



Handwritten Notes
on
Plant Growth and
Development

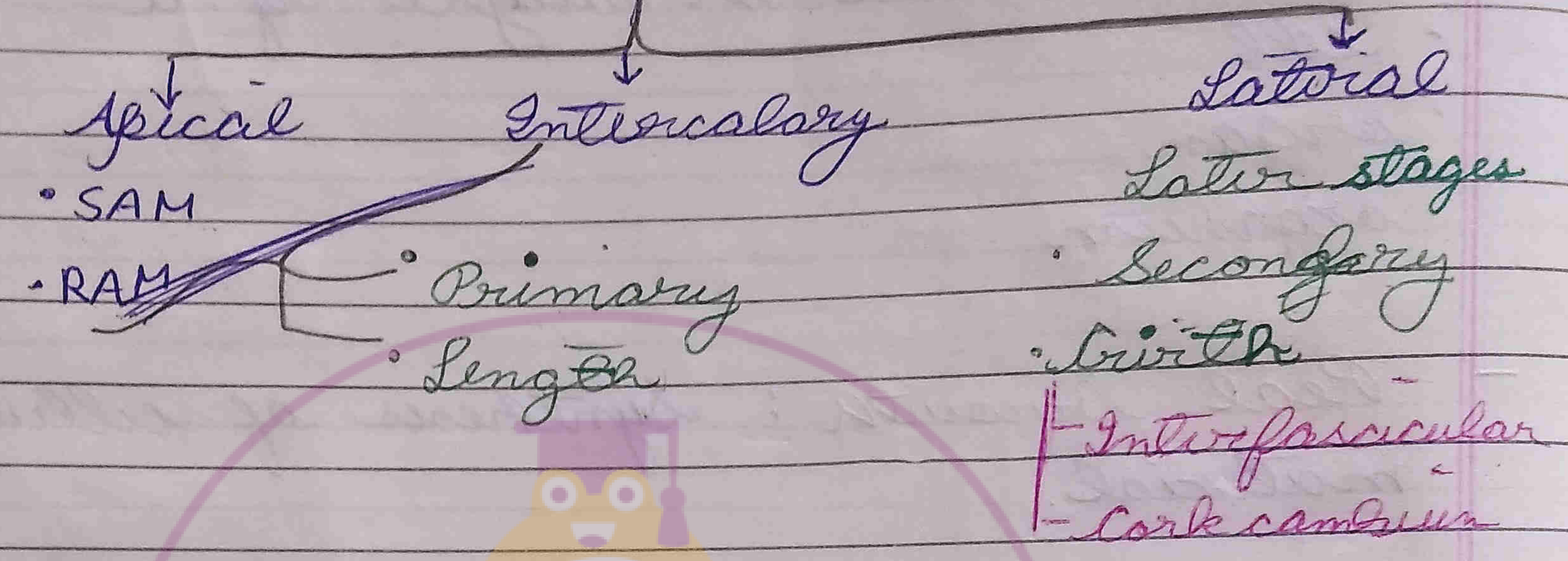
Plant Growth and Development

- **Growth**: Irreversible increase in the mass, volume or weight of a
 - cell
 - organ
 - organism
- **Real Growth**: Synthesis of cellular material.
- **Apparent Growth**: External manifestation of growth.
- **Accentric Growth**: cell enlargement ✓
cell division ✗
- **Multiplicative growth**: cell enlargement ✗
cell division ✓
e.g tissue culture

In animals growth is limited and no. of cells do not increase.

Plant growth features:

1. **Localised** : Specific areas
- Meristem



2. Unlimited growth

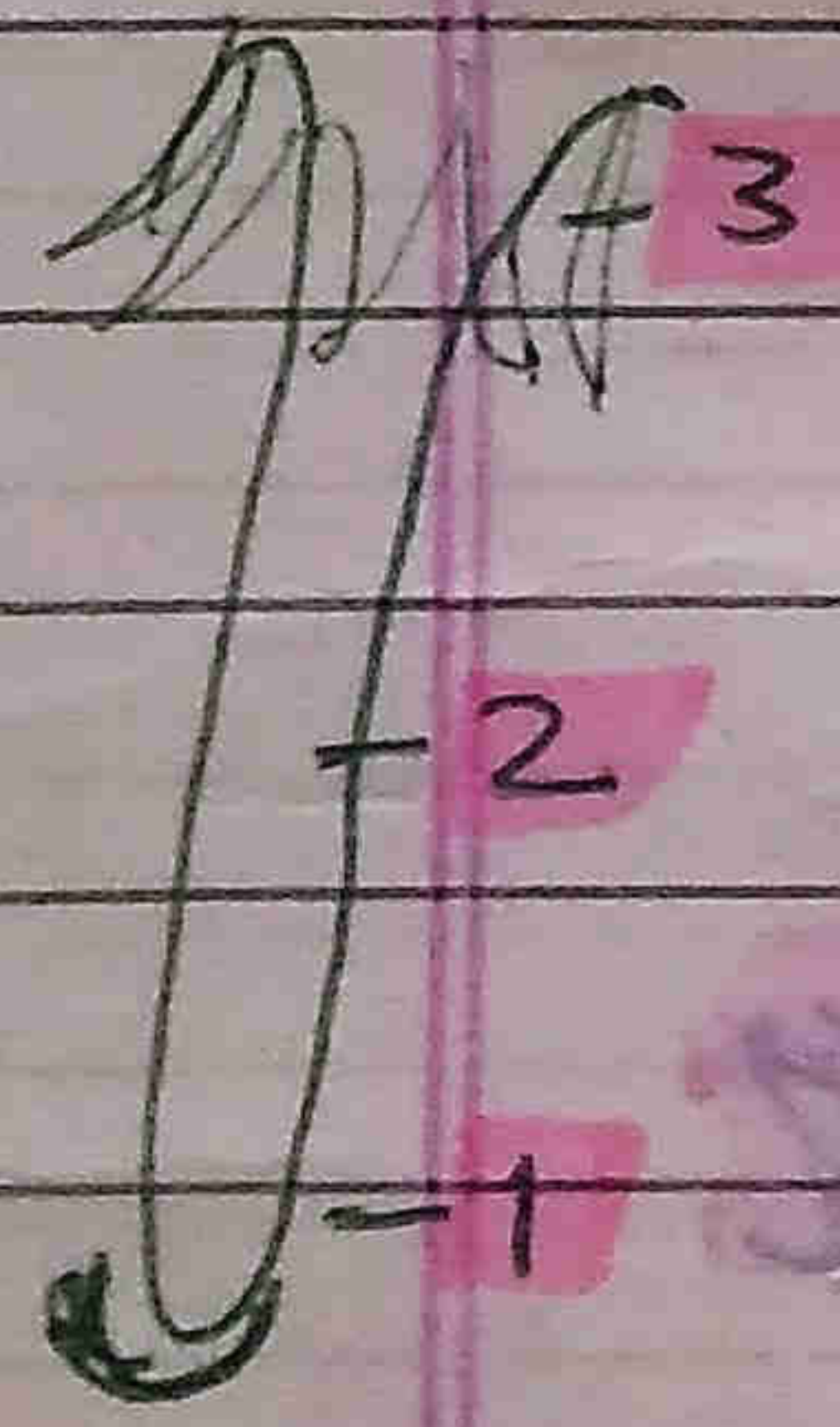
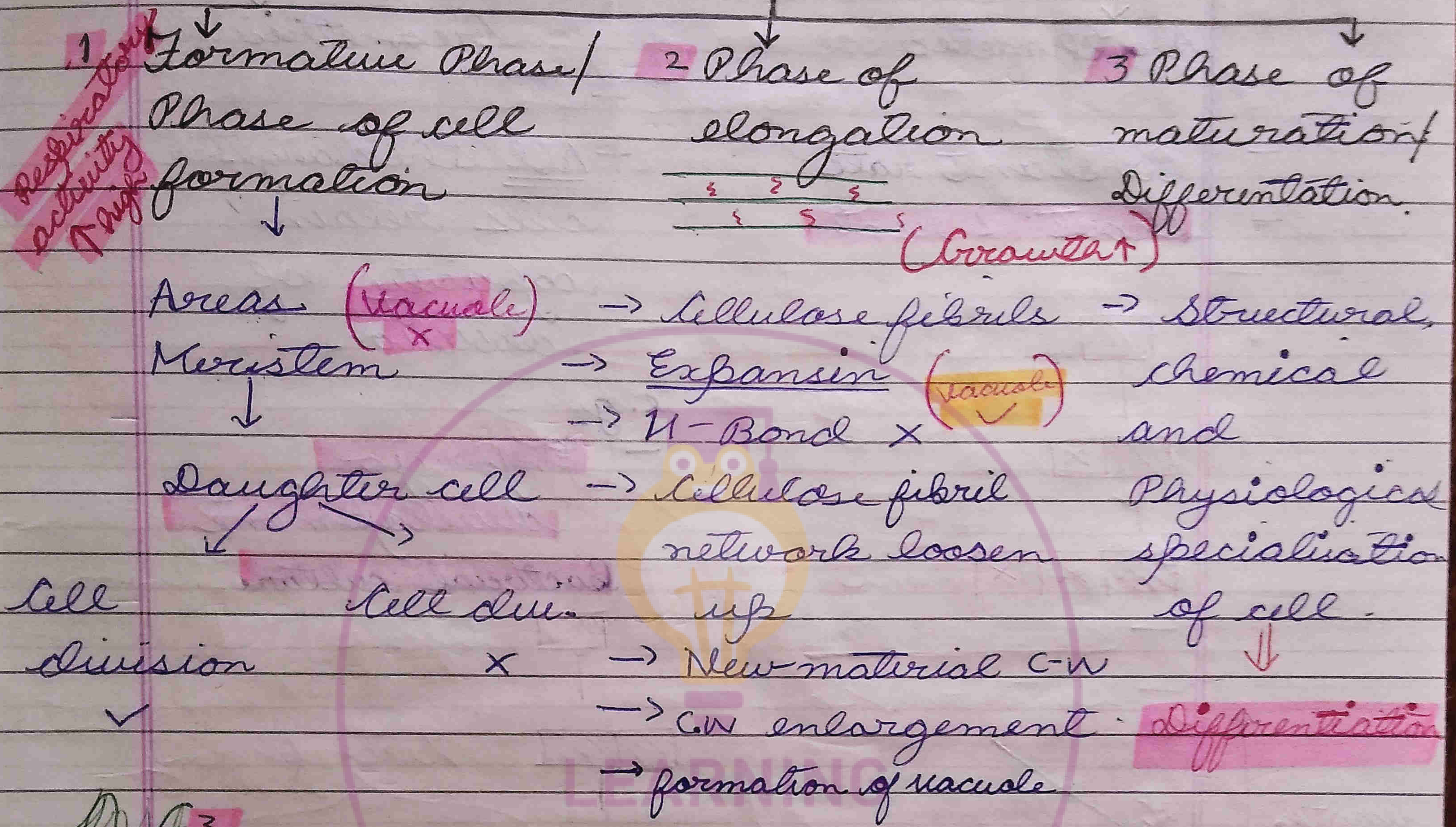
3. Open growth

4. **Increase no. of growth organs.**

5. Juvenile → Mature stages
structure of mature stage is different from that in juvenile stage.

• Expansin enzyme breaks hydrogen bonds in cellulose fibril.

Phases of Growth



• Maximum respiratory activity present in formative phase.

• Maximum growth in elongation phase.

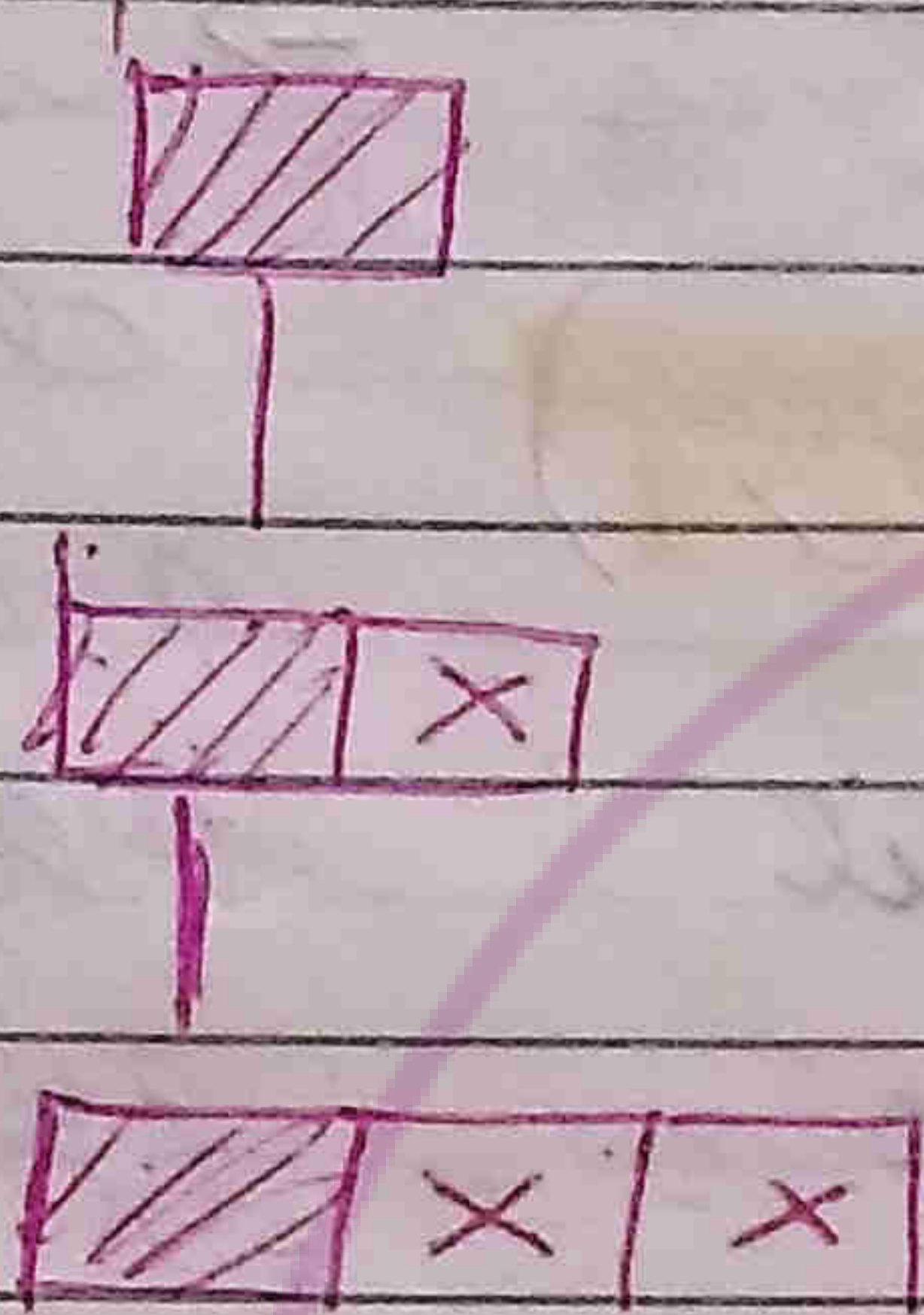
Growth Rate

Arithmetic

Geometric

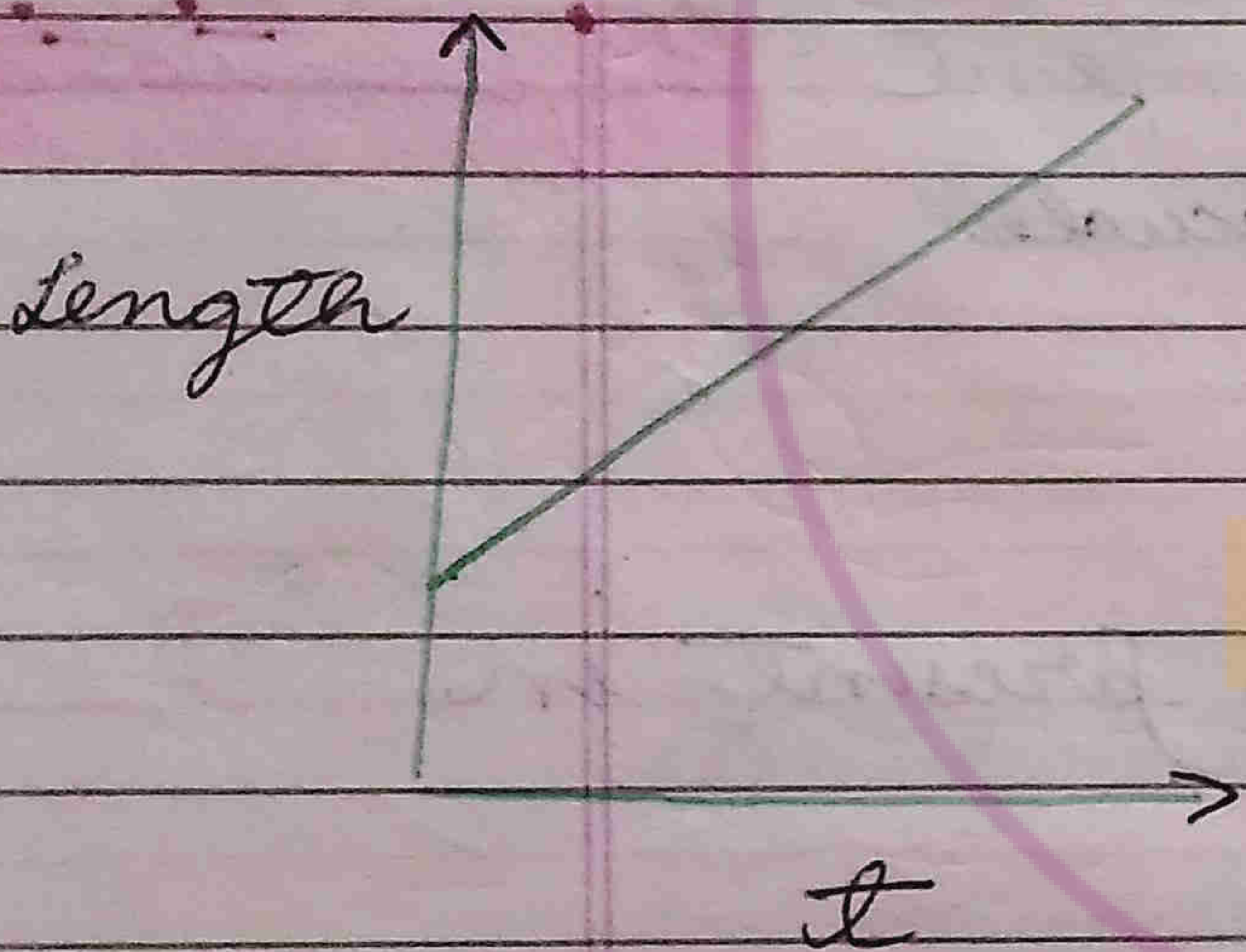
- constant rate
- shoot & root

- All the daughter cells retain capacity of division



e.g.

- Embryos development
- bacterial culture

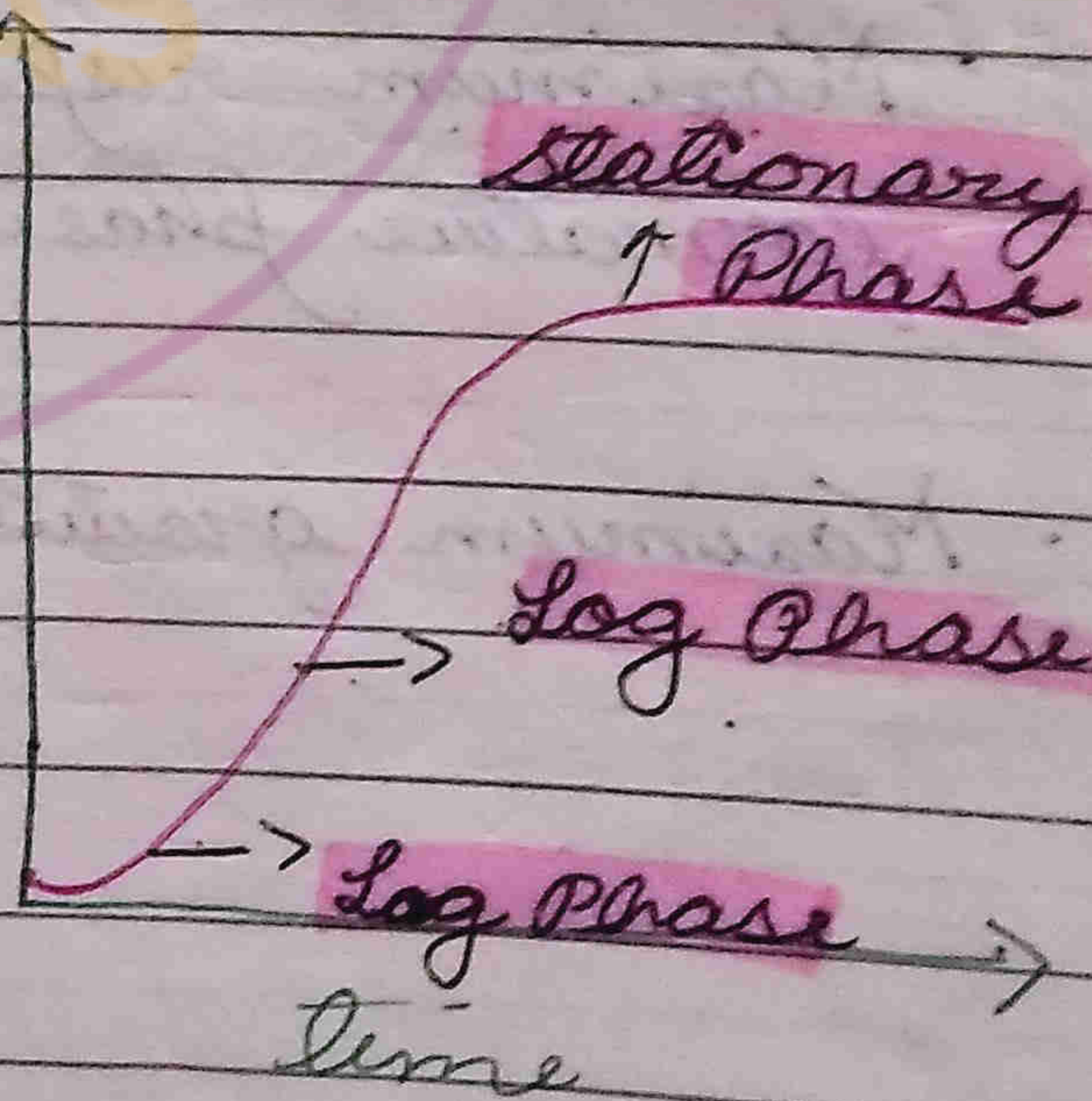
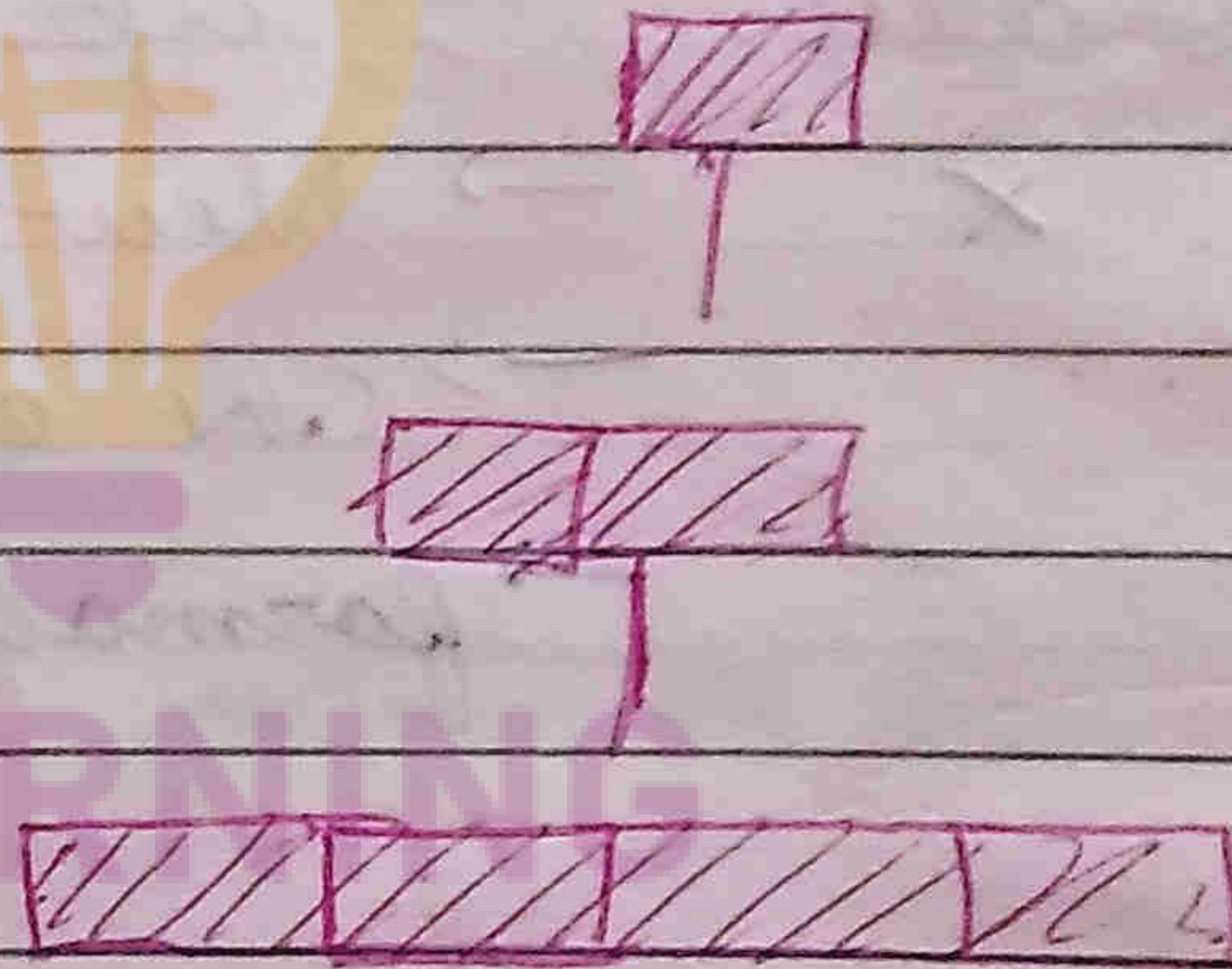


$$L_t = L_0 + rt$$

Here r = growth rate

t = time

L_0 = initial length



$$W_t = W_0 e^{rt}$$

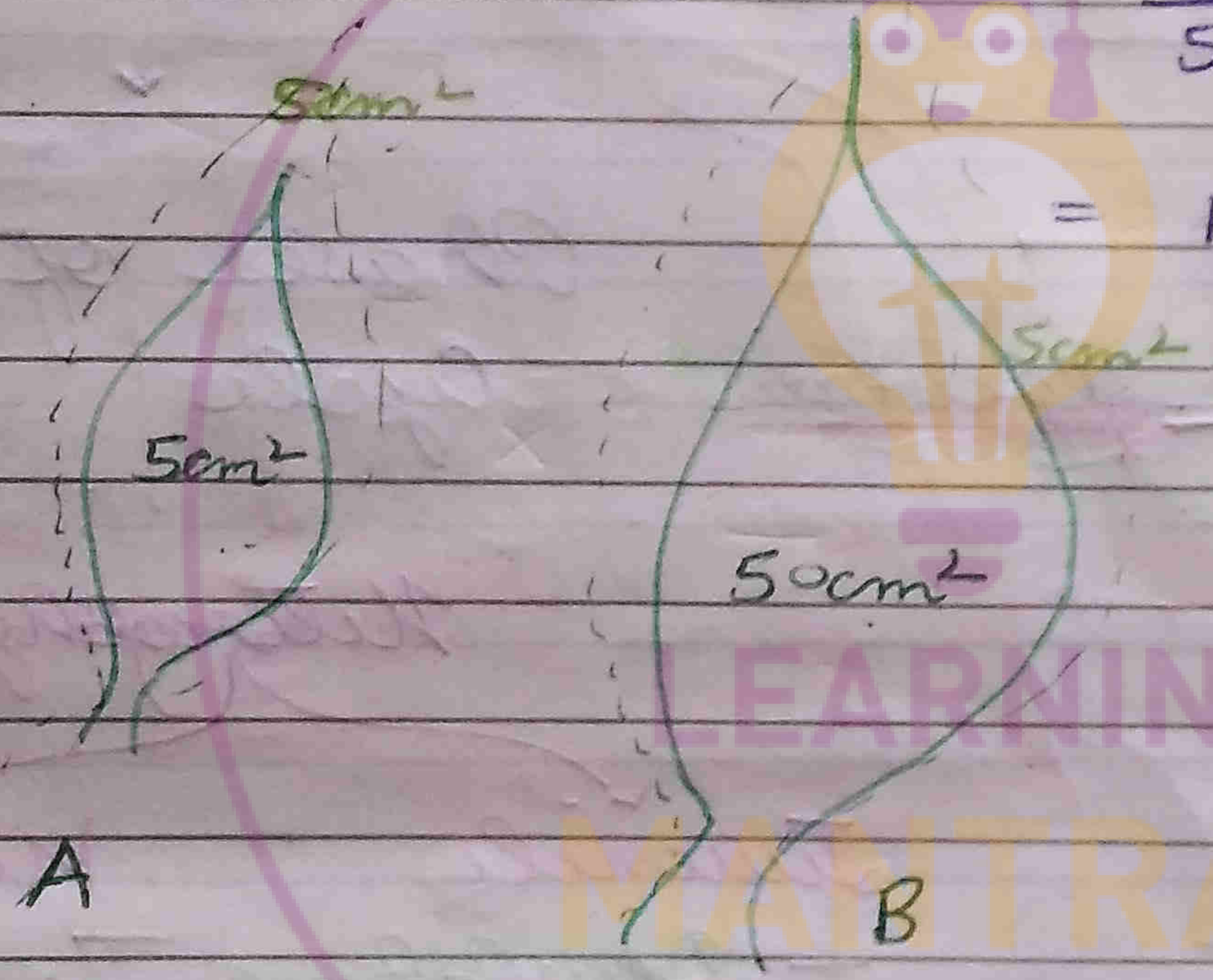
AGR: Absolute Growth Rate
 = Growth per unit time
 = A = B = $5 \text{ cm}^2/\text{day}$

RGR: Relative growth rate

$$\frac{\text{Growth}}{\text{Initial Size}} \times 100 \quad A > B$$

$$= \frac{5 \times 100}{5} \quad \frac{5 \times 100}{50}$$

$$= 100\% \quad = 10\%$$



Terms

• Differentiation

1° Meristem
 ↓ cell division X
 1° Permanent Tissue

specialised
 structurally
 chemically
 physiologically

• Dedifferentiation

Mature
 ↓ cell div ✓ (Despecialisation)
 2° Meristem (eg Intercellular cambium)

• Redifferentiation

2° Permanent tissue

Development

All the changes in structure and function of an organism that occurs throughout its life cycle from seed germination till death.

Plasticity

Ability to change

Environment

- Ranunculus flabellaris
- Buttercup

Phases of Life Cycle

Heterophylly

Juvenile

Mature

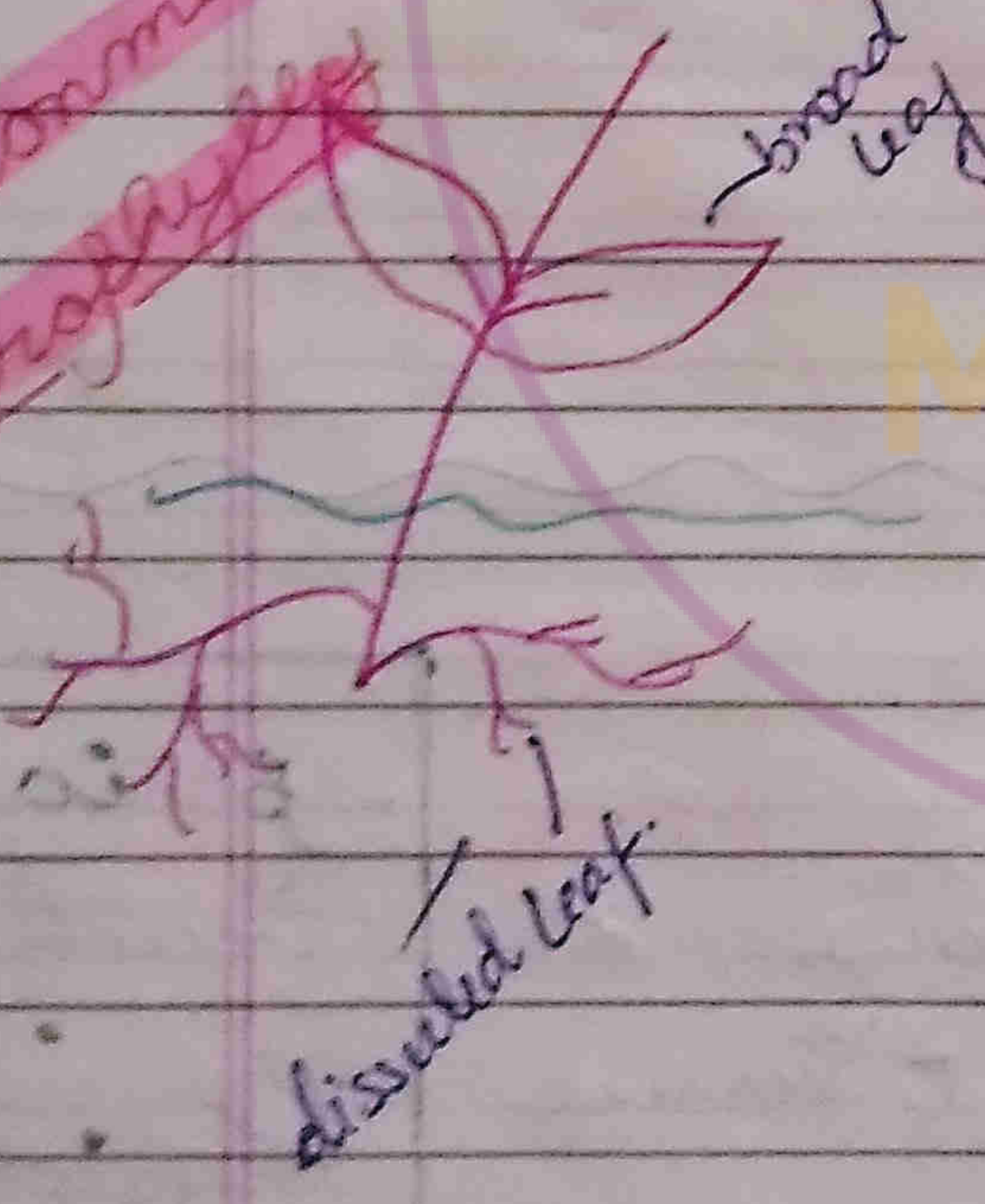
Developmental Heterophylly

- Cotton

- Coriander

- Larkspur

Environmental Heterophylly



LEARNING MANTRAS

Development

controlled by

Intrinsic factors

Extrinsic factors

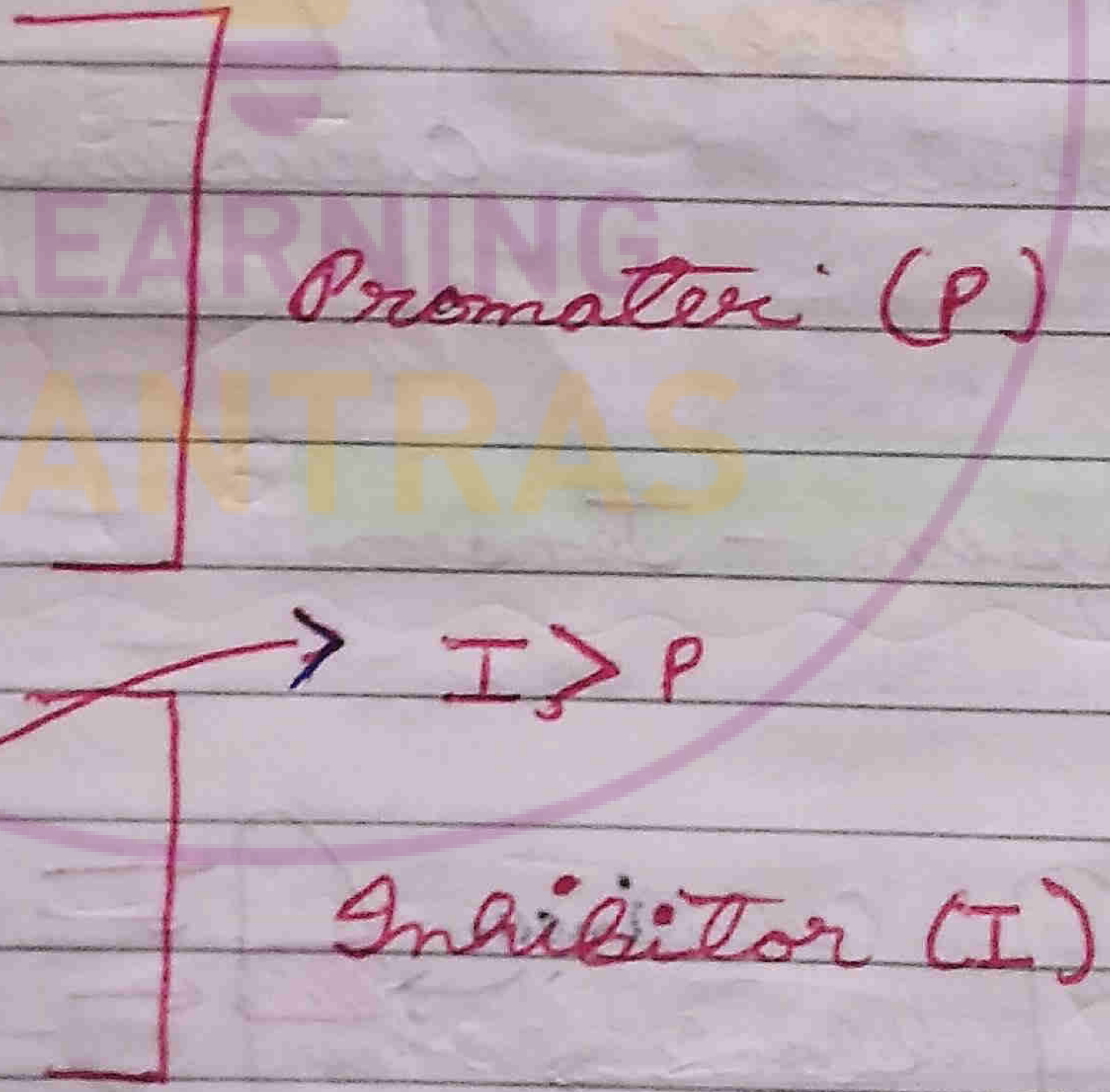
Intercellular
PGR's
Plant Growth
Regulators

Intracellular
Hormones

- Temp
- O₂
- H₂O
- Nutrients

5 Types

- 1 Auxins
- 2 Gibberellins
- 3 Cytokinins
- 4 Ethylene
- 5 ABA

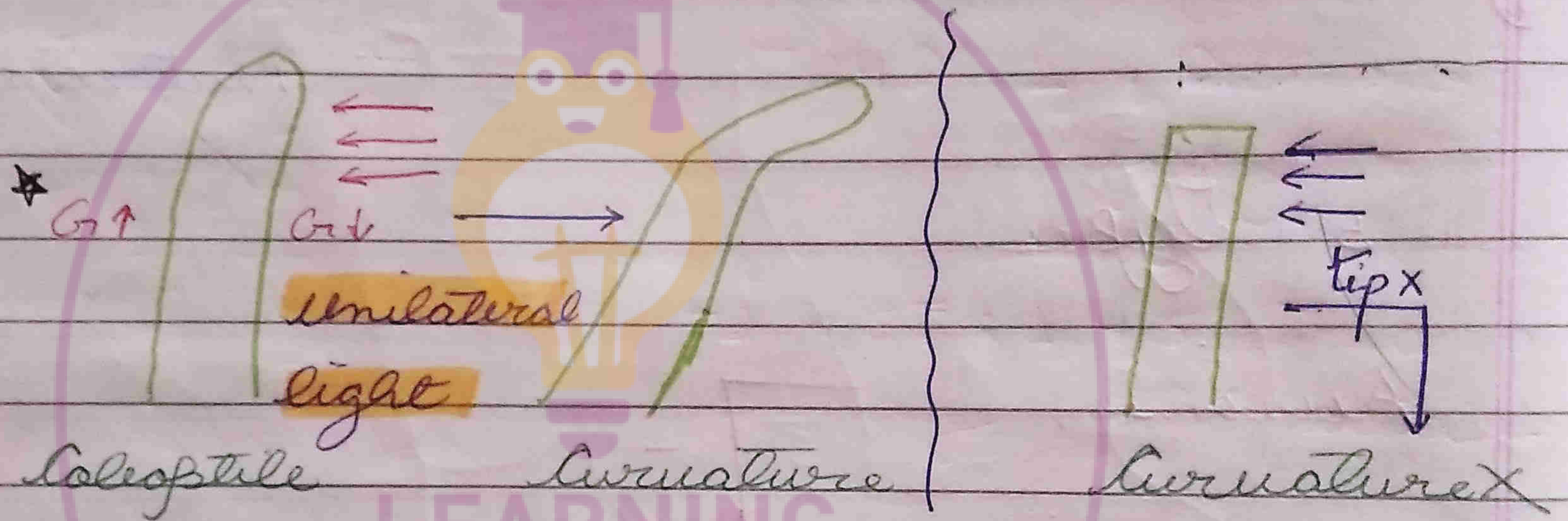


* Differential growth leads to curvature.

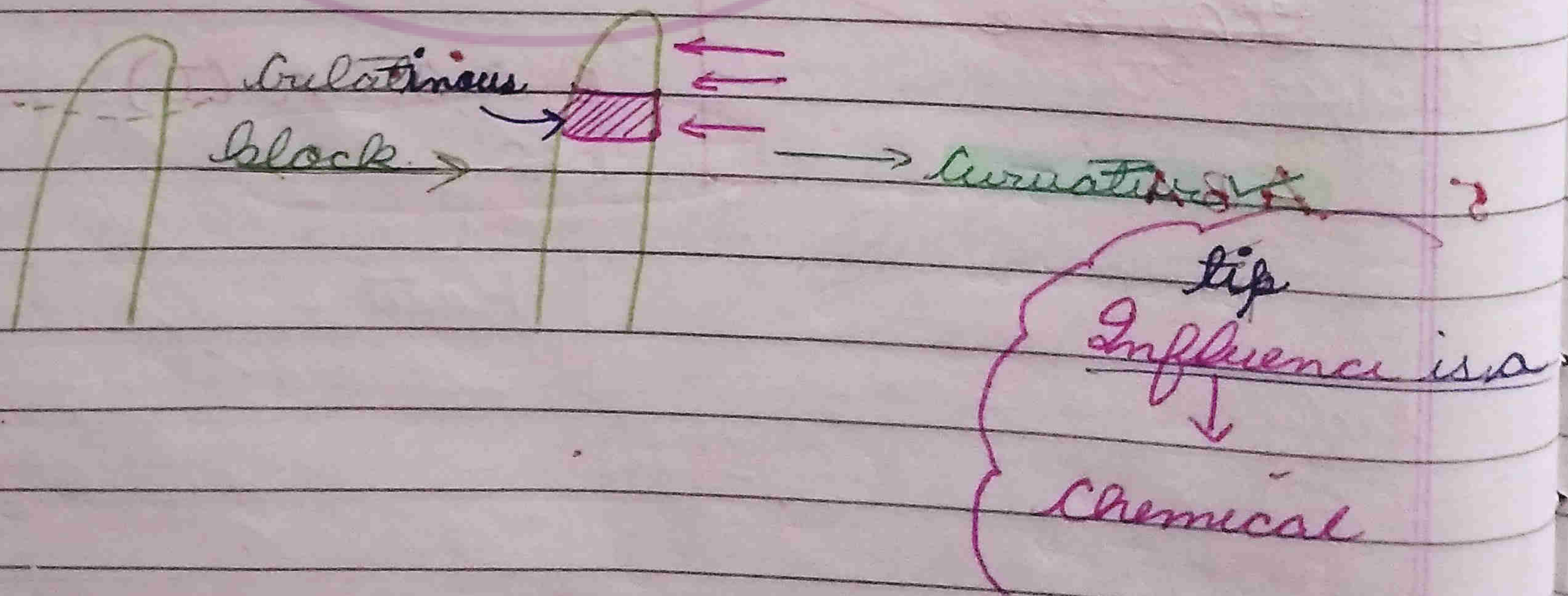
Auxin

- ① Charles Darwin
- Francis "

Canary Grass
(*Phalaris canariensis*)



- ② Boysen - Jensen

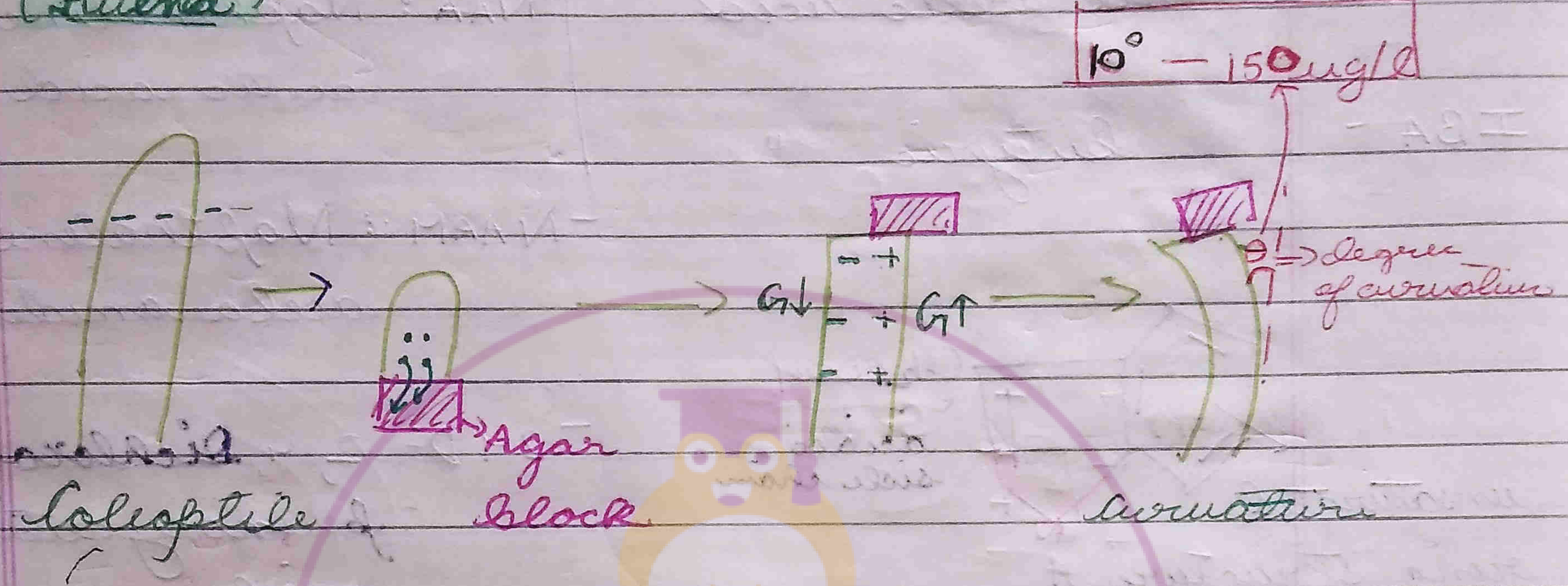


Auxin was first extracted by Went.

★ Auxin first isolated from Kummur wine.

3 Went → gave the name auxin.

Oat seedling
(Avena)



Auxin
↓
Gib Auxin
↓
to grow

extracted

Bioassay of Auxin

- Avena curvature test

• Quantitative ✓

• Qualitative ✓

- Split Pea Test

- Arabidopsis Root Inhibitor test

Structure

- Weakly acidic compound ✓
- Unsaturated ring ✓
- Acidic side chain present ✓

★ For growth of shoot greater amount of auxin is required as compared to root.

Natural

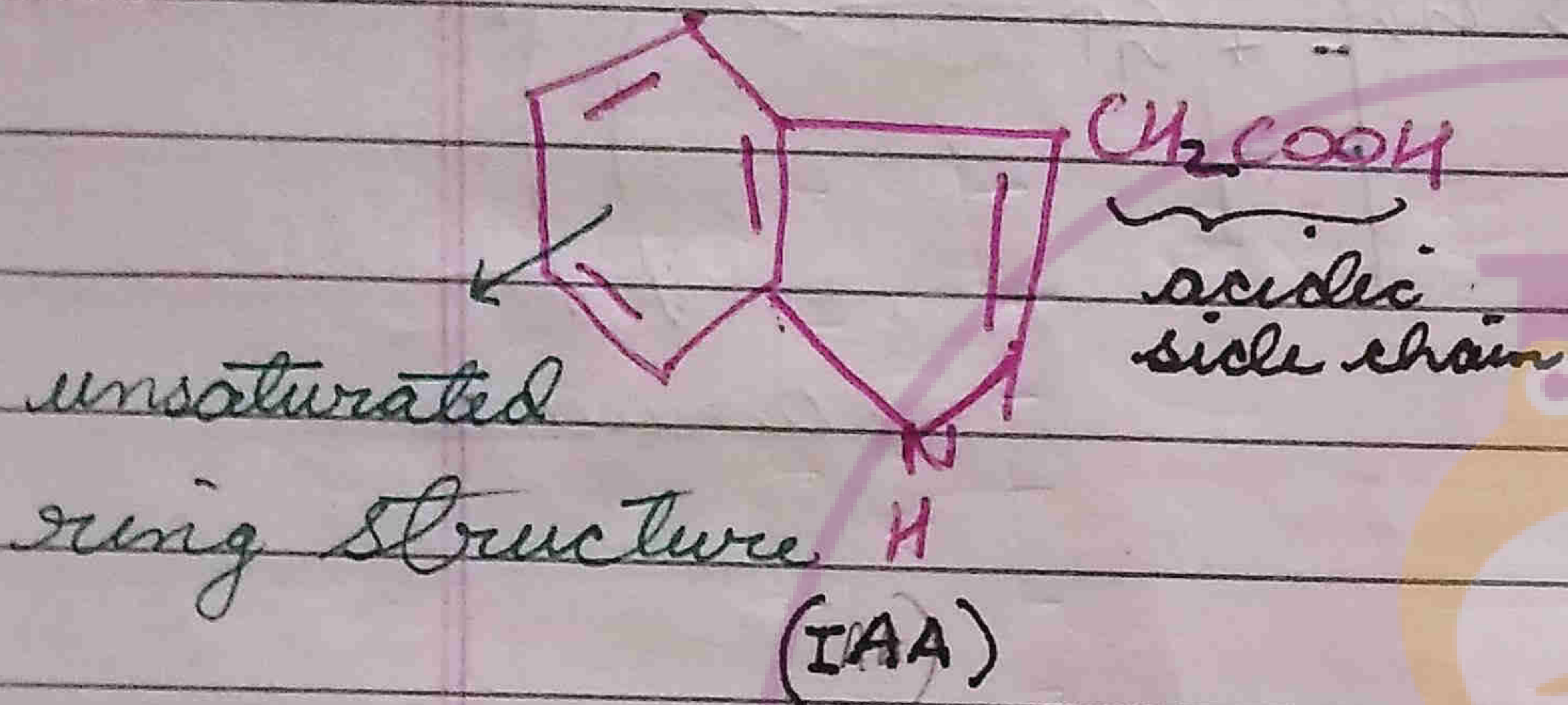
Synthetic

IAA - Indole acetic acid

-NAA = Naphthalene acetic acid

IBA - " butyric "

-NAAM = Naphthalene aceta amides

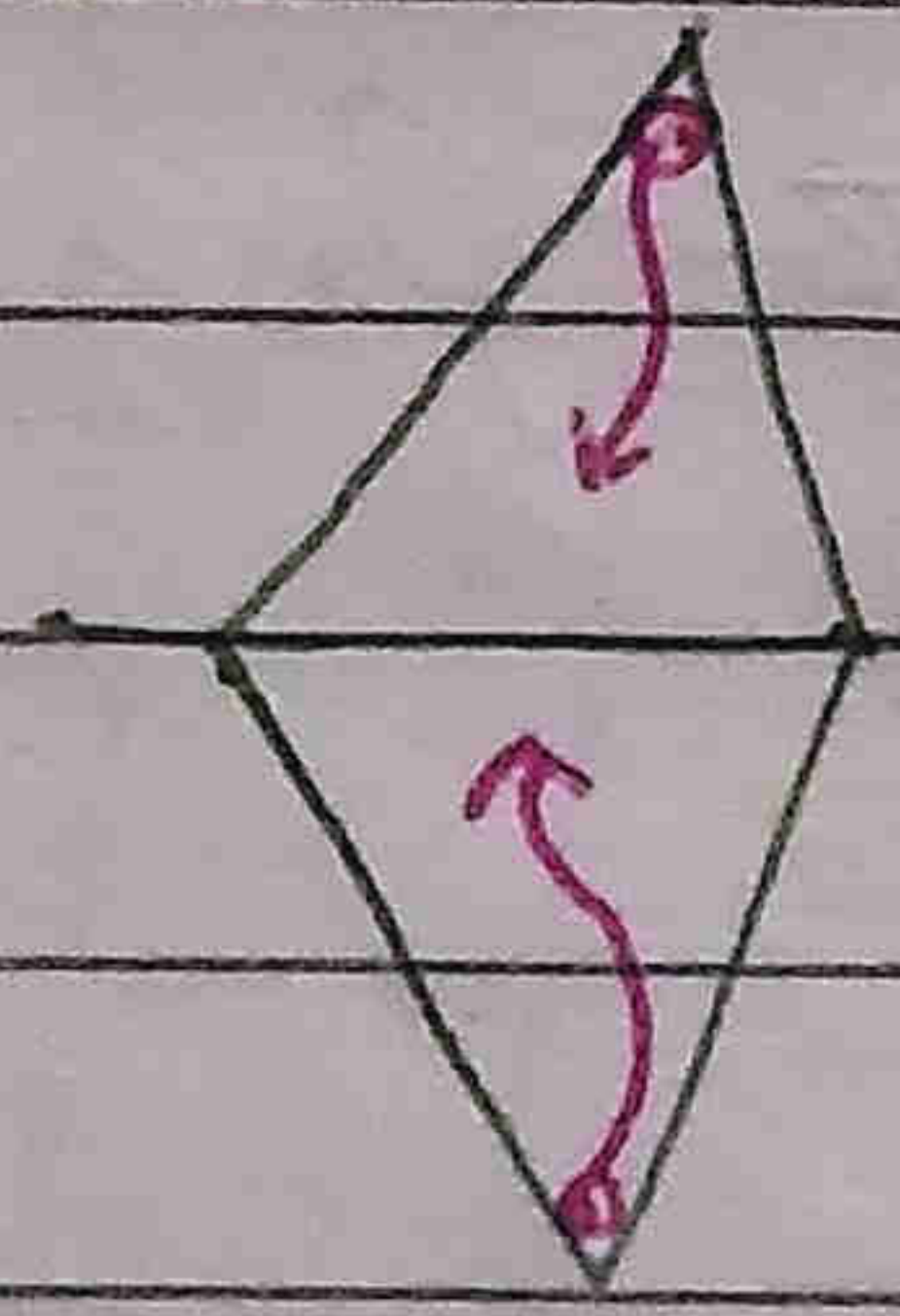


-2,4,D = 2,4 Dichloro-phenoxyacetic acid

-2,4,5,T = 2,4,5 Trichloro phenoxy acetic acid.

Synthesis: Tryptophan, m⁺

Location: Shoot tip 10 ppm
Root tip 0.0001 ppm



↑ "more towards opp. poles"
Polar transport
"Base seeking hormone"
↓
Moves from tip to base.

Auxin

Free state

- unbound
- active ✓

Bound state

- IAA - Alanine
- IAA - Aspartic acid
- Inactive
- storage purpose.

bound with

- Expansin activated in acidic medium.
- Auxin counteracts apical dominance.

Junctions

1. Cell Elongation
2. Apical Dominance

Auxin
↓
(cell wall)
C.W acidic
↓

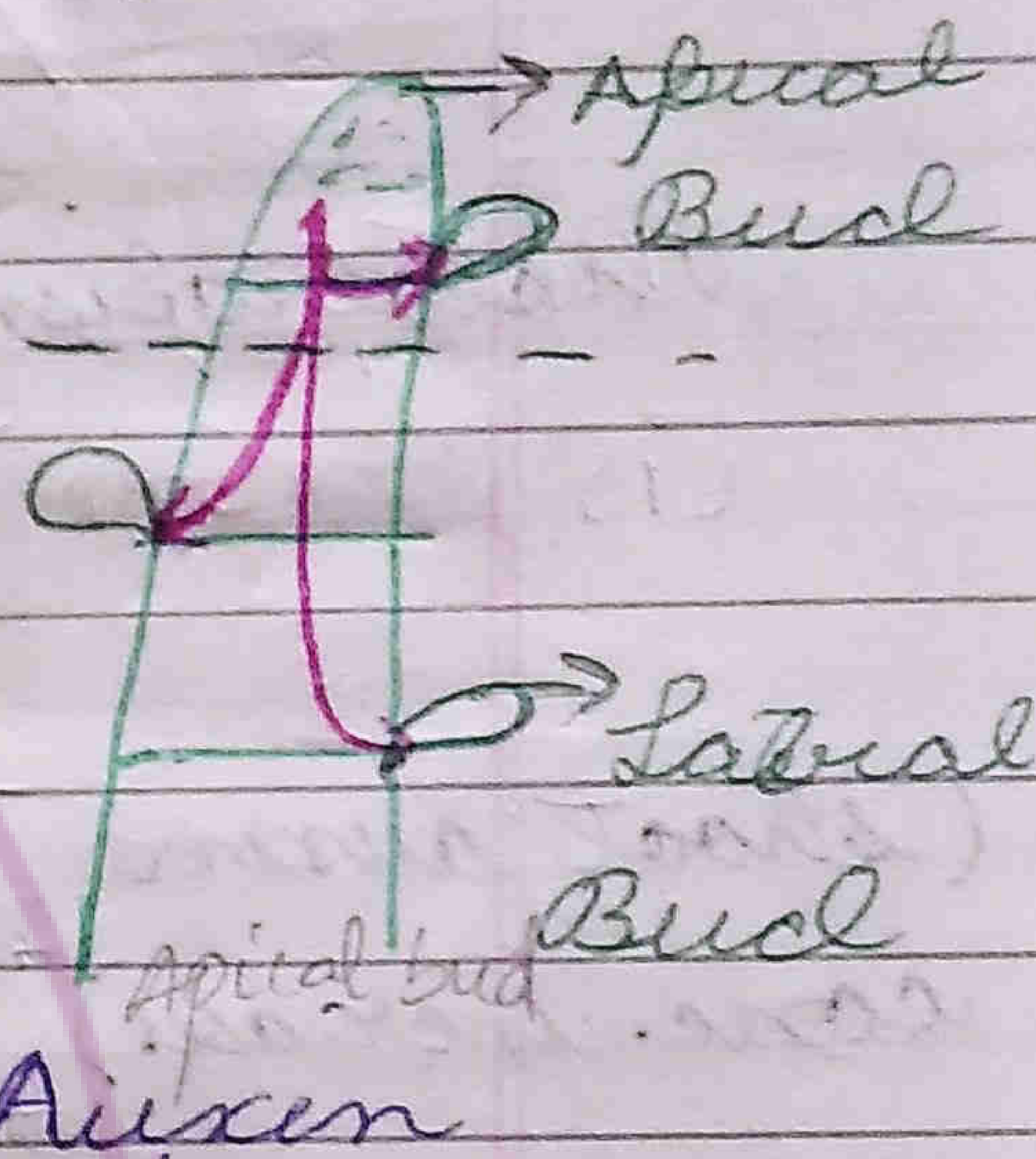
Expansin
↓

Cellulose microfibril
H-Bonds

Loosen-up network

addition → New cell wall material
→ Cell wall enlargement
leading to cell elongation

Inhibits
differentiation of
Xylem/Phloem

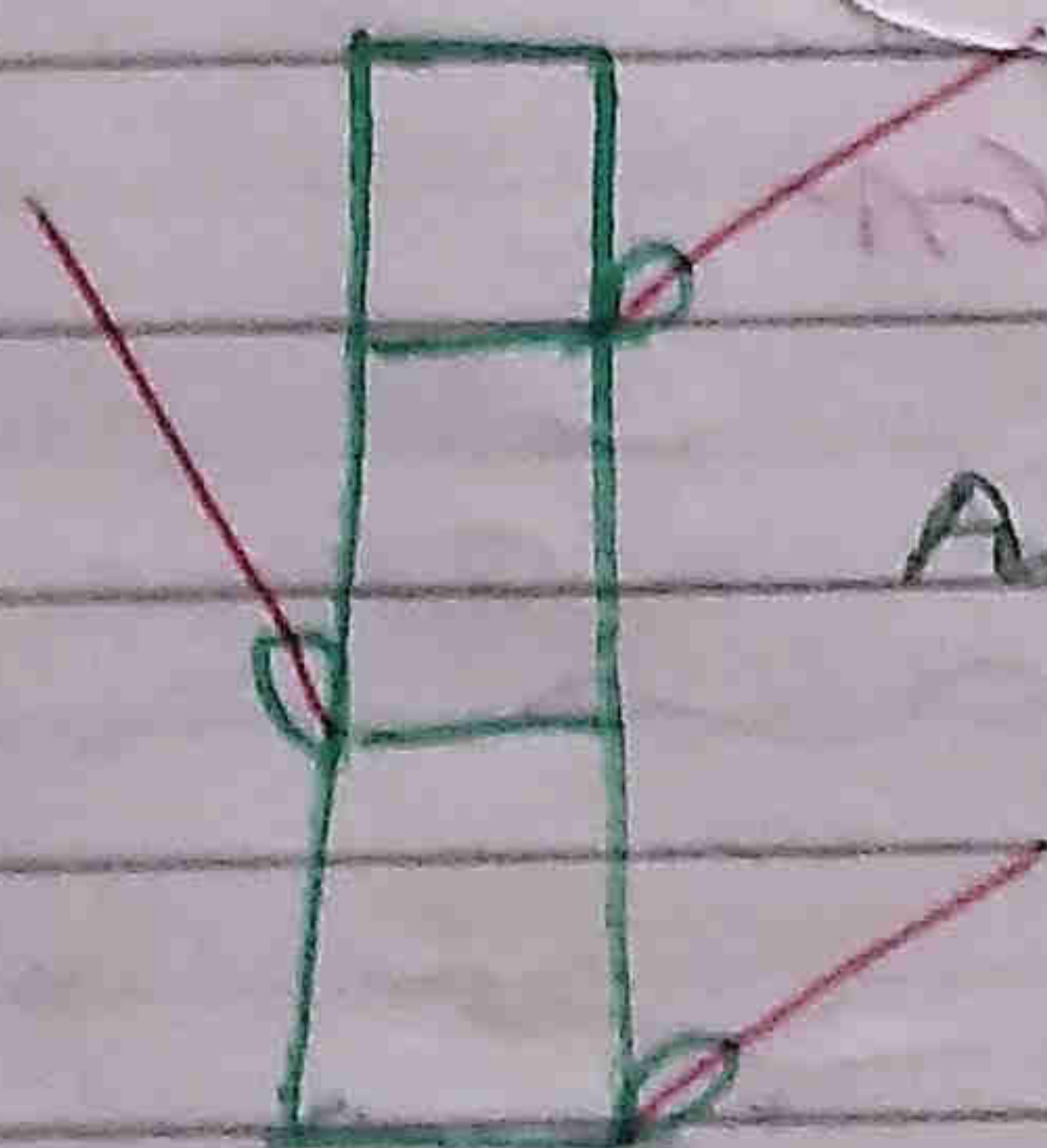


Lateral Bud
↓

Growth of Lateral Bud ↓ (decreases)

Sprout / Branch x

Pruning / removal of apical bud
Decapitation



Auxin ↓

Auxin
Inhibits
differentiation of
X & P

∴ Lateral bud x

Significance of Pruning

- Tea Plantation
- Hedge making

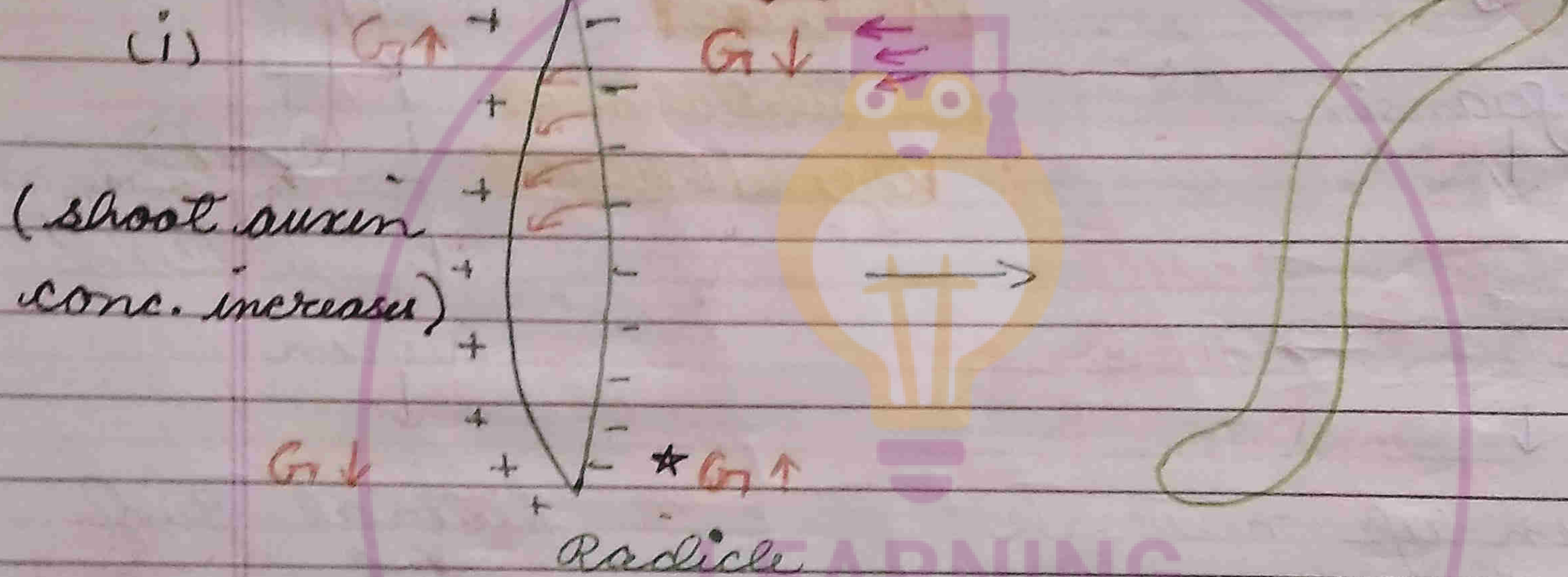
★ For root growth auxin concentration should be less.

[3] Phototropism & Geotropism

◆ Tropic movements

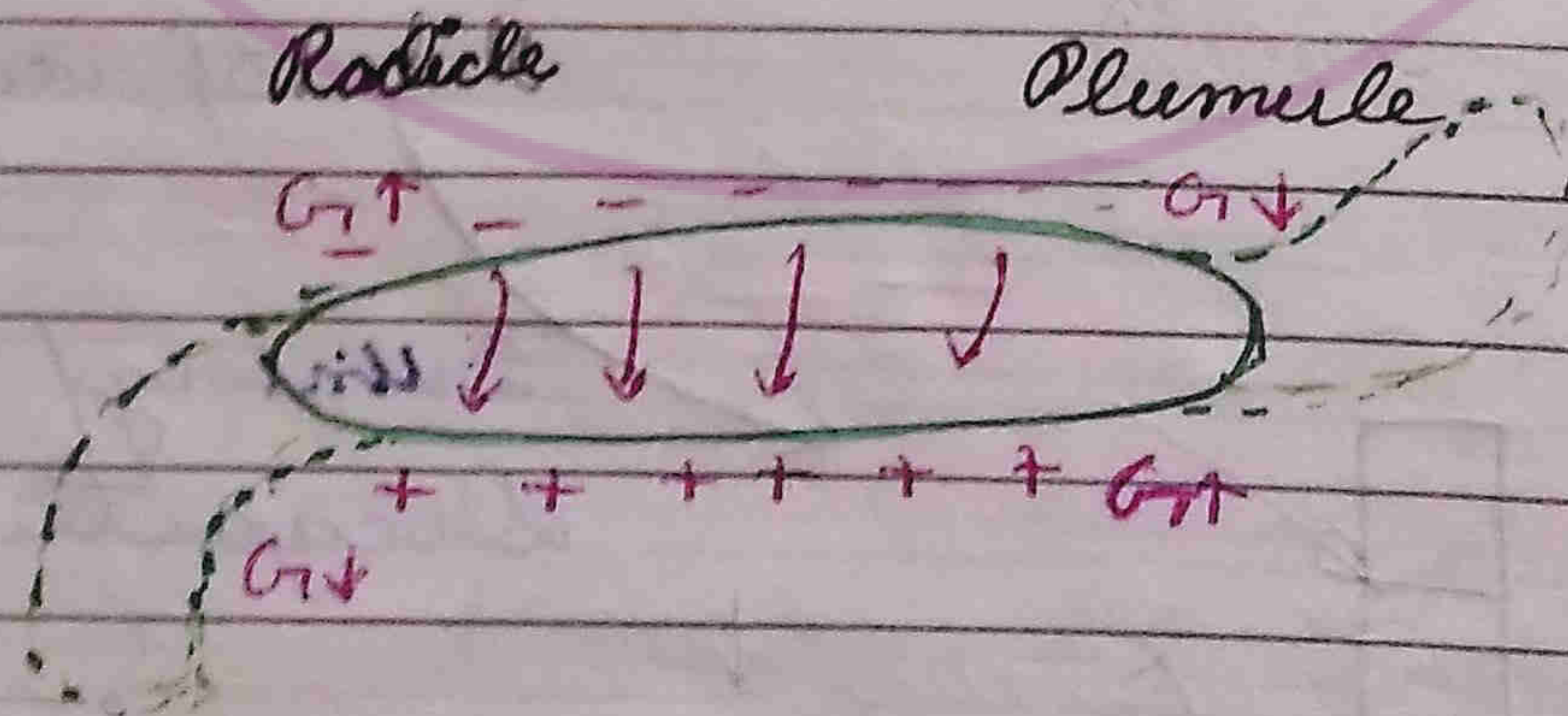
- Curvature movements
- Cylindrical organs (shown by)
- Diff^{erential} growth (due to)
- Stimulus (towards or away from)

Phototropism Plumule



(Root auxin conc. decreases)

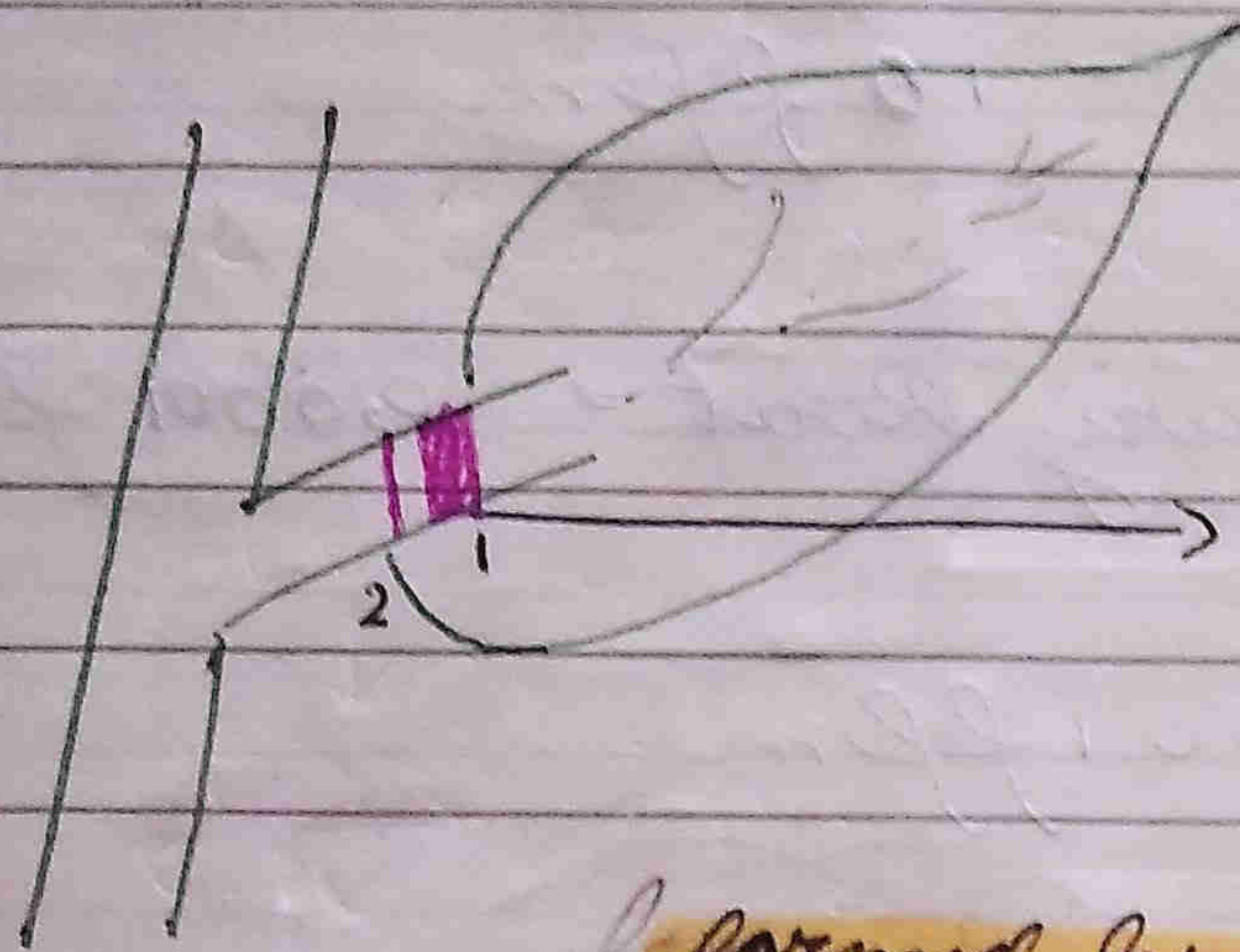
(ii) Geotropism



⇒ shoot = +vely phototropic ; -vely geotropic
 root = -vely phototropic ; +vely geotropic

- Dicot can easily absorb auxin but monocots show poor absorption.
- Ethylene is the main hormone for abscission and not abscisic acid.

4 Abscission → of older mature leaves and fruit.



Abscission zone consists of two layers

- 1: Separation layer
formed by cellulases, pectinases
C.W breakdown

Auxin gradient

Theory

given by

Addicot & Lynch

Protective layer
suberin + nt

Stem

Leaf

Abscission

A

A

A

A

A

A

Start of abscission zone

abscission occurs.

5 Herbicides

2,4-D

2,4,5T

Absorption ✓

Absorption ✗

• Dicot Monocots (Insensitive)

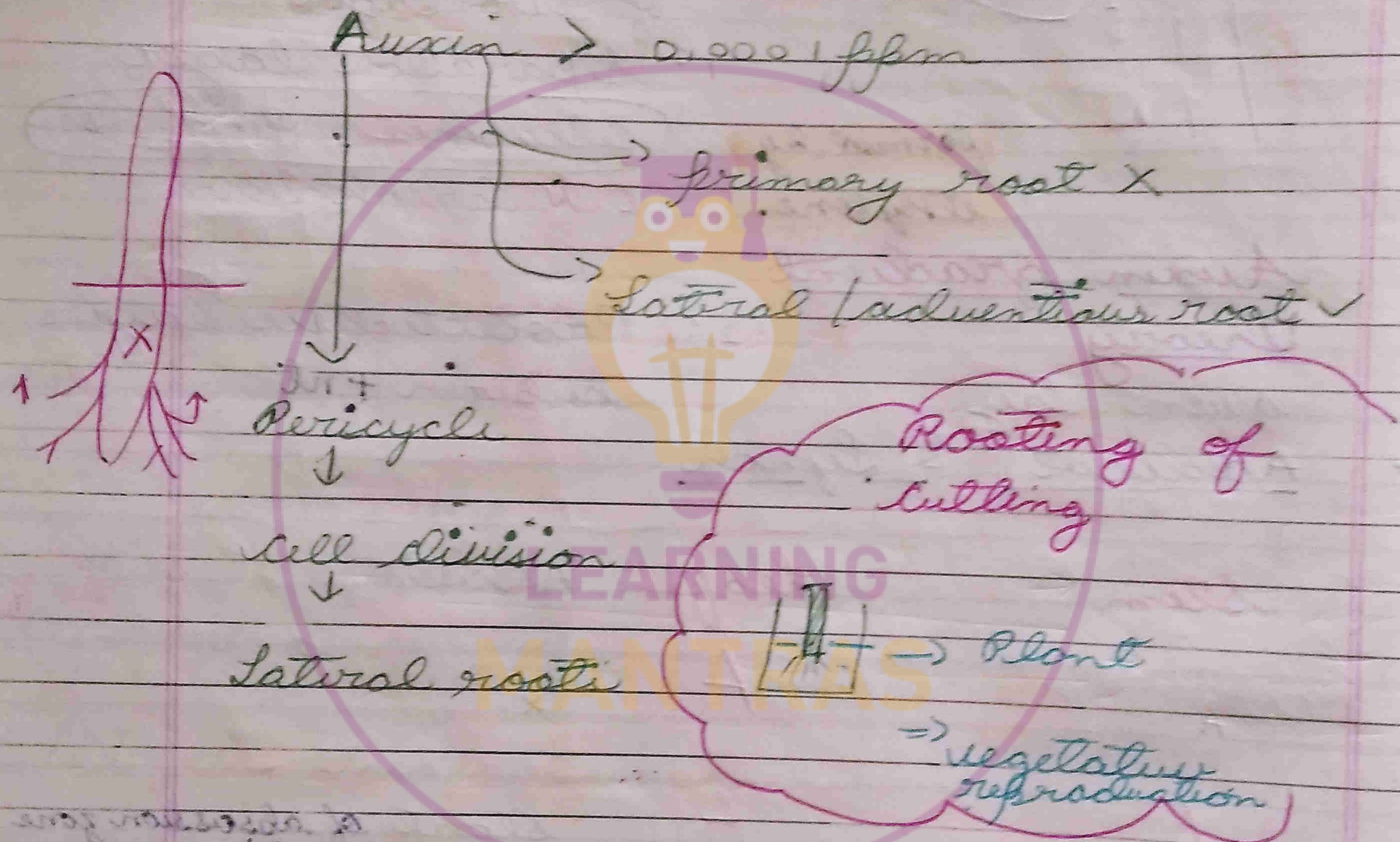
• Broad leaf plants
Kill

6

Lateral root form

shoot growth - 10 fpm

Main Root / Primary Root = 0.0001 fpm



Also called

"RSN -> Root Settling Hormone"
ROOTONE

7

Parthenocarpy -> Tomatoes

8

Root nodule -> Legumes

* Plants
- Auxin

* Bacteria
Cytokinin

In apples fruits are formed on dwarf shoot.

Auxin strengthens the stem of grasses.

~~Indole acetic acid~~ is type of auxin.

SONARCOFFA
PAGE NO
DATE

9 Dwarf shoots in Apples: NAA used
fruit ↑ production

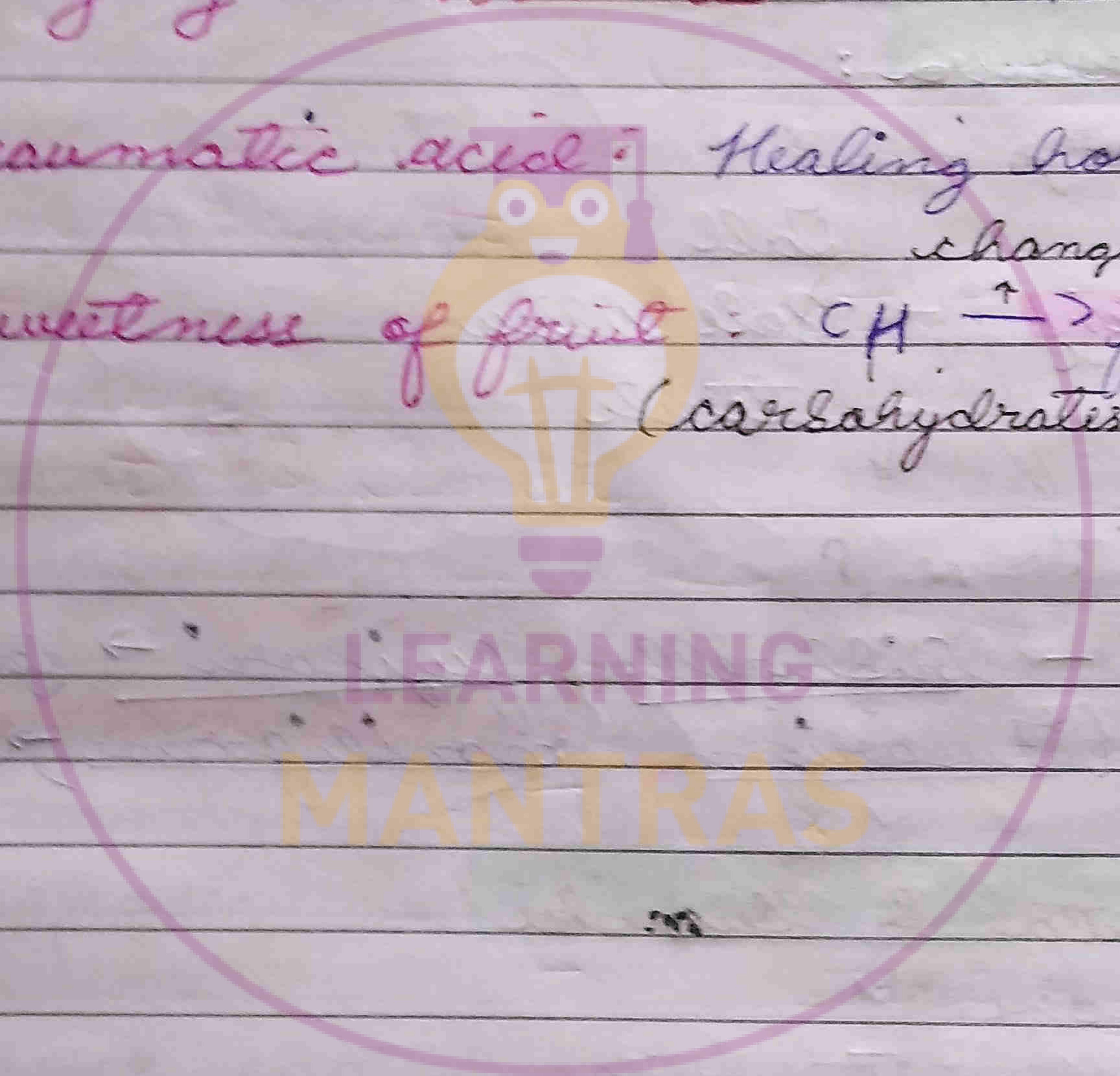
10 Flowering: Pineapple, Litchi

11 Feminish effect: formation of female flowers.

12 Lodging: Prevents ↑ in grasses. NAA used.

13 Traumatic acid: Healing hormone. changes

14 Sweetness of fruit: CH → fructose (carbohydrates)



* Terpenes are derived from acetyl CoA hence gibberellins can also said to be derived from acetyl CoA.

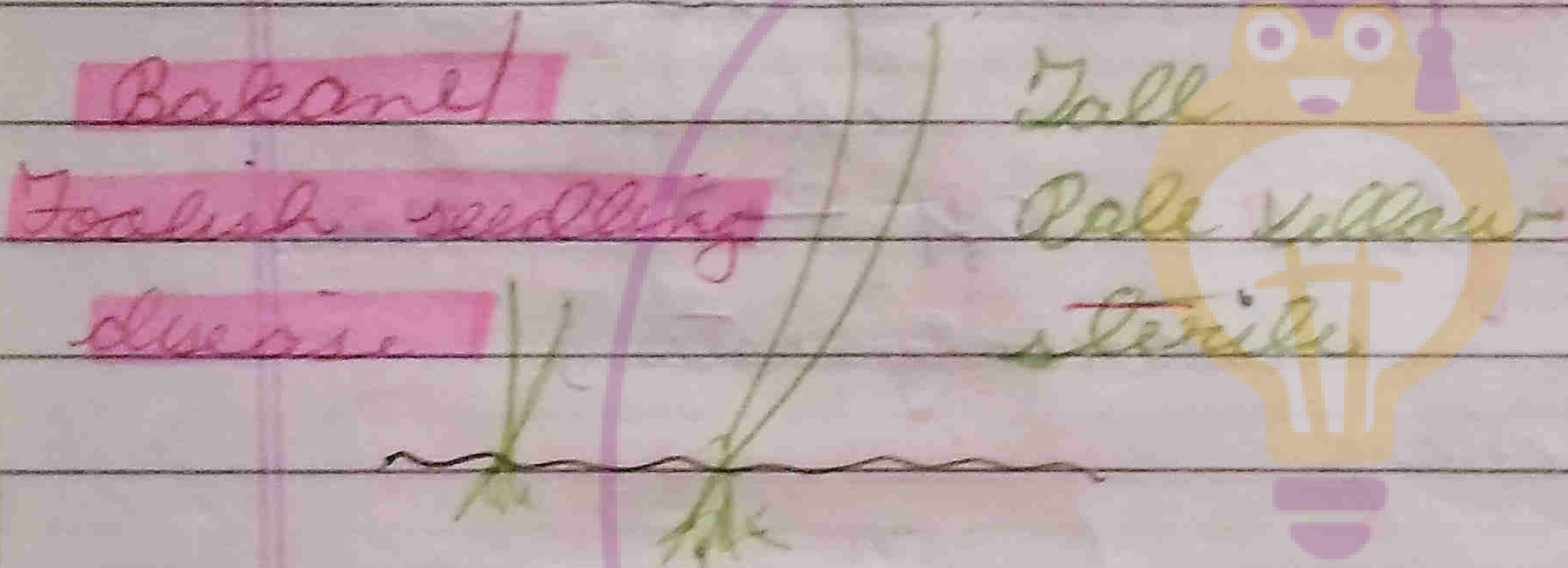
Gibberellins

↑

- Weakly acidic
- Terpenes (derivative)
- Gibberane ring structure

History:

(i) Kurosawa:



- Fungi - Gibberella fujikuroi → perfect stage
(Fusarium moniliforme) → imperfect stage

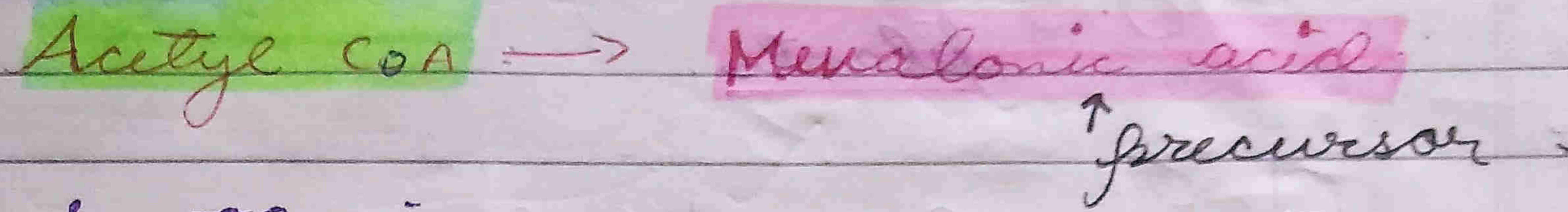
2 Yabuta & Sumiki:

- Hormone
- Gibberellic acid
- 15 Types of GA formed by fungi
GA₂₄, GA₂₅ most common in fungi

> 100 types
of GA found in plants
• GA₃ (most studied)

Gibberellic acid is synthesised in root tip, but performs no role in root growth.

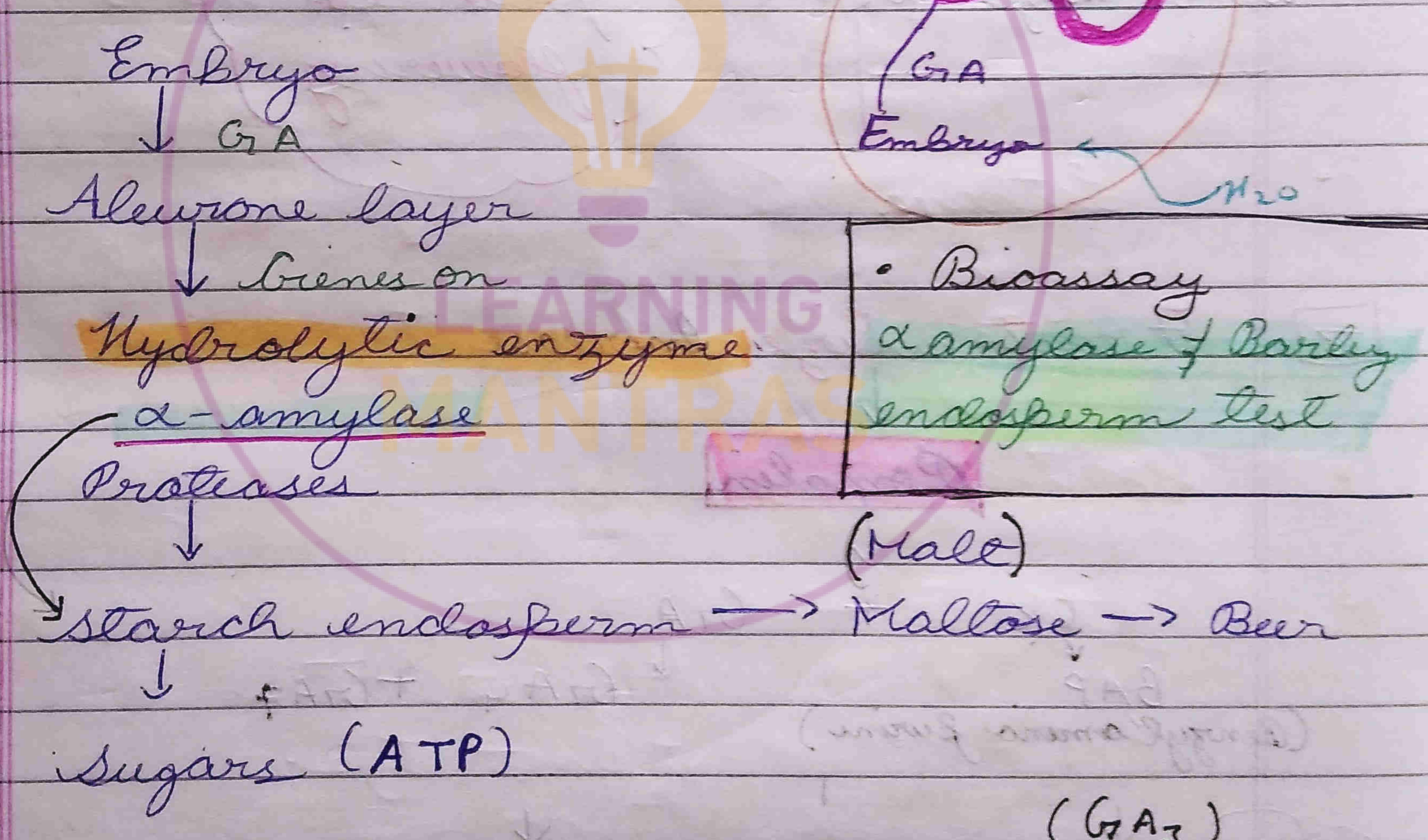
• Precursor:



- Synthesis
- Root tip ✓
- Developing embryo ✓

• Functions →

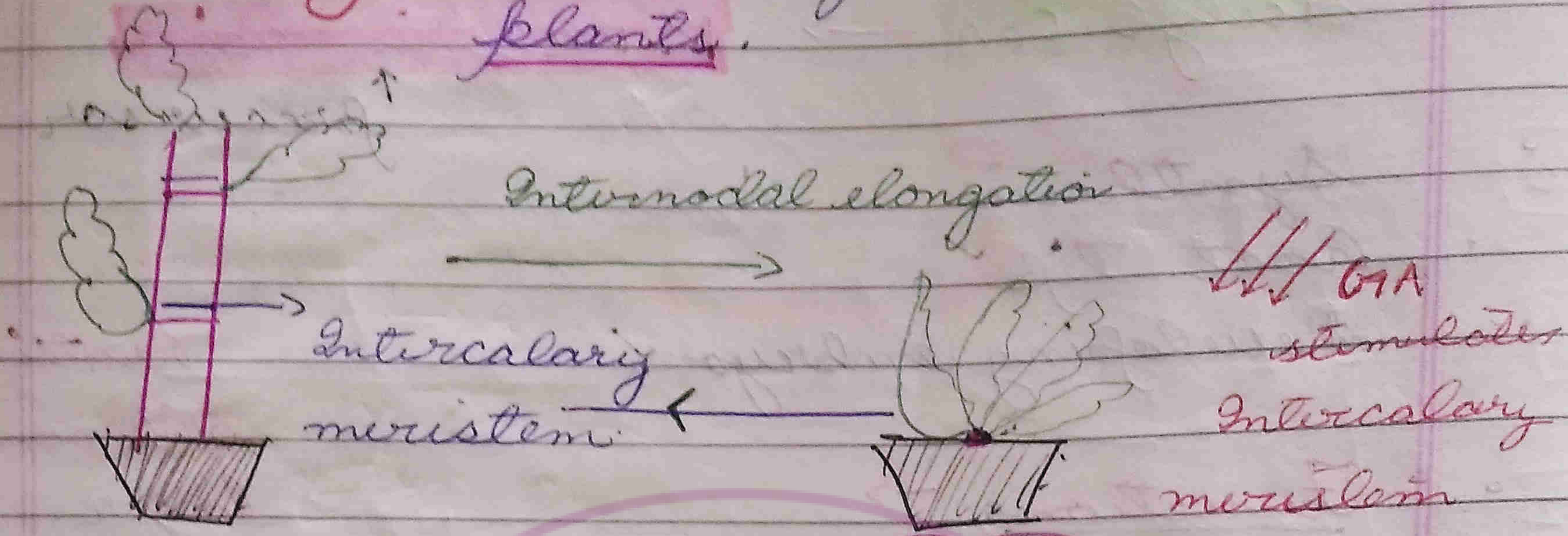
1. Seed germination
Barley seed



• In brewing industry gibberellic acid is used to increase the rate of malting.

- GA can cause elongation in genetically dwarf varieties.
- Thalamus and stalk are type of internode.

2 Bolting : Stem elongation in Rosette plants.

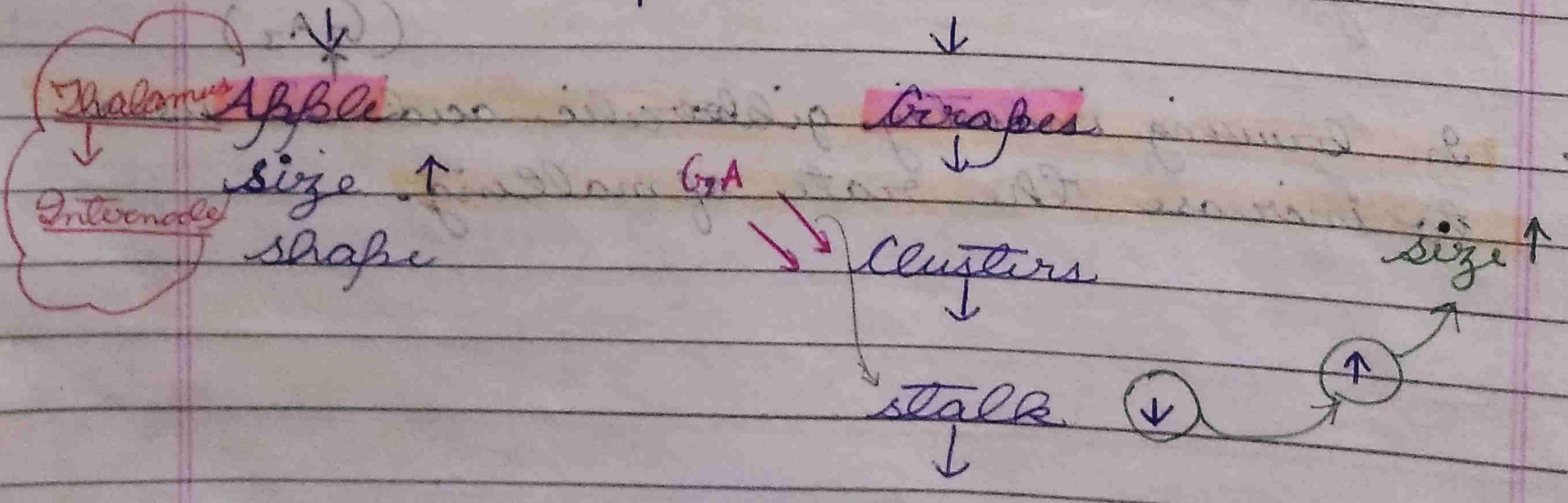
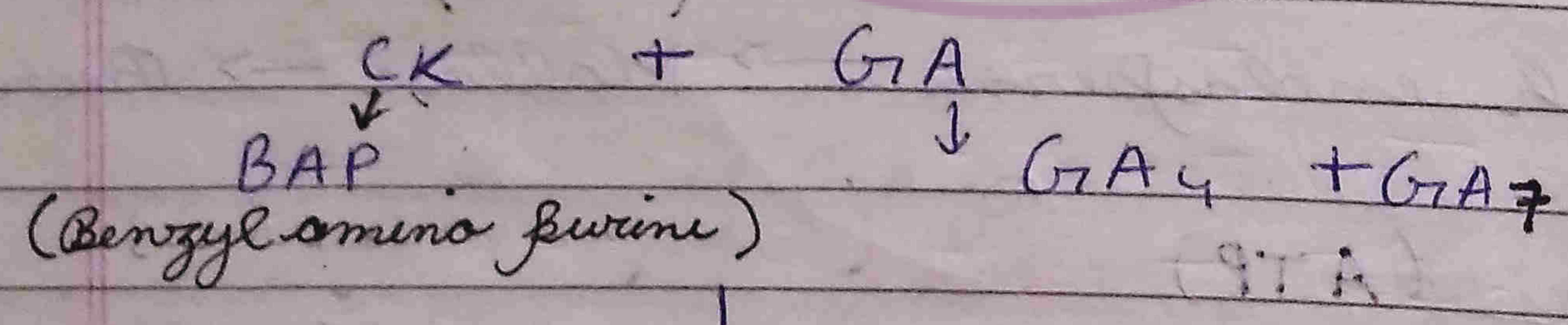


- Bioassay
- Dwarf pea test
 - Dwarf Maize Test

Beet and cabbage bolting occurs naturally prior to flowering

3 Fruit Size Increase

Pomalin



Gibberellic acid is the only hormone which develops male characteristics in flowers.

4 Sugarcane (C₄ plant)

Stem ↓ GA

Stem ↑

Increases Yield by
20 tonnes/acre

5 Flowering - LADP (long day plants)

6 Male Flowers → MSH
(male steroidal hormone)

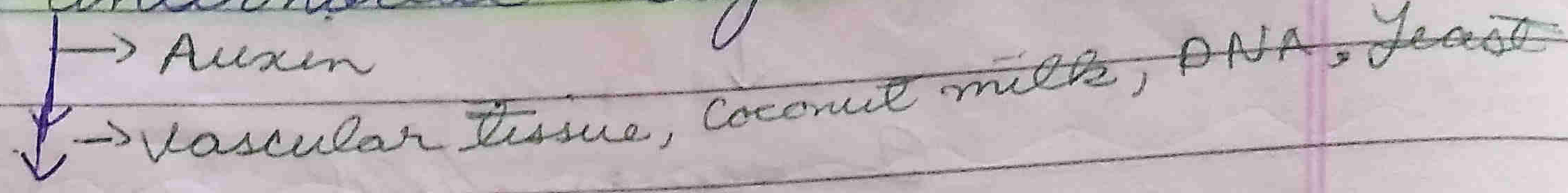
7 * Delay senescence

8 Conifers Juvenile → GA → Seed formation is enhanced.

Cytokinin

Skoog and Miller

Tobacco internodal segments



Auxin Callus

Herring sperm DNA

Kinetin (6-furfurylamino purine)

Letha: extracted natural cytokinin

↓
Corn kernel and coconut milk

↓
Letha

Synthesis →
- Fruits
- Shoot lateral bud
- Root tips

Preursor → Purine
 |
 → Adenine
 → Guanine

★ Cytokinin involved in formation of chloroplast.

Function:

1

Cell division

CK causes synthesis of

• Cyclins

• CDK



M-Phase

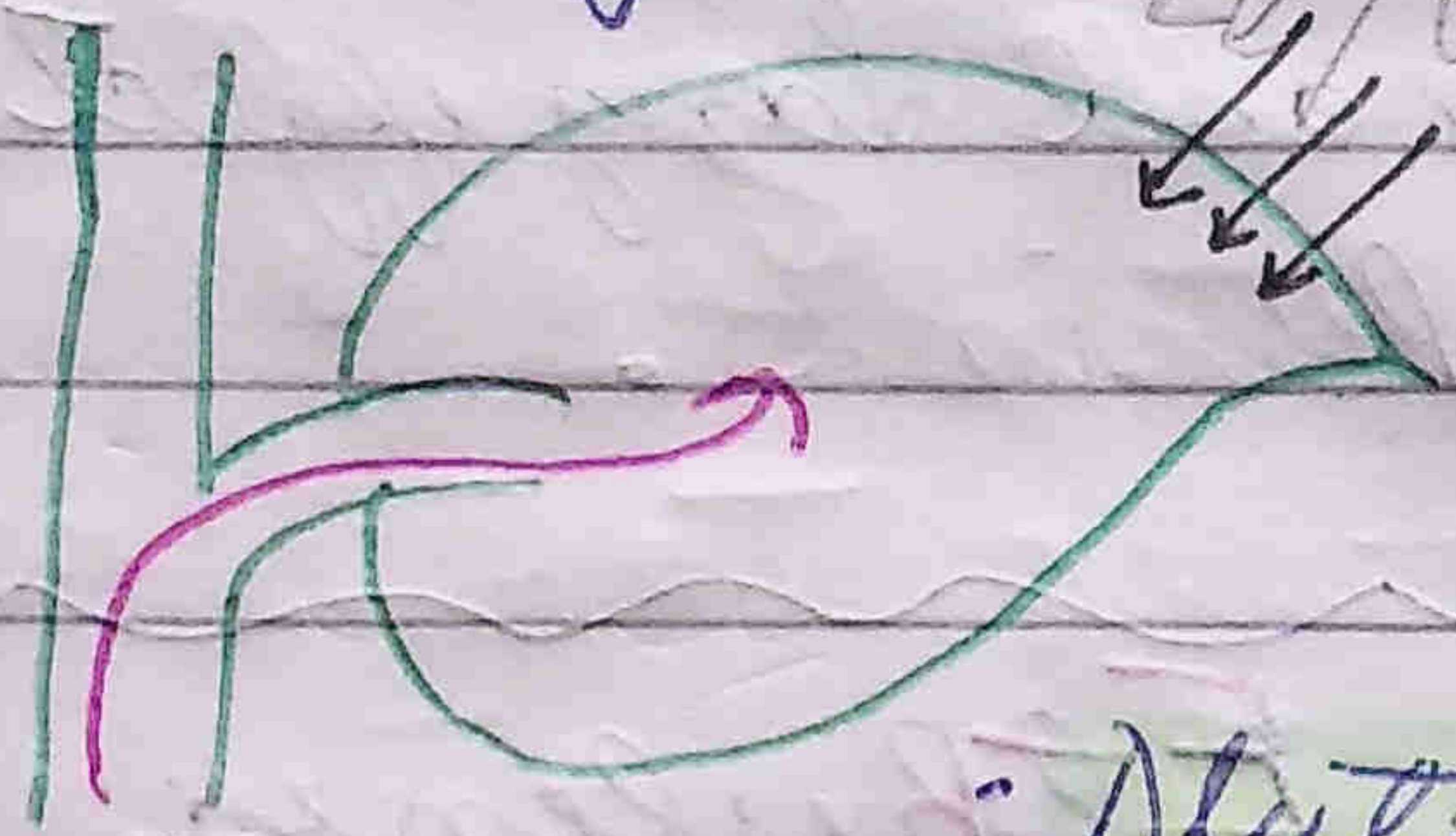


Cell division

2

Delay senescence

(Anti ageing hormone)



• Nutrient mobilisation

• Sink

↑ Phloem Transport

3

Chloroplast: Chlorophyll Preservation

Formation = Test (Bioassay)

4

Overcome Apical dominance:

• shoot - lateral

5

Cell Expansion: Leaves, cotyledons

→ Reddish cotyledon expansion Test

(Bioassay)

(Bioassay)

6

Tissue culture:

Explant: part of plant used in tissue culture.

★ Auxin = CK cell division = Callus

A > CK

Auxin root

CK > Auxin

Auxin shoot

= Morphogenesis / Organogenesis

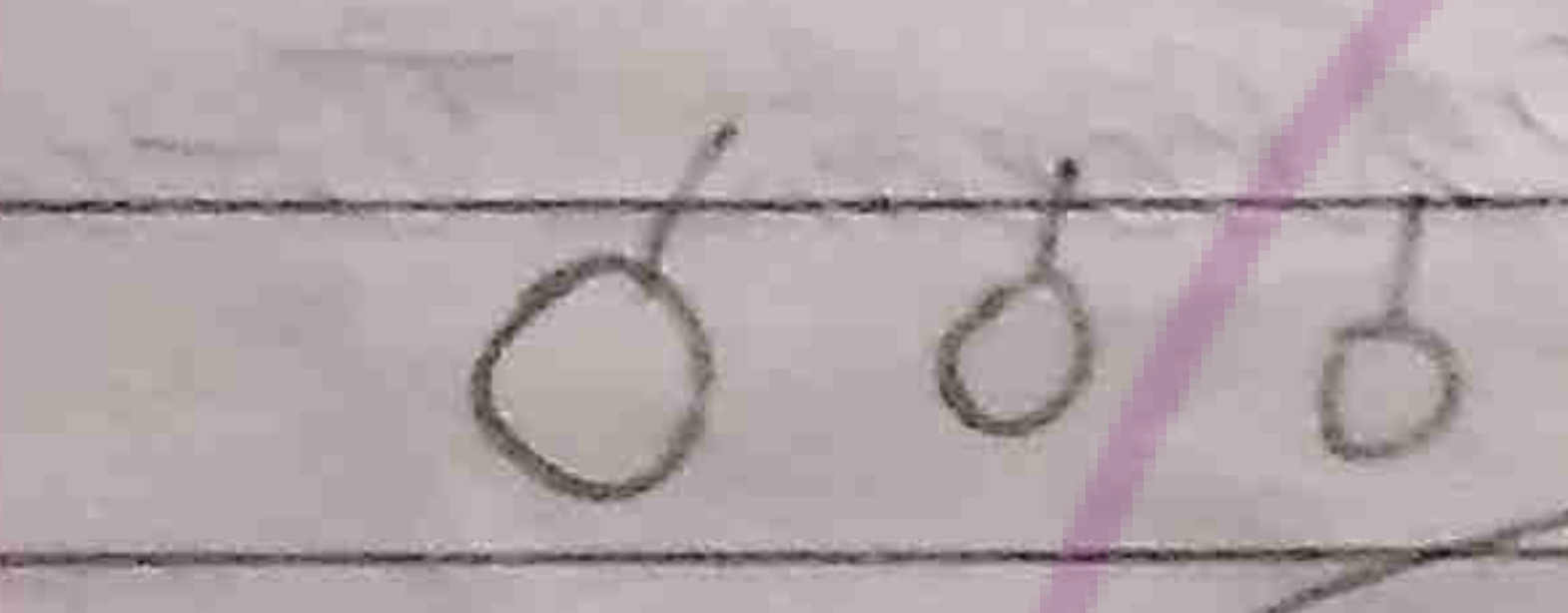
[7] Flowering → Lemna (Water plants)

[8] ♀ flowers

Richmond Lang effect : delaying senescence by cytokinins.

Ethylenes

→ Lourens



ripened oranges

stayed

unripened bananas

Conc. 0.01 - 10 ppm | Conc. in which ethylene is effective

→ Precursor

Methionine (Amino acid)

SAM

S-adenosyl methionine

ACC Synthetase

ACC

Amino cyclo propane carboxylic acid

Ethylene

stimulates

Autocatalytic Effect

Production of Ethylene

Compounds: Increase \uparrow production \downarrow decrease production

- | | |
|--------------|---------------|
| (1) Ethylene | (1) CO_2 |
| (2) Auxin | (2) Ag^{+2} |

Functions:

1 Ripening

Climacteric fruits	Non-climacteric fruits
✓	✗

Increase in Respiration	✗
-------------------------	---

- | | |
|--|---|
| <ul style="list-style-type: none"> • Apple, Banana, Pear, Orange, Peach, Plum | <ul style="list-style-type: none"> • Strawberry • Cherry • Pineapple |
|--|---|

flowering

Ethephon

Ethylene

- > Ripening
- > Abscission - fruits, flowers, leaves

-> hasten fruit ripening in tomatoes, apples.

Thinning of walnut, cherry, cotton (NCERT)

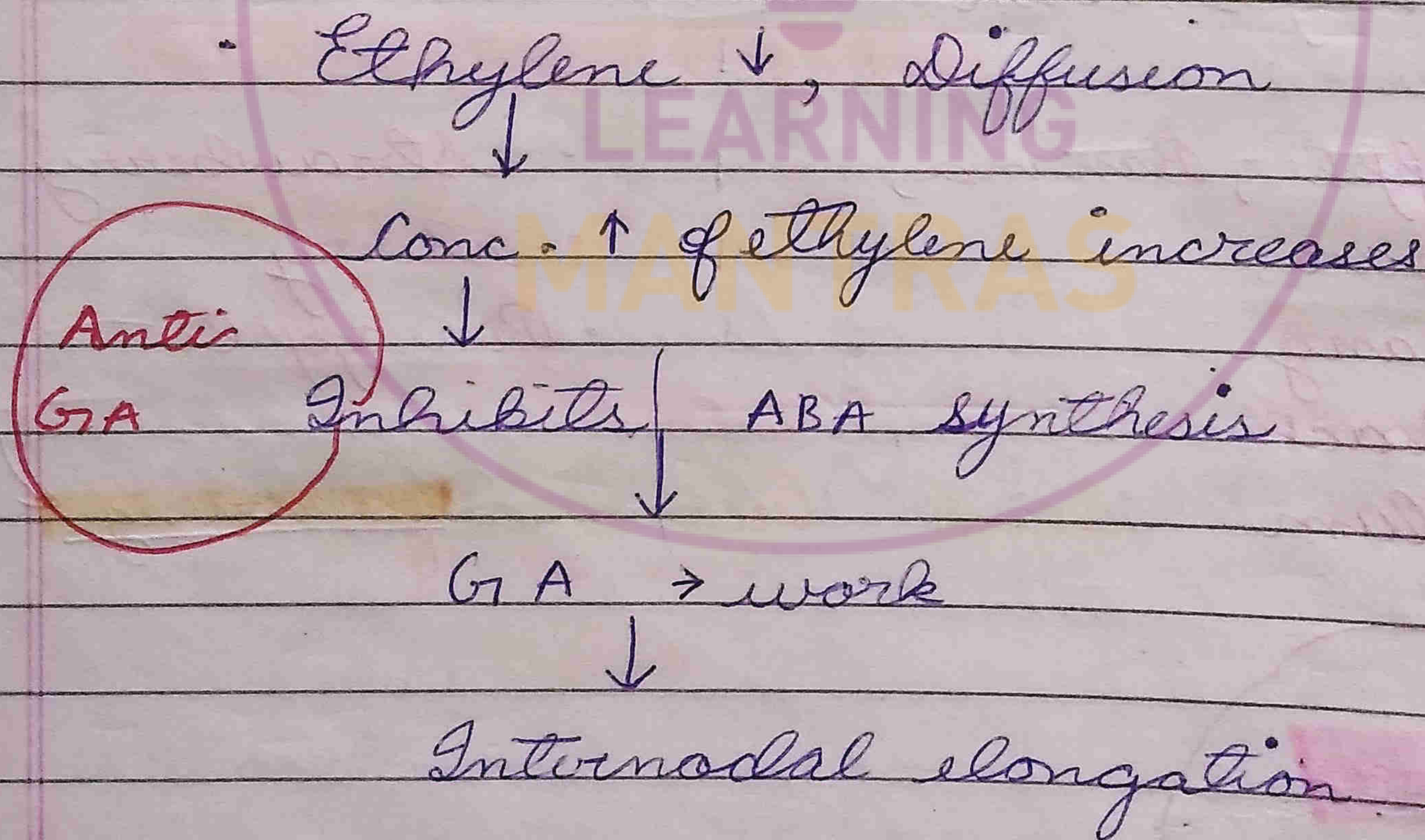
★ Abscicic acid is antagonistic to G.A.

2 Triple response

- Prevents stem elongation
- swelling of axis (causes)
- Horizontal growth of seedling (causes)

★ 3 Promote root growth / root hair formation

4 Internodal Elongation / elongation of petiole in deep water plants.



5 Flowering → Pineapple
Synchronising fruit set

• Mango (Induces flowers in)

★ Female flowers → Cucumber

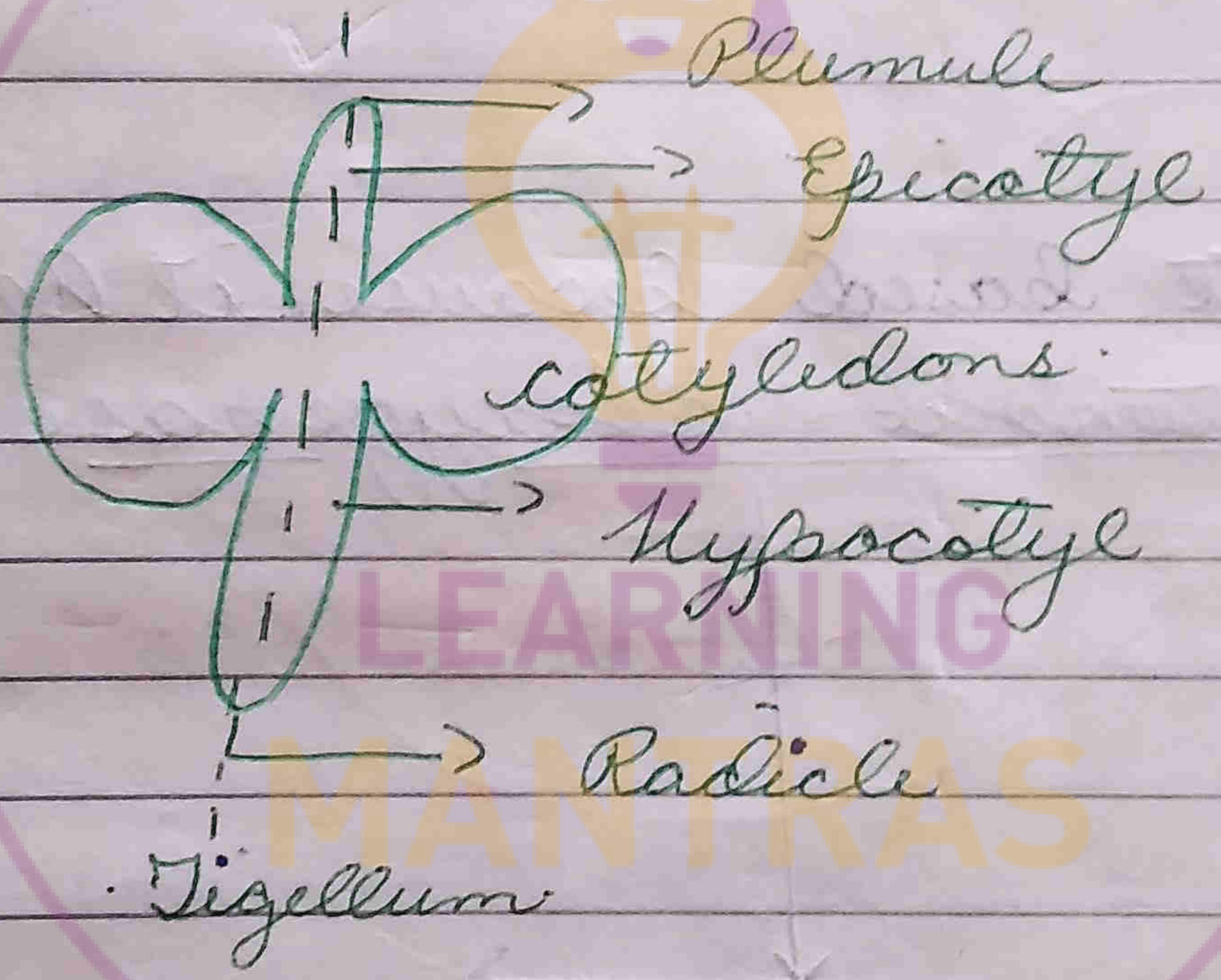
6 Breaks seed & bud dormancy

7 Seed germination in pea-nut.

8 Apical hook - Dicot seedling
Plumule → Protest *

★ Sprouting of potato tubers.

EMBRYO



Seed Germination

Hypogeal

Epigeal

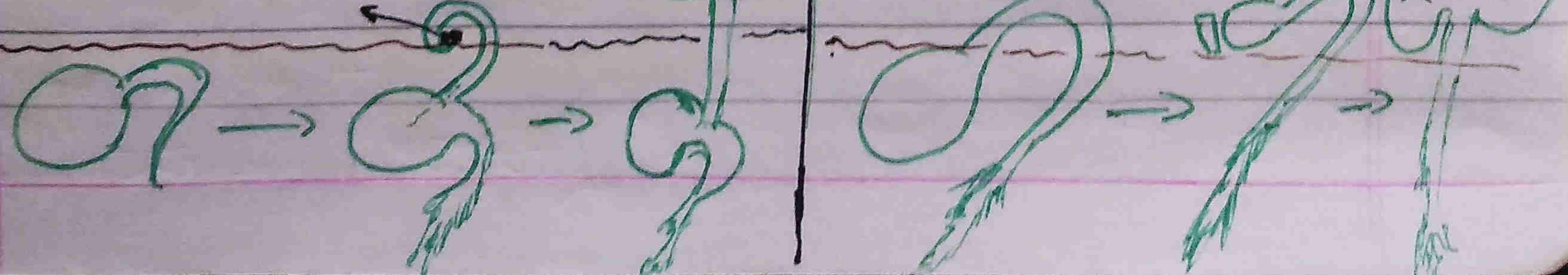
★ Epicotyle forms first
cotyledons → Inside soil

Hypocotyle develop first
come out of soil

Mango, Fabaceae family

Caster, onion, Mustard.

Epicotyle hook (ethylene)



Abscisic acid.

History

Inhibitor - B ✓

Abscission - II ✓

Dormin ✓

Formation

- Chloroplast based because it has enzyme
- Epoxycarotenoid dioxygenase

Precursor

40 carbon

Violaxanthin



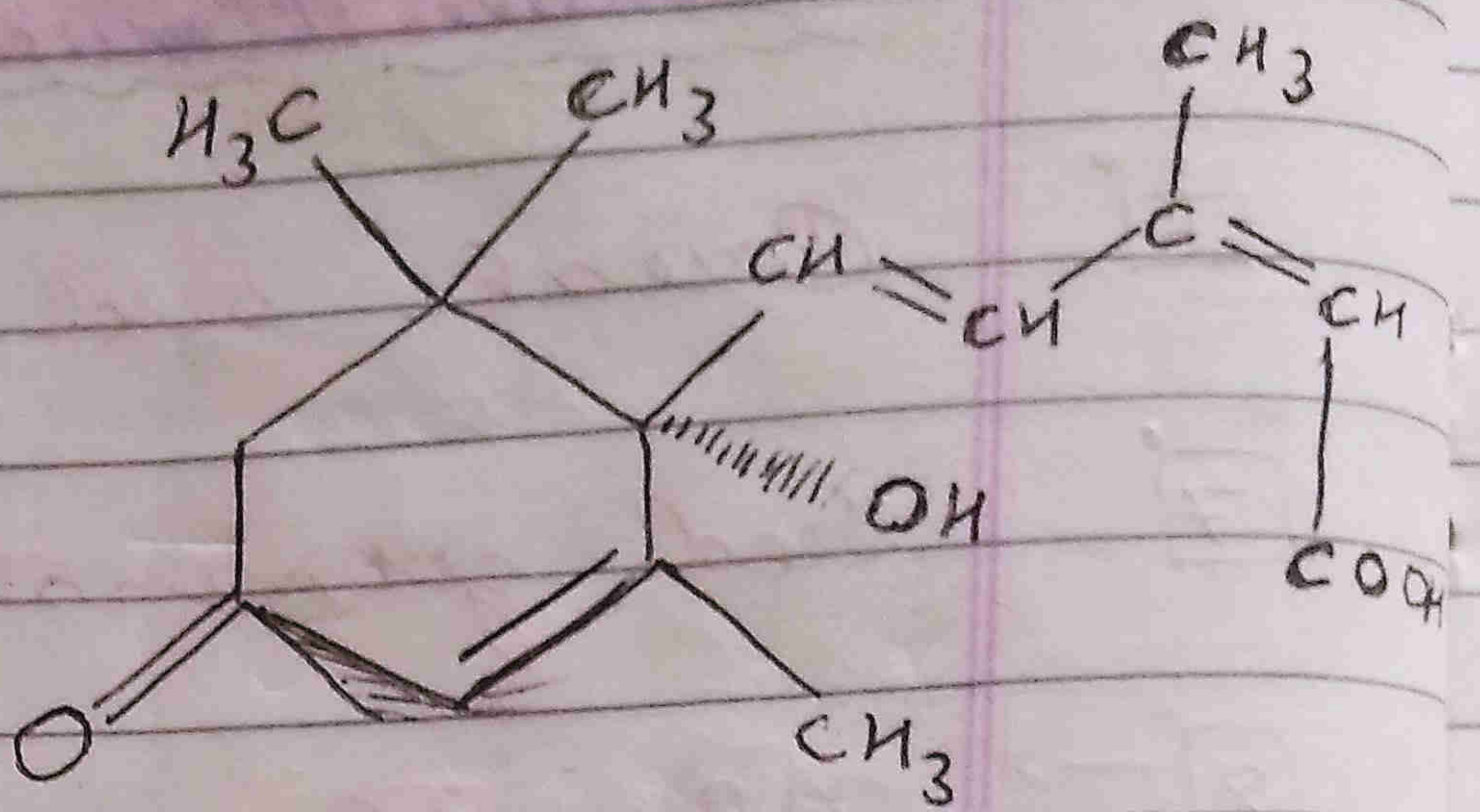
15 carbon

ABA

Dextrorotatory
Terpene derivative
cis-compound.

Function:

- 1 Seed - development
- maturation
- Dormancy

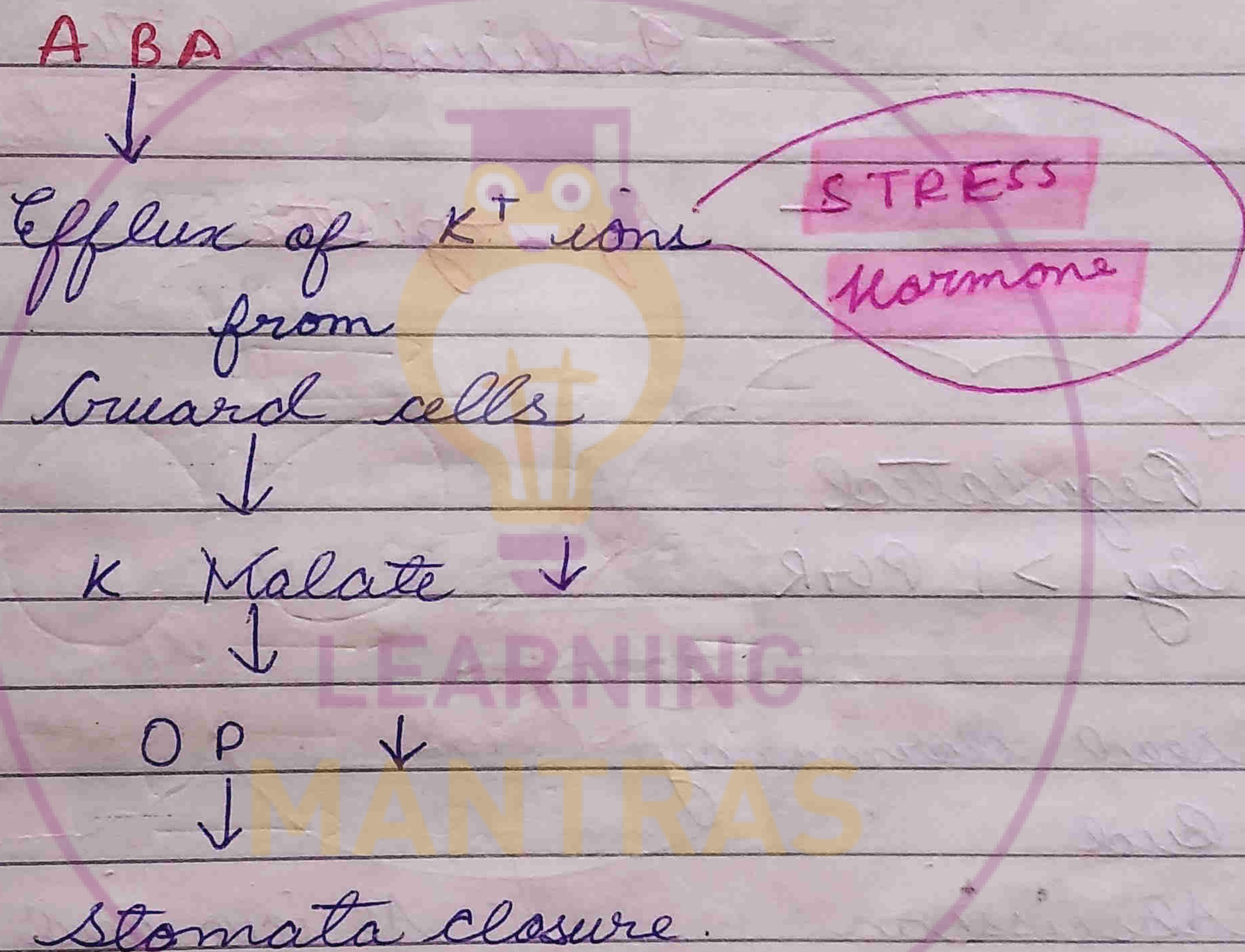


Abscisic acid.

Anti GA

GA	ABA
Greenes on	off
α amylase ✓	α amylase ✗

2



3

Flowering → SDP (Short day plant)

4

Parthenocarpy → Rose.

5

Roots → Guy. (formation)

6

Cambial activity → ↓ decreases

• Roles
↓
PGR

- Complementary

- Antagonistic

- Individualistic

- Synergistic

Regulated
by > 1 PGR

- seed dormancy

- Bud "

- Abscission

- Senescence

- Apical dominance

→ Abscisa acid, ethylene

→ Auxin, ethylene

Photomorphogenesis

↓ Blue light dependent ↓ Red light dependent

- Stomatal opening
- Phototropism
- Chloroplast movement

- seed germination
- Flowering
- Pollen germination
- Anthocyanin synthesis
- Stomatal differentiation
- Cleistogamy

Phytochrome

↓
pigment which absorbs blue light.

↓
pigment absorbing red light

Phytochrome

↓
Seed germination

Boothwick and Hendrick

- Different wavelength of light → seed germination

★ Seed $\xrightarrow{\text{Red } 660\text{nm}}$ G \checkmark • seed germination depends on red light.

Seed $\xrightarrow{\text{Far Red } 730\text{nm}}$ G \times • Seed germination depends on last exposure of light to seed

Seed $\xrightarrow{R+FR}$ G \times

Seed $\xrightarrow{R+FR+R}$ G \checkmark

Bullter: extracted phytochrome.

Phytochrome

Isoprotein

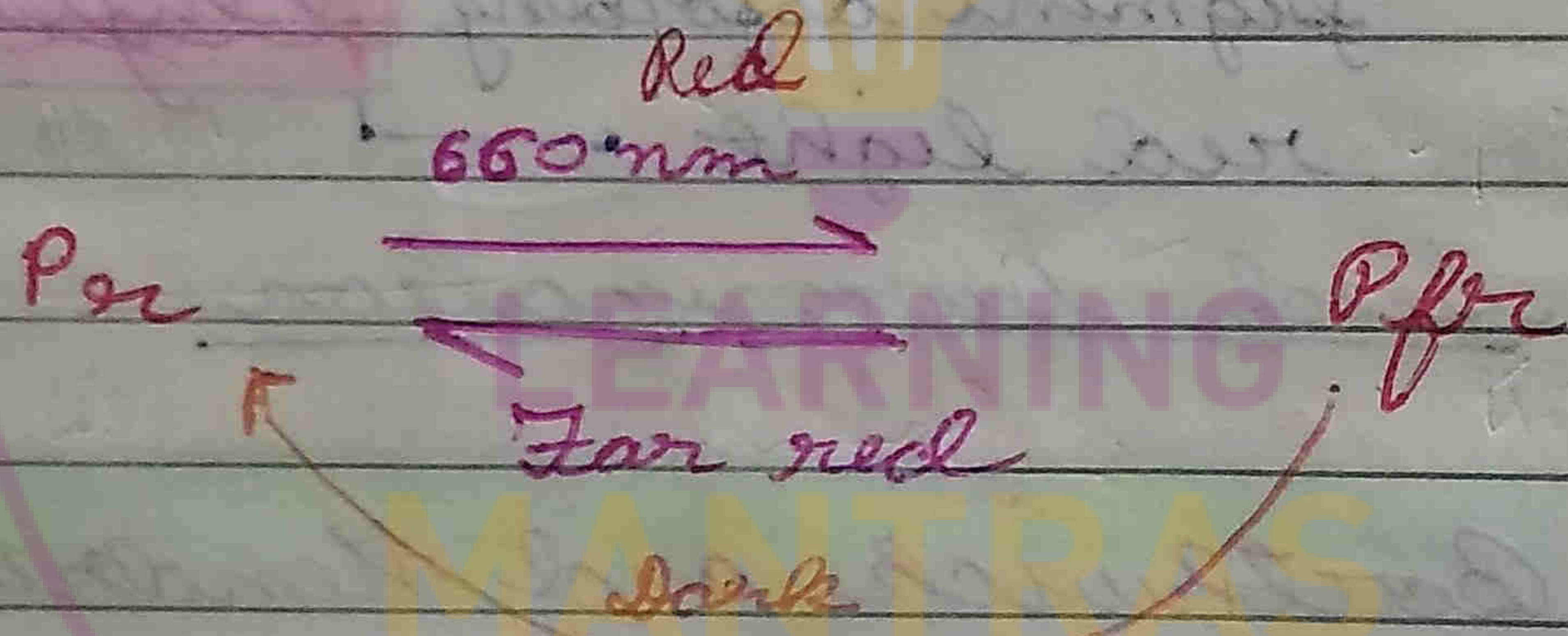
Apoprotein

Chromophore

- Protein ✓
- Kinase

- Protein X
- Light absorbⁿ

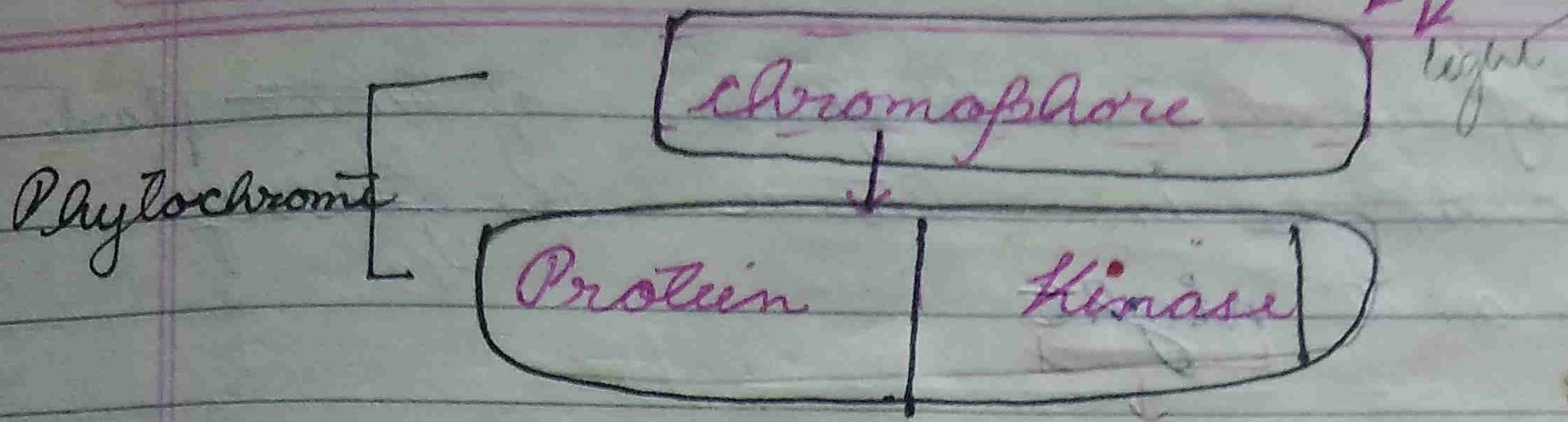
Two forms of phytochrome.



- | | |
|--|---|
| <ul style="list-style-type: none"> Absorb red slow cis form Blue Inactive Stable | <ul style="list-style-type: none"> Absorb far red Trans form γ-6 (yellowish-green) Active Unstable |
|--|---|

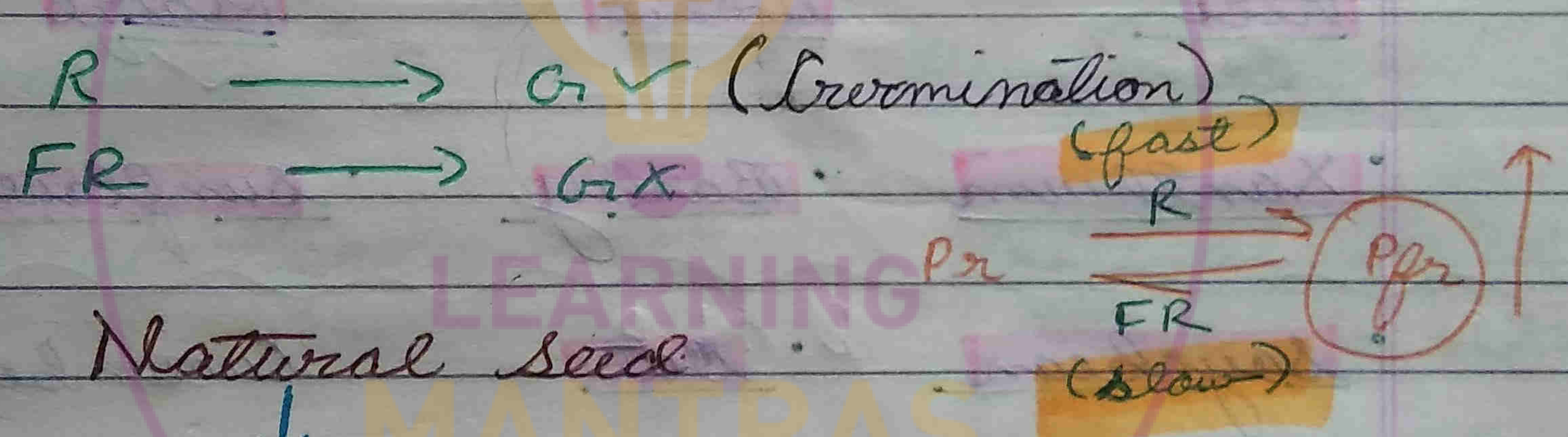
P_{fr} is responsible for seed germination.

P_{fr} is unstable because even in the absence of far red light it is converted into P_{pr}.



- Phytochrome
↓ Activate
- Phosphorylation of Proteins
↓ Activate
- Transcription factors

Gene → G.A (Gibberellic acid)



White light \Rightarrow Red light
(R, FR)

White light has net effect is equivalent to Red light as conversion of Pr to Pfr is faster.

- Critical light period = photo period
- Critical dark period = skoto period

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SOP

LDP

• Dark period - IMP

Photoperiod: important

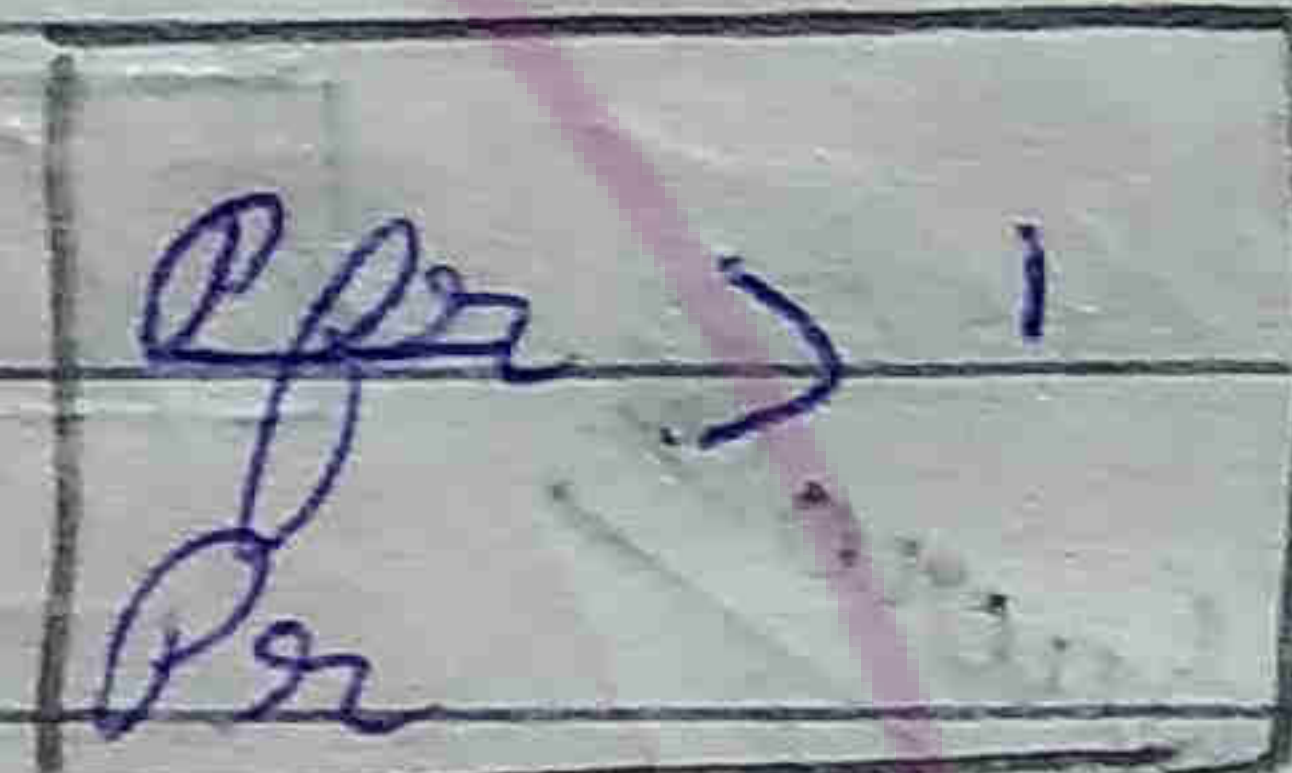
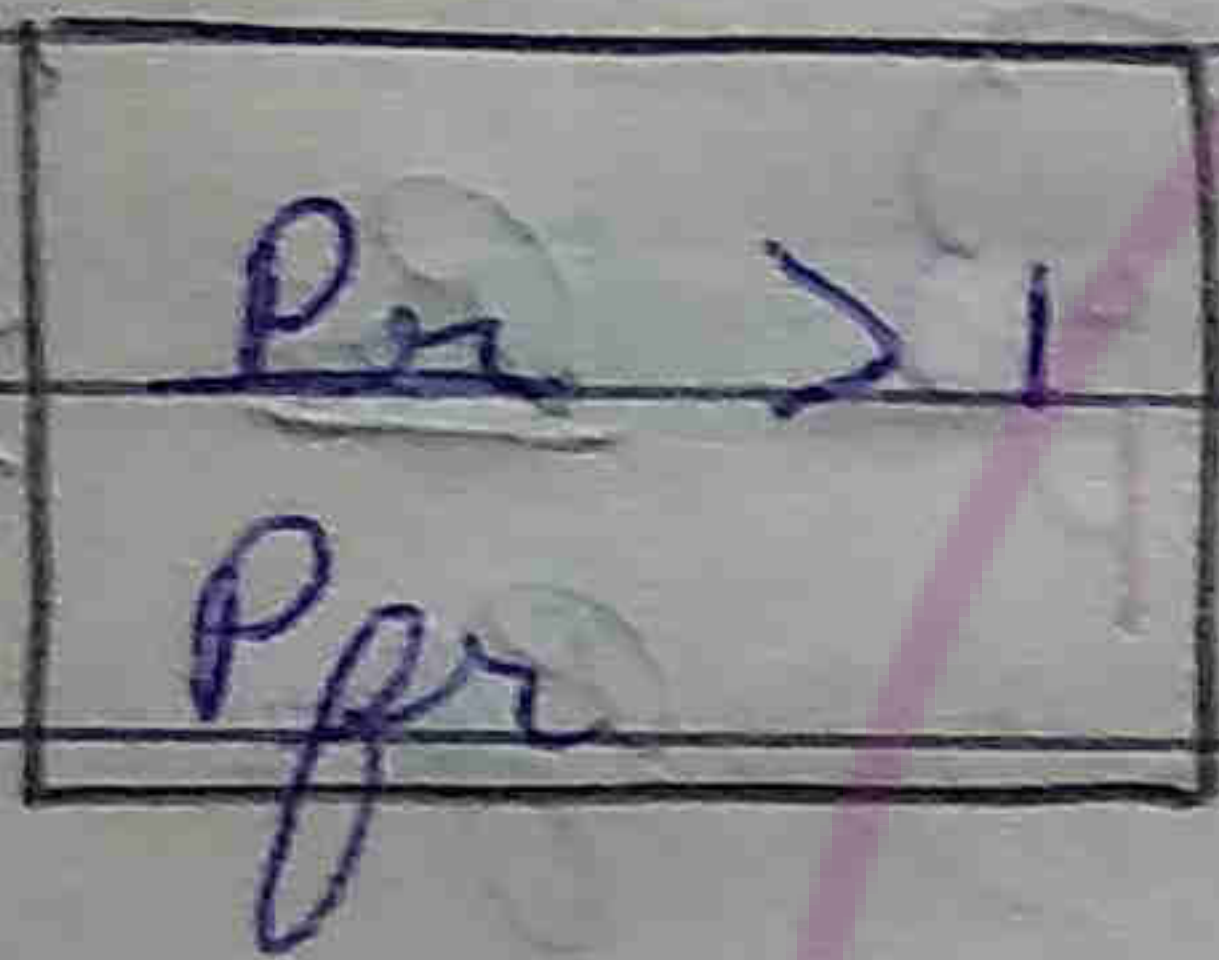
• Long night plants
(LNP)

short night plants
(SNP)

Flowering

• Autumn, winter, early spring

Summer, Late spring



• Eg Xanthium

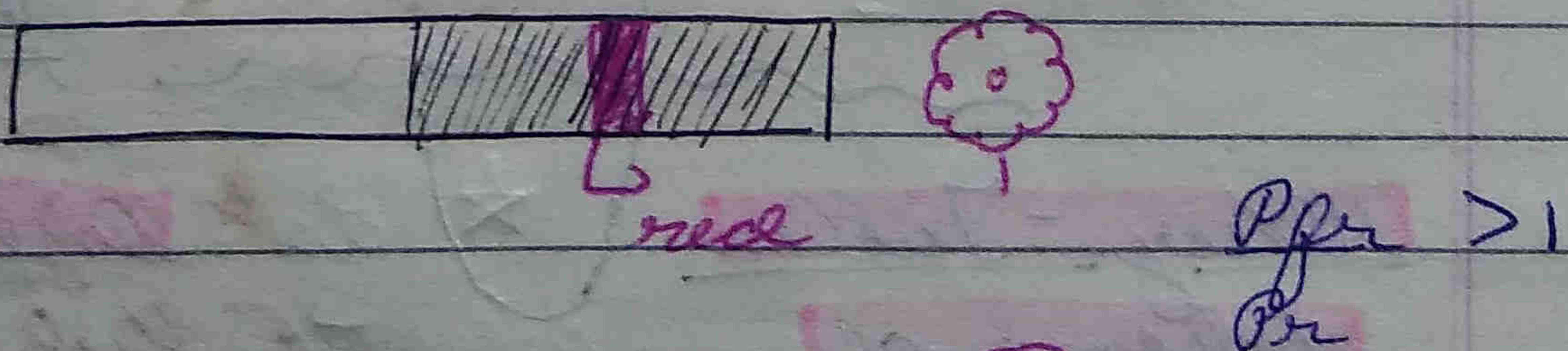
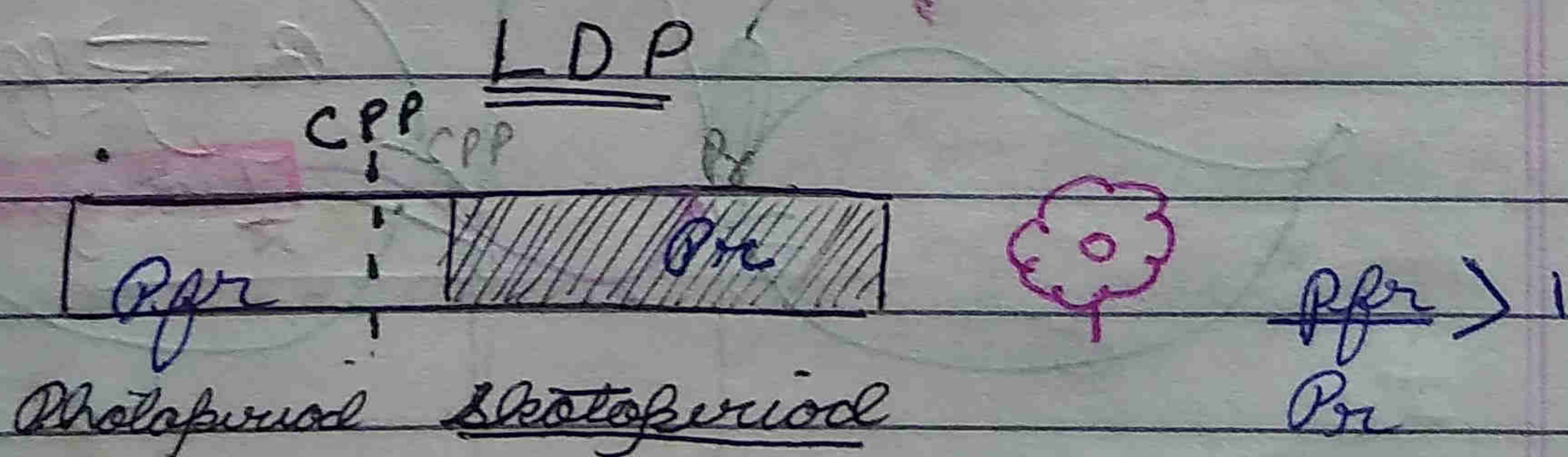
Eg Henbane

• Critical light period < 15.5 hrs

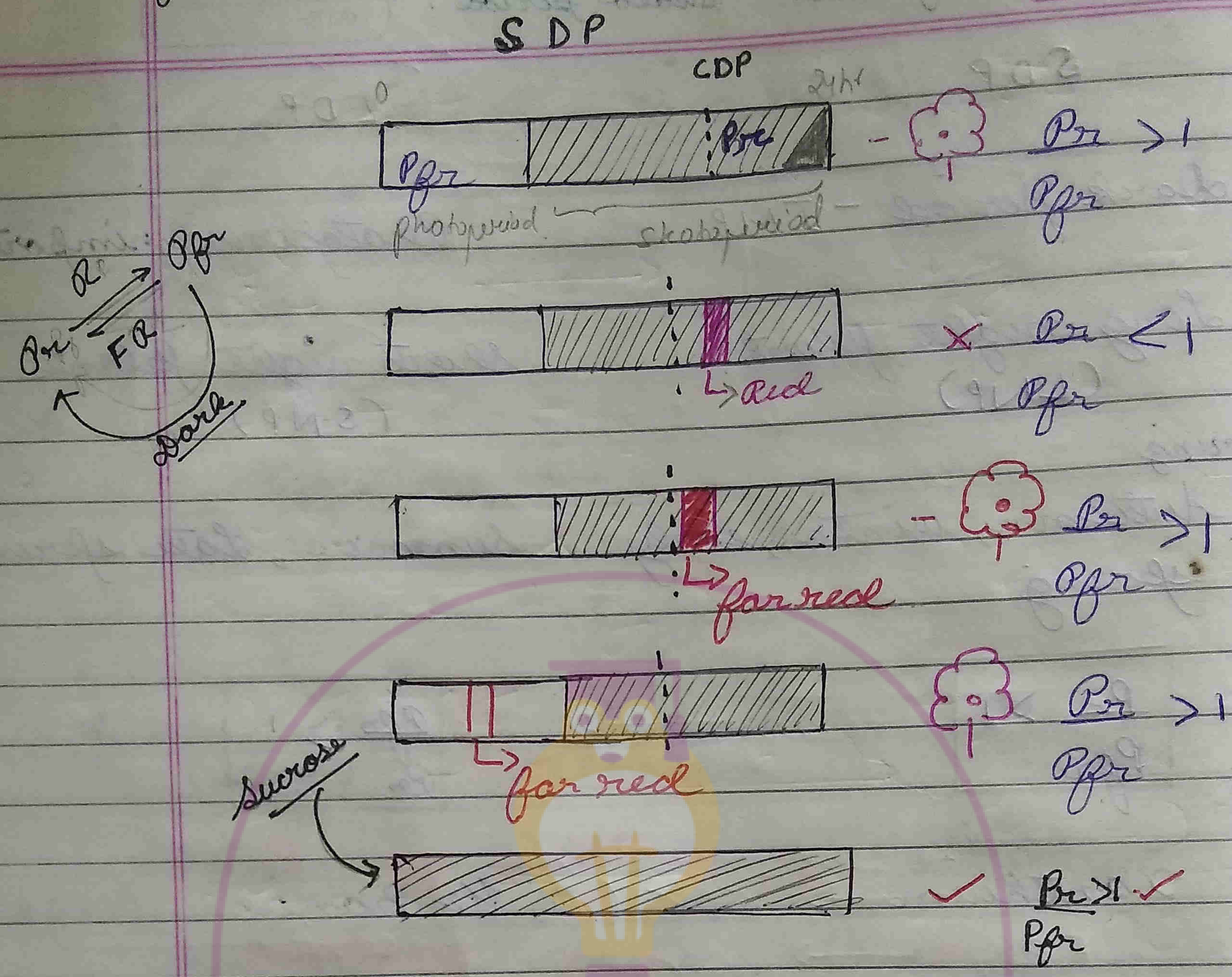
Critical light phase > 11 hrs

✓ "Dark" > 8.5 hrs

Dark < 13 hrs

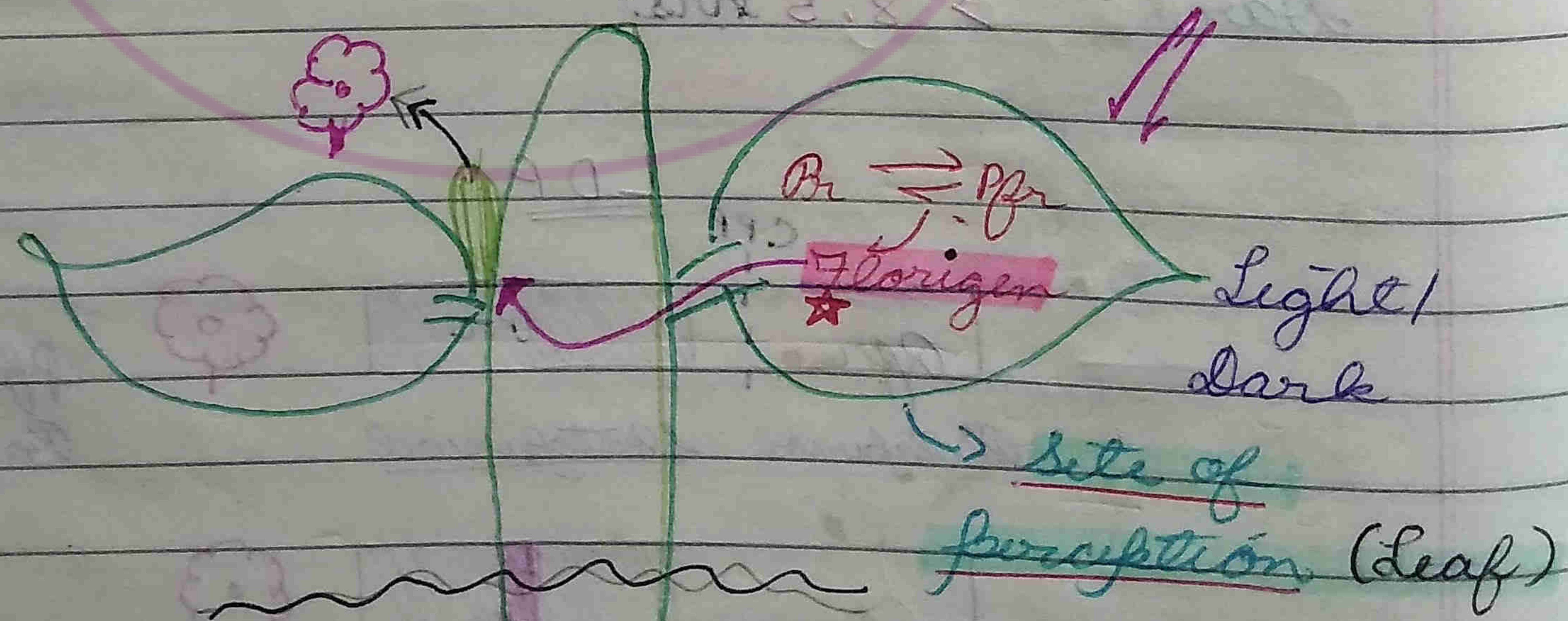


★ Florigen is a hypothetical hormone



D N P

Independent of photoperiod



Wentz - Fuller
Scheme of
flowering

- ★ Rajalakshaman
- Hypothetical
Hormone
- Non-specific hormone
(i.e. its functions in all species is same)

LDP
x Photoperiod
but if given
- GA
FV (flowering)

SDP
x Dark period
but if given
ABA
FV

Florigen

not correct, photoperiod	Components	not correct dark period
GA (deficient)		GA (suff.)
Anthresin (def)		Anthresin (def)

Vernalisation → Lysenko

Springification

Jarousation

Jarousation

Quantitative and Qualitative dependance of plant ↑ on low temperature for flowering

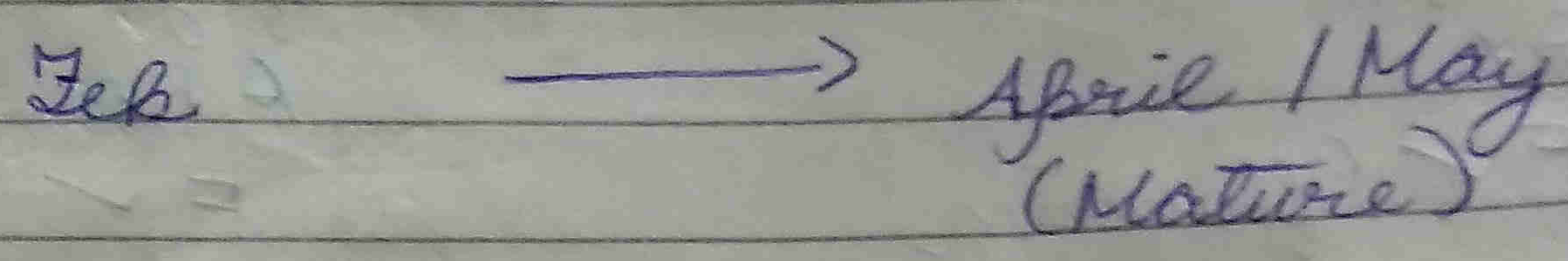
- Annuals
- Wheat
- Barley
- Rye



• Long duration variety can be converted into short duration variety by vernalisation.

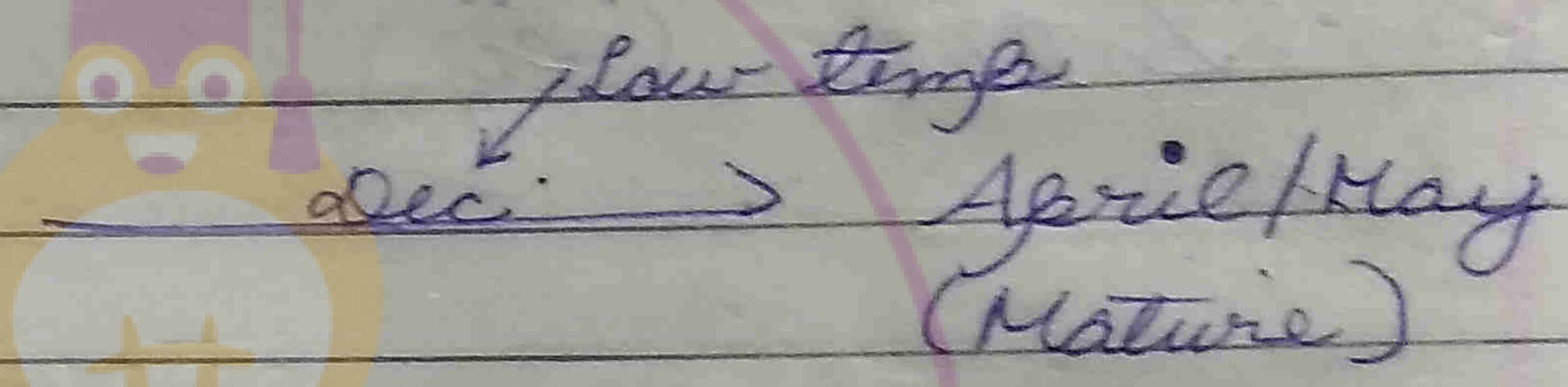
Spring Variety Wheat

- W
- SP
- Su
- A



- Short duration variety
- High yielding
- Low temp x (not required)
- ~~Winter variety~~

Winter Variety
Sept / Oct



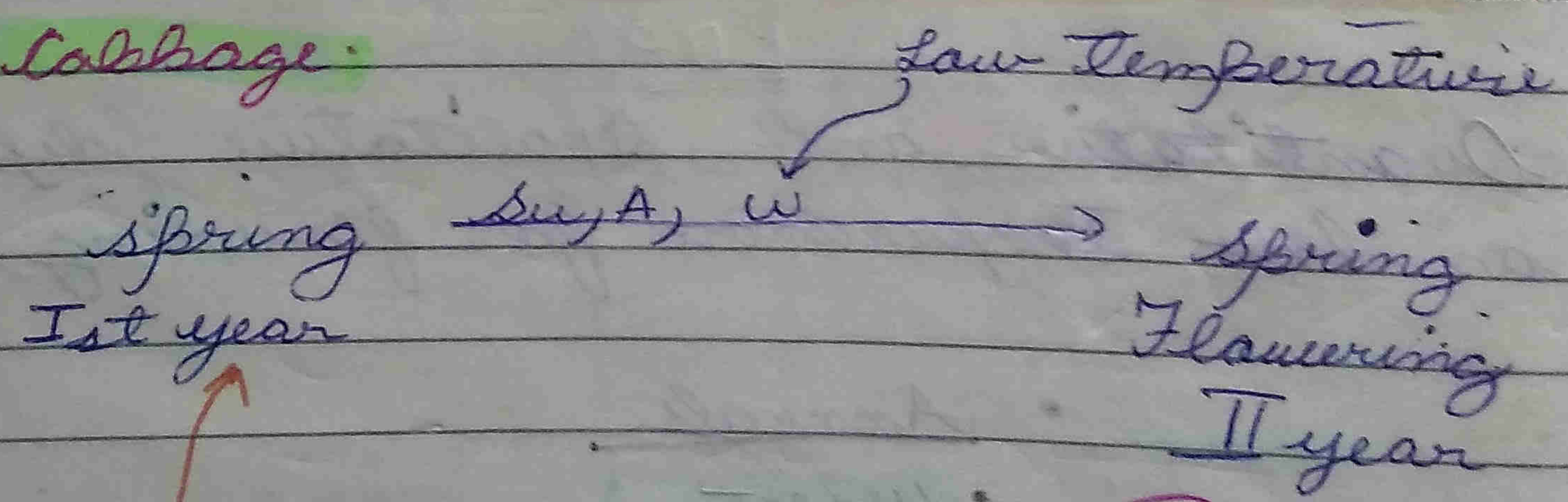
- Long duration
- High yielding
- Low temperature (required)

Winter variety
• 00 seeds
Soak
low temp
artificial
0-5°C
Early flowering

Biennials

- W
- Sp
- Su
- A

- Sugar beet
- Carrot
- Cabbage



★ Low temperature can convert Biennials → into Annuals

- Seed
- Low temp
 - Flowering I year

★ Vernalin is an hypothetical hormone.

Requirements

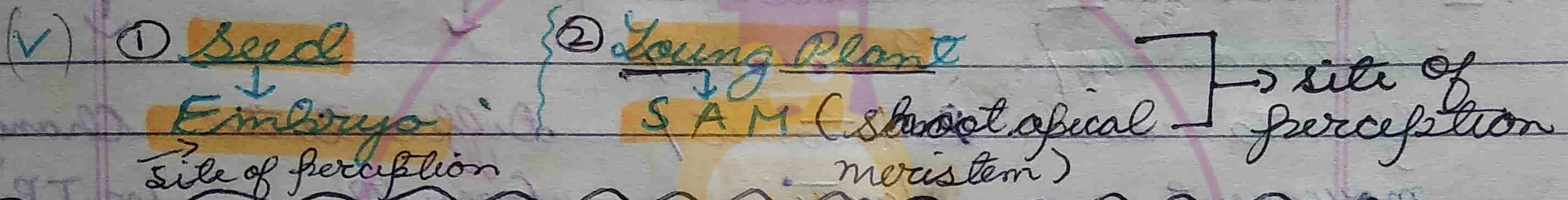
- (i) seed hydrated - 50% H₂O
- (ii) Aerobic conditions
- (iii) Proper nutrition
- (iv) Low temperature 0-5°C → few days - weeks

Melcher
(Scientist)

Hormone

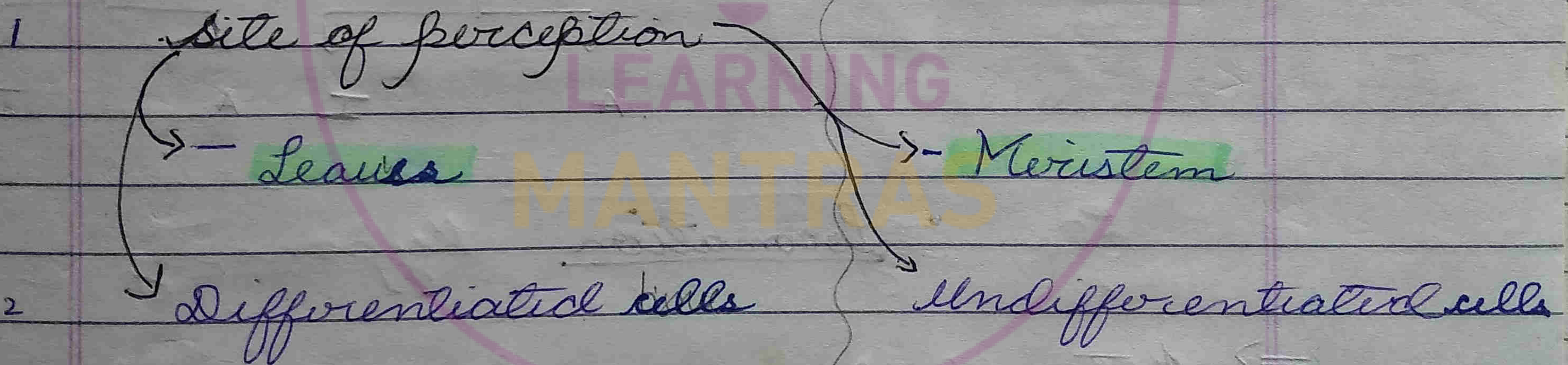
Vernalin (Hypothetical)

GA substance



Photoperiodism

Vernalisation



3. Florigen ← Hypothetical → Vernalin

4. Phytochrome chemical ×

5. LDP → GA vs All → GA

6. All plants vs Temperate / Arctic plants

Plant Movements

Locomotion

• whole organism /
cellular constituents

Factor involved

Internal

• Autonomous /
Spontaneous
movement

External

• Induced /
Paratomic /
Tactic
movement.

Curvature

Plant organs

Differentiated Growth in TP

Growth

Variation

A = autonomous I = induced

Locomotion

⇒ Autonomous

• Ciliary /
Flagellary mov.

• Chlamydomonas

• Volvox

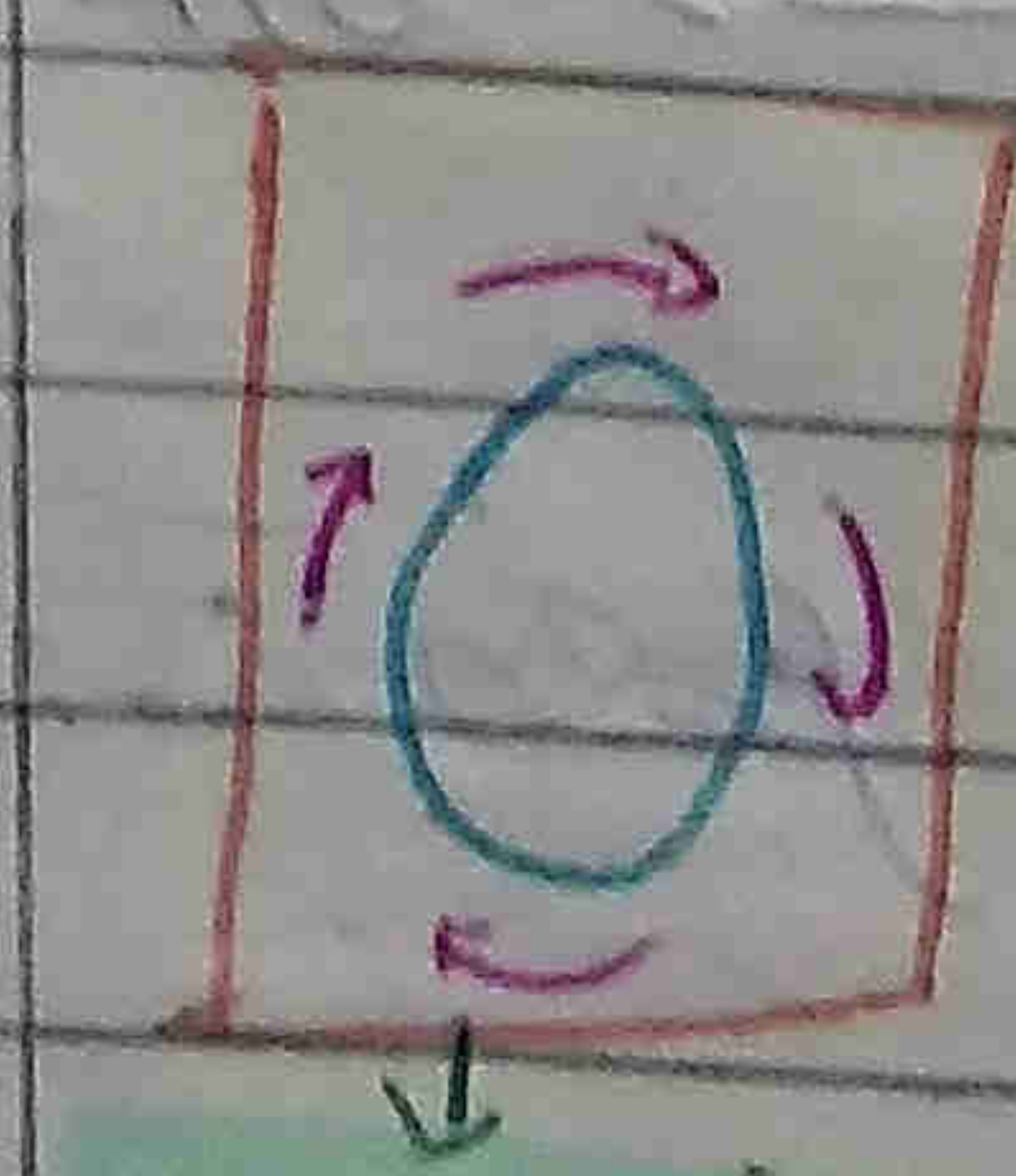
• Paramecium

Amoeboid
movement

- Amoeba

- Slime moulds
• Plasmodium

• Cytoplasmic
streaming
Rotation Circulation



Hydrilla
Nalaeonora



Staminal
hair of
Tradescantia

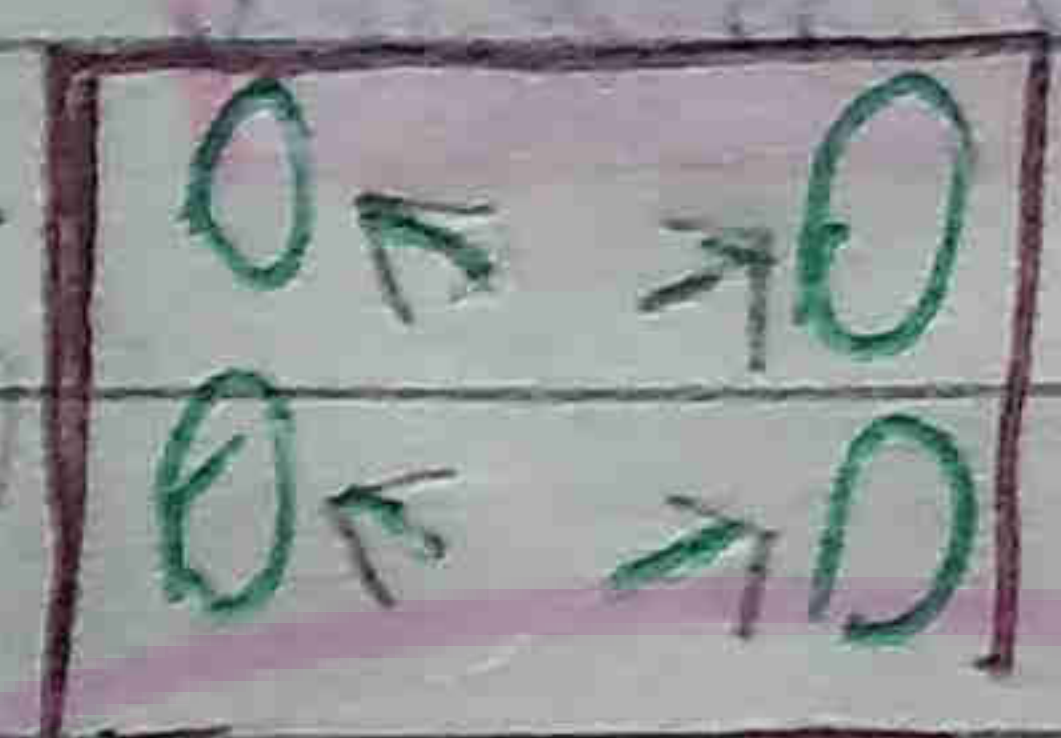
⇒ Induced

- Phototactic movement
- Chlamydomonas
- Chloroplast

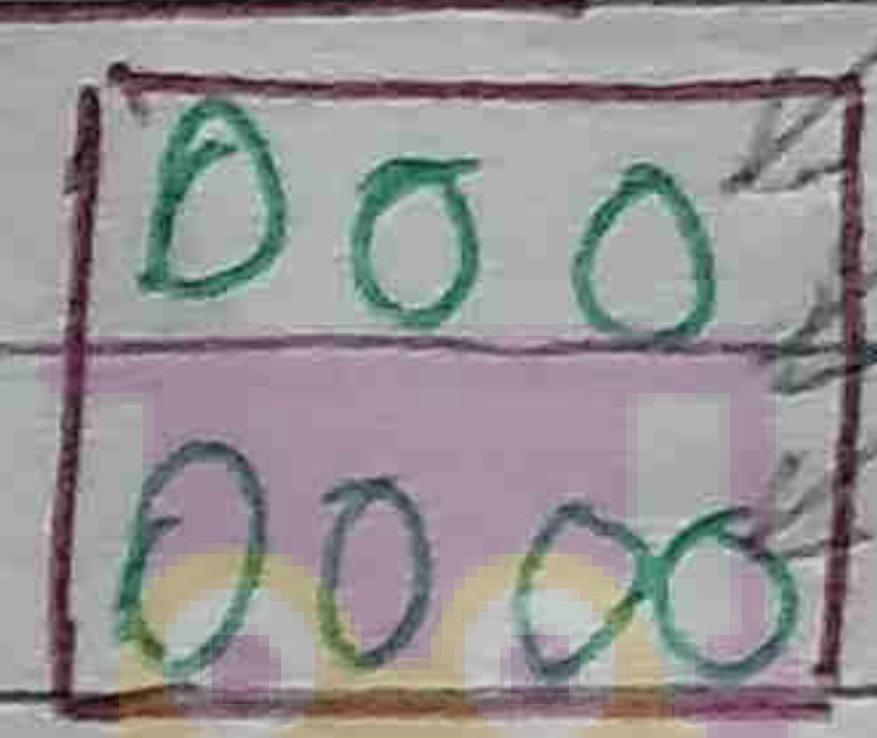
Chemotactic

- Antherozooids of Bryophytes, Pteridophytes

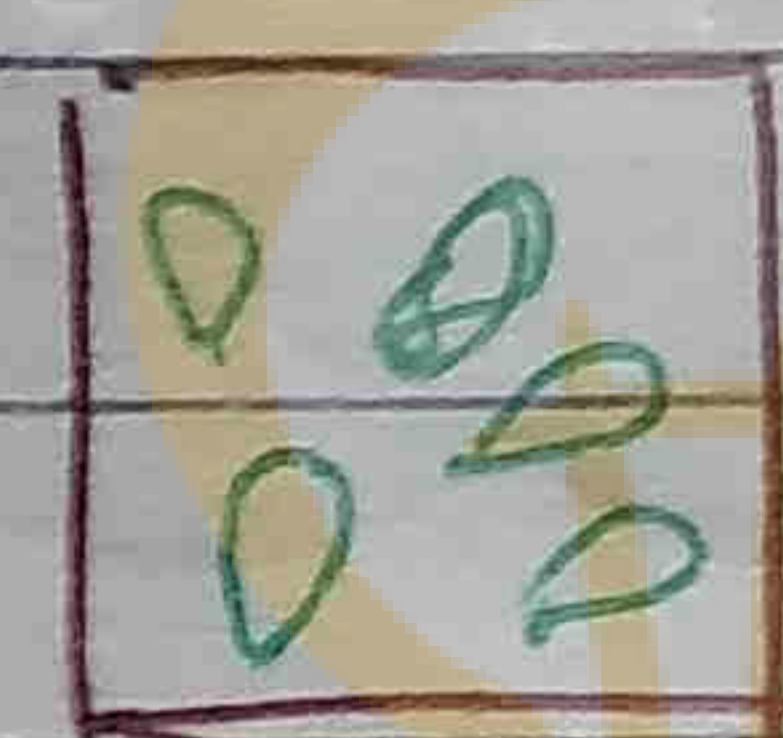
★ P Parastrophic
High light intensity



E Epistrophic
Moderate light



A Anastrophic
Low light



- Slime mould → Myxamoebae

Rheotactic : H₂O currents

Thermotactic : Temp.

Galvanotactic : Electric current

★ When light intensity is high, the arrangement of chloroplast is parallel to the walls in mesophyll cells.

Structure Movement

- Growth
- Autonomous movement

Nastic
Fast
Variation/
Growth

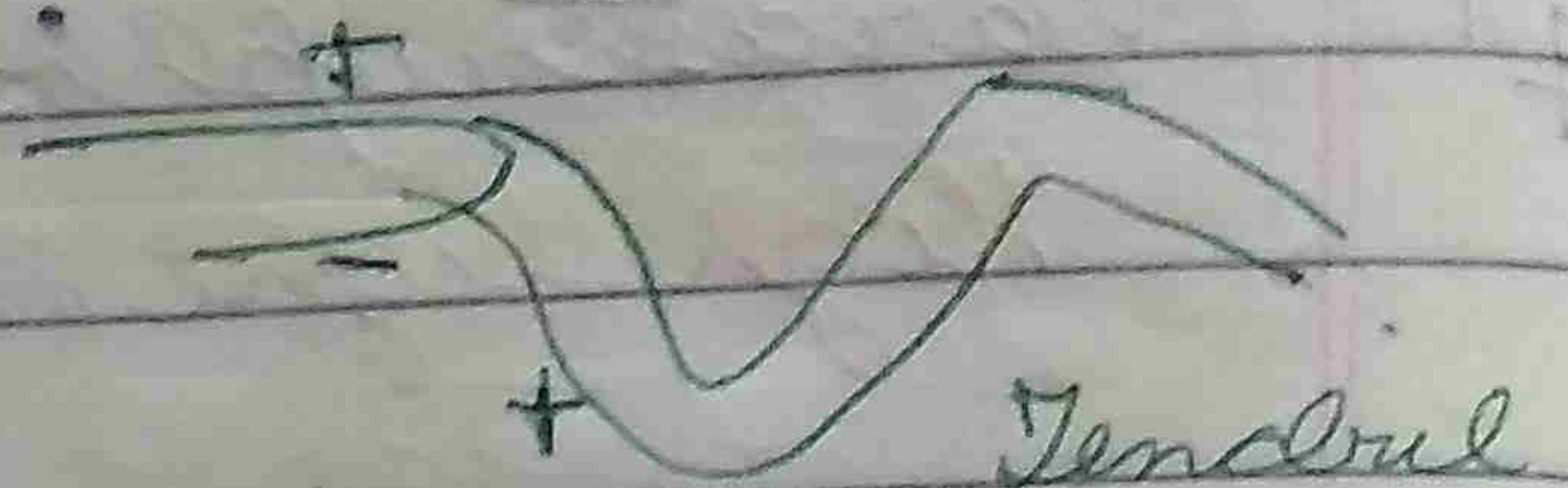
Tropic

Slow

Growth movements

(ii) Mutation

• Runner



A / I

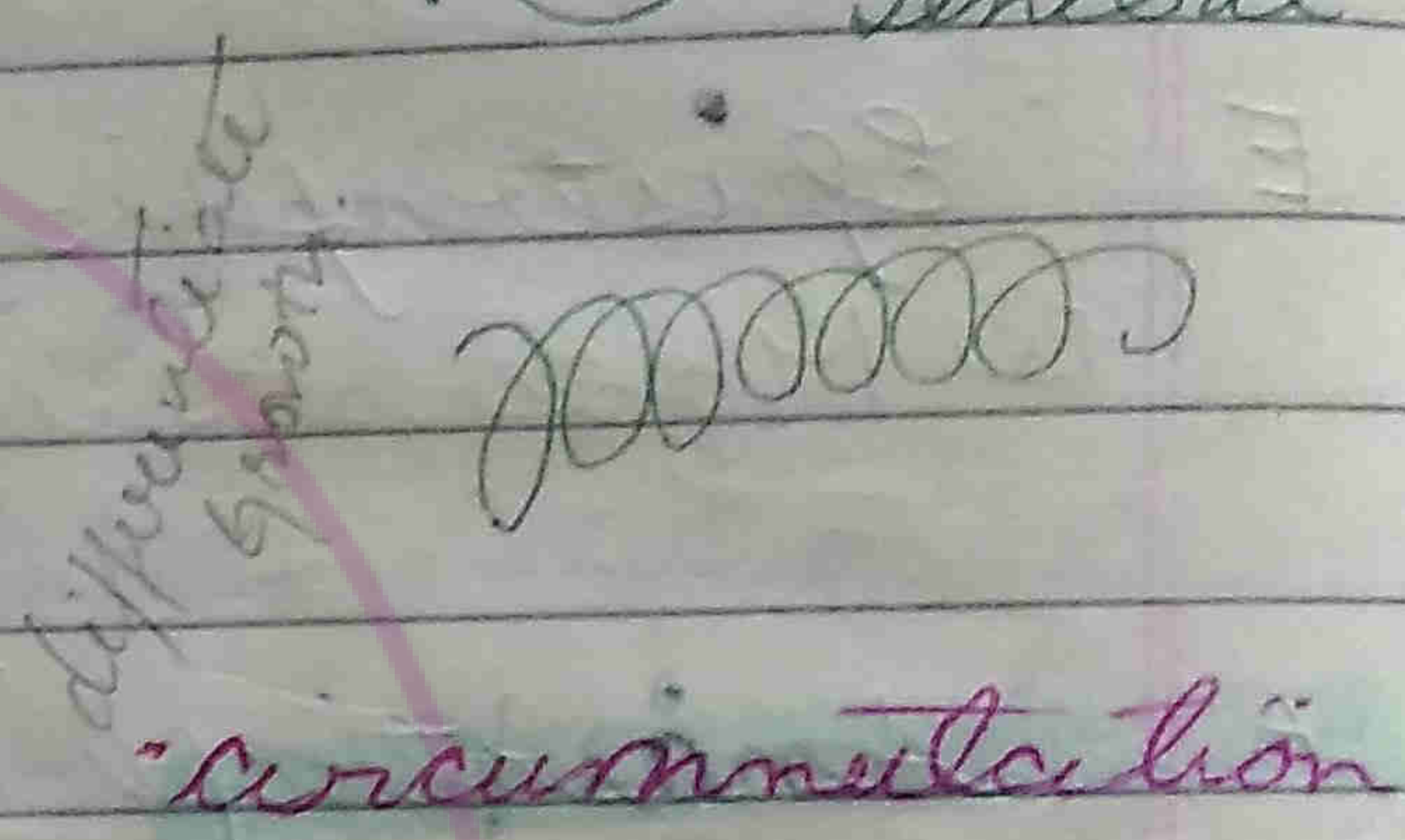
always Induced

Non-
directional
organs

Directional movement.

Asymmetrical
Leaf

Cylindrical organs
stem, root



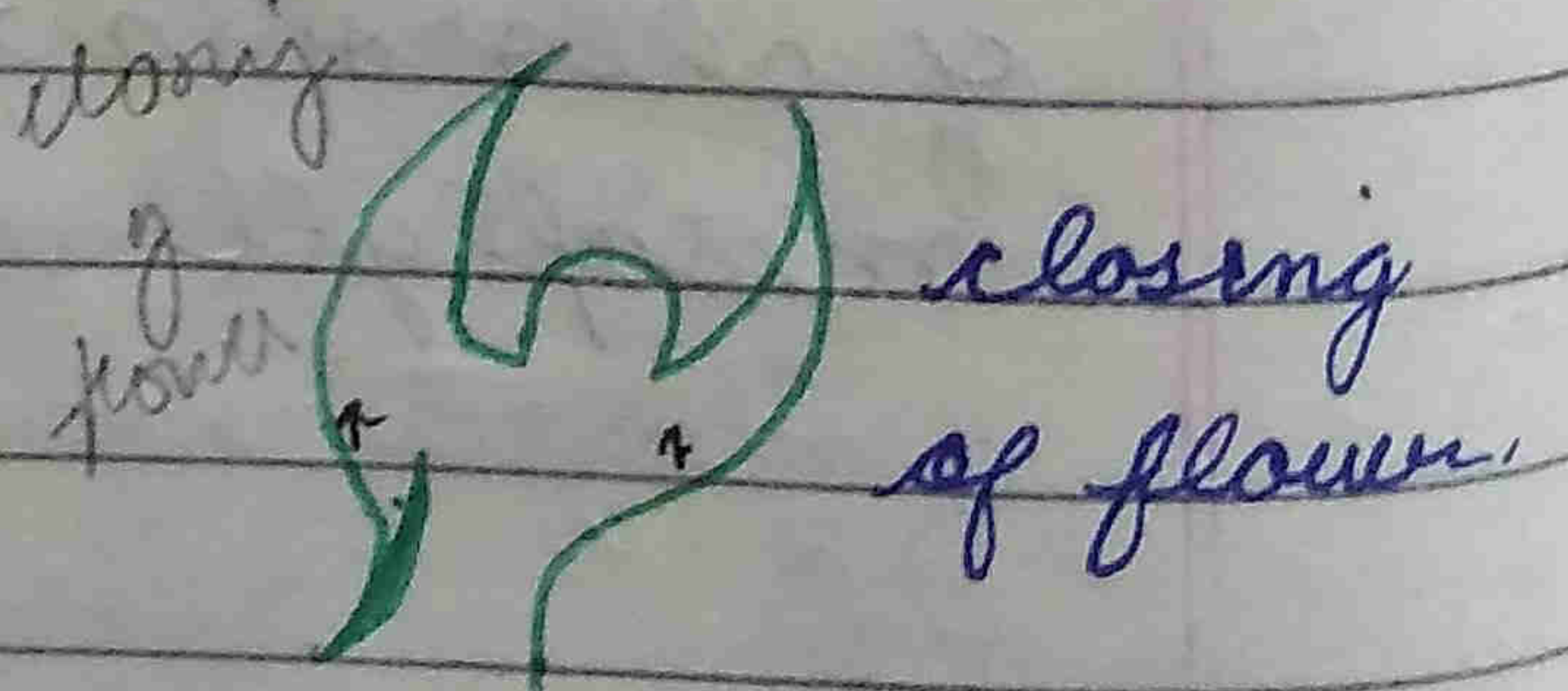
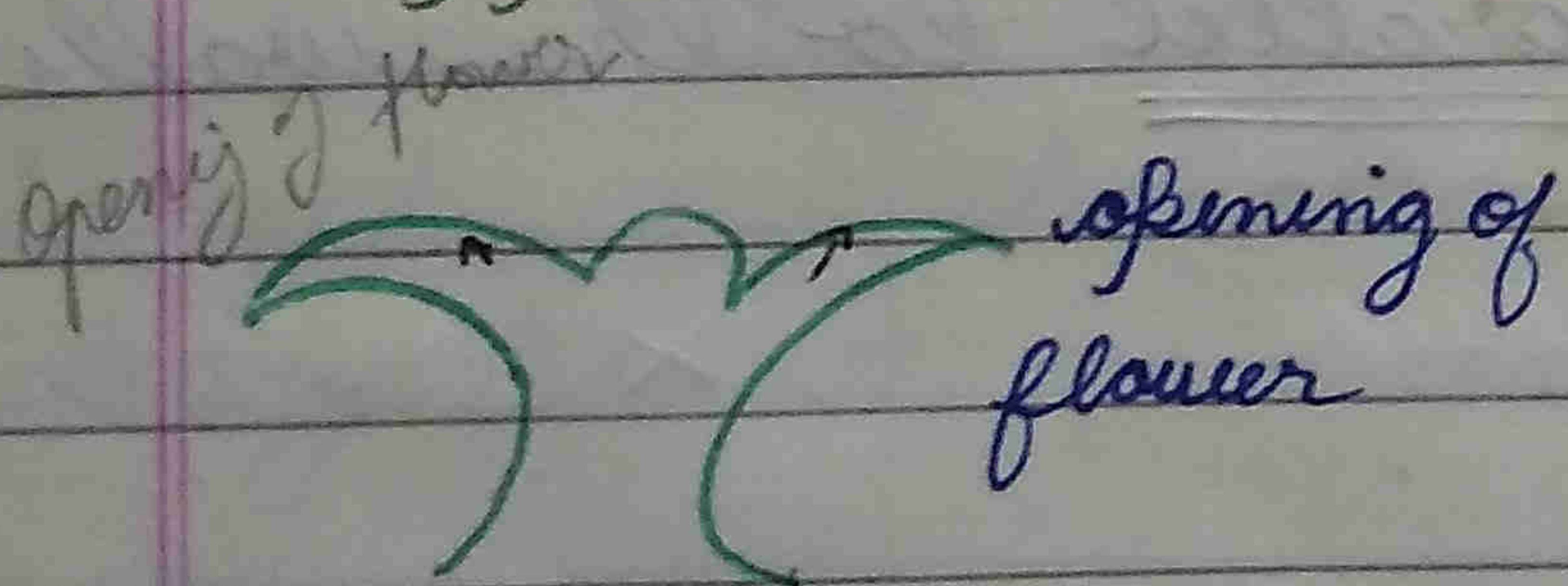
(i) Nastic Movement

Epinasty

Hypostasty

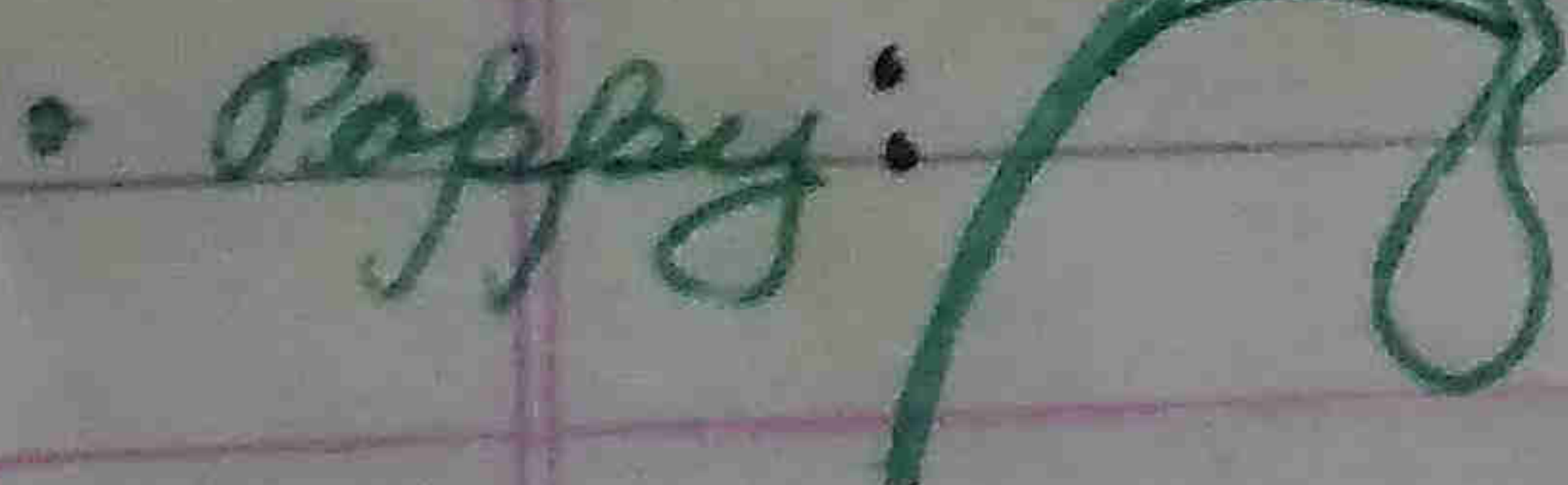
More growth: Upper side ↑

Lower side ↑



Uncoiling of leaf.

Coiling of young leaf - in ferns.



Geotropism / Gravitropism / Barytropism.

Curvature : Curvature

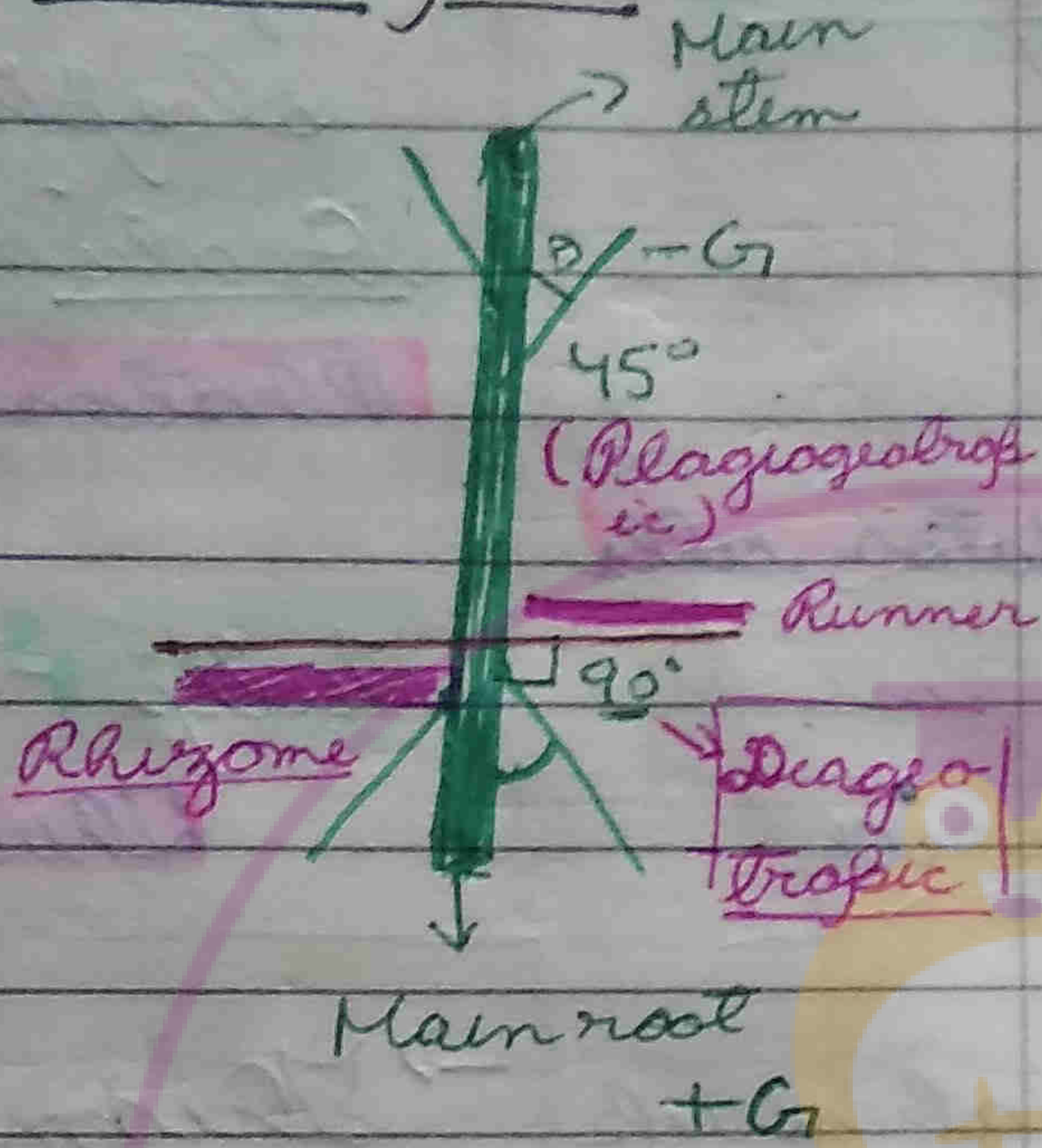
→ Induced movement

Phototropic

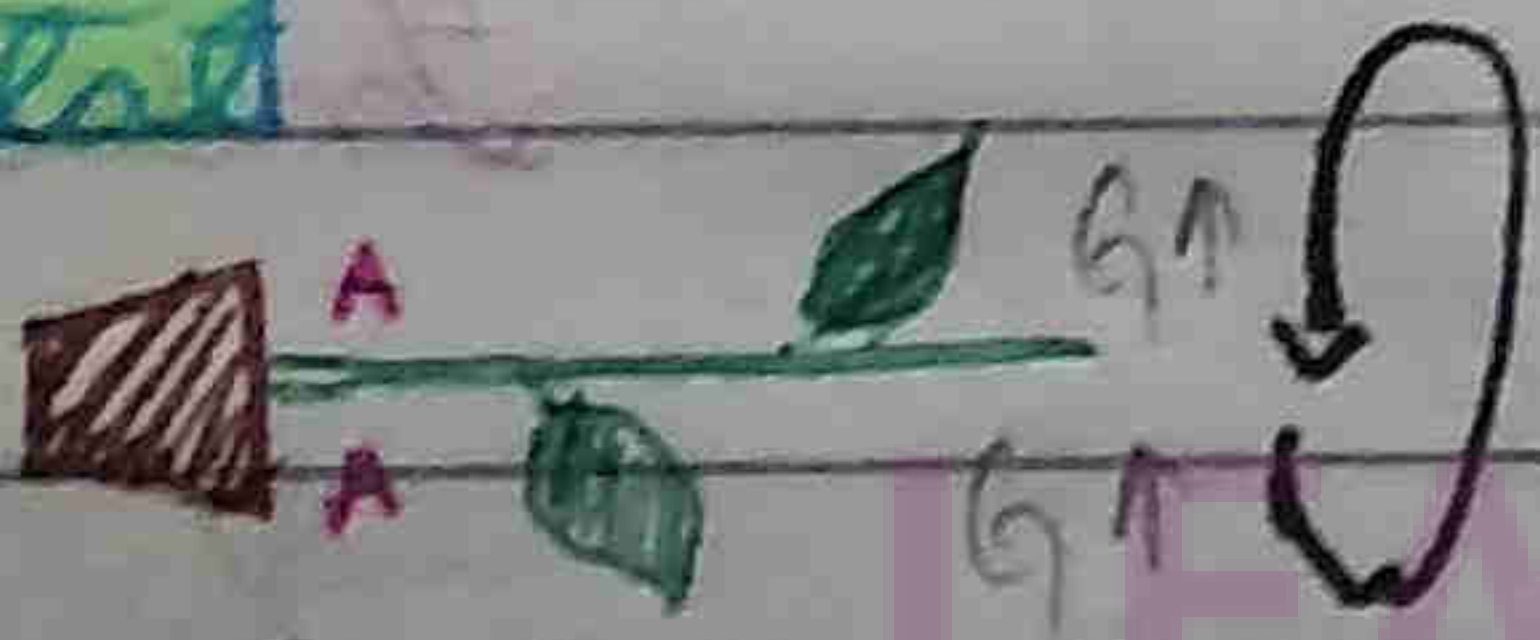
stem = +P

Root = -P

Geotropism



Clinostat

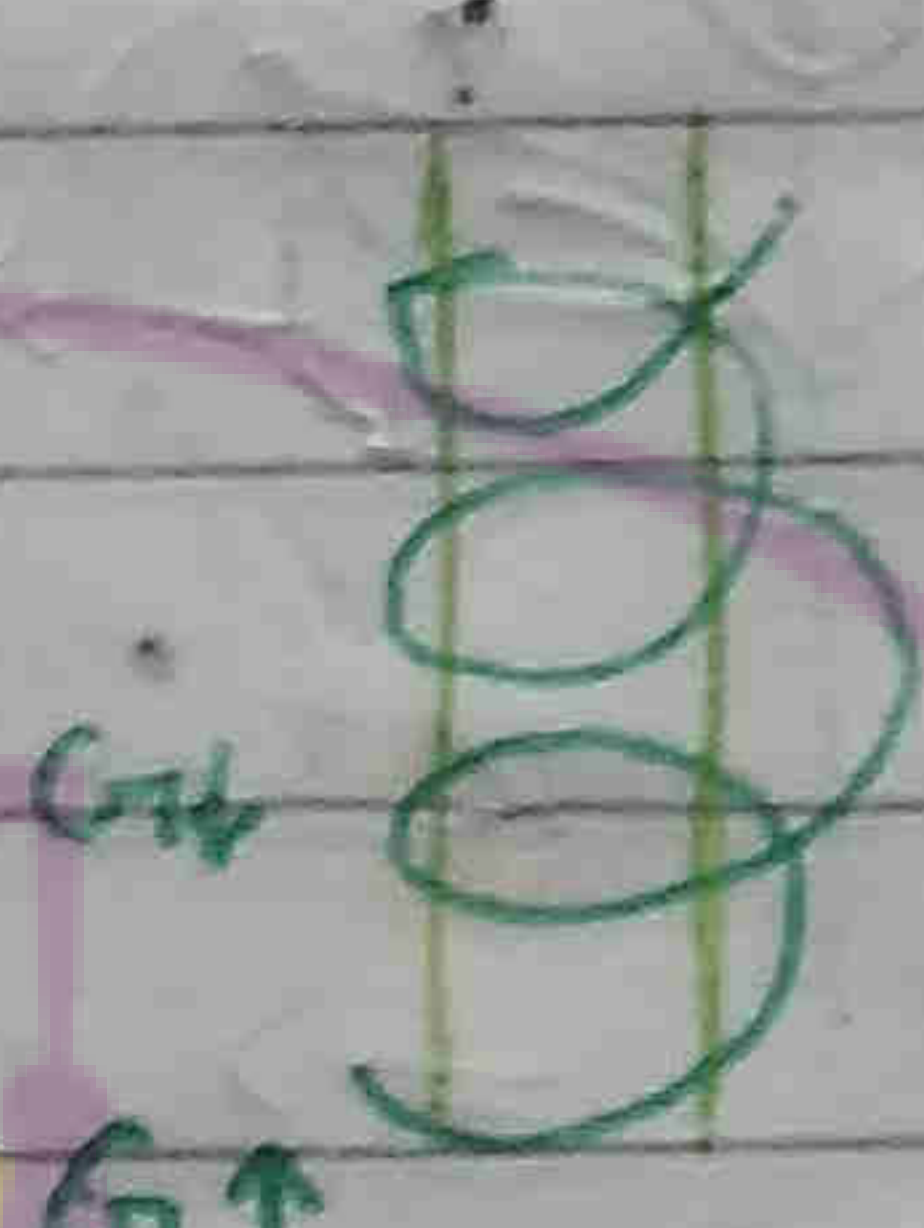


Haptotropism

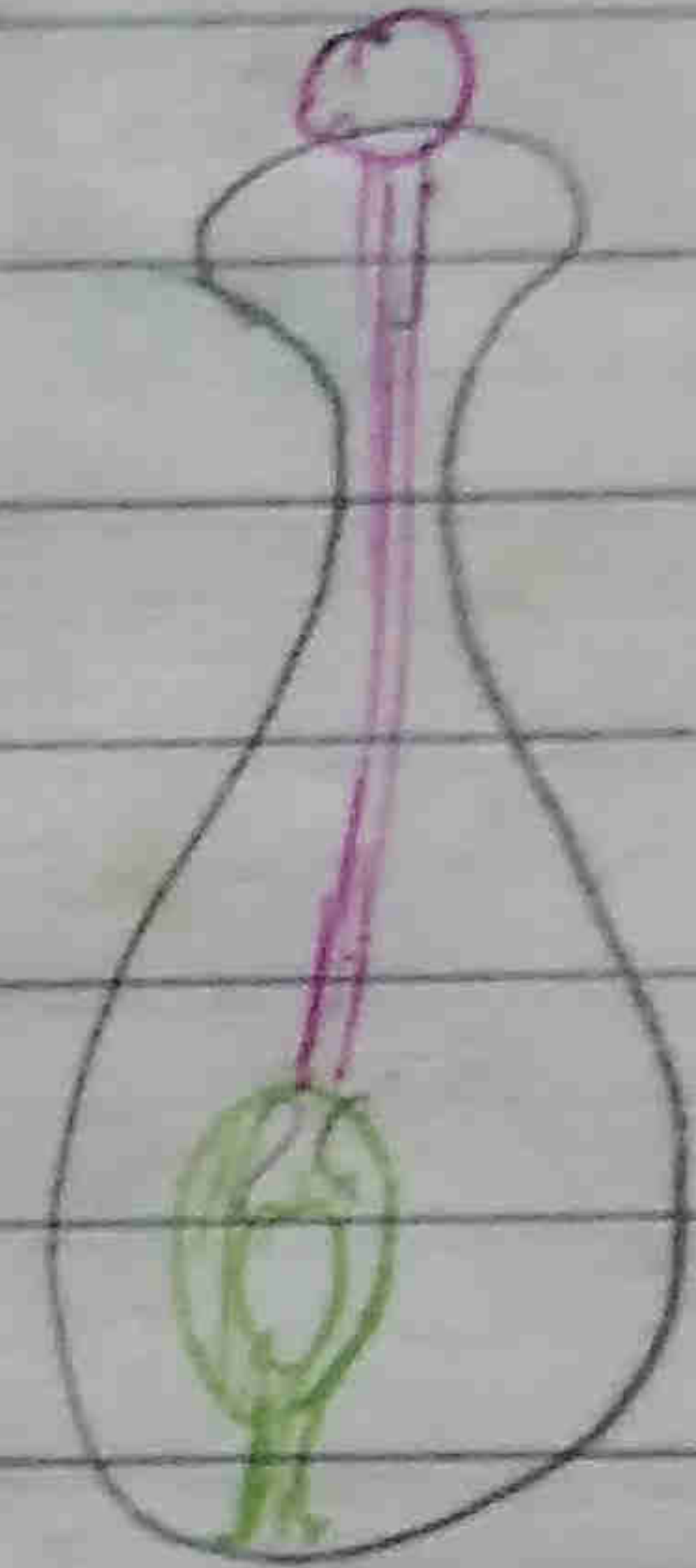
Thigmotropism

Thummers

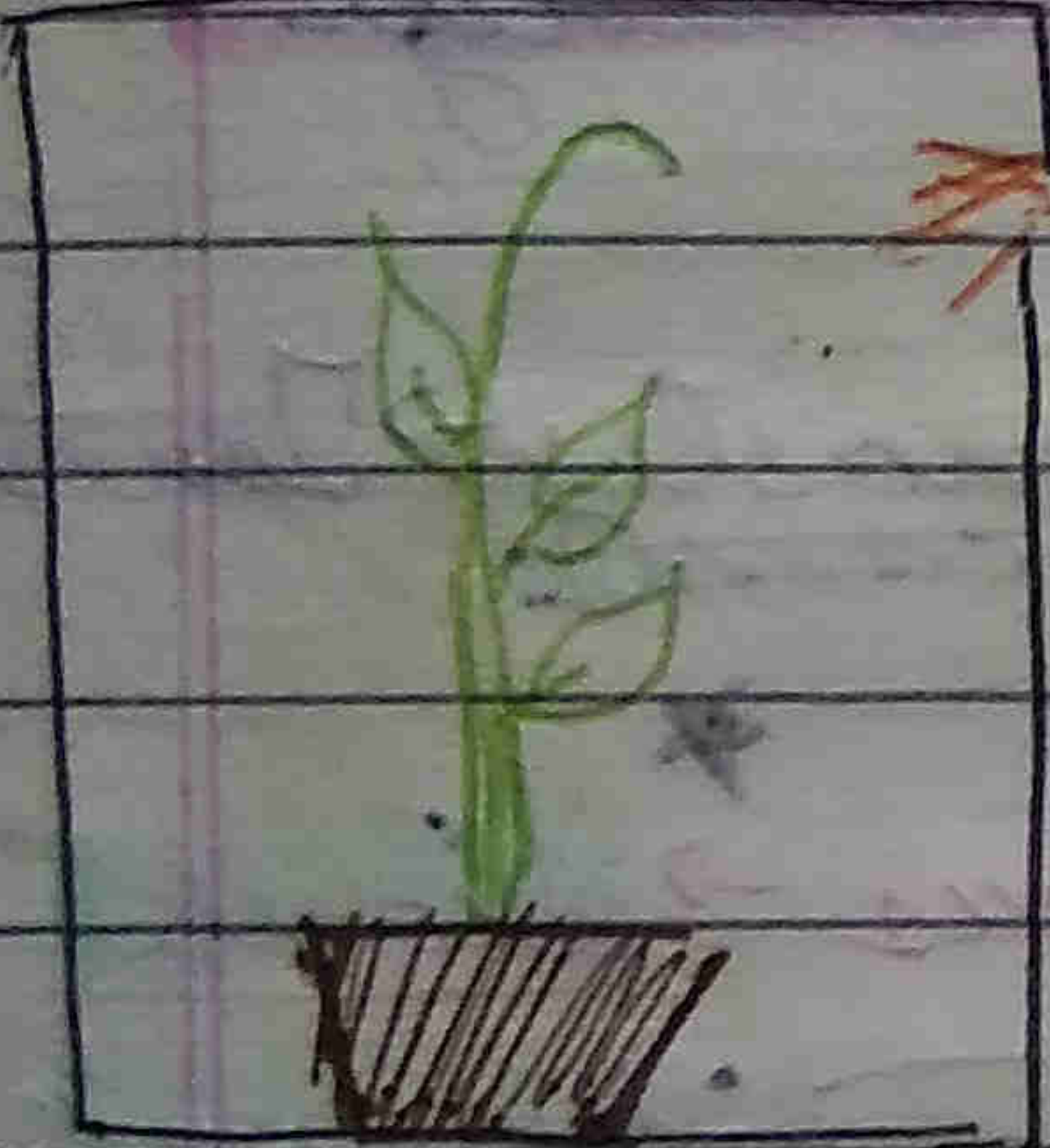
Tendrils



Chemotropism



Heliotropic chamber



due to touch

Hydrotropism

stem = -H

root = +H

Aerotropism

Pneumatophora

Heliotropic chamber is used to study positive phototropism.

45° Plagiogeotropism
root, shoot branches

90° Diageotropic

rhizome	runner
below	above
soil	soil

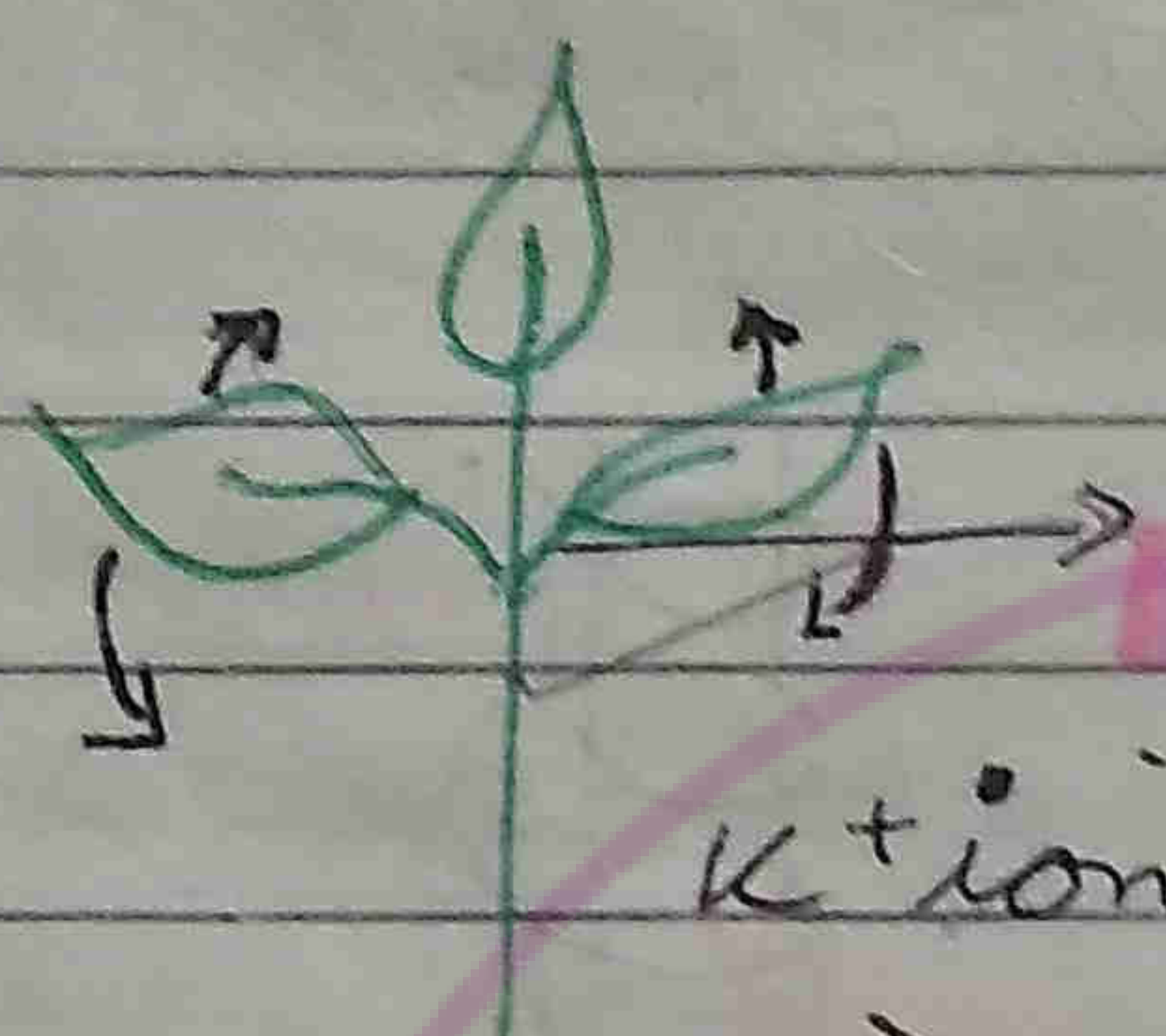
In clinostat effect of gravity is nullified as the plant is rotated, hence the concentration of auxin is same on both sides.

Stimulus: Variation

Autonomous

Induced

• Desmodium gyrans



Motor cells

K^+ ions loss
=> flaccid

K^+ ion taken up
=> Turgid

• Nyctinasty -> sleeping movements

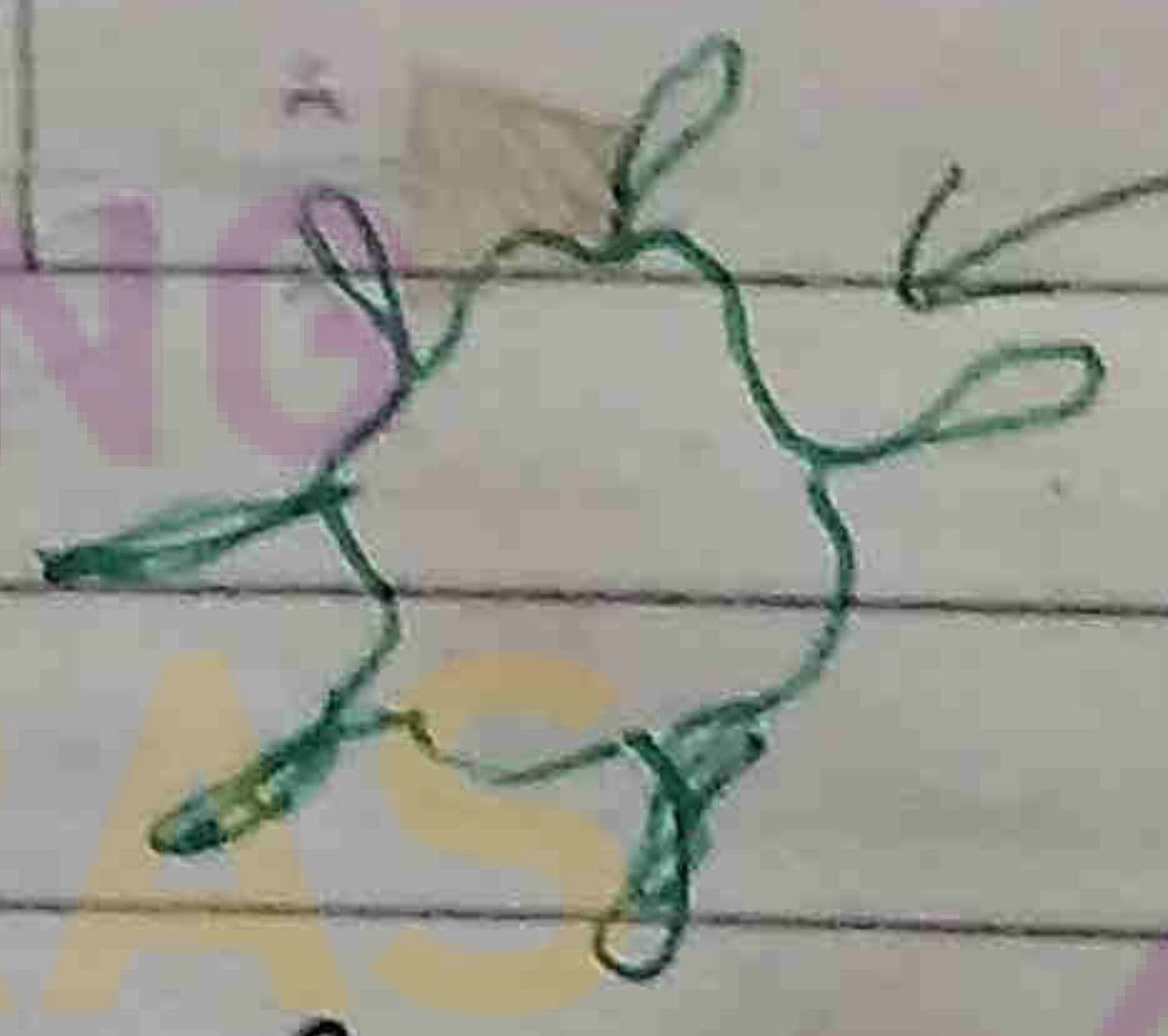
Oxalis, Marselia
Photonastic (light)

Tulip -> Temperature
Thermonastic

-> Thigmonasty -> Touch

Insectivorous -> Dionaea

Drosera
Linguicula



Leaf

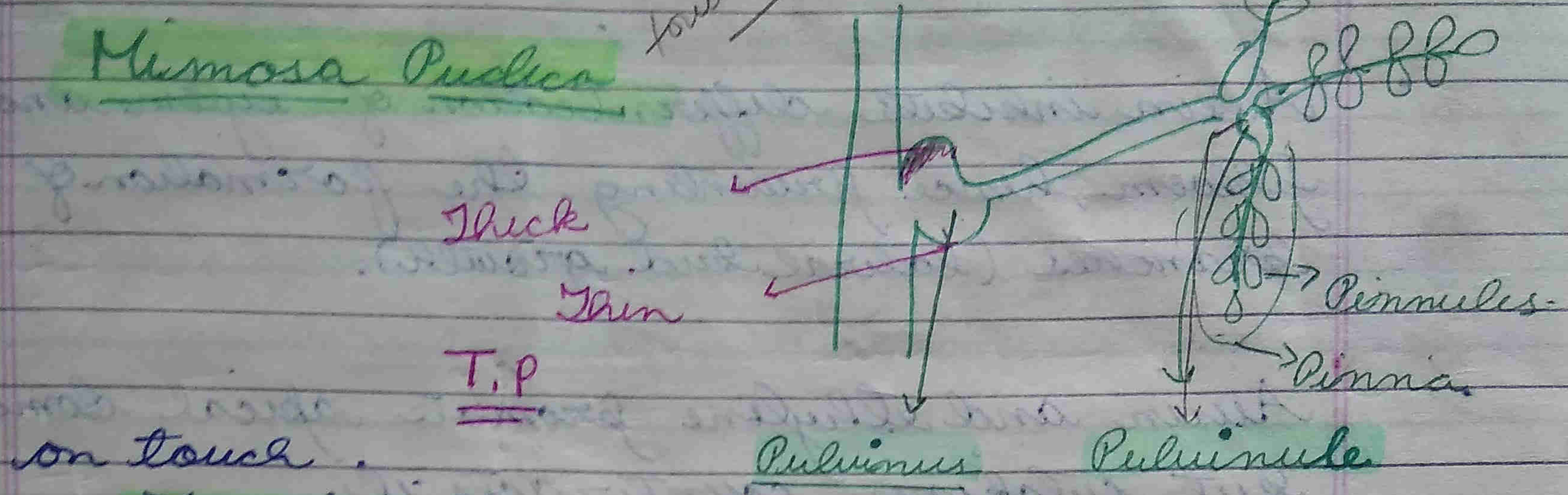
LEARNING
MANTRAS

3

Seismonasty

(short term touch movement)
touch sensitive plant

Mimosa Pudica



on touch

Turgorin (Hormone)

Pulvinus / Pulvinules

K^+ efflux

Flaccid

droop down

LEARNING
MANTRAS

- Auxin inhibits differentiation of xylem and phloem, hence preventing the formation of branches (lateral bud growth).
- Auxin and ethylene promote apical dominance but cytokinin counteracts it.
- Ethylene forms cellulase and pectinases in separation layer of abscission zone.
- Traumatic acid is a type of auxin.
- Gibberallic acid can cause elongation even in genetically dwarf variety of pea and maize.
- Only gibberallic acid leads to formation of male flowers.
- Ethylene causes ripening only in climacteric fruits.
- Ethylene cannot cause ripening in pineapple but it can initiate its ripening.
- GA is main hormone for seed germination although ethylene causes seed germination in peanut.

- For germination of seed red light is required and last exposure decides whether germination will occur or not.
- In photoperiodism, site of perception is leaf but in vernalisation it is meristematic tissue.



LEARNING
MANTRAS