

Concepts of Biology: BIOL 111

Study guide for Exam 1

Alexey Shipunov

Lectures 1–6

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Outline

1 Course in general

1.1 Description

Course description from catalog

- This course is designed to accommodate one semester of the General Education requirement for non-science majors at Minot State University.
- The course focuses on a comprehensive survey of modern biology with an emphasis on enhancing the science literacy of the college educated student.
- Topics include: cell biology, genetics, evolution by natural selection, systematics, and the impact of human activity on the biosphere.

My description

- Biology is the largest of all sciences, and develops most rapidly. It is simply impossible to cover **BIOLOGY** in one-semester course.
- I choose a strategy to elucidate the most important biological concepts from the standpoint of the **History of Life**.
- We will go through the major events in this history and learn basic chemistry of life, cell construction, genes and DNA, organization of animal body and other fundamental biological ideas.
- In general, this course is not recommended for science majors

Instructor

- Dr. Alexey Shipunov
- Office: Moore 229 and University greenhouse (small glass building attached to Cyril Moore)
- Office Hours: Mondays and Wednesdays, 1 pm to 2:50 pm.
- Phone: 858-3116
- E-mail: alexey.shipunov@minotstateu.edu, this is the preferable way of communication.

Lectures Mondays, Wednesdays and Fridays, 12:00 am to 12:50 am, Moore 16

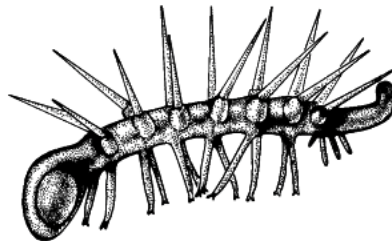
Laboratories See lab manual

Laboratories start next week!!!

Web site

© Shipunov, A. Introduction to Biology [Electronic resource]. 2012—onwards.
Mode of access: http://ashipunov.info/shipunov/school/biol_111

BIOL 111: Introduction to Biology



Course materials:

- [Syllabus](#) (PDF, 0.2 Mb)
- [Lecture 1](#) (PDF, 0.5 Mb)
- [Lab manual](#) (PDF, 1.6 Mb)

[Back](#)

http://ashipunov.info/shipunov/school/biol_111

Please check it regularly. There will be much more material due course. As a rule, slides of every lecture will be available after the lecture.

Textbook

In development, link to the draft version is on the Web site.

Note: students may want to volunteer in the creations of textbook. For that reason, on every exam there are 3 slots to people who want to write essays instead of typical exams.

1.2 Grading

Exams

- **Five** exams are given during the semester.
- Only **four** best exams contribute to the final grade.
- Missed exams count zero points. There are **no make-up** exams!!!
Again, NO MAKE-UP exams in this class.
- Exam sheets will consist of multiple choice questions, we will use scantron.

Absence

I strongly recommend to attend lectures regularly. Lecture contents will be the main source of information required for the exams. There are five legitimate reasons for absence:

- A. emergency situations,
- B. attested medical conditions
- C. military duty,
- D. participation in MSU sports events,
- E. dependent sick leave.

Points

A total of ≈ 580 points can be earned and are distributed as follows (grading points may vary):

Four best exams : 400 points

Laboratories : 180 points (15 points per lab)

Grade calculation

- $A \geq 90\%$
- $B \geq 80\%$
- $C \geq 70\%$
- $D \geq 60\%$
- $F < 60\%$

Academic dishonesty / plagiarism means the **failed class**.

Preparation to exams

- Download and go through all lecture slides / study guide; clarify remaining questions with a textbook.
- Read everything what is listed in “For Further Reading” section.
- Try not only memorize this stuff, but also understand **how things work**.

1.3 Course schedule

Tentative course sequence: from past to present

- Origin of Earth, basic chemistry
- Origin of life, DNA, RNA and proteins
- First cells, structure of cell
- Animals
- Plants
- Reproduction
- Adaptation, rise and fall of dinosaurs
- Current life, humans, and the future evolution

2 Intro test

2.1 Multiple choice questions

Question 1

- 1 Why do deciduous plants drop their leaves?
 - A. To prevent freezing
 - B. To prevent drying
 - C. To get rid of poisonous chemicals

Question 2

- 2 Where does human digestion process start?
 - A. In the mouth
 - B. In the intestines
 - C. In the stomach

Question 3

- 3 Which birds do NOT live in Minot on winter?
 - A. Crows
 - B. Hummingbirds
 - C. Sparrows

Question 4

4 Home country of watermelon:

- A. Central America
- B. Canada
- C. South Africa

Question 5

5 Why do insectivorous plants eat insects?

- A. To obtain the lacking mineral resources
- B. To get an addition to their common “menu”
- C. To get rid of herbivores

Question 6

6 Which insects have no queen?

- A. Bumblebees
- B. Ants
- C. Cockroaches

Question 7

7 Oak tree is pollinated by:

- A. Wind
- B. Bees
- C. Flies

Question 8

8 Spider has:

- A. 6 legs
- B. 8 legs
- C. 4 legs

Question 9

9 Apple flower has:

- A. 5 petals
- B. 4 petals
- C. 3 petals

Question 10

10 Frightened man has:

- A. Bigger pupils
- B. Smaller pupils
- C. Normal pupils

Question 11

11 Polar bears are not eating penguins because:

- A. Penguins run very fast
- B. They cannot meet
- C. Penguins are poisonous for bears

Question 12

12 How many toes are on each of cat's hind legs?

- A. 5
- B. 4
- C. 3

Question 13

13 Pineapple is a:

- A. Tree
- B. Shrub
- C. Herb

Question 14

14 If somebody has an artery cut on the arm or leg, it is recommended:

- A. Put a tight bandage below the cut
- B. Put a tight bandage above the cut
- C. Do nothing

Question 15

15 Which of the following is the most precise statement?

- A. We are breathing to support our life
- B. We are breathing to obtain the energy from food
- C. We are breathing to have enough strength for food consuming

Question 16

16 Which tree is better to plant in Minot house backyard:

- A. Sycamore
- B. Ash
- C. Yew

Question 17



17 Moles eat:

- A. Worms
- B. Roots
- C. Frogs

Question 18

18 Which fish gives birth to the fully developed offspring?

- A. Sturgeon
- B. Shark
- C. Flounder

Question 19

19 Which human organ lives longer?

- A. Heart
- B. Lungs
- C. Brains

Question 20

20 Which plant normally has a longer root?

- A. Spruce
- B. Chokecherry
- C. Blueberry

The key

1B; 2A; 3B; 4C; 5A; 6C; 7A; 8B; 9A; 10A; 11B; 12B;
13C; 14B; 15B; 16B; 17A; 18B; 19A; 20B

Please calculate a sum (every right answer = 1 virtual point)

Summary

- Please download syllabus from the Web site (http://ashipunov.info/shipunov/school/biol_111)
- **Five** exams, best **four** will be counted, **no make-ups**
- Again, no make-ups!
- The course sequence is the history of life on Earth

References

- [1] History of Life. Wikipedia. http://en.wikipedia.org/wiki/History_of_life
- [2] Key for the Diversity and History of Life (a.k.a. “textbook”) http://ashipunov.info/shipunov/school/biol_111/ph_key/ph_key.pdf

Outline

3 Questions and answers

Interesting in being a note taker?

- Disability Services is looking for a note taker in this class. The individual will be paid for taking notes.
- Interested students who will have **consistent attendance** and take complete and legible notes should contact:
- **Melanie Moore**, Student Health and Development Center: Lower level Lura Manor (must enter through South Door facing University Ave) or call 858-**4233**

3.1 Comments to introductory test

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 - B. **To prevent drying**
 - C. To get rid of poisonous chemicals

Question 2

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Amylase and lipase

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Bumblebees

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Oak flowers

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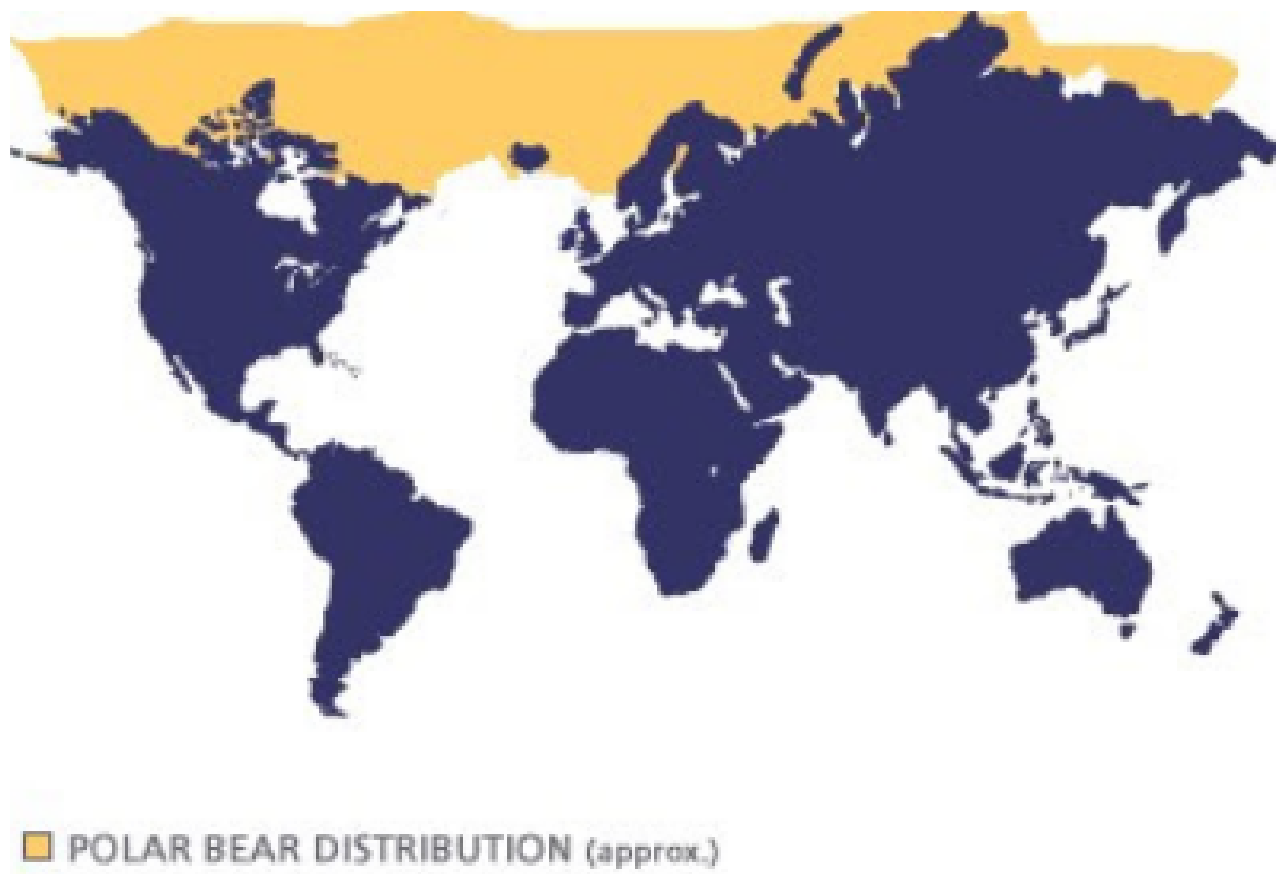


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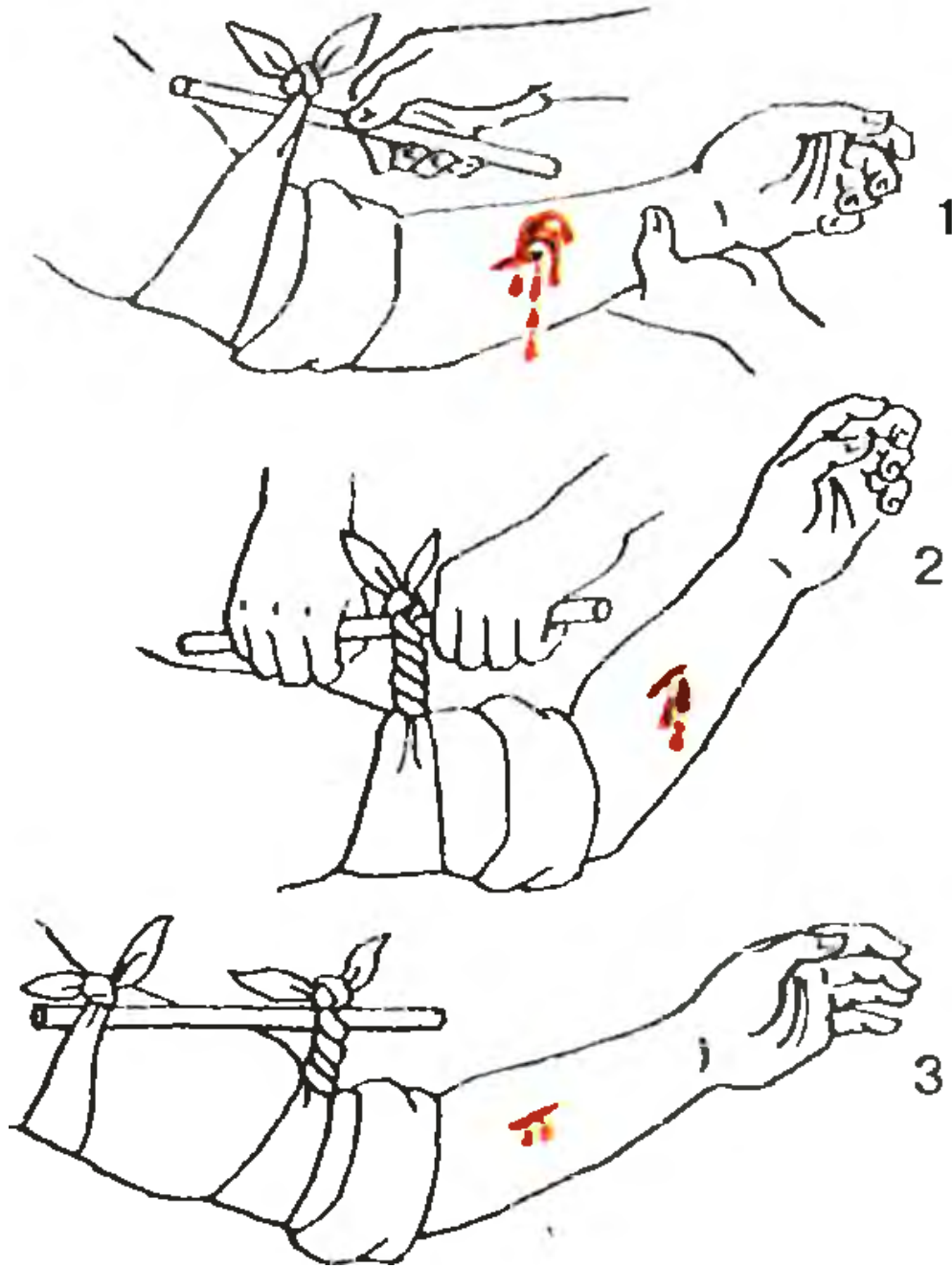
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C. Frogs



Question 18

18 Which fish gives birth to the fully developed offspring?

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B. **Shark**

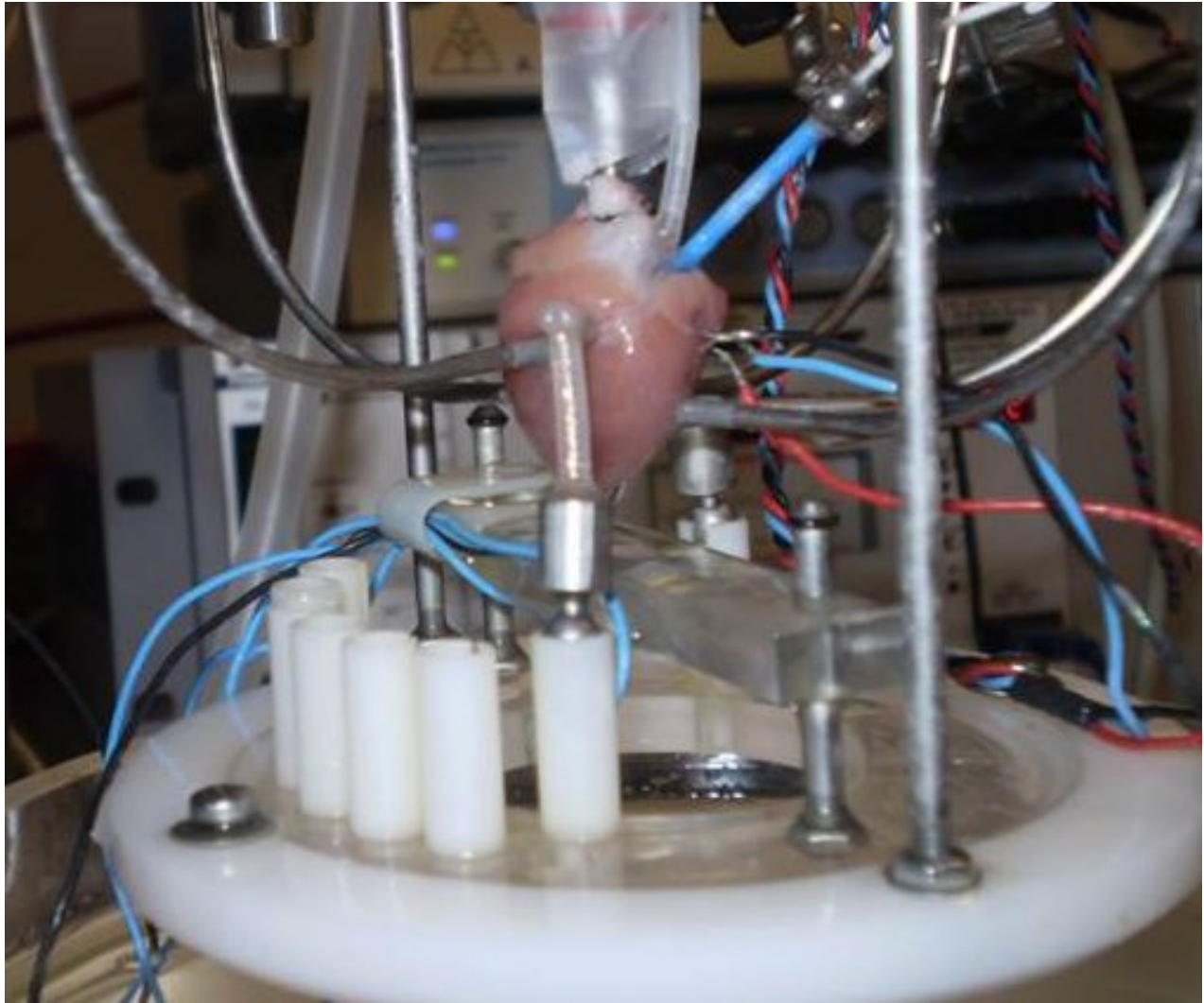
C. Flounder



Question 19

19 Which human organ lives longer?

- A. **Heart**
- B. Lungs
- C. Brains



Question 20

20 Which plant normally has a longer root?

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- B. **Chokecherry**
- C. Blueberry



Fallen

spruce tree

4 Age and time. Basic principles

4.1 Geological time

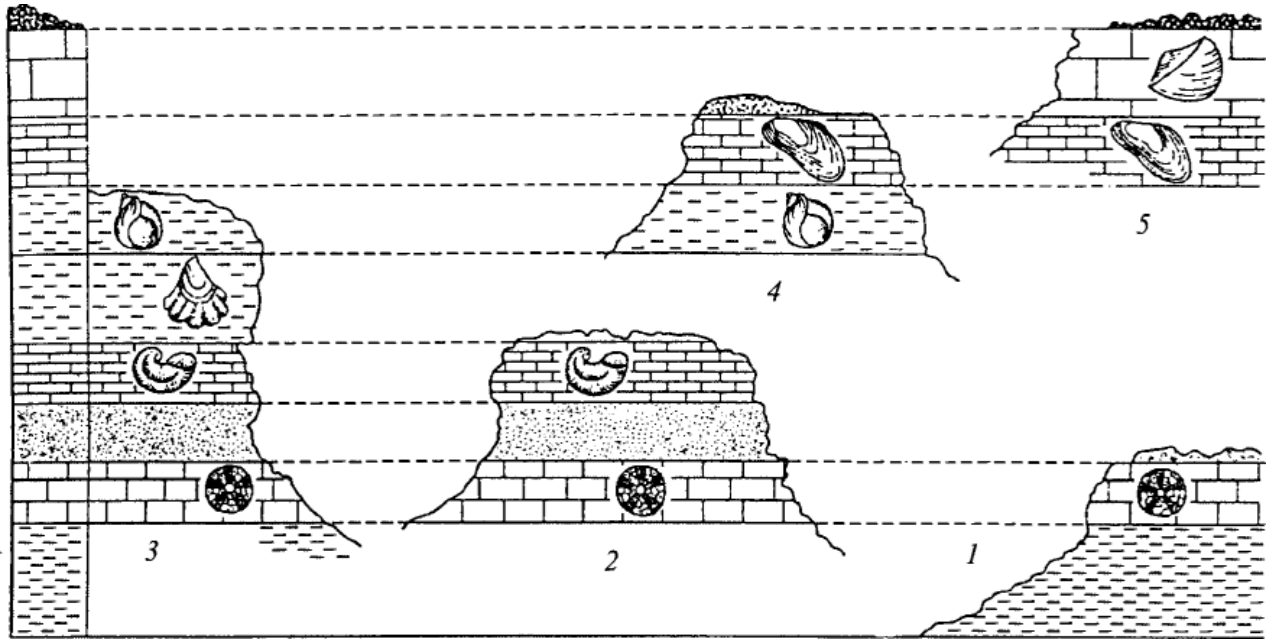
First attempts to calculate age of Earth (1830–1850)

- Helmholtz calculated that if Sun is shrinking to obtain the energy, then the age of Earth should not exceed 18 My (millions of years, 18,000,000 years)
- Lyell calculated that if the **speed of sedimentation was the same in the past**, then age of Earth should be approximately 200 My

Stratigraphy

- Upper layers are younger than lower
- Two layers contained similar species of fossils have the same time of origin

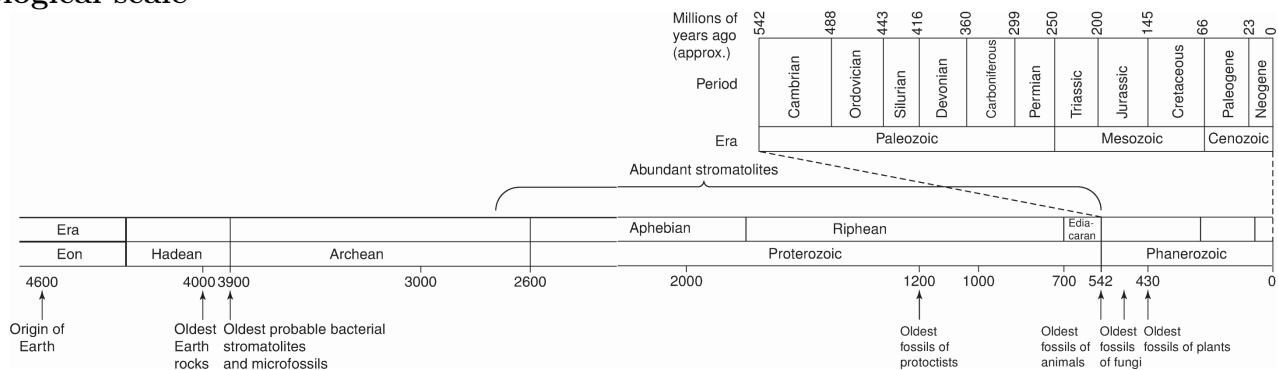
How stratigraphy works



Use of radioactivity

- In 1896, Becquerel discovered **radioactivity**. It was found that some atoms are constantly breaking into smaller ones, sometimes with very slow speed
- Consequently, it is possible to calculate the age of mineral from the concentration of radioactive elements

Geological scale



(see the color version in the textbook)

Summary

- Geological time is calculated on the basis of both relative (stratigraphy) and absolute (radioactivity) methods

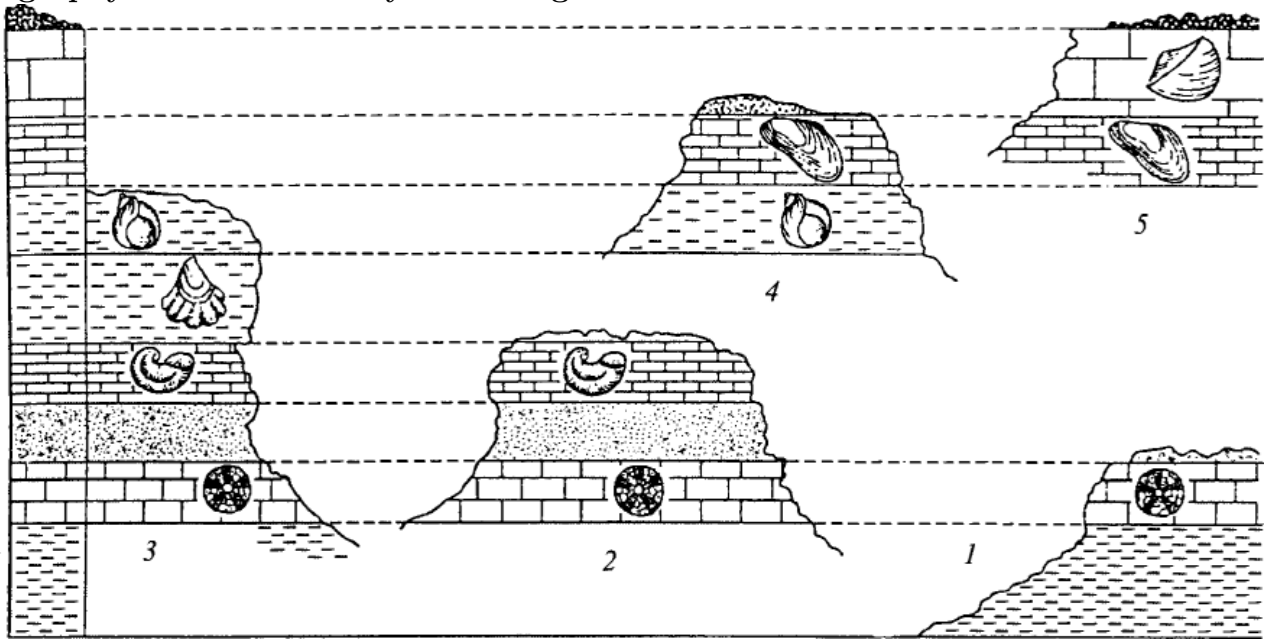
References

- [1] History of Life. Wikipedia. http://en.wikipedia.org/wiki/History_of_life
- [2] Key for the Diversity and History of Life (a.k.a. "textbook") http://ashipunov.info/shipunov/school/biol_111/ph_key/ph_key.pdf

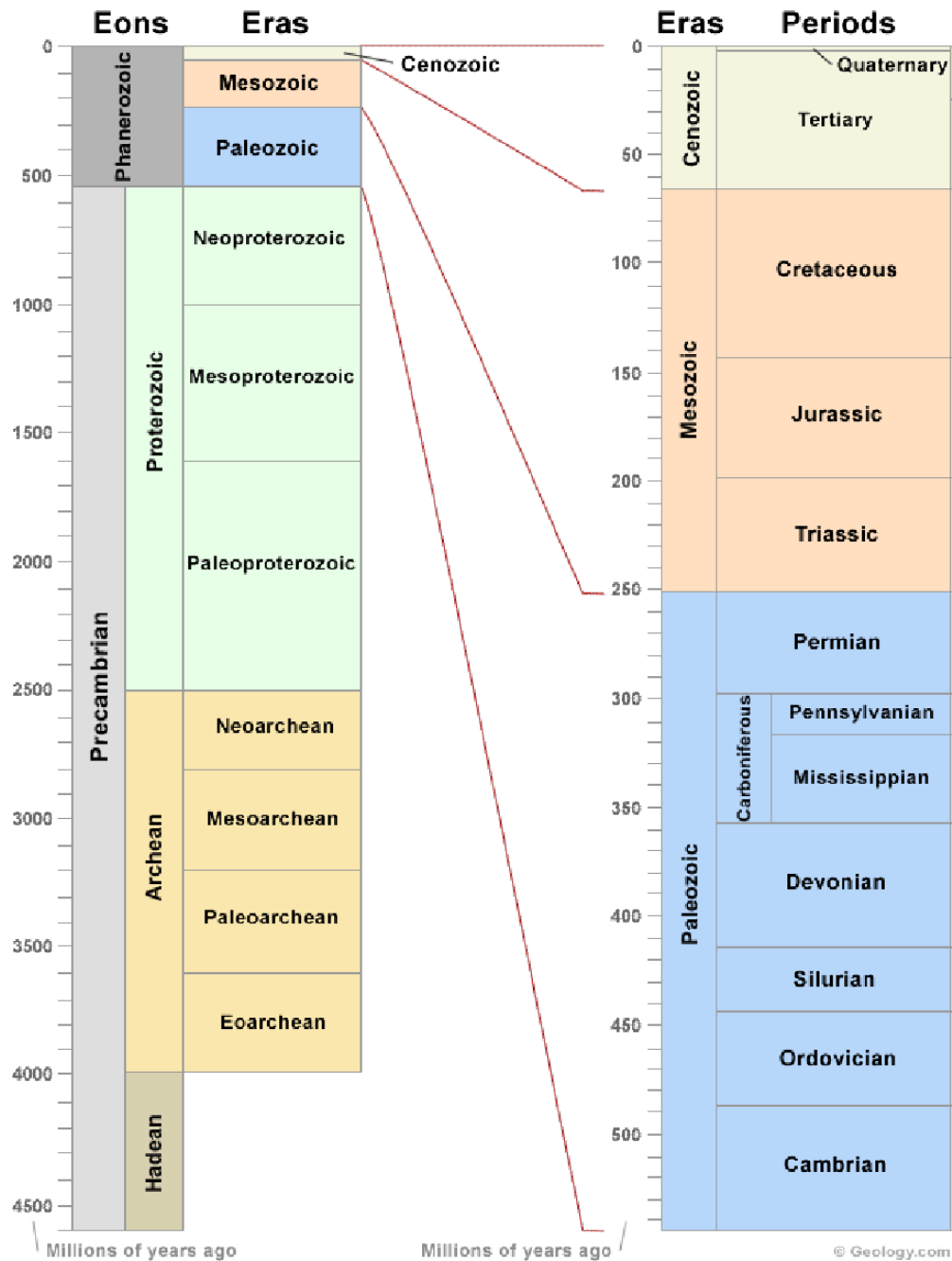
Outline

5 Where we are?

Stratigraphy and radioactivity works together



Geological scale (variant 2)



6 Age and time

6.1 Some basic principles of science

Principle of actuality

- Charles Lyell (1830)
- “The present is the key to the past”

Occam’s razor

- Father William of Ockham (ca. 1300)
- “Plurality must never be posited without necessity”

Science as falsification

- Karl Popper (1963)
- “If something cannot be proved wrong, then it is meaningless”

Example of non-falsifiable hypothesis: Russel’s teapot

... If I were to suggest that between the Earth and Mars there is a china teapot revolving about the sun in an elliptical orbit, nobody would be able to disprove my assertion provided I were careful to add that the teapot is too small to be revealed even by our most powerful telescopes.

(Bertrand Russel, 1952)



Null and alternative hypotheses

- Ronald Fisher (1935)
- **Null**: nothing happened; **alternative**: something happened
- Normally, we are able only to reject one of them and therefore **fail-to-reject** (not “support”!) the other

Basic science principles

- Actuality
- Occam’s razor
- Falsification
- Hypothesis testing

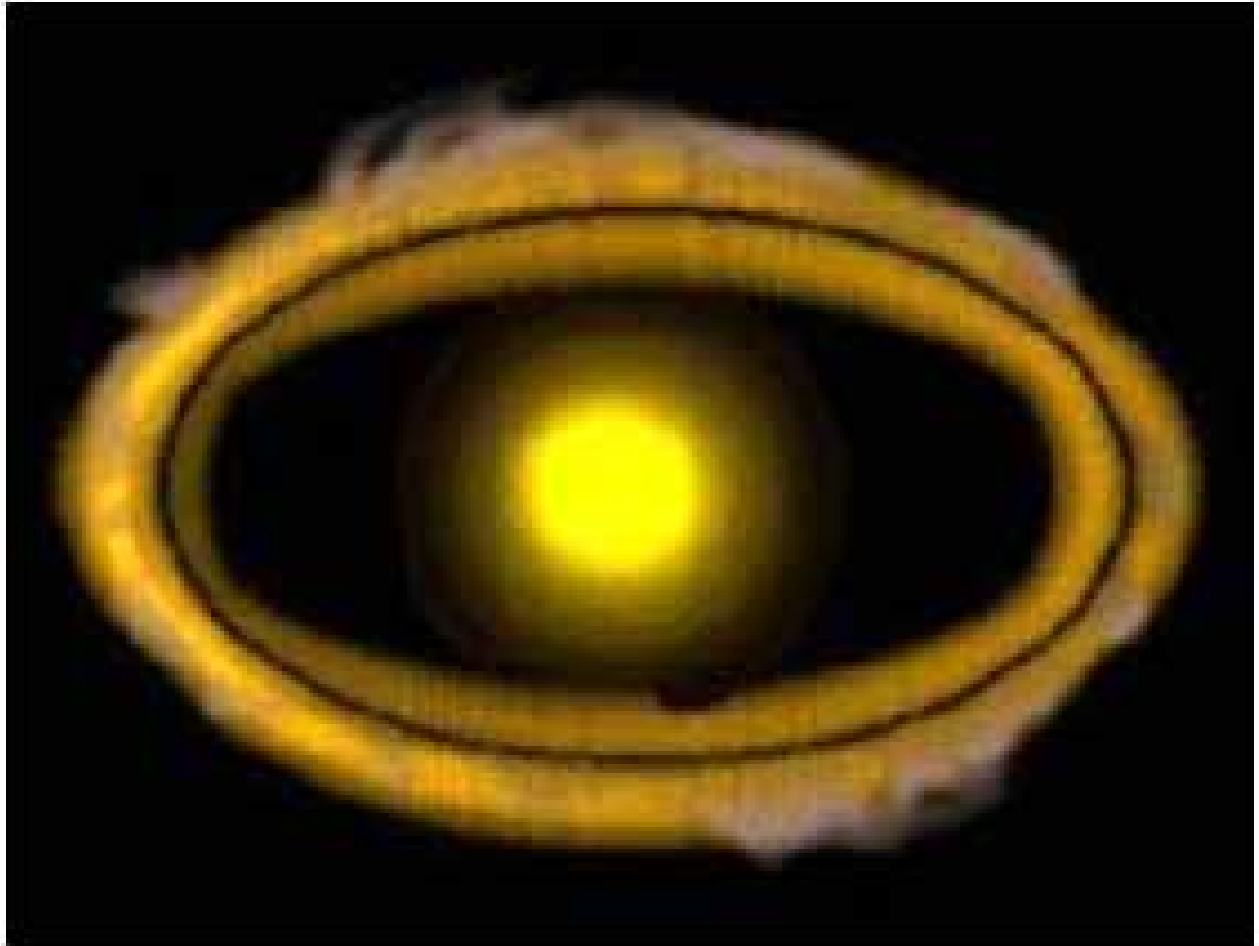
7 Origin of Earth. Basic Chemistry

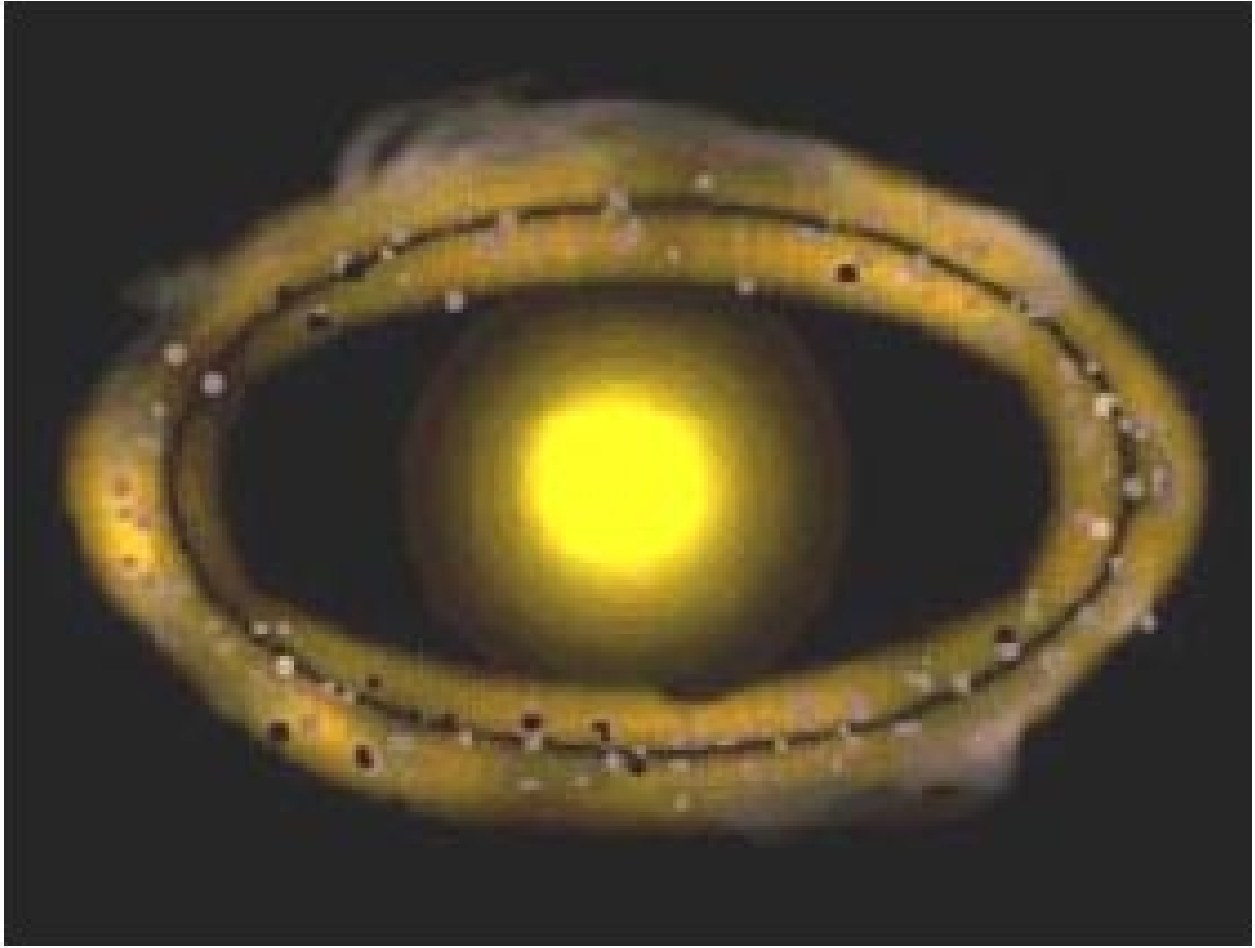
7.1 Origin of Earth

Nebula theory: cold Earth

- Pierre-Simon Laplace (1796): Earth originated from a “dust cloud”
- When cloud started to rotate around the Sun, the differentiation into planets started

Nebula: first and second steps





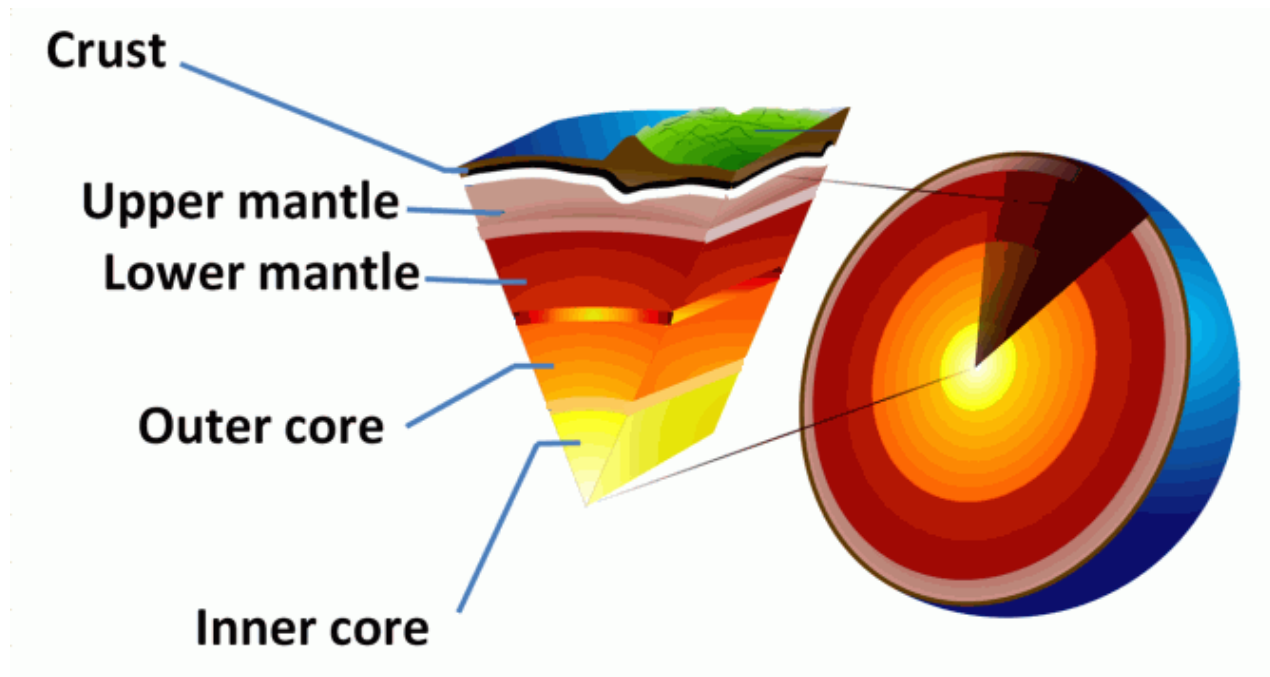
Heating: differentiation of depths

- “Heavy” elements went to the Earth center, light elements—to the surface
- The energy of this movings came out as warmth, and Earth melted (partly)

Structure of Earth

- Now, Earth is spheric drop of extremely viscous and heavy “liquid”
- This drop is structured into several layers. Most important are: crust, mantle and core.

The section of Earth



Atmosphere and hydrosphere

- The differentiation of Earth body finally resulted in developing of lighter gas layer on the surface (primary atmosphere), initially very thin and relatively cold ($\approx 15^{\circ}\text{C}$)
- Therefore, water vapor were condensed into primary ocean (primary hydrosphere)

Chemistry of atmosphere and hydrosphere

- According to the principle of actuality, it should be close to today's volcanic gases
- 15% of CO_2 , plus CH_4 (methane), NH_3 (ammonia), H_2S , SO_2 and different "acidic smokes" like HCl

7.2 Very basics of chemistry

Very basics of chemistry

- **Atoms**
 - **Protons**
 - **Neutrons**
 - Electrons
- Atomic weight
- Isotopes
- Elements and periodic table
- Chemical bonds

- Valence
- Molecules
- Molecular weight

Summary

- Geological time is calculated on the basis of both relative (stratigraphy) and absolute (radioactivity) methods
- Science is based on the principles of actuality, falsification, Occam's razor, and hypothesis testing

References

- [1] Structure of the Earth. Wikipedia. http://en.wikipedia.org/wiki/Structure_of_the_Earth
- [2] Atom. Wikipedia. <http://en.wikipedia.org/wiki/Atom> (until "Identification").

Outline

8 Where we are?

8.1 Very basics of chemistry

Very basics of chemistry

- Atoms
 - Protons
 - Neutrons
 - Electrons
- Atomic weight
- Isotopes
- Elements and periodic table
- Chemical bonds
- Valence and group
- Molecules
- Molecular weight

9 Origin of Earth

9.1 Basics of chemistry

The periodic table is color-coded by groups: 1A (Alkali Metal, yellow), 2A (Alkaline Earth Metal, blue), 3-10 (Transition Metals, purple), 11-12 (Post-transition Metals, light blue), 13-14 (Metalloids, orange), 15-16 (Non-metals, green), 17 (Halogens, light green), 18 (Noble Gases, light yellow), and Lanthanide/Actinide (pink). A legend on the left identifies these categories. A box at the bottom left shows the format for element symbols: Z (atomic number), mass, and name. The main body of the table contains elements from Hydrogen (1) to Oganesson (118), with Lanthanides (57-71) and Actinides (89-103) shown in separate rows at the bottom.

Summary

- If the atomic weight in periodic table is not even, then two or more isotopes exist
- Most frequent isotope is typically the round atomic weight
- Difference between table atom weight (average) and most frequent isotope weight (rounded) hint to what are other isotopes

For Further Reading

References

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

Outline

10 Where we are?

10.1 Very basics of chemistry

Very basics of chemistry

- Atoms

- Protons
- Neutrons
- Electrons
- Atomic weight
- Isotopes: how to guess what are they
- Elements and periodic table
- Chemical bonds: ionic, covalent non-polar, covalent polar and hydrogen
- Valence and group
- Molecules
- Molecular weight: how to calculate

11 Origin of Earth

11.1 Basics of chemistry

Acids and bases

- Acids: take out H^+ (proton), like
 $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
- Bases: take out OH^- (hydroxyl)
 $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$

Molar mass and molar concentration

- Molar mass is a gram equivalent of molecular mass
- For example, molecular mass of salt (NaCl) is $23 + 35^1 = 58$ Da. We take “Da” out and replace it with “g” (grams). Therefore, 1 mole of salt is 58 g.
- Every mole contains $6.02214078 \times 10^{23}$ molecules (Avogadro’s number)
- Concentration is the density of dissolved substance
- In water solution, 1 M (1 molar) concentration of salt means that in 1 liter of distilled water 58 g of salt was diluted
- If we take half of this water, concentration will still be 1 M whereas amount of diluted salt will decrease twice

¹If we accept that atomic mass of chlorine is 35.

Concentration of protons, and pH and acidity

- If concentration of protons is 0.1 M (1×10^{-1} , 0.1 g of protons in 1 l of water), this is an extremely acidic solution
- In distilled water, concentration of protons is equal to 1×10^{-7} (0.0000001) M
- This is because water molecules can (rarely) dissociate: $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$
- pH of distilled water is equal to $-\log(10^{-7}) = -(-7) = 7$
- pH of the extremely acidic solution (first example) is 1

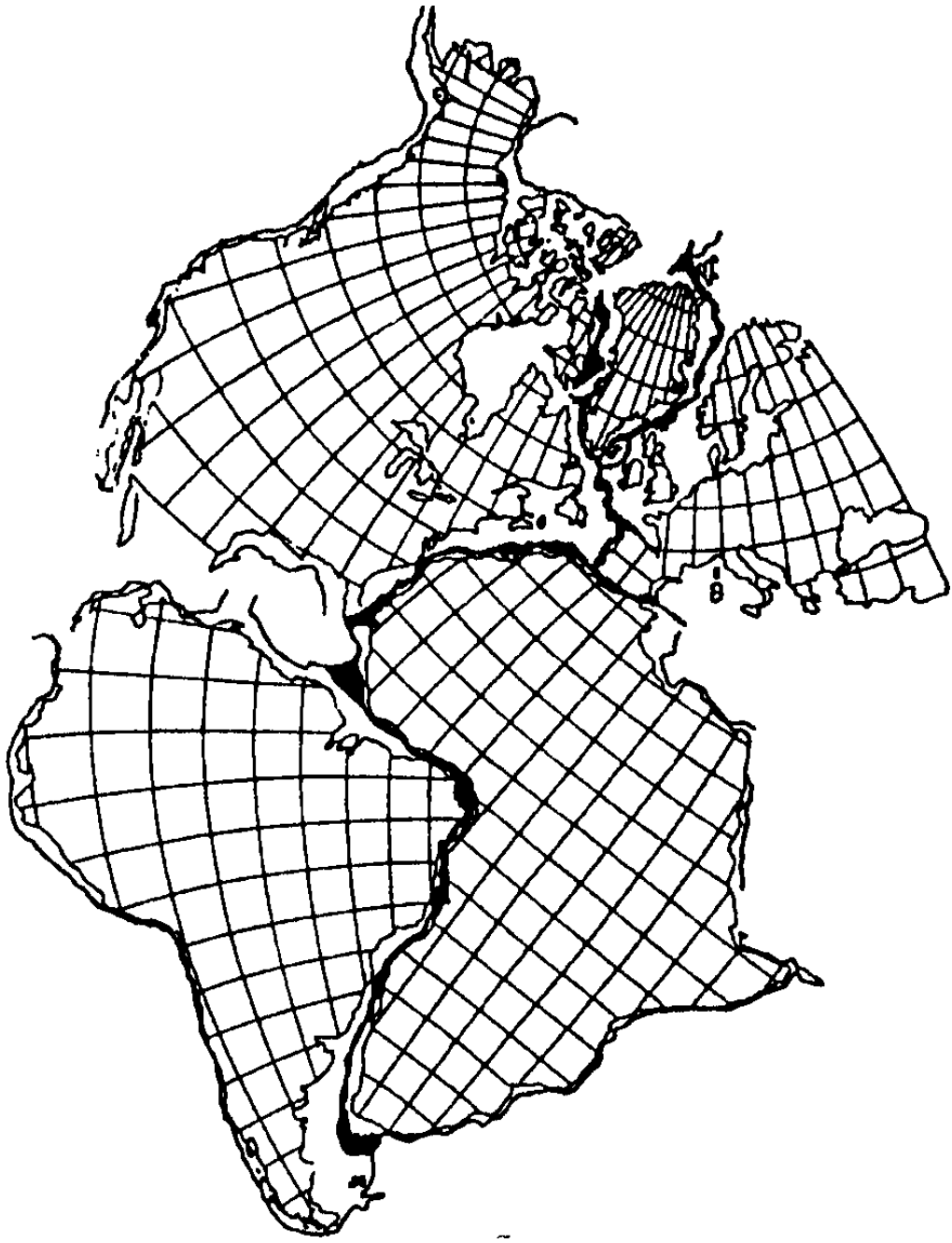
12 Floating continents

12.1 Continental drift

Continental drift

- In 1921, Alfred Wegener invented the idea that South America and Africa were parts of one big continent—Gondwana.
- According to Wegener, in the end of Paleozoic era, there were two big continents—Gondwana and Laurasia separated by Tethys ocean
- Before that, all continents were united in one—Pangaea surrounded by one big ocean.

One of Wegener's arguments



Laurasia and Gondwana



Pangaea

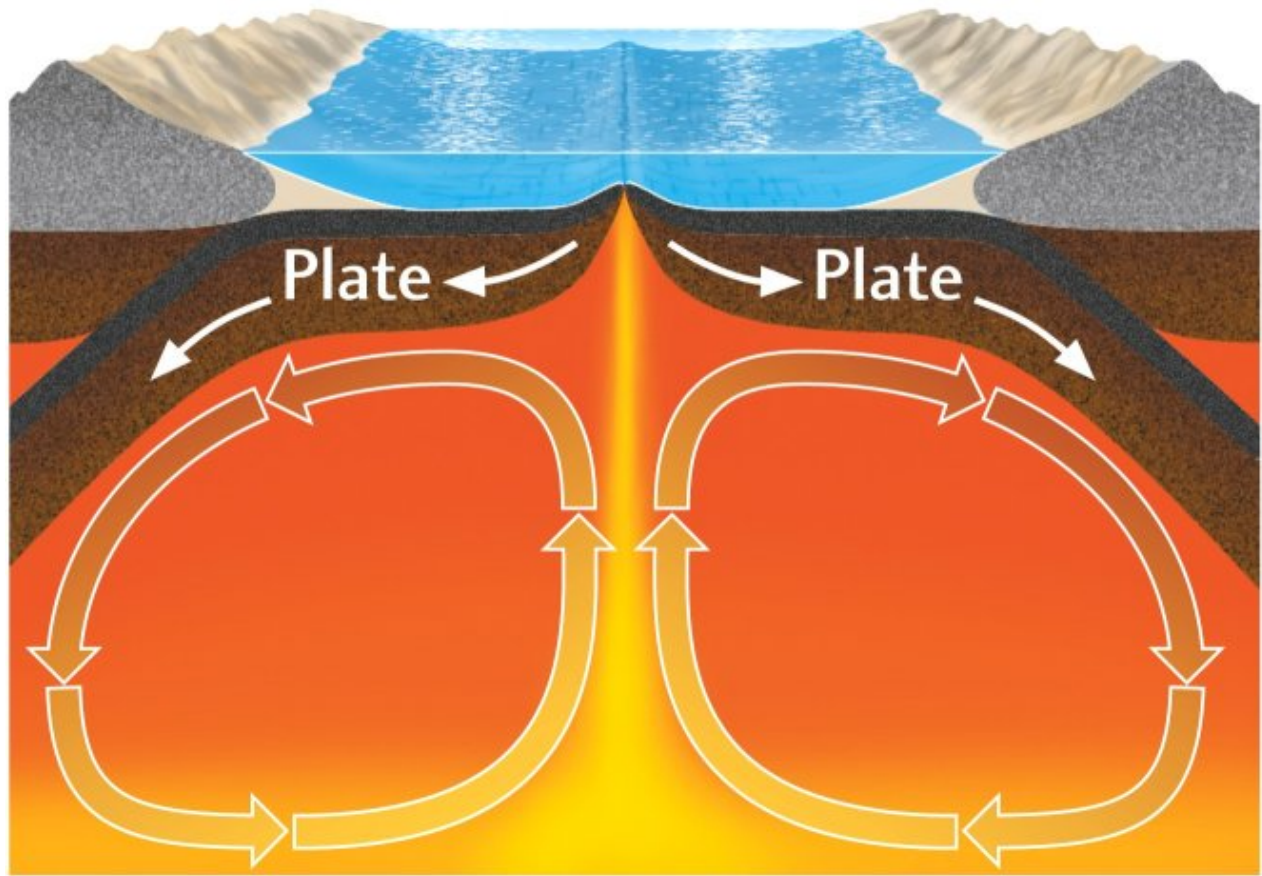


12.2 Plate tectonics

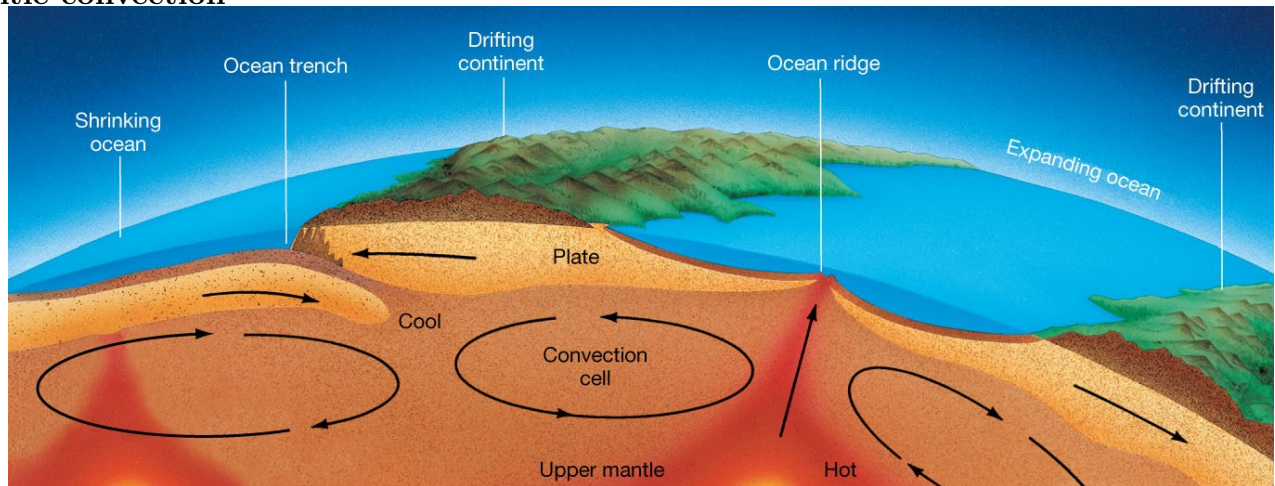
Mantle convection

- The driving force of floating continents is a **mantle convection**
- In ocean ridges, new ocean cortex is constantly forming and expanding
- In ocean trenches and continental ridges, different plates are colliding and often forming mountains

Mantle convection



Mantle convection



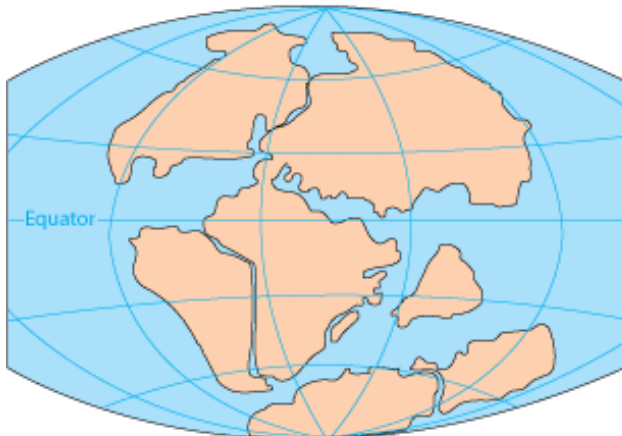
The result of mantle convection



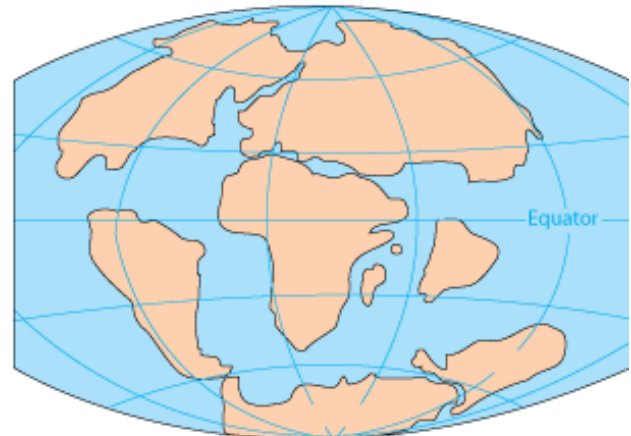
PERMIAN
250 million years ago



TRIASSIC
200 million years ago

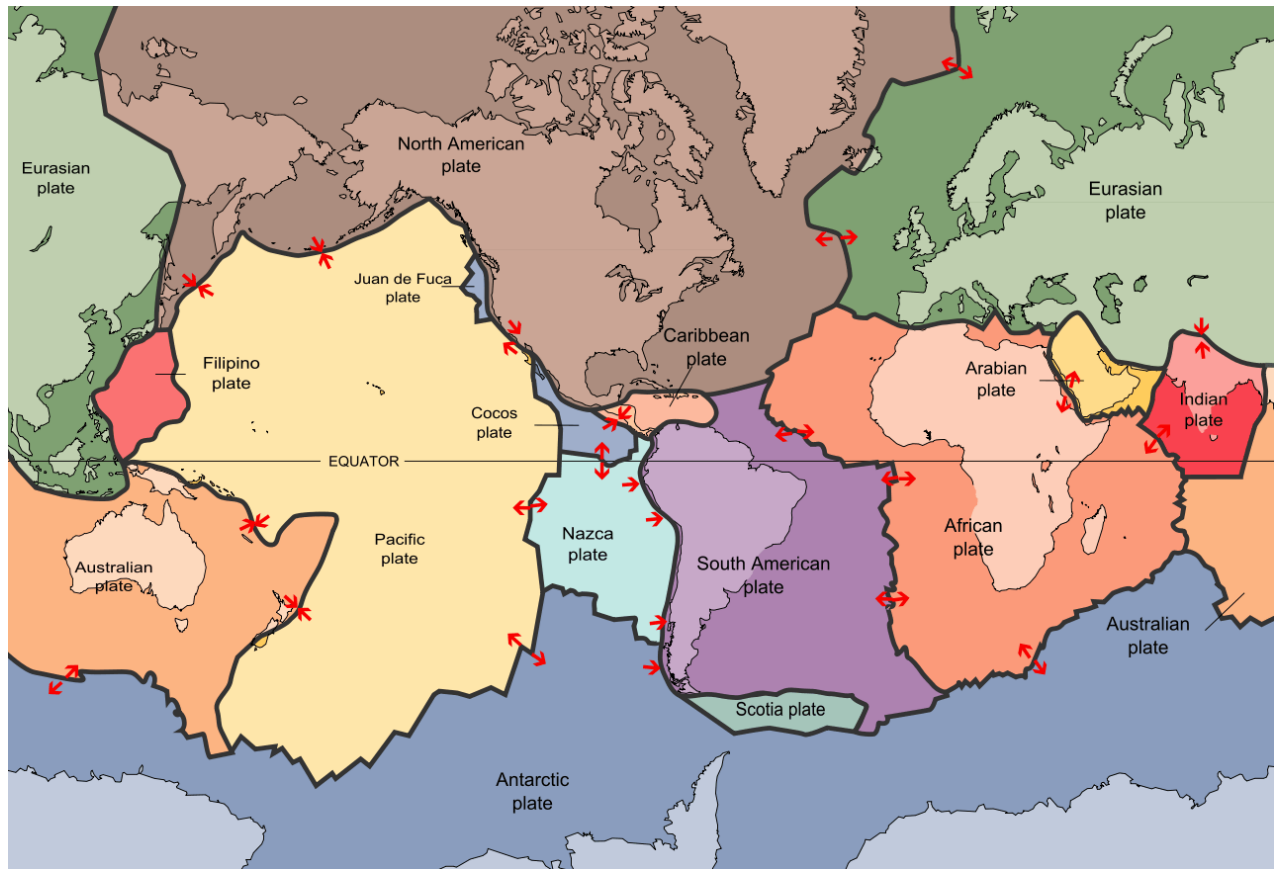


JURASSIC
145 million years ago



CRETACEOUS
65 million years ago

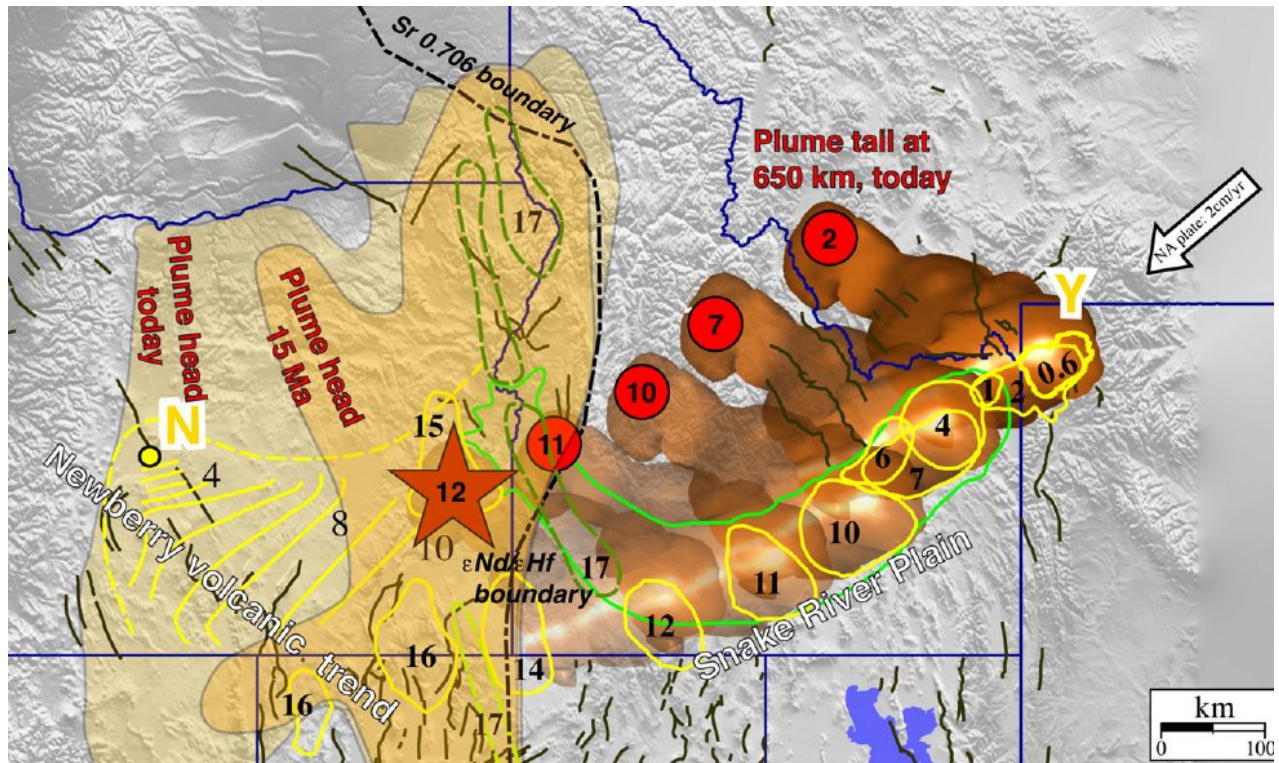
What is going on now



Two living examples of continental drift on U.S. territory

- Yellowstone hotspot
- Hawaiian hotspot

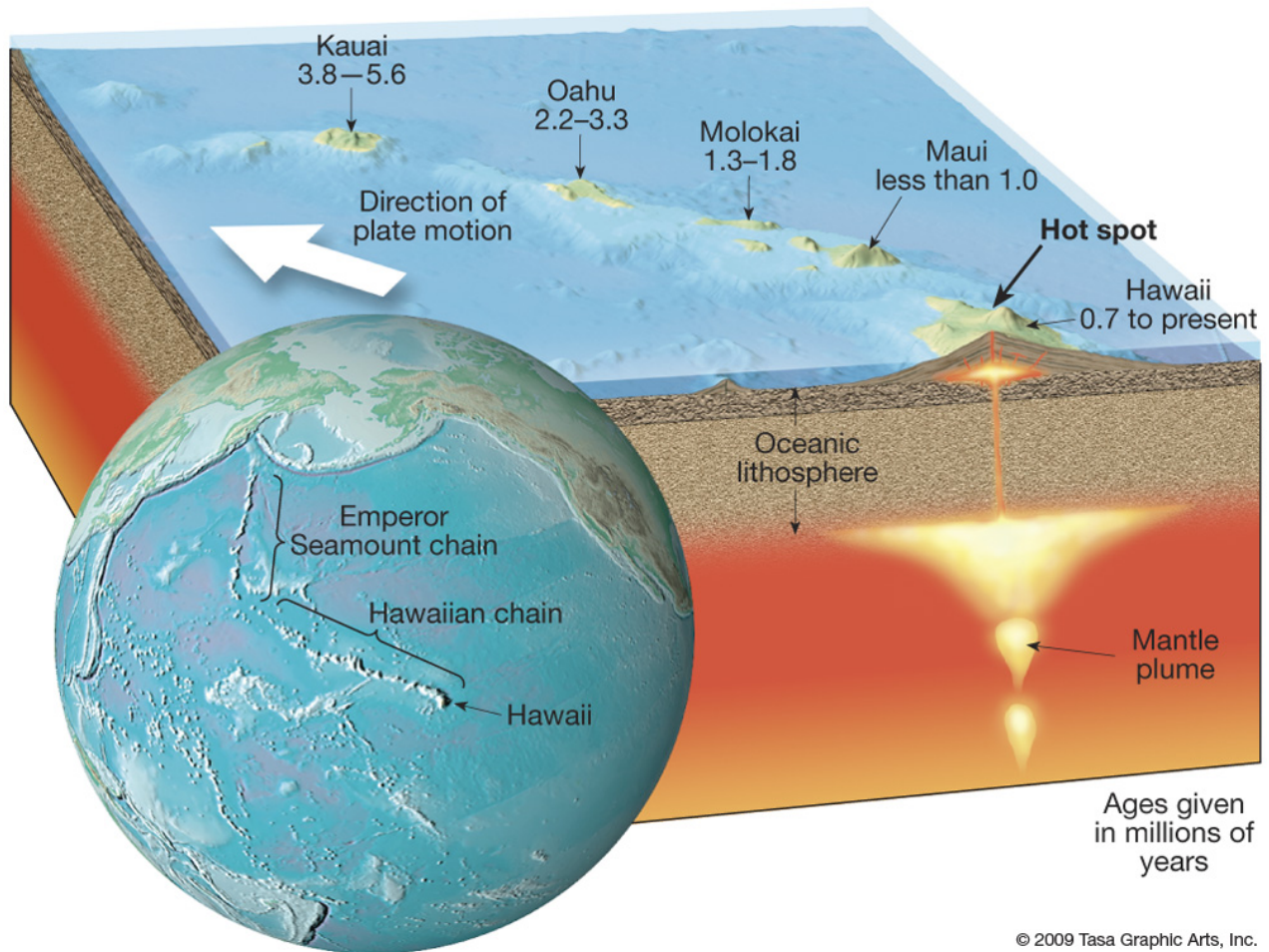
Yellowstone hotspot



Hawaiian hotspot (as pictured in “Moana”)



Hawaiian hotspot (more scientific)



Summary

- In chemistry, moles are used to make chemical reactions go without problems
- Concentration will not change if we throw away half of liquid
- Continents of Earth are constantly changing their position due to the mantle convection ("plate tectonics")
- In the past (Permian period) all continents formed super-continent Pangaea, which then broke into Laurasia and Gondwana

For Further Reading

References

- [1] Mole. Wikipedia. [http://en.wikipedia.org/wiki/Mole_\(unit\)](http://en.wikipedia.org/wiki/Mole_(unit))
- [2] Plate tectonics. http://en.wikipedia.org/wiki/Plate_tectonics

Outline

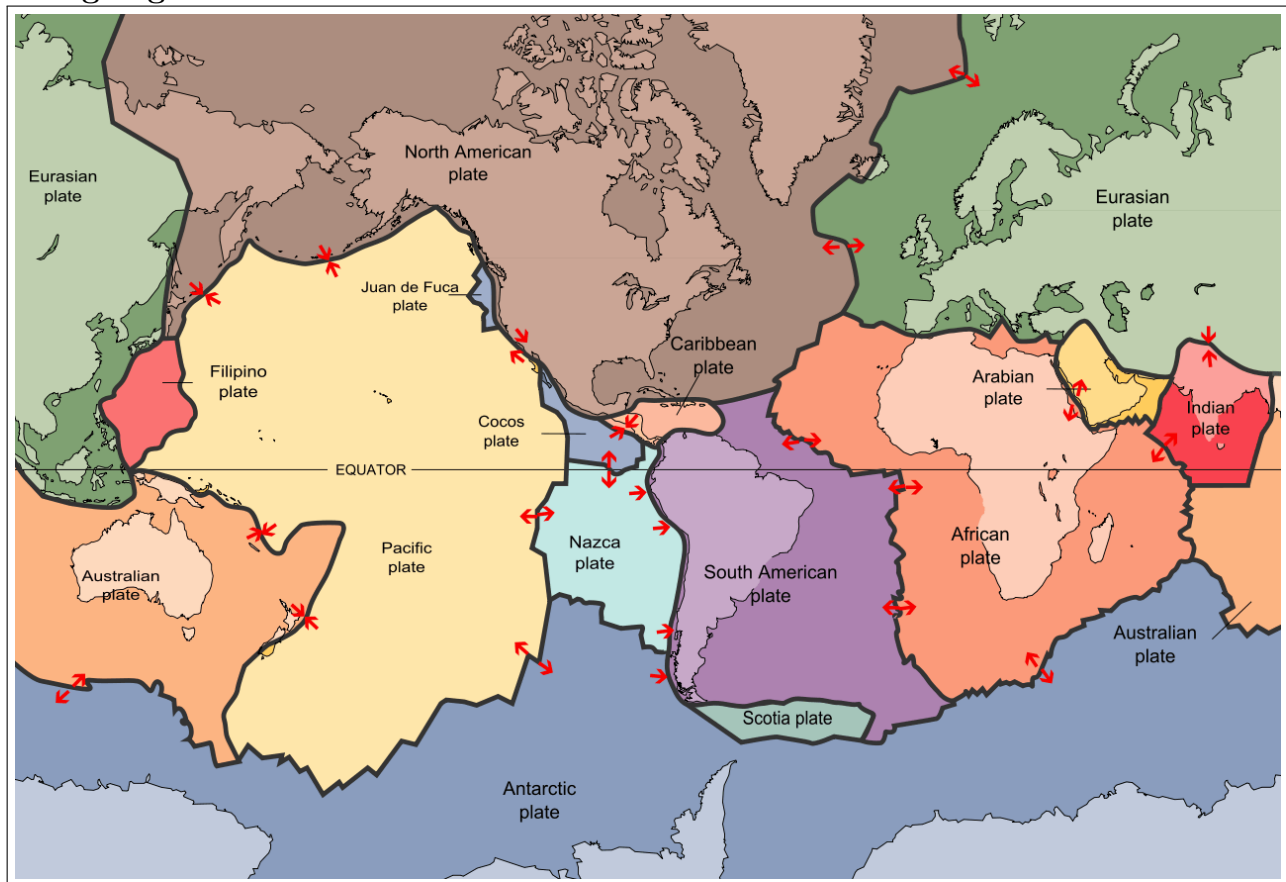
13 Where we are?

13.1 Continental drift and plate tectonics

Continental drift and plate tectonics

- Continents of Earth are constantly changing their position due to the mantle convection (“plate tectonics”)
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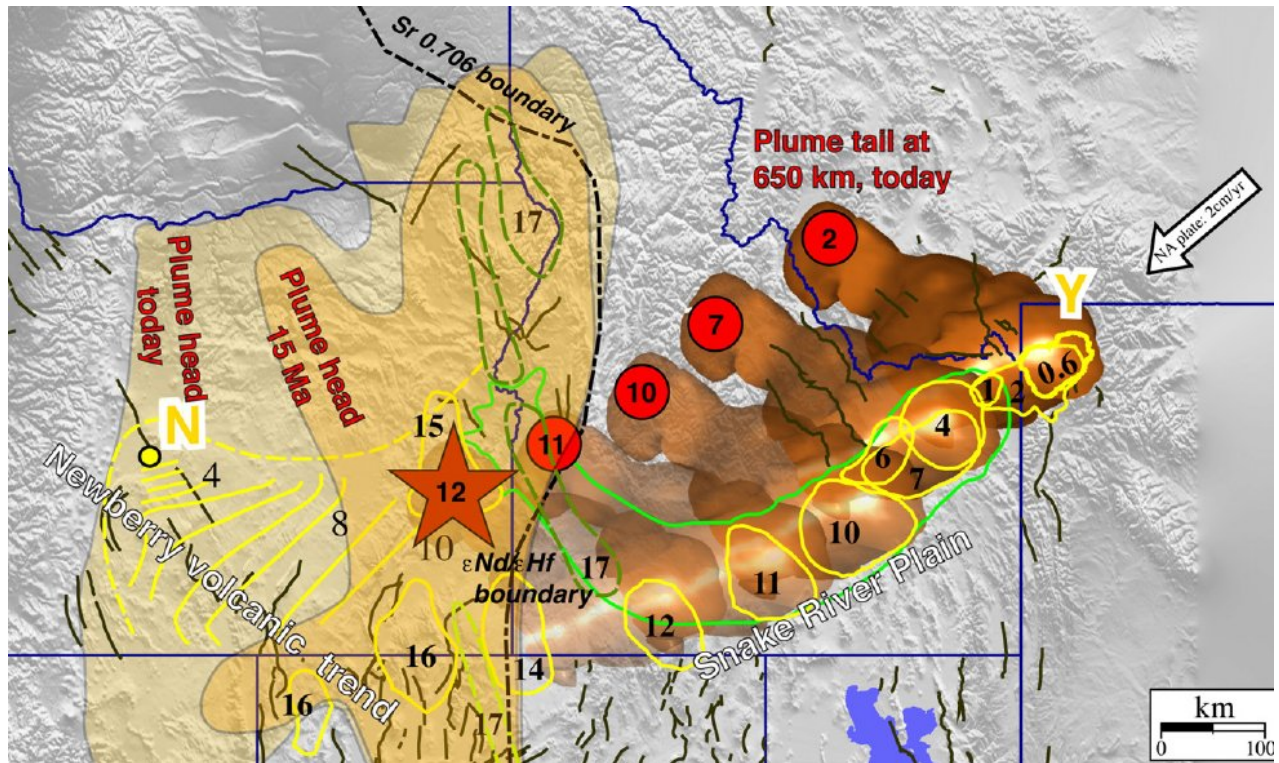
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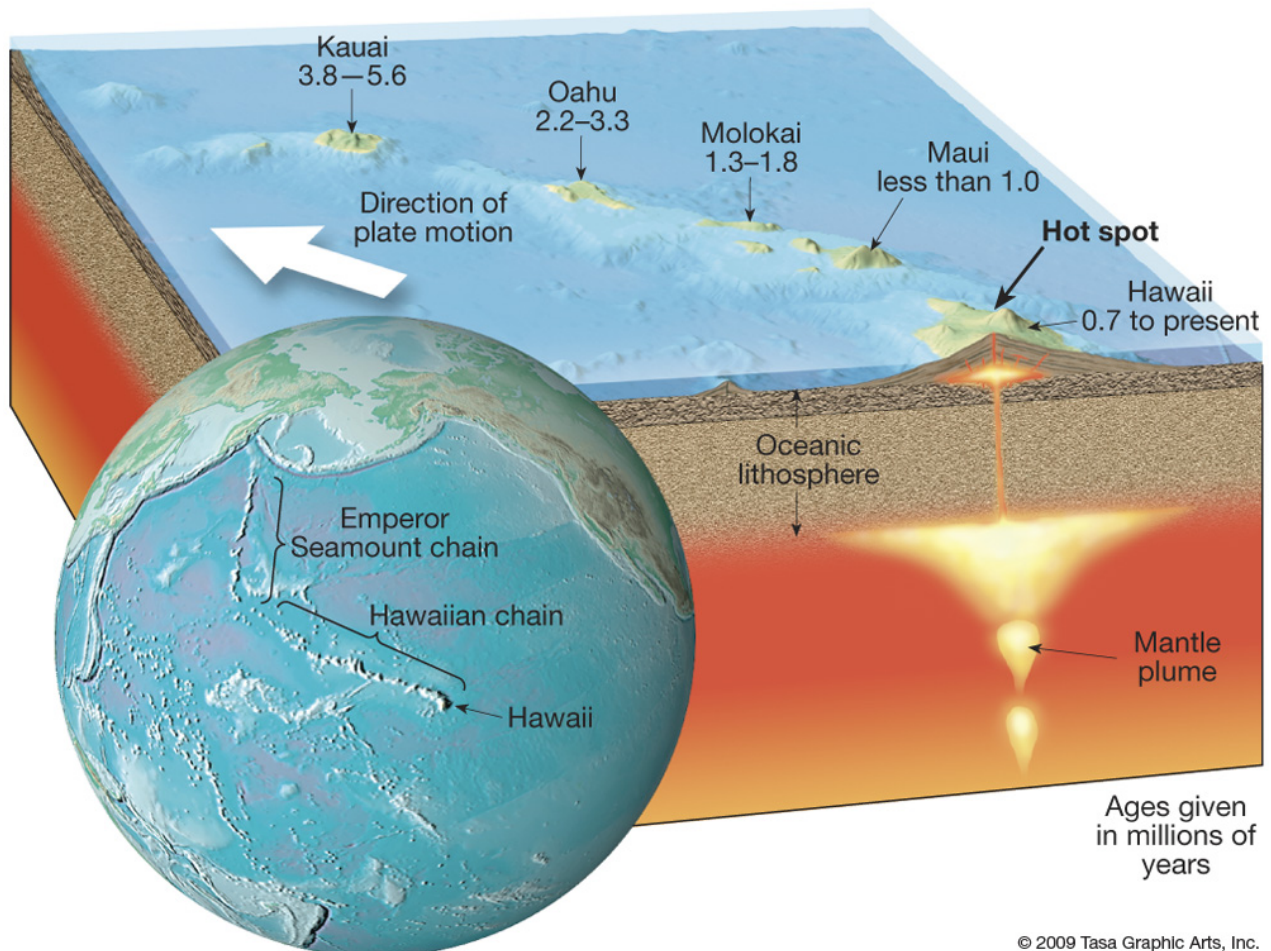
Two living examples of continental drift on U.S. territory

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- Hawaiian hotspot

Yellowstone hotspot



Hawaiian hotspot (more scientific)



14 Origin of life

14.1 Proofs of evolution

Evolution is a working research program

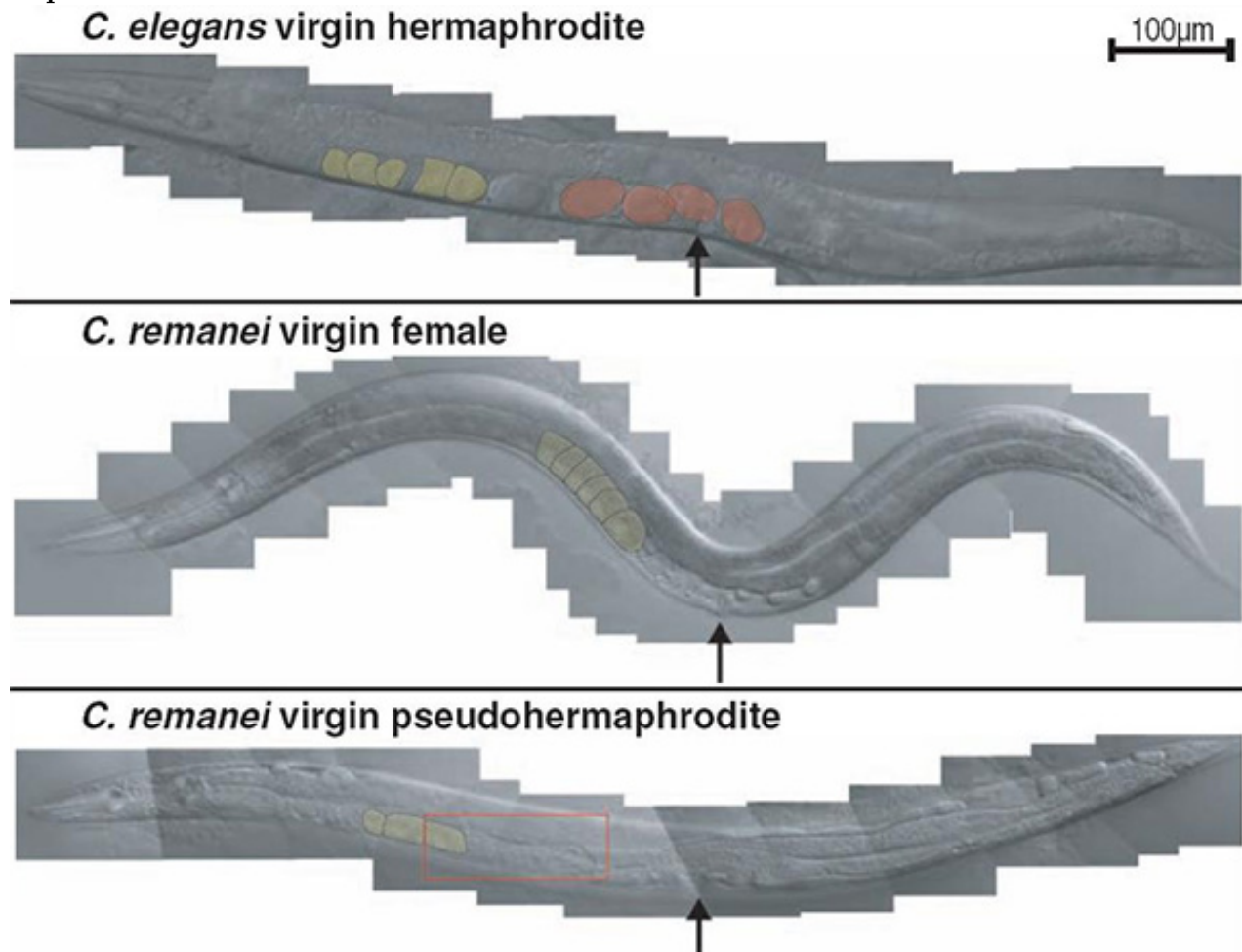
“Nothing in Biology Makes Sense Except in the Light of Evolution”

Theodosius Dobzhansky (1973)

New useful characters appear as a result of mutations

- Wild rice evolved into domesticable by one mutation: <http://www.sciencemag.org/content/311/5769/1936.short>
 - Malaria parasite became resistant to drugs due to one mutation: <http://www.sciencemag.org/content/325/5948/1680.abstract>
 - Two mutations may turn worms into hermaphrodites: <http://www.sciencemag.org/content/326/5955/1002.abstract>
- and so on

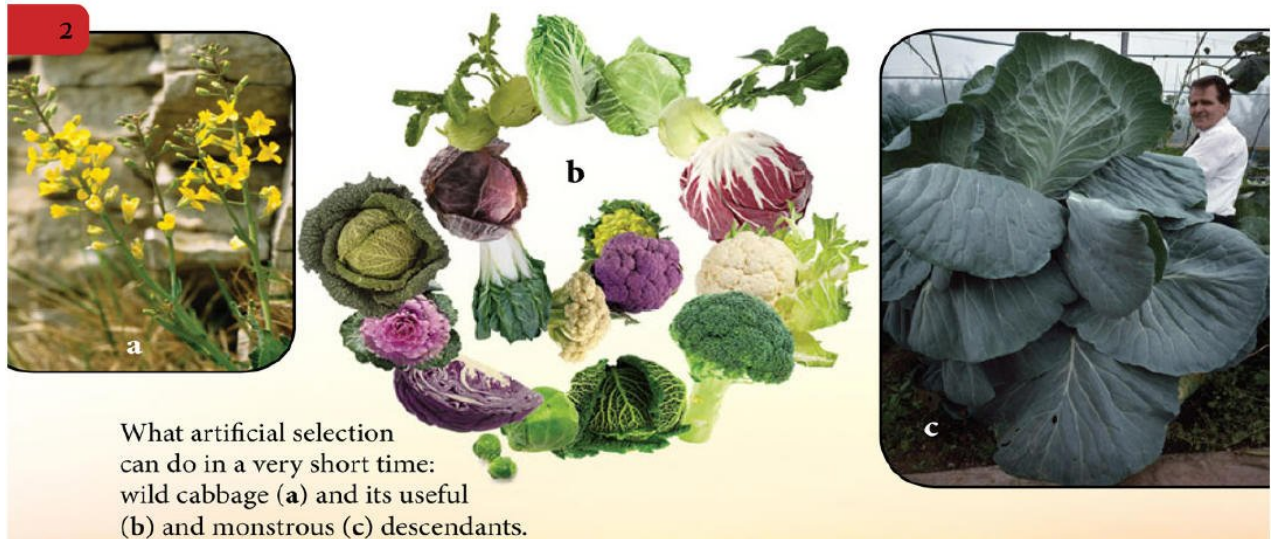
Hermaphroditic worms



Artificial selection is a bridge to natural selection

- Artificial selection is a full analog of natural selection
- Animals are also doing “artificial” selection
- Results of artificial selection may be called “new species”

Cabbages



There are dozens of observed and documented cases of evolution

- Bacteria make major evolutionary shift in the lab (40,000 generations experiment): <http://www.newscientist.com/article/dn14094-bacteria-make-major-evolutionary-shift-in-the-lab.html>
- Harmful insects escaped from viral biological weapons: <http://www.sciencemag.org/content/317/5846/1916.abstract>
- Maggot flies and their parasitic wasps formed several new species for 150 years: <http://www.sciencemag.org/content/323/5915/776.abstract>
- Accidental hybridization turned black chokecherry into delightful fruit (*Aronia melanocarpa* to *Aronia mitchurinii*)
- American evening primrose gave birth to new species, red-stem evening primrose in Europe (*Oenothera biennis* to *Oenothera rubricaulis*) in 100 years

Apple maggot fly: new species



Black choke cherry and Russian *Aronia mitchurinii* (new species)



Evening primroses: American and European (new species)

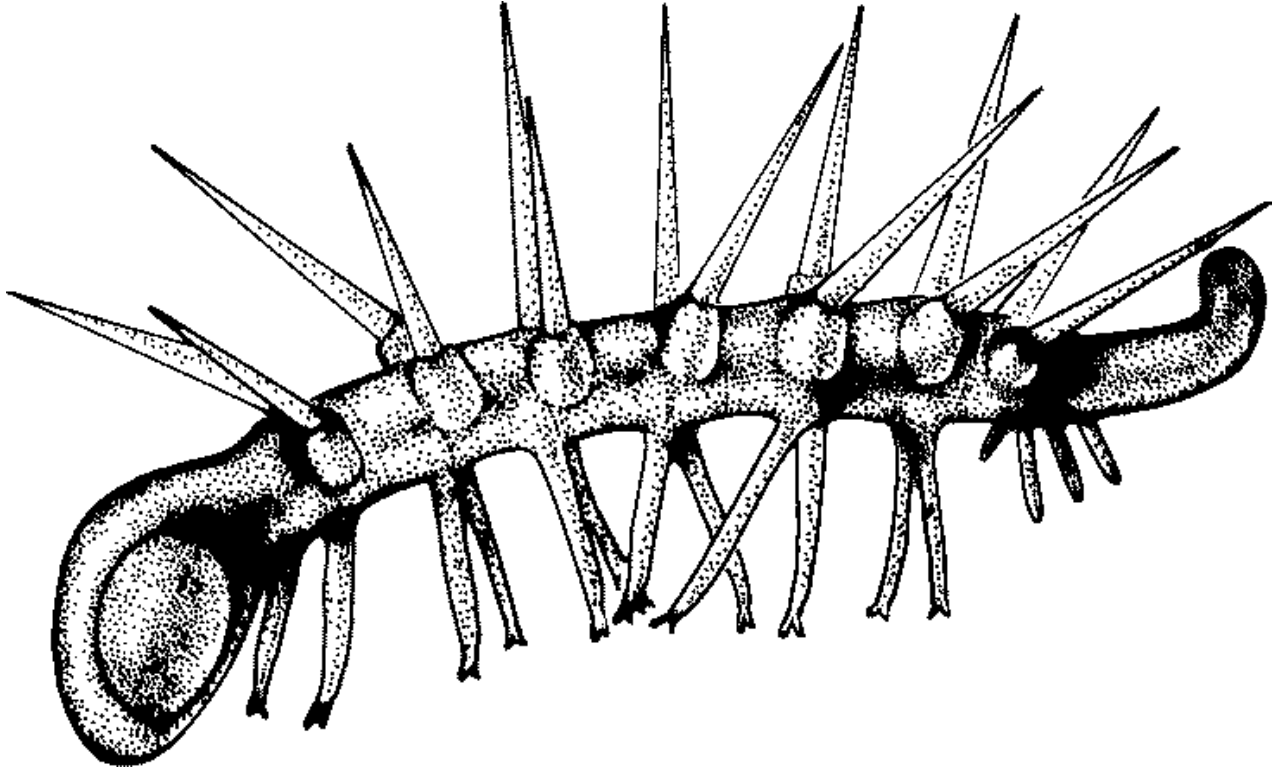


Fossils are direct evidence of evolution

- The older fossils are, the more unusual are they

- Many fossils are transitional forms (see http://en.wikipedia.org/wiki/List_of_transitional_fossils)
- Many fossils could be arranged in well-documented “evolutionary chains”

Hallucigenia—mysterious Cambrian fossil



Hallucigenia in stone

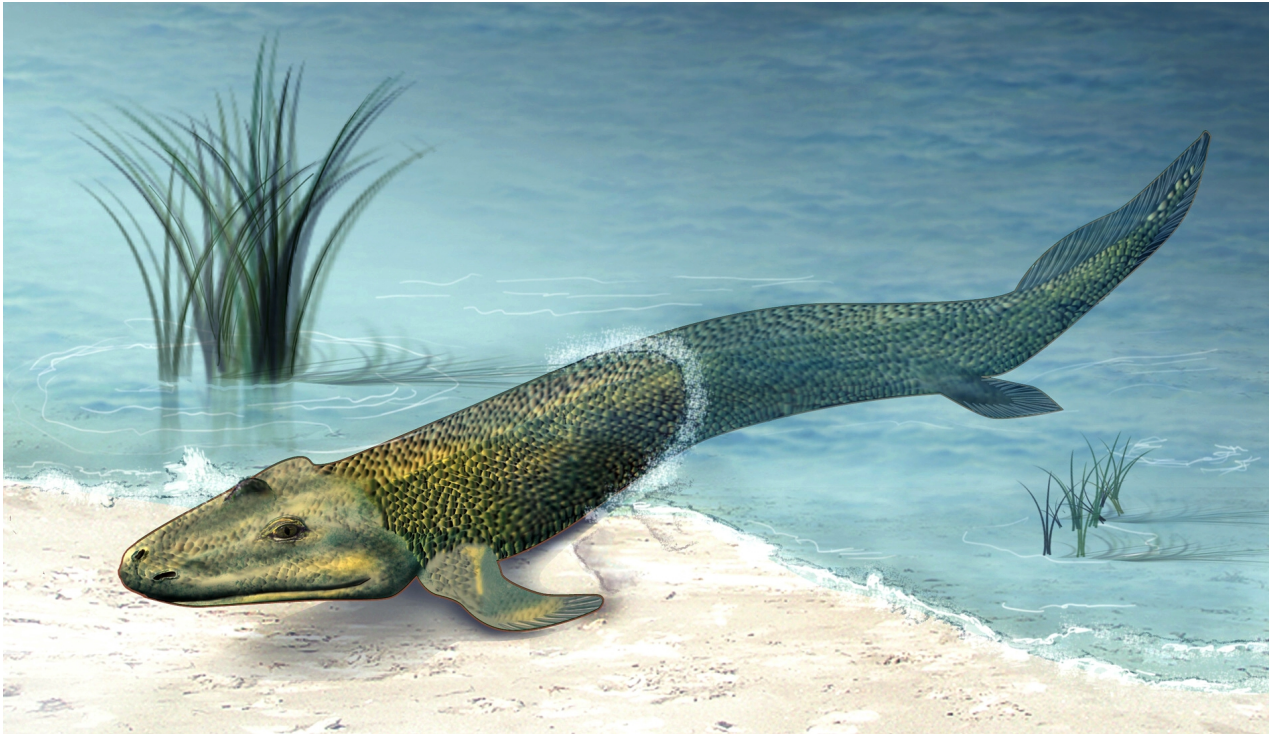


Hallucigenia—new reconstruction, with head!

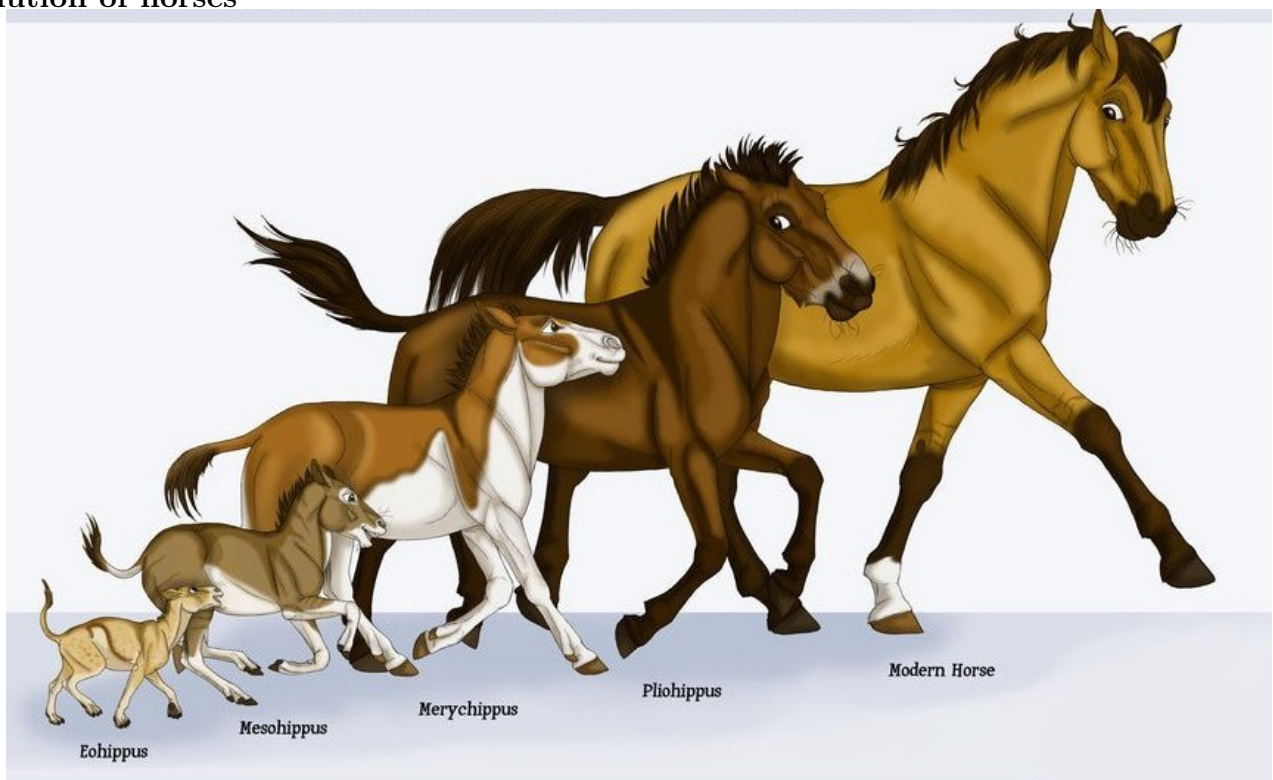


Now clear that it is half-worm, half-arthropod

Tiktaalik—half-fish, half-salamander



Evolution of horses

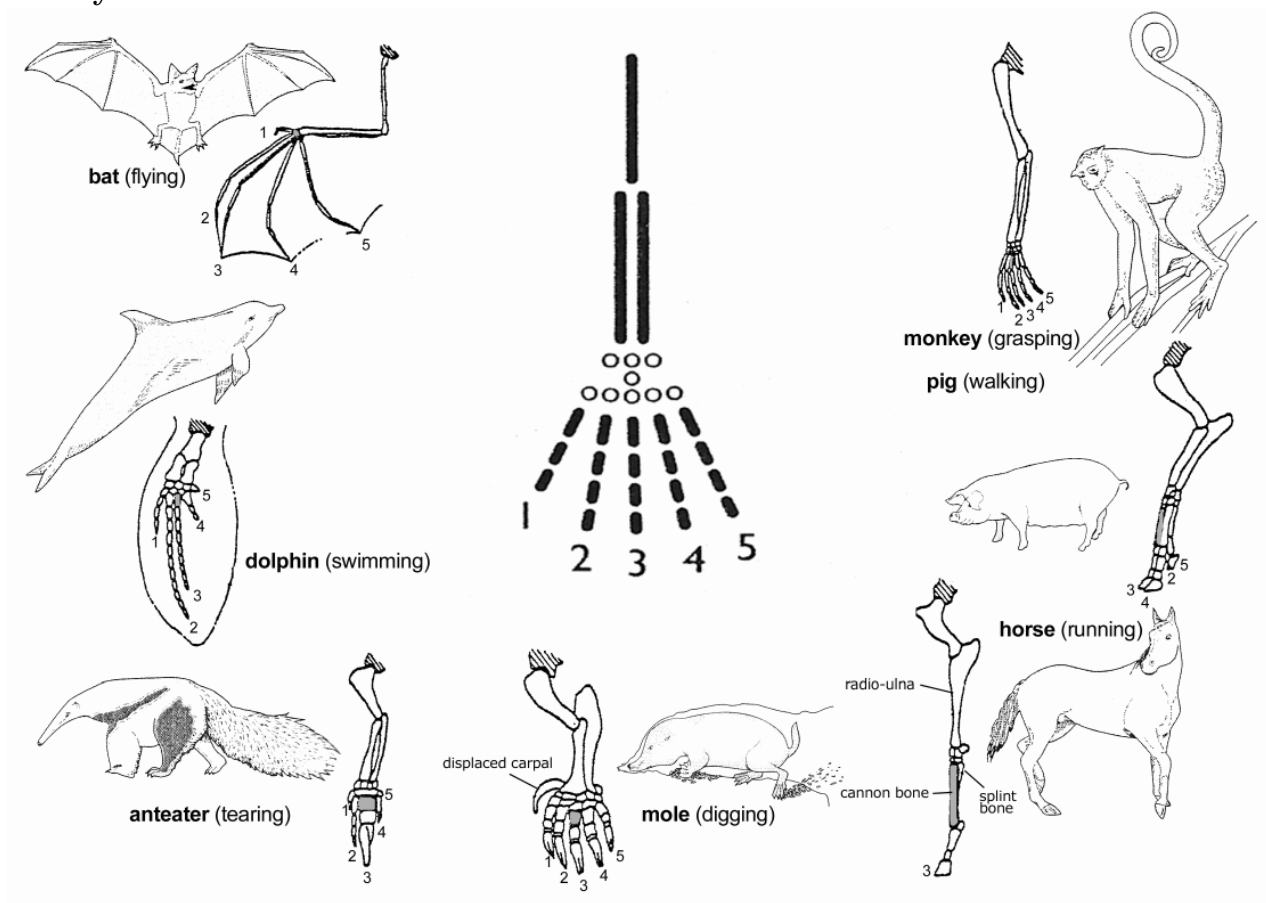


Similarities in structure (morphology) prove evolution

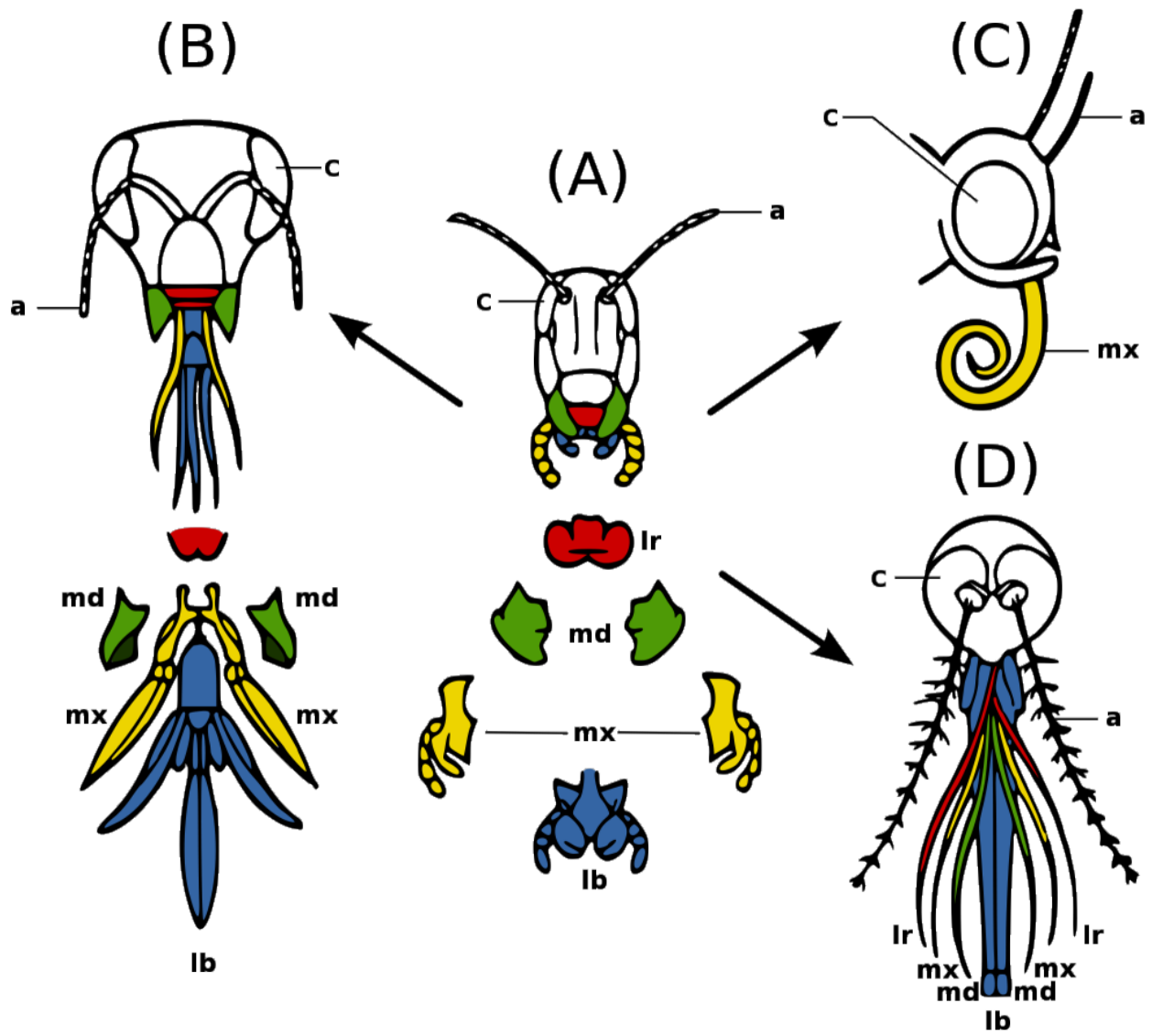
- So-called *homological structures* are descendants of one ancestral structure
- *Vestigial organs* remind us of the past
- *Reversion organs* demonstrate ancestral states

- *Analogous structures* demonstrate how evolution led to the same outcome

Pentadactyl limb of terrestrial vertebrates



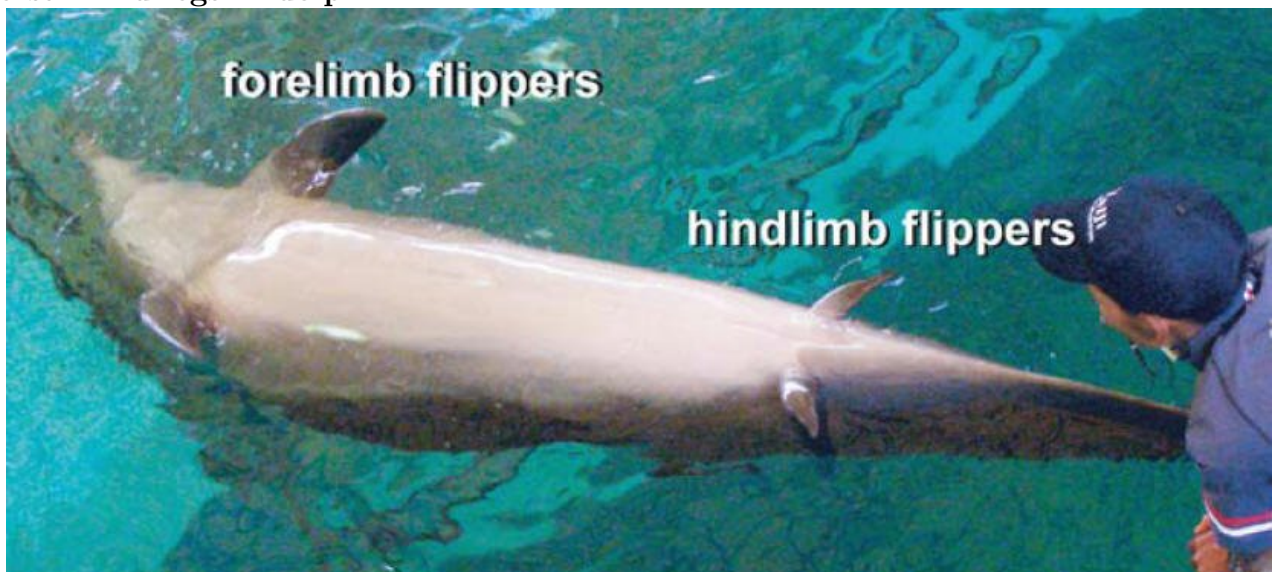
Insect mouth



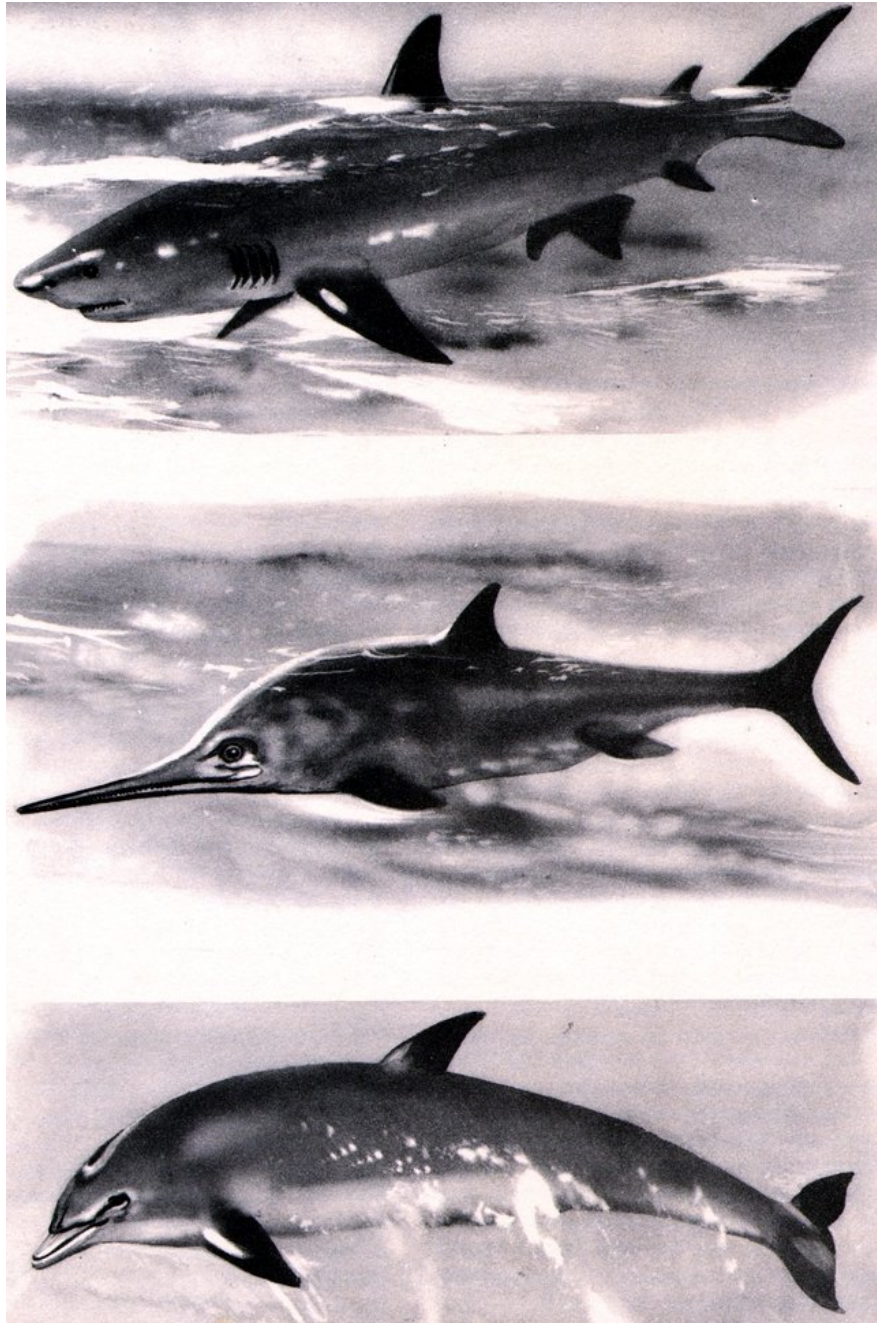
Vestigial hind legs of python



Reversal hind legs in dolphin



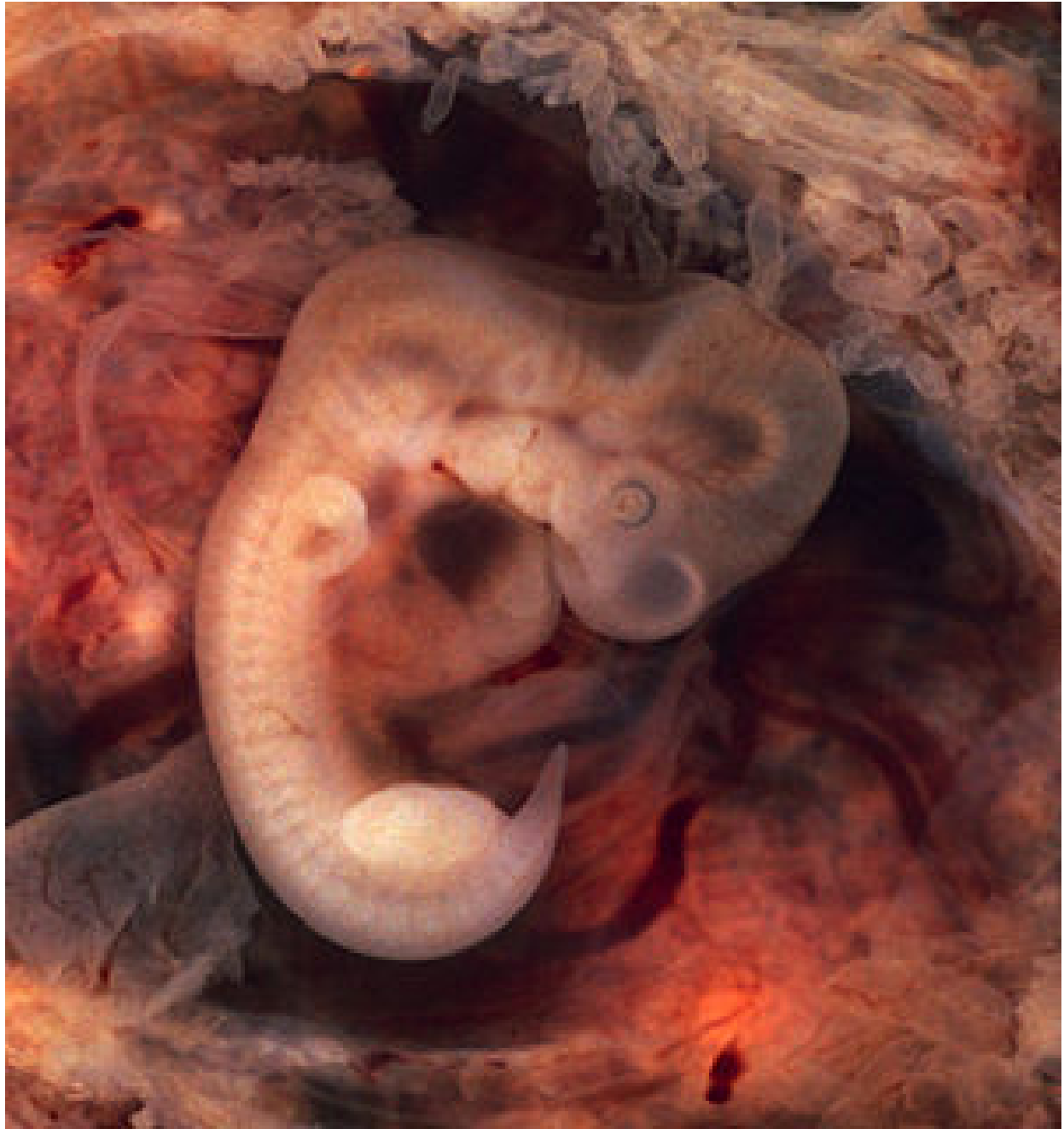
Analogous structures help shark, ichthyosaur and dolphin to swim



Embryonic development is another proof

- Embryos retain ancestral characters
- We may now switch development programs and uncover hidden structures

Mammal embryo with gills



Switching fly back to four wings



Molecular biology tells about common roots

- All living things have same molecular base
- Genetic distance between close species is small
- Human DNA contains “fossil” viruses: <http://www.biomedcentral.com/1471-2148/8/266> and silenced genes (pseudogenes, e.g., olfactory receptor genes in humans)

Chimpanzee and human: only 1% difference

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Biogeography shows why species evolve

- Isolated islands and small continents facilitate analogous forms (parallel evolution and radiation)
- Many groups of animals and plants now reflect Gondwanan distribution

Can you distinguish Australian sugar glider from American flying squirrel?



Araucaria is growing only in South America, New Zealand and Australia



Evolution evolved from the hypothesis to the fact and then to research program

- A. Hypothesis
- B. Theory
- C. Fact
- D. Research program

Summary

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

For Further Reading

References

- [1] Evolution. <http://en.wikipedia.org/wiki/Evolution>
- [2] Evidence of common descent. http://en.wikipedia.org/wiki/Evidence_of_common_descent

Outline

15 Where we are?

15.1 Proofs of evolution

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

16 Origin of life

16.1 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 —OH groups
- Amino acids: N + C + 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 (like collagen in skin)
- Polymeric nucleotides: nucleic acids (DNA and RNA)

The very basic features of life

- Semi-permeable² membrane which consists of lipid layer with embedded proteins
- DNA \rightarrow RNA \rightarrow proteins³

16.2 Primordial living structures

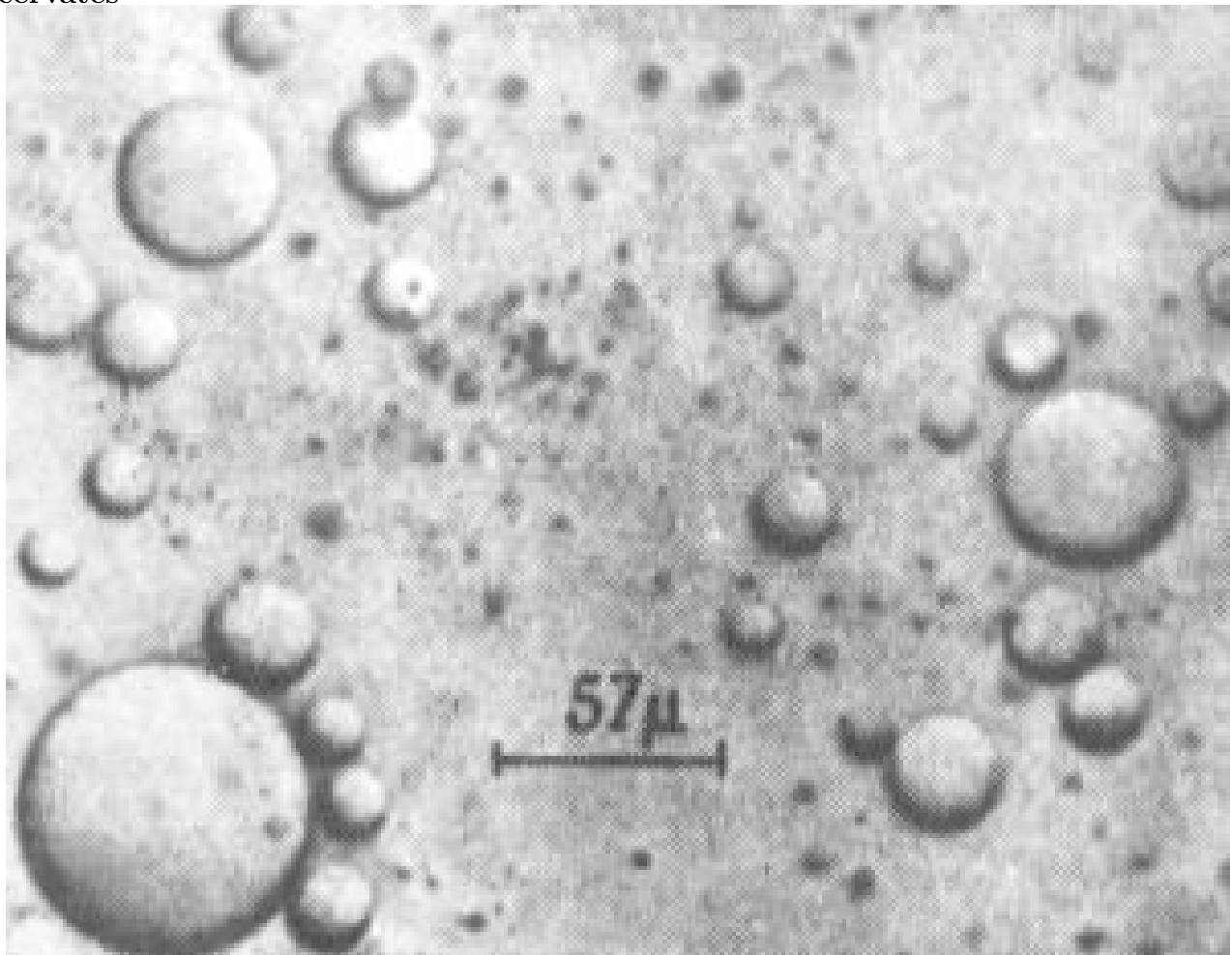
Coacervates

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

²Does not usually allow bigger hydrophilic molecules and ions to come through.

³First arrow is *transcription*, second is *translation*.

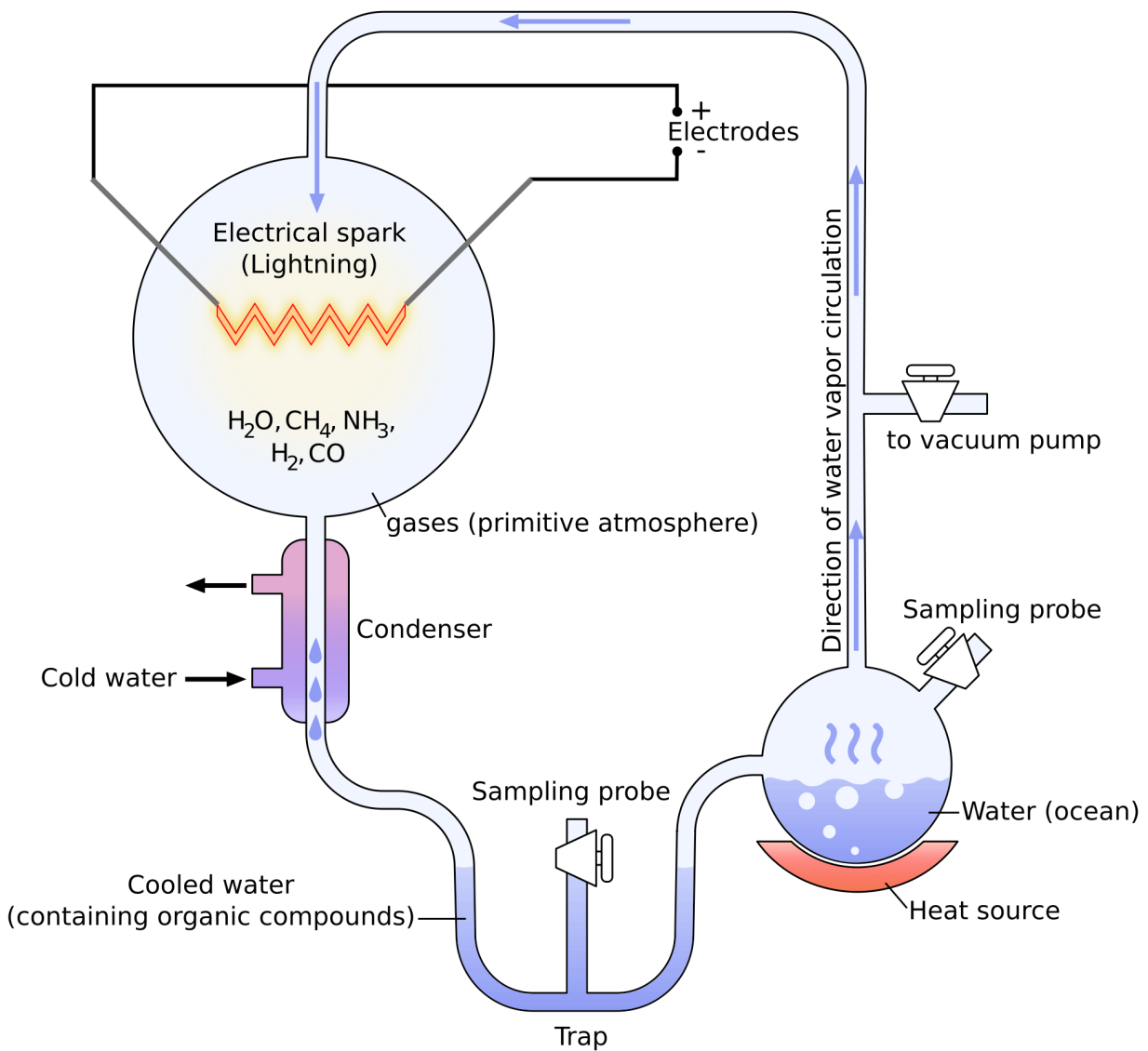
Coacervates



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)

17 Questions and answers

17.1 Exam 1

Questions before exam 1?

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
- [2] Origin of Life. <http://en.wikipedia.org/wiki/Abiogenesis>

Example questions for the exam

Start time _____

End time _____

Multiple choice

Every question in this section costs either 1 or 0. Please **mark** the appropriate answer on the **scantron**.

A. If tap water has pH equal to 6.8, it is:

- (a) Slightly acidic
- (b) Neutral
- (c) Slightly basic

B. Laurasia:

- (a) Was a super-continent which included all contemporary continents
- (b) Was a continent which broke into South America, Australia, Antarctic, Africa and India
- (c) Was a continent which broke into North America and Europe

C. Who did speculate about extra-terrestrial teapot as an example of non-falsified hypothesis?

- (a) Bertrand Russel
- (b) Charles Darwin
- (c) Theodosius Dobzhansky

D. What is the molecular weight of sulfuric acid, H_2SO_4 ? Atomic weights: H=1, O=16, S=32.

- (a) 7
- (b) 49
- (c) 98

Answers

1A, 2C, 3A, 4C