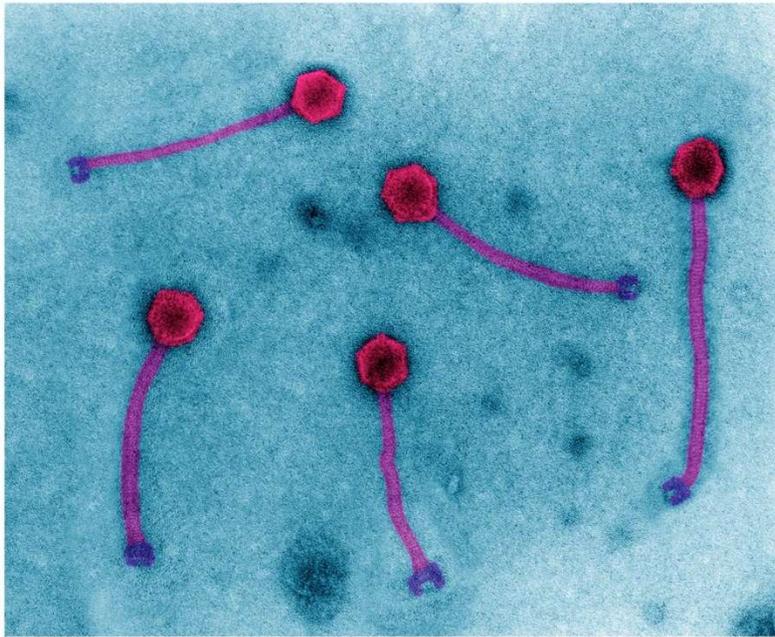


# Chapter 13: Evolution and Diversity Among the Microbes

## Learning Objectives (bacteria)



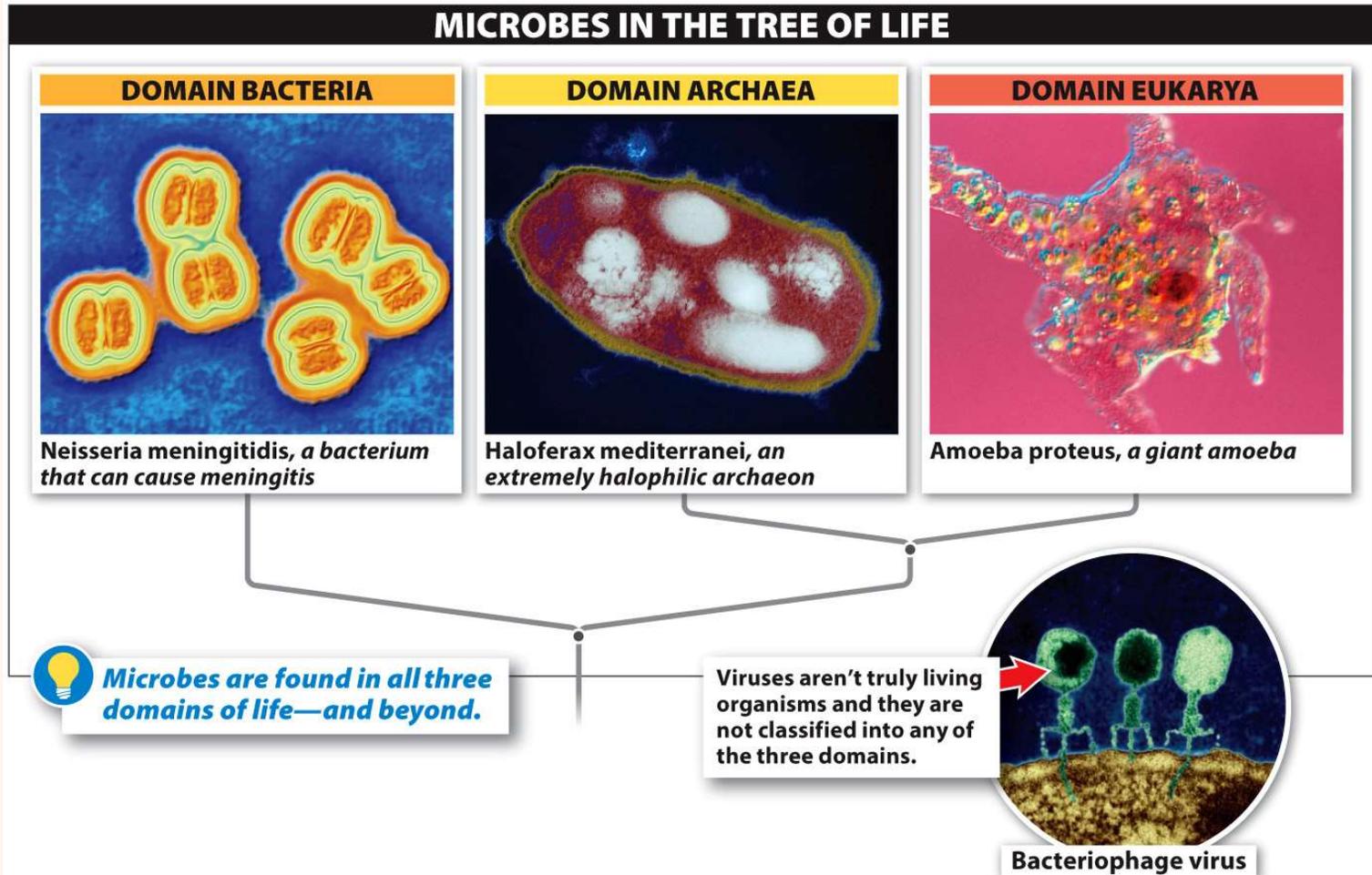
Chapter 13 Opener  
What Is Life? A Guide To Biology, Third Edition  
© Dennis Kunkel Microscopy, Inc.

- ❑ Microbes in all three domains (but prokaryotes only in two domains)
- ❑ Bacterial diversity
- ❑ Bacterial structure
- ❑ Antibiotics

***Bacteria, archaea, protists, and viruses:  
the unseen world***

# Microbes are the simplest, but most successful organisms on earth

## Microbes are not all evolutionarily related



**Figure 13-1**

*What Is Life? A Guide To Biology*, Third Edition

© 2015 W. H. Freeman and Company [Photos: (left to right) (top) Eye of Science/Science Source; Alfred Pasieka/Science Source; Astrid & Hanns-Frieder Michler/Science Source; (bottom) Eye of Science/Science Source]

# Microbes Can Live Almost Anywhere and Eat Almost Anything



**Microbes live in nearly every kind of environment, including water at temperatures of up to 750° F and as low as 5° F!**

**Figure 13-3**

*What Is Life? A Guide To Biology*, Third Edition

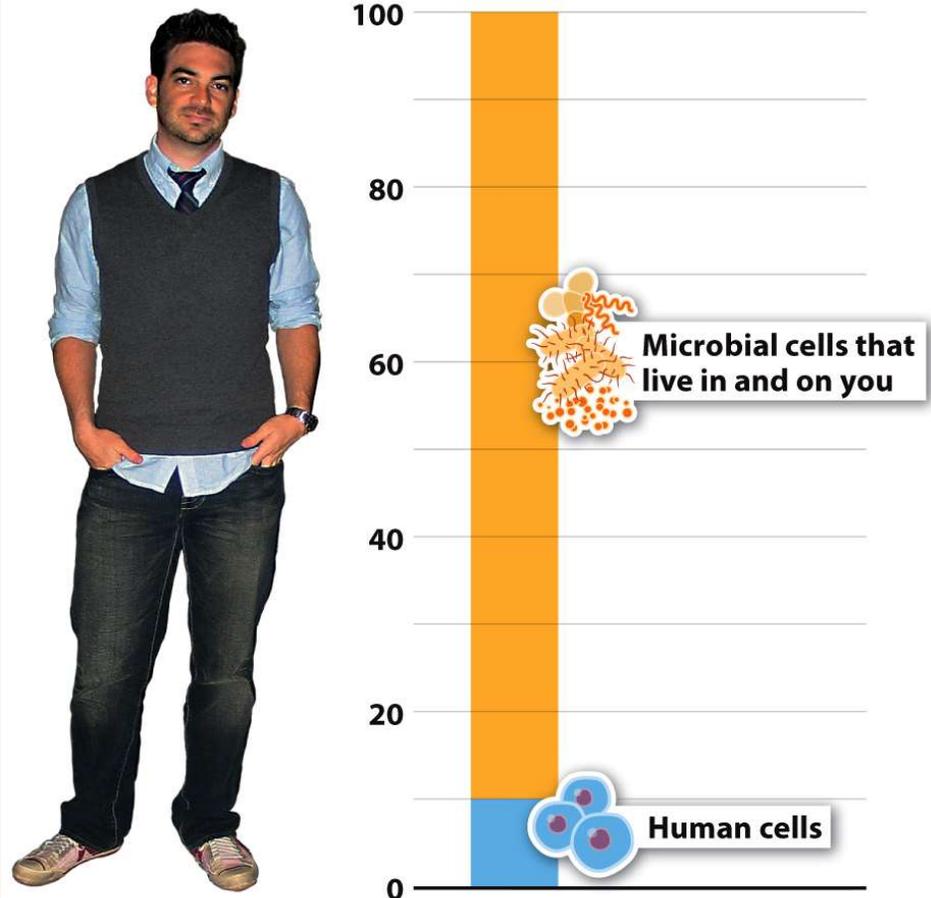
(left to right) CNRI/Science Source; (inset) Phototake/Alamy; © Marc Moritsch/National Geographic Society/Corbis; (inset) © Dennis Kunkel Microscopy, Inc.; © Scott T. Smith/CORBIS (inset) © Dennis Kunkel Microscopy, Inc.

**Bacteria may be the most diverse of all organisms.**

Microbes  
are  
abundant!

Bacterial cells in the  
human body outnumber  
human cells 10 to one

**TOTAL NUMBER OF CELLS IN THE HUMAN BODY (TRILLIONS)**



**Figure 13-4**

*What Is Life? A Guide To Biology*, Third Edition

© 2015 W. H. Freeman and Company [Photo: Courtesy of Jay Phelan]

There are more beneficial bacteria than harmful ones

Human microbiome project

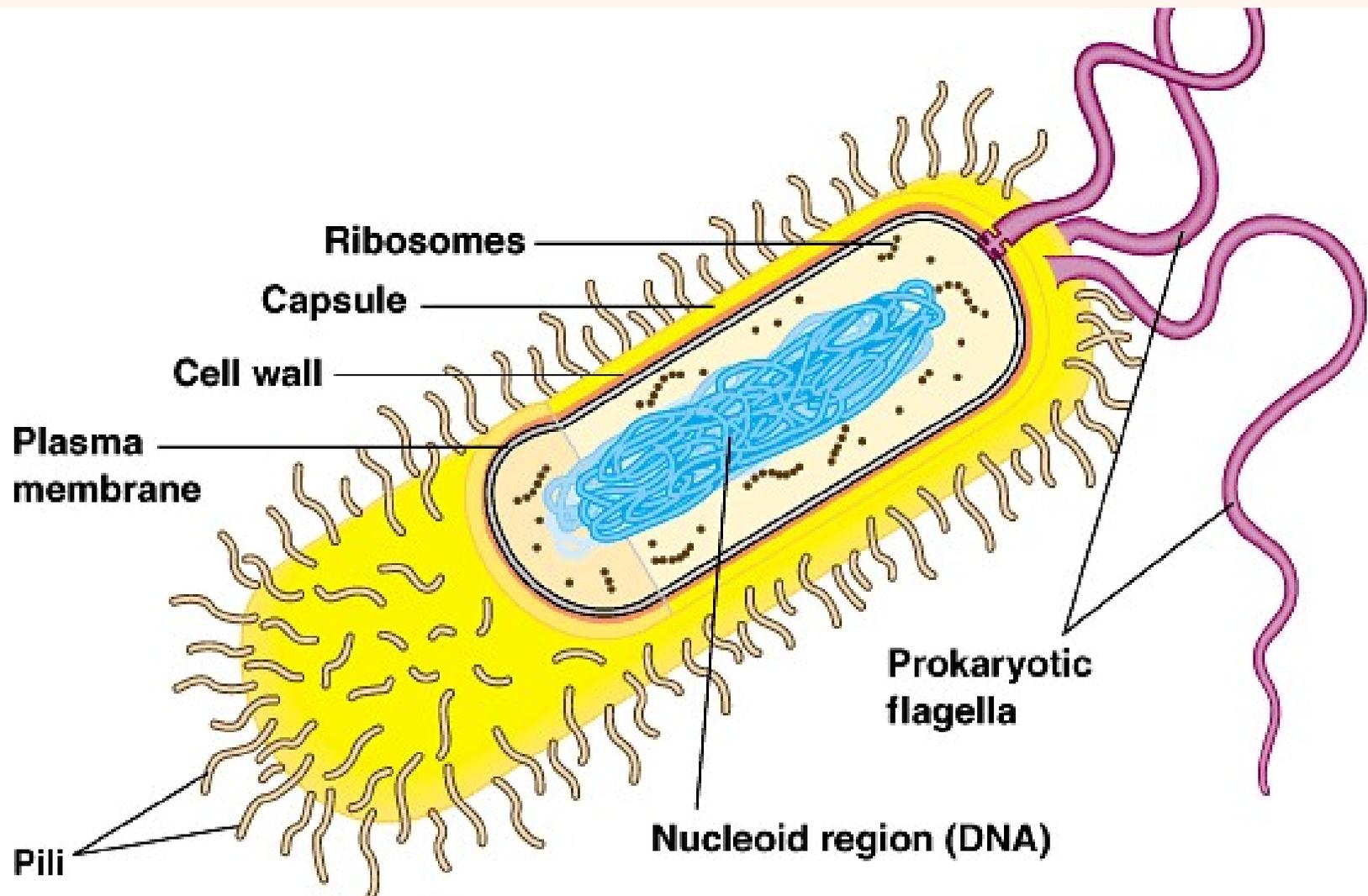


1. Maintain weight
2. Improve immunity
3. Improve baby's health

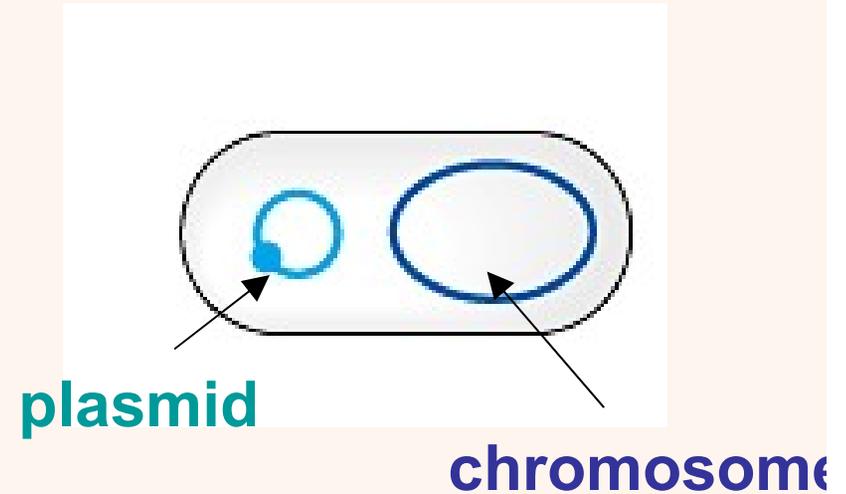
<https://www.youtube.com/watch?v=5DTrENdWvVM>

<http://microbe.net/2013/11/24/microbe-video-of-the-week-npr-animation-of-the-human-microbiome/>

# Bacterial cell



# Bacteria's Genetic material



Loop of DNA : chromosome

Small Circular DNA molecules called **plasmids**

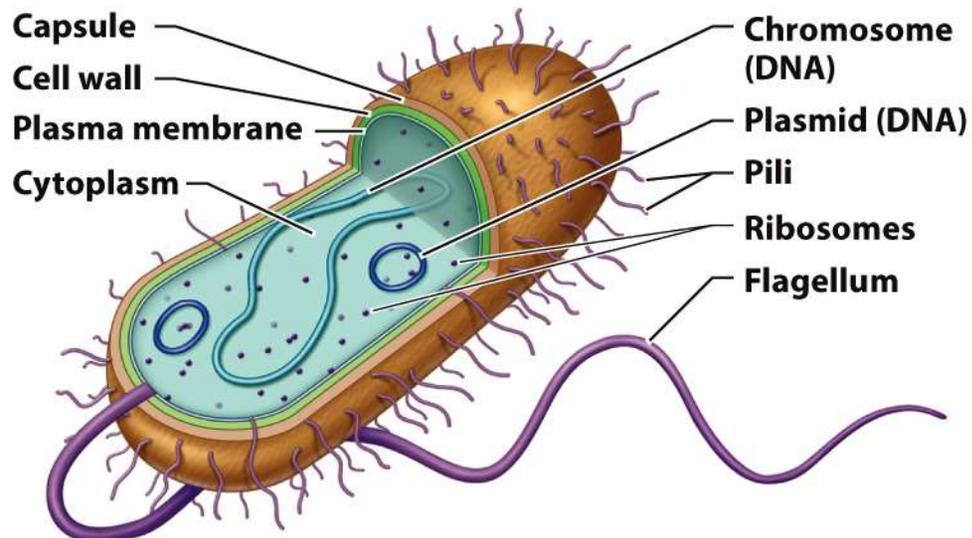
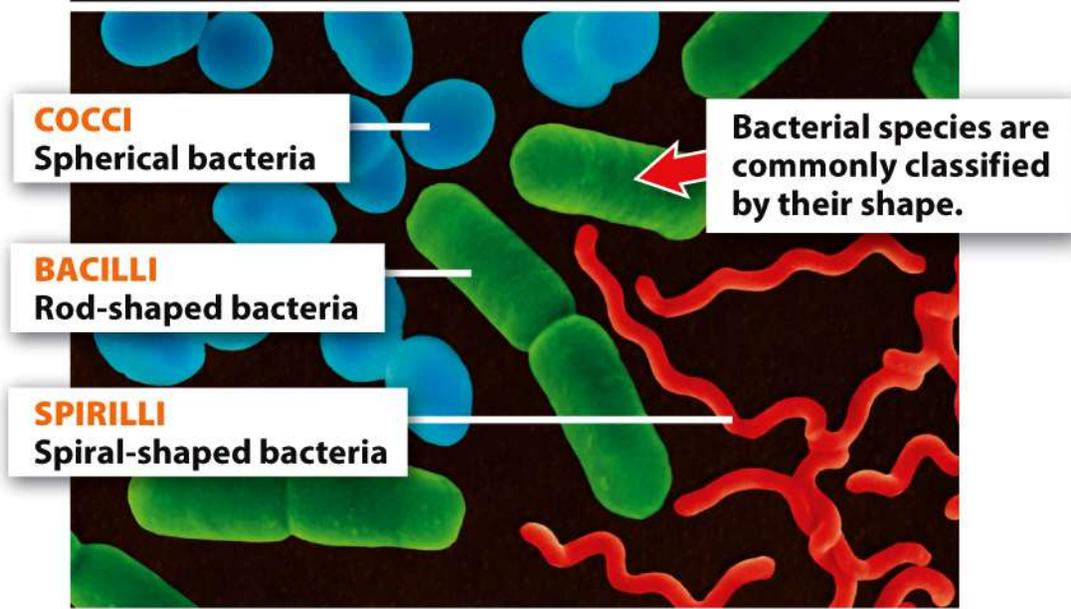
**Plasmids have unique genes**

Break down specific material \_\_\_\_\_ plasmids

Resist antibiotics \_\_\_\_\_ plasmids

Controls the infection rates \_\_\_\_\_ plasmids

## BACTERIA: CLASSIFICATION AND STRUCTURE



**Figure 13-5**

*What Is Life? A Guide To Biology*, Third Edition

© 2015 W. H. Freeman and Company [Photo: © Dennis Kunkel Microscopy, Inc.]

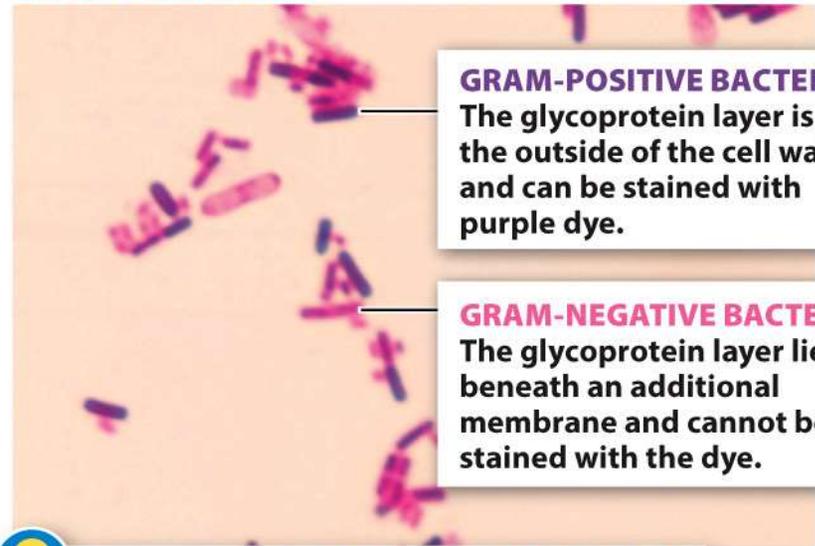
## METHODS OF IDENTIFYING BACTERIA

### APPEARANCE

Some bacteria can be identified by looking at the colors and shapes of their colonies.



### GRAM STAINING



#### GRAM-POSITIVE BACTERIA

The glycoprotein layer is on the outside of the cell wall and can be stained with purple dye.

#### GRAM-NEGATIVE BACTERIA

The glycoprotein layer lies beneath an additional membrane and cannot be stained with the dye.



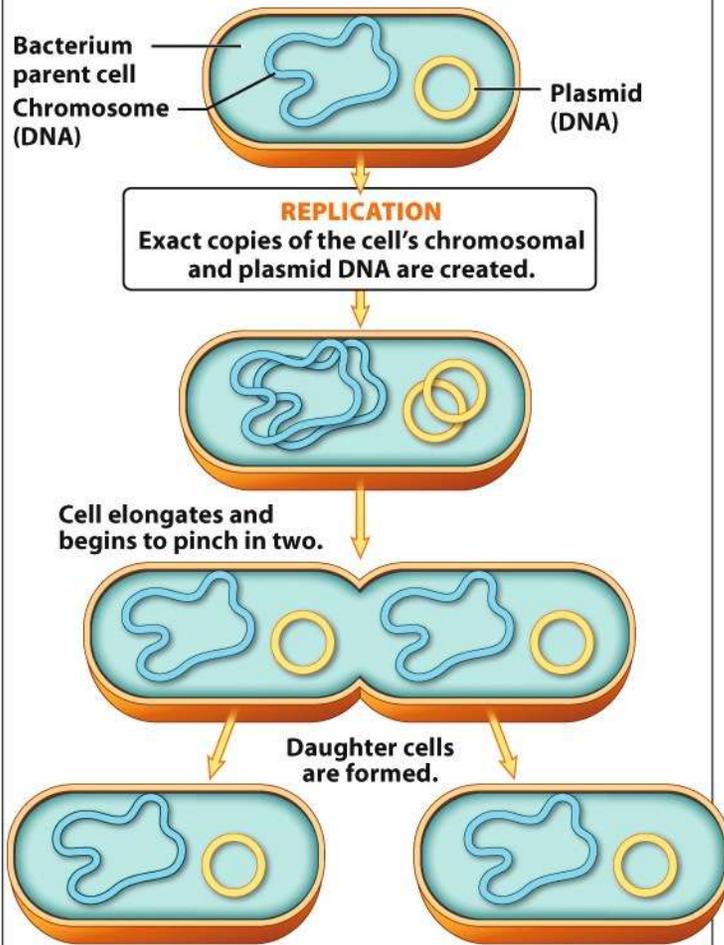
**Gram-negative bacteria—due to their cell membrane composition—are resistant to penicillin.**

**Figure 13-6**

*What Is Life? A Guide To Biology*, Third Edition

(left to right) mediacolor/Alamy; Biophoto Associates/Science Source

## CELL DIVISION IN BACTERIA



**Fission can be extremely fast—in less than 12 hours a single *E. coli* could give rise to a population of 20 billion cells (three times the number of humans on earth)!**

Binary Fission  
Is this asexual or  
sexual  
reproduction?

**Figure 13-7**

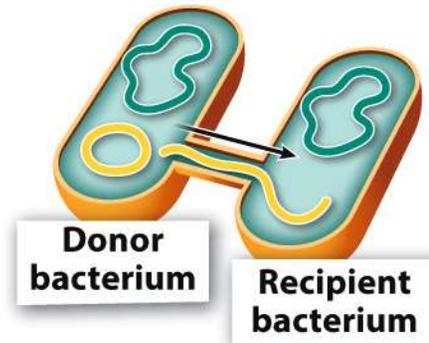
*What Is Life? A Guide To Biology*

© 2010 W. H. Freeman and Company

## METHODS OF GENETIC EXCHANGE IN BACTERIA WITHIN THE SAME GENERATION

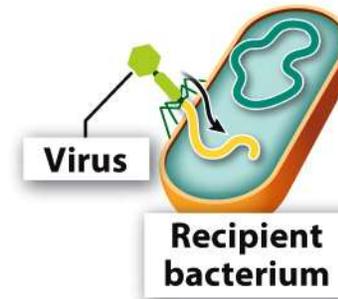
### CONJUGATION

A bacterium transfers a copy of some or all of its DNA to another bacterium, giving the second bacterium genetic information it did not have before.



### TRANSDUCTION

A virus containing pieces of bacterial DNA inadvertently picked up from its previous host infects a new bacterium, and passes new bacterial genes to the bacterium.



### TRANSFORMATION

A bacterium can take up DNA—potentially including alleles it did not carry—from its surroundings (usually from bacteria that have died).

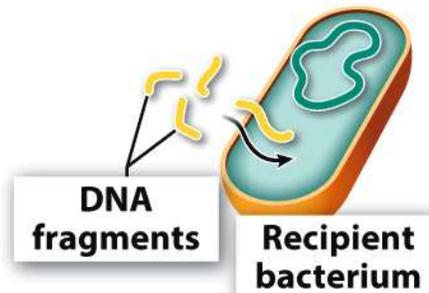
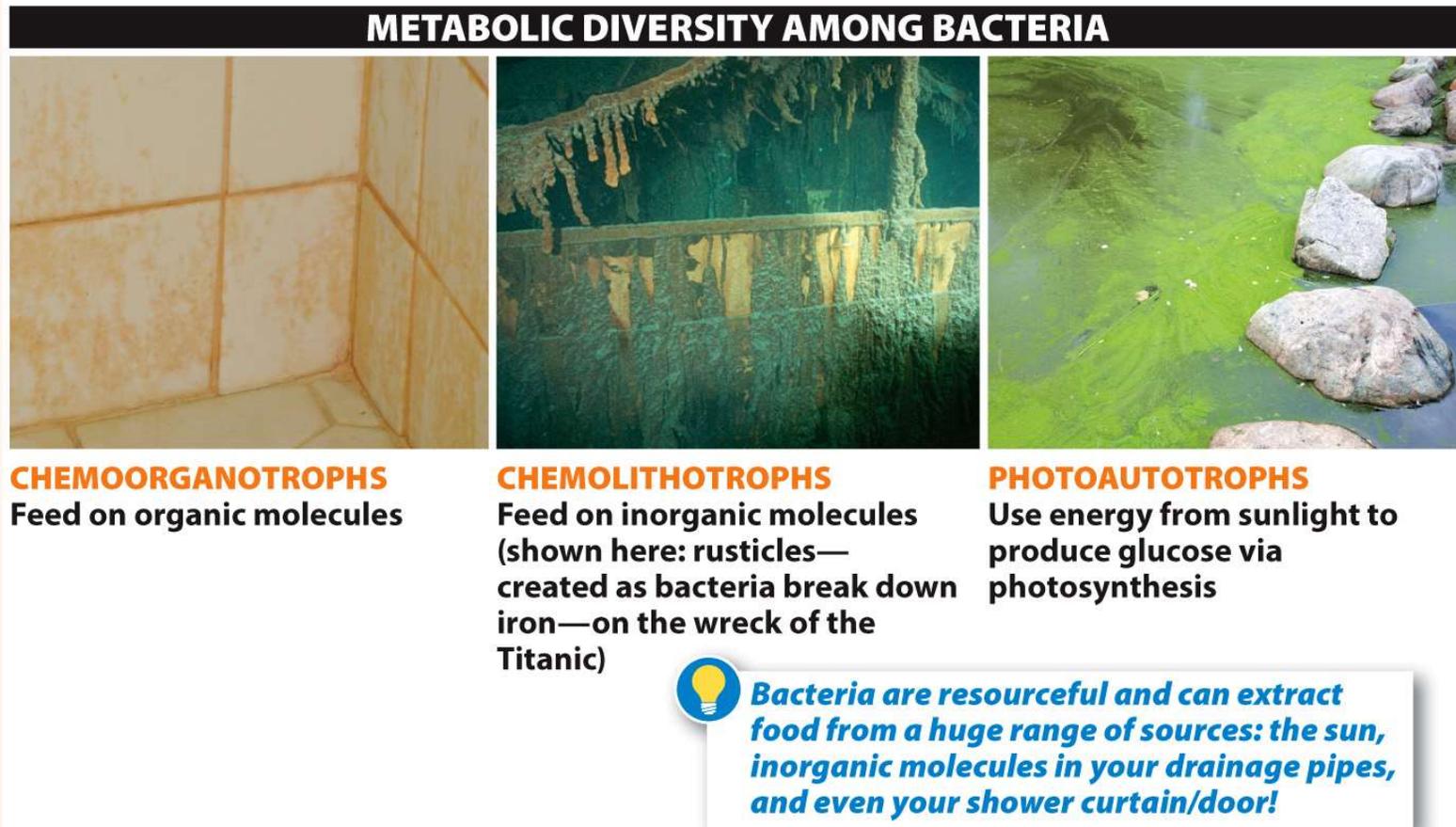


Figure 13-8

*What Is Life? A Guide To Biology*, Third Edition  
© 2015 W. H. Freeman and Company

# 13.5 Metabolic diversity among the bacteria is extreme.



**Figure 13-9**

*What Is Life? A Guide To Biology*, Third Edition  
(left to right) Copyright Dodie Ulery; © Ralph White/Corbis; Reino Hanninen/Alamy

# Photoautotrophs make their own food by photosynthesis

## METABOLIC DIVERSITY AMONG BACTERIA



### PHOTOAUTOTROPHS

- Use energy from sunlight to produce glucose via photosynthesis

Energy source: \_\_\_\_\_  
Carbon source: \_\_\_\_\_

# Chemolithotrophs

## Feeds on inorganic molecules

### METABOLIC DIVERSITY AMONG BACTERIA



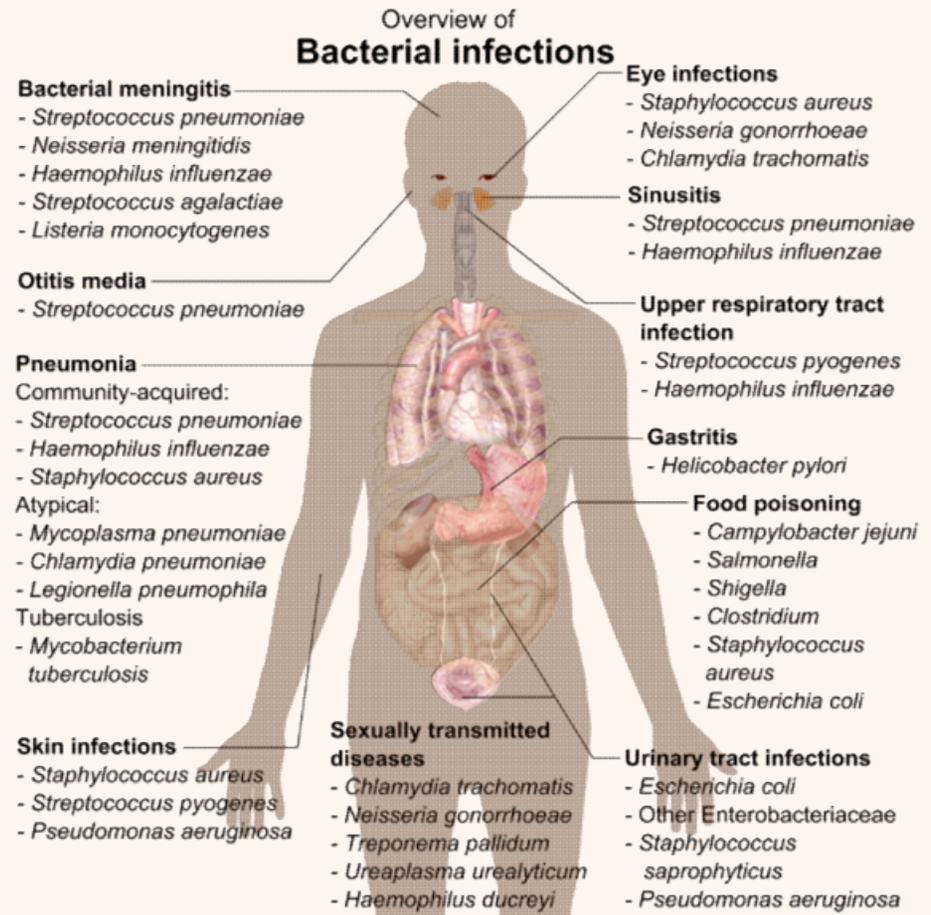
### CHEMOLITHOTROPHS

- Feed on inorganic molecules

Energy source:  
Carbon source:

# Chemoorganotrophs (feeds on organic molecules)

Energy source:  
Carbon source:



# Bacteria cause many human diseases.

## Pathogenic Bacteria

Cholera

Plague

Typhoid

Tuberculosis

Pneumonia

Tetanus



Food poisoning

# Antibiotics

- What's an antibiotic?
- How does it work?
- What do plasmids have to do with it?
- How can bacteria "acquire" resistance?



***Streptococcus pyogenes is usually harmless, but some strains are responsible for strep throat, scarlet fever, and necrotizing fasciitis (flesh-eating bacteria).***

Figure 13-12  
What Is Life? A Guide To Biology  
© 2010 W.H. Freeman and Company

*Helicobacter bacillus* causes peptic ulcer and are **gram negative**. Given this information what do we know about this species of bacteria?

- A. They are rod shaped with a lot of peptidoglycan layer
- B. They are rod shaped with less peptidoglycan.
- C. They are spiral shaped with lots of peptidoglycan layer.
- D. They are spherical with less peptidoglycan

Absorption of free DNA from the environment is called \_\_\_\_\_

- A. Binary fission
- B. Conjugation
- C. Transduction
- D. Transformation

The bacteria that live on our body  
are \_\_\_\_

- A. Heterotrophs
- B. Photoautotrophs
- C. Chemoorganotrophs
- D. Both A and C
- E. Both B and C

## Antibiotics:

**First Antibiotic:** In 1928 Alexander Fleming described antibiotics from a mold called \_\_\_\_\_

In 1939: Ernst Chain and Howard Florey: purified the antibiotic \_\_\_\_\_

**Antibiotics are naturally produced from**

Fungi.....Penicillin

Bacteria.....Streptomycin

Man made : Sulfa drugs

## How do antibiotics work?

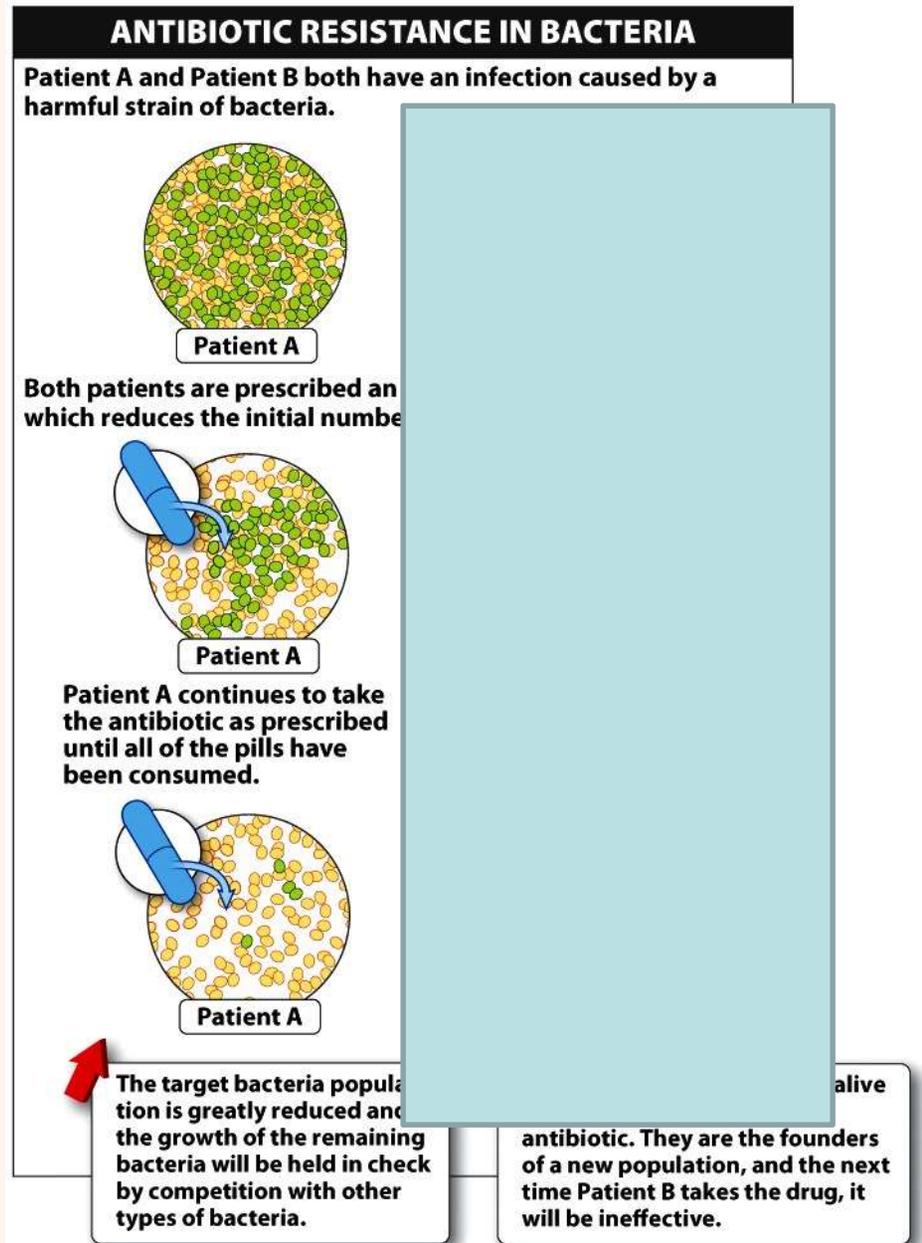
Antibiotics target essential bacterial physiology and biochemistry, causing microbial cell death or the cessation of growth.

**Bacteria evolve drug resistance quickly**

**Bacteria resist antibiotics by:**

- Pumping antibiotics out of their cell
- Proteins that bind to the antibiotic and block its lethal effect
- Enzymes that break down the antibiotic

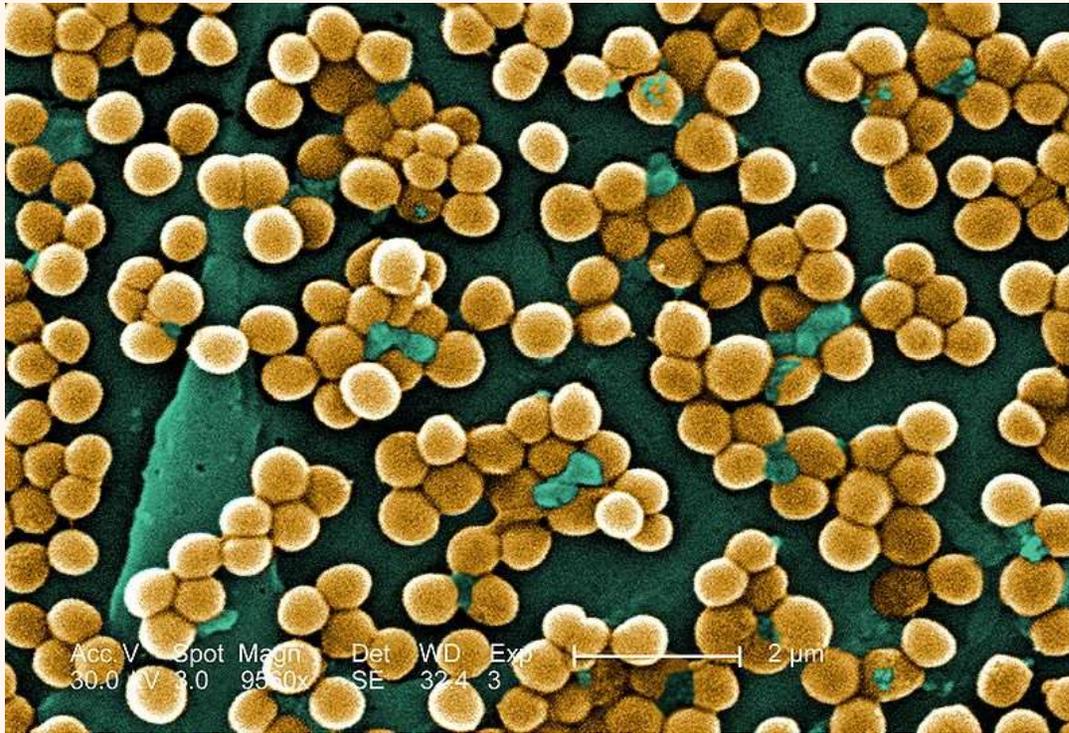
**Bacteria evolve drug resistance quickly.**



**Figure 13-13**  
*What Is Life? A Guide To Biology*  
© 2010 W. H. Freeman and Company

# MRSA: superbug

Methicillin Resistant Staphylococcus  
Aureus



Bacteria can become resistant to antibiotics when \_\_\_\_\_ are transferred from one bacteria to another through \_\_\_\_\_

<http://www.webmd.com/video/truth-about-mrsa>

How did  
Antibiotic  
Resistant  
bacteria come  
to be such a  
problem??



**Agriculture in the United States uses about 25 million pounds of antibiotics each year—about eight times more than is used for all human medicine!**

Figure 13-14  
*What Is Life? A Guide To Biology*  
© 2010 W.H. Freeman and Company

Overuse of antibiotics  
Not completing the  
dosage

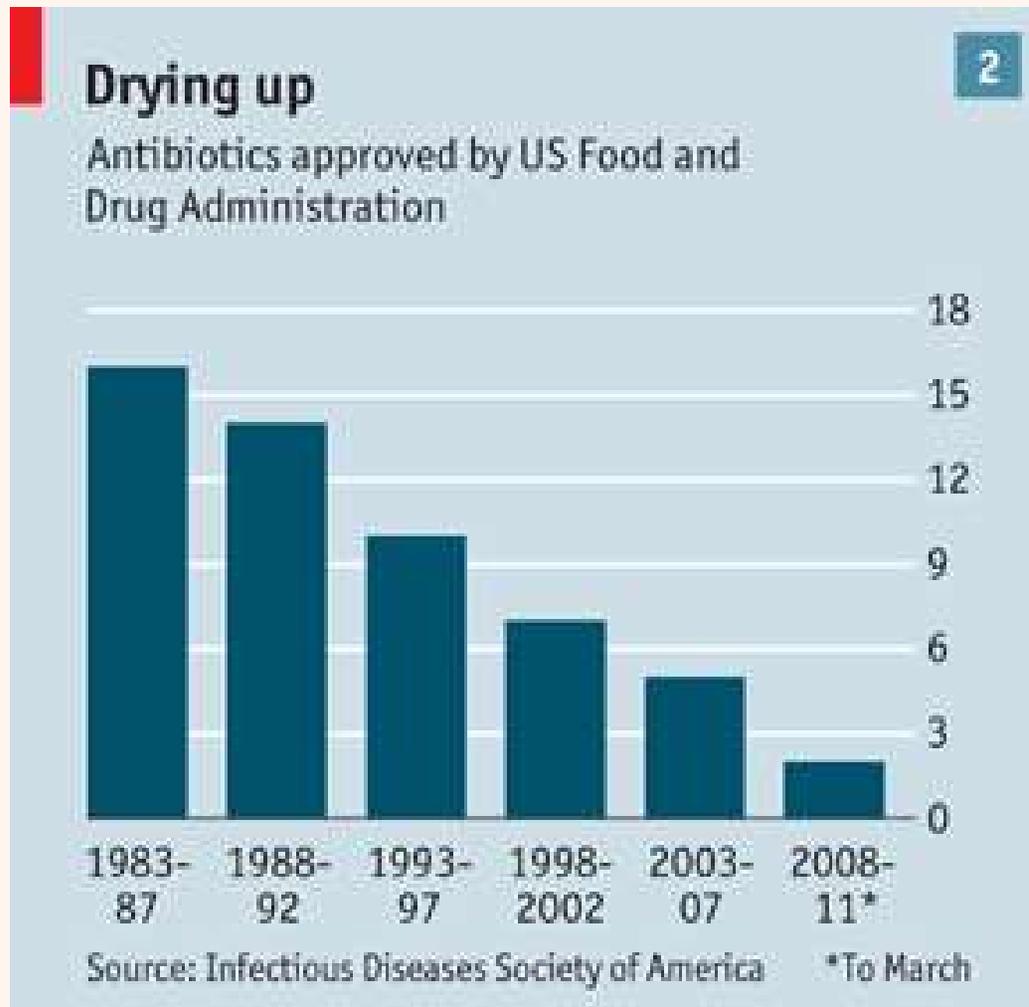
# It does not pay to be too clean!!

## Hygiene hypothesis



- **Washing your hands keeps you from getting sick.**

# Current News: Production of new antibiotics has been decreasing

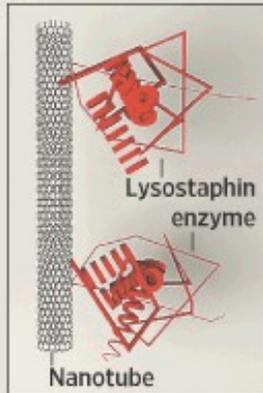


Between 1983 and 1987, **16** new antibiotics won FDA approval. Since 2003 only **7** have been approved

The Infectious Diseases Society of America (IDSA) has put forward its "**10x20**" plan, which calls for the development of **ten** new antibiotics by **2020**.

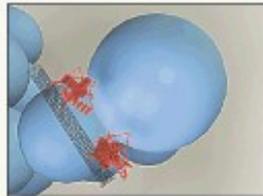
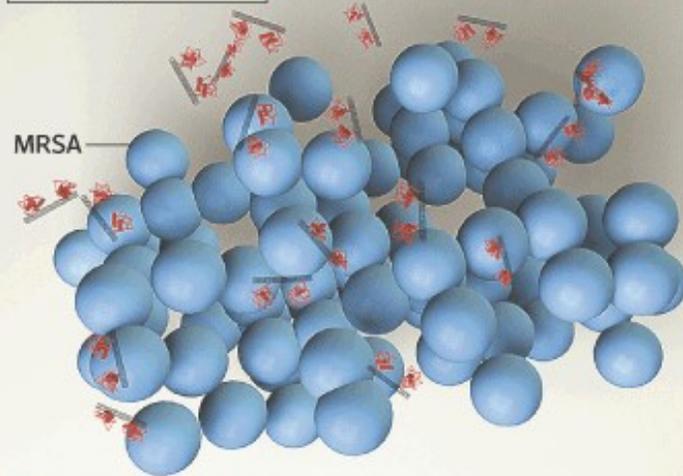
A non-resistant strain of *E.coli* can pick up a resistance plasmid directly from a resistant bacteria, by \_\_\_\_\_

- A. transduction.
- B. Binary fission.
- C. conjugation.
- D. replication.

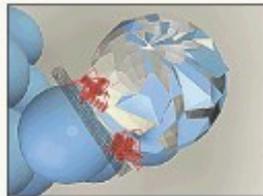


## Battling Superbugs

Researchers are trying a new technology to combat MRSA, an antibiotic-resistant superbug commonly found in hospitals. An enzyme called lysostaphin, which naturally kills the bacteria, is attached to a tiny nanotube a millionth the diameter of a human hair. The nanotube and enzyme can then be embedded in material like paint or coatings for medical devices.



The enzyme breaks a bond that holds up the cell wall of the bacteria.



Like a balloon that has been popped by a pin, MRSA's cell wall collapses and the bacteria dies.

Source: Jonathan Dordick, Rensselaer Polytechnic Institute

## How to combat antibiotic-resistance?

1. Using Nanotechnology
2. Using technology
3. Using viruses

Viruses that infect bacteria are called \_\_\_\_\_

<http://www.cellsalive.com/phage.htm>

Antibiotics kill the good bacteria in our body along with the bad ones

A. True

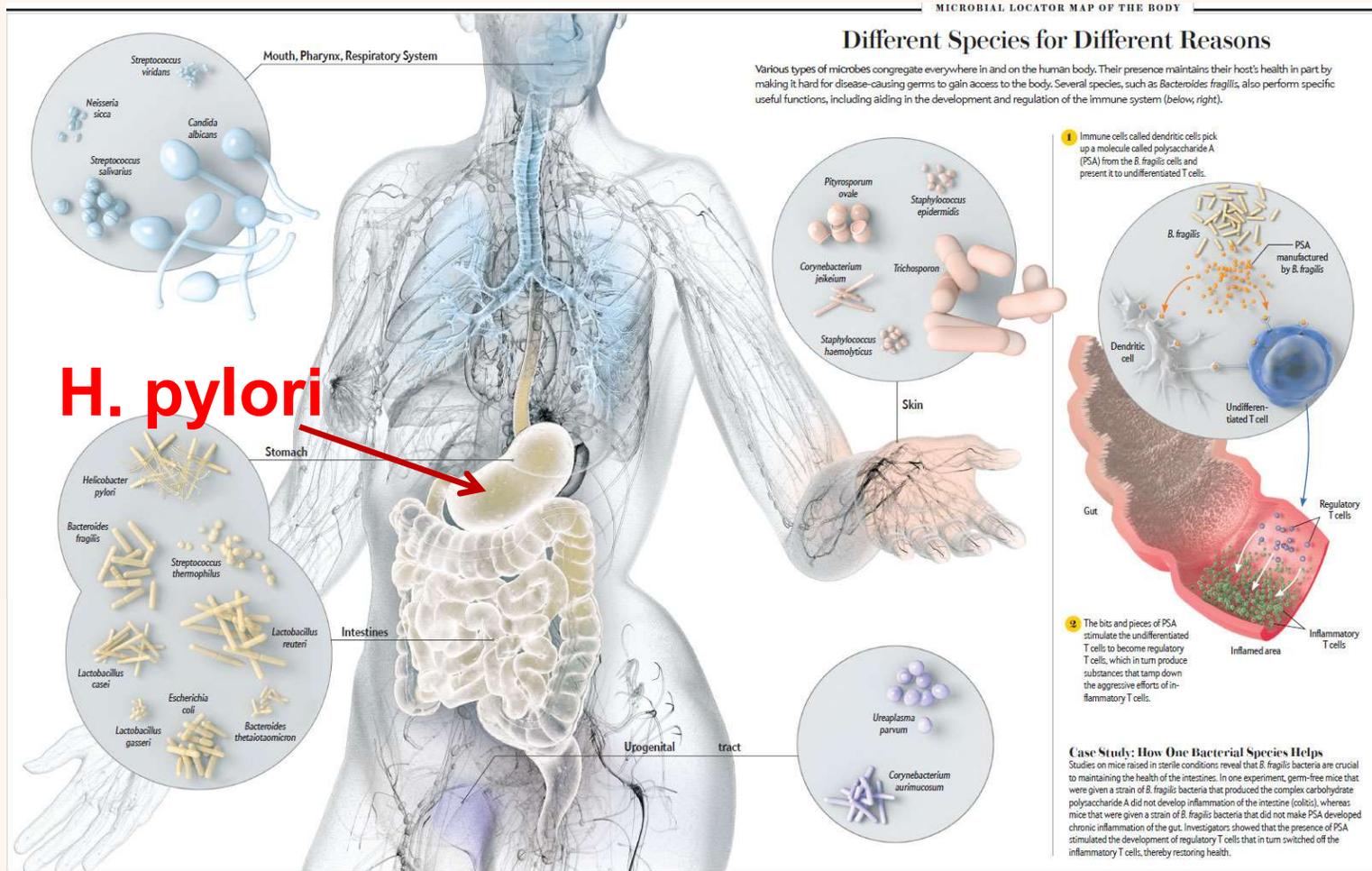
B. False

# Bacteria Research

- Gut bacteria in Chinese is different from Americans !!!
  - Is it differences in diet? Human genes? Geography?

Colic babies: had bacteria that produce gas and fewer to combat inflammation

Microbes linked to colic babies  
Pediatrics: Jan 2013



**H. pylori**

**B. fragilis:** improving our immune system by regulating T cell (decreases incidence of autoimmune diseases)

**H. pylori:** controls obesity by regulating the enzyme ghrelin

# Beneficial Bacteria



## 1. Human health Human microbiome project

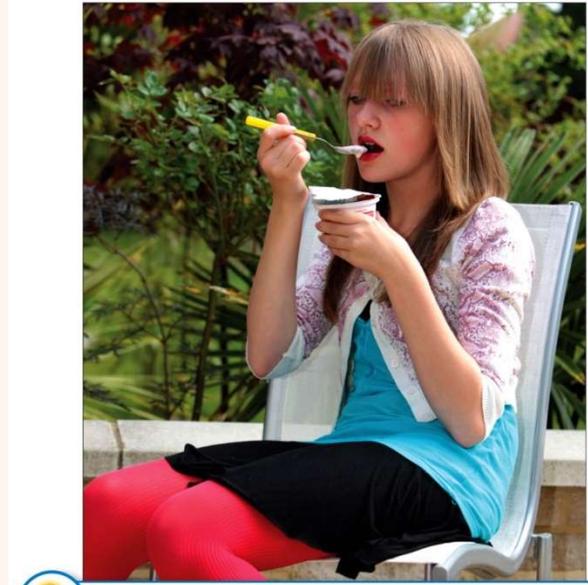


<http://www.microbeworld.org/component/jlibrary/?view=article&id=11707>

You are mainly microbe:  
meet your microbiome

# 2. In industry many bacteria are beneficial

Cheese, Yogurt, Pickled vegetables: are produced by lactic acid fermentation



**Many bacteria are beneficial. Those living in yogurt, for example, can take up residence in your digestive tract and improve your absorption of nutrients from food.**

Side To Biology  
Plan and Company

Probiotic therapy  
What two vitamins  
produced by bacteria



Fermented vegetables:  
kimchi

### 3. In the environment Biodegradation/Decomposers

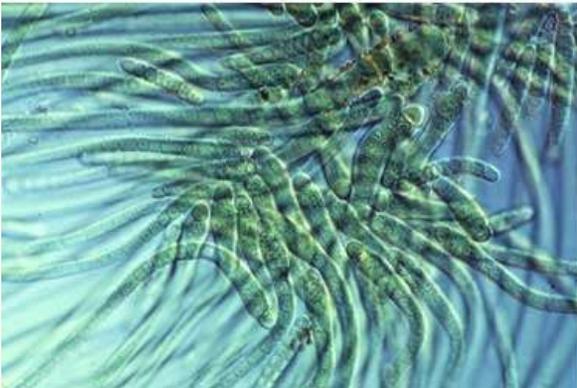


Cleaning Oil spills



# Oxygen production

## Cyanobacteria



Prokaryotes  
appeared  
around \_\_\_\_\_  
bya

# 4. Mutualistic bacteria

## Symbiotic Relationship between bacteria and other species

Nitrogen-fixing bacteria



Mutualism: bacterial  
"headlights"



Ruminant digestion

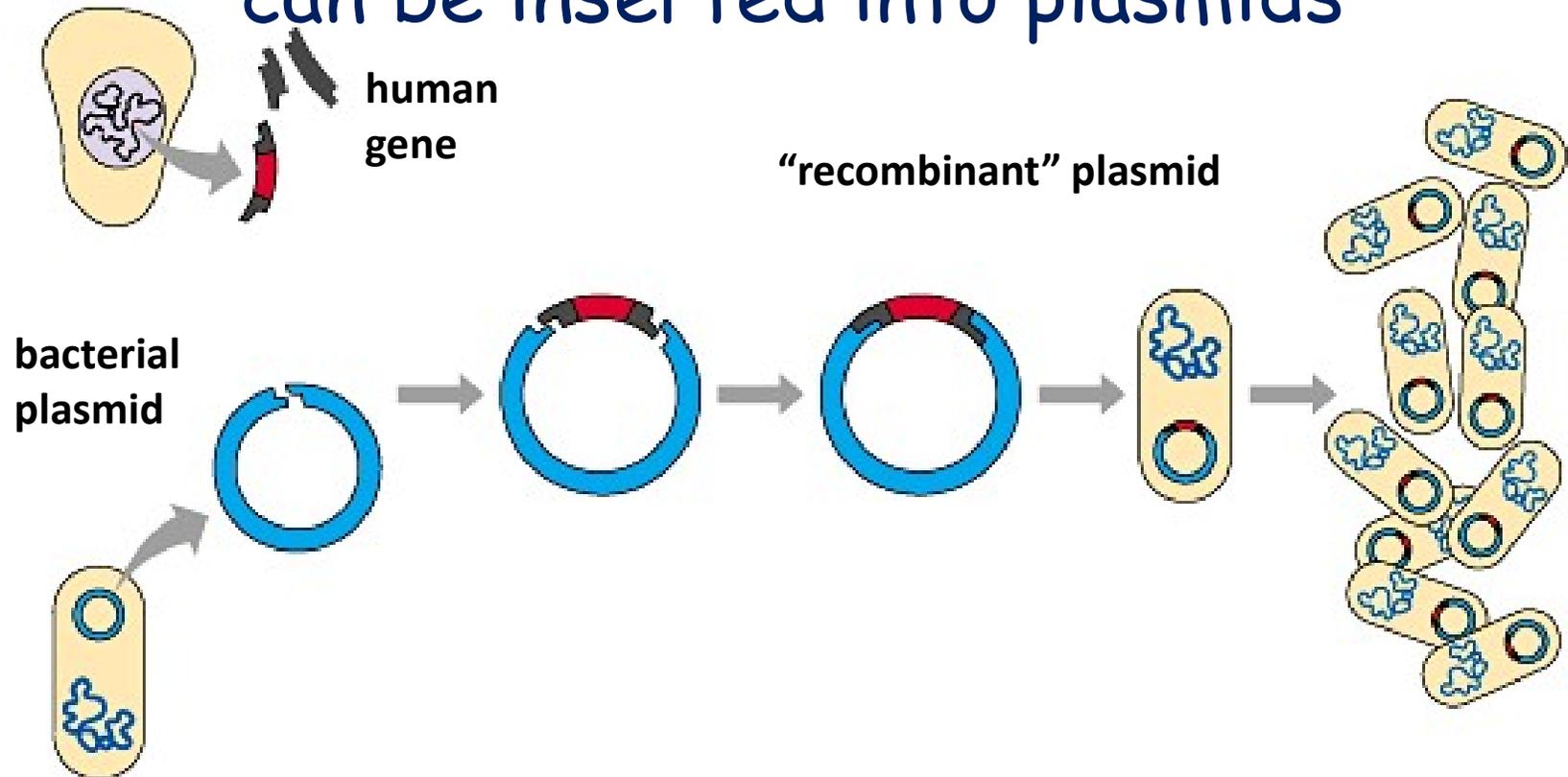
Corbis.com

*E. Coli* in human intestine



# 5. Bacteria is used as a vector in Genetic Engineering

Genes from other species can be inserted into plasmids

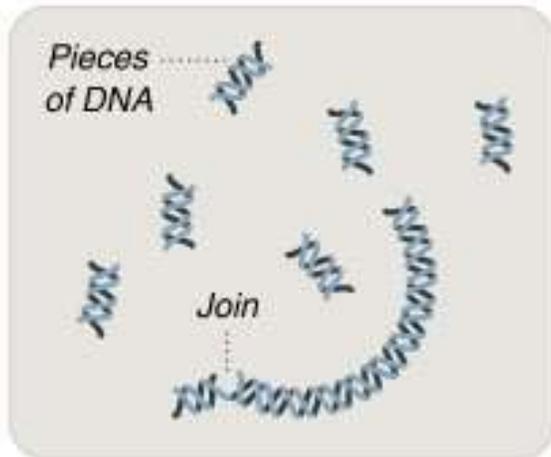


These "recombinant" bacteria can be used as protein factories (e.g. insulin, clotting factors...)

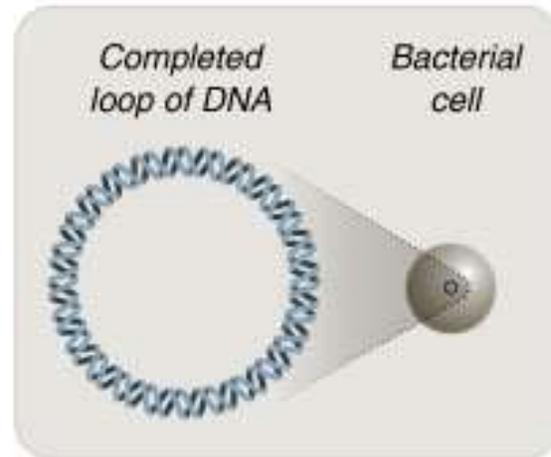
# Synthetic cell with help from bacteria: By Craig Venter

## Synthesizing a Functional Genome

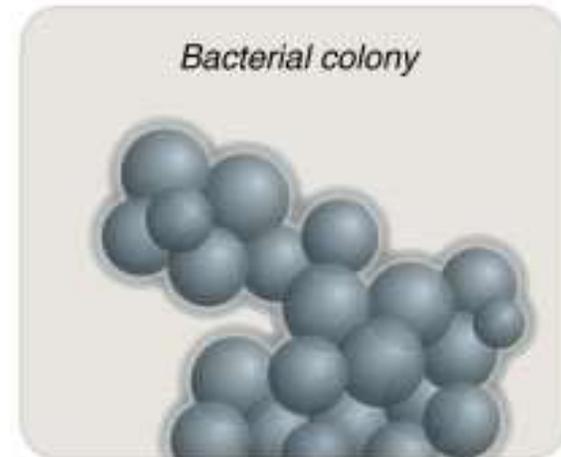
A team led by J. Craig Venter has succeeded in creating a synthetic bacterial genome and using it to control a cell.



**ASSEMBLY** The team began with small pieces of laboratory-made DNA, then used a new technique to join them together into the largest piece of DNA synthesized so far, a loop one million units in length.



**INSERTION** The loop of DNA was designed to closely replicate the genetic sequence of a species of bacterium. To test the DNA, the team inserted it into an empty cell of a different species of bacterium.



**SELF-REPLICATION** The synthetic DNA proved accurate enough to take over the bacterial cell and substitute for the cell's own DNA. The "synthetic cell" then replicated itself to form a bacterial colony.

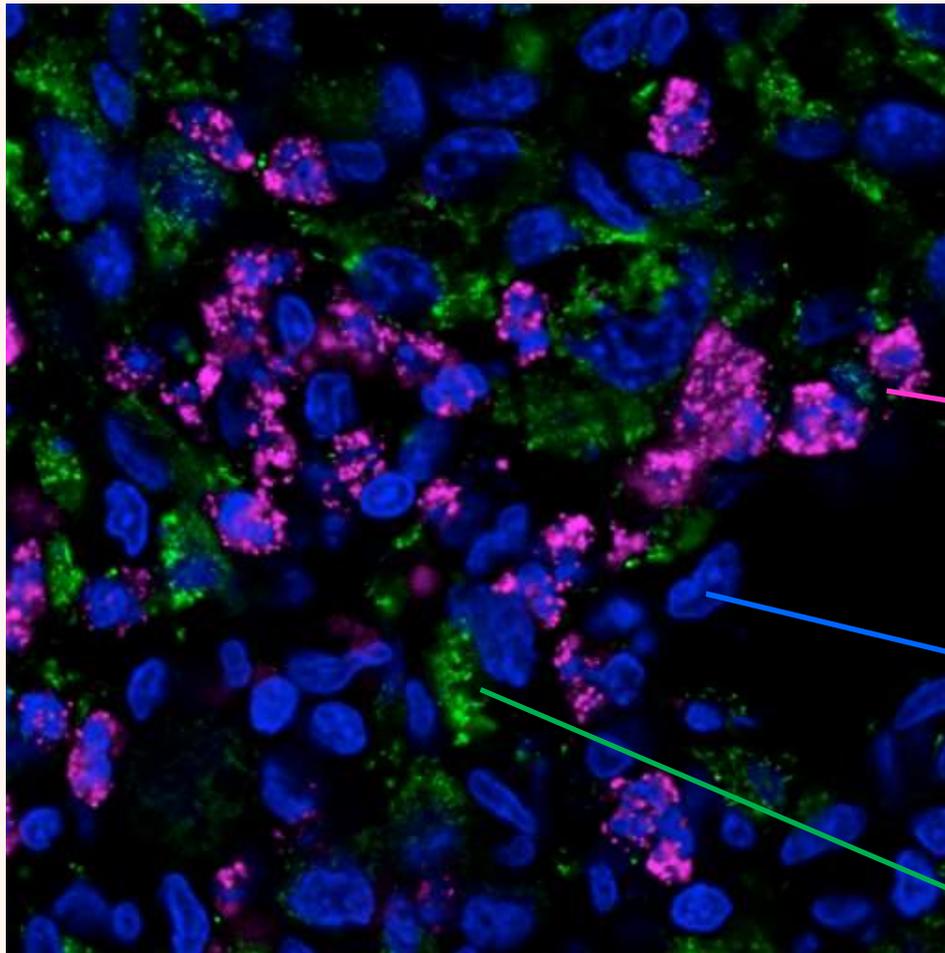
Source: Science

THE NEW YORK TIMES

# 6. In medicine

## Current News: Tumor-seeking Salmonella treats brain tumors !!

journal Molecular Therapy – Oncolytics. Jan 11, 2017



Bacteria

Cancer cells

Mitochondria

③ Archaea  
exploit some of  
the most extreme  
habitats.



## Archaea: Extremophiles

High Temperature: \_\_\_\_\_

Low Temperature: \_\_\_\_\_

Acid: \_\_\_\_\_

Methane: \_\_\_\_\_

Salt loving: : \_\_\_\_\_



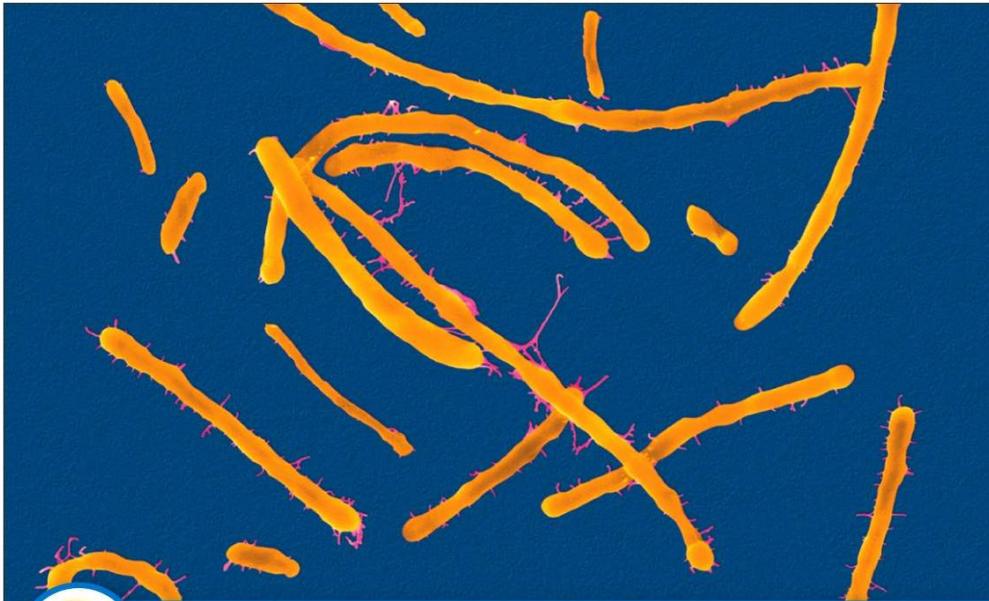
salty pond in the Arabian  
desert, which is colored  
red/pink/purplish due to  
the presence of  
*Halobacterium salinarum*

# Archaea and intestinal Gas !!



**Archaea in your intestine break down a chemical bond found in beans (a bond humans cannot break)...but the process generates gas, which can cause discomfort as it tries to escape.**

# Biochemically Archaea are profoundly different from bacteria.



***Archaea look very much like bacteria. But closer inspection—of their physiology, biochemistry, and DNA—reveals them to be profoundly different from all bacteria.***

**Figure 13-15**  
*What Is Life? A Guide To Biology*  
© 2010 W. H. Freeman and Company

# Uses of Archaea

## 1. In bioengineering

Example: Taq polymerase: heat tolerant bacterial enzyme

## 2. Industrial Use (Bioremediation)

Cleaning oil spills, and mineral deposits from pipes



Figure 13-18  
What Is Life? A Guide to Biology  
© 2010 W. H. Freeman and Company

# Pick the true statement

A. Bacteria and archaea are physically dissimilar

B. Bacteria and archaea are biochemically dissimilar

C. Bacteria and archaea are both physically and biochemically dissimilar