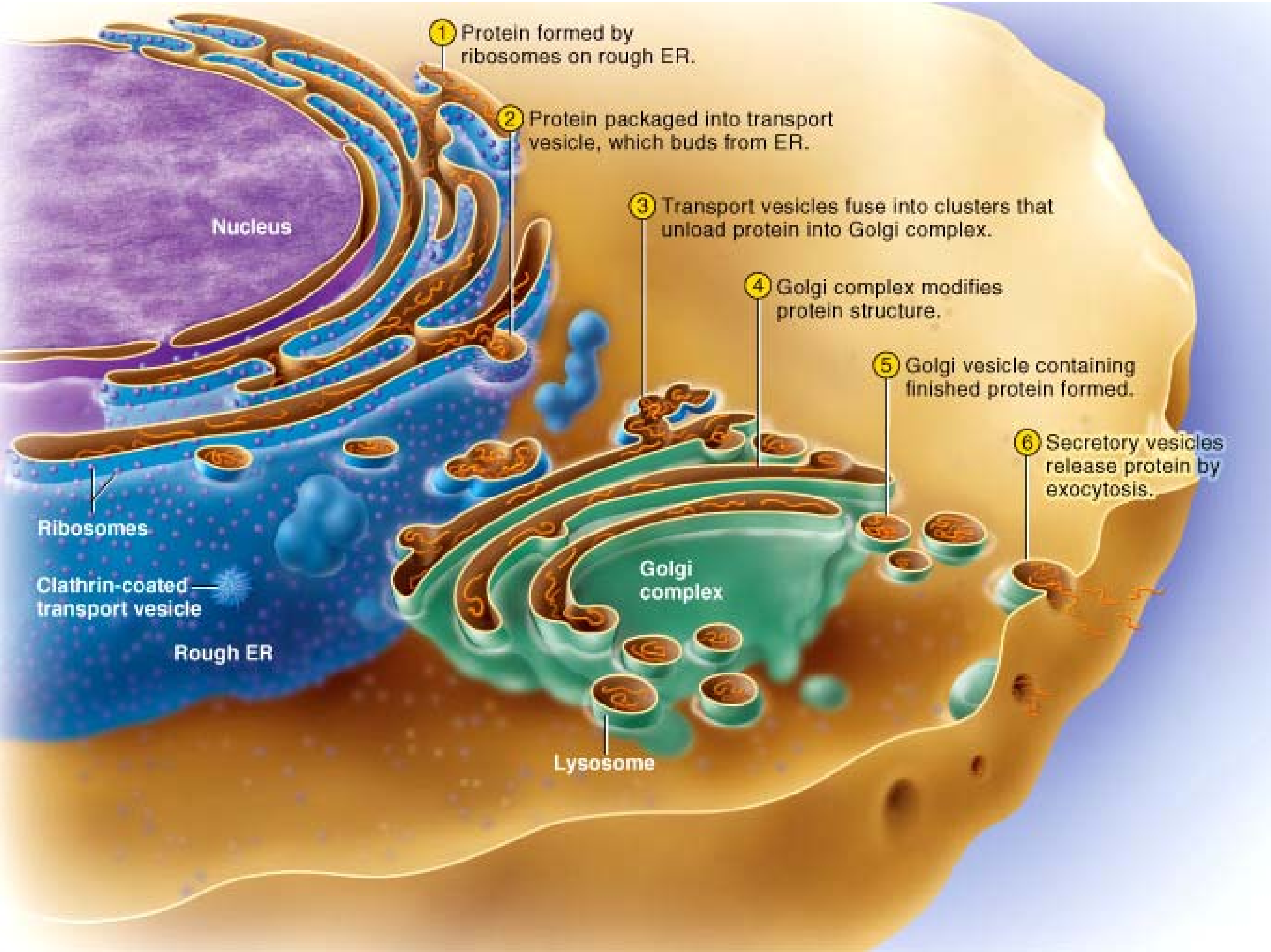
Modes of Membrane Transport

- Transmembrane Transport
  - movement of small substances **through** a cellular membrane (plasma, ER, mitochondrial..)
    - ions, fatty acids, H_2O, monosaccharides, steroids, amino acids…
  - polar substances use integral membrane proteins
  - nonpolar substances pass directly through the phospholipid bilayer
- Vesicular Transport
  - transport of substances that are **TOO LARGE** to move through a membrane
    - proteins, cellular debris, bacteria, viruses…
  - use vesicles to move substances into/out of the cell

Vesicles

- “Bubbles” of phospholipid bilayer membrane with substances inside
- Created by the “pinching” or “budding” of the phospholipid bilayer membrane
  - reduces the amount of membrane at that location
- Can “fuse” (merge) with another phospholipid bilayer membrane within the cell
  - adds to the amount of membrane at that location


1 Protein formed by ribosomes on rough ER.
2 Protein packaged into transport vesicle, which buds from ER.
3 Transport vesicles fuse into clusters that unload protein into Golgi complex.
4 Golgi complex modifies protein structure.
5 Golgi vesicle containing finished protein formed.
6 Secretory vesicles release protein by exocytosis.
Nucleus
Ribosomes
Clathrin-coated transport vesicle
Rough ER
Golgi complex
Lysosome

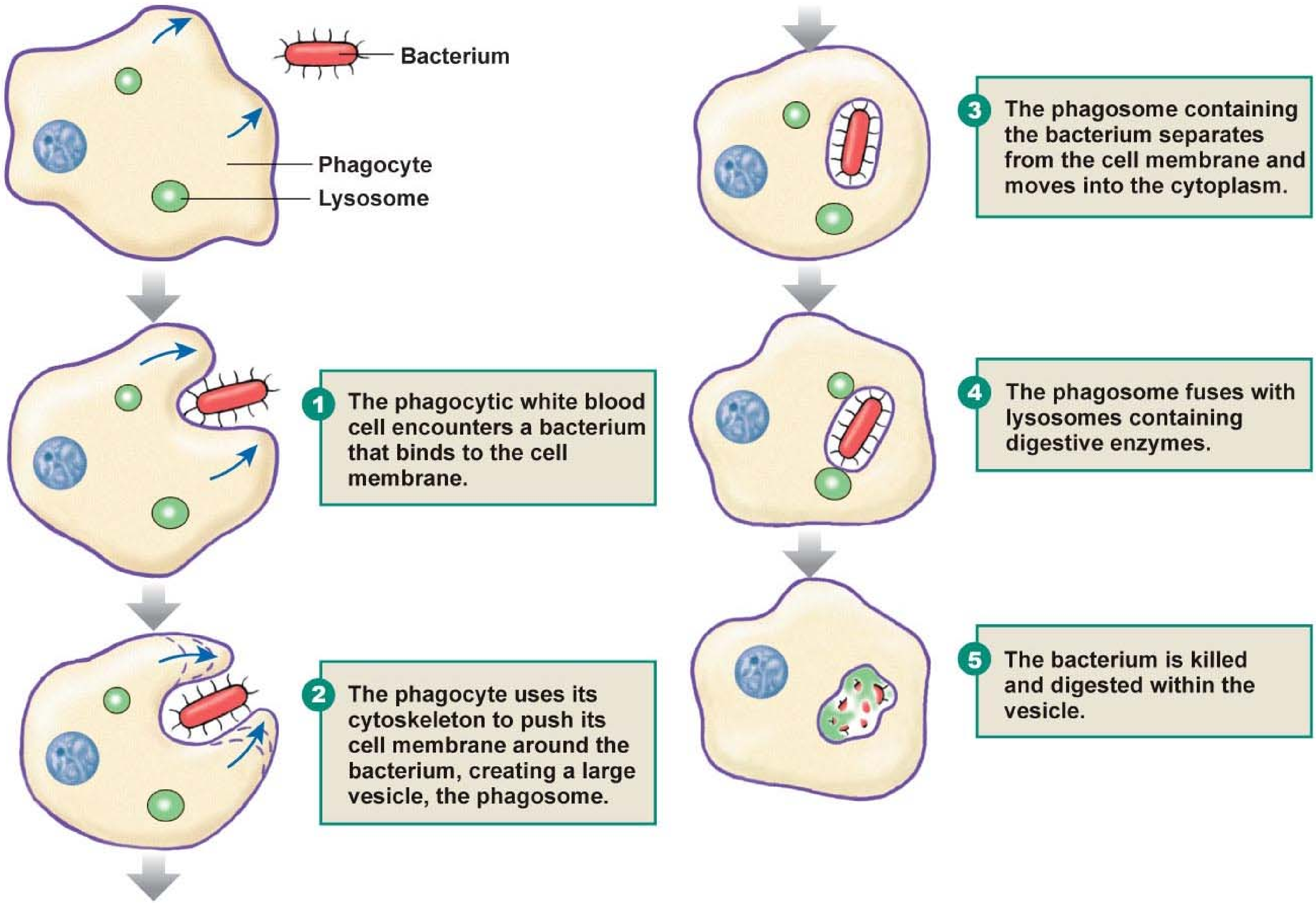
Vesicular Transport

- **Exocytosis**
  - moves substance out of the cell
  - fusion of a vesicle with substances with the cell membrane
- **Endocytosis**
  - moves substances into the cell
  - cell membrane creates pseudopods ("false feet") which traps substances in the ECF within a vesicle

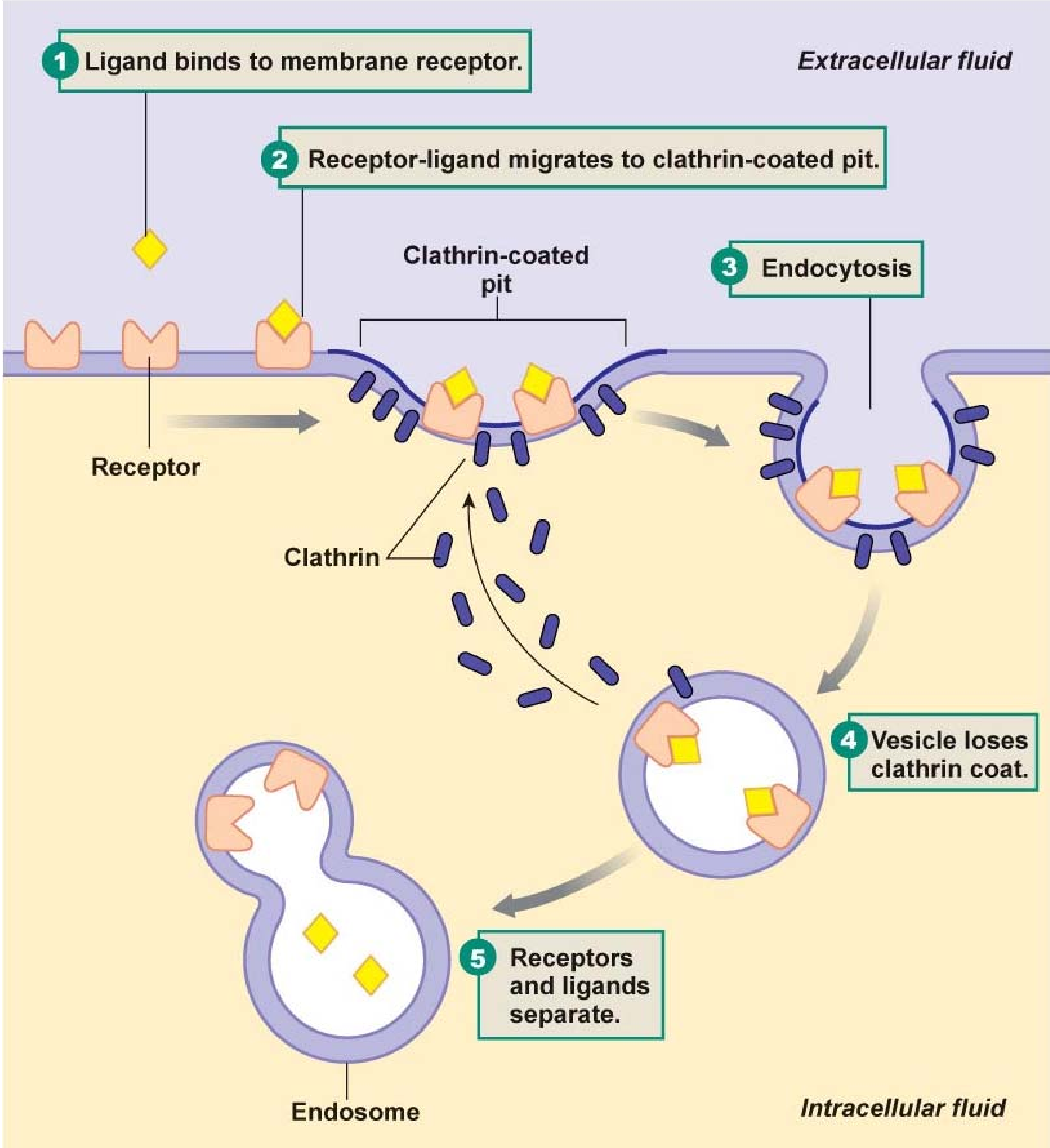
Types of Endocytosis

- **Phago**cytosis
  - “cell eating”
  - endocytosis of few very large substances (bacteria, viruses, cell fragments)
  - vesicles containing cells fuse with lysosomes which digest the cells
- **Pino**cytosis
  - “cell sipping”
  - endocytosis of extracellular fluid
- **Receptor**-mediated endocytosis
  - endocytosis of a specific substance within the ECF
  - requires that the substance attaches to the extracellular portion of an integral membrane receptor protein

Endocytosis and Lysosomes



Receptor-Mediated Endocytosis

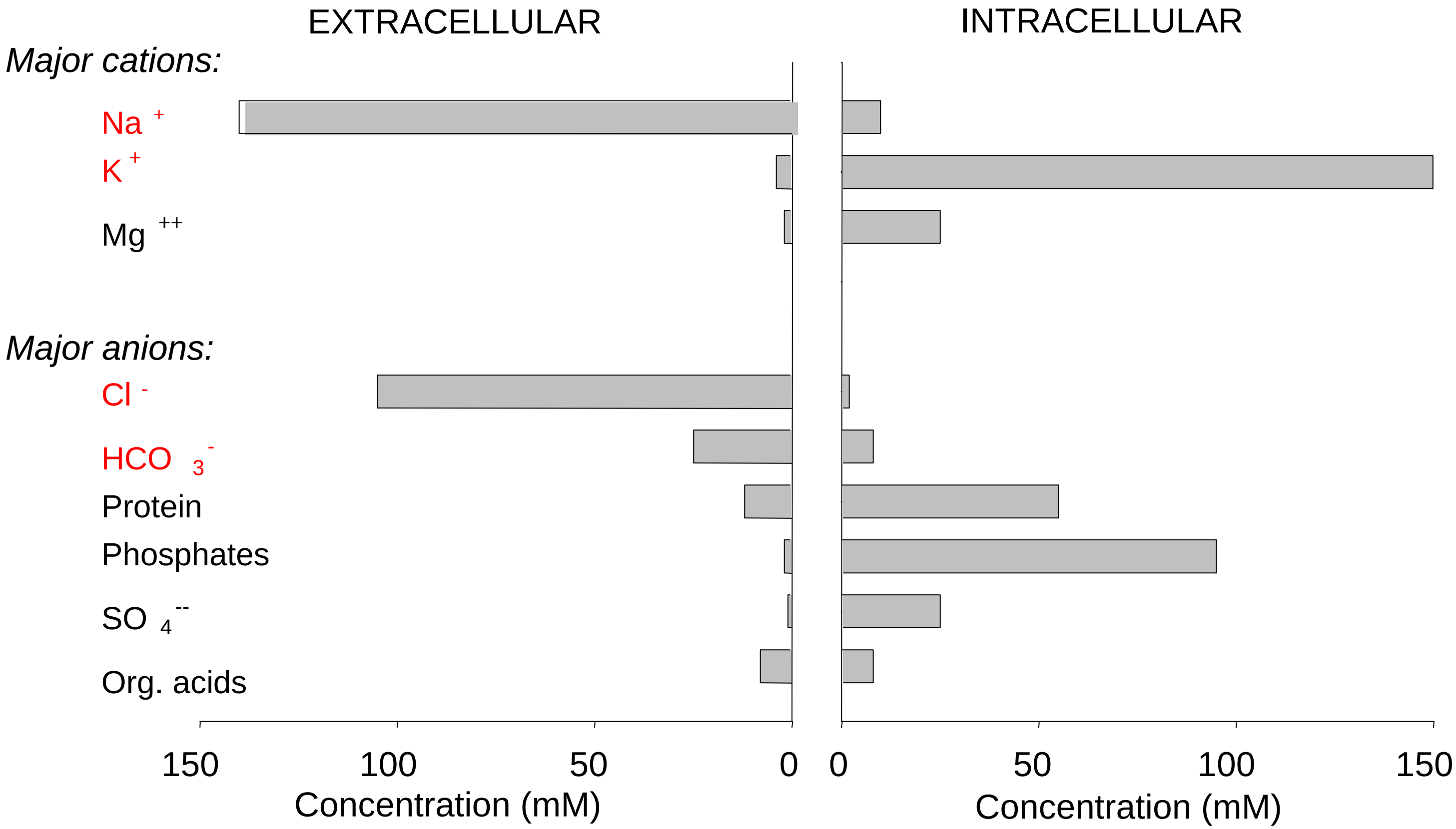


Solutions

- The ICF and the ECF are homogeneous mixtures of substances including water, ions, amino acids, disaccharides, triglycerides… called solutions
- Solutions are divided into 2 parts
  - **Solvent**
    - substance present in greatest amount
    - the solvent of the body is water
  - **Solute(s)**
    - substance(s) present in lesser amounts
    - every other substance in the body is a solute
      - ions, carbohydrates, proteins, fats, nucleotides…
- Solutions are described in terms of their concentration
  - the amount of solutes in a given volume of solution
    - Units include: molarity, %, weight per volume

ECF vs. ICF

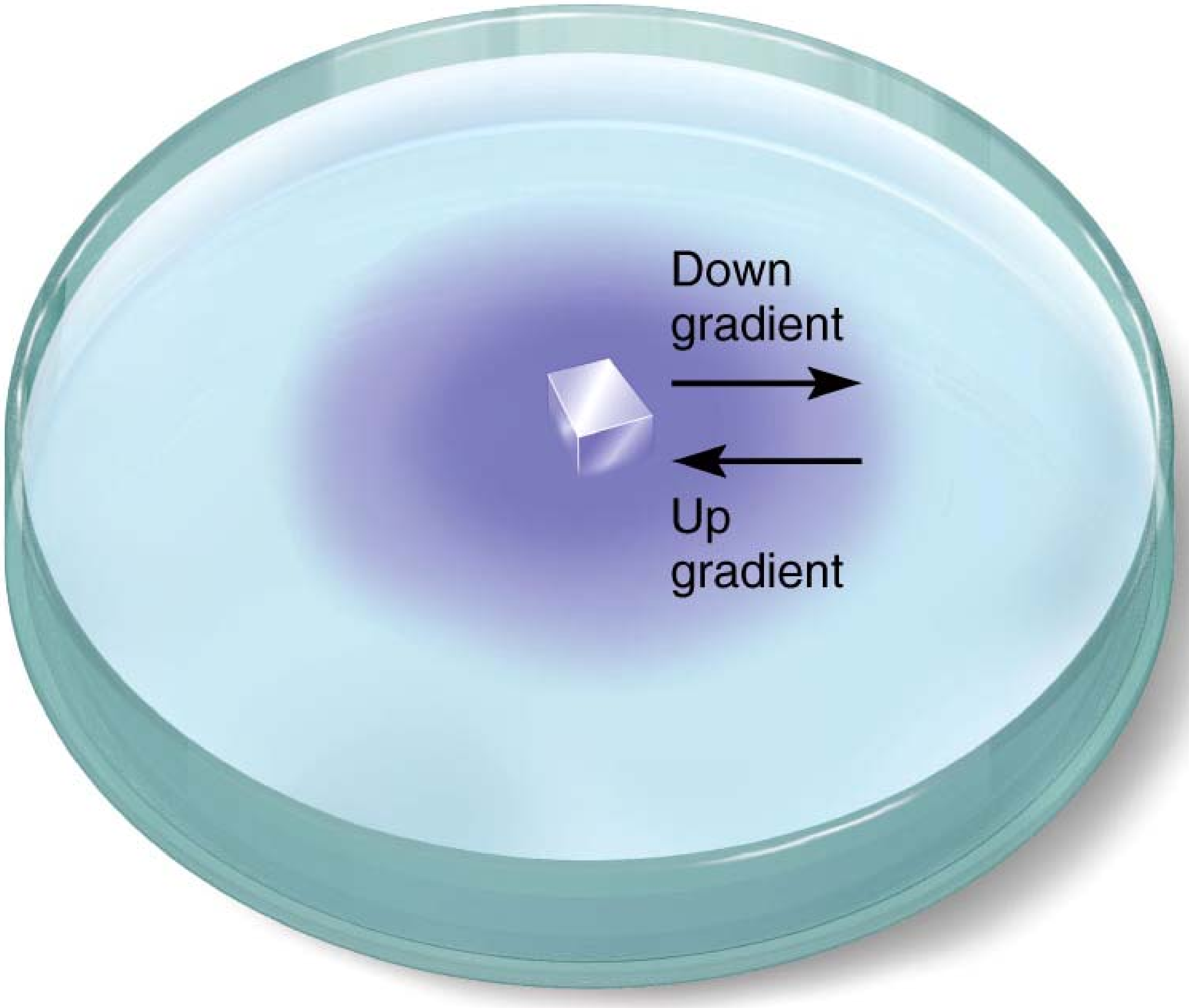
- The **total** solute concentration of the ECF = ICF
- The concentration of each solute in the ECF is different from its concentration in the ICF
  – the cell membrane transports each solute between the ICF and ECF creating gradients for each solute to maintain optimal conditions within the ICF



Concentration Gradients

- The <u>**difference**</u> in the amount of a substance between 2 locations
  - area of greater amount vs. area of lesser amount
  - the difference may be LARGE or small
  - may exist across a physical barrier (membrane) or across a distance without a barrier
- Substances in an area of high concentration naturally move toward regions of lower concentrations
  - Form of mechanical energy where location of greater amount provides more collisions
    - collisions cause substances to spread out

Concentration Gradients



Movement of Substances Relative to Gradients
Active Transport

- The movement of a substance from a region of lesser amount to a region of greater amount is called **active transport**
  - moves a substance UP or AGAINST a **concentration gradient** and **requires** an energy source
  - since this movement subtracts from the area of lower concentration and adds to the area of higher concentration it creates a larger difference between the 2 areas causing the gradient to increase

Movement of Substances Relative to Gradients
Passive Transport

- The movement of a substance from a region of greater amount to a region of lesser amount is called passive transport
  - moves a substance DOWN or WITH a **concentration gradient** and does **NOT** require an energy source
  - actually **releases** the (same amount of) energy required to create the gradient
  - causes the gradient to decrease since this movement subtracts from the area of higher concentration and adds to the area of lower concentration creating a smaller difference between the 2 areas

Transmembrane Concentration Gradients Equilibrium

- Equilibrium
  - a condition that is met when substances move **passively** down a gradient until there is equal concentrations of a substance between 2 locations (**NO** gradient)
    - **no net** movement of substances from one location to another
      - substances continue to move due to heat energy, but movement occurs equally in both directions
  - Equilibrium of substances across the various membranes in the cells of the body = DEATH
    - your body is in a constant battle to ensure equilibrium of solutes across the membranes is never reached

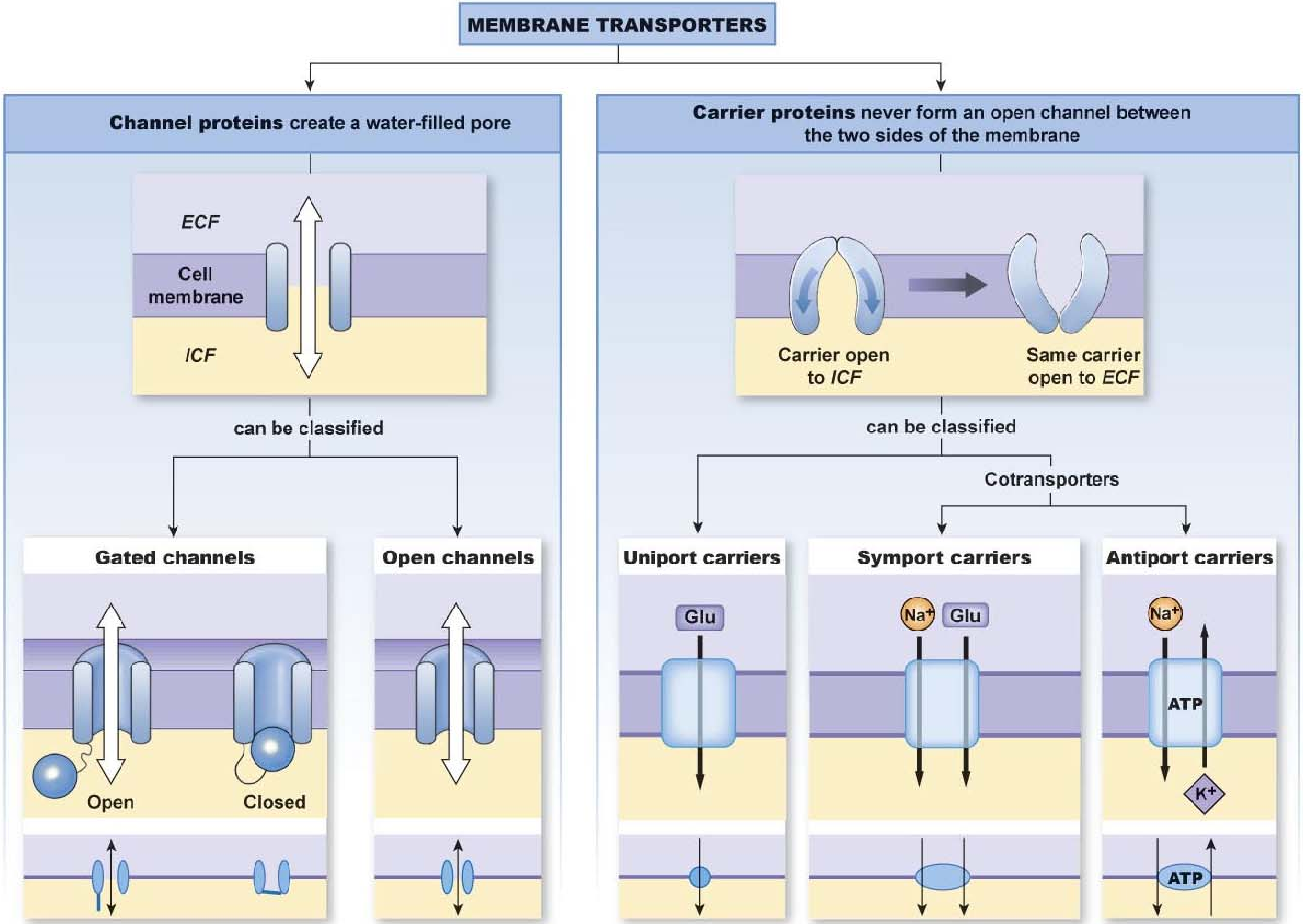
Transmembrane Concentration Gradients
Steady State

- Steady State
  - a condition that is met when substances move **passively** down a gradient, but then are moved **actively** back up the gradient
  - the gradient of a substance is **MAINTAINED** by the constant expenditure of energy by the cell fighting against equilibrium
    - **no net** movement of substances from one location to another
      - one substance moving passively down the gradient, is **exactly balanced** by one substance moving actively up the gradient

  - Life depends upon the ability of the organism to exist in a steady state

Transmembrane Transport of Nonpolar vs. Polar Substances

- Nonpolar substances cross a membrane through the phospholipid bilayer
  - ineffective barrier against the movement of nonpolar molecules across a membrane
    - it is **impossible** to control the movement of nonpolar molecules through a membrane
- Polar substances cross a membrane by moving through integral membrane transporting proteins
  - Carriers or Channels
  - Each carrier and channel has a unique tertiary shape and therefore is designed to transport a different substance across a membrane
    - the cell can control the movement of polar molecules through a membrane by controlling the activity of the transporting proteins


MEMBRANE TRANSPORTERS
Channel proteins create a water-filled pore
ECF
Cell membrane
ICF
can be classified
Gated channels
Open
Closed
Open channels
Carrier proteins never form an open channel between the two sides of the membrane
Carrier open to ICF
Same carrier open to ECF
can be classified
Cotransporters
Uniport carriers
Glu
Symport carriers
Na+
Glu
Antiport carriers
Na+
ATP
K+
ATP

Channels

- Integral membrane proteins containing a water filled hole (pore) which allows the movement of very small polar substances (ions and water)
  - **passively** transport polar substances very quickly across membrane **down** their respective concentration gradient
  - some channels have “gates” which can be:
    - open
      - allows substance to cross
    - closed
      - does **not** allow substance to cross
  - channels that do not have gates are always open and are considered to be “leaky” channels

Carriers

- Integral membrane proteins that "carry" 1 or more small polar substances (monosaccharides, amino acids, nucleotides…)
- The movement of only one substance across a membrane is called **uniport**
- The movement of more than one substance across a membrane is called **cotransport**
- change their shape between 2 conformations
  - "flip-flop" between being open to the ECF and ICF
  - transport substances much more slowly across a membrane compared to channels
    - the maximum rate at which these proteins can transport substances across a membrane is limited by how fast they can change shapes

Patterns of Transport by Carriers

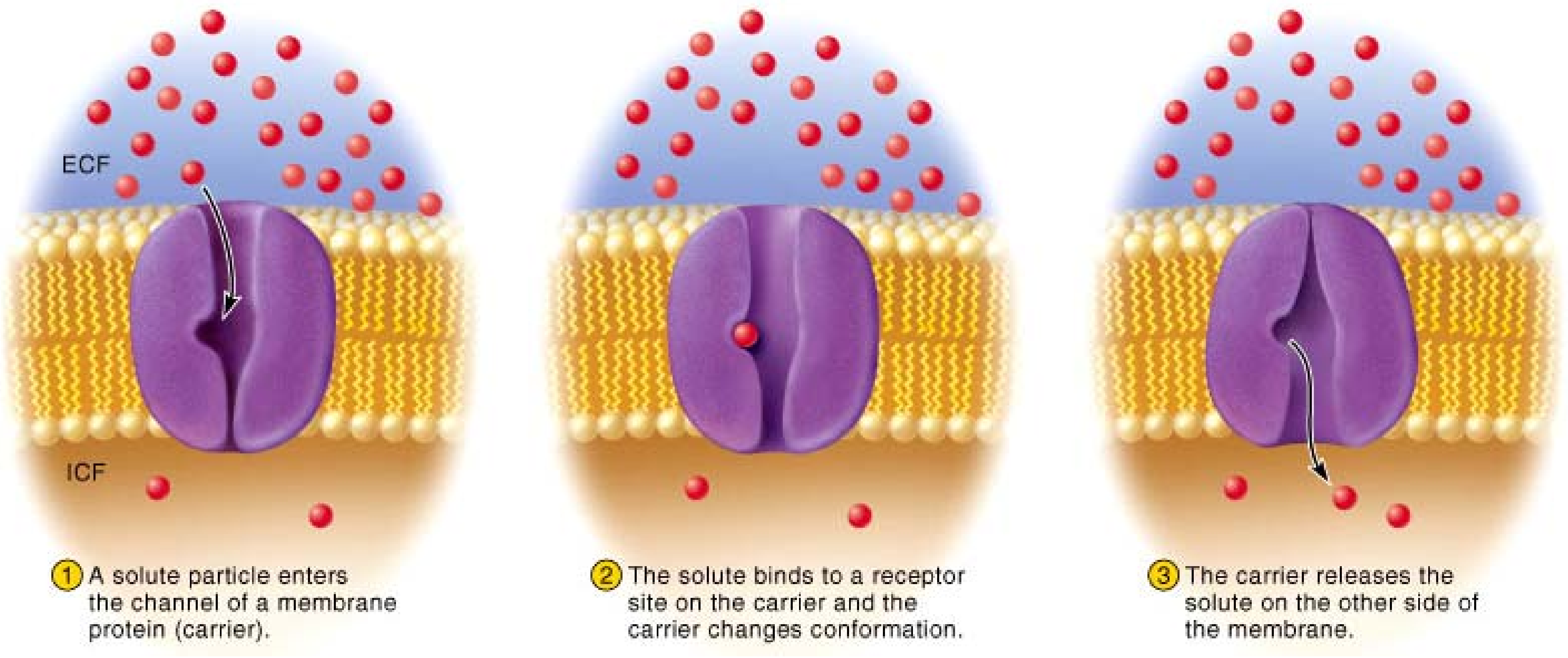
- Symport
  - 2 substances are moved in the same direction
- Antiport
  - 2 substances are moved in opposite directions
- Some carriers **passively** transport substances **down** their respective concentration gradient
- Other carriers **actively** transport substances **up** their respective concentration gradient
  - carriers called **pumps** hydrolyze a molecule of ATP and use the energy to pump substances across the membrane against the gradient
- Still other carriers **simultaneously** transport at least one substance up its concentration gradient and one substance down its concentration gradient

Passive Transmembrane Transport

- Movement a substance to move DOWN its gradient
- Releases energy as a result of the movement
- Nonpolar substances diffuse through the nonpolar **phospholipid bilayer** in a process called **simple diffusion**
- Polar molecules require the help (facilitation) of integral membrane proteins (channels or carriers) to cross the bilayer in a process called **facilitated diffusion**

- Diffusion does not occur if there is no gradient
  - **equilibrium**

Facilitated Diffusion through a Carrier

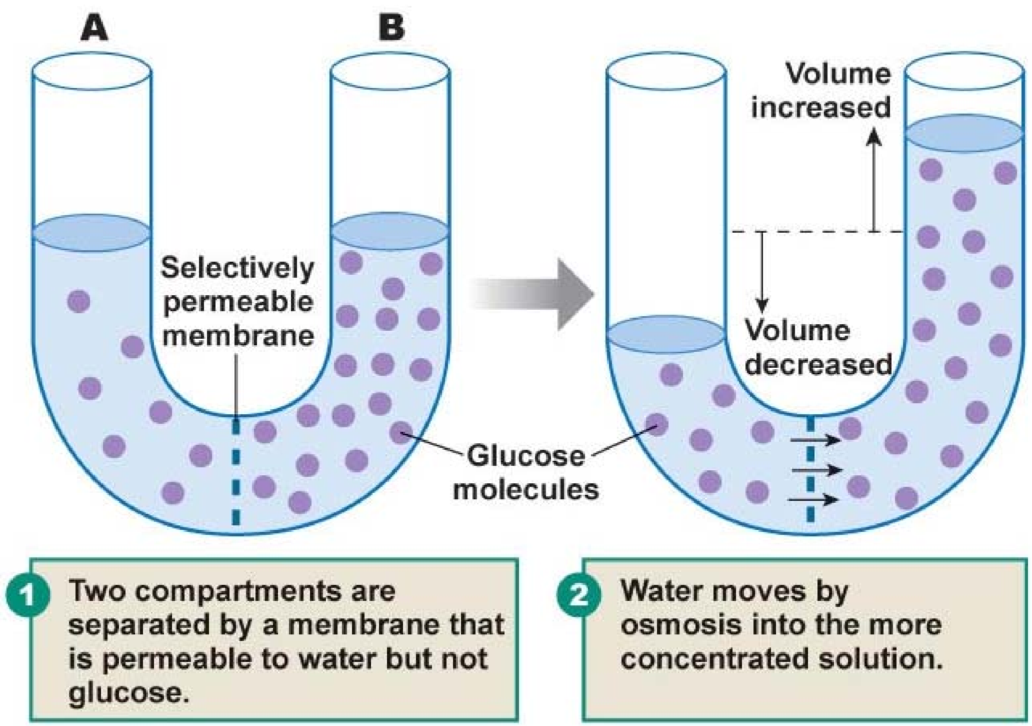


Factors Affecting the Rate of Diffusion

- The rate at which a substance moves by way of diffusion is influenced by 3 main factors
  - **Concentration gradient**
    - a large concentration gradient, results in a high rate of diffusion
  - **Temperature**
    - a high temperature, results in a high rate of diffusion
      - heat causes motion
  - **Size of the substance**
    - a large substance, has a low rate of diffusion
      - larger objects move more slowly

Osmosis

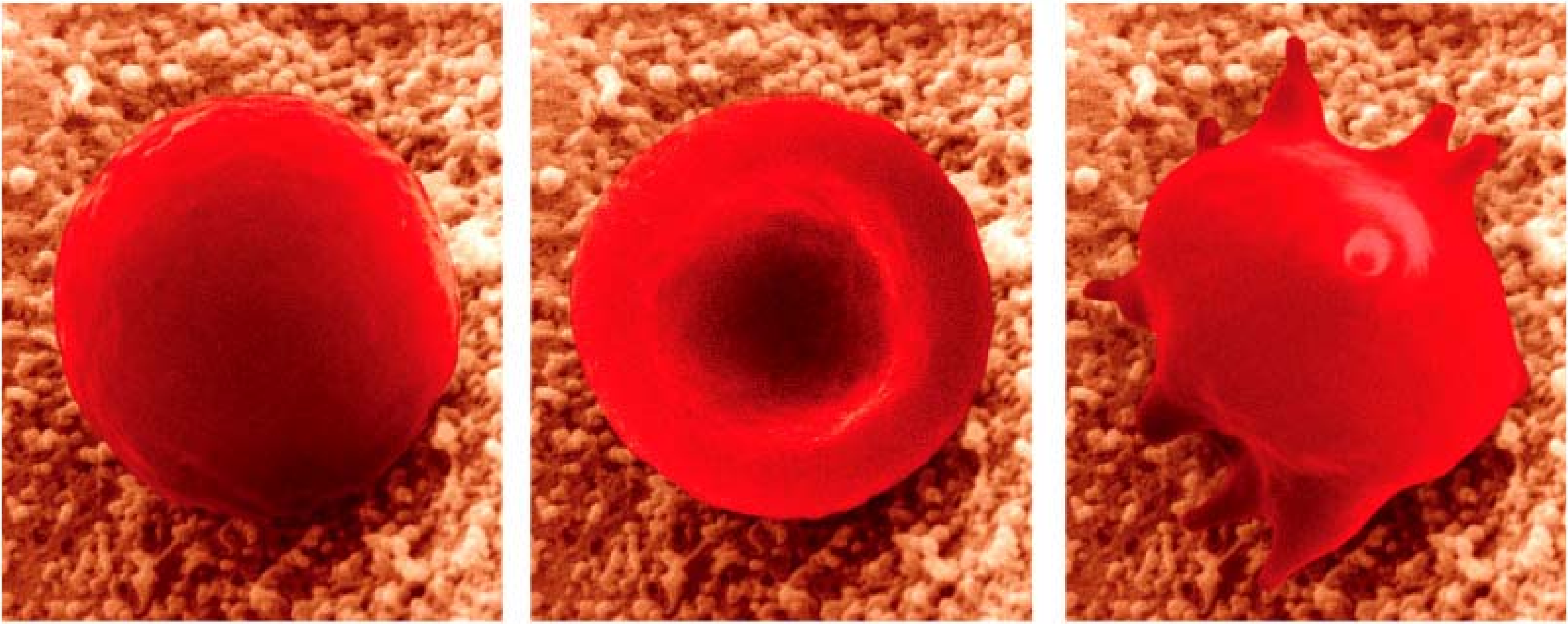
- The diffusion of water (solvent) across a selectively permeable membrane is called **osmosis**
  - requires "water channels" called **aquaporins**
- Solutes generate a force (osmotic pressure) that "pulls" water molecules toward the solutes
  - the greater the osmotic pressure, the greater the amount of water movement



Tonicity

- The difference in the total solute concentration of the ECF vs. the ICF determines the direction and extent of osmosis across the plasma membrane
- If the total solute concentration of the ECF = ICF, then the ECF is considered an isotonic (same) solution
  - water does not move into or out of cell causing **no change in the cell volume**
- If the total solute concentration of the ECF > ICF, then the ECF is considered a hypertonic (more) solution
  - water diffuses out of the cell causing the cell to **shrink** (**crenate**)
- If the total solute concentration of the ECF < ICF, then the ECF is considered a hypotonic (less) solution
  - water diffuses into the cell causing the cell to **swell**

Osmosis and cell volume changes



(a) Hypotonic (b) Isotonic (c) Hypertonic

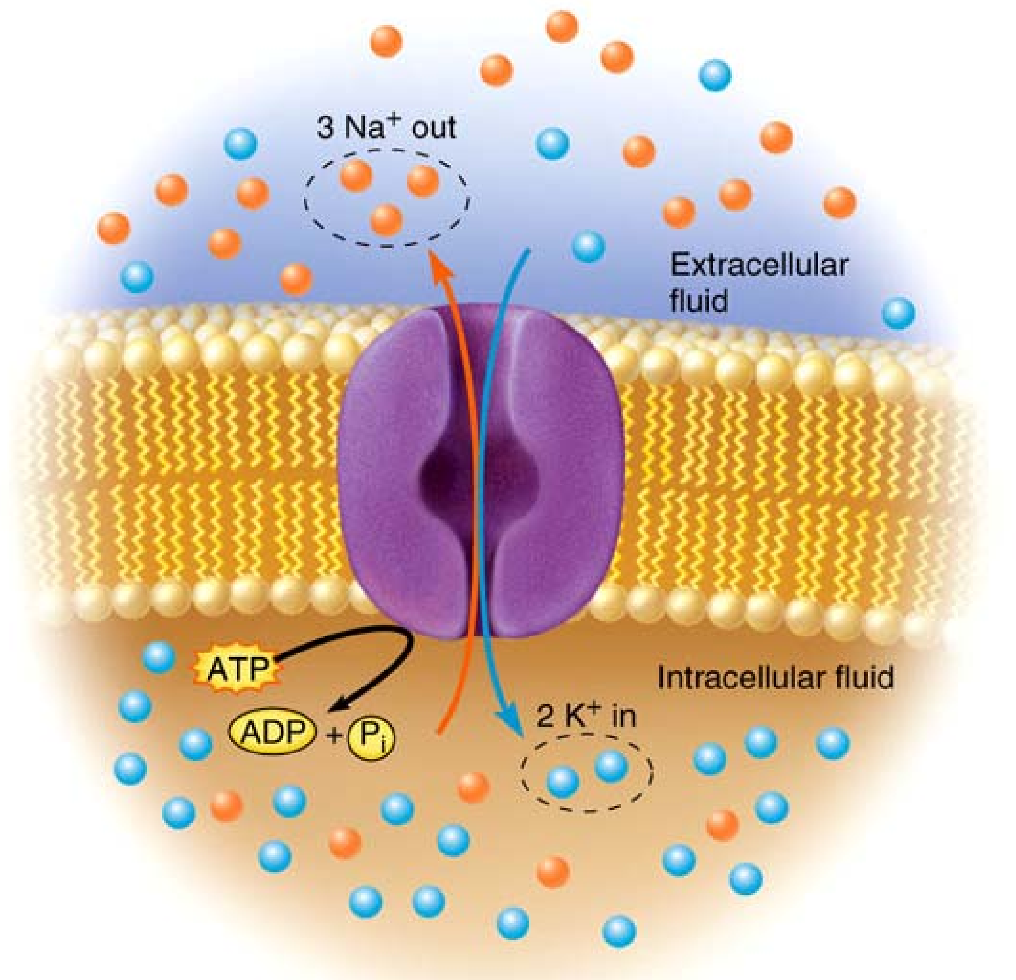
Primary Active Transport

- Integral membrane pumps use the energy stored in a molecule of **ATP** to transport substances across a membrane **UP** a concentration gradient
  - The pump:
    - hydrolyzes the high energy bond in a molecule of ATP (releasing energy)
    - uses the energy of ATP hydrolysis to “flip-flop” between conformations while moving substances **UP** a concentration gradient

- This process converts chemical energy (ATP) to mechanical energy (gradient across the membrane)
  - the gradient can be used if necessary by the cell as a form of energy to do work

Sodium, Potassium ATPase

- **Na$^+$,K$^+$-ATPase** (Na$^+$,K$^+$ **pump**)
  - located in the plasma membrane
  - **actively** cotransports:
    - 3 Na$^+$ from the ICF (lesser amount) to the ECF (greater amount)
    - 2 K$^+$ from the ECF (lesser amount) to the ICF (greater amount)

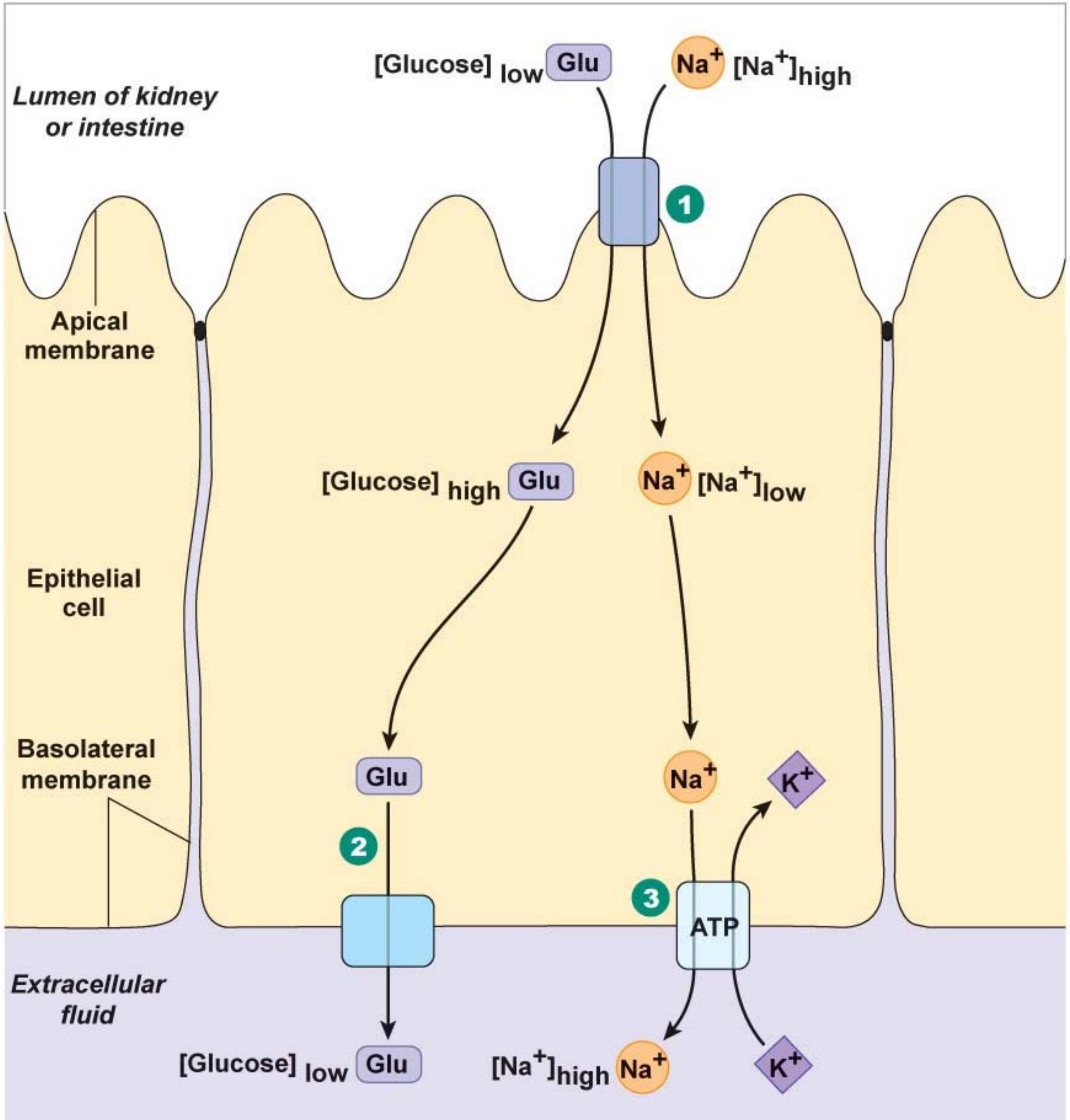


Secondary Active Transport

- Integral membrane carriers move at least 2 different substances across a membrane
  - One substance moves across a membrane **UP** a concentration gradient
  - One substance moves across a membrane **DOWN** a concentration gradient
  - The movements of the substance **DOWN** a concentration gradient releases energy which the carrier uses to “flip-flop” between conformations and move a second substance **UP** a concentration gradient
    - “piggyback” transport
- This type of transport is called secondary because this process is driven by a gradient that is created by a previous occurring primary active transport process

Secondary Active Transport

Na^+, Glucose Cotransporter



1. **Na^+- glucose symporter** brings glucose into cell against its gradient using energy stored in the Na^+ concentration gradient.

2. **GLUT transporter** transfers glucose to *ECF* by facilitated diffusion.

3. **Na^+-K^+- ATPase** pumps Na^+ out of the cell, keeping *ICF* Na^+ concentration low.