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HIGHER LEVELS OF INTEGRATION[1]

By Dr. R. W. GERARD

PROFESSOR OF PHYSIOLOGY, UNIVERSITY OF CHICAGO

OF the several integrating mechanisms which convert a cell population into a multicellular individual, that of transmission is mainly responsible for the differences between "higher" and "lower" organisms. As it has improved, so has adaptive amplification, the ability of an individual to respond to environmental events, including those related to other individuals. This paper will be concerned, consequently, with the evolution of transmissive mechanisms and with the unit-whole relations which they serve—between cells in the organism and between organisms in the social group.

[1] From an address at the University of Chicago Fiftieth Anniversary Celebration. The complete paper will appear in Biological Symposia, Vol. 8.

TRANSMISSION

Protoplasm, subjected to an adequate stimulus, enters a new and often specific state; it gives its characteristic response—a muscle twitches, a gland secretes. But the response is not restricted to the stimulated region: the urchin egg starts to lift its membrane where the sperm enters, but this continues to rise around the whole egg; the end portion of a muscle fiber, far from the point of nerve entry, participates in the general shortening. Something, some form of excitation, must be propagated or communicated from the originally excited region to neighboring ones; and this is the essence of transmission. This universal capacity of protoplasm to hand on excitation is developed into an exquisite talent by the nerve cells, once they appear. Along their fantastically extended straight processes the nerve impulses, propagated excitation waves, rush to various destinations.

Evolution exhibits striking directional changes in the transmissive capacities of organisms. In speed, for example. The egg membrane rise crawls at the rate of a centimeter an hour; in the adult sponge a message goes that distance in a minute. With the appearance and improvement of a nervous system rates jump precipitously—to 10 cm a second in the net-like nervous system of the jellyfish bell, to a meter a second in the longitudinally directed nervous system of the worm, and to ten and a hundred times this speed in the nerve fibers of arthropods and finally of vertebrates. Or in distance. Excitation in the sponge dies out in a centimeter or two, but neural transmission is unlimited since the impulse retains full intensity as it travels. Or in pattern. Transmission is diffuse in the egg or sponge and essentially so along the interlacing nerve cells of the jellyfish. But in the worm, with nerve cells grouped at each segment, most stimuli elicit local reflexes, and behavior is largely segmental and highly stereotyped in terms of fixed nerve connections.

Vertebrates have elaborated these segmental channels but have added control by functional state, have superposed dynamic patterns on structural ones, and have greatly enhanced the modifiable and integrative aspects of behavior. Such attributes are particularly related to the suprasegmental brain, mainly the cerebral cortex, which originates in the reptiles, flowers in the mammals and culminates in man. The cerebrum dominates the brain stem mechanisms and introduces latitude in the type and timing of total response to a fixed stimulus. It permits that gradual shift in behavior with accumulated experience, which we call learning; and when sufficiently developed, as in man, it permits abstraction and the direction of action by language and other symbols.

The nervous system adjusts an animal to its environment; the environment, reciprocally, has fostered the development of the nervous system. The front end of a moving animal receives most stimuli. There sense organs become more sensitive—to feebler and more variegated and more distant changes—and from them an ever increasing rain of impulses pours into the primitive brain. There the raw sensory data must be coordinated if a unified behavior is to ensue, and there the continued lash of excitation somehow led to the great overgrowth of the cerebrum—from the original nervous center for smell, the first "distance" sense. The environment dominates the receptors and these the brain as this dominates the spinal cord or the nervous system the entire body. A higher organism, then, has advanced beyond a lower one in its ability to respond to more kinds and gradations of environmental change with behavior which is more rapid, complex, variable, integrated and especially, adaptive.

The anatomy and physiology of the nervous system have psychological correlates. The automatic segmental portion is dedicated to self-preservation, and the awareness attending its functioning is unthought affect or feeling. This is evoked almost routinely by particular stimuli and serves individual concerns. It is the selfish part of the psyche. Cerebral awareness is more abstract and represents the reasoning, valuing, aspiring part of consciousness. It is the social part of the psyche which transcends the immediate and selfish and makes group living possible. Injury to or removal of the cerebrum impairs or abolishes the unselfish care which the mammalian mother gives, often at her own sacrifice, to her young and so to her race; but it merely exaggerates the aggressive competitive behavior, seen so clearly in the battles between males for possession of a herd.

It is important that suprasegmental function is gaining still over segmental function, if not by anatomical growth at least by physiological exercise—via education and the swelling base of knowledge. And with this must come a relative increase of altruism over selfishness with continued biological or social evolution. Indeed this is seen at all levels of the living world, for with evolutionary advance there is progressive emphasis on cooperation of unlike units relative to competition between like ones. Both elements are always present, in a cell's protoplasm as in a human's nature; but a step towards differentiation of units and their reintegration into a cooperating whole has always been retained—presumably because it has survival value. This is equally clear for the special organelles of cells, the special cells and tissues of many-celled individuals, and the special individuals of colonies or social groups.

Part and Whole

A unit system composed of lesser units in some degree of interrelation, in contrast to a mere unrelated assemblage, is an organism in the broad sense. To avoid confusion with animate organisms, this has been called an org, and the subclass of living systems, animorgs. Orgs differ in degree of integration and level of organization. As integration increases the control of the units by the org becomes relatively greater—as in passing from molecules in a gas, to a liquid, to a surface film; and the units commonly show greater differentiation—surface molecules become different (often permanently so) from others. An org at one level may, in turn, be a unit in an org of higher level—molecules in cells, cells in multicellular organisms. The degree of integration is determined by the relations between penultimate units and whole—a sponge is a poorly integrated org at the multicellular level, although its cells are highly integrated orgs at the cellular level.

Animorgs are distinguished by several criteria: they possess a structure based on carbon and water, on colloids and membranes; they show a continuous change with time, development of the individual or the type; they manifest the same activities of dynamic equilibrium (roughly metabolism), specific synthesis (roughly growth), and adaptive amplification (roughly behavior); and they are integrated by the same gradient, mechanical, transportative and transmissive coordinating mechanisms.

The panorama of evolution shows a strong tendency for animorgs, indeed for orgs in general, to evolve towards increasing integration at any one level and to superpose additional levels of complexity. Thus, at the subcellular level molecular orgs increase in integration until autocatalytic and virus molecules appear. The cellular level is then added, with molecules (including autocatalytic ones) as units, and at this new level integration again advances from that of the simplest micrococci to that of the most elaborate flagellates. Another level, of multicellularity, is then added and metazoans increase in integration and complexity from the sponge through man. There is no obvious reason why the multicellular individual should remain the highest level of evolutionary invention, and in fact it does not.

Multicellular organisms are as clearly built into higher level animorgs, which may be called epiorganisms, as are cell animorgs built into multicellular ones. The colonial coelenterates become that striking individual epiorganism, a Portuguese man-of-war, in the extreme case; the social insects evolve from the most crude and temporary groups into the highly characteristic epiorganism of the single beehive or anthill or termite nest. The physiological structure of a particular termite colony and the physical characteristics of its nest are as unique for each species as are the attributes of the individual insects; yet the nest is the collective achievement of the group and quite beyond the capacities or level of the individual. In the same way, the mammalian family and herd and ultimately the larger human social groups constitute various epiorganisms. These are poorly integrated at the epiorganismic level and such units as a single nomad tribe, the British Empire, the human race and the entire ecological community may be chosen as overlapping examples of human epiorganisms.

Such groups of organisms form a true unit, albeit often a poorly integrated one, and it is an animorg by all the defining criteria—composition, development, activities and integrating mechanisms. Consider, for example, just the question of transmission, since the whole material has been presented elsewhere.

Transmission is called communication in the society and is mediated largely through the seen or heard symbol which is the analogue of the propagated protoplasmic or nerve impulse. Our symbols, our language, correspond still to the graded transmission of undifferentiated protoplasm, rather than to the sharply all-or-none messages carried by nerves; but these are also evolving and their precision is being enhanced with the aid of semantic and semiotic disciplines. Also in the evolving epiorganism, as in the organism, the speed and distance of effective transmission steadily increases, and the units particularly responsible for communication become centralized—we need glance no further than the great newspaper and radio chains. Finally, the driving evolutionary factor in the case of the epiorganism, as of the organism, is the stimulating action upon it of its environment. External stimuli lead to high specialization of receptors which receive them, and the receptors in turn become the dominant elements in the organismic gradient and so lead its development. The social receptors which continually expand their sensitivity to the outer world are the scientists, and these units now point the direction of social evolution. All agree that this is the "age of science," whether they like it or not.

Of the many objections to the organismic view of society, two have been especially urged: (1) coherence of the social group depends largely in inanimate materials, and (2) the component units are spatially separate and independently mobile individuals.

As regards the first, it may suffice to point out that in the organism, likewise, much of the body material and structure is clearly dead, although laid down under the influence of living cells. It is even true that special types of non-living material become increasingly important as multicellularity appears and develops. Thus the wood walls and tubes of the higher plants are completely dead yet highly serviceable to the organism; as are the calcareous or chitinous skeletal structures of many animals. Our own outer skin and nails and hair, most of our bone and cartilage, the great masses of connective tissue fibers which support and give cohesion to our tissue cells and our body fluids, including the great fluid fractions of lymph and blood, are all completely dead. They have been built or accumulated by the action of living cells, but are not themselves alive and in many cases never were. Wood, bone, chitin, sclero-proteins have been overwhelmingly invented or applied by the multicellular organisms. In the same way, not solitary but social man has introduced as new structural materials in the body of his epiorganism such substances as cement, rubber, plastics and metals.

As for the second point, the separation and mobility of the units, similar parallels can be seen in the animal body, as in the wandering digestive cells of invertebrates. But an especially beautiful case is at hand in the slime molds studied by Raper. Through the entire period of vegetative life, the many single amoeba-like cells pursue their independent ways, seemingly an uncoordinated aggregate of separate individuals. Yet when food fails the myxamoebae stream together to form a characteristic ensheathed worm-shaped mass. This has a dominant head end which leads the rather considerable migration of the whole and which finally becomes a particular region of a sporebearing fruiting body. This latter is a morphologically and physiologically distinctive multicellular organism. In the same way, individual men may seem to pursue their "independent" courses (yet far more interdependent than are the vegetative myxamoebae) under "normal conditions"; yet they also promptly manifest their character as units in a greater whole when conditions demand. In the supreme emergency of warfare, the overt integration into a greater whole, the army, is almost as complete as in the ordinary multicellular organism, with the units often in close physical contact and with independent mobility largely abrogated.

Man and Society

Man then is an org, an individual organism, and he is part of an org, a unit in an epiorganism. Many of the problems and conflicts in human nature and in social relations seem to stem from this fundamental duality. As societies develop there is an indubitable trend towards greater cohesion—in the so-called democracies only less than in the avowed totalitarian states. (Reasons for not equating this trend with Naziism or any other existing dictatorship are developed elsewhere.)

Societies evolve into more integrated orgs and the parts, down to individual man, become more subordinated to the larger group. As the royal government overcame and absorbed those of the petty nobles, so our federal government is inevitably growing relative to state governments; and it is not a question of if, but only of when, an effective international unit will supplement, and eventually largely supplant, our present national ones. Isolationism is a biological anachronism.

The individual is also, of course, changing under the influence of the epiorganism in which he develops; and he both gains and loses freedoms. Social man has lost the freedom to run naked in summer, but has acquired the freedom of turning on the furnace in winter; he has lost the freedom to kill his fellows, but has acquired the enormous freedom conferred by a language with which he can discuss disagreements. There is no question that we prefer the new freedoms gained to the old ones surrendered. The important point is that healthy evolution brings about these changes by subordination, not by suppression. The individuals are imperceptibly conditioned to their social mileu, the internal environment of the epiorganism, and overwhelmingly they behave as they do with no feeling of coercion but rather with one of free and voluntary action.

Perhaps the most significant of these gradual changes in individual men, considered collectively, is the progressive growth of altruism. Altruism at the social level is a manifestation of the same cooperative actions which are present always between the units of an org and which are enhanced by evolution at each biological level. As single cells with differentiated cooperating protoplasmic structures have appeared and prospered in the course of evolution; as multicellular organisms have steadily moved towards more specialized and interdependent parts and organ systems; as the mother cares for and sacrifices in behalf of the young in the family org, and the individual member of many a subhuman group helps and sacrifices for his fellows under an impressive variety of conditions; so in humans individual loyalty towards and service or sacrifice in behalf of the group—trade or professional organization, religious body, and particularly the whole state—is marked and is increasing.

There are, however, serious transitional problems which may well become worse before being resolved. They arise peculiarly, I think, from the existence of very highly integrated units in a still very poorly integrated org. The amount of physical power wielded by the society, and the differentiation of its unit members into highly developed specialists of all kinds, have increased faster than have those coordinating mechanisms which must effectively reintegrate these units into the whole. (This one might regard as a consequence of the earlier and more lusty growth of the physical sciences as compared with their social counterparts; and it is a healthy sign that to-day so much constructive thought and support are being given to the development of the latter.)

Society, for example, is in bitter need of better mechanisms for selecting its leaders, the individuals who will play the dominant role in the social gradient, as the brain and receptor cells exercise physiological leadership in our own bodies. When proper leaders—men qualified by talent and training for the duties demanded in the position of social leadership—can be selected by devices which are more dependable and objective than are the accidents of family, rhetoric, ambition and other circumstances which to-day frequently toss undesirable individuals to the apex of the power pyramid, I believe that the most serious of the world's afflictions will have been conquered. The social mechanisms of integration are continuously evolving by invention and the pressure of necessity. They will be tested and will endure or be superseded on the same criteria of fitness for survival that have led, through natural selection, to the highly adapted multicellular organisms.

Man as an org is selfish, individualistic and dominated often by the old brain and its emotional attributes. Man as a unit in the epiorganism is altruistic, cooperative, and depends on the functioning of his new brain and its intellectual attributes. But the subordination of the old by the new is not yet sufficient. Human nature is evolving but is doing so less rapidly than is the epiorganism in which it expresses itself. Altruism is not yet generalized to the full group, to the whole human epiorganism, but only to the larger subordinate groups based on race or religion or state. As the units given adherence have grown, so have the conflicts between these units become more massive and devastating; and perhaps still other wars on a still greater scale are to be encountered on the path to world integration. But ultimately this integration must be achieved and conflicts of the present type become impossible.

The new brain, the cerebral cortex, is evolving continuously and greatly under the influence of education, which profits by cumulative social achievement; the world is ever more at our individual doors, and cooperation is being generalized to larger and larger groups; mankind as a whole will become an integrated cooperative unit; and the ultimate future of human society, however dark it may look to the contemporary sociologist or even to the historian, appears in the eyes of the biologist, sighting down the long perspective of organic evolution, as bright with hope.

HOW PLANT BREEDING PROGRAMS COMPLICATE PLANT DISEASE PROBLEMS

By Dr. NEIL E. STEVENS

PROFESSOR OF BOTANY, UNIVERSITY OF ILLINOIS

THE present interest in breeding crop plants, together with present means of wide and prompt dissemination of new varieties bids fair to still further complicate disease problems, whether of control, prediction or even of estimation. Given a fairly stable agriculture based on varieties long established in a region, serious fluctuations in the severity of a disease, the kind which are of great economic importance and incidentally of much scientific interest, usually were induced in one of two ways—a marked change in the weather for a longer or shorter period, or the appearance, by hybridization or mutation or by actual introduction, of a new parasite. So generally has this been the case that some pathologists have found an apparent relation between the age of an agriculture and the losses from plant disease. To these students it has seemed that plant disease losses were greater in the regions of newer agriculture.

The list of tragic losses in important economic plants due to introduced insect pests and plant diseases is a long one, too well known to need repetition here. Of the converse process, a serious outbreak of a disease or an insect pest following the introduction of a susceptible variety into the domain of a potentially serious parasite, the history of the potato beetle is perhaps the best known example.

If the historical accounts are correct, the potato beetle acquired its appetite for potato plants very soon after the introduction of the new host. The corn-borer was apparently more deliberate and according to Wardle,[1] "We have historical evidence that the corn-borer thirty years ago was in southern Germany a pest of hemp and hops, and that since its adaptation to corn, it will not seriously attack hemp and hops, even when these plants are grown in close proximity to heavily infested corn fields." Of course, the slightly more than four centuries during which corn had then been cultivated in Germany is really a short time compared with the more than forty centuries which DeCandolle believes hemp had been cultivated, but it is entirely too long to be regarded as a practicable test or quarantine period.

To these two well-recognized methods by which the incidence of losses due to disease and insect pests is strongly influenced, namely, weather changes and introduction, there is now being added, I believe, a third, the work of the plant breeders. It may be worth while to consider future possibilities on the basis of past performance, the only method yet devised for any intelligent appraisal of the future.

On the basis of past performance we may reasonably expect interesting developments in the distribution of disease-producing organisms. As an example of this may be cited the case of the introduction into the northern states of the nematode which causes summer dwarf of strawberries. In the spring of 1930 strawberry plants of the then new and highly regarded variety, Blakemore, were shipped from a region where this type of strawberry dwarf was com-

[1] R. A. Wardle, "Problems of Applied Biology." 1929.