CE 421/521 Environmental Biotechnology

The Cell: The common denominator of all living things Chapter 4 in Vaccari et al. Tim Ellis August 24, 2006

Introduction

 Cells were discovered around the same time Robert Hooke in England mid 1600s and Antonie van



Robert Hooke

- Leeuwenhoek in Holland
 - Both were contemporaries of Newton



Hooke and van Leeuwenhoek

- Hooke is best known for The Micrographia which set the standard for microscopic illustration
- Van Leeuwenhoek was unschooled but curious made over 500 microscopes
 - my work, which I've done for a long time, was not pursued in order to gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than in most other men. And therewithal, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed thereof. Antony van Leeuwenhoek. Letter of June 12, 1716



The Protista

- Pro_
 - bacteria
- Eu
 - fungi
 - protozoa
 - plant cells
 - animal cells

Cell Theory

- All living things are composed of o ____ or more cells
- Cells are the basic units of living things and the s_____ for the reactions of life
- All cells come from pre_____
 cells

Main Differences:

In

- Eucaryotic cells are much
 I_____ and far more
- Nuclear m_ eucaryotes.
- Procaryotes divide by binary
 f_____, eucaryotes by

m

С

Mitosis movie on web

Main Differences:

Procaryotes lack: G______
 complex, e______
 reticulum,
 m______
 and c

Cell Structure - Size:

- procaryotes:
 - *E. coli*: 0.5 2 μm
 - Colonies of 107 cells are visible by the
 n _____e (from one cell after 10-18 h growth)
 - 100 mg of a b contains roughly 100 billion (1011) cells
 - Average mass of one c is 2.9 x 10⁻¹³ g dry mass

Cell Structure - Size:

- eucaryotes:
 - <u>g</u>than 5 µm



Cytoplasmic Membrane:

- gram n ______ bacteria have an o _____ membrane and an inner (cytoplasmic) membrane





Figure 12

Comparison of the structure of the Gram-positive and Gram-negative cell envelopes, showing the major molecular components and their approximate dimensions. The region between the outer membrane and the cytoplasmic membrane of the Gram-negative envelope is called the periplasm.

Cytoplasmic Membrane:

- 40 80 thick
- semi-permeable
- p______ bilayer
 fluid m______ model

Movie: phospholipids in plasma membrane movie

All biological membranes are bilayers of phospholipid. The proteins in each type of membrane give it its unique properties.





Model of the *E. coli* cell envelope, showing its various layers and their approximate thicknesses.

Table 1. Functions of the bacterial cell membrane

Osmotic barrier

Transport of specific solutes (nutrients and ions)

Synthesis of membrane lipids (including lipopolysaccharide in Gram-negative cells)

Synthesis of wall murein

Assembly and secretion of extracytoplasmic proteins (membrane periplasmic, outer membrane, extracellular)

Respiratory electron transport

Chromosome segregation (probably)

Chemotaxis (both motility per se and sensing function)

compounds cross membrane by diffusion

 some molecules diffuse r ______across membrane (O2, CO2, NH3, H20)

diffusion is controlled only by d g______ of non-charged molecules (C), p_______ constant (P), and surface area

- to maintain a concentration gradient, gram negative bacteria maintain a very low concentration of nutrients in the p______through binding proteins which sequester nutrients or actively p______them across the cytoplasmic membrane
- diffusion across outer membrane is d from cytoplasmic membrane:
 - outer membrane is impermeable to n______ solutes (provides protection for gram negative organisms, especially from antibiotics)
 - polar solvents pass through special protein channels called p_____. Porins may be h______that separate molecules based on size or may be c______ which are specific for certain substrates

Transport Continued

transport

(facilitated diffusion)

 allows transport of substances that would otherwise be

(e.g.

glycerol)

 steriospecific c _____: membrane bound proteins that "facilitate" the transport of impermeable substances along a concentration gradient

Facilitated Transport Continued

- act as c
- some allow c ______: as one substrate is brought into the cell another is transported out, but still need a concentration gradient for one of the substrates

Active Transport

- allows transport a _____a a concentration gradient
- e a concentration gradient (higher concentration within cell) for example amino acid concentrations are over a 1000 fold higher, galactose 105, and potassium 106.
- s_____, membrane bound proteins (called carriers, or permeases) mediate the transport of specific substrates

kinetics

• exhibits s

Summary of Transport Mechanisms



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endocytosis (eucaryotes)

can be

mediated

includes phagocytosis **(p** and pynocytosis



substances)

Cell Wall

- all bacteria have a cell wall except m_____
- provides rigidity for o_ pressure gradient
- consists of peptidoglycan (murein):
 g______strands cross linked with
 p______chains
- gram positive bacteria have a much higher peptidoglycan content and also contain t______acids in cell wall



Outer Membrane

- gram negative bacteria have an outer m______which consists of phospholipids (inner leaflet), lipopolysaccharides, LPS (outer leaflet), and p______. LPS is a complex molecule not found except in the outer leaflet of the gram negative bacterial cell
 provides an efficient
 - b_____against both hydrophilic and hydrophobic compounds
- p______allow transport of essential hydrophilic compounds and substrates

Outer Membrane



Glycocalyx - capsule

- capsule surrounding cell composed of extracellular p_____ (amorphous, *without form*, slime)
- provides added protection:
 - p______ virulence (e.g., meningitis)
 - p_____ phagocytosis due to making cell "slippery"
 - assists in surface a
 - prevents d_____
 - m_____ complexation
 - microbial f_
 - also can be produced during u growth conditions

Cell Motility - flagella

- composed of helical
 - f_____(flagellin), hook, and basal body (see diagram) which function as a rotating shaft: "biological motor"
- energy for rotation is p______f_____

Cell Motility - flagella

 cilia - shorter and thinner than flagella, also used for I_____ or feeding (in ciliated protozoa)

Flagella movie



Figure 15

Basal body structure of the *E. coli* flagellum. The relationship of the four rings of the basal body and the envelope of *E. coli* are shown. (After DePamphilis and Adler, 1971.)



Cell Motility - flagella

- cells move t
 - f _______ chemotaxis
 I _______ photo taxis
 - a _____ aerotaxis
- cells can also move away from
 t _____ or
 i _____ compound

Pili (hair)

to

- typical *E. coli* has _____
 pili
- 0.2 2 im in I
- play a role in a to surfaces, some are specific for certain receptors, such as glycoproteins on the host surface, also serve as receptors for phages
- some play a role in conjugation, sex pili, form initial attachment between mating pairs



Gas Vacuoles

consist of g_

V

- allows for cell b
- found in c______,
 h______, and
 p______bacteria

Envelope -----

Flagella 6 proteins ($\sim 2 \times 10^4$ molecules/cell)

Pili

1 protein ($\sim 2 \times 10^4$ molecules/cell)

Outer membrane 50 proteins (4 abundant, 10^6 molecules/cell) 5 p-lipids ($\sim 5 \times 10^6$ molecules/cell) 1 LPS (9 × 10^6 molecules/cell)

Capsule 1 complex polysaccharide

Wall Peptidoglycan (1 molecule/cell)

Periplasm

50 proteins (~10⁴ molecules/cell)

Cell membrane

200 proteins ($\sim 2 \times 10^5$ molecules/cell) 7 p-lipids ($\sim 15 \times 10^6$ molecules/cell)

- Nucleoid

DNA (haploid chromosome; ~1 molecule

Cytosol

1,000 proteins ($\sim 10^6$ molecules/cell) 60 tRNAs ($\sim 2 \times 10^5$ molecules/cell) Glycogen (variable)

. Polysomes

~18,000 ribosomes/cell in 1,000 polysomes

55 proteins (~10⁶ molecules; 1 of each per 70S ribosome)

3 rRNAs (5S, 16S, 23S; 56,000 molecules; 1 of each per 70S ribosome)

1,000 mRNAs (~1,400 molecules, 1 per polysome)

Figure 2

CHAPTER THREE

Macromolecular composition of the bacterial interior. This figure is based on the data presented in Table 1, Chapter 1.

Endospores

- some bacteria (most notably *Clostridium* and *Bacillus*) form e_____ within the cell
- most r ______ forms of life on earth
- can withstand h temperatures (>100°C)
- can remain v for long periods of time (endospores on 300 year old root specimen at British herbarium were still viable within minutes when conditions were made favorable for growth)
- some spore forming bacteria produce t (e.g., Clostridium botulinum)
- if you can k _____ spores, you can be certain that other bacteria are also killed

Cell Genetics - DNA

- consists of s circular, double h molecule (chromosome) in procaryotes (also extra chromosomal elements: plasmids)
- consists of a distinct n with nuclear membrane in eucaryotes
- size varies, 1 in length average packed into a cell only 1 to 2 i (like a ball of string)
- DNA replicates f _____ than cell divides cells will have more than one copy on average
- high n _____ charge, requires positive ions to neutralize the charge (Mg++, Ca++, and polyamines) to wrap up in a ball





DNA movie

Nucleic Acids

- deoxyribonucleic acid (DNA) consists of several million

 p______(nucleotides): adenine,
 guanine, cytosine, and thymine. Guanine pairs with cytosine
 on the c______strand, and adenine pairs with
 thymine. Bonding is through h_____-bonds.
- 5-carbon sugar (deoxyribose), p group, and n containing group base linked to #5 and #1 carbons
- in ribonucleic acid (RNA) u replaces thymine and the 5-carbon backbone is ribose instead of deoxyribose (contains an OH group on the #2 carbon)