

# Visualizing Molecular Trends in Bacterial Genomes

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Stats 744: Final Project

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# The Organisms

## Bacteria:

- *Escherichia coli*
- *Bacillus subtilis*
- *Streptomyces*
- *Sinorhizobium meliloti*

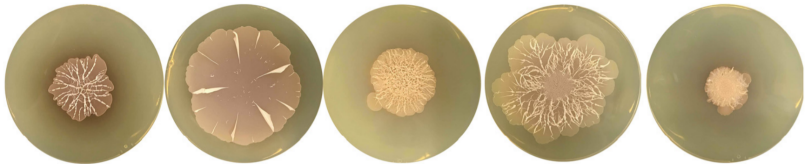
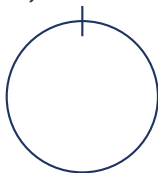


Photo: *Streptomyces* by Stephanie Jones, McMaster University

# Biological Background

## 1) Circular



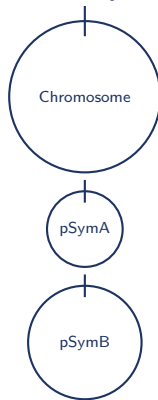
*Escherichia coli*  
*Bacillus subtilis*

## 2) Linear



*Streptomyces*

## 3) Multi-repliconic



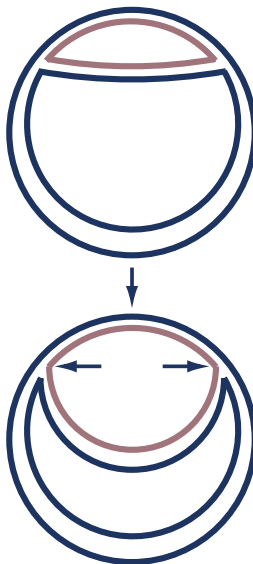
*Sinorhizobium meliloti*

# Bacterial Genome Properties

## Bidirectional Replication

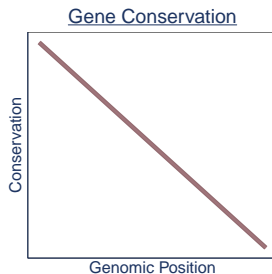
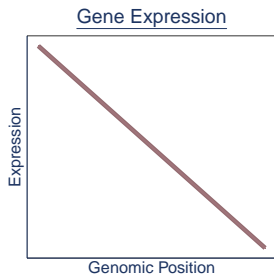
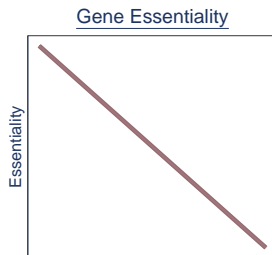
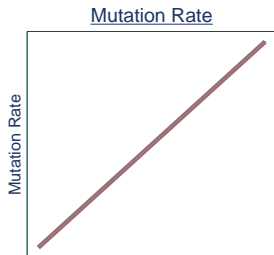
- Gene dosage
- Sequence composition
- Codon bias
- Replication errors
- Strand differences

– new DNA  
– old DNA



Different **replicons** and **positions** of bacterial genomes can have **varying molecular trends**

# Spatial Molecular Trends

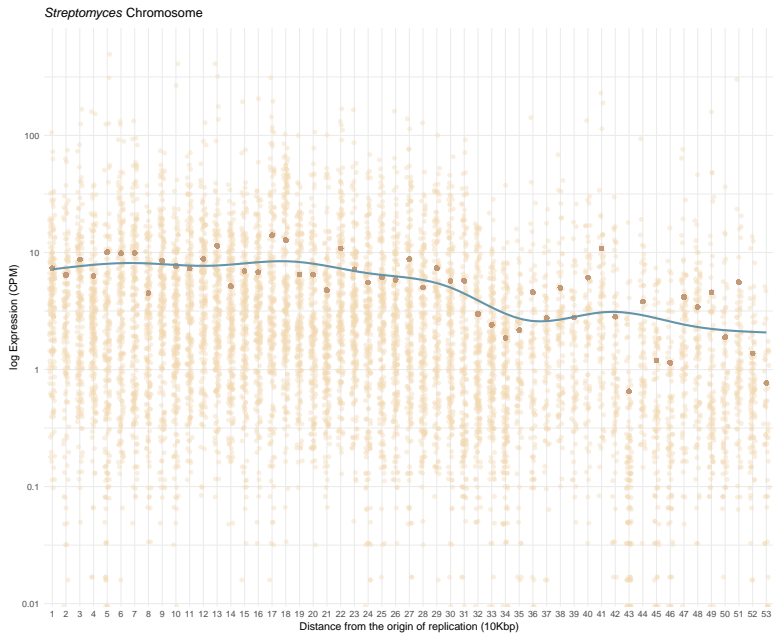


Couturier et al. 2006, Cooper et al. 2010, Sharp et al. 2005, Morrow et al. 2012, Cooper and Rocha 2006

## Gene Expression

- *E. coli*, *B. subtilis*, *Streptomyces*, and *S. meliloti*
- Gene expression + distance from the origin of replication
- **Expectation:** Near the origin or replication = Higher Expression

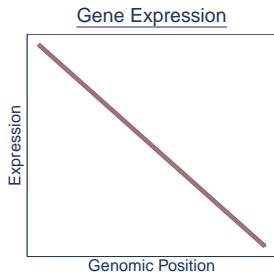
# Gene Expression





# Spatial Molecular Trends

## Expectation:



## Observation:

**Gene expression decreases** with increasing distance from the origin of replication in a **non-linear** manner

# Selection

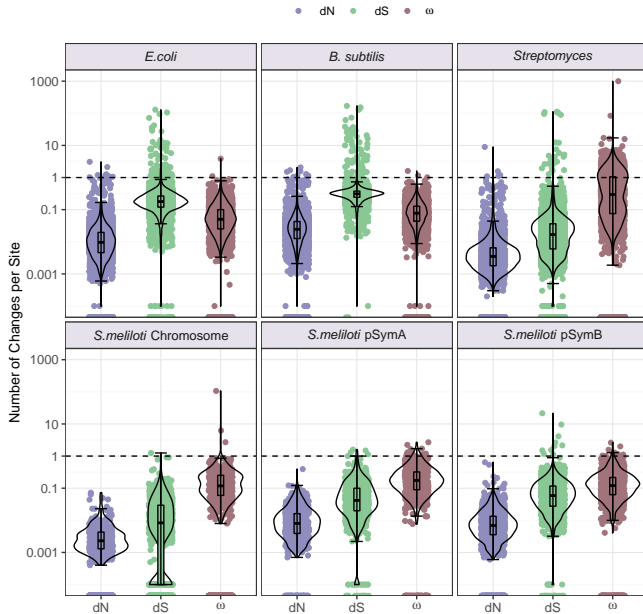
Measuring what evolutionary forces are acting on genes

- **dN** = non-synonymous substitution rate
  - change in amino acid sequence
  - can alter function of the protein
- **dS** = synonymous substitution rate
  - no change in amino acid sequence
  - will not alter function of protein
- $\omega = (dN/dS)$ 
  - $\omega > 1 \rightarrow$  positive selection
    - beneficial to the organism and will likely be maintained over time
  - $\omega = 1 \rightarrow$  neutral selection
    - neither beneficial nor deleterious to the organism
  - $\omega < 1 \rightarrow$  negative selection
    - deleterious to the organism and will likely not be maintained over time

## Selection

- *E. coli*, *B. subtilis*, *Streptomyces*, and *S. meliloti*
- dN, dS, and  $\omega$  + distance from the origin of replication
- $\omega > 1$  (positive selection),  $\omega = 1$  (neutral),  $\omega < 1$  (negative selection)
- **Expectations:**
  1. dS > dN
  2. Most genes are under neutral or negative selection
  3. Genes that are under positive selection should most likely be accessory genes
    - Core genes are near the origin of replication
    - Accessory genes are usually near the terminus

# Selection Summary



# Streptomyces Selection



# Summary

- ✓ Gene expression decreases (non-linearly) with increasing distance from the origin of replication
  - Wave-like pattern at the end of the graph?
- ✓  $dS > dN$
- ✓ Most genes are under neutral or negative selection ( $\omega \leq 1$ )
- ✓ In *Streptomyces*, genes under positive selection ( $\omega > 1$ ) were near the terminus and most likely accessory genome