tive monster comes from my understanding of how emotion is organized in the brain. Although the brain organization of emotion is the subject of other chapters, I will summarize several key points that justify my belief that emotion and cognition are best thought of as separate but interacting mental functions mediated by separate but interacting brain systems.

- When a certain region of the brain is damaged, animals or humans lose the capacity to appraise the emotional significance of certain stimuli without any loss in the capacity to perceive the same stimuli as objects. The perceptual representation of an object and the evaluation of the significance of an object are separately processed by the brain.
- The emotional meaning of a stimulus can begin to be appraised by the brain before the perceptual systems have fully processed the stimulus. It is, indeed, possible for your brain to know that something is good or bad before it knows exactly what it is.
- The brain mechanisms through which memories of the emotional significance of stimuli are registered, stored, and retrieved are different from the mechanisms through which cognitive memories of the same stimuli are processed. Damage to the former mechanisms prevents a stimulus with a learned emotional meaning from eliciting emotional reactions in us, whereas damage to the latter mechanism interferes with our ability to remember where we saw the stimulus, why we were there, and who we were with at the time.
- The systems that perform emotional appraisals are directly connected with systems involved in the control of emotional responses. Once an appraisal is made by these systems, responses occur automatically. In contrast, systems involved in cognitive processing are not so tightly coupled with response control systems. The hallmark of cognitive processing is flexibility of responses on the basis of processing. Cognition gives us choices. In contrast, activation of appraisal mechanisms narrows the response options available to a few choices that evolution has had the wisdom to connect up with the particu-

lar appraisal mechanism. This linkage between appraisal process and response mechanisms constitutes the fundamental mechanism of specific emotions.

- The linkage of appraisal mechanisms with response control systems means that when the appraisal mechanism detects a significant event, the programming and often the execution of a set of appropriate responses will occur. The net result is that bodily sensations often accompany appraisals and when they do they are a part of the conscious experience of emotions. Because cognitive processing is not linked up with responses in this obligatory way, intense bodily sensations are less likely to occur in association with mere thoughts.

The conversion of emotions into thoughts has allowed emotion to be studied using the tools and conceptual foundations of cognitive science. There are now numerous computer simulations of appraisal and other emotional processes[61] and some proponents of this AI approach to emotion believe that emotions can be programmed in computers.[62] The following limerick spun by an AI researcher summarizes the beliefs and hopes of the field:

A computer so stolid and stern
Can simulate man to a turn.
Though it lacks flesh and bones
And erogenous zones,
It can teach—but, oh can man learn?[63]

Simulations do indeed have much to offer as an approach to modeling aspects of the mind. However, as the next limerick (though tasteless) reminds us, minds feel as well as think, and feelings involve more than thinking.

There was once an ardent young suitor
Who programmed a female computer,
But he failed to connect
The affective effect,
So there wasn't a thing he could do to 'er.[64]

And, finally, we are also reminded by a limerick that there may be [illegible] just can't do. This limerick needs to be

prefaced with a reminder that in the old days computers were fed information on cards with holes punched out of them that were read by special sensing devices, and that some aspects of computer memory were stored on endless spools of magnetic tape.

There was once a passionate dame
Who wanted some things made plain,
So she punched up the cards,
Filled tape by the yards,
*But—somehow—*it just wasn't the same![65]

Where Do We Go from Here?

I have tried to make a clear statement about what emotion is not. It is not merely a collection of thoughts about situations. It is not simply reasoning. It cannot be understood by just asking people what went on in their minds when they had an emotion.

Emotions are notoriously difficult to verbalize. They operate in some psychic and neural space that is not readily accessed from consciousness. Psychiatrists' and psychologists' offices are kept packed for this very reason. Yet, much of our understanding of the way the emotional mind works has been based on studies that have used verbal stimuli as the gateway to emotions or verbal reports to measure emotions.

Consciousness and its sidekick, natural language, are new kids on the evolutionary block—unconscious processing is the rule rather than the exception throughout evolution. And the coin of the evolutionarily old unconscious mental realm is nonverbal processing. Given that so much work on unconscious processing (cognitive and emotional) has focused on verbal processes, we probably have a highly inaccurate picture of the level of sophistication of unconscious processes in humans. And we will not likely begin to fully understand the workings of human unconscious processes until we turn away from the use of verbal stimuli and verbal reports.

It is a testament to human vanity and linguistic chauvinism that the ancestral functions of the brain are characterized as the negation of newly evolved ones. Animals were unconscious and nonverbal long before they were conscious and verbal. Fortunately, ancestral functions, like certain emotional processing functions, are preserved in the human brain, and we can turn to studies of animals to discover how these work in humans as well.

Obviously, we cannot explain everything about human emotions by studying animals. But, as I hope to show you, we have been able to come to a very good understanding of some basic emotional mechanisms that are common to humans and other animals. With this information in hand, we are in a much better position to understand how newly evolved functions, like language and consciousness, contribute to emotions, and particularly how language and consciousness interact with the underlying nonverbal and unconscious systems that make up the heart and soul of the emotional machine.

Darwin got his ideas by looking at life around him. He noted that children resemble their parents, but differ from them as well. And he was fascinated with the ability of breeders of domestic animals to build traits in offspring by carefully mixing and matching parents—cows could be made to produce more milk and horses to run faster by preselecting the parents. He reasoned that something similar might occur naturally. Armed with these observations, and others made on his famous voyage to the Galápagos Islands, Darwin proposed that, through heritability and variability, "descent with modification" occurs.

Stephen J. Gould tells us that Darwin did not use the term "evolution" to describe natural selection.[13] At the time, evolution had two other connotations, both of which were incompatible with Darwin's theory. One had to do with the notion that embryos grow from preformed homunculi enclosed in the egg and sperm (tiny preserved versions of Adam and Eve). The other was a vernacular usage that implied constant progress toward an ideal. Darwin felt that a so-called lower form of life, like an amoeba, could be as adapted to its environment as a human is to its—humans, in other words, are not necessarily closer to some evolutionary ideal than other animals. It was really Herbert Spencer, a contemporary of Darwin's, who transformed "descent with modification" into "evolution," the catchier term that we use today.[14]

In rough-and-ready terms, Darwin's theory of natural selection went something like this.[15] Those traits that were useful to the survival of a species in a particular environment became, over the long run, characteristic traits of the species. And, by the same token, the characteristic traits of current species exist because they contributed to the survival of distant ancestors. Because of limited food supplies, not all individuals that are born survive to the point of sexual maturity and procreate. The less fit get weeded out so that over time more and more of the better fit become parents and pass on their fitness to their offspring. But if the environment happens to change, and it does so constantly, then different traits become relevant to survival, and these eventually get selected for. Species that adapt in this way survive, whereas those that do not become extinct.

Darwin's theory is most often thought of as an explanation of how physical features of species evolved. However, he argued that mind and behavior are also shaped by natural selection. James Gould, a behavioral biologist, makes this point forcefully:

> Darwin's revolutionary insights into evolution . . . demonstrated for the first time the inextricable link between an animal's world and its behavior. His theory of natural selection made it possible to understand why animals are so well endowed with mysterious instincts—why a wasp, for example, gathers food she has never eaten to feed larvae she will never see. Natural selection, Darwin hypothesized, favors animals which leave the most offspring. Through countless generations the survivors of the unceasing struggle for a limited amount of food have to be ever more perfectly adapted to their worlds, both morphologically and behaviorally. . . . Carefully programmed behavior like that of the wasp must provide an enormous competitive advantage for animals.[16]

In *The Expression of the Emotions in Man and Animals*, Darwin proposed that "the chief expressive actions, exhibited by man and by the lower animals, are now innate or inherited,—that is, have not been learnt by the individual."[17] As evidence for emotional innateness, he noted the similarity of expressions both within and between species. In humans, Darwin was particularly impressed with the fact that the bodily expressions (especially of the face) occurring during emotions are similar in people around the world, regardless of racial origins or cultural heritage. He also pointed out that these same expressions are present in persons born blind, and thus lacking the opportunity to have learned the muscle movements from seeing them in others, and are also present in very young children, who also have had little opportunity to learn to express emotions by imitation.[18]

Darwin mustered instances of all sorts of bodily expressions that are similar in different species. Although the greatest similarities were found between closely related species, Darwin was able to identify some striking similarities, even within fairly dissimilar organisms. He pointed out how common it is for animals of all varieties, including humans, to urinate and defecate in the face of extreme danger. And many animals erect body hair in dangerous situations, presumably to make themselves look more vicious than they otherwise would. Piloerection, according to Darwin, is probably one of the most general of the emotional expressions, occurring in dogs, lions, hyenas, cows, pigs, antelopes, horses, cats, rodents, bats, to name a few.

Darwin suggested that goose bumps, a mild form of piloerection in humans, occur as a vestige of the more dramatic displays in our mammalian cousins. He points out that it is a remarkable fact that the thinly scattered hairs on the human body are erected in rage and terror, emotional states that cause body hair to stand on end in furry animals, where body piloerection has some purpose. But he noted that piloerection also occurs on the part of the human body that is well endowed with hair, the head, using Brutus' statement to the ghost of Caesar as evidence: "that mak'st my blood cold, and my hair stare."

Darwin gave many other examples of common emotional expression in different species. For example, he equated the snarl of an angry human with similar behaviors in other creatures. Again turning to literature for support, he quotes Dickens' description in *Oliver Twist* of a furious mob witnessing the capture of an atrocious murderer on the streets of London: "the people as jumping up one behind another, snarling with their teeth, and making at him like wild beasts." Darwin goes on to note that "Everyone who has had much to do with young children must have seen how naturally they take to biting, when in a passion. It seems as instinctive in them as in young crocodiles, who snap their little jaws as soon as they emerge from the egg." He also quotes from Dr. Maudsley, who specialized in human insanity and for whom the renowned Maudsley Hospital in London is named: "whence come 'the savage snarl, the destructive disposition, the obscene language, the wild howl, the offensive habits, displayed by some of the insane? Why should a human being, deprived of his reason, ever become so brutal in character, as some do, unless he has the brute nature within him?'" In response, Darwin says, "This question must, as it would appear, be answered in the affirmative."

For Darwin, an important function of emotional expressions is communication between individuals—they show others what particular emotional state one is in. Emission of vicious sounds and enlarging body parts (flashing of feathers, extension of fins or pointy spines, puffing up, and, as we have seen, erection of body hair), are used throughout the animal kingdom to dissuade an enemy from attacking. Sounds, smells, and various postures and displays of body parts or hidden colors serve as signals of sexual receptiveness as well. Sounds are also used to warn others that danger is near. While these

signals are somewhat relevant to humans, in the passage below Darwin describes some emotional expressions that are particularly important to our species:

> The movements of expression in the face and body, whatever their origin may have been, are in themselves of much importance in our welfare. They serve as the first means of communication between the mother and her infant; she smiles approval, and thus encourages her child on the right path, or frowns disapproval. We readily perceive sympathy in others by their expression; our sufferings are thus mitigated and our pleasures increased; and mutual good feeling is thus strengthened. The movements of expression give vividness and energy to our spoken words. They reveal the thoughts and intentions of others more truly than do words, which may be falsified.

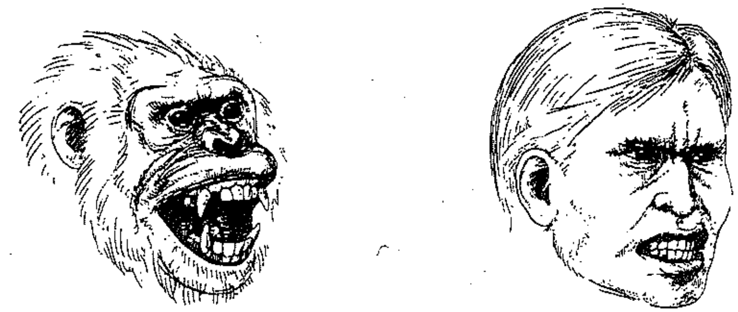

FIGURE 5-1
Commonality of Emotional Expression in the Faces of Animals and People.

Some emotional expressions are similar in humans and other animals. These two drawings illustrate angry facial expressions in a chimpanzee and human. In both species an expression of anger often involves a direct gaze and a partly opened mouth with lips retracted vertically so that the teeth show. (Drawings, by Eric Stoelting, are reprinted with permission from S. Chevalier-Skolnikoff [1973], Facial expression of emotion in nonhuman primates. In P. Ekman, *Darwin and Facial Expression.* New York: Academic Press.)

A picture may be worth a thousand words, but bodily expressions are priceless commodities in the emotional marketplace.

Darwin argued that although emotional expressions can sometimes be muted by willpower, they are usually involuntary actions. He pointed out how easy it is to tell the difference between a real, involuntary smile and one that is feigned. And he gives us an example from his own life to illustrate how difficult it is to suppress an emotional reaction that has been elicited naturally: "I put my face close to the thick glass-plate in front of a puff-ader in the Zoological Gardens, with the firm determination of not starting back if the snake struck at me; but, as soon as the blow was struck, my resolution went for nothing, and I jumped a yard or two backwards with astonishing rapidity. My will and reason were powerless against the imagination of a danger which had never been experienced."

Within the general class of innate emotions, Darwin suggested that some have older evolutionary histories than others. He noted that fear and rage were expressed in our remote ancestors almost as they are today in humans. Suffering, as in grief or anxiety, though, he placed closer to human origins. Nevertheless, Darwin was well aware of the pitfalls of such ideas about the time of origin of different emotions and noted: "It is a curious, though perhaps an idle speculation, how early in the long line of our progenitors the various expressive movements, now exhibited by man, were successively acquired."

Basic Instinct

A number of modern theorists carry on Darwin's tradition in their emphasis on a set of basic, innate emotions. For many, basic emotions are defined by universal facial expressions that are similar across many different cultures. In Darwin's day, the universality of emotional expression across cultures was presumed from casual observation, but modern researchers have gone into remote areas of the world to firmly establish with scientific methods that at least some emotions have fairly universal modes of expression, especially in the face. On the basis of this kind of evidence, the late Sylvan Tomkins proposed the existence of eight basic emotions: surprise, interest, joy,

Specialized versus General-Purpose Neural Systems

Modern evolutionarily minded emotions theorists, like Ekman, argue that emotions deal with "fundamental life tasks."[53] A similar point is made by Johnson-Laird and Oatley, who say that each emotion "prompts us in a direction which in the course of evolution has done better than other solutions to recurring circumstances."[54] And Tooby and Cosmides argue that emotions involve situations that have occurred over and over throughout our evolutionary history (escaping from danger, finding food and mates) and cause us to appraise present events in terms of our ancestral past—that the structure of the past imposes an interpretive landscape on the present.[55]

In a sense, coming up with a list of the special adaptive behaviors that are crucial to survival would essentially be a list of basic emotions. I think starting with universal behavioral functions is a better way of producing a list of basic emotions than the more standard ways—facial expressions, emotion words in different languages, or conscious introspections. However, I'm not concerned with defining, from the start, what the different emotions are and I have no interest in producing yet another basic emotions list. Obviously, it is ultimately important to understand what all the biologically derived and socially constructed emotions are, and to determine where the line should be drawn between them. It is also important to draw the line between mental phenomena that are emotions and those that are not. However, for good reasons, efforts to identify what all of the emotions are frequently get bogged down in arguments over the fringe instances, as when Ortony and Turner took basic emotions theorists to task for their inability to agree about what the various basic emotions are, and especially for disagreeing about the fuzzy cases, like surprise, interest, and desire. I believe that once we've built up a core knowledge about the clear instances we will be in a better position to deal with the fuzzy ones, but we haven't reached that point yet.

To the extent that emotional responses evolved, they evolved for different reasons, and it seems obvious to me that there must be different brain systems to take care of these different kinds of functions. Lumping all of these together under the unitary concept of emotional behavior provides us with a convenient way of organizing things—for

distinguishing behaviors that we call emotional (for example, those involved with fighting, feeding, sex, and social bonding) from those that reflect cognitive functions (like reasoning, abstract thinking, problem solving, and concept formation). However, the use of a label, like "emotional behavior," should not necessarily lead us to assume that all of the labeled functions are mediated by one system of the brain. Seeing and hearing are both sensory functions, but each has its own neural machinery.

I think that the most practical working hypothesis is that different classes of emotional behavior represent different kinds of functions that take care of different kinds of problems for the animal and have different brain systems devoted to them. If this is true, then different emotions should be studied as separate functional units.

At the neural level, each emotional unit can be thought of as consisting of a set of inputs, an appraisal mechanism, and a set of outputs. The appraisal mechanism is programmed by evolution to detect certain input or trigger stimuli that are relevant to the function of the network. We'll call these "natural triggers."[56] The sight of a predator is a good example. It is not uncommon for prey species to recognize predators the first time they see them. Evolution has programmed the prey brain so that certain features of the way the predator looks, sounds, or smells will be automatically appraised as being a source of danger. But the appraisal mechanism also has the capacity to learn about stimuli that tend to be associated with and predictive of the occurrence of natural triggers. These we'll call "learned triggers." The place where a predator was seen last, or the sound it made when it was charging toward the prey are good examples. When the appraisal mechanism receives trigger inputs of either type, it unleashes certain patterns of response that have tended to be useful in dealing with situations that have routinely activated the appraisal mechanism in ancestral animals. These networks evolved because they serve the function of connecting trigger stimuli with responses that are likely to succeed in keeping the organism alive. And because different kinds of problems of survival have different trigger stimuli and require different kinds of responses to deal with them, different neural systems are devoted to them.[57]

The particular functional unit that I have focused my research on is the fear system of the brain. In the next several chapters, we will look closely at the fear system, which is understood as well or better than other emotional systems. Once we see how this system is organized, we will be in a better position to consider the manner in which other emotions are organized in the brain, and how these relate to the fear system.

Why Fear?

I'm going to now lay out some of the reasons why I believe the fear system of the brain is a particularly good one to focus on as an anchoring point. However, I want to first be explicit about what I think the fear system is. The system is not, strictly speaking, a system that results in the experience of fear. It is a system that detects danger and produces responses that maximize the probability of surviving a dangerous situation in the most beneficial way. It is, in other words, a system of defensive behavior. As noted above, I believe that emotional behaviors, like defensive behaviors, evolved independent of, which is to say before, conscious feelings, and that we should not be too quick to assume that when an animal, other than a human one, is in danger it feels afraid. We should, in other words, take defensive behaviors at face value—they represent the operation of brain systems that have been programmed by evolution to deal with danger in routine ways. Although we can become conscious of the operation of the defense system, especially when it leads to behavioral expressions, the system operates independently of consciousness—it is part of what we called the emotional unconscious in the Chapter 3. Interactions between the defense system and consciousness underlie feelings of fear, but the defense system's function in life, or at least the function it evolved to achieve, is survival in the face of danger. Feelings of fear are a by-product of the evolution of two neural systems: one that mediates defensive behavior and one that creates consciousness. Either one alone is not enough to produce subjective fear. Feeling afraid can be very useful, but this is not the function programmed into the neural system of defense by evolution.

With the territory staked out in this way, let's now consider why the defensive system of the brain and its associated subjective emotion, fear, are attractive starting points for studying the emotional

brain. I'll discuss three points below: fear is pervasive, fear is important in psychopathology, and fear is expressed similarly in man and many other animals. In the next chapter, another crucial point will be considered, namely that the neural basis of fear is similar in humans and other animals.

Fear Is Pervasive: William James once said that nothing marks the ascendancy of man from beast more clearly than the reduction of the conditions under which fear is evoked in humans.[58] By this, it would seem that James meant that man has managed to establish a less dangerous way of living. It is certainly true that in comparison to our primate ancestors, who lived in a world in which being someone's dinner was an ever-present possibility, humans have created a way of living in which the likelihood of encountering predators is greatly reduced. But not all dangers come in the form of bloodthirsty beasts. Snakes and tigers are rare in modern cities, except in zoos, where viewing dangerous animals in captivity reinforces our hope that life is safe. But in our quest to conquer nature we have created new forms of danger. Automobiles, airplanes, weapons, and nuclear energy give us a step up on the wild, but each is also a potential source of harm. We've traded in the dangers of a life amongst the wild things for other dangers that may, in the end, be far more harmful to our species than any natural predator. The dangers we face are not fewer or less significant than those of our animal ancestors, they're just different.

Even a casual analysis of the number of ways the concept of fear can be expressed in the English language reveals its importance in our lives: alarm, scare, worry, concern, misgiving, qualm, disquiet, uneasiness, wariness, nervousness, edginess, jitteriness, apprehension, anxiety, trepidation, fright, dread, anguish, panic, terror, horror, consternation, distress, unnerved, distraught, threatened, defensive.[59] The so-called ascent of man occurred in spite of the continued existence of fear rather than at its expense. As the renowned human ethologist Eibl-Eibesfeldt notes, "Perhaps man is one of the most fearful creatures, since added to the basic fear of predators and hostile conspecifics come intellectually based existential fears."[60] Indeed, for the existential philosophers (like Kierkegaard, Heidegger, and Sartre), dread, angst, and anguish are at the core of human existence.[61]

One can find evidence of fear lurking in the background of many kinds of emotions that on the surface might seem to be the antithesis of fear. Courage is the ability to overcome fear. Children learn to be moral to some extent by their fear of what will happen if they are not. Laws reflect our fear of social disorder and, by the same token, social order is maintained, however imperfectly, by fear of the consequences of breaking the rules. World peace is a desirable humanitarian goal, but in practice war is avoided, at least in part, because the weak fear the strong. These are bleak statements, hopefully overstatements, but even as partial truths they emphasize how deeply fear cuts into the mental fabric of persons and societies.

Fear Plays an Important Role in Psychopathology: While fear is a part of everyone's life, too much or inappropriate fear accounts for many common psychiatric problems. Anxiety, a brooding fear of what might happen, was at the core of Freud's psychoanalytic theory. Phobias are specific fears taken to extreme. Phobic objects (snakes, spiders, heights, water, open places, social situations) are often legitimately threatening, but not to the extent believed by the phobic person. Obsessive-compulsive disorder often involves extreme fear of something, like germs, and the patients will engage in compulsive rituals to avoid the feared object or event or to rid themselves of the fear object once it is encountered. Panic disorder involves the rapid onset of a host of physical symptoms and often the overwhelming fear that death is near. Post-traumatic stress disorder (PTSD), previously referred to as shell shock, often occurs in war veterans, who can be sent into intense distress by a stimulus that has some resemblance to events associated with battlefield trauma. Thunderclaps and the sound of a car backfiring are common examples. But PTSD extends to many other kinds of traumatic situations, including physical and sexual abuse. Fear is a core emotion in psychopathology.

Fear Is Expressed Similarly in Humans and Other Animals: It may not be the case that every form of emotional behavior has a long evolutionary history. Guilt and shame, for example, may be special human emotions.[62] Nevertheless, as we will see, human defensive behavior clearly seems to have a long evolutionary history. As a result, we can study fear responses in animals for the purpose of illuminating the mechanisms of human fear, including pathological fear. This is crucial, since for both ethical and practical reasons it is not possible to study brain mechanisms in much detail in humans.

All animals have to protect themselves from dangerous situations in order to survive, and there are only a limited number of strategies that animals can call upon to deal with danger. Isaac Marks, who has written extensively on fear, summarizes these as withdrawal (avoiding the danger or escape from it), immobility (freezing), defensive aggression (appearing to be dangerous and/or fighting back), or submission (appeasement).[63] The extent to which these strategies apply across the various vertebrates is striking.

Consider the following description of human defense by Caroline and Robert Blanchard, pioneers in fear research:

> If something unexpected occurs—a loud noise or sudden movement—people tend to respond immediately . . . stop what they are doing . . . orient toward the stimulus, and try to identify its potentiality for actual danger. This happens very quickly, in a reflex-like sequence in which action precedes any voluntary or consciously intentioned behavior. A poorly localizable or identifiable threat source, such as a sound in the night, may elicit an active immobility so profound that the frightened person can hardly speak or even breathe, i.e. freezing. However, if the danger source has been localized and an avenue for flight or concealment is plausible, the person will probably try to flee or hide. . . . Actual contact, particularly painful contact, with the threat source is also likely to elicit thrashing, biting, scratching, and other potentially damaging activities by the terrified person.[64]

Though anecdotal, the Blanchards' description goes a long way toward accounting for the way people behave when threatened. And different people tend to do roughly the same things in similar kinds of situations. This uniformity suggests that either we all learn to be fearful in the same way, or, more likely, that patterns of fear reactivity are genetically programmed into the human brain.

Research by the Blanchards and others has shown that the reaction pattern described above for a frightened human also occurs when rats are in danger.[65] For example, if a laboratory-reared rat (one that has never had the opportunity to see a cat or be threatened by one) is exposed to a cat, it stops what it is doing and turns toward the cat. Depending on whether the cat is close or far away and whether the two animals are in an enclosed or an open area, the rat will either freeze or try to escape. If trapped by the cat, the rat will vocalize and ultimately will attack the cat. This striking functional correspondence between human and rat fear responses holds for many mammals and other vertebrates: it is quite common to observe startle, orienting, then freezing or fleeing or attack, in the face of danger. We've already seen examples from Darwin about how hair erection is a common defense response in many animals, including people, and how it may be related to the flashing of feathers in birds and fin extensions in fish.

Not only are some general patterns of behavior similar in different animals, but so too are some of the underlying physiological changes that occur in dangerous or stressful situations. For example, it is well known that soldiers in battle fail to notice injuries that would, under less traumatic circumstances, be excruciatingly painful. Similarly, a rat, when exposed to a cat, will fail to notice painful heat applied to its tail.[66] The cat poses a greater overall threat than a wound to the tail, and pain suppression in the face of danger allows the organism to use its resources to deal with the most significant danger. In both humans and rats, stress-induced analgesia is a consequence of activation of the brain's natural opiate system.[67] When the brain detects danger, it also sends messages through the nerves of the autonomic nervous system to bodily organs and adjusts the activity of those organs to match the demands of the situation. Nerves reaching the gut, heart, blood vessels, and sweat and salivary glands give rise to the taut stomach, racing heart, high blood pressure, clammy hands and feet, and dry mouth that typify fear in humans. The cardiovascular responses associated with defensive behavior have been examined in birds, rats, rabbits, cats, dogs, monkeys, baboons, and people, to name a few of the better studied species, and the responses are controlled by similar kinds of brain networks and body chemistry in these different species.[68] Threatening stimuli also cause the pituitary gland to release adrenocorticotropic hormone (ACTH) that results in the release of a steroid hormone from the adrenal gland.[69] The adrenal hormone then travels back to the brain. Initially, these hormones help the body deal with the stress, but if the stress is prolonged the hormone can begin to have pathological consequences, interfering with cognitive functions and even causing brain damage.[70] This so-called stress response is ubiquitous amongst mammals, and also occurs in other vertebrates.[71] These various bodily responses are not random activities. They each play an important role in the emotional reaction and each functions similarly in diverse animal groups.

Nevertheless, it would be wrong to give the impression that all animals respond exactly the same in the face of danger. Obviously, they do not. Each animal is the product of its own evolutionary history. Within the general classes of defense reactions, much variation is possible. In fact, defense reactions should be thought of as constantly changing, dynamic solutions to the problem of survival. They are not static structures created in ancestral species and maintained unchanged. They change as the world in which they operate changes. For example, Richard Dawkins describes predators and prey as involved in evolutionary arms races, where a particular adaptation that makes a prey better at defending against a predator can lead to the selection of traits that then give the predator the edge up—the color of the prey may change so that it blends in better with the environment, and the predator may, in turn, evolve a more sensitive perceptual system for detecting the camouflaged prey.[72] But Dawkins also notes a certain imbalance in these arms races, what he calls the "life/dinner" principle. According to this notion, rabbits run faster than foxes because rabbits are running for their life but foxes are only running for their dinner. As a result, genetic mutations that make foxes run more slowly are more likely to survive in the gene pool than mutations that make rabbits run more slowly, since the penalty of slowness is more severe for rabbits than foxes—a fox may reproduce after being outrun by a rabbit, but no rabbit ever reproduced after being caught by a fox.

In spite of the fact that species can have their own special ways of responding to danger, commonality of functional patterns is the rule. In fact, what distinguishes fear reactions in humans and other animals is not so much the ways in which fear is expressed as the different kinds of trigger stimuli that activate the appraisal mechanism of the defensive system. Each animal has to be able to detect the particular things that are dangerous to it, but there is an evolutionary economy to using universal response strategies—withdrawal, immobility, aggression, submission—and universal physiological adjustments. Added cognitive power opens up the defensive hardware to new kinds of events, new learned triggers. Humans fear things that a rat could never conceptualize, but the human and rat body respond much the same to their special triggers.

The implications of this situation are enormous. For the purpose of understanding how fear is generated, it does not matter so much how we activate the system or whether we activate the system in a person or a rat. The system will respond in pretty much the same way using a limited set of given defense response strategies available to it. We can thus design experiments in rats (or other laboratory animals) for the purpose of understanding how the human fear system works.

Genetic Determinism and Emotional Freedom

All this talk about the evolution of emotional behavior is likely to make the imagination run wild with ideas about genetic determination of our emotions. After all, any characteristic that has evolved has done so because of the representation of that characteristic in the genes of the species. But I want to make clear two different implications of the genetics of emotional behavior.

On the one hand, there is the way genes maintain similar behavioral expressions of defense within a species and similar defensive functions across diverse species. This occurs, as I've argued, because the neural system of defense is conserved in evolution. As a result, all humans have the same general ways of expressing themselves when in danger, and these tend to be similar to the ways that other animals have for expressing themselves in the face of danger. This view of emotional genetics tries to find the common ground of emotional reactions across individuals and species—the stuff that particular emotional systems evolved to do.[73]

On the other hand, there is the question of how genes contribute to differences between individuals. Some people are good fighters, others are not. Some are adept in detecting dangers, others are oblivious to their surroundings. Differences between individuals in fearful behavior are due, at least in part, to genetic variation.

So far, I've emphasized the first implication—the way genes make emotional reactions similar amongst humans and between humans and other animals. But it is important to also consider in some detail the ways in which genes make us different from each other. We will then discuss whether, and if so to what extent, such differences predestine us to act in some particular way, again concentrating on the fear system.

Temperament runs through bloodlines. Some breeds of horses or dogs are jumpy, others complacent. These characteristics can sometimes be side effects of some other trait that was selected for, like running speed, but temperament can also be selected for itself. Indeed, selective breeding has been used to create strains of rats and mice that are particularly timid or courageous.[74]

For example, rats don't normally congregate in wide-open spaces. This makes a lot of sense evolutionarily—open places are unprotected from land and air predators and can be very dangerous for rodents. Those ancestral rodents that tended to hang out in an open area probably did not do so well in their struggle to survive, whereas those that hightailed it out to the nearest safe place did. Psychologists created an apparatus for testing this behavior—a large, well-lit circular arena called "the open field."[75] If you put your garden-variety rat in the center of an open field apparatus, it will make a beeline to the wall, which is the most protected place available. The rats also defecate—like people, rats can have the "$#!+" scared out of them. Defecation is controlled by the autonomic nervous system and the number of fecal pellets (poops) that are dropped is a reliable and measure of ANS activity. Defecation in the open field or other potentially dangerous situations has become a fairly standard measure of "fearfulness" in rodents.[76] But not all rats drop the same number of pellets in the open field, and the amount one rat drops tends to be fairly constant. If you divide a large group into those that drop more and fewer pellets in the open field, and then start breeding them on the basis of this selected trait, you can, in a few generations, create strains of timid and courageous rats—rats from the low pellet-dropping line act more courageous in the open field (they stay in the unprotected area longer) and in a variety of other tests. From this example, it is easy to imagine how personality traits might come to be part of a family, or even a culture. All you need is a few generations of inbreeding amongst a limited gene pool to begin to stabilize behaviorally significant characteristics.

In fact, considerable evidence shows that there is a genetic component to fear behavior in humans.[77] For example, identical twins (even those reared in separate homes) are far more similar in fearfulness than fraternal twins. This conclusion applies across many kinds of measurements, including tests of shyness, worry, fear of strangers, social introversion/extroversion, and others. Similarly, anxiety, phobic, and obsessive compulsive disorders tend to run in families and to be more likely to occur in both identical than in both fraternal twins.

The genetics of defensive behavior has been studied most extensively in bacteria.[78] Although not known as a particularly sophisticated organism from the psychological point of view, they do protect themselves from danger and there may be some biological lessons to be learned. Their defensive repertoire consists of moving away from substances assessed as harmful. The specific gene mutations controlling this behavior, which involves complex coding of chemical constituents in the immediate environment, have been identified. Similarly, much progress has been made in genetic analyses of fruit fly defensive behavior.[79] Through some ingenious experiments, Tim Tully has shown that these creatures can learn to avoid danger (electric shock) on the basis of stimulus cues (odors)—once shocked in the presence of a certain smell, they tend to avoid a chamber that has the smell. Using the modern tools of molecular biology and genetics, mutant flies have been created that are unable to use the smell cues to avoid the shock. They can smell just fine, they just can't link the smell with danger. It is admittedly a far leap from defensive responses in flies to humans, and at least a quantum leap from bacterial to human behavior. However, studies in these simple creatures may pave the way for future researchers to perform similar kinds of experiments in mammals, and these kinds of studies may shed light on the genetics of fear in humans. There is, after all, massive overlap in the genetic makeup of humans and chimpanzees, and a good deal of overlap in humans and other mammals as well.[80]

There's no denying that genes make each of us different from one another and explain at least part of the variability in the way different people act in dangerous and other situations. But we have to be very careful in interpreting differences in behavior between different people. As Richard Dawkins puts it, "If I am homozygous for a gene G, nothing save mutation can prevent my passing G on to all my children. So much is inexorable. But whether or not I, or my children, show the phenotypic effect normally associated with possession of G may depend very much on how we are brought up, what diet or education we experience, and what other genes we happen to possess."[81]

The bottom line is that our genes give us the raw materials out of which to build our emotions. They specify the kind of nervous system we will have, the kinds of mental processes in which it can engage, and the kinds of bodily functions it can control. But the exact way we act, think, and feel in a particular situation is determined by many other factors and is not predestined in our genes. Some, if not many, emotions do have a biological basis, but social, which is to say cognitive, factors are also crucially important. Nature and nurture are partners in our emotional life. The trick is to figure what their unique contributions are.