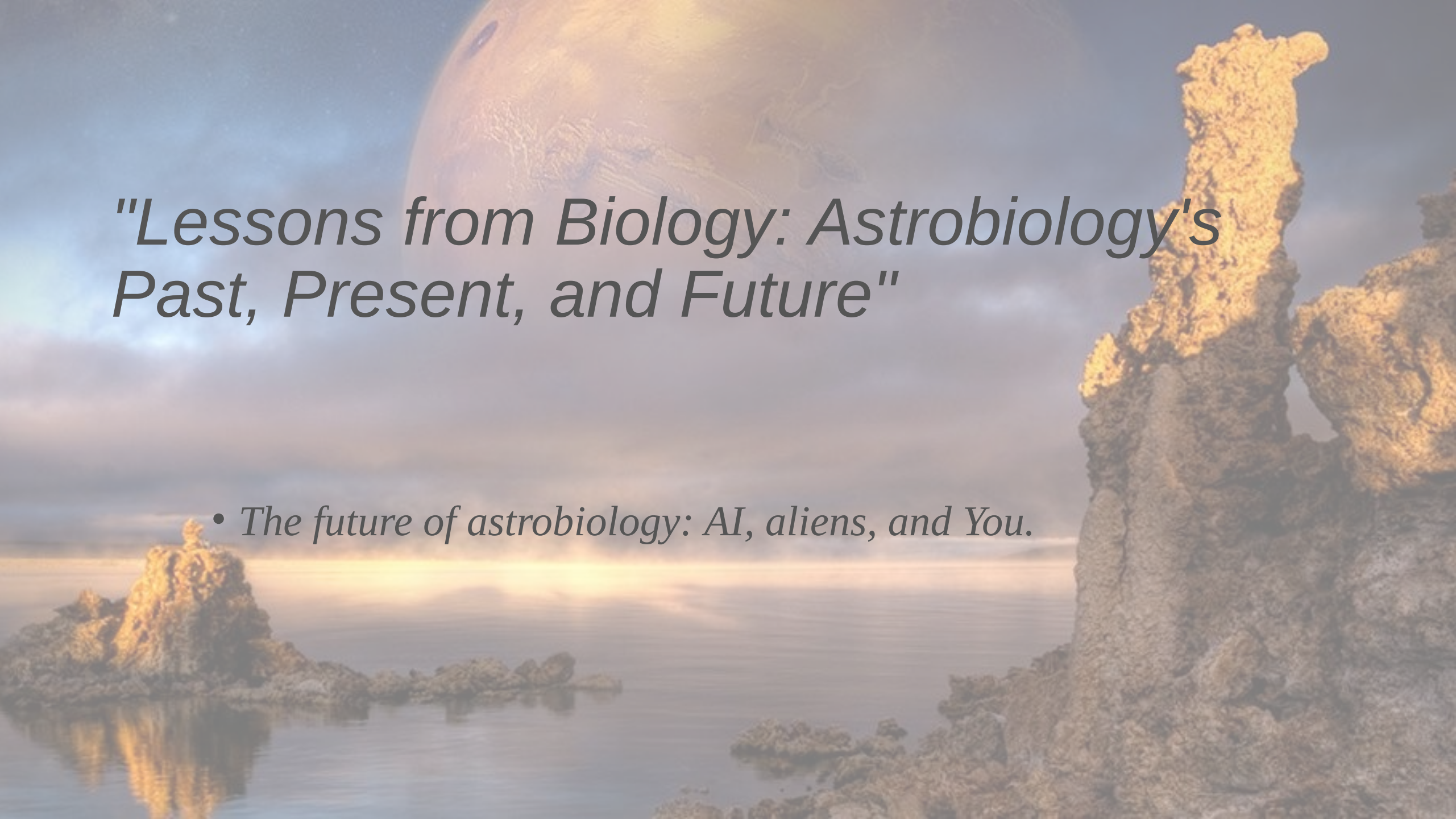


"Lessons from Biology: Astrobiology's Past, Present, and Future"

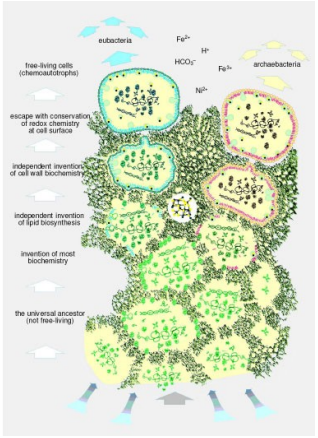
- *The future of astrobiology: AI, aliens, and You.*

Phylogeny of cell shape: A window into origins or adaptive dead end?

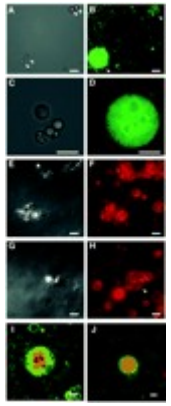
Dogma

Bacterial morphology is generally uninformative concerning evolutionary history.

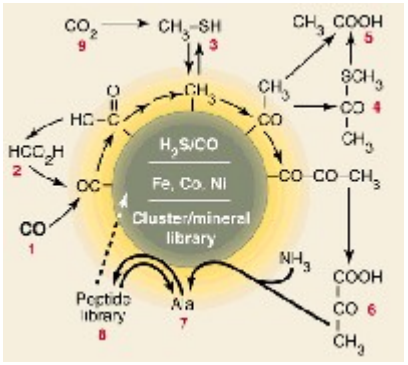
Biology at the interface of prebiotic chemistry and life



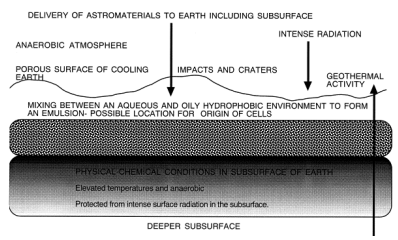
Martin & Russell, 2003



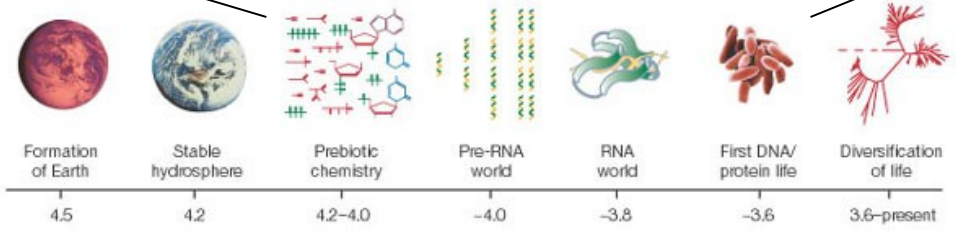
Deamer et al, 2002
Hanczyc & Szostak, 2004



Wachtershauser, 2000



Trevor, 2003

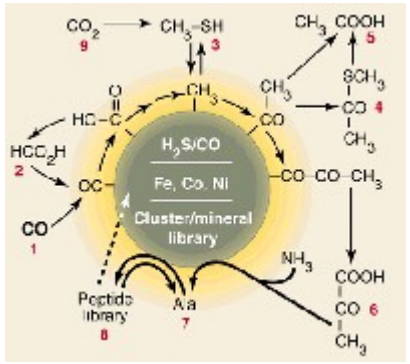


Joyce, 2002

Environmental context

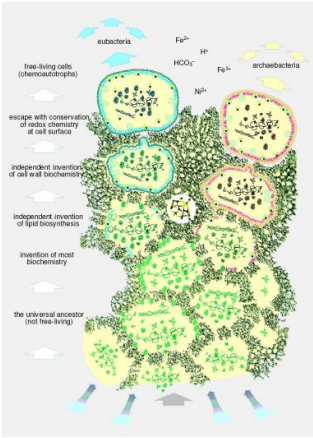
Artists concept of early Archean

Information systems
And metabolism

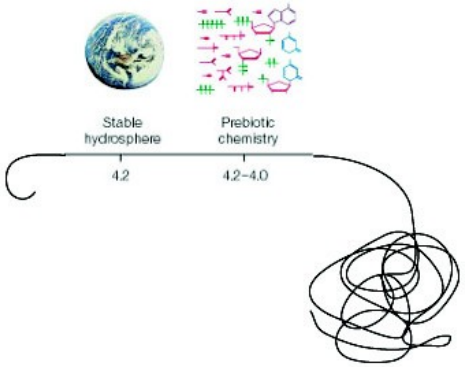


Wachtershauser, 2000

Proto cells

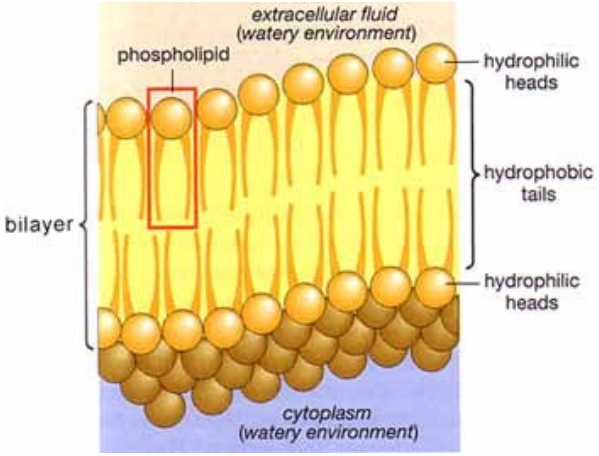


Martin & Russell, 2003

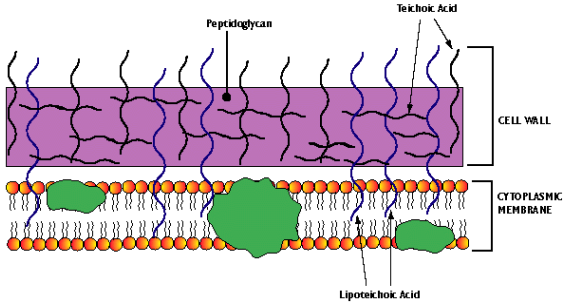


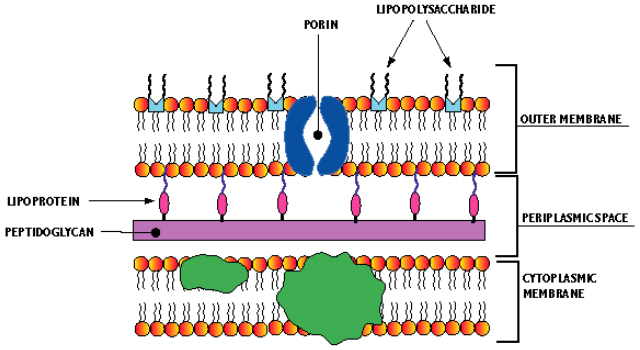
Cellular evolution on earth

- All life has membranes: phospholipid bilayers

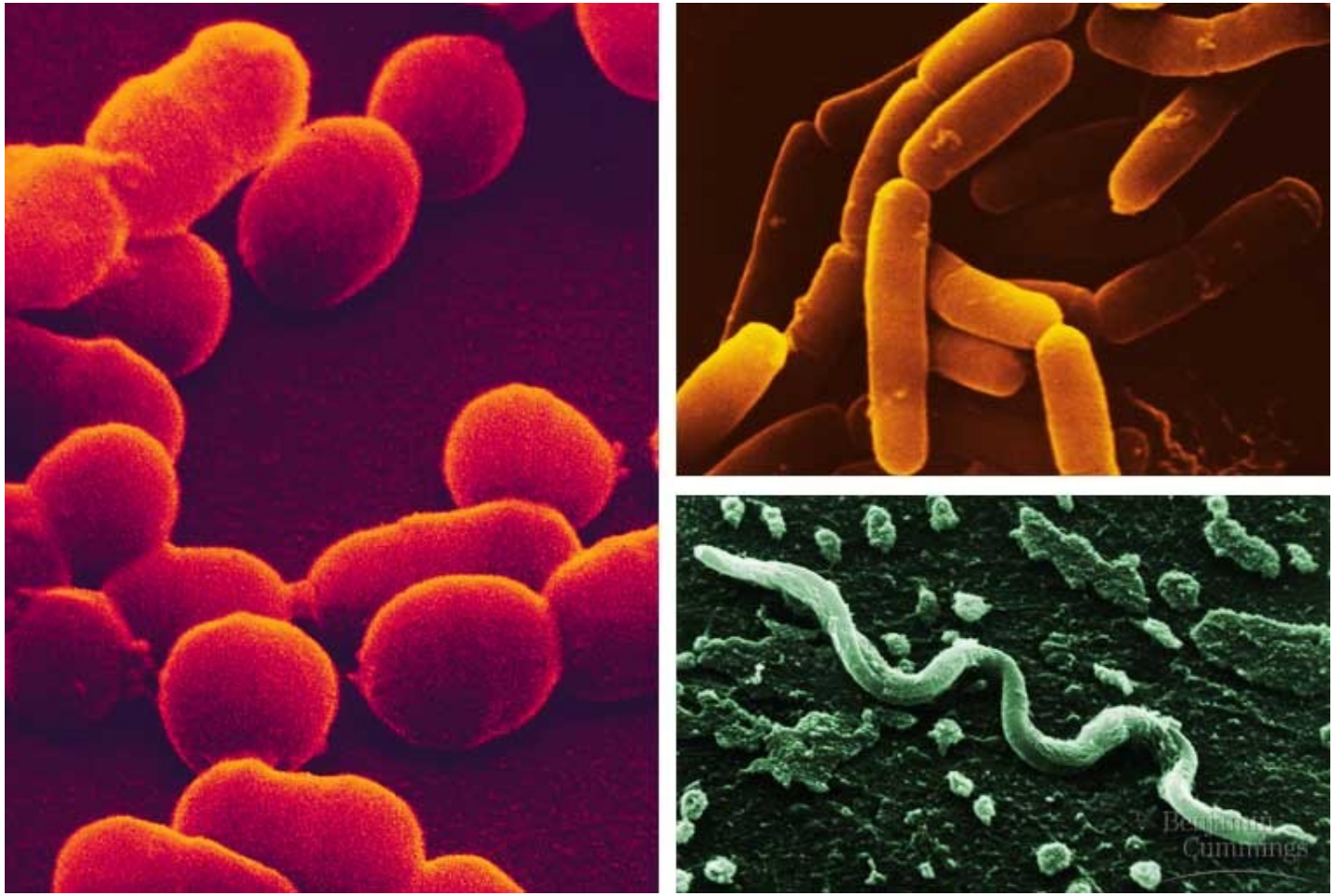


- All bacteria have cell walls





Bacterial Cell Wall = Shape



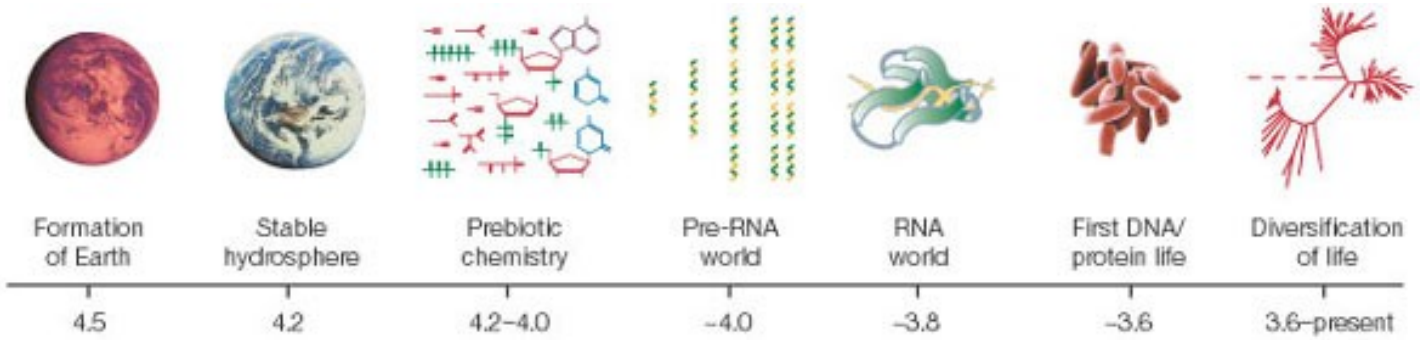
Peptidoglycan

- Opposes internal hydrostatic pressure
- Prevents membrane rupture and death

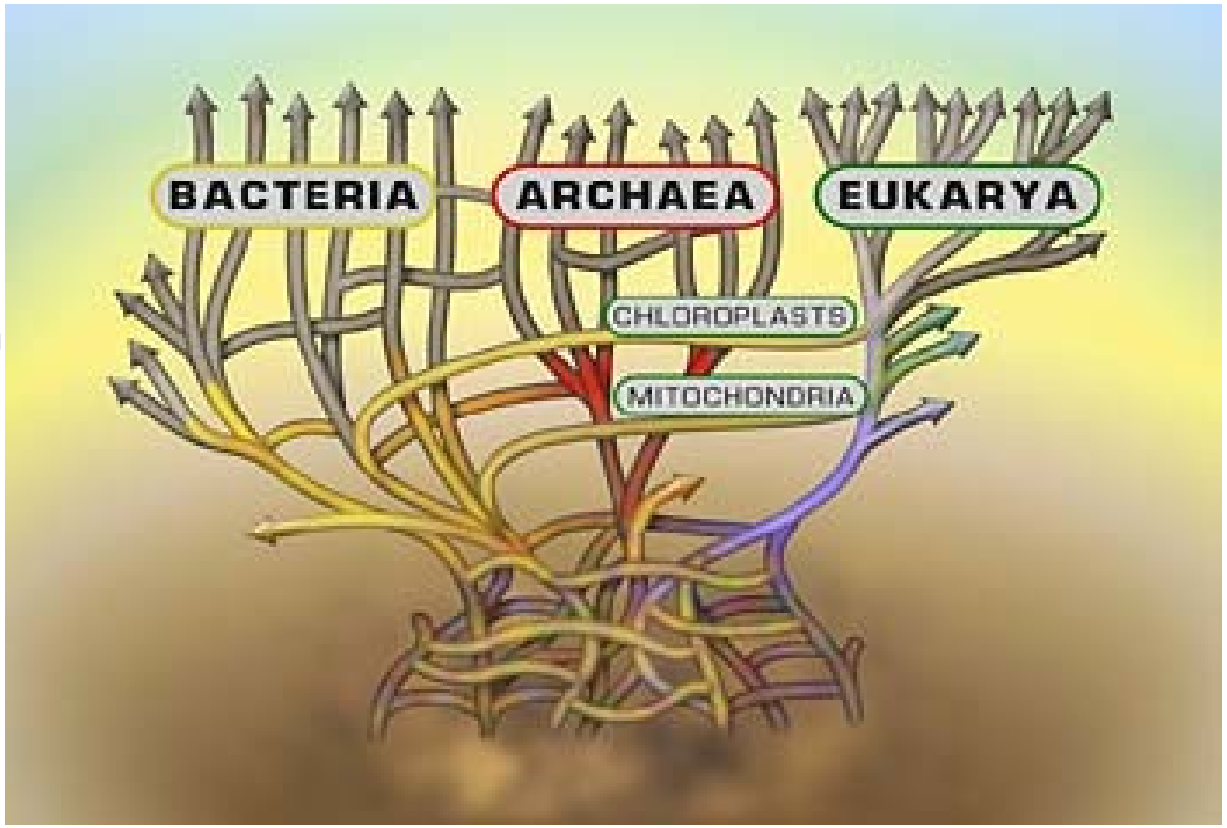
Perspective- top down

- **Must utilize extant organisms.**
- **Selection of processes may or may not allow you to look backwards… Or how far you can look back.**

Timelines

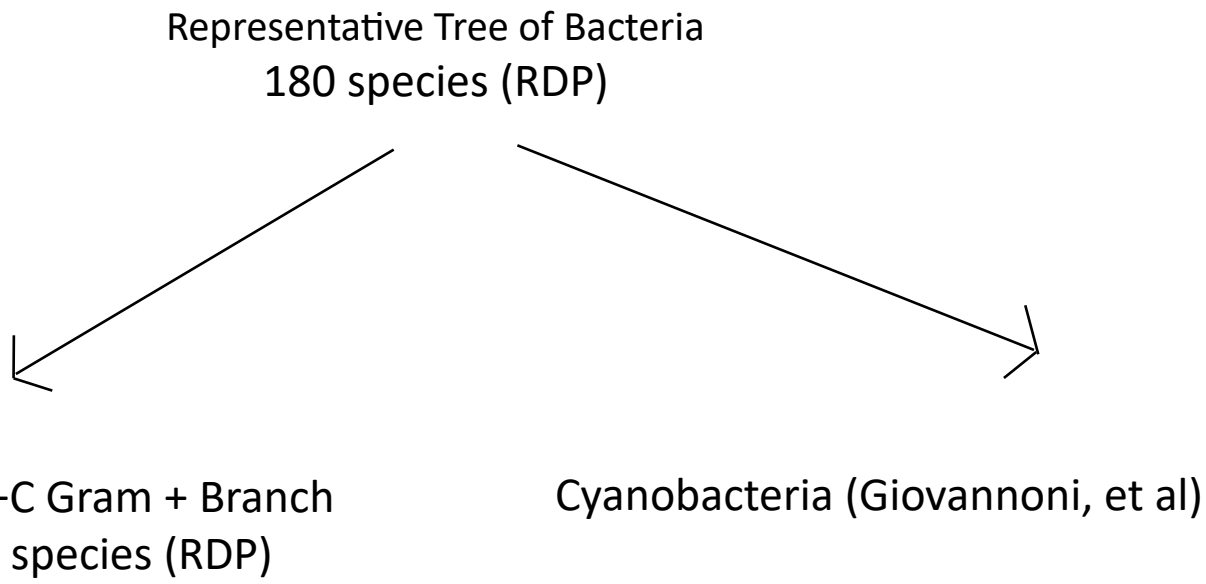


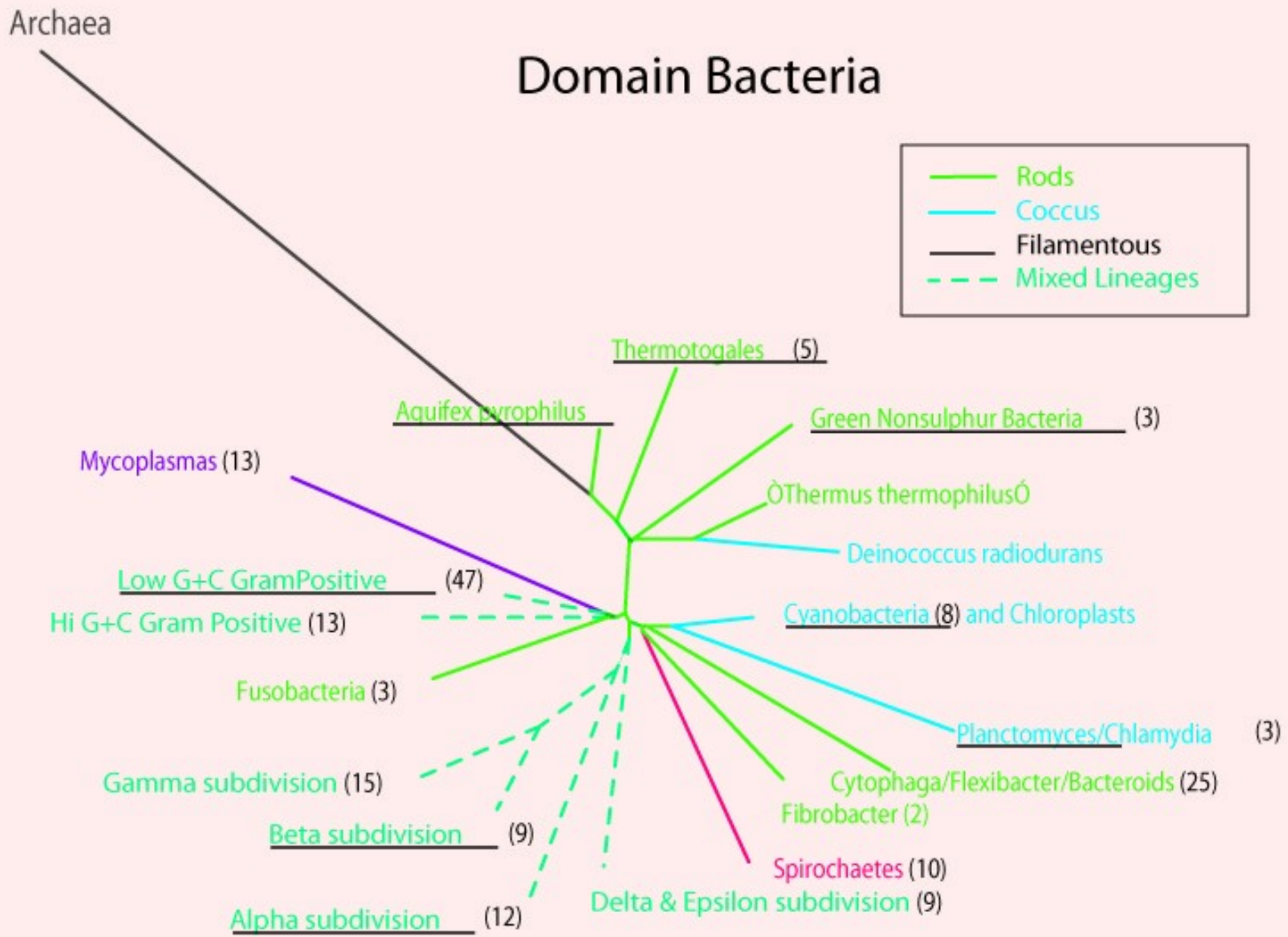
Information system
16S rRNA



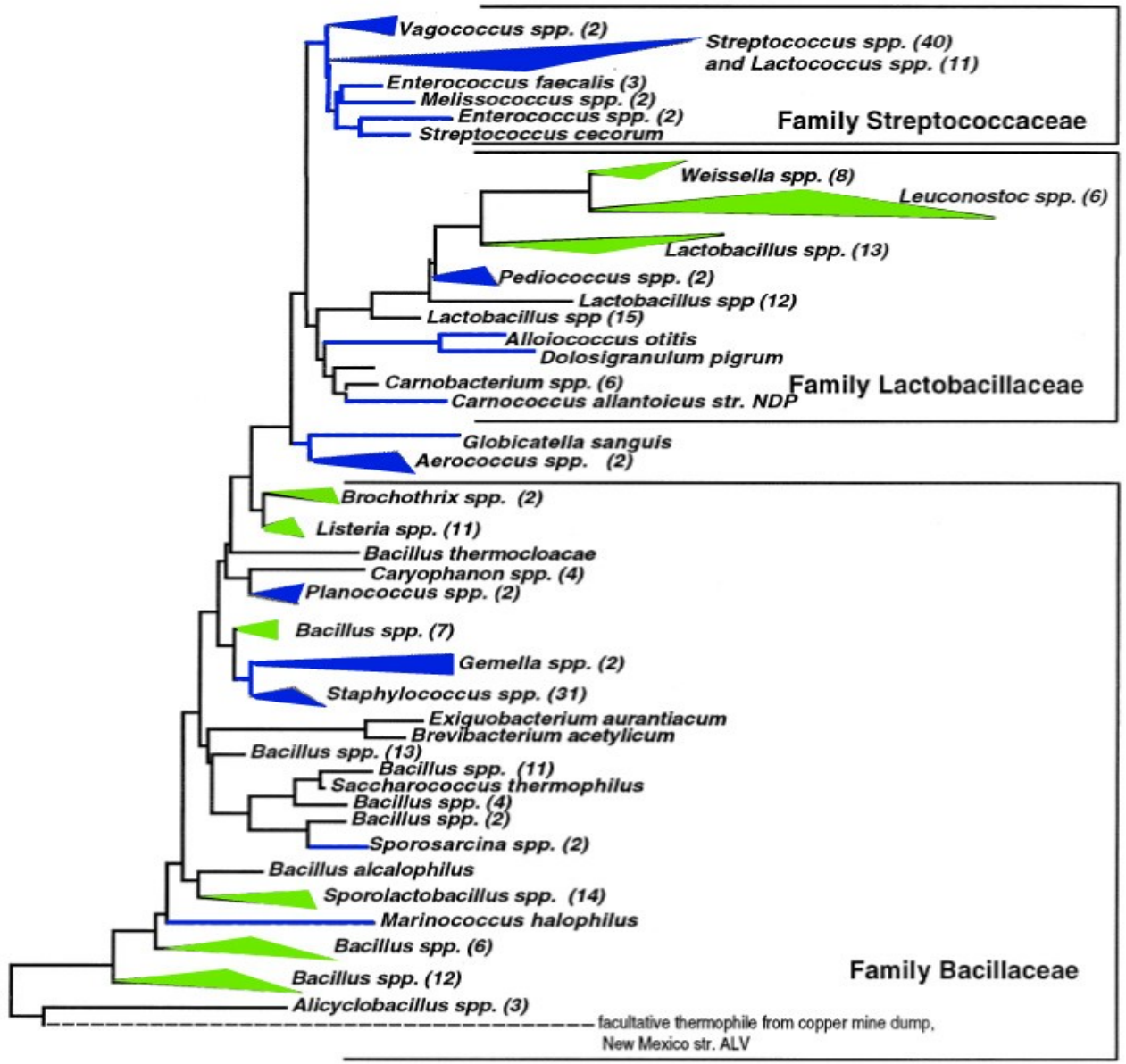
Methodology

Molecular Phylogeny represented by 16s rRNA trees is overlayed with morphologcial descriptions taken from literature search.




Archaea
Domain Bacteria
Rods
Coccus
Filamentous
Mixed Lineages
Thermotogales (5)
Aquifex pyrophilus
Green Nonsulphur Bacteria (3)
Mycoplasmas (13)
ÒThermus thermophilusÓ
Deinococcus radiodurans
Low G+C GramPositive (47)
Hi G+C Gram Positive (13)
Cyanobacteria (8) and Chloroplasts
Fusobacteria (3)
Planctomyces/Chlamydia (3)
Gamma subdivision (15)
Cytophaga/Flexibacter/Bacteroids (25)
Fibrobacter (2)
Beta subdivision (9)
Spirochaetes (10)
Delta & Epsilon subdivision (9)
Alpha subdivision (12)

Order Bacillales



Summary of Results

- **Rods in the deepest branches**
- **The coccal phenotype, evolved many times and persists**
- Some morphologies (eg spriochaetes, mycoplasmas) are highly unique
- Filamentous forms of bacteria are found throughout the tree
- Helical forms are widespread in the Gram - bacteria

The Broader View

Can morphology of extant organisms inform us about any stage of biological evolution?

Which ones?

.

Why are some shapes persistent?

Bacterial shape = cells walls = peptidoglycan

Advances in the last decade have shown remarkable genetics behind cell shape

Rod
To be or not to be…

Cell wall elongation vs cell division

(Who wins determines the results:)

Rods > cocci

(Begg, et al, J. Bacteriol. 170, 1004-1008 (1986)

Antibiotic resistance

(Costa & Anton, Mol. Gen. Genet. 236, 387-394 (1993)

Filamentation

(Pollack & Neuhaus J. Bacteriol. 176, 7252-7259 (1994)

Why a Rod as the earliest ancestor to Bacteria?

- Coccus appear to be degenerate rods.
- Fixation of rod morphology early - chance or choice? Merely a result of the physics of peptidoglycan as the constituent for cell wall? Most definitely the “winning” strategy for combatting osmotic pressure for bacteria as we know them today.
- Coccus was likely the original shape for the bacterial lineage

Peptidoglycan does what?

The early choice of peptidoglyan sacculus greatly influenced the ability of Bacteria to evolve complex structures.

A body plan that allows:

*maximum membrane to cytoplams ratio=no need for internal membranes

*reproduce rapidly

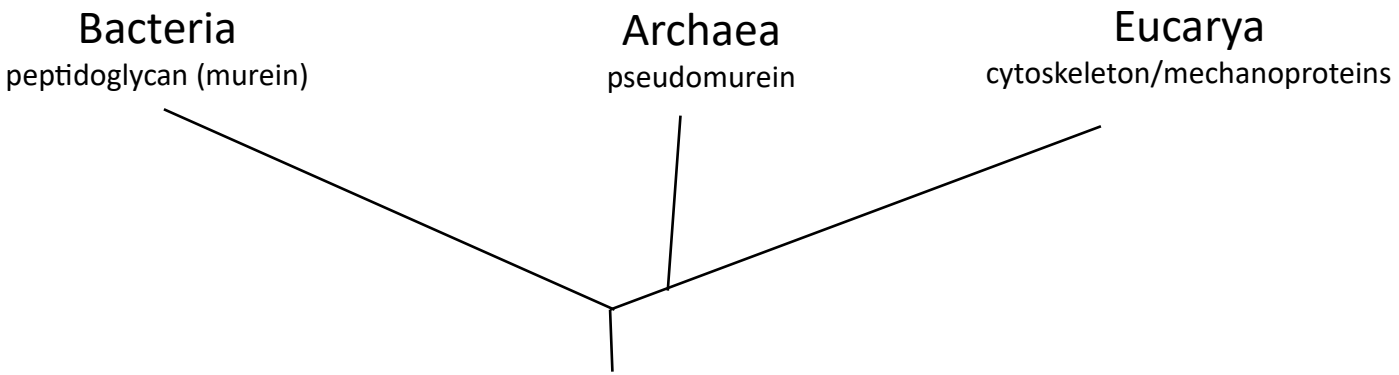
*adaptation

*evolutionary diversity

*controlled interaction with environment

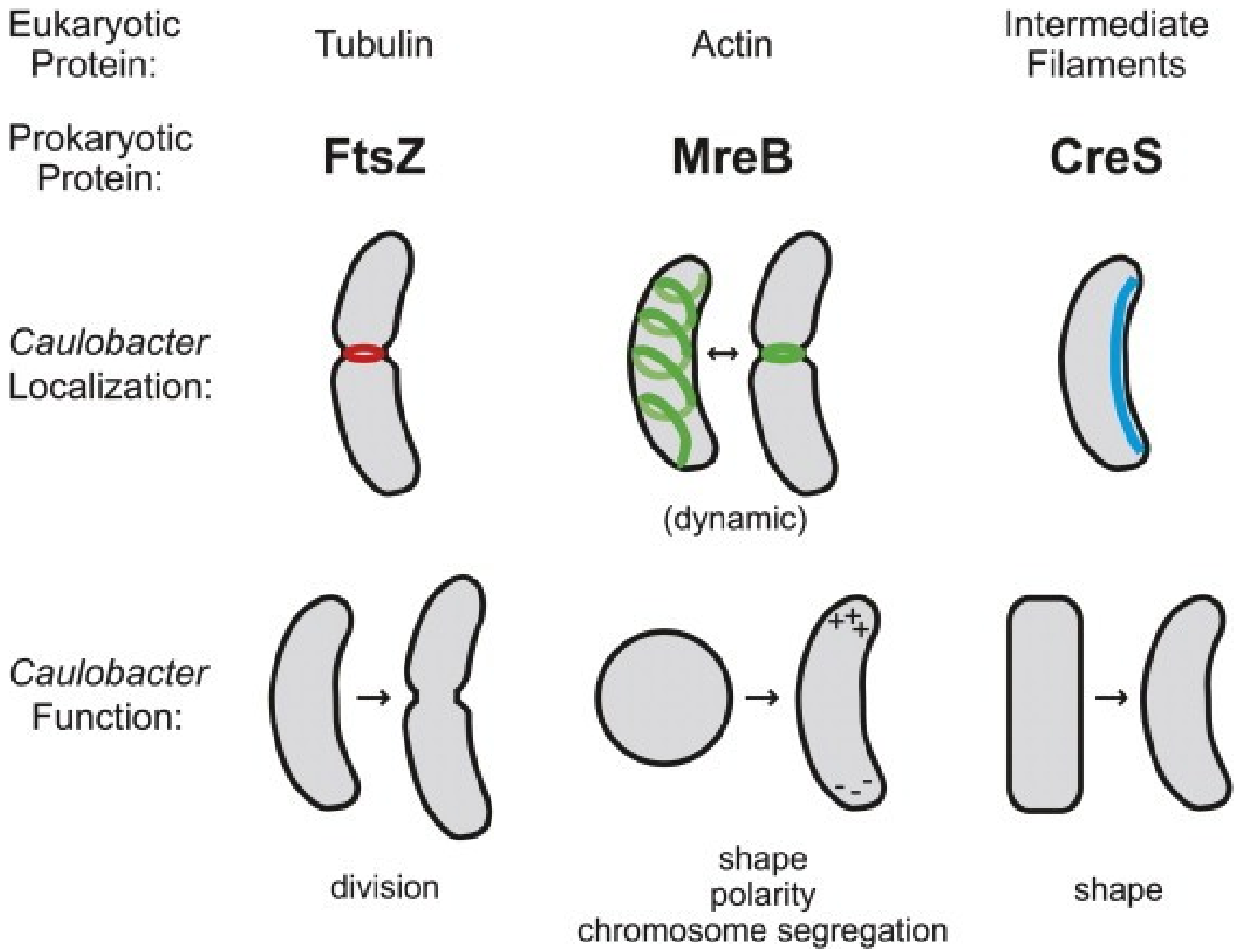
*bacteria to stay small

Cellular evolution :Different strategies to solve a problem.

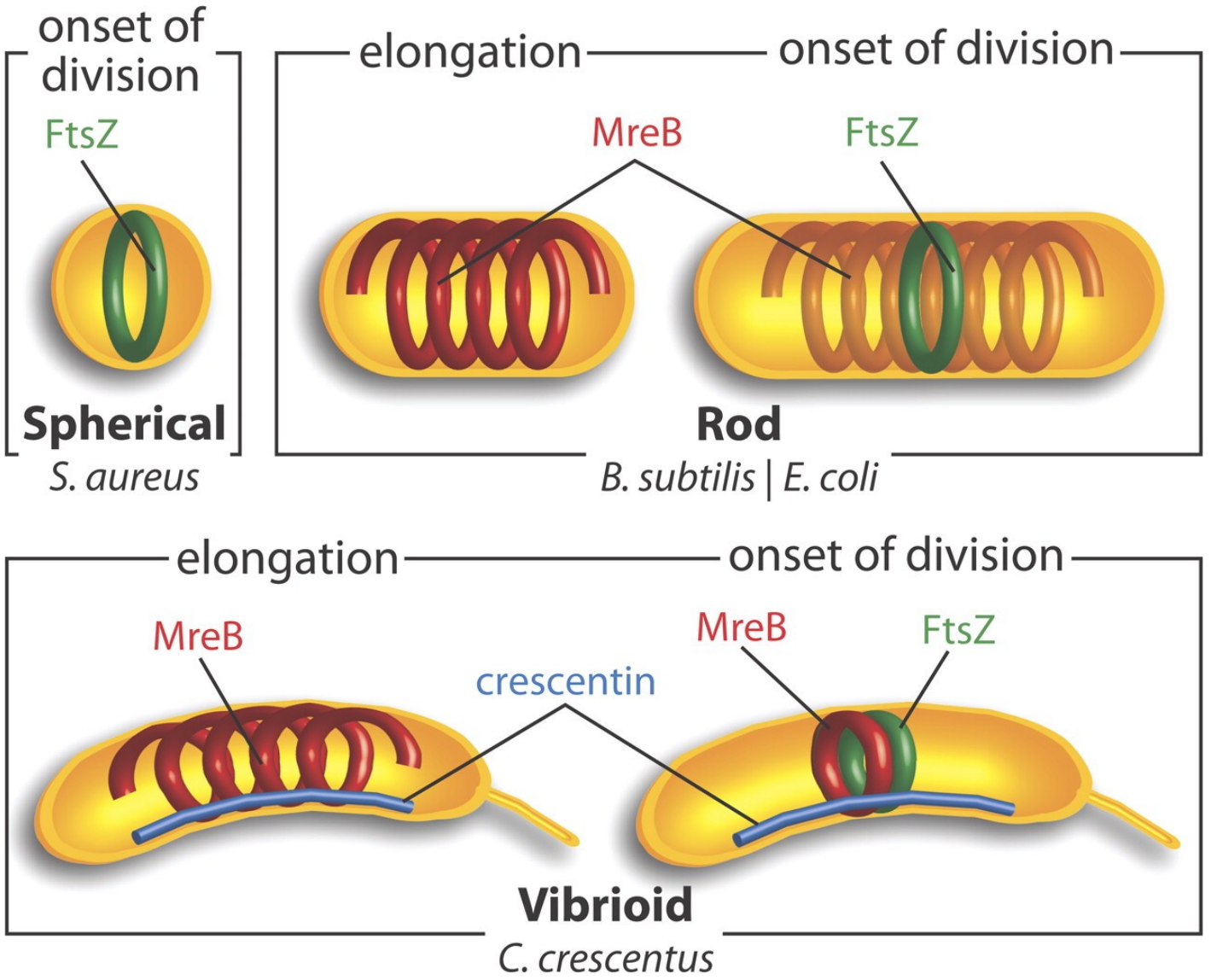


In the last decade…

- The genetic underpinnings of cell shape and division.

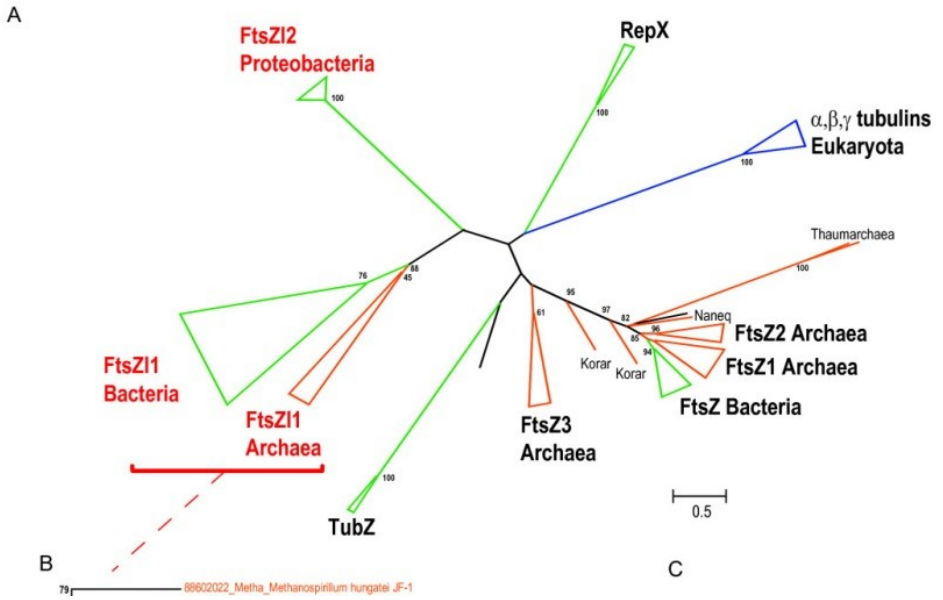

Eukaryotic Protein:
Tubulin
Actin
Intermediate Filaments
Prokaryotic Protein:
FtsZ
MreB
CreS
Caulobacter Localization:
(dynamic)
Caulobacter Function:
division
shape
polarity
chromosome segregation
shape

The bacterial cytoskeleton.



Cabeen M T , Jacobs-Wagner C J Cell Biol 2007;179:381-387

Most rod shaped cells require MreB which assembles into cables that run between the poles of the cell and distribute various components of peptidoglycan metabolism along the cell length.



- FtsZ assembles into the Z ring which recruits the machinery necessary for cytokinesis, found in archaea and bacteria.

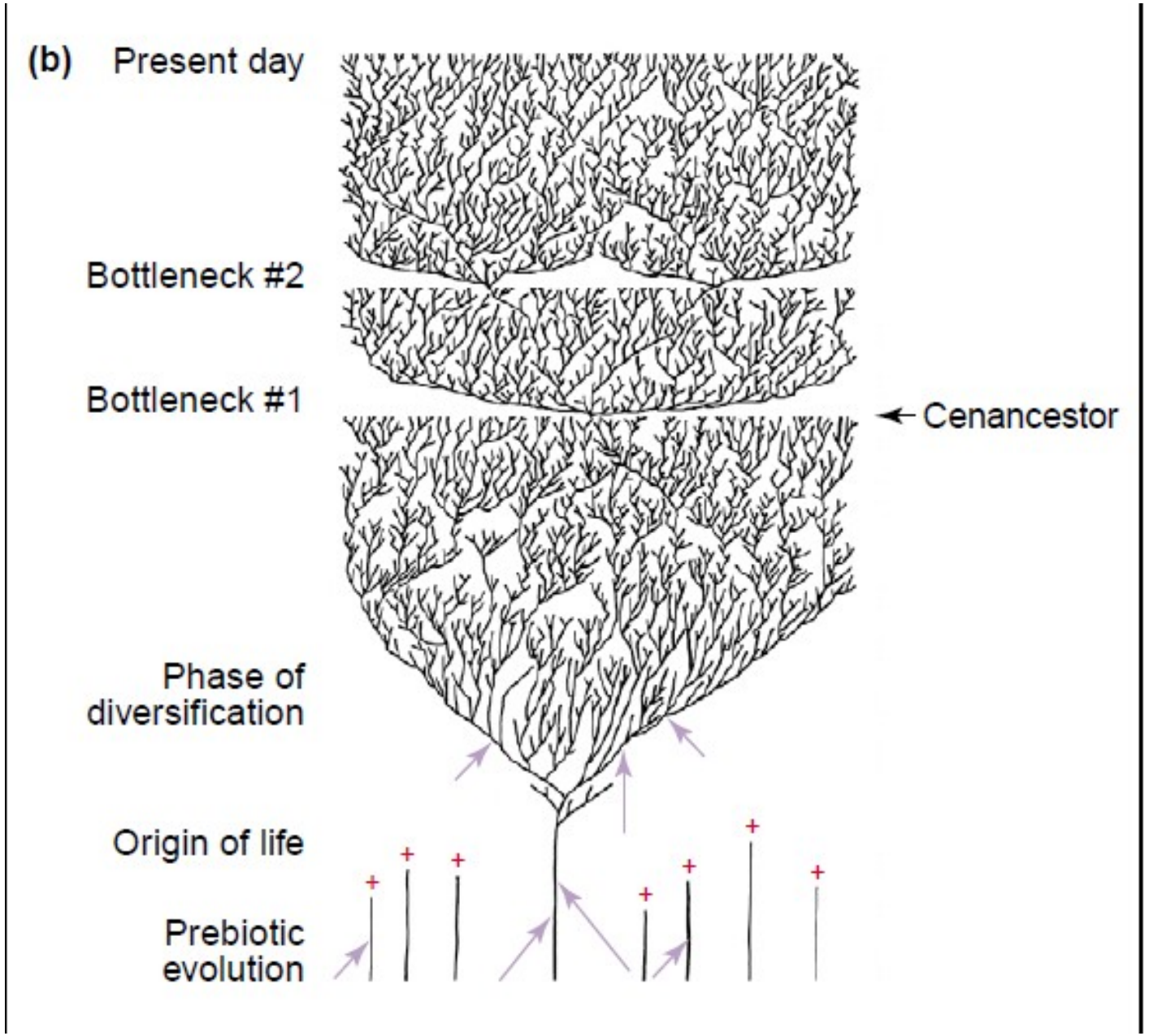
- No true cocci shaped cells have mreB homologues.

Molecular Microbiology
Molecular Microbiology, pages 1052-1061, 6 APR 2011 DOI: 10.1111/j.1365-2958.2011.07635.x
Molecular Microbiology
Volume 80, Issue 4, pages 1052–1061, 6 APR 2011 DOI: 10.1111/j.1365-2958.2011.07635.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2958.2011.07635.x/full#f1

Application to Origins

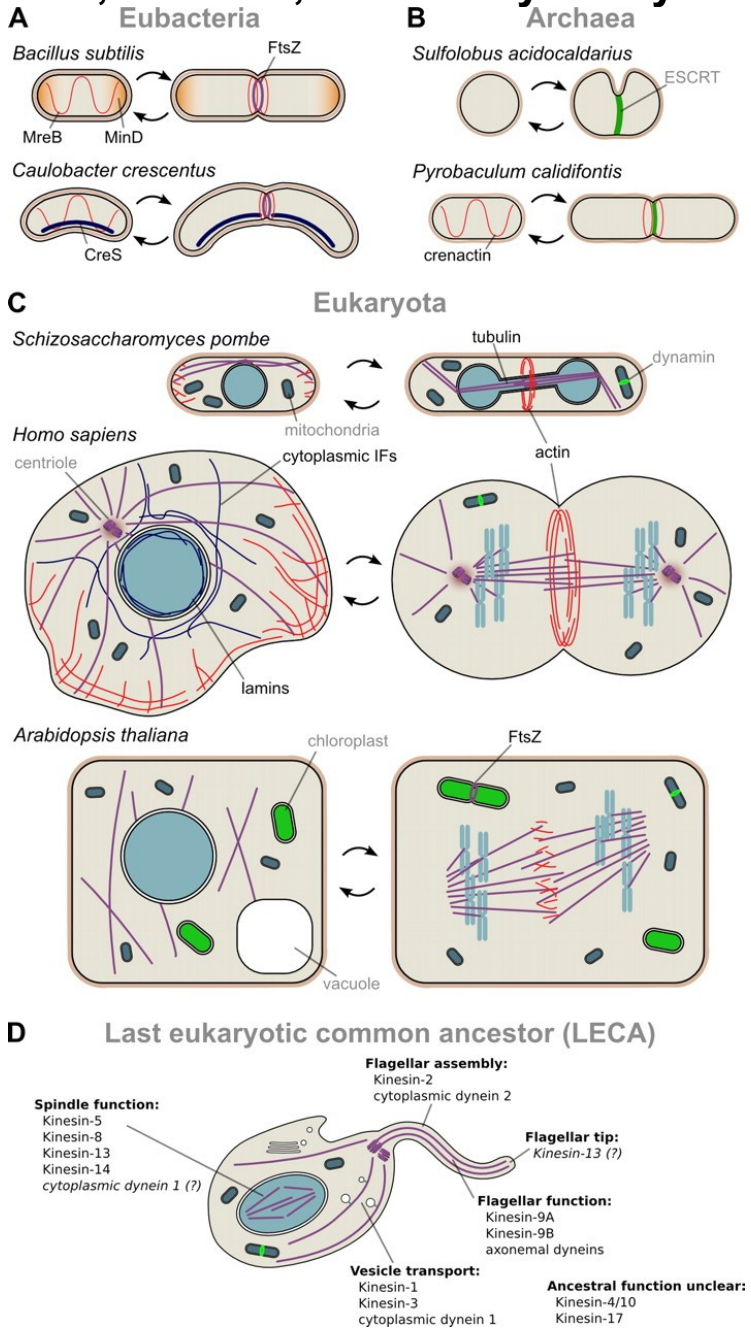
For Bacteria: 16S rRNA backbone provided a historical scaffold of the bacterial lineage that allowed an accurate evaluation of the evolution of cell shape.

Time is not obscured in something as fundamental as morphology



Zhaxybayeva and Gogarten, TIG 2004

Bacterial, archaeal, and eukaryotic cytoskeletons.

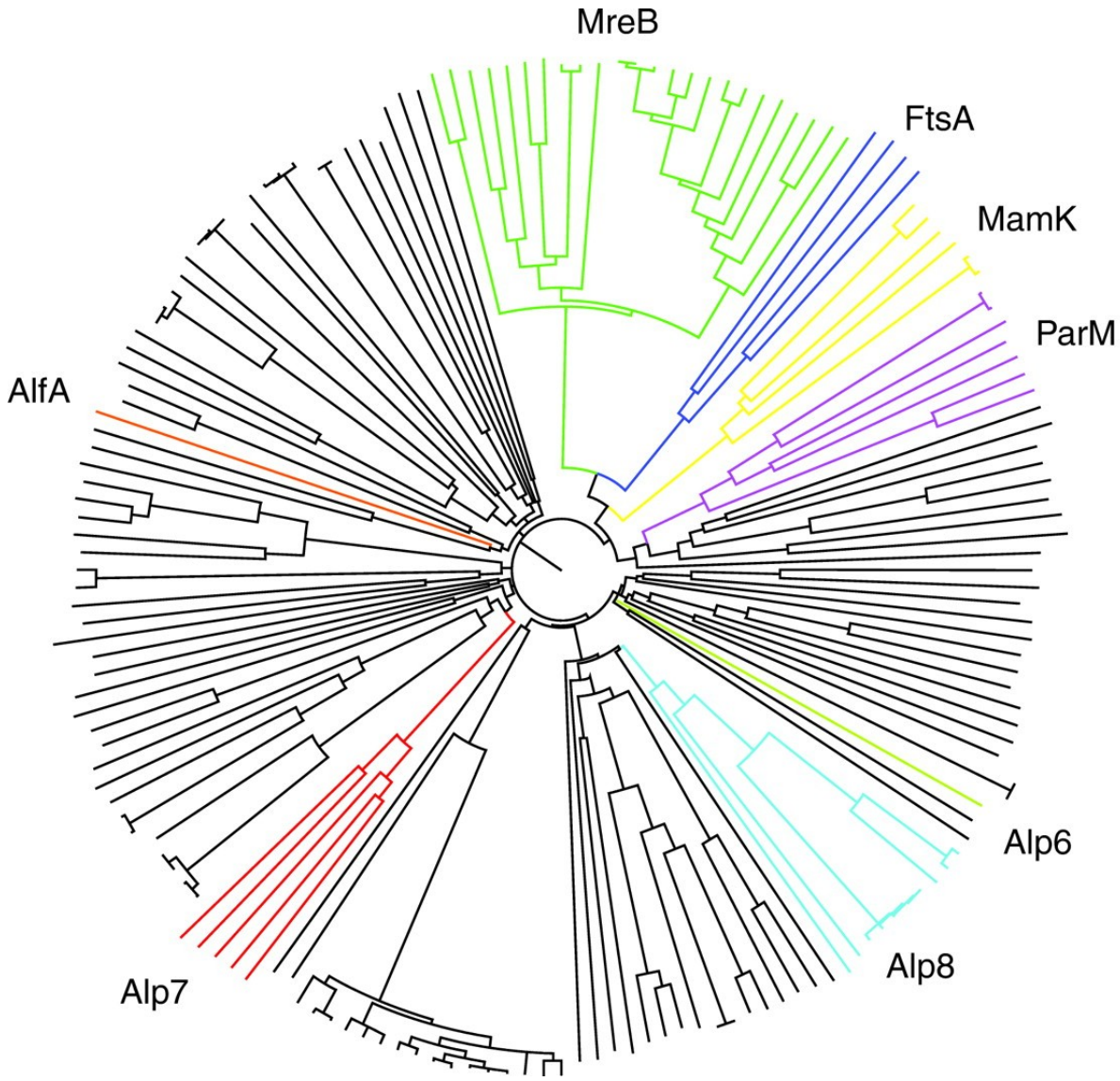


Wickstead B , Gull K J Cell Biol 2011;194:513-525

What is the selective advantage of shape?

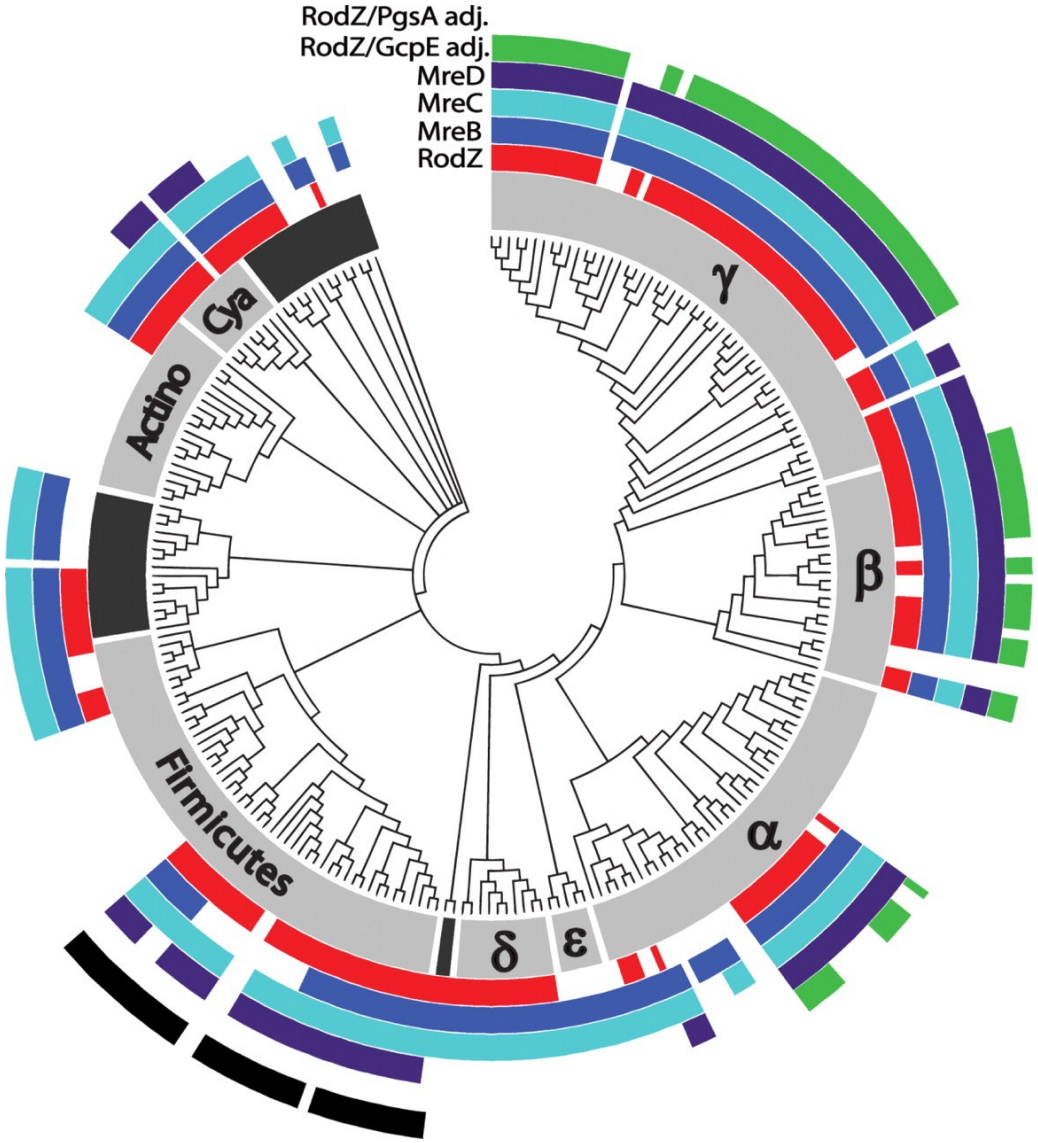
- Physical advantage
  - Volume to surface ratio
- Polarity assignment
- Predator, prey

The superfamily of bacterial actin homologs.



Shaevitz J W , Gitai Z Cold Spring Harb Perspect Biol
2010;2:a000364

Phlyogenetic tree of bacterial species showing the presence of RodZ (red), MreB (blue), MreC (cyan), MreD (purple), adjacency between rodZ and gcpE (green), and adjacency between rodZ and pgsA (black).

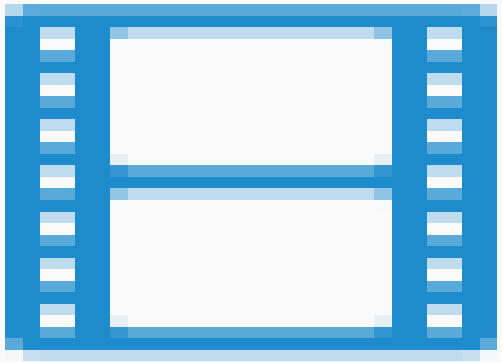


Alyahya S A et al. PNAS 2009;106:1239-1244


ATARI
ATARI


ARGENTINA • BAHAMAS • BERMUDA • BRAZIL • CANADA • CHILE •
DOMINICAN REPUBLIC • GUATEMALA • HONDURAS • MEXICO • NICARAGUA • PANAMA •
URUGUAY • VENEZUELA
LONDON
PARIS

Artificial Intelligence



- Autonomy - a bounded network of processes that self-maintains
- Self-Organization - phenomena where local interactions lead to global patterns or behaviors
- Adaptation - a change in an agent or system as a response to a state of its environment that will help the agent or system to fulfill its goals
- Evolution - Computer science has exploited artificial evolution extensively, initially with genetic algorithms
- Learning - Artificial neural networks are a well known approach to learning

REVIEW article

Front. Robot. AI, 10 October 2014
Sec. Computational Intelligence in Robotics
https://doi.org/10.3389/frobt.2014.00008

The past, present, and future of artificial life

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What is a “mind” (psyche)?

An advanced way of life that is not hampered by physical decay.

What do YOU think?

Obrigado por me convidar.

Estou ansioso para o que você faz na ciência.