

Cell Biology
1.5- The Origin of Cells

RNA

bacterium membranes mitochondrion membranes DNA

Essential idea:

- There is an unbroken chain of life from the first cells on Earth to all cells in organisms alive today.

Nature of Science:

- Testing the general principles that underlie the natural world
 - the principle that cells only come from pre-existing cells needs to be verified. (1.9)
 - Scientific evidence lead us to deduce that cells have always worked using the same basic **principles**

Primitive multicellular fossils from the Canadian Arctic: Left, filament of *Bangiomorpha*, the oldest unambiguous alga from the late Mesoproterozoic Hurting Formation (1,200 million years ago); right, *Tappania*, a possible fungus from the early Neoproterozoic Wynnaiat Formation (around 850 million years ago). *Tappania* has a fossil record extending back at least 1,450 million years. © CAMBRIDGE UNIVERSITY. PHOTOS: NICK BUTTERFIELD.

Theory of Knowledge:

- Biology is the study of life, yet life is an emergent property.
- Under what circumstances is a systems approach productive in biology and under what circumstances is a reductionist approach more appropriate?
- How do scientists decide between competing approaches?

Cell Theory (Revisited)

- Cells can only be formed by division of **pre-existing cells**.
- So where did the first cell come from?
- The idea of spontaneous generation was generally accepted as fact.

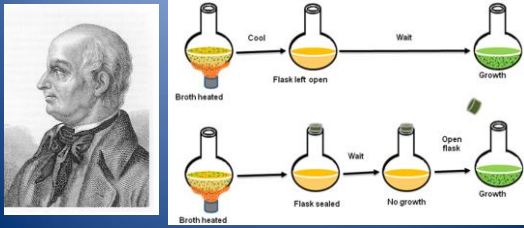
Disproving Spontaneous Generation

- Francisco Redi (1668)**
 - Current belief: Flies come from rotting meat
 - Proof: Flies only come from egg's of other flies

OPEN: FLIES, MAGGOTS
GAUZE: NO FLIES, NO MAGGOTS
PARCHMENT: NO FLIES, NO MAGGOTS

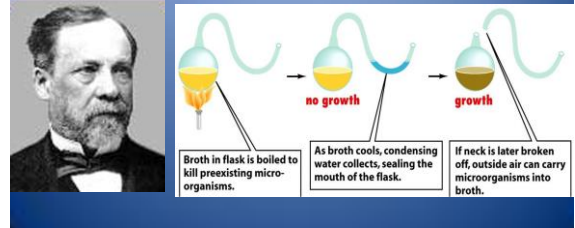
Disproving Spontaneous Generation

- **Lazzaro Spallanzani (1700's)**
 - Current belief: Air forms microorganisms via "vital force".
 - Proof: Boiled broth did not grow microorganisms.
 - Opponents said boiling destroyed the "vital force" in air.
 - Experimental design is critical to gather the relevant data.



Disproving Spontaneous Generation

- **Louis Pasteur (1800's)**
 - Boiled broth in curved-neck flask (allows air in).
 - No microorganisms form till curved neck is removed.
 - Discredited the idea of spontaneous generation.



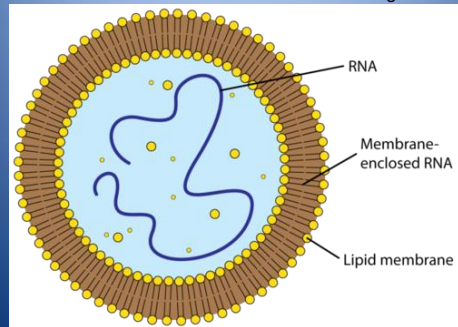
So How Did the First Cell Arise?

- What must a cell do?
- What must a cell have?



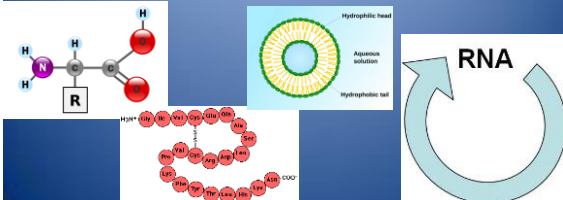
The First Cell

- The first cells must have arisen from non-living material.



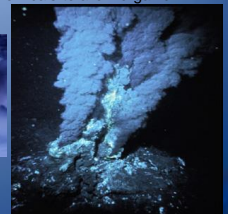
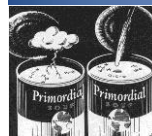
Problems to Overcome

- Non-living synthesis of **simple organic molecules**, e.g. sugars and amino acids.
- Assembly of these organic molecules into **polymers**.
- Formation of polymers that can **self-replicate** (enabling inheritance).
- Formation of **membranes** to package the organic molecules.



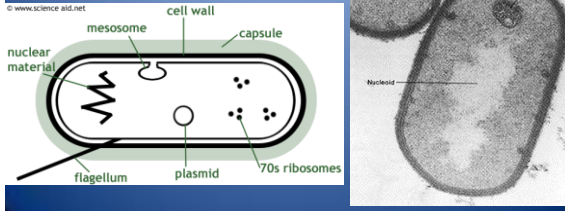
Problems to Overcome

- Primordial conditions used also tended to hydrolyse bonds preventing polymers forming.
- Deep-sea thermal vents
 - Provide heat energy.
 - Provide a ready supply of reduced inorganic chemicals.
 - Vents provide the right conditions and chemicals to allow organic polymers to arise.



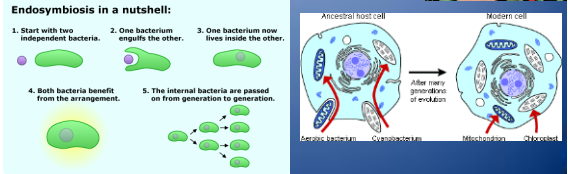
Development of a Nucleus

- As a prokaryote grows in size it develops folds in its membrane to maintain an efficient SA/V ratio (mesosomes).
- The infoldings are pinched off forming an internal membrane.
- The nucleoid region is enclosed in the internal membrane and becomes the nucleus.



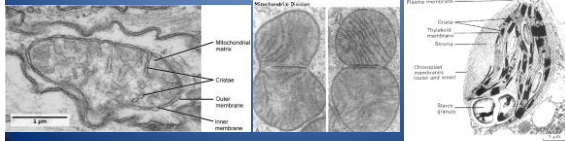
Endosymbiotic Theory

- The origin of eukaryotic cells can be explained by the endosymbiotic theory.
- Proposed by Lynn Margulis (1981)
- Eukaryotes appear 2 billion years ago
 - Mutualism between small aerobic prokaryotes and larger anaerobic prokaryotes
 - Gave rise to mitochondria and chloroplasts



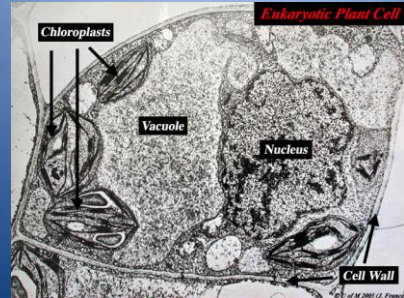
Endosymbiotic Theory

- Proof for Mitochondria and Chloroplasts Endosymbiosis**
 - About the size of bacteria cell
 - Divide by fission
 - Divide independently of host
 - Only produced by division of pre-existing mitochondria and chloroplasts.
 - Have their own 70s ribosomes (like prokaryotes)
 - Have their own DNA (circular)
 - Double membrane (engulfed)
 - Inner membrane has proteins similar to prokaryotes



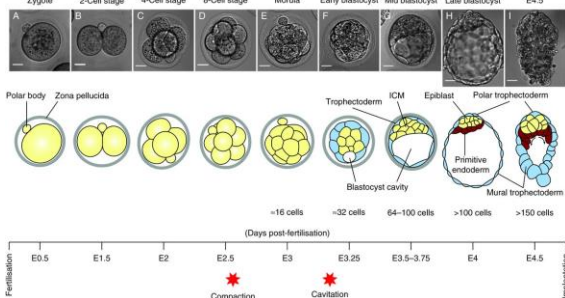
Principles of Life

- No technique or procedure has been developed to form a cell from simpler subunits.



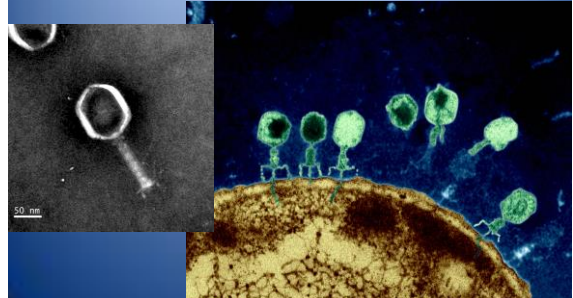
Principles of Life

- All known examples of growth (tissue, organism or population), are all a result of cell division.



Principles of Life

- Viruses do not consist of cells, and they can only be produced inside the host cells that they have infected.



Principles of Life

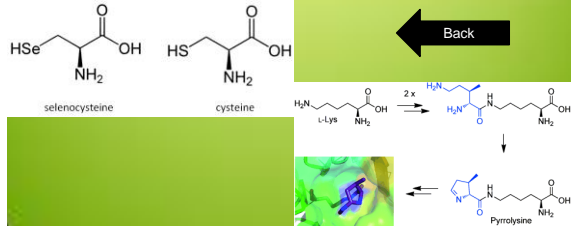
- Genetic code is universal
 - Each of the 64 codons produces the same amino acid in translation, regardless of the organism.
 - Be aware that there are some **minor variations** that are likely to have accrued since the common origin of life on Earth.

		Second Letter																										
		U			C			A			G																	
1st letter	U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U	C	UUC	Leu	UCC	Stop	UAC	Stop	UUA	Leu	UCA	Stop	UAG	Stop	UGC	Trp	U	A	G
	C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U	C	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg	CUA	Leu	CCA	Pro	CAG	His	U	C	A
	A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U	C	AUA	Ile	ACA	Thr	AAC	Asn	AGA	Ser	AUG	Met	ACG	Thr	AAA	Lys	U	C	A
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U	C	GUC	Val	GCC	Ala	GAC	Asp	GGA	Gly	GUA	Val	GCA	Ala	GAA	Asp	U	C	A	
		GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly	U	C																	

Remember 2.4 Notes

Amino Acids

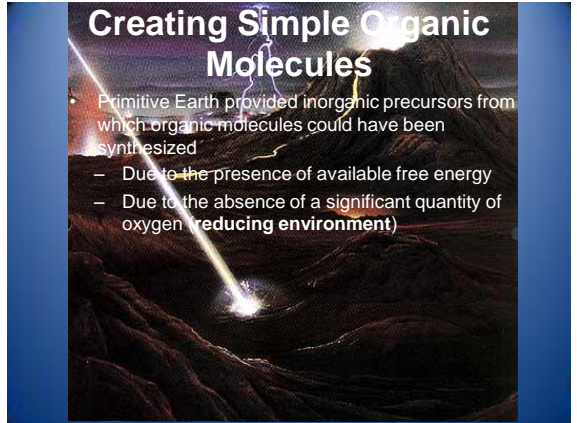
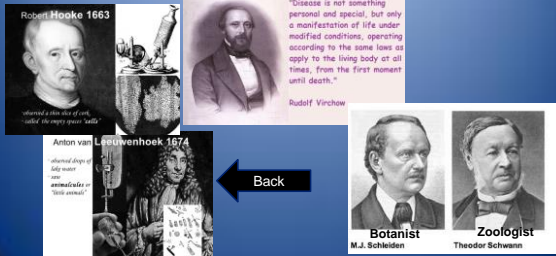
- Most organisms use the same 20 amino acids in the same genetic code although there are some exceptions.
 - 21st: Selenocysteine (derived from UGA stop codon)
 - 22nd: Pyrrolysine (from a methanogen)



Remember from 1.1 Notes

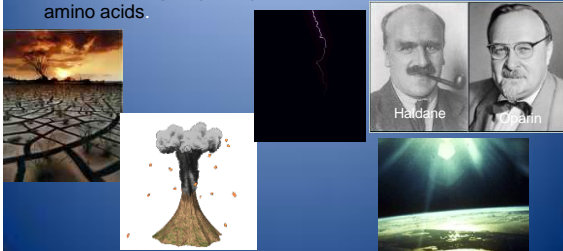
Cell Theory

- Cells are the smallest units of life(1600s).
- All organisms are composed of one or more cells(1839).
- All Cells come from pre-existing cells(1855).



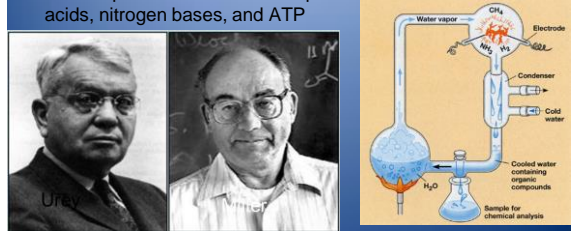
Oparin /Haldane (1923)

- Primitive earth contained ammonia, hydrogen, water vapor, and methane
- No Oxygen (reducing environment)
- Volcanic energy, lightning, and UV radiation could create amino acids.



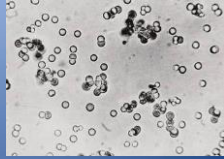
Stanley Miller & Harold Urey (1953)

- Experimented with Oparin's hypothesis
- The gases they used were methane (CH₄), ammonia (NH₃), hydrogen (H₂), and water (H₂O).
- 10-15% of the carbon formed organic compounds.
- Later experiments showed setup can created all 20 amino acids, nitrogen bases, and ATP



Sidney Fox

- Produced proteinoids (abiotic polypeptides)
- Experimental conditions mimic three different scenarios on primordial Earth; hot springs, dried-up lagoons, and pressurized volcanic magma.
- Claimed that the origin of the cell is a microsphere or *protocell*.

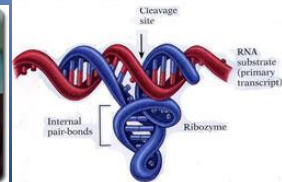


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Thomas Cech

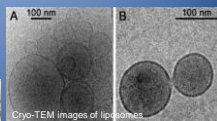
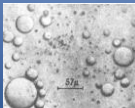
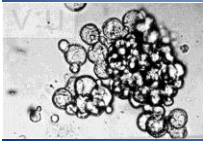
- Discovered the catalytic properties of RNA.
- DNA is not able to self-replicate – enzymes are required.
- RNA can both store information and catalyze the formation of copies of itself.
 - **Ribozymes** can act as enzymes and self-replicate
 - RNA appears to be the **first genetic material**
- Known as the RNA World Hypothesis

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Simple Membranes

- **Microspheres**
 - Form when proteinoids are mixed with cool water
 - Surrounded by a selectively permeable membrane
- **Liposomes**- Form when phospholipids form a bilayered membrane in water
- **Coacervates**- Colloidal drops of polypeptides, nucleic acids and polysaccharides



Cryo-TEM images of liposomes

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Coacervate droplets formed by interaction of gelatin (a protein) & gum arabic A.J. Osorio