EVOLUTION AFTER DARWIN

THE UNIVERSITY OF CHICAGO CENTENNIAL

VOLUME III

ISSUES IN EVOLUTION

SOL TAX AND CHARLES CALLENDER, EDITORS

EVOLUTION

AFTER

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THE UNIVERSITY OF CHICAGO CENTENNIAL DISCUSSIONS

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VOLUME I

THE EVOLUTION OF LIFE

EDITED BY SOL TAX

VOLUME II

THE EVOLUTION OF MAN

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VOLUME III

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PREFACE

On November 24, 1859, Charles Darwin at last saw in print the manuscript over which he had labored for almost a quarter of a century, the book whose ponderous title has become the familiar *Origin of Species.* The world had been waiting, and in a single day the first edition of 1,500 was sold out. One hundred years later, the day was celebrated as marking one of those events that influence the career of man by changing his perspective of himself and his place in the universe.

In December of 1955 the University of Chicago began planning its celebration of the centenary in the most appropriate manner—bringing to bear, on the subject of evolution, current knowledge from a variety of relevant fields, thus advancing once more our understanding of the world and man.

About fifty scientists were selected during 1956, and their themes were agreed upon; during 1957 and 1958, they prepared and exchanged their papers. Armed with new information and insights, all but five of the authors met at the University on November 22, 1959, to prepare for panel discussions of the issues in evolution which were to be held for the public during the five-day Celebration, beginning on the Centennial of the publication date of *Origin of Species.* The discussions were based on the papers that had been distributed in advance, but the papers themselves were not delivered at the Celebration.

This is the third and final volume of the University's Darwin Centennial publications, collectively called *Evolution after Darwin.* Most of the Centennial papers were published earlier this year in the first two volumes, *The Evolution of Life* and *The Evolution of Man.* The present volume, *Issues in Evolution,* includes three papers on the general topic of science and spiritual values as well as an index for the entire set; but it is primarily a record of the Celebration itself.

That record opens with the transcript of a televised conversation among Adlai Stevenson and four Celebration participants, held shortly before the Celebration began, and foreshadowing many of the issues that were discussed during the five-day program. Then follow the five

panel discussions that constituted the heart of the Celebration; and Sir Julian Huxley's convocation address, a delineation of the evolutionary vision that knits together many of the varied themes discussed at the panels; it ultimately became the most controversial event of the Celebration week. An assessment of the panel discussions by three of the participants forms a fitting postscript to the series. The book closes with a personal appraisal of the Darwin Centennial Celebration and its significance by the senior editor, and an album of photographs by Albert C. Flores which illustrate the program.

The editors of this volume—and Mrs. Marie-Anne Honeywell, the Conference Secretary—also administered the Celebration, the one as Chairman of the Committee, and the other as Conference Director. During the month preceding the Celebration, the Committee members—Alfred E. Emerson, Chauncy D. Harris, Everett C. Olson, H. Burr Steinbach, and Ilza Veith—were joined by Sir Julian Huxley and Alfred L. Kroeber; all were essential to its success. Others to whom the Celebration owes much are noted in the proper places.

SOL TAX
CHARLES CALLENDER

CHICAGO
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ILZA VEITH

CREATION AND EVOLUTION IN THE FAR EAST

The tremendous impact of Darwin's *Origin of Species* within the sphere of Western culture is readily understood in view of the need to reconcile the facts and implications of evolution with the supernatural elements in the Judeo-Christian religions. In the Far East, however, neither the revolutionary significance of the evolutionary principle nor the violent opposition it engendered could have been fully comprehended. A review of the earlier Chinese ideology, which also dominated the rest of the Far East, reveals certain similarities with early, as well as post-Darwinian, Western evolutionary concepts. A comparison of these totally independent streams of thought is pertinent to this Centennial volume and, at the same time, may shed light upon the recent events in China's social developments.

China has at various times been credited with the earliest formulation of almost every great thought in the history of ideas; with reference to evolutionary speculations, there is convincing evidence that its ancient philosophers were deeply concerned with these matters. Although their final conclusions were far removed from ours, the original propositions are so germane to our subject that they merit closer analysis than has yet been accorded them. In contrast to the Western world, the Far Eastern philosophers thought of creation in evolutionary terms. Nevertheless, the establishment of a theory of creation satisfactory to them all but terminated further speculation, as it did in the Judeo-Christian West. For that matter, once concepts of creation had been formed early in China's recorded history, they remained unchanged and fundamental throughout the Far East until the introduction of Western evolutionary theories, and these actually proved considerably less alien to traditional Chinese cosmogonic ideas than to those of the West.

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The striking feature of the Chinese concept of cosmogony is the fact that creation was never associated with the design or activity of a supernatural being, but rather with the interaction of impersonal forces, the powers of which persist interminably. Tao, the foremost of these forces, touched every conceivable facet of life and thought. Although it has been defined as "the way," "Tao" is a word with an infinite variety of meanings, and it has even been termed indefinable, "and in its essence unknowable." Its concept goes back to remote antiquity, and it existed long before Lao-Tzu (sixth century B.C.), who was the spiritual father of Taoism, which later became a separate creed. Lao-Tzu neither created the word nor gave it significance. But in his *Tao-tê Ching* he gave to the then existing sporadic conception of the universe a literary form in which Tao was pre-eminent. His Tao, or "Way," is the originator of heaven and earth, it is the source of all things. Yet his "Way" is but a metaphorical expression for the manner in which things came at first into being out of the primal nothingness and how the phenomena of nature continue to go on.[1]

Thus in cosmogony it was held to be the force that had shaped the universe out of chaos. After creation, it was the key to the mysterious intermingling of heaven and earth, and it also means the Way and the Method of maintaining harmony between this world and the beyond, that is, by shaping earthly conduct to correspond completely with the demands of the other world.[2]

That the Chinese were early preoccupied with the phenomena of nature is readily understood when one recalls that long before Lao-Tzu and Confucious they derived their livelihood from agriculture.[3] The crystallization of this development was expressed by the concept of Tao. Since the entire universe followed one immutable course which became manifest through the alternation of night and day, through the recurrence of the seasons, through growth and decay, man in his utter dependence upon the universe could not do better than follow a way which was conceived after that of nature. The only manner in which he could attain the right Way, the Tao, was by emulating the course of the universe and completely adjusting himself to it. Thus, through Tao, man saw the universe endowed with a spirit that was indomitable in its strength and unforgiving toward disobedience.

Yet the ancient Chinese, although subservient to the universe as

[1] Otto Franke, "Die Cinesen" in Chantepie de la Saussure, *Religionsgeschichte* (Tübingen, 1925), Aufl. 4, Vol. I, pp. 195 ff.

[2] Heinrich Hackmann, *Chinesische Philosophie* (Munich, 1927).

[3] Herbert F. Rudd, *Chinese Social Origins* (Chicago, 1928), p. 3.

a whole, realized that within nature itself there was a gradation of power: the earth was dependent upon heaven. When the fields were scorched and men waited for rain, when winter lingered and sun was needed to thaw the frozen earth, man saw that heaven was the more powerful and therefore made heaven his supreme deity. But Chinese imagination never personalized this higher being or speculated about its intrinsic qualities.[4] Heaven, through its visible manifestations, remained the ruler of the world and united its Tao with that of the earth in order to complete the yearly cycle of nature; and it was by this example that man formed his Tao.[5]

Because it was from the sky that most natural blessings and catastrophes seemed to emanate, heaven was always venerated as the supreme power, but it was never credited with having created the world. Confucius knew nothing of a God, of a soul, of an unseen world. Moreover, he declared that the unknowable had better remain untouched. Therefore, mythology has no place in the Chinese concept of creation; instead, the Chinese have groped toward a more scientific explanation of cosmogony.[6] Lieh-Tzu (450–375? B.C.), the oldest author who proposes a theory of creation, starts from chaos, in which the three primary elements of the universe—force, form, and substance—were still undivided. This first stage is followed by a second, the great inception, when force becomes separated; then by a third, the great beginning, when form appears; and a fourth, the great homogeneity, when substance becomes visible. Then the light and pure substances rise above and form heaven, the heavier and coarser sink down and produce the earth.[7]

This concept of the division of substance into a lighter and a heavier part is one of the many forms which express the origin of the important Chinese belief in a dual power. Even though the idea of the chaos—the first stage of the creation of the world—was later replaced

[4] Wilhelm Grube, *Religion und Kultus der Chinesen* (Leipzig, 1910), pp. 27–31.

[5] For a detailed description of the early concepts of the Tao, see J. T. M. de Groot, *Universismus: Die Grundlage der Religion und Ethik, des Staatswesens und der Wissenschaften Chinas* (Berlin, 1918), pp. 1–23.

[6] Almost one thousand years after the philosophers had formulated their theory of cosmogony, a myth arose which designated a primeval being by the name of P'an Ku as the creator of the world. The inventor of this legend was Ko Hung, a Taoist recluse of the fourth century A.D., the author of *Shên hsien chuan*, or "Biographies of the Gods." According to later Chinese writers, the picturesque person of P'an Ku is said to have been a concession to the popular dislike of, or inability to comprehend, the abstract. While P'an Ku figured to some extent in folklore, the concept of a personified creator was never adopted by the educated.

[7] Lieh-Tzu, Book I, chap. 3. See also Alfred Forke, *The World Conception of the Chinese: Their Astronomical, Cosmological and Physico-philosophical Speculations* (London, 1925), p. 34.

by the Great Void, the Absolute, and then by the Great Unity or the Monad, the idea that each of these primary conditions divided into two and then reunited into one has survived.

The dual power that arose from the primary state was held to be the instigator of all change, for change was viewed as an expression of duality, as an emergence of a second out of a first state. The two components of the dual power were designated as Yin and Yang. The two characters which stand for Yin and Yang have received a vast variety of interpretations, but, by analyzing the ideographs themselves, the original and basic meaning of the characters can be ascertained. A literal translation of the components that constitute the two characters results in the meaning of "the shady side of a hill" for Yin and "the sunny side of a hill" for Yang. Other interpretations see Yin and Yang as two banks of a river, one of which lies in the shade, the other exposed to the sun. Dr. Otto Franke combines these two interpretations by stating that Yin represents the river bank that is shaded by a mountain, whereas Yang is that side of the river that is lighted by the sun. These three interpretations agree on the main issue, namely, that Yin represents the shady, cloudy element, while Yang stands for the sunny and clear element.

Since Yin and Yang are supposed to be the primigenial elements from which the universe was evolved, it was natural that they should be endowed with innumerable qualities. But if we keep in mind their original meanings—cloudy and sunny—and their original functions—that of the creation of heaven and earth—we shall find that many of the additional connotations are either directly related to, or at least logically derived from, the original concepts.

Yang stands for sun, heaven, day, fire, heat, dryness, light, and many other related subjects; Yang tends to expand, to flow upward and outward. Yin stands for moon, earth, night, water, cold, dampness, and darkness; Yin tends to contract and to flow downward. As heaven, Yang sends fertility in the form of sun (and rain) upon the earth; hence heaven's relation to earth is like that of man to wife—the man being Yang and the wife being Yin. This classification of Yin and Yang was extended and applied to qualities which no longer bear a direct relationship to the original meaning of "shady" and "sunny," although the relationship can often be logically explained. It would be impossible to enumerate even a small part of the alternatives that Yin and Yang have come to represent. Nevertheless, a few examples showing their extension from the physical to the moral, from the concrete to the abstract, may be instructive. Yang: motion, hence life; Yin: low, hence common. Yang: good-beautiful; Yin: evil-ugly. Fur-

ther contrasts are virtue-vice, order-confusion, reward-punishment, joy-sadness, wealth-poverty, health-disease.

The fact that in these contrasts Yang represented the positive and Yin the negative side must not be interpreted to mean that Yin was a "bad" and Yang a "good" principle. It must always be borne in mind that Yin and Yang were conceived of as one entity and that both together were ever present. Day changed into night, light into darkness, spring and summer into fall and winter. From these, the most striking and regular manifestations, it was deduced that all happenings in nature as well as in human life were conditioned by the constantly changing relationship of these two cosmic regulators. But the general application of this ever present duality also led to the realization that neither of the components ever existed in an absolute state, and the concept arose that within Yang there was contained Yin and within Yin there was contained Yang. The following passages, taken from China's earliest medical text, are illustrative of the importance attributed to these two universal forces:

> The principle of Yin and Yang is the basis of the entire universe. It is the principle of everything in creation. It brings about the transformation to parenthood; it is the root and source of life and death. . . .
>
> Heaven was created by an accumulation of Yang; the Earth was created by an accumulation of Yin.
>
> The ways of Yin and Yang are to the left and to the right. Water and fire are the symbols of Yin and Yang. Yin and Yang are the source of power and the beginning of everything in creation.
>
> Yang ascends to Heaven; Yin descends to Earth. Hence the universe (Heaven and Earth) represents motion and rest, controlled by the wisdom of nature. Nature grants the power to beget and to grow, to harvest and to store, to finish and to begin anew.

The constant interaction of the two basic elements is described in the following paragraph:

> Everything in creation is covered by Heaven and supported by the Earth. When nothing has as yet come forth the Earth is called: "the place where Yin dwells"; it is also known as the Yin within the Yin. Yang supplies that which is upright, while Yin acts as a ruler of Yang.[8]

While the Tao, the Yin, and the Yang were intangible concepts, they received expression through their tangible components, the Five Elements, which must be thought of less as actual substances than as forces essential to life. In spite of the prevalence of elemental ideas in early Greek and Indian philosophies, the theory of the five elements is

[8] Ilza Veith, *Huang Ti Nei Ching Su Wen* (Baltimore, 1949), p. 15.

no doubt of Chinese origin, and its existence in ancient times is proved by many old documents. The essence of this ancient tradition is that Yin and Yang, in addition to exerting their dual power, gave forth water, fire, metal, wood, and earth. Man, who was said to be the product of heaven and earth by the interaction of Yin and Yang, also contains, therefore, the five elements. This close relationship between the five elements and the human body was also extended to human actions, since each element was related to a specific emotion, as well as to a physical sensation.

Despite this apparent emphasis on man's place in the universe, it must be noted that the Chinese thought that all other animate beings and inanimate substances were created together with man, in his image and the image of the universe. All were thought to be regulated by the same laws, activated by the same dual power, composed of the same elements, and endowed by the same spirit of life. As was to be expected, the identity of substantial composition gave rise to the question as to whether there was a fixed and permanent hierarchy of things and beings within the universe. This is reflected in the writings of Lieh-Tzu (450–375? B.C.), who was mentioned earlier as the first to concern himself with the theory of creation, and in the writings of Chuang-Tzu, who lived one century later. In the works of both authors we find an almost identical description of an extraordinarily imaginative scale. The similarity between the two accounts raises the question as to whether Chuang-Tzu borrowed this idea from the earlier philosopher or whether both drew on theories then common in Chinese thought. The following version is the terser one, presented by Chuang-Tzu: [9]

> Certain seeds, falling upon water, become duckweed. When they reach the junction of the land and the water, they become lichen. Spreading up the bank, they become the dog-tooth violet. Reaching rich soil, they become *wu-tsu,* the root of which becomes grubs, while the leaves come from butterflies, or *hsü.* These are changed into insects, born in the chimney corner, which look like skeletons. Their name is *ch'ü-to.* After a thousand days, the *ch'ü-to* becomes a bird called *kan-yü-ku,* the spittle of which becomes the *ssu-mi.* The *ssu-mi* becomes a wine fly, and that comes from an *i-lu.* The *huang k'uang* produces the *chiu-yu* and the *mou-jui* produces the fire-fly. The *yang ch'i* grafted to an old bamboo which has for a long time put forth no shoots, produces the *ch'ing-ning,* which produces the leopard, which produces the horse, which produces man.[10]

It remains undetermined whether this amazing train of thought was inspired by some observations of nature or whether it simply repre-

[9] Many of the names in the following quotation could not be identified even by Chinese commentators.

[10] *Chuang Tzu: Mystic, Moralist, and Social Reformer,* trans. from the Chinese by Herbert A. Giles (2d ed., London, 1926), p. 228.

sents the brilliant speculation of an imaginative brain. Though completely fanciful, this ladder of nature is noteworthy because it was conceived more than two millennia before the Western world began to re-examine its biblical chronology. But, beyond this, the above-quoted passage contains two highly important points: first, a belief in an inherent continuity of all creation and, second, a reference to the merging of one species into another—from primordial germ to man. The significance of these implications was analyzed in 1877 by Ernst Faber, a missionary of the German Lutheran Rheinische Missions-Gesellschaft, whose Sinological publications were among the first to deal with the works of Lieh-Tzu. This missionary seems to have shared the then prevailing German admiration for the new evolutionary doctrines, and in Lieh-Tzu's account of the ladder of nature he even saw "die Darwinsche Hypothese in Chinesischer Gestalt." [11]

While Chuang-Tzu's and Lieh-Tzu's breathtaking journey from plant-germ to man illustrates a concept of a biological evolution, somewhat later and more sophisticated philosophers were concerned with a more careful evaluation of the differences and similarities between existing orders. This question is treated in considerable detail in Chu Hsi's magnificent *Philosophy of Nature,* a compilation of this philosopher's lectures, which was first brought together soon after his death in A.D. 1230. It embodies most of the earlier philosophical concepts and strongly influenced later Chinese thinking. Indeed, according to its translator, J. Percy Bruce, "On almost every page the reader will find modes of thought and expression which may be observed among all classes of people, from peasants to literati." [12] Since Chu Hsi was doubtless one of China's greatest minds, his views on "The Nature in Man and Other Creatures" are entirely representative of Chinese ideas on the subject. Like the one quoted here, many of his lectures took the form of dialogues which permitted greater emphasis on important questions:

1. *Question.* Do the Five Agents [the five elements] receive the Supreme Ultimate equally?

Answer. Yes, equally.

Question. Does man embody all the Five Agents, while other creatures receive only one?

Answer. Other creatures also possess all the Five Agents, but receive them partially.

2. *Question.* What is your opinion of the [Confucian] statement that the Nature consists of Love, Righteousness, Reverence, and Wisdom?

[11] Lieh-Tzu, *Der Naturalismus bei den alten Chinesen . . . Licius,* transl. and annotated by Ernst Faber (Elberfeld, 1877), p. 8.

[12] Chu Hsi, *The Philosophy of Human Nature,* trans. from the Chinese, with notes, by J. Percy Bruce (London, 1922), p. xi.

Answer. It corresponds to the saying "Their realization is the Nature." But preceding this are the stages represented by the statements "The alternation of the negative and positive modes" and "The law of their succession is goodness." When the Moral Law of the negative and positive modes alone existed, and before ever the stage of the creation of man and other beings was reached, these four principles [Love, Righteousness, Reverence, and Wisdom] were already present. Even the lower orders of life, such as reptiles, all possess them, but partially and not in their perfection, on account of the limitations caused by the grossness of the Ether.

3. It is true that in the life of men and other creatures the Nature with which they are endowed differs from the very beginning in the degree of its perfection. But even within the differing degrees of perfection there is the further variation.[13]

Obviously, this question had greatly occupied Chu Hsi's mind, for he frequently discusses it. It is of interest to note that in the following passage, however, he refers to "inferior" creatures, while the one quoted above speaks of "other" creatures:

Just as in the case of the body: within are the five organs and six viscera, and without are the four senses of hearing, sight, taste, and smell, with the four limbs, and all men possess them alike; *so with the moral nature:* within are Love, Righteousness, Reverence, and Wisdom, and these are manifested in solicitude, conscientiousness, respectfulness, and moral insight, and all men possess them; so that in all relationships, such as those of father and son, elder and younger brother, husband and wife, friend and friend, sovereign and minister, the same moral sentiments exist. Even in inferior creatures it is the same, except that in their case these principles are restricted by the rigidity of form and matter. Nevertheless, if you study their habits you find that in some particular direction they too manifest the same principles: they, as well as we, have the affection of parent and child; in their male and female there is the relationship of husband and wife, in their differing ages that of elder and younger brothers, in the flocking together of those of a class that of friends, and in their leadership that of sovereign and minister. It is because all things are produced by Heaven and Earth, and together proceed from the One Source, that there is this prevailing uniformity.[14]

The recurrent stress on the compositional equality and behavioral similarity of all the products of creation gave rise logically to the question as to the causes and nature of the differences which subsequently appeared. These speculations led to evolutionary theories concerning the very beginning of life on earth. Beyond that, however, thought was not carried. This failure is doubtless due to the intense

[13] *Ibid.*, pp. 56–57.
[14] *Ibid.*, pp. 19–20.

veneration for ancient concepts which, once formulated, must be preserved in their original entirety. However, the very injunctions to regard ancient writings as eternal and unchangeable verities provided the basis for reflections on the subject of social and cultural change. And here the results were surprising. Contrary to Western ideas such as that expressed by Nietzsche that man is unfinished and must be refined and completed, mankind, according to Chinese theory, had completed its social evolution and achieved the highest form of life at the very dawn of its history. But it was just this very perfection of social evolution attained so early that resulted in a theory propounding not only stagnation but actual devolution, that inexorably led man into an imagined state of regression. To establish this fact, recourse was taken to the impressive device of "priorism," which appears to be an ancient Chinese practice. This device was also used by Confucius when he created a picture of antiquity and of ancient rulers which corresponded—and was supposed to correspond—less to historical truth than to an ideal established for the princes and their people. It is doubtless dangerous to move the ideals of a people into a remote past, for it interferes with man's normal urge to expect improvement in the future and to work for it. The tendency to priorism becomes even more harmful if historical truth about more recent events is cast aside and a golden age alone is worshiped.

The proponents of the Chinese concept of unequaled perfection were four legendary rulers, often referred to as the *Sages.* They are generally known as Yao, Shun, Yü, and T'ang, although variations of these names were also used, and they were believed to have lived in the third millennium B.C. It was the achievement of these figures that ordered life upon the universe, once creation had taken place. Their feats are recorded by Mencius, of the fourth century B.C., whose writings reflect a picture of early social evolution:

> In the time of Yao, when the world had not yet been perfectly reduced to order, the vast waters, flowing out of their channels, made a universal inundation. Vegetation was luxuriant, the birds and beasts swarmed. The various kinds of grain could not be grown. The birds and beasts pressed upon men. The paths marked by the feet of beasts and prints of birds crossed one another throughout the Middle Kingdom. To Yao alone this caused anxious sorrow. He raised Shun to office, and measures to regulate the disorder were set forth. Shun committed to Yi the direction of the fire to be employed, and Yi set fire to, and consumed, the forests and vegetation on the mountains and in the marshes, so that the birds and beasts fled away to hide themselves. Yü separated the nine streams, cleared the courses of [the rivers] Tsi and Ta, and led them all to the sea. He opened a vent

also for the [rivers] Zu and Han, and regulated the course of the [rivers] Hwai and Sze, so that they all flowed into the [Yangtze] Chiang. When this was done, it became possible for the people of the Middle Kingdom to cultivate the ground and get food for themselves. . . .

The Minister of Agriculture taught the people to sow and reap, cultivating the five kinds of grain [wheat, glutinous millet, millet, rice, beans]. When the five kinds of grain were brought to maturity, the people all obtained a subsistence. But men possess a moral nature; and if they are well fed, warmly clad, and comfortably lodged, without being taught at the same time, they become almost like the beasts. This was a subject of anxious solicitude to the sage Shun, and he appointed Hsieh to be the Minister of Instruction, to teach the relations of humanity:—how, between father and son, there should be affection; between sovereign and minister, righteousness; between husband and wife, attention to their separate functions; between old and young, a proper order; and between friends, fidelity. The highly meritorious sovereign said to him, "Encourage them; lead them on; rectify them; straighten them; help them; give them wings:—thus causing them to become possessors of themselves. Then follow this up by stimulating them, and conferring benefits on them.[15]

The writings of Mencius were elaborated by many later authors. From one of these, Han Yü (A.D. 767–824) of the T'ang Dynasty, we receive an even more detailed description of the evolution of social structure in China. Since it is of particular significance to our subject, it will be quoted here in its entirety:

In former times the population was made up of four classes, the scholars, farmers, artisans and merchants. Now there are six [the four previous ones plus the Buddhist priests and the Taoist monks]. Formerly there was one school of [philosophical] precepts [Confucianism]. Now there are three [Confucianism, Taoism, and Buddhism]. [In reality] there is one class of food producers and six classes who eat the produce; there is one class of artisans and six classes who use the objects made by them; there is one class of merchants and six classes who buy from them. How does one expect the people not to become impoverished and destitute?

In primitive times, many dangers [threatened] man. But there appeared the Sages who made themselves known and subsequently taught them the rules of living together [family relations] and to raise [children]; and they gave them princes and masters [teachers]; they chased [away] the insects, the reptiles, the birds and the animals and installed man in the middle of the land [upon the earth of China]. [The people were] cold and the Sages gave them clothing; they were hungry and the Sages gave them food; those who lived in the trees fell off; those who lived in caves took sick and the Sages gave them houses or huts; [the Sages] set up for them [the class] of artisans, for the purpose of furnishing them the tools to use and [that of]

[15] James Legge, *The Chinese Classics,* Vol. II: *The Works of Mencius* (Oxford, 1895), pp. 250–252.

the merchant to perform the exchange of that which one has for that which one does not have. [They] gave them the art of healing and the medicines to prevent premature deaths, they established for them the burial rites and the posthumous offerings in order to prolong affection and attachment, they gave them the Rites so as to distinguish the ranks [in the social order], they gave them music so as to vent the repressed feelings; they instituted for them the power by which to discipline the lazy and the negligent; they set up for them punishments to distrain the transgressors and the obstinate. The people deceived one another—[the Sages] initiated for them forms of contract, seals, weights and measures which could be trusted. The people fought among each other—[the Sages] gave them fortified towns and adjacent quarters, armor and weapons for their defence. When danger arose [the Sages] made the necessary preparations for them, when calamity threatened [the Sages] found ways for them how to avert it.

And now as Lao-tzu says: As soon as the great Sages vanish, there will be the great thieves. If one breaks the [false?] weights and measures the people will cease wrangling. . . .

. . . .

If in antiquity there had not been the Sages, the human race would have been extinguished long ago. And why? Man does not have feathers, body hair, scales or turtle shells to help him resist the cold and the heat, and he has no talons or tusks to fend for his nourishment. Therefore the function of the prince consists of the giving of orders. The function of the minister consists in putting the orders of the prince into action and to transmit them to the people. As to the people, their function is to produce the crops of rice, hemp and silk, to manufacture tools and [ritual] vessels and to interchange the wealth of commerce—all of it so as to serve their superiors. If the prince does not give orders, he loses that which makes him a prince. If the minister does not put into action the prince's orders and does not transmit them to the people, he loses that which makes him a minister. If the people do not produce the crops, the rice, the hemp and the silk, if they do not manufacture tools and vessels, if they do not interchange the wealth of commerce in order to serve their superiors—then they will be punished.[16]

Both Mencius and Han Yü praise the Sages in exalted terms and imply the superiority of their personalities and their accomplishments which preclude any repetition. Other writers, however, go even further. They picture the accomplishments of these Sages in terms of such high order that, by their very feat of existence, these venerable personages doomed all subsequent generations to degeneracy and failure. The following passages from an ancient medical text, again in dialogue form, are descriptive of such devolutionary thinking:

[16] *Le Kuo-Wen Chinois: Recueil de textes acev introduction et notes par Georges Margouliès* (Paris, 1926), pp. 179–180.

The Yellow Emperor once addressed T'ien Shih, the divinely inspired teacher: "I have heard that in ancient times the people lived [through the years] to be over a hundred years, and yet they remained active and did not become decrepit in their activities. But nowadays people reach only half of that age and yet become decrepit and failing. Is it because the world changes from generation to generation? Or is it that mankind is becoming negligent [of the laws of nature]?"

Ch'i Po answered: "In ancient times those people who understood Tao [the way of self-cultivation] patterned themselves upon the Yin and the Yang [the two principles in nature] and they lived in harmony with the arts of divination.

"There was temperance in eating and drinking. Their hours of rising and retiring were regular and not disorderly and wild. By these means the ancients kept their bodies united with their souls, so as to fulfill their allotted span completely, measuring unto a hundred years before they passed away.

"Nowadays people are not like this; they use wine as beverage and they adopt recklessness as usual behaviour. They enter the chamber [of love] in an intoxicated condition; their passions exhaust their vital forces; their cravings dissipate their true [essence]; they do not know how to find contentment within themselves; they are not skilled in the control of their spirits. They devote all their attention to the amusement of their minds, thus cutting themselves off from the joys of long [life]. Their rising and retiring is without regularity. For these reasons they reach only one half of the hundred years and then they degenerate.

"In the most ancient times the teachings of the sages were followed by those beneath them; they said that weakness and noxious influences and injurious winds should be avoided at specific times. They [the Sages] were tranquilly content in nothingness and the true vital force accompanied them always; their vital [original] spirit was preserved within; thus, how could illness come to them?

"They exercised restraint of their wills and reduced their desires; their hearts were at peace and without any fear; their bodies toiled and yet did not become weary.

"Their spirit followed in harmony and obedience; everything was satisfactory to their wishes and they could achieve whatever they wished. Any kind of food was beautiful [to them]; and any kind of clothing was satisfactory. They felt happy under any condition. To them it did not matter whether a man held a high or a low position in life. These men can be called pure at heart. No kind of desire can tempt the eyes of those pure people and their mind cannot be misled by excessiveness and evil.

"[In such a society] no matter whether men are wise or foolish, virtuous or bad, they are without fear of anything; they are in harmony with Tao, the Right Way. Thus they could live more than one hundred years and remain active without becoming decrepit, because their virtue was perfect and never imperiled." [17]

[17] Veith, *op. cit.*, pp. 97–98.

These Sages were exalted above all later speculations as to whether man was inherently good or evil. They conformed to Confucius' tenets that man was inherently good and fell into error only through lack of instruction. But different views are present in the writings of a later Confucian philosopher, Hsün Tzu (third century B.C.), who held that man is inherently evil:

> Man's nature is evil. Anciently the Sage Kings knew that man's nature was evil, partial, bent on evil, corrupt, rebellious, disorderly and without good government. Hence they established the authority of the prince to govern man; they set forth clearly the Li [Etiquette, Rites] and justice to reform him; they established laws and government to rule him; they made punishments severe to warn him, and so they caused the whole country to come to a state of good government and prosperity.[18]

This passage shows that the concept of the ancient Sages was more than abstractly meaningful. It even prepared a way for the solution of affairs of state brought about by the weakening of the ruler. In China the form of the political organization was never questioned. Monarchy was accepted as the natural and inevitable vehicle of sovereignty. It was the moral foundations on which the monarchy should be based that were the subject of many philosophical rivalries. This preoccupation with moral principles rather than with political forms was characteristic of all Chinese thought and led to the belief that the moral character of the ruler was the factor which determined the quality of his government. Not until the revolution of 1911 did anyone ever advance the view that a change in the form of government would help to establish the rule of virtue and benevolence.

On the other hand, the Chinese did not invest the person of the monarch with the attributes of divinity. Above the king, who was not a god, was T'ien, "Heaven," or *Shang Ti,* "The Supreme Ancestor," and the earthly sovereign was but his deputy, standing in the relation of an adopted son who had received the Mandate of Heaven (*T'ien Ming*), by virtue of which he ruled over the earth. This "Mandate" was not a patent of divine right, irrevocable and eternal. It was conferred upon a sage king whose virtue had entitled him to act as the deputy of Heaven. His descendants enjoyed it only so long as their virtue made them worthy representatives of the Supreme Ancestor. A tyrant who misruled his kingdom and did not possess the virtues of love, righteousness, reverence, and wisdom was deprived of the Mandate of Heaven, and rebellion against his rule was not crime but the just punishment of outraged Heaven acting through the medium of the rebels. The above-quoted passage from Han Yü attests to this

[18] Charles P. Fitzgerald, *A Short Cultural History of China* (London, 1935), p. 93.

practice, and Mencius, on a famous occasion, when questioned about the execution of the king by Wu, founder of the Chou Dynasty, denied that this act could be described as the assassination of a prince by his minister. He replied: "I have heard of the execution of the fellow Chou [last King of Shang]; I have not heard that a prince was assassinated by a minister." Chou, for his tyranny and crimes, was no longer fit to be accounted a king. He had lost the Mandate of Heaven which had already been conferred upon Wu, founder of the next dynasty. Thus he was "executed," and Wu was not a "minister" or subject, but the "true King by the appointment of Heaven." [19]

It is interesting that the principle of priorism also invaded the vast field of Chinese art. As Fitzgerald [20] points out so well, Chinese art, too, became derivative and increasingly stereotyped. Technical skill remained at the same high level as that achieved in the T'ang and Sung periods, but inspiration and originality declined steadily. In bronze the best Ming workmanship is almost flawless, but it consists of the mechanical reproductions of ancient pieces decorated with the classical motifs, and there is a complete lack of invention. When ancient models were forsaken, the productions of the late bronzesmiths were insipid and the decoration trivial. The jade and ivory carving of the Manchu period shows extreme manual skill and delicacy, which maintained these ancient arts on a very high technical level down to modern times. Ivory has perhaps never been wrought into so many intricate forms as by the Cantonese craftsmen, who are able to carve out of one tusk several spheres, one within the other, all pierced with delicate filigree patterns.

Yet in all these crafts, in spite of the fine workmanship of their products, there is a certain self-consciousness, an absence of real purpose, which reflects the character of the age in which they were made. These things, upon which so much skill and patience were expended, were only intended to please. They had no ritual significance, no living inspiration derived from some ardent belief or high ideal. They were made for the wealthy as ornaments, to be admired for their technical perfection or ingenious workmanship, not to be venerated as symbols of a cult or as the expression of the artist's perception of truth. Ancient conventions lay heavily upon all the arts, as upon the mind of the educated class that patronized them.

This archaistic atmosphere was in itself a handicap to evolution. Just as the Confucianist was taught to look back to a remote classical age for his criteria of literary style, so the artist took his standards from the same distant past. The jade carver or bronzesmith was certain to

[19] *Ibid.*, p. 74.
[20] *Ibid.*, pp. 580–81.

please if he made an exact reproduction of an ancient piece; but if he struck out a new design, his efforts would be ranked far below the copy of a classical model. This contempt for all that was not old created a sense of inferiority in the artist who tried new forms. It was accepted as a matter of course that any ancient work was necessarily superior to anything which could be produced in modern times, and the artists, succumbing to this psychological pressure, either copied the past or produced self-consciously trivial work which made no claim to challenge comparison with antiquity.

It is clear from the foregoing that the Chinese idea of devolution and the supreme satisfaction with ancient achievement stifled all subsequent developments in the realms of morality, political institutions, and the arts. Yet this did not preclude isolated advances in certain aspects of Chinese culture. Entirely new styles in poetry and rhymed prose were developed and enriched literature, in spite of the T'ang and Sung movements to return to the prose style of the classical times. In technology the superiority of later methods was perfectly obvious, and even in philosophy the neo-Confucianists clearly felt that the ideas of the ancients could be profitably amplified, even if their basic principles were good for all times.

Hardly any of these advances, however, ever touched the art of healing. Its foundation unalterably rested upon the earliest texts and their universalistic concepts, which saw in the body a microscopic image of the universe and in the practice of medicine largely a rebalancing of Yin and Yang and the five elements. Brief flights into rational medical activity conflicted with hallowed beliefs and were either actively prohibited, as in the case of surgery, or permitted to fall into disuse. The latter fate befell the brief practice of inoculation against smallpox, which was developed in China in the eleventh century, nearly seven centuries before it was introduced into the West. So complete was the contentment with the ancient traditions of Chinese healing that to this day it has never been completely supplanted by modern Western medical science. And, indeed, when first conceived, it was, like China's culture and social system, a completely rational and workable entity, far superior and far more powerful than that of any neighboring people. All further improvement appeared needless.

Thus the grand evolutionary surge that had first carried China so far in so brief a time was deliberately halted at an arbitrarily set point of "perfection." With the suspension of all social change, all other evolutionary tendencies were suspended also until it became apparent that the tenets of the golden age failed to provide safeguards against a world that had accepted change and took advantage of it. The humiliation brought about by the Opium War in the middle of the last

century and especially, the defeat, in 1895, by fellow-Asians, the Japanese, who had but slightly earlier divested themselves of the stranglehold of priorism triggered the sudden change in Chinese attitudes. Since its ancient classics were of little avail in China's adjustment to reality, other and foreign sources had to be found to guide her in her new role of living in a world dominated by Western ideas.

One of the first to provide such texts was Yen Fu, in the late nineteenth century, who combined a classical Chinese education with Western studies. In England he had become familiar with the works of the leading naturalists and philosophers, and he was particularly struck with the pertinence of T. H. Huxley's writings, which first acquainted him with the theories of the "struggle for existence" and "survival of the fittest." He undertook the translation of *Evolution and Ethics* in 1896. Immediately upon its publication in 1899, it became one of the most influential textbooks in Chinese education. One of the reasons for the great impact of Yen Fu's translation was his use of the classical style as well as the introduction of many illustrations and quotations from classical Chinese sources. By doing so, he presented modern evolutionary conclusions as logical outgrowths of ancient Chinese thinking. In general, this made Huxley's ideas immediately acceptable, although Wu Ju-lun, then head of the faculty of Peking Imperial University, commented in a letter to Yen: "If you write a book yourself, you may say what you like; but if you are translating Huxley it is more appropriate to use the ancient quotations and illustrations from the West that are in the original work. It seems undesirable to exchange them for Chinese sayings, since those persons and things Chinese could not be familiar to Huxley." [21]

In Huxley's writings, Darwinism entered China long before the translation of Darwin's own books. But it was Darwinism, speaking through Huxley and made to appear organically related to ancient Chinese thought on evolution, that furnished the intellectual basis for China's great upheaval beginning with 1911. This was attested to in 1920 by one of China's most outstanding scholars, Liang Ch'i-ch'ao, when he wrote:

> Since Darwin's discovery of the principle of the evolution of species, a great revolution has occurred in intellectual circles over the whole world. His service to learning must be acknowledged. But afterwards his theory of the struggle for existence and survival of the fittest was applied to the study of human society and became the core of thought, with many evil consequences. This great European war has nearly wiped out human civilization; although its causes were very many, it must be said that the

[21] Tsuen-Hsuin Tsien, "Western Impact on China through Translation," *Far Eastern Quarterly*, XIII (1954), 321.

Darwinian theory had a very great influence. Even in China in recent years, where throughout a whole country men struggle for power, grasp for gain, and seem to have gone crazy, although they understand nothing of scholarship, yet the things they say to shield themselves from condemnation are regularly drawn from Yen Fu's translation of T. H. Huxley's Principles of Evolution. One can see that the influence of theory on men's minds is enormous. No wonder that Mencius said, "These evils, growing in the mind, do injury to government, and displayed in the government, are harmful to the conduct of affairs." [22]

It is interesting that Liang Ch'i-ch'ao in his review of China's progress nostalgically invoked a saying of Mencius, for he must have been deeply aware that the bonds with the golden age had been broken forever. The gap of evolutionary thinking of two thousand years had been firmly closed, and with it evolution itself had carried China to a destiny which Mencius himself had foretold with dread: "Now here is this shrike-tongued barbarian of the south, whose doctrines are not those of the ancient kings. Your conduct is different indeed from that of the philosopher Tsăng." [23]

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[22] Ssu-yü Teng and John K. Fairbank, *China's Response to the West* (Cambridge: Harvard University Press, 1954), p. 267.

[23] Legge, *op. cit.*, II, 255.

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CURRENT ROMAN CATHOLIC THOUGHT ON EVOLUTION

I refuse to admit that there is a real conflict in terms of head-on, edge-to-edge opposition between science and religion—much less between science and theology. The "conflict," the "opposition," has been that of human beings. On the one side we have had human beings who have had certain experiences and qualities and, on the other, human beings who have had quite other experiences and qualities. What these human beings have most often ignored (lost in the heat of the battle) are such basic facts as the difference in areas for the scientist, the philosopher, and the theologian. Let me illustrate this difference briefly.

The scientist deals with the facts of the material universe. His great goal is to spell out the "How" of things. Let us suppose that a recent study of sexual behavior in the United States was good science (which it was not). The author finds that there are patterns of male sexual behavior. Thus far, so good. Let us suppose (as happened in a subsequent study) that the author says thus and so "should" be the case. The author is jumping from the scientific to the philosophical level, to the level of analysis of human nature, in this case to ethics. Above this level is that of revelation, the scientific approach to which is called "theology."

This paper deals with a problem precisely in the field of science and philosophy and theology. The emphasis in our exposition will be on the last-named area, because of the request of our chairman. But, in dealing with the relationships of Roman Catholic theology with evolution, I shall not include in my discussion many facets of religion. These might be awe, moral implications, personal commitment, prayer, sacrifice, and the I-Thou relationship with God. I shall keep solely within the bounds of a purely intellectualistic approach.

This may seem somewhat strange to those who think that intel-

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lectualism and religion are divorced, if not positively antagonistic. However, as a Catholic, I believe that the intellect, too, is gravely involved in religion. I believe that every Catholic has to make a synthesis of all known truth, no matter whence derived, for his world view. I believe that truth perceived by science or philosophy is ultimately from God, who is the Author of all truth. Of course, the transcendental source of truth is revelation. But, obviously, any adequate concept of God would preclude the possibility that truth learned by a reasonable study of God's universe could ever be in conflict with truth presented to us by revelation. That God should contradict himself is unthinkable.

Although I am also a professional anthropologist, I shall make no further use of this fact than to take for granted, in this paper, the scientific validity of the theory of evolution. Speaking, therefore, as a Catholic priest, I should propose the following three major topics for my discussion: (1) the structure of belief in the Catholic church, as an appropriate background for the further exploration of my theme today; (2) the outlines of the history of Catholic attitudes toward evolution; and (3) the present Catholic position regarding evolution.

The Structure of Belief

For the Catholic, the truths of revelation are contained in what is technically called "the deposit of faith." This deposit was left by Christ himself. The Church, as the continuation of the mission of the historical Christ (what we know as the "Mystical Body of Christ"), guards and interprets this deposit of faith. It guards it because there can be no discrepancy between what Christ taught in the beginning and what the church teaches in each successive age. It interprets it because each age—nay, each culture—has its own particular difficulties and language and circumstances.

The scientific theologian (and theology is a science, although with sources and methods quite different from those of the natural sciences) finds that the truths of revelation are not all of the same rank, much as they may be, for instance, in the mind of a pious peasant.

So we find that some truths are *defined*. This means that the Church (in this case by its pope, or an ecumenical council which includes the pope) has solemnly and precisely spelled out the doctrine in question. Thus, for our future purposes in this discussion, we may note that the existence of a spiritual soul in man was defined by the Council of Vienne (1311–12).

Other truths are so clear from Sacred Scripture or from the universal and continuous belief of Catholics that they are definable. The

Church defines doctrines only when need arises. Thus there would be no particular reason to define the doctrine that God is the Creator of all things outside himself, unless this doctrine were denied in such a way as to call for a reaction from the Church or unless this statement were to be included in a definition for completeness' sake. Still other doctrines are logically derivable from the premises mentioned. Thus we go down the hierarchy of doctrines until we come to the very lowest category in scientific theology, the probable theological opinion.

Other witnesses to the deposit of faith, besides Holy Writ, are notably the Fathers of the Church. These were public teachers of religion, ecclesiastics and usually bishops, who wrote during the early centuries of the Christian Era and formed a link between the time of the Apostles and that of the later church. The fact that they were public figures means that their teaching was eminently open to inspection; and, furthermore, if the Fathers were unanimous in stating that a certain doctrine was of Catholic faith, this results in a very high rank for the doctrine in question. Also, they represented the great body of Catholics of their times, and thus they remind us of the concise formula of St. Vincent of Lerins (fifth century A.D.): "What all men have at all times and everywhere believed must be regarded as true [he was speaking of Catholic belief]."

The Church does not define doctrines right and left or daily. Yet, here and now, in the circumstances of the times, Catholics should be kept in tune with Christ's doctrine and spirit. They look for guidance and inspiration to the church. So the church exercises what is known in Latin as *magisterium ordinarium,* the day-by-day teaching, which is adapted to the day and may even be changed as circumstances dictate. The highest and best example of this ordinary teaching function is to be found in the encyclicals of the popes. The application of revelation to the social problems of the modern world, for example, has been the work of the encyclicals of Leo XIII, Pius XI, and Pius XII. In the encyclical the pope does not normally use his prerogative of infallibility; in other words, he is not defining this or that doctrine. But, short of this, the encyclical is of the highest authority for the Catholic here and now.

Now we come to a consideration that is of prime importance in our thinking about Catholicism and evolution. This consideration is the role of the theologians in the actual doctrinal and moral life of the Church.

We note in the original sources of revelation a certain economy. Thus, in the Bible, God obviously did not establish an encyclopedia of all knowledge (it would be a dull world indeed, with no research

and no learning, had he done so!). So, in the Book of Genesis, we find no erudition about paleontology.

Indeed, God did not satisfy our curiosity concerning every possible subsection and nuance even in the field of religion itself. It seems that he decided to reveal the essentials, those truths necessary for us so that we might love him and our neighbor, that we might observe his Law and achieve our life's goal in him, together with as many other human beings as possible.

Picture a ship's captain and his ship following a coastline into port. He has lighthouses; these are the great truths revealed by God. Close in, he may use his searchlight to illumine the darker parts of the coast. The lighthouses are sufficient for him to reach his port; the searchlight is a help, and he would be a fool not to use it when he can. But the searchlight of reason can never contradict the testimony of the lighthouses, for the coast (truth) was made by God, who created all.

Just as there was an economy in the original deposit of faith, so, too, the Church is economical today. When there is no need of a definition or even of the expression of its ordinary teaching power, it leaves the matter to its theologians. Who are they, and what is their authority?

The theologians we are referring to are official teachers of theology, usually in seminaries where priests are trained but not necessarily so, whose verbal instruction and publications are subject to the scrutiny of the Church. This reminds us of what we said previously about the Fathers of the Church.

If the church is, as we Catholics believe, the Mystical Body of Christ, the continuation into our times of the historical Christ, a body whose guide and informing principle is the Holy Spirit, it could hardly allow its official teachers to propose, en masse and for a long time, doctrines which were wrong.

This concept is different, as you will immediately realize, from what I may call the "human" or "organizational" aspect of the Church. But the human factor operates to the same effect. Rome is the highly centralized center of the Church, and its organization includes human means for supervising theological teaching around the world. Among these human means are the Congregations, which are committees of cardinals and others, set up to help the pope in administering the details of the Church universal.

In areas which fall between the lighthouses of revelation, the Church leaves a great deal to its theologians. The safest course for any Catholic to follow, at any given point in time, is to heed the common teaching of theologians at that time. This is, for the average Catholic, sheer prudence. The theologians are experts, professionals; the average Catholic is not—that is, in the matter of religion.

The phrase we have just employed, "at any given point of time," implies the possibility of theologians changing their opinion from time to time. I imagine the average non-Catholic is puzzled by this. His Catholic friends (and authoritative Catholic sources) tell him that Catholic doctrine is unchangeable. In point of fact, the question of evolution affords us an excellent example of how Catholic theologians could change their opinion, without challenging the immutability of Catholic doctrine. And so we come to the second section of our paper.

The Historical Background

Let us try to see the situation as it appeared to Catholic theologians in 1859, with regard to evolution. In addition to experiencing a sense of shock, in common with many other people, they had three primary concerns in the forefront of their immediate thinking.

The first primary concern was, of course, the Catholic faith. Involved here was the interpretation of certain texts of Scripture, notably in the Book of Genesis, but also in other books of the Old and New Testament; also involved were certain propositions of councils and popes. But let us, for the moment, stay with the Scriptural texts. There had been no reason, up to 1859, to doubt the literal interpretation of these texts.

The first and foremost rule of interpretation, laid down by St. Augustine long before and reiterated in the famous biblical encyclical (*Providentissimus Deus*) of Pope Leo XIII in 1893, is that a text should be regarded as meant literally, unless reason or necessity make us realize that it was not so meant. Some texts are obviously metaphorical. No one thinks that "The arm of the Lord is not shortened" reveals the fact that God has a physical arm. Other texts clearly show what they mean but are examples of the Near Eastern way of expressing things. Finally, there are texts of dogmatic value, because they propound, in language everyone can understand, truths to be believed.

It is of the nature and office of the theologian that he maintain a well-balanced conservatism. He is not dealing with a new dentifrice or a new automobile; nor is he the natural scientist who needs the latest publication. This reminds me of a story about a German-born Jesuit at Georgetown University, a geophysicist. At a meeting he attended, a geologist got up and announced that it was high time that the church bowed to science. Whereupon the Jesuit retorted: "If the church bowed to science, it would be bowing in every direction at vunce!"

Obviously, the theologian does not want to be, nor can he be, a weathervane. It would do religion no good if he plumped for a theory

today, only to have to recant tomorrow. There are those who think that the theologian was too slow to accept the evolution of man's body. May I remind them that the scientific evidence at the time of the publication of *Origin of Species,* and much later, was scant indeed? I am referring to the evidence with regard to human evolution and the evidence as derived from *the* probative source, namely, paleontology; of this there was effectively none in 1859. There was Engis and Gibraltar and Neanderthal, but no one knew what to do with them. I admit that there was plenty of evidence from all sorts of sources for evolution in general, but not for man.

It is difficult for us today to realize this. More human fossils have been unearthed in the last twenty-five years than in the whole previous history of the world. But, at any given point in time, the theologian who asked the scientist for good and certain reasons why he should change his interpretation of a text of Scripture was more often than not met by conflicting opinions, of which, professionally, the theologian was not a good judge.

The weaknesses in Darwin's theory of natural selection, not yet strengthened by modern knowledge of mutations and genetics, were all the more confusing to the theologian, especially as there was an unfortunate tendency to equate Darwin's specific theory with the overall theory of evolution itself.

The third primary concern of the theologian, in 1859 as now, was the total membership of the church. The church is made up of all sorts of people—scientists, theologians, philosophers, littérateurs, and peasants, pirates, and ordinary folks. While there is no question of an esoteric and exoteric doctrine, nevertheless the theologian (and the church) have to think of people, as the phrase goes, "across the board." And—an eminently anthropological consideration, because it involves the integration of culture—the theologian has to think of such a thing as the theory of evolution not as something occurring in a vacuum but as part and parcel of what is going on in the world of business, literature, politics, morals, thought, as well as in that of science, and in that of religion.

From the beginning, Catholic writers made it clear that a spiritualistic evolution—one which allowed of the human spirit and the fact of God the Creator—did not come into opposition with any Catholic dogma. (Here is an element of unchangeability; the theologian says the same today.) But it was difficult to keep this distinction clear in all minds. People like Huxley and Haeckel were identifying evolution with materialism (which is a philosophy and not a science). One could hardly expect the theologian to embrace with open arms what was proposed as a substitute for God!

From the point of view of the organizational, day-by-day operation of the church, the theologian had only what we call "private acts" to guide him; these involved requests of Roman authorities that certain Catholic books approving of evolution be retired from the market. It is clear that these acts were administrative and were concerned with the opportuneness of the writings, in view of the common good of the faithful. No such acts have occurred since 1909, although a goodly number of Catholic writers have expressed opinions favorable to evolution.

WHERE WE STAND TODAY

The historical merges with the actual with the year 1909. In that year the Pontifical Biblical Commission issued certain decrees about the interpretation of Genesis, a part of the Old Testament which has direct bearing on our theological consideration of the evolution of man.

The Biblical Commission was set up in 1902 by Pope Leo XIII. The decrees of this commission, when approved by the pope, are an even safer norm for the ordinary Catholic than the teaching of the theologians, because they are guides even for the theologians.

In spite of the fact that Genesis and the Bible in general were under heavy fire from such scholars as the higher critics and the modernists, the decrees of the commission faithfully held to what I may call a "Catholic moderation," a middle way between two extremes, rejecting fundamentalism (which would make every word of the Bible literally definitive as we understand those words today) and equally rejecting modernism (which would make of the Bible a set of beautiful and religious sentiments with no particular connection with reality); the commission pointed out that Genesis contained elements of true history but that the literary form was not that of a modern history book. And, indeed, such statements as those concerning the creatorship of God, the special nature of man, the fall of man from grace, and the promise of a Redeemer are of essential importance to Catholicism. Without Christ the Redeemer, there would be not much point to Christianity.

In an encyclical (*Divino afflante spiritu*) of Pius XII, issued in 1943, the duty of the Catholic student of Holy Writ to ascertain the true meaning of a text, in terms of Near Eastern literary ways, was re-emphasized. Other minor documents of church officials have also underlined this emphasis.

The most recent ecclesiastical document mentioning evolution is the encyclical (*Humani generis*) of Pius XII, promulgated in 1950. In a small but special section about human evolution, the Pope made

the following statements, which we shall first list and then comment on briefly.

1. In any discussion of evolution, the Catholic must take for granted the spiritual soul of man.

2. Otherwise, such a discussion is left open by the Church.

3. However, such a discussion is for experts in science and theology, and reasons for and against must be gravely weighed. The Catholic must be ready to submit to the judgment of the Church.

4. People should not take it for granted that evolution is a proved fact and should not act as if there were no theological reasons for reserve and caution in their discussions.

Comments on These Points

1. The fact that every human being has a spiritual soul is so basic to true religion that we are not surprised to find that the Catholic church has always believed this to be true. The doctrine that God himself immediately creates each human soul belongs to that group of dogmas which the church proposes and to deny which would make the denier a heretic, even though there has never been any special reason for a formal definition. This is one occasion on which God has to step in with his primary power, because matter cannot produce a spiritual soul.

2. This statement re-echoes what Catholic theologians have been saying from the beginning: a true evolution is not in contradiction to any Catholic dogma.

3. Considering the actual state of affairs today, Pius XII did not want evolution bandied about on the level, let us say, of the tabloid. Here, I should think, he was considering the generality of Catholics, who could easily misunderstand the distinction between a spiritualistic and a materialistic evolution. He also understood the fact that true ideas may start with the intellectuals but eventually filter down to the masses.

4. There is a difference between the terminology of scholastic philosophy and theology and that of modern natural science. I am preparing a special study on the concept of certitude as derived from the sciences, as compared with the same concept in philosophy and theology. But, here and now, I simply wish to state that my introductory remark, describing evolution as a valid scientific theory, is not at variance with the words of Pius XII.

One more factor, that touches on evolution, is treated in *Humani generis*. This is polygenism, the derivation of mankind from more than one stock or from a group of original human beings.

This, for me, offers no problem. Science is in no position to prove a multiple origin for modern mankind, nor would it necessarily make any difference to theology if it could indicate a multiple origin, the offspring of which later fused into a single origin. Science knows nothing of Adam and Eve, considered by Catholic theology as the first parents of all modern human beings. But science, in the work of Sewall Wright, of the University of Chicago, recognizes that mutations are fixed only in small populations; indeed, Wright speaks of the possibility of bottleneck generations, which may be reduced to a single pair.

Modern theologians would say this about the origin of man. God is the Creator of man, body and soul. Whether he used the method of evolution for the preparation of the human body or created it from unorganized matter is not of primary importance. In either case, he is the Creator. But even if he used an already formed body, he touched both body and soul in the creation of man. The changes in the already organized body may have been so subtle, so much in the philosophical order I may say, that no method of physical science could observe them. But, somehow, God raised the body of man to a human plane and, of course, created the human spiritual soul.

"In the beginning . . . God created heaven and earth . . . and God created man to His own image." This is the primal fact in the history of mankind.

EPILOGUE

Catholic thinkers have been, by and large, reserved about evolution. However, currently, more and more theologians are showing themselves favorable to it. One reason for this is extrinsic to the science of theology, but exerting a powerful influence on it. This is the piling-up of evidence, particularly paleontological, which makes human evolution more and more credible. Intrinsic to theology has been the recent climate of opinion among Scripture scholars. The old-fashioned dependence on the immediately verbal exegesis has given way to an appreciation of the "literary form" of Holy Writ. Thus we are becoming increasingly aware of the fact that the human authors of the Bible used story, parable, and statement in keeping with the cultural dictates of the Near East; the most important thing, therefore, is to determine what religious lesson is proposed in any section of the Bible, not as in a modern scientific textbook, but as in a document which is at once very human and divine.

Speaking from personal opinion, I am sorry that all too few Catholic thinkers have been really coming to grips with evolution. They

could supply the philosophy of evolution with the mentally satisfying components of God as Creator and final end of all things in the universe outside himself and God as the Conserver. This latter means very simply that God is continually creating his creatures—if he were to withdraw his creative power for a second from you and me and the worm and the elephant, all would disappear into nothingness. This means that God created not only all beings but also all potentialities for evolution and that he works as a basic co-cause with the activities and development of his creatures.

In the view of Teilhard de Chardin, God is the pole toward which man is tending, by a convergence of evolution. If I may borrow a few words from Darwin's *Origin of Species,* "There is a grandeur in this view." Man, with his genetic roots in the whole material universe, from atoms to primates, still has an element of the divine in him. This latter element was divinized just as far as it possibly could be by the advent of the Son of God, and his assumption of human nature and his redemption of fallen human nature. Now man, as both a natural and a supernatural being, individually and collectively, still evolves—he still grows and trends toward his ultimate realization, in God.

JAROSLAV PELIKAN

CREATION AND CAUSALITY IN THE HISTORY OF CHRISTIAN THOUGHT

Seldom in the history of the Christian church have theologians reacted as violently to a non-theological book as they did to Charles Darwin's *Origin of Species*. Neither the *True Word* of Celsus nor *The Revolutions of the Heavenly Bodies* of Copernicus nor even perhaps *The Communist Manifesto,* damaging though they all were to the cherished beliefs of many Christians, evoked so many wounded reactions in their own time from so many theologians, bishops, clergymen, and Christian laymen. Clearly, Darwin seemed to be a threat to something central in Christian faith and life. Bishop Wilberforce and William Jennings Bryan are partly illustrations and partly caricatures of a defensiveness that pervaded large portions of the Christian world during the two generations following *Origin of Species.*

How are we to explain that defensiveness? Even if the answer confines itself to the area of Christian doctine and ignores the important psychological, sociological, and cultural factors in the life of the church that help to account for its defensive stance, the explanation is not so obvious as either Thomas Huxley and Clarence Darrow or Samuel Wilberforce and William Jennings Bryan thought it was; for diverse and even divergent ideas within the broad Christian tradition found themselves threatened by the doctrine of organic evolution. In the opinion of many theologians, Darwin threatened the trustworthiness of the Scriptures by casting doubt upon the literal accuracy of the narratives in the Book of Genesis; but Copernicus had also been accused of subverting the truth of the Bible. The traditional Christian definition of the image of God in man seemed to clash with the idea of his descent from earlier and lower forms of life, but the voyages of discovery and the beginnings of modern anthropology had already shaken some of the foundations of the classical Christian interpretation of the *imago Dei.* Faith in the direction of divine Providence

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over nature, as formulated by writers like William Paley in his *Natural Theology,* could not stand if Darwin was right; but the rationalism which Paley both attacked and shared had already substituted its own doctrines of historical destiny for the orthodox, largely Augustinian, concept of divine Providence. Darwin's suggestions about the descent of man appeared to make the Augustinian doctrine of original sin through the Fall of one human couple untenable, but so did the various versions of the idea of pre-Adamites that had achieved some currency during the seventeenth and eighteenth centuries.

All these Christian doctrines, and many others besides, seemed to lose their moorings when Darwin cut the rope between man and Adam. One or another of them predominated in the reactions of various churchmen to the Darwinian hypothesis. Yet the one fundamental Christian doctrine to which Darwin seemed to pose the most direct threat was certainly the doctrine of creation. If evolution was right, creation was wrong: on this premise, it appears, Huxley and Wilberforce, Bryan and Darrow were all in agreement. Because that premise was supported by so motley a community of scholars and orators on both sides, it seems to deserve some special examination. This essay is an examination of what creation meant originally and of the subsequent history of the Christian definition of creation. I shall review the origins and then look briefly at some of the chief controversies over the doctrine of creation in the history of Christian thought, with the intention of suggesting how that doctrine had maneuvered itself into a position where the doctrine of evolution was a fundamental threat. From a study of those controversies it is clear that (under some providence or other) the Christian idea of creation had managed by the nineteenth century to emphasize those aspects of biblical and patristic language to which Darwinism represented a challenge; and it had meanwhile tended to ignore, or rather to neglect, those aspects of the tradition that theology could maintain regardless of scientific discoveries about either the origin of species or the descent of man. There is, unfortunately, no history of the Christian doctrine of creation. The closest approximation to such a history of this doctrine is the scholarly work of almost a century ago by Otto Zöckler on the history of the relations between science and theology—a work which is much more balanced than the more familiar and vastly more partisan book by Andrew Dickson White. But even Zöckler's erudite study does not sufficiently document the ambiguity in the very term "creation," which has been present throughout Judeo-Christian history, apparently ever since creation.

Certainly it has been present at least since the Old Testament. Although the story of how God originally fashioned the world and all

that is in it comes first in the sequence of the biblical narratives as we now have them, it is a mistake to interpret this story as the foundation for all the subsequent narratives. Indeed, literary analysis of the creation stories suggests that they come rather late in the history of the development of the Old Testament. But whether or not such analysis is conclusive, it does seem clear, in the apt formulation of Werner Foerster, that

> the primary witness of the Old Testament is [the witness] to the God who is sovereign over history, the God of Abraham, Isaac, and Jacob, the God who led the people of Israel out of Egypt through the Red Sea and the Jordan into the Promised Land, the God who directed the wars of Israel. The sequence in the Old Testament is not from creation to history, but vice versa. Thus it is not: "The Creator (subject) is Jahweh (i.e., the God of Israel)"; but rather "Jahweh (subject) is the Creator."

Therefore, the story or stories of creation in Genesis are not chiefly cosmogony but the preface to the history that begins with the calling of Abraham. Genesis is not world history but the history of the covenant people of God. And as the Book of Exodus is interested in Pharaoh only for his part in the Exodus of Israel and otherwise cares so little about him that the Pharaoh of the Exodus is still difficult to identify historically, so the Book of Genesis is interested in "the heavens and the earth" as the stage for the essentially historical, rather than cosmic, drama it sets out to recount.

The vocabulary of the Bible bears out this literary and theological conclusion. The verb used for "create" in the first verse of the Bible is *bara*. The same verb is used to designate the sovereign action of God in history in other passages of the Pentateuch (e.g., Exod. 34:10, Num. 16:30)—passages which perhaps constitute the earliest instances of *bara* in biblical Hebrew. All instances of the verb support this generalization: *bara* always has God as its subject, never creatures. The same is true in the New Testament of the verb used to translate *bara*, *ktizein*. Sometimes *ktizein* refers to the original constitution of the world; sometimes it refers to an action of God in history, especially to the coming of the Christ as the "new creation." But always it refers to an action whose *ultimate* actor is God, though the action may take place through created agents. Thus the central meaning of the biblical words for "create" is divine activity, regardless of when the "creating" is said to have taken place or how or from what previously existing materials, if any. The most common verb for "create" in the Old Testament is not *bara* at all, but *asah;* and, although it may refer also to what men "make" or "do," it is employed both for God's "making" in the beginning and for his "making" in the processes of history, particularly of Israel's history.

Whatever the Genesis stories mean by "creation," therefore, must be, first, part of what the Bible means by the God of the covenant and, second, part of how the Bible looks at the meaning of the present, empirical world. The "God" who is the subject of the verb "create" is the God of Abraham, Isaac, and Jacob in the Old Testament, the Father of our Lord Jesus Christ in the New. The "world" which is the object of the verb "create" is the world in which Israel lives now as a creature of that God. Creation, therefore, is not principally an account of origins, but of dependence. It is not intended to say primarily how things began, but how they are in relation to God. The most solemn celebration of creation in the Old Testament is not the story in Genesis 1–3, but Psalm 104:

> Thou dost cause the grass to grow for the cattle, and plants for man to cultivate, that he may bring forth food from the earth, and wine to gladden the heart of man, oil to make his face shine, and bread to strengthen man's heart. These all look to thee, to give them their food in due season. When thou givest to them, they gather it up; when thou openest thy hand, they are filled with good things. When thou hidest thy face, they are dismayed; when thou takest away their breath, they die and return to their dust. When thou sendest forth thy Spirit, they are created; and thou renewest the face of the ground.

The Psalmist knows that man must cultivate the earth and squeeze the grape, but he looks with thanksgiving and reverence to the God of the covenant who is at work creating here and now through these very means.

Similar thanksgiving and reverence are the appropriate response to God's creating activity as it extends to man in the here and now. Another Psalm declares (Ps. 139:13 ff.):

> Thou didst form my inward parts, thou didst knit me together in my mother's womb. My frame was not hidden from thee, when I was being made in secret, intricately wrought in the depths of the earth. Thy eyes beheld my unformed substance; in thy book were written, every one of them, the days that were formed for me, when as yet there was none of them.

Obstetrically, the Psalmist was probably not so well informed as we are; but anyone who has passed from adolescence to maturity knows that the acquisition of additional gynecological and obstetrical information does not dispel, but only deepens, the mystery of which the Psalmist is speaking. The issue of obstetrical information should not be permitted to obscure the basic meaning of the Psalm: that the God of the covenant carries out his creating activity through natural means

and that he is no less the God of the covenant, hence no less worthy of reverence, for using such means.

From this insight which Israel had discovered—or, as Israel maintained, had received by divine self-disclosure—into the ways of God in history it necessarily followed that neither nature nor history had ever been without the presence of the divine activity and that therefore God was also the initiator of both nature and human history. Thus it is that the stories of creation take their place in the biblical witness to the ways of God. The sun would not smite by day, nor the moon by night, because the God of the covenant was ultimately trustworthy and had always been so. The story of the creation in six days and the story of Adam and Eve both belong to the history of how God deals with those to whom he has bound himself by a covenant and a law. Hence the origin of the universe and the origin of man are both predicated of the God whom Israel has come to know, through covenant and law, as the God of mercy and of justice. To the New Testament this applies, if anything, with even greater force; for here creation, insofar as it receives any attention at all, is presupposed on the basis of the Old Testament, ascribed to the God and Father of our Lord Jesus Christ, and correlated with redemption. Only seldom in either the Old or the New Testament is the Genesis story referred to as a causal explanation of man's dependence upon his Creator now. More often it is read as an account of what goes on every day.

Because the New Testament presupposed creation on the basis of the Old Testament, there was no controversy about creation so long as Christianity remained part of Judaism. But soon after it ventured forth into the Hellenistic Roman world, it found itself obliged to defend the doctrine of creation. Both the apologetic sermons in the Book of Acts (Acts 14:15; 17:24–28) quote Paul as taking up the defense of creation when he addressed the "cultured despisers" of Christianity. Significantly, in both sermons he is represented as defending the original creation and the continuing creation simultaneously. Justin Martyr, mingling quotations from Plato with the Scriptures, was willing to define creation as the shaping of a matter that was already in existence. Against the enemies of the faith Justin therefore defended the rationality of the notion that God was the Creator in this sense of the word. The earliest-known apology for Christianity, that of Aristides, declared—according to a very late and rather dubious recension of its text—that God is "the one who arranged all things and pervades them [*ton systeesamenon ta panta kai diakratounta*]." This appears to adumbrate the later distinction between the original creation and the continuing preservation of the world. The Syrian Church

Father Tatian, who proved to be a heretic (though on other grounds), wrote that God had first called matter into being and then had fashioned the world from this pre-existent, albeit created, stuff. Other Fathers—for example, Clement of Alexandria—tried various related explanations of the relation between the creating activity of God and matter.

Apparently the first Church Father to assert clearly that creation was *creatio ex nihilo* was Theophilus of Antioch. He writes that "they [the prophets] taught us with one consent that God made all things out of nothing; for nothing was coeval with God: but He being His own place, and wanting nothing, and existing before the ages, willed to make man by whom He might be known; for him, therefore, He prepared the world." Now the doctrine of *creatio ex nihilo* may be implied in the writings of the prophets, as Theophilus claims. But it is taught explicitly in only two places in the Bible, both of them in the New Testament (Rom. 4:17; Heb. 11:3). Neither of these places uses the technical term for "create," *ktizein;* on the other hand, all the instances of *ktizein* appear to ignore the issue of *creatio ex nihilo.* Theophilus finds it a necessary corollary to the biblical understanding of creation and sets it forth as such. He even goes on to say a little later that "matter, from which God made and fashioned the world, was in some manner created, being produced by God." Faced by the doctine of certain Greeks that the world, or perhaps matter, was coeternal with God and that God was therefore dependent upon the world, Theophilus declared *creatio ex nihilo* as proof that the dependency in the relation between God and the world was all in one direction. So began the identification of creation primarily or exclusively with *creatio ex nihilo,* which crowded continuing creation out of the attention of the theologians.

The identification became even more explicit in the man who shaped much of the theological vocabulary of the Latin-speaking Christian West, Tertullian. His *Treatise Against Hermogenes* is a full-scale refutation of the claim that matter existed before creation. Creation must mean *creatio ex nihilo,* even though the creation accounts do not say this in so many words:

> If God could make all things out of nothing, Scripture could quite well omit to add that He had made them out of nothing, but it should have said by all means that He had made them out of matter, if He had done so; for the first possibility would be completely understandable, even if it was not expressly stated, but the second would be doubtful, unless it were stated.

In the argumentation of Theophilus and Tertullian—and later on, as we shall see, in the argumentation of Thomas Aquinas—the polemical

target of the *creatio ex nihilo* was one or another Greek doctrine about the eternity of the world. The implications of this doctrine for the Christian understanding of creation seemed to require the declaration of *creatio ex nihilo*. Thus the Christian war against Greek ideas helped theologians like Tertullian to make the doctrine of creation primarily, though never exclusively, a question of origins.

What helped to save Tertullian from making creation exclusively a question of origins *ex nihilo* was his war against Gnostic ideas, as represented by Marcion. A deep aversion for the created world of matter caused Marcion and the Gnostics to separate God the Creator from God the Redeemer. Marcion taught that these were two separate gods. The Creator, of whom the Old Testament speaks, was inferior to the Father of our Lord Jesus Christ. Tertullian quotes the Marcionites as saying: "Our God, although He did not manifest Himself from the beginning and by means of the creation, has yet revealed Himself in Christ Jesus." Thus Gnosticism taught a radical discontinuity between salvation and creation, including in this latter term the present empirical world of matter. Consistently carried out, such a doctrine of discontinuity would have pushed the idea of creation so far back into history and so far down into matter that the spiritually minded Gnostic would not have to soil himself with creation at all. In their answer to this denigration of creation, Tertullian and the other anti-Gnostic Fathers asserted the identity of the Creator with the Father of Christ. Christ "entered on His ministry with the very attributes of the Creator." Therefore, the God who acts in history is the Creator: this fundamental conviction of Israel's faith found an echo in the church's faith, as patristic theology defended the faith against Gnosticism. Nevertheless, the root meaning of "creation" was now *creatio ex nihilo*.

In the various summaries of the church's faith and of patristic theology, that root meaning took precedence. When the most masterful of these summaries came to be composed in the thirteenth century, Christianity was once more contending with the doctrine of the eternity of the world, revived for it by the skepticism of the Averroists and by the rediscovery of the physical writings of Aristotle. Seeing in Aristotle the most complete documentation of what the unaided human mind was able to discover about God, man, and the world, Thomas Aquinas refused to attempt what some of the Church Fathers had attempted. Instead of trying to prove from reason that the world was a product of divine creation and not coeternal with God, Aquinas declared that this doctrine, like the doctrine of the divine Trinity, was a matter not of reason but of revelation. The dependence of the present empirical world upon God, on the other hand, was part of

the system of motions and causes that underlay his celebrated "five ways"; and thus it belonged to natural theology, not merely to revealed theology. Here once more the polemical situation compelled a theologian to stress original creation more than continuing creation and to make creation chiefly a matter of beginnings rather than of dependence.

So one-sided was this stress than Aquinas found it difficult to apply the word "create" to anything except the original creation at the beginning. He quotes Augustine as saying that "to make concerns what did not exist at all, but to create is to make something by bringing it forth from what was already existing." To this quotation Aquinas opposes the authority of the *Glossa ordinaria,* which comments upon Genesis 1:1 with the definition: "To create is to make something from nothing." Accepting the definition of the *Glossa,* Aquinas concludes: "Augustine uses the term 'creation' in an equivocal sense, according as to be created signifies improvement in things; as when we say that a bishop is created. This is not the way in which we here use the term creation, but in the way already stated," namely, as *creatio ex nihilo.* In the conflict over creation and in the clarification of what creation meant, continuing creation was not at issue, but original creation was. Thus it could be concluded either that continuing creation was dependent for its validation upon the assertion of original creation or that the two were quite separate; whichever of these conclusions was accepted, the connection between the two, which had been characteristic of earlier Christian thought and language, was less prominent than the distinction between them. At the same time, the Thomistic theory of essence and existence provided a framework within which both original creation and continuing creation could be formulated.

Although the Protestant Reformers did not articulate their theories of essence and existence as precisely as Aquinas had, they retained the traditional understanding of creation. Thus, for Luther, God's "resting" on the seventh day meant that "God ceased in such a way that He did not create another heaven and another earth. It does not denote that God gave up preserving and governing the heaven and the earth which had already been created. . . . He has, therefore, ceased to establish; but He has not ceased to govern." In his preaching and in his catechisms Luther spoke about the continuing creation, as did Calvin; but if there is any difference between the Reformers and their scholastic predecessors over the doctrine of creation, it is one only of emphasis, due to the more existentialist cast of Reformation thought. The distinction between creation and preservation, as well as the continuity between them, survived the Reformation and

became a standard part of the vocabulary employed by the codifiers of Reformation thought in the Protestant orthodoxy of the seventeenth century. One of these codifiers, Johann Andreas Quenstedt (1617–85), summarized the continuity thus:

> God preserves all things through a continuation of the action by which He originally produced things. For the preservation of a thing is, strictly speaking, nothing else than the continuing production of it; nor do they [creation and preservation] differ except in their outward designation (*per extrinsecam quandam denominationem*).

It was not, however, through its emphasis upon continuing creation that the Protestant Reformation helped to shape the doctrine of creation, but through its emphasis upon history, specifically through its insistence upon the unrepeatable character of the events in the history of God's dealing with man. The immediate occasion for this insistence was the form which the interpretation of the Mass had sometimes taken in the later Middle Ages. Folk piety said unreflectively—and learned medieval theology said more carefully, though often not very much more carefully—that the sacrifice of Christ on Calvary was repeated every day in the unbloody sacrifice of the Mass. Even after the Council of Trent and the theologians who expounded the decrees of the Council had introduced far greater precision and restraint into Roman Catholic language about the repeated sacrifice, Protestant theology continued to regard such language as a fundamental distortion of the New Testament gospel. Protestant theology, therefore, fastened upon the biblical declarations that what Christ had done was "once and for all" (*ephapax*). Therefore, the sacrifice on Calvary neither could nor should be repeated in the Mass.

For the purposes of this essay the controversy over the "once and for all" is important because of the parallel that could so easily be drawn between redemption and creation. God was always the Redeemer; but he was this on the ground of an unrepeatable historical event, the life, death, and resurrection of Jesus Christ. Since Adam was a type of Christ, as Paul had said in both Romans and I Corinthians, the conclusion was readily available: God was always the Creator; but he was this on the ground of an unrepeatable historical event, the creation of the universe *ex nihilo* at a specific time in the not-too-distant past and the formation of the first human pair from the dust of the earth. *Einmaligkeit,* "unrepeatability," was thus predicated of creation in analogy to redemption. To dispute the historicity of Jesus Christ meant to undermine faith in the unrepeatable redemption of the human race, which had taken place between A.D. 1 and 33. By analogy, to question the historicity of Adam and Eve meant to

subvert the Christian doctrine of the unrepeatable creation of the human race, which had taken place about 4004 B.C.

It is an irony of theological history that the seventeenth century should have been both the period when this notion was developing and the period when science and history were fashioning the weapons for its destruction. The best illustration of this irony was the theological conflict over deism during the seventeenth and eighteenth centuries. Deism carried to its conclusion the definition of creation as the original establishment of the universe *ex nihilo*. It defined God as the First Cause, but it seemed to define the "first" in First Cause chronologically. God was a necessary postulate to explain the origin of things and the enactment of the laws by which things continued to function, but he had no role in history since the creation—or, in any case, a smaller role than traditional supernaturalism assigned to him. Orthodox response to deism was mingled with various shades of orthodox concessions to deism. By defining creation as primarily the doctrine of unrepeatable origins, Protestant theology made the deist attack easier and its own defense more difficult. The theory of "occasionalism," set forth by some Roman Catholics and some Protestants under Cartesian influence, was a noble, but somewhat pathetic, effort to reclaim history as an area for God's intervention. In spite of it, the net result of the controversy over deism was an impairment of the doctrine of creation that rendered it largely incapable of coping with even pre-Darwinian "evolutionism."

This controversy provides the background for the effort of the great Protestant theologian Schleiermacher (1768–1834) to redress the balance between original and continuing creation. In his exposition of Christian doctrine he proposed two theses:

> The original expression of this relation, i.e., that the world exists only in absolute dependence upon God, is divided in Church doctrine into two propositions—that the world was created by God, and that God sustains the world. As the Evangelical [Protestant] Church has adopted both doctrines, but has not in her confessional documents given to either of them any distinctive character, it behoves us so to treat them that, taken together, they will exhaust the meaning of the original expression.

Schleiermacher's treatment of them makes clear that he has at least one eye on the "evolutionism" of his contemporaries, a generation before Darwin's *Origin of Species*. His apologetic concern is to present the Christian faith in a form that will make it palatable to those whose Weltanschauung has been shaped by scientific rather than by biblical cosmologies. The accusations of pantheism and subjectivism that have been directed at Schleiermacher ever since are an indication that nei-

ther his notion of divine immanence in the universe nor his idea of the relation between faith and fact was shared by the main body of Christian theology in the nineteenth century.

The main body of Christian theology in the nineteenth century found itself, on the Roman Catholic side, allied with a philosophy that allowed room for science but not always for new science and, on the Protestant side, tied to an interpretation of the biblical doctrine of creation that ruled out natural processes like evolution as the means of creation. The various theories of British divines recounted by Charles Coulston Gillispie could be duplicated and amplified from a study of Continental theologians, both Roman Catholic and Protestant. All these theories are important for an understanding of the theological defensiveness that we have been analyzing; some of them are important as the immediate sources for the versions of Christian theology that Darwin learned and that Huxley was to discuss in his later years. Because of the controversy over Darwinism, these theories likewise constitute one of the most important chapters in the history of the Christian doctrine of creation and probably the most important chapter in the history of the relations or "warfare" between science and theology. Even the most reactionary theologian today feels obliged to pay serious attention to scientific explanations of the universe and of life, even though he may conclude such attention with the claim that the biblical account of creation gives him all the explanation he wants or needs.

The historian of ideas must always reckon with the possibility that a philosophical or theological formulation has had its day, however glorious that day may have been, and that the time has come to return it to history, to which it now properly belongs. The famous aphorism of Thomas Huxley, "Extinguished theologians lie about the cradle of every science as the strangled snakes beside that of Hercules," exaggerates the valid historical generalization that theological doctrines are born and die. More often, of course, they hibernate, to be awakened by a later thaw in the intellectual and religious climate. Fifty years ago the apocalyptic language of the New Testament seemed to be its more bizarre characteristic, the special province of the grotesque sects along the fringes of the church. Yet that very apocalyptic language, radically reconceived and reinterpreted, moved near to the center of Christian attention on the Continent in the period between the world wars.

Something similar may be happening to the Christian doctrine of creation at the present time, for a variety of reasons both inside and outside theological circles. Not all these reasons are connected with science. The works of Karl Heim and Teilhard de Chardin are perhaps

the most celebrated instances of how theology has responded to recent trends in science and in the philosophy of science; but there are many other illustrations, from quiet corners all over Christendom, that theologians are listening to scientists with seriousness and humility. So serious and humble are they in their dedication to the task of theology that they will not let theologians pose as scientists; so deeply do they believe in the task of science that they will not let scientists pose as theologians. Samuel Wilberforce and Thomas Huxley were not the first, nor yet the last, to confuse these two tasks of the theologian and the scientist. It seems that the climate is changing. What flowers may bloom and what fruits may ripen in the new climate is not for this historian of theology, but for one of his successors, to describe. We may perhaps let Thomas Huxley prescribe our *credo* for us as we work in this climate. At one stage in his intellectual and spiritual evolution, in 1860, one year after *Origin of Species,* he enunciated this *credo:* "Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God."

"AT RANDOM"
A TELEVISION PREVIEW

KUPCINET: Welcome to "At Random," a program dedicated to the lively art of conversation. This is Sol Tax, professor of anthropology at the University of Chicago. Professor Tax is the originator and chairman of the Darwin Centennial Celebration, honoring the hundredth anniversary of the publication of Charles Darwin's *Origin of Species.* It will be held at the University of Chicago starting November 24. This is Sir Charles Darwin, distinguished theoretical physicist, mathematician, and population expert, the grandson and namesake of Charles Darwin. And here is Sir Julian Huxley, the world-famous biologist and former director-general of UNESCO. He is a grandson of Thomas Henry Huxley, the noted nineteenth-century scientist who was one of Darwin's chief supporters during the early years of stormy controversy that surrounded the theory of evolution. This person, of course, is Adlai Stevenson, former governor of the state of Illinois and twice the Democratic party's candidate for the presidency of the United States. Later this evening we shall have Harlow Shapley, professor of astronomy at Harvard University. I am Irv Kupcinet of the *Chicago Sun-Times.*

Now that we are celebrating the centennial of Darwin's *Origin of Species,* I should like to ask Sir Julian what he thinks have been the main contributions of the theory of evolution.

HUXLEY: The first point to make about Darwin's theory is that it is no longer a theory, but a fact. No serious scientist would deny the fact that evolution has occurred, just as he would not deny the fact that the earth goes around the sun. Darwin's great contributions were, first, gathering enormous masses of detailed facts that did not make sense unless evolution had occurred and, second, discovering the principle of natural selection, and so providing a mechanism of evolution that is intelligible on scientific grounds without calling in any external agency.

This abbreviated television broadcast, previewing the coming Darwin Centennial Celebration, was presented on WBBM-TV, CBS, Chicago, on the evening of November 21, 1959.

STEVENSON: Is there no longer any resistance to the theory of evolution?

HUXLEY: Two or three states in your country still forbid the teaching of evolution, and throughout your educational system evolution meets a great deal of tacit resistance, even when its teaching is perfectly legal. Muller, the Nobel Prize-winning geneticist, has written an admirable paper called "One Hundred Years without Darwin Are Enough," in which he points out how absurd it is still to shrink from teaching evolution—the most important scientific development since Newton and, some would say, the most important scientific advance ever made. Indeed, I would turn the argument the other way around and hold that it is essential for evolution to become the central core of any educational system, because it is evolution, in the broad sense, that links inorganic nature with life, and the stars with earth, and matter with mind, and animals with man. Human history is a continuation of biological evolution in a different form.

STEVENSON: Why does Muller say "one hundred years without Darwin"? The theory of evolution has clearly made enormous progress from the time Darwin started, when it was almost universally disputed, until now.

TAX: Muller was writing about our high-school system, where evolution is still taught as a vague theory. What would you think of a schoolteacher who said: "There is a theory that the earth is round, but, on the other hand, it might be flat; and there are two opinions about this"? This, in effect, is what a great many high-school biology teachers say—or, in many schools, find they must say. They call it the *theory* of evolution.

STEVENSON: They are afraid of getting into trouble with the authorities?

TAX: Either that, or they don't know that evolution is a fact. It is hard to say which.

HUXLEY: A bit of both, I suppose.

DARWIN: And then, of course, such attitudes are helped by the fact that every now and then some subtle little point comes up about which there is quite legitimate disagreement among geneticists. Then the antievolutionists seize on this argument and say that even the scientists don't agree.

HUXLEY: But all scientists agree that evolution is a fact. There are two problems involved here: First, whether evolution has happened—and there is absolutely no disagreement among scientists that it has. The second problem is *how* evolution takes place, and here there has been argument, although we have made enormous progress in understanding the process of evolution and the role of natural selection in

it. Natural selection was a deductive theory, and a wonderful stroke of genius. And now natural selection has been analyzed and tested. We have found that it does occur and that it is effective. In certain cases we have even measured the speed at which it operates.

STEVENSON: What was that famous remark of your grandfather's, Sir Julian, after Wilberforce attacked Darwinism so brutally? As I remember, he said he would rather be descended from a monkey than be a man who used great gifts to obscure the truth. I think Wilberforce had asked him whether he was descended from a monkey on his mother's or his father's side.

HUXLEY: It was something like this: "Is it on your grandfather's or your grandmother's side that you trace your descent from an ape?" And then my grandfather was overheard to say, as he slapped his thigh, "The Lord has delivered him into my hands." He had not wanted to speak at the meeting, but after that he felt he had to. And this, so far as I recollect, is what he said: "It seems to me that one has no reason to be ashamed of having an ape for an ancestor. If there were an ancestor whom I should feel shame in recalling, it would rather be a man—a man of restless and versatile intellect—who, not content with success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to their religious prejudice." After that there was nothing left for Wilberforce to say.

STEVENSON: I must say that there is a fairly disturbing note in there about the man with no scientific acquaintance who plunges into scientific questions!

KUPCINET: Some years ago, as a working newspaperman, Governor Stevenson wrote editorials about the Scopes Trial.

STEVENSON: My only possible identification with you distinguished gentlemen. I was on your side at the age of twenty-three, writing editorials denouncing William Jennings Bryan. That was difficult, because in 1900 my grandfather had run for vice-president on the same ticket with Bryan. He always thought Bryan became a little fuzzy as he grew older.

DARWIN: Bryan had a stroke at the trial, didn't he?

HUXLEY: Yes, and the implications of that are very interesting. If Darrow had died of a stroke during the trial, it would have been called an act of God. But nobody has ever said Bryan was killed by divine wrath.

DARWIN: If you or I were struck by lightning now, Julian, it would be a very grim business.

HUXLEY: Yes, indeed. It would go down in history.

STEVENSON: I wonder if there is a parallel between the resistance to teaching about evolution in our schools and the resistance to teaching about Marxism and communism in this country. Until very recently, we practically equated teaching about Marxism (which is absolutely imperative for understanding the Russians) with advocating subversion. I think we are much more enlightened now. I don't know about Great Britain, but certainly we in the United States are now beginning to realize that, to deal with philosophies, you have to understand them. And the more we study Marxism, the better able we are to cope with it.

HUXLEY: Yes. Wouldn't you agree that in the long run we have to think, not in terms of a head-on collision between two entirely irreconcilable systems, but of finding a way to transcend the conflict in a larger synthesis. If you look back historically, in the Middle Ages Islam and Christianity seemed absolutely incompatible.

DARWIN: Or Protestantism and Catholicism during the Reformation.

HUXLEY: But the earlier conflict was even more drastic, because it involved large areas of the world and totally different religions. One can't say that there is complete reconciliation between Islam and Christianity even now, but at any rate the religious difference is not a source of political nor even of violent ideological conflict.

TAX: You achieve coexistence.

HUXLEY: You reach a new pattern of thought that comprehends both systems, up to a certain point. And I think the really evolutionary outlook is able to comprehend many apparently disparate facts and to reconcile many apparently irreconcilably conflicting ideas.

KUPCINET: Is evolution going on today?

HUXLEY: As my old friend Joad would have said, it all depends on what you mean by evolution. Some biologists would restrict the use of the word to living organisms apart from man. But you would agree, Charles, that there has been an evolution of the stars and an evolution of matter. Evolution is a general word, denoting—how would you define it?

DARWIN: Incomplete constancy.

HUXLEY: No—it's much more definite than that. I once tried to define evolution in an over-all way somewhat along these lines: a one-way process, irreversible in time, producing apparent novelties and greater variety, and leading to higher degrees of organization.

DARWIN: What is "higher"?

HUXLEY: More differentiated, more complex, but at the same time more integrated.

DARWIN: But parasites are also produced.

HUXLEY: I mean a higher degree of organization in general, as shown by the upper level attained.

After the general Darwinian theory of the evolution of prehuman life was accepted, there were many poorly thought-out attempts to apply pure Darwinian ideas to human affairs: the struggle for existence, for instance, must be a good thing; therefore, highly competitive economic systems were good, war was good, and so on. At one time, even child labor was justified on such grounds. But the more one looks into it, the clearer it becomes that man does not operate primarily by natural selection, because he has a new method for evolving. Man is able to transmit the results of his experience, his knowledge, his ideas, cumulatively from generation to generation, which no animal can do. So human evolution occurs primarily in the realm of ideas and their results—in what anthropologists call *culture*—with natural selection playing a minor role, so that evolution proceeds much faster and is not always related merely to survival.

KUPCINET: After one hundred years of Darwinism, what future do you see?

HUXLEY: For Darwinism or for man?

STEVENSON: Darwinism is doing better than man.

HUXLEY: Darwinism has come of age, so to speak. We are no longer having to bother about establishing the fact of evolution, and we know that natural selection is the major factor causing evolutionary change. Our problems now concern working out in detail how natural selection operates, defining what we mean by "increase of organization," tracing the general trends that appear in the course of evolution, and so on. Of course, the most striking phenomenon in biological evolution is the emergence of mind out of an apparently mindless universe.

STEVENSON: A mindless universe?

HUXLEY: The emergence of mind from apparently mindless organisms.

STEVENSON: Yes; I understand. Does mind evolve?

HUXLEY: During the two and one-half billion years of life, mind becomes noticeable fairly late, with the appearance of well-developed vertebrates and higher mollusks and insects.

KUPCINET: This is where you and the religionists diverge. Most of them go part of the way with Darwin and agree that perhaps God created man out of a number of animals, but they attribute mind and soul to God alone.

HUXLEY: Darwinism removed the whole idea of God as the creator of organisms from the sphere of rational discussion. Before Darwin, people like Paley with his famous *Evidences* could point to the human

hand or eye and say: "This organ is beautifully adapted; it has obviously been designed for its purpose; design means a designer; and therefore there must have been a supernatural designer." Darwin pointed out that no supernatural designer was needed; since natural selection could account for any known form of life, there was no room for a supernatural agency in its evolution.

KUPCINET: But the churches hold that it was God alone who instilled spirit and soul and mind into man.

HUXLEY: But that, too, is completely contrary to the facts. There was no sudden moment during evolutionary history when "spirit" was instilled into life, any more than there was a single moment when it was instilled into you. I know that certain theological doctrines say it is suddenly pumped into the human embryo at—isn't it the third month?—but that is a completely arbitrary theological postulate. I think we can dismiss entirely all idea of a supernatural overriding mind being responsible for the evolutionary process.

DARWIN: I do, entirely.

HUXLEY: And biologists do, with very few exceptions.

SHAPLEY (*who had just joined the panel*): Julian, earlier this day I gave a talk of fifty minutes on exactly this same subject—science and religion. You spoke of their parting. But there are many kinds of religions. I have had much contact with the liberal clergy of America in the last two or three years; and they accept evolution, without objecting to it or worrying about it. And in that famous address in 1951 the Pope went along with evolution.

HUXLEY: He still said there must be a God who is somehow responsible in some way, didn't he?

SHAPLEY: Well, he didn't deny God, no. And you don't, either.

HUXLEY: I certainly do.

SHAPLEY: Oh, no. If you defined God, you wouldn't.

HUXLEY: Now don't go into semantics.

SHAPLEY: You're not an atheist, Julian; you're an agnostic.

HUXLEY: I am an atheist, in the only correct sense, that I don't believe in the existence of a supernatural being who influences natural events.

TAX: Let's return to this shift from mindless to mind.

HUXLEY: It is a very important point. We only deduce the existence of mind in other persons from their behavior. I don't *know* what you are experiencing; yet I have every reason for thinking that you have a mind and subjective experiences. But it is only through your behavior—what you say, how you gesticulate, and so on. When you get back to the human ovum or early embryo, there is no indication of any effective mindlike quality being present. And just as in the

early stages of the individual human life there is no evidence of mind, so in the evolution of life itself we see no evidences of anything one might call mental properties in organisms less highly organized than insects, octopuses, or fish.

DARWIN: And I should think the ecclesiastics would not accept these as having minds.

TAX: Minds, perhaps, but not souls.

SHAPLEY: Yes, they would; some of them would. I have invitations now to talk at five different theological seminaries—to the faculties, not to the students, whom they still protect. One is Methodist, and one Presbyterian, and one Unitarian, and one is—I don't quite know *what* it is. They want to know what science is saying. And when I get there, they don't say: "We have to draw a line between certain forebears of man, and say, here is where mind came in; and there, soul; and there, spirit." They don't expect that. Where are you going to draw the line, Julian? Does an amoeba have a mind? It chooses between food and non-food.

HUXLEY: That is not choice; we don't know that it chooses, in the proper sense of deciding between alternatives.

SHAPLEY: Well, it gets one and not the other.

HUXLEY: That is another matter.

DARWIN: I should like to bring up another point. We are making calculating machines that are already pretty good at doing the sums we set them. But some persons have been trying to make machines that will learn. A very bright man I once knew wrote an interesting paper about this. He said that if you wish to teach a machine anything, you must have a system of rewards and punishments. If it is a good machine, it is going to be rewarded; and a bad machine is going to be told "Don't do that!" Every time it gives the response you want, it will be more habituated to it; if it gives what you don't want, it will be less habituated. I think that in time—and not so many years hence—we shall have machines that won't need this elaborate complete drill. The time will come when that machine will proceed to take charge and tell us many things we don't know. As I see it, at some time that machine will get up and say: "I am the first creature that has a mind."

HUXLEY: I don't think you can speak of a mind without subjective experience.

DARWIN: But it will say it has subjective experience.

HUXLEY: I doubt it! So far as we know, subjective experience exists only when there is a particular arrangement of sense organs, and these very odd cells called neurons—

DARWIN: Wait a minute. You're talking about the human brain,

which has I don't know how many million cells. The most elaborate machine so far has only about 10,000 cells. By the time we get this number up to a million, won't such a machine be able to do all these things?

HUXLEY: How can it have a subjective experience? It's made of metal instead of protoplasm.

DARWIN: Why shouldn't metal have just as good a subjective experience as carbon hydrides? This same man I mentioned was asked by a journalist, "Could your machine write a poem?" He thought a minute and replied, "Yes, it could write a poem; but I think the kind of poem it could write would be more enjoyed by other machines than by a human being."

HUXLEY: I should like to stress this fundamental point: the real nub of evolution, the aspect which is still the most mysterious, is the fact of subjective experience, which is assuming increasing importance.

TAX: You are much less of a materialist and an atheist than Sir Charles, yet you are the one who was proclaiming his atheism earlier.

HUXLEY: This has nothing to do with atheism.

TAX: If something is unknown and mysterious, it is very easy for people to say it is supernatural—it cannot be explained naturally.

HUXLEY: That is not logical.

DARWIN: I was accusing you of being a solipsist.

HUXLEY: Certainly not! But the point Tax raises is very important, and it comes back to Shapley's earlier statement. At present, the fundamental barrier between most theologians and most scientists is that scientists see no evidence of a supernatural agency interfering with the course of nature, or any need to postulate one.

SHAPLEY: This morning I was talking about religion in an age of science. This religion would suit you very nicely, Julian, because it gets away from superstition and miracles. Science can strengthen religion, and not upset it. There is no need of that. I've learned from anthropologists that every primitive tribe, without exception, has a religion. They thought one group up the Orinoco was without religion, but that has been checked, and it was a misunderstanding. So religious belief is built into us as part of a reaction against mysteries we can't solve easily. To make ourselves comfortable, we turn to miracles and the supernatural.

HUXLEY: Religion need not deal only with mysteries.

SHAPLEY: No; it can be an ethical system.

HUXLEY: It can't be *only* that. I believe that the only way to define religion in general terms is as an organ of man that deals with problems of human destiny and with things and events that are felt (here

is subjective experience again) as in some way *sacred*. Religious ethical systems always have these feelings of sacredness.

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KUPCINET: What about the future of man and the population explosion?

SHAPLEY: This morning I was talking on this general subject of religion and science. I pointed out that the two most serious situations facing us are, first, the hydrogen bomb and its control (either we live with it peacefully, or we don't live at all) and, second, the population explosion.

STEVENSON: I'm glad to hear you say that, because last week I wrote an article for the magazine *Foreign Affairs,* in which I said that in my judgment the two most important problems in the world were, first, nuclear weapons and, second, the disparity in living standards between the rich and poor nations.

SHAPLEY: I don't know who stole the other's ideas, but we agreed, didn't we?

KUPCINET: Governor, what did you say about the population explosion?

STEVENSON: It is not for me to explain the population explosion. It is, however, a political problem for this and other Western countries that, as population explodes, the rich nations are getting richer and the poor are getting poorer. We must find some way of keeping economic growth ahead of population growth. We must provide jobs and employment, because masses of discontented, restless people will turn to severe and authoritarian measures to further their economic development. This problem seems to me equal in importance to that of the existence of nuclear weapons.

KUPCINET: When you visited India recently, I imagine you found a tremendous population problem.

STEVENSON: Yes; but actually the Indian rate of population growth is lower than ours. We always talk about how the growth rate of the more fortunate peoples declines; but the United States has the largest per capita income in the world, and yet our growth rate is now one of the highest. I don't think this is necessarily bad. It depends on the extent of natural resources and the degree of population density.

SHAPLEY: Many areas in India are already highly overpopulated, and their level of living is extremely low. On the whole, it is the countries that are getting poorer that are multiplying faster, and so the disparity increases.

STEVENSON: It has taken about forty to fifty years for any nation

to modernize or industrialize. That was true of the United States, of Britain, Germany, and Japan, and it is true of the Soviet Union. At that rate, India and China will be industrialized at the beginning of the next century. Now the industrialization of populations of that order of magnitude—over a billion people in China by the year 2000—means that the distribution of power and authority in the world is going to shift. The United States has taken for granted for quite a while that we are the center of gravity in world affairs. Now we are sharing this position with the Soviet Union. It will not be long before these new, vast, and overmighty populations emerge industrialized, and then we shall be only one of several centers of world power.

HUXLEY: At the Planned Parenthood International Conference in New Delhi this spring, they were discussing a paper by two American economists—Coale and Hoover—who had been called in to advise India about industrialization. The points they made are somewhat as follows: Industrialization does not happen by itself. A great deal of capital investment is needed, as well as investment of energy and skill and the like. But every million extra people means that some of this capital and skill must go into feeding, housing, servicing, and educating these. After going into the problem quantitatively and very carefully, they emerged with this conclusion: unless India halves its birth rate within about thirty-five years, she will never be able to industrialize. The Indians now realize that their first problem is population control, not industrialization. They will not achieve industrialization unless they cut their population increase.

DARWIN: I think that, in spite of his mind, man is still an animal, and he will obey the rule that no matter how much food is produced, there will be too many people asking for it. Suppose the United States exported its excess of corn to India, let us say; what would be the result? The population of India would jump, and they would still be hungry. We have to attack the other side of the problem of overpopulation, and nobody knows how to do it.

STEVENSON: The old corrective forces of war and pestilence have now been done away with.

DARWIN: Julian and I disagree a great deal about the way population has been increasing in the past, but I think he will agree that there has been a radical change in the last two hundred years—quite a different order of increase. This multiplication began two hundred years ago—or a century ago; I don't care which we say. I maintain that this is because man has solved the problem of natural selection; it does not operate on us any more. The number of people must become constant, since it cannot go on increasing indefinitely. But what

is going to limit it? Either there will be a reversion to the old system of natural selection, or else we shall see this sort of problem: the man down the street has not enough to eat; you have food, but enough for only one person. Are you going to give it to him, and die yourself, or are you going to keep it?

STEVENSON: You don't think productivity will keep pace with increase in population?

DARWIN: It can't.

HUXLEY: I agree with Charles that this idea of a race between production and population is the wrong way to look at the problem. We shall eventually reach some sort of balance; the question is whether it will be a regulated and tolerable balance or an extremely unpleasant one. The only way to tackle the problem constructively is to reduce the rate of reproduction.

Going back to one point, Charles, where I slightly disagree: you said the high rate of multiplication began two hundred years ago. Certainly it did; but since then we have had the extraordinary phenomenon of an accelerated increase. The rate of increase per annum never reached one per cent until the present century; it is 1½ per cent already and still climbing. People just do not realize that when babies born this year are old enough to vote, there will be one billion more people for them to vote about: one billion more by the time they are twenty-one. Absolutely appalling!

STEVENSON: The population of the world is increasing at the rate of 100,000 a day, is it not?

HUXLEY: Oh, much more now. When I first became interested in this problem, I was shocked to find the rate of increase was 76,000 a day. When I had to write about it a few years later and looked into the statistics again, it was 91,000. Now it is about 140,000. That is the net gain every twenty-four hours.

DARWIN: Since we entered this room, six or seven thousand more people have been born.

KUPCINET: Well, our audience is increasing.

STEVENSON: We'd better get out of here in a hurry!

HUXLEY: By the year 2000, the net increase will be half a billion a year.

SHAPLEY: It begins to look as if the human race is one of the worst things that has happened to the earth.

HUXLEY: Either we are going to control the population explosion, or we shall become the cancer of the whole planet. If we are not careful, we shall be back with famine and starvation and all the rest of it.

KUPCINET: What are your suggestions for control?

HUXLEY: First, we need a cheap, simple, oral contraceptive, and then we have to persuade people to take it. In Japan, for instance, they did not have to be forced to use contraception; in fact, they were quite easily persuaded to practice abortion. You can have various degrees of persuasion—economic influence, for instance. Already in India, in Madras State, they pay men fifteen rupees each time they are sterilized—well, I shouldn't say "each time," since you can have it done only once! Of course, this is under certain safeguards, and they must have had four children already.

DARWIN: But we have to face the appalling difficulties involved. If the Chinese, or any other people, are really ready to tolerate a lower standard of living than we are and if both know how to control our populations (which we don't yet), what is the consequence? In a hundred years there will be three times as many Chinese as now. Any group that believes in not limiting its population automatically scores.

HUXLEY: We shall have to establish an international, global policy.

DARWIN: Under whose control?

HUXLEY: Some central organization; not the United Nations in its present form, because it has no mechanism for dealing practically with the population problem.

DARWIN: World government is the obvious answer. But now supposing a world government limits population, but one part of the world says: We don't like your limitations. We are going to have more children because we are more important than anyone else, and you can't have too many pigmies in Central Africa—or whatever race it may be. What is the world government going to do—kill them?

HUXLEY: That is a highly hypothetical situation.

STEVENSON: You said that unless societies like China and India arrest their population growth, their prospects for industrialization are limited. Do I conclude that you would not make an all-out effort to improve their economic growth now?

DARWIN: If you put *all* your effort into this, you would be fighting what is definitely guaranteed to be a losing battle.

STEVENSON: I think two subjects have become a little confused here. I was saying a moment ago that to me the two most important facts in the world today are, on the one hand, the existence of nuclear weapons and, on the other hand, the disparity of living standards among nations; that we shall have to control the nuclear weapons and eliminate them before they eliminate us; and that we must improve the standard of living in those countries that are getting poorer while we are growing richer. Otherwise the political situation will be more unstable, and the consequences are inevitable. Then these gentlemen said that the real problem, of course, is the bursting pop-

ulation, which is what Dr. Shapley had said. Well, we shall have to deal with them both. But we certainly can't suspend our efforts to improve the economic lot of the underdeveloped countries while we wait for them to arrest their exploding populations.

HUXLEY: Governor Stevenson says we must aid other countries to raise their standards of living; I entirely agree. But the key word here is *aid*. Eventually we shall have to combine all the different forms of aid—bilateral, multilateral, and international—and link these up with population control. Coale and Hoover, for instance, make it quite clear that if India's population goes on increasing as fast as it is now, all the money being poured into India, far from helping her to industrialize, it will lead to a point of no return, with fewer jobs and more people living at lower standards. We must evaluate population problems and tie in the remedies with aid. One of the conditions of aid would be that they should have a program, as India and Japan and a few other countries have, of trying to reduce the rapidity of increase. I think this is perfectly legitimate. If a country asks for financial or technical aid and investigation shows that the rate of population growth is so great that all the aid will go down the drain unless the growth is checked, then I think there is every right to say: "You won't get aid unless you put some of it into trying to check your rate of increase." That, I think, is what will happen within twenty-five years.

STEVENSON: You would make reducing the rapidity of increase a condition of giving them aid?

HUXLEY: Some of the aid would be given them in the form of technical assistance, free contraceptives, or expert advice. I don't think that is compulsion.

DARWIN: I wish I could hear an economist discuss this endless talking of industrialization of all these other countries. By the time we have done it, won't we be reduced to starvation ourselves, because half our life depends on export?

STEVENSON: As the world's economy has improved, the economy of every nation is improving, too. The best markets are always the most highly industrialized and most highly developed areas.

KUPCINET: We have been talking about the underdeveloped countries. What about the United States and England? Are we faced with any serious population problems?

HUXLEY: We are faced with the problem of pressure on mere space in Britain. We live on a small island, much of which is uninhabitable and unsuited for agriculture. Communications, house-building, industrial developments, national parks, recreation, and military establishments are all competing for space and the results are becoming

increasingly alarming. We established national parks only ten years ago, and now already three of them have been invaded by industry or atomic energy plants.

KUPCINET: Perhaps we should move to some other planet.

SHAPLEY: Mars is no good, and Venus is probably no good. And planets around other stars are too far away, so I don't think there is any solution to the population problem through astronomical migration.

HUXLEY: Even if Mars were inhabitable, think of shipping off 140,000 people every twenty-four hours, non-return!

KUPCINET: Governor, you made a very important point before, which we rather glossed over. You pointed out that overpopulation can lead to authoritarianism—a communistic or some other kind of totalitarian state—when people are looking for a quick answer to the problem.

STEVENSON: I think that it is now happily becoming generally accepted in the West and in this country—I myself have talked about it for a long time—that this is really a great danger to our country. A fact of greater importance to the Western democracies than the military might of the Soviet Union has been, as I see it, the desire for economic development of the emerging countries. These nations, one by one, are going to try desperately to improve their standards of living. They have reached the conclusion that disease, misery, and poverty are not the immutable destiny of man; they, too, can share the good things of this extraordinary century. So they are going to evolve and develop economically one way or another. We must offer them an alternative to the Communist method of forced labor, forced savings, and economic development, which has great appeal for them because they have the example of the speed with which the Communist states have developed in these last forty years—for example, the Soviet Union—whereas our societies are older and we also bear the burden of colonialism. We have handicaps. Therefore, we must get at this task in concert with our friends and co-ordinate our plans to make the maximum use of the resources we have; and we have enormous resources to bring to bear on this problem of economic development. But this does not answer the population problem; in fact, it may aggravate it.

DARWIN: I should like your opinion as an experienced political figure. It seems to me that by the time your country has twice its present population, the degree of liberty must be lower. You must have more laws to control twice as many people.

STEVENSON: I suppose that is inevitable.

DARWIN: And isn't that really the point of what you are saying about the communistic systems? I fear—and it is a very great fear—

that this country will gradually lose its liberties as its population increases, like all other countries.

STEVENSON: If you say that as population multiplies, the complexity of society increases and therefore the number of rules needed to regulate modern society, I think that is true. But I do not think that this in necessarily a fatal impairment of liberty in the sense of the individual's right to participate in the choice of his government, which is basic.

HUXLEY: That is only one kind of liberty; there is the liberty to park your car, for instance, and the liberty to buy what you fancy. As things get really tight, you will have to curtail that liberty and have rationing again.

DARWIN: I see no escape from it myself. If I may go back about three hundred years, to what I consider the normal condition of mankind when natural selection was, on the whole, holding population nearly constant, in the literature of those times—in Chaucer or Shakespeare, for instance—there is just as much cheerfulness, or even more, than there is now. I believe people in the future will be just as happy, but their happiness will be felt when they feel a little bit safer—something that we take for granted. People in the future would love to have lived now; they will think how happy we must have been.

STEVENSON: My impression is that the Black Plague swept London in the sixteenth century, just over three hundred years ago. I don't believe we want that again.

DARWIN: No, we don't. But I should think people at that time were made happy by much slighter things than we are now; and I believe that happiness is quite a separate thing from prosperity.

STEVENSON: I had not attempted to equate happiness and prosperity; on the contrary, this would be a contradiction of most Christian teaching.

HUXLEY: But isn't that a commonplace of much business thought in this country?

STEVENSON: Yes, unhappily. That is one of our limitations. We are all familiar with day-to-day reporting in the press and the emphasis it puts on the very things we have been talking about here: the complacency in this country, the euphoria, the sense of satisfaction, the preoccupation with getting rather than giving; the idea of "two Cadillacs in every pot and two chickens in every garage." We have a long way to go to restore a sense of purpose consistent with our own traditions and ideals and also with the realities of the world in which we live. We have lived a great deal of mythology, for a long time.

KUPCINET: You blame our communications: press, radio, television?

STEVENSON: They have contributed to it. They have a great re-

sponsibility for correcting all the unrealities in which we live—the mythology, from which I am afraid we have suffered, about the true plight of the world, the very sort of thing we have been talking about here; about the position of this country and the steps it must take to regain its position.

KUPCINET: You think our country might be declining, after our star has been in the ascendancy for a long time.

STEVENSON: The center of gravity in the world has been moving from east to west for a long time. In this century, it suddenly jumped over the Atlantic to this country. Now it is suddenly arrested, and two centers of gravity emerge, Washington and Moscow or, if you prefer, this country and Russia. But I think our day at the center of the stage is going to be brief and that new centers are going to emerge, largely in Asia. I don't know whether countries like China and India will be able to modernize and become centers of power, if population outruns economic growth. But certainly the early assumption that the United States is going to be the dominant influence in the world is something we have to re-examine pretty carefully.

DARWIN: Just like the British in the mid-nineteenth century.

HUXLEY: Which we now know wasn't so.

STEVENSON: I don't think there is going to be any "American Century"; I think more humility is perhaps indicated for this country.

HUXLEY: Humility and a global sense. In the long run, we shall not really get anywhere unless we replace the idea that happiness comes from increased quantity of things—two television sets, for instance—with the idea that it comes from increase in living, however you define that.

TAX: But in much of the world, happiness is correlated, not with material things, but in some degree with having enough to eat; and most people do not have that. A very small part of the world has a problem of too many things.

HUXLEY: But I am talking of the long run. Governor Stevenson said we have to compete with the Soviet Union; we have to compete not only in various economic matters but also in giving a goal, an aim, for living.

STEVENSON: All the reasons why Moscow is a dull city and New York is exciting and interesting.

HUXLEY: The official Russian doctrine, which they are often able to put across, is that in the inevitability of history the whole world is going to go socialist; but the West has no comparable vision of the future.

STEVENSON: We must recapture a similar sense of purpose, and we must dedicate ourselves with the same determination as the Russians.

HUXLEY: But not to the same goal.

STEVENSON: To the objectives that are purposeful for us.

DARWIN: I should have thought you would say liberty is our goal.

STEVENSON: I was going to say that the Communist system is the antithesis of what most of those peoples who are now emerging from long oppression into independence want.

HUXLEY: But so long as they do not have enough to eat, they won't mind about liberty.

STEVENSON: Certainly.

HUXLEY: Liberty, again, is only the foundation; it is freedom to do certain things.

DARWIN: An old friend of mine once said liberty is the privilege to be selfish.

SHAPLEY: The discussion here is very anthropocentric. All this time we have been talking in terms of man about man. To be sure, he is in a mess, and it is a problem for us. But think what a mighty universe this is and what a small part man plays in the whole.

We should remember that in this city a few years ago Harold Urey and Stanley Miller carried out an experiment that assures us of what we had rather suspected for a long time: that one can bridge the gap between the inanimate and the animate and that the appearance of life is essentially an automatic biochemical development that comes along naturally when physical conditions are right. And physics is about the same throughout the universe we know; certainly chemistry is; we can test that. And when physics and chemistry and the climate are right, I think the appearance of life is inevitable.

But now what would it evolve into? I think we fool ourselves in thinking that we are important in the universe. Our sense organs are not so good as those of a good many other animals here on earth. We have a pretty good mind, a pretty good forebrain. But on all these millions and probably millions of millions of suitable planets with the right chemistry, climatology, and all, there must have been other experiments with life. Our sun is an average star, off at the edge of one galaxy. Why should you expect that the only place where there can be high nervous reactions is on this planet, on number three, circling a run-of-the-mill star?

I do not believe that man is duplicated anywhere, for there are a million variations on the animal theme on this planet. But there is no reason to think that there have not been highly sentient developments on other planets. They have had the same length of time, the same sort of experience, some of them; so I think we are a little vain or anthropocentric if we consider ourselves the center of life and the highest beings in the universe.

Coming back to one of your earlier themes, I think we have to admit that the price of social organization is a loss of certain freedoms. The more our society develops, the more some of our liberties will be questioned. We won't let you park your car in the wrong zone, for instance. But I think we are happy to give up some of our liberties for the privilege of being civilized.

HUXLEY: I don't see much consolation in thinking that there are highly sentient beings elsewhere in the universe, when we are in a mess.

SHAPLEY: But why seek consolation, Julian?

HUXLEY: Wasn't that what you were doing?

SHAPLEY: Let's seek adjustment.

HUXLEY: It is very nice to think they are there, but what have they to do with us? They do not help us out of our present mess.

KUPCINET: Would you mind giving your ideas about the existence of life in the universe in more detail, Dr. Shapley?

SHAPLEY: Life, of course, is a natural thing. We can evolve it, and during the coming week we shall hear about evolving it in test tubes. What I should like to emphasize is that there are so very many chances throughout the universe for the conditions leading to life. Within a few hundred light-years of earth there are at least 20,000 stars just like our sun. They have been through the same experience. To deny them this high privilege of having philosophers talking about the universe is not fair.

HUXLEY: Unfair to stars?

KUPCINET: But what form of life would you say exists there? You said that there probably would not be man.

SHAPLEY: Well, high sentient beings. This so-called mental disease, this neurotic complex we call "intelligence," is a pretty common quality. It is not confined to man but goes down through the whole animal world. But the point I want to make is this: There are at least 10^{20} stars within the distance we can reach with our telescopes. That means one hundred thousand million billion stars. At one time, in the past, matter was crowded together, and there was a chance for a great many collisions and planet-forming operations. I do not see why we, who live out on the edge of this galaxy, should think our planet the only blessed place. Now that certainly is relevant to philosophy, and it does and can bear on religion. That is why, when I go around to the colleges, I am always asked to talk about religion in an age of science. And the response I get is very moving. You see, there was a time when we might say we swore by a one-planet god, or deity, or something of that kind. That's over! We have to realize that this is an enormous universe, and it should be a pleasure to be

in such a big operation. Fancy the myopic predictions and concepts of the ancient Church Fathers compared with what we can get now from the laboratories or from the philosophers who are following them.

HUXLEY: The population experts are not very hopeful.

SHAPLEY: Again you are being anthropocentric.

HUXLEY: I should hope so! After all, we are *anthropos*.

STEVENSON: Really, the greatest problem we have to face is the fact that, for the first time in all human history, we have split the atom and released forces of nature that have not heretofore existed. We have, in a sense, become master of the elements, while at the same time we have been unable to master ourselves. That is how far science has outrun politics. Our major failure is our inability to keep pace with the ordering of man's affairs, with his intellectual triumphs. Isn't population just one aspect of this?

HUXLEY: You can look at it in an even more general way. Physics, which is, after all, the most mathematical of the sciences, is also the simplest. Chemistry is more complicated; biology still more so, but we are making progress. Psychology and sociology are still worse. But there has been enormous progress made in this hundred years of biology. They are now showing what the first beginning of life was like, and I am sure that we shall create life in the test tube before the century is out. And, after all, Charles, your grandfather was the first person to start a comparative science of psychology, with his great book on *The Expression of the Emotions in Man and Animals;* and then the Freudians and the ethologists took it a little further. We are beginning to know something about it, but we are still very young. This is what we forget: man is just at the beginning of his evolutionary career.

SHAPLEY: And why are we so far along in our scientific career?

HUXLEY: Physics is easier than biology, and biology is easier—less complicated—than human affairs.

DARWIN: But it does come back to the question, Can we master ourselves? That is the central problem.

HUXLEY: In the long run, as Muller said, we have to master our own genetics.

KUPCINET: What about Muller's theory of freezing the reproductive cells of persons of superintellect and implanting them by artificial insemination at a later date?

HUXLEY: That is not his theory, only his suggested method.

KUPCINET: Can it be done?

HUXLEY: It is being done with animals, of course; and if it can be done with animals, it can be used with man.

KUPCINET: But is it practical?

STEVENSON: I'm not going to run for any office on that platform.

DARWIN: I should put it this way: Do you see yourself as really happy when you know that your wife has had a child by Isaac Newton?

HUXLEY: I can imagine some persons being quite proud.

KUPCINET: Didn't Plato recommend a similar thing?

DARWIN: He did, rather, didn't he?

HUXLEY: It *is* practical. Muller's central point, though, is that if we don't do something about controlling our genetic inheritance, we are going to degenerate. Without selection, bad mutations inevitably tend to accumulate; in the long run, perhaps 5,000 to 10,000 years from now, we shall certainly have to do something about it.

STEVENSON: Is it certain that as the quantity of people increases, their quality necessarily decreases?

HUXLEY: Oh, no. The point is that, in earlier centuries, natural selection wiped out bad mutations. A man with a very serious eye defect—or whatever it might be—simply would not live to maturity. But we correct these conditions with spectacles and other artificial aids. For instance, we keep alive people with hemophilia who would undoubtedly have died otherwise. Most mutations are deleterious, but now we keep many of them going that would otherwise have died out. If this continues indefinitely—and that is the whole point of Darwin and his revolution in thought, that time is of the essence in evolution—then the whole genetic capacity of man will be much weakened.

DARWIN: Muller's plan implies that the masters of the world will be Muller and his fellow geneticists, whereas I know, and you know, that it will have to be the politicians. Can we educate politicians?

STEVENSON: Now you are asking too much.

KUPCINET: We have running around the country a whole flock of presidential candidates who say that they are not candidates; naturally, everybody knows they are. There is a measure of deceit—

STEVENSON: —and strategy—

KUPCINET: —in this, which I think we ought to attack someday. But what advice would you give them, Governor, if you were asked?

STEVENSON: I should advise them to sit down with some of the world's greatest scientists, like this, and they will realize how important science is.

SHAPLEY: Or maybe they will become so pessimistic about it all that they will just withdraw from politics.

STEVENSON: I must say that, after talking here this afternoon, I was never quite so content to be growing older.

KUPCINET: Well, Governor, you set a new record in speaking sense to the public. I suppose you go along with the theory that all political candidates should talk sense; is that possible?

STEVENSON: It will be possible only when the kings are philosophers and the philosophers are kings. That is a long way off. Certainly it should be the ambition of our politicians and the standard that we demand from them; but, until we do so, I do not think we are going to get much better politicians.

DARWIN: What is the definition of sense? I should think the fundamental definition of sense is agreeing with *me*.

HUXLEY: Or with the facts of nature?

* * *

KUPCINET: Governor Stevenson has to leave now for another engagement; but, before he goes, I should like to ask him this question: Thanksgiving Day is just around the corner; and what are some of the things we have to be thankful for?

STEVENSON: I have a great deal to be thankful for: my health, my children, my grandchildren, my friends. And I suppose that as a nation we can be thankful that we are alive. Perhaps this is the most formidable problem we shall have to contend with for a long time yet. It reminds me of a remark I heard the other day: A little girl, asked by her aunt, "What do you want to be when you grow up, dear?" replied, "Alive."

SHAPLEY: And you are thankful you have work to do.

DARWIN: And that you are contributing to the population problem —you referred to your grandchildren.

KUPCINET: And isn't it every man's ambition to leave the world a little better than he found it? Whether we do so, of course, is problematical.

SHAPLEY: It should be better; that is in the evolutionary picture— improving conditions, advancing to further development, subscribing to the growth motif in the whole universe.

* * *

KUPCINET: Professor Tax is largely responsible for assembling all these noteworthy people here for the Darwin Centennial. How did you get the idea, and how did you put this thing into operation?

TAX: About four years ago I happened to be in New York at a conference where they were discussing evolution and physical anthropology; and the date of the *Origin of Species* came up. I thought, somebody should celebrate the centennial of the *Origin*. I came back to the University of Chicago and discussed this with the Chancellor and

various other people, who thought it might be a good idea. But they suggested that we should be cautious, since we had no way of knowing that there would not be other centennials around the world. I did the wise thing and wrote to Sir Charles Darwin and Sir Julian Huxley, asking if they would come to a centennial celebration at the University of Chicago in 1959. I thought their answer might very well be that they would be tied up celebrating the centennial in England. Instead, they wrote that they would be glad to come; so we saw that nobody else had preceded us in thinking about this and that we were not stepping on anyone's toes.

HUXLEY: There was a centennial celebration in England in 1958—the centennial of the Darwin-Wallace paper at the Linnaean Society, in which the idea of evolution by natural selection was first made public.

TAX: From that time, we have been working for four years. We had a committee to choose a theme and select participants, and we finally decided that we should try to find out what is now known, after one hundred years, in various fields of knowledge that impinge on evolution or have been influenced by Darwinian theory. So we brought together scientists all the way from astronomy to biology and anthropology and psychiatry to talk about the evolution of life itself, the origin and evolution of life, and the evolution of man and the mind—themes that in some degree were in Darwin's mind one hundred years ago.

HUXLEY: I was very much honored to receive an invitation to come here for three months with the title of Visiting Professor—but really professing nothing, except helping so far as I can with the business of this Centennial. I am sure that it is going to be very important. To me its most interesting feature is that a great many persons concerned with the sciences of man—anthropology, archeology, psychology—are going to discuss problems with persons concerned with the biological, and some indeed with the physical and astronomical, sciences. There has been too much cleavage between anthropologists—in the broad sense—and biologists. This Celebration should be very fruitful in bridging this gap.

DARWIN: I learned a very interesting thing at the Linnaean celebration last year. The joint paper by my grandfather and Wallace was printed by the Linnaean Society in July of 1858. Only two notices were taken of it. One was by the president of the Society, who at Christmas reviewed the activities of the past year; and he said that they had had a grand year with a great deal of success, but unmarked by any conspicuous events whatsoever. And the other, I think, was a professor at Dublin, who wrote a short paper saying that half the

things Darwin and Wallace said were familiar and the other half wrong.

HUXLEY: The theory of evolution was in the air, however. Asa Gray had got halfway; Lyell, a third of the way. It would have been formulated well before the end of the century, even if Darwin had died. But it would not have happened in the same decisive way. Darwin not only had this brilliant inspiration of natural selection but also collected a great volume of facts to buttress the idea of transformation—which was what evolution was then generally called. And he did what Wallace did not even try to do until much later: he deduced many consequences from the principle of natural selection, which you can still read with profit today. For instance, it is amazing to find in the *Origin* the idea of what we call biological advance or improvement in organization and the idea of branching, or divergence, both of them well documented and clearly explained.

It is very interesting that Darwin was so hesitant to publish his theory for all sorts of psychological and scientific reasons. Actually, I think it was a good thing he timed it as he did; if he had delayed much longer, it might have become stale, and if he had put it out quickly, as Wallace put out his material, it would have been premature and would not have come out in such a convincing way, and we today would not have been anywhere near so far advanced. Look what Darwin did with the whole idea of sexual selection and variation under domestication.

DARWIN: But the majority of the scientists took twenty years after the book appeared before they accepted evolution. Julian's grandfather accepted it at once, but a great many people did not.

HUXLEY: Yes, of course; but the people who mattered did accept it immediately.

DARWIN: I have an enormous admiration for Julian's grandfather. I remember once he was defending the evolutionary theory against a man who was a good scientist but insisted that a species was a species. And Huxley took what I regard as the absolutely perfect example. He said, "Do you really believe that at one moment all the molecules jump together suddenly somewhere in space to create a perfect full-grown rhinoceros?" I think his choice of rhinoceros was perfect; an elephant would not have been nearly as good.

TAX: I think it is important to say—as some things Sir Julian has said imply—that the *Origin of Species* and all of Darwin's works are not being celebrated as something in the past. They are books that still need to be studied, in spite of one hundred years. You cannot say that about many scientific books.

HUXLEY: Not all Darwin's books can still be studied with profit,

of course. *Animals and Plants under Domestication,* for instance, is useful only for historical reasons; but the *Expression of the Emotions* and the *Origin* and much of the *Descent of Man* are still very well worth reading.

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KUPCINET: Before we conclude this program, what hope do you see for mankind? Are we going to regress or progress?

HUXLEY: The three big problems are preventing our civilization's being wiped out by atomic warfare; preventing overpopulation from engulfing the world; and bringing the underprivileged nations up to an improved standard of living. I think that, if we really try, we can deal with all of these reasonably well. Of course, we shall never succeed 100 per cent; evolution never does. All the results of evolution are compromises.

SHAPLEY: You sound like an optimist.

HUXLEY: Well, I am; though I'm a tempered optimist. Charles is the pessimist.

DARWIN: I am afraid my outlook is that we have to let the future happen.

HUXLEY: But can we do nothing to alter it?

DARWIN: I do not think man will master himself, nor do I think we shall develop a world government. There not being enough to eat is what worries me.

KUPCINET: It boils down in your estimation to enough to eat?

DARWIN: Finally, yes. Don't you think so?

KUPCINET: I agree with you, but I am a little more hopeful that we can master such a basic problem.

DARWIN: I contend that whenever we have more to eat, we shall have too many people asking for it. Remember, half the world does not have enough to eat now.

HUXLEY: So we must reduce the number of people.

KUPCINET: Do you see any hopeful signs that birth control will eventually take hold?

HUXLEY: In the last few weeks, two official groups—the Draper Committee and the Senate Foreign Relations Committee—have reported that the United States should take population increase into consideration when granting foreign aid. Even *Life* magazine came out with a spread on birth control in a recent issue, and two major networks have had programs about overpopulation. All this happened in six weeks.

DARWIN: Most encouraging.

KUPCINET: What about the worlds outside this planet?

SHAPLEY: They will get along all right. Even eliminating this planet is not going to affect other planets in this system appreciably, and certainly not the rest of the universe. But the earth will go on, as it has for the several thousand million years before man began messing up this particular planetary surface. And man will not escape this surface; he may pepper the moon, here and there, with rockets, but he can do nothing serious.

DARWIN: I don't think we should ever say with real confidence that we could not throw the solar system into a new star—a supernova.

SHAPLEY: Even a supernova popping up here would die off soon.

DARWIN: We don't know enough yet, but—

SHAPLEY: But if we try, we may learn how to blow up the whole earth.

DARWIN: That would solve our population problem.

SHAPLEY: Seriously, it seems to me that our problem is to try to be rational; to use reason—

HUXLEY: —and a little imagination.

SHAPLEY: It will take imagination and opportunity and freedom from too much fussing around with diplomacy. Man's worst enemy is man; that has been recognized for a long time. So if you get rid of man, man will have no enemies. One of the best things to be said for this planet is that it is a wonderful place on which to set up laboratories and mount telescopes to study the rest of the universe.

HUXLEY: Make the world safe for astronomy!

SOL TAX

INTRODUCTION TO THE PANEL DISCUSSIONS

This evening I shall inaugurate the Centennial Celebration as a whole. Now I introduce only the series of panel discussions on issues in evolution, which is the heart of the Darwin Celebration.

Charles Darwin's book, *Origin of Species,* published one hundred years ago today, did two different things. First, it presented the rich wealth of empirical evidence needed to convince reasonable men that the variety of forms of plant and animal life, including man, owed their similarities and differences to natural causes; all of living nature is part of an ongoing process of evolution. Second, the book presented particular theories of the mechanisms through which evolution operates, particularly the mechanism of natural selection, or the survival of the fittest. Note, indeed, that the full title was *On the Origin of Species by Means of Natural Selection.* The book would not have been convincing without both.

If God did not in six days, six thousand years ago, create the different species we see about us, how did this wonderful variety come about? If all plants and animals, including man, are part of a single system, how did they arise one from another—difference out of sameness? Roses beget roses; termites beget termites; men beget men. Common sense sees this continuity, yet denies the relationship. It requires great imagination, as well as logic and evidence, to see that roses, termites, and men are cousins. It requires a change in habits of thought from seeing things as fixed and static to seeing things as always changing. Europe in the mid-nineteenth century was doubtless ready for a revolution in human thought. Darwin's book provided at once the call to arms and a full arsenal to bring it off—an arsenal of concepts and of facts impossible to explain away.

This week at the University of Chicago we are not examining the notion of evolution itself, which all of us now take for granted as much as we do the fact that the earth is a sphere revolving around the sun. We are looking at the particulars. After one hundred years of Darwinian theory, where do we stand?

Each of forty-five specialists has, in the past three years, reviewed

his special knowledge and reconsidered it from this point of view. We have exchanged our papers, read, learned, criticized, and revised. Meanwhile, our committee in Chicago was reading the papers. Almost a year ago it became empirically evident that we could deal with questions of evolution under five headings: "The Origin of Life," "The Evolution of Life," "Man as an Organism," "The Evolution of Mind," and "Social and Cultural Evolution." By correspondence, the issues so classified began to take form. This autumn at the University of Chicago some thirty faculty members and fifty selected graduate students from twenty different departments volunteered to study the papers and to think and talk through the issues in the study of evolution, as seen under these five headings. By the time we all gathered on Sunday, November 22, we had working documents at hand, and it was possible to agree on the agenda for discussion. All told, there are some fifty major questions for discussion, which in the coming five days will fill in our picture.

Charles Darwin broke through a tremendous fog and, one hundred years ago this very day, gave us a new understanding and perspective, on the basis of which we have done a hundred years of fruitful research. The tremendous knowledge gained in these hundred years of science we hope this week to summarize and synthesize. But more than that, I at least have some hope, or fond illusion, that on this occasion and in this hall we can take a new, great step forward, to begin a second century of understanding ourselves and our cosmos that will do justice to our heritage and give hope for our future.

Without further ado, I think we should turn to the first of these panel discussions and give our fellow scientists every opportunity for discussion of the first topic, "The Origin of Life."

PANEL ONE
THE ORIGIN OF LIFE

Chairmen: Harlow Shapley and Hans Gaffron
Panelists: Sir Charles Darwin; Theodosius Dobzhansky; Earl A. Evans, Jr.; G. F. Gause; Ralph W. Gerard; Hermann J. Muller; C. Ladd Prosser

TOPICS FOR DISCUSSION

1. The scientist's approach to the question of the origin of life is not in need of an exhaustive definition of what life is. We must attack from the naturalistic point of view, namely, that principles unknown or unknowable to science cannot be used to solve the problem. In other words, we proceed under the assumption that life is a process that escapes at present our complete understanding only for reasons of its complexity.
2. Darwinian evolution is now considered a fact and is the basis of modern biology. On the other hand, any answer to the question of what happened before Darwinian evolution began is largely speculation. No existing and recognized forms of life are primitive enough to be considered related to any primordial organism or the first living cell. The viruses, which are not cells but are apparently related to the most important constituents of living cells, namely, the genes, exhibit attributes of living things only as long as they interact with the structure of a living cell.
3. The now dominant idea that living things originated from non-living matter is a consequence of our knowledge of the earlier and later phases of the natural history of the earth—the former as concerned with cosmological inorganic evolution, and the latter with what happened, once life had appeared on earth. The assumption that life originated from non-living matter must be made by the modern scientist if he believes that the question "What is life?" belongs in the natural sciences at all.
4. Therefore, the origin of life presupposes, first of all, the natural ac-

cumulation of suitable raw materials. Astronomy and chemical geology provide methods for solving this question. Further presupposed is a gradual evolution of increasingly complex organic systems from the raw materials until a self-contained unit appears which we would be willing to recognize as a living thing. To attack this problem from the side of living things, microbiology, biochemistry, and genetics provide the tools.

5. Proceeding from this basis, we may subdivide the problem into technical questions that are amenable to straightforward scientific research. For instance:
   A. Did the early conditions on earth favor the accumulation of organic substances? What were these conditions?
   B. Were the first organic compounds of such kind that they could be readily transformed into parts of living things?
   C. At what stage in this development could one assume a complexity that guaranteed self-replication?
   D. What principles govern self-replicating macromolecules?
   E. How does the structure of nucleic acid specify biological properties?
   F. Are enzymes needed for the production of nucleic acids, which are, in turn, needed for the production of the enzymes?
   G. Modern life on earth is extremely uniform in its basic metabolic reactions. How is this to be explained? Is it to be interpreted as a unique (highly improbable) event, or the result of numerous chance combinations followed by selection?
   H. Can life originate under present conditions on earth?
   I. What were the energy sources allowing for a continuous increase in complexity of pre-biological organic systems?
   J. When and how did the change from anaerobic to aerobic conditions occur?
6. What is the probability of life on other planets?
7. What are the possibilities of transport of germs through space?

THE DISCUSSION

SHAPLEY: The Committee, the origin of which is, I suppose, a late phenomenon in the course of evolution, has properly noted that an examination of origin should precede examination of evolution and has assigned us the subject of the origin of life. Once we have taken care of that phenomenon and are convinced that life actually has originated and after we have discussed a bit that interesting activity, other panels will take care of, first, the evolution of life; second, man

as an organism; third, the evolution of mind; and, finally, social and cultural evolution.

SHAPLEY: Let us begin by reading the first item on this afternoon's agenda:

> The scientist's approach to the origin of life is not in need of an exhaustive definition of what life is. We must attack from the naturalistic point of view, namely, that principles unknown or unknowable to science cannot be used to solve the problem. In other words, we proceed under the assumption that life is a process that escapes at present our complete understanding only for reasons of its complexity.

MULLER: I think that, in the course of discussing the origin of life, we shall necessarily come closer to a definition of what life is, so that it is not necessary to define it now. I think the most fundamental property distinguishing a living thing—and that can therefore be used to define life—is its ability to form copies of itself. We call this "reproduction"; but such copies must also include innovations—mutations—that distinguish a given living thing from its parents. It is this property of not merely reproducing itself but also reproducing its mutant types that inevitably led the first multiplying objects through the three-, four-, or five-billion-year course of evolution by which all present-day living things, including ourselves, have gradually taken shape under the directing influence of natural selection. Natural selection could not go on without the necessary basis of an ability or faculty of the material to copy not merely itself but its variations. That, I think, is the heart of life, and such material, when it arose, is rightly called "living."

GERARD: I should want a little more said before I am quite willing to call matter "living." Perhaps this is a good opportunity to make the point that, while one has to think and use words in terms of fairly sharp categories, in reality there are always transitions and continua. It may be a little unwise to think of life and not-life as if these suddenly were or suddenly were not—aside from all the vast changes that have occurred in living things since the appearance of anything that we should agree was living. Not as a geneticist or a microbiologist but as one dealing primarily with more complex organisms, I am certainly aware of some other properties, even of simple organisms, which I should like to see included in any definition of life.

You have certainly put your hand on the essence of life in this ability to reproduce—and reproduce not only substance but pattern. But I should also like to think of life as something that is going on: there

must be some kind of dynamic equilibrium, a flow of matter and energy through the system. Moreover, a living system maintains its integrity. It has an equilibrium state and either maintains that state or attempts to return to it when displaced by the impact of environmental stimuli. So I should include dynamic equilibrium and the ability to use its own energy to restore disturbances—which is called "adaptive amplification"—as well as specific synthesis. Then I should like to add still another quality. I think there must be a certain level or architectural complexity—levels upon levels upon levels. One has subnucleons in a nucleus, and these in an atom, and atoms in a molecule, and molecules in certain patterned groups, and these in still larger patterned groups; and only when a system has gone quite a long way in that direction of onion skin around onion skin do I think you could reasonably call it living.

SHAPLEY: You make life sound difficult.

GERARD: It is.

GAFFRON: Matter can practically always be defined in terms of physics, chemistry, and biochemistry. This certainly is not enough to define life. We might ask: If we ingest food, at what moment does the food become living? Of course it never does. One could follow a particle of assimilated food, no matter how complex, and wherever one finds it in the living organism, it is dead. It is the process in which it takes part that defines life, and not the matter of which it is composed. One may freeze a cell at such low temperature that every reaction ceases. No one could distinguish this cell from a dead one. To see whether it is alive or has the capacity of being alive, one would have to bring the cell back to normal temperature and see whether it still does what it is expected to do: to grow and, particularly, to multiply. So the essence of life is found in the process of living and not in any constituents of living cells.

GERARD: Your frozen cell, which is sufficiently frozen so that nothing is happening in it, when warmed up, will presumably (if it is still alive) show certain processes that a dead cell under the same conditions will not show. Now, what is the difference between the dormant and the dead cell?

GAFFRON: When defrosted, the dead cell will disintegrate, and the dormant cell will multiply.

GERARD: This is good operationalism.

MULLER: I wish to register my disagreement with nearly everything Gerard said. In my opinion all the properties he mentioned are results of the evolution of living matter by the mechanism that Darwin called "natural selection." We do not have an original adaptiveness on the part of life, but adaptation comes as a result of evolution.

PROSSER: My definition of life tends to be a little closer to Gerard's than to Muller's, because I think integration is the term that best covers our ignorance of life. Perhaps it would be useful here to refer to the concept of emergent properties. With each level of increasing complexity of organization, properties emerge that certainly could not have been predicted from the properties of the subunits. Molecules have different properties from atoms, macromolecules add new complexities, subcellular particles are organized chemical systems, and intact cells are much more than the sum of their parts.

GERARD: I think that this discussion brings out the point that the definition of life is a problem of where along a continuum you wish to draw a line. This, of course, is a matter of definition and therefore an individual option. This question of a sharp break or a transition or, as Prosser put it, the emergence of something new is going to appear in almost every panel. It is a choice between demanding the full thing and taking a preliminary stage. Here, one could speak of "proto-life." If you wish to define proto-life as having just the limited properties you specify, then I am happy. If you don't wish to include the other properties as minimal, that is your privilege. I think it should be made clear that these are successive demands we are making about when we wish to call a thing "living."

MULLER: I should draw the line where the Darwinian process of natural selection begins to come in, and that is at the appearance of replication of the self-copying kind—that is, the replication of mutations.

SHAPLEY: I agree. I think we all agree on the really basic points; and our areas of disagreement are often, in a way, not the most important. To reiterate the second topic for discussion:

> Darwinian evolution is now considered a fact and is the basis of modern biology. On the other hand, any answer to the question of what happened before Darwinian evolution began is largely speculation. No existing and recognized forms of life are primitive enough to be considered related to any primordial organism or the first living cell. The viruses, which are not cells but are apparently related to the most important constituents of living cells, namely, the genes, exhibit attributes of living things only as long as they interact with the structure of a living cell.

EVANS: I think one should approach living systems first in terms of their material properties. The chemical analysis of living things—at the level where everyone agrees that a given thing *is* living—always discloses at least three components: proteins, nucleic acids, and some

device or mechanism that serves as energy source. This last component is essential because the organization that is the essence of the living cell is unstable and can be maintained only by the continuous use of some sort of energy. Although these three components are present in all living forms, they can also be found, of course, in non-living systems.

So far as pre-Darwinian evolution is concerned, viruses (assuming that they are all alike) are frequently considered possible examples of what might be involved in the transition from non-living to living. Some of the simple viruses can be isolated and shown to be nothing more than supermolecules that can be taken apart and put back together again. In this isolated condition, they have no energy source and, from that standpoint, are non-living. When introduced into an appropriate host cell, however, the virus replicates by using the machinery and material of the organism it parasitizes. Under these circumstances the virus is able not only to replicate but to mutate as well; and one can regard the virus and host cell together as forming a living system. It should be emphasized, however, that these facts do not in themselves support the view that the evolutionary status of the virus represents a transition from non-living to living.

GAFFRON: I think my position on the definition of life is supported by what Evans just said. What counts is the special organization that makes a certain way of action possible, rather than the matter involved.

SHAPLEY: What would you say are the origins or proposed origins of viruses?

EVANS: To the extent that we know them, viruses are proteins and nucleic acid.

SHAPLEY: I wonder if anybody would like to know what an expert means by "nucleic acid."

EVANS: We have a model of nucleic acid here. This is what is known as DNA, deoxynucleic acid, one of the two types occurring in cells. As you can see from the model, this is a large, complex molecule. DNA exists in the form of a double helix, the two helical strands being held together by secondary chemical forces. In terms of its chemical composition it contains variable amounts of four nitrogenous components, which are referred to as the "nitrogen bases." These various components are specifically arranged to form the strands of the nucleic acid helix; and it is in the specific number and order of these components that the various kinds of nucleic acids differ from each other. We believe that the gene is equivalent to DNA and that one gene differs from another through specific differences in the number and arrangement of the various components of the nucleic acid molecule.

GERARD: What do we mean by Darwinian evolution? Is the term used here to narrow the total scope of evolution, excluding the evolution of stars and rocks, or is it more specific than that?

DOBZHANSKY: It means evolution by natural selection.

SHAPLEY: Biological evolution?

DOBZHANSKY: Natural selection is the most important criterion.

GERARD: Involving genetic mechanisms?

DOBZHANSKY: Yes.

SHAPLEY: There is natural selection in the solar system. But you want to keep it biological?

DOBZHANSKY: I doubt that.

MULLER: Natural selection applies to multiplying things—things that multiply their own variations.

GERARD: Would you include specifically the genetic element?

MULLER: Only that.

GERARD: Because we also see evolution of living things that may not involve genetic mechanisms. That is not Darwinian?

MULLER: Not for our present purposes.

SHAPLEY: I have heard Muller say he had a definite line between the living and the non-living. A good many people think that livingness increased gradually; but you have a definite line between the live and the dead.

MULLER: Yes. Where there is replication of mutations.

SHAPLEY: We shall go on to topic No. 3:

> The now dominant idea that living things originated from non-living matter is a consequence of our knowledge of the earlier and later phases of the natural history of the earth —the former as concerned with cosmological inorganic evolution, and the latter with what happened, once life had appeared on earth. The assumption that life originated from non-living matter must be made by the modern scientist if he believes that the question "What is life?" belongs in the natural sciences at all.

GAFFRON: A natural scientist who wants to study this evolutionary process has no choice but to start and to proceed from the assumption that the living came from the non-living. This in spite of the fact that what stares him in the eye—all life about him—is so fantastically complex that it is hard for him to believe it truly happened.

GERARD: With a fully developed situation, it is extremely hard to see how it started. If I look at Gaffron, it is very hard for me to think how he got that way. But I am sure he did.

GAFFRON: In a very natural way.

SHAPLEY: Our topic No. 4 states:

> Therefore, the origin of life presupposes, first of all, the natural accumulation of suitable raw materials. Astronomy and chemical geology provide methods for solving this question. Further presupposed is a gradual evolution of increasingly complex organic systems from the raw materials until a self-contained unit appears which we would be willing to recognize as a living thing. To attack this problem from the side of living things, microbiology, biochemistry, and genetics provide the tools.

We seem to agree pretty well on that statement, and therefore we move on to No. 5, which is the heart of this afternoon's session:

> Proceeding from this basis, we may subdivide the problem into technical questions that are amenable to straightforward scientific research. For instance:
>
> A. Did the early conditions on earth favor the accumulation of organic substances? What were these conditions?

GAFFRON: About thirty years ago it was thought that if life originated from non-living matter, carbon dioxide was the most important substance involved. One knew that carbon dioxide was an inorganic substance which illuminated plants convert in a miraculous way into foodstuffs and living tissue. A direct conversion of the carbon dioxide present in the early atmosphere of the earth, with the aid of ultraviolet light and water, into something organic was considered the beginning not only of organic substances but of life itself. In the 1920's, however, both A. I. Oparin and J. B. S. Haldane saw that an original atmosphere without much carbon dioxide would conform more closely to the findings of the geochemists. According to the latter, in particular H. Urey, the planets started with an enormous surplus of free hydrogen; given high temperature, a long period of time, and an excess of hydrogen, everything that could combine with hydrogen would do so. Carbon would become, not carbon dioxide, but methane; nitrogen would not be nitrogen, but ammonia; and oxygen would be reduced to water. So the early atmosphere of the earth must have consisted of hydrogen, ammonia, methane, and water vapor.

Of the various theories concerning the composition of the original atmosphere, Urey's hypothesis has become the most favored, because it was tested experimentally and found to be conducive to the formation of organic material. The experiment was done here at the University of Chicago by Stanley Miller, who subjected a mixture of hy-

drogen, water vapor, ammonia, and methane to electrical discharges. Ultraviolet light might be used instead, but in the laboratory it is more practical to work with electrical discharges, which would be equivalent to lightning in the outside world. As expected, organic substances were formed.

SHAPLEY: The Stanley Miller experiments in Harold Urey's laboratory in 1953 and 1954 were remarkable. They radiated in this laboratory the gases Gaffron mentioned as constituting the main part of the atmosphere of the earth a few thousand million years ago.

Harold Urey was in Boston at a meeting on the climatic conditions necessary for the origin of life on this and other planets. We had quite a conference; and I remember George Wald asked me as an astronomer how much time separated the forming of the earth's crust and the beginning of life here. I asked him when life began; he gave it a billion and a half years (I think it would be a bit more than that now). Being generous, I said, "I will give you two billion years," and he got off a nice phrase: "Two billion years. That is just wonderful for the problem of the origin of life. In two billion years the impossible becomes inevitable."

Now this Miller-Urey experiment has been repeated in Germany and in Russia, at Yale, at the Oak Ridge Laboratory, and especially by P. H. Abelson in Washington, using different mixtures and always coming out with these organic substances.

GAFFRON: Prosser, would you like to comment on the minor point, whether carbon dioxide was present in the early atmosphere? Actually, carbon dioxide must have been present all the time or at least have been formed before it was re-reduced; otherwise we could not have it in the form of the carboxyl group of organic acids.

PROSSER: This is a problem of energy sources. The ultraviolet source ceased being effective when the oxygen layer became a filter that prevented ultraviolet light from reaching the earth. Miller's experiment showed that carboxyls can be formed from an atmosphere lacking carbon dioxide and containing oxygen as water. Presumably, energy was stored in organic compounds, perhaps in high-energy phosphates. Some of this energy was released by decarboxylating reactions, and carbon dioxide was liberated. Urey has also shown how carbon dioxide could have been formed from the elementary compounds. Some oxygen could have been released by photochemical reactions prior to true photosynthesis.

GAFFRON: We should mention very briefly that if a certain reaction is not possible in the Urey atmosphere, one might try adding other substances to make it take place.

SHAPLEY: Especially the sulfides.

GERARD: As this discussion developed, I was struck by the real power of science compared with other approaches to knowledge and understanding. Not many years ago, one would have said that we were dealing with events in the almost infinite past and that what could or could not happen would forever be a matter of guess. One finds again this gradualism you brought out earlier, Gaffron—little by little, one makes a tremendous jump. Little by little, we are coming to see that these things were possible. Things that were once matters of observation and calculation are now matters of experiment. It is a great satisfaction to find science able to penetrate experimentally into these vast distances of time and space.

SHAPLEY: It is marvelous. I predicted not very long ago—a year ago—that this Miller experiment is something the youth of our high schools and secondary schools in general might do within a very few years. Two weeks ago, at Dayton, Ohio, I was told of a youth who has actually carried it through. Now I don't think he has fully analyzed the organic material involved, but he carried out the Miller experiment in the high-school laboratory. And this is going to become commonplace.

GAFFRON: Unfortunately. Because, contrary to notions now becoming popular, it does not solve the problem of life. These substances are quite dead. From the point of view of a misleading oversimplification, it would have been even better if we had not found anything as easy to do, because then the difficulty of the true question would not have been obscured at the very beginning. What the Miller experiment does is to allow us to proceed at once to the very point where the problem of life becomes interesting.

SHAPLEY: If there weren't other people here, I should say: Nonsense. We'll get together later. A second technical question:

> B. Were the first organic compounds of such kind that they could be readily transformed into parts of living things?

GAFFRON: The Urey-Miller experiment showed that organic material suitable for further evolution will be produced in a Urey atmosphere. Miller obtained acetic acid, other aliphatic acids, and amino acids. These substances constitute an excellent nutrient medium for many bacteria. Molecules like acetic acid or glycine, the simplest amino acid, are used by the modern cell to build up such complex organic molecules as porphyrins, iron porphyrins, and magnesium porphyrins—usually known as "chlorophylls." These substances play important roles in the metabolism of most living cells. Perhaps Evans could enlarge on this.

EVANS: Miller and Urey found large amounts of the amino acid glycine as well as acetic acid, glutamic acid, and other substances. We know that the purine base (which I have already pointed out as part of the nucleic acid molecule) can be synthesized in living cells from a number of simpler compounds. The largest part of the purine skeleton comes from glycine, and additional carbon and nitrogen come from formaldehyde, glutamic, and aspartic acids. All these substances are produced in the Miller experiment. A number of these same products are also precursors of the pyrimidine portion of the nucleic acid. As for proteins, these are large molecules made up of different numbers and kinds of amino acids—a number of which also occur as products of this experiment. We see, then, that the materials formed in the Miller experiment are precisely those which serve as precursors for the formation of nucleic acids and proteins in living cells.

SHAPLEY: Very well. We will try item C:

> C. At what stage in this development could one assume a complexity that guaranteed self-replication?

MULLER: I should say that one could assume such a complexity at the stage that Evans was talking about, provided that the materials were afforded for the coming-together of the chemical groupings in this fashion. As yet, no protein need be there. In other words, we have here only the coming-together into chains of the chemical groups we call "nucleotides." They don't yet have to be even in the form of the double chain shown in Evans' model. That, in my opinion—which is not merely an opinion, nor solitary—is the point at which, under special conditions in the medium that must have existed on the earth at the time we are speaking of, the chain of nucleotides would have been able to replicate. Now the beginning of that replication is already shown here in the DNA model, because, as you see, this chain is double.

This general idea goes back some forty years to the geneticists' observations that only in the chromosomes (and in a little other material we have since found to contain substances identical with those of the chromosomes) does one find the property of replication of mutations —that is, self-copying and self-copying of changes—and, therefore, the possibility of Darwinian evolution.

Now you may say: Today this material cannot replicate unless it has protein and other things with it. Of course, it can't replicate as we are accustomed to seeing it done, but there you have the basis of replication. And it has already been found in the laboratory that these

strings of nucleic acids are able to select free units (nucleotides) from the medium and arrange them into strings of nucleotides with a pattern like their own. In fact, the pattern is complementary to their own, in a way that it would take too much time to describe here. Thus two spirals are formed, which are complementary rather than identical. Then, when these separate, the first spiral again chooses other nucleotides to form a complement to it and then separates, while the other forms the complement to the complement. So, you see, you get the original back again, and, by a two-step process, you obtain an exact replication.

Here, then, is a sharp breaking point, constituting the beginning of Darwinian evolution. It is this mechanism that has enabled living things so far to surpass non-living things in their complexity of organization and adaptation that we distinguish them by the special term "living." The inherent properties of these nucleotide chains have led to such complexities as to put their later developments out of the class of the inanimate from which they arose.

GERARD: At what stage of complexity do you have guaranteed self-replication? For example, why is not the replication of the architecture of a crystal or the replication of a branching polymer from monomers, which depends on the pre-existing polymer, life? What is your additional criterion?

MULLER: The additional criterion is that it must be self-copying, in the sense that if you introduce a change, it replicates that innovation, too. It replicates the new type.

GERARD: I think that happens with some of the branching polymers, when accidental misbranching occurs and is replicated from then on. This happens with some of the synthetic processes that chemists use. Isn't that so, Evans?

EVANS: A mutation is a failure in copying—that is, the copy is not quite exact. This can occur because the copying mechanism is faulty or, as one probably does with mutagenic agents, by altering a portion of the nucleic acid polymer that is the model for copying. Once you have the faulty copy, it is then replicated as such, and the alteration is perpetuated.

MULLER: Yes, that is the important point. Everything in the world can change, but this material is made in such a way that, after it changes, it then reproduces the new thing, and that quality is not known in anything except nucleotide change of arrangement.

GERARD: In branching polymers that happens.

MULLER: I think not.

EVANS: I am not sure what you are driving at.

GERARD: For example, in synthetic factories where they make plas-

tics or rubber or something like that, I understand that if the reaction starts going wrong, the branching, instead of the straight-chain, polymers will continue to form from that point on. This is exactly like a virus with a mutation that goes on reproducing itself. Sometimes they have to clean the whole thing out and destroy these molecular nuclei and start again.

EVANS: I think that is true.

GERARD: It seems to me that this is exactly the same thing.

MULLER: No, I would not admit that, because, after being changed, the nucleotide chain replicates the changed thing.

GERARD: It keeps making the same error.

MULLER: The same error? You definitely know that for the plastics?

GERARD: I think so. (I know very few things definitely.)

EVANS: It has to keep on replicating.

GERARD: In the same mode, the same error.

EVANS: An essential feature of the system we are discussing is that replication must continue. Your analogy seems to involve a continuing process and to that extent, I think, is not incorrect. We know a number of so-called autocatalytic reactions—such as the conversion of pepsinogen to pepsin—in which the product of the reaction catalyzes the conversion of the precursor into the substance itself. It would be possible, I think, for a small alteration in the autocatalytic molecule to let the autocatalysis still continue. But I think that any major change in the structure of the autocatalytic molecule would stop the reaction entirely. And the ability for *continuous* mutation seems to be an inherent characteristic of living cells.

GERARD: Let me put it this way: Ordinarily, the process forms polymer A. If a molecule of polymer B gets into the system, the process now forms polymer B and goes on doing that. And this polymer B can form "spontaneously" as a result of aberrant circumstances, and then it continues.

EVANS: When chemical systems of a certain specific character—nucleic acids—replicate themselves, Muller chooses to call this "life."

GERARD: I was asking at what level it gets to that.

MULLER: At the level where an unlimited number of changes in pattern are possible, each of which is self-replicating. This chain can be of unlimited length, and its four different kinds of nucleotides can be arranged in any order. Whatever that order is, is the order that will be replicated, with the exception of the occasional mutations. "Guaranteed," I admit, is a matter of degree. I am sure that when these first arose, self-replication was less rigorously "guaranteed" than now, because changes have been selected that increase its stability and guarantee it better, including the "adoption" of protein into it.

GAFFRON: The preliminary stage might have been the manufacture of enormous amounts of similar, but not identical, compounds.

MULLER: It is the copying of the pattern per se that is important in allowing natural selection to act.

GAFFRON: Yes. You would say, then, that the transition from non-living to living occurred just at the point where similar, but not identical, things appeared?

MULLER: It has to be identical in large measure; otherwise it does not have genetic continuity and cannot be subject to natural selection.

GAFFRON: But the selection might be chemical. We are talking here about an early stage of evolution based on the principle of selection, where the selection proceeds by chemical action, thus providing opportunity for molecules of the self-replicating kind first to have a chance to accumulate.

MULLER: We have to distinguish between two kinds of selection: merely chemical selection and Darwinian natural selection. There is a very sharp distinction there.

SHAPLEY: When did natural selection begin?

MULLER: With the nucleotide chain.

GERARD: I think Gaffron implied that it began before that.

GAFFRON: I think that there is first a chemical selection, starting with the solubility of molecules in water.

DOBZHANSKY: I should like to support Muller. "Chemical selection" is a misuse of the term, if you mean "natural selection."

SHAPLEY: Chemical selection is natural.

DOBZHANSKY: Natural selection in the Darwinian sense is differential reproduction, and this is possible only with self-producing entities of whatever kind.

GAFFRON: But we are pre-Darwinian here.

PROSSER: I wonder whether there is not a clear distinction between polymerization and replication in the sense used for DNA. The perpetuation of error in the two cases might be distinguished on this basis: in polymerization, every time a new chain is manufactured or extended, the same mutation is repeated, whereas after mutation has occurred in a replicating DNA chain, one has not a new mutation every time but a copying of the original error, as from a template. The coiling of artificial polyribonucleotides in helical paired structures has been obtained by Rich.

GERARD: I don't think that distinction is valid, because you have a new set of genes that leads to a new set of molecules that gives you the phenotypic mutant.

SHAPLEY: I just asked Gaffron whether that DNA model is what we are made of. Aren't the units much longer than that? He says that they are indefinite in length.

EVANS: Not indefinite. The size of the DNA molecule apparently depends on its particular function. Actually, in terms of genetic combination, genetic units can be made up of a fairly small number—five, six, up to a hundred—of nucleotide pairs. These constitute the coding mechanism for a specific biological feature of a living organism.

SHAPLEY: How many turns have the small spirals?

EVANS: With the bacterial viruses, there is a question whether the DNA is in one piece or a number of pieces. If it is one piece, it is a very large piece indeed.

GAFFRON: Would it not be an interesting proposition to prove that selection on the level of spontaneously formed DNA molecules should never actually have occurred because of the improbability that molecules of this enormous size would come into existence in the first place?

MULLER: That is exactly why we need the process of Darwinian natural selection. What you have in the first place is only a few of the nucleotides because of this impossibility of getting everything just right to begin with. But, having the ability to undergo Darwinian natural selection, then the chain can, step by step, add to its size and improve its pattern.

GAFFRON: Then you would attribute this power of self-duplication to a very short nucleotide chain?

MULLER: A. Kornberg has shown it to occur even with only two or three nucleotides joined together. So you come down to something that is not to be classified separately from ordinary organic chemicals except in the potentiality for further evolution that this property gives it. In other words, one might define life as something able to undergo biological evolution—Darwinian natural selection.

GAFFRON: Then macromolecules appeared only as a consequence of evolution. It follows that the organization to which we attribute life could have been formed by much simpler molecules in protein and nucleic acid form?

MULLER: The beginning of it must have been so, yes.

PROSSER: The distinction between the properties of proteins and nucleic acids has been mentioned, but it cannot be overemphasized. Proteins grow by polymerization and are synthesized from free amino acids. They do not duplicate in the same sense that a chain of nucleotides replicates, by adding corresponding components (purines-pyrimidines) and then splitting into two chains. Also, I think the size of the chain is not critical. Replication may well first have happened with relatively short chains. Perhaps Evans might comment on the recent observations by Benzer.

EVANS: One should remember that, until recently, the chemical structure of nucleic acids was believed to involve a relatively simple type of molecule and that it was impossible to explain how such a

structure could exist in the large number of variations required for the molecular basis of the gene. Since the proteins are made up of a large number of amino acids in different amounts, it was possible to assume that the protein molecules could vary to the enormous extent required for any molecular basis for the genetic material. The structure of the nucleic acids as conceived at present, however, is such that it can produce the necessary structural variation, although the number of components constituting the nucleic acid is far less than that in the proteins. For example, a gene (made up of nucleic acid) must be capable of carrying the information involved in the structure of a given protein made up of some hundreds of the twenty different amino acids. It is possible to devise a coding arrangement of the four variables in nucleic acid structure that will uniquely define the twenty amino acids that occur in protein.

There has been a shift in emphasis, therefore, in the last ten or fifteen years. Earlier, the molecular structure of nucleic acid seemed incapable of accounting for the necessary variations. This is no longer the case, and it now appears that we need look no farther than this chemical structure of DNA for a basis for all genetic information, with five or six nucleotide units being enough to define the particular bit of information.

SHAPLEY: What about single-strand DNA?

EVANS: Investigators in California have recently described a virus in which the nucleic acid of the DNA type appears to consist of a single strand. But I am not prepared to predict what effect, if any, this has on our current idea of DNA structure. Certainly, the available evidence suggests that the general features of the structure as we conceive it are correct.

SHAPLEY: Do you think you defined DNA and RNA sufficiently? Maybe I wasn't listening, but I still don't know what they are.

EVANS: The two types of nucleic acid are distinguished primarily by the nature of their sugars, DNA having deoxyribose, and RNA, ribose. That is, in the sugar characteristic of DNA the hydroxyl group is missing from the second carbon atom. They also differ in the nature of the nitrogen-containing basis. RNA appears to have a structure similar to that of DNA, although our detailed knowledge is less certain. By and large, the RNA is present in the cytoplasm of cells, while the DNA is present in the nucleus and is identified with the genetic material itself.

SHAPLEY: With the genes?

EVANS: Yes.

MULLER: Genes can sometimes be composed of RNA.

EVANS: I should add that viruses apparently contain either one or

the other type of nucleic acid—never both. In the poliomyelitis and tobacco mosaic virus, the nucleic acid is of the RNA type.

SHAPLEY: What about RNA as a genetic determiner?

EVANS: Although the details of the relationship are not clear, it is certain that DNA and RNA are intimately involved in cellular activity. One current idea is that the genetic DNA transmits its information in some fashion to the cytoplasmic RNA, which in turn is responsible for determining the structure of at least some of the other cellular components. In tobacco mesaic virus, where the nucleic acid is of the RNA type and has been shown experimentally to be the sole determinant of the structure of the progeny produced when the virus replicates, it is clear that the RNA does have a genetic function—although this may involve some interaction with the DNA genetic material of the host cell.

MULLER: I don't think we really know enough yet to decide the details here.

PROSSER: On the other hand, RNA does carry information and serves as a template for protein synthesis in the cytoplasm of other cells.

SHAPLEY: The next question is:

> D. What principles govern self-replicating macromolecules?

PROSSER: I think this has already been covered. The emphasis, it seems to me, is on duplication in the sense of forming molecules as mirror images or to serve as a template for an opposing molecule that then separates off.

SHAPLEY: We move on to the next question:

> E. How does the structure of nucleic acid specify biological properties?

EVANS: I have already mentioned that the specific arrangements of the DNA molecules can dictate, for example, the structure of an enzyme, which is a protein. One can work out a so-called "coding system" in which arrangements of nucleotide triplets—three nucleotides—will uniquely define one amino acid. In other words, by a suitable arrangement, in groups of three, of the four variables in the DNA structure, one can evolve a coding system that will specify twenty, and only twenty, variations. By equating each of these twenty variations with a specific amino acid, one has a mechanism—entirely on paper, of course—in which specific arrangements of the four nucleotide variations would completely specify the arrangement of a

protein molecule containing variable amounts of twenty different units.

MULLER: I agree with this, although, like many geneticists, I don't like the terms "code" and "information." Instead of "code" I would say "linear arrangement"—an arrangement in single file, in a line. As you have letters coded in words, so you could figuratively call this a "code." I don't like the word "information" because this is a matter, not of conscious knowledge, but of physical arrangement specifying another arrangement—in this particular case, that of the amino acids.

You were discussing the arrangement of amino acids that gives a particular protein. We must remember that not only the proteins but also everything else in the cell result from the operation of these nucleotides; and just what substances are formed, and where and when, depends on the particular arrangement of these nucleotides in this enormously long chain. It isn't at all solved yet just how the nucleotides operate in producing these effects. However, we know that the arrangement of nucleotides somehow determines the arrangement of the amino acids in the protein. This in turn decides not only what kind of hemoglobin you have but the characteristics of your skin, brain, and everything else. All this is an enormous job for the future, far outrunning all other problems.

I do not want to belittle any other type of work—astronomy, physics, or organic chemistry. But it is a job of a different order of magnitude to find out just how all the different features that are essential in the body of a higher organism are determined by the arrangement of these nucleotides, of which we have about four billion in line in a single set of human chromosomes. This would fill about one hundred Webster's dictionaries if you were to write it all down in print as fine as that used in unabridged dictionaries. All that, taken together, is, if you like, the code—or arrangement, I would prefer to say. We have not only to discover that arrangement but also to find out why that particular arrangement gives rise to all the other complications of our bodies. At the present moment we only know that it does so, and we can be sure that there are changes in it. As has been shown experimentally, these are changes in linear arrangements, and even a change in one nucleotide at one place can profoundly affect the other substances produced in the cell.

SHAPLEY: Here comes a good question:

> F. Are enzymes needed for the production of nucleic acids, which are, in turn, needed for the production of enzymes?

EVANS: The role of enzymes in biological reactions is to alter the rate at which a reaction occurs; they do not create the reaction. There-

fore, it is an inherent property of a chemical reaction to proceed in a certain direction; this will occur if one waits long enough. With an enzyme present, it may occur very rapidly indeed. If it is an inherent property of the small molecules formed in the Miller-Urey experiment to condense and form the large protein and nucleic acid macromolecules, then this will occur if one waits long enough. And, if we have a few billion years to wait, that would seem to be enough time.

GAFFRON: How many billion years are available, Shapley?

SHAPLEY: What do you want; what is your order? There are not too many, to be sure.

MULLER: Might I make a point? Here I accept degrees. You can have a more or a less efficient enzyme as a catalyst; and undoubtedly before our present very much improved enzymes came into existence there were much cruder precursors, which the nucleotide chains were able to produce.

GAFFRON: The particular nucleotide that first invented its own enzyme had an enormous advantage over all the others.

SHAPLEY: The survival of the most active. While enzymes are needed for production of nucleic acids, the acids are not, in turn, needed for fast production of enzymes?

MULLER: According to this view, enzymes are not needed for production of nucleic acids.

GAFFRON: You do it with time first. After a true nucleic acid evolves in the first two billion years, it catalyzes the production of its own enzyme; and from then on reactions move rapidly.

EVANS: We are talking of reactions of which it is an inherent property that they proceed spontaneously. It is only because these reactions do not occur at an appreciable rate under ordinary conditions that catalytic enzymes play such an important role in biological systems.

MULLER: If each of these million molecules could then produce another million molecules, thus increasing exponentially, you would soon recognize it.

SHAPLEY: We are dealing in astronomical numbers. Our next question is:

> G. Modern life on earth is extremely uniform in its basic metabolic reactions. How is this to be explained? Is it to be interpreted as a unique (highly improbable) event, or the result of numerous chance combinations followed by selection?

GAUSE: One manifestation of the uniformity of life can be seen in the optical activity of living matter—in the fact that proteins in all living things on earth from bacteria to man are levorotatory, or left-

handed. I think this points to the origin of all living systems from a common ancestor.

DARWIN: If I understand him correctly, Gause is making the point that we have only levorotatory molecules, and no dextrorotatory ones. It seems likely that both would have arisen equally at first, but they may have got separated one from the other, and one happened to bump into a volcano, leaving only the other.

SHAPLEY: That is a novel idea.

DARWIN: We must think about how one type managed to survive, and not the other.

SHAPLEY: In nature we have only one, and in the laboratory we have two: is that the idea?

DARWIN: I would say that one has to believe that, chemically speaking, the right- and left-handed molecules would have been equally good for supporting life.

GAUSE: It is probable that at some stage in the origin of life the effect of circularly polarized light contributed to the preferential development of one optical form of molecules in living matter at the expense of the other.

DARWIN: I do not mean what I am going to suggest to be taken seriously; but you might imagine that at one time life was developing only in the Northern Hemisphere and that the earth had a strong magnetic field that would polarize the light there right-handedly. This might encourage the survival of the levorotatory molecules at the expense of the dextrorotatory ones. I do not think this is more than a fantasy.

However, looking deeper, you may recall that physicists have recently been much excited by the discovery of what is called the "nonconservation of parity." It is a subtle phenomenon in the theory of the nucleus of atoms; and I cannot describe it here, but it does mean that right- and left-handedness are not equivalent. However, this phenomenon lies very deep, and it is hardly likely to affect the present question. It is much more likely that both rotations were produced equally at first but that, by mere chance, one type got a better prospect and survived, in the end killing out the other.

GAFFRON: If the production of the key substance in question was a rare event in comparison with the number and speed of reactions that it subsequently catalyzed, the dominance of one isomer over the other is easily explained on the basis of "first come, first served." This holds even if the original chances for the appearance of either one are equal. The earlier one spoils the chances for the late comer.

SHAPLEY: You were having me eaten up in a volcano?

DARWIN: I only used the volcano to express this chance for the

survival of one of the two by killing the other one. Am I to understand Gause's point to mean that, since I am right-handed, I shall catch a cold only from bacteria that are also right-handed?

GAFFRON: Special enzymes destroy the unwanted opposite mirror-image type. Is this a new invention or a relic from a time when molecules had to fight off their competitors?

GAUSE: The existence of enzymes eliminating the unwanted optical isomers of molecules in living matter represents an important advantage that has been acquired through natural selection and contributes to the efficiency of living systems.

GAFFRON: The unique event that started all this might be only the historical moment when one isomer evolved first and inhibited the development of the otherwise equally proficient other isomer.

GERARD: Isn't there an entirely different aspect of this problem? The question concerns the uniformity of basic metabolic reactions in modern life. We have been talking about a stereoisomeric aspect of its structure. You can replace part of the substances of a human brain cell with equivalent substances from a yeast cell, and, so far as the chemical reactions are concerned, this mixed or hybrid machine works. It sort of cannibalizes another cell. In basic chemical architecture and in basic chemical traffic, the simple cells and the cells of more complex organisms are essentially alike. Of course, there are differences in the proteins and nucleic acids, but at this level the similarities are much more striking than the differences, whereas practically all the other attributes that organisms have evolved changed markedly with time. In behavior, in the architecture of the whole, and in the mechanisms of maintaining equilibrium, you find vast differences.

I think this ties up beautifully with the point that Muller discussed earlier, and I am delighted to agree completely with his presentation. To follow up this matter of coding and diversification, it seems to me that the simpler the unit with which you are dealing, the fewer kinds there are, and the fewer are the patterns that these can be put into. If you have four nucleic acids, you have to arrange them in three patterns of three to get the twenty amino acids. If you have a limited number of letters and you cannot use them in indefinite numbers, you can get a considerably greater number of words. Now, if you combine those words in larger constellations, you have an infinity of infinity of sentences, of paragraphs, and everything else. Since organisms are built up of successive levels of using the simpler units in newer patterns, each new pattern increases the richness of the array and the numbers you can have. As the possible number of kinds increases, the number of individuals of that kind tends to decrease. It

is for this reason that, at the level of chemical reactions, you find great similarities. But in the ways that those chemical reactions have led to morphological structures and physiological processes, one finds vast differences. This is what one would have to expect from the nature of the organization of living things.

PROSSER: I should like to emphasize that point. We have been talking about the nucleic acids and proteins as if these were the only constituents of living material. Certainly, during the long period of chemical evolution, a great host of other organic compounds appeared. It is sometimes said that evolution might have been accepted more readily if Darwin had based his presentation on the similarity of all living things rather than on their diversity. This common chemical basis of all living things should be emphasized. As biologists, we sometimes fail to realize that biochemically and biophysically the most important and extensive evolution occurred before there were any living things we would recognize as such.

SHAPLEY: We entered life uniquely, and that was a highly profitable event; and then there were numerous changes, followed by selection. I think we have touched this subject fairly well, but I don't believe we have a final answer.

Our next question is:

H. Can life originate under present conditions on earth?

GAFFRON: We all have learned that Pasteur disproved the notion that the simplest organisms we know could appear spontaneously. He showed that a cell comes only from another cell of the same kind. We therefore moved away from that kind of spontaneous generation. We no longer believe in the sudden appearance of a micro-organism but prefer, instead, something like Muller's self-duplicating, very small, nucleic acid screw. From this point of view, one could reopen the question of life originating at the present time.

We know that the atmosphere of the earth has changed enormously. The accumulation of organic molecules dissolved in the ocean, which we had at the beginning, probably would not occur now, when there is so much oxygen on earth. Today, organic substances simply are not stable. If by pure chance an organic molecule approaching that described by Muller should appear, either it would die of malnutrition (there would not be enough free organic material for it to multiply with), or it would be oxidized. Organic material disappears by being eaten, by being burned, or by slow oxidation—which is still a very fast process, considering the millions and billions of years we are talking about.

Let us assume that atomic radiation has killed everything on earth

(which is unlikely, since some bacteria might survive). The chance that life could evolve a second time would depend on whether all the oxygen on earth was used up in the oxidation of organic matter. I have not made the appropriate calculation. We ought to know whether the combustion of the organic material now present on earth would remove all oxygen from the atmosphere. If so, it would mean that the short-wave ultraviolet radiation could penetrate again to the earth's solid surface. Apart from the presence of oxygen, the absence of free hydrogen presents an even greater difficulty. The original hydrogen atmosphere constituted a store of free energy to work with. This has disappeared. Therefore, under present conditions on earth, we should not expect life to evolve a second time spontaneously, once what is now living has been destroyed.

Another possibility, however, is the creation of life in the laboratory. The first step to attempt this is the Miller experiment. Everything that we are now discussing has been learned in the last thirty years or so. According to Oppenheimer, the increase in knowledge is such that every ten years we know twice as much as we knew ten years earlier. If this is so, I am quite hopeful that we shall discover one by one the conditions that were most favorable for the creation of life; and, finally, in the laboratory, we might someday reach the point where Muller's early nuclear type begins to multiply—that is, to feed on unorganized organic matter and incorporate this into itself: a conversion of disorder into order, similar to the growth of bacteria, which we would all agree to call a living action.

GERARD: I think this is a very beautiful picture, if an unhappy one. Incidentally, on the exponential rise of science Derek Price has shown that we seem to have reached the inflection point, where one or two more doublings in about fifteen years will not keep up the rate. It is beginning to slope off.

I am sure Gaffron won't mind my suggesting that Pasteur did not prove that life cannot originate; what he did prove was that reports of the spontaneous origin of life were due to errors and the admission of pre-existing life.

GAFFRON: Strictly speaking, we can only disprove things, never quite prove them. We fall into the habit of talking the other way around, when something has not been disproved for a long time.

GERARD: Pasteur did not disprove the possibility of forming life under the kinds of conditions you were talking about. He showed that life could not be formed in a swanneck glass retort in a few months at the temperatures of the laboratory if he did nothing more to it. This is very different from saying that life could not conceivably form under the conditions that now exist in the universe. However,

I certainly agree that the natural formation of new life is unlikely because, as you pointed out, larger and stronger living things would eat up the prototypes as these appeared; they would never have a chance to survive. To a certain extent, this is also true of higher species. Some of the other panels will discuss the chances of a new form coming in and occupying an ecological niche. And it is perhaps true even at the social level. How do you get a piece of property when all the property belongs to someone?

SHAPLEY: Then new life—what we call life—probably could not start on this planet any more, unless some great changes came about, because either the oxygen would burn it up or the bacteria would eat it up. Therefore, we should take good care of the life we have and not destroy it.

I have been asked to poll the panel for opinions about Gaffron's estimate that life can be created in test tubes in a thousand years.

GAFFRON: That statement probably comes from one of those news releases, in which an article of fifty pages is condensed into fifty sentences and certain things simply get lost. On the same page of my paper where I said it might be possible to solve our problem within the next thousand years, I also said, "provided that one of these famous improbable events is not involved." With one of those interposed, we shall never create life.

SHAPLEY: It seems to me you evaded that rather well.

DARWIN: Do you mean that there will have to be a gestation of the brains of the human race for a thousand years before we see how it can be done, or do you mean that the development itself would take the thousand years? These are two quite different matters.

GAFFRON: If we have to deal with an improbable event, which happened in the course of evolution, we have to wait a little too long for it to happen also in the test tube.

SHAPLEY: Do we believe that before a thousand years life can be created in a test tube? Without any definition of what I mean by "life," do you wish to say "yes" or "no"?

DARWIN: I don't ask for a definition of life because I am afraid you can't define it. But, as I understand it, you think that the researchers will not understand what life means so as to produce it until they have worked for a thousand years.

DOBZHANSKY: I am optimistic enough to believe that in a thousand years we shall know a great deal that we do not know now. I see no reason why the problem of the origin of life should take even that long to be solved. This may be overoptimistic, but I think it is not unjustified.

EVANS: If you are talking in terms of a replicating and mutating

macromolecule, then I would say that it is quite possible within a thousand years.

GAUSE: I think it is better to be optimistic.

SHAPLEY: Isn't a thousand years rather long to wait for this to happen?

GAUSE: If we believe we can do it in a thousand years, perhaps we shall make it in five hundred.

GAFFRON: You auction it off.

SHAPLEY: What will you give, Gerard?

GERARD: I think I am really the optimist. When you remember that practically all we now know has been learned in 250 years of science and most of this in one-quarter of that time; when you find out—as Panel Four will show later in the week—that the growth of human mental capacity is perhaps very great; then Heaven knows what can be done in a good deal less than one thousand years. I am willing to repeat a prediction I made once about understanding one of the important mental diseases: I said that I was quite confident that it would be solved during my lifetime. I am safe on that.

MULLER: I think I am going to shock Gerard, if he thinks he is optimistic. My answer is that those who define life as I do will admit that the most primitive forms of things that deserve to be called living have already been made in the test tube by A. Kornberg.

SHAPLEY: Muller's estimate is minus some years.

PROSSER: I would certainly say that molecules of the DNA type will soon be made to replicate even in the absence of appropriate protein catalysts. Even if you add to this other criteria, such as those Gerard stipulated earlier—most of which I will support—I think one thousand years is pessimistic rather than optimistic. However, it must be recognized that Miller has not found purine-pyrimidine bases, much less nucleotides, in his "primitive" system.

SHAPLEY: I have written down: "It will be accomplished before the end of this century."

The next question is:

> I. What were the energy sources allowing for a continuous increase in complexity of pre-biological organic systems?

That is, what is the source of energy that started all this off? We seem to agree that energy is necessary to go from the inanimate, such as this pencil, to the animate, such as Gaffron. You need some energy, and whence cometh that energy?

I remember discussing this problem with Harold Urey, and together we pointed out that there were at least four sources of energy. One was already mentioned—lightning; undoubtedly there was light-

ning on the surface of the earth, because we had atmospheres moving around. There would be electrical discharges. Lightning was there, all right; it is recorded on Jupiter at the present time. A second source is the earth's body heat, from volcanoes or hot springs. But I favor lightning because it was established by the experiments synthesizing amino acids. A third source was ultraviolet light from the sun. And gamma radiation from the decay of radioactive elements is a fourth source of energy, one that seems to be favored in the research laboratory of General Mills in Minneapolis. Those are four sources of energy, but the process is more complicated than I have outlined, and somebody should pick this up and show why we must sort out these electrical sources—or whatever the sources were—in order to keep life going.

GAFFRON: If the Miller experiment is valid—and we all believe it is—then, of course, the source was ultraviolet light or, let us say, anything that would produce radicals from the otherwise colorless atmosphere of that time.

SHAPLEY: Miller's experiment used lightning, not ultraviolet light.

GAFFRON: Yes; but since the main object is to produce radicals, this is only an exchange of methods. Couldn't electrical discharges and ultraviolet light be considered equivalent, if the result is simply to have one little leg of a molecule dangling where some other thing can come in?

SHAPLEY: And isn't it true that you would not need ultraviolet light if you waited long enough? All you would need is radiation from the sun.

GAFFRON: Yes; but how effective would radiation be without any color? There might have been colored minerals, of a kind not used today in living matter; and certainly on the surface of colored minerals you might have had certain reactions. I don't know any examples of this from our laboratory.

PROSSER: May not porphyrins have been established fairly early from these other sources, with the porphyrins then able to absorb light from the sun?

GAFFRON: But porphyrins are really an enormous step forward. We are still in the colorless Urey atmosphere, where the only thing that can happen is that some bonds of these simple molecules are broken and then put together again in new simple combinations. The problem here is that these new molecules would absorb more of the long-wave ultraviolet light and might be broken up again. How could these survive? One possibility is that they were washed into the ocean. Once a molecule has a carboxyl group or an amino group attached, it becomes water-soluble and can disappear in the depths and is there-

fore protected. In this way, a great deal of organic material could have accumulated with the aid of lightning or ultraviolet light.

When you have larger molecules, you must handle them gently. The chemist, of course, uses the Bunsen burner, and nature might have used volcanoes to cook a little. In the experiments of S. W. Fox, amino acids, when heated, combine into high molecular amino acid polymers, which are protein-like substances. The latest information I have on these experiments is that sulfuric acid does not favor the polymerization but that phosphoric acid and especially polyphosphates and organic phosphates like ATP help considerably. Now we know that phosphoric acid in condensed form is one of the sources of energy in living cells. So this predilection for complexed or polymerized phosphoric acid may have started very early.

Ultraviolet could not continue as a source of energy indefinitely, because, as hydrogen slowly escaped, the atmosphere changed from a reducing one to one in which oxygen began to accumulate. Direct decomposition of water molecules speeded up this process. From free oxygen, ultraviolet light formed ozone and produced in the upper atmosphere an ozone layer, which in turn intercepted the short ultraviolet-wave radiation that had provided energy.

So another source of energy was necessary, and here come in Prosser's porphyrins. Since only acetic acid and amino acid are needed to produce organic molecules of a dye type, which absorb visible light, here is a new energy source. There is a shift from ultraviolet to visible light, and the amount of light available is enormous. This might be a prototype of what we now call "photosynthesis," but the complexity of photosynthesis clearly indicates that it appeared much later; its origin might have been pre-cellular, but certainly it arose by steps. I think Harold Blum was one of the first to note that the simple one-quantum process where molecule A gets a hydrogen atom from molecule B, which it would have to wait a million years for without light, could take place within one second with the aid of an illuminated dye molecule acting as an intermediary. In this way, dyestuffs, once formed, could speed up reactions and use ordinary daylight as an energy source.

SHAPLEY:

J. When and how did the change from anaerobic to aerobic conditions occur?

One current theory about the origin of the earth and other planets holds that a cloud of gas, as it contracted, formed the sun—or the forerunner of the sun—and protoplanets, one of which was the earth.

I think some theories would say that the earth-forming nebula that preceded what we have now was perhaps ten times as massive as the present earth.

What was that mass made of? Hydrogen, very largely, because the sun is mostly hydrogen. Eight-tenths of the sun and all the stars are hydrogen. Here, on earth, hydrogen is relatively scarce and is apt to combine with oxygen into water and with other elements; most of the original hydrogen has escaped because the mass of the earth is not enough to hold it down, and the sun, with its radiation, can heat it up and speed it away. Presumably, during the first billion years of its existence, or much less than that, the earth was steadily losing its hydrogen. The earth shrank, and we now have left this remnant—perhaps one-tenth—of the original earth. There is a good deal in favor of that particular interpretation, and it explains the remarkable fact that in the universe at large hydrogen is predominant and oxygen relatively scarce.

Here on the face of the earth, however, oxygen forms about 50 per cent of the total. Oxygen is common; it is heavier than hydrogen and less easily lost. Nearly one-quarter of earth's atmosphere now is free oxygen, which was not present in the early days. The oxygen of the atmosphere was built up in more than one way: photosynthesis, for instance, and the dissociation of water vapor by radiation of the sun, perhaps at the top of the atmosphere. So we look at this particular oxygen situation as a detail of the evolution of the earth. The earth, together with its atmosphere, evolved over billions of years by building up its content of free oxygen, where there had been practically none. I would say that the atmospheric ozone layer, which is some ten to thirty miles above the earth's surface, is enough to shut off the ultraviolet light, which we could not now stand but which was probably rather important in earlier evolution. In the early days, water —J. B. S. Haldane's "hot thin soup"—could give protection from ultraviolet radiation.

DARWIN: I wish to ask one question about the first appearance of oxygen. I quite accept that hydrogen would leak away at the top of the sky. Would not the next effect be for oxygen not to come into existence but to attack the methane, break that up, and get rid of it into water and carbon dioxide? The water would then decompose, and the hydrogen leak away. Wouldn't it be a very long time before oxygen appeared as O2 and O3; wouldn't it mostly go into carbon dioxide first?

GAFFRON: Oxygen in contact with carbon or organic material very probably would react. Hence the carboxyl groups of the organic compounds found in the Miller-Urey experiment.

DARWIN: It might take one billion years to get rid of the methane. We know there is methane on Jupiter, don't we?

SHAPLEY: Methane and ammonia and water—in fact, the planet Jupiter may be mostly ice. All Jupiter needs is for the sun to become hot enough to get Jupiter's temperature up to liquid-water state (which would scorch us), and then it would have all the materials to start out a Jovian life.

DARWIN: When does carbon dioxide appear in the history of earth?

SHAPLEY: I don't know.

GAFFRON: It might be after the hydrogen had disappeared and water began to be decomposed by the ultraviolet radiation.

SHAPLEY: It could be that, yes.

PROSSER: So far we have been talking about energy sources primarily for synthesis. We have been considering extra-terrestrial sources —ultraviolet, lightning, cosmic rays—and then we considered the fact that, as oxygen increased (perhaps by decomposition of water), the ultraviolet would be cut off as a source of energy.

We know that life today does not rely on ultraviolet or on lightning for energy. Living things make use of organic compounds formed by photosynthesis, which store up energy and are then decomposed by appropriate reactions; usually the energy is transferred by some intermediate, commonly a compound with high-energy phosphate bonds. It is highly probable that such energy stores appeared very early in chemical evolution and that, as these stores accumulated, energy could be transferred for biological work from these pre-existing compounds. Some of the reactions by which stored energy is released, particularly by removal of hydrogen and transfer of energy, often operate without oxygen and must have occurred in the anaerobic period of evolution. This type of metabolism (if we can call it that) in pro-organisms could proceed very well so long as there was an adequate store of energy sources. As soon as oxygen began to appear, the amount of ultraviolet impinging on the air certainly decreased, and energy sources were no longer replenished.

Probably the more important source of oxygen was photosynthesis, and it seems probable that this process appeared in some form, making use of pigments or porphyrins, probably coupled with metals, well before there were organized photosynthetic structures such as we might consider essential for photosynthesis today. With this shift, there certainly was a change in the atmosphere. There was also a change from anaerobic metabolism to aerobic, and it seems to me that this is a rather critical step in chemical evolution. Virtually all living things today have retained most of the enzymes associated with anaerobic metabolism, and most of them have added the aerobic enzymes. As

we mentioned earlier, the principal classes of biochemicals were established before there were any organisms. So it would appear that the transition from anaerobic to aerobic conditions was a very critical step and extended over a long period of time but that living things have retained both types of metabolism.

While I am talking, I should like to bring up a feature of pro-organisms that has not been mentioned so far; in fact, I do not know how this was left out as a question. It seems to me that one of the criteria (and an important one) of living things is that they are different internally from the medium in which they live. In other words, there is a surface, which in living cells we call a "cell membrane," that permits certain substances to pass and prevents others from passing. Not only are organic molecules retained, but some inorganic ions become concentrated inside while others are excluded; different concentrations of ions inside and out are due only slightly to binding by organic molecules but more to properties of the surface. I suggest that the selectively permeable surface is one of the criteria that should be applied to a pro-organism, certainly at a more complex stage of organization than the nucleotide molecule. I should not wish to end this discussion without emphasizing that the surface of the macromolecules that constituted pro-organisms was certainly there before there were organisms.

GAUSE: There is one special point I should like to mention here. It seems that the invention of cytochromes and other mechanisms that made possible the aerobic way of life was very important in the evolution of living matter. We can judge the importance of all these mechanisms now by the analysis of certain retrogressions to a primitive state that accompany the injury of cellular respiratory mechanisms. Cancer is one of these. In tumor cells the impaired respiration is accompanied by many losses, which make their disorganized growth possible. This problem is of wide biological significance, and its manifestations can be observed in various forms of life.

SHAPLEY: Gause is an expert on the relation of cancer to the processes we are talking about.

EVANS: The aerobic process is much more effective from the standpoint of energy supply. For example, the anaerobic use of glucose gives only about one-eighth the energy that can be obtained aerobically. From the standpoint of efficient utilization of foodstuffs, aerobic mechanisms are obviously much more efficient.

SHAPLEY: Would you say what "aerobic" and "anaerobic" mean?

EVANS: Aerobic pertains to metabolic processes requiring and using molecular oxygen, while anaerobic pertains to metabolic reactions that can occur in the complete absence of oxygen.

GAUSE: It is clear that there are important quantitative differences

in the efficiency of utilization of energy under aerobic and anaerobic ways of life. But, as Pasteur pointed out, there are also important qualitative differences: certain processes and differentiations in living matter can occur only in the presence of oxygen.

GERARD: In getting away from proto-life, you frightened me so that I kept quiet for a while. But now we are up to cancer and multicellular organisms, I should like to point out (this really ties back to this question of aerobic metabolism and also back to energy sources) a very striking thing: that this relatively complex porphyrin molecule was used first to make chlorophyll, which captured sunlight energy and made possible the great deployment of plants and therefore of animals.

Second, it was the basis of most of the oxidizing enzymes in cells, which made possible the exploitation of the aerobic mode of life and greatly increased the rate of metabolism. And, since living things are always meeting stresses and are always competing with each other and since survival does depend on a certain degree of fitness, the organism that could move faster "got there fustest," and the early bird got the worm, and all that—not worrying about the worm.

The next advance along the same line happened in multicellular animal evolution, where, with rise in body temperature at a greater rate, it again became necessary to get oxygen into the inner cells that it could no longer reach through diffusion. And respiration and circulation and the like really depended on still another biological invention based on this same basic molecule: the invention of hemoglobin, which made it possible for blood to carry tens or even hundreds of times as much oxygen as it could carry before. And so each step in this molecular evolution made possible new advances that solved bottlenecks in the further advance of living organisms.

PROSSER: It is all based on the same type of molecule.

GERARD: That's the point: all three of these inventions involve the basic porphyrin molecule.

GAFFRON: In certain bacteria one has a model of the adjustment from anaerobic to aerobic life. So long as there is no oxygen, they multiply very nicely at the expense of organic compounds by the inefficient, but quite workable, process of fermentation. As soon as oxygen is admitted, they die. However, if the bacteria find in their surroundings some of these porphyrin iron compounds—ordinary hemin, for instance—they take these in and produce for themselves the proper iron-proto-porphyrin enzymes for respiration and also enzymes to destroy hydrogen peroxide—should this dangerous substance be formed—and under these circumstances they are not killed by oxygen but live happily ever after.

These bacteria must take up their porphyrins from the medium,

just as a diabetic needs a shot of insulin from time to time; so actually what we have here is not yet a permanent adaptation to aerobic conditions. But, should the favorable circumstances continue long enough, one could assume that by the process of Darwinian evolution and selection the bacteria could learn not only to use but also to synthesize porphyrins. This is one of the possible models of a biological adjustment to the change from anaerobic to aerobic conditions.

SHAPLEY: Nature has made two major inventions—photosynthesis and hemoglobin—and without those we wouldn't be here. I shall ask Darwin for a comment about the next question, topic No. 6:

What is the probability of life on other planets?

DARWIN: I hoped you would begin by saying how many planets there are that could support life.

SHAPLEY: Myriads; maybe multillions.

DARWIN: 10^{20}?

SHAPLEY: More than 10^{20} stars. And those stars are competent to provide life for any planets around them. Probably most of them would have planets of some sort, so your 10^{20} is all right.

DARWIN: As I understand the question, it is whether life is an extremely improbable event or whether it could happen easily. I like to put these things in numerical figures, which are easier to grasp. Therefore, let me assume that it has happened only once.

SHAPLEY: Once in 10^{20}?

DARWIN: Let us assume that we have sent out space ships to explore all the planets in the universe where conditions could support life and that we have found them all absolutely bare. Then we can say that the creation of life is an extremely improbable event, having happened only once in 10^{20} times.

I like to put these things in numerical form, and the easiest way is to think of the spinning of a coin. If you spin a coin five times—playing not with a stranger in a bar but with a trustworthy friend—you are unlikely to get heads all five times. But once in about thirty times you will. My calculation is that if the creation of life is an exceedingly improbable event, which has happened only once in the whole universe, that is as though, in playing the game against the other planets, we had won the toss about sixty times running with no failures in between.

SHAPLEY: That is dramatic enough. That 10^{20} is a hundred thousand million billion—American billions.

If we are referring to the planets of this system, I would say the chances of life are pretty dim, but not conclusive. If you will ask the

question a few years from now, we shall be able to answer it a little better than we can now. The conditions on Mars are such that low forms of life, like the algae, maybe mosses—very low forms like lichens—could apparently exist. We don't know very much about conditions on Venus, except that there is very little oxygen in its atmosphere and therefore not much plant life. In the future we might penetrate the shield of clouds and learn something about the surface.

The probability of other life in our solar system is not very high; but, with 10^{20} other suns and a great deal of cosmic time and the method of the birth of planets pretty well worked out (there are two or three methods), we could say that the probability is exceedingly high that there is life—not our life; probably not vertebrates or anything of that kind—on at least one hundred million (I use one hundred million just to be conservative), a hundred million where there has been a long evolution of organisms. This is all speculation; but I have to call to your attention that the one place we have found life—in fact, practice it—is just an ordinary planet around an ordinary star—a run-of-the-mill star—which is out at the edge of a galaxy that has at least one hundred billion other stars; and that galaxy is one of billions. It is asking too much to think that this is the only place. I believe you get "tails" once or twice in your sixty throws, all right.

DARWIN: I agree entirely that it is much more likely that the chances for life are very much stronger. If you only needed to win twenty throws instead of sixty, there would be a good chance of life on a great many planets.

SHAPLEY: As I understand it, you are a little stingy with life?

DARWIN: It gives you much better chances.

SHAPLEY: Oh yes, much better.

Many astronomers would say that, from the way stars are born, every one of them would have a family of planets (unless it is a double star that could perturb planets out of its system). That would mean a tremendous number of stars with planets. To go from that to the number that would have liquid water and from that to the number where life started, of course, diminishes the chances from 10^{20} to a mere, say, one hundred million. But those who speculate on this think I am very conservative.

MULLER: I should like to mention a hypothesis that I think is held by a number of people, one expressed by the Burbidges in *Science* about a year ago: that only in stars of what they call the third generation or later are there enough of the heavy elements to support life as we know it and that our sun is apparently one of the oldest of that youngest generation of stars, and therefore presents much more

suitable conditions for the evolution of life as we have it on earth than the vast majority of other stars would. Do you think there is some basis for that theory?

SHAPLEY: That is included in my calculation. The Burbidges and others—Fowler, Greenstein, and others—have worked out very brilliantly, and it seems to me very convincingly, the evidence that the atoms of matter themselves evolve, and so evolution applies not only to the biological world but to the world of matter. Our sun is a middle-aged star, but we have in our catalogue at Harvard 40,000 stars whose spectra are the same as the sun's. That, I think, is an indication that about 10 per cent of all the stars—that is, more than 10^{19}—would be like our sun. To be like our sun and still able to carry out these particular biological activities, I would be willing to say perhaps only one in a million. In fact, I have said that only one in a million million stars might support life. Therefore, life does not have to appear very often to attain that number of a hundred million. We support the proposition, you see, that the new work on the origin of life—like the Miller-Urey experiment—and the new evidence of an expanding universe and new evidence of the total number of stars give us very good and convincing indications that conditions elsewhere throughout the universe must be very favorable for life. And I think I am doing a service to this group if I point out that you ought to be proud you are in such a grand universe.

DOBZHANSKY: I was rather embarrassed to find myself on the panel discussing the origin of life, which I know nothing about. The only thing I hoped was that I might keep silent and look wise. One of my distinguished colleagues told me that he doubted that I would be able to do either; and you see he was right.

Now, I don't know the probability of life on other planets. I take it that this probability is fairly high. But if life does exist on other planets, and even on a very large number of these, it does not follow that this is very much like the life we know. To put it a little more exactly, it does not follow that the evolution of life on these other planets has been very similar to the evolution of life on earth. Evolution is a long and complex process involving very many changes in the genes and the nucleic acids and so forth. Now the likelihood that these changes could have occurred twice in the same way, either on earth or on other planets, is not great. This seems to me an important point, because very often when people speak of life on other planets, they automatically assume that Martians, for instance, will be pretty much like us. This does not follow from the evidence; personally, I think it is improbable.

SHAPLEY: Topic No. 7 asks

> What are the possibilities of transport of germs through space?

MULLER: Germs in space, unprotected by a good deal of solid material around them, would be destroyed by radiation of varied kinds—protons and photons, ultraviolet and gamma—before they reached another planet. I do not see how they are going to get out into space, short of something like volcanic action, in which case it is hard to understand why they should not be killed, unless, of course, it is done artificially.

SHAPLEY: If it is left to nature to infect us with spores from other planets, the probability is very slight; but if they were pushed in hard with rockets, they might get here with proper protection. I think we agree on that.

GERARD: What about the evidence of meteorites with living things in them; is that valid or invalid?

GAFFRON: Not quite living things. There are meteorites that contain up to 24 per cent carbon; and this carbon is neither methane nor a simple hydrocarbon, but rather complex organic material containing nitrogen. According to Edward Anders, at the Fermi Institute, it is 24 per cent carbon, 8 per cent hydrogen, 4 per cent nitrogen, 8.8 per cent sulfur, and 6 per cent chloride; the rest would be oxygen. This points to a rather complex organic material, supposedly even older than the crust of our earth.

SHAPLEY: Carbonaceous chondrites.

GAFFRON: Yes. And their age has been determined by radioactivity comparisons. Some of the odors they give off on heating have been described as garlic- and cinnamon-like.

SHAPLEY: If it smells like garlic, it is cosmically important. We are indebted to Anders for this new, accurate chemical analysis, which sounds very important.

What about propelled germs? For instance, how about sending rockets to the moon that are full of germs and causing trouble on that body? Gause is an expert on this.

GAUSE: To avoid possible contamination of the moon by microorganisms from terrestrial materials in moon shots, a group of microbiologists at the Institute of Microbiology of the Academy of Science of the Soviet Union is planning a thorough sterilization of materials forwarded to the moon.

SHAPLEY: Of course, they know how to do that. So apparently the moon is all right. To me it sounds a little bit ridiculous, but probably

necessary, so that when we get to the moon we shall find it unsullied.

Arrhenius is one of the persons associated with the idea of pansperms in early times when it was thought that perhaps life did not start on this earth but came in on meteorites or otherwise from other worlds. That theory was pretty generally dropped when we learned about cosmic radiation and other hazards. It is highly improbable that we have any living contact with other planets around other stars.

GAFFRON: *Science* of November 20 contains a note by Carl Sagon on this subject. He says that if spores ever reached the moon, they would have to be imbedded below the soil in order to survive, or they would be destroyed very quickly by solar radiation.

DARWIN: You could guess the sort of speed at which they would hit the moon. Did he estimate what the collision itself would have done to them? Couldn't this be quite enough to burn up anything inside as well as outside?

SHAPLEY: Yes, it would. If anything falls on the moon, it is going to be explosive unless it comes in very slowly; but if you are ingenious, probably you can slow up your infected rocket and come down on the moon without burning it up.

GAFFRON: Anders says that chondrites have not been internally heated above two hundred degrees.

SHAPLEY: Have members of the panel further points to discuss? If not, I shall make a brief summary.

We started out by agreeing that we should not make an exhaustive definition of what life is, because we don't agree on a definition; but we did agree that after a thing had developed a while, we should probably all call it "living." We pointed out that Darwinian evolution is no longer a theory but a fact; and we discussed the viruses. We pointed out that the idea that life came from non-living matter is a consequence of our knowledge about the inorganic world and the biological world.

We went into various questions. We agreed that the early conditions on the earth favored an early accumulation of organic substances. Were the first organic compounds of such kind that they could be readily transformed into parts of living things? Yes, some of them. What about the principles of replication governing self-regulating molecules? We discussed that in a highly technical way. Our discussion of how nucleic acids coat biological products was fairly technical biochemistry.

Can life originate under present conditions on earth? We think the answer is No. Too much oxygen, too many bacteria. Can it occur in a test tube? The decision was Yes. To do it completely, however, may take longer than we think.

We summarized the sources of energy in the origin of life and

mentioned gamma radiation, lightning, the heat of the earth, and especially ultraviolet light from the sun.

What is the probability of life on other planets? I think we agree (although we objected on some details) that it would be presumptuous of us to suppose that the only life that exists is that on the earth. That would be very improbable.

What about the possibility of transporting germs through space? We think it would be hard on them. I think nobody would hold that there is a danger of infection by germs from other planets, especially if these came here by natural methods and were not propelled. That led us then to the moon shots, and we were assured by Gause that thorough sterilization was practiced in the famous Russian shot. This is a quick summary.

Before we adjourn, I wish to ask Gause, our distinguished guest and panelist from Moscow, if he would make some concluding remarks.

GAUSE: Since it seems to me that the discussion we have just had on some problems of the origin of life was very useful, I am pleased to say that it had much in common with, and reached almost the same conclusions as, an earlier discussion of the origin of life, held in Moscow, to which many American participants were invited. I hope this is the beginning of many scientific discussions, and I hope the co-operation now developing in various fields of science will contribute to a better understanding between our countries.

PANEL TWO
THE EVOLUTION OF LIFE

Chairmen: Sir Julian Huxley and Alfred E. Emerson
Panelists: Daniel I. Axelrod; Theodosius Dobzhansky; E. B. Ford; Ernst Mayr; A. J. Nicholson; Everett C. Olson; C. Ladd Prosser; G. Ledyard Stebbins; Sewall Wright

Preamble

Biologists one hundred years after Darwin take the *fact* of evolution for granted, as a necessary basis for interpreting the phenomena of life.

Life, to the biologist, denotes the totality of self-reproducing metabolic organizations of matter and energy comprised under the head of "organisms." The problems of its origin from non-living systems and of intermediate stages between living and non-living have been discussed by Panel One. Life first appeared on this planet over 2,500,000,000 years ago and has been steadily evolving since then.

Evolution is definable in general terms as a one-way, irreversible process in time, which during its course generates novelty, diversity, and higher levels of organization. It operates in all sectors of the phenomenal universe but has been most fully described and analyzed in the biological sector.

Life appears to depend on self-replicating and self-varying (mutating) organic macromolecular strings of DNA, which also act as templates for the function of specific proteins, although RNA molecules may also be implicated. In all organisms except viruses, genetic and evolutionary "information" is carried by DNA organized into chromosomes in combination with protein.

Points for Discussion

1. One major concern of modern evolutionary biology is research on the mechanisms of evolution, particularly as studied by experiment, in the field and in the laboratory.

2. The production of genetic variants resulting in new genotypes is enormously amplified by sexual recombination. This consists of an exchange of material between homologous gene sets. This is perhaps an inherent property of DNA strings and certainly must have started at an extremely early stage.
3. The self-replicating and self-varying properties of DNA inevitably lead to natural selection—i.e., the differential survival and reproduction of biological variants. Mutation and recombination provide the raw materials for evolutionary change; natural selection is the guiding, or directive, agency in such change. Other agencies, such as random "drift," will sometimes lead to non-directive genetic change in populations, which may be combined with directive change.

   Modern studies on the material basis of inheritance and on the efficacy of natural selection rule out Lamarckian or vitalistic-orthogenetic theories of evolution.
4. Natural selection as a mechanism for generating an extremely high degree of improbability. Change-inhibiting (stabilizing) and change-promoting (novelty-producing) forms of selection. Meaning of biological fitness. Selection between individuals of the same sex, within and between populations, between species and higher taxa, between communities. Selection involving competition and selection involving co-operation.
5. Biological evolution always shows a combination of continuity and discontinuity, a compromise between stability and change, and an interplay between randomness and directional selection. Indeed, all characters of all organisms represent compromises between several biological needs or values.
6. The relations of developmental (epigenetic) and physiological processes to selection and evolution are proving to be very important: e.g., stabilization (canalization) of developmental processes, partial simulation of Lamarckian evolution by genetic assimilation and other evolutionary "feedback" mechanisms. The role of pedomorphism and recapitulation in evolution.
7. Natural selection may lead to side effects, which at the time are of no adaptive value ("correlated characters," Darwin; "consequential characters," Huxley). These may later provide the basis for adaptive change or even open the door to new major evolutionary advances.
8. The evolution of sex as an illustration of evolutionary process: "Sex" was originally a mechanism for insuring genetic recombination by interchanging portions of separate gene sets and involved no distinction between male and female. Later came the differen-

tiation of two sexes, first in respect of gametes, later of accessory, and still later of secondary sexual characters.

9. Another major concern of modern evolutionary biology is the study and analysis of the *course* of biological evolution, as actually shown in fossils and as deducible from the data of taxonomy, comparative anatomy and embryology, animal behavior, geographical distribution, and ecology.
10. The process of biological evolution involves the integration of three component processes:
    a. Diversification, leading to branching and to the formation of separate and distinguishable species and higher taxa
    b. Transformation, leading to detailed general adaptation, both structural and physiological, greater efficiency of various functions, more advanced and better-integrated organization, including the organization of behavior and emergent mind (to be discussed in detail by Panel Four)
    c. Stabilization, leading to the formation of stabilized patterns of organization at all taxonomic levels and to their persistence indefinitely or over long periods.
11. Isolation of various kinds appears to be a prerequisite for all degrees of diversification by branching. Stabilization may be brought about by a number of factors—physiological limitations, high specialization, etc.—superposed on a successful stabilized pattern of organization. Long-term stabilized persistence occurs not only in reduced and relict types (e.g., Reptilia; *Xiphosura*), but in new dominant types (e.g., ants, birds). Transformation always leads to adaptive or, better, *teleonomic* results.
12. Evolutionary novelty at all levels from the species up appears to be achieved by means of breakthroughs from one stabilized system (pattern of organization) to another. Such breakthroughs often involve some degree of *preadaptation,* the employment of pre-existing biological and chemical characters to produce novel results. They are always unusual events (e.g., for new species) and for major groups such as classes are very rare (e.g., from Reptilia to Aves and Mammalia).
13. Biologists are increasingly concerned with the formulation of general rules and the study of long-term trends operating in evolution. The major trends include those toward greater size; toward greater efficiency of particular functions, such as digestion or locomotion; toward higher levels of organization (greater differentiation and integration) of structure, physiology, and behavior; and toward the emergence of more elaborate mental functions.

14. Some of these trends can properly be called *progressive*. Biological progress may be defined, or at least described, in terms of the upper levels of "improvement" achieved during evolution in certain properties of organisms. It is neither inevitable nor universal. Regression in some functions may accompany advance in others (e.g., parasites). In most groups stabilization appears to have set in well before the Pliocene, so that no major later evolutionary advance for them was possible.

    It is interesting to compare the criteria of advance or progress in plant and animal evolution.

15. Biological progress is marked by the successive emergence (breakthrough) of new, successful ("dominant") types. The rise of each new dominant type alters the evolutionary-ecological pattern and introduces new factors into the evolutionary process. The study of the emergence and radiation of new dominant types is leading to many important conclusions about the role of time in evolution, the different rates of evolutionary change in different groups and in different times during the rise of single groups, and with different environmental opportunities.

    The emergence of man as the dominant type will be considered in detail by Panel Five. Meanwhile, it has altered radically the evolutionary-ecological situation and has rendered the emergence of any other dominant group impossible. The question whether evolutionary change is still occurring, and by what methods, will be left for Panel Five to discuss.

16. The last few decades have witnessed the growth of a "synthetic" theory of evolution, linking the findings of many separate disciplines. These include genetics, selection theory, paleontology, taxonomy, behavior, embryology, plant and animal physiology, biochemistry, biogeography, and ecology. Though great progress has been made, there are large areas in which new research and study are needed and will undoubtedly yield fruitful results.

THE DISCUSSION

HUXLEY: I hope I can be as good a chairman as Shapley was yesterday. I rather think not; the combination of Napoleonic firmness and humor is very difficult to emulate.

We are meeting to discuss the evolution of life, yesterday's panel having discussed its origin. We have here a number of persons distinguished for work in various fields of biological evolution: Axelrod, in paleobotany; Dobzhansky, in population genetics and in polymorphism; Ford, in genetics in nature and in relation to population; Mayr,

in the formation of species in nature; Emerson, in ecology in nature. Several of us are essentially naturalists who have gone to the laboratory. I have studied various things in nature; Nicholson has done the same. Olson is interested in past nature—paleontology and fossils—and Prosser is interested in physiological nature; Stebbins is a botanical naturalist. Sewall Wright, I believe, likes to be remembered for his classical work on the genetics of guinea pigs, but the world will remember him for his immense contributions to general genetic and selection theory.

The evolution of life is no longer a theory; it is a fact and the basis of all our thinking. It seems extraordinary now that the mere idea of transformation caused such an outcry and occasioned such distress to Darwin himself.

We do not intend to get bogged down in semantics and definitions. We began by taking certain facts for granted, and therefore we drafted a preamble, which I shall now read to you. We say that life, to the biologist, is not an entity but denotes the totality of self-reproducing metabolic organizations of matter and energy, usually comprised under the head of "organisms." The problems of its origin have already been discussed. It first appeared on this planet about two and one-half billion years ago—probably rather more—and has been steadily evolving since then.

By "evolution" we do not mean any mysterious force. We mean a process. It is a one-way process in time, not irreversible in the sense of being irrevocably determined from within but in that it appears not to be actually reversible, as various chemical reactions are. In its course, evolution produces a large amount of novelty and diversity and also generates higher levels of organization. (Later on, we shall try to see whether we can define either "higher" or "organization"; this is not very easy.) Evolution operates everywhere, in the whole universe, but has been most fully described and analyzed in the sector dealing with life.

As we saw yesterday, life appears to depend on self-replicating and self-varying (or mutating) organic macromolecular strings of DNA; and in all organisms except a few viruses, so-called genetic and evolutionary "information" is carried by DNA organized into chromosomes in combination with protein. That is the physical basis of evolution.

STEBBINS: I think at the very beginning we should emphasize the point made yesterday that organization and processes are as much a part of life as are the life-substances—the nucleic acids. We see this, for instance, from experiments with viruses, showing that activities do not occur unless the nucleic acids are organized with proteins but that the nucleic acid determines what kind of activity will take place.

An analogy with a corporation might be made here. The nucleic acid is the head office, but the head office cannot function without workers, materials, factories, and so on. I think this analogy is better than calling the nucleic acid the real or the only basis of life.

Another point I think will come out in this and subsequent panels is one that Wright has often emphasized: when we talk about evolution, we are talking about a succession of higher levels of organization, starting with the chemical and physical level, going up through the level of primitive one-celled organisms into the organization found in the muscles and tissues of a higher animal and, finally, into the kinds of organization found among animals in various sorts of social systems. Here, I think, we should qualify the statement that evolution is irreversible, since simpler forms of organization have often come from more complex forms. Fleas, for example, evolved from more complexly organized insects; and many other examples could be cited.

Perhaps this is a good place to mention a point that Huxley raised in *Evolution: The Modern Synthesis,* that any definition of evolutionary progress concerns the fact that, as a result of natural selection, species with higher levels of organization are more likely to dominate their environment than are species with simpler levels of organization.

HUXLEY: Certainly, a particular direction or trend in evolution can be reversed, but the process as a whole appears to be irreversible, which is a different thing.

You raised a very interesting point about increase in organization. There has been an immense increase in organization, even in the chemical basis of life, from tiny snippets of DNA in viruses and short strips in bacteria, to the enormous "tape recordings" in the chromosomes of higher animals. In the organization of this coded "information," the size of the codebooks has multiplied from a little notebook to volumes and multivolume encyclopedias.

I remember years ago reading of a schoolboy, asked to write an essay on evolution, who produced one immortal sentence for the whole of his essay: "Mr. Darwin said that the first monkey was a sort of jelly." Well, that is an abbreviated description of the course of evolution—not very complete, but a gallant attempt. But it pays no attention to how evolution happened—to the mechanism. This is what we want to get at now.

Item 1 of our agenda says that a major concern of modern evolutionary biology is research on the mechanisms of evolution, particularly as studied by experiment, both in the field—in nature—and in the laboratory.

FORD: First of all, I think it is necessary to clear our minds about

this. Experiment in the field includes carefully controlled observations, which can provide just as good scientific data as experiment in the laboratory. To take a simple instance: in establishing a new colony of butterflies on a small island in the Isles of Scilly, the population was taken from a large island, where its characteristics had remained constant year after year. The spot distribution of the new colony gradually changed, but the population from which it was taken continued steady, acting as a control all the time. That is a perfectly valid control. It is a question of observation rather than experiment, in one sense.

I should like to raise two other points. To study evolution actually going on in the field, it is necessary to pick situations in which natural selection is operating rather powerfully, and those who have worked on evolution taking place in wild populations have been careful to do this.

The third point is that when we say we are studying evolution in the field, we do not mean merely the spread of characters due to changes in the environment but also actual changes in the characters themselves. Let me give you an instance: Black moths have spread in the industrial areas of Britain within living memory. To examine the rate at which they have spread, how they spread, and what conditions make them do so is very important. But a point many people miss is that, in spreading, the black forms themselves have changed and evolved, and, by examining them in the laboratory and breeding from them, one can demonstrate that evolution. One can reproduce it experimentally by genetic methods in the laboratory and demonstrate its occurrence in the field.

HUXLEY: I might add that the blackness is definitely adaptive and that the black form has got blacker. A beautiful experiment in the field is that of H. B. D. Kettlewell, who showed that birds picked off a majority of those moths that did not match their surroundings. This was an actual quantitative experiment.

OLSON: I wonder if I might carry this discussion of experiment a bit further. I am, of course, a non-experimental paleontologist among geneticists. Axelrod and I are often at odds with interpretations of experiments, since we derive data differently. But we are interested in the mechanism of evolution in two ways. First, we are interested in what the experimentalists find out and provide for our studies. We feel, however, that our scale is much greater than theirs, and so we sometimes question its total applicability. Second, since we work on a greater scale, we think that we can see things that should be turned over to the experimentalists for study, and in this way, by direct study

of the fossil record, we can contribute to the understanding of mechanism. I believe we can broaden out further in this direction to the benefit and understanding of all.

HUXLEY: I agree. All progress in any subject, such as biology, involves straight description, comparative observation and analysis, and experiment, with a constant interplay between them all.

Now we come to item 2—the production of genetic variance, which, of course, provides the raw material for all evolution and is enormously amplified by sexual recombination, involving an exchange of material between homologous gene sets. This is perhaps an inherent property of strings of DNA and certainly must have started at an extremely early stage.

I think Stebbins wants to bring up James Thurber's famous question.

STEBBINS: "Is sex necessary?" I think we should always quote from eminent scientists when we can. Muller gave an answer to this question about thirty years ago, when he pointed out that a continual shuffling of genes, which results from sexual recombination, is necessary to generate the large number of gene combinations needed to produce a new adaptation. We can also answer Darwin's question: Why do flowers make so many efforts to insure or enforce cross-fertilization? The selective value of cross-fertilization is the generation of new gene combinations, since we now know that adaptiveness depends not just on one or two genes but on an adaptive complex of many genes.

WRIGHT: I should like to give an estimate here, bringing out the extent to which recombination amplifies the variability due to mutation. With only twelve loci and four alleles (ten compounds) in each, there is the potentiality for 10^{12} or a million million different genotypes. One hundred loci with four alleles each is still a very modest number, considering that mutations have been described at some five hundred loci in the fly *Drosophila melanogaster* and that some twenty alleles have been found at one of these loci. The three hundred mutations in this case imply the potentiality for 10^{100} different genotypes. It has been estimated that there are less than 10^{80} elementary particles in the universe out to the distance made visible by the Palomar telescope. The number of potentialities—not, of course, actualities—from one hundred loci, four alleles each, is thus that of the number of elementary particles in 10^{20} such universes.

HUXLEY: For many years biologists often said or implied that mutation was the source of all evolutionary change. It is the original basis, the raw material out of which the larger bricks are made; but in the last twenty years we have seen that recombination of genes and alleles is equally important, in a sense even more so, and just as essen-

tial. And it is amazing how many of these possibilities can be realized even in one population.

DOBZHANSKY: Again we come back to the problem of sex. Stebbins asked: Is sex necessary? My answer would be that it is at least desirable. Sexual recombination of gene stores in natural populations produces a really tremendous amount of genetic variance, an amount much greater than we dared to suppose even a few years ago. I think one may be justified in making the rather extreme statement that, at least in sexually reproducing higher organisms—taking *Drosophila* to be a higher organism—suppression of the mutation process, if this were possible, would probably have little effect on the evolutionary plasticity of the population for some time to come.

EMERSON: I should like to add one point about the evolution of sex mechanisms. Most of our theory of evolution and most of our data are based on the analysis of individual organisms. Many years ago—as early as 1912, I believe—Huxley wrote a book about the individual; and still most of our biological information is based on the individual. These data on sex recombination mean that, besides the individual, we are all included in higher-level organizations composed of relations between individuals. Sexual recombination and its importance in evolution necessitate an elementary population structure, so that higher levels of organization involve supra-individual systems.

HUXLEY: Yes; and those are acted upon by selection. Stebbins' earlier point that DNA can do nothing unless it is part of a system with proteins is, in a way, obvious—so obvious that it is often neglected. In the same way, an individual organism can't do anything unless it is in an environment in a systematic relation with other organisms.

We say in point 2 of the agenda that sexual recombination must have started at an extremely early stage. Is anybody willing to say how early? Did it exist right from the beginning, or how soon did it appear?

STEBBINS: In my published paper I agree with Ellsworth Dougherty, one of my colleagues from Berkeley, that sex, or at least genetic recombination, started with life itself. There is a question whether the term "sex" should be used for the types of genetic recombination occurring in viruses and bacteria; and the term "parasexual phenomena" has been used for recombination in those organisms. When we realize that these *parasexual* phenomena occur not only in viruses but in various kinds of bacteria, the old idea that recombination did not appear until after we had a full-fledged nucleus with its complement of elaborately constructed chromosomes, as well as the various cytoplasmic structures, must be abandoned. One very important point here is this:

if we say that genetic recombination is necessary to generate new adaptive systems and then say that such highly adaptive and complex systems as the cell of an amoeba, or a euglena, with its nucleus, chloroplasts, eyespots, flagella, etc., evolved without the aid of genetic recombination, we are contradicting ourselves. Even though we don't know that genetic recombination exists in these one-celled organisms, we must postulate its existence at the time they evolved.

HUXLEY: That is a very important point. It seems increasingly probable that DNA is so important because, as Muller said yesterday, it has the two properties of self-replication and mutation or self-variation. It also seems probable that, from the outset, DNA had this ability to recombine bits of itself with other homologous pieces. If so, then this basis for more rapid evolution was present right from the beginning.

This leads to point 3: the self-replicating and self-varying properties of DNA inevitably lead to natural selection. As Darwin himself said, "natural selection" is a metaphorical term and thus has led to misapprehension. No conscious action is involved in natural selection: it is the name we give to the results of the differential survival and reproduction of biological variants. Mutation and recombination provide the raw materials for evolutionary change. Natural selection is the guiding or directive agency in that change. Other agencies, such as so-called random "drift," sometimes lead to non-directive genetic change in populations, which may, however, be combined with directive change.

WRIGHT: As Huxley brought out, the essence of Darwin's theory of natural selection is that the interplay of random variation and selection leads step by step, through thousands of little steps, to results that are utterly unthinkable as occurring at a single step. Modern genetics fully supports this concept. I do not think any prominent geneticist now would question the essential validity of Darwin's conception of natural selection as the guiding principle in evolution. There is, however, a difference of opinion about the roles played by random variability at different levels. The genetic mechanism, as we know it now, provides variability at two general levels: (1) that of mutation, whether genic or chromosomal, and (2) that of recombination.

There is, first, what seems to me the oversimplified view that mutations, classifiable as favorable or unfavorable, provide *directly* the random variability that is sifted by natural selection. In a population that has been living under a constant set of conditions for a long time, all the recurrent mutations would have been tested; fixed if favorable and kept at very low frequencies if unfavorable. It is highly unlikely

that a *novel* mutation will be favorable. Under these conditions, the members of a species would be homozygous in the same sense in nearly all loci, and recombination would play no appreciable role in evolution. The possibility for evolution is thus decidedly limited.

The situation is more favorable in a species living in an environment that changes systematically from time to time. Recurrent mutations that have been unfavorable may give better adaptation to new conditions than did the old-type genes and may displace these fairly rapidly. An example is the beautiful case described by Ford, in which the environment changes from one in which light-colored moths are protectively colored to one of soot-covered trees, in which light-colored moths are very conspicuous to birds. Mutations that darken the color approach fixation with great rapidity. Again, the recent rapid evolution of cyanide resistance by scale insects, of DDT resistance by flies, and of penicillin resistance by bacteria under intensive efforts at control by these agents are examples that are beautiful only from the evolutionary standpoint. The hypothesis that evolution proceeds from the direct selection of favorable mutations is thus a possible view, but only in conjunction with systematic changes in the environment. The process is somewhat like a treadmill, with the species continually trying to keep up with a continually deteriorating environment.

It seems unlikely, however, that the enormous amplification of variability by recombination plays no role. It has been abundantly demonstrated that the effect of a combination of genes is, in general, very far from being merely the sum of the effects assignable to the component genes. This is especially the case with selective value itself as a character, since the optimum grade of any quantitatively varying character, even one that is evolving rapidly, usually differs little from the mean at any given time, with the consequence that each gene with a positive effect tends to be favorable in combinations below the mean and unfavorable in those above. In a population that is breeding at random, favorable combinations of genes are broken up in the formation of the germ cells. There is delay in the case of linked genes, but this is only momentary in terms of geological time. Selection can thus operate effectively in this case only on the net effects of the separate genes, not on the genotypes.

There seem to be only two general ways in which selection may be based effectively in the genotype as a whole. One of these is by the interpolation of many generations of asexual reproduction between crosses, during which selection is between clones. Unfortunately, the most advanced organisms—most insects and practically all vertebrates—do not make use of this. Among these, the only possibility seems to be through the more or less random differentiation of local

populations and selection among these by means of differential expansion and contraction. If the species is divided into a great many largely, but not completely, isolated small communities, these will inevitably drift apart in genetic constitution, partly under the influence of differences in local conditions and partly from random processes. Such random changes occur whenever a population passes through a bottleneck of small size. Moreover, fluctuations from the prevailing trend of selection and of immigration have effects that may be considered random. Under the above conditions, each community will carry many slightly different alleles at each locus, and these will be in different frequencies from those of other communities.

One consequence of selection toward intermediate values of quantitatively varying characters in conjunction with pleiotropy (multiple effects of each gene) is that there are a vast number of selective peaks at different levels of selective value. This presents a serious obstacle to selection under random mating, since the stronger the selection, the more firmly the population is bound to a single selective peak—not, in general, a high one. If, however, the species is subdivided as described, those local communities that have more or less accidentally attained relatively high selective peaks behave as population founts, and those that are held at relatively low selective peaks behave as population sinks. There is continual outflowing from the former and the formation of new founts by interaction. This process can go on indefinitely, though largely invisible over considerable periods of time, since it applies directly only to alleles that differ only slightly in effect (modifiers, isoalleles). It should be added, however, that random differentiation of local populations with respect to modifiers may prepare the ground somewhere for acceptance of a major mutation that has been kept at low frequency by unfavorable side effects.

From a broader standpoint, we may, I think, say that the most favorable condition for evolution, including cultural as well as organic, is a suitable balance between inbreeding, whether in the literal genetic or the figurative cultural sense, and cross-breeding, again whether in the literal genetic sense or the figurative sense of cultural diffusion and interaction.

HUXLEY: The environment of any species is by no means uniform. It often varies seasonally, periodically, and so on, and this may result in polymorphism, based on balanced systems of genes or alleles in the population, one adapted to one set of environmental conditions and the other to another. Dobzhansky has done very interesting work on this.

DOBZHANSKY: That refers to a point I brought up earlier: the existence in natural populations of a tremendous store of potential vari-

ability that can be released by recombination, by the Mendelian process that is going on all the time.

MAYR: Our opinions have been so harmonious up to now that I should like to introduce a slightly dissonant note. Wright said that mutations are practically always injurious. This is certainly true of the majority of the mutations studied by the geneticist. But the geneticist does not work with a random sample of mutations; he picks out those that are easy to work with because they are very conspicuous, and these are nearly always injurious. There is a great deal of evidence —and mounting evidence from the study of isoalleles—that many other mutations have exceedingly slight effects and are not necessarily harmful. They may be injurious or not, depending on the total genetic background of that species or population or individual and on the physical environment. If one thinks in terms of the DNA code, one can easily imagine that some shifts in the code will have such a slight effect on the chemical it produces that it will not be disruptive. So I think that there is a good possibility that a considerable percentage of mutations are not necessarily injurious.

HUXLEY: Isn't it possible that a great number of small mutations gives the gene complex an additional elasticity—a kind of capacity for regulating itself?

MAYR: Very definitely, I should say. The fact that, when a major mutation occurs, its phenotypic expression can very rapidly be modified by selection indicates that all sorts of alleles having this general effect are present in the gene pool.

HUXLEY: Ford just now gave a very good example of how a mutation that is bad in some circumstances may be good in others. The small mutations that made black moths blacker would originally have been deleterious, but, once there was a black form under positive selective pressure, they were advantageous.

Item 4 includes a very important point: the distinction between change-inhibiting (stabilizing) and change-promoting (novelty-producing) forms of selection. Of course, sex is involved in this and, in non-sexual phases or forms, variance will be much reduced.

EMERSON: I think there is a balance between the replicative function of genetic material and its function of change; and this conservative aspect produces a certain degree of stabilization. It is very important for the organism to hold on to the adaptive adjustments it already has. Sometimes this stabilization operates for a very long time, with a high order of genetic identity involved. Also, as the organism becomes reasonably well adjusted to an environment, selection operates against change rather than for it. In some instances, the sexual system has been eliminated by the organism because it pro-

duced possibly too much variation, which was too likely to be deleterious in an organism in a stable environment with a high order of adaptation; so that stability runs along with change in the process of evolution and produces this constancy that we see along with evolutionary change.

HUXLEY: I am afraid that we must pass to the next item of point 4: selection between individuals of the same sex and within and between populations.

NICHOLSON: The distinction has already been made between stabilizing and change-promoting forms of selection. Another division, which seems to me very meaningful, can be made following the theories of natural selection put forward by Wallace and Darwin, which, in fact, were not the same.

The simplest form of selection, as I see it, is that presented by Wallace. The mechanism he described is just this: Animals or plants in any environment are subject to considerable environmental change; and during periods of great adversity those individuals that were not good enough to survive would be destroyed. This process continuing, more and more individuals of the temporarily unfit type would be destroyed. With the return of more favorable conditions, only the best forms would have survived and would exist under those favorable conditions. Thus the mechanism here is the direct elimination of the unfit —or, if you like, of the temporarily unfit. This is quite distinct from Darwin's theory, in which such elimination is an indirect process.

Darwin's theory involves the idea of competition. Darwin held that the fitter forms displace the others—the other forms that were previously perfectly fit—simply because they have a greater chance of survival. As populations are necessarily limited, an increase in one component of the population must necessarily lead to a decrease in the other component. This is not an elimination of the unfit. It is a displacement of normally completely fit individuals, which are unfit only in the sense that they cannot compete successfully with their more effective fellows. So there is a distinction between the type of natural selection due to the direct elimination of the unfit and that due to indirect elimination of individuals that are not quite so fit as the new form.

Later I shall have more to say about the efficiency of the Darwinian type of selection, which is much greater than the Wallacian type. But there is a further point I should like to make now. For evolutionary advance two things are required. One, of course, is the appearance and the preservation of forms that have advantageous properties. The other, equally important, is the disappearance of the preceding form,

which was perfectly fit to go on living in the environment before the new form appeared. This displacement, which in Darwinian selection is caused by competition, frees the gene pool from the influence of these less well fitted or less potent forms, and the properties of the population as a whole are improved as a result of this intraspecific selection. Now, this should be contrasted with interspecific selection. Competing species have no common gene pool. The displacement takes place in exactly the same way—individuals of fitter species displace individuals of inferior species, and do so completely, just as happens within a species.

HUXLEY: Sometimes—not always.

NICHOLSON: Not always, it is true; but my point is that the disappearance of the less fit form—the inferior species—has not in any way improved the properties of the residual population—the superior species—or contributed to its advancement. Evolutionary advancement, then, requires intraspecific selection or intragroup selection when the group of interbreeding individuals is smaller than the species.

Interspecific selection is a process that removes the dross of the less fit forms of life from the earth—but does not contribute to biological advancement. That is left to selection within populations, which have a very powerful mechanism for producing such advancement.

DOBZHANSKY: I should like to emphasize, not how much we know about selection, but how little we know. There is a great temptation, especially when one reaches a certain age—which I have reached, as have most of my colleagues on this panel—to speak about things as really known and to represent them as cut and dried. Perhaps it is better sometimes to talk about how little we know, how much we must learn, and how necessary more research is. We have not properly understood what biological fitness really is. For example, a form may be fit in the short run, but this may injure its fitness in the long run, or vice versa.

I think it is very useful to stress that here, as well as in many other areas, more research is what we really need. We need more work, and work on a broader front. We really need to know far more than we do.

FORD: What I am going to say refers back to what Mayr was saying just now of the way in which mutations having quite small effects may really be useful. That is exactly why one can use polygenic characters (that is, characters controlled by genes having small cumulative effects) for the study of evolutionary changes going on in the field, especially in isolation. With polygenic characters, one has a large amount of continuous variation under genetic control. Further—and this is

Mayr's point—the changes due to the substitutions at each locus are so small that the organism can be adjusted by selection operating on its total gene complex in relation to each of them. Consequently, you can get a harmonious adjustment, in contrast with the very big changes due to mutation of the major genes, which can infrequently be advantageous because they produce such large effects that the organism rarely has a chance to adjust to them. It is possible to get these adjustments very much as Mayr said.

AXELROD: I fully agree about harmonious adjustment. But if we follow climatic trends through long intervals of time, it seems to me we can see the operation of another kind of selection, which we haven't talked about very much. In paleobotany we call this "climatic selection." With a gradual change in climate, certain types, which earlier were wholly fitted or harmonious, gradually disappear while others survive because they are harmonious in more than one environment. An exceptionally good example of this is found in the Mediterranean regions of dry climate, where widespread extinctions, local at least, occurred as summer-rain types disappeared but drought-resistant types persisted. Yet earlier they were all together. Here, selection was operating on a physiological background.

WRIGHT: I should like to comment on a point Nicholson raised about the difference between selection by the environment and selection by social interaction within the species. Under environmental selection, one may equate the terms "reproductive value" and "selective value." This is not so with selection that depends on social interactions. A type that flourishes at the direct expense of others of its own species may continue to displace the latter, while lowering the reproductive rate of the species perhaps to the point of collapse. The closer the approach of the species to the peak in selective value, the lower its reproductive value. Fitness becomes a highly ambiguous term.

What is it that prevents species from succumbing to social parasitism? There seems to be no solution in random-breeding populations. In a population divided into many local communities, which are largely, but not completely, isolated, intergroup selection among these, governed to a large extent by their relative reproductive values, may overcome selection pressures toward social parasitism.

HUXLEY: I don't think we need do more than read point 5, because it is really a statement of fact, whose implications can be brought out later in the discussion. It reads as follows: "Biological evolution always shows a combination of continuity and discontinuity, a compromise between stability and change, and an interplay between ran-

domness and directional selection." Indeed, I think we can say that all characters of all organisms represent compromises between several biological needs or values.

I should like to go on now to point 6: the relations of developmental—or, as we now call them, "epigenetic"—and physiological processes to selection and evolution.

PROSSER: We have been using the word "fitness" in a very general and perhaps loose sense. I should like to put in a plea for an analysis of fitness in terms of functional adaptiveness to environmental stresses. No organisms live in a strictly constant environment. It is the essence of living things that they show remarkable homeostasis or capacity for self-maintenance in fluctuating environments and even in the face of deleterious environmental factors. In general, developing organisms are less capable of withstanding environmental variations than are mature organisms. This homeostatic capacity varies considerably, of course, with the kind of organism.

In considering physiological factors in respect to natural selection, one has to recognize two times at which the environment may affect the individual organism. First, direct responses to environmental changes permit a certain amount of homeostasis. Organisms may respond in either of two ways. Either they may change with the environment and become equivalent to it in a given character, such as the temperature of cold-blooded animals; or they may regulate their internal state in response to a change in the environment. In general, organisms that change with the environment—which we call "conformers"—tolerate a wider range of internal state and a narrower range of environmental state than do organisms that are regulators. Regulators tolerate a wider range of the environment but relatively narrow ranges of internal variation. Both of these are short-term patterns of response from which the organism returns directly to its original state when the environment also reverts.

Then, in the changes that occur over a longer period of time—larger fractions of the lifetime of an individual organism—one often finds compensatory responses that tend toward stabilization. In this state of acclimatization the organism has changed, since if the environment now returns to its original condition, the organism overshoots or goes beyond its initial state.

We must recognize that natural selection is operating on the capacity for such changes. Natural selection is homeostatis, operating over many generations. Natural selection does not select a particular response; rather, it selects the *capacity* for a given response.

Nature seems to operate with very large safety factors. In most of

the long-term compensatory responses, as well as in the direct reactions, one finds multiple pathways for solving a given functional problem. Usually there are feedback mechanisms of considerable variety, which tend toward stabilization. I think if we analyze the sum total of homeostatic responses of organisms in terms of natural selection, we shall go a long way toward getting at the physiological basis of fitness.

HUXLEY: This leads straight to the canalization of the processes of development from the egg to the differentiated adult. Again, there tend to be many kinds of feedback arrangements, canalizing deviations back into the normal channel. Developing from an egg to a human being or an ant or a frog or anything else is a terribly complicated process. These very elaborate processes have to be blueprinted, laid down, and selectively canalized. As a result, the course of development that has been stabilized over millions of years influences the future course of evolution. Each individual more or less has to go along that path. This is the opposite of Haeckel's original "law of recapitulation." Phylogeny does not determine ontogeny; put rather crudely, ontogeny determines phylogeny—at least, it helps to determine it.

MAYR: The important point to stress here is that selection operates on the phenotype, the final product of the interaction of all the different genes. If the phenotype is particularly valuable and if a new mutation occurs that—although otherwise adding to fitness—interferes with the development of this phenotype, compensatory genes will be selected which restore the original phenotype.

The same is true of interactions with the environment. Certain environmental shocks may affect the organism during development. The total interacting gene complement must be prepared to produce the chemical substances needed to buffer the environmental shock, so that development returns to its original pathway and the "normal" phenotype is produced (canalization).

I should like to say just one word about fitness. This term, unfortunately, is used with several meanings. When biologists speak of fitness, they do not mean it in the sense of an athlete who is fit. The strictly operational definition of biological fitness given by R. A. Fisher is the best I know. This states that if a gene maintains the same frequency in the population from one generation to the next, it has a fitness of one. If a gene, owing to its superior survival ability, increases its share in the gene pool of the species, its fitness is above one. When geneticists and evolutionists speak of fitness, they have this meaning primarily in mind.

EMERSON: I should like to point out that we are really saying that

all organisms and all organismic systems have a time dimension. But possibly we have not emphasized as much as we should that this is not a linear time dimension from a cause to an effect but that the effects influence repeated causes. These are the feedback systems.

Not only does feedback operate in this physiological system that Prosser was just describing, but it operates back to the genetic system likewise—from the adult to the embryo and developmental stages, as well as the opposite. Thus we have an evolutionary "feedback" (I don't like that word particularly, but then I know of nothing better). Waddington has written very illuminatingly on this topic, showing this feedback in evolutionary time. He demonstrated it experimentally, and it is also obvious to us in terms of the course of evolution. This, to me, is very important. It also gives us the basis for considering adaptation to future conditions, especially if those conditions are repeated. The cause, for instance, can be influenced by the effect, provided that the cause is repeated. Not only that; we get the opportunity to be adapted to a unique future condition. I shall not elaborate on that at the present time.

HUXLEY: That leads on to point 7: Natural selection may lead to side effects, which at the time are of no adaptive value but may later provide the basis for adaptive changes: they are preadaptive or potentially preadaptive.

OLSON: We are just about winding up the discussion of selection at this point. We have considered natural selection and random drift. It seems to me important to emphasize another aspect supplying material for selection, which fits here because it produces side effects. This is the general area in which we can include events that are random with respect to the adaptive value of the genotype of populations. I refer to the simple matter of accident—for example, the effects of a forest fire on a population, or perhaps something more general, where, in terms of population structure and the environment of existence taken together, any adaptive genotypic superiority that might exist is little, or not at all, expressed in the succeeding populations. This sort of thing, it seems to me, is a necessary factor in interpreting very rapid shifts in evolution and the apparently odd directions (from the standpoint of adaptation) that are taken in evolution. This sort of side effect, the impact of accidents and other factors producing nonadaptive shifts, may cause very rapid changes and give completely new shape to the course of evolution. I think this is an extremely important evolutionary factor.

MAYR: I should like to emphasize a point taken for granted by geneticists but not fully understood by some evolutionists. In the early

days of genetics it was believed that every gene controls one character and that every character is produced by one specific gene. Particularly in higher organisms, however, genes do nothing of the kind. The gene produces some kind of gene product—an enzyme or some other and still unknown kind of protein—which is fed into the total developmental stream and becomes part of the total developmental system of the organism. It has been said—although this is surely an exaggeration—that every gene contributes to every character of the organism and that every character of the organism is affected by every gene. Let us keep in mind that even a gene responsible for such an unimportant thing as, let us say, a slight aspect of pigment pattern of the skin may simultaneously control longevity, aggressiveness, heat tolerance—all sorts of characters. This is one of the most important findings of physiological genetics and has very far-reaching effects on the interpretation of evolution. Therefore, let us never go back to the old concept that a gene determines a character.

HUXLEY: Point 8 deals with the evolution of sex as an illustration of evolutionary process.

STEBBINS: I think we can focus several remarks made during the last few sections onto the evolution of sex. In the first place, we can ask this question: Why is it that in higher organisms sex seems so essential and is never lost, whereas such organisms as fungi and bacteria get along for very long periods without sex or with only a very small amount of genetic recombination?

For an answer we can go back to the point about compromise in section 5 of the agenda. Some years ago, Kenneth Mather pointed out that the genetic recombination system must establish a compromise between two conflicting needs. One need is genetic insurance—generating sexual combinations that at present may have no selective value but may become essential in the future when the environment changes. The other need is to generate the largest possible number of individuals that are fit at the present time. And the balance—the compromise between these needs—is likely to be very different in different organisms.

Take, for instance, a bacterial colony in which millions of individuals are produced in one day, with the generation time a tiny fraction of what it is in man. Here new genotypes can perhaps be generated in large part by occasional mutations or even successions of mutations, as in the adaptation of bacteria to streptomycin. In this case, sex is perhaps of less selective value than in the slowly reproducing higher animals. And in plants the larger, more slowly reproducing perennials and woody plants usually have a high degree of cross-fertilization and

genetic recombination through a high chromosome number, whereas the weeds—the pioneers—usually have self-fertilization and sometimes asexual reproduction. This is associated with the fact that a plant in a vacant and relatively uniform habitat is most successful if it generates a large number of offspring similar to itself.

This seems related to Dobzhansky's remark that in the future we shall have to think in somewhat different terms to find out more about evolution. And in *Evolution: The Modern Synthesis* Huxley suggested that we must think more and more of comparative evolution and comparative fitness of different organisms rather than in absolute terms.

HUXLEY: That is a very exciting statement about sex. Of course, there are a great many other exciting statements to make about sex—the way in which its existence has led on to such consequential characters as sexual display and sexual selection, for instance—but we really do not have the time to deal with them.

We are now on the second part of this enormous subject. We have been discussing mechanism, and now we shall discuss the course, the process, of evolution as shown in fossils and as deducible from animal structure and behavior.

The single process of biological evolution involves at all times the integration of three component subprocesses: first, diversification, leading to branching and the formation of separate species and higher groups; second, transformation, leading to detailed and general adaptation, the greater efficiency of various functions, more advanced and better-integrated organization, including the organization of behavior and mind; third, stabilization, leading to the formation of stabilized patterns of organization at all levels and to their often indefinite persistence.

AXELROD: In the whole sequence of change seen in the geological record, both animal and plant, these three phases—diversification, then transformation, and, finally, stabilization—regularly appear. This is especially well shown by the various major groups of vascular plants, for which we now have records going back into the Cambrian. Each successive group shows the major phases in change.

We do not know enough about change, and we need more fossils so that we can analyze and interpret trends; but I think most of us are in full agreement about the gradual change in time: increasing diversification; then, gradual transformation, so new categories gradually arise, first at smaller and then at higher levels; and these then are stabilized and persist for long periods of time. Every major plant phylum shown in the fossil record is still with us. The older phyla, of course, are relict and not very conspicuous. Those that are dominant

—the flowering plants—cover the earth today in a diversity far greater than the older groups.

HUXLEY: This is the point: that the paleontologist has to depend on fossils. I am glad to hear that there are now more plant fossils than there used to be and that these go back to the Cambrian. Zoologists, on the whole, are more fortunate, and perhaps Olson could tell us whether these processes can be followed in more detail in the animal record.

OLSON: I think it is important to recognize that, although the fossil record itself is very incomplete, we can at one place or another follow the operation through time of almost any process we wish. For example, if we are interested in following species diversification in time, we have to deal in very small units. This can be best done in the Tertiary, with mammals, in the manner of Simpson and many others. If we are interested in higher levels, we can take series of fossils, such as that from the reptiles to the mammals, and follow a transition from one class of vertebrates to another. This is so beautifully drawn that at the present moment no one can adequately define a mammal on the basis of the fossil record of the shift from reptiles. We are in the center of gradual but profound change, and taxonomy is completely confused. In one way, this is an ideal state. We really know something if there is confusion in classification at such a level, because we have crossed the boundary so perfectly that it is not possible to judge in which major group particular animals belong. I speak here of vertebrates; there is much to be done with invertebrates as well; but, so far as fossils are concerned, these have been neglected at this conference.

Just one more word: when we consider the fossil record and evolution, it is extremely important to realize that the record is highly biased, as Simpson emphasizes in one of the Celebration papers. The early record is very scant. Only as we come to modern times do we really see a broad record in a variety of environmental classifications. Earlier, it was ocean margins on both the land and sea sides of the strand.

HUXLEY: Transitions from one major type of organization to another are always gradual and always involve a great number of small steps. G. R. de Beer has pointed this out in the evolution of the birds; certain features of *Archaeopteryx* were reptilian, and others were definitely avian. I know it will be emphasized in the panel tomorrow that the origin of man does not involve a single "missing link" but, rather, many little links. This is a very important point.

Now we come to the statement that transformation leads to adaptation and improvement. Personally, I like the word "improvement."

Darwin used it characteristically in the *Origin of Species* when he said, "Natural selection will inevitably lead to the improvement of most species of organisms in relation to their conditions of life."

FORD: One of the very important things we have to recognize and study is the way in which selection can adjust organisms to the effect of single genes. For example, in butterfly mimicry, two distinct forms may be controlled by a single major gene, and yet it has been possible for selection to modify the gene complex, adjusting and gradually evolving the mimetic characters within the effect of the major gene. A combination of genetics and the study of organisms in their environments can show very well the breakdown of those adjustments. It is very important to note that, although characters may be controlled by major genes, they can be slowly and gradually evolved.

HUXLEY: And, as a result, there can be quite incredibly accurate imitations of a nauseous form by an unprotected form; and when there is no need for such close protection—when the nauseous form is not present, for instance—the exactitude fades. Mimicry provides a beautiful example of detailed adaptation.

NICHOLSON: It might be useful if I briefly described some recent experiments in which natural selection took place before my eyes. I did not set up the experiments for the investigation of natural selection, but to study population dynamics; but, fortunately, natural selection occurred, and we have a detailed record.

I used the Australian sheep blowfly (*Lucilia cuprina*) in a series of experiments. The populations were controlled by supplying the adult insects with a small amount of meat juice each day. The flies had to compete for this, and, in doing so, their numbers first increased up to the point where the depletion of food by competition between the flies prevented most of them from laying any eggs. Throughout each experiment the number of offspring equaled the number of parents, on the average, in spite of extreme oscillations in the size of such populations from some 7,000 adults down to almost nil, in a regular sequence.

When I made conditions more adverse in other cultures governed in the same way by adult competition for food, the populations still remained in being, and the same end result was obtained: the number of offspring equaled the number of parents. There was a readjustment. Competition relaxed to the point where its effect, plus the effect of the adverse factors, prevented the production or survival of more mature offspring than the number of parents, on the average.

In several cultures subjected to differing degrees of destruction, each population fluctuated about different levels, but the mean population level remained constant during successive periods in each cul-

ture. In certain other cultures, natural selection of a very remarkable kind took place, which caused the mean population levels to rise progressively.

I must point out that the unselected flies were able to produce far more eggs than were necessary for survival of the species under the conditions that were maintained. I found it possible to destroy 99.6 per cent of all immature adults each day, and the population still remained in being. In spite of this, selection still took place to improve egg production under the highly favorable conditions prevailing. It proceeded very rapidly, and in about a year the properties of the flies had improved enormously. An individual fly in the population required for egg production only a minute part of the amount of meat juice needed by its ancestors at the beginning of the experiment. Thus selection had taken place to improve a property that was already much more than adequate to cope with the prevailing conditions. The important points are that this took place in a series of small steps and that, although the mean population rose progressively, during any moderate time interval the number of offspring approximately equaled the number of parents. Thus, throughout the experiment, competition had adjusted the population to the changing equilibrium levels.

The important point from the standpoint of natural selection is that automatic compensatory reaction adjusts the efficiency of selection at exactly the right point to preserve preferentially any better form and allow it to multiply. As the better form multiplies and improves the population, so the intensity of competition is increased above the level that the preceding form could withstand. Consequently, the previous form, perfectly well fitted, is displaced by increased competition with the new form. This is the cause of the extreme efficiency of the Darwinian type of natural selection.

Thus natural selection is not a process that depends on the appearance of a new need before it can operate. If that were so, all organisms would be in a very precarious state, because, as soon as the new need arose, it would be necessary for the right type of mutation to appear and to be selected swiftly. But with the type of reaction I described, the population is held in being, even though environmental conditions may change very greatly. It can still adjust itself by reducing in density and thus relaxing the intensity of competition. It can remain stable under the less favorable conditions until some better form happens to occur, which will then be selected.

Each time a better form appears, even though it is unnecessary under the existing conditions, it will be selected. Such selection of properties better than are immediately required provides populations with resilience—if conditions become worse, the species is not de-

pendent for survival upon the selection of improved properties but can hang on—and also helps organisms spread into environments that they were not previously competent to enter.

HUXLEY: Here you have definite improvement in relation to several conditions of life and also what one might call "preadaptation."

NICHOLSON: After this same experiment had continued for another year, selection led to the appearance in the population of a number of individuals able to lay eggs without any meat juice at all—a requirement that was essential to the species earlier.

STEBBINS: This is a very interesting example of adaptation. I should like to describe another example—a radical transformation that probably originated through the establishment of one gene with a major effect rather than through a gradual change. This is the work of Gajewski in Poland on the genetic difference between the common purple columbine and a small white-flowered Asiatic form that lacks the usual columbine spur. Now the purple columbine is pollinated by bumblebees that have a proboscis just the length of the spur. The spurless white Asiatic columbine is pollinated by flies and probably by other indiscriminate insects. Gajewski found that the presence or absence of spur is determined by a single gene. So we can reconstruct a change in adaptation, triggered off by the appearance of the gene that adapted the flower to the proboscis of the bee, with color and other factors then coming in to complete the adaptation.

MAYR: The origin of new species or the multiplication of species is the first major step in evolutionary diversification. I shall not define species, but I should like to point out their significance. We have been talking about recombinations within a gene pool and the tremendous genetic diversity within the total gene pool of a species, so that no two individuals are ever quite the same. However, there is a limit to the degree of difference among the genes that can be combined and still lead to perfectly viable individuals. The fact that organic nature is organized in the form of species is an insurance or protection of gene pools against their being polluted by unsuitable genes from other pools.

Now how does a new species originate? The early naturalists discovered long ago that the geographic ranges of closely related species were often adjacent, and those of incipient species apparently always so. Darwin's observation of this phenomenon on the Galapagos Islands gave him the whole idea of the origin of species; but it took eighty years or so before this empirical generalization of the naturalists found an ultimate explanation by the population geneticist. Up to that time, various alternate ideas of speciation were invoked, such as that individuals within a population became genetically

different as a consequence of ecological specialization. An alternate mode of multiplication of species, which is particularly common to plants, is through polyploidy. But in animals the essential process is geographic speciation, for which the explanation was found by the population geneticists.

HUXLEY: If Edgar Anderson were on this panel, he would object to your saying "pollution" of gene pools by foreign genes. But such introgression is a rather rare phenomenon in animals, and, from the point of view of most animal species, it *is* pollution.

DOBZHANSKY: I have very little to add to what Mayr said, except to stress again that in this field we have so much to learn. Just what process brings about the formation of the isolating mechanisms that separate species? We do not know this as well as we should. There are two hypotheses. One of them is that the isolating mechanisms are simply by-products of the accumulation of genetic differences. If you become different, you become isolated. The other hypothesis is not necessarily contradictory but, rather, complementary. It asserts that reproductive isolation of species in nature is a product of natural selection. Such isolation is built up by natural selection, which tends to minimize the losses to the populations of both species that would arise from gene exchange and recombination of species—foreign genes.

Another question is the extent of gene exchange between populations that is most favorable to the species. Recombination has to be limited to a certain value—a certain frequency—which is optimal; and the optimal amounts differ in different circumstances. We shall have to find out by experiments, as well as by observations, to what extent these two mechanisms—and perhaps others that are still undiscovered—operate in nature.

PROSSER: I shall emphasize another aspect of isolation. I do not believe spatial separation is enough per se to cause speciation, and I feel that there is a great need for identification of the isolating mechanisms which do separate natural populations. Sometimes these also operate for populations that are not at the specific level.

I feel that taxonomists have often been so busy describing species in terms of key characters that they have paid too little attention to the actual mechanisms of isolation. There are two categories of such mechanisms.

The *primary* adaptations are those associated with physical factors in the environment; if two populations are separated, let us say in a geographic cline, they are usually limited by different environmental factors. The identification of such isolating mechanisms can best be made by applying stress tests to populations at the limits of the range.

The other type of isolating mechanism, which we might call *sec-*

ondary, primarily concerns reproductive separation. These mechanisms include many of the behavioral variations in animals. Frequently, when climatic or physical changes cause the ranges of formerly separated populations to overlap, the populations are then separated by reproductive behavior rather than by environmental factors. I think we have to separate these two kinds of isolation.

The study of physiological factors in isolation must proceed by three steps. The first is the description of physiological variation in natural populations. The second is to ascertain by acclimatization or transplantation which variations are determined genetically and which environmentally. Finally, the cellular mechanisms underlying the variations require elucidation.

STEBBINS: I should like to disagree publicly with my good friend Dobzhansky, with whom I have disagreed in private more than once about the mechanisms of speciation. I do not think we have to confine ourselves to the two alternatives he mentioned.

DOBZHANSKY: I expressly said they were not alternatives.

STEBBINS: Well, to the two hypotheses, then. I should like to raise another possibility, that reproductive isolation originates as the by-product of certain specific types of natural selection and comes about because of the nature of those types of natural selection.

The kind of hybrid behavior we find in animals is, in general, rather different from that found in plant hybrids. That is, animal hybrids tend to be inviable in early stages of development or to be sterile because of abortion of the gonads or mechanical disturbances of the meiotic spindle and similar disturbances of meiosis; sterility due to the disharmony of the haploid products of meiosis is relatively uncommon. In plant hybrids, both effects occur; but much more often the main bottleneck—the main limiting factor—is the result of meiosis, the presence of disharmonious gene combinations due to the effects of genetic segregation, which can be rectified by polyploidy. This is probably because the epigenetic sequence of developmental processes is much more complex in animals, and therefore selection for a different sequence of processes can much more quickly lead to disharmony; just as with two well-adjusted Yale locks of different types it is almost impossible to make one key open the other lock, but with an old-fashioned door lock it is not at all hard to change the key to get in someone else's room.

HUXLEY: The point is that organisms are excessively variable, and we expect a great deal of diversity.

MAYR: As far as I am concerned, this is not a third alternative. Stebbins says that the incidental changes occurring during isolation, which will lead to eventual genetic isolation and to completed specia-

tion, are different in plants from those in animals. I entirely agree with him about this difference. But this can be included in the first hypothesis Dobzhansky mentioned, that is, that genetic changes are a by-product of the general adaptive changes of isolated populations.

DOBZHANSKY: I agree with both Mayr and Stebbins.

HUXLEY: That's bad—we're all agreeing. However, I think everybody does agree that some degree of isolation is a prerequisite for the changes that later may lead to speciation.

I think Prosser was a little hard on the taxonomists when he said they were so busy describing new species that they have no time to think about their origin. Some taxonomists certainly have a hard time. I think I am right in saying that 10,000 new species of insects alone have to be described every year; and that is quite a job.

PROSSER: In defense of my statement, I should like to see applied function test as one criterion of speciation.

HUXLEY: You would then have to increase the number of taxonomists about tenfold and give them enough laboratory space and equipment.

EMERSON: As a systematist, I should like to have the physiologist pay much more attention to taxonomic differences and evolution in physiological investigations.

HUXLEY: Good. That's the advantage of getting people together. Now we know what we want.

OLSON: I think peculiar isolation was vaguely mentioned—that is, temporal isolation with modification of time of the sort Axelrod mentioned earlier, never a split or two separate populations. It is going through time and shifting.

HUXLEY: You get both kinds.

OLSON: I think this is extremely important.

HUXLEY: I think everybody agrees that types, once they are successful, do tend to persist for a very long time. They usually are reduced in number by the emergence of new improved types, but they may persist indefinitely. Stabilized systems—stable patterns of genetic or physiological organization—are rather difficult to break out of. Advance of any sort has to be achieved by rather improbable breakthroughs from one stabilized pattern to another. This applies just as much on the species level as it does on higher levels.

MAYR: The point I should like to make here is that species have another significance. Every single species is a new experiment in filling some sort of niche in nature, because no two species are identical in their ecological requirements. The majority of these different species are merely variations on a theme, but occasionally a species will make

a major "discovery"—for instance, the first fish that got out onto land "discovered" the land niche and gave rise to the terrestrial vertebrates and the first pseudosuchian reptile that "discovered" the air niche and gave rise to the birds. So the species level is tremendously important because only one out of thousands or tens of thousands or hundreds of thousands of species is able to make this breakthrough into a totally new type of ecological zone.

Now the question is: What permits a species to do this? Evolution is exceedingly opportunistic, and the first step can be taken only if that particular organism is preadapted for this change of its adaptive or ecological zone. By "preadaptation" we mean that the structures and physiological mechanisms of a species enable it to make the switch. The fishes that gave rise to terrestrial vertebrates had fins that were already like legs. They had an internal skeleton that prevented their collapsing—as a jellyfish would—when they emerged onto land. They had a respiratory system that permitted them to get oxygen directly from the air. They had any number of such preadaptations. And this, I think, is the important point: if an organ has the potentiality of two different functions, the addition of the second function to the primary one opens up possibilities for such a breakthrough.

HUXLEY: These fish were also preadapted by living in an extremely unpleasant ecological niche of little pools liable to dry up, so that they had to get out onto land and walk about from one pond to another if they were to survive.

OLSON: Yes. The preadaptation was a matter of adaptation, which, as Mayr said, was converted to another area, inefficiently at first but later becoming effective.

A point I should like to raise—and a lot of people disagree with me about this—is that I can't conceive of taking, as a point of breakthrough (I don't like that word, but I shall use it because it is here), a single species, such as the one that eventually gave rise to the mammals from the therapsid reptiles. Many species in many lines were making similar shifts.

HUXLEY: But only one got through.

OLSON: No. Many or several got through, I think.

MAYR: I think this is a technical point. The various therapsid reptiles that finally reached the mammalian level or zone go back to one species.

OLSON: Where?

MAYR: I don't care where, but—

OLSON: Back in the amphibians or somewhere.

MAYR: Mammals, I think, are somewhat unfortunate as an example. Birds show the one-point breakthrough more clearly.

OLSON: From your point, yes. I'll give you the birds.

MAYR: I think in many instances the major breakthrough was made in only one line. In other cases, like the mammals, it was made in several lines. This is a technical point. What is more important is the preadaptation of an individual organ. People have always wondered how fishes got lungs, for instance, or how any novel organ, like insect wings, could have been acquired.

I think the development of lungs is now pretty well understood. Certain fishes during the Devonian period lived in stagnant, fresh-water swamps, where oxygen was so scant that respiration through the skin and the gills no longer provided the necessary oxygen. Apparently they came to the surface and gulped air, from which the membranes of the digestive tract took up oxygen. When that stage was reached, there was a tremendous selection pressure for developing diverticles and enlarging this respiratory surface of the digestive tract. As soon as the necessary gene combination providing such diverticles appeared, selection pressure could push this tendency further and further, and this led quite naturally to the development of lungs.

Any major evolutionary novelty that has been examined in detail shows that the potential acquisition of a new function by an existing structure was already present, and, as soon as conditions favored structural modification, selection could take over.

EMERSON: My point is a facetious one, but it seems apropos of Mayr's description of the evolution of the lung. I once asked a professor of biology from the University of Tennessee how he handled the problem of evolution. He said it was very simple, very simple indeed. "I will tell my class that if this were any other state than the State of Tennessee, we would speak of the evolution of the lung; but inasmuch as we are in Tennessee, we will simply call it a diverticulum of the alimentary tract."

AXELROD: Novelty in evolution does not necessarily involve a major change in form. For example, I should call the desert and tundra plants evolutionary novelties. These, I think, have evolved chiefly by internal physiological change. Granting that some change of form has accompanied the shift, the form changed as far back as the Miocene period, or earlier, yet the physiological change accompanied the post-Pleistocene appearance of these ecological zones.

HUXLEY: We are not necessarily talking of form but of any sort of novelty.

AXELROD: The point is that these are wholly new regional environments that have been invaded recently, since the Pliocene.

HUXLEY: And where novel organisms have had to evolve; yes.

PROSSER: One comment about novelty. In biochemical evolution

we see a rather remarkable parallelism with the evolution of morphologic novelties described by Mayr. As we said yesterday, the basic classes of organic compounds—in fact, all the classes of biochemicals—were established before there were organisms that we would call such today. In the process of biochemical evolution, novelty has involved the use of previously evolved classes of compounds for new functions. Frequently this has been accompanied by minor changes in the molecules, additions of side chains here or there; but the basic compounds have not changed even with marked change in function.

In the area of animal nutrition, for instance, the so-called B vitamins function as coenzymes and are quite universal in all living organisms—certainly in all aerobic cells. A number of organisms, especially animals, have lost the capacity to synthesize many of these. Here evolution involved loss of function and reliance on the environment to supply the needed compounds. Similarly, the amino acids, which are essential structural components of protoplasm, are substantially the same from Protozoa to man. Here we have a pattern in which no novelty has been introduced. Finally, the so-called fat-soluble vitamins are modifications of classes of compounds that have other functions in earlier forms. In the vertebrates, these have been modified considerably, and they are required as vitamins only by the vertebrates. So I think we have a distinct parallelism in biochemical evolution with the development of morphological novelty.

HUXLEY: And then, of course, there is the case where the same old compounds are used in different ways. I gather that either urea or uric acid can be excreted, but birds excrete only uric acid because, if they excreted urea, they could not have inclosed (cleidoic) eggs.

PROSSER: It is interesting that the form of nitrogen excretion is first correlated with ecological stresses; it is a very labile character. However, the genetic limits within which it can vary may be very different for different groups of animals.

STEBBINS: This brings us back to something said at the very beginning of this panel. When existing chemical substances are used for new functions, we have evolution primarily in terms of reorganization.

PROSSER: And loss of function.

HUXLEY: I think we should move on to point 13: whether we can detect any general rules in long-term trends—one of the most important problems in the study of evolution.

MAYR: Studies of the geographic variation of species and of the populations of a species throughout its entire range have shown that a species is not the uniform typological entity that the early naturalists thought. Every population of a species is adapted to its particular en-

vironment, as Prosser mentioned a few minutes ago. And as the environment shows regularities, becoming increasingly drier toward the interior of a desert, let us say, or increasingly colder toward the north, so does the variation of species living in such regions. Populations of many species are adjusted to these climatic gradients and form what Huxley has called "clines"—that is, character gradients. These regularities have been formulated in a number of ecogeographic rules—that the size of warm-blooded vertebrates tends to increase in cooler climates, for instance, or that in more humid areas both vertebrates and insects become darker, more heavily pigmented with melanin.

But in recent years the analysis of these rules has shown that, as we stressed earlier, all phenotypes are compromises among a variety of conflicting selection pressures. As a result, there are many so-called exceptions to such rules, where a new selection pressure takes over and adjusts an organism or a local population in a different way.

HUXLEY: I doubt that anybody would disagree with that general conclusion. Clines constitute a very good example of the way selection produces adaptive results related to graded characters in the environment. But much more important and exciting, of course, is the question Can one detect any long-term trends at work in the huge time scale of evolution?

AXELROD: In the plant world, these trends developed through time as each successive group was replaced by another: first, the early simple psilophytes; then the association of lycopods and seed ferns; then conifers and cycadophytes; and, finally, flowering plants. We find in this trend a gradual diversification and ramification, but each successive group appears to have been able to cope with the opportunities offered it by both the physical and the biological world.

HUXLEY: What were the trends?

AXELROD: The trend has been toward increasing diversification in meeting the environment with many kinds of adaptive types.

HUXLEY: Apart from diversification, what long-term, over-all trends—increase in complexity, increase in reproductive efficiency, and so on?

OLSON: I think that, by "diversification," Axelrod was referring to functional diversification within organisms. What has happened in animal evolution is this specialization of functions within the vertebrates (or other advanced organisms), so that each system is much more specific in its functions. While special, however, the systems are very highly integrated with each other. I think this is the most significant point here. It has been an important key.

HUXLEY: Isn't it the evolution of a better-integrated, more complex organization?

OLSON: Right.

STEBBINS: With plants we can be even more specific and say that the major trends on which our phyla, classes, or orders are based represent more efficient ways of doing two things that land plants have to do: (1) securing cross-fertilization of plants that are sedentary and cannot move around and (2) securing more efficient methods of seed dispersal. In each advancing group we see more complex and more efficient ways of doing those two things.

HUXLEY: We have already touched on this point of the successful, so-called dominant, types that rise, radiate, and become stabilized; and I think we generally agree that by "progressive change" we mean change in the direction of greater efficiency of over-all organization.

One point I should like to bring out is that we find a rise in the level of organization, not only of body and structure and function, but also of behavior; and this is accompanied by the emergence and increasing organization of what one must call "mental properties." This is to my mind the most extraordinary feature of biological evolution, and it will be discussed in detail by Panel Four.

I shall try to summarize briefly some of the main points that have been raised, and more or less agreed upon. We all accept the fact of evolution. We all agree that some combination of mutation and recombination is the raw material for change and that natural selection is the main directive or directional principle and that natural selection is not conscious—it is the result of the differential survival of variants through the generations. This means that biologists no longer need—and no longer can—think in terms of Lamarckism, or of so-called orthogenetic evolution—some inner urge, some *élan vital* that makes organisms evolve as they do.

Selection acts on populations rather than on organisms, and it acts through the phenotype of the population—in R. A. Fisher's epigrammatic phrase, "Natural selection is a mechanism for generating an exceedingly high degree of improbability." It produces branching; it produces increasing adaptation, improvement, progress, or whatever you like to call it; and it produces horizonal persistence of branches, or stabilization. As a result, selection operates not only between individuals or populations but also, in the long run, between major groups —classes or even phyla. This results in the succession of so-called dominant types. I think that would summarize most of our main points.

Of course, it is obvious that, although there has been a great deal of agreement among us, there is also a certain amount of disagreement about what we know, and a great deal of agreement that there is a lot we do not know. So I should like each member of the panel to say

where in his field he thinks that ignorance is greatest and most likely to be filled up by further research in the next generation or so.

AXELROD: We need more comparative surveys of major alliances of plants in terms of the environment. Such studies were made some time ago by J. W. Bews in Africa and E. C. Andrews in Australia and more recently by J. S. Beard in tropical America; but, in general, these are almost the only researches in this area—really an ecological deployment in the adaptive radiation of plants—which has scarcely been touched. The age and spatial relations of the different climatic zones are pretty well known, and, by turning to studies of natural alliances that are deploying through time and space, we can see the ways in which these have responded to the environment through time.

Finally, one small point: the recent work in pollen analysis opens up a tremendous vista in research on rates of evolution, not only in mountainous regions where sediments are preserved but also on volcanic islands. Here we can look for pollen preserved in old soil profiles, between lava flows, and also in fine volcanic ash; and what this shows should be eye-opening.

DOBZHANSKY: I can see so many fields in which work is necessary that I cannot even begin to answer the question. Since I have only sixty seconds or so, I shall choose one point: the genetic population structure in different organisms. This is a tremendous problem, which has to be studied both from the standpoint of the theory of evolution and from the somewhat narrower standpoint of genetics. The problem has been brought to our attention in recent years, particularly in connection with genetic damage by radiation. Our knowledge of the basic rules governing the genetic structure of populations is really surprisingly slight, and it is urgent to know more.

HUXLEY: You mean that there is a great deal to be discovered by determining the differences of genetic systems and organization among the different types?

DOBZHANSKY: I mean that the genetic structure of populations probably differs in different organisms.

FORD: I have two or three projects that I consider essential. Many of our really important conclusions are based, not on defective evidence, but on rather good evidence drawn from too small a number of different species or groups. We want much more analysis of the genetic structure of populations. We want more experiments in greater detail on the evolution of the effects of genes and on the ways in which the effects of major genes can be modified. This is particularly relevant to things like evolution of dominance and especially the evolution of heterozygous advantage in genetic polymorphism, because in recent

years there have been some attempts to suggest that this phenomenon is rather rare or unusual. Finally, a point I should have liked to develop much more is that we need far more estimates of the selective advantage of genes in nature. When R. A. Fisher wrote *The Genetical Theory of Natural Selection* in 1930, he was considering selective advantages in nature up to about 1 per cent. We are now finding that selective advantages of 40 or 60 per cent are common in nature. This needs much further study and requires quite a lot of rethinking.

MAYR: I have one point from my own field and it is pretty much in line with what everyone else has said. Most of our knowledge of speciation is based on a few species of birds, butterflies, and moths, and we need to know a great deal about the lower types of animals, particularly those that are specialized ecologically or in their mode of reproduction.

There are one or two other points, from other fields, which I am interested in as an innocent bystander. Paleontologists have described many lines that remained unchanged, completely stabilized, for 120,000,000 to 140,000,000 years, and then suddenly broke out during a new evolutionary outburst. Just what can cause such loosening-up of tightly knit systems is something I think we should work out if we can.

A second point is that we find so many cases of extreme sensitivity of natural selection, doing the most incredible and impossible things; and yet the whole pathway of evolution is strewn left and right with the bodies of extinct types. The frequency of extinction is a great puzzle to me. Far too little attention has been paid to the factors responsible for this failure and breakdown of natural selection.

A third point concerns biochemical novelties. The major ones seem to have been with us for quite some time, perhaps from the beginning. But what about the role of the minor novelties? I should like to know to what extent they may be involved in these sudden breakthroughs of new major groups.

EMERSON: I am going to make my statement extremely brief. I would say that we need much more precise information on the evolutionary time dimension within all the biological sciences—behavior and development and so on. Second, I would say there is a great question of the precise role that is involved in conflicts, incompatibility, coexistence, and co-operation, both within and between species.

HUXLEY: Unfortunately, we did not have time to discuss that important point.

NICHOLSON: I think that there is a very great need to give much more attention to population dynamics in relation to natural selection. Darwin's theory of natural selection had two parts. The first of these was the appearance and the preservation of superior types of indi-

viduals, and that, of course, is the province of modern genetics. The other part concerned the removal of the earlier form, which was not so fit as the new form—not the disappearance of unfit forms but replacement of previously fit forms. For a long time now, attention has been given almost entirely to that first part. I have great admiration for the work of the geneticists and for all the advances they have made; but I feel that this has caused a very one-sided development of evolutionary theory, which is coming to be regarded as almost a branch of genetics. I believe that if the population dynamics aspect of evolutionary theory were properly developed, it would be found to be equally important and probably equally complex. I think that that has been demonstrated this morning. Population dynamics provides a system that holds populations in a state of stability and allows selection to proceed in spite of its disturbing influence upon populations.

One further point is the multitude of different systems of population regulation. We know a little about some of these now, but we do not yet know very much. I am sure that when we know more about these systems, we shall find that they have influences upon natural selection even more important than those I have already indicated.

HUXLEY: I am glad you raised this point. It is clear that we are moving toward increased study of population growth and dynamics from the genetic angle as well as from other angles.

OLSON: The important word is "paleoecology": the placing of the changing populations in their ancient settings in such a way that the movement of whole systems through time could be studied. This should be a major area of study in paleontology in the future. Also, I feel that this panel demonstrates the need for better education of paleontologists as biologists, and—amen—vice versa.

PROSSER: First, I should like to see increased use of functional criteria in the description of natural populations and in identification of isolating mechanisms.

Second, I want to learn how environmental stresses operate to bring about changes in the phenotype. We have evidence that temperature, salinity, oxygen, partial pressure, and the like can bring about biochemical changes and that these changes are essentially enzyme inductions. We believe, from work on micro-organisms, that enzyme induction involves the production of new template RNA. Yesterday we talked a great deal about DNA. We know RNA is produced under the influence of DNA. What I am suggesting is that we have here the possibility of feedback from a physical factor in the environment ultimately to the nucleotides. This is somatic and has no direct effect on the genotype; but it provides the material on which natural selection operates. There is a real opportunity and a real challenge for the next

generation to understand what I would call the "molecular basis" of natural selection.

STEBBINS: I should like to begin where Prosser left off, and I think the facts he developed are most important. Now yesterday we saw on this platform a beautifully colored model of DNA. We can go downtown and find beautifully dressed models of a different sort. We know the second type of model originated from a fertilized egg containing forty-six strings of DNA. When we find out how those forty-six strings of DNA effected all the differentiation of cells, tissues, and organs, all the forward steps and feedbacks, eventually ending in this beautiful form we all admire, then we shall be better able to argue about the selective basis of adaptations, the emergence of novelties, or any other type of change.

WRIGHT: I think anything that I would say would be an anticlimax. Moreover, the points that I had in mind have already been mentioned in one form or another.

HUXLEY: Too bad your name begins with a *W*. But don't you want to say anything?

WRIGHT: I may say, then, that, with respect to the stage in the evolutionary process with which I have been concerned—the lowest—I should go along with Dobzhansky. We need much more detailed studies of population structure of species in nature and many more intensive studies of the genetics of differences among local communities.

HUXLEY: Also, I take it, you entirely agree with Stebbins.

WRIGHT: I agree with everybody.

HUXLEY: I think if Charles Darwin had been alive for this panel, he would have been bewildered by the many new problems, new terms, and new ideas that have come up. But he would also have been very excited. I am sure that if we were to assemble one hundred years hence, we should be equally excited and equally bewildered; but we certainly have a wonderful field full of problems for biologists to follow up.

PANEL THREE
MAN AS AN ORGANISM

Chairmen: George Gaylord Simpson and F. Clark Howell
Panelists. Marston Bates; Cesare Emiliani; A. Irving Hallowell; L. S. B. Leakey; Bernhard Rensch; C. H. Waddington

TOPICS FOR DISCUSSION

I. Introduction: the status of man in the biological world
   A. The systematics of man
   B. The evolutionary status of man
II. The course of human evolution
   A. Early hominoids
      1. The primate background as a basis for human origins
      2. Early (especially Miocene) hominoids
      3. Basic adaptations (limbs and tail; question of brachiation; dentition; habitat and diet)
   B. Early hominids
      1. The australopithecines
      2. Adaptations at this level (posture; anterior tooth reduction in relation to hands and brain; tool-making; habitat and diet)
   C. Hominines
      1. Fossil hominines
      2. Pleistocene time scale and antiquity of fossil men
      3. Ecology of primitive man
      4. Effects of Pleistocene glaciation
      5. Rates of human evolution (changes in rates; environmental pressures; population size and structure)
      6. Evolution of the brain (qualitative and quantitative; psychological reconditioning; instinct, learning, and teaching)
      7. Local differentiation and over-all progression (subspecies; present unity and diversity)
III. The factors of human evolution

A. Genetic factors (mutation, recombination, selection)
B. Ecological factors (adaptive roles; choice and modification of environment)
C. Developmental factors (Is man "pedomorphic"?)
D. Trends
    1. Progressive changes; kinds and degrees of improvement
    2. Interaction of somatic and cultural evolution
    3. Transmission and receiving in genetics and in culture
    4. Development of value systems
E. Present biological status and future of man
    1. Somatic
    2. Cultural

The Discussion

SIMPSON: I think a chairman should be a benevolent policeman rather than a participant. Nevertheless, I have been persuaded to start the discussion with a brief statement about the systematics of man. When one is going to discuss any subject, it is always well to explain what one is talking about; so I think we should say a little more explicitly what man is in the sense of his zoological classification. This will also introduce some of the terms to be used in the subsequent discussion.

Although man is certainly a unique and very extraordinary animal, he is an animal. From the zoological point of view, man must be classified just as is any other animal, and he fits perfectly well into the natural system of organisms. It is simply a matter of defining his place in this system.

Living man, of course, belongs to the single species *sapiens* of the genus *Homo*. This genus belongs to the subfamily Homininae; so hominines are the close relatives of *Homo sapiens*—fossil men in the strictest sense, going back to *Pithecanthropus* and including a great many other forms such as Neanderthal man as well as fossil *Homo sapiens*. The Homininae form one subfamily of the family Hominidae; the other hominid subfamily is the Australopithecinae.

A still broader group to which man belongs is the superfamily Hominoidea; hominoids include not only the hominids (man and the australopithecines) but still more distant relatives, the Pongidae—all the living great apes and a large array of fossil forms, some of which lived before the Hominidae, strictly speaking, had appeared. The superfamily Hominoidea is often put with the monkeys into a group Anthropoidea.

To come down to still broader classifications, the order Primates in-

cludes not only man, apes, and monkeys but also the premonkeys or prosimians—the lemurs, tarsiers, and so on. Primates, of course, forms an order of the class Mammalia. So much for the systematics of man.

I shall ask Waddington to lead off with a brief statement about the evolutionary status of man, bringing out some of the characteristics that make man unique and that are important in man as an organism.

WADDINGTON: Before we go into the nature of man as seen by the anthropologists, we should see how he compares with the rest of the animal world from the point of view of those who are primarily interested in non-human organisms; and particularly we ought to see how man looks in relation to the evolutionary processes of that subhuman world.

Evolution in the animal world takes place by the operation of four major factors; or we may say that there are four main aspects of the evolutionary system. (1) One is what we might call in a broad sense the *genetic system.* (2) Then we have a set of processes that I refer to as the *epigenetic system:* these are all the processes that transform the fertilized egg into the adult organism. (3) What I call the *exploitive system* concerns the way in which the animal utilizes its environmental possibilities: all animals have around them much wider possibilities of life than they are able or willing to utilize, and they do, in fact, live in only one of the possible ways they might have chosen. (4) Finally, we have the fourth system, *natural selection.*

How does man compare with other animals in these respects? The genetic system comprises all the processes that, first, give rise to variation and, second, allow this variation to be transmitted from one generation to the next. It includes the mutation of the genes, the recombination of genes, and the systems for passing on genes from one generation to its offspring. Systems for transmitting variations are quite varied in the lower organisms. Viruses, bacteria, etc. use all sorts of mechanisms to effect the recombination and transmission of hereditary determinants. But all higher organisms rely on one particular mechanism, the sexual system, which involves a diploid stage in the life-cycle combined with reproduction by means of haploid gametes. Any deviations that we find in higher organisms can be regarded as degenerations from this system rather than advances over it. Man, of course, falls into line with other higher organisms in his reliance on the sexual system. The previous panel asked whether sex is necessary. I think the fungi would say No; but for man—and I don't know whether you would consider this to his advantage or not—we should have to say Yes. At any rate, man's genetic system is much the same as that of any other higher organism.

In the epigenetic system, also, I think that man follows the same kind of processes as do most other higher animals. His development, however, takes a very long time, and this lengthy period between the fertilization of the egg and the attainment of the adult state gives man more opportunity than most animals to carry out developmental modifications in response to environmental stresses and thus to adapt himself to the environment to a greater extent.

I think it is very clear that in the exploitive system man has made enormous advances over any subhuman animal type. Man is the most widespread of all highly evolved species, and he can cope with a greater range of environmental possibilities. In the animal kingdom as a whole, the higher and more evolved animals tend to be able to exploit more complicated relations between elementary situations in their environment. Progress in evolution is not so much a matter of exploiting simple situations more fully as of exploiting interrelations. It is this trend that man carries much further than his evolutionary ancestors, first, by his use of tools, which enables him to modify his environment much more than any other animal can, and, second, by his use of intelligent conceptual thought, which is a method of exploring the relations between things in the environment and making use of those relations.

Man is, like other organisms, subject to natural selection. In fact, the occurrence of natural selection is in some ways a truism: if certain organisms reproduce faster than others, they will have more offspring; and man is subject to that law like any other living creature. Human activities have a profound influence in determining which types of human beings will actually leave most offspring. Man himself plays a great part in deciding which types will be favored by natural selection and which disfavored. Yet, however much man alters the criteria of biological fitness, he will still be subject to the general process of natural selection and so fall into the same category as evolving subhuman organisms.

As a purely biological system, then, man's main advance over subhuman organisms is the greater development of his exploitive system.

But, before we end this comparison of man with other organisms as evolving systems, there is another point to be made. Man has acquired what amounts to a totally new evolutionary system. It is a truism that the major characteristics of man include conceptual thought and the communication of information by language, writing, and the like. In this evolutionary context the important point is that conceptual thought and language constitute, in effect, a new way of transmitting information from one generation to the next. This cultural inheritance does the same sort of thing for man that in the subhuman world is done by

the genetic system, which transmits its "information" from generation to generation in the form of a DNA chain. Man can similarly transmit information in the form of actual letters on the page. The analogy often made between the DNA chain and writing can be used in reverse; and language can function as we are used to thinking that DNA does.

This means that, besides his biological system, man has a completely new "genetic" system dependent on cultural transmission. No other animal has developed such a system to anything like the same degree of perfection, although you find traces of it in the subhuman world, as any evolutionary theory would lead you to expect. The human species has developed this system to such a degree that many people—myself among them—think the greater part of the most important "information" transmitted from one generation to the next is passed on by social transmission.

With a new system for transmitting information between generations, one is bound to get a new system of evolution based on it. At this point I think it is necessary simply to mention that man differs from all other animals in this way. We shall pursue this point further at a later stage in the discussion.

SIMPSON: We shall now take up human evolution and human origins chronologically and, in zoological fashion, start with the more distant relatives and work down to modern man. This seems the very core of the subject of man as an organism, especially in a conference on evolution. One of the best ways of understanding any organism is to understand its history; and this is human history, especially in a biological sense.

We begin by taking for granted by far the greatest amount of organic evolution as having already occurred. We assume that the vertebrates, the mammals, and the primates have arisen, and we shall discuss how man happened to arise among the primates. How did it happen that our ancestors were primates and not, for instance, kangaroos?

HOWELL: It is necessary to take as given much of the data that Simpson subsumed under the head of "systematics." We shall not have time to discuss the monkey, prosimian, or pre-primate, arboreal, primitive stages bearing on the ancestry of hominoids and, in particular, on the ancestry of hominids.

Comparative anatomical data shed considerable light on human evolution and appreciably broadened our concept of man. Many characteristics sometimes thought of as distinctively human are actually shared with other animals, including those that made man a hominoid, or a member of the larger category Anthropoidea, or a

primate. Such characters as binocular vision, stereoscopic vision, reduction of the olfactory apparatus, the pattern of dental replacement, and number of teeth relate man to other members of the primate order. It is necessary to keep such facts in mind to avoid regarding as specifically human certain general characteristics relating man to many other organisms. Our program is roughly arranged so that from the more general we proceed gradually in a systematic fashion toward the more specific—or, if you wish, the more human—and the more recent.

BATES: You didn't explain why we didn't come from kangaroos.

HOWELL: I should ask Simpson that, since he has the greatest experience with the paleontological record.

SIMPSON: The early primates were just the sort of animal from which a curious creature like man could arise. Kangaroos simply do not provide the basis for the development of a creature like man. If an equally intelligent organism arose among the kangaroos—which is most unlikely—it certainly would not have the same characteristics at all. Can anyone else add to this statement?

WADDINGTON: Doesn't this matter of why we didn't evolve from kangaroos involve some important aspects over and above the purely anatomical considerations? Supposing there had been in the kangaroos a mutation producing more intelligence or greater ability to communicate, would not the natural selective advantage of such a mutation depend to a large extent on the organization of the animals into social groups? The possibility of conceptual thinking and of the transmission of thought in the way man transmits it seems to depend not only on an anatomical basis but also on what you might call a social-organization basis.

BATES: From this point of view the other group of mammals from which we might have arisen would be the canines, which have a somewhat similar social organization. But there we should have the handicap of being a canine without hands.

SIMPSON: Didn't Clarence Day write a book, *This Simian World,* in which he speculated on what the world would be like if man had originated from cats?

HALLOWELL: Although we have considerable information about the social life of non-hominoid primates in their natural state, it is still a very small sample. But from even these limited data one might say that, since practically all members of the primate order are social animals, almost all the anatomical changes involved in human evolution have occurred in species that were social in their manner of living from very far back. This is why I think Waddington's point is so vital.

RENSCH: The prolongation of postnatal growth in higher primates is also of great importance.

Here we touch a fascinating question, of equal interest to biologists, philosophers, and even theologians: how far the origin of man may be considered an accidental or an inevitable process. In all species of higher animals each individual is unique because of its special set of genes and its specific types of proteins. Spontaneous mutations are undirected, and the conditions of selection occur at random. Hence each phylogenetic step is a unique, unpredictable event.

In evolution as a whole, however, phylogeny is not always so unpredictable but, on the contrary, is governed by many laws. The phylogeny of mammals, for instance, has been guided by the following laws or rules: the law of steady adaptation in consequence of steady mutation and selection; the biogenetical rule; Cope's rule of successive increase of body size; Cope's "law of the unspecialized"; the rule of irreversibility; the rule of progressive brain size and special progress of the isocortex; Bergmann's, Allen's, Glazer's, and other climatic rules; etc.

It is also possible to show that evolutionary progress was not accidental but was forced by the interaction of the law of steady mutation and selection, the law of successive improvement, and the law of the non-specialized. Thus animals with more rational structures and functions arose.

Man could originate only from homoiothermic animals, which alone had a metabolism high enough that human performance and achievement would be possible. And among mammals the monkeys in particular show many characters favorable for the origin of man.

Hence I see the development of higher types of mammals and, to some extent, of a being like man as necessitated.

SIMPSON: I can understand the rise of man being governed by law without being quite inevitable; but this is certainly a very interesting concept.

HALLOWELL: We might say, then, that the social life and social organization of the prehuman primates would represent a stage preadaptive to man?

RENSCH: Yes; that is what I wished to say.

HALLOWELL: That is what I wished to clarify.

SIMPSON: Let us now consider the actual fossil evidence of early hominoids. This panel is fortunate in the presence of Leakey, who has made many essential discoveries in this field.

LEAKEY: We have very few specimens of fossil primates, compared with almost every other order of mammals. While it is not easy to give

a positive explanation for this relative lack of specimens, I will advance a hypothesis. It seems likely that most primate genera inhabited forest or woodland or open country not very close to water. In such circumstances, when they died, their bones would not normally be fossilized. Generally speaking, fossilization occurs only with animals living in fairly open country not very far from lakes, streams, or rivers into which their bones are washed soon after death and mineralized by water carrying minerals in solution.

Although the total number of known fossil primates remains small, there has been a great increase in the number of specimens within certain groups, particularly *Proconsul* and *Limnopithecus,* whose way of life made the fossilization of their bones more likely. We know from studies of the contemporary fauna that these groups lived out in open grassland near a lake shore.

The evidence today indicates that during the Miocene and Pliocene the Hominoidea were diversifying greatly and included a large number of genera. *Dryopithecus,* for instance, is found both in Europe and in the Siwalik Hills of India; and in India we have a secondary center of evolution with a whole series of very interesting fossil Hominoidea: *Bramapithecus, Ramapithecus, Sivapithecus,* and many others. We have too little data to be certain of their exact relation to man or to other members of the Hominoidea, and we need a much more intensive search for fossil primate remains. Most of the known genera seem to have been forest dwellers closely allied to the great apes or Pongidae. For the moment, we also include *Proconsul* in the Pongidae, but it becomes increasingly possible that we shall have to set up a separate family, Proconsulidae, to distinguish him from the Pongidae in the strictest sense.

From our study of the limb bones of *Proconsul* and of the associated fauna, we have increasing evidence that *Proconsul* lived out in the open and had arms and legs of relatively equal length, making him a normal quadruped. Personally, I doubt very much that man ever went through a stage with short legs and very long arms, such as we find in the great apes today. I believe, rather, we shall eventually find that man arose directly from a quadrupedal primate similar to *Proconsul* and acquired an upright stance without developing long arms.

SIMPSON: You vote No, then, on this question of brachiation. Does anyone wish to vote Yes or to add to the evidence for No?

HOWELL: I think the evidence favors most of Leakey's conclusions, and many of us would agree with him. With the brachiation problem it is necessary to specify very clearly what we are talking about. Brachiation, of course, means moving by means of climbing and swinging with the arms—an overhead progression through the trees, like

a trapeze artist. The word was introduced at the end of the last century by Keith, who observed that gibbons, the smallest of the living hominoids, moved about in this way in the forests of Southeast Asia. In one respect it is unfortunate that he chose the gibbon, which is the extreme arm-swinger and probably was the first hominoid to diverge completely and become adapted to a very special way of life. Orangs, of course, are similar arboreal arm-swingers but are heavy and terribly slow. Gorillas are arboreal climbers that have become large and spend most of their time on the ground; but young gorillas or the lighter-bodied chimpanzees move through the trees in a very characteristic fashion. Their use of arms in overhead climbing movements is, in a way, very human, very similar to children playing in trees—another way of saying that man is apelike in his ways of behaving. But whether man went through a brachiating stage has been obscured by the fact that the living apes are very specialized, just as living man is specialized in some respects.

Many of us believe that the hominoid forms living in the Miocene were not specialized in the same sense that the derivative forms are specialized today. Arm-swinging like a gibbon involves many specializations of the hands and fingers—elongation of the digits, some specialized changes in the carpus of the hand, loss of certain muscles or fusion of muscles, great proportionate elongation of the forearms, and many other traits that were not present in these early forms. *Pliopithecus,* a short-armed gibbon from the Miocene of Europe, proves this, and the same is true of *Proconsul,* as Leakey has already mentioned.

Just this year we have had for the first time a detailed study of brachiation among the higher primates, by Virginia Avis. When Keith introduced the term in the 1890's, he meant arm-swinging among gibbons; but this is terribly vague. We now have studies showing how different apes—and they are different among themselves—compare with monkeys, how they use their limbs in locomotion. This sort of combined functional and behavioral study shows that brachiation is indeed a complex term that covers several different locomotor patterns. We ought to distinguish these categories from each other.

In my opinion, *Proconsul* was in many respects a brachiator; that is, it used its hands overhead when moving along through the trees. *Proconsul* certainly did not move in the same way a monkey does, although undoubtedly it had many monkey-like movements. But this genus had this freedom of the shoulder, this primary ability to rotate extensively the forearm at the elbow, and none of the specialized characteristics of the living brachiators. That is very important.

LEAKEY: May I cut in? The word "brachiation" was introduced by our chairman. I expressly avoided it. Instead, I referred to "a stage

with long arms and short legs," because brachiation has been used in so many different ways that, unless we define it clearly and agree on what we mean by this term, it is better avoided. Some of the earliest fossil apes—*Proconsul*, and certainly *Limnopithecus*—had arms capable of much more rotation and of much freer movement above the head than many other animals. But this is also true of many monkeys. That is why we must be careful in our definition of just what constitutes brachiation. As a former student of Keith's, I prefer to use the word only for the conditions under which primates use overlong arms for swinging through the trees.

EMILIANI: I have seen definitions that would include among brachiators a large proportion of the population of New York City traveling in the subway.

HOWELL: This is the whole point, of course. Monkeys are unable to make many specific movements and patterns of movement that humans and apes, and especially certain humans and certain apes, can perform. The apes and modern man—we don't know about fossil man, but we assume that he's in the same category—perform a variety of movements, including the equivalent of hanging from straps or reaching behind the head to pull the left ear with the right arm, which no monkey can do. This great mobility of the shoulder and the particular structure of the elbow and wrist are very special and are common only to man and the apes.

SIMPSON: This problem of brachiation, then, seems to have been a pseudo-problem, or at least has been put in the wrong terms in many discussions in the past.

BATES: It's a shame that we lost our tails. Don't you agree that a nice prehensile tail would be very useful?

HOWELL: Whether man ever had a tail is an important problem. Many lorises do not have tails. Similarly with monkeys: some do and some do not have tails. The question is particularly relevant for the origin of much of the supporting mechanism that restrained man's internal organs during his acquisition of upright posture. So whether man had a tailed or a tailless ancestor, and how much of a tail it was, is vital for understanding the acquisition of certain characters of locomotion.

LEAKEY: One of our main difficulties is that we lack data about such structures as tails from the early part of the period during which the Hominoidea arose. We always hope that one day we shall find a nearly complete skeleton of one of these creatures so that we may know whether they had tails. The recent discovery of the strange primate *Oreopithecus*, which is certainly a hominoid, may give us a partial answer. But even if *Oreopithecus* had no tail—and I understand

Hürzeler is not yet sure—it would not establish this fact for other higher primates. For my own part, I doubt that any of the true Hominoidea ever had tails.

SIMPSON: The subject of the tail is like the barking dog in the night, in that the mystery was that he didn't bark; the mystery in man, of course, is that we lack tails. There might be something to say about the dentition of these earliest hominoids.

LEAKEY: We are beginning to get evidence suggesting that some of the early primates, such as *Proconsul,* had peculiarities of dentition tending toward that seen in the true Hominoidea at a very early stage. There is even a suggestion that milk dentition of the type that developed in the Hominoidea may have begun in some of the very early primates. This needs more study. But I think in the past we have not adequately understood the character of the canine teeth. We have tended to overemphasize and to be preoccupied with the size of pongid canine teeth. I think we must pay more attention to the fundamental character and morphology of canine teeth in different branches of the Hominoidea rather than to the size.

SIMPSON: Of course, the idea that man's ancestors passed through a stage with large canine teeth has been opposed as a contradiction of irreversibility of evolution. This is a false application of the principle, which, as far as it has been authenticated, would by no means exclude the possibility that man's ancestors had large canines, which were first enlarged and then reduced. Such sequences have happened over and over again in evolution. I agree that size is rather trivial compared with structure and function.

BATES: How do the structure and function of the canines differ in different forms; that is, how do you tell from looking at a canine how it was used?

SIMPSON: I prefer not to answer for humans or hominoids. In some other groups, you can tell a great deal from the structure of the canines. There are very gross examples, like the sabertooth tiger, whose canines certainly functioned differently from those of a rodent that lacks canines.

BATES: But Leakey was emphasizing that we should study not the size but the form, and I was wondering What characters in particular?

LEAKEY: We now have many specimens of the canine teeth of *Proconsul* and of early pongids generally; and I am more and more coming to the conclusion that you can clearly distinguish the teeth of this genus from those of many other Pongidae. I think we have been overemphasizing the size of canine teeth while neglecting their morphological type.

HOWELL: These large anterior teeth, specifically the big canines

of the gorilla and orang, were considered significant in early theories of man's origin and relationship to other hominoids. Darwin, for instance, suggested that the size of human canines was reduced because of tool use. Actually, the interior dentition is a very complex structure in all the apes. It is not merely a question of the canines, either upper or lower; for the canines, both upper *and* lower, and certain spatial relationships between them, and the spaces enabling them to interlock and to fit with the lower premolar—the first bicuspid tooth that follows them—are all specialized in a particular way in all the known apes. This specialization of the canine complex was generally present in the Miocene hominoids, but it was not nearly always so extreme as in certain modern forms. This is true even of *Proconsul*.

The size of the canines is part of a whole pattern that, once it begins, seems to carry along in certain hominoids. Some workers think this complex, like very long arms, is a characteristic separating the apelike hominoids from the non-apelike hominoids.

SIMPSON: This discussion becomes more interesting as we approach ourselves. The next group, the australopithecines, has made a tremendous stride in the human direction. Leakey, who with his wife just this summer made one of the major discoveries, is well qualified to discuss the structure and habits of these animals.

LEAKEY: The most important point about the subfamily Australopithecinae is that, beyond all doubt, they walked erect: a conclusion clearly established by the position of their occipital condyles and the shape of the base of the skull and, in the South African genera *Paranthropus* and *Australopithecus*, by the structure of the pelvis and limb bones. These are some of the reasons this subfamily is put into the Hominidae.

Another reason is their dentition. This group lacks any suggestion of the type of large canine found in the great apes today; and the diastema is either absent or very small, quite unlike that of the apes. Moreover, the whole arcade of the teeth in the upper and lower jaws distinguishes the Australopithecinae from the Pongidae. In all the Pongidae, except *Proconsul*, the molar-premolar series tends to be parallel or even converge backward, so that the third molars are closer together than the canine teeth, whereas in most of the Hominidae and in *Proconsul* there is convergence from the back toward the front. In the Hominidae this difference of arrangement is associated with a considerable reduction in the size of the canines, while in *Proconsul* it is associated with a great reduction and crowding together of the incisors. Then there is the milk dentition. Putting aside the *possibility* in the *Proconsul* group of a tendency toward hominid milk dentition,

in the Australopithecinae the first lower milk molars are of exactly the same type as those found in man today, and quite unlike the form seen in the Pongidae.

Next, let us consider the brains of these creatures. While it is true that they are not appreciably larger than those of some of the larger gorillas, they were large in relation to the body size. This incidentally raises an issue that we shall deal with later, but I should like to say at this point that mere size of brain is not so important as people like to believe. Even scientists in other fields repeatedly ask me, "What was the size of the brain in *Zinjanthropus?* Was it of human size?" When taken in relation to total body weight, size has some importance. But, by itself, size, as distinguished from brain complexity within that size range, is much less important. There is no reason to believe that, because the South African Australopithecinae had brains only about as large as that of a gorilla, their mental ability was of the same order. *Australopithecus* could easily have had a brain of the same size or even smaller, but much more complex in respect of the cortex and therefore capable of much more effective use.

Within the subfamily Australopithecinae of the family Hominidae, we now have a third member, *Zinjanthropus*. This form differs in so many ways from both *Australopithecus* and *Paranthropus* that it must be put in a separate genus. In certain characteristics it is much closer to man than to either of the other two genera. For example, *Zinjanthropus* has a very well-developed mastoid process of pyramidal form; a much deeper palate, especially in the anterior part; more clearly defined anterior rim of nasal aperture and well-marked nasal spines; and an entirely modern type of facial architecture.

These differences indicate a great diversification and branching-out of different groups of Hominidae at this level of evolution. I wish to stress this, because there is a growing tendency among anthropologists, anatomists, and paleoanthropologists to think that man is a special animal whose evolutionary steps follow more or less a straight line without side branches. I dispute this. My concept of the evolutionary development of man is much more complex; and not only can it not be drawn in linear form, but it cannot even be shown accurately in two dimensions. It is very complex, with many divergent and even crisscross branches, and emphatically is not a simple sequence of successive stages. On the other hand, I do think the australopithecine subfamily has characters which suggest that the totality of this group represents an evolutionary stage through which the primates passed on their way to becoming man.

SIMPSON: These creatures are beginning to act in ways within your sphere of interest, Hallowell.

HALLOWELL: I wonder whether Leakey would comment on three points: the use of fire by the australopithecines, their capacity for speech, and their use of tools.

LEAKEY: There is no evidence of the use of fire by any of the australopithecines. My colleague and friend Raymond Dart described his second find of *Australopithecus* by the specific name *prometheus* because he believed that it was associated with carbonized material. But when it was examined critically by chemists, it was clear that the black material associated with the bones was manganese and had nothing to do with fire. Remember, however, that the australopithecines were living in Africa, in a warm climate, and perhaps did not need fire; for they certainly had plenty of opportunity to obtain fire from natural sources, such as volcanoes.

It is difficult at present to answer the question of speech with any certainty. I recently examined all the available jaws of *Australopithecus* and *Paranthropus* in Pretoria and Johannesburg. In the few specimens in which the inner region of the lower part of the mandibular symphysis is preserved, I could find no evidence of the type of muscle scar we associate with the use of the tongue muscles for the rapid movements needed in speech. Moreover, the whole shape of the palate in these genera is one I would regard as not being associated with ability to articulate speech, although certainly capable of uttering some sounds. I should therefore say that *Australopithecus* and *Paranthropus* show no evidence of capacity for speech.

We have not yet found a lower jaw of *Zinjanthropus,* so I cannot give a positive answer. The depth and general shape of the palate *suggest* that when the lower jaw is found, we *may* find that it was the type linked with speech, but that is far from certain at present. This would be another strong indication that *Zinjanthropus* is truly human.

The third question was whether the Australopithecinae are associated with tools. Dart has suggested that a very complex series of different kinds of tools was made by the South African Australopithecinae from the bones and the jaws of animals. My own view is that, while some of these bones and jaws were used to some extent as natural tools, I doubt whether they were tools in the strict sense. So far as I can see, they were not made to a set and regular pattern. I believe there is some exaggeration of the evidence used to account for the accumulation of bones and teeth at the South African sites, but I cannot discuss that now. I am quite certain that the stone tools claimed to have been found with *Australopithecus prometheus* were not tools at all.

More recently, in an upper level at Sterkfontein, R. J. Mason and J. T. Robinson found tools claimed to be of the Oldowan culture and

said to be associated with *Australopithecus* teeth. A great many more tools have been found since then, including specimens of the Chellean type. I am not at all happy about the claim that the associated teeth are those of *Australopithecus;* they could just as well belong to some other early hominid, such as *Telanthropus*. I think Robinson would not now claim what he did in 1956; and therefore I think it is not as yet proved that the South African Australopithecinae made tools.

In contrast, the genus *Zinjanthropus* of East Africa was found on a natural, sealed-in living floor, in direct association with nine very well-made regular tools of the Oldowan type, together with 176 waste flakes. Most of the material had been brought in from over four miles away, and some of it from nineteen miles away. Therefore, it definitely can be said that *Zinjanthropus* was a man in the tool-making sense.

BATES: Leakey has a book coming out this spring, a new version of *Adam's Ancestors,* which undoubtedly will explain these things. Raymond Dart has just published a fascinating book, *Adventures with the Missing Link,* giving his views on this bone culture; and I suspect that from these two books one can get a very good idea of the controversy.

SIMPSON: Now we have had the commercial. Next, we are going to discuss the subfamily to which we belong, and I will ask Howell to summarize some of the fossils that belong to the Homininae.

HOWELL: By the beginning of the Middle Pleistocene there is good evidence of man's presence in extensive areas of the Old World—throughout Africa, in southern and western Europe, and in Southeast Asia and the Far East. Evidence in western and southwestern Asia is very poor, largely because of preoccupation with protohistory and biblical archeology and not enough interest in matters prehistorical and geological. The great area from the eastern Mediterranean littoral to and including the Indian subcontinent is literally unknown, so far as the important Middle Pleistocene time range is concerned.

In this respect hominines represent a new grade of development within the hominids; and they seem to have dispersed from a primary center of evolution. A number of workers think, as Darwin believed one hundred years ago, that this center was in Africa, although it might have included areas that are not now geographically part of the African continent.

Some workers in human paleontology see differences of a specific level, others of a generic level, between the western, or European, and the eastern, or Asian, hominines of the Middle Pleistocene. Certainly there are substantial differences in their morphology. The only way to express differences in morphology is to give these adequate taxo-

nomic rank. Some of these differences seem to be of at least a specific nature. I shall not develop this point because I think it is not important.

Relatively little is known about the factors responsible for this wide dispersal of the early hominines; but probably it occurred because the first hominines—or the first men, if you prefer that term—were both able and forced by certain pressures to exploit new environments. They were fully and habitually carnivorous, and meat represented a substantial part of their regular diet, a further shift from the sporadically predaceous and semicarnivorous scrounging of the australopithecines, capable of coping only with small mammals or immature medium-sized mammals and similar animal life. While the earlier hominines were not yet hunting peoples in the sense of those who lived 30,000 to 50,000 years ago, they were none the less sufficiently competent hunters to deal adequately with a variety of game, including all the large animals, under relatively diverse ecological circumstances.

The early hominines apparently had an adequate material culture in stone, with particular types of implements being fashioned according to established traditions of manufacture and to consistent forms. Although its preservation is certainly incomplete, with practically nothing known of bone or wood implements, for example, this partly reflects the neglect of this problem by prehistoric archeologists. A notable exception is Leakey, who in East Africa has excavated several of the actual living sites of such early peoples. From these sites, which cover much of the Middle Pleistocene time range, we begin to know how tools were prepared and what kinds of tools were made, and we can make some inferences about their cultural level. Other such potentially rewarding sites in various parts of the world need attention, especially in Europe, western Asia, and India.

So, with the appearance of the hominines, there is evidence of biological, as well as of cultural, change. Certainly there is evidence of man's widespread radiation into different parts of the Old World. As far as is known, these people were not australopithecines in the strict sense, although often they show resemblances to what probably was an australopithecine source. Hence most human paleontologists think that the hominines passed through an early hominid stage or grade of organization that, broadly speaking, could be called "australopithecine." This may have represented an extremely long period prior to hominine dispersal.

SIMPSON: Human evolution occurs against a scale of time that is slowly being worked out. Emiliani has been doing some exciting work in developing methods of dating.

EMILIANI: I would rather Howell went ahead a bit to introduce the names of some of the sites.

HOWELL: I think it is not important to name all the sites. Fifty

years from now, we hope to have fifty, one hundred, or a hundred and fifty more. We mention them now only because we have so few.

In western Europe the earliest evidence of man appears near what we think is the end of the first great continental glaciation, the Mindel. The site of Mauer, near the town of Heidelberg, is the oldest such well-dated occurrence in Europe. Fossil remains dating from a somewhat later time were found at Steinheim, north of Stuttgart, and at Swanscombe, on the Thames River not far from London. A little younger than the human remains from Mauer are those from Ternifine in Algeria. There are somewhat later sites along the Atlantic coast of Morocco. In eastern Asia the earliest human skeletal remains are from Java, from several beds of differing geological age, but all from the Middle Pleistocene from our present knowledge of the associated mammalian fauna. In China there is "Peking Man" found at Choukoutien, southwest of Peking, one of the few sites providing a satisfactory population sample. There are australopithecine samples, of course, and some good samples from later in the Pleistocene, but very little is known about human populations throughout most of the Middle Pleistocene.

EMILIANI: Ever since it became clear that man was not created abruptly but evolved slowly by normal processes, a basic task of paleoanthropological research has been to attach a time scale to the sequence of events in human evolution. Most human and prehuman fossils have been dated only paleontologically, by determining whether they are Lower, Middle, or Upper Pleistocene. I shall very rapidly define the Pleistocene as the length of time since certain maladjusted species of northern marine mollusks migrated southward to the Mediterranean, because it was too cold in the north, and were buried in the continuous Plio-Pleistocene sequences of Italy. That event was chosen by the Eighteenth International Geological Congress in 1948 as marking the onset of the Pleistocene. We have only a very rough idea of when that was.

Since marine mollusks naturally are buried in marine sediments, it is very difficult to correlate them with the sediments containing continental fauna upon which the terms "Lower," "Middle," and "Upper" Pleistocene are based. Most Pleistocene studies have been based on continental sediments—on moraines, till sheets, and other glacial features or on loess sheets outside glaciated areas. These sediments are always discontinuous and nowhere represent more than one or two glaciations, with only one or two interglacial deposits sandwiched between. For about a hundred years, geologists have been trying to reconstruct the history of the Pleistocene from this very fragmentary evidence.

The classic scheme of four glaciations separated by three major

interglacials was produced fifty years ago by A. Penck and E. Brückner in Austria and southern Germany. Even earlier, North American geologists had postulated five glaciations instead of four. Actually, both classifications were valid, since the European fourth glaciation had two stages that American scholars separated into two different glaciations.

For a complete uninterrupted section covering the whole Pleistocene, one must turn to deposits formed under water. Lakes with a continuous sequence of sediments are very few, and by far the best possibility is offered by the deep sea. About 40 per cent of the ocean floor is carpeted with sediments called "*Globigerina* ooze," consisting largely of the shells of pelagic Foraminifera depositing calcium carbonate. After a brief life these organisms reproduce, and their shells fall to the bottom, where they accumulate at roughly constant rates (2–3 cm. per thousand years), together with clay particles introduced into the ocean by rivers or wind.

With modern devices for sampling such deep-sea deposits, columns as long as 20 meters, covering the whole Pleistocene and going back well into the Pliocene, have been recovered. From such a column one can extract at regular intervals the shells of the protozoans that once lived near the surface and can actually determine the temperature of the ocean surface at the time these shells were deposited. The method, devised and developed here at the University of Chicago by Harold Urey, consists simply in determining the ratio of the two oxygen isotopes—O^{16} and O^{18}—in the shells. This ratio depends essentially on the temperature. Thus one can reconstruct the variations in temperature of the ocean surface throughout the Pleistocene. When this was done, we noticed that in such areas as the equatorial Atlantic or the Caribbean, where there was some proximity to the ice caps surrounding the northern end of the Atlantic, the temperature oscillated about 6° or 7° C. between colder and warmer periods. We have a series of peaks and valleys representing periods of warm and cold weather—reflected in cold and warm water—in these areas.

Dating the deep-sea cores is neither so complicated nor so difficult as dating continental deposits. By radiocarbon methods, which have a range approaching 70,000 years at present, continental deposits can be dated back that far. Marine deposits can be dated back to the same level by this method. Such datings indicate that the last temperature minimum shown in the deep-sea deposits corresponds to the time of the maximum advance of the ice in the Northern Hemisphere.

The first attempt to date marine deposits older than 70,000 years was simply an extrapolation of radiocarbon ages. The method is not very elegant but is fairly reliable, because sedimentation in the open

ocean is nearly constant if averaged through a glacial-interglacial stage. By this method we have been able to date temperature minima that are correlated with glaciations at 18,000, 65,000, 110,000, 180,-000, and 275,000 years ago.

Turning to human evolution, we can say that continental fossils that are correlated with glacial and interglacial stages in the northern latitudes correspond to the date of a particular maximum or minimum temperature shown in the deep-sea cores. John Rosholt has recently verified the extrapolations by direct dating by using two radioactive isotopes—protoactinium-231 (Pa^{231}) and thorium-230 (Th^{230}), both of which are daughters of uranium. Thus our present time scale may be correct, although, when originally proposed, it was based on rather flimsy grounds.

This seems to me the best available method of dating human fossils. Bone itself is physically and chemically very active and is so easily contaminated that it is practically impossible to date it directly. Material associated with bones—shells, for instance—could be dated more easily, but the attempts that have been made are only preliminary. So I suggest that the only possibility of establishing an absolute time scale for human evolution is this indirect method of using the deep-sea cores.

SIMPSON: How old would you say that Leakey's *Zinjanthropus*, for instance, might be, supposing it is about the same age as the Sterkfontein remains?

EMILIANI: *Australopithecus* lived during the so-called Lower Pleistocene, by my estimate perhaps 300,000–600,000 years ago—roughly, half a million years. African sequences are very difficult to correlate with glacial stages. *Pithecanthropus* lived during the First Interglacial, or at least extended through this period, and became extinct about 200,000 years ago. If we consider the Swanscombe skull *Homo sapiens*, modern man dates from 120,000 to 125,000 years ago. On the other hand, the earliest fossils representing modern man may be, instead, the Fontéchevade remains. From what I can gather from published descriptions, their only non-*sapiens* feature is a somewhat greater thickness of the skull bones; and I do not know whether this falls into the range of thickness found among modern man. Certainly, they look very modern. The Fontéchevade remains date from the Last Interglacial, about 100,000 years ago plus or minus a few thousand years.

Of course, this leaves a great deal of time unaccounted for. The Hominoidea may have become a separate branch of the primates as far back as the Oligocene, roughly 30,000,000 years ago. Then we see this development through *Proconsul* and similar Miocene forms, about 10,000,000 or 15,000,000 years. There follows an enormous gap, including the whole Pliocene, during which occurred the basic

steps of iliac evolution that made vertical position possible. This fundamental step had already been achieved at the time of *Australopithecus*. Evolution proceeded through various steps from *Australopithecus* to *Zinjanthropus*, which I estimate might be 300,000 to 500,000 years old. Leakey disagrees. Well, I am willing to make it 600,000 years. It is really impossible to determine its age until the African deposits are correlated with the deep-sea cores, and that can be done only through exhaustive studies with pollen and similar techniques.

HOWELL: The deep-sea cores are unusually complete and provide a truly unique succession of events. As Emiliani said, they can be measured to obtain climatic curves. But I think the curves derived from the Atlantic and Caribbean cores are not well related to what is known about the continental Pleistocene stratigraphy. The upper (recent) end of these cores fits perfectly and confirms everything that is known about continental sequences; beyond the Last Interglacial—which lasted from 100,000 years ago or a little more down to 65,000 or 70,000 years ago—the curves seem to be off. The Riss Glacial, for instance, has three very well-marked peaks in Europe, but the interpretation of the deep-sea cores shows it with only one. This throws the whole scale off. It means that the dates which are said to be about 300,000 years ago and therefore to measure the First Glacial are, in fact, probably measuring the very end of the Mindel Glacial. If this interpretation is correct, these cores are incomplete at the lower, or early, end of the scale. This in turn means that the Pleistocene lasted nearly a million or a million and a half years—a length of time that is much more reasonable and one which most geologists and paleontologists would prefer. Although the method is extremely useful, I question the present application of the deep-sea curves to the continental sequences.

EMILIANI: F. Brandtner has worked on soil profiles in Austria, where there are unusually complete soil sequences. His work shows a perfect correlation—in fact, one that looks almost *too* good—with the climatic oscillations revealed by the deep-sea cores back to and including the so-called Great Interglacial, which is, by definition, the Mindel-Riss.

The Atlantic and Caribbean cores cover only about 300,000 years. Work on similar cores from the Pacific, which cross the Plio-Pleistocene boundary, has yielded a curve of decreasing temperature from the Pliocene into the First Glaciation. This resulted in a conjectural estimate by myself of about 600,000 years for the Pleistocene. At the present time it is a matter of choice where you put the beginning of the Pleistocene, but in the future someone will find a way to correlate

the Italian level that was officially established as the Plio-Pleistocene boundary with these Pacific cores.

Mostly on Brandtner's evidence, I believe that the proposed correlation is probably correct as far back as the Great Interglacial. The fact that in Europe the Riss Glaciation had three peaks is of no consequence. There were many peaks within the Wisconsin Glaciation in North America, but the deep-sea cores do not show this because these peaks were succeeding each other at intervals of about 3,000 years. Every 3,000 years there was a rapid advance of the ice and then a very rapid retreat, and there were four or five such stages between 25,000 and 12,000 years ago. None of these is shown in the deep-sea cores because organisms living on the ocean floor sift the mud and constantly rework the sediments, so that normal *Globigerina* ooze sediments do not show events as close together as 3,000 years. The oscillations during the Riss Glaciation are comparable to those of the Wisconsin, which are lost in the deep-sea cores.

LEAKEY: I agree with Howell that the degree of correlation is good as far back as 100,000 years, but beyond that it seems much less satisfactory. Enormous parts of the Pleistocene cores must still be undiscovered, and perhaps what Emiliani calls the beginning of the Gunz glaciation is, in fact, only the beginning of the Mindel glaciation. I do not think that his dates are well established.

EMILIANI: They are not established at all yet. First of all, we will have to substitute absolute data for extrapolations.

SIMPSON: I think we should discuss the ecology of primitive man, a subject on which Bates should have some ideas.

BATES: The only real way to establish the ecology of the hominids and hominines, of course, is to reconstruct their environmental relations directly, as Leakey is doing. At the moment, however, we shall have to extrapolate and to use comparative studies of contemporary primates to infer the conditions of the past.

Population size is an important factor in ecology. Most anthropologists estimate that in a food-gathering culture each individual needs about two square miles of good territory to survive. Since the amount of good hunting territory is limited, these early populations must have been quite small, and the total protohominid or early hominid population of the globe could not have been more than a few million.

These populations must have been broken up into small groups. Territorial behavior is universal among contemporary primates. Since a phenomenon that is universal within a group of related animals can be pushed far back in time, we can assume that protohominids and

early hominids followed a similar pattern. Territoriality would have several consequences: probably the breeding groups were broken up; diffusion may have been slowed down; and conflict might tend to occur between different territorial groups rather than within the group.

Except for the australopithecines and "Peking Man," no fossilized aggregations of these early populations have been found. But the evidence from these two exceptions indicates the existence of co-operative groups of a size larger than the family. This is what one would expect as a reasonable basis for human evolution.

The essential points of the ecology of primitive man for human evolution are that he was a relatively scarce animal living in social groups of perhaps forty, fifty, or one hundred individuals—small aggregations, each with its definite territory, and presumably showing classical territorial and social relationships.

There is a great deal of discussion of peck-order, the Old Man, and similar phenomena by psychologists. I think this whole concept of peck-order often comes from studies of contemporary pongids, whose behavior may have relatively little significance for human evolution. What I understand from Sherwood Washburn, and similarly from Ray Carpenter's early work on the howler monkeys and some recent observations of the gorilla, suggests that peck-order may be largely an artifact of confinement. It has been studied by S. Zuckerman in the London Zoo; and among humans it shows itself very well in the kindergarten and in jails. I cannot see that it is very basic.

LEAKEY: Primates are generally organized as territorial groups for food-gathering purposes; this is also true of many other animals. Territorial organization, however, is often upset by seasonal climatic changes, particularly extreme drought, which will bring together for short periods members of otherwise isolated groups. For instance, a group of monkeys with a very strong territorial organization will keep every other monkey of the same species out of their area of a forest. But when water is in short supply, four or five groups, sometimes including different species, mingle at the same watering place for a time, returning to their own territorial zone, once they have drunk. I think that the consequences of the brief intermingling of groups that are otherwise territorially isolated have been overlooked in the past.

SIMPSON: One topic which must, by all means, be covered is the evolution of the brain, including instinct and learning as far as these are pertinent to biological studies of man. Rensch is an authority on this subject, and I shall ask him to take over.

RENSCH: The phylogenetic development of the human brain may be judged only from a few casts of brain cases. The *Australopithecus*

cast described by Schepers shows a brain rather similar to that of the great apes, in that the frontal lobe of the forebrain was not much developed. The great enlargement of this part of the brain in Neanderthal Man and in *Homo sapiens* was very important, since it is composed mainly of associative regions allowing much more plastic behavior. As Leakey said, the presence of the motor speech center in the Australopithecinae is very improbable, for it is a part of this frontal lobe. Otherwise, I think, tools would have been developed earlier.

I think it is of some theoretical importance that the improvement of the forebrain took place mainly by *quantitative* steps. This was one of the reasons we studied anatomical, histological, and functional differences of the brain among related animals of different absolute sizes at our Institute in Münster. We compared rats and mice, giant and dwarf squirrels or bats, large and small races of domestic fowl, large and small lizards and fishes.

We could tentatively establish several rules. Particularly in larger mammals, the isocortex (the most complicated and progressive five- and seven-layered part of the cortex) grows faster (with positive allometry) than the whole brain during the main postnatal growth period. This allometry does not always stay the same during phylogeny; the allometrical exponent is often altered. Normally, however, the general tendency remains unchanged. Hence adults of larger species have a relatively larger isocortex than smaller related species and consequently have better mental capabilities. They can learn more tasks, and more difficult tasks, and can retain for a longer time. I believe that the same phenomenon occurred when man originated; the isocortex was enlarged because of its positively allometrical growth. Such quantitative steps of improvement were possible in all levels of brain increase, since spontaneous plus mutations are common and would be selected for because more plastic behavior is advantageous.

By such quantitative steps, however, new *qualitative* characters could also arise. Broca's region—the motor speech center—is a typical example. If this region developed by purely quantitative increase in the cortex, excitations would flow in from all the neighboring regions —that of tone memory, those for movements of tongue and lips, and those from the associative regions of the frontal and temporal lobe. Hence this new region was preadapted to become a motor speech center. The development of language allowed the formulation of more abstract concepts, labeled by words. It made the exchange of personal experience and the development of traditions possible. And this was the main basis for the development of human culture.

I believe, then, that the shift from the more animal-like behavior of the australopithecines to more human behavior in *Pithecanthropus*

and *Homo* was primarily effected by quantitative steps. Would you agree, Leakey?

LEAKEY: I think that we have not yet fully mastered the study of brain casts and that available casts of the earlier primates are still far too few to make such a study well founded. I should say that brain casts of the South African australopithecines show distinct differences from comparable casts of higher apes; but much more data are needed. Later I hope to send Rensch a brain cast of *Zinjanthropus* to study.

SIMPSON: Hallowell, have you anything to say about the evolution of the brain?

HALLOWELL: Only a short time ago this problem was less well defined than it is now that evidence of brain expansion within the evolution of the hominids is clearly established. Assuming an absolute increase in the number of neurons available or in the space between them, this increase in size brings up the problem of its relation to the sociopsychological aspects of behavioral evolution and the cultural adaptation characteristic of *Homo sapiens*. Even if we do not have final solutions yet, the questions that Rensch and Leakey raised are among the most important before us.

HOWELL: I doubt that the expansion of brain size actually was gradual; probably this effect is an artifact of the record. In any case, there was an increase in size up to 65,000 or 70,000 years ago, and after that the essential structure of the brain seems to be maintained, although it may be arranged in a slightly different form.

During the Middle Pleistocene there was a gradual increase in the size of the brain and certain changes in form. These changes included great expansion of certain association areas of the parietal and upper temporal regions and, as far as we know, were associated with the expansion of memory, learning from experience, and the storing-up of information. These were also related to the reception and transmission of speech. Within the coming years there will be major advances in this field, providing answers to problems that can only be posed today.

LEAKEY: The evidence available indicates that, even in persons of comparable body weight, absolute brain size is not a controlling factor in ability, which is connected with the *quality* of the brain. I think my friend Rensch really agrees with this. Some British studies in which I had a part showed that the brain size of leading scientists was often much less than that of pugilists. Looking at those sitting around this table, I can see a tremendous variety of absolute brain sizes; and I stress that quality, rather than brain size, is important.

BATES: It may take more intelligence to be a pugilist.

LEAKEY: That is possible.

RENSCH: Of course, the phylogeny of the human forebrain involved qualitative changes, but these could have originated by quantitative steps. All the special cells of the human cortex—the pyramidal, granular, bifurcated, star-shaped, and compass cells—are also found in the cortex of monkeys. In the brain of *Homo* only, have certain regions and areas been added, and these are characterized only by special increase in the number and density of neurons and cell layers—a difference that can originate by quantitative steps.

LEAKEY: We shall have to agree to differ.

SIMPSON: I am going to expedite our discussion by mentioning that from his most remote ancestry man has been subject to the same genetic factors of evolution as those discussed yesterday. Undoubtedly, man is still subject to these and is still changing in response to them, although, of course, the situation has become complicated by other factors.

Next I shall ask Bates if he wants to add to what he has already said about ecology.

BATES: I would like to interject Harry Harlow's idea that in looking at man we confuse capability with accomplishment and that a rather slight anatomical shift in the brain, in instincts, and so on can lead to the beginning of culture, which then makes an enormous difference. As an animal, man is not particularly unique, but as a culture-bearer he is tremendously different.

Considering man as an ecological agent over his evolutionary history, it seems to me that a very curious thing has happened. Throughout this whole period and now at an accelerating rate, man has been removing himself from particular biological communities so that he no longer belongs to a biological community in any sense. The tendency of civilized man and food-producing man has been to eliminate competitors and to narrow down food chains. These effects make man a very interesting animal from an ecological point of view.

SIMPSON: It has often been said that man is pedomorphic. The idea of pedomorphism is that juvenile characters of an animal are sometimes carried over into the adult state and, as time goes on, more and more juvenile characters come to characterize the adult. It has been suggested that human adults somewhat more closely resemble a juvenile ape than an adult ape; and therefore the suggestion that man is a sort of pedomorphic ape, or at least a pedomorphic primate, has become quite popular. One very often finds it in textbooks. Perhaps Waddington can give us his ideas on this subject.

WADDINGTON: I can speak only from the point of view of general

biology rather than from that of human embryology. The concept of pedomorphosis seems to come from the early days of evolutionary theory, when biologists tried to explain development by saying it was influenced by phylogeny or reflected the phylogeny of the group. Biologists today think of embryonic development as being produced by the interaction of the genes in the fertilized egg with the environment. We consider new steps in evolution the result of modifications of ontogenetic development, but in general we would not suggest any direct causal relationship between the phylogeny of the group and the individual ontogenetic development. In my opinion, the whole sphere of discourse to which the word "pedomorphosis" belongs is rather old-fashioned. I would not be at all surprised to find that some features of the present human adult may be compared with juvenile features of our ancestral forms and that in other features the relation may be the other way around. But in evolution one has to deal with all sorts of modifications of developmental sequences item by item rather than with general alterations of the entire sequence as a whole.

SIMPSON: That seems very sensible. Howell, do you have anything to add?

HOWELL: I agree completely. As Waddington suggested, this problem can be approached in a much more fruitful way; and I think his own studies on subhuman organisms have shown this.

A more detailed understanding of different patterns of growth is needed. Physical anthropologists are just at the point where, with sufficient studies on living hominoids and with a better fossil record, they can put into clearer perspective differences that, at one time or another, have been attributed to pedomorphism, neotony, and other catch-all phrases that are loosely used to cover phenomena about whose mechanisms we are essentially ignorant.

SIMPSON: Perhaps we should move on into the area of overlap with Panels Four and Five and thus, in closing this panel, form a bridge to these. I should like to make the point that we are looking at cultural evolution from the biological standpoint and that cultural evolution, after all, is also a biological adaptation.

HALLOWELL: Several points touched on in this panel indicate a need to phrase some of these problems in terms of a preadaptive stage. This approach fits in with Simpson's idea that, since man is not only an animal but a primate, the cultural adaptation studied in anthropology must, in the last analysis, be interpreted as an evolutionary process.

Bates mentioned ecological adjustment. I think that in this con-

nection we need more information about social organization among the living primates. If we break down the terms "social" and "social organization," we can study primate groups in terms of role differentiation, which H. S. Jennings years ago pointed to as the basis of any kind of social organization. If some such concept as "role organization" is used, then I think the dominance gradient becomes one aspect of role differentiation; and, as you know, there are experts in role theory among sociologists. We might consider the social structure of non-human primates a preadaptive stage.

Incidentally, I understand that systematic studies at the Japan Monkey Center have shown this dominance gradient to be directly related to the socialization of new eating habits. Here again, a phase of adaptive social life among non-human primates involves social transmission of habits.

It seems to me that cultural adaptation could not have developed in hominid evolution outside the context of a system of social action. The complete antithesis would be to assume that any kind of cultural adaptivity could have developed among solitary animals. Thus some kind of organized social existence must be a preadaptive stage to cultural adaptivity. This development, in turn, could not have taken place without certain organic developments, particularly the expansion of the brain, which in the end made cultural adaptation possible through symbolic mediation.

BATES: The co-ordination of hand and eye involved in chipping a flint enables you to learn how to fly an airplane.

SIMPSON: Waddington, I don't think we should close without asking you to elaborate on some of your ideas, particularly your suggestion that, in culture, receiving is as important as transmission.

WADDINGTON: One of the problems to consider in the evolution of man is the relation between the specifically human evolutionary system and the general biological evolutionary system. The latter is dependent on genetic transmission through the chromosomes, the former on transmission by social mechanisms. Both systems succeed in bringing about evolution, and both function at the present day. However, if you compare the rate of advance which they have produced—for instance, if you compare the speed with which man, with his specific evolutionary mechanism, evolved the ability to fly by means of machines, not forgetting the number of miles per hour he can go, with the rate at which reptiles learned to fly—you can easily see that the human evolutionary mechanism is astonishingly rapid. Perhaps man could speed up his biological evolution by a small factor, but it would

be exceedingly difficult and probably quite impossible to make it into a process comparable in efficiency with the sociogenetic mechanism of evolution.

In fact, the biological process seems at present to face man more with evolutionary dangers than with evolutionary possibilities. It carries the danger of rapid evolutionary disintegration if the process of natural selection in human populations gets out of hand; and in compensation for this it offers the possibility only of very slow evolutionary progress. The social processes of evolution, of course, also carry dangers of regression as well as of advance; but the dangers are perhaps easier to see in advance and to mitigate, while the possibilities of advance might be very much more rapid than those offered by the biological process. Although dangers and potential advances are offered by both processes, it seems to me that at present our positive task is to concentrate on the development of our sociogenetic evolution, while not neglecting the negative task of guarding ourselves against the possible harmful effects which could arise from the biological mechanism.

My second point concerns the actual mechanism by which information is passed from one generation to the next in the sociogenetic system. I feel that in the past not enough attention has been paid to considering, not how this information is transmitted, but how it comes to be received. It is no use telling somebody something unless he is willing to believe it. The whole system of human culture is based fundamentally on a mechanism of communication and transmission that requires people to be brought up in such a way that they develop a mental setup which leads them to be ready to believe others. They may not like what they are told; and at some stage they may test it, find it is all nonsense, and reject it; but that is a secondary process. Perhaps the testing of transmitted information corresponds to natural selection, but, before it can operate, there must be something that corresponds to heredity. Ideas or statements must be reliably transmitted before they can be tested.

Now the requirements for a mechanism that will transmit something so that it is received at the other end need much more thought than they have had. I have never really seen this properly discussed, and what follows are my own personal and tentative ideas. As far as I can see, the molding of the newborn human individual into a being ready to believe what it is told seems to involve many very peculiar processes, which can be explained only in terms of such notions as the formation of the superego and the repression of the id. Whether notions of this kind are true in detail or not, the molding of the baby into a transmission-receiver seems a difficult and complicated and even slapdash process, and not at all what one might have thought

out if one had set out to design this job. A frequent result of the process seems to be that people believe much too much and believe it much too strongly. The process that evolution has provided us for doing the job seems often to lead to considerable exaggeration of the ability to believe.

However that may be, it seems clear that any social transmission of information must depend on the formation of people ready to receive it. That means that their minds must be so built that they accept information coming to them from outside. In man this readiness to accept is produced by a mechanism that involves the formation within the mind of mental systems that carry authority and can therefore be believed. Now the mental system that carries the greatest authority and can be believed most thoroughly is the set of beliefs and notions we categorize as "ethical." The good is that which we regard as having the greatest authority in determining the way in which we should spend our lives.

The point I wish to make is that the appearance within man of ethical belief is a result of the processes that mold him into a being capable of acting as a receiver of socially transmitted information. I dare say it might be possible to conceive of molding man into an information receiver in some way other than the particular method by which the process actually occurs in the human race at present. If the psychoanalysts are to be believed, the process we now use is more eccentric than one would have thought possible. But I think that some sort of system by which the mind comes to be willing to believe what it is told is necessary. That means that there would have to be formed within the mind some sort of authority-bearing system. Therefore, any being capable of sociogenetic evolution of the kind that man has developed would also have to entertain ethical or quasi-ethical beliefs.

So I think that there is an absolutely essential connection between human evolution, based on the specifically human sociogenetic mechanism, and the existence of such things as beliefs about ethics and values. That man is an ethical being is an absolutely essential part of the workings of his characteristic evolutionary machinery.

SIMPSON: Rensch, would you be willing to suggest what you think man's biological future might be?

RENSCH: Well, it is a bad job to be a prophet. I believe that in many respects our somatic development has come to a standstill, although selection is still operating to some extent. Particularly, I doubt that the brain will expand further, since there will be no selection pressure in this direction. The main alterations will perhaps be caused by a great increase in recombination of genes.

On the other hand, man's future seems unpredictable, since we are

the only living beings capable of directing our own future evolution. And it will be absolutely necessary that we should try to do this. As Waddington suggested, the steady mutations that produce mainly bad characters will cause a regressive development. I believe that it is the duty of biologists to discuss the problems of the human future, even if this is not exact science but only speculation.

I would like to raise a final point. We had no opportunity to discuss human instincts, which are of great importance. I believe it to be the typical human fate that our inborn drives always conflict with the actions of so-called "free will." One sees this most clearly in our reproductive drives, which are similar to those of other mammals. The double motivation of human actions by such drives and by insight sometimes leads to conflict, in this case to adultery for instance, or illegitimacy, or to stealing children because of the mighty maternal instinct. Of course, human beings normally act according to certain customs, morals, and ethics; but the instincts I mentioned are also an important component of our motivations. Hence, to avoid future conflicts, we must try to channel these drives into harmless directions, as we already divert our instincts for fighting and for rank to football and the like.

Looking forward to the human future, I would like to repeat that it is a bad job to be a prophet. The matter is so complicated that I would say that the future is unpredictable.

SIMPSON: I shall ask Hallowell whether he would add anything about the possible cultural future of man.

HALLOWELL: I would rather comment on Waddington's remarks. I think that it is important to recognize as differentia of this cultural adjustment of man not only that we do have social systems with cultural transmission but that these are systems of social action, where you have a normative orientation in all aspects of life. Human societies function in terms of acquired values, which are part of the socialization process of the individual, and this becomes part of the particular kind of adaptation we have made. So, for the system to function, social sanctions are necessary and information or knowledge must be transmitted in terms of beliefs held by the individual.

SIMPSON: I think that that is a very good final word. I am not going to try to summarize. We are covering such a tremendous topic that the whole session has to be a summary; so I shall simply declare the meeting adjourned.

PANEL FOUR
THE EVOLUTION OF MIND

Chairmen: Ralph W. Gerard and Ilza Veith
Panelists: Henry W. Brosin; Macdonald Critchley; W. Horsley Gantt; A. Irving Hallowell; Ernest Hilgard; Sir Julian Huxley; Alexander von Muralt; N. Tinbergen

TOPICS FOR DISCUSSION

1. *Behavioral science.*—Darwin's work has had a tremendous impact on the behavioral sciences. These, in turn, have contributed analysis and experiment pointing up problems in the evolution of brain and mind. Past benefits, present gaps, and future applications are seen in these areas, to be exemplified by the panelists in the several disciplines.
2. *Orientation and methodology.*—The evolution of mind and behavior can (must?) be studied in the same manner as that of any other organic function. New, but compatible, problems and criteria and methods are involved.
3. *Mind.*—The relation of subjective to objective description is especially important in comparing humans and subhumans as to mind and behavior. Many aspects of mental function appear in the animal world, such as organizing stimuli into perceptions, developing emotional attitudes, performing "purposeful" acts, using and even making tools, learning by imitation, achieving abstractions, perhaps operating with values. It is not a necessary consequence, however, that animals possessing such attributes have consciousness (awareness, self-awareness?).
4. *Culture.*—Other manifestations of mind are harder to trace below man, from culture back to protoculture. A useful formulation of successive stages is the following: learning, signaling, communication between individuals, transmission of learning through a group and on to another generation, use of symbolic communications, self-awareness, and group standards and morals. At the civilized

level these are developed as language and ideas, applied to man's understanding of his world and himself in science, art, and philosophy.

5. *The biological basis.*—The brain has evolved in complexity of structure and function, as behavior has evolved in individual richness and group interrelatedness (culture). The improvements in the neural machine and its performance are related; indeed, culture, involving such performances as tool using, has probably urged on the biological enhancement of the nervous system.
6. *The sociological basis.*—With the advent of civilization, genetic evolution has been largely supplemented by cultural evolution; the new idea does not await the mutated gene. Man is now in a position to supplement his information processing as he did earlier his muscles and senses, and he can control even his genetic future and perhaps guide the biological evolution of his brain. Here valid scientific knowledge merges into value judgments, and the danger of maladaptive developments is great.

The Discussion

Gerard: Our general assignment is to trace the evolution of mind, behavior, and brain—an area that has been rather neglected in the ordinary disciplines of evolution, probably because behavior leaves few fossils. Under items 1 and 2 of the agenda, we shall examine the assumption that mind can be studied in the ordinary mode of biological science, although involving rather different problems. We shall then move on to examine the changes through evolutionary history in the behavioral capacities of organisms—the increasing richness, speed, sensitivity, and variability of behavior—and see what inferences can be made as to what is happening to mind along with these behavioral changes. In item 3 we shall look particularly at those aspects of mental function that seem clearly present below man; in item 4, at those about which there would be considerably more doubt. This is the same problem of continuity versus discontinuity, or the size of the gap that develops, which the previous panels faced. In items 5 and 6, we turn to the mechanisms or the basis of this evolution in behavior: in 5, paying particular attention to the development of the bodily organization of the biological machine, and in 6, paying attention to the epiorganismic or social level and the influence of culture, transmitted symbols, and the like. So much for our general orientation and planning.

Every organism—indeed, every species or every system of any kind—is engaged throughout its life in riding two rails: the "desired"—the equilibrium state or direction or goal toward which it is moving

—and the actual, or real. The environment is continually disturbing the flow in time, perturbing the system; and it is obvious that the smaller the change an organism can detect, the more sensitive its perception of an impending disturbance and the more rapid the adjusting responses it can marshal—in other words, the better it can handle information—the more effectively will it do this "tracking" job and keep on the line it wants to travel.

Earlier panels brought out that in metabolic processes and basic reproductive processes there has been very little evolutionary change from microbe to man. But behavior has evolved explosively; and in man there are great riches of capacities and mechanisms. This is really the basis on which organisms are ordered as higher or lower by biologists.

The reaction to the environment was initially and primarily to the physical environment; in later evolution, more importantly to the biotic environment; and in still later stages of evolution, and not only in man, to the social environment.

All systems—from molecule through cell, organ, individual, small group, to larger groups of species or communities—have three major attributes: a certain "being," or architecture; a certain "behaving," or function; and a certain "becoming," or history, that involves evolution, development, and learning at different stages. Our problem is particularly involuted because we are really concerned with the "becoming" of behavior. This means that at each stage we must be concerned with whether we are dealing with a racial, evolved attribute common to all members of the species; with something that is fairly common because of the uniformity of embryonic or like development; or with something quite distinctive and depending on the individual unique experience of the single organism. Thus species evolution, common development, and individual learning play together on the final behavior. It is exciting that mounting evidence relates these to the nucleotides. The fixation of experience at the racial level, which we learned in earlier sessions depends on changes in the RNA molecule in reproductive cells, is paralleled in the fixation of individual experience—that is, learning—by comparable changes in RNA molecules in the neurones of the brain.

[The above considerations indicate that the panel faces a number of questions, and it is understandable that the disciplines represented here are far-flung, ranging from ethology to the history of medicine.] *

[There is, first, the basic question of subjective and objective, and the validity of interpreting between these on the basis of observable

* These bracketed paragraphs were omitted during the panel for lack of time and were submitted in writing after the session.

evidence. Closely related is the use of causal notions, particularly of statements crossing between the languages of mind and body. An idea cannot fire a neuron, nor, in a rigorous sense, can ether produce unconsciousness. Part of the same problem is the use of such intervening variables as "consciousness," "attention," or "will." A third issue concerns quantitative measurement versus qualitative description or pattern specification; and the closely related problem of the precipitate rise of complexity (and of information) as we move to the higher-level systems of the living and the social.]

[Although we shall not explicitly discuss the remaining three topics, I list them for completeness. First: What is the role of individual experience in "becoming"? The newborn eye and brain must see patterns in order to develop the capacity for pattern vision; and even in very early development the actual anatomical patterns of nerve paths are determined by their functional connection with other parts of the nervous system or the periphery. Natural selection can operate, if not on experience as such, certainly on the ability to profit by experience.]

[Next, what environmental changes constitute stimuli? Evolution has not increased the sensitivity of receptors to all environmental stimuli or stresses. Only certain radiations, movements, substances, etc. have carried meaning to organisms—indicating food or danger or giving guidance or the like—and so have helped direct evolution. Worry requires a worrier; stresses are such only if the organism is coded to them and they carry meaning. This is comparable to the enculturation of the young in a society; perhaps even the poet is a kind of sensitive social reactor.]

[Finally, there is the relation between the role of an organism as a total individual and as unit or member of some superordinate group —a society or ecogroup—and its behavior. There is a continuing conflict between the inborn rigid responses, the simple motor and the more complex emotional reflexes, and the more flexible learned behaviors, involving reason and adaptation. The former depend overwhelmingly on inborn neural mechanisms, those of the brain stem and the limbic system of the cerebrum, which have changed little over mammalian or vertebrate evolution; the latter depend primarily on the cerebrum and mainly the neocortex, which have changed vastly in mammals and particularly in primates. Man's limbic system is approximately the same in size and organization as that of a cat or rabbit; his neocortex is incomparably larger and more complex.]

With this general introduction, then, I am going to ask the members of the panel to give their own views on this problem of the approach to the mind; and I hope they will also indicate the kinds of methodology that their disciplines offer.

BROSIN: I am a physician, psychiatrist, and psychoanalyst, interested in Darwinian evolution because of its profound influence on biology and the other behavioral sciences and therefore on my field of psychiatry, which is, of course, related to and dependent on all these fields of human behavior.

One might define or regard mental disorders as biological deviants or failures in the working of an organism. They may range from such purely genetic failures as the single specific–gene enzyme deficiency in the phenyl–pyruvic acid–oligophrenias, or in focal epilepsy, to the much more complex stress disorders or the familiar character disorders. Consequently, our methods of study must vary with the data we examine. The methods appropriate to astronomy and geology may not be entirely satisfactory for human behavior, particularly if we include the so-called irrational components. In general, we try to use all useful empiric or pragmatic techniques, from quantitative methods in neurophysiology or biochemistry to methods that we believe are similar in all respects to the natural history methods used by Darwin and employed in medicine and biology centuries before quantification became possible.

We have much reason to believe, with Darwin, that systematic study of human behavior, including verbal productions, dreams, delusions, hallucinations, and phobias, is both possible and productive. Verbal behavior is a vital part of the total stream of communication, including the non-lexical vocal modifiers and the kinesic or body-motion markers defined in the past by Edward Sapir and Leonard Bloomfield, of the University of Chicago, which can now be recorded by film and tape. We expect much more accurate delineation of these systems and thereby should gain new data and new hypotheses. At the human interaction level, our units of study are patterns, shapes, relations, and arrangements rather than space or time units. We are now looking forward to much more inciteful and comprehensive periods when we shall have better concepts and methods for dealing with these complex units.

CRITCHLEY: I am a practicing medical doctor, not a biologist or a psychiatrist. I am an organic neurologist, and as such my interest has been the breakdown of speech in man—that is, speech disorders caused by brain injury and brain disease.

Now, in order for speech pathology to be adequate, it should be tied up with a knowledge of, or study of, speech in the normal human subject. I suppose that this is the background or context of this particular panel discussion and the reason we are here.

As one primarily interested in language, I would plead for the most rigid employment always of a terminology that is simple, clear, and precise. The growth of ideas and of knowledge has so outstripped

the growth of our vocabulary that there is always a very real danger of lapsing into confusion. The language used by scientists runs the risk of being not fully comprehended, not only by the world at large, but even by other scientists within the same discipline and, of course, in other disciplines also.

The two devices already used to circumvent this difficulty are in themselves potential sources of error. One very obvious device is for science to erect a vocabulary as it goes along by coining new forms, rigidly defining them, and then always using them in their precise connotations. The alternative is either to borrow words from language in common use or else to filch terms from the vocabulary of other sciences and then to endow these with our own private meaning—a meaning sometimes quite different from the original and one that may differ widely from individual to individual. This is a most fertile source of confusion. Biology, I suppose, is not a conspicuous offender, but I am sure that psychiatry, psychology, and philosophy are often seriously at fault here. Most of our ordinary talk is, of course, fundamentally built upon metaphor; but when you find metaphor piled upon metaphor upon metaphor again and simile added to analogy, there is a very great tendency to lapse first into clichédom, then into jargon, and finally into gobbledegook. Like Voltaire, I would suggest that each of us should be prepared, if called upon, to define his terms at a moment's notice.

GERARD: But please exercise that right with caution, or we shall never get beyond item 1.

GANTT: I am from the Pavlovian Laboratory at the Johns Hopkins University, and the psychophysiological laboratory in the Veterans Administration. I study both normal and abnormal aspects of behavior, including the causes of psychiatric diseases.

At the present time I am especially interested in high blood pressure and the psychogenic or nervous causes of cardiovascular disease. The methods I generally use are those of the conditional reflex. In support of Critchley, I may say that this method gives us precision and a kind of data less dependent on language.

I learned the conditional reflex method from Pavlov. Just after I finished interning, I went to Russia with the American Relief Administration under Herbert Hoover, when we were feeding ten million Russians during the famine. I had the honor of meeting Pavlov there six years after he had officially died, according to the *Encyclopaedia Britannica,* which formerly placed his death at 1916. I began working with Pavlov to learn his methods and continued for six years. This is my earliest remembrance of the feedback mechanism; so I feel that Pavlov gave me more than I was providing.

HALLOWELL: I suppose I might call myself a human animal of a different variety but perhaps of the same species as the gentlemen who have just spoken. I would define myself as a cultural anthropologist with psychological interests. In the past, these interests led me to study the relations of culture and personality and in recent years have led to my interest in problems involving the psychological dimension of human evolution.

For a long time, anthropologists have used the possession of a cultural heritage as a criterion for differentiating man from other animals. Problems of cultural and social evolution were widely discussed in the nineteenth century, and we shall hear contemporary discussion of this topic tomorrow at the fifth panel. I think, however, that there is a gap in our knowledge of the roots of a cultural mode of adjustment in man. That is why I used the title "Self, Society, and Culture in Phylogenetic Perspective" for my contribution to this conference. There *is* a psychological dimension here. It is difficult to investigate, and I fear that my methods may be relatively imprecise compared with those of the other panelists.

VEITH: My field, the history of medicine, might be thought of as the hidden link among all the specialties that deal with evolution, for medical historians deal with evolution in many different ways. With the emphasis on medicine, we are concerned with the influence of evolutionary principles on medical thought, including, of course—and in my case especially—that of psychiatric thought; and we deal with such examples as the direct influence of Darwinism on the work of John Hughlings Jackson, Sigmund Freud, and others. Again with the emphasis on medicine, we study the evolution of physical and mental diseases throughout history; and we try to account for the disappearance of such diseases as the mental and physical epidemics of the Middle Ages. We also try to account for the ascendancy of apparently new and often equally menacing forms of disease. As medical historians with the emphasis on cultural and social history, we try to relate scientific facts to their cultural environment. Thus we deal with man's concept of creation and evolution before Darwin and with the impact of Darwin's work on the cultural world that followed him.

My own interests have especially concerned non-Western—that is, Far Eastern—evolutionary reasoning and its relations to the cultural and even political development of the Orient. It has been a most enlightening observation that in China the human mind was able to conceive of creation in evolutionary terms at least three thousand years ago and that some of the greatest philosophers emphatically endowed the lower orders of life with mental faculties that approached the human level.

HILGARD: I am an experimental psychologist. What this means is simply a psychologist who tries to work on problems that can be studied in the laboratory. It is our faith that this does not limit us very much, but this faith has to be justified by what we do. My own work has been chiefly in learning and motivation; and if Critchley will permit me to use some terms from the vernacular, I have more recently been working on states of consciousness altered from the normal—such as dreams, hallucinations, and hypnosis.

The justification for a psychologist's being on a panel about evolution is clear enough from psychology's position between the science of biology, on the one hand, and the social sciences, on the other. On the biological side is comparative psychology. Physiological psychology is simply one with the biological sciences, and here the debt to Darwin is clear. On the social and personality side, that debt can also be traced, largely through Darwin's cousin, Sir Francis Galton, who began the studies of human inheritance and invented the contrast between nature and nurture that we use so much in talking about human intelligence.

HUXLEY: My approach to the evolution of mind has been complementary to Hilgard's. I have always tried to look at this problem from the point of view of a naturalist—the same sort of attitude that Charles Darwin held. I first became interested in this general subject while studying the courtship of birds, in asking myself what role mind played there. And as a young man I was very much preoccupied with the development of my own mind and behavior and also with that of my fellow men and women. My main concern throughout my biological career has always been evolution, and I have tried to link the various evolutionary fields into a unified picture through comparative study.

What has impressed me most—and I hope this will come out during these discussions—is that during the course of evolution on this planet quality has somehow arisen out of quantity, and the subjective has arisen out of the objective. And, of course, that happens in the development of every one of us, too. Another trend that occurs both in individual development and in evolution is that the patterns of organization of mind and its associated behavior move to higher levels. Finally, one finds the emergence of this or that new quality or character of mind, which in turn affects later evolution; and mind seems to have played an increasingly important role as evolution went on.

VON MURALT: I am a man who likes to stick electrodes into nervous material and study the effects: that is, a neurophysiologist. When the morphologist studies life, he finds an enormous variety of form and function, while the physiologist, on the other hand, is surprised by the

great uniformity of the basic mechanisms. I should like to give an example. We are studying such distantly related animals as the North Atlantic squid, the electric eel, the torpedo, the spider crab, the frog, the cat, and the monkey. We find that the only form of sending a message through the nervous system is the nervous impulse, which is exactly the same in the squid as in the monkey. We find only two modes of conduction of this impulse: in the lower animals, continuous conduction; in the higher animals, conduction in jumps, which we call "saltatory conduction." Studying the chemical substances used for transmission throughout the animal kingdom, we find, generally speaking, only two: actylcholine and neuroadrenalin. And as far as we know today, the only substance used in nervous systems for the supply of energy is adenosine triphosphate, ATP, with its energy-rich phosphate bond.

How did this uniformity evolve? There are several possibilities. Possibly these basic living mechanisms are protected in the genetic background, so that no mutations and no changes can occur. That is, they are set apart from evolution. Another rather interesting possibility is that this uniformity of biochemical and biophysical mechanisms may be the *result* of evolution; and here we are starting to think of evolution as two-dimensional. We have morphological evolution from the primitive form up to the higher, more complex forms; and in the opposite direction we have evolution from a rather complicated biochemical and physical background to a very simple pattern, which is now uniform for the whole animal kingdom.

L. J. Henderson's book, *The Fitness of the Environment,* showed that the physical factors on this earth are apparently such that life was possible because of very specific and unique qualities of water, carbon dioxide, the tetravalent carbon atom, and the like. Perhaps this limited number of chemical possibilities is a principle for selection that has created this uniformity throughout the basic mechanisms. This is one of the problems with which the group of neurophysiologists I represent here is concerned.

TINBERGEN: I am a zoologist and as such, of course, became interested in how animals survive and manage to reproduce and even manage to improve themselves. Very soon it became clear to me that behavior is one component in the functional systems by which animals manage this. My work, therefore, has involved trying to find out how behavior is organized in different animals, how its effects aid survival, and how behavior has evolved in relation to the whole animal. This zoological science of animal behavior is usually called "ethology" in Europe. I should like to say that my colleagues and I do not consider

ethology just the result of talking about releasers and imprinting but would rather define it more widely and say that ethology aims at being a biological science of animal behavior.

Now this, we realize, is an extremely tall order. I remember that Dobzhansky emphasized how much we do not know. Without sounding too pessimistic, I wish to emphasize that ethologists more than agree with him; for our situation, we very strongly feel, is still worse: very often we do not even know what it is that we wish to find out. Ethology is struggling to become a biological science. That may sound pessimistic and perhaps even defeatist; but I think it is necessary to dampen our own sometimes rash enthusiasm, which has played tricks on us in the past.

We do know that the intact animal in its natural surroundings is a hugely complex system. We feel very strongly the need for analysis, and we realize more and more that this analysis has only just begun, that our subject matter is extremely complex even in so-called very simple animals. In that respect, of course, ethology is far behind morphology. The study of evolution has often used morphological criteria. When we wish to use behavioral criteria, we feel we are lagging far behind, just because we have not yet analyzed these systems as fully as the morphologists have theirs. In this panel with so many different people, it may be difficult to communicate. We speak very different languages; that will be clear in the course of the discussion. From my side, I shall try to overcome this difficulty and shall not be too precise or too pedantic in asking for an operational definition each time.

GERARD: I began my career primarily as a neurochemist and neurophysiologist and have drifted over into being a neurophysiologist and a behavioral scientist. I am concerned with getting inside that black box. We put electrodes into brains to stimulate the nerve cells and see what happens—chemically, electrically, behaviorally. We give animals and people drugs and make similar observations. The electrodes in particular brain regions also pick up electrical activity that accompanies neuron functions. This is short-circuiting the system from input and sensation to output and action of some kind. Therefore, physiologists are really getting inside the stimulus-response problem.

Our first topic for discussion is the subjective and the objective and the problems of methodology.

TINBERGEN: We have no direct historical record of behavior, and therefore we have to compare. Comparing animals with other animals is, in principle, relatively easy, because we can learn from the experiences of comparative anatomy, which was at least a hundred years ahead of us. But when comparing animal with human behavior, we

run into great difficulties. And again I feel I have to strike a cautionary note.

We feel there are, in principle, two types of observables when dealing with behavior. One type, which includes the movements of animals, can be shared by different observers; we can observe animals together and check each other's observations. The other observables are the subjective phenomena that coincide with behavior, which we observe, each of us, in ourselves; and these are, by definition, observable only to the subject.

Now projecting ourselves into other human beings is perhaps allowable. We all belong to the same species. Projecting ourselves into animals is often done. People often assume that what they feel when angry is very similar to what an angry dog feels; although they cannot directly observe what a dog feels, they guess at it. Of course, such guessing becomes increasingly difficult, the further removed the animal is from us. It is very hard to imagine what a starfish feels when it is angry, if it ever gets angry. Many persons argue that this is a difference of degree, but many zoologists (and I am one) think that this is a matter of principle with no compromise possible. We must confine ourselves to the first type of observables and act on the assumption that they are determined by preceding events that can be made observable.

I am fully aware that this attitude is no more than a general working hypothesis. If we can adhere to direct observables and try to apply the same method as that used in all the other biological sciences, then we shall see whether this hypothesis works. That is our attitude and, I feel, the only attitude possible. Of course, this makes it very difficult to communicate with those who study human behavior. Some may say our view is very narrow. All right, it is narrow; but we feel we must recognize that science *is* a limited occupation and is only one way of meeting nature.

Our discussion will often be worded in language into which many persons (and I am among these) may read subjective connotations. I feel that it is fruitless to try, every time, to translate our words into operational language, because we should lose a great deal of time quibbling about words. My own difficulty, for instance, begins with the title of this panel: "Evolution of Mind." I would rather speak of the evolution of behavior; but I won't quibble about it; we each attach our own meaning to the same words.

BROSIN: I mentioned earlier that in dealing with human beings in distress the psychiatrist and psychoanalyst must work with the material and the problems that confront them. Such data consist largely of the so-called irrational forces, outside the patient's awareness, which are

often called "unconscious" and "preconscious" activities. There is much reason to believe that these forces are related to the animal-man referred to at the close of Panel Three yesterday by Rensch and Waddington and to the concept of a primary process developed by Freud.

The clinical manifestation of various types of disorientation—leaving aside, for the moment, toxic and organic disease of the central nervous system and such phenomena as delusions, sensory hallucinations, and motor distortion—can now be much better understood by means of the concepts and methods of Freud, the experimental work of Hilgard and others in hypnosis, the LSD-25 series, the sensory deprivation studies initiated by Donald Hebb and John Lilly (and now there are a half-dozen good workers, including Solomon and others, following upon these), and research on the subliminal stimuli, including Charles Fisher's studies of perception and dreams.

These recent studies, supplemented by film and tape, provide new data and methods relating to the meaningfulness of human interaction and the intense pressures upon the organism, which have verified or even surpassed our expectations.

It does not reflect upon the dignity of man to show how closely he is related to his animal cousins, if we recall that at the same time he is indeed a most remarkable creature, with practically unlimited capacities for present and future accomplishments.

HUXLEY: I am afraid I disagree with Tinbergen. I very much welcomed the choice of this title for our panel because it stresses the importance of mind in evolution. I would remind you that Darwin, who really founded the science of ethology with his book *The Expression of the Emotions in Man and Animals,* was perfectly clear that it was proper to speak of the subjective factor in animals—in this case, the emotions—and I am quite sure he was right. Of course, it is clear that the actual study of behavior must begin on a purely behaviorist level. We interpret our friends' behavior in terms of what we think are their mental activities; but our interpretation is always based on detectable sensory signs of one sort or another. In any case, interpretation in mental terms is the essence of what we do. Animals, too, have directly observable modes of behavior and deducible mental attributes. As a scientist, one *must* infer the existence of qualitative or subjective properties in the behavior of subhuman animals. Many lower vertebrates, such as fish and reptiles, react quite distinctively to radiations of different wave lengths, which give us the sensations of *red* and *blue.* I interpret such reactions as indicating that each of these animals subjectively experiences some qualitative differences in its sensations, and I assert that we *must* so interpret them.

TINBERGEN: I know we have been compared to people wearing

monochromatic glasses who stand in front of a painting by Rembrandt and miss the most important part of the picture. But I don't think it would be very useful to spend much time on this point. I shall just say that I disagree. When Huxley says we can deduce something about subjective phenomena, I think he uses "deducing" in the sense of "guessing."

HUXLEY: But from my behavior you would deduce that I see some difference in color between this carpet and your clothes?

TINBERGEN: Right there we are in the middle of semantic difficulties.

HUXLEY: That is to evade what to me is an obvious fact.

TINBERGEN: It is an obvious fact to you, the subject who sees it; it is not an obvious fact to me. The obvious fact to me is that you react differently to the two colors and that you tell me so, which is part of your reaction.

HUXLEY: I must say I disagree with you. I think we have to believe that animals do perceive some difference of quality in colors, for instance.

GERARD: But do you call this a belief, or do you call it a fact?

HUXLEY: I think we have to believe that it is a fact, as we have to do with many other scientific conclusions.

GERARD: The problem, as I see it, is this: in an organism, some antecedent state, which we see externally as material and subjectively perceive as conscious awareness, is followed by a like consequent state. If we recognize and describe the antecedent state in terms of physical aspects and the subsequent state in terms of subjective aspects, we are likely to make such a statement as "ether produces unconsciousness." But this is just a shorthand and really is not correct. The question I should like to throw back at you, Huxley, is this: Granting the adaptive value of behavior, what is the evolutionary value of awareness? Why is it adaptive for organisms to be aware of the world and themselves? I have never been able to answer that to my satisfaction.

HUXLEY: What I did not get across is this: I think we shall never be able to understand this. We have to accept this—to me—mysterious fact of difference in quality of sensation and other subjective phenomena as an irreducible fact. But I think we can quite properly deduce that it appeared during the course of evolution and that it was of value.

I don't see how one can interpret some of the later stages of evolution without such an assumption. In our own case, for instance, how can you possibly interpret the fact that painters paint pictures and that people like to look at them, unless you believe that the basis of these colored pictures was somehow present in prehuman ancestors?

GERARD: Perhaps this is a good time to leave an unanswerable topic. I don't think any of us has the remotest idea why subjective awareness developed. It is not a silly question to ask whether subjective experience may be arising in computers—or what it is in paramecia or leucocytes.

I think we should take a moment for the problem of the quantitative and/or the pattern aspect of the information with which we deal.

HILGARD: There is no need to elaborate on the obvious advantages of mathematics to science for giving systematic formulations precision, economy, and elegance.

A point raised last year by the historian Charles Gillespie intrigued me. This was the difference in quantitative implications between the theories of Darwin and those of Lamarck. Gillespie pointed out that the common cliché of the distinction between these—inheritance of acquired characters—is really not nearly so fundamental as other differences in their approaches. The fact that Darwin dealt with a mass of concrete relationships laid the ground for eventual quantification, so it was very easy for evolutionary theory to assimilate Mendelianism and population dynamics. Even though Darwin did not use mathematics, his way of thinking in concrete terms made possible counting and developing probabilities, and so on.

An interesting by-product of this, which I haven't time to go into, is that if one traces the history of the introduction of mathematics into my own field, psychology, one finds that model-building in learning and correlational techniques and the like come through persons influenced by Darwin. An interesting philosophical point here is that there is a tendency toward the quantitative in any kind of objective thinking of the kind that Tinbergen is proposing.

Whether we lose something by this is, of course, a problem of the appropriateness of mathematics. It is quite as possible to be misled by mathematics as by any other tool; but it does sometimes help us to think clearly. Since mathematics makes us communicate effectively, I suppose we shall see an increasing trend toward its use.

I am sure that part of the quarrel between the objectivists and the subjectivists is solely on this ground of whether or not we can get a systematic and unambiguous communication of what we mean; and mathematics signifies that we have done this. I think that with some sophistication and by keeping our data or our data language objective, we can still make inferences like those Huxley wants us to make. My own reason for working on such borderline states as hypnosis is actually to see whether some such thing can be done.

HUXLEY: Wouldn't you say that, besides his quantitative comparative study, Darwin was always thinking in terms of patterns of organi-

zation? He often used the word "higher" against "lower" organisms. I should have thought this to be an equally important contribution. It is very difficult to mathematize patterns of organization. We shall have to eventually, but meanwhile we have to make do with thinking in terms of patterns. And I would remind you that the ethologists have discovered that sign stimuli consist of distinctive patterns.

BROSIN: I would support the general position that we must have qualitative data and patterning before we can quantify. We are in a pre-Darwinian state of exploration.

GERARD: I think we all agree. But I should like to take exception to calling non-quantitative "non-mathematical." With the possible exceptions of geometry and the theory of numbers, the development of the calculus and differential equations and other mathematics of quantitative difference came before the mathematics of relation or pattern, which are so new and exciting today. I think it was partly because the tools were not available and partly because it is actually harder to understand pattern than to measure amount that biology and even more the social sciences are behind the physical sciences. Only now are we beginning to enter the exciting period of being able to make rigorous statements—not necessarily quantitative ones—about the phenomena with which they deal.

The panel is now ready to discuss the evolution of behavior and what it had to do with mind's evolving.

TINBERGEN: First, a few general words on what we can say about the evolution of behavior. Without a direct historical record, we are confined to indirect methods. (A few minute steps in microevolution can be studied in the laboratory, and with behavior a start is just being made; but the results are so scattered and so few that we can disregard them for the moment.) Of these indirect methods, the most fruitful is, of course, comparison of contemporary forms. Now this comparison is of two types. First is a kind of macrocomparison based on the "ladder-of-life" concept that assumes we can arrange animals in lower and higher, or less and more complex, series and that, by reviewing these, we get some idea of general trends in behavioral evolution. The second method we could call "microcomparison." By comparing very closely related species, we try to get an impression in exactly the same way that an impression of adaptive radiation within a group was acquired in comparative anatomy, acting on the assumption that the animals compared are really closely related and have a common ancestor. Therefore, what we see at present must be the result of divergence.

Now, in macrocomparison, a few things have become clear and are almost commonplace. In the course of evolution of life, there has been

a development toward more patterned sensory perception, more complicated configurational sensory perception. There has also been a general trend toward more complicated co-ordinated movement and, with this, a division of labor among different functional parts of the nervous system. An individual of higher type has a greater variety of behavior patterns than we find in more primitive or lower forms. With the increase in the patterning of sensory reception, we find better spatial orientation. We see an increase in learning capacity. We see at various points on the evolutionary scale an increase in social interaction, which has become possible through a high degree of complexity.

A number of microcomparative studies are now available, mainly on closely related groups of birds. The surface-feeding ducks have been well studied by Lorenz, and some of the songbirds have been extensively worked on. For the purposes of this panel, it is particularly unfortunate that this method has not been extended to the primates—the group in which we are most interested—to the same extent as it has to other animals, although a beginning is now made toward a concentrated and truly biological comparative study of the primates. In Madison, Harry Harlow is making a beautiful study of monkeys. Many parties are now in the field. I hear that my colleague John Emlen has succeeded in approaching gorillas in the field and is using exactly the same methods as those we have been applying to birds. But the primates involve an enormously more complicated set of problems than, say, finches or gulls; and when I consider how long it has taken us to understand something about adaptive radiation in the gulls, I feel a far greater effort still is needed with the primates.

HUXLEY: All those interested in animal behavior are greatly indebted to Tinbergen, to Konrad Lorenz, and to their colleagues and followers. They have illuminated this whole field in a totally new and exciting way. For instance, in my first piece of work I described and tried to interpret—largely unsuccessfully—the courtship of the Great Crested Grebe. Now, thanks to Tinbergen and his colleagues, it has become comprehensible. They have discovered built-in sign stimuli, releasing mechanisms, and motor mechanisms and have found that actual behavior depends on an interaction of different and sometimes conflicting drives, which I would say presumably have some emotional complement.

Another important thing they discovered was that in certain types of conflict or frustration, nervous energy—or whatever you like to call it—flows out into an irrelevant and non-adaptive activity, which they called "displacement activity"—like sham preening during courtship; and this may then be seized on by later evolution as the basis for

some new biologically significant and adaptive function. Then, in recent years, Tinbergen especially has studied the comparative behavior of a related group of animals; and with the gulls, for instance, he found that behavior that seems quite incomprehensible in one species becomes comprehensible when you study the whole group comparatively.

HILGARD: A few years ago, Tinbergen wrote a book with the word "instinct" in the title. This is a good word, one used by Darwin; and I should like him to comment just briefly on that.

TINBERGEN: I wanted to avoid that word because I feared we would end up in semantics again. The main reason that, after having written a book on the study of instinct, I now don't use the word is that I find it covers at least four entirely different concepts.

Instinct is sometimes used in the sense of anything that is not learned and refers to the ontogeny of behavior; it then designates so-called innate behavior, not-learned behavior. As applied to characters, that dichotomy is no longer very popular, although we can retain it for *influences* and for *differences between species*. This is one use of the word "instinct," and it refers to an aspect of ontogeny, learned or non-learned.

But instinct also covers quite a distinct concept that is closer to the original meaning of the word. That is, is behavior purely reactive, a response to external changes—or is it driven from within? Instinct here, I think, means something like driving, urging. This use has nothing to do with the ontogenetic distinction.

We use "instinct" in a third sense, especially in human behavior, when we say someone put his foot on the brake instinctively. Here again, we mean something entirely different—"not deliberately" or "unconsciously"—and refer to a subjective aspect open to our own observation only.

And then, of course, there is a fourth use of the word, and that was the way I meant to use it in my earlier writings. In many animals there are rather separate functional systems, such as the whole mechanism responsible for feeding behavior and the entire (largely unknown) mechanism responsible for sexual behavior. You can call such a mechanism the "feeding instinct" or the "mating instinct." That is again an entirely different use. In that sense, all behavior is instinctive, whether learned or not. This confusion is really the reason I think that the words "instinct" and "instinctive" are not very useful, even if every time you use them you put in a little footnote, saying "I mean this or that."

HUXLEY: The word can still be very useful. I remember when Kon-

rad Lorenz came back from America after a great dispute with proponents of the view that learning is all-important in behavior, he said, "I think I have taken some of the stink out of instinct."

GERARD: Hilgard, are you content with this position, or do you wish to pursue the point?

HILGARD: I am content.

GERARD: I think that, as Tinbergen said, this is purely a matter of a convenient term to epitomize a series of phenomena. The neurophysiologist finds different parts of the nervous system that actively lead to a kind of behavior, which, seen in man or animals, we call "emotional behavior"—fear or rage or sex or something of that kind. We can call it "emotional behavior" or "instinctive behavior" if we know what we are talking about and avoid these mind-behavior mix-ups.

We are forever faced with anecdotal stories of domesticated animals or our garden friends doing things that look highly purposive. There was a paragraph in a recent *Reader's Digest* about a chap who kept squirrels from stealing the seeds from his bird-feeding station by rigging this so that the slightest weight on one side would tip off the squirrel. It worked for several days, but then the seeds began to disappear again. Lo and behold, two squirrels were jumping simultaneously on the two sides. Now is this realistic? If it is a valid description of a phenomenon, would you use the word "instinctive" in connection with it?

HUXLEY: I think we should leave these as essentially philosophical and semantic problems. We have many concrete and more exciting questions to discuss.

GERARD: You don't want to pick it up, Tinbergen?

TINBERGEN: No, I agree with Huxley. Let's turn to concrete questions.

HUXLEY: I should have thought that, as a result of Lorenz's and Tinbergen's work, "instinct" should be used for a rather elaborate built-in system involving a sensory pattern that can be received, the internal releasing mechanism that receives it, and the complex motor pattern that comes out. It is really a definite type of phenomenon, not a general category.

GERARD: Are we all satisfied with this discussion of topic 3 and ready to move on to 4?

HUXLEY: I was going to talk about the evolution of color. This emerges as something new in the world, and the acquisition of color vision by animals had an effect on subsequent evolution. I think nobody would disagree that the capacity to distinguish different wave lengths did lead to the evolution of brightly colored display characters

in fishes, birds, reptiles, and the like—in other words, that had further evolutionary consequences. Apparently mammals lost most of the capacity for color vision during their transition from the reptiles, probably because they were nocturnal and lived underground. In consequence, they do not show any bright colors in their pelage. They show blacks, browns, yellows, russets, whites, and grays, but not true reds, greens, or blues. We know the primates have reacquired color vision, and, as a result, one finds a full range of colors among them, with greens and blues and true reds coming back, often in all sorts of funny places—you remember P. G. Wodehouse's definition of the mandrill as the animal that wears its club colors in the wrong place. And then, of course, in the human species, this has had important biological, social, and economic effects, such as the redness of human lips and the manufacture of lipstick. Thus color vision is the basis of much of the cosmetic industry.

TINBERGEN: Points 3 and 4 list several examples of human behavior in areas where every one of us has been asking whether we can see possible precursors in animal behavior. And I thought it would be well to discuss some of these in more or less concrete terms. I selected at random the last item mentioned under point 3, "Operating with values." I think we can mention some interesting examples of animal behavior that may give just a glimpse of how in animals we can see possible precursors of this type of behavior in man.

Man is a social animal and shares with many social animals a certain set of values. That is how we describe these in man; I think in animals we could call them tendencies to behave or not to behave in a certain way; to behave or to inhibit behavior (or misbehave; but that would be introducing a value, which I won't do). I am thinking of the remarkable conformity in general behavior shown by many social animals. In some birds, for instance, there are indications of special behavior patterns, whose function is to bring an abnormally behaving individual back into normality. This has been reported in social birds, for instance. When a bird behaves very abnormally, fellow members of the group may attack it, and the reaction of the attacked bird is to come back into the flock and be inconspicuous. When one approaches this problem as a zoologist, one begins to wonder about the functions of certain human behavior patterns. One can no longer doubt that we have something similar; and we even have an intensity scale of this kind of action. When a person behaves abnormally, we begin by laughing at him—incidentally, laughing together *at* another person ties the two who are laughing very closely together—which is a very strong stimulus and makes the abnormally behaving individual

want to come back into normality, to rejoin the group. If laughing at him does not work, we "send him to Coventry." That is a still stronger stimulus. It is worse to be sent to Coventry than to be laughed at. If this doesn't help, you use open aggression. In our civilized society, of course, aggression takes a very mild and non-mechanical form, but still it is very much there, and the response of the individual, which makes him want to disappear in the crowd—in other words, to behave like the others—is very strong. I think if we compare these general social devices in behavior in man and in other social animals, we may find a number of such precursors—possible precursors. Of course, I am speaking of functionally similar things—of analogies.

BROSIN: May I ask a question about your ranking of the types of behavior? Curiously, you consider direct aggression and assault a more severe method of correcting unconventional behavior than sending to Coventry. Actually, both personal observation and the communication theory of Sapir and Bloomfield that I mentioned earlier indicate that one of the worst things that can happen to one, and one of the quickest ways of dehumanizing a person and getting quick regression down to the primitive, is to send him to Coventry or otherwise isolate him.

TINBERGEN: The scale of functions may have to be revised. I was just giving a concrete illustration of the kind of comparison that might be useful. Sending to Coventry might be worse than aggression, I admit.

HUXLEY: Do you ever find that higher social animals are sent to Coventry or sent out of the herd?

TINBERGEN: Sent out, yes; but this is done by aggression. You remember Goethe's paper on birds. I don't, offhand, know of any animal equivalent of sending to Coventry.

HALLOWELL: There again the primates might be useful.

GERARD: I was much impressed by the point Leakey made yesterday, that in times of severe drought territoriality is abrogated. It struck me that this looked like a real value judgment. Would you agree with that?

TINBERGEN: There are comparable observations on social birds who live in flocks in winter. It has been reported of rooks that there is a regulatory mechanism of the connection between hunger and aggression. When mildly deprived, they will fight each other over food. When they are very much deprived, under conditions of extreme cold and extreme starvation, all aggression suddenly stops. I think this must mean that in these two circumstances selection has put a premium on two different things.

HILGARD: "Value" is used here in the sense of regulatory social

values, but it is one of those words that cover a great deal. One can study preferences as well as discrimination. For example, besides color discrimination, one can find a sort of primitive aesthetics. Rensch has reported that some of his monkeys prefer to string beads of certain colors rather than other colors. It is not just a matter of whether they can tell them apart. Here at the University of Chicago, Eckhard Hess is experimenting with changing the preference of chicks for different colors. So one can see other kinds of continuity between animals and man. I think this is really a fascinating notion, following different strands in behavior to see how we got the way we are.

HUXLEY: In this, the Satin Bower Bird is perhaps the most remarkable of all. Not only do the males prefer blue and reject red objects for their collections in front of the bowers, but some individuals of the species paint their bowers deliberately. This is definitely the beginning of aesthetics.

TINBERGEN: Let us take another example. The panel yesterday called the use of tools very distinct from preparing or making tools. It is, in a sense, unfortunate that through Wolfgang Köhler's work the use of tools has been linked with something like insight. It is not the use of tools as such but the spontaneous individual invention of the use of tools that Köhler pointed out as being important and "rather human."

We know several animals that use tools in the fullest sense of the word. One is the Galapagos finch, which lives rather like a woodpecker, but, instead of having developed the woodpecker's bill, it uses the spine of a cactus to probe in cracks and get at insects. That is the use of a tool in the fullest sense of the word. But all individuals of the population, as far as is known, do that. Unfortunately, we don't know how it develops in ontogeny, but I think we can make a pretty good guess that this is not learned behavior. Another famous example is the sea otter, which carries a stone on its stomach, and when it has got hold of a mussel, it will float on its back and hammer the mussel against the stone to crack it. That, I think, is by all definitions the use of a tool. But again, the whole population does it, and again we don't know whether they learn this or not.

HALLOWELL: Anthropologists discovered long ago that instinct—at least in one of the definitions mentioned by Tinbergen—was of little use as an explanatory principle in the study of human societies and cultures. I think everyone knows this. What anthropologists call "culture" is assumed to be non-instinctive, to be the consequence of individual learning and the social transmission of learned behavior through symbolic mediation. No formal definition of culture is needed here, but I should like to touch on a couple of other points.

First is the relation of learning and the transmission of behavior patterns and thought in human groups to the question of values. It may be and very likely is important to consider values in evolutionary perspective, but it seems to me that it would be one of the most difficult concepts to deal with in this way. At the primate level, to say nothing of animals other than primates, "value" in relation to the behavior of individuals certainly might be conceived to have some relation to group survival. One of the illustrations Tinbergen mentioned might concern group survival.

Besides group survival in the biological sense, the human level involves survival of sociocultural systems. The survival of these systems depends on the socialization process, learning by individuals, and interiorization of traditional values, which then function in relation to goals in the society but, at the same time, from a psychological point of view, permit the individual to be very deeply identified with the values of his cultural system. This has a double aspect. There is survival in the biological sense, because from an institutional point of view—the economic system, the family, and so on—the biological survival of individuals is secured; but at the same time the sociocultural system becomes an ongoing concern.

As for the tool problem, aside from the differentiation between tool using and tool making, I see a crucial question in the actual psychological processes involved in what has sometimes been called tool making among chimpanzees. I came across a statement by Nissen that the case in which the chimpanzee Sultan actually put two sticks together was, in fact, a unique observation. In other words, the inventive aspect would seem to be less prominent.

I wanted to link this question of invention by primates with the emphasis so frequently given to the perpetuation of sociocultural systems through learning, because undoubtedly we have parallels here to primates and to other animals. It seems that man has psychological potentialities, due to psychological reorganization of the hominids somewhere along the line, which permit perpetuation through learning and social sanctions of cultural values and a cultural pattern and which also provide potentialities for cultural readjustment and change through invention and discovery. This, it seems to me, is very important to emphasize. The very fact that culture patterns are differentiated so widely in *Homo sapiens* is in itself evidence of this. In other words, although we can and do speak of culture in a generic sense and while there are certain universal aspects of culture, in concrete and in historical terms, culture in man is not actually species-specific.

GERARD: Tinbergen, do you think of any clear examples of invention, sanctions, or social transmission of knowledge in the subhuman animal?

TINBERGEN: As many of you may know, titmice in Britain had developed a habit of opening milk bottles left at the front door. From a study of the spread of this habit through Britain, James Fisher and Robert Hinde have concluded that it must have originated in many different places. From these centers, it must have spread through the population, partly through tits of the same generation imitating each other and perhaps partly through transmission from one generation to another. There is very little doubt that here is an example of a discovery by birds, and not by only one individual in the population, but by a number, yet a limited number. It is now so widespread that most houses have a metal cup or a stone ready for the milkman to put on top of the bottles. It is a rare invention, and we know few examples of this; but it does occur.

HUXLEY: There were several centers of origin from which we have been able to measure the rate of spread of the habit. There was one center in the Low Countries.

GERARD: What about the red deer, where the old female in the group is supposed to pass on knowledge of the terrain?

TINBERGEN: I have no information about that.

HUXLEY: There is a much better example available. Do you remember the case of the monkeys in Japan, reported at the International Zoological Congress last year? These monkeys live in troops, each with its own tradition of food preferences. Every now and then these will change. And this is very interesting: the change seems always to be introduced by some naughty young monkey who wants to eat something different. To start with, his mother spanks him; but if he is naughty enough and wilful enough, he goes on eating it, and then she eats it, and then the custom spreads. This is a remarkable example of a youthful individual initiating psychosocial change—a Prometheus, as it were, of monkey diet.

HALLOWELL: It is very interesting that, instead of these new food habits being accepted by older monkeys, they very often are accepted first by the younger animals, from whom the older monkeys then learn. However, Imanishi's use of the terms "culture" and "acculturation" involves a problem we do not have time to discuss here. But, as I mentioned yesterday, it seems to me that in human evolution, both social and psychological, we have to conceive of some kind of preadaptive stage. I should prefer to call this "protocultural," because the life of these animals as compared to man shows qualitative and quantitative differences. I think in discussing evolutionary problems we have to be very careful of our terminology.

CRITCHLEY: It seems to me that one of the principal gaps in our understanding of this smooth, orderly progression between the highest representatives of the Primates and the lowest representatives of *Homo*

sapiens is the abrupt introduction of language, because, no matter how vocal an animal is, however rich its repertoire of sounds, it cannot, strictly speaking, be spoken of as being endowed in the precise sense of the word with either speech or language. At the very most, we can use the term "animal communication." At present, there seems to be a very real distinction between animal communication and human speech or language.

GERARD: What about a man and a dog interacting?

CRITCHLEY: That is capable of a different interpretation altogether. Somebody has said, rightfully perhaps, that it is easier to translate thirty pages of Cicero than to understand fully the meaning of a crocodile's grunt. The matter of the man and the dog is another story.

I think we can say that the main difference between animals and man in this respect is that in their system of communication animals employ signs, whereas man makes use of symbols. That is the big difference.

GERARD: When a dog sits up and begs for sugar, what is it doing?

CRITCHLEY: Making signs.

GERARD: I question that.

CRITCHLEY: When we look at the problem, trying to detect the bridge between animals and man, we can perhaps assert that the right way would be to look not so much for the beginning of articulation or the articulate use of symbols as to seek rather the beginnings of symbolic thought or behavior or a manipulation of symbols in animals. If we can only descry somewhere in the animal scale the beginnings of these phenomena, perhaps then we might be witnessing the very earliest precursors of language and then perhaps we can see things of significance being attached to some inanimate objects outside themselves. For example, when we find an ape choosing an object—a stone or stick or a piece of rag—carefully setting it aside and preserving it and then utilizing it as if it were a sort of plaything (not a tool), then perhaps we are witnessing the beginnings of symbol formation. Perhaps this is the beginning of symbolic thought. Then, from the particularization of one single item in the environment to the endowment of this particular item with a name is really only a step. It is a big step, no doubt; but, anyway, it is the sort of step that we humans can visualize without too much difficulty.

TINBERGEN: What Critchley says is fully borne out by most studies of animal communication. Ethologists also feel there is an enormous gap between the very simple "sign language" observed among animals—of which we know a great deal now—and human speech. Here again, a study of the primates is needed to fill the gap.

Sign languages in birds and fish, for instance, are all of this type:

They carry a message—"Do this now." They elicit something—"Stop this now" or "Come here" or "Go away" or, in very rare cases, "Go there"; and, oddly enough, the best example of that last message is found in the honeybee. In birds and even in mammals this is extremely rare—not because they cannot point somewhere, but because it is so obviously difficult to react to pointing-somewhere (as every dog owner knows).

GANTT: I should like to go back from the heights to which Critchley has brought us and mention one or two common characteristics we see throughout the animal kingdom, parallel, perhaps, to what von Muralt said earlier about the common transmitters of nervous impulses.

Throughout the animal kingdom, whether we study higher or lower organisms, we see that if organisms can form any individual conditional reflex at all, they form it at about the same number of repetitions. That is, a worm will learn as quickly as a human being the kind of things that it can learn. This, of course, has some kind of teleological basis, because if a worm couldn't learn in two or three attempts, there would be little purpose in its learning at all; it does not have a very long schooling period.

I should like to say something about the perversions of our evolution of behavior and mind. Gerard has used the terms "racial reactions" and "becoming" for what, in more restrictive laboratory language, have been called "unconditional" and "conditional reflexes." Now, as we go up through the animal kingdom, we see that it is not the speed at which these individual reactions are formed that increases, but the complexities. As we reach the human level, these reactions become very complex—the interrelations between the symbols—so that, as human beings, we have achieved even the possibility of escaping the gravity of the earth. However, in this formation of the complexities there is also a great liability. As we form more and more individually acquired responses to certain situations, we find that we do not have to be very old for this to occur. We become, as it were, a museum of antiquity, so that, having once formed these responses, it is very difficult to unform them.

I want to mention one example of this, from the studies I have been carrying on. In studying the cardiovascular reactions, we have seen that these form much more quickly than the ordinary conventional conditional reflexes, such as the movement or the secretion of a gland. They will ordinarily form after one repetition. That is, to a certain kind of situation your heart rate and blood pressure will increase. This increase is learned, is acquired during the life of each individual, and, once formed, it is very difficult to get rid of. Pavlov has shown that through the process of extinction you can return an individual to what

seems more or less to be his preconditioning state, and he will seem to be neutral toward that situation. However, if you follow his cardiovascular reactions, you will see that these persist, even though the individual, when looked at externally, seems to be at rest. By studying the more internal autonomic responses, we see that he may be very violently disturbed and that, under certain circumstances, particularly susceptible individuals can never be returned to their normal condition. This is what one finds by studying some of the less observable and autonomic responses, and I think this is one of the chief bases of our psychopathology and the kind of phenomenon we must look at. Aside from our marvelous ability for adaptation, we also have to consider this other side—the hazard and the liability that human beings have because of the special complexities of their possibilities for reacting and forming responses to their individual experiences.

VON MURALT: From the point of view of the neurophysiologist, the integration that occurs in the building-up of the central nervous system is based on organization, and not on the introduction of qualitatively new elements into the system. It is the pattern and the development of pattern, the organization and the working-together, that make the complexity of the structure. Basically, the elements are always the same.

GERARD: You are thinking of the higher levels there, aren't you? As you pointed out, if one starts low enough, there is not even a nervous system; so the appearance of a nervous system is one mechanism for improved behavior. Then comes the more rapid conduction in nerves because messages jump from one break in the insulation to another hole, and so speed up conduction enormously. The receptors are tremendously increased in sensitivity. The light needed to excite the eye of a clam, for instance, is 10^{5} units, and that needed to excite the eye of a human is 10^{8}—ten million million times less. Advances at lower levels are unquestionably related to the improved elements, just as later radio tubes were better than earlier ones.

But the point von Muralt raised certainly comes in at the beginning of the vertebrates and probably improves up to the mammals—we don't really know the facts about this—by better circuits and better patterns rather than by better units. The later developments of the radio involved heterodynes, superheterodynes, and improved designs; similarly, there are impressive developments in the circuitry of the nervous system.

Some of these have been alluded to. For example, the very existence of a synapse connecting neurons with one another allows the separation of input and output, thus dissociating stimulus and response in time and giving variability to their relation. Then, instead of an im-

pulse coming in and going out through a series of neurons and to an act, it may turn back on itself to form a loop of neurons in which messages may be trapped and go round and round—the way the contraction in a jellyfish bell can be made to go round and round when started right.

Next, there are the specific so-called feedback mechanisms. Critchley does not like this term, and, as a biologist, I also objected to it for a long while; but the engineers have had us there, and it has come into general use. These mechanisms act as a sort of volume control. A message getting into the nervous system may be too strong for the circumstances, and feedback cuts down the upward flow of messages. You have perhaps heard of some recent experiments showing variation in the size of the response generated in the cat's ear by a click of constant intensity repeated over and over again regularly. If the click has no special significance to the animal's existence, the response rapidly decays until it is practically undetectable. This is habituation—just as you learn to sleep next to the railroad, despite trains rumbling by. Conversely, if that same click is made the conditioning signal to indicate to the animal that it will be shocked, then the response, instead of decaying, gets much larger. This is obviously a physiological manifestation of what the psychologists would call "alertness" or "attention."

There are many other neurological mechanisms; I can mention only the direct and the indirect or diffuse system. The diffuse system is clearly related to the kind of experience we call "emotional" and again gives the set; the discrete system is associated with the pattern experienced rather than its set or tone. These are some kinds of patterns that have come into existence in the development and evolution of the nervous system. They are probably all present by the origin of the mammals; at least, we have no reason to think that there has been further improvement along these lines.

What does seem to have come in later—a point that came up in yesterday's panel—is simply *more* neurons to do the same things. It is a very interesting point that more of the same can really lead to a qualitative difference. It is not just sheer number of neurons; the elephant has a much bigger brain than man, but man is the more intelligent.

But, disregarding special masses and uses, in the over-all story it is nonetheless true that increase in the number of neurons available to do something seems to increase vastly the skill with which it is done. The largest area in the cortex that controls motion in man is that associated with movements of the tongue, related to the fine manipulations of chewing and particularly to articulation and speech.

Time lacks to develop this further, but one last point needs mention. There may be (this is still hypothetical) a difference in the amount of time taken (that is, the amount of activity that has to reverberate around in the brain) between the time a message comes in and the time it has fixed a memory. We have been able to measure this time as something like fifteen minutes. A blow on the head can give a lasting amnesia for the preceding minutes; an animal given an electroshock each time after running a maze shows no progressive learning if the shock occurs within fifteen minutes after the experience. This failure is not due to damage by the shock, because if it is given four hours after the maze running, learning is perfectly good.

Perhaps even learning can be outside the brain. As I said in opening the panel, RNA molecules may be concerned; and recent work suggests learning in non-neural parts of the body. Flatworms have been conditioned by a bright light or a sound to turn away before a shock is given. They are then cut in two. The head regenerates a tail; the tail, which, as far as we know, has no neurons in it, regenerates a head. The regenerated-tail flatworm remembers what the whole worm learned. This is an exciting problem!

We are nearly at the end of the panel, and, rather than attempt a summary, I am going to ask each member to indicate his vision of the future.

BROSIN: As a clinician, I am sure that we need much more knowledge of the main facets of human relations. More specifically regarding problems of method, there is, first, the problem of the observer and his effect upon the systems on which he is impinging, including such phenomena as transference and countertransference. Second, I should say, is the problem of the barriers to studying such component systems and larger total systems as reciprocal relations, including the dirty word "feedback." A third problem is the possible application of the complementarity principle, enunciated by Niels Bohr and supported by J. Robert Oppenheimer, to the contradictory data we have to put up with every day. And, finally, there are the problems brought up yesterday in Panel Three by Waddington and Rensch: better methods for maintaining this very nice balance between the forces of animal-man and the requirements of society or moral conscience; between the need for stability as exemplified by the verities, and a lively skepticism and a capacity for accelerated change that will enable us to survive.

CRITCHLEY: Briefly, my expectations of the future are (*a*) a short-term hope and (*b*) a long-term prophecy. My short-term hope is (1) more data, better documented, better observed, and better studied,

and (2) a get-together of pathologists of language with linguists. Up to now this has not happened, and it must.

My long-term prophecy is that in the remote future the inhabitants of this earth may possibly use some form of communication other than words, other than a purely verbal system. If they do not, there will have to be a vastly improved linguistic system, because at the present time words are not enough. We have met that fact already today: four meanings for the word "instinct."

GANTT: I do not want to disguise my interest in survival, which has been emphasized here. I think increase in knowledge, although very necessary, will take care of itself because of the highly developed function of curiosity in human beings. I think we need more studies of group activities. Not only do we need studies that will enable us to prevent the individual's getting into pathological conditions—a big problem at present—but we need more studies of activity between groups. I think that the future will depend on our success in maintaining a balance between increasing knowledge and our ability to cope with the results of this increase.

HALLOWELL: In our symposium, nothing has been said about personality structure. I think that for this evolutionary problem we need a model, whether Freudian or of some other kind. The use of such a model is necessary in concrete research. Although the word "mind" is meaningful and significant in a broader way, for actual concrete investigations we need such constructs as ego, even if not in the substantive sense. Heinz Hartmann, for example, has suggested that at the human level the ego may be conceived to have survival value, since adaptive functions, which at a lower level are taken care of by instincts, in man become functions of the ego.

VEITH: As a historian, of course, I have no aspirations toward prediction. I agree with Critchley that we shall need many more data for better knowledge. One point that would interest me very much was touched on by Hallowell, namely, the rise of self-awareness, of ego-consciousness, in the human being. Another question, which one day might be solved by men like Brosin or Tinbergen, is whether the coming into existence of self-awareness might possibly have given rise to the first maladaptation.

HILGARD: I see a kind of division of labor in the things that need doing. On the one hand, we need to move toward precision; on the other hand, we have to be careful that this does not sterilize our investigations so we do not dare face larger and more difficult problems. So I suppose one of the things I would urge is a return to more naturalistic observations of man with considerable freedom; the reintroduc-

tion, for example, of the chapter on "will" into our textbooks. Of course, this is a very difficult word, but how do people make plans and fulfil such plans (which, of course, they do all the time)?

We have to be aware of our subject matter and find appropriate ways of describing it. Because we lack such ways now, we tend to ignore some of these problems by concentrating on others where methods are more precise.

One concrete suggestion concerning evolutionary process is that we might have a somewhat better taxonomy of behavior. In the discussion of brachiation yesterday, for instance, I thought that this was not the best kind of behavior term. This is essentially a taxonomic problem: Would "prehension" (a behavioral term) be any better than "finger-thumb opposition" (an anatomical one)? A careful examination of the kinds of threads we could follow if we are following a behavioral pattern rather than a morphological one seems to me to need rather careful work. I think the ethologists are helping us on that.

HUXLEY: I should like to pick up what Hilgard said. We need much more observation and analysis of the actual facts of the individual development of mind in our own species: development of the interiorization of our environment and of its organization and adaptive types of organization; the investigation of critical periods for learning languages and other things, for the development of conscience, and so on. And then the very exciting new idea that Waddington threw into the discussion yesterday, the idea that the human infant is genetically equipped with something analogous to an imprinting mechanism for beliefs, for accepting what he is told. Of course, the beliefs and ideas afterward have to be corrected by education and experience, but they are based on some sort of acceptance mechanism.

And then, on a more general line, I hope that more attention will be paid to what Gerard stressed, that what we are dealing with in the rise of mind is always connected with the reverberation—a nice word—of sensory input within a bounded field system before it issues in motor output. To me, the crucial point is how this bounded field system of reverberation arises and how it generates consciousness.

VON MURALT: I think that the situation of the neurologists is something like that of the astronomers. We are beginning to understand a little bit about the functioning of a single motor unit or a single nerve cell, and the more we learn, the more we see that we are just at the beginning of understanding. When we realize that in one gram of brain substance there are several millions of such interrelated cells, I think the only attitude we can have toward the future is one of pessimistic courage.

TINBERGEN: My views about what I consider most urgent have

come out during the discussion, but I could briefly sum them up again. I am very much interested in attempts to apply biological concepts and methods to the behavior of animals and of human beings. I feel that we have merely skimmed the surface. I think we ought to develop, in both width and depth, the comparative study of closely related species, especially, of course, the primates. Further, I feel we ought to give more attention to the survival value of behavioral aspects, in order to understand what natural selection has done to behavior. Then, of course, the genetics of behavior must be studied much more intensely; and, last, the application of artificial natural selection in the laboratory has been shown to be possible in certain cases and should be continued on a much larger scale.

GERARD: I would say a word in closing about my own picture of the future development of the human mind. We hear a great deal of discussion about man's improving his brain by genetic processes. I have no doubt that we have enough knowledge to breed for anything we agreed upon. The trouble is that we don't know what we want to breed for, and our social institutions do not encourage that sort of action.

A second way of improvement would be by making maximum use of the developmental capacities of the nervous system, to which Huxley just alluded; and I have no doubt from the experimental evidence that putting more in earlier can develop better patterns of activity. Whether you can do this later on is very doubtful; but young children can be taught a lot more than they often are.

A third aspect is that, as man has learned to supplement his muscles with bulldozers and donkey engines and his sense organs with radar and photocells, he is now learning to supplement his central decision-making processes and reasoning processes with other instruments that have come to be called "computers"—a kind of organism that is evolving more rapidly than anything else in the world. It is going to be possible to help our brains with these to a significant degree.

Finally, the most important thing of all, of course, is not the mind of individual man but the collective mind of collective man. This is more than just a term, because we are developing organs of society, such as libraries and writing, the modern techniques of reclaiming knowledge, with "sensory" machines, the punch-card machines that filter out and organize facts, and so on. These are very powerful techniques and are the beginning of the answer to Critchley's request for something more than words in the future.

Since the whole magnificent picture of evolution is, after all, the product of human brains, I cannot believe that human brains will not be able to find solutions to the ways of men influencing one another

that are superior to that old, inefficient, and very destructive one of beating people over the head, whether with clubs or atom bombs. This is the great hope of the future of the sciences of behavior—that man will learn to interact effectively. I am more optimistic than my fellow neurologist.

PANEL FIVE
SOCIAL AND CULTURAL EVOLUTION

Chairmen: Clyde Kluckhohn and Alfred L. Kroeber
Panelists: Robert M. Adams; Edgar Anderson; Sir Julian Huxley; Hermann J. Muller; Fred Polak; Julian Steward; Leslie A. White; Gordon R. Willey

Preamble

In Panel Five we deal specifically with those creations of societies of man which summatively we call "culture." Culture is an extrasomatic or exosomatic body of products, including languages and systems of ideas or sentiments, or, viewed diachronically, a flow of such products. The term "culture" is used here as the most widely employed with the broadest meaning in anthropology and other sciences of human socialized behavior. Culture has structure, patterns, and functions. It channels human activities. While always the product of man, past or present, it also affects and inescapably influences man, especially when men are congregated in societies.

The concept of the evolution of culture challenges us to recognize or perceive the nature of order in cultural change and to formulate principles which systematize such order. The principle of evolution as applied to culture followed in the wake of the idea of human progress which developed in western Europe in the seventeenth century, spread widely in the eighteenth, and became an almost universal a priori principle and sentiment in the nineteenth. This idea of progress, therefore, definitely antedated the recognition of both the concept of culture and the principle of evolution. It must be assumed to have had a heavy influence in aiding acceptance of the principle of evolution after 1859. After about 1890 it began to be recognized in anthropological science that the assumption of inherent human progress was mainly an a priori sentiment with a posteriori selective shoring-up. The result was first an "antievolutionary" reaction, really directed against ethnocentrism, and then a gradual effort (Childe, Redfield) at em-

pirical determination of definable progress comparable to "grades" in biological evolution.

Points for Discussion

1. In a consideration of cultural evolution we are concerned with past, continuing, and future interactions of societies or individuals under the influence of culture. At the same time, we are concerned with the interrelations between cultural evolution, on the one hand, and both the biological evolution of man and other organisms and the changing physical environment, on the other.
2. The unique ability of human beings to produce culture is due to their special faculty of symbolization, which produces both language and the probably related ability to abstract, to superadd concepts to percepts. These faculties allow knowledge and ideas to be communicated, stored, and accumulated. The consequence is that culture, like speech, is always acquired by learning. It is not congenital. This is a great advantage, allowing much more rapid adaptation to environment and more rapid evolutionary advance.
3. In man, biological evolution through gene shuffling, selection, and mutation can go on simultaneously with cultural evolution, and they are both operative. But cultural evolution has become much the more effective and dominant. The time seems past when biological evolution, in any single species other than man or in all of them combined, could rival or surpass man's cultural evolution. The opposite seems already to be true.
4. As far as we know now, cultural evolution in *Homo sapiens* is essentially independent of gene differences between human subgroups or races. In that respect, the courses of organic and of cultural evolution are different.
5. While involving reticulate aspects, especially among the lower taxa, biological evolution generally takes the form of a branching tree made up of diverging lines of descent. The lines of cultural descent may run parallel, or they may diverge through innovation, isolation, adaptation to a local environment, etc., but at the same time they converge and commingle through contact, spread, diffusion, communication. Cultural evolution is different from biological evolution, in that aspects of culture—ideas, techniques, institutions—can be almost indefinitely combined and hybridized, regardless of the dissimilarities between the cultures that produced them.
6. Cultural accumulation occurs in economy, technology, and science. Small-unit social groupings such as the family tend to per-

sist, while larger political integrations tend to be superadded and to dominate. In other fields, especially the stylistic aspects of culture, successful creative efforts come mostly in non-cumulative intermittent bursts or pulses.

7. On account of their constant interflow, cultural phenomena allow cross-cutting classification into equally valid (1) historical units of cultures ("civilizations") or (2) abstracted "levels of integration" (Steward). The civilizations correspond imperfectly to biological clades or taxa; both represent sequences of historic continuity, and both show potentialities for survival value and further advancement. Sociocultural levels or stages correspond roughly to the biological "grades" attained by innovating anagenetic improvement and maintained by stasigenetic persistence.
8. Organic evolution is always continuous, as are cultural evolution and human history. But it is punctuated by relatively brief periods of crucial change, in which previously non-dominant forms of life achieve an evolutionary breakthrough to a new level or grade of organization and capacities. This new grade then undergoes rapid and intensive adaptive radiation and attains dominance, maintained thereafter with lessened change. Examples are the taking-over of dominance from Triassic-Cretaceous reptiles by warm-blooded mammals and birds at the beginning of the Tertiary and also the breakthrough of cultural evolution with man in the Pleistocene.
9. Within human cultural evolution several corresponding major critical breakthroughs (sometimes called "revolutions" in prehistory and history) have been discerned in the accumulating empirical evidence. These are (1) food production, beginning gradually about 7000 B.C.; (2) a syndrome centering around 3000 B.C., in which writing, metallurgy, urbanization, and political structures were first evolved; (3) from about 600 B.C., religions organized both doctrinally and institutionally; (4) beginning about A.D. 1600, a level or grade of civilization characterized by the rapid and progressive development of science, technology, invention, industry, and wealth.
10. In the light of present evidence, these respective advances concerned primarily subsistence in stage 1, general civilization in 2, religion in 3, and secular activities in 4, with definite, perhaps reactive, change of emphasis or direction in each surge as compared with the preceding one. A world-wide spread (roughly corresponding to "adaptive radiation") in the fourth stage is apparently still taking place. When it shall have covered our planet, a degree of temporary stabilization may occur.
11. While adaptation on the part of the organism has been strongly

stressed as a primary factor and result in the evolution of animals and plants, both by Darwin and by modern evolutionists, it has been a much smaller consideration in the exosomatic physical and organic environment through selection. The function of culture is not only to adapt man to his environment but also to adapt man's environment to himself by suitably *modifying it.*

12. The basic and primal inventions of culture—fire, clothing, shelter and constructions, tools and weapons, food preparation, cooking and cooking utensils, storage of surplus food and later food production by farming and herding—all these modify, change, or abolish difficulties existing in the natural environment by (partly) substituting an artificial (man-made) environment of *artifacts.* This indispensable material basis of human culture is subsumed under the term "technology" and remains the chief means of subjugating environment as well as adapting to it.
13. The result of points 11 and 12 is that most anthropologists and students of culture have been less concerned with adaptation and its relentless flow than have biologists. They deal with change, advance, accumulation, and interpersonal and intersocietal processes, which they have often assumed to be non-adaptive. Their concerns are usually microdynamic. Even the term "evolution" tends to be avoided, partly through persisting reaction against the speculative pseudo-evolutionistic excesses of anthropologists in the immediate post-1859 period. As to the macrodynamics of cultural evolution, its causes and principles, and its interrelations with biological evolution, there is as yet no general agreement. For the near future this subject needs careful research. This is necessary as a basis for any attempt to predict or control the direction of cultural evolution.
14. The nearest counterpart in anthropology and the social sciences to genetic evolutionary science appears to be carried on mainly under the name of "culture history" (including prehistory) and is naturalistic, empirical, holistic, seeking continuities and connections rather than phenomenal identities or "regularities" and yet ready to accept such "regularities" and punctuating cultural "revolutions" insofar as these are demonstrable. Such knowledge is important for gaining a timely and adequate insight into the processes forming the future.
15. The very historization of understanding in science which our present fourth critical stage of innovation has brought with it involves greater awareness of evolution and of the future as well as the past. This awareness will no doubt produce efforts to direct the course of evolution. No precedent exists for predicting what success such efforts may have.

Whether the next grade be attained automatically or partly by willed planning, the orientation and kind of its innovations constitute a most significant problem. The advances of modern science and technology in gaining deeper understanding of physical, biological, and cultural phenomena and in devising means of controlling them place in man's hands tools of unprecedented power. The use of these with insufficient foresight could have undesirable and even disastrous biological and cultural consequences. Conversely, their use with foresight would offer possibilities of human evolution both cultural and biological far exceeding those of the past. What happens in these fields will depend increasingly upon the nature of the goals set and the means employed, provided that men succeed in extending wisdom and conscience into this sphere. Here is an enormous new field for a rethinking of the problems of human life and of life in general from the bottom up, taking into consideration everything that the past has taught us.

The Discussion

Kluckhohn: There have been many leads into this panel from the others. Simpson reminded us that cultural evolution is also a biological adaptation. Waddington said that man has invented for himself a new evolutionary system, since writing, which is one important way of preserving and transmitting culture, has functions analogous to those of the DNA chain. Huxley suggested that the course of cultural evolution centers on a kind of natural selection among a procession of ideas that are successful for longer or shorter periods. Everyone concedes that cultural evolution is an extension to biological evolution, yet different from it. But different to what degree and in what respects? To what extent does either process involve or constrain or channel the other? Such propositions are immensely debatable. Let us return, for example, to Waddington's statement that the new system for the transmission of information, depending on the printed page, implied a new system of evolution. I myself like that formulation, but I am not sure that all my colleagues accept it.

It should be underlined that, while all the propositions in our agenda have some evidence or authority behind them and a number of them are regarded by all members of this panel as empirically established, others are disputed. The weighting and phrasing of still other issues are arguable. Some of these disagreements and shadings will emerge in the discussion.

Over and above questions about the trend of the facts and the interpretation of such trends, there remains the vexing question whether

the concepts of contemporary anthropology are adequate for valid analysis. For instance, do we have sound taxonomic bases for a cultural typology. Mayr has rightly said that you can't talk about dynamic flow until you can recognize types. There are other crucial problems. How much transformation occurs in social change—how much abrupt alteration of cultural principles?

But enough of these preliminary remarks. I shall now ask Kroeber to initiate the consideration of point one of the agenda:

> In a consideration of cultural evolution we are concerned with past, continuing, and future interactions of societies or individuals under the influence of culture. At the same time, we are concerned with the interrelations between cultural evolution, on the one hand, and both the biological evolution of man and other organisms and the changing physical environment, on the other.

In so doing, he will necessarily explicate some parts of the Preamble.

KROEBER: While the word "evolution" is applied to life, to the earth, to the cosmos, the usual term in human affairs is "history." I submit that, except for certain overtones of connotation, the two words mean the same thing, namely, long-term change.

Even more important than Darwin's establishing that change in life-forms occurs, and through natural selection, is the fact that, until 1859, all sciences were essentially static. It was Darwin who triggered the sciences dealing with the earth, life, and culture into becoming more macrodynamic or historic.

The first broad and influential idea of gradualistic development in any domain, though still a prescientific and semiphilosophical notion, was the assumption of human social progress. This idea seemingly originated in France, two hundred years before Darwin, and spread to England, western Europe, and America. It had built up a tremendous pressure of public opinion behind the dam of belief in non-change of a static world, which dogma and a habituated static science had jointly long maintained. This pressure helped enlarge Darwin's great, but specifically biological, discovery into a still greater breakthrough affecting all science.

It was from thinking socially about culture, where it is an actual process, that the idea of transmission of acquired characters was erroneously introduced into biology by Lamarck, Herbert Spencer, and others.

It is worthy of note that the first phylogeny supported by evidence, that of the Indo-European language family, was established in the field of the so-called humanities seventy years before Darwin.

HUXLEY: I entirely agree with Kroeber. We know there is complete continuity between man and prehuman animals; we also know that man is a very unusual and, indeed, unique kind of animal. This transition from animal to unique animal meant crossing a threshold to a new kind or phase of evolution, which may be called "cultural" or "human" or "psychosocial." The panel yesterday pointed out that it took at least a quarter of a million years to pass this threshold. The transition led into a new phase of evolution, with new mechanisms of transmission and transformation. As Kroeber said, the cumulative transmission of experience is a second method of inheritance, acting like an inheritance of acquired characters.

We have, therefore, new methods of directing change. The process of natural selection is teleonomic, to use Pittendrigh's useful term. It directs change toward better chances of survival—which include higher organization and more efficient physiological functions—but without conscious purpose or planning. In man we have the beginning of a process that is, in the strict sense of the word, teleological, since purpose—consciously or unconsciously, but, in any case, subjectively, wanting to do something that is envisaged in the future—comes in. Thus you have a changeover from a teleonomic to a strictly teleological mechanism. And selection is exercised, not mainly by the differential survival of variants (to use the rather forbidding terminology of Panel Two), not by natural selection, but by—well, the anthropologists will have to find out what is the right term; perhaps *telic* selection would serve. For the present, I shall merely call it "psychosocial selection." This implies that there is some kind of competition for survival and further development among ideas, social systems, and types of culture. As a result of this new mechanism, the whole process moves much faster. Instead of reckoning major advance in tens of millions of years, we reckon it in centuries.

As a matter of fact, there is another crucial new consequence of the new methods of psychosocial evolution. If averaged out over the whole two and one-half billion years of biological evolution, the rate of evolution would be more or less uniform, going up and down, but always around a certain average rate. In psychosocial evolution it is quite clear that, at least in the last few millennia and especially in the last few centuries, there has been an acceleration instead of a more or less uniform rate.

As a result of all these differences, the products of psychosocial evolution are totally new and unlike anything produced by biological evolution. They are cultural products, like science, religion, art, and law. I thought Waddington's contribution to the discussion in Panel Three was extremely relevant. He pointed out that certain new built-in

mechanisms of mind were desirable and, indeed, necessary for this sort of evolution to work: especially a built-in acceptability of what we are told by our parents and our elders and betters. Later, of course, we have to be educated or educate ourselves out of accepting such ideas and beliefs as absolute. But our beliefs and values are originally based on this quite new method of transmission.

MULLER: As stated in the discussion of man as an organism, biological evolution laid a genetic basis for those faculties of body and mind that were necessary before culture could develop. Among these were adroit hands, general intelligence, a social co-operative nature, and, more specifically, symbolizing faculties—urges to vocalize, to communicate, and to imitate—and facility in manipulation. Not only did the use of these faculties actually result in the gradual accumulation of primitive culture, but, reciprocally, the modes of life opened up by culture gave increasing opportunity for the effective exercise of these very faculties and so bestowed an increasing relative advantage in the struggle for existence on those individuals, families, and groups of families in which these faculties were better developed. That is, by putting a premium on these faculties, culture intensified the natural selection whereby their genetic basis was still further improved. Thus in the hominids and hominines there must, on the whole, have been a positive feedback lasting for a long time, whereby cultural evolution aided biological evolution and vice versa.

However, as culture advanced to the stage of larger and fewer groups, natural selection among groups necessarily became inefficient. And as the social relations within these groups resulted in a more effective extension of aid to individuals and families in need of it, natural selection within groups also slackened off. Today it is evident that these two processes are rapidly approaching their limit, that of a world-wide *de facto* socialized community where everyone is helped to live according to his need and to reproduce according to his greed—his lack of foresight, skill, or scruple.

Thus we cannot extrapolate from the past to the future and say that culture will inevitably result in biological betterment. On the contrary, there is now a negative feedback from culture to genetics; for, as Rensch pointed out in Panel Three, the saving of lives for reproduction by ever more efficient medical and other technical and sociological aids inevitably results in an increasing accumulation of randomly occurring detrimental mutations. These must adversely affect health, intellect, powers of appreciation and expression, and the genetic basis even of our co-operative disposition itself.

At the same time, the disappearance of subdivision into small groups removes the basis for evolutionary experiments that result in break-

throughs, as Wright pointed out in Panel Two. In fact, with our co-operative disposition that forms the biological foundation of the all-important human system of morals and values, the processes pointed out by Wright come into play even more strongly. Without subdivision into small competing groups, there is no effective check on the higher multiplication rate of those individuals whose genes tend to result in social parasitism, that is, in self-aggrandizement at the expense of the group as a whole. Here, beyond the mere passive accumulation of detrimental mutations, there is a more rapid deterioration through active selection in a direction antagonistic to the welfare of the group; and, by a curious inversion, the less fit for the species as a whole become the more fit in the narrow sense of reproductive survival.

Any attempt by culture to deal with these difficulties by ameliorative measures directed only at the phenotype and lessening for the immediate generation the harm done by the given genetic variations is ultimately self-defeating because of their greater accumulation.

KLUCKHOHN: It is a great pleasure to hear a famous geneticist talk so eloquently about culture and negative feedback from culture to genetics. But I think I should warn you, sir, that you had better be careful, or, like our fellow panelist Huxley, you will find yourself honored with an editorial in the World's Greatest Newspaper.

One topic that Muller introduced was the role of symbols. In an exceedingly influential paper some twenty years ago Leslie White forcefully and clearly wrote about the symbol as the basis of human behavior.

WHITE: In the *Descent of Man* Charles Darwin argued that man is not a unique animal, that his mind differs from those of other animals merely in degree and not in kind. This question is still open, and reputable scientists are arrayed on both sides. But I believe there is enough evidence to close the question once and for all and to establish the uniqueness of man beyond doubt—which means, of course, that I place myself among those who believe that man is a unique animal.

The trait or characteristic that distinguishes man from all other animals is the ability freely and arbitrarily to originate and bestow meaning upon things in the external world and to grasp and comprehend these meanings. I should like to call this the "ability to symbol," and I should like to use the word "symbol" as a verb. I think it would be much better to say that man has the ability to symbol than to say that he symbolizes. Since there is a kind of behavior that consists of originating and bestowing meaning upon things, why not give it a name, and why not recognize it as a verb and call it "symbol"?

"Symboling" can be illustrated by articulate speech, or fetishes, or holy water. Holy water, for example, has a meaning that has been originated, determined, and bestowed upon it, which cannot be grasped and comprehended with the senses. Symboling is essentially a process of trafficking in meanings that cannot be comprehended with senses alone. There is no way to distinguish holy water from ordinary water with the senses or by any means of physical or chemical analysis. The same is true of fetishes or of the sounds of which articulate speech is composed. Of course, articulate speech is the most important and characteristic form or expression of symboling.

At this point it might be well to note that green triangles and red circles used in laboratory experiments with rats are not symbols, although they resemble symbols at some points. The meanings of symbols are not inherent in their physical forms. These red triangles and green circles are not symbols because the rats do not and cannot determine their significance or endow these physical forms with it. This is done by the experimenter. The rats can learn these meanings, but they cannot originate and determine and bestow them. This is the fundamental difference between the mind of man and that of other animals, and it is the only thing that does distinguish man in any significant manner from other animals.

So far as I have been able to discover, virtually nothing is known about the neurological basis and mechanism of symboling. In my paper for this Centennial, I tried to show that the ability to symbol is the logical and biological culmination of a process of the evolution of "minding" that began with the origin of life. I am not going to discuss the four stages in the evolution of minding at this point. I might, however, say in closing that the ability to symbol, primarily in its expression in articulate speech, is the basis and substance of all human behavior. It was the means by which culture was brought into existence and the means of its perpetuation since the origin of man.

KROEBER: White has just mentioned that symbols in language and culture have a quality of arbitrariness. That may sound as if it diminished their value. But it is an inherent property of symbols. And it is important because it makes it necessary for symbols to be learned. They can be acquired only by learning; on account of their very arbitrariness, they cannot be congenital and instinctive. This is a consequence of culture's being—as was said in our agenda—exosomatic.

That word exosomatic—"outside the body"—bothers some people; but there is no doubt that culture is produced and used by man much as a coral reef is exosomatic in being produced by the bodies of polyps and then becoming the basis of their environment. Both coral reefs and culture—I am aware of the contrast, and it is deliberate, but there

is the common element—are social products of multiple lives of organisms, developing continuously, without saltation or leaps, and directly affecting the manner of life of future individuals of the species—and sometimes indirectly of other species also.

Coral reefs consist of calcium carbonate of a certain structure. Culture consists of artifacts and mentifacts in reciprocal counterpart. It is the idea of a machine that is acquired and transmitted by learning, but it is the machine that runs. Books and such are the objective expression of subjective knowledge, values, emotions, and idea systems.

HUXLEY: I was most interested in White's presentation. But I should maintain that a superorganism looking at the process of evolution on earth from the outside would say that man's uniqueness definitely lies in the cumulative transmission of knowledge. This is a new property of evolving life. It depends on this capacity for symbolization but is not identical with it.

Although, as Kroeber said, man has to learn these symbols, something facilitating symbolization must have been put in his germ plasm by natural selection. Man is genetically a symbolizer, although he doesn't know what he is going to symbol. He is genetically a believer, as Waddington pointed out, although *what* he believes is not predetermined. He is genetically a comprehender, although his comprehension may go off the rails. But he has a genetic urge and a genetic capacity to do these things.

KLUCKHOHN: We need a biologist to lead us gently by the hand into point 3:

> In man, biological evolution through gene shuffling, selection, and mutation can go on simultaneously with cultural evolution, and they are both operative. But cultural evolution has become much the more effective and dominant. The time seems past when biological evolution, in any single species other than man or in all of them combined, could rival or surpass man's cultural evolution. The opposite seems already to be true.

Anderson?

ANDERSON: Man is a part of nature. The big evolutionary explosion since the Pleistocene is the plants, the animals, the great unseen clouds of micro-organisms that live in and around our homes, our soils, our crops, our very bodies. We are in an evolutionary flowering. Even our weeds are new—weeds like dandelion, weeds like rats. Even that delightful fly, *Drosophila,* was a garbage-pail weed until domesticated at Columbia University as a great, evolving, scientific tool.

[STEWARD: The view that cultural evolution is psychosocial (Hux-

ley), exosomatic (Kroeber), superorganic, or culturological ascribes different cultural patterns to phenotypical, rather than genotypical, determinants; everyone agrees that cultural differences do not reflect genetic racial factors. This is not to say, however, that biological factors are irrelevant to the nature of culture. We need only imagine a society of asexual individuals who reproduced parthenogenetically, with offspring budded as full adults from the head, let us say, as Athena sprang from Zeus. Such a society would lack families, kinship systems (except unilinear ones), socialization of the young, sexual reciprocity in function, and age distinctions in role or status.] *

[Hallowell has cogently stressed the importance of viewing human society with reference to societies among the lower primates. It is also worth noting that biological factors are particularly obtrusive in primitive societies, which are characteristically structured along lines of sex, age, and kinship. While the panel has not yet discussed whether cultural, like biological, evolution is based on universal principles or processes, I suggest that purely culturological principles probably manifested themselves most clearly after the agricultural revolution. The simple biological facts of life, of course, are culturally patterned in many ways in the primitive world; and they are not absent, although increasingly overlaid by non-biological configurations, in the modern world.]

KLUCKHOHN: If I am not mistaken, Polak, you think that cultural evolution is more like biological evolution than some of us would hold. Is that right?

POLAK: That is quite true. I think that if biological and cultural evolution are viewed as long-term processes, their over-all mechanisms seem fairly identical, as do their operational techniques or general principles for transforming the past and present into the future.

It is my impression that we have been so eager to accentuate the contrasts that we seem to have ignored this important similarity. Early post-Darwinian biology and its related sciences were primarily concerned with a reconstruction of the past and were not much interested in a dimension or continuum of time that included the future. In the struggle against vitalism and similar theories, the idea of an evolutionary agency directed toward the future was automatically condemned as completely unscientific. Modern social and behavioral sciences, for exactly the same reasons, are averse to using such time concepts of progress. Most social scientists, afraid of mystical or philosophical implications, went to the other extreme and excluded all directional progressive agencies from their subject matter.

* This and other bracketed paragraphs were submitted in writing after the session.

After the victory of mechanistic theories in biology, it again became possible to describe the mechanisms of Darwinian evolution in terms of time and orientation directed toward the future. Probably this would have affected the behavioral sciences, had not genetics, meanwhile, become dominant in biology. Since neither genes nor chromosomes nor nucleic acids are factors in culture, which involves mental and social agents, a sharp dividing line between the two kinds of evolution was maintained by most persons, sometimes to the point of denying any cultural evolution at all.

I think that cultural evolution as a long-term process is subject to almost the same guiding or directive agency as that characterizing biological evolution. It is oriented and preadapted toward the future and progressive improvement. Its mechanisms select cultural types by preferring those types that, by their power of qualified anticipation, have acquired optimal potentialities for cultural advancement to a higher level. By developing from an unconscious and mechanical advancement to a level of conscious and purposeful end-directedness, man's cultural evolution widely overstepped the boundaries of biological evolution.

HUXLEY: I agree with Polak about the similarity—not the identity—of many trends in the course of psychosocial evolution and biological evolution. But it seems to me a complete confusion of terms to call the mechanisms similar. The mechanism of biological evolution is the natural selection of genetic variants. From what has already been said here—and from all our knowledge of social anthropology and history—this is not what is primarily operative in cultural evolution. Biological evolution was not deliberate. It was teleonomic, in that the blind mechanism of natural selection forced or guided it along certain directions; but it was not deliberate or purposeful, as cultural evolution is in part.

[STEWARD: Huxley's view of cultural evolution as partly "deliberate" might give the comforting thought that we may in some measure control our destinies. A naturalistic understanding of cultural evolution, however, must assume that goals, no less than other aspects of culture, have determinable causes. In early human evolution, man, like other animals, strove for sheer physical survival. Much later, this essentially biological goal was supplemented by objectives relating to new kinds of production, social statuses, ethical systems, and religions. It is not enough to say that man chooses goals deliberately and with awareness. As students of cultural evolution, it is our job to find out why, in each cultural tradition and development stage, man chooses some goals and not others.]

KLUCKHOHN: Huxley, would you go on to point 4?

> As far as we know now, cultural evolution in *Homo sapiens* is essentially independent of gene differences between human subgroups or races. In that respect, the courses of organic and of cultural evolution are different.

HUXLEY: Muller pointed out that in the very early stages of differentiation of hominids and hominines, natural selection among small groups led to genetic differences between the groups. After *Homo sapiens* became the dominant type and spread over the world, he differentiated into what have been called the major races of mankind (in animals one would call them "subspecies") with certain adaptive differences in structure. But this process never reached the stage of full speciation. Later, man's restlessness and cultural habits brought about convergence again, so that mankind is now a single interbreeding group without sharp subdivisions. It is extremely difficult to measure "racial" or ethnic differences because cultures and genetic backgrounds interact; but, as far as we know, cultural evolution in *Homo sapiens* is essentially independent of genetic differences between human subgroups or races. Significant genetic differences between races are very slight, and there is an enormous amount of overlap. The main differences resulting from cultural evolution are independent of these genetic differences.

KLUCKHOHN: Virtually all anthropologists would be in complete agreement with Huxley.

We are now going to consider points 5 and 6 jointly:

> 5. While involving reticulate aspects, especially among the lower taxa, biological evolution generally takes the form of a branching tree made up of diverging lines of descent. The lines of cultural descent may run parallel, or they may diverge through innovation, isolation, adaptation to a local environment, etc., but at the same time they converge and commingle through contact, spread, diffusion, communication. Cultural evolution is different from biological evolution, in that aspects of culture—ideas, techniques, institutions—can be almost indefinitely combined and hybridized, regardless of the dissimilarities between the cultures that produced them.
>
> 6. Cultural accumulation occurs in economy, technology, and science. Small-unit social groupings such as the family tend to persist, while larger political integrations tend to be

> superadded and to dominate. In other fields, especially the stylistic aspects of culture, successful creative efforts come mostly in non-cumulative intermittent bursts or pulses.

Number 5, you will note, begins with a characteristic academese phrase: "While involving reticulate aspects. . . ." These are rather dark words, and we shall have to ask Anderson to tell us what they really mean.

ANDERSON: Just one fundamental philosophical point. Phylogenies are constructed by the mind. Therefore, when we compare plant phylogeny with cultural phylogeny, we are *not* skating on the useful, but dangerous, thin ice of analogy. There are two basic patterns for all phylogenies: relationships branching like a tree—dendritic—and those like a net—reticulate. We are learning to think in terms of a combination of both patterns. We know that there are many intermediates between the netlike tree and the treelike net. It takes the sharpest minds, with the best data, to visualize the right model and to shift models.

KLUCKHOHN: It is time to take up those phases of cultural evolution that the archeologists know most about. Adams, I don't know whether you are more reticulate or more dendritic, but give us some facts anyway, will you?

ADAMS: I might describe myself as more substantive and less programmatic.

HUXLEY: Are you dendritic?

ADAMS: I shall delay answering that question until we have gone a little further.

It seems to me that one of the main functions of this panel is to deal with the questions of progress and accumulation in culture and to contrast these with the biological record. That cultural accumulation appears to occur more rapidly in economy, technology, and science seems self-evident; yet it is fruitful to analyze and qualify this seemingly self-evident assertion.

One who approaches this question from the kind of data to which the historian or the archeologist is accustomed should be aware at the outset that he cannot escape from certain built-in distortions. Archeology must be concerned primarily with material data, with imperishable remains. From this concern come preoccupation with this kind of information and a tendency to see in imperishable remains and the institutions directly connected with them a fundamental, causative role that in broader perspective one might wish to question.

A good example of this distortion is the importance sometimes attached to the introduction of metallurgy at the beginning of urban

life. A revolutionary role is frequently claimed for the very small number of craftsmen who began to produce metal weapons, cult objects, and the like. I do not question that they were a new feature or that their role was important. But I think that some archeologists, such as V. Gordon Childe, have unduly stressed technology as an independent causative agent, at the expense of the social institutions in which it was imbedded and which gave it influence and meaning.

Another important kind of built-in distortion affects the student of ancient history as well as the archeologist. Whether drawn from texts or excavations, our information comes from cities, temples, and palaces, from the kinds of centralized units on which archeologists naturally concentrate to fill museums and make use of the descriptive detail the texts contain. But these centralized institutions, supported by the small margin of surplus obtained from the countryside, as a result of outside pressures were almost certainly more prone to fluctuate than was the underlying agricultural economy. Hence this preoccupation with dynasties, wars, and institutionalized religions—the old historiographic foci—tends to establish the cyclical aspects of history as more important than they really were. Therefore, it may lead us to overlook accumulation where, in fact, it really did occur. I do not deny all cyclicity, of course, for nomadic resurgences into formerly urban areas are fairly common. But I insist that these must be seen in a perspective that is not gained only from centers that were most subject to disruption.

In a broader sense I am very skeptical about the contrast of a rate of accumulation in technology and science with another rate in values or political institutions. All these changes occur in the matrix of human society, and I don't think they can be understood outside that matrix. The most important aspects of accumulation, to me at least, are those having to do with the size, complexity, and adaptive efficiency in some general way of the social unit; and all the differing aspects of accumulation that have been mentioned are linked in various ways to these much more basic features.

Consider technological changes again. Going back to the period of the urban revolution, which I know best, one sees the associated technological improvements as being primarily of an organizational character: increasing state capitalization, emphasis on weapons, rationalization of the procurement of raw materials, increasing size of production unit, etc. The transformation of a technology is most usefully understood, not as a series of inventions, but as the organization of new inventions and old techniques within a social framework.

Similarly, if we take features of religion, how are we to see ac-

cumulation in the succession of gods and the changing emphases on gods in the ancient Near East? Only by relating these to the expanding empires that are appearing at the same time, to the enlarged social unit, and to the greater consciousness of a wide *oikumene* extending beyond any political boundaries.

Having dwelt somewhat too long on the background of the issue, I would very briefly suggest that, in fact, accumulation is evident, although I would not now put this in the terms used in point 6 of the agenda. One sees accumulation perhaps most strikingly in the increasing complexity of a stratified society—in the emergence of an increasing differentiation in wealth and power as one moves up the scale from village to town to city-state to empire. A second major trend of the same order of importance is urbanization, which is linked with the appearance of militarism and with the formation of larger and larger territorial units. The expansion and increasing capitalization of agriculture is a third trend that I think is beginning to be traced. The development of a greater degree of specialization of labor might be another such trend.

Finally, and less surely, there may have been a trend toward secularization, which, if it is a trend at all, is certainly far more tenuous and subjectively distinguished. Perhaps it proceeds less steadily and, as it were, in disjunctive jumps. At any rate, there is a long span between the man-centered universe of Thucydides and that of Machiavelli, with nothing very similar to either of them. Or, again, there is a sharp decline in this same sense from Elizabethan England into the rather dogmatic Puritanism that followed. But from a sufficiently long-range point of view, I think one might still wish to distinguish this as a trend similar to the others.

WILLEY: In general, I would agree with Adams, but I should rather put it this way: Technological innovations are subject to selective pressures similar to those in biological evolution—subsistence pressures related to the natural environment and, in general, to coping with nature. In such selectivity it is easy to see a fairly obvious adaptive direction. Selective pressures affecting innovation in style, on the other hand, are weighted by cultural and social environment, and, as Adams indicated, an adaptive direction is not easily seen.

HUXLEY: I entirely agree that almost everything accumulates, but I don't see how it can be denied that some things accumulate faster than others. Also, in a propitious environment—and that is what Adams stressed—new inventions may have a decisive effect on the social structure or the social system. It is a feedback system.

ADAMS: One has to attach a causative role to the introduction of

certain inventions, for instance; but frequently these inventions are regarded as capricious elements, essentially external to the society, and their cultural context is not described or understood.

KLUCKHOHN: We shall now move on to points 7 and 8, taken together:

> 7. On account of their constant interflow, cultural phenomena allow cross-cutting classification into equally valid (1) historical units of cultures ("civilizations") or (2) abstracted "levels of integration" (Steward). The civilizations correspond imperfectly to biological clades or taxa; both represent sequences of historic continuity, and both show potentialities for survival value and further advancement. Sociocultural levels or stages correspond roughly to the biological "grades" attained by innovating anagenetic improvement and maintained by stasigenetic persistence.
>
> 8. Organic evolution is always continuous, as are cultural evolution and human history. But it is punctuated by relatively brief periods of crucial change, in which previously non-dominant forms of life achieve an evolutionary breakthrough to a new level or grade of organization and capacities. This new grade then undergoes rapid and intensive adaptive radiation and attains dominance, maintained thereafter with lessened change. Examples are the taking-over of dominance from Triassic-Cretaceous reptiles by warm-blooded mammals and birds at the beginning of the Tertiary and also the breakthrough of cultural evolution with man in the Pleistocene.

KROEBER: I should like to begin with a point that my neighbor and partner Huxley took over from Rensch and enlarged and with which Simpson coincided. They make the point that biological evolution has three major aspects or modes: one that leads to divergence, another to persistence, and the third to improvement. My point is that, although the mechanism of culture is quite different, these three modes can also be distinguished in the evolution of culture.

For correctness of the record, I use the technical terms that these three modes of evolution bear. Cladogenesis, leading to genetic divergence and the enrichment of total life in multiple phyla or grand divisions, corresponds in culture to the development of the greater civilizations, separate in space or time or both, but each with a continuous history—well, I really don't know which it is as between ontogeny or phylogeny. View an entire civilization as an end result, and its development is an ontogeny. But, insofar as each major civilization has many components or strands and has gone on for many generations of men, its growth or history is also a phylogeny.

The second major aspect of evolution is stasigenesis, which is concerned primarily with persistences; and this is exemplified by the minor and belated cultures of primitive populations and partly of peasants.

Third, biological anagenesis or improvement works by breakthroughs to new grades or dominant levels of life; these correspond to what in culture have been recognized and called by White, "stages," or by Steward, "levels of integration," or by the late V. Gordon Childe and by Adams here just now, "revolutions"—as, for instance, the urban revolution, the food-producing revolution as compared with the earlier food-gathering stage, or our contemporary culture seen as an industrial revolution.

In short, all three modes or aspects of evolution are as recognizable in culture as in biology, and all three must ultimately be studied in their interrelations if we are to have a picture of total human evolution.

HUXLEY: Cladogenesis, of course, is Anderson's "tree," the dendritic or branching pattern. It is not confined to the major units, but goes on within the subgroups also, doesn't it? It is perfectly true that in culture you can't distinguish ontogeny from phylogeny: you can't separate them as you can in a higher organism, just as you can't separate germ plasm from soma in a culture. The two are one. As for stabilization or stasigenesis—the tendency leading to persistence—there is always selection for stable forms, which, if successful, tend to persist. We shall discuss improvement later, when we talk about long-term trends.

Finally, I would say that cultural evolution includes a fourth process or mode of evolution, which is diffusion. Gene diffusion and convergence have played some part in evolution above the species in plants but have been of very little importance in animals. In man, both gene diffusion and convergence have played an enormous part. They have fused all the human races into one. And directly that happened, there was convergence of cultures, too, through culture contact and what Kroeber calls "idea diffusion." So you have a new process superposed on the other three.

KLUCKHOHN: We shall now move on to points 9 and 10:

> 9. Within human cultural evolution several corresponding major critical breakthroughs (sometimes called "revolutions" in prehistory and history) have been discerned in the accumulating empirical evidence. These are (1) food production, beginning gradually about 7000 B.C.; (2) a syndrome centering around 3000 B.C. in which writing, metallurgy, urbanization, and political structures were first evolved; (3) from about 600 B.C., religions organized both

> doctrinally and institutionally; (4) beginning about A.D. 1600, a level or grade of civilization characterized by the rapid and progressive development of science, technology, invention, industry, and wealth.
>
> 10. In the light of present evidence, these respective advances concerned primarily subsistence in stage 1, general civilization in 2, religion in 3, and secular activities in 4, with definite, perhaps reactive, change of emphasis or direction in each surge as compared with the preceding one. A world-wide spread (roughly corresponding to "adaptive radiation") in the fourth stage is apparently still taking place. When it shall have covered our planet, a degree of temporary stabilization may occur.

You will note under point 9 a series of four so-called "revolutions." First is food production. When I think of food production, I think of Anderson.

ANDERSON: As a demonstration of its use or as an authority?

KLUCKHOHN: Both.

ANDERSON: Let us first ask What did not happen? *Agriculture did not begin in Europe.* We are looking at the problem with European eyes; our minds are using European words. When we observe and reflect on the patterns of agriculture we find in Africa, Latin America, and Asia, we see that the earliest agriculture in the Near East is very, very late.

KLUCKHOHN: Willey, are you on time?

WILLEY: These revolutions outlined in the agenda, or at least the first two, occurred in the New World also, but the dates shown apply only to the Old World. In timing and sequence there are some very interesting contrasts, as well as similarities, between the two hemispheres.

Food production, beginning about 7000 B.C. in the Old World, means a threshold of village agriculture and a village community sustained by plant cultivation. In the New World, some plants were cultivated in northern Mexico at least as early as the interval between 7000 B.C. and 5000 B.C., but in a context of very simple seed-gathering cultures. (If there are earlier evidences of plants in the New World, we certainly don't have them archeologically. Perhaps Anderson will refer to this again.)

In the New World, it took from around 7000 B.C. to about 1500 B.C. to reach a level of established village agriculture. I don't know whether such a long period of incipient cultivation occurred in the Old World before 7000 B.C., and I should be interested to hear Adams'

views. I should think that glaciation might complicate pushing it back beyond 7000 B.C.

In the Old World, an interval of about four thousand years separated the threshold of village agriculture and the attainment of the city syndrome, with writing, metallurgy, urbanism, and political structures. In the New World, this city syndrome—or a pretty good replica—appeared in Middle America and Peru as early as the beginning of the Christian Era. Not all these city traits are always found in the same context. Writing, for instance, developed in the lowlands of Middle America as early as the beginning of the Christian Era, but it was not associated with metallurgy and probably not with urbanism. In the Valley of Mexico, urban life and the development of a state organization must be associated with the Teotihuacan civilization, dating back to A.D. 1; but neither writing nor metallurgy was present. In coastal Peru, metallurgy and urbanism are found, but not writing. Whether these various city-type traits in the New World would eventually have coalesced into a single culture or civilization, we don't know; this had not happened at the time of the Spanish conquest by A.D. 1500.

There is only a fifteen-hundred-year gap between village agriculture and cities in the New World, and a four-thousand-year gap between these events in the Old World. I should like to hear Adams say something about this.

ADAMS: We have been burned so often in recent years by changing radiocarbon dates that I am no longer sure what chronologies I do believe. There certainly seems to be this contrast, but I have no explanation for it. Until more is known about how it developed, I would rather just leave it as one of those unanswered questions that plague us.

ANDERSON: I should like to interrupt, if I may. Many of you know that I am a heretic on this question. I did not say that agriculture came from Asia; I said we must start thinking about it.

ADAMS: The available archeological evidence bearing on the question that Anderson is asking is that in the Near East before 7000 B.C. we find nothing certainly cultivated except wheat and barely. We are told that some specimens of wheat and barley from Jarmo are very close to their wild state. Perhaps there are questions as to what the wild state was.

ANDERSON: I agree completely. Those facts are all absolutely straight insofar as they have been reported.

KLUCKHOHN: You are both happy then.

You will note that the third revolution listed in point 9 deals with

what, throughout most of recorded history, most people thought of when they thought of development or progress. Now, Kroeber, skepticism has always been the chastity of your intellect; but would you mind talking about religion?

KROEBER: I realize that item 3 has about four spaces less than one line in the agenda: perhaps it does need a little factual elucidation.

The third stage, or revolution, there mentioned is primarily religious in character or, perhaps better, religio-philosophical. It occurred in the Old World, nearly all of it in Asia, within the six or so centuries before Christ and the six or so after.

This 1200-year phase includes both Confucianism and Taoism and the whole classic Chinese philosophy. In India it comprises Buddhism, the rival Jain religion, the Sankhya philosophy, perhaps the Vedanta culmination under Sankara about 800 A.D.; in Persia, Zoroaster and the Avesta; in Palestine, the non-legendary historic prophets of Judaism. It would comprise Greek philosophy, culminating in Plato, Aristotle, and the Stoic school. It would include Jesus, Paul, and Christianity as far as Augustine. It would also include the minor religions of the Near East: Mithraism, Manichaeism, Gnosticism, and most of Talmudism, and, finally, Mohammed and Islam.

These religions are characterized by several features:

First, systematization—a formulated doctrine or dogma.

Second, exclusiveness, incompatibility with other faiths, along with tendencies toward intolerance and propaganda.

Third, institutionalization—becoming social organized bodies as well as faiths.

Finally, most are monotheistic, a few dualistic or atheistic.

These common features, plus the circumscribed area and the limited span of origin, carry some suggestion that all or most of these religious developments may form part of one breakthrough to a new grade of cultural evolution.

ADAMS: One can identify a syndrome of related social, cultural, technological, and economic changes around the food-producing revolution, around the industrial revolution, and around the urban revolution. In time we may very well find that Kroeber's third level, characterized by new features of religion, is also part of a syndrome of change. In the Near East I think we are beginning to identify a very substantial change in the subsistence base that comes in just at this time—a much more massive artificial approach to canal irrigation and so on. I am merely suggesting that we recognize that, while in the light of present knowledge this third level is identified as a primarily religious change, it may very well be a much broader syndrome.

KLUCKHOHN: White, you have always been interested in the sci-

entific energy and similar aspects of evolution. I wonder if you would talk a bit about the fourth revolution.

WHITE: The concept of revolution as it is applied to culture change is useful, but I think it should not be tossed around loosely or indiscriminately. We should distinguish major revolutions from the minor revolutions that are merely aspects of a larger revolutionary change in culture. As yet we lack an adequate taxonomy of revolutions in the course of culture history. I like to regard revolution in culture from the standpoint of the thermodynamic nature of sociocultural systems. A sociocultural system is a thermodynamic system whose main function is to harness energy and put it to work in the service of the human beings embraced by that sociocultural system.

From this point of view there have been only two major cultural revolutions in human history, and the second one has not yet run its course. The first of these two great revolutions that profoundly changed culture from top to bottom has often been called the "agricultural revolution." It consisted of harnessing solar energy in the form of domesticated animals and cultivated plants. The second great cultural revolution in human history was what I would call the "fuel revolution," or perhaps the "power revolution," which began in the eighteenth century with the harnessing of solar energy in the form of coal and petroleum; and, of course, more recently new sources of energy have been harnessed and are being put to work for peaceful purposes as well as for military use.

Compared with these two great, profound, and comprehensive cultural revolutions, all others pale into insignificance. I think that V. Gordon Childe includes too many revolutions in his account of human history. His urban revolution, for example, seems to me merely the culmination of the agricultural revolution.

These great revolutions begin as technological revolutions and are followed by social, and then by ideological, revolutions. The second great cultural revolution of modern times began, of course, as a technological revolution that has not yet run its course; and we are at the present time in the midst of a profound world-wide political, social, and economic revolution.

ANDERSON: May I interrupt again? I like White's point very much. I wish you archeologists—it's your field—would remember it when you start thinking about the domestication of plants; to read your papers, one would think that man had never been anything but hungry. Wasn't he ever scared? Wasn't he ever awed? Didn't he think a flower was beautiful?

KLUCKHOHN: Kroeber, did you ever think a flower was beautiful?

KROEBER: I wasn't asked that. Speaking to Adams' point, I am sure

there were such additional innovations. For instance, among the nonreligious features of this religious syndrome were the invention of coined money and the first fully developed democracies.

[STEWARD: I should like to raise this question: Do these four major breakthroughs, each of which is delineated as distinctive in character, imply successive changes in the very principles of cultural evolution? My question betrays my interest in cultural causality. While Kroeber has often gently reminded me that one does not *have* to be interested in causes—a contention I cannot dispute—it is difficult to see how causes, processes, or principles can be ignored in a discussion of cultural evolution.]

[In order to probe the possibility that there is a continuity of evolutionary principles throughout culture history—principles as invariant as natural selection and heredity in biological evolution—I suggest that we tentatively combine Adams' idea of a syndrome of factors with White's concept of culmination to explain all four breakthroughs. The food revolution permitted internal social-role specialization and led to new inventions, while population growth and centralization of administration and other functions eventually culminated in urbanization and state formation. The spread of the key features of this syndrome by about 1000 B.C. to areas beyond the rather absolutistic states of the great river valleys may well have become preconditions of new social arrangements that underlay the emergence of a series of new religions beginning about 600 B.C. The fourth breakthrough, as White has frequently stressed, is partly a repetition of the first, in that new sources of power and use of machines went hand-in-hand with intellectual development and new technologies and initiated further social transformations.]

HUXLEY: It is extremely important to recognize another similarity between biological and cultural evolution. In both, one finds breakthroughs from one stabilized grade of organization to another, although they are rare and appear difficult to make; and if the new type of organization is successful, it will increase and spread, will become stabilized in its turn, and will persist for a long time.

I know that I am an outsider in anthropology; but I have tried to look at the history of man with the eye of an evolutionary biologist. And it seems to me that each psychosocial grade always involves two distinct aspects: the material and institutional aspect and the psychological or symbolizing or ideological aspect, with ritual and religion, myth and science. Although material technological progress is obviously the *basis* for material advance, as Childe and others have stressed, yet to leave out the other aspect is not scientific, because there is always an interplay or feedback between them. The preagricultural

stage had its own rituals and magic. With the agricultural stage came a totally new type of magic ritual concerned with death and resurrection, based on the seed and its rebirth. The urban grade was based on primitive technology and organized irrigation, but it also soon led to the organization of religious ideas and to the beginning of science and mathematics. Later you have the scientific grade, with its industrial basis and its urge to explore, but still based on the idea of creation and on an essentially static theology. And today I would say that, thanks to Darwin, we are just on the threshold of the evolutionary grade. This is naturalistic. It has rejected the supernatural idea of creation for that of material progress; and it is trying to think in psychological, as well as in economic and technological, terms. I think my anthropological friends will agree with me that in each grade the material and psychological components interact and that both are essential.

KLUCKHOHN: What do you mean, your anthropological friends? You are a visiting professor of anthropology here at the University of Chicago, and you have spoken exactly like one. Now would you be so kind as to take us into the eleventh and twelfth points?

> 11. While adaptation on the part of the organism has been strongly stressed as a primary factor and result in the evolution of animals and plants, both by Darwin and by modern evolutionists, it has been a much smaller consideration in the exosomatic physical and organic environment through selection. The function of culture is not only to adapt man to his environment, but also to adapt man's environment to himself by suitably *modifying* it.
>
> 12. The basic and primal inventions of culture—fire, clothing, shelter and constructions, tools and weapons, food preparation, cooking and cooking utensils, storage of surplus food and later food production by farming and herding—all these modify, change, or abolish difficulties existing in the natural environment by (partly) substituting an artificial (man-made) environment of *artifacts*. This indispensable material basis of human culture is subsumed under the term "technology" and remains the chief means of subjugating environment as well as adapting to it.

HUXLEY: Animals, of course, grow their own tools. The wing of a bird or the tongue of a woodpecker is an incredible implement for its special function. Among animals, one also finds many so-called exosomatic organs: spiders' webs, birds' nests, etc. But these are all genetically determined. Yesterday's panel cited a few cases of the actual use by animals of tools in the strict sense—although never the fashioning of them. But here again, the use of such tools as the twig employed

by Darwin's finch to act like the tongue of a woodpecker seems genetically determined. The big changeover in man was that he started making tools for a purpose and then purposefully improving them.

ADAMS: I think Anderson's earlier complaint about the unfortunate way we have focused ourselves fairly exclusively on adaptation, in the narrow sense of meeting immediate subsistence needs, applies better here than it did earlier; it applies at many points throughout.

Within human societies the notion of survival of the fittest is largely shaped by cultural factors, as has been said. Man does not face his environment alone, as the wording of point 12 seems to imply, but as a functionally specialized member of a group—and, as time goes on, of an increasingly complex group that is exploiting an increasing number of ecological niches under increasingly artificial conditions, created by societies themselves. Here one needs only to mention such processes as deforestation, the creation of grasslands as a result of certain kinds of agricultural and other uses, and the appearance of salinity in large agricultural areas.

It seems to me more important to stress this social aspect of survival than the technological aspect. In fact, rather than say that "technology is the chief means of subjugating environment and adapting to it," we should say that it is the chief *immediate* means and recognize that technology is brought into play by social organization.

KLUCKHOHN: One member of our panel very understandably feels that we have gone on for quite a while in our agenda and in our discussion without saying much, if anything, about ideas. We have said something about ideas, but we have not stressed them. We tave talked about things and food and so on, and even the botanist was rebuking us for not buying hyacinths. So I am going to ask Polak to redress the balance a bit.

POLAK: I think that the very important role of technology as a means of transformation has been somewhat overemphasized. Of course, we are greatly impressed by the agricultural and industrial revolutions, but we should not underestimate the creative impact and molding force of the human mind and man's non-technological creations. Those creations include religious, ethical, philosophical, and humanist ideas as well as art. They have been expressed in value systems and ideologies. Some of these have had a profound influence and played an important role in adaptation to, and of, the environment.

Though our age values technological invention and material goods and rejoices for every point at which the standard of living is raised, this has not always been so. For example, in older China and in the Hellenistic cultures, the spirit of the times was against technological innovation. About two thousand years ago the technologists of Alexan-

dria in most fields knew as much as, or even more than, their counterparts of sixteenth- or seventeenth-century Europe—a time lag resulting mainly from a different hierarchy of values, a different mental outlook toward the goals to be reached by man.

In exactly the same way, idealism was an active driving force in America's rise to world power and cultural expansion. One of these motive forces was, I think, the exciting idea, later to be called the "American Dream," of founding a new world of peace, brotherhood, and happiness, a utopian quest for group society and the full life and human dignity. I like to think that such philosophy as is included in your Declaration of Independence and in your Constitution has had and I hope still has great potential and constructive power to shape the evolution of your culture and to change the world.

[STEWARD: Much of this discussion has turned upon the role of ideas and ideals in cultural evolution. I should like to know how and why specific ideas and ideals evolved in relation to technological improvement, population increase, class and state development, and social transformations.]

KLUCKHOHN: I think we should move now to point 13:

> 13. The result of points 11 and 12 is that most anthropologists and students of culture have been less concerned with adaptation and its relentless flow than have biologists. They deal with change, advance, accumulation, and interpersonal and intersocietal processes, which they have often assumed to be non-adaptive. Their concerns are usually microdynamic. Even the term "evolution" tends to be avoided, partly through persisting reaction against the speculative pseudo-evolutionistic excesses of anthropologists in the immediate post-1859 period. As to the macrodynamics of cultural evolution, its causes and principles, and its interrelations with biological evolution, there is as yet no general agreement. For the near future this subject needs careful research. This is necessary as a basis for any attempt to predict or control the direction of cultural evolution.

That seems to me your baby, White. For years you have poured acid on some members of our trade union because they practiced ceremonial avoidance on this great concept of evolution.

WHITE: This subject is one that interests me very much, and I wish to say something that I think needs to be said, even though it may not be very pleasant or complimentary to certain people.

I see here the phrase, "Even the term evolution tends to be avoided." That is a pretty mild statement for what has taken place in the United

States in the last thirty or forty years. When I was a graduate student, the climate of anthropological opinion was definitely and vigorously antievolutionist. One of our distinguished American anthropologists said: "The theory of cultural evolution is, to my mind, the most inane, pernicious, and sterile theory in the whole realm of science." About thirty years ago I took up the cudgels in defense of cultural evolutionism and tried to rehabilitate the theory. I was virtually alone. Many very uncomplimentary things were said about me for quite a long time. Finally, these were modified somewhat, and I was called a "neo-evolutionist," a term which I and Father Wilhelm Schmidt strongly and vigorously repudiate.

Nowadays, thanks rather largely to the Darwin Centennial Celebration, the theory of cultural evolution is becoming respectable and therefore popular. And I find that most of my fellow anthropologists are evolutionists. They are coming from here and there, saying "Why, I have been an evolutionist all along." I also find that some things that have been called "history" all along are now appearing in the clothing and phraseology of cultural evolutionism. It is really ironical to recall that some thirty years ago one of the arguments used against the theory of cultural evolution was derived from Darwinism. It was argued that the theory of evolution was valid and useful in biology and that it was therefore transferred to the realm of culture, where it was invalid. Now, a generation or so later, a full turn of the wheel, Darwinism is putting cultural evolution on its feet again.

Well, of course I am very glad to see this. I only hope that I won't be excommunicated when the theory of cultural evolution becomes a full-fledged movement in anthropology, as it seems likely to become. However, I am not overly encouraged by the swelling of the ranks of cultural evolutionists at this time, because it takes more than popularity to make a scientific concept sound. And I don't think cultural evolutionists are going to be made overnight by the popularity of television and other public ceremonies and exhibitions. I think it will take a great deal more than that.

I wanted to get that off my chest.

KLUCKHOHN: You certainly did.

POLAK: I should like to draw attention to the triumph and tragedy of cultural macrodynamics. At one time, mostly in Europe, this field was highly fashionable, but now its accomplishments are not considered to have been very successful. Social and behavioral scientists have become wary of all-embracing systems. At present, scientific interest in the time-dimension process as seen in the rise and fall of civilizations seems almost extinct or deeply hidden.

KLUCKHOHN: Excuse me; just one minute. What is cultural macrodynamics? Is it the rise and fall of civilizations, or just what is it?

POLAK: Yes, the long-term process of the recurrence and the rise and fall of civilizations.

KLUCKHOHN: Okay.

POLAK: Perhaps we became discouraged and disillusioned too soon. Here is one of the most important unfinished tasks of social and cultural science. Let me give you one concrete example: A correlation may be drawn between man's imaginative concept of an ideal future and his evolutionary course into the real future. More specifically, such positive, constructive images of the future as the American Dream can be correlated with a rising civilization, and loss of faith in coming destiny, expressed in negative images of the future, with a corresponding decay or disintegration of a civilization. In that case, just as in biological evolution, the essence of cultural evolution would be found in its potentialities for preadaptive improvement: potentialities that may lead to cultural breakthroughs and future progress may be demonstrable and in part measurable.

This point of view has far-reaching implications. Further analysis along these lines might make the direction of future evolution at least partly predictable, and it would also make it more controllable—which means to adapt the future as far as possible to our ideal ends. It better explains the significance of the so-called revolution of expectations—a radical change in the image of the future.

KLUCKHOHN: In point 14 the key word is "culture history."

> The nearest counterpart in anthropology and the social sciences to genetic evolutionary science appears to be carried on mainly under the name of "culture history" (including prehistory) and is naturalistic, empirical, holistic, seeking continuities and connections rather than phenomenal identities or "regularities" and yet ready to accept such "regularities" and punctuating cultural "revolutions" insofar as these are demonstrable. Such knowledge is important for gaining a timely and adequate insight into the processes forming the future.

KROEBER: I have always felt that I was doing culture history. Now it turns out that all this time Leslie White and I have been sleeping in the same bed for thirty years without knowing it. (No, I am not the author of the quotation about cultural evolution that he cited.)

I believe that culture history—I am now emphasizing what it says in the agenda—including prehistory, of course, must be wholly naturalistic and empirical in method. It should be holistic in its ultimate

aim. It should assume continuity as a principle and seek connections as far as they are demonstrable.

There is another point, however, which is not in the agenda, and I think it has a certain importance. This is that culture, even in its simple, merely descriptive presentation, is already a series of regularities. We are likely to forget that fact. Culture is a series of regularities underlying the multitudinous and varying events of human behavior in what is ordinarily called "history."

Historiographers as such do not deal with culture: they take it for granted. They do not bother to tell what the culture is whose events they are presenting, and so they do not describe regularities. They concentrate on events. Such is the customary field of the professional historiographer. But a patterned culture is always implicit in it.

What the anthropologist tries to do is to make explicit, to spread out in open view on the table, the cultural patterning that underlies the stirring events that the historiographer narrates.

WILLEY: It strikes me that the method of cultural evolution is one of examining process and, from cross-cultural comparisons, distilling configurations through time. This I would consider cultural evolution as opposed to culture history. Does White agree?

WHITE: Thorstein Veblen has frequently been quoted as saying that there are no synonyms in the English language, and I subscribe to this opinion. I do not think that "history" and "evolution" are synonyms. I believe that they represent and express fundamentally different concepts. In trying to analyze and interpret the phenomena of the external world, we can distinguish a temporal particularizing process, on the one hand, and a temporal generalizing process, on the other. I should like to call the temporal particularizing process, in which events are considered significant in terms of their uniqueness and particularity, "history" and call the temporal generalizing process, which deals with phenomena as classes rather than as particular events, "evolution." History and evolution are alike in being temporal, dealing with temporal processes. They are fundamentally different, in that the one is particularizing, the other generalizing.

KROEBER: I have only just discovered that White and I have been sleeping in the same bed for thirty years, and now he says that they were two beds.

WILLEY: Let me ask this: Is the statement that, in the Middle American area of the New World, a period of food production by plant cultivation succeeded a period of food gathering a statement of culture history or cultural evolution?

WHITE: It can be placed in either context, depending on whether you wish to particularize or generalize.

HUXLEY: You shift from one bed to the other.

KLUCKHOHN: Watch these metaphors, gentlemen.

WILLEY: One more question. Does the size of a geographical area have anything to do with this?

WHITE: No.

WILLEY: I think some of our colleagues feel that it has.

WHITE: I wouldn't doubt that.

KLUCKHOHN: Well, shall we move on to point 15?

> The very historization of understanding in science which our present fourth critical stage of innovation has brought with it involves greater awareness of evolution and of the future as well as the past. This awareness will no doubt produce efforts to direct the course of evolution. No precedent exists for predicting what success such efforts may have.
>
> Whether the next grade be attained automatically or partly by willed planning, the orientation and kind of its innovations constitute a most significant problem. The advances of modern science and technology in gaining deeper understanding of physical, biological, and cultural phenomena and in devising means of controlling them place in man's hands tools of unprecedented power. The use of these with insufficient foresight could have undesirable and even disastrous biological and cultural consequences. Conversely, their use with foresight would offer possibilities of human evolution both cultural and biological far exceeding those of the past. What happens in these fields will depend increasingly upon the nature of the goals set and the means employed, provided that men succeed in extending wisdom and conscience into this sphere. Here is an enormous new field for a rethinking of the problems of human life and of life in general from the bottom up, taking into consideration everything that the past has taught us.

MULLER: The reasons were given earlier for concluding that the scientific and social advances of our present culture are tending to produce a negative feedback upon our genetic structure, allowing—and, in some respects, even encouraging—its deterioration: a kind of natural selection in reverse. Luckily, however, our present culture has also made us aware of this situation and has brought us knowledge of evolution as a whole, as some of us have found at this series of meetings.

As with the dangerous techniques placed in our hands by physics, chemistry, mass media for thought control, and the means of deple-

tion of our resource, we see that if we would retain the benefits of civilization, there can be no effective renunciation of our powers. Instead, we must meet all these difficulties by mustering greater foresight and greater social responsibility in the use of our knowledge and skills and in the further extension of our knowledge and self-control.

In genetics this means that, with a knowledge of biological evolution and actuated by a greater sense of responsibility to their successors, men will come to extend their social awareness to include not only their contemporaries but also the next and succeeding generations. In learning, as they must, to control their numbers, men will also become aware of the paramount importance of the genetic material within them. A new kind of pride in reproduction will appear when those persons burdened with more than the average share of genetic defects realize that their most valuable services will lie in restricting the multiplication of their own genes and contributing to the community in ways that are not directly genetic. Conversely, those persons more fortunately endowed will feel it their obligation to reproduce to more than the average extent. No one knows better than the geneticist how uncertain is the knowledge of any given individual's genetic constitution, how the effects of environment are interwoven with heredity in molding every individual, and how randomness enters into the determination of what genes any new individual shall have. And no one knows better than the social scientist how vicious and self-defeating would be any attempt at dictation in matters of reproduction.

What counts in evolution, however, is not the individual but the general trend; for over-all selection in a given direction eventually works, and consciously directed selection works much faster than unconscious selection. The important thing, then, is the kind of trend. Here the madness of the racists has taught the world by terrible object lessons the dangers of egotism, ethnocentrism, and particularism. One of the main antidotes to this is a better, more vivid teaching of evolution, which emphasizes the fundamental unity of man and the overriding importance of the species as a whole and underscores the paramount values cherished by men the world over—especially, genuine warmth of fellow feeling and a co-operative nature, depth and breadth of intellectual capacity, moral courage and integrity, appreciation of nature and art, and aptness of expression and communication. The exercise of these faculties has brought man to his present state.

But most persons, if they are honest, will grant that these qualities have never been in oversupply and that, as our culture advances, we can make increasingly good use of a higher quality and quantity of them. At the same time, the furtherance of specialized abilities de-

veloped in response to particular predilections, as for music, will help enrich the whole. Unless men sink into the hands of mad or ignorant dictators, there is, I think, no danger that in the over-all run they will fail to recognize these fundamental values. After all, the same problem of what we should aim for appears when we educate our children. Just as most of us are coming to recognize these same aims in education, so we will naturally follow them also in genetics.

Nor is there a danger that these faculties can be too abundant. As men learn better techniques and acquire better facilities for nurturing, preserving, multiplying, and transferring their genetic material, both male and female, they will not rest content with the primitive methods of the past but will increasingly use their new reproductive powers to further their ideals, even as they will use atomic energy to reach the stars. They will take pride in having their children—whom they will rightly regard as theirs—derived from the best reproductive cells possible, some of which they deliberately "adopted" prior to pregnancy, while the children, thus more happily endowed on the average than their parents, will love these parents that thus made them possible and raised them as their very own. With higher intelligence and a more deep-rooted otherliness of character will come an increasing range of foresight that can plan ahead to reaches far beyond that horizon of ours that in the direction of the future is so very near us and so limited.

As for our horizon in the opposite direction, we have at least glimpsed the grand panorama of the four to five billion years of evolution in the past, and so we know of what seeming miracles the plasticity of protoplasm—or DNA if you like—is ultimately capable. It is true that, with our present genetic basis, culture alone has carried us very far and can carry us very much farther and, wisely developed, can give every man a fitting place under the sun. It is also true that, even with human aid, biological progress is far slower than that of culture. But the total advance is not the sum of these two; it is more like the product or even the exponent. Even as our own culture could not mean very much to the most superior ape, the culture of a mere million years from now will be so rich and advanced in its potentialities of experience and accomplishment that in it we, with our genetic constitution of today, would be like imbeciles in the palace. And so I believe that not only our cultural but also our biological evolution will go on to now undreamed-of heights. Each of these two processes will reinforce the other and with a feedback that is not only again positive but also enormously more effective.

ADAMS: This has been an eloquent statement by a very eminent geneticist, and I certainly do not dispute its biological basis. But, on

the eve of this second century after Darwin, I should like to question the social consequences of Muller's views.

Muller's statement just now, like earlier statements on this panel, concerned overpopulation and referred to a population explosion. A counterpoint was developed between greed or reproduction and need. Unless disagreement is voiced, this emphasis might very well produce a belief that the central focus of an evolutionistic approach must be control of population. (Incidentally, I am not concerned here with the moral objections that might be raised to this plan; others certainly are.)

The first defect in this view of overpopulation as our central problem is that it casts an aura of unjustified pessimism on all efforts to achieve economic betterment and development before some nirvana of population level is reached. The generalization that an increasing rate of per capita productivity is impossible in impoverished and densely populated countries simply does not correspond with the facts, as P. T. Bauer and B. S. Yamey have persuasively argued.

A second defect in this undue concern with overpopulation is that it tends to focus attention on certain quantitative aspects of economic growth, particularly on a simple index of output per head. This ignores the crying need over much of the world for qualitative changes making improved subsistence possible, for such things as land reform, stimulation of investments, and improvements in planning.

Most serious students will agree that rising population is a very serious problem. I should be the last to say that we should not be concerned about this; but it would be a mistake to express our concern about the future only, or mainly, in terms of this single axis of growth.

[STEWARD: I am grateful for the opportunity to comment on our fifteenth point, which properly expresses concern about possible misuses of knowledge in controlling the future and, conversely, implies optimism, "provided that men succeed in extending wisdom and conscience into this sphere." I doubt whether many of my colleagues would subscribe to the implication that a scientist, by virtue of his knowledge or conscience, should dictate man's destiny.

As an individual citizen, any scientist has the undeniable right to advocate what he pleases, but he should not foster the illusion that his goals are external to himself and his time and can be scientifically validated. The evidence of cultural evolution seems clearly to indicate that goals and procedures have cultural determinants. It would, therefore, be extraordinarily dangerous to place our future in the hands of men who claim wisdom and conscience. Hitler and Genghis Khan undoubtedly claimed to be wise; and since all men are shaped by their cultures, in their own lights they had great conscience.

The role of the scientist is to analyze and interpret; and there is still much to learn about the dynamics of cultural evolution. The many-faceted views of this panel, stimulating as they are, indicate the very great disagreement about the nature of cultural evolution. This discussion has only tangentially touched upon the problem of cause-and-effect relationships that might permit even tentative forecasts into the fairly near future.

The present understandings of cultural science are most pertinent to what we might call "negative goals." As scientists we may hope to throw some light on the ways to avoid a war of extermination or to reduce the social stresses and frictions resulting from unequal distribution of opportunity and material goods, from racial, ethnic, and religious prejudices, and from the neuroses and psychosomatic ills to which the imbalances and conflicts of modern life contribute.

But until we know more about non-biological or exosomatic cultural evolution, attempts to control cultural evolution through manipulation of human genetics would be rash. I do not question a deleterious feedback of culture upon our genetic constitution, but this process obviously has no bearing on the mechanisms of cultural evolution. Intelligence may, in the long run, affect the *rate* of evolution, but I know of no shred of evidence that it determines in any way whatever the *direction* of evolution. Our distinguished geneticist has suggested that fellowship, co-operation, moral courage and integrity, appreciation of nature and art, and aptness of expression and communication are desirable human traits. One must agree. But, since each of these qualities has meanings peculiar to its particular evolutionary stage and social type, he surely cannot mean that they are genetically determined.

As for ills of the human flesh, many of them genetically based, it is heartwarming that a blind poet, a deaf musician, a consumptive novelist, and a hunchback physicist have contributed so much to our intellectual heritage as to be classed as geniuses. Since modern medicine now keeps most people alive to fulfil their humble—or exalted—destinies and the principal killers of today are largely cancer and heart disease, an all-out plan of eugenics would have to deprive nearly everyone of offspring.]

HUXLEY: I think I ought to take up what Adams has said, and I should also like to comment on some of the remarkable points my old friend and colleague Muller raised in his eloquent and even prophetic speech.

I have been deeply interested in the population problem. Of course, it is not the only problem we ought to concentrate on; but I don't think Adams' point about not bothering with economic development

until we have dealt with population is well taken. The two are tied together. Coale and Hoover's careful study, for instance, has shown that India cannot achieve industrialization unless it halves its birth rate in the next thirty or forty years. Furthermore, overrapid population growth is destroying many of the world's qualitative resources—resources for enjoyment as well as material resources for use—but I do not have time to go into that now.

I appreciated Polak's admirable phrase that we must learn to adapt the future to our ideal aims. One of man's unique qualities is that in his evolution he is able to preadapt to the future. Polak has reformulated this fact in a striking way.

When one looks at the future in the broadest possible way, it is important always to distinguish two viewpoints: the most ultimate one that you can consider—the ideals that Polak stresses—and the nearer view, of the immediate problems. Each age has its own particular problems. The overproduction of people was not a problem three centuries ago; the overproduction of cars or other products was not a problem fifty years ago; atomic war was not a problem twenty years ago.

But when you look at psychosocial evolution in the long view, you must consider both its material and its mental aspects. Muller quite rightly stressed the long-term importance of genetic improvement. We must not neglect the important and equally essential improvement of purely psychosocial organs—the organization of "mentifacts," to use Kroeber's delightful word. We have to create a social organization that will enable the world to function as a unity. We have to create a world based on science, but not one entirely technological. It must be naturalistic and yet involve moral and religious values. We have to create art and literature to express our new world and a new kind of educational system to prepare the new generations to take their place in it.

But to return to Muller's main thesis, it is clear that, although cultural change has, on the whole, become predominant in psychosocial evolution, genetic change has been going on from the beginning. Muller brought out the fascinating point that, in its early stages, there was positive feedback between genetics and culture but that now the feedback has become largely negative. Undoubtedly a great deal of natural selection is going on, in the sense that different types of people are multiplying at different rates; and this appears to be, on balance, dysgenic, so that we ought to do something about it. Our aim, of course, should be to substitute some kind of conscious eugenic selection. I should like to emphasize that we shall have plenty of material to work with. In the human species there is an enormous range of

variation, providing excellent opportunities for selection. Thus I entirely agree with Muller's main contention—that when we have solved our immediate problems, we should give most attention to improving our genetic heritage.

KLUCKHOHN: Obviously (but this is a good thing, too), just at the point when all of us have something to say and would like to speak, we must stop. I think it is appropriate that we stop with the man who has perhaps played a more central role than anyone else in this whole Celebration.

Before today's session I had been instructed by my betters to give a summary, and I duly started to take some notes today; but I see it is completely beyond my capacity. I shall make just one statement about it, which is what Simpson, in his great book, says about the process of evolution in general: "There is both order and disorder in it."

SOL TAX

CONCLUSION

Yesterday noon I was told that the newspapers would appreciate advance copies of these concluding remarks. With four sessions out of five finished, why couldn't I write this speech? This reminds one of the man who cashed a check for one hundred dollars and asked for it in one-dollar bills. The teller in the bank suggested he count his money, and dutifully he began, "One, two, three, four, five—thirty-five, thirty-six, thirty-seven—it's right so far, so it's probably right the rest of the way," and he stopped counting. After all, it was a local newspaper that headlined the election of Thomas Dewey as president of the United States.

The fact is that this is not a wrestling match that was fixed in advance. We knew each other's papers and general points of view, of course, but not how we stood on these issues for discussion. The panelists became acquainted during these last days and ironed out some differences before coming to this stage. This made the discussion more useful: semantics and misunderstandings were for the most part put to one side.

Last Tuesday afternoon, in introducing these panels, I said: "Charles Darwin broke through a tremendous fog, and one hundred years ago this very day gave us a new understanding and perspective, on the basis of which we have done a hundred years of fruitful research. The tremendous knowledge gained in these hundred years of science we hope this week to summarize and synthesize. But, more than that, I at least have some hope, or fond illusion, that on this occasion and in this hall we can take a new, great step forward to begin a second century of understanding ourselves and our cosmos that will do justice to our heritage and give hope for our future."

All of us realize that we have gone far to summarize and to synthesize our present knowledge of evolution. Never before have so many minds from so many diverse specialties been put so intensively to such a task. At the same time, clearly, nobody expects me at this moment to summarize the summary or synthesize the synthesis. This will rather be done in the years to come by each of us and by many of you—and by readers of the books that will come out of this Centennial. We shall

all do it differently and from different perspectives, for that is the way of science.

In the process of the growth of scientific knowledge, specialization plays the part of sexual difference. As there would be no purpose in sex if there were no mating, so science requires that our different knowledge be brought together so that selection can act on the new recombinations. Only time will tell just how important is the event we have here witnessed. But just as one hundred years ago there was full appreciation that the publication of the *Origin of Species* was an event for history, so one feels that history will take a new turn when it leaves this room.

So that these do not seem the empty words that are spoken politely at the end of a meeting, let me briefly sketch—as an example—how this meeting has begun to change my own thinking.

To an anthropologist, biological evolution is taken for granted, but, generally speaking, we believe—or have believed—that the shift from somatic genetic evolution to psychosocial or cultural evolution is a change as great as that from the inorganic evolution of the universe to the evolution of life. The means of cultural evolution by symboling, as White wants us to call them, extrasomatic as these are, are so different that the concepts of biological evolution seemed not to be very useful. At best, the concepts of biology, like natural selection, seemed to be analogies or even figures of speech, without real meaning or validity for evolution in the human phase.

After this week, it seems to me that, while the difference in the mechanisms of growth are never to be minimized, there is, nevertheless, a larger view in which human society and culture are seen again as part of the natural order and subject to the same laws of evolution as the rest of nature.

In our third panel, for instance, there was a suggestion by Waddington that started a whole new train of thought in my mind. He talked about the biological function of passing on information from one generation to the next, which is done genetically at some levels but in man, for the most part, occurs socially. In fact, it is my understanding that no culture is passed through the chromosomes. I am only saying that information in the sense that Waddington was using it includes genetic characters as well as sociocultural characters. But in all cases the receiving mechanism is as important as the mechanisms for transmission of "information." Since humans transmit most information by means of language and social behavior rather than directly through the chromosomes, the species could not survive without some appropriate receiving mechanism. Part of this receiving mechanism in humans is the predisposition of a child to believe his elders

and to respect them. Later, he can doubt and select, but there must be transmission before there can be selection.

The predisposition to believe must be a biological thing and subject to processes like natural selection. So is the later ability to doubt and to select. Men as individuals need both in order to survive. Human communities have built into them the mechanisms both of continuity and of change.

A human society in a most significant sense is able to control its own destiny. I have felt that culture freed us from our biological base and separated us from our animal cousins, but it becomes clearer now that this ability is in a broader sense a biological mechanism serving a biological need. Polak argued this morning for the unity of all life in some ability to foresee the future; a rose, too, chooses its destiny. I think I follow Huxley's denial. I rather see the unity in man's free will as a mechanism in our own survival that in a large sense should be thought of as biological.

This broader view of man as part of a single evolutionary system, at least of this planet, comes to us—or at least to me—as we bring together our various branches of knowledge. It is for each of us as individuals to take account of new knowledge and relate it to our own personal philosophies.

This afternoon some of us will hear a discussion of the conflict of science and religion. I cannot anticipate the result, but I would hope that in the next hundred years our religious leaders may come to quote the Gospel as saying, "Render unto science that which belongs to science," and our scientists will leave it to all of us to interpret and use facts as part of a human document of which both introduction and conclusion are necessarily enduring cultural values.

Whether or not this theological debate moves in the second hundred years to a new level, our meeting this week should help us, at least in America, to turn the corner in accepting evolution as a fact. I suppose that there are no schools where it is taught that the earth is flat as a pancake; I wonder if there are any classrooms where students are told that there is a "theory" that the earth is a globe and that it may not be true. But perhaps most of our schools still teach evolution, not as a fact, but as only one alternative among explanations of how the world has come to be what it is. No matter what gets done about our religious beliefs, this particular phenomenon must now come to an end. We cannot deal with the difficult problems of the world unless our education takes account of demonstrated empirical fact.

A gentleman of the press during our meeting asked me to say something now about the future of the evolution of man. Putting together what we have learned this week, including this morning, gives us a

fairly clear answer: If man will build on knowledge instead of prejudice; if our society will heed Muller's advice this morning to reward those who look for the good of the whole rather than to their selfish advantage (but not necessarily anything specific that Muller has said this morning)—if we do these things, which it is in our power to do, then and only then are we likely to come out of this alive.

Is it possible, one hopefully asks, that this week will become a turning point in human history to which we are witnesses? My family and I happen to live in the house where Enrico Fermi lived during the war. That great turning point in human technology—the first nuclear reaction—occurred a pistol shot from where we now sit. Could we by setting in motion here the steps that will turn our ingenuity to the survival instead of the destruction of the species, make a new turning point in history? One still fondly hopes.

SIR JULIAN HUXLEY

THE EVOLUTIONARY VISION

Future historians will perhaps take this Centennial week as epitomizing an important critical period in the history of this earth of ours—the period when the process of evolution, in the person of inquiring man, began to be truly conscious of itself. This is, so far as I am aware, the first time that authorities on the evolutionary aspects of the three great branches of scientific study—the inorganic sciences, the life-sciences, and the human sciences—have been brought together for mutual criticism and joint discussion. We participants who are assembled here, some of us from the remotest parts of the globe, by the magnificently intelligent enterprise of the University of Chicago, include representatives of astronomy, physics, and chemistry; of zoology, botany, and paleontology; of physiology, ecology, and ethology; of psychology, anthropology, and sociology. We have all been asked to contribute an account of our knowledge and understanding of evolution in our special fields to the Centennial's common pool, to submit our contributions to the criticism and comments of our fellow participants in quite other fields, to engage in public discussion of key points in evolutionary theory, and to have our contributions and discussions published to the world at large.

This is one of the first public occasions on which it has been frankly faced that all aspects of reality are subject to evolution, from atoms and stars to fish and flowers, from fish and flowers to human societies and values—indeed, that all reality is a single process of evolution. And ours is the first period in which we have acquired sufficient knowledge to begin to see the outline of this vast process as a whole.

Our evolutionary vision now includes the discovery that biological advance exists, and that it takes place in a series of steps or grades, each grade occupied by a successful group of animals or plants, each group sprung from a pre-existing one and characterized by a new and improved pattern of organization.

SIR JULIAN HUXLEY delivered this Darwin Centennial Convocation address on Thanksgiving Day, November 26, 1959. Another essay, "The Emergence of Darwinism," appears in a companion volume, published earlier this year—*Evolution After Darwin. I. The Evolution of Life,* pp. 1–21.

Improved organization gives biological advantage. Accordingly, the new type becomes a successful or dominant group. It spreads and multiplies and differentiates into a multiplicity of branches. This new biological success is usually achieved at the biological expense of the older dominant group from which it sprang or whose place it has usurped. Thus the rise of the placental mammals was correlated with the decline of the terrestrial reptiles, and the birds replaced the pterosaurs as dominant in the air.

Occasionally, however, when the breakthrough to a new type of organization is also a breakthrough into a wholly new environment, the new type may not come into competition with the old, and both may continue to coexist in full flourishment. Thus the evolution of land vertebrates in no way interfered with the continued success of the teleost bony fish.

The successive patterns of successful organization are stable patterns: they exemplify continuity and tend to persist over long periods. Reptiles have remained reptiles for three hundred million years: tortoises, snakes, lizards, and crocodiles are all still recognizably reptilian, all variations on one organizational theme.

It is difficult for life to transcend this stability and achieve a new successful organization. That is why breakthroughs to new dominant types are so rare—and also so important. The reptilian type radiated out into well over a dozen important groups or orders; but all of them remained within the reptilian framework except two, which broke through to the new and wonderfully successful patterns of bird and mammal.

In the early stages, a new group, however successful it will eventually become, is few and feeble and shows no signs of the success that it may eventually achieve. Its breakthrough is not an instantaneous matter but has to be implemented by a series of improvements which eventually become welded into the new stabilized organization.

With mammals, there was first hair, then milk, then partial and later on full-temperature regulation, then brief and finally prolonged internal development, with evolution of a placenta. Mammals of a small and insignificant sort had existed and evolved for over a hundred million years before they achieved a full breakthrough to their explosive dominance in the Cenozoic.

Something very similar occurred during our own breakthrough from mammalian to psychosocial organization. Our prehuman ape ancestors were never particularly successful or abundant. There was not just one "missing link" between them and us. For their transformation into man a series of steps was needed. Descent from the trees; erect posture; some enlargement of brain; more carnivorous habits; the use and

then the making of tools; further enlargement of brain; the discovery of fire; true speech and language; elaboration of tools and rituals. These steps took the better part of half a million years: it was not until less than a hundred thousand years ago that man could begin to deserve the title of dominant type and not until less than ten thousand years ago that he became fully dominant.

After man's emergence as truly man, the same sort of thing continued to happen, but with an important difference. Man's evolution is not biological but psychosocial; it operates by the mechanism of cultural tradition, which involves the cumulative self-reproduction and self-variation of mental activities and their products. Accordingly, major steps in the human phase of evolution are achieved by breakthroughs to new dominant patterns of mental organization, of knowledge, ideas, and beliefs—ideological instead of physiological or biological organization.

There is a succession of successful idea-systems instead of a succession of successful bodily organizations. Each new, successful idea-system spreads and dominates some important sector of the world, until it is superseded by a rival system or itself gives birth to its successor by a breakthrough to a new organization-system of thought and belief. We need only think of the magic pattern of tribal thought; the god-centered medieval pattern, organized round the concept of divine authority and revelation; and the rise in the last three centuries of the science-centered pattern, organized round the concept of human progress, but progress somehow under the control of supernatural Authority. In 1859, Darwin opened the passage leading to a new psychosocial level, with a new pattern of ideological organization—an evolution-centered organization of thought and belief.

Through the telescope of our scientific imagination, we can discern the existence of this new and improved ideological organization; but its details are not clear, and we can also see that the necessary steps upward toward it are many and hard to take.

Let me change the metaphor. To those who did not deliberately shut their eyes or who were not allowed to look, it was at once clear that the fact and concept of evolution was bound to act as the central germ or living template of a new dominant thought organization. And in the century since the *Origin of Species*, there have been many attempts to understand the implications of evolution in many fields, from the affairs of the stellar universe to the affairs of men, and to integrate the facts of evolution and our knowledge of its processes into the over-all organization of our general thought.

All dominant thought organizations are concerned with the ultimate, as well as with the immediate, problems of existence or, I should rather

say, with the most ultimate problems that the thought of the time is capable of formulating or even envisaging. They are all concerned with giving some interpretation of man, of the world which he is to live in, and of his place and role in that world—in other words, some comprehensible picture of human destiny and significance.

The broad outlines of the new evolutionary picture of ultimates are beginning to be visible. Man's destiny is to be the sole agent for the future evolution of this planet. He is the highest dominant type to be produced by over two and a half billion years of the slow biological improvement effected by the blind opportunistic workings of natural selection; if he does not destroy himself, he has at least an equal stretch of evolutionary time before him to exercise his agency.

During the later part of biological evolution, mind—our word for the mental activities and properties of organisms—emerged with greater clarity and intensity and came to play a more important role in the individual lives of animals. Eventually it broke through, to become the basis for further evolution, though the character of evolution now became cultural instead of genetic or biological. It was to this breakthrough, brought about by the automatic mechanism of natural selection and not by any conscious effort on his own part, that man owed his dominant evolutionary position.

Man is therefore of immense significance. He has been ousted from his self-imagined centrality in the universe to an infinitesimal location in a peripheral position in one of a million of galaxies. Nor, it would appear, is he likely to be unique as a sentient being. On the other hand, the evolution of mind or sentiency is an extremely rare event in the vast meaninglessness of the insentient universe, and man's particular brand of sentiency may well be unique. But in any case he is highly significant. He is a reminder of the existence, here and there, in the quantitative vastness of cosmic matter and its energy equivalents, of a trend toward mind, with its accompaniment of quality and richness of existence—and, what is more, a proof of the importance of mind and quality in the all-embracing evolutionary process.

It is only through possessing a mind that he has become the dominant portion of this planet and the agent responsible for its future evolution; and it will be only by the right use of that mind that he will be able to exercise that responsibility rightly. He could all too readily be a failure in the job; he will succeed only if he faces it consciously and if he uses all his mental resources—of knowledge and reason, of imagination, sensitivity, and moral effort.

And he must face it unaided by outside help. In the evolutionary pattern of thought there is no longer either need or room for the supernatural. The earth was not created; it evolved. So did all the animals

and plants that inhabit it, including our human selves, mind and soul as well as brain and body. So did religion. Religions are organs of psychosocial man concerned with human destiny and with experiences of sacredness and transcendence. In their evolution, some (but by no means all) have given birth to the concept of gods as supernatural beings endowed with mental and spiritual properties and capable of intervening in the affairs of nature, including man. Such supernaturally centered religions are early organizations of human thought in its interaction with the puzzling, complex world with which it has to contend—the outer world of nature and the inner world of man's own nature. In this, they resemble other early organizations of human thought confronted with nature, like the doctrine of the Four Elements, Earth, Air, Fire and Water, or the Eastern concept of rebirth and reincarnation. Like these, they are destined to disappear in competition with other, truer, and more embracing thought organizations which are handling the same range of raw or processed experience—in this case, with the new religions which are surely destined to emerge on this world's scene.

Evolutionary man can no longer take refuge from his loneliness in the arms of a divinized father-figure whom he has himself created, nor escape from the responsibility of making decisions by sheltering under the umbrella of Divine Authority, nor absolve himself from the hard task of meeting his present problems and planning his future by relying on the will of an omniscient, but unfortunately inscrutable, Providence.

On the other hand, his loneliness is only apparent. He is not alone as a type. Thanks to the astronomers, he now knows that he is one among the many organisms that bear witness to the trend toward sentience, mind, and richness of being, operating so widely but so sparsely in the cosmos. More important, thanks to Darwin, he now knows that he is not an isolated phenomenon, cut off from the rest of nature by his uniqueness. Not only is he made of the same matter and operated by the same energy as all the rest of the cosmos, but, for all his distinctiveness, he is linked by genetic continuity with all the other living inhabitants of his planet. Animals, plants, and micro-organisms, they are all his cousins or remoter kin, all parts of one single evolving flow of metabolizing protoplasm.

Nor is he individually alone in his thinking. He exists and has his being in the intangible sea of thought which Teilhard de Chardin has christened the "noösphere," in the same sort of way that fish exist and have their being in the material sea of water which the geographers include in the term "hydrosphere." Floating in the noösphere there are, for his taking, the daring speculations and aspiring ideals of man long

dead, the organized knowledge of science, the hoary wisdom of the ancients, the creative imaginings of all the world's poets and artists. And in his own nature there is, waiting to be called upon, an array of potential helpers—all the possibilities of wonder and knowledge, of delight and reverence, of creative belief and moral purpose, of passionate effort and embracing love.

Turning the eye of an evolutionary biologist upon this situation, I would compare the present stage of evolving man to the geological moment, some three hundred million years ago, when our amphibian ancestors were just establishing themselves out of the world's water. They had created a bridgehead into a wholly new environment—no longer buoyed up by water, they had to learn how to support their own weight; debarred from swimming with their muscular tail, they had to learn to crawl with clumsy limbs. The newly discovered realm of air gave them direct access to the oxygen they needed to breathe, but it also threatened their moist bodies with desiccation. And though they managed to make do on land during their adult lives, they found themselves still compulsorily fishy during the early part of their lives.

On the other hand, they had emerged into completely new freedoms. As fish, they had been confined below a bounding surface; now the air above them expanded out into the infinity of space. Now they were free of the banquet of small creatures prepared by the previous hundred million years of life's terrestrial evolution. The earth's land surface provided a greater variety of opportunity than did its waters and, above all, a much greater range of challenge to evolving life. Could the early Stegocephalians have been gifted with imagination, they might have seen before them the possibility of walking, running, perhaps even flying over the earth; the probability of their descendants escaping from bondage to winter cold by regulating their temperature and escaping from bondage to the waters by constructing private ponds for their early development; the inevitability of an upsurge of their dim minds to new levels of clarity and performance. But meanwhile they would see themselves tied to an ambiguous existence, neither one thing nor the other, on the narrow moist margin between water and air. They could have seen the promised land afar off, though but dimly through their bleary, newtish eyes. But they would also have seen that, to reach it, they would have to achieve many difficult and arduous transformations of their being and way of life.

So with ourselves. We have only recently emerged from the biological to the psychosocial area of evolution, from the earthy biosphere into the freedom of the noösphere. Do not let us forget how recently: we have been truly men for perhaps a tenth of a million years—one tick of evolution's clock; even as protomen, we have existed for under one

million years—less than a two-thousandth fraction of evolutionary time. No longer supported and steered by a framework of instincts, we try to use our conscious thought and purposes as organs of psychosocial locomotion and direction through the tangles of our existence—but so far with only moderate success and with the production of much evil and horror, as well as of some beauty and glory of achievement. We too have colonized only an ambiguous margin between an old bounded environment and the new territories of freedom. Our feet still drag in the biological mud, even when we lift our heads into the conscious air. But, unlike those remote ancestors of ours, we can truly see something of the promised land beyond. We can do so with the aid of our new instrument of vision—our rational, knowledge-based imagination. Like the earliest pre-Galilean telescopes, it is still a very primitive instrument and gives a feeble and often distorted view. But, like the early telescopes, it is capable of immense improvement and could reveal many secrets of our noöspheric home and destiny.

Meanwhile, no mental telescope is required to see the immediate evolutionary landscape and the frightening problems which inhabit it. All that is needed—but that is plenty!—is for us to cease being intellectual and moral ostriches and take our heads out of the sand of wilful blindness. If we do so, we shall soon see that the alarming problems are two-faced and are also stimulating challenges.

What are those alarming monsters in our evolutionary path? I would list them as follows. The threat of superscientific war, nuclear, chemical, and biological; the threat of overpopulation; the rise and appeal of Communist ideology, especially in the underprivileged sectors of the world's people; the failure to bring China, with nearly a quarter of the world's population, into the world organization of the United Nations; the erosion of the world's cultural variety; our general preoccupation with means rather than ends, with technology and quantity rather than creativity and quality; and the revolution of expectation caused by the widening gap between the haves and the have-nots, between the rich and the poor nations.

Today is Thanksgiving Day. But millions of people now living have little cause to give thanks for anything. When I was in India this spring, a Hindu man was arrested for the murder of his small son. He explained that his life was so miserable that he had killed the boy as a sacrifice to the goddess Kali, in the hope that she would help him in return. That is an extreme case. But let us remember that two-thirds of the world's people are underprivileged—underfed, underhealthy, undereducated—and that millions of them live in squalor and suffering. They have little to be thankful for, save hope that they will be helped to escape from this misery. If we in the West do not give them

aid, they will look to other systems for help—or even turn from hope to destructive despair.

We attempt to deal with these problems piecemeal, often half-heartedly; sometimes, as with population, we refuse to recognize it officially as a world problem (just as we refuse to recognize Communist China as a world power). In reality, they are not separate monsters, to be dealt with by a series of separate ventures, however heroic or saintly. They are all symptoms of a new evolutionary situation; and this can be successfully met only in the light and with the aid of a new organization of thought and belief, a new dominant pattern of ideas.

It is hard to break through the firm framework of an accepted belief system and build a new acceptable successor, but it is necessary. It is necessary to organize our *ad hoc* ideas and scattered values into a unitive pattern, transcending conflicts and divisions in its unitary web. Only by such a reconciliation of opposites and disparates can our belief-system release us from inner conflicts; only so can we gain that peaceful assurance that will help unlock our energies for development in strenuous practical action.

Somehow or other, we must make our new pattern of thinking evolution-centered. It can give us assurance by reminding us of our long evolutionary rise; how this was also, strangely and wonderfully, the rise of the mind; and how that rise culminated in the eruption of mind as the dominant factor in evolution and led to our own spectacular, but precarious, evolutionary success. It can give us hope by pointing to the eons of evolutionary time that lie ahead of our species if it does not destroy itself or damage its own chances; by recalling how the increase in man's understanding and the improved organization of his knowledge have in fact enabled him to make a whole series of advances, such as control of infectious disease or efficiency of telecommunication, and to transcend a whole set of apparently unbridgeable oppositions, like the conflict between Islam and Christendom or that between the seven Kingdoms of the Heptarchy; and by reminding us of the vast stores of human possibility—of intelligence, imagination, co-operative good will—which still remain untapped.

Our new organization of thought—belief-system, framework of values, ideology, call it what you will—must grow and be developed in the light of our new evolutionary vision. So, in the first place, it must, of course, itself be evolutionary. That is to say, it must help us to think in terms of an overriding process of change, development, and possible improvement; to have our eyes on the future rather than on the past; to find support in the growing body of our knowledge, not in fixed dogma or ancient authority.

Equally, of course, the evolutionary outlook must be scientific, not

in the sense that it rejects or neglects other human activities, but in believing in the value of the scientific method for eliciting knowledge from ignorance and truth from error and in basing itself on the firm ground of scientifically established knowledge. Unlike most theologies, it accepts the inevitability and, indeed, the desirability of change, and it advances by welcoming new discovery even when this conflicts with old ways of thinking.

The only way in which the present split between religion and science could be mended would be through the acceptance by science of the fact and value of religion as an organ of evolving man and the acceptance by religion that religions do and must evolve.

Next, the evolutionary outlook must be global. Man is strong and successful insofar as he operates in interthinking groups, which are able to pool their knowledge and beliefs. To have any success in fulfilling his destiny as the controller or agent of future evolution on earth, he must become one single interthinking group, with one general framework of ideas; otherwise his mental energies will be dissipated in ideological conflict. Science gives us a foretaste of what could be. It is already global, with scientists of every nation contributing to its advance; and, because it is global, it is advancing fast. In every field we must aim to transcend nationalism, and the first step toward this is to think globally—how could this or that task be achieved by international co-operation rather than by separate action?

But our thinking must also be concerned with the individual. The well-developed, well-patterned individual human being is, in a strictly scientific sense, the highest phenomenon of which we have any knowledge, and the variety of individual personalities is the world's highest richness.

The individual need not feel just a meaningless cog in the social machine or merely the helpless prey and sport of vast impersonal forces. He can do something to develop his own personality, to discover his own talents and possibilities, to interact personally and fruitfully with other individuals. If so, in his own person, he is effecting an important realization of evolutionary possibility: he is contributing his own personal quality to the fulfilment of human destiny. He has assurance of his own significance in the greater and more enduring whole of which he is part.

I spoke of quality. This must be the dominant concept of our new belief-system—quality and richness as against quantity and uniformity.

Though our new idea-pattern must be unitary, it need not and should not impose a drab or boring cultural uniformity. A well-organized system, whether of thought, expression, social life, or anything else, has both unity and richness. Cultural variety, both in the world

as a whole and within its separate countries, is the spice of life; yet it is being threatened and indeed eroded away by mass production, mass communications, mass conformity, and all the other forces making for uniformization—an ugly word for an ugly thing! We have to work hard to preserve and foster it.

One sphere where individual variety could and should be encouraged is education. In many school systems, under the pretext of so-called democratic equality, variety of gifts and capacity is now actually being discouraged. The duller children become frustrated by being rushed too fast, the brighter become frustrated by being held back and bored.

Our new idea-system must jettison the democratic myth of equality. Human beings are *not* born equal in gifts or potentialities, and human progress stems largely from the very fact of their inequality. "Free but unequal" should be our motto, and diversity of excellence, not conforming normalcy or mere adjustment, should be the aim of education.

Population is people in the mass; and it is in regard to population that the most drastic reversal or reorientation of our thinking has become necessary. The unprecedented population explosion of the last half-century has strikingly exemplified the Marxist principle of the passage of quantity into quality. Mere increase in quantity of people is increasingly affecting the quality of their lives, and affecting it almost wholly for the worse.

Population increase is already destroying or eroding many of the world's resources, both those for material subsistence and those—equally essential but often neglected—for human enjoyment and fulfilment. Early in man's history the injunction to increase and multiply was right. Today it is wrong, and to obey it will be disastrous. The Western world, the United States in particular, has to achieve the difficult task of reversing the direction of its thought about population. It has to begin thinking that we should aim—not at increase but at decrease—certainly and quickly a decrease in the *rate* of population growth and, in the long run equally certainly, a decrease in the absolute number of people in the world, including our own countries.

The spectacle of explosive population increase is prompting us to ask the simple but basic question *What are people for?* And we see that the answer has something to do with their quality as human beings and the quality of their lives and their achievements.

We must make the same reversal of ideas about our economic system. At the moment (and again I take the United States as most representative) our Western economic system (which is steadily invading

new regions) is based on expanding production for profit, and production for profit is based on expanding consumption. As one writer has put it, the American economy depends on persuading more people to believe they want to consume more products.

But, like population explosion, this consumption explosion cannot continue much longer; it is an inherently self-defeating process. Sooner, rather than later, we must get away from a system based on artificially increasing the number of human wants and set about constructing one aimed at the qualitative satisfaction of real human needs, spiritual and mental as well as material and physiological. This means abandoning the pernicious habit of evaluating every human project solely in terms of its utility—by which the evaluators mean solely its material utility and especially its utility in making a profit for somebody.

Once we truly believe (and true belief, however necessary, is rarely easy)—once we truly believe that man's destiny is to make possible greater fulfilment for more human beings and fuller achievement by human societies, utility in the customary sense becomes subordinate. Quantity of material production is, of course, necessary as the basis for the satisfaction of elementary human needs—but only up to a certain degree. More than a certain number of calories or cocktails or TV sets or washing machines per person is not merely unnecessary but bad. Quantity of material production is a means to a further end, not an end in itself.

The important ends of man's life include the creation and enjoyment of beauty, both natural and man-made; increased comprehension and a more assured sense of significance; the preservation of all sources of pure wonder and delight, like fine scenery, wild animals in freedom, or unspoiled nature; the attainment of inner peace and harmony; the feeling of active participation in embracing and enduring projects, including the cosmic project of evolution. It is through such things that individuals attain greater fulfilment.

As for nations and societies, they are remembered not for their wealth or comforts or technologies but for their great buildings and works of art, their achievements in science or law or political philosophy, their success in liberating human thought from the shackles of fear and ignorance.

Although it is to his mind that man owes both his present dominant position in evolution and any advances he may have made during his tenure of that position, he is still strangely ignorant and even superstitious about it. The exploration of the mind has barely begun. It must be one of the main tasks of the coming era, just as was the exploration of the world's surface a few centuries ago. Psychological

exploration will doubtless reveal as many surprises as did geographical exploration and will make available to our descendants all kinds of new possibilities of fuller and richer living.

Finally, the evolutionary vision is enabling us to discern, however incompletely, the lineaments of the new religion that we can be sure will arise to serve the needs of the coming era. Just as stomachs are bodily organs concerned with digestion and involving the biochemical activity of special juices, so are religions psychosocial organs of man concerned with the problems of destiny and involving the emotion of sacredness and the sense of right and wrong.

Religion of some sort is certainly a normal function of psychosocial existence. It seems to be necessary to man. But it is not necessarily a good thing. It was not a good thing when the Hindu I read about this spring killed his son as a religious sacrifice. It is not a good thing that religious pressure has made it illegal to teach evolution in Tennessee because it conflicts with fundamentalist beliefs. It is not a good thing that in Connecticut and Massachusetts women should be subject to grievous suffering because Roman Catholic pressure refuses to allow even doctors to give information on birth control even to non-Catholics. It was not a good thing for Christians to persecute and even burn heretics; it is not a good thing when communism, in its dogmatic-religious aspect, persecutes and even executes deviationists.

The emergent religion of the near future could be a good thing. It will believe in knowledge. It should be able to take advantage of the vast amount of new knowledge produced by the knowledge explosion of the last few centuries to construct what we may call its "theology"—the framework of facts and ideas which provide it with intellectual support; it should be able, with our increased knowledge of mind, to define our sense of right and wrong more clearly so as to provide a better moral support; it should be able to focus the feeling of sacredness onto fitter objects, instead of worshiping supernatural rulers, so as to provide truer spiritual support, to sanctify the higher manifestations of human nature in art and love, in intellectual comprehension and aspiring adoration, and to emphasize the fuller realization of life's possibilities as a sacred trust.

Thus the evolutionary vision, first opened up to us by Charles Darwin a century back, illuminates our existence in a simple, but almost overwhelming, way. It exemplifies the truth that truth is great and will prevail, and the greater truth that truth will set us free. Evolutionary truth frees us from subservient fear of the unknown and supernatural and exhorts us to face this new freedom with courage tempered with wisdom and hope tempered with knowledge. It shows us our destiny and our duty. It shows us mind enthroned above matter, quantity sub-

ordinate to quality. It gives our anxious minds support by revealing the incredible possibilities that have already been realized in evolution's past and, by pointing to the hidden treasure of fresh possibilities that could be realized in its long future, it gives man a potent incentive for fulfilling his evolutionary role in the universe.

"ALL THINGS CONSIDERED" A TELEVISION POSTSCRIPT

ANNOUNCER: A university draws together men and women concerned with ideas and events. It provides a meeting place for the informed and for the curious, for all engaged in man's pursuit of knowledge. This evening the University of Chicago presents another in its series of discussion programs on "All Things Considered." Tonight's subject concerns "Issues in Evolution." The participants are Sir Julian Huxley, biologist and writer and Visiting Professor at the University of Chicago; Ilza Veith, Associate Professor, Departments of Medicine and History; and Robert M. Adams, Assistant Professor in the Department of Anthropology, and Research Associate in the Oriental Institute. Leading the discussion is Alec Sutherland, Director of Educational Broadcasting, the University of Chicago.

SUTHERLAND: I should like to begin this evening with a personal anecdote. About thirty years ago I invested a day's pay to buy a ticket for a lecture in Glasgow; and at the end of this lecture, which was on biology, there was the usual man in the audience who, in exchange for his half-crown, wanted answers to two questions: What is ultimate truth? and what was the lecturer going to do when we discovered it? And the lecturer said, "I don't know what it is, and when we discover it, I shall be out of a job." That particular lecturer is now sitting at the opposite end of this table. I doubt if he remembers the occasion very well, but I am sure he is still gainfully employed. Do you remember that?

HUXLEY: I have no recollection of it, but I am delighted to learn that I said such a good thing.

SUTHERLAND: We have been celebrating Darwin's centennial here, and I should like to ask each of our participants what the impact of the Centennial was on him.

VEITH: I feel that the greatest impact on me was the exchange of ideas with my fellow panelists and the opportunity to gauge the work

Educational station WTTW (Chicago, Channel 11) presented this television program on the Tuesday following the Darwin Centennial Celebration, December 1, 1959.

they had done and to see that all of them are basically working in fields related to evolution.

ADAMS: That comes rather close to my own reaction. Looking back over the whole series of panels, I think the exchange was particularly important as one moved from the biological to the social and cultural end of the spectrum into fields that have tended to use an approach that is cautious, holistic, essentially differentiating, and analytical. Those of us who were anthropologists came away with an enhanced sense that evolution is continuous and that we are involved with the same kinds of problems as biologists, zoologists, and psychologists. This forceful bringing home of the connection between general theory and substantive studies was very important for me.

HUXLEY: I agree. This mixing up of persons from different disciplines in the discussions was a wonderful thing. Perhaps the most important was bringing together biologists and anthropologists, because they have a great deal to learn from each other; but the physicists and physiologists and biochemists also contributed to the fruitful mixing. And we came to realize that all of us were interested from different angles in this one over-all process that is called "evolution" and that we had to achieve some unification of our thought about it.

SUTHERLAND: All of you were concerned with evolution in rather specialized ways. Have you any views on the effect of your discussions on the lay public?

VEITH: Simply judging from the behavior of the lay public attending our meetings, the interest must have been enormous. They came in masses, stayed to the very end of each panel, and seemed completely lost in what was going on in the discussions.

HUXLEY: It was very remarkable. They even applauded at the end.

VEITH: Another point is that the press reported the events that went on in Mandel Hall; and from the reaction of the press we have a definite impression that what was said was considered tremendously important even by those members of the general public who were not present but wanted to be informed.

ADAMS: Another aspect of the impact of the panels might be worth bringing out here. Too often in the newspapers, on the radio, and also, one would suspect, in the public's mind, research is identified with some discrete and apparently infinitesimal finding, whereas here what was being presented was an entire framework of research in a huge area.

HUXLEY: I think that was extremely important. The first thing the Celebration did, I am sure, was to convince a large number of people that there was no point arguing about the theory of evolution. (By the way, the Centennial was not supposed to commemorate the theory;

it commemorated an actual event, the publication of Darwin's book *On the Origin of Species by Means of Natural Selection.*) It simply is not just a theory any longer; it is a fact, like the fact that the earth goes around the sun and that the planets do all sorts of things. As Adams said, the panels were pursuing the implications of this idea in all sorts of fields, not in relation to any particular discovery, but in working out gradually what evolution meant for different branches of science. If it comes to a particular field, I think one of the highlights of the Celebration was Leakey's presence, with his new finds from Africa. As was brought out very clearly in Panel Three, we can no longer talk about the "missing link"; there isn't such a thing. There was a rapid passage from the prehuman to the human, but it took place in a series of steps over a considerable period of time. The other point that I think was brought home to the people who attended the panels was that you can no longer talk about *creation*. Animals, plants, and human beings evolved; they were not created in the biblical sense.

SUTHERLAND: We have talked about Panel Three. What were the rest of the panels, Dr. Veith? You had a role in planning them.

VEITH: Perhaps it would be best simply to read the titles of the various panels. I think they are descriptive enough. The first panel dealt with the origin of life; the second, with the evolution of life; and the third—the one about which Sir Julian has been talking—dealt with man as an organism. The fourth panel, with which I was most closely associated, dealt with the evolution of mind; and the final one, with which Mr. Adams was associated, concerned social and cultural evolution.

SUTHERLAND: I should like to hear something about the origin of life.

HUXLEY: There, again, I think what happened was very important. This was the first occasion on which at a public celebration the origin of life had become a topic of really scientific discussion. Twenty years ago we could not have discussed it scientifically. Now, thanks to the work of Urey, Oparin, Haldane, and others, it is a subject that can be discussed scientifically. We can begin to see what steps were taken in the passage from the non-living to the living, and we can suggest lines of experimental approach to test our theories. I think this first panel was a very important education for the panelists as well as for the general public.

SUTHERLAND: What about the evolution of life?

HUXLEY: Of course, that is the field in which most work has been done; after all, it is the area where the theory of evolution was launched. I think two main points emerged from the discussion. First, that all reputable evolutionary biologists now agree that the evolution

of life is directed by the process of natural selection, and by nothing else, and that they have demonstrated its happening. Second, that the course of evolution involves three main subprocesses: the process of branching into different forms; the process of biological improvement of the different lines; and the process of stabilization, by which a successful type somehow crystallizes out and persists over many millions of years, unless it is superseded by one of the rare accidental breakthroughs to another type.

ADAMS: I had the feeling that Panel Two came very close to being the central focus of the whole series; we moved out in various directions from the processes and generalizations that were seen there in their clearest and broadest forms. It was interesting to see the extent to which members of other panels picked up terminology from the background papers for this panel and tried to use it in a different context.

SUTHERLAND: Where did evolution of mind fit into this?

VEITH: Actually, evolution of mind fits anywhere; because the mind is part of any human and non-human function, it would have fit into any of the panels. I think it was quite accidental that it happened to be Panel Four. We began with the clear statement and the clear thought that Darwin's work has had a tremendous impact on the behavioral sciences. All those who are in any way connected with the study of behavior of the mind—or the study of the brain, since mind is a very difficult thing to define—have enriched or added to Darwinian principles and Darwinian reasoning. We proceeded on the assumption that the evolution of the mind and the faculty of mind and behavior can be studied as can be any other organic function. Several of our participants were particularly interested in the study of the mind in animals, which has now received the special designation *ethology*—the study of animal behavior. Many signs of mental function appear in the animal world. Emotional attitudes have been discovered in animals. Learning by imitation and even value systems have been recognized as existing in animal groups. Tinbergen, one of the leading ethologists, gave particularly good examples of these value systems among animals. But it is believed or assumed that animals do not yet possess self-awareness. We do not know this, and we cannot judge it; but we must assume it, because there is no evidence of self-awareness.

SUTHERLAND: What do you mean by "self-awareness"?

VEITH: Giving expression to self-consciousness. In man, as we all know, there is self-consciousness. And what sets man apart from animals more than any other single quality is the ability to use lan-

guage. This step was one of those breakthroughs to which Sir Julian referred earlier. It is one of the tremendously important steps that set one group apart from another.

One point that was touched on by Panel Four but not discussed in much detail is the appearance of maladaptation. Did maladaptation set in with the beginning of language? How is it evident in animals? What do animals do in case of maladaptation?

HUXLEY: Maladaptation is evident when either natural or psychological selection steps in to try to correct it, isn't it? I think there are many instances of maladaptation, both physical and mental, in lower animals.

VEITH: I was particularly interested in mental maladaptation.

HUXLEY: That was one of the points that did not emerge very clearly, but Tinbergen did bring out a little about it. A great deal of animal behavior—for instance, the courtship behavior of birds—is the result of conflict—if you like to call it so—between two different impulses: the impulse to attack and drive away the opposite sex, and an impulse to approach or to run away, and so on. There is a conflict, but it is resolved in the behavior.

VEITH: Tinbergen gave another example of maladaptation in an animal group, where other animals attempted to bring the maladapted individual back into the fold.

HUXLEY: I was glad that the title "Evolution of Mind" was used for Panel Four. After all, Darwin himself, who really started the comparative study of mind and so of modern ethology, frankly recognized the existence of mental (subjective) functions by calling his book *The Expression of the Emotions in Man and Animals.* I think Panel Four brought out, first, that one must not shy away from using the term "mind," because it is not only perfectly justifiable but scientifically necessary to extrapolate mind downward from man into animals. Second, that mind emerged during biological evolution and that, since all new phenomena in biological evolution appear to be the result of natural selection, which works by differential advantage, the mental or subjective aspect of behavior must therefore have some biological advantage or value. And a third point that emerged was that mental phenomena in animals can be just as unlike mental phenomena in man as many physical structures in animals are unlike those in man. Language among bees, for instance, depends on sensitivity to the plane of polarized light and on an ability to appreciate the significance of dances. Again, the extraordinary phenomenon of imprinting does not occur in man, or at least occurs only to a very slight degree.

VEITH: I was particularly interested in Tinbergen's example of the

titmice in England which started opening milk bottles by pecking through the paper tops and apparently were able to communicate to each other the message that this could be done.

HUXLEY: Some sort of imitation was involved—learning by following an innovator—but not communication in the strict sense.

SUTHERLAND: I should like to move on to your preoccupation in this field, Dr. Adams. Where does the anthropologist abut on this?

ADAMS: I think there are suggestions of an interesting shift in the position of the anthropologists at the symposium. The initial reaction of at least some of us was one of uncertainty about finding anything in common to talk about with representatives of other disciplines. But a whole series of themes emerged that I am sure will preoccupy us for a long time to come. One such theme was the element of continuity in evolution. As man evolves, he superadds culture to his genetic equipment, and by this new addition he is enabled to adapt in a whole series of much more effective and complex ways—to spread himself over the entire globe, to construct very complex societies, and, in fact, frequently to direct the evolution of species all around him. Human societies are adaptive mechanisms; they have to be understood as having an evolutionary role rather than as uniquely human creations that are not to be compared with the evolutionary development of other organisms.

Two other themes were very insistently brought in upon those of us who are anthropologists. One is that evolutionists deal not with events but with processes. This is a term we shall have to rely upon much more; it reorients the whole basis of inquiry, in a direction in which we can do much more productive work. Second—and this is most important to me—the importance throughout biology of the notion of adaptive radiation, characterizing successive grades of development, is directly applicable to the materials with which an anthropologist deals, beginning with men living in caves and small groups and moving on through sedentary villages to full-scale civilizations. We have usually been too preoccupied with our more limited fields of individual concern to see that a cumulative progression achieved in disjunctive steps is fundamental. Perhaps, for this reason, we have sometimes failed to recognize our common links with our colleagues who are evolutionary biologists.

HUXLEY: Exactly the same thing happened in biology. People were so preoccupied with this or that particular problem that it was really only with the reconciliation of Mendelism with natural selection in the last twenty-five years that biologists have begun thinking in broad evolutionary terms.

SUTHERLAND: What areas do you think it would be best to pursue now—what seems the most rewarding line in each of your fields?

VEITH: In my field, perhaps the most rewarding line would be to find those moments or those evolutionary processes that will present weaknesses, where maladaptation will occur, and where the mind will not continue to function in its normal manner.

HUXLEY: I am sorry you wish to concentrate on maladaptation. I should think it would be much better to concentrate on adaptation from the positive angle.

VEITH: But maladaptation has been studied much less.

HUXLEY: If I might jump over the fence into a field that is not my own, I think that major progress will come in applying evolutionary ideas to man, and doing so in the broadest terms—realizing that man is an extremely peculiar organism, with the cumulative transmission of experience as the basis for his evolution, and that, whether he wants it or not, he is the agent for the whole future of this planet.

ADAMS: It is not enough to maintain our old disciplinary boundaries—in my own case, to carry on a traditional kind of archeological research—and merely to guide this with some new principles obtained from wider fields. What is really called for is the bringing into play of a whole series of disciplines, which can interact and can construct a new, broadly synthetic approach that makes it possible to use these ideas.

HUXLEY: That came out very clearly in the two ideas that to me were the most important novelties in the whole Centennial. One was Muller's point that in the early stages of the development of modern man—when he was really struggling with nature—natural selection and social selection were synergistic and would have worked hand-in-hand to encourage each other. Intelligence would have been at a premium, so we would have had genetic selection for better intelligence, and this would have reacted on the social system. But as you come to the great mass civilizations, the process probably works the other way round and is dysgenic. The essential point scientifically is that we can study interrelation of the purely biological and the social components in psychosocial evolution.

The other point was the one Waddington threw into Panel Three: the idea that man is equipped with some sort of built-in mechanism for accepting what he is told when he is very young; he has to, because he is helpless as a baby and is not provided with a set of adaptive instincts. Of course, unqualified acceptance of authority has to be corrected in later life through learning. When Waddington put this idea to me in conversation before the panel, I said I was feeling just

like my grandfather when he read Darwin's *Origin of Species* and said, "How extremely stupid of me never to have thought of that." This is a very fundamental point, which has to be worked out in all its implications.

SOL TAX

THE CELEBRATION
A PERSONAL VIEW

When Charles Darwin and T. H. Huxley were members of the Royal Anthropological Institute, scholars generally believed that human culture and society had *evolved* to their current states, leaving savages and barbarians as relics of bygone stages. But they also believed that these primitive peoples could progress rapidly to the higher stages—especially with the help of Europeans. Neither fish nor fowl nor reptile could become mammalian, regardless of nurturing; but "Stone Age" aborigines could become calico-wearing Christians. Differences among peoples were considered evolutionary, in other words, but not "organic."

It is obvious that man, in many places, has passed through stages of tribal hunting and village-tillage to achieve large societies with cities and writing. Some surviving cultures remind us of obviously prehistoric stages, but they are regarded as developmental varieties rather than as living fossils. Not only is it now clear that all *peoples* known to us in historic times are equally human, but the notion that different *cultures* might be ranged on an evolutionary scale has also been largely abandoned. The differences among peoples are neither evolutionary nor organic.

The complete separation in the twentieth century of man as an organism from man as a member of society and bearer of culture has resolved the common confusion between race and culture. Hitler's disastrous mythology was one culmination of a general belief that Europeans are more effective than Asians or Africans as builders of civilizations, and Nordics are more so than Mediterraneans or Alpines. The data of anthropology squarely contradicted the claims of the racists. Cultural achievements of populations were shown to have cultural causes, essentially independent of the genetics of the populations developing or carrying them. So culture and cultural history could be treated apart from the organism, as both cultural historians (e.g., Frobenius) and evolutionists (e.g., Spencer) had long known. Culture, the primarily human contribution to biology, is "superorganic" and quite independent of "blood" or "race." A generation of students grew

up convinced that biological and cultural anthropology needed each other mainly to demonstrate the limitations of the biological in man. Since the two branches were also specializing, becoming too extensive together for any one scholar, cultural anthropology and physical anthropology have tended to draw apart from each other.

So we come to a science which proclaims itself "the study of man," yet views culture as though it were not part of man; which studies the evolutionary process and traces the origin of man through the fossil record, yet steadfastly separates man from all other animals; which generally denies social and cultural *evolution,* yet uses the word "primitive"—apologetically—for most of the living peoples and cultures it studies.

This was the split personality of the science when, one evening in 1955, I sat in the library of the Wenner-Gren Foundation in New York City. It was a Friday evening "supper conference" at which William W. Howells of Harvard was talking about physical anthropology. I was there because I had other business in New York, because I like conferences, and because I like anthropologists of all specializations. As editor of the *American Anthropologist,* I had a good excuse to indulge myself, but actually my thoughts had drifted away from Dr. Howells' paper. He had mentioned Darwin's *Origin of Species,* which started me musing. In another four years that book would be a hundred years old, I remember thinking. Somebody would be organizing a celebration for the occasion. Why should not anthropology be center stage? An encyclopedia nearby revealed that the exact date was November 24, a good season in the academic world, since the school year is well underway and the holidays have not yet begun.

My train of thought carried me home to Chicago. What institution in this country was better suited to celebrate the centenary than the University of Chicago, born ten years after Darwin's death, far away—a celebration on behalf of the whole world? No personal interest; purely intellectual and scientific. I promptly began writing letters and talking to people: the president of the American Anthropological Association (little knowing that I would be serving my own term as president during the Centennial year!), the Dean, the Chancellor, biologist friends, a widening circle of enthusiastic advisors.

But surely others must be having this idea, too, I thought. One way to find out: Write to Julian Huxley and Sir Charles Darwin, telling them of our Celebration and inviting them to come. They might tell us that they would be similarly involved in England, and we would graciously give way and not compete. But again, they might not, and we would have some sort of priority. Sir Charles, a renowned physicist, stopped to visit us in Chicago the following March (on his way to Australia) and asked in some puzzlement, "Why particularly the Univer-

sity of Chicago?" When, in September, we met with Zoologist Julian Huxley (he was knighted in the next New Year's list) he did not need to ask, being well acquainted with the historic pre-eminence of our Department of Zoology.

The real mystery is why others did not pre-empt the opportunity of celebrating the publication event of the century. In England celebrations were planned, appropriately, for the 1958 Centenary of the reading of the Darwin-Wallace papers before the Linnaean Society. The centennial of Darwinism was, in fact, celebrated in many quarters, but November 24, 1959—the one-hundredth anniversary of publication of *Origin of Species*—was left to the University of Chicago.

Anyone who has organized or managed an event of these proportions knows of the heart-breaking troubles we had over the years, the mounting excitement as the machinery gets into motion, the obstacles, satisfactions, and unforeseen frustrations encountered. Whether I wanted to be Chairman of the Celebration Committee I cannot tell; but nobody else would take on the job and I have never been able to resist trouble. But I did not expect the sudden death through snakebite of Karl Schmitt, who had been the perfect choice to invite and work with the biological scientists; I did not anticipate that leukemia would sap the strength and then take the life of Robert Redfield, who had been my mentor in anthropology. When S. L. Washburn left the University, I was the only anthropologist left on our Committee, with Alfred Emerson in zoology, Everett Olson in paleontology, Chauncy Harris in geography, and Ilza Veith in history of medicine. Later Zoologist Burr Steinbach joined the group.

As the papers began coming in and correspondence piled up, increasing demands were made of the Committee. As Chairman I was heavily dependent on the others while sharing their responsibility. I did not know the eminent zoologists, botanists, psychologists, physicians, biochemists, and others who had been invited. I did not know their work nor how it related to evolution. People assumed that I knew much more than I did, and like a physician in a difficult case I had to exude confidence while trying frantically to learn. I told myself that, with so great a range of subject matter, nobody could be expected to be omniscient, but when a subjective judgement had to be made, how I hated my ignorance!

One of my most encouraging moments came when a knowledgeable outsider, who had been reading the papers as they came in, told me that he thought they were remarkably creative, the best such collection he had ever seen. This changed things in some subtle way; the amateur gardener who misreads all the directions and works so hard in ignorance that he sees nothing but the weeds is told by an old hand that he has the best perennial garden in the neighborhood!

In reality this praise from our reader may have served most by easing my guilty conscience, for I was not putting as much time and energy into the planning as I had originally intended. Partly by chance, but largely by my own improvidence, I became involved in a number of long-term projects during the years immediately preceding the Centennial. I was Chairman of the Department at the University; program chairman for the 1957 American Anthropological Association meetings held in Chicago; and (taking effect at that convention) President-elect and then President of the Association. Perhaps most improbable of all, I was at the same time engaged in founding the new journal *Current Anthropology*. It was to have world-wide scope, keeping anthropologists everywhere informed of the latest advances; therefore, I spent the first half of 1959, the Centennial year, on three journeys to five continents to determine what the new journal must include. We put the first issue of *Current Anthropology* in the mails on the very eve of the Celebration.

Had the Darwin Centennial Celebration been a miserable failure, I could have taken full blame. Since it all turned out so well, I must look elsewhere to bestow credit. Clearly at least three sets of angels were involved: (1) the Celebration Committee and the scientists they selected; (2) the staff that handled the multiple details in blissful ignorance that they were doing the impossible; and (3) Charles Darwin himself and the genuine importance of the concept of evolution.

In choosing the participants, the Committee must have been extraordinarily wise. There were many good people we missed, but we made almost no positive mistakes. Almost all the papers were first-rate, and as each was distributed it seemed to inspire others. Or was it the occasion that encouraged each to do an especially important piece of work? The quality of the participants must account for the response in advance to the Celebration—the response of foundations to our requests for money; the response to invitations to come to Chicago for the Celebration. The quality of the papers gave confidence to the participants and to the Committee, so that many arrived early to devote as much as a week to preparing for the panel discussions. Sir Julian Huxley and Alfred L. Kroeber had been in residence at the University during the final quarter of 1959; along with Committee members and other participants, they had participated in seminar groups of faculty and graduate students, aimed at proposing issues for discussion, from which the various panels might select their final agendas during their pre-Celebration briefing sessions.

In retrospect it seems as though those panel discussions should have terrified us, like dangerous and unpredictable firecrackers. Bring together highly individualistic scholars chosen for scientific ability, and give them problems for discussion that go beyond the specialties in

which any of them feel comfortable. Let them group themselves "blind" into panels, regardless of personality; give them about thirty hours to become acquainted, some having met for the first time. During that period ask them to agree on topics for discussion, but not on the answers, of course. Then put them on a stage, bright with klieg lights, before large, eager audiences of critical people. By all rights, the firecracker should have exploded in our faces, or, worse, simply fizzed out; but panel after panel—day after day—the atmosphere remained electric, the discussion sparkled.

The Celebration *was* the Panel Discussions; the panels were participants; the participants were great scientists who did what no great scientist should be expected to do. The Celebration was good because, from beginning to end, the Committee and those they had chosen did so well.

The remarkable staff that brought off the Celebration was fortunately inexperienced in a project of such magnitude: hence we could agree happily to do things that experienced people would have dismissed as impracticable. We started out by generously inviting the whole world. Acutely aware of the limitations of our facilities, we decided to protect ourselves by an elaborate advance registration system, taking into account every event listed in the program. The number and variety of the events, plus the fact that some were free, some paid, with special rates to certain groups, made for bookkeeping that would have staggered imaginations which we fortunately did not have.

A resolution to the ticket problem was a universal ticket, covering all events, a sample of which is shown here:

Institute for High School Teachers of Biology

SESSION II
Nov. 28
Judd 126
1:30 P.M.

LUNCH
Nov. 28
The New Dormitory
12:30 P.M.

SESSION I
Nov. 27
Judd 126
1:30 P.M.

PANEL I
Nov. 24
Mandel Hall
1:30 P.M.

PANEL II
Nov. 25
Mandel Hall
9:45 A.M.

PANEL III
Nov. 26
Mandel Hall
9:45 A.M.

PANEL IV
Nov. 27
Mandel Hall
9:45 A.M.

PANEL V
Nov. 28
Mandel Hall
9:45 A.M.

University of Chicago Darwin Centennial Celebration
NOVEMBER 24 to 28, 1959
REGISTRATION AND TICKETS OF ADMISSION FOR:

(Name)

This ticket will admit the bearer to the events listed.
Admission to all events is by ticket only.
Seats will be reserved only until time shown.

CONVOCATION
Nov. 26
Rockefeller Chapel
2:45 P.M.

INSTITUTE ON SCIENCE AND THEOLOGY
Nov. 28
Mandel Hall
1:30 P.M.

Film Preview
"The Ladder of Life"
Nov. 25
Mandel Hall
2:45 P.M.

Lecture by
L. S. B. Leakey
Nov. 25
Mandel Hall
8:30 P.M.

Centennial Dinner
Nov. 24
Hutchinson Commons
6:00 P.M.
Program in Mandel Hall following dinner: 8:30 P.M.

Thanksgiving Dinner
Hutchinson Commons
Nov. 26
6:00 P.M.

When it came to seating the 2,500 registrants, we were determined to allot the 1,000 seats available in Mandel Hall, our largest auditorium, with due consideration for each individual. Each was to have a seat in Mandel for two or three of the five panels, with seats elsewhere, in halls with sound equipment, for the remaining sessions. Each regis-

THE UNIVERSITY OF CHICAGO

DARWIN CENTENNIAL CELEBRATION

November 24-28, 1959

To: Registrants

From: Sol Tax

In this envelope you should find your tickets, program, name badge, and booklet of abstracts of the papers prepared for the Darwin Centennial Celebration discussions. Some of these items need explanation beyond that in the program.

Of nearly 3,000 who have wished to register, we have had to turn away one third. Even so, our space and facilities are being over-taxed. To be fair to all and to protect the comfort and sanity of everybody concerned, we have had to set up an elaborate proceedure which (if it works) will be amusing to watch.

The problem is mainly with the five panel discussions. Leon Mandel Hall is the only appropriate auditorium on campus and it holds only a thousand people. (Prospective donors of a larger hall are referred to the Development Office) Registrants have registered for different panels; but even so, from 1,700 to 1,800 want to get into each one.

The large white ticket is your identification card. It is numbered to correspond to the entry of your registration in our books. If you registered for more than one ticket and gave only one name, all your tickets have the same number. This ticket has on it all the events except the musical show "Time Will Tell". If you did not request tickets for an event, that event has been voided on your ticket. Additional tickets for "Time Will Tell" are available at the Mandel Hall Box Office.

We wanted to be fair to everyone and we knew that not everyone would be equally interested in every panel. Therefore we set up two auxiliary halls -- Breasted Lecture Hall in the Oriental Institute and the auditorium in Kent Hall -- where the panels can be heard but not seen. We then went through our registrants and seated each one individually according to his interests. We gave you a seat in Mandel Hall for those panels which we thought you were most interested in, a seat in Breasted or Kent for panels of marginal interest. This is marked on your tickets in the following manner:

Nothing punched out = a seat in Mandel Hall

A △ punched out = a seat in Breasted Hall

A ○ punched out = a seat in Kent Hall

Seats in Mandel Hall will be held only until time shown on the ticket; THEN, anyone holding a ticket marked for Breasted Hall (a △ punch) will be allowed into Mandel to fill the vacant seats. If you hold a ticket for Breasted Hall, you should therefore join the stand-by line along the east wall of the Mandel corridor. If you don't get into Mandel, you will have 5 or 10 minutes to get to Breasted where a seat will await you.

trant's scholarly discipline, the distance he had traveled, the days he would be attending, and so on were reviewed in deciding those panels most likely to interest him. To attempt such individual seating in the hurry and dash of last minute preparations was clearly ridiculous, but again we did not realize this.

The scope of the registration problems and how the Celebration staff dealt with them may be presented to the interested reader most graphically by reprinting here a copy of the instructions to registrants. An air of amused appreciation pervaded the halls as the visitors went through the complicated contents of the large manila envelope that each was given.

2

Holders of seats in Mandel must get there before the time shown on the ticket or their seats will be taken by those from the stand-by line. If you hold a seat in Mandel and are late, there will be room for you in Breasted.

If you hold a seat in Kent Hall (a ○ punch), you cannot get into Mandel no matter what; do not "stand-by" but go directly to Kent Hall.

<u>Centennial or Thanksgiving Dinner:</u>
If you have a ticket for the dinner, stop at the "seating desk" in the Reynold's Club as soon as possible to reserve your place. We assume that friends will want to make up parties. Since there will be no speeches in the dining hall, the location of your table is not important.

Both dinners are sold out to capacity; but you may add your name to a waiting list at the seating desk in case of cancellations.

<u>Tuesday Evening</u>
On Tuesday evening the entire first floor (300 seats) of Mandel Hall is reserved for those attending the Centennial Dinner. Any other ticket holders may come to the program, to the limit of the balcony.

<u>Wednesday Afternoon</u>
Note that your ticket is valid for the two Wednesday afternoon events -- the lecture by Dr. Leakey and the film "The Ladder of Life". In each case only Mandel Hall will be used, only registrants may attend, and first come, first served. (Participants in the National Conference will have seats reserved for Dr. Leakey's lecture because their conference keeps them from the film.)

<u>Name Badges</u>
The name badges of special groups have been color coded as follows:

Buff for volunteer student workers

Blue for Participants and Darwin Centennial Committee members

Yellow for the Society for the Study of Evolution

Red for The Institute for High School Biology Teachers

Salmon for the University of Chicago Faculty

Green for official delegates

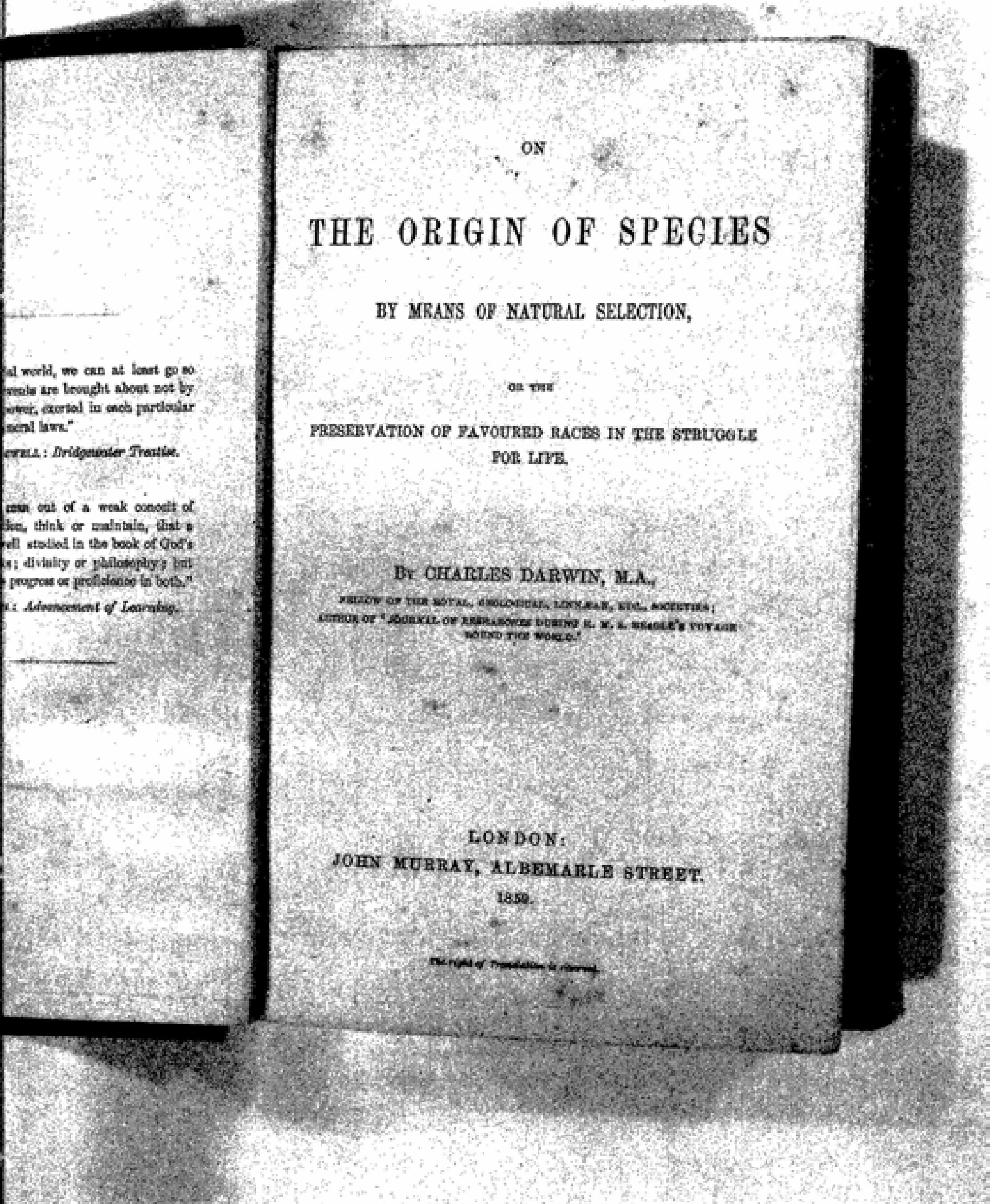
Among the contents of the registrant's envelope was a 64-page booklet of summaries of the Centennial papers. These 45 essays, written in advance and exchanged among the participants, were not to be read at the Celebration itself. To acquaint the audiences with the material, and hence help them appreciate the discussions, it was decided to summarize the papers in the form of a booklet. But who was to do the abstracting? Charles Callender, the Conference Director, was a logical choice, but he had been unable to begin the summaries until shortly before the deadline. Alfred L. Kroeber took responsibility for all the anthropological papers, and several others were done by a young biologist, David Ingle. A neighborhood letter service agreed to work day and night to print the booklets before the Celebration and deliver them to my home, where we were also working day and night. They actually did the job, and delivered them as promised, but then someone discovered that the pages were out of order so that they could not be followed. A moment of panic, and then the solution, an errata sheet, as follows:

> ORDER OUT OF CHAOS:
> or
> Nine Pages That Shook the Editor
>
> When you come to the end of Page 34, turn to Page 39. Read through Page 43. Then turn back to Page 35 and read through Page 38. Then turn to Page 44 and you are out of the maze.

All through that last frantic weekend, we were printing tickets and stuffing envelopes, with as many helpers as we could find. Registration began Monday morning, and at 8 a.m. trucks came to the house to deliver the material to the registration room barely ahead of the crowds.

I have described only a small fraction of the work involved in preparing for the Celebration. The lesson is that to do an *ordinary* job, have experienced people who will follow proved routines and avoid "foolish" things which would be good to do if they were practicable. But if there is an *extraordinary* task to be done unprecedentedly well, get creative, intelligent, and devoted people, wholly ignorant of all pitfalls in the interesting paths they will choose.

Who were these people? In 1958, our Committee was struggling



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

...al world, we can at least go so ...vents are brought about not by ...ower, exerted in each particular ...neral laws."

...WELL: *Bridgewater Treatise.*

...man out of a weak conceit of ...tion, think or maintain, that a ...well studied in the book of God's ...s; divinity or philosophy; but ...progress or proficience in both."

...N: *Advancement of Learning.*

COMMITTEE
for the
DARWIN CENTENNIAL CELEBRATION

SOL TAX, CHAIRMAN, *Department of Anthropology*

ALFRED E. EMERSON, *Department of Zoölogy*

CHAUNCY D. HARRIS, *Department of Geography*

EVERETT C. OLSON, *Department of Geology*

H. BURR STEINBACH, *Department of Zoölogy*

ILZA VEITH, *Department of Medicine*

CHARLES CALLENDER, *Conference Director*

MARIE-ANNE HONEYWELL, *Conference Secretary*

JEAN DAMES AND ROSE WEINER, *Assistants*

ROCHELLE DUBNOW, *Director of volunteer work by students*

MARIANNA TAX, *Assistant*

INSTITUTE AND NATIONAL CONFERENCE FOR HIGH SCHOOL BIOLOGY TEACHERS

RICHARD BOYAJIAN, *University High School*
Director of the Institute

JOHN C. MAYFIELD, *the College*
Director of the National Conference

Committee: G. ERNST GIESECKE and D. BOB GOWIN, *Graduate School of Education;* BARBARA F. PALSER, *Department of Botany;* HEWSON H. SWIFT, *Department of Zoölogy.*

THE UNIVERSITY OF CHICAGO DARWIN CENTENNIAL CELEBRATION

NOVEMBER 24–28, 1959

Joining the University in sponsoring the Darwin Centennial Celebration are the National Science Foundation, the Wenner-Gren Foundation for Anthropological Research, and the National Institutes of Health. The first two have contributed transportation and living expenses for the participants; the third, costs of the panel discussions.

TUESDAY
NOVEMBER 24

Sol Tax

1:30 P.M.
MANDEL HALL

ISSUES IN EVOLUTION—"INTRODUCTION"
Sol Tax

2:00 P.M.
MANDEL HALL

ISSUES IN EVOLUTION—I: "THE ORIGIN OF LIFE"

Panel Discussion
Chairmen: Harlow Shapley *and* Hans Gaffron

SIR CHARLES GALTON DARWIN
TH. DOBZHANSKY
EARL A. EVANS, JR.
G. F. GAUSE
RALPH W. GERARD
H. J. MULLER
C. LADD PROSSER

6:00 P.M.
HUTCHINSON COMMONS AND COFFEE SHOP

CENTENNIAL DINNER
Presiding: Chauncy D. Harris,
Dean, *Division of Social Sciences*

The Citizens Board of the University of Chicago will join the after-dinner program. Other registrants are invited to the limit of seating capacity.

8:30 P.M.
MANDEL HALL

WELCOME
Lawrence A. Kimpton, Chancellor, *University of Chicago*

"THE DARWIN CENTENNIAL CELEBRATION"
Sol Tax

"DARWIN THE TRAVELLER"
Sir Charles Galton Darwin

Sir Charles Darwin

Panel One

A crowd at intermission

The audience in Mandel Hall

WEDNESDAY

NOVEMBER 25

9:45 A.M.
MANDEL HALL

ISSUES IN EVOLUTION—II: "THE EVOLUTION OF LIFE"

Panel Discussion

Chairmen: SIR JULIAN HUXLEY *and* ALFRED E. EMERSON

DANIEL I. AXELROD
TH. DOBZHANSKY
E. B. FORD
ERNST MAYR
A. J. NICHOLSON
EVERETT C. OLSON
C. LADD PROSSER
G. LEDYARD STEBBINS
SEWALL WRIGHT

2:45 P.M.
MANDEL HALL

"THE LADDER OF LIFE"

Advance showing of a film on "evolution in action"
Prepared by the Columbia Broadcasting System
for broadcast on CONQUEST November 29

L. S. B. Leakey

3:30 P.M.
MANDEL HALL

Illustrated Lecture

"THE ORIGIN OF THE GENUS HOMO"

L. S. B. LEAKEY

EXHIBITS ON THE UNIVERSITY CAMPUS

REYNOLDS CLUB, SOUTH LOUNGE

University of Chicago Library Exhibit. The history of evolutionary theory and the influence of Darwin's writings on social thought and theology are shown in a book exhibit assembled by the Department of Special Collections of the University Library. Among the books on display from the Library's collections are first editions of seventeen of Darwin's works, including the *Origin of Species*, presented to the University by Col. William M. Spencer of Chicago.

University of California at Los Angeles Exhibit. A series of posters loaned by the University of California at Los Angeles Biomedical Library illustrates Darwin's precursors, his life and work, and contemporary reaction to his theories, and post-Darwinian developments in genetics, embryology, physical anthropology and psychology.

Panel Two

Sight-seers at exhibits

THURSDAY
NOVEMBER 26

9:45 A.M.
MANDEL HALL

ISSUES IN EVOLUTION—III: "MAN AS AN ORGANISM"

Panel Discussion

Chairmen: GEORGE GAYLORD SIMPSON *and* F. CLARK HOWELL

MARSTON BATES
CESARE EMILIANI
A. IRVING HALLOWELL
L. S. B. LEAKEY
BERNHARD RENSCH
C. H. WADDINGTON

3:00 P.M.
ROCKEFELLER MEMORIAL CHAPEL

DARWIN CENTENNIAL CONVOCATION

Presiding: LAWRENCE A. KIMPTON, Chancellor, *University of Chicago*

Convocation Address:
"THE EVOLUTIONARY VISION"
SIR JULIAN HUXLEY

Awarding of Honorary Degrees

Immediately following the recessional, official delegates will greet the recipients of honorary degrees in Ida Noyes Hall.

Sir Julian Huxley

6:00 P.M.
HUTCHINSON COMMONS

THANKSGIVING DINNER

Presiding: EDGAR A. ANDERSON, President, *Society for the Study of Evolution*

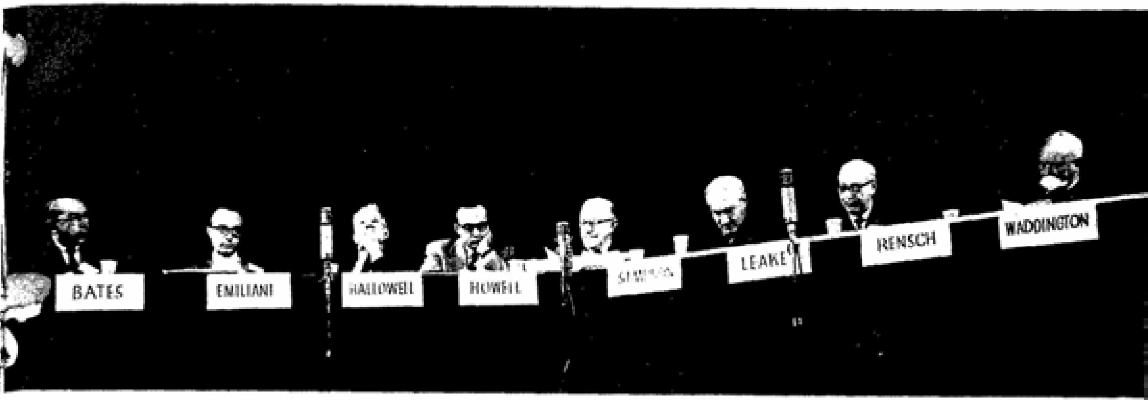
8:30 P.M.
MANDEL HALL

"TIME WILL TELL"

An original musical play written for the Celebration by ROBERT A. ASHENHURST and ROBERT POLLAK

OPENING PERFORMANCE

A scene from "Time Will Tell"



Panel Three

G. G. Simpson, one of the recipients of an honorary degree

Convocation procession

At the Convocation

FRIDAY
NOVEMBER 27

9:45 A.M.
MANDEL HALL

ISSUES IN EVOLUTION—IV: "THE EVOLUTION OF THE MIND"

Panel Discussion

Chairmen: RALPH W. GERARD *and* ILZA VEITH

HENRY W. BROSIN
MACDONALD CRITCHLEY
W. HORSLEY GANTT
A. IRVING HALLOWELL
ERNEST HILGARD
SIR JULIAN HUXLEY
H. W. MAGOUN
ALEXANDER VON MURALT
N. TINBERGEN

1:30 P.M.–4:30 P.M.
JUDD HALL 126

INSTITUTE FOR HIGH SCHOOL BIOLOGY TEACHERS

The National Conference for High School Biology Teachers brings to this Institute teachers from all over the United States. It is financed by a grant from the National Science Foundation as a means of widening the influence of the Centennial Celebration and of this Institute.

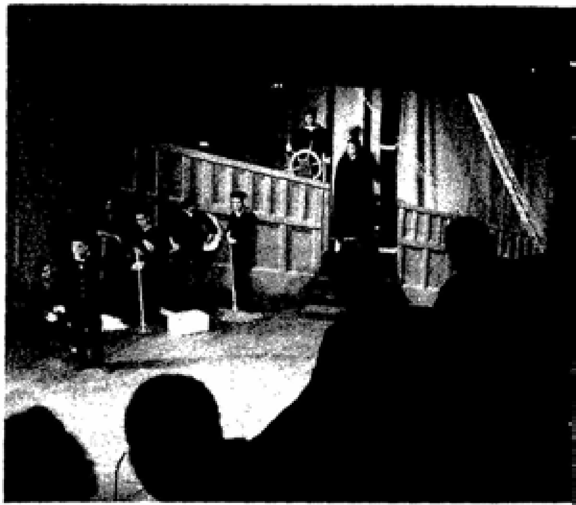
Panel and Discussion Sections

Chairman: H. BURR STEINBACH

EDGAR ANDERSON
TH. DOBZHANSKY
H. J. MULLER
GEORGE GAYLORD SIMPSON

8:30 P.M.
MANDEL HALL

"TIME WILL TELL"



A scene from "Time Will Tell"

SATURDAY
NOVEMBER 28

9:45 A.M.
MANDEL HALL

ISSUES IN EVOLUTION—V: "SOCIAL AND CULTURAL EVOLUTION"

Panel Discussion

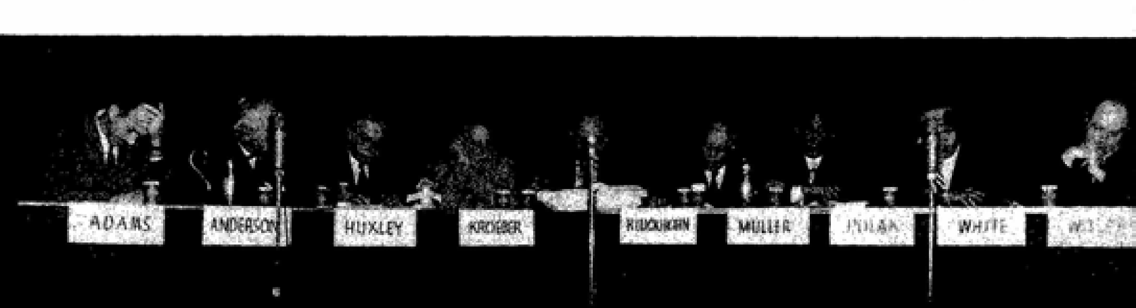
Chairmen: CLYDE KLUCKHOHN *and* ALFRED L. KROEBER

ROBERT M. ADAMS
EDGAR A. ANDERSON
SIR JULIAN HUXLEY
H. J. MULLER
FRED POLAK
JULIAN H. STEWARD
LESLIE A. WHITE
GORDON R. WILLEY

Discussion at the teachers' institute

A scene from "Time Will Tell"

Panel Five



SATURDAY

NOVEMBER 28 (CONCLUSION)

12:00 M.

MANDEL HALL

ISSUES IN EVOLUTION—"CONCLUSION"

SOL TAX

1:30 P.M.–3:30 P.M.

JUDD HALL 126

INSTITUTE FOR HIGH SCHOOL BIOLOGY TEACHERS

Lecture and Film
EVOLUTIONARY ASPECTS OF SOCIAL COMMUNICATION IN ANIMALS
N. TINBERGEN

Remarks
THE PLACE OF EVOLUTION IN THE CURRICULUM
SIR JULIAN HUXLEY

1:30 P.M.–5:30 P.M.

MANDEL HALL

INSTITUTE ON SCIENCE AND THEOLOGY
Arranged with the cooperation of the Federated Theological Faculty

Lecture
"CREATION AND CAUSALITY IN THE HISTORY OF CHRISTIAN THOUGHT"
JAROSLAV PELIKAN, *Federated Theological Faculty*

Lecture
"CREATION AND EVOLUTION IN PRESENT-DAY ROMAN CATHOLIC THOUGHT"

THE REVEREND J. FRANKLIN EWING, S.J., *Fordham University*

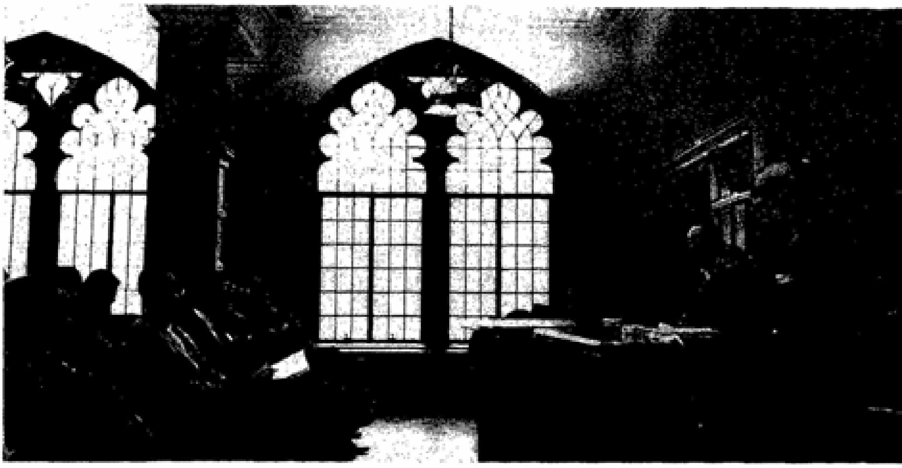
Panel Discussion
"WARFARE OF SCIENCE WITH THEOLOGY"
Chairman: JERALD C. BRAUER, *Federated Theological Faculty*

HARLOW SHAPLEY
SIR CHARLES GALTON DARWIN
C. H. WADDINGTON
WILLIAM O'MEARA, *Department of Philosophy*
H. BURR STEINBACH
LEO STRAUSS, *Department of Political Science*

8:30 P.M.

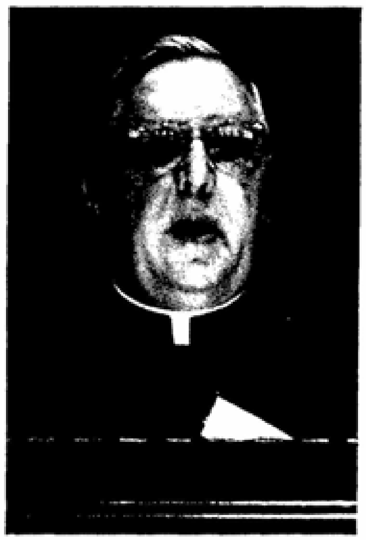
MANDEL HALL

"TIME WILL TELL"



Huxley addressing teachers

Jaroslav Pelikan



Father Ewing

Panel at institute on science and theology

PARTICIPANTS

ROBERT M. ADAMS
University of Chicago
The Evolutionary Process in Early Civilizations

EDGAR ANDERSON
Missouri Botanical Garden
The Evolution of Domestication

DANIEL I. AXELROD
University of California, Los Angeles
The Evolution of Flowering Plants

MARSTON BATES
University of Michigan
Ecology and Evolution

FRANCOIS BORDES*
University of Bordeaux
Evolution in the Paleolithic Cultures

ROBERT J. BRAIDWOOD*
University of Chicago
Levels in Prehistory: A Model for the Consideration of the Evidence

HENRY W. BROSIN
University of Pittsburgh
Evolution and Understanding Diseases of the Mind

MacDONALD CRITCHLEY
National Hospital, London
The Evolution of Man's Capacity for Language

SIR CHARLES GALTON DARWIN
Can Man Control His Numbers?

TH. DOBZHANSKY
Columbia University
Evolution and Environment

ALFRED E. EMERSON
University of Chicago
The Evolution of Adaptation in Population Systems

CESARE EMILIANI
University of Miami
Dating Human Evolution

EARL A. EVANS, JR.
University of Chicago
Viruses and Evolution

PAUL FEJOS
Wenner-Gren Foundation for Anthropological Research
Discussion Participant

E. B. FORD
University of Oxford
Evolution in Progress

HANS GAFFRON
University of Chicago
The Origin of Life

W. HORSLEY GANTT
Johns Hopkins University
Pavlov and Darwin

G. F. GAUSE
U.S.S.R. Academy of Medical Sciences

RALPH W. GERARD
University of Michigan
Becoming: The Residue of Change

A. IRVING HALLOWELL
University of Pennsylvania
Self, Society and Culture in Phylogenetic Perspective

CHAUNCY D. HARRIS
University of Chicago
Committee, Darwin Centennial Celebration

ERNEST HILGARD
Stanford University
Psychology after Darwin

F. CLARK HOWELL
University of Chicago
with S. L. Washburn
Human Evolution and Culture

SIR JULIAN HUXLEY
The Emergence of Darwinism

CLYDE KLUCKHOHN
Harvard University
Discussion Participant

ALFRED L. KROEBER
University of California, Berkeley
Evolution, History, and Culture

L. S. B. LEAKEY
Coryndon Memorial Museum, Nairobi, Kenya

*Unable to attend the Celebration.

H. W. MAGOUN
University of California, Los Angeles

Evolutionary Concepts of Brain Function Following Darwin and Spencer

ERNST MAYR
Harvard University

The Emergence of Evolutionary Novelties

H. J. MULLER
Indiana University

The Guidance of Human Evolution

ALEXANDER VON MURALT
University of Berne

A Decisive Step in Evolution: Saltatory Conduction

A. J. NICHOLSON
Australian Commonwealth Scientific and Industrial Research Organization, Canberra

The Role of Population Dynamics in Natural Selection

EVERETT C. OLSON
University of Chicago

Morphology, Paleontology, and Evolution

STUART PIGGOTT*
University of Edinburgh

Prehistory and Evolutionary Theory

FRED POLAK
University of Rotterdam

Discussion Participant

C. LADD PROSSER
University of Illinois

Comparative Physiology in Relation to Evolutionary Theory

BERNARD RENSCH
University of Münster

The Laws of Evolution

HARLOW SHAPLEY
Harvard University

On the Evidences of Inorganic Evolution

GEORGE GAYLORD SIMPSON
Harvard University

The History of Life

G. LEDYARD STEBBINS
University of California, Davis

The Comparative Evolution of Genetic Systems

H. BURR STEINBACH
University of Chicago

Committee, Darwin Centennial Celebration

JULIAN H. STEWARD
University of Illinois

Evolutionary Principles and Social Types

SOL TAX
University of Chicago

Chairman, Darwin Centennial Celebration

N. TINBERGEN
University of Oxford

Behaviour, Systematics, and Natural Selections

ILZA VEITH
University of Chicago

Creation and Evolution in the Far East

C. H. WADDINGTON
University of Edinburgh

Evolutionary Adaptation

SHERWOOD L. WASHBURN*
University of California, Berkeley
with F. Clark Howell

Human Evolution and Culture

GORDON R. WILLEY
Harvard University

Historical Patterns and Evolution in Native New World Cultures

LESLIE WHITE
University of Michigan

Four Stages in the Evolution of Minding

SEWALL WRIGHT
University of Wisconsin

Physiological Genetics, Ecology of Populations and Natural Selection

* Unable to attend the Celebration.

A scene during the television broadcast, "At Random," with (left to right) *Tax, Darwin, Huxley, Stevenson, Kupcinet, and Shapley*

along without real staff, when the press and public began to take interest and we all realized that "nothing was being done" about publicity, invitations, the special convocation, the Celebration itself. Charles Callender was a recent Ph.D. of our Department of Anthropology with some experience in public relations. An excellent writer and a careful scientist, he had never done administration; but we gave him the title of Conference Director and he went to work.

In February of 1959 I returned from Asia for a two-month furlough between conference trips for *Current Anthropology*. My assistant editor, Malcolm Collier (who had also helped in the first months of the Darwin Committee), produced for me an applicant for a position as a secretary who could keep straight my very tangled affairs. Marie-Anne Honeywell is an M.A. in the humanities who was doing unchallenging office work (while her husband gets his doctorate), and was happy to see such a tangle. A granddaughter of a Nobel prize-winning chemist, she has self-reliance born of confidence; skill and intelligence to match; and the habits of a scholar-scientist to whom the jobs to be done overshadow the time of day, and the reward of solving a problem weighs with a day's wage. Mrs. Honeywell, from February to September, was fully occupied in helping me to manage the variety of my affairs; but as the Centennial Celebration approached and the work snowballed, she devoted more and more of her time to the chores of Conference Secretary. She trained an office staff and eventually student helpers; she found and bargained with printers and movers; she turned the innumerable tricks that magically melt difficulties.

No matter how good our authors, how wise our Committee, or how ingenious its Chairman, the Celebration could not have been accomplished without these two, so different yet so alike in their willingness to plunge into the unknown and their ability to get out alive somehow, if only at the last split second.

Charles Darwin and the genuine universal importance of the concept of evolution might have foreordained the success of the Celebration no matter what. Darwin proves to be more than a mere symbol; his *Origin of Species* is a living classic in science. More than that, the concept of evolution remains among the most significant and appealing ideas of the intellectual world and a socio-religious issue as much as it was one hundred years ago. When the thought of the Centennial first crossed my mind, I evidently felt something about Darwin and evolution that would have been difficult to demonstrate except through this fulfillment: The Centennial was a success because it celebrated something with deep meaning for the people of contemporary America. Evolution is unfinished business for all kinds of people, and the names Darwin and Huxley, with or without the prefix "Sir," call up still the variety of

images they once did. One might have thought that with all the evidence of a hundred years, science by now would have triumphed and hostilities ended—particularly since science generally is so triumphant. (Or is it precisely because science is so triumphant and threatens to destroy us all that we rise to deny it where we can?) But Darwinian evolution also turns out to be one of the rare great tools for understanding ourselves and nature, and it was to this bright star that our Celebration was hitched. In this old but vital context, every scholar and every scientist had something to learn and something to give. And this, more than anything we did, accounted for our success.

Whatever the Centennial did for others, for me it brought Darwin and evolution back into anthropology. It forced me to see some of our contradictions and helped me form some resolutions about the study of man:

1. *Culture is part of the biology of man,* of course, even though it is passed on socially and not through the genes. It is a characteristic of our species, as characteristic as the long neck is of the giraffe. The general biological questions asked about the giraffe's neck are also questions to be asked about the civilizations of man.

2. *Culture is part of the evolution of man.* Man is evolving continually as a species, perhaps more rapidly now than any other species. Hence, processes of natural selection and the like are presumably operative, but they are operative *on the species,* not on the particular cultures of communities of men.

3. *The term "evolution" is applied to both socially transmitted culture and gene transmitted biology* because neither can establish an exclusive claim. However, there is no identity between the two usages. The cultural processes of continuity and change are different, and it is only by analogy, if at all, that one can speak of "natural selection," for example, in the development of cultures.

Culture must be studied as part of the evolution of man; but culture change and growth must be studied in their own terms. Therefore, anthropologists legitimately study culture apart from the organisms who carry it.

4. *Cultural behavior has a quality of arbitrariness,* because it does not flow through the genes and is therefore not anchored to the individual. This is seen most clearly in the arbitrariness of the symbols in language. Characteristically, therefore, cultures differ widely from community to community; the communities of men have this quality in common: each has its own special language, value systems, social systems, etc.

5. *The study of man becomes a comparative study of cultural difference within "genetic" sameness.* The species is uniform, with what-

ever individual differences there are in any population; but every community has its stamp. Both factors must be brought into the comparison.

6. *Culture developed through time;* archeology and common sense both make it clear that culture developed from something rudimentary in primitive australopithecines. Some stages are easy to imagine and also marked in the evidence. By the time man became *Homo sapiens,* he had behind him some important stages—tool-making, fire, speech, and many other socially transmitted behaviors. These had developed to the point where all men could live in the characteristic human community that we have known in history. Kalahari Bushmen and Andamanese share with Londoners and Ukrainians the characteristic of being parts of a self-conscious and ethnocentric community with its distinct language, culture, social system, and convictions of right and wrong. The latest such communities of *Homo sapiens* have the advantage of much accumulated experience that the first lacked. It is fairly easy to talk about "cultural evolution" with respect to science and technology or community size and structure, things that are causally related and for which there are archeological evidences. A *theory* of cultural evolution implies regularities that go beyond archeological evidence.

7. *Only the "theories" of cultural evolution are in dispute.* The cultural anthropologists participating in the Centennial Celebration were more committed to such theories than are many of their colleagues. The general conclusion reached in Panel Five—that we now all believe in cultural evolution—should be qualified: Some anthropologists will accept only the evidences of records through time and believe that these do not supply evidence of regular progression in social-religious-aesthetic types accompanying the technological-economic stages where these have occurred. However, all anthropologists recognize both the general rise of culture from an almost non-existent form in animals to the human stage, where culture seems to be everything. Beyond that, they acknowledge the general progression in technology, shared differentially, and in the size of the society. We are thus evolutionists for the species, including its development of culture; but only some claim the existence of regular progression in the whole of culture. Some of these think of hunting and gathering tribes, or feudal states, as survivors of earlier stages living into the modern world; others are concerned less with temporal succession than with processes of change from one stage to another.

8. *The terms "savage" and "barbarian" have been replaced by "primitive,"* during the course of the century, to express the opposite of "civilized." In any dictionary sense the meaning of "primitive"

makes it appropriate only for designating the *first* men, perhaps australopithecines. It is, therefore, a doubtful courtesy to drop the nineteenth century derogatory terms and call most of the peoples of the world "primitive." It is ironic that the substitution is made most uniformly by those who have abandoned cultural evolution because they deny that any culture can validly be considered more advanced than any other!

So, for me, the Centennial brought Darwin and evolution back into anthropology, not by resurrecting analogies, but by distinguishing man as a still-evolving species, characterized by the possession of cultures which change and grow non-genetically. Human evolution includes the addition of culture to man's biology; "cultural evolution" at the human level is quite a different matter. Anthropologists accept the first without question; they are divided about the second.

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