GIOVANNELLI LAB

DIPARTIMENTO DI BIOLOGIA

University of Naples "Federico II"

Marine Microbial Diversity

Know your Beasts 1:

Bacterial and Archaeal Diversity in Marine Environments

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The Tree Of Life: The Bacteria

- Bacterial diversity is huge! And there is much uncertainty in the classification and total number of phyla
- As of January 2016, there are 30 phyla in the domain "Bacteria" accepted by LPSN
- The ARB-Silva database lists 67 phyla, of which 37 are candidate phyla
- he Ribosomal Database Project 10, lists 49 phyla, including 20 candidate phyla
- NCBI lists 120 phyla, including 90 candidate phyla
- Despite the unclear branching order for most bacterial phyla, several groups of phyla have clear clustering and are referred to as superphyla: The FCB Group, The PVC Group, the Patescibacteria, Terrabacteria and the Proteobacteria as superphylum
- Photosynthesis only occurs within the Bacteria

The Phyla of Bacteria (as used on this site and taken from Bergey's Manual of Systematic Bacteriology 1st Ed.)

Name of Phylum	Number of Species	Number of Genera
Aquificae	27	12
Xenobacteria	29	11
Chrysogenetes	1	1
Thermomicrobia	13	6
Cyanobacteria	78	62
Chlorobia	17	6
Proteobacteria	1644	366
Firmicutes	2474	255
Planctomycetes etc.	13	5
Spirochaetes	92	13
Fibrobacter	5	3
Bacteroids	130	20
Flavobacteria	72	15
Sphingobacteria	76	22
Fusobacteria	29	6
Verrucomicrobia	5	2

International Committee on Systematics of Prokaryotes

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INTERNATIONAL JOURNAL OF SYSTEMATIC AND EVOLUTIONARY MICROBIOLOGY

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International Journal of Systematic and Evolutionary Microbiology (previously *International Journal of Systematic Bacteriology*) is the journal of record for publication of novel microbial taxa and the official publication of the International Committee on Systematics of Prokaryotes and the Bacteriology and Applied Microbiology Division of the International Union of Microbiological Societies. **More**

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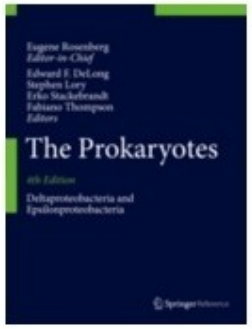
More

IMPORTANT: The ICSP and the Microbiology Society are pleased to announce that our appeal against Clarivate's decision to suppress the journal from the 2019 Journal Citation Reports has been successful. *International Journal of Systematic and Evolutionary Microbiology* will be reinstated in the 2019 Journal Citation Reports (JCR) – the journal's metrics can be found on our Article and journal metrics page. Read more about our appeal.

» Life Sciences » Microbiology



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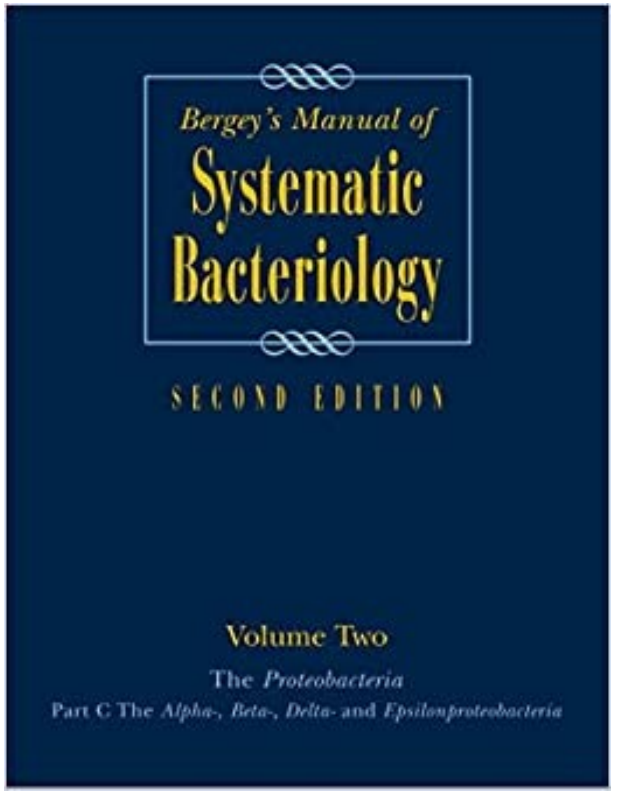
The Prokaryotes

Deltaproteobacteria and Epsilonproteobacteria

Editors: Editor-in-chief: **Rosenberg**, Eugene
DeLong, E.F., **Lory**, S., **Stackebrandt**, E., **Thompson**, F. (Eds.)



International Committee on Systematics of Prokaryotes

Validly published *A name of a prokaryotic species that has appeared on IJSEM validation lists*

The new strain need to be ***available in a pure culture***

The culture needs to be available in at least ***two (2) public culture collections***

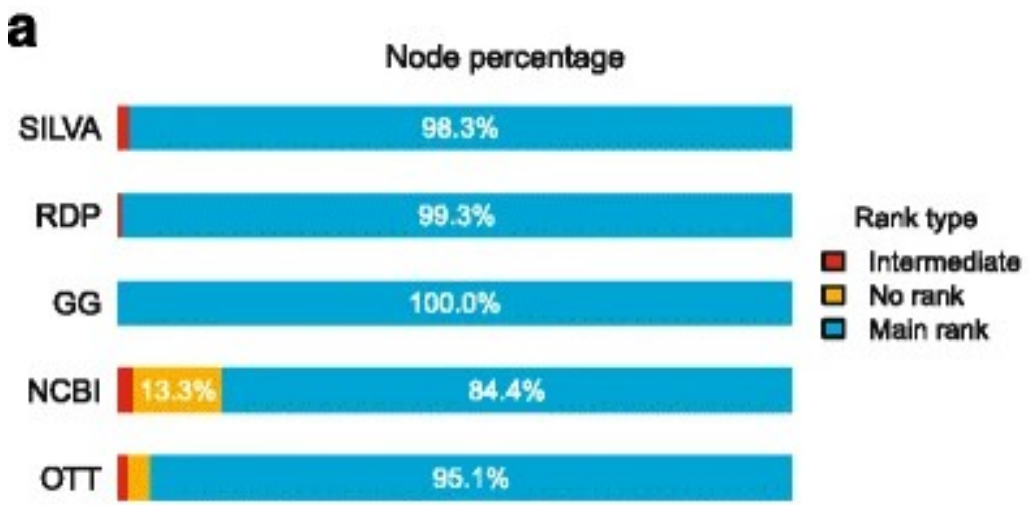
The ***physiology*** *and* ***chemotaxonomy*** *needs to be known*

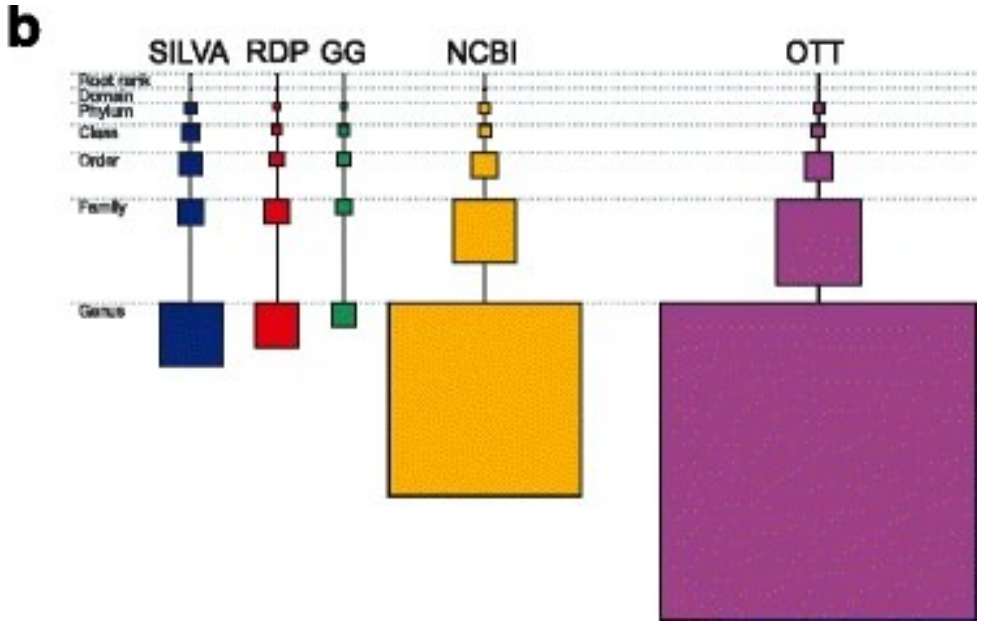
New species are defined as ***Genus species sp. nov.*** *on their fist appearance*

*Non validly published prokaryotic species needs to be preceded by the "****Candidatus*** *Genus species" or "Ca. Genus species"*

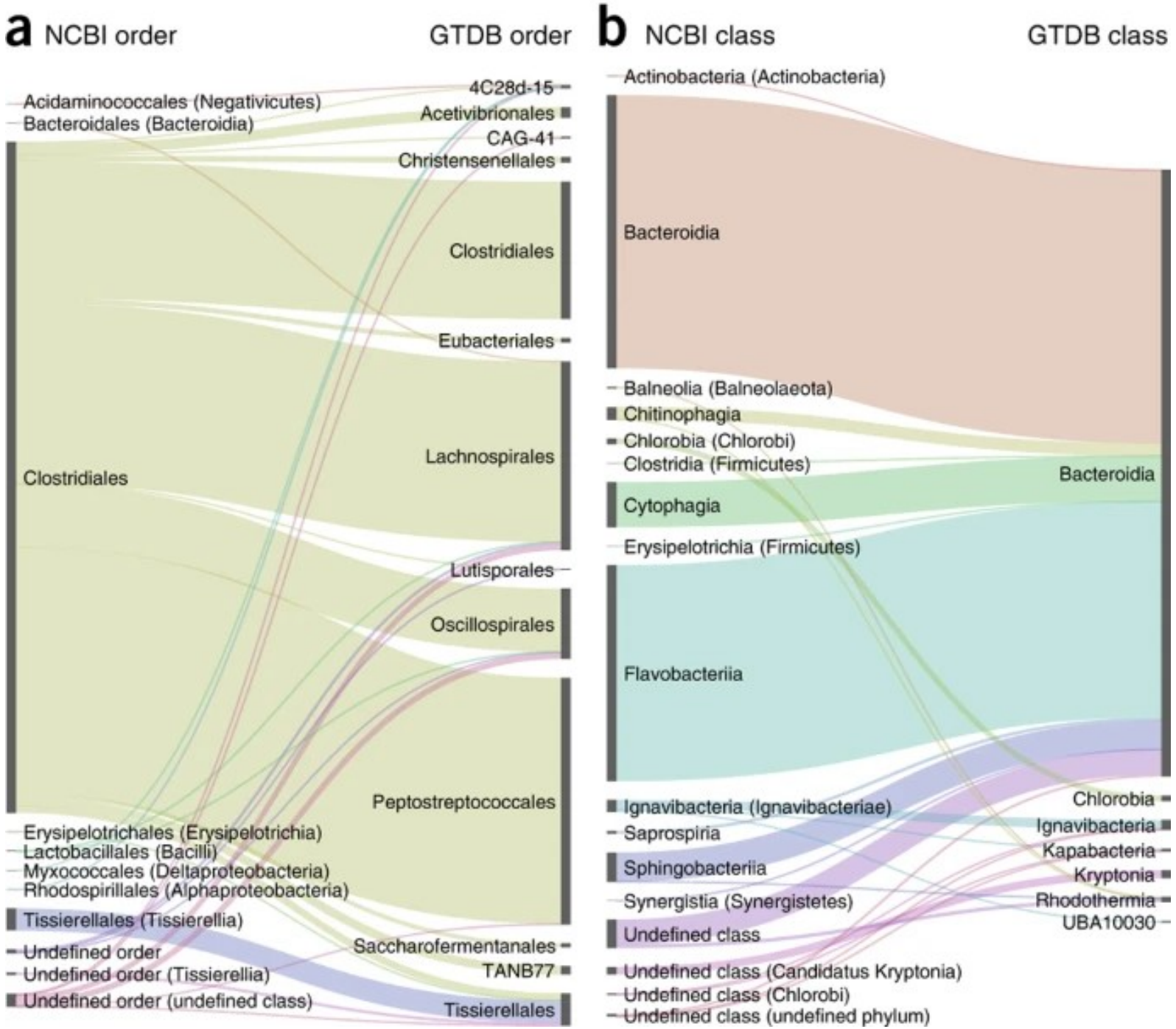
The ***phylum rank is not a validly published*** *taxonomic rank under ICSP code*

As a reminder, valid prokaryotic taxa needs to be in Italics (e.g. Rhodobacterales, Escherichia coli) while not validly published names cannot appear in italics (Ca. Pelagibacter ubique)

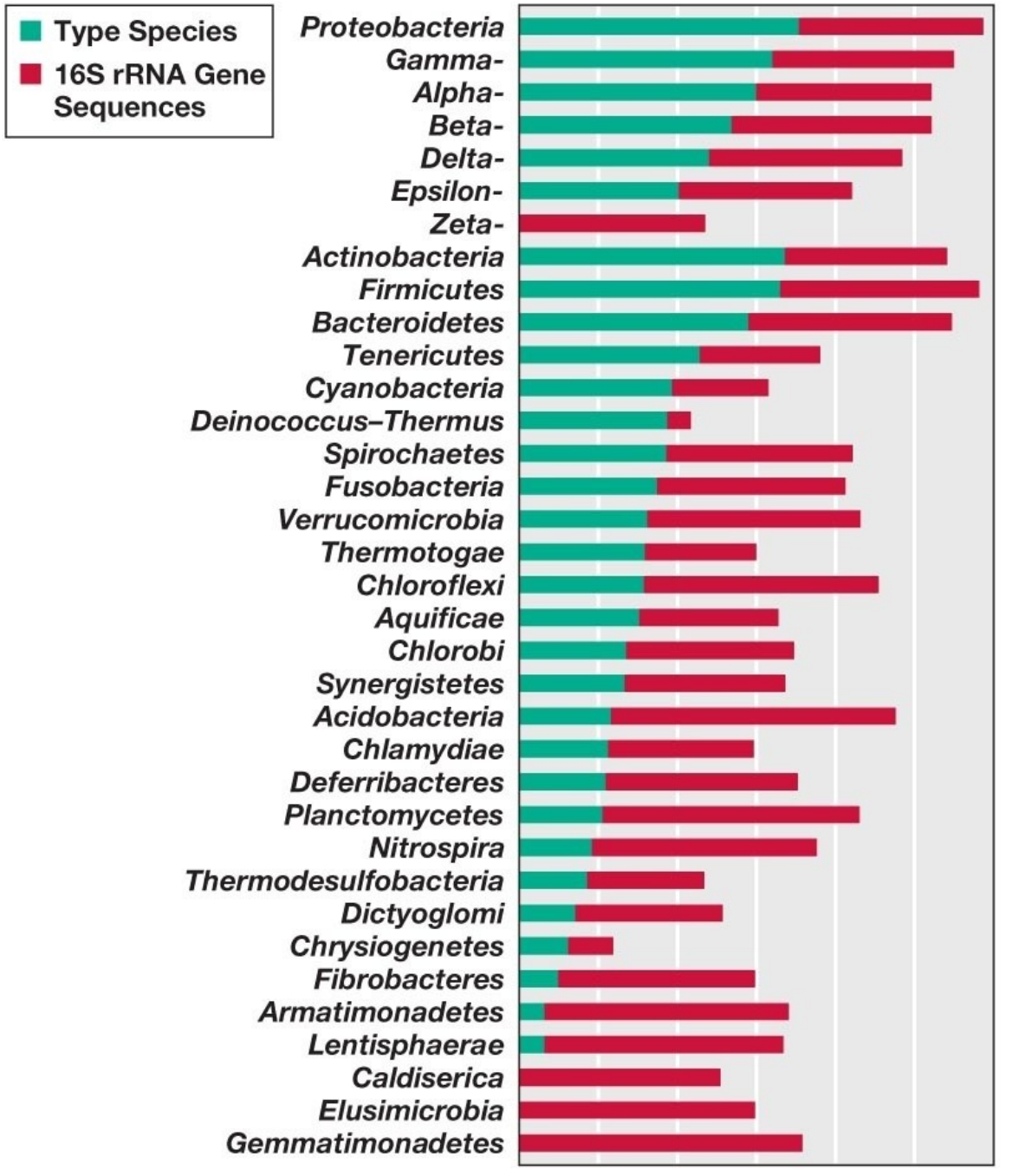




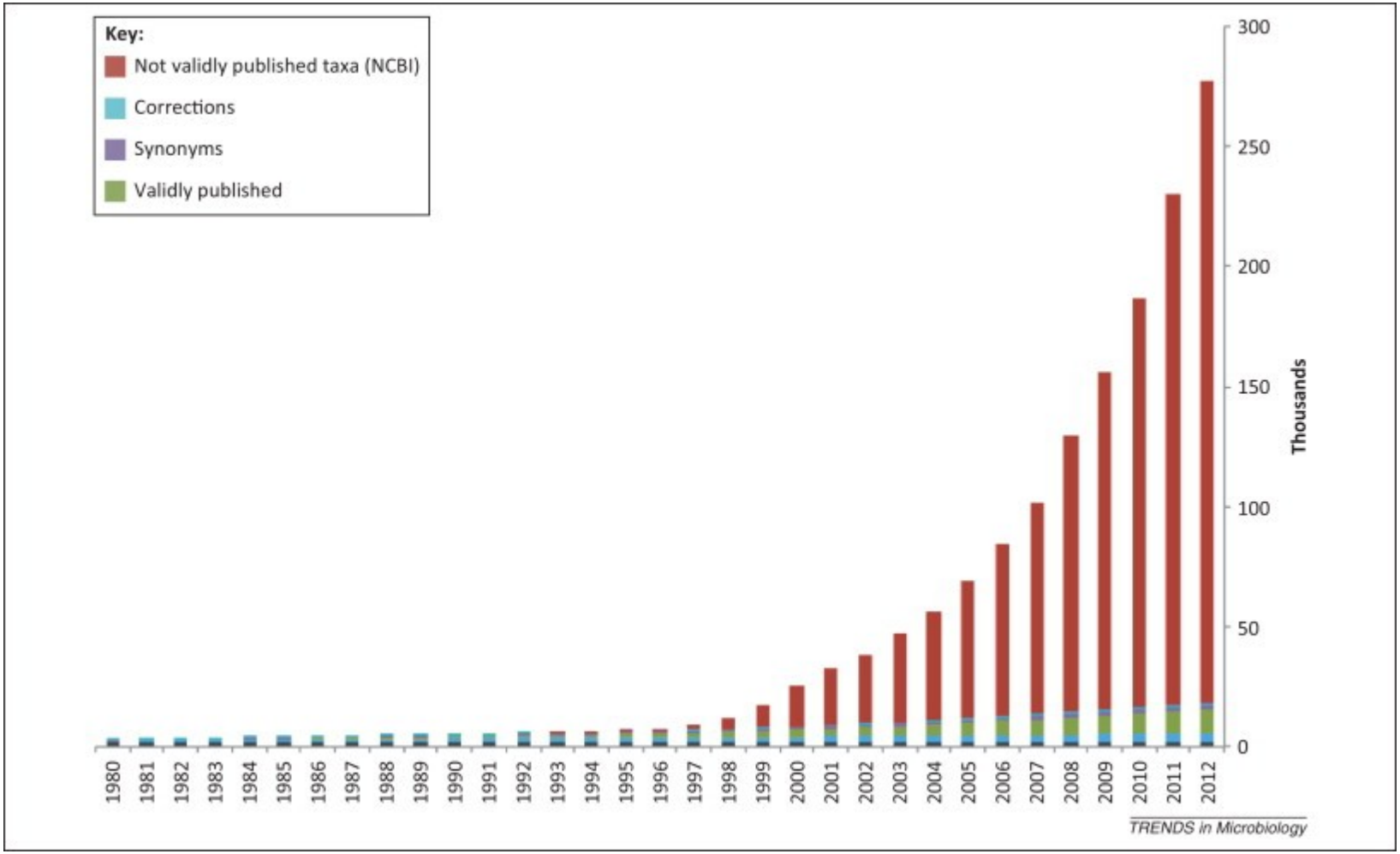
Balvočiute and Huson, 2017 BMC Genomics



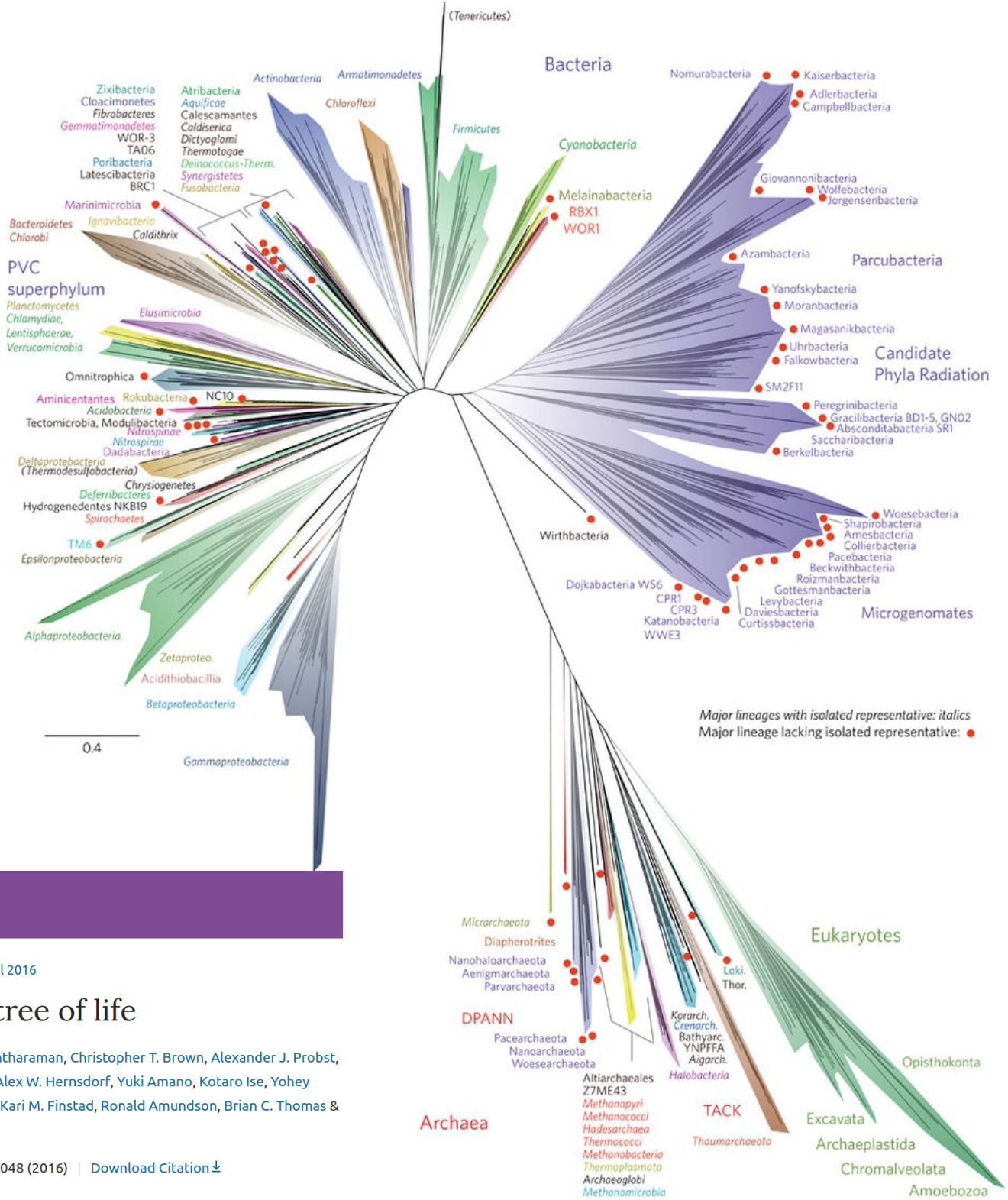
Parks et al 2018 Nature Biotech



(b) **Cultured representatives versus phylotypes**



Garrity and Oren 2013 Trends in Microbiol.



nature microbiology

Letter | Open Access | Published: 11 April 2016

A new view of the tree of life

Laura A. Hug, Brett J. Baker, Karthik Anantharaman, Christopher T. Brown, Alexander J. Probst, Cindy J. Castelle, Cristina N. Butterfield, Alex W. Hernsdorf, Yuki Amano, Kotaro Ise, Yohey Suzuki, Natasha Dudek, David A. Relman, Kari M. Finstad, Ronald Amundson, Brian C. Thomas & Jillian F. Banfield

Nature Microbiology **1**, Article number: 16048 (2016) | Download Citation

nature communications

Article | Published: 27 February 2015

Diverse uncultivated ultra-small bacterial cells in groundwater

Birgit Luef, Kyle R. Frischkorn, Kelly C. Wrighton, Hoi-Ying N. Holman, Giovanni Birarda, Brian C. Thomas, Andrea Singh, Kenneth H. Williams, Cristina E. Siegerist, Susannah G. Tringe, Kenneth H. Downing, Luis R. Comolli ✉ & Jillian F. Banfield ✉

Nature Communications **6**, Article number: 6372 (2015) | Cite this article

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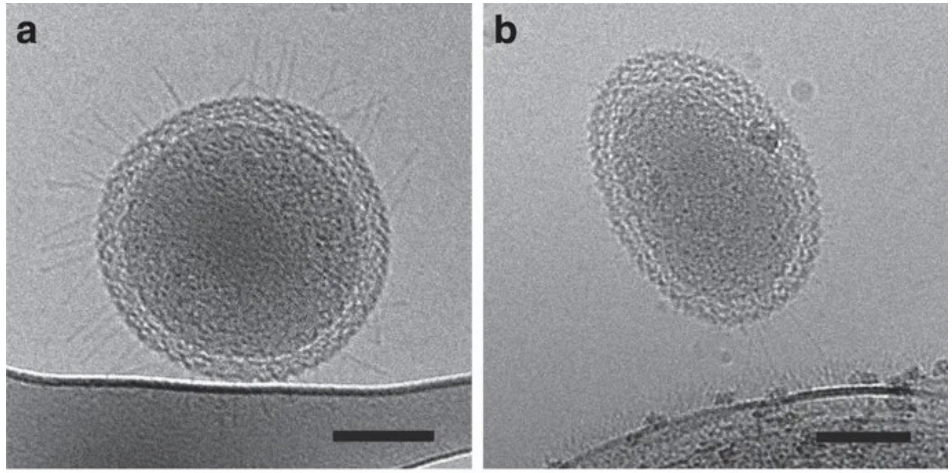


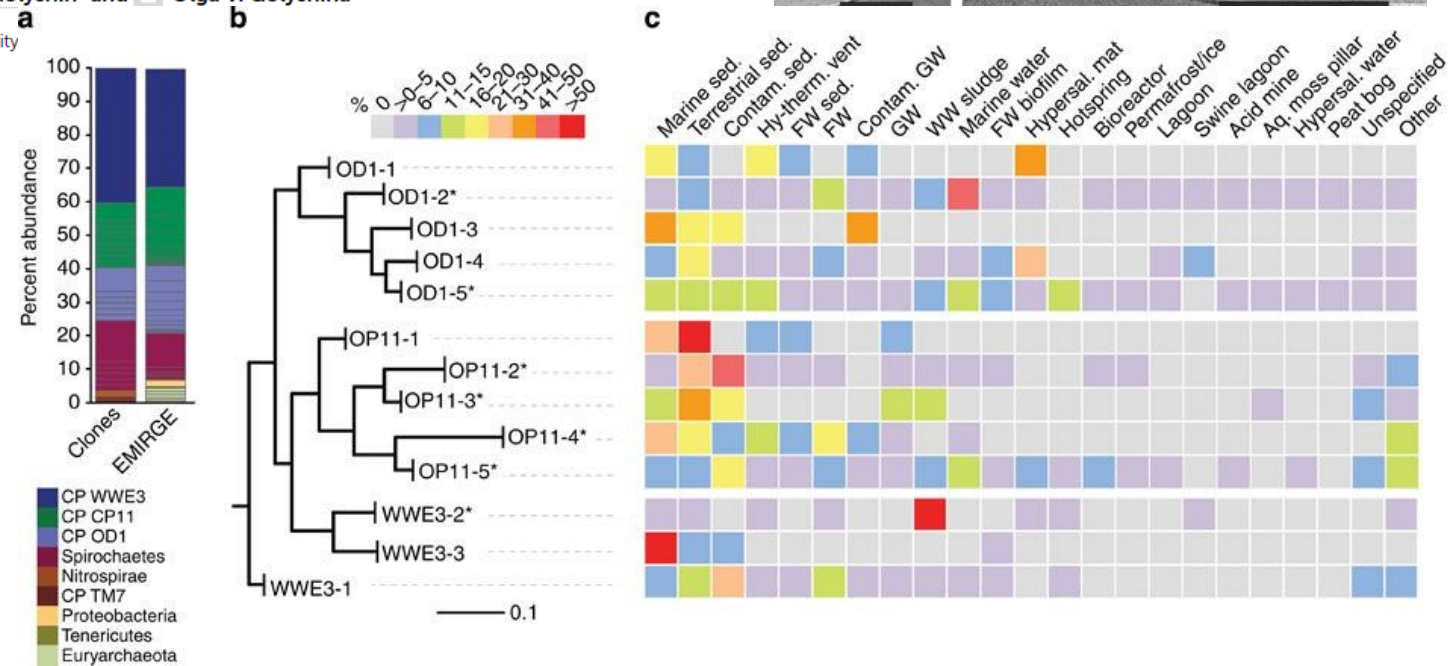
REVIEW ARTICLE

Front. Microbiol., 21 August 2018 | https://doi.org/10.3389/fmicb.2018.01971

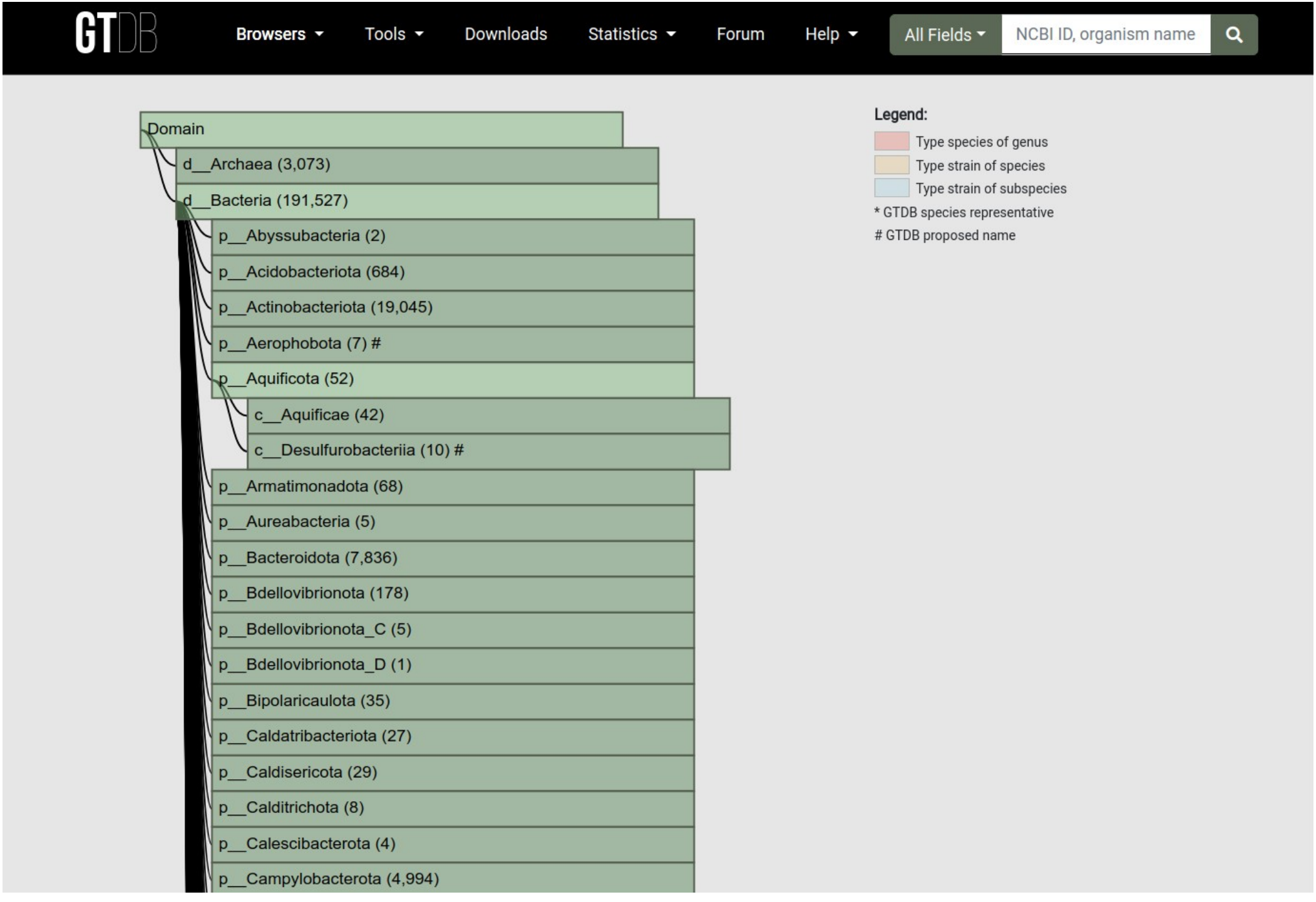
Nano-Sized and Filterable Bacteria and Archaea: Biodiversity and Function

Lydia-Ann J. Ghuneim[1]*, David L. Jones[1], Peter N. Golyshin[2] and Olga V. Golyshina[2]

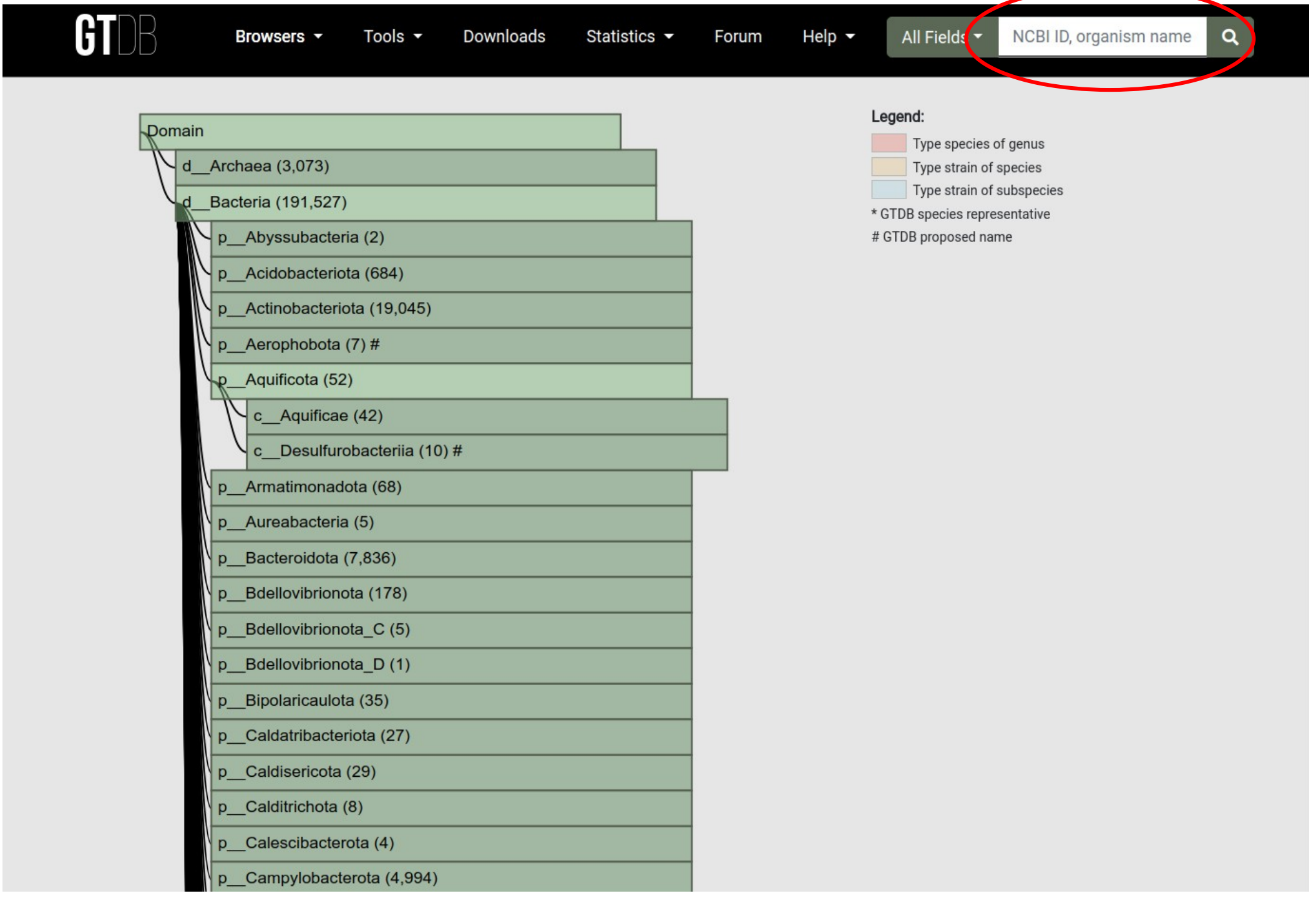
[1]School of Environment, Natural Resources and Geography, Bangor University
[2]School of Biological Sciences, Bangor University, Bangor, United Kingdom



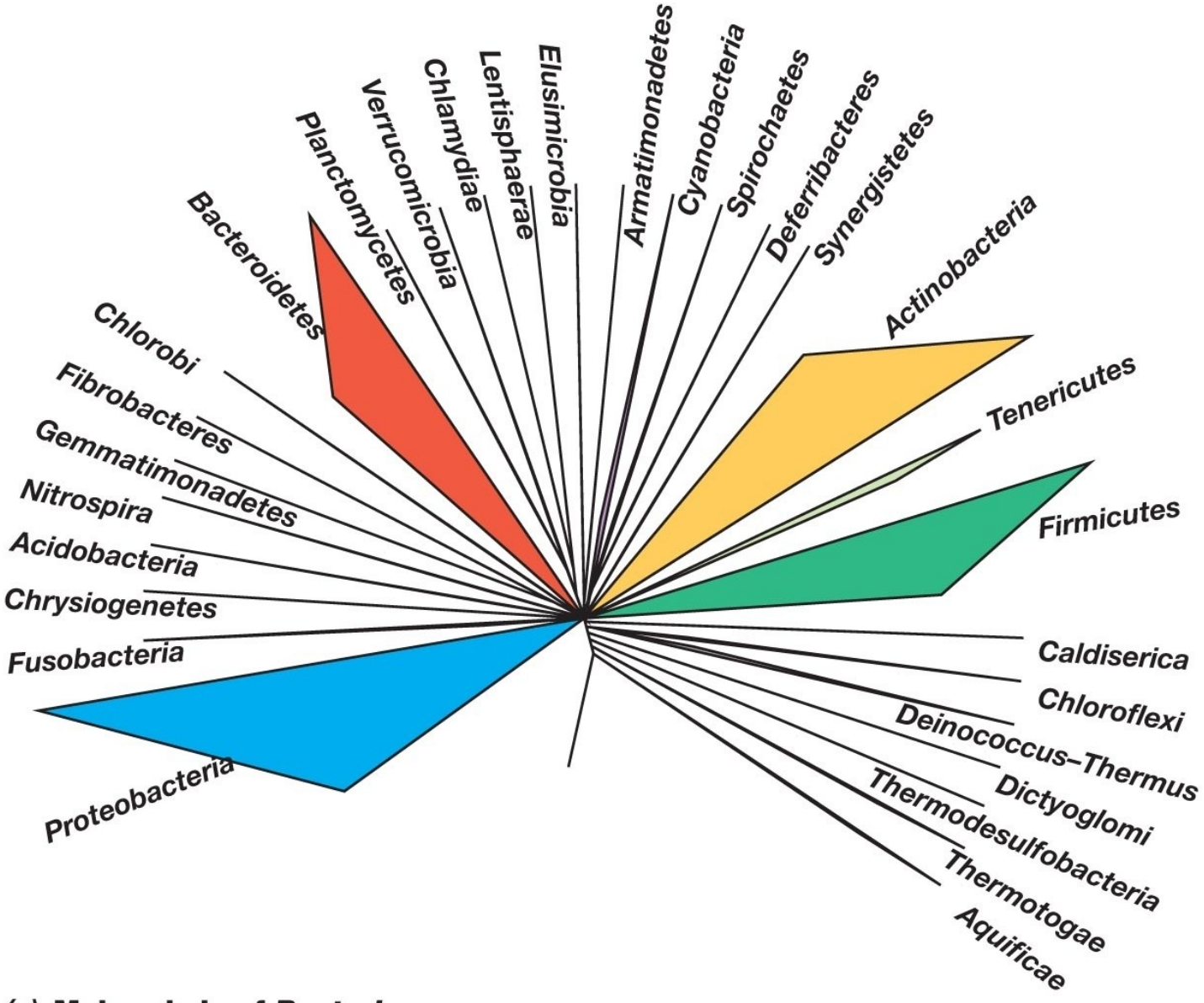
Gene Taxonomy Database - gtdb.ecogenomic.org



Gene Taxonomy Database - gtdb.ecogenomic.org

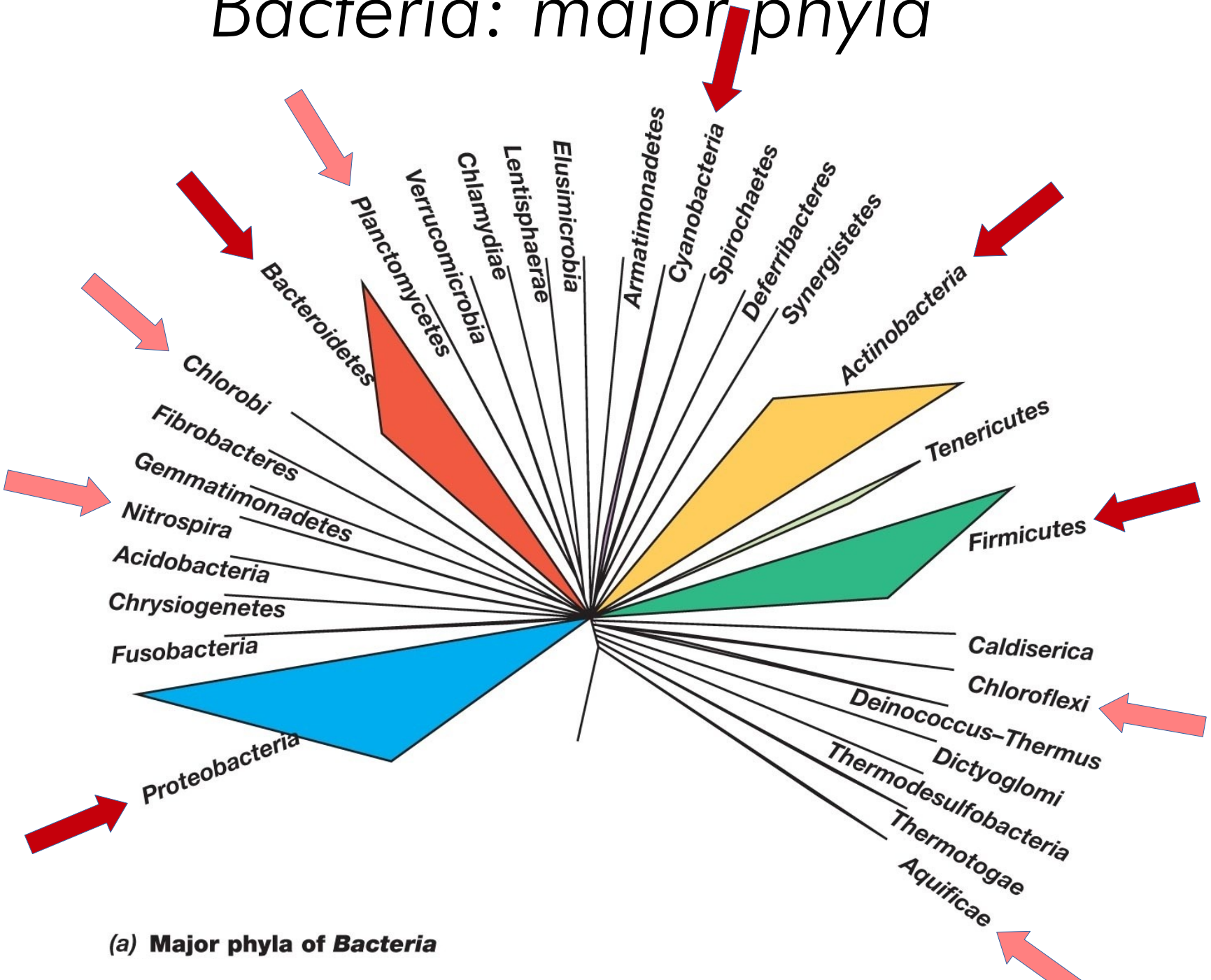


Bacteria: major phyla

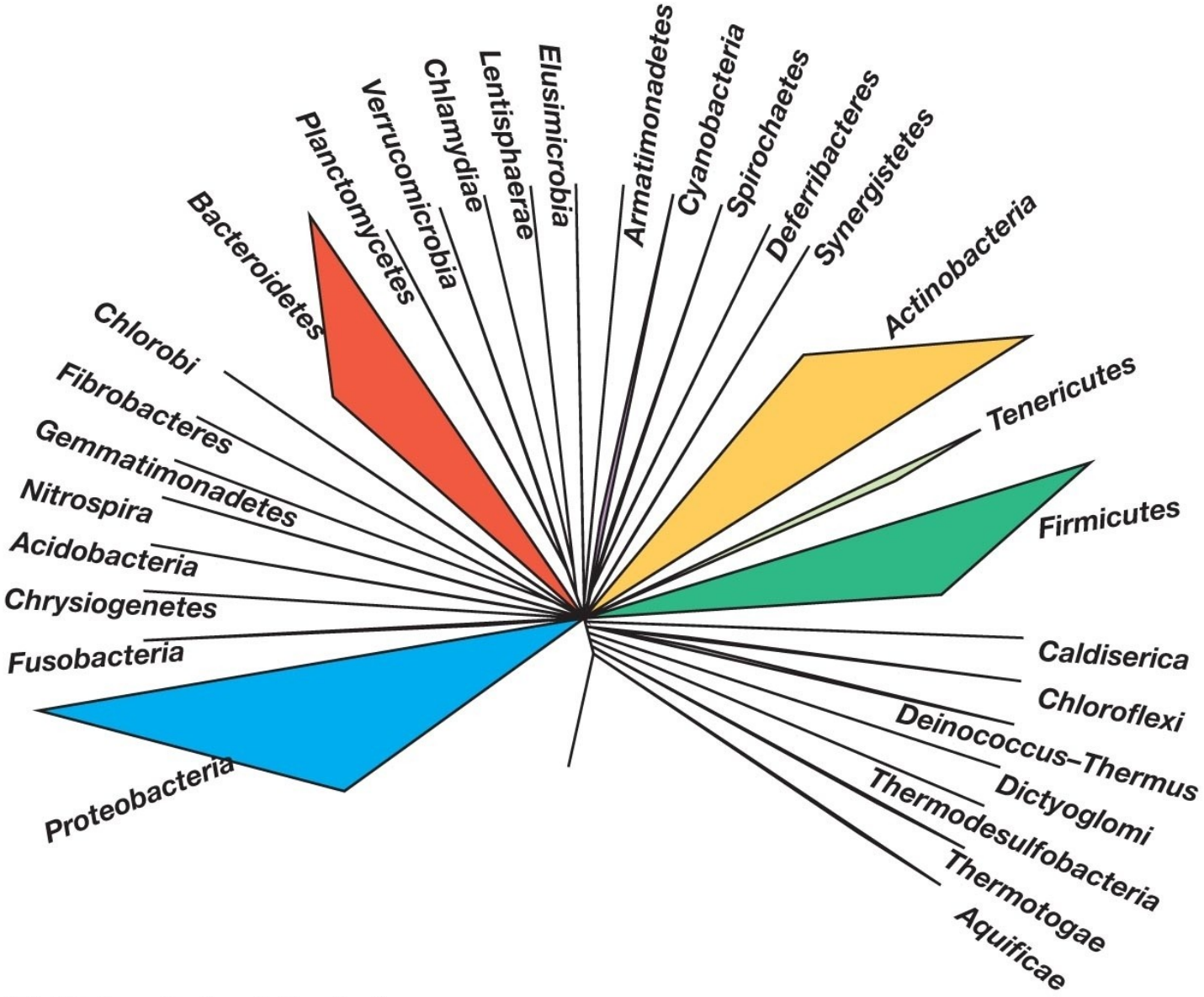


(a) Major phyla of *Bacteria*

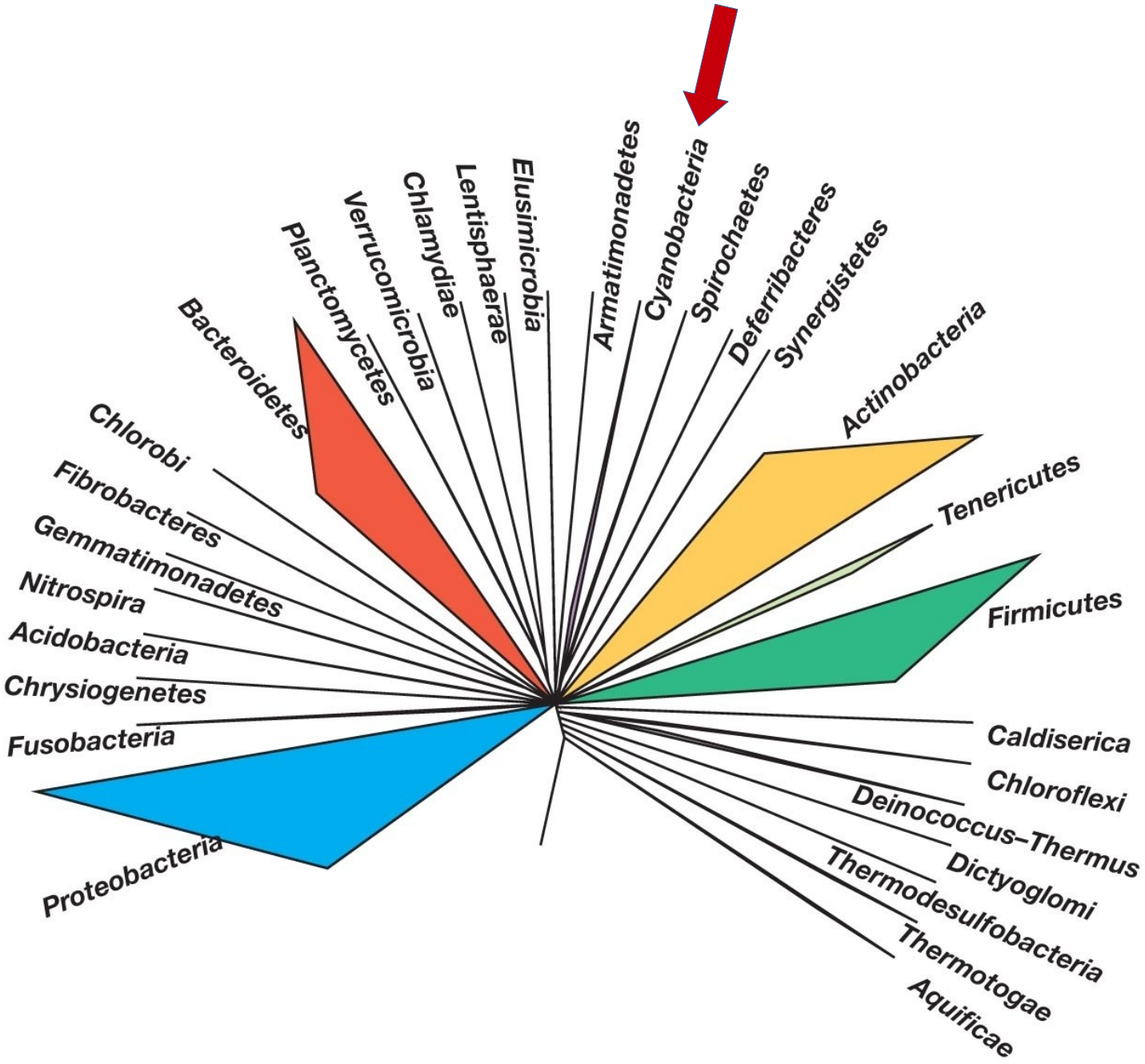
Bacteria: major phyla



(a) Major phyla of *Bacteria*



(a) **Major phyla of *Bacteria***



(a) **Major phyla of *Bacteria***

Cyanobacteria

- *Cyanobacteria (once known as Cyanophyta), are a phylum of photosynthetic, nitrogen fixing bacteria*
- *Cyanobacteria can be found in almost every terrestrial and aquatic habitat—oceans, fresh water, damp soil, temporarily moistened rocks in deserts, bare rock and soil, and even Antarctic rocks. They can occur as planktonic cells or form phototrophic biofilms. They are found in almost every endolithic ecosystem and can form symbiosis.*
- *The morphological diversity of the Cyanobacteria is huge. Cyanobacterial cells range in size from 0.5 μm in diameter to cells as large as 100 μm in diameter. They range from unicellular to filamentous and include colonial species, forming filaments, sheets, or even hollow balls. In filamentous species cells can differentiate into several different cell types: vegetative cells, akinetes and heterocysts*
- *Photosynthesis is performed in distinctive folds in the outer membrane of the cell. Chloroplasts found in eukaryotes, have their ancestry in Cyanobacteria, via a process called endosymbiosis.*

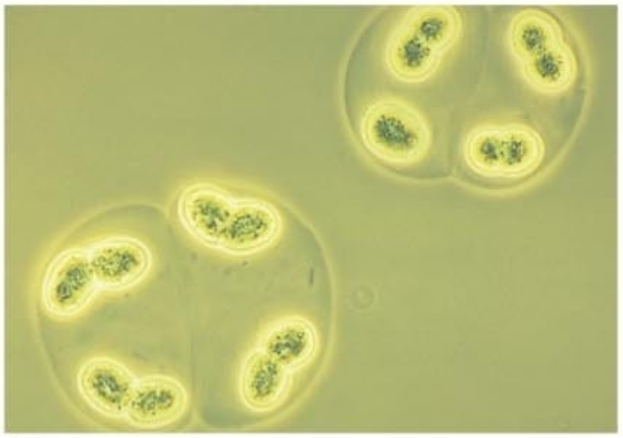
Cyanobacteria

- Cyanobacteria are oxygenic phototrophs, having both type I and type II photosystems. All species fix CO2 by the Calvin cycle, and many can fix N2. Some Cyanobacteria can assimilate simple organic compounds if light is present (photoheterotrophy). A few cyanobacteria, mainly filamentous species, can also grow in the dark on glucose or sucrose, using the sugar as both carbon and energy source. When sulfide concentrations are high, some cyanobacteria are able to switch from oxygenic photosynthesis to anoxygenic photosynthesis using hydrogen sulfide rather than water as electron donor
- Cyanobacteria are thought to have been the main contributor to the Great Oxygenation Event, ca. 2.5 Ga
- Cyanobacteria are of central importance to the productivity of the oceans. Small unicellular cyanobacteria of the genera Synechococcus and Prochlorococcus are the most abundant phototrophs in the oceans. Together these organisms contribute ~80% of marine photosynthesis and ~35% of all photosynthetic activity on Earth

Table 14.1 Genera and grouping of cyanobacteria

Group	*Genera*
Group I, *Chroococcales.* Unicellular or cell aggregates	*Gloeothece* (Figure 14.2*a*), *Gloeobacter, Synechococcus, Cyanothece, Gloeocapsa, Synechocystis, Chamaesiphon, Merismopedia, Crocosphaera* (Figure 14.7*a*), *Prochlorococcus, Prochloron*
Group II, *Pleurocapsales.* Reproduce by formation of small spherical cells called baeocytes produced through multiple fission	*Pleurocapsa* (Figure 14.2*b*), *Dermocarpa, Xenococcus, Dermocarpella, Myxosarcina, Chroococcidiopsis*
Group III, *Oscillatoriales.* Undifferentiated filamentous cells that divide by binary fission in a single plane	*Lyngbya* (Figure 14.2*c*), *Spirulina* (Figure 14.5), *Arthrospira, Oscillatoria* (Figure 14.6*a–b*), *Microcoleus, Pseudanabaena, Trichodesmium* (Figure 14.7*b*)
Group IV, *Nostocales.* Filamentous cells that produce heterocysts	*Nodularia* (Figures 14.2*d*), *Nostoc, Calothrix* (Figure 14.8*a–b*), *Anabaena* (Figure 14.6*c*), *Cylindrospermum, Scytonema, Richelia* (Figure 14.7*c*)
Group V, *Stigonematales.* Cells divide to form branches	*Fischerella* (Figures 14.2*e*, 14.8*c, d*), *Stigonema, Chlorogloeopsis, Hapalosiphon*

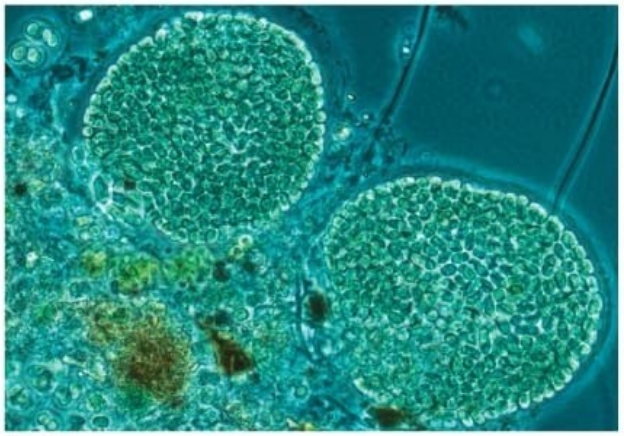
Chroococcales



Susan Barns and Norman Pace

(a)

Pleurocapsales



Daniel H. Buckley

(b)

Oscillatoriales

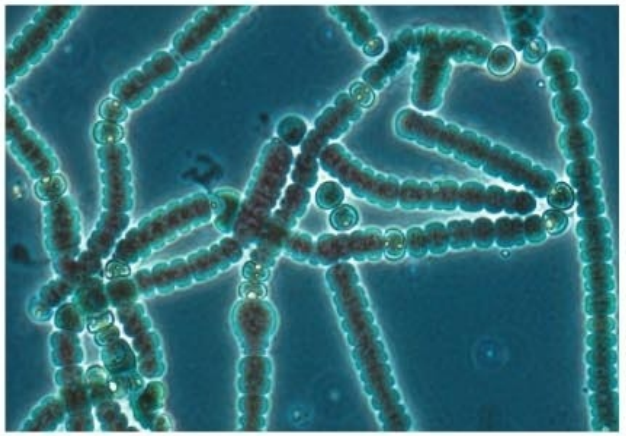
Daniel H. Buckley

(c)

Daniel H. Buckley

(d)

Nostoccales



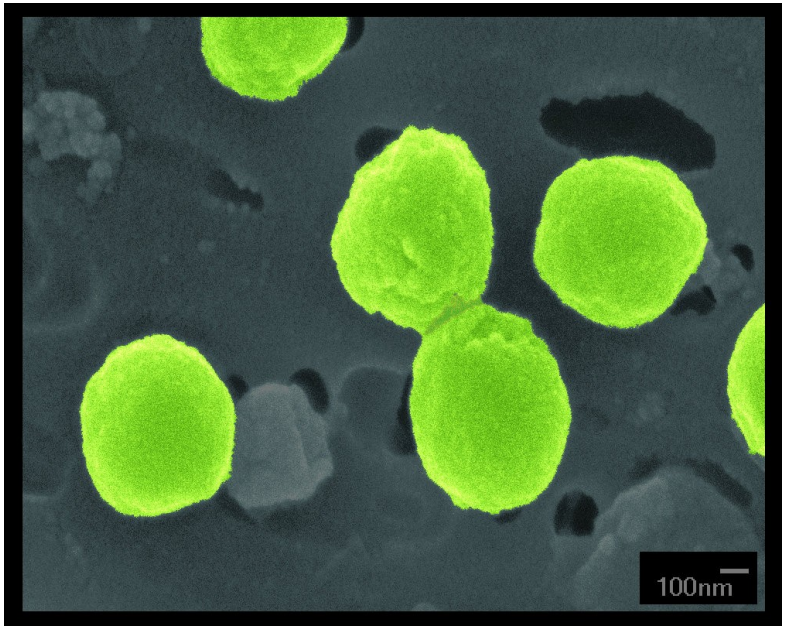
Daniel H. Buckley

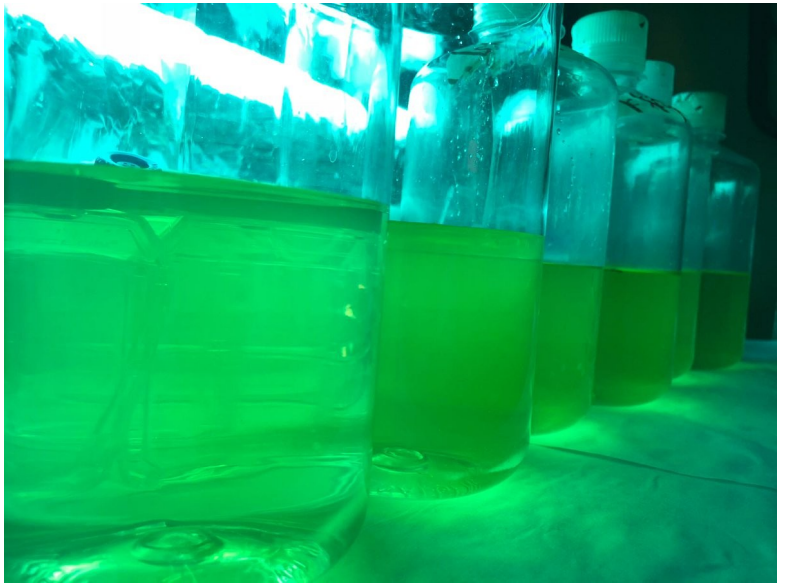
(e)

Stigonematales

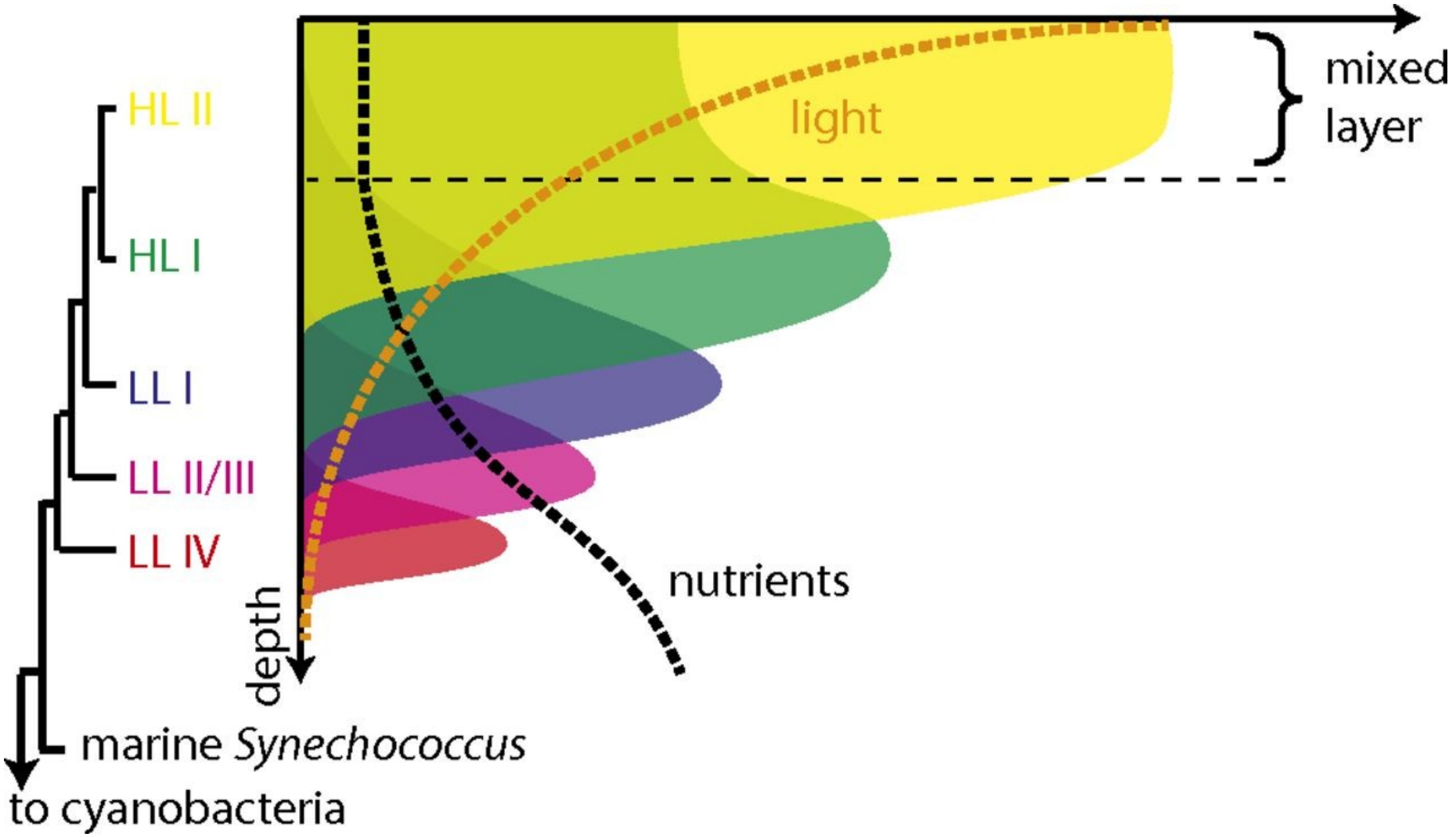
Prochlorococcus marinus

- *Prochlorococcus is a genus of very small (0.6 μm) marine cyanobacteria with an unusual pigmentation (chlorophyll b)*
- *Prochlorococcus has been found to be abundant in the euphotic zone of the world's tropical oceans*
- *Prochlorococcus is ubiquitous between 40°N and 40°S and dominates in the oligotrophic (nutrient poor) regions of the oceans*
- *Prochlorococcus is mostly found in a temperature range of 10-33 °C and some strains can grow at depths with low light (<1% surface light)*
- *Microbes of the genus Prochlorococcus are among the major primary producers in the ocean, responsible for a large percentage of the photosynthetic production of oxygen*

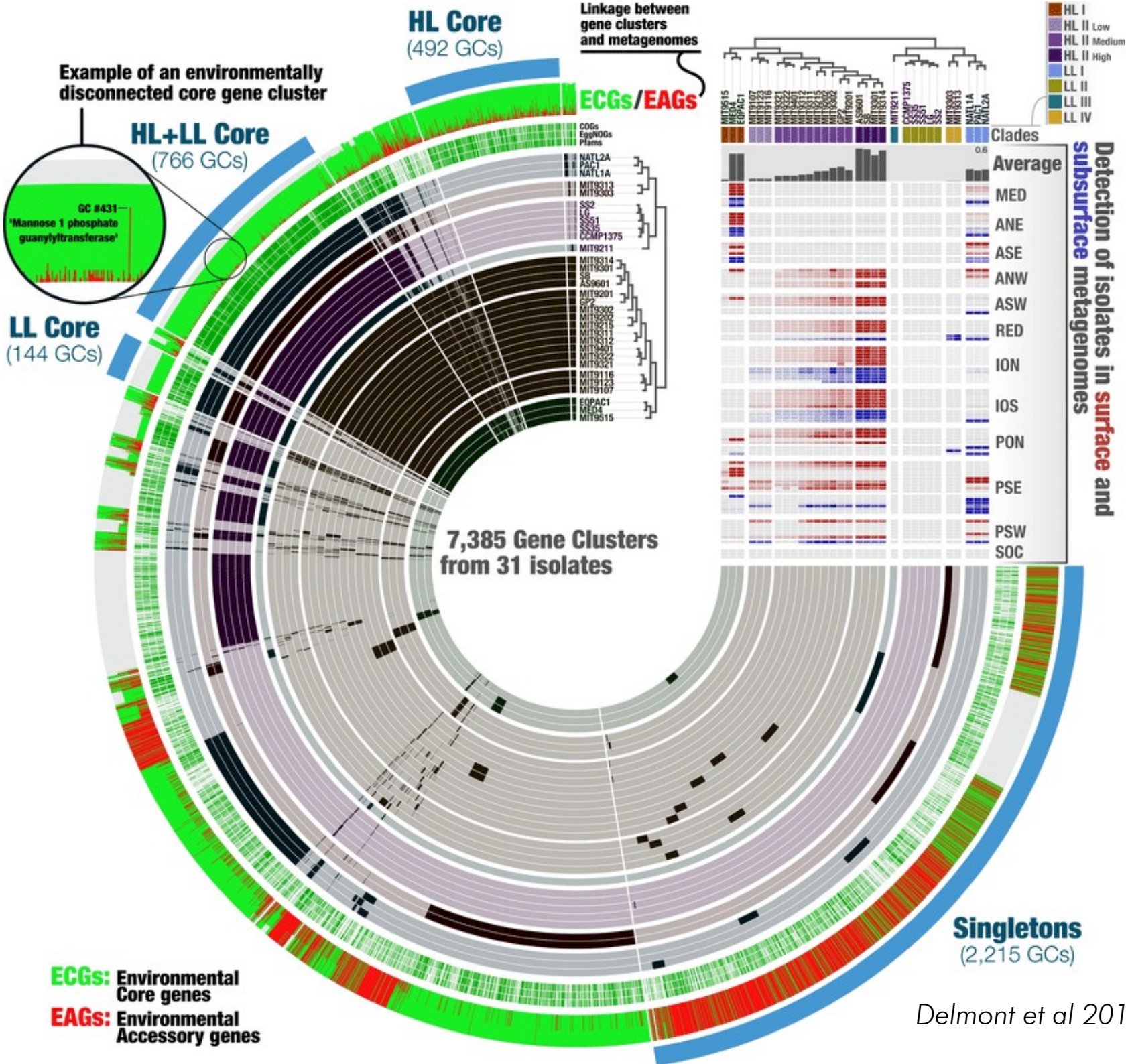




Prochlorococcus marinus



Braakman et al 2017 PNAS



Delmont et al 2018 PeerJ

(a) **Major phyla of *Bacteria***

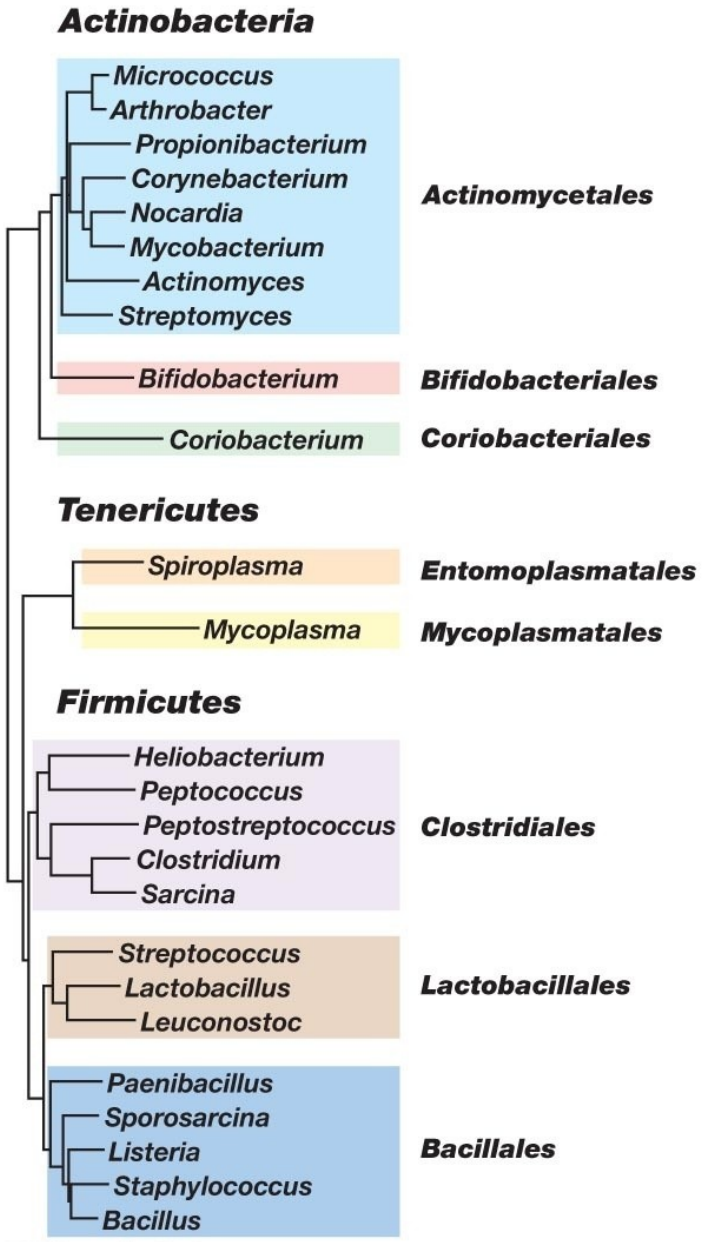
Firmicutes

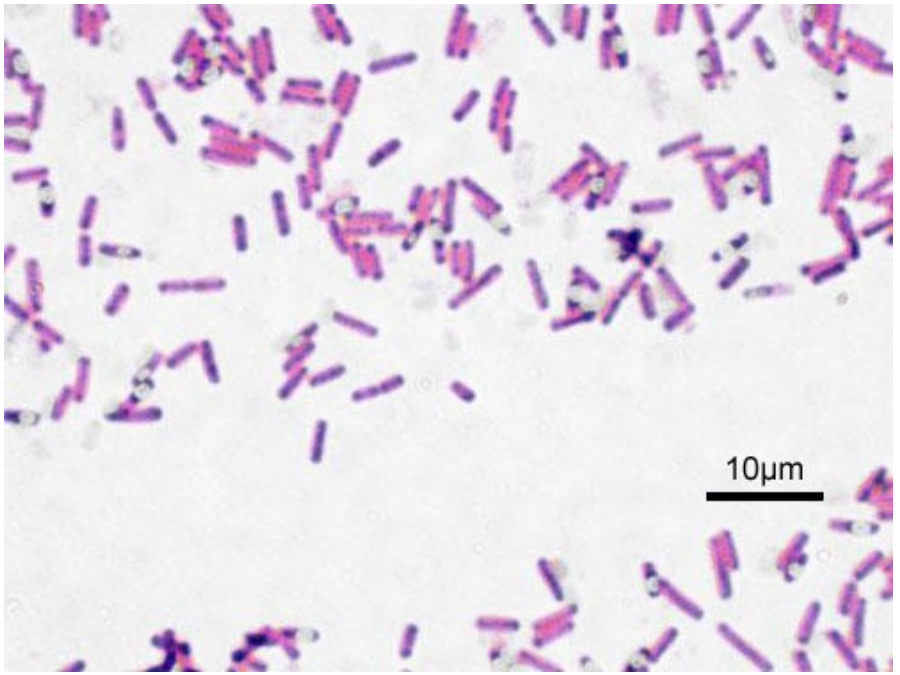
- *The Firmicutes are phylum of bacteria, most of which have Gram-positive cell wall structure. The Firmicutes, once including all Gram-positive bacteria, has been recently defined to contain related forms called the low-G+C group, while Actinobacteria now contains the high-G+C group*
- *They generally have round cells, called cocci (singular coccus), or rod-like forms (bacillus). They are found in various environments, and the group includes some notable pathogens. They play an important role in beer, wine, and food fermentations*
- *Many Firmicutes produce endospores, which are resistant to desiccation and can survive extreme conditions. They are generally heterotrophs and/or fermenters. Those in one family, the Heliobacteria, produce energy through photosynthesis*
- *The group is typically divided into the Clostridia, which are obligate anaerobes, the Bacilli, which are obligate or facultative aerobes*
- *The Clostiridia are a highly polyphyletic class of Firmicutes, including Clostridium and other similar genera. They are obligate anaerobes. Studies show they are not a monophyletic group, and their relationships are not entirely certain. Currently, most are placed in a single order called Clostridiales, but this is not a natural group and is likely to be redefined in the future*
- *Bacillus species are almost ubiquitous in nature, e.g. in soil, but also occur in extreme environments such as high pH (B. alcalophilus), high temperature (B. thermophilus), or high salt (B. halodurans)*

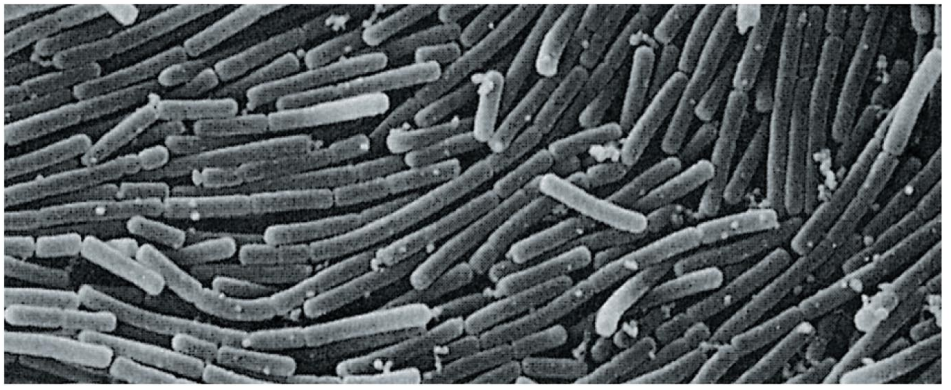
Actinobacteria

- *Actinobacteria is a phylum of gram-positive bacteria. They are found in both terrestrial and aquatic environments.*
- *They have been extensively studied in soils, where they behave much like fungi, helping to decompose the organic matter of dead organisms so that the molecules can be taken up anew by plants. In this role the colonies often grow extensive mycelia, and the name of an important order of the phylum, Actinomycetales, reflects that they were long believed to be fungi*
- *Currently understood primarily as soil bacteria, their role in the aquatic environment is not yet clear*
- *They are of great economic importance to humans because agriculture and forests depend on their contributions to soil systems. Streptomyces, one of the largest bacterial genera, and other Actinobacteria are source of many antibiotics*

Firmicutes and Actinobacteria







V. Bottazi

(c)

Table 15.5 Characteristics of representative species of bacilli

Characteristics	*Species*	*Endospore position*
I. Endospores oval or cylindrical, facultative aerobes, casein and starch hydrolyzed		
Sporangia not swollen, endospore wall thin		
Thermophiles and acidophiles	*Bacillus coagulans*	Central or terminal
	Alicyclobacillus acidocaldarius	Terminal
Mesophiles	*Bacillus licheniformis*	Central
	Bacillus cereus	Central
	Bacillus anthracis	Central
	Bacillus megaterium	Central
	Bacillus subtilis	Central
Insect pathogen	*Bacillus thuringiensis*	Central
Sporangia distinctly swollen, spore wall thick		
Thermophile	*Geobacillus stearothermophilus*	Terminal
Mesophiles	*Paenibacillus polymyxa*	Terminal
	Bacillus macerans	Terminal
	Bacillus circulans	Central or terminal
Insect pathogens	*Paenibacillus larvae*	Central or terminal
	Paenibacillus popilliae	Central
II. Endospores spherical, obligate aerobes, casein and starch not hydrolyzed		
Sporangia swollen	*Bacillus sphaericus*	Terminal
Sporangia not swollen	*Sporosarcina pasteurii*	Terminal

Table 15.6 Characteristics of some groups of clostridia

Key characteristics	*Other characteristics*	*Species*
Ferment carbohydrates		
Ferment cellulose	Fermentation products: acetate, lactate, succinate, ethanol, CO_2, H_2	*C. cellobioparum*[a] *C. thermocellum*
Ferment sugars, starch, and pectin; some ferment cellulose	Fermentation products: acetone, butanol, ethanol, isopropanol, butyrate, acetate, propionate, succinate, CO_2, H_2; some fix N_2	*C. butyricum* *C. cellobioparum* *C. acetobutylicum* *C. pasteurianum* *C. perfringens*
Ferment sugars primarily to acetic acid	Total synthesis of acetate from CO_2; cytochromes present in some species	*C. aceticum* *Moorella thermoacetica* *C. formicaceticum*
Ferments only pentoses or methylpentoses	Ring-shaped cells form left-handed, helical chains; fermentation products: acetate, propionate, *n*-propanol, CO_2, H_2	*C. methylpentosum*

[a]All genus names beginning with a "C." are species of the genus *Clostridium*.

Table 15.6 Characteristics of some groups of clostridia *(Continued)*

Key characteristics	*Other characteristics*	*Species*
Ferment amino acids	Fermentation products: acetate, other fatty acids, NH_3, CO_2, sometimes H_2; some also ferment sugars to butyrate and acetate; may produce exotoxins; causative agents of serious or fatal diseases	*C. sporogenes* *C. histolyticum* *C. putrefaciens* *C. tetani* *C. botulinum* *C. tetanomorphum*
	Ferments three-carbon amino acids (for example, alanine) to propionate, acetate, and CO_2	*C. propionicum*
Ferments carbohydrates or amino acids	Fermentation products from glucose: acetate, formate, small amounts of isobutyrate and isovalerate	*C. bifermentans*
Purine fermenters	Ferments uric acid and other purines, forming acetate, CO_2, NH_3	*C. acidurici*
Ethanol fermentation to fatty acids	Produces butyrate, caproate, and H_2; requires acetate as electron acceptor; does not use sugars, amino acids, or purines	*C. kluyveri*

[a]All genus names beginning with a "*C.*" are species of the genus *Clostridium*.

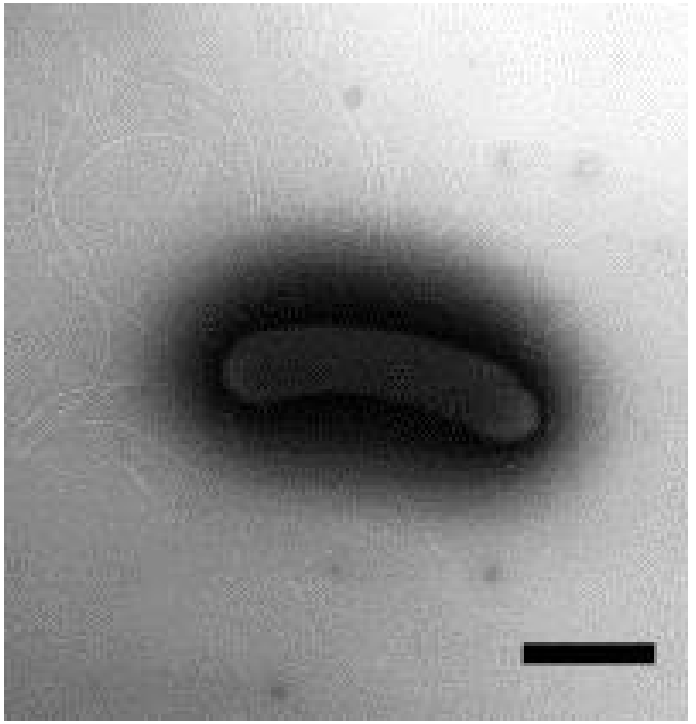
Table 15.8 Some common antibiotics synthesized by species of *Streptomyces* and related *Actinobacteria*

Chemical class	*Common name*	*Produced by*	*Active against*[a]
Aminoglycosides	Streptomycin	*S. griseus*[b]	Most gram-negative *Bacteria*
	Spectinomycin	*Streptomyces* spp.	*Mycobacterium tuberculosis*, penicillinase-producing *Neisseria gonorrhoeae*
	Neomycin	*S. fradiae*	Broad spectrum, usually used in topical applications because of toxicity
Tetracyclines	Tetracycline	*S. aureofaciens*	Broad spectrum, gram-positive and gram-negative *Bacteria*, rickettsias and chlamydias, *Mycoplasma*
	Chlortetracycline	*S. aureofaciens*	As for tetracycline
Macrolides	Erythromycin	*Saccharopolyspora erythraea*	Most gram-positive *Bacteria*, frequently used in place of penicillin; *Legionella*
	Clindamycin	*S. lincolnensis*	Effective against obligate anaerobes, especially *Bacteroides fragilis*, the major cause of anaerobic peritoneal infections
Polyenes	Nystatin	*S. noursei*	Fungi, especially *Candida* (a yeast) infections
	Amphotericin B	*S. nodosus*	Fungi
None	Chloramphenicol	*S. venezuelae*	Broad spectrum; drug of choice for typhoid fever

[a]Most antibiotics are effective against several different *Bacteria*. The entries in this column refer to the common clinical application of a given antibiotic. The structures and mode of action of many of these antibiotics are discussed in Sections 27.11–27.14.
[b]All species names beginning with an "*S.*" are species of *Streptomyces*.

Oceanobacillus iheyensis

- *Oceanobacillus iheyensis HTE831 is an extremely halotolerant and alkaliphilic Bacillus related species*
- *It was isolated from deep sea sediment collected at a depth of 1050m on the Iheya Ridge*
- *In nature, bacillus species are distributed nearly ubiquitously*
- *The genome of O. iheyensis is a single circular chromosome consisting of 3,630,528 nt*



RESEARCH ARTICLE | ECOLOGY

Microbial dormancy in the marine subsurface: Global endospore abundance and response to burial

Lars Wörmer[1,*], Tatsuhiko Hoshino[2], Marshall W. Bowles[3], Bernhard Viehweger[1], Rishi R. Adhikari[1], Nan Xiao[2], Go-ichiro Ur…

+ See all authors and affiliations

Science Advances 20 Feb 2019:
Vol. 5, no. 2, eaav1024
DOI: 10.1126/sciadv.aav1024

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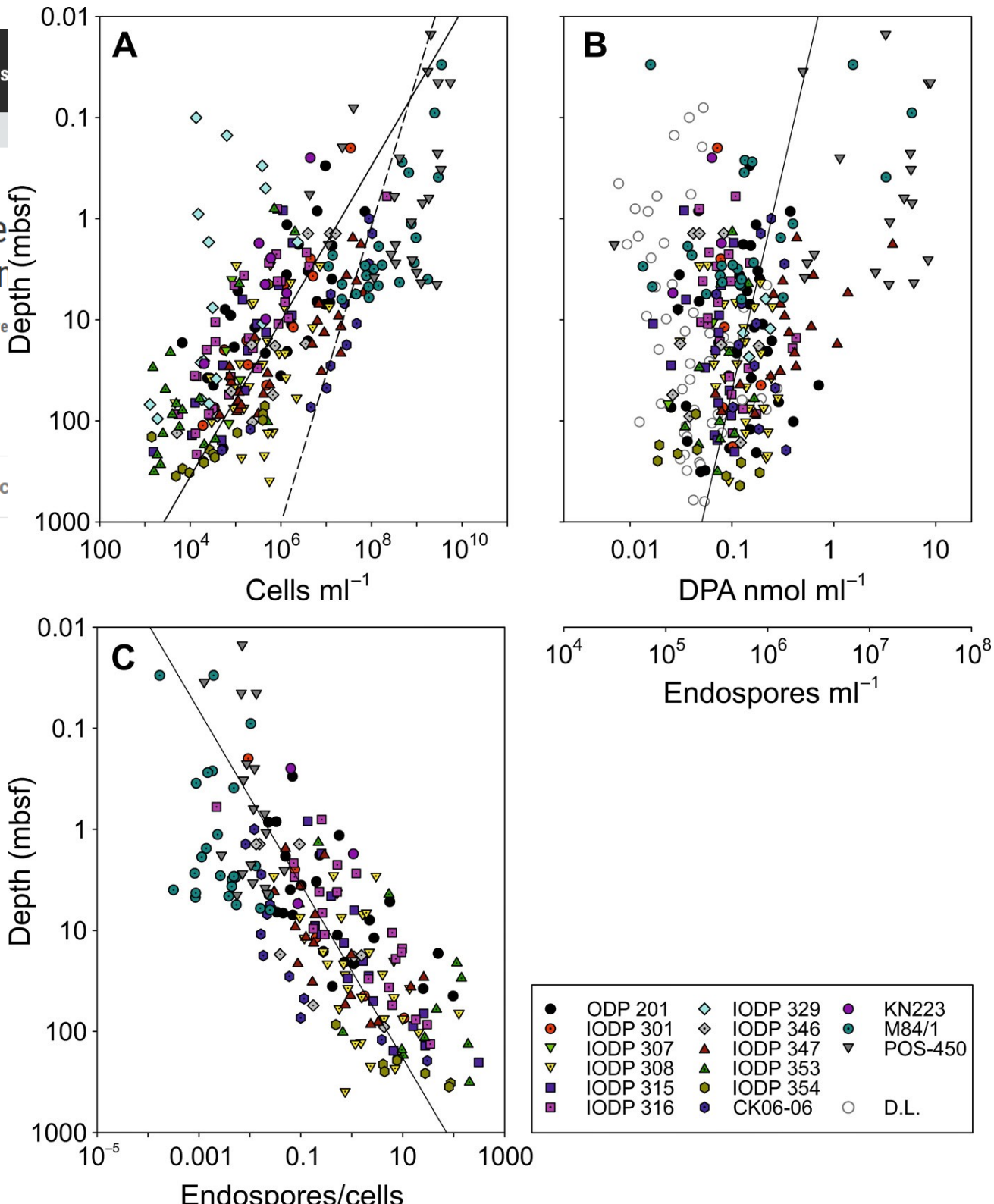

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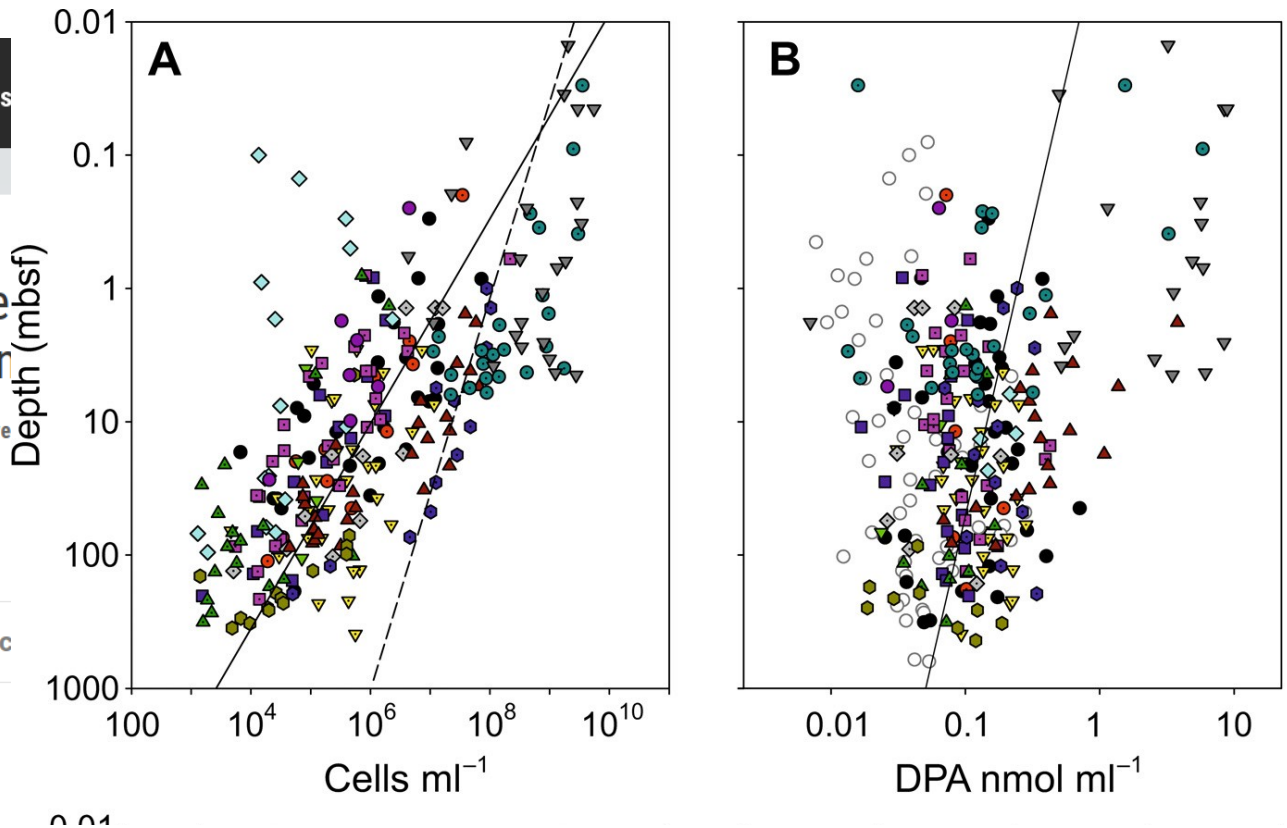


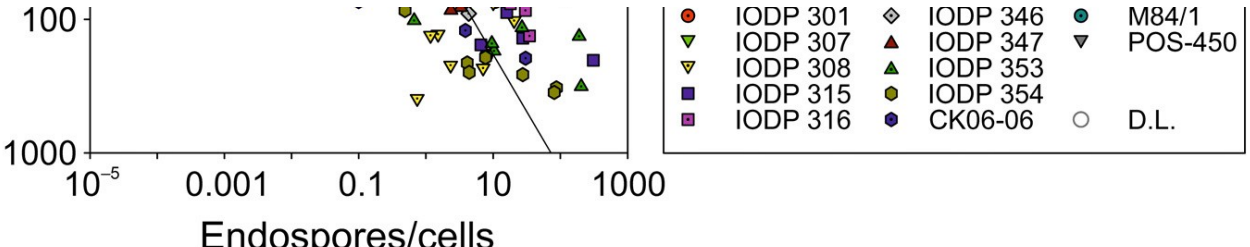
HYPOTHESIS AND THEORY ARTICLE

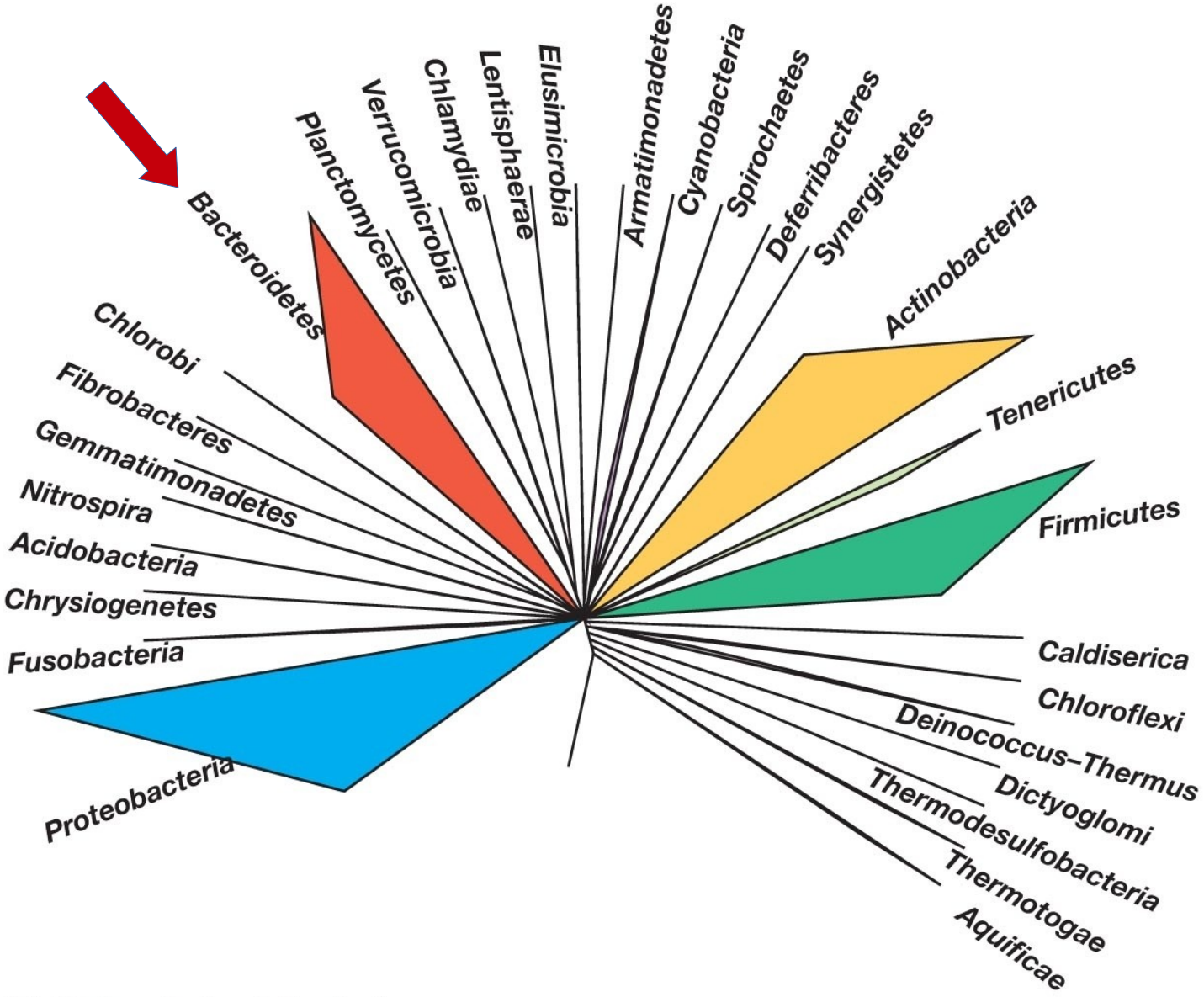
Front. Microbiol., 13 January 2012 | https://doi.org/10.3389/fmicb.2011.00284

Acetogenesis in the energy-starved deep biosphere – a paradox?

Mark Alexander Lever*

Department of Bioscience, Center for Geomicrobiology, Aarhus University, Aarhus, Denmark

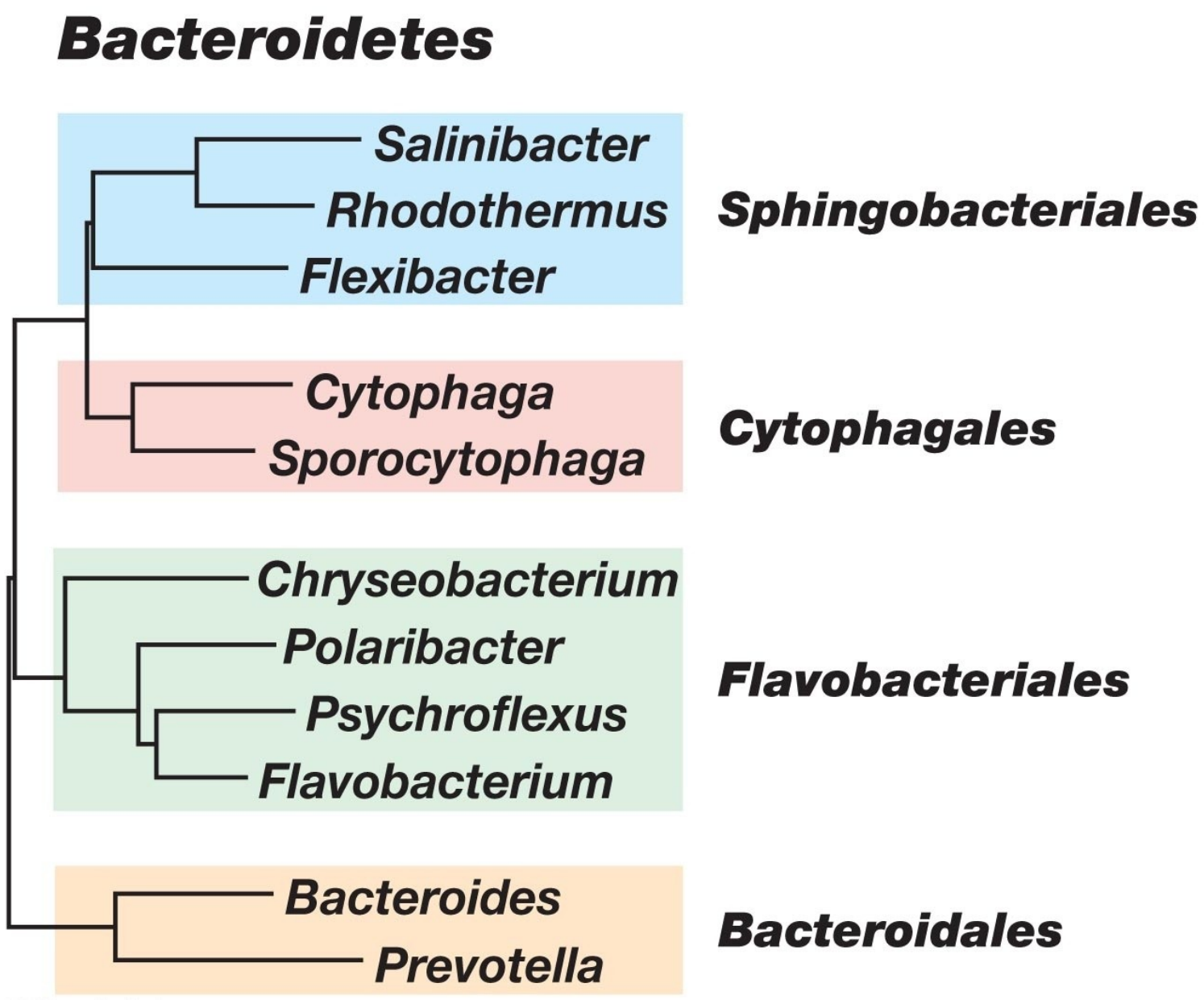




(a) **Major phyla of *Bacteria***

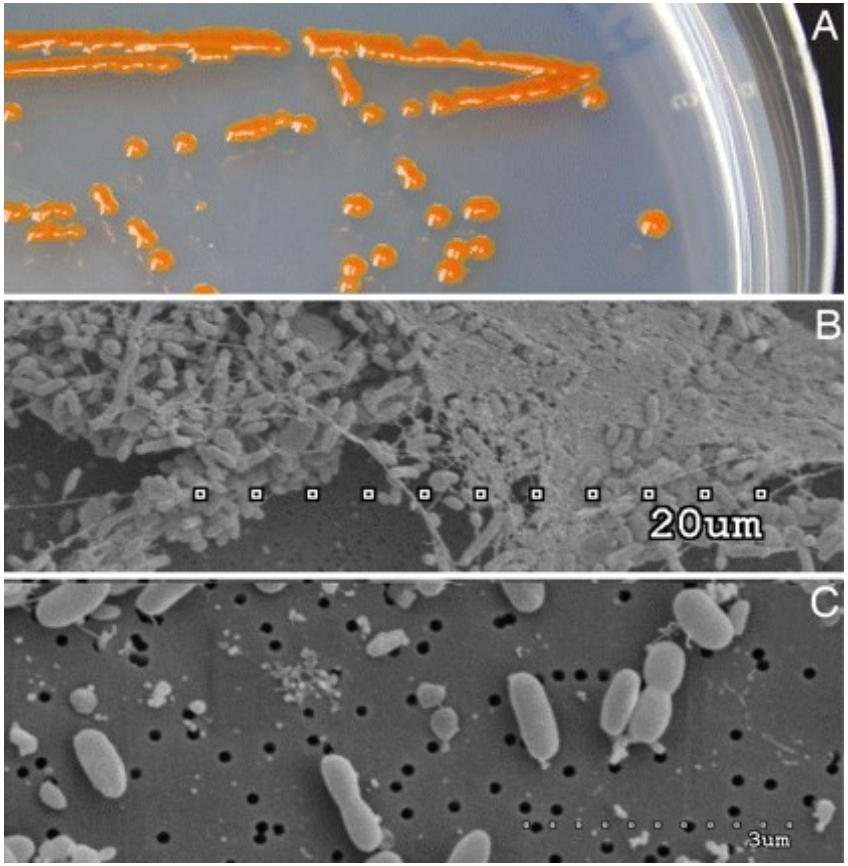
Bacteroidetes

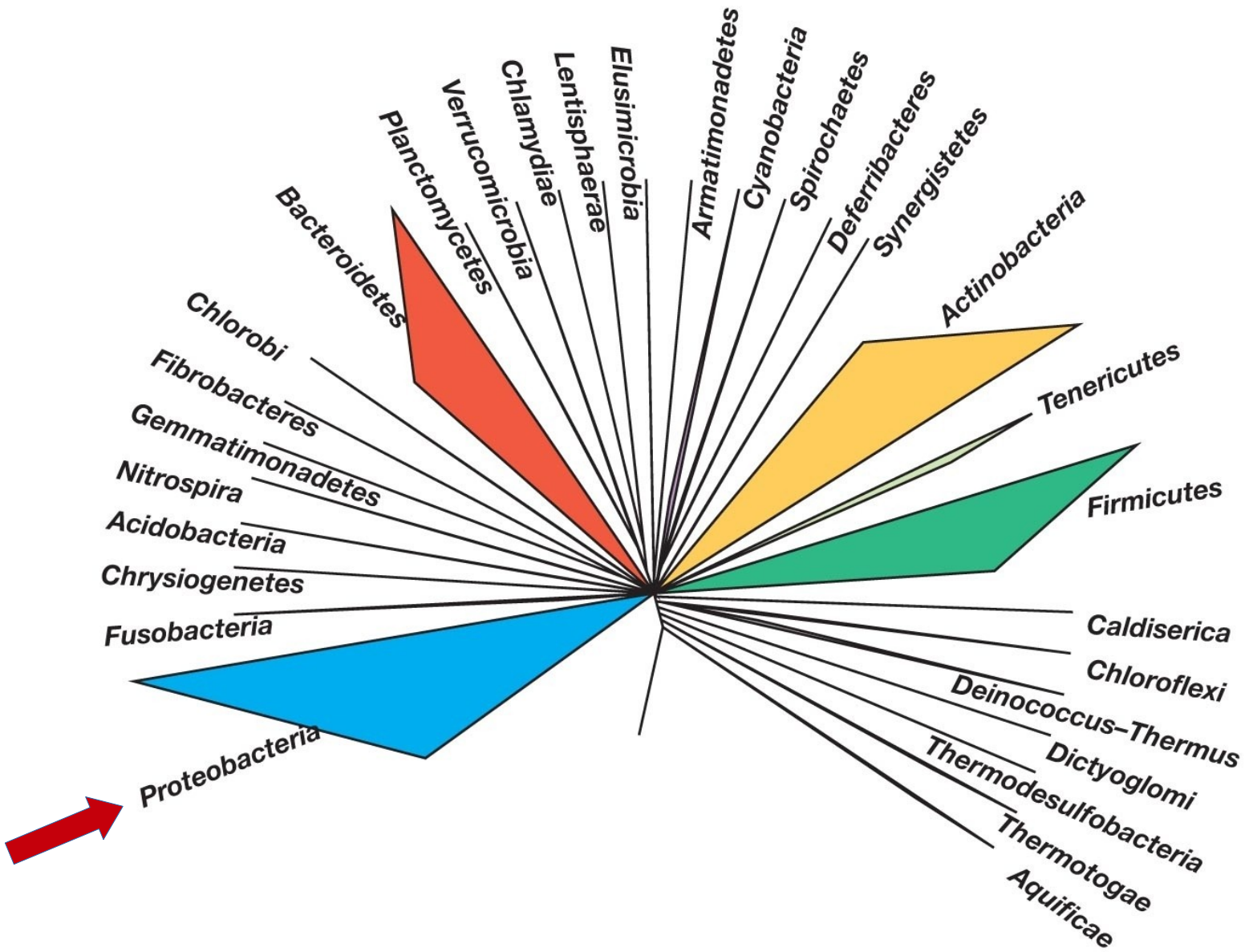
- *The phylum Bacteroidetes (known as the CFB group) is composed of three large classes of nonsporeforming, anaerobic or aerobic, and rod-shaped bacteria that are widely distributed in the environment, including in soil, sediments, and sea water, as well as in the guts and on the skin of animals comprising 7,000 different species*
- *In the marine environment they are ubiquitous, and believed to play a major role in degrading organic matter, and decomposing complex recalcitrant compounds in the form of polysaccharides and proteins*
- *By far, the ones in the Bacteroidia class are the most well-studied, including the genus Bacteroides (an abundant organism in the feces of warm-blooded animals including humans), and Porphyromonas, a group of organisms inhabiting the human oral cavity. Yet, the marine diversity has been poorly investigated*
- *Bacteroidetes can represent the dominant phylum in marine snow aggregates*


Bacteroidetes
Salinibacter
Rhodothermus
Flexibacter
Sphingobacteriales
Cytophaga
Sporocytophaga
Cytophagales
Chryseobacterium
Polaribacter
Psychroflexus
Flavobacterium
Flavobacteriales
Bacteroides
Prevotella
Bacteroidales

Polaribacter sp. MED152

- *Polaribacter is one of the major genera of Bacteroidetes found in the marine environment*
- *They contain a proteorhodopsin functioning as a light-driven H+ pump in the ocean*
- *It can grow only by aerobic respiration,and it is unable to use fermentation or anaerobic respiration for energy conservation.*
- *Its genome contains a number of genes potentially involved in anaplerotic metabolism (fixation of CO2) such as PEP carboxylase and pyruvate carboxylase*





(a) **Major phyla of *Bacteria***

Proteobacteria

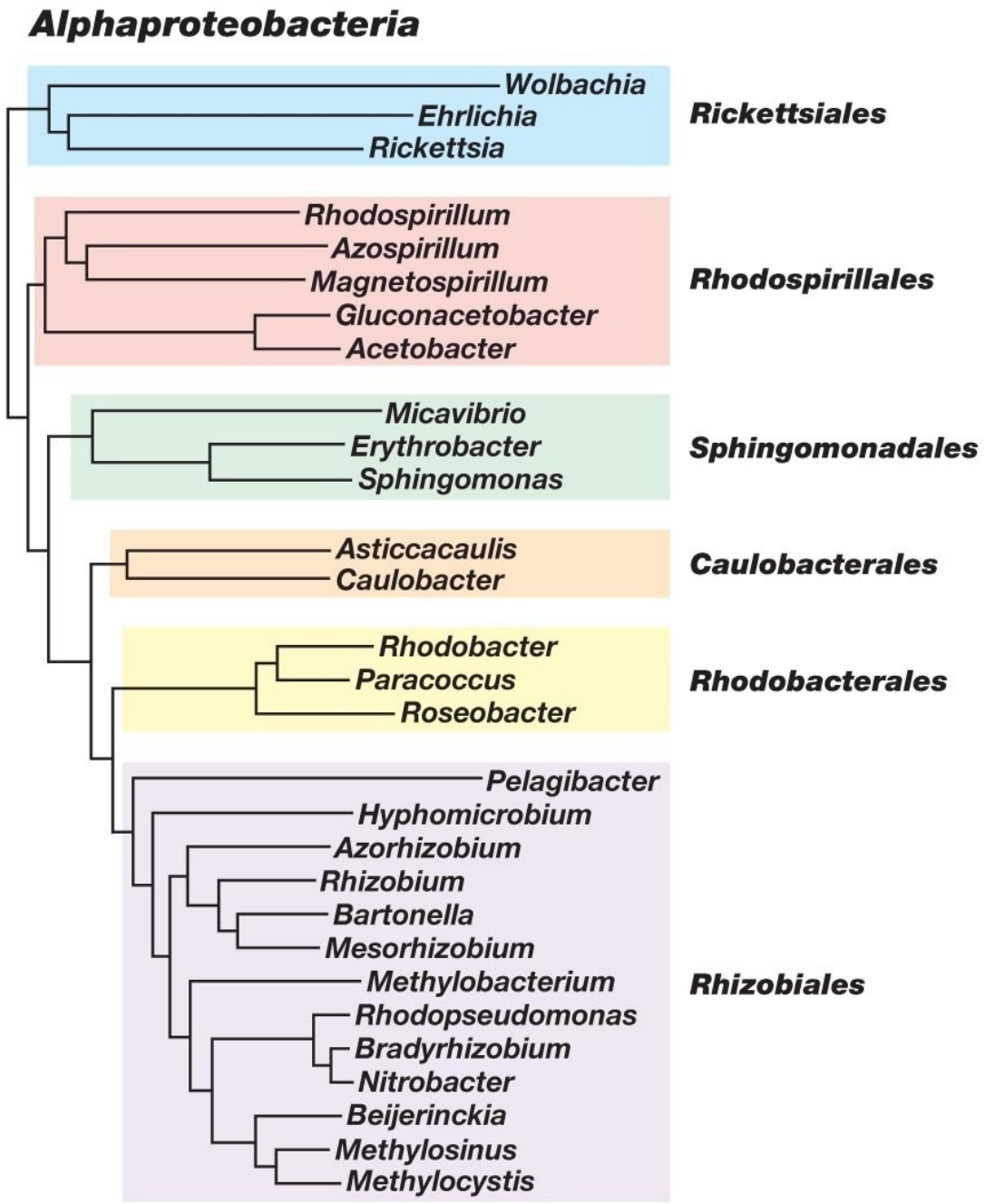
- *The Proteobacteria are a major phylum of Gram-negative bacteria. Carl Woese established this grouping in 1987, calling it informally the "purple bacteria and their relatives". Because of the great diversity of forms found in this group, the Proteobacteria are named after Proteus, a Greek god of the sea capable of assuming many different shapes*
- *They are ubiquitous in the environments and posses a huge metabolic diversity, encompassing facultatively or obligately anaerobes, chemolithoautotrophy, heterotrophy and anoxygenic phototrophy. They include free living, commensal, symbiotic and pathogenic species*
- *They are currently divide in six classes: Alphaproteobacteria, Betaproteobacteria, Gammaproteobacteria, Deltaproteobacteria, Epsilonproteobacteria and Zetaproteobacteria*
- *Given their diversity they have been proposed as superphylum, with the classes promoted to distinct phyla*

Proteobacteria: Alphaproteobacteria

- *With nearly one thousand described species, the Alphaproteobacteria are the second largest class of Proteobacteria*
- *The Alphaproteobacteria is a diverse taxon and comprises several phototrophic genera, several genera metabolising C1-compounds (e.g., Methylobacterium spp.), symbionts of plants (e.g., Rhizobium spp.), endosymbionts of arthropods (Wolbachia) and intracellular pathogens (e.g. Rickettsia). A total of 10 orders have been described within the Alphaproteobacteria*
- *Most species are obligate aerobes or facultative aerobes and many are oligotrophic, preferring to grow in environments that have low nutrient concentration. Several species play a key role in nitrogen fixation in various types of plants*
- *The class includes the protomitochondrion, the bacterium that was engulfed by the eukaryotic ancestor and gave rise to the mitochondria through endosymbiosis*
- *Pelagibacter ubique is an oligotroph and an obligately aerobic chemoorganotroph that inhabits the photic zone of Earth's oceans. This organism can make up 25% of the bacterial cells found at the ocean's surface, and its numbers can reach 50% of cells in temperate waters in the summer; as a consequence, Pelagibacter ubique is likely the most abundant bacterial species on Earth*

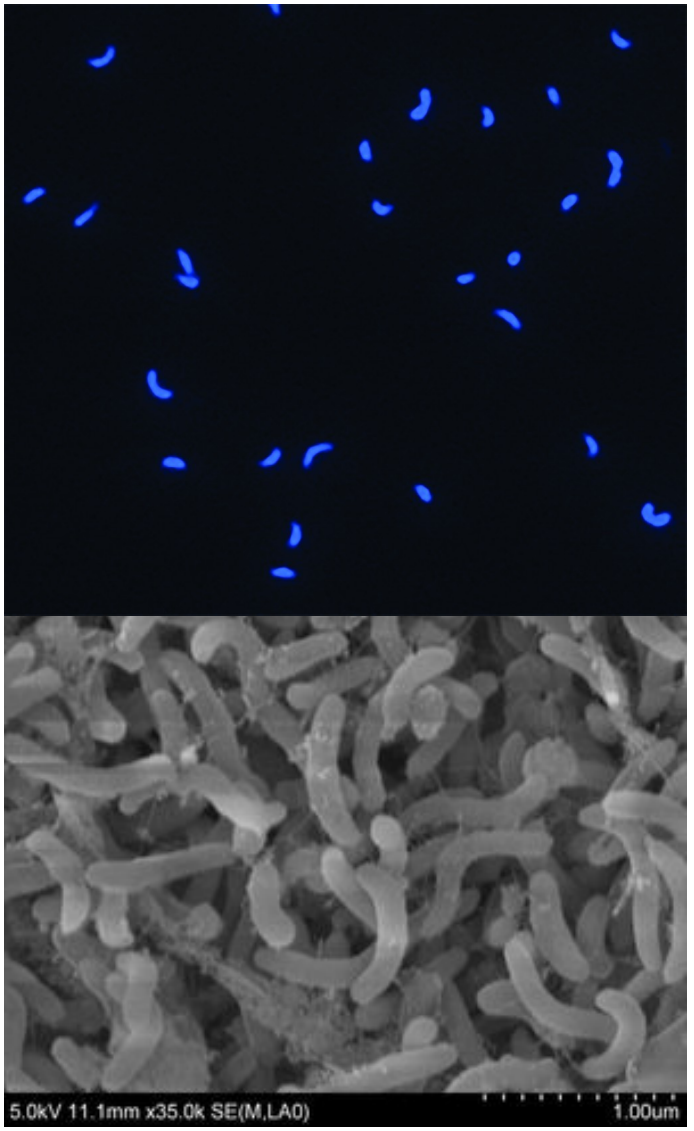
Table 15.1 Notable genera of *Alphaproteobacteria*

Family	Genus	Notable characteristics
Caulobacterales	*Caulobacter*	Asymmetric cell division and formation of prosthecae
Rickettsiales	*Rickettsia*	Obligate intracellular parasites, transmitted by arthropods
	Wolbachia	Live within arthropods and impact their reproduction
Rhizobiales	*Bartonella*	Obligate intracellular parasites, transmitted by arthropods
	Bradyrhizobium	Form root nodules with soybean and other legumes
	Brucella	Facultative intracellular parasites of animals, zoonotic pathogen
	Hyphomicrobium	Stalked cells, metabolically versatile
	Mesorhizobium	Form root nodules with bird's-foot trefoil and other legumes
	Methylobacterium	Methylotroph found on plants and in soil
	Nitrobacter	Nitrifying bacterium that oxidizes NO_2^- to NO_3^-
	Pelagibacter	Oligotrophic chemoorganotroph; high abundance in ocean surface
	Rhodopseudomonas	Metabolically versatile purple nonsulfur bacterium
Rhodobacterales	*Paracoccus*	Species used as a model for studying denitrification
	Rhodobacter	Metabolically versatile purple nonsulfur bacteria
	Roseobacter	Aerobic anoxygenic phototroph
Rhodospirillales	*Acetobacter*	Used industrially for producing acetic acid
	Azospirillum	Obligately aerobic diazotroph
	Gluconobacter	Used industrially for producing acetic acid
	Magnetospirillum	Magnetotactic bacterium
Sphingomonadales	*Sphingomonas*	Aerobic degradation of aromatic organics, biodegradation
	Zymomonas	Ferments sugars into ethanol, potential for biofuel production



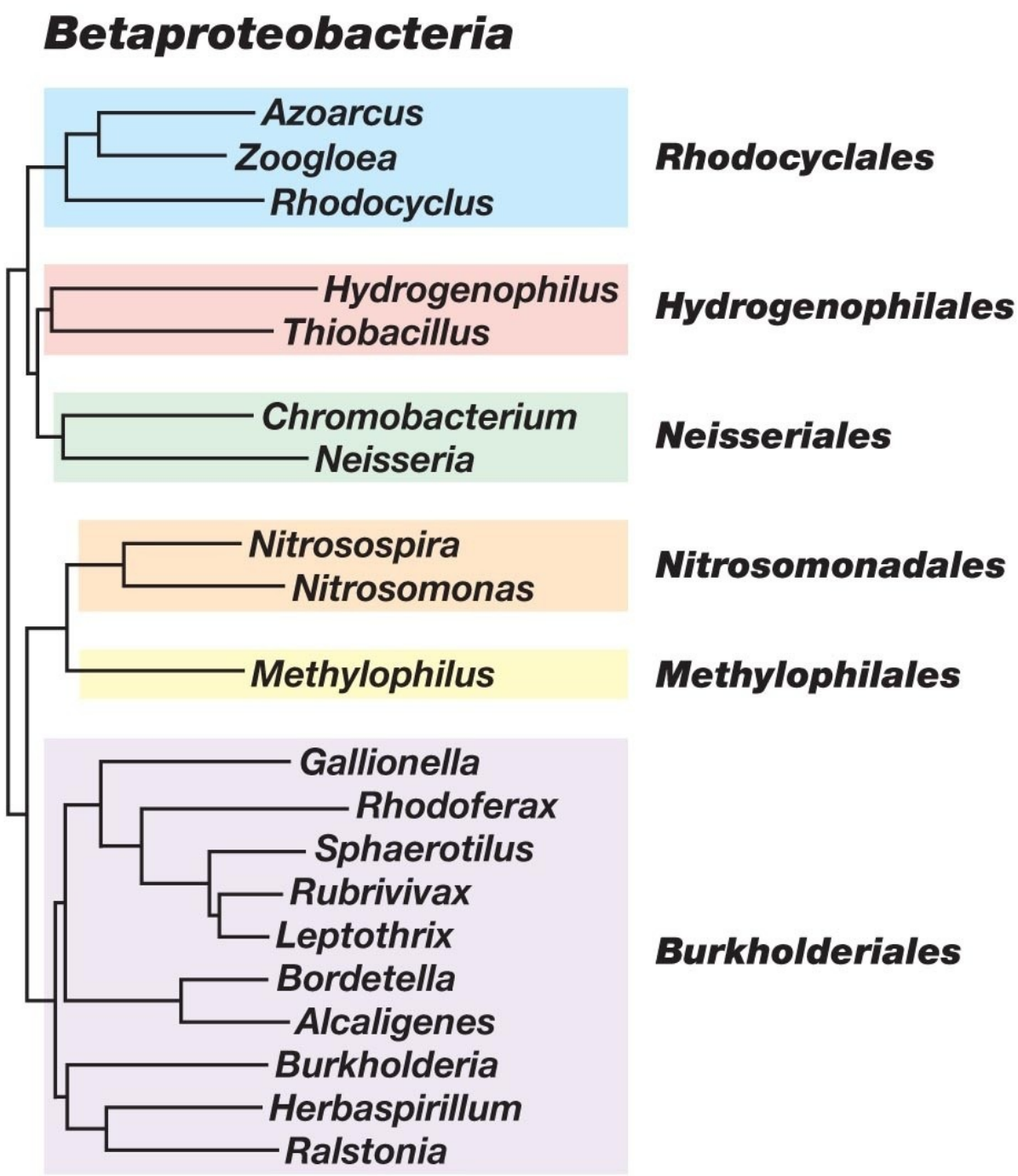
Ca. Pelagibacter ubique

- *Ca. Pelagibacter, with the single species Ca. P. ubique, is an abundant member of the SAR11 clade in the phylum Alphaproteobacteria*
- *SAR11 members are highly dominant organisms found in both salt and fresh water worldwide*
- *It recycles dissolved organic carbon. It undergoes regular seasonal cycles in abundance - in summer reaching ~50% of the cells in the temperate ocean surface waters. Thus it plays a major role in the Earth's carbon cycle*
- *It is rod or crescent shaped and one of the smallest cells known, with a length of 0.37-0.89 µm and a diameter of only 0.12-0.20 µm. 30% of the cell's volume is taken up by its genome*



Proteobacteria: Betaproteobacteria

- *With nearly 500 described species, the Betaproteobacteria are the third largest class of Proteobacteria.*
- *The Burkholderiales contain species with a wide range of metabolic and ecological characteristics. Species include strictly aerobic, facultatively aerobic, and obligately anaerobic chemoorganotrophs, anoxygenic phototrophs, obligate and facultative chemolithotroph*
- *The Betaproteobacteria contain an immense amount of functional diversity, and consist of several groups of aerobic or facultative anaerobic bacteria that are often highly versatile in their degradation capacities, but also contain chemolithotrophic genera (e.g., the ammonia-oxidising genus Nitrosomonas) and some phototrophs (members of the genera Rhodocyclus and Rubrivivax). Pathogenic species within this class are the Neisseriaceae (gonorrhea and meningitis) and species of the genus Burkholderia*
- *The Methylophilales and Nitrosomonadales contain metabolically specialized organisms. Methylophilus species are obligate and facultative methylotrophs that grow on methanol and other C1 compounds, but not on CH4. The order Nitrosomonadales contains obligately chemolithotrophic ammonia-oxidizing bacteria, the key genera being Nitrosomonas and Nitrosospira*

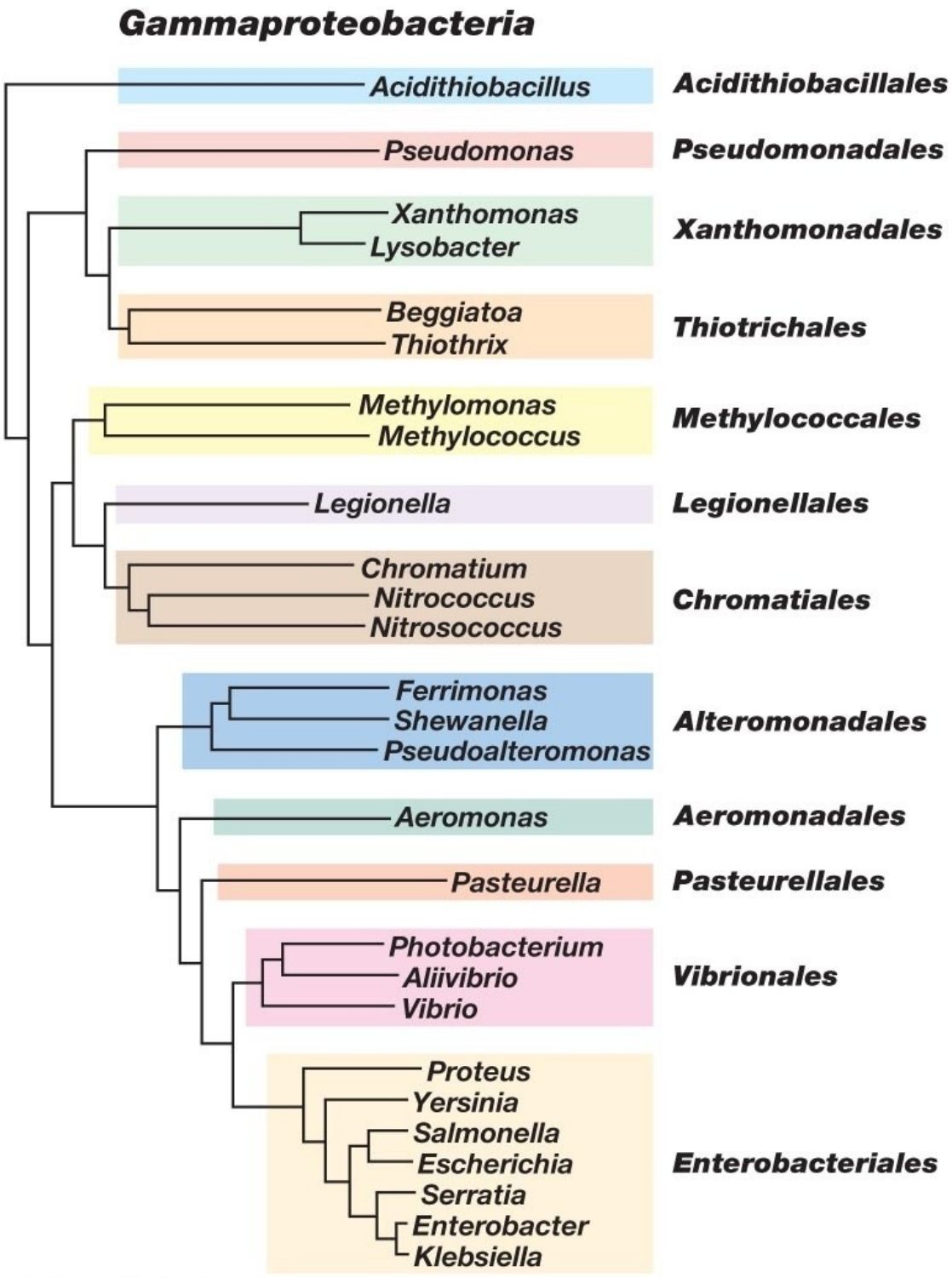

Betaproteobacteria
Azoarcus
Zoogloea
Rhodocyclus
Rhodocyclales
Hydrogenophilus
Thiobacillus
Hydrogenophilales
Chromobacterium
Neisseria
Neisseriales
Nitrosospira
Nitrosomonas
Nitrosomonadales
Methylophilus
Methylophilales
Gallionella
Rhodoferax
Sphaerotilus
Rubrivivax
Leptothrix
Bordetella
Alcaligenes
Burkholderia
Herbaspirillum
Ralstonia
Burkholderiales

Nitrosomonas marina

- *Nitrosomonas is a genus of rod-shaped chemoautotrophic bacteria in the phylum Betaproteobacteria*
- *Nitrosomonas prefers an optimum pH of 6.0-9.0 and a temperature range of 20 to 30°C. Most species are motile with a flagellum located in the polar regions*
- *Nitrosomonas species are aerobic chemolithoauthotrophs using the Calvin cycle and oxidize ammonia to nitrite*
- *Same Nitrosomonas species have been identified as also being able to degrade a variety of halogenated compounds including trichloroethylene, benzene, and vinyl chloride*

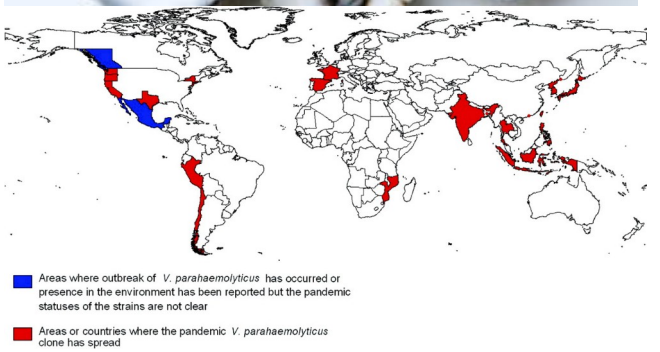
Proteobacteria: Gammaproteobacteria

- *The Gammaproteobacteria comprise several medically, ecologically and scientifically important groups of bacteria*
- *Gammaproteobacteria are major players in diverse marine ecosystems, including extreme environments*
- *The class contains a huge variety of taxonomic and metabolic diversity, including aerobic and anaerobic species, chemolitoauthotrophic, chemoorganotrophic and phototrophic species and include free living, biofilms formers, commensal and symbionts*
- *Chemolitoauthotrophic species use the Calvin cycle to fix CO2, with the exception of the symbionts of the vent tubeworm Riftia which posses also the rTCA cycle*
- *Families of interest include the Thiotrichales and Chromatiales, Pseudomonadales, Vibrionales, Methylococcales and Enterobacterales*


Gammaproteobacteria
Acidithiobacillus
Acidithiobacillales
Pseudomonas
Pseudomonadales
Xanthomonas
Lysobacter
Xanthomonadales
Beggiatoa
Thiothrix
Thiotrichales
Methylomonas
Methylococcus
Methylococcales
Legionella
Legionellales
Chromatium
Nitrococcus
Nitrosococcus
Chromatiales
Ferrimonas
Shewanella
Pseudoalteromonas
Alteromonadales
Aeromonas
Aeromonadales
Pasteurella
Pasteurellales
Photobacterium
Aliivibrio
Vibrio
Vibrionales
Proteus
Yersinia
Salmonella
Escherichia
Serratia
Enterobacter
Klebsiella
Enterobacteriales

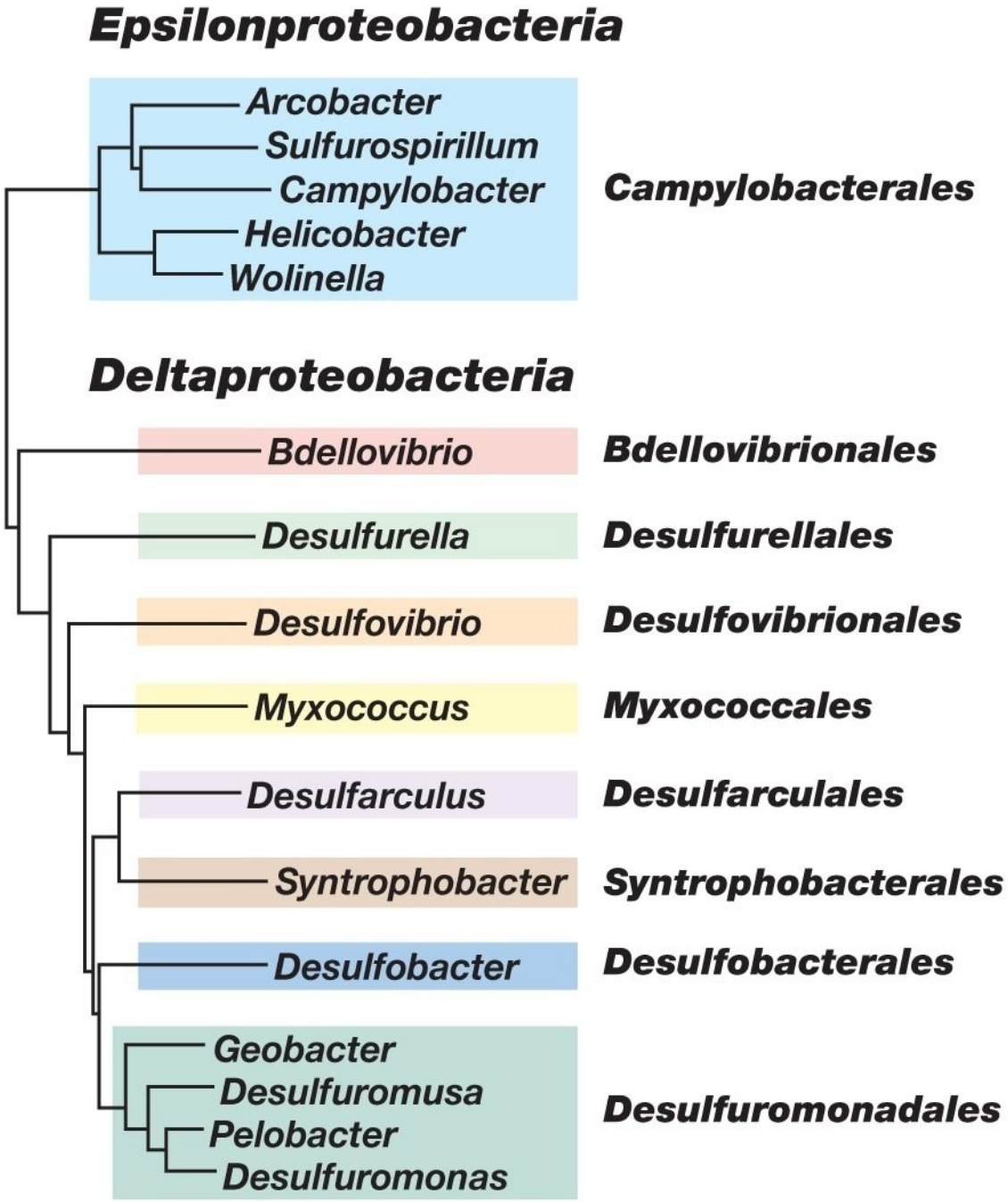
Vibrio parahaemolyticus

- *Vibrio parahaemolyticus is a curved, rod-shaped member of the Vibrionales*
- *It is found in brackish saltwater, and generally associated with shellfish*
- *V. parahaemolyticus is oxidase positive, facultatively aerobic, and does not form spores*
- *It is the predominant cause the acute gastroenteritis caused by V. parahaemolyticus, generally connected to fecal-oral route, ingestion of bacteria in raw or undercooked seafood, usually oysters, squid, makerel, tuna, crabs*
- *Outbreaks tend to be concentrated along coastal regions during the summer and early fall when higher water temperatures favor higher levels of bacteria.*



Proteobacteria: Deltaproteobacteria

- *The Deltaproteobacteria are ubiquitous in marine sediments, and contains most of the known sulfate- (Desulfovibrio, Desulfobacter, Desulfococcus, Desulfonema, etc.) and sulfur-reducing bacteria (e.g. Desulfuromonas spp.) alongside several other anaerobic bacteria with different physiology (e.g. ferric iron-reducing Geobacter spp. and syntrophic Pelobacter and Syntrophus spp.)*
- *The largest and most common order containing sulfate reducers is the Desulfovibrionales, followed by the Desulfobacterales and Desulfarculales. These organisms are readily cultivated from marine sediments and nutrient-rich anoxic environments that contain sulfate*
- *Species of Desulfovibrionales are typically incomplete oxidizers. All use sulfate as the terminal electron acceptor, and all require small organic compounds such as lactate as a source of carbon and energy for growth. Species within the orders Desulfobacterales and Desulfarculales can be complete or incomplete acetate oxidizers. In addition to sulfate, some species in these three orders can also reduce sulfite, thiosulfate, or nitrate, and some are capable of certain fermentations. Some species are able to fix CO2 using the reductive Acetyl-CoA pathway or rTCA cycle*
- *Some but not all Syntrophobacterales are able to reduce sulfate. In nature, however, species of Syntrophobacterales primarily interact with H2-consuming bacteria in a metabolic partnership called syntrophy*


Epsilonproteobacteria
Arcobacter
Sulfurospirillum
Campylobacter
Helicobacter
Wolinella
Campylobacterales
Deltaproteobacteria
Bdellovibrio
Bdellovibrionales
Desulfurella
Desulfurellales
Desulfovibrio
Desulfovibrionales
Myxococcus
Myxococcales
Desulfarculus
Desulfarculales
Syntrophobacter
Syntrophobacterales
Desulfobacter
Desulfobacterales
Geobacter
Desulfuromusa
Pelobacter
Desulfuromonas
Desulfuromonadales

Desulfovibrio desulfuricans

- *Desulfovibrio desulfuricans is a sulfate-reducing bacteria generally found in soils, waters, and the stools of animals, although in rare cases it has been found to cause infection in humans*
- *Desulfovibrio cells typically grow anaerobically, but certain strains have been identified growing in the presence of oxygen. It measures approximately 3 µm by 0.5 µm.*
- *Desulfovibrio is known for its flexbility in response to the extended amount of electron acceptors it utilizes including sulfate, sulfur, nitrate, and nitrite among others*
- *Species of Desulfovibrio were first identified as possible bioremediators. With the ability to reduce several toxic metals such as uranium (VI), chromium (VI) and iron (III)*