

# Concepts of Biology: BIOL 111

## Study guide for Exam 2

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Lectures 7–14

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## Outline

# 1 Questions and answers

## 1.1 Exam 1

### Results of Exam 1: statistic summary

Summary:

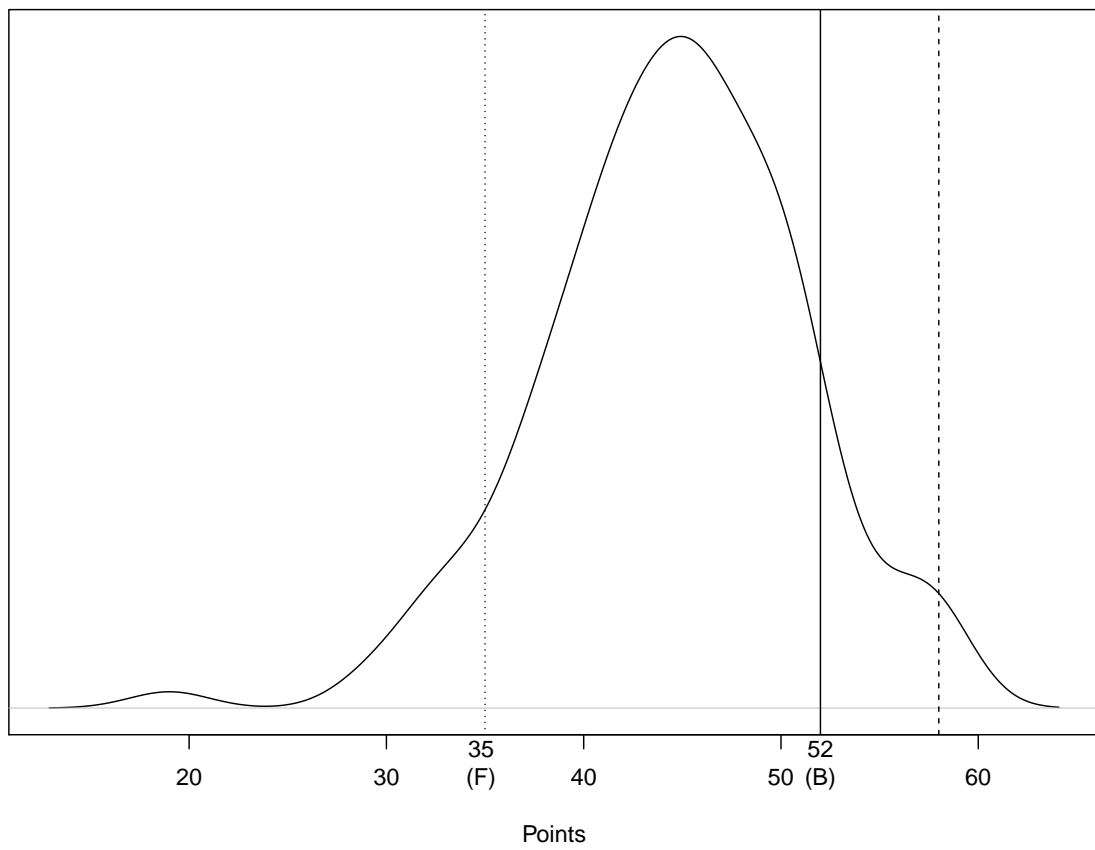
|       |         |        |       |         |       |      |
|-------|---------|--------|-------|---------|-------|------|
| Min.  | 1st Qu. | Median | Mean  | 3rd Qu. | Max.  | NA's |
| 19.00 | 41.00   | 45.00  | 44.51 | 49.00   | 58.00 | 13   |

Grades:

|    |    |    |    |     |
|----|----|----|----|-----|
| F  | D  | C  | B  | max |
| 35 | 41 | 46 | 52 | 58  |

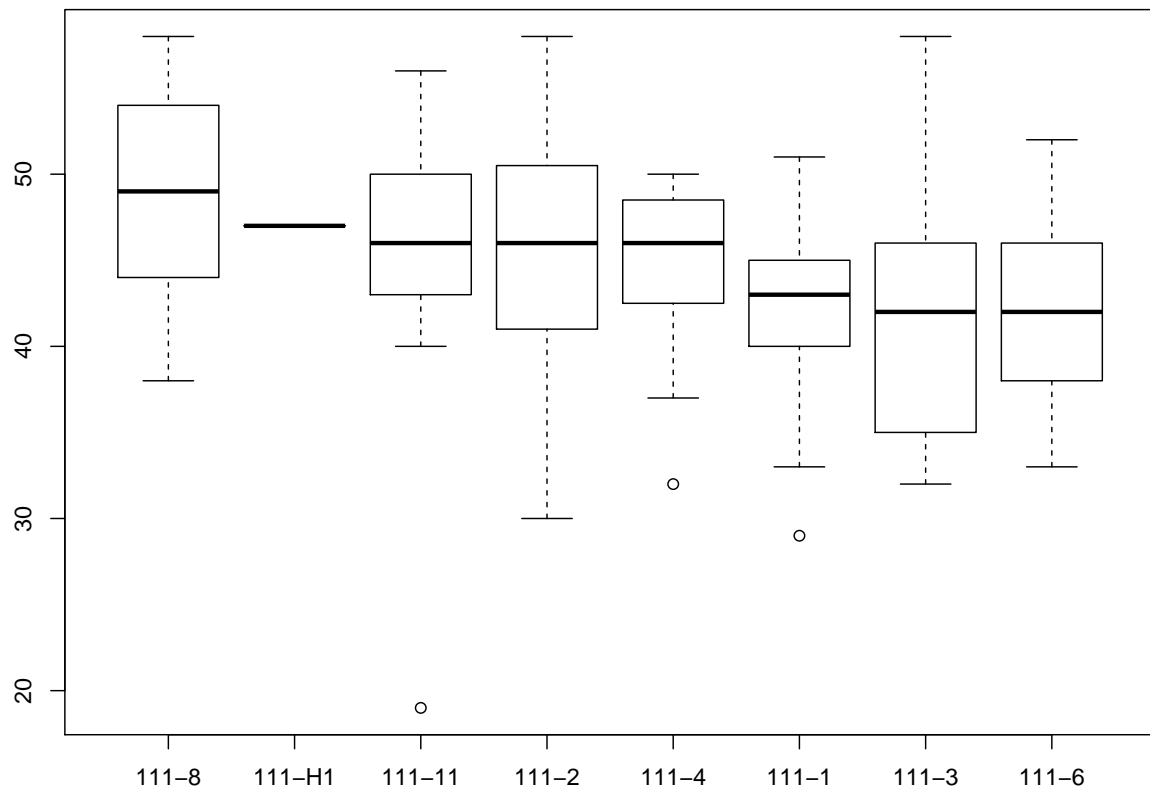
### Results of Exam 1: the curve

### Density estimation for Exam 1 (Biol 111)



Results of Exam 1: sections

### Competition between Biol 111 sections (Exam 1 )



### Results of Exam 1: some questions

32. Radioactivity was discovered:
- A. In XVII century
  - B. **In XIX century**
  - C. In XXI century
56. What is the difference between reversal and vestigial organs?
- A. **Reversal organs are mutations, vestigial organs are normal**
  - B. Vestigial organs are mutations, reversal organs are normal
  - C. Reversal organs are are results of the convergent evolution, vestigial organs are not
57. Homological structures:
- A. **Are descendants of the same ancestral structure**
  - B. Are results of parallel evolution
  - C. Are mutations
58. What are silenced genes (pseudogenes)?
- A. Non-functional genes which are similar to genes working in other organisms
  - B. Malicious genes which may kill its own cell
  - C. **“Fossil” viruses**

## 2 Where we are?

### Evolution is the fact and research program

- Given the amount of evidence presented, evolution is a fact
- Evolution is also an extremely useful, working research program, both in biology and medicine

## 3 Origin of life

### 3.1 Molecules of life

#### Organic chemistry: chemistry of carbon

- Carbon skeleton
- And H, O, N, P, S

#### Four types of biomolecules

- Lipids: hydrophobic
- Carbohydrates (sugars): multiple  $\text{—OH}$  groups
- Amino acids:  $\text{N} + \text{C} + \text{O}$  and hydrogen
- Nucleotides: cycle with nitrogen (heterocycle), sugar and phosphoric acid

#### Organic polymers

- Polymeric carbohydrates: polysaccharides (like cellulose and starch)
- Polymeric amino acids: proteins
- Polymeric nucleotides: nucleic acids (DNA and RNA)

#### The very basic features of life

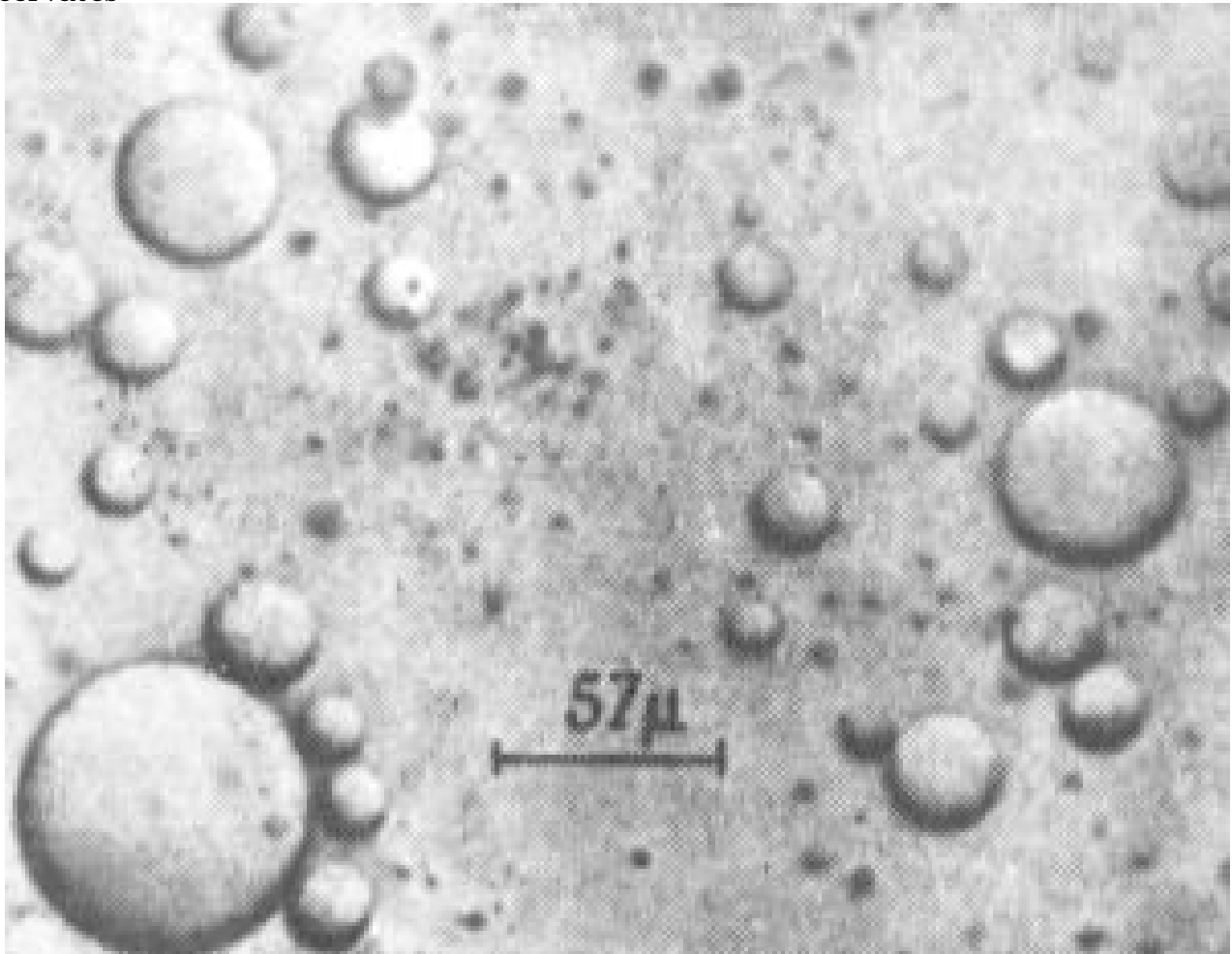
- Semi-permeable (proteins + lipids) membrane
- $\text{DNA} \rightarrow \text{RNA} \rightarrow \text{proteins}$  sequence

### 3.2 Primordial living structures

#### Coacervates

- Lipid globules capable to chemical exchange with environment
- Discovered by 1930s, used as an important proof of **abiogenesis** (Oparin's theory)

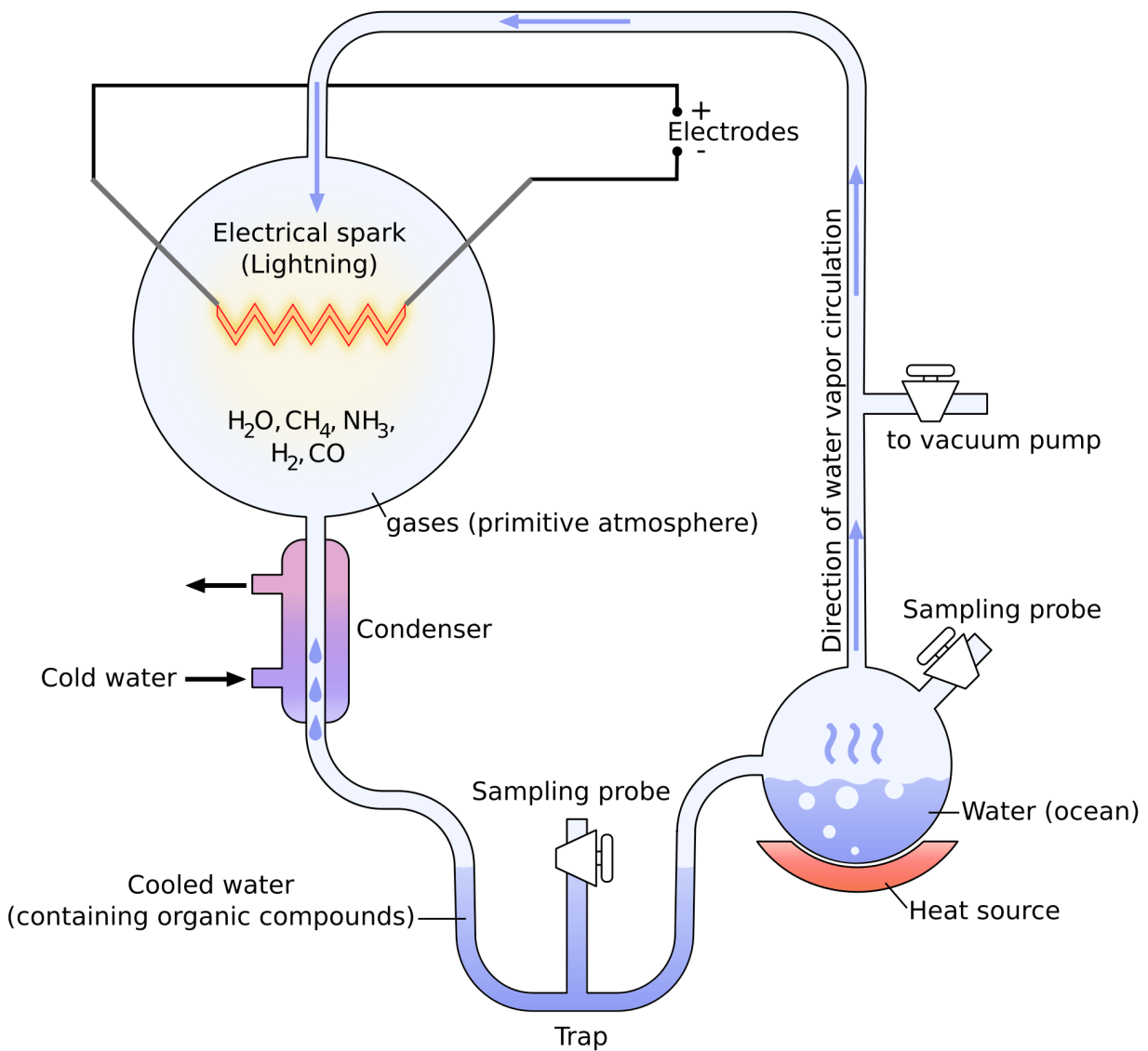
## Coacervates



## Abiogenesis of proteins

- In 1952, Miller-Urey experiment showed that formation of simple organic molecules is possible when Earth ancient atmosphere and temperature were imitated in lab
- In 1958, Fox and Harada found that “proteinoids” (short peptides) may be synthesized in similar conditions

## Miller-Urey experiment



### First steps, according to abiogenesis

- Primordial soup
- RNA world
- Proteins
- Cells: last universal common ancestor (LUCA)

### Summary

- Four types of biomolecules form biological polymers
- Abiogenesis is the most feasible theory of life origin

### For Further Reading

## References

- [1] Organic chemistry. [http://en.wikipedia.org/wiki/Organic\\_chemistry](http://en.wikipedia.org/wiki/Organic_chemistry)
- [2] Origin of Life. <http://en.wikipedia.org/wiki/Abiogenesis>

## Outline

## 4 Where we are?

**Four types of biomolecules form biological polymers**

- Lipids
- Sugars and polysaccharides
- Amino acids and proteins
- Nucleotides and nucleic acids

**Abiogenesis is the most feasible theory of life origin**

- Primordial soup
- RNA world
- Proteins
- Cells: last universal common ancestor (LUCA)

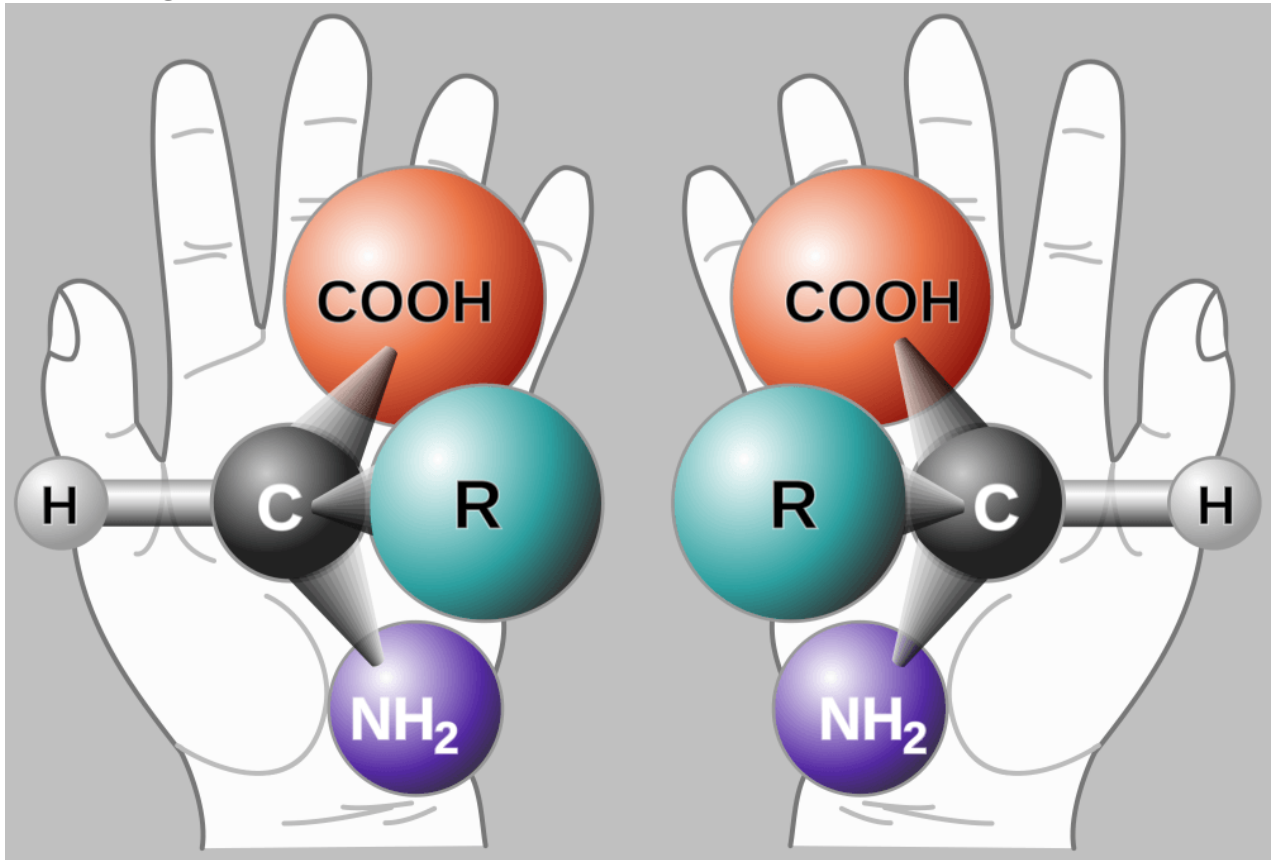
## 5 Origin of life

### 5.1 Alternatives and amendments to abiogenesis

**Problems of abiogenesis: chiral purity of life**

- Most of amino acids are chiral: they have “left” and “right” forms
- *All proteins from living organisms contain only “left” amino acids*
- Sugars (carbohydrates) could also be “left” and “right”
- *Nucleic acids contain only “right” sugars*

## “Left” and “right” amino acids



## Panspermia theory

- Life is a fundamental feature of Universe
- It always exists and constantly spreading

## Self-organization

- Lovelock's (1982) Gaia hypothesis: Earth is a living being
- Life is a way of stabilizing geological cycles on Earth
- Self-organization was based on the principles of Prigogine's **non-equilibrium thermodynamics**
- Life first, organisms second

# 6 First life

## 6.1 Hadean and Archean eons

### First evidences of life

- Earth age is usually estimated as 4600 Mya (million years ago), Hadean eon was the first epoch
- First minerals are  $\approx 4000$  Mya, they mark Archean eon

## Oldest evidences of life and photosynthesis

- The oldest organic carbon is  $\approx 3800$  Mya (Greenland, Mesoarchean)
- Organic carbon: carbon with  $^{13}\text{C}/^{14}\text{C}$  ratio like in living plants
- Oldest remnants of chlorophyll: 3100 Mya (Mesoarchean)

## Photosynthesis

- $\text{CO}_2 + \text{H}_2\text{O} \xrightarrow{\text{light, chlorophyll}} \text{carbohydrates} + \text{O}_2$
- Two stages:
  - A. Light-dependent: production of energy (ATP) and photolysis of water
  - B. Light-independent: assimilation of  $\text{CO}_2$  into carbohydrates
- Then carbohydrates are partly converting into lipids; with addition of N—into amino acids; with addition of N and P—into nucleotides

## ATP

- Universal energy source in the cell, “universal currency”
- $\text{ATP} \rightarrow \text{ADP} + \text{P} + \text{energy}$

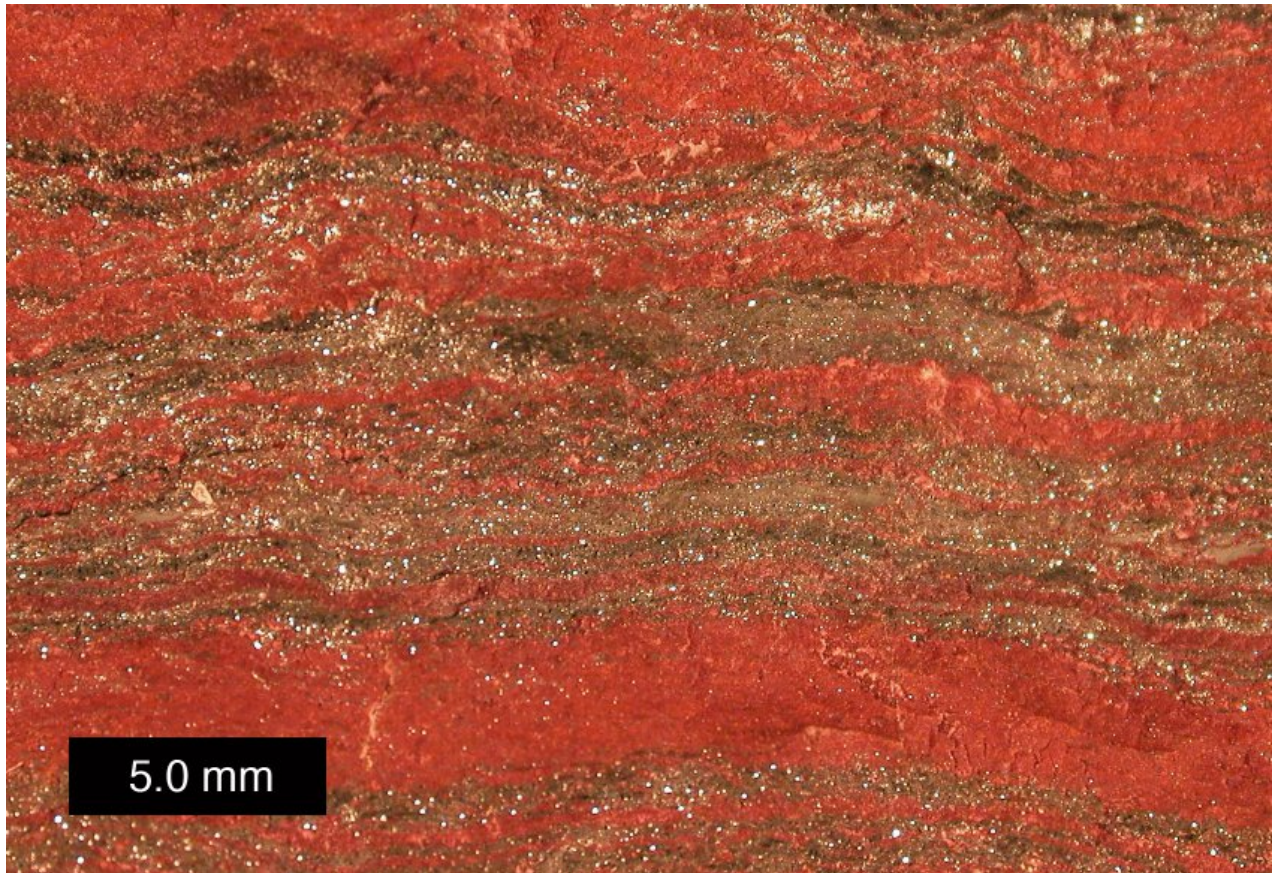
## Oxygen and iron

- Initially, Earth atmosphere contained no oxygen
- Photosynthetic oxygen oxidized free iron into quartzite-like rocks contained hematite and other iron minerals
- New iron was always replenished from ocean water
- However,  $\approx 2000$  Mya, when Proterozoic eon started, almost all iron went deeper into mantle and core

## Wheeler Peak, NV



Hematite



### From oxygen oases to oxygen revolution

- In Archean, photosynthesis could only produce local “oxygen oases”
- But when no free iron was available anymore, atmosphere started to accumulate oxygen
- When oxygen reached 1% (Pasteur point), aerobic life started
- This was the oxygen revolution which allowed cells to obtain energy via respiration

### Fermentation *versus* respiration

- carbohydrates  $\rightarrow$   $\text{CO}_2$  + ethanol + 2 ATP
- carbohydrates +  $\text{O}_2 \rightarrow \text{CO}_2$  +  $\text{H}_2\text{O}$  + 38 (!!!) ATP

## 6.2 First cells

### Who was first?

- Stromatolites: microbial mats from (mostly) cyanobacteria (photosynthetic bacteria)
- *Metallogenium* and others: proteobacteria (e.g., aerobic metal-oxidizing bacteria)

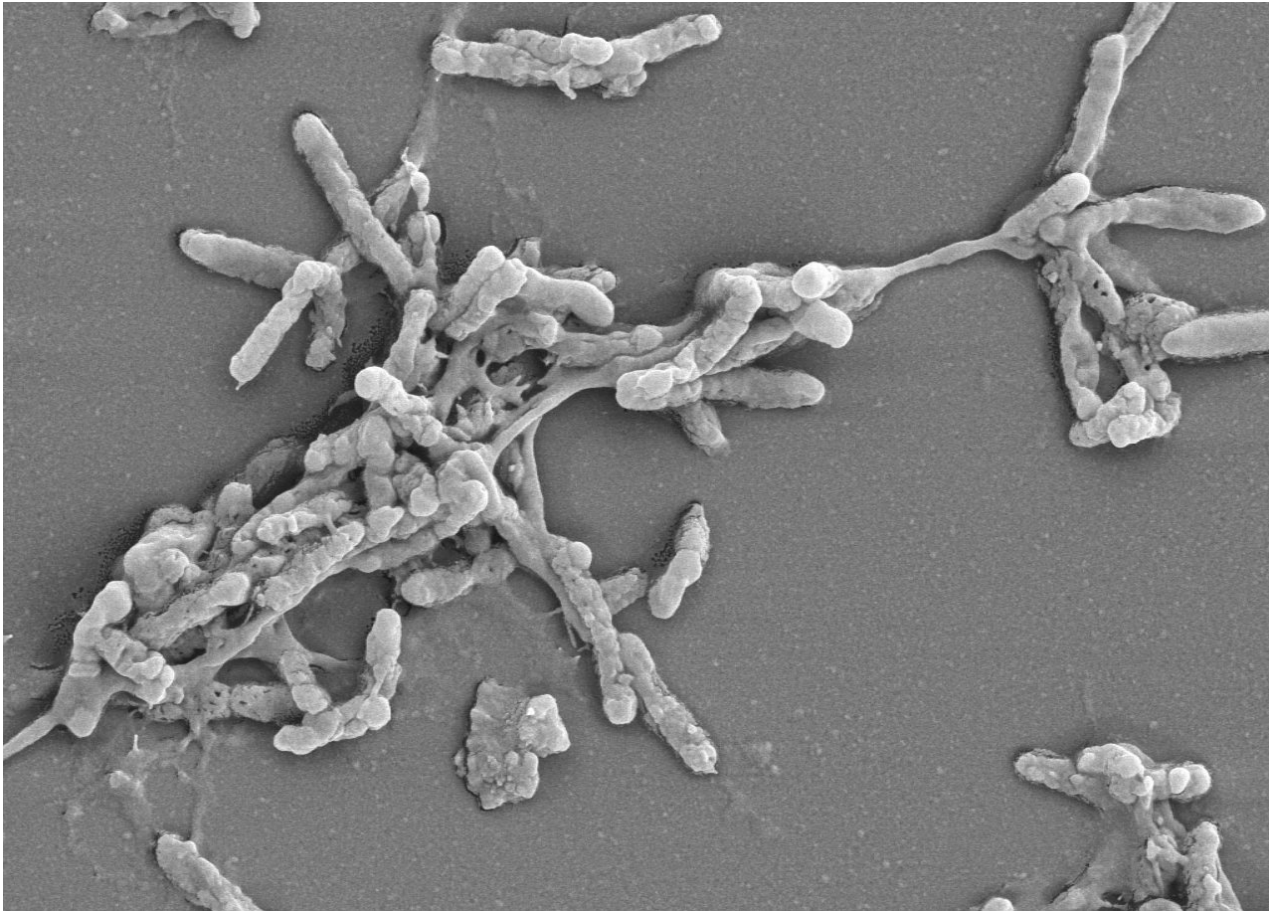
Fossil stromatolite



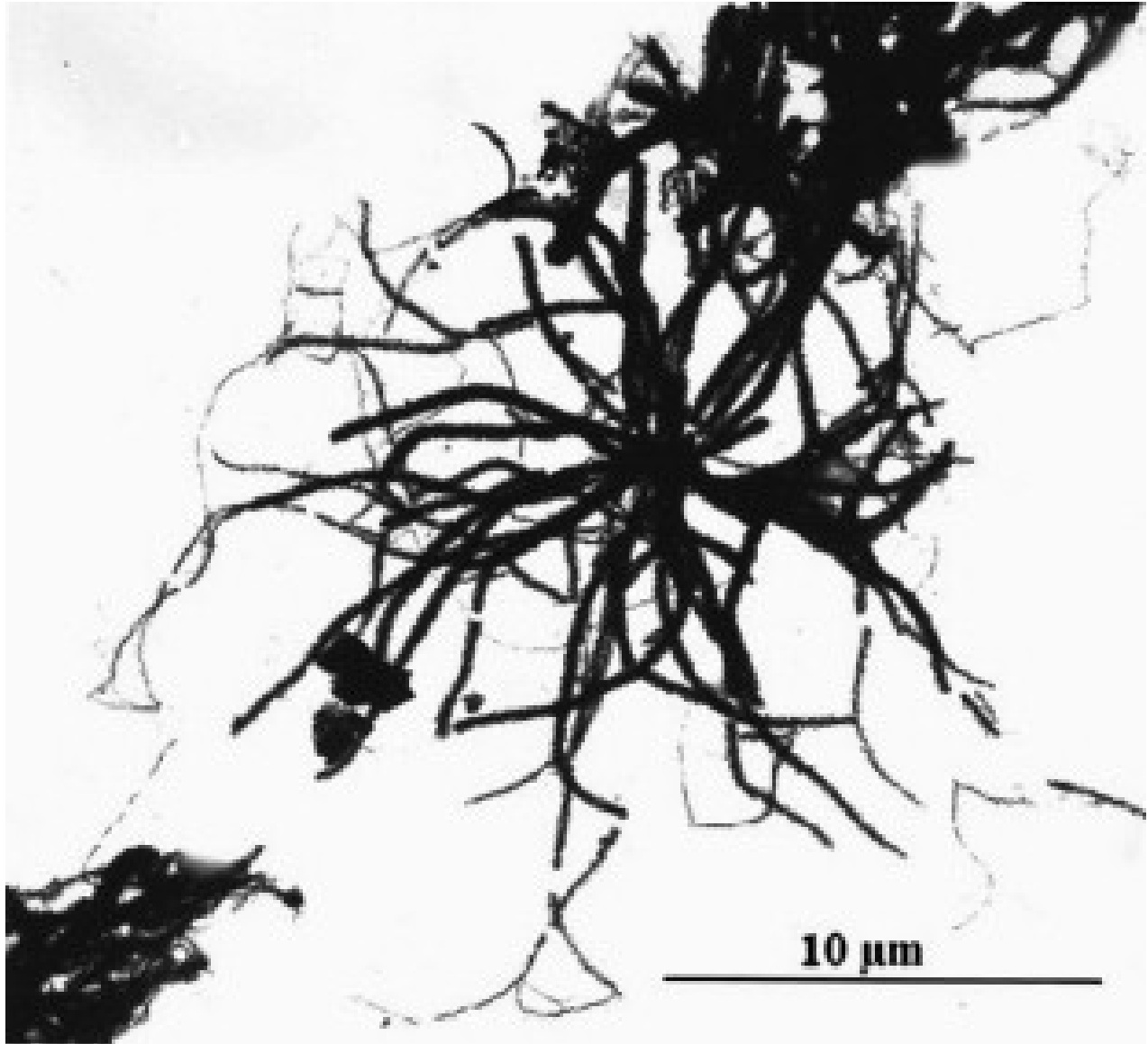
Present-day stromatolite (Shark Bay, Australia)



Present-day iron-oxidizing bacteria



Fossil *Metallogenium*



## Summary

- Bacteria were first
- Photosynthesis changed the atmosphere
- Aerobic life respire to obtain more ATP

## For Further Reading

## References

- [1] Photosynthesis. <http://en.wikipedia.org/wiki/Photosynthesis> (introduction)
- [2] Cellular respiration. [http://en.wikipedia.org/wiki/Cellular\\_respiration](http://en.wikipedia.org/wiki/Cellular_respiration) (introduction)

## Outline

## 7 Where we are?

### First life

- In Mesoarchaeon, cyanobacteria (fossilized as stromatolites) were first
- Photosynthesis changed the atmosphere
- Aerobic life respire to obtain more ATP

### Who was first?

- Stromatolites: microbial mats from (mostly) cyanobacteria (photosynthetic bacteria)
- *Metallogenium* and others: proteobacteria (e.g., aerobic metal-oxidizing bacteria)

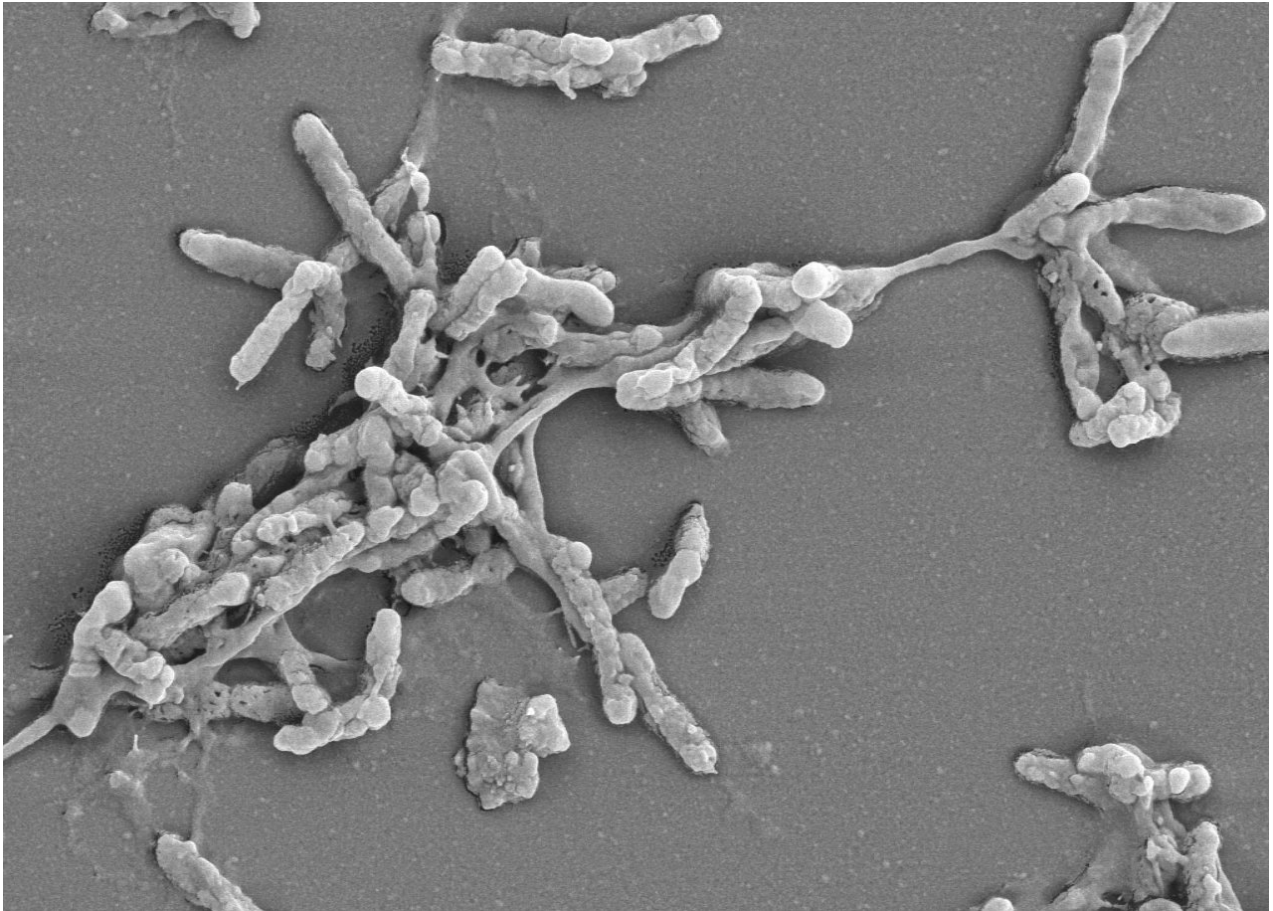
### Fossil stromatolite



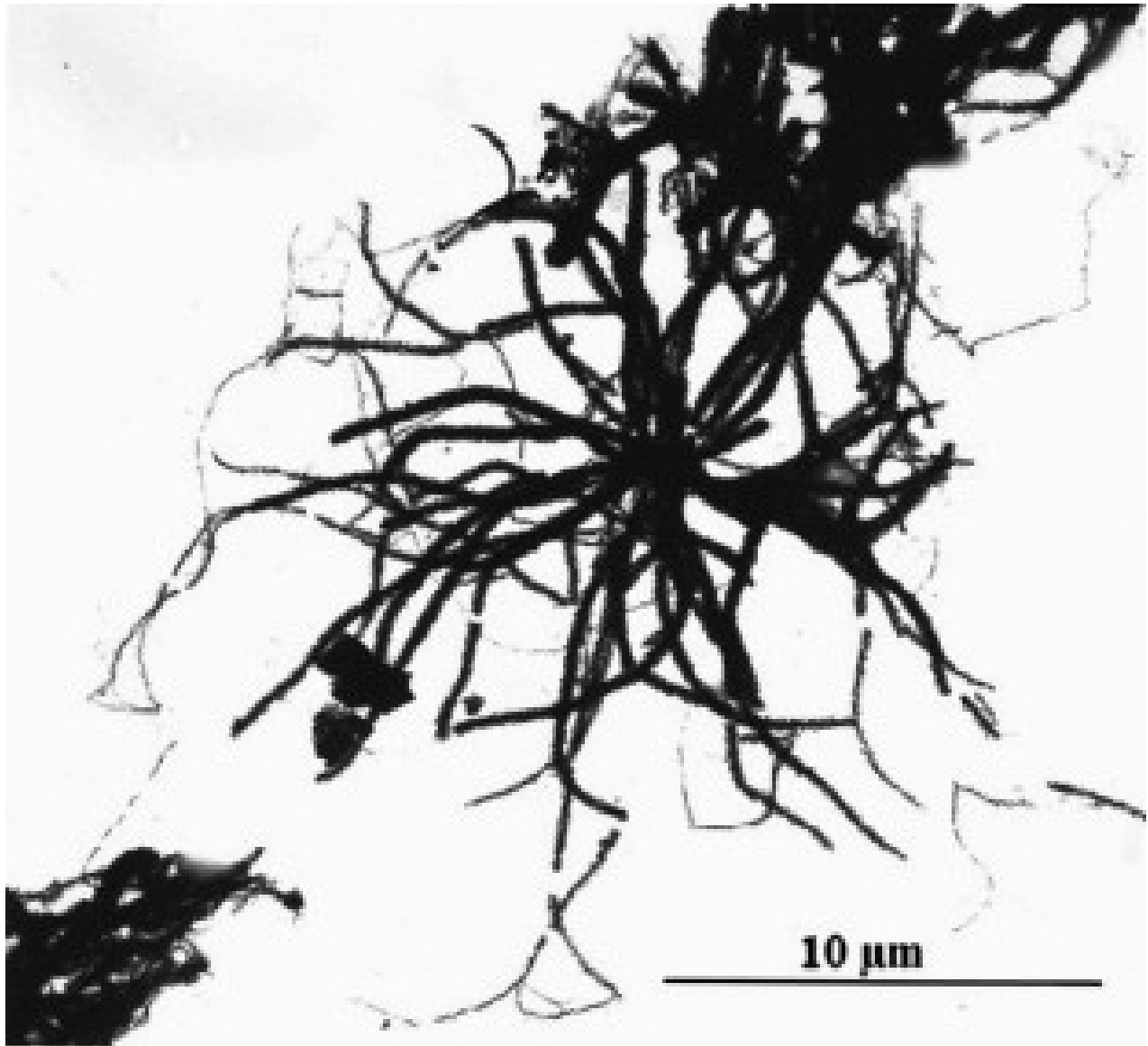
Present-day stromatolite (Shark Bay, Australia)



Present-day iron-oxidizing bacteria



Fossil *Metallogenium*



## 8 Cell

### 8.1 Prokaryotic cell

*Prokaryotic cell*

Main components of prokaryotic cell

- Cell wall
- Membrane
- Cytoplasm
- DNA
- Ribosomes

- Membrane folds and pockets
- Vesicles
- Flagella

## 8.2 How to be a prokaryote

### How to make energy

- Cell respiration and other destructive processes make ATP for all cell
- Photosynthesis and other synthetic processes make ATP and spend it

### How to make proteins

- DNA and RNA contain four types of nucleotides
- The sequence of nucleotides is a cypher
- Each three nucleotides will encode amino acid (“genetic code”)
- Ribosomes translate triplets into amino acids and make proteins

### How to take food

- Digestive proteins are transported outside membrane
- They destroy polymers into monomers
- Monomers then are pumping through membrane into the cell
- If cell is photosynthetic, it produce monomers itself

### How to make body

- Monomers could be spend:
  - in destructive reactions to obtain ATP, **or**
  - in synthetic reactions to make new polymers. These reactions are using ATP

### How to multiply

- DNA is a double helix which may copy itself
- Two copies of DNA untangled and separated, then cytoplasm and membrane divide
- Of course, these processes spend lots of ATP

## Summary

- Bacteria were first
- Photosynthesis changed the atmosphere
- Aerobic life respire to obtain more ATP
- Prokaryotic cells are simplest cells
- They produce energy, obtain monomers, synthesize polymers, e.g. proteins from DNA and RNA, and sometimes also make monomers themselves (with photosynthesis), divide and even perform a sexual process (recombine DNA between cells)

## For Further Reading

## References

- [1] Genetic code. [http://en.wikipedia.org/wiki/Genetic\\_code](http://en.wikipedia.org/wiki/Genetic_code)
- [2] Protein biosynthesis. [http://en.wikipedia.org/wiki/Protein\\_biosynthesis](http://en.wikipedia.org/wiki/Protein_biosynthesis)

## Outline

## 9 Where we are?

## 10 Where we are?

### 10.1 How to be a cell

#### Main duties

- Making energy
- Making proteins
- Digesting food
- Constructing body
- Multiplying
- Making sex

## How to make proteins I

- Proteins are chemical machines of cell
- Each machine is described in gene
- The only way to make them is DNA  $\rightarrow$  RNA  $\rightarrow$  proteins
- DNA is a folded double spiral; it has two chains
- Every chain consists of four “letters”—nucleotides (A, T, G, C)
- Two chains are complimentary, and only A–T and G–C pairs are possible

## How to make proteins II

- DNA may duplicate, then new DNAs will build complimentary chains and become exact copies
- DNA may also “produce” RNA: one of chains serves as matrix for new RNA
- RNA also has four letters (A, U, G, C)
- When RNA is building on DNA, RNA’s “U” will be complimentary with DNA’s “A”; all other rules are the same

## How to make proteins III

- New RNA is a matrix RNA (mRNA)
- It will come into ribosome, and ribosome will translate every three letters (triplet) into amino acid
- mRNA moves within ribosome, and new amino acids are joining into growing protein
- Translation rules are known as “genetic code”
- There are 64 possible triplets and only 20 amino acids—genetic code is redundant

**Translation rules: “genetic code”**

|              |   | Second letter                            |                                      |  |   |                  |
|--------------|---|--|--------------------------------------|--|---|------------------|
|              |   | U  | C                                    | A  | G   |                  |
| First letter | U | UUU } Phe<br>UUC }<br>UUA } Leu<br>UUG } | UCU }<br>UCC } Ser<br>UCA }<br>UCG } | UAU } Tyr<br>UAC }<br>UAA Stop<br>UAG Stop | UGU } Cys<br>UGC }<br>UGA Stop<br>UGG Trp | U<br>C<br>A<br>G |
|              | C | CUU }<br>CUC } Leu<br>CUA }<br>CUG }     | CCU }<br>CCC } Pro<br>CCA }<br>CCG } | CAU } His<br>CAC }<br>CAA } Gln<br>CAG }   | CGU }<br>CGC } Arg<br>CGA }<br>CGG }      | U<br>C<br>A<br>G |
|              | A | AUU }<br>AUC } Ile<br>AUA }<br>AUG Met   | ACU }<br>ACC } Thr<br>ACA }<br>ACG } | AAU } Asn<br>AAC }<br>AAA } Lys<br>AAG }   | AGU } Ser<br>AGC }<br>AGA } Arg<br>AGG }  | U<br>C<br>A<br>G |
|              | G | GUU }<br>GUC } Val<br>GUA }<br>GUG }     | GCU }<br>GCC } Ala<br>GCA }<br>GCG } | GAU } Asp<br>GAC }<br>GAA } Glu<br>GAG }   | GGU }<br>GGC } Gly<br>GGA }<br>GGG }      | U<br>C<br>A<br>G |

### How to make sex

- If DNA will stay unchanged, cells cannot evolve
- To make evolution possible, there are processes which modify DNA:
  - Mutations
  - Recombinations
- Sexual process allows DNA recombination
- Prokaryotic cells simply connect and exchange pieces of DNA (“bacterial conjugation”)

## 11 Origin of eukaryotes

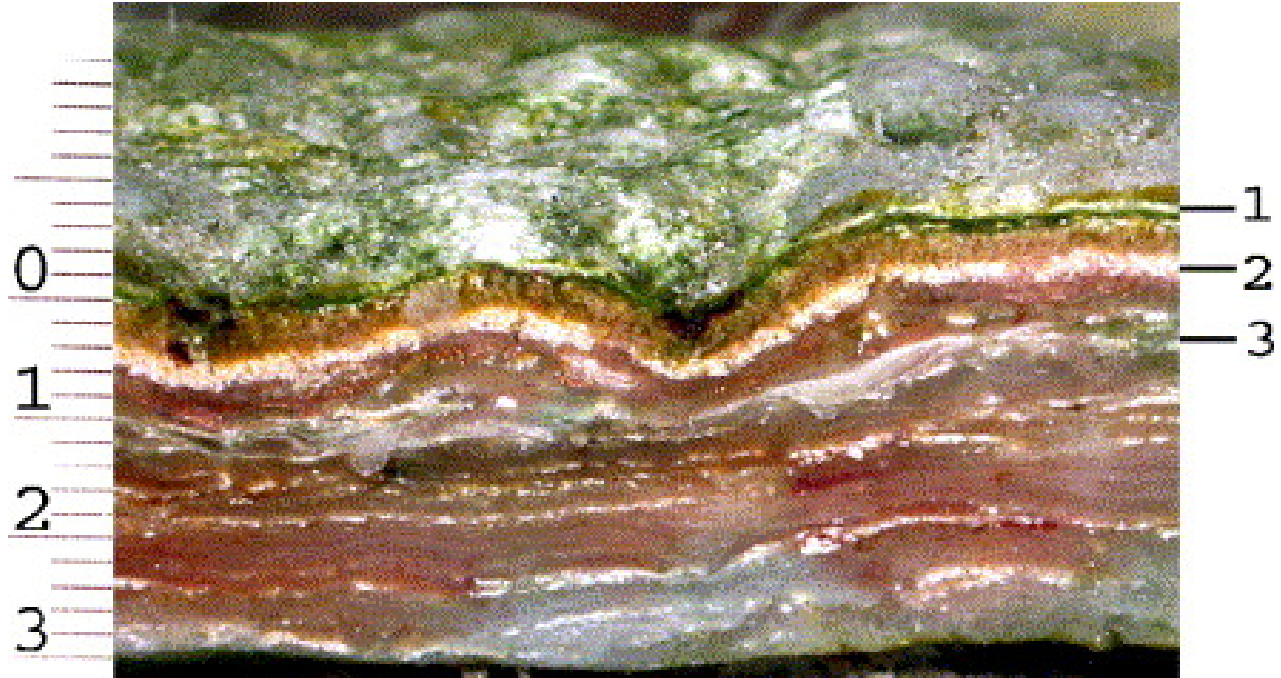
### 11.1 Microbial mats

#### Microbial mats complexity

- Mats were not only cyanobacteria (aerobic photosynthetic autotrophs), but also

- anaerobic photosynthetic bacteria and
- heterotrophic and chemotrophic bacteria
- All these bacteria form the first **ecosystem**

#### Layers in microbial mat



## 11.2 First eukaryotes: first predators

### *Bdellovibrio*

- Bacteria are small and rigid, there is only one example of bacteria which can “eat” others
- However, this *Bdellovibrio* will only eat in the space between membrane and cell wall

### *Bdellovibrio* invading the prey



## Antibiotics

- The other problem was chemicals which bacteria are using to win a competition: antibiotics
- Most of antibiotics change the process of protein synthesis or cell wall construction

## Proterozoic challenge

- Archean ecosystems were based on “clone wars” using antibiotics, horizontal transfer of genes and splitting jobs. However, they were incomplete: no predators.
- To predate, one need to *make large cell and invent the phagocytosis* (cellular “swallowing”)
- To escape from antibiotics, one need a different chemical machines for protein biosynthesis

However,

- Large and complicated cell needs more DNA—but how to divide it equally?
- Horizontal transfer will hinder evolution towards something unusual—but how to stop it?
- Large and complicated cells need much more ATP—how to make it?

## Summary

- Sexual process is the requirement for evolution
- Microbial mats were first ecosystems
- To predate, bacteria must develop the enhanced cell

## For Further Reading

## References

- [1] Bacterial conjugation. [http://en.wikipedia.org/wiki/Bacterial\\_conjugation](http://en.wikipedia.org/wiki/Bacterial_conjugation)

## Outline

# 12 Where we are?

## 12.1 Basics of ecology

### Ways of life

- How to obtain energy?
  - A. From sun light: **phototrophy**
  - B. From chemical reactions with inorganic matter (“rocks”): **lithotrophy**
  - C. From breaking organic molecules into inorganic (typically, carbon dioxide and water): **organotrophy**
- How to obtain building blocks?
  - A. From assimilation of carbon dioxide: **autotrophy**
  - B. From other living beings: **heterotrophy**

### Six life styles

|              | Phototrophs | Lithotrophs | Organotrophs |
|--------------|-------------|-------------|--------------|
| Autotrophs   | ...         | ...         | ...          |
| Heterotrophs | ...         | ...         | ...          |

## 12.2 Ecological interactions

### Two-species model

- Species I and species II may influence each other differently
- For example, species I may facilitate the increase the number of species II individuals (+ interaction)
- At the same time, species II could be neutral to species I (0 interaction)

## Six basic ecological interactions

|   | +         | 0                         | −                         |
|---|-----------|---------------------------|---------------------------|
| + | mutualism | commensalism <sup>1</sup> | exploitation <sup>2</sup> |
| 0 | ...       | neutralism                | amensalism                |
| − | ...       | ...                       | interference <sup>3</sup> |

<sup>1</sup> Includes phoresy (transportation), inquilinism (housing) and “sponging”

<sup>2</sup> Includes predation, parasitism and phytophagy

<sup>3</sup> Includes competition, allelopathy and aggression

## 12.3 Proterozoic challenge

### Proterozoic challenge

- Archean ecosystems were based on “clone wars” using antibiotics, horizontal transfer of genes and splitting jobs. However, they were incomplete: no predators.
- To predate, one need to *make large cell and invent the phagocytosis* (cellular “swallowing”)
- To escape from antibiotics, one need a different chemical machines for protein biosynthesis

However,

- Large and complicated cell needs more DNA—but how to divide it equally?
- Horizontal transfer will hinder evolution towards something unusual—but how to stop it?
- Large and complicated cells need much more ATP—how to make it?

### Two problems

- How to escape from antibiotics?
- How to predate?

### Eukaryotic cell as a response to Proterozoic challenge

- New pathways of protein synthesis
- Cytoplasm motility (flagella, phagocytosis) based on cytoskeleton → no cell wall
- Nucleus for interphase and chromosomes for mitosis (too many DNA)
- Mitochondria for ATP (cell needs much more ATP)

### Summary

- All life styles were exist before eukaryotic origin
- The only interaction absent in prokaryotic communities was predation
- Eukaryotic cell is a “second-level”, enhanced cell

## For Further Reading

## References

- [1] Ecological interactions. [http://en.wikipedia.org/wiki/Biological\\_interaction](http://en.wikipedia.org/wiki/Biological_interaction)
- [2] Symbiogenesis. [http://en.wikipedia.org/wiki/Endosymbiotic\\_theory](http://en.wikipedia.org/wiki/Endosymbiotic_theory)
- [3] Eukaryote. <http://en.wikipedia.org/wiki/Eukaryote>

## Outline

# 13 Where we are?

## 13.1 Proterozoic challenge

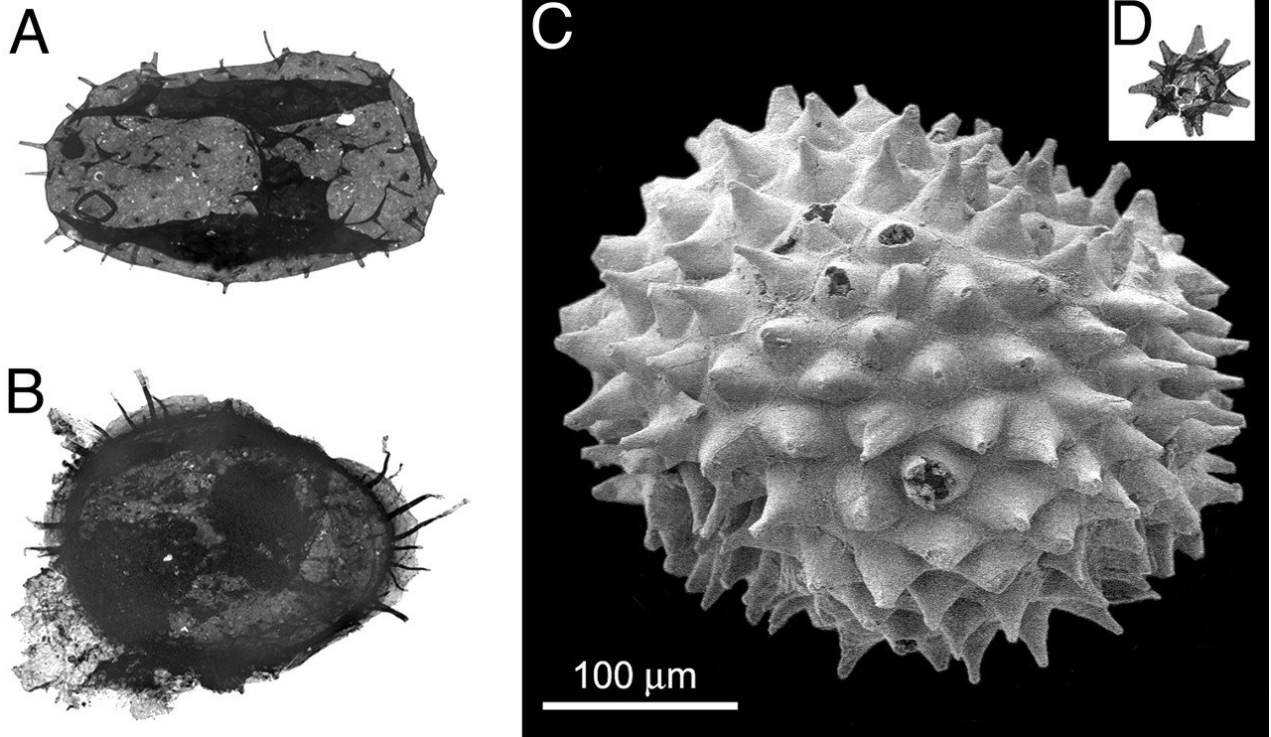
### ATP, carbohydrates, photosynthesis and respiration

- If organism is capable to convert sun energy into ATP, it is a phototroph
- If organism is using carbon dioxide to build its own organic (ATP is required here!), it is an autotroph
- Most of plants are photoautotrophs, because photosynthesis (combination of the above two processes) is prevalent in their life
- Animals are heterotrophs, they do respiration which is opposite to autotrophy: it breaks organic into inorganic and create ATP

### Eukaryotic cell as a response to Proterozoic challenge

- Predators
- New pathways of protein synthesis
- Cytoskeleton allows for cytoplasm motility
- Nucleus for DNA security and distribution
- Mitochondria make ATP

## Acritarchs in Proterozoic (1,900 Mya)



## 14 Eukaryotic cell

### 14.1 Organelles and their functions

#### *Eukaryotic cell*

#### Membrane and cytoplasm

- Cytoplasm is constantly flowing
- Membranes are used for construction of multiple internal organelles

#### Cytoskeleton

- Microtubules and microfilaments
- Flagella
- Phagocytosis
- Motility
- No cell wall (but note that plants and fungi developed cell wall again)

## **Nucleus**

- Regulatory DNA
- Cell division
- Pores

## **Mitochondria**

- Respiration machines
- Mitochondrial DNA

## **Internal membrane system**

- ER
- AG
- Vesicles: vacuoles, lysosomes, peroxisomes etc.

## **Ribosomes**

- Bigger
- Associated with ER

## **Eukaryotic cell: pluses and minuses**

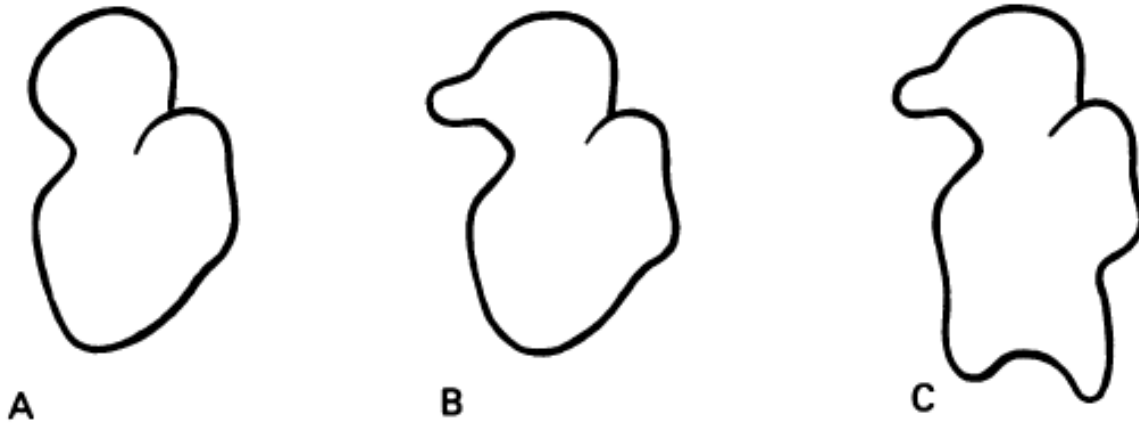
- Flexible, but bigger and no cell wall
- Nucleus, but so many DNA poses a problem
- Mitochondria are very effective, but less controlled

## **14.2 Evolutionary steps towards the eukaryote**

### **Antibiotic resistance and actin**

- Archebacteria were probably first prokaryotes who changed their biosynthetic pathways in order to become resistant to majority of antibiotics
- They also invented actin, the main protein of cytoskeleton

Ribosomes of core bacteria (A), archebacteria (B) and eukaryotes (C)



**Taking mitochondria: symbiogenesis**

- Mitochondria were separate organisms
- Eukaryotic cell is a “second-level” cell, cell from cells

## 14.3 Cell division

**Cell cycle**

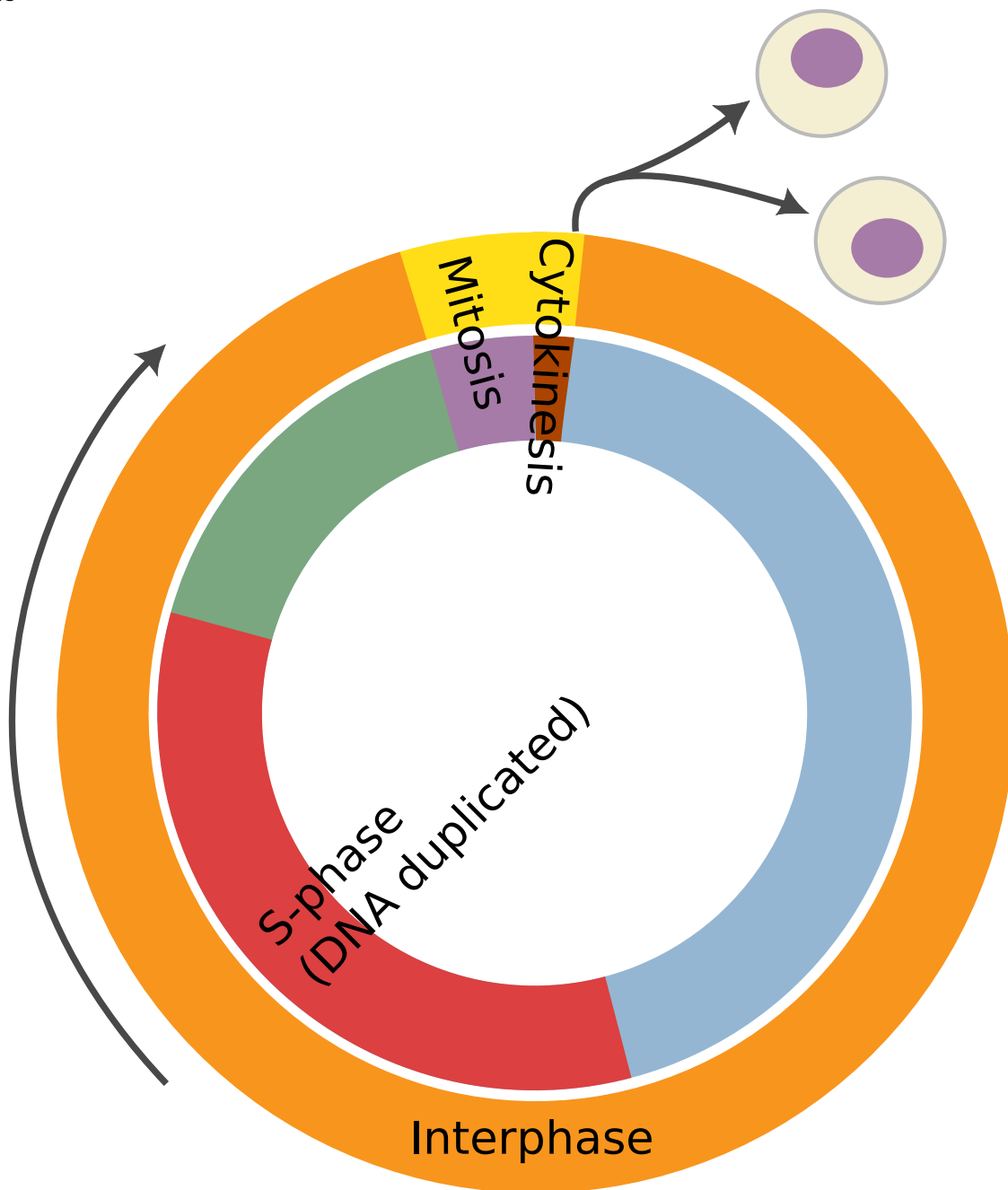
- To multiple, cell should first store energy for DNA duplication
- Then—duplicate its DNA (S-period)
- And only then to divide DNA (mitosis) and the rest of cell (cytokinesis)

This is the **cell cycle**

**Mitosis**

- Mitosis is an equal division of nucleus where daughter cells will receive the same DNA information as mother cell
- **The goal of mitosis** is the equal distribution of pre-duplicated DNA
- Time between two cell divisions is called **interphase** so cell cycle = interphase + mitosis + cytokinesis

## Cell cycle



### Summary

- Eukaryotic cell is a “second-level”, enhanced cell
- Symbiogenesis is one of evolutionary steps towards eukaryote
- Mitosis is an equal division of nucleus

### For Further Reading

## References

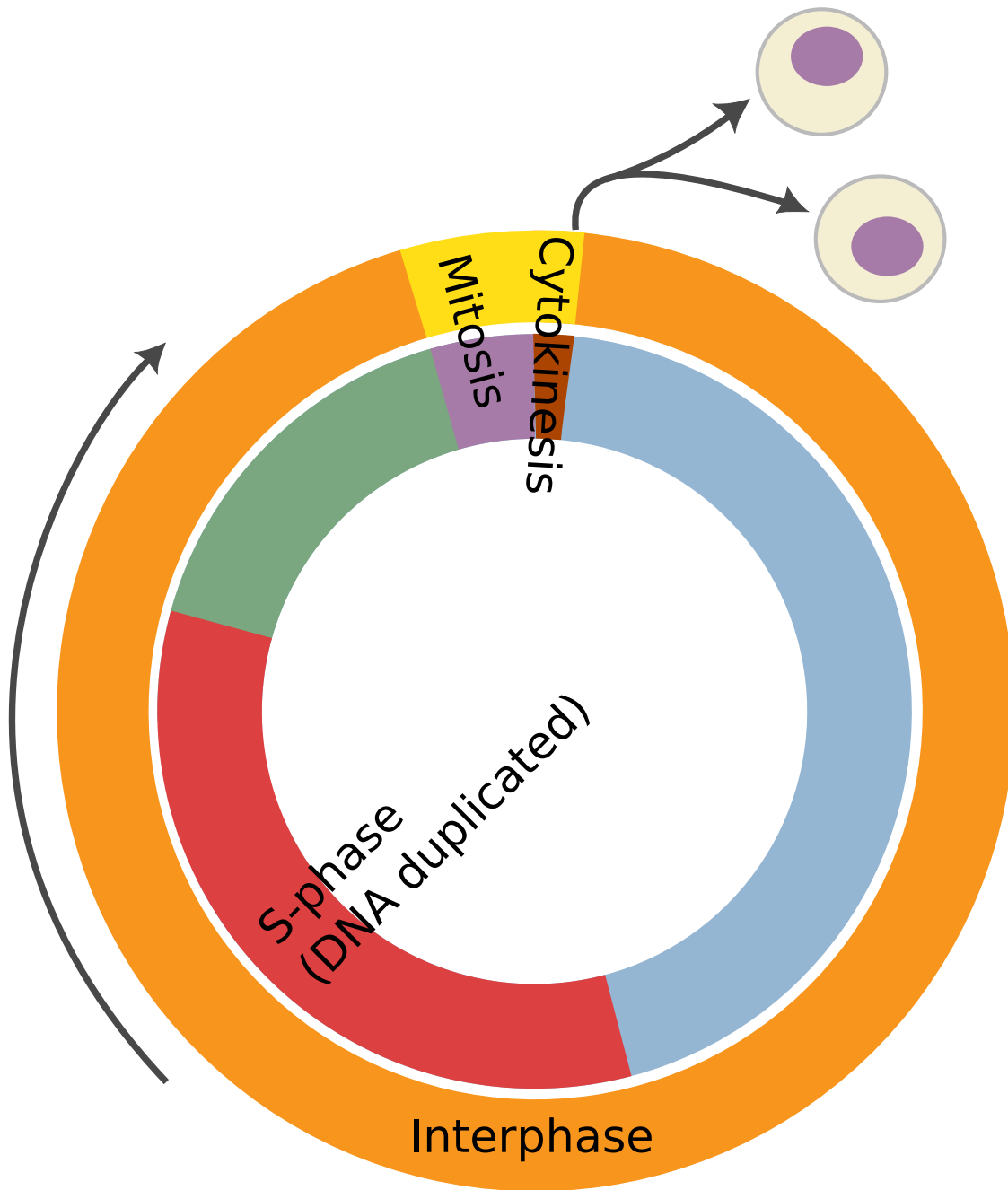
- [1] Symbiogenesis. [http://en.wikipedia.org/wiki/Endosymbiotic\\_theory](http://en.wikipedia.org/wiki/Endosymbiotic_theory)

## Outline

# 15 Where we are?

## 15.1 Cell division

### Cell cycle

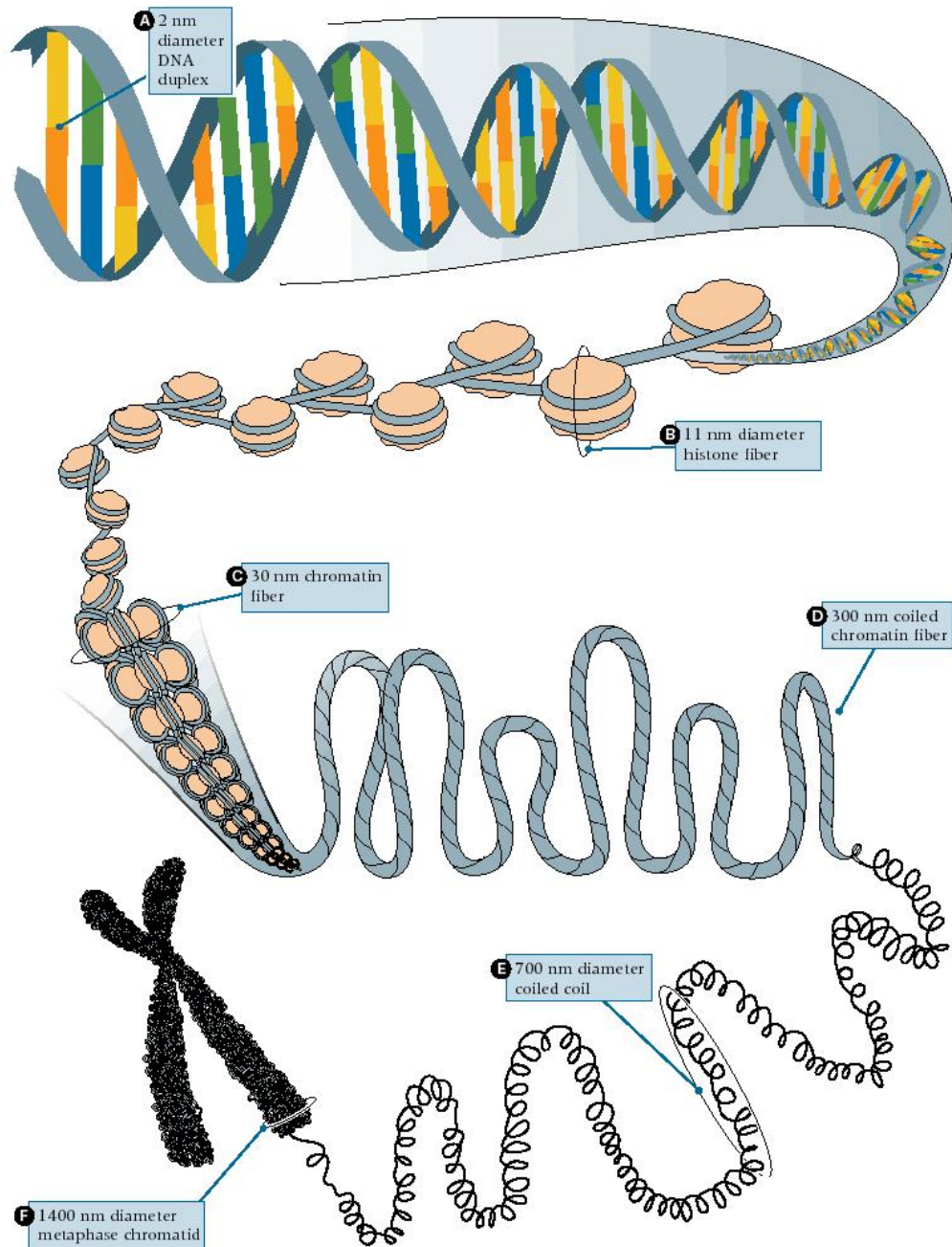


## 15.2 Mitosis

### Stages of mitosis

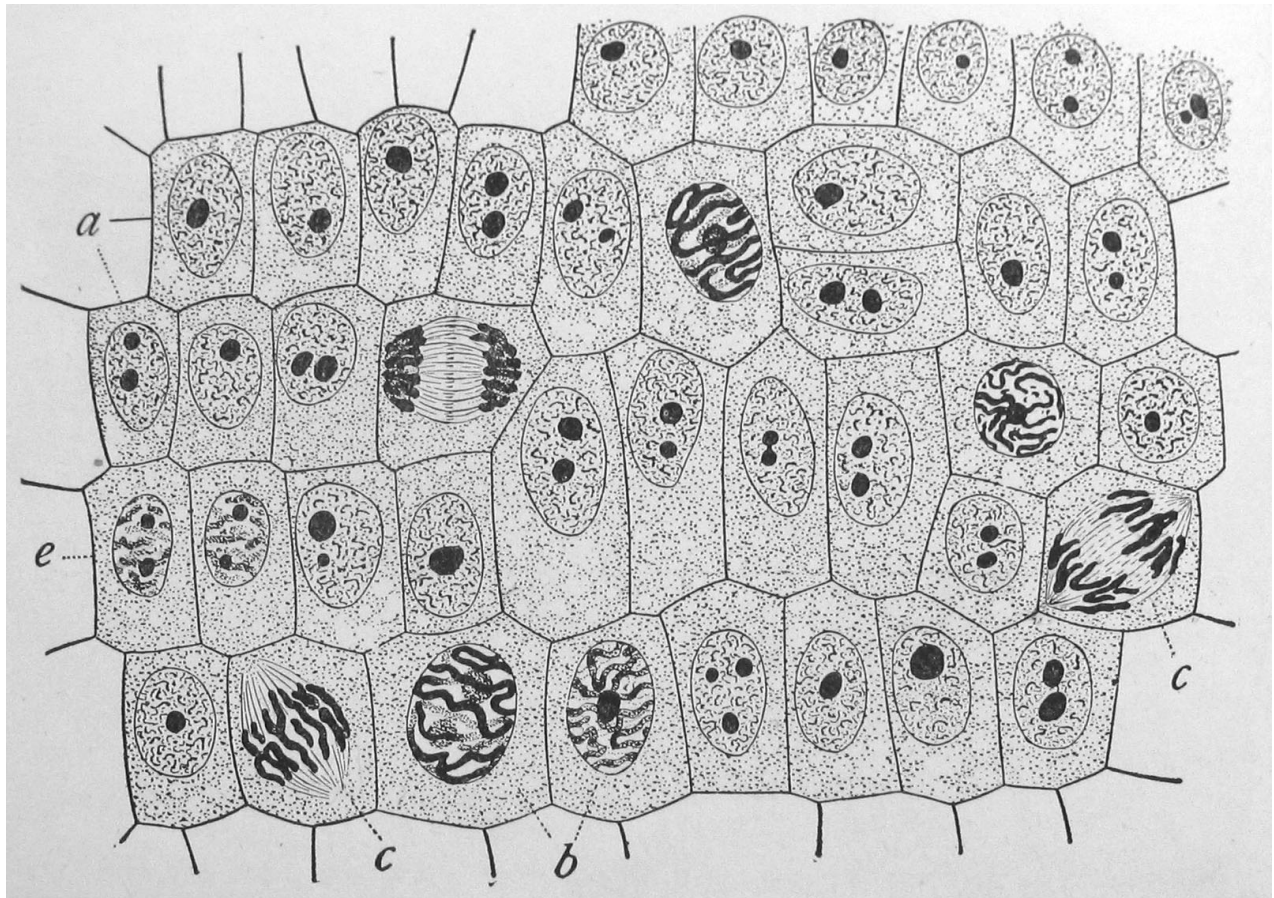
- Prophase
- Metaphase
- Anaphase
- Telophase

### Super-coiling of DNA into chromosome

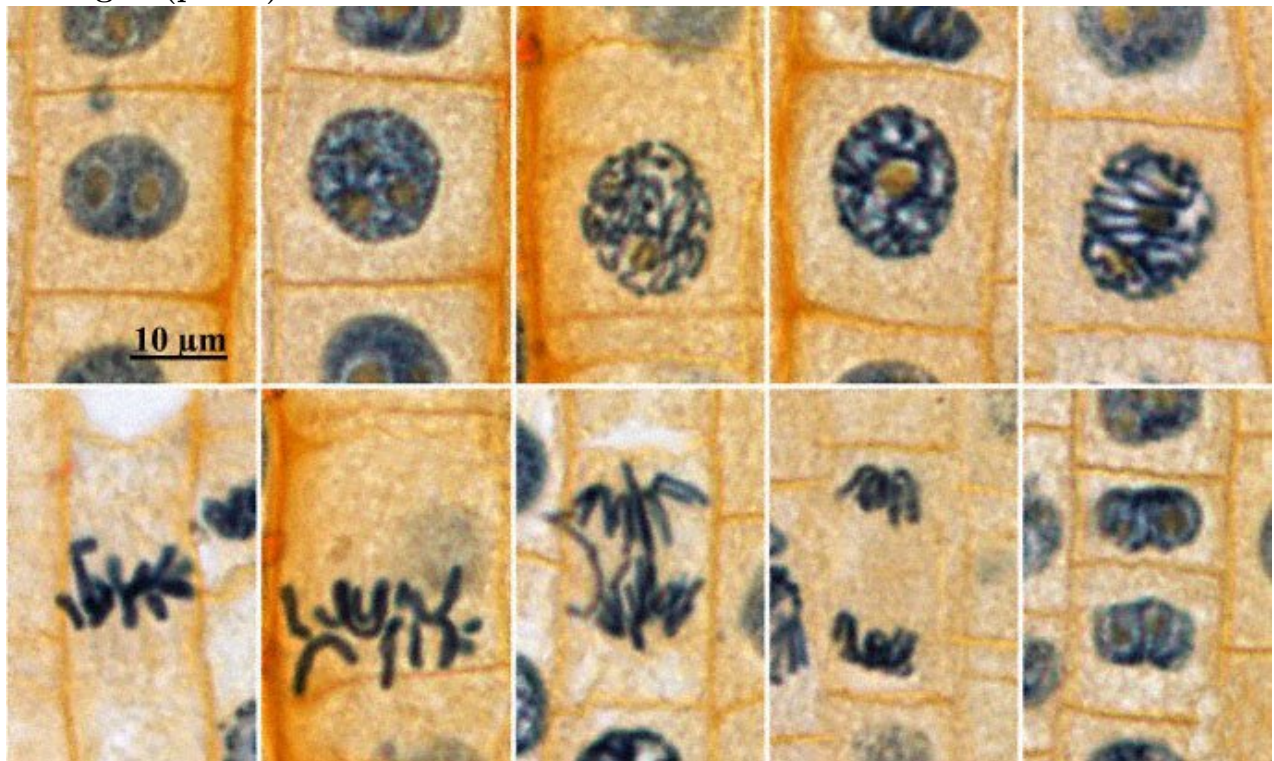


*Stages of mitosis*

Which stage? (drawing)



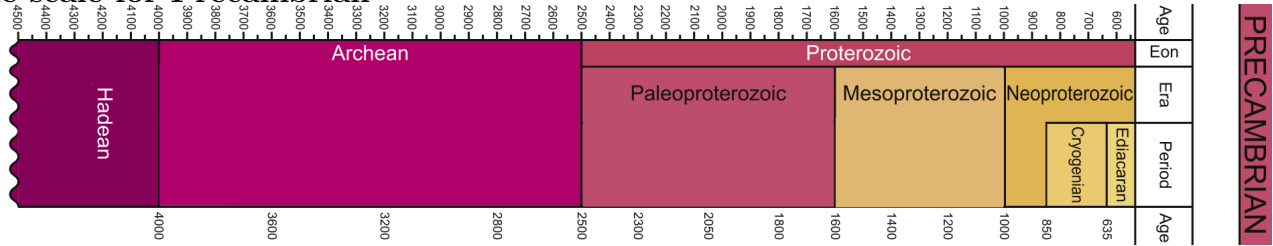
Which stage? (photo)



## 16 Life in late Precambrian

### 16.1 Cryogenian period and Snowball Earth

#### Time scale for Precambrian

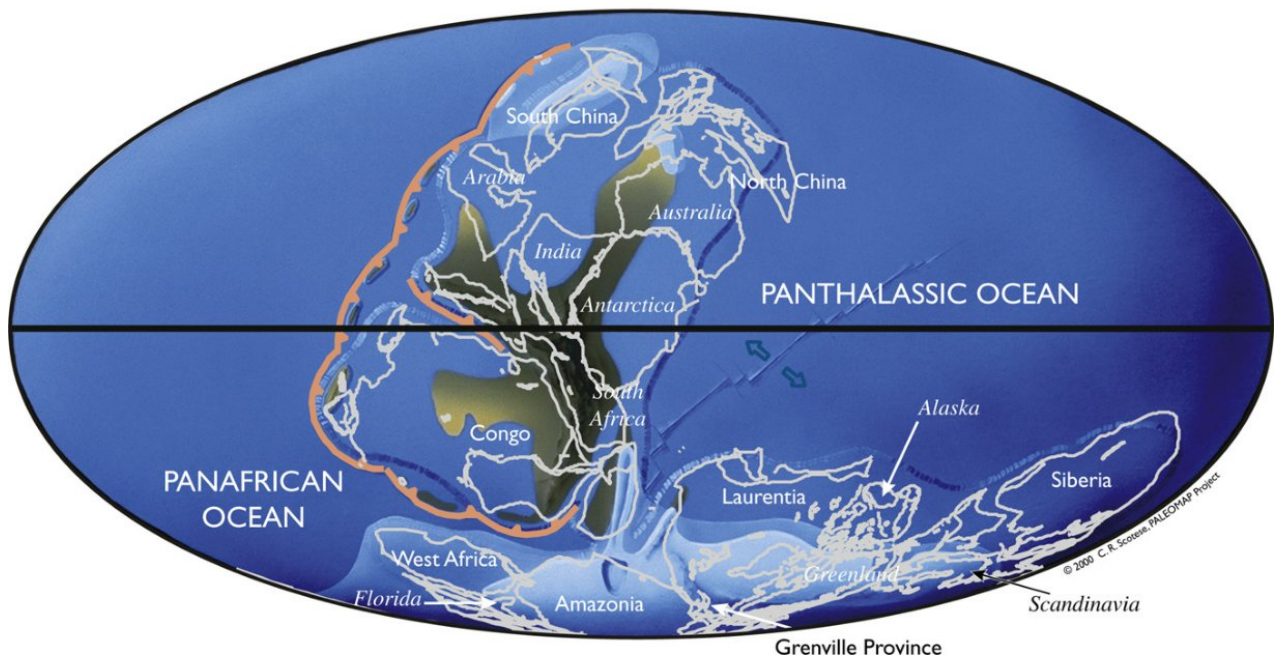


#### Rodinia—the first super-continent

- Tectonic plates formed (and will form) one continent several times
- 650 Mya this continent—Rodinia was formed right over the South Pole

#### Cryogenian continents which formed Rodinia

650 Ma Cryogenian



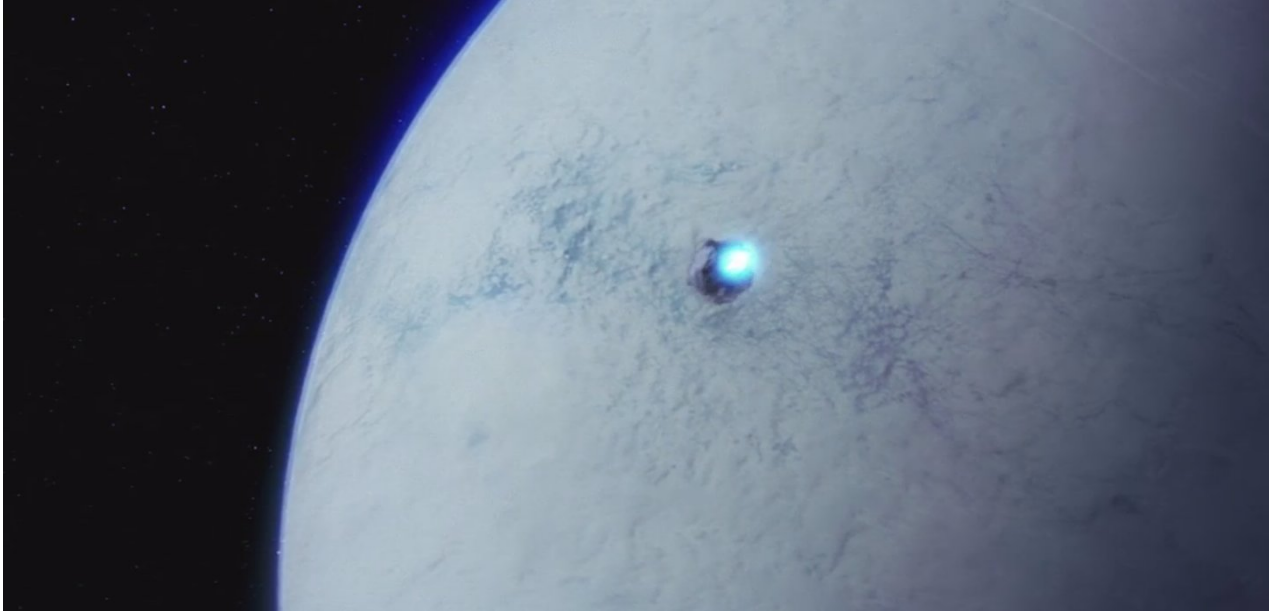
#### Rodinia: view from South Pole



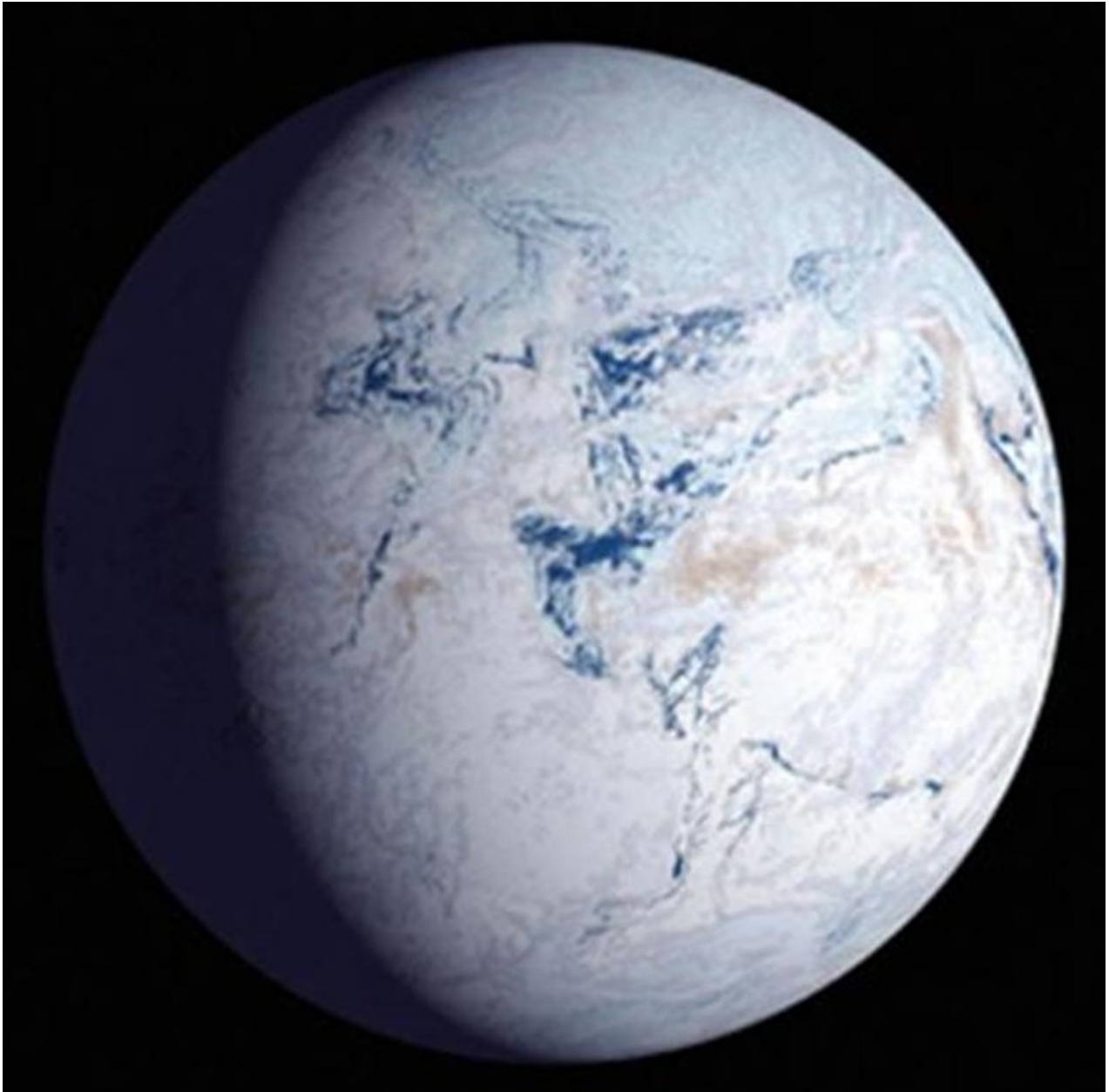
### **Marionan glaciation: Snowball Earth**

- First global glaciation was started because ice started to concentrate over the pole and increase Earth albedo (this is the positive feedback)
- And because the configuration of continents blocked the equatorial warm current
- And because concentration of oxygen was high but greenhouse gases (like CO<sub>2</sub>)—small
- As a result, from time to time Earth was completely covered with ice sheet 1 km tall!

### **Star Wars Hoth—ice planet**



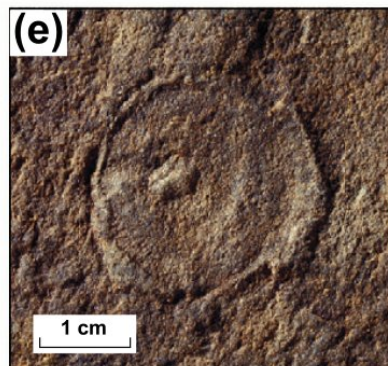
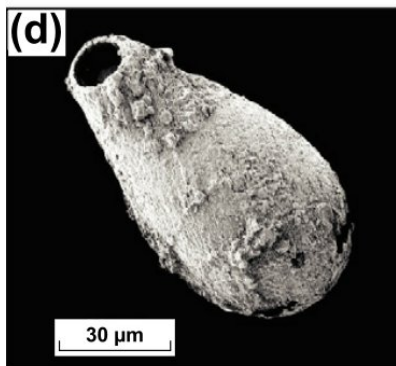
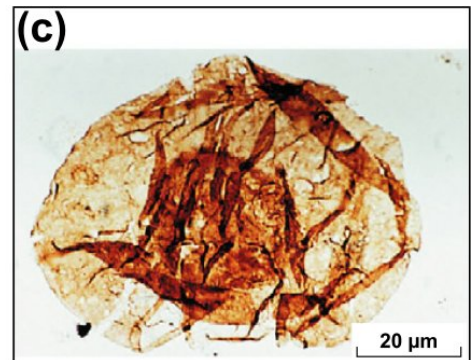
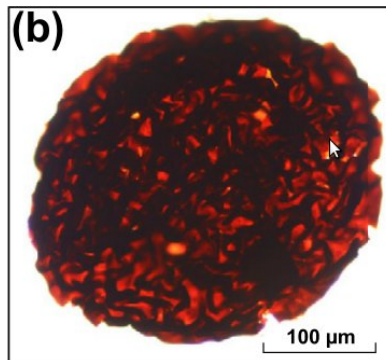
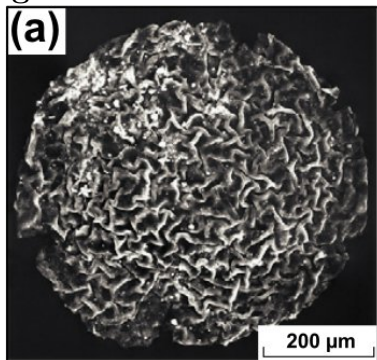
Snowball Earth



The evidence of Marinoan glaciation: diamictite layers everywhere on Earth



### Cryogenian fossils



### Summary

- Mitosis is an equal division of nucleus
- In Cryogenian, Marinoan glaciation covered the whole Earth

### For Further Reading

## References

[1] Mitosis. <http://en.wikipedia.org/wiki/Mitosis>

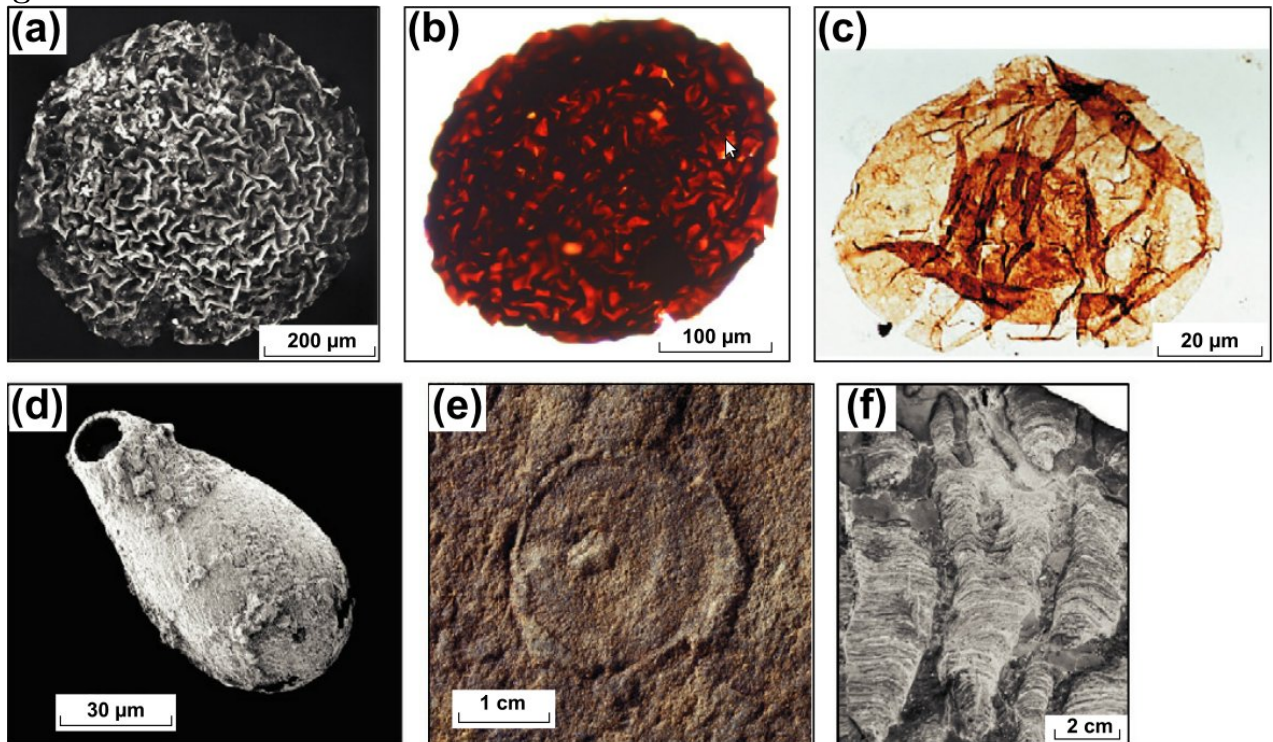
### Outline

## 17 Where we are?

### Marionan glaciation: Snowball Earth

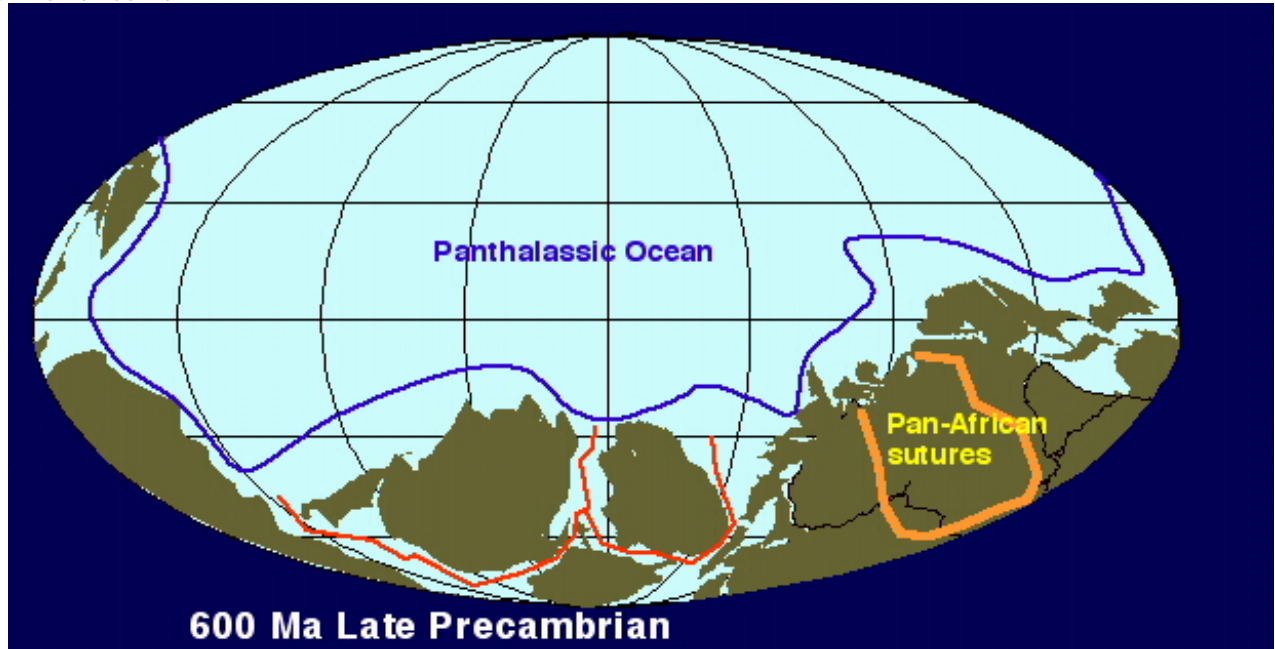
- First global glaciation was started because ice started to concentrate over the pole and increase Earth albedo (this is the positive feedback)
- And because the configuration of continents blocked the equatorial warm current
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- As a result, from time to time Earth was completely covered with ice sheet 1 km tall!

### Cryogenian fossils

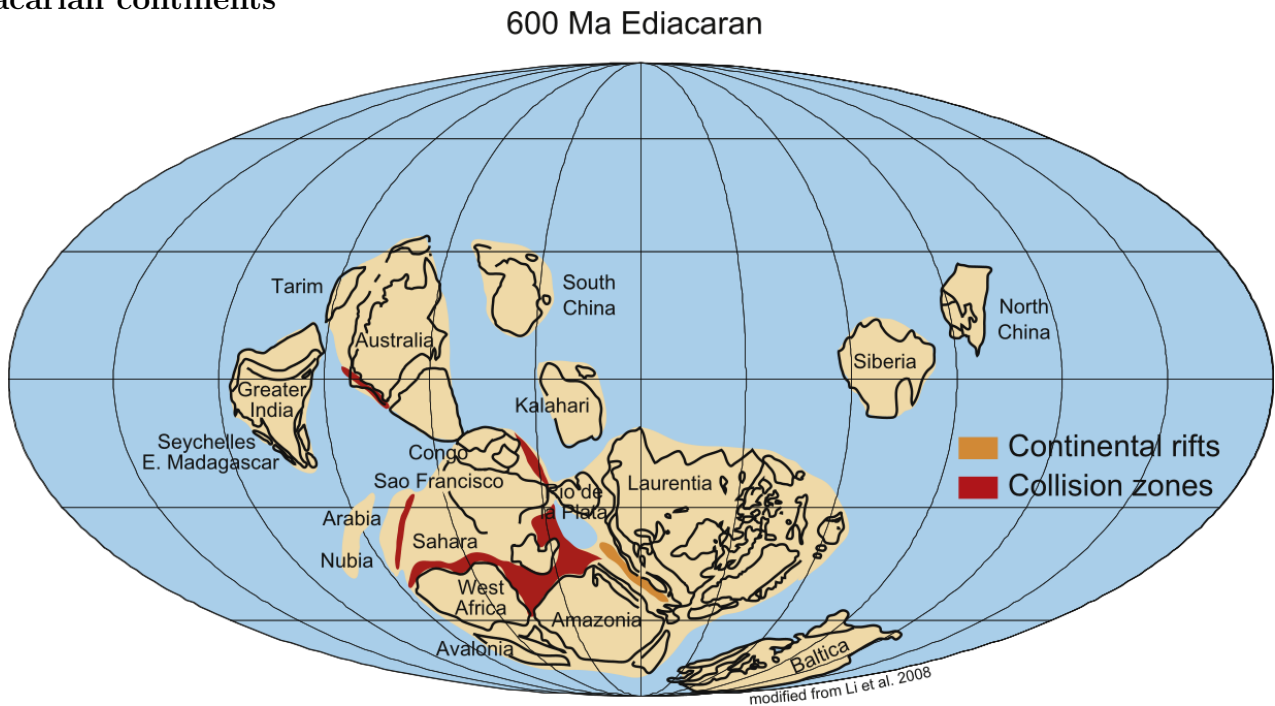


## 17.1 Ediacarian period and multicellularity

### Rodinia breaks



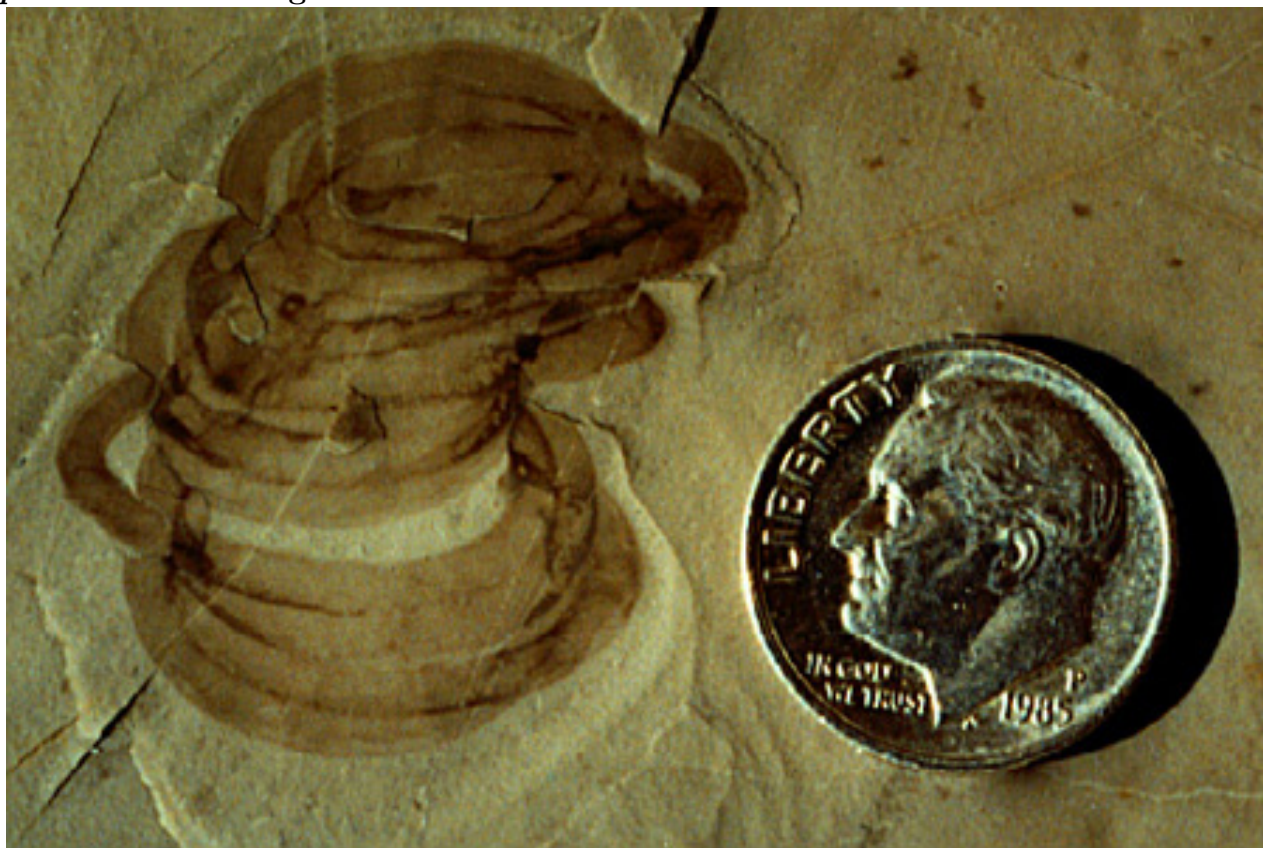
### Ediacarian continents



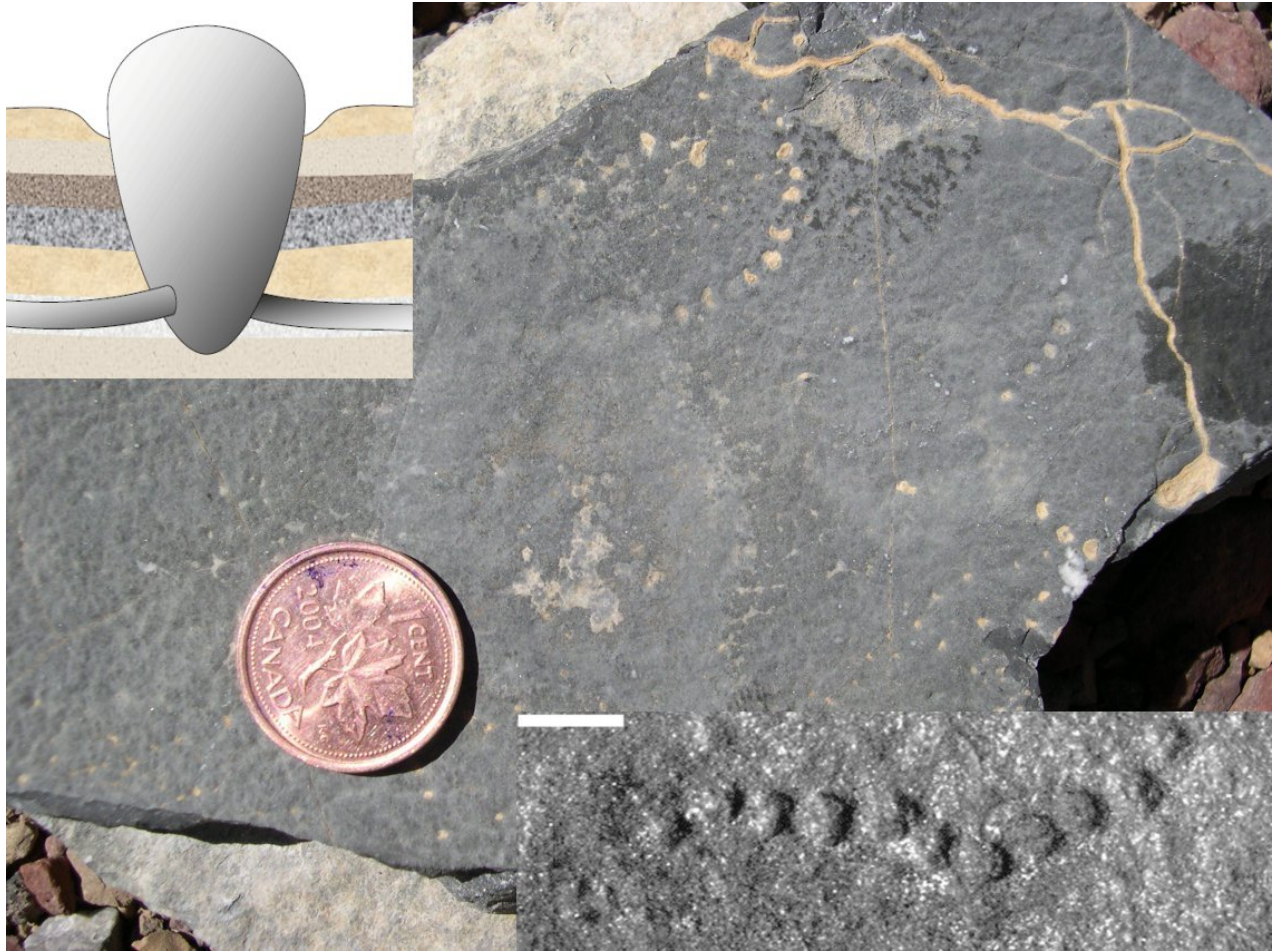
### First multicellular life

- Apart from enigmatic *Grypania* and *Horodyskia*, multicellular eukaryotes were not known before Ediacarian
- From the beginning of Ediacarian, multicellular Lantian algae were known, and then—fabulous “Ediacara garden”, the fauna of animals without skeleton

*Grypania*—the first alga?



*Horodyskia* and its interpretations



### **Multicellularity and origin of death**

- Multicellular assemblages were probably originated from incompletely divided cells
- Initially, those assemblages were only benefit from their size
- Then, they started to use a division of labor: differentiated into somatic and generative cells
- Whereas generative cells are specialized for multiplication and will continue to “live” in next generations, somatic bodies ought to die
- Unicellular living organisms are still potentially immortal

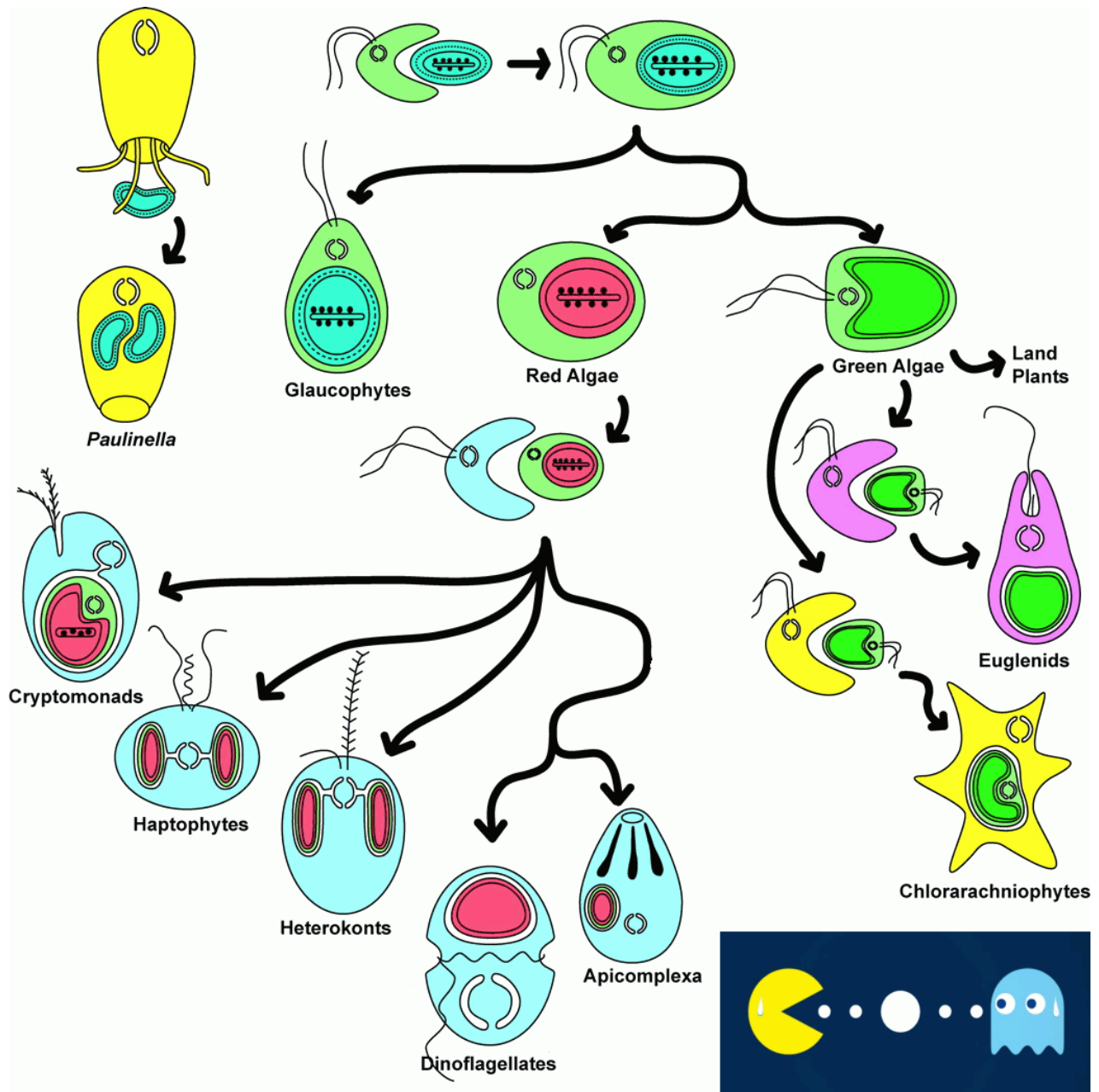
### **Lantian (China) macroscopic algae**



## What are algae?

- Eukaryotes which are capable for photosynthesis with chloroplasts
- All chloroplasts were symbiotic (cyanobacteria in the past), and some even secondary symbiotic (other alga in the past)

## “Pacman game” of algae origin

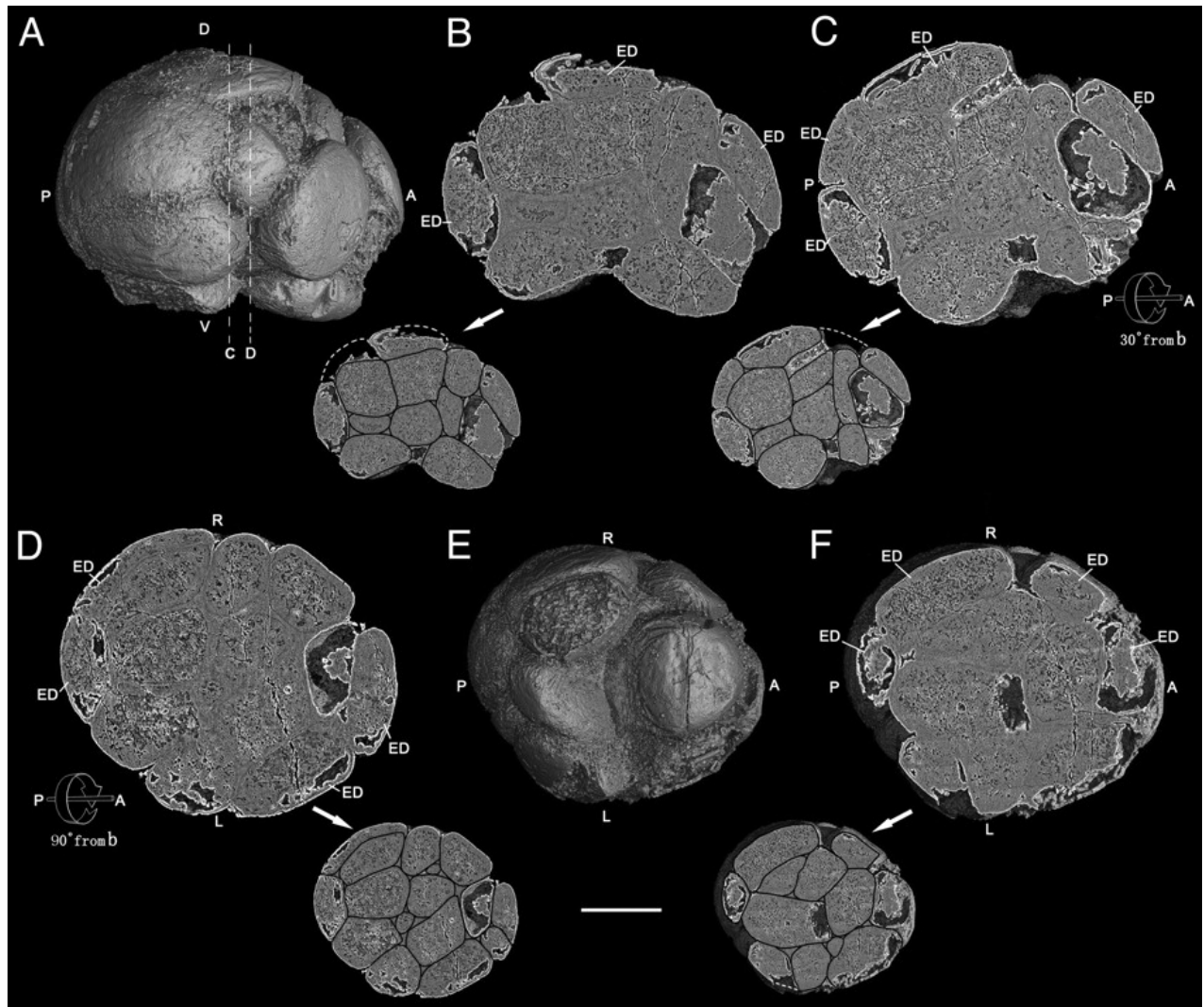


Life without animals



## 17.2 First animals

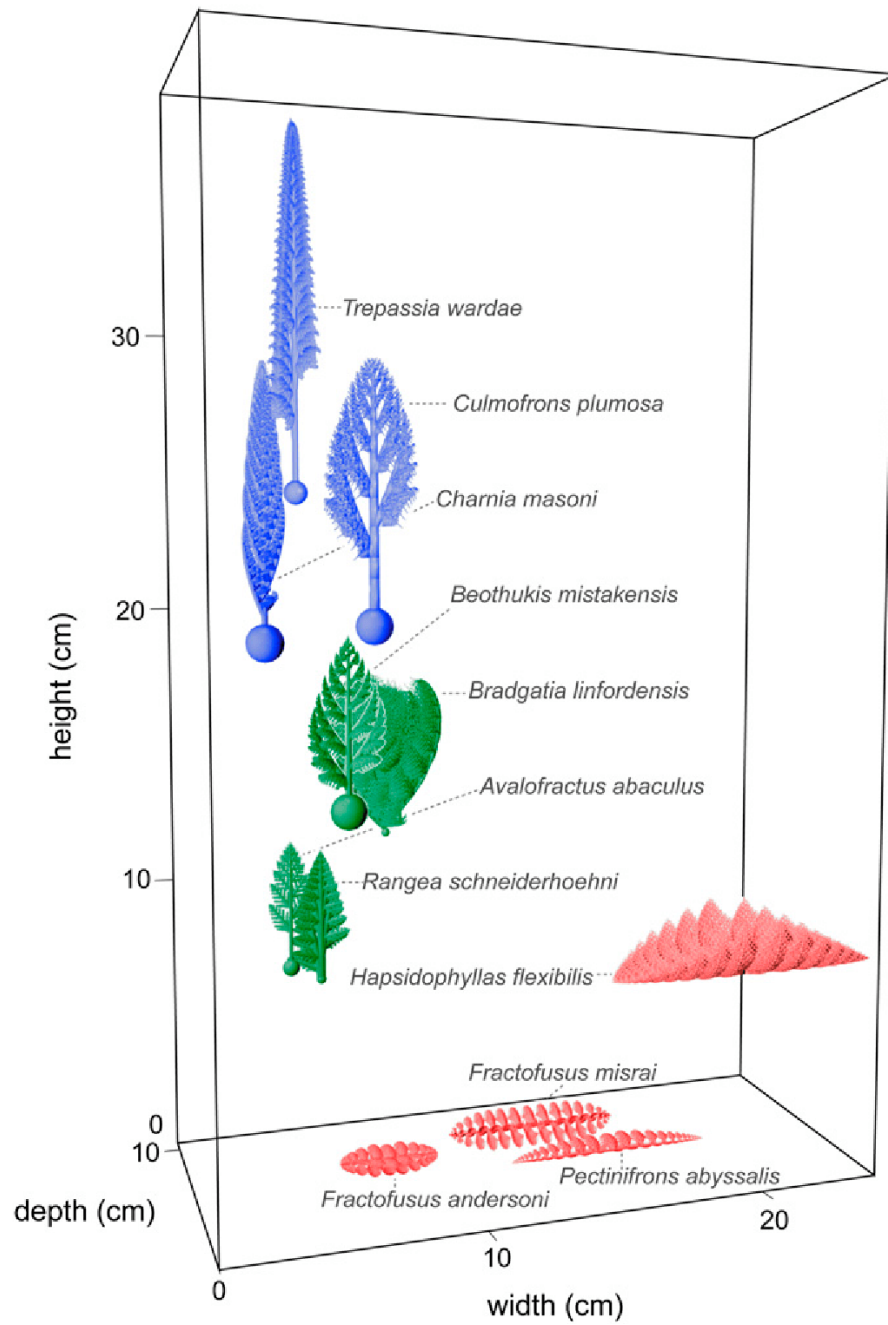
Doushantuo (China) “embryos”—first animals?



Finding Ediacara biota



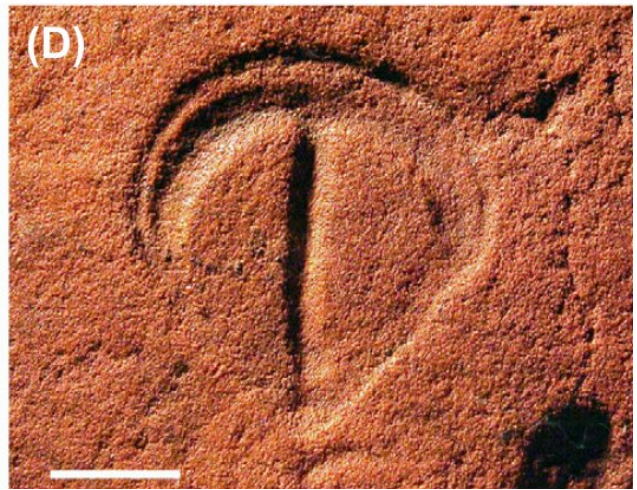
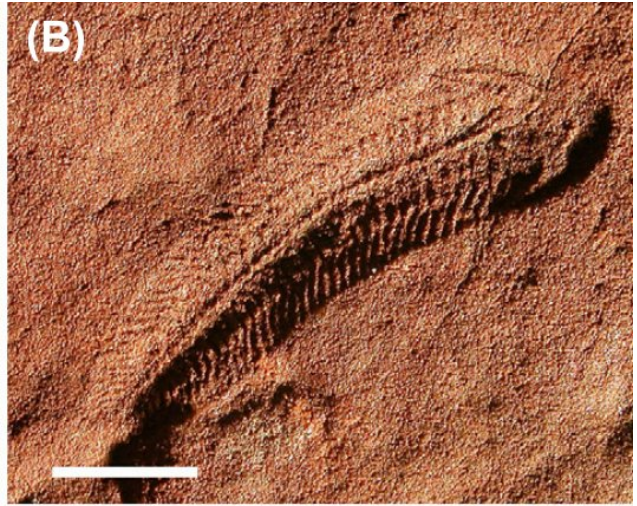
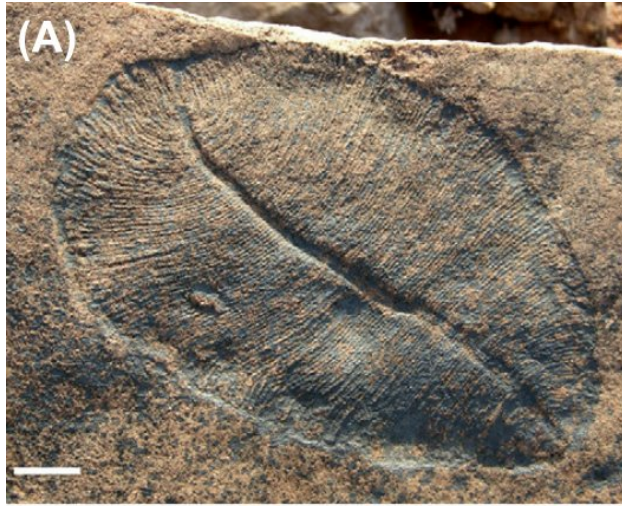
Mistaken Point (Canada) fauna: rangeomorphs



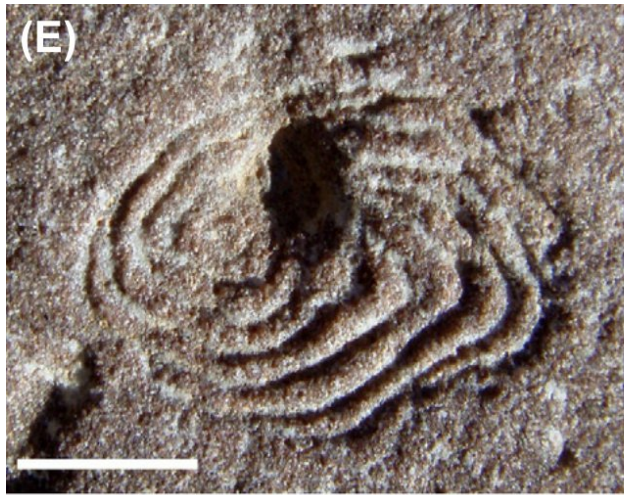
Extant sea pen (Pennatulacea soft corals)



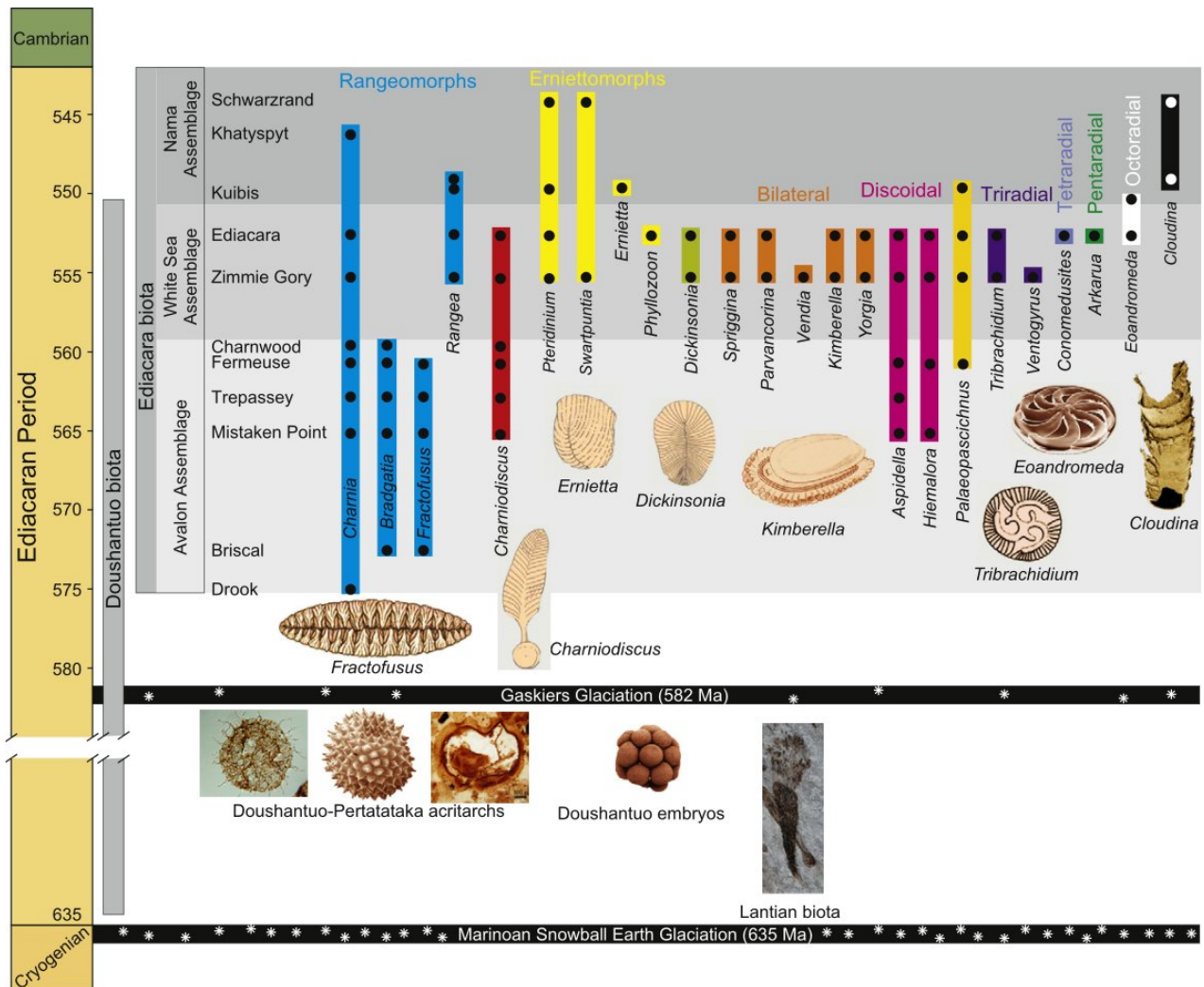
Ediacara Garden: *Dickinsonia*, *Spriggina* etc.



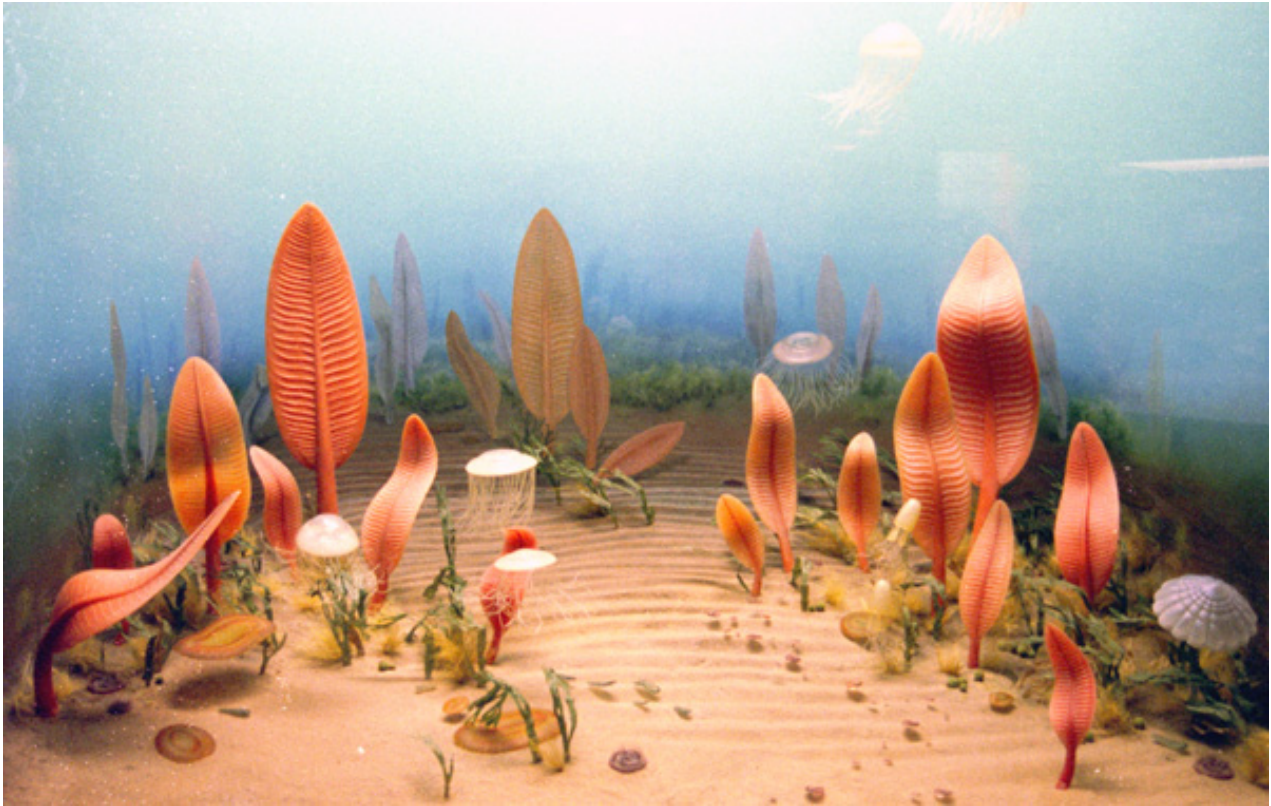
Ediacara Garden: *Eoandromeda*, *Charniodiscus* etc.



Life in Ediacarian



Ediacara “garden”—no predators *of macroscopic size*, nobody had skeleton



## Origin of tissues—the most important event in late Precambrian

- Tissues are assemblages of similar cells doing the similar job
- Tissues are one level more over the eukaryotic cells
- Multicellular animals also have multiple tissues whereas multicellular algae and cyanobacteria are still on pre-tissues level of complexity
- Multi-tissued body is a great achievement, except for cancer...

## Questions before Exam 2?

### Summary

- In Cryogenian, Marinoan glaciation covered the whole Earth
- In Ediacarian, multicellular and then multi-tissued eukaryotes appeared

### For Further Reading

## References

- [1] Mitosis. <http://en.wikipedia.org/wiki/Mitosis>
- [2] Ediacara biota. [http://en.wikipedia.org/wiki/Ediacara\\_biota](http://en.wikipedia.org/wiki/Ediacara_biota)

## Example questions for the exam

- |  |   |
|--|---|
| <p>1. Proterozoic eon:</p> <ul style="list-style-type: none"><li>A. Left no traces</li><li>B. There are Proterozoic minerals only</li><li>C. There are both Proterozoic minerals and Proterozoic fossils</li></ul> <p>2. What is NOT relevant to photosynthesis:</p> <ul style="list-style-type: none"><li>A. Production of CO<sub>2</sub></li><li>B. ATP synthesis</li><li>C. Both of above</li></ul> | <p>3. Cell membrane:</p> <ul style="list-style-type: none"><li>A. Defends the cell mechanically</li><li>B. Is a barrier for water</li><li>C. Both of above</li></ul> <p>4. Chloroplasts:</p> <ul style="list-style-type: none"><li>A. Were independent bacteria in the past</li><li>B. Have no DNA</li><li>C. Both of above</li></ul> |
|--|---|

## Answers

1C, 2A, 3B, 4A