Early Life

1) Early Earth
   a) Formation
      i) Between 4.5 and 4.6 billion years ago
      ii) Formed an outer solid crust of basalt, granite and other low-density rocks, and an intermediate-density mantle, which wraps around a core of very high-density, partially molten nickel and iron
   b) Early Atmosphere
      i) Hydrogen (H₂), nitrogen (N₂), carbon monoxide (CO) and carbon dioxide (CO₂).
      ii) Lacked significant levels of gaseous oxygen (O₂)
      iii) Water was present in clouds, but didn’t for into oceans until the crust cooled.

2) Synthesis of Organic Compounds (The Stuff of Life)
   a) Proteins, Fats, Carbohydrates, Lipids and Nucleic Acids
      i) Simple organic compounds could have formed from methane, hydrogen, ammonia and water with the help of some lightning
         (1) Stanley Miller (1950’s) was able to produce amino acids and other small organic compounds by bombarding methane, ammonia, water and hydrogen with an electric charge.
      ii) Two Theories on the Formation of Complex Organic Compounds
         (1) Clay in Tidal Mudflats and Estuaries
             (a) Served as a template for the spontaneous assembly of proteins and other complex organic compounds. Thin stacked layers of aluminosilicates with metal ions at the surface attract amino acids, which are then warmed and dried repeatedly, and it yields proteins and other complex organic compounds.
         (2) Hydrothermal Vents
             (a) Complex organic compounds formed spontaneously near hydrothermal vents on the seafloor. Experimental tests show that when amino acids are heated and then placed in water, they spontaneously order themselves into small protein-like molecules.
             (i) Because of their structure, some proteins may have been able to hasten the formation of other proteins, thus becoming enzymes (molecules which catalyze biological reactions), or binding metal ions and other agents of metabolism.

3) Origins of Metabolism
   a) Metabolism- all the reactions by which cells harness energy and use it to drive their activities, such as biosynthesis.
   b) During the first 600 million years of the earth’s history, enzymes, ATP and other organic compounds may have assembled spontaneously. If so, their close association would have naturally promoted chemical interactions and the beginning of metabolic pathways.

4) Origin of Self-Replicating Systems
   a) One characteristic of life is that it reproduces
   b) Spontaneous formation of RNA from simpler molecules.
c) Simple, self-replicating systems of RNA, enzymes and coenzymes have been created in laboratories. It may have been an RNA based world.

d) Somehow DNA took the place of RNA

5) Origin of the Plasma Membrane

a) Plasma Membrane - Outer most membrane in the cell

b) Lab tests- Membrane sacs can form spontaneously. Heated amino acids form protein-like chains. When placed in hot water and then let to cool, they form stable spheres, which are selectively permeable to certain substances, just like plasma membranes.

c) Lab tests- Fatty acids and glycerol combined to form long-tailed lipid molecules, which were then dried. The lipids assembled into water-filled sacs, resembling cell membranes.

6) Origin of Living Cells

a) 1st cells originated in the Archean eon, 3.9-2.5 billion years ago (bya)
   i) Prokaryotes- lack a nucleus and membrane-bound organelles
   ii) Little more than membrane bound, self-replicating sacs of DNA
   iii) Because there wasn’t any Oxygen, they must have been anaerobic
       (1) Used fermentation for energy

b) Diverged into two lineages
   i) Eubacteria
      (1) Between 2.5 and 3.2 bya light-trapping pigments, electron transport systems and other metabolic machinery evolved in this lineage
      (2) Early precursors to photosynthesis
   ii) Archaebacteria
      (1) Second major divergence about 3.5 bya formed the ancestors to the eukaryotes
      (a) Eukaryotes- have a nucleus and membrane-bound organelles

   c) Proterozoic Eon- 2.5 bya-570 mya
      i) Photosynthesis derived oxygen begins to accumulate in the atmosphere.
         (1) Oxygen-rich atmosphere stopped further chemical origin of living tissue.
         (2) Aerobic respiration became the dominant energy-releasing pathway.
         (3) Oxygen in the atmosphere formed an ozone layer, blocking harmful UV radiation and allowing life to inhabit shallow waters and the land.
      ii) First eukaryotes evolved through endosymbiosis some time before 1.2 bya
         (1) Endosymbiosis- one species lives permanently inside the other, in an interaction that benefits both
         (2) Pre-eukaryotes were engulfing aerobic bacteria.
         (3) Some bacteria resisted digestion and thrived in the environment within the engulfing cell, and were releasing extra ATP, which the host became dependent upon.
         (4) This is the possible origin of mitochondria and chloroplasts, each of which has its own DNA
         (5) These first eukaryotes were protists.
      iii) 800 to 570 million years ago (mya)- Precambrian
         (1) Fossil evidence of first animals, soft-bodied forerunners of today’s sponges and marine worms.
7) **Bacteria** (singular = bacterium)
   
a) **Most abundant of living organisms and live in the most diverse habitats**
   
i) Practically anywhere you go on the earth will have bacteria
   
   (1) Aquatic habitats- Oceans, lakes, rivers
   
   (2) Terrestrial- On the surface of the earth as well as below it.
   
   (3) Deep sea hydrothermal vents
   
   (4) Within other organisms
   
b) **Greatest metabolic diversity- how they obtain energy.**
   
i) **Photoautotrophic** (‘light’-‘self’-‘feeders’)- Self feeders, they build organic compounds, using solar energy through photosynthesis. Carbon dioxide serves as the carbon source in making organic compounds.
   
   (1) **Aerobic photosynthesizers**- use oxygen for photosynthesis
   
   (2) **Anaerobic photosynthesizers**- use other compounds, such as hydrogen or hydrogen sulfide for photosynthesis.
   
   ii) **Chemoautotrophic** (‘chemical’-‘self’-‘feeders’)- Self feeders, they build organic compounds, using chemical energy from sources such as hydrogen, sulfur and nitrogen compounds
   
   iii) **Photoheterotrophic** (‘light’-‘other’-‘feeders’)- Not self feeders, they use solar energy for photosynthesis, but carbon dioxide is not the source for making organic compounds. Instead they use fatty acids, complex carbohydrates and other compounds produced by autotrophs.
   
   iv) **Chemoheterotrophic** (‘chemical’-‘other’-‘feeders’)- Not self feeders, they are parasites or saprobes. Parasites live on or in a living host and draw nutrients from it, while saprobes get nutrients from wastes and remains of other organisms
   
c) **Differ in size and shape**
   
i) Vary in size between 1 and 10 μm (micrometer, one millionth of a meter)
   
   ii) **Differ in shape**
   
   (1) Spherical= coccus (pl.=cocci; meaning ‘berry’)
   
   (2) Rod = bacillus (pl.= bacilli; meaning ‘small staff’)
   
   (3) One or more twists = spirillum (pl. = spirilla)
   
d) **Prokaryotic** (‘before’-‘nucleus’)
   
i) They lack a nucleus
   
   ii) No membrane-bound organelles
   
   iii) Reactions occur in the cytoplasm or at the plasma membrane
   
   (1) Ex: Protein synthesis occurs at ribosomes distributed through the cytoplasm
   
   iv) **Cell wall** surrounds the plasma membrane
   
   (1) A semi-rigid, permeable structure that helps a cell maintain shape and resist rupturing.
   
   (2) Cell wall structures are used to identify different bacteria
   
   (a) **Gram stain**- Unidentified cells are exposed to a purple dye, then to iodine, an alcohol wash and a counterstain.
   
   (i) **Gram-positive** species remain purple
(ii) *Gram-negative* species lose the purple, but the counterstain turns them pink

(3) **Glycocalyx**—a sticky structure that encapsulates the cell
   (a) Helps the cell from being engulfed
   (b) Allows cells to stick to substrates

(4) Some have **flagella** (sing.=flagellum), whip-like appendages that are used in motility.
   (a) Move the cell by rotating like a propeller

**e) Bacterial Growth**
   i) **Growth is measured by an increase in numbers, not size.**
      (1) Bacteria tend to divide rapidly, with generation times as short as 10 to 30 minutes.
         (a) Under ideal conditions, they can experience exponential population growth.
         (b) Because **Natural Selection** works over generations, this is one of the ways bacteria are able to adapt so quickly to their environments.

**f) Major Groups of Bacteria**
   i) **Archaebacteria** (‘beginning’-‘bacteria’)—unique in their composition, structure, metabolism, and nucleic acid sequences, may resemble the first living cells on earth.
      (1) **Methanogens**—Methane makers.
          (a) Live in swamps, stockyards, the termite and mammalian gut and other oxygen-free habitats.
          (b) Die in the presence of oxygen.
          (c) Produce **ATP** (energy storing compound) by anaerobic electron transport, usually using hydrogen gas.
          (d) Use carbon dioxide as their carbon source and produce **methane**.
              Produce 2 billion tons of methane/year.

(2) **Extreme Haolphiles** (‘salt’-‘lovers’)
    (a) Live in exceptionally salty areas
        (i) Great Salt Lake, Dead Sea
    (b) Most make ATP aerobically.
    (c) Some make ATP by photosynthesis, using a unique pigment, bacteriorhodopsin.

(3) **Extreme Thermophiles** (‘heat’-‘lovers’)
    (a) Most heat tolerant bacteria known.
        (i) Hot springs, hydrothermal vents
    (b) Some live at temps above boiling
    (c) All grow well at temps >80°C.
    (d) Nearly all are anaerobic, and use sulfur instead of oxygen.
    (e) Used as evidence life may have originated around hydrothermal vents.

8) **Viruses**—meaning ‘poison’ or ‘venomous secretion’
   a) Smaller than bacteria (18 to 350 nm(nanometer, one billionth of a meter)
   b) Noncellular infectious agent consisting of a protein coat wrapped around a nucleic acid core
      i) The coat protects the genetic material during the journey between hosts
c) Cannot reproduce on its own, only after it has infected a host's cell.

d) Genetic material is DNA or RNA

e) Can only be studied in particular host cells

f) Examples
   i) Bacteriophages - a group of viruses that infect bacterial cells.
      (1) Because bacteria can be cultured so easily, bacteriophages are well studied.
   ii) HIV - Causes AIDS
   iii) Hepadnavirus - Hepatitis B
   iv) Plant viruses - breach the cell wall by riding on the piercing or sucking parts of an insect.

g) Multiplication Cycle
   i) Attachment
      (1) Virus chemically recognizes a host cell.
      (2) Locks on to specific molecular group at the surface
   ii) Penetration
      (1) Either the whole virus, or just its genetic material penetrates the cell’s cytoplasm
   iii) Replication and Synthesis
      (1) Molecular piracy: the viral DNA or RNA directs the host cell into producing many copies of viral nucleic acids and proteins, including enzymes.
   iv) Assembly
      (1) The viral nucleic acids and proteins are put together to form new infectious particles
   v) Release
      (1) New virus particles are released from cell