ADDRESS OF THE PRESIDENT

THE BIOLOGICAL BASIS OF SOCIAL COOPERATION

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Within the life-time of many of us, the human mind has been shocked by two world wars. Natural scientists are being blamed for the increased intensity and appalling destructiveness of military weapons. The fury of explosives and fire has overwhelmed civilian areas as well as military targets. Even before the advent of the atomic bomb, the annihilation of cultural accumulations and the death and paralyzing misery that man wreaked upon man was stupendous. A future atomic war will surely destroy our civilization and stop human progress for decades if not for centuries. Is it any wonder that the popular mind is concentrating more upon the destructive phases of scientific knowledge and less upon the life-saving, and inspiring advances of scientific discoveries?

Few believe it possible to construct a world government devoted to the well-being of all mankind before rival nations succeed in destroying each other. This pessimism is partly based upon a lack of confidence in the efficacy of traditional diplomacy and statesmanship, partly upon the apparent amoral ingenuity of the natural scientists, and partly upon the conviction that there is an innate principle in human nature or in the universe that drives man inevitably toward national, racial, and class warfare. Man's inborn aggressiveness, the struggle for existence, the survival of the fittest, "nature red in tooth and claw," the "law of the jungle"—all are used to rationalize our failure to attain world peace and security.

The importance of the biological basis of society has been debated. It is also probably an open question whether an intelligent and scientific discussion of the biological factors can in any way influence our political emotionalism. I am of the opinion that, among others, biological factors exert important social influences. Sex, family, and such basic aspects of social integration as the dominance of the top individuals in the social hierarchy antedate the emergence of *Homo sapiens*. Competition, cooperation, and selection have influenced the evolution of these lower population levels and are likewise still affecting the societal evolution of modern man.

I am going upon the assumption that man is a rational rather than merely a rationalizing animal, that intelligence—especially that based upon scientific knowledge—has been and in the future may be used as a guide for social evolution, and that it is one of our immediate objectives to correct social thinking based upon scientifically fallacious concepts. Scientists engaged in teaching, particularly teachers in high schools, colleges and universities, have both the opportunity and the privilege of assisting in the formation of a scientifically sound social philosophy, and in this moment of great global peril, it behooves us to direct our combined efforts in this direction. Once the guiding principles become clear, it is also our duty as citizens to take political action in whatever way becomes possible. Scientists have traditionally avoided mixing their objective laboratory or field studies with their admittedly subjective political opinions. Recent events, however, prove that scientists are immersed in politics whether they like it or not. Instead of avoiding the problem, let us attempt to raise the quality of our social thinking to an approximation of our scientific logic. Let the natural and the social scientists work together toward this end. Democracy is dependent upon an informed and broadly intelligent electorate.

Have scientists formulated guiding principles applicable to social evolution? Many natural scientists have spoken on social problems, and in numerous cases these pronouncements are not considered valid. For example, I recently read an address by the Chancellor of the University of Munich given a decade ago justifying Nazi ideology through biological rationalization. There is always a danger that emotionalism may outweigh scientific logic, particularly in the analysis of human affairs. Let us be explicit in recognizing and evaluating our biases. None of us are infallible, but truth tends to survive error.

Conflict and cooperation are both apparent in human society. Conflict and competition have both constructive and destructive aspects, and cooperation may lend itself to destructive exploitation. What is the biological background for these social manifestations? I think that it can be demonstrated that competition and cooperation are attributes of organization and are as truly characteristic of life as is protoplasm itself. Known natural forces guide living systems away from destructive competition toward toleration, integration, and cooperation. Once such a principle is established, the scientist as such may not be in a philosophical position to state what ought to be done; but he can predict to a certain extent the consequences of our failure to conform to natural law. As a human, the scientist has as much right to make moral judgments as any other individual, and it seems to me quite possible to harmonize our scientific and our ethical thinking.

The concept of cooperation at first sight would seem to be at variance with our usual picture of the relations of organisms in the sea, forest, or desert. These ecological communities, however, are in the process of being carefully investigated and certain generalizations are beginning to emerge. We find much orderability in the community that indicates the existence of an interspecies level of biological integration. Quantitative gradients of a variety of environmental factors order the system in numerous directions. These gradients in turn establish thresholds of survival that result in a q u a l i t a t i v e differential between parts of the system.

As an example, the edge of a forest has more light close to the ground than in the deep woods; there are greater extremes of temperature at the edge than in the middle; there is greater evaporation at the borders; and there is likewise greater air movement. With such contrasts in physical factors goes a quantitave difference in the abundance of many species of organisms including the food-producing plants, the plant-eaters among the animals, and the scavengers, predators, and parasites in the complex food-web.

When the quantitative change in the abundance of any given species reaches zero, a qualitative change of species in the system occurs and gross changes in the interdependent relationships ensue. Not only do gradients occur from the borders toward the interior, but striking variables are found from the forest canopy to the subterranean level resulting in stratification; gradations occur from low-lying swamp forests to well-drained upland forests, from temperate to tropical forests, from island to continental forests, from sandy to clay soils, and from acid to alkaline soils.

Not only do we find gradations giving spatial organization, but we also find temporal sequences. In the Indiana dunes on the shore of Lake Michigan, poplars are replaced in time by pines, pines give way to oaks, and oaks are succeeded by the climax beech-maple forest. The earlier stages of this succession produce conditions that result in the further development of the community. For example, the accumulation of humus in the soil with consequent lessening of the evaporation of moisture gradually eliminates the species adjusted to dry conditions and allows the survival of species adjusted to more moist conditions. The earlier stages of succession are not self-perpetuating, but the climax forest becomes stable and self-perpetuating together with all its dependent organisms.

The development of the community through these temporal stages involves several directional trends. In the early stages, the number of species are few, their environmental conditions fluctuate more widely, and the elimination of individuals and species by physical extremes is more prevalent. In the climax community, the environmental fluctuations are less extreme, the conditions are favorable for more species, the interrelations become more complex, and there is a greater biotic interdependence. In the earlier successional stages, survival depends more upon the adjustment to severe physical conditions. In the mature community, survival depends more upon the adjustment of the species to the other living organisms. Organisms in both the early and simpler as well as in the late and complex stages of community development have to be adjusted to both physical and biotic conditions, but the number of ecological niches increases in the later stages of community development and the biotic factors increase markedly in complexity as the physical factors become more uniform, more stable, and more optimal.

Within these complexes we find species in conflict and competition, species that tolerate each other and live side by side, and species that survive through mutualistic and reciprocal benefit. These relationships set up survival values that sort a large number of genetic variables, thus giving rise to selection pressures that move the whole assemblage along another temporal dimension that is termed organic evolution.

For the purpose of this discussion, I am grouping the various interspecies relationships into four categories—mutual harm or disoperation, unilateral benefit including much conflict and competition, mutual harmlessness or toleration, and mutual benefit or cooperation. Because of selection pressure, these categories have a certain evolutionary order in some cases.

There may be every gradation between these categories, and classification may be quite confused at times. A species may be harmful to another species at one stage in its life cycle and beneficial at another. The activities such as feeding, defense, and reproduction may vary in their beneficial and harmful effects upon other species. However, it is possible to demonstrate that these categories have more than a mere formal order.

Cases of mutual harm are hard to find in nature and the reason is clear. As an example, a lighthouse-keeper on a small island found introduced rabbits eating his vegetable garden. He brought in cats to control the rabbits. The cats ate every rabbit on the island and then starved to death as there was no other available food. The relationship of cats to rabbits was thus mutually harmful. Such a relationship eliminates itself and is usually found only when man has brought unadapted species together or otherwise drastically upset the balance of nature. The Chestnut Blight introduced by man from the orient eliminated the Chestnut tree from our eastern deciduous forests. With the death of the host, the fungus also lost its main food supply. The oriental chestnut, however, has not been eliminated by the Chestnut Blight in its original home and the fungus is also more successful. We may thus state that disoperation is more likely when two species come in contact for the first time and have no common evolutionary history within the same community. Cases of drastic disoperation are not easily found in nature because of the obvious selection against such relationships.

Unilateral benefit including much conflict and competition is a major aspect of community relationships. Some environmental necessities are in superabundance, and species are not in conflict or competition as they acquire what they need. On the other hand, many necessities are in limited amounts insufficient for all, and the struggle of acquisition sets up strong selection pressures. Selection for more efficient predation may direct the evolution of a predator, but such an advantage increases the selection pressure toward more efficient escape mechanisms of the prey, thus tending to balance the relationship. A balance between predator and prey may be reached immediately without evolution. For instance, a food species that is increasing may bring about an increase in the predator or parasite that in turn decreases the food species and thus decreases the number of predators or parasites. Both species will thus fluctuate periodically up and down from the mean population density. This is a form of equilibrium found in nature, but we must not forget that such a relationship sets up selection pressures that in turn result in an evolutionary movement toward better and better predatory devices and better and better escape mechanisms. Consequently a certain balance is maintained in time in spite of the evolutionary progression of the competitive system.

The evolutionary advance of large numbers of species with interdependent relationships of great complexity gives rise to community organization expressed in such terms as the web of life, the food-chain, and the pyramid of numbers. Such integrations are characteristic of very different communities—for example, those of the open sea and tropical continental regions.

It should be recognized, however, that there is an evolutionary movement away from drastic conflict and eliminative competition toward more tolerable relationships. At first sight this directional change is not always apparent, particularly if one focuses upon the individual and not upon the population. For example, an individual puma may be in conflict with an individual deer with a resulting unilateral benefit to the puma. It so happened that, in the Kaibab forest of Arizona, man had "altruistic" regard for the deer because he wished to do the killing of the deer himself. He therefore "saved" the deer by eliminating the pumas. The result was that the deer increased in numbers, could not survive on the limited winter food supply, and died by the thousands. Consequently there was a smaller population of deer than there would have been had man let the puma alone. It is easy to see that what may be a one-sided harmful relation between individuals may be a tolerable or even beneficial relation between populations. Let us also not forget that it is in large measure the populations that are the units of evolutionary change, as has been emphasized by Sewall Wright.

A predator may be better off if it has a diversity of food sources, and this may also be better for the prey species. If efficiency of predation results in specialization on a single food species, the predator is in a somewhat precarious position as far as survival is concerned. Thus we find the whole ecological community tends to move toward balanced interrelations, the parts (or species) guided in large measure by the system as a whole. The whole community tends to attain a relative equilibrium sufficient to carry the quantitative pattern through long periods of time. Competition is maintained at the optimum, and either too much or too little may be deleterious. Optimal competition is the counterpoint in the harmony of nature.

When man upsets the balance of nature, it is often necessary for him to reestablish the balance. About 1900, the sugar-cane leaf hopper was introduced into the Hawaiian Islands and soon afterwards came close to wiping out the sugar industry. The leaf hopper was later found to be native to Australia where the species was neither common nor considered a pest. Parasites and predators were introduced into Hawaii and were so effective in controlling the leaf hopper that it is no longer a serious pest in the islands.

Through the analysis of the relative pathogenicity of ancient parasites in comparison to more recent infections, Clay Huff has recently illustrated the tendency of organisms to evolve from unilateral harm toward mutual toleration. Parasites such as rickettsias, spirochaetes, haemoflagellates and malarial protozoa show much greater pathogenicity in the more recently acquired host and less in the more ancient host. There would seem to be a marked tendency for the hosts to evolve physiological toleration of the parasites and the parasites to evolve away from dramatic elimination of the hosts.

Balance may be the result of opposing competitive pressures without reciprocal adaptation. However, the evidence points to an evolutionary development of balance between populations of different species in some cases at least, to some degree similar to the phylogenetic development of balance in the evolution of organisms and populations of a single species.

With the pronounced tendency of organisms to evolve toward balanced equilibrium and toleration within the ecological community, one would suppose that cooperation between species would be the final chapter in community evolution. Among the generally cited cases of mutual benefit between species may be mentioned the nitrogen-fixing bacteria and their legume hosts, the relation of fungus and alga in the lichen, bacterial intracellular symbiotes, cellulose-digesting flagellates in the intestines of wood-eating roaches and termites, mycorrhizal association of plant roots and fungus mycelia, algae in the tissues of multicellular animals, seed dispersal through fruits attractive to birds and mammals, flower pollination by insects, the cultivation of fungi by certain ants and termites, and the so-called guests of social insects. Added to these are the more recent evolution of plants and animals under domestication by man.

Without going into the details of these mutualistic relations, it is possible to show that a reciprocal adaptation has occurred in many cases leading to interdependence. In a number of instances the symbiote is of as much importance to the host as one of its own tissues or organs, thus establishing an interspecies system strikingly like that of an organism.

Although cooperation does occur in the community, it is noteworthy that it is not nearly as common as one might postulate on theoretical grounds. Many of the cases of mutualism are not strong cases. For example, I know of no evidence to prove that the alga in the lichen association has undergone any evolutionary adaptation to the fungus. Also there is no well-established evidence that the legume has evolved adaptations for harboring nitrogen-fixing bacteria. Mutual adaptation occurs between the termites and their intestinal cellulose-digesting flagellates, but only the primitive termites harbor the protozoa while the derived termites constituting three-fourths of the known species have lost the protozoa and digest their cellulose without symbiotes. One might ask why, if mutualism were the end of evolution, did the termites become so successful after they lost their symbiotic protozoa.

If one examines any one of the large complex ecological communities, one has to hunt for cases of mutualism whereas competition is obvious everywhere one turns. With the exception of flower-pollinating insects, one may even have to travel to remote portions of the world to find certain especially good examples of mutualistic adaptation. Even in the case of insect flower-pollination, found in all terrestrial communities, an analysis of the food habits of over 15,000 species of insects in New York State showed that 75% were predominantly competitive, 23% were predominantly tolerative, and only 2% were mutualistic.

Turning now to the relations within the organism and within species populations, there would seem to be little doubt that cooperation is the successful and dominant adjustment. Cooperation is characteristic between protoplasms in the cell, between cells in the multicellular organism, and between individuals in the majority of aggregations and coordinated animal societies.

No one seems to seriously question the reality of the individual as a biological entity nor to question the fact that the individual is a naturally selected unit. Much controversy, however, still rages over the unity of the intraspecies population. The evolution of the sterile castes in the social insects was explained by Darwin through the selection of the "family" as a whole. Weismann used similar data to show the selection of the "state" as a unit. The social insects are by no means the only coordinated populations. Various gradations of integration occur in aggregated populations from protozoa to man (Allee). The species itself is a population unit basically integrated through hereditary transmission. If selection were acting alone to preserve the fit individual, how would the elaborate adaptations for reproduction have come into existence?

How would sexual adaptation have arisen? By what means would mammals have evolved mammary glands for the nourishment of their progeny? How would a sterile worker ant have evolved? Patently the species is a population unit selected as a whole. Because of the survival or elimination of whole population systems, cooperation between the individuals has evolved. Thus the sacrifice of the individual for the benefit of the whole species may occur and may be understood in both human society and in groups of lower organisms. Just as the cell in the body functions for the benefit of the whole organism, so does the individual organism become subordinate to the population. It is in harmony with natural law to have an individual function for the benefit of other contemporary individuals and also for future generations. This principle gives us a scientific basis for ethics.

Cooperation is probably not an end in itself, but is rather a means to an end. The all-over directional trend in organic evolution seems to have been toward optimum conditions for existence. What was the uncontrolled external environment of the cell became the balanced internal environment of the multicellular organism. Selection of variations lead toward more efficient division of labor and more integration and cooperation between the parts. Differentiation would be useless without integration, and integration would be useless without differentiation. Natural selection has constantly guided organic evolution in the direction of increasing complexity and increasing cooperation. This trend is easily seen in the study of the evolution of intraspecies populations and reaches its culmination in the social insects and in man.

What biological principles emerge from these considerations? A few may be listed.

1. The intraspecies population and the interspecies community exhibit integration in space, development in time, and evolution in time.
2. Development as well as evolution is in the direction of less extreme environmental fluctuations, more optimal conditions, and a more complex relationship between larger numbers of parts.
3. A long-term relative dynamic equilibrium is established in both the population and the community paralleling that in the individual organism (homeostasis).
4. Evolutionary mechanisms tend to guide the evolving system away from harmful relations toward toleration and cooperation.
5. Each individual is a part of a more comprehensive population unit.
6. Each species is a part of an interdependent community with organismic characteristics.
7. The interspecies system is less definite and more loosely knit than the intraspecies system with its germinal continuity.
8. Cooperation is more characteristic and has been carried to a further degree in the organism and in the intraspecies population than in the interspecies community, but it has evolved in all systems.

Do any of these principles have validity in building a social philosophy?

Man, including all races, is one species. At one time isolation produced divergence that if continued would probably have led to a number of distinct species. However, with the increasing development of transportation and communication, the trend is now toward fusion, cohesion, and species consciousness.

What has recently happened to the people of Manchuria, Abyssinia or Poland has greatly influenced the the lives of us all, a fact that dramatically illustrates the interdependence and integration of all mankind. In spite of much destructive conflict, the human species is already integrated through migration, communication, transportation, economics, politics, religion, culture, health, and science. Conflict may be sublimated and controlled in the interests of peace, well-being, and progress. It seems safe to predict that the immediate future will witness much greater coordination.

Diversity of culture is not incompatible with world integration. Cells became more diverse in function as they evolved in a multicellular organism. Species became more numerous as the complex ecological community evolved. Human individuals and cultural groups may be expected to exhibit greater functional variation as they become incorporated into a world society. Selection acts both upon the parts separately as well as upon the whole unit. A certain degree of healthy competition between nations, races, denominations, classes, and institutions may speed progressive social evolution, but present destructive conflict is often deleterious to the world society and to the conflicting organizations.

While recognizing biological parallels, we must also give due weight to the differences between human society and biological systems. Both are doubtless evolving and both are being guided in this evolution along certain perceivable directions, but the evolutionary mechanisms are markedly different as well as markedly similar in the two systems. Human social evolution, through the development of transmissable symbols, has been able to move rapidly from the primitive social systems to high culture and civilization without waiting for the natural selection of mutant genes in the chromosomes. However, there is a social non-germinal heredity that may be compared to biological heredity, and a selection of social variables sorts out the more fit cultural relations for social survival. Also, an intelligent analysis of the factors and synthesis of the principles enables man to control his own rapid evolution and that of his cultivated plants and animals far more efficiently than was possible in the pre-human world. Organic evolution and much social evolution have been largely unconscious, but man's superior intellect enables him to consciously direct his societal evolution. To the survival values of the biological world, man adds the appreciative values that integrate his culture.

Let us frankly recognize and evaluate the differences between the biological and human systems, but let us also not be blind to the similarities. In both, long-term efficiencies may gain ascendency over short-term efficiencies because it is the temporal population that is the unit of selection.

Survival, especially in human social evolution, does not necessarily involve the death of the eliminated. Through the evolution of the capacity to learn from experience, harmful behavior patterns may be suppressed and beneficial patterns developed in the same individual or in the same group. Depending upon long-term benefits to the species as a whole, communism might win or lose in its competition with capitalism without bloodshed. Possibly the better aspects of both social systems may be incorporated harmoniously in a future society through the operation of social selection akin to natural selection.

We cannot settle social problems wholly by recourse to biology. Biologists as such have little detailed advice to offer in building political and social organizations. However, biology may clarify certain fundamental principles that underlie our social behavior and may assist in giving a foundation for a general understanding of the social superstructure.

The formulation of principles has great value, but each principle must be incorporated into our social philosophy in its adjusted niche. "I have often thought," wrote Liebig to his friend Duclaux, "in my long and practical career and at my age (69 years) how much pains and how many researches are necessary to probe to the depths a rather complicated phenomenon. The greatest difficulty comes from the fact that we are too much accustomed to attribute to a single cause that which is the product of several, and the majority of our controversies come from that."

Oversimplification is an error often committed by scientists in their drive to discover basic principles that relate diverse facts. If the terms are general enough to incorporate complex phenomena, they are likely to be ambiguous. Nevertheless on occasion fundamental principles may be stated in language that has meaning to most listeners and in a manner that brings orderability to vast accumulations of knowledge. We may thus be emboldened to summarize our main conclusions concerning biological and human relations. (1) Optimal competitive relations survive and too little or too much competition is eliminated through selection. (2) The probability of survival of individual, or groups of, living things increases with the degree with which they harmoniously adjust themselves to each other and to their environment (Leake). (3) A directional trend in evolution is toward a controlled balance of the important factors within the system. Human society cooperatively brings the social environment under control for the better survival of the species.

If these conclusions are based upon sound evidence and are scientifically valid, we may expect that destructive class, racial, and national war will be largely eliminated. Biology indicates that exploitation of individuals or groups within a population will be superceded by toleration and cooperation. Forces are apparent that are guiding us toward an interdependent world unity. This is not a philosophy of perfectionism. Perfection is probably only in the minds of philosophers. Biology gives us no example of perfection—only an evolution toward a better relationship between parts of a larger whole.

With the advent of the atomic bomb, will the human species become cooperative under some sort of a world government soon enough? This is a question that must be deferred to the social scientists and politicians who must carry the burden of discovering adequate social means for eliminating war. It is now apparent to many that treaties between sovereign nations with exaggerated nationalistic ideologies are insufficient to prevent catastrophe in our own lifetime. The dramatic and terrible potentialities of our present military weapons are in the process of revolutionizing our international thinking. Will such thinking based upon realistic fear of social suicide spur us into effective political and diplomatic action? Can an aroused public force our political leaders to solve this problem and solve it quickly? The issue is clear—it is cooperation or vaporization.

It is a struggle for existence by means of the cooperation of all mankind, or extinction through unnatural destructive competition between individuals, classes, races, and nations already incorporated into a larger interdependent whole. Following the seemingly impossible accomplishments of the natural scientists, can the politicians also accomplish the seemingly impossible? Can the inspiring advancement of natural and social science be directed to the welfare of all mankind? With the development of an energetic public pressure, there is a basis for optimism.