

# The science of love

We each carry an intricate machinery of love, calibrating and attuning our moods and bodies to one another

by Barbara Fredrickson

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A mother and daughter in Chinatown in New York. *Photo by Steve McCurry/Magnum*

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Nearly 60 years ago, a decade before the counterculture erupted throughout the United States and beyond, Aldous Huxley described his first experience with psychedelic drugs in *The Doors of Perception* (1954). The book's title cast back to the metaphorical language of the English Romantic poet and printmaker William Blake, who wrote in *The Marriage of Heaven and Hell* (1790):

“If the doors of perception were cleansed everything would appear to man as it is, infinite. For man has closed himself up, till he sees all things through narrow chinks of his cavern.”

Huxley likened the human brain to a reducing valve. It functions to limit your awareness to only those perceptions, ideas, and memories that might be useful for your survival at any given moment, eliminating all else. Although narrowed awareness prevents you from becoming overwhelmed by a flood of images and impressions, it can become an overlearned habit, a self-limiting cavern that you become convinced is reality. But Huxley believed there were ways out: Certain persons ... seem to be born with a kind of bypass that circumvents the reducing valve. In others temporary bypasses may be acquired either spontaneously, or as the result of deliberate ‘spiritual exercises’, or through hypnosis, or by means of drugs.

Huxley's hypothesis that the doors of perception can temporarily swing open wider than usual — even seemingly spontaneously — is now confirmed by brain imaging experiments. Importantly, however, you don't need drugs, hypnosis, or lofty spiritual experiences to open those doors. Sometimes all it takes is a little love. But to understand this you will need to set aside your preconceptions of what love is.

It's difficult to speak of love in scientific terms, I've found, because listeners have so many pre-existing and strong beliefs about it. Many of these beliefs reflect our shared cultural heritage, like all those proliferating songs and movies that equate love with infatuation or sexual desire, or with stories that end happily ever after, or even the realistic marriage ceremonies that celebrate love as an exclusive bond and commitment. Other beliefs about love are deeply personal. They reflect your own unique life history, with its interpersonal triumphs and scars, lessons about intimacy learnt and not yet learnt. Left unaddressed, these preconceptions can derail any serious intellectual discussion of love. They might even keep you from soaking up the full implications of the new findings on love.

The bedrock for my approach to love is the science of emotions. For more than two decades, I've investigated that subset of emotions that feel good to you, those pleasing states — of joy, amusement, gratitude, hope, and the like — that simultaneously infuse your mind and body. Odds are you shift into and out of states such as these dozens of times each day, sometimes when you're alone, sometimes when you're with others.

Even though you experience positive emotions as exquisitely subtle and brief, such moments can ignite powerful feelings as you come under the influence of any of several positive emotions. With this momentarily broadened, more encompassing mindset, you become more flexible, attuned to others, creative, and wise. Over time, you also become more resourceful. In fact, my research and that of others shows that positive emotions can set off upward spirals in your life, self-sustaining trajectories of growth that lift you up to become a better version of yourself.

Positive emotions are the tiny engines that drive an intricate, ever-churning positivity system. They are the active ingredients that set the rest in motion. When I step back from the proverbial microscope to examine the larger system that orbits around your positive emotions, I see how positive emotions knit you into the fabric of life, the social fabric that unites you with others, and how they orchestrate the ways you grow and rebound through changing circumstances. I needed a new word to encompass that broader system, and that's positivity.

### **Love, and its absence, fundamentally alters the biochemicals in which your body is steeped.**

Keeping an eye on this fuller positivity system enables a more precise definition of love. Love — like all the other positive emotions — follows the ancestral logic of *broaden and build*: those pleasant yet fleeting moments of connection that you experience with others expand your awareness in ways that accrue to create lasting and beneficial changes in your life. Love, as I see it, is found in those moments of warmth, connection and openness to another person. It energizes this whole system and sets it into motion.

Just as your body was designed to extract oxygen from the Earth's atmosphere, and nutrients from the foods you ingest, your body was designed to love. Love — like taking a deep breath, or eating an orange when you're depleted and thirsty — not only feels great but is also life-giving, an indispensable source of energy, sustenance, and health. In describing love like this, I'm not just taking poetic license, but drawing on science: new science that illuminates for the first time how love, and its absence, fundamentally alters the biochemicals in which your body is steeped. They, in turn, can alter the very ways your DNA gets expressed within your cells.

We know now that a steady diet of love — of these micro-moments of positive connection — influences how people grow and change, making them healthier and more resilient. And we're beginning to understand exactly how this works, by tracking the complex chain of biological reactions that cascade throughout your body and change your behavior in ways that influence those around you as you experience love.

It's all too tempting, especially in Western culture, to take your body to be a noun. Like other concrete things that you can see and touch, you typically describe your body with reference to its stable physical properties, such as your height, your weight, your skin tone, your apparent age, and the like. You recognize, of course, that five years from now, your body's physical properties might shift a bit — you might, for instance, become a little shorter, a little heavier, a little paler, or look a little older. Still, you're comfortable with the idea that your body remains pretty much the same from day to day.

Yet constancy, as ancient Eastern philosophies warn, is an illusion, a trick of the mind. Impermanence is the rule — constant change the only constancy. This is especially true for living things, which, by definition, must adapt to their changing environment. Just as plants turn toward the sun and track its arc from dawn to dusk, your own heart alters its activity with each postural shift, each new emotion, even each breath you take. Seen in this light, your body is more verb than noun: it shifts, cascades, and pulsates; it connects and builds; it erodes and flushes.

Mere photographs fail to capture these non-stop and mostly unseen churning dynamics. Instead, you need movies. Increasingly, scientists work to capture these and other dynamic changes as they unfurl within living, breathing, and interacting bodies. True, scientists need to understand form as well as function, anatomy as well as physiology, nouns as well as verbs. Yet when it comes to love, verbs rule. Love lies in the action, the doing, the connecting. It wells up, like a wave forming in the ocean, and then dissipates, like that same wave, after its crash. To fully appreciate love's biology, you'll need to train your eye to see this ever-shifting ebb and flow.

**Here I want to turn a spotlight on two of the main biological characters in the play of your life: the hormone, oxytocin, which circulates throughout your brain and body; and your vagus nerve, the tenth cranial nerve that runs from deep within your brainstem down to your heart, lungs, and other internal organs. Together with the brain (which is the locus for our feeling of being 'in synch' with another person and the subject of compelling new research about how that happens), these are the three central characters in love's biology.**

The mere act of being entrusted with another person's money raised the trustee's naturally occurring levels of oxytocin

As you interact with one person after another during the day, these three biological characters gently nudge you to attend to other people more closely and forge connections when possible. They shape your motives and behaviors in subtle ways, and ultimately their actions serve to strengthen your relationships and knit you in closer to the social fabric of life.

Oxytocin, a neuropeptide that acts both in the brain and the rest of the body, has long been known to play a key role in social bonding and attachment. Evidence of this first emerged in 1994 from experiments by researchers at the University of Maryland with a monogamous breed of prairie voles: oxytocin, when dripped into one animal's brain in the presence of the opposite sex, creates in that animal a long-lasting preference to remain together with the other, cuddled up side by side.

In humans, oxytocin surges during sexual intercourse for both men and women, and, for women, during childbirth and lactation, pivotal interpersonal moments that stand to forge new social bonds or cement existing ones. The natural blasts of oxytocin during such moments are so large and powerful that for many years they all but blinded scientists to the more subtle ebb and flow of oxytocin during more typical day-to-day activities, such as playing with your kids, getting to know your new neighbor, or striking a deal with a new business partner. Technical obstacles also needed to be cleared, as it was difficult, until recently, to reliably and non-invasively measure and manipulate oxytocin during natural behavior.

Dramatic new evidence of oxytocin's power to shape your social life first surfaced in Europe, where laws permitted the use of a synthetic form of oxytocin, available as a nasal spray, for experimental purposes. Among the first of these studies was one from 2005 in which 128 men from Zurich played the so-called 'trust game' with real monetary outcomes on the line. At random, these men were assigned to either the role of 'investor' or the role of 'trustee', and each was given an equivalent pot of starting funds. Investors could give some, all, or none of their allocated funds to the trustee. If they did 'invest' in the trustee, the experimenter would triple their investment. Trustees could then return some, all, or none of their new allotment of funds (the investors' tripled investment plus their own original allocation) back to investors. So the investors were being asked to take a risk on the trustee, who could refuse to pay any money back. But if the trustee was fair, they could each double their money.

Prior to playing, participants received either oxytocin or an inert placebo by nasal spray. The effect of this single intranasal blast of oxytocin on the outcome of the trust game was dramatic: the number of investors who trusted their entire allotment to their trustee more than doubled. Interestingly, related research using this same trust game showed that the mere act of being entrusted with another person's money raised the trustee's naturally occurring levels of oxytocin, and that the greater the trustee's oxytocin rise, the more of his recent windfall he sacrificed back to the investor. These findings suggest that through synchronous oxytocin surges, trust and co-operation can quickly become mutual.

Since the original study on oxytocin and the trust game was published in *Nature* in June 2005, variations on it have abounded. We now know, for instance, that oxytocin doesn't simply make people more trusting with money, it also makes them far more trusting — a whopping 44 per cent more trusting — with confidential information about themselves. The simple act of sharing an

important secret from your life with someone you just met increases your naturally circulating levels of oxytocin, which in turn raises your confidence that you can trust that person to guard your privacy.

Fortunately oxytocin does not induce indiscriminate trust: its effects are quite sensitive to interpersonal cues that tip you off that another person might be the gambling type or irresponsible in other ways. If oxytocin spray were to be aerated through your workplace ventilation system, you'd still maintain your shrewd attunement to subtle signs that suggest whether someone is worthy of your trust or not.

Researchers who have combined the use of oxytocin nasal spray (versus placebo) with brain imaging have also learnt that oxytocin modulates the activity of your amygdala, the subcortical structure deep within your brain linked to emotional processing. Specifically, under the influence of a single blast of oxytocin nasal spray, the parts of your amygdala that tune in to threats are muted, whereas the parts that tune in to positive social opportunities are amplified. A single shot of oxytocin can help you glide through stressful social situations, like giving an impromptu speech or discussing a conflict-ridden topic with your spouse. If you were to face these difficulties under the influence of oxytocin, studies suggest, you'd have less cortisol, the so-called stress hormone, coursing through you, and you'd behave more positively, both verbally, by disclosing your feelings, and non-verbally, by making more eye contact and friendly gestures. Related research shows that behaving kindly in these ways also raises your naturally occurring levels of oxytocin, which in turn curbs stress-induced rises in heart rate and blood pressure, reduces feelings of depression, and increases your pain thresholds.

More generally, oxytocin is a key factor in the mammalian *calm-and-connect* response, a distinct cascade of brain and body responses best contrasted to the far more familiar *fight-or-flight* response. Oxytocin appears both to *calm* fears that might steer you away from interacting with strangers and also to sharpen your skills for *connection*. Rather than avoid new people out of fear and suspicion, oxytocin helps you pick up on cues that signal another person's goodwill and guides you to approach them with your own. Because all people need social connections, not just to reproduce, but to survive and thrive in this world, oxytocin has been dubbed 'the great facilitator of life'.

Oxytocin can also jump the gap between people: another person's oxytocin flow can trigger your own. The clearest evidence that oxytocin rises and falls in synchrony between people comes from studies of infants and their parents. When an infant and a parent — either mum or dad — interact, sometimes they are truly captivated by each other, and other times not. When an infant and parent do click, their coordinated motions and emotions show lots of mutual positive engagement. Picture parents who shower their baby with kisses, tickle their baby's fingers and toes, smile at their baby, and speak to him or her in that high-pitched, sing-song tone that scientists call *motherese*. These parents are super-attentive. As they tickle and coo, they're also closely tracking their baby's face for signs that their delight is mutual. In step with their parent's affectionate antics, attentive babies babble, coo, smile, and giggle back. Positivity resonates back and forth between them — micro-moments of love.

Of course, not every infant-parent interaction is so rosy. Some pairs show little attunement and engagement. Some mums and dads rarely make eye contact with their infants and emit precious little positivity, either verbally or non-verbally. And in those rare moments when they are engaged, the vibe that joins them is distinctly more negative. They connect over mutual distress or indifference, rather than over mutual affection.

It turns out that positive behavioral synchrony — the degree to which an infant and a parent laugh, smile, and coo together — goes hand in hand with oxytocin synchrony. Researchers have measured oxytocin levels in the saliva of dads, mums, and infants both before and after a videotaped, face-to-face parent-infant interaction. For infant-parent pairs who show mutual positive engagement, oxytocin levels also come into synchrony. Without such engagement, however, no oxytocin synchrony emerges.

Positivity resonance, then, can be viewed as the doorway through which the exquisitely attuned biochemical tendencies of one generation influence those of the next generation to form lasting, often lifelong bonds. Love, we know, builds lasting resources. Oxytocin, studies show, helps to swing the hammer.

**The person you are today is also shaped by the second biological character that I want you to meet: your tenth cranial, or vagus, nerve.** It emerges from your brainstem deep within your skull and makes multiple stops at your various internal organs and, most significantly, connects your brain to your heart. You already know that your heart rate shoots up when you feel insulted or threatened — registering the ancestral fight-or-flight response — but you might not know that it's your vagus nerve that eventually soothes your racing heart, by orchestrating (together with oxytocin) the equally ancestral calm-and-connect response.

Your vagus nerve is a biological asset that supports and coordinates your bodily experiences of connection — of love. Outside your conscious awareness, the vagus nerve stimulates tiny facial muscles that better enable you to make eye contact and synchronize your facial expressions with another person. It even adjusts the minuscule muscles of your middle ear so you can better track the other person's voice against any background noise.

Scientists can measure the strength of your vagus nerve — your biological aptitude for connectivity — simply by tracking your heart rate in conjunction with your breathing rate. I can measure how your heart rate, as tracked by sensors placed on your lowest ribs, is patterned by your breathing rate, as revealed by an expandable bellows that encircles your rib cage. This pattern is called *vagal tone*. Like muscle tone, the higher your vagal tone, the better.

In addition to putting the brakes on the big jumps in your heart rate that might be caused by stress, fear, or exertion, your vagus nerve also increases the routine efficiency of your heart, beat by beat, or more precisely, breath by breath. The human heart rate tends to run fairly high, as if we're always on guard for the next danger that might be hidden around the corner.

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When you're breathing in, a fast heart rate is an efficient heart rate. After all, each successive heartbeat during an in-breath circulates more freshly oxygenated blood throughout your brain and body. Yet when you're breathing out, a fast heart rate is not all that helpful because your supply of freshly oxygenated blood is waning. Here again, your vagus nerve steps in to help out. It can very gently apply the brake on your heart while you exhale, slowing your heart rate down a small degree. In turn, your vagus nerve can gently ease up on the brake while you inhale, letting your naturally high heart rate resume grabbing all the oxygenated blood that it can get. This subtle cardiac arrhythmia is the pattern that reflects your vagal tone, the strength or condition of your vagus nerve. It characterizes the nimbleness with which your primitive, nonconscious brain holds the reins on your galloping heart.

Remarkably, people with higher vagal tone are more flexible across a whole host of domains — physical, mental, and social. They adapt better to their ever-shifting circumstances, albeit completely at nonconscious levels. Physically, they regulate internal bodily processes such as glucose levels and inflammation more efficiently. Mentally, they're better able to regulate their attention and emotions, even their behavior, and navigate interpersonal connections. By definition, then, they experience more micro-moments of love. It's as though the agility of the conduit between their brains and hearts — as reflected in their high vagal tone — allows them to be more agile, attuned, and flexible as they navigate the ups and downs of day-to-day life and social exchanges. Indeed, this is what doctoral student Bethany Kok and I have found: compared with people with lower vagal tone, those with higher vagal tone experience more love in their daily lives, more moments of positivity resonance.

But can you change your vagal tone? My students and I work together in our PEP Lab, the Positive Emotions and Psychophysiology Laboratory. Not long ago, we conducted an experiment on the effects of learning the ancient mind-training practice of loving-kindness meditation. Our study participants visited the PEP Lab at the University of North Carolina one by one, and we measured their vagal tone while they sat and relaxed for a few minutes. At the end of this initial laboratory testing session, we instructed participants in how to log on to the study website each evening to record their emotions and social connections of the day. A few weeks later, by random assignment, we chose which participants would learn loving-kindness meditation and which would not. All would continue to monitor their day-to-day emotions and social connections using our study website. Months later, weeks after the meditation workshop ended, one by one we invited all participants back to the PEP Lab, where we again measured their vagal tone under the same resting conditions as before.

In May 2010, I had the honor of presenting the results of this experiment directly to His Holiness the Dalai Lama. Our team had discovered that vagal tone — which is commonly taken to be as stable an attribute as your adult height — actually improves significantly with mind-training. Here is your evidence-based reason for hope: no matter what your biological capacity for experiencing love is today, you can bolster that capacity by next season.

Study participants who had been assigned at random to learn loving-kindness meditation had devoted scarcely more than an hour of their time each week to the practice. Yet within a matter of months, their vagus nerves began to respond more readily to the rhythms of their breathing, emitting more of that healthy arrhythmia that is the fingerprint of high vagal tone. Breath by

breath — moment by moment — their capacity for positivity resonance matured. Moreover, through painstaking statistical analyses, we pinpointed that those who experienced the most frequent positivity resonance in connection with others showed the biggest increases in vagal tone. Love literally made people healthier.

The new science of love makes it clear that your body acts as a verb. Sure enough, some aspects of your body remain relatively constant day in and day out, like your DNA or your eye color. But your brain continually registers your ever-changing circumstances and, in turn, orchestrates the flux of biochemicals that reshape your body and brain from the inside out, at the cellular level. Your body takes action. Most notably, it broadcasts everything you feel — your moments of positivity resonance or their lack — to every part of you, readying you for either health or illness, and rendering you either more or less equipped for loving connection.

Learning how love works can make a clear difference in your life. It can help you prioritize moments of shared positive emotions and elevate your faith in humanity. Science need not inevitably leave you holding a flat corkboard with a dismembered butterfly pinned to it. Science can also glorify, painting a colorful and multidimensional road map for a more potent life journey, one that eliminates the detours of false hopes, false prophets, false claims, and charts a course toward the real thing. It can leave the butterfly alive and whole and set it free.

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