Imperial College London

# Bacterial properties

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Course code (MBBS) : Microbiology 1

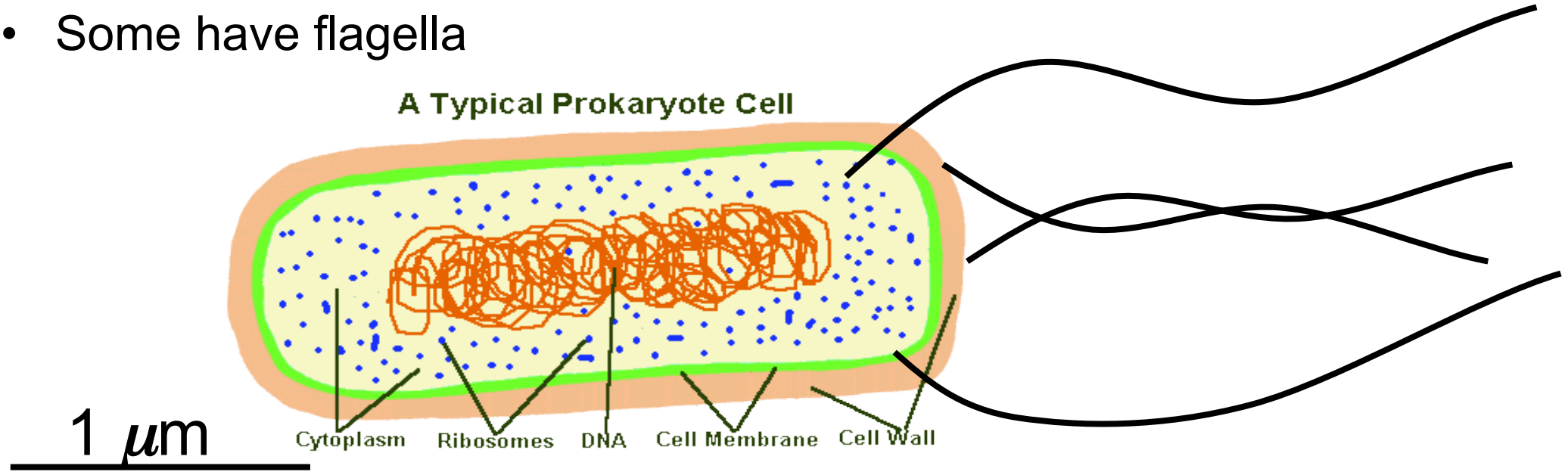
Course code (BMS) : IIP-L6

# Bacterial Properties: Learning objectives

1. Main difference between Gram + and Gram – bacteria
2. Examples of intracellular and extracellular bacteria
3. Flagella and type III secretion – 2 related bacterial multi-protein machines
4. 2 examples of manipulation of host actin cytoskeleton: bacterial entry and movement
5. 3 mechanisms of horizontal gene transfer
6. Genome diversity and evolution

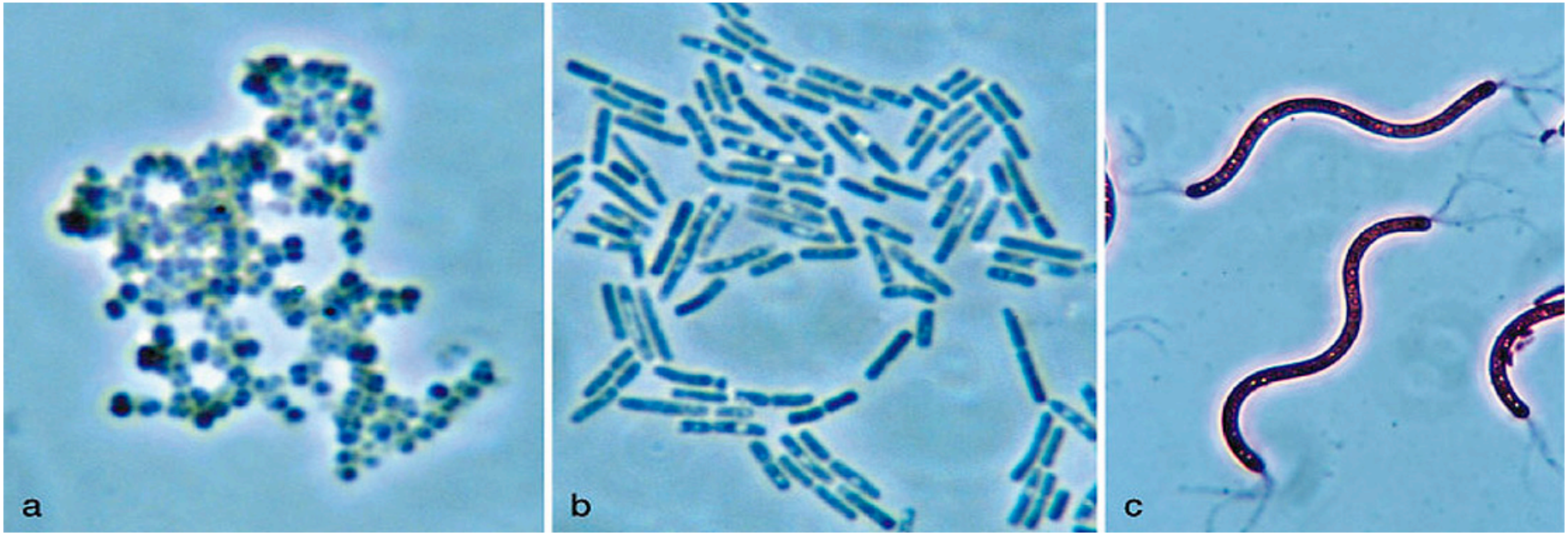
# Bacteria

- Bacteria are small and unicellular
- They have no internal organelles (no chloroplasts, nucleus, ER, mitochondria)
- Haploid
- Some have flagella



# Bacterial forms:

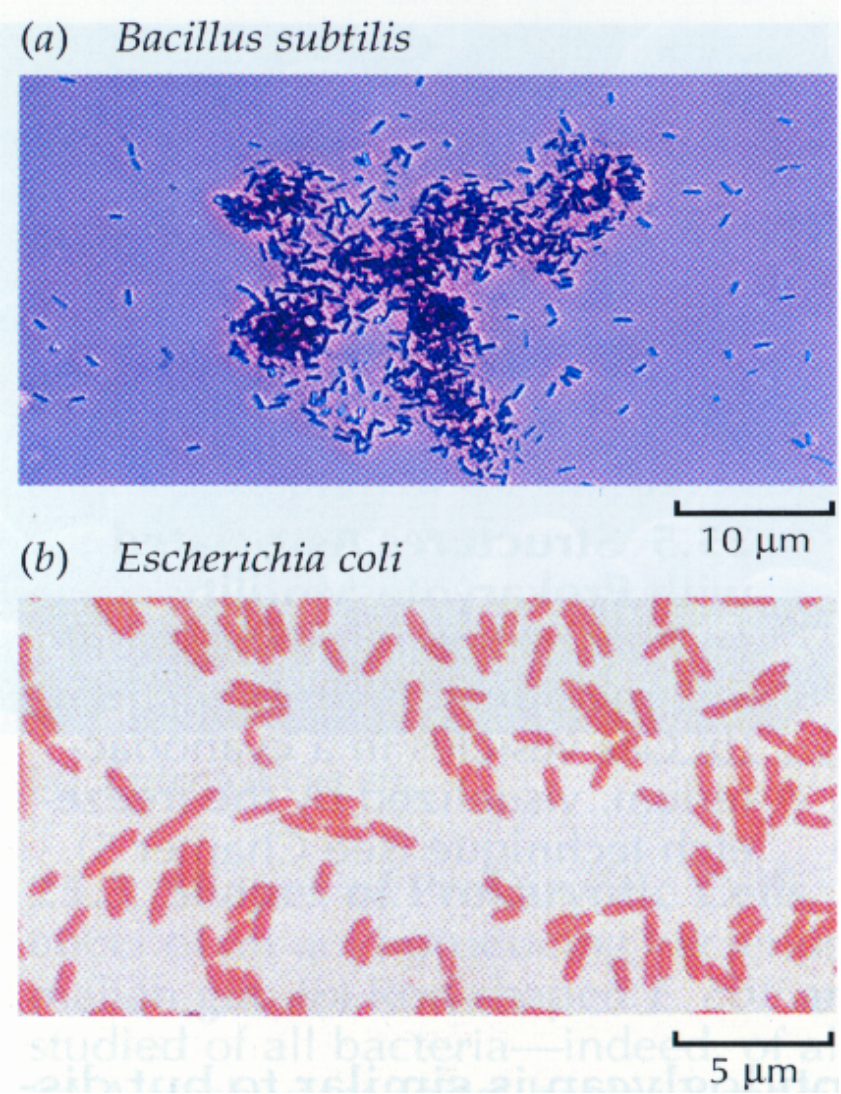
cocci bacilli spirilli



# Identifying Bacteria

- **Gram stain: developed by a Danish physician in the late 1800s.**
  - **Distinguishes between two different kinds of bacterial cell walls.**
  - **Bacteria are stained with a violet dye and iodine, rinsed in alcohol, and then stained with a red dye.**
  - **Stain indicates whether or not you have Gram-negative or Gram-positive bacteria.**

# Gram-stained bacteria



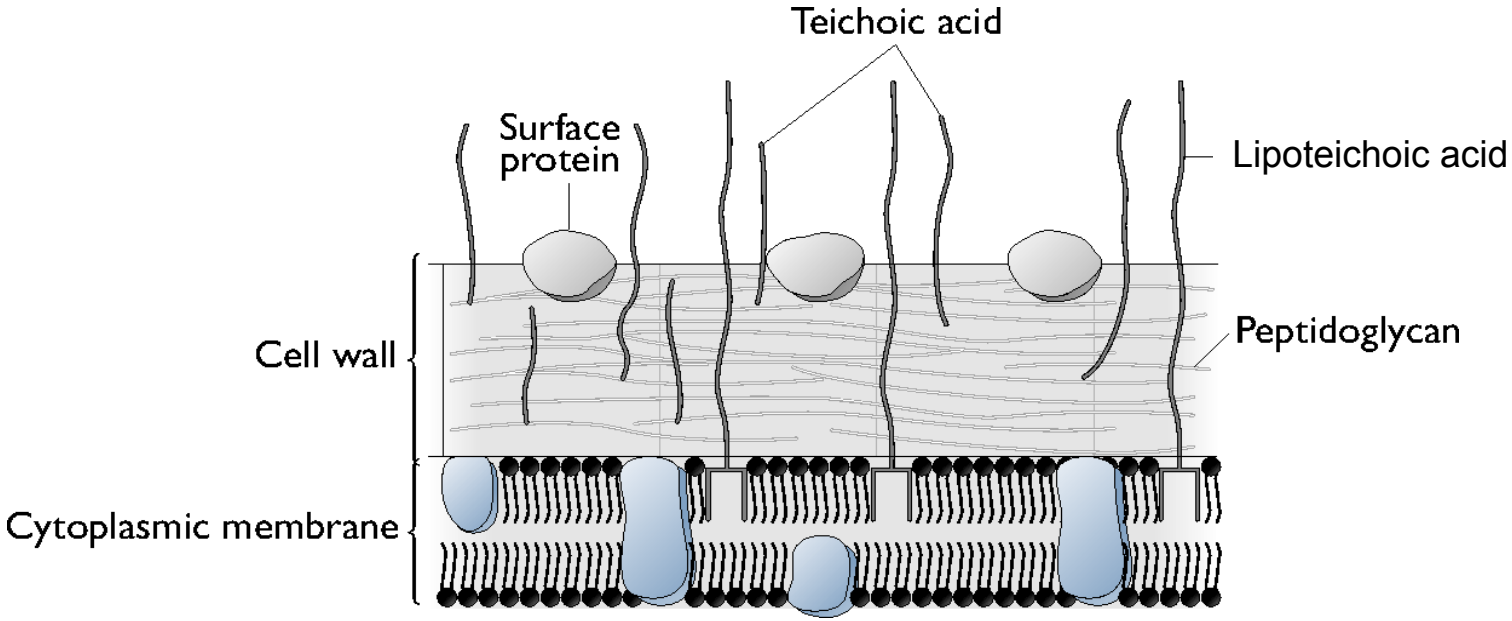

**Gram positive bacteria:**
Peptidoglycan in cell wall retains dye.

High peptidoglycan = deep violet

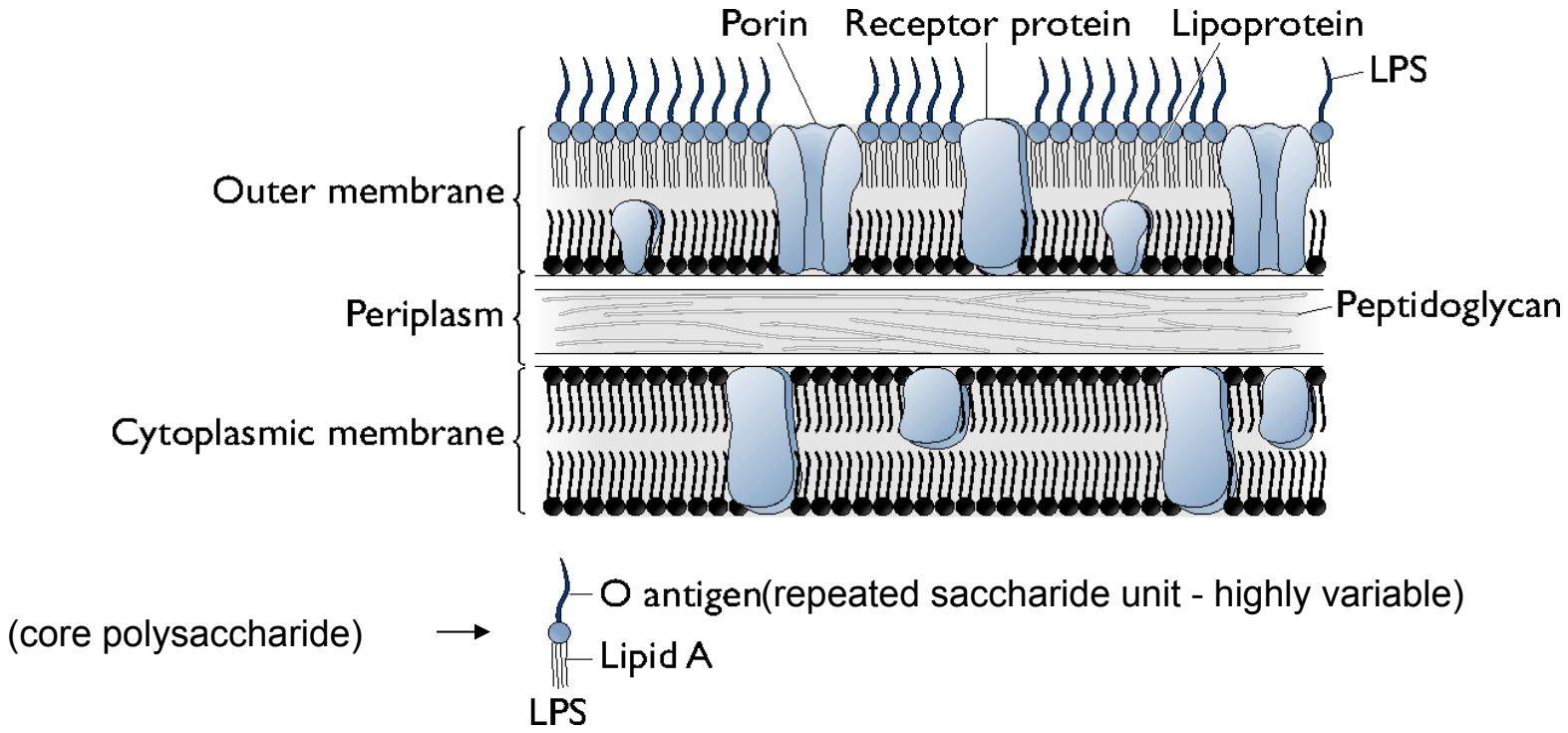
**Gram negative bacteria:**
Outer membrane resists the dye.

The cells absorb counterstain making them appear pink.

# Gram positive cell wall structure



# Structure of gram negative cell wall



# After Gram stain…

- Culture and microscopy
- Biochemical and serological tests
- DNA techniques such as PCR
- Sensitivities to antibiotics

# Vast majority of bacteria are harmless or beneficial (commensal), but some are pathogenic

- **Gram negative**

  *Escherichia coli* (EPEC - diarrhea, EHEC - produces toxin, dysentry and kidney failure)

  *Salmonella* (*typhimurium* - food poisoning, *typhi* - typhoid)

  *Shigella* (dysentry)

  *Vibrio cholerae* (cholera)

  *Neisseria* (*meningitidis*- meningitis, *gonorrhoeae*- gonorrhea)

- **Gram positive**

  *Staphylococcus aureus* (skin diseases, endocarditis, bacteraemia, joint diseases, pneumonia)

  *Streptococcus pneumoniae* (pneumonia, meningitis, otitis media)

  *Streptococcus pyogenes* (tonsilitis, necrotizing fasciitis, bacteremia, scarlet fever)

- **Mycobacteria**

  *Mycobacterium tuberculosis* (TB)

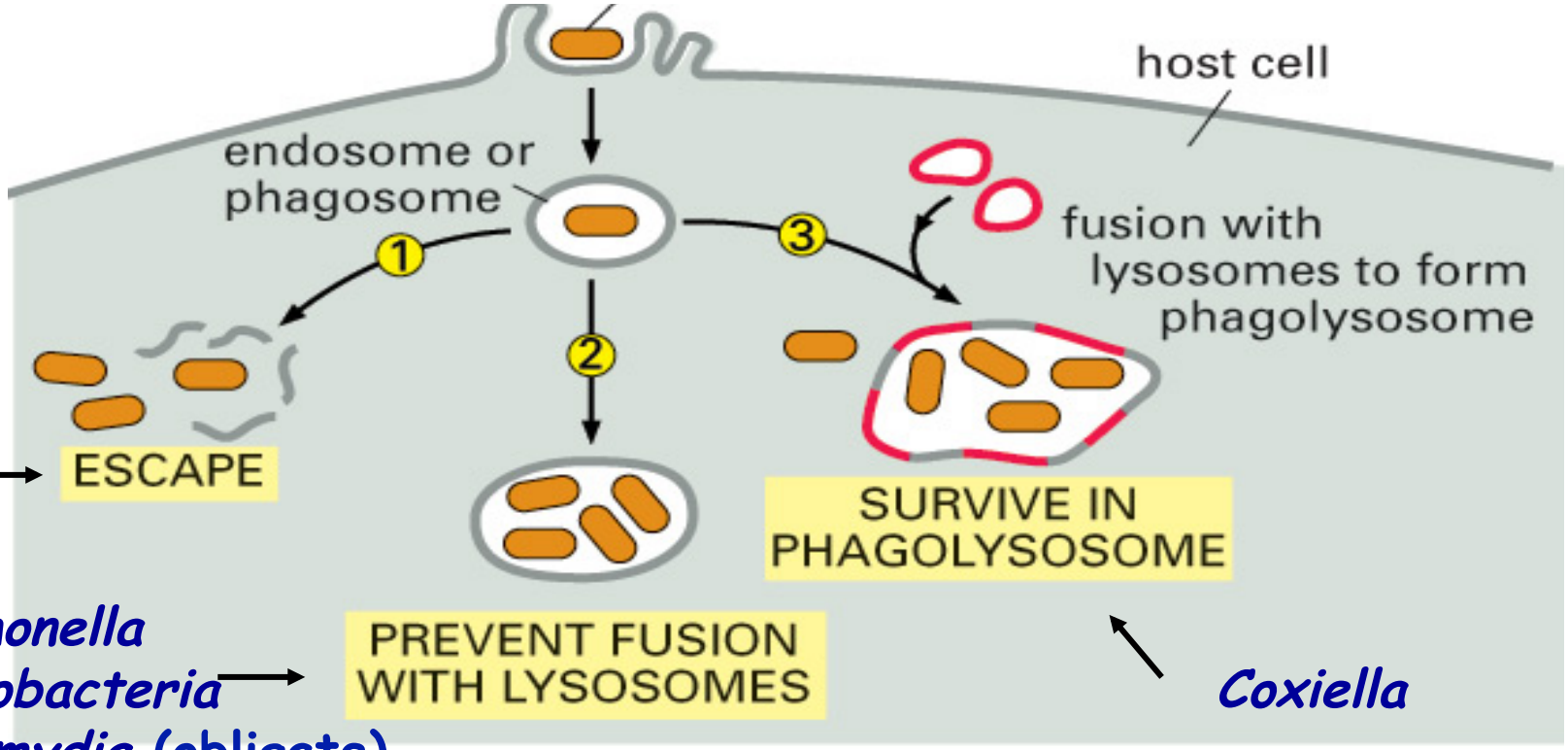
  *Mycobacterium leprae* (leprosy)

# Bacterial pathogens

- **Colonize** (surface structures such as fimbriae, pili)
- **Persist** (avoid, subvert, or circumvent host defenses in or outside cells).
- **Replicate** (acquire nutrients such as iron, energy sources etc)
- **Disseminate within cells, tissues between organs and hosts** (bacterial and host cell motility, through aerosols, faeces etc)
- **Cause disease** (produce toxins that kill host cells, induce diarrhea, dysregulate immune responses)

**extracellular pathogens:** ***Staphylococcus***
***Streptococcus***
***Yersinia***
***Neisseria***

**intracellular pathogens**




***Listeria***
***Shigella***

***Salmonella***
***Mycobacteria***
***Chlamydia* (obligate)**

***Coxiella***

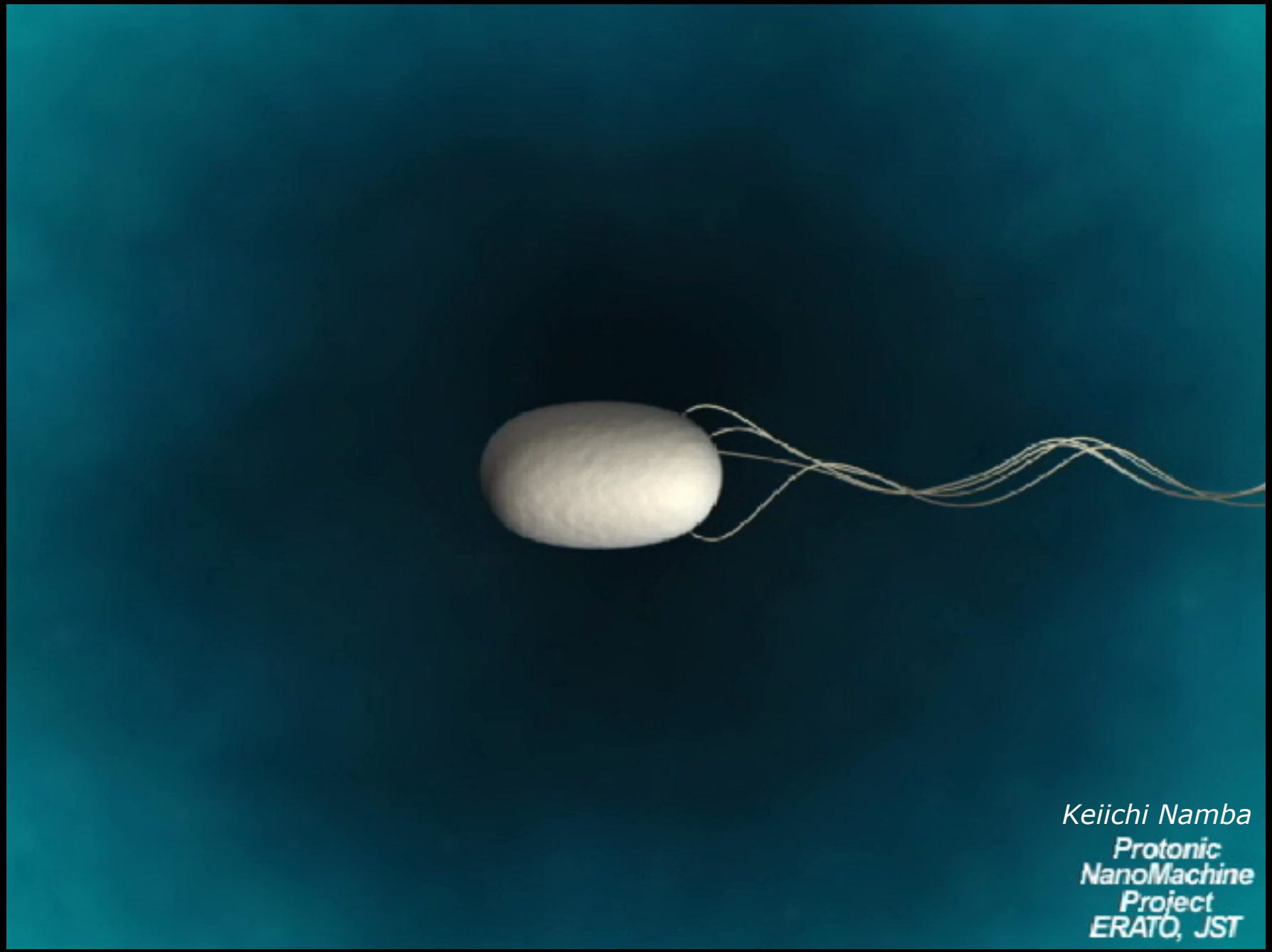
Figure 25–28. Molecular Biology of the Cell, 4th Edition.

# *Salmonella* motility and invasion

*Salmonella* (red) invading HeLa cells expressing GFP-actin (green)
movie = 10 mins

Motility and invasion require two related multi-protein machines –

- flagella
- type III secretion system

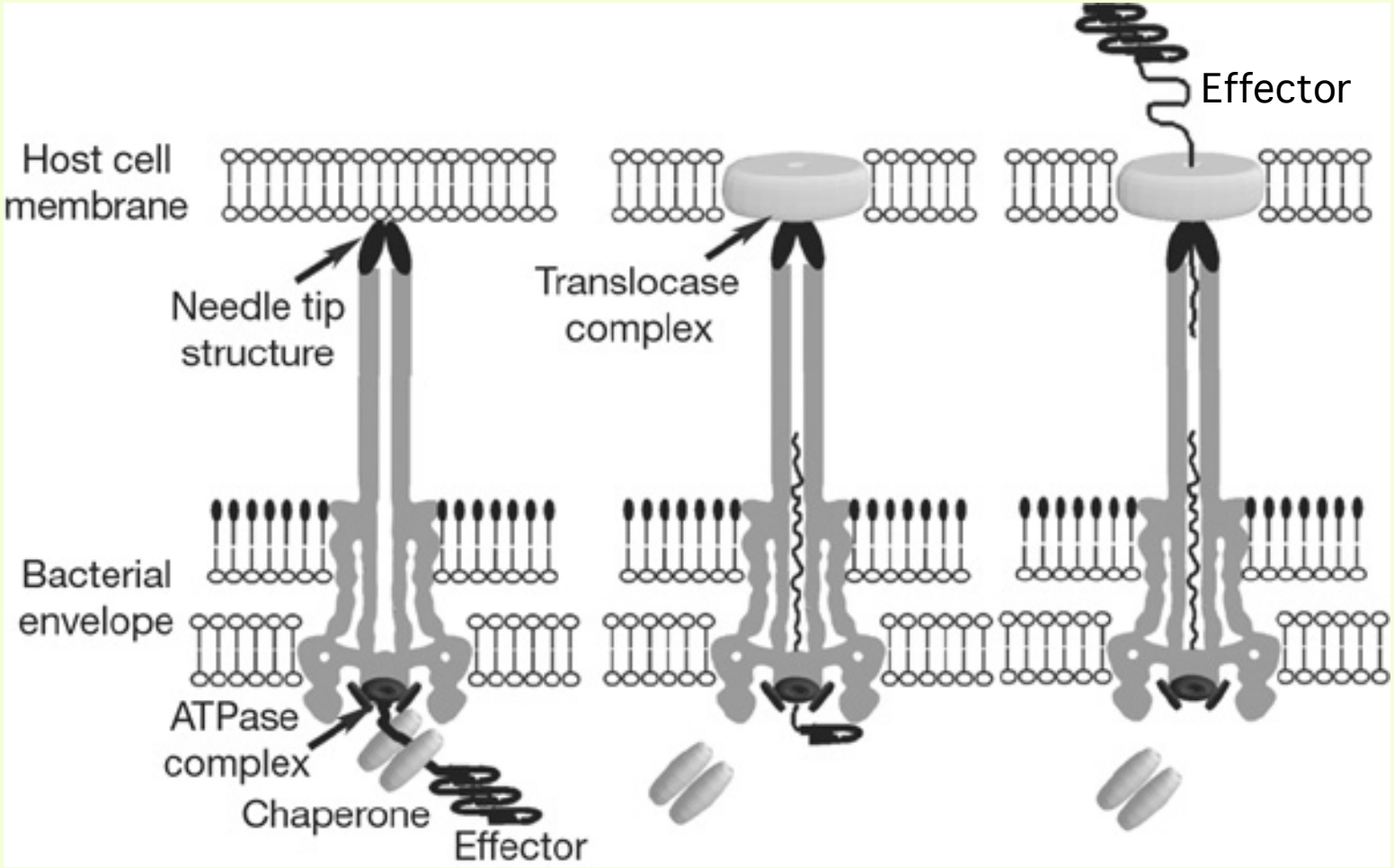

Keiichi Namba
Protonic
NanoMachine
Project
ERATO, JST

# The type III secretion system

similar to flagella machine but
delivers virulence proteins into host cells

# *Salmonella* invasion of epithelial cells via type III secretion system

bacterial virulence proteins (effectors) induce actin polymerisation,
membrane ruffling and bacterial internalisation



another example of manipulation
of actin by a bacterial pathogen…

*Listeria* - causes food poisoning and more serious diseases
in the immunocompromised, elderly and
pregnant women

# Listeria:
## invasion,
## intracellular movement,
## cell to cell spread

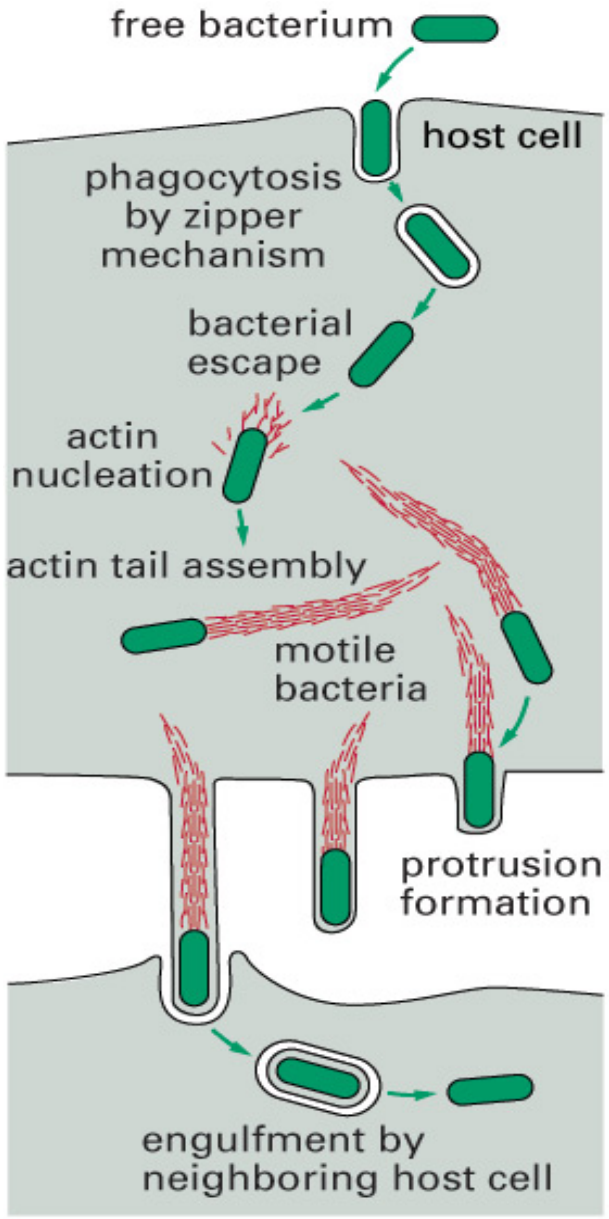



Figure 25–33, part 1 of 2. Molecular Biology of the Cell, 4th Edition.

Movie from Julie Theriot

How could structures as complex
and sophisticated as these have evolved ?

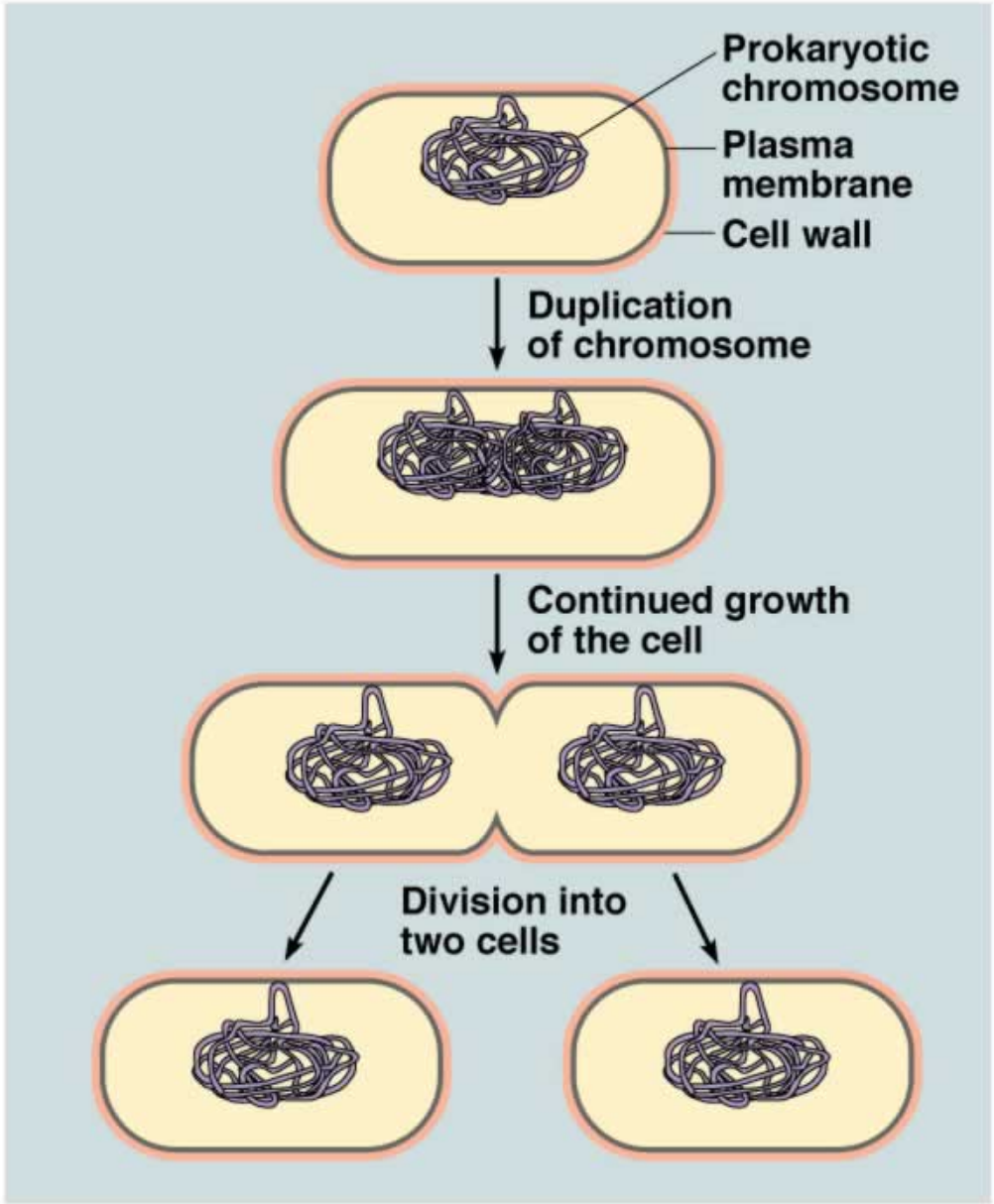
Genomes of bacterial pathogens
encode between 500 and 4500 proteins

Core genes (40%)
+
Accessory genes (vary considerably between different strains)

= **Gene repertoire**

So how were these **accessory genes** acquired?

# Bacteria replicate by binary fission



**And also undergo horizontal gene transfer…**

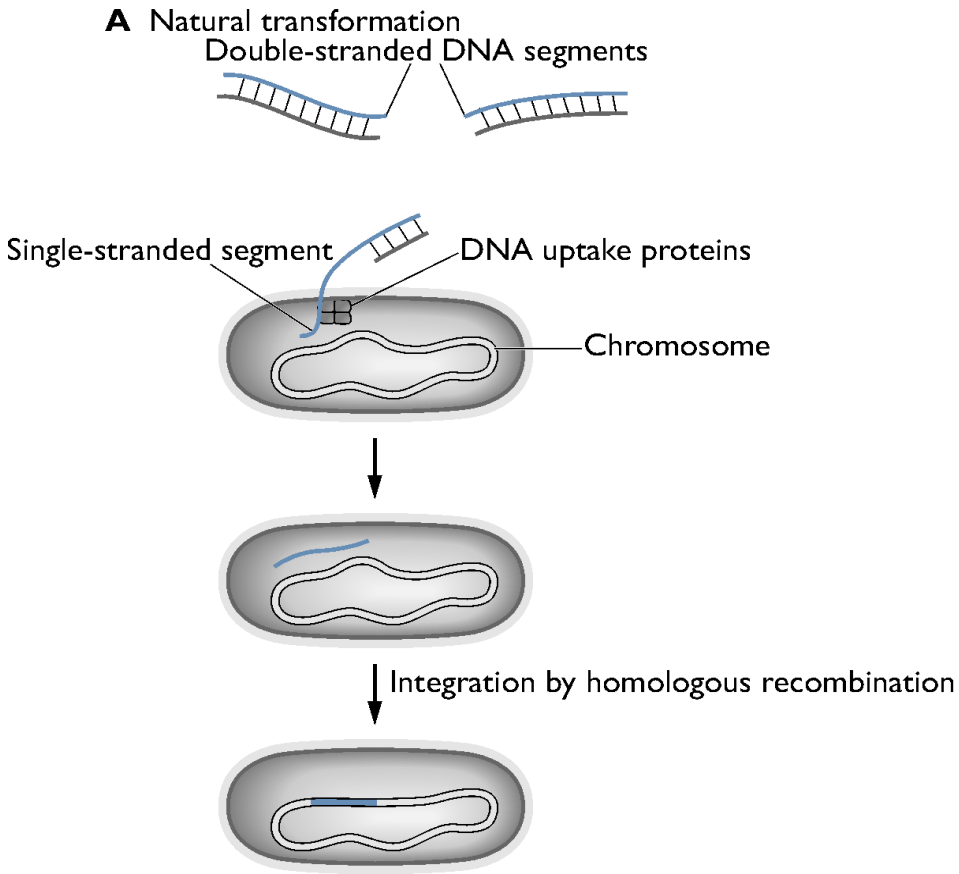
**3 basic mechanisms:**

**transformation**

**transduction**

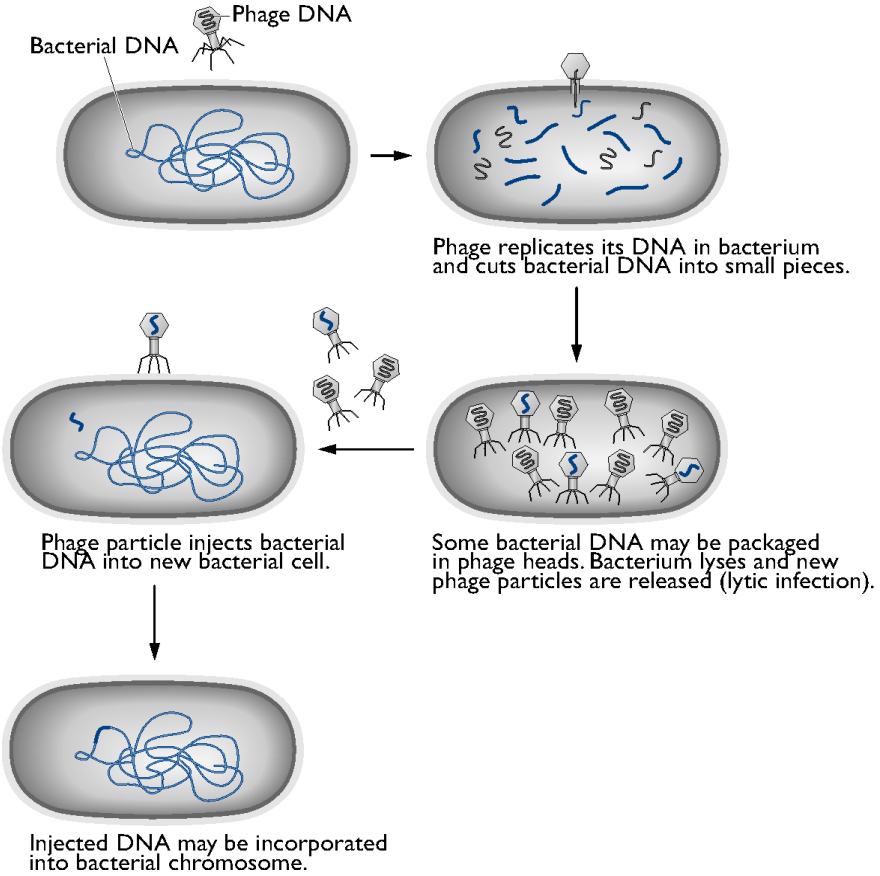
**conjugation**

# Transformation – DNA uptake



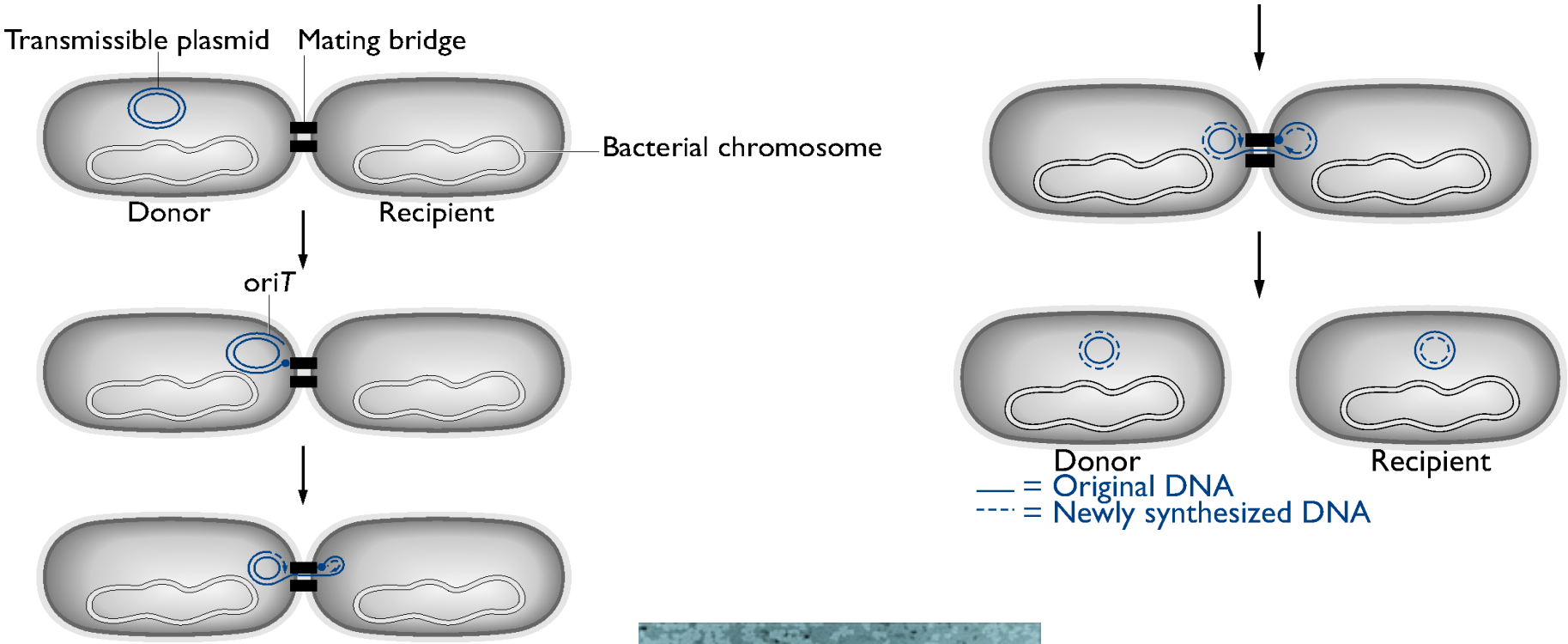

- ***Neisseria***
- ***Streptococcus***

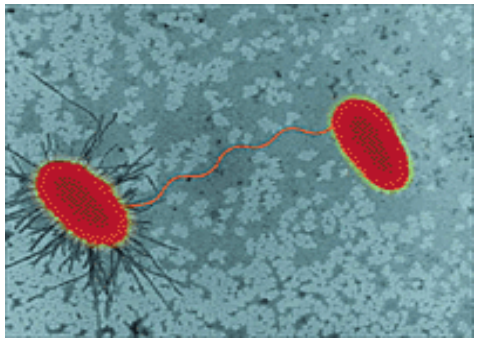
# Generalized phage transduction




**Many Gram - and Gram +**

# Conjugative transfer of a self-transmissible plasmid



**Many Gram - and Gram +**

Vast majority of accessory genes acquired by horizontal transfer from (mainly) unknown sources

Horizontally acquired DNA that contributes to virulence =

# A Pathogenicity Island

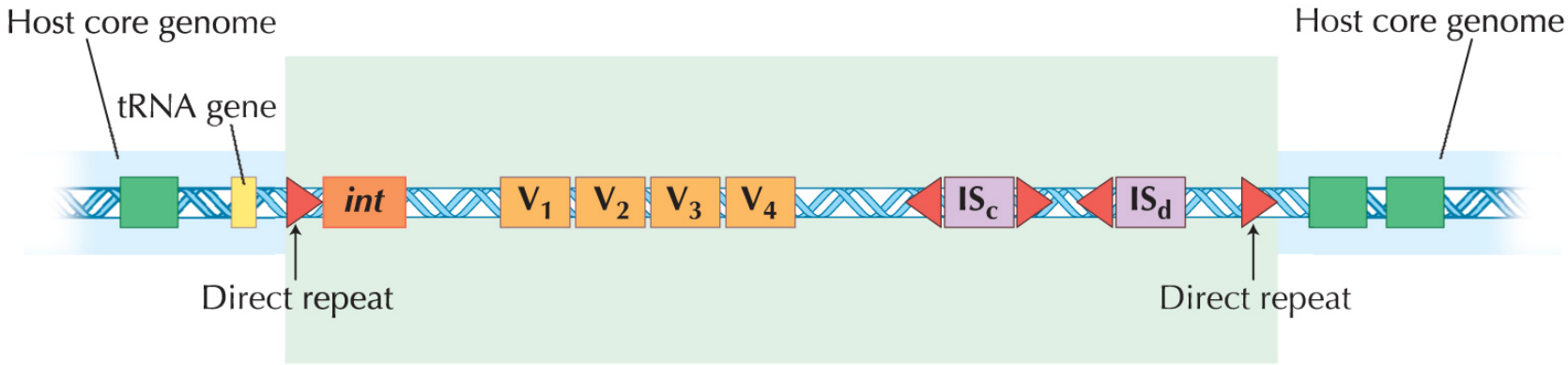
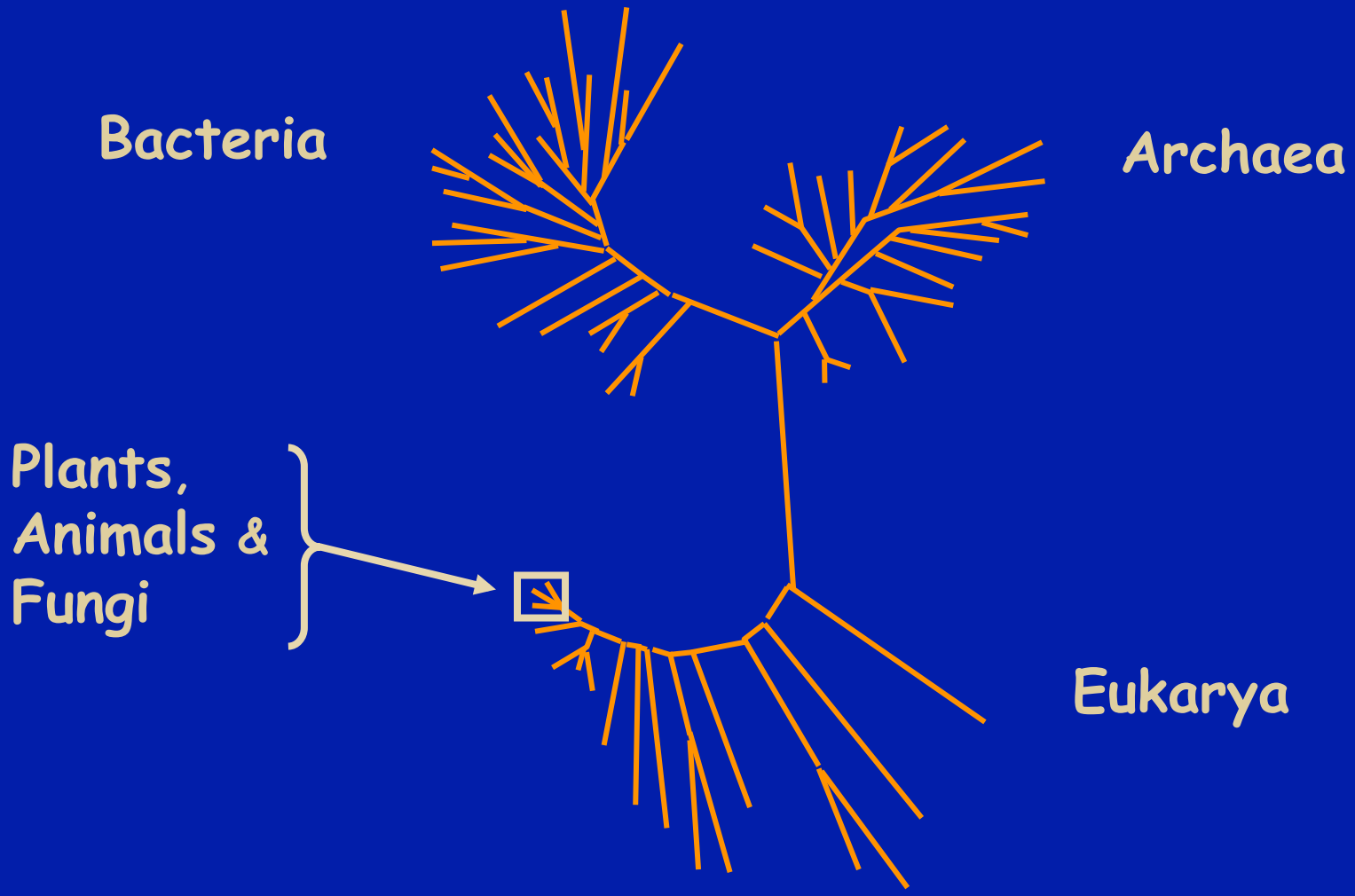



**FIGURE 7.21.** Diagram of a pathogenicity island (within the *large green shaded region*). Flanking the island are core host genes (*small blue shaded regions*). Immediately flanking the island on the *left* is a tRNA gene—many islands are found near or within tRNA genes. At the edges of the island are direct repeats (*red triangles*). Inside the island are virulence genes (*orange boxes*) and some insertion sequences (*purple boxes*).

Pathogenicity islands are a major
driving force of evolution of bacterial pathogens,
but their origin is frequently unknown…

# A world view of biodiversity



So, our planet contains a vast number of different bacterial genomes….

all mixable and mutatable

and bacteria grow with a very rapid generation time

*Streptococcus pyogenes*

Responsible for necrotizing fasciitis, these have been called "flesh-eating bacteria" by the tabloid press

Speed = x 240

- massive source of genetic variation
- rapid generation time

+

- selective pressure
- approx 1000,000,000 years

= **evolution**

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- **Further reading**

Bacterial Pathogenesis: A Molecular approach (Salyers and Whitt)
(2nd Ed)

Cellular Microbiology
(Cossart, Boquet, Normark, Rappuoli) (2nd Ed)