Cell Membranes — Fluid Mosaic Model, Membrane Proteins and Cytoskeleton

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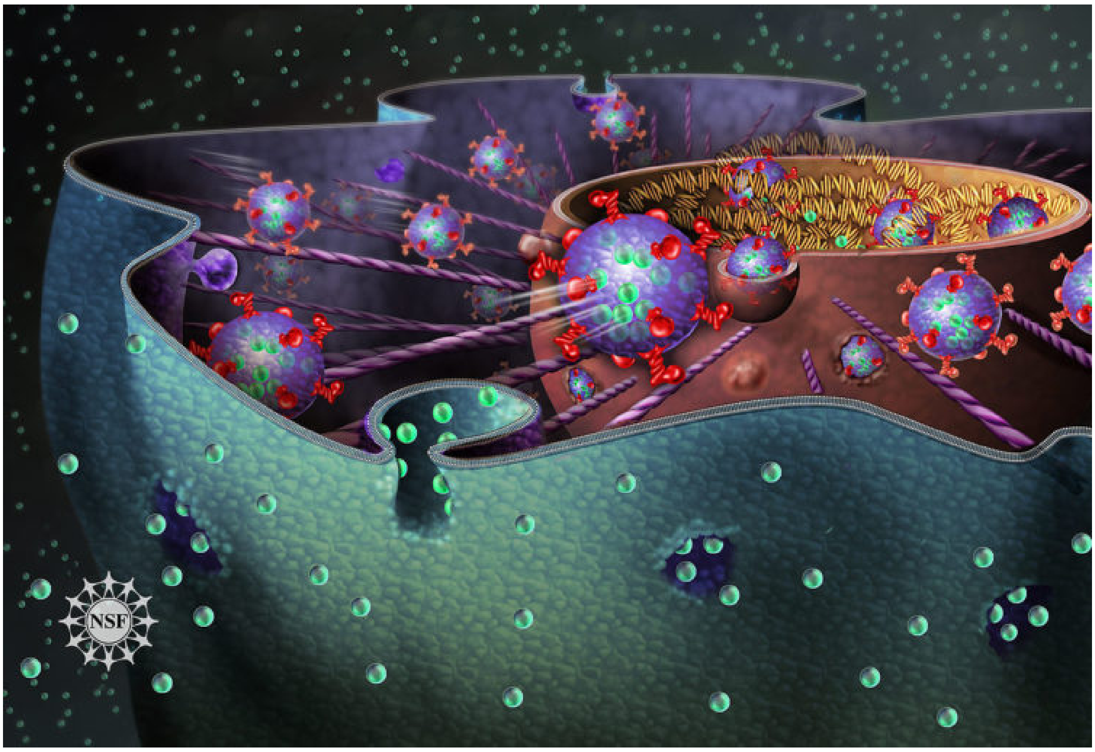
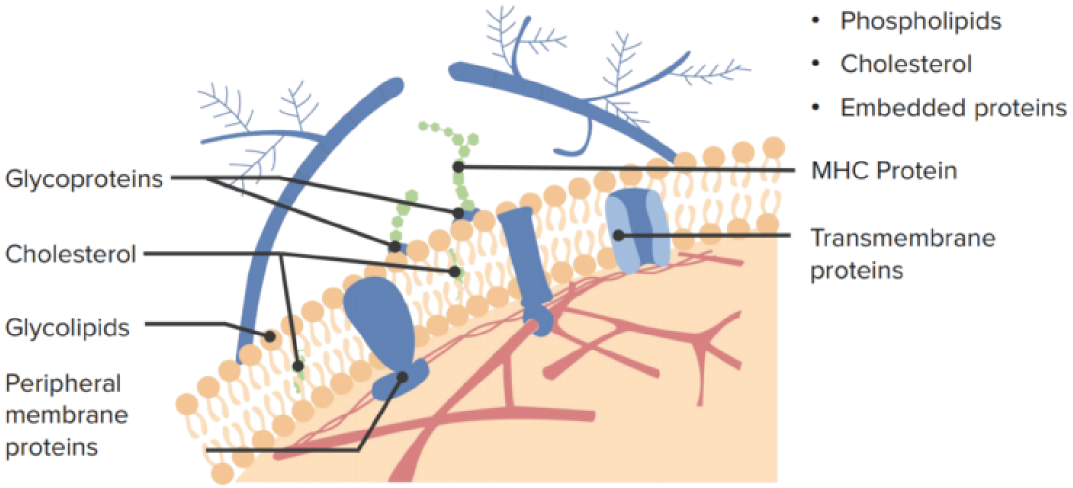
Membranes serve different functions in a cell. They are responsible for keeping unwanted particles out of the cell while letting important macromolecules enter the cell. They are also important in partitioning the cell into segregated and functional compartments. Given emphasis in this article is the fluid mosaic model for cellular membranes, the different proteins embedded in the membranes and the different roles they play in cell activity. Cytoskeleton and extracellular matrix are also discussed in this article.



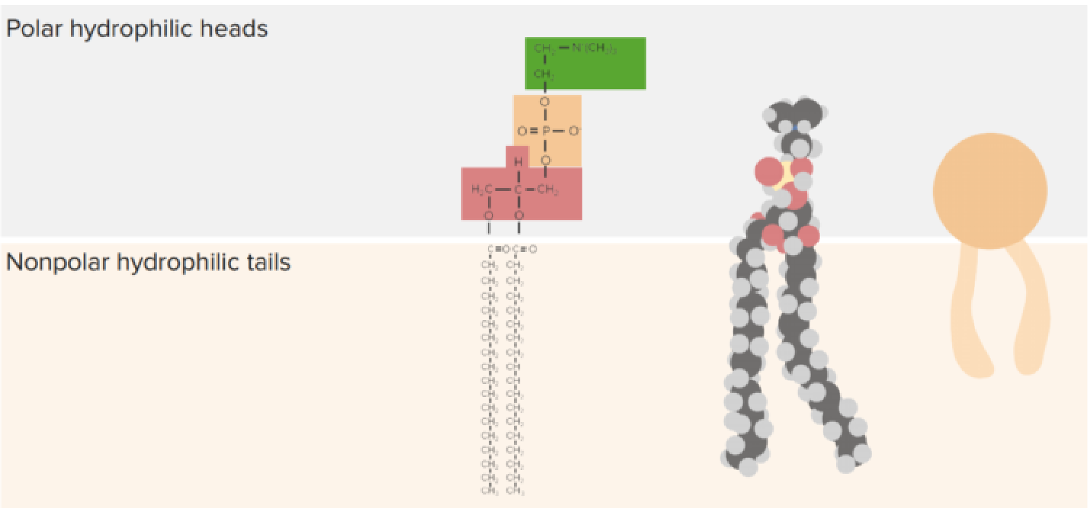
Fluid Mosaic Model

Proposed in **1972** by **S. J. Singer and G. L. Nicholson**, the fluid mosaic model is an accepted theory. It describes the cell structure as containing **phospholipid molecules.** Each molecule consists of a negatively-charged polar head, which is **hydrophilic** and a fatty acid chain that is uncharged (non-polar tail) which is **hydrophobic.**



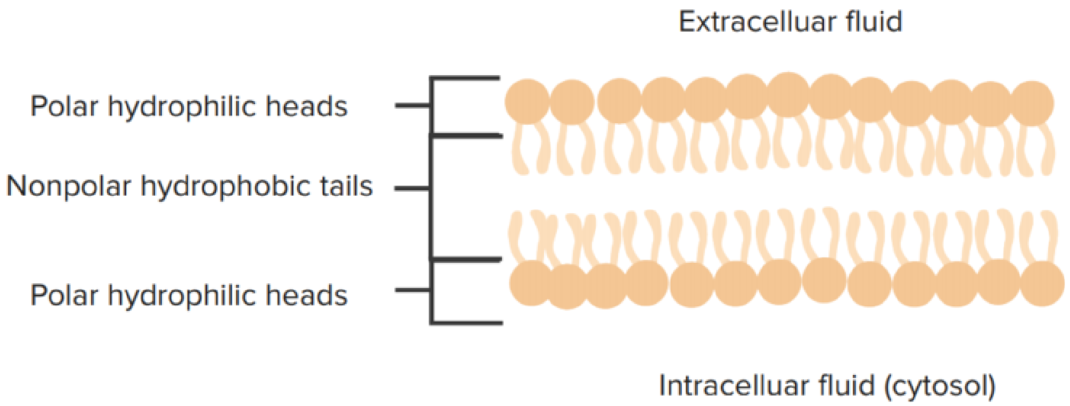
Fluid Mosaic Model. Image by Lecturio

The hydrophobic tail of the molecule repels water from the inside and outside of the cell, while the hydrophilic head interacts freely with water in the inner and outer surface of the membrane. In this way, a **phospholipid bilayer** is formed, where the hydrophilic ends are exposed to water, while the hydrophobic tails are sandwiched by the hydrophilic heads. The structure of the phospholipid bilayer is shown in the figure.



Phospholipid representations. Image by Lecturio

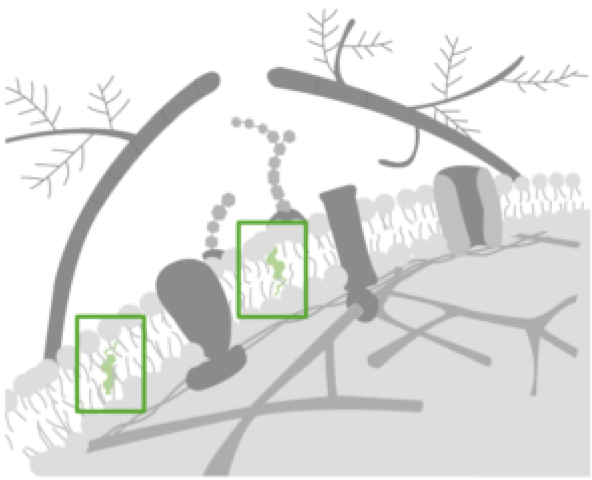
The arrangement of the phospholipid molecules to form the membrane is said to be **fluid** because of having various functional macromolecules embedded in its **matrix**. It is not considered as solid, because it allows **passage of material** through various channels in it.



Phospholipid bilayers form spontaneously. Image by Lecturio

In addition, the model is said to be **mosaic** as each membrane may be composed of different parts consisting of **proteins**, **carbohydrates**, and **lipids**. Depending on the functions, which the membrane will serve, proteins may be embedded to provide as channels for molecules to pass through.

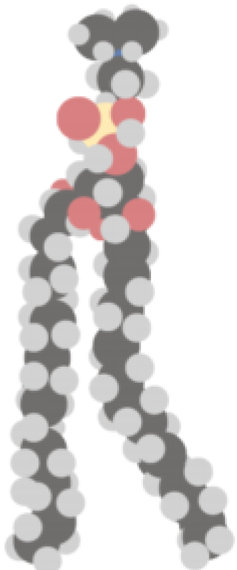
Membrane Fluidity Changes – Role of Cholesterol and Fatty Acid Solution


Cholesterol = maintains integrity in animal cell membranes.
Image by Lecturio

The **viscosity** of the lipid bilayer of the cell membrane is referred to as membrane fluidity. This is primarily affected by how lipids are packed in the membrane. Membrane fluidity is important because it affects the diffusion and rotation of proteins and other biomolecules within the membrane. This also affects the functioning of these molecules.

Saturated fatty acid tails = less fluid membrane. Image by Lecturio

Membrane fluidity is affected by a number of factors, one of which is **temperature**. When you increase the temperature of a cellular system, lipids acquire thermal energy making it move around more vigorously, hence rearranging themselves, making the membranes more fluid. Low temperature enables lipids to organize themselves laterally leading to good packing.



Unsaturated fatty acid = more fluid. Image by Lecturio

Membrane composition also affects membrane fluidity. Phospholipids in membranes incorporate **fatty acids** of varying length and saturation.

Lipid chains with double bonds are more fluid because it makes the lipids less likely to pack orderly because of the presence of kinks due to the unsaturated sites. Membranes composed of this type of lipid have lower melting points which means less thermal energy is needed to make the membranes behave like a membrane composed of saturated lipid chains.

Cholesterol acts as a bidirectional regulator of membrane fluidity. At high temperatures, it stabilizes the membrane by raising its melting point. On the other hand, at lower temperatures, it intercalates between phospholipids to prevent them from clustering together.

Role of Cell Membrane Proteins

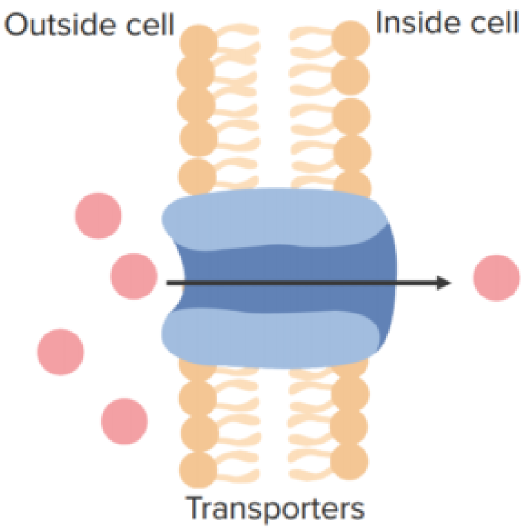
Cell membrane proteins can play **different roles** in cellular activity. There are **transport proteins**, which **span the membrane** and **form channels** that can allow movement of specific molecules into and out of the cell.

They may also serve as **adhesion proteins** responsible for anchoring the cell in position in the extracellular matrix or may anchor other materials inside the cell.

They also play important roles in communication between cells. **Gap junctions** are communication proteins that hook up or connect to other gap junctions in neighboring cells. They serve for chemical and electrical signaling.

There are also **receptor proteins**, which bind to specific molecules causing changes in cell activity.

Recognition proteins are present in cellular membranes to recognize if a cell belongs to the host or not.



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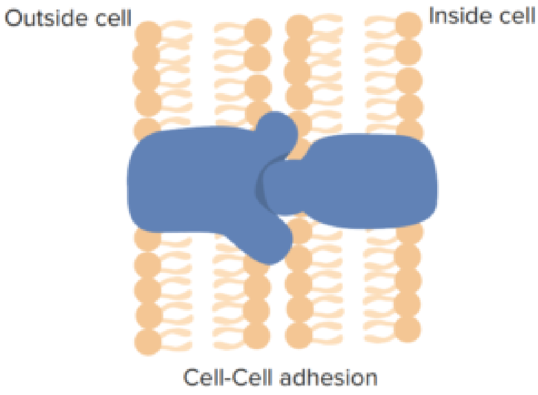

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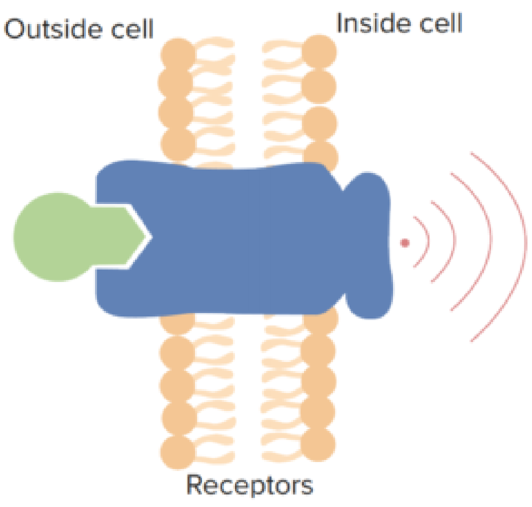

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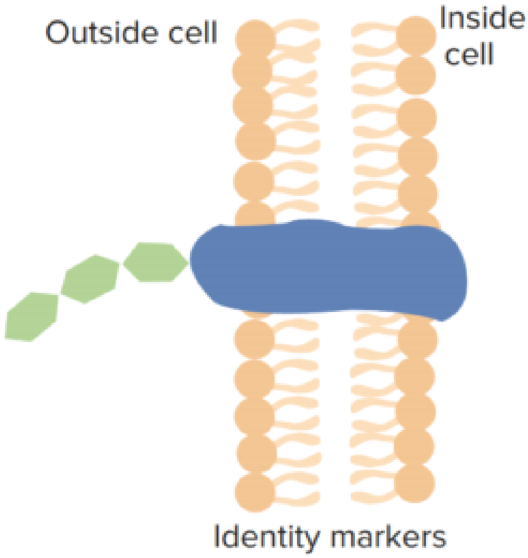

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Cytoskeleton

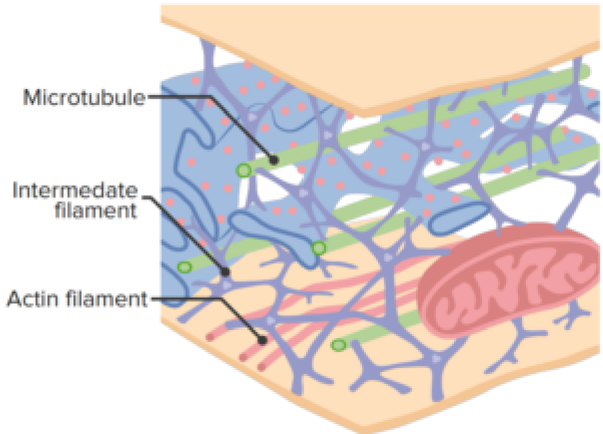


Image by Lecturio

The cytoskeleton is an **interior network of proteins** composed of **interlinked filaments and tubules.** They extend throughout the **cytoplasm**, from the **nucleus** to the **plasma membrane**. In eukaryotic cells, the cytoskeleton may be in the form of three types of filaments: actin filaments, intermediate filaments, and microtubules.

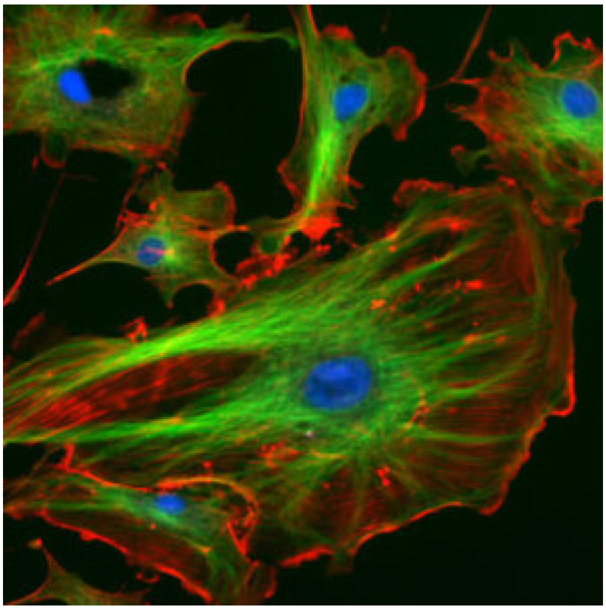


Image: “Endothelial cells under the microscope. Nuclei are stained blue with DAPI, microtubles are marked green by an antibody bound to FITC and actin filaments are labelled red with phalloidin bound to TRITC. Bovine pulmonary artery endothelial cells.” by http://rsb.info.nih.gov/ij/images/. License: Public Domain

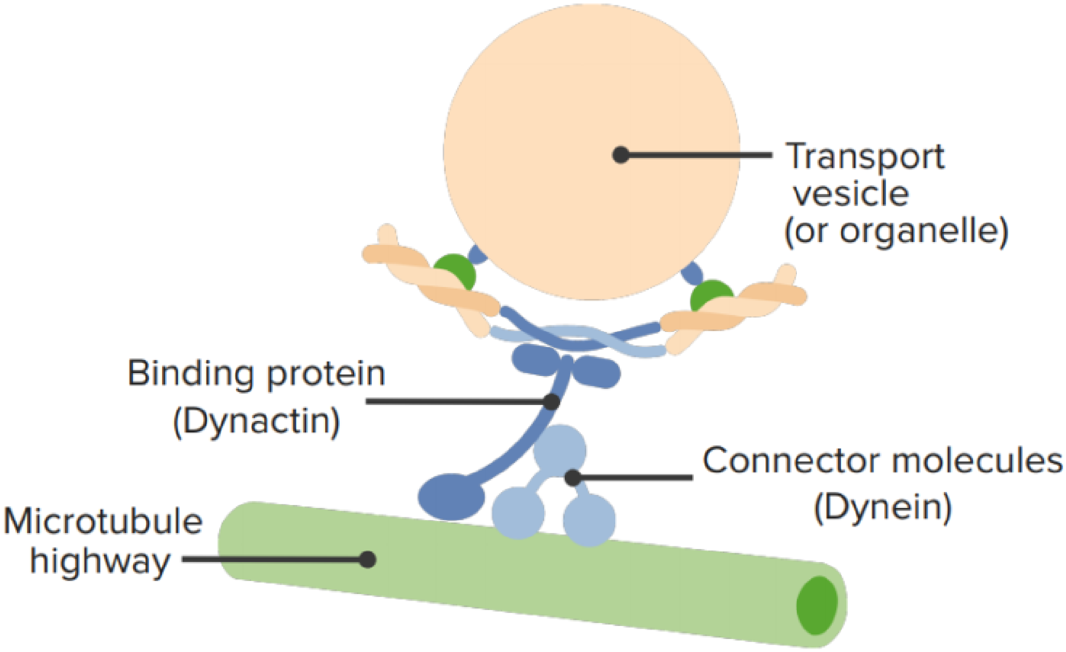
Actin filaments are composed of linear polymers of **G-actin proteins** that can generate force when the growing end of the filament pushes itself against a barrier. They are also called microfilaments, because of having the smallest diameter of the three types of filaments. They typically have a diameter of 7 nm.

Intermediate filaments have diameters averaging at 10 nm. They are responsible for maintaining cell shape. They organize internal structures of the cell by **anchoring organelles**. They can also participate in **cell-cell and cell-matrix junctions**. Some common intermediate filaments include **keratin**, **lamin**, **vimentins**, and **desmin**.

Microtubules have a diameter of 25 nm. They are made up of proteins called **tubulin**. They are particularly important in **transportation** and **mobility**. Inside the cell, microtubules play important roles in intracellular transport. They are also present in **cilia** and **flagella** that are used by some eukaryotic cells for movement. They are also formed in **mitotic spindles** during **mitosis**.

Two important proteins involved in the cellular movement are **kinesins** and **dyneins**. These proteins utilize energy from **ATP hydrolysis** in the process causing movement. Dyneins and kinesin-2 are linked to vesicles and organelles to be transported by a protein complex called dynactin.

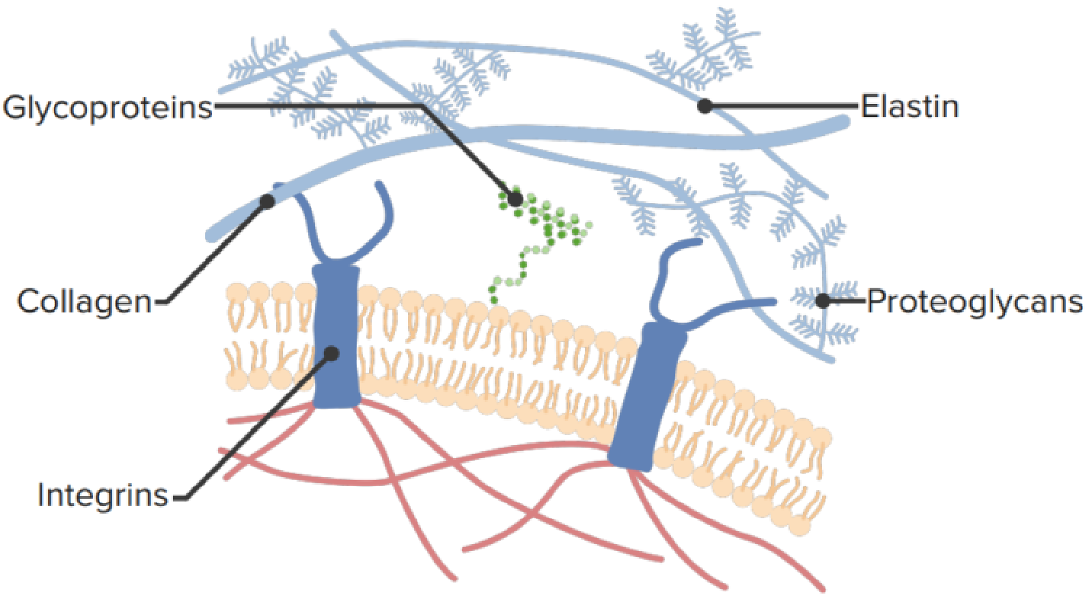
Dynactin aids in bidirectional intracellular transport by modulating the binding of dynein to cell organelles. It also contributes to mitotic spindle pole focusing through binding to NuMA (**nuclear mitotic apparatus**).



Requirements for transport within a cell. Image by Lecturio

Extracellular Matrix

Extracellular matrix (ECM) is a collection of extracellular molecules produced by cells to provide **biochemical and structural support** to the surrounding cells.



Components of the extracellular matrix. Image by Lecturio

Common functions of the extracellular matrix include **cell adhesion**, **cell-to-cell communication**, and **differentiation**. Animal ECM includes interstitial matrix and the basement membrane.

The **interstitial matrix** contains **polysaccharide gels** and **fibrous proteins** that act as a **compression buffer** against stress placed on the ECM.

Basement membranes are sheet-like depositions where various epithelial cells rest. Some examples of ECM are the **collagen fibers** and **bone minerals** in bone tissues, **reticular fibers** and **ground substance** in loose connective tissues, and the **blood plasma** in the blood.

Review Questions

The correct answers can be found below the references.

1. Which of the following is not a role of membrane proteins in cell activity?

A. Catalysis
B. RNA synthesis
C. Transport
D. Receptor

2. Which of the following filaments has the smallest diameter?

A. Actin
B. Intermediate filament
C. Microtubules
D. None of the above

References

Voet, D. & Voet, J.G. (2011). Biochemistry. 4th ed. New York: J. Wiley and Sons.

2. Reece, J. B., & Campbell, N. A. (2011). Campbell biology. Boston: Benjamin Cummings/Pearson.

Correct answers: 1B, 2A

Notes