learning cycle and points out that each one is "transforming" in its own way. My point is that the structure of the brain suggests a major division of function between the reflection and the abstraction step in the learning cycle, and that crossing this division transforms the learner.

2. It is of interest that the structure of the cortex at the ends of this C-like structure, the hippocampus at the "back" end and the olfactory sensory cortex at the "front" end, are also both of an evolutionarily older type of tissue than the remainder of the cortex. Smelling and memory may be the oldest parts of our modern brain.
3. Number one makes a more direct connection between the sensory cortex and the motor cortex. It bypasses major areas of integration.
4. M. Schwartz and P. Sadler, *Goals and Technology Education: The Example of Design Challenges*. Proceedings of the Second AAAS Research in Technology Education Conference. (Washington, D.C.: Am. Assn. for Advancement of Science, 2001).
5. Fischer reviews two decades of his work on skill theory and child development in the *Handbook of Child Psychology*, 5th ed., vol. 1, W. Damon and N. Eisenberg, eds. (New York: Wiley, 1997), pp. 467–561.

4

OUR TRADE AND OUR ART

EVOLUTION OF THE BRAIN AND MOTIVATION OF THE LEARNER

My trade and my art is living
—*Michel Eyquem deMontaigne*

Dave and Eddie were friends of mine in college. They were dear friends, as college friends usually are. But they both puzzled me.

I met Eddie first, because he lived in my dorm. He was one of the brightest people I knew. He liked to talk about IQ, because his was so high, and that annoyed me slightly, but Eddie had redeeming features. He was sensitive and a good listener. And he always understood what I was talking about. I loved him for that.

Surprisingly (to me, anyway), Eddie did not get top grades in college. The reasons never seemed clear. He cared a lot about grades, and he studied hard. But somehow he was always disappointed. He would blame himself for not coming up to his potential, but as far as I know he never found the answer.

Dave was very different. We became friends when I began to help him with chemistry. We had some great times when after a struggle the light would break through, and we would laugh in genuine pleasure. Dave was earnest, good natured, and honest. He didn't care who knew how he struggled; he just wanted to understand. I found myself pulling for Dave. I came to love him, too.

Dave had a plan for his life. He wanted to serve. Specifically, he intended to become a physician and help people in the third world. But I was skeptical. I didn't think he would get into medical school. He truly surprised me as semester after semester he came up with a 4.00 GPA. And, sure enough, eventually Dave became a doctor in what was then the Belgian Congo.

I thought about these college friends for a long time. How could Dave do so much better than Eddie? Something about the way they used their brain was different in an important way. But it was only recently that I found my answer—the answer I will try to explain in this chapter.

* * *

Sometimes we assume that learning only happens in certain places or at certain times. For example, we may think that we only learn in school, or on the job, or when we study our assignments.

However, you may have questioned that idea when we looked at experiential learning and the learning cycle in chapter 2. There isn't any particular time or place especially suitable for the learning cycle. We are always having experience, reflecting, getting ideas, and taking actions. We could say that the learning cycle is about life itself. DeMontaigne's claim that his trade and his art was living can just as well apply to learning. When asked what we do for a living, instead of saying "I teach" or "I trade stocks," we could say, "I learn."

This idea is a biological one. It becomes glaringly obvious when we look at how brains evolved, and their biological role. It will help us understand the difference between my college friends Eddie and Dave. And it will help when we encounter someone who says, "I don't want to learn." It is all a matter of how things fit into our lives.

What the Brain Wants

One way to begin thinking about emotion is to ask ourselves what we want or what we don't want. If we try to answer these questions, we will find out what we care about. We will find our fears and hopes, the things that are the source of our emotions. So we might say that our best chance to help another person learn is to find out what they want, what they care about.

This sounds like an important idea for teachers, but at the same time it seems impractical. How can we find out what is important for every student? Even the student herself is often not so sure about what she wants.

It is useful to go back to biology here. Our common origin through evolution means that we all share some basic wants. Above all, the brain wants *survival*. The sensory, integrative, and motor brains combine to make a survival machine. We sense the facts of our environment, integrate those facts to see if they mean danger or opportunity, and initiate action to avoid the danger or grasp the opportunity.

Even a worm does this. If we pick up a night crawler to bait our hook, the worm senses that it has been picked up, knows this is not good, and twists and wiggles violently to escape.

This survival machine is self-regulated. Each brain controls its own body. Even the worm is in control. Maybe there is no lurking fisherman with his hook, but the worm responds as it will, right or wrong. It must be so because the stakes are so high. To survive we must be in control, or believe that we are. Wanting survival means wanting control.

Tools for Survival (Old Tools)

The most fundamental things required for survival appeared first in evolution. These basic survival tools are ancient, and they are powerful. They have worked for a long time.

There are two fundamental things that brains want: to be safe and happy. We use two parts of our survival machine to achieve these goals: our fear system and our pleasure system. The original versions of these two systems seem to have evolved at least 250 million years ago, and their modern-day forms control the behaviors of simple animals like snakes or lizards. Underneath, even we remain a little bit reptile.

Of course we are much more complex than a snake, or at least we believe we are. We don't think snakes feel jealousy, smugness, or pride. But to a great extent we are still ruled by those two powerful emotion systems of fear and pleasure. They are the "I want this" and "I don't want that" systems. Our fear system makes us want to run, fight, hide, or even "play possum," so we get defensive, short tempered, sullen, or lazy. Our pleasure system makes us want to come closer, get more, make ourselves more visible, or keep doing more, so we smile, make jokes, hug a friend, and go to work.

The value of the fear system for survival is obvious, but it may not be so apparent why we need a pleasure system to survive. But we do. For example, sweets and fats are the main foods that give us energy, and our pleasure system makes us want to eat them. Sex is another example. In fact, sex behaviors and eating behaviors seem to come from the same part of the brain pleasure system. We *must* want these things.

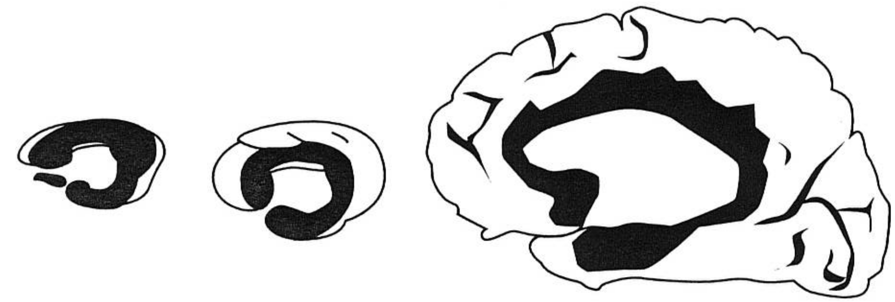
Tools for Survival (Newer Tools)

As far as we know, a worm doesn't think about how it can avoid the hook or how it can stay out of the path of the fisherman. But the human brain would. We survive by thinking, planning, and deciding. Our cognitive brain is a powerful tool for survival.

We are constantly evaluating what is going on around us for danger and for opportunity. Our brain looks to the future, makes generalizations about our environment, and develops strategies to enhance our opportunities and minimize dangers so we can survive. Even our highest mental achievements, our calculus, poetry, or philosophy, come from a brain that evolved these types of skills just to survive.[1]

The thinking, analyzing, and planning part of the brain is the cerebral cortex, which we discussed in chapter 2. It is called the *neocortex (new cortex),* because it is thought to have become a major part of the brain just recently, in evolutionary terms. It may be as young as 5 million to 10 million years![2]

The illustration below demonstrates the evolution of the neocortex. It shows the brain from a different perspective than we have used so far. This perspective is gained by exposing the inside surface of one hemisphere by "splitting" the left side from the right. On the newly exposed surface of either hemisphere we see an inner C-shaped ring of cortex (darkened areas), lying beneath an outer ring of neocortex (light areas.) The inner ring is the *limbic cortex,* and it contains some areas that are apparently evolutionarily much older than the neocortex. We will discuss the limbic cortex later; the point of the picture is to demonstrate the increase in neocortex that took place as smarter animals appeared on the scene in evolution.



Emotion and Learning

We are born with the capacity for fear and pleasure, but not necessarily with knowledge of *what* to fear or *what* gives pleasure.[3] We learn most of those things. Looking at learning emotions helps us see the connection between emotion and cognition.

Think of sensory experience. We feel something that hurts, and that triggers the fear system. Or we feel something good, and that triggers the pleasure system. We only need to be burned once to fear heat, and we only need to taste sugar once to want it again. These tools for survival are also powerful learning tools. Learning what we should fear and what we should love is essential for survival.

As with the fear and pleasure systems, our cognitive brain also learns what gets results. Success in thought generates understanding, and understanding allows survival. If we could not understand our world and plan for our future in it, we could not survive. It is not surprising, then, that cognition also triggers our internal reward system. We enjoy real learning, and we want to learn. In order to survive we had to *want* to learn.

Helping People Learn

I have said all brains want to survive, and they have survived so far by understanding their environment, controlling their own actions, avoiding danger, and searching for pleasure. Cognition, control, fear, and pleasure are four things brains use to survive, and they are fundamental to every brain. We must consider these four things if we hope to help people learn.

This is not an easy assignment. These four "wants" of the brain are not independent of each other. For example, we hope that understanding something will give us control over it, but fear may block understanding. Or we may lose control by seeking to satisfy our pleasure brain. Or we may give up pleasure to gain control or accept fear and suffering to keep it. The entanglements of cognition, control, fear, and pleasure are obvious and endless. And, to complicate matters, our stubborn insistence on control means that we just keep on deciding things, right or wrong!

This may sound slightly ridiculous, and indeed when closely examined, all our lives have their ridiculous elements as we muddle along in response to our thoughts and emotions. But actually, this is serious business. Our brain takes itself very seriously. No matter how we behave, whatever our attitudes, whatever we believe, it all comes from a brain that got that way in the desperate struggle to survive.

Because it is so serious, no outside influence or force can cause a brain to learn. It will decide on its own. Thus, one important rule for helping people learn is *to help the learner feel she is in control.* This is probably the best trick that good teachers have, and we will examine it more in chapter 12.

Our evolutionary view also helps us understand why learning is a natural process when it has to do directly with the life of the learner. If people believe it is important to their lives, they will learn. It just happens. A second rule then is that if we want to help people learn *we must help them see how it matters in their lives.* I stress, we must help *them* see. The learner herself must see it and believe it. That does not happen just because *we* say, "It matters!" Our job is not that easy.

Finally, we should remember that the fear and pleasure machinery in our brains are at work all the time. In basic ways, they run our lives, as they have for millions of years. We may not still consciously worry about survival, but we still respond directly to the fear and pleasure systems. Our emotions still seem very important and if we want to help people learn, *we must expect to encounter emotion, and we must take it seriously.* We cannot dismiss the learner's emotions, even when they seem trivial or unjustified to us.

Motivation

We have been skipping around the edges of a question of great importance for learning and teaching: What motivates the learner?

Our worries about this make us think a lot about rewards for learning. In schools it has led to a complex system of bribes and extrinsic rewards, which sometimes are based on mistaken ideas about motivation. These include grades, gold stars, scholarships, and even praise. If it is really learning that we want, these are all off the mark. We may get people to do things with extrinsic rewards, but we can't get them to learn.

Actually, it is not so much that they are off the mark, but rather that extrinsic rewards are aimed at the wrong target. They are aimed at things outside learning. They have no natural relationship to the internal life of learning.

What the teacher needs is an understanding of intrinsic motivation, rewards that are automatically connected with learning and that we have evolved to want. If we want to help people learn, we should not worry about how we can motivate them but try to identify what already is motivating them.

Alfie Kohn addresses this subject in his book, *Punished by Rewards.*[4] He concludes that when we try to help someone learn by offering an extrinsic reward, the chances are that learning will actually be reduced.

It is not hard to see why Kohn says this. The first thing our controlling brain sees in a reward or punishment is *loss* of control. It may not be a conscious recognition, but the brain evolved to detect and resist exactly this type of thing for over five million years. It is not going to give in now. In fact, one of the things our brain does best is decipher deceptions like extrinsic rewards. This is one of the main things we practice from our earliest childhood!

The brain sees through the extrinsic reward. It sees the extrincity. The reward is tempting, true enough, so we devise all sorts of ways to get the reward without carrying out the learning, the job, or the assignments. Students seem to do this quite effectively in our colleges. Sometimes they even get *As* (the reward) in courses they hardly remember taking a few months later.

The Use of Extrinsic Rewards

Despite everything I just said, I do not think extrinsic rewards are useless. I have too much life experience to throw them out completely. And there is not much hope that we will suddenly drop all our extrinsic reward systems. What I suggest is that we should recognize a couple of positive effects that extrinsic rewards can achieve and try to use them in a more sophisticated way.

One of the values of extrinsic rewards is that they can get a learner started on something. Often people do not actually know what they are going to enjoy, and they may not even start to look into many possibilities unless there is some motivation other than an intense life interest.

We may take those important first steps if we are offered an extrinsic reward. This is quite common in college. Students take particular courses because they believe they can easily get a good grade to "pad" their GPA. But sometimes, once they have started, they realize they actually enjoy the subject and it becomes an important part in their life. This is one reason engineering students sometimes become history majors, or premed students end up as poets. Initially they were enticed by some extrinsic factor, but then they do well because they find they actually care!

Extrinsic rewards can also sustain a learner at times of pressure and difficulty. For example, a premed student may truly enjoy studying cat anatomy, but at times it is exhausting and depressing. Too much to learn! But this student may get over the hump by remembering the extrinsic reward. That 4.0 GPA is still possible, and so our student will get a little burst of energy for her studies. She still must have intrinsic motivation to keep her going in the long run, and to actually *learn,* but she may dig back in better if she has a little extrinsic reward on the side.

The main value of extrinsic rewards is that they may be the first step in moving toward intrinsic rewards.

Eddie and Dave

I'm sure you see my idea about Eddie and Dave by now. Dave was intrinsically motivated. Dave believed that learning chemistry was part of being a doctor. In his mind he was already a doctor, just a developing one. This was his life. He had his plans for control of his life, and learning chemistry was just part of the plan. He was focused on the process, not the goals. Dave viewed learning chemistry as part of the action rather than the fruits. He was a learning doctor.

On the other hand, I think Eddie let extrinsic rewards become his focus. He lost sight of the intrinsic ones. The grades, the end point, became the objective. It is possible that, in fact, school itself was extrinsic for him. He was there because that was what young people did when they finished high school, but he hadn't found out how it fit into his real life. He couldn't really see his life as a professional "grade getter." So Eddie couldn't fit his classes and his studies into his life story. My guess is that Eddie's brain rebelled. It just wouldn't work for those extrinsic rewards any more.

Why Talk about Brain Structures for Emotions?

Our instincts about what we want and what we don't want are produced by physical structures in the brain that have evolved over hundreds of millions of years. With all that history we can't blame emotion on the learner. We might create conditions where her emotions begin to change, but direct control is not possible. There is little use in saying, "Don't feel that way!"

What can we do about emotion and the student? Think for a moment about a car. Specific physical structures make the car work as it does. For example, the gas pedal is directly connected to the engine in a way that lets in more or less gas when we push or release the pedal. If we sense our car sputtering and we notice that the gas gauge indicates the tank is empty, it does no good to curse the car or to encourage it. Instead, we must understand the physical facts and use them to our advantage. We nurse the car along at slow speed, allowing it to coast wherever possible, and guide it gently in the shortest line toward the nearest gas station.

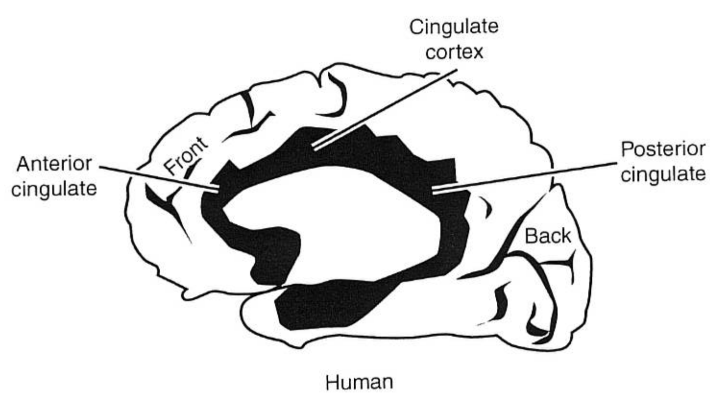
In the same way if we know the structures in the brain that produce emotion and if we know a little bit about how they work, we may see ways to nudge our student toward learning. Then we can be grateful when our students sputter, because that is valuable information. It helps us see what we should do.

The Fifth Cortical Function (But Was It the First?)

Let's define some parts of the brain that seem to be central in emotion. We will start with the limbic cortex. Remember that the cortex is the surface layer of tissue—the bark—that covers the brain. We discussed the limbic cortex earlier when we talked about the evolution of cognition and survival. It is not visible if we look at an intact brain, as the sensory and motor cortex are. But as I explained at the beginning of this chapter the limbic cortex can be seen if we split the brain into its right and left hemispheres and look at the inside surfaces that become exposed.

There has been some debate about the functions of the limbic cortex. For many years it was believed to be the main part of the cortex involved in emotion. But in the last decade, LeDoux[5] has urged abandoning that view and recognizing that emotion engages many parts of the cortex. This is certainly correct, but new research continues to point to a strong connection between the limbic cortex and emotion.

In the illustration below I show you two major areas of the limbic cortex that become more active under emotional conditions: the *anterior cingulate* and the *posterior cingulate,* particularly an area called the *retrosplenial cortex.*[6] This will interest us again in chapter 12, but for now we can just note that the evidence continues to point toward the limbic cortex in humans as a essential player in emotion.

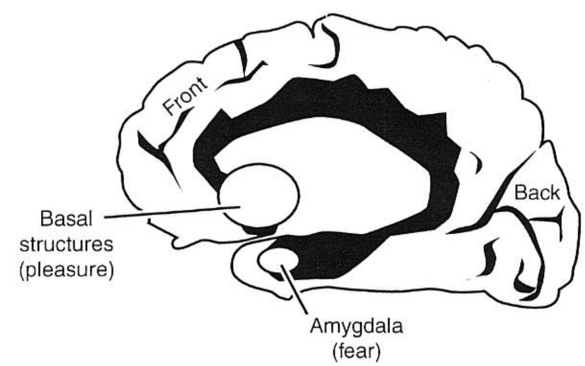


The connection with emotion and the observation that parts of the limbic cortex are evolutionarily older than the neocortex allows us to make a suggestion that I hinted at earlier. Emotional functions may have preceded the appearance of higher cognitive functions in human brain evolution. Emotion may be more fundamental than cognition, even in humans.

The Hidden "Lumps"

Emotions are greatly influenced by parts of the brain buried deep inside the lobes of each hemisphere. These buried parts are lumps, or clusters of cells, rather than the bark-like tissue that forms the cortex. To see these lumps we would need to dig carefully beneath the cortex.

We will not look at pictures of these structures, some of which are immensely complex and convoluted, but in the illustration below I show you the names and approximate locations for two of the major ones: a fear center and important pleasure centers. This illustration cuts away the cortex in the general regions we would have to remove to reach them.



The fear region is called the *amygdala.* This is a little bit of an oversimplification, since the amygdala also plays a role in other emotions, but fear and its related emotions such as anger and rage seem to originate primarily in the amygdala, which is a distinct structure with the shape and approximate size of an almond.

Pleasure regions in the brain are less well defined than fear regions and have not been localized to a single lump of tissue. But they do seem to be in the same general region of the brain. This region, as shown in the illustration above, is deep below the front cortex. Let's call the structures in this area the *basal structures.*[7] You should recognize that this is my own term, and you will generally not find it used this way in neuroscience books.

My Student Tony and Me

Before we look at what the amygdala, basal structures, and cingulate cortex do, let me tell you a story that will help illustrate some of the points I will try to make here. Then we can return to the story at the end of the chapter to see if our brain biology has done us any good.

* * *

Tony was one of those tall, good-looking, dark-haired, young men who usually get the benefit of the doubt when doubts arise. He was cocky, not at all self-conscious, and charming. A freshman, Tony was mostly interested in improving his chances with the girls in the class, and I could see he expected success in that arena.

Now I am a serious person and I take learning seriously. I expect my students to show that they are trying, and I found myself irritated with Tony. His whispered smart remarks from the back row, and the giggles they elicited got to me, I admit.

I reacted to Tony by encouraging him to get into the class discussion. He resisted this, and we settled into battle mode. As he realized I was serious, Tony's body language began to change. The jokes and giggles subsided, but, still in the back row, his posture was slouched, his legs spread and extended straight in front of him, his arms up and hands clasped behind his head. He looked away from me, but not far away—just over my left shoulder, if I recall. Every part of his body said, "I don't care! And I want you to know it!"

Tony didn't know he was doing this. He was surprised when one day one of his classmates said, "You must be really mad at Zull!" Tony looked up, startled, and replied, "What do you mean?" "I can tell by the way you sit" came the reply, and suddenly Tony saw it. His face turned pink and when I wasn't looking, he slowly straightened in his chair and began looking at his assignment.

It was striking. As Tony studied his assignment, his body began to relax. Almost for the first time, it seemed, he was cognitively involved in class. As we went on, he began to take notes, and he physically bent over his work. He began to relax, and so did I.

* * *

Tony's behavior (and mine) probably rings a bell with anyone who has tried to teach a class. The story illustrates the emotional brain at work in the intense dynamic of the teacher-student relationship. As we will see, the amygdala, the basal structures, and the anterior cingulate all played their part in this story.

The Amygdala and the Teacher

We have called the amygdala the fear center. Another, perhaps more useful, name would be the danger center or the negative emotion center. Our amygdala says, "This is bad for me!" It is taking care to be sure that we react to bad developments.

The amygdala is located at the end of that sidewise C under what we have called the back cortex. In chapter 2 we said this part of our cerebral cortex is mainly for analyzing our experience and making meaning of it. This certainly fits our idea of what the amygdala does. It helps decide meaning; it does not solve problems, create new ideas, or plan new actions.

Once again the structure of the brain supports an idea for teachers. Experience is always monitored for danger. We don't need to know all the details, but some physical facts about the amygdala seem relevant for teachers. Perhaps the most important one is that the amygdala gets its information rather directly from concrete experience. In his book *The Emotional Brain,* LeDoux describes how sensory signals go directly to the amygdala, bypassing the sensory cortex *before we are even aware of them.*[8] This so-called "lower" route begins to make meaning of our experience before we have begun to understand it cognitively and consciously. Our amygdala is constantly monitoring our experience to see how things are.

When we want to help someone learn, we should be aware that our learner will be quickly and subconsciously monitoring the situation through her amygdala. This isn't something she decides to do. It just happens.

Our learner may be wary already, since, after all, she is confronted with someone who may want to take control. What else would an "instructor" do? When the amygdala senses this danger, or some other possible danger, it sends signals directly out to the body, and these signals are also subconscious. They produce body language, and in an extreme case, they may directly trigger body movements such as jumping back, pulling someone out of danger, or running away. These ancient survival mechanisms are still at work in all our brains.

The dominance of these amygdalar processes may not be obvious to us at first. To help realize how strong they are, you might remember the 2000 presidential election in the USA. Even people who were known for keeping their cool were overcome by anger and negative emotion. The Sunday morning talking heads literally became the screaming heads! Amygdalar activity was apparent everywhere.

There is another side to the amygdala story. In some situations the amygdala becomes *less* active than normal, and negative emotions seem to diminish. An example of this is the response of the amygdala when we see happy faces. When that happens the amygdala seems to become less active than it is under normal conditions. It seems to drop its guard a bit.

Of great interest to teachers, the same thing seems to happen when the cortical brain becomes involved in cognitive tasks. For example, if someone puts her mind to solving a puzzle, the amygdala becomes less active.

This seems to be a good sign for the teacher! If we learn how to get our students more involved in their work, they will feel *less* nervous and afraid. If we focus on the work itself rather than the extrinsic reward, the intrinsic reward systems can begin to engage.

Brain Structures for Pleasure

Parts of the brain that contribute to feelings of pleasure, joy, satisfaction, fulfillment, or happiness may be even older than the amygdala.[9] If that is so, it seems uplifting. Maybe positive emotions are even more fundamental than negative ones. Maybe love is more important than fear.

As I mentioned previously, these structures in the brain are located deep and low beneath the front cortex. One such structure is called the *septum*. Stimulation of the clusters of cells in this region causes animals to enjoy themselves immensely. For example, cats begin to purr, groom, play, and rub their bodies against any object in their vicinity.[10] Also, the

pleasure drug cocaine and the intrinsic opiate compounds, enkephalins and endorphins, bind strongly to another part of the basal structures, the *globus pallidus*.

These findings and others suggest that noncortical structures beneath the front cortex are involved in positive emotion. The connection between the front cortex and happiness goes further. The generation of feelings of well-being has also been linked strongly to the release of dopamine throughout the front cortex. Since dopamine is thought to be the primary chemical modulator of good feeling, the places it is found in the brain are also implicated in the positive emotion,[11] so the entire front cortex is also implicated. Dopamine also binds to one of the basal structures near the septum, the nucleus accumbens, and this binding is greatly enhanced in cocaine addicts.[12]

Pleasure and Movement

The anatomical location of brain systems associated with pleasure suggests something about the origin of pleasure and the role of these brain systems in learning.

Remember that the front cortex is about action. It is the place where goal-oriented activity is controlled and ideas about actions are generated. In fact, some neuroscientists suggest that the role of dopamine in reward is to produce a "go" signal.[13] That is, the dopamine may not be the reward itself, but rather it may produce action, which is the reward.

It might not surprise you to hear that some of the basal structures are associated with action. For one thing, they regulate the actions needed for us to satisfy our drives such as thirst, hunger, and reproduction. They also are the central structures for control of complex pathways of activation and inhibition that produce coordinated and useful voluntary muscle contractions. They produce actions of great value.

Is there, then, a connection between happiness and movement? Is it possible that activity in these movement centers of the brain also generates pleasure?

At a basic level, this seems to make sense. Play, sex, dance, music, games, eating, talking, and many other pleasures all involve physical movement.[14] But can we take it further than this direct connection with body movement? I suggest we can.

My argument is that we also get enjoyment and satisfaction through anticipation of movement and imagined movement. We see this in progress toward a goal, such as when we solve a puzzle, derive an equation, or construct a work of art or a piece of furniture. And we see it in stories that lead our minds toward a goal. In fact, this is probably the most important thing that keeps us reading a good book or watching a movie. We want something to happen, or we are curious about what will happen—anticipated movement!

Success is progress toward a goal, and nothing succeeds like success. This could be one of the most important aspects of intrinsic motivation. *Achievement* itself is rewarding, and that may simply be because it is recognized as movement.

It goes on and on. When we feel deeply affected by something, we say we are "moved" or "speak of a moving experience." On the flip side, restriction of movement is painful. Loss of our freedom to move is used for punishments ranging from incarceration to making a child stand in the corner.

A rationale for such a connection between movement and pleasure can be found in the fact that movement lets us discover new things. Random reflex movements are the first step as a child learns to turn her eyes and then her head toward sounds. Exploring the results of random movements then leads to laughing, walking, running, and eventually speaking. Natural selection required that we move our bodies, and one way to achieve that, the most productive way, is to connect pleasure with movement. It is how we make discoveries, how we encounter the world, and how we learn.

Passive and Active Learning

The postulated connection between the basal structures and pleasure leads to an interesting prediction about passive versus active learning. Specifically, any learning that involves some sense of progress and control by the learner might be expected to engage the basal structures. This would be learning that is pleasurable. On the other hand, learning that involves recall of associations would be more connected with the back part of the cerebral cortex, the receiving part of the brain. This learning might be less pleasurable and require more effort.

These qualitative generalizations fit our general experience. We know that memorizing associations is hard work. The payoff is that we gain specifics and details because the associations are precise. There are right answers!

On the other hand, active learning that involves choice and actions by the learner is pleasurable and effective for developing concepts and applications. This type of learning gives an understanding of the big picture and the relationships in a topic.

A recent brain imaging study bears out these predictions about the brain and different types of learning. Poldrack and his colleagues[15] found that activation of the basal structures occurred when the learner was engaged in postulating answers and getting feedback on them, an active learning setting. But when the learner was simply asked to memorize associations, the basal structures were less active and the back areas of cortex near the memory systems were more active.

The authors of this paper stress the competition between these two types of learning, but our interest is that a learning protocol where the learner could sense movement by getting feedback on her own propositions triggered the basal structures, while direct memorization did not. It seems that the more pleasurable learning protocol engaged the basal structures.

A Center for Control?

When we eventually figure everything out, the anterior cingulate could turn out to be the most interesting part of the brain. Damasio suggests that this region is key for social reasoning, especially judging the outcome of behaviors. For example, it is the part of the brain responsible for our ability to recognize that we should not undress in public and to decide not to do so! Damasio ties this in with a broader picture of reasoning; in his research he has described how people make intelligent, and often useful, intuitive decisions that depend on their emotions and occur without conscious thought.[16] We will discuss this entanglement of emotion and reasoning in the next chapter.

Another fascinating emotion proposed for the anterior cingulate is the "urge to speak." Certainly part of the control we believe we have in our lives comes through our belief in the power of speech. We are quite convinced that if we can talk, if we can just explain, everyone will understand. We can gain, or regain, control.

What Happened to Tony

One of the best things about brain research is that it helps us realize what is going on as we live our normal lives. As I began to recognize that all these little bits of behavior come from a physical structure in the head, I thought differently about them. I found myself accepting student and teacher behaviors as natural results of the physical world, rather than tending to make judgments about them. And I felt that this made me more professional as a teacher.

My story about Tony may illustrate this. In the past I might have dismissed Tony as a "student from hell." For better or worse, I now view Tony in a totally different way. It goes something like this.

* * *

At first Tony acted for his own pleasure. I suspect that his front brain had the idea of sexual conquest. If so, this was a pleasant idea, and his pleasure centers generated action and anticipated some action! He flirted, joked, and used typical male ways of seeking attention. Whether he was aware or unaware of his courtship behavior, he just couldn't be still if he was to engage those pleasure centers.

But it seems that when I entered the picture, Tony sensed danger. His amygdala warned him that he might be in some trouble. His life was not threatened, but he may have sensed that he might lose some things he valued, not the least of which might have been his pride or his sense of control. He began to evaluate his situation and his options; his anterior cingulate was in high gear, trying to make judgments about what actions he would take.

In the meantime, Tony's amygdala was sending signals to his subconscious movement control system in his front brain and he completely changed his actions. The muscles he began to use and how he used them were driven by negative emotions, and he took on postures and behaviors characteristic of challenge.

Tony's brain was also fighting for control. I was trying to make him change, and his control center resisted that. We would call it stubbornness, but really it was just his control brain responding to the amygdala. He had pretty much decided that he *would not learn* from me!

Tony only decided to take a different tack when he got new information from his classmate. The way this new information came was of great importance. It wasn't in the form of reprimand or persuasion from me, which might well have been fruitless, but simply an observation from a third party, someone who was not engaged in the struggle. Tony's brain felt free to interpret this information on its own, and he began to feel back in control.

In the end, as he became engaged in his cognitive work, Tony's amygdala calmed down. He found new pleasure in regaining control of his own brain, he took on new body language, and he began to do good work.

Our Trade and Our Art

In this chapter I have focused on emotion and its influence on motivation, attitude, and behavior in the teacher-learner relationship. I have tried to show the natural fit between learning and living. Since living is about what we want, we are not surprised to find that learning will also be about what we want. We will always be motivated to learn things that fit into what we want and to resist those that don't, especially things that look like potential threats to our happiness or that seem as if they might take away our control of our lives. Specific structures in our brain deal with this type of thing, and they still function powerfully in our modern human brain. This is the way we evolved and the way we are, so part of the art of changing the brain must be built on these biological realities.

But there is more to this story of emotion and learning. In fact, I worry that I may have given the impression that emotion is driven *just* by certain parts of the brain. You might think that emotion and cognition are physically separated in the brain, and that would be too simple. In fact, we could argue that the entire brain is an organ of emotion, and that emotion, reason, and memory are all linked together. Learning is even more our trade and our art than we have realized!

We will see why in the next chapter.

Notes

1. Some argue that the abilities of the human brain go far beyond what we needed for survival. For example, see Steven Pinker, *How the Mind Works* (New York: W. W. Norton, 1998). Pinker asserts that music has no value for survival. But that is hard to judge. Maybe we can't think of its value for survival, but that does not prove there is none. We might discover it later.
2. To put this number in perspective, it may help to realize that cellular life is thought to have begun about 4 billion years ago. If the human cortex appeared sometime between 40 million and 4 million years ago, this would be about one one-thousandth to one one-hundredth of the evolutionary time up to then.
3. Some emotional responses may be instinctive rather than learned. One possible example is a fear of movements or shapes that resemble snakes. We may also react spontaneously with fear or pleasure to facial expressions.
4. A. Kohn, *Punished by Rewards: The Trouble with Gold Stars, Incentive Plans, A's, Praise, and Other Bribes* (New York: Houghton Mifflin, 1983), Chapter 8.
5. J. LeDoux, *The Emotional Brain* (New York: Putnam, 1997), pp. 85–103.
6. A. W. McDonald III and colleagues, *Science* (2000), 288 p. 1385; T. J. Maddock, *Trends in Neuroscience* (July 22, 1999), p. 310; and J. D. Greene and colleagues, *Science* 293 (2001), p. 2105.
7. Pleasure-related structures include the basal ganglia, basal nuclei, ventral striatum, and septum. All of these are noncortical and are found deep in the brain.
8. *The Emotional Brain,* 160–170.
9. P. D. MacClean, *The Triune Brain in Evolution* (New York: Plenum Press, 1990), Chapter 2.
10. Ibid., pp. 344–345.
11. The exact function of dopamine remains unclear. It may be a producer of pleasure, or it may draw our attention to things that look like pleasure. But it is clear that dopamine is somehow tied importantly into what the brain ends up wanting. Maybe a good way to define dopamine would be to call it the "wanting" molecule. See S. Wickelgren, *Science* 278 (1997), pp. 35–37.
12. C. Pert and S. Snyder, *Science* 179 (1973), p. 1011; M. Herkenham and C. Pert, *Proceedings of the National Acadamy of Sciences,* USA 77 (1980), p. 5532; J. K. Staley and D. C. Mash, *Journal of Neuroscience* 16 (1996), p. 6100.
13. E. T. Rolls, *The Brain and Emotion,* (New York: Oxford Press, 1999), p. 199.

14. MacClean *(The Triune Brain)* also discusses the connection between pleasure and movement, as does C. Hannaford in her clever and intriguing book, *Smart Moves: Why Learning is Not All in Your Head* (Arlington, Va.: Great Ocean, 1995).
15. R. A. Poldrack and colleagues, *Nature* 414 (2001), p. 546.
16. A. Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain* (New York: Grosset/Putnam, 1994); A. Bechard and colleagues, "Deciding Advantageously Before Knowing the Advantageous Strategy," *Science* 275 (1997), p. 1293.