Chapter 3

What the Brain Does When It Reads

Learner Objectives for Chapter 3

- Survey the skills that support proficient reading.
- Understand what eye movement studies reveal about reading.
- Identify and describe the role of four major brain-processing systems in recognizing printed words.
- Contrast the Four-Part Processing model with a cueing systems model.

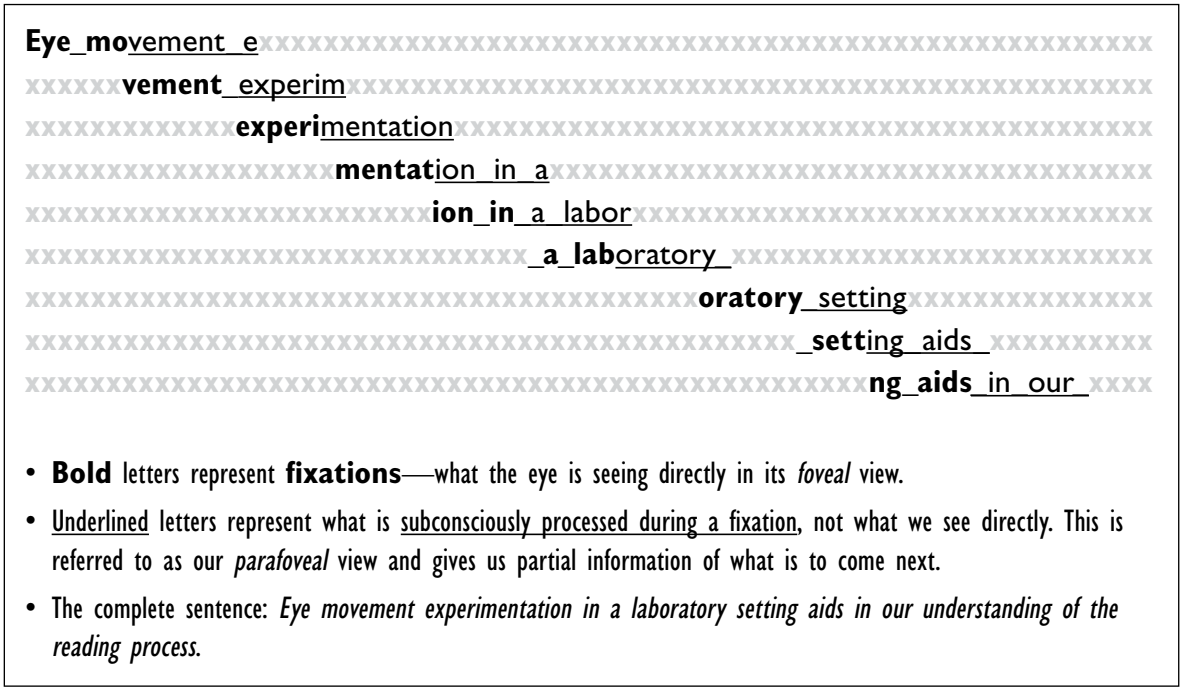
Warm-Up: Watch Eye Movements

- Working with a partner, take turns watching each other's eyes during oral reading of a paragraph or two of this book.

Eye Movements and Reading

You have just watched the eyes of a person scanning text at a normal rate. The eye seems to be ahead of the voice when we read aloud—and indeed, it is. The precision eye-movement research of scientists such as Rayner and Pollatsek (1989) at the Massachusetts Institute of Technology showed in many experiments over 20 years that the reading eye fixates on most content words (especially nouns and verbs) in a rapid series of stops and jumps called *fixations* and *saccades*. When fixated, the eye rests for about .25 seconds (250 milliseconds) on a content word and takes in a span of about seven to nine letters to the right of the fixation and three to four letters to the left before it jumps over to the next fixation point. More letters are processed to the right of the fixation if the eye is scanning from left to right. The opposite would be true for reading a language that is scanned from right to left, such as Hebrew or Arabic.

Figure 3.1 What the Eye Takes in During Fixations



Although we may not be aware of it, we do not skip over words, read print selectively, or recognize words by sampling a few letters of the print, as whole language theorists proposed in the 1970s. Reading is accomplished with letter-by-letter processing of the word (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001, 2002). Fluent readers *do* perceive each and every letter of print. Thus, we can distinguish **casual** from **causal**, **grill** from **girl**, and **primeval** from **prime evil**. Better readers process the internal details of printed words and match them to the individual speech sounds that make up the spoken word. Even when "chunks" are recognized, they can be analyzed into their individual phoneme-grapheme correspondences on demand.

Some children do have inherent vision problems, but they are independent of the types of problems that can be causes of reading difficulty. Visual acuity problems, such as near-sightedness, certainly should be identified and treated with corrective lenses, but language-based reading problems will not be cured with vision therapies. For example, there is no evidence that colored lenses or overlays relieve language-based reading problems or that eye-movement therapy is effective as a substitute for reading instruction. Faulty eye movements or visual fatigue most often are symptoms, not causes, of reading difficulty.

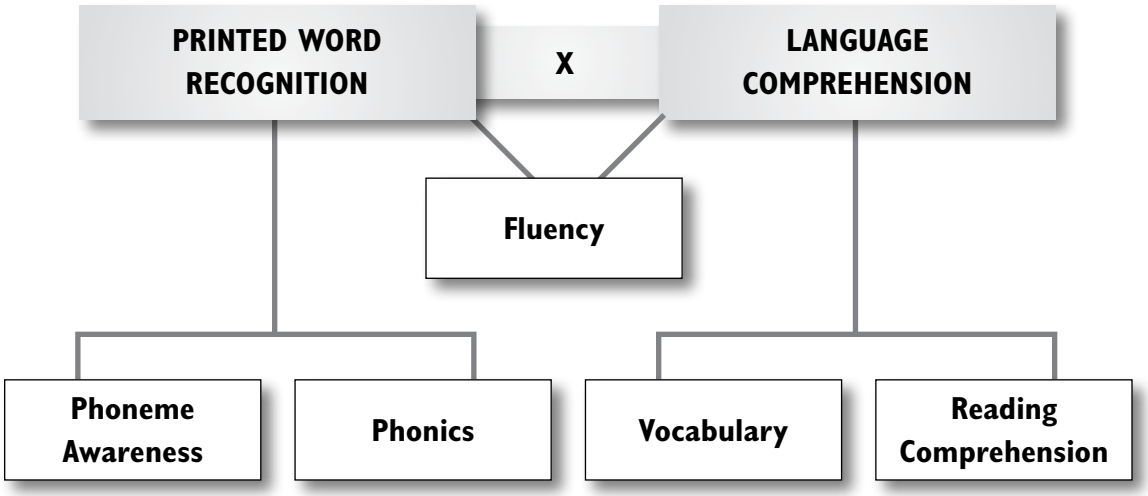
Eye movement studies have shown that mature, proficient readers do not skip words, use context to process words, or bypass phonics in establishing word recognition. Reading requires letter-wise processing of print and the ability to match symbols with the speech sounds they represent.

Proficient Reading Depends on Many Skills

The mechanics of fluent, accurate reading are quite remarkable. A proficient reader appears to scan the print effortlessly, extracting meaning and sifting through it, making connections between new ideas in the text and existing knowledge, and interpreting according to his or her purposes. The proficient reader figures out new words and names very quickly and with minimal effort, consciously sounding out new words if necessary. New words are decoded with minimal effort because the sounds, syllables, and meaningful parts of words are recognized automatically. If the good reader happens to misread a word or phrase or does not comprehend a word or phrase, he or she quickly adapts by rereading to make sense of the information and clarify what was unclear. As she reads along, the reader forms a mental model, or schema, for the meanings just extracted, linking new information to background knowledge. That schema, or mental construction, has a logical framework into which she files the information to remember. Reading is a complex mental activity!

The attainment of reading skill has fascinated psychologists and invited more study than any other aspect of human cognition because of its social importance and its complexity. The study of proficient reading and reading problems earned more funding increases from Congress in the 1990s than any other public health issue studied by the National Institute of Child Health and Human Development (Lyon & Chhabra, 2004). As a consequence of programmatic research efforts over many years, scientific consensus on some important issues in reading development and reading instruction has been reached (McCardle & Chhabra, 2004; Rayner et al., 2001).

Figure 3.2 Two Domains and Five Essential Components of Reading



One important result of research is the finding that fluent reading for comprehension depends on the ability to recognize and attach meaning to individual words. Reading is the product of two major sets of subskills: *printed word recognition* and *language comprehension*. Printed words cannot be interpreted unless they are accurately pronounced or named (e.g., **abroad** is not **aboard**; **scarred** is not **scared**; **etymology** is not **entomology**). Pronouncing or

decoding a word requires knowledge of the sounds in words (*phoneme awareness*) and the alphabetic system by which we represent those sounds (*phonics*). The meanings of those sounds must be recognized at the word level (*vocabulary*) and at the level of connected language (*text comprehension*).

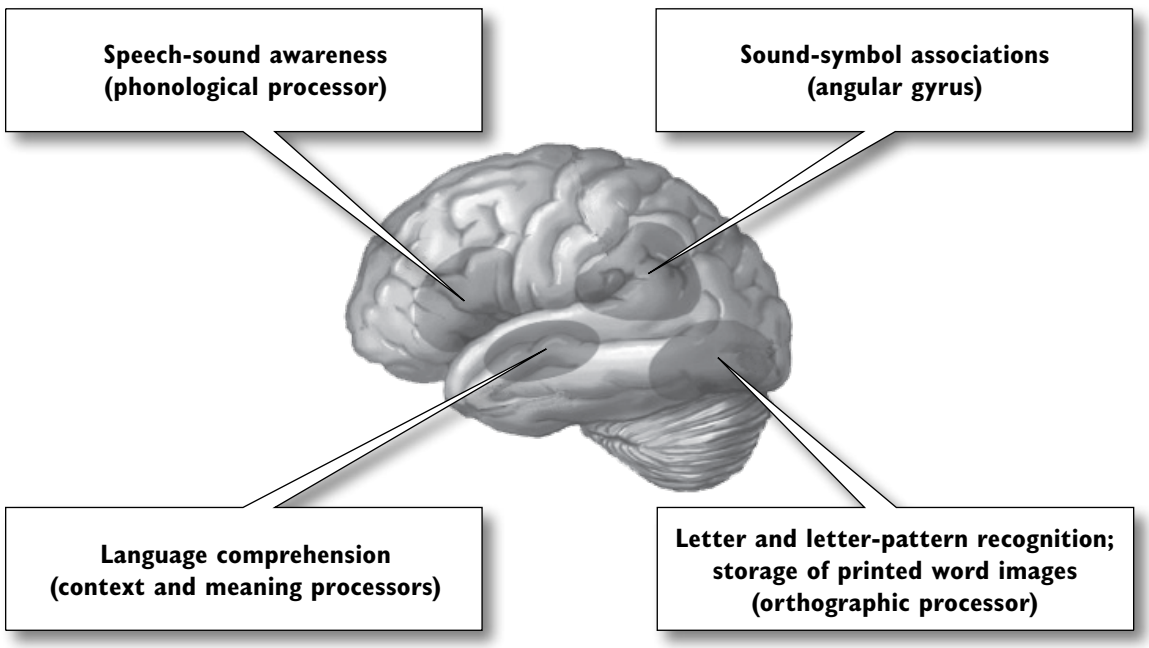
A *fluent* reader carries out the process of word-naming with deceptive ease. A fluent reader recognizes or names words so rapidly and effortlessly that he or she is not aware of those mental processes. Automatic word recognition frees up cognitive resources (i.e., attention, self-monitoring, working memory) that can then be applied to comprehension. A short list of some major subskills of reading, then, is as follows:

- Phoneme awareness
- Use of phonics to decode words accurately
- Automatic recognition of words previously deciphered
- Knowledge of what most words mean
- Understanding sentences and language of books
- Constructing meaning (connecting ideas in the text and with each other and with prior knowledge)
- Monitoring comprehension and rereading or rethinking if miscomprehension occurs.

Four Processing Systems That Support Word Recognition

Areas of the Brain Involved in Reading

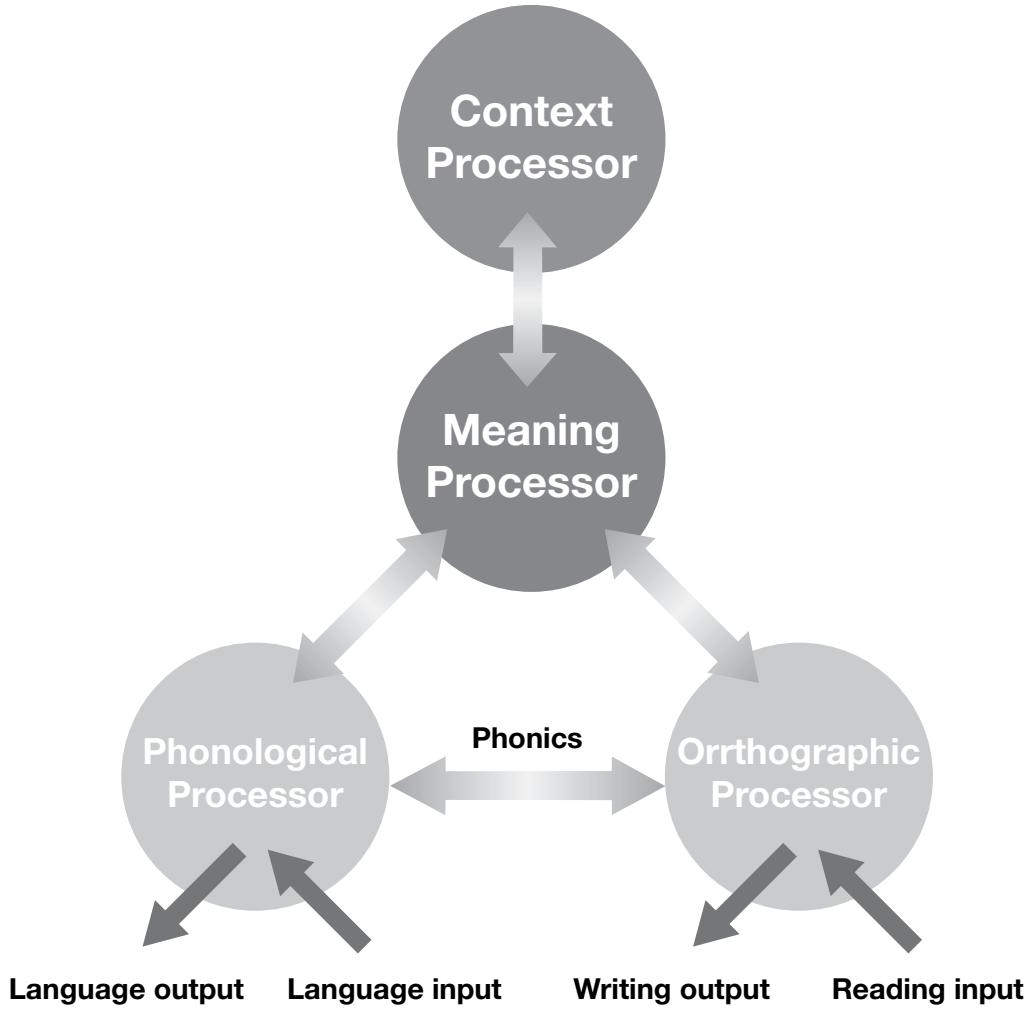
Figure 3.3 Areas of the Brain That Support Reading



In order for reading to occur, several major regions of the left half of the brain must perform specific jobs in concert with the others. In most people, language functions are subsumed by the left cerebral hemisphere, and the processing of written language depends on networks that are located primarily in the language centers. The networks that are highlighted in *Figure 3.3* include the **phonological processor** (in the back part of the *frontal lobe* of the brain); the **orthographic processor** (in the *lower back [occipital]* part of the brain); and the middle area (*temporal-parietal-occipital junction*, or **angular gyrus**), where these two processing systems communicate to support word recognition. In addition, pathways link the back and middle areas to the *temporal* areas, where **word meanings** and **connected language** are processed. Notice that the orthographic processor is on the side of the brain that serves language (left side) and that it is wired into the language centers. Learning to recognize words depends heavily on accurate matching of written symbols with sounds and the connection of those sound patterns with meaning.

Jobs of the Four Processing Systems

Figure 3.4 The Four-Part Processing Model for Word Recognition



The schematic representation of the four brain-processing systems involved in word recognition (*Figure 3.4*) is based on cognitive psychological experimentation. It was originally proposed by Seidenberg and McClelland (1989) as a summation and synthesis of many experiments on the nature of skilled and unskilled reading. This model was developed before functional brain studies showed where and when these mental activities take place during reading (Berninger & Richards, 2002; Eden & Moats, 2002; Shaywitz, 2003). The model is discussed at length in Adams' (1990) landmark book, *Beginning to Read: Thinking and Learning About Print*, and two recent summary articles in *Psychological Science in the Public Interest* and *Scientific American* (Rayner, et al., 2001, 2002). The schematic representation of the systems simplifies the nature of skilled reading because several subcomponents within each processing system have also been identified (Vellutino et al., 2007).

The four-part processor concept, although a simplification, is useful because it suggests: (a) the various ways in which reading problems might develop; and (b) why reading instruction should target several kinds of skills. The model reminds us that *instruction should aim to educate all of the processing systems and enable them to work together*. It shows why recognition and fast processing of sounds, letter patterns, and morphemes—as well as word meanings, language comprehension, and background knowledge—are all important components of skilled reading. The model also helps researchers decide what questions or hypotheses to test in scientific studies. For example:

- Is one processing system more important to educate than the others at a given stage of reading development?
- How do these systems interact?
- What kinds of experiences are necessary for each processing system to learn its job in the reading brain?
- Is it possible to be a good reader if one system is not functioning well?

Next, we will explore in more detail what each of the four processors is responsible for and how each one contributes to proficient reading and writing.

Exercise 3.1 Acting Out the Brain

- Follow your instructor as he or she walks you through the next section on the jobs of the four processing systems.

The Job of the Phonological Processor

This processing system enables us to perceive, remember, interpret, and produce the speech-sound system of our own language and learn the sounds of other languages. The phonological processor enables us to imitate and produce *prosody*, or the stress patterns, in speech, including the rise and fall of the voice during phrasing. It is responsible for such functions as:

- Mentally categorizing and identifying the phonemes in a language system;
- Producing the speech sounds and syllable sequences in words;

- Comparing and distinguishing words that sound similar (e.g., **reintegrate** vs. **reiterate**);
- Remembering and repeating the words in a phrase or the sounds in a word;
- Retrieving specific words from the mental dictionary (lexicon) and pronouncing them;
- Holding the sounds of a word in memory so that a word can be written down; and
- Taking apart the sounds in a word so that they can be matched with alphabetic symbols.

The phonological processor has many jobs, all of them related to the perception, memory, and production of speech. *Phoneme awareness* is one job of the phonological processor. Children who have trouble with phonological processing show a variety of symptoms, such as difficulty remembering sounds for letters or blending them together, difficulty recognizing the subtle differences between similar words, and trouble spelling all the speech sounds in a word.

LETRS Module 2 is all about this processing system. The phonological processor is so important that it needs its own module!

The Job of the Orthographic Processor

The orthographic processing system receives visual input from printed words. It perceives and recognizes letters, punctuation marks, spaces, and the letter patterns in words. The orthographic processor enables us to copy lines of print, recognize words as whole units, or remember letter sequences for spelling. When we look at print, its features are filtered, identified, and matched to images of letters or letter sequences already in our orthographic memory. If the letters or letter sequences are familiar, we associate them with sounds and meanings.

Most people have no trouble interpreting widely varying print forms, including individual handwriting styles, type fonts, or uppercase and lowercase letters. The size, style, and case of print are not major factors in word recognition once a reader knows letters and letter-sound relationships. Letters are recognized by their distinguishing features, including curves, straight lines and angles.

The orthographic processing system stores information about print that is necessary for word recognition and spelling. The speed with which letters are recognized and recalled is very important for proficient reading. Obviously, print images must be associated with meaning for reading comprehension to occur. Children with orthographic processing weaknesses will have trouble forming "sight word" habits, will be poor spellers, and will often read slowly because they are sounding everything out long after they should be doing that.

LETRS Module 3 is all about the organization of English orthography (the information that the orthographic processor must learn), and Module 7 is devoted to the teaching of phonics. Additionally, Module 10 addresses the advanced skills of phonics and word study necessary for reading and spelling multisyllabic words in our language.

The Job of the Meaning Processor

According to the four-part processing model, recognizing words as meaningful entities requires communication among the phonological processor, orthographic processor, and meaning processor. The meaning processor is also called the *semantic processor* because it interprets the meanings of words in and out of context. If we associate speech sounds with print symbols but do not access the meaning processor, we may read a foreign language (or our own!) without knowing what it means, read nonsense words, or read a new name by sounding it out but with no possibility of comprehension. The meaning processor stores the inventory of known words, organizes the mental dictionary or lexicon, and constructs the meanings of any new words that are named during reading. The context of the passage supports the construction of those meanings.

A word filed in your mental dictionary is a linguistic entity with many facets. When words are known in depth, their sounds, spellings, meaningful parts, typical uses, alternative meanings, and customary uses are known. The meaning processor is structured according to a number of semantic organization features such as synonym relationships, roots and other morphemes, spelling patterns, common meaning associations, and connotations. It expands and reorganizes itself as new vocabulary is learned.

In the lexicon, or mental dictionary, words are "filed" in meaning networks. Words are typically learned in relation to one another, not in isolation. We learn words best if we can connect them to something we already know. We learn words more readily if they are connected to images of their sounds and their spellings, as well as the contexts in which they are usually used. Children with weak vocabularies, limited knowledge of English, and/or weaknesses in verbal reasoning ability may have trouble reading. In these cases, children's decoding skills may or may not be better than their skills in meaning-making.

LETRS Module 4 is devoted to an exploration of word meanings and how to teach them.

The Job of the Context Processor

Refer back to page 33 and notice where the context processor is positioned in *Figure 3.4*. Its primary job is to interact with and provide support for the meaning processor. The term "context" refers to the sentence and sentence sequence in which a word is embedded, and the concepts or events that are being discussed or reported in the text. Context provides the referent for a word's meaning. Many same-sounding words have multiple meanings, but only one is correct when used within a specific sentence. For example, the spelling of a word such as **passed** or **past** is determined by its meaning in the context of a sentence:

- The quarterback **passed** the ball to the receiver for the touchdown.
- Champions of the **past** were guests at the start of the game.

Context may help us find or figure out a word's intended meaning if we do not already know the word. Context also enriches our knowledge of how each word is typically used in our language system. Context will resolve ambiguities associated with multiple meanings of many words. Context may also help us catch decoding errors and cause us to reread for

clarification. Well-developed background knowledge and verbal abilities as well as adequate reading fluency enable readers to use context productively.

A major point about the function of context in word recognition is that it plays only a limited role in facilitating word-naming itself. Word recognition and pronunciation are primarily the job of the phonological and orthographic processors. Students cannot comprehend text if they cannot read it accurately and fluently!

Module 6 of LETRS covers the topic of comprehension for young students; LETRS Module 11 addresses research and instructional practices best used for grades 4 and beyond.

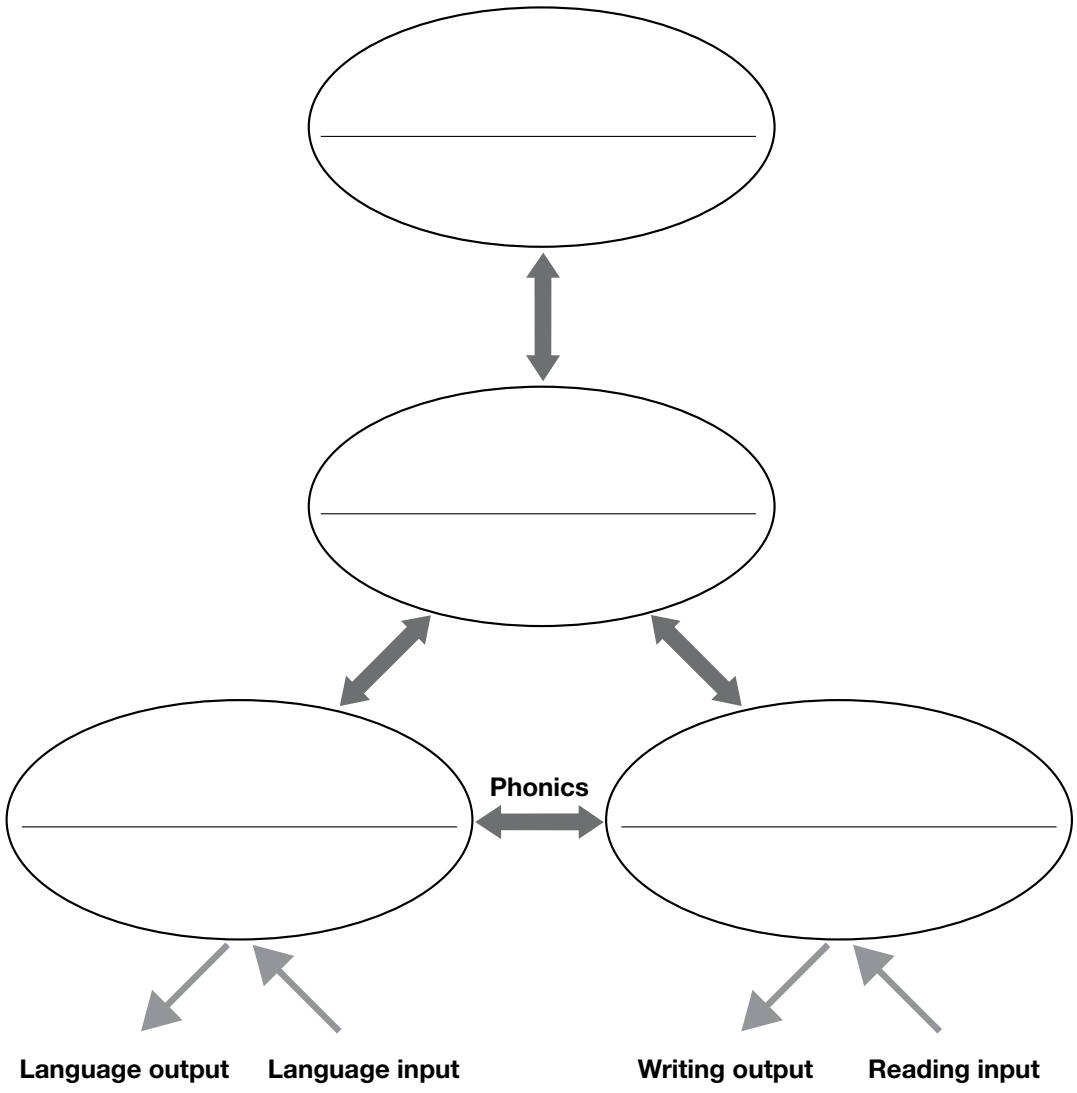
Exercise 3.2 The Four Processors at Work in the Classroom

- Walk through this exercise with your instructor. First, fill in the correct labels for the processors in the diagram on the next page: *phonological*, *orthographic*, *meaning*, and *context*.
- After labeling each processing system in the diagram, match each numbered task below to the processor(s) that is most obviously activated while the task is performed. Place the task number alongside the processor(s). Your presenter will do the first one with you.

1. Decode and pronounce the unfamiliar printed word **chimera**.
2. Repeat the *spoken* phrase "Riki-tiki tembo no serembo."
3. Orally give a synonym for the word **anthology**.
4. Read a passage to determine which meaning of the word **affirmative** is intended.
5. Determine whether the spoken words **does** and **rose** end with the same speech sound.
6. Underline all the words on a page in which the letter **c** is followed by **e**, **i**, or **y**.
7. Write this sentence: *My mental lexicon craves enrichment.*
8. Read and comprehend the next paragraph of this book.

(continued)

Exercise 3.2 (continued)



Exercise 3.2 (Alternative) Processing Systems and Classroom Instruction

- On a blank piece of paper, write out an activity you typically do with your class as you teach reading.
- Crumple the paper and throw your "snowball" into the center of the room. Your presenter will let you know what to do next.
- Are all processing systems addressed? Is one aspect of reading given more emphasis than another?