1.5 Origin of cells

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

In the background you can see Late Mesoproterozoic and Neoproterozoic eukaryotic fossils images of cells. We know from such evidence that cells have always worked using the same basic principles.

By Chris Paine

https://bioknowledgy.weebly.com/

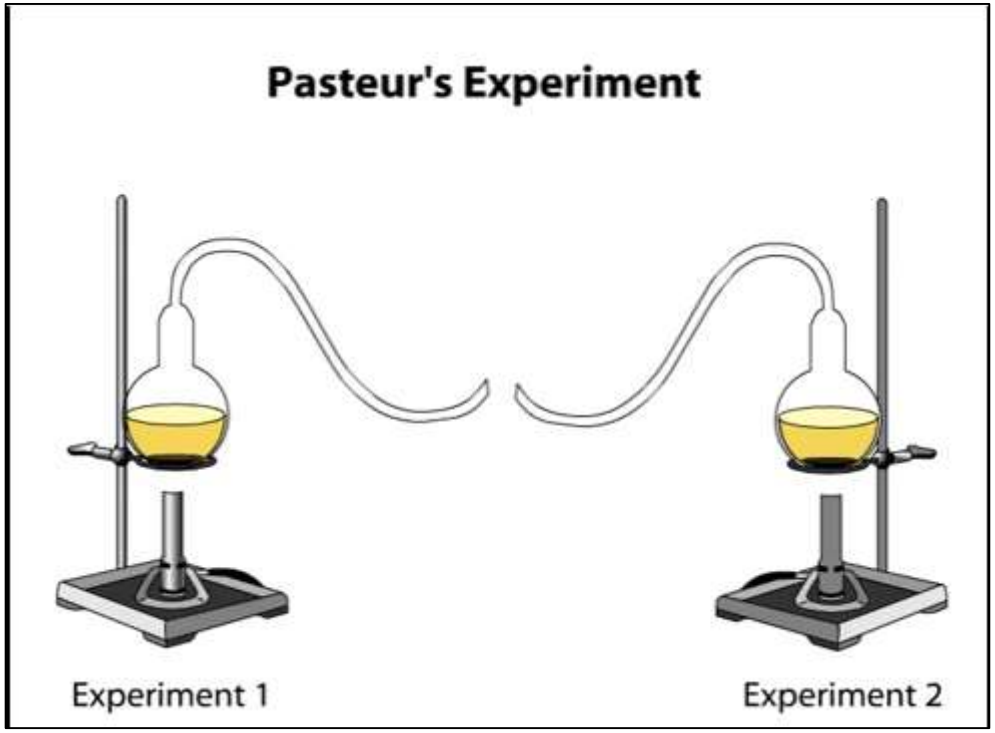
http://rstb.royalsocietypublishing.org/content/361/1470/1023/F3.large.jpg

Understandings, Applications and Skills

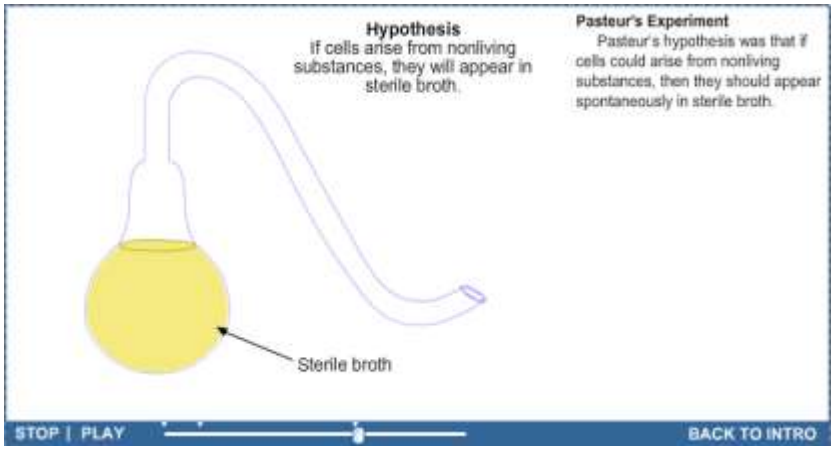
	Statement	Guidance
1.5.U1	Cells can only be formed by division of pre-existing cells.	Students should be aware that the 64 codons in the genetic code have the same meanings in nearly all organisms, but that there are some minor variations that are likely to have accrued since the common origin of life on Earth.
1.5.U2	The first cells must have arisen from non-living material.	
1.5.U3	The origin of eukaryotic cells can be explained by the endosymbiotic theory.	Evidence for the endosymbiotic theory is expected. The origin of eukaryote cilia and flagella does not need to be included.
1.5.A1	Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.	

1.5.A1 Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

Use the tutorials to learn about Pasteur's experiment.



https://youtu.be/Xc-hHhDID9A
http://bcs.whfreeman.com/webpub/biology/sadavalife9e/animated%20tutorials/life9e_0401_pasteurs_exp.swf



http://www.sumanasinc.com/webcontent/animations/content/scientificmethod.html

Repeat Pasteur's experiment and see the results for yourself.

http://biologyjunction.com/pasteur_experiment.htm

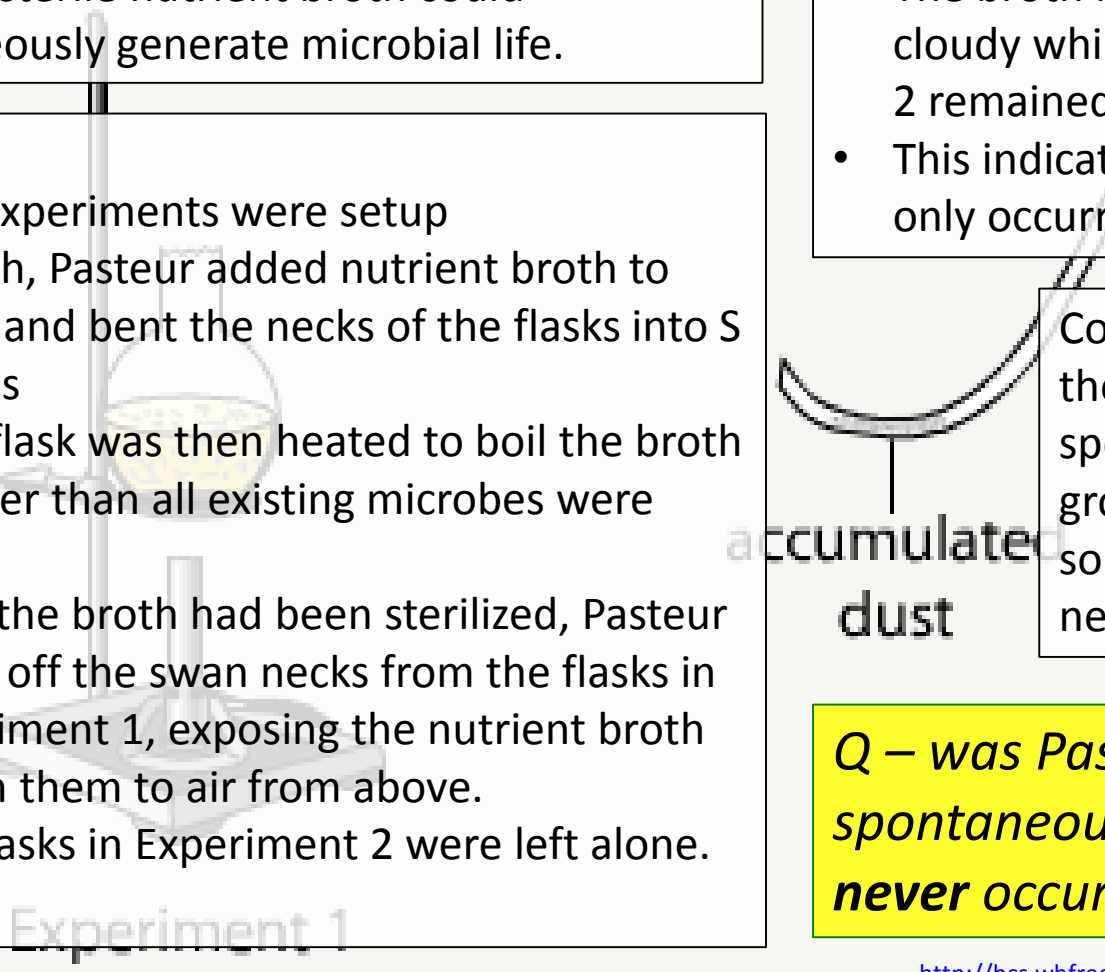
1.5.A1 Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

Pasteur's Experiment

Louis Pasteur designed an experiment to test whether sterile nutrient broth could spontaneously generate microbial life.

Method:

- Two experiments were setup
- In both, Pasteur added nutrient broth to flasks and bent the necks of the flasks into S shapes
- Each flask was then heated to boil the broth in order than all existing microbes were killed.
- After the broth had been sterilized, Pasteur broke off the swan necks from the flasks in Experiment 1, exposing the nutrient broth within them to air from above.
- The flasks in Experiment 2 were left alone.



Results:

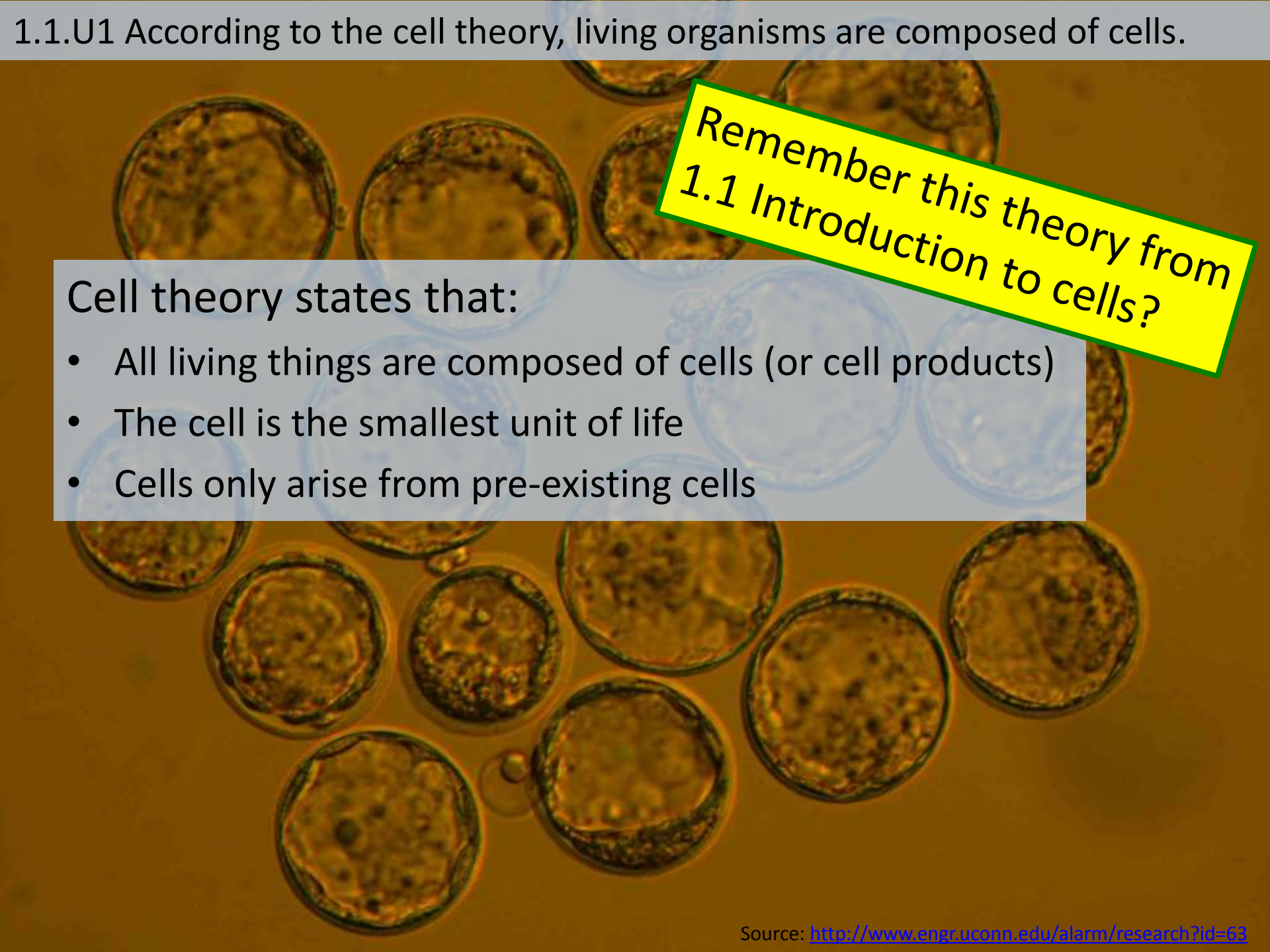
- The broth in experiment 1 turned cloudy whilst the broth in experiment 2 remained clear.
- This indicates that microbe growth only occurred in experiment 1.

Conclusion: Pasteur rejected the hypothesis of spontaneous generation as for growth of microbes to occur a source of contamination was needed.

Q – was Pasteur correct, could spontaneous generation of life ***never*** *occur?*

http://bcs.whfreeman.com/thelifewire/content/chp03/0302003.html

1.1.U1 According to the cell theory, living organisms are composed of cells.



Remember this theory from 1.1 Introduction to cells?

Cell theory states that:

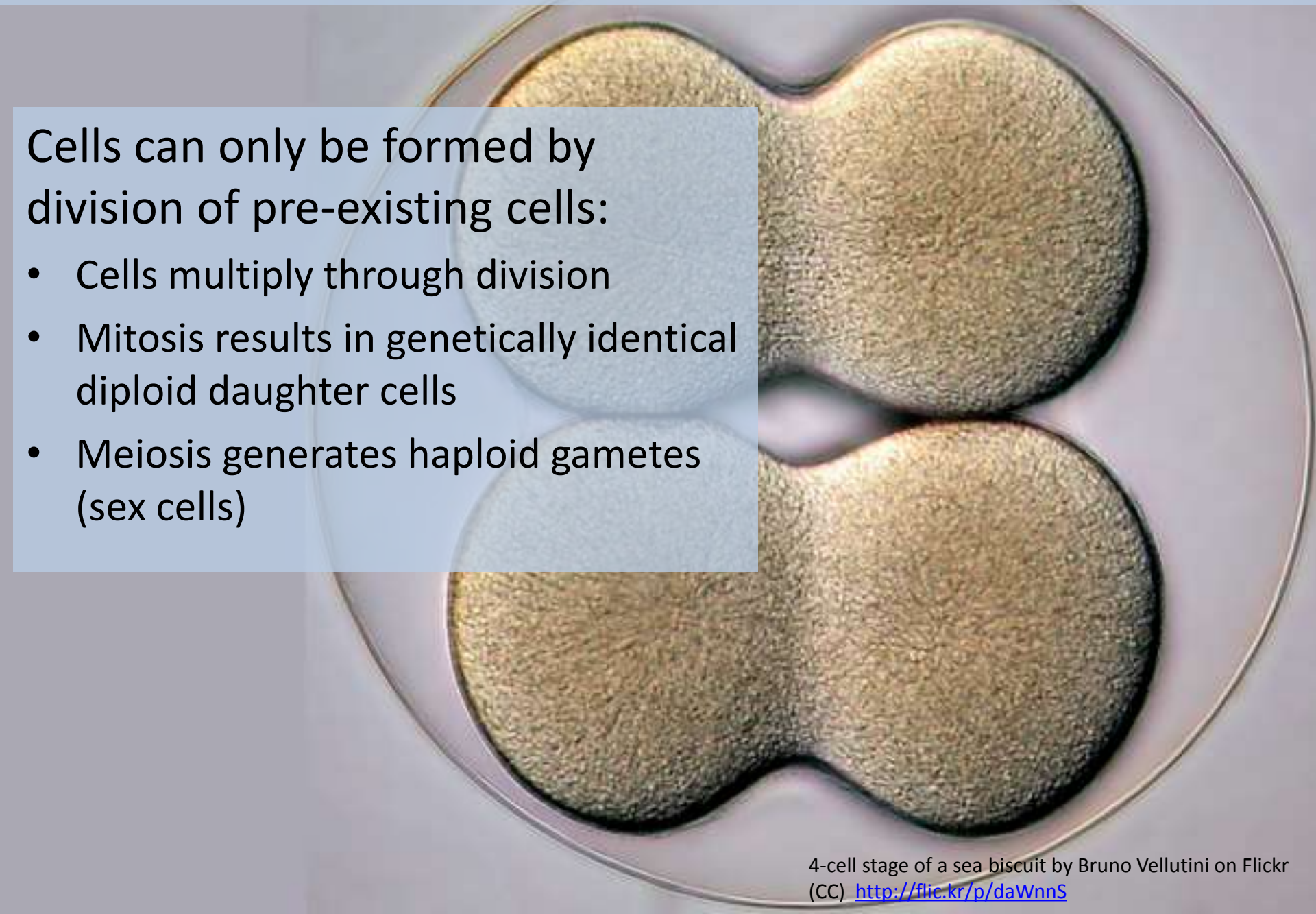
- All living things are composed of cells (or cell products)
- The cell is the smallest unit of life
- Cells only arise from pre-existing cells

Source: http://www.engr.uconn.edu/alarm/research?id=63

1.5.U1 Cells can only be formed by division of pre-existing cells.

Cells can only be formed by division of pre-existing cells:

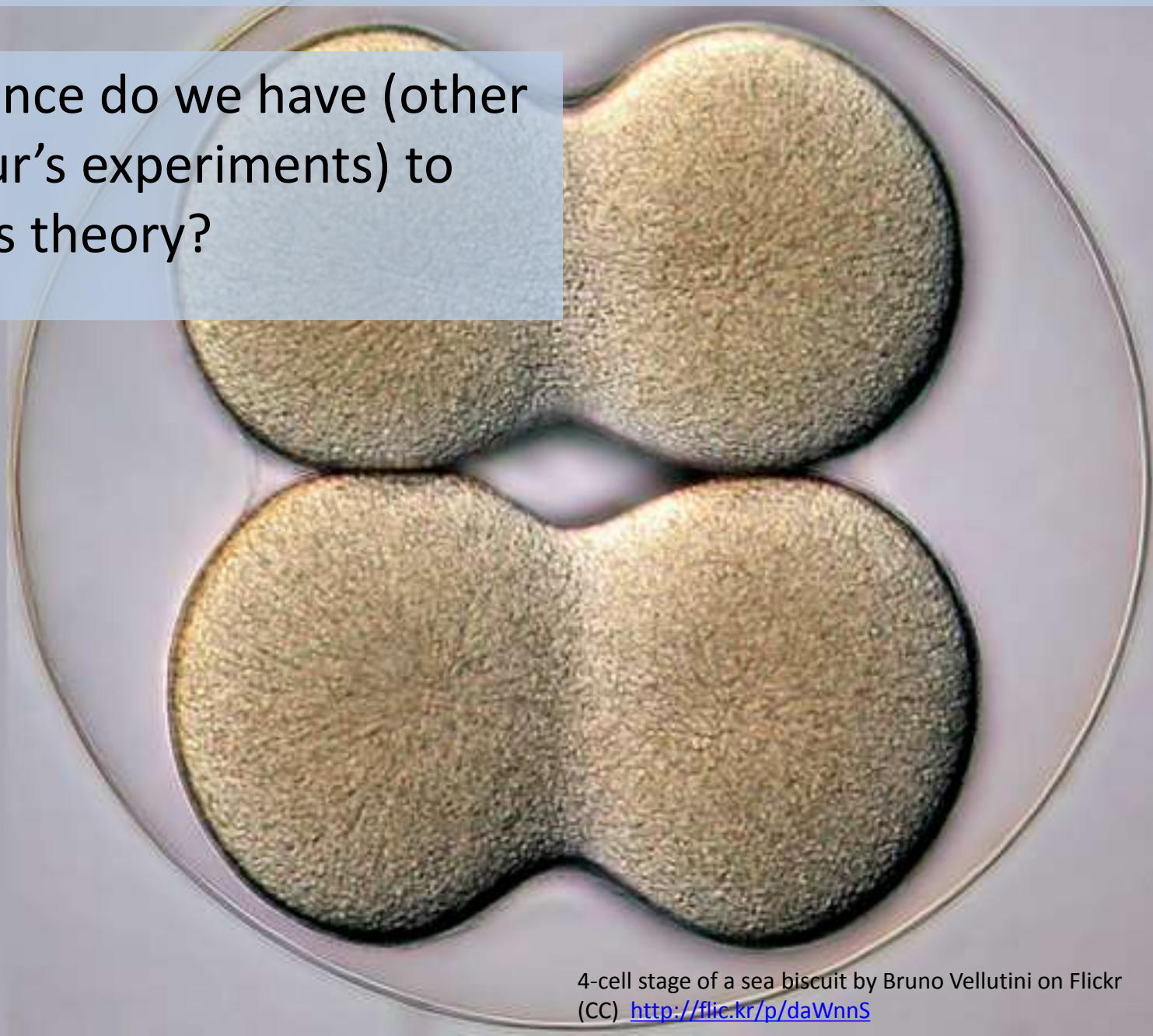
- Cells multiply through division
- Mitosis results in genetically identical diploid daughter cells
- Meiosis generates haploid gametes (sex cells)



4-cell stage of a sea biscuit by Bruno Vellutini on Flickr (CC) http://flic.kr/p/daWnnS

1.5.U1 Cells can only be formed by division of pre-existing cells.

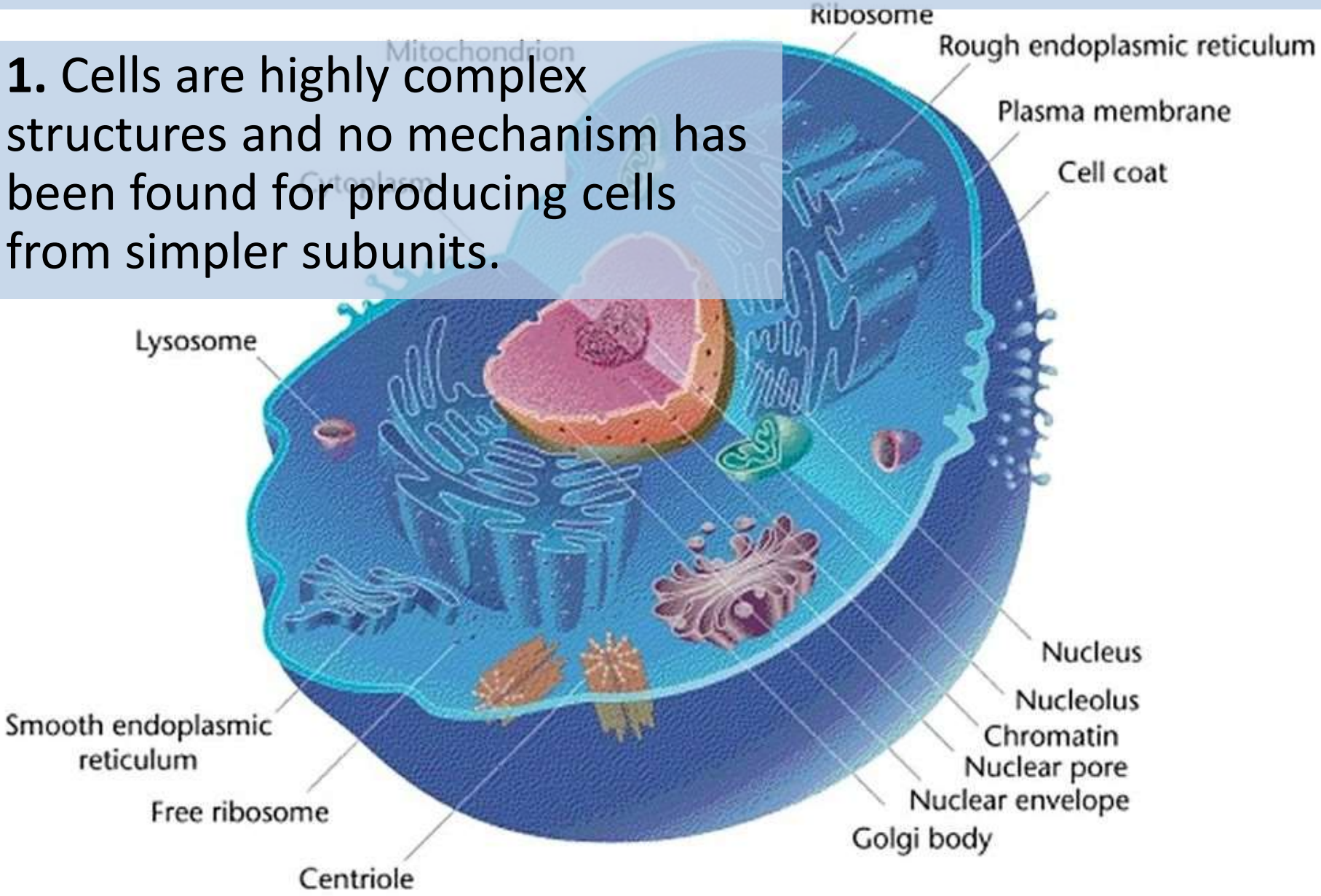
What evidence do we have (other than Pasteur's experiments) to support this theory?



4-cell stage of a sea biscuit by Bruno Vellutini on Flickr (CC) http://flic.kr/p/daWnnS

1.5.U1 Cells can only be formed by division of pre-existing cells.

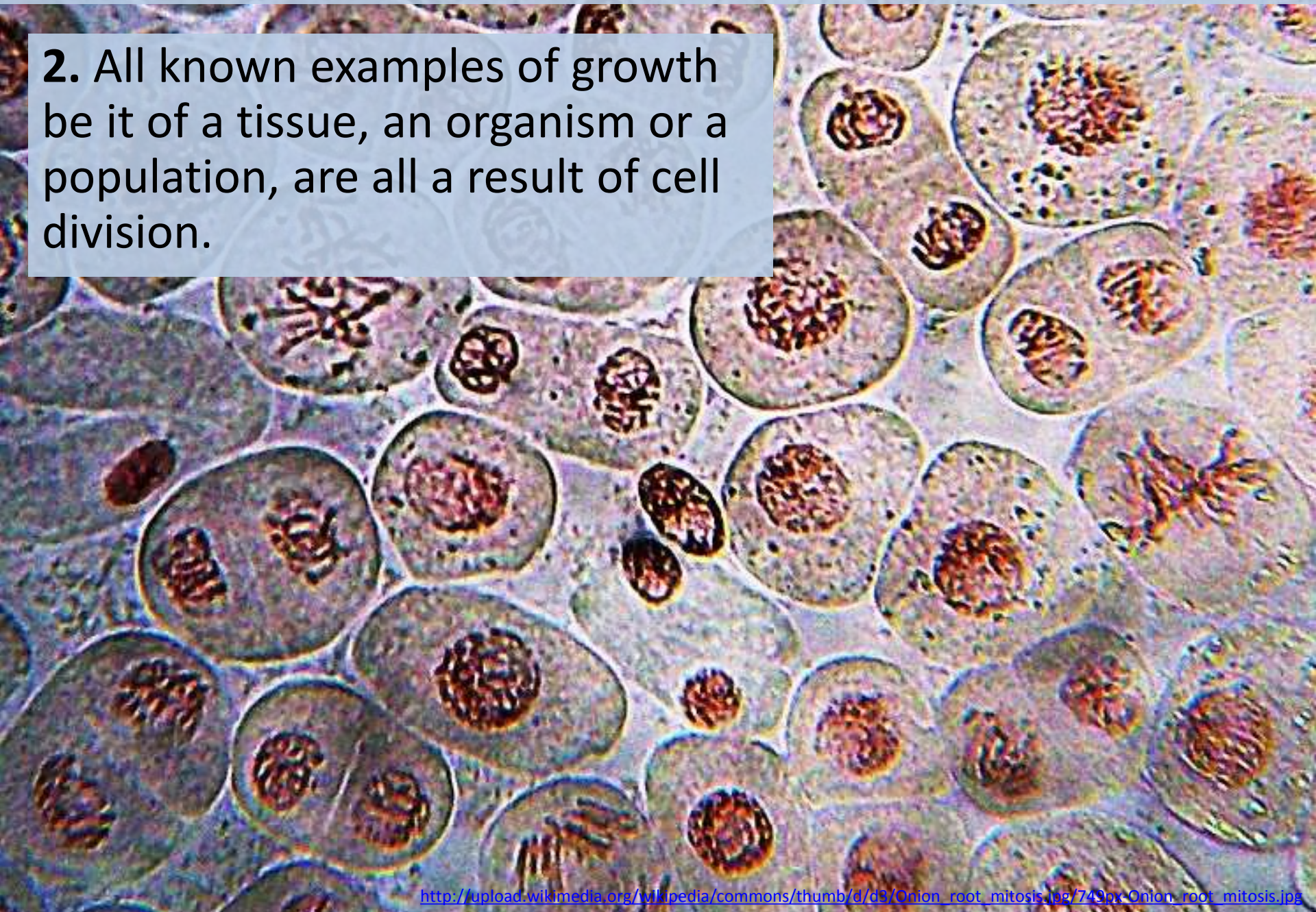
1. Cells are highly complex structures and no mechanism has been found for producing cells from simpler subunits.



http://upload.wikimedia.org/wikipedia/commons/thumb/3/3e/Eukaryotic_Cell_%28animal%29.jpg/1024px-Eukaryotic_Cell_%28animal%29.jpg

1.5.U1 Cells can only be formed by division of pre-existing cells.

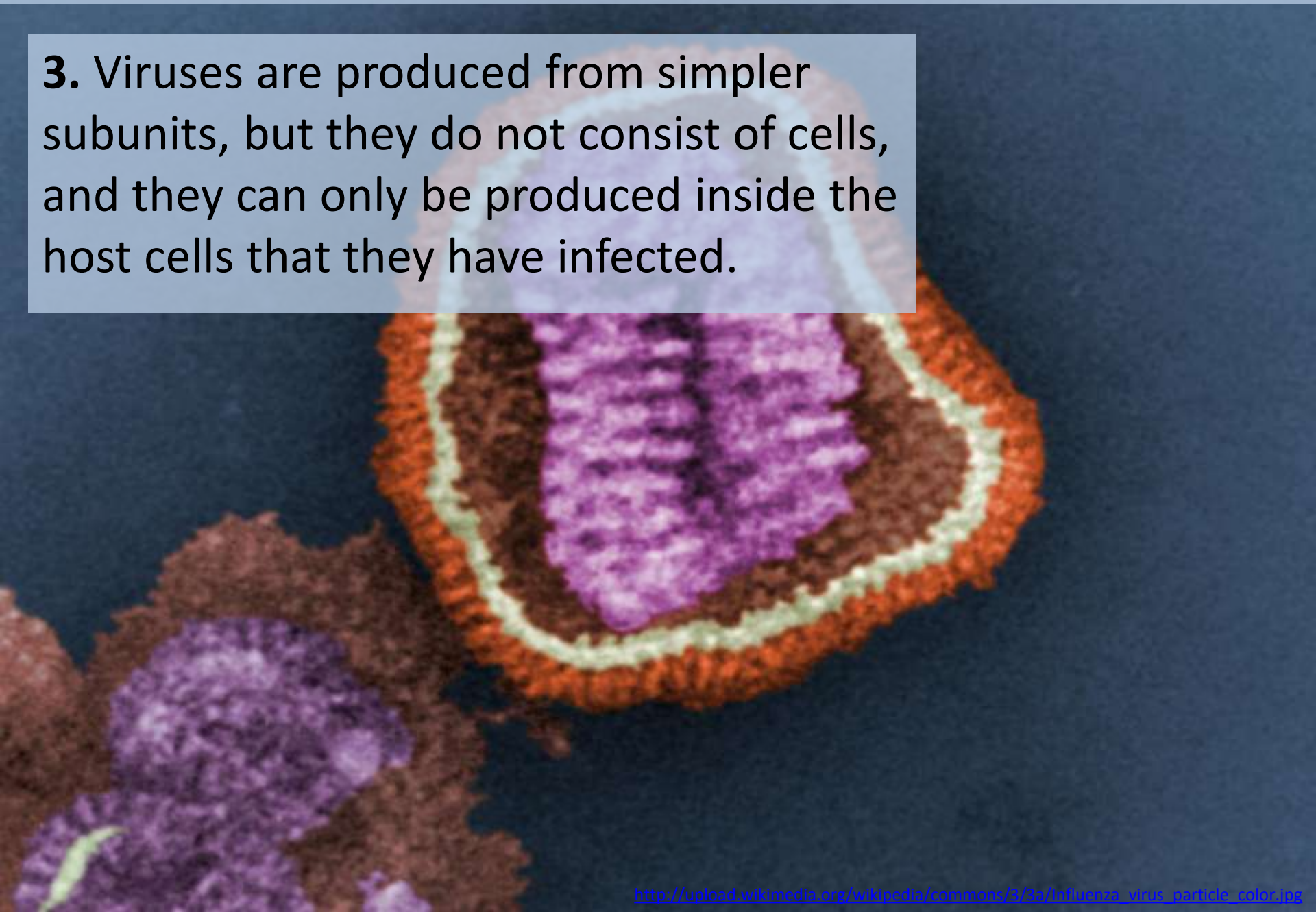
2. All known examples of growth be it of a tissue, an organism or a population, are all a result of cell division.



http://upload.wikimedia.org/wikipedia/commons/thumb/d/d3/Onion_root_mitosis.jpg/749px-Onion_root_mitosis.jpg

1.5.U1 Cells can only be formed by division of pre-existing cells.

3. Viruses are produced from simpler subunits, but they do not consist of cells, and they can only be produced inside the host cells that they have infected.

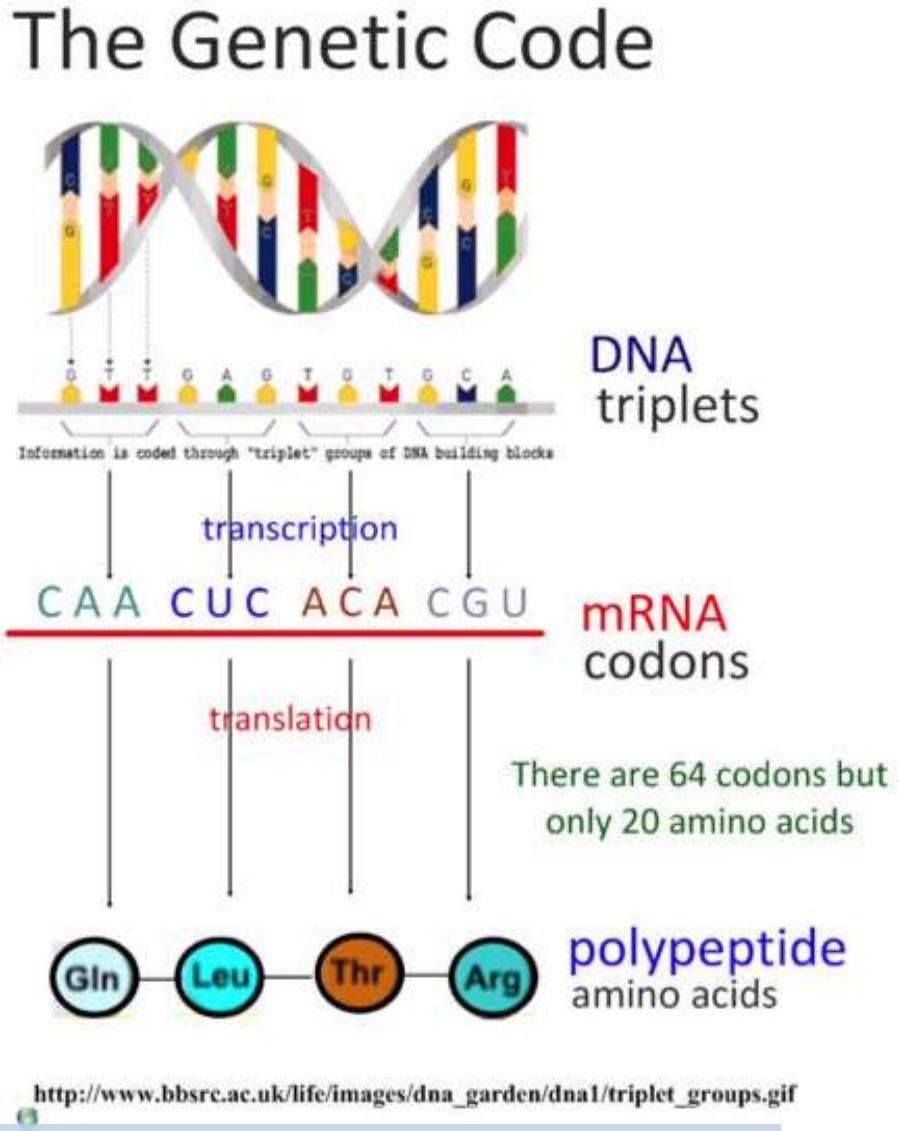


http://upload.wikimedia.org/wikipedia/commons/3/3a/Influenza_virus_particle_color.jpg

1.5.U1 Cells can only be formed by division of pre-existing cells.

4. Genetic code is universal each of the 64 codons (a codon is a combination of 3 DNA bases) produces the same amino acid in translation, regardless of the organism [2.7.A2]*.

The logical deduction is that all cells have arisen as the result of cell division from a single common ancestor.



* *There are some minor variations that are likely to have accrued since the common origin of life on Earth, but these are rare and most of the genetic code is universal most of the time.*

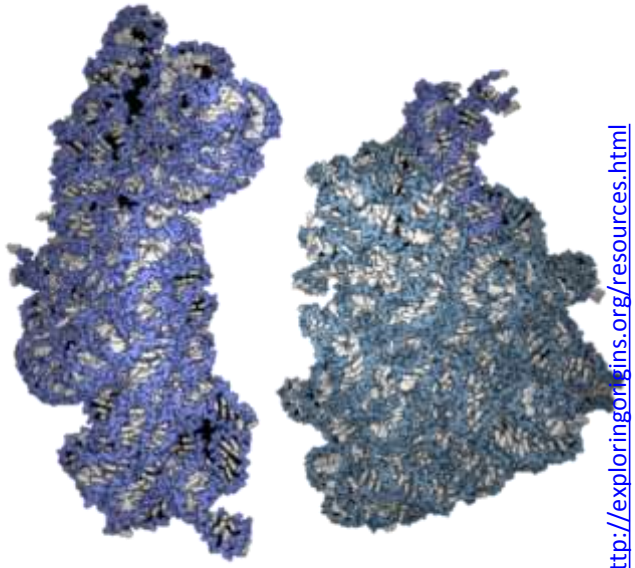
http://www.slideshare.net/gurustip/protein-synthesis-35-transcription-translation-sl

1.5.U2 The first cells must have arisen from non-living material.

If we accept that there were times in the history of the Earth when cells did not exist then it is an obvious point that 'The first cells must have arisen from non-living material'. The only other possible explanation is that life, in the form of cells, was transported here from elsewhere in the universe. As illustrated above, it is extremely difficult (and given our level of technology currently impossible), to generate cells from anything but other cells. So how did the first cells arise?

Some of the key problems are:

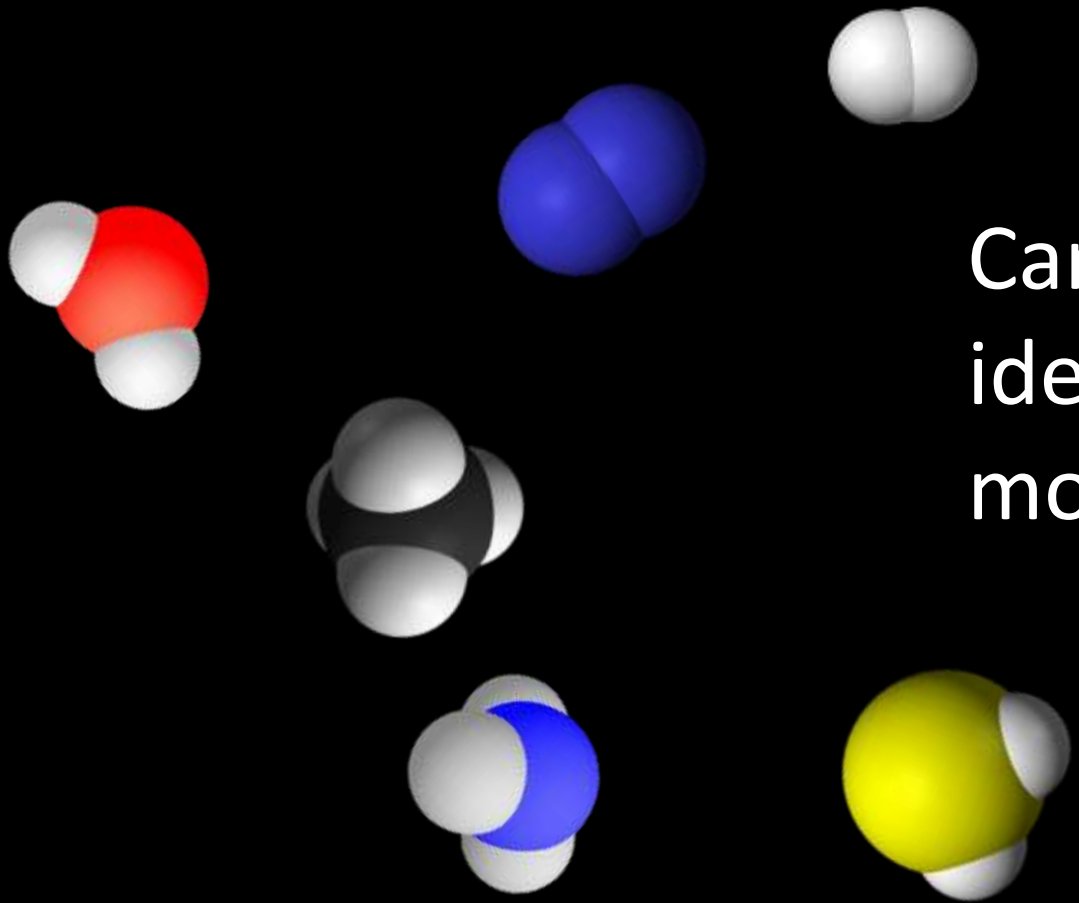
1. Non-living synthesis of simple organic molecules, e.g. sugars and amino acids
2. Assembly of these organic molecules into polymers
3. Formation of polymers that can self-replicate (enabling inheritance)
4. Formation of membranes to package the organic molecules



http://exploringorigins.org/resources.html

1.5.U2 The first cells must have arisen from non-living material.

Earth's atmosphere was 'reducing' in the early days. It did not contain oxygen gas until after plants started photosynthesising



Can you identify these molecules?

1.5.U2 The first cells must have arisen from non-living material.

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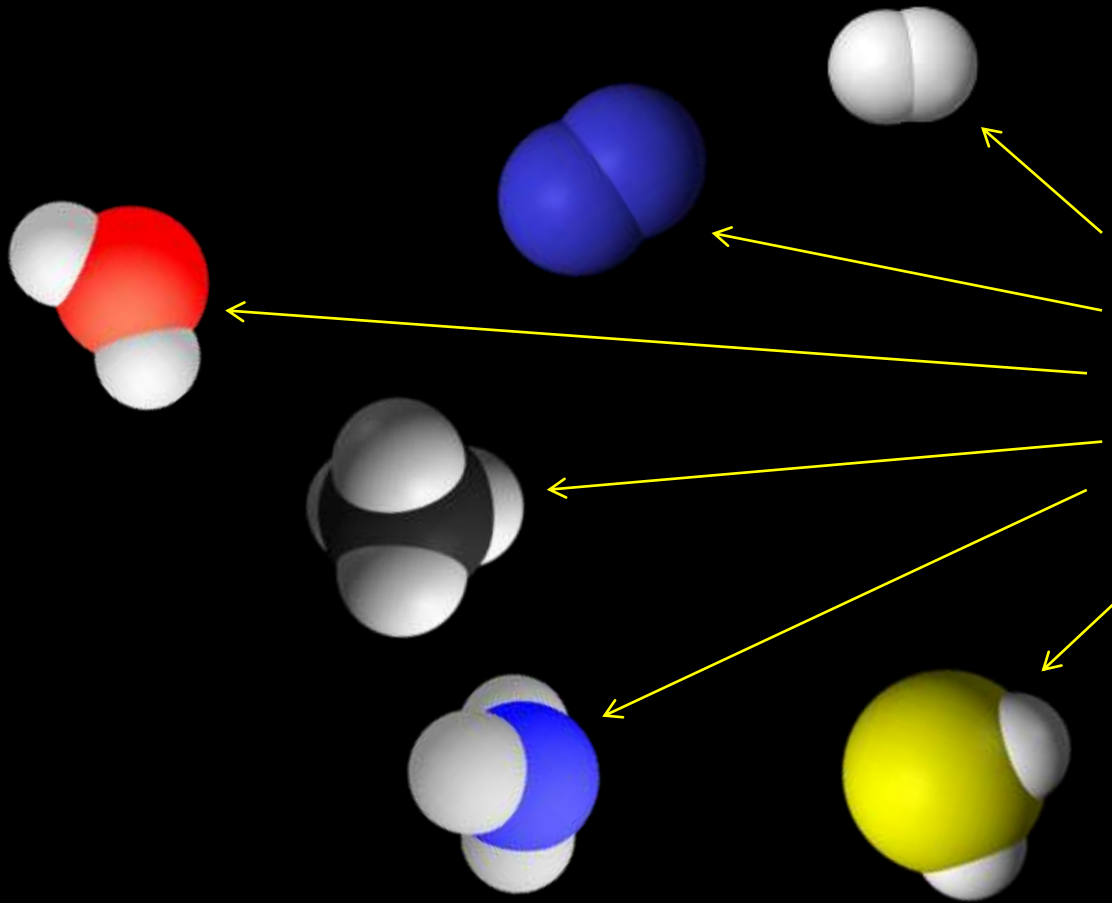


The atmosphere contained:
Hydrogen
Nitrogen
Water vapour
Methane
Ammonia
Hydrogen sulfide

The gases came from abundant volcanic activity

1.5.U2 The first cells must have arisen from non-living material.

These monomers mixed in the **'primeval soup',** shallow oceans laden with chemicals where it is thought that they reacted to form biological molecules

Miller and **Urey** tried to recreate these conditions in the lab in **1953**

They were trying to demonstrate **'chemical evolution',** the formation of more complex molecules from simpler stock in the primeval soup

They combined the molecules from the previous page in a closed glass vessel **(simulated atmosphere),** they heated the water **(simulated volcanic activity)** and sparked electricity through the gases **(simulated lightning)**

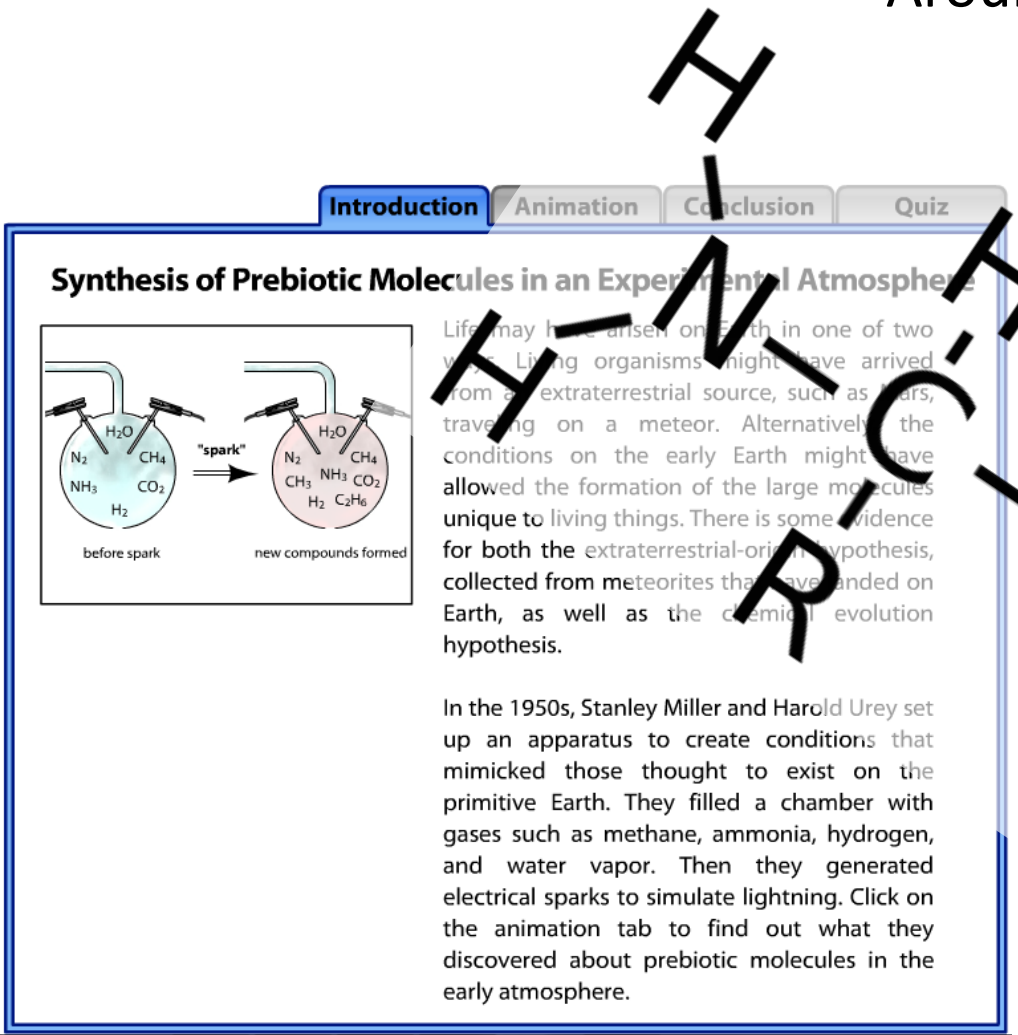
http://www.flickr.com/photos/afeman/663646181/

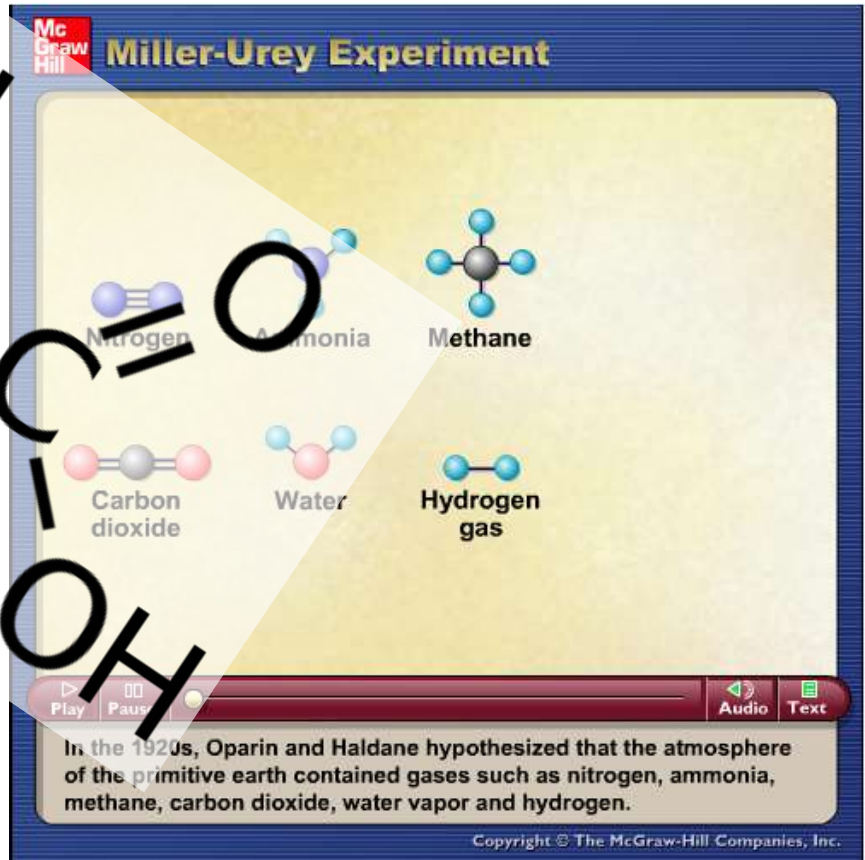
1.5.U2 The first cells must have arisen from non-living material.

After a week they found:

Thirteen of the twenty naturally occurring amino acids

Around 15% of the carbon was now in organic compounds



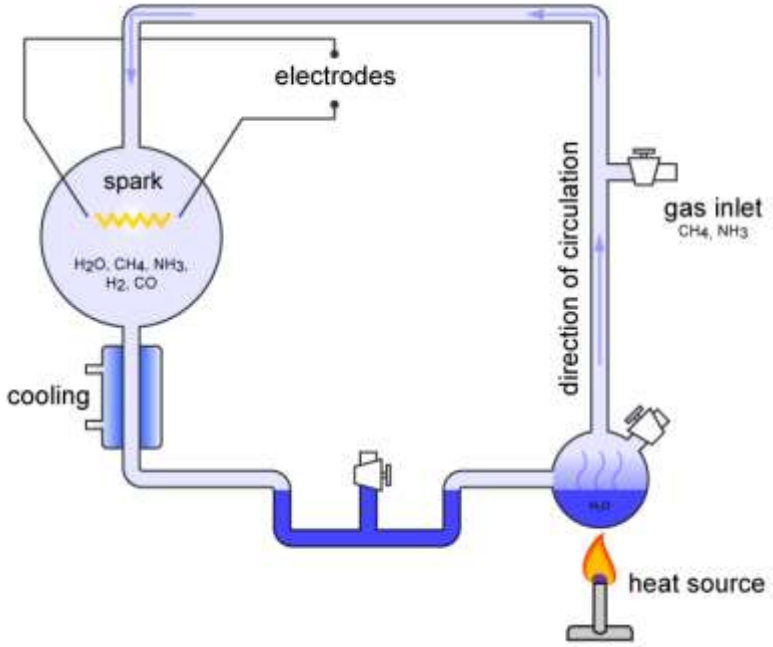


1.5.U2 The first cells must have arisen from non-living material.

1. Non-living synthesis of simple organic molecules:

Miller and Urey recreated the conditions of pre-biotic Earth in a closed system.

- These conditions included a reducing atmosphere (low oxygen), high radiation levels, high temperatures and electrical storms
- Water was boiled to form vapour and then was mixed with methane, ammonia and hydrogen
- The mixture of gases was exposed to an electrical discharge (sparks) to simulate lightning



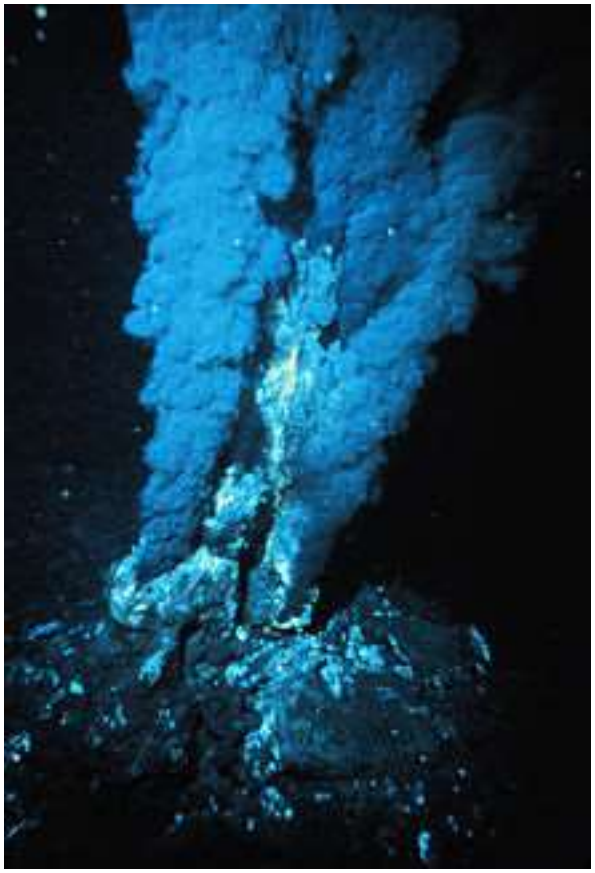
- The mixture was then allowed to cool and after one week was found to contain some simple amino acids and complex oily hydrocarbons
- Based on these findings, it was concluded that under the hypothesised conditions of pre-biotic Earth, organic molecules could be formed

Carny http://upload.wikimedia.org/wikipedia/commons/5/59/MUexperiment.png

1.5.U2 The first cells must have arisen from non-living material.

2. Assembly of these organic molecules into polymers:

Miller and Urey's experiments allowed for the formation of amino acids, **but** the conditions used also tended to hydrolyse bonds preventing polymers forming.



Deep-sea thermal vents

- Fissures in a planet's surface from which geothermally heated water issues. Vents are commonly found near in volcanically active areas)
- Along with heat energy the Vents issue a ready supply of reduced inorganic chemicals
- Vents provide the right conditions and chemicals to allow organic polymers to arise.

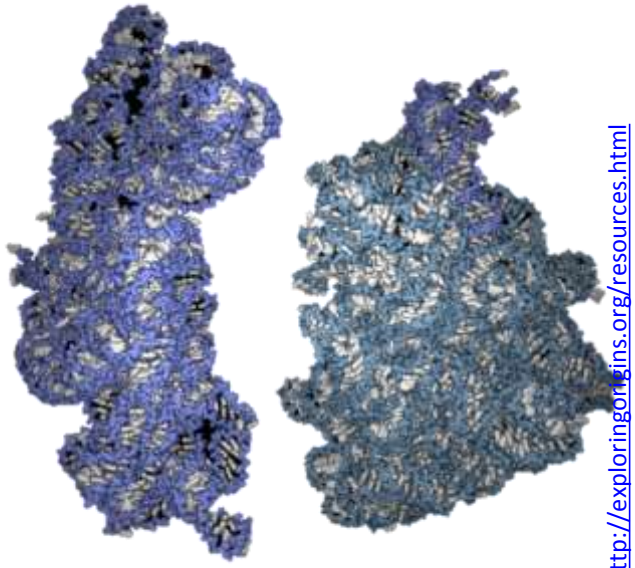
http://upload.wikimedia.org/wikipedia/commons/thumb/6/6f/Blacksmoker_in_Atlantic_Ocean.jpg/220px-Blacksmoker_in_Atlantic_Ocean.jpg

1.5.U2 The first cells must have arisen from non-living material.

3. Formation of polymers that can self-replicate (enabling inheritance)

- DNA though very stable and effective at storing information is not able to self-replicate – enzymes are required
- However RNA can both store information and self-replicate - it can catalyse the formation of copies of itself.
- In ribosomes RNA is found in the catalytic site and plays a role in peptide bond formation

For more detail research the RNA World Hypothesis

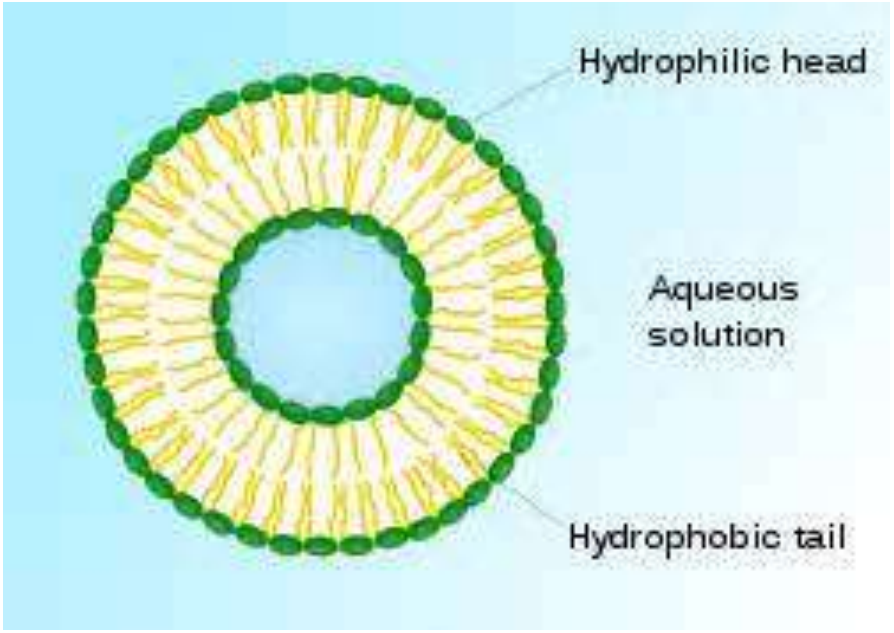


http://exploringorigins.org/resources.html

1.5.U2 The first cells must have arisen from non-living material.

4. Formation of membranes to package the organic molecules

Experiments have shown that phospholipids natural assemble into bilayers, if conditions are correct.
Formation of the bilayer creates an isolated internal environment.
The formation of an internal environment means that optimal conditions, e.g. for replication or catalysis can be maintained.

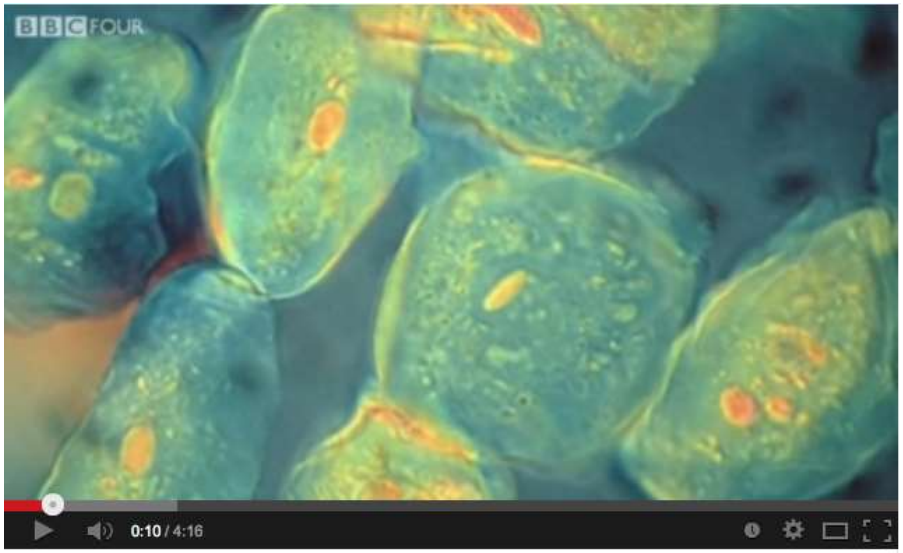


http://upload.wikimedia.org/wikipedia/commons/thumb/0/01/Liposome_scheme-en.svg/220px-Liposome_scheme-en.svg.png

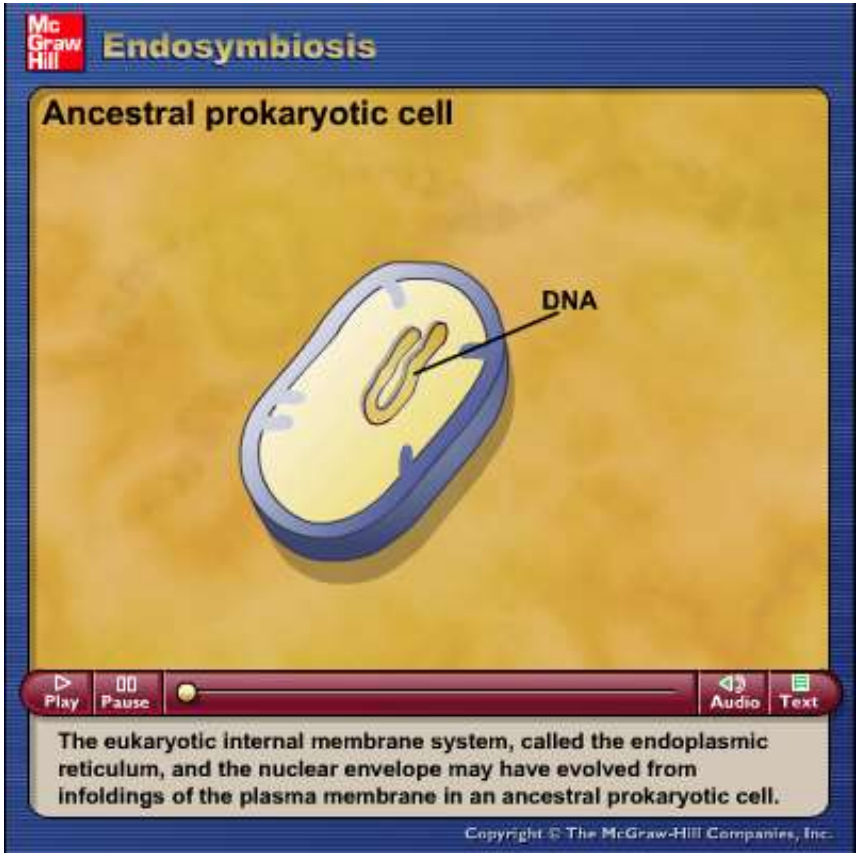
1.5.U3 The origin of eukaryotic cells can be explained by the endosymbiotic theory.

Endosymbiotic theory explains the existence of several organelles of eukaryotes. The theory states that the organelles (e.g. mitochondria and chloroplasts) originated as symbioses between separate single-celled organisms,

Use the video and/or the tutorial to understand how this occurred.



How did the evolution of complex life on Earth begin? - The Gene Code, Episode 1 - BBC Four http://youtu.be/q71DWYJD-dI

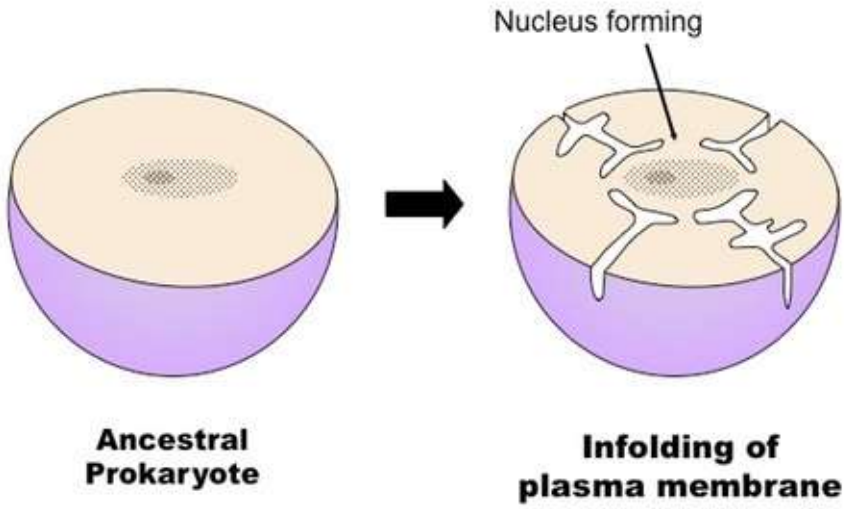


https://highered.mheducation.com/sites/9834092339/student_view0/chapter4/animation_-_endosymbiosis.html

1.5.U3 The origin of eukaryotic cells can be explained by the endosymbiotic theory.

Development of the Nucleus

- A prokaryote grows in size and develops folds in it's membrane to maintain an efficient SA:Vol
- The infoldings are pinched off forming an internal membrane
- The nucleoid region is enclosed in the internal membrane and hence becomes the nucleus



http://ib.bioninja.com.au/options/option-d-evolution-2/d1-origins-of-life-on-earth.html

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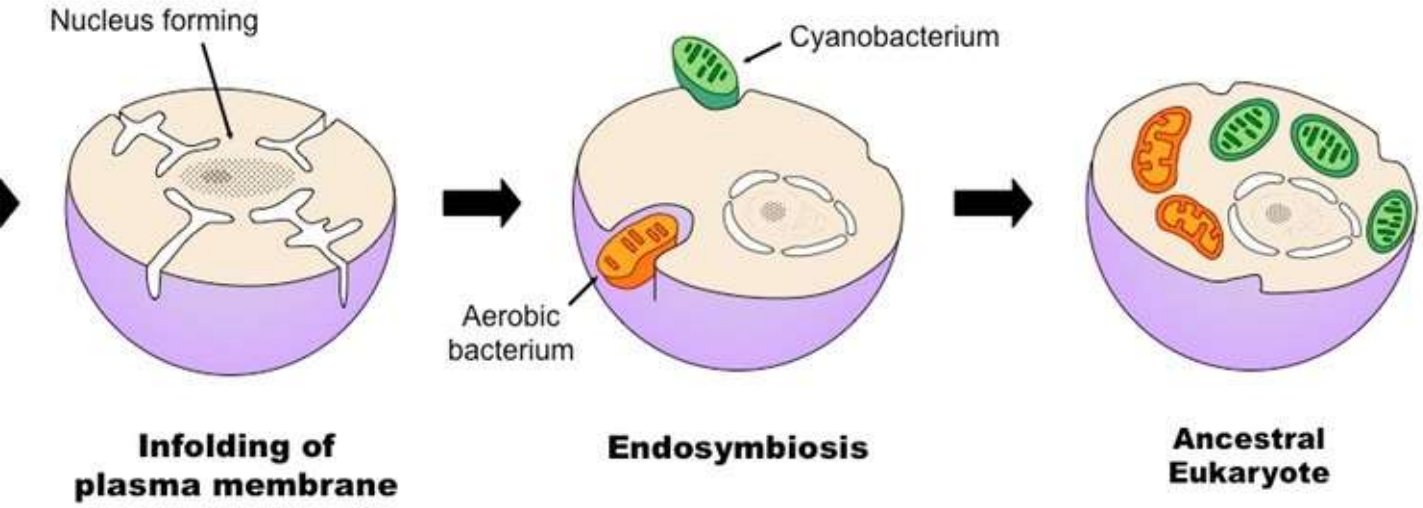

* *An endosymbiont is a cell which lives inside another cell with mutual benefit*

The development of chloroplasts would be a very similar process except the benefit to the cell would be glucose/starch instead of ATP

Development of Mitochondria

- An aerobic proteobacterium enters a larger anaerobic prokaryote (possibly as prey or a parasite)
- It survives digestion to become a valuable endosymbiont*
- The aerobic proteobacterium provides a rich source of ATP to it's host enabling it to out-compete other anaerobic prokaryotes
- As the host cell grows and divides so does the aerobic proteobacterium therefore subsequent generations automatically contain aerobic proteobacterium.
- The aerobic proteobacterium evolves and is assimilated and to become a mitochondrion.

http://ib.bioninja.com.au/options/option-d-evolution-2/d1-origins-of-life-on-earth.html

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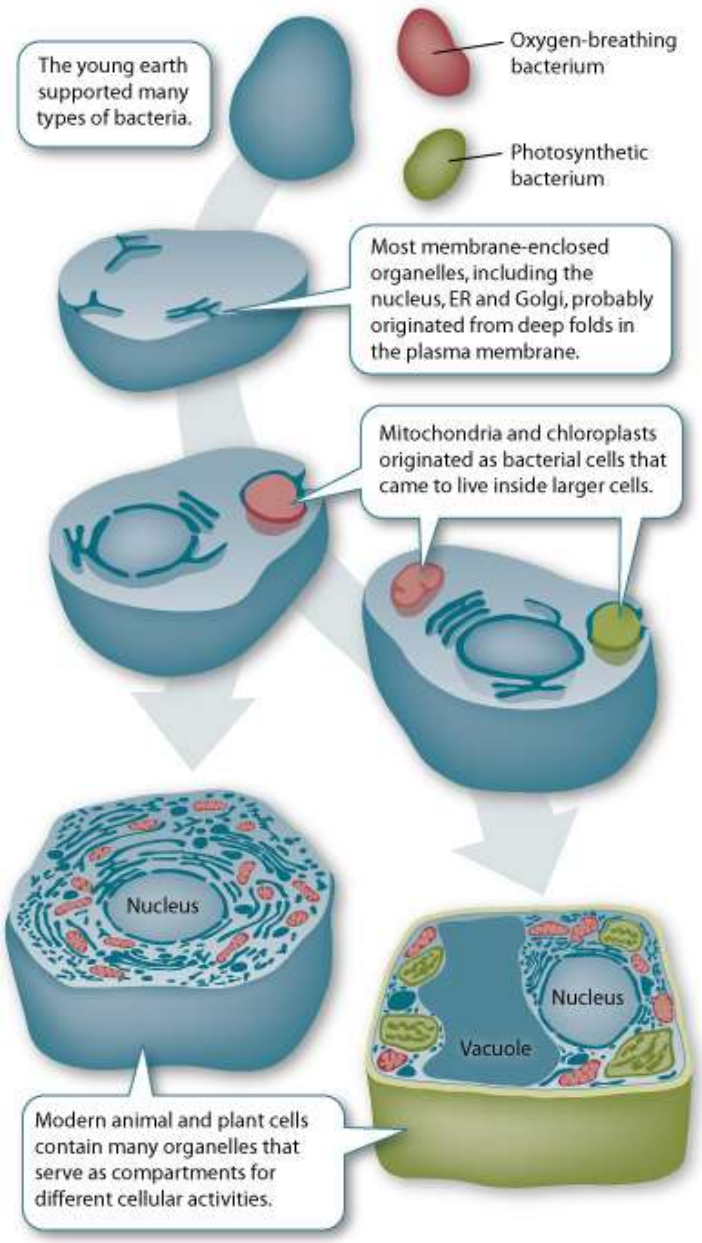

The evidence supporting the endosymbiotic theory for mitochondria and chloroplasts:

- They have their own DNA (which is naked and circular)
- They have ribosomes that are similar to prokaryotes (70S)
- They have a double membrane and the inner membrane has proteins similar to prokaryotes
- They are roughly the same size as bacteria and are susceptible to the antibiotic chloramphenicol
- They transcribe their DNA and use the mRNA to synthesize some of their own proteins.
- They can only be produced by division of pre-existing mitochondria and chloroplasts.

http://sites.roosevelt.edu/mbryson/files/2011/11/endosymbiosis.jpg

Bibliography / Acknowledgments

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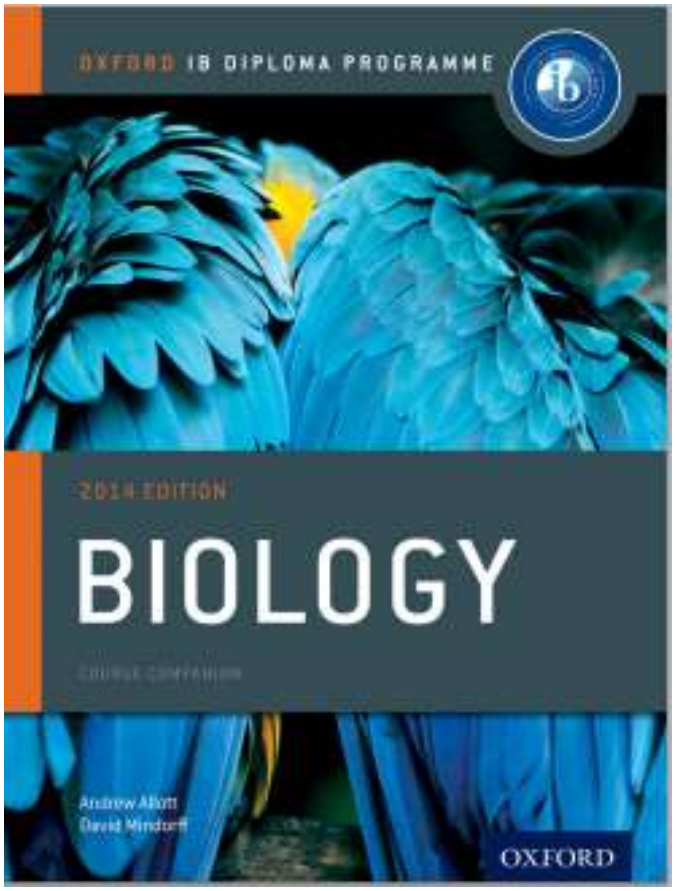

Jason de Nys