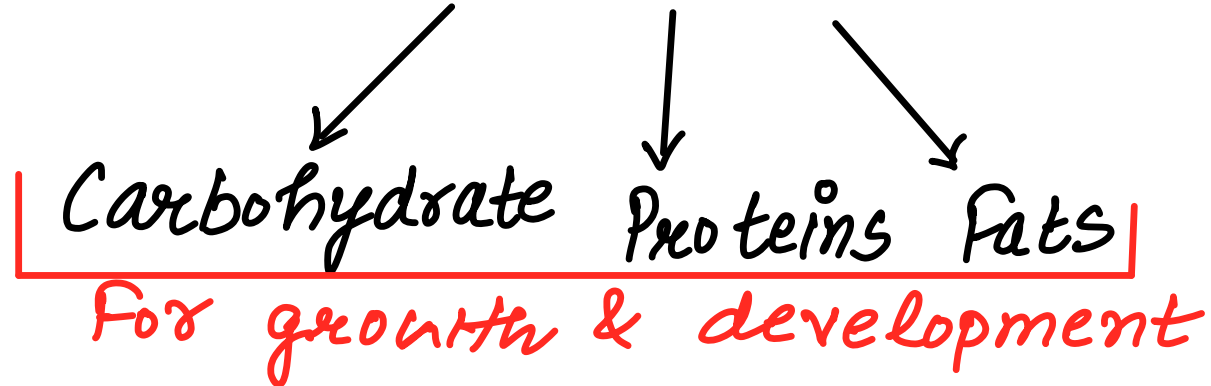


Mineral Nutrition

Mineral Nutrition

Essential basic needs → Macromolecules → Water & Minerals



Topics to be covered in the chapter:

- > Inorganic plant nutrition
- > Criteria for essentiality
- > Role of essential elements
- > Major deficiency
- > Identification of essential element for growth & dev.
- > Mechanism of absorption
- > Biological nitrogen fixation

HYDROPONICS

Commercial
Production of
Vegetables

Tomato,
Seedless
cucumber,
lettuce

Condition:

- > Adequately aerated
- > optimum growth & activity

1860, Julius
Von Sachs,
German
Botanist

Advantages:

- > no interruption of Infeed.
- > pH and air can be regulated
- > Minerals can be added and circulated uniformly with ease

Definition:
Plants grown
to maturity
in complete
absence of
soil
• In a nutrient
solution

Helps in
understanding
role and
essentiality of
elements

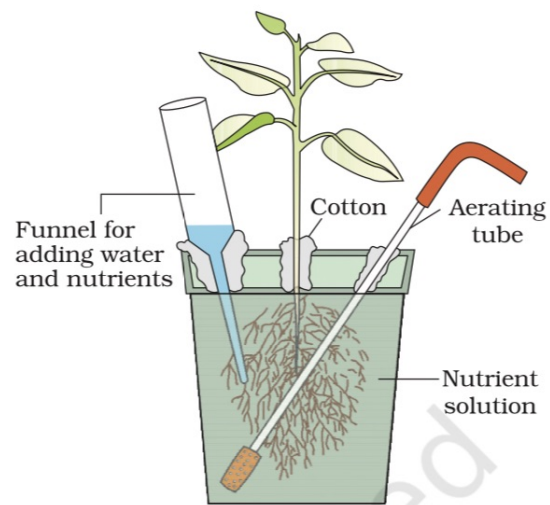


Figure 12.1 Diagram of a typical set-up for nutrient solution culture

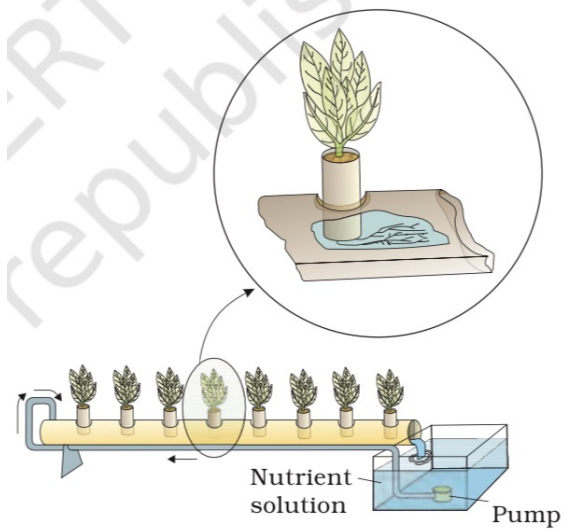


Figure 12.2 Hydroponic plant production. Plants are grown in a tube or trough placed on a slight incline. A pump circulates a nutrient solution from a reservoir to the elevated end of the tube. The solution flows down the tube and returns to the reservoir due to gravity. Inset shows a plant whose roots are continuously bathed in aerated nutrient solution. The arrows indicates the direction of the flow.

Essential Mineral Elements

Most Minerals → enter plants
(In soil) (through roots)

> 60 out of 105 are found in roots

> Some plants

```
graph TD; A[Some plants] --> B[Selenium]; A --> C[Gold]; A --> D[Radioactive Strontium];
```

Radioactive
Strontium

> Technique → detect minerals
↓
very low conc. (10^{-8} /mL)

Q. But are these minerals really essential for plants? how do we decide??

Criteria for essentiality

1.

> Absolutely necessary
For



Growth Reproduction

• Absence →

Plants do not complete life cycle or set the seeds.

2.

> Requirement
↓
specific

> Not replaceable

> deficiency of one should not be met by other.

3.

> directly involved in metabolism

ELEMENTS

(2 categories)



Based on Quantitative Requirements

> Macronutrients

1. Plant tissues

↳ large amounts

(in excess of 10 mmole/kg
of dry matter)

> C, H, O, N, P, S, K, Ca, Mg

> C, H, O → obtained from
CO₂ & H₂O

> Others → absorbed
from soil

> Micronutrients

(trace elements)

1. Very large amount

(less than 10 mmole kg⁻¹
of dry matter)

> Fe, Mn, Cu, Mo, Zn, B, Cl,
Ni

> In addition to above

Na, Si, Co, Se

Beneficial elements
(required by higher plants)

Essential elements

(4 broad categories)
Basis of their diverse functions

① Structural elements
eg. C, H, O, N

② Energy related chemical compounds
eg. Mg → chlorophyll
P → ATP

③ Activator or Inhibitor of enzymes

eg. (i) Mg^{+2} (activation)



Photosynthetic carbon fixation
ENZYMES

↓
PEP

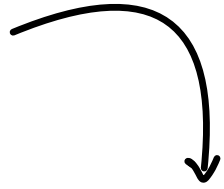
↓
RuBisCo.

(ii) Zn^{+2} (activator) → alcohol dehydrogenase

(iii) Mo → activator → nitrogenase
(N_2 metabolism)

④

Some



alter osmotic pot. of cell

> eg.

K $\rightarrow$ imp. role



opening & closing
of stomata

Roles:

1. Nitrogen: (Greatest amount)

- > absorbed as: NO_3^- (mainly), NO_2^- or NH_4
- > required by all parts, (particularly meristems & metabolically active cells)
- > constituent of: proteins, nucleic acid, vitamins and hormones.

2. Phosphorous : as in ions: (H_2PO_4^- or HPO_4^{2-} from soil)

> Constituent of : Cell membrane, some proteins, all nucleic acids & nucleotides

> required for phosphorylation reactions.

③ Potassium (K^+):

- > abundant in :
 - (1) meristems
 - (2) Buds
 - (3) leaves
 - (4) root tips
- > Maintain Anion-Cation balance
- > Protein synthesis
- > Opening & Closing of stomata
- > Activation of enzymes
- > Turgidity of cells.

④ Calcium : from soil (Ca^{+2})

> required by (i) meristems

(ii) differentiating tissues

(iii) during cell division

(synthesis of cell wall) → as calcium pectate in middle lamella

(iv) Formation of mitotic spindle

> accumulates in older leaves

> normal function of membranes

> enzyme activation

> Imp. role in metabolic activities

5. Magnesium (Mg^{+2})

> activates enzymes

↓
respiration

↓
synthesis of
DNA & RNA

↓
photosynthesis

> constituent of ring structure
of chlorophyll

> maintain ribosome structure

6. Sulphur (SO_4^{2-}) : Constituent of

(i) several coenzymes

(ii) Vitamins

(thiamine, biotin,
Coenzyme A)

(iii) Ferredoxin

Amino acids

Cysteine

Methionine

7. Iron: (Fe^{3+})

> (larger amount in micro nutrient)

> Constituent of: Proteins

↓
Involved in transfer of e^-

↙
Cytochrome

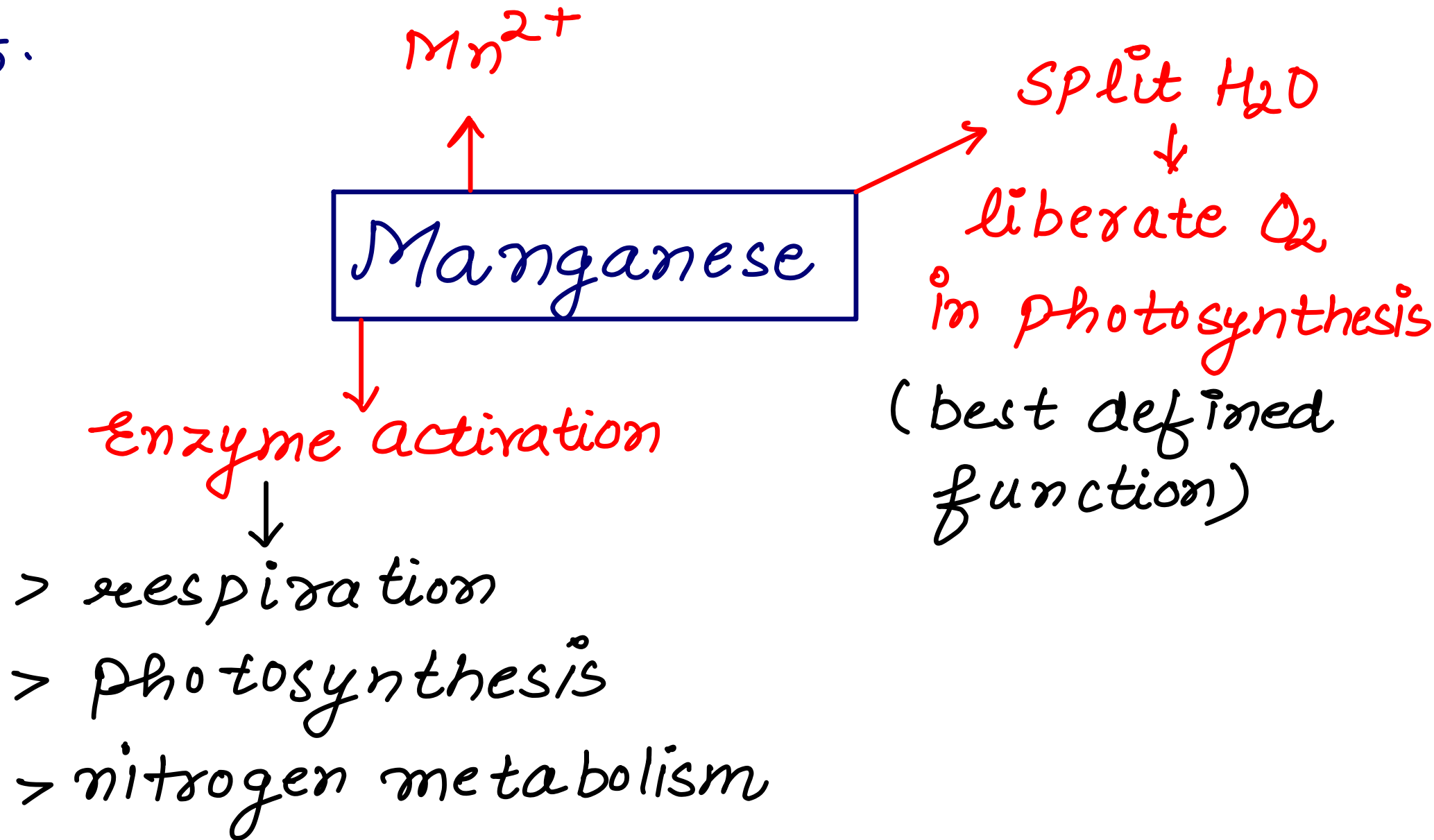
↘
Ferredoxin

> reversibly oxidised
(Fe^{2+} to Fe^{3+})

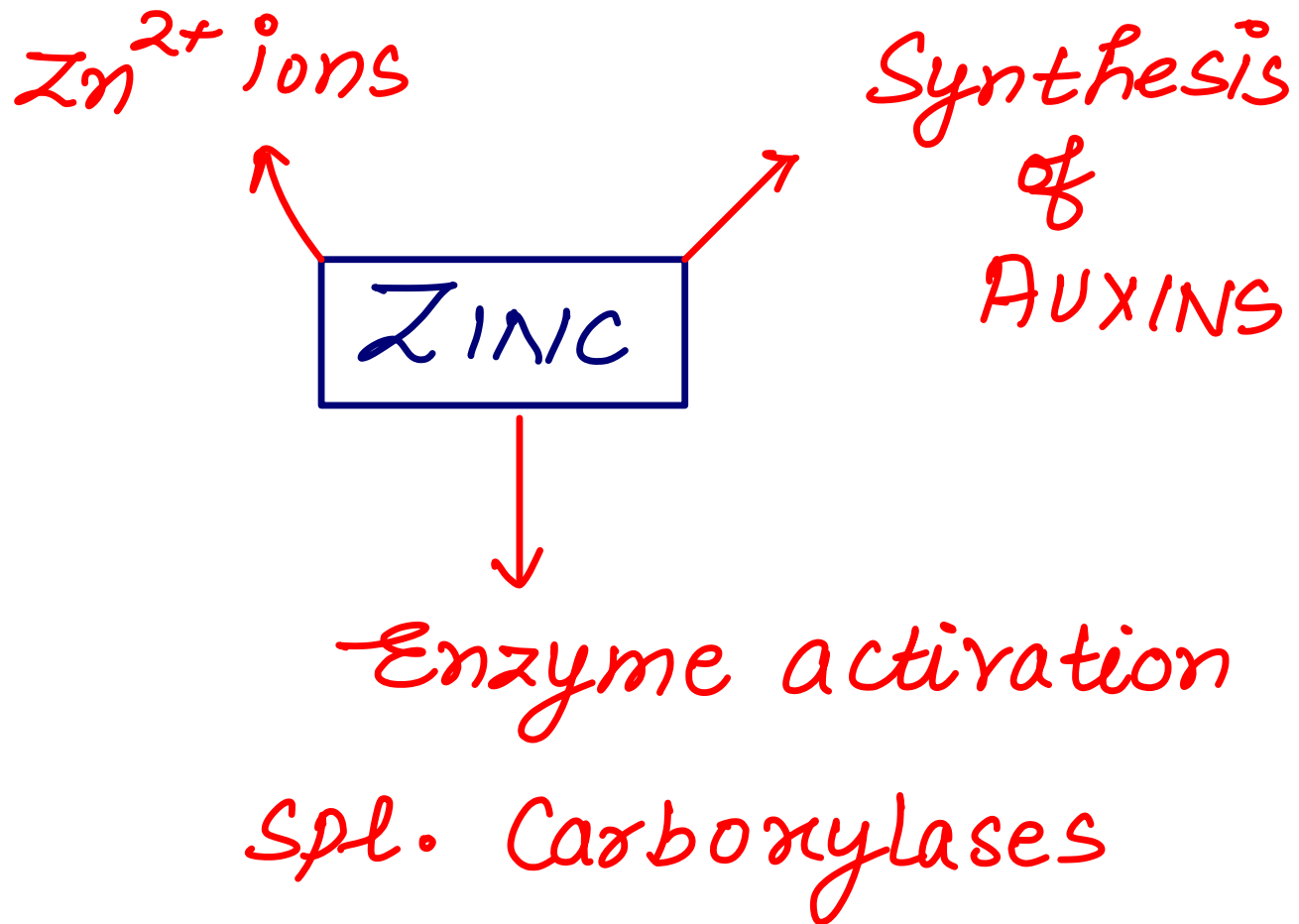
> Catalase enzyme activation

↳ essential for formation of chlorophyll.

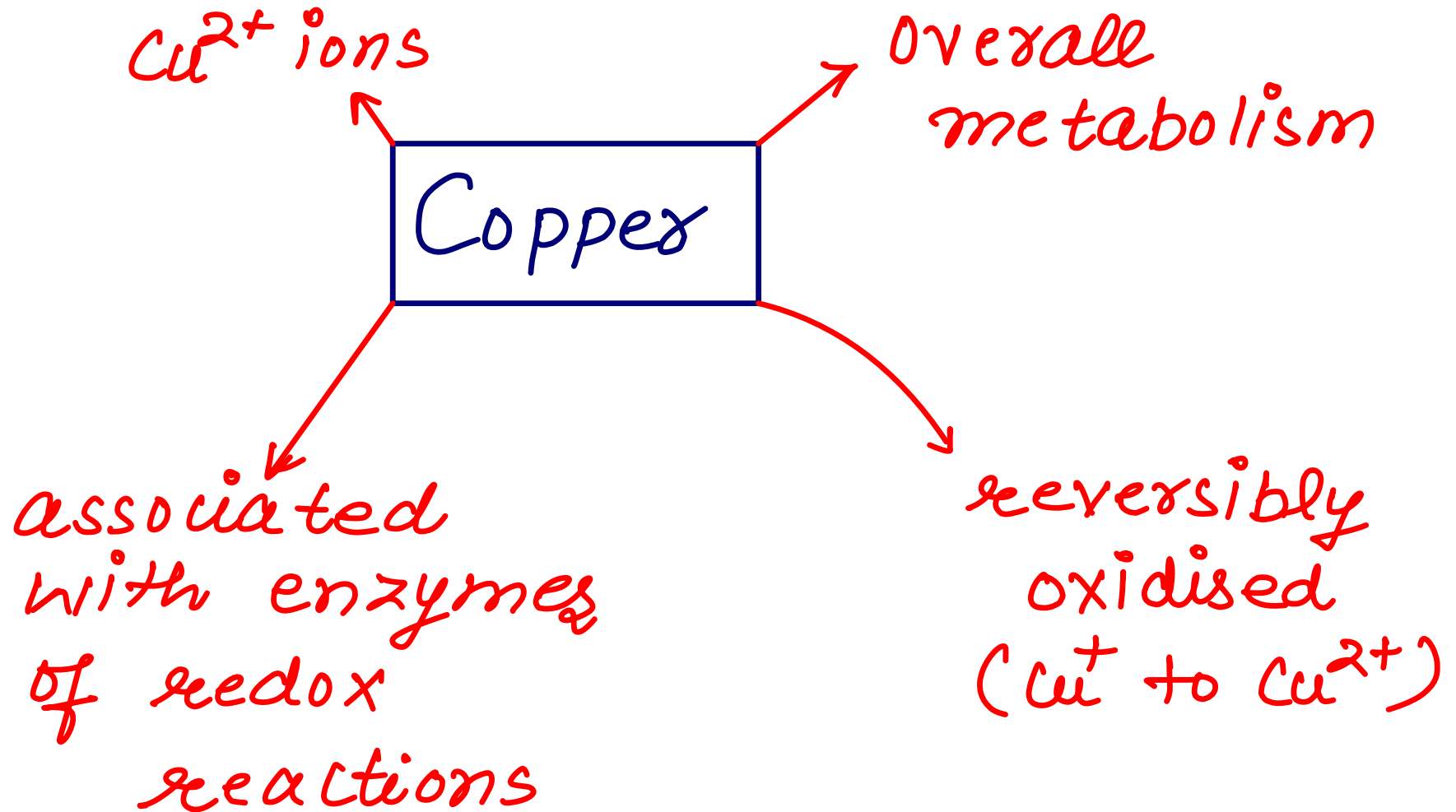
8.



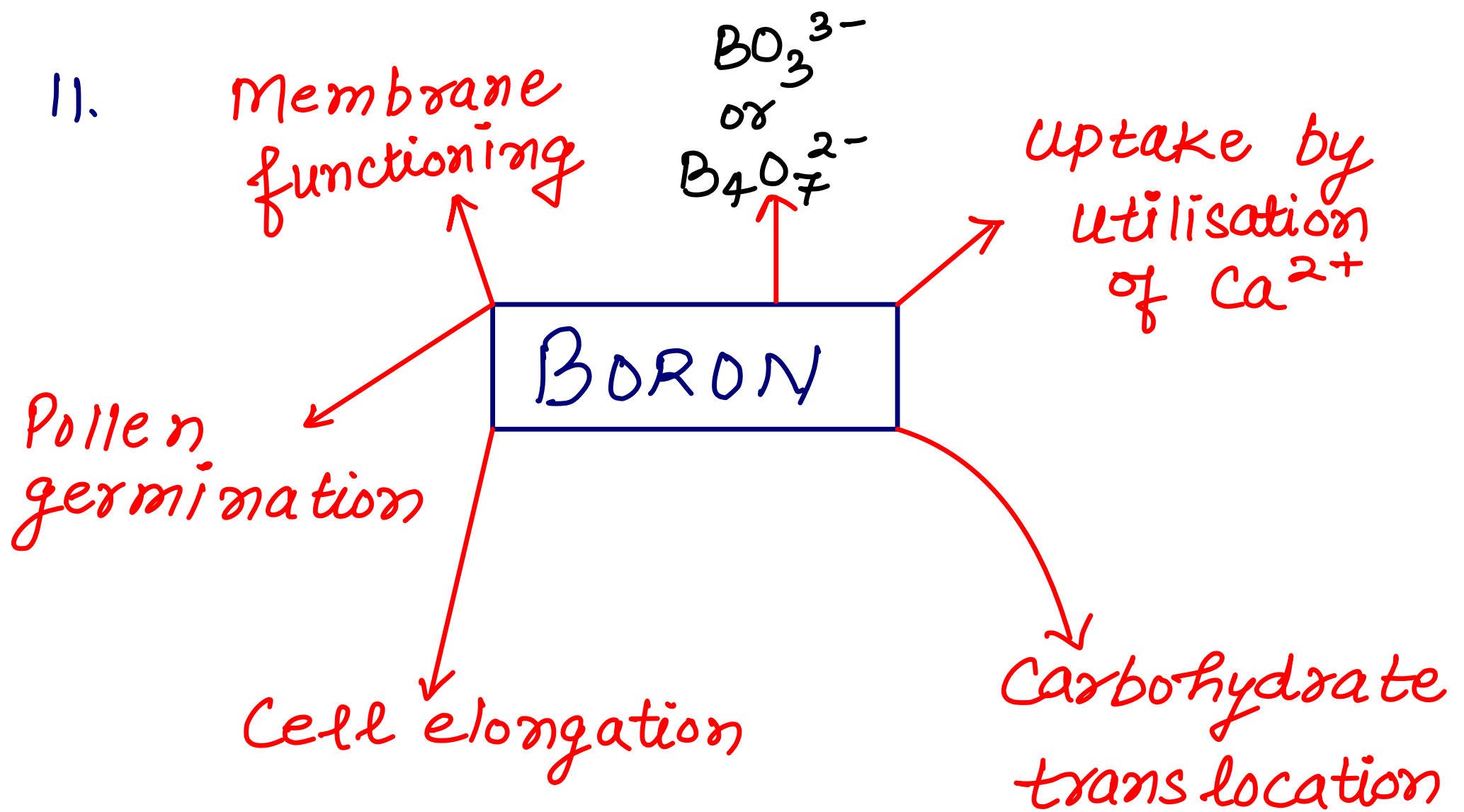
9.



10.



11.



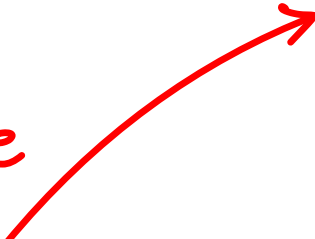
12. Molybdenum (MoO_4^{2-})

> Component of : several enzymes

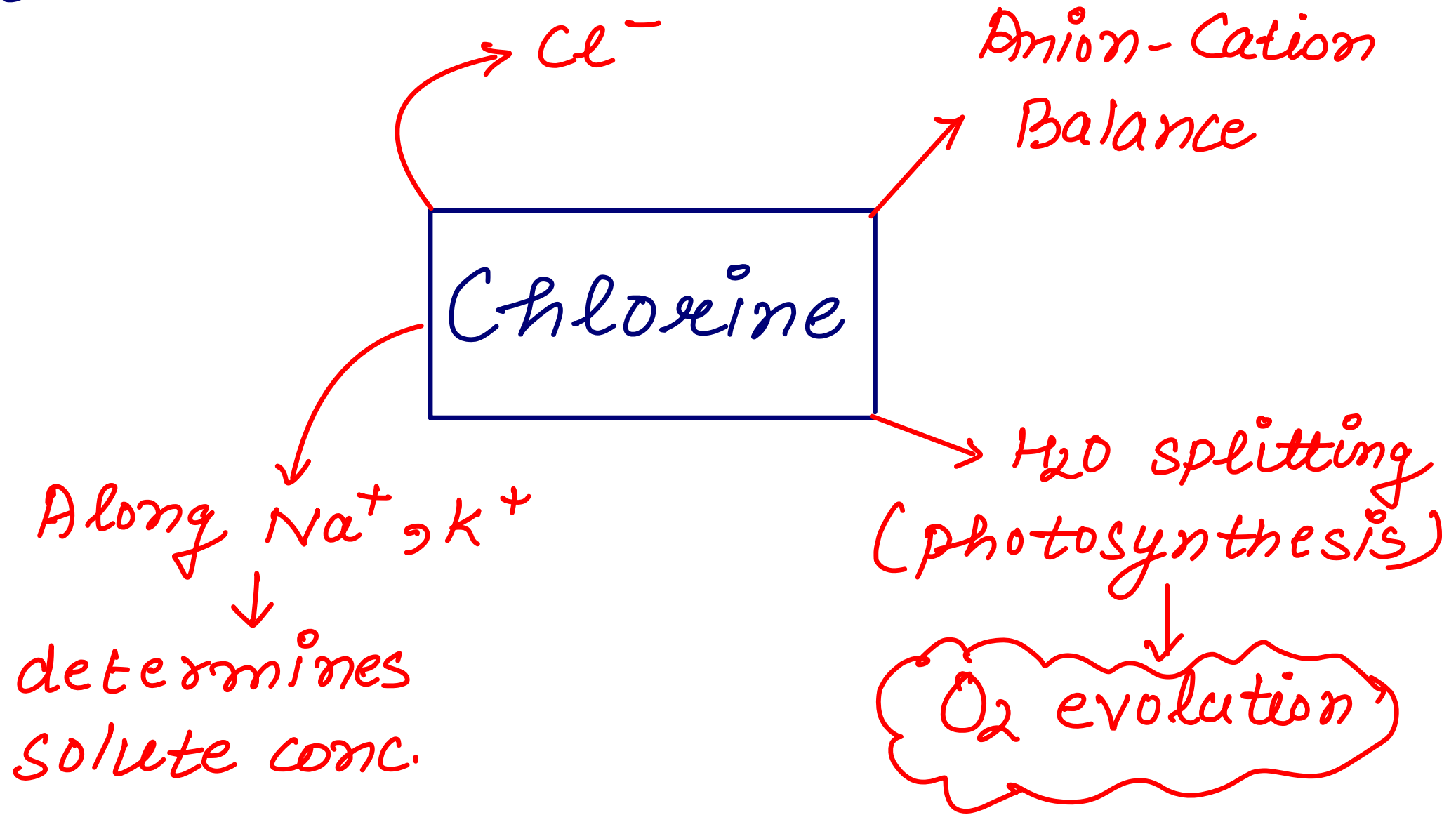
→ nitrogenase

→ nitrate
reductase

Both participate
in N_2
metabolism



13.



Deficiency Symptoms

Critical conc. : below which plant growth is retarded.

↓
show morphological changes

↓
K/a Deficiency Symptoms
(vary plant to plant)

↓
may lead to death if not provided
> depends on mobility

elements → actively mobilised

↓
exported to young
developing tissues

↓
Symptoms → appears first in older tissues

eg. N, K, Mg (actively mobile)

Biomolecules containing these elements
In older leaves ↓ Break down

↓
making these elements available
for young tissues.

Symptoms : appear first in young tissues
↓
relatively immobile elements
↓
not transported

eg. Sulphur, Calcium
↓
as a part of cell structure
are not easily released.

Chlorosis

- > loss of chlorophyll
- > yellowing of leaves
- > deficiency of N, K, Mg, S, Fe,
Mn, Zn, Mo

Necrosis

- > death of tissue → particularly leaf tissue
- > deficiency of : Ca, Mg, Cu, K

Inhibition Of Cell division :

Lack or low level



N, K, S, Mo

Delay flowering :

N, S, Mo

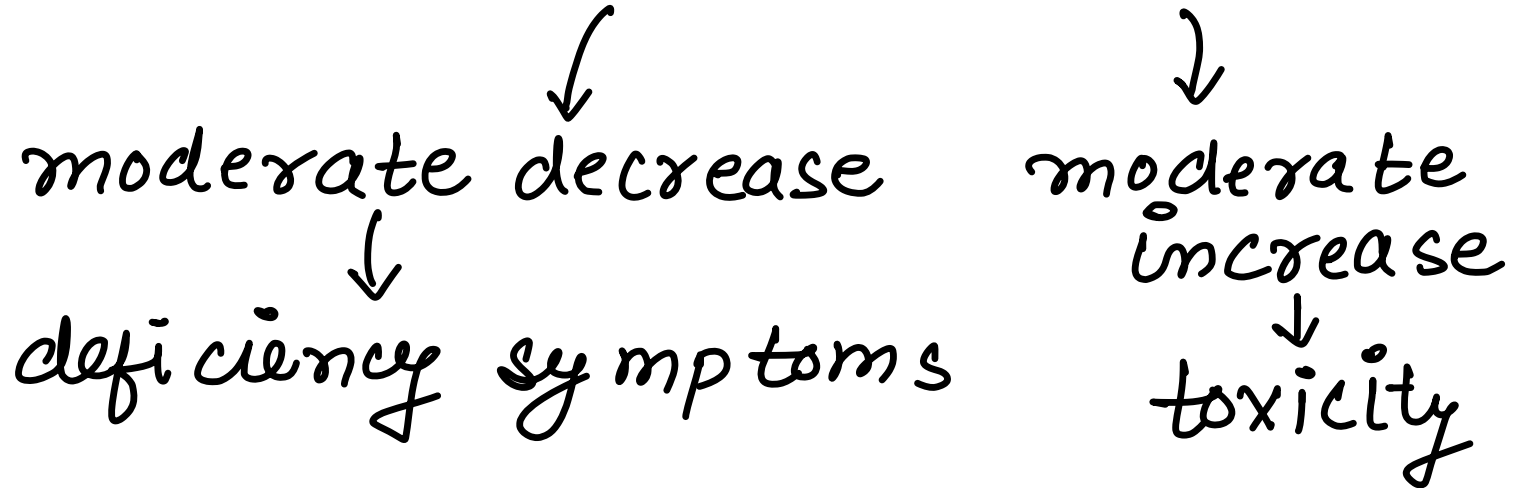


low conc.

- > Deficiency of one $\rightarrow$ Can Cause multiple symptoms
- > One deficiency symptom $\rightarrow$ Can be caused by multiple elements
- > Different plant respond differently to deficiency of same element.
- > Hence, one has to study all symptoms developed by various parts of plants.

Toxicity of Micronutrients

> Micronutrients → low amount requirement



> Narrow range → optimum

> Toxicity: conc. of element reduces dry weight by 10%.

- symptoms are difficult to identify
- Sometimes excess of an element: inhibit uptake of one

↓
vary widely among diff. micronutrients.

eg. Mn toxicity

↓
appearance of brown spots surrounded by chlorotic veins.

Manganese competes with

Mg

↓
Binding with enzymes

↓
Inhibit Ca translocation in shoot apex

Fe & Mg

↓
uptake

> Therefore, excess Mn induces Fe, Mg & Ca deficiency.

Mechanism Of Absorption

First Phase

- > Initial rapid uptake.
- > Into 'free space'
or
'outer space'
- > Apoplast
- > Passive movement
- > Through ion-channels
(transmembrane proteins)
↓
Function as selective
pores.

Second Phase

- > Slower
- > Into inner space.
- > Symplast
- > Active movement
(requires energy)
- > Usually ion movement
is through 'Flux'
↓
Inward Outward
↓ ↓
Influx Efflux

Translocation Of Solutes

Mineral salts → translocated → Xylem
+
ascending stream of water by transpirational pull

(Use of radioisotopes → evident that they are transported through xylem)

Soil as reservoir of essential elements

Majority of Nutrients → responsible for growth and development

→ available to roots (due to weathering and breakdown of rocks)

↓
enrich the soil → dissolved ions and derived from inorganic salts rocks.

Soil → harbours N_2 -fixing bacteria
+
other microbes
+
holds water
+
supplies air to roots

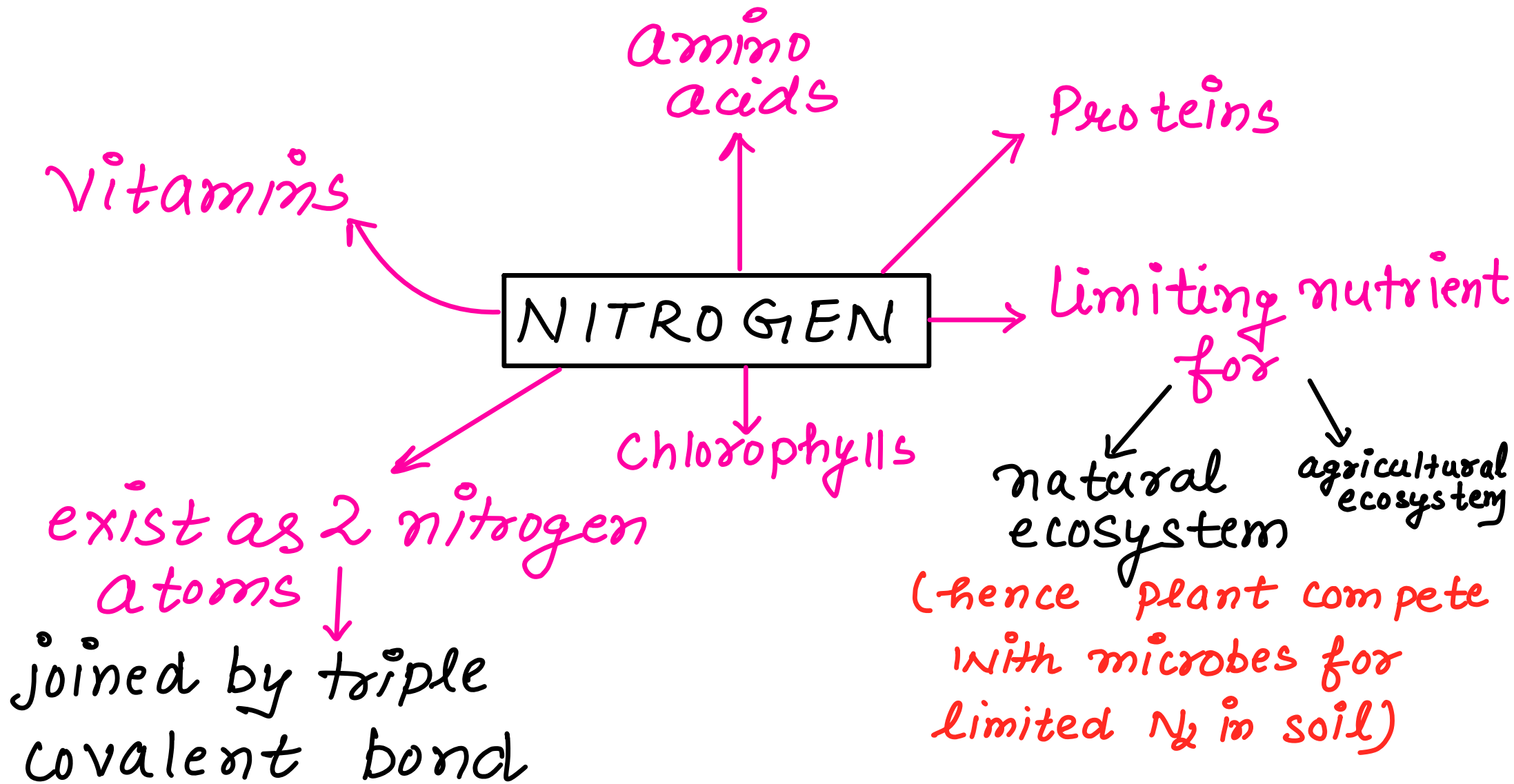
(And act as matrix)
↓
stabilises plant

Deficiency of minerals → affect crop yield
need for supply of fertilizers

Macro nutrients
(N, P, K, S)

Micro Nutrients
(Cu, Zn, Fe, Mn)

Nitrogen Cycle



Nitrogen (N_2) $\longrightarrow$ Ammonia (NH_3)

this process is called nitrogen fixation

Energy for conversion of
 $N_2 \longrightarrow (NO, NO_2, N_2O)$

Nature, lightning & UV radiation

Dead Plants & Animals $\xrightarrow[\text{Ammonification}]{\text{Decomposition}}$ Ammonia

Some re-enter atm.
but most gets converted
into nitrates

$\rightarrow$ Industrial Combustion
 $\rightarrow$ Forest fires
 $\rightarrow$ Automobile exhaust
 $\rightarrow$ Power generating stations

Source of atm. N_2 oxides

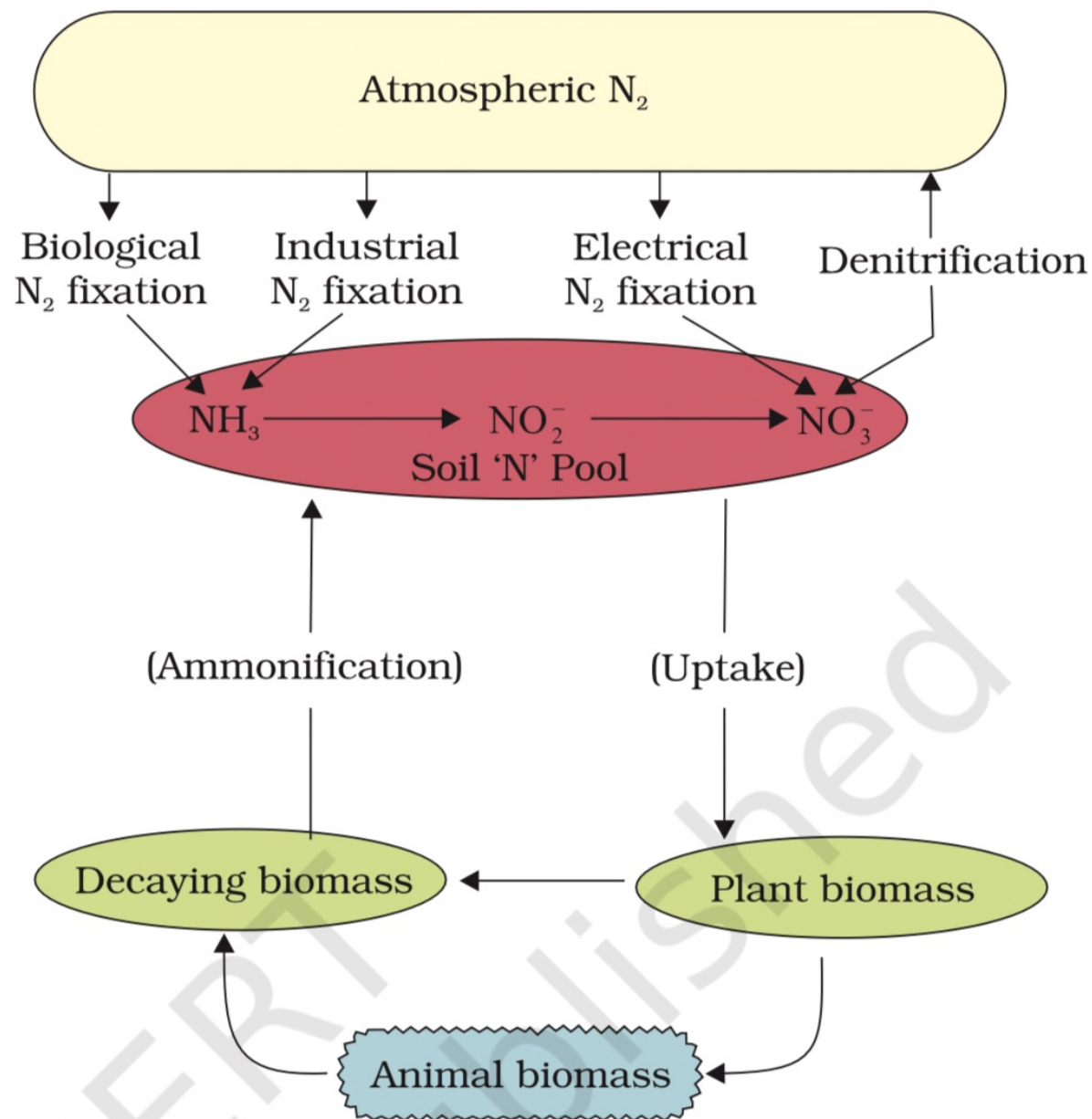
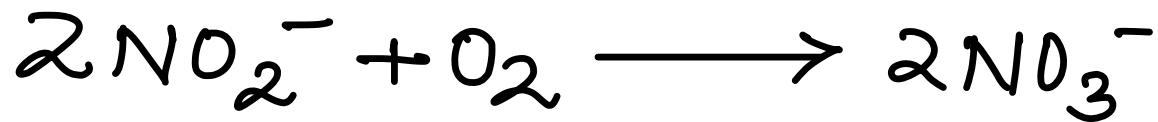


Figure 12.3 The nitrogen cycle showing relationship between the three main nitrogen pools – atmospheric soil, and biomass



Ammonia to nitrite
by

Nitrosomonas, Nitrococcus



Nitrite to Nitrate
by Nitrobacter

> reduces to nitrogen

↓
Denitrification
(Pseudomonas & Thiobacillus)

> absorbed by plants & transported to leaves

↓
> In leaves, reduces to NH_3

steps

↓

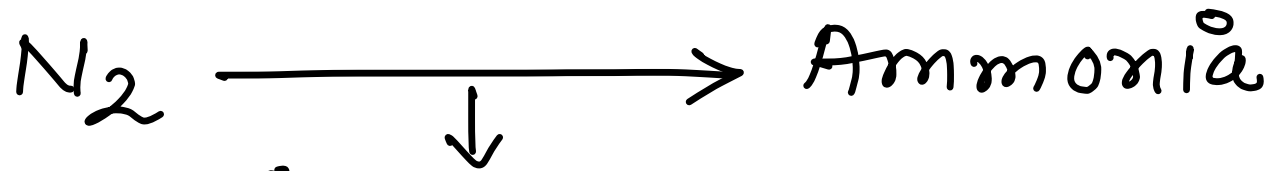
↗ Nitritification

Nitrifying
bacteria

↓

Chemoauto-
trophs

Biological Nitrogen fixation



living org. (only certain prokaryotic sps.)

Prokaryotes (containing nitrogenase)

↓
N₂-fixers

Capable of N₂ reduction



↓
N₂ Fixers

↓
Symbiotic

↓
Freeliving

↓
Cyanobacteria

↓
Anabaena & Nostoc

aerobic ↓ Rhodospirillum
an aerobic ↓
Azotobacter & Beijerinckia

Symbiotic Biological Nitrogen fixⁿ:-

Several associations are known

↓
(most prominent → legume - bacteria relationships)

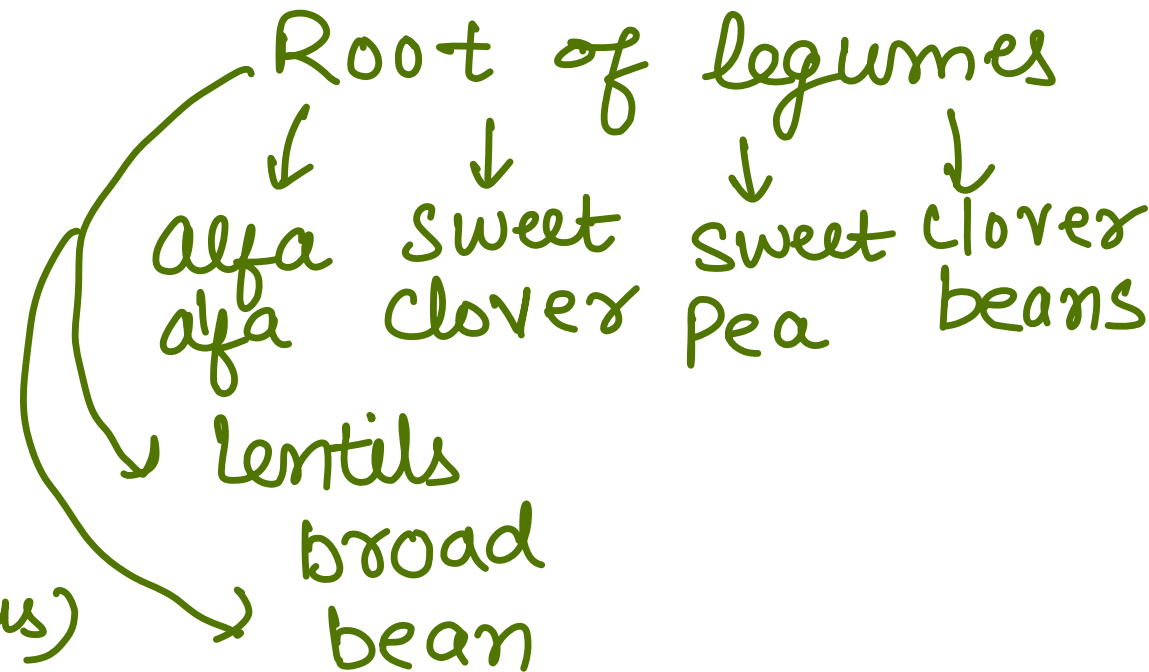
most common association
on roots

eg. species of Rhizobi-um

↓
nodules
(small outgrowth)

> Frankia → N₂
Produce Fixing
nodules

↓
roots of non-leguminous
plants (eg. Alnus)



Rhizobium & Frankia → free living
↓
(in soil)
Symbionts
(fix atm N_2)

Modules: Spherical outgrowth on roots

Central position

Pink $\rightarrow$ due to presence of
leguminous haemoglobin
or leg haemoglobin

Nodule formation:

Multiple interaction b/w rhizobium & roots (host plant)

Stages of nodule formation:

1. Rhizobia multiply
2. Colonise the surrounding of roots
3. Get attached to epidermal & root hair cells.

4. Root - hair curl
5. Bacteria invade root hair
6. Infection thread produces
 - ↳ carry bacteria to Cortex of Root
- ↓
7. Initiate nodule formation
8. Bacteria released into cells.
- ↓
9. differentiation of specialised N_2 -fixing cells.
10. Nodule formed → forms direct conn. with vascular system of host
for ex. of nutrients

↓
Containing necessary
components

ex. enzyme nitrogenase
(leg haemoglobin)

highly sensitive
↓

molecular O_2
↓

requires anaerobic cond.
[have adaptations]
↓

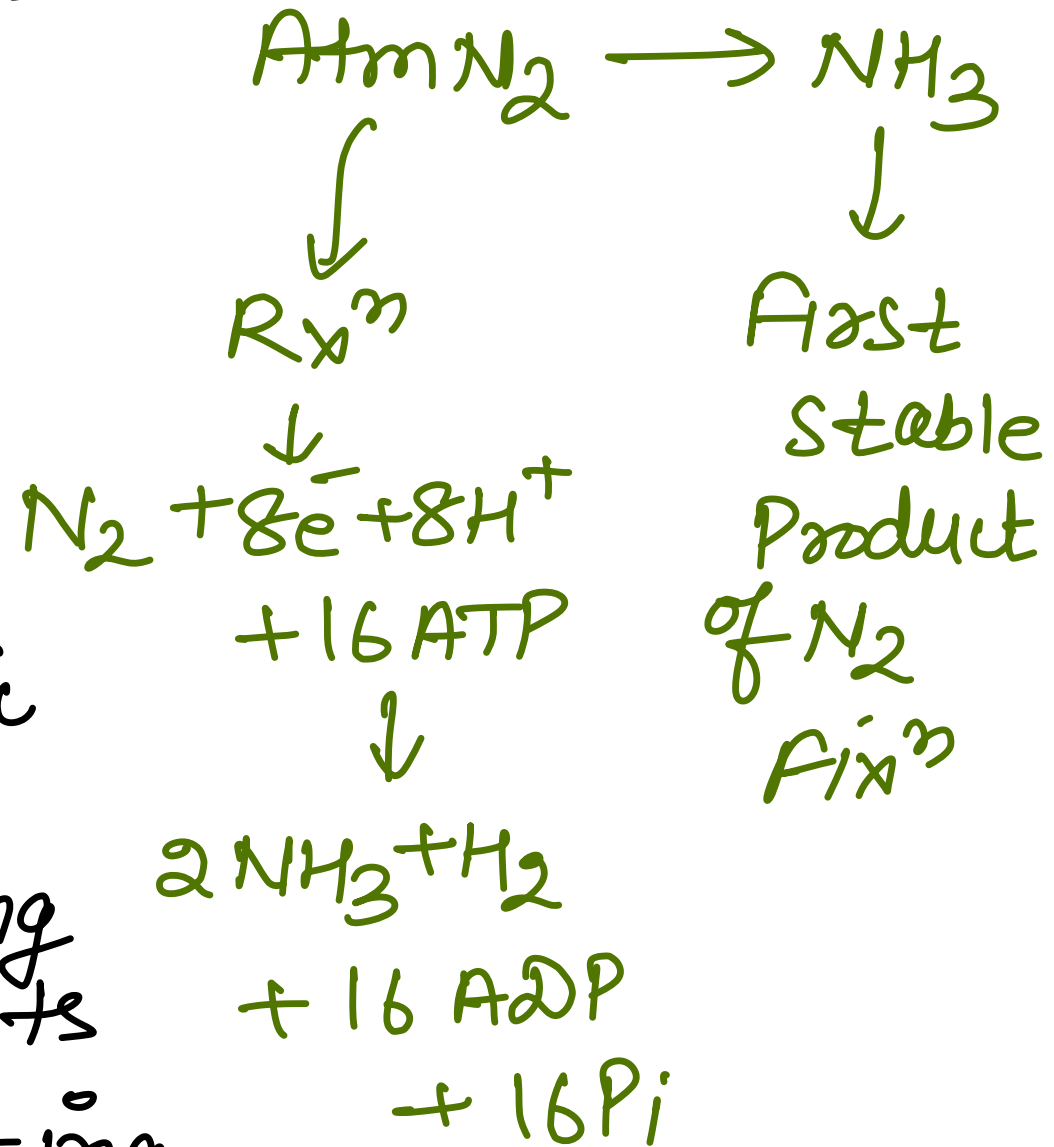
ensure non-availability of O_2
↓

Mo-Fe

Protein → Catalyses

leg haemoglobin
↓
O₂ scavenger

Such microbes
↓
Free living
aerobic
↓
normal
cond.
↓
anaerobic
↓
N₂ - Fixing
events
↓
thus protecting
nitrogenase
enzyme



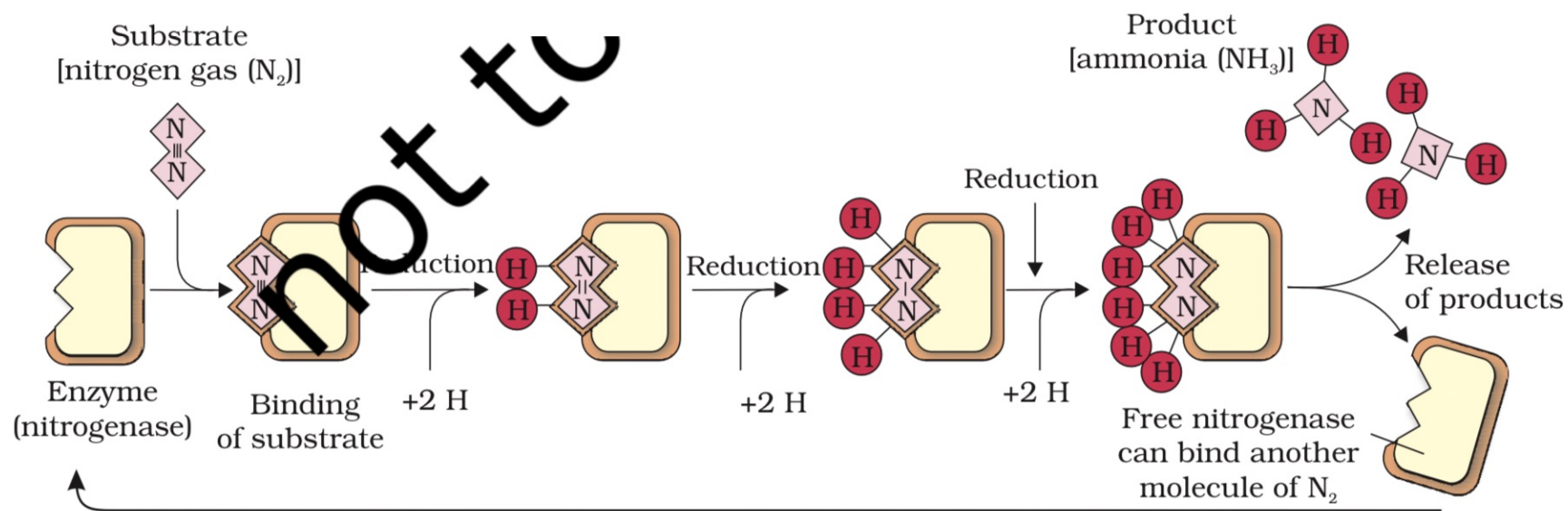


Figure 12.5 Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

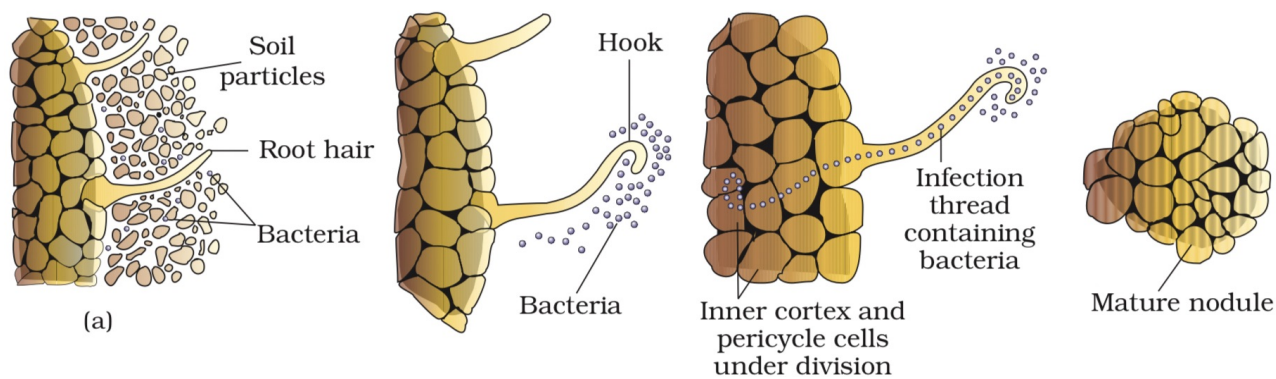


Figure 12.4 Development of root nodules in soybean : (a) *Rhizobium* bacteria contact a susceptible root hair, divide near it, (b) Successful infection of the root hair causes it to curl, (c) Infected thread carries the bacteria to the inner cortex. The bacteria get modified into rod-shaped bacteroids and cause inner cortical and pericycle cells to divide. Division and growth of cortical and pericycle cells lead to nodule formation, (d) A mature nodule is complete with vascular tissues continuous with those of the root

obtained from respiration
↑

Ammonia Synthesis → requires high energy
input

↓
8 ATP for each NH_3

Fate of Ammonia
↓

most plants assimilate

both
↓ ↓
 NH_3 Nitrate

(Ammonia)
↓

quite toxic → cannot accumulate in them
↓

2 ways to synthesis amino acids.

(i) Reductive Amination:

α -ketoglutaric acid + NH_4^+ + NADPH

↓ Glutamate
dehydrogenase

Glutamate + H_2O + NADP

(ii) Transamination: Transfer of amino group from amino acid to keto acid

Glutamic acid $\rightarrow$ main amino acid
 $\downarrow$
transfer of NH_2

Catalyses by transaminase enzyme

2 imp. amides: Str. part of protein

$\downarrow$
asparagine $\rightarrow$ glutamine $\rightarrow$ transported to other parts of plants via xylem vessels
 $\downarrow$ $\downarrow$
aspartic acid glutamic acid
formed from
amino acids.
Since amides contain more nitrogen.