NAUTILUS

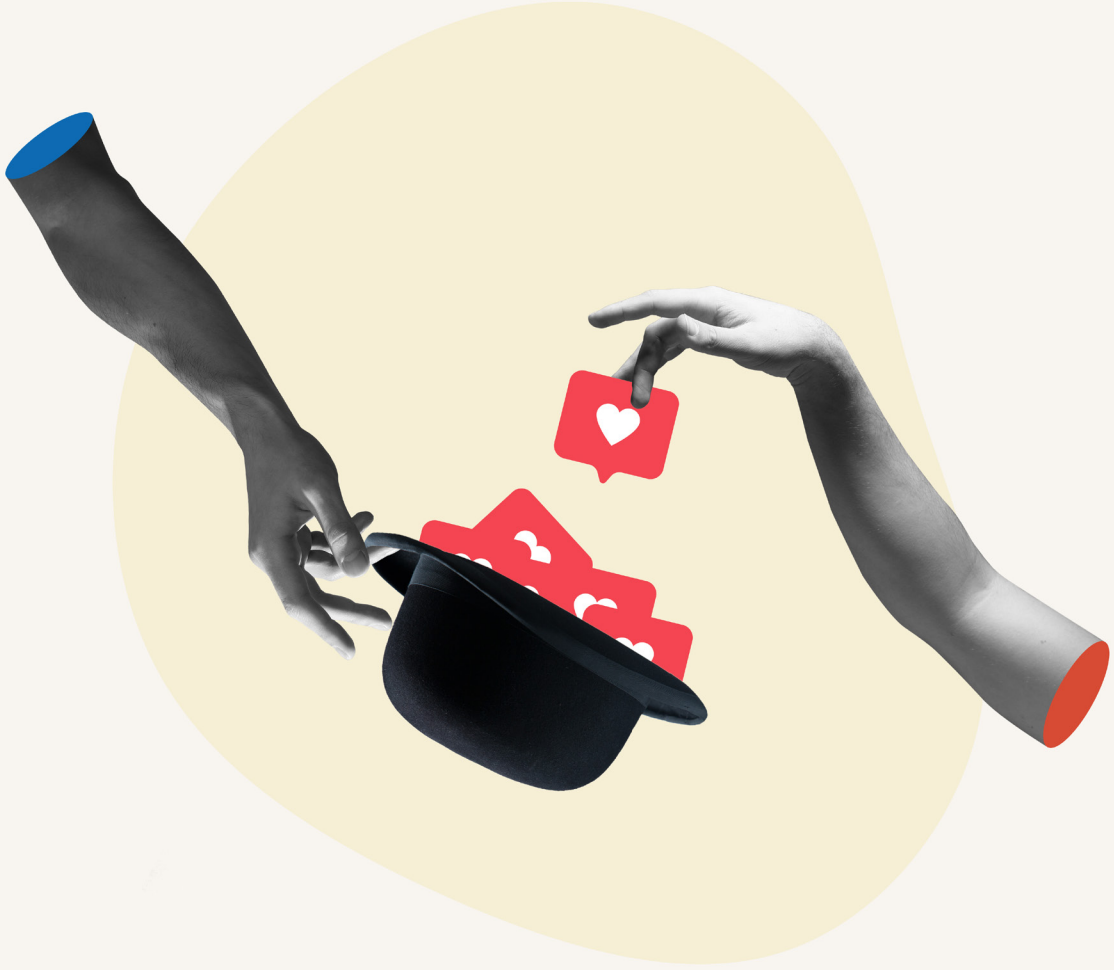
The Brave New Science of Love

Learning that romantic feelings, the fireworks of joy and transcendence that represent the height of living, are ignited by nothing but biochemistry is, especially on Valentine's Day, a total downer. Or so it might seem. But we bet you will come away from reading this *Nautilus* eBook of articles feeling like researcher Anna Machin, who says the more she studies love, "the more in awe I am of its complexity in the human species." You will learn how biochemistry, concocted by evolution, binds us to others. And those "others" are not just humans. The same natural potions of love bind animals, too. But the science of love is not as reductive as you might imagine. It also takes the air out of culturally conservative views. Only love can break a heart, but you will read that in the brave new science of love, chemistry can repair it, too.

Contents

Features

COVER ILLUSTRATION BY IXO AMINOX / SHUTTERSTOCK



Love Is Biological Bribery

Evolution uses all its tricks to make sure we procreate. But love in humans is a many-splendored thing.

BY BRIAN GALLAGHER

IN AN EPISODE of the satirical comedy *The Great*, the reign of the reason-and-science-loving Russian empress Catherine nearly collapses when her husband Peter, the deposed emperor, storms into her private quarters, determined to imprison her. But seeing her tearful and in despair, he forgets his vindictiveness and hugs her. Later, he tells her, "I wanted your happiness more than my own." "Wow," she responds. "Indeed," Peter says. "Love has done a strange thing to me. I wonder if you cut a man who has loved fiercely, you will see a different-shaped heart from a man who has not?"

Of course, no literal imprint of fierce love would be found in the heart if scientists went looking. But it's safe to say that Peter was on to something. Love, scientists have shown, leaves noticeable and widespread traces of its impact on us. "Love is so important," says evolutionary anthropologist Anna Machin, "that evolution has seen fit to engage every mechanism in your body to make sure you're as close and bonded as you can be."

Machin, who studies the genetics and neurochemistry of love—and has collaborated with the renowned Oxford anthropologist Robin Dunbar, of "Dunbar's number"—is the author of a new book, *Why We Love: The New Science Behind Our Closest Relationships*. In a recent interview with *Nautilus*, she says she tackles the whole spectrum of loving relationships from a variety of scientific perspectives to explain the nature of love. "If you're a neuroscientist, you give one particular answer. If you're a psychologist, give another one," she said. "As an anthropologist—it's a bit of a magpie profession—I gather all that together." Machin's responses to my questions were articulate and energetic, despite how far into the evening it was for her in England.

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COLIN KITCHEN

LOVE SCIENTIST What does Anna Machin want to learn more about? People who are aromantic. "Aromanticism fascinates me because these are people who do not experience romantic love, but they experience all the other ones," she says. "I would love to get deeper into the neuroscience of that."

Why do you call love a form of bribery?

The reason love evolved was to motivate and reward us for taking part in relationships, critical to our survival. That goes for our reproductive partners, children, and extending to our friends. Humans are highly cooperative because we have to be. A species will be solitary unless it absolutely has to cooperate with somebody else. And that's fine, except it's incredibly stressful. You have to spend a hell of a lot of time monitoring everybody else's behavior, making sure you're spotting those people who are trying to cheat you or steal from you.

And the way evolution made sure we cooperate was to come up with chemical bribery. At the basis of love are four neurochemicals. Each has a different role but together they motivate us or to give us confidence to go into social relationships. Ultimately, we get addicted to those chemicals. We get this hit of joy, of euphoria, of reward when we interact with the people important to our survival. It's biological bribery. It's like if I give my kids a sweet because they've done something good, which is bad parenting, but it works.

You also say love is about control. Why's that?

Because the only point of evolution is to pass genes down. This form of bribery is controlling us to make sure we do that. It's a benign control. For most people, most of the time, the experience is lovely and warming and beneficial in terms of health. Unfortunately, our biology to seek love, crave love, find love, keep love, is a weakness. That visceral need can be exploited, it can be used to make us do things we don't necessarily want to do. And that's the cost of love. It can be used to manipulate or abuse or coerce us. That's what separates us from the animals. Animals don't use love to manipulate others. We do.

You say it's scary that a baseline level of oxytocin, one of the neurochemicals of

We get this hit of joy, of euphoria, of reward when we interact with the people important to our survival.

love, can predict whether a couple will be together six months later. Why's that scary?

When it comes to a relationship, it's a little bit scary to know that part of that relationship is written in the stars before you even started. That's because people with higher levels of oxytocin generally are more open to relationships, they are more committed to wanting to work toward a relationship. In fact, there are many things that go into whether a relationship will last—oxytocin levels, genetics, upbringing, your attachment profile, the support of your family. So it's the private me talking, saying, "Oh my God, you meet someone, you think they're wonderful, but the relationship is partly already written."

Is love blind?

Yes. What happens when you fall in love for the first time is the activation of various areas of the limbic system and the neocortex. But we also see deactivations. These deactivations occur mainly in the brain area linked to "mentalizing." Mentalizing is the ability to tell someone's intentions, and you need to be good at mentalizing to spot a liar or a cheat. To be able to tell if somebody is lying, you need to be good at understanding what their motivation is. But what happens when you fall in love for the first time is that bit shuts down. It just decides it's not going to work anymore. For that reason, your friends can see this person is not necessarily good for you, that maybe they're going to cheat on you or they're lying to you, but you cannot see it.

Why would being blind in love have evolved?

It's interesting. Why *would* that have evolved? Why would that be something that was retained? Is it something to do with the same way that oxytocin lowers your inhibitions? Maybe it's to remove some of the hurdles that you might place in your own way when you're going to try and start a relationship. If you were constantly paranoid that everybody's going to cheat on you or steal from you or lie to you, the species wouldn't get very far. So maybe we have to remove that ability so that we have confidence and enough belief in the person that we fall in love with that we will carry on doing this. We see the same deactivation occurring when people listen to a charismatic religious leader.

Why do we fall in love with one person and not another? Or maybe I should ask, Why do we have lust for one person and not another?

That's very much a sensory input. Lust is an unconscious emotion. It takes place entirely in the limbic area of your brain. It happens within the first nanoseconds of you seeing somebody across a room. You're going to use all your senses. They're going to tell you things about that person's health, their ability to protect, to provide, about the strength of their genes, particularly if you're looking at sort of asymmetry within the face. You'll listen to the tone of voice and what they say. And what they say is a good indication of cognitive ability or flexibility of intellect, or sense of humor.

Animals don't use love to manipulate others. We do.

Initially, you take in this information unconsciously. The algorithm in your head will decide, OK, this is somebody for you or this isn't somebody for you. We all have a biological market value on our head, which is linked to the likelihood of reproductive success. The more likely you are to be reproductively successful, the more wealthy you are in terms of your biological market value. That classic thing when you see someone across the room and you think either, "Oh my God, they're completely out of my league." That's basically what your brain's thinking or, "I can do so much better." That's part of the calculation. If you get a tick from your algorithm, then oxytocin and dopamine are released and off you go, and you fill that chemical sort of job, that lustful feeling, that chemistry that develops between two people. The conscious brain kicks in pretty quickly after that, but the first moments are completely unconscious.

Why do you say the biology of love can sound non-feminist?

The reason for that is I often get called out. I do a lot of public speaking and I explain to people the rules of mate choice as biology sees them. But a lot of women, in particular, find it hard to accept that they are still looking for a protector and a provider. I try to explain that even though they are now capable of being independent, financially independent, they're still looking for that in the man. These mate-choice rules are evolutionarily incredibly ancient. Whenever we see mate choice in any species, this is what we see. One reason why some women are in a position where they're financially comfortable, and don't need a man for that, is because they live in a culture where there's a certain amount of gender equality. That has come about partly from feminism. But feminism hasn't touched evolution, partly because it's very recent. Women have only been able to control their contraception, for example, for about the last 70 years. That's nothing in evolutionary time. Something as deep-seated as mate choice only changes in human behavior when it's pretty much universal among the species, and there is not equality in a vast number of countries in the world, so it's not going to touch it.

What do you mean when you write that "cross-sex cooperation is cognitively the costliest of all cooperation?"

This is something that people find difficult to accept. You always get cooperation within a sex before you get cooperation between the sexes. You're only driven to cooperate with the opposite sex when you've exhausted your own. The reason is we're trading similar currencies in our own sex.

When we look at the environment in which we evolved, the biggie was childcare. We have these dependent babies. To be able to function, you need help with those children. And women would turn to their female kin first to do that. Cooperation is all about reciprocity. We want to make sure the balance sheet is even. You don't want to be the one always doing all the helping and never getting anything back. From a survival point of view, that's not a good thing to do.

With men, you tend to be trading things like alliance, support, help in fights. When you get men and women cooperating, particularly in the human evolutionary line, you are trading those different things. Women still want childcare. I would like you to help me raise our children, but the man is there because he basically wants to have sex and produce some more children with her. You're trading sex for childcare.

So those are two different currencies. Your brain is having to do a currency calculation. And when we look at the way the brain has evolved, we see the development of cognitive architecture that enables you to start doing those more complex calculations. So cross-sex cooperation is so much harder at the fundamental level than cooperating within your sex.

You say there's a difference between how mothers and fathers form attachment to their kids. How so?

Attachment is a deep, psychological bond between two people. A mother's attachment is based purely on nurture. The strength of that attachment will be based upon the sensitive and positive way she nurtures that child. For a father, nurture is important, but there's an added element that comes from the cortical area of the brain. That's the bit saying, "OK, I'm going to push your developmental boundaries. I'm going to make you more resilient. I'm going to push you into the world beyond the family." What joins all fathers around the world is they have this role in scaffolding the child's entry into the social world. That's the underpinning of what they're involved in developmentally.

People can sometimes find that difficult because they're like, "Well, those are just culturally gendered roles." Yes, you can argue that, but it also has an evolutionary explanation, which is the fact that evolution doesn't do redundancy. It doesn't cause two individuals who have input into something to have the same role if that's not required because that's just a waste of energy. Bear in mind that human children take a huge amount of emotional, cognitive, and practical input to raise. So it's important that the parents fit together well and give that developmental environment.

Animals don't use love to manipulate others. We do.

What does your research say about parenting in a non-traditional family?

What happens is we see changes in the brains of a single parent or a parent in a same-sex couple. The human brain is incredibly plastic. All parents have the ability to nurture, to challenge, to build resilience. We see changes that enable the brain in a single individual to behave in ways like a mom or dad. If we look at say, the Aka people in the Congo, where the fathers spend about 60 percent of their time in physical contact with their children, you will see a different way of parenting. As with everything, some parenting is biological, and some is environmental and contextual. What we found universally with men is they have a role in building resilience in pushing their child into the world, but they do that in a culturally specific way. It depends on the environmental context of what that world is.

How does our upbringing as kids affect our love lives?

Let's say you had a secure attachment to your parents when you're a child. That means you had sensitive parenting, they were aware of your emotional and physical needs, and met those needs. You were secure, you did not suffer anxiety, you did not suffer abandonment. That's bathing your brain in oxytocin and dopamine and beta endorphin, and you're producing low levels of cortisol, you're producing this highly efficient brain, you're not going to see neuronal death, which is what happens with neglect. When you go forward, you're going to have the biological underpinnings and the psychological underpinnings to be able to build good attachments, to build healthy relationships, and know when a relationship is not healthy for you, in which case you should leave.

Unfortunately, the opposite happens. We see brains bathed in a high degree of cortisol. We see active neuronal death, which means you see reductions in gray and white matter in those pro-social areas of the brain. They do not go forward with those abilities to do all that, to do the reciprocity, the trust, the empathy. The behavior they have watched, which is relationship behavior, is not good and that's something that they will replicate going forward. But they also do not have the powerful biological underpinnings to enable them to be able to have good relationships.

You say we underestimate the love that comes from friendships. That might be starting to change. There was a widely read article in The Atlantic recently that touched on this titled, "It's Your Friends That Break Your Heart: The older we get, the more we need our friends and the harder it is to keep them." How does that headline strike you?

We tend to privilege romantic relationships and maybe parental relationships, but we take our friendships for granted. But they are incredibly important to you. They are the only platonic relationships you get to choose yourself. You don't get to choose your

family but you get to actively choose your friends. In fact, our research shows that you are much more similar to your friends than you are to your lover. If you're a woman, you are more emotionally intimate with your friends than you are with your lover. If you're a man, your friends bring this ease of being able to really be you.

So our friends provide a lot to us. And we neglect our friendships at our peril because often our friendships outlast our romantic relationships, and they are the ones that are really your stable foundation. You need them in your life for your mental health, your physical health, for your longevity, and your well-being. But I do think we underestimate them. I interview so many people for my research, and particularly when I interview British people, I'll ask them, "Do you love your friends?" And they'll go, "Hmmm, I don't know whether I love them." And then I'll say, "Well, do you love your dog?" "Oh God, yeah! I love my dog." And it's just this thing that we don't consider the fact that we could love our friends. And I think that's maybe a peculiarly British thing that's quite restrained that we wouldn't admit that.

The philosopher Alain de Botton has argued that romanticism has severely distorted how people think about love and what to expect from it. What do you think of that?

I agree with him. The narrative is unhelpful. This idea of the chivalrous prince rescuing his princess from a castle. It sets up an incredibly idealistic view and very gendered view of what romantic love is, which doesn't reflect the reality for most people. The idea that there is the one—well, we can quite clearly tell from the inputs that go into what attracts people that there's more than one person in the world for you. Also, from an anthropological and sociological point of view, it's a narrative that works for society because it's a controlled narrative: We can have everybody pairing up with one other person and we set in place all these rules. We have these zero-sum ideas of love. But the idea of romantic love doesn't reflect the reality of people's existence, particularly with increasing singledom. The idea that romantic love is the most powerful love is unhelpful because it demotes all the other ways that you can love in your life. And none of them are weaker than romantic love, but we seem to think that they're not as good. They're not as important.

The narrative also doesn't help people get out of abusive relationships. If you tell a child that love is like a fairy tale, you'll get swept off your feet, that love lasts against all odds and will help get over any hurdle, that doesn't help in the context of abuse. It leads to the idea that you have no control over this person that is abusing you. When you do. So it's a really unhelpful narrative. And it's a narrative that's spun mostly today by commerce. You can have the perfect wedding with your soulmate. That's the be-all-and-end-all of life. I sound cynical, but I completely agree that romantic love is not a helpful narrative.

Has becoming scientifically knowledgeable about love affected your personal relationships in any way?

It hasn't affected it in a negative way at all. People say, "Well, it must have been because you spend your life in cold science, analyzing what love is." I think if that's all I did, I think it would. I think if you reduced it constantly to a set of neurochemicals or a genetic driver, I think maybe you would. But because I do it from an anthropological perspective, and spend a lot of time talking to people about their love, I just find love an amazing phenomenon. The more I study it, the more in awe I am of its complexity in the human species.

BRIAN GALLAGHER is an associate editor at Nautilus. Follow him on X (formerly known as Twitter) @bsgallagher.

Casual Sex May Be Improving America's Marriages

One-night stands and friends with benefits are just what your brain ordered.

BY HELEN FISHER

AN AMERICAN MAN AND a French woman meet on a train in Eastern Europe. They live on different continents. But before the sun comes up, they have spent the night together. What happens next?

You'd expect the answer to be, nothing. It's just a one-night stand in a faraway place. But in director Richard Linklater's trilogy, *Before Sunrise, Before Sunset,* and *Before Midnight*, their romance blooms into commitment and kids.

While some might dismiss this as Hollywood romanticism, it is actually a common experience. For the past five years, my colleagues at Match.com and I have conducted an annual national study called *Singles in America*, and in each year, a majority of survey respondents have reported having a one-night stand. And 27 percent of our 2014 respondents reported having had a one-night stand turn into a long-term, committed partnership.[1]

We humans are a romantic tribe. Over 54 percent of American singles (which make up over half of the adult population) believe in love at first sight; 56 percent believe laws should make it easier to wed; 89 percent believe you can stay married to the same person forever. And, remarkably, 33 percent of American singles believe it's ok to leave a "satisfactory marriage" if you are no longer passionately in love. In America, as in much of the post-industrial world, romantic love is in full bloom.

Yet between 43 and 50 percent of American marriages will fail, and some 67 percent of American cohabiting couples report that they are terrified of the social, legal, emotional, and economic consequences of divorce.[2] Divorce, men and women wanly joke, is in the drinking water.

So I have come to believe that—motivated by romance and afraid of what sociologist Andrew Cherlin calls the marriage-go-round—today's singles are ushering a long *pre-commitment stage* into the courtship process. Fast sex is part of the package. Couples want to get to know everything about a potential life partner before they tie the knot. Welcome to the age of slow love.

SINGLES IN AMERICA is not a poll of the Match.com population. Instead, it probes an annual representative sample of over 5,000 Americans, based on the U.S. census. To date we have queried over 25,000 men and women—to my knowledge, the largest national representative study of singles. And what we have found is an abundance of caution.

Take hooking-up—an uncommitted sexual encounter between two people who are not currently in a

PAGE 11: ILLUSTRATION BY FEDERICA BORDONI

HOW IT STARTS A scene from *Before Sunrise,* in which Ethan Hawke and Julie Delpy play characters that meet on a train and have a one-night stand. In the final movie of the trilogy, they have been together for years and have twin girls.

romantic relationship with one another. Hooking up appears reckless. Certainly those who engage in one-night stands are risking sexually transmitted infections, unwanted pregnancy, and emotional trauma. Nevertheless, in the 2014 *Singles in America* study, 66 percent of single men and 50 percent of single women reported that they had engaged in a one-night stand—and these numbers have varied little over the past five years. Why do we hop into the sack with someone we hardly know?

Perhaps because you learn a lot about a person between the sheets. You might even kick-start a real relationship: Any stimulation of the genitals promotes dopamine activity, which can potentially push you over the threshold into falling in love. At orgasm, oxytocin and vasopressin—neurochemicals linked with feelings of attachment—spike. With just one night of casual sex, risky as it is, you may win life's greatest prize: a devoted mating partner.

Nevertheless, few race to the altar after a night in bed together. Instead, many take the next cautious step, a friends with benefits relationship—commitment-lite. In this sexual arrangement, a pair has coitus when convenient, but they don't appear in public as a couple. In 2013, 58 percent of men and 50 percent of women in our *Singles in America* study reported that they'd had a friends with benefits relationship, including one in three people in their 70s. And 28 percent of our 2014 participants had had a friends with benefits relationship turn into a long-term partnership.

Next, many couples move in together—another cautious step toward permanent pairing, which first entered the public discourse with a famous 1966 article

Romantic love is like a sleeping cat; it can be awakened at any time. Feelings of deep attachment, however, take time.

by anthropologist Margaret Mead. Mead suggested that a young couple with no immediate plans to reproduce should first make an "individual marriage," a legal tie that excluded bearing children, did not imply a lifelong commitment, and had no economic consequences should the couple part. A "parental marriage" could come later if they so decided.

"Living together," a version of the first step of this two-step marriage, emerged in the 1970s; and today what had been scandalous has become routine. In 2012, 58 percent of those in our *Singles in America* study reported that they have lived with one to five partners outside of wedlock. And as the Pew Research Center notes, some 64 percent of Americans believe this living arrangement is a step toward wedding.[3]

But discretion still reigns after partners have agreed to marry. In 2014, 36 percent of singles in our *Singles in America* study said they wanted a pre-nuptial agreement.

Even marriage is becoming provisional. Civil partnerships in England, civil unions in the U.S., and de facto partnerships in Australia enable a couple to start and end a partnership relatively easily. France's *pacte civil de solidarité*, or PACS, is particularly intriguing. Enacted in 1999 primarily to enable gays and lesbians to obtain a legal means of attachment without conventional matrimony, it immediately became popular among heterosexuals. All you do is go to a federal office with your partner and sign some papers to initiate a legal relationship. If you want to end it? Send in a form.

ONE-NIGHT STANDS; HOOKING-UP; FRIENDS with benefits; living together; pre-nups; civil unions. These all spell caution. But they also spell logic—because our brain is soft-wired to attach slowly to a partner.

The basic circuits for romantic love lie in primitive regions of the brain, near those that orchestrate thirst and hunger. Romantic love is a drive—one of three basic brain systems that evolved to direct our fundamental human mating and breeding strategy. The sex drive predisposes you to seek a range of mating partners; romantic love enables you to focus your mating energy on a single individual at a time; and feelings of attachment incline you to form a pair-bond at least through the infancy of a single child. Feelings of romantic love and deep attachment to a partner emerge in a pattern highly compatible with the spirit of the times—that is, with slow love.

I say this because my colleagues Lucy Brown, Art Aron, Bianca Acevedo, and I have put new lovers into a brain scanner (using functional Magnetic Resonance Imaging, or fMRI) to measure neural activity as these men and women gazed at a photo of their sweetheart. Those who had fallen madly in love within the past eight months showed activity in brain regions associated with energy, focus, motivation, craving, and intense romantic love. But those who had been passionately in love for eight to 17 months also showed activity in an additional brain region associated with feelings of attachment.[4]

Romantic love is like a sleeping cat; it can be awakened at any time. Feelings of deep attachment, however, take time, and they can endure. In another of our studies, led by Acevedo, we put 17 men and women in their 50s and early 60s into the brain scanner. These participants had been married an average of 21 years, and all maintained that they were still madly in love with their spouse. Their brains showed that they were: They were deeply attached as well.

We have even begun to map some of the brain circuitry responsible for this marital happiness. In our study of long-term lovers, those who scored higher on a marital satisfaction questionnaire showed more activity in a brain region linked with empathy, a trait they had most likely retained from their initial passion.5 Moreover, when psychologist Mona Xu and her team used my original research design to collect similar brain data on 18 young men and women in China, she found that those who were in love long term showed activity in a brain region associated with the ability to suspend negative judgment and overevaluate a partner,[6] what psychologists call "positive illusions."[7] Much like men and women who have just fallen madly in love, these long-term partners still swept aside what they didn't like about their mate and focused on what they adored.

Because feelings of attachment emerge with time, slow love is natural. In fact, rapidly committing to a new partner before the liquor of attachment has emerged may be more risky to long-term happiness than first getting to know a partner via casual sex, friends with benefits and living together. Sexual liberalism has aligned our courtship tactics with our primordial brain circuits for slow love.

I AM OPTIMISTIC about the emergence of slow love. During our long agrarian past, our forebears married to please God, the local community, and their extended family. Spouses were tied to the land and to one another. Where could you go with a ton of wheat? A host of associated beliefs about the sexes emerged, including strictly arranged marriages, virginity at marriage, till death do us part, and the credo that a woman's place was in the home. Unchained from the constraints of farm living, today's singles are turning inward, choosing partners for themselves—and taking time to wed. Where marriage was the beginning of a partnership in farming societies, today it is the finale.

Slow love appears to be working, too. In 2012, with Match.com, I surveyed 1,095 married Americans (not on their dating site, of course). Among our questions was: "Knowing what you now know about your spouse, would you marry the same person again?" Eighty-one percent said yes. Moreover, 76 percent of these men and 73 percent of these women said they were still "very much in love." And a 2013 survey of more than 12,000 adults in 15 countries established that 78 percent of married men and women were also "happy."[8]

The marriage revolution going on today may actually enable more happy partnerships. Slow love is, after all, in our DNA.

DR. HELEN FISHER is a Biological Anthropologist and Senior Research Fellow at The Kinsey Institute. She has written five internationally best selling books on love and personality and is currently Chief Scientific Advisor to Match.com.

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What Pigeons Teach Us About Love

The sweet, avian romance of Harold and Maude.

BY BRANDON KEIM

LAST SPRING I CAME to know a pair of pigeons. I'd been putting out neighborly sunflower seeds for them and my local Brooklyn house sparrows; typically I left them undisturbed while feeding, but every so often I'd want to water my plants or lie in the sun. This would scatter the flock—all, that is, except for these two.

One, presumably male, was a strapping specimen of pigeonhood, big and crisp-feathered in an amiably martial way. The other, smaller bird presented a stark contrast: head and neck feathers in patchy disarray, eyes watery, exuding a sense of illness that transcends several hundred million years of divergent evolution.

She didn't have the energy to take wing as I approached. Instead she'd take several desultory steps away. Her mate would fly to the deck railing, where he paced back and forth. He gave every impression of wanting to flee—but not without his mate, at whom he looked back with apparent concern. This caught me by surprise. I spend a fair amount of time watching animals and writing about them—not just about their populations or interactions or physiologies, but about their minds, what they might think or feel—yet I hadn't much tried to put myself in a pigeon's feathers, so to speak.

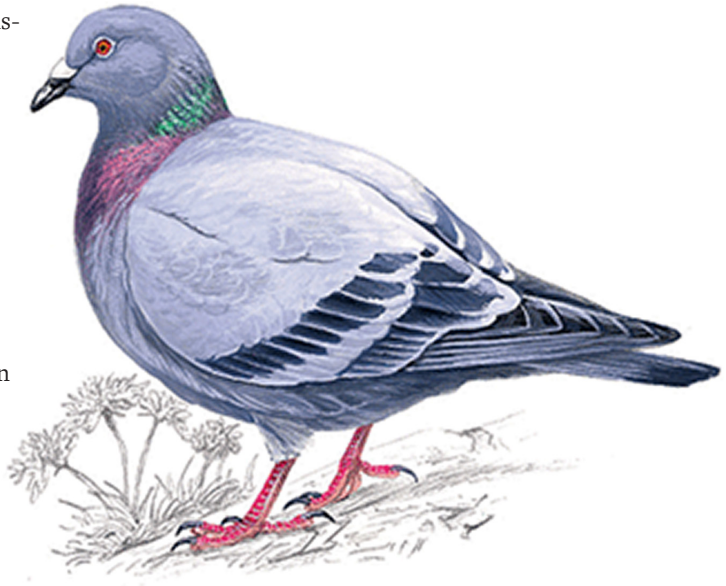
Moreover, I slipped into that easy habit of interpreting behaviors through a narrowly evolutionary lens, assuming their decisions to be coldly calculated to maximize reproductive success. From which perspective the male's loyalty made little sense: Better for him to fly off and find another, healthier mate with whom to pass on his genes, than to stick around with this sick bird.

Of course, I wouldn't frame my own life that way. Where I have meaningful feelings, they would have imperatives. Yet as I watched Harold and Maude, as I so unoriginally named them, their drama unfolding beside murals my girlfriend and I had painted as expressions of our own feelings, I began to wonder. Harold behaved in a manner expressive of devotion, tenderness, and affection: the foundations of what in humans we call love.

It's a word not often associated with pigeons, or even other animals. "Our highest esteem is accorded romantic love, which is considered the most suspect to ascribe to animals," writes Jeffrey Moussaief Masson in *When Elephants Weep: The Emotional Lives of Animals.* Indeed, science for most of the last several centuries would have found the suggestion risible, suggesting instead that Harold felt—if pigeons could even be said to feel—some instinctive, unconscious urge to stay nearby, an urge with no more emotional resonance than an itch.

Love, after all, is central to the human condition. How could a creature with a brain the size of a bean possibly feel something so profound? Something that gave rise to *Romeo and Juliet* and "Unchained Melody" and the Taj Mahal?

Part of the reluctance to talk of bird love, I suspect, is rooted in our misgivings about our own love's biological underpinnings: Is it just chemicals? A



ROCK PIGEON (*COLUMBA LIVIA*)

Sex Status: Monogamous. Behavior: Social, vocal, usually on the go. Habitat: Cities, cliffs, your local public square.

CHRIS WINSOR

set of hormonal and cognitive patterns shaped by evolution to reward behaviors that result in optimal mating strategies? Perhaps love is not what defines us as human but is something we happen to share with other species, including the humble pigeon.

CITY DWELLERS OFTEN SEE pigeons as an eyesore and a nuisance. The more nature-inclined regard them as marvels of natural history and urban adaptation. Descended from birds bred by European hobbyists, *Columba livia* now nest on building ledges rather than their ancestral cliffs. They scratch out sustenance from refuse, handouts, and the seeds of weeds, become symbols of a certain indomitability.

But can pigeons be in love? Considering the possibility, it's worth stepping back and looking at where society and its knowledge-defining practices now stand in regard to the notion of nonhuman thoughts and feelings.

The old habit of treating other animals as so many furred and feathered automata—Descartes famously likened animals to clocks—is in fast recession. Scientists talk regularly about animal intelligence. But that automatic habit shaped scientific discourse and public imagination. Every assertion of complex experience could be met by the default rebuttal of anthropomorphism: Might we merely be projecting human qualities onto something much simpler, even alien?

Its legacy is still felt. Animal consciousness tends to be most appreciated in a select class of animals: big-brained creatures like great apes or whales, or domestic companions like cats and dogs, who can't be ignored. As a class, birds receive comparatively little attention. And when they do, it tends to focus on intelligence, on easily quantifiable feats of problem-solving and cognition, rather than emotion. Most anyone who follows science knows about brainy crows using tools and high-level reasoning. But avian love remains beyond the pale.

A telling example is *Partnerships in Birds: The Study of Monogamy*, a collection of studies

"I've known mourning doves who were more in love than a lot of the people I've known."

published in 1996 with the express intent of explaining why birds are monogamous, which makes not a single mention of emotion. Affection appears once, in connection to a brief mention of attachment in so-called pair bonds between mates; attachment, readers are reminded, need not be understood in potentially loaded terms of strength or weakness, but rather measurements of "proximity and synchrony of behaviours which may influence fitness." It's a fascinating book, but also slightly ridiculous, like watching old video of lawn tennis matches, in which custom dictates the players wear white slacks and not run too hard.

The conservatism is understandable: Feelings are hard enough to measure in humans, much less animals, and "you can't think of birds as little humans," says Kevin McGowan, a Cornell University ornithologist who specializes in the social behavior of crows. Yet evolution is conservative too, notes McGowan, shaping the animal kingdom's diversity from common biological elements. Of emotions, McGowan says, "there's no reason to think that we humans have some brand-new thing."

WOODPIGEON (*COLUMBA PALUMBUS*)

Sex Status: Monogamous. Behavior: Shy, vigilant, communal.
Habitat: Cities, woods, and sometimes trees.

Indeed, love's essential biology is evolutionarily ancient. Oxytocin and vasopressin, the hormones most closely associated with mammalian bonding, have the near-identical avian analogues of mesotocin and vasotocin, which shape the interactions of zebra finch couples. Birds likewise possess the basic reward-system neurotransmitters serotonin and dopamine. Birds might not have much in the way of easily recognizable facial expressions, but their biochemistry's symphonic chain reactions play out in neurological structures that evolved early in life's history, long before the cerebral cortex itself.

That alone is no guarantee of romance. Jane Goodall, the legendary primatologist who so powerfully described the abiding love of chimpanzee mothers for their children, has written that she cannot conceive of our closest living relatives as experiencing anything comparable to romantic love. To Goodall, chimp courtship is too brief to permit deep feelings. Their proclivities, she has noted, were not shaped by evolutionary circumstances conducive to love, namely long-term relationships with single partners, which are the norm for modern humans.

In this respect we diverge markedly from chimpanzees—but not from birds, in whom monogamy is found in some 90 percent of all species, including pigeons. Neither their nor our monogamy is a pure, idealized sort, exclusive of infidelity or a succession of partners. Extra-pair copulation, or what we call cheating, can be quite common. But monogamy is the baseline and pigeons, who frequently mate for life, are among the more fidelitous of birds. Within the evolutionary context of monogamy, a capacity for love makes perfect sense.

Monogamous couples share food, information, and offspring-rearing duties, especially in species whose young are born requiring constant care—as is the case with pigeons, their helpless chicks so carefully hidden that few city-dwellers have ever seen one. Love—an attentiveness to the needs of another being, reinforced by emotional rewards—should enhance cooperation and improve a couple's chances of raising healthy offspring. And as noted by Claudia Wascher, a zoologist at Anglia

Ruskin University, whose Ph.D. research described how mated greylag geese have lower levels of stress hormones than single birds, there's no question that pair bonds are powerful.

"Social bonds in general seem to be terribly important for birds," says Wascher, "and the most important social bond for most birds is the pair bond." Monogamy, then, should be fertile evolutionary ground for love's blooms.

Part of the reluctance to talk of bird love is rooted in our misgivings about our own love's biological underpinnings: Is it just chemicals?

MCGOWAN AND WASCHER readily recognize emotion in birds. "I would suspect they do have affection for each other," says McGowan, who has observed crow couples stay together for more than a decade. "It's not going to be the same as what humans have, but I suspect it's close enough that we'd recognize it," she says. Yet McGowan stops short of love: Science describes behaviors easily, but is in murkier terrain with complex states of mind.

Indeed, it might seem a flight of fancy to equate pair-bonding's neurobiological rewards with love, no matter how much evolutionary sense it makes. Pigeons have the necessary pieces and life history, but can their experiences of bonding really compare to what in humans inspired eighth-century poet Chang Chi's lamentation of the unrequited: "So I must give you back your pearls / with two tears to match them"? Can pigeon-brained attachment manifest in love's full spectrum, from butterflies-in-the-stomach infatuation to the ecstasy of consummation?

It's still possible, however, to imagine that avian love is more than a mindless itch. Perhaps human love is unusually complex, invoking not just physiology but our unique cognitive sophistication. Still, many species display a cognitive complexity—awareness of self and others, long-term memory, a capacity for abstract concepts—comparable to primates. The gentle social courtship of "allopreening," in which birds groom one another's feathers, is especially sophisticated. Just as I can think fondly of my lover while she's away, so might a pigeon think fondly of its absent mate.

We can consider observational evidence to buttress the biological. About a decade ago, Rita McMahon found a pigeon with a broken leg on her deck in New York City's upper west side. The pigeon was otherwise quite fortunate. McMahon would go on to cofound the Wild Bird Fund, which cares for some 3,500 sick and injured birds every year. A veterinarian amputated the pigeon's leg; while it recovered, it would rest on a cushion in McMahon's apartment window. On the other side stood her mate, day after day, keeping her company until she was released and the couple rejoined.

"They were devoted to each other," says McMahon, who also recalled how one of her volunteers once found a broken-winged robin in a depression in a snow bank, his mate nearby. The volunteer picked up the injured bird and put him in a bag for transport to the hospital. With little fuss she then gathered the mate—which was quite unusual, as healthy wild birds are uniformly skittish. "I understand being able to pick up a broken-winged robin easily, but not one who's intact," MacMahon says. At the hospital, they learned that the break wasn't fresh. The robin was in surprisingly good health. His mate, believes MacMahon, had been taking food to him on the snowbank, "and decided to stay with her man."

Love is as love does. "There's no reason to think it would be much different for humans than nonhumans," says Marc Bekoff, author of *The Emotional Lives of Animals*. "I've known mourning doves"—a species closely related to pigeons—"who were more in love than a lot of the people I've known." To Bekoff, love's ultimate measure is the presence of its converse, grief.

Apparent grieving exists in the avian world, most notably among greylag geese, in whom individuals who've lost a partner display the classical symptoms of human depression: listlessness, a loss of appetite, lethargy lasting for weeks or even months. The same applies to pigeons. On Pigeon Talk, a website of pigeon-breeding hobbyists, anecdotes abound of birds sinking

into a funk after losing their mates, and sometimes refusing to take another mate for up to a year afterward—no small time for a species that typically lives for less than a decade.

One of the most moving stories involves mourning doves. After a dove was eaten by a hawk in the backyard of a forum member called TheSnipes, the mate stood beside the body for weeks. "I finally couldn't stand to watch it any more and picked up every feather and trace of remains that was left there and got rid of it," wrote TheSnipes. "The mate continued to keep a vigil at that spot though, for many months, all through the spring and summer."

MCMAHON NOTED SOMETHING I hadn't considered: There are good and bad pigeon couples. Some are attentive and physically affectionate, constantly stroking one another's feathers. Others appear distant and peckish. As human love varies, so might theirs. Not every pigeon's tale need be so romantic as *Fly High, Fly Low*, Don Freeman's delightful children's book about the search of Sid for his mate Midge, lost to him—though only for a while—when workers take down the sign in which they've made their nest. Others might better resemble Maud and Claud of Patricia Highsmith's "Two Disagreeable Pigeons," regarding each other with pique and scorn, kept together by inertia and habit.

It's also worth considering whether pigeons might experience aspects of love that we don't. Could a bird whose basic physiology adapts to changing seasons, who can perceive atmospheric infrasound, and see Earth's magnetic field, have emotional capacities beyond our own? Including, perhaps, forms of love that are not merely analogues of our cherished feelings, but something unique to them?

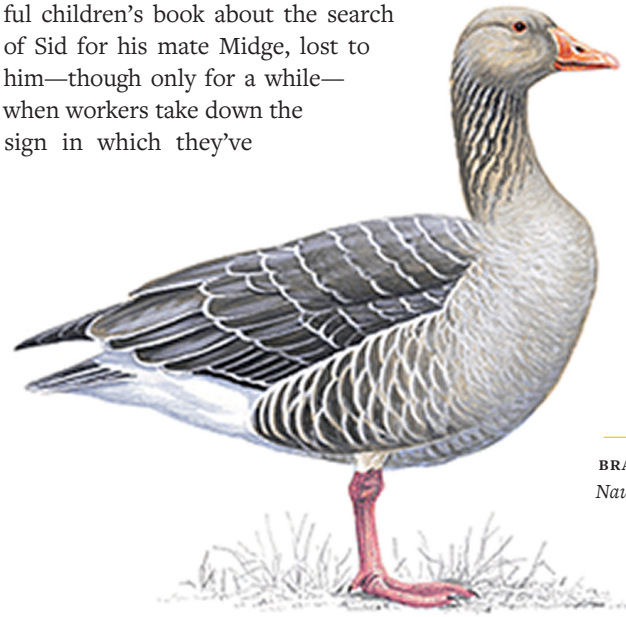
It's something to imagine. "Love among animals might appear as mysterious and baffling as human love has over the centuries," writes Masson.

At risk of sounding unromantic, though, I'm not convinced that love is so mysterious. It just feels good.

As for Harold and Maude, I don't know how their story ended, or indeed whether it continues. They roosted in a partially abandoned building on my fast-gentrifying block. It's now being turned into condos, making them victims of Brooklyn's rising real estate prices, albeit with a better chance than most humans at finding a decent place to live nearby.

Their example stayed with me, though, and now colors the way I think of my winged neighbors. Ubiquitous and unappreciated, typically ignored or regarded as dirty, annoying pests, pigeons mean something else to me now. Perched on building ledges, chasing scraps of food, taking to the skies at sunset: Each one is a reminder that love is all around us.

BRANDON KEIM is an independent journalist and the editor of *Nautilus* Ocean section.



GREYLAG GOOSE (*ANSER ANSER*)

Sex Status: Monogamous. Behavior: Gregarious, social, low on stress.

Habitat: Lakes, marshes, and moors.

Your Romantic Ideals Don't Predict Who Your Future Partner Will Be

Why birds of a feather don't flock together for long.

BY ALICE FLEERACKERS

LAST YEAR, I BRIEFLY ran an analogue dating service. I'll never know what inspired me to start it—maybe my stable relationship had me missing the excitement of single life—but I loved the simplicity of it. There were no questionnaires, no algorithms, no thoughtful matchmaking. Instead, I collected phone numbers from singles I met at bars, soccer games, and dinner parties, and arbitrarily set them up with each other. While most of my "matches" never went anywhere, I was surprised by how many turned into second or third dates. Even more surprising was how easy it was to recruit singles. Everywhere I went, it seemed there was someone frustrated enough in their love life to take a chance on a date arranged by a complete stranger.

This strategy may not be as crazy as it sounds. When it comes to predicting who we'll click with, your guess truly may be as good as mine. At least that's what a recent study, "Negligible evidence that people desire partners who uniquely fit their ideals," suggests.[1] It was published this June in the *Journal of Experimental Social Psychology*. "The data were very compelling in telling the story that we might not have a lot of insight into what's really driving our romantic desire," says Jehan Sparks, a postdoctoral researcher at the University of Cologne and the lead author of the paper. "We tested it in a lot of different ways and got really consistent results."

Singles' own romantic ideals weren't any better at predicting their romantic interest than the ideals a random other person in the study came up with.

Sparks and her team conducted two studies exploring whether our romantic ideals—the qualities we say we want most in a partner—predict who we're actually interested in dating. In the first study, singles went on a blind date with a stranger and reported how things went. In the second, almost 600 people (both single and partnered) nominated five friends or acquaintances of their preferred gender and rated them on how romantically desirable they were. (Partnered participants were asked to rate their current partners instead of friends or acquaintances.)

In both studies, the researchers asked participants to list their top three romantic priorities—whatever qualities they themselves found most important in a partner—and then rate romantic candidates on each. That is, participants from each study reported how well they thought each of those qualities described their candidates—dates for the first group, personal acquaintances for the second—using a scale ranging from 1 ("Extremely uncharacteristic") to 11 ("Extremely characteristic"). They also reported how romantically interested they were in the candidates by stating how much they agreed with statements like "____ is very much my ideal romantic partner," and "_____ is always on my mind." Because the question about romantic priorities was open-ended, the list of qualities people came up with across the two studies was varied, including everything from having tattoos to being good with kids.

This was the catch: In both studies, not only did people evaluate potential partners using their freely chosen romantic ideals, they also had to judge a romantic candidate's desirability using *someone else's* romantic ideals—the three priorities nominated by some random other person in the study. (The researchers made sure these qualities were different from the qualities participants came up with themselves.) For example, if Nadya's three priorities were "good cook," "loyal," and "funny," and Mira's were "smart," "outgoing," and "has a great body," Nadya would rate her romantic candidate(s) on six qualities: good cook, loyal, funny, smart, outgoing, and has a great body. In theory, if a candidate scored high on the three characteristics Nadya said were important, she should also rate that candidate as highly desirable; however, if Nadya's candidate scored high on *Mira's* three characteristics, it shouldn't make much difference for Nadya's romantic interest.

But that's not quite what the researchers found. While singles' own romantic ideals did predict who they said they'd be interested in dating, those ideals weren't any better at predicting their romantic interest than the ideals a random other person in the study came up with. In other words, Nadya would be just as likely to be interested in Taylor if she thought he was loyal, funny, and a good cook (her own ideals) as if she thought he was smart, outgoing, and had a good body (Mira's ideals). Only partnered participants were slightly more self-aware—their personal romantic priorities *were* better predictors of their romantic interest than those of random strangers—but even in this case, the difference was small at best. Across the board, romantic "priorities" seemed to be less related to romantic interest than you'd expect.

The results raise questions about whether we really have special insight into what we want. When it comes to romance, many people like to think they have a

People could also just be inept at figuring out what will make them happy in love.

"type," and they know what it is. Sparks' research suggests this is an illusion. "Are we just describing positive qualities that everyone wants?" she says. "We might not fully understand our own preferences."

This is consistent with prior research by Patrick Markey, a professor of psychological and brain sciences at Villanova University. He says, "It's hard to predict the sort of person you're going to end up with." Markey has found that people tend to say they want partners who are similar to themselves—to believe that being with someone more or less like them will make them happy.[2] But the people they end up going for—and, more importantly, staying with in the long term—often end up being different from them in unexpected ways.

The research, conducted with Markey's ex-wife, psychology professor Charlotte Markey, used surveys and statistical modelling to explore the connection between personality, romantic attraction, and relationship quality. When the duo surveyed singles about the personality traits they were looking for in romantic partners, they found that a similarity model—the age-old idea that birds of a feather flock together—best described the data. But when they asked people in long-term relationships to rate their current partners using the same personality dimensions, the similarity model didn't quite hold up. It seemed the happiest couples differed in terms of dominance, the tendency to take control of the situation. Other research has found similar results: From best friends to married couples, the most compatible people seem to differ on this key personality dimension.[3]

The only problem is, we're very bad at realizing this: "If I were to ask the average person, they're going to say they want a person just like themselves in terms of dominance," says Markey. "But what we get isn't that at all. What actually works is the opposite of what we want." Psychologists don't know for sure why this might be, but it might have something to do with the challenges of predicting how life, and relationships, will evolve in the long term. "Especially if you're younger, it's hard to know what life is going to be like as you grow older and start to add things to your life like mortgages, housework, and children," says Markey. "A person might be a lot of fun to go on a date with but it's hard to understand how the daily interactions you're going to have with them as a romantic partner are going to play out. We don't really think about that."

Research by biological anthropologist Helen Fisher provides some support for this perspective. Her work with brain-imaging technology has identified three distinct but overlapping neurological systems that drive our romantic desires: *lust*—also known as the "sex drive"; *romantic attraction*—the rush we feel when we first fall in love; and *attachment*—the comfortable, stable connection partners experience over months, years, or decades together. Each of these systems is associated with its own brain patterns and hormonal activity, and each, Fisher argues, developed to ensure the survival of our species in a different way. Lust motivates us to pursue a range of sexual partners—to explore and experiment with possible "mates"—while attraction encourages us to get selective, to conserve precious time and energy by coupling with someone specific.

Finally, attachment ensures partners stay together long enough to raise their own children—to provide the support needed to set the next generation on its way.

These three different motivations may be one reason why, when it comes to the long term, many of the factors that predict successful relationships are remarkably practical. The way couples argue with each other is linked to whether or not they stay together.[4] Bringing positive emotion into conflict can keep couples together, while withdrawing or bringing up past disagreements can drive them apart.[5] Also significant to a couple's relationship longevity is whether they split up household chores evenly, or whether they practice the same religion.[6,7] "It's not *When Harry Met Sally* kind of stuff," Markey says. "But it's these very mundane things that are usually the most important in our relationships. After all, that's what most of our life is consumed with." We may be attracted to dreamy ideals like "handsome" or "inspiring" in the early stages of attraction, but when it comes to sharing a life with someone, a partner who's willing to pick up the groceries or take care of the kids once in a while might be a better bet.

Of course, this disconnect between romantic ideals and realities may be a simple question of circumstances. People sometimes settle. You're lucky to find someone who matches your romantic ideals. And even if you do, they may not be single—or even interested in you, for that matter. People could also just be inept at figuring out what will make them happy in love, or struggle to express what they want a romantic partner to be like.

"I think people are miscommunicating what it is that they really want," says Moe Brown, a licensed marriage and family therapist. In his work, he helps both couples and single people navigate romantic relationships. Like Sparks and Markey, he's found that many people struggle to align what they say they're looking for with what they truly desire. "There is this other part of us that we're often operating from, but it's hidden from our conscious level of thinking," he says. A person whose parents were often angry while they were growing up may say they want to end up with a "nice" partner, but often what they really want is someone who won't yell at them like their parents did—someone who will stay calm in times of conflict. "What I find a lot is that people don't clarify that bigger theme," Brown says. "They don't break it down further."

Sparks, at least, is optimistic about our lack of self-awareness. "When I think about the people I've ended up really liking or falling in love with, they all had something that violated the things that I really think I want. We're more open to other qualities than we realize."

Instead of evaluating potential dates on strict criteria, she encourages us to lean into that openness—to take a chance on love and see where it takes us. "Go with what you're feeling as you experience it," she says. "That's going to be a more reliable indicator than these things that you say you want on paper."

ALICE FLEERACKERS is a freelance writer and a doctoral student at Simon Fraser University, where she studies health and science communication. Find her on X (formerly known as Twitter) @FleerackersA.

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Bioluminescence Is Nature's Love Light

When sparks fly, new species follow.

BY SARAH DEWEERDT

IMAGINE BEING a 22-year-old woman, wondering where new species come from. Imagine this question, burning brightly in your mind, has drawn you to the Florida Keys. One night, you pile into a boat with your graduate school advisor and some labmates, head for open water, and cut the lights. You adjust your snorkel mask, tip your face into the Caribbean Sea, and stare downward.

Nothing.

You wait. Fear prickles your body: The ocean is vast, the pitch blackness that surrounds you disorienting. Did you pick the wrong spot? Did you get the time wrong?

Then, finally—a pinprick of bright blue light.

Another.

Then an array of arcs, swirls, and flashes so dense that it is difficult to tell where one light ends and another begins. "All of a sudden, it was like this whole show that was happening," says Emily Ellis, now a molecular biologist at a biotech company in California, who was once the 22-year-old student in question. "It seemed like it was happening just for us."

But the show was not for Ellis and her companions. It was a mating display of grain-of-sand-sized crustaceans called ostracods. About half of the more than 300 species of ostracods in the world are capable of bioluminescence, meaning that chemical reactions in their bodies produce light. And 75 bioluminescent ostracod species, found only in the Caribbean, use the light in their mating displays.

Specifically, just after dusk on dark nights, male ostracods spew bioluminescent mucus from their mouths into the water to attract females. What transfixed Ellis that night was essentially a Moulin Rouge sign of glowing vomit.

KYLE MCBURNIE

MATING DANCE In this long-exposure photo, an undescribed ostracod species performs their mating displays. Each trail of multiple lines is a single display caught through time—in life, each blurred streak appears as a delicate, ephemeral dot to the human eye, and each trail of streaks is more a string of twinkling lights that only last a few seconds each.

GHOSTLY DANCERS Another example of bioluminescence in the ocean, this predatory siphonophore Rhizophysa is four inches high when contracted (middle) but its stinging tentacles stretch to a couple of feet when fishing. Here, we see three views of one animal.

Each species emits light in its own distinctive pattern of dots, dashes, descending arcs, ascending lines, squiggles: a Morse code of diverse desires. In some parts of the Caribbean, half a dozen or more species inhabit the same waters and display at the same time, yet females seem to have no trouble picking out their own kind.

And it turns out that bioluminescence is more than just a passing spectacle. It can help illuminate the whole grand pageant of evolution.

Bioluminescence has evolved independently at least 94 times, in bacteria, mushrooms, jellyfish, fireflies, shrimp, octopuses, brittle stars, and more. The tree of life is spangled with twinkling lights. One conspicuously dark branch: our own. Plenty of fish bioluminesce, but the phenomenon is unknown among terrestrial vertebrates.

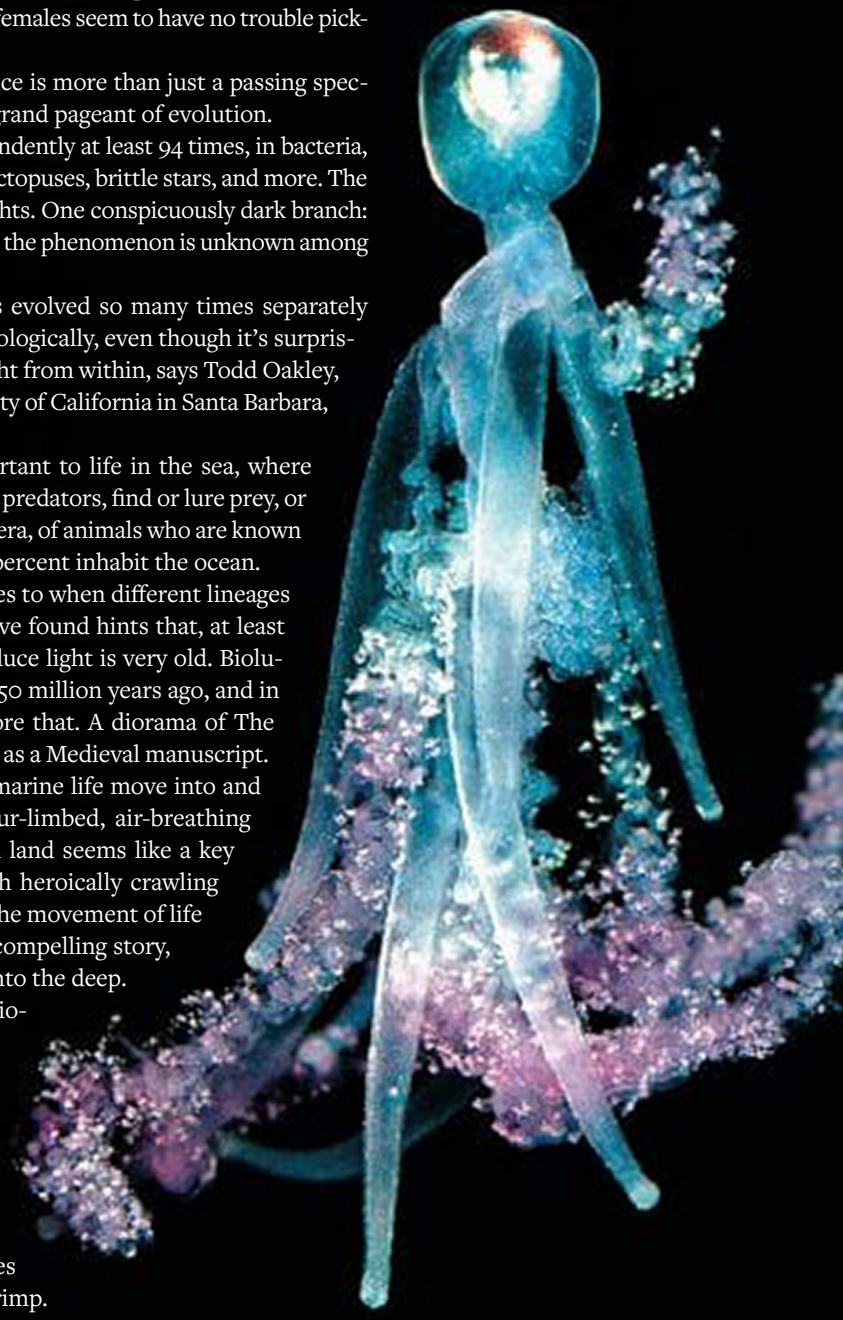
"The fact that bioluminescence has evolved so many times separately indicates that it's not that hard to do biologically, even though it's surprising to us" because of our own lack of light from within, says Todd Oakley, an evolutionary biologist at the University of California in Santa Barbara, who was Ellis' Ph.D. advisor.

Bioluminescence is especially important to life in the sea, where animals use self-produced light to avoid predators, find or lure prey, or attract mates. Of the 700 groups, or genera, of animals who are known to contain bioluminescent species, 80 percent inhabit the ocean.

By searching creatures' DNA for clues to when different lineages diverged from each other, scientists have found hints that, at least in certain animals, the capacity to produce light is very old. Bioluminescence evolved in fish as early as 150 million years ago, and in ostracods almost 50 million years before that. A diorama of The Ancient Seas ought to be as illuminated as a Medieval manuscript.

Bioluminescence may have helped marine life move into and thrive in deeper waters. From our four-limbed, air-breathing vantage point, the transition to life on land seems like a key moment in evolution: the ancestor fish heroically crawling out of the water on its fins. But maybe the movement of life in the opposite direction is an equally compelling story, with creatures lighting their own way into the deep.

Today, not only do the majority of bioluminescent animals live in the sea but the majority of animals who inhabit the deep sea are bioluminescent."I think it's this universal language that animals share" in the deep sea, says Heather Bracken-Grissom, an evolutionary biologist at Florida International University in Miami who studies the evolution of bioluminescence in shrimp.



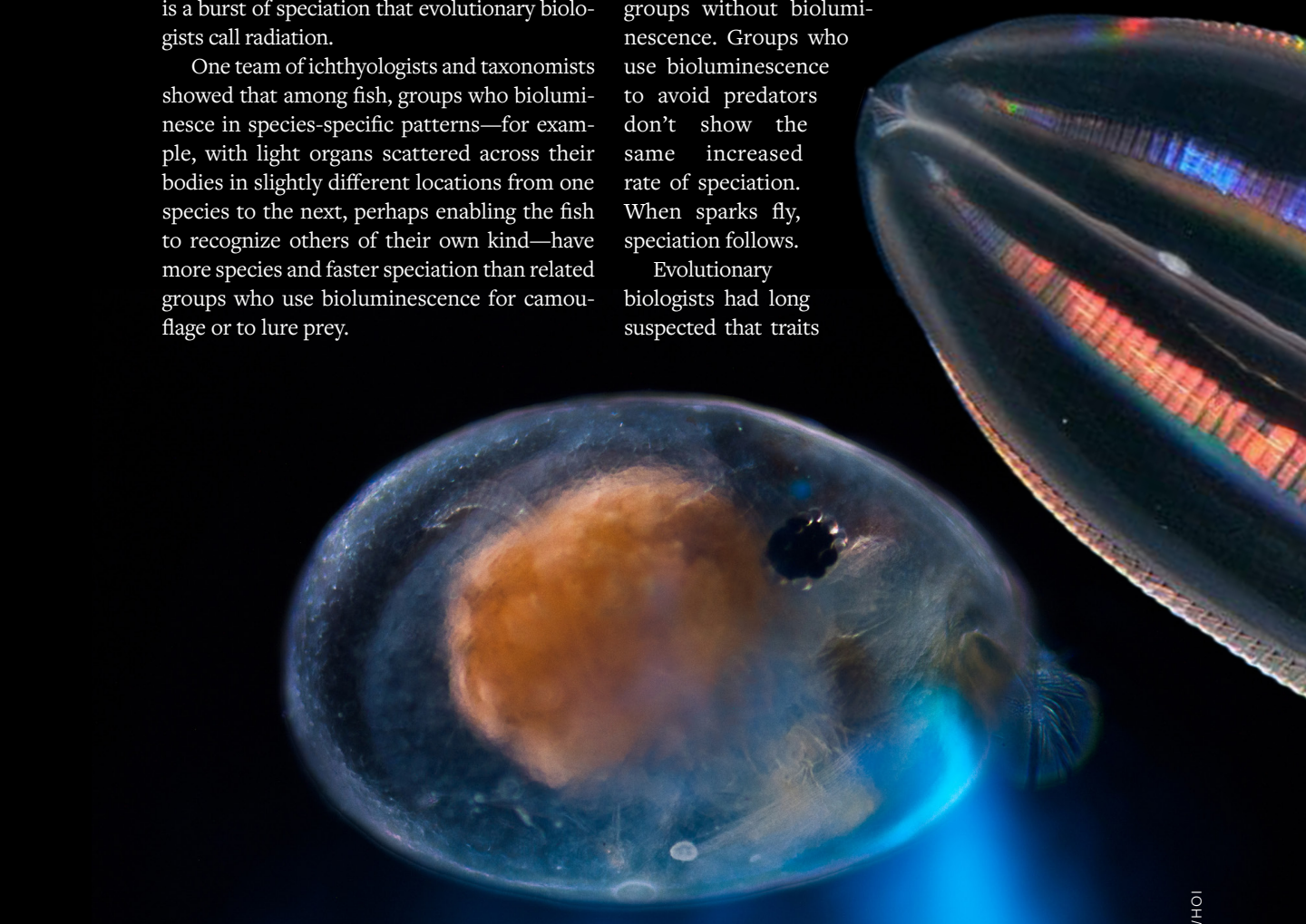
LARRY MADIN / WHOI

The usefulness of self-made light in a dark environment may not completely explain why so many species in the sea are bioluminescent, though. Bioluminescence itself makes more species. Over the past decade or so, multiple studies have shown that when animals harness bioluminescence to communicate among their own kind, especially in courtship displays, the result is a burst of speciation that evolutionary biologists call radiation.

One team of ichthyologists and taxonomists showed that among fish, groups who bioluminesce in species-specific patterns—for example, with light organs scattered across their bodies in slightly different locations from one species to the next, perhaps enabling the fish to recognize others of their own kind—have more species and faster speciation than related groups who use bioluminescence for camouflage or to lure prey.

Ellis and Oakley found similar patterns in their own analysis. They looked across 10 different types of organisms, including insects, crustaceans, segmented worms, and octopuses as well as fish. Groups with bioluminescent mating displays, like the Caribbean ostracods, have more species and diverge into new species faster than related groups without bioluminescence. Groups who use bioluminescence to avoid predators don't show the same increased rate of speciation. When sparks fly, speciation follows.

Evolutionary biologists had long suspected that traits



FIREFLY OF THE DEEP. Animals in the sea use self-produced light to avoid predators, find or lure prey, or attract mates. Here, a lone female ostracod *Photeros annecohenae* releases bioluminescence.

ELLIOT LOWNDES / WHOI

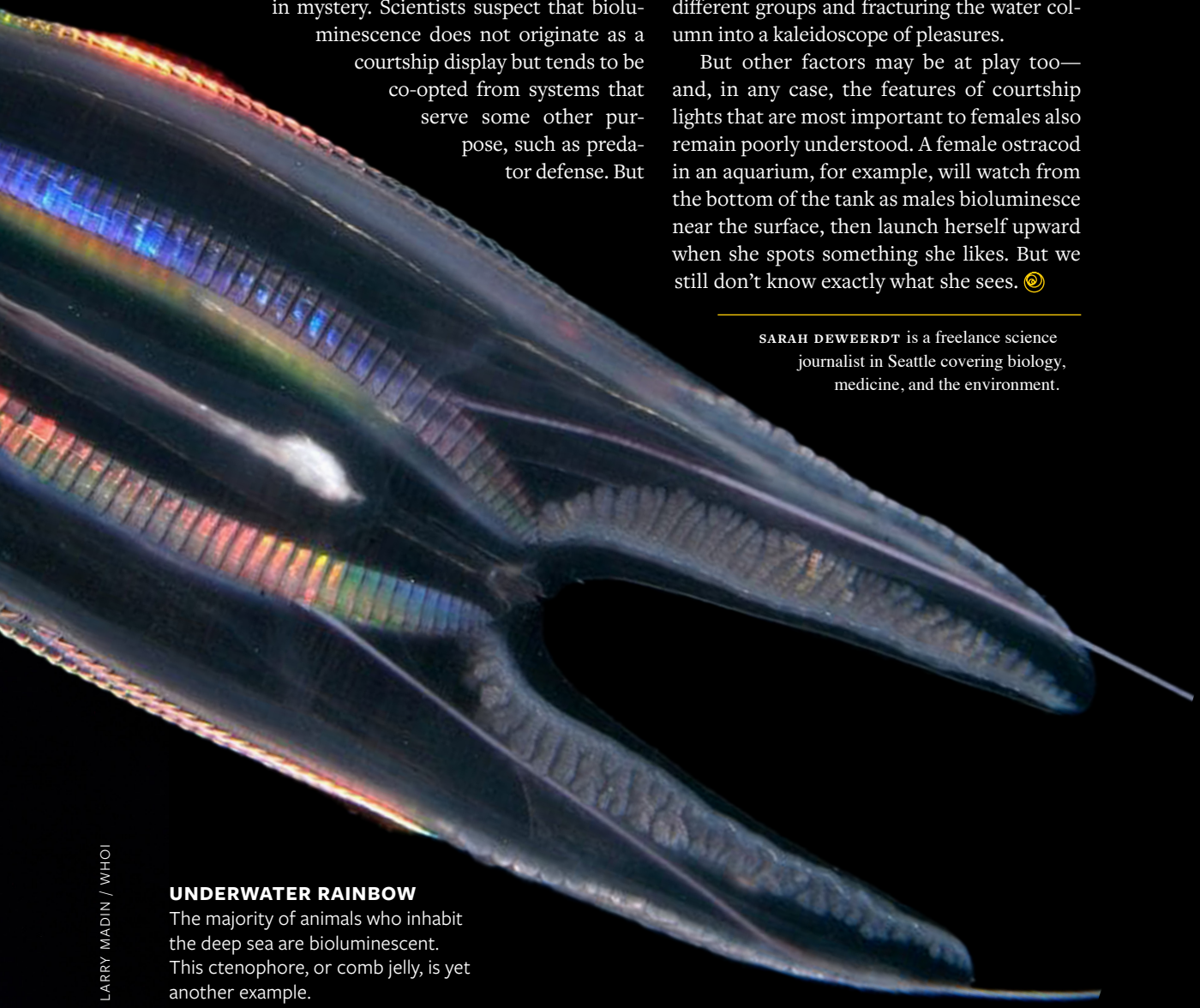
involving sex appeal—like a peacock's tail or an ostracod's glowing vomit—drive increased rates of speciation and help explain biodiversity's patterns, but it had been difficult to verify. It took bioluminescence to shed light on the question.

Even with these tantalizing portions of evolution's luminous narrative revealed, the details of what happens before and after bioluminescent courtship evolves remain shrouded in mystery. Scientists suspect that bioluminescence does not originate as a courtship display but tends to be co-opted from systems that serve some other purpose, such as predator defense. But no one knows how a warning signal turns into a come-hither ploy.

Nor do scientists know exactly how the advent of bioluminescent courtship spurs light-speed speciation. Chance probably has something to do with it: that is, chance variations in how males put on their light shows, and chance variations in how females perceive them, combining to sort otherwise similar creatures into different groups and fracturing the water column into a kaleidoscope of pleasures.

But other factors may be at play too—and, in any case, the features of courtship lights that are most important to females also remain poorly understood. A female ostracod in an aquarium, for example, will watch from the bottom of the tank as males bioluminesce near the surface, then launch herself upward when she spots something she likes. But we still don't know exactly what she sees.

SARAH DEWEERDT is a freelance science journalist in Seattle covering biology, medicine, and the environment.



LARRY MADIN / WHOI

UNDERWATER RAINBOW
The majority of animals who inhabit the deep sea are bioluminescent. This ctenophore, or comb jelly, is yet another example.

This Drug Can Mend a Broken Heart

A new therapy promises to take the sting out of traumatic memories

BY SHAYLA LOVE

ON VALENTINE'S DAY in 2016, Anne Lantoine received not flowers, but divorce papers. In the months preceding, she had been preparing for her family's move from France to Canada—or so she thought. She arrived in Quebec early with one of her three children, who was preparing to start college there, while the other two remained in Europe for school. Her husband stayed behind to manage the sale of their house in Marseille.

Then the realtors began to complain, through a barrage of calls and emails, to Lantoine. Her husband was not acting like a man who wanted his house sold. He wasn't answering phone calls and was never available for showings. In January 2016, Lantoine called him after yet another complaint from a realtor. The next morning, he sent her an email with a notice for a court hearing, and she discovered her husband had actually filed for divorce, without telling her, months earlier.

That February, she finally got the paperwork, not from her husband, but from her real estate agent. "It was not my last shock," Lantoine, now 59, recalls. "I also discovered that my husband's mistress was living in my home." These revelations were a huge blow practically: It disrupted the immigration paperwork, and Lantoine and her daughter lost their visa applications. But the searing pain was in the betrayal and deceit.

"I became very anxious and had constant nightmares," she says. "I was tired all the time and had panic attacks each time I opened my mail or my emails, or when I had an unidentified phone call."

Though the details of each case vary, romantic betrayal through infidelity, abandonment, or emotional manipulation can upend one's life in an instant. For Lantoine, her future plans, and the person they were attached to, were suddenly gone, and her functioning along with them.

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"It doesn't erase what happened to you. It just changes the impact it has on your life."

Exhausted and an emotional wreck after almost a year, Lantoine learned about a clinical trial at the Douglas Mental Health University Institute, a Canadian psychiatric hospital in Montreal, that sought to ease the pain of romantic betrayal. The study did not rely on traditional psychotherapy sessions. It claimed it would dampen the emotional reverberations of what happened to her by pairing a beta-blocker medication called propranolol with a series of "memory reactivation sessions." She signed up.

It sounds like science fiction, or science romantic-fiction. The 2004 movie *Eternal Sunshine of the Spotless Mind* often gets brought up, says Michelle Lonergan, now a postdoctoral fellow at the University of Ottawa who led the trial as part of her Ph.D. In the film, a couple, post-breakup, use a service to erase their memories of one another in response to the suffering of heartbreak.

But the experiments that Lantoine enrolled in were an attempt to use a very real feature of the brain—albeit one we're still learning the ins and outs of—called memory reconsolidation to attenuate agonizing romantic memories.

"Memory reconsolidation" describes how, when we recall a memory, it can become pliable. There is hope—and some intriguing early data—that, at the moment of recollection, we might be able to intentionally change a memory and make it less burdensome. This ability to modulate distressing memories is being investigated as an intervention to treat post-traumatic stress disorder,[1] addiction,[2] phobias,[3] and is thought to have promise for depression or anxiety more broadly. It rests on an idea that's emerged from our understanding of memory over the past few decades: Memories are not fixed, even the ones that haunt us the most.

Described in the *Journal of Affective Disorders* in 2022, the study Lantoine enrolled in is the first application of a memory reconsolidation-focused treatment for adjustment disorder resulting from romantic betrayal.[4] (Adjustment disorder is defined as an emotional and behavioral maladaptive reaction to a stressful event, but not a life threatening one, so it doesn't meet criteria for PTSD.)

Unlike *Eternal Sunshine*, Lantoine's memories didn't vanish in a dramatic collapse of a beach house into the Montauk coastline. She still had the declarative memory of what had happened.[5] But, as Lantoine describes it, the memories were no longer debilitating.

"The treatment doesn't remove the remembrance of the events," Lantoine says. "It just removes the pain that was associated with the events. It doesn't erase what happened to you. It just changes the impact it has on your life."

WHEN A MEMORY INITIALLY FORMS, or is consolidated, it relies on chemical interactions between neurons in our brain. When a memory is remembered, or retrieved, it can be momentarily destabilized while those same chemical processes reconsolidate the memory.

"We feel that our memories, whether they're conscious or unconscious memories that influence our behavior, are fixed and rooted in fact," says Joff Lee, a professor of memory neuroscience at the University of Birmingham who was not involved in the trial. "But actually, pretty much everything that we know about memory suggests that these memories are malleable, and they change for potentially good reasons."

When presented with new information, it's helpful for our memories to be able to update so that we can learn and adapt to our surroundings. By hijacking this feature, researchers have shown in animal models that when memories become labile, it's possible to intervene.

"Visualize a monster, with big long claws, digging deep into your heart, ripping your heart out while you are still breathing."

More than 50 years ago, scientists found they could induce something called "post-retrieval amnesia."[6] Rats could forget a fear response if given an electroconvulsive shock at just the right time to interrupt the reconsolidation of that memory. The study was one of the first to challenge the idea that memories, once formed, were unchanging. There are now dozens of animal studies that show that when drugs are given to block the molecules needed for memory consolidation, memories seem to vanish, even when those memories aren't new.[7]

It soon became clear that memory reconsolidation could be a powerful therapeutic tool. But the methods used in animal studies to interfere with reconsolidating were often harmful to humans. Enter propranolol: a common beta blocker used for lowering blood pressure as well as for treating anxiety and preventing migraines. Propranolol impairs adrenaline hormones in the brain and is thought to impact the production of other molecules needed for memory reconsolidation.

Starting in the early 2000s, researchers showed that, in rats, the drug could have similar post-retrieval effects as the more toxic compounds. And in 2009, researchers found that propranolol could help people disengage from a learned fear response.[8] In this study, scientists showed human participants images of spiders, paired with an electric shock. One day later, some were given propranolol and others a placebo. On the third day, when participants saw the same images, those who had received the placebo noticeably startled, a physical manifestation of the fear response usually paired with a negative emotional state. But those who had been given the propranolol no longer had that reaction. These participants could still remember what had happened to them; propranolol didn't erase the facts. But they no longer exhibited the biological signs of being afraid.

Researchers soon began applying these findings to try to treat severe conditions, such as PTSD. Alain Brunet, a psychologist and researcher at the Douglas Institute and McGill University, and senior author of the study Lantoine participated in, described in a 2018 paper that people with PTSD who took propranolol and received six 25-minute trauma reactivation sessions had fewer PTSD symptoms compared to a group that underwent the same sessions paired with a placebo. (He has even trademarked "Reconsolidation Therapy," and the "Brunet Method," which describe the protocol of pairing propranolol with memory retrieval sessions.)

Brunet has long felt that reconsolidation therapy could have wider appeal. "We wanted to broaden the uses of reconsolidation therapy," Brunet says. So he and his team went looking for people suffering from an unfortunately common adjustment disorder—that spurred by romantic betrayal.

Even if we can change memories, should we?

ANNE LANTOINE WAS of course not alone in suffering heartbreak in Quebec. Brunet and Lonergan recruited 61 people in total who were cheated on, abandoned, wiped out financially, "all kinds of horrendous stories," Lonergan says.

The participants described being unable to sleep, gaining or losing weight, starting smoking, losing their hair, and suffering from nosebleeds. "It hurts everywhere!" as one 44-year-old woman described in a follow-up qualitative paper from the research team.[9] "Your throat hurts. You can't breathe. When you think about it you hurt ... You have these really graphic images, and you can't block them, there's nothing you can do. It's in your face all the time." A 44-year-old man described his intrusive thoughts replaying "like a movie all the time."

Being reminded of their former partners was especially distressing, like the anniversaries of when they discovered they were being cheated on, seeing photos of them online, or even seeing people who walked or talked like their former partners.

"When I really knew that he had betrayed me, the pain, and the torture it was like I had been cut off at my knees ... if you want to visualize you know like some sort of monster, with big long claws, and just digging deep into your heart, ripping your heart out while you are still breathing and alive and very conscious, and taking a bite out of your heart right in front of your face, that's what it feels like," a 50-year-old woman said.

In the trial, there was first a four-week waiting period when no one got any treatment. This limbo served as the control condition against which to compare the treatment. Then each person wrote a narrative of their betrayal, in as much detail as possible. In five memory reactivation sessions, they read their own descriptions one hour after taking propranolol. Compared to the waiting-period, the researchers found there was an overall significant reduction in symptoms, including intrusive thoughts, avoidance, and hypervigilance, as well as a decrease in anxiety and depression, starting after the first session. Up to four months later, those benefits remained.

"They were really in trouble," Lonergan says. "And so we offered them treatment. And luckily, for a good chunk of them, it really seemed to work."

THE MEMORY RECONSOLIDATION THEORY tells a tidy story about how practitioners might be able to help people, at least emotionally, rewrite their narratives. But does it tell the full story?

Lonergan acknowledges that there might be other factors at play. For example, the empathetic support in the retrieval sessions could have played a role in participants' improvements, and she hopes to do future work on adjustment disorder and romantic betrayal with a full placebo group, the way the PTSD trial ran.

Lee thinks we should also have some humility about which mechanisms these therapies might be

MAX4E PHOTO / SHUTTERSTOCK

COMFORTABLY NUMB
When a memory is remembered, or retrieved, it can be momentarily destabilized with a drug therapy, numbing its emotional pain.

tapping into. Memory reconsolidation is likely a complex process that co-occurs with many other cognitive and neurobiological systems.

This is underscored by the fact that results of reconsolidation therapies have not always been consistent.[10,11] Several studies have failed to replicate,[7] and some even found reconsolidation attempts can lead to adverse events.[12,13] A randomized, double-blind placebo-controlled study in smokers from 2015 didn't find any effect on physical reaction after being given a dose of propranolol.[14] Three other placebo-controlled studies in people with PTSD also didn't show any reduced symptoms.[15]

There could be rules and caveats to using memory reconsolidation as an effective tool that we simply don't understand yet. Other research into memory reconsolidation has found, for example, that updating an existing memory is most effective when the brain gets just enough new information, such as a new stimulus in place of an old one that had triggered

If just the facts of a memory remain, can we really say it's the same?

fear or loathing.[16,17] If the new information introduced is too strong, a *new* memory might be created instead of an alteration to the older memory, and the two memories will compete. "Those are all technical things that people are still figuring out," Lonergan says.

Nevertheless, given its promise, attempting to use memory reconsolidation in therapeutic interventions seems obvious to Brunet. If we know that sometimes memories are malleable, why *wouldn't* we try to target that, he says?

BUT EVEN IF WE *can* change memories, *should* we?

Memory researchers Tom Beckers and Merel Kindt raised this point in a 2017 review.[7] "Concerns have been voiced as to how desirable of a therapeutic goal it is to make people forget about significant events that have happened in their personal lives and that may play a central role in defining who they are," they wrote.

Is it okay if just emotional parts of memory are being stripped away, as long as the declarative elements remain?

In his 19th-century essay, "What Is an Emotion," psychologist William James challenges us to try to imagine an experience of emotion, like anger, without the elements of a racing heart or flushed face. If just the facts of a memory remain, can we really say it's the same, once it's been neutered of its emotionality?

But that's somewhat the point, Lonergan says. The people in the study were not able to move on or find peace after what happened to them. Emotional memories are not sequestered to the mind. These individuals needed the intensity of the emotions dialed down so that they could sleep, eat, and resume normal day to day functioning. "We're not specifically targeting and removing them from people's brains—they still remember what happened," she says. "But instead of being a traumatic memory, it's just a bad memory."

Further, our ability to update and modify our memory is built into us—whether aided by a drug or not. Other forms of psychotherapy similarly seek to change our relationship to and framing of our memories. The goal of a targeted, pharmaceutical intervention would be to achieve that result by way of going after the memory directly.

Lantoine says, five years out, she still feels the positive effects from the treatment. It was an improvement that came after about the third reactivation session. The daily torment she had felt receded into the background.

"It's like a chronic pain you get rid of," she says. "A bit like the scars I have on my knee and on my hip: I can see them, I remember I got them after painful surgeries. I remember I felt this pain. But *they* are not painful anymore. Those events have left scars in my brain," she says of her experience of betrayal. "It's impossible to forget what happened and to erase those scars. But they don't hurt."

SHAYLA LOVE is a freelance science journalist based in Brooklyn. Follow her at @shayla__love.

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