Chapter 1

introduction

Evolution and education, like nature and nurture, have often been put into opposition. Here, our aim is to bring them together. The brain has evolved to educate and to be educated, often instinctively and effortlessly. The brain is the machine that allows all forms of learning to take place—from baby squirrels learning how to crack nuts, birds learning to fly, children learning to ride a bike and memorizing times tables, to adults learning a new language or mastering how to program a video recorder. Of course, the brain is also our natural mechanism that places limits on learning. It determines what can be learned, how much, and how fast.

Knowledge of how the brain learns could, and will, have a great impact on education. Understanding the brain mechanisms that underlie learning and memory, and the effects of genetics, the environment, emotion, and age on learning could transform educational strategies and enable us to design programs that optimize learning for people of all ages and of all needs. Only by understanding how the brain acquires and lays down information and skills will we be able to reach the limits of its capacity to learn.

Neuroscientific research has already shed a great deal of light on how the brain learns. Recent advances in technology have provided an amazing tool for neuroscientists to discover more about how the human brain functions. Techniques such as brain imaging, which measures activity in the brain as humans perform a certain task, have significantly pushed forward our knowledge of the human brain and mind. Brain scientists can now offer some understanding of how the brain learns new information and deals with it throughout life.

In the past few years, interactions between educators and brain scientists have begun to take place. One of the authors spent three months in the spring of 2000 working at the Parliamentary Office of Science and Technology (POST), on secondment from her PhD in Neuroscience at University College London. The remit of POST is to provide the British Houses of Commons and Lords with timely briefing material on topical scientific issues.

At the time, the Early Years Education subcommittee was holding an inquiry into the appropriate care and education of children between birth and six years. The subcommittee had been bombarded with letters, reports, and manifestos from early years charities, schools, psychologists, and educators, many of whom cited research on brain development as grounds for changing early years education in the UK. Some of the arguments put forward contradicted each other. On the one hand, some argued that formal education should not start until six or seven years old because the brain is not ready to learn until this age. On the other hand, others argued that it was clear from research on brain development that children should be "hothoused"—taught as much as possible as early as possible. What were the Members of Parliament on the subcommittee to make of the conflicting evidence?

Both authors were engaged in these kinds of debates when, in June 2000, we compiled a report for the Economic and Social Research Council (ESRC) to indicate whether insights from neuroscience could inform the research agenda in education. The first thing we did was to organize a multidisciplinary workshop on brain research and education at the beginning of September 2000. Given the very short notice and the fact that the workshop was being held on a Saturday at the end of the summer, we predicted that it would be a very small meeting. Advertising the meeting locally, and only to people we thought might have a specific interest in the subject, we nevertheless received over 140 emails from people interested in participating—scientists and educators in equal proportions. It was an exciting and fascinating day. The only criticism of the workshop was that one day was not enough. In our discussions with teachers and education researchers, it became clear, to our surprise, that there is almost no literature on the links between brain science and education.

Yet scientists now know a considerable amount about learning—how brain cells develop before and after birth; how babies learn to see, hear, talk, and walk; how infants acquire a sense of morality and social understanding; and how the adult brain is able to continue learning and growing. What amazed us was, despite this growing body of knowledge and its relevance to education policy, how few links exist between brain research and education policy and practice.

One of the major contributions neuroscience is capable of making is illuminating the nature of learning itself. Despite major advances in our understanding of the brain and learning, neuroscientific research has not yet found significant application in the theory or practice of education.

Why is this? It might, in part, be due to difficulties of translating knowledge of how learning takes place in the brain into information of value to people concerned with education. We know one brain scientist who, after giving a talk about the brain to a group of educators, was told that "there is no point in showing teachers pictures of brain images—they just aren't interested in that."

We do not believe this to be true of all teachers, but we have to admit that there is currently very little material about the relevance of brain research to education that is readily accessible to the nonspecialist. In writing this book our aim was to reduce the gap that unfortunately separates brain science and education science.

Misconceptions about neuroscience

There are many obstacles to interdisciplinary understanding, not least the confusion caused by claims and counterclaims in brain research. One finding about the brain can be contradicted just months later by another scientist's research. But disagreements, findings and counterfindings, are part and parcel of normal scientific progress and integral to the evolution of our understanding about the brain.

Misconceptions about neuroscience—what neuroscientists are interested in, and how far neuroscience can extend in terms of its application to education—are only too easy to foster. Take, for instance, the popular idea about how few brain cells (is it 5 percent? 10 percent?) we actually use. There is no evidence for this whatsoever! Let's consider the percentage of the brain used just to tap one finger. As you can see in the brain image shown in Figure 1.1, a large proportion of the brain is activated when a finger is tapped. Tap your finger at the same time as reading this, and as well as maintaining your balance, breathing, and body temperature, almost *all* of your brain will be active. But don't worry—the brain has a fantastic capacity to reorganize itself, and although you use all of your brain at some point, you can always learn more.

But what about Mrs. W., who has massive brain damage and apparently lives a perfectly normal life? Does such a case demonstrate that the brain plays an insignificant role in controlling behavior—that we can effectively do without it? The contradictions in this example are less real than apparent. This brain-damaged person reveals remarkable but counterintuitive facts about the brain.

First, the case demonstrates the resilience of the brain: just a tiny proportion of brain cells remaining can, in certain circumstances, enable the person to behave normally. Indeed, neuroscience is crucial for discovering how the small number of remaining brain cells enable the repair of processes that underlie normal behavior.

Secondly, the case demonstrates not only the possibility for compensation but also its limits. Mrs. W. may well not have undergone extensive psychological assessments. So, superficially, she may seem to behave normally, but this might be because she has learned strategies to compensate for any difficulties caused by her condition. Indeed, she might well show abnormalities when tested on appropriately sensitive tasks. Before her brain damage she was right-handed.

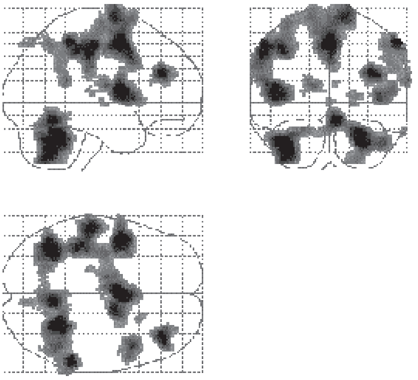

Figure 1.1 We use a lot of the brain a lot of the time. This brain image (showing brain activations viewed from the side, front, and top) shows that a large proportion of the brain is activated during the simple act of tapping one finger.

Now she would be unable even to pick up a pen with her right hand. She has learned to compensate almost perfectly with her left hand, using only her left hand to pour tea, pick up objects, write, and so on. This is just one example of the need for rigorous science when drawing conclusions about how much we depend on a properly working brain.

What about genetics?

The expansion in genetics research over the past few decades has revealed how important genes are in creating the individual. It is likely that genes play a significant role in learning and learning disabilities, and this is the kind of question beginning to be investigated by research groups worldwide. Thinking about the educational implications of genetics research will be a hugely important task for the future. The jump from gene to behavior is much greater than the jump from brain to behavior. We believe this jump can be made more easily once we have understood the links between brain and behavior.

A word about nature and nurture interaction

Genetic programming is not enough for normal brain development to occur. Environmental stimulation is needed as well. It is a scientific fact that sensory

Figure 1.2 Research into the genetics of learning is beginning. Can we imagine a day when it will be possible to select genes for teaching and learning?

areas of the brain can develop only when the environment contains a variety of sensory stimuli—visual stimuli, textures, and sounds. We will discuss this in more detail in the next chapter. It is plausible that the same is true for all areas of the brain, not just the sensory areas, and for all mental functions. From well before birth, the brain is shaped by environmental influences, not just by genetic programs. Take an acorn seed, which cannot grow without the right conditions of light, water, and nourishment, even though it contains all the necessary genetic material to become a mighty oak. It is meaningless to debate which is more important, nature or nurture, since both are needed to produce a living plant. Similarly, both nature and nurture are needed for normal development of the brain.

Here is another example that shows how nature and nurture go together. Many people like to lie in the sun to achieve a desirable tan. Melanin is responsible for this, and the more you have, the deeper your tan. To modern eyes, at least in the West, this looks healthy and beautiful. Imagine a Northern European woman with very pale skin, an African woman with very dark skin, and a Mediterranean woman with what is often called olive skin. No matter how much the Northern woman lies in the sun, her skin will only burn and will not turn dark. No matter how much the African woman avoids the sun, her skin will not turn pale. But in the case of the olive-skinned woman, we can see pronounced differences in skin color that are directly correlated with the amount of exposure to the sun. In this case, environmental effects (sun exposure) are the most striking observation; in the case of the other women, genetic effects (melanin production) are the most striking. When one type of effect is highlighted in some examples, say nature, this does not mean that the other effect, nurture, is thereby diminished.

Disorders of the developing brain

It may be possible to ignore the brain when talking about normal child development, but the brain cannot be ignored when discussing developmental disorders. Throughout this book when we talk about developmental disorders, we mean disorders that are caused by some subtle genetic programming fault that has an effect on brain development. Examples are autism, attention deficit/hyperactivity disorder (ADHD), and dyslexia. These disorders may have subtle origins in the brain but can have far-reaching consequences for cognitive development. They can come in mild to severe form and they usually persist for life. They are very different from temporary difficulties of, say, attention or language, which can occur from time to time during development for all sorts of reasons.

Diagnosing a developmental disorder and distinguishing it from a temporary difficulty is sometimes difficult. It depends not just on a few incidental observations, but can be arrived at only after systematic assessment of a child's developmental history. Because there are as yet no biological markers for most developmental disorders, the diagnosis depends on reports and analysis of behavior. This is not a trivial matter and the assessment tools used are constantly being improved.

What happens once a diagnosis is obtained? A chance conversation with a youth worker revealed the following anxiety. One of the young people he supervised had been diagnosed with dyslexia. He felt that this had given the student a passport to be lazy and not to bother with written work. As he saw it, the young man in question could now use the excuse of having a neurological disorder whenever somebody demanded an effort of learning.

In another conversation with a 30-year-old woman, she told us about her great relief when she was at last diagnosed with dyslexia, only after her son, who was experiencing the same difficulties that she had experienced as a child, had been seen by a specialist. She got in touch with other people who had similar problems and who had feared until then that they were just too stupid to learn. She now reports that both she and her son have made vast improvements in reading since their diagnoses. They each obtained remedial teaching that they would not have received without the diagnosis.

Between the double dangers of using a diagnosis as an excuse for opting out of learning and, conversely, of having low self-esteem due to lack of explanation for a learning problem, there are many other shades of experience. The value of diagnosis depends on the attitude of individuals and their willingness and motivation to overcome their difficulties. These issues surrounding developmental disorders will be discussed in Chapters 4–7.

A common vocabulary

If brain research is ever to inform education, then what is needed most urgently is a common vocabulary between brain scientists and educators. We have included a short Glossary of terms at the end of this book. In this book, we use the word *learning* to encompass all kinds of learning. When we refer to *neuroscience*, we include all kinds of study of the brain. That is, we include the study of molecules and cells in the brain although we concentrate mainly on cognitive and neuropsychology studies. By *cognition* we mean anything that refers to the "mental domain," which includes thinking, memory, attention, learning, mental attitudes, and, importantly, emotions. When we refer to *cognition* or *mind*, we do not mean to separate them from the *brain*. We believe that the brain and mind have to be explained together.

Brain science sheds counterintuitive light on learning

It might be hazardous to suggest that educational research itself does not or could not provide the best approach to many educational issues from its own resources and sound scientific thinking. As well as asking how neuroscience can inform education, it might often be useful to think about how brain science challenges commonsense views about teaching and learning.

The brain can work "behind your back"

One topic that comes to mind, and which will be discussed later in this book, is learning without awareness.

Did you know that the brain can acquire information even when you are not paying attention to it and don't notice it? This tendency of the brain to do things "behind one's back" is pervasive and is likely to have repercussions on theories

Figure 1.3 Scientists are notorious for using jargon, which can only be understood by other scientists in the particular field. This is a real obstacle when different disciplines attempt to interact and understand each other. In this book, we try not to use too much scientific jargon. Where it is impossible to avoid using a specialist term, we define it in the Glossary.

of teaching. We will discuss this ability of the brain to process information *implicitly* in Chapter 10.

The aging brain can change

Until relatively recently, it was widely believed that the adult brain is incapable of change. There used to be a strong assumption amongst brain scientists that after the first few years of life the brain is equipped with all the cells it will ever have, and that adulthood represents a downward spiral of loss of brain cells and deterioration in learning, memory, and performance generally. But research is beginning to show that this view of the brain is too pessimistic: the adult brain is flexible, it can grow new cells and make new connections, at least in some regions. Although laying down new information becomes less efficient with age, there is no age limit for learning.

The brain's *plasticity*—its capacity to adapt continually to changing circumstances—depends critically on how much it is used. Research on plasticity suggests that the brain is well set up for lifelong learning and adaptation to the environment, and that educational rehabilitation in adulthood is possible and well worth investment. On the other hand, the research also suggests that there is no biological necessity to rush and start formal teaching earlier and earlier. Rather, late starts might be reconsidered as perfectly in time with natural brain and cognitive development. Of course, the aging brain becomes less malleable and, as everyone getting older experiences, learning new things takes longer.

What about cognitive psychology?

Interdisciplinary dialogue needs a mediator to prevent one or other discipline dominating. When it comes to dialogue between brain science and education, cognitive psychology is tailor-made for this role. We believe that brain science can influence research on teaching and learning most readily through cognitive psychology.

However, although we believe that psychology is an important mediator of brain science, and has its own implications for education, we strongly feel that now is the time to explore the implications of brain science itself for education. From time to time in this book we necessarily refer to cognitive psychology experiments, since, in the words of John Bruer, the most outspoken critic of a premature application of brain research to education, it is cognitive psychology that "bridges the gap" between neuroscience and education.

Nevertheless, the aim of this book is to explore the world of the brain. So we try to focus on the results of brain research, and only mention cognitive psychology research when the brain science doesn't yet reach far enough to bridge the gap itself.

We are very aware that this book is not an exhaustive review of all the brain science that is relevant to learning—we simply cannot cover everything. In each chapter, we pick out and focus on a few seminal studies that we believe demonstrate the vigor of the field. You will see that we have written several pages about certain experiments, while other equally important studies are only briefly mentioned, or not even mentioned at all. This is just because we have had to be selective, and we think it is more interesting for the reader to hear about recent experiments that have not yet been widely reported. Naturally, we often dwell on studies that have been performed in our lab or by close colleagues.

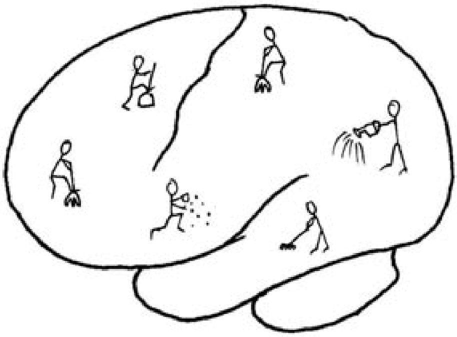

Figure 1.4 Teachers are a bit like gardeners when it comes to learning. Just like gardeners, teachers can sow seeds in a learner's mind, and can nourish and sustain good ideas and important facts, and weed out misunderstandings and mistakes.

Landscaping the brain

Individual brains, like individual bodies, are different from each other, but there is almost nothing that you cannot improve or change. When we look at the world around us there are many examples of how culture has enhanced nature, or improved on nature. A few examples that come to mind are glasses that improve eyesight, nutrition for growth, and orthodontists for crooked teeth. The brain is just the same. While orthodontists can improve your teeth, teachers can improve your brain.

Education may be considered a kind of "landscaping" of the brain and educators are, in a sense, like gardeners. Of course, gardeners cannot grow roses without the right soil and roots in the first place, but a good gardener can do wonders with what is already there. Just as with gardening, there are many different ideas of what constitutes the most admirable, and there are distinct cultural differences and fashions over time. Nevertheless, individual gardens involve making the best of what is there and it is possible to make astonishing new and influential designs. As we shall see throughout this book, this analogy can illustrate what we mean by shaping the brain through teaching and learning.

How does the brain work?

The brain is one of the most complex systems in the universe, and although we are starting to learn a great deal about it, we are still a long way from understanding exactly how it all works. This remains a puzzle that thousands of scientists all round the world are trying to figure out. But we do know some facts about the brain (see Figure 1.5).

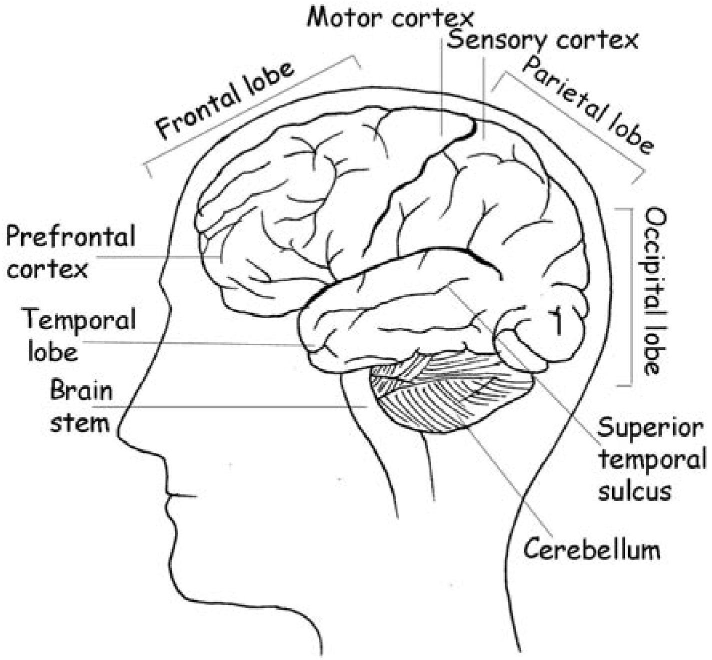

Figure 1.5 The brain viewed from its surface. The brain is divided into four lobes: the temporal, frontal, parietal, and occipital lobes. These are sometimes known as the cortex because they constitute the brain's outermost surface.

The adult brain weighs about 3 pounds (about 1.4 kg) and contains about 100 billion brain cells (or *neurons*—see Figure 1.6). This is a gigantic number of cells. Neurons have both short and long fibers that contact the bodies of other neurons, and there are about one million billion connections between cells in the brain. 100 billion cells is such a large number, it is hard to imagine. One million is 1,000 times 1,000, the population of a very large town, for example. One billion is 1,000 times one million. The number of connections in the human brain is much bigger than the whole earth's population, which is about 6 billion.

In discussing relevant functions such as "experiencing fear," "learning words," "doing sums," or "imagining movement," we are never talking about individual nerve cells. Instead, it is regions of brain tissue containing millions of neurons that are responsible for cognitive functions like these.

So how do neurons do these things? Like all other cells in the body, neurons act like tiny batteries. There is a difference in voltage (nearly one-tenth of a volt) between the inside and the outside of the cell, with the inside being more negative. When a neuron is activated it fires an impulse, called an *action potential*. Here, sodium ions rush in through pores in its membrane, briefly reversing the voltage across the membrane. This causes the release of chemicals (*neurotrans-*

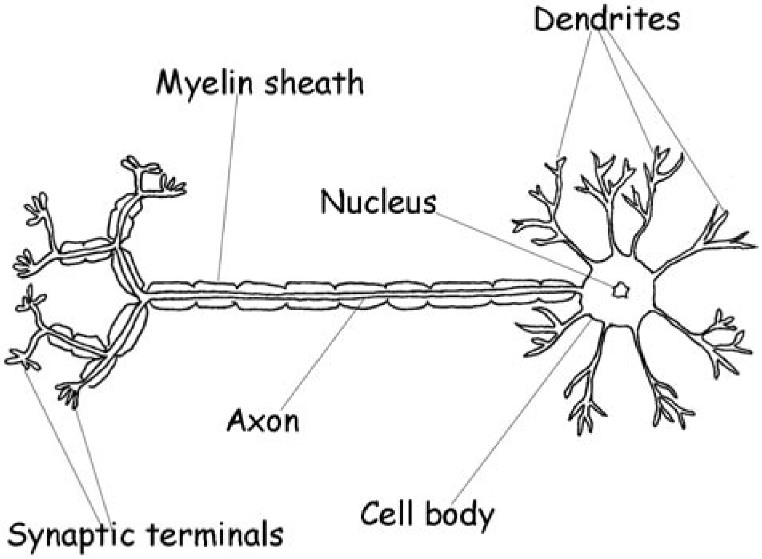

Figure 1.6 A neuron comprises a cell body, an axon, and dendrites. The axon of most neurons is covered in a sheath of myelin, which speeds up transmission of impulses down the axon. The synaptic terminals on the dendrites are the contact points with other neurons.

mitters) from the axon terminal of one neuron. These chemicals cross the synaptic gap and are received by receptor sites on another neuron's *dendrites*. This is illustrated in Figure 1.8. This is the "language" of the brain, the action potentials causing the brain's "activity."

Almost all sensory information crosses from one side of the body to the opposite side of the brain. So a touch to your left arm is processed by the right side of your brain, and the sight of objects on the right side of you are sent to the left visual cortex to be processed. This is true for all the senses except smell; it is also true for movement—your right *motor cortex* controls movement of your left arm. There are structures in the brain that are not crossed in this way, such as the cerebellum, which, for some reason that we do not yet fully understand, controls movement on the *same* side of the body.

How do we study the brain?

Here we give only a very brief taste of the kinds of techniques used to study the brain. If you want to know about these in more detail, you should have a look at

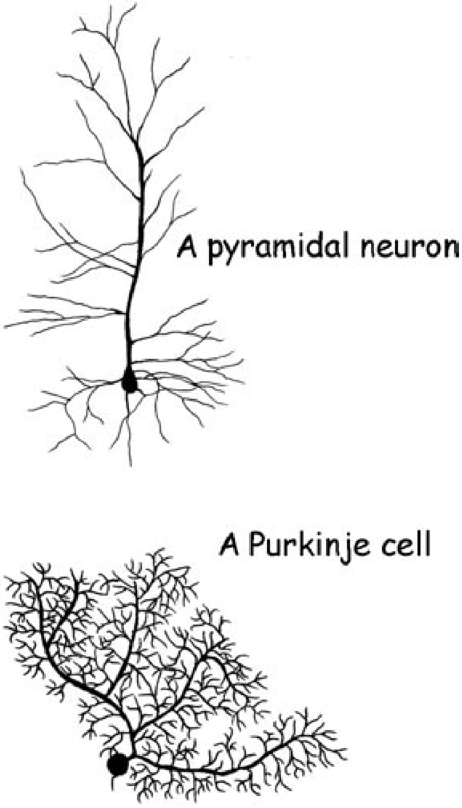

Figure 1.7 There are several different types of neurons in the brain, including pyramidal neurons and Purkinje cells. Pyramidal neurons, which appear pyramid-shaped under a microscope, are found in the cortex. Purkinje cells, named after the Dutch scientist who first discovered them, are only found in the cerebellum.

the Appendix at the back of this book, in which we explore in detail the different techniques that are currently used in brain research.

There are now several tools that can be used to study the brain. *Electrophysiology* studies involve recording from single neurons in the brains of animals while the animal is performing a certain task. This technique gives a direct measure of neuronal activity. Recording neuronal activity in humans is difficult, and studies recording from neurons of the human brain (for example, during open skull surgery) are extremely rare. But such studies are astounding in the wealth of detail they reveal about memories and actions that can be accessed by a mere "touch" of a particular tiny part of the brain's surface.

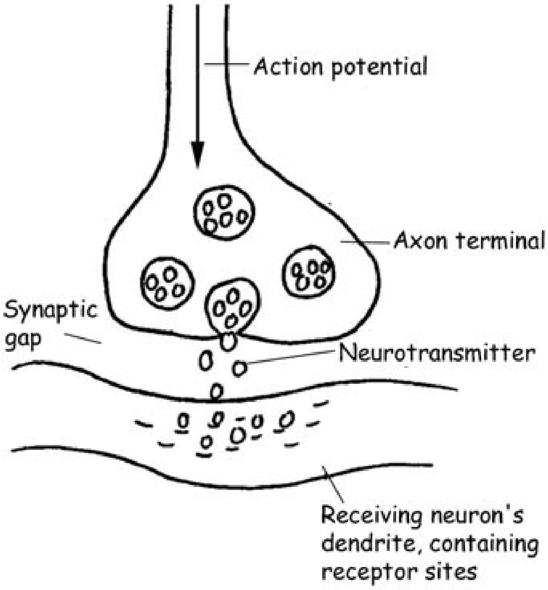

Figure 1.8 Action potentials are the language of the brain. When a neuron is activated it fires an impulse—an *action potential*. This briefly reverses the voltage across the cell membrane, which in turn causes the release of chemicals (*neurotransmitter*) from the axon terminal of one neuron. These chemicals cross the synaptic gap and are received by receptor sites on another neuron's *dendrites*.

Fortunately, there are several other noninvasive ways of evaluating electrical brain activity in humans and these relate to the behavior of thousands or millions of neurons that are linked together in particular brain regions. *Electroencephalography* (*EEG*) and *magnetoencephalography* (*MEG*) measure electrical and magnetic activity (respectively) arising from the brain. Recordings are made with electrodes placed on the skull.

Blood flow is an indicator of brain activity and can be measured using brain-imaging techniques. Blood flows to regions of the brain in which neuronal activity is highest and that require a replenishment of oxygen and glucose. *Positron emission tomography* (*PET*) and *functional magnetic resonance imaging* (*fMRI*) detect changes in blood flow. Recordings are made in special brain scanners.

Neuropsychological studies investigate the behavioral consequences of brain damage, and thus give an indication of what functions a particular brain region normally subserves. There is now also a way to study the effects of a temporary disruption of the brain using a technique called *transcranial magnetic stimulation* (*TMS*).

The story told in this book

The aim of this book is to demonstrate by examples how research on the brain and learning could influence the way we think about teaching. All the time while discussing brain research on learning at different ages, we attempt to point out implications, often speculative, for education where there are any. We are not trained as teachers, and we do not do educational research, so it would be presumptuous of us to make concrete suggestions about teaching. But we would imagine that readers with qualifications in and experience of teaching might be able to come up with their own ideas based on the research we discuss. On the other hand, much of the research is not yet ready for implications to be drawn, and where we believe this is the case, we say so.

We go on a neuroscientific journey through childhood, teenage years, and adulthood. If you are only interested in adult learning, feel free to start at Chapter 9—you will not need to have read the early chapters to understand the later chapters. The Glossary and Appendix will hopefully help with any jargon we inevitably use.

The book starts by giving an overview of research on brain development and considering whether such research can directly inform educational practice or policy. Many spurious beliefs about brain development still pervade educational dogma. We hear all the time about *critical periods* in learning. A friend of ours told us that she believed that the best thing for her young child would be "hothousing" by listening to classical music and recordings of grammar and vocabulary in several different languages, and by being shown flash cards with numbers and letters on. She wanted to make sure her child learned everything possible during his critical period, and was worried that after four years it might be "too late" for her child to learn as much as he could.

But are there really critical periods for learning in early childhood? Is it ever too late to learn? Do enriched early childhood environments improve brain development? Or are normal environments rich enough? Is hothousing a good thing or could it harm a baby's development? How do children learn about the world and other people? Does this knowledge arise from formal instruction? Or does it develop better without any explicit teaching, through play, exploration, everyday talk, and social interaction with peers and siblings? In Chapter 2, we attempt to tackle controversial questions such as these by evaluating the scientific evidence of how the brain develops.

Many people think of education as learning to read, write, and do arithmetic. We know someone who claimed that their six-month-old baby could count after being taught using flashcards. Can this really be true? Surely, skills such as arithmetic thrive through formal instruction? Or do babies have subtle mathematical abilities? What develops before instruction even begins? Would children develop mathematical understanding through everyday behaviors such as sharing?

Many of our Japanese friends cannot hear the difference between R and L sounds. Why is this? How can infants learn grammatical rules without explicitly being taught them? In many countries children are starting school earlier and earlier and being taught to read and write before the age of five. But brain science has shown that fine finger coordination does not usually develop until at least five years and is slower to develop in boys than in girls—so is five too early to teach children to write? Some children have profound difficulties with writing, and often this is due to problems in motor coordination called *dyspraxia*. The development of reading, writing, and arithmetic will be discussed in Chapter 3.

Chapter 4 describes the brain processes involved in mathematics. Why is it that certain types of math depend on spatial calculations and others depend on language? We explore how different parts of the brain are involved with different aspects of math. We address the subtle brain abnormalities that can lead to developmental *dyscalculia* and innumeracy.

Do you think of yourself as left-brained or right-brained? Should this influence the way people are educated? Or is this all a load of hyped-up nonsense?

Surely we know that women are worse at math and have poorer spatial abilities than men? Or is it really that simple?

In Chapter 4 we tackle these two controversial issues: the left brain/right brain theory, and gender differences in the brain.

Brain research has started to reveal the brain systems involved in literacy and Chapter 5 explores these. This research has shown that the effect of literacy on the brain also affects spoken language processing. Are there sensitive periods for learning language? What about learning more than one language early and late? How do deaf people's brains process sign language?

In Chapter 6, we discuss what brain research has told us about learning to read and dyslexia. Is learning to read music the same as learning to read words? Is it possible to show changes in the brain after training dyslexic people to read?

In Chapter 7, we look at developmental disorders that affect social and emotional experience, in particular autism, conduct disorder, and attention deficit disorders. Theories of these developmental disorders and their basis in the brain have implications for remedial teaching.

Research is revealing that the brain undergoes a second wave of brain development during adolescence. Adolescence is a time characterized by change—hormonally, physically, and mentally. In the last few years, a number of pioneering projects have been initiated that evaluate the development of brain processes during the secondary school years. These studies have shown that the brain is still developing during adolescence, and this will be the subject of Chapter 8.

In the remaining chapters, we look at how the adult brain learns. As hinted at above, recent research on the brain has revealed the exciting finding that, contrary to what was previously believed, the adult brain is able to change in size. Did you know that in London taxi drivers, whose spatial memories have to be exceptional, the part of the brain that stores spatial memories is much bigger than usual? And, remarkably, its size depends on the numbers of years the person has been driving taxis around London. In Chapter 9, we look at research that shows that the adult brain can change, in size and activity, and these changes generally occur as a result of usage. This research demonstrates that learning can be lifelong.

Perhaps the most important implication from neuroscience for education is that it may be possible to identify and modify the neural structures that underlie different learning and memory processes without having to pay attention. How can we learn without awareness? Is there a difference between remembering names and dates, and remembering events in one's life? One of the major contributions of neuroscience is illuminating the nature of learning itself, and this is the subject of Chapter 10.

Is imitation a good thing or does it stifle creativity? How does exercise boost both learning and brain function? Can you learn a new skill just by thinking about it? How can learning be enhanced? Neuroscientists are beginning to understand the brain mechanisms underlying different methods of learning, and these will be the focus of Chapter 11.

Based on findings from neuroscience, we can imagine a day when we will be able to use all sorts of radical new ways to improve learning and memory. In the final chapter, Chapter 12, we speculate about how various diverse lines of research are currently shedding light on how context, which includes biological as well as social factors, affects learning. How does your brain lay down memories while you sleep? Does your diet affect how efficient you are at learning? Why are negative emotional events better remembered than nonemotional events? Should learning be rewarded and nonlearning be punished? Can a time be envisaged in which you could pop a pill to improve learning for an exam?

Finally, if you are really interested in the brain and the tools used to study brain function, consult the Appendix at the back of the book. We also give suggestions for further reading and a Glossary of terms.