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# SOCIAL IMPLICATIONS OF VITAMINS[1]

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THE theory of evolution has profoundly influenced the philosophical and religious thought of our generation as well as that of its predecessor. In alliance with the sciences of genetics and neurology it has shaped much of our thinking concerning the psychological and nervous organization of the human personality. At one time, especially under the influence of Herbert Spencer, the evolutionary concept had a profound influence upon theories of government and social organization. Perhaps it would not be going too far to say that the doctrine of *laissez-faire* had for a generation some of its main roots in the soil of our views of the evolutionary process. In the present day of world-wide acceptance of planned economies and of various forms of paternalistic regimentation *laissez-faire* has become disreputable and scarcely any one is so poor as to do it reverence. Increasingly, popular thought classifies human social organization as a thing apart from nature, something to be dealt with as seems to us expedient.

Believing that it is a grave mistake to divorce any broad aspect of human life from its setting as a part of nature, I beg your indulgence to-day in departing from the shop talk of chemists, namely, chemical compounds and chemical reactions, and ask you to consider with me what man may learn from chemistry

[1] Lecture given on the occasion of the fiftieth anniversary celebration of the University of Chicago, September 22, 1941.

about how his own life may be reshaped with a maximum promise that it shall turn out nearer to his heart's desire.

The Darwinian theory of evolution drew its more certain data largely from morphology and particularly from the shapes of the skeletal remains of living creatures which have left their imprints in the rocks. This trustworthy morphological evidence was embellished and fortified with many rather speculative inferences from the conduct habits of creatures still living. This latter type of evidence has been increasingly discredited in our own times. The remaining morphological evidence presents relatively minor similarities amid major contrasts of the forms lying but a few inches or a few feet apart vertically in successive strata of the rocks. So long as the soundness of the idea of development of species by progressive changes was in dispute, the tendency was to emphasize how great changes may occur without complete eradication of tell-tale similarities. Alteration was exaggerated and the persistence of inherited traits was minimized so that, for the popular mind at least, the time scale was unduly foreshortened.

Consideration of the chemical descent of man, emphasized particularly by our new knowledge of the vitamins, corrects in great degree the illusory sense of gross, rapid and radical alteration suggested by morphology. It brings into prominence the underlying conservative principles in nature. Vitamin chemistry brings new and more intimate visions of the steps of evolutionary progress, for we find chemical evidences of community of inheritance in living things so far separated in the evolutionary scale that nearly all similarities of outward form have been erased. The far more pervasive and persistent chemical inheritances permit us to verify the successive inventions which have made an expanding life possible and to enrich the record with manifold new details.

Let us now review briefly the chemical evidence in support of the common inheritance of all living things. First, we should recall for the benefit of those less versed in chemistry that living matter is composed predominantly of compounds of carbon. Carbon, of all the elements, possesses the singular property of uniting with itself to form long chains which may be straight or forked or may double back upon themselves to form single or multiple rings. Occasionally an atom of nitrogen, oxygen or sulfur is enticed into a place in these chains or rings, but predominantly living matter is an interlacing linking of carbon to carbon with hydrogen atoms clinging at the sides of each carbon along the chains.

The significance of this peculiarity of carbon compounds may perhaps be rendered clearer by an analogy. The compounds of other elements which make up inorganic nature may be compared to discrete word signs such as the Chinese use. There have to be as many signs as there are words to be expressed. By contrast carbon atoms resemble letters of an alphabet which may be linked together to form thousands of words from a few characters. The analogy is not perfect, for all carbon atoms are alike while the letters differ from one another, but the lack of diversity of carbon atoms is more than offset by the great variety, complexity and size of the spatial arrangements which they form, arrangements which we call molecules. There are approximately as many known compounds of carbon as there are words in the English language, and the structural formulas of even relatively simple ones often contain more characters than a German jaw-breaker.

It is a commonplace that the derivation of words in Caucasian tongues can be traced readily by the recurrence of familiar sequences of characters, often modified according to accepted rules. When one examines the significant carbon compounds which occur in living matter, one can not fail to be astounded by the recurrences of identical compounds throughout the entire evolutionary scale from unicellular microscopic yeasts to man himself. When one considers the scores, or hundreds, or even thousands of patterns into which those same carbon atoms might have arrayed themselves, any explanation of such recurrences of identical compounds, other than that of the common chemical inheritance of all living things, becomes virtually impossible.

In considering the complex carbon compounds which recur again and again in living nature, we shall pass over those which are common to animal forms alone. Among these are the hormones secreted by the endocrine glands. The use in human medicine of extractives from the glands of oxen or sheep is of course based on the fact that the active compounds are normal products of the physiological activity of man and beast. Thyroxine, for example, controls basal metabolism for frog, snake, bird and mammal.

We shall turn rather from these near relatives of ours and survey what is common to a much wider range of living things. We may mention first the role of glucose in nature. This substance is present to the extent of about five grams in the blood streams of each of us at this moment. Turn where you will, you will find it also in other blood streams and in the saps of plants, not as a trace substance but as an important intermediate of vital processes. The green plants make it from carbon dioxide and from it they produce starch and proteins. These plant carbohydrates and proteins are degraded by animals which consume them as food. In doing so, the animals retrace the downward steps again to glucose which is in common burned as the source of vital activity, heat and mechanical work. Even the degradation of glucose to spent carbon dioxide and water we evidently learned from very distant progenitors for the process of glycolysis in our muscles follows for the most part a pathway common to that used by the humble yeast cell in the process of alcoholic fermentation. Many of the intermediate stages are identical.

If this were a single instance, it might be supposed fortuitous. Water is equally or even more universally and uniformly distributed in living things. As it is also abundant in inorganic nature, it is quite conceivable that the various forms of life just happened to incorporate water in their systems. Glucose differs in that it is not present in the inorganic world in perceptible amounts. However, the significance of the community of its role in living things rests on something far more profound than that. The metabolism of glucose follows a common pathway in diverse living things because it proceeds by the action of a whole series of complex organic catalysts known as enzymes. These enzyme molecules are too vast and complex for the chemist to decipher completely to-day, but we can now say that the prosthetic groups or business ends of these molecules are in many instances what we earlier came to call the vitamins. These vitamins are, therefore, the bits, the working ends, of the keys which unlock the stores of vital energy from glucose and other foods. The keys are master keys which perform the same function within the cells of all living things alike, to the best of our knowledge and belief. Since the keys turn smoothly in a thousand locks, can we suppose otherwise than that the keys and locks were fashioned by the same hand and mind when life first began to breathe?

There are many of these chemical mechanisms common to plants and animals. Vitamin C is a characteristic constituent of plants during growth but not during dormancy. Sprout a seed and vitamin C appears overnight. It is also present in the tissues and particularly in the livers of all animals so far examined. Man, the monkey and the guinea pig have to get it from the plants; other animals can make it for themselves. Vitamin E, occurring in wheat germ and lettuce leaf, is essential to the fertility of mammals. Oestrone, a mammalian female sex hormone, produces visible stimulation of the growth of young pea seedlings.

Still more conspicuous examples are found among the members of the vitamin B complex. Of these no other quite equals $B_1$, the antiberiberi vitamin, in the profundity and universality of its essential action. It is present in every living tissue which has been critically examined. It is demonstrably required not only by every common mammalian species including man but is also indispensable for flies, beetles, certain worms, bacteria, molds, fungi and yeasts. The higher plants fabricate hundreds of tons of it annually and store it in their seeds in quantity. Without it the sprouting seed can not form a root system. This may be demonstrated by sprouting tomato seeds in water and cutting off the rootlets when they have grown to a length of a half inch or so. The severed roots are then transferred to a solution of pure sugar and small amounts of nutrient salts. No further growth of the rootlets occurs unless vitamin $B_1$ is also added to the solution. If added in amounts ranging from one part in 40 million million to one part in 40 million, growth of the roots occurs in proportion to the amount added.

Vitamin $B_2$ or riboflavin also enters into several enzymes as part of the wide-spread oxidative mechanisms of living things. It occurs in most plant tissues and plays a role there like it plays in animals. Recently its importance in human nutrition has been emphasized by clinical observation of eye disturbances and lip sores which respond with amazing rapidity to small doses of the yellow pigment. A deficiency of it is now rated among the four or five most important deficiencies in the American diet, but the immediate causes of the shortage are not yet clear.

Nicotinic acid, a familiar substance, long known to chemists as a constituent of foods, turned out only four years ago to be the pellagra vitamin. Thousands of people died in the insane asylums of our South for lack of it and many thousands more still suffer some degree of impairment from a shortage of supply. Even before its efficacy for the treatment of pellagra was published evidence was forthcoming that staphylococcus, the common pus-forming organism, finds it equally indispensable for its humble life, as do also the roots of tomato plants. It is the prosthetic group of cozymase which floats in our blood stream and in the fluid contents of yeast cells, performing in each the same necessary function.

Another member of the B complex is pyridoxine, which was first found essential for the growth of rats and for the prevention of a dermatitis long confused with true pellagra. Its utility for several plants and microorganisms was tested at a venture with positive results. Tomato roots and certain molds, for example, require it as man does. It is coming into a limited use in human medicine.

The worth of most of the vitamins was first proved for animals, and it was not till many years had elapsed that attempts were made to prove that plant tissues which supply them actually fabricate them for their own needs. There are, however, three vitamins which were first recognized as growth substances for plants and were tried on animals only years later. These three are inositol, pantothenic acid and biotin.

They were known as useful for plants about fifteen, ten and five years respectively, before their animal functions were recognized. From these experiences, biochemists have come to feel that utility of a new natural substance in either kingdom justifies tentative presumption of utility in the other.

All these substances have been isolated in a pure state from nature and the structure of all of them except biotin has been determined and verified by synthesis. In general, their structures are highly specific and slight alterations of nature's pattern result in physiological inutility for the whole range of the evolutionary scale. Their structures vary greatly in complexity from one vitamin to another and there are no features which are common to them all. Each of them apparently represents an independent invention made by some of our common forebears and handed down impartially to all their heirs. The leaves of the ginkgo tree whose imprints, estimated to be twenty million years old, are found, true to the modern pattern, in the carboniferous rocks, as well as the leaves of the latest Burbanked fruit alike make the same vitamins and utilize them for the internal economies of the plants. The animals came much later than plants and can claim no share in the inventions but only in their adaptive application. More and more we who have long boasted ourselves as lords of creation find that we are also mendicants in nature's bread line and heirs of the grass of the fields.

So much for the water-soluble vitamins. The special function of the quite dissimilar fat soluble vitamins is less clear. They are not known to be components of enzyme systems, but they do definitely belong to both plant and animal kingdoms.

The existence of vision in animals is one of the outstanding marvels of nature. That the light reflected from a distant object can produce a faithful image in the consciousness of creatures at humble levels of the evolutionary scale seems to the reflective mind a miracle of adaptation. If all life were to be wiped out and the whole drama of evolution reenacted, would sight come again to the earth? If so, would nature employ new agencies or resort again to her lost art? That the latter might be the case is suggested by the fact that the photochemistry of vision appears to be similar wherever we encounter it.

The retinas of most vertebrates contain two groups of light receptors distinguished by their shapes as rods and cones. The rods function in dim light; the cones, in bright. Both rods and cones contain closely related photopigments which comprise a carotenoid in combination with a protein. Just as light affects the silver halide in your camera film and makes a picture from the varying darkness of the resulting silver particles, so light bleaches these pigments in each microscopic rod and cone to make an image on the retina which is somehow transferred along the optic nerves to our brains and our consciousness. The photopigment of the rods is called rhodopsin or visual purple. It is a compound of a giant protein molecule with a molecule of vitamin A. By exposure to light, this compound is partly split into free protein and free vitamin A. The two cleavage products, however, are constantly recombining. In the dark, the recombining process overtakes the splitting process so the eye is fully rested to see again.

Before discussing further the function of vitamin A in the rods, let us refer briefly to the cones which contain a closely related violet pigment called iodopsin which also bleaches to a substance which is probably a simple derivative of vitamin A. Its chemistry is yet to be fully worked out. In chickens, color vision is achieved by three light filters, each consisting of colored oil globules. Wald has fractionated from the red globules a red hydrocarbon, astacene, the substance which gives the characteristic color to a boiled lobster, from the yellow globules the golden xanthophylls, lutein and zeaxanthin, which give also color to the yolks of chicken eggs, and from the third type of globules an unidentified greenish yellow carotene which appears to be identical with the coloring matter of the bacterium *Sarcina lutea.*

Let us now consider the molecular structure of carotene, the yellow coloring matter of carrots from which the name is derived. It comprises two six-carbon atom rings attached to either end of a straight chain of eighteen carbon atoms. From carotene the animal body can and regularly does derive vitamin A by splitting the chain in two in the middle and introducing the hydroxyl group, OH. There are many other carotenoids similar in structure to carotene or vitamin A but differing from them in the length of the chain, the position of the double bonds in the side chain and in the number of hydroxyl groups on it.

It is now clear that all vertebrates have constructed their visual systems by elaboration of a single theme. The isolation and identification of visual pigments is difficult chemistry and little has been done with the lower forms of life. Rhodopsin has recently been found in large quantities in the eye of a squid and such other fragmentary evidence as exists strongly suggests that some other invertebrates see by a closely kindred mechanism.

Perhaps we see beauty in verdant landscapes because our eyes mystically sense a kinship with the colors of the scene. If one prepares a water-free extract of the pigments of leaf or flower, protecting them the while from atmospheric oxidation, he can effect a beautiful separation of them into their principal class components by simple means. It is only necessary to filter the extract slowly through a close-packed column of fine chalk, and color bands appear which become sharper as more fluid passes through. At the bottom are the yellow carotene bands which may be driven lower by pouring still more fresh solvent through the filter till the yellow colors collect in the flask at the bottom. From carotene, as we have already seen, all animal life is able to derive vitamin A. Without it there ensues blindness and general failure of the body mechanism.

Next, above the carotene band in our filter column are the reddish orange xanthophylls whose chemistry is unfortunately less well understood. They are, however, related to the hydrocarbon carotenes and differ from them principally by being dialcohols. (Vitamin A is a monoalcohol.) Among the xanthophylls which have been isolated is the red pigment of the tomato, lycopin and fuco-xanthin which colors the brown algae in our ponds. Another xanthophyll has already been mentioned as an essential component of the light filter of a chicken's eye and also as present in the yolk of its egg.

Above the xanthophylls in our filter column appear the green bands of the chlorophylls. Here is the spectrum of nature's color beauty: the yellow of the carotenes, the reds of the xanthophylls and the blue greens of the chlorophylls. Herewith she bedecks the flowers, fruits and foliage of her myriad higher plants and has some to spare for the wattles of the turkey and for the bodies of inconspicuous and forgotten primitive bacteria, mosses and fungi.

Something very like chlorophyll is in your blood—at least a huge portion of its molecular skeleton is there. Hemin is the prosthetic group or business end of the hemoglobin of mammalian blood. It contains four pyrrole rings joined in a giant circle with four intervening CH groups. At the center is an atom of iron which is "it" in this game of ring-around-the-rosy. The molecule of chlorophyll shows the same players in the same game except that now magnesium is "it." It is true that some of the little girls have different ribbons on their pigtails, but you could not mistake their identity.

Their common structural element is known as porphyrin. This vast carbon-nitrogen skeleton recurs again and again in the breathing systems of plant and animal life as an integral part of the substances which we have come to refer to as the respiratory pigments. When the hemin of blood is heated with soda lime, porphyrin is obtained identical in every detail with the porphyrin derived from chlorophyll. When you peel an apple with a steel knife and see the fresh cut surface darken presently in the air, you are witnessing the action of a porphyrin-containing oxidase. Put a drop of hydrogen peroxide on the surface and watch the oxygen evolve due to another porphyrin-base enzyme of the apple or of most any other vegetable tissue. It is called catalase.

Another well-nigh if not universal constituent of tissues is cytochrome, which may be recognized with a spectroscope by its absorption bands associated with its porphyrin nucleus. If yeast is kept from contact with the air the cytochrome bands appear strongly. They fade and return as oxygen is admitted and again excluded. Choke a wax moth and the absorption bands of cytochrome appear throughout its body tissues, the more quickly as its struggles exhaust its internal oxygen supply. Let it breathe freely again and the bands disappear. Cytochrome is one of a number of links in the chain whereby glucose is oxidized by living tissues. It serves to transfer oxygen from the air to the food molecule which is to be oxidized. We do not know that animals depend on plants in any way for their daily supplies of porphyrin base enzymes, but we can guess whence they inherited the skill to use them.

Surely we need not labor through further examples. The revelation provided by vitamin chemistry seems sufficient to convince the skeptic that while nature has *altered* much in proceeding from amoeba to Einstein or Dorothy Lamour, she has *preserved* even more through all the vicissitudes of evolutionary history.

(*To be concluded in the issue of Science for November 28*)

# THE USE AND MISUSE OF SCIENCE IN GOVERNMENT[1]

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IN this country we do not believe in bureaucracy. Our national genius has evolved a system by which the activities of officials are continually subject to the advice and help and criticism of public-spirited citizens. The wise officials appreciate this; the stupid ones do not. Let us never abandon this principle, otherwise, with our traditions, we are in for a long spell of trouble. Let us rather praise and extend it, whatever our totalitarian youth may say. One way to extend it is to insist that independent scientific advice shall be given a constitutional place, and a con-

[1] From an address given at the Conference on Science and World Order of the British Association for the Advancement of Science, organized by the Division for the Social and International Relations of Science.