THE HISTORY OF LIFE

The Record of Life

A. Early history of earth
   1. about 4.6 billion years old
   2. 1ST life – 3.5 billion years ago

B. History in the Rocks
   1. Fossils – any evidence of an organism that lived long ago
   2. Classified by the way they're found
      a. Casts
         - mold of organism is created, b/comes filled in by minerals in surrounding rock
         - produces a replica of the original organism
      b. Trace fossils (ex – footprints)
         - markings or evidence of animal activities
      c. Imprints
         - fossils form before sediments harden into rock
      d. Mold
         - organism is buried- it decays; leaves an empty space in the rock that is the exact shape of the organism
      e. Petrified fossils
         - hard parts of organisms are sometimes penetrated and replaced by minerals, atom-for-atom
         - when minerals harden, an exact stone copy of the original organism is produced
      f. Preserved (amber) or frozen (whole organisms)
         - entire, intact organism can be found frozen in ice or preserved in fossilized tree sap
         - rare but valuable because even the most delicate parts of the organism are usu. preserved
   3. Fossil Pollen – gives clues to ancient climate and environmental conditions
   4. Found in sedimentary rocks – small pieces of sand/mud/clay
   5. Dating methods
      a. relative dating – sedimentary layers closer to Earth's surface are younger
         - organisms are related to the layer they're found
      b. radiometric dating – finds absolute ages of fossils

- uses isotopes that break down over time

C. Trip Through Geologic Time (compared to 1 year)
    1. 1ST of January – Earth formed (4.6 billion years)
    2. March 20 – Precambrian Era begins
        - oldest evidence of life
    3. Mid-October – end of Precambrian Era
        - algae, sponges, jellyfish
    4. Mid-October – Paleozoic Era begins
        - explosion of life!
            - land plants
            - earliest vertebrates – amphibians & reptiles
    5. December 10 – Mesozoic Era begins
        - continental drift separates the continents
        a. Triassic – 1ST small mammals
        b. Jurassic – (mid-December) – Age of Dinosaurs
        c. Cretaceous – mammals and flowering plants
        d. December 26 – Cenozoic Era begins
            - current era
        e. December 31 – humans appear
    6. Fossil record shows evidence of many extinctions

Origin of Life

A. Origins: Early Ideas
    1. Spontaneous generation – life was thought to be produced from nonliving matter
    2. Experiments of Francesco Redi (1668)
        - disproved this theory for large organisms
    3. Louis Pasteur (1800's) disproved the belief that microorganisms grew spontaneously from the air
B. Biogenesis – important law of biology – living organisms come only from other living organisms
C. Origins: Modern Ideas
    1. Question to be answered – How did life begin on Earth?
    2. Answers based on experimental evidence, not fossils
    3. Alexander Oparin (1930's) – proposed theory that life began in the oceans (primordial 'soup')
    4. Stanley Miller and Harold Urey (1953) – simulated early Earth's atmosphere – and created amino acids and other organic compounds

5. Small pools of warm water – theorized to be sites for production of proteins, ATP, and nucleic acids – which become surrounded by a membrane
6. Sidney Fox – produced protocells (large ordered structure that carried out some activities of life such as growth, division, or metabolism)

D. Evolution of Cells
1. First cells – anaerobic heterotrophic
Prokaryotes – simple cells that did not use oxygen and got their food from their surroundings
2. Over time – chemosynthetic autotrophs appeared – could make own food – similar to present-day archaebacteria that live in harsh conditions
3. Finally – photosynthesizing prokaryotes – 3.5 billion-year-old fossils have been found in Australia
4. These cells produced oxygen and changed Earth's atmosphere, leading to evolution of aerobic respiration – 'oxygen revolution'
5. presence of oxygen led to development of ozone (O3) layer that shielded Earth from UV rays and allowed for evolution of more complex organisms

NATURAL SELECTION AND THE EVIDENCE FOR EVOLUTION

<u>Charles Darwin and Natural Selection</u>

A. Evolution – change over time
B. Development of Evolutionary Theory-
1. Geologic evidence showed that Earth is very old
2. Fossil evidence pointed to changes in life forms over time
3. Scientists wondered where species came from, and how they changed over time
4. Charles Darwin proposed an explanation that has become accepted by the majority of scientists

C. Charles Darwin (1809-1882)
1. Founder of modern evolutionary theory
2. 1831 – naturalist aboard *H.M.S. Beagle* – spent 5 years on an expedition to South America and the South Pacific Ocean
3. Visited Galapagos Islands – volcanic islands 1000 km off western coast of Ecuador, South America
- observed and gathered many specimens

4. Back in England – influenced with population studies and idea of struggle for survival
5. Conducted his own experiments with artificial selection-breeding for specific traits
6. 1859 – proposed mechanism of natural selection for evolution
7. Natural Selection
    a. Stabilizing Selection
        1) Favors average individuals
        2) Ex. spider size = too large – can be captured
                = too small – can't hunt well
    b. Directional Selection
        1) Favors one of the extreme forms of a trait
        2) Ex woodpeckers = long beak may be more favorable if insects live deep w/in trees
    c. Disruptive Selection
        1) Favors both extreme forms of a trait
        2) Ex limpet (mollusk) = both white and black forms can hide on rocks; grey-colored forms are visible and tend to get eaten by birds

<u>Evolution of Species (speciation)</u>

A. Geographic Isolation
    - physical barrier separates a population into groups
    - this is what occurs on islands
B. Reproductive Isolation
    - organisms that once interbred are prevented from producing fertile offspring
    - may be the result of seasonal differences in mating
C. Polyploid Speciation
    - results from chromosomes not separating during meiosis
    - results in an immediate new species -> common in plants
D. Speciation can occur quickly or slowly
    1. Gradualism -
        - adaptive changes over time
        - supported by the fossil record
        - example – camels and horses
    2. Punctuated Equilibrium
        - rapid bursts of speciation w/stable periods in b/w
        - may result from climate change
        - also supported by fossil records

- example – elephants

Patterns of Evolution

A. Adaptive Radiation
   - process of evolution of an ancestral species into many species that occupy different niches
   - niche = role a species plays in a community regarding food, space, reproduction, and how it interacts w/nonliving factors
   EX. Honeycreepers (birds) of Hawaiian Islands
      - similar in body size & shape
      - very different in plumage and beak shape
      Cichlid fish in Lake Victoria, Africa (300 species)
B. Divergent Evolution
   - species begin to adapt to different environmental conditions
   - species become less and less alike
C. Convergent Evolution
   - distantly related organisms evolve similar traits
      - response to similar environments and similar selection pressures
   - Dolphins and fishes; Marsupial and placental mammals

MECHANISMS OF EVOLUTION

Population Genetics and Evolution

A. Populations evolve; individuals don't
   1. w/in the lifetime of one individual, new features cannot evolve
   2. Natural selection operates only on populations over many generations
B. Vocabulary for Population Genetics
   1. Gene Pool = entire collection of genes in a population
   2. Genetic Equilibrium = population in which the frequency of alleles does not change from generation to generation
   3. Frequency = how often a particular allele occurs in the gene pool
C. Changes in genetic equilibrium leads to evolution
   1. Mutation – rare that mutations result in a favorable variation
   2. Genetic Drift –
      - changes in allelic frequencies by chance processes
      - more likely to occur in small populations
         - why? - In small populations, individuals with recessive genes are more likely to mate

- EX. high incidence of polydactyly in an Amish population in Pennsylvania

3. Migration of individuals in and out of a population

D. Natural Selection can be summarized as follows:
   1. Variations exist w/in populations
   2. Some variations are more advantageous for survival and reproduction than others
   3. Organisms produce more offspring than can survive
   4. Over time, offspring of survivors will make up a larger proportion of the population
   5. Depending upon the environmental factors, after many generations, a population may come to look very different from the original population

<u>Natural Selection and Adaptations</u>

A. Structural adaptations arise over many generations
B. Examples of structural adaptations
   1. Mimicry = an organism copies, or mimics, another
   2. Camouflage = an organism can blend in w/its surroundings
   4. Physiological Adaptations
      - changes in metabolic processes
      - occur quickly in bacteria
         - resistant to antibiotics

Evidence for Evolution

A. Fossils
B. Anatomical Studies
   1. Homologous Structures
      - modified structure that is seen among different groups of descendents
      ex. forelimbs of crocodiles, bats, and chickens

   * similarity of structure DOES NOT always mean that 2 organisms are closely related

   2. Analogous Structures
      - similar in function, but different in structure
      ex. bird and butterfly wings have the same function, but DOES NOT indicate a close evolutionary relationship
   3. Vestigial Structures
      - structures w/out a function; shows structural change of a species over time
      - ex. appendix; flightless birds; eyes of sightless cave fish
C. Studies of embryos – similarities in embryo appearance

D. Genetic studies – similarities in DNA patterns suggest close ancestors