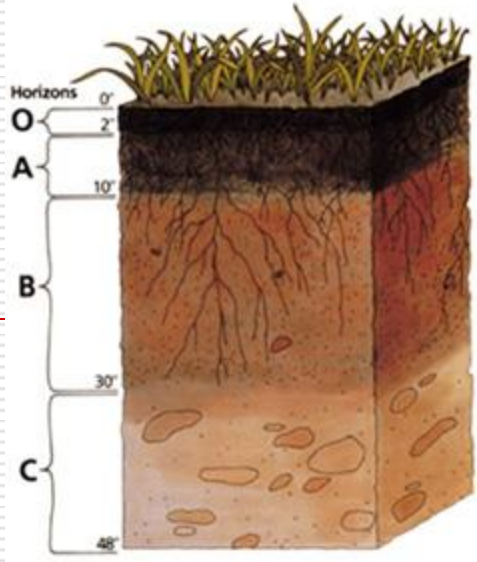
Title: Nutrient Movement Towards and Into Plant Roots

Speaker: Bill Pan

Unit 1, Lesson 4



Nutrient Movement Towards and Into Plant Roots

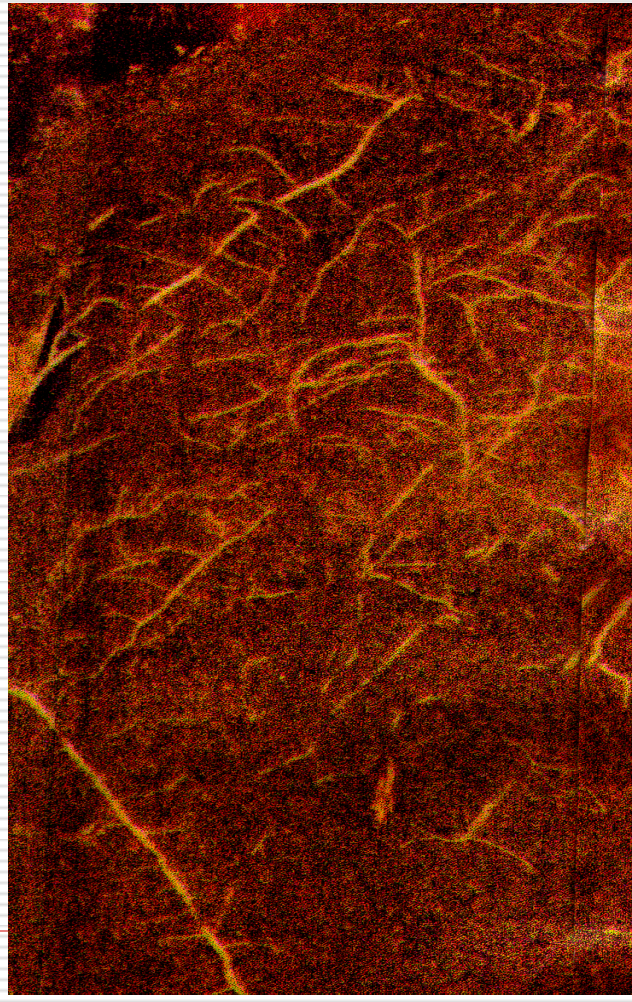
http://soils.usda.gov/education/resources/k_12/lessons/profile/

Learning Objectives

- Modes of nutrient movement to plant roots
- Ion uptake by plant roots
- Ion interactions affecting ion uptake

Nutrient Movement to Plant Roots

Ions in the soil solution in proximity to plant roots are immediately reactive and available for plant uptake.



Nutrient Movement ***to*** Plant Roots

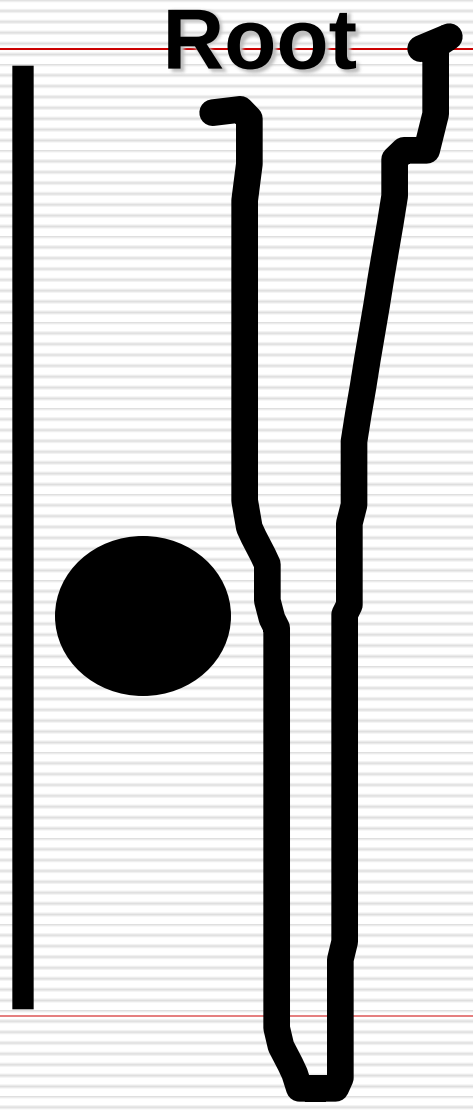
- **Root Interception**
- **Mass Flow**
- **Diffusion**

Root Interception

- **Sometimes referred to as "contact exchange."**
- **Immediate exchange of ions between the root and the adjacent soil colloids.**

Typically accounts for only a small percentage of total uptake.

Root Interception



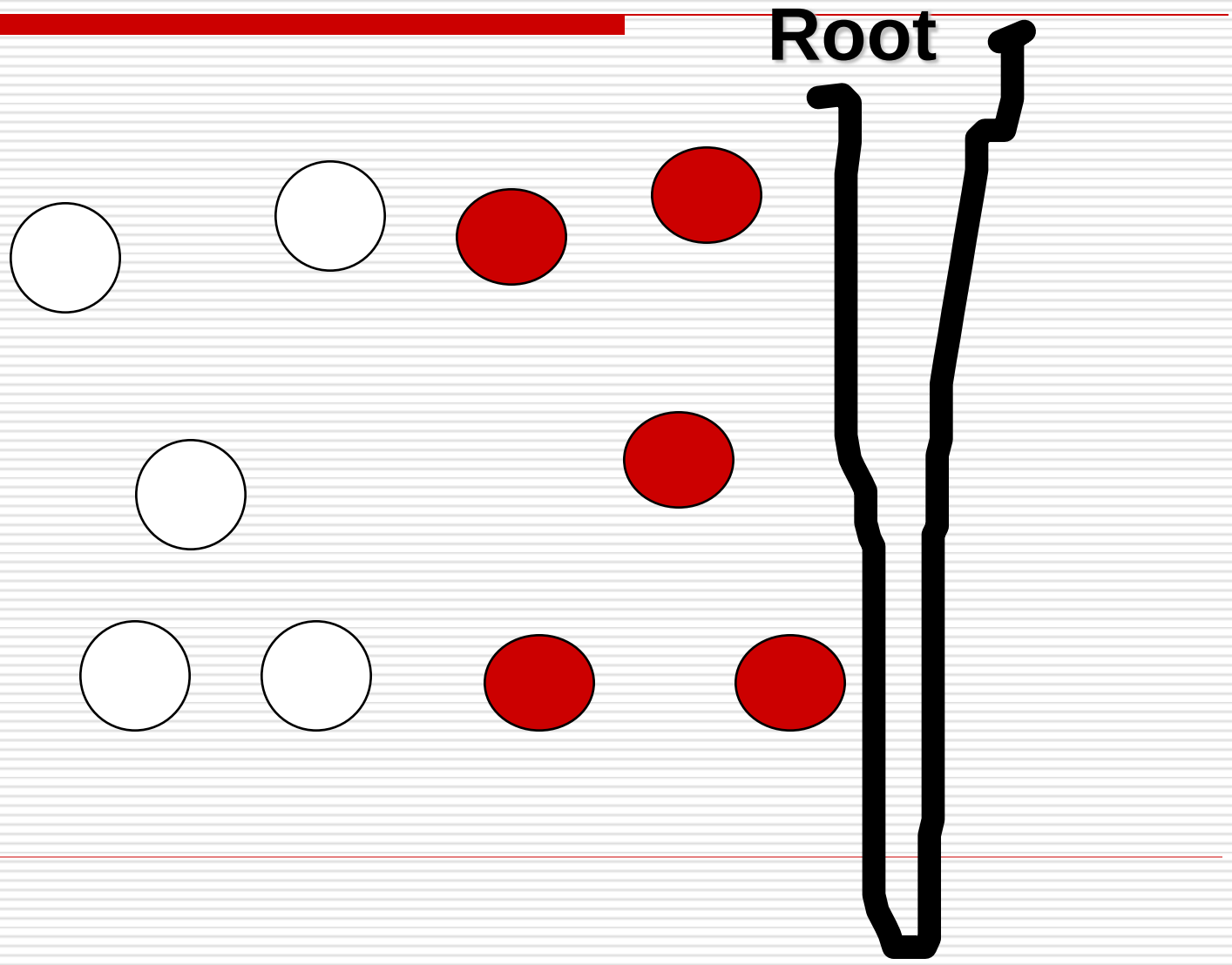
Soil Colloid

Mass Flow

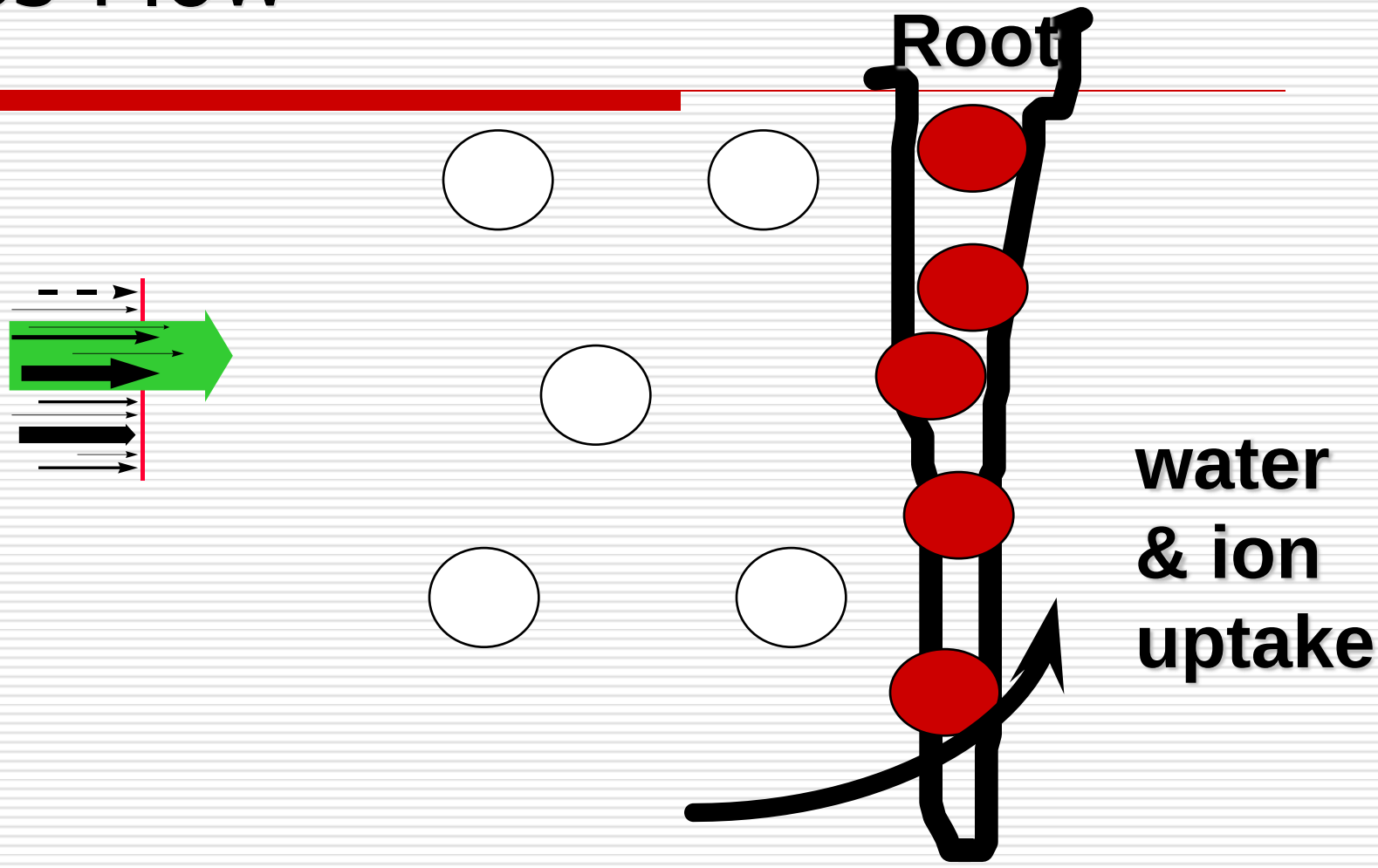
- **As plants absorb water, ions in solution travel with soil water to root surfaces.**
- **Typical ions that move via mass flow: Ca, Mg, NO_3.**
- **The amount transferred to roots via mass flow is calculated as:**

amount of plant water transpired
x nutrient concentration in solution

Mass Flow



Mass Flow



Diffusion

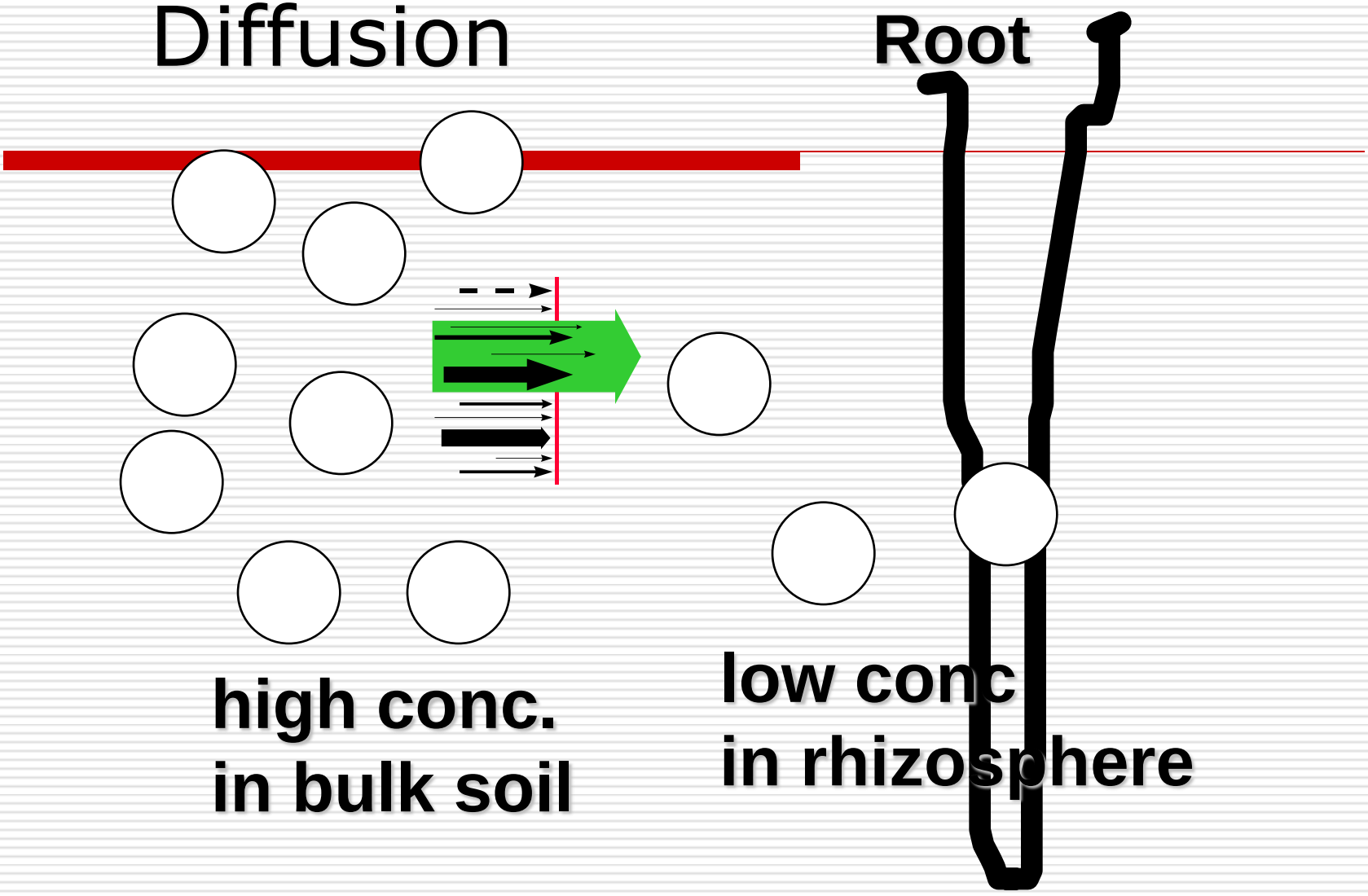
- **Migration of nutrients to root surface in response to a concentration gradient.**
- **The concentration of an ion in the bulk solution must be higher than the concentration in the rhizosphere.**
- **Typical ions that diffuse: P, K, NH_4.**

Definition:

<u>Rhizosphere:</u> The zone of soil immediately adjacent to plant roots in which the kinds, numbers, or activities of microorganisms differ from that of the bulk soil.

(usually extends about 2 mm from root surface)

Diffusion



Factors affecting diffusion

$$J = -D_l \times \Theta \times f_l \times \frac{dC_l}{dx}$$

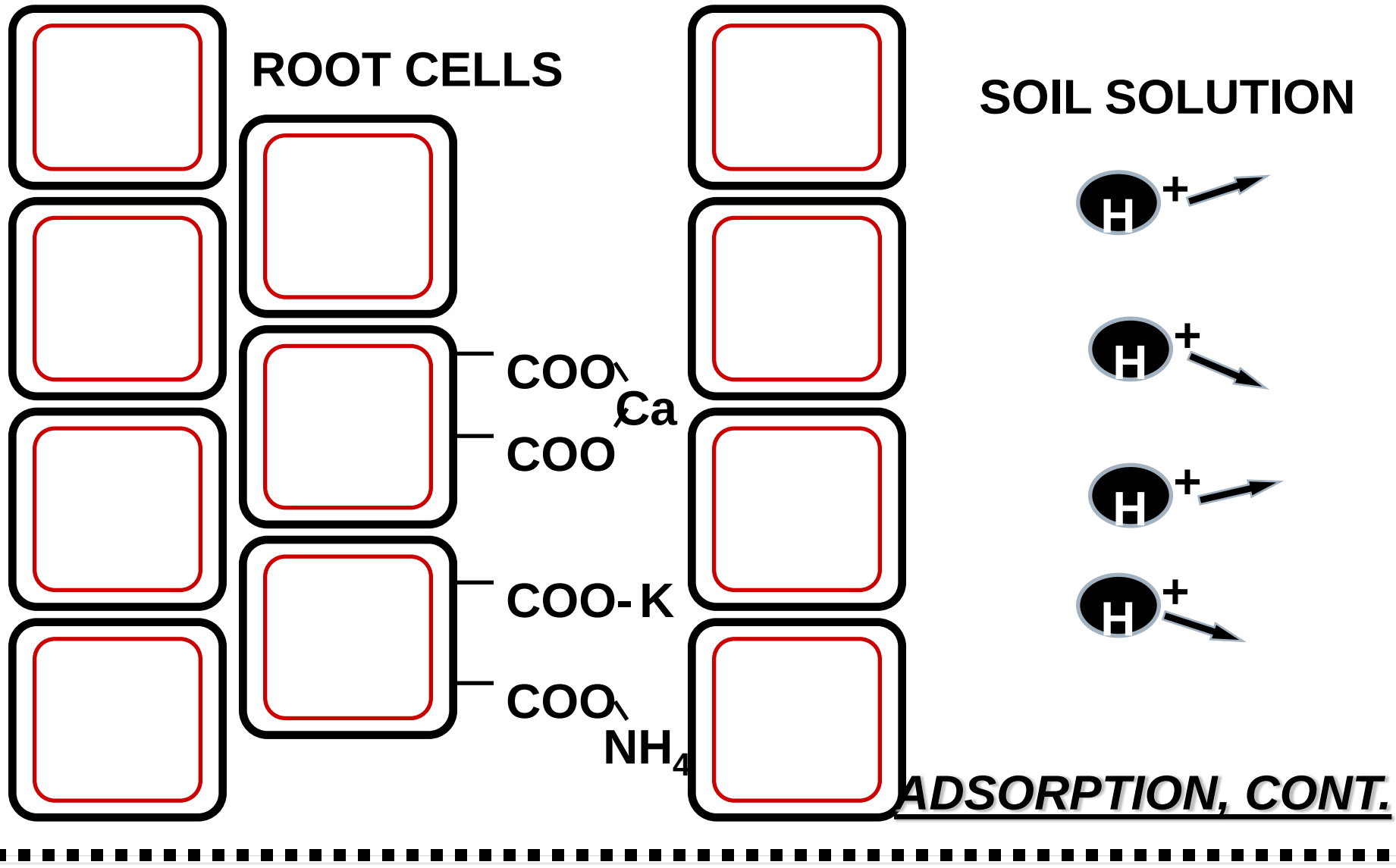
- J = diffusive flux
- D_l = diffusion coefficient
- Θ = soil water content
- f_l = tortuousity
- $\frac{dC_l}{dx}$ = concentration gradient

(Rate of ion Movement)

Relative Importance of Mechanisms of Ion Movement

Nutrient	Amt in 150 bu/A corn	Root interception	Mass Flow	Diffusion
		% of total		
N	170	1	99	0
P	35	3	6	94
K	175	2	20	78
Ca	35	171	429	0
Zn	0.3	33	33	33
B	0.2	10	350	0
Mn	0.3	33	133	0

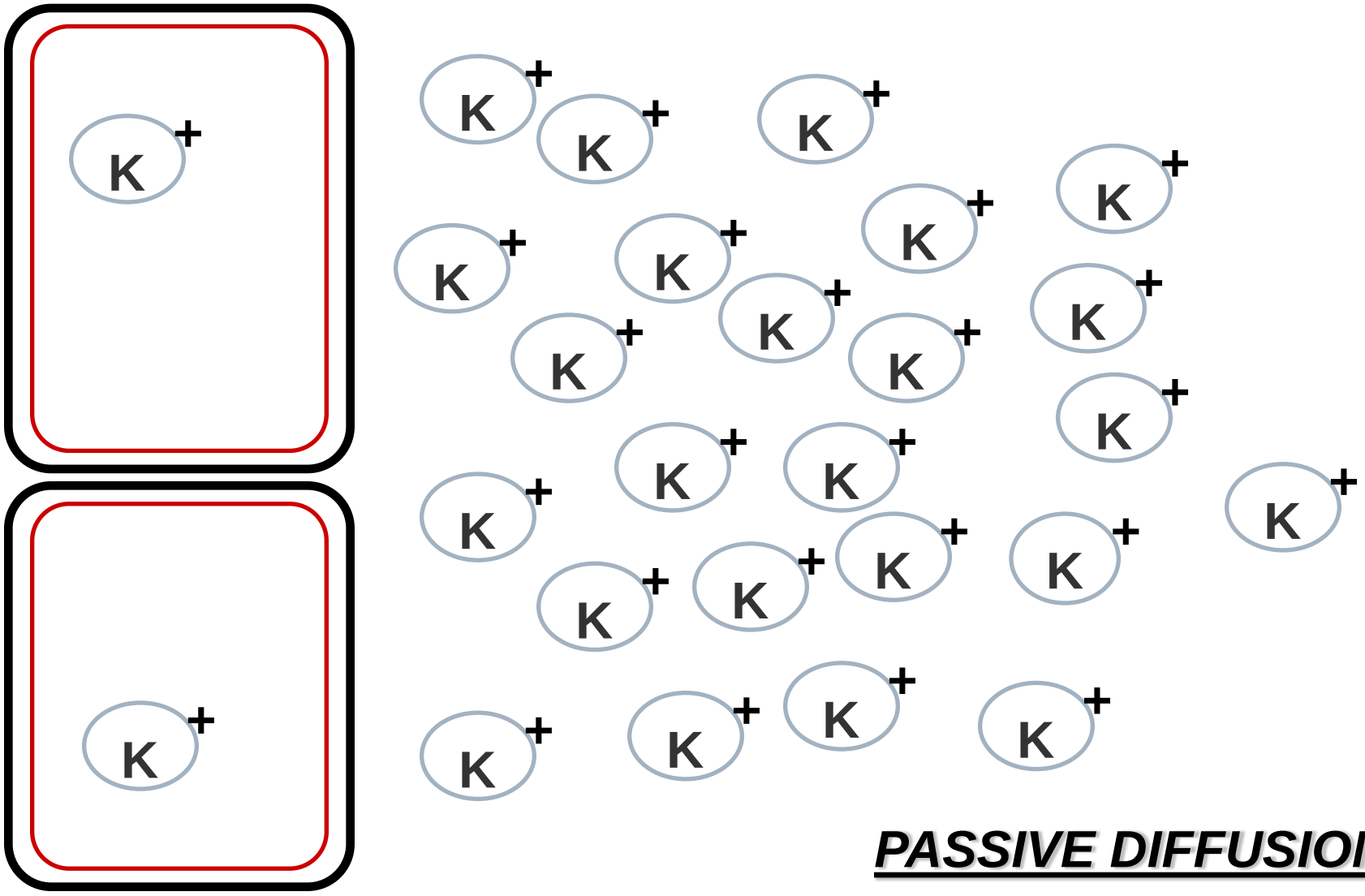
Nutrient Absorption by Plant Roots



ADSORPTION, CONT.

PHYSIOCHEMICAL DESCRIPTIONS, CONT.

2. ION ABSORPTION BY PASSIVE DIFFUSION is the ion entry into the root cell cytoplasm in response to electrochemical gradient between outer solution and cytoplasm across the plasmalemma. May or may not require direct expenditure of energy.


K+
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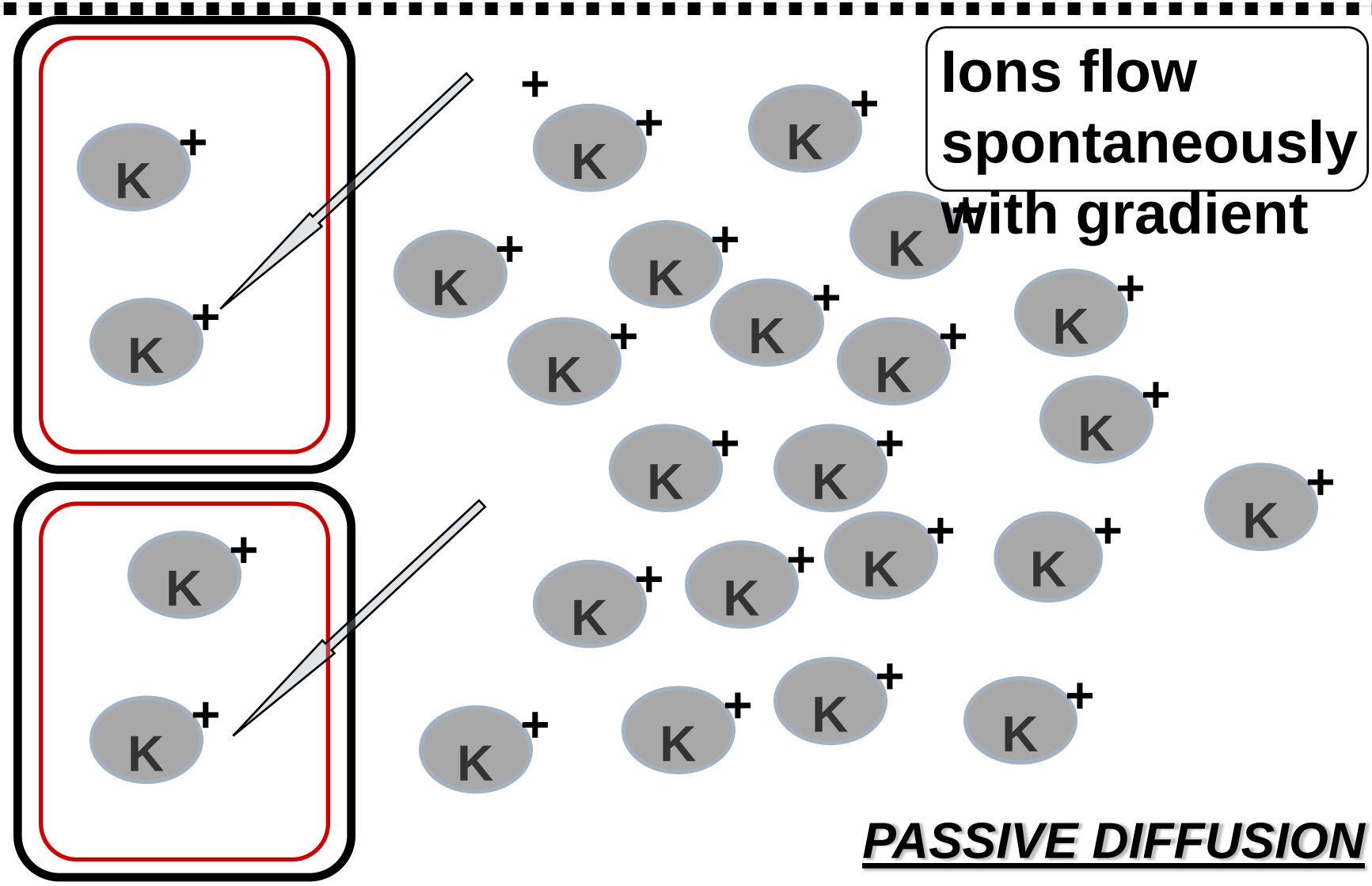
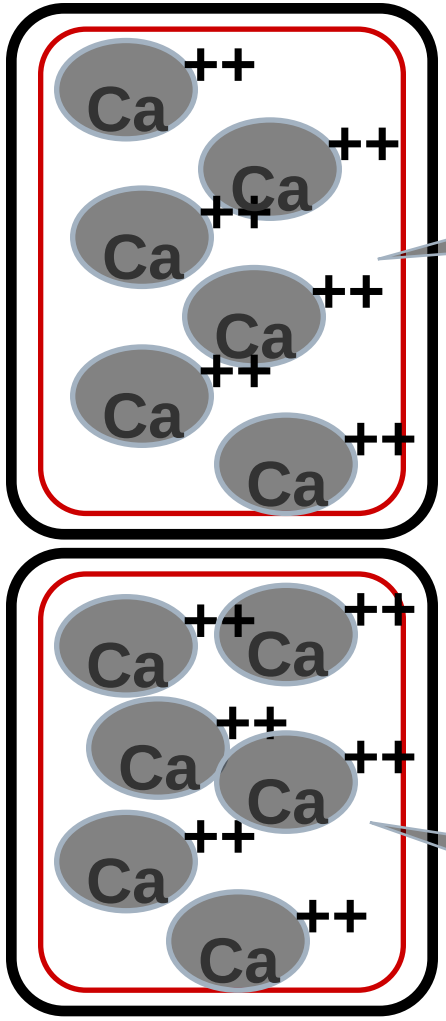
PASSIVE DIFFUSION

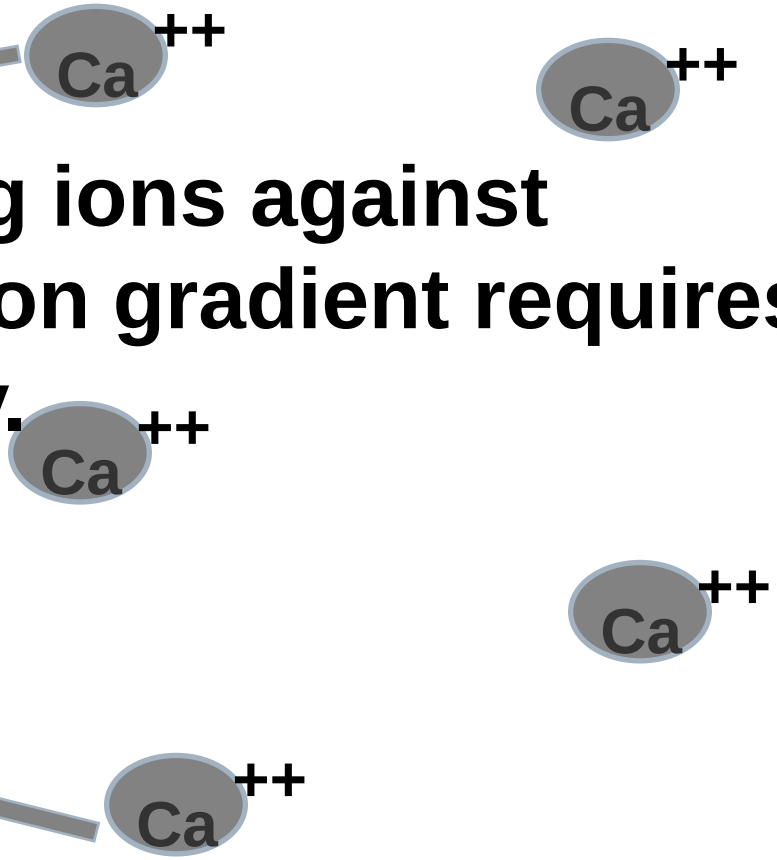

Ions flow spontaneously with gradient
PASSIVE DIFFUSION

PHYSIOCHEMICAL DESCRIPTIONS, CONT.

3. ACTIVE TRANSPORT against an electrochemical gradient.
   Always requires energy.



Moving ions against diffusion gradient requires energy.

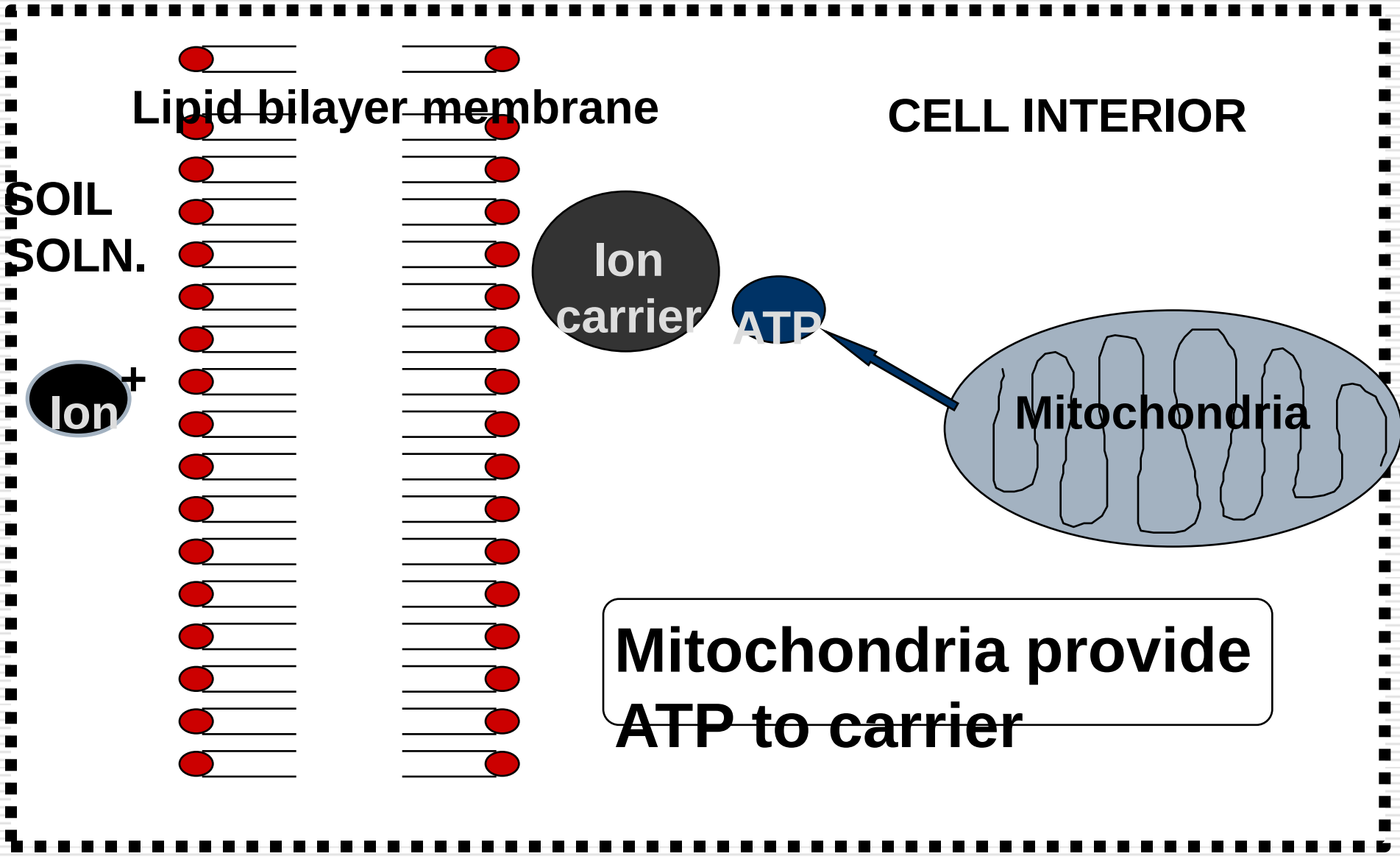


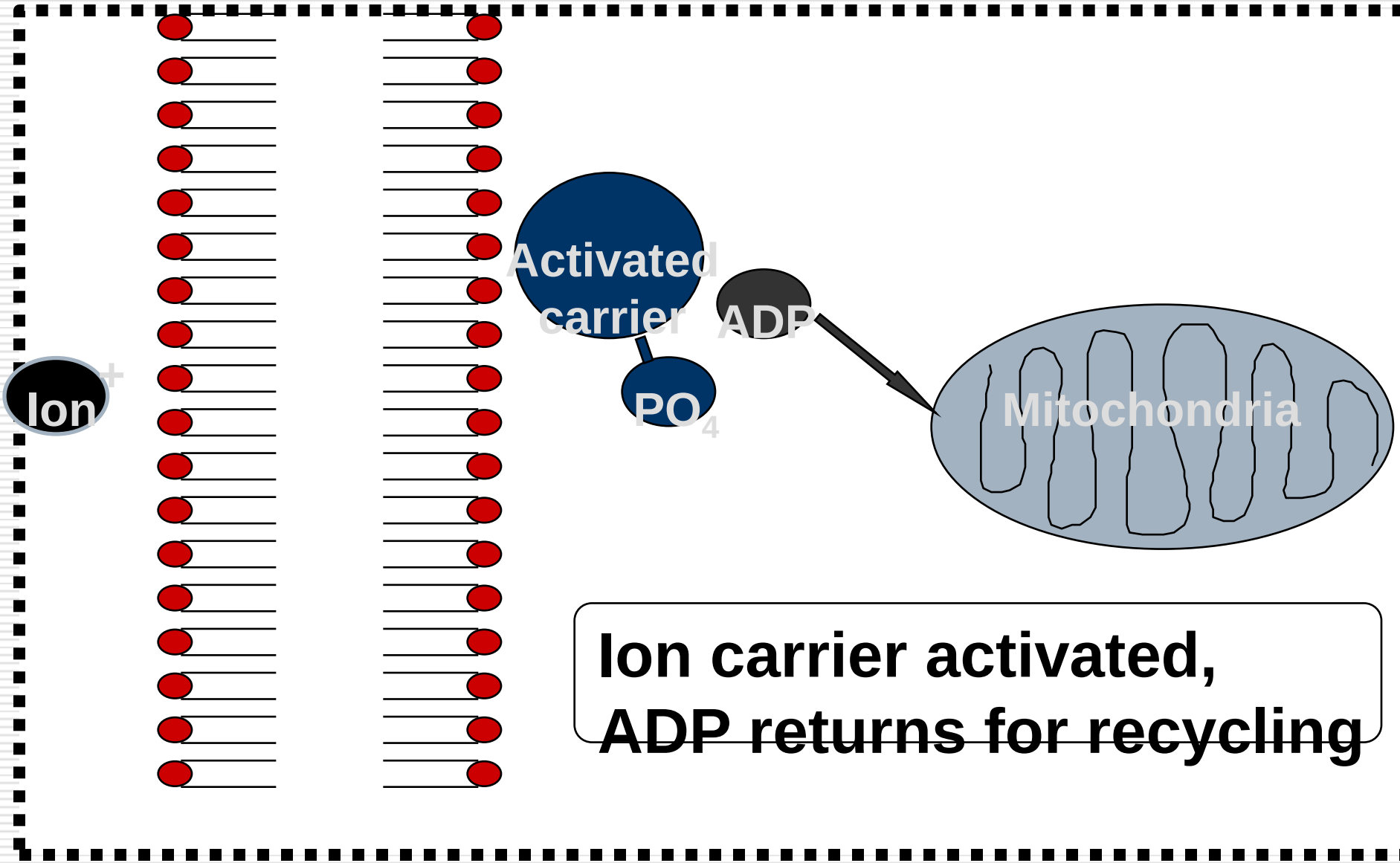
II. BIOCHEMICAL MODELS of ACTIVE TRANSPORT of ION ABSORPTION

1. CARRIERS
2. ION PUMPS
3. ION CHANNELS

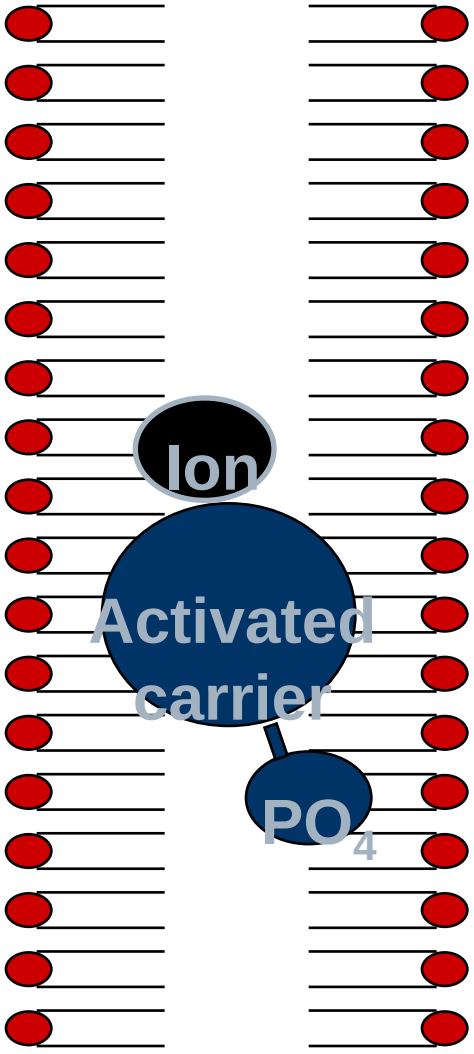
1. CARRIER MODEL

Carriers (metabolically activated ion binding compounds) provide passage through ion repelling lipid bilayer

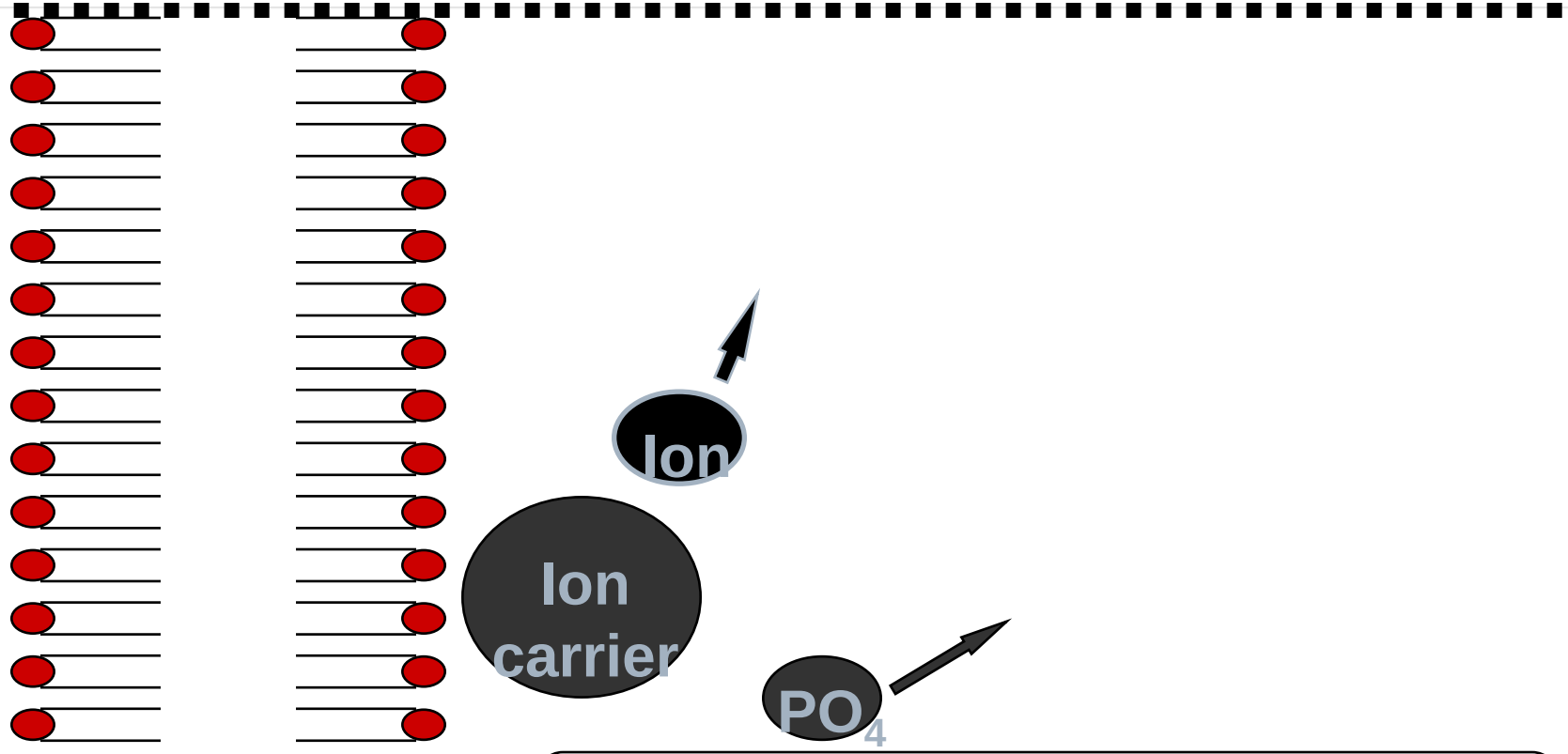

Lipid bilayer membrane
CELL INTERIOR
SOIL SOLN.
Ion carrier
ATP
Ion +
Mitochondria
Mitochondria provide ATP to carrier



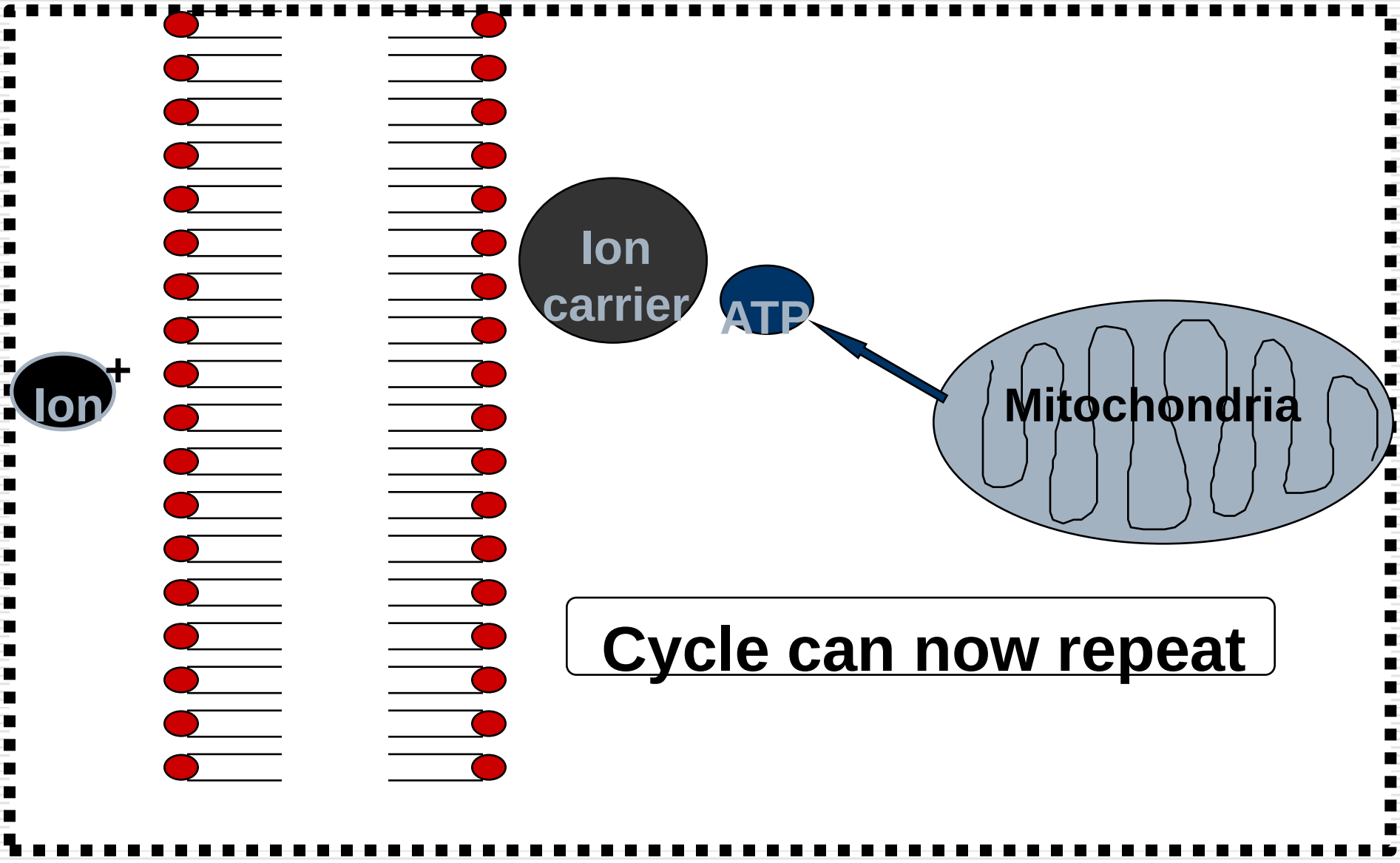
Ion carrier activated, ADP returns for recycling



Ion carrier enters membrane, picks up ion

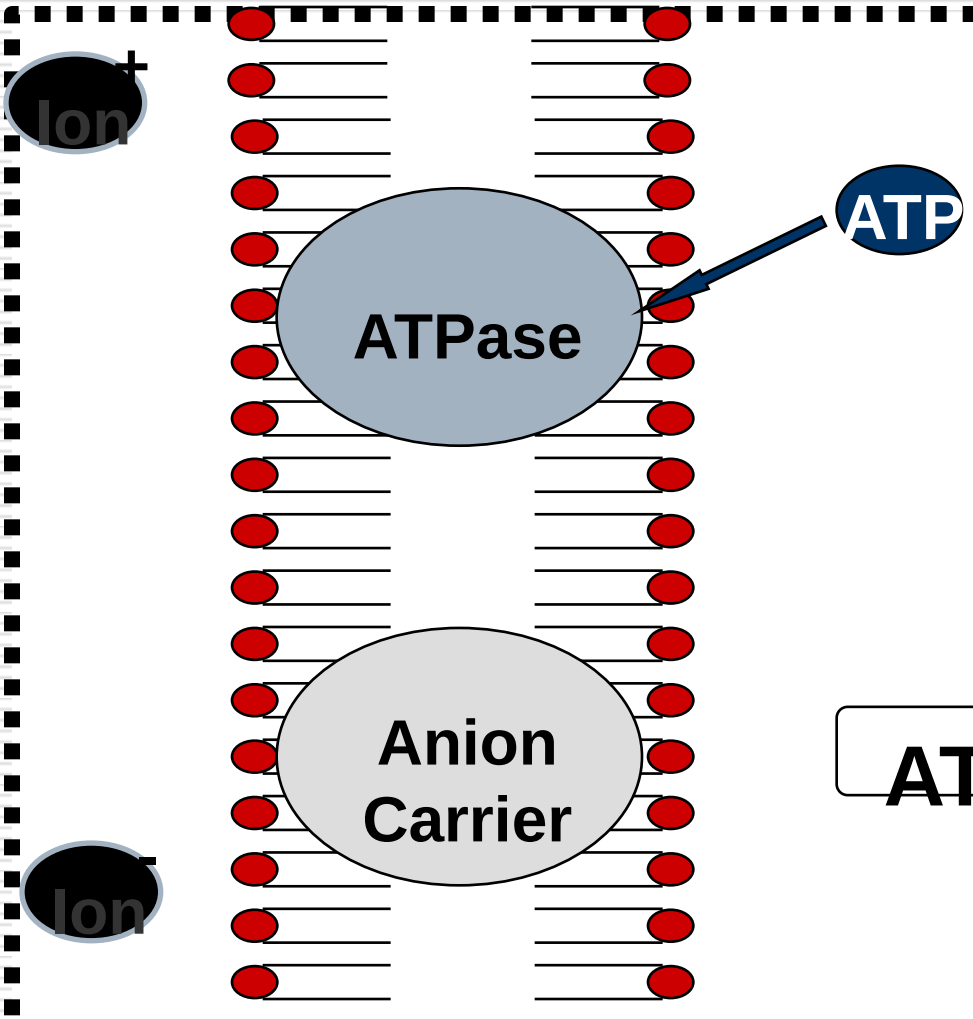


Ion carrier brings ion into cell. Energy from PO_4 ion is spent.

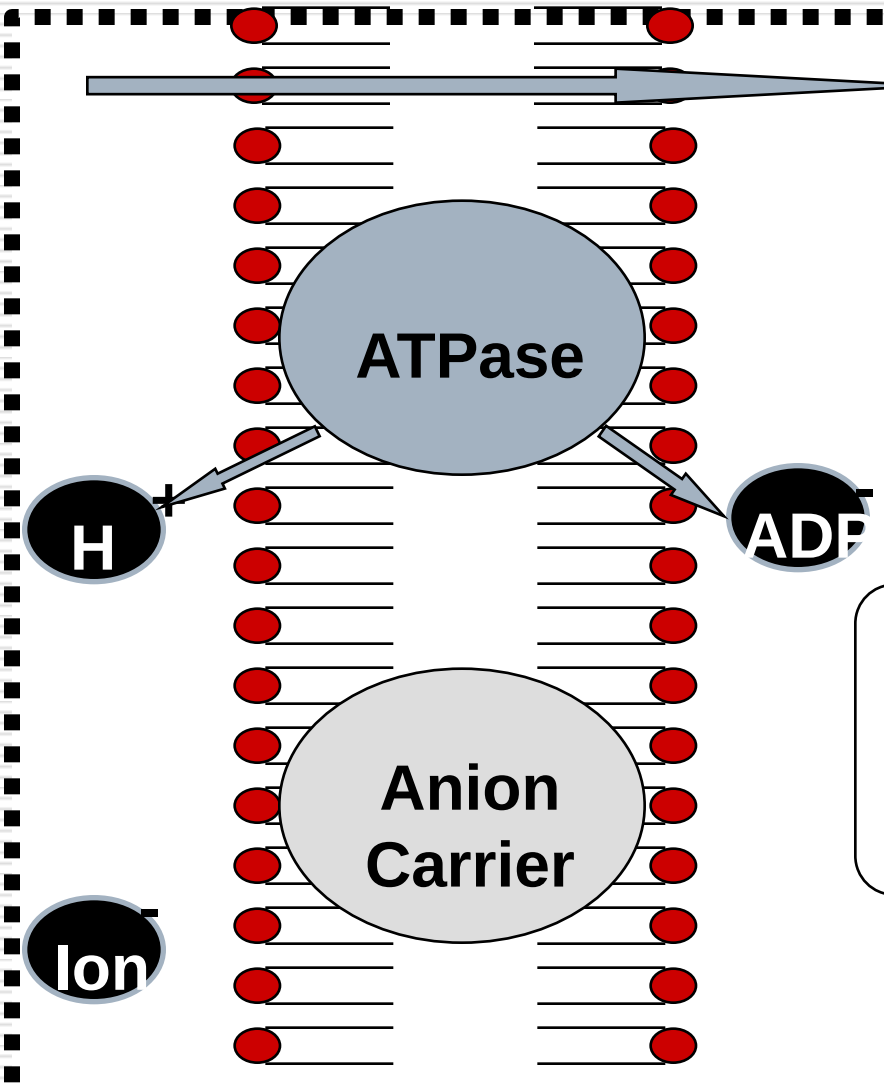

Ion
+
Ion carrier
ATP
Mitochondria
Cycle can now repeat

2. ION PUMPS

Ion pumps (e.g. ATPase) force ions through cell membrane to maintain charge in cell.

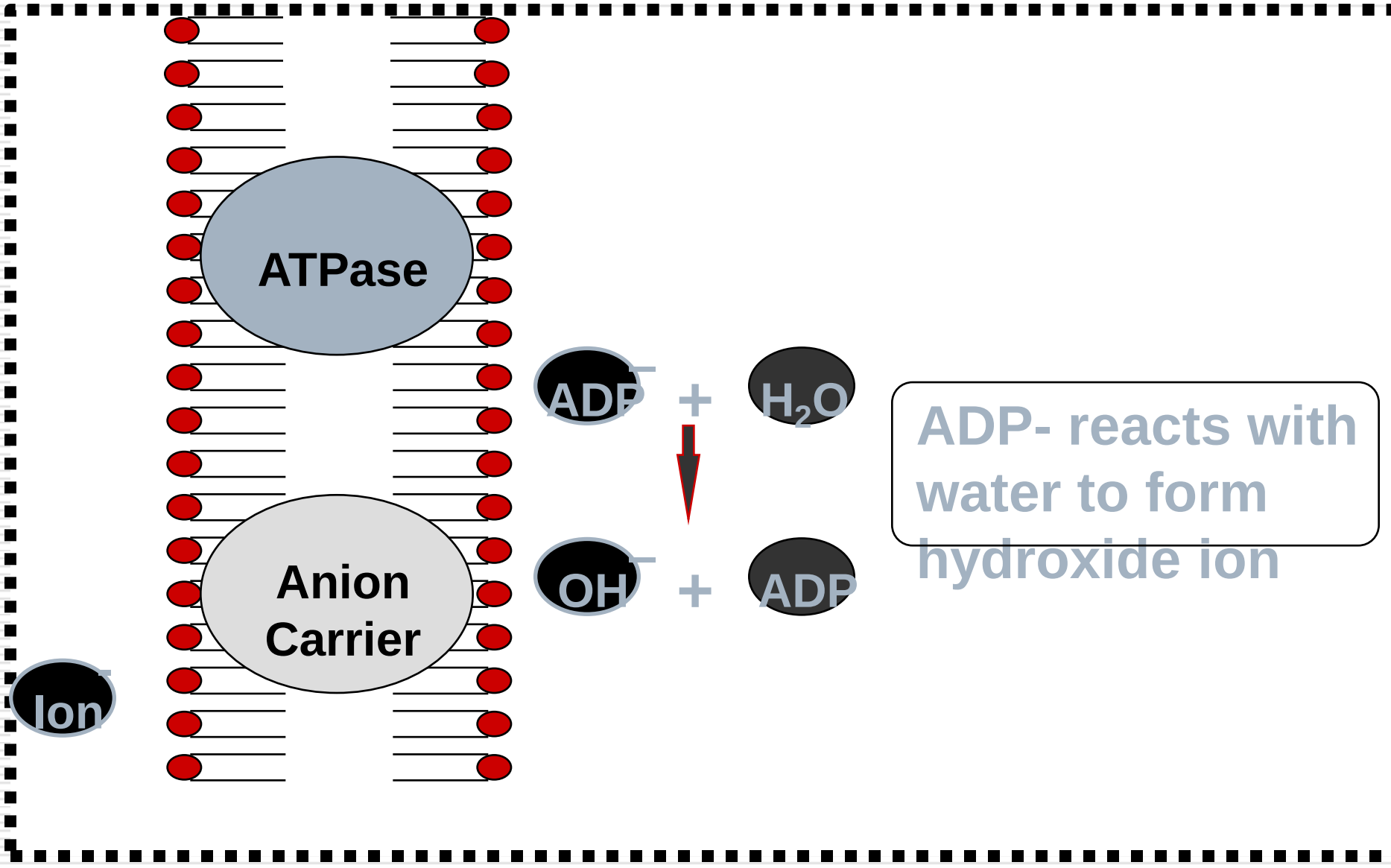


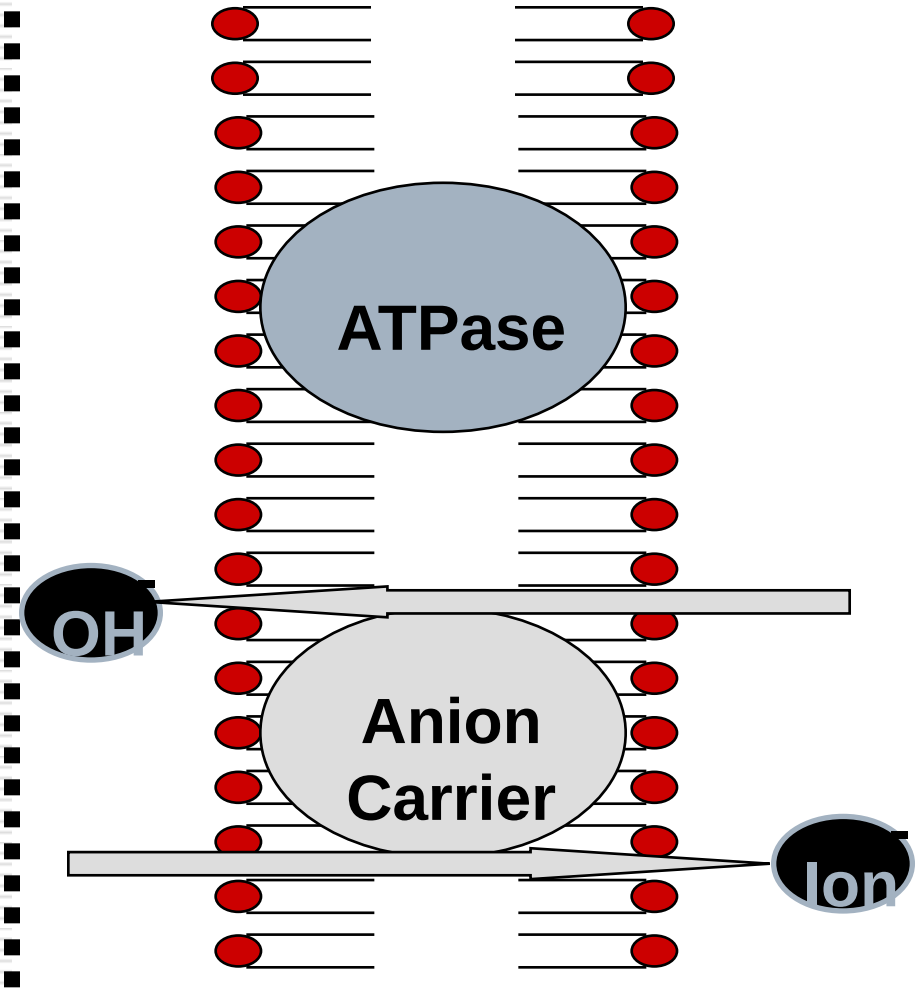
ATP Activates ATPase



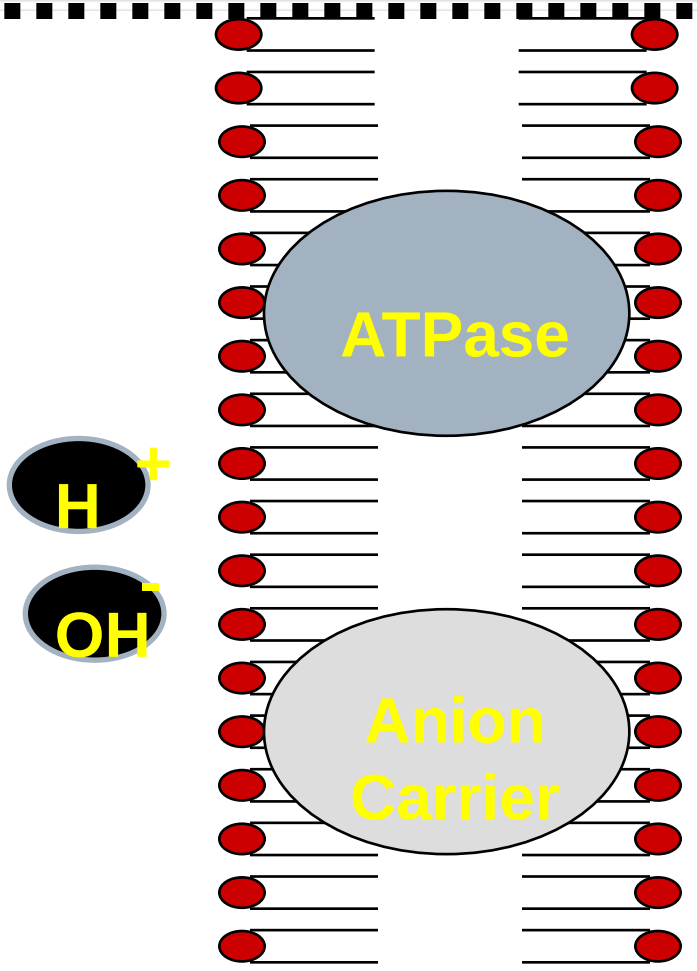
2. H+ ion “swaps” with outside cation

1. ATPase splits ATP, ejects H+ ion into soil solution. ADP is left with net negative charge


ATPase
Anion Carrier
Ion
ADP
+
H2O
OH
+
ADP
ADP- reacts with water to form hydroxide ion



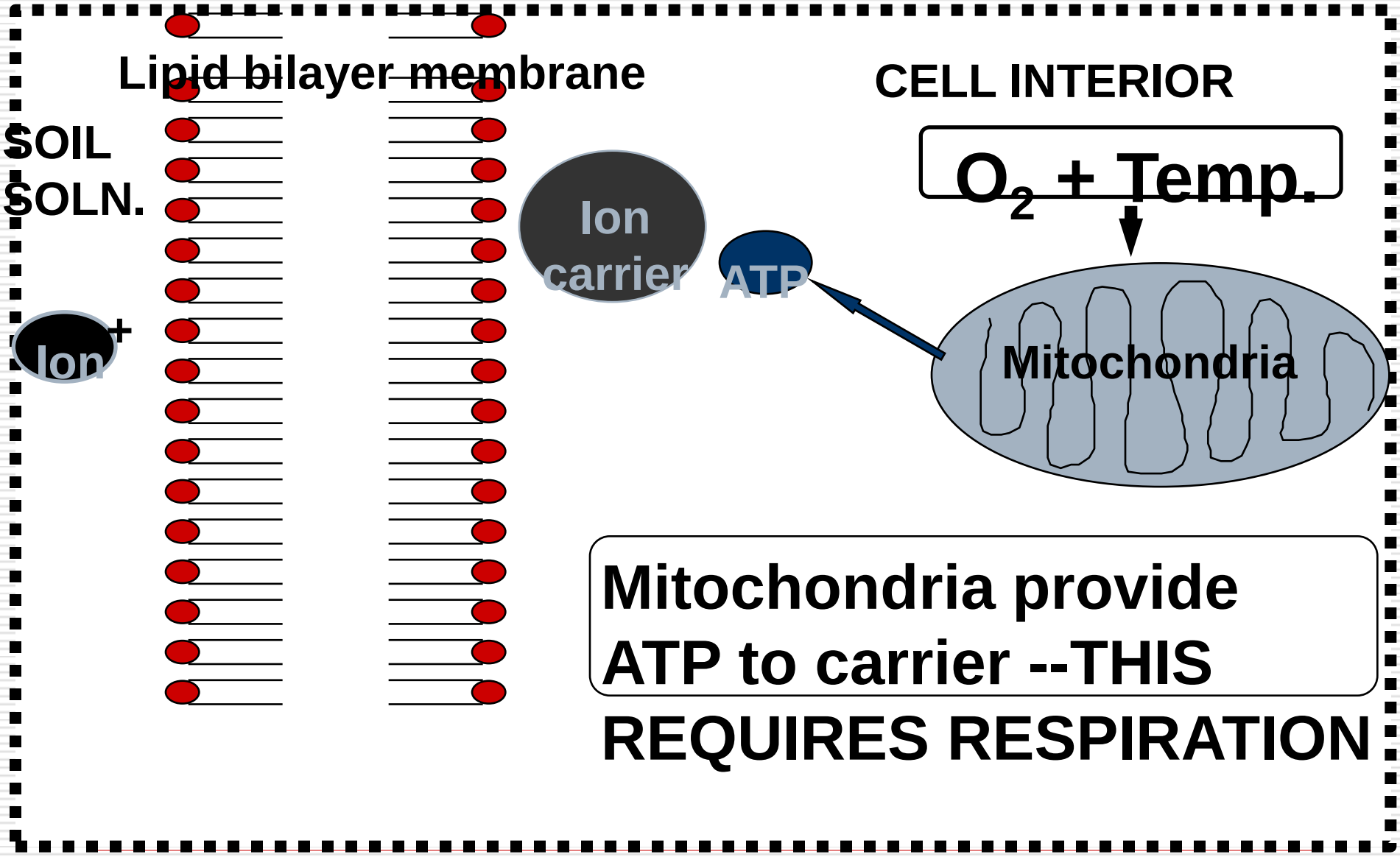
OH^- ion "swaps" with outside ion



Ion+

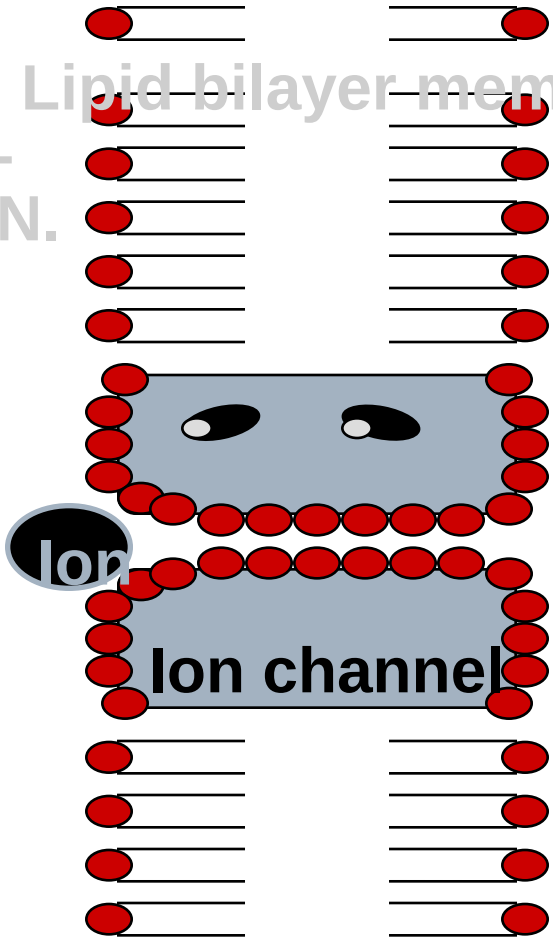
Ion-

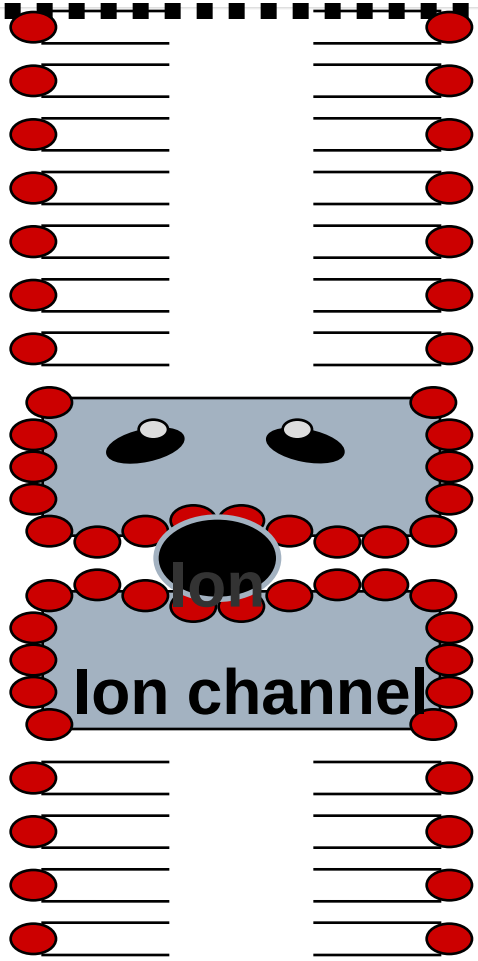
Net reaction:
External ions exchanged for H+ and OH-. No net change in charge.

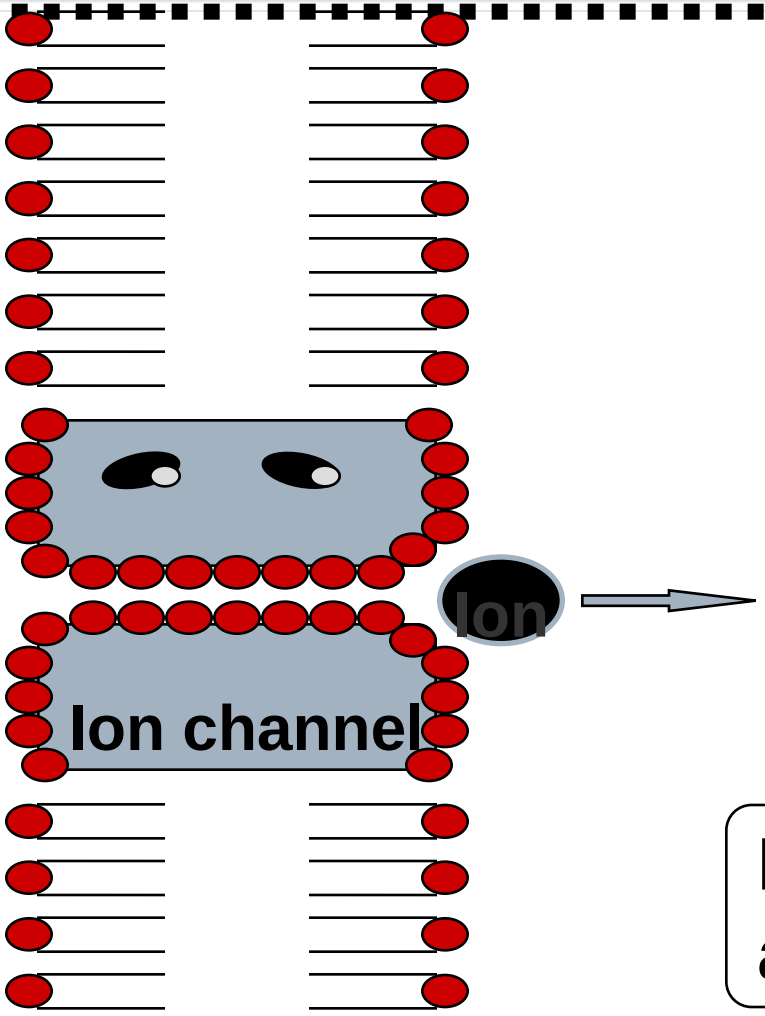

Lipid bilayer membrane
CELL INTERIOR
SOIL SOLN.
Ion carrier
ATP
O_2 + Temp.
Mitochondria
Mitochondria provide ATP to carrier --THIS REQUIRES RESPIRATION

3. ION CHANNELS

Proteins in plasmalemma (cell membrane) form hydrophilic channels. Aqueous ions can pass through channel.


Lipid bilayer membrane
SOIL
SOLN.
CELL INTERIOR
Ion
Ion channel


Ion
Ion channel



Note: the ion channel also requires energy to function

FEATURES OF ACTIVE TRANSPORT

- Absorption of ions against a concentration gradient. Concentration in the cytoplasm is higher than that of the outer solution
- Requires expenditure of energy. Sensitive to temperature, requires oxygen for generation of energy.

FEATURES OF ACTIVE TRANSPORT

- Can be highly selective
  - Example: In some species, K uptake with Na exclusion
- Specific or non-specific antagonism: inhibition of ion uptake by another ion. "Specific" means particular ions will compete for absorption sites
  - Al can inhibit Ca uptake
  - Potassium, Rubidium and Cesium compete for same carrier

FEATURES OF ACTIVE TRANSPORT, cont.

- Synergism: opposite of antagonism: presence of one ion enhances the absorption of another.
  - Example: N enhancement of P uptake

Summary of Terms

- Antagonism: Negative interaction between 2 elements, where the presence of one reduces the uptake of the other.
- Competition: Specific antagonism where ions compete for common uptake sites.
- Synergism: Positive interaction between ions.

Characteristics of ion absorption that relate to soil fertility principles:

- The rate of ion uptake is directly related to the activity (roughly represented by concentration) of that ion in solution.
- The presence of other ions in solution will potentially interfere.
- Ion uptake, a metabolic process, is affected by temperature, oxygen conditions, and availability of energy.

Relate these principles to field crop behavior!

Summary

- The general principles described in this section will provide the basic framework for discussion of individual essential nutrients throughout the semester.
- It is essential that you feel comfortable with these concepts before we move forward!