MBIOS 401: Lecture 1.3 Cells

Slide #1

Introduction to Cells

- Cells are the "building blocks of life" – Life begins with a cell
- Robert Hooke's 1664 drawing of the cell-like structure of cork.
- The word cell comes from the Latin cellula, a small room.
- The name was chosen by Robert Hooke when he compared the cork cells with small rooms.

Audio:
Cells are the fundamental building blocks of all living things on this planet. The word "cell" was first used by Robert Hooke in the 1600's. Hooke was involved in the development of microscopes and made many unique discoveries as a result. One of the specimens he looked at was a thin slice of cork material, probably from a wine bottle he had lying around. The structures he saw reminded him of the small rooms in monasteries where monks lived. These small rooms were called cells after the Latin word "cellula", or small room, and so that is why we call cells "cells".

Slide #2

Cell Theory

- Around 1850, three component "Cell Theory" was proposed by Theodor Schwann, Mattias Schleiden, and Rudolf Virchow.
    1. The cell is a basic structural unit of life; it has hereditary information and it is surrounded by semipermeable membrane.
    2. An organism is composed of one or more cells.
    3. Cells arise only from preexisiting cells; it is a basic unit of reproduction.

Audio:
Around 1850, three scientists, Theodor Schwann, Mattias Schleiden, and Rudolf Virchow came up with something called the "Cell Theory". There are three components to the Cell Theory. First, cells are the basic unit of life. Anything less than a cell isn't alive. Second, all living things are made of cells. Finally, cells arise only from other cells. Although these statements seem logical now, at the time, much of this was not entirely clear. For example, people had observed that a mixture of hay, mud, and water would give rise to a broth that would contain many different forms of microorganisms. And so there was a heated debate about whether or not it was possible for living things to arise from nonliving materials.

Slide #3

The Commonality

- Cells share similar structural features and carry out the complicated biochemical processes in basically the same way.

A cell is surrounded by plasma membrane.
A cell has genetic information.

Audio:
Living things are astonishingly diverse. However, all living things exhibit equally remarkable similarities. These include some of there fundamental structural organizations. For example, all cells are surrounded by some form of lipid membrane. In addition, all forms of life that we know about use nucleic acids to transfer heritable information from one generation to the next. The conservation of this mechanism is remarkable. For example, if you take DNA from humans or elephants or some other complex vertebrates and put it into a bacterium, the bacteria will read the DNA code correctly and make a protein, that in many cases, is identical in form and function to the same protein made by vertebrate cells.

Slide #4

Commonality cont.

Similar biochemical processes

- Metabolic processes
- Genetic processes
- Signaling

Audio:
There are other similarities among living cells. For example, all living cells produce ATP and use its energy to drive metabolic processes. All living things use ribosomes and transfer RNA molecules during the conversion of the DNA code to protein. And all living things use small ions, like calcium, for communication purposes.

Slide #5

Cells Diversity

Cells come in a variety of shapes and sizes

Audio:
Despite the basic commonalities among living things, modern organisms are amazingly diverse and much of the diversity is generated by modifications in cell structure and also by building complex structures out of more than one cell. These are just a few images to show this. Bacteria

and yeast have relatively simple shapes and some cells found in more complex organisms, such as our own red blood cells, are also simple spheres and ellipses. However, individual cells can also display incredibly complex shapes, like the neuron shown on the bottom left of this slide, and cells can also bind together to form very complicated structures, such as the intestinal lining shown in the top right and the plant tissue shown in the middle of the slide at the bottom.

Slide #6

Cell Organization Complexity

- Different Cell Organizational Complexity between Prokaryotes and Eukaryotes – Cell Classification/organization based on Having or not having nucleus
- Prokaryotes and Eukaryotes: Nevertheless, all cells from common ancestor cell
- Archaea: extremophiles – hot springs, salt lakes, but actually broad habitat, soils, ocean, marshland, etc

Audio:
The diagram on this slide shows the overall organization of living things that we know about. The most fundamental division is between prokaryotes and eukaryotes. The root of both of these words is the Greek word "karyon", which means nucleus. "Pro" means before and "eu" means true. So prokaryotes lack nuclei and eukaryotes truly have them. Prokaryotes have been further classified into two groups known as bacteria, or eubacteria as in true bacteria, and the archaea, also known as archaebacteria. We are not going to spend much time talking about archaebacteria but they are fascinating organisms, some of which live in some of the most extreme environments on earth such as hot springs where the temperature may be greater than that of boiling water and the pH can be more acidic than stomach acid. Archaea resemble bacteria with regard to their overall organization and many metabolic processes but they are intriguingly similar to eukaryotes with respect to the systems that handle DNA replication and RNA production. I've already mentioned the remarkable similarities of all living things and this diagram illustrates this by showing that all living things are thought to have arisen from a single ancestral cell.

Slide #7

Bacteria

- "Relatively simple", but greatest diversity
- Classified by morphology
- Or recently, by comparision of the nucleotide sequenc of ribosomal rRNA gene

Audio:
Because bacteria are so important to disease, a lot of effort has gone into classifying them. The classification of bacteria is increasingly dominated by the comparison of genetic information and

within a few years it is likely that the complete genome sequence of the bacteria will be determined routinely. However, bacteria are currently still classified using relatively simple characteristics such as shape and their affinity to take up certain diagnostic stains. We're going to look briefly at these characteristics. This slide shows some of the morphological traits that bacteria display including spheres, rod shapes, and spiral bacteria. As shown here, some bacteria also move on their own using a structure called a flagellum. Some bacteria have more than one while others have none. Despite the apparent simplicity of prokaryotic organisms, the overwhelming majority forms of life on this planet are prokaryotes.

Slide #8

Gram-positive and Gram Negative Bacteria

- E. coli: Gram staining was developed as a diagnostic tool for identifying bacteria by Hans Christian Gram in 1884. It uses a purple stain that binds to proteins and peptides. Gram negative are enclosed in an outer membrane that does not bind this stain.

Audio:
Another major classification scheme assesses whether bacteria are surrounded by an outer membrane or are instead enclosed by in a coat of peptides and polymeric sugars, called a peptidoglycan layer. Hans Gram developed a staining method in 1884 using a dye called crystal violet which stains proteins a dark purple color. Crystal violet is still used in research and forensic laboratories today as a general stain for proteins and things like fingerprints. Bacteria that have an outer peptidoglycan coat stain with this dye and are called Gram-positive while bacteria that surrounded by an outer lipid membrane are not stained and these are called Gram-negative bacteria. The protocol frequently also uses a red-counter stain and you can see what this looks like in the image on the left-hand side of the slide.

Slide #9

Prokaryote and Eukaryote

- There are two major organizational (structural) differences between prokaryotes and eukaryotes
- Eukaryotes have organelles and cytoskeleton.
- Organelles are membrane-bound structures inside the cell.
- The cytoskeleton is a system of protein filaments (actin filaments (microfilaments), microtubules, inermediate filaments) in the cytosol of eukaryotic cells that give a cell the shape and the capacity for movement.

Audio:
The most fundamental differences between prokaryotes and eukaryotes is there internal organization. Prokaryotes have a relatively simple internal organization and that limits there complexity in terms of function and shape. For example, prokaryotes, in addition to lacking a

nucleus, also lack any sort of internal membrane-bound organelle. We will be spending the next several lectures studying membrane-bound organelle systems and you will see how these structures are important for giving cells the ability to perform specialized functions. In addition, prokaryotes lack major internal structural systems that together are known as the cytoskeleton. The cytoskeleton is used by eukaryotic cells to generate complex shapes such as the neuron I showed you a few slides ago. We will spend most of the second section of this course talking about these structures. Interestingly, in recent years it has been determined that this second rule is not entirely correct. Some of the eukaryotic cytoskeletal proteins are related to older proteins found in prokaryotes and the prokaryotic versions of these proteins serve primitive structural functions. So maybe, we'll have to start listing structural proteins as one of the commonalities among living cells at some point. However, it remains true that the cytoskeletal system is much more elaborate in eukaryotes than it is in prokaryotes.

Slide #10

Prokaryote and Eukaryote

- Prokaryotes lack membrane-bound organelles

Prokaryotic cell: Some Prokaryotes have two compartments: e.g., E. coli

- Cytosolic compartment
- Periplasmic space.
-

Eukaryotic cell: Many compartments

Audio:
This slide and the next one illustrate the points we've just made about prokaryotes and eukaryotes. Most prokaryotes have single compartment that contains water-soluble proteins and DNA that is collectively known as the cytoplasm. The cytoplasm is surrounded by one double-layered lipid membrane also known as the plasma membrane. A few prokaryotes has two outer-membranes and there is a therefore a second compartment, know as the periplasmic space, between them. But that is about as complex as prokaryotes get. In contrast, eukaryotes have a large number of membrane bound compartments, or organelles, which we will spend several lectures talking about.

Slide #11

Prokaryote and Eukaryote

- Prokaryotes lack* a cytoskeleton

Audio:
This slide shows a few representative images of cytoskeletal filament arrays found in eukaryotic

cells. They are three of these systems in eukaryotes: the actin microfilament system, the intermediate filament system that has larger filaments than actin, and microtubules which are the largest filaments in cells term of their diameter. This image of microtubules also shows one of their important functions, which is to organize the internal components of cells including membrane-bound organelles. For example, you can see that the Golgi apparatus, which is stained green in this image, is found at the center of radiating organization of red stained microtubules.

Slide #12

Prokaryote and Eukaryote

- Prokaryotes: Are typically Unicellular (only rare exceptions)
- Eukaryotes: Are Unicellular or a component of Multicellular Organisms
- Humans have an estimated 100 trillion or 1014 cells; a typical cell size is 10-20 µm; a typical cell mass 1 nanogram.

Audio:
Another organizational difference between prokaryotes and eukaryotes is the way in which they interact with each other. Almost all prokaryotes are unicellular and even the rare exceptions to this rule are very simple grouping of cells. In contrast, eukaryote cells form highly complex multi-cellular organizations. For example, a human being has something like a hundred trillion cells all organized in an amazingly complex but highly defined system.

Slide #13

Prokaryote and Eukaryote

- Eukaryotes can be unicellular, the Protists family

Audio:
Even unicellular eukaryotic cells tend to be much more complex than prokaryotic cells. There's a whole class of eukaryotic single-celled organisms known as protists and a few of them are shown on this slide. Even though these are single cells, they show great complexity of structure and function as a result of there ability to produce membrane-bound compartments and build cytoskeletal arrays.

Slide #14

Comparison Table

- Prokaryotes: Eubacteria, archeabacteria, small ~1 µm, no organelles, DNA in nucleoid region, no mitochondria, no chloroplasts, primitive cytoskeleton, RNA/protein synthesis in cytosol, 50S and 30S ribosomes, simmple cell division (fission)

- Eukaryotes: Protists, fungi, plants, animals, 10-100 µm, many organelles, DNA in nucleous, ATP prod. By oxidative phosphorylation in mitochondria, photosynthesis in chloroplasts, three protein families of cytoskeleton, RNA in nucleus, protein in cytosol, 60S and 40S, cell division by mitosis and meiosis

Audio:
Finally, here's an overview chart that summarizes the differences between prokaryotes and eukaryotes. I've already discussed most of these. There is some organization to DNA in prokaryotes and the structure that contains the DNA in these prokaryotes is known as a nucleode. However, it is not a membrane bound structure and consequently the process of making an RNA copy from DNA and DNA replication itself is conducted in the cytoplasm of prokaryotes. In contrast, it occurs in the nucleus of eukaryotes. We will be discussing ATP production by mitochondria and carbon fixation by chloroplasts in later lectures. These structures are only found in eukaryotic cells. Prokaryotes can do both these things, but they don't have specialized compartments for doing so. We also haven't discussed the process of cell replication yet. In prokaryotes, this occurs by simply pinching one large cell into two smaller ones. Eukaryotic cells have a much more complex mechanism for ensuring that the DNA is divided between daughter cells equally and we will cover this in great detail later on in this course.