Neuropsychology: A Study of the Discipline's History

Michael Holmes

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Approved by:

Dr. Howard Berthold, Associate Professor of Psychology

Dr. Kurt Olsen, Assistant Professor of Psychology

Dr. Stephen Griffith, Associate Professor of Philosophy

Judge Thomas Raup, Visiting Professor of Legal Studies

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Michael Holmes

Lycoming College

Neuropsychology: A Study of the Discipline's History, Current Trends, and Future Considerations

The Penguin Dictionary of Psychology defines neuropsychology in the following manner: "A sub-discipline within physiological psychology that focuses on the interrelationships between neurological processes and behavior" (Reber, 1995, p. 491). Since his "ascendance," man has searched for an understanding of the mechanisms which govern his own behavior. Figure 1 places some of the thinkers, including specialists in philosophy, medicine, psychology, physiology, etc., who helped shaped neuropsychology's lengthy history, along a time line in order to aid in maintaining a proper perspective. Evidence exists which suggests prehistoric man may have had a rudimentary understanding of a relationship between the head and behavior and even had the capability to perform successful cranitomies. The ancient Egyptians kept and maintained detailed records of their systematic explorations of the human brain.

Reason replaced observation as the basis for later, "more sophisticated" theories with little exception. Many of the great thinkers in recorded history denied man's lowly, earthly status by attributing his behavior to the soul or mind, a non-physical entity unique to the beneficiary of God's creation. Despite their foundation in metaphysical methodologies, many of these theories strongly resemble modern, empirically based models. It has only been within the last 200 years that the experimental method has been restored as the standard that it is today, not only in neuropsychology, but in all sciences.

The obstacles faced by man as he undertakes neuropsychological investigation are complicated by several necessarily connected, deeply complex issues. As one studies the history of neuropsychology, he inevitably witnesses concurrent arguments concerning the mind-body problem, free will versus determinism, and the influences of nature and nurture. Controversy erupts between those who ascribe an active role in the life of man to a superior entity and those who see life as a product of chance and as governed by the same. For most of its recorded history, the theories concerned with man's behavior have had at their foundations an immaterial soul around which all other theoretical aspects, including the body, were molded. Like a pendulum, however, current views have gone in the opposite direction, placing biology at the core of man's existence.

As more light is shed on the relationship between neurological mechanisms and behavior, the question of how much control man has over his actions has become a turbulent debate. A body of evidence is being amassed which suggests that, in many situations, we are only "mindless" slaves to physiological mechanisms which have been shaped by millions of years of evolution and are designed to be non-rational tools of survival. As always, however, these ideas are not without their opponents, and the debate continues.

Although neuropsychology in its present form is considered to be a recent development, man has pondered the nature of the mechanisms underlying his own behavior, often forming complicated and, perhaps to the modern ear, fantastic theories since late Paleolithic times (Walsh, 1981).

Trepanning, a premodern form of craniotomy, the surgical opening of the skull, was apparently a widespread practice in prehistoric times (Walsh, 1981). Trepanned skulls have been found in Europe, Africa, South America, North America, and a number of South Pacific islands. Interestingly, China, Vietnam, and India have thus far produced no such evidence. Although actual operation on the brain cannot be verified, the fact that few of the procedures were preceded by some kind of traumatic injury can be confirmed. Evidence in the form of post-surgical growth of the skull and the presence of multiple openings, including one specimen with five separate craniotomies, attests to the remarkably high survival rate of these operations (Walsh, 1981).

The instruments used in the trepanning procedures range from simple stone and obsidian tools to ornate iron and bronze implements (Walsh, 1981). Graña, Rocca, and Graña (1954), while studying pre-Columbian surgical techniques beginning with those of the Paracas culture, which flourished around 3000 B.C., and ending with the sixteenth century practices of the Inca, have added to the literature

> illustrations of (1) operations of every part of the human skull; (2) operative openings of different shapes, circular, oval, rectangular, triangular, and irregular; (3) sets of craniotomy instruments from different eras which include chisels, osteotomes, scalpels, and retractors as well as bandages and tourniquets (Walsh, 1981, p. 4).

In 1953, the researchers operated on a patient who had suffered a head injury using an array of these ancient implements and successfully relieved a consequential subdural hematoma (Walsh, 1981).

Due to the lack of a written language among all of the various early peoples who employed trepanning, investigators can only speculate about why such operations were performed (Walsh, 1981). Hypotheses include a method for relieving headaches, a means by which demons could be released from the skull, and a part of some kind of religious or mystical ceremony. Gurdjian (1973) notes "the fact that some of the openings in the skull have been repaired with silver alloy suggests surgical treatment for the possible skull wound caused in battle" (as cited by Walsh, 1981, p. 5).

It is also impossible to determine whether any of these peoples observed the effects of injuries and, perhaps, trauma caused by the surgery, on patients' behavior (Walsh, 1981). It is clear, however, that, prior to the invention of writing or its introduction from an outside source, the systematic and accurate collection of observational data would be impossible.

Concrete evidence reveals that the ancient Egyptians, with their complicated system of hieroglyphics, carefully recorded the results of their own neuropsychological investigations. In 1862, a man named Edwin Smith acquired what is now referred to as the Edwin Smith surgical papyrus (Walsh, 1981). This Egyptian document is thought to be at least 3,500 years old with some scholars placing its age at closer to 5,000 years. Contained within the papyrus are 48 cases of individuals suffering from traumatic injuries including damage to the head and neck. Detailed observations of the patients were made and recorded along with descriptions of the treatments utilized in each case. The word brain appears for the first time in this earliest of scientific documents. Gibson (1962) implies the importance of Smith's finding by noting that the papyrus "opens the door on cortical localization of function with the description of injuries to the brain" (as cited by Walsh, 1981, p. 1).

The ancient Egyptians had a dynamic approach to neuropsychology. Physicians actively inspected wounds, recording both the anatomy and any consequential abnormal behavior and somatic effects. The first eight cases reported in Smith's papyrus deal directly with head and brain injuries (Walsh, 1981). Breasted (1930) translates one passage as saying

> If thou examinest a man having a smash of his skull, under the skin of his head, while there is nothing at all upon it, though shouldst palpate his wound. Shouldst thou find that there is a swelling protruding on the

> outside of that smash which is in his skull, while his eye is askew because of it, on the side of him having that injury which is in his skull; (and) he walks shuffling with his sole, on the side of him having the injury which is in his skull... (as cited by Walsh, 1981, p. 2).

Early Egyptian physicians clearly understood that a relationship existed between the brain and the function of other parts of the body.

The investigation of this relationship undertaken by these physicians was dynamic as is evidenced by additions and corrections made to the original text of the papyrus (Walsh, 1981). Explanations of obsolete terms found in the original text are written on the back of the papyrus, apparently for the sake of a new generation of physicians by whose time the medical jargon had evolved (Walsh, 1981).

Modern researchers have rediscovered the method of directly stimulating the brain and observing subsequent behavior. For example, in the 1930's, Wilder Penfield developed a method of mapping, in a vary detailed manner, the cortex using direct electrical stimulation (Purves, Augustine, Fitzpatrick, Katz, LaMantia, & McNamara, 1997). Penfield's technique not only added to the field's general understanding of how the brain is organized functionally, it also gave neurosurgeons a tool for determining the boundaries of language areas of a patient's brain prior to the removal of tissue reducing the risk of nonessential impairment. A less intrusive but nonetheless direct way of assessing language lateralization, developed by Juhn Wada in the 1960's, uses an injection of sodium amytal into one of the two carotid arteries (Purves et al., 1997). The drug anesthetizes the ipsilateral hemisphere of the brain, rendering it inactive and allowing the untreated hemisphere to be tested in isolation.

In the fifth century B. C., Alcmaeon of Croton, a Greek and founder of a new form of medicine based in science rather than in religion, is known only from a few fragments of his writings (Watson, 1963). A number of these excerpts report on subjects of a psychological-physiological nature. "After discovering passages from the eyes to the brain, Alcmaeon boldly concluded that the brain both received perceptions of vision, audition, and olfaction, and was also the seat of thought. The brain, being the central organ of intellectual activity, he called the soul" (Watson, 1963, p. 10). His use of the word soul had no connection to the word as it was, and is, used in the theological sense and did not imply immortality. Rather, "soul was a convenient name for the central psychological [and physiological] agency" (Watson, 1963, p. 10). By drawing this conclusion, Alcmaeon successfully unified the so-called two-aspect theory of soul which was commonly accepted by the Greeks at that time. According to this theory, each soul was composed of two parts referred to as *thymos* and *psyche*.

Thymos, which perished along with the body, was involved in thought and emotion. Because the diaphragm, or the lungs in some cases, was considered to be the organ which housed the *thymos*, this particular belief was deemed the pneumatic theory of consciousness, thought, and mind. "As Onians puts it, to the ancient Greeks thoughts are words, words are breath (*pneuma*), and the organs of the mind consequently are the lungs" (Watson, 1963, p. 11).

Although immortal, *psyche* was not involved in waking experiences and, upon the passing of the body and *thymos*, retained no memory of an earthly existence. Watson (1963) quips "it is interesting to observe that psychologists, whose very name is derived from the latter meaning of soul, more accurately should have been called 'thymolotologists,' since conscious experience is definitely the concern of psychologists while immortality is not" (p. 11).

Alcmaeon's soul was a single entity responsible for all functions and seated in the head (Watson, 1963). He taught that the brain contained the factor which governs the soul and was the place where all sensations are marshaled. The physician also concluded that the brain is the center where thought and belief occur and the organizer and keeper of perceptions. According to Alcmaeon, sensations were able to reach the brain by way of channels which have their origin at the organs of sense. "These passages were not the nerves, as such, but rather channels for breath, the *pneuma* , mentioned earlier in connection with the thymos" (Watson, 1963, p. 11).

Like Alcmaeon, Hippocrates rejected the use of temple medicine and, despite his training in the Asclepiad tradition, never mentions the school's mystical views in his works (Watson, 1963). Much of what is known about Hippocrates is taken from accounts written by Plato, a younger contemporary of the physician. According to the philosopher, Hippocrates stressed his notion that, to understand the body, one must consider the whole man (Watson, 1963).

When considering the discourses of Hippocrates, one is faced with a complicated problem: "There is a strong possibility that Hippocrates, himself, wrote not a single one of the works which are attributed to him" (Watson, 1963, p. 13). Clarke and O'Malley (1968) assert a less equivocable opinion according to Walsh (1981). "The Hippocratic writings were clearly the product of a group of physicians between the latter part of the fifth century B. C. and the middle of the fourth century B.C." (Walsh, 1981, p.5). For this reason, scholars have made a distinction between the study of Hippocrates and the study of the Hippocratic Works (Watson, 1963).

Included among the Hippocratic Works are materials that, in modern terminology, would be referred to as "textbooks, papers, case histories, speeches, extracts, aphorisms, monographs, and manuals" (Watson, 1963, p. 13). Among the topics discussed are catalogues of symptoms and diagnoses and the proper treatments for acute diseases, epidemics, ulcers, hemorrhoids, and injuries to the head (Watson, 1963). One Hippocratic writer recorded his observation that damage to one side of the brain can cause spasms and convulsions on the contralateral side of the body (Walsh, 1981). Another writer, according to Gibson (1969), "warned against prodding blindly at a wound of the temporal area of the skull lest paralysis of the contralateral side should ensure" (as cited by Walsh, 1981, p. 5).

McHenry (1969) argues that the work entitled "On the Sacred Disease," a careful study of epileptic patients, is antiquity's superlative treatise on the human brain (Walsh, 1981). One can imagine that, to the ancient observer, just as to the modern observer, a Grand Mal seizure, with its characteristic falling, muscular spasms, loss of consciousness, and frothing at the mouth was a horrid and frightening event (Watson, 1963). It was not unusual for the victim of the attack, upon regaining consciousness, to report having endured sensations similar to physical blows from some unknown source. When considered together by the superstitious mind of the average ancient Greek, these symptoms strongly suggest demonic possession as a cause of the attack. For this reason

> one has a feeling of admiration and scientific kinship for its unknown author of about the fifth century B. C. when he wrote sturdily and with no compromise that, "it appears to me to be nowise more divine nor more sacred than other diseases, but has a natural cause from which it originates like other affections" (Watson, 1963, p. 14).

The brain, specifically a congested brain, according to this author, is the cause of the malady (Watson, 1963).

The Hippocratic writers emphasized the importance of the brain beyond the scope of Alcmaeon's view (Watson, 1963). The brain was the ultimate destination of the *pneuma* as it traveled through the body and the organ in which thinking and feeling took place. Although they credited the *pneuma* with the ability to produce thought, they recognized the brain as a communications center where thoughts were translated into a somatic "language" and sent to the proper bodily structures, and specifically denied that any thought took place in the heart. "Rather, the pneuma thinks and communicates this thought to the brain. The responses of the heart, its palpitations in fear and anger, are secondary 'reverberations of the motion of the brain'" (Watson, 1963, p. 15). A definite connection between conscious life, including all of its theoretical and actual constituent parts, and the brain, was first set forth within the Hippocratic Works (Watson, 1963).

> Men ought to know that from the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant . . . . It is the same thing which makes us mad or delirious, inspires us with dread and fear, whether by night or by day, brings sleeplessness, inopportune mistakes, aimless anxieties, absent-mindedness, and acts that are contrary to habit (attributed to Hippocrates, as cited by Kandel, Schwartz, & Jessell, 1991).

Although Plato wrote accounts of Hippocrates' success, his ideas concerning human behavior differed significantly from those of the early physician (Watson, 1963). The philosopher held a dualistic view of human psychology: "Body and soul are fundamentally different" (Watson, 1963, p. 26), though he toyed with the magnitude of this division. In his "*Theaetetus,*" the soul is completely independent of any structure within the human body. In the "*Phaedo* " and the "*Timaeus,*" however, various relationships are drawn between the soul and aspects of anatomy and physiology. In his descriptions of these relationships, according to Watson (1963), Plato still draws a distinct dichotomy between these components of the whole person and makes clear the inferiority of the body.

> The body is a hindrance to the functioning of the soul in that it may be an unruly instrument. Strong natural appetites of the body may upset the functioning of reason. Due to the action of the humors of the body, the mind may be affected. Madness and ignorance are diseases of the mind brought about by the body. Excessive pain and pleasure are the greatest diseases of the soul since a man in great joy or great pain cannot reason properly. Sense perception, desire, feeling, and appetite are of the body and at war with the soul, in this connection interfering with apprehension of the Forms (Watson, 1963, p. 27).

Plato described the soul as having three divisions, reason, feeling, and appetite, with each having its own location within the physical body (Watson, 1963). The brain housed reason, the only rational and immortal aspect of the triune soul. The two mortal and irrational parts, feeling and appetite, were located in the thoracic and abdominal cavities respectively. The heart was connected to reason, and, due to its close proximity to appetite and feeling, served as a sort of outpost for the rational part of the soul. When any wrong was carried out, reason roused anger within the heart which sent the emotion to the rest of the heart by means of the blood vessels. The blood vessels also served as paths for sensations to travel throughout the body (Watson, 1963). Watson (1963), when considering Plato's mechanism by which sensations are perceived, sums up the relationship by saying "the instrument is the body; the function and source belongs to the soul which directs the acts of the body"

(p. 28).

A pupil of Plato's, Aristotle took his teacher's interest in human psychology much further, establishing a method of systematic study in the discipline and, because of this, is considered to be the first psychologist (Watson, 1963). Plato's influence on his student are made clear in Aristotle's writings. In the work "*Eudemus*, " penned, according to some, by Aristotle, a dualistic view that is much stronger than any ever described by Plato is expressed. In this work "Aristotle expresses a yearning for death, treating it as a release of the immortal soul from the body. The souls exists before the body, and is released by death to return to its real existence" (Watson, 1963).

Upon Plato's death in 347 B. C., Aristotle left Athens for Asia Minor (Watson, 1963). He continued his studies including writing dissertations and collecting biological specimens. In the twelve years spent abroad, his thinking began to shift away from that of his teacher's. "In broad outline Aristotle's thinking progressed from the Platonism of the dialogues and other earlier works to the point where eventually he was much more concerned with empirical research" (Watson, 1963, p. 39). His works continued to show Plato's influences following this transition. When empirical evidence contradicted Platonic or any other philosophical convictions, however, Aristotle modified the latter to fit with his observations without hesitation (Watson, 1963).

Perhaps influenced by his early training in medicine, Aristotle became increasingly convinced of the necessity of sensual observations, an opinion not shared by and even discouraged by Plato (Watson, 1963). This stark contradistinction in thinking is made sensible when one considers the general views of the two thinkers and the spheres in which they searched for understanding. "Plato's other-worldly and idealistic view stands in sharp contrast to Aristotle's practical and empirical outlook. It is natural that instead of the perfect but lifeless mathematics that was the science of Plato, Aristotle turned to biology with its imperfect but living and changing organisms" (Watson, 1963, p. 40).

Aristotle's method of investigation has been described as being the sum of five steps (Watson, 1963). His first step, when confronting an object to be observed, was to determine the fundamental characteristic or characteristics of that object. In his "On Psyche," the principle was living, sensing, and knowing. Indeed, "to Aristotle, the principle of the object of investigation was always what the object does; how it operates" (Watson, 1963, p. 45). After making this determination, he examined previous opinions on the subject selecting some and discarding others. "He then brought out the difficulties and problems that he has now established from their views and examined them dialectically to see where they lead - 'to bring out the consequences that follow from hypotheses'...as it has been put" (Watson, 1963, p. 45).

Aristotle's fourth step involved finding relevant facts specific to the question. Finally, he attempted to show how the facts related to one another, thereby explaining the subject matter. "In carrying out this method, Aristotle explicated some of the methodological rules of investigation with which we are familiar. Rigorous, unprejudiced observation is primary. Explanation advanced must be both relevant and not contradictory to the facts" (Watson, 1963, p. 45).

Aristotle used the word *psyche* to mean a soul that is integrated with matter, marking him as a vitalist (Watson, 1963). Living beings are composed of a physical body and *psyche* gives those beings their essential characteristic of being alive. He draws a distinction between animate and inanimate objects by observing behavior. "Living things have a capacity for self-direction; they do things for themselves, and what they do, show that they are alive" (Watson, 1963, pp. 48-49).

In Aristotle's view, the *psyche* and the body were unified and inseparable in reality, although, in thought, can be pondered separately (Watson, 1963). Moreover, one cannot survive without the other. His scientific investigations into the nature of the body led him to draw what are logically sound but ultimately erroneous conclusions. Despite his conviction that the *psyche* was distributed throughout all parts of the body as evidenced by an insect's ability to survive for some time following bisection and the regenerative capabilities exhibited by other creatures, Aristotle recognized the need for a functional center in the body. As the organizational sophistication of the animal increases, "the greater the degree of centralization and the less need for psyche in each part" (Watson, 1963, p. 52). He identified the heart as this center based on rational observations including the lethality of diseases which affect the heart, the relationship between heart rate and emotional experiences, and the clear presence of a beating heart in an embryo (Watson, 1963).

By suggesting that the heart was the center of the body, Aristotle refuted Plato's notion that the brain was the organ of the soul (Watson, 1963). He rejected the validity of the Platonic view further, citing the brain's apparent insensitivity to stimulation. Concerning these opposing conclusions and their preceding arguments, Watson (1963) notes that

> it is ironical that Plato was right for the wrong reasons. Plato assigned reason to the brain on the basis of several irrelevant reasons typical of which is the fact that the brain was the part of the man nearest the heavens. Aristotle, on the other hand, was wrong for the "right," i.e., naturalistic reasons (p. 52).

A friend and student of Aristotle's and fellow naturalist, Theophrastus, identified as the founder of botany, is credited with the authorship of at least 227 treatises on topics including mathematics, religion, ethics, and of course, psychology (Watson, 1963). Like his mentor, Theophrastus relied upon empirical observations when formulating and otherwise considering theories and "argued that the facts should not be forged artificially into a theory (Watson, 1963, p. 71). He proposed that scientists study mechanical arts and use their observations to draw analogies between natural and artificial processes as a method of explaining natural phenomena. Unlike Aristotle, Theophrastus developed theories of spirituality and physiology which allowed for a closer relationship between the soul and the body (Watson, 1963).

Theophrastus focused on observable mental processes such as sensation, perception, and emotion and tended to emphasize the soul's apparent dependence on the body (Watson, 1963). In his physiologically oriented work "On the Senses," he establishes the brain as the seat of intellect once again and gives detailed accounts of his findings on vision, audition, olfaction, taste, and touch. He held that perception is in accord with nature and that "whatever the effects of the objects on the sense organs, these effects are carried to the brain before having the quality of sensory experiences" (Watson, 1963, p. 72).

Upon Theophrastus' death, Strato became the preeminent naturalist of Greece (Watson, 1963). However, despite his scientific efforts, Greece eventually lost its place as the center of Hellenic thought. With the shift in location from Greece to Alexandria came a change in the character of science (Watson, 1963). In the third century B. C., under the leadership of Ptolemy and Ptolemy II, two great institutions, the Museum and the Library, were established. The Library was the largest in the ancient world. The Museum, located in the Royal City along with the Library, was a research institute which eventually included living quarters for scientists and their assistants, laboratories, an observatory, and both botanical and zoological gardens. The

Ptolemys paid out stipends to the scientists of this establishment, making them the first researchers in history to receive financial support. Strato followed the intellectual shift, and, as the first leader of the Museum, emphasized science at the expense of philosophy, guaranteeing it continued attention (Watson, 1963).

From the newly established perspective of the Alexandrian scientists, psychology was not governed by natural laws and therefore was not a science (Watson, 19863). As a result, anatomy and physiology, which were considered to be sciences then as they are now, were investigated separately from psychology. For this reason, it is necessary to view the scientific findings of Herophilus and Erasistratus as accomplishments in anatomy and physiology only, although their work is seen as relevant to psychology now (Watson, 1963).

A founder of anatomy and contemporary of Euclid, Herophilus of Chalcedon enjoyed the "scientifically free atmosphere of Alexandria" (Watson, 1963, p. 76) by publicly dissecting and examining human corpses. He compared human anatomy to that of animals and saw that the brain was the center of the nervous system and recognized it as the seat of intelligence. "He distinguished tendons from nerves and through the name given to the latter (*neura-aisthetica*) implied a recognition of their function of sensitivity" (Watson, 1963, P. 76). Some disagreement exists as to whether it was Herophilus or his younger contemporary Erasistratus who first made the distinction between sensory and motor nerves (Watson, 1963).

There is no question that it was Erasistratus who made clear the differences between veins, arteries, and nerves, making it clear that it was the function of nerves to carry the *pneuma* which was necessary for motion and sensation (Watson, 1963).

Nerves and their functions were also described by an anonymous physician in a very modern-sounding text entitled "Book of Medicine" (Watson, 1963). The author describes the nerves as exiting the spinal cord and dispersing throughout the entire body. Within these structures are the substances necessary for sensation and motion. In addition, a rudimentary division between the somatic nervous system and the autonomic nervous system in conjunction with other involuntary mechanisms is drawn. "Voluntary powers are distinguished from what is called natural powers, which include attraction, growth, digestion, and expulsion, taking place whether we wish it or whether we do not. This view contains an anticipation of the concept of reflex or involuntary action" (Watson, 1963, p. 76).

At about the same time that Alexandria was becoming a mecca of science, "the rest of the Mediterranean World was showing a slow intellectual decline" (Watson, 1963, p. 76). Extreme forms of supernaturalism, irrational thought, and a growing interest in mystery cults, magic, and astrology in combination with military and political clashes and epidemics had profound impacts on intellectualism. Indeed, even Alexandria showed signs of such deterioration such as an increasing interest in alchemy and the outlawing of human dissection (Watson, 1963).

To get around the handicap placed on medical research by the prohibition of human dissection, Galen, a student of both medicine and philosophy, looked to the anatomical analysis of apes and other large mammals, especially oxen, as the source of data for his studies (Walsh, 1978; Watson, 1963). Because of this, a few organs were assigned to the human body which, in reality, are found only in nonhuman specimens. In some cases, as in the identification of the rete mirabile, a network of blood vessels at the base of the ungulate brain which Galen imputed to man as well, the errors remained uncorrected and understood as truth for centuries (Walsh, 1978). Upon his return to Pergamum, his birth city, at the age of 28, he was appointed to the post of surgeon to the gladiators, a position which would allow him to study the human body directly (Watson, 1963).

Galen divided all forms of life into three categories similar to hierarchical organization found among Aristotle's works and based on observable characteristics (Watson, 1963). Plants occupied the lowest rank of life because they showed the single attribute of growth. Animals show both growth and locomotion and must therefore be placed above plants in the scheme. The highest order of life, man, is separated from the animals by the addition of reason to the qualities of growth and locomotion. These attributes were seen as the explicit results of each category's combination of the three forms of the *pneuma* : Plants contained only the natural spirit; animals had both the natural and the vital spirit; humans possessed the natural, vital, and animal spirit, or soul (Watson, 1963).

When considering man from a physiological standpoint, the liver and the veins were understood as the organs involved in growth, locomotion was made possible by the arteries, and the brain and nervous system were the origins of intellect (Watson, 1963). Galen also observed the four spaces, now referred to as ventricles, within the brain of humans and apes. Clearly, these chambers, which contain a transparent fluid, were the areas of the body where the animal spirit, or soul, was generated. This highest form of *pneuma* was then dispersed throughout the body by the nerves (Watson, 1963). Walsh (1978) cites a passage authored by Magoun (1958) describing Galen's understanding of human physiology.

> Nutritive material passed from the alimentary canal through the portal vein to the liver, where natural spirits were formed. These ebbed and flowed in the veins, taking origin from the liver, to convey nutriment to all parts of the body. A portion of these natural spirits passed across the septum, from the right to the left of the heart, and joined with material

> drawn from the lungs to form the vital spirits. These ebbed and flowed to all parts of the body through the arteries, taking origin from the heart, to provide heat and other vital requirements. A part of these vital spirits passed to the base of the brain, to be distilled there in a marvelous vascular net, the rete mirabile, and to mix with air inspired into the cerebral ventricles through the porous cranial base, for, all this time, the pulsing of the brain in the opened cranium was conceived as an active process, much like that of thoracic respiration. As a consequence, animal spirits were formed, and 'animal,' in this use, was derived from the Latin 'anima' and Greek 'psyche,' meaning soulful, and was not animal in any lowly sense. This psychic pneuma, stored in the brain ventricles, passed by the pores of the nerves to the peripheral organs of sense and to the muscles, to subserve sensory and motor functions. Its equivalently important role in managing central functions in the brain was effected either within the ventricles themselves or in the immediately bordering substance of their walls (p. 6).

Sherrington (1951) notes that Galen observed what in reality are passive pulsations of the brain as being a property of the brain itself, supporting his notion that fluid was indeed being pumped from the ventricles to the rest of the body (as cited by Walsh, 1978). "Sherrington supposed that Galen had not only seen it in the scalp of the young child before the vault closes but that he had observed it often after trauma since Galen had written that 'war and the gladitorial games were the greatest school of surgery'" (Walsh, 1978, p. 7).

Galen's interest in the ventricles of the brain probably stemmed from their conspicuousness upon gross dissection of a brain that has not been treated in such a way as to retain its shape (Walsh, 1978). When removed from the skull, the untreated brain is more comparable to a viscous goo than a solid mass. One of the few distinguishable features of the shapeless jelly is the presence of cavities,or, in the modern terminology, ventricles. The emphasis placed on these hollows would continue to influence future neuropsychological theories (Walsh, 1978).

The ventricular localization hypothesis, or Cell Doctrine of the brain, as it is now referred to, is based on the notion "that the mental processes or faculties of the mind were located in the ventricular chambers of the brain" (Walsh, 1978, p. 5). Supporters of the theory likened the ventricles to cells and divided them up into three distinct units. The first cell was comprised of the lateral ventricles, the second cell the third ventricle, and the third cell the fourth ventricle. The Church Father, St. Augustine, along with another religious leader, Nemesius, asserted this theory in a nearly fully developed condition in the fourth century A. D. (Walsh, 1978).

St. Augustine believed that "it is necessary to believe in order to know; understanding comes from faith" (Watson, 1963, p. 92). To him, knowledge, especially scientific knowledge, was only useful, and therefore good, if it could be used to serve religion in some way, and irrelevant, and therefore bad, if it could not. In general, Augustine hindered scientific progress, but his "firm conviction of the certainty of inner experience" (Watson, 1963, p. 92) ensured him a place of importance in the history of neuropsychology.

Augustine believed that humans possessed an immaterial soul that worked in conjunction with the body, providing the physical aspect of man with animation and direction (Watson, 1963). As a consequence of this relationship, the mind, the thinking aspect of the soul, is limited to indirect knowledge of the world. The senses do not provide us with knowledge and it is only within the mind that experiences are had.

"Life is a unity known through self-consciousness" (Watson, 1963, p. 94).

Augustine viewed the mind as unitary and at the same time attributed to it three faculties which accounted for its multiple and relatively independent capabilities (Watson, 1963). The three faculties included reason, memory, and will, one for each cell within the brain.

Interestingly, Augustine did not consider reason to be the human mind's dominant function, but rather attributed primacy to will, saying that "we are nothing but wills" (as cited by Watson, 1963, p. 95). "Will permeates many other psychological activities. Even before sensation, there is an intention, a form of will. The mind watches over the body and selects those impressions over which it will be aware" (Watson, 1963, p. 95). This notion about the dominance of will is one that remains problematic when the present and future roles of neuropsychology are considered.

Augustine's Cell Doctrine of brain function would continue to influence neuropsychological thought for the next 1000 years (Walsh, 1978). Around the year 1504, Gregor Reisch, a Carthusian Monk, produced an encyclopedia which contained a woodcut which serves to validate the above statement. At the front of the first chamber, then considered to be the center of fantasy and imagination and now identified as the lateral ventricles, the senses of sight, smell, hearing, and taste converge into the *sensus communis* . The second cell or third ventricle, housed the faculties of cogitation and estimation. Memory was located in the fourth ventricle, or third cell according to the Doctrine. The name *vermis* , meaning worm, is given to the choroid plexus which connects the lateral and third ventricles.

Another illustration of this scheme, dated to 1501, is credited to Magnus Hundt and is remarkable for its inclusion of the *rete mirabile* , the structure erroneously attributed to humans by Galen over 1300 years earlier (Walsh, 1978). The illustration also includes the cranial nerves according to the early physician's descriptions as well as the sutures of the skull and layers of the scalp. Walsh (1978) quotes Magoun (1958) as interpreting the Cell Doctrine in the following manner:

> On passing to the brighter functional aspects of these early views, they first proposed that incoming information from a peripheral receptor was conveyed to a sensory portion of the brain, where it could be interrelated with other afferent data. Activity was thence transmitted to a more central integrative region, equivalently accessible to internal impressions related to sense and to general memory. Last, activity was capable of involving a motor portion of the brain, so as to initiate movement or behaviour. The sequential ordering of these Aristotelian faculties from the front to the back of the brain conveyed an implication that central neural function normally proceeded through such successive stages. Such conceptualization is not excessively different from that reached by Sherrington in his founding studies of modern neurophysiology nor from that which confronts us continually today (p. 8).

Thus far and with only a few exceptions, theories pertaining to the origins of man's behavior, even those that seem remarkably accurate when compared to modern models, were largely influenced by the dogma of the cultures and times in which they were originated (Walsh, 1978). However, in the middle of the sixteenth century, a new emphasis on careful, unadulterated, and systematic observations became prevalent within the scientific community. The work of Andreas Vesalius, a pioneer of this trend, has been considered by many to be "the most influential factor in establishing the modern era of observation and research" (Walsh, 1978, p. 10).

As a student of Sylvius, Vesalius was taught the ventricular hypothesis and even recounts in his writings copying Gregor Reisch's descriptions of the functions of the various chambers (Walsh, 1978). Clarke and O'Malley (1968) provide the following description taken from Vesalius' notes:

> Indeed, those men believed that the first or anterior, which was said to look towards the forehead, was called the ventricle of the sensus communis, because the nerves of five senses are carried from it to their instruments, and odors, colors, tastes, sounds, and tactile qualities are brought into this ventricle by the aid of those nerves. Therefore, the chief use of this ventricle was considered to be that of receiving the object of the five senses, which we usually call the common senses, and transmitting them to the second ventricle, joined by a passage to the first so that the second might be able to imagine, reason, and cogitate about those objects; hence cogitation or reasoning was assigned to the latter ventricle. The third ventricle (our fourth) was consecrated to memory, into which the second desired that all things sufficiently reasoned about those objects be sent and suitably deposited" (as cited by Walsh, 1978, pp. 10-11).

One can detect a little skepticism on Vesalius' part, making it clear that what he has just recorded is a belief held by figures who lived prior to the 1500's, perhaps a result of the large discrepancy between his own neuroanatomical work and the ventricular model of physiology accepted as truth at the time, a discrepancy that would last until the twentieth century (Walsh, 1978). Despite his near reverence for Galen, whom he considered to be "prince of physicians and perceptor of all" (Walsh, 1978, p. 11), Vesalius could not ignore his own findings which contradicted those recoded by the authorities of antiquity (Watson, 1963).

As mentioned above, Vesalius' specific contributions were in the area of anatomy and his visual illustrations, based on observations made of actual specimens, are characterized by unprecedented, exacting detail (Walsh, 1978, p. 11). In 1543, he published his strikingly modern anatomical masterpiece the "*De humani corporis fabrica*" along with its supplementary tome "*Epitome*" (Watson, 1963; Walsh, 1978), considered by many to be "the embodiment of the spirit of the Renaissance" (Walsh, 1978, p. 10). Despite the indubitable influence of Vesalius' work and methods on the scientific world, Watson (1963) notes "it was the scientific movement of the seventeenth century which gave us the modern world" (p. 131).

René Descartes, French mathematician, philosopher, and physiologist, helped usher in this seventeenth century scientific movement and is the man responsible for the first "systematic account of the mind/body relationship" (Wozniak, 1996). As a student of both math and philosophy, Descartes was aware of the marked dichotomy between the certainty of the methods and products of the two disciplines. He was convinced that the sciences were capable of producing results as certain as those of mathematics (Wozniak, 1996). After successfully combining the disparate mathematical fields of algebra and geometry into the unified discipline of analytic geometry, Descartes began pondering the notion that perhaps all areas of science could be combined. "Could not the method of analytic geometry be applied to other fields of knowledge in such a fashion as to make a unity of science?" (Watson, 1963, p. 141). Indeed, Descartes became firm in his conviction that, with respect to his unification of the sciences, "that it is more efficient to study them all together, than to deal with them one at a time" (Watson, 1963, p. 142).

A consequence of his combining scientific methodologies, Descartes argued against the syllogistic reasoning and dependence on experience traditionally used in science (Watson, 1963). Syllogism, he reasoned, is not suitable for the discovering of new knowledge, only for the clarification of previously accumulated knowledge. Except when analyzed with deductive methods, data gained through experience lacks methodological strength. The key to the acquisition of new knowledge, in Descartes' opinion, lay in mathematical deductions. "Mathematical deductions, starting as they do, from simple clear self-evident truths, cannot, in his view, go wrong" (Watson, 1963, p. 142).

In his work "Rules for the Direction of the Mind," the philosopher explains how to apply this mathematical method in a series of twenty-two rules (Watson, 1963). The four most important rules can be found in his later work "Discourse on Method." They include "(1) never accept anything as true which is not known clearly to be such; (2) divide difficulties into as many parts as possible; (3) proceed from the simplest and easiest to understand to the more complex knowledge; (4) make the connections so complete and the reviews so general as to insure that nothing is overlooked" (Watson, 1963, pp. 142-143).

It is among the pages of his "Discourse on Method" that Descartes, after putting forth the question of what, if anything, he could be absolutely certain about, draws the now famous conclusion "I think, therefore I am" (as cited by Watson, 1963, p. 144). According to his mind/body dualism, the immaterial mind, or rational soul, is likened to a flame or an ether that spread throughout but was distinctly different from the material body. Descartes discussed at length the two basic faculties of the mind, namely volition and understanding. From these two "powers," all other abilities of the mind were derived (Watson, 1963).

While often concerned with what the mind could do, Descartes did concede that this "free" entity is not without its limitations (Watson, 1963), and in so doing, pointed out the existence of a physiological dualism: The voluntary and involuntary divisions of the nervous system. "He held that the greater part of muscular action of the human body does not depend upon the mind at all. Beating of the heart, digestion, respiration, and even walking and singing are performed without the mind attending to them" (Watson, 1963, p. 152). "Descartes also used as an illustration of our unability to control the enlarging of the pupil by thinking, because nature has not made this connection but instead connected its movement with looking at far or near objects" (Watson, 1963, p. 152).

Descartes used the phrase *undulatio reflexa* in his descriptions of motion in the absence of volition (Watson, 1963). He proposed a mechanism for this automatic response to external stimulation which relied upon the flow of vital spirits and, despite the hypothesis' obvious inaccuracy, eventually led to his recognition as the founder of reflex theory (Watson, 1963; Wozniak, 1996). "According to his proposal, external motions affect the peripheral ends of the nerve fibrils, which in turn displace the central ends. As the central ends are displaced, the pattern of interfibrillar space is rearranged and the flow of animal spirits is thereby directed into the appropriate nerves" (Wozniak, 1996, chap. 1, sec. 1, p. 2).

The mind is not always aware of the shifting of the vital spirits (Wozniak, 1996), as in the case of the automatic responses described above. However, when the mind is aware of the shift, a conscious sensation is experienced. In response to the sensation, the mind may initiate a different outflow of spirits and give rise to a voluntary motion (Wozniak, 1996). Descartes' conception of the interaction between mind and body, and on a more specific level, mind and brain, was aptly referred to as interactionism and is not to be confused with the later theories of parallelism (Watson, 1963). In 1633, he completed his "*De homine*," recording for the first time the details of the theory, composing what was to be "the world's first extended essay on physiological psychology" (Wozniak, chp. 1, sec. 1, p. 1).

In order for any kind of interaction to occur between the utterly different mind and body, Descartes had to identify a place of contact, of mutual communication (Watson, 1963). He chose as this "seat of the soul" the pineal body, or epiphysis cerebri, a gland located posterior to the thalamus now believed to be involved in the secretion of the hormone melatonin (Watson, 1963; Glanze, Anderson, & Anderson, 1992). His choice was made based on the structure's strategic location with respect to the ventricles which, in keeping with the accepted theory, allowed it to affect and be affected by the flow of spirits (Walsh, 1978) and his erroneous beliefs that the gland is uniquely human and the only singular (ie. not bilaterally replicated) body in the brain (Watson, 1963; Wozniak, 1996).

It was at this point of conjunction where the various and separate sense modalities, each of which is made possible by repeated organs, came together before reaching the unitary mind. Walsh (1978) quotes Descartes as saying "it can easily be conceived how these images or other impressions could unite in this gland through the mediation of the spirits that fill the cavities of the brain. There is no other place in the body where they could be thus united unless it be in this gland" (pp. 12-13). The mind then has the option to act in response to the sensory input. This symmetrical mechanism is summed up by Watson (1963) in the following manner:

> The mind sometimes acts independently of the brain (as illustrated by innate ideas), sometimes in interaction with it. Thought, originating in the mind, may have consequences, such as movement. These movements are not thought, but activities of the body. In other instances the mind is present in what today might be called a sensory-motor process. In this

> instance, mind affects the machinery at the critical point of transmission from sensory to motor channels. In both kinds of mental activity-thought as such affecting the body, and sensorially derived functioning of the mind, in turn affecting the body-mind does not due so directly but by directing the vital spirits that pass from the heart through the brain to the muscles (pp. 153-154).

Descartes referred to "the passions" when he spoke about the effect of the vital spirits on the mind (Watson, 1963). These mental experiences, including emotions and perceptions, are made possible by the passivity of the mind rather than its activity. The active agents responsible for effecting these psychological phenomena are the vital spirits flowing within the brain. In this way, the body can influence the mind without prior environmental stimulation and in the absence of the mind's will to be affected. "Although sometimes the movements of the passions are accompanied by thought in man, they need not be so accompanied because they can arise in spite of his intentions" (Watson, 1963, p. 155).

In essence, Descartes is describing how intrinsic emotion, which modern neuroscience is attempting to understand in terms of biochemical reactions and electrical phenomena in the brain and body, can affect behavior, even overriding rational thought and judgment. He concedes that, in this, respect, humans act in the same manner as do other, "lower" animals, the only difference being the absence of the uniquely human passions (Watson, 1963).

> A comparison of emotion in man and animal is enlightening. A sheep fleeing from a wolf is not afraid since he is an automata, but he behaves in a way which we interpret as terror. This is because we are afraid when our body is in the same condition. In the same setting as that of the

> sheep, our body goes through the mechanical actions, but, since we have a mind, we experience passion due to the motions of the body (Watson,1963, p. 156).

Although the mind is activated during such an emotional response in that it is experiencing a passion, it is clearly not in control of "the motions of the body" (Watson, 1963, p. 156). Because the mind, according to Descartes, is the seat of human will, its passive role with respect to the action of the body in a scenario like the one described above makes the state of acting individual's will inconsequential. The individual who reacts to danger like the sheep reacts to the wolf cannot be said to have willed himself to run, at least initially. The notion of responsibility for one's actions is a volatile area of debate into which modern neuropsychology has been drawn. This subject will be investigated in a later section of this essay.

Watson (1963) points out that Descartes' description of how the mind is affected by the body, most notably the brain and the vital spirits contained therein, foreshadows the James-Lange theory of emotion. According to this theory, in an emotionally arousing situation, a physiological response, or, more precisely, a series of physiological responses, precedes the emotional experience (Pinel, 1997; Watson, 1963). After the body has reacted, the brain, Descartes' "mind," interprets the physiological responses and generates the appropriate emotion.

Descartes' ideas about the relationship between the mind and body would continue to have a profound effect on science for several centuries (Walsh, 1978; Watson, 1963; Wozniak, 1996). In the case of several of Descartes' followers, arguments were made which countered his interactionism, pushing the understanding of mind and body away from the direction of current thinking which Descartes foretokened so closely, though with quite different intentions.

Post-Cartesian logic held that "if the natural world is radically divided into the mental and the physical such that the physical is extended in space and the mental is not, and if the nature of causality is such that causes and effects must have a necessary connection and be of a similar type, then mind/body interactionism of the Cartesian sort is obviously untenable" (Wozniak, 1996, chp. 1, sec. 2, p. 1). To deal with this contradiction, Nicolas Malebranche, influenced by the work of Géraud de Cordemoy's "*Le discernement du corps et de l'ame* ," promulgated the idea of occasionalism (Wozniak, 1996). According to Malebranche, neither mind nor body can be causal. Rather, God is the only entity in the universe that is causally effective. In fact, he argued, God is true governor over all causality, producing all regularities which occur in nature. "Thus, for example, when a person wills to move a finger, that serves as the occasion for God to move the finger; when an object suddenly appears in a person's field of view, that serves as the occasion for God to produce a visual perception in the person's mind" (Wozniak, 1996, chap. 1, sec. 2, p. 2).

Geulincx, a contemporary of Malebranche's and fellow occasionalist, though he placed less emphasis on the role of God, advanced the theory of the "two clocks" which attempted to explain why the interaction between mind and body seemed so apparent (Watson, 1963). He envisioned two clocks that were so perfectly coordinated in their timekeeping that hearing one strike while reading another would cause the observer to draw a causal connection between them.

> This, he went on, is what happens with the mind and body. They are so perfectly tuned that events in one realm keep time with the other. On an occasion, such as in willing movements, though it is purely physical laws which cause movement and the will does not really act on the body, the will seems to cause movement (Watson, 1963, p. 157).

The theories put forth by the occasionalists were transient and limited in their influence on future thought (Watson, 1963). A more abiding response to Cartesian thought came from Benedictus de Spinoza (Wozniak, 1996). God retained an essential role as the one, true, universal cause, as espoused by the occasionalists, in Spinoza's paradigm. However, so that the mind and body could retain the property of causation, God was characterized as the single, universal substance (Wozniak, 1996), that is, God was the substance from which reality was and continues to be formed. As a result, body and mind could be seen as attributes of the one infinite substance, ie., God, and not the attributes of two finite substances as Descartes had proposed (Watson, 1963; Wozniak, 1996). Consequently, a man was thought of as a whole made up of two separate and equivalent qualities which do not share a causal relationship but are correlated in their activities (Watson, 1963; Wozniak, 1996).

Watson (1978) explains the relationship between mind and body posed by Spinoza in the following manner:

> Every bodily event coexists with, and is coordinate to, a mental event. Body and mind correlate, but they do not cause one another any more than the convex side of a glass causes the concave. In this connection Spinoza stated clearly that it follows that body cannot determine the mind nor can mind determine the body to motion and rest (p. 158).

Unlike Descartes as well as perhaps all scholarly figures up to this point, Spinoza denied the mind a free will and viewed it as a mechanism subject to the same natural laws as the body (Watson, 1963). Worthy of note is the support lended to many of the implications of Spinoza's deterministic view of the functionings of the mind by modern neuropsychology's current biologically based understanding of the physiology of the brain. Indeed, the notion that the electrical and chemical activities that take place within the brain follow the same physical laws that govern all of nature is undisputed.

Spinoza's theory, which has come to be known as monistic parallelism, is one of a number of post-Cartesian theories which rejected Descartes' belief in separate sources for mind and body, a two-substance view, and assumed a common fount for the two qualities, the essence of a double-aspect theory (Watson, 1963; Wozniak, 1996). Spinoza's concept, as its modern title "monistic parallelism" suggests, can also be described as belonging to the category of parallelistic theories, which have at their foundations separate but coordinated qualities. These two descriptive fields in which monistic parallelism can accurately be placed are not mutually inclusive as Spinoza's arguments would suggest.

One theory which psychophysical parallelism, usually accredited to Gottfried Wilhelm Leibniz continued the dualistic nature of mind and body as well as the exact coordination the events of each while avoiding all hypotheses concerning causality (Wozniak, 1996). "Psychophysical parallelism eschews interactionism on the grounds that events so totally dissimilar as those of mind and body could not possible affect one another. It also rejects occasionalism and dual-aspect theory on the grounds that not third entity, whatever that might be, could be responsible for such vastly different effects" (Wozniak, 1996, chp. 1, sec. 2, p. 2).

Leibniz's argument was founded in his notion of pre-established harmony (Watson, 1963). He denied the reality of matter by denying the extension of substance. Rather, substance exists as an infinite number of individual, unextended psychic entities he called monads. These monads have properties similar to that of a physical point and, when combined, formed an extension, thereby establishing a reason behind the appearance of an extension into reality if not a reason for an actual extension. When in an aggregate, the units act independently but in harmony, an attribute bestowed upon them by God at the time of their creation. The result of this flawless harmony is the appearance of interaction (Watson, 1963).

Leibniz claimed that monads, because of their activity, and the direct relationship between activity and consciousness, are the source of consciousness (Watson, 1963). Also, because all perceived matter was composed of monads, all matter, from living organisms to non-living material, has consciousness. The differences among forms of matter are the result of varying degrees of consciousness, with lifeless material having the lowest level of consciousness possible (Watson, 1963).

Wozniak (1996) offers a concise summarization of Leibniz's famous argument, an adaptation of Geulincx's "two clocks" (Watson, 1963) discussed earlier, supporting psychophysical parallelism and its underlying precept of pre-established harmony, which is recorded in his works "*Système nouveau de la nature*" and "*Enclaircissement du nouveau sisteme.*"

> Comparing soul and body to two clocks that agree perfectly, Leibniz argued that there are only three possible sources for this agreement. It may occur through mutual influence (interactionism), through the efforts of a skilled workman who regulates the clocks and keeps them in accord (occasionalism), or by virtue of the fact that they have been so constructed from the outset that their future harmony is assured (parallelism). Leibniz rejects interactionism because it is impossible to conceive of material particles passing from one substance to another and occasionalism as invoking the intervention of a Deus ex machina in a natural series of events. All that remains is parallelism -- the notion that mind and body exist in a harmony that has been pre-established by

God from the moment of creation (chap. 1, sec. 2, p. 2).

The current thinking in neuropsychology can accurately be called parallelistic in its form. Modern investigative techniques such as electroencephalography, positron emission tomography, computed tomography, pneumoencephalography, and magnetic resonance imaging have allowed researchers to observe even the most discrete physiological activities which correlate with very specifically defined behaviors. However, despite the extraordinary technology on which such techniques are based, science is still unable to identify the fundamental causes of what are presumably complex phenomena such as cognition and memory.

Lesion studies have enabled the localization of many of the normal brain's functions, however, a causal relationship between a structure and a function cannot be concluded. The plasticity of the brain, what is essentially the "learning," as opposed to a "relearning," of a lost function by a structure of the brain normally not associated with that function, invalidates such conclusions. Clearly, particular structures do not cause but rather house particular functions.

A schism exists in today's thought when the nature of the mind and body is in question. Neuropsychology dictates that all behavior, including thought and emotional responses, are the products of physical processes which have as their sources particular structures in the body: A dual-aspect theory. Those who reject the idea that the total of the human experience can be accounted for by physiological phenomena, perhaps citing neuropsychology's inability to explain completely the mental events which humans take for granted. These individuals hold that such events are actually due to an immaterial quality which cannot be simplified into physical components and processes. Whether this attribute is referred to as a soul with a divine origin or a mind which has as its source some yet unknown metaphysical reservoir, this stance clearly belongs with the two-subtance views.

In the late seventeenth and eighteenth centuries, the problem of describing a method by which the disparate human qualities of mind and body could interact was dealt with by avoidance of the situation altogether (Wozniak, 1996). This single strategy, however, lead to two distinct schools of thought: Materialism and immaterialism. Materialism is based on the presumption that matter is the fundamental which makes possible the existence of all things including a mind or soul.

> In its most extreme version, materialism completely denies the existence of mental events, a view which would appear to have its roots in Descartes' conception of animals as purely physical automata. In a less extreme form, materialism makes mental events causally dependent on bodily events, but does not deny their existence (Wozniak, 1996, chp. 1, sec. 3, p. 1).

Primarily a political philosopher and best known for his contribution of psychological hedonism to the social sciences, Thomas Hobbes, chronologically the first English empiricist, had a materialistic view of humanity which was influenced by Galileo's conceptualizations concerning motion (Watson, 1963).

The relationship between brain and behavior, as described by Hobbes, now labeled as materialistic monism (Wozniak, 1996), is remarkably similar to the basic premise on which modern neuropsychology is based: All behavior, including mental behavior, has its origins in the physical world.

> Hobbes held that everything that happens is matter in motion; mental activities are motions of the nervous system arising as reactions to motions on the external world. Thinking is, in reality, nothing more than movement excited in the brain. Motions account not only for cognitive

processes but also for action and emotion. Everything in nature is material. Thinking implies a thinking thing, just as walking implies a walking thing; in both instances this thing is the body (Watson, 1963, p. 165).

Hobbes' empiricist ideations are epitomized by his disbelief in the importance of innate thoughts and claim that all mental events are the result of experiences (Watson, 1963). Complex experiences can be broken down into simpler units which are the products of sensation. It is ultimately from sensation, according to Hobbes, that all human cognitive powers are derived. Whenever we manipulate these sensory experiences through cognition, we subvert their integrity. "For example, imagination and memory are 'decaying' conceptions in that they are slowly fading sensations" (Watson, 1963, p. 166).

Hobbes also emphasizes what he described as motions which emanate from within man, the passions, the concept of which was introduced by Descartes, as having great influences on human behavior (Watson, 1963). The passions could be separated on one level into appetites and aversions and further into those with which we are born and those which we acquire through experience. When discussing these passions, Hobbes makes clear their potential to influence, and in some cases dominate, reason. "As a consequence, passions are regarded as infirmities of man" (Watson, 1963, p. 166). When humans contemplate decisions, they are merely choosing between the appetites and aversions, the pleasures and pains, which are the primary governors of their conduct (Watson, 1963). Hobbes' continued influence on science is clear to anyone who is familiar with the psychological school of behaviorism.

The materialistic views of Julien Offray de la Mettrie (1709-1751), along with the publication of a medical satire in 1745 entitled "*Histoire naturelle de l'ame*," earned him such infamy in his native France that he fled to Holland (Wozniak, 1996). In 1748, while still in Holland, he penned his "*L'homme machine* " which places man among Descartes' automata. In this work, La Mettrie argues for a "uniform material dependence of states of the soul upon states of the body" while maintaining "a distinctly antimetaphysical tone" (Wozniak, 1996, chp. 3, sec. 2, p. 1). He also suggests that the sole aspect which differentiates voluntary behavior from instinctual behavior is the complexity of their respective, elementary, physical processes. Blaspheme of this degree was not acceptable even in the tolerant atmosphere of Holland and the book was publicly burned. La Mettrie was forced to flee to Berlin. Here, under the protection of Frederick the Great, he continued to produce works which strongly challenged commonly accepted religious dogma (Wozniak, 1996).

Despite the religious establishment's many, often successful attempts to supress his ideas, Le Mettrie was not without followers among whom was Pierre Jean Géorges Cabanis (1757-1808) (Wozniak, 1996). Cabanis, perhaps the most fervid materialist of the French enlightenment, argues Le Mattrie's ideas to the extreme in his "*Rapports du physique et du moral de l'homme* ." In it, he states that "'to have an accurate idea of the operations from which thought results, it is necessary to consider the brain as a special organ designed especially to produce it, as the stomach and the intestines are designed to operate the digestion, (and) the liver to filter bile...'" (as cited in Wozniak, 1996, chp. 2, sec. 3, p.2).

In direct opposition to the materialistic view of human psychology, the linear ancestor of modern neuropsychological models, was the school of immaterialism which denied the importance of any physical aspect of human existence, (Wozniak, 1996). George Berkeley (1685-1753) held an extreme position within this school which has since been given the name mentalism (Watson, 1963; Wozniak, 1996). As a deeply religious man, he was aware of the danger that materialism posed to the church (Watson, 1963). One aim of his arguments was the renunciation, by all people, of "the belief in the primordial character of matter which made it possible for impious persons to deride immaterial substance, to consider the soul corruptible, and even to deny providence" (Watson, 1963, p. 178).

In 1709, Berkeley published his "An Essay Towards a New Theory of Vision," his first work dedicated to his mentalistic ideas (Watson, 1963). He made a more forceful but balanced statement the following year in "A Treatise concerning the Principles of Human Knowledge" (Wozniak, 1996). In these documents, Berkeley denies even the possibility that matter can exist without a mind perceiving it. Indeed, the only things that can exist are minds and objects which are perceived by minds (Wozniak, 1996).

Because he emphasized the importance of perception, stating that perception and reality are one in the same, he is accurately classified by some as a phenomenologist (Watson, 1963). He questioned the validity of explanations of mental events which relied upon references to the physical world, posing queries like how are the smell and the color of a rose experienced together and what unifies the collected experiences of an individual mind. In Berkeley's view, the underlying cohesive of mental events is the soul (Watson, 1963).

If man is the experiencer of mental events, the ultimate active cause of these events is God, or, in Berkeley's words, the "Permanent Perceptor." God's eternal perception of the universe allows for the continued existence of physical objects. The following limerick, sent to Berkeley by Ronald Knox, and Berkeley's response, also in the form of a limerick, clearly illustrate this notion.

There was a young man who said, "God
Must think it exceedingly odd
    If he finds that this tree
    Continues to be
When there's no one about in the quad."

Dear sir:
    Your astonishment's odd:
I am always about in the quad.
    And that's why the tree
    Will continue to be,
    Since observed by
        Yours faithfully,
            God (Watson, 1963, p. 180).

While Berkeley's arguments hinged on mental events as the only knowable phenomena, John Locke (1632-1704) saw such processes as the product of environmental stimulation. He conceded not only the existence of, but also the importance of, matter yet maintained a dualistic view of man. Perhaps Locke's most well-known contribution to psychology, and in a less direct way, neuropsychology, is his advocacy of the notion of the human mind as a blank slate, a *tabula rasa* as it had been called by Aristotle (Watson, 1963).

Locke held that innate, universal ideas are nonexistent, for if they are real, why then are children and developmentally disabled adults without them? To explain what seemed to be clear evidence of at least a few congenital mental concepts, he employed an argument centered around habitual mechanisms. For example, when a child is told something repeatedly by his caregivers, he accepts that thing as being true. As an adult who has lost the ability to recall when and from what source a particular belief was drawn, the individual concludes that he or she has held that position since birth (Watson, 1963).

Locke, in response to an accepted analogy at the time comparing a child's mind to a pantry filled with innate ideas, referred to the young mind as "'the yet empty cabinet'" (Watson, 1963, p. 172). Experience stocks the mind with ideas, and experience has as its progenitor sensation. "Sensing takes place when the impression from the sense organs is transmitted to the mind. These sensations are simple ideas. In receiving simple ideas, the mind is essentially passive; it must sense when it senses and cannot refuse impressions or blot them out" (Watson, 1963, p. 172).

Modern psychology takes for granted the notion that a child's environment plays a significant and necessary role in his or her development on a number of levels. In 1979, Urie Bronfenbrenner reacted to traditional studies in child development, which isolated the participants from the surroundings to which they were accustomed and therefore were unable to observe the interactions of child and environment, by creating an ecological theory of development (Hoffman, Paris, & Hall, 1994). He described developmental psychology with its conventional methods as "'the science of strange behavior of children in strange situations with strange adults for the briefest possible periods of time'" (Hoffman, Paris, & Hall, 1994, p. 47).

Lev Vygotsky's (1978) socio-historical theory defines knowledge as a creation of society which is passed on by means of social interaction (Hoffman, Paris, & Hall, 1994). Because, according to the theory, thoughts are generated as one experiences socially structured activities, the settings in which children normally function are the principal sources for understanding processes of mental development. Vygotsky emphasized the importance of social interaction in learning with his concept of the zone of proximal development, the area in which all "good learning" takes place (Hoffman, Paris, & Hall, 1994).

On a more fundamental level, sensory and social experience have been shown to have essential roles in normal motor development. In 1990, American psychologists were given the opportunity to study the effects of long-term isolation on child development (Hoffmann, Paris, & Hall, 1994). "They found that when youngsters are ignored by adults and surrounded by an unstimulating environment, the children show retarded motor development from the time they are two months old" (Hoffman, Paris, & Hall, 1994, p. 129).

Even when investigated at the cellular level using the sophisticated tools of the twentieth century, support is found for the postulate made by Locke almost 400 years earlier, albeit with a materialistic twist.

> The mature brain is precisely wired to process sensory information into coherent patterns of activity that form the basis of our perception, thoughts and actions. This precise wiring is not fully developed at birth, however. The patterns of connections that emerges as a result of cell recognition events during prenatal development only roughly approximates the final wiring. This initially course pattern of connections is subsequently refined by activity-dependent mechanisms that match precisely the presynaptic neurons to their appropriate target cells. This activity-dependent matching can be modulated by normal or aberrant sensory experience. As a result, at critical stages of postnatal development the integrative action of the brain, and at the cellular level

the detailed wiring of the brain, is dependent upon specific interactions between the organism and its environment (Kandel, Schwartz, & Jessell, 1991, p. 945).

Influenced by Locke and Newton and a contemporary of Hume, David Hartley (1705-1759), best known for his systematic organization of earlier theories, returned to physiology as the basis of his own conception of human mental functioning (Watson, 1963). After giving up on his original career goal of becoming a clergyman because of qualms he had with religious doctrine, he found that life as a medical practitioner suited him. The initial heading in his 1749 work "Observations on Man" seems to reflect this peculiarity of his past: "'Man Consists of Two Parts, Body and Mind'" (Watson, 1963, p. 189).

After setting up the dualistic framework of his theory, Hartley stresses the importance of studying both aspects of man's nature for they must, in some way, be related (Watson, 1963). He describes the mental and physical mechanisms in two separate propositions, each dealing with one attribute independently. "Thus, one proposition states that sensations, often repeated, leave certain vestiges which may be called simple ideas. The companion proposition holds that sensory vibrations, being often repeated, leave in the brain a disposition for minute vibrations" (Watson, 1963, p. 190).

Using Newton's work on motion which speaks of physical impulses in terms of vibrations, Hartley believed that environmental stimuli reaches the white matter of the brain as vibrations and in turn sets the white matter in motion (Watson, 1963). These vibrations travel along nerves, which, he suggested, are solid, a form that facilitates the transmission of the waves better than the traditional tubal form (Watson, 1963).

Vibrations in the cortex correlate perfectly with ideas, defining a parallel relationship between physical and mental events rather than a causal one, a characteristic which denotes the theory as a type of psychophysical parallelism (Watson, 1963). Because of this invariable relationship, Hartley argued that without external stimulation, there can be no sensations and without sensations there can be no ideas. As a result, he found himself agreeing with Locke's analogy of a blank slate for the mind at birth. Watson (1963) describes the succession of mental phenomena in the following manner:

> Simple sensations supply all states of consciousness. Sensations are internal states of the mind arising from impressions made by external objects; all other internal states are ideas. Ideas are fainter vibrations of the brain substance occurring when the vestiges of former vibrations are stimulated. Sensations and ideas fundamentally are the same, differing only in degree of intensity (p. 190).

Hartley described memory, emotion, reasoning, and both voluntary and involuntary actions in terms of his law of association, a law pertaining to the temporal relation, either simultaneous or successive, between or among vibrations (Watson, 1963). A memory, for example, is the result of an enduring vibration in the brain following a sensation. After experiencing simultaneous or successive sensations, a connection is made between or among the sensations such that when one sensation is reactivated, those that are linked to it are activated and are manifested as ideas (Watson, 1963).

As it is described above, the resemblance between Hartley's model of memory and the model posed by Collins and Quillian in the late 1960s is clear (see Ashcraft, 1994). These twentieth century researchers suggest that long-term memory is organized into a network of interconnected nodes, or concepts. The connections, referred to as pathways, vary in length and immediacy in direct proportion to the strength of the relationship between the two nodes which they connect. When a particular node is activated, that is, when a concept that is already incorporated into the network is experienced as a sensation, the activation spreads across the pathways and activates other nodes. The first nodes to be reached and therefore energized by this activation are those linked by the shortest pathways, the most closely related to the primary node (Ashcraft, 1994). The detection of deficits in cognitive processes has become a considerable function of present-day clinical neuropsychology.

Hartley's ideas reemphasized man as a sum of two separate yet interactive constituents (Watson, 1963). His Associationism made possible the explanation of mental activity in mechanistic terms and moved the field one step closer to mental atomism (Watson, 1963), or, in current scientific jargon, reductionism, modern neuropsychology's dominating premise. The introduction of faculty psychology, based on the division of mental processes into discrete, specialized units, brought the field even closer to its present state.

Ironically, a direct source used heavily by the founders of faculty psychology were the works of three Scottish philosophers, Thomas Reid (1710-1792), Dugald Stewart (1753-1828), and Thomas Brown (1778-1820), who, seeing the theories of Hartley and others as damaging to man's true nature, were determined to return man to his proper, lofty place in creation as dictated by religious dogma (Watson, 1963; Walsh, 1978). The three spurned any theory which linked human behavior to physiology with the exception of associationism which they modified to fit their own agendas (Watson, 1963).

Brown conceded that the mind was a combination of elements, but "there was a unity of an operating, controlling self, quite apart from the action of what his predecessors had called association" (Watson, 1963, p. 192). Although he followed closely the associationists that came before him, he rejected the school's title and advanced his own "laws of suggestion." The primary laws took into consideration the similitude, contrast, and nearness in space and time of two sensations.

Variations on these limited properties were accounted for by the secondary law which included the following factors: "Duration, liveliness, constitutional differences of mind or of temperament, differing circumstances of the moment, state of health or efficiency of the body, and prior habits" (Watson, 1963, p. 193). Worth of special regard is Brown's inclusion of the mental state of the observer as a modifier of perception, a phenomenon that is very familiar to psychologists, especially to those in the sub-discipline of sensory psychology.

Interestingly, Brown can also be credited with providing a rudiment for the current field of cognitive psychology. Watson (1963) notes "Brown's recognition of a capacity to grasp relations of varying complexity, as a complement to learning simple association, was a contribution of some originality, anticipating the day when combination of simple mental elements would be recognized as insufficient to account for learning and perception" (p. 193).

"Reid and Stewart also did much to maintain an acceptance of faculty psychology, so little different from the position of Wolff...as to require no exposition" (Watson, 1963, p. 192). "In founding the system which came to be known as phrenology, Gall leaned heavily on the lists of faculties provided by the Scottish philosophers" (Walsh, 1978, p. 13).

Franz Joseph Gall (1758-1828) was impressed as a child by what seemed to be correlations between his friends' talents and their unique cranial characteristics (Wozniak, 1996). In 1796, he began giving lectures on his "cranioscopy" in Vienna but was soon forced to leave the city on the grounds of his materialism. He arrived in Paris some years later and was joined by Johann Gaspar Spurzheim (1776-1832) (Wozniak, 1996) "who in fact coined the term 'phrenology' and was to develop a moralizing version of Gall's ideas which was to become as keenly supported as it was contested" (Walsh, 1978, p. 13). Together they published the "*Anatomie et physiologie du système nerveux en général* ," the most significant contribution to neuroanatomy ever made by Gall (Wozniak, 1996).

Gall's cranioscopy was a method of localization by which attributes of an individual's character are "read" via cranial elevations and depressions (Wozniak, 1996). The validity of this technique rests on three assumptions: The shape of the cranium reflects accurately the shape of the brain, the characteristics being read, which amount to personality traits in the modern vernacular, are intrinsic and fixed, and the degree to which each attribute was developed was proportional to the size of the corresponding cerebral organ. Despite the eventual rejection of all three of these assumptions and therefore Gall's entire theory, "it was Gall who lay the foundations for the biologically based, functional psychology that was soon to follow" (Wozniak, 1996, chp. 1, sec. 5, p. 1). By describing the cortex as the general location for his faculties, he placed a new focus on this highly evolved division of the brain which, until this time, was largely ignored (Walsh, 1978). Marie-Jean-Flourans (1794-1867), Gall's strongest opponent, credited Gall with fully establishing, for the first time, the brain as the seat of the mind (Wozniak, 1996).

In his "*Recheres expérimentales sur les propriétés et les fonctions du système nerveux* ," Flourens illustrated "the first experimental demonstration of localization of function in the brain" (Wozniak, 1996, chp. 1, sec. 5, p. 2). Unlike previous researchers who utilized a trephining technique when attempting to locate damage which made localization of function impossible, Flourens removed the skull covering the portion of the brain to be removed and isolated it completely. "Taking care to minimize operative trauma and post-operative complications, he employed ablation to localize a motor center in the medulla oblongata and stability and motor coordination in the cerebellum" (Wozniak, 1996, chp. 1, sec. 5, p. 2).

When experimenting on the cortex, Flourens, whose subjects consisted mainly of birds, found that systematic lesioning of the cerebral hemispheres effects deficits in all higher functions (Wozniak, 1996; Walsh, 1978). The degree of deficiency varies according to the amount of damage inflicted, not to its location. Normal functioning can be restored if enough intact tissue remains but a permanent loss of the higher functions results from total ablation. He concluded that the basal sensory and motor functions are localized on a sub-cortical level, but the higher mental functions including volition, perception, and intellect are spread evenly throughout the cortex and operate in a unitary fashion (Wozniak, 1996). "His work anticipated the notion of equipotentiality, the ability of other parts of the brain to take over the functions of damaged neural tissue. Flourens stated quite clearly that he did not believe that the nervous system was a homogeneous mass but he did believe that it operated in a concerted, integrated fashion unlike the theory of discrete localization" (Walsh, 1978, p. 14).

Flourens' conclusions fueled his attack on Gall's principle of localization of function which lay at the base of his cranioscopy (Wozniak, 1996). In rebuttal, Gall noted that the experimental procedures utilized by Flourens "'mutilates all the organs at once, weakens them all, extirpates them all at the same time"' (as cited in Wozniak, 1996, chp. 1, sec. 2, p. 2). Unfortunately for the field, this ongoing and highly visible controversy, which "one writer refers to as the controversy between the skull palpators and the bird brain ablators" (Walsh, 1978, p. 15), eclipsed the valuable observations being made by other brain-behavior researchers "because of their association in people's minds with one or other side of the controversy" (Walsh, 1978, p. 15).

Walsh (1978) notes, as examples, that "Bouillaud in 1825 pointed out the frequent association of loss of language with lesions of the anterior or frontal lobes but clouded the contribution by stating that this could be taken to support Gall's contention that the faculty of language lay in this region" (p. 15). "Even when Dax read a paper in 1836 clearly relating the left half of the brain with aphasia it remained unpublished until his son brought it forward 25 years later" (p. 15).

At the same time as Gall and Flourens were exchanging criticisms, political economists and social theorists, James Mill (1773-1836) and his son John Stuart Mill (1806-1873), were leaders among the Utilitarians, the school which virtually controlled British philosophy in the early 1800s (Watson, 1963). The overriding principle of this school, as it was advanced by Jeremy Banthem (1748-1832), was that the sum of human behavior had as its impetus usefulness to self. As a result, all actions, political, legal, social, etc., have, as their ultimate ends, "the acquisition of pleasure or the avoidance of pain" (Watson, 1963, p. 194). Modern philosophy and psychology each have names for this basic premise: Psychological egoism and operant conditioning, respectively.

According to the senior Mill, all complex phenomena of the mind are composed of simpler ideas and sensations (Watson, 1963). Watson (1963) summarizes a drawn-out illustration utilized by Mill.

> The complex idea of wall is made up of ideas of brick, mortar, position, and quantity. Complex ideas of plank, wall, and nail united with ideas of position and quantity compose an idea of floor. In similar fashion glass,

> wood, and the like give a complex idea of window. These ideas united together give the even more complex idea of a house. After progressing through furniture and merchandise, Mill reaches the most complex idea of all, the idea of "everything" made up of these and all other ideas (pp. 194-195).

He argued against the importance of any synthesizing process and the unessential pursuit of its study. With Mill, associationism was carried to a mechanistic extreme (Watson, 1963).

John Stuart Mill, the son of James Mill, reacted strongly against his father's atomistic theory and described the mind as an active agent and not just a storehouse for experiences (Watson, 1963). Asserted that the process of unification was of great importance in that the emerging compound was not the same as the sum of the initial parts (Watson, 1963). This sentiment, which Wundt would later refer to as creative synthesis (Watson, 1963) has remained intact to the present day, but when used by adherents to the dominating mechanistic view, has a slightly different significance. "This statement in no way implies a vital force but rather recognizes that integration of an enormous number of individual physical and chemical events occurring at all levels of organization is required for biological systems to function" (Vander, Sherman, & Luciano, 1994, p. 2).

Along with John Stuart Mill, Alexander Bain (1818-1903) edited and annotated the elder Mill's "Analysis of the Phenomenon of the Human Mind," adding explanatory notes which detailed the text's original associationistic scheme and introduced revisions and modifications of the system (Watson, 1963). Of the content of his books, which include once standard psychological texts "The Senses and the Intellect" (1855) and "The Emotions and the Will" (1859), "Bain was the first English writer of note to make considerable use in his psychology of physiological material, including the reflex" (Watson, 1963, p. 197; Wozniak, 1996).

His writings place him among the psychophysical parallelists but his personal conviction was that of a monist, believing that mind and body were one (Watson, 1963). Perhaps his caution is justified in a period in which the church had much influence, enough, it is said, to see to it that, prior to the publication of his highly praised books, he was not given a position by any of the numerous educational institutions to which he applied. The aim of his work was to reformulate associationism so that it could serve as the basis of a new psychology based on physiology (Watson, 1963).

Wozniak (1996) quotes Young's (1970) summary of Bain's view on human behavior:

> " 'Action is a more intimate and inseparable property of our constitution than any of our sensations, and in fact enters as a component part into every one of the senses, giving them the character of compounds...' (Bain, 1868, p. 59)...Spontaneous movements are a feature of nervous activity prior to and independent of sensations. The acquired linkages of spontaneous movements with the pleasure and pains consequent upon them, educate the organism so that its formerly random movements...(are) adapted to ends or purposes. Bain defines volition as this compound of spontaneous movements and feelings. The coordination of motor impulses into definite purposive movements results from the association of ideas with them (p. 115)" (chp. 1, sec. 5, p. 3).

Bain's ideas formed a rational framework for a physiological basis of higher mental faculties (Wozniak, 1996). However, Bain himself never formulated a sensory-motor account of the functions of the cortex as he concluded, along with others, based on the region's apparent lack of the ability to respond to stimuli, that "whatever the function of the cerebrum...it could not be sensory-motor" (Wozniak, 1996, chp. 1, sec. 5, p. 3).

Herbert Spencer (1820-1903) published "The Principles of Psychology" in 1855, the same year that Bain published his "The Senses and the Intellect" (Wozniak, 1996). This book, a deeply involved and difficult text, establishes a foundation of psychology in evolutionary biology. From three basic tenets of evolution, adaptation, continuity, and development, Spencer drew logical conclusions about the localization of function in the cortex. Psychology, in his view, is a biological science centered around adaptation of an organism to its environment. Wozniak (1996) quotes Spencer as saying " 'all those activities, bodily and mental, which constitute our ordinary life...(as well as) those processes of growth by which the organism is brought into general fitness for those activities' (p. 375) consist simply of 'the continuous adjustment of internal relations to external relations (p. 374)'" (chp. 1, sec. 5, p. 4).

Spencer concludes from his evolutionary concepts that the brain is the extreme example of evolutionary development and the cortex is the brain's most sophisticated level (Wozniak, 1996). It follows logically that the organ is heterogeneous, differentiated and complex. Being that the cortex is a continuation of the underlying structures which have been shown to operate on sensory-motor principles, the cortex must also operate according to these principles.

> Finally, if higher mental processes are the end product of a continuous process of development from the simplest irritation through reflexes and instincts, there is no justification for drawing a sharp distinction between mind and body. The mind/body dichotomy that for two centuries had supported the notion that the cerebrum, functioning as the seat of higher

> mental processes, must function according to principles radically different from those descriptive of sub-cerebral nervous function, had to be abandoned (Wozniak, 1996, chp. 1, sec. 5, p. 5).

In his "Principles," Spencer makes a bold and challenging statement that predicts the tone of all neuropsychology from that point on.

> No physiologist who calmly considers the question in connection with the general truths of science, can long resist the conviction that different parts of the cerebrum subserve different kinds of mental action. Localization of function is the law of all organization whatever...every bundle of nerve-fibres and every ganglion, has a special duty...Can it be, then, that in the general hemispheric ganglion alone, this specialization of duty does not hold (Wozniak, 1996, chp. 1, sec. 5, p. 5).

In the new atmosphere created by Spencer's conclusions, Paul Broca (1824-1880) added clinical support to the notion of localized cortical functions (Wozniak, 1996). Spurred on by cases cited by Ernest Aubertin, the son-in-law of Bouillaud, mentioned above, who swore that he would abandon the localization theory if one case of apahsia was found in which the patient did not suffer from a frontal lobe injury, he awaited his chance to participate in the challenge (Wozniak, 1996).

The waiting quickly paid off for within one week, Broca was studying the brain of M. Leborgne, ie. Tan, an aphasic, hemiplegic patient who died on Broca's surgical ward as a result of gangrene (Wozniak, 1996). He published his findings, a superficial lesion located in the left frontal lobe, in the journal Bulletins de la société anatomique de Paris in 1861. This observation was soon confirmed by a similar case (Walsh, 1978; Wozniak, 1996). A careful investigator, Broca wondered if a more precise localization was possible, thereby allowing the issue to remain open for further research.

Clarke and O'Malley (1968), according to Walsh (1978), cite Broca as saying

> " 'It is a much more doubtful question to know if the faculty of articulate speech is dependent upon the whole anterior lobe or particularly upon one of its convolutions; in other words, to know if the localization of cerebral faculties happens by faculty and by convolution, or only by groups of faculties or by groups of convolutions. Further observations must be collected with the object of solving this question. It is necessary for this purpose to indicate exactly the name and place of the diseased convolutions and, if the lesion is very extensive, to seek, wherever possible by anatomical examination, the place or rather the convolution where the disease appears to have begun"' (p. 15).

Even after accruing the consistent findings of eight cases, he refrained from drawing a definite conclusion. "Finally, in 1885, Broca published his famous dictum which was to become such a landmark in the history of brain function - 'Nous parlons avec l'hémisphère gauche'" (Walsh, 1978, p. 16).

The first experimental evidence of localized functions in the cortex was presented in the "*Archiv für Anatomie, Physiologie, und wissenschaftliche Medicin* ," published in 1870 through the combined efforts of Gustav Theodor Fitsch (1838-1927) and Eduard Hitzig (1838-1907) (Wozniak, 1996). The work also voided the traditional objection to localization based on cerebrum's failure to exhibit irritability following stimulation. By stimulating the hemispheres of a dog's brain using electricity, the two researchers produced "conclusive evidence that the circumscribed areas of the cortex are involved in movements of the contralateral limbs and that ablation of these same areas leads to weakness in these limbs" (Wozniak, 1996, chp. 1, sec. 5, p. 6). The electrophysiological technique of cortical stimulation quickly became and has remained a standard among neuropsychology's experimental tool's (Wozniak, 1996).

Concurrent with Fritsch and Hitzig's work, John Hughlings Jackson (1835-1911) was developing his concept, based on the principles of evolution, of cerebral localization of function (Wozniak, 1996). "This conception was, of course, developed under the inspiration of Spencer. As Young (1970) describes it, "Spencer's principles of continuity and evolution provided Jackson with a single, consistent set of variables for specifying the physiological and psychological elements of which experience, thought, and behaviour are composed: sensations (or impressions) and motions. All complex mental phenomena are made up of these simple elements -- from the simplest reflex to the most sublime thoughts and emotions. All functions and faculties can be explained in these terms" (Wozniak, 1996, chp. 1, sec. 5, p. 6).

Jackson's theory was confirmed by the experiments carried out by his friend and collegue Daid Ferrier (1843-1928) (Wozniak, 1996). By extending Fritsch and Hitzig's work, Ferrier tested Jackson's notion of the sensory-motor organization of the cortex. Using precise ablations and the advanced faradic technique of electophysiological stimulation, he successfully mapped the sensory and motor areas of the cortices of a number of species. He brought the results of this research together in his 1876 publication "The Functions of the Brain" in which he confirmed the "installation of sensory-motor analysis as the dominant paradigm for explanation in both physiology and psychology" (Wozniak, 1996, chp. 1, sec. 5, p. 7).

Two years prior to Ferrier's publication of "The Functions" and "several years after Broca's demonstration of the importance of the left posterior frontal region for spoken language Wernicke described a case where a lesion of the left superior temporal gyrus caused difficulty in the comprehension of speech" (Walsh, 1978, p. 16).

Walsh (1978) quotes Geschwind's summary of Wernicke's significant, but often overlooked, role in the understaning of brain function:

> "Wernicke was one of the first to see clearly the importance of the connections between different parts of the brain in the building up of complex activities. He rejected both of the approaches to the nervous system which even today are often presented as the only possible ones. On the one hand, he opposed the doctrine of equipotentiality of the brain; on the other, he rejected the phrenological view which regarded the brain as a mosaic of innumerable distinct centers. He asserted that complex activities were learned by means of the connections between a small number of functional regions which dealt with the the primary motor and sensory activities. Although this third view dominated research on the neurological basis of behaviour for a period of nearly fifty years, it has been omitted almost entirely form the discussions of the higher functions in recent times" (p. 17).

Building upon a rich, thoughtful, and often turbulent history, researchers of the early twentieth century redefined the field of neuropsychology.

With the firm establishment of a physiologically based model of the mind established by the work of Jackson and Ferrier and confirmed by the clinical observations of Broca and Wernicke, researchers of the late 1800's and early 1900's began looking for new ways to study the brain directly. One new development in neurohistology, referred to as cytoarchitectonics, is "the study of the architecture of cells or the disposition of cells and their type and density in the layers of the cortex" (Walsh, 1978, p. 17). This sub-field is grounded in techniques for creating fixed perparations of nerve tissue and staining the tissue to improve visibility under a microscope (Kandel et al, 1991; Walsh, 1978). One contributor to the investigation into cytoarchitecture was Camillo Golgi who invented a method of impregating neurons with silver salts, allowing the the anatomy of the entire cell, including the soma, dendrites, and axons, to be seen under a light microscope (Kandel et al, 1991, Purves et al, 1997).

Using Golgi's staining technique and a light microsope, Santiago Ramón y Cajal observed and labeled different cells within the system (Kandel et al, 1991; Purves et al, 1997; Walsh, 1978). He showed that nerve cells are separated by synapses and are not connected by protoplsmic links as suggested by the reticular theory of cell communication (Purves, 1997). Largely as a result of this finding, Cajal argued in support of the Neuron Doctrine which states that the nervous system is composed of discrete functional units, the neurons, which make a communicative connection at specialized points called synapses (Kandel et al, 1991). Cajal also suggested that the tips of the axons, known as growth cones, are the bodies responsible for guiding axons to their targets in a developing nervous system (Kandel et al, 1991).

Walsh (1978) comments on the significance of the conclusions drawn by Cajal and his fellow neuroanatomists:

> Soon after the development of these techniques of neurohistology by Ramon y Cajal and others it became apparent that the composition of the cortex was not everywhere the same and the discovery that the cortex could be subdivided into differently composed areas invited the possible inference that differences in structure might mean differences in function. Again the relationship between morphology and function could be demonstrated for the sensory and motor areas of the cortex which left the

> tantalizing possibility that the same might hold for higher functions. Though few such relationships have been found to date this story is nt yet concluded (p. 18).

The second major development in neurohistology, myeloarchitectonics, was championed by Flechsig (1849-1929) who found a correlation between the myelinization of developing axons and the development of particular cortical areas (Walsh, 1978). This finding suggests that higher mental functions are the product of interactions taking place between the cortex and subcortical systems rather than of the cortex alone (Walsh, 1978).

In 1905, Campbell devised a map of the cortex which differentiated 20 regions based on histology (Walsh, 1978). His aim, as the title of his work "Histological Studies on the Localization of Cerebral Function" implies, was to correlate the regions with their functions. Brodmann, a name with which all neuroanatomists are familiar, assembled his map of 50 discrete zones. Later maps divided the cortex into more than 200 histologically, and presumably functionally, different regions. Walsh (1978) quotes Milner's (1970) comment on the increasingly detailed mapmaking trend:

> "The difference between many adjacent regions in these later maps were so small as to be imperceptible to all but the anatomists who first described tham. This problem was pointed out by Lashley and Clark (1946), who found only a few regions of the cortex that they could recognize from anatomical sections alone if they did not know beforehand what part of the cortex the sections had come from" (p. 18).

Along the anatomical plan put forth by Brodmann, known widely as Brodmann's areas, the earliest plot of the cortex which delineated six large sections, or lobes, and named them named after the bones of the skull beneath which they lay remains current in its use (Walsh, 1978). Students of the brain, from unversed undergraduates to veteran researchers, are familiar with and utilize this scheme. However common, this system is not without its adversaries. Critics have stressed the abstract nature of this scheme. But, as Milner (1970) points out, again, according to Walsh (1978), "'as far as the psychologist is concerned the acid test of (any) such subdicisions is whether or not they can be shown to mean anything behaviorally. Does a lesion of an anatomically or physiologically defined area produce a more isolated and clear cut behavioral disturbance than a lesion that ignores such boundaries?'" (p. 18). Walsh (1978) goes on to say that "a century of lesion studies has demonstrated that these abstractions, the 'lobes' of the brain, are still more useful at this stage in discussing brain-behaviour relationships than those based on the finer subdivisions of cytoarchitecture" (p. 18).

Wilder Penfield continued the tradition of the neurocartographers with his sytematic explorations of the postcentral gyrus, also known as the primary somatosensory cortex or Brodmann's area 3a, and the precentral gyrus, or primary motor cortex or Brodmann's area 4, in the late 1930s (Pinel, 1997; Purves, 1997). Using electrical techniques, Penfield stimulated very specific points of the brains of neurosurgical patients under local anesthetic. During those cases in which the somatosensory cortex was the focus, the patients, who remained conscious throughout the procedure, gave verbal reports of the location of any sensation they felt (Pinel, 1997). As a result, Penfield discovered that the organization of the postcentral gyrus is somatotopic, that is, it follows a blueprint of the body. This blueprint is known as the somatosensory homunculus (Pinel, 1997).

Penfield found that the primary motor cortex is organized in a manner similar to that of the postcentral gyrus, that is, it too is somatotopic. By stimulating points in this are and observing consequential muscle contractions, Penfield rendered a motor homunculus.

Despite the general acceptance of localized faculties in the cortex, the localization of one aspect of mental functioning, memory, has baffled researchers since its systematic study began, and continues to do so today. Beginning in 1915, Karl Lashley, "the most influential physiological psychologist of his era" (Pinel, 1997, p. 351), systematically studied the brains of rats, cats, and monkeys in an attempt to localize memory (Pinel, 1997). He trained his subjects to perform complex learning tasks and then cut, lesioned, or removed parts of the animals' brains hypothesizing that by rendering the correct section inoperative, the memory would be erased. "For example, in one series of studies, rats received lesions of various sizes to different parts of the cerebral cortex after they had learned a maze task. Ten days later, their retention of the tasks was assessed" (Pinel, 1997, p. 351).

After conducting many such studies, Lashley was unsuccessful in locating any memories. However, he observed that large cortical lesions did affect his subjects' abilities to retain the learned information regardless of their location. These findings led Lashley to formulate two principles: The principle of mass action which states "that memories for complex tasks are stored diffusely throughout the neocortex" (Pinel, 1997, p. 321) and the principle of equipotentiality which holds that the sum of the neocortex's parts play an equal role in the storage of these memories. The theory of memory based on Lashley's two principles was prominent during the 1950s (Pinel, 1997).

Another theory pertaining to the physiological basis of memory, which stood out during the 1950s and remains widely accepted today, was based on the separation of memory into a long-term and a short-term system (Pinel, 1997). The theory, as it is are and observing consequential muscle contractions, Penfield rendered a motor homunculus.

Despite the general acceptance of localized faculties in the cortex, the localization of one aspect of mental functioning, memory, has baffled researchers since its systematic study began, and continues to do so today. Beginning in 1915, Karl Lashley, "the most influential physiological psychologist of his era" (Pinel, 1997, p. 351), systematically studied the brains of rats, cats, and monkeys in an attempt to localize memory (Pinel, 1997). He trained his subjects to perform complex learning tasks and then cut, lesioned, or removed parts of the animals' brains hypothesizing that by rendering the correct section inoperative, the memory would be erased. "For example, in one series of studies, rats received lesions of various sizes to different parts of the cerebral cortex after they had learned a maze task. Ten days later, their retention of the tasks was assessed" (Pinel, 1997, p. 351).

After conducting many such studies, Lashley was unsuccessful in locating any memories. However, he observed that large cortical lesions did affect his subjects' abilities to retain the learned information regardless of their location. These findings led Lashley to formulate two principles: The principle of mass action which states "that memories for complex tasks are stored diffusely throughout the neocortex" (Pinel, 1997, p. 321) and the principle of equipotentiality which holds that the sum of the neocortex's parts play an equal role in the storage of these memories. The theory of memory based on Lashley's two principles was prominent during the 1950s (Pinel, 1997).

Another theory pertaining to the physiological basis of memory, which stood out during the 1950s and remains widely accepted today, was based on the separation of memory into a long-term and a short-term system (Pinel, 1997). The theory, as it is described by Hebb (1949) holds that information is stored in the short-term system by means of reverberating neural activity. This activity eventually leads to relatively permanent changes in the synaptic connections of the circuit, thus forming a long-term memory. This relationship clearly implies that if information is not held in short-term memory for a sufficient amount of time, long-term memory is impossible (Pinel, 1997).

Memory and other higher mental functions have commanded increasing attention from neuropsychology. The study of the neurological bases of behavior, as it exists today, can be described as having two distinct branches: Experimental neuropsychology and clinical neuropsychology. Experimental neuropsychology continues to explore the role of the nervous system as it relates to human behavior with a particular focus on impairments brought about by a damaged or otherwise abnormal system.

"Clinical neuropsychology is an applied science concerned with the behavioral expression of brain dysfunction. Its rapid evolution in recent years reflects a growing sensitivity among clinicians to the practical problems of identification, assessment, care, and treatment of brain damaged patients" (Lezak, 1995, p. 7).

In a typical neuropsychological assessment, the clinician is charged with the responsibility of answering a number and wide variety of questions and must deal with a broad range of behaviors and mental capacities (Lezak, 1995). "Moreover, in this complex and broad-ranging field, few facts or principles can be taken for granted, there are few techniques that cannot benefit from modifications, and few rules of procedure that will not be bent or broken as knowledge and experience accumulate" (Lezak, 1995, p. 7).

Lezak (1995) discusses four functions of a neuropsychological examination, each requiring a slightly variant assessment strategy. The first role of the neuropsychological assessment she discusses is that of a diagnostic tool. The results of an examination often can be used to differentiate between symptoms with a psychological etiology and those with a neurological etiology. In cases of neurological impairment, specific conditions may be identified by the exam. The resulting behavioral data may also indicate the location of the lesion (Lezak, 1995).

The second purpose for such an examination is that of patient care and planning (Lezak, 1995). The objective of an examination ordered for this purpose is a complete and accurate descriptive evaluation of the patient's cognitive status and personality characteristics. Questions concerning the client's capacity for self-care, ability to comprehend the importance of money, and reliableness in following prescribed therapies, among many others, can possibly be answered. "When all the data of a comprehensive neuropsychological examination...are taken together, the examiner should have a realistic appreciation of how the patient reacts to deficits and can best compensate for them, and whether and how retraining could be profitably undertaken" (Lezak, 1995, p. 10).

A great deal of work in clinical neuropsychology is dedicated to treatment and rehabilitation evaluation (Lezak, 1995). As a result of this trend, demand for accurate and sensitive assessments upon which appropriate and effective treatments of brain dysfunction can be built has increased. Professionals from many disciplines, including psychiatry, speech pathology, physical therapy, and occupational therapy, who are often called upon to provide care to a common patient, may require continued evaluations of the patient's mental state based on his or her abnormal behaviors which can best be provided by the neuropsychologist. The others can then adjust their particular rehabilitative regimen accordingly.

The final purpose of neuropsychological assessment, according to Lezak

(1995) is research.

> Neuropsychological assessment has been used to study the organization of brain activity and its translation into behavior and in investigations of specific brain disorders and behavioral disabilities. Research with neuropsychological assessment techniques also involves their development, standardization, and evaluation. The precision and sensitivity of neuropsychological measurement techniques make them valuable tools for investigation of small, sometimes quite subtle behavioral alterations, such as those that may follow certain neurosurgical procedures or metabolic changes (Lezak, 1995, p. 14).

Neuropsychology continues to accumulate roles outside of both the clinical and experimental settings. As the field is increasingly looked upon as a possible source for solutions to turbulent issues, concerns over the validity of the discipline's tools have been the impetus for research and controversy.

These new controversies are in actuality the controversies that have followed neuropsychology since its nascency. The issues of free will versus determinism, the mind-body problem, and the role of a god continue to haunt the field. Some relief can be found in the general acceptance of nature and nurture as interacting forces.

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Figure Caption

Figure 1. A timeline including the names of the individuals discussed as being contributors in the area of neuropsychology.

5th century B. C. - Alcmaeon of Croton

Late 5th and early 4th centuries B. C. -

Hippocrates and the Hippocratic writers

3rd century B. C. - Death of Plato; Work of

Aristotle; Start of work by Theophrastus

Ptolemys establish the Library and the

Museum in Alexandria

Herophilus of Chalcedon; Erasistratus

2nd century A. D. - Galen

4th Century A. D. - Augustine

1501 - Magnus Hundt

1504 - Gregor Reisch

1514 - 1564 - Andreas Vesalius

1588 - 1679 - Thomas Hobbes

1596 - 1650 - René Descartes

1638 - 1715 - Nicolas Malebranche

17th - 18th centuries - Geulincx

1632 - 1677 - Benedictus de Spinoza

1632 - 1704 - John Locke

1646 - 1716 - Gottfried Wilhlm Leibniz

1685 - 1753 - George Berkeley

1705 - 1759 - David Hartley

1709 - 1751 - Julien de la Mettrie

1710 - 1792 - Thomas Reid

1753 - 1828 - Dugald Stewart

1757 - 1808 - Georges Cabanis

1758 - 1828 - Franz Joseph Gall

1776 - 1832 - Johann Gaspar Spurzheim

1778 - 1820 - Thomas Brown

1794 - 1867 - Marie-Jean-Flourens

1773 - 1836 - James Mill

1806 - 1873 - John Stuart Mill

1818 - 1903 - Alexander Bain

1820 - 1903 - Herbert Spencer

1824 - 1880 - Paul Broca

1838 - 1907 - Eduard Hitzig

1835 - 1911 - John Hughlings Jackson

1843 - 1928 - David Ferrier

Late 9th and 20th centuries - Flechsig,

Golgi, Cajal, Brodmann, Penfield, Lashley