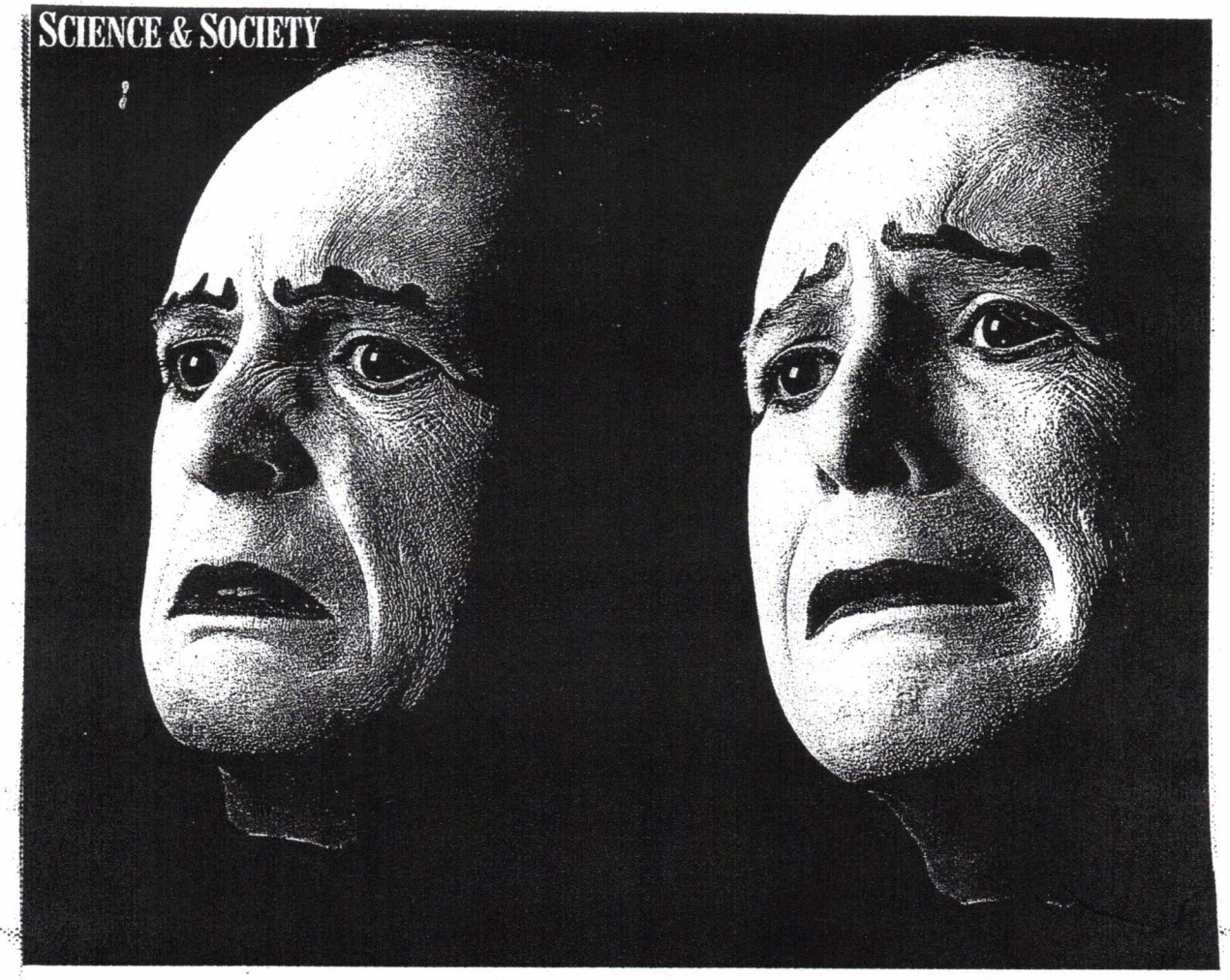


Where emotions come from

Joy and disgust. Sorrow and shame. Science is plumbing the passions that make us human

"We humans are full of unpredictable emotions that logic cannot solve."
—Capt. James Kirk, "Star Trek"

Pop singer Morris Albert crooned about them. Wives complained that their husbands wouldn't discuss them. And by the 1970s, an entire generation of Americans had learned to "get in touch" with their feelings. Scientists, however, were preoccupied with thinking, not emotion. Rational thought, after all, was the faculty deemed by the English philosopher Francis Bacon "the last creature of God." Leagues of researchers devoted their attention to how people solved problems, made decisions, formed opinions and learned skills. Fear and joy, anger and disgust were seen as peripheral, of interest mostly when they interfered with thought or became deviant or extreme, as in mental illness.

It was, in the words of psychologist Silvan Tomkins, an "overly imperialistic cognitive theory." Tomkins, who died last week at age 80, published two thick volumes in the early 1960s arguing that emotions were a crucial component of evolutionary design, even more important than basic drives such as hunger and sex. Anxiety, he pointed out, could drive a man from the bedroom. Fear could pre-empt appetite. Despair could lead to a fatal flirtation with a razor blade.

Tomkins was a lone voice, and he was almost entirely ignored by mainstream psychology. Yet there was a very small core of scientists who took his work seriously, and, building upon it, began to pioneer a new field of emotion research. Today, in disciplines ranging from psychology to neuroscience, from semiotics to genetics and anthropology, emotions have moved center stage. What was once a trickle of journal articles has become a publishing torrent. Researchers have developed methods for mapping the face and measuring emotional responses. They are studying the development of emotions in infants. Their work meshes with the efforts of biologists and neuroscientists who, using increasingly sophisticated technologies, were beginning to trace the "pathways" of emotion in the brain. Cognitive scientists, too, are talking about "hot" cognition, realizing that emotions and moods influence memory, judgment and learning.

It is not that there are, as yet, any solid answers. Even the most elemental question posed by turn-of-the-century psychologist William James—"What is an emotion?"—remains controversial. But researchers are beginning to untangle the first threads of an enormously complex tapestry, finding clues not only to normal emotions but also to how feelings go awry, fear turning to phobia, sadness to debilitating depression.

In the process, they are rejecting the notion of man as simply a "thinking machine," seeing human beings instead as biological organisms whose survival depends upon constant interaction with the environment. In this interplay, evolved over countless centuries and through dozens of steps on the evolutionary ladder, emotions have a critical role. Far from being "trivial," they contain, as one expert put it, "the wisdom of the ages"—warning us of danger, guiding us toward what is good and satisfying, signaling our intentions and our reactions to others. Emotions are the most familiar—and the most intimate—aspect of human experience, and they are gradually yielding their secrets.

Brain researchers, like other scientists, have spent much of the 20th century engrossed in the study of thinking and memory. But earlier investigators took some first steps toward tracing

PHOTOS BY JEFFREY MacMILLAN – USN&WR/MIME BY MARK JASTER

the biological underpinnings of emotion. In the late 1900s, for example, physiologists discovered that surgically removing a dog's cerebral cortex—the brain's thin outer layer of gray matter—did not prevent it from displaying primitive rage responses. By the late 1950s, researchers were identifying specific brain regions that seemed to play a central role in emotion. But only in the last few years have high-tech brain scanners, new methods of staining cells, powerful computers and other developments allowed scientists to begin systematically mapping the highways and traffic patterns of the emotional brain.

Neural pathways. While earlier investigators probed the emotional roles played by specific brain regions, scientists now put more emphasis upon the complex circuitry that interconnects them. Until recently, the limbic system, a loose network of brain structures beneath the cortex, was thought to do the majority of the work in coding "emotional" information and orchestrating the body's responses. But studies are now linking more and more areas of the brain—both in the cortex and in subcortical regions—to the complex mix of perceptions, sensations and judgments we call emotion.

At the same time, brain centers once viewed as intimately involved in emotions are now known to be more marginal. The sea horse-shaped hippocampus, for example, one of several limbic regions, appears more involved in memory and other cognitive tasks than in emotion, as previously believed. Much more critical, scientists are finding, is a tiny almond called the amygdala, buried deep in the temporal lobe (see diagram).

Indeed, the fingernail-size amygdala, which communicates with many other brain areas, is increasingly being viewed as a kind of "Emotion Central." As far back as 1937, studies showed that damage to the amygdala region produced changes in emotional behavior in monkeys: They became tame and oblivious to normally frightening situations, copulated with other monkeys of the same sex and ate nearly anything they were offered. Recent work has refined this understanding—showing, for example, that amygdala nerve cells fire selectively in response to emotionally laden stimuli, and that some of these neurons are more sensitive to unfamiliar stimuli.

Quick and dirty. According to New York University neuroscientist Joseph LeDoux, the amygdala may make the first, crude judgment of an event's emotional significance. Consider a man walking through a forest who hears what sounds like a rifle shot at close range. Scientists previously believed that sensory information traveled first to the cerebral cortex, where the sound was consciously perceived. The cortex then sent signals to subcortical areas of the brain like the amygdala, which evaluated the sound's emotional importance. These "lower" regions then sent return messages back up to the cortex and fired up the autonomic nervous system, producing the pounding heart, rapid breathing and rising blood pressure that are the familiar accompaniments of fear.

But LeDoux's research indicates that, at least for primitive emotions like fear, the brain is constructed to respond even more quickly to potentially threatening events. He and his colleagues have identified in animals an additional nerve pathway carrying impulses directly between the thalamus—an early processing station for sensory input—and the amygdala. Information sent along this "shortcut" reaches the amygdala two to three times faster than that sent

FALSE OR GENUINE?

Anatomy of a smile

Not all smiles are the same. Psychologist Paul Ekman describes 18 different types, including the miserable smile, the false "cocktail party" smile and the smile of relief, each marked by different movements of the facial muscles. Most striking is the disparity between the "social" smile and the smile of true enjoyment, called the "Duchenne smile" after French anatomist Duchenne de Boulogne, who first described it in 1862. Smiles of real joy draw in the *Orbicularis oculi* muscle around the eyes, as well as the *Zygomaticus major* cheek muscle (see below). But when people put on a phony expression of pleasure, they smile only with their cheeks, not their eyes. Ten-month-old infants, experts find, are more apt to display a Duchenne smile when their mother approaches, while the approach of strangers often elicits "false" smiles.

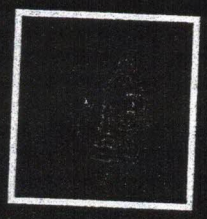
[illegible]
This muscle "does not obey the will," wrote Duchenne de Boulogne, but "is put in play only by the sweet emotions of the soul . . ."

[illegible]
Faked smiles exercise voluntary cheek muscles; eye muscles remain unsmiling.

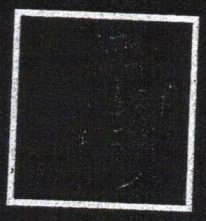
GRIMACE & GRIN

Faces of emotion

When people are anxious, cerebral blood flow – a measure of brain cell activity – increases in an area at the tips of the brain's temporal lobes just behind the eyes, according to brain-scanning studies by University of Arizona psychiatrist Eric Reiman.



Would you stir your coffee with a new comb? Eat a sterilized cockroach? Most Americans wouldn't, though both are perfectly safe. Psychologist Paul Rozin argues that the things we find disgusting often evoke primitive beliefs about contamination.



Moments of intense happiness are not necessarily the key to an overall sense of well-being, says psychologist Ed Diener. Long-term happiness, his studies suggest, depends more on the frequency than the vividness of happy experiences.

Darwin believed blushing was like the appendix, a fluke with no purpose. But Wake Forest University psychologist Mark Leary finds that turning red may serve to repair people's social image after they have appeared stupid or incompetent.

MODELS BY CENTRAL CASTING

up to the cortex first. Studies also demonstrate that even when the "longer" route through the cortex is destroyed, animals still are able to learn fear of sudden noises, or, in very recent work, flashing lights.

Such high-speed transmission, LeDoux contends, may allow the amygdala to make an almost instantaneous analysis of whether the sound is something to be afraid of, probably even before it is consciously heard or identified. This "quick and dirty" assessment, he speculates, is then elaborated and refined by the neocortex and other brain regions, allowing the hunter to conclude, for example, that the sound was the crack of a tree branch, not a rifle.

LeDoux's findings support the view that at least some emotional processes take place unconsciously, and that cognition and emotion – though they interact – are separate systems in the brain – both points that have been vigorously debated for decades. In addition, the studies imply that the brain is designed, quite sensibly from an evolutionary standpoint, to react more to some things – loudness, for instance, or abrupt movement – than to others.

No fear of mushrooms. The idea that human beings are "programmed" to be wary of particular events may help explain why some people develop irrational fears of spiders, snakes, heights or close spaces, but never of electrical outlets or daffodils. Northwestern University psychologist Susan Mineka and her coworkers have found that monkeys quickly acquire an exaggerated fear of snakes – even toy reptiles that don't move – when they watch videotapes of other monkeys reacting fearfully. But if the same monkeys watch concocted videos of monkey role models jumping in fright at mushrooms or flowers, they remain unswayed.

Twenty years ago, much was made of reports that the brain's left and right hemispheres seemed to "specialize" in different types of thinking, though media accounts of this "right brain/left brain" division were often greatly oversimplified. Now a growing body of work suggests that the two sides of the brain may play distinct emotional roles, perhaps because such a division of labor is more efficient. Neurologists have known for many years that stroke patients whose right hemispheres have been damaged have trouble both expressing emotion and perceiving the emotional signals of others. They will understand the statement, "I am angry," for example, but fail to detect the speaker's injured tone or the angry expression on his face.

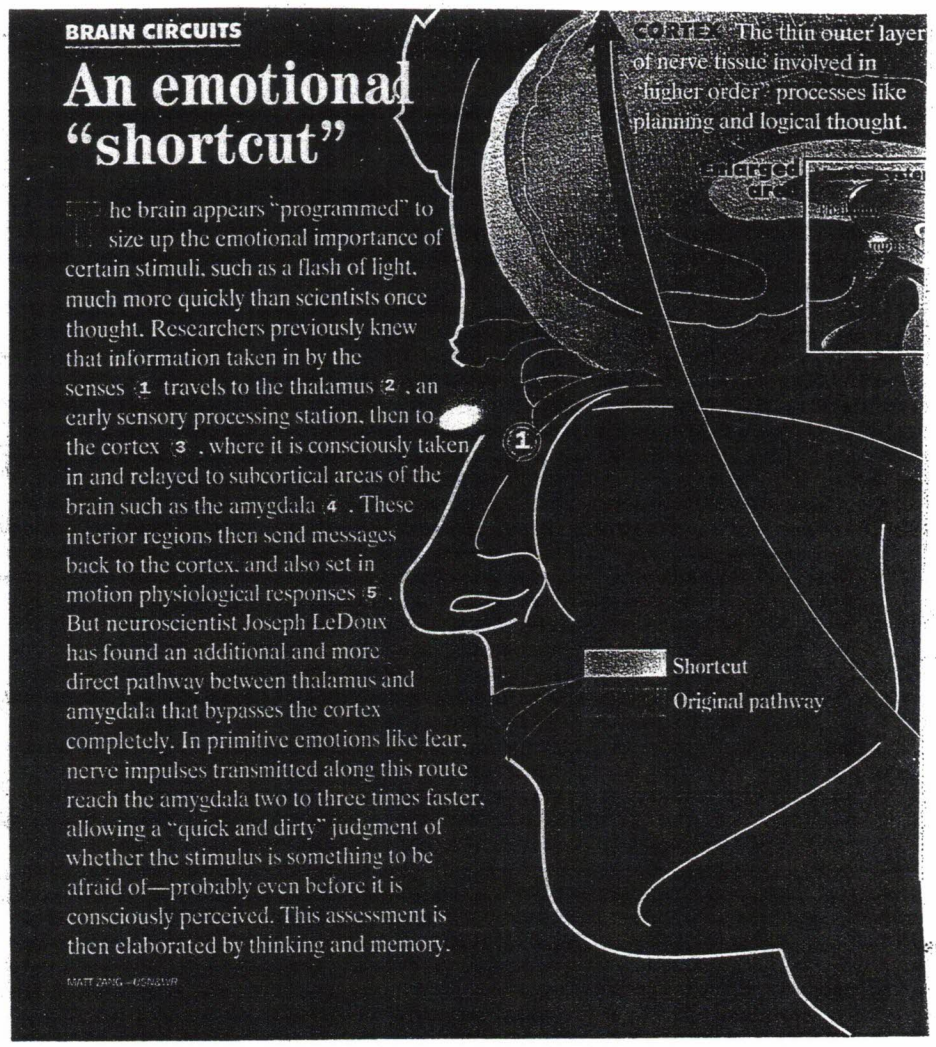
University of Florida neurologist Kenneth Heilman suggests that the right hemisphere may contain a kind of "lexicon" of emotion-laden images, which is impaired when the hemisphere is injured. In a series of studies, Heilman and his colleagues found that patients with right hemisphere damage had great difficulty imagining and describing a smiling face, though they could easily describe imagined objects such as pennies or horses. Yet such patients do retain some ability to grasp emotional concepts, the scientists have found, perhaps relying upon a combination of logical reasoning and past experience. Told that a man "drank the water and then saw the sign," for example, they can usually figure out that the man is anxious about what he just drank.

The brain's right and left hemispheres may divide negative and positive emotions as well. When subjects report feeling emotions such as fear and disgust, their right frontal lobes show increased electrical activity, according to studies by psychologists Richard Davidson at the University of Wisconsin

and Donald Tucker at the University of Oregon. Sadness seems to diminish activity in the left frontal lobe as measured by an electroencephalogram (EEG), while certain positive emotions like happiness and amusement increase it.

Right and left brain asymmetries may even prove to be a marker of differences in overall temperament. In a series of studies, Davidson and his colleagues have found that infants more prone to distress when separated from their mothers show increased activity in the right frontal lobe, as do people with a more pessimistic outlook. People who have at some point in their lives been clinically depressed show decreased left frontal lobe activity compared with subjects who have never been depressed.

Such emotional lopsidedness, Davidson suggests, may be adaptive in a broader, evolutionary sense. Positive emotions draw people toward things that are pleasant or satisfying, engaging them with the world; negative emotions encourage withdrawal from what may be threatening or dangerous. In the hostile environment in which early man evolved, it may have been useful to have approach and avoidance unmistakably delineated in the brain.



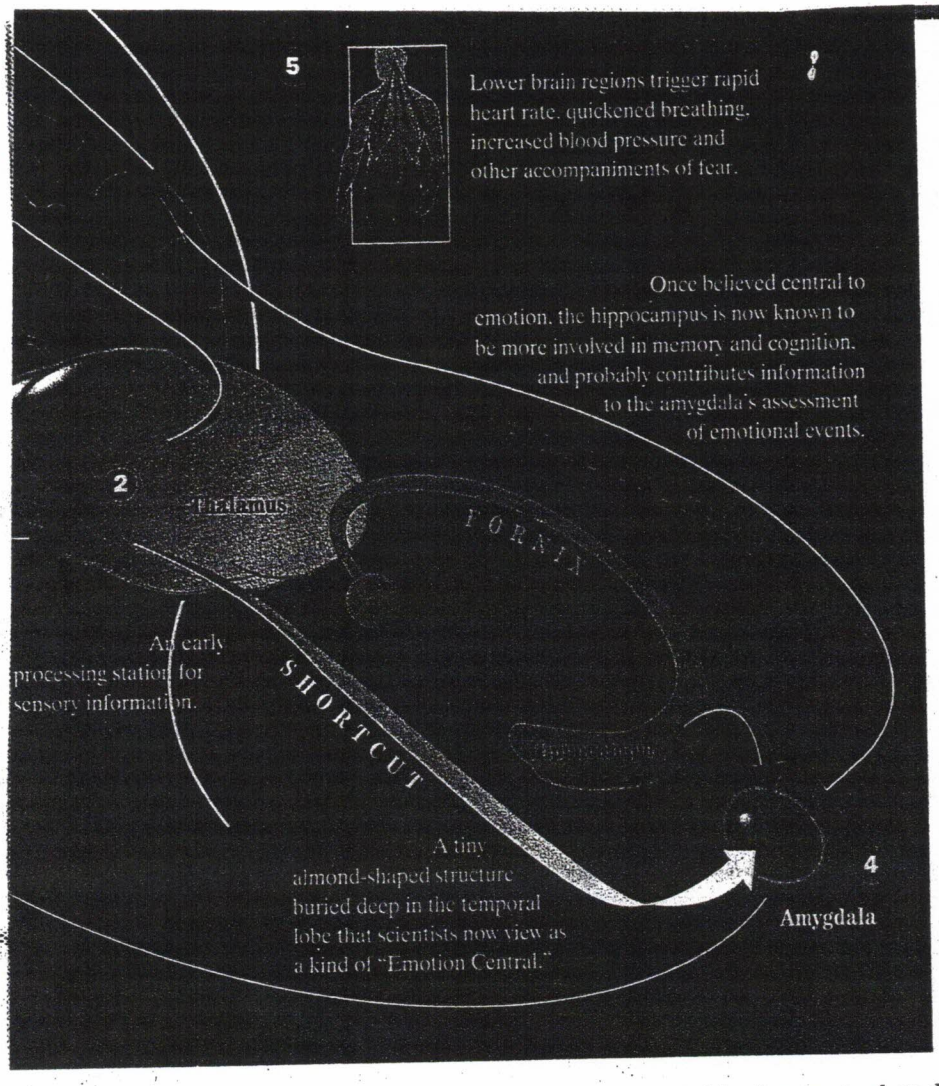
Your face, my thane, is a book where men may read strange matters," Lady Macbeth warns her husband in Shakespeare's great tragedy, knowing that a furrowed brow or curled lip can be a revealing barometer of emotional life. But it remained for psychologists, inspired by Silvan Tomkins, to develop systematic ways to measure and compare the precisely tuned movements of more than 30 facial muscles, and to link the language of sneers, smiles and grimaces to other aspects of emotion.

Their work has challenged long-held assumptions about facial expression. It was widely believed, for example, that the way emotions are expressed by the face was learned after birth and differed from culture to culture. But in cross-cultural studies over the past two decades, psychologists Paul Ekman at the University of California at San Francisco and Carroll Izard of the University of Delaware have demonstrated that facial representations of sadness, fear, anger, disgust and other emotions are remarkably constant and recognizable around the globe.

Darwin's delight. The social roles for displaying emotion *do* vary culturally. The Japanese, for example, are more likely to hold back negative expressions in public. Individuals, of course, also differ in the intensity of their emotional expressions, and to some extent in the events that trigger different emotions. But the researchers found familiar scowls and grins even in members of isolated cultures in New Guinea and Indonesia and in blind children, who cannot learn them by visual imitation.

Such findings would have pleased biologist Charles Darwin, who explored the universality of emotion in his 1872 book, "The Expression of Emotions in Man and Animals" (see box). The findings are equally sweet to modern investigators who believe that humans possess innate, genetically wired templates of emotional expression and recognition, refined versions of those seen in primates and other "lower order" species.

But how does the face, with its Esperanto of feeling, fit into the larger emotional system—the rising pulse and rapid breathing of a man who has just been called a "sniveling scum bucket," for example, or the intangible experiences we label grief and joy? In an intriguing series of studies, their results still being debated, Ekman and his colleagues Robert Levenson and Wallace Friesen have shown that instructing people to produce the muscular movements of a particular emotional expression—a grimace of disgust, for example—produces changes in autonomic nervous system response, such as heart rate and skin temperature, even though the subjects



from the other guests. Arriving at his own house, Mr. H. will stare blankly at the two children in the driveway. "Are those your children?" Etcoff will ask him. "I guess they must be," her patient replies. "They're in my yard."

Yet Mr. H., whose condition is called prosopagnosia, still retains some ability to discern emotions, lending support to the notion that facial recognition and emotional interpretation are separate in the brain. Shown a picture of a sad face, he cannot at first name the feeling he sees. But he *is* able to mimic the downcast expression and in some way, Etcoff believes, this re-creation of sadness on his own face "teaches" his brain, which then correctly labels the emotion in the picture. Still, such maneuvering makes any sojourn into the social world difficult. Says Etcoff: "People who can't recognize facial emotions feel like they can't read between the lines, and there's a tremendous awkwardness in relating to other people."

The snubbing of emotion in scientific theory was not confined to the study of adults. Child psychologists, too, were riveted by logical reasoning, as if infants and toddlers were, as one expert put it, "little computerized robots dealing with their environment." Even Swiss psychologist Jean Piaget—whose meticulous observations of his own children's intellectual growth serve as a primer for every student of child psychology—barely nodded at emotion, stressing instead the child's developing powers of thought and analysis. Feelings seemed irrelevant to infants, who could not even form goals or distinguish cause and effect.

In the last decade, the scientific work that has reshaped the understanding of emotion has transformed the field of child psychology as well. A rapidly expanding body of work now makes it clear not only that infants have emotions, but that they are crucial from the very first moments of life. Nonverbal expressions of enjoyment, anger and other sentiments have been detected in children younger than 8 months old, and even a 10-week-old baby can distinguish his mother's smile of joy from her scowl of

are not told which emotion they are displaying. The scientists also found that these physiological patterns are, to some extent, specific for different emotional expressions, particularly negative ones such as anger, fear and disgust. The research team recently reported that distinctive heart rate and skin temperature patterns are also produced when subjects are asked to relive the memory of a particular emotional experience.

The person who communicates his feelings is, of course, only half the equation. In a complex social world, we are readers of emotion, too. Using ever more sophisticated tools, researchers are beginning to find out how the brain detects and analyzes emotional signals. Working with monkeys, for example, neuroscientist Edmund Rolls and his colleagues at Oxford University have isolated a group of nerve cells, located in part of the brain's temporal lobe that processes visual information, that respond exclusively to faces and appear capable of recognizing individual faces as well. A second set of neurons, about 2 millimeters away, apparently helps determine which emotion a face displays. Together, Rolls says, the two sets of cells allow monkeys—and probably humans as well—to determine who and what they are dealing with in the environment.

Unfamiliar faces. Just how crucial these mechanisms are is evident in the extraordinary case of a 41-year-old brain-injured patient studied over several years by Massachusetts Institute of Technology neuroscientist Nancy Etcoff. Mr. H., who suffered damage to the temporal lobes of his brain in a car accident many years ago, has no trouble conversing. He holds a responsible job and can quickly distinguish a Mercedes from a Mazda. But he has entirely lost the ability to recognize faces—even those of the people closest to him. He asks his wife to wear a ribbon in her hair at parties, so he can tell her

anger. "By nine months, the infant is an emotional being," writes Alan Sroufe, at the University of Minnesota.

It is not just that the infant is joyful upon seeing his mother's face or fearful at a loud noise. University of California at Berkeley developmental psychologist Joseph Campos and others argue that emotions are powerful tools for becoming a human being. Through them, children signal their needs and wants and are spurred to satisfy them. Feelings help forge—or sever—bonds with other people. By closely observing the emotional reactions of others—a mother's welcoming look when a stranger approaches, for example—a child also learns to size up uncertain situations, a process Campos and his colleagues call "social referencing."

Language adds sophistication and subtlety both to the expression of emotion and to children's ability to influence the feelings of others. By the age of 20 months, most children possess an emotional vocabulary, voicing in words their distress, pleasure or fatigue: In one study, each of six children said, "I love you" to a parent before his or her second birthday. By 28 months, discussions of feelings take place in a wide variety of contexts, from squabbles with siblings to pretend tea parties given for imaginary guests. And during their third year, children begin to refer to past and future states of emotion, and probe the reasons behind feelings, asking, for example, why an older brother is crying.

Jokes and affection. Experts in child development once devoted their attention mostly to how children learned to "damp down" emotional extremes, controlling tantrums, for example. But in groundbreaking studies, Pennsylvania State University child development expert Judith Dunn has shown that children also actively use emotional expression to obtain comfort, give affection, learn social rules, make jokes, irritate siblings, form friendships and deepen intimacy in relationships.

According to new research by Dunn's group, how much time parents devote to discussing emotions with their children may influence sensitivity to the feelings of others later in life. Studies indicate, for example, an association between the frequency of mothers' exchanges about emotions with firstborn children and the friendly behavior of those children toward their infant brothers and sisters. Dunn and her colleagues have recently suggested that the frequency and content of family conversations about feelings may affect children's ability to recognize emotions in adults six years later.

Even at birth, investigators are finding, children vary in their emotional reactions to people and events, suggesting a hereditary contribution to temperament. Studies of children over a period

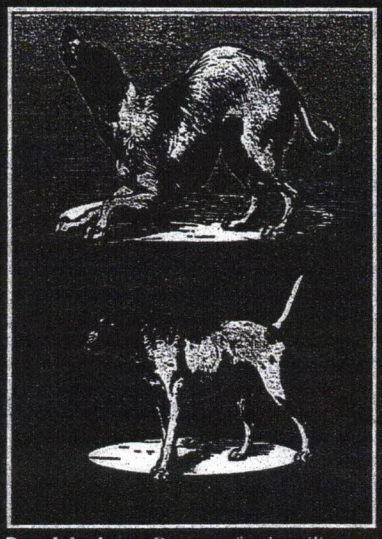
ANCIENT TRADITION

The philosophy of feeling, the biology of barks

The nature of emotion has bedeviled great thinkers ever since Cain slew Abel in a jealous rage. Plato and Aristotle argued over how sharply the "rational" and "irrational" parts of the "soul" were divided—a question that modern scientists, with a modern vocabulary, still quarrel about. Philosophers proposed master lists of "basic" emotions, only to have the next pundit in line revise them or object that there were no such things—an avocation still popular among emotion researchers.

Enlightenment theories of emotion tended to credit mysterious fluids for emotional life, regarding emotions as "provided by God to protect us," says Colby College philosopher Cheshire Calhoun, co-author of "What is an Emotion?" Descartes, for example, explained that the approach of a "strange and frightful figure" triggers the action of "animal spirits" that "proceed thence to take their places partly in the nerves ... and dispose the legs for flight."

In the 19th century, the notion of emotional "instincts" grew stronger. But William James, writing in 1890, contended that the experience of "feeling" followed the physiological sensations of emotion, rather than the other way around. "We feel sorry because we cry, angry because we strike, afraid because we tremble," James asserted.



Darwin's dogs. *Patterns for hostility (bottom) and humble affection (top)*

But the scientist who first tried to study emotional expression systematically was not a psychologist but a biologist. Charles Darwin, who delved into emotion to gather support for his broader theory of evolution, contended that emotions were universal and not unique to human beings. He described characteristic displays of fear, rage or joy in a variety of animals, including dogs, monkeys, swans and cats. A dog, Darwin pointed out, stiffens, its tail erect, the hairs on its neck bristling when it approaches a stranger. But upon recognizing its master, its demeanor instantly changes to one of affectionate submission.

Human beings required different tactics of study. Darwin sent out questionnaires to missionaries and ambassadors around the globe, asking if emotional expressions were the same in different cultures. Among his questions: "Is astonishment expressed by the eyes and mouth being opened wide, and by the eyebrows being raised?"

Thirty-six questionnaires were returned to the biologist, allowing him to argue his case in his now classic 1872 book, "The Expression of Emotions in Man and Animals." Today, emotion theorists remain split between those who emphasize the contribution of thinking to emotional experience, and those who stress biology. But Darwin's belief that emotions are innate, adaptive mechanisms for dealing with the environment is slowly gaining ground in a field that once scorned such notions.

DRAWINGS BY RIVIERE FROM "THE EXPRESSION OF EMOTIONS IN MAN AND ANIMALS" BY CHARLES DARWIN

of time by Harvard University psychologist Jerome Kagan show marked differences between those who are "inhibited"—by which Kagan means shy, quiet and socially withdrawn—and their more talkative, outgoing and sociable peers. Kagan has found that inhibited children have higher and more stable heart rates, react more to stress and may be more prone to depression and anxiety disorders later in life.

Primatologists are now finding that similar temperamental differences are present in monkeys studied in the wild, and may play a role in evolutionary adaptation. Male rhesus monkeys who are highly reactive emotionally, for example, display differences in heart rate similar to those of Kagan's socially inhibited children, according to research by Stephen Suomi and Kathlyn Rasmussen of the National Institute of Child Health and Human Development. These heart rate patterns appear to predict how male monkeys will react at puberty, when they typically emigrate from their own troop and join another. Unusually "shy" monkeys, the scientists found, tend to hang back, working their way into the new group slowly over months or years, while more aggressive monkeys tend to fight their way into the group instead. Both strategies, says Suomi, have pros and cons: "Outgoing individuals have the opportunity to get into the gene pool earlier, but they run a greater risk of getting killed. Shy ones, slower to integrate, are at greater risk for starving to death, but their chances of being killed in a fight are lower."

Sadly, cancer stole the seven more books that Silvan Tomkins hoped to write. But before his death, he completed the final two volumes of "Affect/Imagery/Consciousness," the treatise he began 30 years ago. The books, one just published and the other soon to follow, make their appearance in a vastly changed climate. Emotion research is now everywhere, its importance no longer argued before indifferent auditors. Scientists, finally, are joining the poets in granting the "passions" their rightful place as "the elements of life." ■

BY ERICA E. GOODE WITH JOANNIE M. SCHROF AND SARAH BURKE

HORMONE OF LOVE

The chemistry of romance and nurturance

The romantic notion that love is a matter of the right chemistry may not be far off the mark. Scientists are now finding links between behavior and the brain's many chemicals; and recent animal studies of one particular hormone, oxytocin, suggest the chemical promotes the social bondings involved in choosing a mate and reproducing. Scientists speculate that the hormone may do the same for humans, fostering friendship, love and nurturance.

Oxytocin is well known for its ability to hasten childbirth and promote lactation, but it is also present in areas of the brain linked to emotions and seems to influence how animals relate to one another. For example, when the hormone is given to two prairie voles, according to zoologist Sue Carter, they immediately form a monogamous bond. In the wild, the small mammals pair up only after sex, when oxytocin floods their systems. In sociable mice, adding oxytocin boosts the instinct for cuddling to a frenzied pitch.

The hormone not only seems to ensure that animals are attracted in the first place, it also appears to promote good parenting later on. Studies by Cort Pedersen and Jack Caldwell at the University of North Carolina and Gustav Jirikowski at Scripps Research Institute show that virgin female rats, normally nasty to babies, will respond to oxytocin by acting in a more motherly way. Parent rats will even mistreat their children if oxytocin is blocked.

In humans, oxytocin levels rise dramatically during sex, and scientists believe the chemical's presence may promote accompanying feelings of love or infatuation. Some researchers even suspect that oxytocin may play a part in most social behavior. "Human relations are influenced by the model of the parent-child relationship in that they include the notions of nurturing, care, help," says Pedersen. "The deficiency of a hormone tied to that parenting instinct may account for some of the anti-social behavior we think of as psychopathic."

Scientists emphasize that no hormone acts alone. Several dozen chemicals combine in intricate ways to influence emotions. "You will never find one specific hormone for one emotion," neurologist Marsel Mesulam notes. "Rather, it's the overall pattern that's important, just as in music it is the song that makes you feel happy or sad, not a particular instrument." Even so, scientists hope that understanding how oxytocin works may illuminate the most powerful of human emotions.

BY JOANNIE M. SCHROF