Man and the changing environment

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Preface

Interest in environmental problems is intensifying, especially since Earth Week, 1971. Many dedicated specialists, such as economists, engineers, and scientists, are putting their expertise and energy in this direction foremost. More lay persons, also, are looking for ways to express their concern. In many communities recent developments involving environment, such as recycling centers or picketing local industries that heavily pollute, have been initiated by energetic lay people. This action has brought results, although too often for every sign of progress, new environmental problems are uncovered. Whether expert or lay person, anyone concerned with "doing something" about environmental problems soon realizes that solutions need hard work and dedication and the expertise of many specialists.

One specialist who is always consulted sooner or later is the biologist, specifically the ecologist. *Biology* is the study of life; *ecology* is the division of biology that includes the study of the environment and all organisms in it — plants, animals, and man. Hence the biologist–ecologist is aware of the principles by which life-forms have existed in their environments for millenia. He can provide insight into what must be done to set right once more the relationship between earth and man.

Until the last few years, when the interest of expert and lay person in man's environmental problems became intense, ecological principles remained the domain of the biologist. Now, with environmental crises threatening our resources, our life style, and perhaps our very lives or our children's lives, the basic laws by which plants and animals relate to their environment must be made public knowledge. No senator can responsibly decide a public issue or lay person responsibly vote without having been exposed to such basic biological information.

The widespread dissemination of basic biological ideas is difficult. Beside television, the most effective medium is probably the classroom. School boards and administrators throughout the country are sensing the opportunities for environmental education. Slowly, curriculum changes are being made. Higher education is rallying, too, and many are providing environmental biology courses for a general education audience in which some basic biological principles, together with a description of our environmental problems, are the subject. More courses of this kind, and more qualified teachers, are needed. Vital, too, is the development of more appropriate teaching materials. This book was written to help meet this need.

Man and the Changing Environment is basically a biology text. The broad overview of biology and environmental problems is constantly stressed; and, as often as possible, the relationship of biology and the environmental problems to man is emphasized. The book is not intended for advanced biology courses, such as ecology, but for students in introductory biology courses. Consequently, *Man and the Changing Environment* should be useful wherever an introductory biology course emphasizing environmental problems is taught, from university to community college.

The book begins with the description of biological evolution, introducing the student to the process that relates organisms and environment. It continues with a description of man as one of these organisms, eventually discussing man's difficulties in managing his existence in the environment. In an attempt to maintain continuity from chapter to chapter and not lose sight of the overview, some subjects have been omitted, and others treated generally. Only use of the text will make clear if the careful inclusion or omission of material has been appropriate.

Many people have contributed a great deal to this book. Some are research scientists whose work produced the material that has been recorded here. Others have been concerned writers who took the time to dig out and collate significant information. Information has been generously borrowed from all these people. Those who deserve special thanks are Dr. Clark Bowen, whose vision led to the creation of the biology program at Iowa State University, including the course "Environmental Biology"; Dr. Fred Smith, Chairman of the Department of Botany and Plant Pathology, who encouraged the writing of the book in many ways; Dr. Lawrence Mitchell, who read and commented on many of the chapters; Drs. Marilyn Bachmann and David Ehrenfeld, who read, criticized, and suggested many improvements in organization, emphasis, and wording; and the Iowa State University Library personnel, who secured many references.

Dr. Robert O. Richards, Department of Sociology and Anthropology, Iowa State University, deserves special thanks for his interest, enthusiasm, and criticism during the final stages of manuscript preparation.

Finally, we thank Lillian Johnson, who in addition to her full-time work still found time to help in innumerable ways. It is no overstatement to say that without her contribution this book could not have been written.

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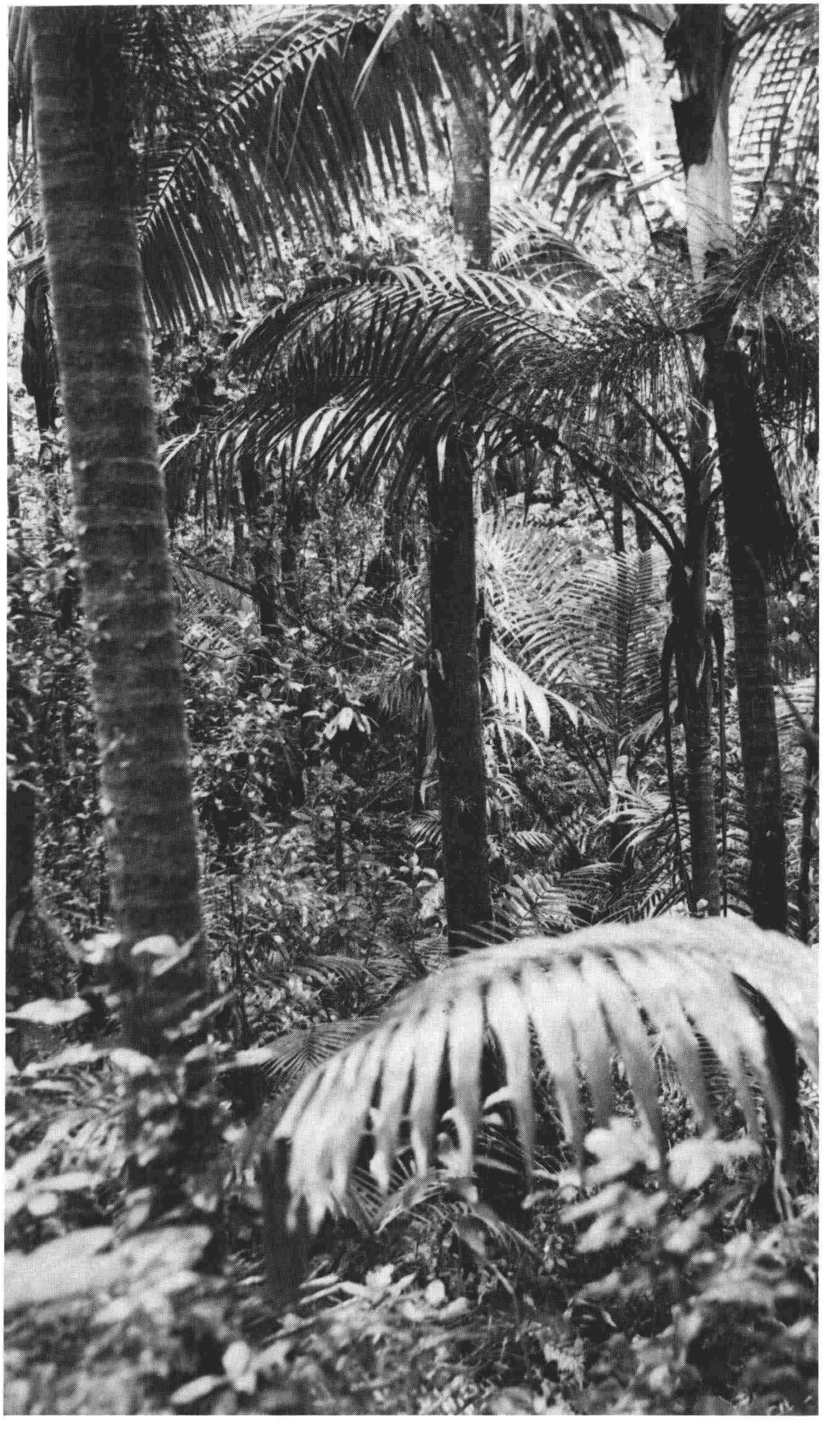

Chapter 1

But I am not equipped to philosophize and this book will not attempt it.

This only will it assert: a man's philosophy is likely to be truer and deeper if he has a knowledge of biology and organic evolution. Heaven knows we are artificial enough these days in our town-bred existence. A little feeling of oneness with the rest of life may even make us as intelligent and as sensitive as the men who, thrilled and awed and elevated at touching the skirts of creative understanding, painted the cave walls of Lascaux and Altamira two hundred long centuries ago.

The Story of Life
H. E. L. Mellersch

Evolution, organisms, and environment

Today man is living in a critical relationship with his environment. He is overrunning the world with too many people, overusing it by rapidly removing its resources, and abusing it through neglect and thoughtlessness. This book is concerned primarily with these crucial problems. Continued existence for man on earth — to say nothing of a better existence — depends on identifying our environmental problems, understanding their causes, and discovering ways to solve them.

Of these tasks, perhaps the easiest is the *identification* of environmental problems. You do not have to be an environmentalist to recognize smog in Los Angeles or the ravages of strip mining in Appalachia. Once identified, the *solution* of environmental problems is most challenging, because problem resolution requires an understanding of causes.

To understand the causes of ecological problems — where man "went off-base" — we shall first examine the type of relationship that man has had with his environment in the past. Man, always changing, evolving, has lived on the earth for millions of years. Why has he endured? What kind of relationship did he have which proved so life-sustaining? What biological principles help explain his past success? How significant would this information be in assuring man of a future? Of course, these questions are answered best by examining the clues left by ancient man. However, insight can also be gained by a close look at how other species relate to their environments. Thus, we shall look into the life-sustaining nature of the relationships that organisms maintain with their environments. In examining the adaptations of ancient man and of other organisms to their environment, you will soon appreciate a major biological truth: life is a product of its interaction with the environment through time. The identity of any plant or animal — from its survival in the past, to its appearance and activities today, to its potential for survival in the future — is intimately related to the environment.

The specific factor that binds organisms (including man) with their environments is revealed when their relationships are examined closely. That factor is change. Environments change and organisms change, and as a consequence the relationship between them also changes. In fact, the significance of change in the relationship leads to a second biological truth: the strongest bond between organisms and environment appears to be the influence that each has on the other for change.

So, the book is about the change in plants and animals (man in particular) as the organisms relate to their environments. In this sense it is a book about *biological evolution,* the change through time of living things and the relationships of the organisms with their surroundings.

At the same time the book is about *ecology.* Ecology is the study of how plants and animals interact in their environments. The origin of the word, from the Greek "study of the house" (*oikos,* house; *logus,* study), emphasizes the complex subject of ecology. Ecology is a study of how the occupants in their "house" *interact,* not just study of the house itself. This is a book about ecology in that we examine the complex interactions of plants and animals in the natural environment, especially those that involve man, which produce change.

We shall begin by examining examples of change in plants and ani-

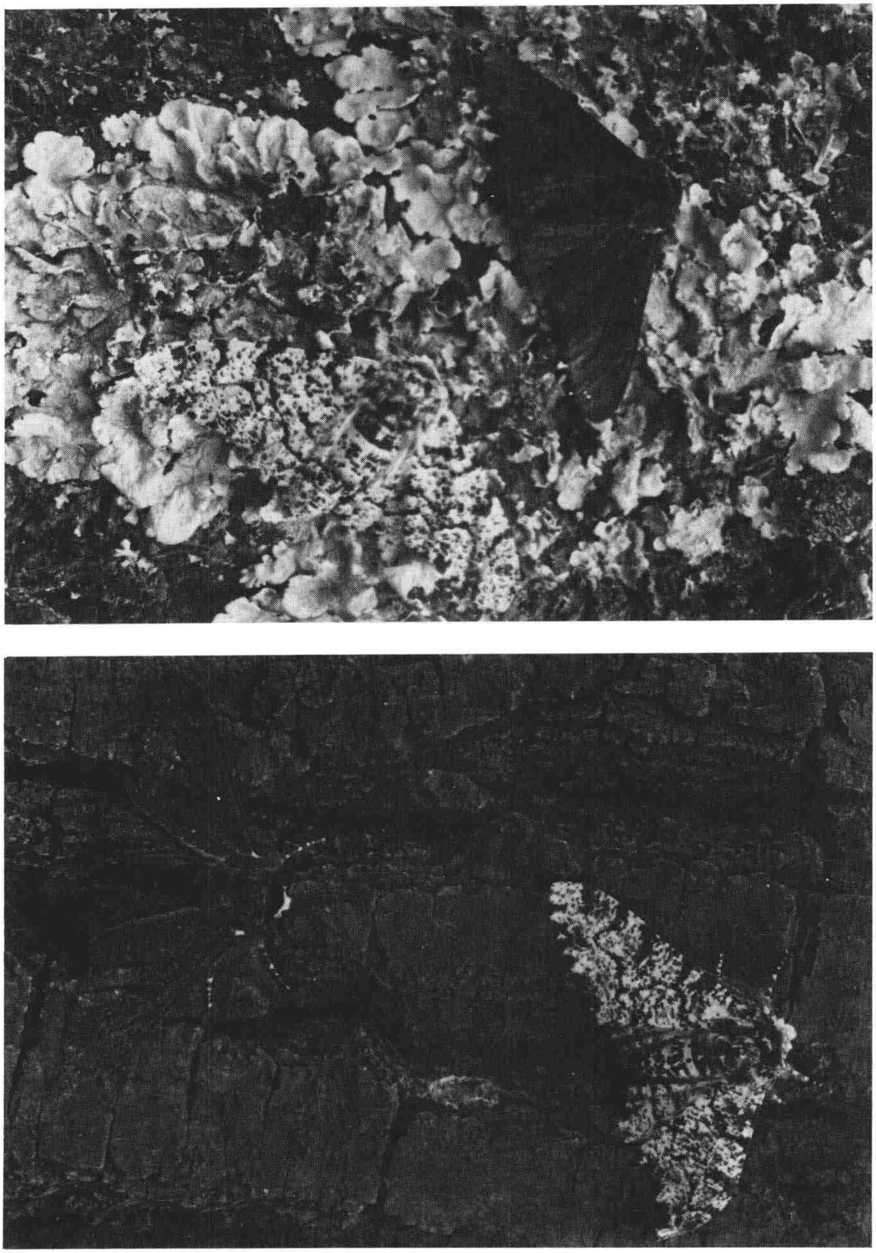

Figure 1–1
White and dark forms of the peppered moth *Biston betularia*. Top: At rest on a light background in an unpolluted countryside. Bottom: On a soot-covered tree trunk near Birmingham, England. (H. B. D. Kettlewell, Department of Zoology, Oxford, England.)

mals. We will note how the environment appears to influence these changes and then look at explanations for the changes. Finally, we shall examine the evidence that biologists accept as proof of change. Out of this should come better insight into man's nature, his current difficulties in relating to the environment, and his prospects for the future.

Changing organisms in changing environments

A few examples that can be found today will illustrate the changes that some organisms have undergone as a result of interaction with their changing environments. We shall look at the change in a species of moth (the peppered moth) over only a few decades of changing environment, the changes in species of pasture plants in grazed and ungrazed fields through only a few generations, and the result of changes in a plant species of yarrow in California which apparently developed over generations in response to the diverse environmental conditions at various altitudes. These simple illustrations hint at the awesome dynamics behind environmental change and organismic transformation.

Examples of changes in organisms

Extensive studies of the peppered moth (*Biston betularia*), especially in Great Britain, reveal a most interesting change in the color of the moth's populations over a few decades in areas surrounding industrial towns. Before the mid-1800s, most representatives of the species that were collected were light in color. When moths rested on the trunks of lichen-covered trees, they were often difficult to see (Fig. 1–1, top). Then in 1948 collections of this insect made near Manchester, a thriving industrial town, differed greatly from previous collections. It was a dark melanic form (Fig. 1–1, bottom). In the following decades throughout England, notably near industrial areas, increasing numbers of the dark form were found. Today, in some areas *only* this form occurs, the light variety seemingly having been replaced.

The change of color in the peppered moth over a few decades illustrates change in a species over a very short time. Other examples can be cited, such as the changes in pasture plants that grow in heavily grazed areas. A mixture of grass and *Trifolium* clover seed was planted in a pasture in Maryland. After sowing, a fence was built down the center of the field. During the next 3 years the pasture on one side of the fence was cut several times for hay; the other side was heavily grazed. Then an investigator dug up plants from each side of the fence and planted them in his experimental plot. Most of the plants from the grazed pasture remained short; most of the plants from the other side of the fence grew tall. Seed was collected from many of the plants and sowed. In general, plants derived from the collected seed were found to exhibit the same height characteristic as the parent plants. In other words, the plants and their descendants from the grazed side of the fence appeared to be permanently changed.

Yarrow plants of the genus *Achillea* illustrate changes in a species over many generations. *Achillea* are very widespread in the Northern Hemisphere. Among the many structural variations seen within the several species is height. Generally, this characteristic appears to be correlated with the altitude at which the yarrow grows: the greater the altitude, the shorter the plant. Figure 1–2 illustrates the mean heights of plants collected at various altitudes across California.

Biologists experimented with the plants collected at these altitudes. Clonal plants — plants made from cuttings from an original plant — were grown from tall specimens originally collected at the coast (Fig. 1–3). These clonal plants were planted at three different altitudes: at sea level, at about 5,000 feet above sea level, and at about 10,000 feet. Clones of the coastal plants when planted at the midelevation produced shorter plants than at sea level. When planted at the highest elevation all clones but one died.

A similar experiment was done with clones of plants collected at the midelevation. These plants when collected were generally shorter than those found at sea level. However, when they were planted at sea level, the plants grew larger than at 5,000 feet. At 10,000 feet, some of the plants died; those that did grow were shorter than the same plants grown at the 5,000-foot level.

These observations suggested that yarrow plants had developed a survival ability that was, in some way, correlated with their particular heights and respective environments in which they were annually collected. Presumably, this adaptation to environment took a long time to come about, because clones transplanted to atypical altitudes showed only a limited tendency (if any at all) to adapt quickly, and sometimes they even died. What can explain this tendency of some plants to adapt to new environments and others to die? For that matter, what can explain the natural occurrence of tall plants at sea level, short plants at high elevations, and intermediate plants at moderate elevations?

How organisms change

Some generalizations about the changes observed in plants and animals in nature are illustrated in the changes described in the three organisms cited above:

1. Changes in organisms appear to accompany changes in the environment.
2. The relationship between a plant or animal species and its environment is not static but appears to be dynamic, in that any change in one may induce change in the other.
3. Organisms appear to better their survival chances because of an innate tendency to change over generations.
4. Man, directly or indirectly, can strongly influence the changes.
5. If the changes in the environment are too severe, individual organisms may die.

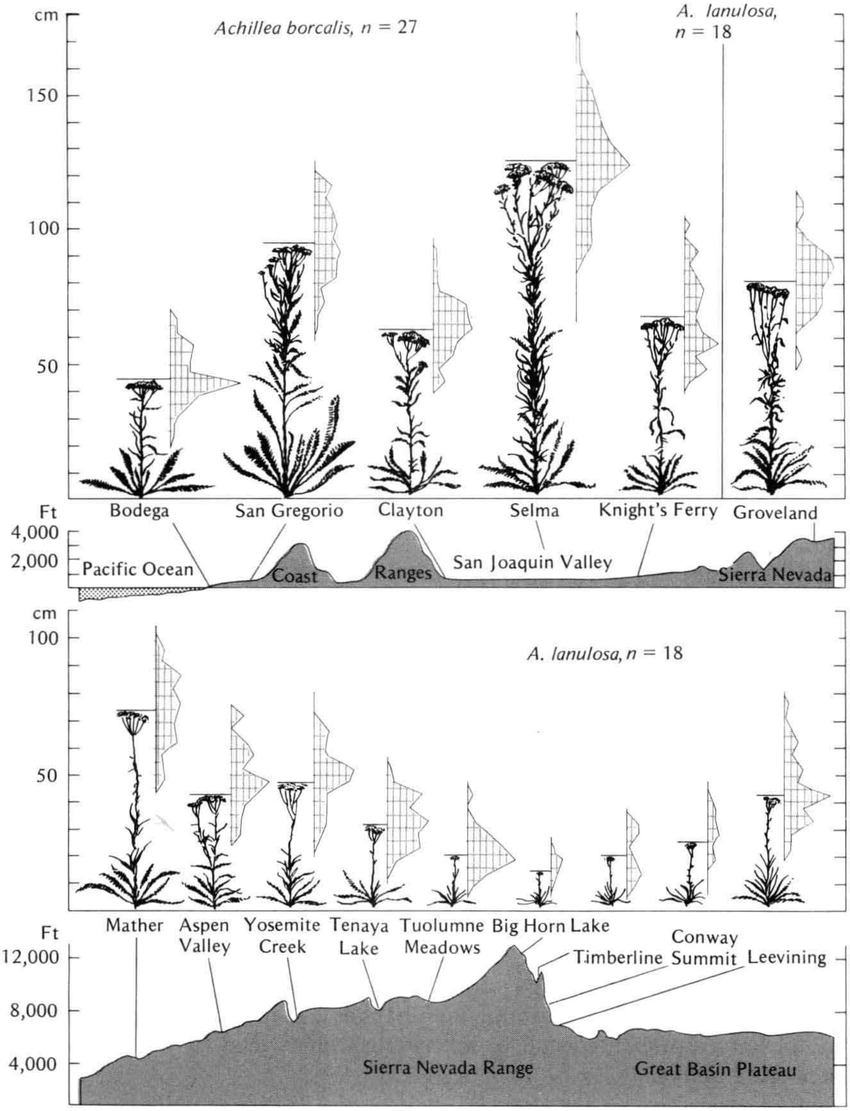

Figure 1–2

Variation in yarrow (genus *Achillea*). Top: Ranges of variation in height in collections of yarrow plants from sea level to the Sierra Nevada Mountains in California (arrows point to average heights). Bottom: Approximate sites of collection within a 200-mile range across California at latitude 38°N. (From Clausen, Keck, and Heisey, Publication 581, Carnegie Institution of Washington, Washington, D.C.)

The changes in the moth and the pasture plants as a result of the influence of environment is clear, mainly because the changes occurred in the obvious characteristics of color and height over only a few generations.

The change in the yarrow is not so clearly recognized from the observations cited, although the suggestion is implicit that the slight variations seen in members of the population when transplanted to foreign environments may be the cause of the unique heights of the populations found growing naturally at different elevations. In brief, the yarrow plants, the peppered moth, and the pasture plants are all illustrations of change in species over time within changing environments.

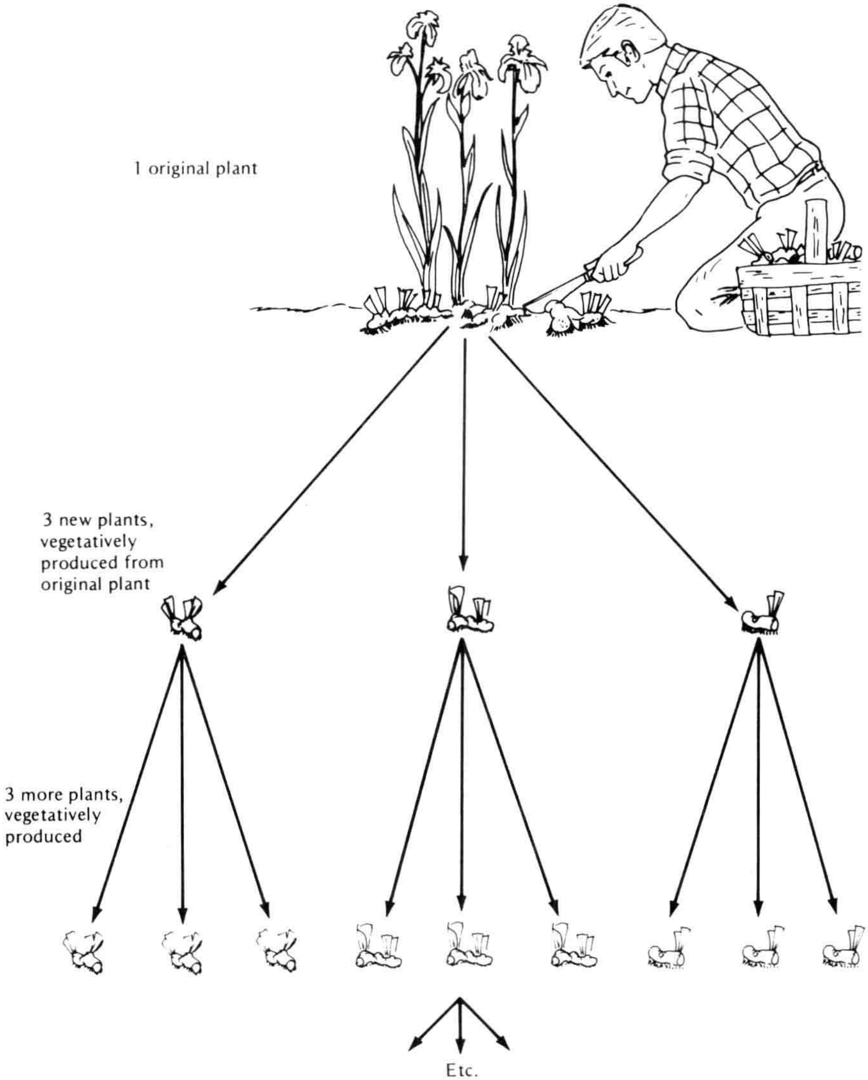

Figure 1–3
How "clones" are produced.

The important question for us to ask now is: How can these aspects of change in populations through time be explained? However, before that question can be answered, more must be said to specify the type of change that we are discussing. Two types of change occur in plants and animals: (1) the change to an individual in its lifetime, and (2) the change to a group of similar interbreeding individuals, a *population*. The first is often easy to explain. Inadequate fertilizer will produce a field of deformed plants; a poor diet may produce a bowlegged baby. Often adverse changes in individual organisms can be corrected by improving their environment. Furthermore, changes in individuals have significance only while a particular organism is alive, because the alterations to the body of the organism are not genetic and cannot be transferred to offspring.

The evolution of a population is less readily explained. Changing the environment during the lives of the members of the population of a particular species will not suddenly transform the individual organisms into a different kind of organism that warrants a new name. Such change is apparently subtle, always requires many generations, is a genetic phenomenon, and often results in a new *species* of organisms. It is the process known as *biological evolution*. This population change, a result of biological evolution, is the type of change in organisms that will be discussed in the remainder of the chapter.

The synthetic theory of evolution

How can such aspects of change in populations be explained? To answer this question we shall examine an explanation for the origin of new kinds of organisms, or *species*, resulting from populational changes. This explanation is known as the *synthetic theory of evolution*. An understanding of the theory explains changes in populations through time. The theory also illustrates the intimacy and balance of the relationship between all organisms and their environments and should make clear why disruption of either a population of organisms or their environments profoundly affects the other — often with serious consequences, and even death to the organisms involved. For man, an understanding of the synthetic theory of evolution can lead to a clearer understanding of how *Homo sapiens* evolved to his present position in the hierarchy of life and what can happen to him as a species if his present environment is disrupted carelessly.

The synthetic theory of evolution is a broad explanation for the origin of diverse types of organisms on earth throughout time. The theory is constantly being updated as new information regarding genetics and heredity becomes known. The basis for the theory is not recent. In fact, Charles Darwin, a British naturalist, first published the basis of the theory in 1859 in his famous book *The Origin of Species* (Fig. 1–4). In his book Darwin stated the following ideas:

1. *Organisms tend to overproduce.* Plants and animals always produce an abundance of offspring. For example, Darwin once calculated that 19 million elephants could theoretically descend from *one* pair

of elephants in 750 years if each generation of offspring survived to reproduce.
2. *Of the many offspring born, only a few survive.* Darwin pointed out that the number of creatures in the wild normally stay about the same. He concluded that this is so because only a few of them survive after birth. Such a mathematically possible profusion of elephants is, therefore, highly unlikely. Darwin observed that those offspring most likely to die are those least able to survive in their en-

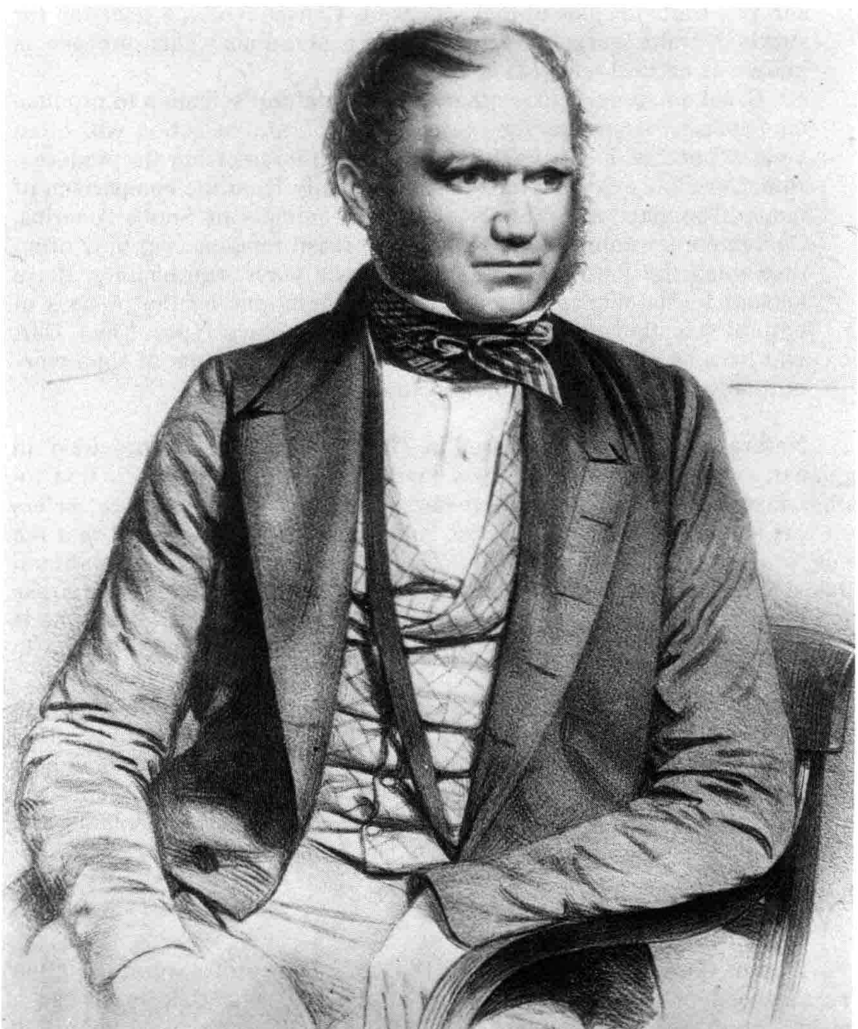

Figure 1–4
Charles Darwin, 1809–1882. (Radio Times Hulton Picture Library.)

vironment. Their deaths are a result of the intense competition among the offspring for basic needs, such as food and space. Darwin called such competition a *struggle for existence*. The victory of the best-adapted he called *the survival of the fittest*.

3. *Individuals within a population show variation*. Darwin pointed out that some members of a population survive and others die because individuals in that population vary. Such variation appears to be *innate* in the individuals, that is, a characteristic they are born with. The plants or animals that survive and reproduce often pass the survival traits to some of their offspring. Consequently, a selection for survival traits goes on through the generations. This process is known as *natural selection*.

4. *Great amounts of time are needed for natural selection to produce new species*. If enough time is available, natural selection will often yield a population of organisms greatly different from its predecessors. Darwin's evidence for this came mainly from the comparison of modern animals with fossils of extinct animals in South America. Contemporary animals were unlike the fossil remains; yet they often resembled the fossil forms in many basic ways. Presumably, those ancient forms changed through many generations by the process of natural selection to give rise to the contemporary types. Thus, Darwin became increasingly convinced that great amounts of time were normally necessary for evolution to occur.

Natural selection as expressed in *The Origin of Species* provided an explanation for the creation of new kinds of living things which tied together many observations. Nevertheless, Darwin's idea of natural selection was severely attacked by critics, mainly because it suggested that the same process also produced man. This suggestion challenged a literal Biblical interpretation of man's creation because it meant that man arose from a nonhuman form. If man is closely akin to other forms of life, he is not unique. Historically this has been a difficult idea for many people to accept.

As the decades passed, new observations in biology were added to Darwin's original ideas as expressed in his book. The new and old ideas eventually formed the synthetic theory, which today provides a convincing explanation for the origin of new kinds of organisms and explains the origin of the complex intimacy and interdependence between plants and animals and their environments that we see today.

Gene theory

One of the new ideas added to Darwin's theory of natural selection was the concept of *gene*, an element of the sex cells that serves as a transmitter of heredity characteristics. Darwin could not explain the origin of variation among individuals in a population; the gene concept could. Gene theory accounted for the origin of characteristics of an organism and their transmission to offspring. From it developed several new biological ideas which helped explain how organisms and environment interact through time to produce new species. These ideas included *mutationism* and *gene recombination*, the significance to species change of the *isolation* and the *migration* of population fragments, and the *size* of a population.

In the early 1900s the gene, carrier of characteristics that unfold as a plant or animal develops, was found to undergo relatively permanent changes, *mutations*, arising from causes other than those of normal gene recombination. This discovery was very important to evolutionists, because a changed or mutated gene may produce a new characteristic in some offspring. It appeared to evolutionists as if a source had been found of individual variation essential as raw material to Darwin's natural selection.

An additional factor found to influence species formation was *genetic recombination*. Genetic recombination is the assorting of the genes (1) in the production of each egg and sperm, and (2) upon fusion of the eggs and sperms, the *gametes*, in fertilization. Recombination, together with mutation, produces the differences in individuals in a population. In turn, it is the differences that are "worked on" by natural selection to produce populations of different characteristics.

With regard to the interaction of organisms and environment, three major conditions prevail that influence the fate of gene changes resulting from mutation and genetic recombination and in turn allow natural selection to operate. One influence is the *migration* into the population of individuals from nearby different populations of the same species. The individual organisms that mix into the original population introduce forms or combinations of genes not occurring there or add to the percentage of genes already in the population. Migration of members out of a population also may change the number of genes making up a population.

Another influence is *population size* in a given environment. In a large population any effect of a change in the percentages of genes due to mutation or migration, for example, is obscured by the large percentage of unchanged genes. However, in a small population, any new gene may represent a great proportional change within the total number of genes. Thus, the effects of the gene change will be more readily observed in the smaller population. This rapid change in the percentages of genes in a small population, which in time may affect the appearance of a population, is known as *genetic drift*.

A third influence on the evolution of new species is the *isolation* of breeding segments of the population. When this occurs, the forces of natural selection operate within each isolated population segment and may eventually transform, or *evolve*, the separated populations into increasingly unique groups. This is because isolation prevents any mixing of the genes between isolated sectors of the total population. Eventually, natural selection may differentiate the isolated populations so much that individuals of one can no longer reproduce with individuals of the other. At that point, two new species have evolved where originally there was one.

A classic example of the development of two species from (presumably) one is that of squirrels living on the rim of the Grand Canyon. Both species have almost identical characteristics, except that those on the northern rim of the canyon are white-tailed and black-bellied, whereas those on the southern rim have gray tails and white undersides. Between