HANDBOOK of PSYCHOLOGY: VOLUME 1, HISTORY OF PSYCHOLOGY

Donald K. Freedheim
Irving B. Weiner

John Wiley & Sons, Inc.

CHAPTER 1

Psychology as a Science

ALFRED H. FUCHS AND KATHARINE S. MILAR

ORIGINS OF SCIENTIFIC PSYCHOLOGY

Historical accounts of the development of scientific psychology place the origins of the discipline in Germany at about the middle of the nineteenth century. The ferment produced by British and continental philosophies of mind and the advances of research in sensory physiology provided the immediate context for the beginning of the new psychology. The pursuit of knowledge about mind and its processes has a history that is embedded in the history of philosophy. The late-eighteenth-century declaration that a true scientific study of the mind was not possible posed a challenge that was answered in the nineteenth century when the possibility of a scientific study of mind emerged within philosophy by the adoption of the experimental methods employed to study the physiology of the senses. The synergy of these nineteenth-century developments gave impetus to the "new psychology" whose history embodies continued efforts to develop and maintain psychology as a scientific discipline and to extend the methods of science to an ever-widening field of inquiry within the discipline.

The Philosophical Context

Christian Wolff (1679–1754) first popularized the term *psychology* to designate the study of mind. Wolff divided the discipline between empirical and rational psychology. The data of mind that resulted from observing ourselves and others constituted empirical psychology; rational psychology referred to the interpretation of the data of empirical psychology through the use of reason and logic. These psychologies were characterized as using knowledge acquired through experience (empirical psychology) or using knowledge that the mind possesses independent of experience (rational psychology) (Murray, 1988).

Immanuel Kant (1724–1804) denied the validity of any rational psychology because, he argued, rational mental processes must be activated by mental content derived from experience; therefore, the study of mind must be confined to questions appropriate to an empirical psychology (Leary, 1978). An empirical psychology of mental content could not, Kant contended, become a proper natural science because mental events cannot be quantified (i.e., measured or weighed), and thus its data are neither capable of being described mathematically nor subject to experimental manipulation. Finally, Kant asserted, the method of observing the mind—introspection—distorts the events observed by observing them. However, Kant suggested, psychology might improve its status as an empirical science by adopting the methods of anthropology to observe the activities of human beings in realistic settings. This study (Leary, 1978), supplemented by drawing upon literature, history, and biography as sources of information about the manifestation of mind in human activity, would base psychology upon objective observations of public events and avoid the limitations of an empirical psychology based solely on internal observation of private events.

Responses to Kant were not long in coming. Jakob Friederich Fries (1773–1843) raised the status of introspection

by arguing that it was not inherently more problematic than observing external phenomena; if introspection was unreliable, at least it was not any more so than any other kind of observation. At the same time, Johann Friederich Herbart (1776–1841) offered a system of psychology that was both empirical and mathematical. If psychology needed to be mathematical to be a true science, Herbart proposed that numbers could be assigned to mental events of different intensities and a mathematical description of the relationship among them could be formulated. Herbart could assign numbers to describe experiences of different intensities, but he could not actually measure the subjective intensities in accord with an objective standard. Eduard Friederich Beneke (1798–1854) argued that it was premature to apply mathematics to relationships among mental events absent more accurate empirical observations and reliable means of measurement; psychology could hope to become an experimental discipline by testing "empirical results and theoretical hypotheses under controlled conditions and with the systematic variation of variables" (Leary, 1978, p. 119).

Kant's suggestion that psychology should utilize observations of human beings in their social environment, the rescue by Fries of introspection as a method for observing internal events, Herbart's suggestion that psychological phenomena could, in principle, be described mathematically, and Beneke's suggestion that psychological experiments were possible contributed to the inception of scientific psychology. By suggesting that a science of psychology was not possible, Kant stimulated both counterarguments and the search for the means to make psychology a scientific discipline of equal rank with the natural sciences. It remained for others to attempt to establish introspection as a scientific method, to devise the conditions and methods of an experiment in psychology, and to quantify psychological phenomena and formulate theoretical and mathematical descriptions of the relationships among them.

The Scientific Context

The emerging natural sciences of the eighteenth and nineteenth centuries became increasingly specialized as knowledge increased and as opportunities for specialized teaching and research came into being in the German universities (Ben-David, 1971). The study of physiology emerged as a discipline separate from anatomy as the nineteenth century began. Studying intact physiological systems, *in vivo* or *in vitro,* accelerated the understanding of the functional characteristics of those systems and built on the knowledge gained from the study of anatomy via dissection. The methods and subject matter of physiology, especially sensory physiology, helped to provide the scientific basis for psychology.

Sensory Physiology

Johannes Müller (1801–1858), the "Father of Physiology," produced the classic systematic handbook (*Handbuch der Physiologie des Menschen,* 1833–1840) that set forth what was then known about human physiology and offered observations and hypotheses for further research. Among the formulations that Müller provided in the *Handbuch* was the law of specific nerve energies, which stated that the mind is not directly aware of objects as such but can only be aware of the stimulation in the brain conveyed by sensory nerves. The perceived qualities of stimulation depend upon the sense organ stimulated, the nerve that carries the excitation from the sense organ, and the part of the brain that receives the stimulation.

Müller's pupil, Hermann von Helmholtz (1821–1894), extended the law of specific nerve energies by theorizing that qualities of stimuli within a sensory modality are encoded in the same way that they are encoded among modalities. That is, distinguishing red from green, or a low pitch from a high one, depended upon specialized receptors in the eye or ear, distinct nerve connections within the visual or auditory system, and specific locations within the visual or auditory areas of the brain that receive the stimulation. The testing of the theory depended upon an individual's report of the sensory experience ("I see red"), the nature of the stimulus to which the individual responded (a specific wavelength of the energy spectrum), and knowledge of the physiological organization of the sensory systems. Relating the experience to the stimulus was a matter of experimental research that could be carried out with intact human beings; detecting the activity of nerves and the location of the brain to which stimulation was transmitted was possible then only with *in vitro* preparations of animals. Relating subjective, psychological experience to specific external stimulation was one step in suggesting how psychology might become a science.

Psychophysics

Experiments on the sense of touch were carried out by the physiologist E. H. Weber (1795–1878), who distinguished among the feelings of pressure, temperature, and the location of stimulation on the skin. In conducting experiments in which he stimulated his own skin, Weber explored skin sensitivity and demonstrated that "on the tip of the forefinger and lips two fine compass points could be felt as two when they were less than one-twentieth of an inch apart, but if they were nearer they seemed to be one" (Hall, 1901, p. 727). Not only could touch sensitivity be measured at different points on the skin, but relative sensitivity at a single point could also be

measured. Placing a standard weight at a given spot on the skin and then asking for a second weight to be judged "heavier" or "lighter" showed that the amount of weight that could be judged heavier or lighter than the standard varied as a proportion of the magnitude of the standard weight. Thus, the minimal detectable difference between two weights was relative to the weights involved; for heavy weights, differences would have to be large, but smaller differences could be detected when the weights involved were light.

G. T. Fechner (1801–1887), a physicist, saw in Weber's results the possibility of relating mental events to physical events; subjective judgments about physical magnitudes could be compared to the actual physical magnitudes. Fechner had believed since his student days "that the phenomena of mind and body run in parallel" (Marshall, 1982, p. 67). His solution to the problem of relating these two aspects of the world was to make "the relative increase of bodily energy the measure of the increase of the corresponding mental intensity" (Adler, 1966, p. xii). Although Fechner conceived of the possibility independently of Weber's results, he came to realize that his speculations about arithmetic and logarithmic relations between physical and subjective magnitudes were in fact demonstrated by Weber's observations (Adler, 1966; Marshall, 1982).

Weber's results showed that sensory judgments of magnitude formed ratios that were sufficiently regular to assume the status of a law. Fechner designated as Weber's law the mathematical equation that stated that the increase in perceived intensity of a stimulus (the "just noticeable difference") was, as Weber had demonstrated, a constant proportion of the intensity of the stimulus to be increased. The regularity in ratios across a wide range of intensities led Fechner to rewrite the law in terms of a logarithmic progression, with the strength of a sensation equal to the logarithm of the intensity of a stimulus multiplied by a constant established experimentally for the sensory system under study (Murray, 1988, pp. 176–185). "Weber's law" now typically refers to the "simple statement that the just noticeable difference in a stimulus bears a constant ratio to the stimulus" (Adler, 1966, p. xiv), while "Fechner's law" typically refers to the logarithmic relationship that Fechner formulated.

Fechner called the new science that he established *psychophysics* and developed laboratory procedures that became part of the laboratory experiments of the new psychology as well as of the physiological research on the special senses. The measurements of the smallest detectable intensity (absolute threshold) and the smallest detectable difference in intensities between stimuli (difference threshold) for the different senses were pursued by the several methods that Fechner had devised for the purpose (see, e.g., Woodworth, 1938). Resolving differences in results obtained for different methods, testing psychophysical laws over a wide range of stimulus intensities, and developing scales of psychological measurement offered significant research challenges for psychological laboratories well into the twentieth century (Stevens, 1951; Woodworth, 1938).

Mental Chronometry

Johannes Müller had speculated in his *Handbuch* that the speed of transmission of a nerve impulse was greater than the speed of light. Helmholtz tested that hypothesis by measuring the time to react ("reaction time") to stimuli applied to motor nerves of different lengths in a frog and found the time to be much slower than the speed of light (Boring, 1950; Hall, 1901). He extended this research to sensory nerves by measuring the time to respond by a human to a touch on the toe and a touch on the thigh and demonstrated that he time to respond was slower for the impulse that had longer to travel. Helmholtz extended the use of time to measure a sensory-motor response to include spoken responses to words, providing a measure of the time necessary to associate words or ideas.

The determination of reaction times to measure the speed of mental processes was investigated by the Dutch physiologist F. C. Donders (1818–1889). Donders began with the time to make a motor response to a stimulus (simple reaction time) and then added more stimuli, each with a different response. By subtracting simple reaction time from the time taken to make the correct response to one of several stimuli, Donders believed that he had measured the time required to make a choice (Boring, 1950; Woodworth, 1938). He then recognized that his experimental procedure required not only that an observer choose a response from among the several responses possible but also that an observer detect which stimulus had been presented from among the several possible stimuli (discrimination reaction time). Using the subtractive method that he devised, Donders estimated the time for a simple reaction, the time taken to discriminate one stimulus from others, and the time taken to choose a response. The possibility of measuring the time required by mental processes appeared to have been realized, and the reaction-time experiment as well as the subtractive procedure became part of the science of psychology (for modern adaptations, see Posner & Raichle, 1994; Sternberg, 1969).

PSYCHOLOGY'S FIRST LABORATORY

The founding of the first laboratory in experimental psychology has generally been credited (but not without some

debate; see Green, 2000) to German physician and physiologist Wilhelm Wundt (1832–1920). Wundt received his MD degree from the University of Heidelberg in 1855. The natural sciences had become legitimized as a proper field of study and were allied with medical training in the universities. Research laboratories for scientific investigations were an accepted part of the university structure, and careers in scientific research were made possible (Ben-David, 1971, pp. 123–124). Wundt, trained in physiology as part of his medical education, pursued independent research as a student and chose physiology, not medicine, for his career (Bringmann, Balance, & Evans, 1975). As a lecturer at the University of Heidelberg, Wundt offered courses privately for a fee, conducted research, and became an assistant to Helmholtz. In 1862, he offered his first course in "psychology as a natural science" (Bringmann et al., 1975) at Heidelberg, and in 1873–1874, the first edition of his book, *Grundzüge der physiologischen Psychologie (Principles of Physiological Psychology)* called for the recognition of psychology as a discipline independent of philosophy and physiology (Blumenthal, 1985a; Fancher, 1996; but see Danziger, 1990).

In 1875, at the age of 42, Wundt accepted a position as professor of philosophy at the University of Leipzig, where he established the first experimental research program in psychology. Chairs in science carried more prestige than those in philosophy, but the limited number of chairs available in science at the time made one in philosophy attractive to Wundt (Ben-David & Collins, 1966). Thus, psychology, like other sciences before it, began as part of the curriculum in philosophy; the acceptance of research laboratories as part of the university establishment permitted the founding of a laboratory in conjunction with Wundt's research.

Wundt had been engaged in psychological research for some time. As early as 1857, he constructed an apparatus in his home to measure reaction time and began accumulating a collection of instruments (kymographs, chronoscopes, tachistoscopes, and devices to measure responses) that were eventually employed in his laboratory (Blumenthal, 1985a, p. 29). Upon his arrival at Leipzig, a space in a former university refectory building was assigned to Wundt to permit him to store his apparatus and to conduct demonstrations associated with his lectures. In 1879, Wundt and students Max Friedrich and American G. Stanley Hall began a program of independent research (Boring, 1965; Bringmann, Bringmann, & Ungerer, 1980) that initiated psychology as "the organized and self-conscious activity of a community of investigators" (Danziger, 1990, p. 18). In 1881, the first issue of Wundt's journal, *Philosophische Studien,* appeared featuring Friedrich's dissertation research, and by 1883, the laboratory had acquired the status and budget of a research institute within the university (Boring, 1965; Bringmann et al., 1980; Danziger, 1990).

Experimental psychology as practiced by Wundt and his students at Leipzig employed the methods of physiology to study the contents and processes of individual human consciousness. Among the studies pursued in Wundt's laboratory were psychophysical experiments to analyze and measure sensations, reaction-time experiments to measure the duration of mental processes, and experiments on attention, memory, and the association of ideas (Cattell, 1888). Wundt extended Donders's subtractive procedure to the measurement of other mental processes, including association and judgment. His American student, James McKeen Cattell (1860–1944), elaborated on Donders' method in his research investigations at Leipzig between 1883 and 1886 and measured the speed of verbal associations. In a particularly innovative set of experiments, he varied the number of letters, numbers, words, or sentences a stimulus card contained and exposed the card to observers very briefly (.01 sec) to measure the number of items that could be contained in consciousness at one time; the result was an estimate of the span of attention, or span of apprehension (Ladd, 1888). Early reports of experiments were enthusiastic in detailing the empirical results that the laboratory could provide but that were beyond the reach of the older philosophical psychology. Reports that the time taken to name a short word was .05 seconds less than the time taken to name a letter of the alphabet (Jastrow, 1886), or that the time taken to name colors or pictures was "about twice as long as the corresponding times for recognizing and naming letters or words" (Cattell, 1947b, p. 25), exemplify this fascination with quantifying dimensions of mental processes. Intrigued by the individual differences in performance that he observed, Cattell would later explore the range of individual differences in a program of mental testing at Columbia University (Cattell, 1947c; Wundt, 1974; Fancher, 1996; Sokal, 1987).

In addition to the psychophysical and reaction time measures that he employed, Wundt's physiological psychology made use of reports of conscious experience. He distinguished between *Selbstbeobachtung* (self-observation), the introspection of the philosophers, and *innere Wahrnehmung* (internal perception); the basis of conscious experience. Self-observation, as traditionally employed, could not meet the standard of scientific observation. To make a *scientific* introspection possible required careful control over the stimulus that was to produce the mental event to be observed and as short an interval as possible between the observation of the event and its recall and report. This was to be achieved by the experiment conducted in the laboratory under carefully

controlled conditions; *experimentelle*. *Selbstbeobachtung* was the form of introspection raised to scientific status by experimental procedures (although terminology when translated from the German can be problematic; compare Blumenthal, 1985a, p. 28 and Danziger, 1980, p. 244). In any case, to ensure that this observational procedure could be a rigorous scientific method to assess mental events and did not lapse into the older philosophical reflection, Wundt established rules or guidelines by which introspection might achieve scientific validity: "(1) The observer, if at all possible, must be in a position to determine when the process is to be introduced; (2) He must be in a state of 'strained attention'; (3) The observation must be capable of being repeated several times; (4) The conditions of the experiment must be such as to be capable of variation of the strength and quality of the stimuli" (R. I. Watson & Evans, 1991, p. 280).

By knowing when a process is to be introduced (a stimulus presented), an observer may concentrate (strained attention) on the observation to be made and, to ensure reliability, be able to repeat the process. Varying conditions allowed the observer to identify changes in consciousness as a function of changes in the conditions of the experiment. Replicating conditions enhanced the reliability of the observations to approach those of the observation of external events. These tight restrictions meant, with minor exceptions, that "the introspective reports from his laboratory are very largely limited to judgments of size, intensity, and duration of physical stimuli, supplemented at times by judgments of their simultaneity and succession" (Danziger, 1980, p. 247).

Confidence in the results of introspection depended upon confidence in the skill and experience of the observer who, as the source of the data, was the critical component in psychological experiments. In Wundt's laboratories, the observer possessed psychological authority and expertise. Experimental control over the introspective process was obtained not only by the rules for the conduct of an experiment but also by the use of observers whose habits of attentiveness and quickness of observation and reporting provided reliable data (Danziger, 1980). Published reports of experiments conducted in German and American laboratories identified each of the observers and their level of experience in introspection (e.g., Geissler, 1909; cf. Bazerman, 1987). The experimenter played a secondary role in manipulating the apparatus, presenting stimuli, and recording responses. The division of labor between experimenters and observers, who were colleagues and collaborators, was primarily one of convenience; roles were routinely exchanged, with few exceptions: Wundt, for example, served as an observer in some of the Leipzig experiments but never as experimenter.

However, the published reports of experiments by Oswald Külpe (1862–1915), a former student of Wundt, failed to identify the observers in experiments that used introspection in his laboratory at the University of Würzburg. Külpe's experiments were designed to explore the thought processes involved in making inferences and judgments. The Würzburg method of introspection, "systematic introspection" (Danziger, 1980; 1990) or "systematic introspectionism" (Blumenthal, 1985b, p. 64), was a form of self-reflection that required thinking about a problem to solve and then retrospectively recounting the thought processes that led to its solution. In these experiments, the experimenter would interrupt the observer's introspective report with questions designed to probe the content of consciousness. This procedure, which shifted the power and authority in the experimental situation from the observer to the experimenter, represented a departure from the careful experimental control over introspection exercised in Wundt's laboratory. Wundt vigorously opposed the Würzburg method as unreliable (Blumenthal, 1985a; Leahey, 1981), particularly as it was applied to those higher mental processes that Wundt believed to be beyond the reach of introspection and, indeed, of any laboratory method. Others pointed out that the "demand characteristics" inherent in this interrogation procedure (Müller, 1911; cited in Kusch, 1995) were likely to bias an observer's responses. The status of introspection as a laboratory method would concern psychology well into the twentieth century.

Wundt argued that experimental self-observation could reveal the existence of mental processes such as apperception (an active attentional process that organized perceptions), volition (will or effort), and emotion, but he strongly believed that these higher mental processes could not be studied using the experimental method. The only methods appropriate for the study of these hidden, higher cognitive processes were naturalistic observation and history. Wundt's physiological psychology was one of "outer phenomena," sensation, perceptions, and movement, while his "*Völkerpsychologie,*" the study of language, religion, myth, and culture, was one of "inner phenomena" (Leahey, 1981). Wundt's *Völkerpsychologie* encompasses 10 volumes.

Because so many American students studied at Leipzig (Benjamin, Durkin, Link, Vesta, & Acord, 1992), Wundt assumed a position of particular significance in the accounts of the origins of the new psychology. Nevertheless, pioneers in the new discipline at other German universities attracted their share of students from the United States and from other countries. The development of psychology, even in its early stages, was not the work of a single individual. Much of the development of psychology consisted of attempting to study

in the laboratory those psychological processes that Wundt had declared beyond the reach of experiment.

BEYOND THE FIRST LABORATORY: EVOLUTION OF THE DISCIPLINE

Psychology in Germany

One of Wundt's contemporaries who believed that higher mental processes could be the object of experimental investigation was Hermann Ebbinghaus (1850–1909). Inspired by the psychophysics of G. T. Fechner and philosopher J. F. Herbart's attempt to apply mathematics to mental representations, Ebbinghaus used precise quantitative methods to investigate memory (Murray, 1976). He served as both the experimenter and the subject of his investigations. In order to have relatively homogeneous material to learn and to reduce the impact of any previous semantic associations, such as occurred in his early experiments in learning and remembering poetry, Ebbinghaus developed the "nonsense syllable," largely pronounceable consonant-vowel-consonant combinations. He created syllable lists of various lengths that he learned and then later relearned after different lengths of time. The percentage of time saved in relearning the lists became known as the "savings method" of memory (Murray, 1976, p. 206; Hoffman, Bringmann, Bamberg, & Klein, 1987). Ebbinghaus found that the amount of time spent in relearning lists was greater for longer lists and for longer retention intervals. The graph of his results became the standard curve of forgetting, still reproduced in textbooks as a classic result. The curve showed that recall of learned lists was perhaps 85% after one hour, approximately 50% after one day, and as little as 15% after about six days. These findings stimulated a long tradition of memory research (e.g., Postman, 1968). After publication of his monograph *Über das Gedächtnis (On Memory),* Ebbinghaus established laboratories at several universities and attracted some American students, but his time was increasingly devoted to a editing a journal and writing (Fuchs, 1997). Leadership of memory research fell to Georg Elias Müller (1850–1931) at Göttingen University.

Müller, a dedicated experimentalist, invented the memory drum, a mechanical device for presenting one verbal stimulus at a time, used in conjunction with experiments on serial list learning and list retention. The memory drum, modified subsequently by Müller for research in paired associate learning (Haupt, 1998), became a standard piece of laboratory equipment for studies of verbal learning and memory until replaced by the computer. Müller's research reports on his studies of memory extended from 1893 to 1917 and included "the theoretical contributions of retroactive inhibition, perseveration, and consolidation" (Murray & Bandomir, 2000). Müller initiated what later was termed the interference theory of forgetting, a position that argues that forgetting is a function of the interference among competing memories at the time that a particular memory is being retrieved and not a function of a decay or loss of memory traces (Murray, 1988). The topic was not addressed directly by Ebbinghaus, but the rapid forgetting that his retention curve recorded has been interpreted as offering evidence of the role of interference in memory (Murray, 1988; Underwood, 1957).

Müller's experimental interests were not limited to memory research. He built on the contributions of Fechner, Ewald Hering, and Mary Whiton Calkins in becoming a leader in the development of the methodology of psychophysics, conducting studies on color vision and investigating paired-associate verbal learning (Blumenthal, 1985b; Murray, 1976). His laboratory was well supplied with experimental apparatus (Haupt, 1998) and attracted a number of psychologists to pursue research with him. Müller's laboratory seems to have been especially hospitable to women interested in psychology; among those studying at Göttingen were, for example, Americans Mary Whiton Calkins, Eleanor Gamble, and Lillien Jane Martin. Other laboratories and universities were less open in this regard (Furumoto, 1987; Scarborough & Furumoto, 1987).

Psychology in America

The results of German investigations in sensory physiology and their significance for the philosophy of mind did not go unnoticed by Americans in the period after the Civil War. William James, abroad for his health and to further his medical studies, wrote to a friend: "It seems to me that perhaps the time has come for psychology to begin to be a science—some measurements have already been made in the region lying between the physical changes in the nerves and the appearance of consciousness at (in the shape of sense perceptions) and more may come of it. Helmholtz and a man named Wundt at Heidelberg are working at it" (James, 1920, pp. 118–119).

In antebellum America, the dominant philosophical tradition was derived from England and Scotland, as exemplified in John Locke's *Essay on Human Understanding* and the texts of the Scottish commonsense realists, Thomas Reid, Dugald Stewart, and Thomas Brown (Evans, 1984, Fay, 1939; Fuchs, 2000a, Roback, 1952) with only modest representation of German (Hickok, 1854; Rauch, 1840) and French (Cousine, 1864) philosophy. British philosophy was empirical, gathering information about mind and mental

processes from introspective observation, observation of the behavior of others, and observations of individuals recorded in medical treatises, court proceedings, literature, and poetry. The data were classified under general faculties or categories of mind, such as the intellect and the sensibilities (cognitive and conative, emotional, or motivational states) and the many possible subdivisions, such as memory and reasoning, instincts, and desires (Fuchs, 2000a, 2000b). Results from the investigations in psychophysics, sensory physiology, and the early experiments in psychology were incorporated into later textbooks of intellectual and mental philosophy (e.g., Porter, 1868; McCosh, 1886, 1887). Adding the empirical data to the theological concerns for "soul" did not change the traditional philosophical position of these texts. Even a textbook by G. T. Ladd (1842–1921) that represented the new psychology did not escape fully the theological concerns of the "old psychology" (Ladd, 1888; Evans, 1984; E. Mills, 1969).

Americans traveled abroad for advanced education at British and continental universities after the Civil War; painters, writers, and scientists went in large numbers. With the postwar establishment of the new land-grant universities, professional opportunities arose for faculty members, especially in the sciences, for education not yet available in the United States. With the zeal of converts and crusaders, the first generation of North American psychologists returned from their study abroad to stimulate the development of graduate education within established American colleges and universities and the newer land-grant universities (Kohler, 1990). They wrote textbooks to incorporate the results of the continental laboratories, developed courses for undergraduate and graduate students, created laboratories for teaching and research, and founded journals for the publication of research from the newly established laboratories. The laboratories came to be the locus of education in psychology in universities and colleges (Calkins, 1910; Sanford, 1910) and came to symbolize psychology as science, while psychology, lodged within departments of philosophy, became the introductory course required for further study in philosophy (Fuchs, 2000b).

William James and Evolutionary Theory

The essential break with the mental philosophical past was achieved by William James, whose *Principles of Psychology* (James, 1890) represented the first of the modern textbooks (Evans, 1981). James was a transitional figure, with one foot in philosophy and the other in the empiricism of the new science. His text, while still too philosophical for some of his more empirical colleagues (see, e.g., Evans, 1981; Ross, 1972), nevertheless effectively cut the discipline's past ties to theology. James was attracted to the new psychology by the possibility of using science to pursue philosophical issues more deeply (Croce, 1999) and called for psychology to be a natural science (James, 1892a). He recognized that while psychology was not yet an established science, it constituted the hope of a science (James, 1892b). His textbooks (James, 1890, 1892b) attracted recruits to psychology's banner to attempt to realize that hope.

William James had been appointed an instructor at Harvard in physiology in 1872; like Wundt, James had earned an MD degree and, again like Wundt, had no real interest in practicing medicine. In 1875, he offered a graduate course at Harvard on the "Relations between Psychology and Physiology" and, again like Wundt, had rooms assigned to him to use for experimental demonstrations to augment his teaching. James, however, was never very enthusiastic about laboratory work; he once declared the psychophysics could never have arisen in a country in which the natives could be bored (Boring, 1950). As a text for his course in psychology, James adopted *Principles of Psychology* (1855) by Herbert Spencer (1820–1903). A course featuring discussion of evolutionary theory was a novelty, since the older, pre–Civil War mental philosophy texts ignored evolutionary theory, while textbooks written after the war wrestled uncomfortably and unsuccessfully with integrating evolutionary theory with theological concerns.

The theory of evolution by natural selection proposed by Charles Darwin (1809–1882) had an enormous influence on American psychology. In his book *On the Origin of Species* (1859), Darwin presented evidence to support his theory of evolution and proposed natural selection as the mechanism responsible. To account for the evolution of intelligent behaviors, Darwin appealed to two mechanisms, sexual selection (the evolution of traits that facilitate mating success) and, more tentatively, as a second mechanism, the inheritance of acquired characteristics (Darwin, 1871). Jean-Baptiste de Lamarck (1744–1829) had proposed that learned changes in behavior that occur during an animal's lifetime can be passed down to that individual's offspring through biological inheritance. This view was shared by Herbert Spencer, who, unlike Darwin, viewed the evolutionary process as a linear progression from "lower" to "higher" forms (Spencer, 1855). Spencer coined the phrase "survival of the fittest" to suggest that those individuals who were best adjusted to their environments would survive. Learned behaviors that facilitated this adjustment to the environment would then be passed to subsequent generations. Adjustment was to the individual's survival what adaptation was to the survival of the species (Boakes, 1984; Buxton, 1985a; 1985b). The absence of evidence for Lamarck's theory led to

its abandonment, and evolutionary theory was left with natural selection as the only mechanism of evolutionary change. Nevertheless, Spencer's focus on adaptability during an individual's lifetime (learning) and Darwin's emphasis on individual development during childhood, differences among individuals, the relation between structure and function, and the continuity between animals and humans contributed substantially to the expansion of the topics that psychologists pursued in the name of psychological science.

THE PSYCHOLOGICAL LABORATORY AND THE PSYCHOLOGICAL EXPERIMENT

The Rise of Laboratories in America

William James saw in the early results of experiments in psychophysics and sensory physiology the beginning of science in the measurement of phenomena that the mental philosophers could only describe. Like James, G. Stanley Hall (1844–1924) was impressed by the impetus given to the new psychology by the results from experiments on sensory physiology. Hall, while preparing for the ministry, studied theology and philosophy in Germany and found that science was relevant to these pursuits, especially scientific empiricism.

Hall founded the first American laboratory in the new science of psychology at the Johns Hopkins University in 1883. While Hall's laboratory at Johns Hopkins usually is acknowledged as the first psychological laboratory in the United States, the designation was not without other claimants. Debate over credit for the establishment of laboratories provides some measure of the importance, real and symbolic, that psychologists attached to the laboratory and to the experimental research that it was designed to foster (Capshew, 1992).

By 1893, 20 psychological laboratories were operating in the United States, nearly twice as many as in Europe (Nichols, 1893, as cited by Capshew, 1992). By 1904, there were 49 laboratories of psychology in colleges and universities in the United States (Benjamin, 2000; Camfield, 1973). Psychology had become an accepted part of the curriculum, required for the undergraduate degree in 8 universities and represented in 62 institutions by three or more courses (Miner, 1904). Psychologists argued their case for the new science (and for their own professional careers) to the general public and to trustees and governing boards of academic institutions with some success (Leary, 1987). Not only were courses in psychology and laboratories begun, but journals were established, beginning with Hall's *American Journal of Psychology* in 1887, to make public the results of laboratory investigations as well as to provide an outlet for the theoretical and philosophical articles that were part of the young science. The American Psychological Association (1892) provided annual meetings for the reports of investigations and for psychologists to consider ways to advance the profession. Graduate programs in universities produced over one hundred PhDs between 1892 and 1904; between 1898 and 1903, psychology ranked fourth after chemistry, zoology, and physics in the number of PhDs awarded (Camfield, 1973).

The laboratories founded in American colleges and universities served to initiate students into laboratory practices, familiarize them with standard pieces of laboratory apparatus, and introduce them to the subject matter and opportunities for research in scientific psychology. The experiments of the early laboratory reflected the scientific beginnings of the field: Studies of psychophysics, sensory capacities and sensitivity, memory, attention, and voluntary movement (reaction time) were emphasized in manuals written for the laboratory course (e.g., Judd, 1907; Langfeld & Allport, 1916; Sanford, 1897; Seashore, 1909; Titchener, 1901–1905). The topics represented by these laboratory experiments were also those that continued to be a part of the research agenda of psychologists. Increasingly, however, the interests of psychologists extended beyond Wundt's line of demarcation between topics that could properly be pursued through laboratory experiments and those that could not. Much of the development of psychology consisted of expanding the range of psychological processes that were amenable to scientific investigation within and outside the laboratory while continuing to debate the definition of the field and the methods most useful to its development.

The Evolution of the Laboratory Experiment

In the experiments with which psychology began, such as Weber's study of tactual sensitivity, Fechner's research in psychophysics, or Ebbinghaus's study of memory, a single individual served as both experimenter and observer. In subsequent research in psychophysics and memory, the roles of experimenter and observer became separated in order to eliminate, or control for, possible biases that might stem from knowledge of the experiment and the expectations that might influence an observation, such as knowing the intensity of stimulus to be judged quantitatively (Dehue, 1997, 2000). Separating the role of experimenter from that of observer, interpolating "catch-trials" (in which no stimulus was presented), and randomizing the presentation of stimuli became common practices in psychophysical research and were adapted to other psychological experiments (Dehue, 1997). Moreover, as psychological research expanded to include

experiments that assessed the responses of children and animals, requiring little or no introspection, authority became increasingly centered in the experimenter and participants became "subjects" rather than "observers."

Data Treatment and Research Design

Early published reports of "even narrowly focused laboratory studies conducted with small samples were capable of generating reams of detailed data; readers of journal reports were sometimes confronted with tables of data that ran on for pages" (Smith, Best, Cylke, & Stubbs, 2000, p. 260). Summary data were presented not only in tables but also in graphic form. Graphs were a common form of data summary in turn-of-the-century scientific reports [the forgetting curve of Ebbinghaus (1885) and the learning curve of Thorndike (1898) were two influential examples of graphic representation]. In addition, graphs helped to pave the way for the later development of correlation and regression analyses (Smith et al., 2000). In attempting to assess the degree of relation between physical and mental characteristics to each other, Francis Galton (1822–1911) used scatter plots in which one set of scores was arranged as a function of another set, such as the height and weight measures of a group of individuals. From such graphic plots evolved the regression line, the steepness of which reflected the degree of relation between two variables, and, in the hands of Karl Pearson (1857–1936), developed into the mathematical technique of correlating variables and measuring the degree of their relationship by the coefficient of correlation (Fancher, 1996). The development of these statistical methods became critical to the assessment of individual differences and the use of tests in psychology.

Other statistical procedures were employed to assess comparisons between different groups of individuals. Galton's research, for example, on the efficacy of prayer asked "whether those who pray attain their objects more frequently than those who do not pray, but who live in all other respects under similar conditions" (Galton, 1872, p. 126, as cited by Dehue, 2000). A control group was employed in educational research to assess the effects of transfer of training (the influence of practice in one task on performance in another), and, despite arguments over whether participants should be assigned to an experimental or control group at random or by matching individuals, the use of control groups in psychological experiments became an integral part of research design (Dehue, 1997).

The comparison of control and experimental group performances led to the use of statistical procedures for testing the significance of any differences that might be obtained. Inferential statistics was unknown until the twentieth century: Student's "t" test for comparing mean scores from two groups appeared in 1908. Analysis of variance tests were devised in the 1920s (Smith et al., 2000) but did not become a common part of psychological research designs until the 1930s (Rucci & Tweney, 1980).

With the publication of his *Experimental Psychology* (1938), R. S. Woodworth "introduced a clear distinction between experimental and correlational research" (Winston, 1990, p. 391). The critical distinction made between the two kinds of research was that only in experimental work could the cause of behavior be determined by manipulation of an independent variable; the definition "provided one powerful rationale for the animal research of the thirties, forties, and fifties" (Winston, 1990, p. 397) because manipulations of "causal" variables in animal research provided fewer ethical or practical problems than research with humans. The search for causes of behavior and the theoretical models of learning embodied this definition of the psychological experiment as the means of testing hypotheses. This model of the experiment helped to establish prescriptions for the use of t-tests and analyses of variance as the statistical treatments of choice for the results of experiments, while correlational techniques and regression analyses were utilized by those interested in individual differences.

The methodology of research and standards for analyzing and reporting results of experiments in keeping with psychology's status as a science is reflected in the standardization of the reports of experiments and the definition of the experiment. The model for reports of empirical research for publication in journals of the American Psychological Association evolved from a six-and-a-half-page style sheet published in 1929 (Bently et al., 1929) to the 1983 *American Psychological Association Publication Manual* (3rd edition) that contained about 200 pages of rules for preparing a manuscript (Bazerman, 1987) to the current fifth edition of the manual (2001) of 439 pages. Reports initially emphasized either how quantitative experimental results might aid in understanding philosophical problems or simply let complex data speak for themselves (Bazerman, 1987). The emphasis on hypothesis testing and statistical analyses of comparisons between control and experimental group performance that later came to dominate experimental design and instructions to authors preparing manuscripts reflected the success of Woodworth's definition of what constituted an experiment in psychology.

Defining Psychology and Its Methods

Changes in the psychological experiment in apparatus and methods and the shift in roles of observer and experimenter

occurred amid debate over the subject matter of psychology and the methods appropriate to it. The growth in the range of subject matter under experimental investigation and in the methods employed in the study of psychology reflected James McKeen Cattell's definition of psychology's subject matter as anything that a psychologist is interested in, as a psychologist (Cattell, 1947a). The experimental psychology that arose in North America resembled the research practices of G. E. Müller more than those of Wilhelm Wundt in the range of topics addressed in the laboratory and the apparatus and methods that were employed. The psychology that evolved in college and university departments of philosophy and, as the century matured, in independent departments of psychology reflected the functional spirit of the mental philosophers and the influence of the theory of evolution.

Mental philosophy had attempted to describe how mind worked, how its cognitive and conative processes operated to produce volitional acts. American psychologists, imbued with the spirit of evolutionary theory, were focused on the utility of mind and consciousness in the adaptation of species and individuals to the environment. This concern with function (what is mind for? what is its function?—presumably, to aid adaptation) was coupled with other aspects of function, namely, how mind works (how does it function?) and on what mind depends (of what is mind a function? how complex must a nervous system be before mind becomes possible?). These implicit and broad concerns for mental function in psychology were made more explicit and embodied in a self-conscious school of psychology by James Rowland Angell (1869–1949) in response to the programmatic statement of E. B. Titchener (1867–1927), who advocated a structural psychology. These schools of thought were but two among general systematic positions that competed for dominance in psychology (Heidbreder, 1933; Murchison, 1926, 1930; Woodworth, 1948).

Structural and Functional Psychologies

Oswald Külpe's method of systematic introspection had a very strong proponent in Edward Bradford Titchener at Cornell University. Titchener had become interested in Wundt's psychology while studying philosophy and physiology at Oxford University. He translated the third edition of Wundt's *Gründzüge* into English and, when he could find no one in England with whom to study the new science, went to Leipzig to complete his doctorate with Wundt in 1892. English universities were unreceptive to the new psychology; Titchener accepted a professorship at Cornell University, where he remained until his death in 1927.

Titchener presented himself as Wundt's representative in North America, but his psychology was not Wundt's voluntarism (Leahey, 1981; Danziger, 1990). Titchener's view of mind was influenced by the English philosophy of John Locke and his heirs that he had studied at Oxford. The British philosophers viewed mind as a recipient of stimulation: Mental content was whatever had entered mind through the senses. The purpose of the study of mind was to understand how complex mental experience and function could arise from combinations of these elements. Laws of association, by which elements combined, played a significant role in understanding how mind grew from sensory elements.

Similarly, mind was, for Titchener, composed of elements that he identified as sensations, images, and affections. Sensation was the primary experience resulting from stimulation of the senses, images were complex representations that carried thought, and feelings were the elements of which emotions were comprised. Through the direct systematic introspection of consciousness under laboratory conditions, Titchener pursued three goals: the reduction of conscious experience to its basic elements, determining how the elements were connected to form complex perceptions, and identifying the underlying physiological processes. The first of these goals provided the primary focus of research at the Cornell laboratory, as the elements were themselves analyzed for their attributes (which, in a later version of the system, became the new elements of consciousness; see Evans, 1972). Pursuit of the other goals was secondary because they depended upon the successful completion of the first.

The subject of psychology, Titchener argued, was the understanding of the human, adult, normal, generalized mind through the use of introspection; only after psychology had completed that task could the nonhuman, child, abnormal, or individual mind be understood. For Titchener, psychology needed to emulate physics, with its pursuit of the analysis of matter into the smaller units of which it was composed. Titchener stood for rigorous experimental pursuit of the elements of mind, pursued for their own sake and not for any potential application. He disparaged "functional psychology" as essentially the "mind in use" approach of the older, discarded philosophical psychology.

An early response to Titchener's postulates for his structural psychology came from John Dewey (1859–1952), chair of the Department of Philosophy, which subsumed psychology and pedagogy, at the University of Chicago. Dewey perceived that the new method of laboratory experiment would free the older barren mental philosophy from the theological and philosophical constraints of its past and open the way for a useful psychology that would help resolve problems of the asylum, the classroom, and other practical affairs (Dewey,

1884). He facilitated the establishment of a laboratory at the University of Michigan before moving to Chicago. In 1896, Dewey argued against reductionist approaches to the study of consciousness and for a functional analysis and understanding of mind (Dewey, 1896). A functional approach to mind was embedded in the nineteenth century mental philosophy taught in American colleges (Fuchs, 2000a) and its development at the University of Chicago was influenced by pre-Chicago Associations among Dewey and others (Raphelson, 1973).

James R. Angell, a graduate of the University of Michigan and a student of psychology there, built on Dewey's approach in his presidential address to the American Psychological Association in 1906 (Angell, 1907), in his successful textbooks (e.g., Angell, 1905), and from his position as Professor of Psychology at the University of Chicago. Functional psychology dealt not with mental elements as its primary focus but with mental operations; the role of consciousness in helping to adapt an organism to its environment involved psychology in a concern for mind and body relationships (Angell, 1907, p. 86). Functionalism was interested in the uses of consciousness and its role in guiding behavior; it was profoundly practical and reformist. Psychology and other social sciences were useful to a variety of educational and social reforms promoted during the progressive era (Fitzpatrick, 1990; Milar, 1999).

Angell's approach to psychology encompassed the broad range of interests and methods that had developed in psychology since 1879 and reflected the influence that evolutionary theory exerted on psychology in the United States. The science of mind was pursued in the laboratory; mind was its subject matter, and many methods were available for its study. Psychophysical experiments, research on the connections between physiology, especially the nervous system, and mental processes, and direct observation of others, including children and animals, provided data that could supplement the results of introspection under laboratory conditions (Angell, 1905). The use of a variety of methods would, in Angell's view, supplement the results of the direct observations of mind that introspection provides. Functional psychology was interested in how mind worked (i.e., how it functioned) and on its functional relation to the physiological substrate (i.e., on what did mind depend) and its purpose (i.e., its use or function) and was less concerned the content of mind.

Mary Whiton Calkins (1863–1930) attempted to reconcile the differences between the structural and functional psychologies by proposing a psychology of the self that possesses both conscious contents and mental functions. Calkins had begun her study of psychology unofficially at Harvard with William James and Josiah Royce in 1890; Clark University professor Edmund Sanford tutored Calkins privately in experimental psychology. In 1891, Calkins established the first psychological laboratory at a women's college at Wellesley College, one of the first 12 laboratories in the United States (Furumoto, 1980). She developed the paired-associate technique for the study of verbal learning and memory and published papers on her research and on experiments conducted with students in the Wellesley laboratory (Calkins, 1894a, 1894b).

She pursued further study in psychology with Hugo Münsterberg at Harvard, but not as an officially registered student. Münsterberg petitioned Harvard's president to allow Calkins to be admitted as a candidate for the PhD, but his request was refused. In May 1895, after an unauthorized examination, the following communication was forwarded to The Harvard Corporation: "At the examination, held . . . before Professors Palmer, James, Royce, Münsterberg, Harris, and Dr. Santayana it was unanimously voted that Miss Calkins satisfied all the customary requirements for the degree" (cited in Furumoto, 1980, p. 62). Again, the PhD was denied (Harvard refused to grant the doctoral degree to a woman until 1963). In 1902, four women who had completed graduate study at Harvard were offered PhD degrees from Radcliffe College. Radcliffe, established in 1894, offered almost exclusively undergraduate courses; women who completed graduate work did so at Harvard University. Calkins refused the Radcliffe degree, seeing it as a symbol of Harvard's refusal to admit women on an equal footing with men (Scarborough & Furumoto, 1987). In 1905, Mary Whiton Calkins became the first woman elected to the presidency of the American Psychological Association.

By 1905, the functional point of view had become the dominant view in American psychology (Leahey, 1992). For his part, Angell claimed that functionalism could easily contain Calkins's "Self Psychology," "were it not for her extreme scientific conservatism in refusing to allow the self to have a body, save as a kind of conventional biological ornament" (Angell, 1907, p. 82). Calkins, and Titchener, did not reject the pursuit of identifying the physiological substrates of mental content and processes but placed that pursuit at a lower priority to the study of mind more directly. Indeed, Calkins extended the use of introspection to the study of abnormal experiences of the normal self and included the study by comparative means of abnormal individuals (Calkins, 1901, 1919) among the range of topics to be studied in the new psychology.

In these psychologies, introspection continued to serve as a method for the direct examination of conscious experience, but problems arose when introspective reports from different

laboratories contradicted each other. Doubts about the capacity of introspection to serve as a scientific method were brought forcefully into focus by the "imageless thought" controversy. Titchener's psychology proposed that images were the carrier of thoughts, and introspective observations carried out in his laboratory supported his position. Oswald Külpe and his colleagues at the University of Würzburg, however, failed to observe images in their studies of thought processes and concluded that thinking was carried out by "imageless thoughts." How could introspection, as a method, reconcile incompatible results when conscious experience was private and not open to public inspection?

Supporters of introspection as the primary method of scientific psychology added more instructions in an attempt to improve the method (English, 1921) while others advocated its more limited use among other psychological methods (Angell, 1905; Dodge, 1912). The question of whether introspective analysis could indeed serve as a scientific method producing reliable data was present at the start of psychology's history as a science. Introspective observations were reliable within limits: A wavelength of light at a given frequency was reported to evoke the same color sensation in all observers of normal vision. The question lay in the capability of introspection to go beyond such limited observations in the search for elements of mind. Meanwhile other research traditions arose.

Child Study

At Clark University, G. Stanley Hall established a graduate program in psychology that attracted students in numbers sufficient to make Clark a leader in psychology after its opening in 1889. In its first decade, 30 of the 54 doctorates in psychology awarded in the period were earned at Clark (White, 1992). In his laboratory of psychology, Hall fostered the experimental methods that he had learned in Germany and appointed E. C. Sanford (1859–1924) to supervise the experimental work. Hall's primary interest lay in developmental psychology; his recapitulation theory of development reflected the nineteenth-century view that the course of development of an individual parallels the stages of human evolution (Richards, 1992). Thus, "every child, from the moment of conception to maturity, recapitulates, . . . every stage of development through which the human race from its lowest animal beginnings has passed" (Hall, 1923, p. 380). Although the theory was later discredited, it served a useful purpose in stimulating research.

In 1891, Hall introduced the use of child-study questionnaires, the "Clark method" (Danziger, 1985, 1990). Questionnaires were designed to investigate "(a) simple automatisms, instincts, and attitudes, (b) the small child's activities and feelings, (c) control of emotions and will, (d) development of the higher faculties, (e) individual differences, (f) school processes and practices, and (g) church processes and practices" (White, 1992, p. 29). Much of Hall's research on childhood and that of his students culminated in his two-volume *Adolescence* (1904).

Child psychology was not, however, uniquely the property of Hall and his university. James Mark Baldwin's *Mental Development in the Child and the Race* (1895) and its companion volume, *Social and Ethical Interpretations of Mental Development* (1897), were attempts to bring a genetic account of development into the new psychology and "to bridge the gap between the study of social institutions (i.e., sociology) and the study of individual functioning (i.e., psychology)" (Cairns, 1992, p. 17). Baldwin's contributions were fleeting, for many reasons (see Cairns, 1992, p. 22), among which was that his theoretical formulations were out of step with the heavy empirical emphasis prevalent in psychology at the time. Similarly, Hall's influence was limited by the critical attack from those closely tied to laboratory investigations that his questionnaire research was methodologically weak. Nevertheless, Hall and Baldwin made the psychology of child development and the methods appropriate to its study part of the new psychology.

Individual Differences

Although recapitulation theory influenced Hall's approach to child study, the direct influence of evolutionary theory on child study was slight (Charlesworth, 1992). However, the theory of evolution strongly influenced the study of individual differences. For natural selection to serve as the primary mechanism of evolution, variation in species populations was necessary for the selection of traits that were the basis for adaptation and survival within different and changing environments. Francis Galton, a cousin of Darwin, contributed to the history of psychology through his measures of physical and mental characteristics of individuals who visited his Anthropometric Laboratory.

The measures of physical characteristics such as head size, arm length, height and weight, and performance characteristics such as reaction time and sensory acuity, used by Galton and adapted from the tasks of the psychological laboratories, were employed as mental tests of intelligence. Head size, for example was (falsely) assumed to indicate brain size and intellectual capacity, and speed of responses and visual acuity were assumed to indicate adaptability and survival capability. The term *intelligence* came to be used to designate differences among individuals in their capacity for such

complex behaviors as reasoning and problem solving rather than to denote differences among species in adapting to the environment, the more common use of the term in the nineteenth century.

James McKeen Cattell, who had studied with Hall at Johns Hopkins before earning his PhD with Wundt, pursued his interest in individual variation, labeled *"ganz Amerikanisch"* by Wundt (Boring, 1950), while in Francis Galton's London laboratory. Cattell returned to establish a laboratory at Columbia University and adapted laboratory tasks familiar to him from both Leipzig and London to identify and measure differences in reaction time, sensory sensitivity, time estimation, and memory span in undergraduate students (Sokal, 1987; Tuddenham, 1962). Like Galton, he theorized that such tasks as reaction time, sensory acuity, memory, and apprehension spans would reveal an individual's intellectual abilities. His attempt to relate scores on these tasks to academic performance demonstrated little relationship between the performance scores on the laboratory tests to academic performance in courses at Columbia (Sokal, 1987) but nevertheless represents an early effort to measure the intelligence of individuals.

Assessing individual differences among human beings did not necessarily result in appropriate conclusions about the consequences of evolution because of the importance of social and cultural factors in determining differences among individuals. For example, Galton's study of sex differences in psychological characteristics reflected social and cultural views of the capabilities and proper roles for women and men rather than differences that could be attributed to evolutionary forces. This bias was common at the time and addressed by the research of one of James R. Angell's graduate students, Helen Bradford Thompson. Her dissertation, completed at the University of Chicago in 1900 and later published as *The Mental Traits of Sex* (1903), was the first systematic, experimental investigation of sex differences in motor ability, sensations, intellect, and affect. Careful, detailed analysis of the results led to her conclusion that "the psychological differences of sex seem to be largely due, not to difference of average capacity, nor to difference in type of mental activity, but to differences in the social influences brought to bear on the developing individual from early infancy to adult years" (p. 182).

Hall, too, had employed evolutionary arguments to bolster stereotyped ideas about the psychological nature and proper roles of men and women. His rather unflattering assessment of women's abilities attracted little argument from American male psychologists of the time (see Diehl, 1986; Shields, 1975) and played a role in denying opportunities for graduate study and professional employment for women (Milar, 2000). In 1910, Helen Thompson, writing under her married name, Helen Thompson Woolley, reviewed the literature on sex differences and asserted, "There is perhaps no field aspiring to be scientific where flagrant personal bias, logic martyred in the cause of supporting a prejudice, unfounded assertions, and even sentimental rot and drivel, have run riot to such an extent as here" (Woolley, 1910, p. 340). Similar conclusions could have been drawn about comparisons among races begun before the development of evolutionary theory. These comparisons had also served to justify a hierarchy that placed Caucasians in a superior position, and later studies under the aegis of evolutionary theory continued to be carried out and interpreted in terms of long-held cultural biases (see R. Guthrie, 1998).

Influenced by Cattell and Hall's child study movement, Lightner Witmer (1867–1956), attempted to put performance on laboratory tasks to practical use in the new discipline that he labeled "Clinical Psychology" (McReynolds, 1996). The apparatus and methods of the laboratory experiment were successful in assessing differences among individuals but proved to be of little value for Witmer's purposes (McReynolds, 1996). The failure of laboratory tasks for these applied ends led, in the case of intelligence testing, to the refinement and development of tests modeled on those of Alfred Binet and, in Witmer's case, to the search for more suitable methods for assisting individuals. These efforts also led to attempts to identify characteristics of individuals that, like intelligence, were both measurable and offered promise of relevance, such as personality assessment (Allport, 1937), attitude and aptitude measures, and clinical diagnostic tests (Gregory, 1992). For many psychologists, individual differences were a distraction to the understanding of the general principles governing mind, while for others, the understanding of the individual mind was the most interesting task for psychology. The difference in emphasis and the somewhat separate paths of development of the two pursuits within psychology came to be seen as the two disciplines of scientific psychology (Cronbach, 1957).

The Study of Nonhumans: Animal Psychology

Darwin's theory of evolution had raised questions about the adaptive utility of consciousness; the relation of human to animal ancestry had raised issues of whether there are instincts in humans and whether animals exhibited human intellectual capacities and consciousness in adapting to changed or changing environments. Learning capacities and consciousness seemed in turn to depend upon the complexity of the nervous system: "If there is a Comparative Anatomy there is also a Comparative Psychology" (Chadbourne, 1872, p. 22). George

J. Romanes (1848–1894), a devoted younger friend of the aging Darwin, explored these concerns by collecting anecdotes of wild and domestic animals that provided evidence of capacities for reasoning and problem solving analogous to those exhibited by humans. As part of an animal's intelligent adaptation to an environment, he sought evidence of reason, which he defined as the conscious knowledge of the relation of the means to an end. In addition, Romanes described patterns of instinctive responses that occurred without a conscious awareness of the end to which they were adapted (Romanes, 1892).

Romanes' research methods and anthropomorphic conclusions about the capacities of animals were criticized by C. Lloyd Morgan (1852–1936) for relying on unsubstantiated anecdotes and weak analogical reasoning. Morgan emphasized the importance of observation and encouraged parsimony in interpreting observations of animal behavior (Morgan, 1890–1891, 1896). His caution in this regard came to be known as Morgan's Canon: "In no case should an animal's activity be interpreted in terms of higher psychological processes if it could be interpreted in terms of processes standing lower in the scale of psychological evolution" (R. I. Watson & Evans, 1991, p. 329). Morgan provided a necessary methodological corrective to enthusiastic but unscientific fact gathering by emphasizing both care in making observations and caution in interpreting them.

Morgan employed experimental methods and observation in naturalistic settings and hypothesized that animals learned through association of ideas, in accord with the philosophical tradition of associationism (Warren, 1921) that described how the human mind operated (Cumming, 1999; Furumoto & Scarborough, 1987). Although we can know our own consciousness, we can only infer consciousness in others, including animals; for Morgan, the criterion for inferring consciousness in animals is "circumstantial evidence that the animal . . . profits by experience" (Morgan, 1900, p. 42). In this way, Morgan stimulated interest in the study of learning, not only as an adaptation to the environment, but also as the criterion for inferring animal consciousness or mind.

At Clark, research in animal behavior attempted to describe the animal mind and to study the development of the nervous system. The former research was represented by Willard Small's use of the maze to study the mental processes of the white rat involved in learning (Small, 1900, 1901). The latter research was represented by H. H. Donaldson, who attempted to describe the growth of the nervous system in rats and humans (e.g., Donaldson, 1908). One purpose of this research by Donaldson and Small was to relate the complexities of the nervous system between species and between individuals in the same species to differences in behavioral and mental abilities. Small employed a version of the Hampton Court maze (Munn, 1950) that later gave rise to the many variations (e.g., the T-maze, multiple T-maze, and the straight alley maze) that became standard laboratory equipment for the study of learning and the testing of learning theories of the 1930s through the 1950s. Donaldson and Swiss American psychiatrist Adolf Meyer are credited with helping to establish the albino rat as the dominant laboratory animal in American psychological laboratories for many decades (Logan, 1999).

The work at Clark proceeded in the spirit exemplified by Morgan and by E. L. Thorndike (1874–1949), who, in 1898, had insisted that "experiment must be substituted for observation and the collection of anecdotes" (Thorndike, 1898, p. 1126). Thorndike's dissertation, *Animal Intelligence* (1898), signaled a major shift from a subjective, introspective, anecdotal study of animals to an objective, quantitative experimental approach with an emphasis on learning (Galef, 1998; Stam & Kalmanovitch, 1998). Thorndike's emphasis on controlled observation was welcomed by Morgan, who advanced "the hope that comparative psychology has passed from the anecdote stage to the higher plane of verifiable observation, and that it is rising to the dignity of science" (Morgan, 1898, p. 250).

Thorndike had pursued graduate study at Harvard with an investigation of the behavior of chickens, until the protests of his landlady forced him to move his chicken experiments to the basement of William James's house (Dewsbury, 1998; Thorndike, 1936). Thorndike subsequently took his two "most educated chickens" to study the inheritance of acquired traits at Columbia University with James McKeen Cattell (p. 265). The topic did not prove very fruitful, and Thorndike chose instead to examine the performance of cats and small dogs in puzzle boxes. The choice of puzzle boxes was influenced by the work of Romanes and Morgan, who had described dogs and cats learning to open garden gates through trial and error (Morgan, 1900). Thorndike's boxes were designed to permit observation of animals' attempts to escape from the box to reach food (Burnham, 1972). Various boxes required manipulation of levers, pulling of loops, or combinations of responses to escape (Chance, 1999; Galef, 1998). Thorndike recorded and graphed the time taken to escape from the box as a function of the number of trials. He interpreted the gradual decline of the curve describing the time taken to escape from the box revealed by the graph to mean that learning proceeded gradually, through trial and error.

Responses that resulted in escape from the puzzle box appeared to be selected from random movements, in a manner analogous to the process of evolutionary selection. Thorndike insisted that responses were made directly to the

stimulus situation, without the mediation of ideas. The bond between response and situation was strengthened if the response was followed by a satisfying outcome, or weakened if it was followed by an unsatisfactory consequence. This statement constituted Thorndike's "law of effect." He also held that bonds between the situation and response became strengthened through exercise and weakened by disuse: the "law of exercise" (Thorndike, 1913). Thorndike claimed that these two laws, together with the animal's "readiness" to respond in the situation, accounted for most of animal learning (Thorndike, 1913). In his early work in comparative psychology, Thorndike emphasized a discontinuity between animals and humans. By 1911, however, he reversed his position to emphasize instead the universality of the law of effect and other laws of learning (Bruce, 1997).

Although the thrust of Thorndike's laws was to specify regular relations between a situation and the responses that it may come to evoke, without any attempt to assess the content of the mind of the responding animal, comparative psychology did not immediately follow his lead. Concerns for the adaptive value of consciousness in humans and animals continued to be addressed in the early decades of the twentieth century (e.g., Judd, 1910). Identifying the levels of complexity of nervous systems that would justify inferences about the nature of animal consciousness and capacity for intelligent behavior (e.g., Yerkes, 1905) is best exemplified by what has sometimes been called the first textbook in comparative psychology, Margaret Washburn's *The Animal Mind* (1908) (Jaynes, 1968, cited in Furumoto & Scarborough, 1987). Margaret Floy Washburn (1871–1939), the first woman to earn a PhD in psychology and the second woman president of the American Psychological Association (1921), summarized and organized the scattered literature on animal psychology, provided a history of the movement, and offered an extensive discussion of methodology for research with animals (Washburn, 1908; Goodman, 1980). E. B. Titchener's first doctoral student, Washburn had applied to study psychology with James McKeen Cattell at Columbia, but Columbia, like Harvard and the Johns Hopkins University, permitted women to attend classes only unofficially as "hearers." Cattell, however, encouraged her to apply to Cornell, where she completed her degree in 1894. A report of her Cornell dissertation on the effects of visual imagery on tactile sensitivity was one of the few studies published in Wundt's *Philosophische Studien* that had not been completed at Leipzig.

Washburn sought to understand the animal's conscious experience in an approach to comparative psychology characterized as "subjective, inferential and rigorously logical" (Goodman, 1980, p. 75). Washburn was influenced by the research and writing of both Morgan and Thorndike; like Thorndike, she advocated the use of objective and rigorous experimental procedures, but, like Morgan, she persisted in her view that animals possessed a consciousness that psychology was obliged to define and characterize (Washburn, 1917, 1926, 1936). To carry out its responsibility, psychology needed to adopt objective and rigorous experimental procedures. Despite the growing emphasis on the sufficiency of behavioral data and the emphatic rejection of mind and consciousness as the only legitimate subject matter for a scientific psychology, as Thorndike advocated, Washburn held to her position (Goodman, 1980).

Behaviorism

Animal psychology had drawn attention to the importance of behavior as a clue to mind, but inferences from behavior about animal consciousness were part of the expected interpretations of experimental results. But the focus of study was changing: "There is unquestionably a widespread movement on foot in which interest is centered on the results of conscious process, rather than in the processes themselves. This is peculiarly true in animal psychology; it is only less true in human psychology. In these cases interest [is] in what may for lack of a better term be called 'behavior'; and the analysis of consciousness is primarily justified by the light it throws on behavior, rather than vice versa" (Angell, 1911, p. 47).

The proposal that psychology reject its traditional definition as the science of mind and consciousness and redefine itself as a science of behavior came from John B. Watson (1913). Watson arrived at the University of Chicago in 1900 to begin graduate work following an undergraduate degree in philosophy and psychology from Furman University (Harris, 1999; O'Donnell, 1985). H. H. Donaldson, who had moved to the University of Chicago from Clark University, brought with him his research program that investigated the relation between the development of the nervous system and the behavior of the rat. Animal laboratories were few; in 1909, only about six laboratories were actively engaged in animal research (O'Donnell, 1985). For his dissertation, Watson chose to investigate the neurological correlates of problem solving in the white rat and carried out additional experiments with rats to determine which sensory modalities were necessary for learning a maze by systematically eliminating one modality at a time. He removed the eyes, tympanic membrane, olfactory bulbs, and whiskers and anesthetized the feet of rats and discovered that the animals seemed to use kinesthetic feedback to reach the goal box (Carr & Watson, 1908; Goodwin, 1999; J. B. Watson, 1907). Watson's first report of these experiments at the annual meeting of the APA held in

December 1906 in conjunction with the American Association for the Advancement of Science (AAAS) led to an outcry by antivivisectionists. He was publicly defended by Angell and by then APA president James Mark Baldwin (Dewsbury, 1990).

Watson had become disenchanted with the language of consciousness and mind, with the method of introspection, and was increasingly concerned about the status of animal research in psychology. Writing to fellow comparative psychologist Robert Mearns Yerkes in 1910, Watson expressed his identity problems: "I am a physiologist and I go so far as to say that I would remodel psychology as we now have it (human) and reconstruct our attitude with reference to the whole matter of consciousness. I don't believe the psychologist is studying consciousness any more than we are" (Watson, 1910, cited in J. A. Mills, 1998, p. 60).

In a series of lectures given at Columbia University in December 1912, Watson laid out his discomfort with a psychology of consciousness and proposed a psychology of behavior to take its place: "Psychology as the behaviorist views 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 on the readiness with which they lend themselves to interpretation in terms of consciousness" (Watson, 1913, p. 158). Although this so-called "Behaviorist Manifesto" did not produce a revolution in psychology (Leahey, 1992; Samelson, 1981), it did help to raise the status of animal research and place a greater emphasis on explaining behavior rather than mind, especially in research on animals (Watson, 1914). Watson's notion that the goal of psychology was to predict and control behavior incorporated the vision of psychology as a tool for social control and, therefore, its application to education, industry, and other areas of applied psychology (e.g., Buckley, 1982). Titchener accused Watson of turning psychology into a technology rather than a science (Samelson, 1981). But technology or not, Watson's view of science as requiring reliability of observations, public and repeatable, vitiated introspection as a scientific method. Watson argued that verbal reports to a stimulus, in a psychophysical experiment, such as "I see red," were behavioral in the same way that an animal might be trained to discriminate the color red from other colors (Watson, 1919).

J. B. Watson (1916) proposed that the conditioned motor reflex could be applied to animals and humans and thus form the building block of behavior. Like Titchener, Watson believed that science proceeded by analysis, but instead of the elements of mind, Watson sought the elements of behavior. The conditioned reflex was the elemental unit from which Watson proposed to build a science of behavior.

The study of reflexes has a long history within physiology (Boakes, 1984; Fearing, 1930). The Bell-Magendie law (Boakes, 1984; Goodwin, 1999) distinguished between the sensory and motor nerves at the level of the spinal cord. This distinction set the stage for an understanding of reflex action and stimulated research on the nature and speed of conduction of the nerve impulse that led to the studies of reaction time by Johannes Müller and Hermann von Helmholtz. Russian physiologist Ivan Mikhailovich Sechenov (1829–1905) demonstrated that cerebral processes could affect reflexive action by stimulating certain areas of the brain with salt crystals to decrease the intensity of reflexive movement of a frog's leg (Boakes, 1984; Koshtoyants, 1965). Sechenov (1863–1965) argued that the cause of psychical or psychological events is in the environment; external sensory stimulation produces all acts, conscious and unconscious, through the summation of excitatory and inhibitory activity in the brain. He suggested that a science of psychology based on introspective reports of humans is too complex and too subject to "the deceptive suggestions of the voice of our consciousness. . . . [O]nly physiology holds the key to the scientific analysis of psychical phenomena" (Sechenov, 1973 cited in Leahey, 2001, p. 216; see also, Boakes, 1984).

Ivan Petrovich Pavlov (1849–1936) was able to instantiate Sechenov's theoretical claims (Koshtoyants, 1965). Pavlov's research on the physiology of digestion that earned him the Nobel Prize in 1904 involved a method of "sham feeding" in which a fistula, or tube, in the esophagus prevented food placed in the mouth of the dog from reaching the stomach. A second tube inserted into the stomach was used to collect gastric juices. In the course of these experiments, Pavlov noted that gastric secretions occurred not only in response to food in the mouth but also merely to the sight of food, or of the assistant who usually fed the animal. He called these "psychic secretions." By using a fistula that could collect salivary secretions for the studies on digestion, Pavlov's student Stefan Vul'fson noted that not only did the salivary glands respond differently to different substances placed in the mouth, for example, sand, wet food, dry food, but, unlike other digestive organs, they showed the identical response when the dog was teased by only the sight of the substance (Boakes, 1984; Todes, 1997). Vul'fson and Pavlov used mentalistic terms in describing the reaction of the salivary glands to the sight of food: Dogs "judged," "sorted out," or "chose" their responses (Todes, 1997, p. 950).

Pavlov later changed "psychic reflex," to "conditional reflex," after experiments demonstrated the experimental regularity of what his co-worker Tolochinov referred to as a "reflex at a distance" (Todes, 1997, p. 951). Drawing on Sechenov's early experiments with inhibition of spinal

reflexes, the work in Pavlov's laboratory focused on the establishment (conditioning) and removal (extinction) of reflexes to a variety of stimuli and their control by excitatory and inhibitory activity in the brain. Other investigators who explored questions of adaptation of organisms to environments paid more attention to the acquisition of new behavior than to the removal of established behaviors (Boakes, 1984).

J. B. Watson attempted to demonstrate how research on conditioned reflexes could reveal the origins of complex behavior patterns. In his most famous experiment, conducted with graduate student Rosalie Rayner, he conditioned emotional responses in an 11-month-old infant, "Albert B." By striking a steel bar with a hammer, Watson and Rayner were able to elicit crying in the infant; when they subsequently paired presentation of a white rat, to which Albert had shown no fear, with the striking of the bar, Albert showed fear to the rat. They reported successfully conditioning fear of the rat in Albert, and, further, the fear generalized to a rabbit, a dog, a fur coat, and a Santa Claus mask (J. B. Watson & Rayner, 1920; see Harris, 1979). The study was more a dramatic demonstration than a carefully controlled experiment, but nevertheless exemplified Watson's vision for identifying the origins and development of behavior and provided an approach to the study of the growth and development of children (Mateer, 1918).

Gestalt Psychology

A response to the introspective analysis of consciousness advocated by Titchener and the behavioral analysis of J. B. Watson came in the form of an approach to psychology that arose in Germany at about the same time that behaviorism had arisen in the United States. The term *gestalt,* translated as "whole" or "configuration," referred to an organized entity that was different from the sum of its constituent parts. The term was initially introduced by Christian von Ehrenfels, who pointed out that a melody played in two different keys is recognized as such even though the notes in each case are different. He suggested that combinations of elements produced a *"gestaltqualität,"* or whole-quality, that constituted a new element of consciousness. The use of the term by the triumvirate of Max Wertheimer, Kurt Koffka, and Wolfgang Köhler referred not to a new element but to the organized nature of conscious experience. The gestalt psychologists opposed what they perceived to be artificial attempts to reduce experience or behavior to constituent parts and then to synthesize them again into organized wholes, and articulated their views in influential books (e.g., Köhler, 1929).

Gestalt psychology was initiated by observations on apparent movement (Wertheimer, 1912), in which two lights located at some distance apart give rise to the experience of one light moving from one location to the other when the lights go on and off in sequence. The phenomena seemed incapable of explanation by introspective identification of sensory elements. The gestaltists proposed that the introspection appropriate to psychology was a description of experience, a naive introspection that described the experience without any attempt to subject it to analysis. Perceptual phenomena and conscious experience were not the only domains of gestalt theory; Köhler's research on chimpanzees (Köhler, 1926) suggested that learning occurred not through trial and error but by insight that resulted from a perceptual reorganization that produced a new way of seeing the problem to be solved. Neither Thorndike's trial-and-error explanations of learning nor behavioral analysis of organized goal-directed behavior seemed adequate to account for the behavior of the chimpanzees.

The disagreement with the structural approach to mind and the behavioral approach to behavior derived from fundamentally different assumptions about the nature of science. Titchener, and Watson as well, assumed that science proceeded by analysis, by breaking down chemical and material objects into the elements of which they are composed. The elemental analysis that Titchener perceived to be the hallmark of physics was a nineteenth-century model that had given way to analyses in terms of fields in which forces operated to determine organization of particles rather than particles or elements giving rise to organization (e.g., introducing a magnetic force placed among a random pattern of iron filings organizes the filings in terms of the directions of force). Field theory and the laws of organization were proposed to account for many phenomena (e.g., Ellis, 1950), not only of perception and problem solving and learning, but of, for example, social behavior (Asch, 1955), child development (Koffka, 1927), and thinking (Wertheimer, 1959), and served to prompt research designed to test theories in these areas.

Logical Positivism and Operationism

The abandonment of mind as psychology's subject matter, the increased attention to ensuring that scientific standards were met by procedures for gathering and treating data in laboratory and nonlaboratory research, and increased attention to theory building appeared to be signs of scientific maturity in psychology. These characteristics were most closely identified with the neo-behaviorist theories of learning and behavior that were the focus of much of the laboratory psychology from the 1930s to the 1960s. These theories focused on animal subjects and models of learning and behavior; their

theoretical language was influenced by a philosophy of science of the period.

Continuing concern for the scientific status of psychology attracted psychologists to an approach to science advocated by Harvard physicist P. W. Bridgman (1927), who made the case for defining unobservable phenomena, such as gravity or hypothesized physical elements such as an electron, in terms of the operations by which their effects on observable events could be measured (Leahey, 2001; Smith, 1986). E. G. Boring's student, S. S. Stevens (1906–1973), at Harvard in psychology, proposed that psychology adopt a strict operationism (Stevens, 1935a, 1935b, 1939). Only terms that could be defined operationally were scientifically meaningful; for all practical purposes, only a behavioral psychology could meet this criterion (Leahey, 2001; J. A. Mills, 1998; Smith, 1986). The emphasis on operational definitions influenced the language of psychology (Mandler & Kessen, 1959) and the theories of behavior that evolved in the context of operationism and its philosophical forebear, logical positivism, an approach that limited science to observable phenomena. For psychology, it meant defining hunger, for example, in terms of such operations as hours of food deprivation, or a measure of blood sugar level, or the amount of time spent eating, each of which is an observable indicator of the unobservable hypothesized motivational condition of hunger. The neo-behaviorists who shaped what is known as the "Golden Age of Learning Theory" from 1930 to 1950 adopted some ideas from logical positivism and operationism, although each of them was to formulate his own vision of behaviorism (J. A. Mills, 1998; Smith, 1986).

The Neo-Behaviorists: Guthrie, Tolman, and Hull

Edwin R. Guthrie (1886–1959), the "most starkly empiricist of all the neo-behaviorists" (J. A. Mills, 1998, p. 79), defined mind as "a mode of behavior, namely, that behavior which changes with use or practice-behavior, in other words, that exhibits learning" (E. R. Guthrie, 1935/1960, p. 3). The ability to learn, as C. Lloyd Morgan had suggested, characterized the possession of mind in living creatures. Guthrie's theory of learning was deceptively simple: Learning occurs through the development of associations between stimuli and responses. These associations are formed by contiguity: "A combination of stimuli which has accompanied a movement will on its recurrence tend to be followed by that movement" (p. 23). He rejected Thorndike's laws of effect and of exercise, claiming instead that the apparently gradual nature of learning was a result of a series of one-trial situations in which movements, small muscle responses, rather than acts were learned in response to stimuli. The role of the consequences of responding, whether satisfying or annoying, was to change the stimulus situation, not to strengthen some unobservable bond between stimulus and response.

In contrast to E. R. Guthrie's molecular approaches to learning, Edward Chace Tolman (1886–1959) offered a molar theory of the psychology of learning. For E. R. Guthrie and for J. B. Watson, descriptions of learned behavior were confined to descriptions of stimulus events and responses. Tolman, in contrast, proposed a theory that interpreted behavior in terms of "motive, purpose and determining tendency" (Tolman, 1922, p. 53). For Tolman, cognitive events intervened between the antecedent stimuli and their behavioral consequences. Learning and performance were not synonymous (Innis, 1999; Kimble, 1985; Tolman & Honzik, 1930); performance was the observable behavior, while learning was the hypothesized state that accounted for the change in behavior. Tolman described the action of intervening variables on the functional relationship between the independent and dependent variables; that is, between the environmental stimuli and physiological state of the organism on the one side and the overt behavior on the other (Tolman, 1932, p. 2; see also Innis, 1999; Kimble, 1985). The most important intervening variables were cognitions, defined as expectations about the relationship between signs, stimuli, and significates, rewards or goal objects (J. A. Mills, 1998; Smith, 1986). Tolman hypothesized the formation of "cognitive maps" or cognitive representations of the environment in rats learning a maze. These cognitive maps could be empirically demonstrated in maze experiments in which, for example, blocking a previously used route to a goal resulted in rats choosing the next shortest path to the goal (Tolman, Ritchie, & Kalish, 1946).

Clark Hull (1884–1952) proposed a formal logico-deductive theory of behavior: "In science an observed event is said to be explained when the proposition expressing it has been logically derived from a set of definitions and postulates coupled with certain observed conditions antecedent to the event" (Hull, 1943, p. 3). Hull's theoretical treatment of psychology consisted of a set of postulates and corollaries and their mathematical statements to enable quantitative predictions about behavior. Hull's goal was to develop psychology as a natural science by demonstrating that behavioral phenomena obey universal, quantitative laws that can be stated by equations comparable to physical laws, "of the type governing the law of falling bodies" (Hull, 1950, p. 221). Even centuries after Kant, Hull was striving to demonstrate that psychology could indeed become a science that met the same standards as the physical sciences. For example, Hull (1934a, 1934b) proposed that the serial position effect in learning a list of words (the phenomena that errors occur more frequently in learning and in the recall of words from the middle

of a serial list) exemplifies the same general law that describes the pattern of errors made by rats learning a complex maze (more errors occur in the center of the maze than at the start and the finish).

Hull's research program was directed toward the discovery of such laws and the formulation of the equations that described them. His theory of behavior formulated theoretical variables in operational terms, defined them by equations, and predicted experimental results. Experiments by Hull, Tolman, and their students were designed to provide crucial tests of predictions from their respective theories. For example, Hull's theory hypothesized that learning occurred through reinforcement, defined in terms of the extent to which reinforcement reduced a motivational drive; Tolman, on the other hand, argued that reinforcement in this sense was unnecessary for learning (Tolman & Honzik, 1930). Resolution of such theoretical issues was difficult; moreover, the precise predictions from Hull's formal theory were frequently not confirmed, and criticism of the theory began to mount from a variety of sources, including Hull's own students (J. A. Mills, 1998). Differences between the theories of Hull and Tolman came to seem less substantive and more a preference for particular terminology and the reification of intervening variables (Kendler, 1952).

The Radical Behaviorism of B. F. Skinner

Burrhus Frederick Skinner (1904–1990) questioned whether theories of learning were necessary in view of what appeared to be fruitless theoretical tests (Skinner, 1950). He argued instead for a purely empirical description of behavior, eschewing any hypothetical or intervening nonobservable variable in his description of behavior, a position that he had established in his first major publication (Skinner, 1938). His manipulation of the contingency between an operant (emitted) behavior and a reinforcer constituted his program of research, carried out in the operant-conditioning chamber more popularly known as a "Skinner Box." With rats and later pigeons as his experimental subjects, Skinner measured cumulative responses over elapsed time as a function of reinforcement schedules (Ferster & Skinner, 1957). Intervening variables, such as drive or motivation, were defined operationally in terms of number of hours of deprivation or percent of free-feeding body weight. The reports of experiments by Skinner and his followers, with few animals but a large number of responses, met with rejection from editors whose definition of an experiment required a research design comparing experimental and control groups with a statistical test of the significance of the difference between them. The result was the establishment of the *Journal for the Experimental Analysis of Behavior* in 1958 (Krantz, 1972). Skinner's approach to behavior extended to the development and use of language (Skinner, 1957) and to the technology of teaching (Skinner, 1968).

The Rise of Cognitive Psychology: Mentalism Revisited

The experiments engendered by the debates among the different approaches to learning and behavior continued to dominate the literature of experimental psychology at midcentury. However, the traditional methods and research topics of the psychological laboratory also flourished; although the era of the schools had ended, they left a legacy of influence on the research conducted within psychology. Introspection as a source of psychological data lost its primacy with the end of structuralism; introspective reports resumed their more limited role in assessing the quality and/or intensity of sensory experience in psychophysical experiments. Articles reporting on experiments on perception, stimulated in part by gestalt psychology's emphasis upon perceptual organization, continued to appear in psychological journals, together with studies of the higher mental processes of thinking and problem solving (e.g., Wertheimer, 1959). Functional psychology, more of an attitude than a systematic position, characterized American psychology generally and fostered experiments on serial list and paired associate learning and the interference theory of forgetting, continuing the research tradition emanating from the laboratories of Ebbinghaus and G. E. Müller (McGeoch, 1942). Although research on higher mental processes in animals had not been entirely neglected (Dewsbury, 2000), behaviorism left a legacy of animal research that focused on stimulus-response interpretations of the results of maze learning studies, classical conditioning experiments, and, increasingly, of behavior in operant-conditioning chambers. Psychology redefined itself from the science of mind to the science of behavior. References to mind or mental processes were found only infrequently in textbooks and journals.

The molecular, elemental, and mechanistic analyses of behaviorism, emphasizing peripheral sensory-motor relations, were not limited to research on learning. Child psychology, for example, was strongly influenced by studies of the conditioned reflex (e.g., Mateer, 1918) and Watson's admitted premature claim that, given a dozen healthy infants, he could make of them anything he chose (J. B. Watson, 1924). Emphasis on the study of sensory-motor and nervous-system development in young children led to an emphasis on developmental norms that were postulated to follow relatively fixed maturational principles (e.g., Gesell & Ilg, 1946). These principles and norms were challenged by research that combined

behavioral and maturational approaches in examining motor development in children (e.g., McGraw, 1935; 1943).

In the decades of the 1950s and 1960s, the language and models that stimulated psychological research began to change. Explanations of behavior derived from experiments on maze learning and classical and operant-conditioning research came under attack from those studying more complex behavior patterns (e.g., Harlow, 1953). Rote learning of serial lists and verbal paired associates were acknowledged to represent only a limited domain of human learning (Melton, 1956). Information theory, developed during World War II as a tool for measuring the capacity of humans as processors and transmitters of information, provided a new measure of human performance and implied capacities for making judgments and choices (Attneave, 1959). Information theory offered fresh interpretations of choice reaction-time experiments (e.g., Hick, 1952) and the limits of human attention and immediate memory (Miller, 1956). Discussions of human capacities to reduce, transmit, or create information renewed interest in cognitive capacities of decision making and problem solving that suggested analogies to the recently developed technology of the computer.

Interest in cognitive development revitalized child psychology in moving from a focus on sensory-motor development to a focus on thinking, the formation of concepts, and the child's understanding of the world. The theories of Jean Piaget (1896–1980) that describe the development of language and cognition in childhood had appeared in the 1920s and 1930s in Europe (e.g., Piaget, 1929) but had an impact in the United States only decades later (Flavell, 1963). Experimental research that explored cognitive and social development in children came to dominate the field of *developmental* psychology, no longer simply *child* psychology but soon to cover the life span. This shift in emphasis in the study of human development paralleled changes in research on adults and on animals.

Psychologists appeared to be less self-consciously concerned with the status of psychology as a science and more concerned with the kind of science psychology was to be. The behavioral view of a largely passive organism whose mechanical behavior was governed by environmental events became an increasingly less satisfactory model. Calls for a humanistic, rather than a mechanistic, science of psychology (Giorgi, 1970; Maslow, 1966) called for a view of human beings as actively engaged with the environment, thinking and deciding rather than simply responding to external events. The results of Pavlovian conditioning experiments began to be interpreted in terms of cognitive events (e.g., Rescorla, 1966) and signaled the increasing willingness to consider the role of mental processes that determined behavior in both humans and animals. The journals *Cognitive Psychology* (1970) and *Memory and Cognition* (1973) were founded to provide an outlet to the burgeoning research in human memory that was less characteristic of traditional associationistic theories (Warren, 1921; Robinson, 1932/1964) and more influenced by analogies to computers and conceptions of information processing. Topics of the older mentalistic psychology, such as attention, concept formation, and thinking, became more prominent in psychological research. The term *mind,* banished from the psychological lexicon in the heyday of behavioral theories, began to reappear in textbooks and, more significantly, in developing theories of human and animal cognitive capacities. The magnitude of the shift in research agendas and theoretical constructs suggested that psychology had undergone a revolutionary change, while others regarded the shift as part of the normal historical development of the discipline (Leahey, 1992). Nevertheless, these developments in scientific psychology represent the continuing vitality of the discipline as psychologists address traditional problems of mind and behavior in forging the science of psychology. These efforts inform the content of the volumes and chapters that follow and properly belong to contemporary psychology.

REFERENCES

Adler, H. E. (1966). Translator's foreword. In D. H. Howes & E. G. Boring (Eds.), *Gustav Fechner: Elements of psychophysics* (pp. xix–xxvi). New York: Holt.

Allport, G. (1937). *Personality: A psychological interpretation.* New York: Holt.

American Psychological Association. (1983). *Publication manual* (3rd ed.). Washington, D.C.: APA.

American Psychological Association. (2001). *Publication manual* (5th ed.). Washington, D.C.: APA.

Angell, J. R. (1905). *Psychology.* New York: Holt.

Angell, J. R. (1907). The province of functional psychology. *Psychological Review, 14,* 61–91.

Angell, J. R. (1911). Philosophical and psychological usage of the terms mind, consciousness, and soul. *Psychological Bulletin, 8,* 46–47.

Asch, S. E. (1955). Opinions and social pressure. *Scientific American, 193,* 31–35.

Attneave, F. (1959). *Applications of information theory to psychology.* New York: Holt.

Baldwin, J. M. (1895). *Mental developmental in the child and the race: Methods and processes.* New York: Macmillan.

Baldwin, J. M. (1897). *Social and ethical interpretations of mental development: A study in social psychology.* New York: Macmillan.

Bazerman, C. (1987). Codifying the social scientific style: The APA *publication manual* as a behavioristic rhetoric. In J. S. Nelson, A. Megill, & D. N. McCloskey (Eds.), *The rhetoric of the human sciences* (pp. 125–144). Madison: University of Wisconsin Press.

Ben-David, J. (1971). *The scientists role in society.* Englewood Cliffs, NJ: Prentice Hall.

Ben-David, J., & Collins, R. (1966). Social factors in the origins of a new science. *American Sociological Review, 31,* 451–465.

Benjamin, L. T., Jr. (2000). The psychology laboratory at the turn of the century. *American Psychologist, 55,* 318–321.

Benjamin, L. T., Jr., Durkin, M., Link, M., Vestal, M., & Acord, J. (1992). Wundt's American doctoral students. *American Psychologist, 47,* 123–131.

Bently, M., Hodge, F. W., Passano, E. B., Peerenboom, C. A., Warren, H. C., & Washburn, M. W. (1929). Instructions in regard to preparation of manuscript. *Psychological Bulletin, 26,* 57–63.

Blumenthal, A. (1985a). Shaping a tradition: Experimentalism begins. In C. E. Buxton (Ed.), *Points of view in the modern history of psychology* (pp. 51–83). New York: Academic Press.

Blumenthal, A. (1985b). Wilhelm Wundt: Psychology as a propaedeutic science. In C. E. Buxton (Ed.), *Points of view in the modern history of psychology* (pp. 19–50). New York: Academic Press.

Boakes, R. (1984). *From Darwinism to behaviourism: Psychology and the minds of animals.* Cambridge, England: Cambridge University Press.

Boring, E. G. (1950). *A history of experimental psychology* (2nd ed.). New York: Appleton-Century-Crofts.

Boring, E. G. (1965). On the subjectivity of important historical dates: Leipzig, 1879. *Journal of the History of the Behavioral Sciences, 1,* 5–9.

Bridgman, P. W. (1927). *The logic of modern physics.* New York: Macmillan.

Bringmann, W. G., Balance, W. D. G., & Evans, R. (1975). Wilhelm Wundt 1832–1920: A brief biographical sketch. *Journal of the History of the Behavioral Sciences, 11,* 287–297.

Bringmann, W. G., Bringmann, N. J., & Ungerer, G. A. (1980). The establishment of Wundt's laboratory: An archival and documentary study. In W. G. Bringmann & R. D. Tweney (Eds.), *Wundt studies: A centennial collection* (pp. 123–159). Toronto, Ontario, Canada: C. J. Hogrefe.

Bruce, D. (1997). Puzzling over animal intelligence. *Contemporary Psychology, 42,* 879–882.

Buckley, K. W. (1982). The selling of a psychologist: John Broadus Watson and the application of behavioral techniques to advertising. *Journal of the History of the Behavioral Sciences, 18,* 207–221.

Burnham, J. (1972). Thorndike's puzzle boxes. *Journal of the History of the Behavioral Sciences, 8,* 159–167.

Buxton, C. (1985a). American functionalism. In C. Buxton (Ed.), *Points of view in the modern history of psychology* (pp. 113–140). New York: Academic Press.

Buxton, C. (1985b). Early sources and basic conceptions of functionalism. In C. Buxton (Ed.), *Points of view in the modern history of psychology* (pp. 85–111). New York: Academic Press.

Cairns, R. (1992). The making of a developmental science: The contributions and intellectual heritage of James Mark Baldwin. *Developmental Psychology, 28,* 17–24.

Calkins, M. W. (1894a). Association I. *Psychological Review, 1,* 476–483.

Calkins, M. W. (1894b). Wellesley College psychological studies. *Educational Review, 8,* 269–286.

Calkins, M. W. (1901). *Introduction to psychology.* New York: Macmillan.

Calkins, M. W. (1910). The teaching of elementary psychology in colleges supposed to have no laboratory. *Psychological Monographs, 12*(4, Whole No. 51), 41–53.

Calkins, M. W. (1919). *A first book in psychology* (4th rev. ed.). New York: Macmillan.

Camfield, T. (1973). The professionalization of American psychology, 1870–1917. *Journal of the History of the Behavioral Sciences, 9,* 66–75.

Capshew, J. (1992). Psychologists on site. *American Psychologist, 47,* 132–142.

Carr, H., & Watson, J. B. (1908). Orientation in the white rat. *Journal of Comparative Neurology and Psychology, 18,* 27–44.

Cattell, J. M. (1888). The psychological laboratory at Leipsic. *Mind, 13,* 37–51.

Cattell, J. M. (1947a). The conceptions and methods of psychology. In A. T. Poffenberger (Ed.), *James McKeen Cattell: Man of science* (Vol. 2, pp. 197–207). Lancaster, PA: Science Press. (Original work published 1904)

Cattell, J. M. (1947b). On the time required for recognizing and naming letters and words, pictures and colors. In A. T. Poffenberger (Ed.), *James McKeen Cattell: Man of science* (Vol. 1, pp. 13–25). Lancaster, PA: Science Press. (Original work published 1885–1886)

Cattell, J. M. (1947c). Physical and mental measurements of the students of Columbia University. *Psychological Review, 3,* 618–648. In A. T. Poffenberger (Ed.), *James McKeen Cattell: Man of science* (Vol. 1, pp. 305–330). Lancaster, PA: Science Press. (Original work published 1896)

Chadbourne, C. (1872). *Instinct: Its office in the animal kingdom and its relation to the higher powers in man.* New York: Putnam.

Chance, P. (1999). Thorndike's puzzle boxes and the origins of the experimental analysis of behavior. *Journal of the Experimental Analysis of Behavior, 72,* 433–440.

Charlesworth, W. (1992). Darwin and developmental psychology: Past and present. *Developmental Psychology, 28,* 5–16.

Cousine, V. (1864). *Elements of psychology* (4th ed., C. Henry, Trans.). New York: Ivison, Phinney, Blakeman.

Croce, P. J. (1999). Physiology as the antechamber to metaphysics: The young William James's hope for a philosophical psychology. *History of Psychology, 2,* 302–323.

Cronbach, L. (1957). The two disciplines of scientific psychology. *American Psychologist, 12,* 671–684.

Cumming, W. W. (1999). A review of Geraldine Joncich's: The sane positivist: A biography of Edward L. Thorndike. *Journal of the Experimental Analysis of Behavior, 72,* 429–432.

Danziger, K. (1980). The history of introspection reconsidered. *Journal of the History of the Behavioral Sciences, 16,* 241–262.

Danziger, K. (1985). The origins of the psychological experiment as a social institution. *American Psychologist, 40,* 133–140.

Danziger, K. (1990). *Constructing the subject.* Cambridge, England: Cambridge University Press.

Darwin, C. (1859). *On the origin of species.* London: Murray.

Darwin, C. (1871). *The descent of man, and selection in relation to sex* (Vols. 1–2). London: Murray.

Dehue, T. (1997). Deception, efficiency, and random groups. *Isis, 88,* 653–673.

Dehue, T. (2000). From deception trials to control reagents. *American Psychologist, 55,* 264–268.

Dewey, J. (1884). The new psychology. *Andover Review, 2,* 278–289.

Dewey, J. (1896). The reflex arc concept in psychology. *Psychological Review, 3,* 357–370.

Dewsbury, D. A. (1990). Early interactions between animal psychologists and animal activists and the founding of the APA Committee on Precautions in Animal Experimentation. *American Psychologist, 45,* 315–327.

Dewsbury, D. A. (1998). Celebrating E. L. Thorndike and a century after *animal intelligence. American Psychologist, 53,* 1121–1124.

Dewsbury, D. A. (2000). Comparative cognition in the 1930's. *Psychonomic Bulletin and Review, 7,* 267–283.

Diehl, L. A. (1986). The paradox of G. Stanley Hall: Foe of coeducation and educator of women. *American Psychologist, 41,* 868–878.

Dodge, R. (1912). The theory and limitations of introspection. *American Journal of Psychology, 23,* 214–229.

Donaldson, H. H. (1908). Comparison of the albino rat with man with respect to the growth of the brain and of the spinal cord. *Journal of Comparative Neurology and Physiology, 18,* 345–392.

Ebbinghaus, H. (1913). *Über das gedächtnis: Untersuchen zur experimentellen psychologie* [Memory: A contribution to experimental psychology] (H. A. Ruger & H. Bussenius, Trans.). Leipzig, Germany: Duncker & Humblot. (Original work published 1885)

Ellis, W. D. (1950). *A source book of Gestalt psychology.* London: Kegan Paul. (First published 1938)

English, H. B. (1921). In aid of introspection. *American Journal of Psychology, 32,* 404–414.

Evans, R. (1972). E. B. Titchener and his lost system. *Journal of the History of the Behavioral Sciences, 8,* 168–180.

Evans, R. (1981). Introduction: The historical context. In F. Burkhardt & F. Bowers (Eds.), *The works of William James: The principles of psychology* (Vol. 1, pp. xlx–lxviii). Cambridge, MA: Harvard University Press.

Evans, R. (1984). The origins of American academic psychology. In J. Brozek (Ed.), *Explorations in the history of psychology in the United States* (pp. 17–60). Lewisburg, PA: Bucknell University Press.

Fancher, R. (1996). *Pioneers of psychology.* New York: Norton.

Fay, J. W. (1939). *American psychology before William James.* Brunswick, NJ: Rutgers University Press.

Fearing, F. (1930). *Reflex action: A study in the history of physiological psychology.* Baltimore: Williams & Wilkins.

Ferster, C., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Fitzpatrick, E. (1990). *Endless crusade: Women social scientists and progressive reform.* New York: Oxford University Press.

Flavell, J. (1963). *The developmental psychology of Jean Piaget.* Princeton, NJ: Van Nostrand.

Fuchs, A. (1997). Ebbinghaus's contributions to psychology after 1885. *American Journal of Psychology, 110,* 621–633.

Fuchs, A. (2000a). Contributions of American mental philosophers to psychology in the United States. *History of Psychology, 3,* 3–19.

Fuchs, A. (2000b). Teaching the introductory in psychology circa 1900. *American Psychologist, 55,* 492–495.

Furumoto, L. (1980). Mary Whiton Calkins (1863–1930). *Psychology of Women Quarterly, 5,* 55–68.

Furumoto, L. (1987). On the margins: women and the professionalization of psychology in the United States, 1890–1940. In M. Ash & W. Woodward (Eds.), *Psychology in twentieth century thought and society* (pp. 93–113). Cambridge, England: Cambridge University Press.

Furumoto, L., & Scarborough, E. (1987). Placing women in the history of comparative psychology: Margaret Floy Washburn and Margaret Morse Nice. In E. Tobach (Ed.), *Historical perspectives and the international status of comparative psychology* (pp. 103–117). Hillsdale, N.J: Erlbaum.

Galef, B. G. (1998). Edward Thorndike revolutionary psychologist, ambiguous biologist. *American Psychologist, 53,* 1128–1134.

Geissler, L. (1909). The measurement of attention. *American Journal of Psychology, 20,* 473–529.

Gesell, A., & Ilg, F. (1946). *The child from five to ten.* New York: Harper.

Giorgi, A. (1970). *Psychology as a human science.* New York: Harper & Row.

Goodman, E. S. (1980). Margaret, F. Washburn. (1871–1939): First woman PhD in psychology. *Psychology of Women Quarterly, 5,* 69–80.

Goodwin, C. J. (1999). *A history of modern psychology.* New York: Wiley.

Green, C. (Ed.). (2000). *Institutions of early experimental psychology: Laboratories, courses, journals and associations* [Online]. Retrieved from www.psychclassics.yorku.ca/Special/Institutions/

Gregory, R. J. (1992). *Psychological testing: History, principles, and applications.* Boston: Allyn & Bacon.

Guthrie, E. R. (1960). *The psychology of learning* (Rev. ed.). Gloucester, MA: Peter Smith. (Original work published 1935)

Guthrie, R. (1998). *Even the rat was white* (2nd ed.). Boston: Allyn & Bacon.

Hall, G. S. (1901). The new psychology. *Harper's Monthly Magazine, 103,* 727–732.

Hall, G. S. (1904). *Adolescence: Its psychology and its relations to physiology, anthropology, sociology, sex, crime, religion, and education* (Vols. 1–2). New York: Appleton.

Hall, G. S. (1923). *Life and confessions of a psychologist.* New York: Appleton.

Harlow, H. (1953). Mice, monkeys, men, and motives. *Psychological Review, 60,* 23–32.

Harris, B. (1979). Whatever happened to Little Albert. *American Psychologist, 34,* 151–160.

Harris, B. (1999). John Broadus Watson. In J. A. Garraty & M. C. Carnes (Eds.), *American National Biography* (Vol. 22, pp. 795–797). New York: Oxford University Press.

Haupt, E. (1998). Origins of American psychology in the work of G. E. Müller: Classical psychophysics and serial learning. In R. W. Rieber & K. Salzinger (Eds.), *Psychology: Theoretical-historical perspectives* (pp. 16–75). Washington, DC: American Psychological Association.

Heidbreder, E. (1933). *Seven psychologies.* New York: Century.

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology, 4,* 11–26.

Hickok, L. P. (1854). *Empirical psychology.* New York: Ivison & Phinney.

Hoffman, R. R., Bringmann, W. G., Bamberg, M., & Klein, R. (1987). Some historical observations on Ebbinghaus. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and learning: The Ebbinghaus centennial conference* (pp. 57–75). Hillsdale, NJ: Erlbaum.

Hull, C. L. (1934a). The concept of the habit-family hierarchy and maze learning: Part I. *Psychological Review, 41,* 33–54.

Hull, C. L. (1934b). The concept of the habit-family hierarchy and maze learning: Part II. *Psychological Review, 41,* 134–152.

Hull, C. L. (1943). *Principles of behavior.* New York: Appleton-Century-Crofts.

Hull, C. L. (1950). A primary social science law. *Scientific Monthly, 71,* 221–228.

Innis, N. K. (1999, August 20–24). *Expectation and hypotheses: E. C. Tolman and animal cognition.* Paper presented at the 107th annual meeting of the American Psychological Association, Boston.

James, W. (1890). *The principles of psychology* (Vols. 1–2). New York: Holt.

James, W. (1892a). A plea for psychology as a "natural science." *Philosophical Review, 1,* 146–153.

James, W. (1892b). *Psychology: The briefer course.* New York: Holt.

James, W. (1920). Letter to Thomas Ward, Nov., 1867. In H. James (Ed.), *The Letters of William James* (Vol. 1, pp. 118–119). Boston: Atlantic Monthly Press.

Jastrow, J. (1886). Experimental psychology in Leipzig. *Science, 8,* 459–462.

Judd, C. H. (1907). *Laboratory manual of psychology* (Vol. 2). New York: Scribner's.

Judd, C. H. (1910). Evolution and consciousness. *Psychological Review, 17,* 77–97.

Kendler, H. (1952). "What is learned?" A theoretical blind alley. *Psychological Review, 59,* 269–277.

Kimble, G. A. (1985). Conditioning and learning. In S. Koch & D. E. Leary (Eds.), *A century of psychology as science* (pp. 284–335). New York: McGraw-Hill.

Koffka, K. (1927). *The growth of the mind.* New York: Harcourt, Brace.

Kohler, R. (1990). The Ph.D. machine. *Isis, 81,* 638–662.

Köhler, W. (1926). *The mentality of apes.* New York: Harcourt, Brace.

Köhler, W. (1929). *Gestalt psychology.* New York: Liveright.

Koshtoyants, K. (1965). I. M. Sechenov (1829–1905). In I. Sechenov (Ed.), *Reflexes of the brain* (pp. 119–139). Cambridge, MA: MIT Press.

Krantz, D. L. (1972). Schools and systems: The mutual isolation of operant and non-operant psychology as a case study. *Journal of the History of the Behavioral Sciences, 8,* 86–102.

Kusch, M. (1995). Recluse, interlocutory, interrogator: Natural and social order in turn-of-the-century psychological research schools. *Isis, 86,* 419–439.

Ladd, G. T. (1888). *Elements of physiological psychology.* New York: Scribner's.

Langfeld, H. S., & Allport, F. H. (1916). An elementary laboratory course in psychology. Boston: Houghton & Mifflin.

Leahey, T. H. (1981). The mistaken mirror: On Wundt's and Titchener's psychologies. *Journal of the History of the Behavioral sciences, 17,* 273–282.

Leahey, T. H. (1992). The mythical revolutions of American psychology. *American Psychologist, 47,* 308–318.

Leahey, T. H. (2001). *A history of modern psychology.* Upper Saddle River, NJ: Prentice Hall.

Leary, D. (1978). The philosophical development of the conception of psychology in Germany, 1780–1850. *Journal of the History of the Behavioral Sciences, 14,* 113–121.

Leary, D. (1987). Telling likely stories: The rhetoric of the new psychology, 1880–1920. *Journal of the History of the Behavioral Sciences, 23,* 315–331.

Logan, C. A. (1999). The altered rationale for the choice of a standard animal in experimental psychology: Henry, H. Donaldson, Adolf Meyer, and "the" albino rat. *History of Psychology, 2,* 3–24.

Mandler, G., & Kessen, W. (1959). *The language of psychology.* New York: Wiley.

Marshall, M. (1982). Physics, metaphysics, and Fechner's psychophysics. In W. R. Woodward & M. G. Ash (Eds.), *The problematic science: Psychology in nineteenth thought* (pp. 65–81). New York: Praeger.

Maslow, A. (1966). *The psychology of science.* New York: Harper & Row.

Mateer, F. (1918). *Child behavior.* Boston: Badger.

McCosh, J. (1886). *Psychology: The cognitive powers.* New York: Scribner's.

McCosh, J. (1887). *Psychology: The motive powers.* New York: Scribner's.

McGeoch, J. (1942). *The psychology of human learning.* New York: Longmans, Green.

McGraw, M. (1935). *Growth: A study of Johnny and Jimmy.* New York: Appleton-Century-Crofts.

McGraw, M. (1943). *The neuromuscular maturation of the human infant.* New York: Columbia University Press.

McReynolds, P. (1996). Lightner Witmer: A centennial tribute. *American Psychologist, 51,* 237–240.

Melton, A. W. (1956). Present accomplishments and future trends in problem-solving and learning theory. *American Psychologist, 11,* 278–281.

Milar, K. S. (1999). A coarse and clumsy tool: Helen Thompson Wooley and the Cincinnati Vocation Bureau. *History of Psychology, 2,* 219–235.

Milar, K. S. (2000). The first generation of women psychologists and the psychology of women. *American Psychologist, 55,* 616–619.

Miller, G. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63,* 81–97.

Mills, E. (1969). *George Trumbull Ladd: Pioneer American psychologist.* Cleveland, OH: Case Western Reserve.

Mills, J. A. (1998). *Control: A history of behavioral psychology.* New York: New York University Press.

Miner, B. (1904). The changing attitude of American universities toward psychology. *Science, 20,* 299–307.

Morgan, C. L. (1898). Animal intelligence: An experimental study. *Nature, 58,* 249–250.

Morgan, C. L. (1890–1891). *Animal life and intelligence.* London: Edward Arnold.

Morgan, C. L. (1896) *Habit and instinct.* London: Edward Arnold.

Morgan, C. L. (1900). *Animal behaviour.* London: Edward Arnold.

Munn, N. (1950). *Handbook of experimental research on the rat.* Boston: Houghton Mifflin.

Murchison, C. (Ed.). (1926). *Psychologies of 1925.* Worcester, MA: Clark University.

Murchison, C. (Ed.). (1930). *Psychologies of 1930.* Worcester, MA: Clark University.

Murray, D. J. (1976). Research on human memory in the nineteenth century. *Canadian Journal of Psychology, 30,* 201–220.

Murray, D. J. (1988). *A history of Western psychology* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Murray, D. J., & Bandomir, C. A. (2000). G. E. Muller (1911, 1913, 1917) on memory. *Psychologie et Histoire, 1,* 208–232.

Nichols, H. (1893). The psychological laboratory at Harvard. *McClures, 1,* 399–409.

O'Donnell, J. M. (1985). *The origins of behaviorism: American psychology 1870–1920.* New York: New York University Press.

Piaget, J. (1929). *The child's conception of the world.* New York: Harcourt Brace.

Porter, N. (1868). *The human intellect.* New York: Scribner.

Posner, M. I., & Raichle, M. E. (1994). *Images of mind.* New York: Scientific American Library.

Postman, L. (1968). Hermann Ebbinghaus. *American Psychologist, 23,* 149–157.

Raphelson, A. (1973). The pre-Chicago association of the early functionalists. *Journal of the History of the Behavioral Sciences, 9,* 115–122.

Rauch, F. (1840). *Psychology, or a view of the human soul, including anthropology.* New York: M. W. Dodd.

Rescorla, R. (1966). Predictability and number of pairings in Pavlovian fear conditioning. *Psychonomic Science, 4,* 383–384.

Richards, R. (1992). *The meaning of evolution.* Chicago: University of Chicago Press.

Roback, A. A. (1952). *History of American psychology.* New York: Library Publishers.

Robinson, E. S. (1964). *Association theory today.* New York: Hafner. (Original work published 1932)

Romanes, G. J. (1892). *Animal intelligence.* New York: Appleton.

Ross, D. (1972). *G. Stanley Hall: The psychologist as prophet.* Chicago: University of Chicago Press.

Rucci, A. J., & Tweney, R. D. (1980). Analysis of variance and the second discipline of scientific psychology: A historical account. *Psychological Bulletin, 87,* 166–184.

Samelson, F. (1981). The struggle for scientific authority: The reception of Watson's behaviorism, 1913–1920. *Journal of the History of the Behavioral Sciences, 17,* 399–425.

Sanford, E. C. (1897). *A course in experimental psychology. Part 1: Sensation and perception.* Boston: D. C. Heath.

Sanford, E. C. (1910). The teaching of elementary psychology in colleges and universities with laboratories. *Psychological Monographs, 12* (4, Whole No. 51), 58–61.

Scarborough, E., & Furumoto, L. (1987). *Untold lives: The first generation of American women psychologists.* New York: Columbia University Press.

Seashore, C. E. (1909). *Elementary experiments in psychology.* New York: Holt.

Sechenov, I. M. (1965). *Reflexes of the brain.* Cambridge, MA: MIT Press. (Original work published 1863)

Shields, S. A. (1975). Functionalism, Darwinism, and the psychology of women: A study in social myth. *American Psychologist, 30,* 739–754.

Skinner, B. F. (1938). *The behavior of organisms.* New York: Appleton-Century-Crofts.

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57,* 193–216.

Skinner, B. F. (1957). *Verbal behavior.* New York: Appleton-Century-Crofts.

Skinner, B. F. (1968). *The technology of teaching.* New York: Appleton-Century-Crofts.

Small, W. (1900). An experimental study of the mental processes of the rat. *American Journal of Psychology, 11,* 133–165.

Small, W. (1901). Experimental study of the mental processes of the rat. *American Journal of Psychology, 12,* 206–239.

Smith, L. (1986). *Behaviorism and logical positivism.* Stanford, CA: Stanford University Press.

Smith, L., Best, L., Cylke, V., & Stubbs, D. A. (2000). Psychology without *p* values. *American Psychologist, 55,* 260–263.

Sokal, M. (1987). James McKeen Cattell and mental anthropometry: Nineteenth-century science and reform and the origins of psychological testing. In M. Sokal (Ed.), *Psychological testing and American society 1890–1930* (pp. 21–45). New Brunswick, NJ: Rutgers University Press.

Spencer, H. (1855). *Principles of psychology.* London: Longman, Brown, Green, and Longmans.

Stam, H. J., & Kalmanovitch, T. (1998). E. L. Thorndike and the origins of animal psychology. *American Psychologist, 53,* 1135–1144.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. In W. G. Koster (Ed.), *Acta psychologica, 30, attention and performance II* (pp. 276–315). Amsterdam: North Holland.

Stevens, S. S. (1935a). The operational basis of psychology. *American Journal of Psychology, 47,* 323–330.

Stevens, S. S. (1935b). The operational definition of concepts. *Psychological Review, 42,* 517–527.

Stevens, S. S. (1939). Psychology and the science of science. *Psychological Bulletin, 36,* 221–263.

Stevens, S. S. (1951). Mathematics, measurement, and psychophysics. In S. S. Stevens (Ed.), *Handbook of experimental psychology (*pp. 1–49). New York: Wiley.

Thompson, H. B. (1903). *The mental traits of sex.* Chicago: University of Chicago Press.

Thorndike, E. L. (1898). Animal intelligence. *Psychological Review Monograph* (Suppl. 2, Whole No. 8).

Thorndike, E. L. (1913). The laws of learning in animals. In E. L. Thorndike (Ed.), *Educational psychology: The psychology of learning* (Vol. 2, pp. 6–16). New York: Teachers College Press.

Thorndike, E. L. (1936). Edward Lee Thorndike. In C. Murchison (Ed.), *A history of psychology in autobiography* (Vol. 3, pp. 263–270). Worcester, MA: Clark University Press.

Titchener, E. B. (1898). The postulates of a structural psychology. *Philosophical Review, 7,* 449–465.

Titchener, E. B. (1901–1905). Experimental psychology, a manual of laboratory practice. New York: Macmillan.

Todes, D. (1997). From the machine to the ghost within: Pavlov's transition from digestive physiology to conditional reflexes. *American Psychologist, 52,* 947–955.

Tolman, E. C. (1922). A new formula for behaviorism. *Psychological Review, 29,* 44–54.

Tolman, E. C. (1932). *Purposive behavior in animals and men.* New York: Appleton-Century-Crofts.

Tolman, E. C., & Honzik, C. H. (1930). Introduction and removal of reward, and maze performance in rats. *University of California Publications in Psychology, 4,* 257–275.

Tolman, E. C., Ritchie, B. F., & Kalish, D. (1946). Studies in spatial learning. I: Orientation and the short cut. *Journal of Experimental Psychology, 36,* 13–25.

Tuddenham, R. D. (1962). The nature and measurement of intelligence. In L. Postman (Ed.), *Psychology in the making* (pp. 469–525). New York: Knopf.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review, 64,* 49–60.

Underwood, B. J., & Schulz, R. W. (1960). *Meaningfulness and verbal learning.* Chicago: Lippincott.

Warren, H. C. (1921). *A history of the association psychology.* New York: Scribner's.

Washburn, M. F. (1908). *The animal mind.* New York: Macmillan.

Washburn, M. F. (1917). *The animal mind* (2nd ed.). New York: Macmillan.

Washburn, M. F. (1926). *The animal mind* (3rd ed.). New York: Macmillan.

Washburn, M. F. (1936). *The animal mind* (4th ed.). New York: Macmillan.

Watson, J. B. (1907). Kinaesthetic and organic sensations: Their role in the reactions of the white rat to the maze. Psychological Review Monograph Supplement, 8, no. 2.

Watson, J. B. (1913). Psychology as the behaviorist views it. *Psychological Review, 20,* 158–177.

Watson, J. B. (1914). *Behavior: An introduction to comparative psychology.* New York: Holt.

Watson, J. B. (1916). The place of the conditioned reflex in psychology. *Psychological Review, 23,* 89–116.

Watson, J. B. (1919). *Psychology from the standpoint of a behaviorist.* Philadelphia: Lippincott.

Watson, J. B. (1924). *Behaviorism.* New York: Norton.

Watson, J. B., & Rayner, R. (1920). Conditioned emotional reactions. *Journal of Experimental Psychology, 3,* 1–14.

Watson, R. I., & Evans, R. (1991). *The great psychologists.* New York: Harper-Collins.

Wertheimer, M. (1912). Experimentelle studien über das sehen das Bewegung. (Experimental studies on the perception of movement). *Zeitschrift fur Psychologie, 61,* 161–265.

Wertheimer, M. (1959). *Productive thinking.* New York: Harper.

White, S. (1992). G. Stanley Hall: From philosophy to developmental psychology. *Developmental Psychology, 28,* 25–34.

Winston, A. (1990). Robert Sessions Woodworth and the "Columbia Bible": How the psychological experiment was redefined. *American Journal of Psychology, 103,* 391–401.

Woodworth, R. S. (1938). *Experimental psychology.* New York: Holt.

Woodworth, R. S. (1948). *Contemporary schools of psychology* (Rev. ed.). New York: Ronald.

Woolley, H. T. (1910). A review of recent literature on the psychology of sex. *Psychological Bulletin, 7,* 335–342.

Wundt, W. (1873–1874). Grundzüge derphysiologische psychologie (Principles of physiological psychology). Leipzig: Englemann.

Wundt, W. (1974). Excerpts from publications on the reaction experiment. In S. Diamond (Ed.), *The roots of psychology* (pp. 695–700). New York: Basic Books.

Yerkes, R. M. (1905). Animal psychology and the criteria of the psychic. *Journal of Philosophy, Psychology, and Scientific Methods, 6,* 141–149.