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THE CONFUSION OF TONGUES[1]

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THE large brood of zoological sciences has filial concern in an event of just 100 years ago. From October, 1835, to the following January—and from weeks in the Galapagos Islands to the arrival of the *Beagle* in New Zealand—the idea of evolution first came clearly into Darwin's mind. Only after a lapse of nearly 25 years of further investigation did Darwin publish (1859) what he termed an "abstract" entitled, "The Origin of Species by Means of Natural Selection, Or the Preservation of Favored Races in the Struggle for Life." If there are such things as ferments in the sphere of ideas this century-old idea must outrank all others—because of its significance to man and because of what it has already done to synthesize, develop and then to split off the many units or branches of biological science. Just now we may witness the result of 100 years of action of this ferment.

It is not my purpose here to discuss either Darwin's work or the notable later developments in which the geneticist has been able to assist and observe the formation of new species. As a preface to the real theme of this hour I nevertheless ask permission to make some use of this intellectual ferment—first considering its fruitful accelerating action in building and splitting off zoological sciences, some of which have become capable of dealing effectively with questions of great intellectual interest which Darwin's own idea of organic evolution touched only in part or by implication only.

We do well to remember that if the many aspects of the living animal body were now less known, if specialization had not proceeded so far, Section F—the zoological sciences—would now be the natural

[1] Address of the vice-president, Section F (Zoological Sciences), American Association for the Advancement of Science, St. Louis, January 1, 1936.

primitive home of psychology, anthropology and the medical sciences. Thus, four of the sixteen sections of this Association for the Advancement of Science are largely and quite properly zoological sciences. In addition, zoological science shares heavily in the Section for Agriculture; and the incurable optimists among us will perhaps cling to a hope that our science will some day be discovered by the Section for Education. But let us now note one or two points of action of our ferment on some of these sciences, or group of sciences, which have already budded off from the parental body.

That large aspect of anthropology which deals with structure and proportions in human races quickly got a new orientation from its first impact with Darwinism. Immediately following the publication of "The Origin of Species" Sir Richard Owen, renowned professor at Oxford, and his friend, the Bishop of Oxford, poured fine scorn on the Darwinian idea and claimed particularly that the human brain had certain structural features never seen in the brain of anthropoid apes. At the meeting of the British Association at Oxford in 1860 this question was settled for all time by what Keith has called "that spectacular fight in which the Bishop of Oxford left his scalp in Huxley's hands." Not long afterwards Huxley published the necessary details—"The Evidences of Man's Place in Nature"—showing that from the standpoint of anatomy man is not a separate order of being but is properly classed with the primates. This was a quick decision, and thereafter trained intellects everywhere have had a chance for a hitherto unhinted freedom.

The action of our ferment on psychology has been both unique and profound. Unique, because in its earlier days psychology claimed closer kinship with philosophy and metaphysics than with zoological science; but here, in much less than 100 years, the reversible action of the ferment has proceeded with the rebuilding of a science, and modern psychology now leans upon respectable relatives—physics, physiology, animal behavior and neurology. To psychology it was the breath of life to verify within its own field, as had already been done outside of it, the principle that vital processes are natural events, not capricious acts of some supernatural spirit.

Probably nowhere more than in the medical sciences has the Darwinian ferment, with its ardent intellectual awakenings, supplied us with births and rebirths of sciences. To men of a hundred or a thousand years from now it will not seem accidental that the Physiological Society of London was established in 1875—sixteen years after "The Origin of Species" and four years after Darwin's second great contribution, "The Origin of Man." Nor that within a few years or decades after 1859 the sciences of bacteriology, cellular pathology, biochemistry, genetics, endocrinology and nutrition were born; nor again, that within this same period physiology, the several residual zoological disciplines and medical education all took on a new life. At this short distance it would seem that the ferment made more men willing to work with the life-stuff; that the ferment multiplied the results of their efforts; and that the ferment made the laboratory itself begin to live.

In a word, and in a way quite well known to this audience, this ferment—plus the co-ferment offspring which developed the evolution idea into the now established evolution principle—has speeded the coming of new sciences, has made a great contribution to the health and economic power of all later generations of man, and for many educated men in most countries it has swept away fear and superstition and brought quite new conceptions of the origin and destiny of man.

It should now be noted that some risks and liabilities attend the growth, splitting off and specialization of various sciences from the parental body of zoological science. It is unthinkable that the tree shall not possess and profit by the great achievements of two of the branches it has catalyzed to growth and sustained in life; but this profit depends upon firm bonds of attachment of the tree to its branches. If one very specialized discipline wholly monopolizes the most interesting product of the evolution principle, namely, consciousness; and if another specialized discipline wholly monopolizes the field dealing with the origin of life, it is clear that the central core and the disjoined extremities of a common body of knowledge all run one great risk. Unless workers in each of these disciplines retain familiarity with the texture of related thought and progress in the others, they risk failure to grasp the principle of continuity which is at the basis of all facts and of all connected thinking about the phenomena of life. On the one hand this means that the training of men in life-science must not be too narrowly conceived; on the other, it should mean that a text-book of biology or zoology which does not present available data for the origin of the organic from the inorganic and for the evolution principle in its present and broadest meaning—including the origin of consciousness—is omitting or excluding essential elements of modern biological science.

These two questions, the origin of life on the earth and the origin of consciousness in the animal series, require further consideration because they are complementary to Darwin's principle and because they are useful to the main purpose of this address. Darwin did not deal directly with the problem of the origin of life, though the principle which he did so much to establish as holding from the simplest living thing to complex conscious man would have to be broken if living matter did not originate by natural processes from non-living matter. The very soul of Darwin's conception of evolution was that every organism—simplest or highest—is the resultant of a particular organization of matter existing under and subjected to natural conditions and influences, past and present.

From Darwin's day and somewhat later it has been known that large numbers of inorganic compounds which probably could not exist during very early phases of earth history did come into existence—accompanied almost necessarily by many types of significant inorganic colloids—in epochs preceding the appearance of living things. Some decades ago Gautier showed that simple but very reactive hydrocyanic acid, HCN, on mere standing in water gives rise to many nitrogenous substances found in living matter—such as urea, carbamic acid and alanine. Within the past twenty years, as noted meanwhile by several investigators, it has been definitely proved by Professor Baly and others that formaldehyde, sugars and other organic substances—some of them nitrogen-containing—are generated under conditions which must have prevailed on the earth's surface before, during and after the origin of living matter. The agents necessary to the building of such organic matter are none other than sunlight, ordinary temperatures, colored surfaces, water and carbon dioxide. Moreover, from one such sugar, glucose, in alkaline solution, plus a time factor, some hundreds of different organic substances have already been derived in laboratory experience. With only nitrate or nitrite added to the system already mentioned the very reactive nitrogenous substance, formhydroxamic acid, is formed; and, with additional active formaldehyde this acid combines to form a whole series of compounds which are the commonest constituents of plants and animals—pyridine, purine and α amino acids.

There exists scarcely a doubt that during long periods of earth history, preceding the appearance of living matter, many localized areas of the earth's surface provided suitable conditions for the synthesis of sugar and some amino acids. Thus the natural forces at work on the earth's surface prior to the appearance of living matter had almost certainly already provided a variety of both inorganic and organic compounds characteristically utilized by living matter—including the particular sugar, glucose, from which most living matter still derives an obligatory flow of free energy, and some α amino acids which must serve as building blocks for the protein which is the chief constituent of living matter. These syntheses of organic matter wholly apart from life are facts which must now be utilized in dealing with the question of the origin of life. Any general biological instruction that fails nowadays to direct attention to these facts is vitally deficient in its presentation of modern life-science.

There is a new word to add to this discussion of the borderline between living and non-living substance. For some years it has been fairly evident that the substances or units known as viruses are smaller than any visible cell or organism and that they nevertheless show the one property which is most characteristic of life—that of reproduction. They have seemed part of a bridge between those smaller but lifeless organic molecules which—as we have just noted—form spontaneously at or near the earth's surface (precisely where all known life exists) and those larger molecular aggregates which are bacteria and cells endowed with all the properties of life. Though apparently simpler than known living matter the virus has seemed to fit a biological frame somewhat better than a chemical one. The virus appears to stand nearer to life than to the spontaneously formed sugars and amino acids. Within recent months—only half a year—these earlier indices have been much strengthened and extended by Stanley's successful preparation and study of "A Crystalline Protein Possessing the Properties of Tobacco-Mosaic Virus."

These crystals were found to consist of protein having a molecular weight of a few millions, and thus a much larger molecule than that of egg-albumen. This protein is practically insoluble in water, and it passes a Berkefeld "W" filter. Its chemical composition and its power to infect—that is, its ability to propagate itself—were quantitatively unchanged by 10 successive crystallizations. Its activity was destroyed by peptic digestion; by heating to 94° C.; by alkalinity greater than pH 11.8, and by acidity greater than about pH 1.0. Here we seem to have beautiful facts concerning an *autocatalytic* protein—a protein which will indefinitely build itself anew when given contact with a suitable bit of living tissue, and which then seemingly exhibits only this single characteristic of living matter.

Two further considerations are close at hand. *First:* When we remember that at present there is no possibility of knowing of the existence of molecules similar to virus molecules unless they produce *disease,* we are warned that we have not yet been permitted even half a look into that region which lies between spontaneously formed sugars or amino acids and the higher level represented by the simplest bacteria.

Second: When these properties of the autocatalytic virus protein are compared with the known and probable properties of the *gene* we find parallels which can hardly be fortuitous—and possibly we here encounter other planks for that bridge leading from spontaneously formed organic molecules to those molecular aggregates (protoplasm) which are fully endowed with life. Let us first note that both the virus molecule and the gene are known to have the capacity to duplicate themselves exactly. Also that in every known instance for both of them this duplication occurs only when these molecules are in intimate contact with more complex molecular aggregates which show *all* the properties of life. Indeed, in a genic system it has been shown that the absence or malformation of a particular gene may so alter or terminate autocatalysis in the associated genes (or entire cells) as to result in the death of the cell or organism. Again, there is strong presumptive evidence that the gene is a single molecule and that it is a protein molecule. It is practically certain that the various genes (or rather the various pairs of genes) associated in a cell have at least slight molecular differences, and such differences quite certainly exist among the different types of virus. The limits at which, and the means by which, the virus molecule is disabled are of the type and general order of magnitude that we might reasonably expect of some protein gene molecules if good fortune permitted our making suitable tests upon them. Finally, both genic and virus molecules defy the highest powers of the microscope, and they may differ neither greatly nor consistently in size.

These parallels require still a further word. Several years ago Duggar first, and later Müller, drew attention to ways in which the virus is like a gene got loose from its companion genes; and, by its power to reproduce, is creating disturbance—the virus disease in other cells of the host. In my opinion further knowledge of both virus and gene has made it rather improbable that the virus is an escaped gene, and I venture the suggestion (a) that some of the similarities of virus and gene rest upon the circumstance that a gene standing alone can not be considered as fully alive; (b) that the commonly observed property of the gene molecule to suppress its own reduplication over long periods, and to correlate closely in time such later duplication with the occurrence of the same thing in all associated genes, is apparently a more advanced biological property than that observed in any virus molecule; and finally (c) that the virus molecule is apparently more free than the gene to obtain its stimulation to reduplication from living substance with which it has had no previous contacts or association.

I ask the privilege to develop this suggestion briefly. When matter is considered at the biological level it is organization and interaction of organic molecular aggregates that is of first importance. Just as in the case of inorganic compounds, we must conceive the properties of living matter as more than the sum of the properties of the separate component (atoms or) molecules. Quite new properties certainly come with each new combination; and, in a microscopic bit of protoplasm not only does the probable number of combinations still elude us, but we are assured that the organization and free interaction of parts is presenting us with that which is truly biological. How then could we be justified in considering any single individual *gene* as necessarily more alive, or more nearly alive, than the protein molecule which is a virus? Does the increase in "liveness" issue from the *aggregation* (and organization) of several chemically *different* genes—each individually having power to reproduce itself under proper contacts—with aggregation of genes (along with other simpler molecules supplying matter and energy) automatically providing much or most of the requisite conditions of contact? If this should prove true, or partly true, it would mean that the bridge of which we have spoken has less length than we have imagined. The longest single missing span may be that reaching from spontaneously-formed sugars and amino acids to a protein molecule like that of a virus.

Studies of the past thirty years on the structure and functions of the brain, and on the relation of other parts of the body to brain function, have resolved but a fraction of the primary problems of the mind. But the mind has been firmly placed in an evolutionary frame, and several gaps in our knowledge formerly filled by myth or magic have been displaced by verifiable experience.

For nearly all competent investigators of life phenomena the Cartesian philosophy of duality of mind and body has, like Noah's ark, sailed out of the picture. Or, shall we say that while immersed in the Darwinian ferment during a few decades the experience of physiology, animal behavior, neurology and psychology has yielded crystals of a common kind—these crystals having been shown to be composed of body-mind, not of body *and* mind. The consciousness of dog and man has evolved, and redevelops in every ontogeny, in the same unbroken way that the function of the digestive or glandular system has evolved. The evidence on this important point to-day is probably stronger than that adduced in 1859 for the principle of evolution. Consciousness, as well as some related subconscious phenomena, is associated with organization at a high biological level and chiefly though not solely with organization of the brain.

Permit me to cite two recently found means by which somatic or extra-neural elements may affect the mental product—in one case quantitatively, the other qualitatively. *First:* Both Hindzé and Donaldson find evidence that well-developed pial blood-trees go with the brains of able men, while such blood supply tends to be less to the brains of those whose performance in life indicated less mental ability. *Second:* During the past year studies alone with colleagues in my own laboratory have shown that the incubation and maternal instinct—as this occurs in fowl and virgin rats—is released or mediated by the anterior pituitary hormone, prolactin. The hormone acts in a now unknown way on nerve and brain function. But instincts are recognized as basic elements from which intelligence or consciousness arose and arises; and in this case the instinct normally appears only near the end of growth and development—where it is most accessible to study. In these otherwise fully equipped animals the birth of this instinct awaits and requires the cooperation of the hormone. It is thus found that a hormone, a thing of somatic origin, shares in bringing a new element of consciousness into the body-mind of these animals.

It will now be useful to turn for a moment to our ancestral zoological tree with a view to tagging a few of those branches which it has added to itself within the short span of 30 or 35 years. One such tag reads "genetics," and this branch has already ripened some fine fruit: First, that all men are created *un*equal. No politics or poetry or dogma in this; just a straight clean fact of prime importance to decent thinking on human social problems; and possibly a fact that must be learned, digested and assimilated by the great majority of men—particularly in democracies—before unreason ceases to be a threat to all forms of democratic government. Second, a single gene can produce feeblemindedness. Here is found not only a nexus of body and mind, but mental development is seen to depend upon the same pill-box of genes that decides the color of our skin or our degree of resistance to diabetes. Third, changes within the gene and genetic system of just the types apparently required for progressive evolution, and on which natural selection can work, have been witnessed and analyzed. The origin of some species by natural means has now been attested by controlled observation. Thus, it is nowadays the *phenomenon* of evolution that intelligent men study and describe; and nowadays only a brain moving in reverse bogs down on a question of its reality.

Another new branch of the tree of zoological science is labeled "nutrition." A first flower or fruit on this branch reveals that the growth and well-being of our bodies require no fewer than eleven inorganic elements —those age-old ancestors of the first organic matter whose continued interaction with such organic stuff probably produced the first life—and, in addition, we require not fewer than twenty-three rather simple organic compounds, most of which can not be formed in our own tissues but must be obtained from the less evolved plant world. Second, several human diseases can be cured, and better still they can be avoided, as a consequence of this new knowledge. The fruit from this branch, grown within 30 years, has already endowed our generation with beautiful victories of the laboratory, and all later generations of civilized man with somewhat better health, fuller growth—and even a firmer grip on their teeth. We pause to note, however, that these great values—like those from most branches of life-science—are potential only. Whether these good cheques are turned into the gold of better health, greater happiness and more effective living depends primarily upon their being brought to all youth by elementary and secondary education.

Among the other new branches of this tree we here remark only another one, called "endocrinology." Not all the fruits on this new branch are ripe, but let us here taste of two that are. *First:* It has been shown that the ductless glands share largely with the nervous system in regulating those several complicated processes—development, growth and the maintenance of active, healthy bodily states. Nervous regulation and hormonal regulation form a superb partnership which permits existence at a human level. The manifold duties and talents of the endocrine partner are known to share largely in determining our strength, our diseases and our outlook upon life. *Second:* All or nearly all the main elements in the normal hormonal control of mammalian and human reproduction are now known, though fifteen years ago not one of the several hormones chiefly concerned had been separated or assayed. The women of the first human generation that could possibly know or learn the basis and meaning of the cycles and reproductive adjustments which are peculiarly theirs are the women and girls now with and beside us.

(To be concluded)

OBITUARY

LAFAYETTE BENEDICT MENDEL

DR. LAFAYETTE BENEDICT MENDEL, Sterling professor of physiological chemistry in Yale University, died on December 9, 1935, after an illness of eighteen months.

He was born at Delhi, New York, on February 5, 1872, and received both his undergraduate and graduate training at Yale, where he was awarded the degree of A.B. in 1891, and that of Ph.D. in 1893. He was a member of the Yale staff continuously from the age of twenty: Assistant in physiological chemistry, 1892–94; instructor, 1894–97; assistant professor, 1897–1903; professor since 1903, and Sterling professor since 1921. On leaves of absence, he worked at Breslau and Freiburg in 1895–96, traveled and lectured widely in subsequent years, and served on the Inter-Allied Scientific Food Commission during the world war.

Always a Yale man, he was both a product and a builder of the institution of which he saw the emergent evolution, from a rather conservative college with a