Representatives of the Prokaryotic (Chapter 12) and Archaeal (Chapter 13) Domains
(Bergey's Manual of Determinative Bacteriology: Kingdom: Procaryotae (9th Edition)
XIII Kingdoms p. 351-471

Sectn.	Group of Bacteria	Subdivisions(s)	Brock Text	Examples of Genera	Gram Stain	Morphology (plus distinguishing characteristics)	Important Features
12.2 354	Phototrophic bacteria Anaerobic Purple Sulfur Bacteria Table 12.2 p.354	*Chromatiaceae*	356	*Purple sulfur bacteria* *(Chromatiun; Allochromatium)*	*Gram Negative*	Anoxygenic photosynthesis Bacterial chl. a and b Spheres, rods, spirals (S inside or outside)) Anoxic - develop well in meromictic lakes - layers - fresh above sulfate layers - Figs. 12.4, 12.5	Purple nonsulfur bacteria; photoorganotrophic for reduced nucleotides; oxidize H_2S as electron donor for CO_2 anaerobic photosynthesis for ATP S inside the cells except for *Ectothiorhodospira* Major membrane structures Fig.12..3 -- light required.
	Purple Non-Sulfur Bacteria Table 12.3 p. 358	*Rhodospirillales*	358 354, 606 82-83	*Rhodospirillum, Rhodobacter* *Rhodopseudomonas*	*Gram Negative*	Diverse morphology from rods (*Rhodopseudomonas*) to spirals Fig. 12.6	Anoxygenic photosynthesis H_2, H_2S or S serve as H donor for reduction of CO_2; Photoheterotrophy - light as energy source but also directly use organics
12.3 359	Nitrifying Bacteria Chemolithotrophic bacteria Inorganic electron donors Ammonia, nitrite, nitrate	*Nitrobacteraceae* (nitrifying bacteria) (Table 12.4)	361	*Nitrosomonas* *Nitrosococcus oceani - Fig.12.7* *Nitrobacterwinograskii - Fig.12.8*	*Gram negative*	Wide spread , Diverse (rods, cocci, spirals); Aerobic ● ammonia [O] = nitrosofyers - ($NH_3 \rightarrow NO_2$) ● nitrite [O]; = nitrifyers ;($NO_2 \rightarrow NO_3$) Energy generation is small	Obligate chemolithotroph (inorganic e′’ donors) Note major membranes Fig. 12,7) Soil charge changes from positive to negative Difficult to see growth. - Use of silica gel. cf. no organics
12.4 360	Sulfur and Iron oxidizing Bacteria Chemolithotrophic bacteria (Table 12.5) Aerobic	Sulfur and Iron oxidizers Proteo-bacteria ; α, β, or γ Proteo - gamma	360 361 363	**Thiobacillus ferro oxidans* *T. thiooxidans* *Beggiatoa - facultative* *Fig. 12.11 chemoautotroph* *Thioploca* *Thiothrix Fi. 12.13* *Thiomargarida*		Fe">Fe" Short rods pH 1-3.5 (Not S) pH 1.3 Discoverers - Jaffe and Waksman, Cook College gliding filaments (pH 6-8); in H_2S environments. Mixotrophic growth - chemoautotroph but cannot fix CO_2 S oxidizer. pH 6.8. [O] H_sS. Also converts nitrate to nitrogen gas H_2S [O] (Internal S) (v. large - 0.5 mm wide!!!)	Oxidation of reduced sulfur compounds (H_2S, S^1, etc.) Acid production helps in the release of Fe but is also the cause of acid mine wastes The growth of *Beggiatoa* allowed Winogradsky to develop the concept of chemoautotrophy. Also Rhizosphere - rice - detoxifies H_2S - loose symbiosis. Can be one of the causes of the bulking of sewage Marine mats. CO_2; H_sS. and nitrogen cycling
12.5 363	Hydrogen oxidizing bacteria a diverse property	*[O] Hydrogen* *Table 12.6* p365	363	*Ralstonia Fig.12.14* *Alcaligenes* *Hydrogenobacter*	*Gram Negative*	[0] hydrogen	Tend to be facultatively chemoautotrophs Include carbon monoxide users *Pseudomonas carboxydovorans*
12.6 365	Methanotrophs & Methylotrophs (microbes using C1 compounds	Proteobacteria gamma gamma alpha	365Tab,12.7 367	*Methylomonads Methylomonas* *Methylobacter* *Methylosinus*	*Gram negative*	Rod N.b. Fig.12.15 - membranes Coccus ellipsoid Rod	C_1 (Methanol) use Ribulose monophosphate to fix carbon dioxide C_1 (Methanol) uses Ribulose monophosphate to fix carbon dioxide C_1 (Methanol) serine pathway to fix carbon dioxide In gill tissue of mussels as symbionts (Fig.12.67)
12.7	*Pseudomonas* and Pseudomonads aerobic rods	Table 12.10 Table 12.11 (pathogens)	368 371 Tab) 371 368, 939	*Pseudomonas aeruginosa* *Commamonas testeroni* *Burholderia cepacia* *Ralstonia solancearaum* *Xanthomonas* *Zymomonas* *Zooglea*	*Gram Negative*	General: Straight or curved rods; – polar flagellation Aerobic, chemoorganotrophic Never fermentative Use of diverse substrates; opportunistic pathogen Grows on testosterone Nutritionally versatile - some plant pathogens Plant pathogen (others spp. use H_2,) Necrotic rots of many plants Ethanologen, Non specific vaginitis Sewage flocs (activated sludge) Fig. 28.7 p. 941	N_2 fixation (free/symbiotic) Ps. Phyllosphere/pathogen burns, Cystic Fibrosis Entner Doudoroff pathway Fig. 12.17 Pulque in Mexico and Brazil drink. Beer contaminant - hydrogen sulfide

12.8 371	Acetic Acid Bacteria	Page 371		*Acetobacter *Gluconobacter*	*Gram Negative*	Incomplete [O] of substrates ethanol ➜ acetic acid glucose ➜ gluconic	Ac =ethanol to acetic acid = vinegar (wine) Can form cellulose pellicles sorbitol ➜ sorbose used for vitamin C synthesis
12.9 372	Free-living aerobic Nitrogen Fixers	Page 372	Fig. 12.9	*Azotobacter* *Azospirillum Beirjerinckia* *Azomonas Derxia gummosa*	*Gram Negative* *Fig.12.21*	Fix N_2 - free living – pleomorphic rods (lge 2-4µm) cysts– Fix nitrogen - soil- & associated with plant roots spirals Fix nitrogen - aquatic - rods no cysts	*A. chrococcum* Beijerinck & then Lipman - *A. vinelandii (NJ).* In addition to the classic nitrogenases this group has 2 further alternative nitrogenases - vanadium + Fe, and another based on Fe (cf. normal Mo system). Proposed as a replacement for corn fertilizer
12.10	Cocci bacilli diverse group non-motile anaerobic	Neisseriaceae Table 12.13	374--477	*Neisseria* *Chromobacterium* *Acinetobacter* *Legionella Gamma p.860's*	Gram negative negative	Flattened cocci to short rods Rods purple pigment Short plump rods twitch v. small rods	*N. gonorrhoeae* and *N. meningitidis* *(Penicillin)* Soil microbe - pigment with tryptophan Fig. 12.22 Nutritionally versatile Legionaire's disease (air conditioners)
12.11 p.375	Gram-negative facultative anaerobic rods oxidase negative	*Enterobacteriaceae* 12.10 (p.375) ENTERICS	479 *480-4811*	*Escherichia *Erwinia,* *Proteus, Fig.12.26* *Salmonella p.378 "n" others [Table 12.15.-- p377] *Enterobacter*, p.379 *Serratia* p.379	Gram negative butanediol fermenters (neutral pH)	Small rods; peritrichous flagellation or nonmotile IMViC Indole Methyl red Voges Proskauer. citric acid Fig. 12.24 – Tables 12.15 and 12.16 Salmonella - Typhoid Mary p.853 common water and soil (diagnosis = not *E. coli*) prodigiosin - once a germ warfare test organism	E. coli 0157: H7/Traveler's disease Heterotrophic; *Salmonella* (800 serotypes), Typhoid; intestinal upset (eggs). Shigella Chemoorganotrophic *Color Fig 12.27*
		Yersinia	926	Discussed under disease *Yersinia pestis - plague*		Ring-a ring-a -roses	
12.12 p.379	*Vibrio Photobacterium*	*Vibrionaceae*	380 380	*Vibrio* *Photobacterium*		Short straight or curved rods; polar flagella Vibrios – Oxidase positive; fermentative (Enterobacteriaceae oxidase negative, fermentative Pseudomonadales - oxidase positive; non-fermentative) (photoluminescence - Figs. 12.28 p.380) Saprophytes and also in marine fish organs	*V. cholerae* - cholera see later Chapters 28.5 and p. 855 (John Snow) *V. parahaemolyticus* - acute enteritis *V. fischeri* Luciferase enzyme is autoinduced (N-β-ketocaproyl-homoserine lactone). Density sensitive induction (Quorum sensing) - not occur when free swimming
12.13	Rickettsias & Chlamydias (Table 12.17)		381 Table 12.17 Fig. 12.29 Fig. 383 382 382	*Rickettsia rickettsii* *R. typhi,* *R. prowazekii* *Wolbachia* *Coxiella burnetti* *Ehrlichia*	*Gram-negative*	Often small and pleomorphic (cocci rods) Obl. intracellular parasites - Ticks (goats/cattle) ATP DEPENDENT Arthropods and respiratory route sporelike form (milk) Tick borne ehrlichiosis	Fastidious (obligate intracellular parasites) Rocky Mountain Spotted Fever Typhus Louse; Typhus flea Insect symbiont. Plus coversion of males into females. Q fever (p. 920 - bioterroism?) Ehrlichiosis

12.14 p 383	SPIRILLA Spiral and curved bacteria. Aerobic/Micro-aerophilic. Spp. 1832 Ehrenfeld created the genus	Spirillum; Bdellovibrio; Campylobacter Table 12.18 Non motile gram curved bacteria	383 Table 12.18 385 384 386 386	*Aquaspirillum GC 38* α *or* β *Azospirillum GC 42-51* α **Spirillum GC70* β *S. volutans* *Magnetospirillum magnetotacticum Proteo-* α *Bdellovibrio delta* *Campylobacter epsilon* *C. fetus* *C. jejuni* *Helicobacter pylori epsilon* *Ancyclobacter* *Brachyarcus*	***Gram Negative***	Facultative anaerobes, some are pathogens Spiral Spiral Spiral 0.5 to 60 μm (non-pathogenic) volutin granules (polyphosphate Fig. 12.31) Tuft of polar flagella - monstrous Fig. 31.31c 5-40 magnetic particles / cell; oxic/anoic interface Move to the north or the south according to position Curved rod (0.5 μm); Figs.12.32. bloody diarrhea cattle abortion Chronic gastritis; ulcers; Curved rod (0.5μm) *A. aquaticus* - gas vesicles Fig. 4.55-58 p.94-95	Chemoorganic - Aquatic Symbiotic N_2 fixation "in" roots Chemoorganotrophs; free-living *E. coli* pathogen (4hr cycle; plaques); intraperiplasmic Human and Animal Pathogen Stomach pathogen Unusually shaped curved cells; Diverse chemo-organotrophs - waters and soils
12.15 387	Sheathed Proteo bacteria	Sphaerotilus *Leptothrix*	387 388	**Sphaerotilus* (sewage "fungus") Fig. 12.35 *Leptothrix* (Fig. 12.36)	*Negative*	*Rods; flagellated; sheathed; often grow in long filaments* *NOT A FUNGUS* *Fe^{++} crusts*	Can oxidize and precipitate metals (iron): manganese oxides and hydroxides. - strict aerobe Papermill effluents, trickling filter, sewage sludge digestors May clog water systems.
12.16 389	Budding and/or appendaged bacteria (Prosthecate// stalked)	(Table 12.19 p. 389)	390 392 392	**Hyphomicrobium* *Caulobacter* *Gallionella*	*Negative*	*Buds from apex of hyphae* *Stalk; rosette Fig. 12.42* *Ferric hydroxide Fig. 12.44 Excreted stalk*	Metabolize one-carbon compounds (e.g., methanol) (Dilute !) Chemoorganotrophic. Low concen. nutrients Chemolithotroph (may clog water systems due to production of insoluble iron compounds).
12.17	Gliding Myxobacteria Tab. 12.10	*Myxobacterales*	393 393	*Myxococcus* *Stigmatella*	*Negative*	*Glide; form fruiting bodies with myxospores (Myxocysts)* *Fruiting cycle Fig.12.47*	Some species predatory on other bacteria. Fruiting -- Soil, bark + agar (or rabbit dung)
 12.18 397	Dissimilatory SO_4/S[R] Table 12.21 p.500 Sulfate and Sulfur reducing bacteria	Mainly delta Proteobacteria	500 Table 12.21 List 24 spp!	*Desulfovibrio* *Desulfobacter* *Desulfuromonas* *Desulfotomaculatum*	*Negative* *Positive*	Curved rod Coccoid/ovoid to (CO_2) Ovoids rods Endospores (to acetate CO_2)	Anaerobic respiration: $SO_4 \rightarrow H_2S$ Use lactate, ethanol, as electron donors Venice, Italy; AngkorWat, Cambodia S° to H_2S blackened sandy beaches Canned food - sulfide stinker

12.19 399	KINGDOM II G+ve Gram-positive cocci (Aerobic or facultatively anaerobic)	*Micrococceae* *Staphylococci*	Table 12.22 p. 399	*Micrococcus (High GC = Lactobacillus)* *Staphylococcus*	*Positive*	Single or grape clusters. Fig 12.52 Salt tolerant - skin (Street vendor Food - Mayonnaise - 12/24 hr.	Chemoorganotrophs Fermentative some pathogenic *Staph . aureus* pimples, boils; sepsis; toxic shock syndrome ; β-lactams Food enterotoxins 6 hr Lobster
			400	*(Gaffkya -- lobster pathogen)* *Sarcina (8's - cubes)*		Ear wax. *S. ventriculi* -	Acid tolerant - stomach // pyloric ulcerations also cases of "drunks"
	LACTIC ACID BACTERIA	Streptococcus Leuconostoc Lactobacillus	Table 12.23 & 12.24 403	*Streptococcus; Lactococcus; Leuconostoc; Pediococcus GC=* *Lactobacillus has many species of diverse GC ratio*	*Positive*	Lack cytochromes (no TCA cycle) Substrate level phosphorylation anaerobic but tolerate oxygen pairs, chains. Fermentative (Strep throat)	Homo-fermenters ➜ lactic acid Heterofermenters ➜ lactic acids, plus ethanol carbon dioxide, etc (lack aldolase can only [O] Glc.6.P to 6 phospho-gluconate ➜ pentose path See Fig.12.53
				Streptococcus;		Streptococcus;	Buttermilk, silage; nosocomial spread; Dental plaque *Strep . pyogenes* - β-hemolytic (clearing of blood plates) Rheumatic fever Lancefield antigenic typing
			401-2	*Leuconostoc;*	*Positive*	Leuconostoc; heterofermentative; dairy starters	Flavor diacetyl and acetoin from citrate Polysaccharides dextrans -blood extenders; also levans
			399, 659	*Ruminococcus*	*Positive*	obligate anaerobe: cellulolytic in the rumen	
	Gram-positive Asporogenous Irregular Rods Anaerobic	*Lactobacillaceae* (Table 12.23)	403	*Lactobacillus*	Positive	Rods/chains sometimes	Fastidious; anaerobic or facultative; chemoorganotrophic. Yogurt, sauerkraut, olives, cheese, pickles.
			(404, 952) Not in Brock	*Listeria* *Caryophanon*		Animal pathogen *L. monocytogenes* Organic fecal matter - cow dung	Cheese contamination (Pathogen) Rods - 3 *u*m width
12.20 404	Endospore-forming Low GC- Gram Positive Rods and cocci	Table 12.26 Bacillus	405	*Bacillus* (aerobic or facultative anaerobe) Table 12.27	Positive	*B. stearothermophilus* thermophile *B. thuringiensis* - Insecticide *B. anthracis* - Anthrax *B. coagulans* - flat sour Hot springs 70°C	Chemoorganotrophic. Lytic - cellulose, pectins Highly resistant endo-spores Antibiotics bacitracin; polymyxin; tyrocidin Parasporal protein insecticide - genetically engineered into plants
		Thermoanaerobacter Clostridium	404 407	*Clostridium*		ANAEROBIC Spores	*Clostridium botulinun* - botulism; *C. perfringens* - gangrene and also food poisoning. *C. tetani* - tetanus *C. acetobutylicum* acetone// butanol *C. pasteurianum* nitrogen fixation
			64, 65	*Epulopiscium* (600µm)		v. large bacterium	60- 1,000 µm
			408	*Sporosarcina*		unique endospores from a coccus	*S. . ureae* urea degradation to $CO_2 + NH_3$ ➜ soil pH rises
			409	*Heliobacter*		phototrophic. strict anaerobes Cell bundles (Fig. 12.62)	Nitrogen fixation in paddy fields
12.21 409	Mycoplasmas (pleuropneumonia group or PPLO) (Table 12.28; p..410)	*Mycoplasmataceae* cell walls are lacking	409	*Mycoplasma*	Positive but no cell wall	Minute!! no cell wall ("soft skin - mollicutes"); "fried egg" colonies (Fig. 12.63); p. 411); small cells 0.2-0.3 micrometers (genome 600-1250 Kb)	Require sterol but can have supportive lipoglycans (some species do not require sterols). Small *M. genitalium* sequences (530Kb). Pneumonia and other diseases
			411	*Spiroplasma* (Table 12.28)		v.v. small	Plant disease (stubborn citrus; corn stunt); animal spiroplasmas of bees and beetle. A species induces the female status in *Drosophila* (Fig. 12.64).

12.22 412	High GC Irregular Rods	Corynebacteria and Propionic bacteria	412 412 412	*Arthrobacter (also p. 520 Actinos)* *Corynebacterium Brevibacterium* *Propionibacterium*	Positive	Sphere to rods: irregular rods - arthrospores (Fig. 12.67) Soil & dead plant material Irregular rods - snap: V's -- - saprophytes and diverse animal and plant pathogens (Section 23.2). Lactate to proprionate plus carbon dioxide Fig.12.68	Organotrophs Diphtheria/Mono sodium glutamate (MSG) Cheese (Swiss Emmentaler) - gas cheese holes; acne p.730
12.23 12.24	High GC Gram-positive MYCOBACTERIA ACTINOMYCETES (Tables 12.30)	Mycobacteria Table 12.29 *Streptomycetaceae* *Thermoactinomycetes*	415 416 416 417	*Mycobacterium* *Streptomyces* (500 spp.) *Oerscovia* *Nocardia* *Cellulomonas* *Bifidobacterium* *Thermomonospora*	Gram Positive; also mycolic acids	rods, pleomorphic; mycolic acids *M. tuberculosis,* *M. avium M. bovis* *M. leprae,* Fast growing strains *M. smegmatis; M phlei* Hyphae; conidia; Gram-positive Irregular rods to mycelium Cellulolytic Branched cells Hypha; (*Microbispora* - double -spores)	T. B. virulence correlated to glycolipid (cord factor Fig. 12.71) also can affect man - opportunistic infection for instance in relation to AIDS leoprosy Aerobic soil; slow, efficient, degradation - lysis organic matter - soil GEOSMIN; Antibiotics (streptomycin, neomycin) Tab.12.31 Cellulolytic Colostrom - transient growing on mother's "milk" at birth 65°C Compost (White fang) 5
12.25	KINGDOM III Cyanobacteriales (Blue-green bacteria) Prochlorophytes	>1000 spp. (170 → 22 genera)	421 Table 12.32	*Gloeothece (single cells)* *Lyngbya, Oscillatoria , Spirulina* *single cell filaments* *Nostoc, Anabaena filaments, H* *Stigonematalean* *Fisherella (branching)*		1-2 microns to large filaments 60 microns Fig.12.78 Hyphal/Heterocysts/chl. a Fig.12.80 Nitrogen storage in cyanophycin (10% cell - aspartic arginine polymer page 422) Hormogonia fragment ➜ akinetes Some have gas vacuoles Only form one of Chlorophyll = Chl. a; Phycocyanins (blue) and phycoerythrins (red)	Photosynthesis (thylakoids) N_2-fixation (nitrogenase oxygen protected in heterocysts) Phycobiliproteins Some spp. glide also produce geosmin - see Actinomycetes Cyanobacterial Mats (evolutionary remnant?) Symbiont with *Azolla* water fern (rice paddies) and liverworts and cycads. Also with some animals (Tunicates)
12.26	Prochlorophytes		424	*Prochloron*		Chlorophyll a and b (like green algae and not like Blue greens which only have Chl. a. Note membranes Fig.12.82-83	Symbionts with marine invertebrates -(didemnid ascidians) Idea of the original chloroplast endosymbiont, as it has Chl. a and b, and not phycobilins. Even so it is not thought to be directly linked to the algae
12.27	KINGDOM IV Chlamydia (Classification being developed Endosymbionts in Protozoa/Insects/ Fungi/Arthropods	Three species Table 12.33 T12.34 Rickettsia Chlamydia, Virus	425	*Chlamydia pneumoniae;* *C. trachomatis (also STD)* *Cycle Fig.12.85* *C. psittaci* *Caedibacter* *(e.g. Kappa of Paramecia)* *Not in Brock Atlas p. 996*	*Negative*	Respiratory pneumonial syndromes - airborne Leading human blindness disease - scars the cornea Also the leading STD -Lymphoma venereum Parrot disease (and humans) Symbionts ????	Very small (0.5 µm) intracellular Enters by cell phagocytosis of the elementary body - quite resistant. In the cell it converts to the vegetative form and replicates as a "reticulate body" , and then reverts to the "elementary body". Energy intermediates from the host cell - but the genome shows genes for synthesis of ATP. Penicillin insensitive but murein synthesis genes are present Kills sensitive Paramecia strains
12.28	KINGDOM V	Planctomyces/Pirella	Membranes	*Nucleus in membrane p.428*		*Gemmata* Unique stalked bacterium -	No cell wall murein. - Protein S-sheath. Novel group See Fig. 12.86

12.29	VERRUMICROBIA		429	*Warty*		*Verrumicrobia* Fig.12.88	Completely distinctive group. Aerobic. Soil - degradative (NEW)
12.30	KINGDOM VI Gram-negative bacteria (Straight, curved). Identification FAME p. 344	*Bacteroidaceae* (plus curved and helical bacteria) *Cytophagales*	ANAEROBIC 430 AEROBIC 430	*Bacteroides* *Flavobacterium* *Cytophaga Fig. 12.90*	*Gram Negative*	Pleomorphic rods ; obligately anaerobic. Intestinal commensals . Dominate the intestine. up to 10^{11}/ml. Periodontitis can cause occasional diarrhea Aerobic, aquatic. limited nutrition. Yellow colonies Slender rods, aerobic. Glide. No fruiting bodies Lytic Needs solid to grow on - cellulose agar.(GC 30-70%)	Chemoorganotrophic; Form sphingolipids (Fig. 12.89) in place of glycerol *F. menigosepticum* can cause infant meningitis 2 pathogens. of fish *C. columnaris* and *C. psychrophila* (strongly proteolytic)
12.32	KINGDOM VII 432	Green Sulfur Bacteria *Chlorobium* *Prosthecochloris* *Pelodictyon* Diverse group	Anaerobic photo-synthesis	*Chlorobium*		Anoxygenic photosynthesis H_2S or S serve as H donor for reduction of CO_2; S outside of the cell -Strict autotrophy by reverse Calvin cycle. Photoheterotrophy - light as energy source but also directly use organics	Ecologic yellowish Sulfuretum plus bright green bacterium - Fig. 12.91. Chlorosomes around the periphery of the cell contain bacterial Chl. a, and one of Chl. b, c, or d. Bacterial consortia can aggregate with an organotroph. **Such consortia** have been termed "Chlorochromatium aggregatum" (1 green + 12 bacteria) p.433
12.33	KINGDOM VIII The Spirochetes - tightly coiled	*Spirochaetales* 434 Table 12-36 p.436	 435 436 437 437	*Spirochetes* *Spirochaeta* *Cristispira* *Treponema* *Leptospira* *Borrelia* *(Clevelandia)*	All Negative	Slender, flexuous, helical, 3 to 250 µm long, central axial filament = Endoflagella , (flagella + outer flexible sheath) Free living anaerobes or facultative anaerobes Syphilis: *Treponema pallidum* = focus but its 53% GC is distant from others at 25-40% *T. denticola* teeth, and *T. saccharophilum* (bovine rumen) are commensals. Polysaccharases Leptospirosis - kidney infection even death **Lyme** disease *B. burgdorferi* {*Ixodes* tick}; Relapsing fever *B. recurrentis* {louse}	Chemoorganotrophic; general saprophytes but some species fastidious and are pathogenic Glycolysis in some spp. One termite gut species converts H_2 + CO_2 to acetate - a homoacetogen *Cristispira* in the bivalve mollusc associated with the degradative Style - syphilis---anaerobic never grown in pure culture One of a few bacteria with a linear chromosome Untreated can cause death (40%) of cases. Tetracycline sensitive (Cockroaches - wood)
12.34	KINGDOM IX	Deinococci *Thermus*	438	*Deinococcus* *Thermus aquaticus*	 *Negative*	Radiation resistant. 5 Gy kill a human - Resistant to 30,000 Gy (1 Gy = 100 rad). DNA Repair mechanisms Hot water pipes 70°C. *Taq* DNA polymerase	
12.35	KINGDOM X	The Green Nonsulfur Bacteria	439 439-40	*Thermomicrobium* *Chloroflexus Fig. 12.101* *Heliothrix*	*Negative*	Rod, aerobic, 75°C. Membrane lipids are 1,2-dialcohols (not ester or ether linkages Fig. 12.100). Esp. at neutral to hot alkaline springs. A "blend of purple and green sulfur bacterial photosynthesis (details in text)	

12.36 12.37	KINGDOMS XI, XII XIII Hyperthermophiles 442		441 441 442 442	**Thermotoga* Fig. 12.102* *Thermodesulfobacterium* *Aquifex* *Thermocrinus*	*Gram Negative*	Rods with a toga (Fig. 12.10); chemo organotroph Growth at 80°C up to. 90°C. ether -lipids; chemo-autotrophic Growth at only 70°C Highest for a bacteria sulfate reducer Unique ether -lipids (C_{17} hydrocarbons Fig. 12.102) Deepest branch of the Bacteria Fig 12.1. Pink streamer. Yellowstone 1966 Brock	Hyper thermophile (70-90°C) Terrestrial & marine Can grow organotropically - source of thermally stable polysaccharase enzymes ("Beano")autotrophic in Italy Obligate chemo- autotroph. (H_2, S^0, or S_2O_3 as electron donors, and O_2 or NO_3 as electron acceptors and grows up to 95°C Has a reverse citric acid cycle (cf. green sulfur bacteria). A rare aerobic hyperthermophile. Genome has been sequenced. Early model life form along with certain Archaea. Fig. 12.104 Evidence of life in boiling water

	Archaebacteria (Chapter 13; p. 1056) Chapter 17; p. 937	*Methanobacteriales* Table 16-36 and 18-23 (p. 1080)	940 1069 1061	*Methanobacterium CO_2 - Reduction p. 1080		Diverse; cocci, rods, spirals (G + tve but lack murein; also G=ve and G + ve) Fluorescence (CoEnz F 420) Protozoan endosymbionts	Obligate anaerobes Energy from oxidation of H_2 and $CO_2 \rightarrow CH_4$ Rockingham George Washington
	1. Euryarchaeota p. 939 Methanococcales	Methanococus	1079				(1066-[R} Acetyl CoA for CO_2
	Methanobacteriodes		1076			Rod	
		Thermoplasma					
	Methanomicrobiales	Haloferax	1061	*Halobacterium* (Fig. 18.30: p.1085)		> than 15% salt	20% NaCI: bacteriorhodopsin
	Thermophiles - sulfur dependent		1077 1059	*Natrobacterium* (Table 18-10: p. 1086)		G-ve Rod. S. [O]; H_2SO_4 p. 1084 Protein wall.	Low Mg. pH10
	Halophiles		1064 1084	*Sulfolobus* *Archaeoglobus* (1067)		Only [SO_4] Reduction	
			1065 1087	*Thermoplasma* (1062)		(p. 1074) 60 - 90°C. [R] Acetyl CoA for CO_2 fixation; Wall-less 60°C pH 2.0	Hot (70°C), acid pools. Coal refuse piles
	2. Crenarchaeota p. 938 Pyrodictium (Heat -1076)						
	Sulfolobus						
			1088	*Pyrodictium* *Pyrococcus furiosus*		sulfur metabolism *P. brockii* -105°C 105-112°C	Ocean thermal vents
	3. Korarchaeota p. 571						

	Gram-negative anaerobic cocci	*Veillonellaceae*	Not cited 684	Veillonella Megasphaera Butyrivibrio Brucella Bordatella Francisella tularense		Single, clusters, nonmotile Curved rod Whooping cough (pertussis) Tularemia	Chemoorganotrophic (complex requirements - CO_2) oral cavity Beer contaminant Cellulolytic, rumen
	Pasteurellaceae			*H. influenzae - meningitis (fastidious)*		Pasteurella - compromised hosts	