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Walter Bradford Cannon: Reflections on the Man and His Contributions

Bradford Cannon[1,2]

My father's early research was with X-rays and led him to a serendipity finding concerning the role of distress in the physiological responses of cats. This chance finding led to further studies of the effects of emotional stimuli on various organs and systems in the body. These studies were the foundation for Cannon's discovery of the fight-or-flight, or stress response, and the development of his companion notion of homeostasis, embodied in The Wisdom of the Body. *While being fond of William James from undergraduate coursework under him, Cannon challenged and refuted the validity of the James–Lange Theory of emotions during his research career. Always fascinated by the psychological and emotional realm of human functioning, Cannon enjoyed warm and close relationships with Robert Yerkes and Ivan Pavlov over the years. The only time in my father's life when he felt strong pressure to produce may have been during World War I when he was part of the Allied medical team solving the problem of traumatic shock experienced by Allied troops in Europe.*

KEY WORDS: adrenaline; fight-or-flight; homeostasis; James–Lange Theory; serendipity; stress.

INTRODUCTION

Over the years, stimulated by an ongoing dialogue about my father's work with his biographers, I have come to appreciate more fully his contributions to stress, psychophysiology, and psychosomatic medicine. Although it may seem strange for a surgeon to address research relating to the field of stress, I have a front-row seat for observing my father's widespread interests and activities in

[1]Lincoln Center, Massachusetts.
[2]Correspondence should be directed to Bradford Cannon, 12 Silver Hill Road, Lincoln Center, MA, 01773.

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several different spheres of knowledge. Moreover, my professional education and experience have provided a meaningful framework for understanding his work, which permits me to offer some thoughtful reflections.

In the following pages, I will endeavor to trace the sequence of events that led to my father's studies of the emotional responses of the body, his elucidation of the neurological pathways involved, and his interpretations of the meaning and significance of these responses. I will also report some recollections of his relationship with contemporary colleagues such as William James, Robert Yerkes, and Ivan Pavlov (see Evans, Sexton, & Cadwallader, 1992 for details), and will conclude with incidents of his personal life which I happily remember. More detailed information may be found in my father's autobiography (Cannon, 1945), a volume of scientific recollections (Brooks, Kozumi, & Pinkerten, 1975), and the biography of my father's early years (Benison, Barger, & Wolfe, 1987).

IN THE BEGINNING

Walter Bradford Cannon's entry into the Harvard Medical School coincided with Boentgen's demonstration of the X-ray. As a first-year medical student, with a rich background of research experience as a Harvard undergraduate, he sought an opportunity to work with Professor H. P. Bowditch, whom, it is interesting to note, he succeeded 10 years later as Professor of Physiology at Harvard. Bowditch suggested using X-rays to study the swallowing mechanism in order to determine if liquids and semi-solids were forcibly squirted into the stomach by rapid contraction of the muscles of the mouth, or whether there was peristaltic motion in the wall of the esophagus (see Cannon, 1934).

Using radiopaque bismuth subnitrate, the studies of the swallowing mechanisms were begun with the goose, whose long neck lent itself to observing the esophagus. Not only was persitalsis present in the goose esophagus, this was also later observed in the stomach and intestine of the cat. Most unexpected, however, was the cessation of gastric peristaltic motility when the cat showed signs of alarm or distress. But motility promptly returned when the animal was consoled. This chance observation serves as an example of *serendipity*, Horace Walpole's word which Cannon often used in later years. A number of such chance observations during his career are referred to in his chapter, titled "Gains from Serendipity" (Cannon, 1945).

The fortuitous observation of the cessation of gastric motility had a marked influence on the research activities of Harvard's Department of Physiology for a number of years. The first studies endeavored to identify the effects of emotional stimuli on other organs and systems, and to define the role of the

autonomic (sympathetic) nervous system and the adrenal medulla in these responses. As the studies progressed, several effects became apparent. Among them were facial grimaces, showing of teeth, acceleration of the heart rate, increase in blood pressure, mobilization of sugar from the liver, increased depth and rate of breathing with relaxation of bronchial walls, decrease in muscle fatigibility (second wind), and redistribution of blood flow to the brain, lungs, and muscles, all of which are commonly recognized today. These bodily changes, which resulted from emotional disturbances, appeared to have a purpose, which the words, *fight or flight* seemed to describe. In other words, involuntary discharge of the sympathetic nerves and the simultaneous release of adrenaline from the adrenal medulla, the latter stimulated by the sympathetic nerve impulse, prepared the animal or man for either defense or escape as a means of survival in the struggle for existence (Cannon, 1915). Today, we hear sports announcers and others speak of "getting the adrenaline flowing."

I recently came across a few sentences by Professor Horace Davenport, one of Cannon's admirers from Ann Arbor, describing Cannon's lecture to first-year medical students on the invitation of his successor, Professor Eugene Landis. "I sat in the back row along with the medical students to hear Cannon describe the emergency function of the sympathetic nervous system. As we walked out one member of that brilliant class said: 'What's so great about that? We know all about that.' He was too young and too naive to realize that the old man in the pit of the lecture theater, an old man suffering from three kinds of cancer as a sequel to his early X-ray studies, was the man who had done it."

Hans Selye (1975), whose name is indelibly identified with "stress," followed Cannon years later in his own studies. Although he recognized Cannon's observations of the acute responses to emotional tension, Selye's researches differed since he was concerned with long term rather than the acute response. Selye identified other endocrine secretions, particularly those of the adrenal cortex, as involved in his *stress syndrome*.

In the preface of *The Wisdom of the Body*, Cannon (1932) commented on the current status of his researches: "another step in the natural sequence of ideas is apparent. In the main it pertains to the relations of the autonomic system to the self-regulation of physiological processes. That relation was only slowly disclosed. Indeed, not a few researches on the service of the autonomic in providing for stability of the organism had been completed and published before the connection of that system with regulatory arrangements was clearly understood. We found that we had been working on the role of the autonomic system in maintaining steady states without realizing we were doing so! The facts already discovered took on new significance. Thus considerable work of an earlier date became pertinent."

HOMEOSTASIS

One can somewhat rashly accept a teleological presumption that nature, in its evolutionary wisdom, anticipated and prepared the body for all possible vicissitudes. To define the bodily equilibrium of a *steady state* controlled automatically by the autonomic system in the face of disruptive external or internal forces, Cannon coined a new word, *homeostasis* (Cannon, 1929). This term, which has now become commonplace in medical and lay usage, denotes a condition that may vary in minor degrees but remains essentially constant. In his studies, Cannon elucidates on these constants and the subjective and objective ways by which stability is maintained, such as the requirement for water by the dry mouth; for oxygen by deeper breathing; for temperature control by surface vasoconstriction, erection of hair, and shivering or by vasodilation and sweating; and for retention or disposal of water, electrolytes, sugar, or wastes by the kidney.

Consider now some of the most interesting and directly applicable examples of the homeostatic mechanism which sustain the stability of the organism. Muscular activity is associated with a shift of the slightly alkaline pH of the tissue fluids and blood to the acid side with the accumulation of lactic acid. Initially, the alkaline buffers in the blood neutralize the acid which, combined with oxygen, is reduced to carbon dioxide and carried in the blood to the lungs where it is exhaled. More vigorous muscular activity requires greater amounts of oxygen, so respiratory rate and depth are increased as is the heart rate. These responses are automatic. If the exertion is prolonged, the acid may accumulate in the tissues, creating an "oxygen debt," which may require minutes or longer of cardio-respiratory acceleration to return to normal.

After Banting and Best isolated insulin from the pancreas of the dog, leading to its commercial production and availability, Cannon was generously supplied with samples of insulin by the Eli Lilly Company. A "homeostatic" response was observed when hypoglycemia was produced with high doses of insulin. The sympathico-adrenal system responded with sweating, rapid pulse, apprehension, etc., a condition promptly relieved by restoring the blood sugar level to normal. The Lilly Company warned of these symptoms in their product label, which is a well recognized precaution today. One wonders, however, whether Banting and Best would have been permitted to do the study with its dramatic result, given today's arbitrary restrictions on the use of animals for the welfare of mankind.

Thirst provides another interesting example of homeostasis. The first manifestation of thirst is a dry mouth and throat. Fear and anxiety can also be associated with a dry mouth. Even the swishing of a small amount of water in the mouth will temporarily stop the sensation. The sensation can also be eliminated by topical anesthesia of the nerve ends in the mouth and throat with

cocaine. In the dog, which cools itself by evaporation from tongue and throat, deprivation of water has been shown to diminish salivary flow with consequent drying of the mouth. Flow is promptly resumed when the dog is given water. This study finding was documented by exteriorizing a salivary duct. The fistula made precise quantitative measurement of salivary flow possible in different experimental conditions. In his original demonstration of the "conditioned reflex," Pavlov used the measured salivary flow as evidence that the experimental animal had been conditioned by repeated gustatory stimuli.

Hunger and its accompanying contractions of the stomach was nicely demonstrated graphically by simultaneous objective recording of the contractions and subjective recording of the sensation. This was demonstrated in man by placing a loosely inflated balloon in the empty stomach, which was connected by tubing to a recording needle which measured the changes in stomach volume. The subject had an electric key with which he recorded the sensation of hunger pangs. The kymograph record clearly demonstrated the close timing of the two markings.

The direction of studies on the sympathico-adrenal system concerned with the emotions was interrupted by a controversy with two Cleveland physiologists who maintained that adrenaline was secreted at a constant rate, and did not increase from emotional stress. This controversy enlivened the annual meetings of the American Physiological Society for many years. Repeated questions were raised which had to be answered at each annual meeting.

To prove his point, Cannon used the denervated heart as an indicator of circulating adrenaline, since the denervated heart beats at a constant rate unless responding to a blood born neurohumoral agent. Stimulation of the sympathetic nerve to the adrenal resulted in acceleration of the denervated heart rate; a response which was absent when the adrenal glands were either removed or deactivated. The circulating adrenaline proved to serve a second purpose, that of reinforcing and prolonging the response to the initiating sympathetic nerve impulse which is brief and of lesser magnitude.

Total extirpation of the sympathetic nerve ganglia on either side of the spinal column, leaving only the cranial and sacral autonomic nerve fibers intact, may have been inspired by the studies on the denervated heart. An interesting series of studies followed to demonstrate the effect of total sympathectomy on the experimental animal. Although it was found that the animal could survive total sympathectomy, the studies revealed significant limitations. The sympathectomized cat endured heat and cold poorly; exposure to a low oxygen tension was soon followed by unconsciousness; and mobilization of blood sugar and response to hemorrhage were impaired. In the relatively sedentary cat, exercise was poorly tolerated in contrast to the active dog who was less affected. The female cat was bred and delivered offspring but lactation was scanty; the male proved impotent.

WILLIAM JAMES' INFLUENCE

William James was one of Cannon's heroes, under whom he studied as a Harvard undergraduate. In his autobiography, Cannon tells of a conversation with James in which he told of expressing an interest in pursuing philosophical studies as a career, doubtless stimulated by James' teachings. James is quoted as replying, "Don't do it . . . You will be filling your belly with East wind." Cannon concludes, "The remark probably sprang from his recognition of my lack of fitness rather than from his disdain of philosophy" (Cannon, 1945, p. 19). During his lifetime, Cannon came full circle back to the philosophy of the emotions and responses to stress.

As a student of James, Cannon undoubtedly learned of the James–Lange Theory of emotions, but it wasn't until many years later that he had occasion to question its validity (Cannon, 1927). According to James, after one or more sense organs have been stimulated, afferent impulses pass to the cortex where the nature of the stimulus is perceived. Thereafter, impulses are transmitted to the viscera and muscles which react in complex ways. Afferent impulses from these disturbed organs course back to the cortex, and when consciously perceived transform the stimulus, simply apprehended, into one emotionally felt. To quote James, "The bodily changes follow directly the perception of the exciting fact and our feeling of the same changes as they occur is the emotion."

Cannon proved that total separation of the viscera from the central nervous system did not alter emotional behavior, thus raising questions of the validity of a visceral intermediary in the emotions. The human quadriplegic, paralyzed from the neck down, experiences and feels emotions just as deep as does the nonparalyzed individual. Decorticate cats, whose cortical nerve pathways had been cut or destroyed, demonstrated evidence of intense anger when disturbed. This reaction was labeled "sham rage" since the decorticate animals were unable to perceive the cause, appreciate the emotion, or organize the direction of their attack.

The next step was to localize the zone or level in the brain stem critical for sham rage. Philip Bard, Professor of Physiology at Johns Hopkins, studied the behavior of animals after removing the cerebral cortex and various amounts of the brain stem. He found that typical sham rage, accompanied by vigorous discharge of sympathetic impulses, occurs when both hemispheres, the corpora striata, and the upper half of the diencephalon have been completely excised. The additional extirpation of the diencephalon promptly abolished the spontaneous activity.

The posterior hypothalamus of the brain stem proved to be the focal center for reflex synapses where stimuli are received and then transmitted directly upward to the cortex, and distally to the viscera and blood vessels by the sympatheco-adrenal nervous system. When freed from inhibitory cortical control,

responses were more intense but exhibited the same elaborate independent stereotyped character typical of strong emotion. For example, semi-decorticate cats, with the hypothalamus intact, manifested emotional responses characterized by extreme pleasure when gently stroked on the involved side, but flew into a sham rage if stroked the wrong way. Responses on the uninvolved side were normal.

Among the tragic victims we cared for during WWII was a soldier whose visual centers in the occipital lobes were destroyed by a shell fragment wound. Although clinically blind, his eyelids blinked in reaction to any threatening motion towards his intact, uninjured eyes. Obviously, this was similar reflex response through the hypothalamic synapses. No doubt these observations challenging James were reluctantly accepted by those who, like Cannon, held him in high esteem. However, the facts were irrefutable, and the hypothalamic neurological pathway of emotional response replaced the James–Lange theory of emotions.

RELATIONSHIP WITH ROBERT YERKES

Robert M. Yerkes, chosen President of The American Psychological Association in 1917, and Cannon were close colleagues during Yerkes' years at Harvard, but their closest association came as summer neighbors in New Hampshire over three decades. In a recent communication from Yerkes' daughter, Roberta Blanshard, she writes of her father, "I wish I knew what Cannon and Yerkes discussed in those talks which were so precious to father. I treasure only the picture of him throwing the sleeves of his heavy sweater around his neck and setting off down the hill. I surmised that sometimes it was concerned with the National Research Council's Committee for Research on the Problems of Sex, which RMY chaired for 25 years. I know they fought together the fanatics who tried to shut down research on animals."

At the farm in New Hampshire, Yerkes constructed a maze for multiple choice testing, using the pig as the test subject. My youngest sister (age 5) was subjected to the same test. In returning home, she reported that "Uncle Robert (we children held our elders in high respect) says I'm as smart as a pig." As it turned out she was the smartest of the five Cannon siblings.

In 1923, Yerkes purchased a pair of young chimpanzees who were given the names of "Chim" and "Panzee" by philosopher and colleague, Professor Ralph Perry. They were a friendly pair, walking hand in hand with us children, and were agile in the birch trees, instinctively making nests by folding branches together. My father was friendly with both until, on one occasion, when Chim was being a nuisance and he pushed him aside. Chim became angry, showing his teeth, stamping on the ground with all fours, and making threatening

sounds. Doubtless blood pressure and pulse rate also increased, and his adrenal medulla poured out adrenaline. Apparently, Chim did not find that all humans looked alike and, much to my father's distress, Chim reacted with similar anger whenever they met, even weeks and months later.

This was the beginning of Yerkes' studies of the great apes which continued the rest of his active career (Yerkes & Yerkes, 1929). Because of the severe New England winters, a colony was established in Orange Park, Florida. Most of Yerkes' later publications were reports of studies conducted at this laboratory. About 40 years ago the animals were moved to Emory University in Atlanta with the very appropriate name, "Yerkes Regional Primate Research Center," one of several such centers throughout the United States.

FRIEND TO IVAN PAVLOV

Cannon's early investigations of the effects of emotions on gastro-intestinal mobility involved neurological patterns similar to those studied by I. P. Pavlov's conditioned reflex. There soon began an active correspondence between the two men, Pavlov in German and Cannon in English. Unfortunately much of this correspondence was lost many years ago. They first met in 1923 when Pavlov came to the United States with his son, Vladimir, who acted as guide and interpreter, although the two could communicate in simple German. It is rumored that Lenin, before he died, said, "Don't let anything happen to Pavlov." Judging by the esteem in which Pavlov and his teachings were held in the USSR, Lenin was right.

In *Way of an Investigator*, Cannon (1945) describes Pavlov's 1923 visit to the United States. Roughed up, and robbed in New York, Pavlov found a safe haven in Cambridge and enjoyed a visit to the Woods Hole Biological laboratory, as it was then called. On the train to Woods Hole, Cannon writes, "The man sitting in front of us held up a newspaper on which there was a large headline, stating that something was a fizzle. Pavlov turned to me and asked, Was Meint das Wort, 'fitzel?' Fiasco? I told him his surmise was correct. Since then I never see the double *zz* in a word without a sudden recall of the *tz* Pavlov gave it" (Cannon, 1945, p. 186). Pavlov had conditioned a word for him. Thanks to American generosity, funds were forthcoming so that Pavlov could continue his travels in the United States.

In 1929, Pavlov returned to the United States for the International Physiological Congress in Boston, where he was the hero of the meeting. That summer I worked as a messenger for the Congress Bureau and met Pavlov on a number of occasions. I recall his lively step, his energy, and the rapid gesticulations accompanying his speech. After the meeting he joined us for a brief family gathering in New Hampshire.

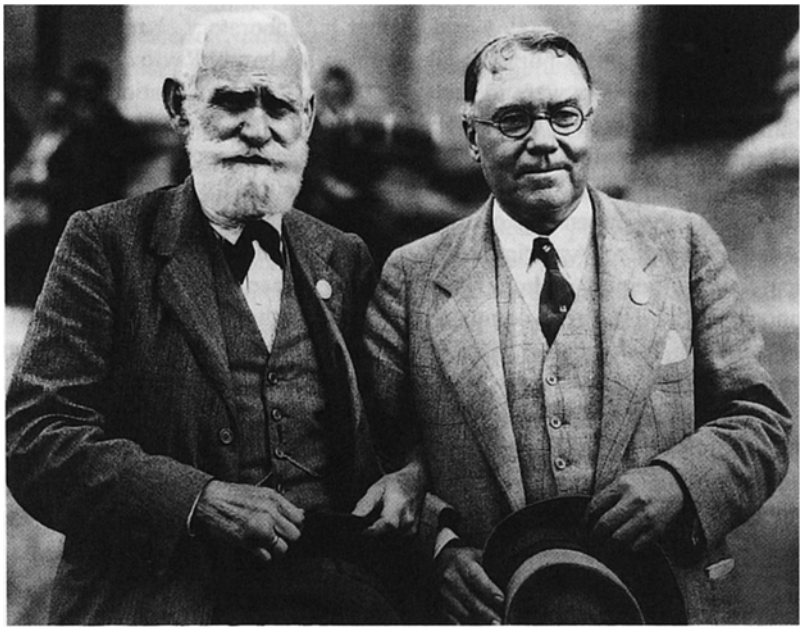

Fig. 1. Pavlov (left) and Cannon in 1929 when Pavlov visited the U.S.

The last meeting between Pavlov and Cannon was in Leningrad in 1935 at another International Physiological Congress, where Cannon gave the keynote address on his observations of the chemical transmission of nerve impulses. In the introductory paragraphs of that address he made a plea for freedom of inquiry in scientific research, calling attention to limitations set by hostile social and political establishments and the feelings of uncertainty and insecurity that follow. He strongly believed that freedom included freedom from the pressure to produce promptly and to show evidence of investigative progress in any given time. As might be expected, his strong words produced very different reaction among the assembly of multinational delegates during those troubled times.

Probably the only time in his long career that Cannon felt strong pressure to produce was during World War I, when he was the director of studies aimed at unfolding the mysteries of traumatic shock in the severely wounded in order to establish appropriate treatment routines (Benison, Barger, Wolfe, 1991). He was deeply emotionally involved in the tragedy of critically wounded patients in the "shock wards." As a child, I recall vividly his description of the massive wounds.

I had the privilege of attending the 1935 meeting in Leningrad as a delegate, where I again met Pavlov and visited his laboratory. I remember little about this visit except for numerous dogs under study and Pavlov's vigor in his mid eighties. His juniors were in such awe of him that conversations were often quotations of "Pavlov said this or Pavlov said that."

During the final decade of his life, Cannon became increasingly concerned about the unhappy world situation, stimulated undoubtedly by the depression of the 1930s and the impending conflict in Europe. In his 1940 presidential address to the American Association for the Advancement of Science, he sought to apply the principles of homeostasis in the human body to human society (Cannon, 1941). He drew comparisons between the automatic responses to changes in the body and corresponding automatic adjustments to economic fluctuations, emergency needs, setting aside surpluses for unanticipated requirements, etc. in society. Whether these ideals could ever be achieved in today's overcrowded, belligerent world certainly seems remote, but the concept of unwittingly insuring mankind's essential needs is an interesting analogy (Cannon, 1933, 1941).

THE MAN AND THE SCIENTIST

At this point I would like to share with you some of my recollections that may cast light on my father's personality in relation to his achievements. A paragraph from the writing of biologist David Starr Jordan (1910), former President of Stanford, has always intrigued me because it expresses so well the character of that generation of scientists.

> These men of the old school were lovers of nature. They knew nature, as a whole, rather than as a fragment or a succession of fragments. They were not made in Germany nor anywhere else, and their work was done because they loved it, because the impulse within would not let them do otherwise than work, and their training, partly their own, partly responsible to their source of inspiration, was made to fit their own purposes . . . Nothing could head them off and they took orders from no one as to what they should do, or what they should reach as conclusions. They did not work for a career—many of them found none—but for the love of work. They were filled with a rampant exuberant individuality which took them wherever they pleased to go. They followed no set fashions in biology. Such methods as they had were their own, wrought out by their own strength. They were dependent on neither libraries nor equipment, though they struggled for both. Not facilities for work, but endeavor to work, if need be without facilities, gave them strength.

Such exuberant individuality is no better exemplified than by George Pierce, a physicist and pioneer of radio communications and sonar, the underwater precursor of radar, and one of Cannon's close friends. An expert in sonic and ultrasonic vibrations, Pierce became intrigued by the cricket sounds both

within and above audible ranges. A fascinating account of the production, propagation, detection, and measuring of these sounds was published in *The Song of Insects* (Pierce, 1946), which the author humbly inscribed in its presentation to me as "this worthless volume."

I recall the resourceful selection of available materials for their studies; of the use of 4-1/2 x 6 inch single translucent sheets of toilet paper to trace the outlines of the stomach and intestine (toilet paper rolls came later); the fine sharp pointer on a straw lever recording on smoked paper; the balloon in the stomach to record hunger contractions; Yerkes' multiple-choice maze constructed by local carpenters. And I marvel at the noteworthy results they achieved without today's sophisticated measuring and recording devices.

Research in the first decades of this century was carried out with macroscopic techniques and the simplest of tools. Interpretation of results required imagination, insight, and a high degree of originality. Like many of his predecessors and contemporaries, Cannon was concerned with the integrated function of organisms and systems, content to leave the finer chemical analyses and functions of the individual living cell to those who would come after him.

My father was always intrigued by nice mechanical devices and methods. My sister recalls his unswerving devotion to the Ford motor car in her book about the Cannon family (Schlesinger, 1979). This loyalty originated in an appreciation of the uncluttered simplicity and ingenuity of the Model-T Ford, whose ignition, timing, lubrication, cooling, and carburation were so understandable and accessible, and whose planetary transmission was the precursor of the modern automatic shift.

He had a knack for turning a phrase and also delighted in those of others. For example, my mother was quick to get things done. Her carpentry (ours was a family of carpenters) was atrocious, but it was finished with dispatch and unabashed pride, and when she looked upon her work, she made no bones about expressing that pride. Father's comment about this trait was: "With Cornelia it is no sooner done than said." On an icy winter expedition to a summer cottage in New Hampshire, the family became "hewers of water and drawers of wood," and we children were constantly reminded that "anything worth doing was worth doing well." Previously mentioned were his word, homeostasis, which is now used in medical publications throughout the world, and Horace Walpole's serendipity (the making of discoveries by accident or sagacity). The latter word, while especially applicable to scientific investigation, is also used in the popular press. I remember Cannon reminding us that "when I mentioned serendipity to one of my acquaintances and asked if he could guess the meaning, he suggested that it probably designated a mental state combining serenity and stupidity—an ingenious guess but erroneous." The frustrated laboratory diener's definition of an amphibian became one of his favorite quotations: "An amphibian is an animal which can't live on land and dies if left in the water."

All of these examples indicate his enjoyment of language, as well as his special ability to select interesting and precise words in talk, and in his writing.

Several incidents during his lifetime that are not well known deserve recording. In 1915 a cartoon appeared in a Dallas newspaper with the caption: "Man is sweeter when angry"—an allusion to the recently reported increases in blood sugar with stress. Or the closing of a pajama factory since adrenaline proved a substitute for sleep.

The title for his 1918 Croonian lecture before the Royal Society in London was "The Physiological Basis of Thirst." During this lecture, prompt physiological insight saved the day. He told me that he began to feel faint while reading the manuscript as it rested on the lectern. World War I was still being fought and the uniforms at that time had high, stiff collars, quite different from the loose collars worn by us in World War II. He promptly deduced that the high collar was pressing on his carotid sinus, resulting in a lowering of blood pressure. He immediately held the manuscript higher, carried his head erect, and at once the faintness disappeared.

The tempo of life at the turn of the century sharply contrasted with today's urgency. Although the Medical School was in Boston, my father lived in Cambridge and kept his ties with the College Faculty, with Harvard President Charles W. Eliot with whom he shared innovative ideas about medical education, and with intimate Cambridge friends, traveling daily to Boston by trolley car. The Harvard College Faculty was a small, close-knit body. Because travel was slow and inconvenient, many walked from their homes to the lecture halls or laboratories. They were not distracted by the cinema, radio, or television, not even by the incandescent light bulb. In fact, our house was lighted by illuminating gas, and only years later electrified, room by room. Satisfactions of the highly intelligent individuals in this group came from their studies, writing, and conversational eloquence. Evening diversions lay in good talks. Much of their writing and the assembling and interpreting of experimental data in final form, was done during the summer vacation months while freed from teaching and administrative obligations.

SUMMARY: A LIFE OF CONTRASTS AND CONTRIBUTIONS

Although not a radiologist, he learned to use primitive X-ray equipment to perform his early studies.

Although not a gastroenterologist, he made significant contributions to understanding the mechanical factors of digestion.

Although not an endocrinologist, he alerted the profession to the functions of the adrenal medulla and its allied sympathetic nervous system in the maintenance of homeostasis.

Although not a neurologist, he clarified the role of the hypothalamus in emotional states and proved the chemical mediation of autonomic nerve impulses across the synapse.

Although not a psychiatrist, through his research, summarized in his classic *Bodily Changes in Pain, Hunger, Fear and Rage* (Cannon, 1915), he contributed to the development of modern psychosomatic medicine.

Although not a clinical surgeon, he carefully observed the nature of traumatic shock and thus paved the way to a better understanding of this ominous emergency.

Although not a psychologist, he clarified the pathways of emotional responses and proved the error of the James–Lange theory.

Although not a politician, he suggested corrective measures for instability in the body politic and became a public defender of medical research, mobilizing the profession to apprise legislators of the fruits of animal experimentation, and to defeat efforts by the anti-vivisectionists to curb by legal action the use of animals for scientific investigation.

Finally, although not mountaineers, he and my mother on their honeymoon in 1901 were the first to reach the summit of an unclimbed peak at the head of Lake McDonald in what is now Glacier National Park. It was subsequently named Mount Cannon by the United States Geological Survey!

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