procaryotic, archaeal rRNA, isoprenoid glycerol diether or diglycerol tetraether lipids

eucaryotic, eucaryotic rRNA, diacyl glycerol diester lipids

procaryotic, bacterial rRNA, diacyl glycerol diester lipids

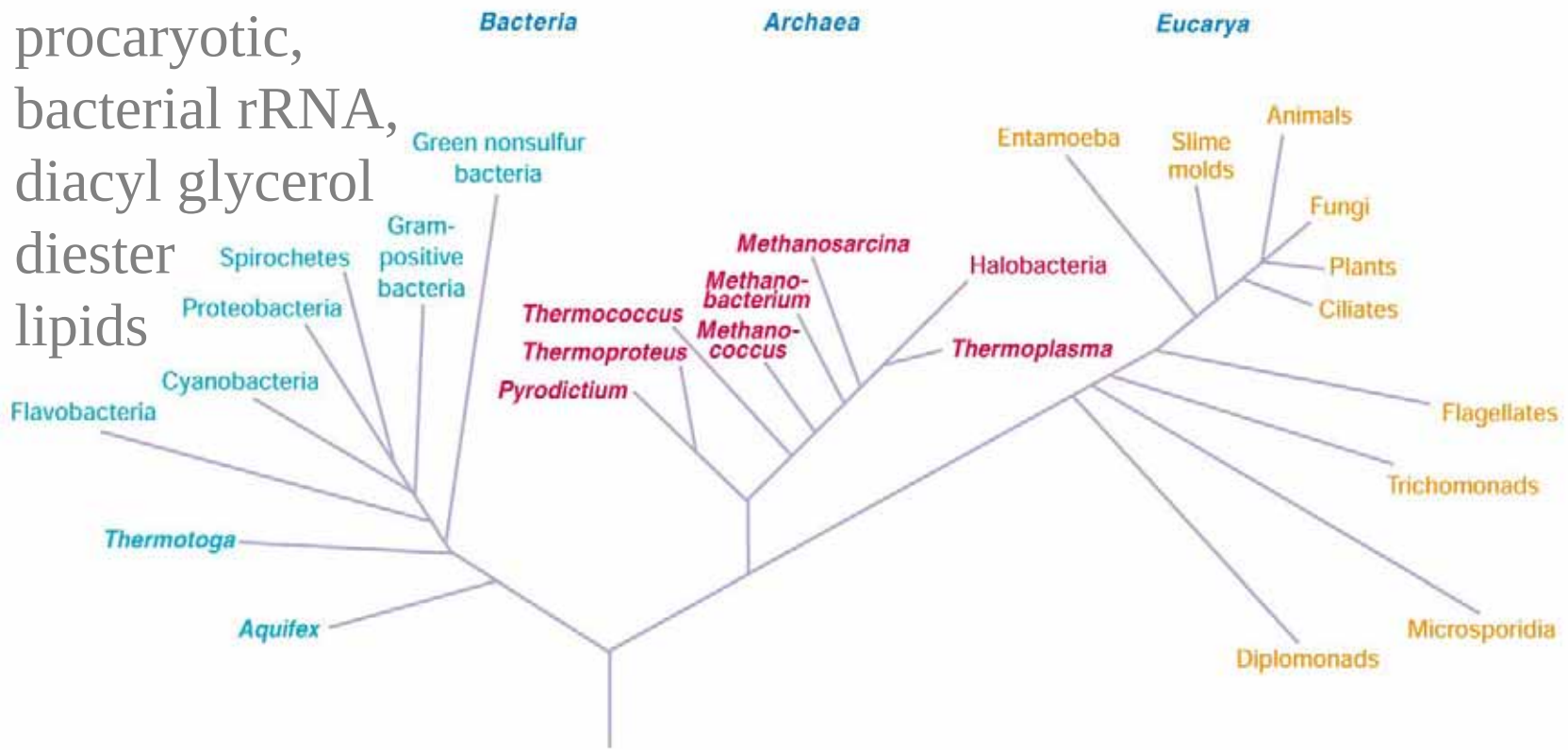

Figure 19.3

Taxonomic Ranks

- microbiologists often use informal names
  - e.g., purple bacteria, spirochetes, methane-oxidizing bacteria

Table 19.1 An Example of Taxonomic Ranks and Names

Rank	Example
Domain	*Bacteria*
Phylum	*Proteobacteria*
Class	γ-Proteobacteria
Order	*Enterobacteriales*
Family	*Enterobacteriaceae*
Genus	*Shigella*
Species	*S. dysenteriae*

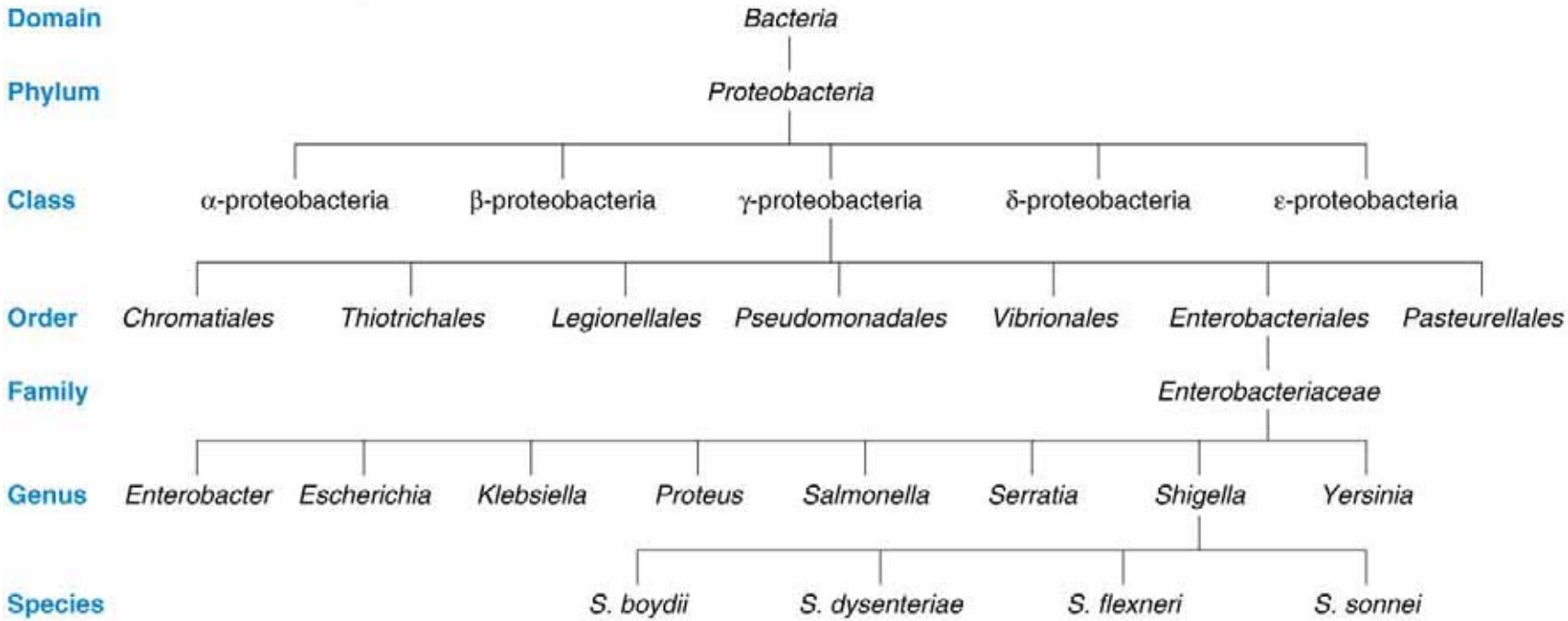

Figure 19.4

genus – well defined group of one or more species that is clearly separate from other genera

Defining procaryotic species

- can’t use definition based on interbreeding because procaryotes are asexual
- possible definitions:
  - collection of strains that share many stable properties and differ significantly from other groups of strains
  - collection of strains with similar G + C composition and $\geq$ 70% sequence similarity
  - collection of organisms that share the same sequences in their core housekeeping genes

Strains

- population of organisms that is distinguishable from others within a taxon
- descended from a single organism or pure culture isolate
- vary from each other in many ways
  - biovars – differ biochemically and physiologically
  - morphovars – differ morphologically
  - serovars – differ in antigenic properties

Type strain

- usually one of first strains of a species studied
- often most fully characterized
- not necessarily most representative member of species

Binomial system of nomenclature

- devised by Carl von Linné (Carolus Linnaeus)
- each organism has two names
  - genus name – italicized and capitalized (e.g., *Escherichia*)
  - species epithet – italicized but not capitalized (e.g., *coli*)
- can be abbreviated after first use (e.g., *E. coli)*

Classification Systems

- natural classification
  - arranges organisms into groups whose members share many characteristics
  - most desirable system because reflects biological nature of organisms
- two methods for construction
  - phenetically
    - grouped together based on overall similarity
  - phylogenetically
    - grouped based on probable evolutionary relationships

Phenetic Classification

- groups organisms together based on mutual similarity of phenotypes
- can reveal evolutionary relationships, but not dependent on phylogenetic analysis
  - i.e., doesn’t weight characters
- best systems compare as many attributes as possible

Phylogenetic Classification

- also called phyletic classification systems
- phylogeny
  - evolutionary development of a species
- usually based on direct comparison of genetic material and gene products

Major Characteristics Used in Taxonomy

- two major types
  - classical characteristics
  - molecular characteristics

Classical Characteristics

- morphological
- physiological and metabolic
- ecological
- genetic analysis

Table 19.3 Some Morphological Features Used in Classification and Identification

Feature	Microbial Groups
Cell shape	All major groups[a]
Cell size	All major groups
Colonial morphology	All major groups
Ultrastructural characteristics	All major groups
Staining behavior	Bacteria, some fungi
Cilia and flagella	All major groups
Mechanism of motility	Gliding bacteria, spirochetes
Endospore shape and location	Endospore-forming bacteria
Spore morphology and location	Bacteria, algae, fungi
Cellular inclusions	All major groups
Color	All major groups

[a]Used in classifying and identifying at least some bacteria, algae, fungi, and protozoa.

Table 19.4 Some Physiological and Metabolic Characteristics Used in Classification and Identification

Carbon and nitrogen sources
Cell wall constituents
Energy sources
Fermentation products
General nutritional type
Growth temperature optimum and range
Luminescence
Mechanisms of energy conversion
Motility
Osmotic tolerance
Oxygen relationships
pH optimum and growth range
Photosynthetic pigments
Salt requirements and tolerance
Secondary metabolites formed
Sensitivity to metabolic inhibitors and antibiotics
Storage inclusions

Molecular Characteristics

- comparison of proteins
- nucleic acid base composition
- nucleic acid hybridization
- nucleic acid sequencing

Nucleic acid sequencing

- usually comparison of rRNA genes
- increasingly, comparison of entire genomes

Molecular Chronometers

- nucleic acids or proteins used as “clocks” to measure amount of evolutionary change over time
- use based on several assumptions
  - sequences gradually change over time
  - changes are selectively neutral and relatively random
  - amount of change increases linearly with time

Problems with molecular chronometers

- rate of sequence change can vary over time
- different molecules and different parts of molecules can change at different rates

rRNA, DNA, and Proteins as Indicators of Phylogeny

- all are used
- do not always produce the same phylogenetic trees

DNA and proteins

- DNA
  - most effective for comparing organisms at species and genus level
- proteins
  - less affected by organism-specific differences in G + C content
  - easier to do sequence alignment
  - proteins evolve at different rates

The Major Divisions of Life

- based primarily on rRNA analysis
- currently held that there are three domains of life
  - *Bacteria*
  - *Archaea*
  - *Eucarya*

Table 19.8 Comparison of *Bacteria, Archaea,* and *Eucarya*

Property	*Bacteria*	*Archaea*	*Eucarya*
Membrane-Enclosed Nucleus with Nucleolus	Absent	Absent	Present
Complex Internal Membranous Organelles	Absent	Absent	Present
Cell Wall	Almost always have peptidoglycan containing muramic acid	Variety of types, no muramic acid	No muramic acid
Membrane Lipid	Have ester-linked, straight-chained fatty acids	Have ether-linked, branched aliphatic chains	Have ester-linked, straight-chained fatty acids
Gas Vesicles	Present	Present	Absent
Transfer RNA	Thymine present in most tRNAs	No thymine in T or TψC arm of tRNA	Thymine present
	N-formylmethionine carried by initiator tRNA	Methionine carried by initiator tRNA	Methionine carried by initiator tRNA
Polycistronic mRNA	Present	Present	Absent
mRNA Introns	Absent	Absent	Present
mRNA Splicing, Capping, and Poly A Tailing	Absent	Absent	Present
Ribosomes			
Size	70S	70S	80S (cytoplasmic ribosomes)
Elongation factor 2	Does not react with diphtheria toxin	Reacts	Reacts
Sensitivity to chloramphenicol and kanamycin	Sensitive	Insensitive	Insensitive
Sensitivity to anisomycin	Insensitive	Sensitive	Sensitive
DNA-Dependent RNA Polymerase			
Number of enzymes	One	Several	Three
Structure	Simple subunit pattern (4 subunits)	Complex subunit pattern similar to eucaryotic enzymes (8–12 subunits)	Complex subunit pattern (12–14 subunits)
Rifampicin sensitivity	Sensitive	Insensitive	Insensitive
Polymerase II Type Promoters	Absent	Present	Present
Metabolism			
Similar ATPase	No	Yes	Yes
Methanogenesis	Absent	Present	Absent
Nitrogen fixation	Present	Present	Absent
Chlorophyll-based photosynthesis	Present	Absent	Present[a]
Chemolithotrophy	Present	Present	Absent

a Present in chloroplasts (of bacterial origin).

Impact of horizontal transfer

- extensive horizontal gene transfer has occurred within and between domains
- pattern of microbial evolution is not as linear and treelike as once thought

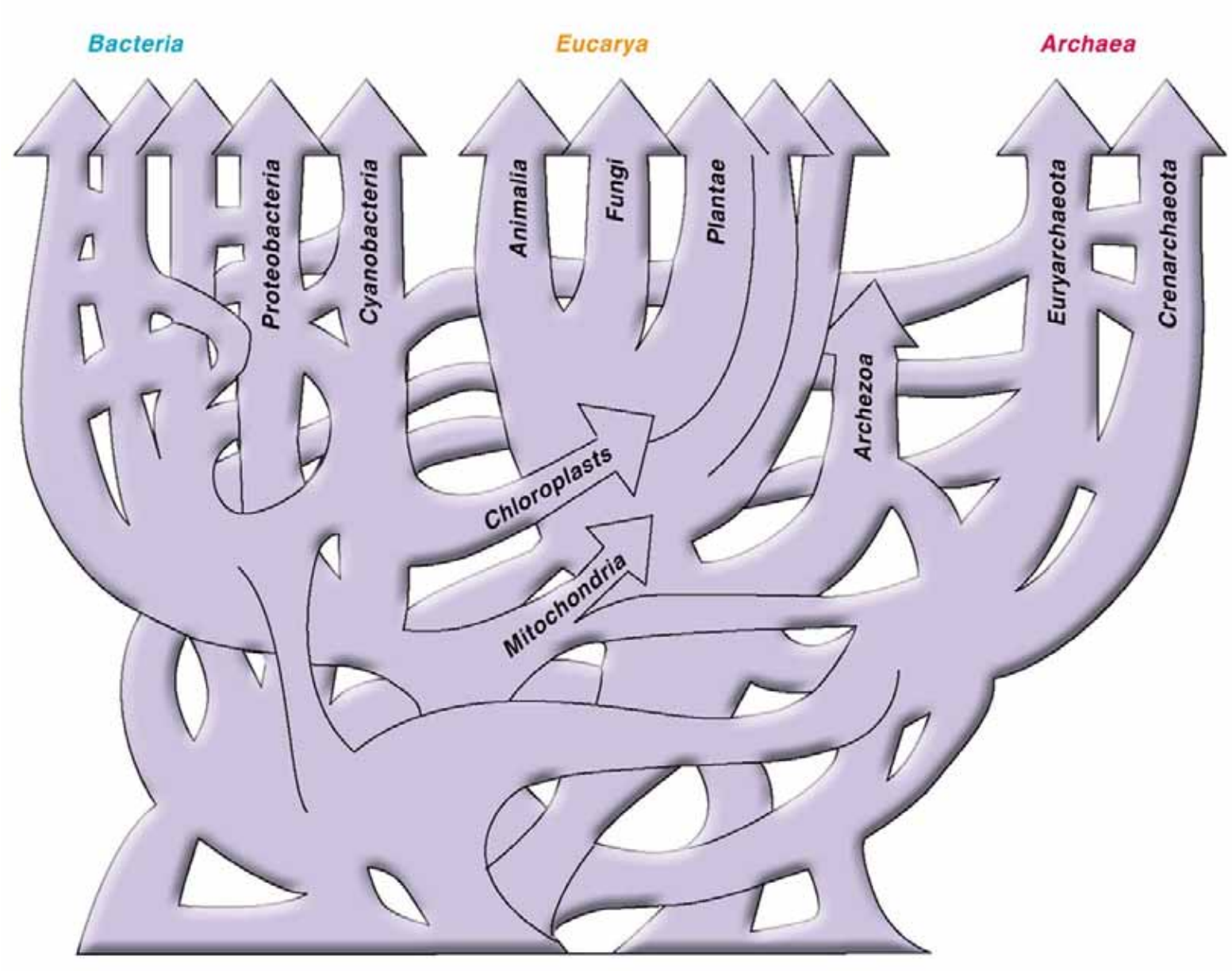
Bacteria
Eucarya
Archaea
Proteobacteria
Cyanobacteria
Animalia
Fungi
Plantae
Archezoa
Euryarchaeota
Crenarchaeota
Chloroplasts
Mitochondria

Figure 19.11

Table 19.9 Some Characteristic Differences between Gram-Negative and Gram-Positive Bacteria

Property	Gram-negative Bacteria	Gram-positive Bacteria	Mycoplasmas
Cell wall	Gram-negative type wall with inner 2–7 nm peptidoglycan layer and outer membrane (7–8 nm thick) of lipid, protein, and lipopolysaccharide. (There may be a third outermost layer of protein.)	Gram-positive type wall with a homogeneous, thick cell wall (20–80 nm) composed mainly of peptidoglycan. Other polysaccharides and teichoic acids may be present.	Lack a cell wall and peptidoglycan precursors; enclosed by a plasma membrane
Cell shape	Spheres, ovals, straight or curved rods, helices or filaments; some have sheaths or capsules.	Spheres, rods, or filaments; may show true branching	Pleomorphic in shape; may be filamentous, can form branches
Reproduction	Binary fission, sometimes budding	Binary fission	Budding, fragmentation, and/or binary fission
Metabolism	Phototrophic, chemolithoautotrophic, or chemoorganoheterotrophic	Usually chemoorganoheterotrophic	Chemoorganoheterotrophic; most require cholesterol and long-chain fatty acids for growth.
Motility	Motile or nonmotile. Flagellation can be varied—polar, lophotrichous, peritrichous. Motility may also result from the use of axial filaments (spirochetes) or gliding motility.	Most often nonmotile; have peritrichous flagellation when motile	Usually nonmotile
Appendages	Can produce several types of appendages—pili and fimbriae, prosthecae, stalks	Usually lack appendages (may have spores on hyphae)	Lack appendages
Endospores	Cannot form endospores	Some groups can form endospores.	Cannot form endospores