SAM SINGER • HENRY R. HILGARD

The Biology of People

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Preface

In his clear and enthusiastic way, George Gaylord Simpson has recently proclaimed that biology and people are the two most interesting subjects in the world. We agree that the two are at least challenging and inviting subjects and have written this book in hopes of sharing with you what we think are the fundamentals—and some of the highlights—of the biology of people.

For whom is this book intended? Most of our readers will probably be college students enrolled in introductory, relatively nontechnical, courses in biology or human biology. But we warmly welcome the attention of general readers, too, and have therefore tried to make our discussion of the biology of the human species intelligible to anyone who has enough interest in the subject to pick up this book and browse through it.

Human beings are surely the most perplexing and intensively studied creatures that have yet evolved on earth. In fact, so much is already known about human biology that any general discussion of the subject runs the risk of being haphazard. In an effort to make this book both comprehensive and understandable to those who have little or no background in biology, we decided to divide our discussion into three main parts.

Part I is "The Human Species," in which we first establish the context for the rest of the book by discussing the theory of evolution and the concept of biological species and then turn our attention to the evolution, behavior, and ecology of the human species.

Part II is "The Human Machine." Here we first discuss the structure and function of cells and tissues, as well as how the activities of the myriad parts of the human organism are interconnected and coordinated. We then provide a system-by-system description of the structure and function of the human machine and an overview of the major bodily changes that take place in the course of a human lifetime.

Part III is "Human Genetics," a relatively nontechnical introduction to the principles of genetics in general, and of human genetics in particular. (This part of the text is also available as a separate paperback.)

It took four years to write and produce this book, and both authors would like to express thanks to some of the people whose comments and artistic talents were particularly helpful to us as the manuscript progressed. First, we would like to thank each other. Our collaboration was productive and gratifying in that our relative strengths and deficiencies happen to offset one another rather nicely. Thanks are also due to professors J. Z. Young, Kenneth S. Norris, Arthur J. Vander, C. Ladd Prosser, Cedric I. Davern, Robert S. Edgar, and Ursula W. Goodenough, whose critical comments surely helped to improve our rough drafts. Finally, we happily express our appreciation for the expert editorial guidance of Gunder Hefta, John Painter, and especially Linda Chaput; the finely wrought drawings of Eric Heiber and Associates; the sense of design of Jack Nye, who styled the pages; the vigilance of Ruth Allen, who helped with the permissions; and the careful efforts of Betsy Wootten, who typed many, and proofread all, of the chapters.

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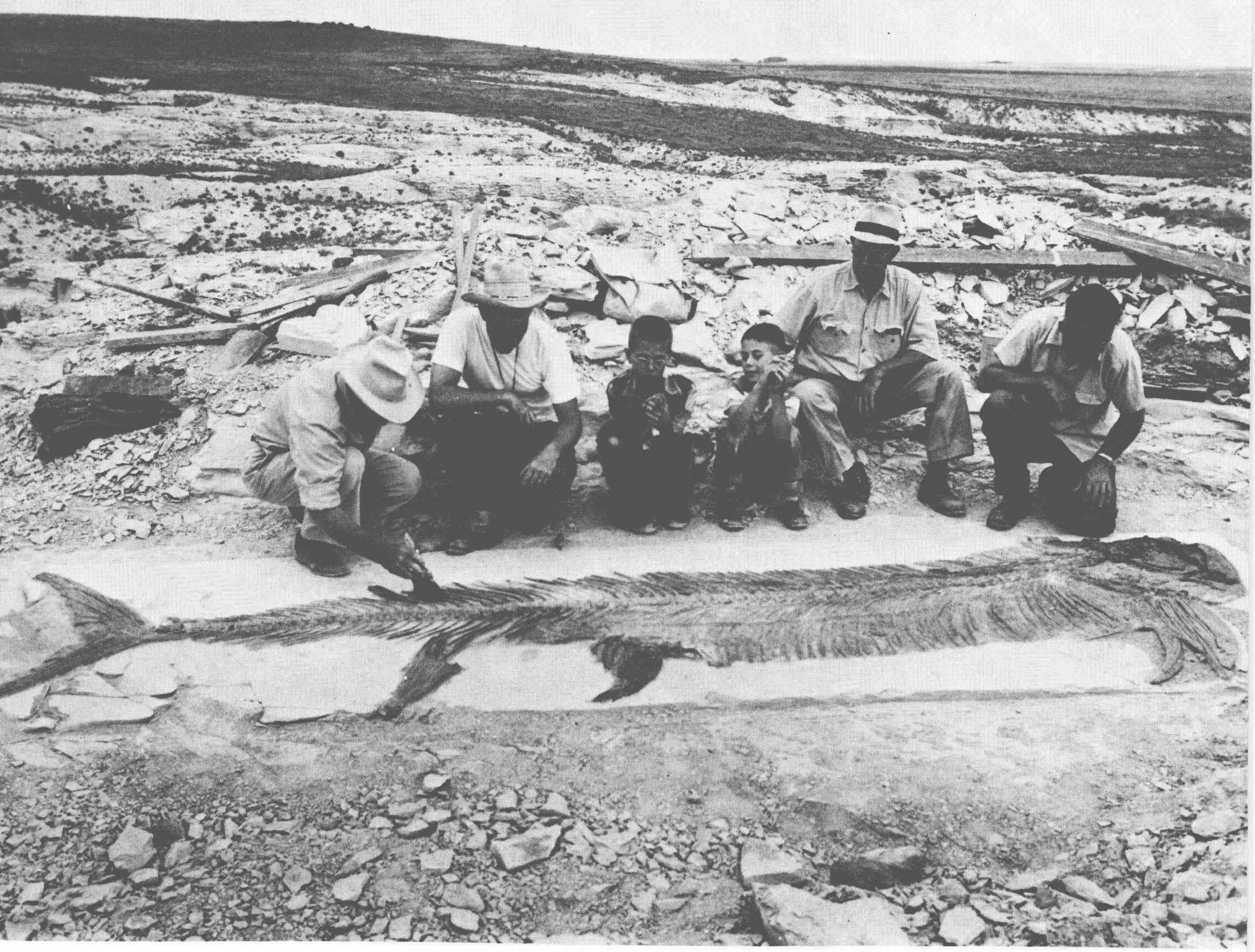
Contents

PART III
Human Genetics

PART
I

The Human Species



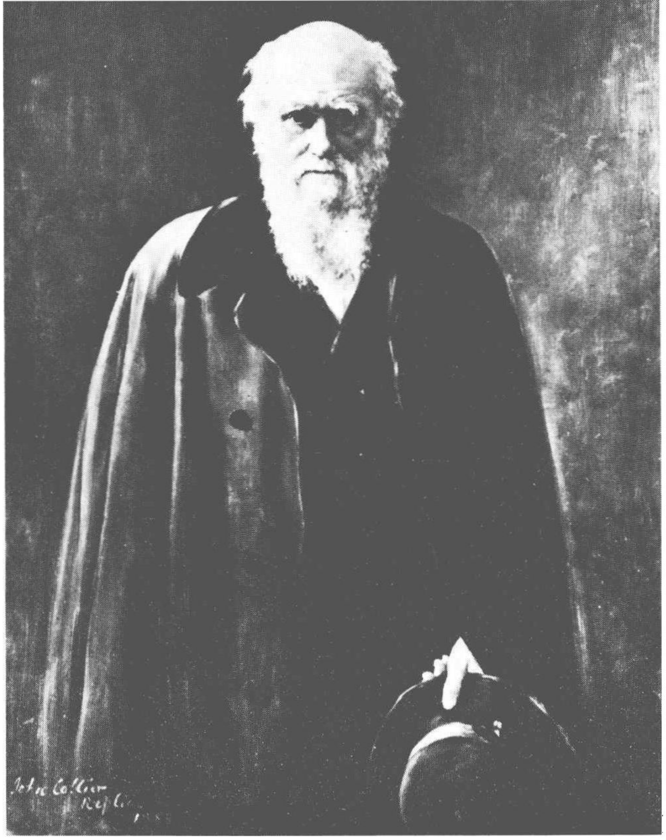
These people have just unearthed the fossil remains of a giant bony fish, Portheus. *About 70 million years before this photograph was taken, the creature was entombed by sediments in an ancient sea that then covered Western Kansas. (Courtesy of The American Museum of Natural History.)*

CHAPTER 1

Evolution, Species, and People

Our planet is home to an astounding array of living things. A leisurely walk through a green canopied forest, along a rocky ocean shore, or even across an abandoned lot or a well-manicured city park is all that it takes for any of us to encounter several kinds of familiar creatures. But no one person can ever experience the total diversity of life on earth, even in a lifetime of observing nature closely. This is because of the enormous diversity of living creatures; about one and a half *million* kinds have already been described and named by persons engaged in the science that studies living things—biology. Nonetheless, the task of describing the diversity of living things remains largely undone: biologists estimate that between 5 and 10 million kinds of creatures actually exist.

Environmental conditions on the surface of the earth are far from uniform. Yet living things are found virtually everywhere—in the sea, in the desert, on mountaintops, in tropical lowlands, and even in sunless caves deep within the earth. Wherever they may be found, all organisms are especially suited to life in the particular environment in which they normally live. In other words, there is a *good fit* between an organism and its particular surroundings. This common observation is an extremely important one. Living things cannot be understood in isolation from the environment in which they are normally found. Whatever else they may be, organisms are things that do something somewhere.



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Our modern understanding of how evolution works dates from 1859, at which time Charles Darwin (right) and Alfred R. Wallace (opposite page) published the same theory based on independent observations of plants and animals in different parts of the world. Darwin usually gets most of the credit. He had been working at documenting his theory for about twenty years before 1859. (Photo courtesy of The Bettmann Archive.)

Although it is easy to be impressed by the diversity and the environmental good fit of the creatures around us, it is not so easy to explain how the present situation may have come about. But it is worthwhile to try to find an explanation. After all, human beings are living things, and like other creatures, we are well suited to our environments. In trying to explain why living things are diverse and well fitted to the environment, we find ourselves addressing a question well known to all of us: "Where did I come from?"

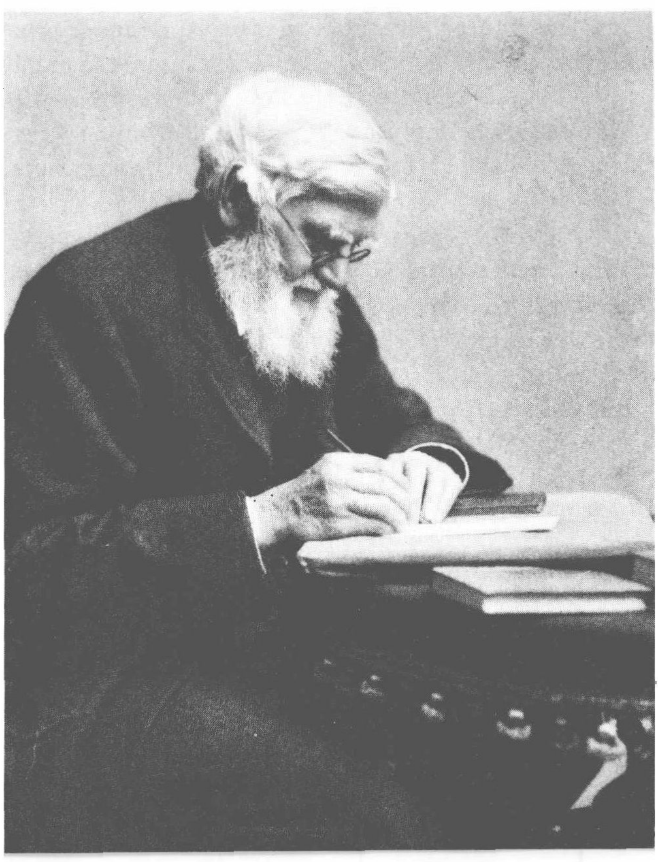
Biologists explain both the diversity and the goodness of fit by the theory of evolution. Indeed, evolution is at the core of all biological explanations of the natural world. The theory that underlies the evolutionary explanation, at least as it relates to the goodness of fit, was first proposed in 1859 by Charles Darwin and Alfred R. Wallace, independently (Figures 1-1 and 1-2). The theory was formulated to explain the appearance, distribution and activities of those organisms with which naturalists of about a century ago were most familiar—plants, and especially animals. But since that time, year by year and decade by decade, the evolutionary explanation has been successfully applied to newly discovered creatures whose existence was not even known of when the theory was first thought up. That is a sign of great strength for any scientific explanation.

But evolution is not the *only* explanation for the existence and order of the natural world. How one explains nature depends on what one sees there, and it is well known that not all people perceive the world in the same way. What people see in nature depends upon their world view, which is one aspect of a uniquely human activity called culture (see Chapter 3). In some nontechnological societies, people look at the natural world and see, not isolated creatures in different environments, but rather a continuum, a blending of living and nonliving things into a harmonious whole. It is not surprising that their explanations of how things got that way may differ from ours. The theory of evolution is a product of the world view held by twentieth-century science. It is a fitting explanation for the state of the natural world insofar as it makes sense to those of us who share the same world view.

The theory of evolution maintains that all living things evolve. There are no exceptions. This means that human beings have evolved and are evolving, a fact that has never been taken lightly. When the wife of the Bishop of Worcester first heard in 1860 of the idea that people evolved from some kind of nonhuman ancestors, she supposedly exclaimed to her husband, "My dear, let us hope it is not true, but if it is, let us pray that it will not become generally known!" But although it has, in spite of the wishes of the Bishop's wife, become generally known that people have evolved, it is not generally appreciated how clearly the theory of evolution explains characteristics observed in human populations and in individual persons. This book describes people primarily in evolutionary terms. In chapters to come, we will try to explain many human characteristics as the products of evolution. In so doing we will learn more about other living things and more about ourselves. But before we can apply evolutionary concepts specifically to people, we must first discuss the theory of evolution itself. That is the purpose of the present chapter. Let us begin our discussion of evolution at the beginning, with the origin of life on earth.

The Origin of Life on Earth

Living things have inhabited the earth for about 3.5 *billion* years. We are able to make this extraordinary statement with assurance because a record exists from which we can infer the time of the first appearance of living things and in which are found some of the remains of the organisms themselves. These remains are called *fossils,* and the record is in the form of sedimentary rocks. Sedimentary



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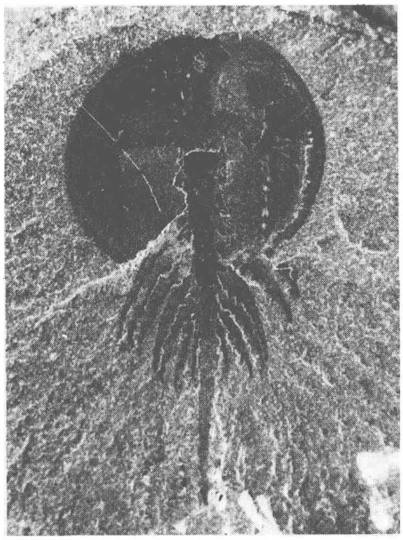
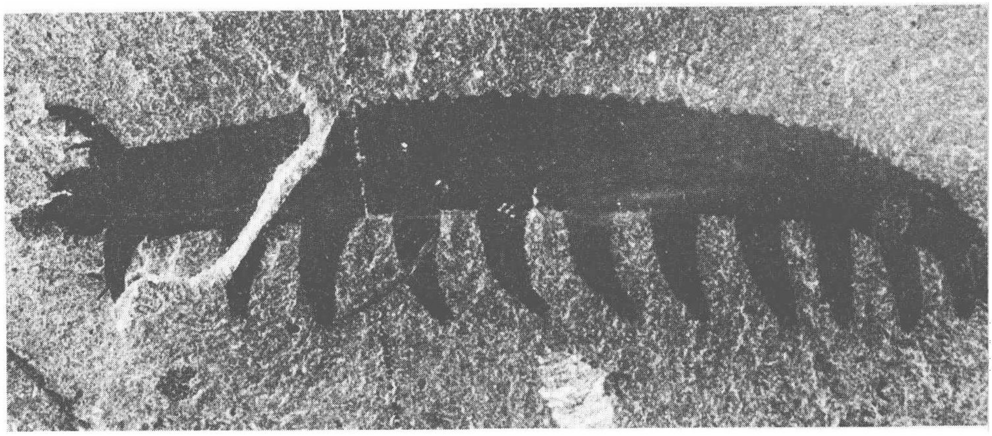
Alfred Russel Wallace (left) and Charles Darwin (opposite page) reached the same conclusions concerning evolution at about the same time in the mid-nineteenth century. The two men presented a paper before the Linnaean Society of London on July 1, 1858. (Photo courtesy of The Granger Collection, New York.)





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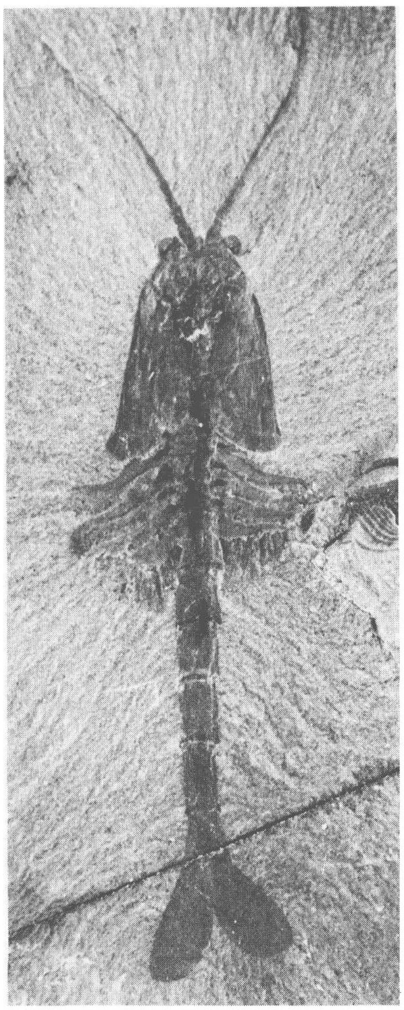
Fossils from the Burgess Shale in British Columbia. These animals were entrapped by sediments about 550 million years ago. All photos are slightly larger than the original creatures. (Courtesy of the Smithsonian Institution Press.)



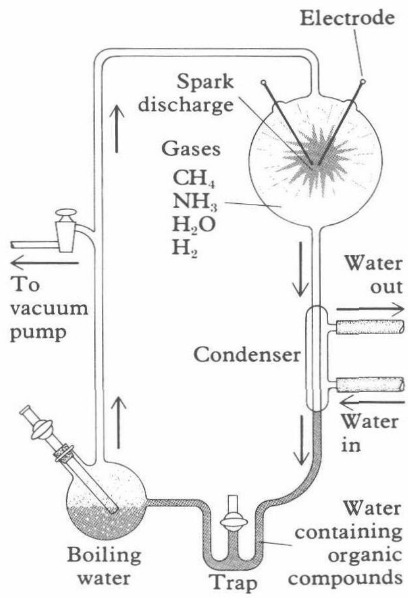
rocks are formed by the accumulation and consolidation of sediments over long periods of time, and some of these sediments provide direct evidence for the existence of ancient organisms (Figure 1-3).

When life began, the envelope of gases surrounding the earth—the atmosphere—had a composition very different from its present one. It contained mostly hydrogen, ammonia, carbon dioxide, and various other gases that are generally toxic to most modern organisms. These simple molecules were converted into more complicated ones by means of energy supplied from various sources such as ultraviolet rays from the sun and lightning during ancient storms. (Figure 1-4 illustrates an artificial means of achieving the same end.) This generation of complicated molecules from the simple compounds present in the atmosphere and oceans of the primitive earth is called *chemical evolution.* Well over 3.5 billion years ago, it resulted in the formation of a variety of chemical compounds that were dissolved in the ancient oceans, thus forming a soup of nonliving chemicals from which the first living things were born.

We can only guess how the transition from nonliving to living things occurred, and we have no way of knowing exactly what the first living things were like. But most biologists agree that the first living creatures showed at least the following characteristics which are common to all living things today: (1) they must have been composed of complicated molecules, (2) they must have been separated from the environment by some kind of selective barrier (a membrane of sorts), and (3) they must have reproduced themselves in nearly exact copies.

All living things consist of complicated molecules that are constantly being broken down and replaced by new ones. In order for this to happen, living things require a source of energy. The first organisms almost certainly found their source in energy stored in the chemical bonds of some of the compounds that surrounded them in the soup of the ancient oceans. Organisms that depend on obtaining preformed energy-rich compounds from somewhere in the environment are called *heterotrophs* (a word whose literal meaning is *other feeders).* We can well imagine that as living creatures reproduced themselves and became more numerous, they probably tended to use up these environmental compounds faster than the compounds were generated by chemical evolution. Unless living things were to remain few in number or perhaps to live only in widely scattered places, they could not continue to survive on such a limited source of energy. And, in fact, they did not have to for long because evolution occurred.

What happened was that some organisms acquired the capacity to manufacture their own energy-rich compounds from very simple substances that were readily available in the environment. Creatures that synthesize energy-rich compounds (mostly sugars) from simpler molecules obtained in the environment are called *autotrophs* (self-feeders). Today virtually all autotrophs engage in a chemical reaction called *photosynthesis.* In photosynthesis, light energy is used to convert molecules of carbon dioxide and water into molecules of sugar and oxygen. The sugar then serves as an energy source for the organism that manufactured it (see Chapter 4).



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In this apparatus, complicated chemical compounds can be generated from simpler gases by means of an electrical discharge. Lightning during ancient storms probably had a similar effect on the gases of the primitive atmosphere. (After Sidney W. Fox and Klaus Dose, Molecular Evolution and the Origin of Life. *Copyright © 1972, W. H. Freeman and Company.)*

We have no way of telling how long it took living things to develop the ability to carry out photosynthesis, but we do know that photosynthesizing organisms existed by about 3 billion years ago. We presume that they evolved from nonphotosynthesizing ancestors. This presumption is a reasonable one because among the most primitive kinds of organisms now living those that do not photosynthesize are generally less complicated biochemically than those that do. Thus, photosynthesis can be thought of as a biochemical process that some organisms added to and integrated with the basic chemical machinery of life that had already evolved earlier.

With the evolution of photosynthetic autotrophs, living things probably became more abundant, perhaps because they were able to colonize parts of the seas where heterotrophs could not find enough large preformed molecules to sustain them.

As unlikely as it may seem, we have a good idea of what some of these ancient photosynthesizing organisms were like. We find unmistakable evidence of their presence in rocks that are nearly 3 billion years old. Their remains are in the form of structures called *stromatolites,* which are shown in Figure 1-5. Stromatolites are produced when sediments accumulate on top of colonies of simple organisms called *blue-green algae.* We know this because stromatolites are still being formed this way today, and they are indistinguishable from those that appear in the fossil record. This raises an important question. Why is it that the process of evolution, which has resulted in the fantastic diversity of living things we see around us, has not appreciably changed the appearance of blue-green algae over the course of 3 billion years? Although the matter is far from settled, the answer is probably found in the fact that blue-green algae consist of basic units (called *cells*) that are very different from those which make up more familiar creatures.