BBS2710

# MICROBIAL PHYSIOLOGY

# COURSE OUTLINE

Course Convenor: Assoc. Prof Bharat Patel
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| Week | Topic | Who |
|---|---|---|
| 1<br>28 Feb | Module 1:<br>Introduction to Microbial Physiology | Bharat |
| 2<br>6 March | Module 1:<br>Macromolecular Synthesis | David |
| 3<br>13 March | Module 1:<br>Structural Assembly | David |
| 4<br>20 March | *Revision: Module 1* | Bharat |
| 5<br>27 March | Module 2:<br>Bacterial Growth, Environmental Effects and Strategies | Bharat |
| 6<br>3 April | Module 3:<br>Genetic Adaptation I<br>Bacterial Genomes, Plasmids and Mutations | David |
| 7<br>10 April | Module 3:<br>Genetic Adaptation II<br>Transposable Elements and Genetic Exchange | David |
| 8<br>17 April | *Revision: Module 2 and 3* | Bharat |
| 24 April | Mid-semester break | |
| 9<br>1 May | Labour Day Holiday | |
| 10<br>8 May | Module 4:<br>Physiological Adaptation I<br>Regulation of Enzyme activity and Gene Expression | David |
| 11<br>15 May | Module 4:<br>Physiological Adaptation II<br>Specific Examples | David |
| 12<br>22 May | Module 5:<br>Energy and Metabolism | Ben |
| 13<br>29 May | *Revision: General* | |

Teaching Team:

Assoc. Prof. Bharat Patel

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Module Notes:

- Available through the science bookshop

Prescribed Text:

- *Principles to Microbiology*
  Ronald M. Atlas

Other Texts:

- *Principles of Genetics*
  D. Peter Snustad, …

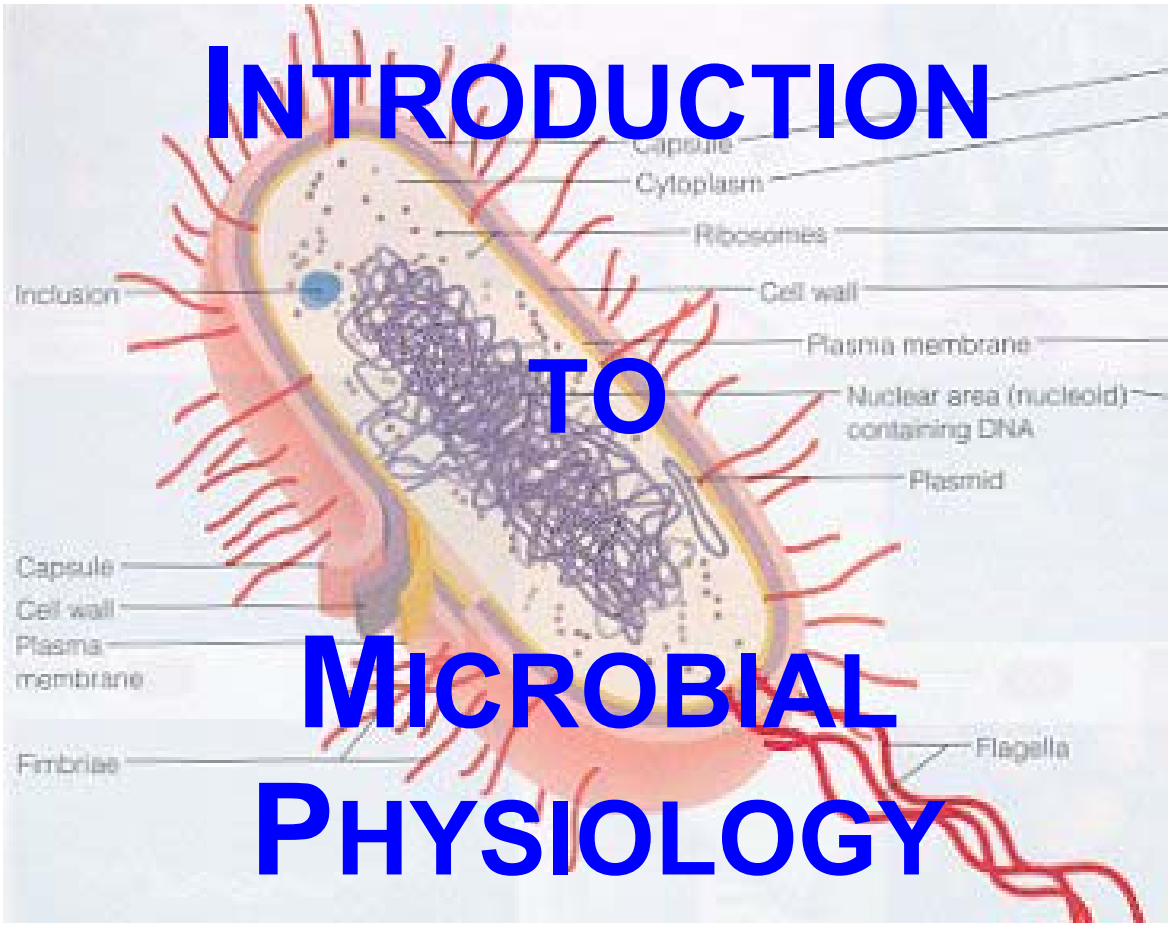
Assessment:

- 80% End-of-Semester Exam

- 20% 2000 word assignment
  - topic available in week 4
  - assignment due Monday 15 May (Week 11)

Module 1

# INTRODUCTION TO MICROBIAL PHYSIOLOGY



## Topics:

1. Introduction to Microbial Physiology (Week 1)

2. Macromolecular Synthesis (Week 2)

3. Structural Assembly

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## Aims:

- Introduce Microbial Physiology as a subject
- Describe the importance of microorganisms and their diversity in nature
- Describe *Escherichia coli* and the general molecular and structural composition of cells
- Describe the differences between Gram-positive and Gram-negative cells

## What is Microbial Physiology?

- Physiology
  - the understanding of the processes of life as mediated by its structures, operating together to accomplish the common tasks of life

- Microbial Physiology
  - an understanding of cell structure, growth factors, metabolism and genetic composition of microorganisms

  - introduces the inter-relatedness of microbiology, biochemistry and genetics in the context of a functioning bacterial cell

  - looks at single-celled organisms as a paradigm for trying to understand much more complex organisms

  - understand
    - how a cell functions in the environment
    - how it can alter to suit changes in the environment
    - how it can reproduce from very simple substrates available in the environment

## Importance of Microorganisms

- ubiquitous
  - found in nearly all environment niches

- found in environmental extremes
  - found in environments with extremes of temperature, pressure, salinity etc.

  - eg. -10°C seawater to volcanically heated pools with temperatures exceeding 100°C

- important in environmental processes
  - eg. natural bacterial flora in guts of ruminant animals

- important in industrial processes
  - eg. bioremediation and fermentation of natural substrates to produce important metabolites
  - antibiotics

- community structure of microorganisms
  - individuals play a part in a particular process
  - but a complete community is required for the complete process

## Description of Microorganisms

- originally, all life was classified as belonging to one of 5 Kingdoms

- more recently, all life is divided into 3 Domains
  - Eukarya
    - all multicellular and some single celled organisms
  - Bacteria
  - Archaea
    - both Bacteria and Archaea domains contain single-celled organisms with no membrane bound nucleus
    - have much simpler structure
    - have much smaller genome

  - **Note:** Bacteria (upper case B) refers to the domain), bacteria (lower case b) refers to prokaryotes
    - members of both domains Bacteria (sometimes called Eubacteria) and Archaea are prokaryotes

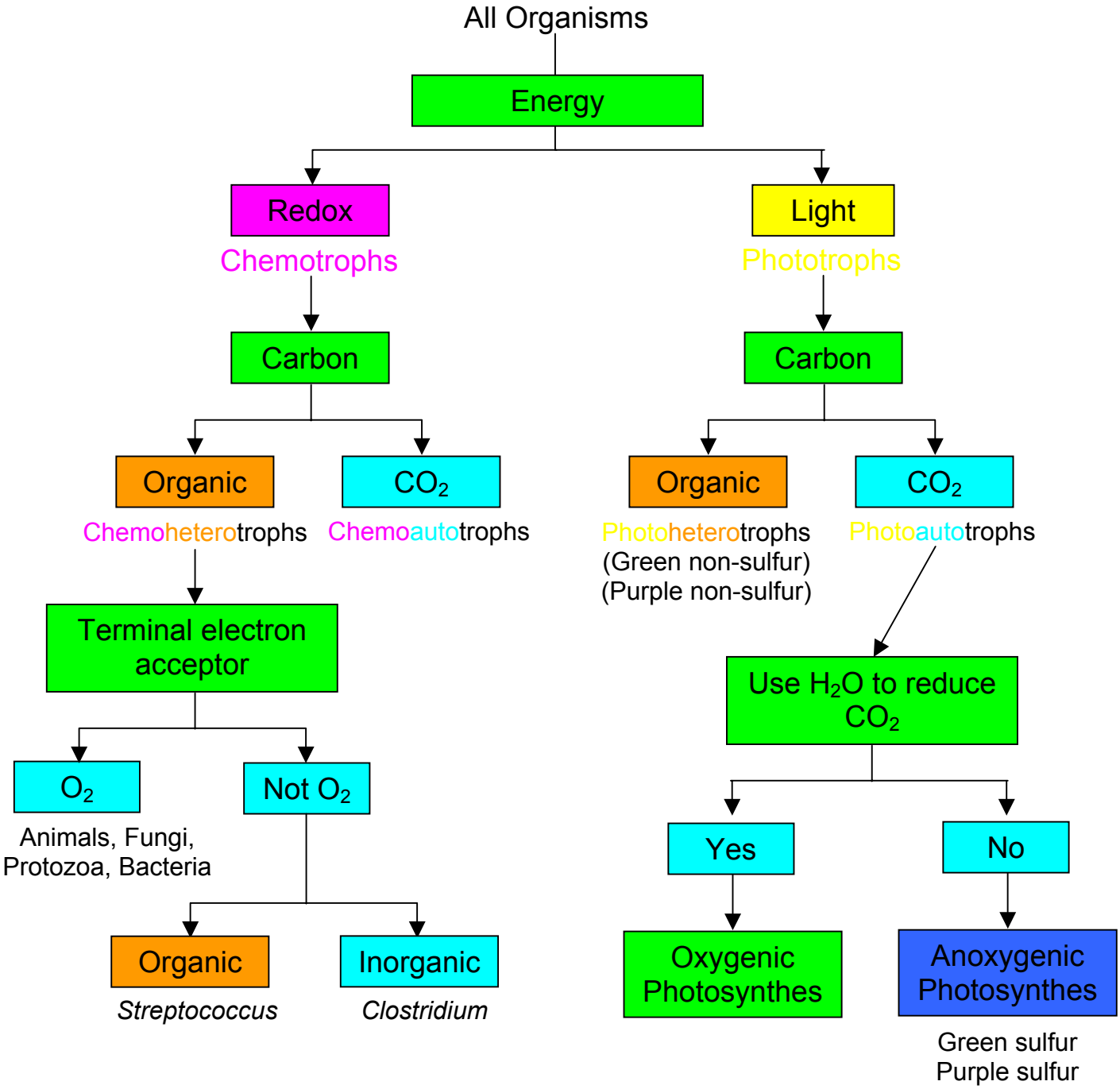
- Microorganisms are defined by their phenotypes or physical characteristics
  - characterized with respect to
    - Temperature
      - Psychrophile: -12 to 20°C
      - Mesophile: 14 to 45°C
      - Moderate thermophile: 42 to 69°C
      - Extreme thermophile: 66 to 105°C
    - pH
      - Acidophile: low pH (eg. 3)
      - Neutrophile: ~pH 7
      - Alkalinophile: high pH (eg. 10)
    - Salinity
      - Halophiles
    - Oxygen
      - Obligate aerobe: require $O_2$
      - Facultative aerobe: $O_2$ not required but better growth when present
      - Microaerophile: low levels of $O_2$ required

- Aerotolerant: $O_2$ not required and growth not improved in the presence of $O_2$
- Obligate anaerobe: $O_2$ inhibits bacterial growth

➢ Morphological characteristics
- shape
- size
- Gram stain
- sporulating (spore forming)

➢ Motility
- flagella
- cilia
- fimbriae

- Nutrition
  - energy sources: light vs chemical
  - carbon sources: organic vs inorganic
  - terminal electron acceptor



Example:

- *Caloramator indicus*
  - Gram-positive filamentous rod that is non-motile and does not sporulate
  - chemorganotrophic and obligately anaerobic
  - alkalinophilic thermophile that can ferment a wide variety of carbohydrates

Importance of Microorganisms in Physiology

- Short generation time
  - can reproduce as quickly as every 20 minutes
  - good for studying mutation
  - study a large number of identical cells

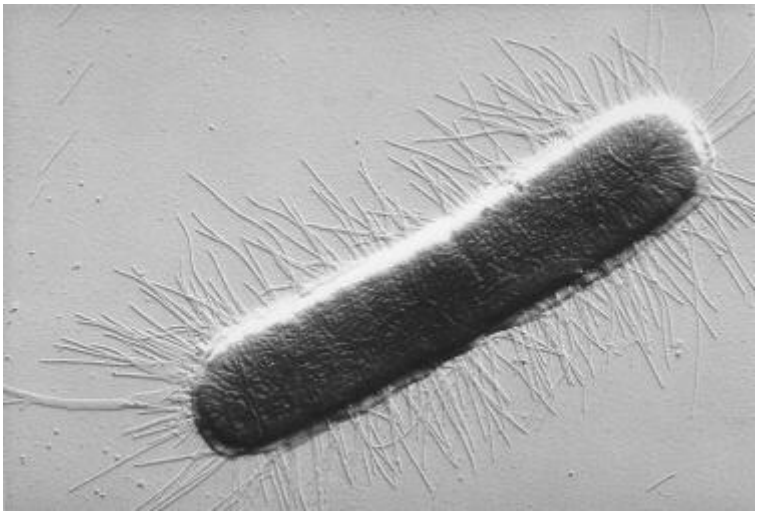
- Small size
  - enables a large population to be easily studied

- Small genome size
  - much smaller genome that higher organisms
    - organisms still capable of much the same functions

- Nutritional diversity

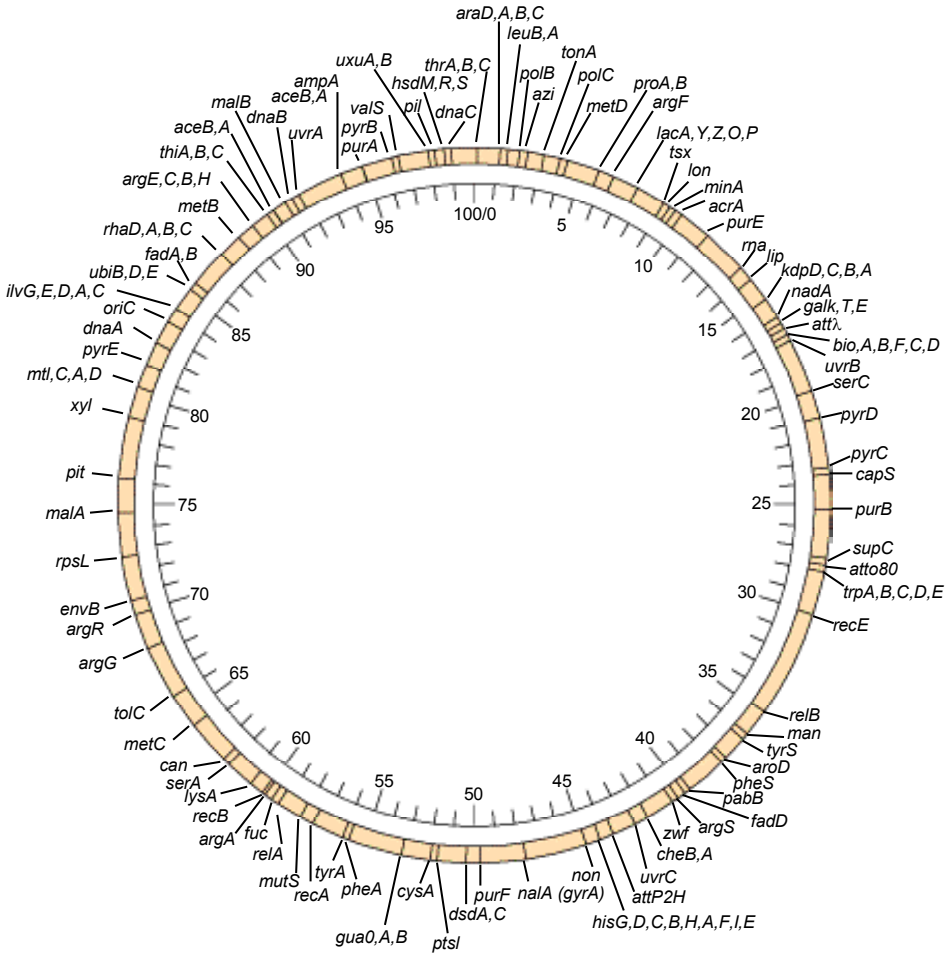
## Description of the *Escherichia coli* model

- Domain Bacteria
- Family Enterobacteriaceae
- First characterized in 1885
- found in the intestinal tract of many animals
- *E. coli* is a
  - Gram-negative rod
  - temperature optimum of 37°C (Mesophilic)
  - pH optimum of 7 (Neutrophilic)
  - doubling time of 40 minutes in minimal media
    - 20 minutes in rich media
  - although haploid
    - can reproduce sexually (see Module 3)
  - supports the survival of a wide variety of plasmids and viruses
    - significant to modern molecular biology
  - complete genome sequence of *E. coli* K-12 (strain MG1655) is known



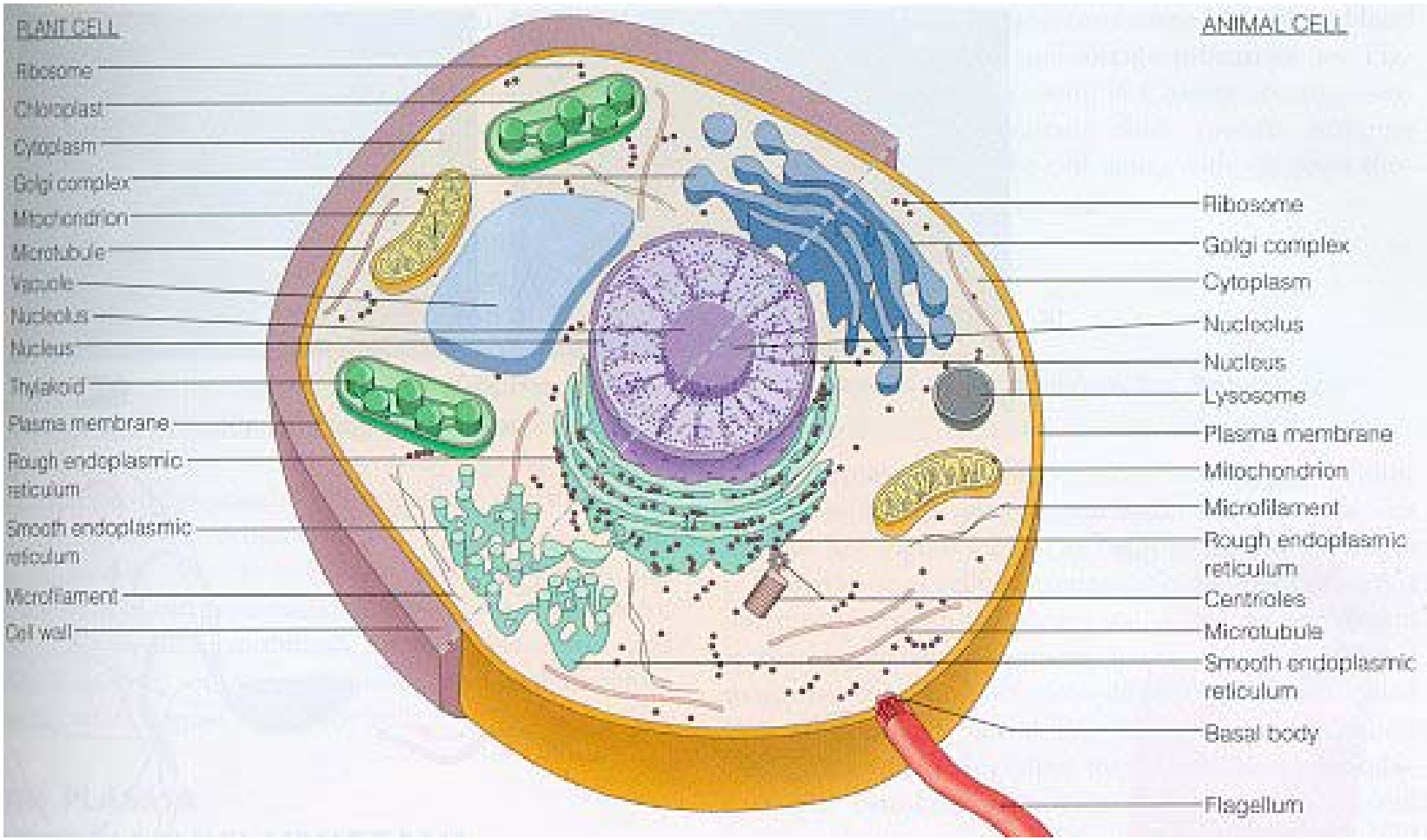
# The *E. coli* Genome

- genome size is > 4.5 megabases
- complete sequence is known
  - 4505 theoretical open reading frames
  - function not assigned to all
- Additional genetic elements
  - F' plasmid (episome)
    - ➢ fertility factor
- See Module 1 notes for chemical composition of an *E. coli* cell

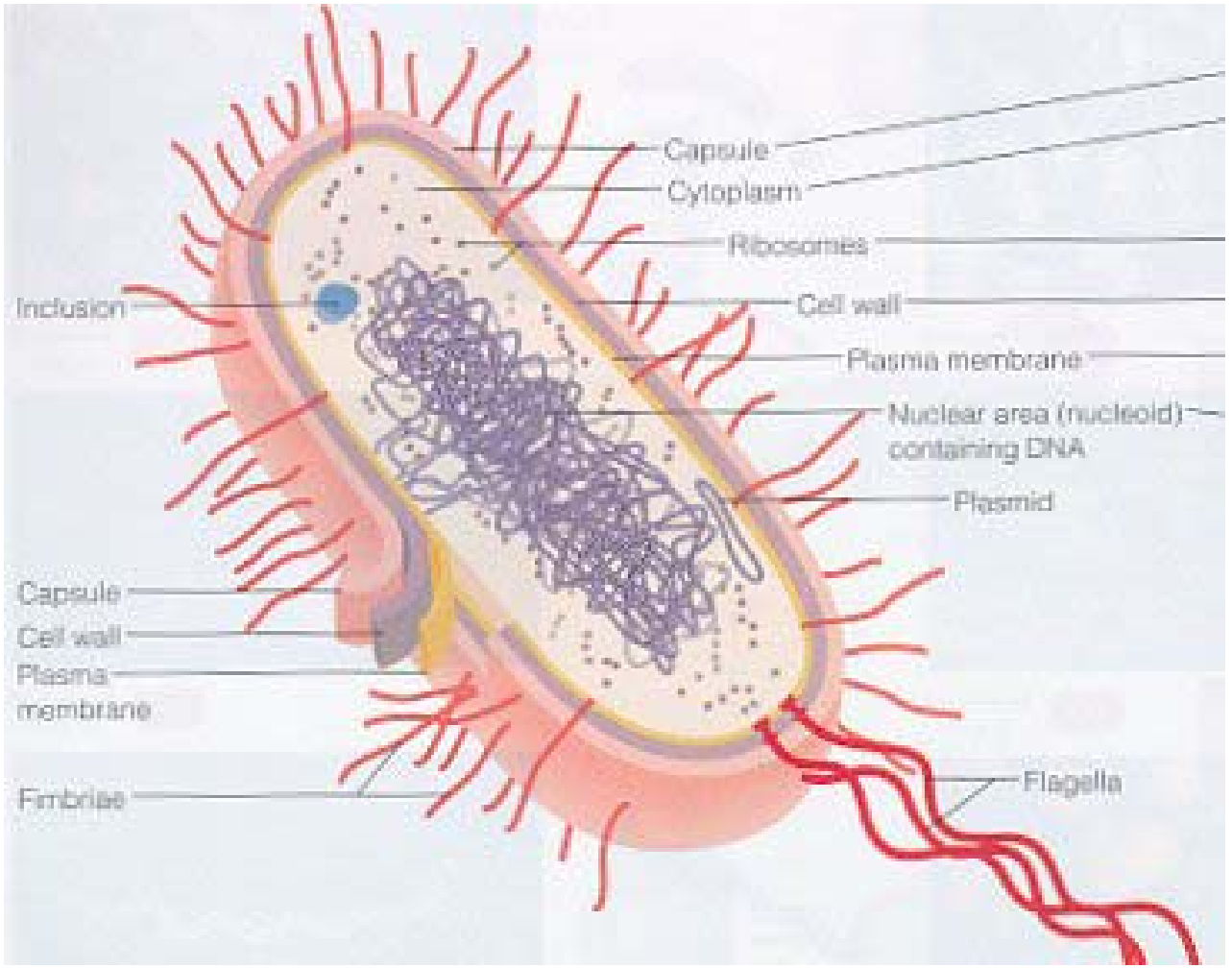


## Cell Structure and Function

- The eukaryotic cell



- The bacterial cell



## Bacterial Cell Structure

- Chromosome
  - single circular chromosome anchored to the cytoplasmic membrane (nucleoid)

## Cell wall

- surrounds the cytoplasmic membrane
- directly reflects adaptive strategies involved with
  - uptake of nutrients
  - excretion of waste products
  - movement
  - protection
  - adhesion
- in some organisms >25% of the genome is devoted to its synthesis, regulation and maintenance

- Gram Positive Cell Wall
  - rigid structure
  - contains many layers
  - based on a cross-linked polymer
    - peptidoglycan
  - also contains teichoic acids (2 types)

- wall teichoic acids
  - polymers consisting of ribitol and phosphate
  - confer antigenic specificity for the bacteria
- membrane teichoic acids
  - also called lipoteichoic acids
  - polymers consisting of glycerol and phosphate

- Gram Negative membranes
  - consists of outer and inner (cytoplasmic) membranes separated by the periplasm
  - outer membrane
    - flexible outer phospholipid bilayer with an inner peptidoglycan layer
      - strong negative charge of phospholipid bilayer helps evade phagocytosis
      - also protects against some antibiotics

- outer membrane also contain hydrophobic lipopolysaccharides and lipoproteins
- porins
    - involved in transport of materials into the cell
- peptidoglycan layer attached to the outer membrane by a murien lipoprotein
- lipopolysaccharides project outwards from the outer membrane
    - comprised of three parts
        - Lipid A
        - Core sugar
        - variable polysaccharide (O-antigen)

- Periplasm
    - solution between the inner and outer membrane
    - contains specific periplasmic proteins
        - usually invoved in hydrolysis and transport of materials

- Cytoplasmic (inner) membrane
  - feature of both Gram-positive and Gram-negative cells
  - phospholipid bilayer
  - allows the passage of membrane components through
  - has peripheral or integral proteins associated with it

Permeability and Transport

Glycocalyx

- also referred to as a capsule
- gelatinous material
- survival strategy
  - inhibits phagocytosis
  - aids in pathogenicity by increasing adherence
  - can increase motility
- present either as a capsule (discrete) or slime layer (indiscrete)

## Cellular Projections

- movement is important for microbes to adapt to changing environments
- many different strategies employed
  - chemotaxis
    - movement to towards a beneficial chemical (attractant)
    - movement away from a detrimental chemical (repellant)
  - phototaxis
    - light
  - oxytaxis
    - oxygen
  - most movement is mediated by the flagella
    - flagella consist of a basal body, hook and filament
    - movement is achieved by rotation of the flagella

  - Pili
    - another cellular projection
    - 1-2 per cell
    - associated with DNA transfer (conjugation)

  - Fimbriae
    - more numerous
    - involved in attachment

## Endospores

- not produced by all bacteria
  - only members within the Gram-positive group
  - spores are formed as a survival mechanism
  - morphological change as a result of hostile conditions
    - increased temperature
    - decreased substrate availability
  - endospores endure the harsh environment until conditions become more suitable

Learning Exercise

* revise the function of organelles in eukaryotic cells

You should be able to…

* discuss what microbial physiology involves

* discuss why *E. coli* is such a useful organism to use as a model for microbial physiology

* draw a typical prokaryotic cell, noting structures and functions

* describe the differences between Gram-positive and Gram-negative cell types

* describe the differences between eykaryotic and prokaryotic cell types

* recall that all life is divided into three domains, and a large diversity is present in the Bacterial and Archaeal domains

Next Week…

* Macromolecular synthesis