and its chemical traveling companions, and—voila!—an extraordinary rush of ecstasy (akin to what has been described in response to, for instance, cocaine). The great mystery—not yet revealed by scientific inquiry—then, is why that particular stranger, in that particular room, on that particularly enchanted evening?

Biological Meaning

The neurochemical mechanisms that likely underlie the process of falling in love have been identified, but many questions remain to be answered: can we confidently transpose animal experimental results to human beings? Which way does the arrow of causation go? Do emotional responses to visual stimuli trigger release of dopamine-based reward systems? Or, conversely, are dopamine and its related chemical agents *responsible* for the emotional reaction? In essence, then, what is responsible for launching one into the throes of falling in love? Studies show that, not surprisingly, visual triggers set it off. But how many strangers have you exchanged glances with across a crowded room without inaugurating this cascade of neurochemical events that would put you in the remarkable mental condition of "being in love"?

If we accept that a *coup de foudre* is basically just a chemical event, we are still left with the mystery of why does one fall in love in the first place? It's a very singular, irrational emotional state that defies common sense, one that will typically self-destruct in a matter of months. And, in more cases than not, that rupture fill one or both parties with pain and depression or even worse. We again have to stop and wonder: why *do* fools fall in love? The siren call of the *coup de foudre* appears to be irresistible, indicating that some particular biological "meaning" is at play.

The traditional, seemingly-obvious Darwinian biological explanation for the experience of falling in love (as defined in this chapter) lies in its support of evolutionary natural selection of reproductive fitness. As Fisher et al. proposed, "romantic love is a …survival mechanism to encourage human pair-bonding and reproduction, seen cross-culturally today in Homo sapiens….Its [evolutionary] purpose may have been to motivate our forebears to focus their mating time and energy on a single partner at a time, thus initiating the formation of a pair-bond to rear their young together as a team. Thus, as products of human evolution, the neural systems for romantic love and mate attachment could be considered as survival systems among humans."[12]

Reproduction and successful child-rearing—the obligate markers of human evolution—require a coupling of humans with subsequent sexual congress and long-term attachment. So, would go the proposal, the magnetic attraction of one person to another via romantic love serves as the initial catalyst which eventuates in these other critical forms of love necessary for propagation of the species. It is difficult to argue persuasively against this idea. Still, a number of thoughts provide some hesitancy—or even a soupcon of skepticism. That euphoric high experienced in the sudden rush

of romantic love has not, by itself, been considered to driven by a desire for sexual relations. Typically, such romantic love is short-lived, and it would be expected that the frequency of a transition to a more mature, committed spousal form of love is not high. That is, romantic break-ups must well outnumber—by multi-fold—those that proceed to marriage. Consider: an experience of romantic love is characterized by emotional instability, irrational obsessions, anxiety, towering feelings, anorexia with weight loss, and insecurity, as well as a suspension of a rational awareness of the qualities of the love object. Hardly, it could be argued, does this sound like a mental state that should serve as a valid basis for coupling in order to maintain the species.

Are there other possible means of providing a biological "meaning" to falling in love? Here's one idea: in the end, despite obsession with another person, falling in love could be considered as a egocentric, self-centered act. That is, the ultimate desire is that this magnetic attraction be reciprocated, that the loved object will respond with love and undying affection as well. In this way, falling in love might be considered as an ego-supportive, self-affirming search to bolster a sense of self-worth. In this sense, the insecure individual with a poor self-image, full of self-doubts, might be particularly vulnerable to falling in love, as displayed by a pattern of repeated attempts at romantic liaisons.

Perhaps a more central question would seek the biological meaning of the dopamine-based pleasure-reward system in the brain itself. In animals, to secure pairing and reproductive success for propagation of the species, yes. But why should the same system trigger obsessive wheel-running by caged rodents for hours at end? The concept that similar reproductive outcomes in human beings via marriage are proffered by this system seems logical. But one immediately runs head on into the fact that the same reward system is responsible for the life-destructive, tragic scenario of drug addiction. Within this spectrum of effects, one's morning coffee habit, not usually fatal, is driven by the brain's pleasure-reward system as a mildly-addictive, pleasurable, but not a convincing Darwinian exercise. The same could be said for other "obsessive habits" driven by dopamine—gambling, eating, shopping, promiscuous sex, and the like. Where would these fit into a drive for reproductive survival of the fittest? It is evident that the dopamine reward system plays out in both positive adaptive and negative outcomes.

In essence, then, the biological meaning behind a *coup de foudre* may not be as straightforward as it would seem. Certainly, there is much to be learned.

Breaking Up *is* Hard to Do

The euphoria and "soaring feelings" of falling in love come with a price. No one who has experienced the spirit-crushing anguish of rejection of unrequited love or break up of a love relationship needs (nor desires) to be reminded. What goes up must come down. Breaking up with a love partner is not only simply hard to do; it is, for all, at least painful and for some, emotionally destructive and even dangerous. Of course, most romantic breakups are survived with eventual resolution over time of the incurred emotional wounds. For some, however, the insult to self-esteem leaves chronic scars of depression and other mental disorders. The frequency of incapacitating, extended emotional distress following a romantic breakup is not known. Anecdotal reports would suggest, however, that the magnitude of such outcomes is grossly underestimated and has been overlooked as a significant mental health issue.

Unfortunately, in some cases the mental disturbance accompanying unrequited love or break down of a romantic relationship can eventuate in homicide, stalking, or suicide. Such tragic outcomes are the stuff of legend, but also, sadly, of the everyday.[18] Romantic breakup is commonly assumed to be responsible for suicidal behaviors, but statistical confirmation of this relationship is hard to come by. In one study of 142 successful suicides among youth 10-17 years in the state of Utah between the years of 2011 and 2015, 37 (26%) were said to be related to "intimate partner problems" or "dating partner problems."[19]

According to the Federal Bureau of Investigation, in a given year around 10% of murders in the United States are committed by the lover of the victim.[20] Excessive jealousy in a romantic relationship may serve as a source of such tragedies, even before a romantic relationship is severed.[21] Many of these, too, are sad outcomes of *stalking,* in which a jilted lover obsessively haunts a former romantic partner. Such situations are not rare, estimated to have affected 8-15% of women and 2-14% of men. As Marazitti et al. have remarked, "the deactivation of cognitive processes that take place when we fall in love (even though this is a short lived process!), may imply a sort of stalker blindness to understand the risks involved and the consequences of his/her behavior, and the misconception that he/she might be able to change the victim's feeling via the persistence, harassment, and constraints."[22]

Is Romantic Love an Addiction?

The similarities between falling in love and substance addiction have not been lost on neuroscientists, psychologists, and composers of popular songs alike.[23] Helen Fisher and her co-authors have nicely described these parallel behaviors (Front Psychol. 2016;7:687):

> "Mean and women in the early stage of intense passionate romantic love express many of the basic traits associated with all addiction. Like all addicts, they focus on their beloved (salience); and they yearn for the beloved (craving). They feel a 'rush' of exhilaration when seeing or thinking about him or her (euphoria/intoxication). As their relationship builds, the lover seeks to interact with the beloved more and more frequently (tolerance). If the beloved breaks off the relationship, the lover experiences the common signs of drug withdrawal, too, including protest, crying spells, lethargy, anxiety, insomnia, or hypersomnia, loss of appetite or binge eating, irritability and chronic loneliness. Like most addicts, rejected lovers also often go to extremes, even sometimes doing degrading or physically dangerous things to win back the beloved."

This parallel between romantic love and drug addiction is supported, too, by the finding that the dopamine-based reward system acting in the brain which underlies these behaviors is similar in the two. At the same time, there exist, it can be readily pointed out, certain differences that distinguish falling in love from opiate addiction. The proposed evolutionary "purpose" of romantic love, a universal phenomenon, as a Darwinian survival mechanism is hardly consistent with the destructive force of narcotic addiction. Unlike the sad outcome of drug addiction, unrequited love, by itself, is presumably not fatal. And people, perhaps abetted by popular culture, seek to fall in love, which is certainly not an antecedent to drug addiction.

Such considerations of the addictive nature of love may bear more than just academic interest. Some authors have suggested, in fact, that given the potential for romantic love to induce serious and destructive emotional disease, treatment is a viable option. "Although one would not normally think of offering 'treatment' to individuals who are in love, once we begin to realize that at least some cases of love and love-related phenomena are similar to behavioral or substance addictions—in form, function, as well as effect—then the possibility becomes worth taking seriously."[24] This might include traditional psychiatric strategies such as cognitive-behavior approaches as well as psychoanalysis, and drug-based therapies could be ethically-appropriate in some situations.

To Be "In Love" Just to be "In Love"?

One cannot leave the topic of romantic love—the "rush" of a *coup de foudre*—without raising the possibility that it's just "being in love" that provides the euphoria, not "being in love with somebody." That is, perhaps romantic love is in reality selfish and intrinsic, sought after for its "kick," rather than being directed at some person (albeit with mythical qualities). We're talking here about "being in love with being in love." Certainly, this idea is portrayed in a raft of popular songs, all on the theme that one is "looking for someone (anyone?) to love." (For definitive evidence of this concept, one need look no further than the movie *When Harry Met Sally,* in which Sally Albright (played by Meg Ryan) confesses to Harry Burns (portrayed by Billy Crystal) that she does not yearn for her recent boyfriend after a break-up, but she does miss the "idea of him.")

Conclusion: Love *is* Strange

In the spectrum of human emotional experience, romantic love is truly unique. Consider: the deal is almost truly Faustian—an exquisite, euphoric, mind-blowing "high" gained in accepting the high risk of an eventual hellish withdrawal payback—except that in this case one doesn't have a choice in the matter. Instead, in falling in love one is at the mercy of yet-unknown, powerful subconscious biological and psychological factors, outside of one's control. Here is a clear violation of any contention of the strength of free will in human beings. "We do not ordinarily *choose* to love someone (at least not consciously) and it would be a hard thesis to defend that we should be held *responsible* for falling in love—even though such an occurrence can have very far-reaching and sometimes destructive consequences for those involved."[25] Falling in love, then, is something that happens to you, for the better or worse.[26] The seriousness of the "worse", it has been contended, has not been adequately appreciated by mental health professionals.

Notes

1. Frank Zappa would not be pleased with this author's employment of lyrics of popular music in discussing romantic love. Zappa felt that such songs of love's joy and lament to vulnerable youth were sadly disillusionary. As the iconoclastic musician expressed in *The Real Frank Zappa Book* (Poseidon Press, 1989), "I detest love lyrics. I think one of the causes of bad mental health in the United States is that people have been raised on 'love lyrics'…It's a subconscious training that creates a desire for an imaginary

situation which will never exist for you. People who buy into that mythology go through life feeling that they got cheated out of something."

That said, it must be admitted that popular music has remarkably-well documented the highs and lows, the ecstasy and the anguish, the futility and inescapability of romantic love. Indeed, a connoisseur of popular music lyrics—particularly of songs written during the early rock 'n roll era—would be well-acquainted with the majority of concepts presented in this chapter. (It would seem that more recently popular music has largely moved on to more mundane themes—learning to fly, consuming margaritas, shooting sheriffs, and the like.)

2. This quote is from Fisher HE, Xu X, Aron A, Brown LL. Intense, passionate, romantic love: a natural addiction? How the fields that investigate romance and substance abuse can inform each other. Front Psychol. 2016;7:687. Helen Fisher, from the Kinsey Institute at Indiana University, is also author of a comprehensive book entitled *Why We Love* (New York: Owl Books, 2004) which provides an excellent overview of this field.

3. Many colorful expressions have described the exhilarating experience of falling in love. Andrew Christy and his colleagues at Texas A&M University noted that many of these involved the idea of physical force—such as love "sweeps us off our feet, causes sparks to fly, and ignites flames of passion." Of course, too, the entire *coup de foudre* is based on attraction of one body to another. According to what is known as *conceptual metaphor theory,* "activating the concrete concept in a metaphor should alter perceptions and judgements related to the linked abstract concept." (Translation:) These researchers performed a study (PLoS ONE 2016; 11:e0155943) in which 80 female college students (78% who were currently in a romantic relationship) held blocks together for one minute which were either magnetized to attract or not-attract each other, followed by a questionnaire seeking subjects' interpretation of their romantic relationship (past or present). They found that, overall, subjects who held the attracted magnetic blocks reported higher levels of satisfaction, attraction, intimacy, and commitment with their romantic partner. One possible explanation for this result, suggested Christy et al., was that "exposure to magnetism may actually have changed participants' experience of romantic attraction in certain ways that led them to report greater satisfaction" in their love relationships.

4. Choukas-Bradley et al. (J Adolesc. 2015;45:112-26) compiled questionnaire data from 18,392 American adolescents ages 12-19 years which asked for their expected desires in a hypothetical romantic relationship. The most common behavioral temporal sequence was "holding hands, going out alone, telling others they were a couple, kissing, saying 'I love you,' sexual touching, and finally having sex." Several other authors have emphasized that individuals having fallen in passionate love are, at least initially, obsessed with an emotional union rather than sexual intercourse. That is, the romantic love being detailed in this chapter would—at least initially—appear to not overtly driven by concupiscent goals.

5. See Connolly J, McIsaac C. Adolescents' explanations for romantic dissolutions: A developmental perspective. J Adol. 2009;32:1209-1223. The study by Baumeister et al. is cited by Fisher et al. (see Note 2).
6. That falling in love is not always simply a happy event has been witnessed in studies of adults (Bajoghli H et al. "I love you more than I can stand!" – Romantic love, symptoms of depression and anxiety, and sleep complaints are related among young adults. Int J Psychiatry Clin Pract. 2014;18:169-74) and adolescents (Soller B. Caught in a bad romance: adolescent romantic relationships and mental health. J Health Soc Behav. 2014;55:56-72; Ha T, et al. The blues of adolescent romance: observed affective interactions in adolescent romantic relationships associated with depressive symptoms. J Abnorm Child Psychol. 2014;42:551-562).
7. For details of this study, as well as list of citations which offer a review of fMRI findings in the midst of falling in love, see Fisher et al. Front Psychol. 2016;7:e687.
8. Aron A et al. Reward, motivation, and emotion systems associated with early stage intense romantic love: an fMRI study. J Neurophysiol. 2005;94:327-337.
9. Brain imaging studies have also been utilized to study other forms of "love." Duarte IC et al. investigated the neural basis of the passion exhibited by fanatic supporters of a particular football team by fMRI (Tribal love: the neural correlates of passionate engagement in football fans. Soc Cogn Affect Neurosci. 2017;12:718-728). They showed 56 participants video clips of winning and losing moments of their loved, rival, or neutral team. The fanaticism of the subject was linked to activity of the amygdala, ventral tegmental area, and substantia nigra, areas recognized for their emotional "rewards" not dissimilar to those engaged in romantic love.
10. See review of experimental studies documenting the function and localization of dopamine-based reward systems in animals in Rowland T. *Biologic Regulation of Physical Activity.* Champaign IL: Human Kinetics, 2017, pp. 45-46. This role of dopamine in reward-seeking behavior and modifying locomotor activity has been observed throughout the animal kingdom, indicating a long evolutionary history for this mechanism (see Barron AB et al. The roles of dopamine and related compounds in reward-seeking behavior across animal phyla. Front Behav. Science 2010;4:e163). That the dopamine-reward system is not confined to hamsters and mice in cages was indicated by a fascinating study performed by Meijer and Robbers, who wanted to determine if rodents would engage themselves in obsessive wheel-running in their natural environment instead (Proc R Soc Brit. 2014;281:1-5). They placed a 24-cm diameter running wheel in an outdoor environment, monitored by camera and motion sensor. To their surprise, "wheel movement was not caused by mice but was caused by shrews, rats, snails, slugs, or frogs," that visited the testing site.
11. See Berridge KC, Robinson TE. What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? Brain Res Bran Res Rev. 1998;28:309-69.

12. Fisher HE, et al. Intense, passionate, romantic love: a natural addiction? How the fields that investigate romance and substance abuse can inform each other. Front Psychol. 2016;7:687.
13. References examining central nervous system neurochemical correlates with animal courtship behavior: Gingrich et al. Behav Neurosci. 2000;114:173-183; Fabre-Nys et al. Eur J Neurosci. 1997;9:1666-1677; Wang et al. Behav Neurosci. 1999;113:602-611; Robinson et al. J Neurosci. 2002;10477-10486.
14. Young IJ, Wang Z. The neurobiology of pair bonding. Nat Neurosci. 2004;7:1048-1054.
15. See Takahashi K et al. Imaging the passionate stage of romantic love by dopamine dynamics. Front Neurosci. 201;9:191.
16. Regarding the role oxytocin in the chemical basis of human love, see Wudarczyk OA, et al. Curr Opin Psychiatry 2013;26:474-484.; Algoe SB et al. Psychol Sci. 2017;28:1763-1772.
17. Any enthusiasm here for the use of dopamine as the ultimate aphrodisiac must be tempered by the fact that this agent does not cross the blood-brain barrier. This means, unfortunately, there is no means of introducing dopamine into one's brain either by its ingestion or intravenous administration. So this agent will not make it as a love potion #9 or any others.
18. This discussion deserves at least one tragic example. Carlos Casagemas was a Spanish art student and poet who became close friends with Pablo Picasso, moving with him from Barcelona to Paris in 1901. Casamegas fell madly in love with a model, Germaine Pichet, who, being already married, refused his desperate advances. It was just too much for the love-sick young Spaniard, and in February of 1901, while at a dinner party with friends, he stood up and shot himself fatally through head. (He also fired at Germaine, who suffered only superficial wounds.) The grief of Picasso over the suicide of his close friend was reflected in the somber paintings of his so-called Blue Period from 1901-1904.
19. See Annor FB, et al. Characteristics of and precipitating circumstances surrounding suicide among persons aged 10-17 years—Utah, 2011-2015. MMWR. 2018;67:329-332.
20. Access this information at http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s.-2011/tables/expanded-homicide-data-table-10
21. See Sun Y., et al. Neural substrates and behavioral profiles of romantic jealousy and its temporal dynamics. Sci Rep. 201`6;6:27469.
22. See Marazziti D, et al. Stalking: a neurobiological perspective. Riv Psichiar. 2015;50:12-18.
23. A number of authors have examined the parallels between romantic love and chemical addictions (narcotics, alcohol). Most colorful, however, are the lyrics to Robert Palmer's song, "Addicted to Love," which can be consulted as an authentic, accurately-descriptive source of information.
24. See Earp, B.D. Philos Psychiatr Psychol. 2017;24:77-92; Earp BD, et al. Am J Bioeth. 2013; 13:3-7.