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THE SPECIES COMPLEX IN BIOLOGY AND EDUCATION[1]

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THIS afternoon I propose to discuss a certain mental trait which looms conspicuously in the background whenever I reflect upon the history of biology or upon academic procedures as I have observed them these many years. It is the innate propensity of active minds to form species, *i.e.*, successively to make distinctions, to point out similarities and then to assemble the things that are alike into their kinds. It applies to everything from chemical elements to college fraternities. Since the Latin word "species" is synonymous with the English word "kind" even to the point of being adequately indefinite I shall employ it in a wide and general sense which, indeed, accords with its earlier usage.

This mental trait is not a simple one. It is made up of a strong emotional factor, an inborn urge to put things in order and, alas, keep them there; of the intellectual faculty of discernment and discrimination which perceives distinctions and similarities; and of the constructive imagination which makes it possible to assemble in the mind things that are widely separated in space and time. For convenience I presume to call this trait the species-forming complex or, for short, the "species complex."

I shall first point to a few characteristic effects, good and bad, of the operation of the species complex in general; then to some of its accomplishments in the field of biology; and finally, shall venture to suggest that the recognition of the characteristics of this trait in human beings is desirable as we face the problems of the day inside and outside of the university.

The species complex often manifests itself in the

[1] Address at the Graduate Convocation of Brown University, June 17, 1939.

degree of importance assigned to nice distinctions and to exact definitions. It is, of course, to its credit that it does seek to make fine and clear-cut distinctions; but so highly is this function esteemed in academic circles that extraordinary powers of fine discrimination are sometimes mistaken, by the unwary, for scholarship itself. Again, instinctively we admire that which is definite, unequivocal and normal and we tend to ignore that which is vacillating, confused or abnormal, *i.e.*, mugwump, the mule and the freak. Is there not, however, a salutary moral to be found in the reflection that not long ago the political mugwump turned the tide of a major election in all but the two American states; that the hybrid established the science of genetics; and that the freak, under the polite name of mutation, largely restored the waning prestige of natural selection as a major factor in the modus operandi of evolution? Clear, sharp incisive definitions are admirable, but only when they do not throw out of proper consideration items which may be potentially important.

The most commonly recognized manifestation of the species complex is the blind adherence, or better the emotional adherence, to some particular definition of a species once it has been established, especially when the species in question is a doctrine of politics, economics, social organization, government or religion. Perhaps no other manifestation has greater possibilities for usefulness, and also for mischief. It engenders loyalty, it promotes solidarity, and it tends to satisfy the intuitive desire for a solid base or anchorage that is once and for all secure, immovable and permanent. But it tends also to favor dogmatism and to prevent or retard the candid, unprejudiced, fruitful study of relationships. It encourages debate and even war, and discourages deliberation as a method of deciding issues. This insistence upon permanence of species may sometimes have its explanation in proprietary interests or pride as the founder or beneficiary of the particular system, or in a long-time commitment to it as sponsor or adherent. But whatever the reason, and despite the useful service which it may perform in preserving the existing order, the sinister effects of this insistence are, as we all know, often very far-reaching. By way of contrast one of the significant contributions of science to humanity has been its attitude toward the permanence of its own hypotheses. For example, since many of us were studying science in college such fundamental tenets of classical physics as the indestructibility of matter, the conservation of energy and the integrity of the atom have been relinquished and superseded without serious emotional disturbance. We look forward toward the millennium when this attitude shall generally prevail, when deliberation shall everywhere be exalted above debate and missions shall give way to parliaments.

The greatest of all adventures in the study of species has been in biology; naturally so because of the characteristics of living material—the incomparable diversity of its forms and the paradox of their being at the same time persistent and changeable. Conversely, the greatest episode in biology has been the study of species plus the interpretation of its results. I refer to the stupendous enterprise which, in the eighteenth century, was inspired and for many years largely conducted by that extraordinary genius, the "immortal Swede," Linnaeus, and which was interpreted later in the Darwinian presentation of the hypothesis of evolution. This enterprise was a well-organized world-wide drive of which the objective was nothing less than to discover, describe, name and classify every living thing—as the housekeeper in Maine would say, to "neaten up" the living world and put it in "apple pie order." Literally the whole world was combed for new species by the agents and correspondents of the great impresario; and it should be remembered that the world was then a score of times larger than it is to-day.

As the work progressed it gained momentum, and in fact it has never ceased. At the present time the number of existing species of plants and animals recorded, described and named in accordance with the Linnaean system is considerably over a million, and new ones are being added continually. (Several have been announced this week.) It is evident, moreover, that the number of species existing to-day is only a fragment of the total number that have inhabited the earth.

Since this was by far the greatest, most systematic and most mature species study ever undertaken it should be profitable to review its consequences, immediate and latent. Directly from it two major generalizations were derived, both of them highly significant, and both utterly contrary to expectation and to immemorial tradition; first, that the number of species of plants and animals is of an entirely different order of magnitude than had ever before been imagined; second, that a specificity itself is an attribute equally of all living things, which means that every individual organism living or dead, animal or plant, the eagle or the earthworm, the rose or the mildew on its leaves, has an equally valid passport certifying its good standing as a regular member of some species; and that any individual amoeba, shellfish or insect, with respect to lineage and pedigree, stands, in the eye of nature, on equal footing with a Pharaoh.

So much for the direct consequences. The greater significance of this monumental labor was latent and potential. It became manifest and effective, not by the distinguishing of more species (although this work continued), but, on the contrary, by a half century of vigorous research into the relations between the very species that had been distinguished. Herein precisely

is one of the practical lessons which this long and mature experience in biological species-study holds for the workers in other domains.

Several ingenious ways of getting at these relations were found out by the generations following Linnaeus. Let me recall very briefly three of them. First, the comparing of the whole internal and external structure of representatives of similar species established a new biological discipline, the science of morphology. With this work the name of Cuvier must always be associated, but it also held the distinguished attention of the poet Goethe and of a long list of savants of the early nineteenth century.

Another means of access to the relationships of species was paleontology, with which also the name of Cuvier must be associated. We commonly think of paleontology as relating to extinct species but, for purposes of this discussion, that which it reveals about living species is even more important. Through the study of fossils it became evident, not only that the kangaroo once lived a wild life in Paris, the mastodon (if not the elephant) was at home in Albany, the sabre-toothed tiger wrought havoc in Hollywood, and the superannuated giant-sloth retired to Pasadena, but also that man himself, and nearly all the kinds of animals and plants that are now living, have existed upon the earth only a few minutes of the geological day. Among all the creatures that have dwelt upon the earth since the beginning, they are comparatively recent arrivals.

A third means of access, geographic distribution, revealed a most significant relation among sciences; a relation which obtains also in human cultures and therefore directly concerns one of the paramount problems of our day and generation. The biologists have a name for it, but in plain English it is this: Species naturally occupy definite areas limited by barriers, geographic or physiologic, which, unaided, they can not cross but, once assisted across the barriers, they not only may continue to exist but may enjoy "the more abundant life," like rabbits in Australia and Buddhism in China and Japan. To this phenomenon in relation to human cultures, I shall revert later.

Now geographic distribution is not a subject to arouse the enthusiasm of the man on the street, yet it was the prolonged reflection upon this phenomenon, as he had observed it in the Galapagos Islands, that greatly stirred the imagination of the reputedly unemotional Darwin and first turned him toward the evolutionary interpretation of the nature of species. In 1844, seven years after returning from the voyage of the *Beagle,* he wrote to Hooker, the English botanist:

> . . . . I have now been, ever since my return, engaged, in a very presumptuous work, and I know no one individual who would not say a very foolish one. I was so struck with the distribution of the Galapagos organisms, etc., and with the character of the American fossil mammifers, etc., that I determined to collect, blindly, every sort of fact, which could bear in any way on what are species. . . . At last, gleams of light have come, and I am almost convinced (quite contrary to the opinion that I started with) that species are not (it is like confessing a murder) immutable.

That all these general phenomena and others like them probably held the key to some great common mystery did not escape the notice and the comment of the savants of the nineteenth century. Questions about the significance of these constant relations were inevitable and insistent: Why the morphological resemblances? Why the short duration of a species? Why the apparently arbitrary restriction of a species to a single natural habitat?

The hypothesis of organic evolution as presented by Darwin in 1859 was formulated as an answer to these and similar irrepressible questions. A revised hypothesis of special creation as presented by Professor Louis Agassiz, also in 1859, was another and a very different answer.[2]

Great issues were at stake in these strictly alternative answers; nothing less in fact than the question of the place of man in the universe and of the operation of secondary causes in the living world.

The service which this gifted naturalist, Agassiz, performed in clarifying the evolution hypothesis by his adverse criticism, which was continued for fourteen years and up to the time of his death, is not always appreciated. Agassiz did not deny the validity of the relations between species as demonstrated in morphology, paleontology and geographic distribution—he emphasized them; but he gave to all of them severally and collectively an interpretation which showed what extraordinary postulates were required to adapt and adjust the time-honored doctrine of special creation to those newer findings.

In Agassiz's view, the human hand and the bat's wing have an identical plan of structure because the architect who designed both had the same plan in mind. He explained the fact that species live only a short period in geologic time by postulating an indefinite number of successive creative periods. To explain the

[2] Referring to the phenomena of morphology, paleontology and geographic distribution Agassiz wrote in 1863 in "Methods of Study in Natural History," pp. 100–102:

> What, then, does this correspondence teach us? . . . Surely not that the connection between animals is a material one. . . . If, then, this connection is not a material one, what is it?—for that such a connection does exist throughout the Animal Kingdom, as intimate, as continuous, as complex, as any series which the development theorists have ever contended for, is not to be denied. What can it be but an intellectual one? These correspondences are correspondences of thought . . . the same thought that spans the whole succession of geological ages controls the structural relations of all living beings as well as their distribution over the surface of the earth. . . .

enigma of geographic distribution, he postulated the special creation of each species in the region it now occupies.

The difference between the tenets of Darwin and Agassiz hinges on a cardinal difference in the definition of organic species or, as Darwin himself put it, on the question, "What are species?" To Darwin, species were abstract things, the temporary phases or manifestations of a continuous series, having separate entities only as infancy, childhood, youth, manhood and old age would have specific and separate entities if there were no knowledge of the transition from one to the other within a single individual lifetime. In fact, the child of five years has no direct knowledge of this transition, and so to him grandfather has always belonged to the distinct species "old man"; and father and mother too have always been grown-ups. In other words, were all facts known the exact lines separating species would be as elusive as lines separating the several stages of a man's life, and the search for them as futile as grappling for the equator. To Agassiz, on the other hand, a species was a concrete entity, in the sense that it was the sum total of all the individuals descended from an original pair. In summary, it might almost be said that Agassiz and his school sought to discover species; the evolutionists made them.

That, in biology, species turned out to be abstract entities and that species grade one into another does not mean that they have no legitimate status. It is legitimate and useful to distinguish infancy, youth and old age, although we know that somewhere in time one merges into another. For that matter, every biologist realizes that the term "individual," as applied to a particular animal or to a man as a physical organism, is also an abstract and indefinite one. The process of maturation, fertilization and early development of the egg are so perfectly continuous that, even when the whole span from one generation to the next is observed continuously under the microscope in concrete material form, the observer can not point to an exact moment when the egg becomes a new individual. To indicate that moment would be an utterly arbitrary act.

The profound, far-reaching consequences of the wide acceptance of the hypothesis of organic evolution is a matter of history. It directly involved mankind in new material relationships with the other animal species. It brought the living world wholly under the immediate operation of secondary causes, as the astronomical discoveries and interpretations had brought the inanimate world centuries earlier. It established a new kind of biological order. It created a new respect for things that lie in the indefinite zone between adjacent categories. It conduced to the general adoption of the genetic view-point in other domains of thought. Would that Linnaeus could behold how great a matter a little fire kindled!

As I reflect upon the considerable number of discussions which I have listened to or have read in the past four or five decades concerning the aims, purposes, organization, programs and procedures of collegiate education, the impression deepens that there is an increasingly abundant and diversified fauna and flora of educational propositions which would profit by the same kind of analysis and treatment; which invite and challenge the genius of a Linnaeus to distinguish the legitimate species, a Cuvier to compare them and to demonstrate their fundamental relationships, and eventually a Darwin to construct out of these relationships a new rational order and unity in a science of education.

However, this is the comprehensive task which confronts the generations to come. This afternoon I shall refer simply to one unfortunate characteristic of the species complex in the educational field, namely, the unconscious tendency to confuse convenient distinctions with incompatible alternatives—the tendency to set over against each other as more or less antithetical certain factors, in the methods of teaching and learning or in educational purposes, whose relationships to each other are really so very important that they ought not to be thus obscured; but, on the contrary, ought to be regarded as a subject of major concern.

For example: Humanities set over against the sciences as the substance of a liberal education; teaching against research as the function of the faculty and as a criterion of the usefulness of a professor; diversification against specialization as the way to comprehensive understanding; pedagogical training against knowledge of subject-matter as the best preparation for teaching; production of a continuous apostolic succession of "scholars" against the perfusion of the laity with the extract of scholarship, as the function of the university and the criterion in the selection and the training of students; classics against studies of modern thought and affairs as preparation for life; and many others.

The false antithesis between science and the so-called humanities is, perhaps, the most deplorable of all these examples. It is unwarranted and unnecessary, and is disastrous to the great interests of both. Philosophy, literature and art need constantly the substantial contributions of science. Science needs the penetrating criticism of philosophy to preserve its equilibrium and it needs the wings of literature and art to bear its conclusions to their destination.

Unhappily both the intellectual factor of the species complex and the emotional factor contribute to keeping science and the humanities apart. The chief role of science in college, that of aiding the student in building his own Weltanschauung, is not kept sufficiently in evidence. Again science is still defined occasionally as the study of the stage upon which man plays his part;

the humanities as the study of man himself. So to restrict science is, of course, to overlook that most pertinent corollary of organic evolution which admitted man into the association of animal species and conferred upon him all the rights and privileges thereunto appertaining. This made the manifestations of his mental and emotional life amenable to investigation by ordinary scientific methods. The findings of experimental and genetic biology and psychology are then common assets of science and the humanities.

Probably the instinctive or emotional component of the species complex must be held accountable for the notion that the sciences belong on McGuire's side of the railroad track; the nicer humanities on the other side in the older and better residential district. A former colleague at Brown used gleefully to relate the adventure of an ardent devotee of the humanities when on an exploring expedition through a biological laboratory; how her amazed delight over the exquisite beauty of color and texture of a section under a microscope suddenly turned to dismay when she learned that the object of her admiration was the kidney of a rat.

The idea that specialization necessarily conduces to narrowness of vision is a matter on which I speak with feeling and assurance, for I gave four years of merry youth to the intensive and extensive study of the egg of a worm under the impression, which has in no wise diminished through the years, that the polychaetous annelid in the ocean, as truly as "the flower in the crannied wall," is custodian of the eternal mystery. To change the figure abruptly; in delving below the surface in search of the underlying relations of things, one may start his tunnel from one point or from ten points or from fifty points. The number of entrances does not determine the extent of the ramifications.

To ask whether it is the obligation of the college to produce a succession of scholars or to educate the laity is like asking whether it is the business of the germ-plasm to produce more germ-plasm or to produce a corporeal body. It must do both, for if it fails in either the race perishes. In a democracy it is the prospective laity who will perpetually decide whether or not the college shall exist and, if existing, shall be bond or free. It is essential that the layman, even though himself not a scholar, shall have a sympathetic understanding of the content and aims of scholarship, and this is best learned in college. The prospective scholar, that is the academic germ-plasm, must then continue to produce still other scholars but also still other laymen.

Finally, a word concerning a general species problem of the future. If there are responsible institutions in the world, they are the colleges and universities situated in and supported by the democracies. These institutions must play the part of seers and prophets; they must lead and not follow in the thought of the times. Nevertheless, and because this is so, the conditions that obtain in the world in each generation are necessarily reflected in the total educational program of the college.

We have already observed that the biological phenomena attending geographic distribution of plants and animals, especially the effects of isolation, apply also to human cultures. Isolation, by means of more or less effective barriers, has been a primary condition both of the origin and the maintenance of these cultures; but it is abundantly evident that human cultures may thrive in regions other than those in which they originated. At the present time the confining barriers that have hitherto separated human cultures and have tended to maintain them as distinct are being broken down with unprecedented swiftness and unprecedented thoroughness.

The consequent complete, sudden, world-wide commingling of cultural species will be, I venture to say, the central problem of coming generations—even taking precedence over the problem of the vanishing frontiers.

It is true that the interpretation and mixing of cultures has been slowly going on for ages untold; that no human culture nor human race, for that matter, is pure, unmixed and homogeneous; but we have now entered upon a period of cultural diffusion that is something new under the sun. Hitherto cultures have spread from this or that center, sometimes very far indeed, but yet have had their territorial and ethnic limits. To-day they start from many centers at once and the earth is their limit. Hitherto the spread of a culture was determined by some governmental power which had a locus, Thebes, Athens, Rome, Agra, Peking. To-day it is spread by the instrumentality of science, which has no locus either territorial or political.

In the future, unless the existence of the science of physics and the technology of engineering are forgotten by civilized man, the airplane, telephone, radio, phonograph, cinema and their successors will continue to convey goods, persons and cultural ideas to and fro incessantly and almost or quite instantaneously over the whole world in defiance of every geographic and political obstacle. Not America, but the world is becoming the melting pot of cultural ideas.

What is to be the outcome of this, who can tell? It seems inevitable that the present cultural species, including systems of government, economics, ethics, morals, religions and philosophies, can not maintain themselves unmodified in the new conditions, but that from them new species will arise.

The species problem of the future is—how to direct the course of this inevitable cultural evolution so that the new species will include the finest elements that experience can contribute from all quarters of the world.

None should be better qualified to attack the problem than those prospective scholars, and laymen also, whose complex of impelling motives, powers of discernment and discrimination, and constructive imagination it is the privilege of the college and the university to educate.

SCIENTIFIC EVENTS

THE CORNELL ORNITHOLOGICAL EXPEDITION

THE Cornell Ornithological Expedition, under the leadership of Dr. Arthur A. Allen, head of the department of ornithology at the university, returned to Ithaca on September 3 after a four-months journey to the southwest and the west coast.

Color movies and sound records of the Attwater prairie chicken, the rare trumpeter swan and the almost extinct California condor were obtained.

Albert R. Brand, research associate in ornithology at Cornell, a retired stock broker who is an authority on the sound recording of bird-songs, provided funds for the expedition, which left Ithaca on May 2 in a sound truck and traveled over 12,000 miles. The truck was equipped not only for recording the songs and calls of birds and making color-films, but with camping facilities. Assistants to Dr. Allen were David Allen, his thirteen-year-old son and Charles Brand, son of the sponsor of the expedition.

The object of the trip was to secure recordings of the songs and calls of birds new to the Cornell collection; to make color-films of as many birds as possible; to inspect various wildlife refuges and conservation projects of the different states through which the expedition passed and of the Federal Government and to gather as much data as possible relative to the organization and management of these projects for course-work to be conducted at Cornell.

Describing the expedition, Dr. Allen said:

> We proceeded first to Texas and Louisiana, following the southernmost route, through Brownsville, El Paso and Tucson, to Pasadena and Berkeley, where I gave a course in ornithology at the University of California, between June 26 and August 4. On the return we took the northern route, through Oregon, Washington, Montana, North Dakota, Minnesota, Michigan and Ontario.
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> We visited about two dozen of the state and federal wildlife projects, including seven of the national parks. We recorded the songs or calls of over a hundred kinds of birds not previously recorded; and we secured color-films of about 120 species, taking about 6,500 feet of color-film and 1,200 stills, which will greatly improve our classroom instruction, as well as being used to illustrate public lectures and general articles.

One of the accomplishments of the trip was the discovery of the nest of the coppery-tailed trogon, a tropical species which is found in the mountains of southern Arizona. The ornithologists of Arizona have been hunting for this nest unsuccessfully ever since the bird was first discovered in Arizona, about fifty years ago. The Cornell expedition was fortunate in being able to locate the nest and secure recordings of its voice and color-films of the bird, which has the reputation of being the most beautiful bird in North America. Other interesting or colorful birds recorded and filmed were the roseate spoonbills, on the Texas coast, the purple gallinules of Louisiana, wild turkeys, chachalacas, California, Gambel's and mountain quails, pelicans, vermillion flycatchers, cardinals, western tanagers and blue grosbeaks.

BALLOON FLIGHTS INTO THE STRATOSPHERE

THREE recent flights into the stratosphere over Beltsville, Maryland, by means of groups of rubber sounding balloons reached heights of 14 to 16½ miles above the earth. The balloons, sent up as a joint project by the National Geographic Society and the National Bureau of Standards, carried on each flight with an "observer," an ingenious robot consisting of electric batteries, a tiny motor, photo-electric cells, moving screens and radio tubes.

The object of the flights was to gather additional information about the atmosphere's ozone layer—an important concentration of the gas which screens away from the earth's surface certain rays of sunlight injurious to vegetable and animal life. The metal and glass robot made "readings" of the varying concentrations of ozone at different altitudes and automatically radioed them to a receiving station on the ground. The results are being compared with other observations for a later report by the National Bureau of Standards.

On each of the three flights the lifting power was furnished by six rubber, hydrogen-filled balloons attached in tandem. Four-and-a-half feet in diameter when they were released, these balloons expanded to diameters of 14 feet or more in the rare upper air near the top of the ascents.

The string of balloons continued to rise until one of them burst as a result of expansion. The remaining balloons lowered the observing apparatus slowly to the ground and in every case it was recovered. The flights were made under the supervision of Dr. Lyman J. Briggs, director of the National Bureau of Standards, and Dr. W. W. Coblentz, chief of radiometry at the bureau.

In the hope of reaching greater altitudes for the cooperative study of ozone concentrations, the National