Early life and the prokaryotes

1

Part I: Early life

Learning goals:

Describe how early life diversified

Identify the three domains of life

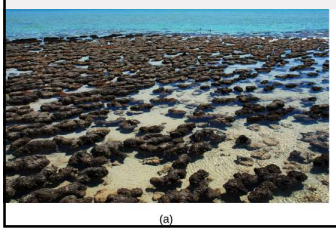
2

Early life (review from last week)

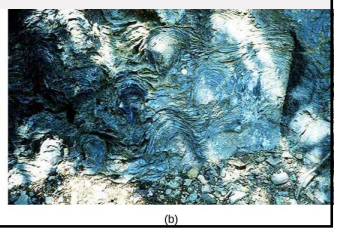
Single-celled organisms were the first life-forms

3.5 bya microfossils resembled prokaryotes

3.2 bya microfossils resembled eukaryotes

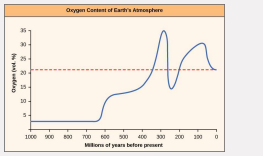


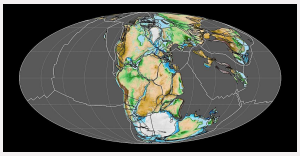
(a)



(b)

3





Diversification of early life

Evolution of photosynthesis released O_2 to the ocean and atmosphere, making it conducive to evolution of cellular respiration

Continental motion affected evolution by reproductively isolating populations and allowing previously separate populations to interbreed

4

Three domains of life

- **Eubacteria**
- **Archaea**
  - Both were the first organisms and existed alone for 1 billion years
- **Eukaryotes**
  - Eukaryotes evolved compartmentalization and extensive undo membrane system

5

Part II: Prokaryotes

Learning goals:

Differentiate among archaea, bacteria and eukaryotes
Describe and contrast features of bacteria and archaea
Explain the methods used to classify prokaryotes
Explain the ways that prokaryotes increase genetic variation
Distinguish various modes of prokaryotic metabolism

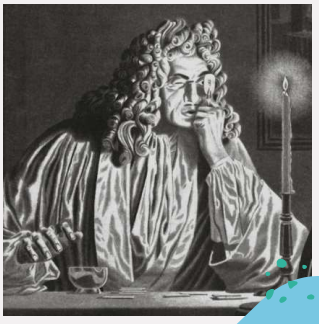
6

History of the discovery of Prokaryotes

Antony van Leeuwenhoek (1674): First to observed microbes from lake water through a glass lens

Louis Pasteur (1800s) demonstrated that life arises from life (not spontaneous generation)

Robert Koch (1800s): Discovered the causal relationship between microorganisms and diseases



7

Prokaryotes

Oldest, simplest, most abundant

Evolved around 3.5 bya

Ubiquitous

Have DNA but no nucleus

Fall into 2 domains; **Eubacteria and Archaea**

8

How do you know you have a prokaryote?

By sight:

Unicellular (one cell)

Tiny cell size (<1 µm in diameter)

Nucleoid but **no nucleus**

Did you find it in a hot spring?

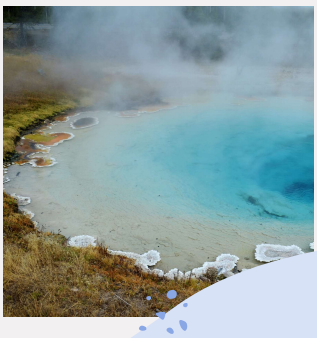
Through physiology:

Types of genetic recombination

Types of flagella

Composition of cell wall

Some unique metabolic diversity

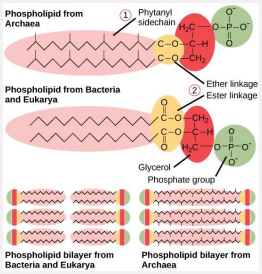


9

Differences between Bacteria and Archaea

Plasma membrane lipids:

- **Bacterial**: lipids have ester linkages
- **Archaean**: lipids have ether linkages
  - Tetraethers form a monolayer instead of a bilayer; allows **extremophiles** to withstand high temperatures



10

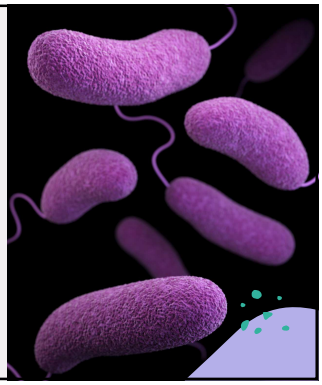
Other notable differences between Bacteria and Archaea

Cell wall
- Bacteria: peptidoglycan
- Archaea: lack peptidoglycan

DNA replication
- Bacteria: single replication origin
- Archaea: single replication origin, but similar proteins to eukaryotes

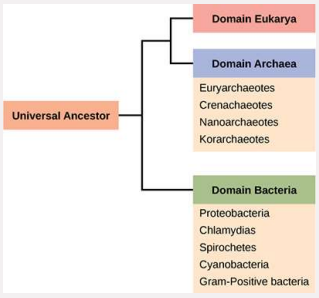
Gene expression
- Bacteria: single RNA polymerase
- Archaea: single RNA polymerase that resembles eukaryotic RNA polymerases

Do you sense an evolutionary theme here?



11

Evolutionary connections between domains



12

Understanding check

What are the three domains of life?

What is the difference between bacterial and archaean plasma membrane lipids?

What adaptive edge does ether linkages give to archaeans?

13

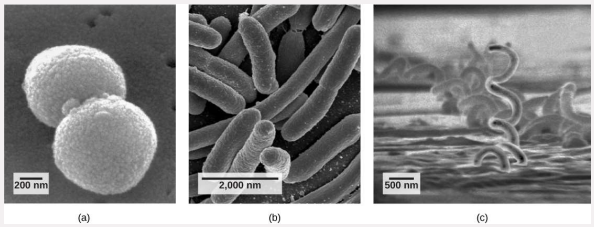
Identifying types of prokaryotes (biological species concept does not work here)

Phenotypes
- Photosynthetic or non-photosynthetic
- Motile or non-motile
- Unicellular, colonial or filamentous
- Formation of spores or binary fission
- Human pathogens

Molecular
- Amino acid sequences
- % G and C
- Compare genome of different species
- Gene and ribosomal RNA sequence
- Whole-genome sequencing

14

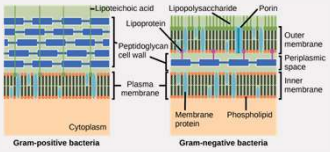
Basic cell shapes of prokaryotes



Coccus Bacilli Spirilli

15

Bacterial cell wall



Peptidoglycan

Maintains shape

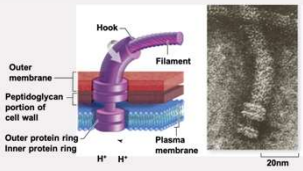
Withstands hypotonic environments

Gram-positive (thicker/purple) vs.

Gram-negative bacteria (thinner/pink)

16

Structures found on some bacteria



Capsule
- Gelatinous layer
- Used for attachment
- Protects from host immune system

Flagella
- Slender, rigid, helical
- Flagellin protein
- Used for locomotion

Pili
- Short, hairlike structures
- Found in gram-negative bacteria
- Aid in attachment and conjugation

17

More structures found/produced in some bacteria

Nucleoid region
- Single, circular chromosome
- May contain plasmids

Ribosomes (used in protein synthesis**)**
- Smaller than those of eukaryotes
- Differ in protein and RNA content
- Targeted by some antibiotics

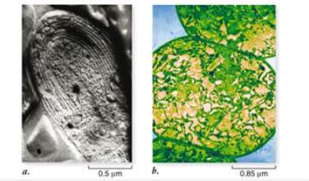
Production of **endospores**
- Thick wall around genome
- Protects from environmental stress (e.g. heat)
- Can germinate and return to normal cell division (e.g. tetanus, botulism, and anthrax)

18

Invagination of plasma membrane

Invaginated plasma membrane in some prokaryotes used for respiration or photosynthesis.

What is the advantage to an invaginated membrane?



19

Understanding check

What are the three cell shapes of prokaryotes?

What is the differences between Gram-positive and Gram-negative bacteria?

20

Prokaryotes do not sexually reproduce

Prokaryotes reproduce by binary fission (covered in Bio I)

How is genetic variation maintained?

1) Horizontal gene transfer (as opposed to vertical gene transfer: parent to offspring)

- Conjugation: Cell to cell contact
- Transduction: By bacteriophages (viruses)
- Transformation: From the environment

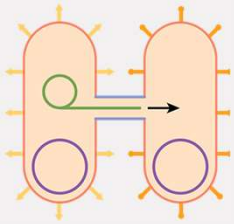
2) Mutation

21

Conjugation

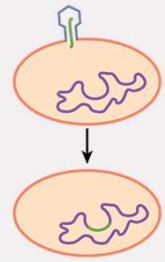
Plasmids: Small circular extrachromosomal DNA

- *F plasmid* (fertility factor)
- *F*+ contain plasmid
- *F*− do not



22

Transduction



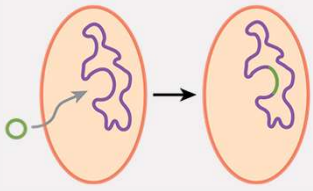
Transfer of DNA via a **virus**

- Any gene can be transferred
- **Accidents** in the life cycle of bacteriophage
- Viruses package bacterial DNA
- Transfers it in a subsequent infection

23

Transformation

Uptake of DNA from the environment

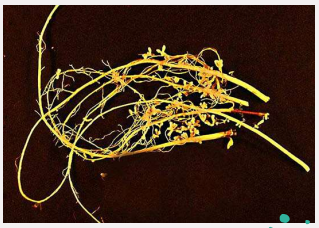


24

Photoautotrophs:	Light as energy source Carbon from inorganic molecules
Photoheterotrophs	Use light as their source of energy but obtain carbon from organic molecules
Chemolithoheterotrophs:	Oxidize organic molecules with high potential energy
Chemolithoautotrophs:	Oxidize inorganic molecules with high potential energy

25

Nitrogen fixing bacteria in root nodules



Certain plants (e.g., legumes) have a mutualistic relationship with **nitrogen (N) fixing bacteria**.

N fixing bacteria take N out of the atmosphere and make it biologically available

Most of the solid forms of N in the environment are derived from N fixation

N fixation is **very rare** trait in nature

- *Anabaena* in aquatic environments.
- *Rhizobium* in soil

26