Finding the Freedom, Finding the Joy
Emotion and Progress Toward Mind

The joy of learning is as indispensable in study as breathing is in running.

—Simone Weil

One of my colleagues had to miss his class, so he asked me to fill in for him. Without much thought, I agreed. All I had to do was explain one of the methods I used in my research. It would be a snap.

But when I sat down to plan the class, I began to get nervous. I realized that, although I used that method almost every day, my actual understanding of it was shallow. I understood the ideas, but not the theory. There were equations for predicting the outcome of experiments, but I didn’t actually know where those equations came from. Did I dare just present the equations to the students without actually explaining them? More to the point, would I be happy doing that?

I decided that I would have to work through the theory.

I will never forget that evening in the library. I found some books that I hoped would be helpful, but they weren’t. I began to think things through starting from the beginning, which is where my students would start!

As I worked, I found my insecurity being replaced with some confidence. But progress was slow, and I began to worry that I had started preparing too late. Maybe I would have to work through the night. Maybe I wouldn’t get it done by the time the class met!

Then I recognized a key point. I wrote down the steps that had led to that point and began to feel exhilarated. Yes! This would work. My
students would be able to start at the very beginning, with things they already knew, and I could lead them to the answers from there. That was exciting, but my exhilaration did not come from this realization. Rather, it came from the excitement of actually understanding things myself! I felt a surge of power and control over this little tiny bit of the world, and I had reached those feelings through my own work—not simply by being told!

No one could duplicate that feeling of excitement by leading me along; it was all mine. I had escaped dependency. I was free!

In addition to action, I frequently mentioned feelings and emotion in chapter 2. Very early in our journey we begin to feel the excitement and joy of discovery. We look forward to exploration. The imitative sensory-motor actions of chapter 2 are also driven by emotion. Emotion impels action. In fact, emotion itself has been defined as a “tendency to act.” In Slaughterhouse-Five, when Billy Pilgrim says, “Everybody has to do exactly what he does,” it seems likely that he is referring to the underlying emotion and feelings that drive us to all our actions. Our emotions tell us what we “have to do.” Learning takes place through action, but it is driven by emotion.

The story above is an example of this from my own life. I had never consciously recognized the freedom that understanding brings. But this particular experience was so powerful that it worked its way through all of my mind’s cognitive layers and broke into the sunshine of my own awareness. I was joyful!

Keeping the Joy

Joy is an integral part of any learning experience. It is what keeps us going on our journey. We discuss some of those pleasures in following chapters, but I want to introduce this subject now because this joy is what drives everything discussed in those chapters. Virtually from the beginning, the journey—the education—has the potential to be joyful.

Notice that I say, “has the potential.” However, as we move into more formal educational environments, we can begin to lose the joy. We start to feel pressure to “learn.” Everyone feels it: students, teachers, administrators,
and even parents can become anxious and frustrated. Everything is tested, and if the results don’t meet expectations, we may become fearful or angry. We lose track of the journey and begin to focus more and more on the destination. We develop negative ideas about learning and studying. We forget that the joy is an essential part of the learning—the development of mind.

This loss may not be irreversible. We may regain the joy later in life when we become engaged in a profession, hobby, or some other challenge of our own making. When schooling is finished, we may begin to search, and often find, what we enjoy. But for many, the joy never returns.

The Price of the Loss

There is a serious price to pay for losing the joy; it has a profound impact. Dissatisfaction extends from the sense of loss itself to frustration and anger. Ultimately, we may begin to encounter difficulties with student behaviors in school settings. This can happen at all levels, even in graduate and professional schools. In the worst cases, teaching becomes policing and punishing in an effort to control behaviors, or to persuade students to do assignments. It can be a daily and debilitating struggle; often, just keeping order becomes the main goal and the measure of success of each day. The positive feelings I described in my story seem distant from the reality of daily experience in school.

To emphasize the point, we return to Billy Pilgrim. Students will just keep doing what they “have to do.” So will teachers, administrators, and parents. That being the case, the challenge is to arrange things so that more of us “have to” experience satisfaction and freedom in our learning. We are searching for environments, activities, and techniques that naturally generate positive feelings and that automatically lead students to say, “I have to learn.”

Somatic Markers

One way to think about this challenge is provided by Antonio Damasio, who has written extensively about the brain, emotion, and consciousness. He divides feelings into three categories: primary feelings (Darwin’s six universal expressions—fear, anger, sorrow, disgust, surprise, happiness); secondary feelings (a wide range of complex social feelings); and background feelings
(feelings of bodily state). Primary and secondary feelings are strong, and we are generally conscious of them, although that consciousness may not be expressed in language or specific images. Nonetheless, when asked, we have little difficulty in recognizing that we are angry or happy (for example).

Damasio argues that these strong responses are linked to consciousness. The primary and secondary feelings reach our awareness exactly because they are strong. As Damasio says, “In organisms equipped to sense emotions, that is, to have feelings, emotions also have an impact on the mind, as they occur, in the here and now.” He continues: “Consciousness allows feelings to be known . . . and allows emotion to permeate the thought process, through the agency of feeling.”

What about the third category, “background feelings”?

The proposal is that these feelings are always present. They go with experiences of the moment. For example, we may feel mildly energized but still relaxed as we look out a window on a snowy winter afternoon. Or we may feel a bit uneasy as we leave the house, unconsciously leaving our keys behind. Damasio calls feelings such as these “somatic markers.” They are the low-intensity feelings in the body (the somatic) that accompany particular experiences. We may be unaware of them, but as the term says, those feelings are body (somatic) labels (markers) for moment-to-moment experience. They are in the background; some might say they are intuitions, or that they lead to intuitions. To identify them we have to make an effort; we have to pay attention. The primary emotions reveal themselves, but we have to look for the somatic markers.

It makes great biological sense to believe in somatic markers. If a primary emotion such as fear is marked by the feelings associated with elevated levels of stress hormones in the body (sweating, increased heart rate), it is no great leap to believe that a complicated mix of small amounts of emotion chemicals—for example, adrenalin and dopamine—will produce lower-level feelings in the body. An example might be a touch of fear mixed in with a bit of pleasure. That chemical process will lead to complex body responses that we sense and that “mark” the experience. For example, right now I am aware of a body response as I type quickly to capture a pleasing idea in words, before I forget it! This complicated feeling is a mix of small amounts of excitement, joy, fear, and anxiety, all produced by an ill-defined mix of small amounts of stress hormones and reward hormones.
I might not put a conscious label on this body feeling, but I still type quickly.

Feelings, Consciousness, and Reasoning

We might argue that we always have such background feelings; they come with everything we do. And if we can become conscious of them, they might be of value in reasoning and problem solving. Furthermore, if recognizing our background feelings improves problem solving, this will lead to the types of positive feelings I described in my story at the beginning of this chapter.

Damasio places feelings at the interface between the conscious and unconscious aspects of mind. Strong feelings can demand our attention, thus producing consciousness. In turn, consciousness can illuminate feelings. When that occurs, we may be better able to apply what Damasio calls “high reason,” which involves the pursuit of wise application of our energies in solving problems and making plans. When that occurs, it leads to action—responses to problems, which we call behavior.

This line of thought suggests that reasoning can alter feelings and seems to contradict the notion that we cannot control how we feel. However, both are true. Our emotional responses of the moment are difficult to control or even predict. They arise in the experience. But if we improve our ability to consciously identify and think about those feelings, we may gain more control than we expect. If we get to the feelings before they drive us to action—that is, if we discover our own feelings and understand their origins—our actions may be greatly modified. By understanding feelings, we open the path to “high reason” and the most effective action.

The most effective education.

In the Here and Now

The quotations above contain the phrase, “emotions have an impact on the mind, as they occur in the here and now.” This raises an issue that came up in my earlier work. I divided back cortex and front cortex in the dimension of time: back cortex is about the past, and front cortex is about the future. This is not to suggest a sharp boundary, or any lack of communication between back and front, but rather an overall functional outcome of these regions of cortex. My point here is that this earlier perspective is enhanced
by thinking of the time implications. In particular it makes us wonder about the "here and now," the present.

When one puts things in terms of synapses and neuronal wiring, the present hardly exists. There is only past (memory) and future (planning). The present is simply represented as the interface between them. Even as you read, you are moving across that interface. The words to come next are in the future, and once you have read them they are in the past. In neuronal terms, the present exists only for some milliseconds, which is the order of magnitude for the time required when signals pass from one group of neurons (for example, sensory) to another group (for example, motor.)

When we realize that human experience is about more than just networks of neurons, that is, it also includes the emotion systems, we can see another perspective on this issue of the "present." Perhaps the best way to perceive and define the present is through our feelings; maybe it is the only way. Often, our feelings last much longer than the time required for synapses to fire. This is not always true, as I discuss below with regard to rapid responses to threats mediated by the amygdala. But the firing of neuronal pathways via existing synapses and the impact of dopamine or adrenalin through modulation of those synapses are distinct from one another. They work through different physical mechanisms. Synapse firing is a fast transfer of electrical energy directly from one neuron to another, while modulation of the synapses proceeds through much slower processes of chemical secretion and diffusion. To see this difference, think of the electrical event at the synapse as the passage of a spark from one wire to another, while the impact of the emotion chemicals is more like pouring heavy cream into your coffee.

Thus, we experience emotion in our bodies through the surge of a feeling and its slow dissipation over a period of seconds to minutes. So, if someone asks me how I feel, they use the present tense: "How am I at the moment?" Although I may embellish and modify my reply to include how I felt before this moment, or how I want to feel in the future, I still refer to the present when I try to produce the most accurate response to the question.

The neuroscience basis for this is that feelings are caused by changes in the chemical environment of neurons and neuron-muscular connections. For example, feelings of tension and preparation for aggression arise in our body when adrenalin increases in the bloodstream. But it takes a little time for the adrenalin to reach the places in the body where actions are exerted; it takes time for the feelings to change. Dissipation of our fear does not happen
instantly. This is part of the reason we put the emotion chemicals in a category called “slow neurotransmitters.” Given the longer time it takes for these emotion chemicals to act in our body and our brain, the sense of the “present” becomes more meaningful.

Amygdala

We are going to begin the biological discussion of positive emotion by looking at a brain structure that is actually associated with negative emotion, the amygdala. We will gain insight into positive emotion by analyzing brain aspects of negative emotion.

The amygdala processes sensory information and takes part in judging whether it represents a possible threat to survival. Below is a figure that outlines how this information flows. Sensory data are channeled first to a structure called the thalamus. They then split into two pathways.

In one pathway, a small amount of the data goes directly to the amygdala. It is then passed directly to the brain stem and then out to the muscles of the body, generating rapid but crude actions somewhat like reflexes. This has been called the “lower pathway” because the amygdala is known to be older (evolutionarily) than the cortex, and thus has more direct but less refined actions. It is crude, hence low.

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\text{Cortex} \Rightarrow \text{Amygdala} \Rightarrow \text{Action}
\]

\[
\text{Sensory event} \Rightarrow \text{Thalamus} \Rightarrow \text{Amygdala} \Rightarrow \text{Action}
\]

In the upper but less direct route, sensory data flow from the thalamus to the cortex before reaching the amygdala. In this path, both short-term and long-term memory systems of the brain are engaged. Since the cortex is part of this pathway, it is thought of as the “higher” path, a path involving Damasio’s “high reason.” The involvement of the cortex draws in more complex and potentially modulating data and memories, which allows for a less reflexive and slower response to the sensory data, and a deeper understanding of its significance and meaning. The upper route has the potential
to bring emotions into new experience, and those emotions allow us to judge the experience and to analyze whether it is truly dangerous, or whether it might in fact have positive implications.

This amygdala-cortex complex is one place in the brain where emotion and cognition both enter into our understanding of experience, and our judgments of actions that are appropriate and helpful. In this way, the amygdala can be a part of positive emotion.

The Lower Pathway

The small amount of initial information that skips the cortex, reaching the amygdala directly, has a very rapid impact. It goes to the brain stem and the hypothalamus, both of which send direct signals to the body. The brain stem sends electrical signals through the spinal column to the muscles, producing almost instantaneous behaviors such as the "startle reflex," which manifests itself in humans by jumping back, ducking, or freezing. The hypothalamus responds by secreting chemicals into the bloodstream, and those chemicals trigger more slowly developing yet powerful feelings throughout the body. We begin to feel fearful, sick, angry, embarrassed, or other powerful negative body responses to this brain activity.

The increased activity of the amygdala can be produced not only by the specific negative stimuli, but also by the environment in which those stimuli have been experienced. For example, mice that learn to respond to a tone or a light by associating it with an electrical shock give the same response when simply placed in the cage that is used for such experiments.

We know from our own experience that people are the same. Some students (we hope not many) freeze in fear when they find themselves in the "cage" used for our experiments in education: the classroom.

A Positive Perspective of the Negative

But back to joy. The upper pathway can lead to cognitive analysis of experiences that initially seem dangerous, but actually turn out to be harmless or even healthy and helpful. This can be the outcome when we engage the cerebral cortex because it has the power to provide more accurate and deeper understandings of experience.
Another way to include the amygdala in this story is more direct. We can think of joy as the opposite of fear; if fear is negative, joy is positive. The amygdala also responds to positive stimuli, the only difference being that this kind of response is a reduction in activity. For example, when people look at happy faces, their amygdala becomes less active. Emotion can always be thought of in this way. Less fear means more happiness, and vice versa. The amygdala is like a thermometer, responding to both heat and cold. Thus both negative emotion and positive emotion have an impact on the amygdala. "Normal" is somewhere in the middle.

The action output of the amygdala triggered through the lower pathway will decrease when the sensory environment is positive. On the other hand, receptivity, openness, and thoughtful reactions will increase. Thus, in education, using threat and punishments in an attempt to achieve positive goals seems bound to fail. Behaviors may change temporarily, but the emotions and amygdala activity actually increase. Ultimately this increase will produce negative emotional outcomes expressed in actions, one way or another. When negative responses are triggered by the environment, positive outcomes are unlikely.

These properties of the amygdala lead to a logical conclusion. Educators may be able to enforce certain behaviors with threats or punishments, but these approaches probably will not alter lifetime attitudes or produce true learning. The only way negative experiences can become positive is through cognitive processing that actually changes our comprehension of a given experience from negative to positive.

The Rewarding Brain

We can think of the amygdala as the defensive component of our emotion system. Its function is to reduce or eliminate threat. The goal is reduction. The other end of the emotion spectrum is linked to brain structures that are part of what we call the reward system. This system is attractive, not defensive; its goal is acquisition.

We can identify three aspects of the reward system. First, there is a process of analyzing sensory data to determine whether they are likely to generate reward. Second, there is the initiation of "reward-seeking" behaviors. Third, there is the experience of the reward itself. An example of these three can be found in voluntary physical movement (sports, dance, etc). We consider the
anticipated behavior and conclude that it will be (or may be) pleasurable, begin the behavior and find that progress toward the reward is, indeed, pleasurable. Finally, we reach the reward (which we often consider to be the main point).

Similarly, mental movement that we sense in stories or in solving problems is also rewarding. There is reward in the process, and in the end point. Often the three aspects of reward can be integrated into what we identify as a single rewarding experience.

In time, a rewarding experience is remembered through the feelings it generates. Those feelings can be anticipated, experienced, and remembered as one thing, or we may analyze them in greater detail and see the different aspects of reward separately. In any case, as we noted earlier, reward extends over a longer time frame than that of the instant. We can legitimately claim that we feel happy, in the present tense. The present becomes identified through the time span of our feelings.

This process can apply both to concrete and abstract (imagined) experiences. For example, it is fun to anticipate playing a game, actually play the game, and win the game. All very concrete. But people also enjoy and feel rewarded when they create mental goals, make mental progress, and finally attain the goal—for example, when they experience a desire to learn calculus, work through the concept of differential equations, and feel success when the basic idea becomes clear.

Problem solving engages the reward system in a similar way. It is fun to figure out exactly what the problem is (Aha! I see the problem!). Then we begin to work toward a solution, and finally solve it. We can extend this idea to the process of moving from one image to another, which is described in chapter 4. This type of mental movement will also trigger our reward system.

Another rather simple example might be students’ classroom assignments. If a student has an image of a paper that has been assigned but not yet written, some elements of that image could include empty sheets of paper and a tense, anxious self. On the other hand, an image of the pages covered with fine prose and a self that is relaxed and satisfied is one that the student can create in his or her mind. Moving from the first image toward the second one is the pleasurable part. In fact, if a student can create the second image in his or her mind, the student may actually begin to want to write the paper. The student may be motivated in the best way possible: the intrinsic motivation of enjoyment of the process itself, and reaching the goals that he or she has set by the learner!
The Biology of Motivation

What is being learned about the biology of satisfaction and enjoyment? What actually is going on in the nervous system?

Let's begin with research on an ancient animal, the sea slug. This example deals with primitive behavior, but nonetheless behavior that the slug might be said to want to do—to be motivated to do. This behavior is eating: specifically, biting and swallowing.

The biological processes associated with this primitive but rewarding behavior turn out to be directly related to the reward chemical, dopamine. In fact, when dopamine is sprayed on a specific neuron that is known to cause the biting action, the animal bites more often and enthusiastically, even when there is no food.12

We have no real measure of "enjoyment," no "enjoyment meter," so we can't prove that the slug "enjoys" eating. But we do know that dopamine is a significant component of the reward system, not only in slugs, but also in more complicated animals like us. The fact that the same chemicals are involved with the behavior of simple and complex creatures suggests that if we did have an "enjoyment detector," it might well start beeping when the slug eats. We might even argue that the slug truly "wants" to eat, using the same terms that we use for our own species.

This apparent ubiquity of the connection between dopamine and the reward system suggests that, if we want to understand motivation and reward, we should look for the regions of the human brain that are naturally exposed to dopamine or that have receptors for dopamine. If we locate such regions, we may also find clues for new ideas about motivation and reward in education.13

But even before we go hunting for dopamine, we should remind ourselves that the brain always reacts to the environment. The reaction can be fear and escape, boredom and disengagement, interest and enthusiasm, or anything in between. Perhaps rather than saying the brain "reacts," we might better say that our environment always influences the "state" of our mind. These "states of mind" depend on our experience, and thus will be different in detail for each of us. But the potential for engagement and motivation is a feature of every brain. In education, the challenge is not to create emotions, but to unearth them.

They are always there.
Front Cortex and the Rewarding Brain

In simple animals, the dopamine system is ancient and direct. But, as with the fear systems of the amygdala, things are more complex in the human brain. This complexity can be traced to the neocortex, not all regions of cortex but rather the cognitively most powerful one, the front integrative cortex! That is primarily where the dopamine is delivered. There is a strong connection between the ancient brain stem neurons that make dopamine and the most evolutionarily recent and analytically powerful part of the human brain, the frontal cortex.

Of the emotion-related neurotransmitters, this front cortex delivery appears to be unique. Other modulating neurotransmitters such as adrenalin or serotonin are released throughout the entire neocortex, but there is little or no dopamine delivery to the back. This is illustrated in the figure below, which shows the locations of the dopamine-producing neurons, and the regions of cortex they reach and to which they deliver this neurotransmitter (the arrows.) This is the same perspective as shown at the beginning of this chapter (left, medial). The point is that the arrows do not extend to the back regions (right side of the image) of the cerebrum.

![Diagram of brain showing dopamine delivery](image)

Even though, at the level of the intact organism, the functions of dopamine remain poorly defined, the fact that front cortical regions can receive more of this modulatory neurotransmitter than can the back regions is thought provoking. The impact of dopamine on changing synapse function is greater in front than in back. And if, indeed, dopamine is an obligatory component of the reward system, then the front cortex is more associated
with reward than is the back. This idea meshes with our experience that front cortex functions such as using working memory to solve problems, intentional recall of facts and stories, and decision making, are all rewarding, satisfying, and even exhilarating. That is not to say that back cortex activities cannot be pleasurable and satisfying, but natural selection clearly has responded to pressures to provide more dopamine in front, whatever the selective pressure may be.

In our context, this striking difference between back and front cortical regions illustrates the fact that these regions of cortex are different from each other, biochemically and thus functionally. That difference draws attention to the suggestions that education should engage the entire cortex. Front and back are different, so we must use both to get the full package.

This speculation goes beyond what I proposed in earlier work. Reward is related not only to voluntary movement—either primitive physical movement such as biting and swallowing, or imagined movement toward a goal—but also from the most advanced cognitive functions that characterize our brain: functions identified with the front integrative cortex.

Thinking is rewarding. It is work, but also fun—as long as there is movement and progress toward a goal.

A Reward Center: Name and Function

In the past, I have referred to pleasure centers in the brain as “basal structures.” I created this term because it seemed unnecessary to list the extensive, highly complex, specific structures to which that term refers. Also, less was known about these structures than about the amygdala. Since then, a great deal of new work has been done on the positive emotion centers. It will be helpful now to identify and discuss one important structure by its correct name, the nucleus accumbens. It is located in the lower center regions of the two hemispheres and is one of the aforementioned “basal structures.”

The nucleus accumbens is rich in dopamine receptors, suggesting that it has a major role in the positive emotion pathways of the brain. It also receives strong signals from the amygdala, the movement centers, and, ultimately, the action centers. Metaphorically, the nucleus accumbens is the linchpin of emotion.

Here is an example from some recent research about the interactions among amygdala, nucleus accumbens, and front cortex. I will not describe
the experiments themselves, just summarize the idea that emerged from them. Quoting the authors of this research, this summary is as follows: the prefrontal cortex can "modulate the consequences of amygdala activity by suppressing dopamine release in the nucleus accumbens."16 This summary is also illustrated in the figure below, which brings back integrative cortex, front integrative cortex, nucleus accumbens, amygdala, and motor cortex into a sequence that ultimately prevents actions driven by the reward system. This occurs because front cortex predicts the possibility of negative outcomes to imagined future actions, thus instructing the amygdala to block dopamine actions in the nucleus accumbens (the "blocking" is indicated by the black inverted triangle).

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Perception of possible reward
(sensory and post-sensory back cortex) ⇒ Dopamine-driven, reward-seeking behavior
(nucleus accumbens-front cortex)

↓
Analysis of perception-memory
(back association cortex) ⇒ Warning of negative outcome
(amygdala)
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In the absence of these signals from the amygdala, we are not aware of the danger and plunge ahead toward the immediate reward, as shown in the top line of the diagram. Given additional time for cortical processing, we sense some danger and slow down or even totally stop our instinctive reward-seeking behavior, through the action of the amygdala on the nucleus accumbens.

Given the time and opportunity, our cortex can tell our amygdala to warn our reward system that mindless actions, "going for the gusto," may not always be the best idea. The reward system can be regulated by the cortex-amygdala team. Reasoning alters feelings and, thus, action.

**Two New Players in the Game of Feelings**

I have stressed the role of the slow neurotransmitters as major players in negative and positive emotion. However, many other chemical regulators are important in such processes. These include the morphine-like natural chemicals such as endorphins, and two other physiologically important hormones, vasopressin and oxytocin. The latter two have been the subject of highly interesting research on control of emotion and feeling in the amygdala.
Vasopressin is an important hormone in the regulation of salt, water balance, and blood pressure. It also initiates negative and aggressive behaviors by triggering stress, anxiety, and fear-related memories. The exact relationship between the physiological actions on blood pressure and the behavioral actions is not understood. However, parts of the amygdala have an abundance of vasopressin receptors, and when vasopressin interacts with these receptors, negative and aggressive behaviors are increased.

Oxytocin is similar to vasopressin in that it has both physiological and behavioral effects. Physiologically, it is involved in uterine contraction during birth and stimulation of milk release in new mothers. In addition, both males and females respond to oxytocin with mating and positive social behaviors. This hormone decreases anxiety and stress while facilitating social encounters and inhibiting avoidance behaviors. It is the one chemical we could most count on if we wanted to follow the advice of the hippies in the 1960s and '70s and "make love, not war."

The Devil Made Me Do It

Some of you may remember Flip Wilson's (a comedian in the 1960s and 1970s) skits about decision making. Faced with a choice—perhaps between deceiving a friend to get even for some real or imagined insult, and forgiving the friend—Flip would work out the conflict he felt by consulting an angel on his right shoulder and the devil on his left. He would debate the issue back and forth, turning his head toward the devil to listen to negative "evil" advice, then toward the angel to hear positive "good" advice. If he decided to make the "evil" choice, he would shrug and say, "The devil made me do it!"

One reason this scenario was humorous was that it came so close to the truth. It seems like we are always debating our choices, second-guessing them, defending them, even blaming them on something or someone else. But, in any case, moving from the ridiculous to the sublime, we encounter new research that suggests something very much akin to the Flip Wilson gig. In fact, the neurons in the amygdala that respond to vasopressin to produce negative feelings and aggressive actions (devil on the left) are inhibited by neurons that respond to oxytocin (angel on the right). At least part of the battle between Flip Wilson's devil and angel occurs at the vasopressin receptor in the amygdala.
This connection is shown in the schematic figure of the amygdala, above, which shows the receptor systems for both hormones (OR and VR) and how they affect each other. There are synapses between the neurons that respond to oxytocin and others that respond to vasopressin; the two systems are directly and physically connected. The result is that oxytocin blocks the action of vasopressin in the amygdala (shown by the X crossing the arrow from the vasopressin system.) Thus, our behaviors are strongly influenced by whether the vasopressin receptors are more effective or are reduced in activity by oxytocin. A direct, physical link between the two systems seems to be one likely source of our right-shoulder, left-shoulder behaviors.

I am stressing this neuroscience discovery, not because it gives us unexpected or unpredicted ideas about behavior, but because it allows us to understand our sense of emotion, feelings, and behaviors as physical and explainable functions of neurons rather than as mysterious and/or “character issues.” This knowledge can influence our values and judgments. It may make us less likely to judge or criticize behaviors that displease us, and to help us remember that any feelings and behaviors may be found in any person under the right conditions. We all have these connections.
These discoveries also give us the hope that, instead of generating more discomfort and negative feelings by trying to control behaviors through force, we might discover ways to stimulate the oxytocin pathways for positive behaviors and use nature’s balancing system in the mind. Ultimately, oxytocin rules!

Oxytocin inhibits the vasopressin system directly, particularly reducing consolidation of fear memories and avoidance behaviors. Education environments that have oxytocin-enriching characteristics could have a major impact on the negative behaviors we sometimes see in schools. These behaviors frequently appear early and, indeed, may be a direct result of negative experiences that occur in formalized education. We should also remember that they are not limited to children, but often are observed in educators and administrators themselves. The biology of the amygdala tells us that in behavior, negatives accumulate and lead to more negatives, but positives can and do block out the negatives.

**Revisiting the Upper and Lower Pathways**

The vasopressin/oxytocin system in the amygdala is strongly reminiscent of the “upper and lower” pathway for sensory information that we discussed earlier in this chapter. The vasopressin system directly transfers action signals to the body through the brain stem, so it seems likely that this pathway is at least partially responsible for negative body language and other defensive responses that do not require planning or thought. On the other hand, the oxytocin-responsive system appears to originate primarily in the cerebral cortex and may well be a component of the upper, high-reason pathway.

Thus, the modulating actions of oxytocin may depend on cognition, while the vasopressin system may be more instinctive. The drawing above suggests that the upper pathway controls the lower one, rather than vice versa. Biology suggests that positive emotion can win out over negative emotion.

The journey toward mind is supported by the positive emotion systems.

**Intrinsic Reward**

Earlier I suggested the existence of three components of the reward system: identification of reward, progress toward reward, and reaching reward. I
emphasized progress more than actually reaching a goal. If we accept the assumption that release of dopamine, or the presence of large amounts of dopamine receptors, is indicative of intrinsic reward, we can look to neuroscience for information about this subjective aspect of mind.

New research confirms this general assertion and also identifies new and more specific aspects of intrinsic reward. As I said earlier, this research indicates that dopamine release in the brain is not dependent on receiving the reward itself. This is suggested by studies with mice, using a new and highly sensitive method for measurement of dopamine. The first cue that a reward will be forthcoming, that is, the expectation of a reward first develops (or even the reminder that the reward exists), causes nearly as much dopamine release as does the actual receipt of the reward itself. It produces an anticipatory burst of dopamine, not a sustained release, strongly suggesting that the expectation of doing well and being rewarded is a powerful neurological event in itself.²⁰

Beyond anticipation, actually organizing and executing actions is also rewarding. Psychologists call carrying out actions designed specifically to achieve certain goals “instrumental conditioning.” We take actions because they are associated with intrinsic reward, and this behavior produces learning. Doing things we have learned produces results that please us.

Some psychology researchers divide the process of instrumental conditioning into two sub-functions: the “critic” and the “actor.” The critic makes judgments about what behaviors (actions) will generate the greatest reward or the least punishment, while the actor initiates the behaviors and modifies them to carry out the judgments of the critic.

These two functions engage brain structures associated with the nucleus accumbens. The critic function is associated with one such structure (one physically below the other), and the actor function is associated with the dorsal (upper) regions. Of interest, the critic region has significantly greater numbers of dopamine receptors than does the actor region, suggesting that the critic function may be the more rewarding of the two. Making judgments and decisions may be more rewarding than putting them into action.²¹

So What About Education?

My objective in this chapter is to suggest ways to activate the elements of the brain's intrinsic reward systems in educational settings. Doing this effectively is an important aspect of my views about our journey from brain to mind.
It appears that the more negative aspects of behavior derive from the evolutionarily older functions of "survival brain." They are the unreflective and instinctive elements of emotion. However, the reward systems take us to the ideas of self-awareness, reflection, thought, and conscious control; We associate these ideas with mind. Moving from the instinctive lower path in the amygdala to the more cognitive upper path epitomizes this idea.

To the extent that our journey takes place in schools, it is obvious that this is a tough assignment. Educational environments often seek to remove control from the student. This mentality extends throughout all organized education. Teachers may spend most of their time and effort keeping students "under control." Administrators may believe they should control what teachers do in classrooms, and watching over the entire scene are parents and boards of education. This control pyramid discourages the freedom that is so essential for intrinsic motivation. It reduces the freedom of students, teachers, and administrators.

Throughout this book, starting with the first story about Henry and square roots, I have tried to stress the relationship between freedom and effective education. When we are free to dream and to anticipate, when we know we are in control of our own learning, and when we actually begin to do more than just imagine and dream, when we are free to act, we will discover the joy!

Our question is: Can this happen in educational environments?

Can Fear Lead to Joy?

Often educators try to eliminate fear in learners. This has not always been the case, and by no means is it universal in our modern educational environments. We realize that fear can be paralyzing or pathological. At the same time, challenge is an important part of learning. In fact, overcoming challenge is part of the joy. How can we have positive feelings about success if we don't respect the task? In addition, there probably is no way to eliminate the concern, and even worry, inherent in learning new things. If they are new, we cannot predict the outcome, or even assess our progress, with confidence.

As we have discussed, natural selection has given us brain-machinery for dealing with challenge. Our amygdala continually scans sensory information and evaluates whether it is safe. Awareness of danger and alertness to its possibility are part of our neurological condition. But nature has also given us
the tools to deal with challenges. We can learn what we should fear and how
to respond to pressure. The answer is in overcoming the challenge, not in
avoiding it.

What are the elements of “overcoming”? As I have implied, one of these
elements is confronting it. Ignoring the reality of threat, or even searching
blindly for ways to stress the positive, are not solutions. For one thing, the
lower pathway in the amygdala is fast. Its direct wiring to the brain stem and
the body means that the signals begin to exert their effects more quickly than
does the upper pathway through the cortex. When challenged, we may well
react before we think. In fact, this early response may be necessary to give us
the signal that processing is needed. It activates our more-conscious
awareness.

In addition, it is important to consciously recognize that challenge is
valuable. There are often very real dangers that cannot be avoided. They may
even be essential content of what is to be learned. Those dangers may be part
of the truth. An example of this from my own experience is the behavior of
college students. As freshmen, many of these students are uncertain, if not
actually fearful. But different students respond to this fear in different ways.
Some view it as useless and distracting. They seek escape rather than under-
standing, and they do not see their discomfort as valuable. They are locked
into the more primitive brain functions of survival; their journey toward
mind is blocked.

Other students react very differently. They use their experience to gather
information about themselves. They see it as part of the truth. So they may
be disappointed when a “C” shows up on their grade report, but their
response is simply that they are learning where their talents lie. The “C” is
information, not failure. And in some cases, this produces intense joy. Free-
dom is increased. Such students can then follow paths they have defined for
themselves! Part of this joy comes from their continued progress on the jour-
ney toward mind. They process the fear.

The route to joy must include the truth. Our amygdala helps us find it.

Mistakes and Joyful Education

The route from brain to mind has many detours and dead-ends. These can
make us fearful, but as we just discussed, they often are inevitable and ulti-
mately can enhance our growth and increase both our knowledge and cour-
age. Often they become part of the rich and joyful experience that
characterizes progress in the journey toward mind.
Particularly in formal education, we may think that fear and mistakes are bad and should be avoided, but I am suggesting that a “mistake rich” environment is preferable. It produces a better education and leads to more insight and more truth. Mistakes are expected and become information. It is a cause for worry if a student does not make any mistakes.

When the value of every outcome is determined by whether it is right or wrong, pressure and high stakes become an integral part of the school experience. It turns the focus from learning and understanding to fear, tension, and crisis. It produces the primitive fear and tension of the primal brain rather than the joy found in growth, freedom, and development of mind.

Pay Attention to Feelings

Neuroscience has given the world important information by delineating the difference between the upper and lower route through the amygdala, and the ability of oxytocin to override the more primitive aggression and fear behaviors. Our belief that there is value in retaining awareness of our emotions is reinforced by defining the neurosystem responsible for that conclusion. Awareness of this information engages cortical processes that alter behavior of individuals and, eventually, of cultures. Knowledge that there are different routes through which information can be channeled in the brain, and that we can consciously decide which route to use, provides a way to deal with some of the most difficult moments in our lives. These are moments that otherwise may lead to conflict and even wars, or, alternatively, to taking a deep breath and analyzing how we feel and why. The outcomes can be dramatically different.

The journey toward mind must include experiences that challenge us. Meeting such challenges is an integral part of gaining knowledge and wisdom. Treating emotions as tools rather than as enemies should become a primary goal of education. To use them as tools, we must have control and self-awareness. This awareness of our own feelings is central to development of mind. From the earliest childhood through adult life, it is of great benefit to ask ourselves continually, “How am I feeling?”

Do Front Cortex Things

As we saw above, the region of cortex innervated by dopamine neurons in the human species, the front cortical regions, is primarily responsible for the
creative and directing functions that are so characteristic of human activity and behavior. Among others, these functions include creating images, solving problems, making decisions, planning actions, generating language, evaluating options, predicting events, and directing the body's actions.

These front cortex functions can be motivating and rewarding for children and adults. If education is to be joyful, the freedom and control associated with front cortex activity must be part of the experience of students, teachers, and administrators. Not that everyone associated with education can be in charge at once. In fact, too much choice creates confusion and actually reduces our ability to choose. Further, our decisions and choices are based on experiences and things we know about, so it is actually impossible for every person to have equal say in every problem.

A practical goal in education is to acknowledge that all of us have some experiences in which we can take control and feel ownership. This can only happen in a culture that acknowledges the necessity of freedom in learning. This freedom can be expressed in many ways, and those expressions are part of the freedom. The key is choice—not an infinite range of choices, but choices within an existing knowledge framework.

I suggest that this can be achieved in all subjects, at least to some extent. Let's take the subject of arithmetic. Everyone agrees that this subject is of great importance, but how does choice enter the picture? Arithmetic is arithmetic, after all. Answers are either right or wrong!

Nevertheless, making choice a component of learning arithmetic is not a matter of right or wrong, even in schools. There can be choice of assignments and what learners actually do to learn arithmetic. And keep in mind that this approach can be used in college-level teaching in philosophy or physics, for example. This is possible in spite of the established structure in most schools where teachers control students, administrators control teachers, and a formal board controls the administrators. Each of these three stakeholders can have points of control and choice if they agree to give up choice in other aspects. To illustrate this, imagine a school where the following categories of choice exist:

- Student's choice. Students use arithmetic to explore any subject that interests them: money, distances, sports, populations, etc. Students choose the kind of problems they will work on. In this category, students are free of teacher control.
- Teacher’s choice. Teachers regularly choose additional specific assignments as well as pedagogical approaches (how students will be taught). In this category, teachers are free of administrative control.
- Administrator’s choice. Administrators choose the big picture in arithmetic instruction. They set the overall philosophy and educational goals. In this category, an administrator can be independent of the board.

I choose these examples, not because they are free of complications, but as illustrations only. They are meant to stimulate discussion about how formal education can create more freedom of choice within a hierarchical structure. I believe that such freedom can play a major role in creating more joy at all levels in the system. It may actually be essential!

The Value of Past Success

One of the neuroscience findings discussed earlier in this chapter demonstrated that the mind rewards more than the experience itself. It rewards anticipation of the experience. If affective neuroscience is our guide, and if increased dopamine levels are evidence of reward, then the image or anticipation of enjoyable experiences is a reward in itself.

Is it possible to create an environment in the classroom in which everyone associated with it can either remember or imagine the experience of success? Everyone should have the experience of setting goals and achieving them. It is the success that matters, not the subject. Our goal should be to find some area of success for everyone. For example, if a teacher remembered a time in his or her life when he or she succeeded in a sporting event, it might generate the dopamine pulse associated with visualizing success and provide new energy and motivation for a new task such as working with a difficult student. If success is its own reward, then remembering success might become a reward for trying new endeavors. The trick would be to remember and revitalize any success when faced with a frustrating or new challenge.

This is not a novel idea, but the neuroscience perspective might lead us back to it.

The Group

Up to this point, we have primarily discussed feelings derived from individual experiences of students. However, education is almost always experienced
in a social setting. Indeed, the most powerful feelings students experience are
driven by the social environment. Being part of the group, having friends,
being approved or disapproved of by the teacher, and being aware that such
approval/disapproval is apparent to the group are the kinds of feelings stu-
dents carry home with them most strongly and most often.

There is a growing body of research examining how the brain responds
to pain or pleasure generated by the social environment itself, and some of
this work may encourage us to invent new ways to educate. One example is
new research on the pain of social loss. The suffering that is generated by
exclusion from the group is one of the most common and damaging negative
experiences in school. In these experiments, neuroimaging studies were con-
ducted with people who were rejected by a group playing a virtual ball-toss-
ing game. The most striking finding was that the areas of the brain associated
with this social rejection were remarkably similar to those areas that are activ-
ated when physical pain is experienced.

Rejection hurts—literally!22

The Deepest Joy

Beyond avoiding the pain of exclusion, the social nature of learning itself, the
experiences of joint discovery, teamwork, and participation are all of great
importance for success in education. They have been stressed repeatedly, and
a great deal of pedagogical theory and practice has been directed toward
them in the past decade. I do not downplay them in any way.

I do, however, feel a need to nudge the pendulum back the other way.
Ultimately, understanding and learning are highly personal experiences.
Each of us builds on our own neuronal networks, and for that reason the
social aspects of schooling are not, by themselves, adequate to lead us far
along the route from brain to mind. Their impact is to provide an environ-
ment in which fear is reduced and spontaneity is more likely. However, that
in no way assures developing deep insights or satisfying new ideas. For that
kind of progress toward mind, I suspect that individual reflection and hard
work are necessary. As happened in my story at the beginning of this chapter,
we are most likely to experience this “deepest” joy when we work alone, are
immersed in our thoughts, and are struggling in serious and individual bat-
tles with ideas and skills. In chapter 2, this is illustrated by my need to prac-
tice dribbling, by myself, intensely and repeatedly. In experiences like that,
it will not do to discover someone else's answers. This growth of mind is selfish; we want to own it.

In this view, experience is broadened to include both social interactions and private, deep experience. Both are essential. At times we travel alone in our journey from brain to mind, but we are not lonely or sad. We have ourselves and the joy inside us.

New Questions for Educators

Emotion is probably the most important factor for learning. Our feelings determine the energy with which we begin new challenges and where we will direct that energy. The actions we take are determined by how we feel and how we believe those actions will make us feel. Not that we only seek out experiences that look easy or even joyful; we also respond to challenge and often are motivated by confidence and pride. We may want to show how good we are. A challenged student has a better chance of successful learning than does a bored one. It is important to balance confidence and challenge. This balance is one key to the art of educating.

What questions might we ask ourselves about keeping the joy in this emotional experience? One possibility focuses on understanding and using the difference between the upper and lower pathway in the amygdala. The question this raises might go something like this: “Can educators enhance the probability that learners will recognize the value of channeling their experiences toward the upper path? Can they realize how important that is?” And asking that question will lead us to think seriously about it for our own purposes. We will begin to wonder how we can stress this upper path, and how we can help learners view it as an explicit goal. The way our brains work suggests that learning this skill as a child may be as important as learning to read.

Second, but related to the above, let’s ask how we can design the experiences of learners in ways that minimize the negative. An example would be the question, “How can I generate a mistake-rich environment.” Our own awareness of this goal will enhance the experience of our learners and ultimately create opportunities for them to become more self-aware. They will begin to think about how their own bodies are feeling, and how their own “somatic markers” can help them learn. Learned early in life, when everything seems so easy, this skill will be invaluable. Stressing the positive, using
the upper path in the amygdala, will lead us to reflect on successes rather than failures. Learners may develop the habit of taking frequent inventory of successes, asking themselves questions such as, “What did I do well today?” or “What were my greatest successes?”

Third, we should educate and reeducate ourselves about the capabilities of our front cortex. We should remember what it evolved to do and stress those things. We all should have more choices, more creative challenges, and more opportunities for problem solving. We will feel rewarded already when we have choice, and that reward may be greater than any we could gain through “acting out.” A question, then, that directs our thoughts along those lines might be, “What aspects of front cortex am I going to emphasize to help my learners understand my goals today?”

**Toward Making Meaning**

Finding the joy happens very early in our journey. And, as I argued both in this chapter and in chapter 2, once it happens we will continue to make discoveries, all the while feeling more and less fearful. We are prepared for new steps along the journey. In fact, we are eager for them!

In the narrative of this book, the next stage of our journey leads to comprehension of our experiences. Moving from the sensory-motor way of learning, we begin to process what has happened. This includes what we have seen, heard, touched, smelled, tasted, and understood about our actions and how to carry them out. Our interpretation of this information is personal, involving our individual experiences and bringing them together to produce an integrated picture of our world and our experience in it. I call this “making meaning,” and it heavily involves a region of cortex that we have not yet discussed extensively.

**Notes**

1. This phrase is found in discussions of emotion over the past century, possibly beginning with William James, and continually showing up in modern scholarly work.


3. Some readers may question whether these problems are also found in advanced education environments such as medical or graduate schools. I claim they are because of my experience with education at this level. Often, when trying to
work seriously with these students, I find that they turn to idle chatter and go "off task" as soon as they believe I am not watching or listening to them. Also, medical educators tell me that students retain their obsession with grades, even when trying to learn things that are essential for their professional practice. If they receive an evaluation that is less than excellent, they will pay more attention to the evaluation than to the errors they made. I have come to believe that it is the school setting itself, with its accompanying threats and rewards, that generates problems of this sort. I discuss this more in later parts of this chapter.

4. In this section I quote extensively from Antonio Damasio's book *Descartes' Error*. Forced to use one sentence to define the message of this book, we might say that the message is "emotion is necessary for reason."


6. The quotes in this paragraph come from *The Feeling of What Happens*, p. 56.


8. I have not previously mentioned the thalamus, because until now it didn’t seem necessary. However, I have been uncomfortable with the omission, so here I would like to draw your attention to the sensory elements of the body that send their signals through this structure, where they are routed to the correct parts of the cortex. In general, the thalamus is involved in forwarding information from the sense organs to different regions of cortex as well as from one region of cortex to another.

9. This model is based on a similar one presented by Joseph LeDoux in his book, *Synaptic Self*, Viking, New York, NY, 2002, p. 123. This low route has been studied with both the auditory and the visual sensory systems.

10. Cortex is considered "higher" since it is the area of brain most engaged in the more advanced functions and is the most recent to appear in evolution. Thus, creative, cognitive, and analytical functions characteristic of human thought are "higher" than reflexes, or more ancient behaviors such as fight-or-flight or reproduction.

11. The notion of the amygdala as a detection system for negative sensory information has recently been complicated by a report of a patient (SM) with bilateral lesions of the amygdala. SM does not respond to pictures of fearful faces, as is expected in such patients, but the defect turns out to be that SM simply does not focus on the eyes in a face. This is in contrast to the normal behavior of looking frequently at the eye regions in a face. An explanation for this abnormal behavior and its relationship to amygdala function is not currently available. See: Adolphs, R., et al. (2005), *Nature*, 433, pp. 68–72.


13. Recent work by Hnasko, Sorak, and Palmer (Nature, 438, 2005, pp. 854–857) suggests that dopamine itself may not be responsible for the "hedonic" or "wanting" experience, but that it is necessary for the actions associated with these feelings. This
work seriously with these students, I find that they turn to idle chatter and go “off task” as soon as they believe I am not watching or listening to them. Also, medical educators tell me that students retain their obsession with grades, even when trying to learn things that are essential for their professional practice. If they receive an evaluation that is less than excellent, they will pay more attention to the evaluation than to the errors they made. I have come to believe that it is the school setting itself, with its accompanying threats and rewards, that generates problems of this sort. I discuss this more in later parts of this chapter.

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work provides a warning for research that demonstrates behaviors (actions) indicative of internal motivating feelings, when we have no direct measure of the feelings themselves.

15. A link between the reward system and positive emotion was identified in *The Art of Changing the Brain*, p. 61.
18. LeDoux, J. (2002), *Synaptic Self*, Viking (Penguin), New York, NY, pp. 121–123; the “quick and dirty” term refers to the fastest but least accurate pathway with regard to content. A “dirty” pathway is one that contains basic information but that appears “smudged” through lack of detail and clarity.
19. Positive behaviors seem to be more learned, and thus are strongly associated with growth and development. We revisit these ideas in chapter 7, which focuses on that topic.
22. Eisenberger, N. I., et al. (2003), *Science*, 302, pp. 290–293; also see commentary on this research by Jack Panksepp in the same issue of *Science*. 
General areas of integrative cortex seen from left lateral (top) and left medial (bottom) perspective. These regions and their functions are discussed next.