

## Chapter 13 Bacterial Genetics



### Why study bacterial genetics?

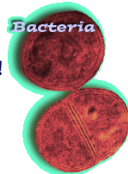
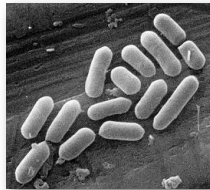
- Its an easy place to start
  - ◆ history
  - ◆ we know more about it
    - systems better understood
  - ◆ **simpler genome**
  - ◆ good model for control of genes
    - build concepts from there to eukaryotes
  - ◆ **bacterial genetic systems are exploited in biotechnology**



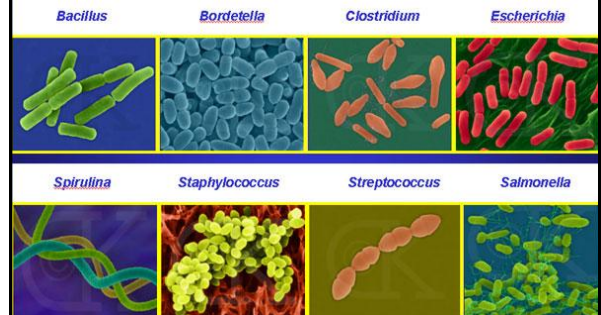
### Bacteria

#### ■ Bacteria review

- ◆ one-celled organisms
- ◆ **prokaryotes**
- ◆ reproduce by mitosis
  - binary fission
- ◆ **rapid growth**
  - generation every ~20 minutes
  - 10<sup>8</sup> (100 million) colony overnight!
- ◆ dominant form of life on Earth
- ◆ incredibly diverse



### Bacterial Diversity



### Bacterial Diversity



*Borrelia burgdorferi*  
Lyme disease



*Treponema pallidum*  
Syphilis



*Escherichia coli* O157:H7  
Hemorrhagic E. coli

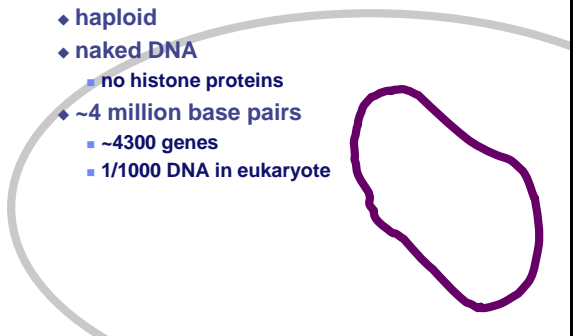


*Enterococcus faecium*  
skin infections

### Bacterial Genome

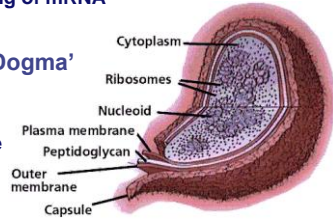
#### ■ Single circular chromosome

- ◆ haploid
- ◆ naked DNA
  - no histone proteins
- ◆ ~4 million base pairs
  - ~4300 genes
  - 1/1000 DNA in eukaryote



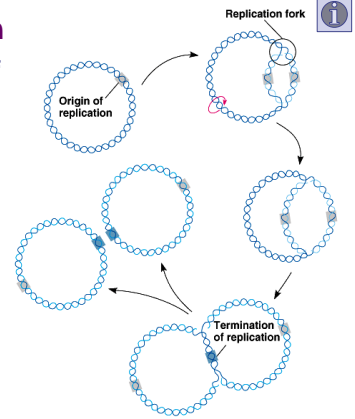
### No Nucleus!

- No nuclear membrane—**prokaryotic!**
  - ◆ chromosome in cytoplasm
  - ◆ transcription & translation are coupled together
    - no processing of mRNA
  - ◆ no introns
  - ◆ but 'Central Dogma' still applies
    - use same genetic code



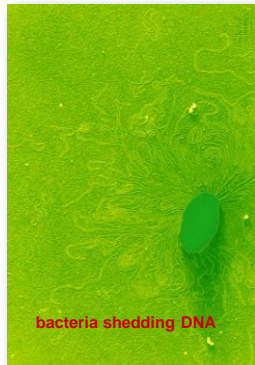
### Binary Fission

- Replication of bacterial chromosome
- Asexual reproduction
  - ◆ offspring genetically identical to parent



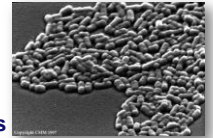
### Variation in Bacteria

- Sources of variation:
  - ◆ spontaneous mutation
  - ◆ transformation
    - plasmids
    - DNA fragments
  - ◆ transduction
  - ◆ conjugation



### Spontaneous Mutation

- Spontaneous mutation is a significant source of variation in rapidly reproducing species
- Example: *E. coli*
  - ◆ human colon (large intestines)
  - ◆  $2 \times 10^{10}$  (billion) new *E. coli* each day!
  - ◆ spontaneous mutations
    - for 1 gene, only ~1 mutation in 10 million replications
    - each day, ~2,000 bacteria develop mutation in that gene
    - but consider all 4300 genes, then:  
 $4300 \times 2000 = 9 \text{ million mutations per day per human host!}$

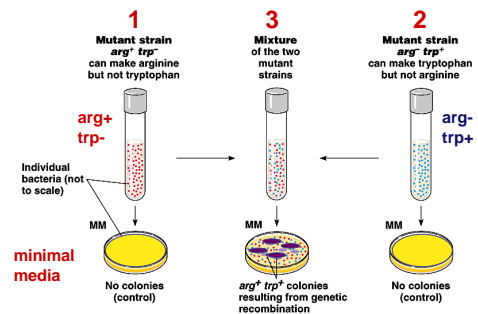


### Transformation

- Bacteria are opportunists
  - ◆ pick up naked foreign DNA wherever it may be hanging out
    - have surface transport proteins that are specialized for the uptake of naked DNA
  - ◆ import bits of chromosomes from other bacteria
  - ◆ incorporate the DNA bits into their own chromosome
    - express new gene
    - form of recombination

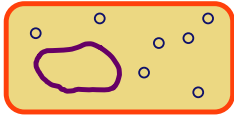
### Swapping DNA

- Genetic recombination by trading DNA



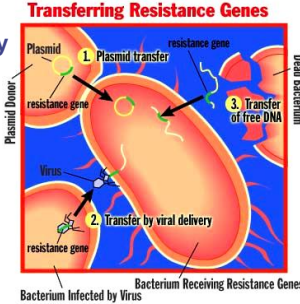
### Plasmids

- Plasmids
  - small supplemental circles of DNA
    - 5000 - 20,000 base pairs
    - self-replicating
  - carry extra genes
    - 2-30 genes
  - can be exchanged between bacteria
    - bacterial sex!!
    - rapid evolution
    - antibiotic resistance
  - can be imported from environment



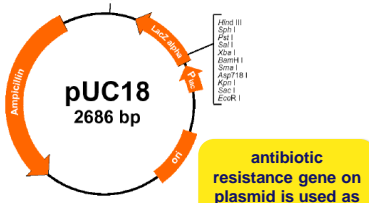
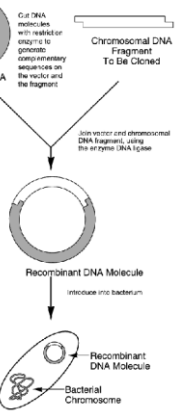
### Plasmids & Antibiotic Resistance

- Resistance is futile?
  - 1<sup>st</sup> recognized in 1950s in Japan
  - bacterial dysentery not responding to antibiotics
  - worldwide problem now
    - resistant genes are on plasmids that are swapped between bacteria



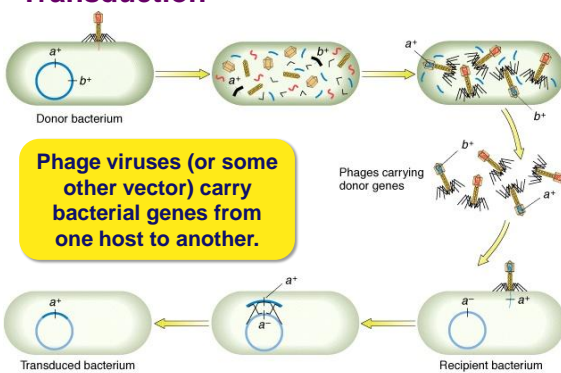
### Biotechnology

- Used to insert new genes into bacteria
  - example: pUC18
    - engineered plasmid used in biotech

antibiotic resistance gene on plasmid is used as a selective agent

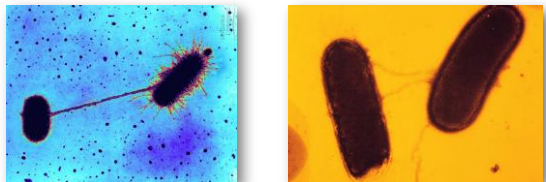
### Transduction



Phage viruses (or some other vector) carry bacterial genes from one host to another.

### Conjugation

- Direct transfer of DNA between 2 bacterial cells that are temporarily joined
  - results from presence of F plasmid with F factor
    - F for "fertility" DNA
  - E. coli "male" extends sex pilli, attaches to female bacterium
  - cytoplasmic bridge allows transfer of DNA



### Bacterial Metabolism

- Bacteria need to respond quickly to changes in their environment
  - if have enough of a product, need to stop production
    - why? waste of energy to produce more
    - how? stop production of synthesis enzymes
  - if find new food/energy source, need to utilize it quickly
    - why? metabolism, growth, reproduction
    - how? start production of digestive enzymes

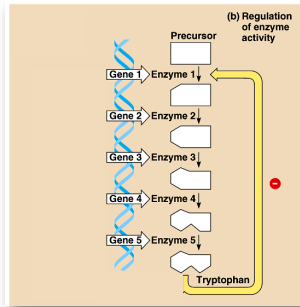


### Reminder: Regulation of Metabolism

#### Feedback inhibition

- product acts as an allosteric inhibitor of 1<sup>st</sup> enzyme in tryptophan pathway

⊖ = inhibition

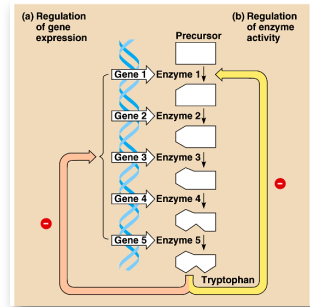


### Another Way to Regulate Metabolism

#### Gene regulation

- block transcription of genes for all enzymes in tryptophan pathway
- saves energy by not wasting it on unnecessary protein synthesis

⊖ = inhibition



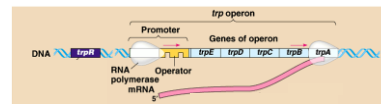
### Gene Regulation in Bacteria

- Control of gene expression enables individual bacteria to adjust their metabolism to environmental change
- Cells vary amount of specific enzymes by regulating gene transcription
  - turn genes on or turn genes off
    - ex. if you have enough tryptophan in your cell then you don't need to make enzymes used to build tryptophan
      - waste of energy
      - turn off genes which codes for enzymes



### So how can genes be turned off?

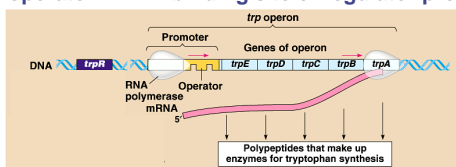
- First step in protein production?
  - transcription
  - stop RNA polymerase!**
- Repressor protein
  - binds to DNA near promoter region blocking RNA polymerase
    - binds to operator site on DNA
    - blocks transcription



### Genes Grouped Together

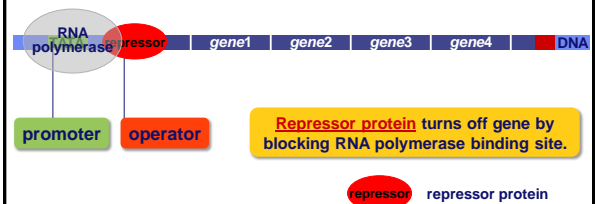
#### Operon

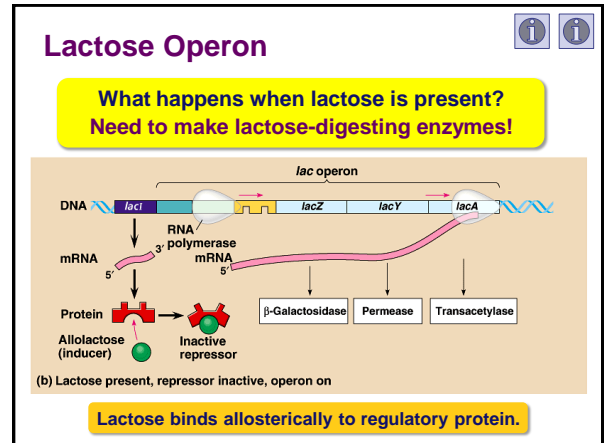
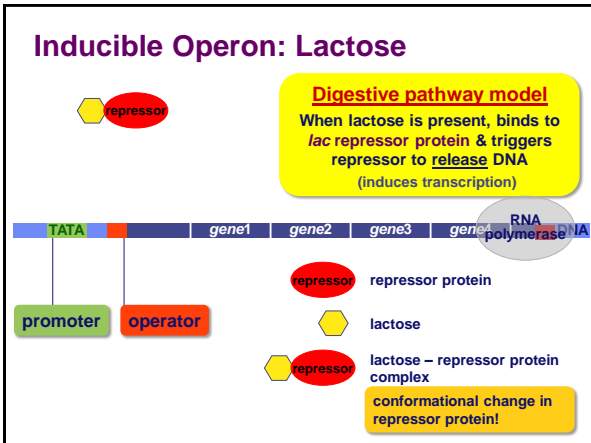
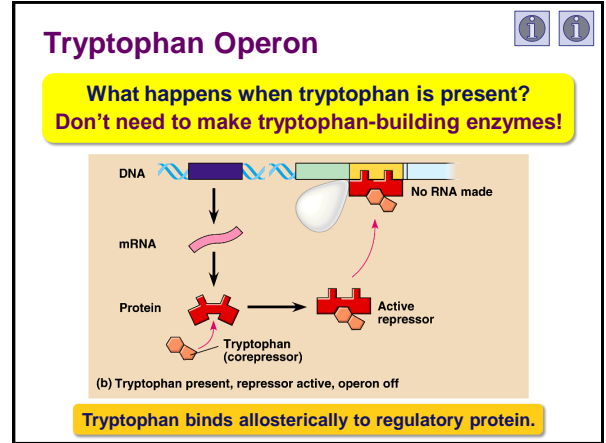
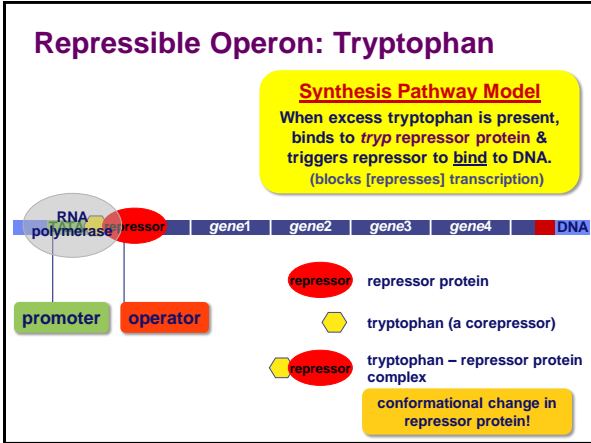
- genes grouped together with related functions
  - ex. enzymes in a synthesis pathway
- promoter = RNA polymerase binding site
  - single promoter controls transcription of all genes in operon
  - transcribed as 1 unit & a single mRNA is made
- operator = DNA binding site of regulator protein



### Repressor Protein Model

**Operon:**  
The operator, promoter & genes they control serve as a model for gene regulation





### Jacob & Monod: *lac* Operon 1961 | 1965

- Francois Jacob & Jacques Monod
  - ◆ first to describe operon system
  - ◆ coined the phrase “operon”

Jacques Monod      Francois Jacob

- ### Operon Summary
- Repressible operon
    - ◆ usually functions in **anabolic** pathways
      - **synthesizing** end products
    - ◆ when end product is present in excess, cell allocates resources to other uses
  - Inducible operon
    - ◆ usually functions in **catabolic** pathways
      - **digesting** nutrients to simpler molecules
    - ◆ produce enzymes only when nutrient is available
      - cell avoids making proteins that have nothing to do, cell allocates resources to other uses