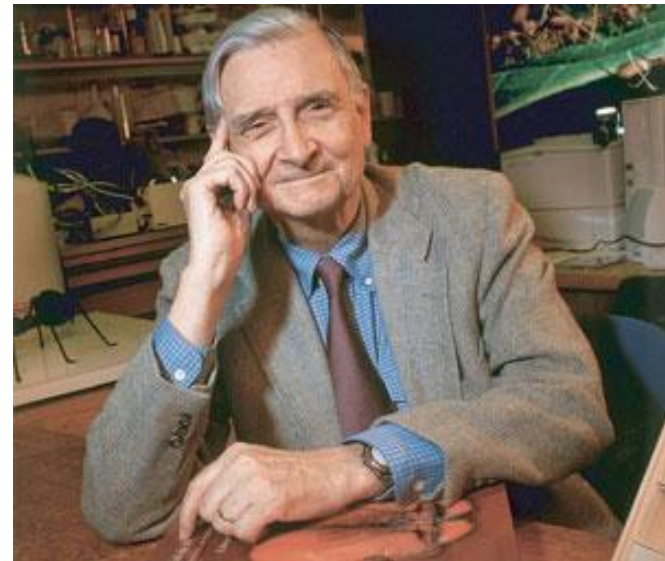


Lecture 4 – Diversity of Prokaryotes

‘If I could do it all over again, and relive my vision in the twenty-first century, I would be a microbial ecologist. Ten billion bacteria live in a gram of ordinary soil, a mere pinch held between thumb and forefinger. They represent thousands of species, almost none of which are known to science. Into that world I would go with the aid of modern microscopy and molecular analysis.’

E.O. Wilson



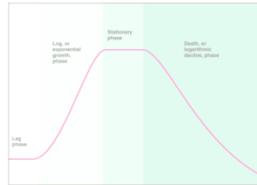


Prokaryotes versus Eukaryotes

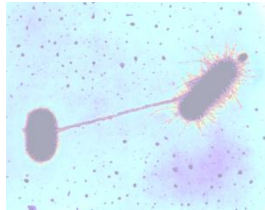
Replication



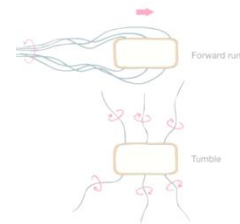
Growth



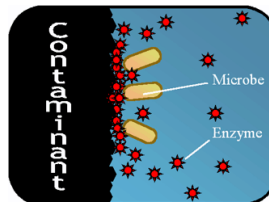
Sex?



Movement



Metabolism



Most plants are photoautotrophs and all animals are chemoheterotrophs

		Carbon Source	
		CO ₂ : <i>AUTOTROPH</i>	ORGANIC COMPOUNDS: <i>HETEROTROPH</i>
Energy Source	LIGHT: <i>PHOTO-</i>	Most Plants	
	CHEMICAL: <i>CHEMO-</i>		All Animals All Fungi

Photoautotrophs may, or may not, produce oxygen



Rhodospirillum
Purple Bacteria
PhotoAutotroph
Oxidizes Sulfur

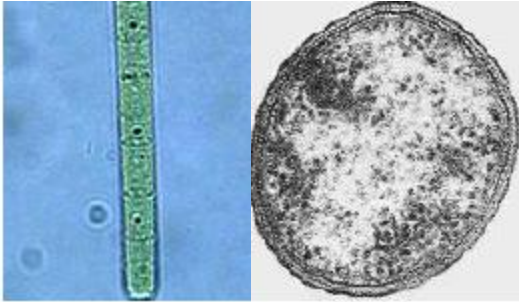
Chlorobium
Green Sulfur Bacteria
PhotoAutotroph
Oxidizes Sulfur

Blue-green algae
Photoautotroph
Produces oxygen

Carbon Source

		Carbon Source	
		CO ₂ : AUTOTROPH	ORGANIC COMPOUNDS: HETEROTROPH
Energy Source	LIGHT: PHOTO-	Prokaryotes	Prokaryotes
	CHEMICAL: CHEMO-	Prokaryotes	Prokaryotes

Photoheterotrophs are photosynthesizers that require carbon in organic form.



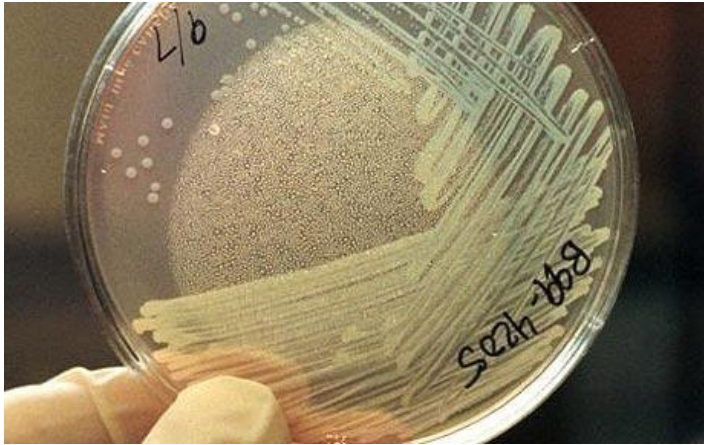
Chloroflexus
Green Filament
PhotoHeterotroph

Heliobacterium
Gram Positive
PhotoHeterotroph

Carbon Source

		CO ₂ : AUTOTROPH	ORGANIC COMPOUNDS: HETEROTROPH
		Energy Source	LIGHT: PHOTO-
CHEMICAL: CHEMO-	Prokaryotes		Prokaryotes

Most of the bacteria we can know are chemoheterotrophs
 – but these are the easiest to culture



		Carbon Source	
		CO ₂ : AUTOTROPH	ORGANIC COMPOUNDS: HETEROTROPH
Energy Source	LIGHT: PHOTO-	Prokaryotes	Prokaryotes
	CHEMICAL: CHEMO-	Prokaryotes	Prokaryotes

Chemoautotrophs derive energy from chemical reactions and synthesize all necessary organic compounds from carbon dioxide

		Carbon Source	
		CO ₂ : <i>AUTOTROPH</i>	ORGANIC COMPOUNDS: <i>HETEROTROPH</i>
Energy Source	LIGHT: <i>PHOTO-</i>	Prokaryotes	Prokaryotes
	CHEMICAL: <i>CHEMO-</i>	Prokaryotes	Prokaryotes

Within the chemoautotrophs there is a wide range of metabolic diversity.

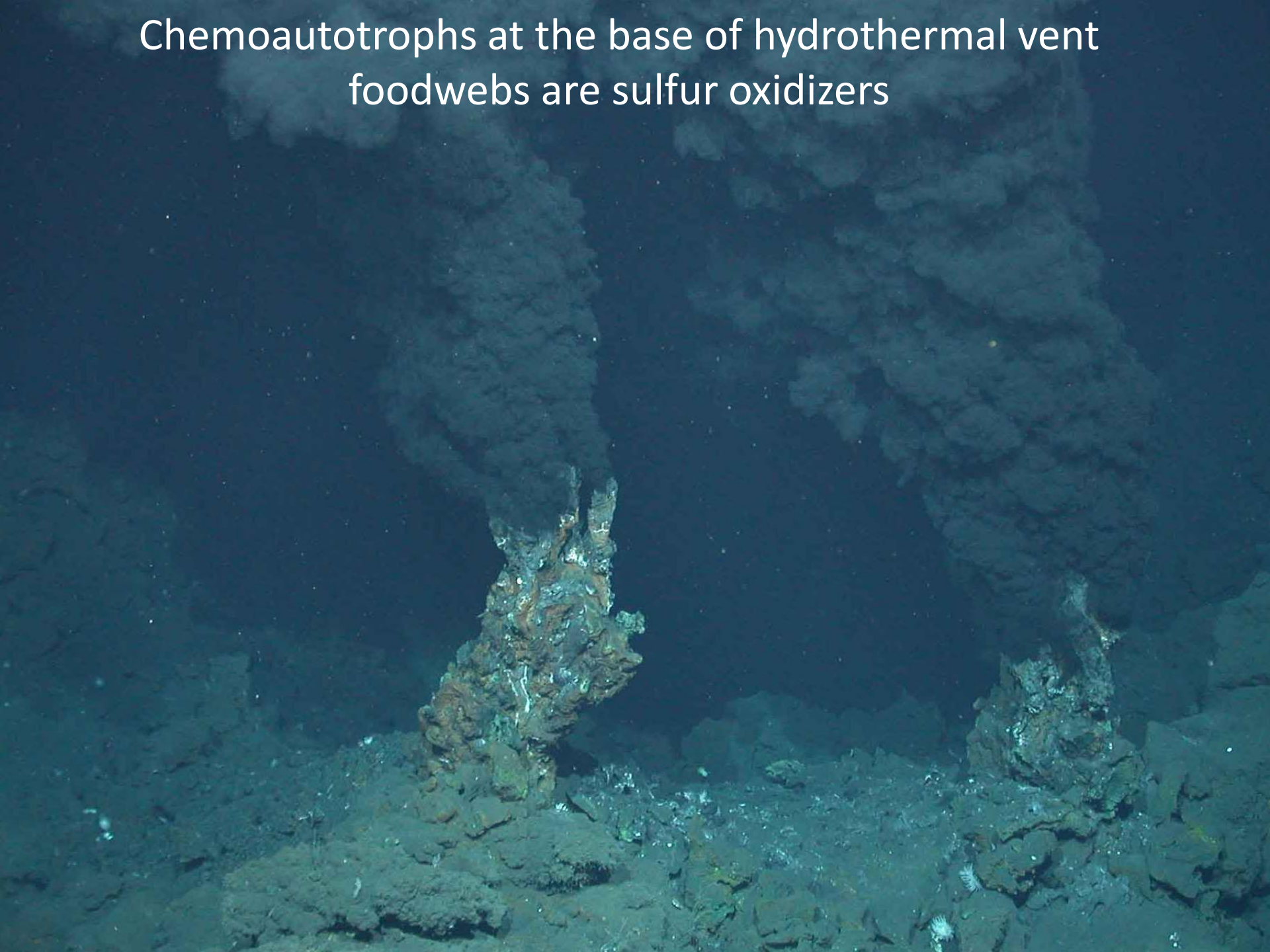
Some Electron Donors and Acceptors Used by Bacteria and Archaea

<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Product</u>	<u>Metabolic Strategy *</u>
H ₂ or organic compounds	SO ₄ ²⁻	H ₂ S	sulfate-reducers
H ₂	CO ₂	CH ₄	methanogens
CH ₄	O ₂	CO ₂	methanotrophs
S or H ₂ S	O ₂	SO ₄ ²⁻	sulfur bacteria
organic compounds	Fe ³⁺	Fe ²⁺	iron-reducers
NH ₃	O ₂	NO ₂ ⁻	nitrifiers
organic compounds	NO ₃ ⁻	N ₂ O, NO or N ₂	denitrifiers (or nitrate reducers)
NO ₂ ⁻	O ₂	NO ₃ ⁻	nitrosifiers

* This column gives the name biologists use to identify species that use a particular metabolic strategy

Some examples only, this is NOT a complete list!

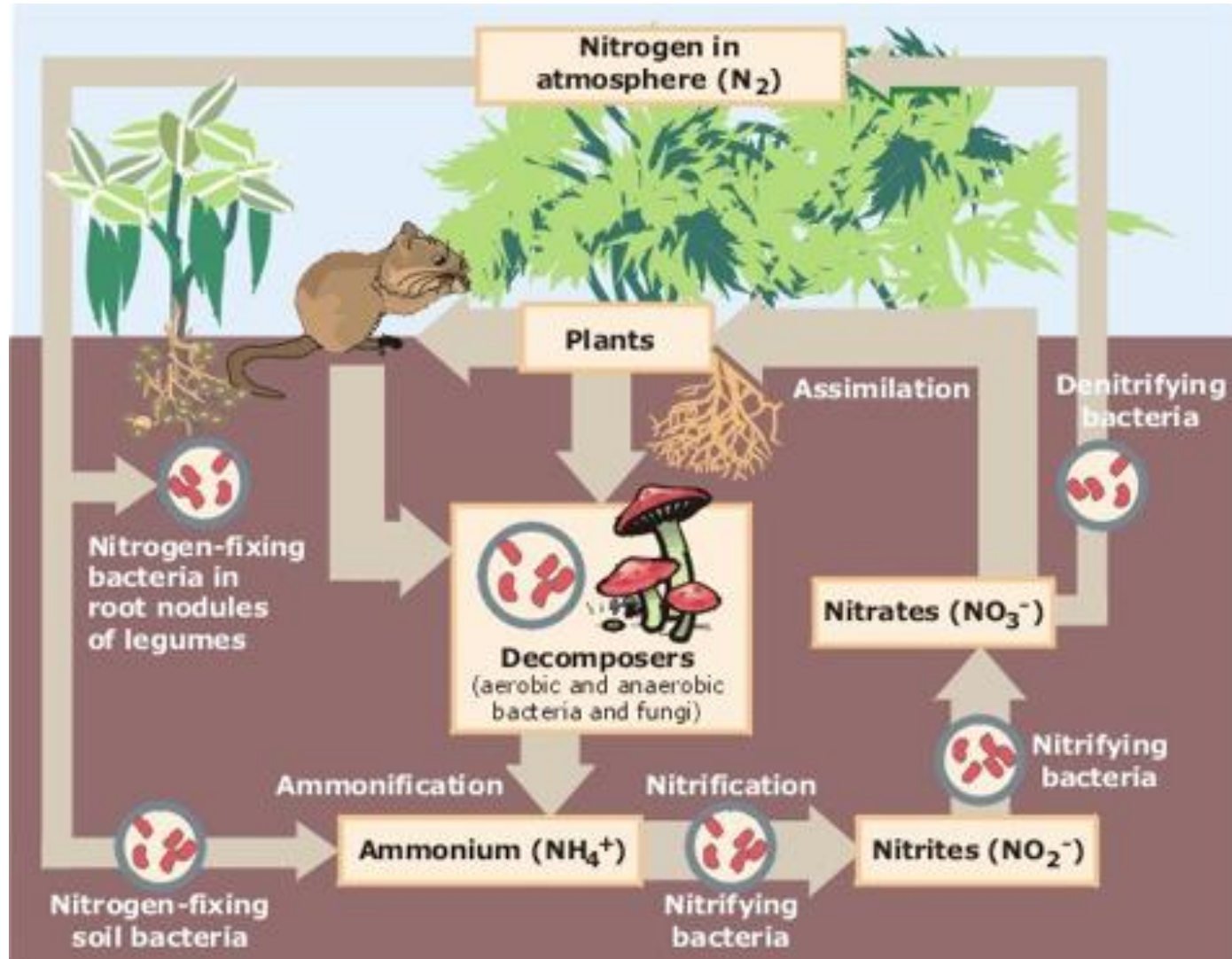
Chemoautotrophs at the base of hydrothermal vent foodwebs are sulfur oxidizers



Tube worms in these ecosystems can grow several meters long and have no mouth no digestive tract.



Both nitrifying and denitrifying bacteria are chemoautotrophs



All methanogens are in the Archaean domain.

Some Electron Donors and Acceptors Used by Bacteria and Archaea

<u>Electron Donor</u>	<u>Electron Acceptor</u>	<u>Product</u>	<u>Metabolic Strategy *</u>
H ₂ or organic compounds	SO ₄ ²⁻	H ₂ S	sulfate-reducers
H ₂	CO ₂	CH ₄	methanogens
CH ₄	O ₂	CO ₂	methanotrophs
S or H ₂ S	O ₂	SO ₄ ²⁻	sulfur bacteria
organic compounds	Fe ³⁺	Fe ²⁺	iron-reducers
NH ₃	O ₂	NO ₂ ⁻	nitrifiers
organic compounds	NO ₃ ⁻	N ₂ O, NO or N ₂	denitrifiers (or nitrate reducers)
NO ₂ ⁻	O ₂	NO ₃ ⁻	nitrosifiers

* This column gives the name biologists use to identify species that use a particular metabolic strategy

Energy
Source

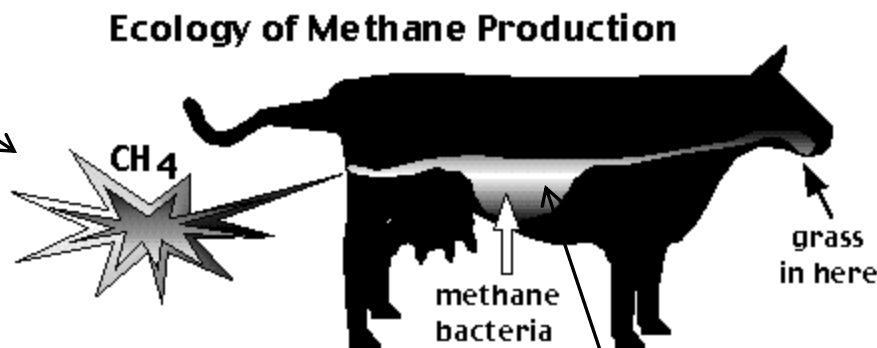
CHEMICAL:
CHEMO-

Prokaryotes

Prokaryotes

Methanogens are chemoautotrophs that produce methane
– a potent greenhouse gas.

Ignition source is
required before
cow explosion



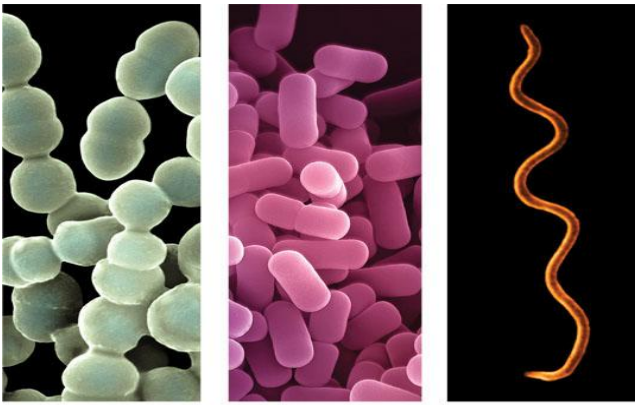
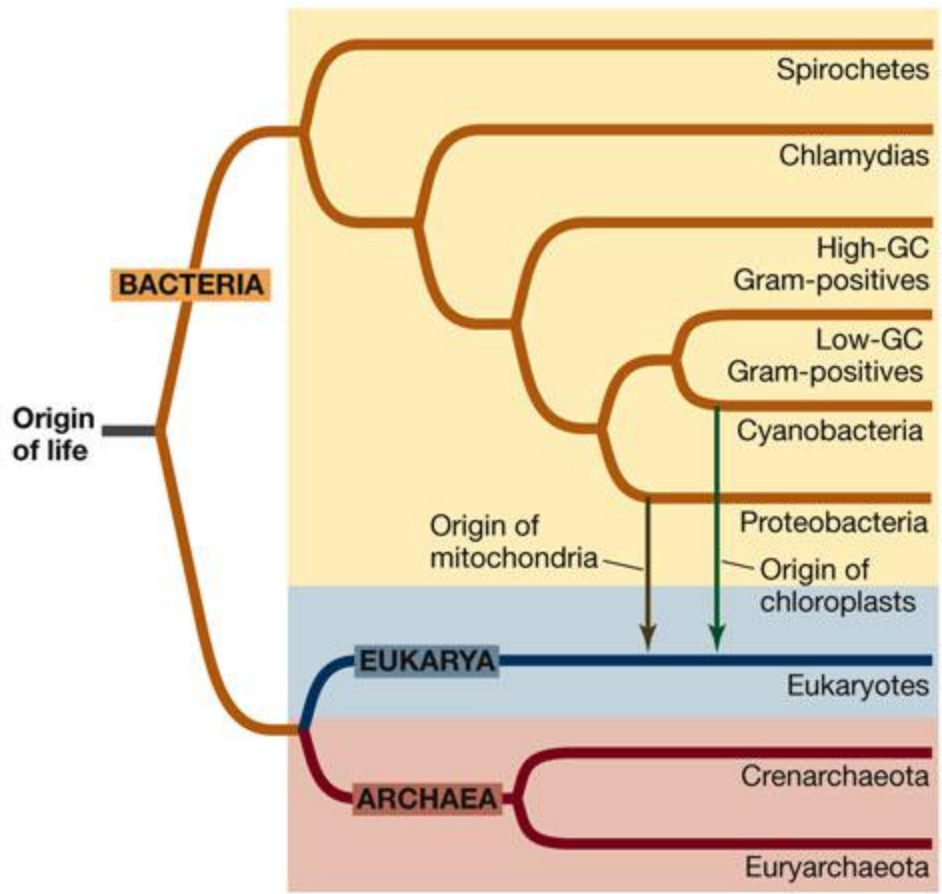
All methanogens
are Archaea not
bacteria.

Key fact missing:
methanogens produce
methane from the H₂ and
CO₂ released by other
anaerobic gut bacteria.

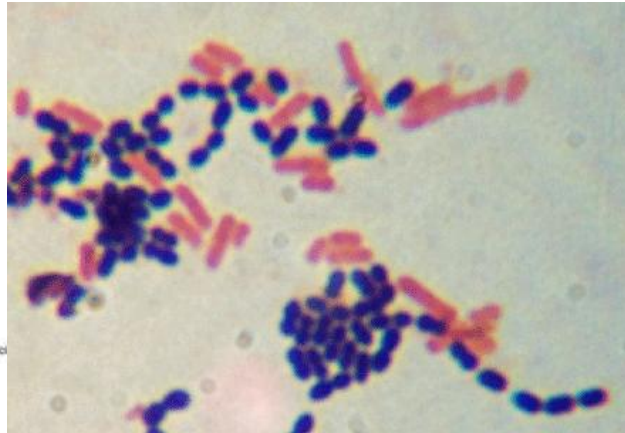
Maybe it's a bad omen...



Historically bacteria were largely grouped by shape and how they stained (reflecting the type of cell wall).



Coccus Bacillus Spirillum




















Gram+ (blue) and Gram- (pink)

LIFE 9e, Figure 26.11

© 2011 Sinauer Assoc.

Bacterial shapes and arrangements

 Coccus		 Rod, or Bacillus		 Curved forms: Spirillum/Spirochete
 Diplococci (cocci in pairs)	 Neisseriae (coffee-bean shape in pairs)	 Coccobacilli		 Vibrios (curved rods)
 Tetrads (cocci in packets of 4)	 Sarcinae (cocci in packets of 8, 16, 32)	 Mycobacteria	 Corynebacteria (palisades arrangement)	 Spirilla
 Streptococci (cocci in chains)	 Micrococci and staphylococci (large cocci in irregular clusters)	 Spore-forming rods	 Streptomycetes (moldlike, filamentous bacteria)	 Spirochetes

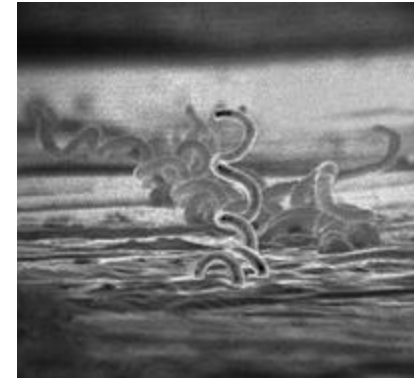
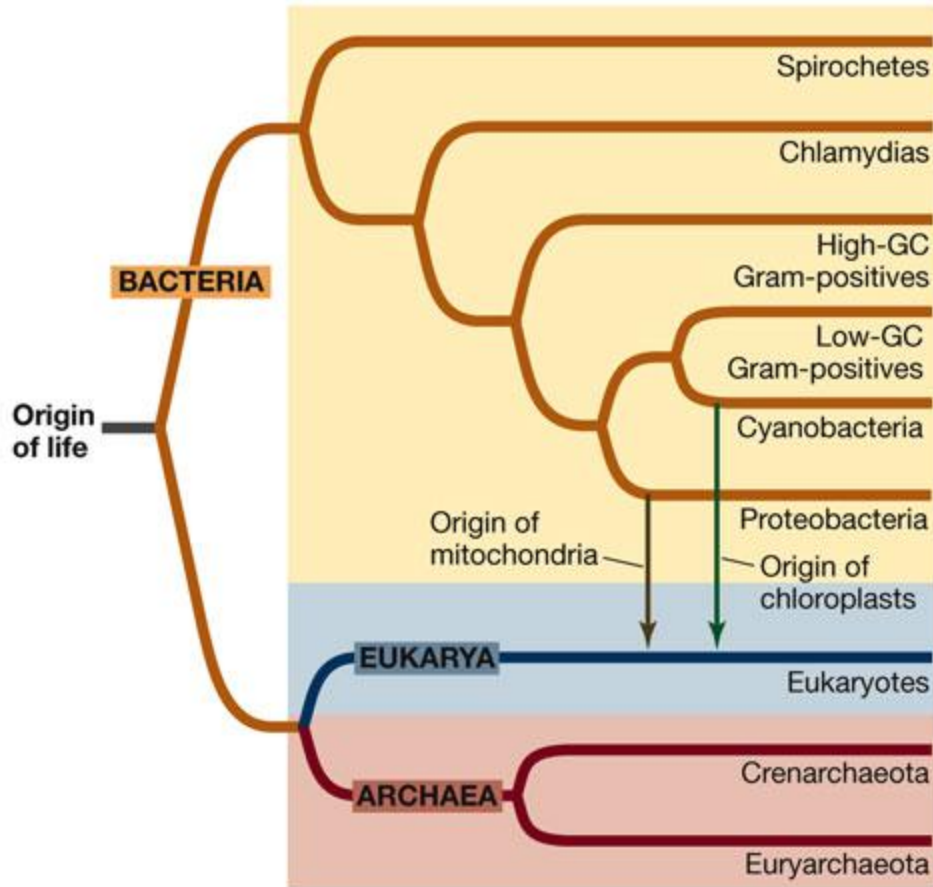
Streptococcus pharyngitis

Mycobacterium tuberculosis

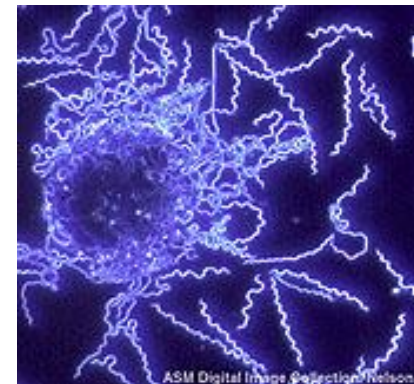
Vibrio cholerae



All spirochetes are chemoheterotrophs and have a long, slender, coiled shape.

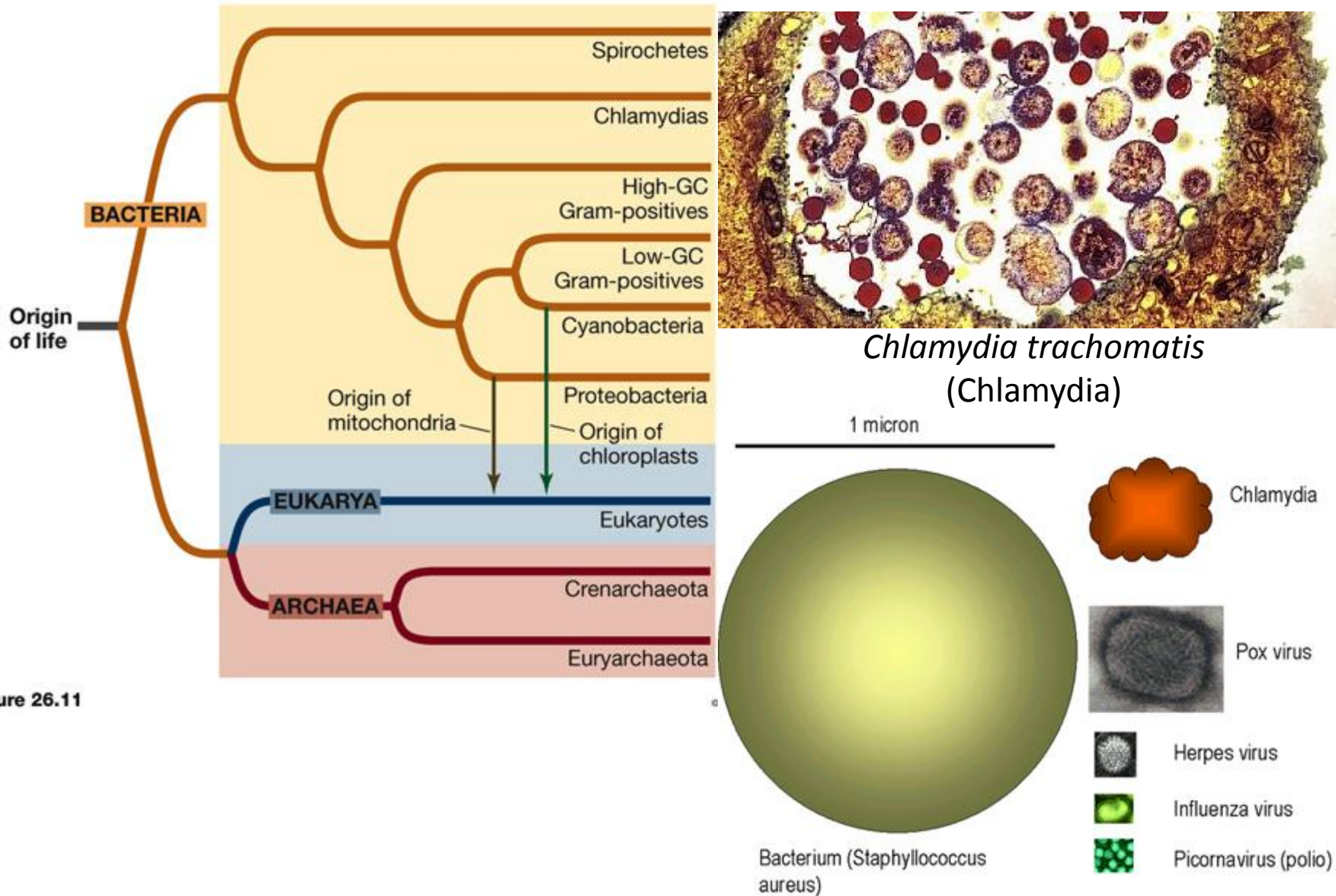


Treponema pallidum
(Syphilis)



Borrelia burgdorferi
(Lyme disease)

Chlamydias are all very small intracellular parasites you don't want to meet.

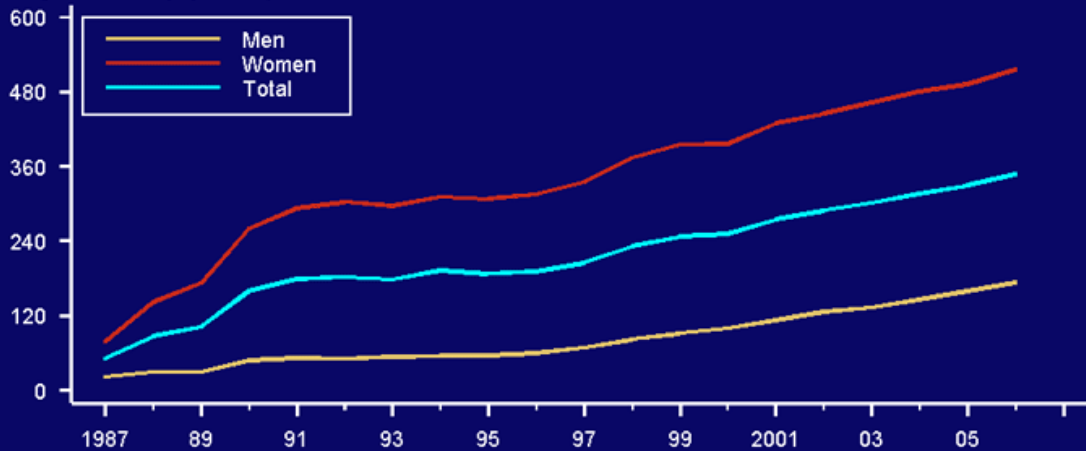


LIFE 9e, Figure 26.11

The United States has a *Chlamydia trachomatis* epidemic with 3 million estimated cases per year and rising.

Chlamydia — Rates: Total and by sex: United States, 1987–2006

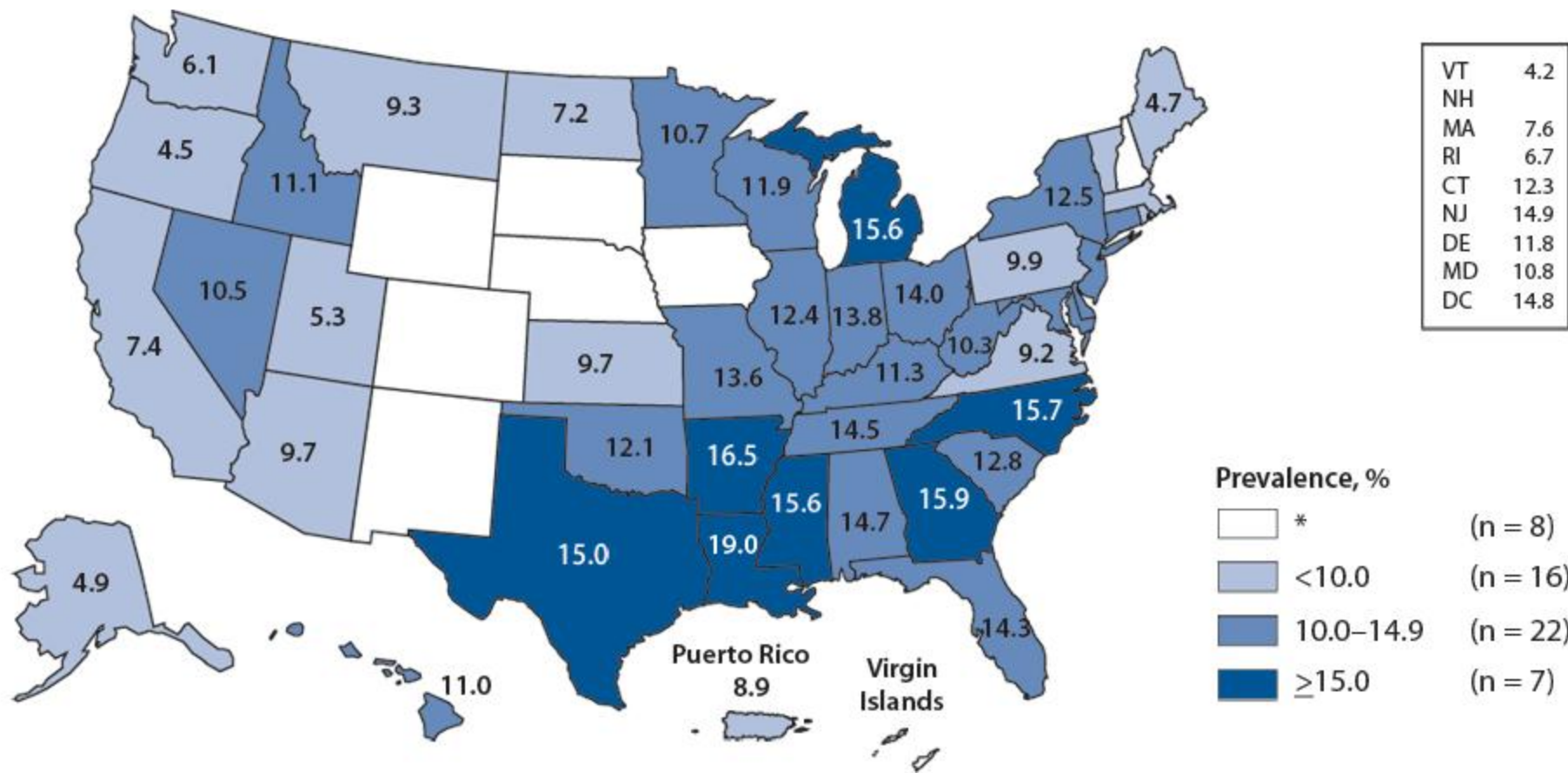
Rate (per 100,000 population)



Note: As of January 2000, all 50 states and the District of Columbia had regulations requiring the reporting of chlamydia cases.

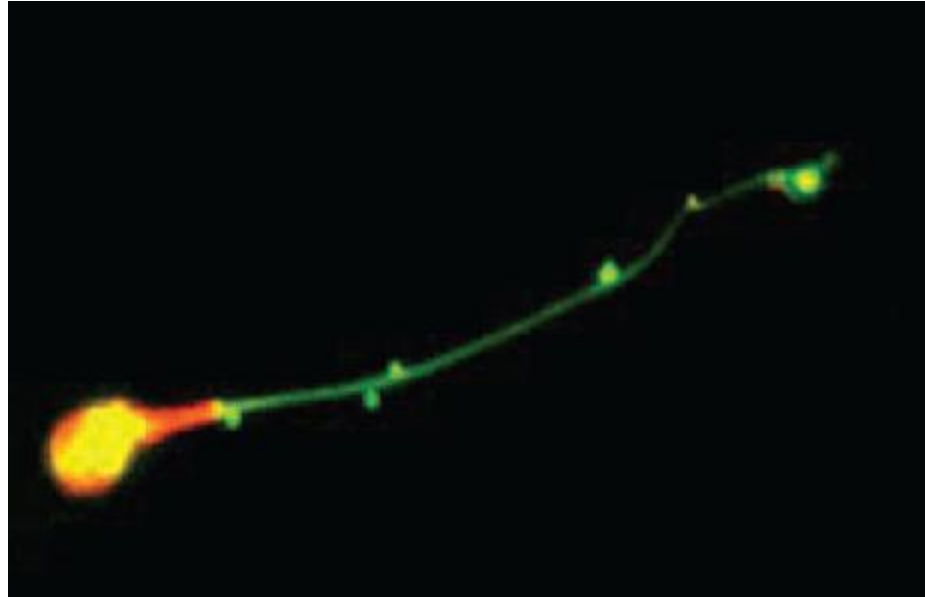


Chlamydia prevalence varies across the country but can approach 20% in some states.



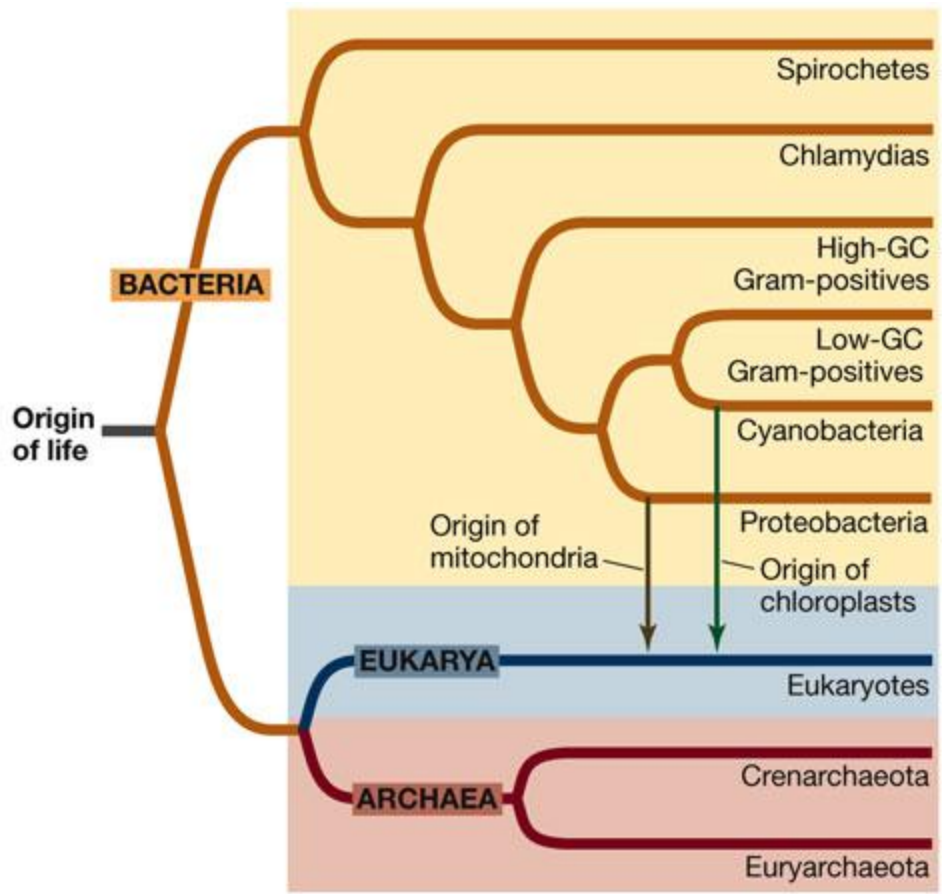
Chlamydia—Prevalence Among Women Aged 16–24 Years Entering the National Job Training Program, by State of Residence, United States and Outlying Areas, 2009

Chlamydia can catch a ride on sperm



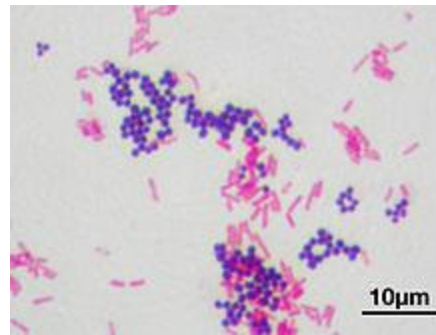
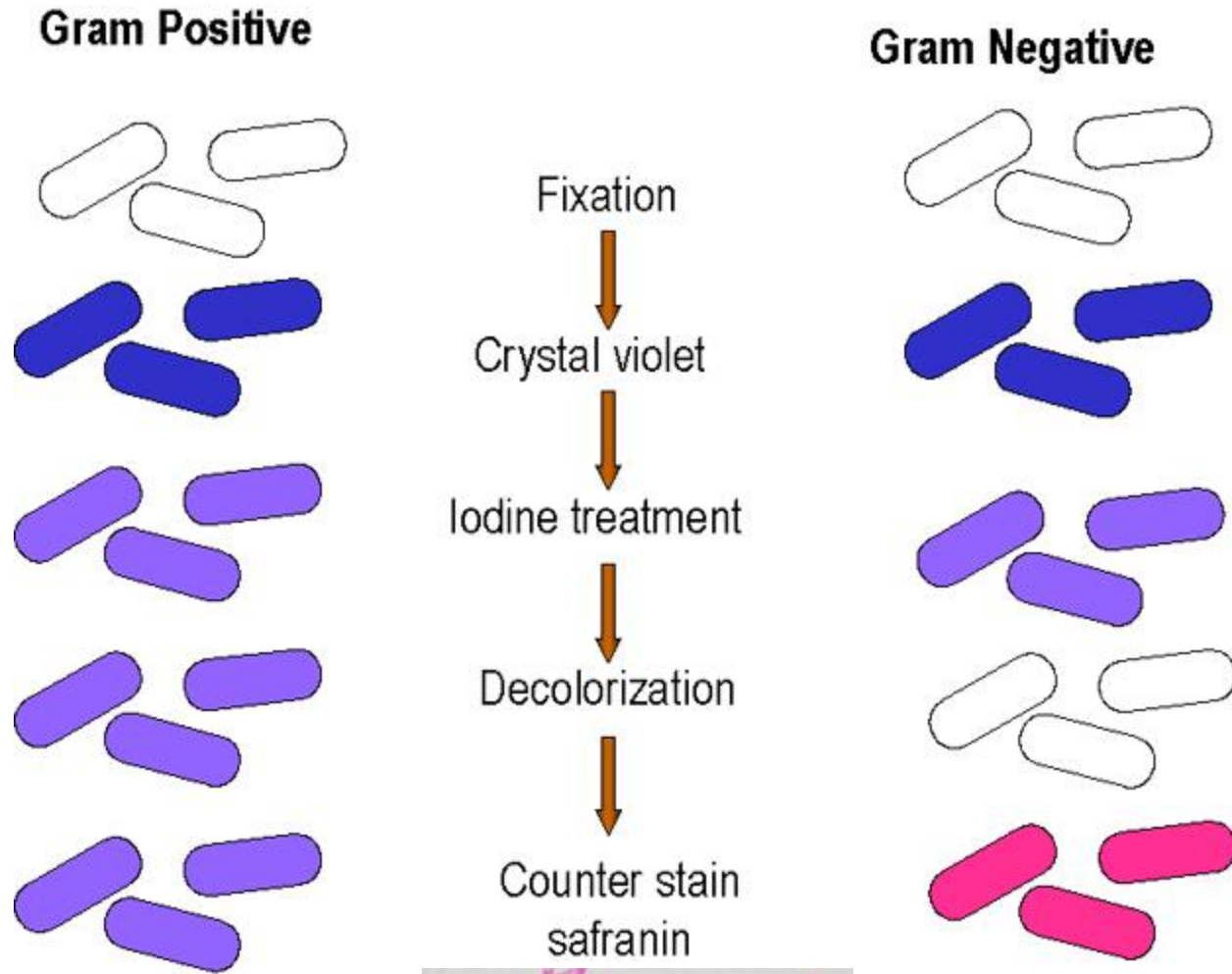
*Attachment of green fluorescent
Chlamydia trachomatis elementary
bodies to human sperm.*

The high-GC gram-positives are also known as the Actinobacteria



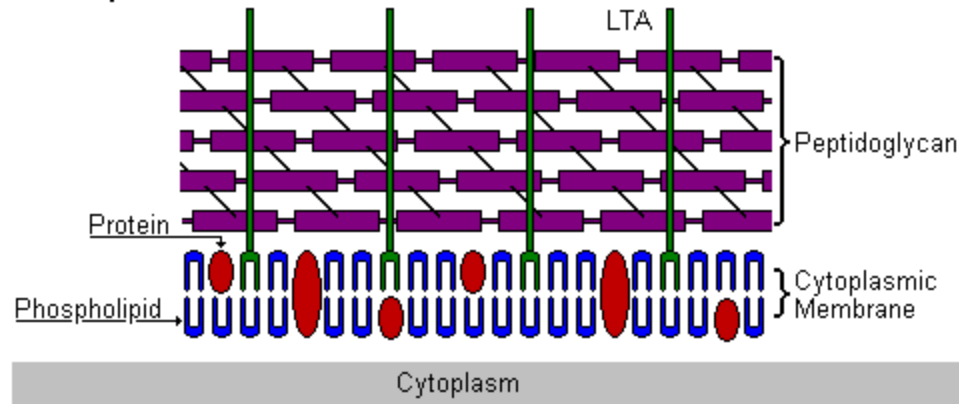
LIFE 9e, Figure 26.11

The Gram stain (1884) distinguished two types of bacteria.

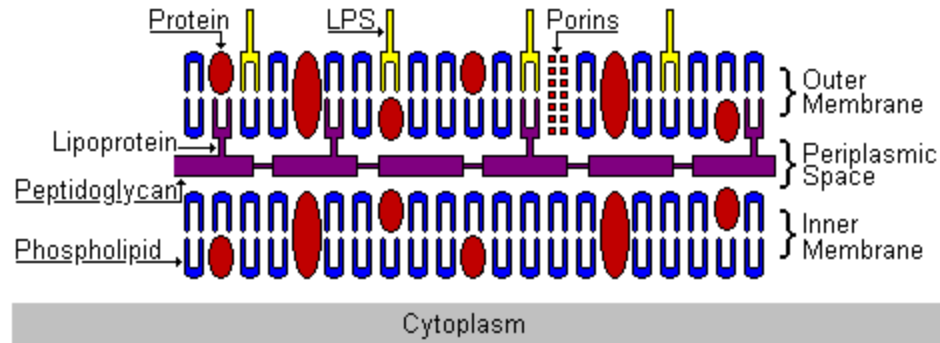


All bacterial cell walls contain peptidoglycan, but some have much more than others.

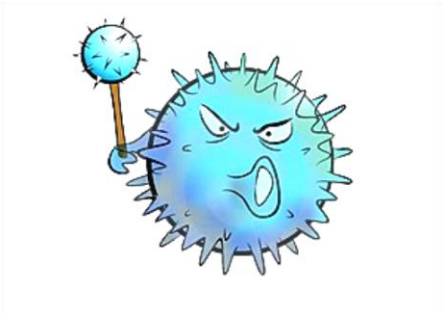
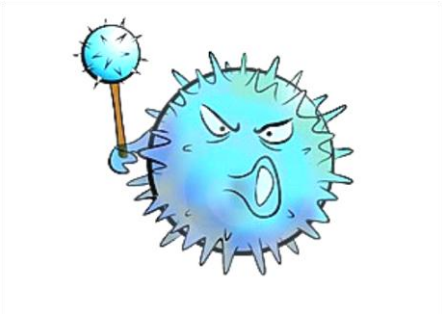
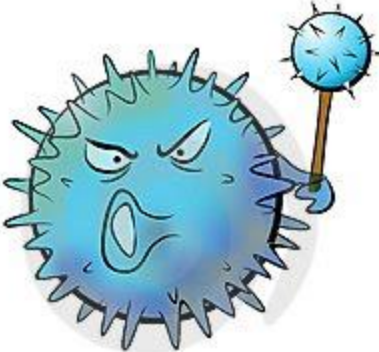
Gram-positive Cell Wall



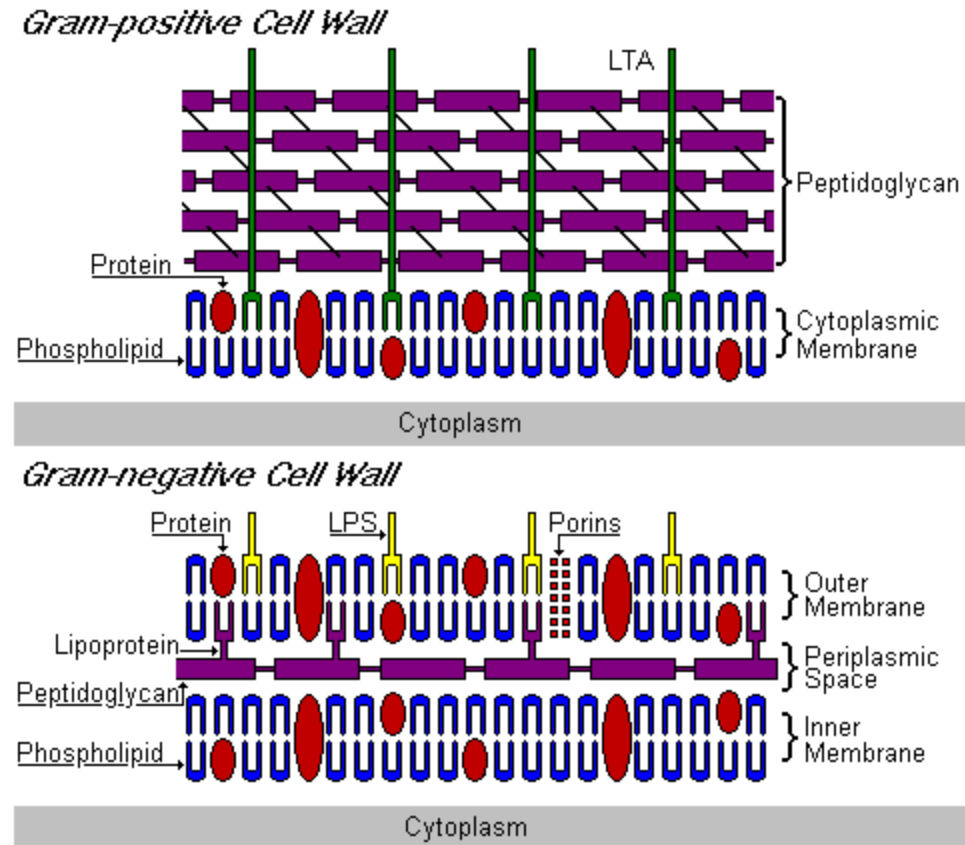
Gram-negative Cell Wall

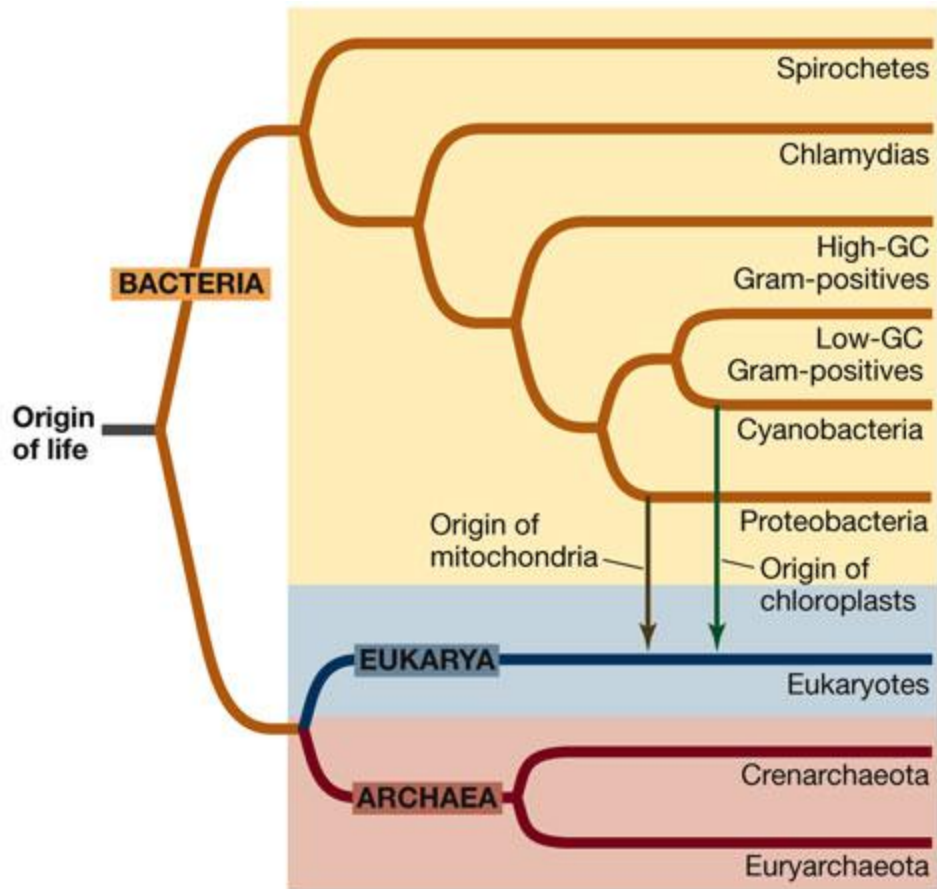


Bacteria have been competing for resources for billions of years.
They are pretty good at it.



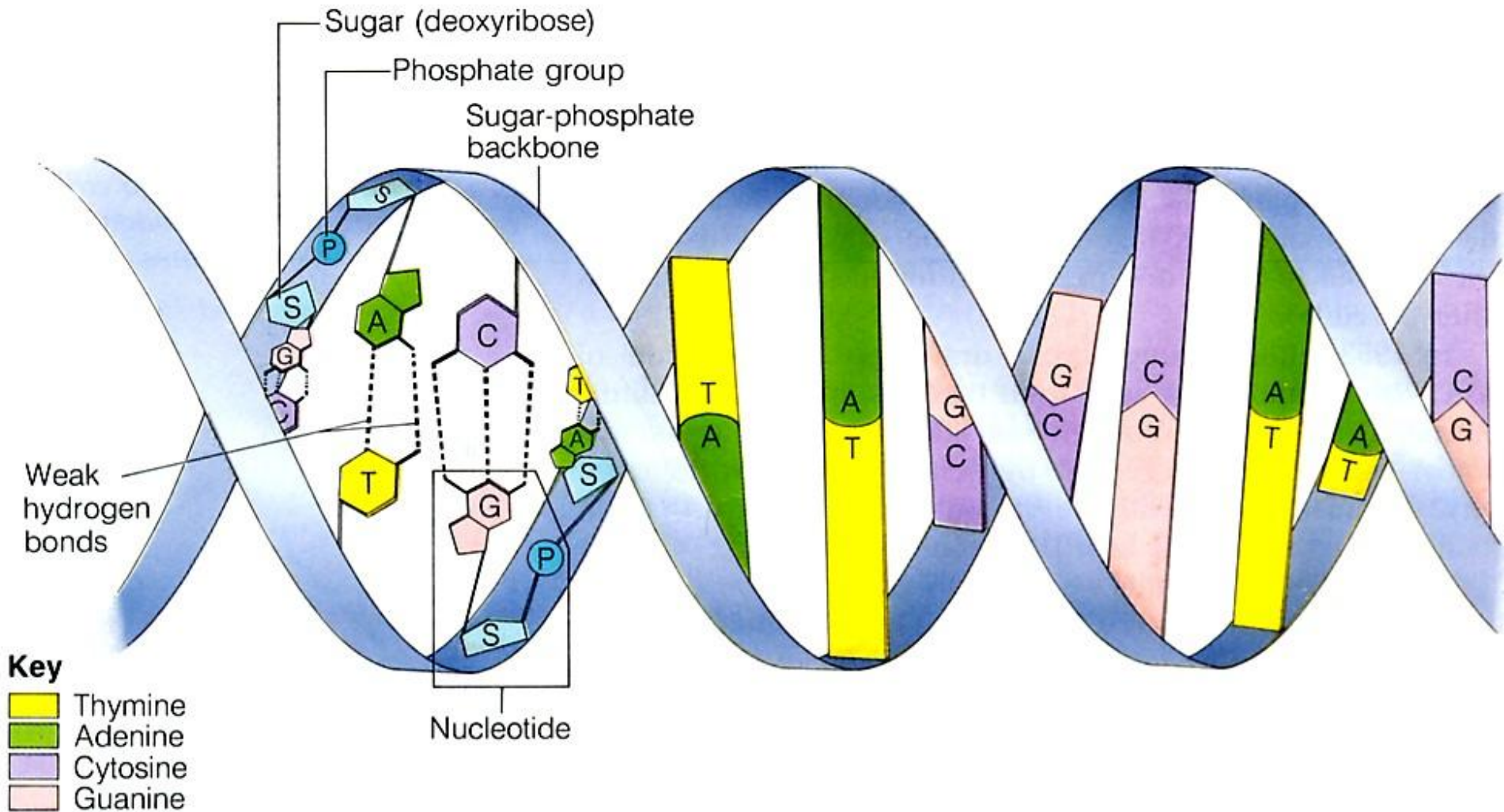
Beta lactam antibiotics are effective against gram positive bacteria but not against gram negative.



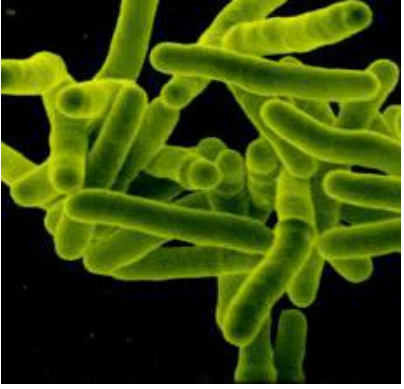
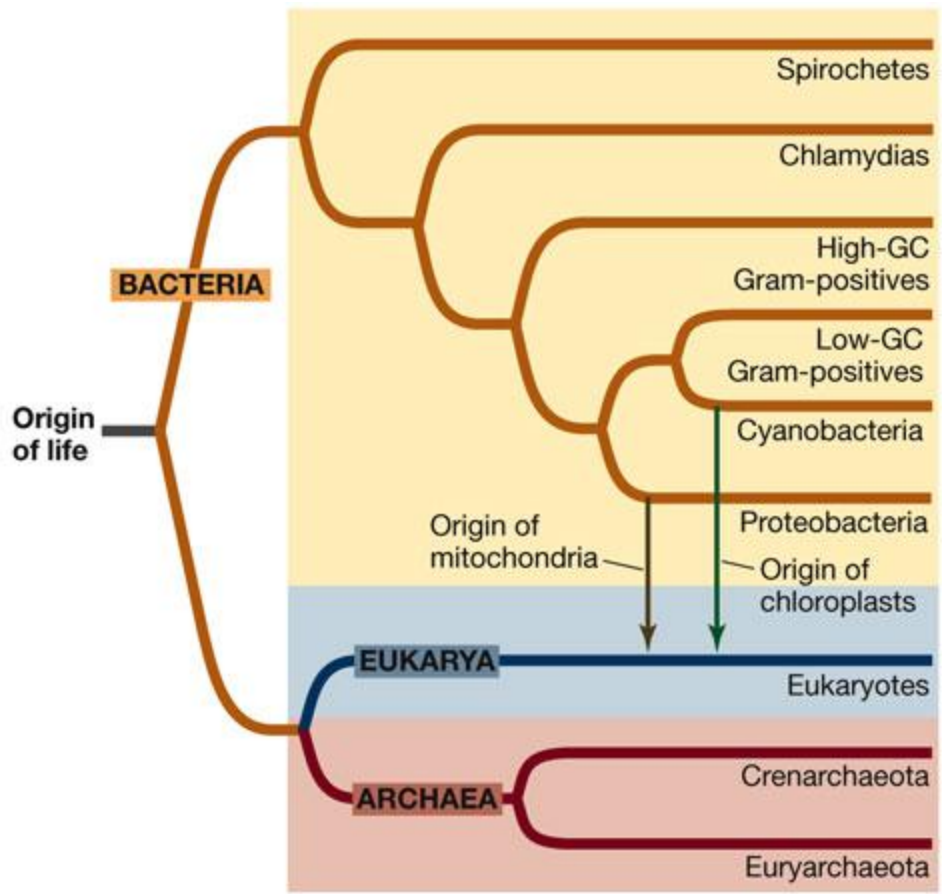


LIFE 9e, Figure 26.11

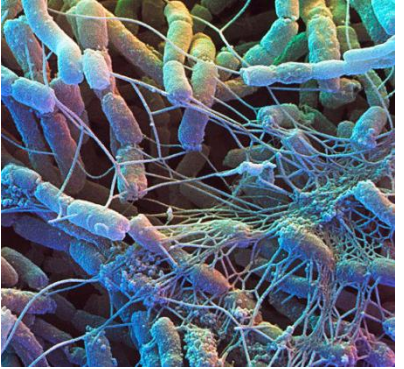
Hydrogen bonds link the DNA bases.



High-GC Gram positive bacteria are very common and although a few are pathogens most are probably decomposers.



Mycobacterium tuberculosis
(Tuberculosis)

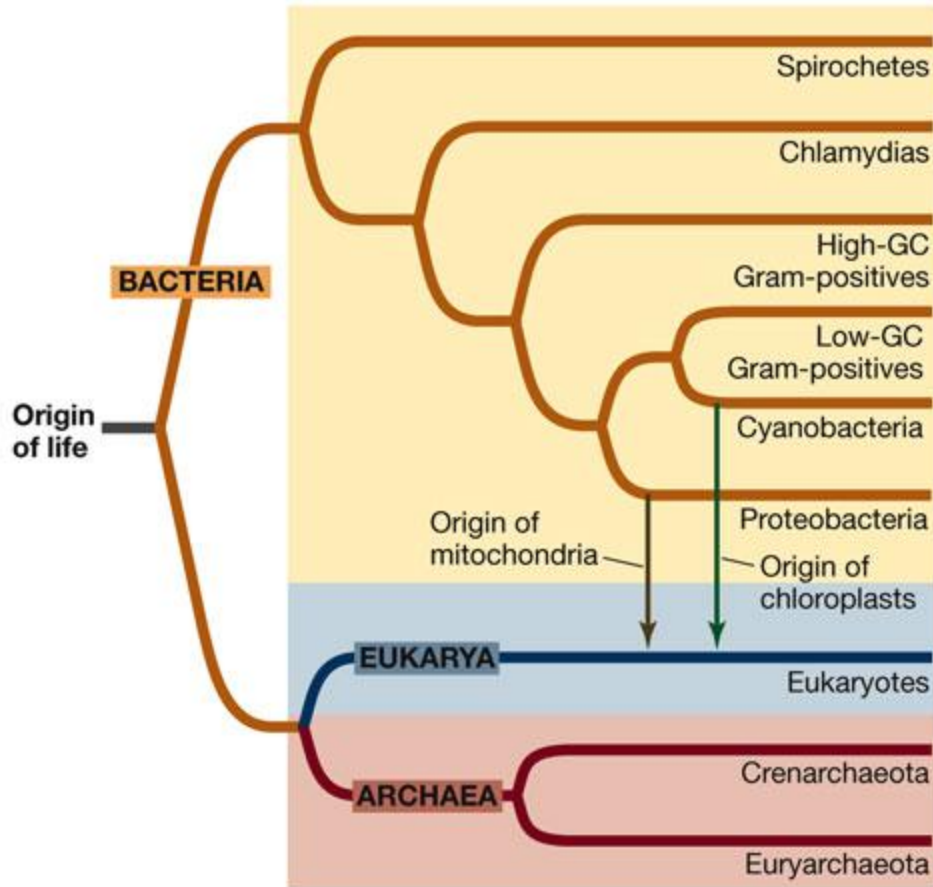


Streptomyces spp.
(in soil)

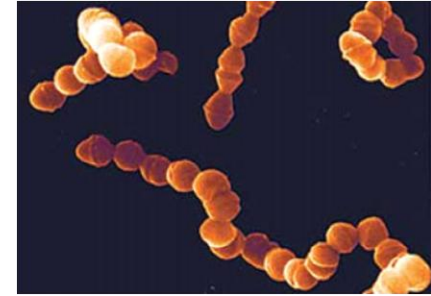
LIFE 9e, Figure 26.11

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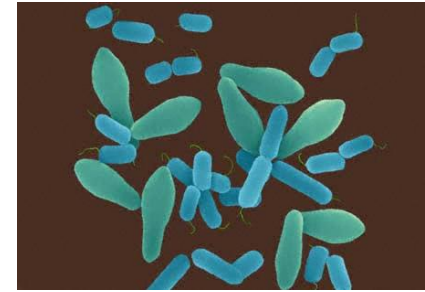
Low-GC Gram-positives or Firmicutes include a large number of human pathogens, many, but not all, producing endospores.



Streptococcus pharyngitis – causes strep throat

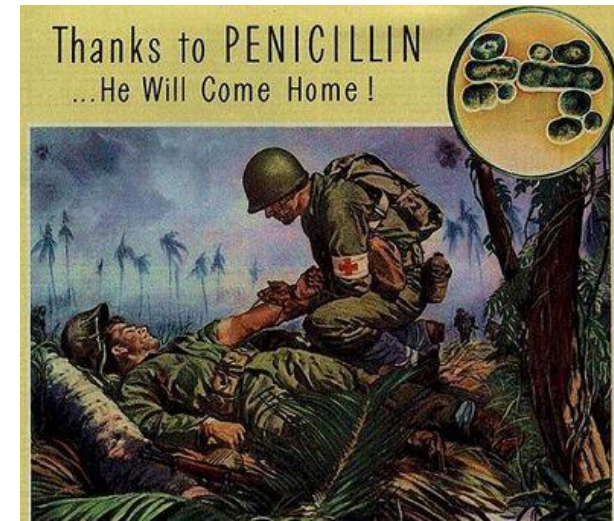


Clostridium perfringens – causes gangrene



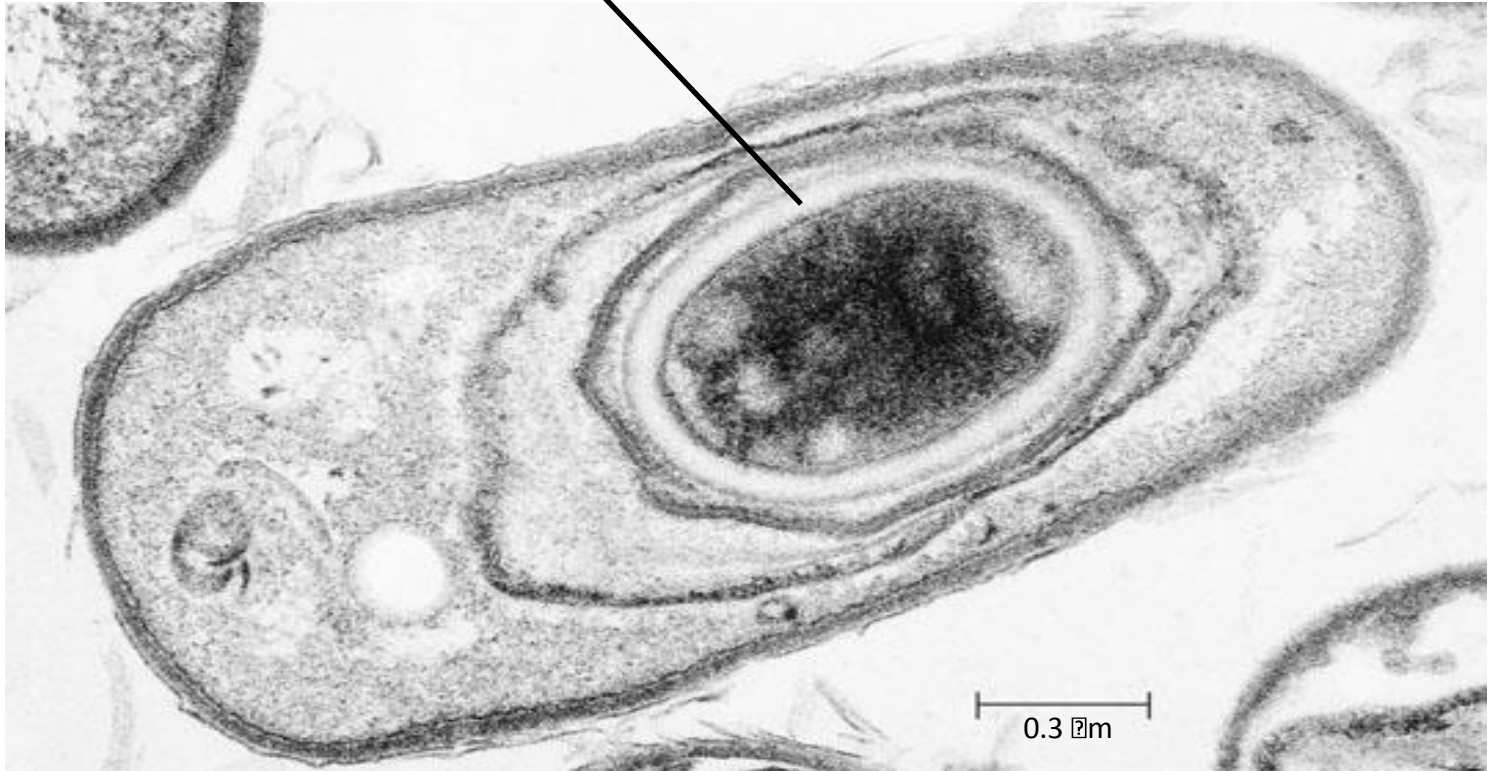
LIFE 9e, Figure 26.11

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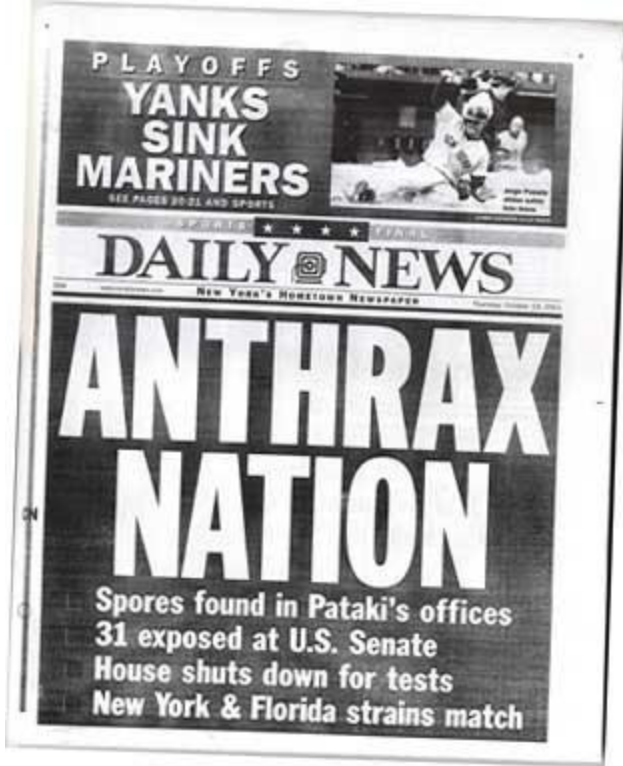


Endospores are a dormant, tough non-reproductive structure that can live for centuries

Endospore



Endospores make certain low-GC gram-positives (the firmicutes) a top choice for bioweapons



A black banner with white text. On the left and right sides are circular logos. The text in the center reads 'SPECIAL REWARD' in a bold, sans-serif font, followed by 'Up to \$2.5 million' in a larger, bold, sans-serif font.

For information leading to the arrest and conviction of the individual(s) responsible for the mailing of letters containing anthrax to the New York Post, Tom Brokaw at NBC, Senator Tom Daschle and Senator Patrick Leahy:



AS A RESULT OF EXPOSURE TO ANTHRAX,
FIVE (5) PEOPLE HAVE DIED.

The person responsible for these deaths...

- Likely has a scientific background/work history which may include a specific familiarity with anthrax
- Has a level of comfort in and around the Trenton, NJ area due to present or prior association

Anyone having information, contact America's Most Wanted at 1-800-CRIME TV or the FBI via e-mail at amerithrax@fbi.gov

All information will be held in strict confidence. Reward payment will be made in accordance with the conditions of Postal Service Reward Poster 296, dated February 2000. Source of reward funds: U.S. Postal Service and FBI \$2,000,000; ADVO, Inc. \$500,000.



Botulinum Toxin from *Clostridium botulinum* is the most powerful neurotoxin yet discovered.



BOTOX[®]
—Cosmetic
Botulinum Toxin Type A

It therefore only seems sensible to inject it into your face.