

# 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 2

### Results of Exam 2: statistic summary

Summary:

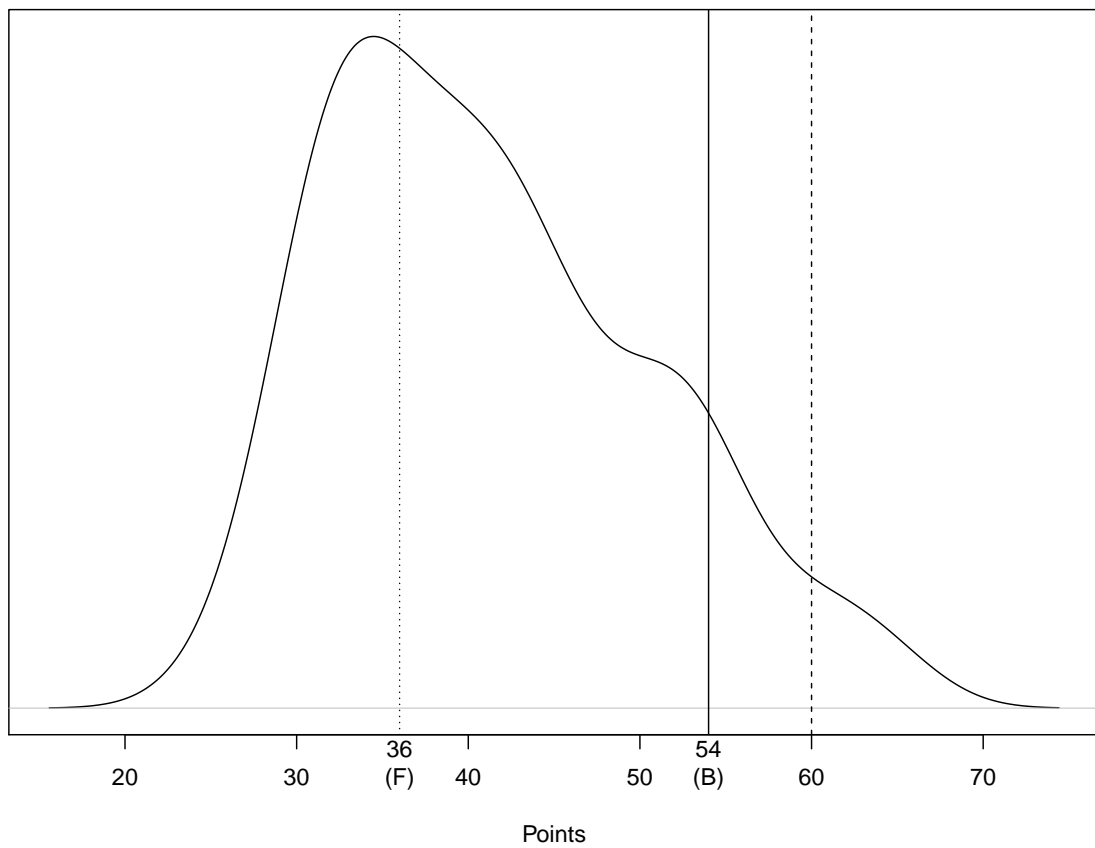
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
25.00	34.00	40.00	41.34	47.75	65.00	9

Grades:

F	D	C	B	max
36	42	48	54	60

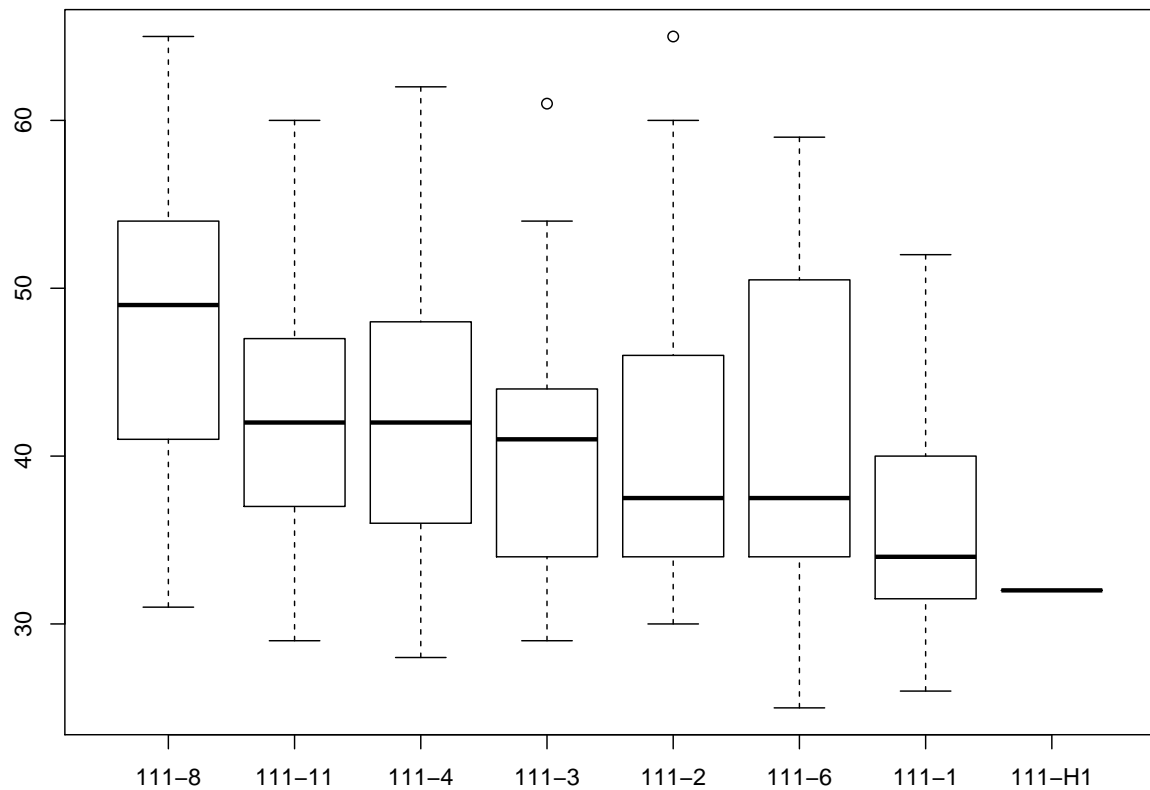
### Results of Exam 2: the curve

### Density estimation for Exam 2 (Biol 111)



Results of Exam 2: sections

### Competition between Biol 111 sections (Exam 2 )



### Results of Exam 2: three questions

- What is ATP?
  - A. Universal source of energy in the cell
  - B. Molecule which is similar to nucleotides
  - C. **Both of above**
- Cell wall:
  - A. **Defends the cell mechanically**
  - B. Is a barrier for water
  - C. Both of above
- Since DNA is two complimentary chains, duplication of each chain:
  - A. Makes two exact copies
  - B. Makes two “mirror” copies
  - C. **Makes one exact and one “mirror” copy**

## 2 Where we are?

### 2.1 Nucleus, introns and telomerase

#### The logic of acquiring nucleus

- In bacterial mat, many bacterial groups coexist
- Due to the evolution, they become more and more dissimilar
- However, **horizontal transfer** of DNA continued
- To prevent the transfer of alien genes, some cells “decided” to separate DNA with membranes

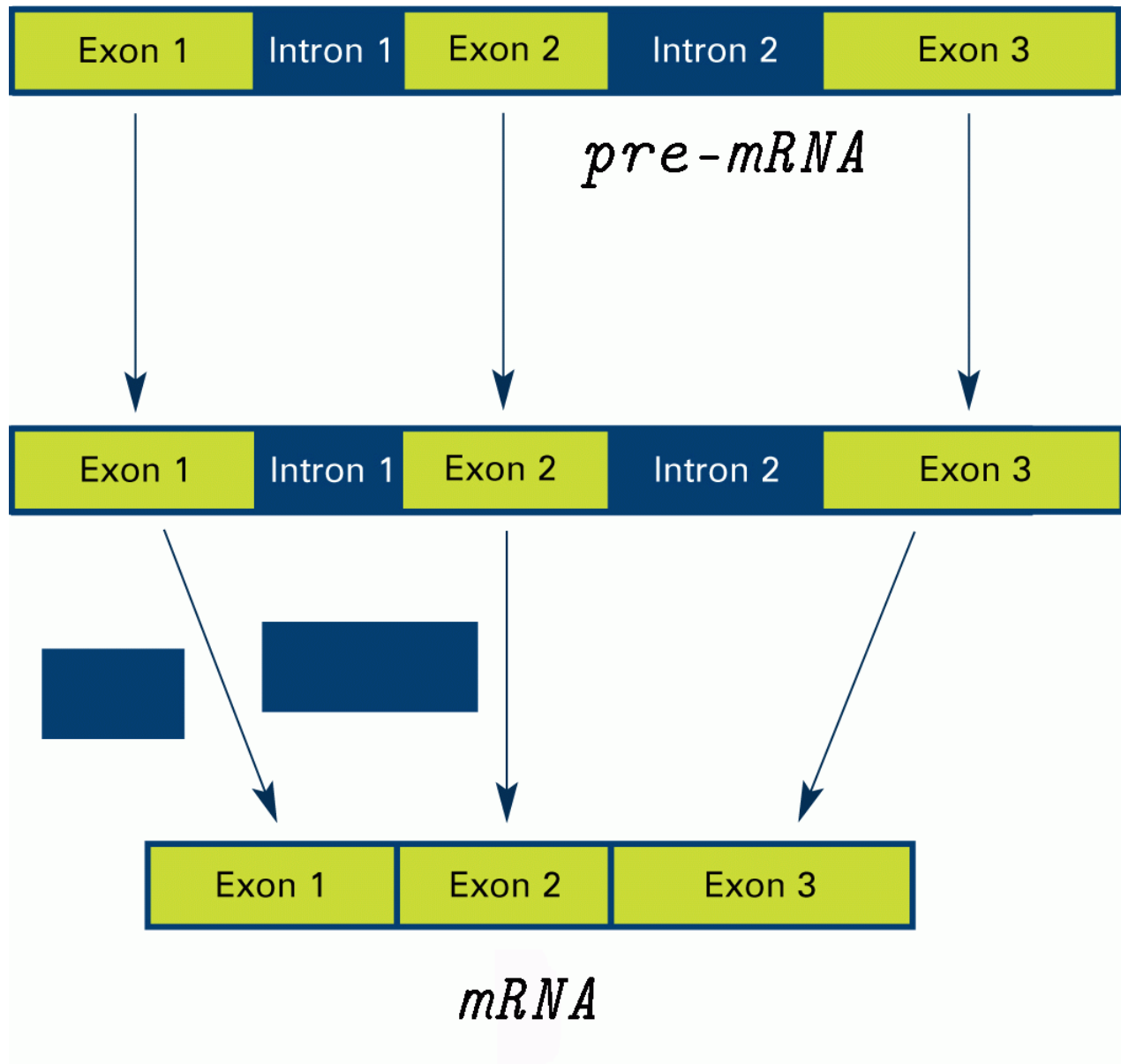
#### Nuclear envelope

- There are many ways to create nucleus-like structures. For example, it could be guarded with one membrane but then pores will be impossible
- Eukaryote ancestors created the *nuclear envelope from ER*

#### Introns

- Creating a nucleus run the cascade of consequences. First of all, cell now may keep much more DNA
- Some of this DNA may now contain insertions—**introns** which are removed before mRNA go through the nuclear pore
- Introns increase the variability of DNA and allow to make many variants of proteins

#### Introns and exons



Only archebacteria and eukaryotes have introns

### Linear DNA

- Circular molecules of DNA are harder to keep, difficult to enlarge and slower to duplicate
- Eukaryotes change circular DNA into linear
- Every linear DNA molecule is “I-chromosome”

### Telomerase and aging

- Unfortunately, replication of linear DNA has a problem: with every replication, the very end of DNA molecule *is not replicated*
- **Telomerase** adds some nonsense DNA to the telomere and thus prevent the shortening of DNA molecule
- Unfortunately, sometimes telomerase is not working well and DNA was cut... This is one of main reasons of **aging**

## 2.2 Precambrian life

### Precambrian life

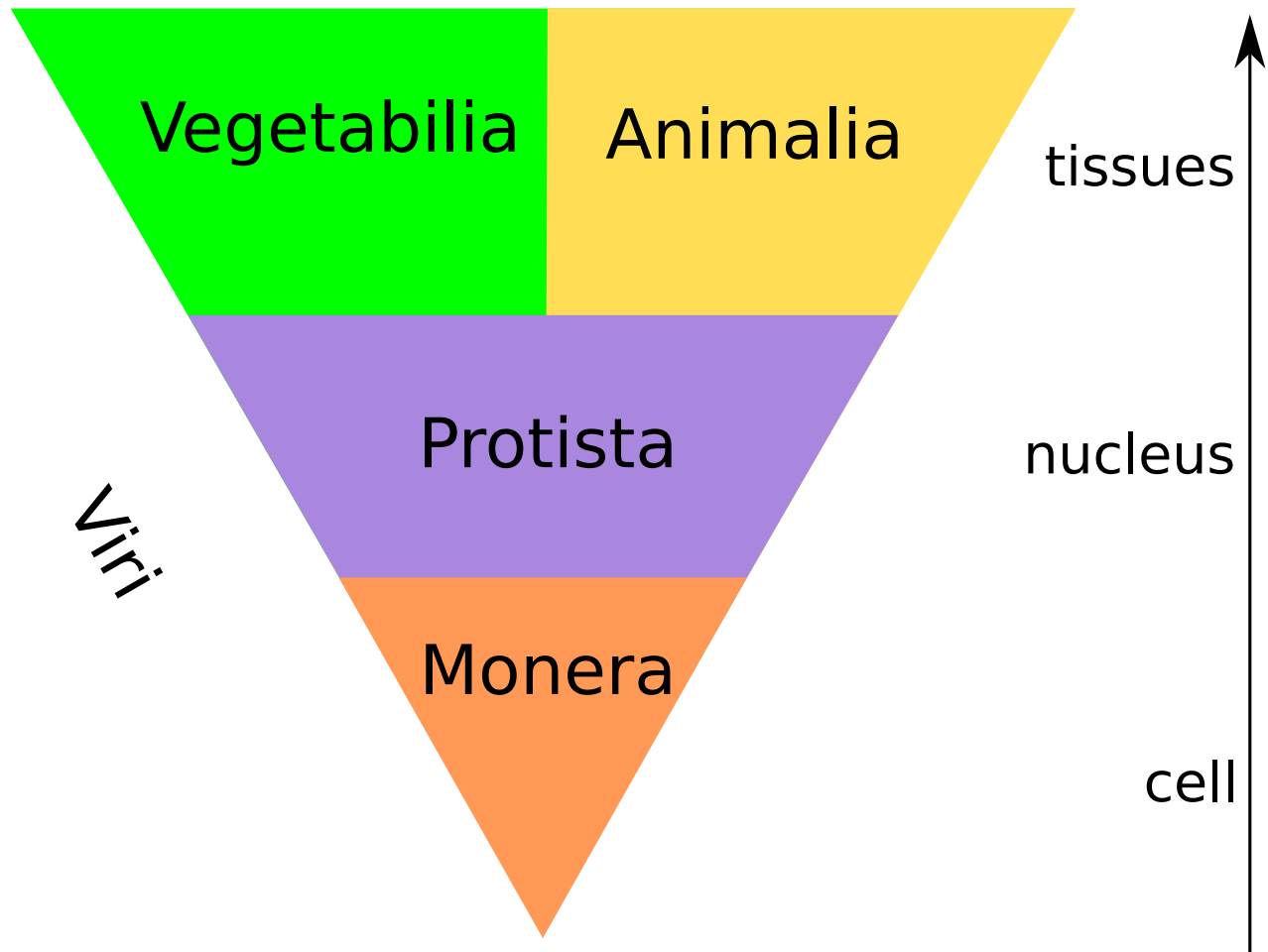
- In Cryogenian, Marinoan glaciation covered the whole Earth
- In Ediacarian, multicellular and then multi-tissued eukaryotes appeared

One of first multicellular alga with reproductive cells



*Bangiomorpha*, putative red alga from Proterozoic

Cells, tissues, kingdoms and viruses



## Summary

- Introns, linear DNA molecules and telomere/telomerase system differ eukaryotes from most prokaryotes

## For Further Reading

## References

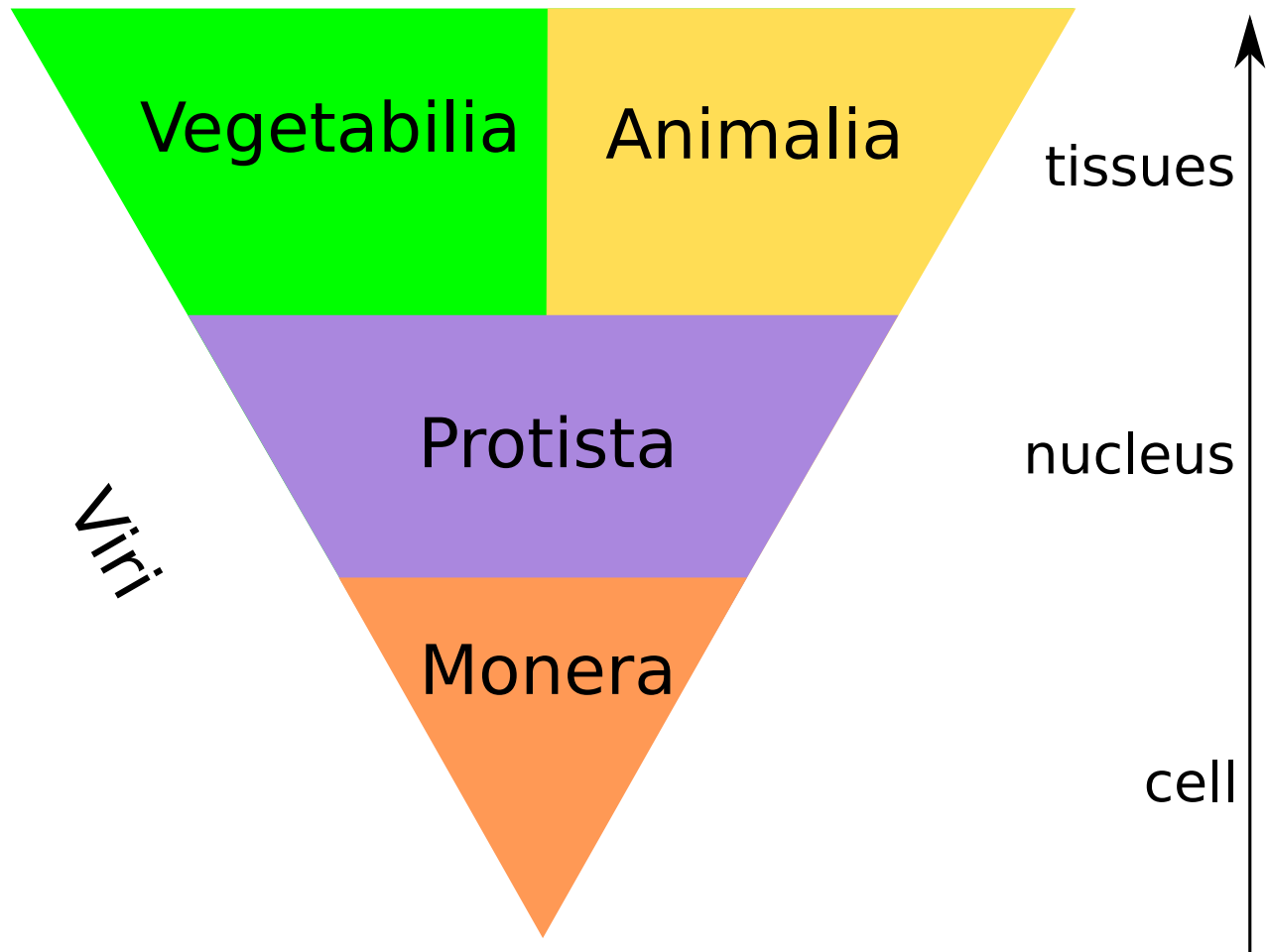
[1] Introns. <http://en.wikipedia.org/wiki/Intron>

## Outline

### 3 Where we are?

#### 3.1 Cells, tissues, kingdoms and viruses

Cells, tissues, kingdoms and viruses



## 4 Cambrian period

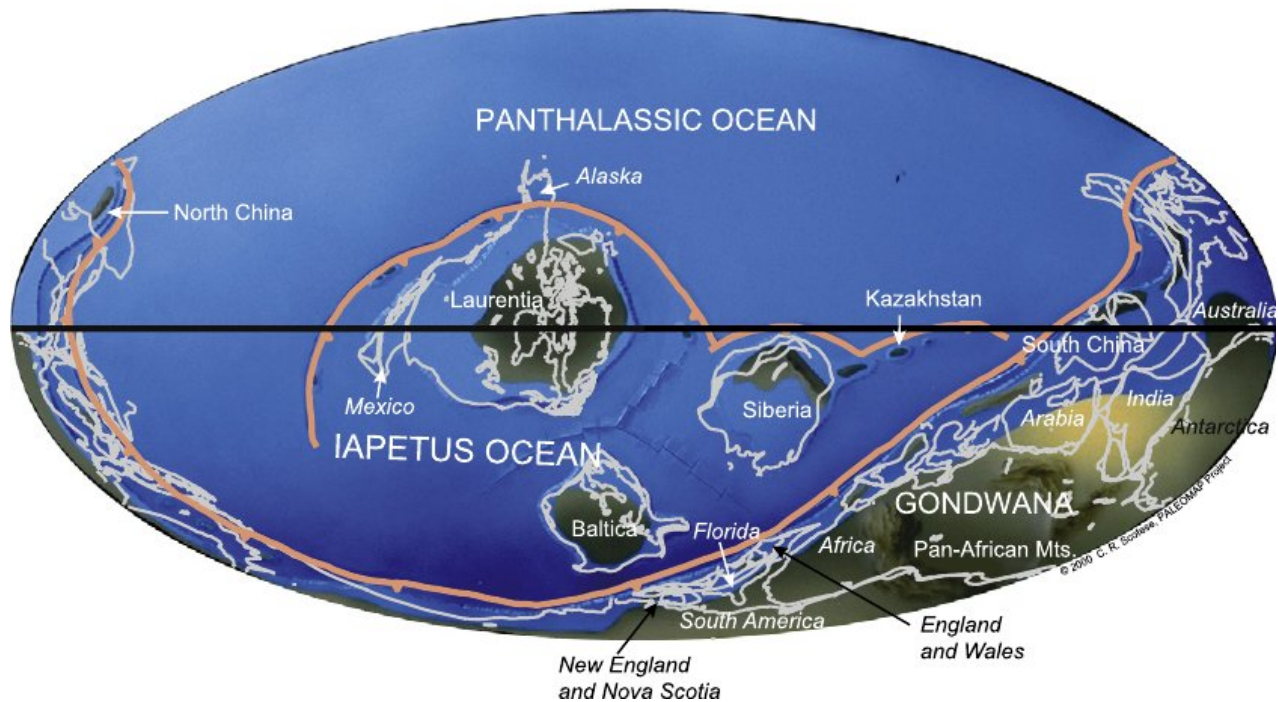
### 4.1 Life in Cambrian

Timescale of Phanerozoic eon, Paleozoic era

- Phanerozoic eon
  - Paleozoic era
    - \* Cambrian period: 541 Mya
    - \* Ordovician period: 485 Mya
    - \* Silurian period: 443 Mya
    - \* Devonian period: 419 Mya
    - \* Carboniferous period: 358 Mya
    - \* Permian period: 299–252 Mya

Cambrian map

## 514 Ma Cambrian



### Cambrian climate

- Gradually changed from colder to warmer
- Polar ice caps were most probably present

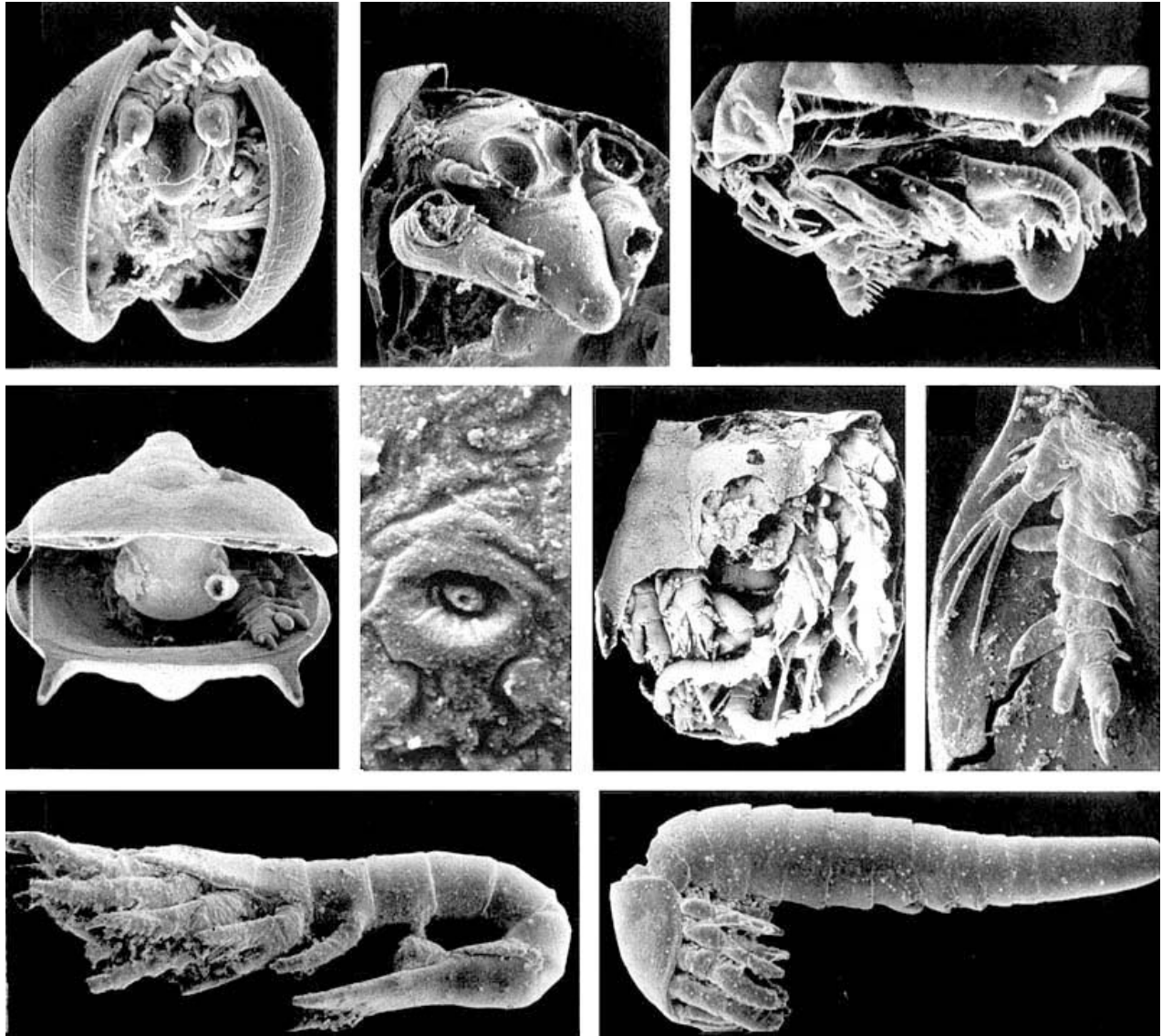
### Main Cambrian biotas

- Burgess shale (505 Mya)
- Orsten fauna (498 Mya)
- These fossils were kept in Lagerstaettes—exceptionally well preserves clay deposits
- This excellent preservation could be consequence of the rarity of Cambrian destroyers

### Burgess shale



Orsten fauna



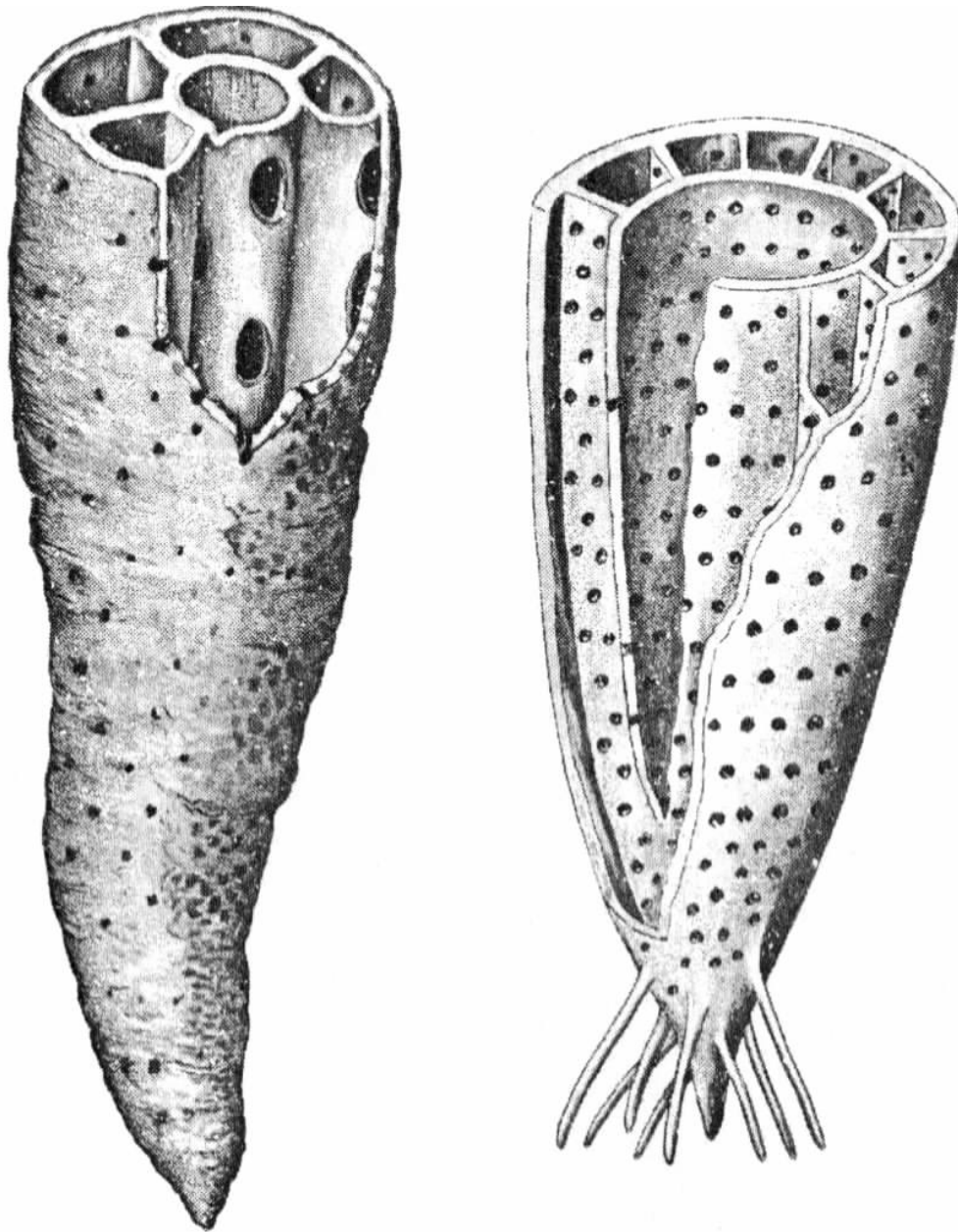
## 4.2 Cambrian explosion of skeletal fauna

Life in Cambrian



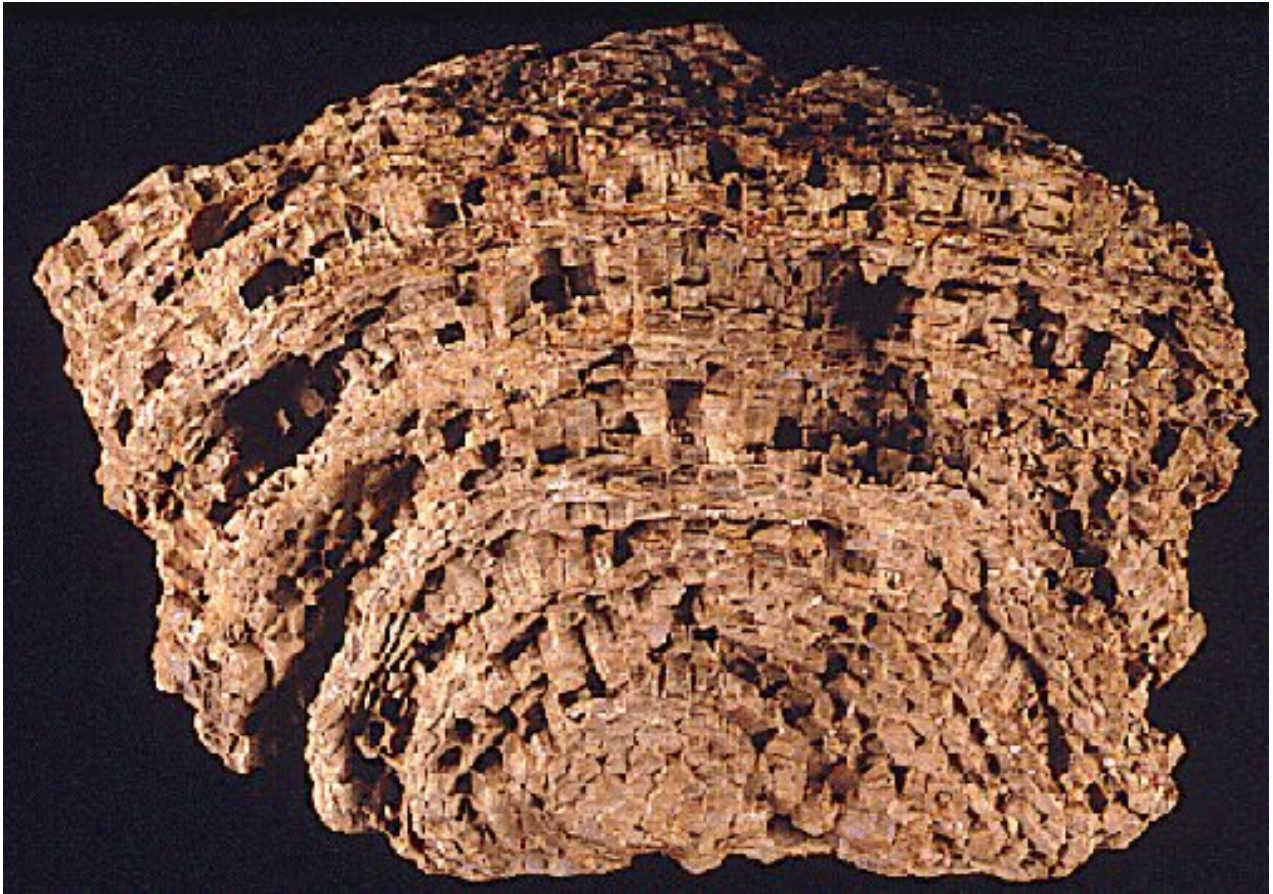
This is the picture of famous Czech artist Zdenek Burian

Archaeocyaths (most probably sponges)



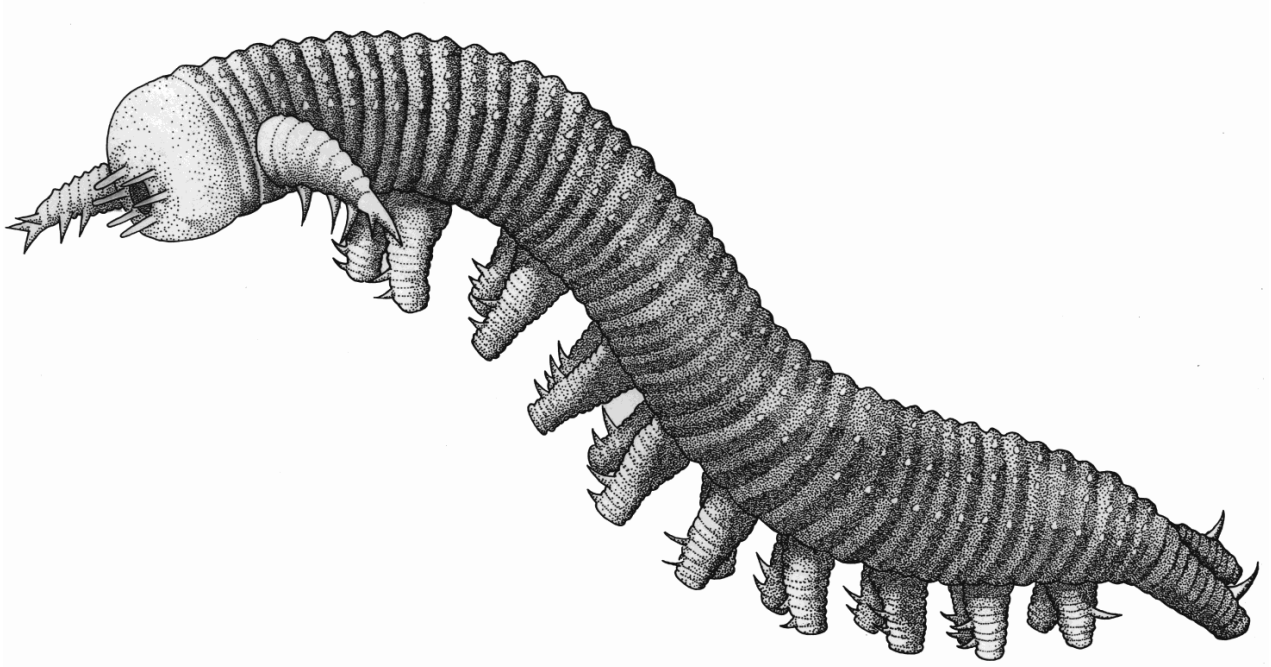
Most probably, Archaeocyaths were sponges

Cnidaria



Tabulate coral

### Lobopod worms



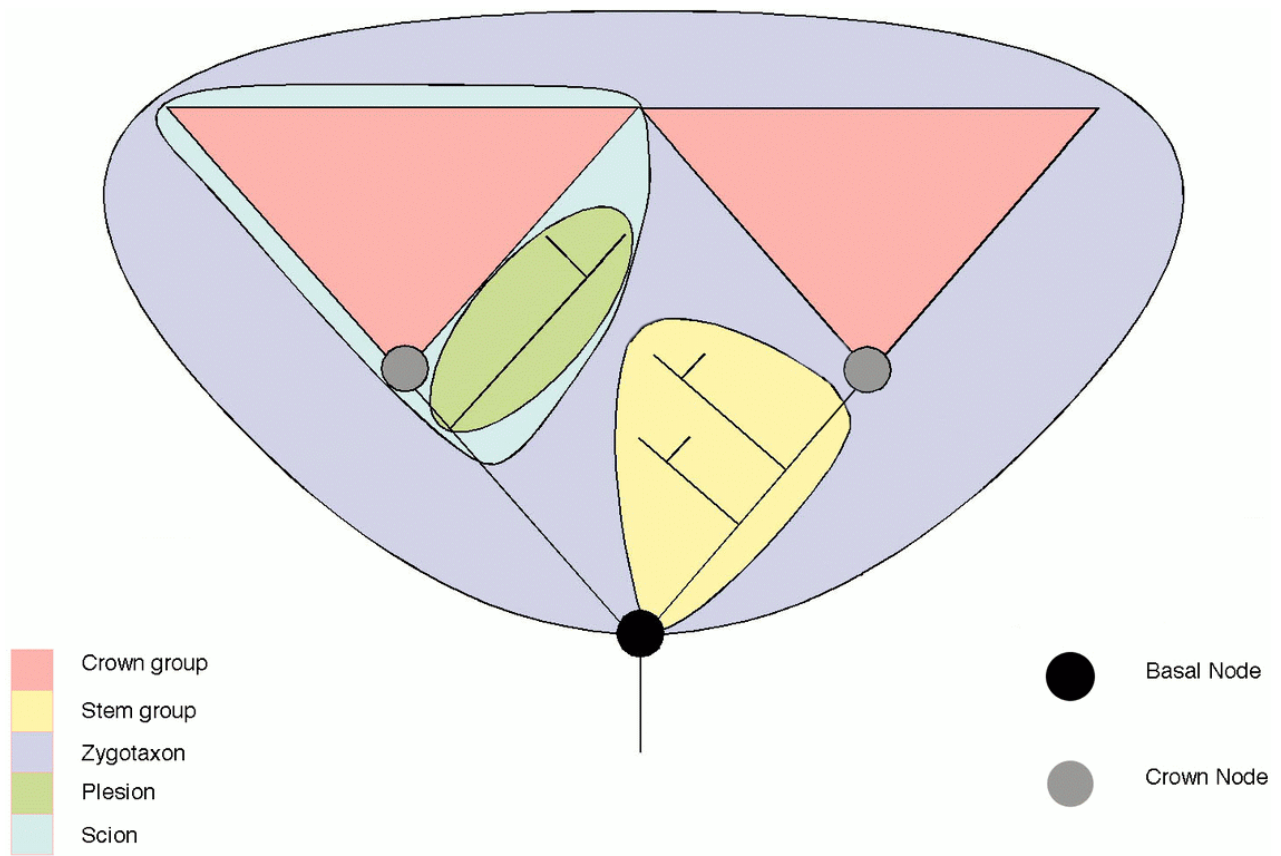
This is *Aysheaia*

Our *Hallucigenia* is also a lobopod worm!

### Stem Arthropods



Stem and crown groups

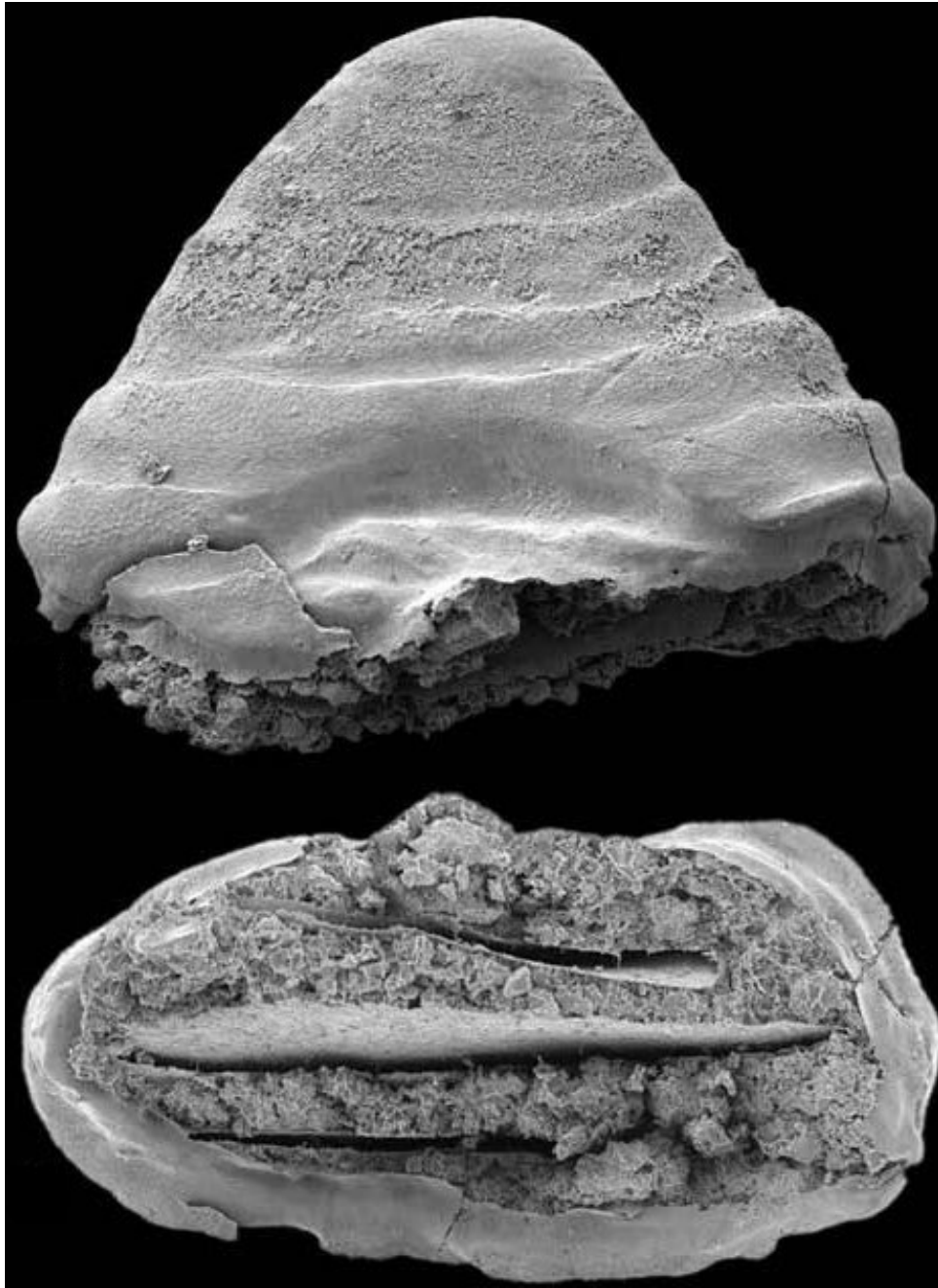


Mollusks: naked



*Odontogriphus* – stem naked mollusk

... and shelled

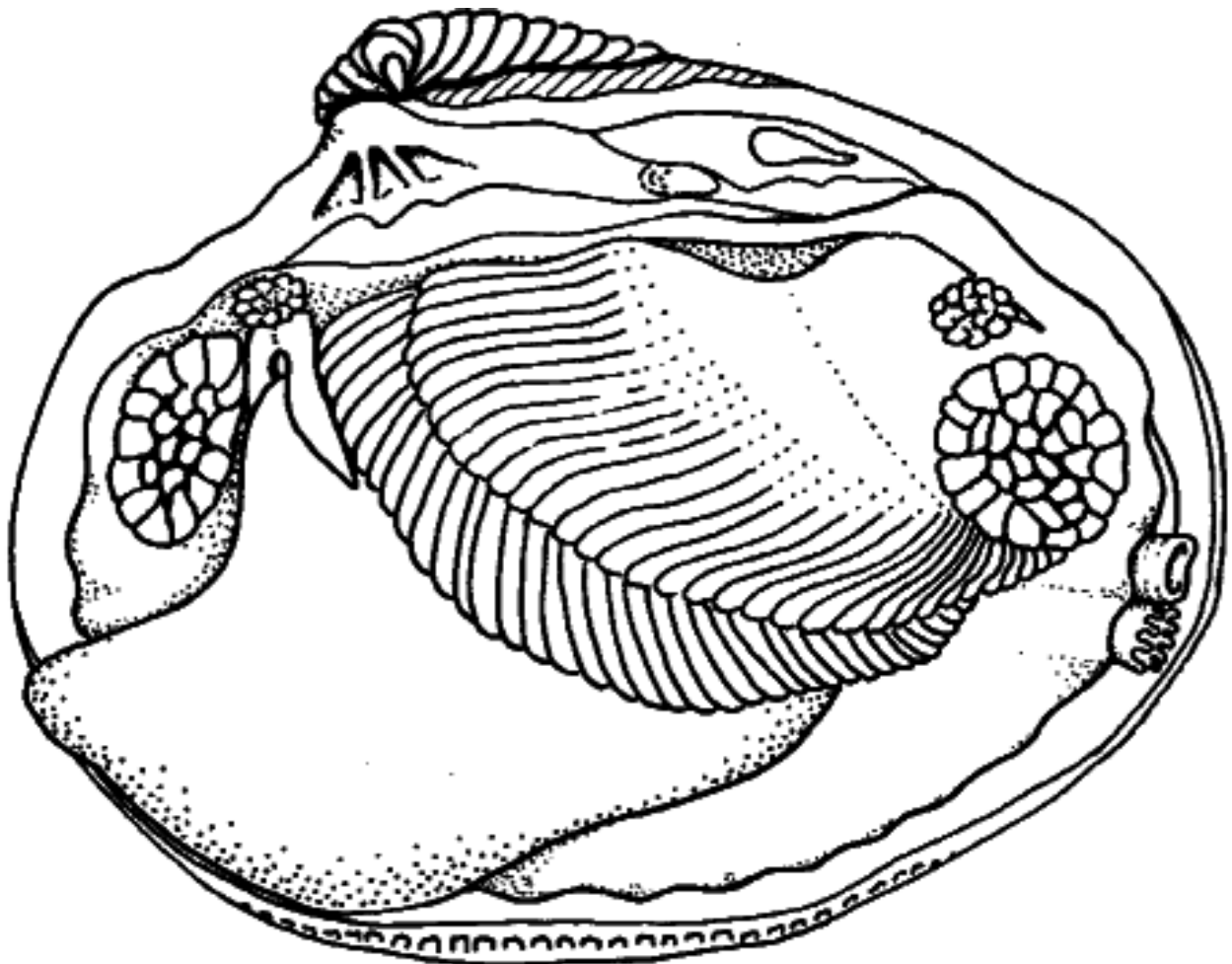
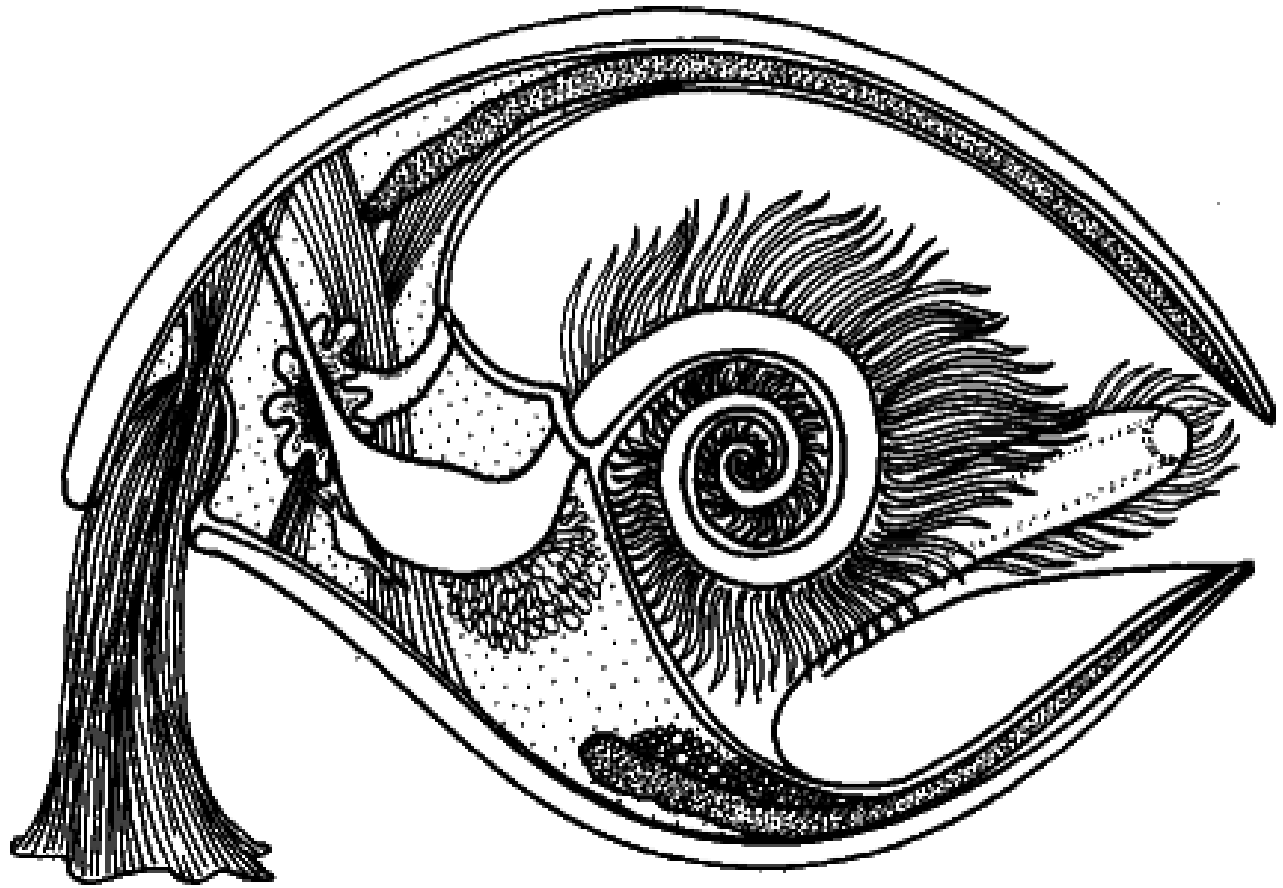


Helcionellid shell-bearing mollusk from Greenland

Brachiopods



Brachiopods are not mollusks!



Brachiopoda (left) are completely different internally from bivalve mollusks (right)

### Echinoderms



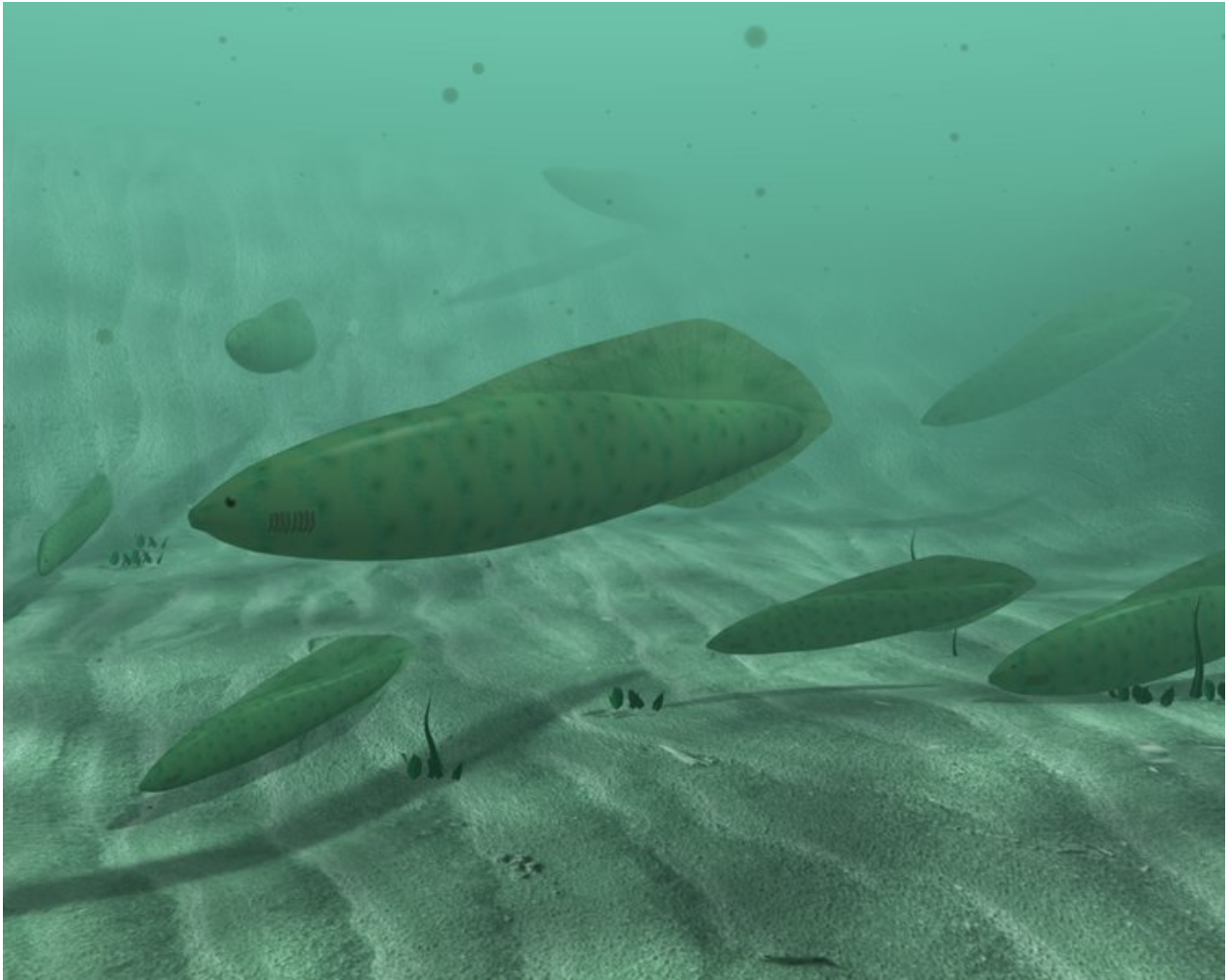
Sea lily *Gogia* from Nevada

### Soft-bodied chordates



*Pikaia* from Burgess shale

First fish-like animals: craniate *Haikouichthys*

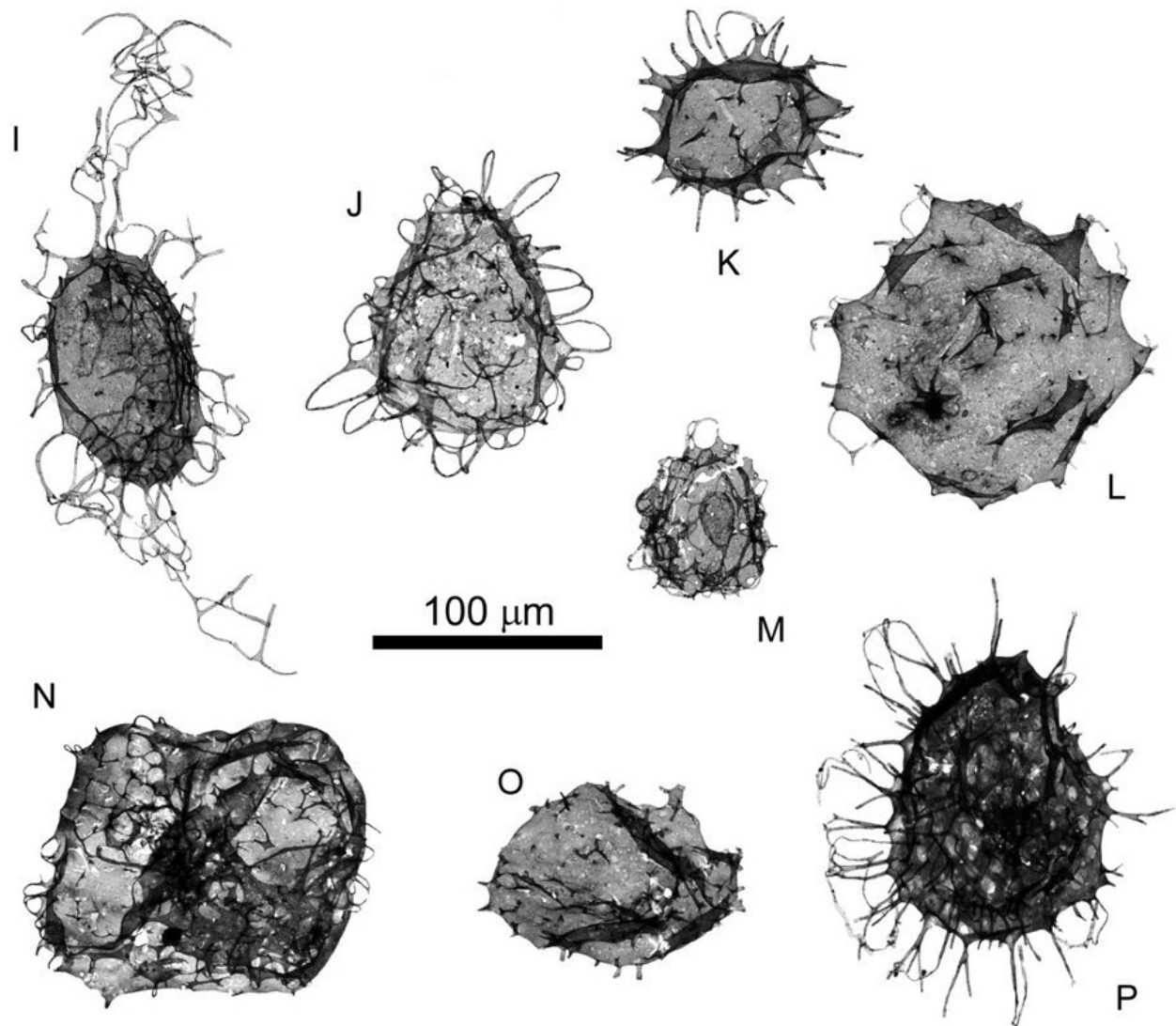


Algae



*Yuknessia* is a fossil green alga from Utah

**Fungi**



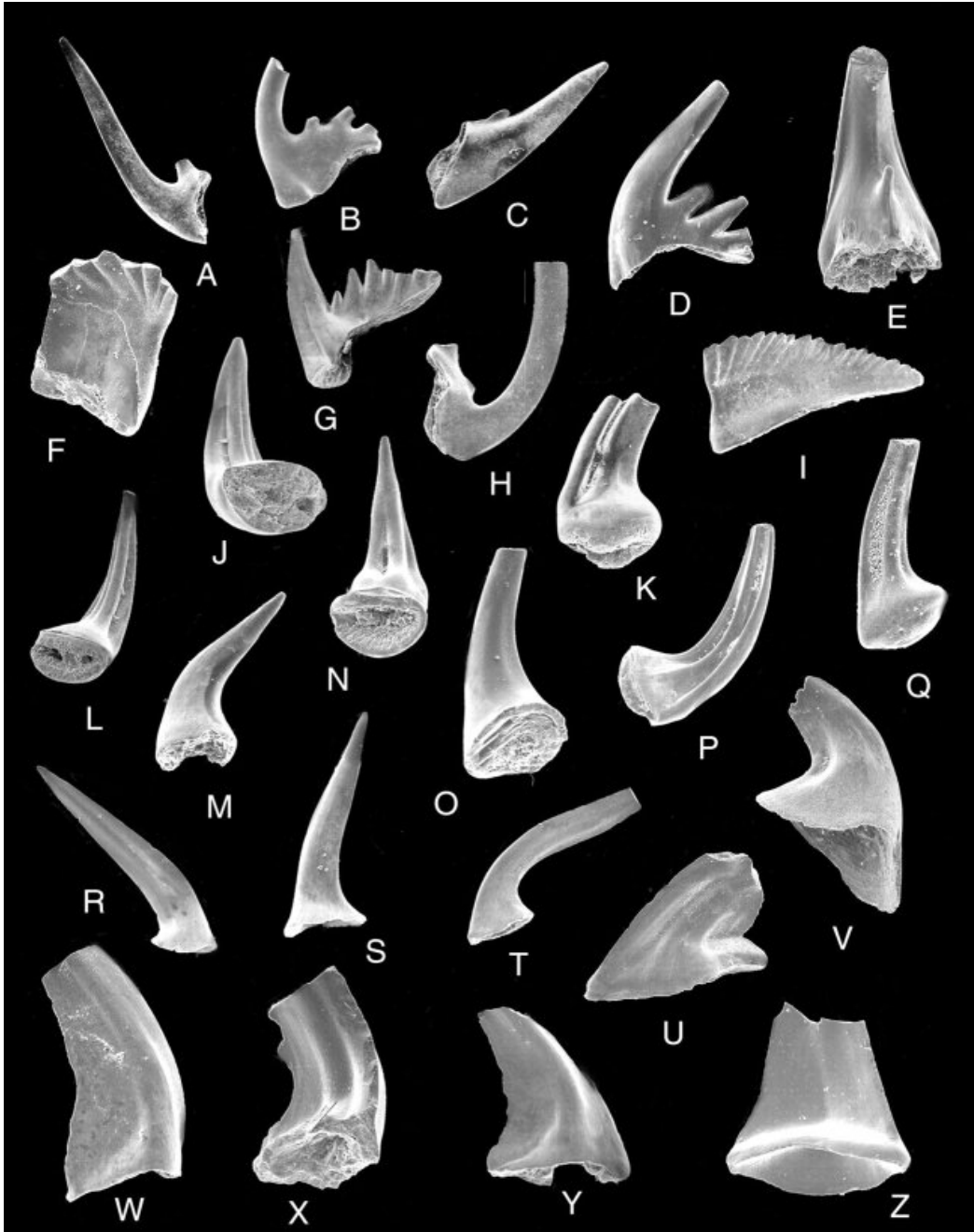
*Tappania* fungus was known even before Cambrian

Problematics: *Aldanophyton*



Terrestrial plant? Or alga?

**Problematics: conodonts**



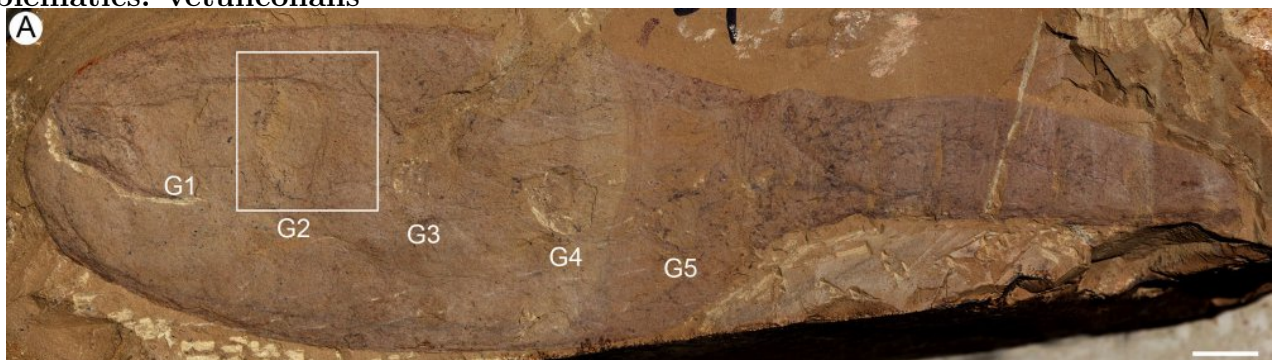
Conodonts are just teeth of unknown animal, it is still not clear what was it. Jawless fish?

**Problematics: hyoliths**



*Haplophrentis*, mollusk? Or separate branch on the tree of life?

#### Problematics: vetulicolians



Ancestors of both echinoderms and chordates?

#### Summary

- Introns, linear DNA molecules and telomere/telomerase system differ eukaryotes from most prokaryotes
- Cambrian period started with massive appearance of skeletal fauna: “Cambrian explosion”

#### For Further Reading

# References

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

[2] Cambrian explosion. [http://en.wikipedia.org/wiki/Cambrian\\_explosion](http://en.wikipedia.org/wiki/Cambrian_explosion)

## Outline

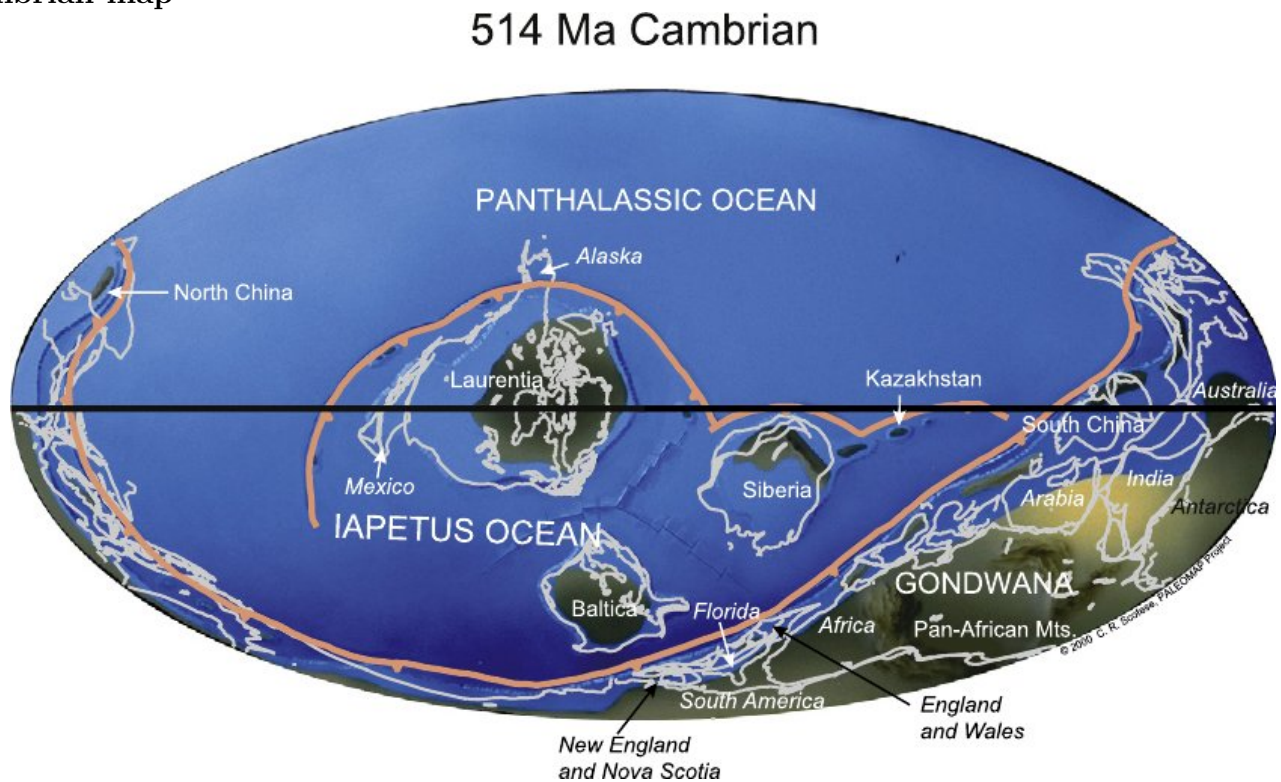
## 5 Where we are?

### 5.1 Cambrian life

#### Timescale of Phanerozoic eon, Paleozoic era

- Phanerozoic eon
  - Paleozoic era
    - \* Cambrian period: 541 Mya
    - \* Ordovician period: 485 Mya
    - \* Silurian period: 443 Mya
    - \* Devonian period: 419 Mya
    - \* Carboniferous period: 358 Mya
    - \* Permian period: 299–252 Mya

#### Cambrian map



## 5.2 Cambrian explosion

### Animal phyla in Cambrian

- Porifera
- Cnidaria
- Mollusca
- Brachiopoda
- Arthropoda (including Lobopoda)
- Echinodermata
- Chordata

### Theories of Cambrian explosion

- Pellet revolution
- Acquiring the ability of making hard tissues
- Absolute predator

### Evolutionary cascade resulted in skeletal revolution

- Muddy water: all dust and microscopic feces is slowly subsiding down
- Plankton arthropods appeared, they are making pellets from dust and excretions
- Water became more transparent, oxygen is not spending for dust oxidation
- More photosynthesis, more oxygen, more organic on bottom
- Animals became more active
- Big predators appeared
- Animals acquire skeleton and other defensive structures

### Skeleton

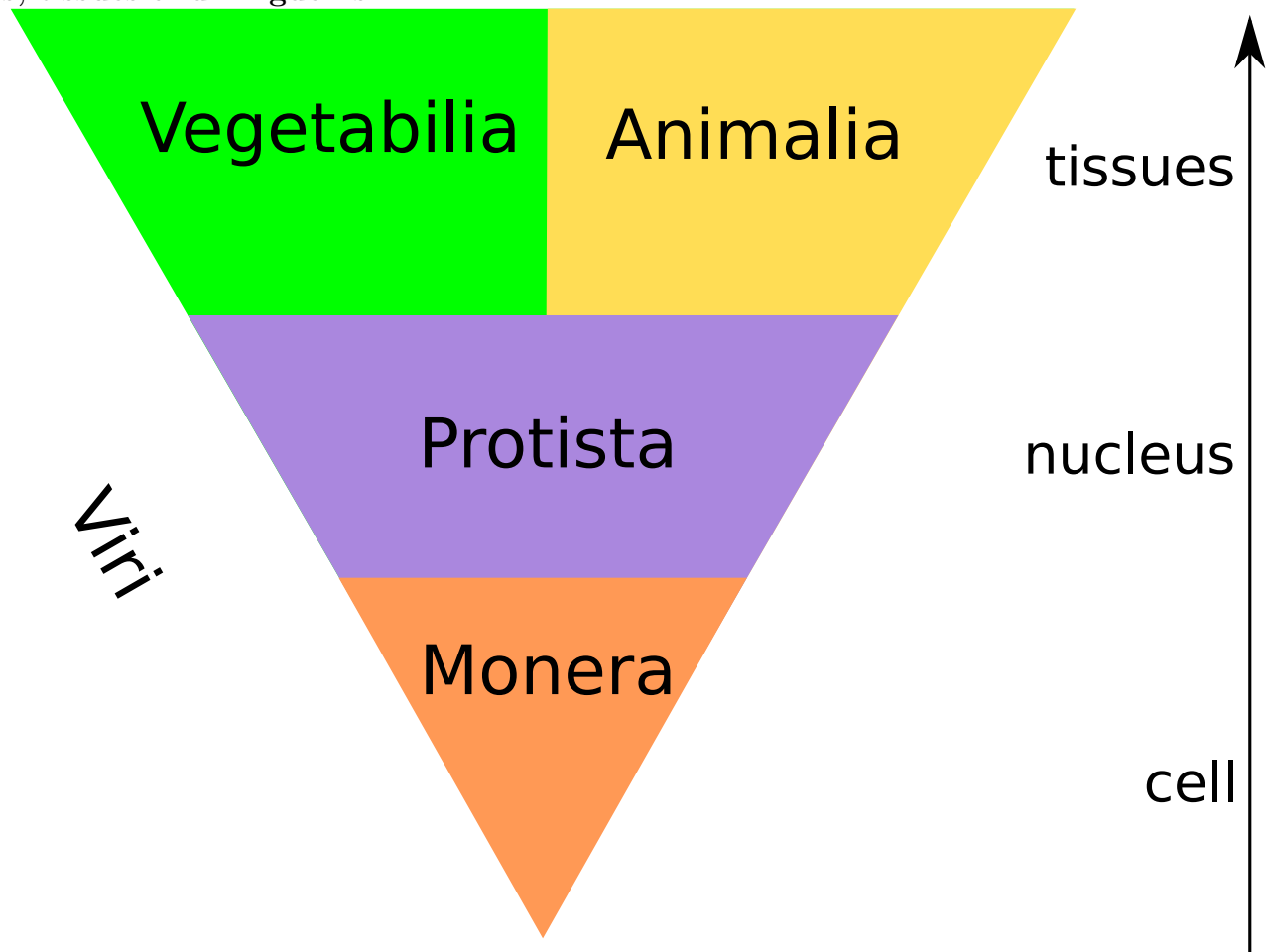
- Internal (endoskeleton): hydrostatic (worms), spicules (sponges), bones and cartilage
- External (exoskeleton): chitinous, shells, skin plates

Since volume grows faster with size than surface, animals with exoskeleton will suffer from the big size more than animals with endoskeleton. This is why arthropods do not reach size of chordates.

## 6 Animals

### 6.1 Origin of animals

Cells, tissues and kingdoms



#### Origin of animals

- Blastaea: not the animal yet. *Volvox*, *Proterospongia*.
- Phagocytella. Two tissues: kinoblast and phagocytoblast. *Trichoplax*.
- Gastraea. Three tissues: ectoderm, entoderm and mesoderm. Closed gut.

#### Summary

- The main driving force of animal evolution was feeding on bigger and bigger pray

#### For Further Reading

## References

- [1] Skeleton. <http://en.wikipedia.org/wiki/Skeleton>
- [2] Animal. <http://en.wikipedia.org/wiki/Animal>

## Outline

# 7 Questions and answers

## 7.1 Where we are?

The main driving force of animal evolution was feeding on bigger and bigger pray

- Blastaea
- Phagocytella
- Gastraea

## Main organ systems in animals

- In higher animals, tissues are members of organs, and organs—of organ systems
- Every organ system is responsible for the particular aspect of animal life:
  - locomotion and support;
  - feeding, excretion and osmoregulation;
  - circulation and gas exchange;
  - signaling and reception;
  - reproduction.

# 8 Animals

## 8.1 Basic principles of animal body construction

*Generalized animal*

## Summary

- The structure of animal body follows few basic principles of construction

## For Further Reading

# References

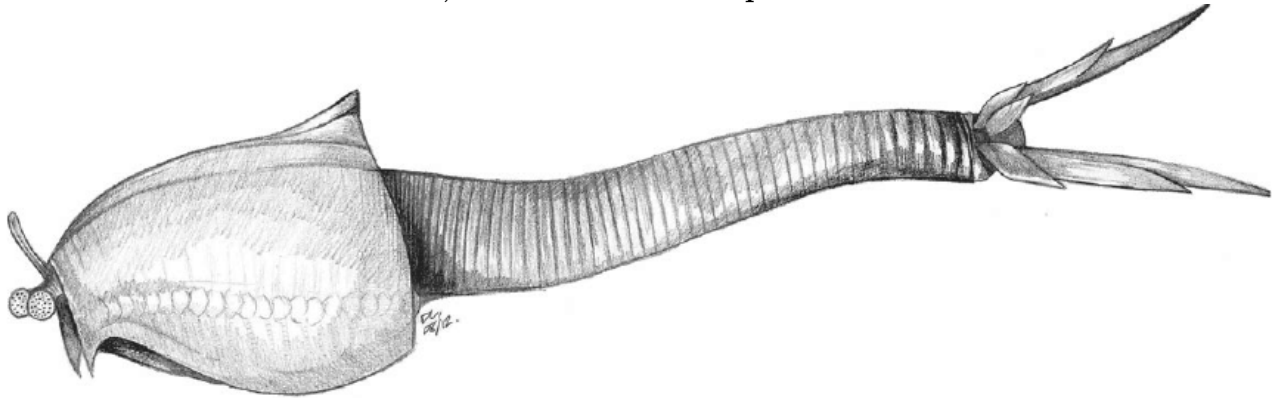
- [1] Skeleton. <http://en.wikipedia.org/wiki/Skeleton>
- [2] Animal. <http://en.wikipedia.org/wiki/Animal>

## Outline

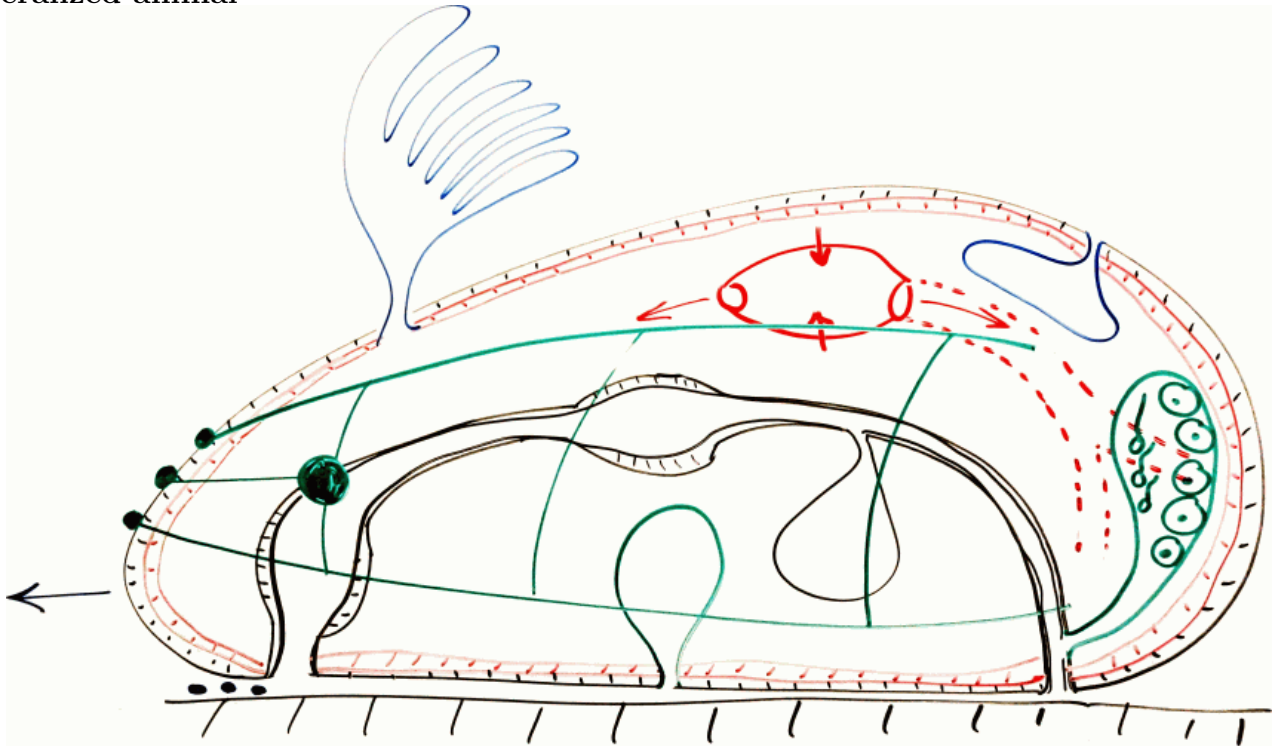
## 9 Questions and answers

### 9.1 Where we are?

*Neocaris*—fossil Orsten filtrator, ancestor of arthropods



Generalized animal



## 10 Animals

### 10.1 Basic principles of animal body construction

Symmetry

- Absent
- Radial
- Bilateral
- Secondary radial

## **Body parts**

- Cup-shaped whole body
- Vermicular body
- Segmented body
- Body with appendages
- Head and tail

## **Locomotion**

- Peristaltic motion: crawling without appendages (vermicular motion)
- Bending motion (nematode worms)
- Swimming with appendages
- Crawling with appendages
- Walking with appendages
- Walking with water-vascular system
- Jet motion

## **Skin**

- One- or multi-layered epithelium
- Basal membrane with collagen
- Skin-muscular bag

## **Muscle system**

- Muscle layer
- Separate muscles
- Water-vascular system

## **Body cavity**

- Mesoderm, no cavity
- Primary cavity
- Secondary cavity (coelom)

## Digestion

- Closed or open gut
- Pharynx
- Jaws and teeth
- Stomach, esophagus etc.
- Digestion glands: liver etc.

## Blood system

- Open and closed
- Heart
- Hemoglobin and hemocyanin

## Summary

- Basic organ systems of animals are responsible for
  - locomotion and support;
  - feeding, excretion and osmoregulation;
  - circulation and gas exchange;
  - signaling and reception;
  - reproduction.

## For Further Reading

## References

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

## Outline

# 11 Questions and answers

## 11.1 Where we are?

### Animal motion

*Peristaltic: earthworm Bending: nematode Swimming upside down: horseshoe crab Swimming: horseshoe crab Walking: crab Swimming: ray Water-vascular: starfish Jet: jellyfish Jet: squid*

# 12 Animal

## 12.1 Animal body

### Blood system

- Open and closed
- Heart
- Hemoglobin and hemocyanin

### Respiration

- Gills
- Lungs
- Tracheas

### Osmoregulation

- Nephridia
- Kidneys

### Nervous system

- Diffuse neurons
- Trunks and circles
- Ganglia
- Brain

### Reproduction and development

- External and internal fertilization
- Direct development or development with metamorphosis

### For Further Reading

## References

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

### Outline

# 13 Animals

## 13.1 Animal phyla and their phylogeny

### Where we are?

- Basic organ systems of animals are responsible for
  - locomotion and support;
  - feeding, excretion and osmoregulation;
  - circulation and gas exchange;
  - signaling and reception;
  - reproduction.

### Four subkingdoms

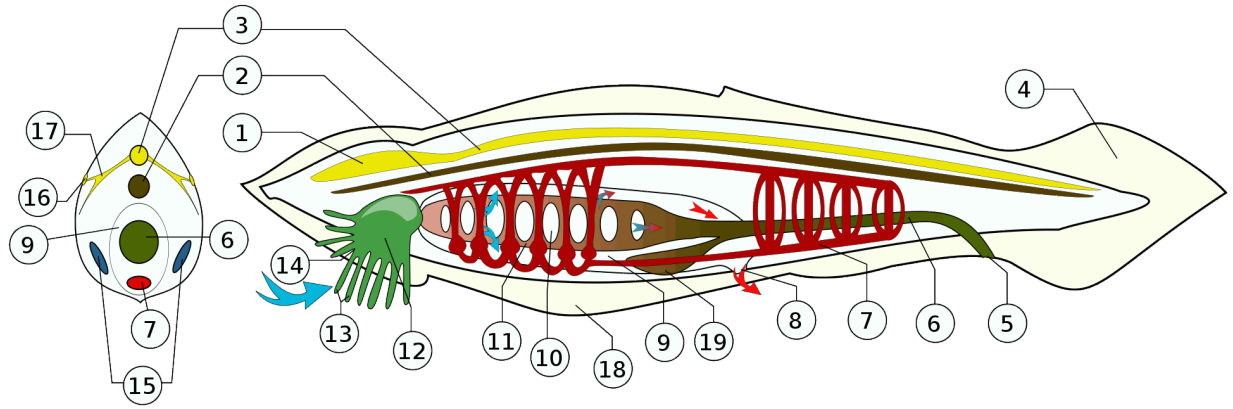
- Spongia: asymmetric filtrators
- Phagocytellozoa: asymmetric crawlers
- Cnidaria: radial stinging predators
- Bilateria: bilateral

### Nine phyla

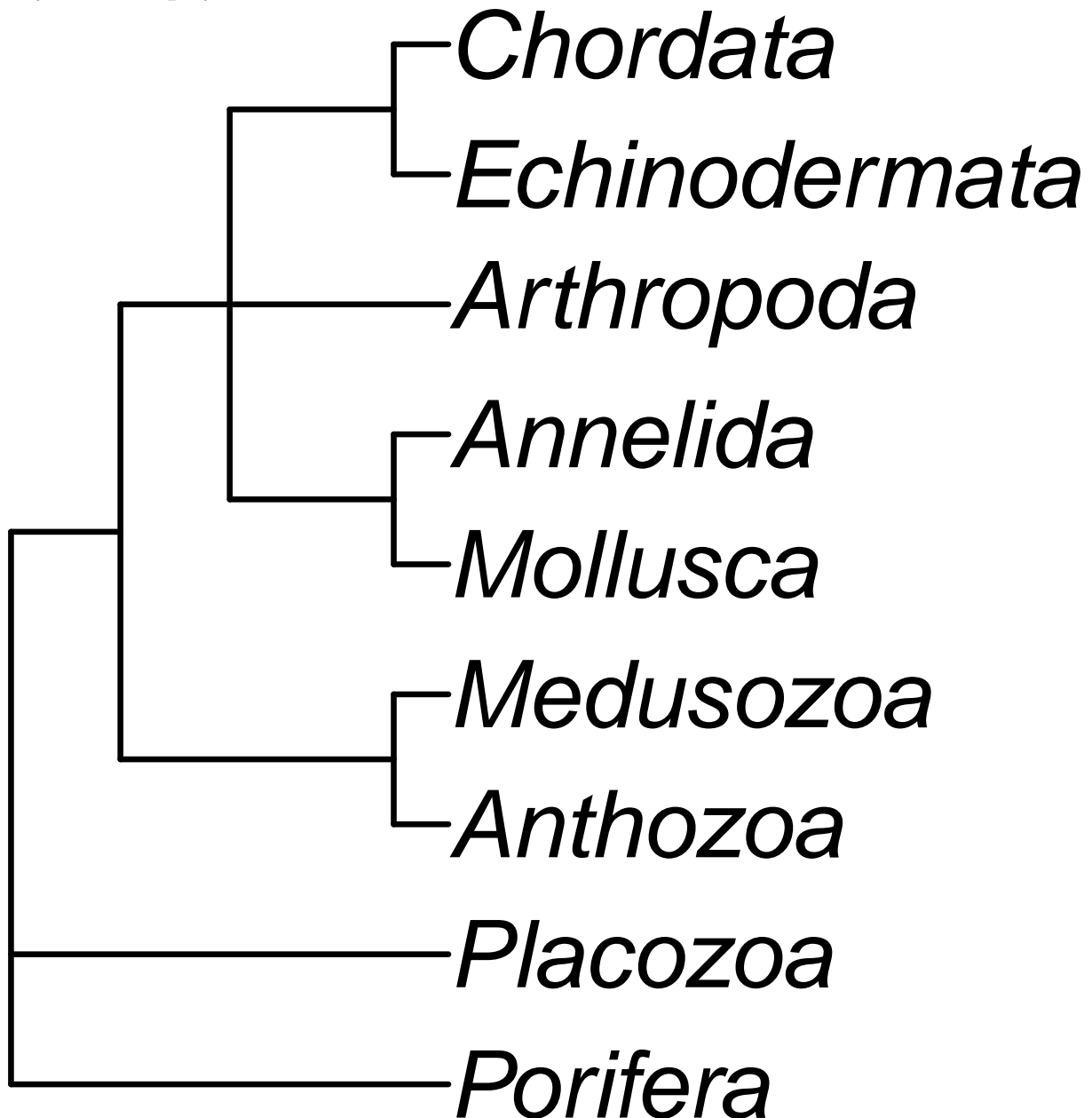
- Spongia
  - Porifera, sponges
- Phagocytellozoa
  - Placozoa, *Trichoplax*
- Cnidaria
  - Anthozoa, corals
  - Medusozoa, jellyfish
- Bilateria
  - Mollusca
  - Annelida
  - Arthropoda
  - Echinodermata
  - Chordata

*Nine phyla = nine body plans*

## Chordate body plan



## Phylogeny of nine phyla



## 13.2 Classes of chordates and their phylogeny

### Eight classes of Chordata

#### Acrania:

Class 1. Leptocardii: lancelet

#### Vertebrata:

- Pisces:

Class 2. Chondrichthyes

Class 3. Actinopterygii

Class 4. Dipnoi

- Tetrapoda:

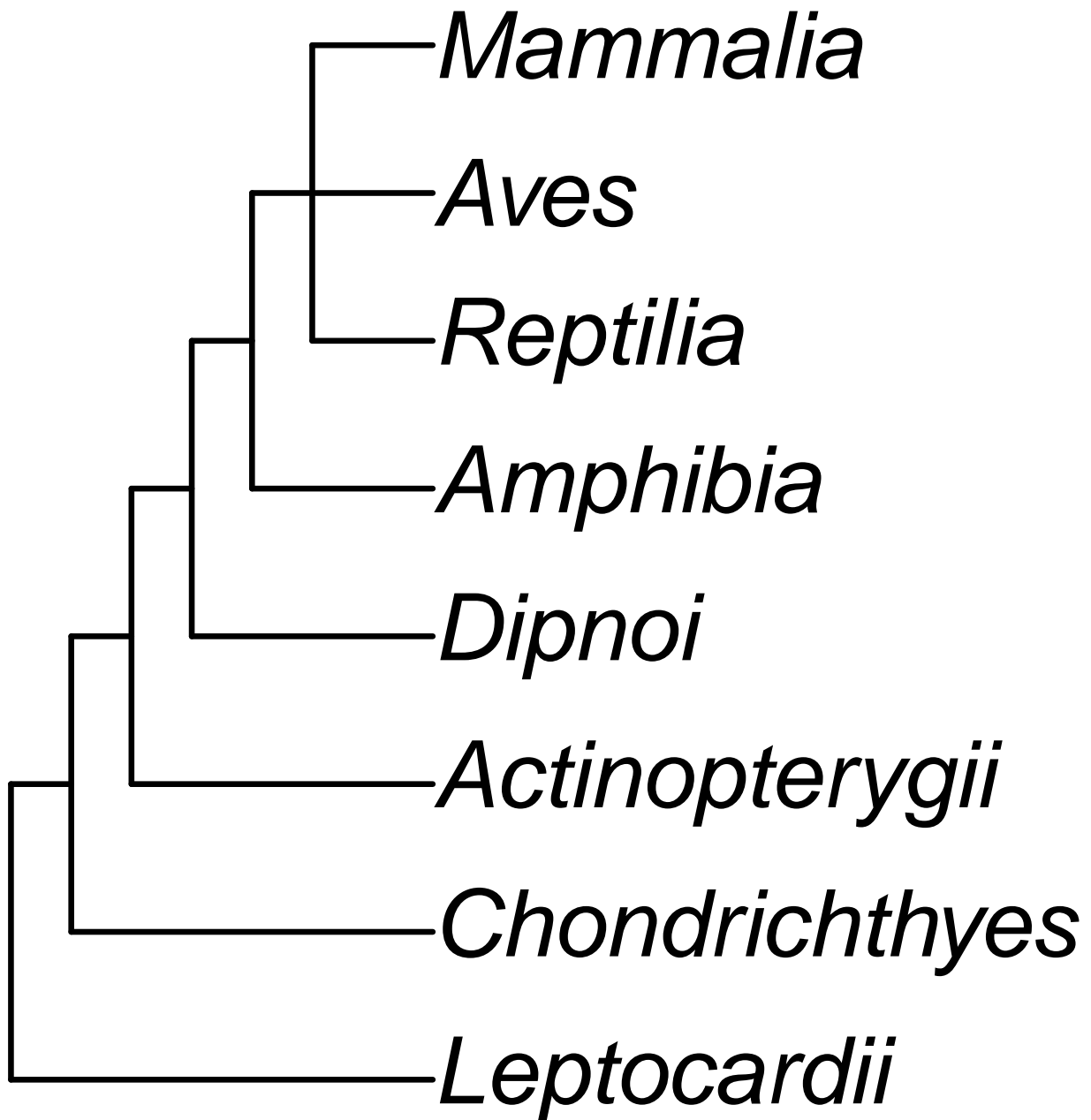
Class 5. Amphibia[.5ex] \*Amniota:

Class 6. Reptilia

Class 7. Aves

Class 8. Mammalia

### Phylogeny of eight classes



Optional homework: in preparation for the 3rd test, fill this table:

	1	2	3	4	5	6	7	8	9	10
Porifera										
Placozoa										
Anthozoa										
Medusozoa										
Annelida										
Mollusca										
Arthropoda										
Echinodermata										
Chordata										

Characters: 1 ...

Characters will not be necessary relevant to all members of phylum!

## Summary

- Classes of vertebrates differ mostly in overall optimization of their body functions and in adaptations to the specific environment

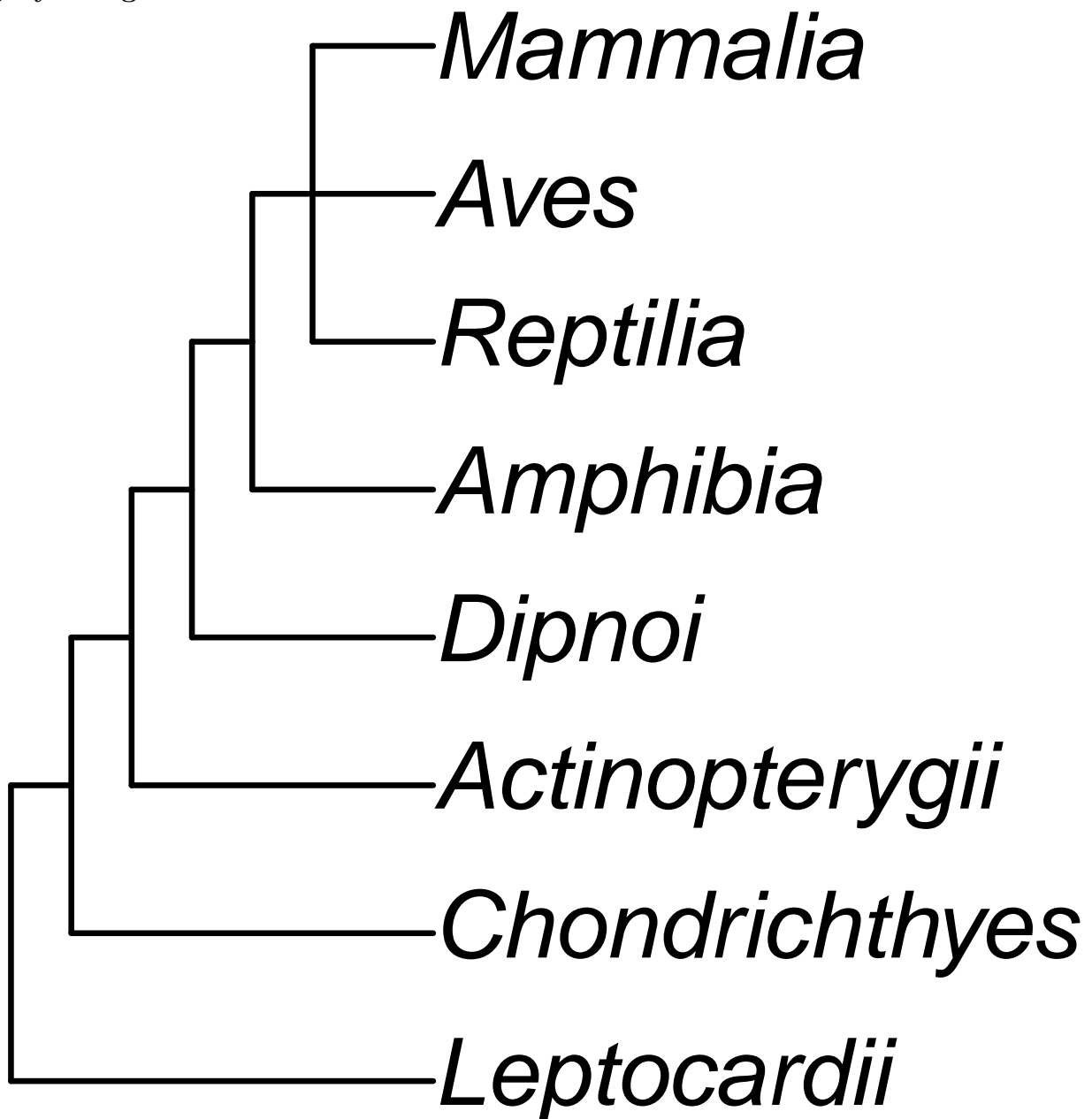
## For Further Reading

## References

- [1] Animal phyla. [http://en.wikipedia.org/wiki/Phylum#Animal\\_phyla](http://en.wikipedia.org/wiki/Phylum#Animal_phyla)
- [2] Vertebrates. <http://en.wikipedia.org/wiki/Vertebrate>
- [3] Fishes. <http://en.wikipedia.org/wiki/Fish>

## Outline

### Phylogeny of eight classes



## Timescale of Phanerozoic eon, Paleozoic era

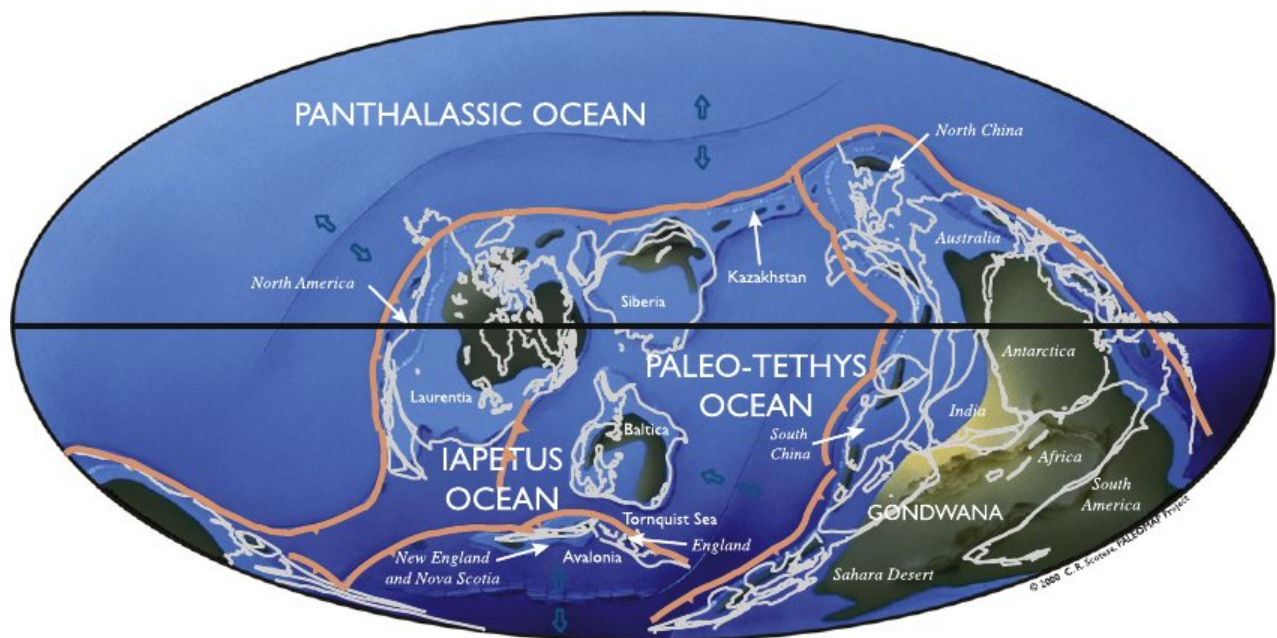
- Phanerozoic eon
  - Paleozoic era
    - \* Cambrian period: 541 Mya
    - \* Ordovician period: 485 Mya
    - \* Silurian period: 443 Mya
    - \* Devonian period: 419 Mya
    - \* Carboniferous period: 358 Mya
    - \* Permian period: 299–252 Mya

## 14 Everybody is going terrestrial

### 14.1 Ordovician, Silurian and Devonian: three ages of fishes

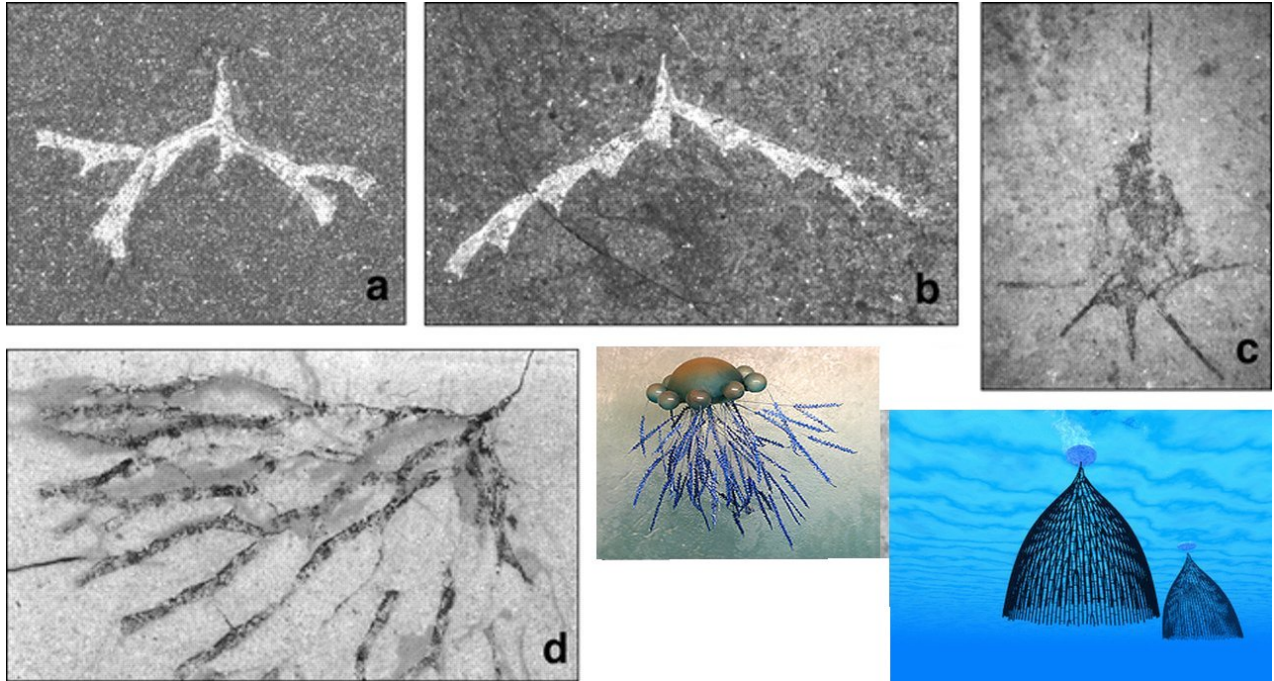
#### Ordovician period

458 Ma Ordovician



- Climate changed from hot to glaciated (Gondwana hits the South Pole)
- Marine fauna spread out, especially cephalopods, conodonts and graptolites
- In the end, the first great extinction: 85% of marine species extinct

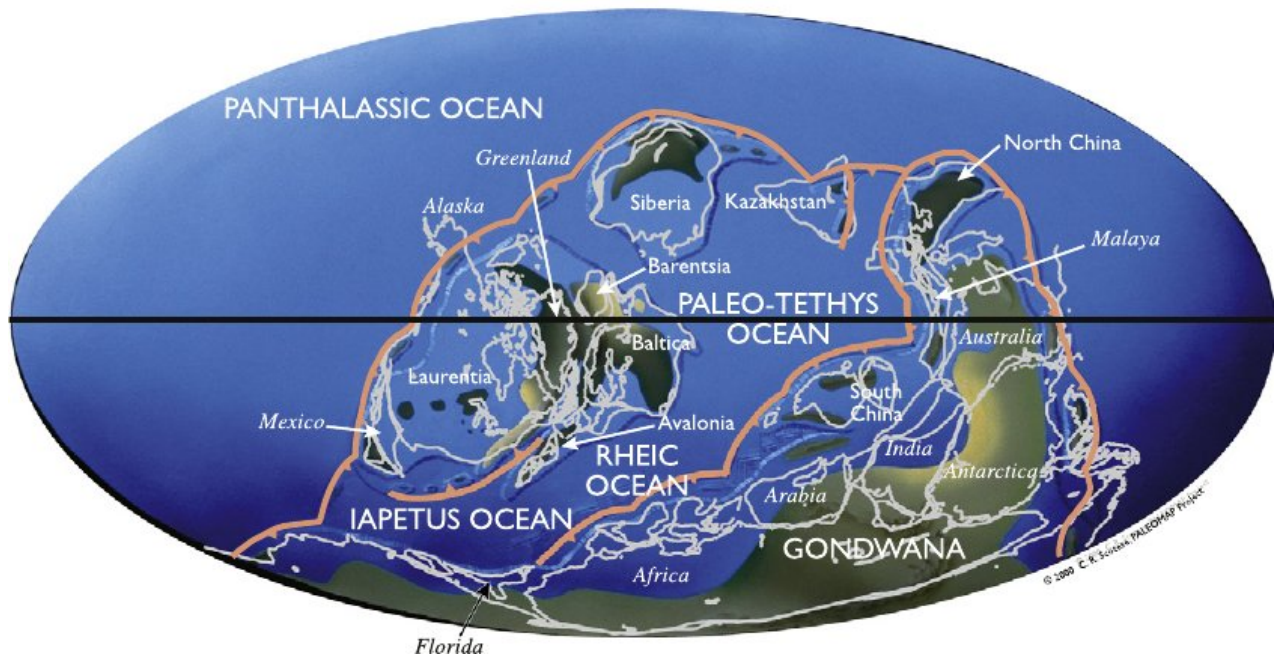
#### Graptolites



They were plankton colonial animals close to echinoderms and chordates

## Silurian period

425 Ma Silurian



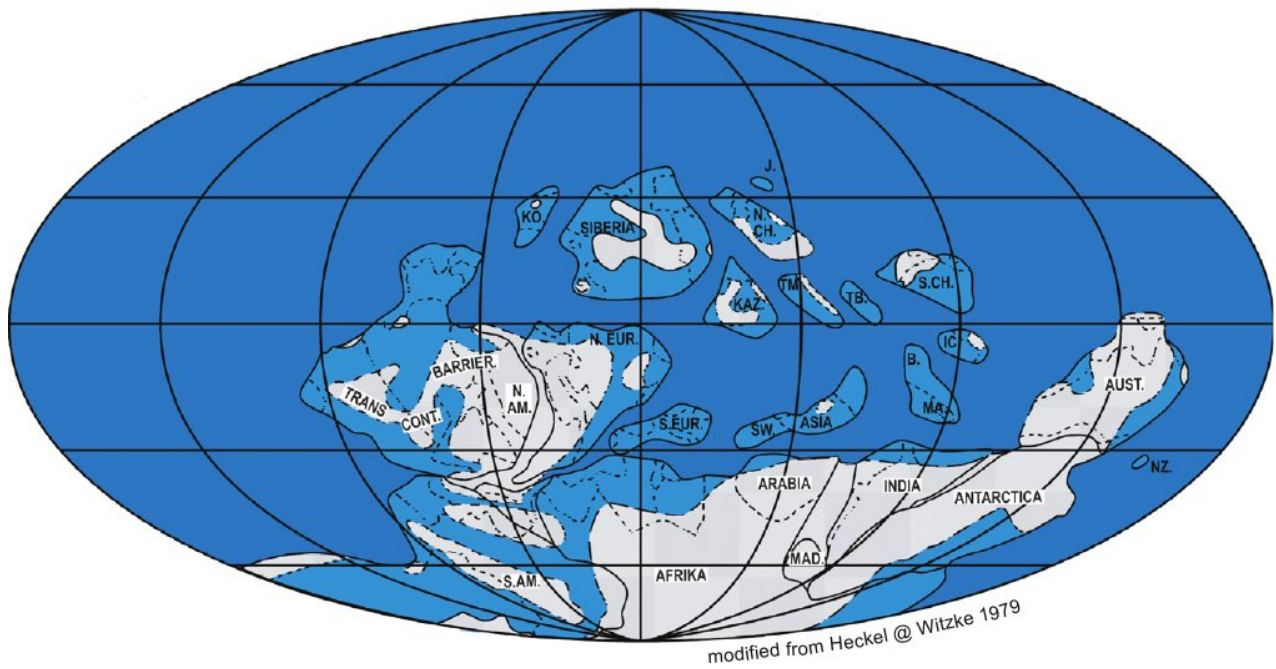
- Fluctuating climate
- Prospering of marine fauna again
- Land colonization started from plants and arthropods!
- South Pole still in the Gondwana

## Silurian sea



## Devonian period

### Middle Devonian



- Moderate climate becoming warmer
- Exceptionally high sea level
- Greatest diversity of marine fauna in Paleozoic (especially fishes)
- Terrestrial vertebrates: tetrapods appeared!

## 14.2 Plants are going terrestrial

### Protists, algae and plants

- Photosynthetic protists are algae
- Plants are descendants of green algae, they developed tissues in the process of land colonization

*Primordial plant cell: cell wall, chloroplasts and turgor, plasmodesmata*

*Origin of tissues and organs of plants: first steps*

### Terms associated with origin of plants

- Thallus
- Epidermis
- Cuticle
- Transpiration
- Stomata, guard cells
- Compound tissues
- Ground tissue
- Supportive tissues
- Shoot system
- Absorption tissue, mycorrhiza
- Root system

### Summary

- Plants are photosynthetic multi-tissued eukaryotes
- Plants developed tissues independently from animals, in the process of land colonization

### For Further Reading

## References

- [1] Plant cell. [http://en.wikipedia.org/wiki/Plant\\_cell](http://en.wikipedia.org/wiki/Plant_cell)
- [2] Plant tissues. [http://en.wikipedia.org/wiki/Tissue\\_%28biology%29#Plant\\_tissues](http://en.wikipedia.org/wiki/Tissue_%28biology%29#Plant_tissues)

### Outline

## 15 Where we are?

### Primordial plant cell

- Cell wall: primary (cellulose) and secondary (cellulose + lignin and suberin)
- Chloroplasts with thylakoids
- Turgor: vacuole and cell wall pressures
- Plasmodesmata

## 16 Plants

### 16.1 Origin of plant tissues

*Origin of tissues and organs of plants: first steps*

*Availability of light, temperature-gases conflict and competition pushed plants to land. Two first tissues, compound epidermis and ground tissue were response to desiccation. Epidermis could be developed in advance as adaptation to spore delivery. Next stages: supportive tissues, vascular tissues and absorption tissues.*

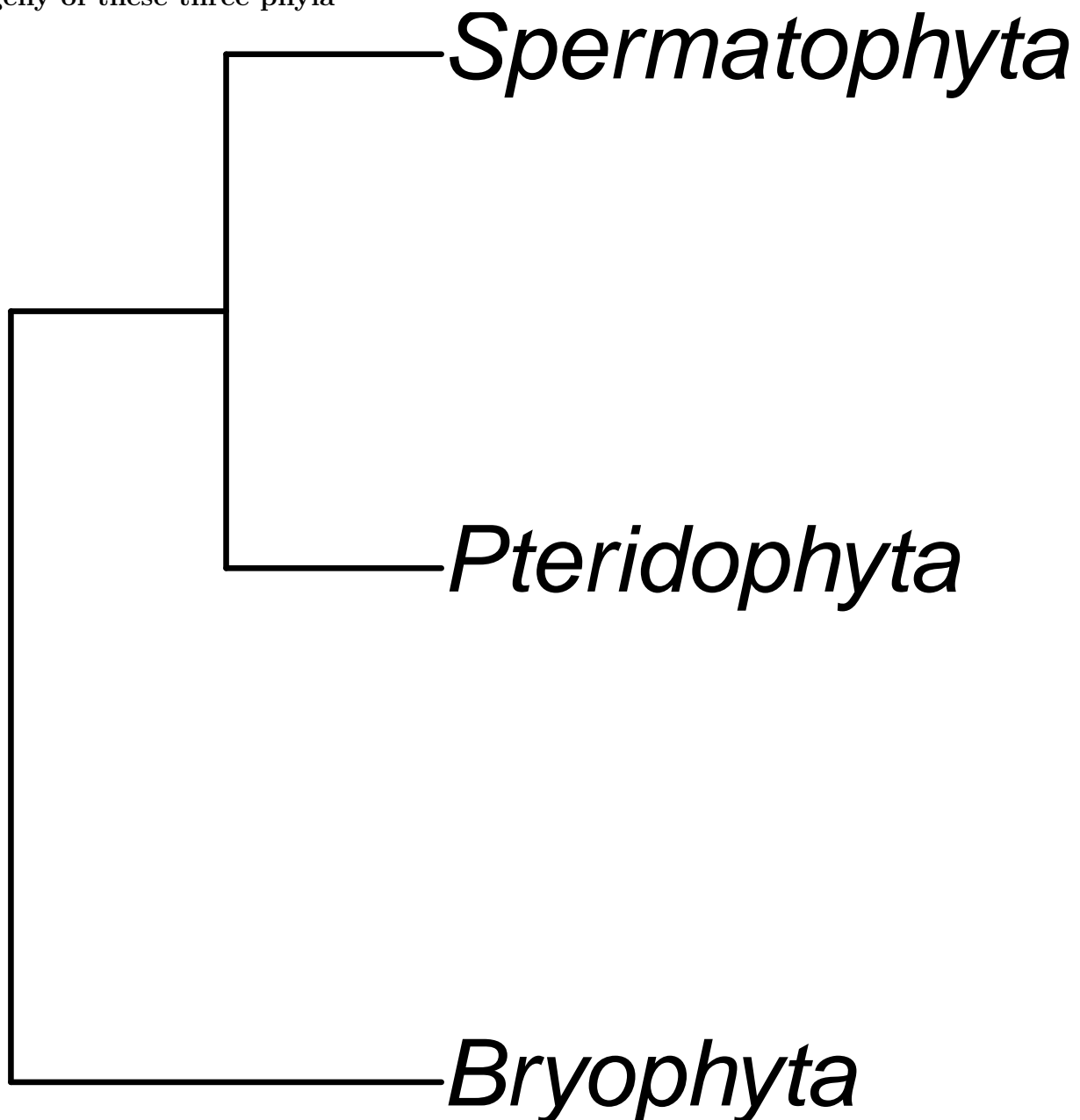
### Terms associated with origin of plants

- Thallus
- Epidermis
- Cuticle
- Transpiration
- Stomata, guard cells
- Compound tissues
- Ground tissue
- Supportive tissues
- Shoot system
- Absorption tissue, mycorrhiza
- Root system

## Three main phyla of plants

- **Bryophyta:** mosses  
No roots, leaves thin or absent, withstand desiccation, **gametophyte dominance**
- **Pteridophyta:** ferns and allies (like clubmosses and horsetails)  
Roots adventitious, leaves are not associate with buds, stem-like or scale-like, water-savers, **sporophyte dominance, no seeds**
- **Spermatophyta:** seed plants (including conifers and flowering plants)  
Body with two poles, typical leaves associate with buds, water-savers, sporophyte dominance, **seeds**

## Phylogeny of these three phyla



# 17 Genetics and inheritance

## 17.1 Meiosis

### Exchange and renovation of DNA

- To sustain with the ever-changed environment, organisms must evolve
- To evolve, they need a genetic diversity: different genotypes in different organisms
- To be genetically diverse, they need a process of genetic exchange
- One of ways of exchange is a sexual process in a form of **syngamy**
- However, constant syngamy will result in constant increase of DNA amount
- Meiosis is a counterbalance to syngamy

### Definition of meiosis

- Chromosome formula:  $XX \longrightarrow X + X \longrightarrow I + I + I + I$
- **The goal of meiosis** is to counterbalance the syngamy
- Meiosis changes genotype of cells because: (1) chromosomes are **recombined** and (2) chromosomes exchange their genetic material

### Ploidy, or chromosome set

- In diploid ( $2n$ ) organisms, chromosomes form pairs
- Paired chromosomes ( $XX$ ) are **homologous**
- In haploid ( $n$ ) organisms, all chromosomes are single
- In mitosis, ploidy will be the same:  $2n \longrightarrow 2n + 2n$
- In syngamy, ploidy will increase:  $n + n \longrightarrow 2n$
- In meiosis, ploidy will reduce:  $2n \longrightarrow n + n$

### Stages of meiosis

- First division: reductive part
  - Prophase I: homologous chromosomes form pairs (**synapses**) and start to exchange DNA (**crossing-over**)
  - Metaphase I
  - Anaphase I: homologous chromosomes will go *independently* to different poles
  - Telophase I becomes Prophase II, without interphase (and typically without cytokinesis)
- Second division: equal part (similar to mitosis)

- Prophase II
- Metaphase II
- Anaphase II
- Telophase II

### **For Further Reading**

## **References**

- [1] Plant tissues. [http://en.wikipedia.org/wiki/Tissue\\_%28biology%29#Plant\\_tissues](http://en.wikipedia.org/wiki/Tissue_%28biology%29#Plant_tissues)
- [2] Plants. <http://en.wikipedia.org/wiki/Embryophyte>
- [3] [For the lab]: Mendel's laws. [http://en.wikipedia.org/wiki/Mendelian\\_inheritance](http://en.wikipedia.org/wiki/Mendelian_inheritance)

## Example questions for the exam

- |   |   |
|---|---|
| <p>1. Which of the following is a name of Cambrian animal group:</p> <ul style="list-style-type: none"><li>A. Mosses</li><li>B. Chordates</li><li>C. Rangeomorphs</li></ul> <p>2. Choose the correct sequence:</p> <ul style="list-style-type: none"><li>A. Carboniferous, Cambrian, Ordovician, Devonian</li></ul> | <ul style="list-style-type: none"><li>B. Ediacarian, Ordovician, Silurian, Devonian</li><li>C. Cambrian, Ordovician, Silurian, Devonian</li></ul> <p>3. Radial symmetry is characteristic for:</p> <ul style="list-style-type: none"><li>A. Mollusks</li><li>B. Anthozoans (corals)</li><li>C. Arthropods</li></ul> |
|---|---|

## Answers

1B, 2C, 3B