

Module 1: Cell Basics

BMES Cell Team

Fall 2020



Outline

- Components of a Cell
- Protein Synthesis and the Central Dogma
- Cell Morphology
- Cell Confluency and the Basics of Microscopy
- Separable Differential Equations to Model Cell Growth
(Time Permitting)
- Group Zoom Picture for Website
- Worksheet Breakout Room Session
- Reminders and Announcements
- Optional Class Advising and Recommendations Session

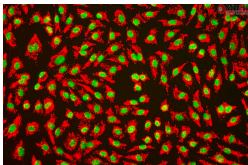
Cells

- **Definition:** Cells are the basic blocks of life. (Informal)

→ Cells make up tissues

→ Tissues make up organs

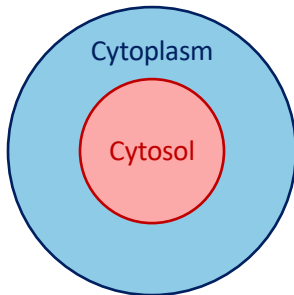
→ Organs make up organisms



Basic Make-up of a Cell

- Generally, cells are made up of a cell membrane, organelles, and cytosol
 - Cytoplasm is **everything** that is enclosed inside the cell membrane
 - Cytosol is **only** the fluid component of the cytoplasm

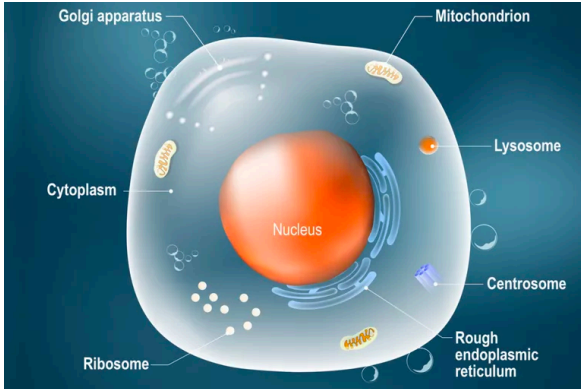
“The cytosol is contained within the cytoplasm”



Basic Make-up of a Cell

- Important Organelles
 - **Nucleus:** The control center (contains DNA in the form of chromosomes)
 - **Endoplasmic Reticulum:** Proteins are created here.
 - **Mitochondria:** Generates ATP during cellular respiration to provide energy
 - **Cell Membrane:** Contains proteins and a phospholipid bilayer to allow for transport of essential molecules

Basic Make-up of a Cell



Question:

Do all cells look like this?

Answer:

→ No

→ This is just a general *model* of a cell

- As you will see later, there are many types of cells, and each of them has a specialized function

Basic Make-up of a Cell

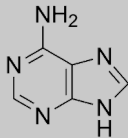
The Nucleus

- The nucleus contains DNA in the form of **chromosomes**
- If you **zoom** in all the way, you can see that DNA is made up of four different bases that pair in specific ways:
 - Adenine (A) pairs with Thymine (T)
 - Cytosine (C) pairs with Guanine (G)
- The order of the four nucleic acids serve as the “code” to create proteins
 - Proteins are the “essential workers” of a cell

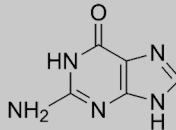


Purines vs. Pyrimidines

The Purines

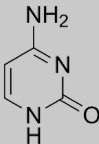


Adenine

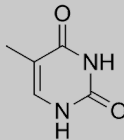


Guanine

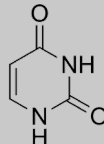
The Pyrimidines



Cytosine



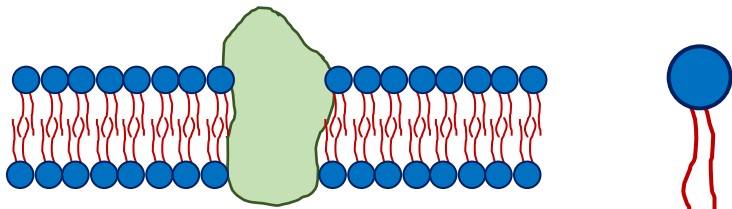
Thymine



Uracil

Basic Make-up of a Cell

Cell Membrane



- The cell membrane is made of a “phospholipid bilayer”
- This structure allows it to be *selectively permeable*, meaning that only certain molecules can pass through
 - Thus, the cell can filter out most harmful molecules and maintain homeostasis

Basic Make-up of a Cell

Cell Membrane

- So what molecules could pass through the cell membrane, exactly?
 - **Small, uncharged molecules** can freely pass through the cell membrane
 - **Large molecules that are beneficial to the cell** can pass through with the aid of a *transport protein*
 - **Large molecules that are detrimental to the cell** cannot pass through



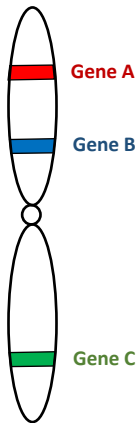
Central Dogma

- **Definition:** The **Central Dogma** describes the process by which proteins are synthesized.
- DNA → RNA → Proteins
- This is how cells use DNA to accomplish their function
- All cells in your body carry the same DNA sequence¹, but only a unique combination of *genes* end up being expressed
- Thus, different cells produce different proteins, and this determines the overall function of the cell

¹ Except B-cells, which are part of the immune system

Central Dogma

Protein Synthesis Theoretical Example



Chromosome N

- Every cell in your body will have a Chromosome N that contains genes A, B, and C like the figure shown on the left
- However, “ $\alpha\beta$ -cells” will only express proteins coming from genes A and B
- “ δ -cells” will only express proteins coming from gene C

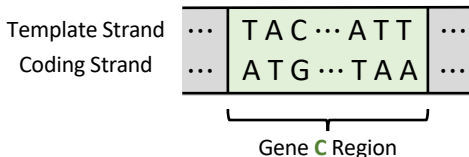
Central Dogma

- The Central Dogma is divided into two steps: **transcription** and **translation**
 - **Transcription** occurs when the *coding DNA strand* is copied onto **messenger RNA** (mRNA) via the *template strand*
 - **Translation** occurs when a complementary **transfer RNA** (tRNA) attaches a particular amino acid onto the polypeptide chain
- The final result is a functional protein
- Remember that different cells produce different proteins

Central Dogma

Transcription Theoretical Example

- **Transcription** is the first step of the Central Dogma
- Consider δ -cells from the previous example, which will only produce proteins coming from gene **C**
 - Thus, genes **A** and **B** will not be transcribed



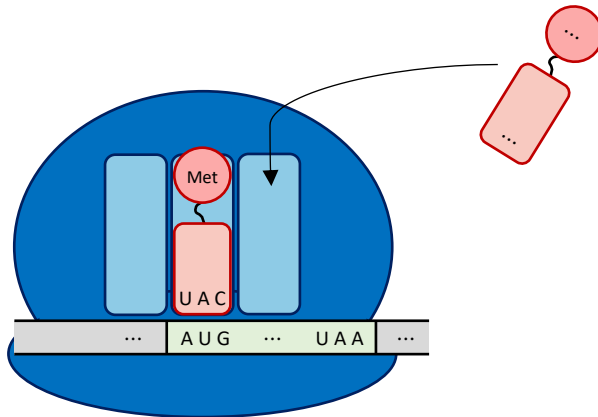
Transcription Theoretical Example

- Things to note from the example you just saw:
 - mRNA is the end product of transcription
 - mRNA contains four bases just like DNA but there are two major differences:
 1. RNA is single stranded
 2. Thymine (T) is replaced by Uracil (U)
 - The sequence of mRNA is the same as that of the coding strand
 - The sequence of mRNA is complementary to the template strand

Central Dogma

Translation Theoretical Example

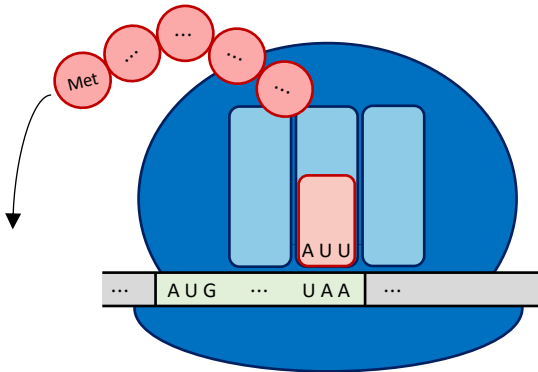
- **Translation** is the second and last step of the Central Dogma



Central Dogma

Translation Theoretical Example

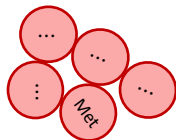
- Fast forward until it reaches the STOP codon



Central Dogma

Translation Theoretical Example

- The final protein appears as follows:



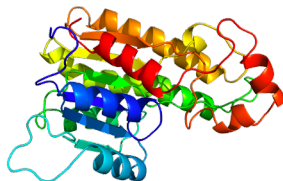
Cartoon Rendition 1

≡



Cartoon Rendition 2

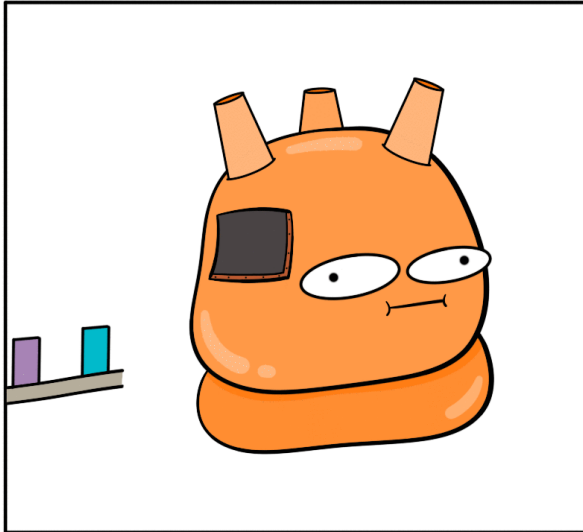
≡



Homology Model

- Remember that proteins fold right after they are released from the ribosome due to intermolecular forces generated between amino acids

RIBOSOME



Protein synthesizers of the cell

Cell Morphology

- **Definition:** **Cell morphology** describes the *qualitative* properties of a cell.
- You can describe a cell by its **size, shape, and physical appearance**
- There are many kinds of cells, each with a different function
 - As we saw earlier, this is because each cell-type has a unique set of proteins
 - Directed by their DNA
- The *morphology* of a cell is reflective of the cell's function

Types of Cells

Important Remarks:

- Since the appearance of a cell is determined by its function, certain types of cells may contain more of a particular organelle compared to another
 - For instance, a hair cell will contain **less mitochondria** compared to a muscle cell because it requires less energy

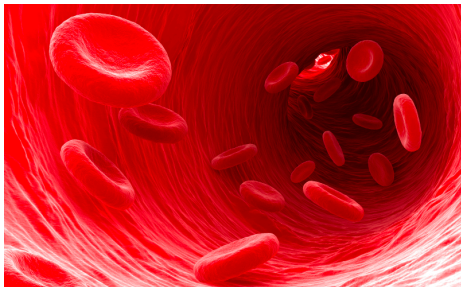
Red Blood Cells

Function:

- Carries oxygen from the lungs to the tissues
- Carries carbon dioxide from the tissues back to the lungs
- Moves passively, as they are pumped by the heart

Structure:

- Round and biconcave
- Flexible
- Contains hemoglobin, which is a protein that binds oxygen
- No nucleus



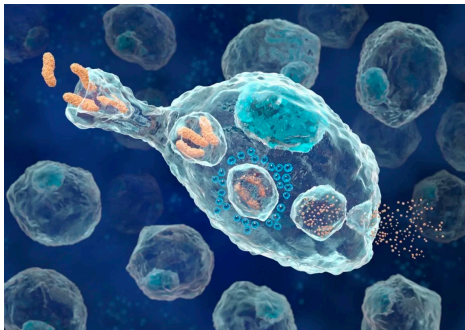
Macrophages

Function:

- Part of the immune system
- Destroys foreign material, microorganisms, and tumor cells
- Secretes signals for inflammatory responses

Structure:

- Membrane-bound lysosomes
- Contains a lot of digestive enzymes
- Many surface receptors on the membrane



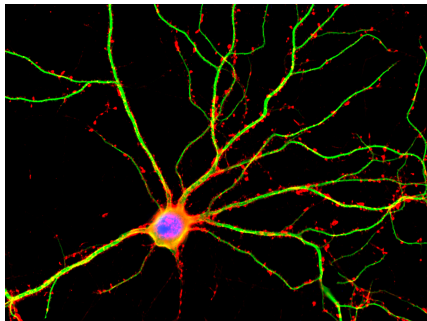
Neurons

Function:

- Communication through electrical signals converted to chemical signals (neurotransmitters)
- Both sensory and motor functions

Structure:

- Cell body with a nucleus
- Elongated
- Extensions called axons and dendrites
- Connect to other neurons at junctions called synapses



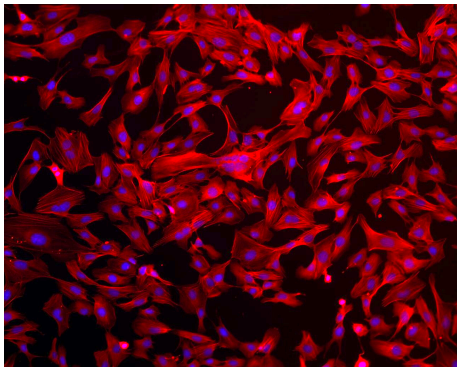
Endothelial Cells

Function:

- Make up inner linings of blood vessels and organs
- Regulate blood clotting by producing proteins

Structure:

- Thin and flat
- Cells connected by *tight junctions*
- Selectively permeable



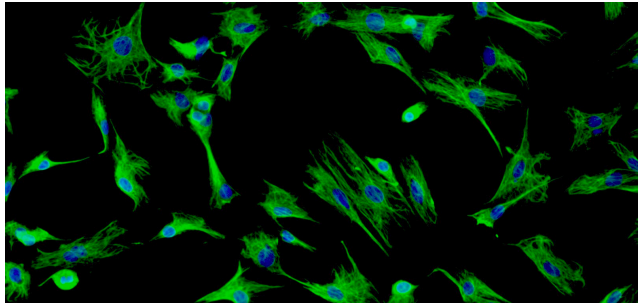
Fibroblasts

Function:

- Part of connective tissue
- Produces proteins that make up the extracellular matrix (ECM)
- Participates in wound healing

Structure:

- Spindle-shaped
- Closely packed
- Branched



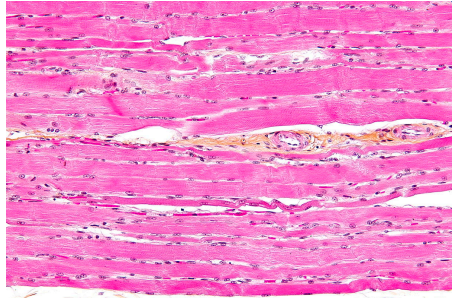
Myocytes – (Muscle Cells)

Function:

- Convert potential energy stored in the form of ATP into kinetic energy (motion)

Structure:

- The structure varies between the three types of myocytes
 - Smooth, cardiac, and skeletal
- In general, they are elongated and contain many nuclei



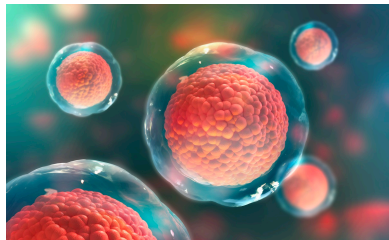
Stem Cells

Function:

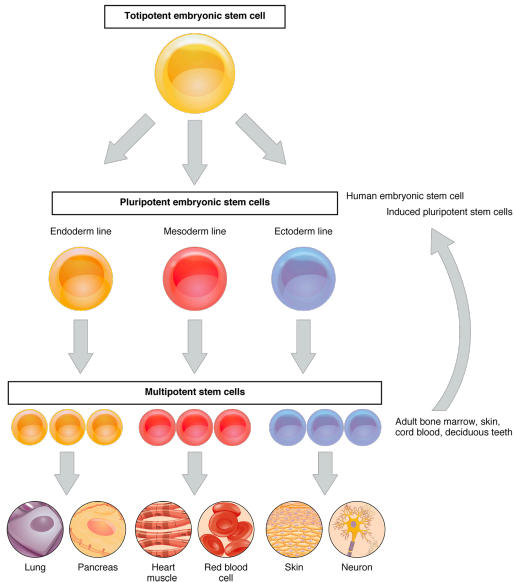
- Can mature into one of several cell types
- Capable of self-renewal

Types of Stem Cells:

- **Totipotent** stem cells can differentiate into any cell-type in the body
- **Pluripotent** stem cells can differentiate into a certain category of cell-types
- **Multipotent** stem cells can differentiate into a more specific category of cell-types



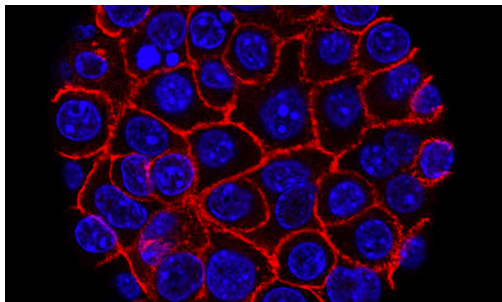
Stem Cells



Cancer Cells

Function:

- Grow and divide at an abnormally high rate
 - Use up oxygen and nutrients that healthy cells need
- Genes responsible for regulating cell division are mutated
- Rapid growth leads to a tumor
- Cancers can *metastasize* (spread to other parts of the body)



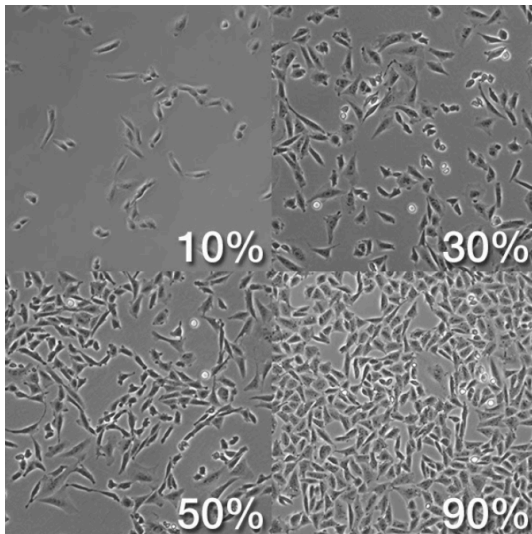
Cell Confluency

- **Definition:** **Cell confluency** describes the density of cells in a plate or flask.

$$\text{Cell Confluency} = \frac{\text{Surface area occupied by cells}}{\text{Total surface area}} \times 100\%$$

- When a flask reaches a certain level of confluency, cells need to be split
 - If the confluency is **low**, cells will **lack communication**
 - If the confluency is too **high**, cells start to **compete for resources** and die
 - Due to lack of nutrients and O₂

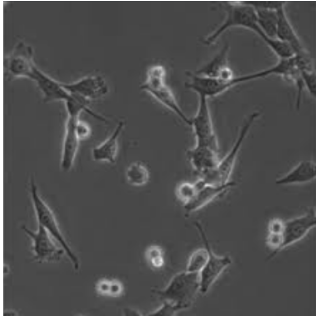
Cell Confluency



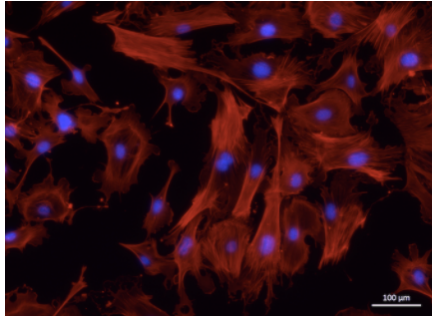
Basics of Microscopy

- Different types of microscopes serve different purposes
- **Brightfield microscopy**
 - White light is transmitted onto the sample
 - Dense areas appear darker
 - Used for samples that have natural contrast
- **Fluorescence microscopy**
 - Used to detect *gene expression* by the presence of certain proteins
 - Fluorophores are molecules that are attached to these proteins, and they emit a specific wavelength (λ) if successfully attached
 - Emission filter on microscope filters out the transmitted light

Basics of Microscopy



**Brightfield
Microscopy**

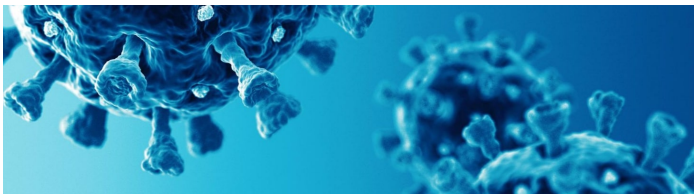


**Fluorescence
Microscopy**

Reminders and Announcements

Cell Team Events

- **Journal Club #1 this Thursday at 6pm PT**
 - *COVID-19 Vaccines in Development*
 - Please read over the article on our website before the meeting
- **Module #2 next Monday at 7pm PT**
 - Western Blots



Reminders and Announcements

BMES Events

- **Class Planning Workshop**



Unsure of which classes to choose for Winter Quarter or have questions on how to plan out your class schedule?

Join BMES on Monday November 9th from 7:30 – 9:00pm PT for drop-in advising with Academic.

November 9 (7:30–9pm PT)

Make sure to RSVP!

Reminders and Announcements

BMES Events

- Keck Graduate Institute (KGI) Workshop and Info-session



Join Dr. Anna Hickerson for a presentation on “**Artificial Intelligence Applications for Medical Devices**, Current and Future Ideas.”

Then, we will hold a short info-session on KGI and learn more about the graduate school application process.

November 10 (6–8pm PT)

Make sure to RSVP!