9-12

Modern ideas about evolution provide a scientific explanation for the history of life on earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. 5F/7 BE

Evolution builds on what already exists, so the more variety there is, the more there can be in the future. But evolution does not necessitate long term progress in some set direction. Evolutionary change appears to be like the growth of a bush: Some branches survive from the beginning with little or no change, many die out altogether, and others branch repeatedly, sometimes giving rise to more complex organisms. 5F/9 BE

Chance alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism. …5F/6…

from CORRELATION

The continuing operation of natural selection on new characteristics and in changing environments, over and over again for millions of years, has produced a succession of diverse new species. (*SFAA*, p. 69)

The basic idea of biological evolution is that the earth's present-day species developed from earlier, distinctly different species. 5F/1 BE

When an environment, including other organisms that inhabit it, changes the survival value of inherited characteristics may change. …5F/6

from CHANGES IN THE EARTH'S SURFACE

Natural selection leads to organisms well suited for survival in particular environments. 5F/6…

Offspring of advantaged individuals, in turn, are more likely than others to survive and reproduce in that environment. The proportion of individuals that have advantageous characteristics will increase. …5F/3

Heritable characteristics… influence how likely an organism is to survive and reproduce. …5F/4

New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. 5F/5…

from DESCRIBING CHANGE

Small differences between parents and offspring can accumulate (through selective breeding) in successive generations so that descendants are very different from their ancestors. 5F/1

6-8

Individual organisms with certain traits are more likely than others to survive and have offspring. 5F/2…

Changes in environmental conditions can affect the survival of individual organisms and entire species. …5F/2

to and from CHANGES IN THE EARTH'S SURFACE

In all environments… organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. In any particular environment, the growth and survival of organisms depend on physical conditions. …5D/1

to and from DNA AND INHERITED CHARACTERISTICS

to and from VARIATION IN INHERITED CHARACTERISTICS

People control some characteristics of plants and animals they raise by selective breeding. 8A/2…

3-5

Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. 5D/4

Some likenesses between children and parents are inherited. Other likenesses are learned. 5B/1

to and from AGRICULTURAL TECHNOLOGY

For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all. 5D/1

Individuals of the same kind differ in their characteristics, and sometimes the differences give individuals an advantage in surviving and reproducing. 5F/1

Some plant varieties and animal breeds have more desirable characteristics than others, but some may be more difficult or costly to grow. 8A/1…

K-2

There is variation among individuals of one kind within a population. 5B/1

Offspring are very much, but not exactly, like their parents and like one another. 5B/2

to VARIATION IN INHERITED CHARACTERISTICS

to DNA AND INHERITED CHARACTERISTICS

Different plants and animals have external features that help them thrive in different kinds of places. 5F/1

Living things are found almost everywhere in the world. There are somewhat different kinds in different places. 5D/2

Some animals and plants are alike in the way they look and the things they do, and others are very different from one another. 5A/1

All kinds of living things have offspring. 6B/1…

changing environments *variation and advantage* *inherited characteristics* *artificial selection*

Evolution of Life:

NATURAL SELECTION

CLUSTER: **Evolution of Life**

MAPS: **BIOLOGICAL EVOLUTION** BE
NATURAL SELECTION NS

Natural selection explains how the diversity of species we see today and in the fossil records could all descend from common ancestors. The idea of natural selection requires a fairly complex sense of both similarities and differences evident in diverse organisms and the advantages or disadvantages of those differences (relative to particular environments).

Students' growth of understanding about the mechanism of natural selection relies on benchmarks about artificial selection (breeding), inherited characteristics, variation and advantage, and changes in the environment. A subtlety in this story is that other organisms, too, are part of the environment. So organisms adapt in part to one another—all of life evolves together. Consequently, the interdependence of life, a topic that will be mapped in the next edition of *Atlas*, relates closely to this map.

Ideas about natural selection are also intimately related to the explanatory and predictive role of scientific theories. Further, the **Explaining the Diversity of Life** section in *Science for All Americans* and *Benchmarks* Chapter 10: HISTORICAL PERSPECTIVES could be used to elaborate on the benchmarks in this map.

NOTES

Three essential benchmarks in K-2 deal with differences and similarities within families and within kinds of organisms. They are difficult to grasp because they appear paradoxical: siblings are like one another, but they are also different. To pull this apparent paradox together, students have to realize that every organism is different from every other—but they are less different from their close relatives.

The *inherited characteristics* strand omits several 6-8 benchmarks about heredity that appear in the **DNA AND INHERITED CHARACTERISTICS** and **VARIATION IN INHERITED CHARACTERISTICS** maps because they are not specifically relevant to natural selection.

The *artificial selection* strand makes the point that some characteristics of plants and animals can be changed significantly over a few generations through selective breeding. Nearly all of this strand is repeated in the **AGRICULTURAL TECHNOLOGY** map (in Chapter 8), where it is related to agriculture in general and to 9-12 benchmarks about genetic manipulation.

The 9-12 benchmark "The continuing operation…" shows a connection from the **CHANGES IN THE EARTH'S SURFACE** map (in Chapter 4), providing evidence through the extreme age of the earth for the enormous time available for natural selection to act. The theme of scale from *Benchmarks* Chapter 11: COMMON THEMES is particularly relevant here.

RESEARCH IN *BENCHMARKS*

High-school and college students, even after some years of biology instruction, have difficulties understanding the notion of natural selection (Brumby, 1979; Bishop & Anderson, 1990). A major hindrance to understanding natural selection appears to be students' inability to integrate two distinct processes in evolution, the occurrence of new traits in a population and their effect on long-term survival (Bishop & Anderson, 1990). Many students believe that environmental conditions are responsible for changes in traits, or that organisms develop new traits because they need them to survive, or that they over-use or under-use certain bodily organs or abilities (Bishop & Anderson, 1990). By contrast, students have little understanding that chance alone produces new heritable characteristics by forming new combinations of existing genes or by mutations of genes (Brumby, 1979; Clough & Wood-Robinson, 1985b; Hallden, 1988). Some students believe that a mutation modifies an individual's own form during its life rather than only its germ cells and offspring (see almost any science-fiction movie). Students also have difficulties understanding that changing a population results from the survival of a few individuals that preferentially reproduce, not from the gradual change of all individuals in the population. Explanations about "insects or germs becoming more resistant" rather than "more insects or germs becoming resistant" may reinforce these misunderstandings (Brumby, 1979). Specially designed instruction can improve students' understanding of natural selection (Bishop & Anderson, 1990).

Middle-school and high-school students may have difficulties with the various uses of the word "adaptation" (Clough & Robinson, 1985; Lucas, 1971; Brumby, 1979). In everyday usage, individuals adapt deliberately. But in the theory of natural selection, populations change or "adapt" over generations, inadvertently. Students of all ages often believe that adaptations result from some overall purpose or design, or they describe adaptation as a conscious process to fulfill some need or want. Elementary- and middle-school students also tend to confuse non-inherited adaptations acquired during an individual's lifetime with adaptive features that are inherited in a population (Kargbo et al., 1980).