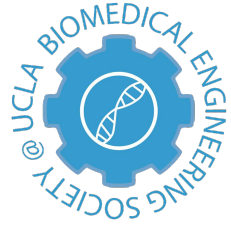
Module 1: Cell Basics

BMES Cell Team

Fall 2020



Outline

- Components of a Cell
- Protein Synthesis and the Central Dogma
- Cell Morphology
- Cell Confluency
- Basics of Microscopy

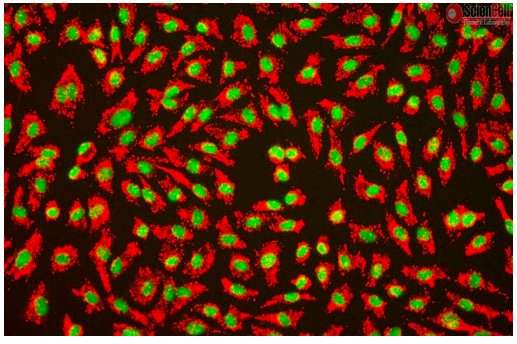
Cells

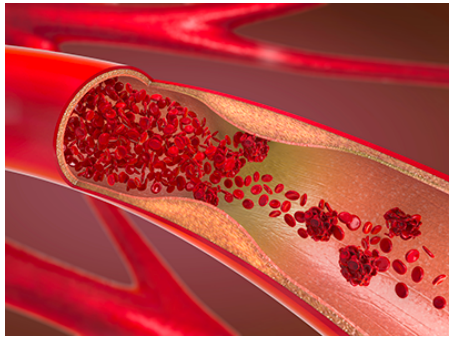
- **Definition:** Cells are the basic blocks of life. (Informal)

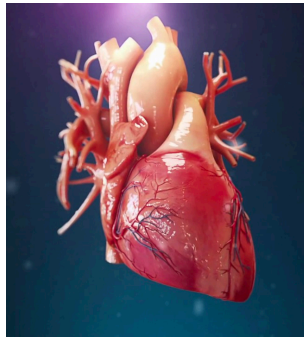
→ Cells make up tissues

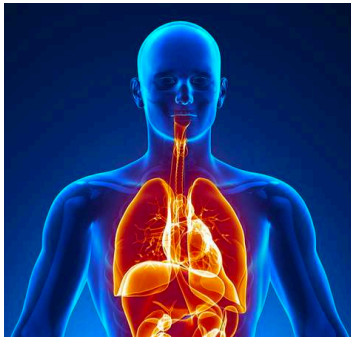
→ Tissues make up organs

→ Organs make up organisms





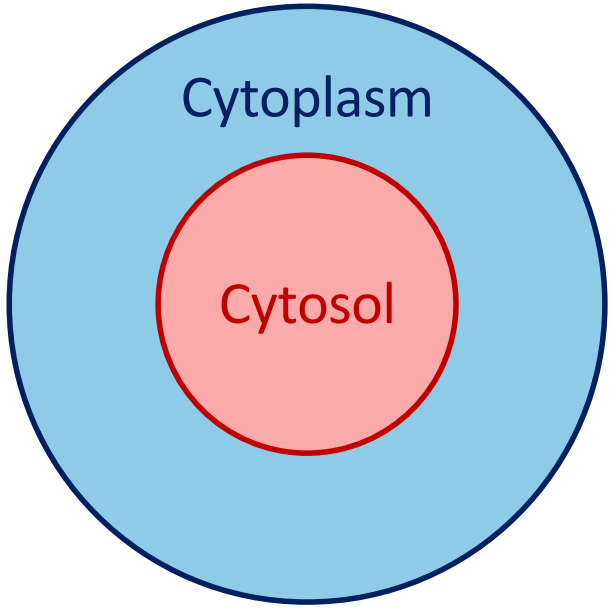




Basic Make-up of a Cell

- 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

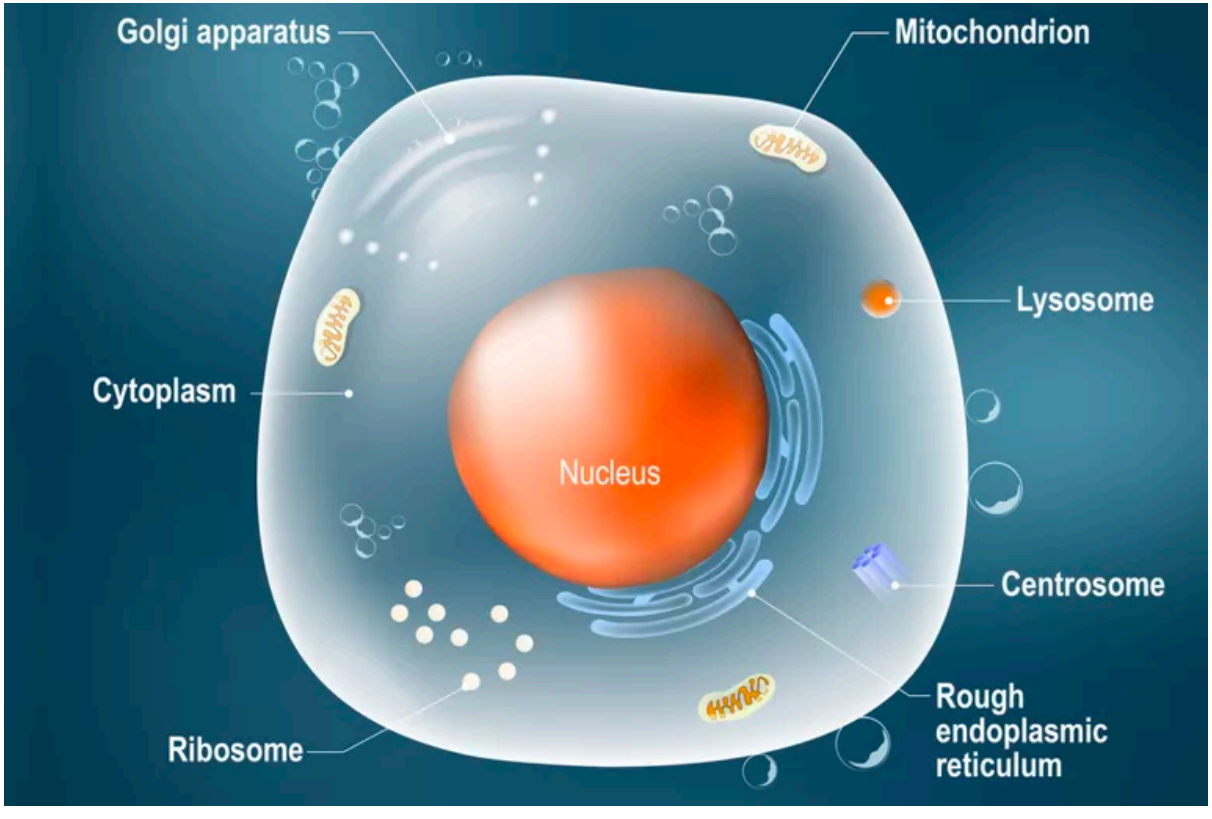
"The cytosol is contained within the cytoplasm"



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

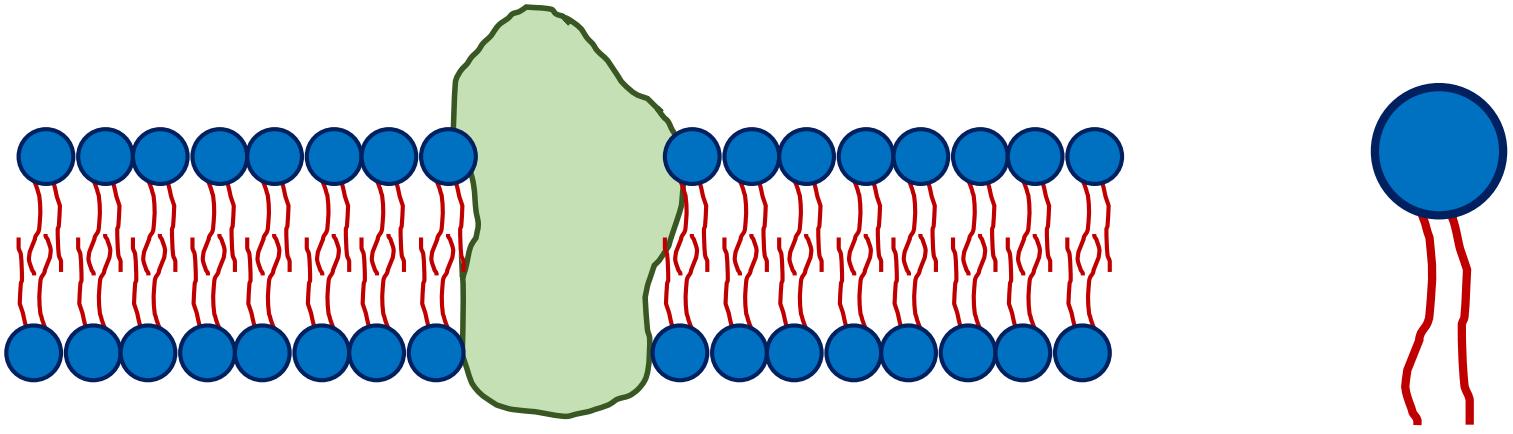
Basic Make-up of a Cell

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

Basic Make-up of a Cell

Cell Membrane

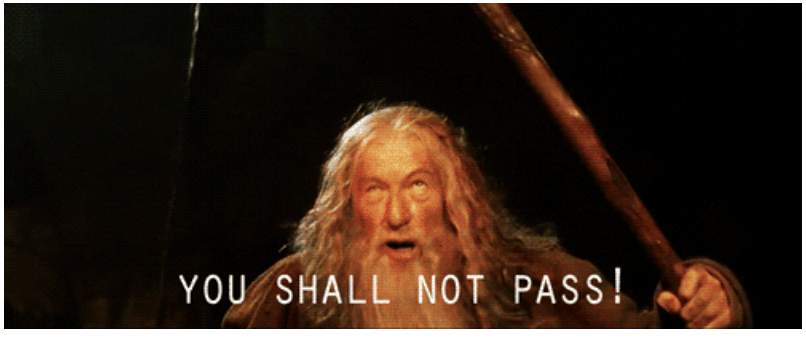


- The cell membrane is made of a “phospholipid bilayer”
- This structure allows it to be *selectively permeable*, meaning that only certain molecules can pass through
    - Thus, the cell can filter out most harmful molecules and maintain homeostasis

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

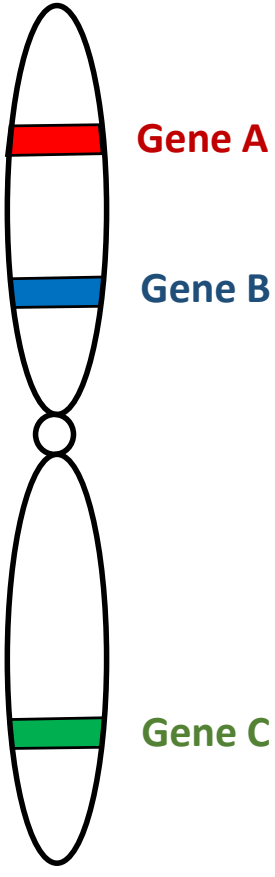
- **Definition:** The Central Dogma describes the process by which proteins are synthesized.

- DNA → RNA → Proteins
- This is how cells use DNA to accomplish their function
- All cells in your body carry the same DNA sequence[1], 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, “αβ-cells” will only express proteins coming from genes A and B
- “δ-cells” will only express proteins coming from gene C

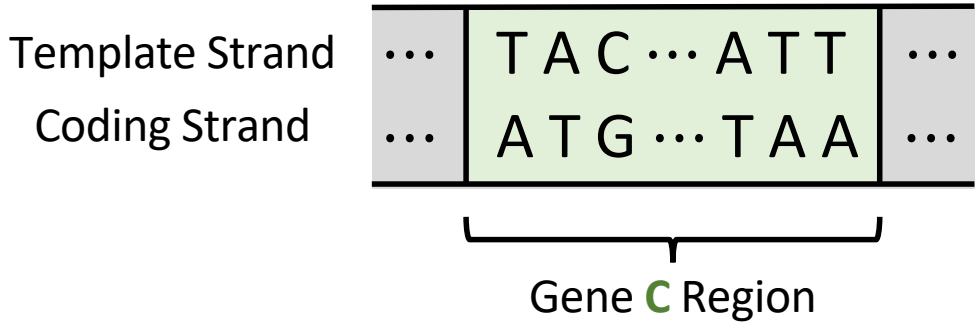
Central Dogma

- 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



Central Dogma

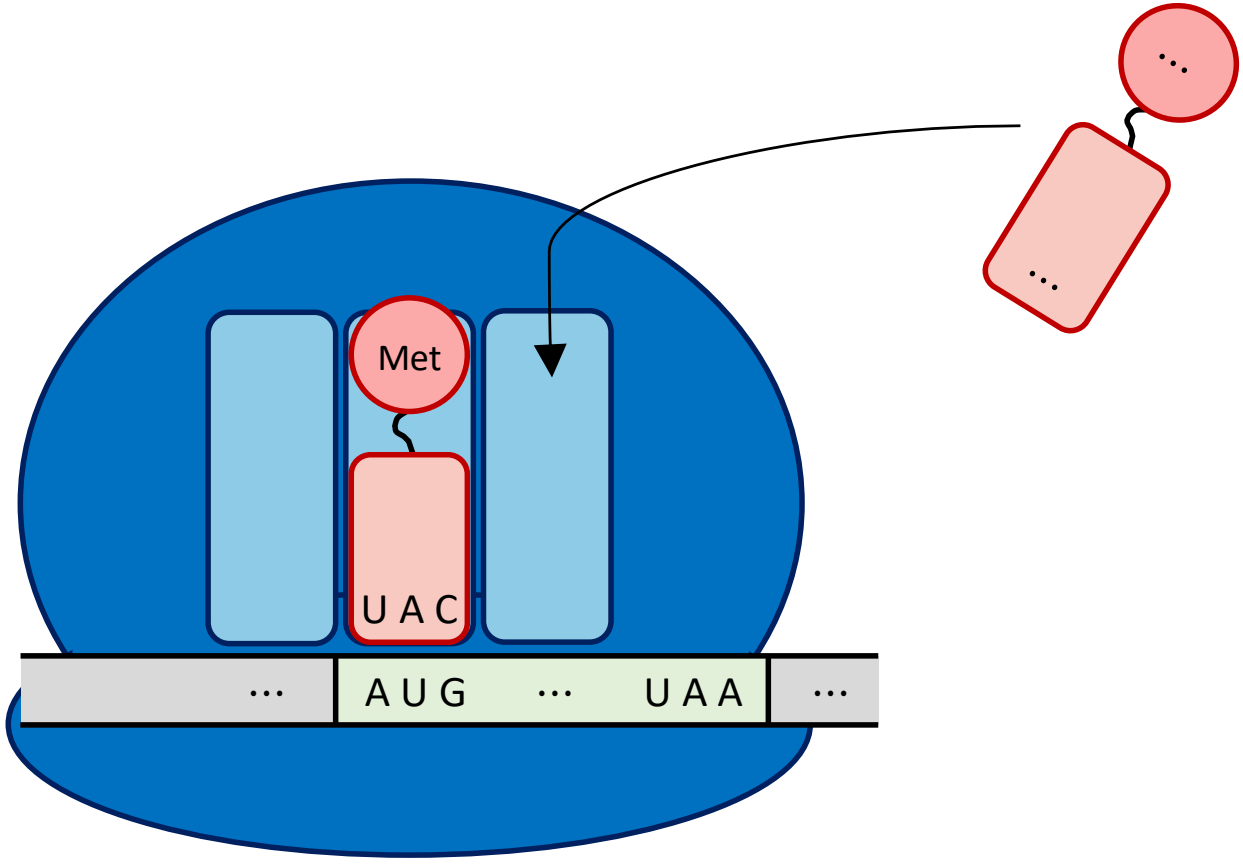
Transcription Theoretical Example

- 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

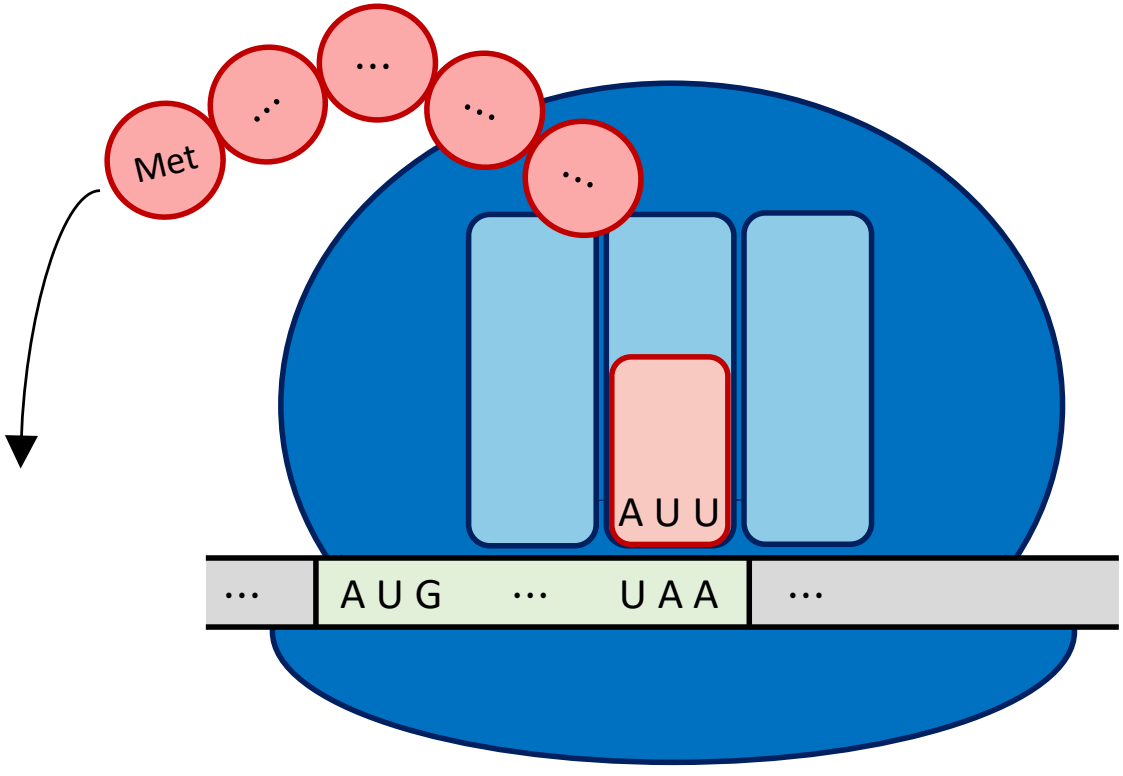
- Translation is the second and last step of the Central Dogma



Central Dogma

Translation Theoretical Example

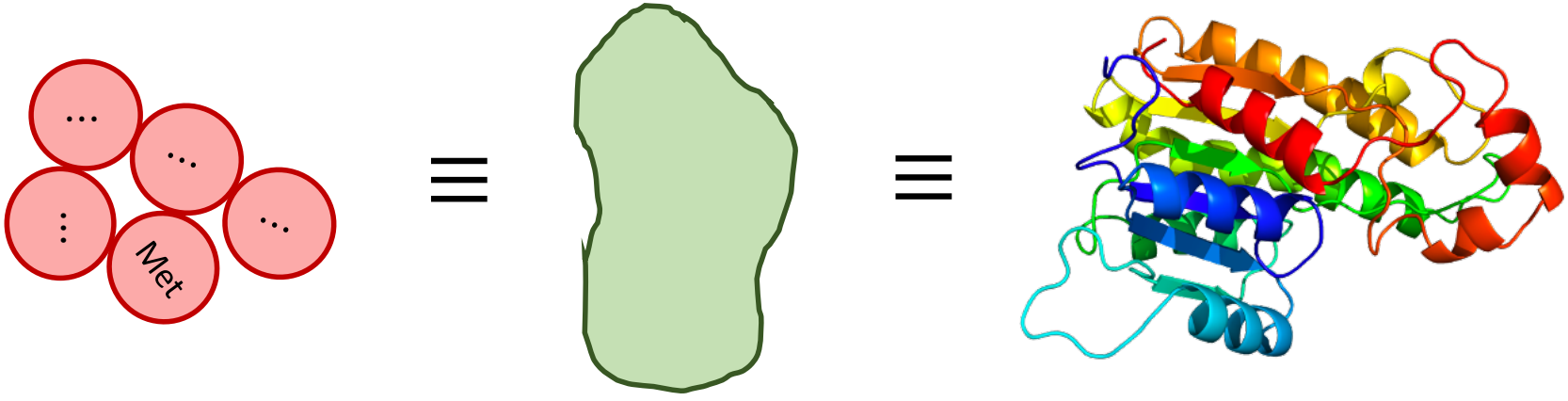
- Fast forward until it reaches the STOP codon



Central Dogma

Translation Theoretical Example

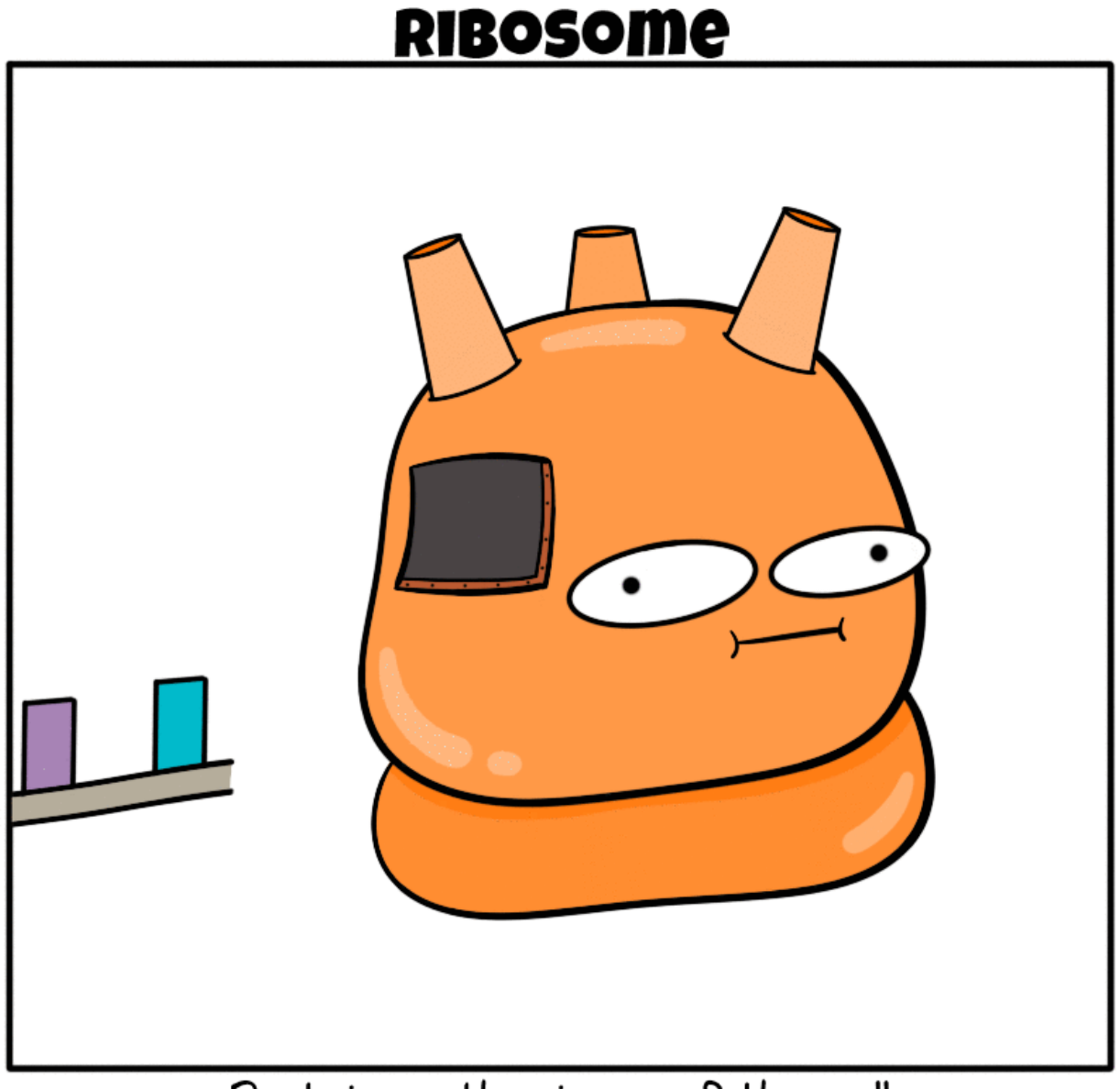
- The final protein appears as follows:



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

Central Dogma



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

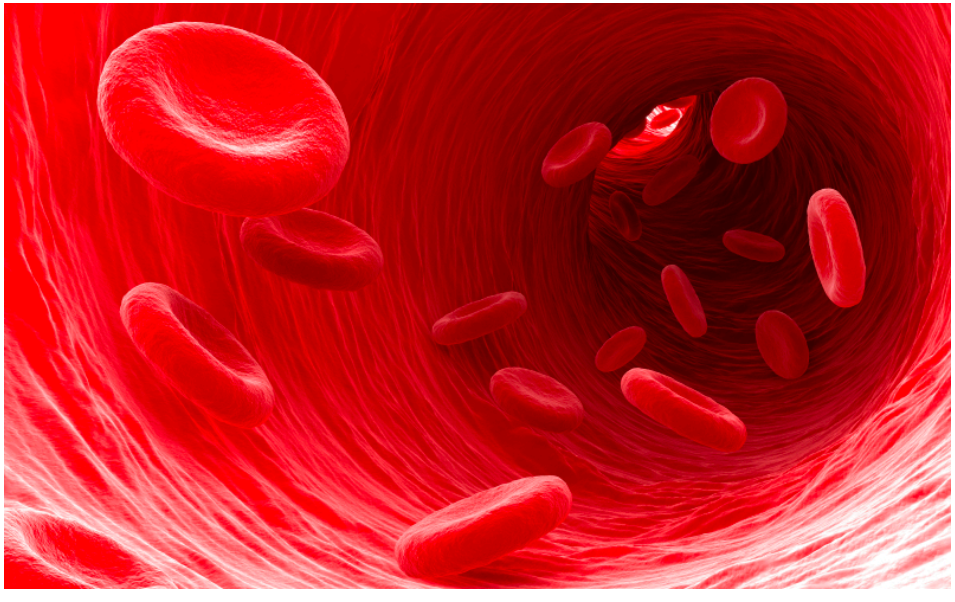
Red Blood Cells

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



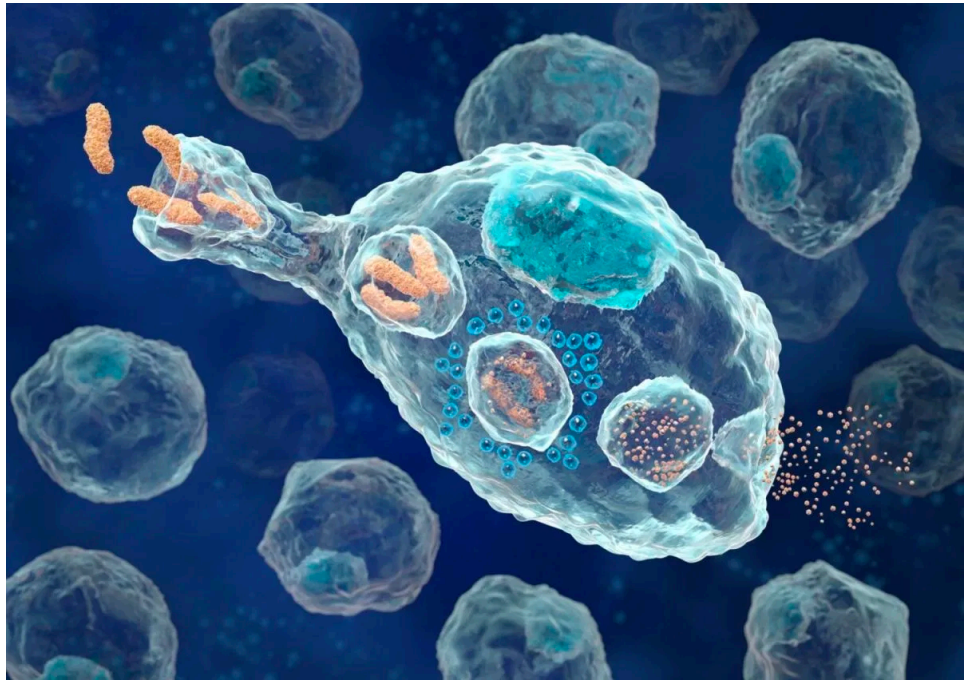
Macrophages

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



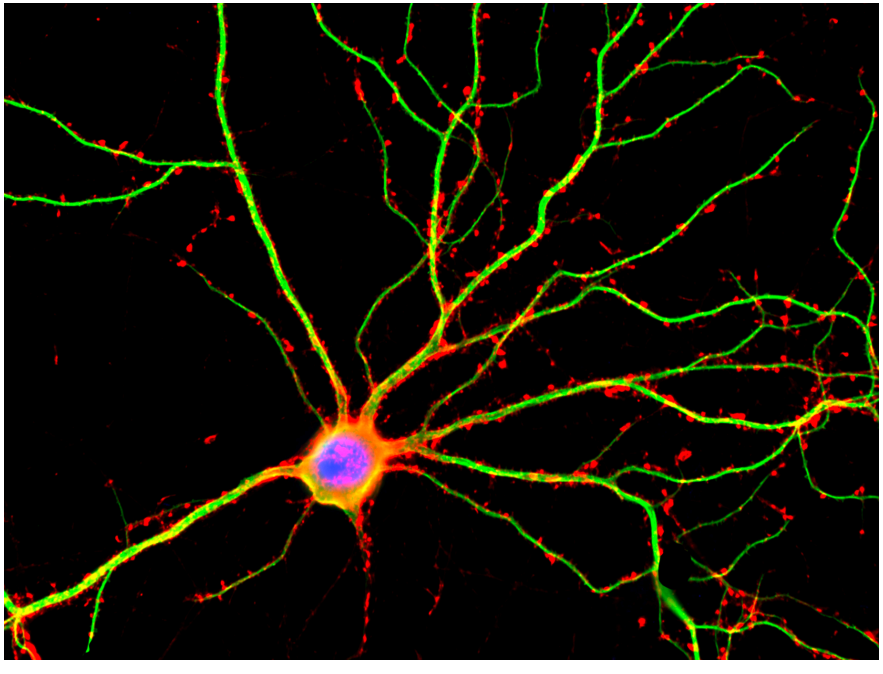
Neurons

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



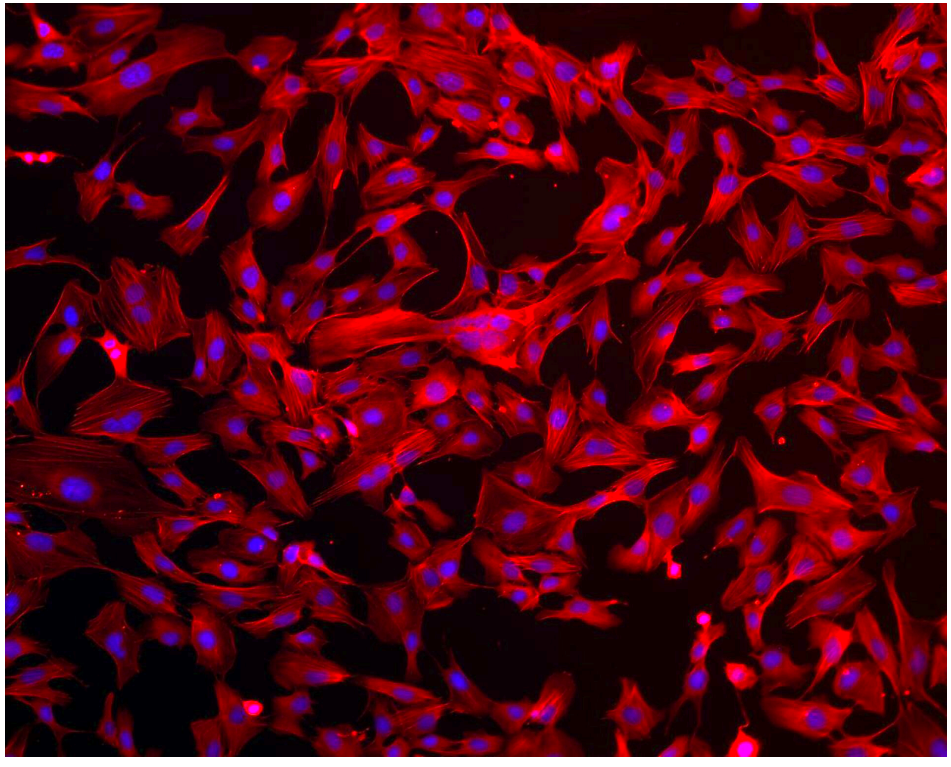
Endothelial Cells

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



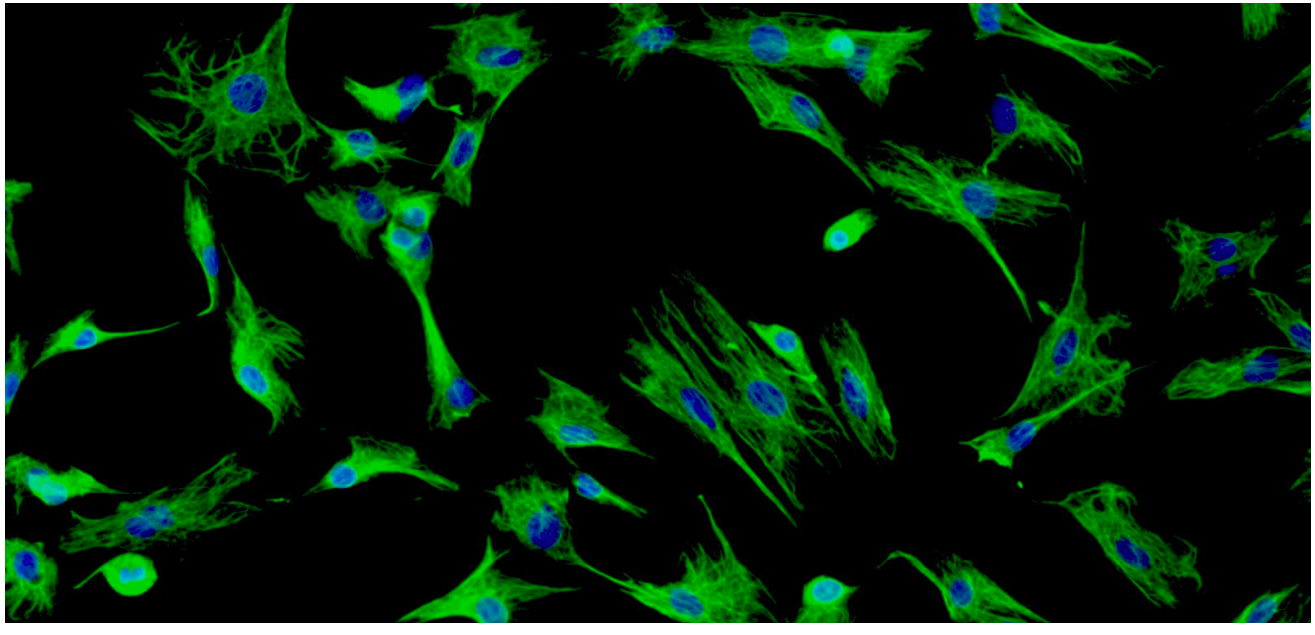
Fibroblasts

Function:

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

Structure:

- Spindle-shaped
- Closely packed
- Branched



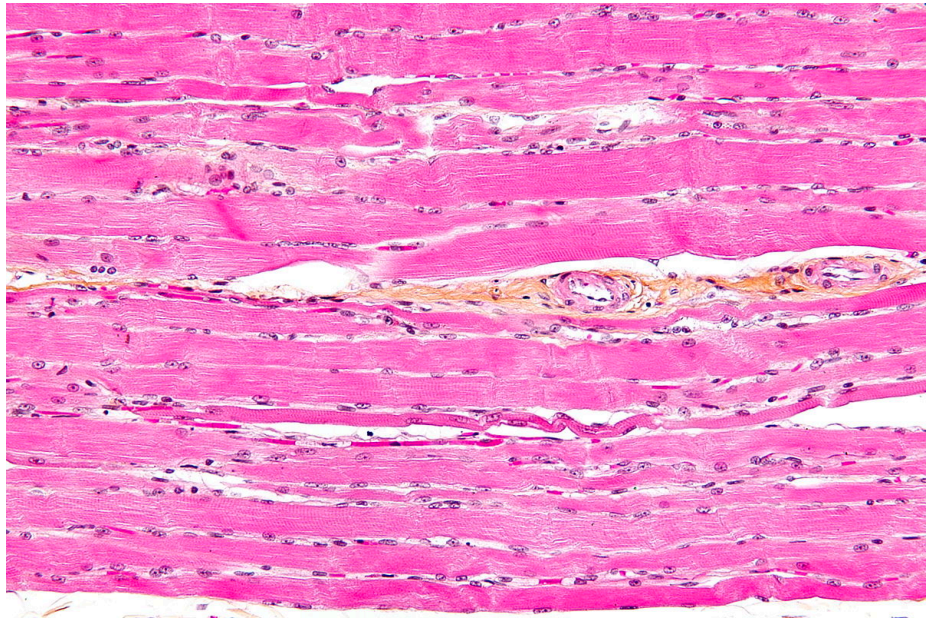
Myocytes – (Muscle Cells)

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:

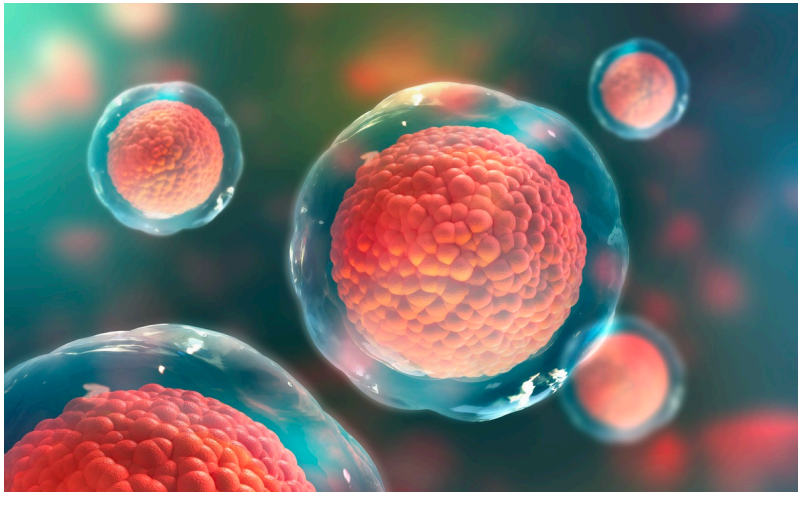
- Can mature into one of several cell types
- Capable of self-renewal

Types of Stem Cells:

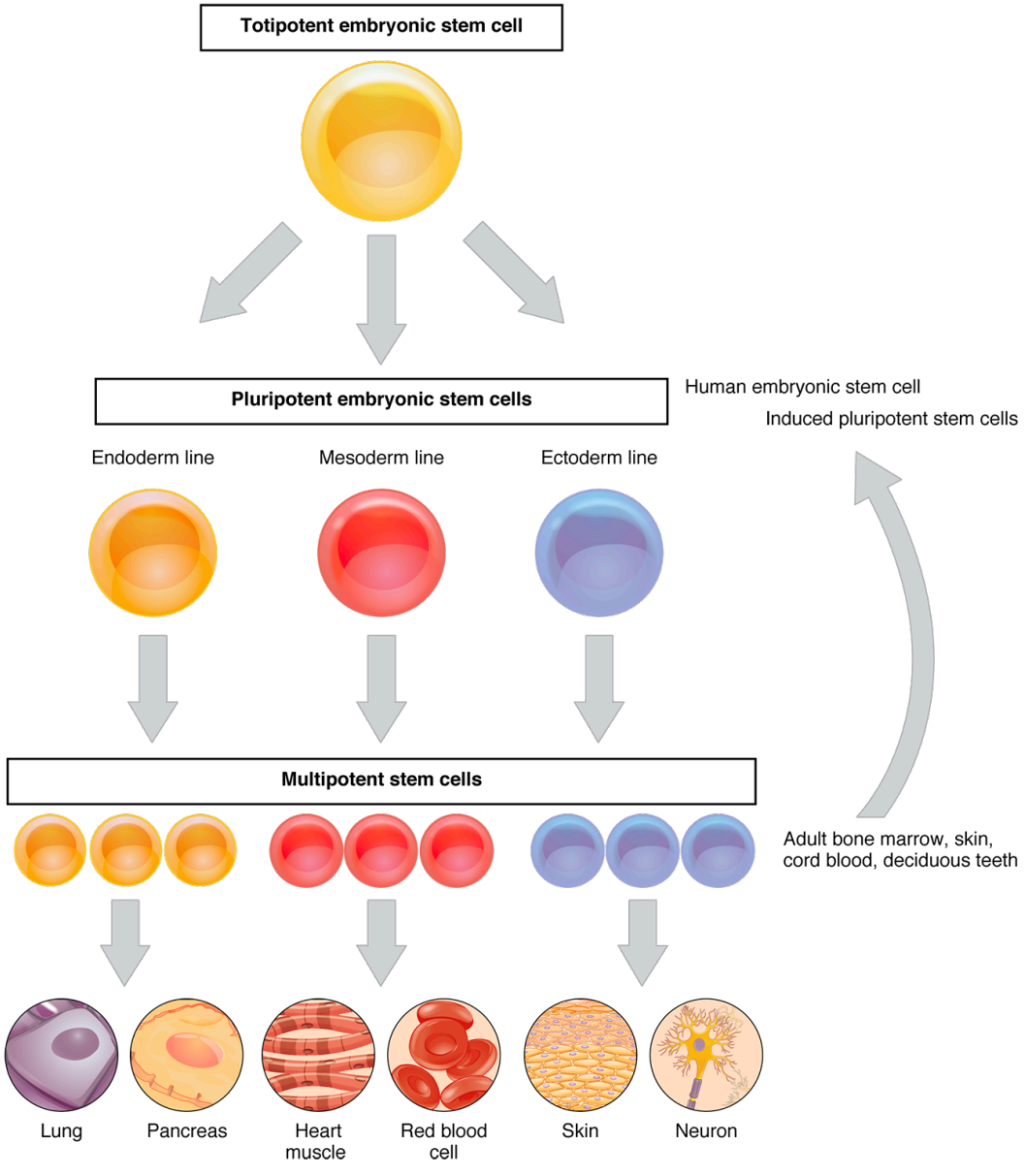
- Totipotent stem cells can differentiate into any cell-type in the body

- 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



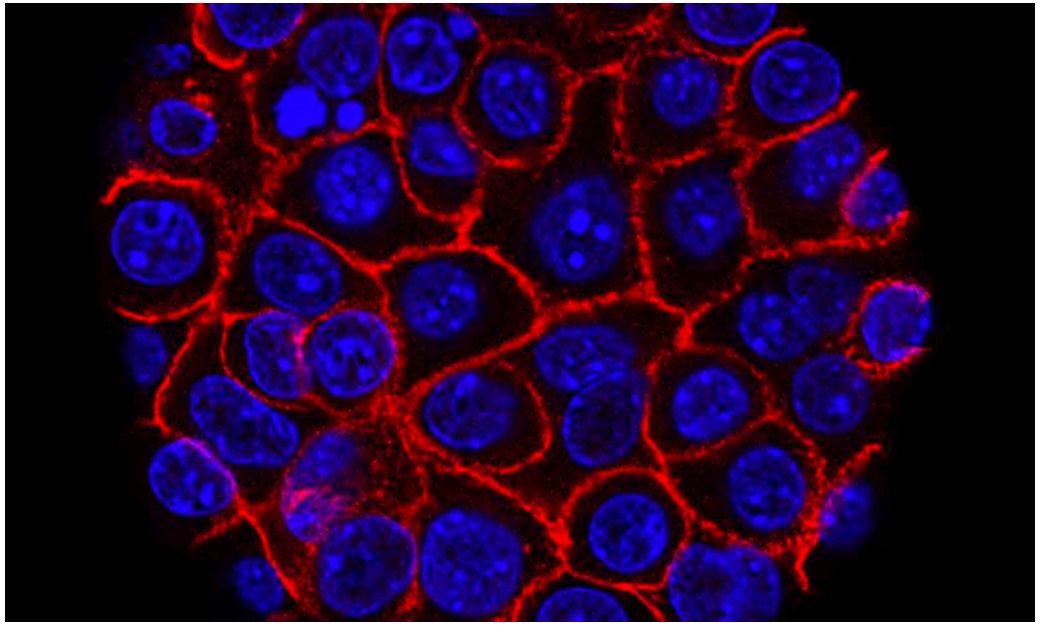
Stem Cells


Totipotent embryonic stem cell
Pluripotent embryonic stem cells
Human embryonic stem cell
Induced pluripotent stem cells
Endoderm line
Mesoderm line
Ectoderm line
Multipotent stem cells
Adult bone marrow, skin, cord blood, deciduous teeth
Lung
Pancreas
Heart muscle
Red blood cell
Skin
Neuron

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)



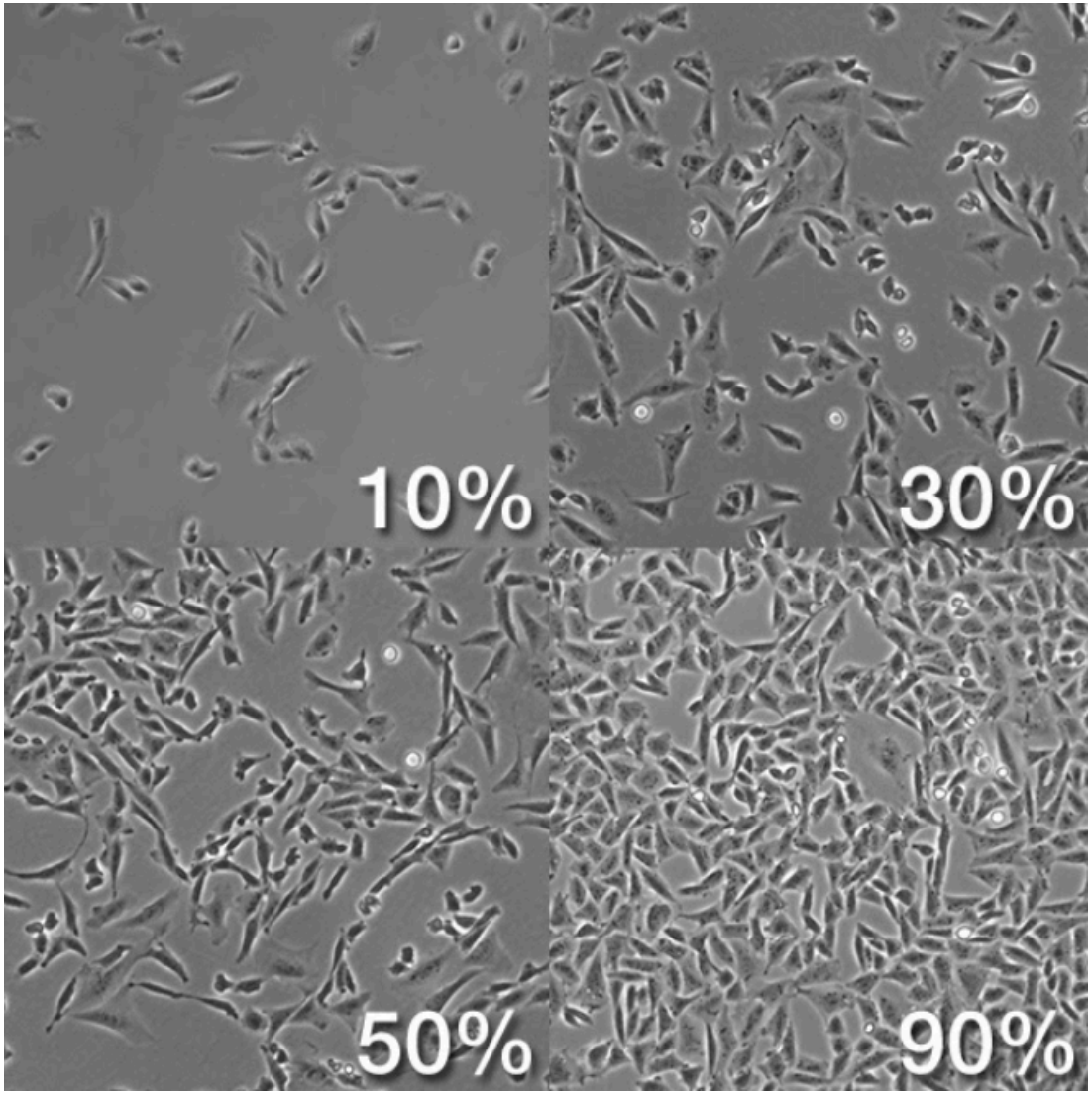
Cell Confluency

- **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 O_2

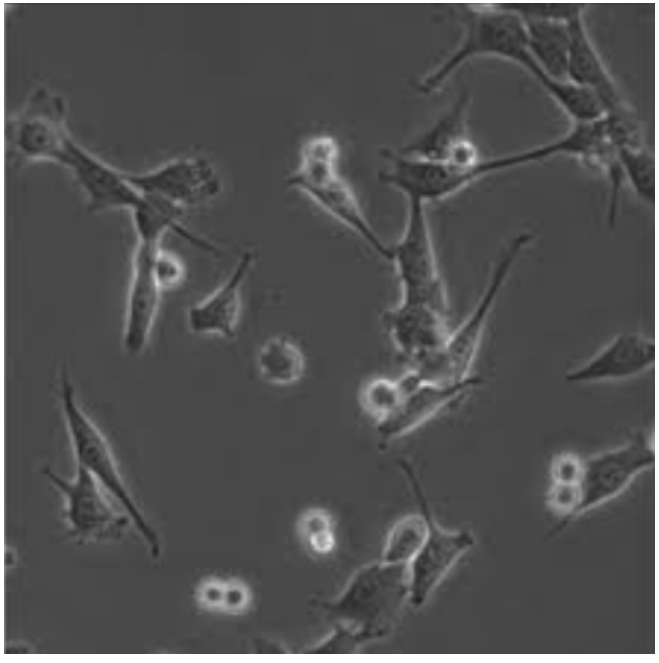
Cell Confluency



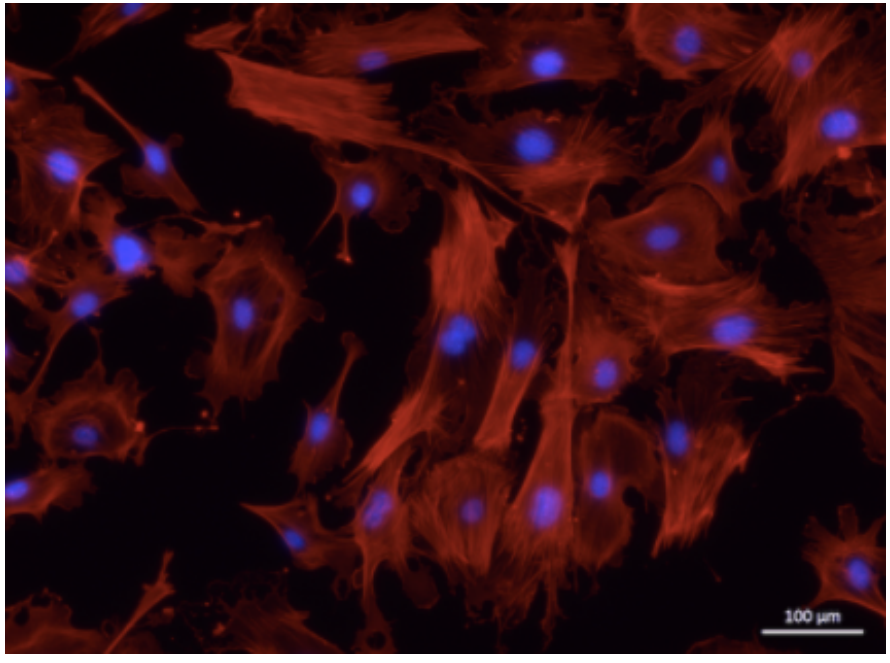
Basics of Microscopy

- 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