WHERE WE OUGHT TO BE
THE NATURAL RELATIONSHIP BETWEEN
BRAIN STRUCTURE AND LEARNING

'tis a gift to come down where we
ought to be.
—Amish hymn

It was so pretty, it had to be true.
—James Watson on discovering
the double helix

Being director of a teaching center had some terrific perks. One of the best was that I was expected to learn about learning. You might not consider this a perk, but I did. It was a luxury for me to read and study about how people learn. I never had time before.

So I looked for new reading. What I wanted wasn't in biology or psychology books I had seen. I needed to get beyond synapses, stimulus/response, habituation, and Pavlov's dogs. My hope was to understand understanding. What must a brain do to comprehend?

It was then that I discovered David Kolb's book, *Experiential Learning.*¹ It wasn't particularly about biology, but still it came closer to what interested me, so in I plunged.

Kolb began by talking about people I had heard of, but never read before, people like Dewey, Piaget, and Lewin. Combining their ideas about development and learning, he described a new "learning cycle." He said deep learning, learning for real comprehension, comes through a sequence of experience, reflection, abstraction, and active testing. These four cycle 'round and 'round as we learn.
I was skeptical of this idea at first. Surely there were many other ways to explain learning. It seemed too simple, too arbitrary.

But I gave it a chance. And, without warning, as I sat in my office on one warm spring afternoon, it all came together. I still remember taking that slow, deep breath, holding it for a second, and then releasing it with a sound somewhere between a laugh and a sigh.

I stood up and began to pace and talk to myself. "It is biological! Of course, it has to be. Everything is in the right place! It's too pretty not to be true!"

I surprised myself. I turned from skeptic to believer on that day. Things just came down where they ought to be.

* * *

In biology, the way things work depends on their structure—their physical structure. Genetic inheritance depends on the structure of DNA. Digestion depends on the structure of the gut. Any function found in any living organism must depend on some structure of some part of that organism.

This was my habit of thinking, and so it seemed that if the function we are interested in is learning, we should look for the structure that produces it, and the place we should look is in the brain. Ultimately, the structure of the brain should explain learning. It's only natural.

That is what I saw on that warm spring afternoon. What I knew about the brain told me that the learning cycle should work, and it told me why. For the first time I saw a structure designed for human learning, for understanding and comprehension.

First Look

In this chapter I will give you my proposal for this natural connection between brain structure and learning. We don't need to know much about the brain to do this. Neurons and synapses can wait until later, as can the complicated structures that lie deep in the brain. For now we can simply look at the outside of the brain and talk a little bit about what different parts do.

In the illustration shown below you can see a view of the left side of what is called the cerebral cortex. The cerebrum is the large part of the human brain that is thought to be responsible for much of the thinking
and learning we do, and the cortex is the layer of tissue that coats the cerebrum, like the bark of a tree; hence the name cerebral cortex.

This illustration shows three functions of the cerebral cortex, and roughly which parts of the cortex are engaged in each. The functions are sensing, integrating, and motor (which means moving). Notice that there are two integrating regions of cortex; we will discuss the difference between them later in this chapter.

These three functions of the cortex are not an accident. They do the key things that are essential for all nervous systems. They sense the environment, add up (or integrate) what they sense, and generate appropriate movements (actions):

\[ \text{Sense } \Rightarrow \text{Integrate } \Rightarrow \text{Act} \]

These three functions are seen in nervous systems ranging from those in simple animals to the human brain. In the paragraphs that follow I expand on this somewhat and describe more about these three brain functions.

The sensing function refers to the receipt of signals from the outside world. In people, these signals are picked up by the sense organs; eyes, ears, skin, mouth, and nose. They are then sent on to special regions of the brain for each of the senses. These signals come in small bits and have no meaning in their raw form. They are just little individual pulses of electrical energy coming in from the sense organs.

Integration means that these individual signals get added up so that whatever is being sensed is recognized in the sum of all these signals.
The small bits merge into bigger patterns that become meaningful things like images or language. In the human brain these meanings are then integrated in new ways that become ideas, thoughts, and plans. At their most basic, these integrated meanings become plans for actions. For example, they get added up in ways that generate a plan for what action is needed and where the action is needed.

Finally, the motor function is the execution of those plans and ideas by the body. Ultimately, motor signals are sent to the muscles that contract and relax in coordinated ways to create sophisticated movements. Importantly, we should realize that even speaking and writing fit in here because they involve some of the most sophisticated patterns of muscle contractions that the body carries out.

Brain Connections: An Overview

This transfer of signals from sensory input through the brain to motor output is a general pattern for all nervous systems, including the human brain. The most direct and simplest route for signaling in the brain, then, would be as shown in the illustration below. Sensory input could come from the outside world or from our own body, but once those signals have entered the sensory part of the cortex, they flow first through the integrative part of the brain nearest the sensory part, then through the integrative part nearest the motor brain, and then to the motor brain itself. Once action has been initiated, that action is detected by the sensory brain, so the output of the brain becomes new sensory input.
I want to stress that this picture is highly oversimplified. Later we will see that there are many other links, including parallel links and connections where signals go in both directions. What I have shown you is probably the simplest way to look at what the brain does.

Looking for Learning

Our objective is to get ideas about learning from the structure of the brain. We are looking for a structure that generates comprehension and understanding in people, something more than pure memory of facts or physical skills. It isn’t necessarily obvious how this type of learning can come from the structure we have been talking about. Somehow deep learning should emerge from sensing, integrating, and acting.

But this is where biology takes us, so we have to keep looking.

The Learning Cycle

The learning cycle explained in Kolb’s book is a key part of this search for learning, and this is the point where we can bring it into the story.

The cycle is shown below, in a simplified form. It relies heavily on the ideas of Dewey and Piaget, among others, and you may recognize some of the terminology as originating from these giants in the study of human learning.

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Concrete experience

Active testing  Reflective observation

Abstract hypothesis
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The cycle is based on the proposal that learning originates in concrete experience; hence the term *experiential learning*. But experience is *not*
the whole thing. In fact, it is just the beginning. Learning depends on experience, but it also requires reflection, developing abstractions, and active testing of our abstractions.

As you reflect on the learning cycle, remember that this is just the basic idea and that its implications are important and complex. I can’t do it justice at this point, but I will expand on it in later chapters.

**Natural Learning**

Let me remind you that when I first saw the learning cycle, I was skeptical. It seemed arbitrary. Why does the cycle stress these particular four things? Why are they placed in this sequence? Why is there any sequence at all? And what about other things like memory, feedback, or trial and error?

I might still be struggling with these and other questions if I had not seen the natural link with biology. You may have seen it already, but if not, the idea is illustrated below.

![Brain Diagram](image)

Put into words, the figure illustrates that concrete experience comes through the sensory cortex, reflective observation involves the integrative cortex at the back, creating new abstract concepts occurs in the
frontal integrative cortex, and active testing involves the motor brain. In other words, the learning cycle arises naturally from the structure of the brain. This is a pretty idea!

Is This about Teaching?

I will explain more about this connection between the learning cycle and the way brains are put together shortly. But I am worried that you may be wondering how this connects with teaching. Maybe you think that I am so enamored by my pretty idea that I have forgotten what the book is supposed to be about.

So I want to take a short break and talk about a teaching connection that comes up immediately if we accept the brain cycle that I propose in my model. Let’s start with a story.

* * *

Lilly Conferences on college teaching were a discovery I had made when I became director of our teaching center. They were always interesting and energizing, and I was looking forward to the session on this particular morning. The title was something like “Improving Teaching in Large Classes.”

I was surprised when the presenters began by discussing the record-keeping problems with large classes. How can you avoid making mistakes when you have a class of 1,000?

I agreed that this is important, but I began to get bored as the session went on. My real interest was in learning.

Finally, my frustration got the best of me, and I blurted out my question. “This is useful, but before we finish could you talk a little about learning? What is your experience with improving learning in large classes?”

She looked blank for a moment and then replied, “Well, this session isn’t really about learning; it is more about teaching!”

This startled me, but I persisted, “But how can you separate teaching from learning?”

In all sincerity, she replied, “You can teach well, do all the right things, without any learning. Learning is up to the student. If I am teaching right, I am doing my part!”
The Teaching Trap

Is this right? Can we teach without anyone learning?

It does seem true in some ways. You may have experienced something similar yourself. You may have tried your best to help someone learn, but discovered that it just didn't work. You were there, you taught, but learning just didn't happen.

Or did it? Just because your learner didn't understand what you hoped he would, does that mean he learned nothing?

This is where our model comes in. If indeed learning begins through sensory experience, then the teacher is in a trap. *Anything* she does can produce learning, because it is sensory experience.

It happens in school all the time. A student may not learn history in our history class, but he may learn that his teacher thinks history is interesting. Or he may learn that his teacher dislikes students, or that he is just overwhelmed. The student has an experience of some sort. His brain processes that experience, and ultimately he acts on it in some way. His action may be to close the book and look out the window, but that is because his experience has taught him that he doesn't need to listen, or that he doesn't care to listen.

You can plug in your own examples. You may remember when your "teaching" was wasted on an employee, a child, or a parent. It was wasted because your "student" didn't learn what you hoped he would. But he did have an experience; he did have sensory input. And his brain did something with that experience.

The more we understand learning, the more we will realize this. We can't separate teaching from learning. The brain won't let us off the hook that easily.

Rationale for Natural Learning

The brain cycle, then, provokes us to think about the sensory input that students get in our classes. But it doesn't end there. It also suggests that we should look at its implications for other parts of learning.

However, before we can do that, we need more details about what happens in the four parts of the cerebral cortex we have identified and how these functions match up with the learning cycle.
I have tried to summarize this match by lining things up in the two lists below. On the left side, I have listed a few things that our four parts of the cortex are known to do, and on the right side I have tried to show how a particular stage of the learning cycle seems to fit the capabilities of its matched region of cortex.\textsuperscript{5}

<table>
<thead>
<tr>
<th>Important functions of each part of cortex</th>
<th>Match with each stage of the learning cycle</th>
</tr>
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<tbody>
<tr>
<td>The sensory cortex receives first input from the outside world in form of vision, hearing, touch, position, smells, and taste.</td>
<td>This matches with the common definition of concrete experience, with its reliance on direct physical information from the world.</td>
</tr>
<tr>
<td>The back integrative cortex is engaged in memory formation and reassembly, language comprehension, developing spatial relationship, and identifying objects, faces, and motion. In short, it integrates sensory information to create images and meaning.</td>
<td>These functions match well with what happens during reflection, for example, remembering relevant information, daydreaming and free association, developing insights and associations, mentally rerunning experiences, and analyzing experiences.</td>
</tr>
<tr>
<td>The frontal integrative cortex is responsible for short-term memory, problem solving, making decisions, assembling plans for action, assembly of language, making judgments and evaluations, directing the action of the rest of the brain (including memory recall), and organizing actions and activities of the entire body.</td>
<td>This matches well with the generation of abstractions, which requires manipulation of images and language to create new (mental) arrangements, developing plans for future action, comparing and choosing options, directing recall of past experience, creating symbolic representations, and replacing and manipulating items held in short-term memory.</td>
</tr>
</tbody>
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(Continued)
<table>
<thead>
<tr>
<th>Important functions of each part of cortex</th>
<th>Match with each stage of the learning cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>The motor cortex directly triggers all coordinated and voluntary muscle contractions by the body, producing movement. It carries out the plans and ideas originating from the front integrative cortex, including the actual production of language through speech and writing.</td>
<td>This matches with the necessity for action in completion of the learning cycle. Active testing of abstractions requires conversion of ideas into physical action, or movements of parts of the body. This includes intellectual activities such as writing, deriving relationships, doing experiments, and talking in debate or conversation.</td>
</tr>
</tbody>
</table>

The point of the list above is to point out that the four parts of the cortex do things that are qualitatively different from each other. When we look at those things, we see the many ways they fit the four parts of the learning cycle.

Example: Learning a New Word Through the Learning Cycle

Let’s go through a specific example of how the learning cycle meshes with the functions of these different parts of the brain. Then we will examine actual brain imaging studies that seem to support this proposal directly.

Suppose my task is to learn a new word from another person who knows its definition. Let’s say the word is *flabmonk*. When I see or hear *flabmonk*, I have concrete experience. This is a visual and/or auditory sensory event for my brain. When I reflect on the word *flabmonk*, I remember other words and images that seem related or similar. I may recall that flab suggests fat, monk could be a religious person, or it could be an animal. This is the reflective brain at work; it primarily involves memory. As various possibilities come to me, I begin to develop an abstract idea for the meaning of *flabmonk*. I may think, for example, that a *flabmonk* is a new species of animal, or it may be a fat religious person, or a pompous fundamentalist. This is my abstracting brain at work. It is converting past images into new images, and then
into new words—new symbols for the real thing. Finally, I test my hypothesis. To do this I must act; I must speak or write. So I ask, "A pompous fundamentalist?" This requires activity by my motor brain. Instantly, my teacher responds. "Yes!" she says and laughs out loud! I have tested my idea.

Or he says, "Sorry, good guess! Try again." I have tested and my test failed, but now my sensory brain has new input and the cycle can start again.

Here is a summary of this example:

1. Hear words or see words = concrete experience
2. Remember related words, images, or ideas = reflection
3. Generate new words or ideas = abstraction
4. Speak or write new words or ideas = active testing
5. Hear or see new words and teacher's response = new concrete experience

Our hypothesis about the brain would say that number 1 involves the sensory cortex, number 2 involves the back integrative cortex, number 3 involves the frontal integrative cortex, number 4 involves the motor cortex, and number 5 reengages the sensory cortex.

**Brain Imaging Studies**

One of the most important developments in neuroscience over the past few decades is the creation of methods for examining what parts of the brain are most active when we are doing different things. These brain imaging tools have opened the way to much deeper understanding of how brains think and what parts are most strongly engaged for specific tasks. A brief description of two of these methods is included in the notes for this chapter.7

Many brain imaging studies support the suggestions I made for learning a new word. Let's look at one of them.

The experiments illustrated in this chapter are related to brain processing of words. Each image shows the areas of the brain that are most active when we are seeing and hearing words, mentally creating a verb, and speaking words.
We can clearly see the activation of specific parts of the cortex in the sensory events of seeing and hearing. (And, by the way, it also is our first demonstration of the actual location of the visual cortex and auditory cortex.) Experiments like this have been done for many visual and auditory processes, and these regions are well established.

The mental generation of verbs, which involves comprehending meaning (activating the back integrative region of the brain) and preparing to speak the verb (which activates the lower region of the frontal lobe), is shown in the lower right panel of this illustration.¹

Actually speaking the words activates the motor cortex region responsible for driving the muscle contractions needed in speech, which is shown in the lower left panel.

Together, then, these results demonstrate the separation of the experience, reflecting, abstracting, and active testing parts of the learning cycle in different parts of the brain.⁹
How Long Does a Learning Cycle Take?

You may be bothered by this example because it happens rather quickly. You might have gone through the whole cycle in a few seconds. But it wasn't instantaneous. You did need a second or two to reflect on flabmonk and make a guess about its meaning. It could have taken much longer, of course. If the word were a French word and you had taken French in high school, without a dictionary you might have thought for days, developing and testing several different ideas about a definition in that time. Only if you already knew the word could the process be instantaneous.

You also might have tried to speed things up by using a dictionary. But you would still be using the learning cycle. After reflection you would develop the hypothesis that you won't be able to recall the word, or at least not in a reasonable time, so you act on that hypothesis by turning to a dictionary.

This may seem like cheating, somehow, but my point is that we always seem to go through the four steps in one form or another. It could even be that we reflect on an experience for years, eventually arrive at an abstract understanding, and finally we confirm our understanding through some action. For example, we change our behavior as a test of our new hypotheses about how to live. Eventually we attain wisdom and regulate our lives by use of the learning cycle.

Our brain has the capacity to reflect, develop ideas, and take actions continually. We are always in the middle of a multitude of learning cycles, getting new sensory information, thinking about different experiences, getting new ideas about their meaning, and testing those ideas. This is the story of our day-to-day lives.

Potential Confusions

Drawing the learning cycle the way we have is a little misleading. We can get the idea that the cycle goes just in one direction all the time. That is true in the sense that a cycle can't be completed until all steps have occurred, but the structure of the brain tells us that the communication between the different regions of the brain can go both ways. Signals can bounce back and forth between different parts.
In fact, the reverberation of signals between meaning and hypothesis reminds us of what seems to happen anytime we think hard about something. We conceive meanings that have implications, and when we put those implications into a hypothesis, we are reminded of other, possibly conflicting, meanings that imply something else or add complexity to the implications. As a result we create a new hypothesis or modify our old one. So it goes until we decide to act on our hypothesis, and then we find out how well we have done our thinking!

There are also shortcuts that make it possible to skip over one part or another. We will see this more clearly in chapter 3 and in chapter 12, but it is important that you realize here that we are not talking about a simple merry-go-round.

Of course, the same is true of learning. We bounce back and forth between reflection and ideas all the time as we think about our experiences and try to make sense of them. Often we will almost skip reflection completely and try a shortcut directly to an idea or even an action. Trial-and-error learning in its least complex forms can be considered simply use of the sensory and motor brain, omitting the integrating brain completely. We try (act) and we fail (sense).

As we would expect, the way the brain is put together and the way learning goes overlap each other in these more complex ways as well as in the simple linear path suggested by our drawings.

Questions for Teachers

The idea that the learning cycle is the natural result of the structure of the brain should encourage us to think about how we might use it to help people learn. We will examine that approach more extensively later in the book, but in the mean time here are some questions that may lead to a few interesting ideas.

- What if we view our “teaching” simply as sensory input? Could we use knowledge of the sensory brain to guide us in our practice? Would this change how we plan our teaching and how we present information?
- What if the assignments we give were intentionally designed to integrate experience and memory through reflection? Could we
use our knowledge of the integrative brain to guide us? Would
assignments be different? Assessments?

- Could we insist that students develop their own abstract ideas and
  explanations—that is, use their integrative frontal cortex?

- How would we bring the motor brain into our teaching? How
can we insist that students actively demonstrate their ideas—not
our ideas, but theirs?

- How can we challenge students to use their sensory brains to
  observe their own active testing of ideas. How can we make them
  aware of their own learning?

- When we try to help people learn, can we find ways to encourage
  them to use all parts of the learning cycle?

- Why not say that all learning is experiential, school learning
  included? The structure of the brain does not change when we
  enter a school, so why should we think school learning is
different? Aren’t classes experiences? Won’t students reflect on
  that experience? Won’t they generate their own ideas about what
  the experience means? Won’t their actions come from these ideas?
  In fact, isn’t that the way it has always been?

As I have indicated, we will address some of these questions later in
the book, but that doesn’t mean you can’t begin to think of your own
answers now!

Starting a Foundation for Learning

This chapter is the first step in creating a foundation for learning. The
building blocks for our foundation are the sensory, reflective, abstract-
ing, and acting brain. We use those parts of our brain through experi-
ence, reflection, hypothesizing, and active testing. Everything I say
from here on can be supported by these ideas.

Without biology, the learning cycle is theoretical. But with biology,
it seems that we are closer to fact. The brain is actually constructed
this way. We can build our ideas about teaching on a solid and secure
foundation.
In the next chapter we may find ourselves feeling even more secure. As we look deeper into the structure of the brain, we will get a strong sense of the need for proportion in our foundation. And of greatest interest, we will begin to see that if we get the proportions right, our foundation becomes something more than a support. It becomes an agent of change in the learner.

Notes

2. The chemical senses, taste and smell, are located in regions of the cortex that are not visible in this illustration.
3. This brief description does not show the deep conceptual foundation on which the cycle rests. This cycle combines experience, perception, cognition, and behavior into one learning theory. Each of these represents a major field of psychology/biology.
4. *Experiential learning* is often thought of as simply giving people experience. But I stress that little true learning takes place from experience alone. There must be a conscious effort to build understanding from the experience, which requires reflection, abstraction, and testing of abstractions.
5. It is important not to overinterpret these illustrations. They are not meant to be precise or anatomically accurate, but to help convey these general ideas. Here are a few potential misunderstandings: (1) The connections do not directly follow the pathway shown by the lines or arrows. For example, the connections sometimes follow the folds of the cortex and sometimes pass through other, deeper brain structures on the way. (2) The connections simply mean that the process can occur. There are no physical, lock-step mechanisms implied. Also, there is no implication that these are the only connections one could draw. (3) The brain illustrations are not exact. For example, in the sensory brain we have not really labeled the exact cortical sections for visual, audio, or touch. I will be more precise about this in later chapters. (4) The drawings showing sensory input and motor output do not imply direct entry or exit of information and actions to or from the cortex. This requires connections with the sensory organs such as the eye or the skin and connections with the muscles of the body through the spinal cord.
6. The reader should not take these lists of function as rigid or absolute. Different functions dominate different anatomical parts of the brain, but some of these functions also involve multiple areas. This is true in general about cognitive activities, which are complex and undoubtedly involve interactions between different brain regions.
7. The two imaging methods that I will mention are called PET and fMRI. In PET a small amount of radioactivity is injected into the subject, and when parts of the brain become active, they take up more of that radioactivity. Uptake is measured by sensitive detectors that send the information to a computer to produce the image. PET images are quite diffuse and tend to exaggerate size of the brain area that is affected. In fMRI no radioactivity is needed. Instead, a large magnet detects changes in the amount of oxygenated hemoglobin in the bloodstream that supplies specific areas of the brain. When such areas of the brain are more active than others, their oxygen requirements increase, which is detected and imaged by a computer. fMRI images show changes in smaller areas of the brain than those seen in PET images; they sometimes appear confusing because of the scattered appearance of these small areas. All PET and fMRI studies are averages of several subjects and require careful controls so that the background signals can be subtracted.

8. The area of the brain engaged in comprehension of language was identified by Wernike long before imaging techniques had been developed. Likewise, the frontal region required for assembly of language has been known for over half a century (Broca's area). In fact, all four of the imaging results shown in this illustration are merely confirmatory of the functions of these regions of cortex, whose functions have been previously known.

HOLDING A JUST BALANCE
BRAIN CONNECTIONS THAT CHANGE DATA INTO KNOWLEDGE

Fortunate is the man who takes the right measure of himself and holds a just balance between what he can acquire and what he can use.
—Peter Mere Latham

Hamilton was a sincere young man from the Midwest. He struggled in my class, so I asked him to come in for help. I learned his story as we worked together that semester.

A “latchkey” child, Ham had spent a lot of time watching television. His parents were both teachers and they valued learning. They encouraged Ham to watch educational TV, and he grew up on Sesame Street, PBS, Nature, and The Discovery Channel. Ham remembered a great deal of what he saw on TV, and his knowledge helped him in school. Compared to other students, Hamilton learned and remembered a lot from his school subjects.

He continued his affair with TV in college. “Did you see Discovery last night?” he would ask his classmates, but they would just laugh and talk about the soap operas.

It may or may not surprise you to learn that things did not go well for Ham in college. I learned later that his troubles began immediately in English composition, which all freshmen take. He struggled to produce logical arguments in his writing or even to assemble coherent paragraphs. He seldom rephrased things or asked questions. In my
class, Ham was virtually inactive. He listened intently, but he didn’t take notes and he didn’t ask any questions. It was as if he were watching a movie.

I felt that I helped Ham some, and he did pass my course. But I didn’t see him at the beginning of the next semester, and eventually I found out he had withdrawn from college. I never heard anything more about him.

* * *

I have touted the learning cycle as a way to deep understanding. What this means is that the bits and pieces of information, or data, that enter the brain through experience ultimately get converted into what we call knowledge.

So how does this work? What is the origin of this transforming power?

One of the keys lies in what I call balance. As we realize more about how the brain divides its work and how the pieces are connected to each other, it will become apparent that balanced use of all parts is essential for the kind of learning we are discussing. We will also begin to realize what we should balance and the fulcrum on which this balance turns. We see another aspect of our foundation for learning.

Hamilton’s Problem

I have had many suggestions about Hamilton’s problem, the most common one being that he had some sort of learning disability. In a generic sense, it is hard to disagree with that diagnosis. He was disabled in some way.

But my thought is that his disability was not necessarily of a clinical nature. It is just speculation, of course, but it seemed to me he had simply formed the habit of acquiring more than he could use. Or, put another way, he never understood that what he was acquiring should be used. His learning was out of balance. He soaked up information and enjoyed it greatly, but that was the end. He didn’t do anything with his information. He didn’t use it to create ideas or actions.

If I am right, it is an extreme case, I admit, but students who remind me of Ham are not uncommon. In fact, I often hear complaints about such students from my colleagues: “They are too passive.” “They don’t
ask questions.” “They don’t put things in their own words.” And, the most common of all, “They just memorize!”

My amateur diagnosis of such passive students is that they do not use the idea and action parts of the brain effectively and rely almost totally on their sensory and memory brain. They have information, but it does not produce useful knowledge.

**Transforming**

To get a deeper appreciation for my idea of balance, it will help to look more carefully at some of the things that happen when information in the brain is changed into understanding.

The process of changing data into knowing is what Kolb calls “transformation of experience.”! It becomes evident in different ways, and here I divide it into three parts. First is a transformation from past to future. Our experience is in the past, by definition, but the ideas we create are for actions we will do in the future. They are plans. Without this transformation we rely totally on the past and our reflections about it. Ultimately we rely on memory. But if we use our experience to produce new thoughts and actions, we create a future. The potential of knowledge gained in this way is unlimited, and it can change how and what we do indefinitely into the future.

Second is a transformation of the source of knowledge from outside ourselves to inside ourselves. Our experience comes from outside the brain, but the brain has the ability to turn that outside experience into knowledge and understanding. The new knowledge comes from within. We no longer need to repeat, or even remember, exactly what we experienced from the outside. I suggest that this is the essence of what we mean when we speak of taking ownership of knowledge. It is a *change in the learner* from a receiver to a producer. Since we do not rely on the outside for understanding, we do not have to wait for new information to arrive to deepen our comprehension. We can move from passive to active and become creators of knowledge.

The third part is a transformation of power. If we bring our entire brain into learning, we will find control passing from others to ourselves. We will know what we need for further learning and we will take charge of getting it rather than remaining dependent on others.
Our own brain will begin to give the orders. We will move from a position of weakness and dependence to one of strength and independence.

You can see that this transformation is important. It represents at least part of what we can legitimately call "deep learning." It is learning that changes a life.

I will argue that all these changes happen at the same juncture in the learning process, a juncture defined by the structure of the brain itself. I believe that this juncture is the fulcrum on which information is leveraged into understanding.

Back to Balance

Ham was missing all these elements of transformation. His mind was in the past, it depended on sources outside himself, and thus he had no power. He had no control over his own learning.

I am not saying that he didn't need information or that he should abandon his television programs. Experience and information are necessary parts of learning. They are the raw materials for it. But by themselves they are not enough; they are about half of what it actually needed.

The structure of the brain tells us this. There is a part for receiving, remembering, and integrating information that comes from outside. And there is a second part for acting, modifying, creating, and controlling. If we are to learn in the way that transforms, we must use both of these parts of the brain.

Brain Structure

Generally, the receiving and remembering part of the brain is located toward the back of the cerebrum, and that which generates ideas and actions is in the front. Metaphorically, we might say that the brain turns its back on the past and points forward to its future.

The division between back and front of the cerebrum is illustrated below. You should not confuse this division with the terms forebrain and hindbrain, which have precise meanings used by biologists to describe different parts of the brain as they develop in the womb. The division I am talking about is really a separation between the front and back parts of the cortex. I will use the terms back cortex and front cortex to refer to them.
The way I have illustrated this division may seem obvious, but in fact it is somewhat deceiving. In all our illustrations, it appears that the "back" of the cortex is at the far right of the drawing. But that is just the back of the head, not the back of the cortex.

We can understand this apparent contradiction by looking at how the cerebral cortex develops in the womb. The illustration below shows this process, starting with a small bulblike structure at the end of some complex structures that make up older parts of the brain we are ignoring for the moment. Pay attention to the arrows and the B and F (back and front) locations as the brain grows during embryonic and fetal development of the cortex, through stages A to B to C to D.
As shown, the front and back segments of the original small knob remain in the same relative positions, while the tissue between them expands dramatically. This growth is up and out, so the final structure is shaped like letter C turned face-down. Technically, then, the ends of the C represent the parts of the cerebrum that are farthest from one another structurally and developmentally.²

This developmental picture shows how the front cortex and back cortex come from the development of the brain as well as from the function. It tells us that if we want to compare the functions of the front and back of the cortex, those most distant from one another, then we should look at the ends of the C structure, the so-called prefrontal and temporal cortex, respectively. I stress this not only to be accurate, but because we will shortly see that it is the connections between these two regions of cerebral cortex that are key to the transformations we are examining.

Review of Functions

In chapter 2 we outlined some specific functions for the sensory, integrative, and motor cortex. Now we are talking about the two types of integrative cortex, that in the front and that at the back.

What happens in these two "ends" of the cortex? Consider these functions that are associated with each.

<table>
<thead>
<tr>
<th>Back integrative cortex</th>
<th>Front integrative cortex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory of stories, memory of place, understanding</td>
<td>Choice, decisions to act, inhibition, emotions</td>
</tr>
<tr>
<td>language, flashbacks, emotions related to experiences,</td>
<td>associated with action, responsibility, mental</td>
</tr>
<tr>
<td>(facts, people, faces, experiences)</td>
<td>energy, consequences, predicting, creating</td>
</tr>
</tbody>
</table>

This comparison shows the functional difference between the back and front integrative cortex. Sensory input to the brain, input from the outside world, goes predominantly to the back half. This part of the cortex is heavily involved in long-term memory—the past. It is the part where our knowledge of both the inanimate and living world is mapped. It is where we remember people and their personalities. And
it is the part where connections are made between different past experiences. Much of what is there came from the outside world.

The front integrative cortex is about the future. It is where we develop ideas and abstract hypotheses. New things appear, and plans are developed here. It is where we organize our thoughts into bigger pictures that seem to make sense. Things are weighed here; it is where we decide to do or not to do something. It is where we take charge.

**Reversing the Scales**

If we look at Ham and other passive students, we can see they are using predominantly the back half of their cortex. Very few of the prefrontal functions show up in these students.

Could it be the other way? Is it possible that some students underuse their sensory and reflective cortex, while overusing their idea and acting cortex? Is it possible to find imbalance on the other side of the scales?

I think so. Let me tell you about another student of mine who seems to illustrate that type of imbalance.

* * *

Michelle took my biochemistry course for nurses. The students were all pretty nervous about this course. Many of them thought they already hated chemistry, and biochemistry sounded even harder.

In contrast to Ham, it was difficult to keep Michelle quiet. Her hand would shoot up all the time. At first I was happy about this, but soon I began to sense something strange. I was confused by her questions. Although they sounded logical, they began to seem empty.

It took me some time to realize that they were empty! She was fishing without bait, drawing a hook back and forth through the water hoping to latch onto something.

This continued after class and in my office hours. Her vocabulary began to change, and she would use words from biochemistry, but underneath it was the same. Her sentences were fine, even her paragraphs, but in the end they had no content.

On her exams, Michelle would write long answers in good English, but still they were vacuous. She would fill pages with prose that seemed intelligent and meaningful at first but which evaporated when read carefully.
At that time, I was not able to help Michelle much. I might do better now, but I’m not sure. Like Ham, she was disabled in her learning, and during the time in my class she never seemed to understand the value of using her back cortex—the value of gathering information.

* * *

Michelle is another extreme example, but I suspect that you have seen parts of this behavior in many students. Our gut response to them is that they need discipline. These students just need to go home and study! They need to get their information and think about it instead of speculating, going off the track in an irrelevant direction, or guessing.

My proposal is that, for a variety of reasons, these students under-use their sensory brain and their reflective brain. Some of my colleagues call these students “experience poor.” The scales are tipped heavily toward generation of ideas and actions, but there is not enough experiential data to work with and no time spent in reflection.

Connecting Back and Front

Both Michelle and Ham need better communication between the back and the front of their cortex, between temporal cortex and prefrontal cortex.

But since the prefrontal and temporal cortex are so distant from each other, you might wonder if the connections between them are strong. Maybe it isn’t so easy to keep balance. Maybe the front and back parts of our brains don’t talk to each other much.

But, again, the actual physical structure of the brain gives us new insight. In fact, some of the most obvious wiring in the brain is designed exactly for this front/back connection.

You could confirm this yourself with the simplest of dissections of one of the cerebral hemispheres. If you were to gently slice open the top of one hemisphere from front to back and a few centimeters from the midline, you would see large tracks of fibers running along from back to front. And if you dissected carefully, you would find four major bundles of nerves that carry signals between front and back.

These nerve bundles are called fasciculi. They are shown diagrammatically in the picture below. Each one has a specific name, but for
our purposes I have labeled them with numbers. As you can see, numbers two, three, and four directly connect temporal integrative cortex with prefrontal cortex. And as I mentioned in chapter 2, the signals on these fasciculi travel in both directions. They allow the receiving brain to communicate back and forth with the idea brain.

It is clear that the brain is wired so that the front and back talk to each other and that evolution placed great value on these connections. Other than the major connection between the two hemispheres, this back-front connection is the most obvious wiring in the brain.

What might this mean for educators?

You probably see my point and wonder why I make so much of it. After all, it’s not that educators ignore passivity in some students or superficiality in other students. We don’t need brain anatomy to tell us that these are serious problems. But once we see the fact in this physical form, it becomes more compelling. At least for me, this is true. It is the basis for my speculations about Ham and Michelle. I just can’t ignore this signal from biology. We are meant to use both front and back of our cortex!

The Transformation Line

Earlier in this chapter we talked about the transformation of the learner from a receiver to a producer of knowledge. Specifically, we pinpointed a physical place in the brain that defines this transformation. By now, it should be clear that I am speaking of this bridge between front cortex and back cortex.
We can also see this bridge in the learning cycle, as shown in the illustration below. It carries us over the line that separates the experience and reflection part of the cycle from the abstraction and active testing part. Data enters learners through concrete experience where it is organized and rearranged through reflection. But it is still just data until learners begin to work with it. When learners convert this data into ideas, plans, and actions, they experience the transformation I have described. Things are now under their control, and they are free of the tyranny of information. They have created and are free to continually test their own knowledge.

A Practical Example

I have proposed that the balanced use of the back cortex and front cortex will produce better learning. Often, however, we tend toward pedagogical approaches that stress one over the other. The traditional, didactic approach (delivering information) tends to focus on back cortex functions, and the discovery approach (proposing and testing ideas) on the front cortex functions.

You can imagine my enthusiasm when I discovered that this idea of balance has been developed into a specific middle school science curriculum by Marc Schwarz and Phillip Sadler, who are educators and researchers associated with the Mind, Brain, and Education program at the Harvard Graduate School of Education.4
Their project focused on the value of asking students to improve various physical devices, such as an electromagnet, based both on information that they were given didactically and on their own experimentation. In the example I saw, the teacher showed students an electromagnet, talked about what they do and how they are used, and prompted the students to think along lines that the teacher felt were important by using a questionnaire. This was followed by a hands-on experience in which students were asked to design their own electromagnet and to make improvements in it. They were also asked to develop their own hypotheses about electromagnets and test them.

This work was strongly based on theories of skill development advanced by Fischer, and the importance of “scaffolding” to help students perform at their maximal level. But, what drew my attention was the way it uses the learning cycle and how it engages all the parts of the brain that we have discussed here. It combines concrete experience with reflection, both arranged and supported by the teacher, with freedom (and requirement) for student abstraction and active testing of those abstractions. It is exquisitely balanced.

And it works!

Schwartz and Sadler showed that students taught solely by the traditional method gained understanding slowly and at a low level, while students using the discovery approach alone seemed to learn quickly at first, but their comprehension did not grow over time. In contrast to both of these methods alone, students using the balanced approach increased their understanding steadily and reached levels significantly higher than the other two groups in the end.

**Balance and Justice**

Up to now we have developed this idea of balance as a practical matter. The structure of the brain teaches us that we should challenge our learners to use both the front and back cortex.

Now I want to turn our attention to the idea of a “just” balance, the phrase used by Latham in the quote at the beginning of this chapter. Balance is also a matter of justice. If we do not teach to both the back and the front cortex, it is unjust for students. Keeping a just balance is our duty.
I hope this is apparent to you, but let me explain what I mean if it is not.

We provide an unjust education if we do not give every student the maximum opportunity for learning. Depending on their natural abilities, imbalance in education deprives some students of learning more than others. Those who are naturally more creative, or have better memories, or are more reflective, or are more active have different opportunities if we do not provide balance. That is unjust.

Pressures Toward Imbalance

I believe teachers are under pressure to deliver an imbalanced, hence an unjust, education for our students. The greater risk is that there will be more Hams than Michelles in our classrooms, but it goes both ways. Let's look first at some pressures that drive teachers toward teaching for the back cortex.

The “information age” is itself a major factor in this pressure toward acquiring. Notice that we do not call it the “understanding age.” In this era it often seems that information itself is the highest value; the more we have, the better.

That idea, however, can be challenged. We could argue that it is possible to have too much information. Information comes too fast for us to integrate and comprehend. Despite this danger, there is constant pressure to increase the amount of information in our classes. The number of things we feel we should tell our students continually increases.

A second component of this pressure comes from within. Our image of what it means to be a teacher is distorted in favor of the back cortex. We feel it is more important to have subject knowledge that it is to be creative as a teacher. Our greatest fear is that we will be found wanting in our subject knowledge. If we do not have enough facts, we are not qualified to be teachers.

A possible unexpected result of this pressure is that we may actually overwhelm our students with facts. I speak from personal experience. Early in my career I occasionally found myself intentionally cramming extra material into my plans for a lecture. I did this because I was slightly nervous that my students might ask too many questions and
find out that my understanding of the material was not as deep as I would like them to think.

There is also pressure in the other direction. Here we find the newer ideas of active learning and learning through play. These are the result of the strong reactions—some might say overreactions—to the old-fashioned methods such as lecturing or structured lessons. The shortcomings in these traditional methods are apparent, so we try something new. One new thing is an emphasis on social interaction and talking in learning. We are reminded of the effortless learning of children at play, and so we try to make the classroom more playful.

But this can also produce imbalance. It can swing too far. We can find ourselves stressing action and creativity at the expense of scholarship and information. We may make the classroom into a playroom but lose track of the intense concentration needed for true accomplishment. We find our learners drifting far off track and even devising ways to reduce serious grappling with challenges. We risk trivializing learning.

**Toward a Just Balance**

There will be a great deal more on pedagogy and how one might teach for understanding in later chapters, but as we close this discussion, I would like to direct our thinking toward ourselves and our practices. I would like to ask if they have the elements needed for a just balance.

First, we should recognize that a basic element of justice is the question of who it is about. One could argue that in a court, it is about the defendant, and in a class it is about the learner.

For most of my thirty-five years in teaching, I did not think of that. And I am not alone. Recently one of my more honest colleagues blurted out as much. “It is all fine to talk about different students and how we can help them learn,” he said. “But the fact is that I hardly ever think of that. I mostly worry that I might make a mistake, or that I might give out wrong information. I don’t worry about learning.”

Beyond this fundamental point, we can critique ourselves by looking at the transformations we spoke of early in this chapter. We can ask if our teaching is designed to support those transformations or not.

What about the transformation from past to future? If we stress balance, then we must include both past and future in our thinking.
The teacher can enrich students' minds by telling them things that are already known. That is the past. She can even tell her students what she believes will happen in the future, but for the students that is also the past. Information that enters the brain from outside is, by definition, in the past for that brain. The question really becomes, "Do teachers create opportunities, even make demands, for students to transform the information which came from their past into their future?" Do we even think about this? Or do we emphasize what is known, rather than what students think or do? Balance would require both.

What about the "outside-to-inside" transformation? Again, the outside is necessary and important for balance. As teachers, we are on the outside, but we have great influence by the way we manipulate, mold, and enrich the information our students need. For balance, we must give equal thought to how students take ownership of that information. How is it transformed from "ours" to "theirs"? How does the learner move from receiver to producer? It is possible that he must first be a receiver, that he must first get something with which to work. We know how to do this part. But how often do we challenge our learners to become producers of knowledge?

Finally, and most interesting, is the transformation of power. At the beginning, through sensory input, learners are dependent on some outside authority to inform them. This can be the teacher, or it can be a book, or today it often is the Internet. The source is not important, but for learning to happen, learners must continually take in new sensory input from outside themselves. The question is, when do they take over power themselves? How do teachers facilitate that? Or might they even resist it?

I believe this is an issue and a challenge for all teachers. I have changed immensely in the past decade, but occasionally I still resist when student questions begin to take up too much time. I have my plan and I have to get on with it. My old instincts still show up once in a while when I resist yielding power to learners. Balance is not easy.

Looking for the Enemy

We are unhappy with our Hams and Michelles. How did they get that way? Why are there so many of them? Whose fault is it?
Unless we believe that genetics has played a nasty trick on us and the "smart gene" has mutated, we tend to blame society for problems like these. With Ham we might blame television, and with Michelle, weak discipline at home or elsewhere. Or we can blame computers, calculators, videogames, liberals, or conservatives. Whatever.

This is unproductive and probably ultimately irrelevant, but it is our nature. So while we are looking for the enemy, we might glance briefly in the mirror. Again, speaking for myself, I can see some clear problems close to home.

What does school teach children? What do teachers actually teach? Arithmetic, reading, and writing, we all hope. But what do we model for them day after day?

On the one hand, school is about authority and control. It is about waiting for someone else to give assignments. It is about knowledge being located somewhere outside us: in books, in the teacher's brain, on educational television, or on the Internet. It is about facts and information. In short, it is about the back cortex.

At the other extreme, school can ignore the back cortex. We may stress creativity without requiring facts. We may encourage talk without substance. We may promote students who have little knowledge. We may deny students quiet time. We may model what our Michelles become.

Adding to Our Foundation

The message in this chapter is that our structure for learning should have a well-proportioned foundation. There should be balance between receiving knowledge and using knowledge. If this is achieved, then our foundation can do more than just support. It can be an integrated part of the larger structure.

But we still are missing one key element, perhaps the most important part. We still need the mortar that holds everything together, and that mortar is emotion.

Notes

1. See David Kolb, *Experiential Learning* (New York: Simon & Schuster, 1983). Transformation of experience into knowledge is a process, not a single step, and not even four steps. Kolb stresses the four stages of the
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.
