MemoryJogger

Recall that at the beginning of meiotic cell division, the chromosomes line up and can exchange parts. What ends up in each gamete is the result of chance, just as any hand of cards dealt to you after shuffling is the result of chance. As a result of this shuffling, the gametes (sperm and egg) each contain a unique combination of genetic information. Since any sperm may combine with an egg, the number of possible combinations becomes enormous.

Sources of Variation

As you may recall, the arrangement of an individual's DNA bases determines all the inherited characteristics of that individual. Any change in bases or their sequence may bring about a change in the individual. But not all of those changes can be passed on to the individual's offspring. In sexually reproducing organisms, only changes in the genes of sex cells can be passed on to the next generation and become the basis for evolutionary change. Other types of variation (such as changes to body cells) die with the individual. For example, a father who has built huge muscles due to exercise does NOT pass those large muscles to his offspring.

There are two major ways an organism can wind up with genes that differ from those of its parents. Some genetic variations arise because of mutations in the genes of an organism. Others are due to "genetic shuffling," the routine sorting and recombination of genes that occurs during sexual reproduction.

Mutation A **mutation** is a change in the base sequence of a DNA molecule. Mutations occur as random, chance events that cannot be predicted. Some mutations occur as errors in DNA as cells function. Radiation and some chemicals can also cause them. Mutations are an important source of totally new forms of genes.

When mutations occur in body cells, they affect only that individual. However, a mutation in a single-celled organism or in the sex cells of a multicellular organism can be passed on to the offspring. In organisms that reproduce sexually, only mutations in the genes of sex cells can become the basis for evolutionary change.

Nearly all mutations are harmful and may affect the offspring so severely that it cannot survive. A few mutations benefit the individual, however, and can increase its chance of surviving, reproducing, and passing the mutation to the next generation. A beneficial mutation may lead to the evolution of a new species. For example, the ancestors of polar bears probably had dark fur. If a mutation resulted in a bear with white fur, that bear probably would have died young. However, if the mutation occurred in a snowy environment, the white fur would be a useful mutation, allowing the bear to stalk its prey more effectively.

Genetic Shuffling The sorting and random recombining of genes during meiosis and fertilization results in new and different combinations of genes. These genes can be passed on to individual offspring. The process is similar to shuffling and dealing cards. The deck stays the same, but nearly every hand will be slightly different because of mixing and rearranging during shuffling. At fertilization, even more variety is introduced because now cards from "two decks" are combined. Although mutations provide new genetic instructions, genetic shuffling is the main source of the variation that exists among the members of any sexually reproducing species.

Review Questions

15. Which statement is basic to the theory of evolution by natural selection?

(1) In general, living organisms maintain a constant population from generation to generation.
(2) Changes in living organisms are almost completely the result of mutations.
(3) Natural variations are inherited.
(4) There is little competition between species.

16. Which statement is *not* included as part of our modern understanding of evolution?

(1) Sexual reproduction and mutations provide variation among offspring.
(2) Traits are transmitted by genes and chromosomes.
(3) More offspring are produced than can possibly survive.
(4) New organs are formed when organisms need them.

17. The modern theory of evolution states that a basis for variation within a species is provided by

(1) mutations
(2) asexual reproduction
(3) cloning
(4) overproduction

18. Sexual reproduction is related to evolution because sexual reproduction

(1) occurs only in more recently evolved forms of animal life
(2) increases the chances of extinction of different species
(3) increases the chances for variations to occur
(4) is the more usual kind of reproduction

19. Mutations can be transmitted to the next generation if they are present in

(1) hormones
(2) gametes
(3) body cells
(4) muscle cells

20. A new chemical was discovered and introduced into a culture containing one species of bacteria. Within a day, most of the bacteria were dead, but a few remained alive. Which statement best explains why some of the bacteria survived?

(1) They had a genetic variation that gave them resistance to the chemical.
(2) They were exposed to the chemical long enough to develop a resistance to it.
(3) They mutated and became a different species after exposure to the chemical.
(4) They absorbed the chemical and broke it down in their digestive systems.

21. Which characteristics of a population would most likely indicate the lowest potential for evolutionary change in that population?

(1) sexual reproduction and few mutations
(2) sexual reproduction and many mutations
(3) asexual reproduction and few mutations
(4) asexual reproduction and many mutations

22. Which two factors provide the genetic basis for variation within many species?

(1) asexual reproduction and meiosis
(2) mutations and sexual reproduction
(3) competition and the synthesis of proteins
(4) ecological succession and mitosis

23. Which statement best describes a current understanding of natural selection?

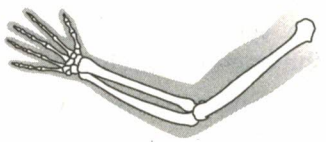
(1) Natural selection influences the frequency of an adaptation in a population.
(2) Natural selection has been discarded as an important concept in evolution.
(3) Changes in gene frequencies due to natural selection have little effect on the evolution of species.
(4) New mutations of genetic material are due to natural selection.

The Results of Genetic Variation

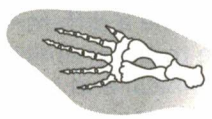
The changes that result from mutation or genetic shuffling in the sex cells may affect the offspring in several ways. Most of the changes can be categorized as structural, functional, or behavioral.

Structural Change The structure of any organism is the result of its species' entire evolutionary history. There are millions of examples of variations that have resulted in structural changes. For example, the polar bear (like other bears) has thick fur that keeps it warm in its cold environment.

Bird wing



Human arm



Whale flipper

Bat wing

Figure 5-6. Similar bone structure of different species: The limbs shown above are from different species and have different functions, but they share many structural similarities. They are all made of the same type of bones and are attached in a similar way. The whale flipper is actually much larger than the other limbs. Notice that the ulna and radius of the bat wing are almost fused.

Polar bears, however, have evolved an extra protection from the cold. The soles of their feet are also mostly covered with thick fur. This extra fur not only keeps their skin off the ice but also improves traction.

The theory of evolution has helped scientists explain many of the structural variations and similarities found in organisms. For example, in Figure 5-6, notice that each limb has one thick "long" bone, two thinner "long" bones, and a "hand" with five digits. The ancestor of these animals most likely had a similar limb structure. At one point, however, limbs began to vary, evolving into arms, legs, wings, or flippers.

Structures that are no longer used by modern organisms give scientists clues to the evolutionary history of a species. Some snakes, for example, have tiny, nonfunctional leg bones—an indication that they probably evolved from four-legged, lizard-like ancestors.

Functional Change Molecular or biochemical changes affect how an organism works. These are functional changes. For example, all working muscles emit an extremely tiny electrical output. In some eels, however, that electrical output has evolved into an adaptation that helps it find and capture food. The muscles of these eels can produce a massive shock that stuns or kills its prey.

Changes in DNA often lead to functional changes. One example is a mutation in the DNA of certain one-celled organisms that led to their ability to make enzymes that digest wood. Another is the evolution of the ability of some snakes to make a poisonous venom.

Behavioral Change Behaviors have also evolved through natural selection. Many of the specific behaviors we find in species today have become common because they resulted in greater reproductive success.

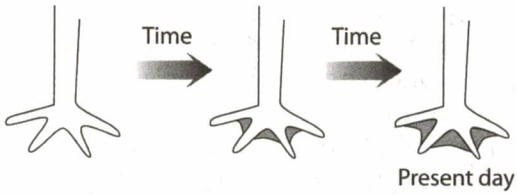
- Fighting among the males of a walrus population for a harem of females is one evolved behavior. Because of the fighting, the stronger, healthier male mates with the most females.
- The correct rate of "blinking" allows males and females of firefly species to find each other. A different pattern or rate of blinking would isolate the individual from potential mates.

The Importance of Variation

If environmental conditions change, organisms that have adapted to those conditions may die. If all the members of the species had exactly the same combination of characteristics, an environmental change could be disastrous, wiping out the entire species. The variation of organisms within a species increases the likelihood that at least some members of the species will survive in a changed environment. Once the diversity present in a species is lost, it is next to impossible to get it back. Today's endangered species have such small populations that biologists worry that they may not have the genetic diversity to adapt to even slight changes in their environment.

Review Questions

24. The changes in the foot structure in a bird population over many generations are shown in the diagram below.



These changes can best be explained by the concept of

(1) natural selection
(2) extinction
(3) stable gene frequencies
(4) cloning

25. Explain how the lack of genetic diversity found in populations of endangered species might hinder their recovery. [1]

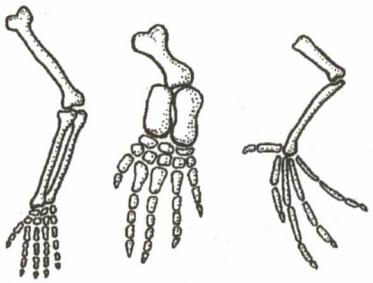
26. The Florida panther, a member of the cat family, has a population of fewer than 100 individuals and has limited genetic variation. Which inference based on this information is valid?

(1) These animals will begin to evolve rapidly.
(2) Over time, these animals will become less likely to survive in a changing environment.
(3) These animals are easily able to adapt to the environment.
(4) Over time, these animals will become more likely to be resistant to disease.

27. Which statement could be used as evidence to show that two different species of organisms most likely developed from a single, common ancestor?

(1) They eat the same types of food.
(2) They have different digestive enzymes.
(3) They lived during the same time period.
(4) They contain similar amino acid sequences.

28. The diagrams below show the bones in the forelimbs of three different organisms.



Differences in the bone arrangements support the hypothesis that these organisms

(1) are members of the same species
(2) may have descended from the same ancestor
(3) have adaptations to survive in different environments
(4) all contain the same genetic information

29. In most populations, the individuals that produce the greatest number of offspring are

(1) always the strongest
(2) usually the best adapted
(3) those that have only inheritable traits
(4) those that are the most intelligent

30. The best scientific explanation for differences in structure, function, and behavior found in different species of organisms is provided by

(1) carbohydrate electrophoresis
(2) population chromatography
(3) the theory of carrying capacity
(4) the theory of evolution

Patterns of Change

Evolution appears to follow certain patterns that appear repeatedly in the fossil record. For example:

- Changes in species are often related to environmental change.
- Species with short reproductive cycles that produce many offspring tend to evolve more quickly than species with long lifespans and few offspring.
- The failure to adapt to a changing environment may result in the death of the species.