Four

A FIERCER SEA

How relationships permeate the human body, mind, and soul

When Romeo hears of Juliet's demise (a report that turns out to be false), he goes immediately to her mausoleum to join her in death. So mad with grief and intent on their funereal reunion is he that he says to Balthasar, his trusted servant, who he thinks may try to stop him:

But if thou, jealous, dost return to pry
In what I further shall intend to do,
By heaven, I will tear thee joint by joint,
And strew this hungry churchyard with thy limbs.
The time and my intents are savage-wild,
More fierce and more inexorable far
Than empty tigers or the roaring sea.

Love is no less ferocious today. Romeo's anguished cry rings true because it resonates within the same emotional architecture the Bard intuited. What is the nature of aching loss and the desperate urge for reunion with those we love? What makes passion savage and inexorable? Our culture has forgotten that primordial knowledge, now buried beneath an impenetrable layer of lectures and instructional videotapes. Relationships have taken on the status of weather—everyone talks about them, but who knows what to *do*?

Relatedness, affiliation, loyalty, and nurturance are woven so thoroughly into our lives that we tend to presuppose their ubiquity throughout the animal kingdom. But most creatures do not know

these motivations. Cannibalism—specifically, parents ingesting offspring for nutritive value—revolts human beings, but for many species the line between progeny and delicacy is blurred. A friend who kept guppies gave them up upon realizing she would have to segregate the young to prevent their wholesale consumption by parents. Such indiscriminate dining habits are, the pet store manager told her, normal for grown guppies. "Not in my house, they aren't," she answered grimly, and expelled the fish into the toilet. If they made it to the sea, they may be cannibalizing still. The diminutive crocodilian we encountered in the last chapter had good reason to be wary: nine out of ten baby crocodiles finish life in the belly of a predator before their first birthday; in most instances, the poacher is an adult croc. Given how primal the urge is to gobble up a smaller organism, feelings of tenderness, care, and concern for the tiny and frail may rightly strike us as near marvels. They are limbic endowments, and so are the rage and tears that erupt at the fracture of a mammalian bond. Of what is that miraculous tie made? For animals as social as we, that question defines our lives.

FINDING THE TIES THAT BIND

The Austrian physician and Nobel laureate Konrad Lorenz launched the scientific study of relatedness in response to a children's book. The child of parents "supremely tolerant of my inordinate love for animals," Lorenz grew up on a large estate in Altenburg, Germany, where he kept a menagerie of insects, fish, reptiles, dogs, and monkeys. But after he read *The Wonderful Adventures of Nils,* in which a mischievous boy joins a flock of migrating geese, Lorenz's avian pets became his lifelong love. "From then on, I yearned to become a wild goose and, on realizing that this was impossible, I desperately wanted to have one," Lorenz wrote. His

devoted observations of the waterfowl in his backyard convinced him that much of their behavior, including mother-offspring bonding, was instinctual. Lorenz's best-known studies concerned ducklings and goslings, who huddle by their mother while she rests, and clamber after her when she is on the move.

Baby ducks tagging along behind their mother are a familiar sight to anyone acquainted with kindergarten reading primers. But how, Lorenz wondered, do they know whom to follow? As a boy, he was delighted to see that hatchlings would trail after him instead of their mothers. As a scientist, Lorenz found that ducklings would tail *anything*—no matter how implausible a mother—provided they saw it move early in their lives.

Lorenz realized that when goslings in the wild follow a mother goose, they do so not because they recognize a parent who will lead them to food and away from danger. Evolution has instead equipped goslings with a hardwired neural rule ("follow *that*"), and the dictum applies to any object falling within some sketchy guidelines for motherhood ("seen early in life" plus "moving"). The first entity a freshly hatched bird normally sees *is* its mother, but the bird's neural system is programmed to detect only a few of her relevant characteristics before fixating on her, and the system can be fooled. Lorenz used the word *imprinting* for the tendency of birds and mammals to lock on to an early object. In work done since, lambs have been tricked into forming a bond to television sets, guinea pigs to wooden blocks, and monkeys to cylinders of wire bent into the rough outline of a simian mother.

Imprinting is a manifestation of rudimentary neural systems dabbling in relatedness, and its rigidity owes much to the primitive nature of those circuits. Human relationships show similarly lawful properties. Even though primate attachments are more flexible than a gosling's, they bend much less than people expect.

Frederick II, a thirteenth-century Holy Roman emperor and king of southern Italy, unwittingly conducted the first study of human bonding. His Imperial Majesty, who spoke several languages himself, thought he could determine the inborn language of mankind by raising a group of children who would never hear speech. Saltimbene de Parma, a Franciscan monk who chronicled the exploits of the experimental monarch, wrote that Frederick proceeded by "bidding foster-mothers and nurses to suckle and bathe and wash the children, but in no wise to prattle or speak with them; for he would have learnt whether they would speak the Hebrew language (which had been the first), or Greek, or Latin, or Arabic, or perchance the tongue of their parents of whom they had been born." But, the good brother wrote, Frederick's exercise terminated before yielding any linguistic result: all of the infants died before uttering a single word. The emperor had stumbled upon something remarkable: that "children could not live without clappings of the hands, and gestures, and gladness of countenance, and blandishments." *

Eight hundred years later, in the 1940s, psychoanalyst René Spitz reported on infants caught in a repetition of Frederick's experiment. Spitz described the fate of orphaned children reared in foundling homes and institutions, as well as babies separated from young mothers in prison. In deference to the newly validated germ theory of disease, institutional babies were fed and clothed, and kept warm and clean, but they were not played with, handled, or held. Human contact, it was thought, would risk exposing the children to hazardous infectious organisms.

Spitz found that while the physical needs of the children were met, they inevitably became withdrawn and sickly, and lost weight. A great many died. In a mortal irony, the babies exhibited a vast

* Frederick cannot have been pleased with the outcome of the experiment. He was not a man to be trifled with—Saltimbene reports the king once cut off a notary's thumb for the sin of misspelling his name.

vulnerability to the same infections their isolation was meant to guard against. Forty percent of children who contracted measles succumbed to the virus, for example, at a time when the measles mortality rate in the community outside the institution was .5 percent. "The worst offenders," Spitz wrote, "were the best equipped and most hygienic institutions." Death rates at the so-called sterile nurseries near the turn of the century were routinely above 75 percent, and in at least one case, nearly 100 percent. Spitz had rediscovered that a lack of human interaction—handling, cooing, stroking, baby talk, and play—is fatal to infants.

Why should human contact—"gestures and gladness of countenance"—rank with food and water as a physiologic need? The British psychoanalyst John Bowlby picked up this trail in the 1950s. A natural renegade, Bowlby had barely completed his psychoanalytic training before he launched a revolution against the mother church. His creative blend of Freudian metapsychology and Lorenzian ethology produced *attachment theory,* a model that draws parallels between the bonding behavior of humans and animals. Bowlby theorized that human infants are born with a brain system that promotes safety by establishing an instinctive behavioral bond with their mothers. That bond produces distress when a mother is absent, as well as the drive for the two to seek each other out when the child is frightened or in pain. The same behavioral template is manifest in other young mammals, who also cry and cling and seek out their mothers when danger looms.

At the time, Bowlby's ideas were scandalous. The Freudians viewed the mother-infant bond as the "cupboard of love": an infant values his mother because she gratifies his id, as she does when she feeds him. Bowlby's biological bonding system and its infringement on the id's supremacy infuriated the psychoanalysts. They alternately denounced him as naïve and a blasphemer. After Bowlby published his pivotal paper "The Nature of the Child's Tie to His

Mother," Anna Freud rebuked him in frosty and regal tones: "[W]e do not deal with happenings in the external world as such but with their repercussions in the mind." These are fighting words. Accusing a psychoanalyst of realism is verbal annihilation, like calling a composer tone-deaf or a surgeon ham-fisted. Donald Winnicott, English pediatrician turned psychoanalyst and then-president of the British Psychoanalytic Society, wrote that Bowlby's theories were giving him "a kind of revulsion." Even Bowlby's own therapist, Joan Riviere, rose to condemn him at one of the psychoanalytic meetings called for that purpose.

In Bowlby's day, nearly all American psychoanalysts were psychiatrists, and vice versa. While Spitz and Bowlby struggled against the orthodoxies of one profession, their psychologist colleagues in America were burdened by a different but no less restrictive ideology. Psychology, the nonmedical branch of the behavioral sciences, operated for decades under the iron rule of behaviorism. Psychological models of the mother-infant relationship bore the stamp of that withering reign. Reward and punishment, the twin monoliths that taught pigeons to peck levers and rats to run mazes, were invoked as all-purpose tools for shaping human relatedness. Behaviorists advised parents to treat their babies like unruly lab animals. Comforting crying infants was verboten; rewarding distress with attention, they taught, merely reinforces and promotes noxious displays of whining. "Mother love is a dangerous instrument," cautioned the renowned behaviorist John Watson, maintaining that parental affection usually transforms healthy children into contemptible emotional invalids. "Never hug and kiss them," he advised parents, "never let them sit in your lap. If you must, kiss them once on the forehead when they say goodnight."

Harry Harlow's famous work in the fifties dealt synchronous hammer blows to the Freudian and the Pavlovian models of relatedness. In an experiment destined for perpetual notoriety in the

pages of college textbooks, Harlow offered young monkeys a choice of two surrogate mothers: a wire mesh cylinder outfitted with a feeding milk bottle, and a terrycloth figure that offered no nutritive sustenance. Without fail, the immature monkeys frequented the wire mother only long enough to dine and treated the furry mother as Mom: they clasped her, squealed at her, embraced her, hid behind her when alarmed. Milk, whether a reinforcing reward or an id-satisfying elixir, failed spectacularly to establish any bond. In trial after trial, the more a doll could be made to resemble a mother monkey, the more infatuated the little monkeys became.

Only Bowlby's attachment theory, which held that proximity to the mother herself is an inborn need, fit the facts. In his view, an infant is born with few motor skills, and so, when his mother strays, he can keep her near by crying—a genetically inherited clarion call that makes a normal mother seek *him* out. As a baby develops muscular coordination, attachment behaviors become more elaborate: a child reaches, grasps, beckons, crawls, or clamors to bring his mother close. Attachment behaviors are clumsy and sputtering in their initial forms, as most behaviors are, but over time they become part of a fluent interaction between child and mother. Children express their separation-related distress first in a nonspecific bleat, and later in pointed communications ("I want you to hold my hand *now*."). But even crying is not as general a signal as one might suppose: an infant's hunger cry has a unique sound signature. When a mother reaches for the bottle and not the diaper when her baby cries, she is more than guessing about what her child needs.

Certain conditions elicit forceful expressions of a child's instinctive desire to be at a parent's side: unfamiliar places, people, or things; fear, pain, cold, illness, and imposed separations. Adults evidence the same template, although we rarely recognize its outline.

But fear's propensity to amplify bonding is what drives high school couples to see scary movies together. An identical mechanism weaves the ties between people who share a traumatic experience, as in wartime or a disaster. Designers of boot camps, and fraternity and sorority initiations, with varying degrees of consciousness exploit the same process to forge affiliations between dissimilar strangers who must be made to cohere.

Children show fewer outward markers of attachment as they grow up. An eight-year-old is less likely to hold his mother's hand in a department store than a four-year-old, and a fourteen-year-old may not be willing to hold a parent's hand under any circumstances. But the underlying bond endures. An attachment can flourish without overt sign until a disruptive event brings out its expression. People hug each other on departures and arrivals—an act so familiar we might think it nothing more than a custom. But this style of embrace contains silent evidence of attachment: an imposed separation, or the threat of one, reflexively makes people want to reestablish skin-to-skin contact.

The Pliant Years

Psychiatrists are notorious for claiming that pivotal events in the first years of life determine personality. Some skeptics regard this assertion with suspicion, but the study of human attachment has proven it true.

More than twenty years ago, developmental psychologist Mary Ainsworth investigated mothers and their newborn infants and found that the kind of mother a baby has predicts his emotional traits in later life. She first watched how mothers looked after babies and divided caretaking styles into three categories. A year later, Ainsworth then tested the children's emotionality by observing their response to brief separations. A mother who had been consistently attentive, responsive, and tender to her infant raised a *se-*

cure child, who used his mother as a safe haven from which to explore the world. He was upset and fussy when she left him and reassured and joyful when she came back. A cold, resentful, rigid mother produced an *insecure-avoidant* child, who displayed indifference to his mother's departures and often pointedly ignored her on her return, turning his back or crawling away to a suddenly fascinating toy in the corner. The baby of a mother distracted or erratic in her attentions became an *insecure-ambivalent* toddler, clutching at his mother when they were together, dissolving into wails and shrieks when the two were separated, and remaining inconsolable after their reunion.

As the children matured, mothers' parenting aptitude predicted more and more budding personality traits. Babies of responsive mothers developed into grade-schoolers who were happy, socially competent, resilient, persistent, likable, and empathic with others. They had more friends, were relaxed about intimacy, solved problems on their own when they could, and sought help when they needed it. Infants reared by the cold mothers grew up to be distant, difficult-to-reach kids who were hostile to authority, shunned togetherness, and wouldn't ask for comfort, particularly when they were hurt. They often had a mean streak and seemed to take pleasure in provoking and upsetting other children. The offspring of the unpredictable mothers metamorphosed into children who were socially inept, timid, hypersensitive, and lacking in confidence. Hungry for attention and easily frustrated, they frequently asked for assistance with simple tasks that should have been within their competence.

The modest study that Ainsworth began has since swelled into a mountain of meticulous investigation. Long-term data are still rolling in; children have been followed from infancy to their teenage years. Attachment security continues to be a powerful predictor of life success. The securely attached children have a considerable edge in self-esteem and popularity as high school students, while the insecurely attached are proving excessively susceptible to the sad ensnarements of adolescence—delinquency, drugs, pregnancy, AIDS. Almost two decades after birth, a host of academic, social, and personal variables correlate with the kind of mother who gazed down at her child in the cradle.

Ainsworth (and the many researchers who followed her) proved that what a mother does with her baby *matters.* Mothers shape their children in long-lasting and measurable ways, bestowing upon them some of the emotional attributes they will possess and rely on, to their benefit or detriment, for the rest of their lives. The results of this research accord agreeably with common sense. If raising children entails any talent or skill, if one supposes that parenting is more neurally complicated than a reflex, then some people will inevitably possess a greater adeptness at nurturing emotionally healthy children. And from the study of attachment, we can learn who these parents are and how they do what they do.

Ainsworth found no simple correlation between the length of time a mother spent attending to her child and his ultimate emotional health. The securely attached children were not necessarily the infants who were taken up into their mothers' arms most frequently or held the longest. Ainsworth observed instead that secure attachment resulted when a child was hugged when he wanted to be hugged and put down when he wanted to be put down. When he was hungry, his mother knew it and fed him; when he began to tire, his mother felt it and eased his transition into sleep by tucking him into his bassinet. Wherever a mother sensed her baby's inarticulate desires and acted on them, not only was their mutual enjoyment greatest, but the outcome was, years later, a secure child.

By the grace of what miraculous intermediary do mothers know when to approach an infant and when to let him be, when a baby needs the warmth of her embrace and when he needs room to

breathe? Limbic resonance gives her the means to that telepathy. By looking into his eyes and becoming attuned to his inner states, a mother can reliably intuit her baby's feelings and needs. The regular application of that knowledge changes a child's emotional makeup. The precise details of that process are now coming to light, as the neural systems underlying relatedness yield up some of their secrets. Bowlby thought the goal of attachment was to establish physical security for an infant, whose helplessness requires a nearby protector. His thinking was audacious in its day, but the reach of relationships is far greater than he imagined. Investigations into the physiology of relatedness now tell us that attachment penetrates to the neural core of what it means to be a human being.

THE ANATOMY OF LOVE

Mourning Becomes Electric

Take a puppy away from his mother, place him alone in a wicker pen, and you will witness the universal mammalian reaction to the rupture of an attachment bond—a reflection of the limbic architecture mammals share. Short separations provoke an acute response known as *protest,* while prolonged separations yield the physiologic state of *despair.*

A lone puppy first enters the protest phase. He paces tirelessly, scanning his surroundings from all vantage points, barking, scratching vainly at the floor. He makes energetic and abortive attempts at scaling the walls of his prison, tumbling into a heap with each failure. He lets out a piteous whine, high-pitched and grating. Every aspect of his behavior broadcasts his distress, the same discomfort that all social mammals show when deprived of those to whom they are attached. Even young rats evidence protest: when their mother is absent they emit nonstop ultrasonic cries, a plaintive chorus inaudible to our dull ape ears.

Human adults exhibit a protest response as much as any other mammal. Anyone who has been jilted in an infatuation (i.e., just about everybody) has experienced the protest phase firsthand—the inescapable inner restlessness, the powerful urge to contact the person ("just to talk"), mistaken glimpses of the lost figure everywhere (a seething combination of overly vigilant scanning and blind hope). All are part of protest. The drive to reestablish contact is sufficiently formidable that people often cannot resist it, even when they understand that the other person doesn't want anything to do with them. Human beings manifest searching and calling in lengthy letters, frantic phone calls, repeated e-mails, and telephoning an answering machine just to hear another's voice. The tormented letter that a rejected lover composes turns out to be an updated version of a baby rat's constant peep: the same song, in a slightly lower pitch.

BEHAVIOR
Increased
Motor activity
Vocalization
Demeanor
Searching

PHYSIOLOGY
Increased
Heart rate
Body temperature
Catecholamine synthesis
Cortisol synthesis

The behavior and physiology of the protest phase. (Adapted from Hofer, 1987.)

A mammal in protest shows a distinct physiology. Heart rate and body temperature increase, as do the levels of *catecholamines* and *cortisol.* Catecholamines (like adrenaline) elevate alertness and activity. A young mammal who has lost his mother ought to stay alert long enough to find her, and the rise in catecholamines during protest promotes his vigil. This part of the ancient attachment machinery may also keep a human being staring at the ceiling all night after a breakup. Cortisol is the body's major stress hormone, and its sharp elevation in separated mammals tells us that relationship

rupture is a severe bodily strain. Cortisol levels rise sixfold in some mammals after just thirty minutes of isolation.

The Heart's Discontent

A lone puppy's protest phase doesn't last forever. Reunite the pup with his mother, and protest terminates. If the separation is prolonged, a mammal enters the second stage: *despair.* Like protest, despair is a coherent physiologic state—a set of behavioral inclinations and bodily reactions common to mammals. Despair begins with the collapse of fretfulness into lethargy: the animal stops his back-and-forthing, stops whimpering, and curls up in a despondent lump. He drinks little and may show no interest in food at all. If a peer or playmate is introduced into the pen, he may regard him with a bleary eye and turn away. He will have a slumped, dejected-looking posture and a sad facial expression. As the universality of emotional expressiveness lets us know, a mammal in despair looks miserable.

The physiologic signature of the despair phase is that of widespread disruption of bodily rhythms. Heart rate will be low, and on the electrocardiogram we will find abnormal, serrated beats in-

An isolated rhesus monkey. (From *Kaplan and Sadock's Synopsis of Psychiatry,* Eighth Edition. Reprinted with permission of Lippincott, Williams & Wilkins.)

truding into the regular procession of slender spikes that demarcate a healthy heart's metronomic cadence. Sleep will change considerably: lighter, with less dreaming or REM sleep, and more spontaneous nocturnal awakenings. Circadian rhythms, which coordinate the rise and fall of physiologic parameters with the light-dark cycle of the day, will also shift. The level of growth hormone in the blood will plummet. Even immune regulation undergoes major alterations in response to prolonged separation.

Anyone who has grieved a death has known *despair* from the inside: the leaden inertia of the body, the global indifference to everything but the loss, the aversion to food, the urge to closet oneself away, the inability to sleep, the relentless grayness of the world. Grief can give some insight into what it is like to have a major depression. Despair and depression are close cousins, enough so that despair in laboratory animals is often used as a model for human depressive illness. The disease state we call major depression in human beings may be a twisted variant of the despair reaction. But how and why the neural adaptations to loss can be unleashed inside the brain absent the usual trigger, death of a loved one, remains unknown.

Prolonged separation affects more than feelings. A number of somatic parameters go haywire in despair. Because separation deranges the body, losing relationships can cause physical illness. Growth hormone levels plunge in despair—the reason why chil-

BEHAVIOR	
Decreased	
Motor activity	Vocalization
Socialization	Food/Water intake
Play	**Demeanor**
Increased	Slouched posture
Self-huddling	Sad facial expression

PHYSIOLOGY	
Decreased	
Heart rate	O_2 Consumption
Body temp. & wt.	REM Sleep
Growth hormone	Cellular Immunity
Increased	
Sleep arousals	Irregular heartbeat

The behavior and physiology of the despair phase. (Adapted from Hofer, 1987.)

dren deprived of love stop growing, lose weight no matter what their caloric intake, and dwindle away. Children confined to a hospital for extended periods of time used to surrender to this syndrome in droves. René Spitz called their affliction "hospitalism," a term overtaken by the politely tautological phrase still employed, "failure to thrive." Once doctors appreciated the physical damage contained in social loss, they increased the survival of these children simply by allowing them more contact with their parents.

Children aren't the only ones whose bodies respond to the intricacies of loss: cardiovascular function, hormone levels, and immune processes are disturbed in adults subjected to prolonged separation. And so medical illness or death often follows the end of a marriage or the loss of a spouse. One study, for instance, found that social isolation tripled the death rate following a heart attack. Another found that going to group psychotherapy doubled the postsurgical lifespan of women with breast cancer. A third noted that leukemia patients with strong social supports had two-year survival rates more than twice that of those who lacked them. In his fascinating book *Love & Survival,* Dean Ornish surveyed the medical literature on the relationship between isolation and human mortality. His conclusion: dozens of studies demonstrate that solitary people have a vastly increased rate of premature death from all causes—they are three to five *times* likelier to die early than people with ties to a caring spouse, family, or community.

With results like these backing the medical efficacy of mammalian congregation, you might think that treatments like group therapy after breast cancer would now be standard. Guess again. Affiliation is not a drug or an operation, and that makes it nearly invisible to Western medicine. Our doctors are not uninformed; on the contrary, most have read these studies and grant them a grudging intellectual acceptance. But they don't *believe* in them; they can't bring themselves to base treatment decisions on a rumored phantom like attachment. The prevailing medical paradigm has no capacity to incorporate the concept that a relationship *is* a physiologic process, as real and as potent as any pill or surgical procedure.

The Hidden Persuaders

Science is an inherent contradiction—systematic wonder—applied to the natural world. In its mundane form, the methodical instinct prevails and the result, an orderly procession of papers, advances the perimeter of knowledge, step by laborious step. Great scientific minds partake of that daily discipline and can also suspend it, yielding to the sheer love of allowing the mental engine to spin free. And then Einstein imagines himself riding a light beam, Kekule formulates the structure of benzene in a dream, and Fleming's eye travels past the annoying mold on his glassware to the clear ring surrounding it—a lucid halo in a dish otherwise opaque with bacteria—and penicillin is born. Who knows how many scientific revolutions have been missed because their potential inaugurators disregarded the whimsical, the incidental, the inconvenient inside the laboratory?

In 1968, Myron Hofer (now professor of psychiatry and director of the Division of Developmental Psychobiology at Columbia University) was looking into the brain's control over heart rate when felicitous accident struck. He came to work one morning to find that a freedom-loving mother rat had chewed through her cage and escaped during the night. Hofer happened to notice that her abandoned litter of pups showed heart rates less than half normal. He surmised that the pups' cardiac cells had cooled without a mother's warmth, and decided to run a test on his idle hypothesis. He provided lone baby rats with a heat source that mimicked a maternal presence. To his surprise, the hearts in the pups beat just as slowly before warming as after. Somehow, a mother rat possesses an organic thermoregulatory power that disembodied heat does not.

Intrigued by this mysterious maternal force, Hofer set about divining the arcane physiology of orphaned rat pups. In experiment after experiment, he replaced the missing mother with single frag-

ments of her sensory qualities. A piece of cloth with her scent on it, a lamp that radiated heat at her body temperature, strokes on a pup's back with a brush, simulating her grooming—Hofer used them as deliberately partial substitutes for a mother rat.

Hofer found that restoring a *single* maternal attribute could prevent just *one* physiologic aspect of despair, without affecting any of the others. A mother's body warmth and olfactory cues direct her infant's activity level, while her tactile stimulation determines her pup's growth hormone level. Milk delivery to a pup's stomach fixes its heart rate, while the periodicity of feeding modulates sleep-wake states.

Hofer realized not only that the tie linking a mother rat to her baby is vital and corporeal, but also that the bond itself is woven from separate strands, each a distinct regulatory pathway in the body. A mother continuously adjusts her infant's physiology. One can interrupt a single thread of her influence and disrupt the corresponding physiologic parameter in her baby. When the mother is

INFANT SYSTEM		Decreased by	Increased by
Behavioral	Activity level	body warmth	tactile, olfactory cues
Sucking	Nutritive	nutrient (distention) tactile (perioral)	signal unknown
Neurochemical	Norepinephrine/ Dopamine levels	tactile & olfactory	body warmth
	ODC levels	sensorimotor	tactile
	Opiate levels		sensorimotor
Metabolic	O_2 consumption	signal unknown	sugar content of milk
Sleep	REM		milk periodicity; tactile
	Arousals	milk periodicity; tactile	
Cardiovascular	Heart rate		milk
	Vasoconstriction	milk	
Endocrine	Growth hormone		tactile, body warmth
	Corticosterone	tactile, milk	
Immune	B-cell and T-cell response	signal unknown	signal unknown
Circadian	Phase set		milk, body warmth
	Period length	melatonin?	melatonin?

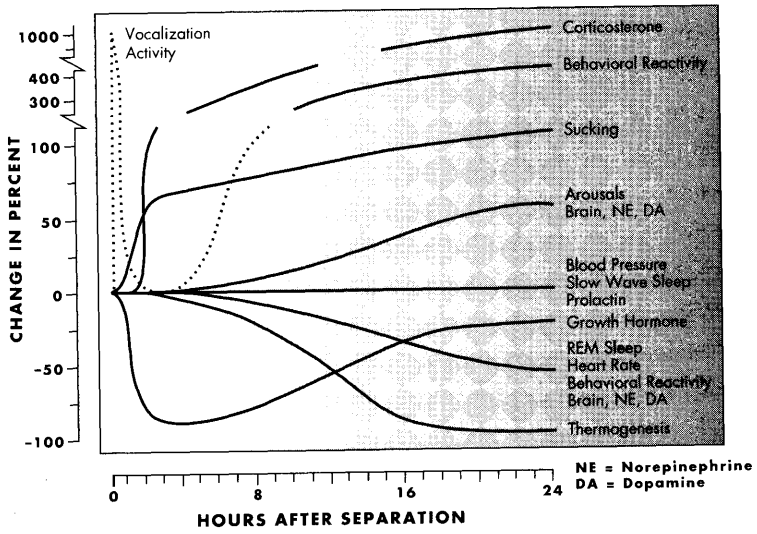
MATERNAL REGULATOR

Hidden regulators in a rat relationship. (Adapted from Hofer, 1987.)

absent, an infant loses all his organizing channels at once. Like a marionette with its strings cut, his physiology collapses into the huddled heap of despair.

The figure below demonstrates the disharmony that motherlessness unleashes in the bodily rhythms of a baby rat.

Once separated from their attachment figures, mammals spiral down into a somatic disarray that can be measured from the outside and painfully felt on the inside. The rate of disintegration differs—infants are most dependent upon external support, and without it they lapse quickly. The stability of older children decays more slowly, and that of many adults, slower still. Whatever the age, the eventual slide is inevitable; the physiology of social mammals is unstable at any speed. Hofer's delineation of this frailty opened the door to a novel view of human relatedness.



Physiologic chaos unleashed by separation. (From *Attachment Theory: Social, Developmental, and Clinical Perspectives,* edited by S. Goldberg, R. Muir, and J. Kerr, 1995. Reprinted with permission of the Analytic Press.)

The Open Circle

Most people assume that the body they inhabit is *self*-regulating—that their own physiologic balance occurs within a *closed loop.* Cruise control is the classic example of a closed loop, with a car's self-contained system checking its speed and adjusting its own throttle accordingly. An auto under manual operation, on the other hand, is one half of an *open-loop* duo—here the car rolls on; an utterly external agent takes in the speed of the rushing landscape and, with his feet pushing pedals, instigates throttle changes; the car's velocity rises and falls. A car minus cruise control is no master of its fate; alone, it cannot maintain any desired speed above zero.

Is the human body an open- or closed-loop affair? Do we possess internal cruise control analogues that monitor and modify our physiologic oscillations, or is someone else in the somatic driver's seat? Both, to an extent. Some of our somatic systems are closed, self-regulating loops. Others are not. Consider, for instance, that women who spend time together frequently find their menstrual cycles coming into spontaneous alignment. This harmonious, hormonal communion demonstrates a bodily connection that is limbic in nature, because close friends achieve synchrony more readily than those who merely room together.

A number of scientists now believe that somatic concordances like these are not just normal but necessary for mammals. The mammalian nervous system depends for its neurophysiologic stability on a system of interactive coordination, wherein steadiness comes from synchronization with nearby attachment figures. Protest is the alarm that follows a breach in these life-sustaining adjustments. If the interruption continues, physiologic rhythms decline into the painful unruliness of despair. Evolution has given mammals a shimmering conduit, and they use it to tinker with one another's physiology, to adjust and fortify one another's fragile neural rhythms in the collaborative dance of love.

We call this mutually synchronizing exchange *limbic regulation.* The human body constantly fine-tunes many thousands of physiologic parameters—heart rate and blood pressure, body temperature, immune function, oxygen saturation, levels of sugars, hormones, salts, ions, metabolites. In a closed-loop design, each body would self-monitor levels and self-administer correctives, keeping its solitary system in continuous harmonious balance.

But because human physiology is (at least in part) an open-loop arrangement, an individual does not direct all of his own functions. A second person transmits regulatory information that can alter hormone levels, cardiovascular function, sleep rhythms, immune function, and more—inside the body of the first. The reciprocal process occurs simultaneously: the first person regulates the physiology of the second, even as he himself is regulated. Neither is a functioning whole on his own; each has open loops that only somebody else can complete. Together they create a stable, properly balanced pair of organisms. And the two trade their complementary data through the open channel their limbic connection provides.

A baby's physiology is maximally open-loop: without limbic regulation, his vital rhythms collapse, and he will die—as Frederick II and René Spitz both proved. In current parlance, babies outsource most physiologic governance to parents and gradually bring those duties back in-house over months to years. Their early exposure to the external order that parents provide teaches babies how to manage some physiologic rhythms on their own. Two studies, for instance, compared premature infants who slept with a standard teddy bear to those supplied with a "breathing" bear—an ordinary stuffed animal connected to a ventilator and set to inflate and deflate at a rhythmic fraction of the baby's own respiratory rate. The infants with the breathing bear later showed more quiet sleep and more regular respiration than those who slept with a static Winnie-the-Pooh. Regular sighs taught the preemies respira-

tory stability, with modern technology providing the means to an ancient source of inspiration.

As the nervous system matures, a baby reclaims some regulatory processes and performs them autonomously. Even after a peak parenting experience, children never transition to a fully self-tuning physiology. Adults remain social animals: they continue to require a source of stabilization outside themselves. That open-loop design means that in some important ways, people cannot be stable on their own—not should or shouldn't be, but *can't* be. This prospect is disconcerting to many, especially in a society that prizes individuality as ours does. Total self-sufficiency turns out to be a daydream whose bubble is burst by the sharp edge of the limbic brain. Stability means finding people who regulate you well and staying near them.

Taking a rhesus monkey away from his mother too soon or subjecting him to lengthy maternal absences will produce a monkey with a lifelong vulnerability to despair. Limbic regulation explains why: with less internalized capacity for self-supervision, such a mammal slips precipitously into physiologic chaos whenever his extrinsic source of stability moves out of range. Human children of erratic mothers are clingy for the same reason. Because they haven't been able to absorb sufficient closed-loop control over their physiology, they need to stay near an external regulator to remain in balance.

This necessary intermingling of physiologies makes relatedness and communal living the center of human life. We recognize instinctively that healthy humans are not loners. Of his famous retreat to Walden Pond, Thoreau wrote, "I went to the woods because I wished to live deliberately, to front only the essential facts of life," but he did not front them alone. His nearest neighbor was but a mile distant, and Concord two miles; Thoreau depended on both liberally, and dined frequently with friends. In

children's stories and in life, disease creates hermits and cabin-dwelling Kaczynskis. Limbic regulation makes expulsion from the company of others the cruelest punishment human beings can devise. When his friend Friar Laurence tells Romeo that his death sentence has been commuted to interminable exile, Romeo's heart prepares to break:

And say'st thou yet that exile is not death?
Hadst thou no poison mix'd, no sharp-ground knife,
No sudden mean of death, though ne'er so mean,
But "banished" to kill me? "Banished"?
O friar, the damned use that word in hell;
Howlings attend it: how hast thou the heart,
Being a divine, a ghostly confessor,
A sin-absolver, and my friend profess'd,
To mangle me with that word "banished"?

THE OUTSIDERS

Limbic regulation mandates interdependence for social mammals of all ages. But young mammals are in special need of its guidance: their neural systems are not only immature but also growing and changing. One of the physiologic processes that limbic regulation directs, in other words, is the development of the brain itself—and that means attachment determines the ultimate nature of a child's mind. The importance of limbic contact for normal brain development shows itself most starkly in the devastating consequences of its omission.

Feed and clothe a human infant but deprive him of emotional contact and he will die. But infant monkeys are hardier than humans in the face of such privation. Monkeys reared without their mothers often survive, but their neural systems are permanently maimed.

Gary Kraemer, professor and chair of the Department of Kinesiology at the University of Wisconsin, and a leading researcher on the neurobiology of social deprivation, has described and investigated the effects of what is termed the *isolation syndrome.* Monkeys raised alone cannot engage in reciprocal interactions with normal monkeys, who consistently reject them. They are unable to mate. If solo-reared females undergo artificial impregnation, they show a striking lack of mammalian attitudes toward their infants: indifference and neglect alternate with savage attacks. Isolates are unpredictably vicious to adults as well. Ordinary monkeys usually break off a conflict when dominance has been settled, but those reared in isolation often fight to the death and beyond, rending and dismembering opponents. Self-mutilation is another of solitude's legacies: these monkeys bite their own arms, bang their heads against the wall, and gouge out their eyes. Social environment even fixes the normal formation of such behavioral basics as eating and drinking: isolates typically engage in prolonged food and water binges.

An isolated monkey becomes a grotesque caricature because the mammalian nervous system cannot self-assemble. Many subsystems of the mammalian brain do not come preprogrammed; maturing mammals need limbic regulation to give coherence to neurodevelopment. Without this external guidance, neural cacophony ensues: behavioral systems are constructed, but without proper harmony between the interdigitating parts. Like the isolates described above, mammals that grow up in the absence of central coordination are jagged and incomplete. Their brains produce fractured behaviors that emerge at the wrong times, in the wrong places, in the wrong ways. They have aggression, for instance, but not the modulated, momentary fierceness that serves to challenge or defend a place in the pecking order. Instead they show wild swings of unpredictable violence incompatible with membership

in a social group. A monkey cannot even grow up knowing how to eat or drink in a balanced way unless his mother was at his side during childhood.

Love, and the lack of it, change the young brain forever. The nervous system was once thought to unfold into maturity in accordance with the instructions in its DNA, much as a person alone in a room might, with a set of directions and a flurry of creases, produce an origami swan. But as we now know, most of the nervous system (including the limbic brain) needs exposure to crucial experiences to drive its healthy growth. In work that netted the 1981 Nobel Prize for medicine, David Hubel and Torsten Wiesel showed that kittens raised with one eye covered grew up to be cats with marked aberrancies in the brain areas serving vision. The same holds true for the neural systems that direct limbic resonance and regulation: relevant experience is a necessary part of the process that leads to the brain's final structure. The lack of an attuned mother is a nonevent for a reptile and a shattering injury to the complex and fragile limbic brain of a mammal.

Raising a monkey in seclusion provides direct data on the neural effects of *total* social deprivation. Human infants almost never survive such drastic conditions. To evaluate the impact of subtler bonding derangements, a group of researchers devised an ingenious way to make healthy monkeys into poor mothers. They place monkey mother and infant in an environment where food is not always readily available. Sometimes the mother has easy access to nutrients; at other times she must search diligently to find enough to feed herself and her baby. The unpredictability of that circumstance preys on the mother's mind and erodes her parental attentiveness.

Such distracted, apprehensive mothering endows juvenile monkeys with emotional vulnerabilities and altered neurochemistries. The monkeys so raised show magnified despair and anxiety reactions, and their brains reveal changes in the neurotransmitter sys-

tems that control these emotional states. Unlike the sweeping harm that isolation rearing unleashes, these defects are focal and faint enough that a mother's presence can mask them: at her side, the impaired young monkey seems normal. But separate the two and his apparent stability evaporates—a condition called *pseudoindependence.*

Full-grown, these monkeys are living proof of limbic regulation's enduring power: they are timid, clingy, subordinate, and clumsy in their efforts to establish ties to other monkeys. The brains of these animals evidence permanent alterations in neurochemistry. Just because their mothers once lived under a pall of uncertainty, these adult animals show lifelong changes in levels of neurotransmitters like serotonin and dopamine. With their vulnerability to anxiety and depression, their social awkwardness and failures to attach as adults, these monkeys exhibit a close animal counterpart to the multifaceted misery that in human beings is labeled neurotic.

Despite the centrality of limbic regulation, not all mammals live to link and link to live. Giant pandas spend their lumbering and bamboo-munching days alone, and come together only for the essential sexual union that preserves their species. Even the order of the great apes has a member that is at best semisocial: the orangutan, whose male members find one another so intolerable they cannot manage a peaceful assembly. Only a mother orang and her offspring can stand each other for any appreciable period of time.

How are we to make sense of these apparently casual desertions of the organizing principle of mammalian life? The meandering path of evolution supplies an answer. When necessity hatches a breed of organisms with a novel skill, some of them may, in time, find it advantageous to abandon their hard-won heritage and resume their former lives. Thus the world contains reptiles that have returned to the same sea from which their fishy forebears labored to escape, and birds that relinquished the skies so long ago their

wings have shrunk to aeronautically useless flaps. Among this group of backward creatures are the asocial mammals: furry, milk-bearing beings whose ancestors huddled together as families, and who have slipped back into a solitary way of life older still.

BUILDING BLOCKS OF LOVE

When people have trouble with their emotions—a bout of anxiety or depression, say, or seasonal gloominess—they often want science to pinpoint an offending neurotransmitter in the way that a witness picks the perp out of a lineup. Is it excessive norepinephrine, too little dopamine, errant estrogen? The answer is apt to dissatisfy: no single suspect can be fingered with confidence because the question itself attributes a fallacious simplicity to the brain.

When trying to fathom an immense, intricate system, drawing direct arrows of causality between micro- and macrocomponents is perilous. Which stock caused the crash of '29? Which person triggered the outbreak of World War I? Which word of Poe's "The Raven" suffuses it with an atmosphere of brooding melancholy? Neuroscientists understand the immediate chemical effect of a handful of medications, but connecting the dots of those minute molecules to sketch human actions, thoughts, feelings, and traits means tracing a baffling, blossoming tangle of biochemical events. The brain's dense thicket of interrelationships, like those of history or art, does not yield to the reductivist's bright blade.

Statements reading "Chemical A causes Human Trait B" have no meaning, despite their popular appeal. The brain is no simple machine, with a lever here releasing joy and a pulley there prompting panic. We can nonetheless wring valuable information about relatedness from neurochemistry. Neurotransmitters are not created equal, and some are far more important than others in directing limbic

functions, including love. Ongoing investigations have implicated three crucial chemical players: serotonin, opiates, and oxytocin.

The Notorious Transmitter

Medical science chanced upon antidepressants in the 1950s, and for thirty years most physicians were too frightened to prescribe them in sufficient quantities to permit their efficacy. The reason was simple: conventional antidepressants were among the easiest drugs one could use to kill oneself. In many cases, a meager week's worth of medication was lethal enough to effect a suicide. In 1988, when Eli Lilly introduced an antidepressant that didn't kill people even when taken in bulk, relieved physicians began prescribing it like crazy. Within months, Lilly's medication became the most widely prescribed antidepressant in the world—the infamous Prozac, the drug that made *serotonin* a household word.

Originally conceived as a treatment for depression, Prozac and the other serotonin agents soon proved to be multifunctional molecules with a host of unforeseen and beneficial uses. As tens of millions of patients tried these medications, the adventitious effects piled up. Anxiety, hostility, stage fright, PMS, road rage, bulimia, low self-confidence, premature ejaculation—and the proclivity of restless dogs to lick the hair off their forelimbs—all are potentially remediable through some judicious tinkering with a few of the brain's many serotonin circuits. A lesser-known property of the serotonin agents is that they sometimes attenuate the pain of loss. It doesn't happen to everyone, but a select group derives benefit from serotonin agents because they weaken the heartache that comes from losing someone.

One person we know, for instance, was trapped in a dismal relationship simply because she could not get around the pain of loss. No matter how much unhappiness her mate caused her, at every attempt to break with him a taller wave of wretchedness welled up inside her. And so her inner scales regularly tipped in favor of staying with a man who could not satisfy her. "I want to stop *so badly* with him," she said. "Our relationship goes on and on, and I keep thinking, 'This time, it's over,' but it's never going to be. I feel like moving across the country just to get away from him because it's been going on for so long—I'm fighting with myself constantly over it. I tell myself, 'Just go away, don't ever contact him again,' and I can't. I *can't*." Years of therapy clarified her misery but did not diminish it. But when she took a serotonin agent, the balance of her sorrows shifted slightly. Loss hurt a little less. She did then what she had been unable to do: leave her lover without intolerable suffering.

The freedom to leave a relationship is a bequest, not a birthright. As the burgeoning research on primate attachments tells us, early nurturance can stretch forward in time to insulate adults from the destabilizing pangs that solitude brings. As a society, if we do not attend to the limbic needs of our own young, we risk creating an epidemic of loss vulnerability. Serotonin agents will then become not just a remedy to retrieve those few teetering on the brink of desolation's abyss, but a way of life for a culture that has settled on the lip of the precipice itself.

The Religion of the Masses

The juices of the flowering plant *Papaver somniferum* possess an exceptional quality: they alleviate pain. Scrape and dry the poppy's exudations and the result is opium—a mixture of homologous compounds from the opiate dynasty, an extended chemical family that includes such notables as morphine, heroin, and laudanum. *Papaver*'s extract eliminates pain because the selfsame opiates are vital components of the brain's own analgesic system. Prompt deliverance from physical torment was miraculous to the first physicians who dispensed it. Thomas Sydenham said in 1680: "Among the remedies which it has pleased Almighty God to give to man to

relieve his sufferings, none is so universal and so efficacious as opium."

Sydenham was telling only half the story. Opiates not only extinguish the pain that comes from physical wounds but they also erase the emotional excruciation arising from the severing of a relationship. The limbic brain has more opiate receptors than any other brain area, perhaps for this purpose. Separation studies attest to the brisk effectiveness of opiates as anesthetics of loss: if a dam is taken away from her puppies, their distress erupts. Give them a tiny dose of opiate (too small to be sedating), and the pups' protest vanishes.

Poets and other disreputable types have known about this power for thousands of years. The fourth book of Homer's *Odyssey* contains this medically accurate description of a dinner party where the conversation has taken a sorrowful turn to talk of lost comrades:

A twinging ache of grief rose up in everyone . . .
But now it entered Helen's mind
to drop into the wine that they were drinking
an anodyne, mild magic of forgetfulness.
Whoever drank this mixture in the wine bowl
would be incapable of tears that day—
though he should lose mother and father both,
or see, with his own eyes, a son or brother
mauled by weapons of bronze at his own gate.

The amelioration of mourning fell to the opiates through the happenstance of biological history. Bodily damage risks death—a stark fact that drove the evolutionary development of a neural system that senses injury. The business end of that brain function is *hurt*—a potent incentive for animals to get out of harm's way. But inside the body's endless opposing rhythms, every physiological

tendency exists alongside its polar opposite. And so the brain contains not only neurotransmitters that produce pain but also those that assuage: the opiates. By the time the limbic brain arose, and mammals came to depend on mutual regulation for survival, a refined mechanism was already in place to manage the mental aftereffects of physical trauma. Evolution then recruited parts of that system to process the emotional pain of loss.

While a neocortical brain post-Descartes can wax eloquent on the division between mind and body, the other brains draw no such distinction. Damage to one's arm or to one's neurophysiology are equally real and, to a mammal, the latter may be more crippling. What matters most to Pain Central is not the philosophical category a slight belongs to but the level of jeopardy it threatens. Given the open-loop physiology of mammals and their dependence on limbic regulation, attachment interruptions are dangerous. They ought to be highly aversive. And so they are: like a shattered knee or a scratched cornea, relationship ruptures deliver agony. Most people say that no pain is greater than losing someone they love.

The intertwining of loss with the opiates permits the brain to be hot-wired in circumstances of dire need. Psychiatrists often see people who deliberately injure themselves in minor but stinging ways—like making shallow razor cuts to the forearm or cigarette burns to the thigh. These individuals have garnered a multiplicity of polysyllabic labels over the years, and their self-destructive bent has been ascribed to various convoluted motives: a desire for attention, an attempt to manipulate, a turning of anger against the self.

Most of them have one thing in common: an exquisite, lifelong sensitivity to separation's pain. The miniature losses contained in a rebuke, a spat, and other transient relationship rifts can arouse in them an unbearable blend of despondency and grief. Then follows an episode of self-harm—a prick, a burn, an incision into the skin. Beneath and within the abused epidermis, palpitating pain fibers

send their drumbeat signal to the brain, warning of damage. These messages release pain's counterweight: the blessed, calming flow of opiates, and thus, surcease of sorrow. Chronic self-mutilators provoke the lesser pain to trick their nervous systems into numbing the unendurable one.

Less drastic routes abound: warm human contact also generates internal opiate release. Our lovers, spouses, children, parents, and friends are our daily anodynes, delivering the magic of forgetfulness from the twinging ache of mammalian loneliness. Potent magic indeed.

A Prairie Dog's Life

The third neurotransmitter directing attachment coordinates physiologic events around childbirth—it stimulates uterine contractions and milk ejection—but until recently no one suspected its striking emotional power.

The passionate properties of *oxytocin* have been elucidated inside the brain of an unlikely candidate for scientific fame: the prairie dog. Thomas Insel, psychiatric researcher and the director of the Center for Behavioral Neuroscience at Emory University, has studied two species of prairie dogs (known also as *voles*). Prairie voles (*Microtus ochrogaster*) affiliate: adults are monogamous, both parents nurture their young, and husband and wife spend most of their time sitting side by side. Mountain-dwelling montane voles (*Microtus montanus*) are not nearly so social: mating patterns among these more casually attached rodents tend toward the promiscuous, and parents engage in much less caretaking of the young than do their flatland cousins. Paternal montane voles frequently ignore their offspring, and mothers often abandon their young ones two weeks postpartum.

Insel compared the brains of the two species and noticed they differ in the activity of just one neurotransmitter system—

oxytocin. The limbic brains of the affiliative prairie voles are loaded with oxytocin receptors, while the more aloof montane voles have far fewer. Oxytocin activity rises in the montane vole only around the time of birthing pups, when affiliation is a necessity. After rearing is done for the montane vole, oxytocin falls again, and so does bonding. Mother and her young then go their own ways.

The love lives of prairie dogs implicate oxytocin in forging the bonds of relatedness. Oxytocin levels surge in human mothers around birth—to stimulate labor and nursing, it was thought, but science sees those hormone levels in a new light. Experts have debated for decades about whether mothers and infants form a bond in the hours after parturition, and about the wisdom of separating the two at this time, as was the custom in Western in-hospital childbirth. High oxytocin levels around birth point to a crucial relationship event. They tell us that a mother and her child are meant to be together postpartum, when their neurochemistries are busy weaving the ties between them.

Oxytocin also gushes at puberty, when teenage crushes first bloom. It may seem strange that a simple molecule could initiate infatuation's sweet adolescent spell, but everything that happens in the brain begins with neurochemistry—including the wonder of puppy love, whose complex secret resides within the limbic brains of prairie dogs as surely as it does within ours.

THE BREADTH OF THE BOND

Human beings can decipher some of the limbic manifestations of other mammals, and vice versa. Some emotional communications are species specific: when a cat blinks her almond eyes and looks away, this signal, seemingly so rich to other felines within range, rests safely beyond human ken. But despite the variety of emotional expressiveness among mammals, they partake of a common

neural infrastructure. A consequence of this shared limbic inheritance is often taken for granted: different species can attach to one another.

On the average Sunday here in Marin County, ample evidence awaits in front of the nearest grocery store, where one or two golden retrievers will often be tied outside while their owners shop. Most of the time, the dogs are standing up, peering through the glass door, trying to catch a glimpse of the one person inside who means something. From time to time, someone will come by, in or out, and pat a dog on the head. The dog accepts this affection, if a little impatiently. But as his owner heads out the door, he trembles and leaps with unmistakable eagerness. Separation, vigilant scanning, indifference to those outside the bond, reunion, and joy have taken place in a ten-minute span in front of the local market, and all between two species separated in evolutionary time by tens of millions of years.

Somehow the attachment architecture is general enough that a human being and a dog can both fit within the realm of what each considers a valid partner. And the two can engage in limbic regulation: they spend time near each other and miss each other; they will read some of each other's emotional cues; each will find the presence of the other soothing and comforting; each will tune and regulate the physiology of the other. Limbic regulation is life-sustaining. This is why pets can make people not only feel better but also live longer. Several studies have shown dog-owning cardiac patients die at one quarter to one sixth the rate of those who forgo canine companionship.

More than twenty-five years ago, Lewis Thomas wrote, "Although we are by all odds the most social of all social animals—more interdependent, more attached to each other, more inseparable in our behaviors than bees—we do not often feel our conjoined intelligence." The science of our day is allowing us to understand what

interdependence is for, to know the intended outcome of the inseparability, to divine the nature of our conjoined state.

We are attached to keep our brains on track, in a process that begins before birth and sustains life until its end. The earliest portion of that duet must catch our attention: attachment changes a young mammal forever, as limbic regulation carves enduring patterns of knowledge into the developing circuits of the mind. To understand how attachment sculpts a person, we need to apprehend *memory*—the process whereby the brain undergoes structural change from experience. Memory does not travel a straight line, and neither does the human heart.