corals will not live in water which goes below sixty degrees in temperature, so the obvious conclusion is that the reef was formed at least under sub-tropical conditions.

Comparatively little has been done along the line of paleobotanical research and it is very likely that a thorough working over of the material will clear up many matters of interest in establishing plant origins and plant relationships. It is a wide field of which only the borders have been touched, and it has a fascination to many people equal to the fascination of discovering and studying lost civilizations.

M. Dorisse Howe

## HOW OUR ANIMALS BECAME THEMSELVES

"COWS furnish food for man and eat other harmful insects." This rather startling statement was once given by a city girl in answer to an examination question regarding the economic value of cattle. Amusing as it is, it reveals an ignorance of facts which should be matters of general information for everyone. Most striking is the lack of knowledge shown concerning the nature of man in relation to other animals. It is doubtful if the girl in question would have liked it had her comrades called her an insect, and equally uncertain that she had any clear idea of what constitutes an insect, let alone a human being.

A full and complete knowledge of man's position in the universe, even that infinitesimal part of it which we call the earth, is possibly the most useful factor in giving to us individually the broad, sympathetic tolerance and understanding needed to make of us teachers who are something more than mere imparters of information. The study of biology will go a long way toward giving us this knowledge, but even biology as we usually think of it, lacks perspective in that it deals with the world of living things, plants and animals, now dwelling on the earth. No matter how much we may know of this phase of the subject, our knowledge is a good deal like the view one has of a forest when one is passing over in a plane. One sees the tops of the trees, and may get an oblique glimpse once in a while, but actually learns very little of what lies underneath, or of the forces which have made the trees what they are. To get a true perspective on biological interrelationships, one needs to know at least some of the big steps in the making of our modern world. Elsewhere in this number Miss Howe has told something of the plants which have preceded those which we know and which have largely determined what our plants of the present must be. In the present article I am attempting to sketch with a few bold strokes, the fascinating picture of the world of animals that lived in the ages of the world's youth, and to show how they solved problems, problems so important that had they not been successfully met, the modern world could never have come to be.

We do not know how living matter began. We possibly have a hint in those mysterious substances, the bacteriophages and the mosaic diseases of certain plants. These two, bacteriophage and mosaic, have many of the attributes of living substance, yet do not seem to be truly alive as we understand life. It is even barely possible that we have, here in these substances, matter which is in our own time undergoing that most important of all steps, the transition from the non-living to the living state. That some such process took place at some time very early in the earth's history we are reasonably certain. That it took thousands and hundreds of thousands of years, we may be sure. Creation is a mighty and a very gradual thing, a force which has been operative for ages and is still continuing.

Although we know nothing positive concerning the origin of living matter, we may be sure that the earliest living beings were very simple, and doubtless minute, probably microscopic. The oldest rocks contain substances such as graphite, certain types of iron ore, and limestones which we know were produced by living beings and only by this means. Fossils, save those of bacteria, are wanting in these ancient rocks, simply because the living organisms which gave origin to these deposits were so simple that they left no hard parts which could be preserved as fossils. It is interesting to know that the impressions of the bacteria which formed certain of the oldest deposits of iron have been discovered in sections of the ore which have been ground to microscopic thinness. Even if the most primitive organisms were minute, that is no barrier to their having been present in such enormous numbers as to have formed thick layers of rock. The chalk cliffs of Dover and Calais have been formed by unicellular animals similar to species now living in the ocean. Their shells sink to the bottom after the animals perish, and gradually, in the course of thousands of years, lay down thick chalk deposits on the ocean floor. In course of time the sea bottom is elevated, becoming dry land, and we have beds of chalk or limestone. Such has been the course of events on the earth, and so it will continue until the end of time.

The element of time has been a puzzling one to paleobiologists, as those who study the course of ancient life on the earth are called. All sorts of speculations have been made as to how long it has taken our present world to emerge from the past. Various so-called measuring sticks have been devised, but none of them have been wholly satisfactory. The discovery of radium with all that it has done to profoundly alter our understanding of the nature of matter and of energy, has among other things, given us a measuring stick to use in determining the length of geologic time, more accurate than any hitherto devised. This is the so-called lead-uranium ratio. It is known that a given amount of uranium eventually produces a given amount of uranium-lead in a given time. The amount of this lead present in rocks may, therefore, be used in determining the age of the rock. It takes one-half of any given piece of uranium about five billion years in round numbers to change into uranium-lead. Now five billion years, or longer, is just about the amount of time which biologists have believed must have been necessary for life to have progressed from its very simple beginning to its present complex state.

The first primitive animals were mainly, if not all, water-dwellers. For ages upon ages there was no animal life on the land except possibly a few soil amebae or other protozoa that had come to live in moist earth instead of in the water. There was very likely some verdure, for simple plants, such as algae, lichens, or simple bryophytes probably emerged to cover some of the earth's surface before it was occupied by animals to any extent. It must have been a strange and dreary landscape had there been eyes to see.

Animal life has always been more abundant along the shores of the ocean than in the great deeps. These littoral regions have always been very busy places, indeed, teeming with creatures great and small, all occupied in earning their livelihood. We think of clams, snails, shrimps, worms, crabs, and like creatures, but above all, fish as being abundant in such places. Picture an ocean without any fish! Yet the ocean for millions of years was fishless. Fish leave well-marked fossil remains, and such are completely lacking in the very early rocks. There were no back-boned animals. All animals, and there were thousands of different species, some of which have come down to us almost unchanged, were invertebrates. For ages it was so, and this time is known as the age of invertebrates.

One of the great mysteries of biology is the origin of back-boned animals, the vertebrates. Whence came they? Thus far we have made little progress toward answering this question. True it is that there are simple animals having many of the characteristics of vertebrates, but lacking the back-bone. However, the gap is still very great between a sea-squirt, for instance, and a clam worm. It is still greater between the clam worm and the simplest true fish. Be that as it may, the first animal to discover the back-bone made the most epoch-making discovery of them all, for this creature established a body-type which had in it all the latent possibilities of humanity. From that point the progress was slow, but sure, and, as various difficult problems were surmounted, certain, toward the establishment of a type of being who should eventually develop our modern civilization. The only other animal kind to come into serious competition with the ultimate progress of the vertebrates has been the insects, and we have to admit that this competition has been, and now is very serious.

Once established in the seas and in the fresh waters of the globe, the fishes showed that they were creatures of great ability. All manner of forms and shapes of these creatures appeared, adapted to all sorts of environment that could be found in the water. They even dared to venture out of the water! The first vertebrates to try life on land were just "fish out of water." They managed to crawl more or less effectively on limb-like fins, and they had learned to use their swim-bladders to breathe with. They had to have moisture, and do not seem to have given up their gills, but they were learning. After a long time they found the solution of the question, how to get out of the water and stay out, at least most of the time. They had managed to reduce the number of fin rays in their fins, and also the amount of webbing between them until they had toes, more or less free from web, just enough of that to swim with in some forms. For some reason they fixed upon the established number for toes as five, any departure from this number being in the nature of a variation from the primitive type. They had even dispensed with their gills for breathing in the water. However, they were not able to escape entirely from the water. They had to go into it to keep their skins moist, though some of the more advanced managed that by secretions from skin glands. More important still, it was absolutely necessary for them to lay their eggs in the water. This problem of the transition from water to land was solved by these simple amphibians, as you have guessed them to be, during the carboniferous time.

As that time drew to a close, as that vast duration of age upon age, so long that it was longer than all time subsequent to it, the Paleozoic, spent itself, there came a marked change in climate. The Carboniferous was, generally speaking, a time of relative humidity, of great swamps. Elevation of the land, possible shifts in the ocean currents, etc., changed everything and many of the amphibious vertebrates were faced with the choice of perishing or adapting themselves to the changed conditions. That they had real stamina is evidenced by the fact that they tackled this problem with all the patience that they had used in learning to live out of the water. There were two very troublesome aspects to their puzzle. They had a moist skin. A hot, dry climate would cause this to dry and shrivel. They got around this difficulty by covering themselves with scales. The next problem was that of their young. For ages they had been laying eggs richly supplied with food in form of yolk for their tiny children, but they had been laying these eggs in the water and their young had been spending their babyhood there. Now there was no water, or not enough to depend upon for this purpose. What could be done? They proceeded to surround their eggs with a shell. Within the shell was included not only enough food-yolk, but sufficient water, and as the young developed within the egg shells they grew membranes of different sorts which enveloped the yolk to absorb it, covered their bodies to protect them, all surrounded and cushioned by water, and still another membrane to lie closely applied to the inner surface of the somewhat porous shell and absorb the life-giving oxygen. By the time these babies had used up all the food in the egg they were sufficiently developed to shift for themselves, and bursting the shell, hatched out to face their world. Such creatures were the first reptiles. So successful were they that they spread over all the world, invading its every life zone, even the air, for there were flying reptiles.

The next great discovery which vertebrates made was that of the four-chambered heart, and the warm-blooded type of circulation. Just when this came about we do not know, for the skeletons of some of these denizens of the age of reptiles were so much like those of warm-blooded animals that we can not be sure that they did not have the four-chambered heart. Contrary to opinion, hearts do not fossilize! The warm-blooded type of animal advanced in two great directions. One remained very reptile-like in all characteristics save the circulation, changed its scales to feathers, and founded the great bird family. The other, made up of small, very retiring and modest, but withal persistent animals, learned still another way of caring for its young by carrying them through their early stages of development within the body of the mother, nourishing them during infancy by a peculiar secretion, milk, from glands of the skin, and substituted hair for scales as covering for their bodies. These were the mammals, and they too were destined to become great upon the face of the earth, and their most successful member, who rejoices in the sometimes unsuitable name, Homo sapiens, modern man, now rules them all.

Such, very briefly told, has been the story of the progress of animal life through geologic time down to the present, which is after all so like the past, that the general features of our landscapes have not changed for millions of years. What future progress shall be, we do not know, but we may feel sure that this marvelous progression will not stop. Problems will arise, but they will be solved, as they have been in the past until the end of the present phase of the solar system with its tiny earth shall have been reached. Ruth Phillips

## CREATING INTEREST IN BIOLOGY

BIOLOGY is the science of life—a study of living things—and only when it is presented as such will it become interesting and important in the sight of the child. And every successful teacher knows that his first problem is that of leading his pupil to become interested in the subject and to realize its worth. In order to do this the teacher must first convince himself of the fact that the subject is worth while, that it has direct values which can be linked up with the life of the child. Less than fifty years ago this would have been almost impossible because the acceptance of any biological subject as entrance credit to college dates back less than fifty years,[1] and the subject as first taught concerned itself with anatomy and classifications. Those taking the subject in its infancy concerned themselves chiefly with learning numerous structural and descriptive terms. Botany of the early period, especially, could almost be called a vocabulary subject. "When biology was introduced into the secondary schools, the sub-

[1]Finley—*Biology in Secondary Schools and the Training of Biology Teachers*, 1926.