

Organelles, Trafficking, and the Cytoskeleton

BIO 120 B – Lecture 2

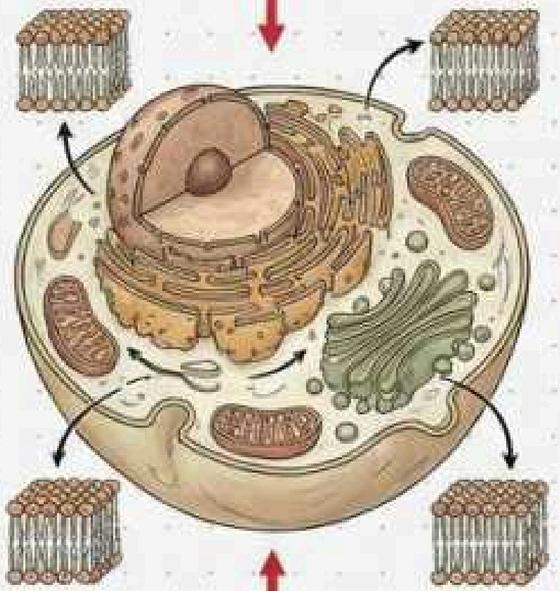
- Organelles
- Protein trafficking
- Vesicles
- Mitochondria
- The cytoskeleton
- Motor proteins

The Logistical Architecture of the Eukaryotic Cell

¶ 2.2

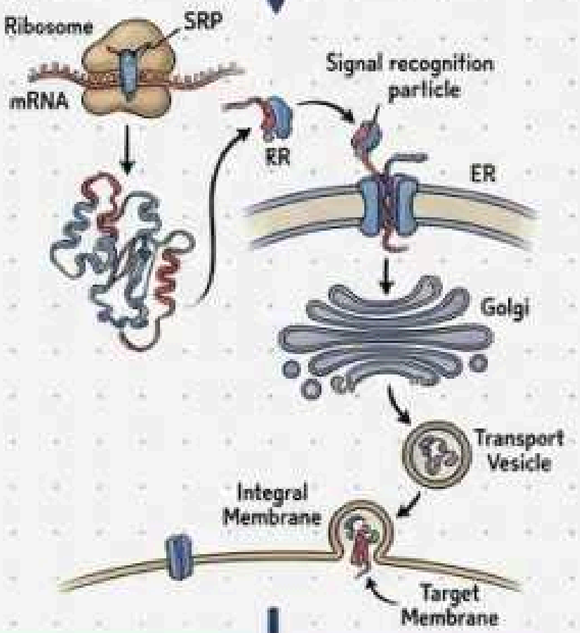
1. Compartments

Dividing the physical space.



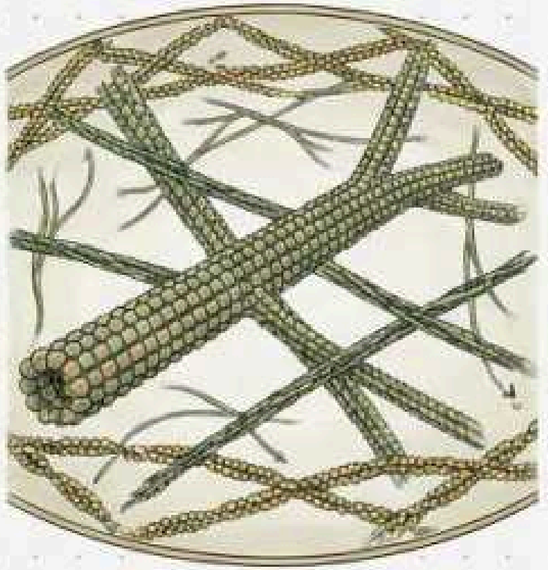
2. Protein Destination

Tracking a single protein from ribosome to target.



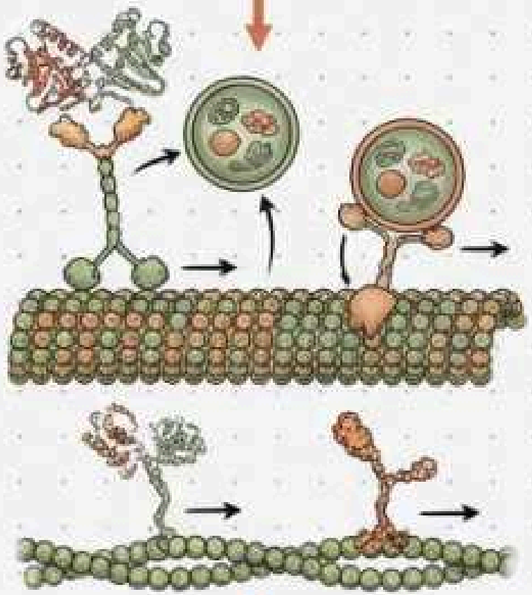
3. Cytoskeleton

The cellular tracks and infrastructure.



4. Motor Proteins

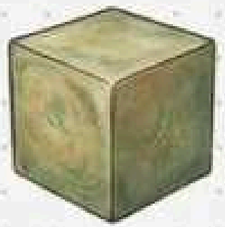
The active transport system.



Tracing matter, energy, and information from the interior to the membrane.

Internal Membranes Solve the Physical Limits of Scale

Bacterium



1 μm

$SA \propto r^2$

$V \propto r^3$

Animal Cell

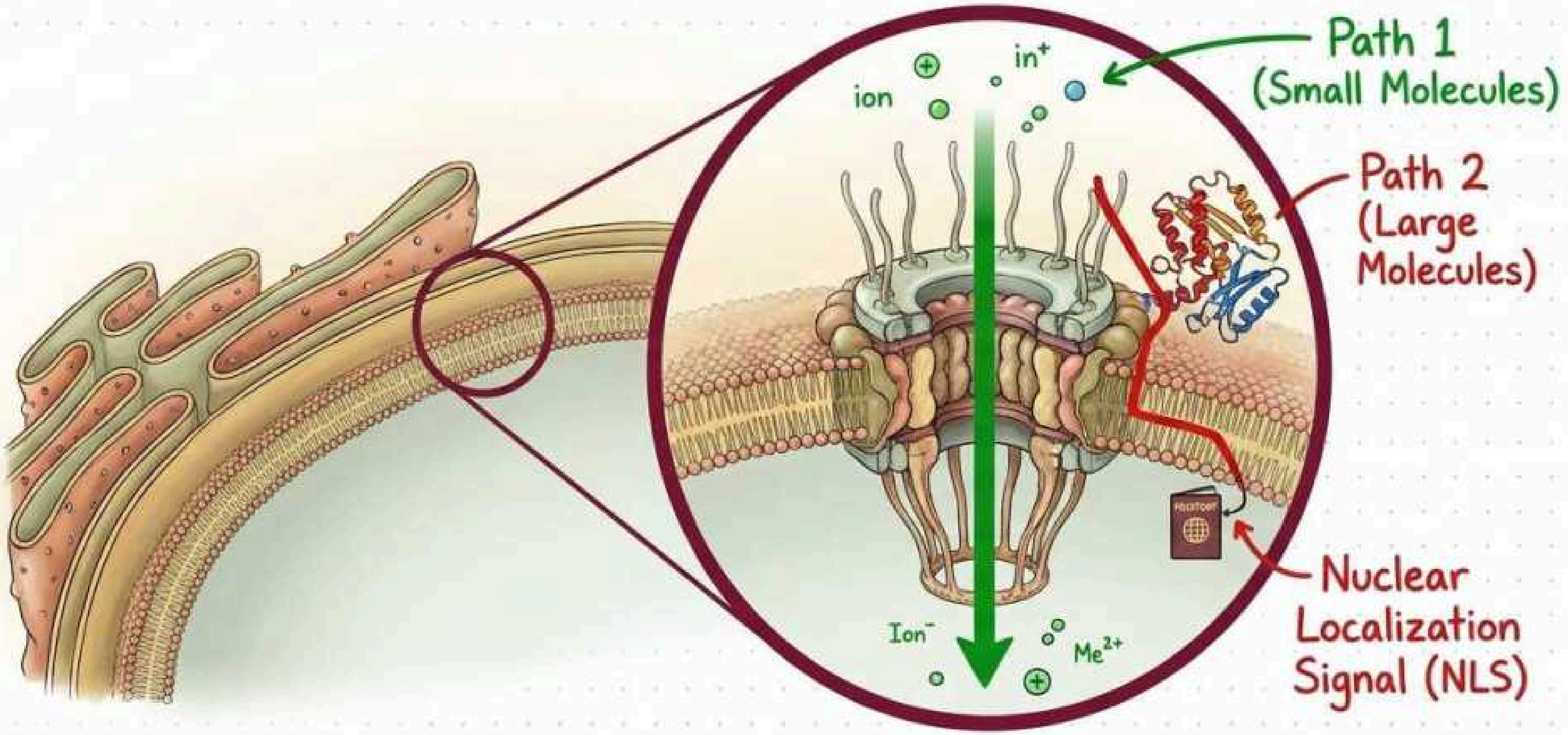


100 μm

As size grows, volume rises faster than surface area. A large cell cannot rely on its outer membrane alone. Internal membranes create parallel reaction rooms running side by side without interference.

The Nuclear Envelope Acts as a Selective Gatekeeper

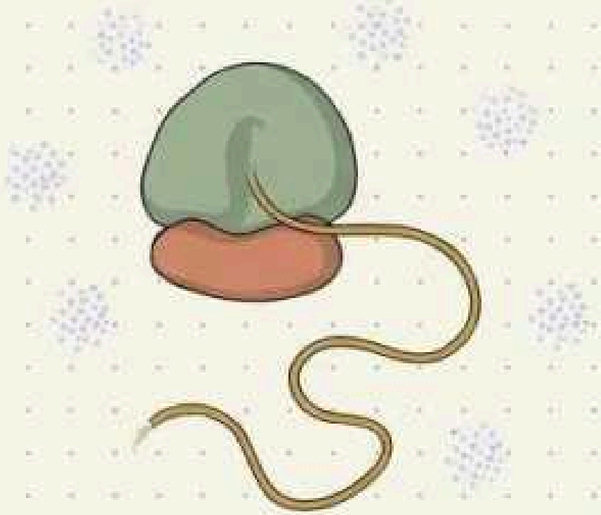
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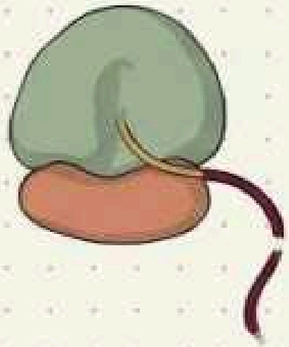
The nucleus is the largest compartment. Large molecules require a Nuclear Localization Signal—a biochemical passport to enter.

The Signal Hypothesis Dictates Protein Destinations

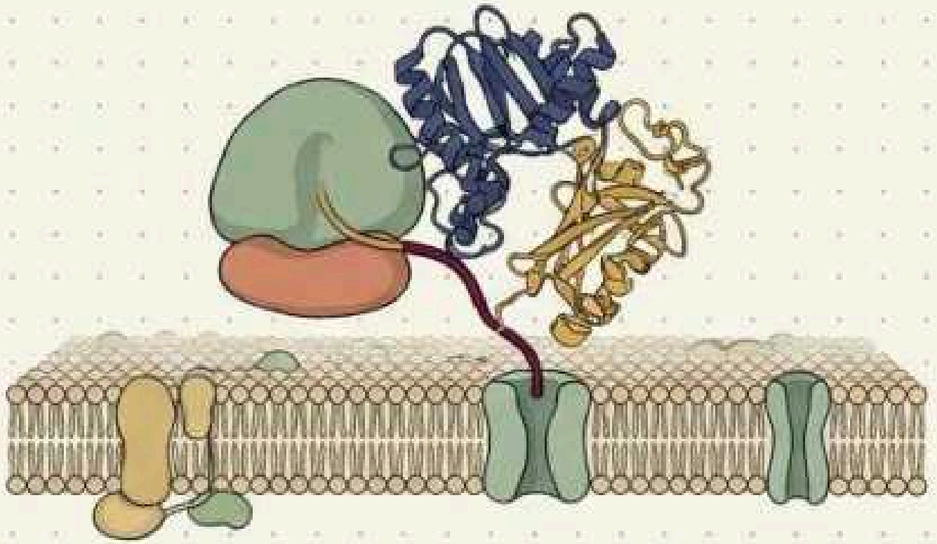
1. Cytosol Destination:
   Free ribosome translation

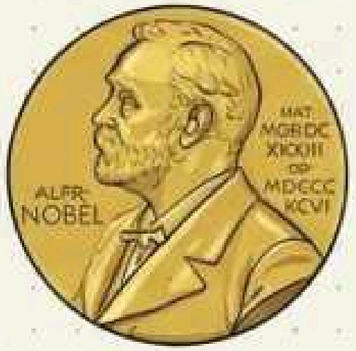


2. Membrane/Export:
   Translating a signal sequence



3. Docking: Ribosome anchored to Endoplasmic Reticulum



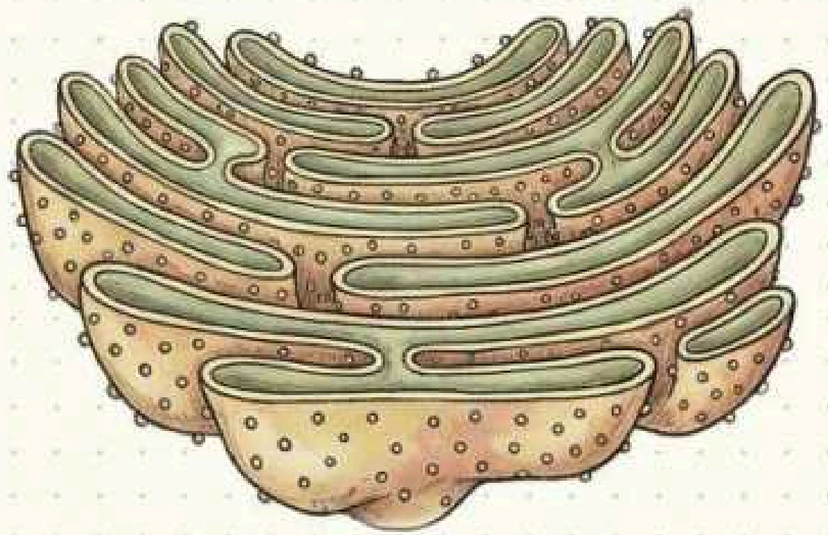


Günter Blobel – 1999
Nobel Prize for the
Signal Hypothesis.

Every protein begins on a ribosome. Proteins destined for membranes or export carry a distinct signal sequence dictating their docking location.

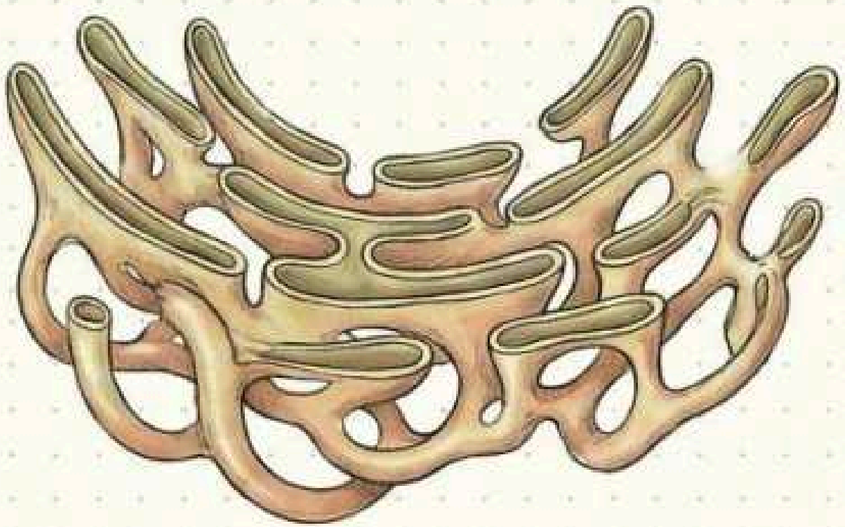
The Endoplasmic Reticulum: Manufacturing and Detoxification

Rough ER



Threads new proteins into the interior. Responsible for folding and attaching sugar chains.

Smooth ER

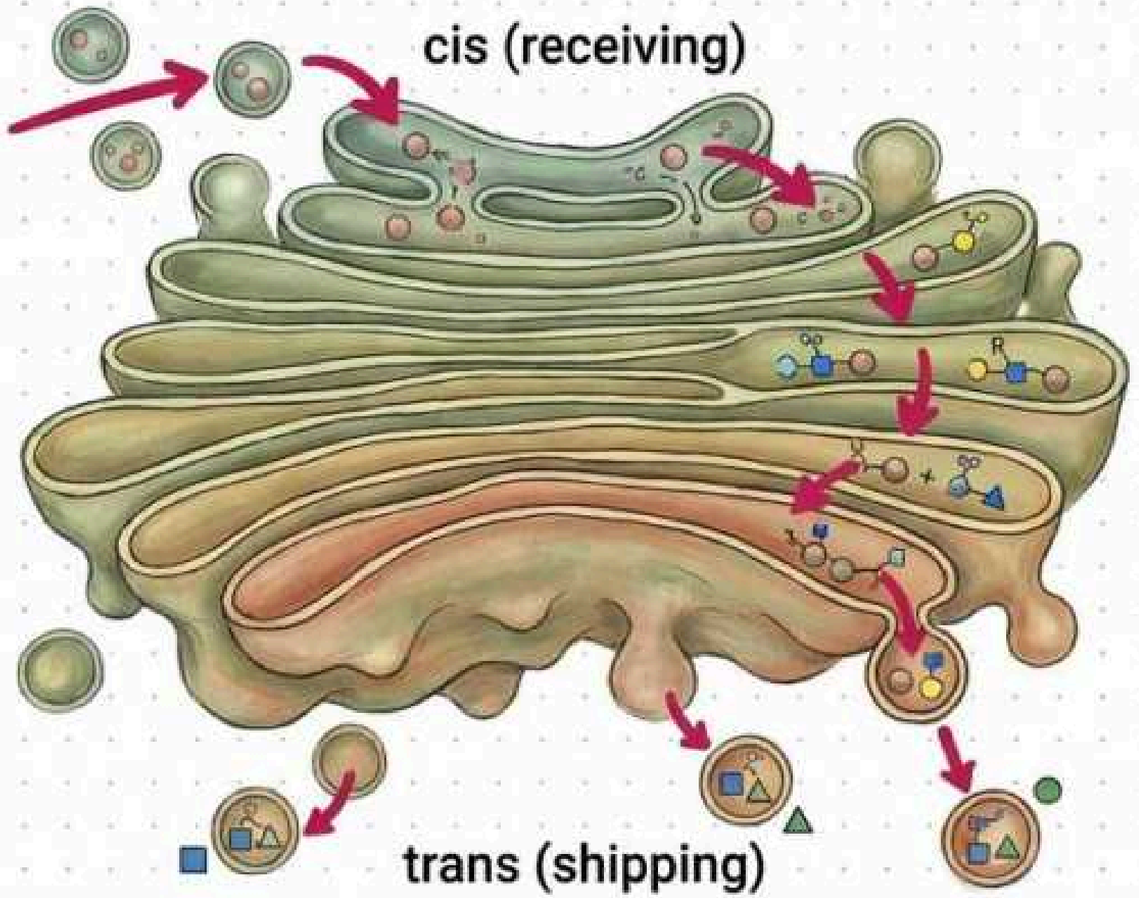


Manufactures lipids and detoxifies drugs.

Clinical Note: Liver cells process heavy drug loads and therefore maintain massive volumes of Smooth ER.

The Golgi Apparatus Operates as a Chemical Sorting Office

1. Vesicles arrive from the ER.



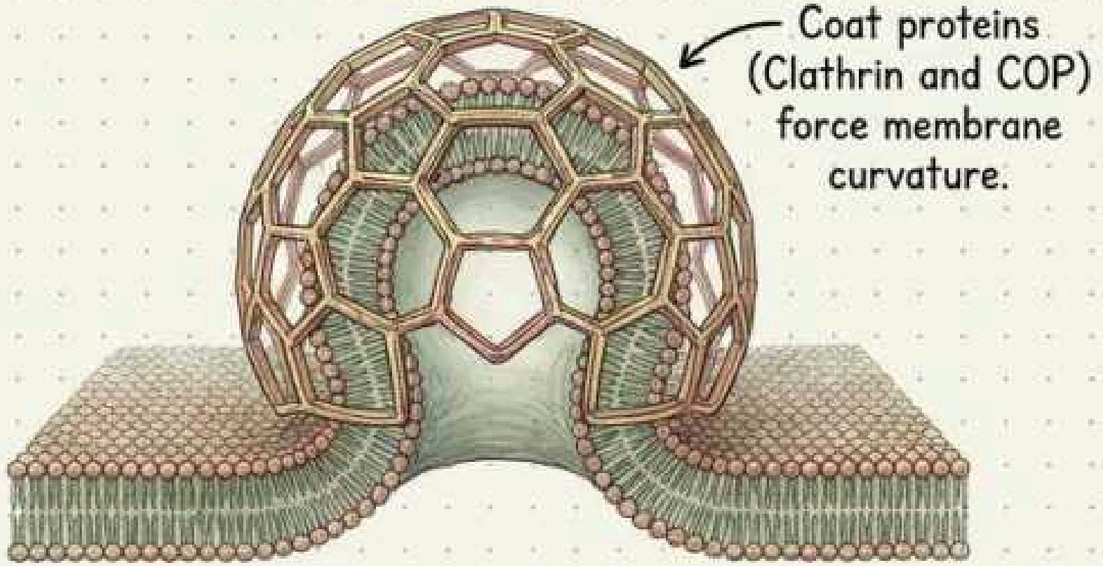
2. Enzymes modify the cargo as it passes through sequential sacs.

3. Cargo is packed into new vesicles with specific address labels.

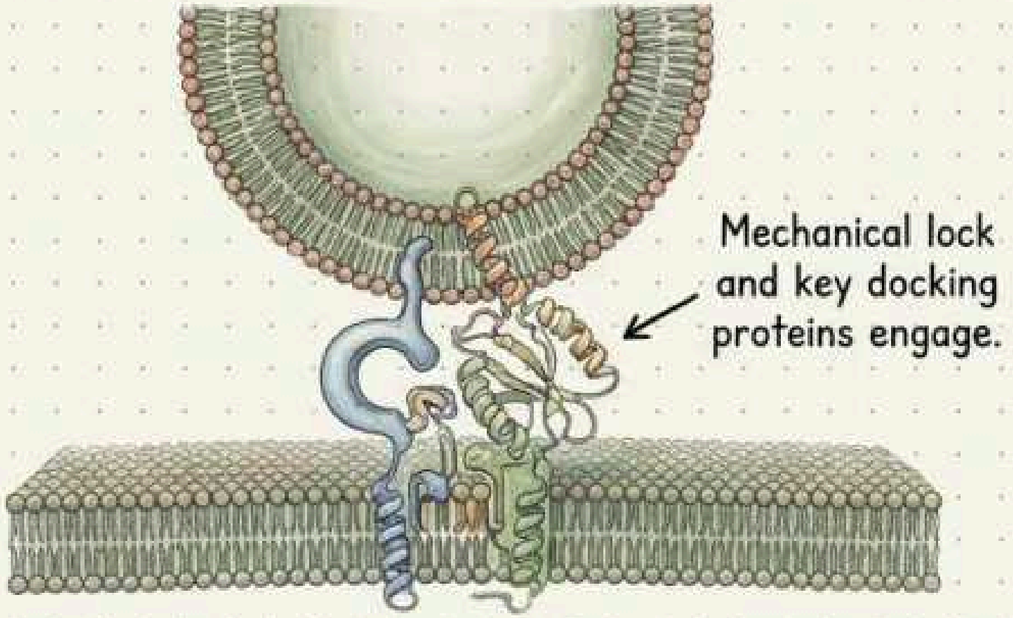
Shipped to three distinct destinations: the cell membrane, lysosomes, or outside the cell entirely.

Vesicle Traffic Relies on Strict Mechanical Rules

Formation



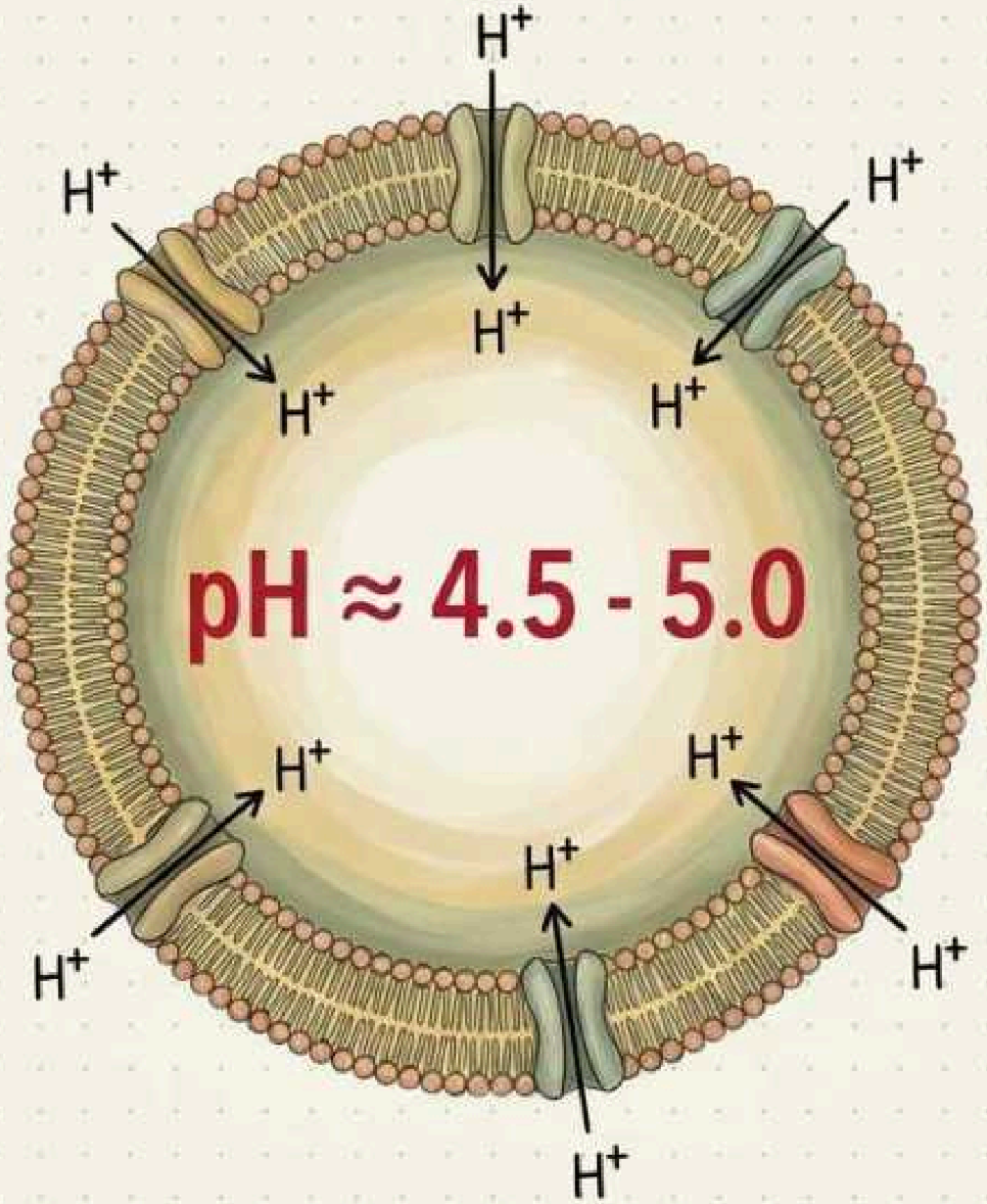
Fusion



The lock and key must match perfectly to fuse. This exact system maintains distinct organelles despite constant membrane flow between them.

Lysosomes Confine Dangerous Chemistry

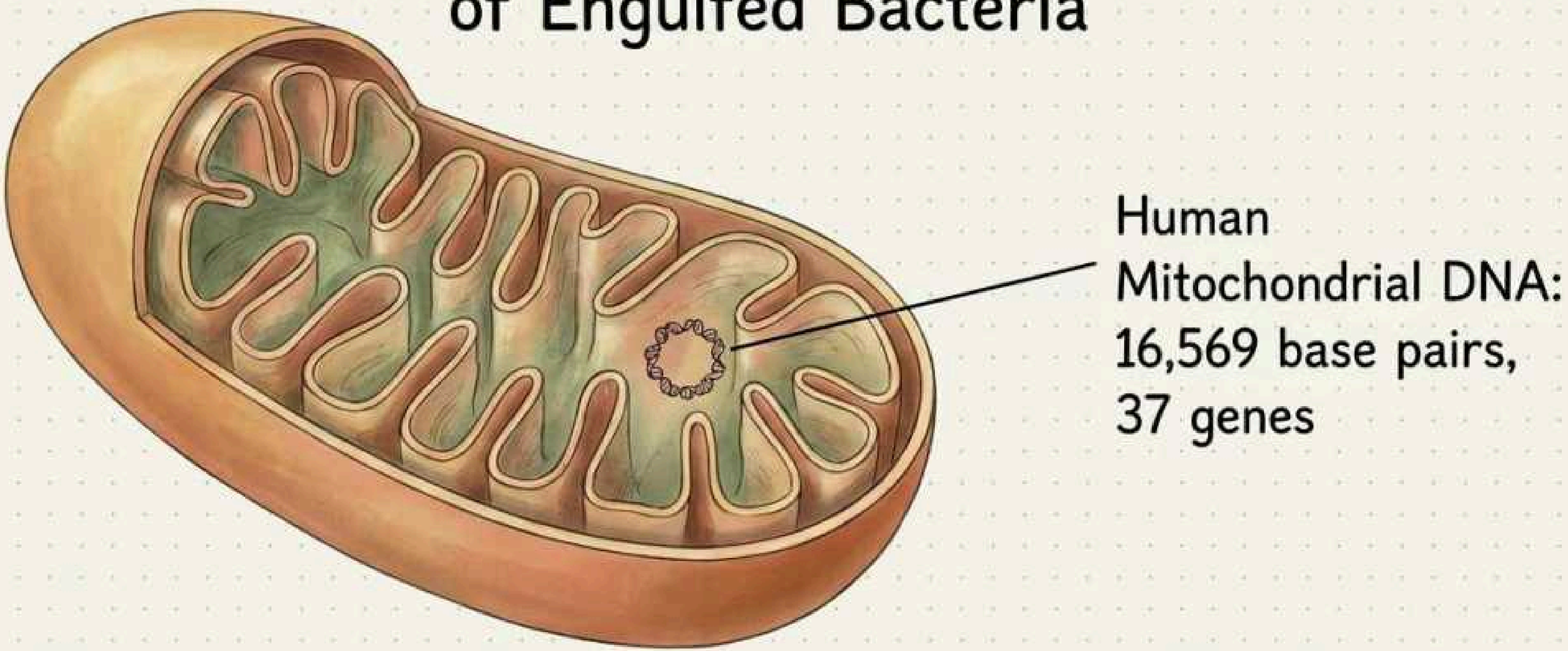
- Contains ~50 distinct digestive enzymes.



- Protection Mechanism: Enzymes are manufactured in an inactive state and only function in severe acidity, protecting the cytosol.

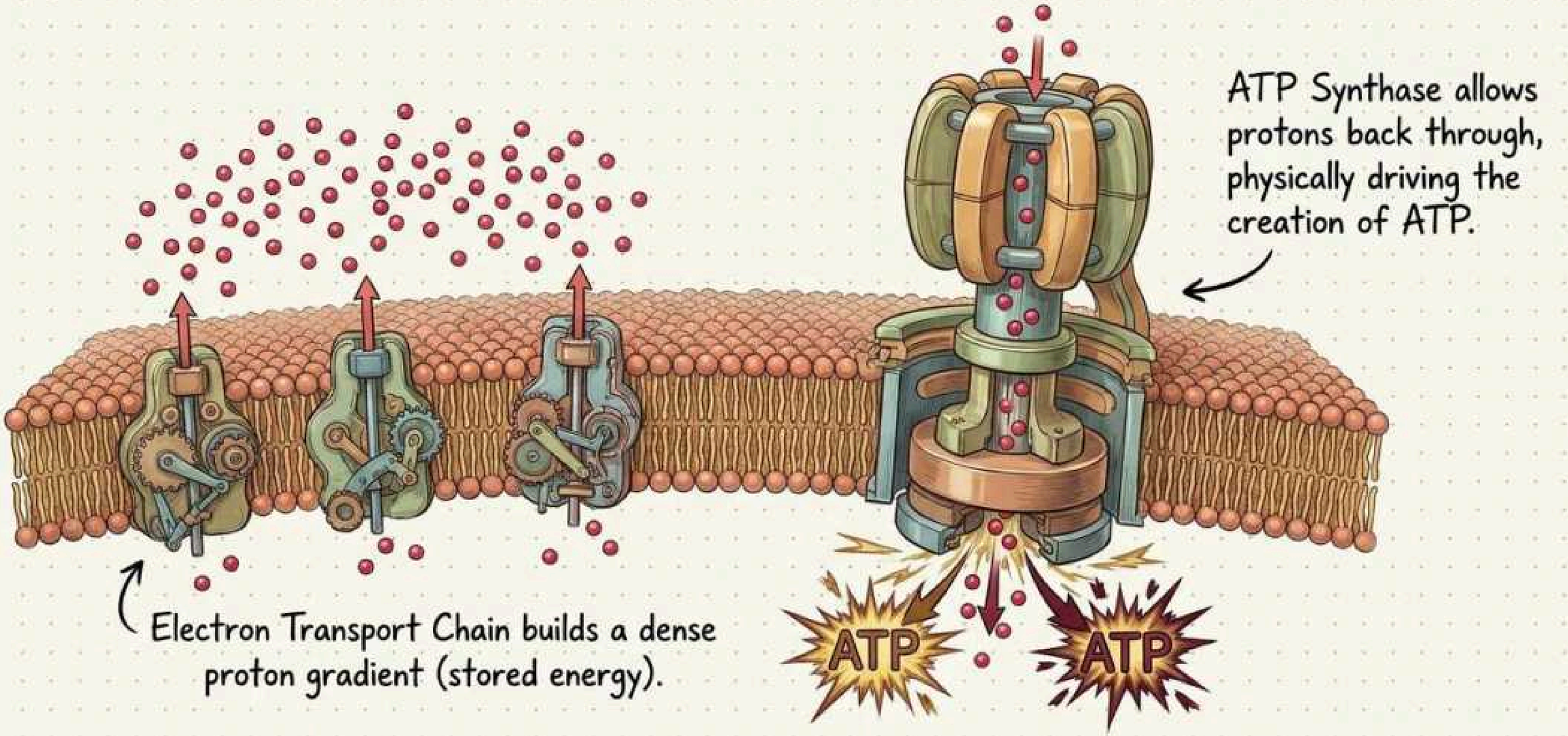
- Pathology: Faulty enzymes result in severe storage diseases where waste builds up uncontrollably.

Mitochondria Carry the Architecture of Engulfed Bacteria



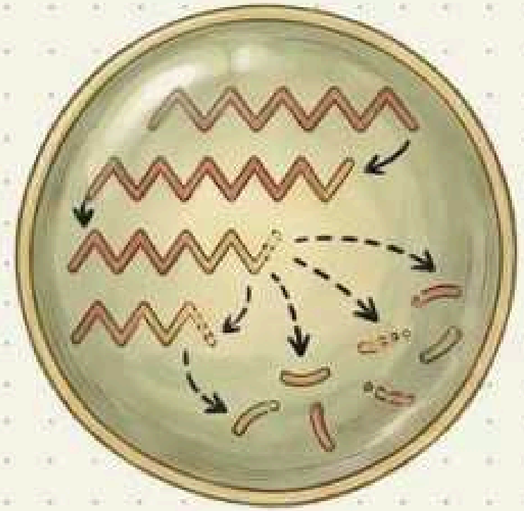
Echoing Biology 101 B: The double membrane and circular DNA strongly support the endosymbiotic theory—descended from ancient engulfed bacteria.

The Molecular Turbine Forging Cellular ATP



A single mitochondrion contains thousands of these molecular turbines.

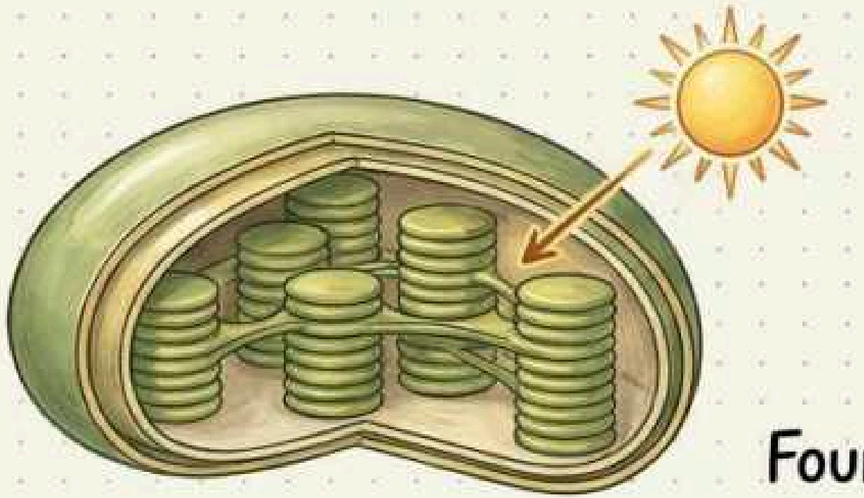
Specialized Compartments Enable Unique Chemistry



Peroxisomes

$$H_2O_2 \xrightarrow{\text{(catalase)}} H_2O + O_2$$

Neutralizing toxic by-products.

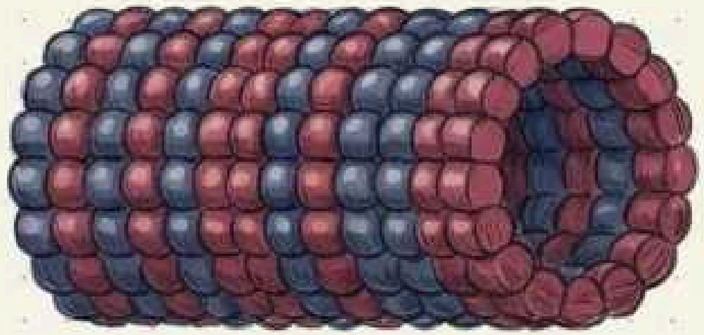


Chloroplasts

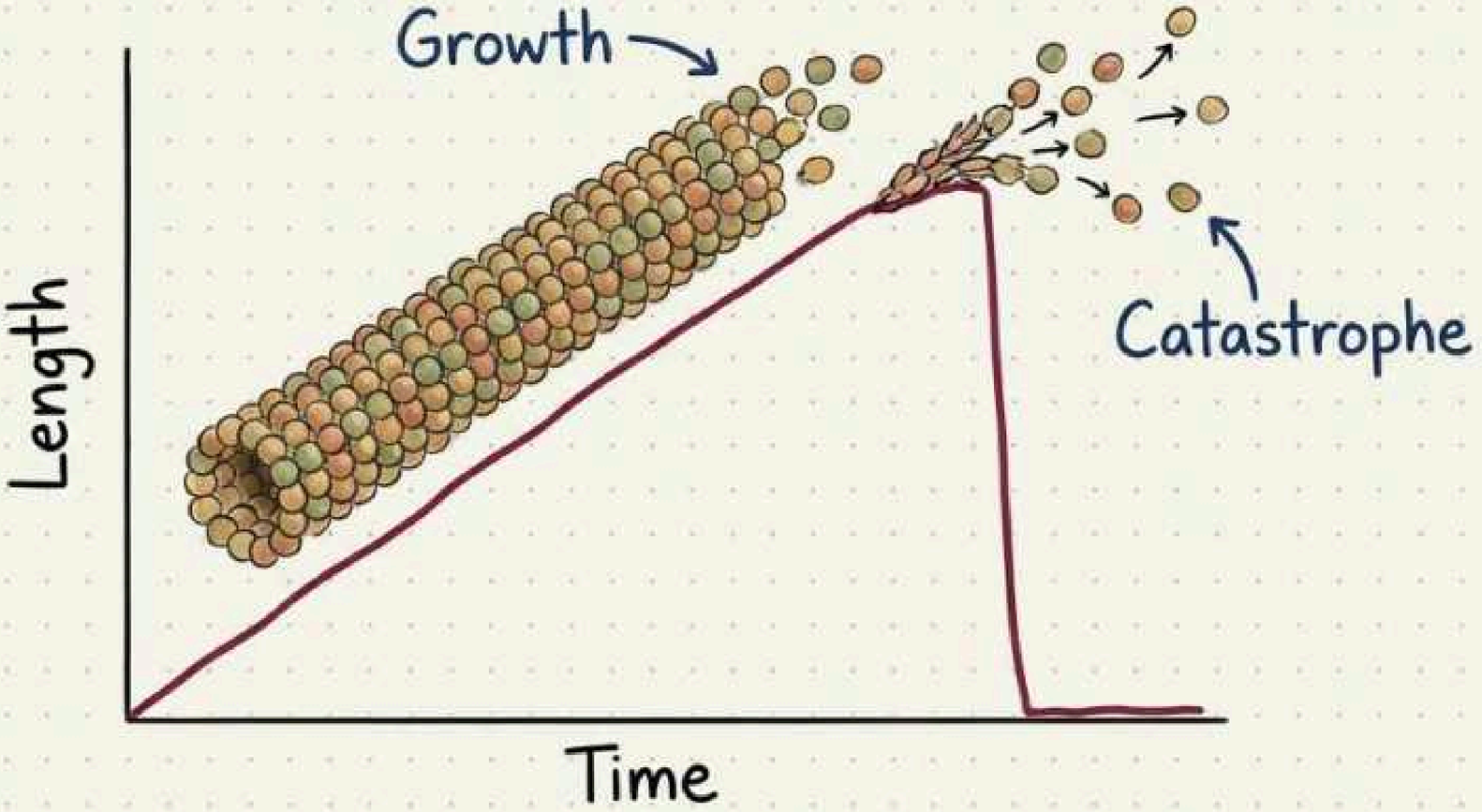
Found in plants and algae, capturing light to build sugar.

Every compartment operates by its own unique protein import rules.

The Cytoskeleton: Structure, Movement, and Transport

Actin Filaments	Intermediate Filaments	Microtubules
		
Width: 7 nm	Width: 10 nm	Width: 25 nm (Hollow tubes)
Drives cell crawling and muscle contraction.	Provides mechanical strength and stability.	Forms transport tracks and builds the chromosome-separating spindle.

Microtubules Rebuild the Cellular Scaffold in Minutes

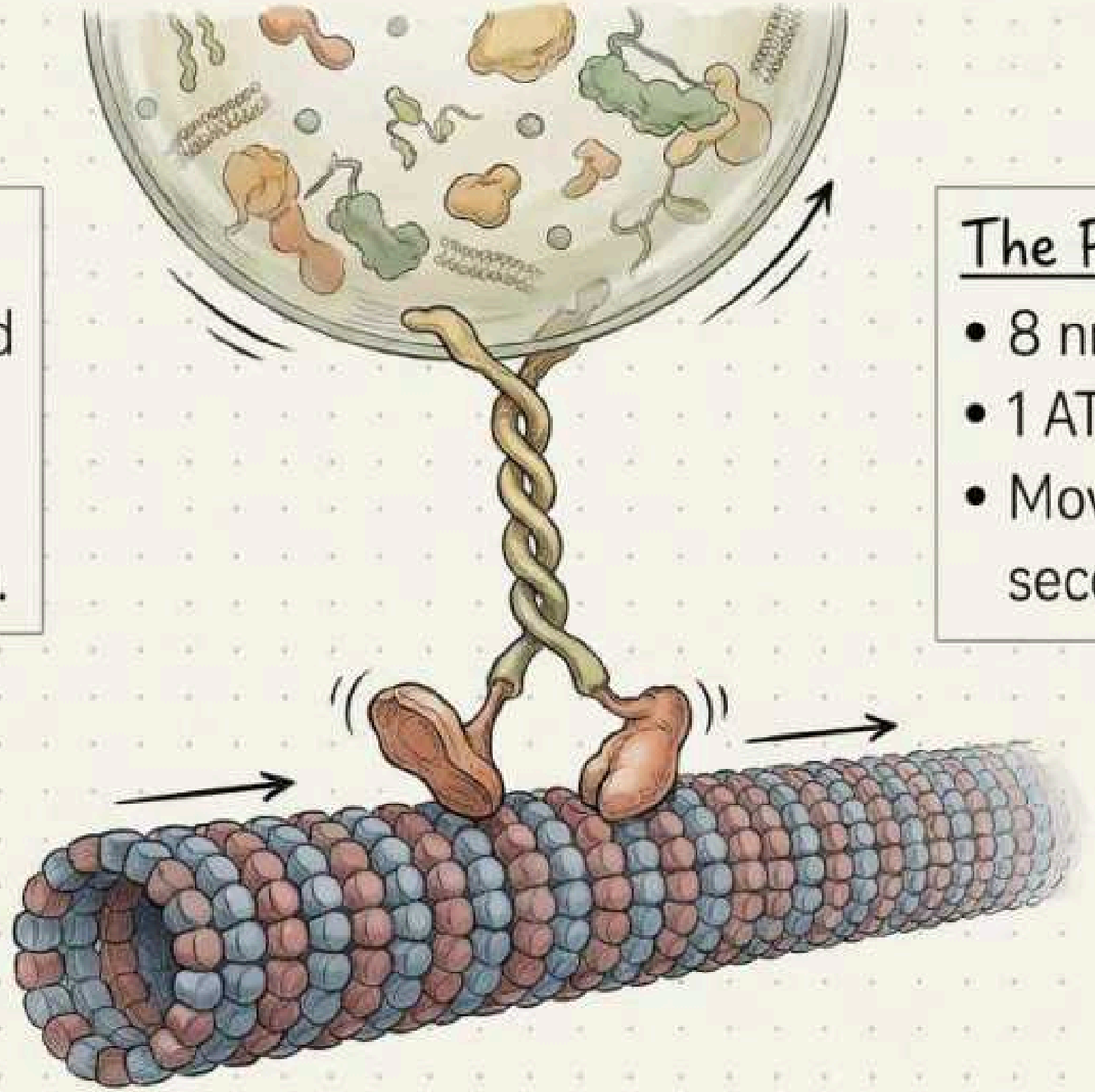


Built from tubulin protein with strict polarity (fast vs. slow growing ends).
This dynamic instability allows constant, rapid remodeling of the cell's interior.

Motor Proteins Walk Hand-Over-Hand Along the Tracks

Motor Rules:

- Kinesin: Walks toward the growing (+) end.
- Dynein: Walks the opposite way (– end).

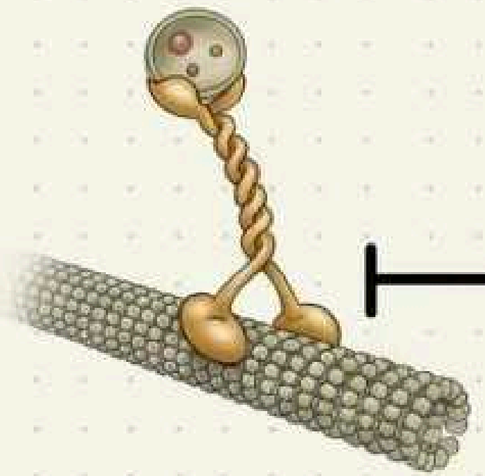


The Physics of Movement:

- 8 nm per step.
- 1 ATP consumed per step.
- Moves at ~100 steps per second.

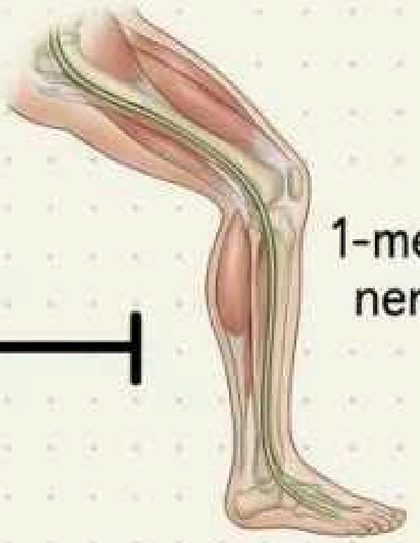
The Mathematical Limits of Active Transport

$$100 \frac{\text{steps}}{\text{s}} \times 8 \frac{\text{nm}}{\text{step}} = 800 \frac{\text{nm}}{\text{s}}$$



1-meter motor neuron axon at 800 nm/s

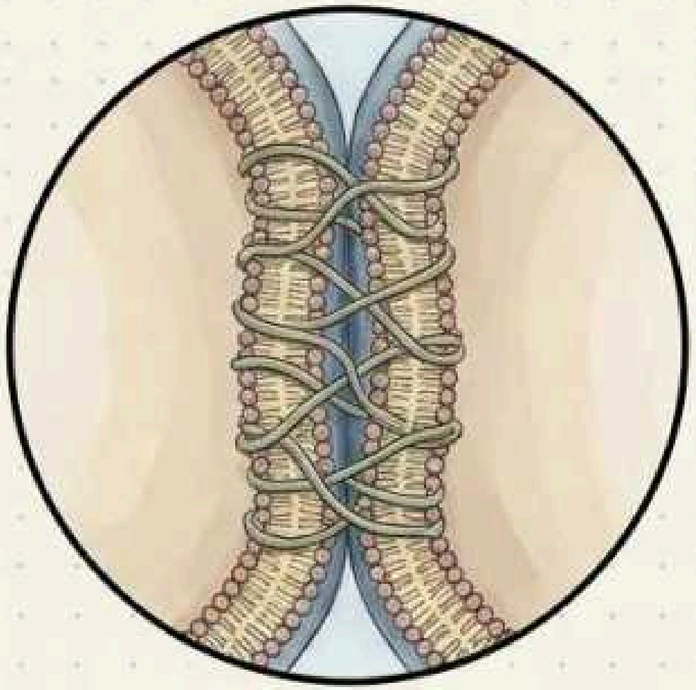
$= 1.25 \times 10^6$ seconds (>14 days)



It takes one kinesin a little over 14 days to travel the length of your leg. Cells must meticulously plan for this biological delay.

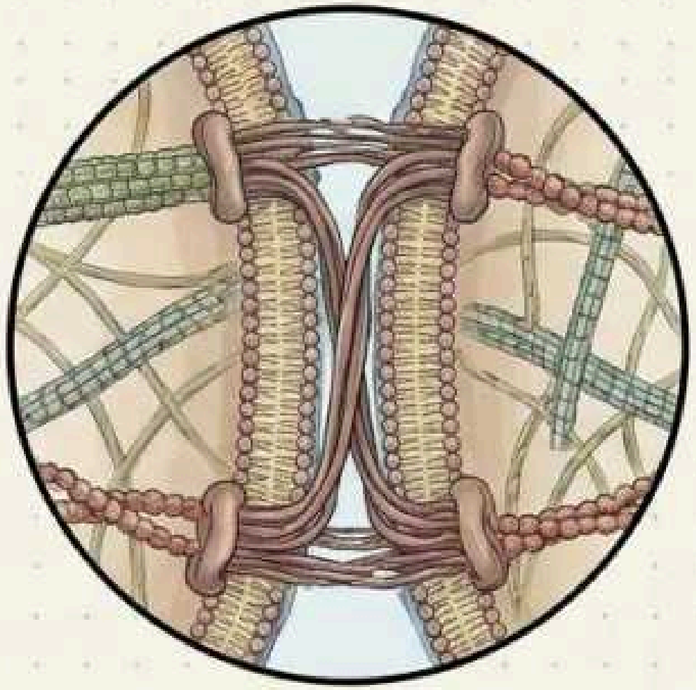
Cell Junctions Tie Individual Cells into Tissue

1. Tight Junctions



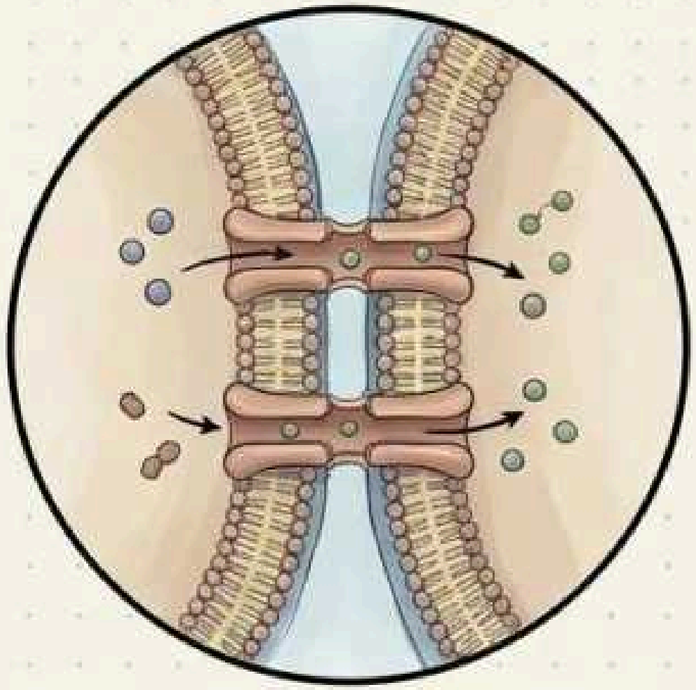
Drawn like physical stitching.
Seals cells so no fluid can leak.

2. Anchoring Junctions



Ties internal cytoskeletons together
for immense mechanical strength.

3. Gap Junctions

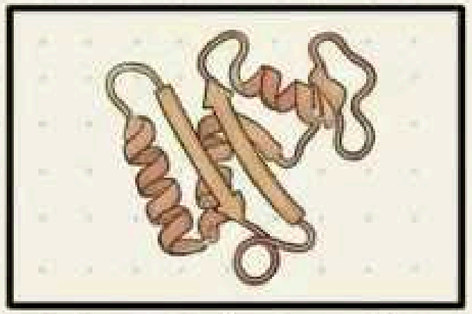


Forms direct tunnels allowing
ions and small molecules to pass.

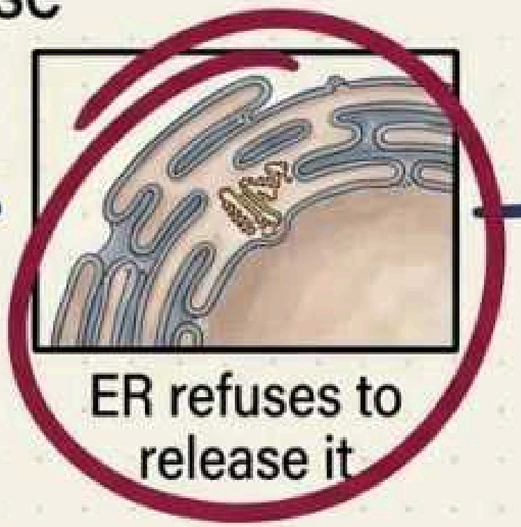
Skin, gut lining, and heart muscle rely on these mechanical junctions to behave as one unified entity.

When Trafficking Fails: Disease and Therapeutics

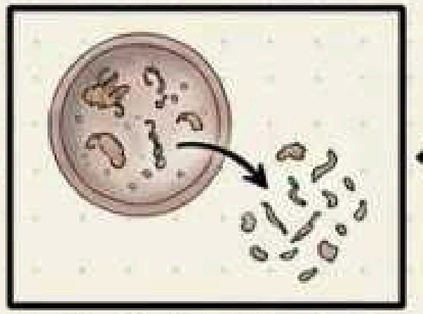
Path A: Inherited Disease



Mutated protein misfolds



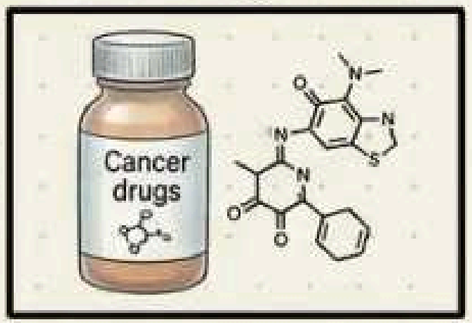
ER refuses to release it



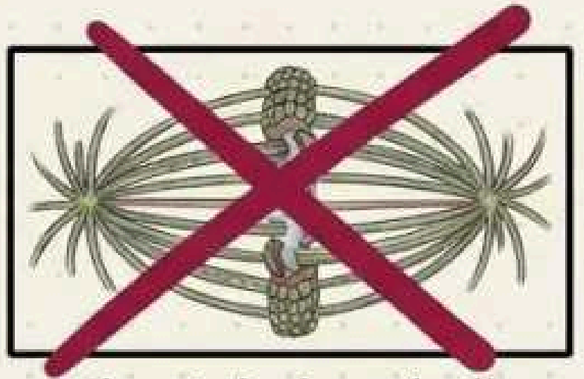
Cell destroys it entirely.

Modern Intervention:
Drugs designed specifically to assist protein folding.

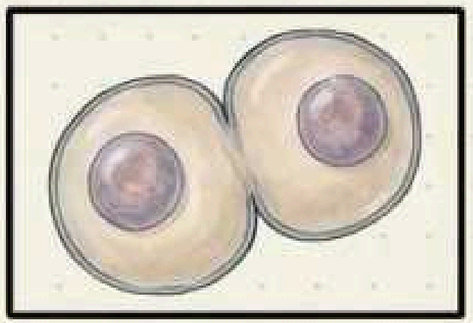
Path B: Targeted Therapy



Cancer drugs introduced

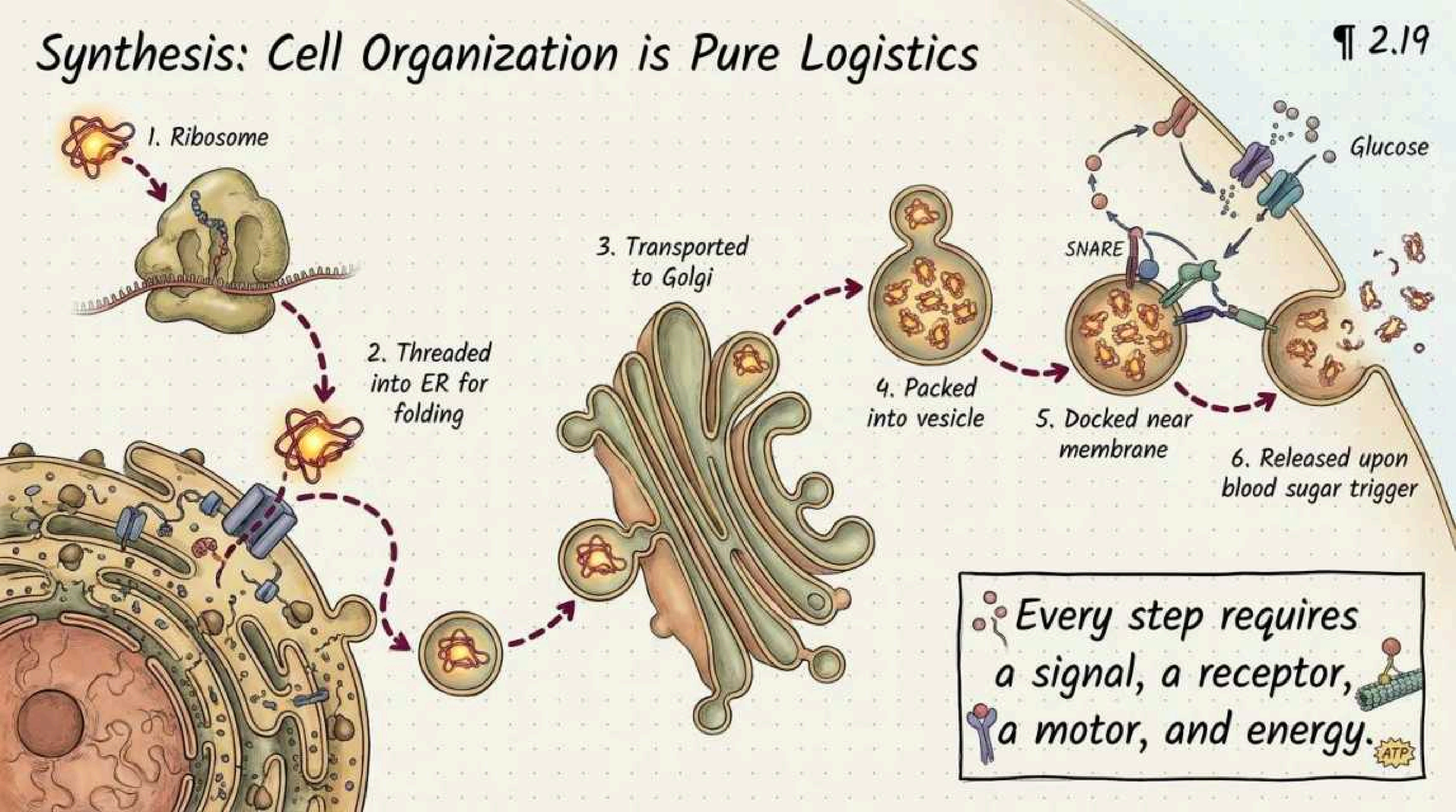


Microtubule spindle is chemically frozen



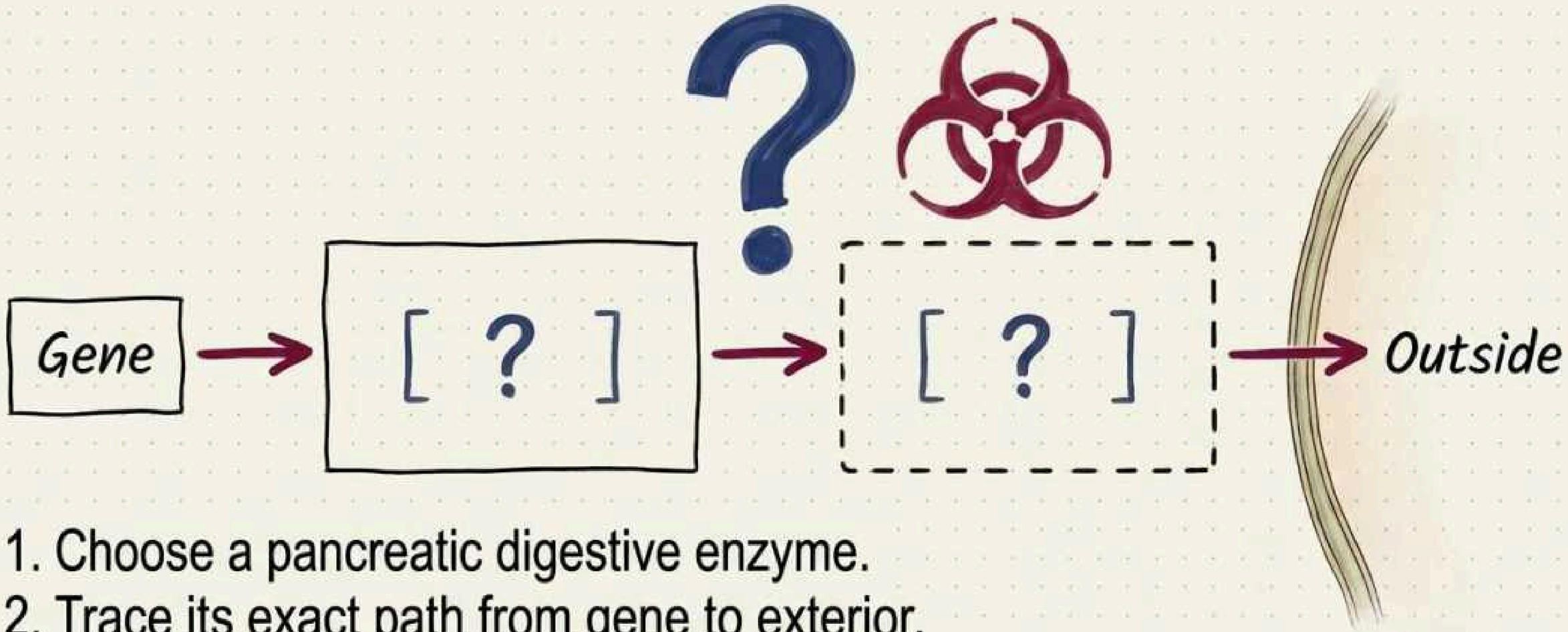
Cell division permanently halted.

Synthesis: Cell Organization is Pure Logistics



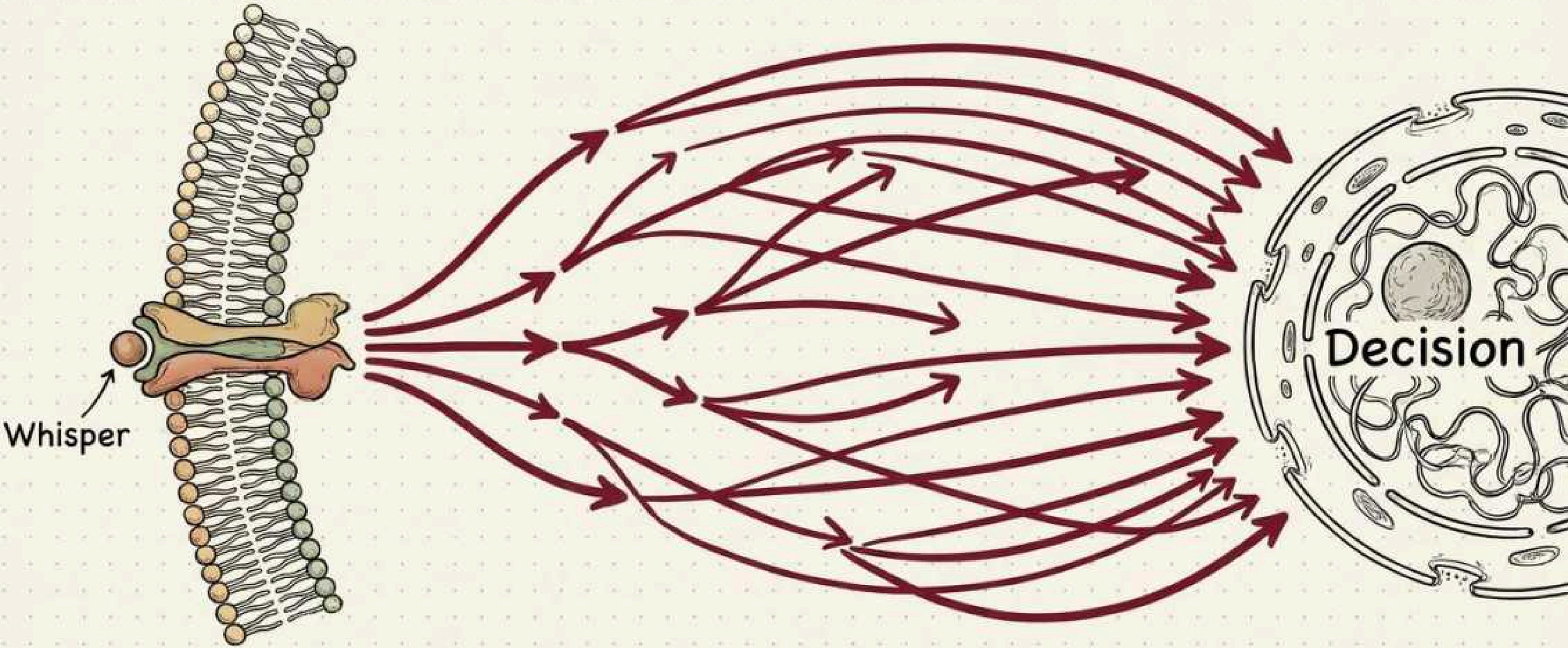
Logistical Challenge: Trace the Secretion Pathway

¶ 2.20



1. Choose a pancreatic digestive enzyme.
2. Trace its exact path from gene to exterior.
3. Name every compartment, signal, and vesicle involved.
4. Identify one specific step where a single fault could cause a disease.

Looking Ahead to Lecture 3: Cell Signaling



Next time: How cells receive messages from the outside, and how a whisper at the surface becomes a decision inside.