Chapters 11 and 12 Life

I. Origin of Life
   A. Theories for the origin of life:
      1. The Beginning of Life - simple to complex structures
      2. Atoms of elements essential to organisms
         a. carbon, oxygen, hydrogen, nitrogen, sulfur, and phosphorus
         b. built into inorganic molecules
      3. Simpler molecules
         a. added components that would gradually transform them into the complex organic molecules essential to living things
         b. Large and complex molecules organized themselves into bodies capable of performing specific functions
      4. Organelles
         a. unicellular organisms combined to form larger entities that grew, metabolized, reproduced, mutated and produced mutations
   B. Preliminary Considerations - Oldest fossil evidence of life
      1. 3.5 billion-year-old rocks - Pilbara shield of Australia
      2. Living things existed even before as indicated by carbon found in 3.8 billion year old BIF
         a. carbon extracted have $^{13}\text{C}/^{12}\text{C}$ similar to those in present-day organisms
   C. Earliest organisms must have been anaerobic
      1. did not require oxygen for respiration
   D. Essential components of life
      1. protein: strings of comparatively simple organic molecules
      2. amino acids: building blocks of proteins act as building materials
      3. Compounds that assist in chemical reactions within the organism
         a. nucleic acids: DNA and RNA
         b. Organic phosphorous compounds- serve to transform light or chemical fuel into the energy required for cell activities
         c. Cell membrane
            1. provides a relatively isolated chemical system within the cell
            2. keeps the various components in close proximity so that they can interact
   E. Test Tube Amino Acids and a Step Beyond
      1. 1953, laboratory synthesis of amino acids and other molecules
      2. Stanley Miller and Harold Urey performed the now famous experiment
         a. infused an atmosphere to be like that of the Earth's earliest including methane, ammonia, hydrogen, and water vapor
         b. mixture was circulated through glass tubes
         c. sparks of electricity were discharged into the mixture
         d. after 8 days water became turbid and deep red
      3. Analysis
         a. amino acids and more complicated compounds that enter into composition of all living things
         b. similar organic compounds could also be produced from gases of the preoxygenic atmosphere
      4. Main requirement - lack, or near absence, of free oxygen
      5. Amino acids are relatively stable
         a. increased gradually in abundance
         b. enhance their abilities to join together into more complex molecules
      6. In order to come together and form protein-like molecules amino acids must lose water
         a. accomplished by heating concentrations of amino acids to temperatures of at least 140$^\circ\text{C}$
         b. volcanic activity
         c. the reaction also occurs at temperatures as low as 70$^\circ\text{C}$ if phosphoric acid is present
         d. produce protein-like chains from a mixture of 18 common amino acids
      7. Proteinoids the transitional structures leading to true proteins
         a. hot, aqueous solutions of proteinoids will, on cooling, form into tiny spheres
         b. show many characteristics common to living cells
      8. Microspheres
         a. have a film-like outer wall
b. capable of osmotic swelling and shrinking exhibit budding
c. divide into "daughter" microspheres
d. occasionally aggregate linearly to form filaments
e. exhibit a streaming movement of internal particles similar to that observed to living cells

F. The Birthplace of Life - Earliest organisms originated in the sea - Surface versus Deep evolution
Life originated before there were organisms to cause decay and before there was sufficient free oxygen to be troublesome
1. Surface advantages
   a. Surface contains the salts needed for health and growth
   b. ocean waters serve as universal solvents capable of dissolving organic compounds
2. Disadvantages
   a. any organic matter or amino acids would be oxidized by the O₂ from photochemical dissociation
   b. environment lacked a protective atmospheric shield of ozone, derived from oxygen absorbs the Sun's uv radiation
   c. UV radiation may not have been a hindrance, rather served to impel molecules to interact and form complex associations
3. Deep Ocean:
   Direct observations made from diving submersibles cruising near the surface of mid-oceanic ridges have provided evidence that life may have originated in total darkness
   a. the bacteria are called hyperthermophiles
   b. the bacteria are able to live deep within fissures below the vents
   c. the organisms derive energy from chemosynthesis, a process within the cell that causes hydrogen sulfide to react with oxygen so as to produce water and sulfur
   d. the chemosynthetic bacteria around vents form the base of a food chain
   e. One can envision the steps by which the Earth's first hyperthermophiles originated
   f. superheated water would react readily with surrounding rocks, extracting elements needed to build organic molecules
   g. molecules would begin to form as the hot waters gradually returned to the surface
   h. amino acids and other org. compounds might be synthesized and combined to form first protocells
   i. growth, proliferation, and evolutionary processes operating on the protocells might then lead to primitive chemosynthetic bacteria

G. Metabolic Pathways
1. Heterotrophs - food was externally digested by excreted enzymes before being converted to the energy required for vita function
2. Fermentation -organisms able to dissemble organic molecules, rearrange their parts, and derive energy for life functions
   a. a simple fermentation reaction: \(6C₆H₁₂O₆ \rightarrow 2CO₂ + 2C₂H₅OH + \text{Energy Glucose} \)
   Organisms evolved the ability to synthesize their needs from simple inorganic substances
3. Autotrophs - able to manufacture their own food
4. Photoautotrophs
   a. capable of carrying on photosynthesis, the process of dissociating CO₂ into carbon and free O₂
   b. carbon combined with other elements to permit growth
   c. O₂ escaped to the atmosphere and began to change primeval non-oxygenic atmosphere to oxygenic
   d. Iron in rocks provided suitable oxygen acceptors - After the surficial iron had combined to its capacity with oxygen, the gas began to accumulate in the atmosphere and hydrosphere
   e. solar radiation acted upon atmospheric oxygen to convert part of it to ozone - provided a protective shield against harmful uv radiation
5. Anaerobic organisms - use oxygen to convert their food into energy
   a. provides far more energy in relation to food consumed than does the fermentation reaction
   b. surplus of energy an important factor in the evolution of more complex forms of life

H. Prokaryotes, Eukaryotes, and Symbiosis
Transition from chemical or prebiotic evolution to organic evolution occurred prior to 3.5 billion years ago
1. Prokaryotes
   a. oldest forms of life
   b. Lack definite membrane-bounded organelles
c. do not have a membrane-bounded nucleus in which genetic material is neatly arranged into discrete chromosomes
d. **Cyanobacteria**
   1. prokaryotes that are capable of photosynthesis
   2. restricted in the level of variability they can attain
   3. have shown little evolutionary change
   4. represent an important early step in the history of primordial life

2. **Eukaryotes**
   a. organisms with definite nuclear wall, defined chromosomes, and capacity for sexual reproduction
   b. contain organelles such as chloroplasts
   c. convert sunlight into energy
d. **Mitochondria**
   1. metabolize carbohydrates and fatty acids to carbon dioxide and water
   2. releases energy-rich phosphate compoundse.
e. **Organelles**
   1. once independent microorganisms that entered other cells and established symbiotic relationships with the primary cell
   2. genetic variations could be passed from parent to offspring in variety of new combinations
   3. led to a dramatic increase in the rate of evolution
   4. ultimately responsible for the evolution of complex multicellular animals

**II. The Fossil Record for the Archean**

A. Archean Fossil remains were first detected in 1965 by E.S. Barghoorn and J.W. Schlopf
   1. Oldest currently known prokaryotes are those found by paleobiologist J. William Schopf who reported his find in 1994
   2. **3.5 billion-year-old Archean** rocks of Western Australia
   3. Filaments of organic matter and hydrocarbons of organic origin
      a. clear evidence of the presence of abundant microscopic life in the Archean
      b. indicates that photosynthesis was in operation at least 3.5 billion years ago
   4. **Stromatolites**
      a. Laminar, organic sedimentary structures formed by the trapping of sedimentary particles and precipitation of calcium carbonate in response to the metabolic activities and growth of mat-like colonies of cyanobacteria and fewer numbers of other prokaryotes
      b. develop when fine particles of calcium carbonate settle on the sticky, filamentous surface of cyanobacterial mats to form thin layers
      c. cyanobacteria grow through the layer and form another surface for the collection of additional fine sediment
      d. resulting structures can be cabbage-like, columnar, tabular, or branching in shape
      e. more common in Proterozoic rocks than Archean rocks
      f. a reflection of warm shelf environments conducive to their growth
      g. **oldest stromatolites occur in 3.2 billion year old** rocks

**III. The Fossil Record for the Proterozoic**

A. Life at the beginning of the Proterozoic was not significantly different from that of late Archean
   1. blue-green scums of photosynthetic cyanobacteria constructed filamentous algal mats around the margin the ocean
   2. prokaryotes floated in the well-illuminated surface waters of seas and lakes
   3. anaerobic prokaryotes multiplied in environments deficient in oxygen, including the thermophiles

B. **Stromatolites** proliferated in the early Proterozoic and continued to flourish throughout the remainder of the Proterozoic.
   1. expansion enhanced by the greater number of epeiric sea and shallow shelf environments
   2. evidently provided food for newly evolved small shelly fossils and older primitive invertebrates
   3. extensive overgrazing decimated the stromatolites during the early Paleozoic

C. **eukaryotes** begin to appear in the fossil record
   1. begin to appear in the fossil record by about **1.6 billion years ago**
   2. expansion began about 1.4 billion years ago
   3. followed in late Proterozoic time by the early evolution of multicellular animal life
D. The Rise of Eukaryotes
1. Evolution of the eukaryotes was one of the major events in the history of life
   a. possess the potential for sexual reproduction
   b. provides enormously greater possibilities for evolutionary change
2. First eukaryotes were microscopic unicells
   a. identifying characteristics rarely preserved
   b. important clue to identification which is based on the size of cells
   c. living prokaryotic cells rarely exceed 20 microns in diameter
   d. eukaryotic cells are nearly always larger than 60 microns
3. Another clue consists of fossils known as acritarchs, unicellular, spherical microfossils with
   resistant, single-layered walls
   a. walls may be smooth or variously ornamented with spines, ridges, or papillae
   b. planktonic algae that grew their thick coats during a resting stage in their life cycle
   c. resemble the resting stage of unicellular, biflagellate, marine algae
4. Dinoflagellates
   a. range in size from 20-120 microns
   b. known from rocks as old as 1.6 billion years but rare in rocks older than 0.9 billion years
   c. guide fossils for upper Proterozoic strata
E. Late Proterozoic glaciation caused widespread extinctions
   Oldest acritarchs recovered
1. Advent of the Metazoans
   a. Important discovery of large, multicellular late Proterozoic animals
   b. Australia, Africa, South America, Russia, China, Europe, Iran, and North America
   c. Consist of impressions in sedimentary rocks of animals that are clearly metazoans
   d. multicellular animals that possess more than one kind of cell and have their cells organized into
      tissues and organs
   e. Best-known fossils of late Proterozoic metazoans
2. Exposures of the fossil-bearing rock occur in Ediacara Hills of southern Australia
3. Fall into 3 groups according to their shape
   a. Discoidal forms - Cyclomedusa - initially thought to be jellyfish
   b. Frond fossils
      1. resemble the living soft corals informally called sea pens
      2. also known from Africa, Russia, and England
      3. ovate to elongate in form
4. Ediacaran animals lived with symbiotic algae in their tissues
   a. would have provided the animals with a way to derive nutrition from the photosynthetic activity of
      the algae
   b. broad, thin shapes gave them sufficient surface area to allow for diffusion respiration
   c. essential to animals that had not yet evolved complex circulatory, digestive, and respiratory
      systems of thicker animals
5. Survived for about 50 million years
   a. appeared about 630 million years ago
   b. important as a record of the Earth's first evolutionary radiation of multicellular animals
   c. probable ancestor to Paleozoic invertebrates
6. Only one known genus of a shell-bearing animals of Ediacaran age
   a. Cloudina: named after geologist Preston Cloud
   b. also been reported in Brazil and other continents of the Southern Hemisphere
   c. fossils are tabular, calcium carbonate shells only a few centimeters long
   d. interpreted as a tube-dwelling annelid worm
7. Increase in complexity, diversity, and abundance of metazoan fossils from Proterozoic to Cambrian
   a. sudden appearance of Ediacaran fossils may be related to accumulation of sufficient free oxygen in
      the atmosphere
   b. permit oxidative metabolism in organisms
   c. may have evolved more gradually from earlier small and naked forms that were incapable leaving a
      fossil record