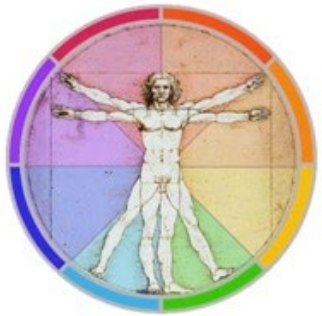
# HUBS 191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,
it is NOT a substitute for the lecture !



Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

# HUBS 191

Jeff Erickson – Department of Physiology

## Lecture 7
## Active Cell Physiology

# Objectives and Study Guide

*After this lecture you should be able to:*

- Understand the terms “diffusion” and “osmosis”.
- Predict how water will move across a membrane to balance tonicity.
- Understand chemical and electrical gradients and define the term “Resting Membrane Potential”
- Briefly describe what is occurring during a depolarization and repolarization.

Related reading: Martini et al. Modules **3.14** (p. 162), **3.15** (p. 164), and **11.7** (p. 456)

# Excitable cells use chemical and electrical gradients for rapid signalling events

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# Excitable cells use chemical and electrical gradients for rapid signalling events

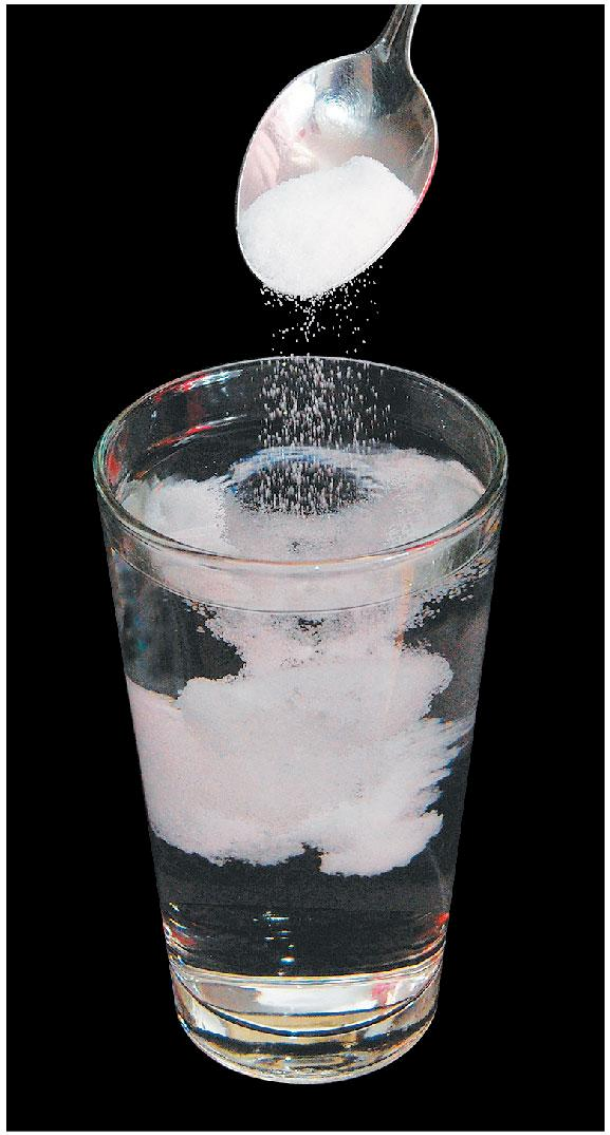
**What If Tiger???**

# Diffusion is the movement of molecules from high to low concentration

**Concentration Gradient**

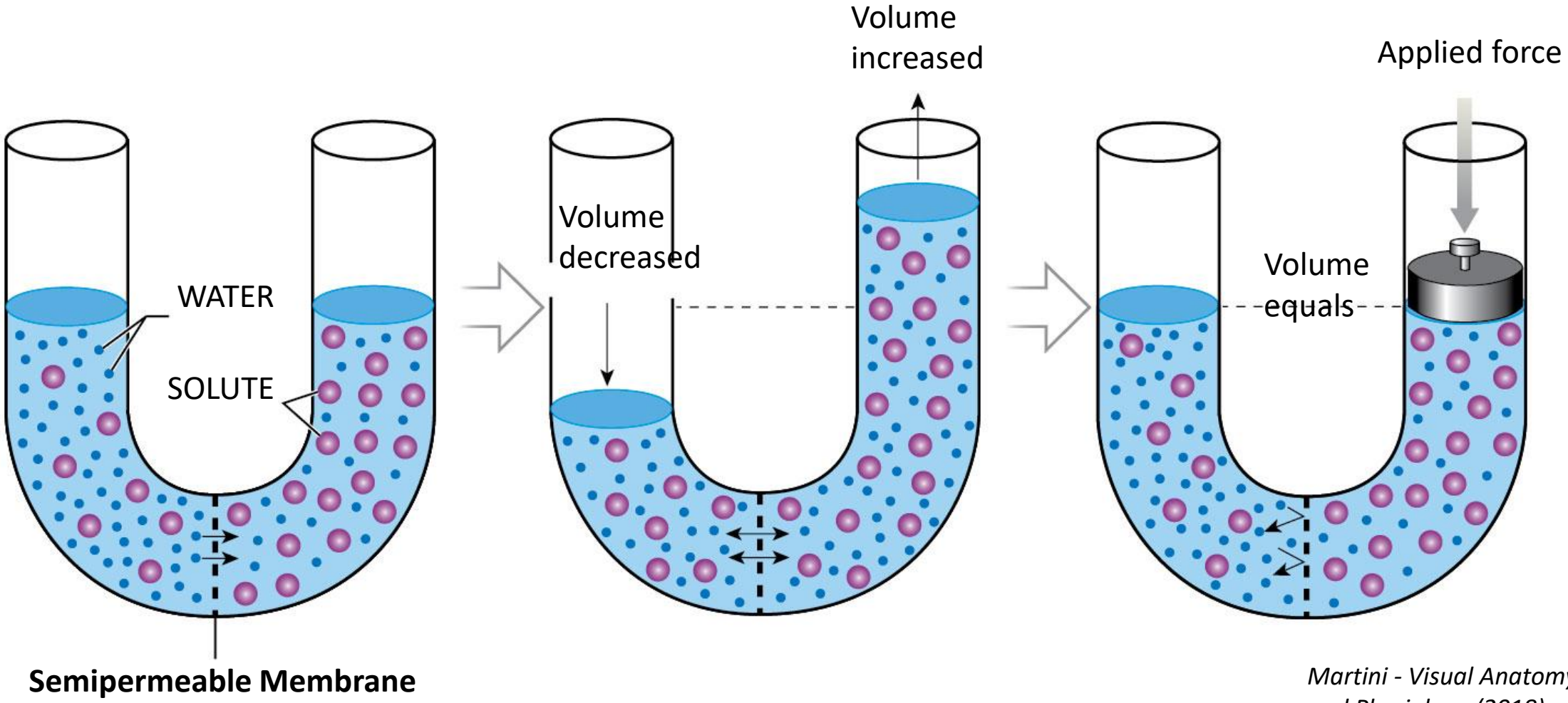
The glass has areas of high and low concentration of sugar

Through diffusion, the sugar will redistribute through the water to equalize concentrations



*Martini - Visual Anatomy and Physiology (2018) Module 2.5 p. 101.*

# Osmosis is the movement of water across a membrane to equalize solute concentration

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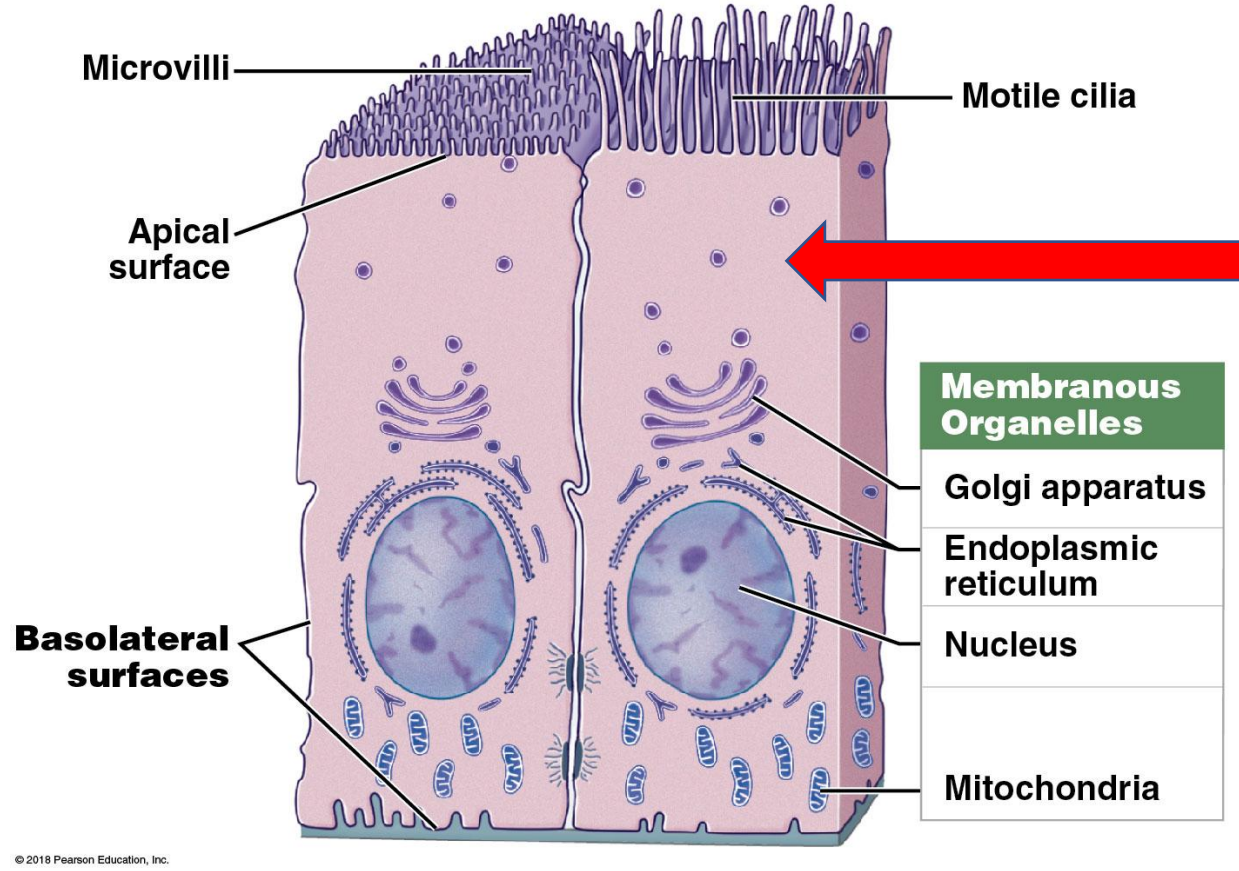
# The cell membrane divides our body fluid volumes into intracellular and extracellular spaces

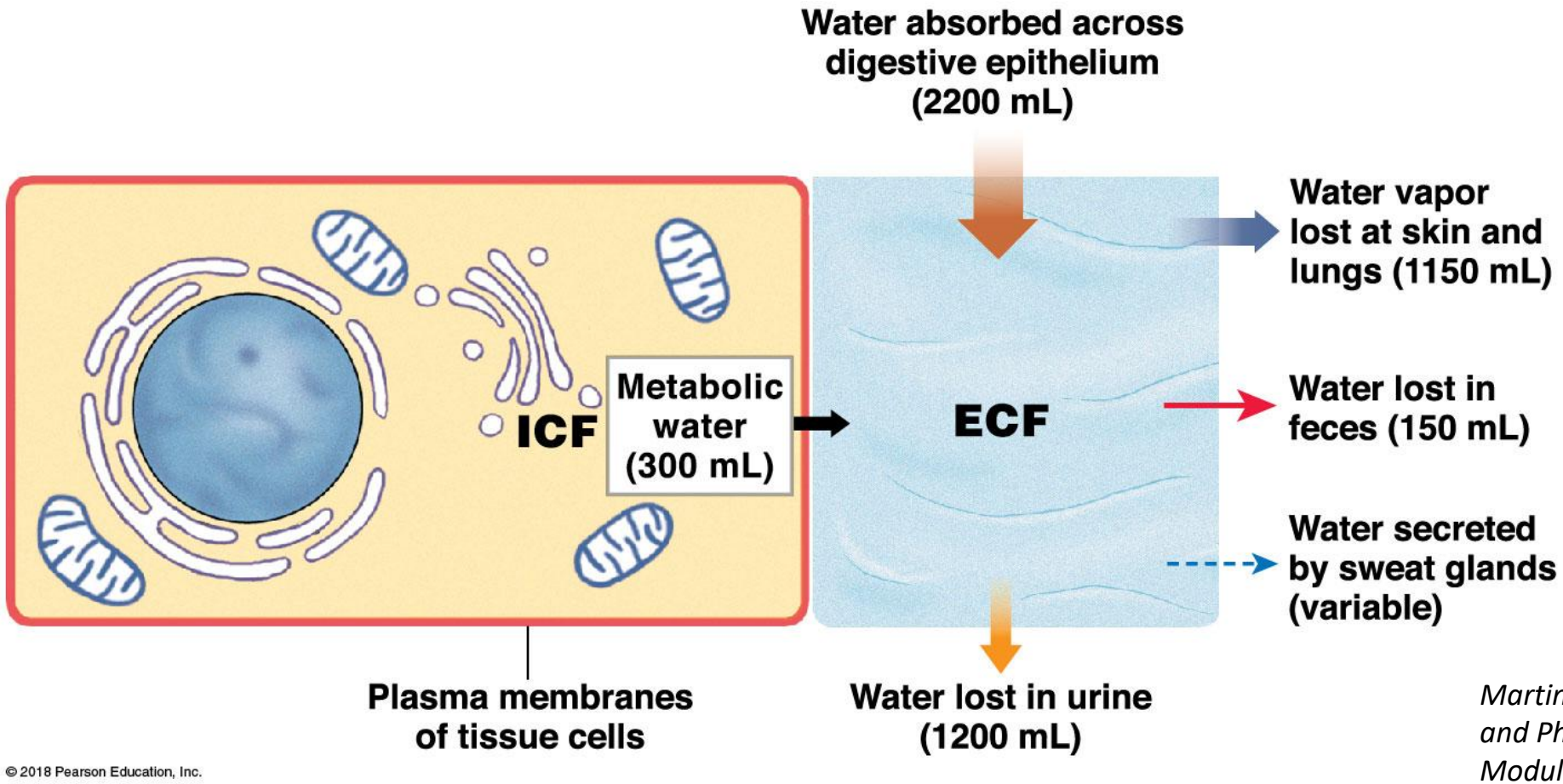
Extracellular Space




Intracellular Space

*Martini - Visual Anatomy and Physiology (2018) Module 4.3 p. 189.*

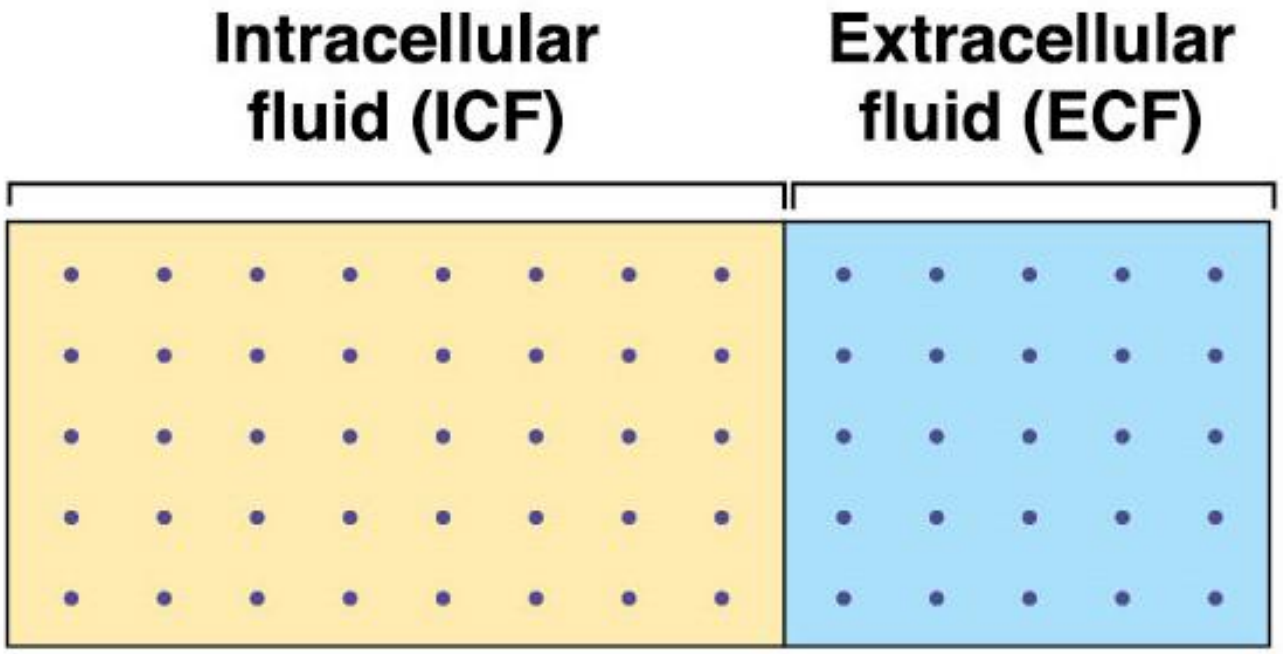
# Water concentration is dynamic on both sides of the membrane…




*Martini - Visual Anatomy and Physiology (2018) Module 25.2 p. 1017.*

…as is the concentration of solutes and ions!

# Osmosis works to balance tonicity between the intracellular and extracellular spaces




**The ECF and ICF are in balance, with the two solutions isotonic.**

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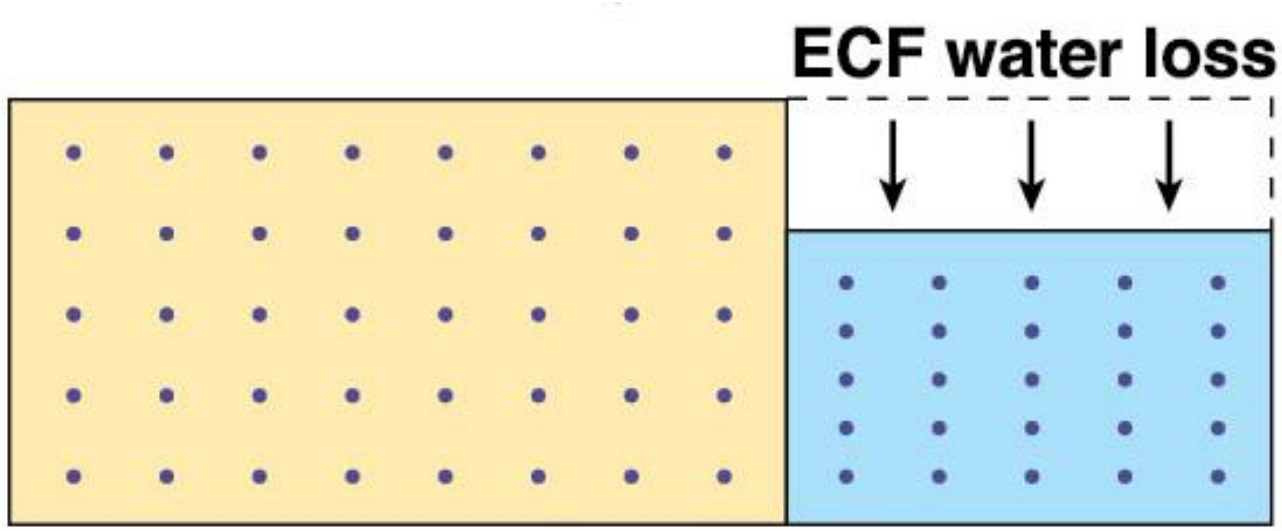
**ISOTONIC**

# Osmosis works to balance tonicity between the intracellular and extracellular spaces




**HYPERTONIC**

**Water loss from ECF decreases volume and makes this solution hypertonic with respect to the ICF.**

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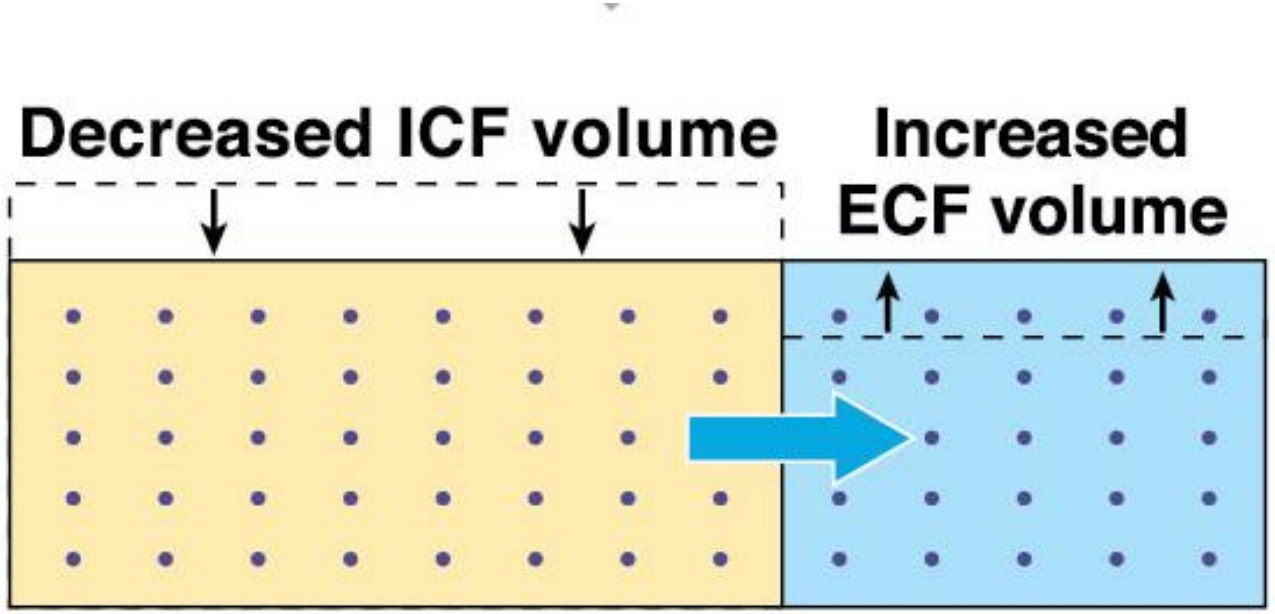
# Osmosis works to balance tonicity between the intracellular and extracellular spaces




**An osmotic water shift from the ICF into the ECF restores osmotic equilibrium but decreases the ICF volume.**

**ISOTONIC**

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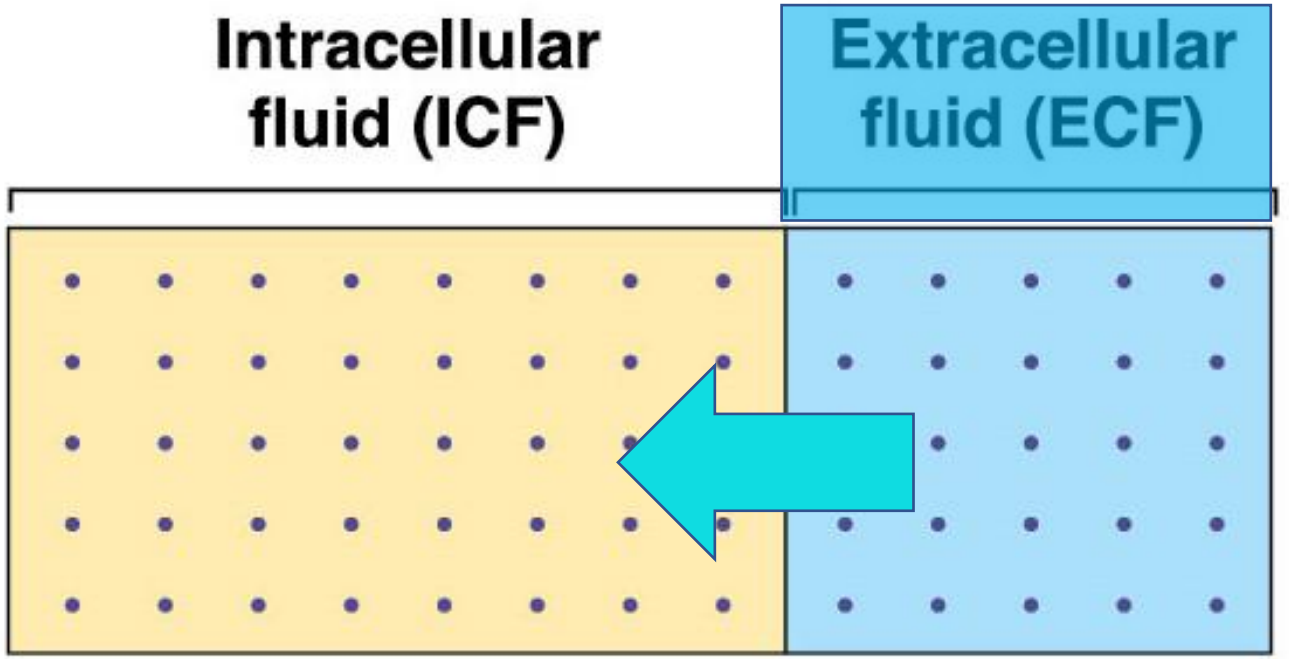
Water moves from the side with low concentration to the side with high concentration

# Osmosis works to balance tonicity between the intracellular and extracellular spaces

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# Did you catch it?


Credit: Adam Japko

- What is osmosis?  How is it different from normal diffusion?
- What do the terms isotonic, hypertonic, and hypotonic mean?
- If there is an imbalance of water and solute concentrations on each side of the cell membrane, what will happen?

# Gummy Bears vs. Osmosis

Before exposure to distilled water

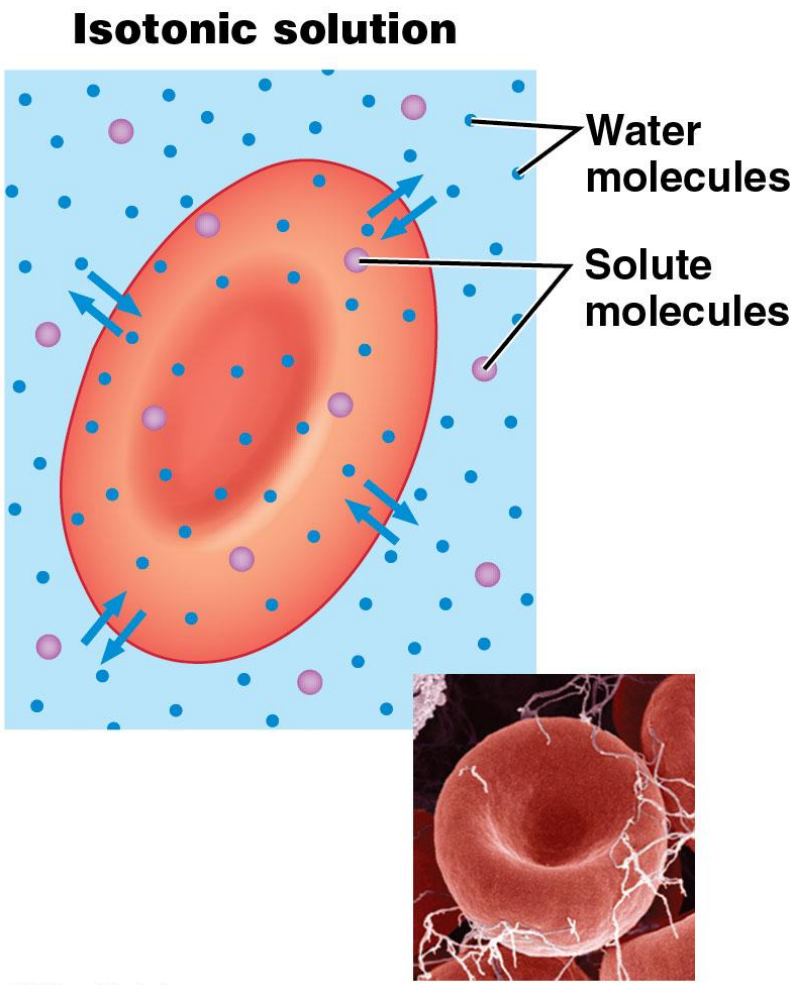
4 hours in distilled water

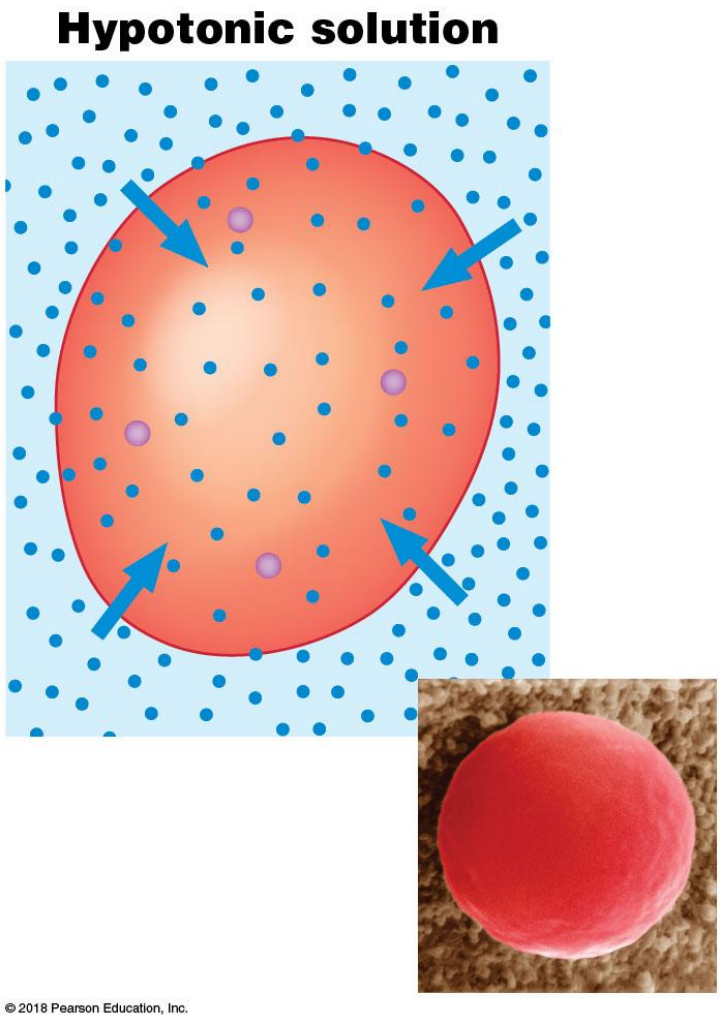
# Why do we administer IV saline or Ringer's solution to patients that need fluids instead of regular water?

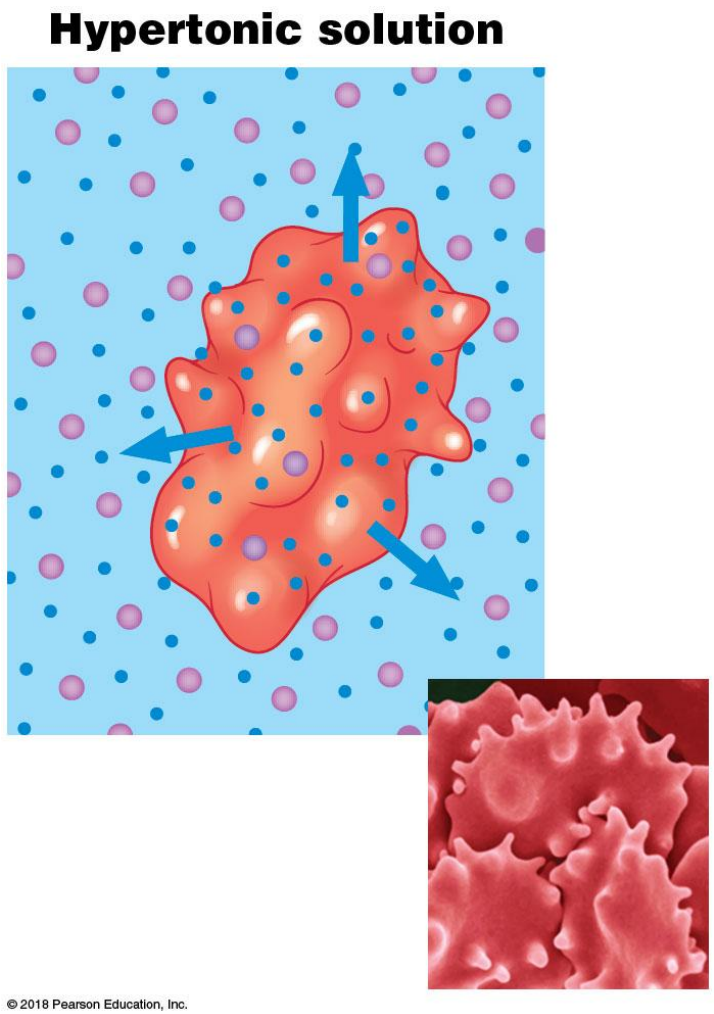
*Adobe Stock Images*

Tonicity! A saline or Ringer's solution is relatively isotonic compared to the intracellular fluids of your blood cells…perfect for preserving their osmotic balance.

# Imbalanced tonicity can affect the integrity of cells!

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# Over-consumption of water can lead to water intoxication and death

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## US woman dies after water contest

**A Californian woman who took part in a water-drinking contest to win a video game system has died of water intoxication, tests have shown.**

The contestants started on small bottles and worked up

Jennifer Strange had taken part in the "Hold Your Wee for a Wii" game run by KDND 107.9 radio in Sacramento, which promised the winner a Nintendo Wii.

A work colleague said Ms Strange had reported her head was hurting hours after the contest and was going home.

Ms Strange, 28, was found dead on Friday at her house in Rancho Cordova.

### Health warning

Local assistant coroner Ed Smith said initial tests showed death was "consistent with water intoxication".

Contestants were first given eight ounce (225 millilitre) bottles to drink every 15 minutes.

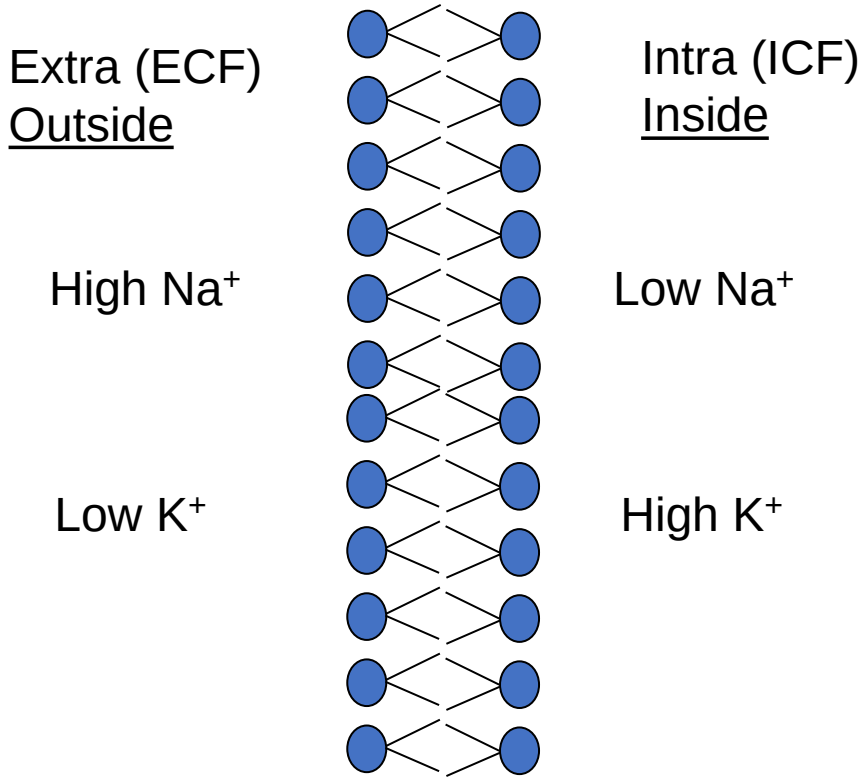
Credit: BBC News

# *Example exam question*

If a cell has intracellular and extracellular fluids that are equally matched in water and solute concentrations, what term describers their osmotic state?

A. Hypertonic
B. Exotonic
C. Isotonic
D. Hypotonic

# Uneven distribution of molecules across the membrane creates a “chemical gradient”




Both the $Na^+$ and $K^+$ are imbalanced

# Uneven distribution of charges across the membrane creates an “electrical gradient”

CATIONS

+

Sodium $Na^+$
Potassium $K^+$
Calcium $Ca^{2+}$

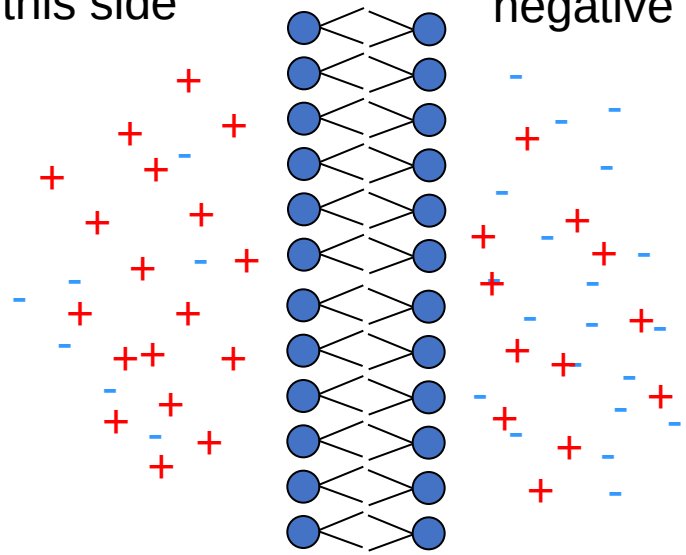
ANIONS

Chloride $Cl^-$
Proteins

−

Slightly more positive this side

Slightly more negative this side



The cell membrane resists ionic flow

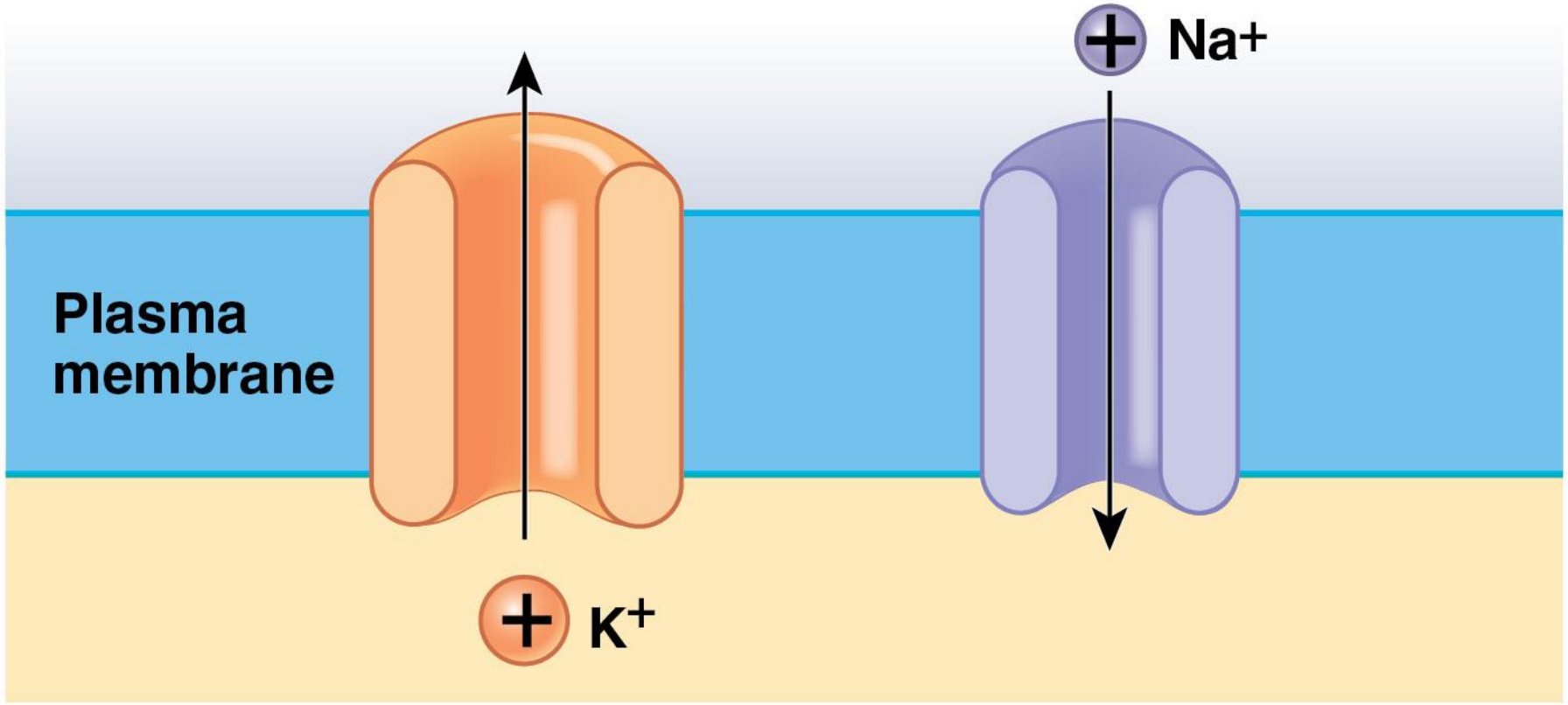
# Chemical and electrical gradients allow rapid signalling in excitable cells

- Ions are highly driven to move down their concentration and electrical gradients…to equilibrate the inside and the outside of the cell.
- But they can't! The cell membrane is semi-permeable and won't allow the ions through.
- The moment a pathway opens, the ions will rush in/out along their gradient.
- The bigger the gradient, the faster and stronger the signal!

# Passive ion channels allow the movement of ions down their chemical/electrical gradients

Extracellular

Intracellular

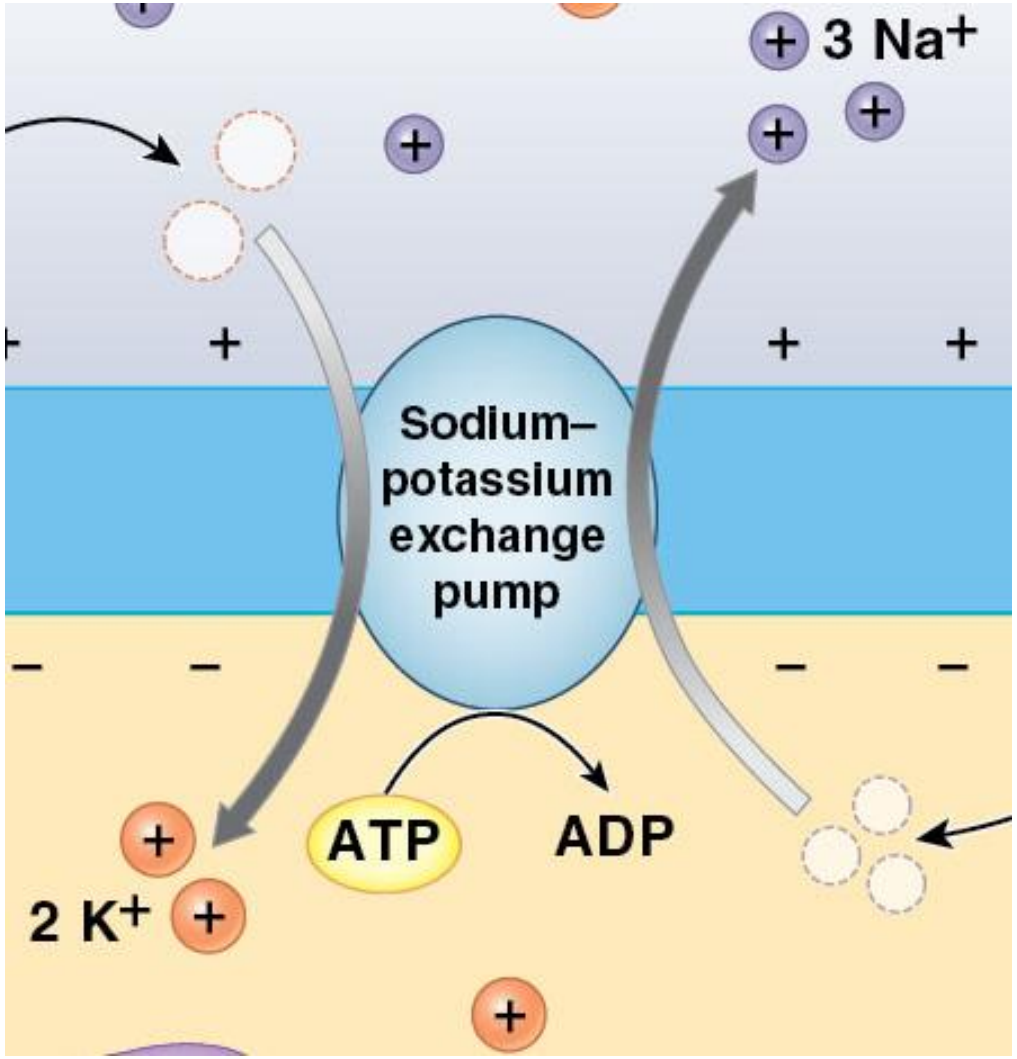





*Martini - Visual Anatomy and Physiology (2018) Module 11.7 p. 456.*

# The sodium-potassium exchange pump maintains the chemical and electrical gradients across the cell membrane

- The sodium-potassium exchange pump is an ACTIVE pump, meaning it uses energy (ATP) to move molecules.
- It has to be active, because it's working against chemical and electrical gradients!
- It moves three sodium ions out of the cell and brings two potassium ions into the cell for every ATP used.
- This creates chemical gradients for both sodium and potassium, as well as maintaining the electrical gradient (more positives leaving the cell means more negative inside the cell)




High $Na^+$
Low $K^+$

High $K^+$
Low $Na^+$

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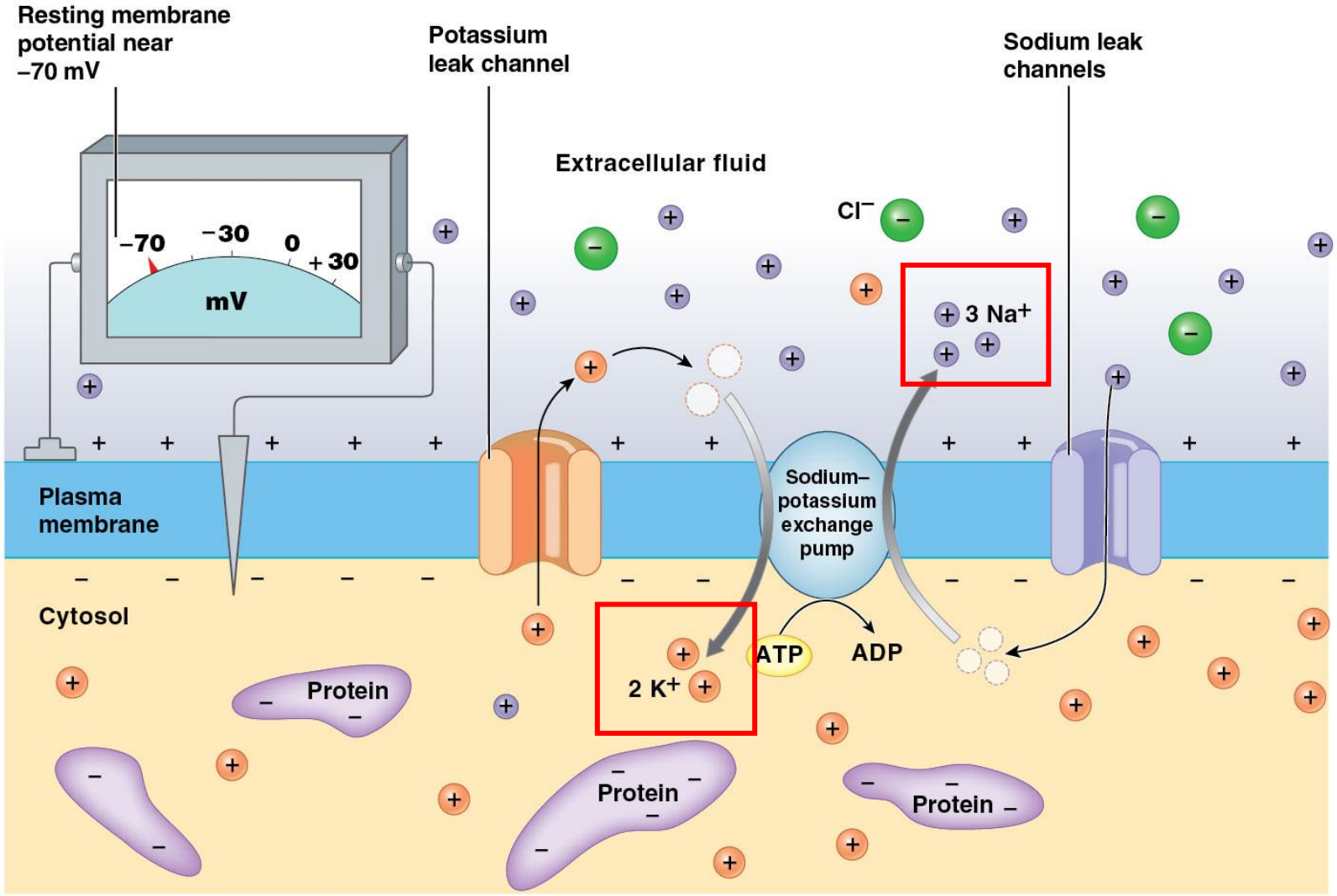
# At rest, the intracellular space has more negative charge than the extracellular space, creating an "electrical gradient":

## Resting Membrane Potential




High $Na^+$
Low $K^+$

High $K^+$
Low $Na^+$

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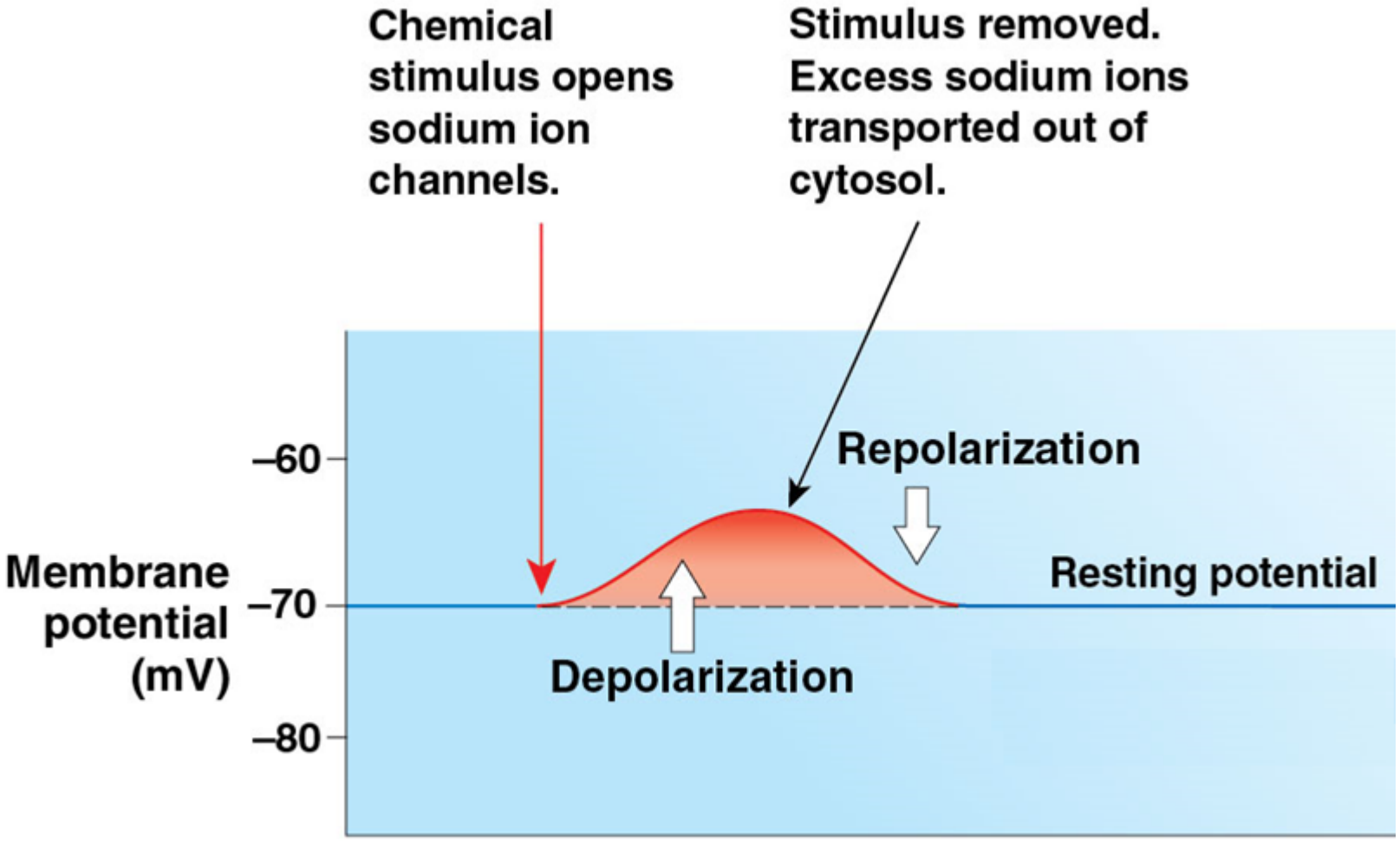
# Excitable cells (nerves, muscles) use the movement of ions as a signal via depolarization

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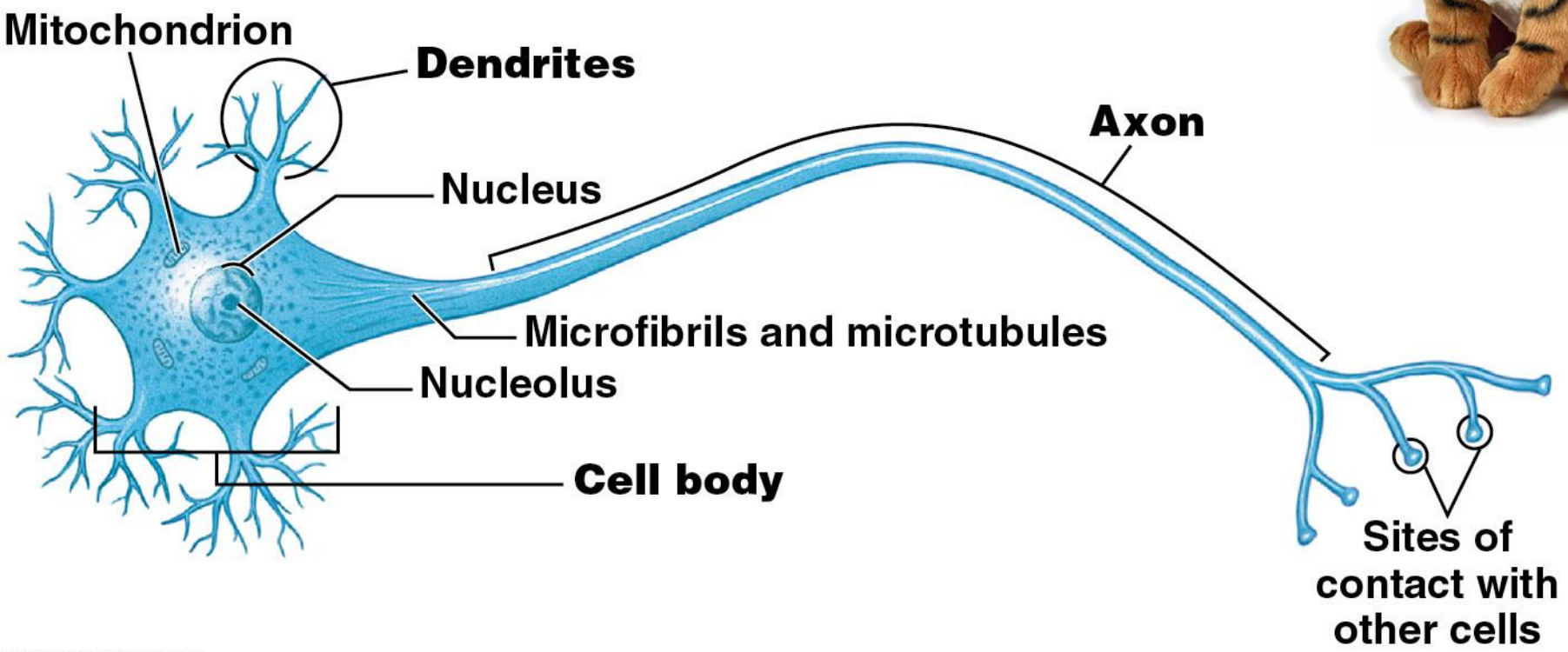
# What If Tiger?






Sodium channels open → Depolarization moves down the cell → Signal is passed to the next cell

# Did you catch it?

Courtesy: Giphy

- What are chemical and electrical gradients?  What is the resting membrane potential?
- At rest, where are the Na+ and K+ ions with respect to the intracellular and extracellular spaces? What gradients are created by the distribution of those ions?
- What is the difference between a passive channel and an active pump?
- What is a depolarization?  What is a repolarization?

# *Summary*

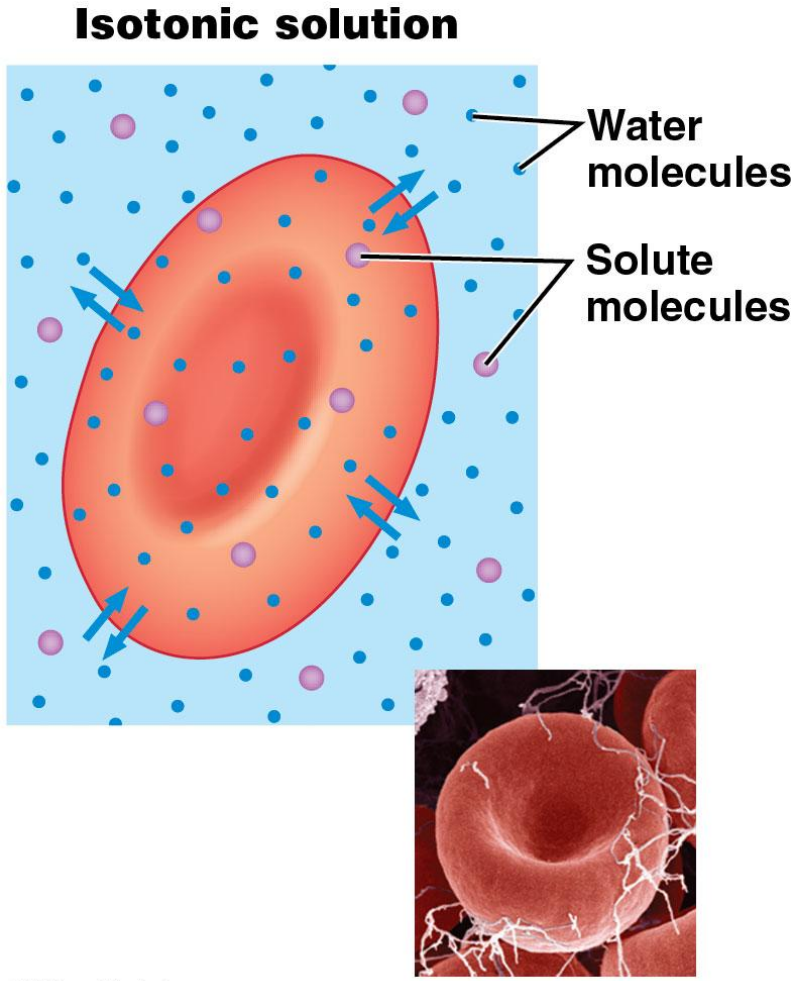
- Diffusion is the movement of molecules down a concentration gradient, while osmosis is the movement of water across a membrane to balance tonicity on both sides.

- Ions are distributed unevenly across the cell membrane at rest to create chemical and electrical gradients.

- At rest, the intracellular space is more negatively charged than the extracellular space. The electrical gradient when the cell is at rest is known as the resting membrane potential.

- Positive ions enter the cell during a depolarization, which acts as a signalling event for excitable cells. The positive ions are then removed during repolarization to return to the resting membrane potential.

# *Example exam question*






If the cell on the left was moved to a hypotonic solution of pure water, which of the following would be most likely to occur?

A. Solute molecules would move into the cell, making it heavier.
B. Water would move into the cell, making it swell.
C. Solute molecules would move out of the cell, disrupting its function.
D. Water would move out of the cell, making it shrivel.

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# HUBS191