AP Biology Reading Guide
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Chapter 25: History of Life on Earth

1. What is macroevolution?

Macroevolution is the broad pattern of evolution above the species level. Examples of macroevolutionary change include the emergence of terrestrial vertebrates through a series of speciation events, the impact of mass extinctions on the diversity of life, the origin of key adaptations such as flight in birds, and the return of terrestrial vertebrates, such as the ancestors of dolphins, to marine environments through a series of speciation events.

2. How old is the planet?

There is scientific evidence that Earth and the other planets of the solar system formed about 4.6 billion years ago, condensing from a vast cloud of dust and rocks that surrounded the young sun. For the first few hundred million years, life probably could not have originated or survived on Earth because the planet was still being bombarded by huge chunks of rock and ice left over from the formation of the solar system. The collisions generated enough heat to vaporize the available water and prevent seas from forming. This early phase likely ended about 4.2–3.9 billion years ago. Direct evidence of life on early Earth comes from fossils of microorganisms that are about 3.5 billion years old.

3. The current theory of the origin of life suggests a sequence of four main stages.

First, the abiotic synthesis of small organic molecules, such as amino acids and nitrogenous bases, occurred. Second, these small molecules joined into macromolecules, such as proteins and nucleic acids. Third, these molecules were packaged into protocells, droplets with membranes that maintained an internal chemistry different from that of their surroundings. Finally, self-replicating molecules originated, eventually making inheritance possible.

4. What gas was "missing" from the early atmosphere and why?

The first atmosphere was probably thick with water vapor, along with various compounds released by volcanic eruptions, including nitrogen and its oxides, carbon dioxide, methane, ammonia, hydrogen, and hydrogen sulfide. As Earth cooled, the water vapor condensed into oceans, and much of the hydrogen escaped into space.

5. What did Oparin and Haldane suggest as the source of energy for early organic synthesis?

Oparin and Haldane independently hypothesized that Earth's early atmosphere as a reducing (electron-adding) environment, in which organic compounds could have formed from simpler molecules. The energy for this organic synthesis could have come from lightning and intense UV radiation. Haldane suggested that the early oceans were a solution of organic molecules.

6. Explain the elements of the Miller-Urey experiment.

As the water mixture in the "sea" at the bottom of the flask was heated, vapor entered the "atmosphere" of the flask, containing a mixture of hydrogen gas, methane, ammonia, and water vapor. Sparks were discharged to mimic lightning. A condenser cooled the "atmosphere," raining water molecules down into the "sea". As material cycled through the apparatus, Miller periodically collected samples for analysis.

7. What was collected in the sample for chemical analysis and what was concluded from the results of this experiment?

Miller collected several organic compounds, both simple (such as formaldehyde) and complex (such as hydrocarbons), commonly found in organisms. Though his methodology is not undisputed, his results support the concept that abiotic synthesis of organic compounds could have been an early stage in the origin of life.

8. What are protobionts? What property of life do they demonstrate?

Protocells are droplets with membranes that maintain an internal chemistry different from that of their surroundings.

9. What did Thomas Cech propose was the first genetic material?

Thomas Cech proposed that RNA, not DNA, was most likely the first genetic material.

10. What are ribozymes?

Cech and Altman found that RNA, which plays a central role in protein synthesis, can also carry out a number of enzyme-like catalytic functions. Cech called these RNA catalysts ribozymes.

11. Explain the evidence for an early "RNA world".

Natural selection on the molecular level has produced ribozymes capable of self-replication in the laboratory. The molecular biology of today may have been preceded by an "RNA world," in which small RNA molecules that carried genetic information were able to replicate and to store information about the vesicles that carried them.

12. What type of rock are fossils found in?

Sedimentary rocks are the richest source of fossils. The fossil record is based primarily on the sequence in which fossils have accumulated in sedimentary rock layers, called strata. Useful information is also provided by other types of fossils, such as insects preserved in amber (fossilized tree sap) and mammals frozen in ice.

13. What do we not know from analyzing rock strata?

The known fossil record is biased in favor of species that existed for a long time, were abundant and widespread in certain kinds of environments, and had hard shells, skeletons, or other parts that facilitated their fossilization. While the order of fossils in rock strata tells us the sequence in which the fossils were laid down – their relative ages – it does not tell us their actual, absolute ages.

14. Explain the concept of radiometric dating. ✏

Radiometric dating is based on the decay of radioactive isotopes. In this process, a radioactive parent isotope decays to a daughter isotope at a fixed rate. The rate of decay is expressed by half-life, the time required for 50% of the parent isotope to decay. Each type of radioactive isotope has a characteristic half-life, which is not affected by environmental variables such as temperature or pressure. Fossils contain isotopes of elements that accumulated in the organisms when they were alive. By measuring the ratio of the decayed form of an isotope to the original form of the isotope in a fossil, its age can be determined.

15. What is the age range for which carbon-14 dating may be used?

Carbon-14 has a half-life of 5,730 years. Carbon-14 dating works for fossils up to about 75,000 years old. Fossils older than that contain too little carbon-14 to be detected with current techniques. Organisms do not use radioisotopes with long half-lives, such as uranium-238, which has a half-life of 4.5 billion years, to build their bones or shells.

17. What are three groups of tetrapods?

Tetrapods include reptiles, amphibians, and mammals.

18. Cite three ways of distinguishing mammal fossils from the other two groups of tetrapods.

The lower jaw is composed of one bone (the dentary) in mammals but several bones in other tetrapods. Mammals also have a unique set of 3 bones that transmit sound in the middle ear (the hammer, anvil, and stirrup), whereas other tetrapods have only one such bone (the stirrup). Mammals' teeth are differentiated into incisors (for tearing), canines (for piercing), and the multi-pointed premolars and molars (for crushing and grinding). In contrast, the teeth of other tetrapods usually consist of a row of undifferentiated, single-pointed teeth.

19. What was the earliest form of life on the planet?

The earliest direct evidence of life, dating from 3.5 billion years ago, comes from fossilized stromatolites. Stromatolites are layered rocks that form when certain prokaryotes bind thin films of sediment together. Present-day stromatolites are found in a few warm, shallow, salty bays. If microbial communities complex enough to form stromatolites existed 3.5 billion years ago, it is a reasonable hypothesis that single-celled organisms originated much earlier, perhaps as early as 3.9 billion years ago.

20. What unique ability was originated with cyanobacteria?

Early prokaryotes were Earth's sole inhabitants from at least 3.5 bya to about 2.1 bya. Bacteria similar to today's cyanobacteria (oxygen-releasing, photosynthetic bacteria) originated well before 2.7 bya. The amount of atmospheric O_2 increased gradually from about 2.7 to 2.3 bya, but then shot up relatively rapidly to between 1% and 10% of its present level. This "oxygen revolution" had an enormous impact on life. The rising concentration of atmospheric O_2 probably doomed many prokaryotic groups because certain chemical forms of oxygen attacks chemical bonds and can inhibit enzymes and damage cells. Some species survived in habitats that remained anaerobic. Among other survivors, diverse adaptations to the changing atmosphere evolved, including cellular respiration. Gradual rise in atmospheric O_2 levels was probably brought about by ancient cyanobacteria. One hypothesis is that this rise allowed the evolution of eukaryotic cells containing chloroplasts.

21. Explain the evolution of eukaryotes by endosymbiosis.

The endosymbiont theory posits that mitochondria and plastids were formerly small prokaryotes that began living within larger cells. The prokaryotic ancestors of mitochondria and plastids probably gained entry to the host cell as undigested prey or internal parasites. A heterotrophic host could use nutrients released from photosynthetic endosymbionts. Over time, the host and endosymbionts would have become a single inseparable organism. Although all eukaryotes have mitochondria or remnants of these organelles, they do not all have plastids. Thus, the hypothesis of serial endosymbiosis supposes that mitochondria evolved before plastids through a sequence of endosymbiotic events.

22. Summarize three lines of evidence that support the model of endosymbiosis.

The inner membranes of both mitochondria and plastids have enzymes and transport systems that are homologous to those found in the plasma membranes of living prokaryotes. Mitochondria and plastids replicate by a splitting process that is similar to that of certain prokaryotes. Each of these organelles contains a single, circular DNA molecule that, like the chromosomes of bacteria, is not associated with histones or large amounts of other proteins. Mitochondria and plastids also have the cellular machinery (including ribosomes) needed to transcribe and translate their DNA into proteins. In terms of size, RNA sequences, and sensitivity to certain antibiotics, the ribosomes of mitochondria and plastids are more similar to prokaryotic ribosomes than they are to the cytoplasmic ribosomes of eukaryotic cells.

23. Explain the clock model.

The clock model serves as an analogy for some key events in Earth's history. The clock ticks down from the origin of Earth 4.6 billion years ago to the present.

24. How can continents move?

According to the theory of plate tectonics, the continents are part of great plates of Earth's crust that essentially float on the hot, underlying portion of the mantle. Movements in the mantle cause the plates to move over time in a process called continental drift. As the continent shifts its position over time, the direction of magnetic north recorded in its newly formed rocks also changes.

26a. Discuss various manifestations of plate tectonics.

The San Andreas fault in California is part of a border where two plates slide past each other, forming a region where earthquakes are common. When two oceanic plates or two terrestrial plates collide with each other, violent upheavals occur and mountains form along the plate boundaries, such as the Himalayas, which have resulted from the collision of the Indian and Eurasian plates. Fossil freshwater reptiles can be found in both Brazil and west Africa, areas today separated by a wide expanse of ocean, because these regions were joined when these species were living. Eutherians (placental mammals) are not indigenous to Australia because the few eutherians living on the continent went extinct after its break from Gondwana.

27. What caused the Permian mass extinction 250 mya? Summarize the species that were lost.

The Permian mass extinction, which defines the boundary between the Paleozoic and Mesozoic eras (251 mya) claimed about 96% of marine animal species and drastically altered life in the ocean. Terrestrial life was also affected: 8 out of 27 known orders of insects were wiped out. This mass extinction occurred in less than 500,000 years, possibly in just a few thousand years, at a time of enormous volcanic eruptions in what is now Siberia. This period was the most extreme episode of volcanism known to have occurred during the past half billion years. The eruptions may have produced enough carbon dioxide to warm the global climate by an estimated 6ºC.

28. What caused the Cretaceous mass extinction 65 mya?

The Cretaceous mass extinction occurred about 65.5 mya and marks the boundary between the Mesozoic and Cenozoic eras. This event extinguished more than half of all marine species and eliminated many families of terrestrial plants and animals, including all dinosaurs, except birds. Walter and Luis Alvarez suggest that a massive asteroid collision caused the cataclysm.

29. What are adaptive radiations?

Adaptive radiations are periods of evolutionary change in which groups of organisms form many new species whose adaptations allow them to fill different ecological roles, or niches, in their communities. Adaptive radiations have occurred after mass extinctions and in groups of organisms that possessed major evolutionary innovations, such as seeds or armored body coverings, or that colonized regions in which they faced little competition from other species.

30. Why did a large-scale adaptive radiation occur after each mass extinction?

Large-scale adaptive radiations occurred after each of the big five mass extinctions, when survivors became adapted to the many vacant ecological niches.

31. What two areas of biology are merged in the field of study commonly called evo-devo?

Research at the interface between evolutionary biology and developmental biology is illuminating how slight genetic divergences can produce major morphological differences between species.

32. What is an evolutionary change in the rate or timing of developmental events?

Heterochrony is an evolutionary change in the rate or timing of developmental events. Changes to these rates can alter the adult form substantially, as seen in the contrasting shapes of human and chimpanzee skulls.

33. What do the Hox genes, a class of homeotic genes, control?

Master regulatory genes called homeotic genes control the placement and special organization of body parts. The products of one class of homeotic genes, the *Hox* genes, provide positional information in an animal embryo. This information prompts cells to develop into structures appropriate for a particular location. Changes in *Hox* genes or how they are expressed can have a profound impact on morphology. For example, among crustaceans, a change in the location where two *Hox* genes are expressed correlates with the conversion of a swimming appendage to a feeding appendage.