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Let's Talk About Stress: History of Stress Research

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The reference to stress is ubiquitous in modern society, yet it is a relatively new field of research. The following article provides an overview of the history of stress research and its iterations over the last century. In this article, I provide an overview of the earliest stress research and theories introduced through physiology and medicine and eventually as a concept in psychology. I begin with an exploration of the research of biological stressors 1st explored by experimental physiologist Claude Bernard and eventually adopted as a foundational concept in stress research when Walter Cannon expanded on Bernard's work and identified homeostasis. The contributions of Hans Selye, considered the father of stress research; Sir William Osler; Yerkes and Dodson; and Richard Lazarus are also discussed. Finally, I discuss how, in the new millennium, research on psychological stress has expanded across disciplines ranging from physiology to medicine, chemistry, endocrinology, neurosciences, epidemiology, psychiatry, epigenetics, and psychology, reflecting the complexity of the construct both theoretically and biologically.

Keywords: stress, homeostasis, history, health, hormones

> Stress in health and disease is medically, sociologically, and philosophically the most meaningful subject for humanity that I can think of.
>
> —Hans Selye (1907–1982)

The reference to stress is ubiquitous in modern society, and the term *stressful* is a recurrent descriptor of negative experiences related to anything from daily hassles, relationship issues, and pressures at work to health concerns and debilitating phobias. It is interesting that most popular definitions would likely describe purely psychological phenomena, yet less than 100 years ago, the term *stress* as a psychological phenomenon did not exist. Today the concept of stress is pervasive in popular as well academic literature. Despite its prevalence, stress remains an elusive concept.

Modern stress research was birthed out of divergent interests in medicine and physiology before it was introduced as a novel concept in psychology. Stress research eventually evolved to include the consideration of cognitive processes that influence how an individual responds to both ordinary and extraordinary conditions of daily life. Perhaps what is missing in both the popular and scientific discussion of stress is the recognition of a shared history with medicine and physiology before its introduction as a novel concept in psychology. So why study the history of stress, or any discipline for that matter? There are arguably several reasons, with the most obvious being that one must understand the major developments in that body of research in order to systematically and scientifically build on it. Studying the history of stress research may also elucidate the vast possibilities yet to be explored in the discipline. Having conducted stress research over the past decade ranging from the basic sciences using the laboratory rat to epidemiology studies with thousands of participants, I have found it increasingly obvious that those who talk about or even study stress may use the same language but do not necessarily share the same operational definition of *stress.* This may be due in part to the diversity of stress research applications, and it may also be due to a lack a historical understanding of how the concept of stress developed. To address this knowledge gap, the following article is meant to provide a brief history of stress research for students of health psychology, those new in the field of stress research, and those who are curious about the evolvement of stress research.

The following article outlines the major developments in stress research beginning in the late 19th century through to the most recent developments. In the process of tracing the historical events that led to the subdiscipline of stress research in psychology, I developed two distinct orientations regarding the development of the concept of stress—one physiological and the other psychological—that would eventually converge post–World War II. Finally, postwar developments of stress research are described, as well as the current advances in the field.

Early Use of the Word *Stress*

Prior to the term *stress* being used as a psychological term, it was used to describe various types of physical pressures. The concept of stress (not the word) was understood by the ancient Romans, who, understanding the significance of forces acting upon an object, built arched bridges and coliseums utilizing compressive stresses (Baratta & Colletta, 1998). The word *stress* is a derivative of the Latin verb *strictus,* meaning "to draw tight" (Strictus, n.d.). *Strictus* could also mean "to graze, touch, pluck, or prune" (Stress, n.d.). The term *strictus* was incorporated into Old French as *estresse,* signifying "narrowness, constriction, oppression" (Stress, n.d.), and the Middle English *distress*, denoting "hardship or force exerted on a person" (Stress, n.d.). By the 16th

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century, the term *distress* was used to indicate a form of physical injury. The early use of the term in both French and English referred to some sort of unpleasant environmental condition. The first account of the term *stress* being used to describe a combination of external and internal responses appears in William Shaw Mason's *Statistical Account of Ireland* (1814–1819), in which he identified that the poor, "particularly females, die in their youth, of what they call stresses, that is violent heats from hard work" (as cited in Hayward, 2005, para. 3). However, these sorts of observations, which have actually been noted across the centuries (Hinkle, 1973), were not systematically explored until the 19th century.

Claude Bernard (1813–1878)

The French physiologist Claude Bernard (1813–1878), provided perhaps the most significant foundational contribution to stress research. Bernard is considered by many to be the father of experimental medicine (Gross, 1998). Although not much of a success in other domains, according to his obituary, Bernard was tirelessly devoted to experimental medicine ("Obituary: Claude Bernard," 1878). Bernard's work in experimental physiology brought him international recognition. Despite his poor performance in medical school, upon graduation Bernard apprenticed in the lab of internationally renowned physiologist François Magendie (1783–1855) at the College de France. Eventually, Bernard took over Magendie's laboratory and chair at the College de France. Bernard made many important discoveries in his lifetime, including the glycogenic function of the liver, the role of the pancreas in secreting digestive fluids, and the vagal control of cardiac function. In 1865, Bernard published a highly influential textbook, *An Introduction to the Study of Experimental Medicine,* which was so well received he was elected into the prestigious French Academy in 1869. There is a great deal more that can be said about Claude Bernard, but of critical importance to the development of the modern concept of stress was his theory of the *milieu intérieur,* translated as "the environment within" (Bernard, 1872). Bernard noted that the body is constantly working to maintain a stable, well-balanced internal environment. In particular, Bernard identified the portion of the nervous system that controls the constriction and dilation of the blood vessels in relation to the control of internal temperature. For example, when an organism is cold, the blood vessels narrowed in order to prevent body heat from escaping, and the opposite occurred on hot days. He also discovered the glycogenic function of the liver in regulating blood sugar levels. With these two relatively limited observations, Bernard developed his novel hypothesis of a regulated internal environment. These discoveries laid the foundation for what has come to be understood as homeostatic mechanisms, which is a cornerstone of stress research.

Initially, Bernard considered the blood to be what maintained the internal environment. However, he eventually expanded his idea to consider that the bodily fluids (i.e., humors) and their regulators (e.g., glycogenic mechanisms) are under the control of a central regulation.

> *The fixity of milieu supposes a perfection of the organism such that the external variation are at each instant compensated for and equilibrated* [emphasis added]. . . . All of the vital mechanisms, however varied they may be, have always one goal, to maintain the uniformity of the conditions of life in the internal environment. (Bernard, 1878/1974, p. 188)

Although this seems like an intuitive idea, at the time, most scientists believed that the organs functioned independently. Surprisingly, Bernard's concept of an internal environment did not gain popularity until nearly 50 years later when, as will be discussed, Walter Cannon expanded on Bernard's ideas of homeostatic mechanisms in response to noxious insults.

Sir William Osler (1849–1919)

One of the earliest contributors to the concept of stress and health outcomes was Sir William Osler, born in Ontario, Canada. Osler studied pathology and then taught at many of the most prestigious schools in Europe and North America, finally in the most esteemed position in Great Britain as the Regius Professor of Medicine at Oxford University (Roland, 1982). Osler was the opposite of Bernard in personality; he was a warm and compassionate doctor who seemed to be liked by all. At the time of his death, Osler was considered the most influential doctor of his era ("Obituary: Sir William Osler," 1920).

The Hippocratic rule that states physicians are to treat diseases, not symptoms, was based on Osler's philosophy of medicine (Ghaemi, 2008). The current practice of medicine is based on an approach developed by Osler that uses algorithmic analysis of symptoms to diagnose disease (Osler, 1892) as well as a method to generate symptoms through testing (Institute of Medicine, 2011). In collecting information about presenting symptoms, one of the important observations that Osler made was that the bodily response to environmental conditions might have long-term consequences on health. He described the personality of the typical heart disease patient as a highly driven and ambitious man—long before the Type A personality connection to cardiovascular disease was explored (Brody, 1993). As a pathologist, Osler also noted that a patient's general disposition and outlook had an influence on the trajectory of disease (Osler, 1913). Although Osler did not directly identify a causal relationship between stress and health, he did recognize the role of cognition in health outcomes, something that was not taken under consideration at that time.

Walter Cannon (1871–1945)

Although Claude Bernard was the first to systematically explore the regulatory mechanisms involved in stabilizing the internal environment, his ideas were not taken up until Walter Cannon began to further explore these mechanisms. With a keen interest in science, Cannon set off to study medicine, entering Harvard College in 1892. Putting himself through school, he was hired as a research assistant at a lab studying digestion using the new X-ray technology. One of Cannon's first experiments was studying the movement of a button through a dog's digestive system. His first article, "The Movements of the Stomach Studied by Means of the Röntgen Rays," was published in the *American Journal of Physiology* in 1898 (W. B. Cannon, 1898). According to a biography of Cannon written by his son, Bradford Cannon (1994), it was through these experiments that he serendipitously observed the phenomenon of a change in peristaltic motion. Bradford Cannon wrote that while observing peristalsis in a cat, his father had noticed that when the cat became distressed or alarmed, peristalsis

ceased. It was this rather serendipitous observation that led to Cannon's interest in the emotional effects of stimuli on internal functions. Like Bernard, Cannon's main interest was in physiology, and having the advantage of advances in both experimental psychology and physiology, he was able to elaborate on Bernard's theory of the *milieu intérieur* as well as develop an alternative to the dominant theory of emotion that had been developed (primarily) by William James, which is also discussed later.

Another significant influence on Cannon's research occurred when he was commissioned to France, along with a Harvard Medical unit, to study the phenomena of "shell shock" soon after World War I broke out (Myers, 1916). The war provided a sort of natural experiment on the psychological impact of extreme stress. World War I introduced unexpected and unprecedented mass exposure to the horrors of combat. As soldiers returned from the front lines, many of them exhibited peculiar symptoms that were not easily explained by physical injury. They exhibited symptoms such as dizziness, headaches, fatigue, amnesia, tinnitus, sweating, and tremors (Myers, 1916). In World War I, some thought that the symptomatic phenomenon of soldiers who had experienced combat was due to neural damage resulting from blast injuries or toxic exposure (Jones, Fear, & Wessely, 2007). Military doctors, neuropathologists, and psychologists were divided as to whether to attribute the symptoms to psychological or physical trauma (Benison, Barger, & Wolfe, 1991). Unfortunately, there was a push from commanders to attribute the symptoms to physical trauma in order to "treat" soldiers and, once physical injury could be ruled out, send them back into combat (Shephard, 1999).

Eventually, due in part to the research of Capt. Charles S. Myers, the term *shell shock* was used to describe this presentation of symptoms of trauma when no obvious injury or brain lesion could be identified (Myers, 1940). Myers, a specialist in psychological medicine, was commissioned to study the phenomena of shell shock. In 1915, he published an article in the *Lancet* comparing the case studies of three soldiers suffering a variety of symptoms that could not be explained by physical injuries such as loss of memory, vision, olfaction, and sensations (Myers, 1940). Myers treated each patient with hypnosis and reported a reduction of symptoms posthypnosis. A year later, after spending another year observing patients, he submitted a follow-up article that explored various cutaneous symptoms of shell shock (Myers, 1916). Myers suggested the label *hyperasthesia* to describe the increase in sensitivity to heat, cold, and touch in addition to previously identified observations of anesthesia. He proposed that delayed onset of anesthesia was due to emotional stress (terror, horror) that initially triggers bodily pain (or hyperasthesia) before inducing a period of loss of sensation. It was estimated that approximately 10% of soldiers presented with shell shock in World War I (Mitchell & Smith, 1931).

Unlike Myers, who was concerned with the long-term consequences of shell shock, Cannon focused his interest during the war on acute bodily changes in response to fear (W.B. Cannon, 1929a). Throughout the war, Cannon focused his research on shock related to physical trauma. Due to his observations of soldiers suffering from shock, both in vivo and postmortem, he became specifically interested in the role of the circulatory system. He observed that patients in shock had decreased blood pressure, acidosis, altered dispersion of blood, and decreased blood volume (W. B. Cannon, Fraser, & Hooper, 1918). He proposed various treatments focused on increasing circulation and blood volume (including blood transfusions) and decreasing acidosis. He differentiated *traumatic shock* from *shell shock* that Myers and others were primarily interested in. Based on his observations during the war, Cannon published an article on traumatic shock, "Some Alterations in Distribution and Character of Blood in Shock and Hemorrhage" (W. B. Cannon et al., 1918). He also maintained his interest in the role of hormones in response to fear and introduced the idea of the "sympathico-adrenal system" in his book *Bodily Changes in Pain, Hunger, Fear, and Rage* (W. B. Cannon, 1915), a book he had been working on prior to leaving for France.

Homeostasis

Following the war, Cannon continued his research on the internal responses to trauma and fear. In 1929, Cannon wrote one of his more influential articles, "Organization for physiological homeostasis" (W. B. Cannon, 1929b). It is in this article that Cannon built on the earlier and otherwise forgotten work of Claude Bernard's *milieu intérieur*. He began his article with a description of how organisms maintain internal stability. Cannon proceeded to describe the process by which bodily systems have built an internal system, *a fluid matrix,* to help organisms maintain a stable internal state, which he defined as *homeostasis*. Cannon proposed two ways that homeostasis is maintained: through the sense organs and through the negative feedback of the autonomic nervous system. These two systems work together to maintain stable internal states, he asserted, providing several examples of the working systems when responding to external changes such temperature regulation in a cool room or physiologic adaptations to oxygen deprivation (W. B. Cannon, 1929a). He further emphasized the important role of the autonomic nervous system in the establishment and maintenance of homeostasis: "If a state remains steady, it does so because any tendency toward change is automatically met by increased effectiveness of the factor or factors which resist the change" (W. B. Cannon, 1929a, p. 425). Homeostasis was an important development in physiology and medicine, but it continued to be understood as a fully automatic process, so not yet close to a psychological notion of stress.

Later in his career, Cannon began to explore the connection between psychological stress and psychosomatic symptoms. In his provocative article "'Voodoo' Death," W. B. Cannon (1942) explored the phenomenon of death from fear. Cannon considered various reports from anthropologists and others concerning observations of death after being vexed by a curse. He posited that prolonged exposure to an ominous and persistent state of fear could in fact produce a fatal outcome. This observation was a critical bridge between psychological and psychosomatic medicine.

It is interesting that Cannon did not incorporate the actual term *stress* in his writings until 1935, and even then the term appears in the title, "Stresses and Strains of Homeostasis," but the actual term *stress* is not defined, referenced, or explained in the body of the article (W. B. Cannon, 1935). Regardless, the article describes the adaptive physiological responses of the body to what he identifies as "disturbances" (p. 5), which have come to be understood as "stressors". To fully appreciate the importance of Cannon's observations, one must understand the held theory of emotions developed by William James and Carl Lange.

Refuting the James–Lange Theory of Emotion

William James (1842–1910) is considered by many to be the father of American psychology. One of the contributions James made was to offer a functionalist theory of emotional consciousness. Building on his interest in the conditions that afford various experiences, he began to contemplate emotional life. He was particularly interested in how feelings are evoked from physical experiences. In his article "What Is Emotion?" James, 1884 argued that when an object activates a sense organ(s) an afferent impulse is produced and sent to the cortex. The cortical response is translated to the viscera and muscles before returning to the cortex. It is upon return to the cortex that an object is emotionally felt. Thus, the emotion is secondary. He used the following example to explain emotional responses: "It is not that we see a bear, fear it, and run; we see a bear and run; consequently, we fear the bear. Our mind's perception of the higher adrenaline level, heartbeat, and so forth is the emotion" (p. 190). Expanding on this theory in James, 1894 wrote an article for the *Psychological Review* titled "The Physical Basis of Emotion". In this article, James attempted to connect cognition to physiology. The theory holds that emotion is the mind's perception of physiological conditions that result from some stimulus. Around the same time, Carl Lange, a Danish physician, was working on a similar theory of emotion, attributing the experience of an emotional life to the vasomotor system (Lange, 1885). Like James, he argued that emotions are a secondary response to stimulus. The main idea shared by James and Lange was that emotion did not begin with the conscious experience of an affect (Lang, 1994).

In 1927, Cannon wrote a critique of the James–Lange theory of emotions based on physiological and experimental evidence. Cannon began his article by challenging James's idea that emotional feelings arise primarily from visceral organs as well as from the muscles and Lange's idea that the vasomotor center is responsible for emotional experience. To challenge this idea, Cannon cited the earlier work of Sherrington's (most disturbing) experiments with transected cats and dogs (p. 570). Sherrington's research elucidated the role of neural processing in that even once the vasomotor center was abolished, the animals still demonstrated emotional responses such as fear, excitement, and rage (Sherrington, 1900). Furthermore, according to Sherrington, when visceral changes are induced artificially (e.g., using adrenalin), it does not elicit specific emotional responses.

Cannon's (1927) next point of contention was that the same visceral changes occur in very different emotional and nonemotional states. He compared various physical responses such as pupil dilation, heart rate increases, respiration increases, and blood sugar increase to various states of excitement and observed a similar response whether the stimulus was evoking fear or rage. Cannon argued that physical responses are too uniform to be used to interpret the wide range of emotions. He also noted that the viscera are relatively insensitive structures—people are generally unaware of contractions of their smooth muscles or the processes of their liver. Not only are they mostly unaware of visceral organs but most of the visceral organs are too slow to be a source of emotional feeling. Working with his graduate student Philip Bard, he proposed an alternative theory that came to be known as the Cannon–Bard theory of emotion. The Cannon–Bard theory proposes instead that there are emotional centers in the brain, specifically the thalamic areas, that organize different emotional expressions.

Fight or Flight Response

Combining his theory of emotion with his theory of homeostasis, Cannon moved beyond exploring the physiological mechanisms of the response to physical emergencies and psychological stress and developed a theory to answer the *reasons* for the observed changes in bodily function when an organism is confronted stressor. In the second edition of his book *Bodily Changes in Pain, Hunger, Fear and Rage*, Cannon (1929b) proposed that the release of adrenalin (i.e., epinephrine) into the bloodstream has several adaptive functions that allow an organism to respond to an acute stressor by preparing it to "fight" or to take "flight". He noted that the release of adrenalin has differential effects on the body's organs, which combine to help maintain homeostasis. In the peripheral organs such as skeletal muscles, adrenaline facilitates blood flow by relaxing the blood vessels. The increase in blood flow provides the skeletal muscles with glucose and increases the removal of metabolic by-products that would otherwise accumulate and interfere with performance. Conversely, adrenaline constricts cutaneous blood vessels, minimizing blood loss from physical trauma and promoting clotting. Again, building on Bernard's work, he concluded that adrenaline is the hormone that signals the liver to release glucose into the bloodstream. He also noted that adrenaline increases respiration. It is important to note that Cannon saw all the adaptive responses as regulated by adrenalin and did not appreciate the role of other biochemical interactions or the psychological influences on these responses. Despite this limitation, Cannon offered a new theory of emotion-associated behaviors and biological responses. Although Cannon's critique of the James–Lange theory of emotion has generally shifted the understanding of emotional processing, the matter is not entirely decided. For example, contemporary studies in neuroscience such as those conducted by Damasio over the past 20 years (e.g., Damasio, 1994/2005) adhere to the idea that much of the processing for the fear response occurs in the amygdalae at a subthreshold level. If the brain perceives that signals from external stimuli reached the threshold of emotional competence (e.g., a shrill scream), only then would it activate nuclei in other regions of the brain (e.g., hypothalamus) to produce the requisite physiological responses leading to the emotional state of fear.

Hans Selye (1907–1982)

While Cannon was conducting experiments and prolifically writing on his theories about the acute stress responses (although he did not use that term), Hans Selye was noticing something different in response to chronic stress. Like Bard, Cannon, and Osler, Selye was trained as a medical doctor. Selye's main interest was research, and he managed to avoid clinical practice. It should also be noted that although Cannon published an article that used the term *stress* in its title in 1935, Hans Selye is regularly credited with being the first to reference *stress* in the medical literature (Hinkle, 1973). However, according to Selye's students, Selye would regularly point out that although he coined the term *stress response,* he was not the first to use the term (Szabo, Tache, & Somogyi, 2012). Selye borrowed the word *stress* from a term

already used in physics and engineering. He defined *stress* as mutual actions of forces that take place across any section of the body, physical or psychological.

One of Selye's first experiments was injecting ovarian extract to discover the unknown influence of sex hormones on physiology (Selye, 1936). In the process, he discovered an unexpected widespread nonspecific physiological response on several organs accompanying the injection of ovarian extract. He decided to use other substances agents (e.g., formaldehyde, morphine, adrenaline) to see whether there would be a similar effect. In a brief communication to the editor of *Nature* titled "A Syndrome Produced by Diverse Nocuous Agents," described how, in using rat models to study the physiological effects of diverse nocuous insults, he observed patterns of enlarged adrenal glands, damage to the lymphatic system, and stomach ulcers. He also observed these effects in response to adverse situations such as surgery, extreme cold, and excessive physical strain. He concluded that these physiological changes were the nonspecific adaptive responses to various types of stress (Selye, 1936, 1950).

Selye (Selye, 1936), using the same rat model, also recognized a consistent three-stage pattern of physiological responses to stress that he referred to as the general adaptation syndrome (GAS), which he later renamed the *stress response.* In the first stage, the alarm reaction, the body prepares to fight or flee. This is followed by a stage of resistance, where the body prepares for sustained attack against the stressor. In this second stage, the immune response continues to increase and the body adapts to the specific stressor. For example, if the stressor is nutritional deprivation, the body may become lethargic to conserve energy while the absorption of nutrients is maximized. In the third stage, exhaustion, the system becomes exhausted and resistance to the stressor cannot be sustained. Selye's central point was that the prolonged effect of stress would have a negative impact on general health. This observation was the beginning of an understanding of why stress, really distress, can be pathological and is the reason the word *stress* has earned such a negative association. The physiological effects of stress were important for giving the concept a place in medicine, but psychologists had yet to incorporate this knowledge into a comprehensive theory of psychological stress.

In addition to describing various ways the body responds to stress, Selye was able to isolate and identify several specific hormones involved in the stress response, in particular, glucocorticoids (Selye, 1943). One of his doctoral-level students, Roger Guillemin, even received a Nobel Prize for isolating the hypothalamic releasing factors–hormones (Szabo et al., 2012). With the identification of specific stress hormones and a better understanding of the hypothalamic–pituitary–adrenal (HPA) axis, researchers are now able to study the multiple ways that the body responds to stress rather than the one general adaptation. Although Selye's theories have been significantly elaborated upon since the time of their inception, even in some of his own later works, such as *Stress Without Distress* (Selye, 1974), his research and theories laid the foundation for the study of the deleterious effects of prolonged distress on health outcomes. It was Hans Selye's pioneering work on the effects of chronic stress on the HPA axis that led to contemporary research's exploring the causal relationship of chronic stress and the hyperactivity of the HPA axis (e.g., Zhu et al., 2014). It is important to highlight that the major difference between the theory and research conducted by Selye and Cannon was that Selye was interested in the effect of chronic stress whereas Cannon was more interested in transient responses to acute stressors.

Yerkes–Dodson Law (1908)

Deserving of at least brief mention in the literature on stress research is the Yerkes–Dodson Law, developed by Robert Yerkes (1876–1956) and John Dodson (1879–1955) quite independently of the studies conducted by Cannon and Selye. In 1908 at Harvard University, Yerkes and Dodson conducted experiments with mice to test the relationship between the strength of stimulus and habit formation (Yerkes & Dodson, 1908). Mice were placed in a rectangular box that was divided into an open area (nesting chamber), entrance chamber, and two electrical boxes: one white and one black. If the mouse entered the black box (which would likely be its natural inclination), an electric shock was administered. The shock given in each condition was weak, medium, or strong. Yerkes and Dodson tracked the number of days it took for the mouse to learn to enter only the white box. To their surprise, the results indicated that the medium shock produced an optimum amount of stimulus in the learning task. Mice that were given a mild shock did not seem motivated to learn to enter the white box, even after 20 days of testing. Conversely, mice that were given the medium shock learned the white–dark discrimination task in an average of 4 days. However, the strong shock did not improve habit formation, and the strong shock condition results were similar to those in the weak shock condition.

From these findings, the Yerkes–Dodson Law was developed. Although the men did not explicitly state the law as such, today the law is generally expressed as performance increases with physiological or mental arousal, but only up to a point. When levels of arousal become too high, performance decreases. This law is often represented by an inverted U to describe the optimal level of arousal. As appealing as this model was, and as influential as it was in the study of anxiety, it was eventually recognized that the main problem with any U-shaped function is that it can explain anything and everything, and therefore it explains nothing. Regardless, Yerkes went on to apply these ideas to the testing and training of pilots in World War II (Dewsbury, 1992).

World War II

Just as with World War I, the second was horrific and, for many, psychologically traumatizing. It would hardly be possible to talk about stress research without including the findings related to the massive scale of stress introduced by World War II. It is interesting that Myers, one of the main researchers and a theorist on shell shock during the World War I (as already discussed), was so frustrated at the military's dismissal of his recognition of psychological trauma as it related to shell shock that he refused to conduct further research (Shephard, 1999). At the dawn of World War II, the British actually banned the use of the term *shell shock* in an attempt to avoid a repeat epidemic and potential malingering (Shephard, 1999). As an alternative, the term *post trauma concussive state* was proposed by Schaller (1939), and after many debates, the term *post concussion syndrome* was agreed upon (Jones et al., 2007). The following symptoms were identified: dizziness, fatigue, tinnitus, memory loss, and poor concentration. The med-

ical community continued to argue that based on these diagnostic criteria, it was difficult to distinguish postconcussion syndrome from an organic concussion. Psychologists and psychiatrists alike offered alternative diagnostic labels such as *operational fatigue* or *combat neurosis* to try to capture the psychological aspect of the symptoms (Grinker & Spiegel, 1945).

Grinker and Spiegel, psychiatrists from America who were commissioned to the U.S. Army Medical Corps in North Africa during World War II, contributed to the growing body of research on psychological stress. In 1945, Grinker and Spiegel wrote a book titled *Men Under Stress,* which explored the psychodynamics underlying various stress responses of World War II pilots. The authors focused primarily on the cumulative effects of being under chronic threat that could lead to a range of "psychotic-like states" such as aggressiveness, paranoia, depression, pervasive guilt, and psychosomatic symptoms (as already described with shell shock). Grinker and Spiegel attributed the symptoms of "combat neurosis" (p. 63) to the psychological strain of combat rather than the physical strain. They also described adjustment problems of men returning home with "war neuroses" (p. 132) that included symptoms strikingly similar to the criteria for posttraumatic stress disorder in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 1994). Regardless of the politically correct labels, it was due to this tragic time in history that the medical and psychological community could no longer dispute the deleterious effects of extreme stress in the absence of an organic insult.

Postwar Research

As discussed, early research on stress focused primarily on physical stressors (e.g., noxious substances, nutritional deprivation, temperature deregulation). The world wars brought attention to the psychological contribution of extreme stressors. By the end of World War II, psychological stress was recognized as an important factor in the onset of certain psychopathologies and psychosomatic symptoms. Medical doctors were particularly interested in the influence of stress on the etiology of disease. In 1949, Adolf Meyer presented an article at the annual Association for Research in Nervous and Mental Diseases, which that year focused on the topic "Life Stress and Bodily Disease". He was also the first to propose using a life chart to map out significant life events to be used as an aid for medical diagnosis. This line of research led to a whole branch of epidemiology devoted to exploring the correlations between stress and metabolic disease, which is briefly described in a later section.

Another area of postwar stress research was to learn the effects of "ordinary" psychological stressors (i.e., noncombative). Stress researchers began to explore the effects of various types of psychological stressors (e.g., anticipation of a negative event, threat, anxiety, grief). As further attempts were made to offer psychological explanations for the biological responses to external nonphysical stressors, psychologists began to recognize that the simple stimulus–response explanation offered by Selye did not capture the dynamic of how a stimulus is interpreted as stressful.

Richard Lazarus (1922–2002)

One of the individuals to first challenge Selye's general adaptation syndrome (GAS) theory was Richard Lazarus (1922–2002). He was educated as a cognitive psychologist at a time when behaviorism was losing its foothold in psychology, but there was still little interest in stress research save the military's interest. Lazarus played an important role in advancing stress research, synthesizing fragmented findings from multiple disciplines in an attempt to develop a theory that considered the multiple factors involved in the "stress response". Most of his research and work was conducted at the University of California, Berkley, where he was a professor from 1957 to 1991 (Ekman & Campos, 2003).

Lazarus introduced the idea of individual differences and variance in response to stress. At the time Lazarus began his research, Selye, with his dominant GAS theory, and those promoting the behaviorist models in psychology were not interested in individual differences and were focused on establishing general laws of stimulus–response. Lazarus argued that the study of psychological stress required a unique type of analysis that is necessarily different from the study of exclusively physiological stressors, such as noxious injections (Lazarus, 1966).

Lazarus argued that what makes psychological stress unique is that it involves personal meaning, or appraisal, as well as emotions. However, he soon recognized that there is a remarkable variance in how individuals interpret or appraise stressful conditions (Lazarus & Eriksen, 1952). He attributed this variance to individual differences in motivational and cognitive variables that intervene between the stressor and the reaction (Lazarus & Eriksen, 1952). This highlights the importance of individual appraisal, because one individual may interpret an environmental situation as innocuous, whereas another may perceive the same situation as stressful.

Unlike the behaviorists, Lazarus introduced cognition and subsequent emotions as important considerations in the behavioral response to a stimulus. In an attempt to incorporate various aspects of psychological and environmental interactions, he developed the transactional model of stress (Lazarus, 1966). The transactional model focuses primarily on the psychology of stress and offers an explanation for the variety of responses to environmental or psychological stressors. The transactional model highlights the cognitive process of appraisal as a mediator when confronted with a stressor—how a person thinks about, or *appraises,* an event mediates the stress reaction.

Lazarus identified that there are primary appraisals and secondary appraisals. In his book *Psychological Stress and the Coping Process,* Lazarus (1966) highlighted three outcomes of primary appraisals[1] that are critical to the emotional response to a stimulus: Is the transaction benign, challenging, or harmful[2]–threatening? *Harm* refers to psychological damage that was already done (e.g., a loss), whereas *threat* is the anticipation of harm that has not yet taken place but may be imminent. Once the primary appraisal has been processed, the secondary appraisal can evaluate the effectiveness of available coping resources. The delineation of stress into primary and secondary appraisals is important to psychology because it moves stress research away from a purely physiological exploration of stimulus and response to a cognitive mediation involving numerous factors and feedback loops that include both

[1] In his later works (e.g., Lazarus, 1975), he identified a fourth appraisal: Will the transaction produce positive well-being?

[2] *Damaging* is the term he subsequently used.

cognitive and somatic responses (Lazarus, 1975). Lazarus (1975) also identified four main classes of reactions to stress: (a) disturbed affect, (b) motor behavioral reactions, (c) change in cognitive functioning, and (d) physiological changes (i.e., biochemical and autonomic).

Lazarus continued to expand the field of stress research by introducing coping as one of the mediators of stress. In 1980, Lazarus along with his graduate student Susan Folkman, posited that people use two general coping styles that are highly contextual (i.e., based on the appraisal of the situation; Folkman & Lazarus, 1980). First, if individuals identify a situation as something that can be resolved using resources available to them (e.g., physical, communicative, interpersonal), they will take actions to ameliorate the situation. This is what Folkman and Lazarus identified as problem-focused coping (although I think it should be called solution-focused coping). For example, if a work supervisor continually places unrealistic demands on an employee's time, the employee could negotiate a more reasonable schedule. If the supervisor and employee can agree to the proposed schedule, the communication is no longer challenging and the threat of being fired or reprimanded is eliminated or at least minimized. However, if the stressor is something that is beyond a person's control, such as terminal illness, layoffs at work, and so forth, individuals tend to engage in what Lazarus and Folkman identified as emotion-focused coping. In emotion-focused coping, individuals try to prevent having an emotional response to a stressor. Examples of emotion-focused coping strategies could be avoidance of the threat (i.e., stressor), denial, distraction, procrastination, distancing. Lazarus and Folkman described emotion-focused coping as an ego-defense mechanism (Folkman & Lazarus, 1980). Lazarus went on to conduct several more experiments and refine his theories throughout the 1980s and 1990s. He pioneered a new exploration of stress research that introduced cognitive appraisals and coping strategies as a mediator of emotional outcomes. He expanded stress research to consider the complex interactions between stimulus, appraisal, and responses.

Proliferation of Stress Research

By the early 1980s, stress research had blossomed to include a wide variety of approaches. In the field of psychology, stress research has been incorporated into almost every subdiscipline, and psychologists further differentiated the various types of psychological stressors, including mental illness. To be noted, the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013), which has the most widely accepted nomenclature used by clinicians and researchers for the classification of mental disorders, includes the requirement of the presence of distress to be considered as part of the diagnostic criteria for the classification of most mental disorders. In addition to clinical considerations, psychologists have operationalized and empirically studied the impact of various types stressors, ranging from daily hassles (Rollins, Garrison, & Pierce, 2002), workplace stress (Borteyrou, Truchot, & Rascle, 2014), parenting stress (Lee, Gopalan, & Harrington, 2016), and perceived stress (Nielsen et al., 2016) to posttraumatic stress (Torres, Skidmore, & Gross, 2012).

Stress Research Into the Next Millennium

Today stress is recognized as ubiquitous in people's daily lives and is considered a driving force in evolution as well as physical and mental health. From the early works of Selye and Cannon, there has been a growing interest in the deleterious effects of stress over time. With the relatively new appreciation of how acute and chronic types of stress impact physical and mental health outcomes, epidemiologists and public health researchers have been exploring the impact of stress on population health (Operario, Adler, & Williams, 2004; Whitehead & Dahlgren, 2006).

Perhaps the most recent advancement in stress research is the study of transgenerational effects of stress. For centuries, evolutionary biologists have observed that physical and behavioral traits are often passed on to subsequent generations (Gould, 2002; Wilson, 1978). Over the past three decades, advances in the understanding of genetics, including the use of the polymerase chain reaction, have helped scientists study gene expression. By the late 1980s, scientists were better able to understand how gene expression produced phenotypic changes. This understanding was a catalyst for Hales and Barker to develop the "thrifty phenotype" hypothesis as a potential explanation for the association between poor fetal and infant growth and increased risk of developing impaired glucose tolerance and metabolic syndrome in adult life (Hales & Barker, 1992, p. 595). The thrifty phenotype hypothesis proposes that poor fetal and infant growth, resulting from the effects of poor maternal uterine conditions, can produce permanent deleterious phenotypic changes (Hales & Barker, 2001). This theory suggests that the maternal environment acts as a nongenomic factor involved in an organism's phenotype. The next section discusses what this has to do with future directions of stress research.

Stress and Epigenetics

Recently, nongenomic inheritance has gained considerable attention. In particular, the field of epigenetics introduced a profound shift in the basic understanding of disease inheritance (Bird, 2007). Epigenetic changes are heritable changes in gene expression within the genome that do not directly change genomic DNA (Anway & Skinner, 2008). Epigenetic research explores mechanisms involved in the heritable changes in gene expression and subsequent phenotypic changes. There is a growing body of research in perinatal epidemiology exploring the transgenerational epigenetic effect of maternal psychosocial stress on health outcomes (Drake & Liu, 2010; Yao et al., 2014). By identifying health outcomes that are strongly correlated with an environmental factor such as psychosocial stress, researchers can target potential diseases that may be linked to nongenomic disease inheritance. There is also a burgeoning body of research on prenatal stress and the developmental origins of health and disease that incorporates the biological, psychological, physiological, genetic, and neurochemical impact (Gluckman, Buklijas, & Hanson, 2016). Prenatal stress has been correlated with adverse birth outcomes such as preterm birth, metabolic disease, cardiovascular disease, and psychopathology (Dominguez, Schetter, Mancuso, Rini, & Hobel, 2005; Malaspina et al., 2008). Even more stunning is that the impact of prenatal exposure to stress has been shown to cause epigenetic changes affecting phenotypic expression across generations (Yao et al., 2014). Needless to say, this new and exciting field of

research on the transgenerational effects of prenatal exposure to stress highlights the enduring significance of stress research at every level of human development.

Conclusion

Throughout the past 100 years, the study of stress has captured the interest of many disciplines, ranging from physiology, medicine, chemistry, genetics, endocrinology, neurosciences, and epidemiology to psychiatry and psychology, reflecting the complexity of the construct both theoretically and biologically. Early research was conducted through rather narrow lenses of either physiological processes or psychological phenomena. Occasionally, one would be almost forced to acknowledge the other, but only to receive honorable mention. The onset of World Wars I and II created a sort of natural experiment that forced the disciplines to work together to better understand the biological impact of psychological stress. The foundational ideas of Osler, Cannon, James, Selye, and Yerkes converged by sharing a language for the phenomena that is now called "stress". Lazarus reintroduced cognition as a factor in stress responses and firmly established stress as a psychological interest. However, the discipline continues to be challenged with the problem of operationalizing the concept: The ways in which the term *stress* is used in research is almost as subjective as an individual's experience of a stress. Despite the term's definitional problems, almost every discipline in the biological and social sciences today has some sort of subdiscipline devoted to the study of stress, reflecting both its relevance and mystery.

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