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Stress and Physical Activity

It was indeed with great pleasure that I accepted the invitation to write an article for the *McGill Journal of Education,* because my ties with McGill have been very close ever since I arrived in this country in 1931. My first contact with that venerable institution was as an Assistant Professor of Biochemistry; later, I became an Associate Professor of Histology. Not only can I consider myself an ex-Professor, through having received a D.Sc. from McGill, I am also an alumnus. Last but not least, since I have made my home just across from the University Street entrance to McGill, I use my alma mater's campus for physical exercise, bicycling through its convoluted and hilly roads between 5 and 6 o'clock in the morning.

It is this latter endeavor that gives me the courage to speak about the field of stress in relation to physical activity, for it furnishes positive proof that I firmly believe in exercise as a means of mastering the stress of my work, even now that I have reached the age of 69 and have to ride my old bicycle using two artificial hips. Let this be the basis of my credibility!

For almost four decades I have been engaged in laboratory research on the physiological mechanisms of adaptation to the stress of life. When I began my first experiments in 1936, the stress concept had not yet been formulated. Today, in my position as director of the University of Montreal's Institut de Médecine et de Chirurgie Expérimentales, I see that the acceptance of the stress concept is widespread, not only in virtually all fields of medicine, but also in the behavioral sciences and philosophy. Indeed, stress is such a fast growing field of medical research that the documentation service of our Institute has accumulated hundreds of books and over one hundred thousand articles on stress and stress-related topics. The notion is common, too, in our everyday experience. At social gatherings we hear a great deal about the stress of executive life, pollution, city life, marriage, and so on, yet few who discuss stress so glibly really know what it means. They have never taken time to study its scientific meaning or its mechanism.

Technological advances in our rapidly changing world are making more and more special demands on our capacity for readaptation. Every day the media expose us to new and often threatening events wherever they occur on earth or even in outer space. At the same time, the greater mobility of our society has made many of us feel uprooted and virtually homeless. Ever-increasing requirements for travel create the need for adaptation to different time zones, customs, languages, lodgings, and a sense of instability results from such unpredictable changes in schedules. Added to the needs that have always motivated man's behavior (e.g., food, shelter, personal safety), these new demands challenge our ability to adapt to our complex environment.

The surgeon who must race against time to prevent his patient from dying, the businessman who wants to keep his clientèle satisfied, and the manager who is under constant pressure from his customers and employees alike, all feel the effects of stress. The difficulties they encounter are undoubtedly very different; nevertheless, their bodies react with similar changes designed to adjust to the increased demands. In other words, the stressors, though dissimilar, provoke an identical stereotyped bodily response.

Laboratory observations have convinced me that to enjoy the challenge of meeting stress and yet avoid its harmful effects we have to learn more about its nature. Only then can we savor the pleasure of fulfillment and formulate our own philosophy of life. It seems that today more than ever before we need to have a scientific basis for our actions, and I think that the rules which act so efficiently to minimize stress on the levels of cells and organs can also be the source of a natural philosophy of life, leading to a code of behavior based on scientific principles. But before delving further into the philosophical and behavioral applications of the stress concept, it is important to review some of the biological facts that we have learned.

what is stress?

Stress, as we have defined it, is *the nonspecific response of the body to any demand*. In order to understand this definition, we must first comprehend what is meant by "nonspecific." Each demand made upon our body is in a sense unique, that is, specific. When exposed to cold, we shiver to produce more heat, and the blood vessels in our skin contract to diminish loss of heat from the body surface.

When exposed to heat we sweat, because evaporation of perspiration from the surface of our skin has a cooling effect. If we eat so much sugar that the blood sugar level rises above normal, we excrete some of it and try to activate chemical reactions which will enable us to store or burn up the rest so that the blood sugar may return to normal. A great muscular effort, such as running up many flights of stairs at full speed, makes increased demands upon our musculature and cardiovascular system. The muscles will need more energy to perform this unusual work; hence, the heart will beat more rapidly and strongly, and the blood pressure will rise to accelerate delivery of blood to the musculature. Yet, whatever their specific effects, these agents all have one common denominator – they produce an overall nonspecific response which increases the need for readjustment. This nonspecific reaction calls for adaptation to a problem, regardless of what that problem may be.

At first it may seem strange that different types of tasks should elicit the same response, but there are many analogies in everyday life where objects or events share the same nonspecific feature. Take, for example, a house in which there are heaters, refrigerators, bells, and light bulbs which respectively produce heat, cold, sound, and light in a most specific manner, yet in order to function they all depend upon just one common factor – electricity. A member of a primitive tribe, never having heard of electricity, would find it very difficult to believe that these manifold phenomena depend upon the satisfaction of a common demand – the provision of electrical energy.

Likewise, in everyday stress-producing situations, it does not matter whether the circumstances we confront are pleasant or unpleasant. All that counts is the intensity of the demand for readjustment. Sorrow and joy produce different specific results, yet their stressor (nonspecific) effects may be the same. All occasions, whether happy or tragic, necessitate adaptation.

what stress is not

Stress is not simply nervous tension. The average person usually relates stress exclusively to nervous exhaustion or intense emotional arousal. But stress reactions can and do occur even in plants and lower animals which have no nervous system. Nor is stress the nonspecific result of damage; any activity, even working on a crossword puzzle, can elicit stress without precipitating noticeable damage. As mentioned earlier, it is immaterial whether an agent is pleasant or unpleasant; it is only the intensity of the demand that matters.

Stress is not something to be avoided. In fact, by definition, it cannot be avoided. No matter what we do, or what happens to us, there arises a demand to provide the necessary energy to perform the tasks required to maintain life and to resist and adapt to the changing external influences. Even while fully relaxed or asleep, we are under stress. The heart must continue to pump blood, the intestines to digest last night's dinner, the muscles to move the chest to permit respiration, and even the brain is not at complete rest while we are dreaming.

When we define stress in this way, we realize that absolute freedom from stress is death. Contrary to public opinion, we must not – indeed we cannot – avoid stress. We can, however, try to minimize damaging or unpleasant stress, that is *distress*.

how the stress concept developed

It is difficult to see how such diverse things as cold, heat, drugs, hormones, exercise, sorrow and joy could provoke an identical biochemical reaction in the body. Nevertheless, it can be shown by highly objective quantitative determinations that certain reactions are nonspecific and common to all types of stressors.

This problem first presented itself under conditions suited to analysis in the course of biochemical experiments at McGill in 1936. While seeking a new ovarian hormone, we injected extracts of cattle ovaries into rats to see if their organs would display unpredictable changes that could not be attributed to any known hormone. Three types of changes were produced. First of all, the cortex (outer layer) of the adrenal glands[1] became enlarged and hyperactive. The second change was the shrinking of the thymus, spleen, lymph nodes and all other lymphatic structures.[2] Furthermore, deep bleeding ulcers appeared in the stomach and upper intestine. Being closely interdependent, these changes formed a definite syndrome.

It was soon discovered that all toxic substances, irrespective of their source, produced the same pattern of response. Moreover, identical organ changes were evoked by cold, heat, infection, trauma, hemorrhage, nervous irritation and many other stimuli. Adrenal enlargement, gastrointestinal ulcers and thymicolymphatic atrophy were constant and invariable signs of damage to the body when faced with meeting the attack of any disease. These bodily changes became recognized as objective indices of stress, and furnished a basis for the development of the entire stress concept.

We soon realized that what we recognized as an "alarm reaction" was only part of the body's reaction to various agents, and that, actually, there are three stages in what subsequently became known as the *general adaptation syndrome* or G.A.S., also called the *biological stress syndrome*. I suggested the name "alarm reaction" for the initial response, arguing that it probably represents the somatic expression of a generalized "call to arms" of the body's defensive forces.

Upon continued exposure to any noxious agent capable of eliciting this alarm reaction, a second stage of adaptation or resistance ensues. No organism can be maintained continuously in a state of alarm. If the agent is so drastic that continued exposure becomes incompatible with life, the animal dies during the alarm reaction within the first hours or days. If it can survive, the animal enters the "stage of resistance," the duration of which depends upon the body's innate adaptability and the intensity of the stressor. The manifestations of this second phase are quite different from, and in many instances, opposite to those which characterize the alarm reaction.

Curiously, after still more exposure to the noxious agent, the acquired adaptation is lost again. The animal enters a third phase, the "stage of exhaustion," which persists as long as the stressor is severe enough and is applied for a sufficient length of time. Because of its great practical importance, it should be pointed out that the triphasic nature of the G.A.S. gave us the first indication that the body's adaptability, or "adaptation energy" is finite since, under constant stress, exhaustion eventually occurs. We still do not know precisely what is lost, except that it is not merely caloric energy, since food intake is normal during the stage of resistance. Hence, one would think that once adaptation has begun and ample energy is available, resistance should go on indefinitely. But, just like any inanimate machine which eventually wears out, the human machine sooner or later becomes the victim of constant wear and tear. This makes the stages of the G.A.S. reminiscent of the three phases of human life: childhood, with its characteristic low resistance and excessive responses to any kind of stimulus; adulthood, during which the body has adapted to most commonly encountered agents and resistance is increased; and senility, characterized by loss of adaptability and eventual exhaustion, ending with death.

Our reserves of adaptation might be compared to an inherited fortune from which we can make withdrawals but to which there is no evidence that we can make additional deposits. After exhaustion by extremely stressful activity, sleep and rest can restore resistance and adaptability very close to previous levels, but complete restoration is probably impossible. Every biological activity causes wear and tear and leaves some irreversible "chemical scars" which accumulate to constitute the signs of aging. Thus, adaptability should be used wisely and sparingly rather than recklessly squandered by "burning the candle at both ends."

adaptability is probably the most distinctive characteristic of life

In maintaining the independence and individuality of natural units, none of the great forces of inanimate matter is as successful as that alertness and adaptability to change which we designate as life, the loss of which is death. Indeed, there is probably a certain parallelism between the degree of aliveness and the extent of adaptability in every animal, in every human.

Many maladies are due not to any particular pathogen but to a faulty adaptive response by the body to the stress induced by the pathogen. Such maladaptations are brought about by derangements in hormonal secretion, and we have called the resulting ailments "diseases of adaptation." Included in this category are insomnia, indigestion, high blood pressure, gastric and duodenal ulcers and certain allergies, as well as cardiovascular and kidney diseases. Ideally, adaptation consists of a balanced blend of submission and defense. Some ailments are due to an excess of defensive, others to an overabundance of submissive, bodily reactions.

Within the body there are two types of chemical messengers: the so-called messengers of peace, or syntoxic stimuli, which tell the tissues not to fight; and the messengers of war, or catatoxic agents, which signal the body to attack, or to defend itself. Unfortunately, an agent may sometimes elicit a response of the wrong messenger. If, for example, we inject a drop of an irritant into the hind paw of a rat, the whole leg will become inflamed. Inflammation is a defense reaction, and if the irritant is potentially harmful, it is a good reaction, for it delimits the injured area. This would be beneficial, for instance, if we injected leprosy bacillus or tuberculosis bacillus. But if a harmless irritant were applied, such as a drop of dilute formalin solution, it would become innoxious immediately upon contact with living tissues. It might kill a few adjacent cells which the rat would not even notice, but the actual disease would be a result of the rat's reaction. People who suffer from hay fever give evidence of this. Although there is nothing inherently dangerous in pollen, if one is allergic to it, it will provoke inflammation, sneezing, etc.; in other words, a faulty adaptive reaction ensues.

The indirect production of disease by inappropriate or excessive adaptive reactions can be further illustrated by an example drawn from daily life. If we meet a loudly insulting, but obviously harmless drunk, nothing will happen if we take a syntoxic attitude and go past and ignore him. But if we respond catatoxically – by fighting, or by only preparing to fight – the outcome may be tragic. We will discharge adrenaline-type hormones that increase blood pressure and pulse rate, while our whole nervous system becomes alarmed and tense. If this happens to a coronary candidate, he may end up with a fatal heart attack or brain hemorrhage. In that case, death will have been caused by a biologically suicidal choice of the wrong reaction. The proper response to a stressor always depends on the particular circumstances involved.

stress and physical activity

We have seen that physical activity can itself be a stressor; the question now is whether it can be useful in minimizing distress as well. In most cases, exercise is one of the least dangerous stressors. The stress of frustration is much more likely to produce disease than would excessive muscular work. Even the greatest experts in the field are not sure why this is so. Presumably it is because the nonspecific stressor effects are always complicated by the specific effects of the stressor itself, and also by inherited or acquired predispositions which can greatly modify the manifestations of stress. Certain emotional factors, such as frustration, are particularly likely to produce distress, whereas in most instances, physical exercise has an opposite effect. But even here there are exceptions. For example, in a coronary candidate, unaccustomed physical exertion can undoubtedly provoke a cardiac accident.

In one experiment we performed, we divided fifty rats into two groups of twenty-five each. The first group was conditioned with exercise, the second was not. Then we chemically predisposed all the rats to develop heart attacks under stress. When they were put into running mills and exercised to exhaustion, the first group of rats survived, while the second group all died of cardiac failure. Why? Because the first group was "in condition" for the exercise while the others were not. This may explain some of the conflicting opinions we hear from cardiologists on whether exercise is good or harmful for heart patients; it all depends upon whether the person has led an active or sedentary life in the past.

In a similar experiment, we used exercise as a conditioning agent, and bone fracture as the pathogenic (damaging) agent. Again the conditioned rat was protected. Thus it can be demonstrated by objective evidence that making an animal physically fit has a cross-resistance effect; one agent crosses over and resists another agent. When a person is gradually trained by exercise, the same result will occur in most cases. His hormonal defense mechanism will be sufficiently mobilized to resist not only the stress of exercise, but many other stressors as well. In addition to preventing disease, exercise and physical activity in general can have a curative value in combating the manifestations of existing ailments (i.e., through physical therapy) and in counteracting the effects of distress.

After a pilot leaves the ground in his plane he cannot stop the motor before he returns to earth again – he must complete his mission. Yet there is a lot he can do, through voluntary choice of conduct, to get as far as possible with the given equipment and fuel supply. He can fly at a speed and on a course best suited to his machine under the prevailing weather conditions. The only two limiting factors over which he has no control are the fuel supply and the wear and tear that the weakest vital part of his plane can tolerate.

When a human being is born, he cannot stop before he has completed his mission on earth. Yet he too can do much, through the behavior he adopts, to get as far as possible with his bodily structure and supply of adaptation energy under given social conditions. He can live and express his personality at a tempo and in a manner best suited to his inherited talents under the prevailing social circumstances. Just as the pilot is limited by what his plane can withstand, man is restricted by the amount of wear and tear that the weakest vital part of his body can tolerate, and this is genetically fixed at birth.

It is clear that our adaptation energy is finite, a fixed amount of vitality which must necessarily be spent for man to satisfy his innate urge for self-expression by completing whatever he considers his mission, whatever tasks he feels he needs to perform. This is not a rule born of some artificially rationalized code. Rather, it is the manifestation of a deeply rooted natural law, related to the cyclicity of biological phenomena. Countless examples can be found in nature of phenomena which must run in cycles. Consider, for instance, the seasonal and diurnal variations in diverse metabolic reactions, the recurring need for food, water, sleep, sexual activity. Many technical studies have dealt with the intimate mechanisms of each of these cycles. For our purposes, it suffices to say that these are essentially due to the periodic accumulation or exhaustion of chemical materials in the course of normal life. Therefore, unless each cycle is allowed to run its full course, damage is inevitable.

This biological necessity for cyclical completion also applies to controllable human behavior. Blocking the fulfillment of man's natural drives causes as much distress as does the forced prolongation and intensification of any activity beyond the desired level. Ignoring this rule leads to frustration, fatigue, and exhaustion which can progress to a mental or physical breakdown.

However, the human body is not built to take too much stress on the same part repeatedly. We have found, in stress research, that when completion of one particular task becomes impossible, diversion – a voluntary change of activity – is frequently as good as, if not better than, a rest. For instance, when fatigue or forced interruption prevents us from finishing a mathematical task, it is far better to go for a swim than to just sit around and continue to worry about the problem.

When we substitute demands upon our body for those previously made on our intellect, it not only gives our brain a rest, but also helps us to stop thinking about the frustrating interruption. If completion becomes temporarily impossible, the diversion of some other activity simulates completion quite efficiently and, as a bonus, usually provides its own satisfaction.

Physical activity, then, is an excellent way to relieve the pressures bearing on our minds and to equalize the wear and tear throughout the body, giving the overworked parts time to recover. Most people seek diversion intuitively for these reasons – just as an athlete may read for relaxation, the sedentary man may engage in sports for a change of pace. The rich executive, although he would not dream of relaxing by moving heavy furniture, may enjoy a regular workout in the gym of his club. Furthermore, we must not forget that while exercise is beneficial in reducing distress, it also helps us combat the physical decay of aging – indeed, this is one of the reasons I race about the campus on my bicycle each morning.

But what can we do to *prevent* distress? Muscular work may be beneficial in relieving the effects of distress, but it alone cannot always prevent it. What we need is a strategy for optimal living, designed to minimize distress and promote agreeable stress or "eustress."

a new code of behavior

In 1956, in my book *The Stress of Life,* a broad, technical discussion of stress, I presented as afterthoughts some ideas on a philosophy of gratitude. To my surprise, these rather subjective digressions from my description of the medical problem of stress raised a disproportionate amount of interest among pyschologists, sociologists, anthropologists, and even clergymen of different faiths. Indeed, over the years I received so much more mail about the philosophy of gratitude than about any of the more tangible medical subjects discussed in that book that it became a basis for a later book, *Stress Without Distress,* and has been dealt with more extensively in the second edition of ***The***

Stress of Life.

Throughout the centuries, all sorts of suggestions have been made about how to achieve peace and happiness through technical or political advances, higher living standards, better law enforcement, or strict adherence to the commands or teachings of a particular leader, sage or prophet. Yet history has proven, over and over again, that none of these means is reliably efficacious.

Since I believe man needs more natural ideals than those which presently guide him, I have attempted to lay the foundations for a code of behavior based primarily on the laws of nature, to which we are all subject, and which we must accept. This code is compatible with – and at the same time independent of – any religion, political system, or philosophy. It is based on the view that to achieve peace of mind and fulfilment through self-expression most people need a commitment to the service of some cause that they can respect. Work as such is a biological necessity. Just as our muscles become flabby and degenerate if not used, so our brain slips into chaos and confusion unless we constantly engage it in some work which to us seems worthwhile. The question, then, is not whether we should or should not work, but what kind of work suits us best. Our principal aim should be not to avoid work but to find the occupation that, for us, is play. The best way to escape from harmful stress is to select an environment that is in line with our innate preferences – to find an activity which we like and respect and which other people appreciate. Most men must have recognition and cannot tolerate censure, for that is what, more than any other stressor, makes work frustrating and harmful.

We must make clear the distinction between our final aims – the ultimate achievements that give purpose to life – and the means through which we hope to attain them. Few people think about the fundamental difference between aims and means, but without clearly recognizing this distinction, we cannot find peace of mind. Means are only good to reach some final accomplishment we can truly respect. In well-balanced, happy people, this is almost always the urge for self-expression and the desire to earn the love and esteem of their neighbors.

The only philosophy in which ultimate aims and means virtually coincide is the purely hedonistic way of life; it disregards all aims except those that give immediate personal gratification (e.g., the pleasures of the gourmet, the passive enjoyment of art, travel, nature). No value judgment is implied here, only a distinction between introverted and extroverted means of obtaining one's own aims. Whether we admire, share, or disagree with the pleasures of the gourmet or the aesthete, their aims are, in essence, always purely introverted and self-centered, unlike the achievements of the superb chef, musician, or sculptor who craves to be creative and to earn the goodwill of his neighbor by giving him something to appreciate and enjoy.

Which attitude is the most beneficial – the purely selfish or the desire to earn goodwill? Granted, egoism or selfishness is the most ancient characteristic feature of life. All living beings must protect their own interests first of all. But despite our inborn egoism, many of us are strongly motivated by altruistic feelings. These two impulses are apparently contradictory, yet they need not be incompatible; the instinct for self-preservation need not conflict with the wish to help others. Altruism can be regarded as a modified form of egoism, a kind of collective selfishness that helps the community in that it engenders gratitude. This is the attitude which I have designated "altruistic egoism." Throughout the course of evolution, single cells have unconsciously combined into multicellular organisms on the basis of this principle. Similarly, individual people have formed the cooperative "mutual insurance" groups of families, tribes and nations, within which altruistic egoism is the key to success. It is the only way to preserve teamwork, the value of which is ever-increasing in modern society.

However, the earliest historical guideline designed to maintain equanimity and peace among men conflicts with this idea. That is, of course, "Love thy neighbor as thyself." In Biblical times, there was no better way of convincing the multitudes to cooperate than to issue this command, and it is true that the effort to "Love thy neighbor as thyself" has probably done more good and more to make life pleasant than any other guideline. The only trouble is that strict adherence to such behavior is incompatible with the laws of biology. Whether we like it or not, egoism is an essential feature of all living beings and, if we are honest with ourselves, we must admit that none of us really loves all our fellow men as much as himself. This self-deception leads only to feelings of inferiority or guilt; it gives us a bad conscience for not acting according to our avowed principles.

I am convinced that, without rejecting this principle, we can adapt it to conform with biological laws discovered in our time and still be compatible with, yet independent of, any particular religion or political creed. As such, it can rid us of the guilt caused by our inability to love on command. Moreover, it neither presupposes nor excludes the existence of God, thereby allowing us to retain whatever faith we may or may not have in a Supreme Being. And, most important, it does not deny the essentially egoistic nature of living creatures. All that is needed for this is a simple rewording of the dictum to: "Earn thy neighbor's love."

earn thy neighbor's love

Thus expressed, the code does not tell us to love on command those people who are truly unlovable; we need not love others as much as ourselves, which would be contrary to the laws of biology. Instead, each of us learns to make himself lovable to others. He who follows this doctrine will greedily hoard wealth and strength, not in the form of money or domination of others, but by earning the goodwill, gratitude, respect and love of those who surround him. Then, even if he has neither money nor power to command, he will still become virtually unassailable and safe, for no one would have a personal reason to attack him.

Viewed from the pinnacle of the eternal great laws governing nature, we are all surprisingly alike. Nature is the fountainhead of all our problems and all our solutions, and the closer we keep to her the better we realize that, despite the apparently enormous divergencies in interpretation and explanation, her laws have always prevailed and can never become obsolete. The realization of this truth is most likely to convince us that, in a sense, not only all men but all living beings are brothers. To avoid the stress of conflict, frustration and hate, to achieve peace and happiness, we should devote more attention to a better understanding of the natural basis of motivation and behavior. No one will be disappointed if, in daily life, he learns to follow the rule of "Earn thy neighbor's love."

notes

1. The adrenals are two small endocrine glands which lie just above and on either side of the kidneys. Each adrenal consists of two portions: a central part, the medulla, and an outer rind, the cortex, both of which produce hormones. Although my extracts did not affect the medulla, the cortical portion was not only enlarged, but showed features of increased activity — cell multiplication and a discharge of stored secretion droplets into the blood.
2. The lymphatic structures are made up of innumerable small white blood cells, similar to the lymphocytes, which circulate in the blood. Exactly what the lymphocytes do is not very well known, but they seem to play a role in the defense of the organism against various types of damage. For instance, in people exposed to x-rays, the lymphocytes tend to disappear, and then resistance against germs and poisons is much impaired.