BIOLOGICAL FOUNDATIONS OF EDUCATION

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PREFACE

Biology deals with all living things. Too often it has been regarded as dealing with plants and with animals but not primarily with man. Man, as the animal who is conspicuous for his ability and desire to think, needs to treat biology so that it includes him as a thinking animal. Recent tendencies interpret human behavior as, in considerable part, the result of inherited and environmental factors, and it becomes important that man shall know what biology can tell him of these two types of causal factors. Therefore, modern biology deals with man, and thinking man cannot safely omit biology from his consideration.

The manifestations of life change often; therefore exact studies regarding life responses are not easily made. It is not always possible for biological knowledge to possess the desired exactitude and clarity which may be had more frequently in mathematics and the physical sciences. This fact, instead of making biological study less desirable, makes it more imperative, since life, which is the essential fact of biology, manifests itself in complicated and perplexing ways. Its study seems unavoidable unless man relinquishes the quest for constantly improved knowledge and progress. The science is becoming more and more exact, however, and its guidance in directing human behavior is becoming more and more dependable.

For some years the authors of this book have been engaged in experiments in organization and use of these materials. It has been their desire to present those aspects of biology which are foundational to education, psychology, and sociology. While efforts have been primarily directed toward helping those who will deal with education in some form, we have kept in mind those various groups of adults who desire and seek a better understanding of the contributions of biology to human problems. Several types of possible readers, therefore, have been considered during the final writing of the manuscript; citizens who have benefited by the program of public education, and who thus have the desire, the capacity, and the leisure for reading serious books which deal with modern problems; individuals and groups engaged in adult education and in the relations of parents to schools; college and university courses of instruction, such as those in psychology, education, sociology, biology, and hygiene. We have also kept in mind the course specifically designed to present the biological foundations of education, which has been introduced in many universities and teachers' colleges.

It is hoped that biological knowledge, as here presented, may contribute to a more purposeful development not only of the general philosophy of education but of an individual philosophy of living. Ideas as to what education is and what it is for seem to be in process of adjustment. The authors believe that knowledge of biology will help in this readjustment of purposes and practices.

In such a new venture, in which the wealth of material is so large, the problems of what to include and what to omit are constantly present. It cannot be hoped that our decision on these problems will be approved by all. It is not possible, and not advisable, to include all good material in so rich and varied a field. We have, therefore, provided abundant citations to valuable related publications in which further studies may be made beyond the discussions of these chapters. It is hoped, however, that the presentation here given is sufficiently complete, accurate, and pertinent to provide the reader with clear and helpful knowledge of the topics that are treated. To this end we have assembled evidence and discussions, and have cited experimental studies from a wide range of sources. We have also endeavored to state clearly and constantly the limits of existing knowledge and of reported experiments. The reader is urged to accept with the biologist the point of view that knowledge is always growing and that an important aspect of this study is to distinguish clearly between what is known and what is not known. That is, it is hoped that what truth is known may be understood and used; and that what is not known may not be assumed but may be treated as unknown, with expectation that new knowledge may change our present thought.

Acknowledgment is gratefully made to the thoughtful students who by their questions, suggestions, discussions, and special reports have coöperated in the development of this work; and to all of our colleagues who have given helpful criticisms and who gave encouragement regarding the needs and values of the undertaking.

THE AUTHORS

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CHAPTER I

BIOLOGY IN RELATION TO SPACE, TIME, AND ENERGY

The enlarged universe. Many living things remain in one place throughout their lives. A tree, unless transplanted by man, begins, lives, and closes its life period without travel. A range of a few miles is the life limit of most individual animals, except migratory animals, such as birds and insects. Most men, like most other animals, pass their entire lives within the same limited range as their ancestors. Human migrations have been occasional. Until recently those who had traveled "around the earth" were conspicuous examples of men who had done unusual things. They had made travels that were scarcely hoped for by others, and to regions not even within the consciousness of many.

It is still easy to find persons who have never been in a railway coach, or even those who only occasionally see their own county seat. In a well-populated county in New York State, a county whose first settlements were made prior to 1700, a farmer recently took a load of fine poultry to the market in his county seat. The town is nine miles from this farmer's home, which was the home of his fathers to the fifth generation. Neither he nor any of his ancestors, he said, had been out of the county since their first ancestral home was made, none had been in a railroad coach, and only quite recently had he acquired his first automobile. When one of his listeners at the market spoke of a recent automobile trip of a thousand miles in four days, the farmer's lack of belief was quickly made evident by an elemental shoulder shrug understood by traveled and untraveled alike.

It seems safe to say that most of the human race has had little experience beyond a very narrow range. The earth is small to them, and its center of occurrences lies within their own circle.

The earth *is* small, seemingly almost negligible, when its neighbors are considered. Indeed, while the earth seems small to persons of no travel, it seems even smaller, relatively, to those who think of the earth's neighbors and of the distances traversed when these neighbors are visited. We travel over the earth by moving ourselves from place to place. We visit the earth's neighbors by letting the light from these neighbors tell us about them. In this sense we visit by causing the light to bring these neighbors to us. When this is done we get a new notion of the earth as a home for living things. We sense its smallness, its remoteness from other heavenly bodies, its extremely limited but essential ability to intercept and absorb energy from our sun. At the same time a new significance is given to the earth's varied conditions for life, its climate and seasons, its energy from the sun by means of which all life and all productive occurrences of life are made possible. Its wide range in the conditions of its atmosphere, its surface, its soil and water, are given added significance when we realize that the earth, which is seemingly almost negligible among the heavenly bodies, is, so far as we know, the only one of all these heavenly bodies which serves as the home for living things.

How "far away" from other bodies and how important in size is this home for living things, — this earth? The earth's diameter is about 8000 miles. Its greatest circumference is about 25,000 miles. Again we must use light to tell us what we want to know, because ordinary measurements of distances alone do not mean much. Light travels about 186,300 miles each second. This means that light could travel around the earth more than seven times each second, or that in the same time it could travel through the distance of twenty-three earths placed side by side. In one minute light would travel 60 times as far; in one hour, 60 times that; in one day, 24 times that; and 365 times that in one year. Light travels $365 \times 24 \times 60 \times 60 \times 186{,}300$ miles in one light year — to state it in another way. The number of miles traveled by light in one year is called a light year, and this is used as a measure of astronomical distance. Now, it is about 93,000,000 miles from the earth to the sun, or a distance of some 3720 times the circumference of the earth. Light travels from the sun to the earth in a little over 8 minutes. Thus one light year is about 63,300 times the distance from the earth to the sun. Our nearest fixed star is about 4.2 light years from the earth. The diameter of the whole Milky Way, or galaxy, of which our earth and our sun are parts, is at least 200,000 light years, possibly much more. There are other galaxies, or systems of suns and stars, besides the one of which our earth and sun are parts. The galaxy nearest to ours is, from its center to the center of our galaxy, some 900,000 light years, and there are other galaxies much farther away.

But these distances are too great to have much meaning for most of us. Can they be made to mean more by any other methods? One of our students tried to give more meaning to the earth in relation to the size of other heavenly bodies by some calculations regarding the constellation known as the Great Dipper. Some of his conclusions are given:

It takes seven years for light, which travels at the rate of 186,300 miles a second, to pass across the top of the Big Dipper. The distance is over 41,000,000,000,000 miles. This means that, if a track were provided, an express train traveling at the rate of 60 miles per hour would require about 78,120,000 years to make the trip. And, allowing 40 years for the average period that an engineer is able to function at the throttle, and providing for the 8-hour shift, it would take the active lives of 5,859,000 different engineers to guide the train to the other star. At the rate of three cents a mile, the fare for the trip would be $1,231,796,160,000. If a person should have that amount of money to spend, this would be a useless way to part with it, for, relatively speaking, his threescore and ten years would be over before the train hardly pulled out of the station. If an observer at the end of the handle of the dipper had a telescope so powerful that he could see as far as the opposite side of the dipper, he would be able to witness the start of the trip nearly 17 years after it took place.

If this huge dipper were of the size and shape that the cross section indicates, it would hold approximately 1,220,541,302,774,293,635,-320,000,000,000,000,000,000 cubic miles of water. And if there were a giant who would care to use a dipper of that size, he would be so large that the highest balloon ascension ever made would not clear the epidermis on the bottom of his foot. The distance to the top of his toe would be thousands of times the distance from the earth to the sun. If our earth should fall into his dipper he would swallow it and never realize our presence in his system. The Big Dipper, however, is only a very small group of stars in the universe.[1]

Among the unnumbered stars and nebulous bodies of the galaxies, some of which are inconceivably hot, others as cold as can be, our earth is the only one that we surely know to be a home for living things. In comparison as to size, our earth is so small that it would scarcely have a place as large as a dot in a map of all the heavens. Yet to travel around it is an epoch in anyone's life, and its unknown regions still call for exploration by those with fortitude and a desire to go into untraveled places. The earth receives but a pittance of the radiant energy of its distant sun, yet by means of this energy it has plant and animal life, and, above all, it harbors human beings, who by means of reasoning power undertake to learn about the tremendous and far-reaching wonders of their universe. Is not the mind of man, with its consciousness, bigger than the space relations of the universe?

Time and change. Not only must we possess some measure of appreciation of the spaces through which the earth and

[1] William E. Doe, An Attempt to Illustrate the Elements of Time and Distance. An unpublished student report, 1928.

other bodies are moving, some conception of the large number of these bodies and their huge masses, as well as some notion of the myriads of smaller bodies with which our little earth is associated and held by gravitational force, but we need some small insight into the stretches of time during which the earth and life upon it have been developing. No definite time limits can be set. Enough is known, however, to make possible a picture of time periods in relation to one another, and to assign numbers roughly, it being understood that these numbers may be in error by some millions of years.

It will help us in gaining a general notion of the stretch of time if we consider cosmic, or astronomic, time as related chiefly to the periods preceding the beginning of the formation of records in the earth; geologic time as related chiefly to the periods during which records have been made in the surface of the earth; and the time of human history as related to the period of life of man upon the earth. It is clear that no sharp line can be drawn to limit these divisions of time. But cosmic time, the time of the earth preceding so-called geologic time, is now known to be much longer than the geologic eras. The earth is thought to have formed slowly by accumulating particles and masses which came to it from astronomic dust, from meteors, and from other falling bodies which came close enough to be attracted to it. Inestimable ages passed during this process of earth building. Other heavenly bodies are thought to be in process of being made in just such a way, and in fact the earth still receives small additions to itself. Estimates made by geologists, astronomers, and mathematicians indicate that the proportion of astronomic time of the earth to its geologic time is approximately as shown in Fig. 1, on page 6.

The earliest geologic records are of very ancient rocks and of very simple kinds of living things. As the geologic strata are followed upward toward the most recent deposits the rocks and their fossils tell a marvelous story of constant change in the life of plants and animals. The corresponding geologic eras are commonly spoken of as the Archeozoic (in which the unicellular organisms originated), the Proterozoic

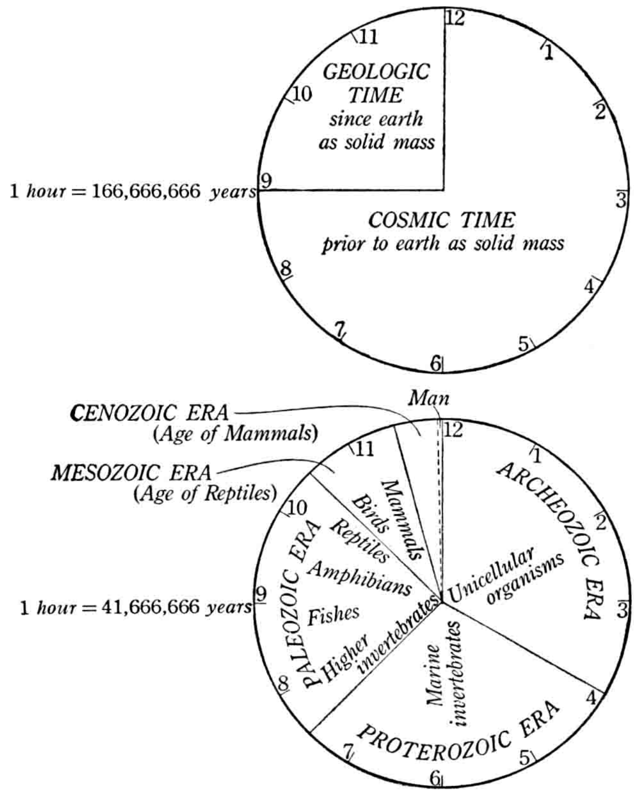

FIG. 1. Graphic illustration of estimated time periods

Above, the relative proportions of cosmic and geologic time. Below, the probable length of time covered by each of the geologic eras and the shortness of the period of mammals as compared with the whole span of life

(marine invertebrates), the Paleozoic (higher invertebrates, fishes, amphibians, and reptiles), the Mesozoic, or Age of Reptiles (birds and mammals), and the Cenozoic, or Age of Mammals, in which human beings first appeared on the earth.

The time distribution of these geologic eras is significant. All together they are estimated to have covered about five hundred million years. The Archeozoic and Proterozoic eras are estimated to have consumed about five eighths of all this time; the Paleozoic, one fourth; the Mesozoic, about one tenth; and the Cenozoic, about one twenty-fourth. If man's part of the Cenozoic era were roughly plotted on a clockface, it would occupy not more than two or three minutes. On such a clockface diagram each hour would therefore represent approximately forty-two million years. The divisions are approximate. It must also be understood that beginnings of animal groups are found in preceding ages and that some forms persist through succeeding ages. The time estimates by geologists must be regarded as approximations.

Significance of energy. We have referred to the earth's intercepting and absorbing energy from the sun. We do not know enough as yet to make possible a full statement of what energy is, or of its complete action on the earth and other astronomical bodies. We are hardly likely to overstate its importance, however, even though our knowledge of its nature is undergoing rapid change. The conditions that exist upon and about the earth provide the possibility for manifestations of energy from the sun which would not otherwise be shown. The earth has atmosphere about it, and there is water in the atmosphere, upon the surface of the earth, and in the earth. The gases of the atmosphere and the moisture and solid particles in the atmosphere compose a blanket about the earth. How far above the earth this blanket extends is not known, but it extends at least two hundred miles, though more and more diffuse as the distance from the earth increases. The moon has no atmosphere, and if it has water, it must be in the form of solid ice. With no atmosphere the heat energy from the sun, when reflected from the surface of the moon, is not absorbed or held as on the earth. Thus very great extremes of temperature — so great as to prevent life as we know it — exist upon the moon. Even upon the earth the polar regions have such an extremely low temperature as to make life of most kinds impossible, and in the temperate and torrid zones most kinds of life persist by having an adjustment of reduced living or dormancy during the coldest or the hottest periods. Heat energy from the sun, acting upon the earth and the atmosphere of the earth, and possible changes in heat due to physical factors within the earth provide the explanation of the earth's temperature.

The energy by means of which living things do whatever they do cannot be had merely from a temperature which is favorable or merely endurable. No one knows how the earliest living things got their energy from the sun. There is an extensively developed coöperative plan for using the sun's energy. The green material in plants, called chlorophyll, itself produced under the influence of sunlight, absorbs energy from the sunlight, and in some way not wholly known this energy is then used in constructing, from carbon dioxide and water, carbohydrates which can be used to nourish plants and animals. At the same time oxygen is liberated. Much research has been and is being directed to discover the exact ways in which energy operates in the intricate processes of constructing food materials from things which cannot be used directly as foods. Much is known of the process, and what is now known, together with the "unknowns" that are slowly being transferred into the column of the "known," will sometime provide a full and fascinating chapter not only in biology but in our better understanding of the real meaning of energy in relation to life upon the earth.

The general significance of energy stored up in foods, we now know. Foods are used to build new parts and to replenish old parts. Protoplasm, the living substance of all plants and animals, is used — is broken up for release of its energy — whenever work of any kind is done. Protoplasm is a storehouse of energy without which no act, no thought, no emotion, no wish even, may occur. Protoplasmic energy is constantly being released, and thus constant sources of replenishment are needed. Foods of various kinds are these energy sources, and foods of all kinds trace their beginnings back to the work of chlorophyll in living plants. This work, called photosynthesis (construction by means of the light) is a fundamental biological process upon which all life and all life processes depend. It is the agency by means of which the sun's energy is caught, made to do chemical work in food-making, and thus stored for immediate or deferred uses as energy for living things. A shipload of wheat is essentially a shipload of sun's energy held by the compounds of carbon, hydrogen, oxygen, nitrogen, iron, sulfur, phosphorus, etc., which compose the foods, the whole being transported about the earth to places where people will pay most for this type of stored energy. Fatted cattle, sheep, or hogs are all en route to the packing houses, there to be preserved to await the call of the retail market. All sorts of plant and animal products are assembled upon the dining tables of those who have learned that our wasteful energy-using bodies have, in our recent past, gathered foods from so many kinds of sources that we must still keep a balanced diet just to keep our bodily mechanisms working according to their structural and functional habits. Life is a constant manifestation of energy.

There are many manifestations of the energy which the earth receives. Recently men have made use of radio waves. Other radiations, or waves, from astronomic bodies — the so-called cosmic waves — may, when adequately known, become the foundation of devices, operations, the transfer and extension of thought, of sight, of hearing, or some other kinds of understanding as strikingly in advance of the radio as the radio is in advance of the simplest telephones of decades ago. Energy may finally prove its relations as the causal agent of all occurrences.

QUESTIONS

1. Why did the discussion of this subject begin with a consideration of the time and space elements in their relation to biology?

2. Some of the gigantic sequoia trees in California are thought to be four thousand years old. Make a list of some of the scientific achievements of man that have happened during the lifetime of a single tree. How can the age of a tree be estimated?

3. What outstanding facts are shown relative to time involved and types of life that were dominant in the different geologic periods?

4. What inventions and discoveries have made man's traveling to far distant points commonplace? What means has nature improvised which enable some seeds, plants, and birds and other animals to reach distant regions?

5. If the sun were to remain in a state of total eclipse, so far as the earth is concerned, what effect would it probably have upon plant and animal life on the earth?

6. Why is the light year used as a measure of astronomical distance? How far away from the earth is the nearest fixed star? How was this distance calculated?

7. What conditions on and about the earth provide the possibility for manifestations of energy from the sun?

8. What is nature's extensively developed plan for using the sun's energy?

9. What is the relation of photosynthesis to life processes?

10. What meaning do you put into the last sentence of this chapter? What are the implications of this statement?

TRUE-FALSE STATEMENTS

Which of the following statements are correct and which incorrect, and what changes will make correct statements of those that are incorrect?

1. A knowledge of the smallness of the earth, its remoteness from other heavenly bodies, and its limited ability to intercept and absorb energy from the sun adds a new significance to the interpretation of life and behavior.