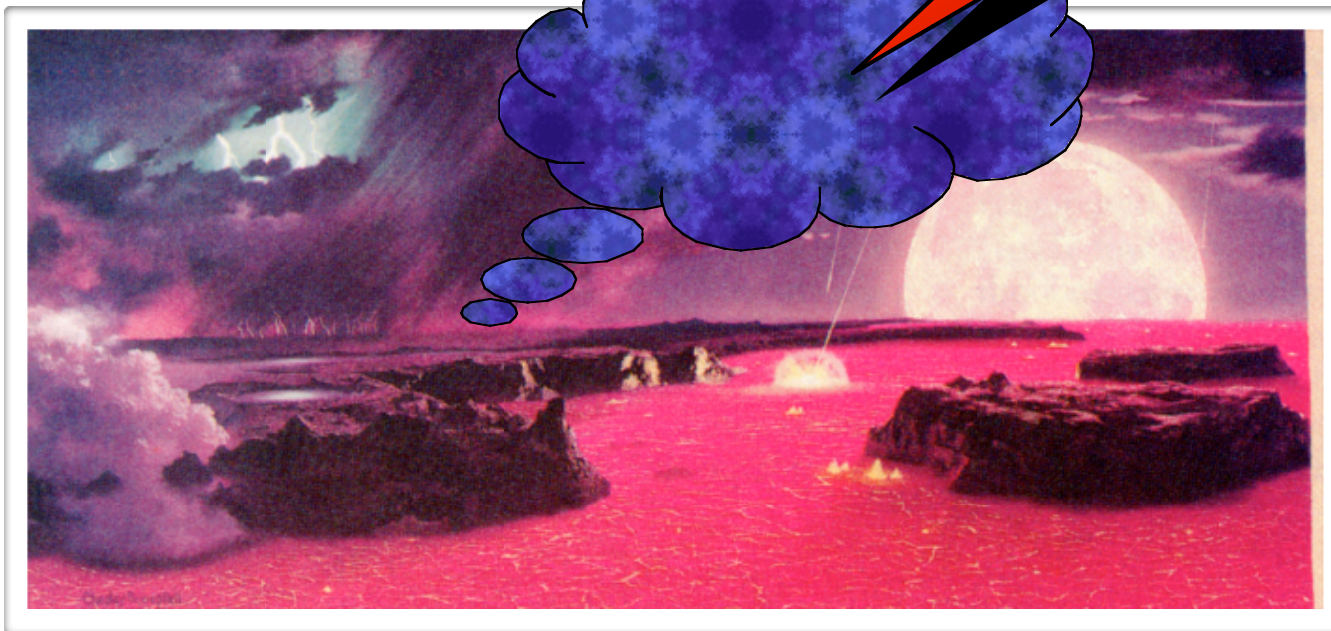


# SCENARIOS FOR THE ORIGIN OF LIFE



# WHAT IS LIFE?

## Definition by Components

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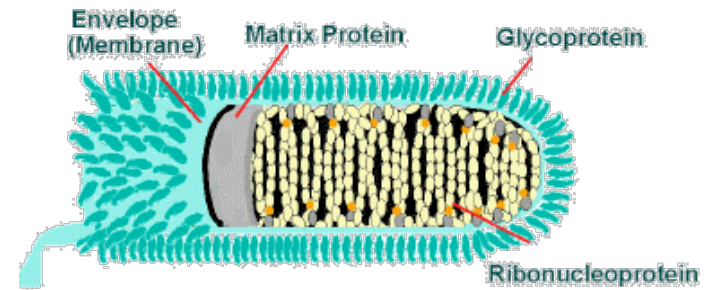
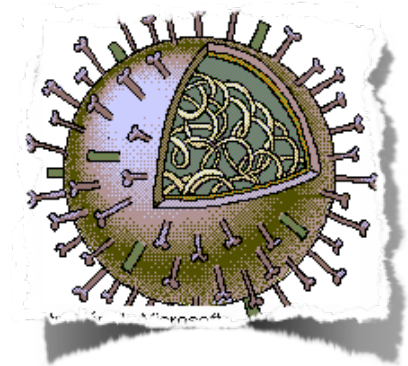
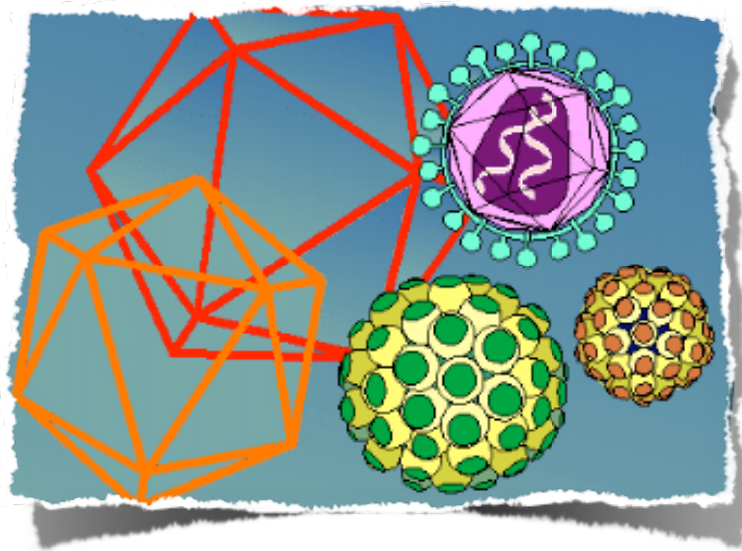
- Water - universal solvent
- Carbohydrates - energy source
- Fats - energy storage
- Adenosine phosphates - energy transfer
- Proteins - building blocks and chemical reactions (amino acids - ~20 alpha).
- Nucleic acids - RNA & DNA

# What is life?

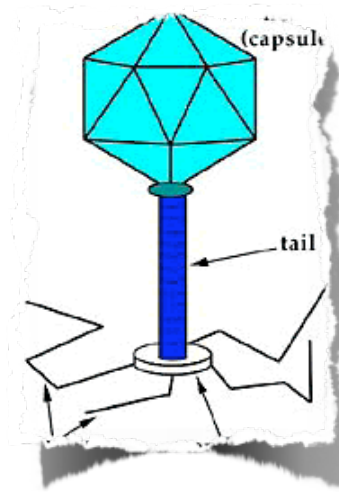
## Definition by Activities

- Auto conservation - self-maintenance
- Auto reproduction
- Information storage
- Breathing-fermentation
- Stability
- Control
- Evolution
- Death

# Is a virus 'alive'?



Protein coat  
RNA



★ Proteins in living organisms are from only 20 different amino acids.

★ Proteins include enzymes (biological catalysts) that are essential for development, survival and reproduction.

★ RNA and DNA specify amino acid sequences of all proteins an organism needs.

★ Nucleotides consist of a sugar (deoxyribose in DNA and ribose in RNA), a phosphate group and one of four different nitrogen-containing bases.

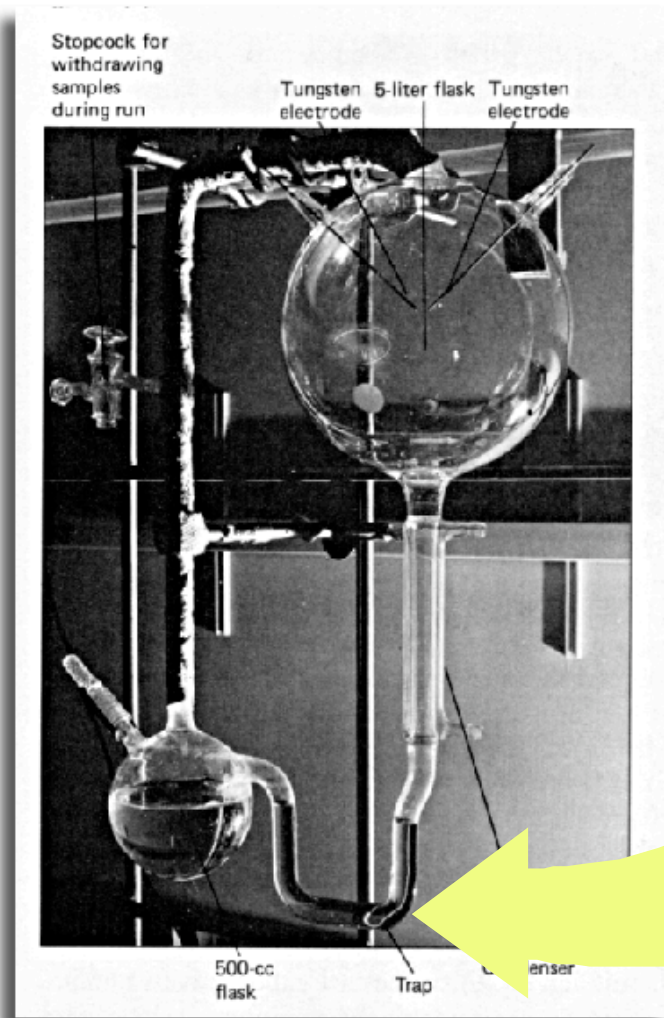
★ Central question - “By what series of chemical reactions did this interdependent system of nucleic acids and proteins come into being?”

★ PARADOX - Today nucleic acids are synthesized only with help of proteins and proteins are synthesized only if their corresponding nucleotide sequence is present.

# OPARIAN AND HALDANE



- 1920s
- Hypothesized that early oceans would contain large amounts of organic molecules
- These were formed spontaneously with energy from volcanoes, solar radiation and lightning
- Life would arise by reactions occurring between this dense association of organic compounds.



Tested at University of Chicago in 1953

## Urey-Miller Experiment

Methane ( $\text{CH}_4$ )  
Ammonia ( $\text{NH}_3$ )  
Hydrogen ( $\text{H}_2$ )  
Water ( $\text{H}_2\text{O}$ )

- ★ 'Organic Soup'
- ★ Amino acids
- ★ Carbohydrates
- ★ Proteinoids

## Microspheres and Proteinoids

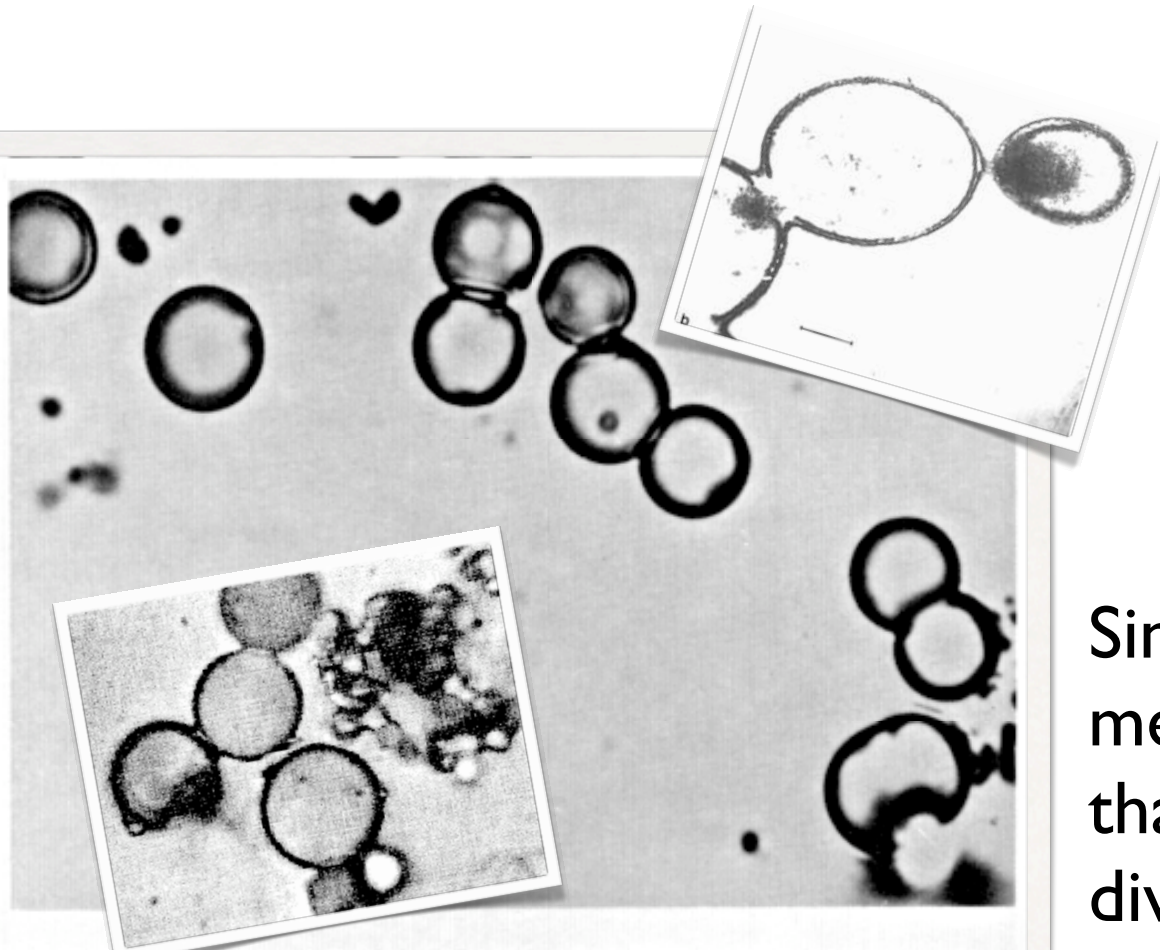


FIGURE 6-26 Proteinoid microspheres formed in hot aqueous solutions of proteinoids that have been permitted to cool slowly. The spheres are about 1 to 2  $\mu\text{m}$  in diameter. (Photo by Sidney W. Fox.)

Single and double membrane vesicles that grow and divide. Some show 'protoplasmic' streaming.

The types of amino acids and their proportions are the same in carbonaceous chondrites (meteorites) and in the Urey-Miller experiments

- About 80 amino acids, including a number that occur in natural proteins
- Purines
- Pyrimidines
- Carboxylic acids
- Carbohydrate compounds derived from ribose and deoxyribose (sugars in RNA and DNA)



This implies that amino acids could have been supplied to ancient seas not only by the reactions that Urey and Miller discovered but also from extraterrestrial sources.

Subsequent experiments have produced organic compounds without heat or electrical discharges.

Though DNA is only used as a reproductive template, RNA is more versatile (and, of course) more primitive. Most modern RNA has the following functions:

- Genetic template for Bacteria
- Genetic template for mitochondria
- Transfer RNA (tRNA)
- Messenger RNA (mRNA)
- Can act as a catalyst for certain reactions (ribosomes).

But, the most primitive RNA in the most primitive bacteria has an older function, it is part of a primitive metabolic pathway!

Late 1960's Carl R. Woese, Francis Crick and Leslie Orgel independently suggested that RNA might have come first and established an "RNA World". In this world, RNA would catalyze all the reactions necessary for a precursor of life's last common ancestor to survive and replicate. They suggested that RNA could subsequently have developed the ability to link amino acids together into proteins.

This could happen if prebiotic RNA had a capacity to replicate without the help of proteins and the ability to catalyze every step of protein synthesis.

In the past 20 years quite a bit of evidence seems to support the RNA world hypothesis.

In 1983 Thomas Cech and Sidney Altman discovered ribozymes, enzymes made of RNA. The first ribozymes that were identified could only cut and join preexisting RNA, but the fact that they behave like enzymes adds support to the idea that early RNA was catalytic.

Subsequently more ribozymes have been identified that carry out important reactions in RNA replication.

Today we define life as being composed of two parts: The Genome and the Phenome.

It appears that this distinction may not have been present in the earliest life -

the Phenome was the Genome.

Some have suggested that RNA itself is too complicated to have arisen *denovo*. Therefore current theorists suggest that the RNA World actually followed an earlier 'World' in which some other reactive precursor chemicals occurred.

The most popular scenario for the origin of life depends on the regular surface properties of minerals that acted as templates for the organization of organic molecules into the first metabolic pathways.

These simple metabolic pathways were the first organisms!

Eventually RNA was catalyzed by these earlier reactive chemical sequences.

## Scenario for the Earliest Life



1. Pathways (organisms) establish themselves on the surfaces of pyrite crystals. Some suggestion this also might have been in chambers in pyrite.
2. First pathways are chemosynthetic and the result of their function is the growth of the pyrite crystal surfaces (and therefore the growth of the organism).
3. These pathways are delicate and are subject to a variety of chemical processes in the water to which they are exposed.



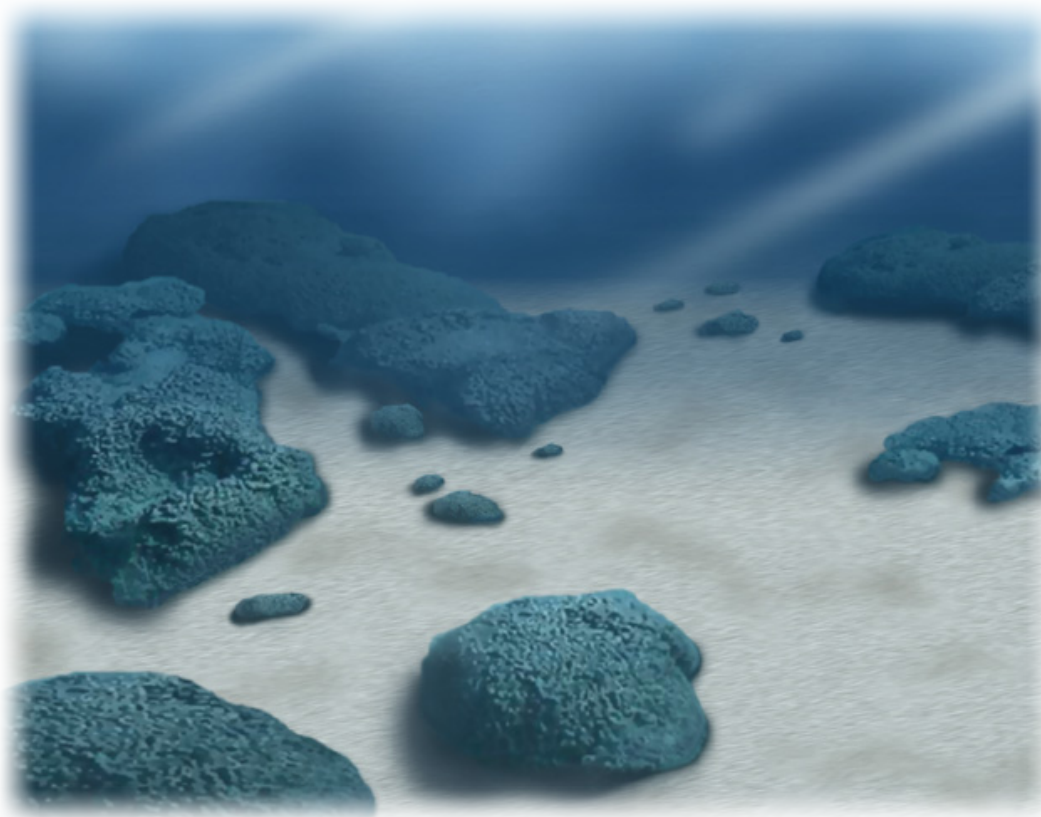
4. Membranes begin to develop that enclose the pathways (they attach to the edges of the pyrite crystal faces): these protect the pathways and sequester the 'inside' of the organism - protecting chemical processes.
5. New metabolic pathways begin to develop on the inside membrane surfaces that are more efficient than those forming on the pyrite surfaces. Eventually the new pathways become the most important.



6. Eventually the membrane comes to surround the 'organism' and it is liberated from the pyrite surface - it is now no longer dependent on the pyrite template. Eventually an 'early RNA' is synthesized. This is the start of the RNA World
7. In the RNA World, RNA is "THE" reactive chemical - involved in protein synthesis, energy transfer and replication (Phenome=Genome). With the advent of the DNA World the two 'worlds' become separated.

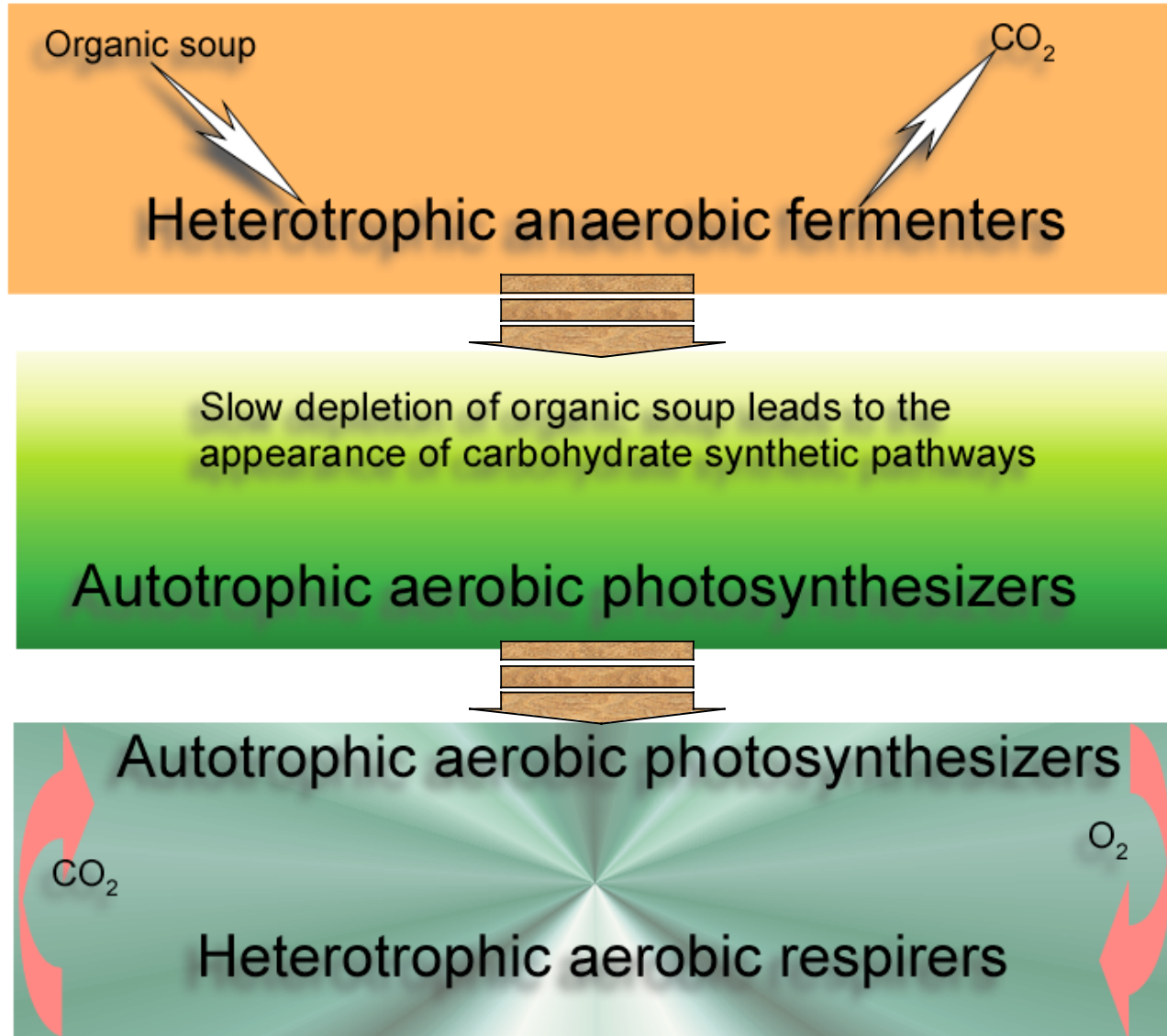
# RECENT DEVELOPMENTS

- Within the last few years it has been shown that some amino acids can themselves catalyze the formation of sugars without being in proteins or enzymes!
- Acetate (an important chemical in all biosynthetic pathways) is bound to sulfur. In all bacteria the 2 enzymes that make it have a core of iron, nickel and sulfur. The arrangement of these atoms is the same arrangement in which they occur in pyrite!

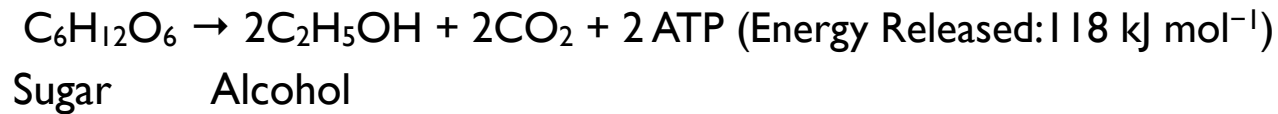


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# ORIGIN OF METABOLIC SCHEMAS AND MAJOR CELL TYPES

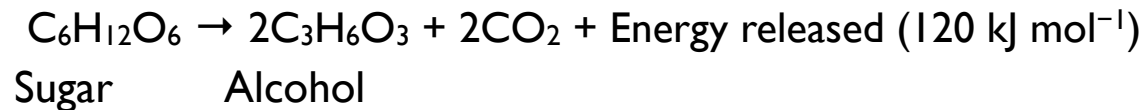


## Fermentation

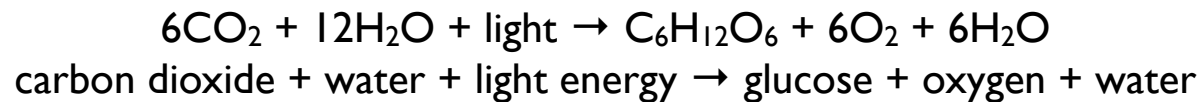


is basically

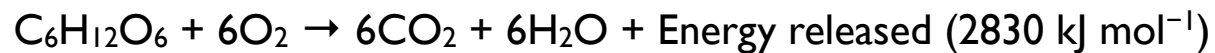
## Anaerobic respiration

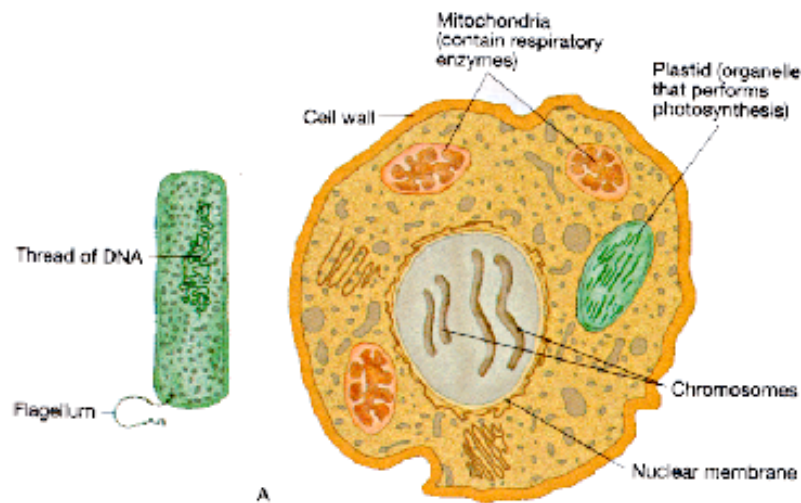


## Photosynthesis



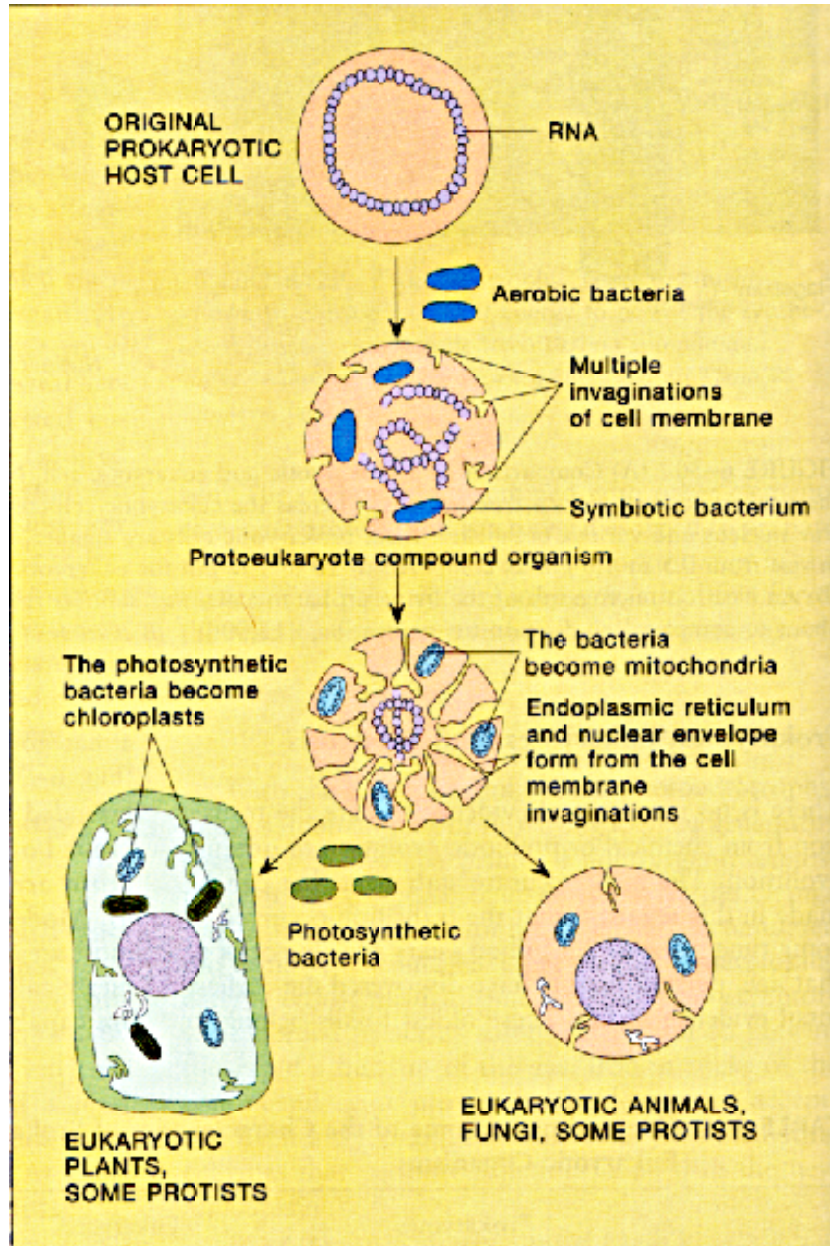
## Aerobic respiration





**TABLE 6-4 Comparison of Some of the Characteristics of Prokaryotic and Eukaryotic Organisms**

	Prokaryotes	Eukaryotes
<b>Organisms</b>	Bacteria and cyanobacteria	Protists, fungi, plants, animals
<b>Cell size</b>	1 to 10 $\mu\text{m}$	10 to 100 $\mu\text{m}$
<b>Genetic organization</b>	Loop of RNA in cytoplasm	DNA in chromosomes in membrane-bounded nucleus
<b>Organelles</b>	No membrane-bounded organelles	Membrane-bounded organelles (chloroplasts and mitochondria)
<b>Reproduction</b>	Binary fission, dominantly asexual	Mitosis or meiosis, dominantly sexual



# Lynn Margulis Origin of Eukaryotes from Prokaryotes

Multicellular

Heterotrophs  
no cell wall

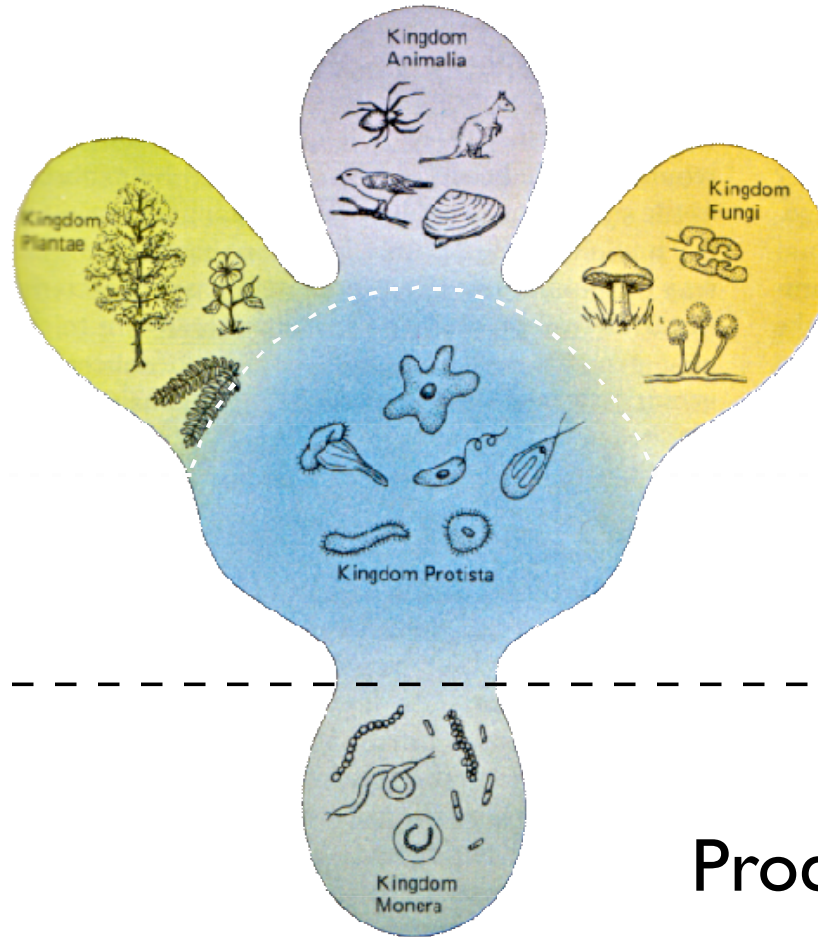
Autotrophs

Heterotrophs  
cell wall

Unicellular

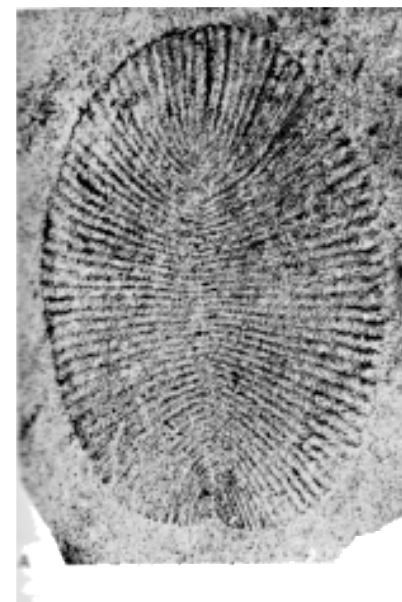
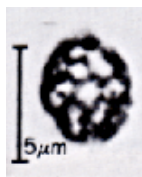
Eucaryotes

Procaryotes

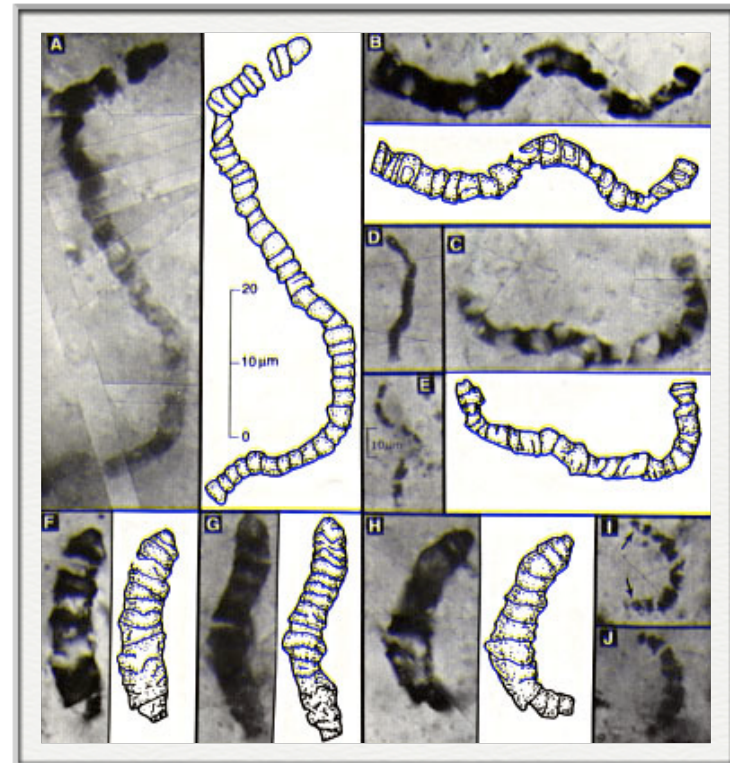




# PRECAMBRIAN FOSSILS: THE PATTERN OF LIFE



- Before the 20th century it was thought that life had basically appeared at the Cambrian-Precambrian boundary.
- Expanded and Careful collections during the 20th century revealed both the antiquity of life and also the pattern of appearance of various organisms during the Precambrian.



North Pole Locality  
3.5 ga  
Australia



FIGURE 6-33 Electron micrographs of rod-shaped *Eobacterium isolatum*, about 0.6 micron in length. Specimen at lower right has been interpreted as a transverse section through a cell. (Courtesy of J. W. Schopf.)

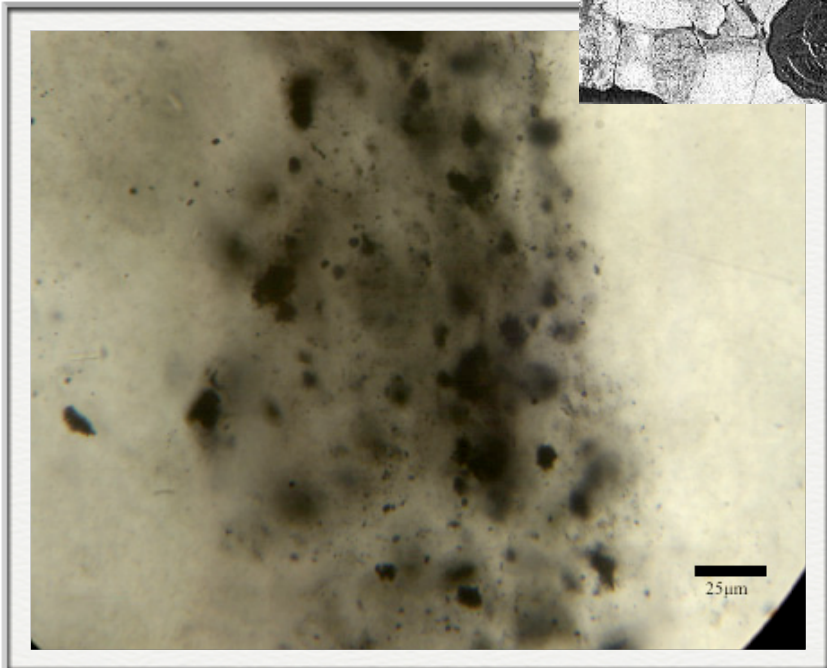
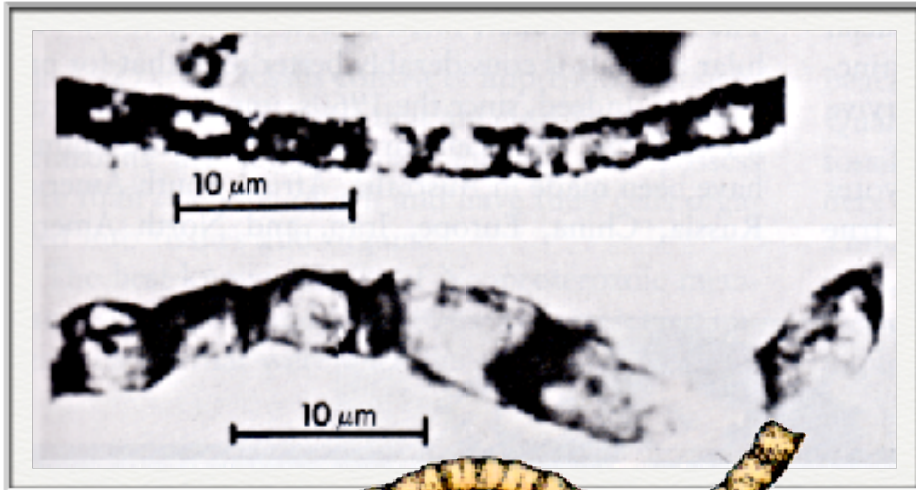


Fig Tree Chert  
3.4 ga  
South Africa

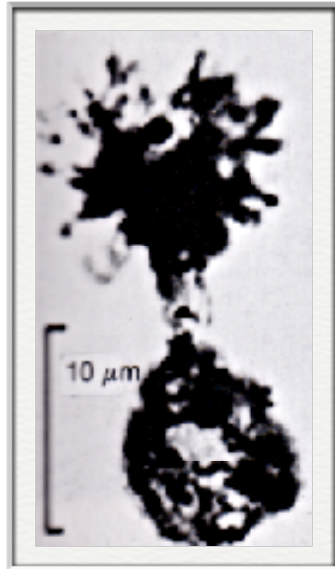


Bulawayo  
2.6 - 2.7 ga  
Zimbabwe, Africa

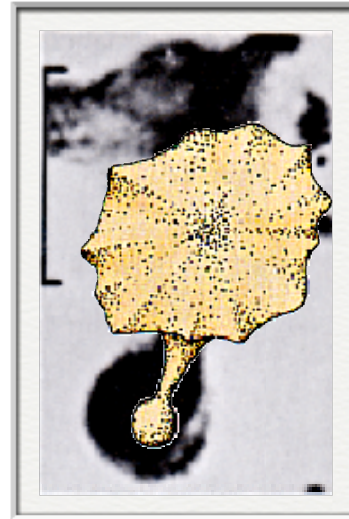
Abundant stromatolites  
forming reefs



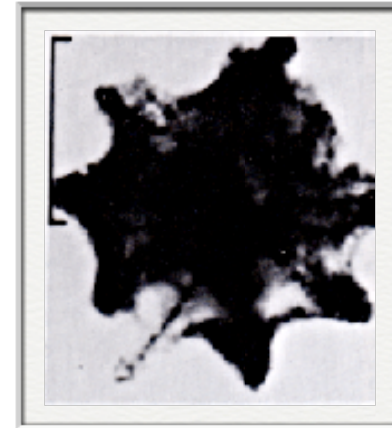
Gunflint Chert (BIF)  
1.9 ga  
Canada



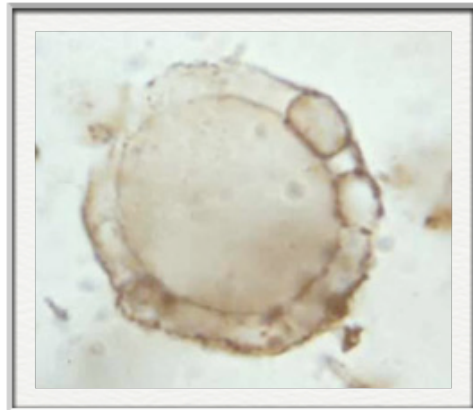
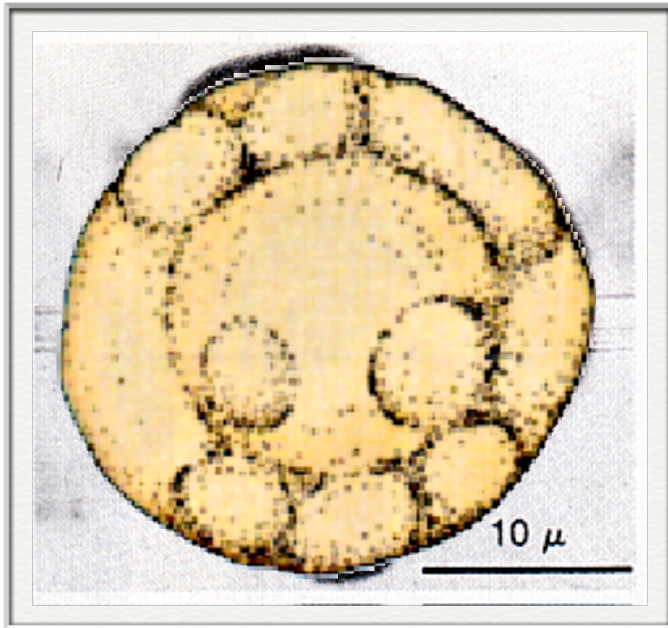
*Kakabekia*



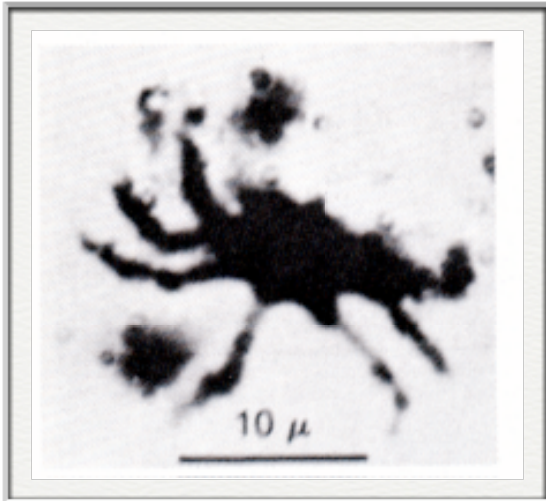
Gunflint Chert (BIF)  
1.9 ga  
Canada



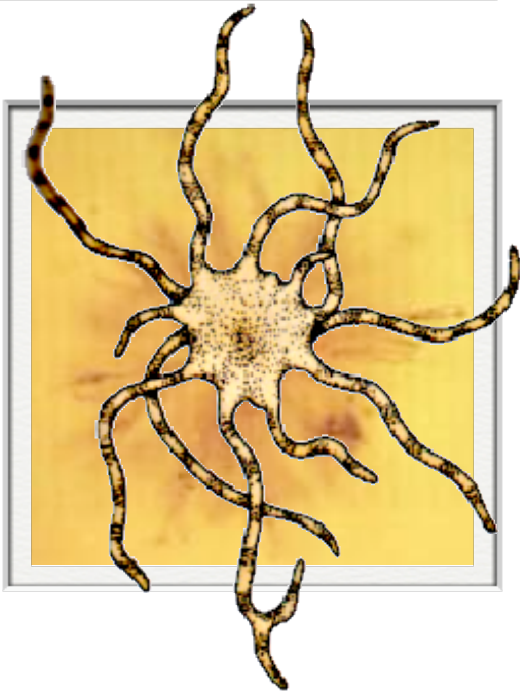
*Eosphaera*



Gunflint Chert (BIF)  
1.9 ga  
Canada



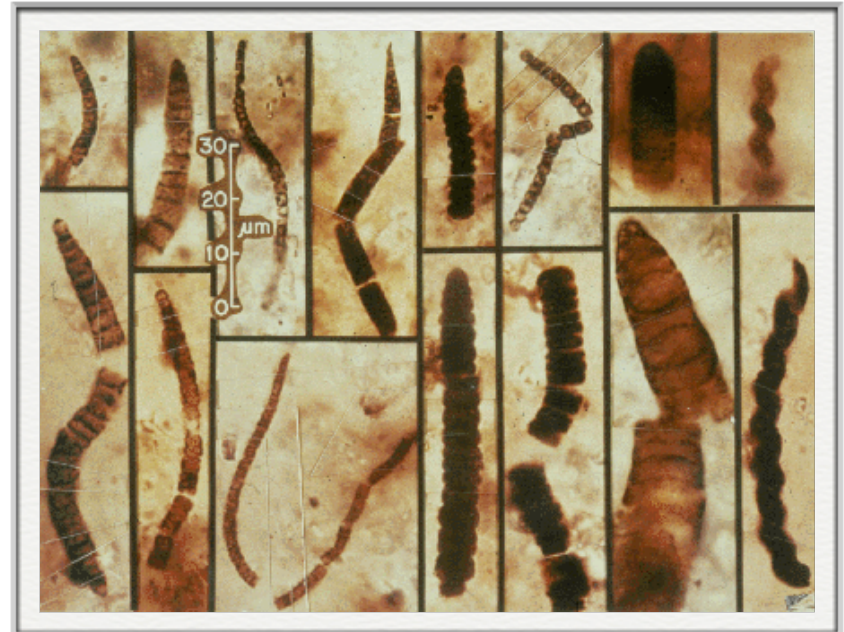
*Eoastrion*



Gunflint Chert (BIF)  
1.9 ga  
Canada

Amelia Dolomite  
1.65 ga  
Australia - FIRST FOSSIL EUKARYOTES

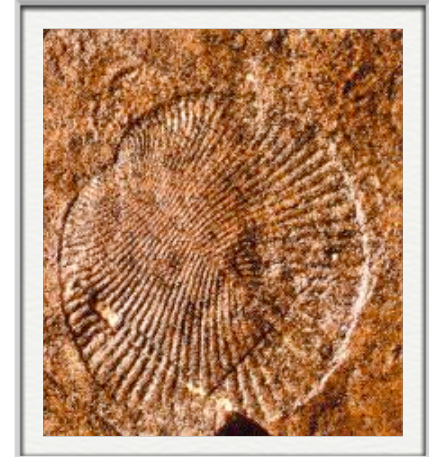
Bitter Springs Chert  
0.9 ga  
Australia - Green algae,  
fungi, protozoans, metazoan  
trace fossils





# EDIACARA FAUNA

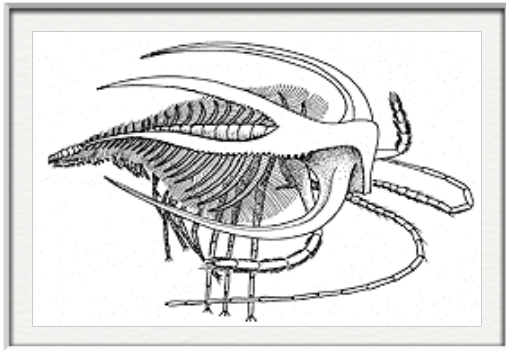
- When this fauna was first described all the taxa were placed in modern phyla
- Later it was suggested that everything here belong in new phyla that had gone extinct at the start of the Cambrian
- Now we believe the truth is somewhere between



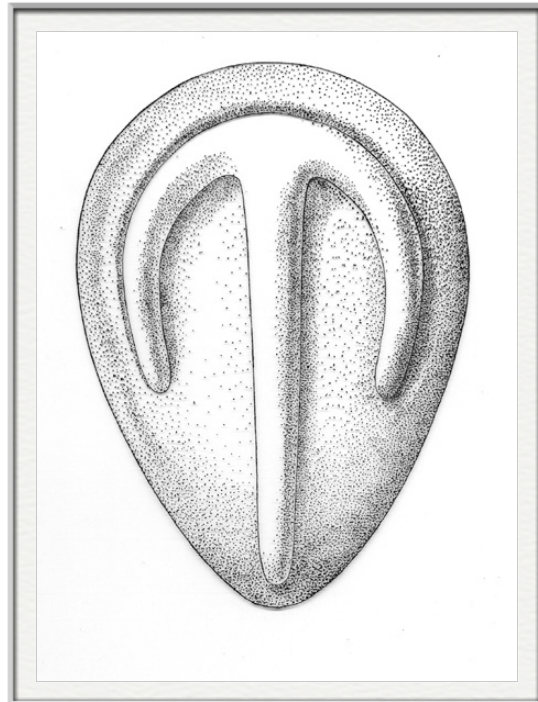
*Dickinsonia* Resembles modern flatworms (Phylum Annelida)



*Spriggina* - Seems to be a very primitive arthropod (Phylum Arthropoda)



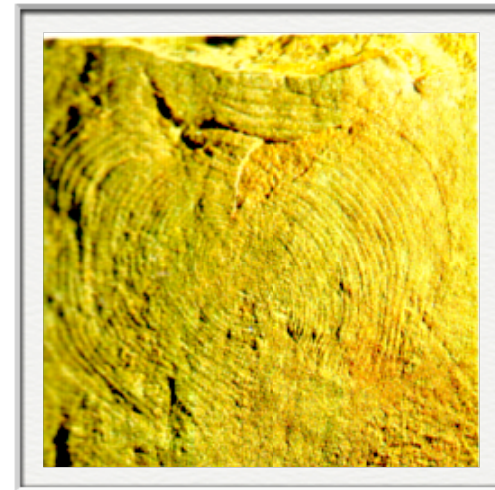
“Lace Crab”-  
Cambrian



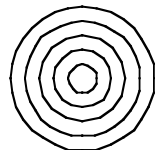
*Parvancorina* - This might be some sort of arthropod - it has a body structure similar to primitive arthropods but without a skeleton.



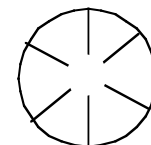
*Ovatoscutum*



Though some circular impressions seem to be jellyfish (Phylum Cnidaria) *Ovatoscutum* has the wrong symmetry to belong to this group.



?????

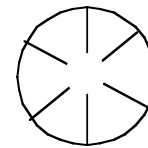


Cnidaria

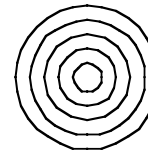


*Mawsonites*

a jellyfish



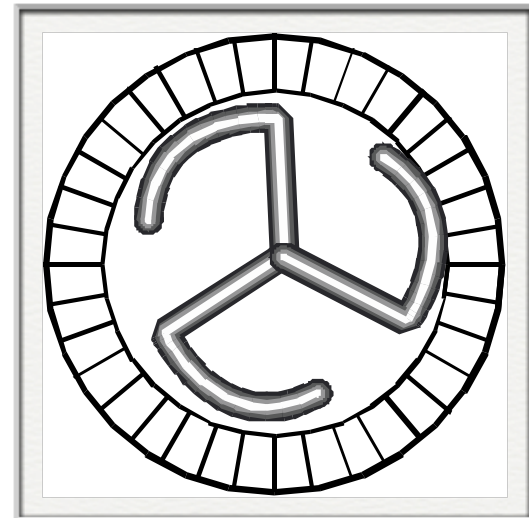
Cnidaria



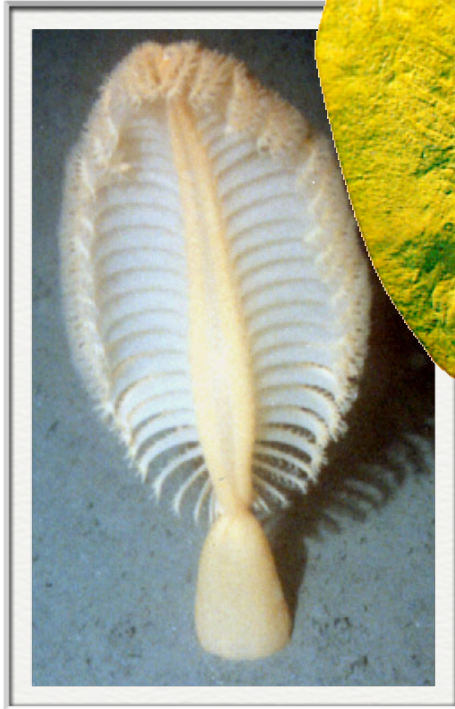
?????



*Tribrachidium*



Phylum ?????  
Some think primitive echinoderm??????



*Charniodiscus*  
Sea Pen (Phy. Cnidaria)

“Waffle animal”

