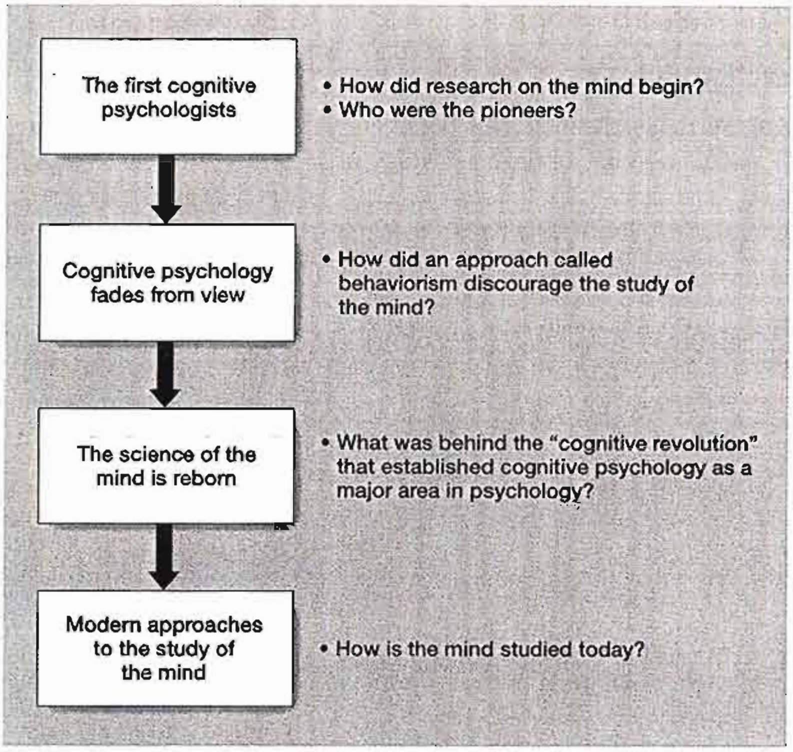



■ **Figure 1.2** Flow diagram for this chapter.

century (Figure 1.2). We then consider the first half of the 20th century, when studying the mind became unfashionable; the second half of the 20th century, when the study of the mind began to flourish again; and how psychologists and researchers in other fields approach present-day research on the mind.

## The First Cognitive Psychologists

Cognitive psychology research began in the 19th century before there was a field called cognitive psychology—or even, for that matter, psychology. In 1868, eleven years before the founding of the first laboratory of scientific psychology, Franciscus Donders, a Dutch physiologist, did one of the first cognitive psychology experiments.

**Donders' Reaction-Time Experiment** Donders conducted research on what today would be called **mental chronometry**, measuring how long a cognitive processes takes. Specifically, he was interested in how long it took for a person to make a decision. He determined this by using a measure called *reaction time*.

## Method

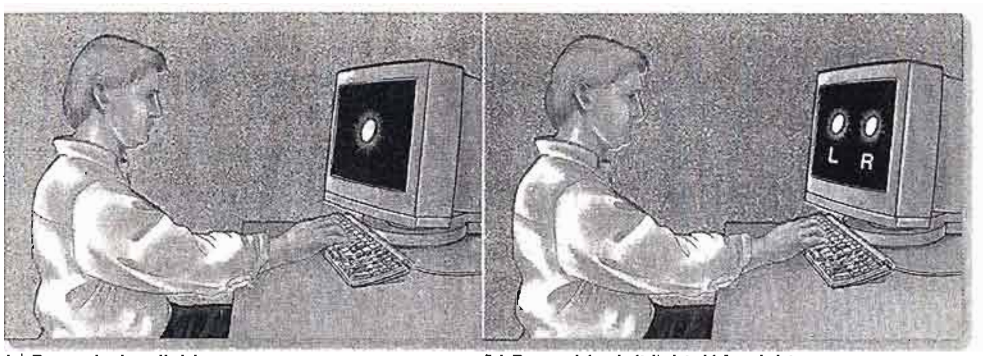
### Reaction Time

**Reaction time**—the interval between presentation of a stimulus and a person's response to the stimulus—is one of the most widely used measures in cognitive psychology. One reason for its importance is that measuring the speed of a person's reaction can provide information about extremely rapid processes that occur in the mind.

Reaction time is typically measured by presenting a stimulus and having a participant respond by pressing a button or a key on a computer keyboard as soon as the participant has completed a task. Tasks can range from simply indicating that the stimulus was presented ("Press the button when you see the light"), to making a decision about stimuli ("Press the key if the letters you see form a word" or "Press Key #1 if the statement is true and Key #2 if it is false"). In each of these cases, reaction time can provide insights into the nature of mental processing involved in these tasks. ◆

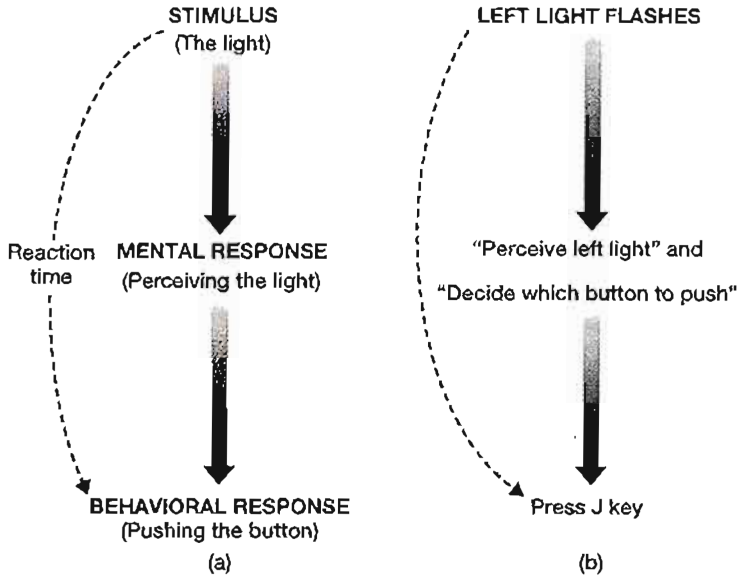
Donders measured the reaction time to perceiving a light. In the **simple reaction-time** task there was one location for the light, and participants pushed a button as quickly as possible after the light was illuminated (Figure 1.3a). In the **choice reaction-time** task, the light could appear on the left or on the right, and the participants were to push one button if the light was illuminated on the left, and the other button if the light was illuminated on the right (Figure 1.3b).

The rationale behind the simple reaction-time experiment is shown in Figure 1.4a. Presenting the stimulus (the light) causes a mental response (perceiving the light), which leads to a behavioral response (pushing the button). The reaction time (dashed line) is the time between presentation of the stimulus and the behavioral response.




(a) Press J when light goes on. (b) Press J for left light, K for right.

■ **Figure 1.3** A modern version of Donders' (1868) reaction-time experiment: (a) the simple reaction-time task; and (b) the choice reaction-time task. For the simple reaction-time task, the participant pushes the J key when the light goes on. For the choice reaction-time task, the participant pushes the J key if the left light goes on, and the K key if the right light goes on. The purpose of Donders' experiment was to determine the time it took to decide which key to press for the choice reaction-time task.

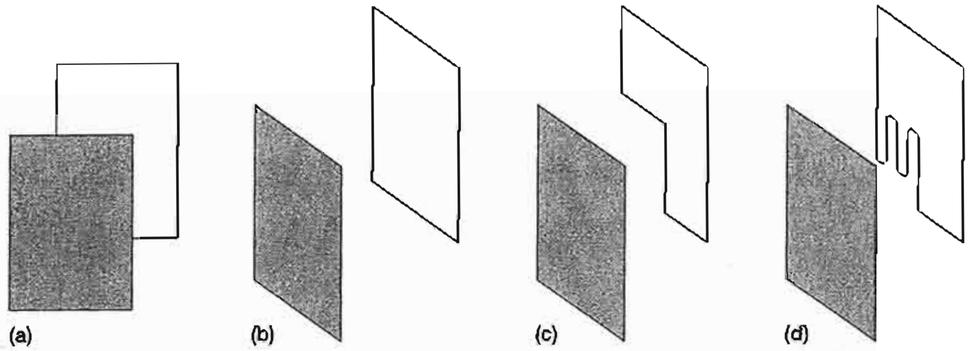



■ **Figure 1.4** Sequence of events between presentation of the stimulus and the behavioral response in Donders' experiment. The dashed line indicates that Donders measured reaction time, the time between presentation of the light and the participant's response. (a) Simple reaction-time task; (b) choice reaction-time task.

In Figure 1.4b, a similar diagram for the choice reaction-time experiment, the mental response includes not only perceiving the light but also deciding which light was illuminated and then which button to push. Donders reasoned that choice reaction time would be longer than simple reaction time because of the time it takes to make the decision. Thus, the difference in reaction time between the simple and choice conditions would indicate how long it took to make the decision. Because the choice reaction time took one-tenth of a second longer than simple reaction time, Donders concluded that it took one-tenth of a second to decide which button to push.

Donders' experiment is important both because it was one of the first cognitive psychology experiments, and because it illustrates something extremely important about studying the mind—mental responses (perceiving the light and deciding which button to push, in this example) cannot be measured directly, but must be inferred from the participants' behavior. We can see why this is so by noting the dashed lines in Figure 1.4. These lines indicate that when Donders measured the reaction time, he was measuring the relationship between the presentation of the stimulus and the participant's response. He did not measure the mental response directly, but inferred how long it took from the reaction times. The fact that mental responses can't be measured directly, but must be inferred from observing behavior, is a principle that holds not only for Donders' experiment, but for all research in cognitive psychology.

**Helmholtz's Unconscious Inference** Hermann von Helmholtz was another 19th-century researcher who was concerned with studying the mind. Helmholtz, who was professor of physiology at the University of Heidelberg (1858) and professor of physics at the



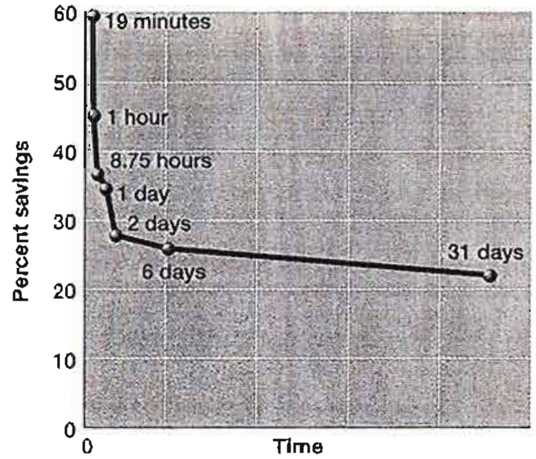

■ **Figure 1.5** The display in (a) looks like (b) a gray rectangle in front of a light rectangle; but it could be (c) a gray rectangle and a six-sided figure that are lined up appropriately or (d) a gray rectangle and a strange-looking figure that are lined up appropriately.

University of Berlin (1871), was one of the preeminent physiologists and physicists of his day. He made basic discoveries in physiology and physics, and also developed the ophthalmoscope (the device that an optometrist or ophthalmologist uses to look into your eye) and proposed theories of object perception, color vision, and hearing.

One of the conclusions Helmholtz reached from his research on perception is a principle called the theory of **unconscious inference**, which states that some of our perceptions are the result of unconscious assumptions that we make about the environment. For example, consider Figure 1.5a. This display could be caused by one rectangle overlapping another (Figure 1.5b), or by a six-sided shape positioned to line up with the upper-right corner of the gray rectangle (Figure 1.5c), or a rectangle overlapping a strange shape (Figure 1.5d). However, according to the theory of unconscious inference, we infer that we are seeing a rectangle covering another rectangle because of experiences we have had with similar situations in the past. This inference is called unconscious because it occurs without our awareness or any conscious effort. Helmholtz's idea that we infer much of what we know about the world was an early statement of what is now considered to be a central principle of modern cognitive psychology.

**Ebbinghaus's Memory Experiments** Hermann Ebbinghaus (1885) performed his classic experiments on memory by learning lists of nonsense syllables like DAX, QEH, LUH, and ZIF. He used nonsense syllables so that his memory would not be influenced by the meaning of a particular word. He read lists of these syllables out loud to himself over and over and determined how many repetitions it took to repeat the lists with no errors. This initial learning is the first step in the **savings method**.

Ebbinghaus then waited a period of time and relearned the list using the same procedure. For short intervals between initial learning and relearning, it usually took fewer repetitions to relearn the list than it had taken him to initially learn it. For example, if Ebbinghaus had to repeat the list 9 times to initially learn it, it might take only 3 repeti-




■ **Figure 1.6** Ebbinghaus's retention curve, determined by the method of savings. (Based on data from Ebbinghaus, 1885.)

tions to relearn the list after a short interval. Based on this data, he calculated a savings score, using the following formula:

Savings = [(Initial repetitions) − (Relearning repetitions)] / Initial repetitions.

Multiplying the result by 100 converts the savings to a percentage, so for the example above,

Savings = [(9 − 3) / 9] × 100 = 67 percent.

By learning many different lists at retention intervals ranging from 19 minutes to 31 days, Ebbinghaus was able to plot the "forgetting curve" in Figure 1.6, which shows savings as a function of retention interval. Ebbinghaus's experiments were important because they provided a way to quantify memory and therefore plot functions like the forgetting curve that describe the operation of the mind. Notice that although Ebbinghaus's savings method was very different from Donders' reaction-time method, they have something in common: They both measure *behavior* to determine a property of the *mind.*

**The First Psychology Laboratories** People like Donders, Helmholtz, and Ebbinghaus, who were investigating the mind in the 19th century, were usually based in departments of physiology, physics, or philosophy, because there were no psychology departments at the time. But in 1879 Wilhelm Wundt founded the first laboratory of scientific psychology at the University of Leipzig, with the goal of studying the mind scientifically. He and his students carried out reaction-time experiments and measured basic properties of the senses, particularly vision and hearing.

The theoretical approach that dominated psychology in the late 1800s and early 1900s was called **structuralism**. According to structuralism, our overall experience is determined by combining basic elements of experience called sensations. Thus, just as

**Table 1.1** Early Cognitive Psychologists

| | | |
|---|---|---|
| Donders | 1868 | Experiment: Simple vs. choice reaction time<br>Idea: Mental processes cannot be observed directly, but must be inferred from behavior |
| Helmholtz | 1860–80 | Principle: Unconscious inference |
| Ebbinghaus | 1885 | Experiment: Memory for nonsense syllables<br>Method: Savings technique<br>Result: Forgetting curve |
| Wundt | 1879 | Established the first laboratory of scientific psychology<br>Theory: Structuralism<br>Method: Analytic introspection |

chemistry had developed a periodic table of the elements, which organized elements on the basis of their molecular weights and chemical properties, Wundt wanted to create a "periodic table of the mind," which would include all of the basic sensations involved in creating experience. Wundt thought he could achieve this by using **analytic introspection**, a technique in which trained participants described their experiences and thought processes in response to stimuli. For example, in one experiment, Wundt asked participants to describe their experience of hearing a five-note chord played on the piano. Wundt was interested in whether they heard the five notes as a single unit or if they were able to hear the individual notes.

Although Wundt never achieved his goal of explaining behavior in terms of sensations, he had a major impact on psychology by establishing the first laboratory of scientific psychology and training PhDs who established psychology departments at other universities. By the beginning of the 20th century, psychology was taking hold in the United States, and much of the research was inspired by the work of the early cognitive psychologists mentioned in this chapter, who were interested in understanding mental functioning (Table 1.1). As we will see, however, events early in the 20th century would shift the focus of psychology away from the study of mental processes and toward the study of observable behavior. One of the major forces that caused psychology to reject the study of mental processes was a negative reaction to the technique of analytic introspection.

## The Decline and Rebirth of Cognitive Psychology

Research in most early departments of psychology was conducted in the tradition of Wundt's laboratory, with its emphasis on using analytic introspection to reveal hidden mental processes. This emphasis on studying the mind was to change, however, because of the efforts of John Watson, who received his PhD in psychology in 1904 from the University of Chicago.

## The Rise of Behaviorism

The story of how John Watson founded an approach to psychology called behaviorism is well known to introductory psychology students. We will briefly review it here because of its importance to the story of cognitive psychology.

**Watson Founds Behaviorism** As a graduate student at the University of Chicago, Watson became dissatisfied with the method of analytic introspection. His problems with this method were (1) it produced extremely variable results from person to person, and (2) these results were difficult to verify because they were interpreted in terms of invisible inner mental processes.

In response to what Watson perceived to be deficiencies in analytic introspection, he proposed a new approach called **behaviorism.** One of Watson's papers, "Psychology as the Behaviorist Views It," set forth the goals of this approach to psychology in this famous quote:

> Psychology as the Behaviorist sees it is a purely objective, experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. . . . What we need to do is start work upon psychology making behavior, not consciousness, the objective point of our attack. (Watson, 1913, pp. 158, 176)

There are three key parts of this quote: (1) Watson rejects introspection as a method, (2) he eliminates consciousness as a topic for study, and (3) he suggests that psychology's main topic for study should be behavior. In another part of this paper, Watson also proclaims that "psychology . . . need no longer delude itself into thinking that it is making mental states the object of observation" (p. 163). Watson's goal was to eliminate the mind as a topic of study in psychology, and to replace it with the study of directly observable behavior.

As behaviorism became the dominant force in American psychology, psychologists' attention shifted from understanding the mind by inferring mental processes from behavior, to understanding behavior in terms of stimulus-response relationships, without any reference to the mind. Watson's most famous experiment was the "little Albert" experiment, in which Watson and Rosalie Rayner (1920) caused a 9-month-old boy named Albert to become frightened of a rat by presenting a loud noise every time the rat (which Albert had originally liked) came close to Albert.

Watson's ideas are associated with classical conditioning, which focused on how pairing one stimulus (such as the loud noise presented to Albert) with another, previously neutral stimulus (such as the rat) causes changes in the response to the neutral stimulus (Pavlov, 1927). Watson used the conditioning of little Albert to argue that behavior can be analyzed without any reference to the mind. For Watson, what was going on inside little Albert's head, either physiologically or mentally, was irrelevant. He cared only about how pairing one stimulus with another affected behavior.

**Skinner's Operant Conditioning** In the midst of behaviorism's dominance of American psychology, a young graduate student at Harvard named B. F. Skinner provided another tool for behaviorism, which insured this approach would dominate psychology for decades to come. Skinner introduced operant conditioning, which focused on how behavior is strengthened by presentation of positive reinforcers, such as food or social approval, or withdrawal of negative reinforcers, such as a shock or social rejection. For example, Skinner showed that reinforcing a rat with food for pressing a bar maintained or increased the rat's rate of bar pressing. Like Watson, Skinner was not interested in what was happening in the mind, but focused solely on determining the relationship between stimuli and responding (Skinner, 1938).

## The Decline of Behaviorism

The behaviorists' idea that behavior can be understood by studying stimulus-response relationships influenced an entire generation of psychologists and dominated psychology in the United States during the 1940s, 1950s, and into the 1960s. Psychologists applied the techniques of conditioning to things like classroom teaching, treating psychological disorders, and testing the effects of drugs on animals. However, beginning in the 1950s, changes began to occur in psychology, which would eventually lead to a decline in the influence of behaviorism. One of the important events that led to the decline of behaviorism was the publication of Skinner's book *Verbal Behavior*, in 1957.

**Noam Chomsky's Critique of Skinner's *Verbal Behavior*** In his book *Verbal Behavior*, Skinner explained the development of language in children in terms of operant conditioning. Skinner argued that children learn language through operant conditioning. They imitate speech that they hear, and repeat correct speech because it is rewarded. But in 1959 Chomsky, a linguist from the Massachusetts Institute of Technology, published a scathing review of Skinner's book, in which he pointed out that children say many sentences that they have never heard ("I hate you, Mommy," for example), and that during the normal course of language development, they go through a stage in which they use incorrect grammar, such as "the boy hitted the ball," even though this incorrect grammar may never have been reinforced.

Chomsky saw language development as being determined not by imitation or reinforcement, but by an inborn biological program that holds across cultures. Chomsky's analysis led psychologists to reconsider the idea that language and other complex behaviors such as problem solving and reasoning can be explained by operant conditioning, and they began to realize that to understand complex cognitive behaviors it is necessary not only to measure observable behavior, but to consider what this behavior tells us about how the mind works.

**The Misbehavior of Organisms** Another event that led people to question behaviorism was the publication in 1961 of a paper titled "The Misbehavior of Organisms" by two of Skinner's students, Keller Breland and Marian Breland (1961). The title of their paper was, significantly, a takeoff on the title of Skinner's 1938 book *The Behavior of Organisms*, in which Skinner described how behavior can be controlled by reinforcements.

Drawing on their experience in using operant conditioning to train animals for circuses, TV, and film stunts, the Brelands described a number of situations in which their attempts to condition an animal's behavior ran head-on into the animal's built-in instincts. For example, according to the theory of operant conditioning, rewarding a behavior should increase its frequency. However, when the Brelands attempted to train a raccoon to drop two coins in a piggy bank by rewarding this response with food, the raccoon did not cooperate. After the raccoon was rewarded with food for dropping two coins into the bank, it took the next two coins and began rubbing them together, just as they do to remove the shells of newly caught crayfish. Eventually, the coin-rubbing response overpowered the coin-dropping response, and the Brelands had to abandon their attempt to condition the raccoon. The Brelands used this and other examples to emphasize the importance of biologically programmed behavior.

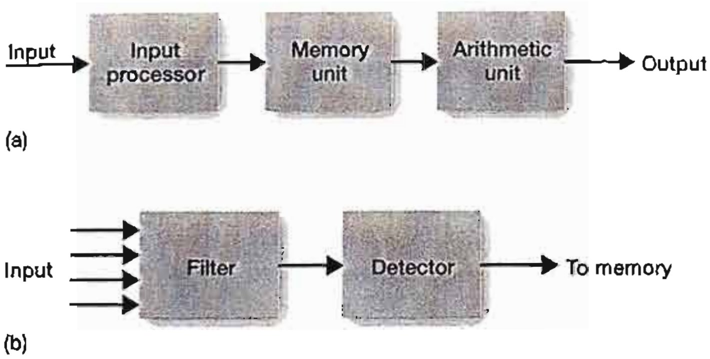
Although some researchers were questioning the ability of reinforcement to explain complex behavior like language in humans and the "coin rubbing" of Breland's raccoons, other researchers were developing an alternative approach to studying behavior, based on the idea that the mind is a processor of information.

## The Cognitive Revolution

A number of events occurred in the 1950s that resulted in what has been called the **cognitive revolution**—a shift in psychology from the behaviorist's stimulus-response relationships to an approach in which the main thrust was to explain behavior in terms of the mind. These events provided a new way to study the mind, called the **information-processing approach**. One of the events that inspired psychologists to think of the mind in terms of information processing was a newly introduced information-processing device called the digital computer.

**Introduction of the Digital Computer** The first digital computers, which were developed in the late 1940s, were huge machines that took up entire buildings. But in 1954 IBM introduced a computer that was available to the general public. These computers were still extremely large compared to the laptops of today, but they found their way to university research laboratories, where they were used both to analyze data and, most important for our purposes, to suggest a new way to think about the mind.

One of the characteristics of computers that captured the attention of cognitive psychologists in the 1950s was that they processed information in stages. For example, the diagram in Figure 1.7a shows the layout of a computer in which information is received by an "input processor" and is then stored in a "memory unit" before it is processed by an "arithmetic unit," which then creates the computer's output. Applying this stage




■ **Figure 1.7** (a) Flow diagram for an early computer. (b) Flow diagram for Broadbent's filter model of attention. This diagram shows that many messages enter a "filter" that selects the message to which the person is attending for further processing by a detector and then storage in memory. We will describe this diagram more fully in Chapter 4.

approach to the mind led psychologists to ask new questions and to frame their answers to these questions in new ways. British psychologists Colin Cherry and Donald Broadbent sought to answer two questions: "How much information can the mind take in?" and "Is it possible to attend to just some part of the incoming information?" These questions led to some pioneering work on attention.

**Early Experiments on Attention** To study how well people can pay attention to some information when other information is presented at the same time, Cherry (1953) asked participants to listen to two different messages, one presented to the left ear and the other presented to the right ear. To ensure that his participants were attending to one of the messages, Cherry asked them to repeat, out loud, the message presented to one of the ears. Cherry found that participants were able to focus on the message they were repeating, but could take in very little information from the other message.

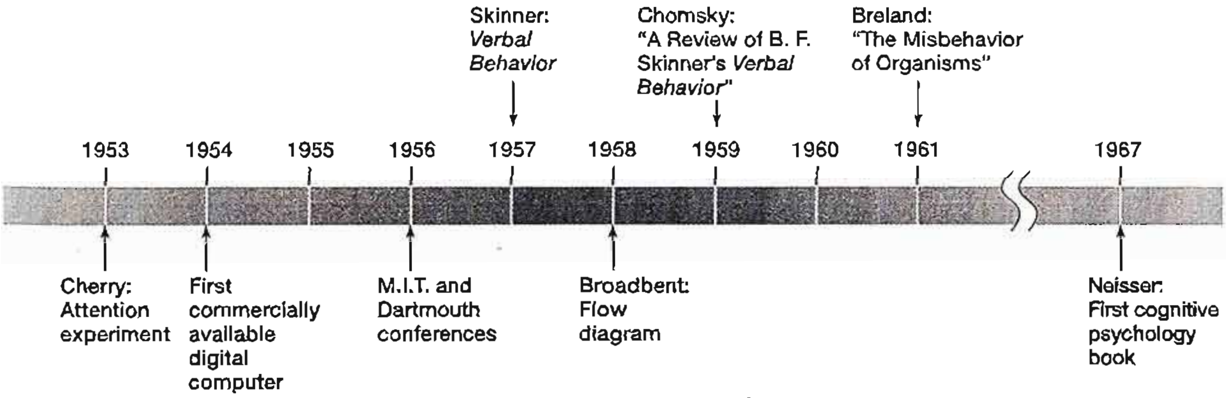
Cherry's result was important because it showed both that people were able to focus their attention on one message among many, and also that there are limits to the amount of information that people can deal with. But what made this result even more important is what happened next: Donald Broadbent (1958) proposed a flow diagram (Figure 1.7b) to represent what happens in a person's mind as he or she directs attention to one stimulus in the environment, like Cherry's participants did when they focused their attention on the message presented to one ear.

This flow diagram, which we will describe in more detail in Chapter 4, is notable because it was the first to depict the mind as processing information in a sequence of stages. Applied to Cherry's experiment, "input" would be the sounds entering the person's ears; the "filter" lets through the part of the input to which the person is attending; and the "detector" records the information that gets through the filter. The important point for now is that the flow diagram provided a way to analyze the operation of the mind in terms of a sequence of processing stages. You will see many more flow diagrams like this throughout this book because they have become one of the standard ways of depicting the operation of the mind.

**Two Historic Conferences** At about the time Cherry and Broadbent were studying attention in England, two meetings were held in the United States that also played an important role in reintroducing the mind to psychology. In the summer of 1956, Dartmouth University held a research seminar on artificial intelligence. On September 10–12 of the same year, the Second Symposium on Information Theory was held at MIT. A notable paper presented at both conferences was Alan Newell and Herb Simon's (1956) description of their "logic theorist" computer program that enabled computers to solve logic problems. Both of these conferences brought together researchers from a number of fields, including psychology, linguistics, computer science, and anthropology.

All of the events we have described represented the beginning of a shift in psychology from behaviorism to the study of the mind. This shift has been called the cognitive revolution, but the word "revolution" should not be interpreted as meaning that the shift from behaviorism to cognitive approach occurred quickly. The scientists attending the conferences in 1956 had no idea that these conferences would, years later, be seen as historic events in the birth of a new way of thinking about the mind (Miller, 2003). In fact, the conferences were so influential that scientific historians have called 1956 "the birthday of cognitive science" (Bechtel et al., 1998; Neisser, 1988). But ten years after these meetings, a textbook on the history of psychology makes no mention of cognitive psychology (Misiak & Sexton, 1966), and it wasn't until 1967 that the first cognitive psychology textbook appeared (Neisser, 1967).

Nonetheless, events that began in the 1950s resulted in a new generation of psychologists who began conducting experiments in perception, attention, memory, language, and problem solving, and were interpreting their results in terms of the flow of information within the mind. It soon became evident that the information-processing approach worked, and so more and more psychologists became interested in using it, and by the 1980s, American psychology had evolved from being a behaviorist world to a cognitive one. It happened gradually, more like an *evolution* than a *revolution*, but the overall result was revolutionary (Figure 1.8).




■ **Figure 1.8** Time line showing events associated with the decline of behaviorism (above the line) and events that led to the development of the information-processing approach to cognitive psychology (below the line).