physiological responses during panic attacks, one is much more struck by the similarities than by the differences."[16] He goes on to argue that panic, phobic fear, and PTSD reflect the "activation of one and the same underlying anxiety response." This is essentially the case that I will make. However, I state the idea in terms of brain systems rather than symptoms: anxiety disorders reflect the operation of the fear system of the brain. Öhman leaves generalized anxiety out of his grouping because it involves a stable personality trait rather than discrete episodes of anxiety, a distinction that is often referred to as one between trait and state anxiety. However, generalized anxiety most likely involves the same underlying brain system (at least partly) as the other anxiety disorders.

Little Albert Meets Little Hans

Anxiety disorders can arise at any time, but most often appear in early adult life. Why does this happen? How does the brain go from a state in which it is not especially anxious to one in which it is pathologically worried or exhibiting neurotic behaviors that keep the worry in check?

Most theorists from Freud onward have assumed that clinically debilitating anxiety is the result of traumatic learning experiences that create unpleasant memories. Breuer and Freud,[17] in the famous case of Anna O., for example, argued that "hysterics suffer mainly from reminiscences," or as Matthew Erdelyi puts it, "traumatic memories which they have expunged from consciousness."[18] Since fear conditioning is the *sine qua non* of traumatic learning, it should come as no surprise that fear conditioning has been proposed to be involved in the genesis of pathogenic anxiety. Though long considered controversial and incomplete, as we will see, new findings have made it seem more likely, and even quite plausible, that fear conditioning contributes significantly to anxiety disorders.[19]

The conditioning theory of anxiety arose in the 1920s, a time when psychologists were beginning to explain most aspects of behavior in terms of learning experiences, and particularly in terms of Pavlov's

conditioned reflexes.[20] John Watson, the father of behaviorism claimed to have conditioned an animal phobia in an eleven-month old boy, Little Albert, by making a loud clanging sound while the bo was happily playing with a rat.[21] Thereafter, the boy avoided playin with the rat and cried when he was near it. To explain this finding Watson proposed that certain stimuli (loud noises, painful stimul sudden loss of physical support) are innately capable of eliciting fea reactions. When these unconditioned stimuli occur, other stimul that happen to be present acquire the capacity to elicit conditione fear. According to Watson, neuroses arise as a result of these trau matic learning situations and then persist and influence behavio throughout life.[22]

Watson's theory of anxiety, as well as his behaviorist view of psychology, was based on Pavlovian conditioned reflex learning. But by the 1930s, another form of learning, called instrumental conditioning, had come to be of equal importance to behaviorists.[23] In instrumental conditioning, an arbitrary response (like pressing a bar or making a turn in a maze) is learned if it is reinforced, which means it is either followed by the presentation of a reward or the omission of a punishment. The response is learned because it is reinforced, and thereafter is performed in order to get the reward or avoid the punishment. While Pavlovian conditioning involves the transfer of meaning from an emotionally arousing to a neutral stimulus, in instrumental conditioning the association is between an emotionally arousing stimulus and neutral response.

Behaviorism and psychoanalysis were radically different approaches, but both sought to understand why we act the way we do. O. Hobart Mowrer, a leading behaviorist, saw value in both approaches and set out in the 1940s to translate Freud's theory of anxiety neurosis into the language of learning theory.[24] Using the principles of Pavlovian and instrumental conditioning, Mowrer hoped to solve what he called the "neurotic paradox": "a normal sensible man, or even a beast to the limits of his intelligence, will weigh and balance the consequences of his acts. . . . If the net effect is unfavorable, the action producing it will be inhibited, abandoned. In neurosis, however, one sees actions which have predominantly unfavorable consequences, yet they persist over a period of months, years, or a lifetime."[25]

Anxiety, according to Mowrer, motivates us to deal with traumatic events in advance of their occurrence. And because anxiety reduction brings about relief or security, it is a powerful reinforcer of instrumental behaviors (arbitrary responses that are learned because they satisfy some need or accomplish some goal). Responses that reduce anxiety are thus learned and maintained.

Mowrer felt that anxiety is initially learned much like Watson had suggested—stimuli that are present during painful or traumatic stimulation acquire the capacity to elicit anxiety. Because anxiety is uncomfortable, when the stimuli that elicit it are present the anxious person will be motivated to change the circumstances, to remove himself from where the anxiety-causing stimuli are, and to avoid such situations in the future. The reduction in anxiety that these responses produce then reinforces the behaviors and perpetuate their performance. This is often useful, but sometimes it leads to neurotic symptoms.

Consider a real-life example. A man is mugged in an elevator. From that day on, he becomes afraid of riding in elevators. He avoids them as much as possible. He consults a therapist, who tries to reassure him that it is highly unlikely that he will be mugged again in an elevator, especially if he rides at busy times. But the reassurance is not helpful. The man must get to his office on the thirteenth floor. This makes him anxious. In spite of the inconvenience that it causes him, each day he takes the stairs. The reduction in anxiety that results from taking the stairs, according to Mowrer's theory, maintains the neurotic behavior of taking the stairs.

Mowrer, like existentialist philosophers, saw anxiety as an important part of human existence, as fundamental to what is special about humans, but also as a clue to our frailty:

> By and large, behavior that reduces anxiety also operates to lessen the danger that it presages. An antelope that scents a panther is likely not only to feel less uneasy (anxious) if it moves out of the range of the odor of the panther but also likely to be in fact somewhat safer. A primitive village that is threatened by marauding men or beasts sleeps better after it has surrounded itself with a deep moat or a sturdy stockade. And a modern mother is made emotionally more comfortable after her child has been properly vaccinated against a dreaded disease. This capacity to be made uncomfortable by the mere prospect of traumatic experiences, in advance of their actual occurrence (or reoccurrence), and to be motivated thereby to take realistic precautions against them, is unquestionably a tremendously important and useful psychological mechanism, and the fact that the forward-looking, anxiety-arousing propensity of the human mind is more highly developed than it is in lower animals probably accounts for many of man's unique accomplishments. But it also accounts for some of his most conspicuous failures.[26]

Mowrer paved the way for a behavioral interpretation of Freud, but this pursuit was most successfully implemented by another behavioral psychologist, Neal Miller.[27] Miller had been attempting to work out in detail how fear might serve as a drive, like hunger or sex, an internal signal that motivates one to act in a way that reduces the drive. Just as a hungry animal looks for food, a fearful one tries to get away from the stimuli that arouse fear. He trained rats to avoid being shocked by jumping over a hurdle that separated two compartments whenever a buzzer sounded.[28] The first phase involved fear conditioning: the buzzer came on and the rats were shocked. Then, through random actions, they learned that if they jumped over the hurdle during the buzzer, they could avoid getting shocked. Once the rat figured this out, it would jump every time it heard the buzzer, even if the shock was turned off. The shock was no longer present and was thus no longer the motivator. The avoidance response seemed, as Mowrer had suggested, to be maintained by the anticipation of shock, by the fear elicited by the warning signal. But to prove that fear was the motivator, Miller changed the rules on the rat. Previously, when the rat jumped over the hurdle, the buzzer went off, and turning the buzzer off seemed to be sufficient reinforcement to keep the rat jumping. But now the buzzer stayed on when the rat jumped and would only go off if the rat pressed a lever. And once this was learned Miller changed the game again, forcing the rat to learn still another response to turn the buzzer off. While the initial response was learned because it allowed the rat to avoid the shock, the subsequent ones were never associated with the shock. They were reinforced by the fact that they turned off the sound. According to Miller, the findings showed that fear is a drive, an internal energizer of behavior, and that behaviors that reduce fear are reinforced and thereby become habitual ways of acting (note, however, that "fear" is an in-

ternal bodily signal, like hunger, and does not necessarily refer to subjective, consciously experienced fear in this theory).

Miller felt that this new view of fear as a drive was the key to a truly scientific approach to psychoanalytic principles. Together with John Dollard, a trained analyst, Miller attempted to account for unconscious neurotic conflict and its expression as symptoms in terms of the principles of animal learning.[29] Just as a rat could learn any response that allowed it to escape from or avoid an anxiety-provoking situation, humans learn all sorts of instrumental responses that allow them to escape or avoid anxiety and guilt caused by neurotic conflict.[30] As Dollard and Miller put it:

> the symptoms of the neurotic are the most obvious aspects of his problem. These are what the patient is familiar with and feels he should be rid of. The phobias, inhibitions, avoidances, compulsions, rationalizations, and psychosomatic symptoms of the neurotic are experienced as a nuisance by him and by all who have to deal with him. . . . When a successful symptom occurs it is reinforced because it reduces neurotic misery. The symptom is thus learned as a habit.[31]

Conditioned fear theories of anxiety took a different turn in the early 1960s. In contrast to the tradition of Mowrer and Miller, who saw Freud as scientifically imprecise but on the right track, the new theorists had little patience with the psychoanalytic view of anxiety and its emphasis on unresolved and unconscious conflict. Joseph Wolpe was one of these. He reinterpreted Freud's famous phobic case, Little Hans,[32] in terms of simple Pavlovian conditioning.[33] Hans, a five-year-old boy, became afraid of horses one day while witnessing a frightening event in which a horse fell down. Freud's view was that the horse phobia was an unresolved Oedipal conflict—Hans' fear of being castrated by his father for desiring his mother was displaced to horses. The trauma of witnessing the horse falling was the occasion that allowed the phobia to cover for the underlying conflict. But Wolpe saw it differently. Like all good conditioning theorists, he argued that a neutral stimulus, like a horse, that occurs in the presence of a trauma will acquire the capacity to elicit fear reactions, and that phobias are nothing more than fear (anxiety) that has been conditioned to some otherwise meaningless event. In making his case,

Wolpe severely criticized Freud's selective use of information that confirmed his theory and his selective disregard for information that went against it. For example, Hans himself supposedly said that he "got the nonsense" when he saw the horse fall down, and his father, in support of this view, said the anxiety broke out immediately after the incident. Freud dismissed these surface explanations, but Wolpe took them at face value. For Wolpe, Little Hans was just like Little Albert. The conditioning theory had come full circle.

The distinction between Watson's and Wolpe's purely Pavlovian approach and Mowrer's and Miller's psychoanalytic translations is more than just one of the language used to describe how anxiety arises. It also impacts importantly on the issue of how anxiety should be treated. Freudians, and their behavioral protégés, saw the goal of therapy as the resolution of unconscious conflict. The other school, typified by Wolpe, had no use for unconscious explanations and saw neurotic symptoms as nothing more and nothing less than conditioned responses. In the words of Stanley Rachman and Hans Eysenck, two other leaders in this movement, "Get rid of the symptom . . . and you have eliminated the neurosis."[34]

In spite of many important differences, there is a common theme that runs through psychoanalytic and the various conditioning theories—anxiety is the result of traumatic learning experiences. Since traumatic learning involves (at least in part) fear conditioning, it is possible that similar brain mechanisms contribute to pathogenic anxiety in humans and conditioned fear in animals. If so, findings from easily performed animal experiments could be used to understand how anxiety is learned, unlearned, and controlled in humans. However, before we can accept this rather strong, and some would say controversial, conclusion, we need to consider some additional ideas about the relation of fear conditioning to anxiety disorders, and some additional facts about the organization and function of the fear system of the brain.

Ready to Fear

In the early 1970s, Martin Seligman, an experimental psychologist who had been studying conditioned fear in animals, pointed out

some striking differences between human anxiety and laboratory conditioned fear.[35] Especially important to Seligman was the fact that avoidance conditioning extinguishes quickly if the animal is prevented from making the avoidance response and alternative solutions for escape or avoidance are not provided. Recall that Miller's rats kept jumping over the hurdle when the buzzer sounded even when the shock was turned off. They never had the chance to find out that the shock was off because they kept jumping. But Seligman's point is that if the hurdle is replaced with a wall, thus preventing the avoidance response, the rat soon learns that the buzzer is no longer followed by a shock and begins to ignore the buzzer. If the wall is now removed and the hurdle returned, jumping no longer occurs in response to the buzzer. Forcing the rat to see that the buzzer doesn't lead to danger extinguishes the fear and this leads to the extinction of the neurotic avoidance response. In contrast, telling an acrophobic that no one has ever accidentally fallen off the Empire State Building and that he will be just fine if he goes to the top, or forcing him to go up there to prove the point, does not help, and can even make the fear of heights worse rather than better. Human phobias seem more resistant to extinction, and more irrational, than conditioned fears in animals.

The key to this difference, in Seligman's view, is the fact that while laboratory experiments use arbitrary, meaningless stimuli (flashing lights or buzzers), phobias tend to involve specific classes of highly meaningful objects or situations (insects, snakes, heights). He argued that perhaps we are prepared by evolution to learn about certain things more easily than others, and that these biologically driven instances of learning are especially potent and long lasting. Phobias, in this light, reflect our evolutionary preparation to learn about danger and to retain the learned information especially strongly.

In a relatively stable environment, it is generally a good bet that the dangers a species faces will change slowly. As a result, having a ready-made means of rapidly learning about things that were dangerous to one's ancestors, and theirs, is in general useful. But since our environment is very different from the one in which early humans lived, our genetic preparation to learn about ancestral dangers can get us into trouble, as when it causes us to develop fears of things that are not particularly dangerous in our world.

With the notion of preparedness, Seligman injected a dose of biological realism into the plain vanilla conditioning theory that Watson and later behaviorists popularized. Ironically, the phenomenon of preparedness may have played a seminal role in Watson's conditioning of Little Albert. Several later studies failed to reproduce Watson's findings[36] and these results have often been used as ammunition against fear conditioning theories of anxiety. But Seligman notes that in choosing a furry animal as the conditioned stimulus, Watson may have unwittingly used a prepared stimulus, and the failure of the later studies may well be because they used inanimate, meaningless stimuli.

Preparedness theory quickly received strong support from studies by Susan Mineka.[37] It had long been thought that monkeys have an inherited fear of snakes, so that the first time a monkey saw a snake it would act afraid and protect itself. However, Mineka showed that laboratory-reared monkeys are in fact not afraid on the first exposure to a snake. Most of the earlier work had involved testing of the young monkeys in the presence of their mothers. If the young monkey is shown the snake when separated from its mother, it doesn't act afraid. It appears that the infant learns to be afraid of the snakes by seeing its mother acting afraid. The young monkeys did not learn about nonfrightening things in this way, suggesting that there is something special about biologically relevant stimuli that makes them susceptible to rapid and potent observational learning. Humans learn many things by observing others in social situations and it has been proposed that anxiety, especially pathological anxiety, is sometimes or even often learned by social observation.[38]

In recent years, preparedness theory has been championed by Öhman.[39] Öhman believes that evolution has equipped contemporary humans with a propensity to associate fear with situations that threatened the survival of our ancestors. To the extent that this propensity evolved, it must be based in our genes, and genetic variation must therefore exist. As a result, although humans are in general prepared to acquire fears of ancestral dangers easily, some individuals must be more prepared than others to acquire specific fears. These super-prepared humans are, he proposes, vulnerable to phobias.

Öhman has subjected preparedness theory to stringent tests. He started with the assumption that snakes and insects are common objects of phobias and are likely to be prime examples of prepared stim-

uli, whereas flowers are not common phobic objects. He then used these fear-relevant (prepared) and fear-irrelevant stimuli in conditioning studies in humans. In support of preparedness theory, he found that conditioned fear (measured by autonomic nervous system responses) was more resistant to extinction with fear-relevant than with fear-irrelevant stimuli. Further, when modern fear-relevant stimuli (guns and knives) were used, no evidence for resistance to extinction was found, suggesting that evolution has not yet had enough time to build these dangers in. He also showed that phobics respond to a greater degree when they see stimuli relevant to their own phobia than when they see other fear-relevant stimuli—snake phobics gave bigger conditioned responses to snake pictures than to spider pictures and spider phobics did the reverse. This is consistent with his contention that phobics are super-prepared genetically to respond to the objects of their phobia. Finally, using special procedures to prevent conditioned stimuli from being consciously perceived, he was able to produce the prepared conditioning in the absence of awareness of the conditioned stimuli. This shows that phobias can be learned and expressed independently of consciousness, which may be related to their seemingly irrational nature.

Preparedness theory goes a long way toward dealing with some of the shortcomings of the traditional fear conditioning theories of anxiety, particularly the fact that in anxiety disorders fear doesn't extinguish easily and is especially irrational. Nevertheless, important aspects of phobias and other anxiety disorders remained unexplained. People become anxious about objects and situations that are not evolutionarily prepared—like fear of cars or elevators. Anxiety disorders can and often do exist in the absence of a memory of a traumatic experience, suggesting that maybe traumatic conditioning is not so important. And sometimes a clear trauma precedes the onset of an anxiety disorder, but the trauma is unrelated to the disorder (for example, the death of one's mother preceding the development of a fear of heights)—this doesn't make sense if the anxiety was conditioned by the trauma. However, our understanding of the brain mechanisms of conditioned fear, together with new observations about the effects of stress on the brain, give us additional clues that help fill these gaps.

New Twists on Anxiety: Clues from the Brain

In further pursuing the nature of anxiety disorders, we'll draw upon the notion, developed in the previous chapter, of multiple memory systems. In particular, we'll examine some of the implications of the idea that during a traumatic learning situation, conscious memories are laid down by a system involving the hippocampus and related cortical areas, and unconscious memories established by fear conditioning mechanisms operating through an amygdala-based system. These two systems operate in parallel and store different kinds of information relevant to the experience. And when stimuli that were present during the initial trauma are later encountered, each system can potentially retrieve its memories. In the case of the amygdala system, retrieval results in expression of bodily responses that prepare for danger, and in the case of the hippocampal system, conscious remembrances occur.

It is very helpful to keep the workings of the declarative system separate from other memory systems when considering how anxiety disorders might arise and be maintained. This point was made by Jake Jacobs and Lynn Nadel in a 1985 article that greatly influenced my thinking about the effects of stress on the fear system.[40]

Stress-Induced Loss and Recovery of Traumatic Memories: The fact that some clinically anxious persons do not recall any particular traumatic event that might be the cause of their anxiety has been an especially sharp thorn in the side of conditioning theories. In contrast, the main competition, Freud's psychoanalytic theory, assumes that anxiety will only result when traumatic memories are dispatched to the unconscious corners of the mind. Not wanting to call upon anything so mysterious and scientifically unfounded as repression, conditioning theorists have struggled with instances where there is no memory of an instigating trauma. Either no trauma, and thus no conditioning, occurred, or the trauma occurred but is not remembered. Both possibilities leave conditioning theorists with something to explain.

A possible solution to this puzzle has emerged from recent work showing that stressful events can cause malfunctions in the hi

pocampus. This suggests that at least in some instances the failure to recall an instigating trauma may be due to a stress-induced breakdown in hippocampal memory function.[41] In order to understand how and why this occurs, we need to explore the biological effects of stress.

When people or other animals are exposed to a stressful situation, the adrenal gland secretes a steroid hormone into the bloodstream.[42] Adrenal steroids play an important role in helping the body mobilize its energy resources to deal with the stressful situation. As we saw in Chapter 6, the amygdala is critically involved in the control of the release of adrenal steroids. When the amygdala detects danger, it sends messages to the hypothalamus, which in turn sends messages to the pituitary gland, and the result is the release of a hormone called ACTH. ACTH flows through the blood to the adrenal gland to cause the release of steroid hormone. In addition to reaching target sites in the body, the steroid hormone flows through the blood into the brain, where it binds to receptors in the hippocampus, amygdala, prefrontal cortex, and other regions. Because the adrenal and pituitary secretions are reliably elicited by stressful events, they are called stress hormones.

It has been recognized for some time that the hippocampal steroid receptors are part of a control system that helps regulate how much adrenal steroid hormone is released.[43] When the hormone binds to receptors in the hippocampus, messages are sent to the hypothalamus to tell it to tell the pituitary and adrenal glands to slow down the release. In the face of stress, the amygdala keeps saying "release" and the hippocampus keeps saying "slow down." Through multiple cycles through these loops the concentration of the stress hormones in the blood is delicately matched to the demands of the stressful situation.

If stress persists too long, the hippocampus begins to falter in its ability to control the release of the stress hormones, and to perform its routine functions. Stressed rats are unable to learn and remember how to perform behavioral tasks that depend on the hippocampus.[44] For example, they fail to learn the location of the safe platform in the water maze task described in the last chapter. Stress also interferes with the ability to induce long-term potentiation in the hippocampus,[45] which probably explains why the memory failure occurs. Im-

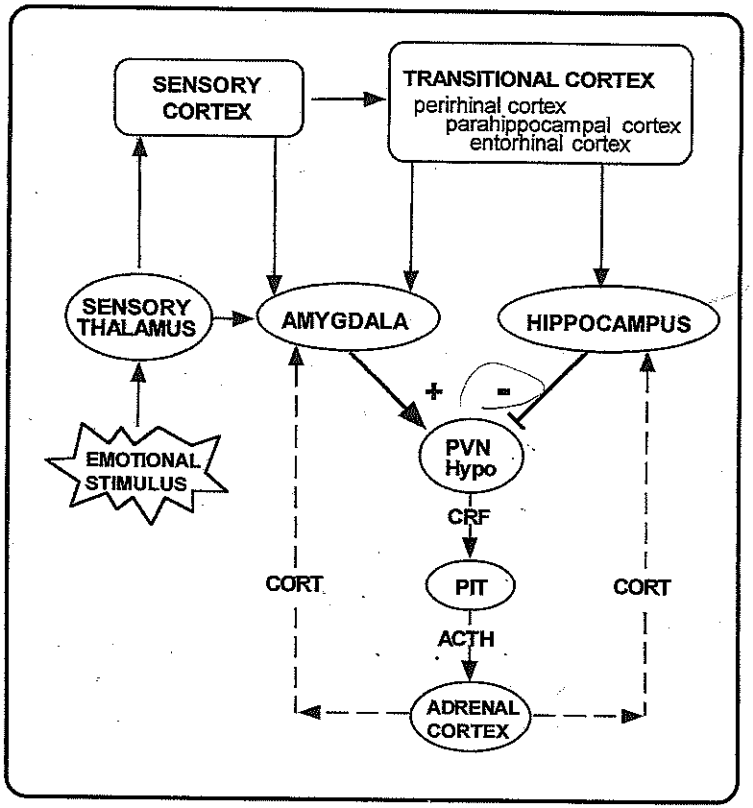

FIGURE 8-1
Stress Pathways.

Stimuli associated with danger activate the amygdala. By way of pathways from the amygdala to the paraventricular nucleus of the hypothalamus (PVN Hypo), corticotrophin-releasing factor (CRF) is sent to the pituitary gland, which, in turn, releases adrenocorticotropic hormone (ACTH) into the bloodstream. ACTH then acts on the adrenal cortex, causing it to release steroid hormones (CORT) into the bloodstream. CORT freely travels from the blood into the brain, where it binds to specialized receptors on neurons in regions of the hippocampus and amygdala, as well as other regions. Through the hippocampus, CORT inhibits the further release of CRF from the PVN. However, as long as the emotional stimulus is present, the amygdala will attempt to cause PVN to release CRF. The balance between the excitatory inputs (+) from the amygdala and the inhibitory inputs (-) from the hippocampus to PVN determines how much CRF, ACTH, and ultimately CORT will be released.

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ng events that happen after the memory is established, or to cre-
rom scratch a memory of an experience that never happened.
subjects in these studies fully believe their memories, but be-
e they have occurred in controlled laboratory experiments it is
ible to show that the memory is fabricated. At the same time,
e are also carefully controlled laboratory studies showing that in-
nation that was initially processed consciously and stored, but
r forgotten, can be brought back, a phenomenon called hyperme-
that we looked at in Chapter 3.[56]

The only thing that is clear about memory recovery in real life is
t there is no way for outsiders to definitely determine whether a
rticular memory is real or fabricated in the absence of solid cor-
borating evidence (fabrication does not imply that the person is ly-
g, only that the memory is false). There are surely victims of
rrible incidents who have lost their memory of the event, and there
ay be some who can later piece together a memory of what hap-
ened. However, distinguishing between fabricated and real memo-
es simply on the basis of self-knowledge can be tricky. Salvador Dali
nce said, "The difference between false memories and true ones is
he same as for jewels: it is always the false ones that look the most
eal, the most brilliant."[57] Whether he was right might be debated,
ut as we saw earlier (Chapters 2 and 3), introspective knowledge of
hought processes provides a highly inaccurate window into the
mind, even in mundane (nontraumatic) situations. Things are likely
to be even worse when confusion abounds, as it must during and fol-
lowing trauma. The waters of memory recovery are treacherous and
should be walked through very carefully.

As far as is known, stress does not interfere with the workings of
the amygdala, and, as we'll see below, stress may even enhance amyg-
dala functions. It is thus completely possible that one might have
poor conscious memory of a traumatic experience, but at the same
time form very powerful implicit, unconscious emotional memories
through amygdala-mediated fear conditioning. And because of other
effects of stress to be described below, these potent unconscious
fears can become very resistant to extinction. They can, in other
words, become unconscious sources of intense anxiety that poten-
tially exert their opaque and perverse influences throughout life.
However, there is no way for these powerful implicit memories to

then be converted into explicit memories. Again, if a conscious memory wasn't formed, it can't be recovered.

That Freud was correct in his belief that aspects of traumatic experiences are sometimes stored in memory systems that are not directly accessible from consciousness seems clear. Less certain is whether repression (in the Freudian sense) is involved. The failure to remember traumatic events may sometimes be due to a stress-induced shutdown of the hippocampus, although this remains to be proven. In light of this, though, there is nothing particularly devastating to the conditioning theory of anxiety about the fact that the traumatic origin of the anxiety is not always remembered. Of course, repression of unpleasant experience may well be a real phenomenon, one that we still don't understand scientifically. And some anxiety disorders may develop without an initial trauma. Nevertheless, we at least have a possible mechanism that might account for some aspects of these disorders in easily understood biological terms.

Amplification of Emotional Memory by Irrelevant Stressors: There is a flip side to the debilitating effects of intense stress on explicit conscious memory of trauma. The same amount of stress that can lead to an amnesia for a trauma may amplify implicit or unconscious memories that are formed during the traumatic event.

For example, recent studies have shown that if rats are given injections of adrenal steroids at levels that mimic very severe stress, there is a dramatic decrease in the amount of a certain chemical, called corticotropin-releasing factor (CRF), in the part of the hypothalamus that controls the release of the stress hormone, ACTH, from the pituitary gland.[58] CRF is in fact the neurotransmitter that stimulates ACTH release. The decrease in CRF in this pathway reflects the negative feedback control over stress hormones by the hippocampus—once the blood level of adrenal steroids reaches a certain level, the hippocampus tells the hypothalamus to slow down the secretions. And when the steroid level reaches a critical point, the hippocampal circuits begin to falter. In stark contrast, there is a dramatic increase in CRF in the central nucleus of the amygdala under the same conditions—as blood levels of steroids increase, the amygdala may keep getting more and more active. The bottom line is

that the effects of stress on the amygdala seem very different from the effects on the hippocampal-hypothalamic circuit.

On the basis of these observations, Keith Corodimas, Jay Schulkin, and I predicted that during intense stress the learning and memory processes mediated by the amygdala might be facilitated and we examined the effects of stress hormone overload on conditioned fear behavior.[59] In line with the prediction, we found that the strength of learned fear was increased in the steroid-treated rats relative to other rats that didn't have the steroids. Although this result is somewhat preliminary, studies using other forms of Pavlovian conditioning have also found that stress enhances conditioned responses.[60]

If indeed the hippocampus is impaired and the amygdala facilitated by stress, it would suggest the possibility that stress shifts us into a mode of operation in which we react to danger rather than think about it. It's not clear whether this is a specific adaptation or whether we're just lucky that when the higher functions break down our fallback position is one in which we can let evolution do the thinking for us.

The finding that stress hormones can amplify conditioned fear responses has an important implication for our understanding of anxiety disorders, and in particular for understanding why these sometimes seem to occur or get worse after unrelated stressful events.[61] During stress, weak conditioned fear responses may become stronger. The responses could be weak either because they were weakly conditioned, or because they were previously extinguished or were otherwise treated into remission. Either way, their strength might be increased by stress. For example, a snake phobic might be in remission for years but upon the death of his spouse the phobia returns. Alternatively, a mild fear of heights, one that causes few problems in everyday life, might be converted into a pathological fear under the amplifying influences of stress. The stress is unrelated to the disorder that develops and is instead a condition that lowers the threshold for an anxiety disorder, making the individual vulnerable to anxiety, but not dictating the nature of the disorder that will emerge. The latter is probably determined by the kinds of fears and other vulnerabilities that the person has lurking inside.

Brain Malfunctions Can Make Unprepared Learning Resistant to Extinction: Neurotic fears are notoriously difficult to shake. This is the bane of a therapist's professional existence, but also his or her bread and butter. While preparedness provides one way out of this dilemma, there is another. Fear responses conditioned to arbitrary tones or lights in rats can be made highly resistant to extinction if certain cortical areas that project to the amygdala are damaged. This suggests that these areas of the cortex may be malfunctioning in some cases of pathogenic anxiety, allowing ordinary stimuli to be conditioned by the amygdala in a way that resists extinction.

Several years ago we were examining the effects of damage to visual areas of the cortex on the ability of rats to be conditioned to visual stimuli.[62] The lesioned rats learned just fine, supporting our contention that there are subcortical pathways that take sensory information to the amygdala during conditioning. But when we tried to extinguish the fear responses in these animals, something unusual happened. We couldn't do it. Normal rats, after several days of seeing the light without the shock, stopped acting afraid in the presence of the light. But the rats with lesions of the visual cortex were like Energizer batteries—they just kept going and going and going.

We never thought that the visual cortex was the seat of extinction. Instead, we proposed that the visual cortex might be a necessary link between the visual world and other higher order cortical areas that are necessary for extinction. One area that seemed like a possible regulator of extinction was the medial prefrontal cortex. This area receives signals from the sensory regions of the cortex and from the amygdala, and sends connections back to the amygdala, as well as to many of the areas to which the amygdala projects.[63] The medial prefrontal cortex is thus nicely situated to be able to regulate the outputs of the amygdala on the basis of events in the outside world as well as on the basis of the amygdala's interpretation of those events. When Maria Morgan made lesions of this region, rats continued to act fearful in the presence of a conditioned fear stimulus long after rats without lesions of this area had stopped acting afraid.[64]

The amygdala of the cortically lesioned rat, like the neurotic human, stubbornly expresses its fear memories in the face of information showing that the stimulus is no longer associated with danger. Extinction appears to involve the cortical regulation over the amygdala, and even unprepared conditioned fear can be resistant to extinction when the amygdala is freed from these cortical controls.

One of the hallmarks of frontal lobe damage in humans is perseveration, the inability to stop doing something once it is no longer appropriate.[65] For example, when frontal lobe patients are performing a task in which a rule must be followed, they have great difficulty in changing their behavior when the rule is switched. In a standard version of this test, the patient is given a stack of cards, each with one or more colored symbols on it. The patient's job is to figure out, on the basis of feedback about whether each response is correct, which kind of cue (color, shape, or number) is the current solution. Once they get going on a principle (like shape) they can do the task fine. But if all of a sudden the principle shifts (say, to color), they keep following the old rule. Sometimes they even know what they should do, but can't make their behavior match their knowledge. They are rigid and inflexible, and perseverate in their ways, even when it is obvious that the behavior is not appropriate to the situation. This seems to characterize their behavior in real life as well.

Although perseveration is usually thought of as a cognitive or thought disorder, it seems that our findings about fear extinction in rats with prefrontal lesions might reflect the same kind of difficulty, but in the domain of emotion. In fact, we used the expression "emotional perseveration" to describe the failure of our rats to extinguish conditioned fear responses.[66] While cognitive perseveration is produced by damage to the lateral areas of the prefrontal cortex, emotional perseveration resulted from damage to a small part of the medial prefrontal region.[67] The lateral and medial prefrontal areas may perform the same operation, adapting behavior to changing conditions, with the involvement in cognitive or emotional functions determined by the areas with which the prefrontal region works in conjunction. The medial cortex, in other words, engages in response switching behavior because it is part of the prefrontal cortex, and it engages in response switching guided by emotional information because it is connected with the amygdala. Edmund Rolls has proposed a similar role for the medial prefrontal cortex in emotion on the basis of studies in which he has recorded from neurons in this region while monkeys performed tasks where the reinforcer (reward or punishment) associated with certain responses changed frequently.[68] Other

ideas about the contribution of prefrontal cortex to emotion have been proposed as well, and the work of Antonio Damasio is particularly notable.[69] Some of these ideas will be considered in the next chapter on emotional consciousness.

The prefrontal cortex, like the hippocampus, may be altered by stress. Recent research has shown that the prefrontal cortex, like the hippocampus, offers a counterforce that keeps too much of the stress hormones from being released.[70] Since prolonged stress results in a breakdown in this negative feedback control function, it may be the case that both the prefrontal cortex and hippocampus are adversely affected. A stress-induced shutdown of the prefrontal cortex might release the brakes on the amygdala, making new learning stronger and more resistant to extinction, and possibly allowing previously extinguished conditioned fears to be expressed anew.

Just because clinical fear is difficult to extinguish does not mean that it involves a different brain system from the one that mediates extinguishable conditioned fears in animals. Differences in the ease of extinction of conditioned fear in laboratory experiments and in anxious persons are more likely to reflect differences in the way the fear system works in normal and anxious brains rather than differences in the system used by the brain to learn conditioned fear and clinical anxiety. This doesn't mean that anxious persons, like our rats, are walking around with holes in their prefrontal cortex. There are many subtle ways in which disruptions in electrical and chemical functions can adversely affect a brain region, with lesions being just an extreme example of this.

Gone but Not Forgotten—The Indelibility of Emotional Memory: Our finding that when the medial prefrontal cortex is damaged routine fear conditioning becomes resistant to extinction has another important implication. It also suggests that extinction prevents the expression of conditioned fear responses but does not erase the implicit memories that underlie these responses.[71] Extinction, in other words, involves the cortical control over the amygdala's output rather than a wiping clean of the amygdala's memory slate.

The idea that extinction does not involve the erasure of emotional memories but instead prevents their expression is consistent with a number of findings about conditioned responses.[72] Pavlov, for example, found that extinguished responses would, with simply the passage of time, *spontaneously recover.* It is also known that if a rat is conditioned by pairing a tone and shock in one box, and the fear response elicited by the tone is completely extinguished in another box, the conditioned response elicited by the tone will be *renewed* if the rat is returned to the original training box. An extinguished response can also be *reinstated* by giving the rat an exposure to the US or, importantly, to other forms of stressful stimulation. Stress, in other words, can bring back extinguished, or perhaps weakly established but unextinguished, conditioned responses.[73] Each of these examples, like our lesion study, demonstrates that emotional memories are not erased by extinction but are simply held in check. Extinguished memories, like Lazarus, can be called back to life.

I recently had a scientific "ah ha" experience, one of those rare, wonderful moments when a new set of findings from the lab suddenly makes you see something puzzling in a new, crystal clear way. The studies involved recordings of electrical activity of the amygdala before and after fear conditioning by Greg Quirk, Chris Repa, and me.[74] We found dramatic increases in electrical responses elicited by the tone CS after conditioning, and these increases were reversed by extinction. However, because we were recording from multiple individual neurons at the same time, we were also able to look at the activity relationships between the cells. Conditioning increased the functional interactions between neurons so that the likelihood that two cells would fire at the same time dramatically increased. These interactions were seen both in the response to the stimulus and in the spontaneous firing of the cells when nothing in particular was going on. What was most interesting was that in some of the cells, these functional interactions were not reversed by extinction. Conditioning appears to have created what Donald Hebb called "cell assemblies,"[75] and some of these seemed to be resistant to extinction. Although the tone was no longer causing the cells to fire (they had extinguished), the functional interactions between the cells, as seen in their spontaneous firings, remained. It is as if these functional couplings are holding the memory even at a time when the external triggers of the memory (for example, phobic stimuli) are no longer effective in activating the memory and its associated behaviors (for example, phobic responses). Although highly speculative at this point, the observa-

tions suggest clues as to how memories can live in the brain at a time when they are not accessible by external stimuli (Figure 8-3). All that it would take to reactivate those memories would be a change in the strength of the input to the cell assembly. This may be something that stress can accomplish.

Unconscious fear memories established through the amygdala appear to be indelibly burned into the brain. They are probably with us for life. This is often very useful, especially in a stable, unchanging world, since we don't want to have to learn about the same kinds of dangers over and over again. But the downside is that sometimes the things that are imprinted in the amygdala's circuits are maladaptive. In these instances, we pay dearly for the incredible efficiencies of the fear system.

Psychiatrist Roger Pitman has astutely noted that findings from studies of fear conditioning in rats have important implications for how anxiety is treated.[76] The classic treatment, based on Mowrer's and Miller's theory, was to force the patient to be exposed to the anxiety-causing stimuli without allowing any avoidance or escape behavior and thereby try to extinguish the anxiety that the stimuli elicit. But in light of the indelibility of the amygdala's hold on traumatic memories, he suggests a bleaker, though perhaps more realistic, assessment. We may not be able to get rid of the implicit memories that underlie anxiety disorders. If this is the case, the best we can hope for is to exercise control over them.

The Fear System and Specific Anxiety Disorders

Until fairly recently, the various anxiety disorders were not distinguished and were not treated differently.[77] Panic and PTSD, for example, did not appear in the DSM until 1980. And although phobias have long been associated with neuroses, they were typically thought of as neurotic symptoms rather than a particular kind of anxiety disorder. With the emergence of clear diagnostic distinctions between different anxiety disorders, disorder-specific fear conditioning theories have been proposed. Below, I'll attempt to buttress disorder-specific theories of phobias, PTSD, and panic with findings about the brain mechanisms of fear conditioning.[78]

- You *can't* have a complete feeling of fear without the activation of the amygdala. In the presence of a fear-arousing stimulus, and the absence of amygdala activation (for example, if your amygdala were damaged), you might use your cognitive powers to conclude that in situations like this you usually feel "fearful," but the fearful feelings would be lacking because of the importance of amygdala inputs to working memory, of amygdala-triggered arousal, and of amygdala-mediated bodily responses that produce feedback. Cognitive mechanisms, like "as-if" loops, might compensate to some extent, but they can't fully.[76]
- You *can't* have a sustained feeling of fear without the activation of arousal systems. These play an essential role in keeping conscious attention directed toward the emotional situation, and without their involvement emotional states would be fleeting. You might be temporarily aroused but your emotion would dissipate as soon as it occurred. Although all novel stimuli activate arousal systems, particularly important to the persistence of emotional responses and emotional feelings is the activation of arousal systems by the amygdala. Amygdala-triggered arousal not only arouses the cortex but also arouses the amygdala, causing the latter to continue to activate the arousal systems, creating the vicious cycles of emotional arousal.
- You *can't* have a sustained emotional experience without feedback from the body or without at least long-term memories that allow the creation of "as-if" feedback. But even "as-if" feedback has to be taught by real-life feedback. The body is crucial to an emotional experience, either because it provides sensations that make an emotion feel a certain way right now or because it once provided the sensations that created memories of what specific emotions felt like in the past.
- You probably *can* have an emotional feeling without the direct projections to the cortex from the amygdala. These help working memory know which specialized emotion system is active, but this can be figured out indirectly. Nevertheless, the emotion will be different in the absence of this input than in its presence.
- You *can* have an emotional feeling without being conscious of the eliciting stimulus—without the actual eliciting stimulus being represented in a short-term cortical buffer and held in working memory. As we saw in Chapter 3, stimuli that are not noticed, or that are noticed but their implications aren't, can unconsciously trigger emotional behaviors and visceral responses. In such situations, the stimulus content of working memory will be amplified by the arousal and feedback that result, causing you to attribute the arousal and bodily feelings to the stimuli that are present in working memory. However, because the stimuli in working memory did not trigger the amygdala, the situation will be misdiagnosed (recall Schachter and Singer's subjects who were artificially aroused and who misattributed their arousal to their surroundings). And if there is nothing particular occupying working memory, you will be in a situation where your feelings are not understood. If emotions are triggered by stimuli that are processed unconsciously, you will not be able to later reflect back on those experiences and explain why they occurred with any degree of accuracy. Contrary to the primary supposition of cognitive appraisal theories, the core of an emotion is not an introspectively accessible conscious representation. Feelings do involve conscious content, but we don't necessarily have conscious access to the processes that produce the content. And even when we do have introspective access, the conscious content is not likely to be what triggered the emotional responses in the first place. The emotional responses and the conscious content are both products of specialized emotion systems that operate unconsciously.

What's Different About Thoughts and Feelings?

Conscious emotional feelings and conscious thoughts are in some sense very similar. They both involve the symbolic representation in working memory of subsymbolic processes carried out by systems that work unconsciously. The difference between them is not due to the system that does the consciousness part but instead is due to two other factors. One is that emotional feelings and mere thoughts are generated by different subsymbolic systems. The other is that emotional feelings involve many more brain systems than thoughts.

When we are in the throes of emotion, it is because something important, perhaps life threatening, is occurring, and much of the brain's resources are brought to bear on the problem. Emotions create a flurry of activity all devoted to one goal. Thoughts, unless they trigger emotional systems, don't do this. We can daydream while doing other things, like reading or eating, and go back and forth between the daydream and the other activities. But when faced with danger or other challenging emotional situations, we don't have time to kill nor do we have spare mental resources. The whole self gets absorbed in the emotion. As Klaus Scherer has argued, emotions cause a mobilization and synchronization of the brain's activities.[77]

Do Fish Have Feelings Too?

Philosophers have something called "the problem of other minds." In simple terms, it is the difficulty, if not the impossibility, of proving that anyone, other than oneself, is conscious. This is an onerous problem that applies both to the minds of other humans and other animals. We are somewhat better off in the case of other humans than other animals though. Depending on how strict we are (philosophically), we can usually convince ourselves that most other humans have emotional feelings and other conscious states of mind because we can talk to them and compare notes about our mental experiences with them—this is one of the beauties of having natural language. We may not be completely justified philosophically in our conclusion that other people are conscious, but from a practical point of view it is useful to live our lives in violation of philosophical certainty and treat others as if they are conscious. Fortunately, though, there is another reason to adopt the belief that other humans are conscious. Since all humans have pretty much the same kind of brain architecture we can assume that, barring pathological conditions, the same general kinds of functions come out of all human brains—if I'm conscious and you have the same kind of brain that I do, then you are probably conscious as well. This kind of reasoning holds for brain functions that we know something about (like perception and memory), so we might reasonably expect it to also hold for conscious awareness.

But no matter how firm or flimsy the arguments about consciousness in other humans are, when it comes to making the leap to the minds of other animals, we are on considerably shakier ground. Our ability to hold conversations with other animals is somewhere between not at all and not much.[78] And while our brain is, in many ways, incredibly similar to the brains of other creatures (this is what makes much of brain research possible), it also differs in some important ways. The human brain, most especially the cerebral cortex, is much larger than it should be, given our body size.[79] This alone would give us reason to be cautious about attributing consciousness to other animals. However, there are other facts to take into account. First, as we've seen, the part of the human cortex that has increased in size the most is the prefrontal cortex,[80] which is the part of the brain that has been implicated in working memory, the gateway to consciousness. Some brain scientists believe that this part of the cortex doesn't even exist except in primates.[81] And there is behavioral evidence that only the higher primates, in whom the prefrontal cortex is especially well developed, are self-aware, as determined by their ability to recognize themselves in a mirror.[82] Second, natural language only exists in the human brain.[83] Although the exact nature of the brain specialization involved in making language possible is not fully understood, something changed with the evolution of the human brain to make language happen. Not surprisingly, the development of language has often been said to be the key to human consciousness.[84] Clearly, the human brain is sufficiently different from the brains of other animals to give us reasons for being very cautious about attributing consciousness beyond our species. As a result, the arguments that allow us to say with some degree of confidence that other humans have conscious states do not allow us to insert consciousness into the mental life of most other animals.

My idea about consciousness in other animals is this. Consciousness is something that happened after the cortex expanded in mammals. It requires the capacity to relate several things at once (for example, the way a stimulus looks, memories of past experiences with that stimulus or related stimuli, a conception of the self as the experiencer).[85] A brain that cannot form these relations, due to the absence of a cortical system that can put all of the information together at the same time, cannot be conscious. Consciousness, so defined, is

undoubtedly present in humans. To the extent that other animals have the capacity to hold and manipulate information in a generalized mental workspace, they probably also have the potential capacity to be conscious. This formulation allows the possibility that some other mammals, especially (but not exclusively) some other primates, are conscious. However, in humans, the presence of natural language alters the brain significantly. Often we categorize and label our experiences in linguistic terms, and store the experiences in ways that can be accessed linguistically. Whatever consciousness exists outside of humans is likely to be very different from the kind of consciousness that we have.

The bottom line is this. Human consciousness is the way it is because of the way our brain is. Other animals may also be conscious in their own special way due to the way their brains are. And still others are probably not conscious at all, again due to the kinds of brains they have. At the same time, though, consciousness is neither the prerequisite to nor the same thing as the capacity to think and reason. An animal can solve lots of problems without being overtly conscious of what it is doing and why it is doing it. Obviously, consciousness elevates thinking to a new level, but it isn't the same thing as thinking.

Emotional feelings result when we become consciously aware that an emotion system of the brain is active. Any organism that has consciousness also has feelings. However, feelings will be different in a brain that can classify the world linguistically and categorize experiences in words than in a brain that cannot. The difference between fear, anxiety, terror, apprehension, and the like would not be possible without language. At the same time, none of these words would have any point if it were not for the existence of an underlying emotion system that generates the brain states and bodily expressions to which these words apply. Emotions evolved not as conscious feelings, linguistically differentiated or otherwise, but as brain states and bodily responses. The brain states and bodily responses are the fundamental facts of an emotion, and the conscious feelings are the frills that have added icing to the emotional cake.

Qué Será Será

Where is evolution taking our brain? While it is true that whatever will be will be, we have the opportunity to take a peek at what evolution is up to. It's not that evolution is forward thinking. It only has hindsight.[86] However, we *are* evolution in progress and we can see what sorts of changes might be happening in our brain by looking at trends in brain evolution across related species.

As things now stand, the amygdala has a greater influence on the cortex than the cortex has on the amygdala, allowing emotional arousal to dominate and control thinking. Throughout the mammals, pathways from the amygdala to the cortex overshadow the pathways from the cortex to the amygdala. Although thoughts can easily trigger emotions (by activating the amygdala), we are not very effective at willfully turning off emotions (by deactivating the amygdala). Telling yourself that you should not be anxious or depressed does not help much.

At the same time, it is apparent that the cortical connections with the amygdala are far greater in primates than in other mammals. This suggests the possibility that as these connections continue to expand, the cortex might gain more and more control over the amygdala, possibly allowing future humans to be better able to control their emotions.

Yet, there is another possibility. The increased connectivity between the amygdala and cortex involves fibers going from the cortex to the amygdala as well as from the amygdala to the cortex. If these nerve pathways strike a balance, it is possible that the struggle between thought and emotion may ultimately be resolved not by the dominance of emotional centers by cortical cognitions, but by a more harmonious integration of reason and passion. With increased connectivity between the cortex and amygdala, cognition and emotion might begin to work together rather than separately.

Oscar Wilde once said, "It is because Humanity has never known where it was going that it has been able to find its way."[87] But wouldn't it be wonderful if we did understand where our emotions were taking us from moment to moment, day to day, and year to year, and why? If the trends toward cognitive-emotional connectivity in the brain are any indication, our brains may, in fact, be moving in this direction.