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THE BODY PHYSIOLOGIC AND THE BODY POLITIC[1]

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AT this bewildering time, when ancient customs are not respected, when new forms of society are being advocated and tried, when doubts cloud plans for present and future action, it is pertinent to inquire whether we might seek and find a social organization which would yield more of the benefits of security than we now enjoy. This search is natural. In the evolution and behavior of living beings the trend towards security has been one of the outstanding features. The oyster's shell, the bird's quick wings, the tiger's teeth and such human devices as clothing, houses and the varieties of insurance illustrate the universality of provisions for assured existence. The search for security is also important. In the relations among men in civilized nations there are many harrowing uncertainties. Industries are destroyed by inventions; business catastrophies create misery as hosts of laborers are suddenly thrown out of employment or realize that they hold precarious jobs; wars inflict on great populations death or painful and debilitating wounds and spread far and wide wretchedness and want. Under such stressful conditions masses of men may be led into precipitate and violent action. No wonder, then, that we look for a more stable society. Yet there are values we would not lose in the effort to gain greater stability of social organization. We would by all means wish to avoid the blight of a fixed rigidity of occupations or classes. We would wish also to avoid any check on human ingenuity directed towards advancing the welfare of mankind. Those

[1] Address of the retiring president of the American Association for the Advancement of Science, Philadelphia, December 27, 1940. This essay is an elaboration of ideas expressed in an epilogue to a volume published in 1932, entitled "The Wisdom of the Body."

consequences would be blighting. Freedom must be preserved—for fresh discoveries and contrivances, for novel enterprise and for the emergence of eminent ability whatever its origin. A social order assuring not security alone, not freedom alone, but both security and freedom, is the desirable goal.

If we examine any social or industrial group we note that it presents two sorts of relations, internal and external. The family, for example, must have regard for the intimate accommodations among its members in the home; and it must encounter in its environment the school, the regulations of local government and other conditioning agencies. Industry, likewise, must arrange for adjustments within and without; inside the walls of its plant it must consider the numbers and activities of its employees, their superintendence and their pay; and outside it must be on the alert for altered demands for its manufactured goods, for maneuvers of its competitors, for shifts in the community, for changes of style and for governmental requirements. Even among nations inward and outward concerns are distinguished routinely; some officials are assigned to meet the problems and to administer the country's interior affairs, other officials are assigned to study its relations with other powers, *i.e.,* to attend to foreign affairs.

Observe that states of stability and instability in the nation, in industries and in homes are closely linked. When a break occurs in the even course of activities of larger aggregations, having widespread influence, the harmful consequences are likely to reach down to the ultimate units in the social structure, human beings. They, who are least influential in the very complicated social and economic hierarchy of influences, are the almost helpless victims. Recognition of that fact is the stimulus for the efforts to devise an organization of society which will furnish a greater assurance than hitherto that mankind shall not suffer distress and privations which are of human origin and which might be avoided by applying human intelligence.

For purposes of later discussion it is pertinent to note at this point that in the functional organization of our bodies there are relations and activities which can be distinguished as external and internal. Our *external* activities are directed towards modifying our surroundings or changing our position with regard to them—manufacturing merchandise, or engaging in hard play, or working for food and shelter—indeed, they include all the voluntary uses of our muscles. Such outwardly directed actions, however, have effects within; they use up our stores of energy-yielding material, they produce acid which might clog the working parts, they increase the amount of waste which must be discharged. These alterations, unless corrected, are capable of interfering to a serious degree with the efficiency of our bodily performance. It is the function of the *internal* activities of the organism to prevent or correct these alterations and maintain stability; thus our bodies are held in a fit state for continued action, or are made ready for special efforts when critical situations arise. Furthermore, the internal activities preserve a fitness for work despite variations in the outer world, such as excessive heat or cold, that might be deeply disturbing. The remarkable effectiveness of the regulative processes of the body's department of the interior in preserving fitness is one of the marvels of biology.

Wonderment over the maintenance of steady states in the human organism increases when we consider that we are composed of substances that are in the highest degree unstable and are commonly responsive to extremely slight modifying influences. The retina, for example, is many hundreds of times more sensitive than the most sensitive photographic plate, and brain cells are instantly dependent on a continuous supply of oxygen-bearing blood. A persistent stability of these supremely labile parts appears all the more astounding when we recognize that the organism is an open system, receiving periodically from the outer world material for its repair and for the doing of work, and giving forth continuously the products of its own decomposition. We should observe, furthermore, that this stability is manifest not only in adulthood but also in the early decades when the body is undergoing a manifold increase of size, and that it is steadfast at all stages of life, although powerful alterative forces may be operating from both within and without. Here is an outstanding achievement, the result of evolutionary processes during immeasurable eons of past time. We are warranted in examining this supreme triumph of organization by nature for possible light on present defects of organization by man.

The most important device which enables our bodies to preserve steady states, notwithstanding conditions which might hamper or be destructive, is the constant character of the circulating fluids of the organism, especially the circulating blood. Our living parts are bathed by these fluids. We exist, therefore, not in the air which surrounds us—we are separated from that by a layer of inert material. We exist in a fluid matrix which provides us each with a private internal environment. Just in so far as this internal environment or fluid matrix is kept from noteworthy variations, there are no internal adjustments to be made; the internal organs can perform their functions undisturbed by the ups and downs of external circumstance or by possible consequences of our own strenuous activity.

A few examples will make these statements clearer. There is, first, the steadiness of our body temperature,

a trait we share with most other mammals and with birds. Though these forms may be exposed to wide variations of temperature without they preserve an equable degree of heat within. The development of a nearly thermostable state in higher vertebrates should be regarded as one of the most valuable advances in biological evolution. Animals which maintain an approximate uniformity of temperature are released from the limitations which might be imposed by seasonal changes; they are not forced to escape either from the torpor of winter's frost or the stroke of summer's torrid heat. Again, there is the steadiness of the mild alkalinity of the blood. A slight shift to an acid reaction would result promptly in coma and death; a slight shift to a more alkaline reaction would bring on convulsions. We avoid both these dangerous possibilities because of arrangements which preserve a striking constancy of the acid-alkali relations of the internal environment. Another example of steadiness is seen in the sugar concentration of the blood. If the concentration rises to a moderate degree the sugar is wasted by spilling through the kidneys; if the concentration falls to a low level convulsions and coma ensue. These hazards might arise in prolonged and vigorous exercise. Then much heat is set free by the contracting muscles, also a large amount of acid is discharged from them, and blood sugar is abundantly utilized. In spite of the possibility of serious consequences—coma, convulsions and thermal damage—they rarely occur. Regulatory processes slip into action and preserve in the fluid matrix a relatively constant state. So characteristic is this constancy, and so peculiar are the processes which maintain it, that it has been given a special name, *homeostasis*.

Homeostasis is accomplished by different means according as processes or materials are involved. For instance, a process of discharging heat from our bodies is always going on at a moderate pace. If the bodily temperature tends to fall the discharge of heat is checked and at the same time there is greater heat production; if the temperature tends to rise the discharge is accelerated. Thus by varying the rate of a continuous process a relatively stable thermal condition is maintained. Similarly, in preserving the mild alkalinity of the blood, governing agencies are nicely adjusted. If a slight amount of acid begins to accumulate, as happens in exercise, breathing becomes more rapid, the heart beats more frequently, the circulation is hastened, more oxygen is delivered to the active organs to burn non-volatile acid, and simultaneously the faster processes rid the body of the resultant excess of volatile carbonic acid. Again homeostasis is preserved.

In so far as materials are concerned steady states are assured by storage in times of plenty and release from storage in times of need. We take in provisions occasionally, we are using them constantly. When food is plentiful, for example, starchy reserves are stored in the liver. If now the sugar in the blood becomes reduced, these hepatic reserves are drawn upon and thereby a safe concentration in the blood is maintained. Excessive increase of material in the blood is avoided by overflow. Too much salt, too much water or too much sugar, taken at one time, are not allowed to accumulate and alter the relative constancy of the internal environment. The kidneys, acting as a spillway, permit the surplus to flow out of the body.

In relation to the maintenance of homeostasis three points may be emphasized. First, it is noteworthy that a special portion of the nervous system has become established that coordinates, in an automatic manner, the variable processes and the material reserves which are involved in keeping a comparatively uniform consistency of the blood. Second, this nervous organization is mainly for emergency use. Experiments have demonstrated that there can be, to a considerable extent, local autonomy in the functioning of the cooperative parts. The liver, for example, can by itself store and release its carbohydrate reserves; the island cells of the pancreas can act independently to manage the use of sugar in the organism; and the heart can perform its functions as a pump quite isolated from nervous government. Third, when stability is threatened, even to an apparently mild degree, extremely sensitive indicators are affected which promptly bring into operation the proper corrective agencies. Thus the oscillations on either side of a homeostatic norm are slight. Indeed, the responsible organs of the body react to any disturbing condition as if they were directed towards preserving a steady state in the internal environment.

Besides the regulatory arrangements which work for stability we should recognize the significant fact that our bodily organization is set up, as a rule, with a large margin of safety. Except in parts of the brain we are not built on a scant and skimpy plan. For example, we have two kidneys, we need only one; we carry much longer intestines than are actually required; half of the lung area, half of the thyroid gland, more than half of the pancreas can be removed without markedly altering the uniform state of the fluid matrix. When we consider the possible damage to organs by accident or disease this liberal mode of construction is obviously important for the persistence of the organism.

Another arrangement making for stability is, interestingly enough, characterized by temporary alteration of the fluid matrix. That is manifest when bodily welfare is imperiled by enemies. If there is a bacterial attack the number of protective corpuscles in the blood is augmented, or an antitoxin is developed to counteract a circulating toxic substance, and the body tem-

perature rises in fever as part of the defense. If larger foes appear, requiring flight or combat, fear or rage is aroused, emotional reactions which are attended by a remarkable and commonly the greatest possible mobilization of the bodily forces for physical struggle. Even though fierce muscular conflicts between man and man or between man and beast are rare in civilized countries, the internal adjustments appropriate for victory are fully retained in us and are ready for instant response. The body is unified, integrated, for a single purpose—survival. Blood sugar is increased, the heart beat is accelerated, blood is specially distributed to the active regions and is circulated at a faster pace, respiration is deeper and more frequent, extra corpuscles are set moving to carry more oxygen, and adrenaline is discharged to reinforce the adaptive nerve impulses. Of course, all these reactions profoundly disturb the internal environment; they disturb it, however, to render the organism more effective in a contest which may issue in either life or death.

In violent struggle non-volatile acid waste is produced in muscles more rapidly than available oxygen can burn it. The accumulation of unburned acid may in the end greatly lessen muscular efficiency, but when there is an emergency that risk is run. It is obvious, however, that when the emergency has passed, extra oxygen must be delivered to remove the liability created by the waste, *i.e.*, an "oxygen debt" has been created. That debt is not deferred by the body; it is promptly paid by persistent deep breathing and rapid blood flow to provide an oxygen delivery of the requisite amount. Thus a condition which might seriously limit freedom of action is soon abolished. Whether foes be small or large, therefore, an admirable readiness and ability to assemble protective forces are disclosed. And after danger has vanished normal homeostasis is quickly restored.

A final notable feature of bodily organization is the special favoring of certain organs when internal conditions take an unfavorable turn. Of these the brain and the heart are the two most privileged. Both are specially dependent on a continuous supply of oxygen; the brain because it contains nerve cells which are exquisitely sensitive to oxygen lack, and the heart because it requires oxygen for its ceaseless pulsing. In a condition which reduces the oxygen delivery, as after a severe hemorrhage, these two organs are soon receiving a normal blood flow, but at the expense of other parts. In starvation also, heart and brain are spared while other structures are slowly consumed.

Mention of the favored treatment of the brain makes pertinent at this point an interpretation of the significance of physiological homeostasis. It is a condition which in the course of organic evolution has been only slowly acquired. Among lower vertebrates, for example, most amphibians are bound to a nearby water source lest they desiccate. And during the long winter they must lie sluggishly at the bottom of an icy pool. Reptiles, having developed a dry skin, may move freely over the land without danger of a disastrous water loss, but they too are rendered inert for months by seasonal cold. When higher vertebrates, during stupendous ages of evolution, acquired a constant temperature and other constancies of the internal environment, when the functions of the body were more and more liberated from disturbing or limiting conditions, what is the advantage that was gained? The answer to that question is that homeostasis has released for the exercise of their peculiar services the higher functions of the brain. If we had to attend momentarily to preserving a proper alkaline reaction in the blood, or preventing its sugar concentration from falling dangerously low, or checking harmful variations of body temperature, we should have time for little else. In the myriads of millennia during which vertebrates were evolving, these functions developed and became automatically controlled. And to the degree that the control was perfected, man, in his complex external environment, has attained freedom of action. Thus our bodies disclose a type of organization in which both stability and liberty have been achieved.

We have previously noted that there are other organizations—domestic, industrial, governmental—which, like the human organism, face problems of internal and external adjustments. Their external adjustments relate to circumstances which may profoundly affect many included units or groups. In a similar situation, as we have just seen, our bodies, by the evolution of a self-regulated internal economy, have become to a high degree liberated from deranging external influences. Can this sort of liberty be achieved in human society? Historical evidence clearly reveals that human society has been undergoing an evolutionary development; and observation indicates that even in civilized nations it is still in an early stage of that development. Wherever complicated functions are performed there appear to be general principles of organization which are more or less realized. It may be that our bodies, which are the culmination of ages of experience, have learned secrets of management that are worthy of our study. We must admit that organisms have long shown abilities beyond the present reach of human ingenuity—for example, the compounding of elaborate chemicals (proteins, fats, carbohydrates), the contrivance of self-reproduction, the nice control of a gradual increase in size of a manifold structure. Only within our memory has man learned to fly as birds have flown for millions

of years. Indeed, the manner in which our bodies have found both stability and liberty may have lessons for larger and less perfect organizations.

The resemblance between the body biologic and the body politic has long attracted the interest of philosophers, biologists and historians. Among sociologists, economists and men of affairs, however, the analogies have been largely discredited, because, it is said, the comparisons have not contributed to the understanding of social structure. The failure to be helpful seems to have been due to pressing to an absurd degree resemblances in the minutiae of that structure. We are not illuminated by a likening of manual laborers to muscle cells, manufacturers to gland cells, bankers to fat cells and policemen to white blood corpuscles. On the other hand, analogies may be instructive if, instead of a comparison of structural details, there is inquiry into relative functional accomplishments in the physiological and social realms. Naturally, on undertaking this inquiry a physiologist must proceed not as an expert in the social realm but as a layman. In the realm of physiological organization, he finds that, despite inherent structural instability and despite constant exposure of unstable organic stuff to powerful destructive forces, an almost incredible steadiness has been achieved. Are not the principles exemplified in the workings of our bodies sufficiently fundamental to have social applications? Might not the outstanding achievement of bodily homeostasis, the means of which have been revealed by fairly recent discoveries, be indicative of ends to be sought, and the means of attaining them, in social evolution? An attempt to answer these questions may not present to students of society any new ideas; the success of the physiological organism, however, may add emphasis to some ideas which are already well recognized. With this admission of hazard in the venture, standing as a boundary post between observed facts and possible pertinencies, a comparison of the body politic and the body physiologic is undertaken.

What corresponds in a nation to the internal environment of the body? The closest analogue appears to be the whole intricate system of production and distribution of merchandise. It would include the means of industry and commerce—the agencies of manufacture and agriculture, the rivers, the roads and railroads, trains and trucks, wholesale and retail purveyors—all the factors, human and mechanical, which produce and distribute goods in the vast and ramifying circulatory system which serves for economic exchange. Into this moving stream products of farms and factories, of mines and forests, are placed, at their source, for carriage to other localities. In the operations of this stream one is allowed to take goods out of it only if one puts back into it goods of equivalent worth. As a rule it is not possible to do that immediately, or to furnish the full replacement value exactly when goods are removed. Money, therefore, is used to facilitate the process of exchange, or credit may serve as a temporary substitute. Thus money and credit become a part of the internal environment of society.

The bodily analogue has been regarded by some as indicating that just as there is fixity of the units (*i.e.*, the cells) in the internal organs, there must be fixity of the human units in the diverse parts of the social structure. That condition, however, is not essential. Emphatically, the essential condition is *functional*—a continuity of service. Men are needed, of course, to operate farms, factories and railroads, but so long as these services are maintained, men may move freely from one position to another. As we shall see later, society, unlike man, is not limited by death; society lives on, for indefinite time, precisely because the human units are replaceable. In social organizations, therefore, the closest analogues to the parts of the body are not the ultimate units, the human beings; the closest analogues are the functional groups—the special trades and professions and the various labor types. They correspond to the bodily organs.

On the assumption that industry and commerce constitute the internal environment of society what has the experience of the biological organism to suggest as a result of its own attainment of stable states?

It suggests, first, that the primary condition for freedom from the operation of disturbing forces, both within and without, is a maintained constancy of the internal environment. According to that required preliminary the moving commercial stream should deliver continuously, to units which are recognized as serving society, at least the necessities of existence—food, shelter and protection and assured assistance if there be injury or disease. Constancy would involve also reliable opportunity for every man to have uninterrupted work and the payment of a wage or other recompense sufficient to permit him to obtain from the stream what he and his dependents actually require. Only in recent years have some of these practices begun to be respected. Others are only discussed. In these regards the body biologic has developed further and become more effective than the body politic in its organization for internal homeostasis.

A second suggestion which physiological organization offers is that trends towards dangerous shifts of stability should be noticed at the start and controlled immediately. We have seen that any even minor tendency towards such a shift in the bodily organism is quickly detected by delicate indicators, and corrective processes are at once evoked to prevent further change

and to restore the former state. In society these regulatory devices are little known or are lacking altogether. We do note that a crude sort of oscillation occurs: loose government is followed by reform and that in turn by loose government again; a boom ends in a depression, and after recovery there is another boom. These swings of social mood by their cumulative effects can cause intense distress. Deeper insight into what starts them, what stops them and how they can be avoided is highly desirable. Furthermore, in the body politic an initial disturbance, instead of promptly arousing protective and corrective factors, often starts a harmful process which spreads through a community with accelerating speed. Thus, when a run on a bank begins, it is self-intensifying. As the claims of depositors force a closure, fears are aroused, and the run extends to other banks, until a national moratorium may be required to permit recovery. Still another example of self-aggravating damage to social stability is seen when stock prices decline; margin calls which are sent out provoke a further fall of the prices and the sending out of further calls; an unchecked circuit of injurious behavior ensues, ending in panic. In short, when danger threatens, stabilizing agencies do not act on the instant to guarantee security; instead, disruptive factors have full sway. The situation demands research on economic fluctuations and on modes of governing them, for the human organism has demonstrated that in an extremely unstable structure there are ways of maintaining steadiness. It is of interest to note that efforts have been made to find sensitive signals of perilous economic tendencies and to set in motion corrective measures. Thus, an index of velocity of deposits was intended as a warning of excessive business activity; and theoretically the condition might be remedied by raising the discount rate. Control of this remedy, however, is subject to influences playing on human prejudice, and its operation will probably remain imperfect until greater knowledge and experience permit more precise decisions.

A further hint offered by bodily homeostasis is that industries and commerce should be organized to operate smoothly in caring not only for routine but also for emergency conditions. In the organism storage of excess material when it is plentiful and release from storage as want arises provide for variable supplies and variable demands without altering the uniformity of the internal environment. The prime value of these methods has recently been recognized by both government and industry. Within the last few years the establishment of agricultural and commodity credit policies, which allow the withholding of surpluses in fat periods, for sale in lean periods, illustrate governmental recognition of the importance of uniform distribution for both producers and consumers. Also commercial storage by preserving perishable foods, by permanent sterilization or by freezing, has been much developed of late, with the result that former seasonal glut or dearth in the markets has become almost obsolete.

In the organism smooth operation under variable demands is achieved also by changing the rate of continuous processes. Those processes are characteristically conducted at a moderate pace, an arrangement which permits them to be varied, *i.e.,* slowed down or speeded up according to requirements. In the body politic the control of processes still has far to go. Instead of a change of rate a frequent alternative is a total stoppage of the process; men are thrown out of their jobs and drift in idleness. How industry and commerce can be adjusted to inconstant or temporal demands has not yet been discovered. Various schemes for coordinating production and consumption and for assuring regularity and continuity of employment prove that thoughtful men are deeply concerned with the fear, the despondency and the hardship which result from uncertain economic existence. Control to a greater degree than now prevails might lead, however, to more extensive liberty of action, as control by stop-and-go signals has eliminated traffic jams and promoted free movement, or as control of infections has enormously expanded the liberties of mankind by providing safe food and drink and by isolating the carriers of disease. More control is tolerable if it results in greater human freedom.

Instant readiness for defense against dangerous and destructive enemies is also suggested by the body. We have noted that, when faced with the necessity of physical combat, almost every part of the organism is almost at once intensely aroused to defensive action and that, for gaining victory, mobilization of the internal forces is likely to reach the utmost limit. No "oxygen debt" is allowed to persist that might be a source of weakness if an emergency should arise. Again observe that security is a primary objective. In a world where predatory nations, powerfully armed, are ready to attack, the ideal of security often is not adequately respected. Internal forces are not trained for action. Protective instruments of warfare are lacking. At a time of crisis industry is obliged to begin to construct buildings and design tools and machines to manufacture the instruments which the crisis demands. Compare this unpreparedness with the preparedness of our bodies which through many generations of little use still retain the elaborate reactions of defense.

Physiological homeostasis would suggest, further, that stability is more important than economy. As previously remarked, excess of water or salt or sugar

is thrown away when derangement of a steady state is approached. The violent shivering which attends a fall of body temperature is, in terms of obvious accomplishment, wasteful of energy, because the muscular contractions do no external work. They are useful, however, in producing heat and thus keeping uniform the fluid matrix. Further evidence that security comes before economy is revealed by the wide margins of safety found throughout the organism. Extra blood volume, lung capacity, blood pressure and cardiac power—much more than ordinarily required—all indicate generous preparations for meeting unusual demands, which might create disorder if they were not met. In personal and governmental practice, also, the principle of preferring security to economy has been to some degree recognized. Life insurance and accident insurance may be paid year after year with no advantage except a sense of being protected. Fire departments are maintained, and armies and navies are kept in fighting trim at great expense, again with special regard for safety rather than economy.

The idea has been expressed that functional groups in the organism, *i.e.*, the various organs, compete with one another for nutriment. There is little evidence to support that idea, so long as the body is in a healthy and well-nourished condition. All groups receive adequate support, not only those which are routinely active, but also those which may be active at some time or occasionally. The reproductive organs offer a striking example of prolonged sustenance before and after functional service, and perhaps through an entire lifetime of no service whatever. Here again is illustrated a liberal treatment of valuable parts rather than strict economy.

In emergencies, when life is in peril, there is, as already observed, discriminative treatment of specific organs. Those on which the organism depends for the proper conduct of its external affairs and for the internal distribution of its supplies receive special care. During protracted starvation, for example, the brain and the heart remain unchanged in weight while other structures waste away in furnishing them with nutriment. And if there is a serious hemorrhage, which drops the arterial pressure and greatly reduces the circulation rate and thereby the oxygen delivery, the pressure is soon raised so that the flow is fast again in brain and heart; but this is effected at the expense of a normal blood supply to other parts, which suffer until the normal blood volume can be restored. In short, the agency which is on the alert for changes in the outer world and which reacts to these changes, and also the agency by which the fluid matrix as a common carrier is kept moving for aid to the body as a whole, despite privations, are supremely favored. In the body politic, likewise, administrative and distributive agents, charged with conducting important external or internal business, receive in time of crisis exceptional consideration. In warfare, for example, the general staff and the service of supply are protected from the perils of the fighting line. And in civil life members of essential functional groups are retained at their usual work instead of being drafted for military duty.

In surveying the evidence thus far presented we see that social, like biological organizations, are characterized by having external relations with the surrounding environment and internal relations among the operating parts or groups; that the higher biological organisms, composed of extraordinarily unstable stuff, have learned the secret of stability by developing wide margins of safety in their bodily structure and ample provisions for defense against dangerous foes, and preeminently by producing for their internal parts a common environment which is automatically held in a relatively uniform state by corrective factors set in action by delicate signals of deviation from that state. The body politic exhibits many processes which resemble those found in the body physiologic; the analogies are so close and so numerous, not only for nation but also for industry, as to intimate strongly that there are indeed general principles of organization, widely applicable to complex aggregations of collaborating parts. Although there are these analogous processes and systems in the social organization they are effective only within very broad limits in providing stable conditions. Without definite regulations for social homeostasis—without an equable flow of the necessities of life to all, without arrangements for variable demands for labor, without signals of economic danger when that danger impends—booms alternate with depressions, hunger alternates with abundance, and overtime work alternates with forced idleness. Also adequate defense against attack by insidious disease or by gross external foes is often neglected; and tight economy and maximal efficiency are demanded with little regard for the welfare of the units in the functioning groups on which the very existence of society must rest. In such respects the body physiologic has evolved methods of operation which are more efficient than those thus far prevailing in the body politic.

A question which properly arises is whether an organized control of the internal environment of society is consistent with human freedom. That control, would, indeed, involve assignment of power to store goods in times of plenty and to release them in times of need, to lay aside wage and job reserves to care for temporary unemployment, to train labor in new skills when they are required, to accelerate or retard essential processes of production and distribution according to demands or needs, to check perturbing and distressing shifts of price level, and to assure to all the opportunity for expert attention in case of illness or injury.

Analogous arrangements exist in our bodies, with the possibility of local control by functional groups, to be sure, but ultimately under a central, automatic, coordinating system. Precisely because that coordinating system is automatic we are free—free from consciously meeting the exigencies of a variable outer world, and from attending to harmful variations of the inner world of the organism. If we were not protected against these perturbing states we should be either compelled to remain inert in a carefully and uniformly regulated chamber, or checked at every move by the need of attentively avoiding such perils as coma or convulsions. Just because there is an inner homeostasis the higher functions of the brain are released for their special uses—for work and play, for adventures, for research and exploration, for the production and enjoyment of literature and art and for all manner of social interests.

We should recognize that the functioning of the human brain has made social homeostasis differ markedly from physiological homeostasis. By use of the brain in seeking new devices we as discoverers and inventors are occasionally changing the internal environment of social organizations. Only thus do we improve it. But an upset of constancy necessarily results. Railways replace canals, automobiles crowd out the horse and buggy, and now airplanes compete with previous means of travel. Such disruptive inventions profoundly derange the functional groups of a social system. Experienced workmen find that their skill can no longer be applied. During a period of transition thousands may be thrown out of work. Then the personal security which social homeostasis might provide would be, for many, sadly lacking. The brain, however, is not only an organ for discovery and invention; it is also an organ for adaptation and adjustment. As possessors of brains we should be able to apply them to finding ways to care for our fellowmen who will suffer from inventions having general social value. By planning employment which is expansible in nontechnical directions, by extending processes of education and specialized training for new skills, by stimulating fresh enterprise, the distress due to penurious idleness can be greatly lessened. Already the humanity of such social conduct is being recognized by the state and by industry. A very important step towards establishing a sense of security will be taken when these and similar measures are regarded as necessary in order to avoid the harassing fears and anxieties and the needless pain of insecurity.

The peculiar service of the brain in adapting the organism to its external environment raises questions as to its rôle in the congeries of organs which constitute the body physiologic. Is the brain in a dictatorial position? Does its relation to the other organs suggest an unchecked dominance? It can, indeed, so act that it and all other organs of the body are destroyed, as in suicide. But if the brain performs its proper functions, it is revealed as acutely dependent on these other organs; a momentary inadequacy of the oxygen supply from lungs and heart abolishes the cerebral processes which are basic for consciousness, and a few minutes of that condition will produce irreparable damage, a state of idiocy. Idiocy results also if an almost incredibly minute amount of thyroid secretion is not routinely produced during the period of childhood. In short, the body physiologic is a collection of organs, the brain among them, which are interdependent and which, for the welfare of the whole, cooperate. Each one needs the others for perfect function.

The brain has almost no *direct* government of the autonomous homeostatic mechanisms; we can not, at will, increase sugar in the blood, accelerate the heart or stop the secretion of digestive glands. On the other hand, if the brain does so direct behavior in relation to outer circumstance that the organism is endangered, the corrective self-regulatory devices will be supremely stimulated. Fever, inflammatory barriers, antitoxic agents, corpuscular defenders, all arise to check infective incursions; and against attack by beast or man emotional reactions summon the forces of the entire body for physical effort. In either case the internal economy as a whole is placed on a survival basis; reserves are lavishly distributed; even portions of the organism itself may be destroyed in meeting the emergency. In these critical conditions the functions of the brain are no longer free; they are confined to solving problems of survival; and creative activities in art and science, apart from those problems, are largely obliterated.

Such disastrous consequences of human conduct have their analogues in the calamities which fall upon nations when governmental leaders act in such ways as to bring on war. The body politic, to be sure, like the body physiologic, is then unified, integrated, and for one purpose—self-preservation. Men are mobilized for military service; women are called by industry and commerce to replace the men; hours of work are lengthened; the arts of peace are neglected; scientists cease their untrammeled labors and concentrate on inquiries of importance for the army and navy; immense resources which might be used to carry comfort and conveniences to the under-privileged or to lessen ignorance and disease are appallingly spent in reckless and malicious destruction; the lives of tens of thousands of citizens are extinguished, and privation and misery become universal. In avoidance of these calamitous disruptions of social stability the problem is that of finding conditions which are least

likely to allow damage and destruction through acts of a functional group responsible for directing conduct related to external affairs.

Before touching on that problem we must consider an inevitable difference between the body physiologic and the body politic. The body physiologic must die. The body politic can live indefinitely. When death of the body physiologic occurs it results from failure of proper performance by one of its essential organs—for example, impaired activity or an ended service in kidneys, lungs or heart. Death is due, therefore, to dependence on irreplaceable parts. By substitution of new parts a machine may continue operating without limit of time. Likewise in social organization there can be unending continuity of efficient existence so long as there are arrangements for continual renewal of the functional groups. The body politic runs the risk of extinction, however, if one or other of its essential functional groups, like those of the body physiologic, is lacking proper provision for strong and useful replacement. There are illustrations of this possibility in the failure of a group in the body politic which is analogous to the brain in its highest functions.

The human cerebral cortex is the climax of biological evolution. The triumphs of its processes in solving the mysteries of natural phenomena, in transforming knowledge into power, in designing ingenious mechanisms, in making and using symbols in place of things, in providing means of perpetuating the past, and in guiding behavior through appropriate ways in the novel world which it creates, give the cortex the supreme position among the functional groups of the body. It happens, however, that among all the units of which our organs are composed the units of our nervous system are least replaceable, either immediately or by substitution. We have only a thin sheet of cortical tissue over the brain surface and it is so indispensable that if portions of it are damaged we may be paralyzed, or rendered blind or deaf or be utterly deranged. In the social body, also, the functional group which corresponds to the organ of intelligence —the revealers, the creators, the directors of affairs—are least easily replaced. It is of the utmost importance, therefore, that whenever unusual ability of social value is disclosed, no matter what its source, it should be allowed every chance to rise to its highest level of accomplishment. Thus the vigorous persistence of the social organism is best assured. Obviously the casting forth of highly gifted, irreplaceable units, its discoverers and interpreters, from a society, is an act partaking of social suicide. And obstacles placed in the ways of advancement to posts of managerial responsibility and direction, so that the members of the administrative group are not supplanted by able successors, may lead to disaster. In that direction revolutions lie, and the fall of dynasties and the distintegration of empires.

The success of the body physiologic would seem to intimate that in the body politic there should be a thorough cooperation of functional groups, with the administrative groups dependent, like the others, on a common welfare. And the failure of the body physiologic to survive would seem to emphasize the importance of adequate replacement of functional groups as an elemental necessity for the social body's persistence. Its firmest basis for longevity and stability would appear to be a generally accepted mode of replacement, socially sponsored as being orderly and just. When a leader is thus chosen for responsibility he becomes a temporary advocate for public opinion. And when he is no longer representative he in turn can be replaced. Thus, in a democratic society, the diffused functional groups have possibilities of continuing the life of the social organization and of controlling their own circumstances. When an arbitrary dictator seizes power these possibilities vanish. The circumstances are now dominated by the personal pride or ambition or whim of a single man. Experience has shown that the social body, like the human body, is integrated by martial emotions and by preparations for conflict. A dictator, therefore, praises military powers, and rouses martial emotions by pointing to national insecurity or national destiny, and finally drives on to open aggression. Thus he obtains the support of a unified people. But despotic domination lacks precisely what is required for continuance of despotic rule—provision for replacement by an equally despotic ruler.

The use of insecurity by dictators as a basis for rousing hopes and fears and hatreds well illustrates the plasticity of people when they are uneasy and anxious. When they are in dire want, or are uncertain of support, or are fearful of their future, they are easily persuaded by any one who firmly promises them relief. And if their distress is definitely attributed to a certain class or another nation, they are easily persuaded to hate and to call for vengeance. The unscrupulous demagogue grasps for power and becomes a menace because he knows that the needy are not free; he knows that they are sure to follow a course in which they are offered abundance. For any democratic society this situation is not without peril. Social homeostasis becomes, therefore, a consideration of prime significance. It is foolhardy to be smug and self-satisfied and disdainful of efforts to establish a more perfect social justice. As remarked before, human society is in the process of evolution, and probably is in what will be regarded as an early stage of that process. Stability of the internal environment of social organization has not been attained. So long

as men have not the right to work and earn their bread, so long as they are left ignorant of vital information, so long as they are ill and not attended, so long as they are in misery and wretchedness without care, further evolution of society should not only be expected but sought, not only advanced by trial and error but promoted by applied intelligence.

We have seen that conditions in the nation, in industries and in homes are intimately related. Harmful consequences of unsteadiness in the nation finally bring misery to the ultimate social units, ourselves and our fellows. But steadiness in society as a whole and steadiness in its members are also intimately related. Just in so far as social stability fosters security, both physical and mental, of the members of the social organization, so also it fosters their higher freedom, assuring them opportunity for self-support, replacing fear by confidence and providing for health and reasonable leisure. These are the prime conditions for wholesome living, for the enjoyment of natural and created values, for the discipline and exercise of individual aptitudes and for the pursuit and acquisition of new knowledge. They are prime conditions also for safety of the body politic.

OBITUARY

GLADWYN KINGSLEY NOBLE[1]

(September 20, 1894–December 9, 1940)

DR. GLADWYN KINGSLEY NOBLE died on December 9, 1940, at the age of forty-six. But his years were crowded with achievement and that must be remembered in mourning the loss of one of the most gifted and dynamic of men. More, the work he set in motion, which will extend his ideas and methods into the future, will be his continuing memorial.

Dr. Noble left behind him two great departments in the American Museum of Natural History. The Department of Herpetology's catalogue of specimens now includes more than 110,000 entries; while his Department of Experimental Biology, which crowds the two upper floors of the African Wing of the Museum, is the crowning achievement of his life. His results are recorded in 182 scientific papers and one invaluable text-book, "The Biology of the Amphibia." His first paper was published in 1913, while he was an undergraduate student at Harvard University; his last three papers may even now be coming off the press. During this period of twenty-seven years our always young friend took his several degrees at Harvard and Columbia, served a year in the United States Naval Reserves, was a lecturer in biology at Columbia University, was visiting professor of biology at New York University and Chicago University, and built up his two departments in the American Museum.

He took an active part in many scientific societies, especially the New York Academy of Sciences, the Society of Ichthyologists and Herpetologists, the American Association of Anatomists, the Society for Experimental Biology and Medicine. He was a corresponding member of the Zoological Society of London, an associate editor of the *Journal of Morphology* and one of the editors of *Biological Abstracts*. His field studies took him to various parts of North America, as well as to the West Indies and Peru; it was doubtless his intimate knowledge of the living animals in their own natural environments that contributed greatly to his success in rearing the same or related creatures in the laboratory. It was also this varied experience in the field and in the laboratory that enabled him to pose his experimental set-up in such ways that his animal subjects could give unequivocal answers.

At Harvard University Noble was a student of Dr. Thomas Barbour, who evidently succeeded in inspiring his pupil with an abiding interest in field studies, in thorough and sound taxonomic work, in the living creature and its individual and racial history. These qualities are evident in all of Noble's early papers on birds and reptiles, a number of which were prepared in collaboration with Dr. Barbour.

In many careers chance plays a conspicuous part. Noble's career was one of purpose and determination from his college days; in his relatively short life there was no lost period. He knew that in the long run the savings banks of learning and hard work pay cumulative dividends; figuratively speaking, he was always reinvesting his earnings to enlarge his plant and productive capacity. And assuredly his products became more valuable as they increased in number and diversity. As we follow his papers through the years, we see that he never ceased to broaden and deepen his interest in taxonomy; he was always searching for individual variations, varietal and subspecific differences, specific, generic, family, subordinal and ordinal characters; but having discovered and recorded these differences, the questions, how, why and by what steps led him to examine each fact from whatever points of view seemed most likely to be productive.

The first really great work that Noble produced was a classification and phylogeny of the frogs and toads. It is based on the analysis of a huge mass of data, patiently assembled from many sources, and an original and extensive examination of many specimens.

[1] A fuller notice of Dr. Noble's scientific work was given in an address by Dr. Gregory at a memorial meeting held at the American Museum of Natural History on December 19, 1940.