CE 521 Environmental Biotechnology - Fall 2005

1. **Introduction.** Field of environmental microbiology emerged in the _______. Related to the field of m____________ e_____________. Study of interaction of microorganisms with the environment, be it air, water, and/or soil - emerging fields of aeromicrobiology, bioremediation, water quality, occupational health and infection control, f______ safety, and i_______________ microbiology.

2. Historical perspective.

— by early 1900's d________________ of water supplies practically eliminated w___________________ disease outbreaks.

— discovery of _____structure by Watson and Crick in 1953

— improvement in a_________ and microscopic techniques

— spread of airborne, waterborne and foodborne diseases - L____________ disease, G_____________ (Cryptosporidium), N_________ virus, Cyclospora (outbreak on raspberries from Guatemala)

— L______ Canal other Superfund sites (cost of cleanup in the US is estimated at $1 trillion)

— Exxon V_______ oil spill

— field of environmental microbiology has emerged in this context

FIGURE 1.1 Environmental microbiology interfaces with many other fields of microbiology

1.2 An Historical Perspective

TABLE 1.1 Recently Discovered Microbes That Have Had a Significant Impact on Human Health

Agent	Mode of transmission	Disease/Symptoms
Rotavirus	Waterborne	Diarrhea
Legionella	Waterborne	Legionnaire's disease
Escherichia coli 0157:H7	Foodborne Waterborne	Enterohemorrhagic fever, kidney failure
Hepatitis E virus	Waterborne	Hepatitis
Cryptosporidium	Waterborne Foodborne	Diarrhea
Calicivirus	Waterborne Foodborne	Diarrhea
Helicobacter pylori	Foodborne Waterborne	Stomach ulcers
Cyclospora	Foodborne Waterborne	Diarrhea

TABLE 1.3 Scope of Environmental Microbiology

Subject	Microbial issue
Aeromicrobiology	Collection and detection of pathogens or other microbes in aerosols, microbial movement in aerosols
Agriculture, soil microbiology	Biological control, nitrogen fixation, nutrient cycling
Biogeochemistry	Carbon and mineral cycling, control of acid mine drainage, control of loss of fixed nitrogen
Bioremediation	Degradation of organic contaminants, immobilization or removal of inorganic contaminants found in contaminated soil or water environments
Biotechnology	Detection of pathogens or other microbes in the environment, detection of microbial activity in the environment, genetic engineering
Food quality	Detection of pathogens, elimination of pathogens
Resource production	Production of alcohol, single-cell protein
Resource recovery	Microbially mediated recovery of oil and metals
Wastewater treatment	Degradation of waste, reduction of pathogens
Water quality	Removal of organic and inorganic contaminants, detection of pathogens, elimination of pathogens

The Microbial World

The Protista

- Pro_____________________

  bacteria

- Eu_____________________

fungi – protozoa – plant cells – animal cells

Main Differences:

1. Eucaryotic cells are much

   l______________ and far more

   c________________

2. Nuclear m_____________________

   in eucaryotes.

3. Membrane bound

   o______________________ in

   eucaryotes.

Table 4. Comparison of procaryotic and eucaryotic cell organization[a]

Structural/functional feature	Procaryotes	Eucaryotes
Endoplasmic reticulum	Absent	Present
Number of chromosomes	1	> 1
Chromosome with histones	Absent	Present
Nucleolus	Absent	Present
Genetic exchange by conjugation	Plasmid-mediated, unidirectional	By gamete fusion
Nuclear membrane	Absent	Present
Golgi apparatus	Absent	Present
Lysosomes	Absent	Present
Mitochondria	Absent	Present
Chloroplasts	Absent	Present in plants
Glyoxosomes	Absent	Sometimes present
Microtubules	Absent	Present
Ribosomes	70S structure	80S structure
Phagocytosis	Absent	Sometimes present
Pinocytosis	Absent	Sometimes present
Cellular endosymbionts	Absent	Sometimes present
Ameboid motion	Absent	Sometimes present
Cytoplasmic streaming	Absent	Present
Site of electron transport	Cell membrane	Organelle
Cell wall with murein	Present, except in mycoplasma and archaebacteria	Absent

[a]Adapted from Stanier et al., 1986.

4. Procaryotes divide by binary f______________, eucaryotes by m____________

5. Procaryotes lack: G__________ complex, e________________ reticulum,

m____________________________, and c________________

Cell Structure — Size:

Procaryotes:

- *E. coli*: 0.5 - 2 µm
- Colonies of 10^7 cells are visible by the n___________

  e______ (from one cell after 10-18 h growth)

- 100 mg of a_________ b______________ contains roughly

  100 billion (10^{11}) cells

- Average mass of one c_______ is 2.9 x 10^{-13} g dry mass

Eucaryotes:

- g____________ than 5 µm

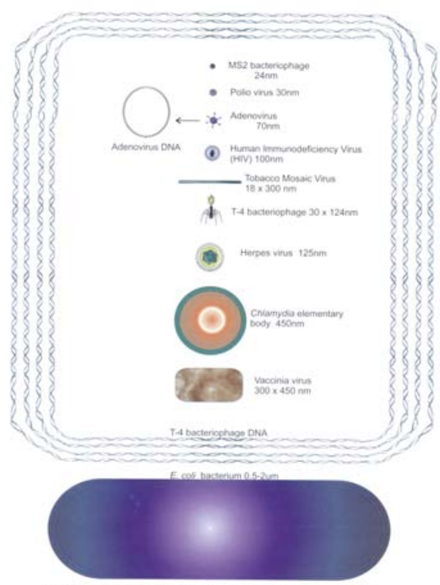


FIGURE 2.2 Comparative sizes of selected bacteria, viruses, and nucleic acids.

C________________ Membrane:

− gram n__________________ bacteria have an o__________

membrane and an inner (cytoplasmic) membrane

− gram positive bacteria have a p______________________ (murein) layer and a cytoplasmic

membrane

◦ cytoplasmic membrane:

- 40 - 80 Å thick
- semi-permeable p______________________ bilayer

- fluid m__________________ model
- compounds cross membrane by
  - **d______________________**
    - some molecules diffuse r_____________ across membrane (O_2, CO_2, NH_3, H_20)
      - diffusion is controlled only by

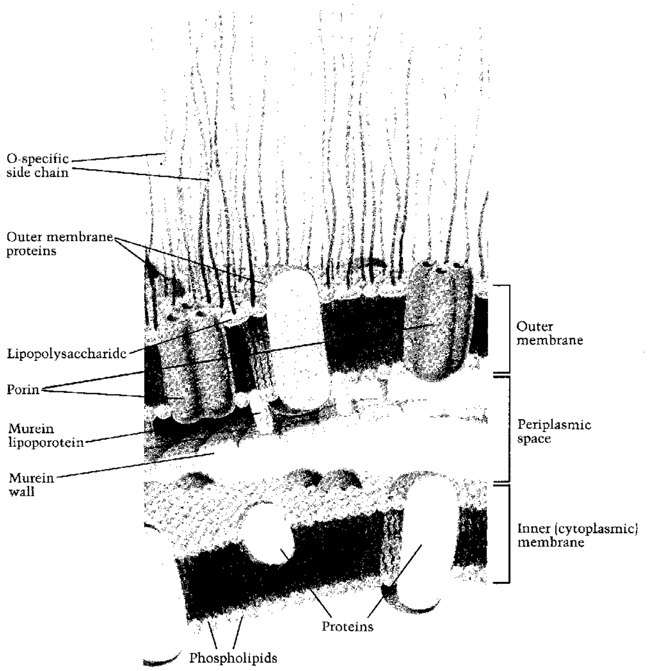


Figure 9
Model of the Gram-negative cell envelope.

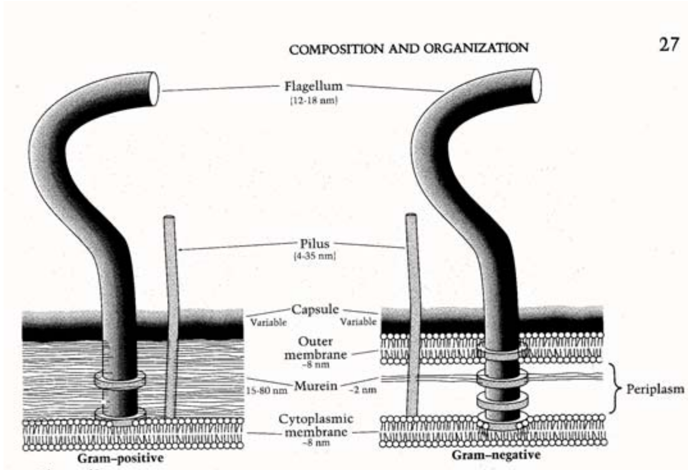
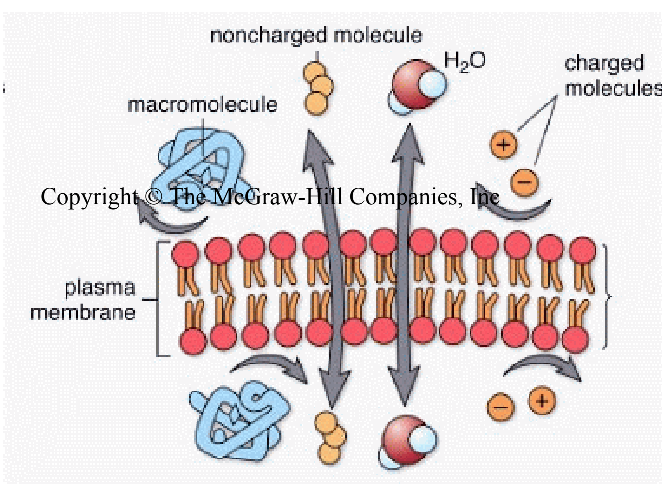


Figure 12
Comparison of the structure of the Gram-positive and Gram-negative cell envelopes, showing the major molecular components and their approximate dimensions. The region between the outer membrane and the cytoplasmic membrane of the Gram-negative envelope is called the periplasm.

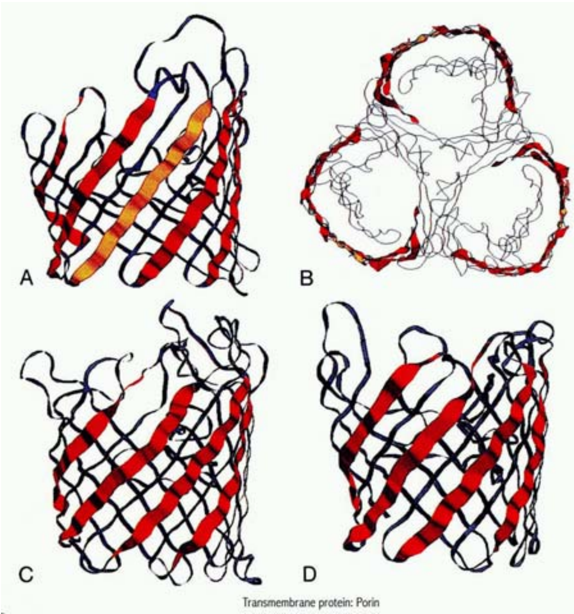
d____________

g__________________ of non-charged molecules (△C),

p____________________ constant (P), and surface area



- to maintain a concentration gradient, gram negative bacteria maintain a very low concentration of nutrients in the p_____________________ through binding proteins which sequester nutrients or actively p_______________ them across the cytoplasmic membrane



Prediction of porin protein structure, Protein Sci, 1995, 1618.

- diffusion across outer membrane is d_________________ from cytoplasmic membrane:
    - outer membrane is impermeable to n_______________ solutes (provides protection for gram negative organisms, especially from antibiotics)
    - polar solvents pass through special protein channels called p___________. Porins may be h_____________ that separate molecules based on size or may be c__________________ which are specific for certain substrates

CHAPTER TWO

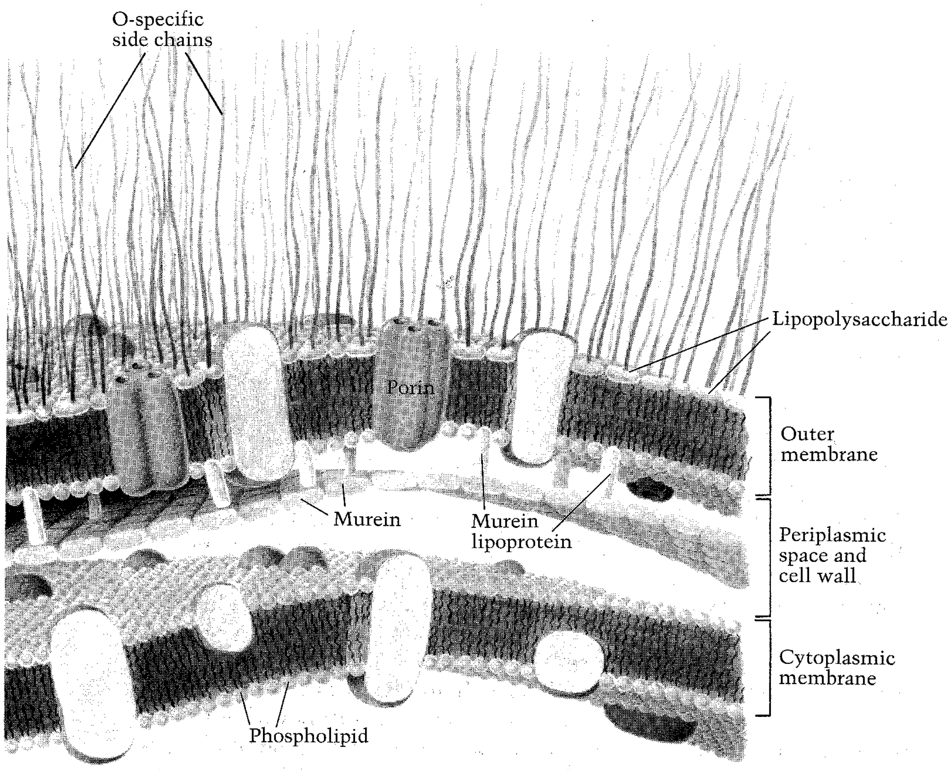


Figure 2

Model of the *E. coli* cell envelope, showing its various layers and their approximate thicknesses.

- f____________________ transport (facilitated diffusion)
    - allows transport of substances that would otherwise be i_______________________ (e.g. glycerol)
    - steriospecific c_____________: membrane bound proteins that "facilitate" the transport of impermeable substances along a concentration gradient

- act as c______________________
- some allow c___________________: as one substrate is brought into the cell another is transported out, but still need a concentration gradient for one of the substrates

- a___________________ transport
  - allows transport a_______________ a concentration gradient
  - e_____________________ a concentration gradient (higher concentration within cell) for example amino acid concentrations are over a 1000 fold higher, galactose 10^5, and potassium 10^6.
  - s__________________, membrane bound proteins (called carriers, or permeases) mediate the transport of specific substrates
  - exhibits s_____________________ kinetics
- endocytosis (eucaryotes)
  - can be r______________ mediated
  - includes phagocytosis (p___________________) and pynocytosis (d______________________ substances)

Cell Wall

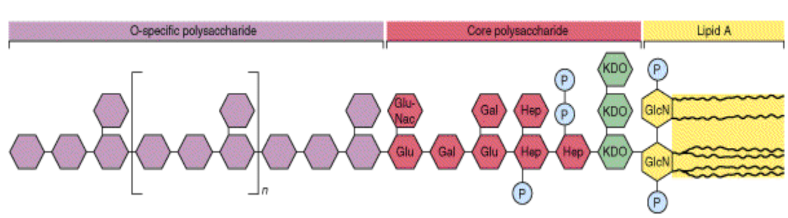
- all bacteria have a cell wall except m___________________________
- provides rigidity for o________________ pressure gradient
- consists of peptidoglycan (murein): g_____________ strands cross linked with p________________ chains
- gram positive bacteria have a much higher peptidoglycan content and also contain t__________________ acids in cell wall

Outer Membrane

- gram negative bacteria have an outer m__________________ which consists of phospholipids (inner leaflet), lipopolysaccharides, LPS (outer leaflet), and p_______________________. LPS is a complex molecule not found except in the outer leaflet of the gram negative bacterial cell
- provides an efficient b_______________________ against both hydrophilic and hydrophobic compounds
- p________________________ allow transport of essential hydrophilic compounds and substrates

Glycocalyx - capsule

- capsule surrounding cell composed of extracellular p__________________ (amorphous slime)
- provides added protection:
  - p__________________________ virulence



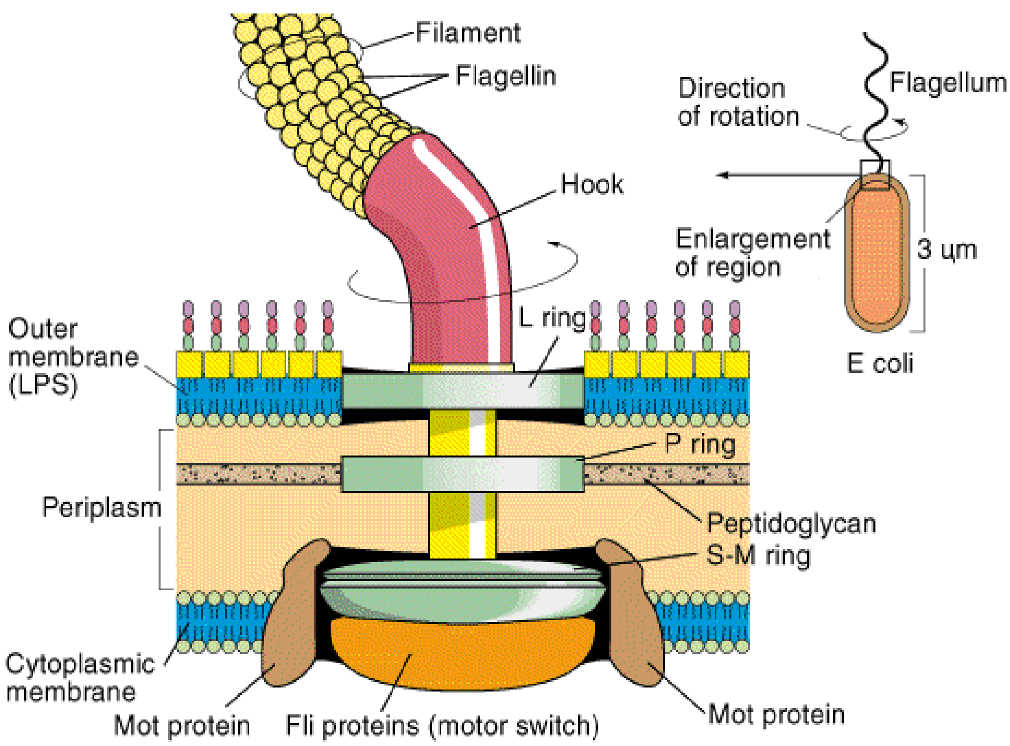
(e.g., meningitis)

- p______________________ phagocytosis due to making cell "slippery"
- assists in surface a______________________________
- prevents d____________________________________
- m_________________________ complexation
- microbial f______________________________

- also can be produced during u___________________________ growth conditions

Cell Motility

- flagella
  - composed of helical f__________________ (flagellin), hook, and basal body (see diagram) which function as a rotating shaft: "biological motor"; energy for rotation is p___________ m_____________ f_____________



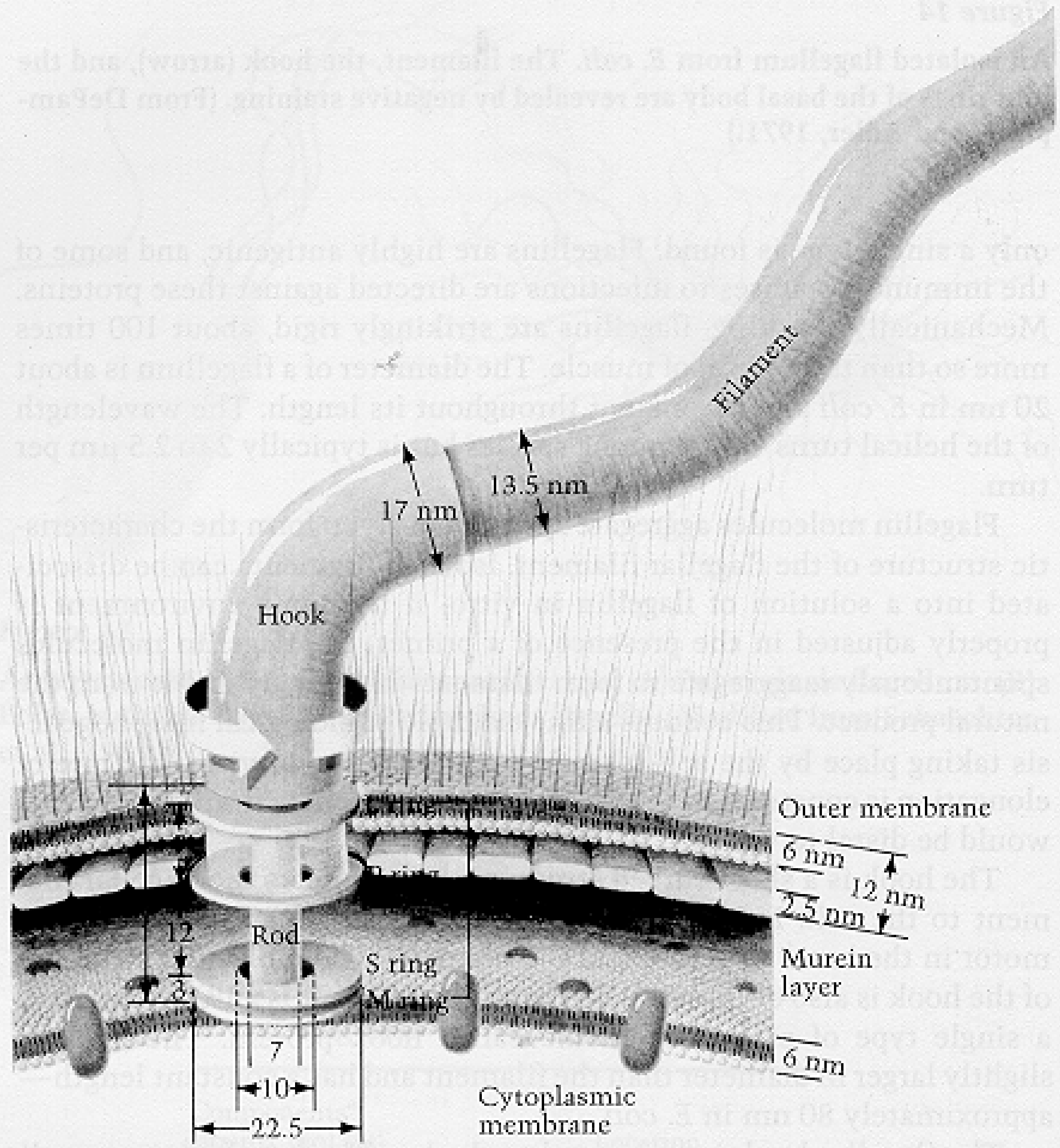


Figure 15

Basal body structure of the *E. coli* flagellum. The relationship of the four rings of the basal body and the envelope of *E. coli* are shown. (After DePamphilis and Adler, 1971.)

- cilia - shorter/thinner than flagella, also used for l__________________ or feeding (in ciliated protozoa)
- cells move t_________________
  - f_____________ - chemotaxis
  - l_____________ - photo taxis
  - a_____________ - aerotaxis
- cells can also move away from t_____________ or i______________________ compound

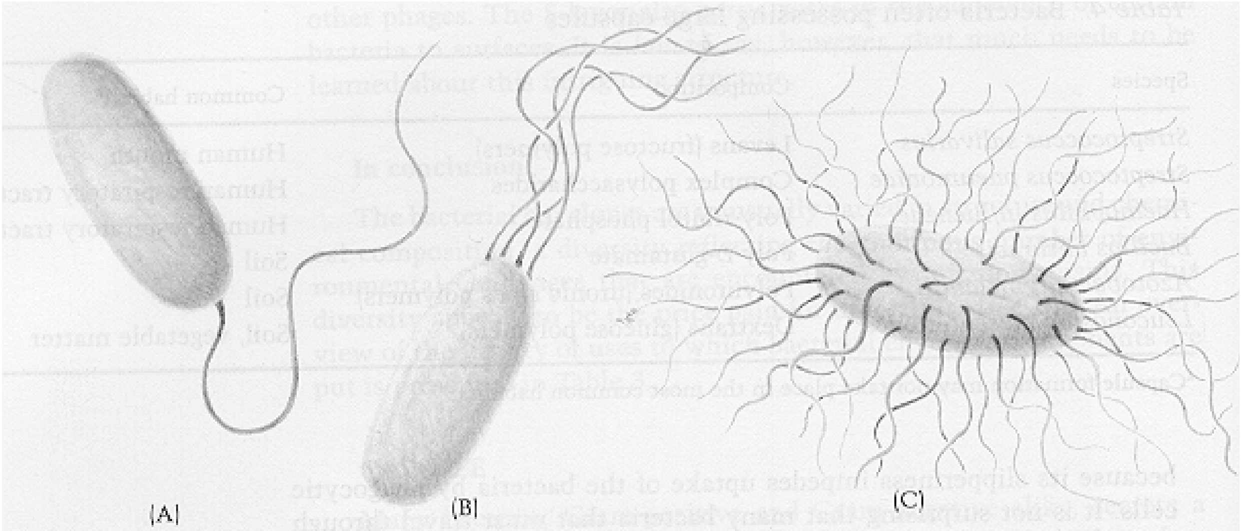


Figure 13
Arrangements of flagella in different bacteria. (A) Polar, single flagellum. (B) Polar, multiple flagella. (C) Peritrichous flagella. (Modified from Schaechter et al., 1989.)

Pili (hair)

- typical *E. coli* has _________ to __________ pili
- 0.2 - 2 µm in l_________________________
- play a role in a_______________________ to surfaces, some are specific for certain receptors, such as glycoproteins on the host surface, also serve as receptors for phages
- some play a role in conjugation, sex pili, form initial attachment between mating pairs

Storage Products

- c______________ (energy) storage:
  1. g_________________________
  2. s________________________
  3. p_________-β-h____________b_________________ (PHB) only found in procaryotes
- p______________________________ granules (e.g., in *acinetobacter*)
- s_______________________ granules

Gas Vacuoles

- consist of g_________ v_____________________
- allows for cell b____________________________
- found in c_________________, h_____________________, and p_________________________ bacteria

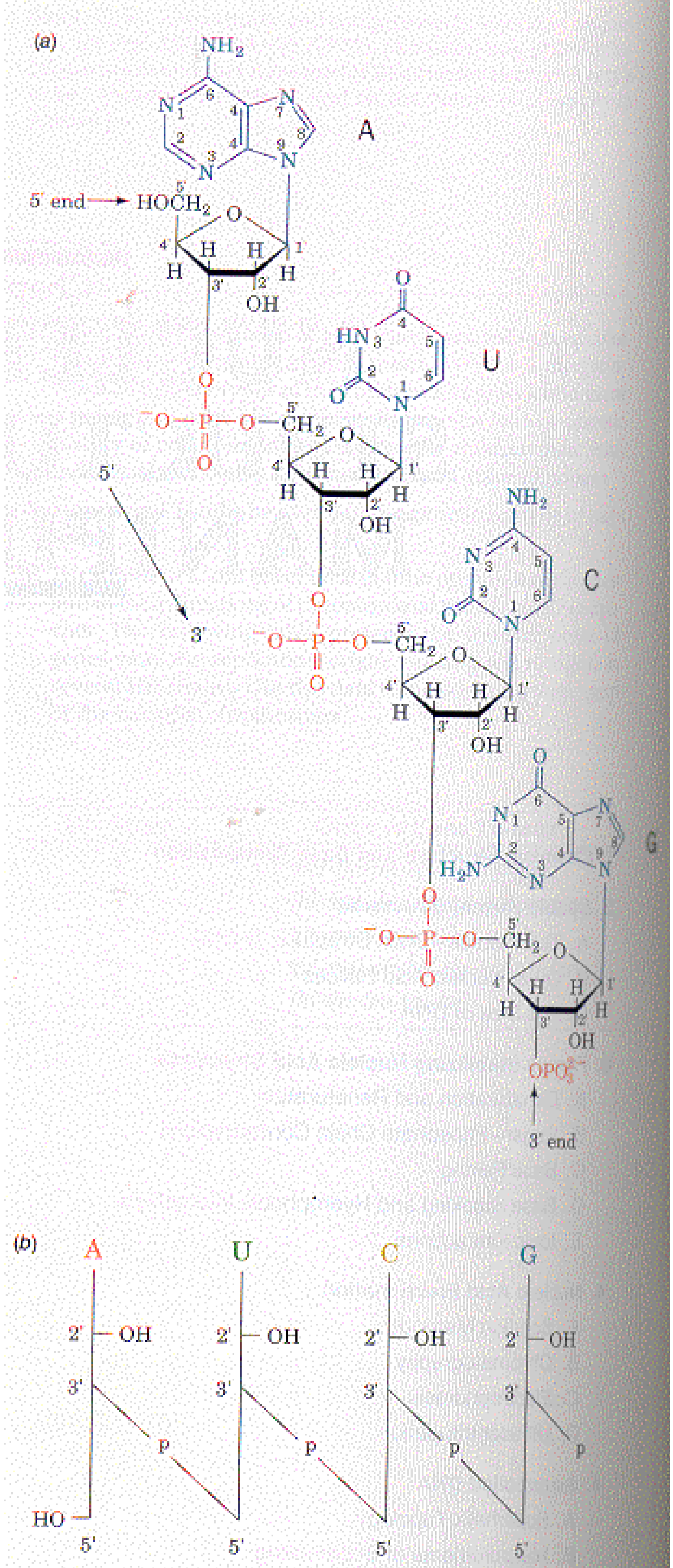
Endospores

- some bacteria (most notably *Clostridium* and *Bacillus*) form e________________________ within the cell
- most r_______________________________ forms of life on earth
- can withstand h______________ temperatures (>100˚C)
- can remain v______________ for long periods of time (endospores on 300 year old root specimen at British herbarium were still viable within minutes when conditions were made favorable for growth)
- some spore forming bacteria produce t______________ (e.g., *Clostridium botulinum*)
- if you can k_____________ spores, you can be certain that other bacteria are also killed

Cell Genetics

DNA

- consists of s_____________ circular, double h______________ molecule (chromosome) in procaryotes (also extra chromosomal elements: plasmids)



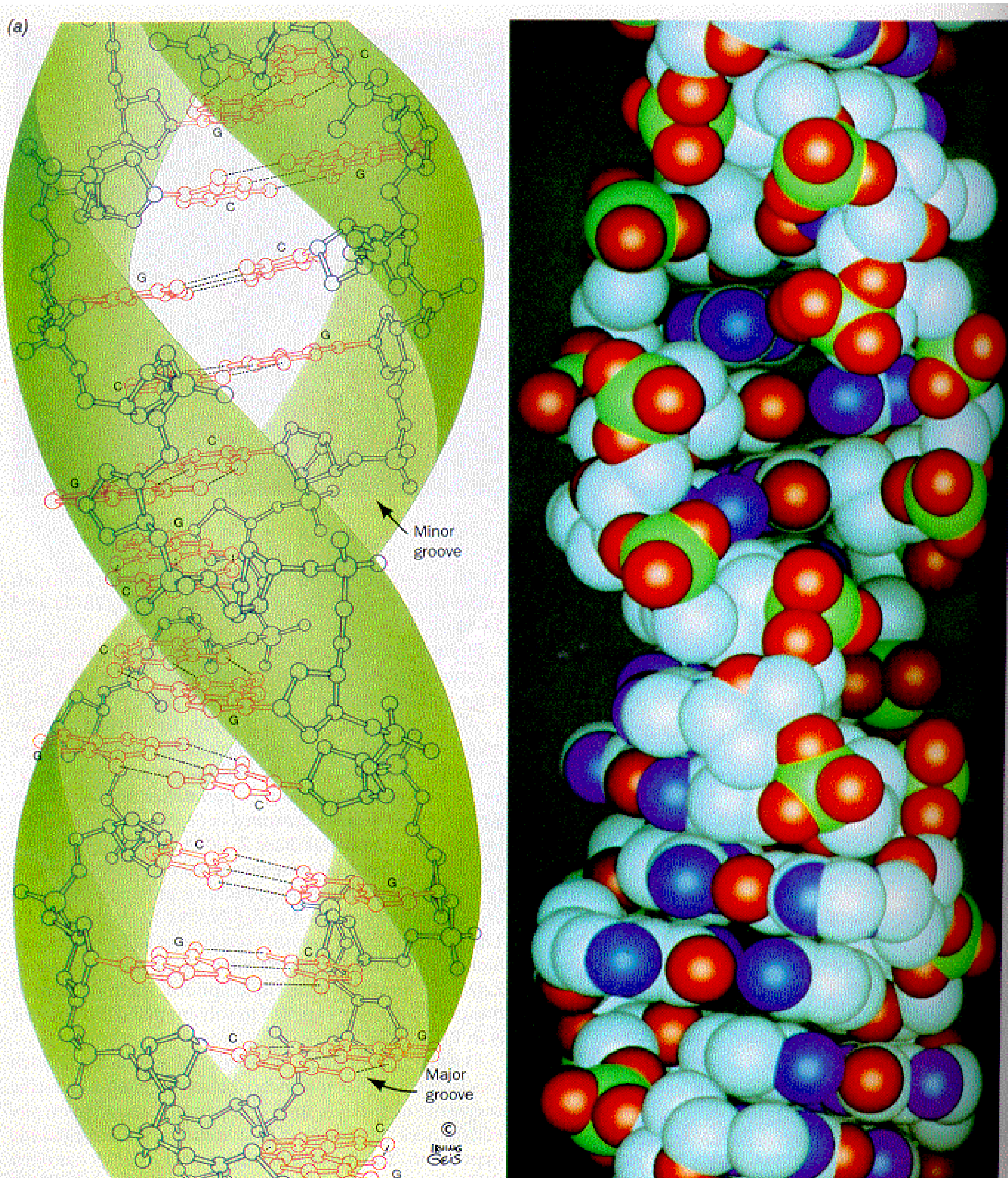


Figure 28-9
Ball-and-stick drawings and the corresponding space-filling models of Z-DNA as viewed (*a*) perpendicular to the helix axis and (*b*) (*opposite*) along the helix axis. The color codes are given in Fig. 28-5. The repeating helix was generated by Richard Dickerson based on the X-ray structure of the self-complementary hexamer d(CGCGCG) determined by Andrew Wang and Alexander Rich. Note that the helix is left handed and that the sugar–phosphate chains follow a zigzag course (alternate ribose residues lie at different radii in Part *b*) indicating that the Z-DNA's repeating motif is a dinucleotide. Compare this figure with Figs. 28-5 and 28-8. [Drawings copyrighted © by Irving Geis. Computer graphics courtesy of Robert Stodola, Fox Chase Cancer Center.]