General Bacteriology

Lec. 1

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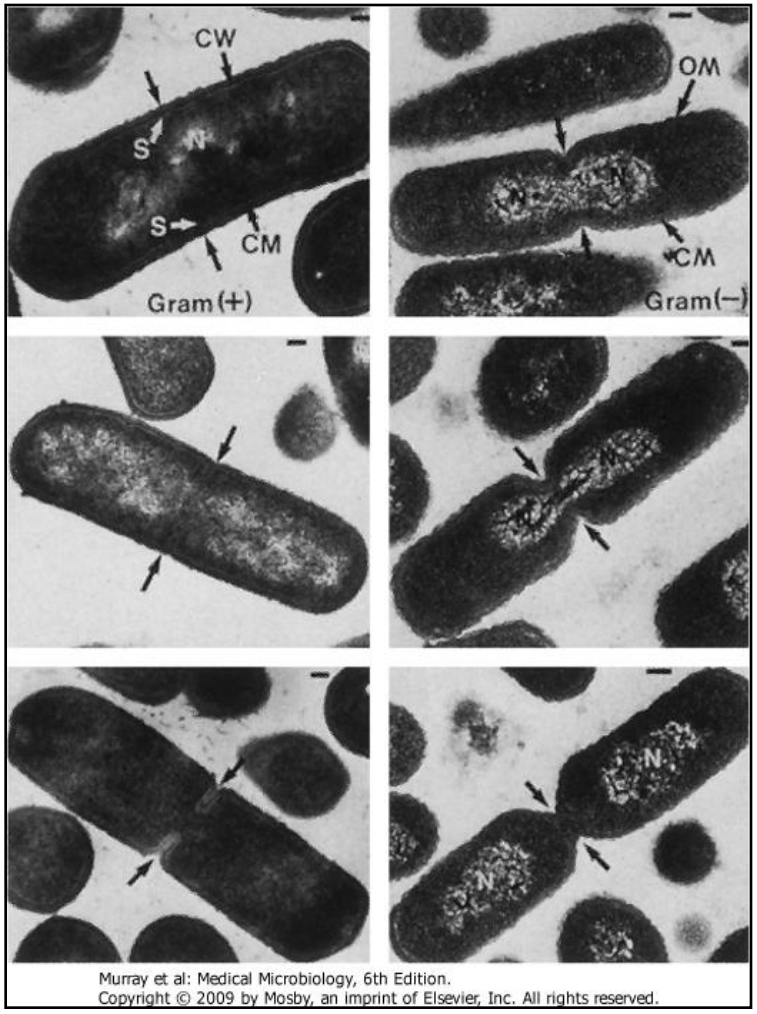
Features of Bacteria



Unicellular organism

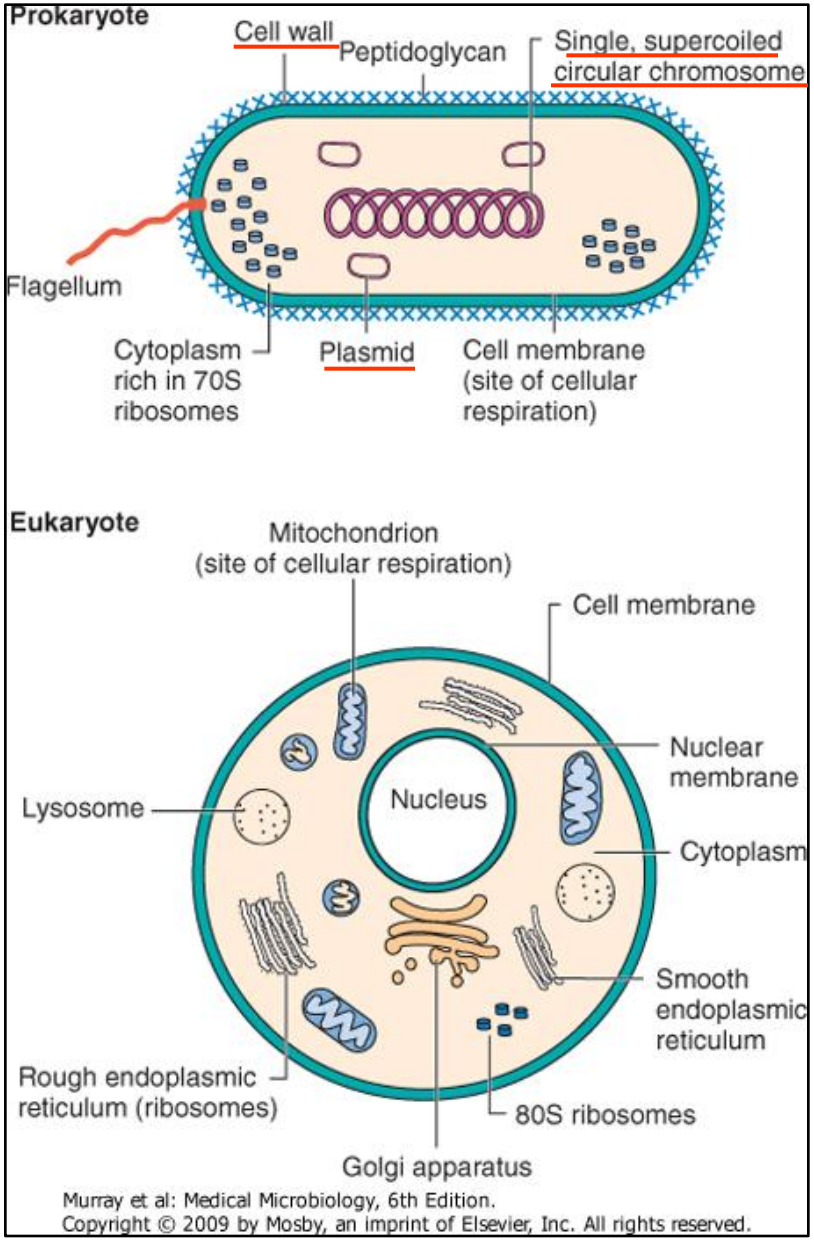
Small size: 1~2 μm in length

Haploid: number of a gene (or allele) is one

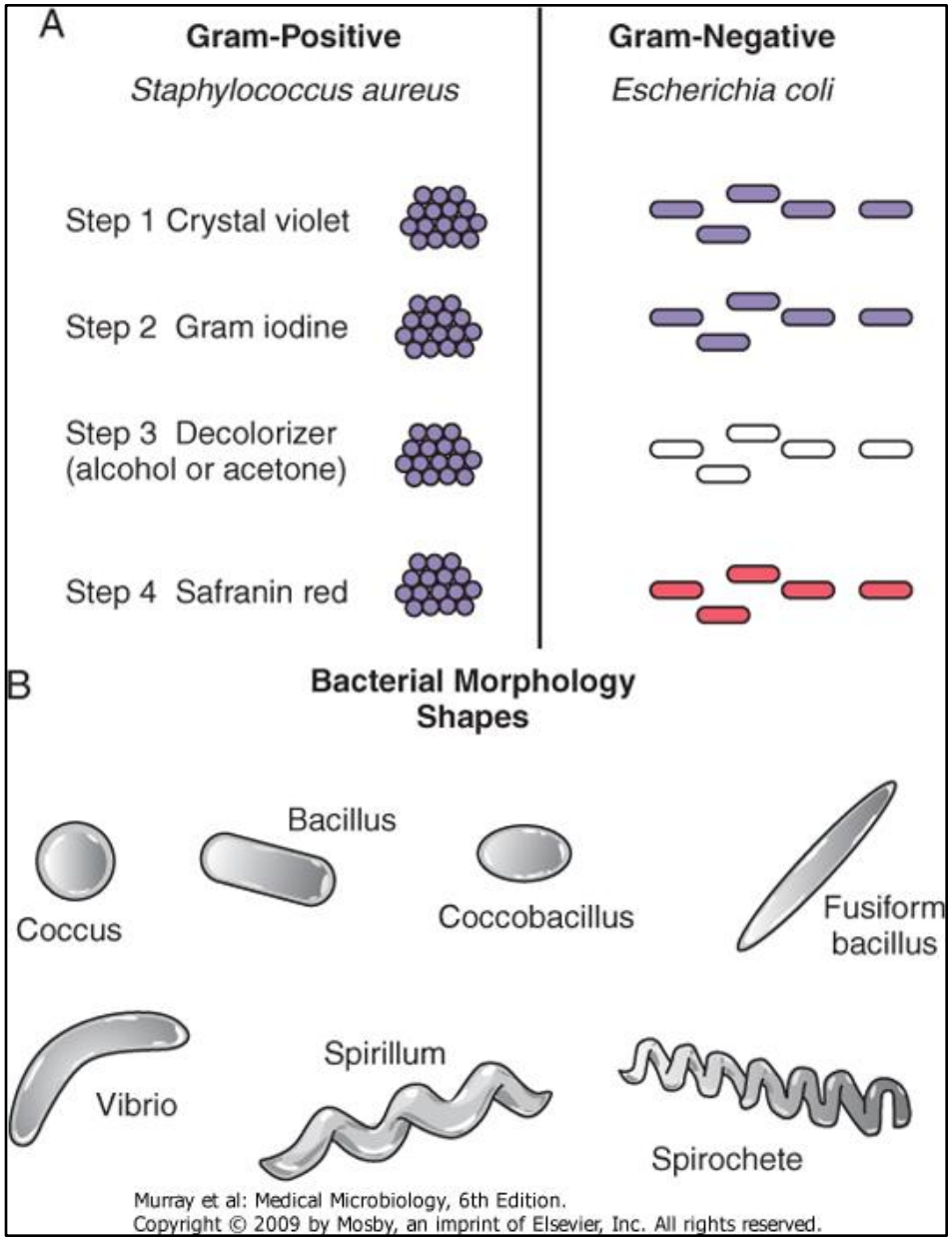
Short generation time: in the case of *E. coli*, ~20 min

Asexual replication

Structure of a Bacterial Cell



Classification of Bacteria



BACTERIAL PHYSIOLOGY

Classification on the basis of nutrition

Phototrophs: Bacteria using sunlight as a source of energy
Chemotrophs: Bacteria using chemical reactions as a source of energy

Classification on the basis of source of compounds needed for survival

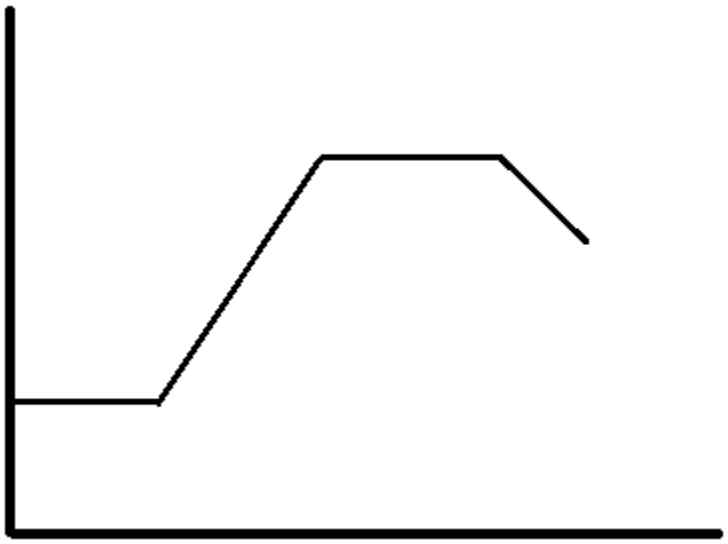
Autotrophs: Bacteria which can synthesize all organic compounds on their own
Heterotrophs: Bacteria which are unable to synthesize their organic metabolites and rely on preformed compounds

Classification on the basis of bacteria's relationship with oxygen and carbon dioxide

Category	Requirement	Examples
Obligate aerobe	15% to 21% O_2	*Mycobacterium tuberculosis* *Pseudomonas* *Micrococcus*
Microaerophilic	5% O_2	*Campylobacter* *Helicobacter* *Brucella abortus*
Facultative anaerobe	Multiplies equally well in the presence or absence of O_2	Enterobacteriaceae *Staphylococcus*
Aerotolerant anaerobe	Reduced concentration of O_2	Most strains of *Propionibacterium*, *Lactobacillus*, some *Clostridium* species (*C. histolyticum*)
Obligate anaerobe	Strict anaerobic environment (0% O_2)	Most bacteroid spp., many *Clostridium* spp. (*C. novyi*), *Eubacterium*, *Fusobacterium* spp., *Peptostreptococcus* spp.
Capnophilic	5% to 10% CO_2	*Neisseria*, *Haemophilus* spp.

BACTERIAL GROWTH CURVE

The typical results of bacterial growth when plotted in a graph with numbers of bacteria expressed in logarithmic form will be as below.



Generation time: The time required by a bacterium to undergo one cell division

lag phase : short time is generally seen while the inoculated bacteria adjust to the new culture.

exponential –also referred to as **logarithmic** or **log** phase, in this phase that microbes are growing rapidly in numbers and are most metabolically active, the bacteria are most **susceptible to an antimicrobial agent.**

stationary phase this is a transition phase as the culture fails to provide needed nutrients to allow bacterial cell division

death phase in this phase many more bacteria are dying than are reproducing.

In some bacterial species (notably the Gram positive genera *Bacillus* and *Clostridium*), **endospores** may be formed as the culture nears death phase, these are tough dry spherical bodies that can endure long periods (often many years) in harsh chemical and climatic conditions, and will germinate to produce a new bacterial cell when conditions are suitable.

BACTERIAL APPENDAGES

Flagella: Organs of locomotion and motility

Type	Arrangement	Examples
Monotrichous	Bacteria which have one polar flagellum	*Vibrio cholerae*
Lophotrichous	Bacteria with a tuft of several polar flagella	*Spirilla*
Amphitrichous	Bacteria with flagella at both the ends	*Campylobacter* (some species)
Peritrichous	Bacteria with flagella distributed all over the surface of the bacterium	Members of Enterobacteriaceae, *Bacillus* sp., *Listeria monocytogenes*

Fimbria: Organs of attachment and adhesion. Demonstrated by electron microscopy or agglutination by fimbriae-specific sera**.**

Normal Flora of Human Body

General Overview

The mixture of organisms regularly found at any anatomical site is referred to as the **normal flora**, **normal microbiota** or **indigenous microbiota**.

In a healthy animal, the internal tissues, e.g. blood, brain, muscle, etc., are normally free of microorganisms.

The surface tissues, i.e., skin and mucous membranes are constantly in contact with environmental organisms and become readily colonized by various microbial species.

Normal flora may be categorized into two types:

1. Resident flora - always present
2. Transient flora - only present for short period of time

Associations between Humans and the Normal Flora

Three types relationships between host and normal flora

1. Commensalism (Commensals) - no harm, no benefit to host
2. Mutualism (Mutualistic): beneficial relationship, both microbe and host benefit
3. Opportunistic (Opportunists): potential pathogens producing infection when host defenses depressed or when normal flora disturbed

Normally commensal flora but become potential pathogen and produces infection when host defenses depressed or when normal flora disturbed

· While most of the activities of the normal flora benefit their host, some of the normal flora are **parasitic** (live at the expense of their host), and some are **pathogenic** (capable of producing disease). Diseases that are produced by the normal flora in their host may be called **endogenous diseases**.

· Most endogenous bacterial diseases are **opportunistic infections**, meaning that the organism must be given a special opportunity of weakness or let-down in the host defenses in order to infect. An example of an opportunistic infection is chronic bronchitis in smokers wherein normal flora bacteria are able to invade the weakened lung.

Tissue Specificity of Normal Flora

Most members of the normal bacterial flora prefer to colonize certain tissues and not others. This "tissue specificity" is usually due to properties of both the host and the bacterium. Usually, specific bacteria colonize specific tissues by one or another of these mechanisms.

1. **Tissue tropism:** This is the bacterial preference or predilection for certain tissues for growth. One explanation for tissue tropism is that the host provides essential nutrients and growth factors for the bacterium, in addition to suitable oxygen, pH, and temperature for growth.
2. **Specific adherence:** Most bacteria can colonize a specific tissue or site because they can adhere to that tissue or site in a specific manner that involves complementary chemical interactions between the two surfaces. Specific adherence involves biochemical interactions between bacterial surface components (**ligands** or **adhesins**) and host cell molecular **receptors**. The bacterial components that provide adhesins are molecular parts of their capsules, fimbriae, or cell walls. The receptors on human cells or tissues are usually glycoprotein molecules located on the host cell or tissue surface.
3. **Biofilm formation**: Some of the indigenous bacteria are able to construct **biofilms** on a tissue surface, or they are able to colonize a biofilm built by another bacterial species.

Anatomical Location	Predominant bacteria
Skin	staphylococci and corynebacteria
Conjunctiva	Gram-positive cocci and Gram-negative rods
Oral cavity	
teeth	streptococci, lactobacilli
mucous membranes	streptococci and lactic acid bacteria
Upper respiratory tract	
nasal membranes	staphylococci and corynebacteria
pharynx (throat)	streptococci, neisseria, Gram-negative rods and cocci
Lower respiratory tract	none
Gastrointestinal tract	
stomach	*Helicobacter pylori* (up to 50%)
small intestine	lactics, enterics, enterococci, bifidobacteria
colon	bacteroides, lactics, enterics, enterococci, clostridia, methanogens
Urogenital tract	
anterior urethra	sparse, staphylococci, corynebacteria, enterics
vagina	lactic acid bacteria during child-bearing years; otherwise mixed

Virulence Factor: a substance produced by pathogen that promotes the establishment and maintenance of disease.

Types of Virulence Factors

Adherence components (attachment)

Capsules (evasion)

Invasion enzymes (entry into host, colonization)

- hyaluronidase: breaks down the polysaccharide that glues the host cells together
- collagenase: breaks down collagen network in connective tissues
- fibrinolytic enzymes (e.g., streptokinase) that destroys fibrin of blood clots (escape)
- coagulase: promotes blood clotting (protection)
- various other proteases, nucleases, lipases

Toxins

- Exotoxins (including enterotoxins)
- Endotoxins

Exotoxin	Endotoxin
Excreted by organisms	Integral part of cell wall
Both by Gram-positive and Gram-negative bacteria	Found mostly in Gram-negative bacteria
Polypeptide	Lipopolysaccharide complex
Relatively unstable, heat labile (60°C)	Relatively stable, heat tolerant
Highly antigenic, neutralized by antitoxin	Weakly immunogenic, antibodies are antitoxic
Can be toxoided	Cannot be toxoided
Highly toxic, fatal in µg quantities	Moderately toxic
Usually binds to specific receptors	Specific receptors not found
Not pyrogenic usually	Fever by induction of interleukin 1 (IL-1) production
Located on extrachromosomal genes (e.g., plasmids)	Located on chromosomal genes

Additional Features

- Microbial genome sequencing projects show that virulence genes are often clustered in “pathogenicity islands”
- Pathogenicity islands may be found in pathogenic strains, while being absent in closely related avirulent strains.
- Many bacterial pathogens also carry virulence genes on large plasmids

Power of Rapid Evolution of Bacteria

Bacterial Gene Transfer

- **Inter-strain transfer of DNA provides ‘genetic diversity’ of bacteria: Horizontal Gene Transfer**

- e.g. Evolutionary process of pathogenic bacteria from nonpathogenic bacteria

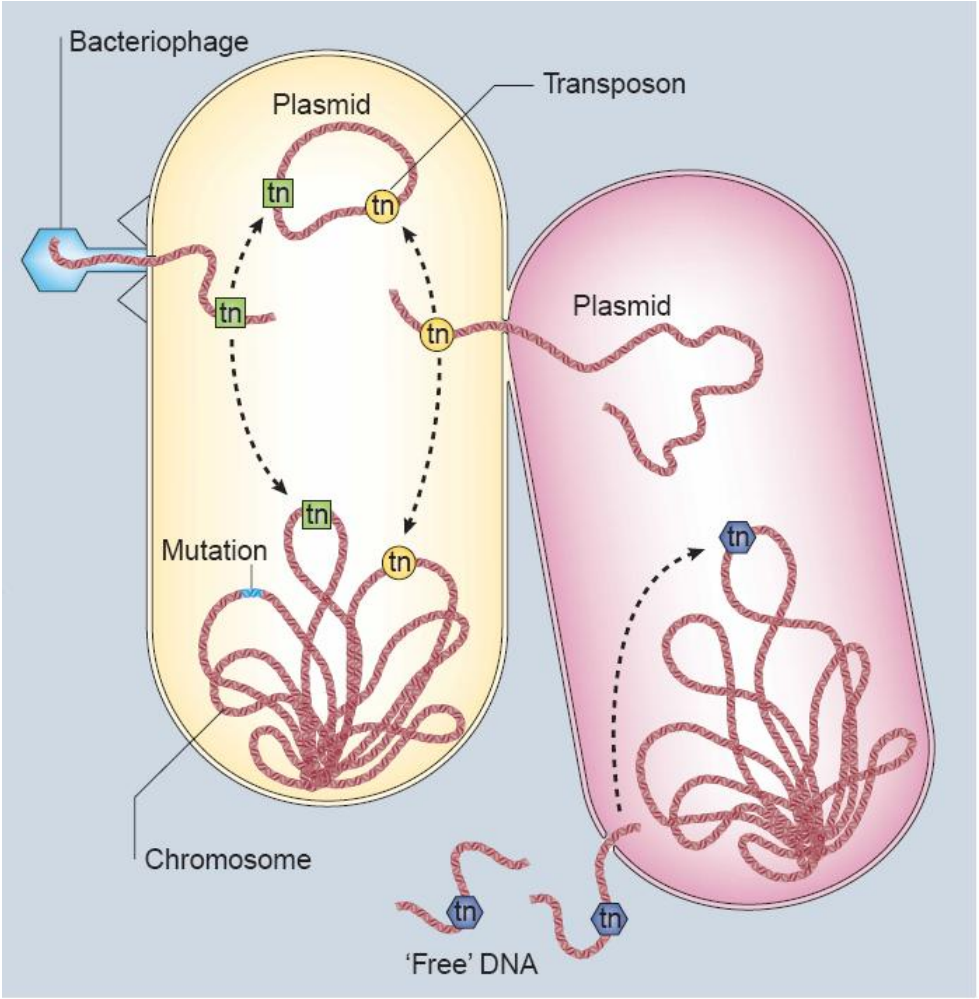
- e.g. Spread antibiotics resistance among bacteria

- **Three ways of bacterial gene transfer**

- Conjugation: by physical interaction

- Transformation: transfer of a naked DNA

- Transduction: by bacteriophages



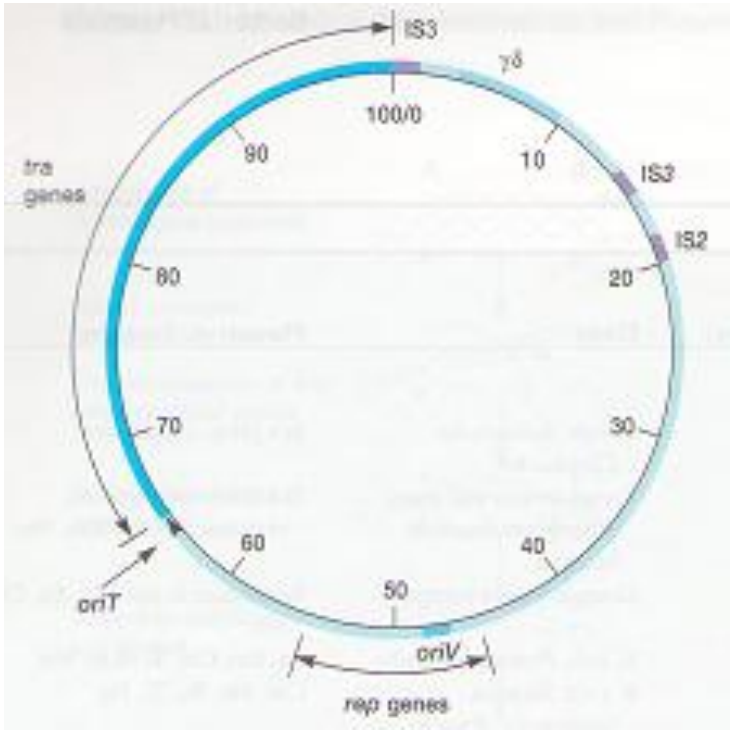
Bacterial Plasmids

- **Plasmid**

-Small and circular dsDNA molecules that can exist independently of host chromosome

-Contains own replication origin

-e.g. F plasmid



Bacterial Plasmids

Type	Names	Size (kb)	Copy No.	Hosts	Phenotypes
Fertility Factor	F Factor	95-100	1-3	*E. coli, Salmonella*	Conjugation
R plasmids	R1	80	1-3	G(-) bacteria	Ap^R, Km^R, Cm^R
Col plasmids	ColE1	9	10-30	*E. coli*	Colicin production
Virulence plasmids	Ent	83		*E. coli*	Enterotoxin
	pZA10	56		*S. aureus*	Enterotoxin B
Metabolic plasmids	TOL	75		*Pseudomonas*	Toluene degradation

Bacterial Conjugation

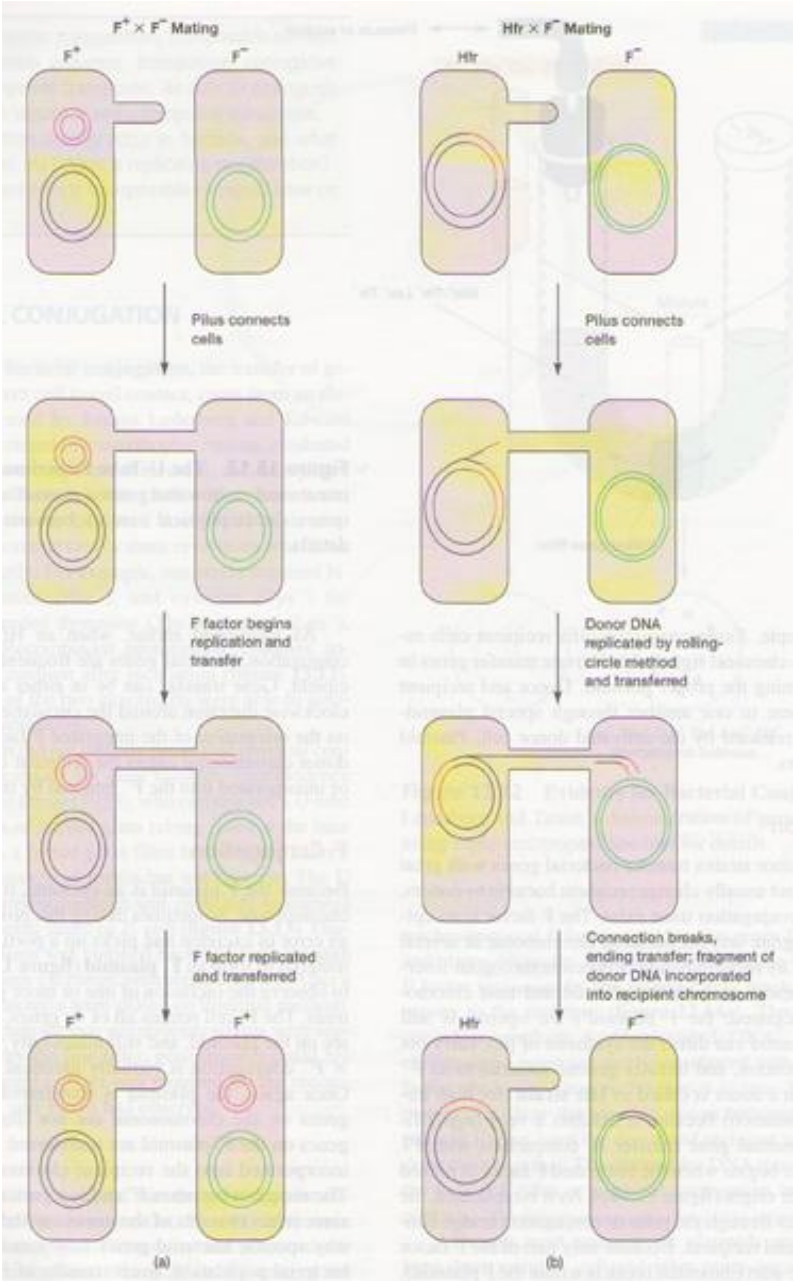
- **Conjugation**

- Transfer of genetic information by direct cell to cell contact

Bacterial Conjugation

e.g. $F^+ \times F^-$ mating

- Donor strain (F^+) contains F factor carrying the genes for pilus formation and plasmid transfer



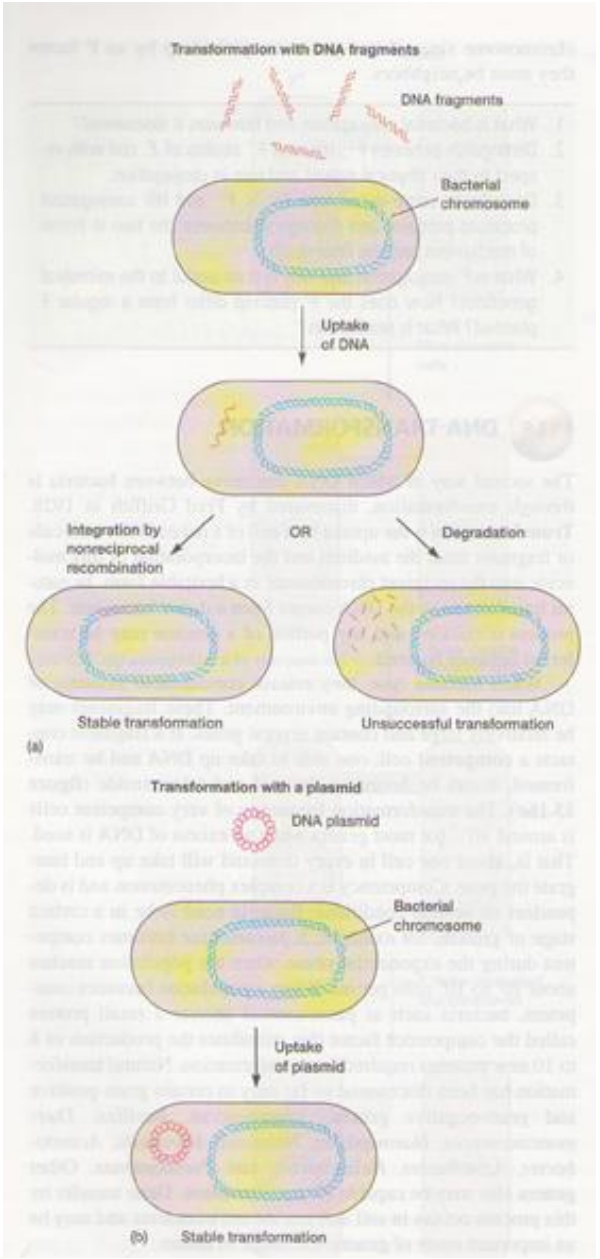
DNA Transformation

- **Transformation**

- Uptake of naked DNA by a cell

- **‘Competent’ cell**

- One able to take up DNA and be transformed



DNA Transformation

1. Natural transformation

- *Streptococcus*, *Bacillus*, *Thermoactinomyces*, *Haemophilus*, *Neisseria*, *Moraxella*, *Acinetobacter*, *Helicobacter*, *Pseudomonas*

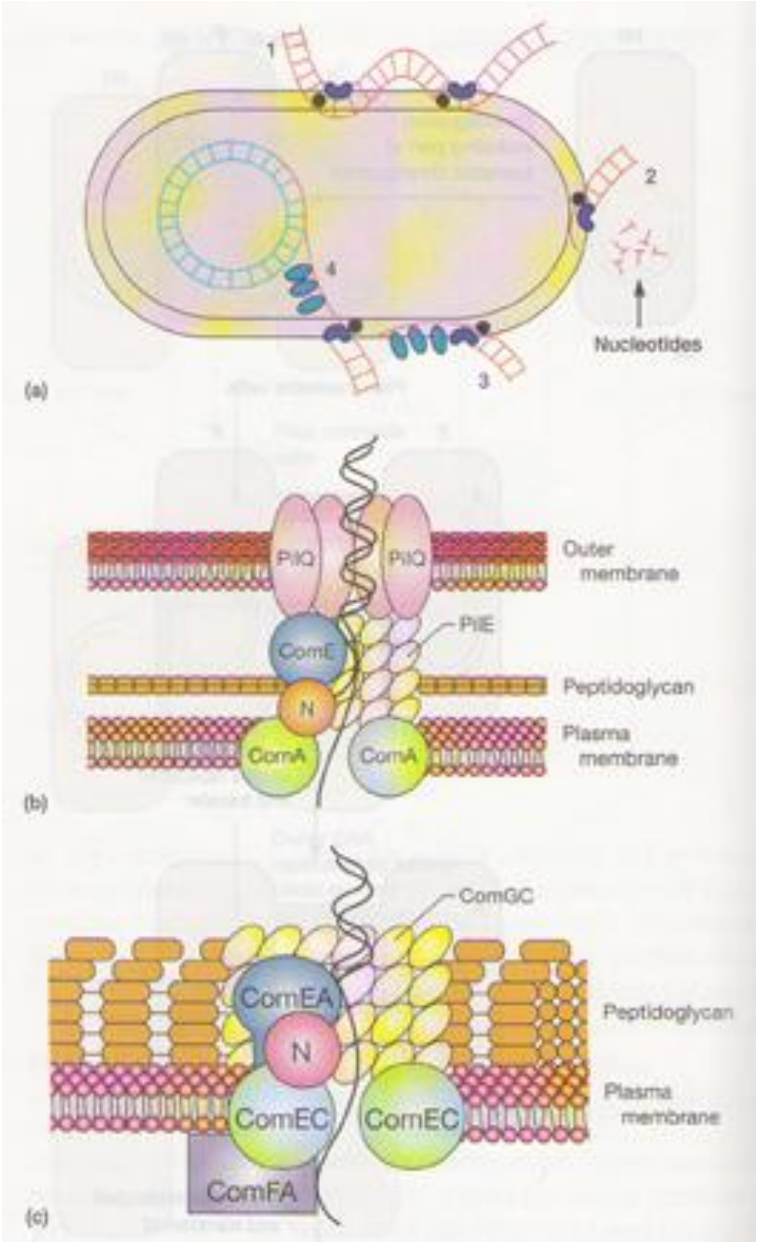
- Mechanism in *S. pneumoniae*

- <u>DNA uptake machinery</u>

2. Artificial transformation

- Treatment of *E. coli* with $CaCl_2$

- Electric shock (electroporation)



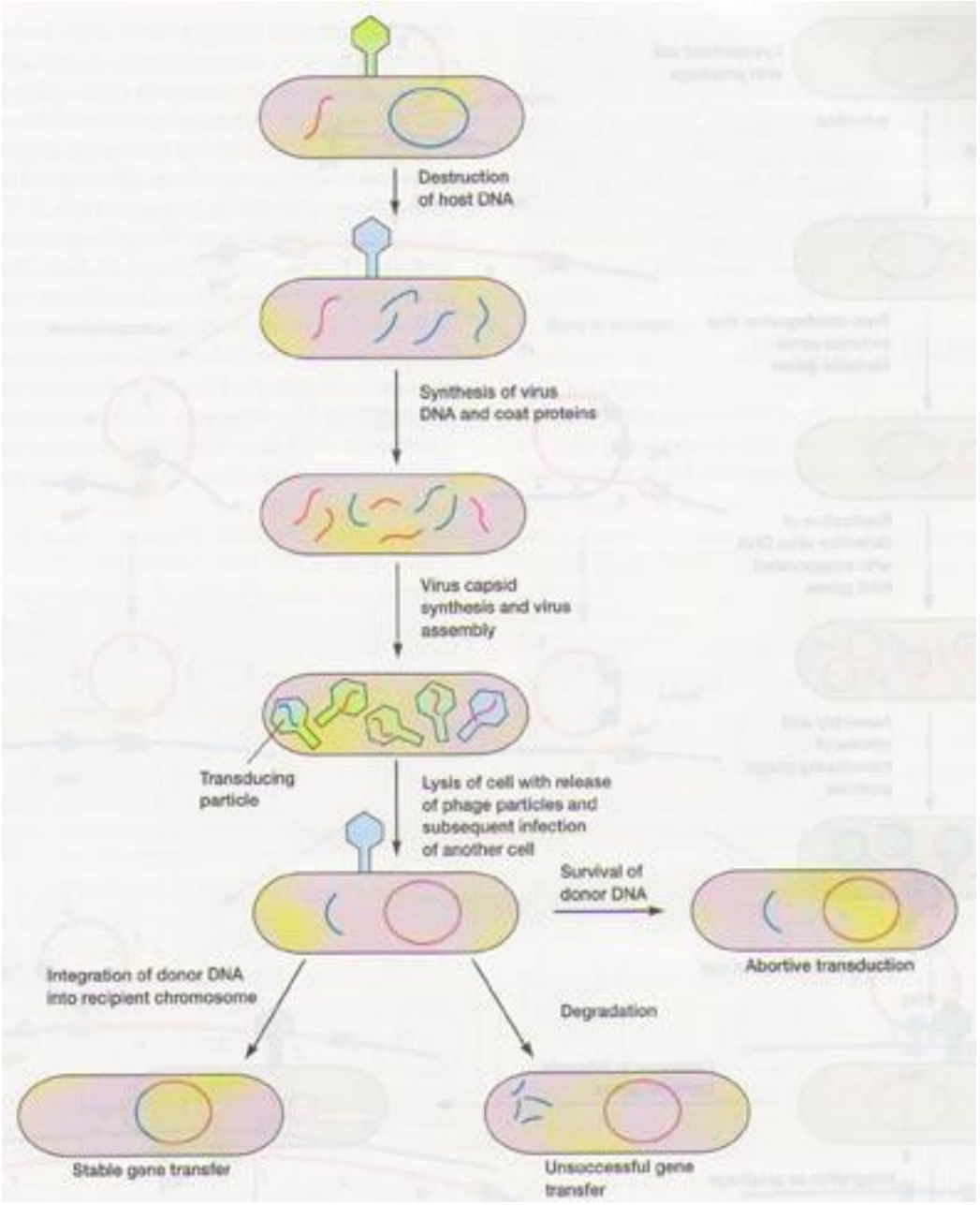
Transduction

e.g. Generalized transduction

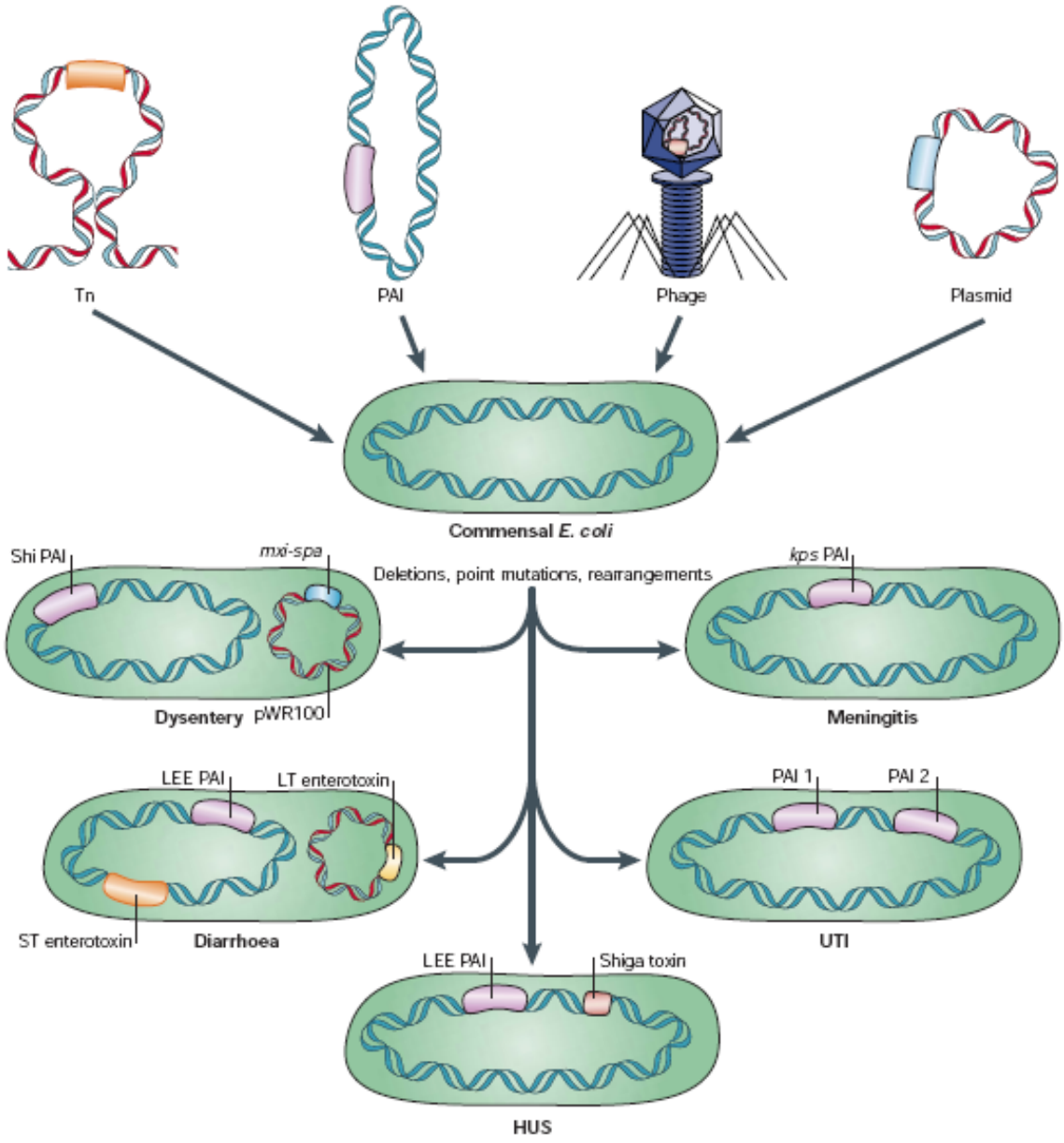
-Occurs during the lytic cycle of phages and can transfer any part of the bacterial genome

-Formation of transducing particle

-*E. coli* P1 and *Salmonella* P22 phages

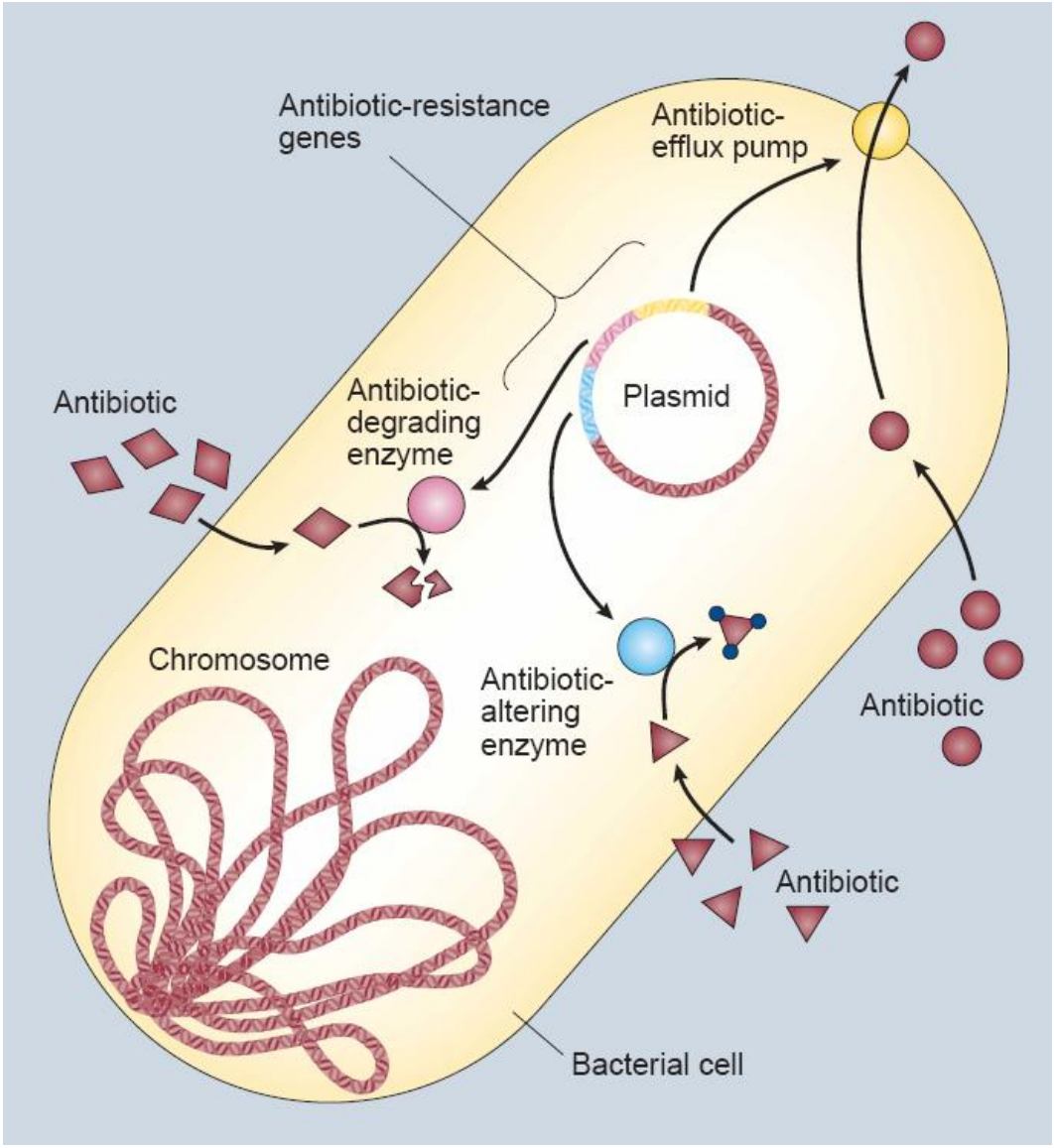


● Genetic mechanism of evolution of pathogenic *E. coli*

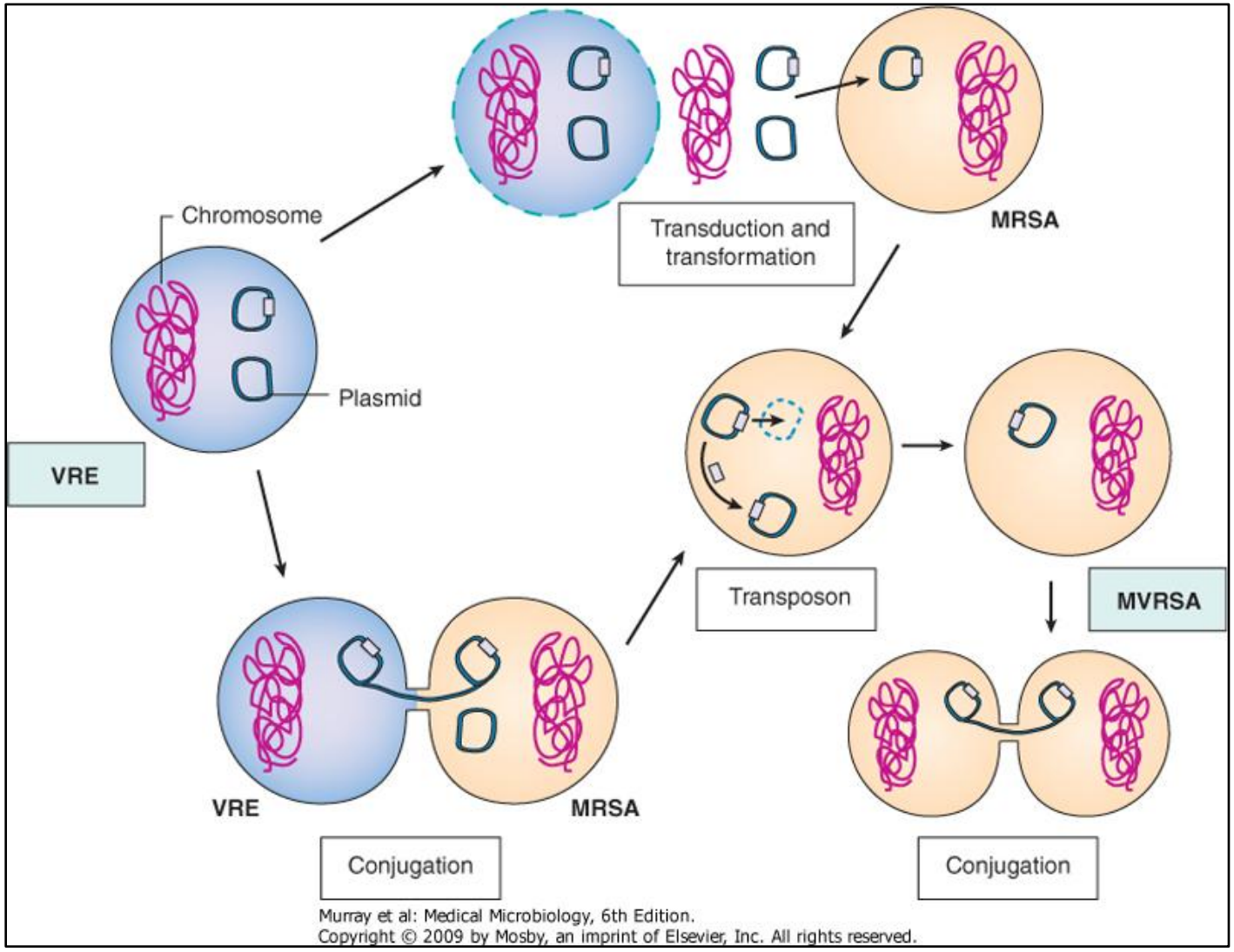


Contribution of mobile genetic elements to the evolution of pathogenic *E. coli*.

Biological Mechanisms of Drug Resistance



● Genetic mechanism of evolution of methicillin and vancomycin resistant *Staphylococcus aureus*



Thank You