Name____ Class____________ Date____________

ACTIVITY 20-2. EARLY THEORIES OF EVOLUTION

Speculations about the history of the earth and the development of life have been made since ancient times. In the sixth century B.C., Anaximander suggested that men were first formed as fishes, and that eventually the fish lost their skins and began life on land. In the fifth century B.C., Xenophanes recognized fossil bones as the remains of ancient animals. Aristotle, in the fourth century B.C., thought that there was a gradation in nature from inorganic substances to the most complex living things. He developed the idea of the phylogenetic tree, or chart.

LAMARCK—THEORY OF USE AND DISUSE

Jean Baptiste Lamarck (1744-1829) made some important contributions to the theory of evolution. His theory of need stressed that organisms need to adjust, or adapt, to their environment. When the environment changes, the organism must adapt or die. Lamarck theorized that organs needed for the adjustment to environmental stress remained strong and functional, while those not needed gradually disappeared because of disuse. Finally, Lamarck thought that traits acquired in the course of adaptation to the environment were passed on to offspring. According to Lamarck, organisms evolved, or changed, because of alterations in environmental conditions. Such change stimulated the development of some organs and the disappearance of others. Changes in structures that occurred in the course of adaptation were then passed on to future generations.

Questions

1. What were the three major concepts in Lamarck's theory of evolution?

2. The part of Lamarck's theory that stressed the necessity for organisms to change with their environment was his theory of ____________________.

3. According to Lamarck's concept of use and disuse, what happened to organs that were little used?

4. What were Lamarck's ideas about the inheritance of acquired characteristics?

DARWIN—THEORY OF EVOLUTION BY NATURAL SELECTION

In 1831, Charles Darwin sailed as naturalist aboard the British ship *HMS Beagle*, which was to explore and chart some Pacific Islands and the coast of South America. The ship visited the Galapagos Islands, on which finches and huge tortoises lived. Darwin studied these animals and found that tortoises on different islands displayed different characteristics. The finches also displayed differences from one island to another, particularly in the structure of the beak. Although the birds were obviously similar, the beaks differed in size and shape, allowing the birds on different islands to feed on different types of food. Darwin proposed that the fourteen species of finches on the islands originated from a common ancestor. Since the islands were separated by stretches of water, the finches were isolated on their respective islands. Thus, Darwin concluded that the differences between the animals on the various islands resulted from geographic isolation.

Over the next twenty years, Darwin organized the data from his trip and gathered other information for his theory of evolution. In 1858, Darwin received a letter from another naturalist, Alfred Wallace, in which Wallace explained his own theory of evolution. To Darwin's amazement, Wallace's ideas were very close to his own. In a spirit of cooperation, the two men made a joint presentation of their theory to the Linnaean Society of London.

The theory of evolution by natural selection can be divided into five parts.

1. *Overproduction* refers to the capacity of every species to produce more offspring than can survive. In this Darwin was influenced by Thomas Malthus, who theorized that populations increase at a higher rate than their food supply and that the size of a population is limited by the availability of food.
2. A *struggle for existence* results from the competition between organisms for available food, shelter, and living space.
3. *Variations*, or differences, between members of a species make every individual different from every other individual. Variations may be inherited.
4. By the process of *natural selection,* those members of a species that are best adapted to the environment will survive longer and reproduce more successfully than individuals that are less well adapted. Thus, favorable variations will be preserved and unfavorable ones gradually eliminated in future generations.
5. New species result from accumulated variations in an isolated population. With each generation, new variations arise that are passed on to the next generation. Eventually, the changes are great enough that a new species results.

Questions

1. The theory of natural selection was developed independently by two naturalists. These were
   ______________________ and ______________________.

2. List the major points of the theory of evolution by natural selection.

3. Darwin's concept of overproduction within a species was influenced by ______
______.

4. What did Darwin mean by "natural selection"?

5. What conclusions about the effects of geographic isolation did Darwin draw from his observations of finches on the Galapagos Islands?

WEISMANN—CONTINUITY OF GERMPLASM

Auguste Weismann, a German biologist, disproved the theory of inheritance of acquired characteristics. Weismann cut off the tails of mice and then allowed the mice to mate. He repeated this for twenty generations. The tails of the mice of the twenty-first generation were not affected, disproving Lamarck's theory. Weismann explained why acquired characteristics are not inherited in his concept of the continuity of the germplasm. According to this concept, the body is composed of two types of cells—*somatic*, or body, cells, and *germ*, or reproductive, cells. The somatoplasm represents all the body cells and the germplasm all reproductive cells. Changes in body cells cannot be passed on to offspring because these cells are not involved in reproduction. Changes in germ cells, however, can be passed on to future generations.

Questions

1. How did Weismann disprove the theory of inheritance of acquired characteristics?

2. According to Weismann, why weren't acquired characteristics passed on to future generations?

DeVRIES—THEORY OF MUTATION

Hugo DeVries, a Dutch botanist, published his theory of mutation in 1901. He based this theory on investigations of the evening primrose, a flowering plant. During his studies, DeVries noted abrupt, permanent hereditary changes in the plants. He called the changes *mutations* and concluded that mutations must occur frequently in other organisms as well. He postulated that mutations were the source of the changes that brought about the development of new species and, therefore, the cause of evolutionary change.

Question

What role did DeVries think that mutation played in evolution? Was he correct?

ACTIVITY 20-3. MODERN THEORY OF EVOLUTION

The theory of evolution has been modified since its presentation to the scientific community by Darwin and Wallace. The central point of evolution is now the gene pool of a population and the range of genetic variations contained within that gene pool (all the genes of a population). Variations within a population are caused by a number of factors: gene mutations, chromosome mutations, and genetic recombination at fertilization. The migration of individuals into the population from outside populations also introduces variation by introducing new gene combinations. Individuals leaving the population remove genes. The genetic makeup of a population is fluid and subject to change. Evolution can now be defined as the progressive change of genes in a population.

Questions

1. Define the term evolution.

2. In terms of the modern theory of evolution, there are several mechanisms by which variations are introduced into a species. List three of them.

3. All the genes of a given population form the ____________________.

4. How can new genes enter the gene pool?

5. How can genes be removed from the gene pool?

population genetics

Population genetics deals with hereditary factors affecting a population. Members of a species inhabiting a given area and having the opportunity to interbreed make up a *population*. Biologists consider this capacity to interbreed in nature a defining characteristic of a species.

Within the gene pool of a population, some genes are more common than others—they are carried by a greater percentage of the population. The distribution of genes within a population is discussed in terms of *gene frequencies,* the percentage or fraction of the population carrying the gene.

Questions

1. The study of the hereditary factors affecting a population is called ____________________.
2. Organisms that are very similar and are able to interbreed in nature are members of the same ____________________.
3. Organisms of a given species inhabiting the same locality make up a ____________________.

Name ____________________ Class __________ Date __________

Hardy-Weinberg law

The Hardy-Weinberg law deals with the distribution of genes within a population. In a natural population, there are two opposing forces in operation—forces that produce a stable, unchanging population and forces that cause the population to change. The Hardy-Weinberg law applies only to stable populations. Such populations will occur under the following conditions:

1. There must be random mating within a population large enough to allow the laws of probability to operate.
2. There must be no selective migration into or out of the population.
3. There must be no mutations, or the rates of mutation among pairs of alleles must be such that there is no alteration in the gene frequencies.

The Hardy-Weinberg law states that in stable populations (as defined above), gene frequencies remain constant from one generation to another. This can be stated mathematically by the following formula, in which p is the dominant allele and q is the recessive allele.

$$p^2 + 2pq + q^2 = 1$$

Sample Problem

In field mice, gray coat color (G) is dominant and black (g) is recessive. Within a given population, the frequency of the dominant allele is .80, or 80%. The frequency of the recessive allele is .20, or 20%. Find the distribution of genotypes in this population.

$p = .8$
$q = .2$

$$p^2 + 2pq + q^2 = 1$$

$$(.8)^2 + 2(.8)(.2) + (.2)^2 = 1$$

$$.64 + .32 + .04 = 1$$

homozygous dominant = p^2 = .64 = 64%
heterozygous dominant = $2pq$ = .32 = 32%
homozygous recessive = q^2 = .04 = 4%

Questions

1. What is the Hardy-Weinberg law?

2. How is the Hardy-Weinberg law expressed mathematically?

3. For the Hardy-Weinberg law to be valid, what conditions must exist within a population?

4. In a population of field mice, the frequency of the recessive allele for black coat color is .30. What percentage of the population has the homozygous recessive genotype? What percentage is heterozygous?

5. In a population of 400 rabbits, 300 have the dominant allele (W) for white fur.
   a. What is the frequency of the recessive allele (w) for black fur in this population?

   b. In the same population, what percentage of rabbits is hybrid for white fur?

factors affecting gene frequencies

The conditions necessary for unchanging gene frequencies within a population rarely exist. Migration, mutation, and genetic recombination do change the frequency of certain alleles within the gene pool. Some of these genetic variations produce traits harmful to the individual carrying the gene, some have no particular effect, and a few improve the chances of the individual to survive and reproduce within the environment. Variations that aid in survival are called *adaptive variations*. The frequency of genes that are adaptive will increase in the population with time because the bearers of such genes will reproduce more successfully than those organisms without the adaptive genes. When environmental conditions change, a new set of alleles may prove of high survival value, and the gene distribution within the population can change within a relatively short period of time. This is natural selection. Thus, environmental factors exert pressure for selection of certain genes and affect gene frequencies within a population.

Isolation of a population also affects gene frequencies. Isolation may be caused by geographic factors, as in the finches of the Galapagos Islands, or it may involve any other factor that separates the gene pool of some members of a species from the rest of the species at large. Eventually, differences in the selective pressures between the isolated population and the rest of the species will result in enough accumulated genetic variations so that a new species will have evolved. In the case of the Galapagos finches, geographic isolation resulted in *reproductive isolation*—when brought together, birds from the different islands could not interbreed and produce viable offspring. This marked them as separate species.

Questions

1. Within a given population, what will happen to the frequency of an allele that has positive survival value (increases the chance of survival) over time?

2. What may happen to existing gene frequencies within a population if environmental conditions change?

Name ______ Class ______ Date ______

3. How does isolation of a population affect gene frequencies in that population?

speciation In general, the formation of a new species—*speciation*—results from the geographic isolation of a population or a portion of a population. Over the course of generations, the different accumulated variations within the gene pools of the separated populations make them two genetically separate species.

Under favorable environmental conditions, one species may, in time, undergo an evolutionary "branching" that results in production of a number of different species that fill available niches in the environment. This is called *adaptive radiation*.

Questions

1. What factors are generally involved in the evolution of a new species?

2. The evolution of a single species into a number of different species that fill available niches in the environment is called ______.

ACTIVITY 20-4. THE ORIGIN OF LIFE

SPONTANEOUS GENERATION

The concept of *spontaneous generation*, or *abiogenesis*, refers to the production of living things from nonliving substances. Aristotle believed that some fish developed from mud and sand. Virgil, the Roman philosopher, claimed bees could be produced by killing and burying a calf. In 1652, Jean Baptiste van Helmont published a recipe for making mice from a combination of dirty shirts and wheat.

Questions

1. What is spontaneous generation?

2. Another term for spontaneous generation is ____________________.

experiments with spontaneous generation

In the 1600s, *Francisco Redi* decided to test the belief that fly maggots arose from rotting meat. Redi set up three jars containing meat. One was left open, the second was sealed with parchment, and the third was covered with a fine net. The meat in the first jar developed maggots. The meat in the second jar had no maggots. Meat in the third jar also had no maggots, but on the fine netting covering the jar, flies were seen landing and depositing eggs on the surface, thus explaining how the maggots arose in exposed meat.

In the 1700s, *John Needham*, an English scientist, reported evidence in support of abiogenesis. He boiled mutton broth in flasks sealed with corks. After a few days he examined samples from each flask and found they were teeming with microorganisms. It was later shown that Needham's techniques were faulty—he did not boil the broth or corks long enough to kill all microorganisms.

Lazzaro Spallanzani boiled broth both in corked flasks and in flasks sealed with glass. He found that broth in the glass-sealed flasks that had been boiled for an hour would remain free of contamination. This experiment was criticized, however, on the grounds that spontaneous generation required free access to air.

In 1864, *Louis Pasteur* designed an experiment that finally disproved the theory of abiogenesis. He sterilized flasks and their contents, but instead of sealing the flasks as Spallanzani did, he drew the glass necks into a curve. The curved neck allowed free passage of air, but dust and spores were trapped in the U-shaped curve. The broth contents remained sterile.

Questions

1. Three scientists whose experiments helped disprove the theory of spontaneous generation were ____________________, ____________________, and ____________________ ____________________.

Name ______________________ Class __________ Date __________

2. Briefly describe one of the experiments that helped disprove the theory of abiogenesis, and give the name of the scientist who performed it.

HETEROTROPH HYPOTHESIS

If life did not originate by spontaneous generation, how did it happen? A widely accepted modern theory of the origin of life on earth is called the *heterotroph hypothesis*, which states that the earliest living organisms on earth were very primitive heterotrophic cells.

According to the heterotroph hypothesis, the atmosphere of the primitive earth was composed of hydrogen (H_2), ammonia (NH_3), methane (CH_4), and water vapor (H_2O). These gases dissolved in rainwater and washed into the forming oceans. Minerals from the earth's crust also became dissolved in the oceans. It is thought that at this stage the earth was very hot and that there was much more energy in the environment than there is now. In addition to heat, energy was present in the form of lightning and various types of radiation, including X rays, cosmic rays, ultraviolet radiations, and radiation from radioactive elements in the crust.

At this stage in their development, the oceans are commonly described as being like a "hot, thin soup," in which the abundance of energy led to chemical bonding. Such bonding is thought to have led to the formation of simple organic compounds, including amino acids and simple sugars. As concentrations increased, these organic molecules began to interact in the "soup," forming larger molecules and, eventually, aggregates, or clusters, called *coacervates*. The aggregates became still larger and developed surrounding membranes. Organic molecules from the environment passed through the membrane into the complex aggregate within. At some point, the aggregates developed the capacity to reproduce. At this point, they can be considered to have been "alive."

These first living cells were anaerobic heterotrophs that carried on a form of respiration resembling fermentation. This process added carbon dioxide to the atmosphere. These organisms obtained organic nutrients from the environment.

Autotrophic cells with the capacity to use carbon dioxide for the synthesis of organic compounds evolved from the heterotrophic cells. This process released oxygen into the environment. Eventually, some heterotrophic and autotrophic cells evolved the capacity to carry on aerobic respiration. Since this process is so much more efficient than fermentation for releasing energy from nutrient molecules, it became the dominant form of respiration.

Questions

1. According to the heterotroph hypothesis, the atmosphere of the primitive earth was probably composed of ______________, ______________, ______________, and ______________.

2. What were some of the forms of energy thought to be present in the environment of the primitive earth?

3. Why would the earliest living forms have carried on anaerobic respiration rather than aerobic respiration?

4. At what point could the complex aggregates of organic molecules be considered to be alive?

5. Why is it thought that heterotrophs evolved before autotrophs?

6. The forming oceans of the primitive earth have been called a "____________________."