Teaching the brain to read

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How does the brain learn to read? How do we teach reading to a group of different brains or to a specific type of brain? Reading is an artificial process and was never part of the brain’s original design. As reading is a man-made process, what parts of the brain are involved? During reading visual images are linked to sound through a series of connections in the brain and these project forward within the left hemisphere.

This book explains the neuroscience behind reading and explores the brain-based implications that it has for teaching. ‘Teaching the Brain to Read’ is written for teachers, parents and reading specialists, using brain research to support theory and practice. It reviews the major developments in brain imaging research over the past ten years, as well as parallel changes in the philosophies behind teaching reading and best classroom practice.

The miraculous process of reading can be explored by looking inside the brain. How does this ability develop? How does teaching change the way the brain is wired? What specific areas can be targeted for reading remediation or accelerated learning? This book provides an understanding of how the brain develops reading connections. It will benefit all of those interested in reading acquisition as they explore the latest research on the brain’s ability to process this complex area of human achievement – reading and writing.
INTRODUCTION

The human brain is still the most remarkable piece of circuitry in the world. It has evolved over millions of years to provide humans with a system that can access information, compute a calculation or remember an event. While the brain’s hardware was designed to ensure our survival in the world, the brain’s software has more complex functions. The amount of information available today is increasing more rapidly than the brain can evolve to absorb it. To keep up, the brain must function in miraculous ways to engage in learnt processes such as reading. Our knowledge base is growing exponentially and reading remains the favoured means of accessing new information.

Modern technology allows scientists to actually look inside the brain and watch it at work. Experiments can test how the brain goes about doing different things. For example, the brain’s activity can be monitored as it solves a problem. By using functional imaging to look inside the brain, neuroscientists can begin to understand how the brain learns, how every brain is different and what conditions are best for learning (Figure 1.1). By separating out the components behind reading, neuropsychologists can explore the most effective ways to teach the brain in an effort to make learning faster and easier. Specialists can also develop techniques for teaching a brain with learning differences, such as the dyslexic brain.

Learning processes like reading, spelling and writing involve complex neural circuitry linking specialised processing areas of the brain. Reading circuits are normally formed in the left-brain, as around 95 per cent of us have left-brain dominance for language. Within the left-brain there are different processing centres with different specialisations. These are sometimes referred to as mod-
ules and provide us with the processing power to analyse our senses. Different language modules in the left hemisphere work together to achieve tasks such as reading, writing and spelling.

FIGURE 1.1 ILLITERATES AND LITERATES

Brain imaging has been used to compare illiterates who never went to school with literates who did go to school (Petersson et al., 2000). Each participant was required to repeat made-up words. The illiterates found this task difficult in comparison to the literates. Inside the brains of literates there is a complex activation pattern, particularly in the left hemisphere. The illiterates on the other hand show considerable under-activation of the left hemisphere. Thus, teachers are programming the brain by putting the right connections in place!

While the left hemisphere is almost always dominant in language functions, control of the right hand is typically dominant for writing. This is because the brain is cross-wired, giving most of us better control of the right side of the body. But there are also same-side connections, which ensure that each side of the brain is capable of sending and receiving information to both sides of the human body. Furthermore, the two hemispheres are connected together by a thick bundle of nerves called the corpus callosum. The corpus callosum ensures that information can flow left-to-right and right-to-left. The left-brain/right-brain dichotomy is in many respects an oversimplification as the corpus callosum allows us to use both our hemispheres as an integrated whole. One can’t simply switch a hemisphere off. When it comes to literacy we spend a lot of time in our left-brain, but undoubtedly receive some support from our right-brain.

The human brain is made up of billions of interconnected brain cells. Connectionism can explain how the brain operates and
learns, based on an almost infinite number of connections that can be formed between brain cells. Connectionism explains how specialised modules of the brain communicate with each other. Both within and between regions of the brain there are connections, which create an information-processing matrix. These networks of connections provide feedback loops and ancillary support for learning. In accordance with connectionism, reading in the brain is a self-teaching system. Once the brain has learnt to read a word, it can use this knowledge to read new words. The brain quickly learns which words look right and which words need to be checked in a dictionary. The self-teaching function of the brain means that once the correct circuits are in place, the brain continues to reinforce these circuits, making them stronger. The reading system is intelligent. Eventually the brain will no longer require explicit instruction on how to read. At this stage the brain has learnt to teach itself.

Research into reading has increased dramatically in recent years. The most common method for studying reading is behavioural research. This examines the behaviour of the reader while performing different reading tasks, such as word recognition, phonemic awareness and spelling pattern tests. Behavioural research cannot give us answers about the brain directly, as it only tests the reading output observed. However, it does allow us to answer questions about how the reading system works through the observation of different reading tasks. Significant findings can then be repeated with functional brain imaging to examine where and when these processes are occurring.

There are numerous reading tests available that allow the researcher to gain an understanding of the strengths and weaknesses behind reading mechanisms. Norms from standardised tests are established across a large sample of readers, selected to represent the general population. Most standardised reading tests access competency by comparing actual skill with age-based expected skill. How is a child performing at reading relative to others of the same age? Other tests compare actual skill with expected skill based on a closely related skill. For example, expected reading abilities can be predicted based on spelling abilities, because reading and spelling are related. When a related skill diverges against predictions, the unusual pattern of strengths and weaknesses can be identified and the most appropriate method for teaching that child to read can then be determined.
Another research technique for studying the process of reading is computer simulation. Different theoretical models have been proposed to explain how word recognition occurs in the brain. Computer simulations of these theories have been created to explore how the brain reads words. Manipulations can also be performed using computer simulations to predict dyslexic reading patterns. For a theoretical model of reading to be effective, it must be capable of explaining the different types of reading patterns reported behaviourally. It must also be capable of explaining how the brain learns to read.

More recently, functional brain imaging has become a popular technique for examining the reading process. Functional brain imaging can be used to test how the different sub-processes involved in reading interact within the brain. Popular methods include electroencephalography (EEG), magneto encephalography (MEG), positron emission topography (PET), and functional magnetic resonance imaging (fMRI). Each of these techniques has its own advantages and disadvantages based on image quality and cost. One question which brain imaging techniques have enabled scientists to answer is: “When do changes associated with reading a word occur in the brain?” Temporal resolution is knowing when a change is occurring in the brain. It allows the investigation of different time windows during reading. For example, EEG research shows that accessing a word from the brain’s word bank happens between 150 and 250 milliseconds after the word has been presented. Sounding out words is slower than accessing a word and occurs 300 to 500 milliseconds after a word is presented.

EEG measures brain wave patterns by placing electrodes on the scalp (Figure 1.2). Participants sit in front of a computer monitor and perform different reading experiments that have been time-locked into the EEG recording procedure. From here, brain waves can be averaged across hundreds of trials and brain responses to different types of words can be computed. By varying the types of words used in the experiment the different sub-processes of reading can be manipulated in the brain. For example, high frequency words (such as was, that, and) can be accessed rapidly and directly, whereas nonsense words (such as minlop, trusnap, hinu) require longer processing times to decode the unknown word.

The disadvantage of EEG is that it gives poor spatial resolution relative to temporal resolution. Spatial resolution allows us to know exactly where in the brain these differences are occurring.
MEG works on the same principles as EEG, but is also equipped with a giant magnet to co-register where changes are occurring in the brain. Other researchers have used EEG in an fMRI scanner to collect both spatial and temporal information. An advantage of the fMRI approach is the excellent spatial information provided. Unlike EEG, fMRI works by calculating areas of activation based on changes in blood flow and oxygen levels (Figure 1.3). Subtractions are often used to isolate the process being studied. By subtracting

**FIGURE 1. 2 ELECTROENCEPHALOGRAPHY**
Electroencephalography (or EEG) works by placing electrodes on the scalp to measure brain wave patterns. Hair is moved aside and a saline solution or gel is applied to lower impedance. EEG measures the brain’s electrical signals that pass through the skull. The more electrodes placed on the scalp at one time, the better the spatial resolution. The strength of EEG is knowing when changes are occurring. Recording the electrical signal shows when different reading responses are taking place with millisecond accuracy.

word identification tasks from letter judgement tasks, an activation pattern of the different sub-components of reading remains. Implicit learning occurs when we learn something without being consciously aware of learning it. This type of learning is an ancient function of the brain and makes learning easier. Consciousness does not take up the entirety of the brain’s function. Many processes in the brain occur at a subconscious level, that is without our conscious awareness. For example, when reading we do not consciously go through the brain’s dictionary to recognise each word as this information is provided subconsciously. Reading is a mixture of conscious and subconscious processes. Conscious processing is more energy consuming as it places a load on work-
ing memory. Reading is, at first, a very conscious process, just like learning to ride a bike or play a piano. As we pick up the crucial elements of reading, we start developing subconscious processing capabilities. We can then enjoy the meaning behind what we are reading in our conscious, and leave the ‘nuts and bolts’ of reading to our subconscious. The ability to utilise subconscious processing makes the brain a more efficient reading machine both in terms of speed and accuracy. As we follow meaning in our conscious we can also direct attention to any possible mistakes.

**FIGURE 1.3 FUNCTIONAL MAGNETIC RESONANCE IMAGING**

This machine is a functional magnetic resonance imaging (fMRI) scanner at the Brain Research Institute, Melbourne, Australia. While MRIs are found at most hospitals, this machine is equipped with a functional scanner, so it not only measures the structure (or shape) of the brain, but can also record changes in blood flow and oxygen levels as the brain goes about performing different tasks or experiments. The fMRI scanner doesn’t use a radioactive tracer (like positron emission topography) so it is safe to use with children and even babies. This machine has a 3 Tesla magnet, which is one of the largest used for testing humans. The head coil contains a mirror so that no head movement is required to read the screen. Different words are presented on the screen and with a mouse click the subject can respond in accordance with the demands of the reading task. Numerous resting conditions are also recorded so that the brain’s basal state can be subtracted out.
made at the subconscious level, such as accessing the wrong word. Subconscious feedback loops detect mistakes so that self-corrections can be made.

Multisensory learning is a teaching method that provides implicit clues to the subconscious. When children are learning implicitly, they pick up the rules of letter/sound relationships without conscious effort. This reduces the workload on conscious processing during decoding, effectively making learning to read easier. For example, with colour-coded letters, not only is it easier for children to learn how to sound out new words, it is also enjoyable. The generation effect is another form of implicit learning that makes learning easier and fun through the creation of a new word. The generation effect, often referred to as learning by doing, improves learning when something is actually created. For example, children are more likely to learn a new word when they have actually constructed it for themselves with moveable letters. The multisensory approach becomes the training wheels for acquiring new reading skills. Once these skills have been acquired, the multisensory support will no longer be needed, and the training wheels can come off (Figure 1.4). Our understanding of reading has increased significantly in the past ten years. For the first time the physiological behaviour of the brain can be examined during the reading process. This exciting new field of cognitive neuroscience provides a platform for integrating findings across different disciplines such as medicine, education, neuropsychology, computer science and brain imaging. By considering reading across these different domains, a new frontier emerges – the reading brain.

**FIGURE 1.4 MULTISENSORY SCAFFOLDING**

The multisensory approach is used to include children with different learning needs and prevent the development of reading difficulties. Multisensory learning relies on kinaesthetic, auditory and visual training wheels to help build the reading circuits. Once the correct reading circuits are in place, these multisensory training wheels can come off, as the brain is now fully prepared for independent learning.
Although reading acquisition involves a complex multitude of brain connections, no two readers share exactly the same reading hardware. Each brain’s connections are as individual as a set of fingerprints. Neurological diversity explains the variability in the propensity of different brains to acquire reading. Some brains acquire reading very quickly, and are soon two or more years ahead of their reading age. Other brains find developing reading extremely difficult, no matter how hard they try.

THE ORIGINS OF LANGUAGE

Scientists estimate that language is at least 2 million years old. Our early language had no spoken component, as it involved communication through gesture. Over the course of almost 2 million years, the human brain evolved to support speech. It is estimated that speech developed sometime between 150,000 and 250,000 years ago and is believed to be an innate function of the brain, like walking or breathing. The ability to speak provides humans with different survival advantages over other animals. Spoken communication frees up the hands so that working and communicating can occur at the same time. Mothers can speak to their children, while at the same time have their hands free to care for them. Spoken communication allows us to communicate at night or around corners. Today, modern telecommunications allow instant contact between people almost anywhere in the world.

Unlike speaking, writing and reading are new inventions. Writing is about 4,000 years old. Just like the television or the
radio, writing was invented as an additional means of communication. Reading and writing in mainstream schools is even newer. The development of a written communication system is so recent that the brain has not yet had time to evolve and acquire these skills naturally – that is, reading and writing are still skills which must be taught. The invention of writing gave birth to the cognitive operation of reading. But because reading is a newly invented operation, there is no inherited brain module for reading. Reading must therefore be built on existing brain systems, across visual and auditory modules. Reading is a completely unnatural and artificial process in the brain and takes many years to acquire properly. It is not surprising that so many children initially find learning to read such hard work. Nevertheless, reading is important, as it provides an extremely effective way to acquire new information rapidly.

**SYMOMETRICAL VARIATION**

Most brains are asymmetrical, favouring the left hemisphere, which is the hemisphere dominant for speech. How does the brain develop this asymmetry? The foetal human brain has far more brain cells than the adult brain. During the third trimester, the foetal brain undergoes a pruning process where brain cells migrate to form connections with other brain cells. Brain cells that fail to make connections die off. The left asymmetry in the human brain represents connections being formed between regions in the left hemisphere. This process has developed through evolution. It provides us with a brain that has language dominance in the left hemisphere. From here, language processes that are developed form naturally in the left brain, which has a processing advantage. Later, this unilateral form of processing becomes a very effective way of learning to read, write and spell, as it means that information does not have to be duplicated by each hemisphere.

Human evolution has mechanisms for randomly creating diversity. Internally, the brain can rebel against the cell migration process through an abnormality called ectopias. Ectopias are clusters of brain cells that form to disrupt the migration during the third trimester, reducing the brain’s development of a left hemisphere asymmetry (Figure 2.1). This disruption results in less cells dying off as abnormal connections are formed.
Animal research has been used to investigate the effects of ectopias on foetal brain development. If foetal brain cell migration in rodents is interrupted through microscopic lesions, abnormal connections form with other regions of the brain. If the left front brain is disrupted, extra connections are formed with the right back brain. Some animals develop neurological differences naturally. Around half of New Zealand brown mice develop ectopias, resulting in rewiring and differences in spatial learning.

THE PARADOX OF READING SPECIALISATION

The discovery of ectopias explains how each person’s genes can vary the degree of brain asymmetry, and subsequently affect the ease with which reading is acquired. Differences in symmetry affect inter and intra hemispheric connectivity, resulting in functional differences during reading (Figure 2.2).

A disruption would not have been a disadvantage in the hunter-gather days, as reading was a long time away. Back then (pre-reading) the symmetric brain provided the tribe with another way of thinking about things (like using a boomerang when everyone else had a spear). Tasks like developing new weapons for hunting or new tools for farming may have required a more symmetrical brain to think differently. This is why neurological diversity is an important part of evolution. Having different types of problem solvers within the group is essential. By having both symmetrical and asymmetrical brains working in the same team, synergies lead to better problem solving. Anecdotal evidence points to a long list of scientists with creative strengths who were reluctant learners. They contributed to society by thinking differently and developing new ways of doing things. Famous people who struggled with reading include Leonardo da Vinci, Albert Einstein, Thomas Edison and Winston Churchill (Figure 2.3). Interestingly, after overcoming learning difficulties, Michael Faraday, James Maxwell and Nikola Tesla each contributed to discovering the mathematical principles behind today’s modern brain imaging.

Diversity is essential to evolution as it allows us to develop better problem solving skills. Humans generally work in groups and interact with others in their environment. Having different types of brains ensures that new ideas can be discussed, debated and created from different angles and with different points of view. Within a typical classroom there are groups of children with mixed abilities, not only in terms of life experiences, but also in
terms of neurological diversity. Some children have problems with reading (dyslexia), some with coordination (dyspraxia) and some with handwriting (dysgraphia). Others have problems with attention (ADHD), with oral language (dysphasia), with spelling (dysorthographia) or with mathematics (dyscalculia). All of these problems are in many respects man-made. These difficulties stem from neurological diversity to help with group problem solving rather than being learning disabilities. Thus, the prevalence of learning differences is controlled by an evolutionary mechanism designed to increase diversity. The concept of a dys-constellation, described by Habib (2003b), is used to explain different learning difficulties and how they are often interrelated (Figure 2.4). The constellation is far from a complete exploration and many of the learning difference stars have only recently been recognised as distinct conditions. Researchers in the field refer to these typologies as the new neuropsychology. There are an abundance of...
questions in the form of research projects waiting to be answered through testing. The different stars in the dys-constellation are as follows:

- **Dyslexia** is a condition that affects the ability to acquire reading skills. Dyslexics may have problems sounding out words or accessing whole word forms.

- **Dyscalculia** is a condition that affects the ability to acquire arithmetic skills. Dyscalculics may have problems telling the time, calculating or measuring things.

- **Dysgraphia** is a condition that affects the ability to acquire handwriting skills. Dysgraphics have problems with fine motor coordination, especially that which involves forming letters.

- **Dysorthographia** is a condition that affects the ability to acquire spelling skills. Dysorthographics have problems with visual memory recall of words.

- **Dyspraxia** is a condition that affects motor learning and balance. Dyspraxics have poor coordination skills, and may demonstrate problems with eye-hand co-ordination.

- **Dysphasia** is a condition that affects oral language development. Dysphasics can have problems finding the right words to express themselves.

- **ADHD or attention deficit hyperactivity disorder** is a condition that affects attention. Children with ADHD are often impulsive and may have problems maintaining concentration.

Teaching brains that have been wired differently is all about positive encouragement for building confidence and motivation. It is a pleasure to learn, but it is a sufferance to fail. Mixed-ability children wonder why they are so good at some things and so hopeless at others. Explain to them that our brains were never designed to read and that we all have a mixture of different strengths and weaknesses.

**SUMMARY**

Humans evolved with neurological diversity. This is a fundamental part of evolution because the more differences there are between brains, the better it is for group problem solving. Neurological diversity means that some brains are wired differently within the group, providing potential advantages for creativity, diver-
gent thinking and visio-spatial problem solving. Ironically, these strengths can come at the expense of reading. Nevertheless, with proper instruction, prevention and motivation, every child can learn how to read. In doing so, children can learn how to take advantage of their individual talents in today’s literate world.
During reading we activate a complex circuitry of specialised brain areas and connections. The neural architecture responsible for reading decides which parts of the brain are used for different components of the reading process. Over time, humans have developed different modules (processing regions) that are capable of processing different modalities, such as images or sounds. From our environment, we have learned how to develop links or circuits between these modules, providing us with the connections we need to read effectively (Figure 3.1). The foundations of reading are the modules that we build the reading circuits from. The reading circuits and the connections between modules can explain how the brain reads words.

**Modules**

Within the brain, two important modules are used during reading. These are:

1. An auditory module in the front of the brain that is in charge of speech processing; and

2. A visual module in the back of the brain that is responsible for accessing visual images.

Modules are areas in the brain that have developed specialisations for processing different modalities (Figure 3.2). Within the auditory and visual reading modules, there are also sub-processing mechanisms specialising in different units: sounds and pronunciations (auditory) and letters and words (visual).
Two million years ago there was no reading. In fact, there was no speaking. All communications involved gesture. It took the brain almost two million years to develop speech, which is considered a built-in ability, like walking or breathing. Just 4,000 years ago humans invented writing, giving birth to the cognitive operation of reading. But 4,000 years hasn’t been long enough for the brain to develop reading processes. It must therefore use older mechanisms – the visual and auditory modules – and link these by developing reading circuits. This link is something that must be taught, as it does not develop naturally like speaking does. In today’s literate world the brain needs to form reading circuits so that it can acquire new information rapidly.

**THE AUDITORY MODULE (FRONT BRAIN)**

The auditory module in the front of the brain houses two sub-components used during reading: pronunciation and phoneme sounds.

*Pronunciations*

All the word pronunciations that we learn during our lifetime are housed within the auditory module in the front of the brain. Verbal fluency is a measure of the number of spoken words a child knows, recognises and uses. Having verbal fluency is an important building block for learning to read, as speech is the output that we produce during reading. Pronunciations have to be present before connections can be made to whole word shapes. Children develop verbal fluency naturally through exposure to new vocabulary because speech is a natural ability while reading is not. Parents and teachers have a responsibility to explain the meanings of words children don’t know and should encourage the use of new words. All communication, including reading to children, helps to develop verbal fluency in the auditory module.
Phoneme sounds

At the front of the brain there is also a phoneme sound subcomponent in the auditory module that contains representations of sound units smaller than the whole word pronunciation. When children gain phonemic awareness they are capable of breaking up pronunciations into phonemic units of sound within the auditory module. Behaviourally, they now have an understanding that spoken words are made up of smaller units of sound that can in turn be manipulated. They also become aware of different units of sound. The largest unit of sound within a word is the syllable (e.g. caterpillar: cat/er/ pil/lar), followed at the sub-syllabic level by onset/rime (e.g. cat:/c/-/at/). The smallest unit is the phoneme (e.g. cat: /c/-/a/-/t/). While phonemic awareness is specific to individual
phoneme units of sound (/c/ /a/ /t/), phonological awareness also includes larger units of sound within words (/c/ /at/ or / cat/ /er/ / pill/ /lar/). Developing an awareness of sounds within words is a prerequisite for learning to read as it prepares us for breaking up and sounding out words (decoding). Phonemic awareness is in itself a strong predictor of later reading achievement.

How do we teach phonemic awareness in the front brain? Fun games and activities are one of the most effective strategies for developing phonemic awareness. Picture or object groups can be used for the ‘I spy’ game. Children identify a picture that they know the initial sound of, for example, ball, and say: “I spy with my little eye something beginning with the /b/ sound.” The I spy game teaches children that words are made up of different units of sound and how to isolate these sound units within words. Nursery rhymes are an excellent way to begin developing phonological awareness as they provide repetition, rhythm and rhyme. Children can hear similar sounds embedded over and over in the words

FIGURE 3.3 PHONOLOGICAL AWARENESS
There are six main operations of phonemic awareness that can be used to manipulate sounds within words. Matching (do big and bat start with the same sound?); isolating (what is the middle sound in dog?); substituting (change the /pi/ sound in play with a /st/ sound); blending (bring these sounds together (/f/ /r/ /o/ /g/)); segmenting (separate the sounds in frog); and deleting (say date without the /d/ sound). There are also different units of sound that we can identify and manipulate (Goswami, 2003). The largest unit of sound is the syllable, followed at the sub-syllabic level by onset/rime. Finally, the smallest unit of sound is the phoneme. When children master these different operations across the different units of sound they become phonologically aware.
of nursery rhymes. Rhyming bingo games let children compare the sounds behind pictures to see which pictures share the same sounds. Children do not need to ‘pass’ one unit of sound before gaining experience with another (Figure 3.3).

Larger units of sound may be easier for some children to initially acquire, since the smaller phonic units can be harder to isolate. Children can develop syllabic awareness by clapping out the syllables of a word. For example, by clapping out the syllables in butterfly – but/ter/fly. All of these activities help to develop the auditory module in the front of the brain.

THE VISUAL MODULE (BACK BRAIN)

The visual module in the back of the brain houses two subcomponents used during reading: word form recognition and letter shape identification.

Word recognition

The word recognition area in the visual module is specialised in recognising whole word shapes. As part of normal development, children begin to recognise symbols. Children may see the golden arches of McDonalds and say, “McDonalds.” The brain accesses the visual form of the golden arches in the visual module at the back of the brain and sends this information forward to the pronunciation subcomponent in the front of the brain (Figure 3.4).

FIGURE 3.4
SYMBOL RECOGNITION
Before children start learning to read they will begin to recognise common objects or words. They may see the golden arches of McDonalds and say, “McDonalds.” Here they are accessing the whole shape of the image in the visual module and are mapping this forward to the pronunciation subcomponent in the auditory module. This early logographic stage is a precursor to developing the lower circuit for reading.
Children may also begin to recognise simple words such as STOP from stop signs, before any instruction in what sounds the letters make has been given. This type of reading, referred to as the logographic stage, involves remembering words based on their visual characteristics (Figure 3.5). For example, the word ‘tall’ contains letters that are tall, allowing the shape to be recognised based on its characteristics. Children may learn the word ‘bed’ as it looks like a bed with two bed heads. Bingo games and flash cards can be used to introduce whole word forms for establishing and developing the visual word form module. High frequency words can be introduced on cards or magnets with their whole shape outlines. Here, the whole shape of the word supports early word recognition.

**Letter identification**

A letter identification subcomponent in the visual module is specialised for identifying the letters of the alphabet. Letter reversals are sometimes observed when children first start writing letters because the brain relies on spatial processing for learning the correct shapes. Spatial processing involves understanding the physical properties of letters in space. One way to tap into this spatial processing is the kinaesthetic approach. Letters made of sandpaper allow children to feel the shape of a letter and to see the shape it makes. By placing a piece of paper over a sandpaper letter, children can trace the shape for themselves before writing skills have been properly developed. Play dough can be used to construct letter shapes and large cut-out cardboard letters allow children to feel the shape of letters, see the shape of letters and trace the shape of letters. Another fun activity is to stick objects or pictures that start with a letter of interest onto the cardboard letters. Word examples can then be introduced to show children that words are made up of letters. The ability to identify the shapes of letters and then recognise the whole word form is referred to as graphemic awareness.

Parents and teachers often seek guidance on how to best prepare children for reading. Although there is no natural way to teach reading, because reading is an artificial process, the foundations of reading should be built in a way that is consistent with a child’s natural development. Much of this preparatory work in teaching reading can be done with games and fun activities. To prepare the brain for reading, two important modules must be activated: the auditory module and the visual module. By the time that children learn that spoken words are made up of smaller units of sound
they are developing phonemic awareness in the auditory module. When children become aware that written words are made up of letters, they are developing graphemic awareness in the visual module. The brain is now ready to start forming reading circuits between these modules. These circuits become the basis of their future reading ability.

*Reading circuits*

This book adopts a cognitive neurological model to explain reading acquisition. This model accepts that reading is an advanced cognitive operation within the brain and that reading is a skill which must be learned. The directionality of the reading stream is from the visual module in the back of the brain to the auditory module in the front of the brain. Reading involves visually perceiving the word in the back of the brain, and then mapping this perception to sound in the front of the brain. Within this directional flow, we know that there are two principal circuits used to read words: an upper circuit and a lower circuit.

**DECODING (THE UPPER CIRCUIT)**

The upper circuit is involved with decoding or sounding out words. This is scientifically referred to as grapheme-to-phoneme conversion. The upper circuit begins at the back of the brain in the letter identification subcomponent of the visual module. After analysing the letters of a word, and their sequence, information is then passed through this upper circuit to the phoneme sound subcomponent of the auditory module at the front of the brain (Figure 3.6). Each letter is mapped onto its corresponding sound so that a word can be decoded. This circuit is formed after instruction in letter/sound relationships (phonics).

The formation of the upper circuit in the brain provides a new mechanism for reading unknown words (Figures 3.7 and 3.8). Rather than guessing the word based on a picture clue, words can be decoded by computing the most likely pronunciation. The upper circuit can decode an unknown word based on knowledge of letter/sound relationships. As most of the words we see are novel when first learning to read, the upper circuit is a very powerful tool for acquiring new words as it helps us crack the phonological code.
When we read the word ‘cat’ for the first time, we have no entry in the word form recognition area of the visual module at the back of the brain. We therefore sound it out using the upper circuit, mapping the letter shapes onto the phoneme sounds. Phonemic awareness allows us to blend these sounds together to pronounce the word. Now that we can see and hear the word, we can take a snapshot of it and form an entry in the word form subcomponent of the visual module, which is linked to the pronunciation subcomponent in the auditory module at the front of the brain. This process of memorising a whole word shape is called a lexicalisation.

FIGURE 3.6 (left) PHONOLOGICAL STAGE
Try to read the Greek word καλισπέρα. Unless you know that the letter p actually makes the /r/ sound in Greek you will have problems decoding it. Once letters and their corresponding sounds are learned we can map from the letter shape to the phoneme sound. From here we use phonemic awareness to blend these sounds together and produce “kalispera” - meaning “good afternoon” in Greek.

FIGURE 3.7 (right) ORTHOGRAPHIC STAGE
When we see the word ‘cat’ and we know the word, we automatically access it in our visual module’s word form subcomponent. The lower circuit links quickly to the pronunciation subcomponent in the auditory module and we can then pronounce the word.

FIGURE 3.8
LEXICAL ACCESS
When we see the word ‘cat’ and we know the word, we automatically access it in our visual module’s word form subcomponent. The lower circuit links quickly to the pronunciation subcomponent in the auditory module and we can then pronounce the word.
The phoneme sound subcomponent in the front of the brain is not only specialised in recognising the units of sound within words, but is also used during sound manipulation. Sound manipulation refers to the ability to handle small units of sound within words. Different manipulations make up different phonological awareness operations. While these operations can be taught through the manipulation of sounds, they are often easier to acquire with the visual support of letters. Children can then see that the manipulation of letters leads to the manipulation of sounds. This is the basis for developing decoding skills and forming the brain’s upper circuit for reading.

**DIRECT ACCESS (THE LOWER CIRCUIT)**

Children first show signs of reading when they can recognise symbols (such as the golden arches of McDonalds) or simple words based on their visual characteristics (such as the words tall and bed). Here, children are directly accessing the pronunciation subcomponent of the auditory module. The lower reading circuit connects from the word recognition subcomponent of the visual module at the back of the brain to the word’s pronunciation (speech output) subcomponent in the auditory module at the front of the brain. Thus, no knowledge of letters, or letter/sound relationships is used to read words at this early logographic stage.

Once the upper circuit for reading has been developed and new words can be decoded, a whole word ‘snapshot’ is taken so that the visual word form linked to pronunciation can be stored in the lower circuit. Thus, there are two ways to create a word representation in the brain’s word bank (housed in the lower circuit). The first is direct learning from meaning or picture association, without decoding, such as learning the word ‘tall’ based on its features. The second is code-based learning that occurs in the upper circuit where the word is decoded, allowing a connection to be formed between word form identification and pronunciation.

By adulthood we should have properly established both the upper and lower reading circuits. As we read, the lower circuit takes control, providing direct access to the brain’s word bank. Mature readers have an extensive knowledge of words, so the lower circuit can directly access most of the words they read. This becomes the most effective way to read, as it is fast and accurate. We don’t want to decode every word, as this would take too long.
Besides, we don’t need to, as these words are already sitting in our word bank. It is only when we come across a word we haven’t seen before that we rely on the upper circuit to decode the new word for us. Scientific experiments have established that the lower circuit is significantly faster than the upper circuit, and that the lower circuit grows stronger as reading matures. However, the upper circuit is required for reading nonsense words (such as groob), as these words are not stored in the word bank of the lower circuit and must be decoded (Figure 3.9).

**SUMMARY**

Our brain’s visual and auditory modules are connected by two circuits. Words that can be recognised are accessed directly by the lower circuit, which houses the brain’s word bank. The lower circuit connects the visual word form in the back of the brain to pronunciation (speech output) in the front of the brain. Words that cannot be recognised are processed by the upper circuit, which computes the most likely pronunciation. The upper circuit is in charge of decoding, mapping letter identification in the back of the brain to phoneme sounds in the auditory module at the front of the brain. In this module, these sounds are blended together to produce the word’s pronunciation. This information is then passed back to the lower circuit so that a new entry can be made in the brain’s word bank. The next time the word is seen, the lower circuit can instantly access it.
Mature readers typically use the lower circuit to read words, because this circuit is fast and efficient. The lower circuit accesses words within a time window of 150 to 250 milliseconds after a word is presented. This is much faster than the upper circuit, which computes words between 300 to 500 milliseconds after a word is presented. Brain imaging research shows that the lower circuit has stronger activation patterns for words we know as opposed to words we don’t and that activation in the lower circuit increases with age as we learn more words (Pugh et al., 2000). The upper circuit still plays an important role in decoding words that we don’t know and shows a stronger activation pattern for unknown words than for known words.
Educationalists have developed different methods for teaching the brain to read based on observations and more recently through guidance from educational research. Today, with the help of brain imaging, neuroscientists can now directly study how reading instruction can influence the brain’s reading development. They can also separate out components of the reading system and consider the most effective ways to teach reading.

When learning new words, either the brain’s upper or lower circuits can be used. For reading new words in isolation the most effective approach is decoding the words using the upper circuit. However, the lower circuit plays an important role in working out new words based on meaning or contextual learning. Often the brain uses a combination of these two circuits, which involves partial decoding in a search to find a word that fits with the meaning of the sentence as well as with the letter/sound relationships of the word.

PHONICS AND WHOLE LANGUAGE

There are two popular ways to teach reading. One is phonics, which teaches children to recognise individual letter sounds. The other is whole language, which teaches children whole words within a meaningful context. These two teaching approaches target different circuits in the brain (Figure 4.1).

Phonics instruction stimulates the brain’s upper circuit. This circuit processes individual letter shapes in the back of the brain and
Two popular methods for teaching reading are phonics and whole language. Each targets a different circuit in the brain. Phonics targets the upper circuit, providing strategies for decoding new words. Whole language focuses on the lower circuit, with the goal of increasing overall understanding by teaching words in context. While debates continue about the benefits of whole language and phonics, both are important for developing our reading circuits. A balanced approach to literacy provides a synergic mix of both phonics and whole language in reading programmes.

connects these to letter sounds in the front of the brain. Whole language activates the brain's lower reading circuit. This circuit processes whole word shapes in the back of the brain and connects these to word pronunciations in the front of the brain. Whereas the upper circuit contains a set of rules that can be used to decode new words, the lower circuit stores vocabulary so that a word can be recognised in an instant when seen again. As we become fluent readers we rely less on the upper circuit, as most of the words we read are stored in the lower circuit. The upper circuit is useful for learning new words, as it provides a strategy (apart from meaning) for deciphering the pronunciation of a word. It analyses the visual features of a new word and then calculates the most likely pronunciation based on the rules of letter/sound relationships.

Although no instructional method is purely phonetic (no exposure to contextual print) or purely whole language (no decoding...
instruction), these two methods develop different ways of reading unknown words. The phonics approach encourages decoding the word in an effort to calculate the most likely pronunciation. The whole language approach also encourages predicting the unknown word’s pronunciation, but based on the meaning of the sentence and its context within the story.

While unknown words read in isolation must be decoded for calculating the most likely pronunciation, unknown words read in context can either be decoded or predicted based on meaning clues. Research with electroencephalography (EEG) shows that the brain predicts words in a sentence based on meaning. When reading a sentence that doesn’t quite make sense, the brain will respond to the word that doesn’t belong. These are known as semantically incongruent words. For example, when reading the sentence ‘She drank a cold glass of nails,’ it is the word ‘nails’ that produces the inconsistency. Four hundred milliseconds after the word nails is presented, the brain responds: “Wait a minute, something’s not quite right here,” and a negative electrical potential is produced (Figure 4.2). This demonstrates that the brain uses meaning when reading words in context to help predict the likely pronunciation of an unknown word.

Individual learning differences bring the phonics/whole language debate into question. A fundamentalist whole language or phonics programme neglects the instruction of either the upper or lower circuit. While some children can develop untaught skills implicitly, most children need explicit instruction. Fundamental-
ist teaching of phonics or whole language does not cater for all learning needs and leads to reading disparities. Children within the classroom have mixed abilities and are at different developmental stages. Some will need phonics as a means of decoding new words quickly whereas others will already understand letter/sound relationships and demand contextual text. Teachers should therefore combine a balance of phonics and whole language instruction depending on the individual needs of the children they are teaching. Without providing a balanced mix of phonics and whole language, there is a risk that irregularities will develop between the relative strengths and weaknesses of the upper and lower reading circuits. Children who only receive phonics instruction will have difficulties identifying words within meaningful text, a function of the brain's lower circuit, but will decode words using the upper circuit with relative ease. Children only receiving whole language instruction will have problems sounding out new words using the brain's upper circuit, but will develop good contextual reading skills using the lower circuit.

SYNTHETIC AND ANALYTIC PHONICS

There are two methods for teaching phonics: synthetic phonics and analytic phonics (Figure 4.3). Synthetic phonics teaches the 44 sounds of the English language together with corresponding letter relationships. This method is effective as it provides a tool for decoding any new word. However, some children can have problems identifying phonemes, as they are very small units of sound. This is quite understandable considering the artificial nature of phonemes themselves. For example, some phonemes such as /b/ are impossible to pronounce on their own without adding the ‘uh’ sound. Nevertheless, the ability to manipulate individual sounds and letter relationships is a significant predictor of future reading performance.

Analytic phonics makes use of word stems in words the brain has already learnt, to help decode new words (Figure 4.4). Research shows that children develop this skill very early in reading acquisition. With analytic phonics, the brain draws on common letter/sound relationships found in word families. It analyses new words against the word patterns already retained. Analytic phonics places fewer demands on working memory as the co-articulation (the joining together of sounds) has already been made. For example, it is easy to decode ‘crash’ as /cr/ /ash/ because the letter
There are two popular ways to teach phonics: analytic phonics and synthetic phonics. Synthetic phonics teaches letter/sound relationships to the brain’s upper circuit. Typically, synthetic phonics contains a strong aural component based around the 44 phonemes of the English language. Analytic phonics is a more visual form of phonics and uses common patterns in words that are already learnt to help decode new words. This is represented within the brain by connections between the lower reading circuit, which provides the analogous word, and the upper circuit that computes letter/sound relationships.

Patterns from other words (such as crab, crane and cash, ash) are easy to recognise, whereas synthetic phonics takes more processing to decode /c/ /r/ /a/ /sh/.

**FIGURE 4.3 SYNTHETIC AND ANALYTIC PHONICS**

There are two popular ways to teach phonics: analytic phonics and synthetic phonics. Synthetic phonics teaches letter/sound relationships to the brain’s upper circuit. Typically, synthetic phonics contains a strong aural component based around the 44 phonemes of the English language. Analytic phonics is a more visual form of phonics and uses common patterns in words that are already learnt to help decode new words. This is represented within the brain by connections between the lower reading circuit, which provides the analogous word, and the upper circuit that computes letter/sound relationships.
FIGURE 4.4 COMPUTATIONAL READING MODELS

The brain is so good at decoding unknown words based on words previously learned that scientists have created computerised reading simulations to account for the reading process (Share, 1995). The connectionist model reads a new word by breaking up similar patterns in previously learned words. In this experiment, the computer read a list of nonsense words with 66 per cent accuracy after acquiring 2,897 base words. Another computerised model, the dual route cascaded model, uses the same principles but also has a letter-to-sound decoding mechanism, which operates in a similar manner to the brain’s upper circuit. It reads the same list of nonsense words with 98 per cent accuracy after acquiring the 2,897 base words. Human participants read the nonsense words with 91 per cent accuracy after learning the 2,897 base words. Thus, to account for how the brain decodes new words, we must accept that the brain has a direct decoding mechanism (the upper circuit), but there are also connections between the words we have already learnt and this decoding mechanism. These are known as analytic connections. The human error factor should also be taken into consideration.
Some words with changeable vowel sounds are initially predicted from known visually similar words (Figure 4.5 and 4.6).

FIGURE 4.5 NON WORD “FOUGH”
Try to read the word ‘fough.’ How do you sound it out? There is no right or wrong answer because it is a made up word. If you found this task confusing, consider how difficult it is for children when they are first learning to read. Sometimes just sounding out a word isn’t enough.

FIGURE 4.6 NON WORD “FOW”
Now try sounding out the word ‘fow.’ Do you read it as /foul, like the words cow, how or now, or as /foe/, like the words tow, flow or grow? Your strategy will depend on how strongly each group of words is represented in your brain.
Synthetic phonics teaches the brain’s upper circuit to read by developing an understanding of letter/sound relationships that enables us to decode new words, whereas analytic phonics involves a more central activation, representing interconnection between the two reading circuits. In this model, analogy involves an analysis of common letter relationships and their corresponding sound patterns, transferring from known words to the unknown word. Here, the decoding of an unknown word is supported through comparing known words with similar letter/sound relationships.

Recent fMRI research (Beneventi and colleagues) shows that the smallest unit of sound, the phoneme, is processed in the upper circuit and a larger unit of sound, the rime (such as the word ending -ime), is processed in a more central location between the upper and lower reading circuits. Analytic rime processing is faster than phoneme processing. Within the brain’s left hemisphere, the two reading circuits are indeed connected and support each other. Integration of these two circuits provides additional support for decoding, not only using meaning and context, but also through analogy word support. The brain’s word bank in the lower circuit does not contain a list of words in alphabetical order like a standard dictionary. Rather, the brain’s word bank is multidimensional. While some words are grouped around meaning, they can also be grouped around sounds. All of this happens at a subconscious level. At a conscious level, phonological assembly then allows us to manipulate the sounds in new words to find common patterns. We can identify single sounds from within words and compare these sounds with words that look the same. In the brain, analytic phonics allows connections to be formed between different sounds, letters and whole word shapes for new words that are acquired.

Synthetic phonics involves teaching the sound relationships of the different letter combinations of the English language. This method is typically introduced with letter-name/letter-sound associations, letter-name/picture associations or actions relating to the initial sounds of words that are already known. After children become familiar with letters and their corresponding sounds, movable letters can be used to construct new words. CVC words (consonant-vowel-consonant) are easy to manipulate as they are closed syllabled, make the short vowel sound and contain simple letter/sound rules that are easy to follow (for example, dog, cat, pig). The –VC component at the end of CVC words is the rime stem. Through analytic phonics children can see that words ending in the same stem share the same sound pattern. The initial sound can then be
manipulated to make new words. For example, change the /m/ sound in mat to a /b/ sound to make bat. Children can also perform other operations on CVC words with the moveable alphabet. Letters can be brought together to blend sounds, known as co-articulating, and separated to explain segmenting, deleting or isolating. Children can also substitute letters (with other letters) to make new words. For example, swap the /e/ sound in peg with an /i/ sound to make pig. Once children have mastered these operations, they become aware that words are made up of different sound units that correspond to different letters and can in turn be manipulated. Word-level work using moveable letters combines synthetic phonics, analytic phonics and phonemic awareness into one lesson. However, phonics instruction is only one part of a broader literacy programme and should be placed in the context of real reading.

**BALANCED LITERACY**

Balanced literacy involves developing reading programmes that teach the upper circuit (synthetic phonics), the lower circuit (whole language) and connections between the two (analytic phonics). The benefit of developing both reading circuits through explicit instruction is an essential component of a balanced literacy approach (Figure 4.7).

Balanced literacy programmes must also have the flexibility to teach groups of mixed ability children with different developmental needs. The philosophy behind balanced literacy is to maintain an equal balance of reading to, with and by children. Shared or guided reading approaches are used when text is too difficult for children to read on their own.

Shared reading is widely used for introducing children to text. A group of children are encouraged to read along with the teacher. The shared approach makes the text accessible to all the children as they enjoy the feeling of reading for the first time. Predictable texts containing repetition should be selected for shared reading instruction. Children gain a feel for reading, both by recognising words and by following meaning. During shared reading, questions at phoneme, word, grammar and meaning levels can be targeted to the individual abilities of each child. Teacher-led questioning with support is known as scaffolding. With teacher direction, explicit attention can be drawn to the letter/sound rules
FIGURE 4.7 BALANCED LITERACY MODEL
How is balanced literacy represented in the brain? The brain has two modules: a visual module in the back of the brain and an auditory module in the front of the brain. Once we have learnt that spoken words are made up of smaller units of sound, using the auditory module, we have developed phonemic awareness. Once we have learnt that words are made up of letters, using the visual module, we have developed graphemic awareness. From this foundation we build reading circuits between these two modules. Synthetic phonics teaches children to identify the shape of a letter and link it to the phoneme sound; whole language enables them to link the word form recognition subcomponent to pronunciation; and analytic phonics enables them to use learnt words to help decode new words (analogies).

and their location in words, words and their location in sentences and the overall meaning of the text. Auditory support can come from shared reading itself or through repetition of the text during a listening activity. As children begin to get the feel of reading by listening to the story, they should be encouraged to engage with the text so that letter, word and sentence level skills are acquired. Students develop verbal fluency and sight vocabulary as they read. By using text containing embedded letter sounds, children develop an awareness of the letter sound and an awareness that words are made up of letters and that phrases are made up of words. In this way the relationships taught with word level work, using synthetic and analytic phonics, can then be transferred from words in isolation to words in context. Highlighting the letter/sound of interest in embedded phonics text gives children extra
clues as to the letter/sound relationship and where it usually falls within words. Highlighting makes it easier to break up a word into different units of sound, as the division has already been made. Repetition of a highlighted letter/sound throughout the text provides implicit reinforcement (figure 4.8).

**FIGURE 4.8 SHARED READING WITH EMBEDDED PHONICS**

Shared reading with embedded phonics is used to teach both synthetic and analytic phonics in the context of real reading. Components of the reading process are demonstrated to children during one group lesson. Teacher led questioning is used to tailor instruction to the needs of the mixed ability group and children can learn from each other during these group discussions. The multisensory approach supports children with different learning styles and ensures that all children are engaging in the acquisition of reading skills.

Guided reading is an instructional part of a balanced literacy programme and is used to make texts accessible to children at different reading levels. Once children have acquired reading and language skills they can make their own attempts at decoding new text. Guided reading involves teaching small groups made up of children with similar abilities. The teacher listens to the children read a story and provides support when needed. Children can be directed to different aspects of the story to ensure they are following the meaning as they read. When a child comes across a word that cannot be read, the teacher then guides him or her to
use an effective method for deciphering that word. Often, the initial method requires the child to go back to the beginning of the sentence and reread it up to the unknown word. Then the child can attempt to predict the word from what has come before. If the word is still unclear, the child can then read on to the end of the sentence and a further attempt can be made to decipher the word based on its meaning within the complete sentence. Questions that the teacher can ask during guided reading are shown in Figure 4.9. Alternatively, the method can be based on phonology, either decoding the word letter-by-letter using synthetic phonics or by using analytic phonics to consider words that look the same to provide extra clues as to the sound pattern of an unknown word. Sometimes it is useful to draw out more difficult words through discussion before reading the story. This can be done when introducing the book. Having difficult words fresh in working memory can support fluency during guided reading. Guided reading texts should be selected at an appropriate reading level where children can read most of the words (90-95% percent accuracy), otherwise they will become frustrated and meaning will be lost.

Independent reading allows children to read for pleasure by themselves and should be encouraged. Reading materials available should include a range of fiction and non-fiction titles, designed to stimulate interests. The appropriate reading level for independent reading is above 95% accuracy. Fostering motivation is an important part of reading instruction. A child’s reading
is associated with two types of motivation: intrinsic motivation and extrinsic motivation. Intrinsic motivation involves engaging in reading for personal interest, exploring the new world of reading and discovering exciting topics of interest. Intrinsically motivated children gain a sense of pleasure by being involved in reading. When faced with difficulties they are self-determined. They persist and receive great enjoyment from the conquest of a challenging task. Intrinsically motivated children invest a great amount of time in reading as they are rewarded with cognitive and emotional satisfaction. Variables such as curiosity and involvement are used to measure intrinsic motivation. When curiosity is stimulated, a child will concentrate on the description of events and show increased interest in following the story. Greater cognitive effort leads to more appropriate judgements and a deeper understanding of the text. Extrinsic motivation involves participation in reading due to external demands and values. It is measured by variables such as recognition, grades, social values, competition and compliance. Extrinsically motivated children read to avoid negative outcomes and to receive external rewards rather than reading for cognitive and emotional satisfaction. Unfortunately, extrinsic motivation is counterproductive to text comprehension, as the reader only pays limited attention to aspects of the text, resulting in ineffective learning strategies and inaccurate inferences. Extrinsic motivation negatively affects reading for enjoyment, while intrinsic motivation increases comprehension, as well as the amount children will read for personal enjoyment.

SUMMARY

Educational research and classroom practice offer a range of techniques for effective reading instruction. While advanced brain research did not exist when these instructional methods were first deployed, it now provides scientific recognition of these methods. We no longer need to debate whether one technique is better than another. We can see the big picture. Different approaches target different parts of the reading brain, and we should strive to simultaneously target multiple modules, circuits and connections to produce learning synergies and to develop children who enjoy reading.
Spelling is a skill that involves both the upper and lower circuits of the left brain. While reading is processed from the back brain to the front brain (visual to sound), spelling operates from the front brain to the back brain (sound to visual). The output of spelling is whole word shapes, whereas the output of reading is word pronunciations. Spelling begins with a word pronunciation in the front of the brain and accesses the visual word form in the back of the brain. This involves a directionality change in the lower circuit of the left brain.

**DIRECT RECALL (THE LOWER CIRCUIT)**

The brain’s lower circuit contains a word bank that connects to the pronunciation subcomponent in the front of the brain and the visual word form subcomponent in the back of the brain (Figure 5.1). The word bank provides words in their whole shape form for direct recall during spelling. The brain does not contain different word banks for reading, spelling and writing. Rather each skill (reading, spelling and writing) draws on the brain’s single word bank, but with different inputs and outputs (directionality). Having one word bank that connects all the important properties of words explains why reading, spelling and writing abilities are so closely related.

A sight vocabulary can be quickly developed in the brain’s word bank through repeated exposure to new words within reading and writing. This not only provides rapid access to the correct
word pronunciation during reading, it gives a visual image of the whole word form that can be used during spelling. These word representations will begin to weaken if they are not repeatedly reinforced during reading and spelling.

Words that are used less frequently are the hardest to read or spell. Reading can become slower when switching from a favourite novel to a specific non-fiction subject. This also occurs with spelling. When trying to spell a word that is not seen or used often, it is likely that the word bank only has stored a weak representation of this word with a low activation threshold, so it will be difficult to spell correctly. The lower circuit is very much ‘use it or lose it.’

Acquiring the spelling patterns of high frequency words saves emergent readers considerable time and energy as these words make up over half the words that are read and spelt. Many of these high frequency words will be learned directly using the lower circuit. High frequency words are familiar from reading and already have representations in the brain’s word bank. Access to a word’s form can be developed from its pronunciation. Direct recall provides perfect spellings when words have been correctly memorised. After a word has been memorised it is no longer

**FIGURE 5.1 DIRECT RECALL SPELLING**

Most of our spelling involves a direct link from the brain’s pronunciation subcomponent to the visual word form subcomponent. This link enables us to directly access the correct spelling without having to sound it out. The lower circuit also enables us to access the correct spellings of irregular words, which are often very difficult to encode.
5 SPELLING AND WRITING

**FIGURE 5.3**
NONWORD “GHOSTI”

George Bernard Shaw’s capricious mis-spelling of fish as “ghoti” demonstrates some of the orthographic irregularities found in the English language. But how many words do we know that start with /gh/ and make the /f/ sound? How often does /o/ make an /i/ sound? In what type of words does /ti/ make an ish/ sound? During spelling we subconsciously use words that we can spell to help us encode. This makes the process of encoding unknown words somewhat simpler than the ‘ghoti’ example initially suggests.

Considered just a group of letters, but a whole word form that has a pronunciation, meaning and spelling. However, often spelling is not as simple as accessing a whole word shape. The brain cannot always remember the words it wants to spell. Sometimes when trying to recall a word’s spelling, the lower circuit provides no answer. In fact, when first learning to spell, there will be very few words that can be accessed directly. When a spelling cannot be accessed directly from the word bank, the brain’s upper circuit can be used to produce the most likely spelling.

ENCODING (THE UPPER CIRCUIT)

Whereas the brain’s lower circuit is a database for storing the different properties of whole words, the brain’s upper circuit specialises in recognising letter/sound relationships in words. The brain sometimes needs to rely on the upper circuit to decode a new word during reading. Decoding is the process of computing or calculating the most likely pronunciation of a word based on its letter patterns. Decoding is also referred to as grapheme-to-phoneme conversion as it involves taking a letter pattern (grapheme) and mapping it onto a sound pattern (phoneme). Spelling words that are not known also engages the upper circuit of the brain, but in the reverse direction. The computation behind spelling unknown words is encoding, working from the front of the brain to the back of the brain (Figure 5.2).

Encoding is the process of computing or calculating the most likely spelling based on units of sound. Encoding can be referred to as phoneme-to-grapheme conversion as it involves taking a unit of sound (phoneme) and mapping it onto a letter pattern (grapheme). If the lower circuit can learn to spell through repeated exposure and whole word shape clues, what is the purpose of encoding? Encoding is used when a word’s whole shape cannot be accessed, but a ‘best guess’ spelling is required. During written expression, by quickly producing a possible spelling for an uncertain word, writing can continue ensuring that meaning is not lost. The encoded spelling can later be checked in a dictionary. In a spelling test, the most likely spelling is attempted, however encoding will not always produce the right spelling (Figure 5.3). The rules of decoding are more likely to produce a correct pronunciation during reading; the rules for encoding are more likely to produce a correct spelling during writing. This is because there are many more spelling pattern possibilities
for each sound than there are pronunciations, making encoding sometimes fail to produce the correct spelling. Why does encoding sometimes fail to produce the correct spelling? Inconsistencies observed in English spellings can be explained historically (Figure 5.4).

English orthography evolved through a systematic layering of alphabet, patterns and meaning. Old English existed between 500 and 1000 AD. Unlike today’s English, the orthography of Old English showed remarkable consistency, or transparency, in letter/ sound relationships. However, the Norman conquest of 1066 AD led to an overlay of French onto Old English by the ruling class. Any new vocabulary during this period followed French orthographic patterns and some of the words in Old English were changed to become consistent with the French structures. The Renaissance period during the 16th Century saw a large-scale borrowing of new vocabulary as the educated rediscovered classical Greek and Roman knowledge and culture. Greek and Latin words brought in a morphemic (meaning) layer to English orthography and accommodated an explosion in learning.
The history of orthographic structure provides different frequency-based tiers. Old English gives us most of our high frequency words such as prepositions, pronouns, conjunctions and auxiliary verbs (such as had, was, does). Many of our less frequent words were introduced during the Norman period (such as royal, guard, conquer). Finally, the classical period introduced low frequency words with Latin and Greek origins (such as auditorium, philosophy, spectator).

Word sorts, where words containing similar stems or meanings are ordered, can be used to compare and contrast orthographic features across words. Children can make generalisations about the spelling consistencies in certain groups of words as they observe specific letter-phoneme correspondences, patterns and morphemes. Although word sorts promote an analytic phonics approach to teaching spelling patterns, teachers can also encourage a synthetic phonics approach as children deconstruct letter-sounds from within words. Finally, words can also be sorted based on meaning, creating a whole language approach.
INVENTED SPELLING

When children are writing, they need quick access to written word forms so that they can get their ideas down without interrupting their train of thought. As long as children follow the rules of encoding during writing, they will produce words that are phonologically accurate, that is, words that can be decoded to produce the correct pronunciation, even if they are spelt incorrectly. By using invented spellings, children can later check words they are unsure of in the dictionary to see how they are spelt. Children should be encouraged to underline invented spellings if they don’t look right, then they can be checked when editing. These words should also be added to individual spelling lists, provided the child’s approximation is relatively close to the word being attempted. Invented spellings are useful during both child and teacher proof-reading, as the story can be followed without having to guess the meaning behind a random mis-spelling. Children who use invented spellings write longer stories with more expressive vocabulary and make greater use of more complex grammatical structures. Thus encoding, which is a subcomponent of spelling, is also an important subcomponent of writing. Once the letters of a word have been selected, sequenced and written down, the brain needs to self-check, to make sure the spelling is correct. The brain uses the lower circuit to access the word from its word bank, which is a reading process. If the word is not recognised, then it is not stored in the brain’s word bank and must be checked using a dictionary or an editing card (Figure 5.5).

If the word is recognised, then it is accessed in the brain’s word bank. The more the word bank is accessed, the stronger the word will become. The brain no longer needs to use the time and energy consuming upper circuit, as it gains direct access to the spelling from the lower circuit.

WRITING

Just as reading instruction involves a balance of reading to, with and by children, writing instruction involves a balance of writing to, with and by children. Shared writing is used to demonstrate the links between spoken and written text, where teachers use the children’s ideas to construct the story. Children can take part in planning, discussing and revising the writing. Shared writing can be used to introduce new genres to the class such as let-
ter writing and poetry. Non-fictional texts, such as recollection, instruction, report, explanation and discussion can also be introduced through this medium. Guided writing moves from teacher demonstration to teacher modelling, where the teacher and the children plan the writing together, but the children then construct their own pieces.

Teachers should not be side-tracked by spelling errors when working with children on their writing. If a teacher’s first comments on a child’s writing are concerned with spelling or handwriting then the child will start to think that these things are the most valued in writing. Moreover, both reading and writing are principally meaning-driven processes. The writer has to construct meaning for the intended reader. Just as good readers re-read when they lose meaning, good writers must re-read and re-write when meaning
is lost. Conferencing during guided writing is used as a form of direct scaffolding. For example, the meaning of a story might be lost because a child has omitted an introductory sentence to put a story into context. By discussing this with the child, an introductory sentence can be created to enhance the story. In the same way, a better word can be introduced to describe something. This learning affects children’s future written expression, when scaffolding is no longer needed. The final edited product can be prepared on a word processor and printed so the child has a copy of the published version. The published story is then available for a broader audience to read and enjoy, such as other children, teachers and parents. The more children engage in conferencing, revising and publishing, the better their reading, spelling and writing skills will become. As children master the skill of writing they can interchange between the roles of storyteller and story reader and develop self-conferencing.

**SUMMARY**

Writing and spelling use the same circuits of the reading brain, but in reverse directions. When spelling a word, the pronunciation at the front of the brain is connected to the whole word form at the back of the brain through the lower circuit. When inventing the spelling of a word that cannot be accessed in the word bank of the lower circuit, the upper circuit is used for encoding. Here, the sounds of the pronunciation are broken up in the front of the brain, and then mapped onto the letter formations in the back of the brain. When a word is correctly spelt it looks and feels right. Other words, that don’t look right, are checked in the dictionary and the correct spellings are learnt for future writing experiences. During proof-reading, the brain is trying to access written words from the word bank to ensure correct spellings have been made. This is a reading process that involves the lower circuit. Much of the writing process involves moving from writing to reading and then reading to writing. By switching the directionality of the reading circuits the brain can self-correct, revise and self-conference. Reading, writing and spelling have equal importance within a balanced literacy programme because they are closely related and support each other.
Although dyslexia was first reported over 100 years ago, there has been, and still is, much confusion as to what dyslexia actually is. Different professionals use different definitions. Paediatricians, psychologists, neurologists, optometrists, teachers, parents and journalists commonly express different views as to what they think dyslexia is. While poor reading can be identified quickly, the causes behind it, such as developmental dyslexia, require a broader investigation. The following sub-sections will consider the differences between developmental dyslexia and acquired dyslexia, developmental dyslexia and garden-variety poor reading and will explain recent brain-imaging research on dyslexia.

**DEVELOPMENTAL DYSLEXIA AND ACQUIRED DYSLEXIA**

Neuropsychology describes two forms of dyslexia: developmental dyslexia and acquired dyslexia. Developmental dyslexia is the natural development of a brain which functions differently, resulting in reading acquisition problems. Acquired dyslexia represents damage to the brain resulting in reading loss, but its cause is injury rather than a genetically inherited difference (Figure 6.1).

Acquired dyslexia occurs after an injury in which the reading circuits have been damaged. When an injury is specific to one part or module of the brain, a component of reading can be lost, while other components can remain intact. For example, a head injury can damage the brain’s ability to acquire new words using the
upper circuit, while existing words that have already been learned remain intact and can be read using the brain’s word bank in the lower circuit. It is possible to temporarily simulate this condition with a brain technology called trans-cranial magnetic stimulation (TMS). TMS involves disrupting part of the reading brain so that it is temporarily paralysed. Disrupting the upper reading circuit of a normal brain will result in temporary acquired dyslexia where nonsense words cannot be read by the upper circuit, but real words can be read using the lower circuit. There is an argument that an adverse environment in the womb can cause dyslexia, such as high pollutant levels (lead, toxins, alcohol) or a traumatic birth. Such cases may represent acquired dyslexia as they are not genetically inherited and do not result in the same abnormal brain re-organisation found in developmental dyslexia. Although acquired dyslexia is considered a form of dyslexia, from here on the term dyslexia will refer to the developmental or genetically inherited form.

FIGURE 6.1 ACQUIRED AND DEVELOPMENTAL DYSLEXIA
Neuropsychology describes two forms of dyslexia: acquired dyslexia and developmental dyslexia. Acquired dyslexia comes from damage to a part of the brain that is used during reading, resulting in reading loss. Whereas acquired dyslexia results from head injury, developmental dyslexia is a genetically inherited condition. Developmental dyslexics have differences in neurological wiring from birth, resulting in developmental problems in reading acquisition.
DEVELOPMENTAL DYSLEXIA AND GARDEN VARIETY POOR READERS

Generally speaking, there are two groups of children who have problems with reading acquisition: dyslexics and garden-variety poor readers. Dyslexics have different brain connections that disrupt reading acquisition, whereas garden variety poor readers have under-developed reading circuits because of insufficient instruction or developmental delay. Both garden-variety poor readers and dyslexics represent the lower end of the bell shaped curve for reading (Figure 6.2).

Genetically, children may have inherited dyslexia resulting in a disruption in brain connectivity, or alternatively they may have inherited a poor propensity to acquire reading, resulting in them becoming garden-variety poor readers rather than dyslexics. Environmentally, children who have low exposure to print or
insufficient reading instruction show signs of reading difficulties. A deprived reading environment can intensify the effects of poor reading through what is known as the Matthew effect. The Matthew effect explains how good readers get better as poor readers continue to fall behind. As reading is a self-teaching mechanism, any irregularity produces a less efficient system that cannot learn and grow as quickly. Children need considerable print exposure to develop their reading skills. When print exposure is lost, children fall further and further behind at the time when their brain development is most suited to learning to read. As their peers become better at reading, they turn away from it and the subsequent lower motivation results in lower exposure to print.

Traditionally, the term dyslexia has been used to explain an inability to acquire reading despite adequate intelligence and educational opportunities. Here, a classification of dyslexia is made after ruling out other possibilities. Garden-variety poor readers are not considered dyslexic if they have lower intelligence or have missed educational opportunities. They may have received inadequate reading instruction or may have behavioural problems that disrupt their learning in class. They may come from a low socio-economic environment where there are very few books in the home, or where reading is not encouraged. Without identifying the cause of reading problems, it is difficult to estimate the prevalence of dyslexia in relation to garden-variety poor reading. While many suggest poor reading accounts for 20 per cent of the population, estimations of dyslexia range from four to 10 per cent. The exclusionary definition of dyslexia defines it as an unexpected failure to acquire reading despite adequate intelligence and educational opportunity. Children with other external factors, such as mental retardation or behavioural problems are excluded, but genuine dyslexics with low IQs can also be excluded.

The IQ discrepancy diagnosis of dyslexia places great weight on the IQ test, which may not necessarily be a valid measure of dyslexic intelligence. Furthermore, IQ discrepancy measures are best suited to children over eight years of age, at a time when the benefits of early intervention have been lost. Nevertheless, IQ testing, with all its limitations, still provides an effective means of separating the garden-variety poor reader from the dyslexic. It can also raise self-esteem in those identified as dyslexic, which is an important factor in overcoming the reading problem (Figure 6.3).

Statistical validity issues regarding the exclusionary definition of dyslexia (based on IQ testing) have been raised. When are those
FIGURE 6.3 IQ DISCREPANCY MODEL

The developmental dyslexic profile shows an unusual mix of strengths and weaknesses according to their IQ sub-scores, resulting in a subscale discrepancy. In comparison, the garden-variety poor reader shows global deficiencies, where the score of one subscale can predict the score of another. Psychologists use IQ subscales to distinguish between the two groups. While both show poor reading, as measured by reading, spelling and phonological skills, only the dyslexics, although this is a classification criterion, show significantly higher verbal or non-verbal skills than would be predicted by their reading scores.

with low intelligence excluded? Where is the cut-off line? At some point, an arbitrary line is used to separate those who have dyslexia from those who don’t. Once this dyslexia cut-off line is established, are all the dyslexics separated from all the garden-variety poor readers? Indeed, the use of exclusionary criteria to define dyslexia has received much criticism. Any definition that defines by exclusion must be questioned, as the criteria for inclusion beyond poor reading performance remains uncertain. Conversely, a child may have average reading for his or her age, but considerably lower reading than would be predicted by his or her intelligence. Is this child dyslexic? Possibly. Are there dyslexics with low IQs who are not identified as dyslexic? Probably. Are IQ tests always accurate for measuring dyslexic intelligence? Probably not.
The latent variable behind developmental dyslexia is the connectivity differences observed in the brain. The most effective way of diagnosing dyslexia is to examine the dyslexic brain itself. Today, brain imaging can provide insights as to what the brain does during reading. The technology now exists for a neural assessment of dyslexia, although a working diagnosis seems a long way off. Without a neural diagnosis, today’s preferred method is the identification of a statistically significant difference in the sub-scales of intelligence tests. The idea behind this diagnosis is that a considerable variability between strengths and weaknesses represents a different type of processing system – the dyslexic brain.

**DYSLEXIC BRAIN RESEARCH**

At Harvard University in the 1980s, a collection of dyslexic brains were examined under post-autopsy. The results provided a significant breakthrough in the field of dyslexia research, focusing interest on the brain. Dyslexic brains were compared with normal brains and different regions of the brain were analysed for symmetries and abnormalities. The dyslexic brain showed numerous differences under the microscope during post-mortem examinations (see chapter 2).

![FIGURE 6.4 ADULT DYSLEXIC COMPENSATION](image)

This dyslexic adult shows under-activation in the back of the left hemisphere and compensatory activations in ipsilateral regions on the right (Milne et al., 2002). Dyslexics may use more mixed-lateralised strategies during reading.

The first study of dyslexia with functional imaging took place in 1996 and involved adult dyslexic subjects. While adult dyslexics try to activate the left hemisphere during reading, they also rely on the opposite areas in the right hemisphere for assistance. This strategy, called ancillary compensation, is similar to what stroke patients do to recover function post trauma (Figure 6.4).
Behaviourally, adult dyslexics can read, but their reading skills are unlikely to equal those of the non-dyslexic brain. Relying on the brain’s right hemisphere for support during a serial task like reading is not as efficient, accurate or fast as engaging in unilateral processing using just the left hemisphere.

Functional brain imaging is now considered safe to use with children. Recent studies, such as the MEG experiments of Simos and colleagues (2002), have examined the development of reading in the brains of dyslexic children. These studies show that in dyslexics, the junction between the front and back brain is not functioning normally and is under-activated resulting in disconnection. However, after intervention with research-supported programmes that are phonologically based, the dyslexic brain appears to operate in a more normal manner by increasing activations in the left-brain (Figure 6.5).

This is not to say that providing additional instruction to the dyslexic brain will make it normal. Rather, this research explains that dyslexics use the same language regions in the left hemisphere during reading as non-dyslexic brains. The dyslexic brain does not represent a global reorganisation where modules are randomly represented across the brain. However, the dyslexic brain does have problems communicating between these modules due to disrupted connections. Functional brain imaging reveals how the modules appear disconnected from each other in the dyslexic brain.
brain. At the same time, the converging results of Aylward and colleagues (2003) show that appropriate intervention results in improvement within the left hemisphere for dyslexic children. Here, after processing capacity is improved by effective intervention, left brain regions, or modules, begin to operate in a more normal manner until the difficulty level rises above capacity.

Recent research by Temple and colleagues (2003) examining the effectiveness of intervention on the brains of dyslexic children reported recovered activation of the auditory and visual modules in the left brain, as well as novel activation in the right (Figure 6.6). Phonological intervention may have awoken a sleeping bilateral (left and right brain) upper circuit, a possible feature of a more symmetric dyslexic brain. In any case, the dyslexic brain has structural and functional differences to the normal brain and that appropriate intervention is beneficial. This enhances reading performance, behavioural function and the brain's ability to process words.

As dyslexics and garden-variety poor readers receive the same reading interventions, why do we need a label for dyslexia? Because readers need to know why they have problems learning to read. The dyslexic brain is different to the brain of a garden-variety poor reader for neurological reasons. Although the brain...
was never designed to read, dyslexic brains are born with dyslexia – it is a genetically inherited condition. Dyslexic brains show differences in both structure and function. Thus, labelling children as having a specific learning disability such as dyslexia should be done carefully. If brain-based information is not included we can never be completely certain of the assessment. At the same time, a dyslexic parent who observes or recognises dyslexic traits in their child can be assured that the cause is most probably dyslexia.

What should be done if a child shows the symptoms of dyslexia? With the help of an educational psychologist, a full assessment of his or her learning strengths and weaknesses should be undertaken. Assessment records of dyslexic children across their development provide powerful clues to the dyslexic profile and can rule out the possibility of a developmental delay. When the dyslexic reaches higher education, a history of the reading deficit provides evidence for special examination conditions. Many dyslexic adults shy away from these conditions, as they want to be treated like everyone else. However, it is appropriate to make special examination conditions available for dyslexics considering the extra energy consumed by their brains as they perform tasks such as reading, spelling and writing.

There is no research to show that remediation programmes for dyslexic readers should contain any special components which would not also be available to garden-variety poor readers. While many new approaches such as multi-sensory and hands-on learning are especially beneficial for dyslexics, they appear to help all readers, including the more able. Some argue that resources should not be specially budgeted for those who have dyslexia, as classified under the exclusionary diagnosis, as all poor readers have a reading disability that requires immediate attention with similar forms of intervention. Others even joke that all children have dyslexia on the first day of school – they actually mean that all children are initially garden-variety poor readers. Indeed all children who are having problems should be provided with adequate resources so that they can learn to read, irrespective of the cause, but dyslexics require additional support because of their neural differences, which have caused a disruption to their reading circuits from birth. Garden-variety poor readers on the other hand require additional support because their reading circuits are underdeveloped and require further instruction.
SUMMARY

If a child has reading problems, does the child have dyslexia? To answer this question, all the possible causes of poor reading must be considered:

- Do other members of the family also have similar reading problems?
- Were there any abnormalities in the child’s birth that may have resulted in damage to the reading system?
- What was the child’s early reading environment like?

The myriad causes of reading problems explain why much confusion has arisen in the field of dyslexia. Historically, in the absence of brain-based research, the dyslexia field swung from theory to theory in the hope that a unitary cause would be discovered. For many years, dyslexia has been seen as an umbrella term for all people who have problems with reading or have other learning difficulties. Not only does the umbrella approach distort the significant results of research studies into dyslexia, it also provides potentially inaccurate information to the individual who is struggling to learn to read. An extensive analysis of the possible causes of reading problems is therefore an important part of any reading assessment, as it can answer the question of why that person is experiencing reading difficulties.
PATTERNS OF READING

All readers have a combination of genetic and environmental factors that influence how their reading circuits operate. Inside the reading brain, poor reading can affect different parts of the reading system. Environmentally, this can be explained by an imbalance in reading instruction, such as an over-emphasis on phonics without sufficient contextual word exposure, or vice-versa. Alternatively, there may be neurological disruptions responsible for poor reading development or an imbalance between the strengths and weaknesses of the two reading circuits.

When researchers look inside the brain to examine how reading circuits work together, they consider the brain’s reading pattern. They are interested in how the internal mechanisms of the machine are working together (Figure 7.1), as opposed to how the machine was built or how much use it has had. Knowledge about the reading pattern is very valuable, as it is from here that intervention programmes can be developed. These programmes are customised to meet the individual needs of the specific brain requiring help. The reading pattern is the most important factor in developing intervention programmes. Inside the brain, reading problems represent imbalances within the reading system itself. And you don’t need to suffer from dyslexia to develop imbalances within the reading system. Poor or insufficient instruction and/or motivation can result in abnormal distributions of strengths and weaknesses within the reading brain. All causes, such as neurological diversity, exposure to print, instructional methods or reading motivation, can lead to differences in the internal operations of the reading system, and the reading brain itself.
Item specific reading tests are used to measure the strengths of the upper and lower reading circuits. Irregular word lists test the lower circuit (Bader and Jarrico, 1982). The lower circuit must be used to access irregular words directly, as the upper circuit cannot sound them out. Nonsense word lists can be administered to test the skills of the upper circuit (Frith and Gallagher, 1997). Nonsense words cannot be accessed in the word bank of the lower circuit because they have never been seen before. Instead, the upper circuit is used to compute the most likely pronunciation. In normal readers there is a relative equality between the abilities of the lower and upper circuits.

Researchers have endeavoured to use functional brain imaging to distil different types of reading patterns as a basis for studying the neurobiology of reading problems. The reading brain contains two principal circuits, the upper and the lower circuits. To examine individual differences in reading patterns, the relative strength/weakness differences between the reading circuits are identified. Individual variability can occur across the upper circuit, the lower circuit or both. While most readers have strengths in both upper and lower reading circuits, some readers have imbalances that favour one circuit over the other.

There are two ways in which a word can be read aloud. The first involves direct access of the word from where word forms are represented in the brain’s lower circuit, and the other involves decoding words using grapheme-to-phoneme conversion in the brain’s upper circuit. Just as there are two reading circuits, there are two types of reading patterns (Figures 7.2 and 7.3). Dyseidetics have
difficultly accessing word shapes and are poor at reading irregular words (such as yacht or listen), suggesting problems with the lower circuit’s ability to access visual word forms. Dysphonetics have difficulty decoding words and are poor at reading nonsense words (such as groob), suggesting problems with the upper circuit’s grapheme-to-phoneme conversion.

**FIGURE 7.2 DYSPHONETIC READING PATTERN**

In dysphonetic readers (those who have problems decoding words), the skills of the lower circuit are more advanced than those of the upper circuit. Dysphonetics are better at reading irregular words than they are at reading nonsense words (Milne et al., 2003). Another characteristic of dysphonetics is phonologically inaccurate spellings. They are poor at encoding, which requires working from the phoneme sound back to the letter shape. Dysphonetics rely on memorising words based on their whole shapes, giving them a ‘Chinese’ style to their reading (learning words by rote memorisation).
Dyseidetics and dysphonetics show different reading patterns within the brain (Figure 7.4). Dyseidetics appear to focus neural activity at the back of the brain in an effort to access the whole word shape. Dysphonetics appear to focus neural activity in frontal regions of the brain associated with phonological articulation (Figure 7.5).

By focusing neural activity in an area of weakness, these readers improve their performance on reading tasks. Although it requires effort, dysphonetics do learn to decode and dyseidetics do learn to access whole word forms, including irregular words. This is a form of strategic compensation, and involves increasing activity to improve performance in language areas across the left hemisphere that are not connected properly. However, strategic compensation comes at a cost, as focusing neural activity consumes
energy. Strategic compensation may also fail under conditions of stress, such as reading aloud to the class or even to the teacher.

Different reading patterns can be used to help tailor intervention programmes that target the reading imbalance. Interventions can then be tested on the reading brain to see how connectivity is improved. After intervention, the reader should no longer need to focus neural activity on areas of weakness, as the specific processing capacities have increased. Dyseidetics and dysphonetics do share the same core trait, unexpectedly low reading performance, but there are different reading circuits responsible for the reading deficit.
A reading test alone is not sufficient for understanding the type of reading variability, as these tests only indicate that there is a reading problem present. To gain insight into the type of reading variability, teachers can closely monitor reading patterns during guided reading by considering the following questions:

- What strategies are favoured for decoding new words?
- Which strategies work for the child?
- Are mispronunciations phonologically acceptable?
- Are some words semantically swapped for words with a similar meaning?
- Are some words incorrectly accessed for visually similar words?
- At what stage is meaning lost and why?
- How do reading strategies change across development?

During guided reading children are expected to make some errors or else the reading level is too low. Use these errors as clues to how the two reading circuits are functioning together during reading. An analysis of the child’s spelling patterns can provide further clues. Can the child spell novel words with phonological accuracy? How good are they at remembering sight words, such as high frequency words or irregular words? A relative imbalance
favouring phonological accuracy over direct recall suggests the dyseidetic type, while a relative imbalance favouring direct recall over phonological accuracy suggests the dysphonetic type.

**THE DYSEIDETIC PATTERN**

Dyseidetics strongly rely on the brain’s upper circuit. They read new words ‘letter-by-letter’ to decode the pronunciation. This over-reliance will often result in slower reading and regularisation errors. Here, irregular words or words that contain letter patterns with inconsistent sounds (/ow/ in show or cow) are sometimes pronounced with consistent sounds. Accessing visual representations of words is difficult for dyseidetics, forcing increased involvement of the upper circuit during reading. However, the upper circuit is a lot slower than the lower circuit because decoding is a computation, whereas word access uses direct recall. So dyseidetics are generally slower readers who have problems reading irregular words because they are decoding and not accessing. Dyseidetics also have problems with their spelling, but this is generally more specific to irregular words. They have surprisingly strong encoding skills because they favour the upper circuit. Although stories written by dyseidetics are peppered with spelling errors, these mistakes are generally phonologically accurate, so the meaning of the written piece is often retained during proof reading.

**THE DYSPHONETIC PATTERN**

During guided reading dysphonetics have problems reading words that they don’t know. Most high frequency words can be learnt ‘Chinese style,’ which involves rote learning based on whole word form recognition. However, low frequency and unfamiliar words typically need to be decoded. Dysphonetics often try to skip words that they don’t know, or predict words based on meaning. When decoding a word, they have problems manipulating the units of sound, emphasising the importance of phonological awareness training at a young age. They often use partial decoding clues in combination with meaning to read new words correctly. This prevents them from selecting a semantic neighbour (such as table for desk), as they are guided by the initial sound when predicting the appropriate word. Thus, dysphonetics can
learn to search for a new word based on initial sound as well as meaning. Dysphonetics, like dyseidetics, have persistent problems with their spelling. Although dyseidetics can spell with some phonological accuracy, dysphonetics display phonological inaccuracy. Their mistakes make written work harder to follow and in an effort to preserve meaning they may revert to using small words that they know how to spell.

Why is poor phonological assembly commonly reported in most poor readers? Both dyseidetics and dysphonetics are likely to have problems using analogy to sound out or spell new words, as this process requires the two reading circuits to work together. When using analogy, the lower circuit provides visually similar words to help the upper circuit with the decoding process. If the lower circuit is not working properly, as is the case for dyseidetics, fewer words are passed on to the upper circuit. For dysphonetics, phonological assembly problems are more marked as the upper circuit plays a greater role in decoding. Although dyseidetics are reported to show a mild phonological deficit, this can be explained by weaker analogous support. The important distinction here is that despite mild phonological assembly problems in dyseidetics, the dyseidetic pattern is not a mild form of the dysphonetic pattern, but a distinct pattern in its own right. As phonological assembly draws on both reading circuits, thanks to visual analogies, both dyseidetics and dysphonetics have problems using analytic strategies, stemming from different deficits.

When first learning to read, the dysphonetic is the most identifiable. The lower circuit has only a few entries, so most words will be new to the child and will require sounding out. Dysphonetics appear to have problems decoding new words, favouring direct learning (lower circuit) for building their sight vocabularies. Dyseidetics can decode words, but have problems adding these words to their word banks. At this early stage of reading acquisition, dyseidetics appear quite normal, as they are capable of decoding regular words, and they have small sight vocabularies like their peers (matched on reading age). As these readers mature, dyseidetics become more identifiable, whereas dysphonetics appear more normal. Dyseidetics fail to develop a quick and effective word bank in the brain’s lower circuit, and rely more on decoding words that cannot be accessed directly. In contrast, by the time dysphonetics have become more mature readers, after considerable exposure to print, they have developed extensive word banks and are only stumped by new words that they have not been seen before. So at the mature reading level (when reading a common
text without a lot of novel words) dysphonetics appear more like normal readers relative to dyseidetics who appear to have a more severe reading disability.

**CAUSATION**

Fluent adult readers are unlikely to show dyseidetic or dysphonetic patterns of reading, unless placed under pressure. As children, dyseidetic and dysphonetic characteristics can change during the development of the reading brain. Fluent reading requires the brain’s upper and lower circuits to be integrated and to work together. This allows us to access words rapidly, decode new words without losing momentum and use analogous words to help decoding and to accurately self-check. The internal cause of dyseidetic/dysphonetic characteristics is variability inside the reading brain. Internally, there is a difference between the function of the upper circuit and the function of the lower circuit. By identifying the variability (upper or lower circuit) we can then consider the possible cause (Figure 7.6) and the recommended intervention (Figure 7.7).

A possible cause of dysphonetic reading could be a ‘fundamentalist’ whole language approach where children have not received explicit instruction in decoding words. Whole language instruction provides children with considerable exposure to text, immersing them in the excitement of reading. Children are often encouraged to use semantic clues to predict the pronunciations of unknown words. Although most children learn decoding implicitly through text exposure, the overall reading pattern changes if they are taught in this way.

Reading can become ‘Chinese style’ if children over-rely on rote-learning words in the lower circuit without sounding them out in the upper circuit. Whole language instruction involves a risk that some children will not pick up decoding implicitly when a child’s dialect is different to that of the teacher’s, placing them at a greater risk of developing the dysphonetic pattern of reading. Children with differences in dialect may be penalised by a whole-language curriculum that neglects decoding and word recognition strategies.

Children receiving phonics instruction are taught explicitly how to decode words. Phonics instruction provides more word-level work
Where do these different patterns of reading come from? There are multiple ways to develop dyseidetic or dysphonetic reading characteristics.

1) A child’s reading pattern changes during development. When first learning to read children enter a logographic stage where only the lower circuit is used. Instruction in phonics develops the upper circuit, changing the child’s reading profile. Subsequently, the upper circuit facilitates acquisition of many new words that are then entered into the brain’s lower circuit, changing the reading profile again.

2) Instructional methods can influence the pattern of reading variability. Some children have problems developing the upper circuit without explicit phonics instruction, creating the dysphonetic pattern. If children are only taught phonics, there is very little contextual word exposure, resulting in an underdeveloped lower circuit or the dyseidetic pattern.

3) The environment influences children’s reading patterns. Limited exposure to reading means children won’t have strong connections for words in the brain’s lower circuit, creating the dyseidetic pattern.

4) Neurological diversity in the brain’s wiring may create an imbalance where one circuit has a processing advantage over another, either an upper deficiency (dysphonetic) or lower circuit deficiency (dyseidetic). Neurological diversity (such as in dyslexia) may be harder to correct, but the same intervention methods apply.
Reading problems can develop from multiple external, or distal, causes. Within the brain, the internal cause of reading problems, or the proximal cause, manifests across the upper reading circuit in dysphonetics and the lower reading circuit in dyseidetics. Two intervention programmes are described in this flow chart, one with a phonological basis and the other with an orthographic basis. Both interventions contain some analogy training.

As opposed to whole-text exposure. The upper circuit will therefore develop faster than the lower circuit, creating a dyseidetic (or Phonetian) profile. This has its advantages when children are first learning to read, as decoding words using the upper circuit is an effective way to read new words. When first learning to read, children often over-rely on the upper circuit and under-rely on the lower circuit. As they develop and become independent readers, the increase in text exposure strengthens the lower circuit and they should begin to lose these dyseidetic characteristics. During development, reading skills are influenced by the child’s environment and attitude towards reading. For example, children from a low socio-economic background are more likely to show
dyseidetic characteristics because their low exposure to print has stunted the development of the lower circuit. English as a second language (ESL) students may also show dyseidetic characteristics, as their initial acquisition of a new language means that their English word bank in the lower circuit contains very few word forms or pronunciations. Yet just like children from an English speaking background who are learning to read, language students acquire the skills of the upper circuit in a shorter period of time than the lower circuit. Developing extensive representations in the brain’s word bank requires considerable print exposure. Children from low socio-economic backgrounds with a dyseidetic style of reading will continue to be dyseidetic if their exposure to print is not increased. However, this can become difficult as many lose the desire to read early on.

INTERVENTION

The multisensory approach, including visual, auditory and kinaesthetic learning, is considered the most effective way to teach children with reading problems. Transcoding is the name given to a powerful form of multisensory learning, one that targets a weakness (such as the auditory module) through support from a functionally effective strength (such as the visual module). Research has investigated audiovisual transcoding as an effective way to increase the capacity of the auditory module through support from the visual module. Poor readers often have problems with auditory discrimination. Kujula and colleagues (2001) found that if sound discrimination is taught with related visual patterns, the visual component enables the auditory module to learn. The auditory module then rewire, simultaneously improving auditory discrimination and improving reading skills.

How can we use transcoding to teach readers who have disruptions in or between the auditory and visual modules? Dysphonetics appear to show an over-activation in the auditory module (Figure 7.8). Their auditory processing centres (in charge of manipulating units of sound) work at maximum capacity, requiring considerable mental effort and energy consumption. This is why dysphonetics can become tired during reading or writing and have problems maintaining concentration. It is important to target the module of weakness in order to increase functional capacity. This is achieved by teaching synthetic phonics and phonemic awareness to dysphonetics, skills that require a strong
FIGURE 7.8 TRANSCODING FROM VISUAL TO AUDITORY

How is transcoding used to teach dysphonetics? Dysphonetics have a problem linking letter shapes to phoneme sounds. During reading their auditory module is overloaded. Teaching phonemic awareness and synthetic phonics can increase the capacity of the auditory module so that it doesn’t have to work as hard. However, the dysphonetic is resistant to this type of intervention, as auditory processing is found difficult. An alternative is transcoding from the module of strength to the module of weakness. Colour coding allows dysphonetics to see differences between letter/sound groups. Moveable letters allow children to see what happens when we take a letter sound away. Analytic phonics allows dysphonetics to see common letter patterns within word families and relate these to common sounds.

auditory component. Unfortunately, dysphonetics are typically resistant to this form of intervention, as they find manipulating sounds very difficult. They are not good at discriminating and manipulating sounds, and quickly become frustrated as these processes require considerable conscious effort. However, dysphonetics can benefit from visual support such as colour coding sounds into groups. These children then see different sound relationships. With moveable letters they can also see that by manipulating letters they are in fact manipulating sounds. Furthermore, by introducing word families they can see that words with common patterns have common sounds. All of these examples involve transcoding – using the visual module to assist the auditory module (figure 7.9).

Dyseidetics use different strategies during reading to dysphonetics. The difficulty for dyseidetics is achieving rapid access to whole
word configurations. Rapidly accessing words requires considerable effort for dyseidetics, because this is where their neural activity is focused (Figure 7.10). The best way to build the capabilities of the visual word form area is through extensive exposure to print. But dyseidetics can become resistant to reading, as they know that they are not good at it. In order to overcome this, the auditory module can be used to prime the visual access of words. An effective way of doing this is the use of poetry or music. Poetry and music automatically establish a rhythm or tempo within the auditory module, supporting word access. Often poetry and music use repetition, enabling words to be recognised in an instant because they are fresh in the working memory. Finally, poetry and music use rhyme, so the word can be predicted from the auditory modality even if it is irregular. Taped stories or poetry allow children to learn these words as they listen while following the text. Children can listen to the story multiple times for reinforcement of word knowledge. These methods are good ways to transcode from the auditory module to the visual module, helping dyseidetics access words (figure 7.11).

During reading, dysphonetics should be encouraged to use decoding strategies when they come across a new word. In some cases the word might be an exception word and will require the teacher to help with decoding by pointing to phonological con-
In dyseidetic reading, the problem resides in the lower circuit where visual word forms are accessed and linked to pronunciations. Specifically, there is an increased concentration of brain wave activity in the visual module—the area of weakness. The best way to develop the visual word form area is to increase the exposure to print—get dyseidetics reading more. But dyseidetics can be resistant to this as they already find reading laborious. To counter this, use predictable text, such as poetry or songs, where there is repetition, rhythm and rhyme. Here, the strong auditory modality transcodes onto the weak visual module, providing easier access to words.

Talking books support rapid access of the visual word form through phonological or meaning based priming.
sistencies. When writing, dysphonetics should be encouraged to use inventive spellings when they don’t know the word. They can practise sounding the word out, then write the letters that correspond to the sounds. Dysphonetics will initially be quite poor spellers because of their weak upper circuits, however as their word banks grow they will be able to spell the majority of words with accuracy from direct access using the lower circuit. The best remediation for dysideidetics (if not all poor readers) is increased exposure to print, so it is important to find reading material that motivates and encourages further reading. Reading words in context is the most effective way for dyseidetics to learn new irregular words. Reading also supports the visualisation of these words, so that later, during spelling, direct access can be provided via the lower circuit.

Meaning clues can be used to correct regularisation errors during guided reading. Alternatively, partial help can be offered for the phonologically inconsistent components of words. Reading in context is important for dyseidetics, as meaning supports access to words. The brain can read words faster by predicting them based on the context of the sentence and the storyline. From syntax it can predict the type of word, for example, a noun or an adjective, because without the appropriate word the sentence doesn’t make sense. All of these processes support an ability to directly access whole word forms. The more words are read in context, the faster and easier they are to access from the brain’s word bank. Spelling is difficult for dyseidetics, as their word-memorisation cameras do not work properly. Dyseidetics have to learn the spelling of irregular words directly, perhaps with partial decoding support. Flash cards are commonly used with dyseidetics in an effort to increase their sight vocabularies. Different flash

**FIGURE 7.12 POSTING BOX AND FLASH CARDS**
Flash cards are commonly used to increase sight vocabularies and processing speed.
cards can be used at the whole-word level including picture/word recognition and irregular nouns (Figure 7.12). Mnemonics can also be used to teach irregular spellings (e.g. it is necessary to have 1 cream and 2 sugars in your coffee).

Another bridging idea is introducing Latin and Greek derivatives. Prefixes, suffixes and rootwords are phonologically friendly, as they are generally monosyllabic. Understanding their meanings provides additional clues during reading, spelling and writing (Figure 7.13). Morphemic knowledge is valuable for both dyseidetic and dysphonetic readers.

**SUMMARY**

Poor readers generally fall into two distinct categories: dyseidetics who have problems accessing words, and dysphonetics, who have problems sounding out words. The dyseidetic pattern results from an imbalance favouring the upper circuit, whereas the dysphonetic pattern results from an imbalance favouring the lower circuit. Intervention should include remediation targeting the circuit where the weakness lies, as well as bridging between the circuits as a form of scaffolding. Within the circuit of weakness, look for ways to help the weak module receive support from the strong module. This powerful technique is called transcoding and should be encouraged across auditory, visual and kinaesthetic learning styles.

Balanced literacy suggests three techniques that can be used for reading an unknown word:
1. predicting the word’s pronunciation based on a meaningful word that would fit the sentence (lower circuit).

2. decoding the letter/sound relationship by sounding out the word (upper circuit).

3. analysing the word’s letter/sound relationship from visual analogies (upper and lower circuits working together).

4. All of these reading strategies should be encouraged during reading intervention.
Any reading model must be capable of explaining how reading is represented in the brain. It must be able to account for the variety of reading problems that are seen in the classroom. It must be capable of being tested across different domains and it must be able to provide real, practical advice to teachers and parents on the best approaches for teaching reading. Traditionally, the reading brain has been considered a black box where words are inputted and pronunciations are outputted. However, this conceptualisation gives very little information as to how the system operates and what factors are responsible for the individual differences observed in children who are learning to read.

Numerous approaches to teaching reading from different fields have been included in this book. Much of this research comes from education and psychology. Working with children provides an insight into individual differences and which teaching techniques work. However, this is not enough as some questions are left unanswered. From a completely different perspective, theories of reading and computation models have been included, allowing the reading brain to be considered as a functional machine. Evolutionary psychology has been used to explain where this machine has come from and the different specialisations that the reading brain draws on. Finally, and perhaps most importantly, functional brain imaging provides the missing piece of the puzzle because it can monitor the reading brain as it learns and grows. The variability of reading patterns observed within the classroom is the result of different neural connections within the brain itself.

The reading brain is a new phenomenon, less than 4,000 years old. Because the brain was not designed as a reading machine, the process of reading is achieved by using brain systems that are considerably older than reading. The oldest system within the
reading brain is the visual module and it is here that words and letters are recognised. The other module used for reading is the auditory module in the front of the brain. Linking visual to auditory, the lower circuit enables direct access of pronunciations from whole word forms and the subsequent links to meaning. That’s reading! But the brain also has a mechanism for decoding unknown words. With a similar directionality from visual to auditory, the upper circuit allows us to map individual letters onto sounds in an effort to sound out the most likely pronunciation. When we spell a word, we are using the same mechanisms, but in the reverse direction, starting within the auditory module and working back to the visual module. Thus, to spell a known word the lower circuit is used from pronunciation to whole word form. Alternatively, to encode an unknown word in an effort to compute the most likely spelling, the upper circuit is used from phoneme sound to the corresponding letters. This is the basic neural architecture of the literate brain for reading and spelling.

FIGURE 8.1 LANGUAGE MODULES
There are two modules in the brain which need to be stimulated: an auditory module in the back of the brain and a visual module in the front of the brain. After learning that spoken words are made up of smaller units of sound, in the auditory module, the brain has developed phonemic awareness. After learning that words are made up of letters, in the visual module, the brain has developed graphemic awareness.
When it comes to teaching reading, different instructional methods target different components of the reading brain. Rather than debating the merits of one method over another, all methods can be introduced in a synergistic way to ensure the development of the reading brain as a unified system. This is achieved through balanced literacy - teaching synthetic phonics, analytic phonics and whole language (Figures 8.1 and 8.2).

As much reading, writing and spelling as possible should also be included in order to reinforce multi-directionality and efficient connectivity. Within the classroom there are a variety of different brains. Some children are brilliant readers, while others struggle. Even on day one of school, when children are first learning to read, some brains will already have an advantage, while others will be at a disadvantage, irrespective of effort. Scaffolding should be used to include all of these different brains into one reading lesson. Question prompts and explanations target the individual needs of children. Multisensory techniques make learning easier for those who find it difficult, establishing connections between the auditory and visual modules. Because reading is an artificial process, the multisensory approach is beneficial for all learning brains.
There are multiple causes of reading development problems. Teachers can take an historical perspective by considering the child’s past learning environment to discover what has led to the reading problem. Dyslexia is just one possible cause of reading problems. Reading ability combines a mixture of genetic and environmental factors. In cases of developmental dyslexia, it is accepted that there is a genetically driven disruption in the left hemisphere, leading to disconnections between the auditory and visual modules and making reading acquisition difficult. But there are also garden-variety poor readers who have not received sufficient instruction, or exposure to print, and who are also in need of urgent intervention.

When considering the reading pattern, it is now possible to look inside the brain to see how the different modules and circuits interact with each other. No longer is this a past account of reading problems, but a dynamic look at what the brain is actually doing. The reading pattern is used to customise the intervention. Two patterns of reading problems have been identified within the brain: dysphonetics who favour the lower circuit for reading and subsequently have problems decoding words and dyseidetics who favour the upper circuit for reading and subsequently have problems accessing whole word forms. Reading tests alone, or even tests of phonological assembly, do not measure the capabilities of the individual reading circuits but measure larger phenomena across the whole reading system, so they often fail to differentiate between the two groups. An understanding of the differences between the strengths and weaknesses of a child’s reading circuits can be gained by closely monitoring his or her strategies and errors during guided reading. Children’s spelling mistakes can also be analysed for evidence of upper circuit skills, as observed through phonologically accurate mis-spellings. This provides an insight as to how the two circuits work together. Once a profile of the reading pattern is created, intervention can be targeted towards the weakness, as this is the area where increased capability is desired. As strengthening a child’s reading weakness is an extremely energy consuming and effortful process, resistance to intervention is common. An alternative is to target the weakness through a module of strength. The use of transcoding involves bridging different learning modules, auditory, visual or kinaesthetic to support the area of weakness. At the same time, continued support is directed towards strengths as part of balanced literacy. Furthermore, children should be immersed in as much reading as possible so that they can practise their new skills within real contextual reading.
The goal of learning to read is fluency. Fluency results in automated, accurate and energy efficient functioning. As fluent readers, most of our consciousness is dedicated to following and enjoying the meaning of a text. We subconsciously access words in their whole word form, until we come across a word that is infrequent or that we haven’t seen before. We then engage our sounding out mechanisms to decode the word. At the same time, information is continuously passed back to visual and auditory modules in an effort to subconsciously locate the word from a long-term store. The fluent reading system is self-teaching. Mature and fluent readers can read any text without help and can decode any new words and add these to the brain’s word bank. This is the ultimate goal for teachers of reading – to develop an intelligent reading system where all students become fluent readers capable of independent learning.
acquired dyslexia: When a person loses reading ability as a result of brain damage.

alphabet principle: Learning the shapes and names of the letters of the alphabet.

analogy: Relating something known to something new. In reading and spelling, using knowledge of one word to read and spell other words, e.g. shell = /sh/ as in shoe and /ell/ as in bell.

analytic phonics: Teaching children how to decode new words by breaking up words that they already know and finding similarities.

antonyms: Words that are opposites, e.g. near is an antonym for far.

asymmetrical: When one side is bigger than the other side, e.g. the human brain shows a left hemisphere asymmetry, where the left side of the brain is bigger than the right.

audiovisual transcoding: Teaching auditory skills with support from the visual module.

auditory discrimination: The ability to distinguish between different sounds.

auditory module: A processing centre in the front of the brain in charge of pronunciations and phoneme sounds.

balanced literacy: A method of teaching reading that places equal weighting on synthetic phonics, analytic phonics and whole language.

behavioural research: Research that involves measuring behaviour and does not look at brain processing.

blending: Bringing sounds together, e.g. blend these sounds together, h/a/n/d.

changeable vowel sounds: Those vowel sounds that make two different sounds, e.g. /oo/ as in good and goose and /ow/ as in cow and tow.

Chinese reading: A style of reading where words are learnt directly through rote memorisation.

compliance reading: Reading because of an external goal or requirement.

connectionism: Considering the brain as a complex interconnection of neurons that form a learning system.
contralateral: opposite side of the midline of the body, e.g. the left visual field is projected to the right visual cortex.

corpus callosum: A thick bundle of nerves that connects the left and right hemispheres of the brain.

curiosity reading: The desire to read about a particular topic of interest in an effort to find out new information.

CVC: A spelling pattern referring to a consonant-vowel-consonant sequence of letters. It is associated with the short vowel sound, e.g. c/a/t, d/o/g, m/a/n, h/i/d.

decoding: Conversion from letter to sound (an upper circuit reading process).

deleting: Removing a sound within a word, e.g. say plate without the /p/ sound.

developmental delay: When cognitive development occurs at a slower rate than normal.

developmental dyslexia: A genetic condition marked by severe reading and spelling difficulties despite adequate instruction and intelligence.

direct access: A way of getting straight to the brain’s word bank from visual input. From here meaning and pronunciation are provided (a lower circuit reading process).

direct recall: A way of directly accessing the brain’s word bank from a pronunciation to its visual word form (a lower circuit spelling process).

dyscalculia: A condition that affects the ability to acquire arithmetic skills. Dyscalculics may have problems telling the time, calculating or measuring things.

dys-constellation: A group of associated learning difficulties.

dyseidetic: A type of reader who has problems with the perception of whole word configurations.

dysgraphia: A condition that affects the ability to acquire handwriting skills. Dysgraphics have problems with fine motor coordination, especially involving letters.

dyslexia: A condition marked by severe reading and spelling difficulties.

dysorthographia: A condition that affects the ability to acquire spelling skills. Dysorthographics have problems with visual memory recall of words.

dysphasia: A condition affecting oral language development. Dysphasics can have problems finding the right words to express themselves.

dysphonetic: A type of reader who has problems with grapheme-to-phoneme conversion or sounding out words.
**GLOSSARY**

**dyspraxia:** A condition affecting motor learning and balance. Dyspraxics show poor coordination skills and may have problems with eye-hand coordination.

**ectopia:** A tiny bundle of brain cells that disrupts the cell migration process during the third trimester.

**electroencephalography (EEG):** A method for measuring brain wave patterns that uses electrodes placed on the scalp. encoding: Conversion from sound to letter (an upper circuit spelling process).

**fluency:** Having command of reading. Reading easily and effortlessly.

**functional magnetic resonance imaging (fMRI):** A method for measuring brain activation patterns by placing the brain inside a large magnetic field.

**garden-variety poor reader:** A reader who has underdeveloped reading circuits because of insufficient instruction or developmental delay.

**generation effect:** An effect that improves learning (memory) when you actually create something for yourself (learning by doing).

**grapheme:** The written representation of a sound, which may consist of one or more letters.

**grapheme-to-phoneme conversion:** The computation involved with sounding out a word (working from letter to sound).

**guided reading:** Small group reading instruction where the readers are grouped according to their reading ability. The teacher sets the purpose for the reading and works intensively with the group to support the reading of a carefully selected text.

**high frequency words:** The most commonly seen and used words, e.g. come, going, up, look.

**homonyms:** Words that sound alike but have different meanings, e.g. blue and blew.

**implicit learning:** Learning something without consciously being aware of learning it.

**inclusion:** Creating environments that include all types of learners.

**independent reading:** Providing texts at an appropriate level that can be read without guided or shared support from teachers.

**intervention:** A programme designed to modify the pattern of reading behaviour.

**inventive spelling:** When children make up the spelling of a word they don’t know based on sound-letter relationships, often producing phonologically acceptable mis-spelling.
IQ discrepancy: A method for diagnosing developmental dyslexia based on a discrepancy between the sub-scales of intelligence tests, e.g. superior performance at block design while low average for coding.

irregular words: Words that don’t follow the letter/sound relationships of English. Sometimes called exception words.

isolating: Focusing on one sound in a word, e.g. what is the first, middle or last sound in cat?

kinaesthetic: A learning style which uses touch and movement.

latent variable: The underlying variable that you want to measure.

lexicalisation: The process of storing a word in the brain’s word bank (like taking a snapshot of a new word).

logographic stage: An early stage of reading development where words are memorised from their visual properties.

lower circuit: A ventral pathway from the visual module at the back of the brain to the auditory module at the front of the brain. The lower circuit is in charge of accessing whole word forms (direct access). The lower circuit is also used in spelling for accessing the orthographic properties of a known word (direct recall).

matching: Comparing sounds between two words, e.g. do big and bat start with the same sound?

Matthew effect: An effect where poor readers have less reading experience due to low confidence or motivation.

microscopic: So small as to only be visible with a microscope.

millisecond (msec): One thousandth of a second.

modality: Relating to a sensory mode, e.g. visual, auditory or kinaesthetic modalities.

module: An independent unit within the brain that is specialised for a particular type of processing or analysis, such as the visual module or the auditory module.

monosyllabic: Containing only one syllable.

mnemonic: A method of aiding the memory to learn a particular spelling, e.g. there is a piece of pie.

morpheme: The smallest unit of meaning. Prefixes and suffixes are morphemes.

multisensory learning: A method of teaching that focuses on engaging the different senses: auditory, visual and kinaesthetic.

nonsense words: Made up words (that are not in the dictionary) used to test how children go about sounding out new words. Sometimes called nonwords.

onset: The initial consonant or consonant cluster of a syllable, e.g. c-at, br-ick.
orthography: Correct or conventional spelling.

palindrome: A word or line that reads the same backwards as forwards, e.g. dad.

phoneme: The smallest unit of sound within a word, e.g. /c/ - /a/ - /t/.

phonemic awareness: An understanding that words are made up of small units of sound called phonemes. It is also the ability to consciously manipulate and hear the individual phonemes in words.

Phonetian reading: A style of reading where words are read letter-by-letter or sounded out.

phonics: A systematic instructional method for teaching the relationships between letters and sounds.

phonological assembly: The processes where words can be constructed or manipulated based on their letter to sound relationships.

phonological awareness: An awareness of various speech sounds such as rhyme, syllables and individual phonemes.

phonological dyslexia: A type of dyslexia where the sounding out mechanism appears deficient (upper circuit), while the word accessing mechanism remains intact (lower circuit).

phonologically accurate mis-spellings: Spelling mistakes that follow the rules of letter/sound relationships.

phonologically inaccurate mis-spellings: Spelling mistakes that do not follow the rules of letter/sound relationships.

polysyllabic: A word that contains more than one syllable.

precocious readers: Children with premature development of their reading circuits.

preference for challenge: The satisfaction of mastering or assimilating complex ideas in text.

prevention: Designing inclusive early reading programmes to stop or minimise reading failure.

reading efficacy: Refers to the belief that one can be successful at reading.

reading circuits: Two circuits in the left hemisphere that map from the visual module in the back of the brain to the auditory module in the front of the brain. While the slower upper circuit performs a computation for sounding out the most likely pronunciation of an unknown word, the faster lower circuit provides direct access to the whole form of a known word.

reading pattern: The observed behaviour of a reader in terms of sounding out (upper circuit) and word access (lower circuit) skills.
**reading variability:** The range of individual differences in reading patterns.

**recognition reading:** The pleasure in receiving a tangible form of recognition for success.

**remediation:** Programmes designed to help children who are slow readers or who are experiencing difficulty acquiring reading skills.

**rhyme:** A word rhymes with another word when it has a similar sound in its final syllable, e.g. rode and toad.

**rime:** A unit of sound composed of the vowel and any following consonants within a syllable, e.g. -at as in cat, mat or bat.

**scaffolding:** Temporary support provided by teachers to enable independent learning.

**segmenting:** Separating sounds in a word, e.g. what are the separate sounds in dog?

**semantic:** Relating to meaning in language.

**semantically incongruent:** Where the meaning is out of place, e.g. she drank a cold glass of nails. ‘Nails’ is the semantically incongruent word.

**shared reading:** The teacher models the reading process by reading to the pupils. The text may be at a level too difficult to be read independently. Pupils join in with the reading and are later encouraged to re-read all or part of the text.

**sight words:** High frequency words that are learnt directly. Often these are function words (e.g. of, the, that) that lack simple semantic association or are irregular and lack phonological transparency.

**spatial resolution:** The clarity of knowing exactly where a change is occurring in the brain.

**statistical validity:** Whether something is statistically sound and is measuring what it is supposed to measure, i.e. the latent variable.

**substituting:** Replacing a sound within a word, e.g. change the first sound in cat to an /m/ sound.

**suffix:** A letter or group of letters that can be added to the end of a word to alter its meaning.

**surface dyslexia:** A type of dyslexia where the word accessing mechanism appears deficient (lower circuit), while the decoding mechanism remains intact (upper circuit).

**syllable:** A part of a word that contains a single vowel sound and is said as one unit, e.g. looking has two syllables, cat has one syllable.

**symmetrical:** A structure where the parts are an equal shape and size.
synonyms: A word with the same or a very similar meaning to another, e.g. a synonym for loud is noisy.

synthetic phonics: An instructional method that explicitly teaches the 44 phonemes of the English language and their corresponding graphemes.

temporal resolution: The clarity of knowing exactly when a change is occurring within the brain.

transcoding: A form of multisensory learning where a module of weakness is supported by a module of strength, e.g. teaching sound discrimination (auditory) with colour-coded letters (visual).

transcranial magnetic stimulation (TMS): A brain imaging methodology where the cortex is temporarily disrupted through magnetic stimulation.

upper circuit: A dorsal pathway from the visual module to the auditory module. The upper circuit is in charge of computing letter/sound relationships for sounding out unknown words (decoding). The upper circuit is also used in spelling for computing the most likely sound/letter relationship of an unknown word (encoding).

verbal fluency: The number of words a child knows and uses during oral expression.

visual module: A processing centre in the back of the brain in charge of word recognition and letter shapes.

visual word form area: An area in the back of the brain in charge of storing whole word forms.

whole language: A technique for teaching new words in the context of real reading. An emphasis is placed on meaning, syntax and sight vocabulary.

word families: Families of words that contain analogous properties, e.g. cat, bat, and sat make an -at rime word family.


