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SCNA-CCPA
PAGE NO.:
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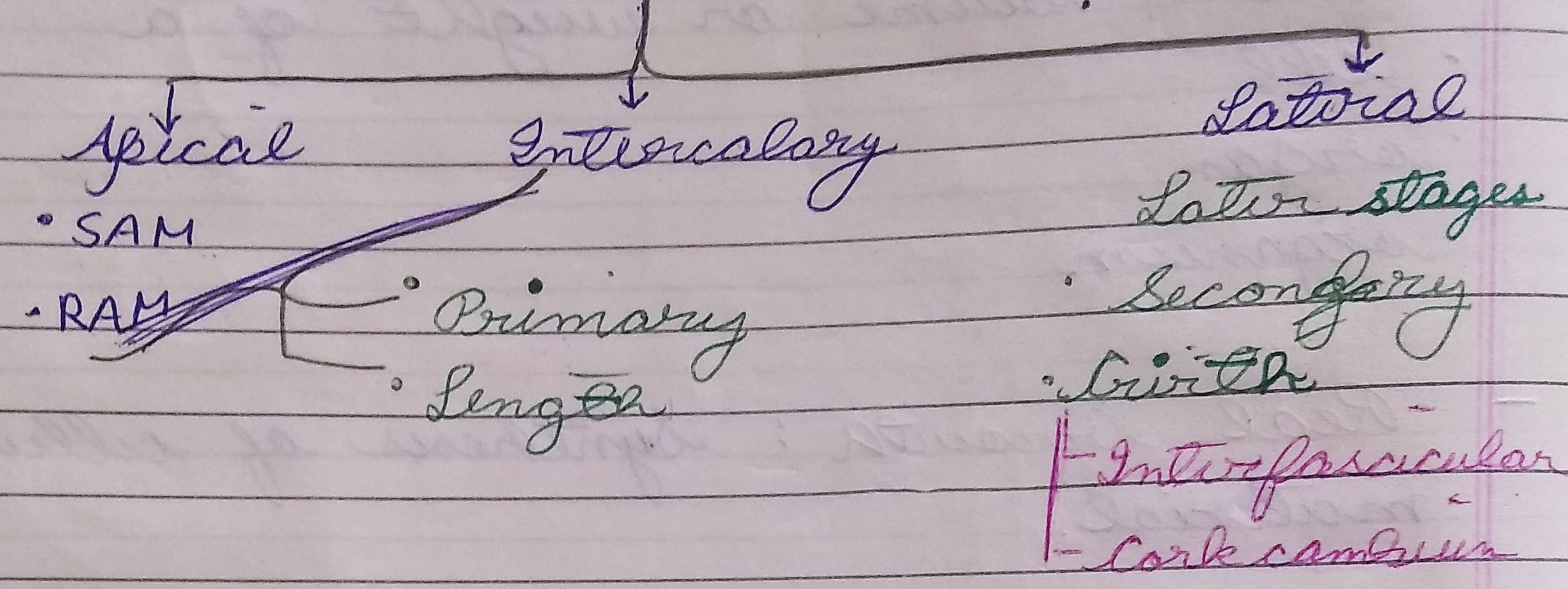
Plant Growth and Development

- **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

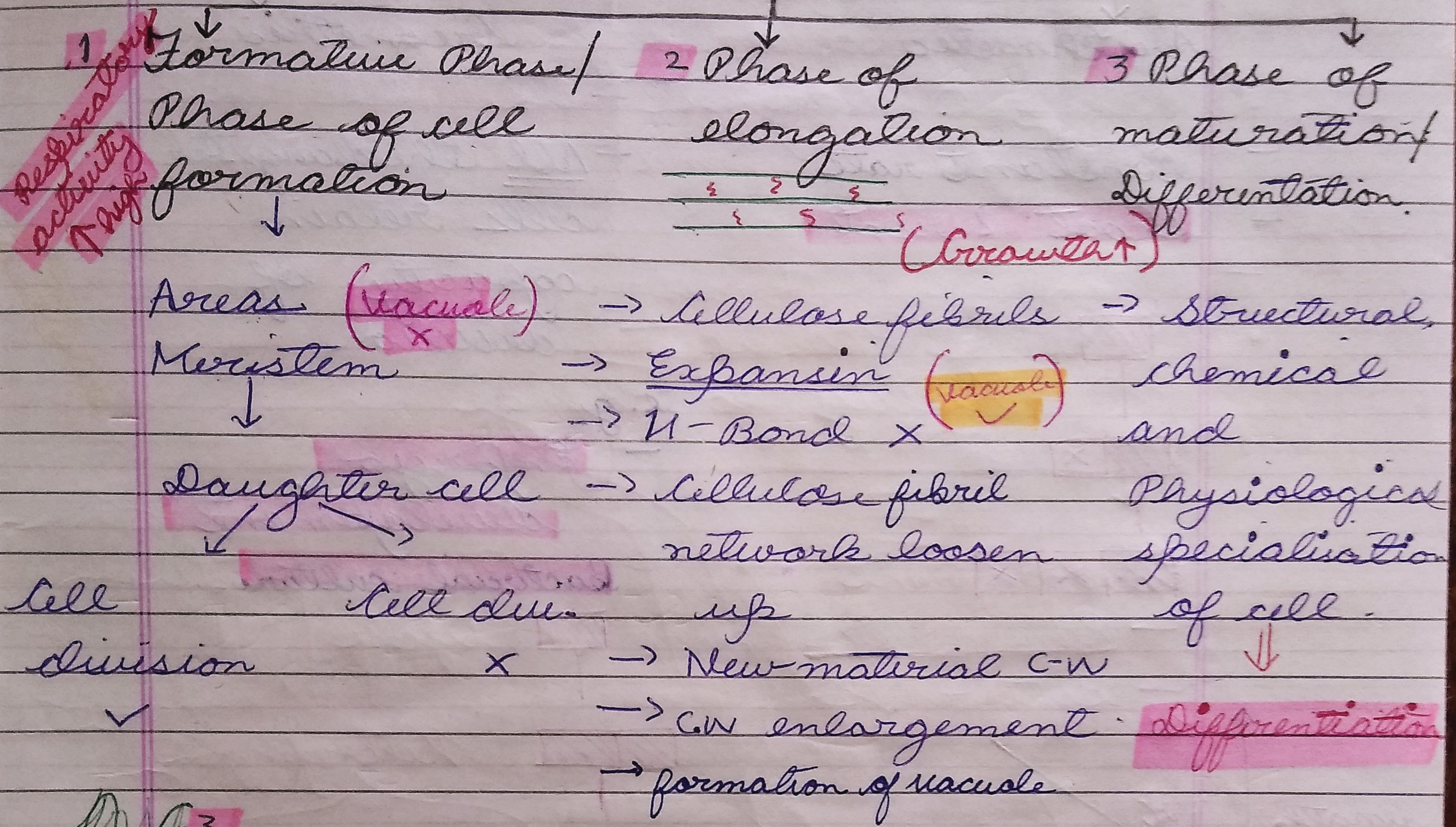
3. Open growth

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

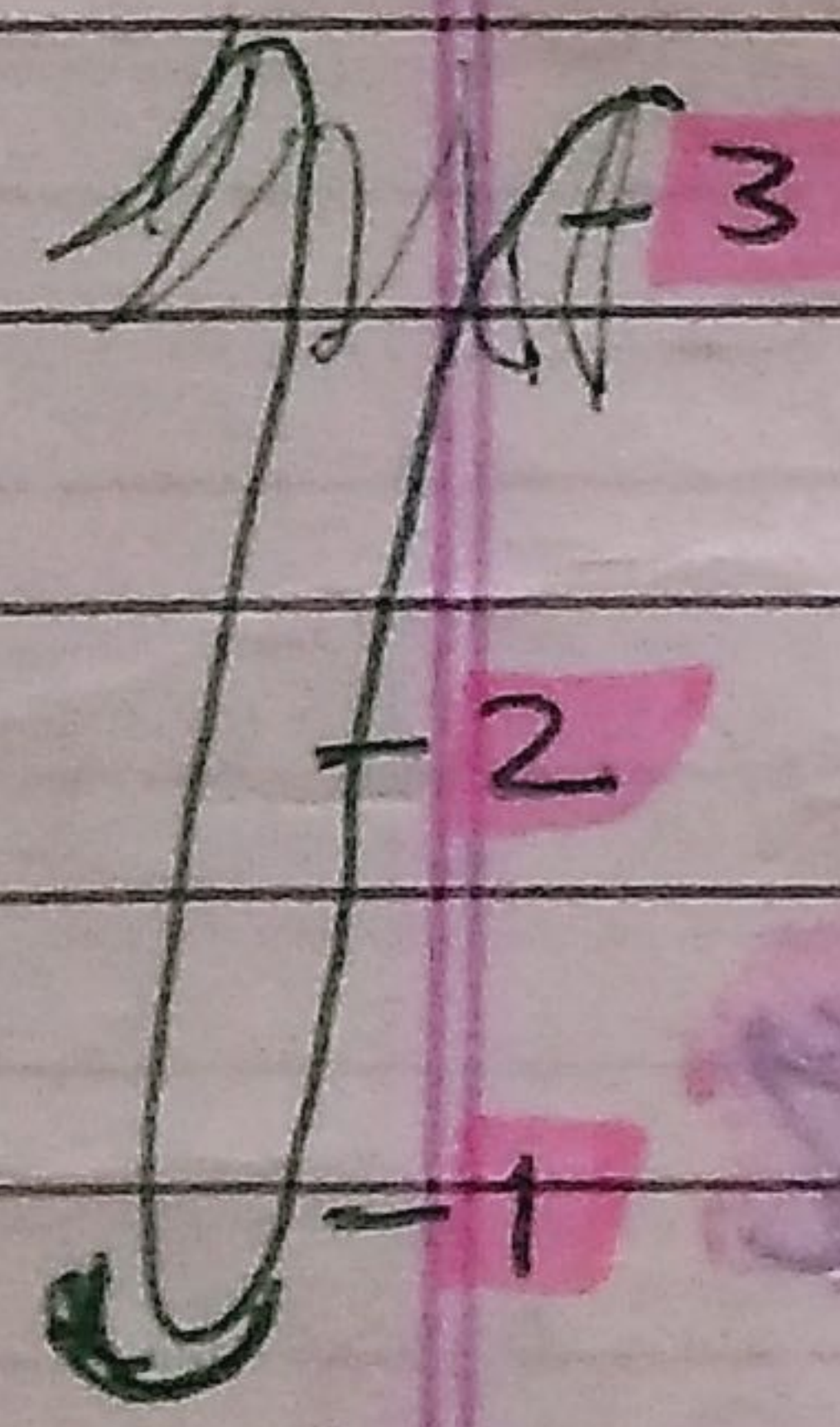
5. Juvenile → Mature stages
structure of mature stage is different from that in juvenile stage.

• Expansin enzyme breaks hydrogen bonds in cellulose fibril.

Phases of Growth



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• Maximum respiratory activity present in formative phase.

• Maximum growth in elongation phase.

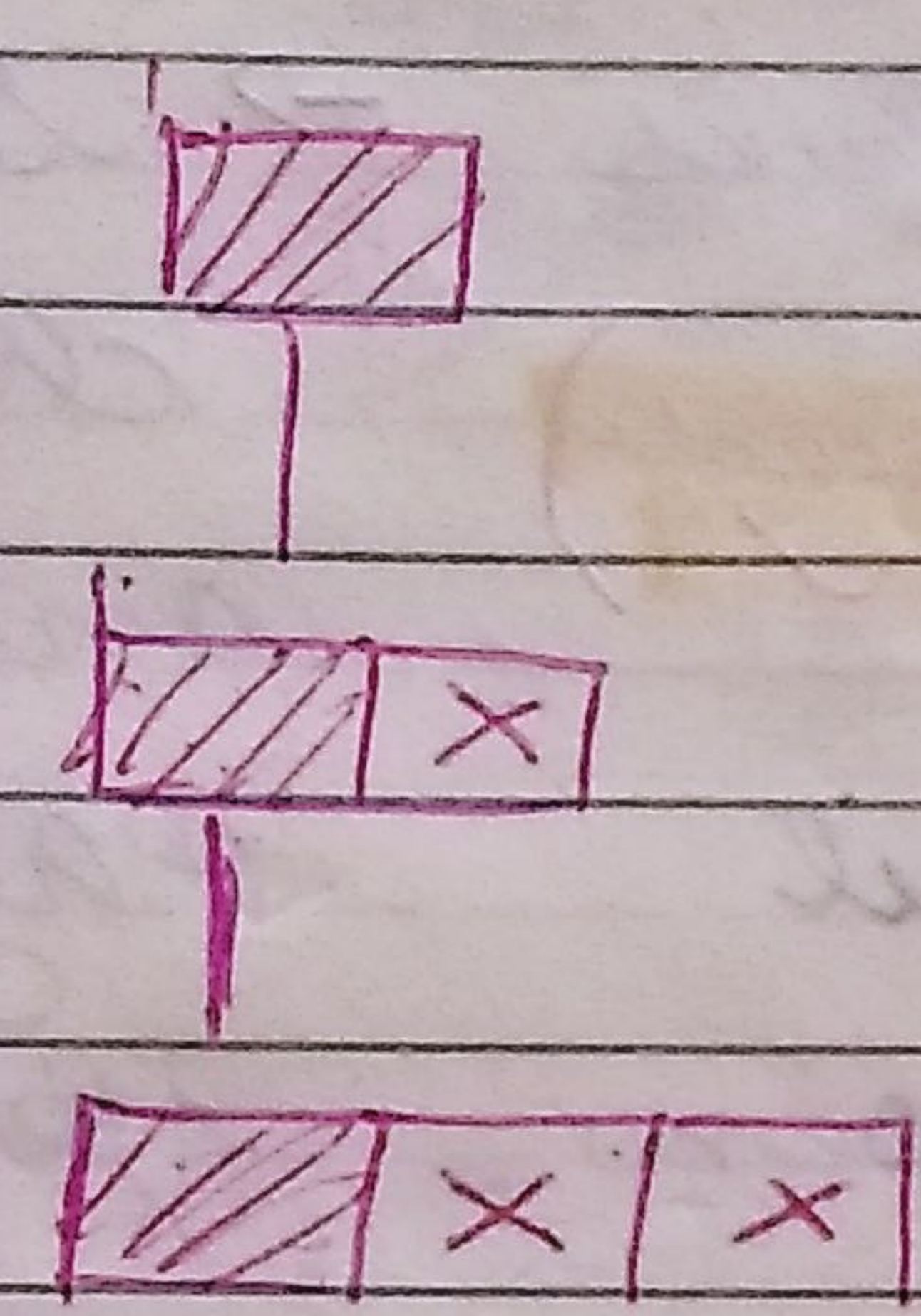
Growth Rate

Arithmetic

Geometric

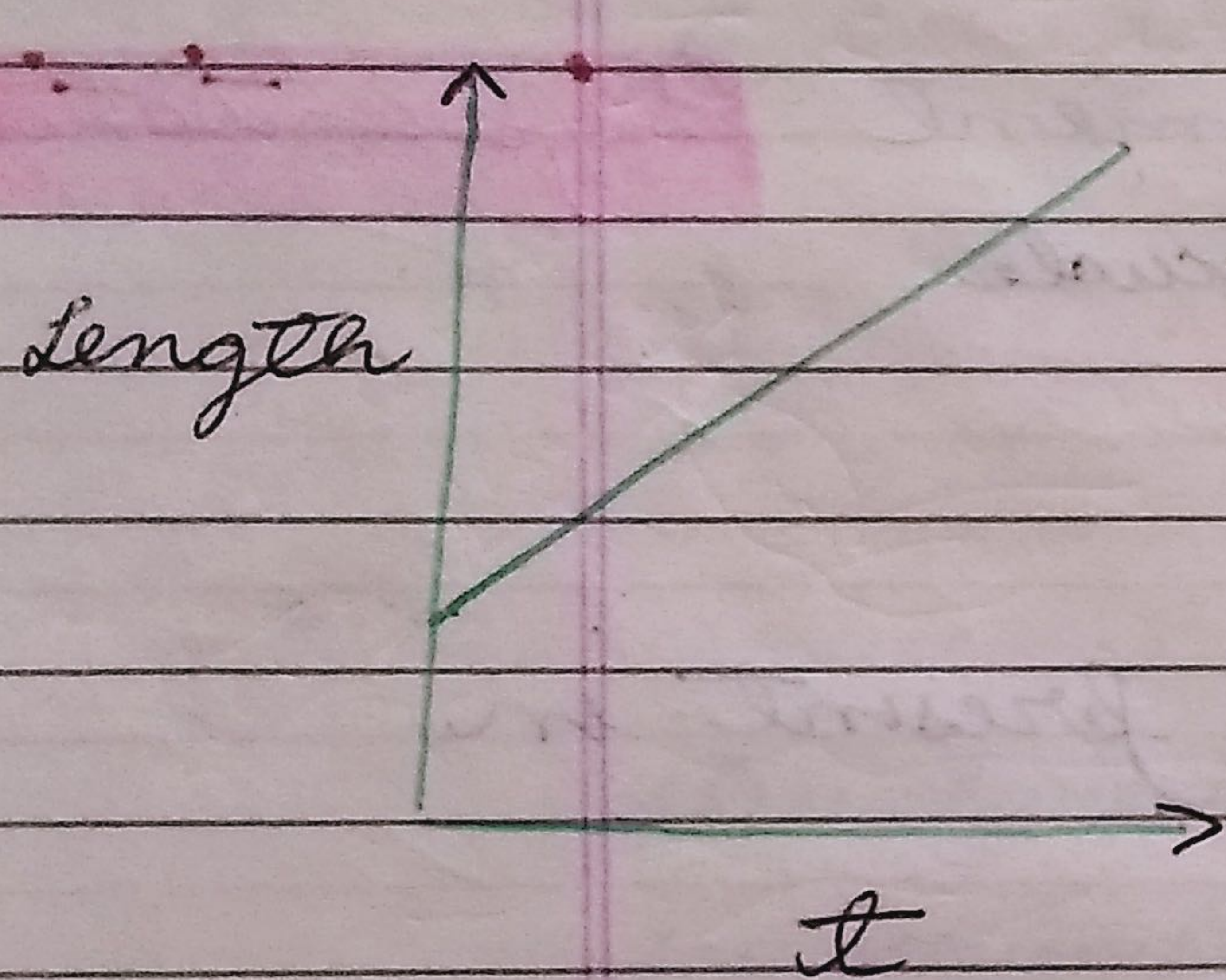
- Constant rate
- shoot & root

- All the daughter cells retain capacity of division



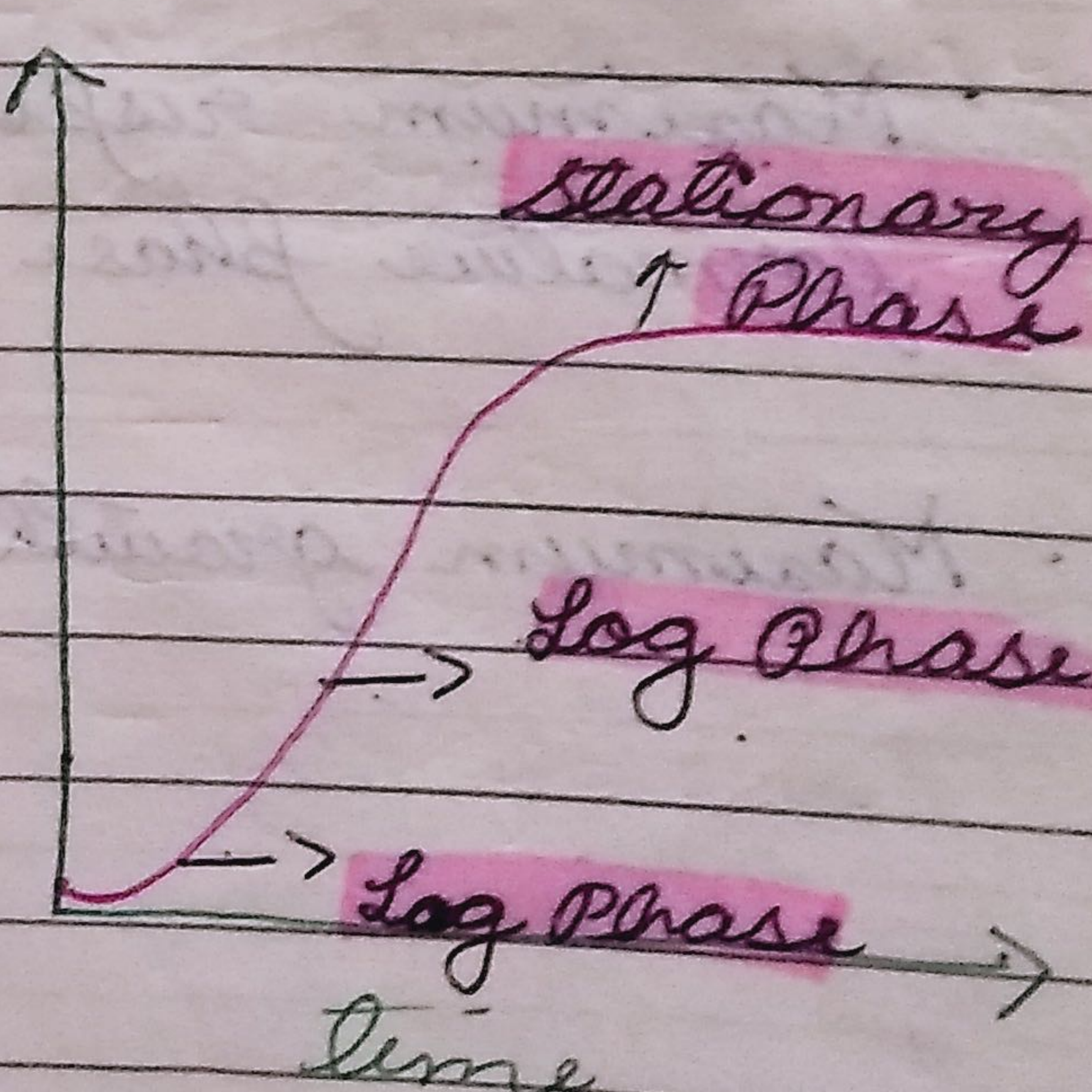
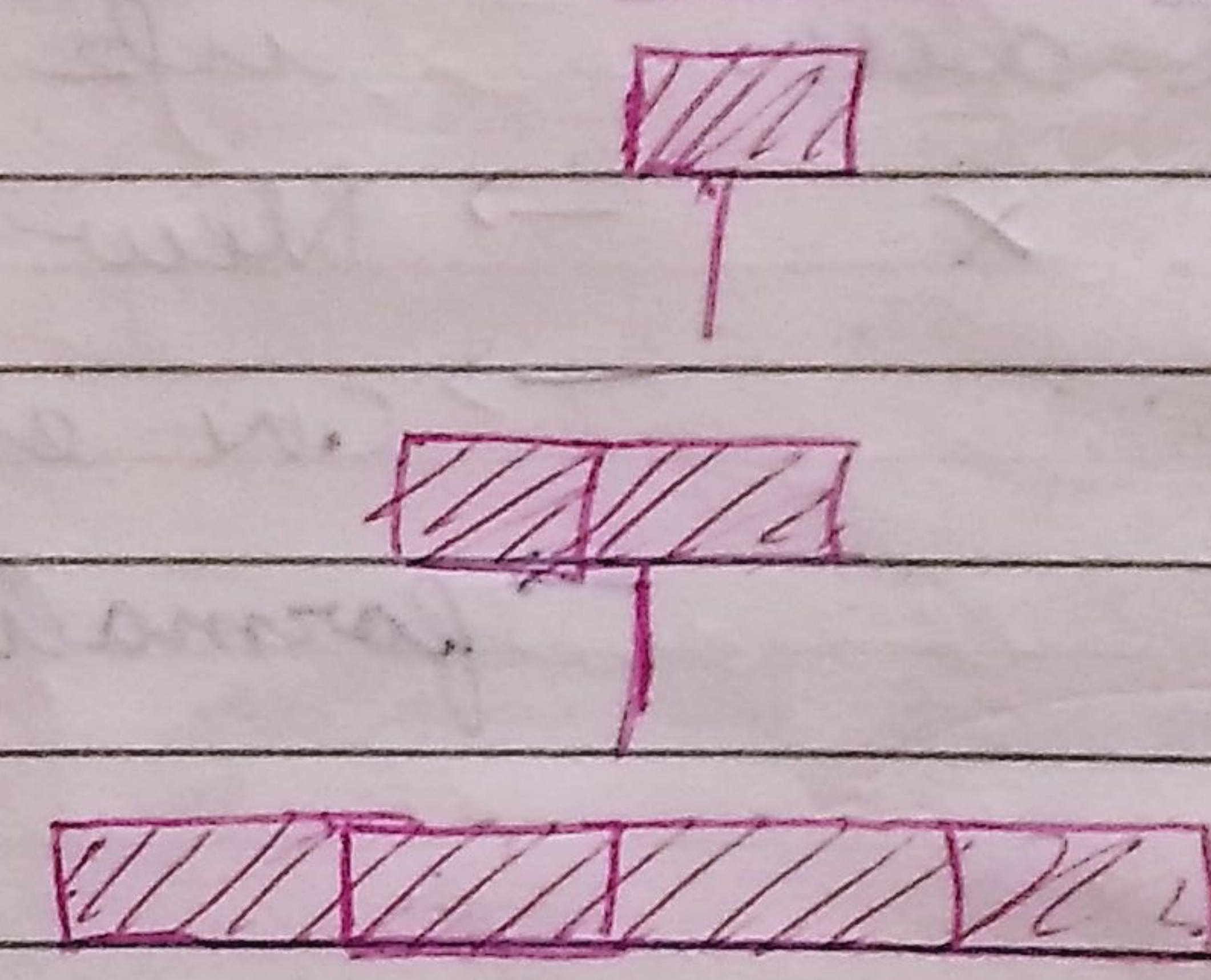
e.g.

- Embryo development
- Bacterial culture



$$L_t = L_0 + rt$$

Here r = growth rate
 t = time
 L_0 = initial length



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

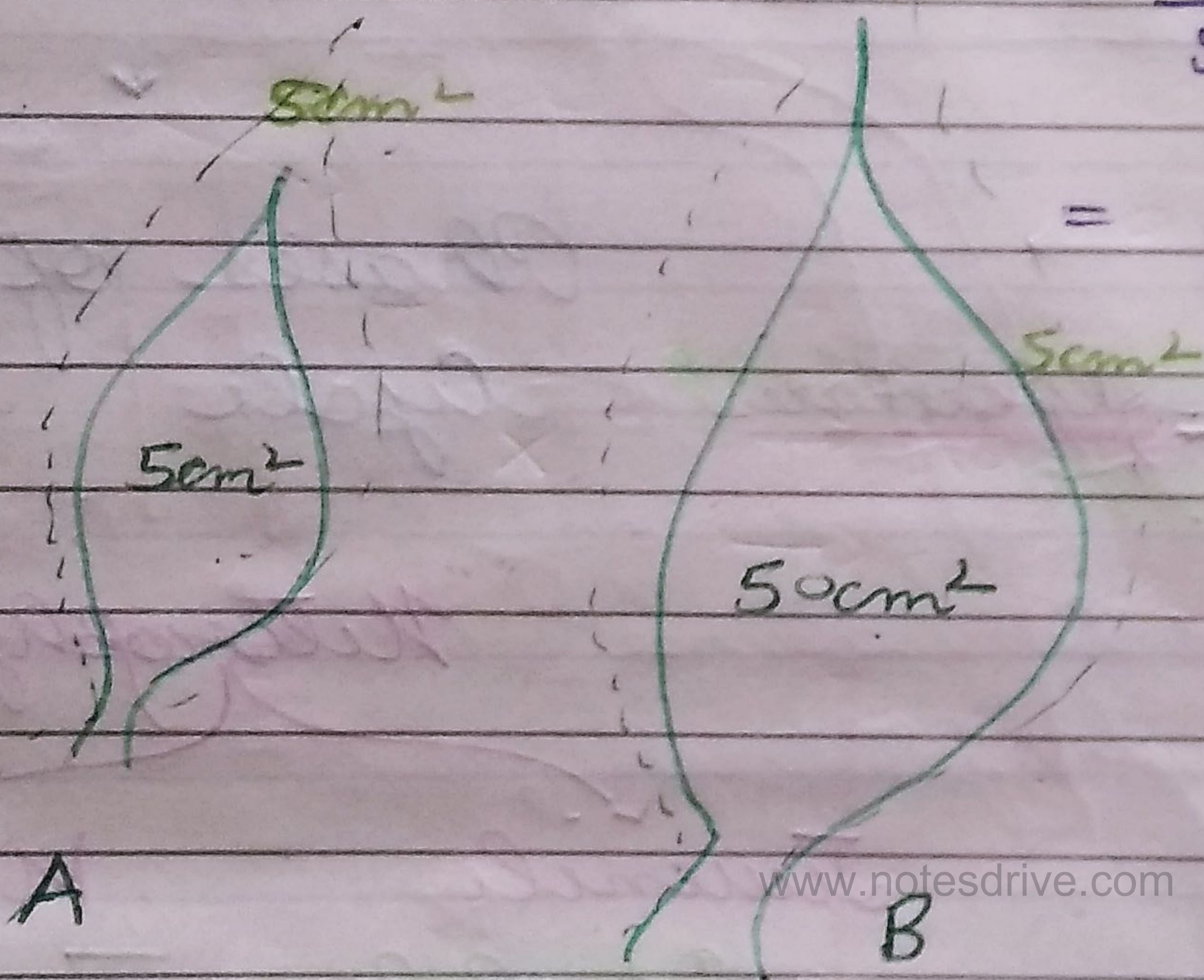
A.G.R: Absolute Growth Rate
 = Growth per unit time
 = A = B = $5 \text{ cm}^2/\text{day}$

R.G.R: Relative growth rate

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

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

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



Terms

- Differentiation**

1° Meristem
 ↓ cell division X
 1° Permanent Tissue
 ↓ Mature
 Cell Div ✓ (Despecialisation)

specialised structurally, chemically, physiologically
- Didifferentiation**

2° Meristem (eg Intercellular cambium)
 ↓ cell div X
- Redifferentiation**

2° Permanent tissue

Development

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

Plasticity Ability to change

Environment

- Ranunculus flabellaris
- Buttercup

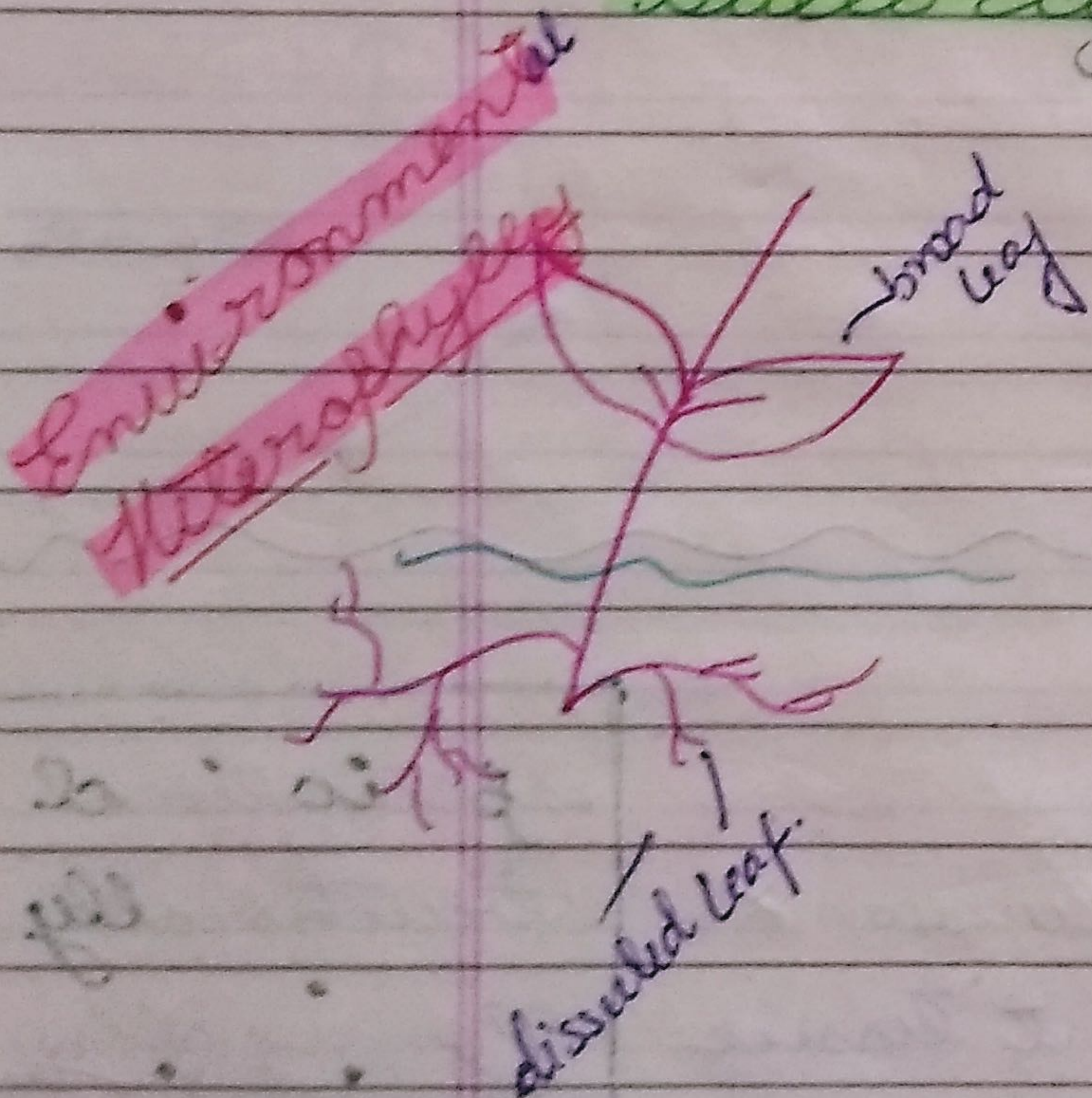
Phases of Life Cycle

Heterophylly

Juvenile Mature

Developmental Heterophylly

- Cotton
- Coriander
- Larkspur



Development
controlled by

Intrinsic factors

Extrinsic factors

Intercellular
P or R's
Plant Growth
Regulators

Intracellular
Hormones

- Temp
- O₂
- H₂O
- Nutrients

5 Types

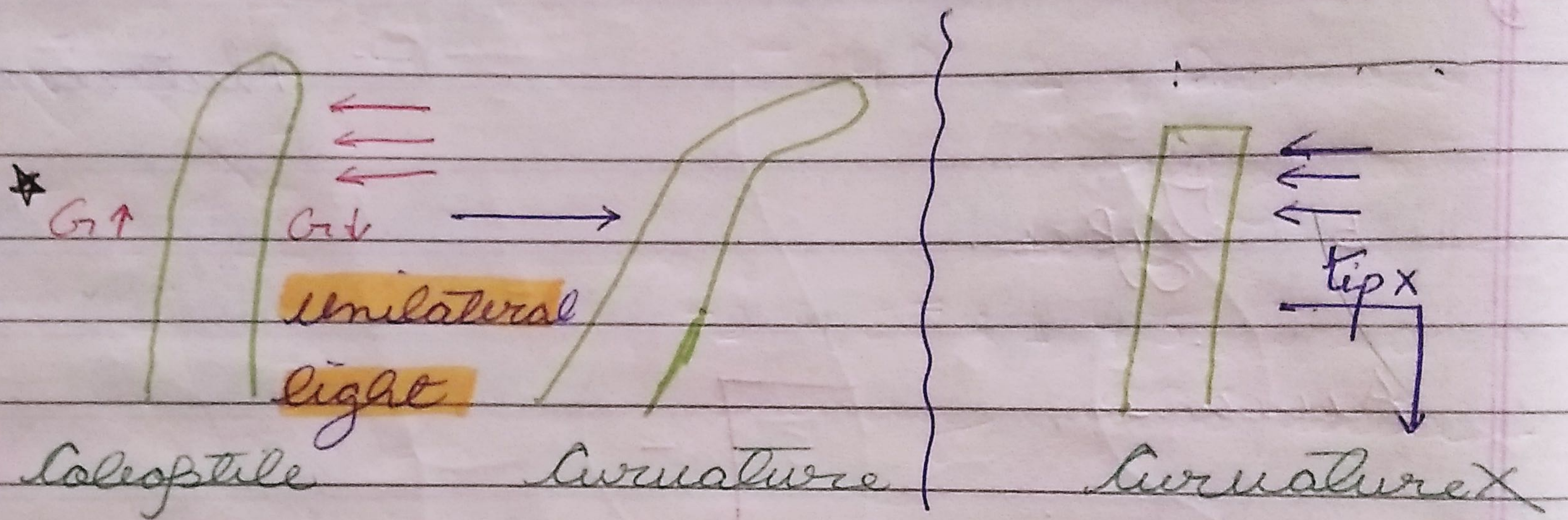
- 1. Auxins
 - 2. Gibberellins
 - 3. Cytokinins
 - 4. Ethylene
 - 5. ABA
- Promoter (P)
- Inhibitor (I)
- I > P

* Differential growth leads to curvature.

Auxin

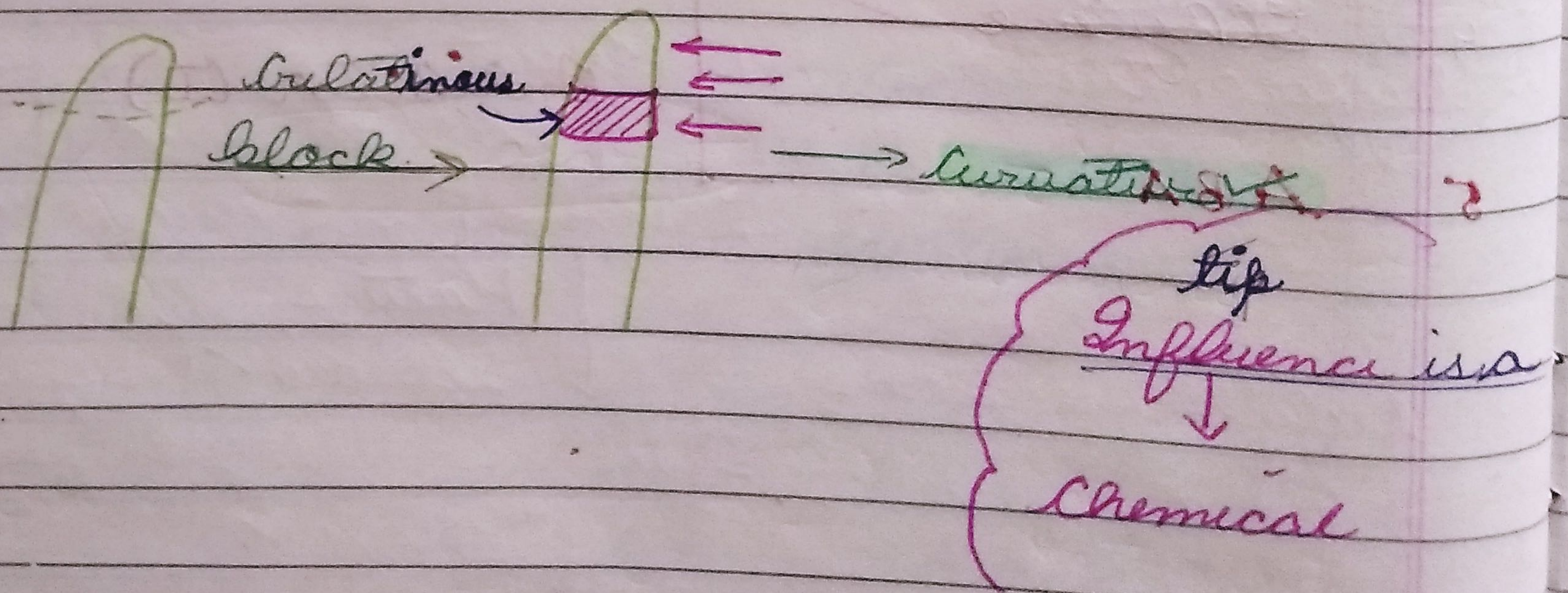
① Charles Darwin
Francis "

Canary Grass
(*Phalaris canariensis*)



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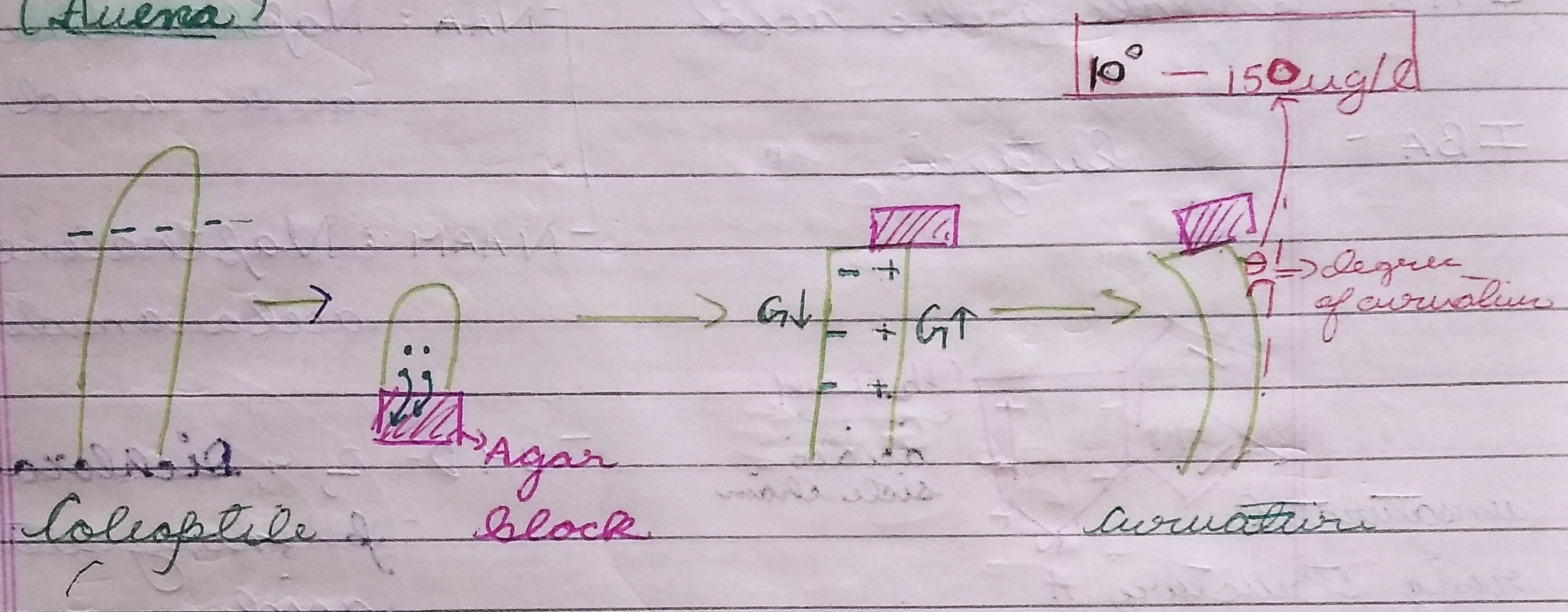
② Boysen - Jensen



- Auxin was first extracted by Went.
- ★ Auxin first isolated from human urine.

3 Went → gave the name auxin.

Oat seedling
(Avena)



Auxin
↓
Gib Auxin
↓
to grow

Bioassay of Auxin

- Avena curvature test
- Quantitative ✓
- Qualitative ✓

extracted - Split Pea Test

- Sear's 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

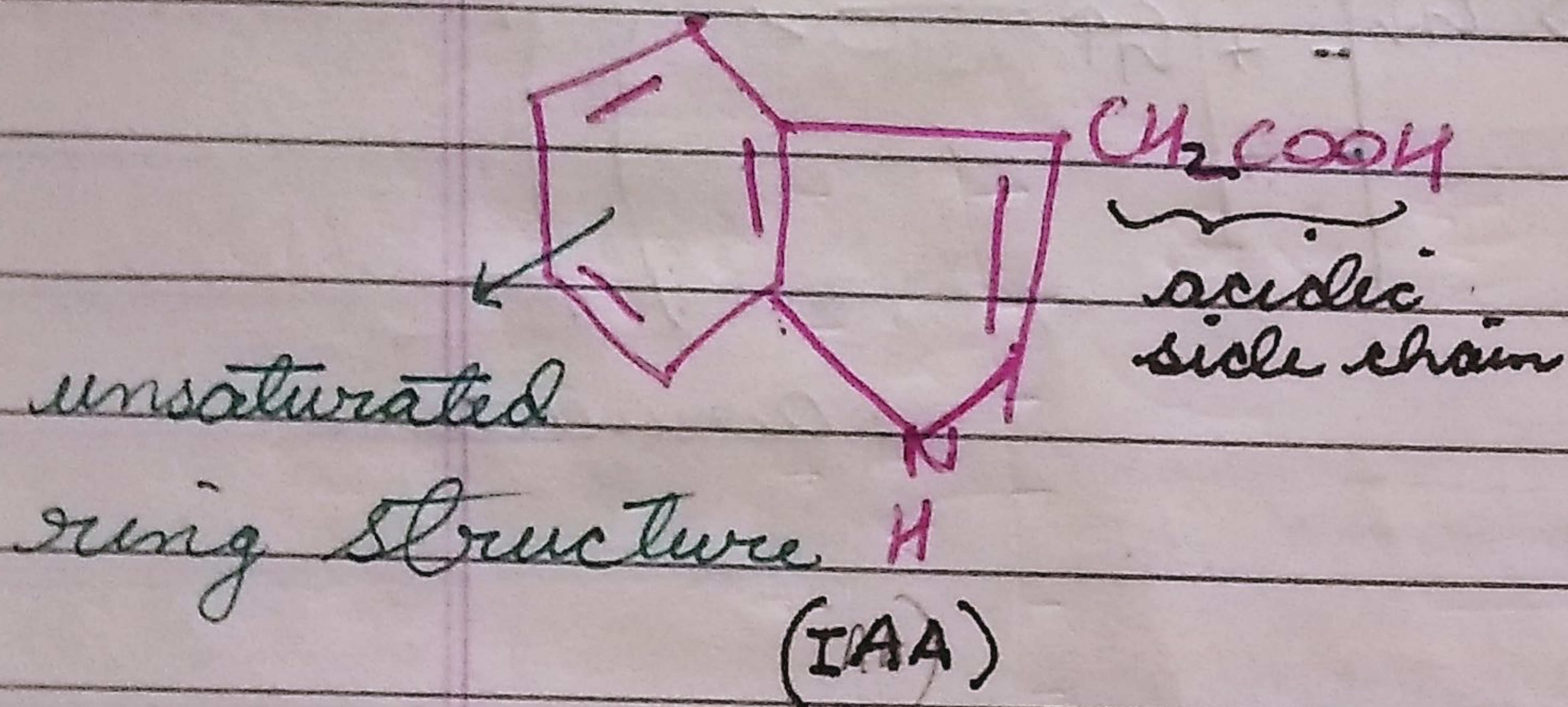
Synthetic

IAA - Indole acetic acid

-NAA = Naphthalene acetic acid

IBA - " butyric "

-NAAm = Naphthalene acetyl amides

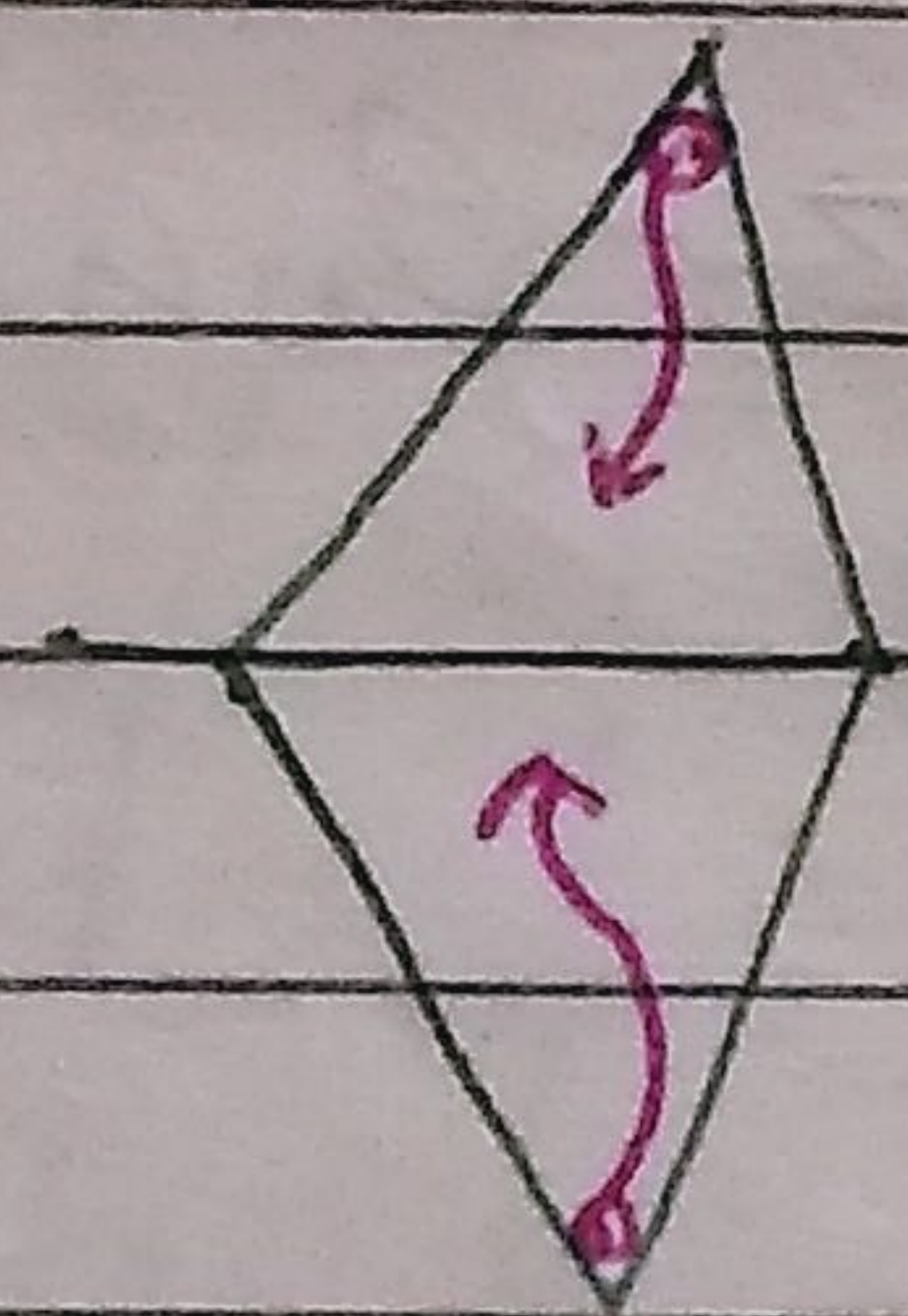


-2,4,D = 2,4 Dichloro-phenoxyacetic acid

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

• Synthesis: Tryptophan, m⁺

• Location: Shoot tip 10 ppm
Root tip 0.0001 ppm



∴ move 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.
- Cytokinin counteracts apical dominance.

Junctions

1. Cell Elongation
2. Apical Dominance

Auxin
↓
(at wall)
C.W. acidic

Expansin
↓

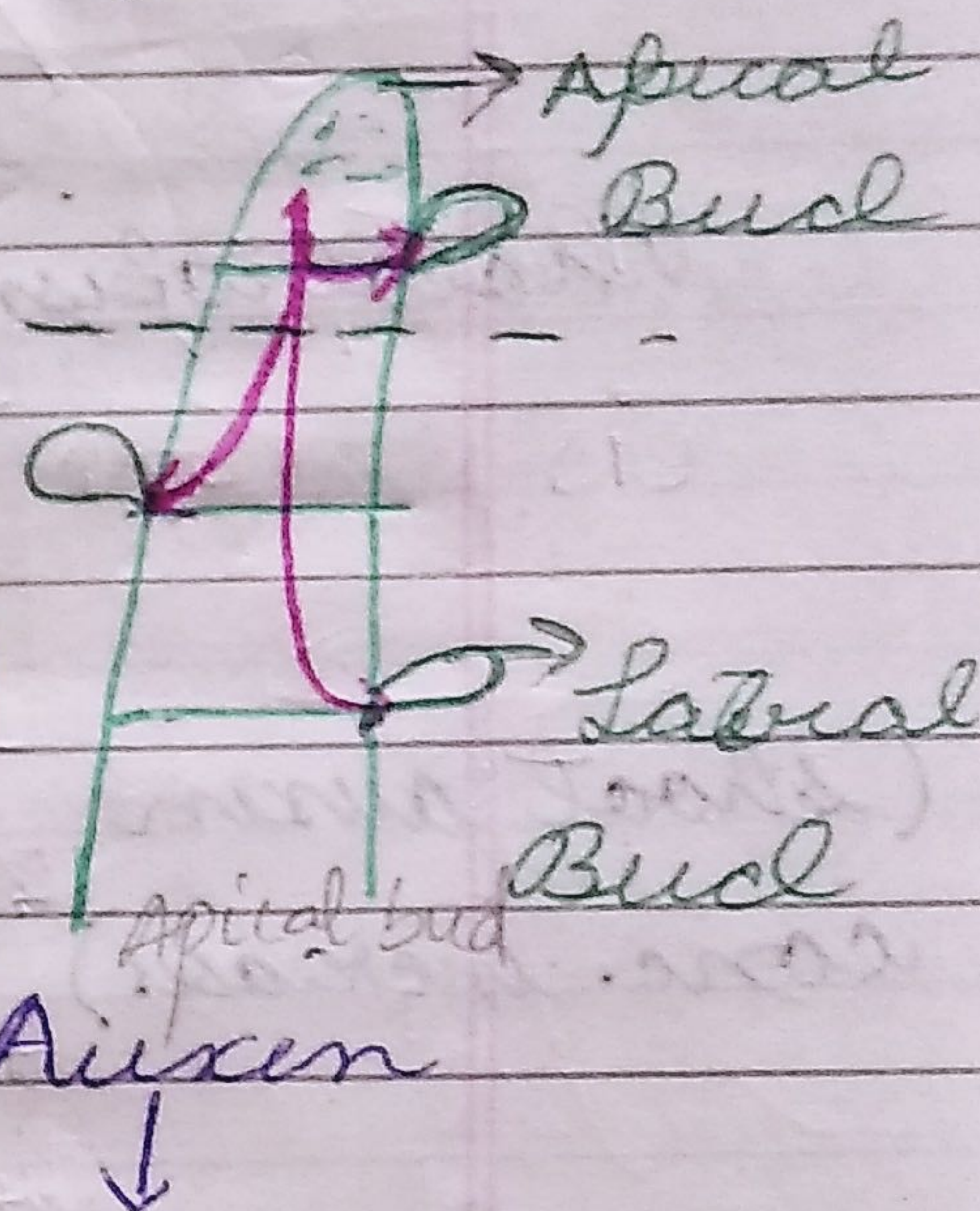
Cellulose microfibril
H-Bonds

Loosen-up network

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

Apical bud suppresses the growth of lateral buds

Inhibits differentiation of Xylem/Phloem

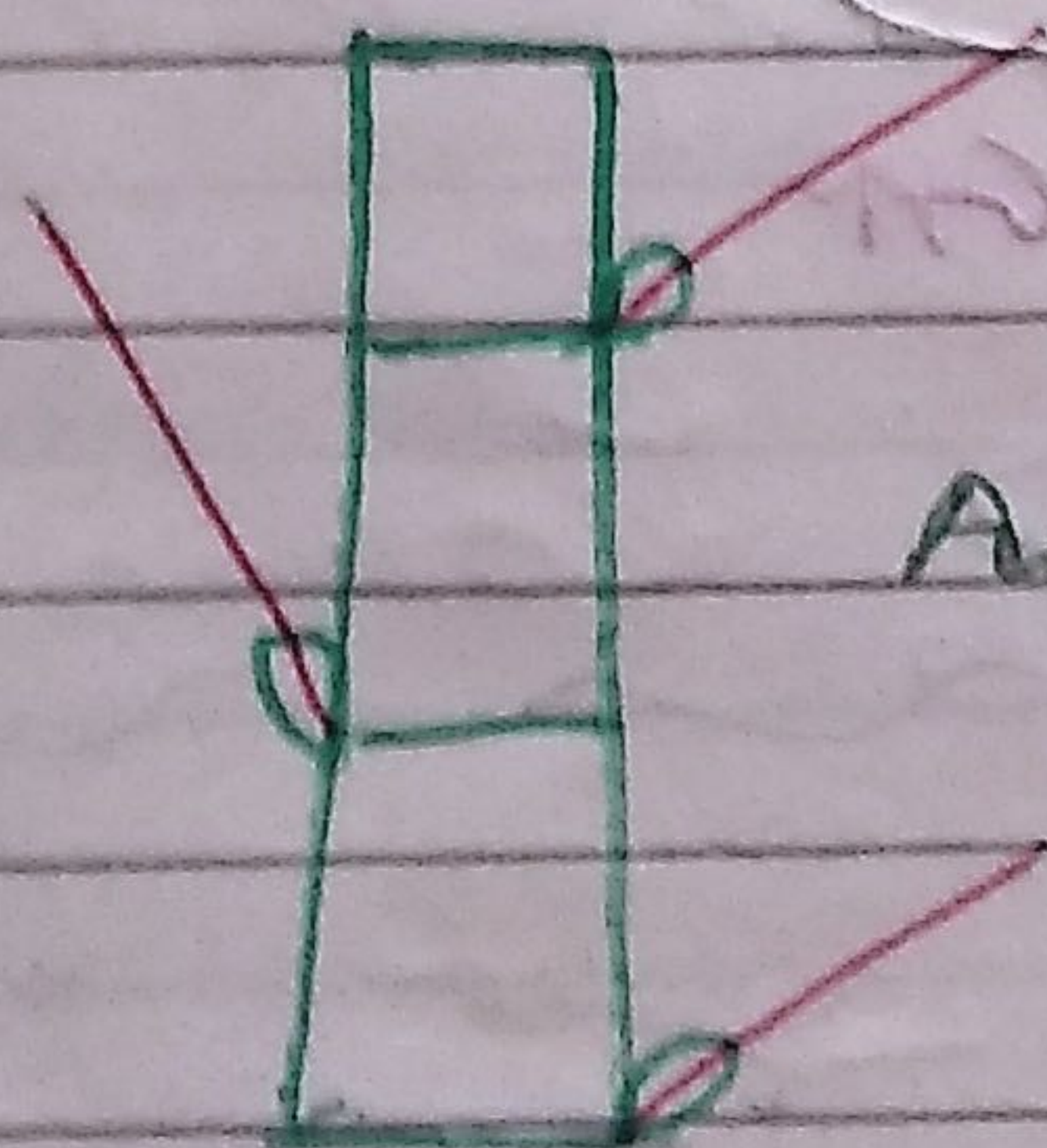


Lateral Bud
↓

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

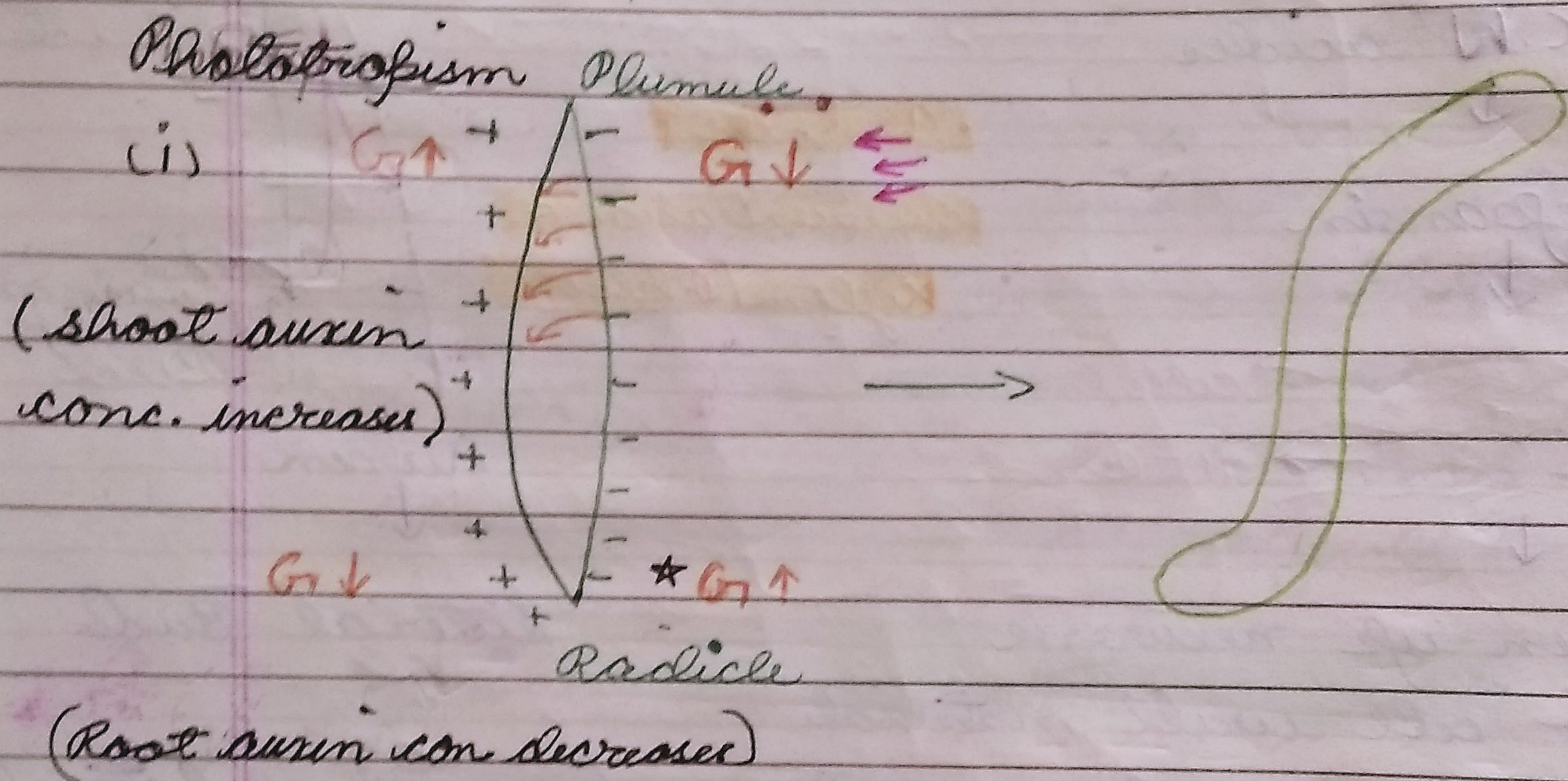
- Tea Plantation
- Hedge making

★ For root growth auxin concentration should be less.

[3] Phototropism & Geotropism

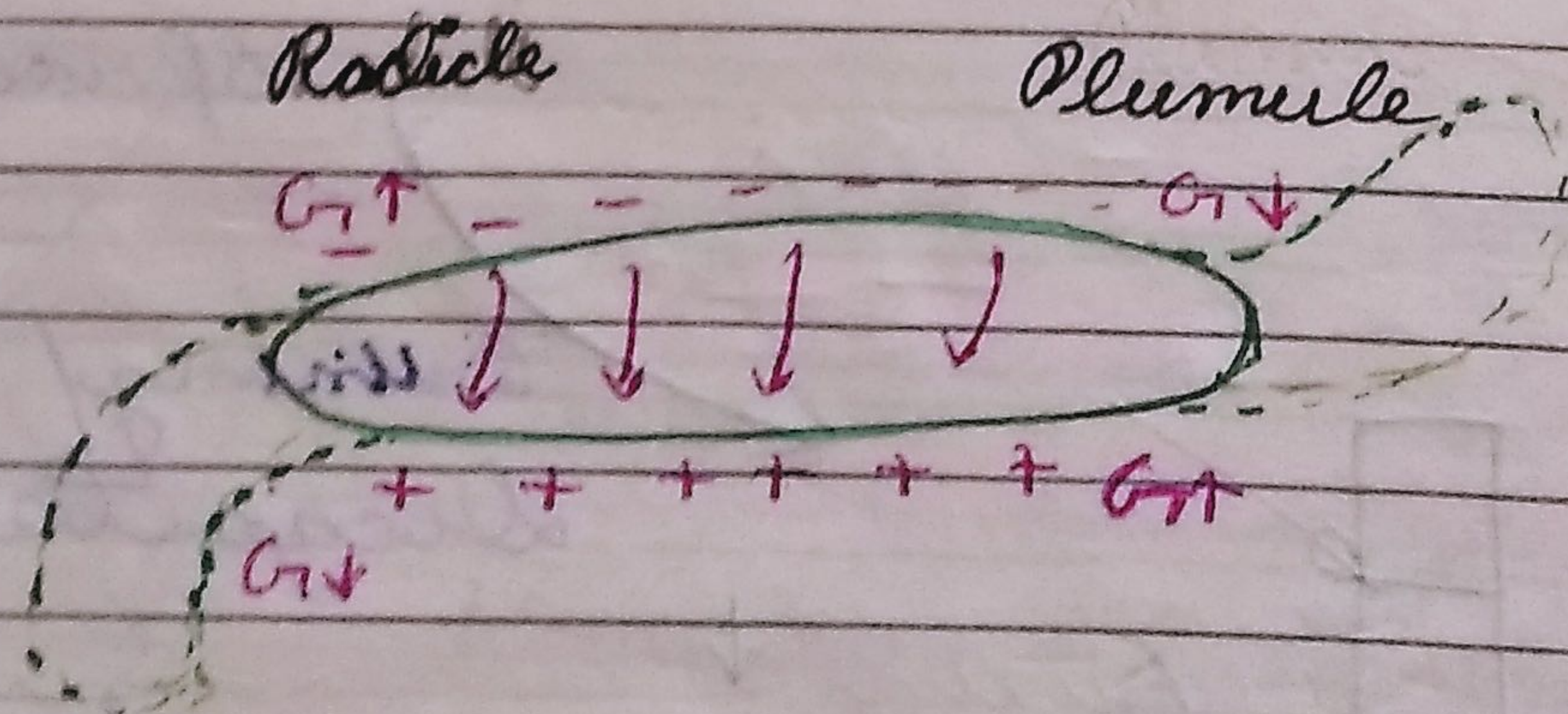
◆ Tropic movements

- curvature movements
- cylindrical organs (shown by)
- Diff^{erential} growth (due to)
- stimulus (towards or away from)



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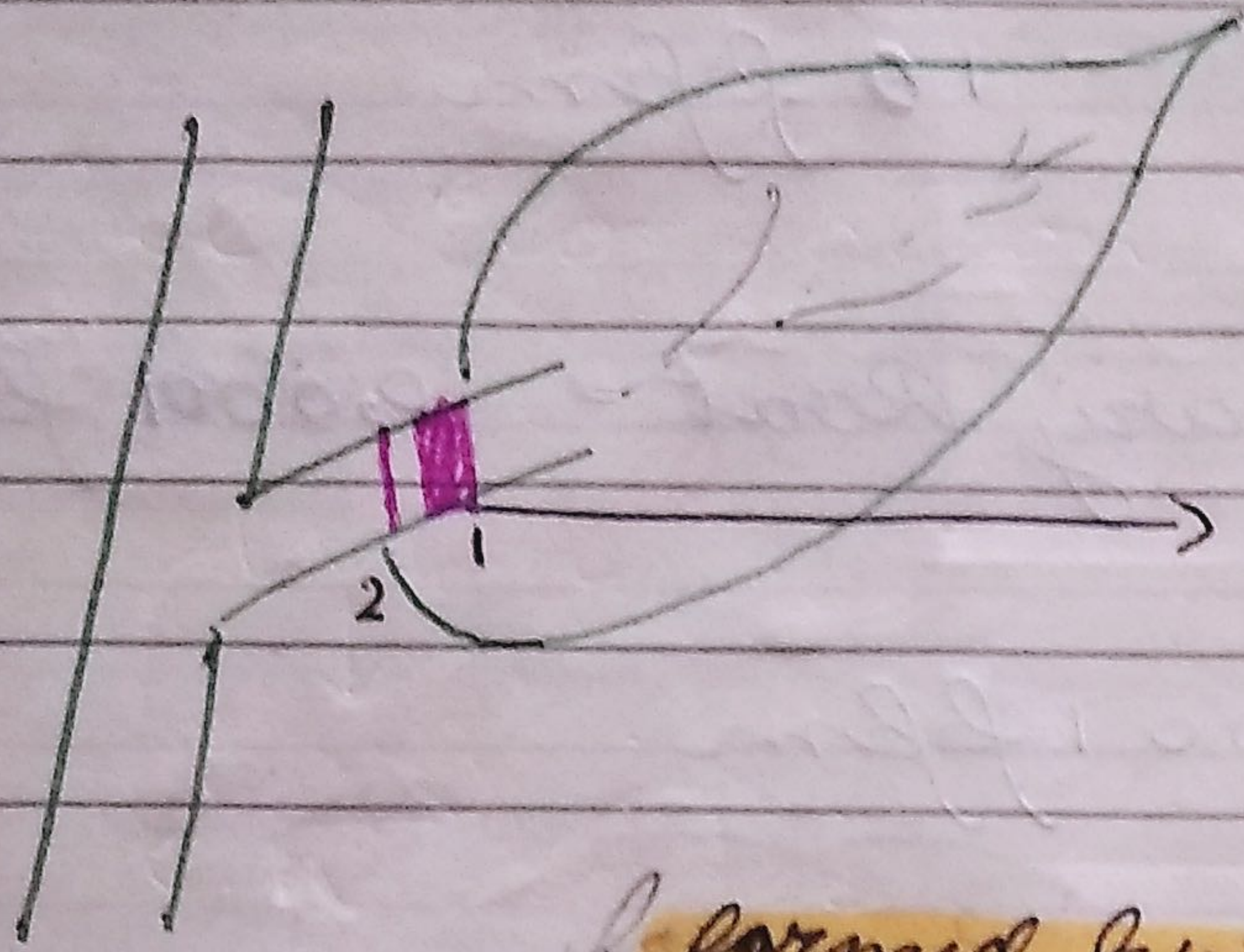
(ii) Geotropism



⇒ 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



formed by ethylene.

Abscission zone consists of two layers

1: Separation layer

Cellulases, Pectinases

C.W breakdown

• Auxin gradient

Theory

given by

• Addicot & Lynch

2: Protective layer
suberin + nt

Stem

Leaf

Abscission

A

A

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A

A

Start of abscission zone

A

A

abscission occurs.

5 Herbicides

2,4-D

2,4,5T

Absorption ✓

Absorption ✗

• Dicot

Monocots (Insensitive)

• Broad leaf plants

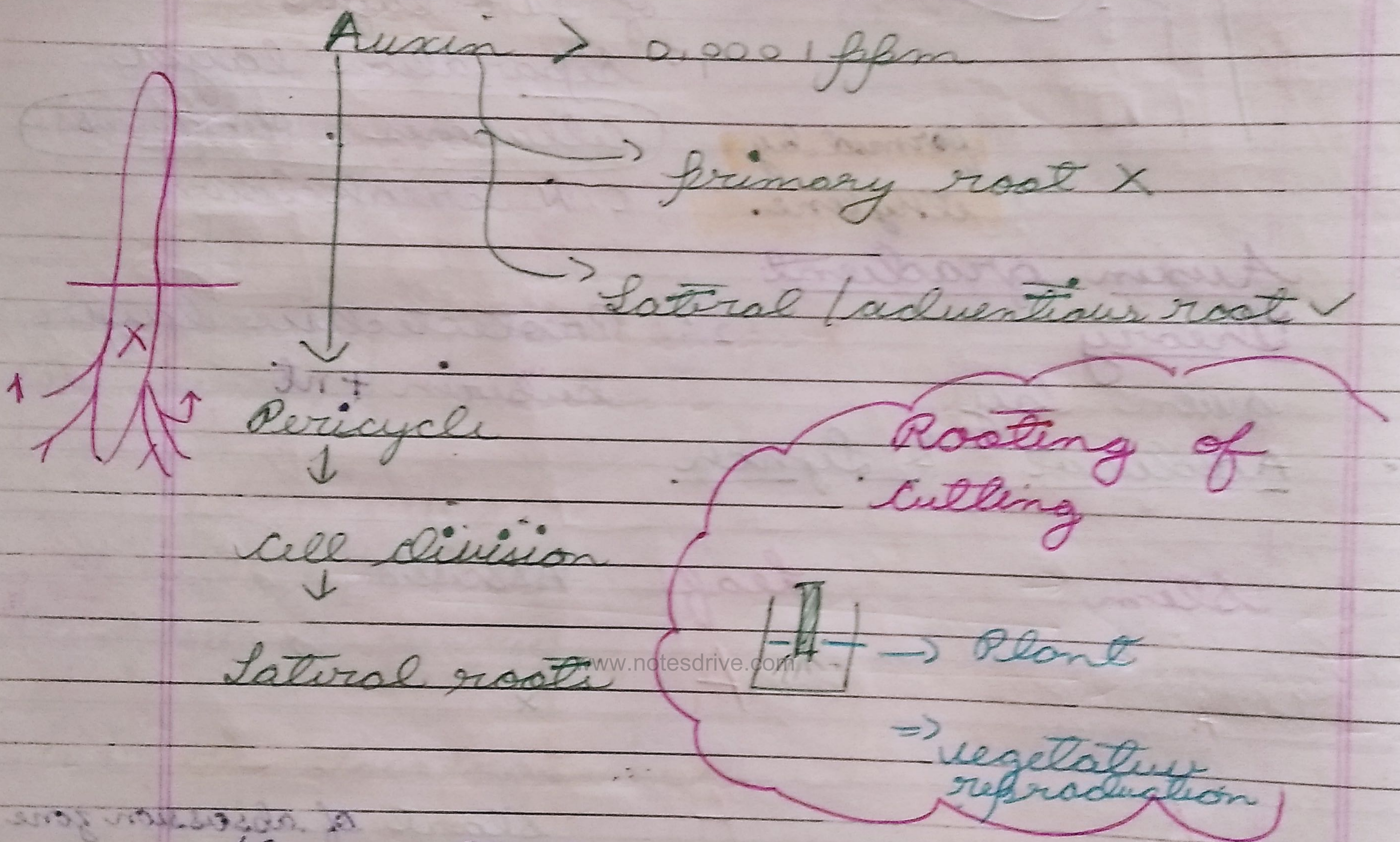
Kill

6

Lateral root form

shoot growth - 10 fpm

Main Root / Primary Root = 0.0001 fpm



Also called

"RSN → Root Setting Hormone"
ROOTONE

7

Parthenocarpy → Tomato

8

Root nodule → Legumes

* Plants

- Auxin

* Bacteria

Cytokinin

In apples fruits are formed on dwarf shoot.

Auxin strengthens the stem of grasses.

~~auxin~~ acid is type of auxin.

9 Dwarf shoots in **Apple**: 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.

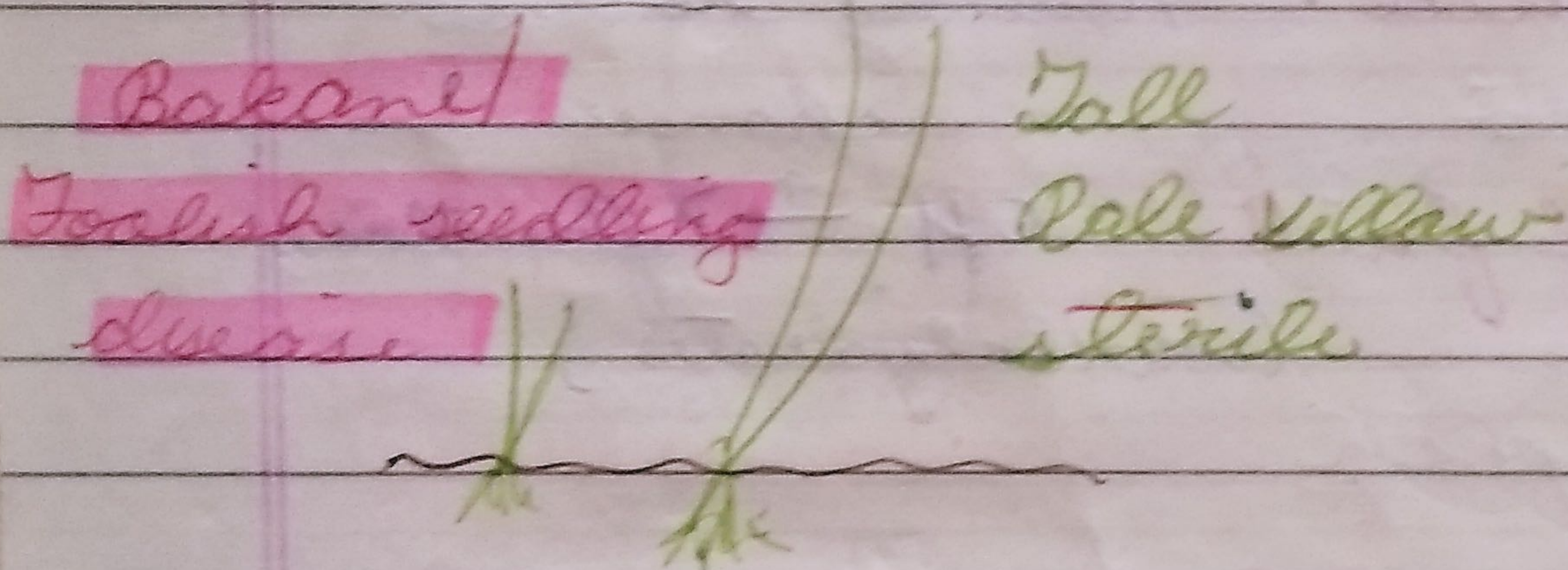
Gibberellins

↑

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

History:

(i) Kurosawa:



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

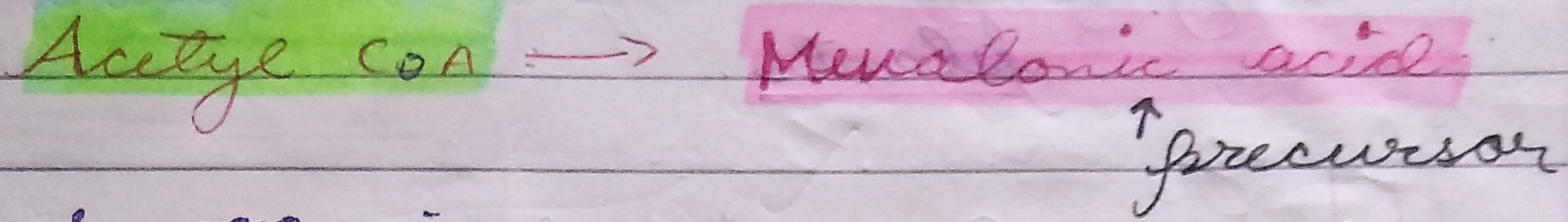
2 Yabuta & Sumiki:

- Fungal 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.

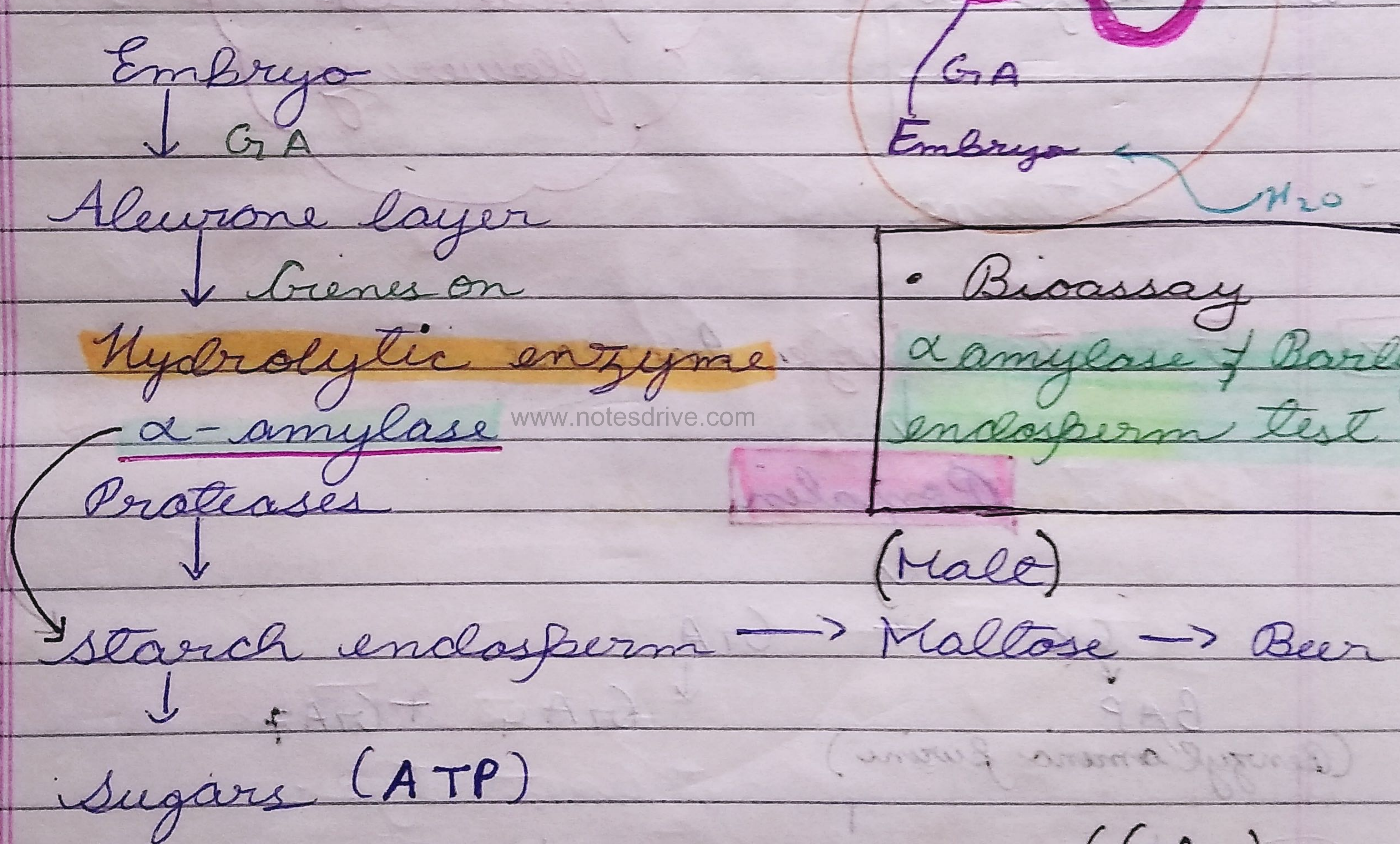
• Precursor:



• Synthesis
 • Root tip ✓
 • Developing embryo ✓

• Functions →

1. Seed germination
Barley seed



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

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 - ALDP (long day plants)

6 Male Flowers → MSH (male steroidal hormone)

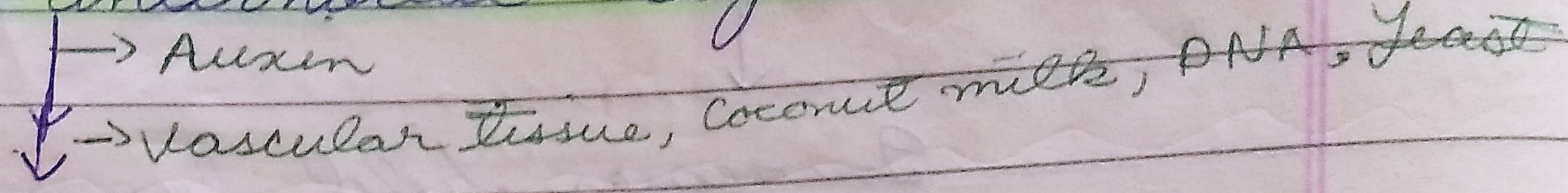
7 ★ Delay senescence

8 Conifers Juvenile → GA → Seed formation is enhanced.

Cytokinin

Skoog and Miller

Tobacco internodal segments



Auxin Callus

Herring sperm DNA

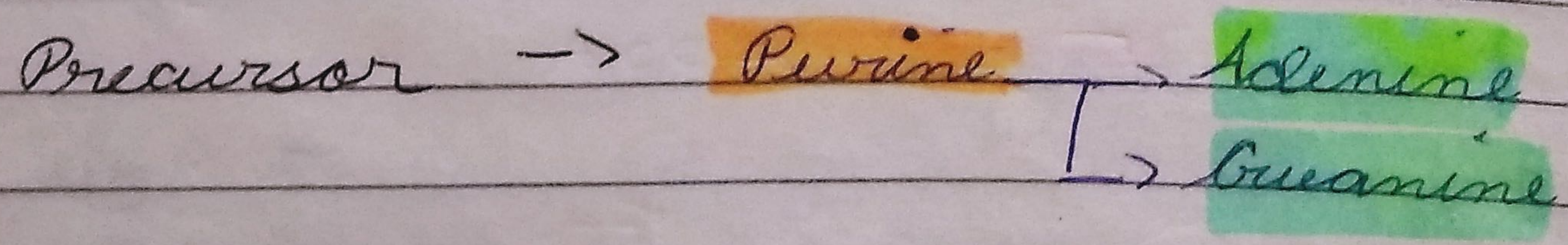
Kinetin (6-furfurylaminoⁿpurine)

Zeatin: extracted natural cytokinin

↓
Corn kernel and coconut milk

↓
Zeatin

- Synthesis →
- Fruits
 - Shoot lateral bud
 - ✓ Root tips



★ Cytokinin involved in formation of chloroplast.

Function:

1

Cell division

CK causes synthesis of

• Cyclins

• CDK



M-Phase

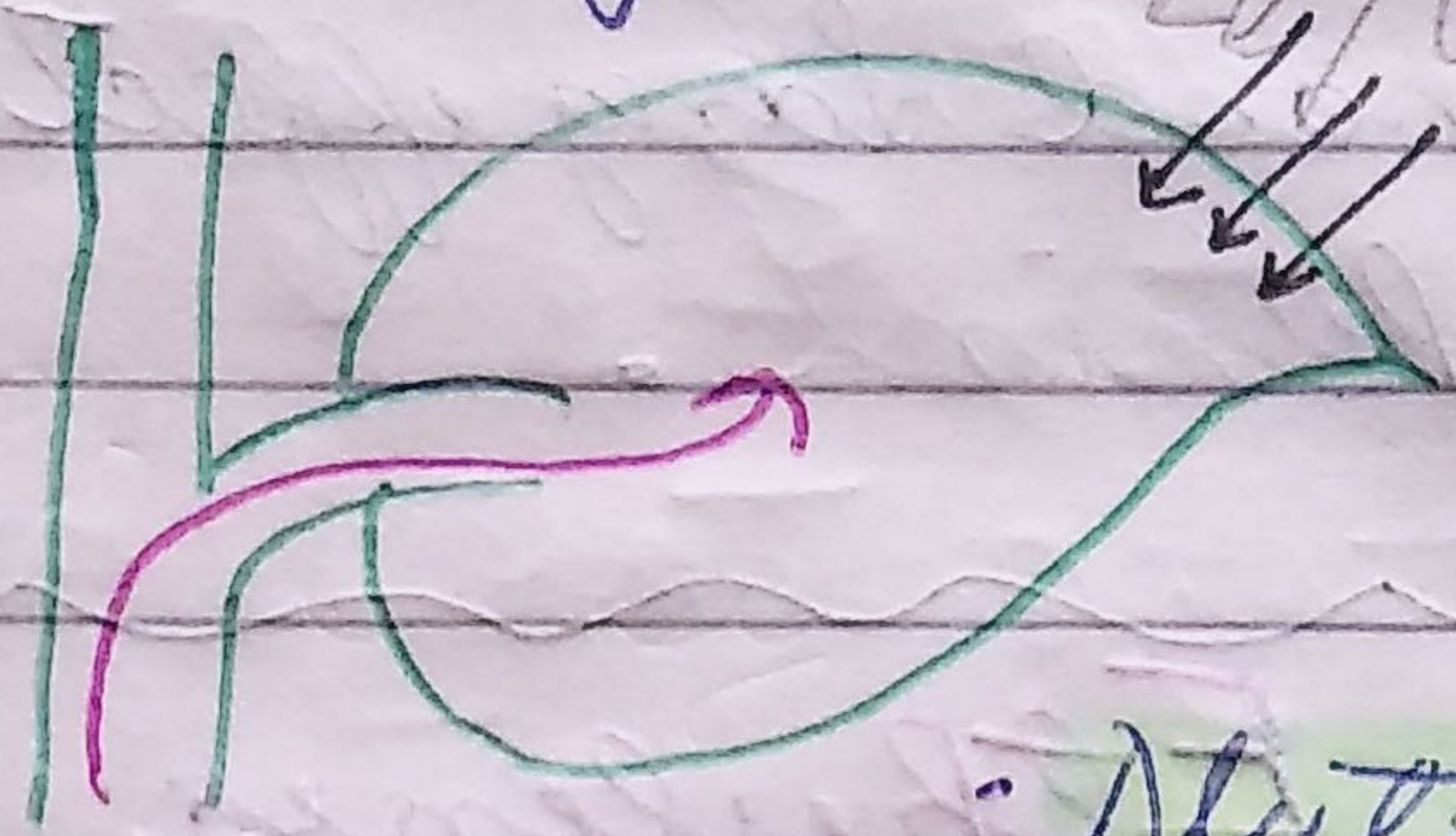


Cell division

2

Delay senescence

(Anti ageing hormone)



Nutrient mobilisation

• Sink

↑ Phloem Transport

3

Chloroplast: Chlorophyll Preservation

Formation = Test (Bioassay)

4

Overcome Apical dominance:

• shoot-lateral

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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

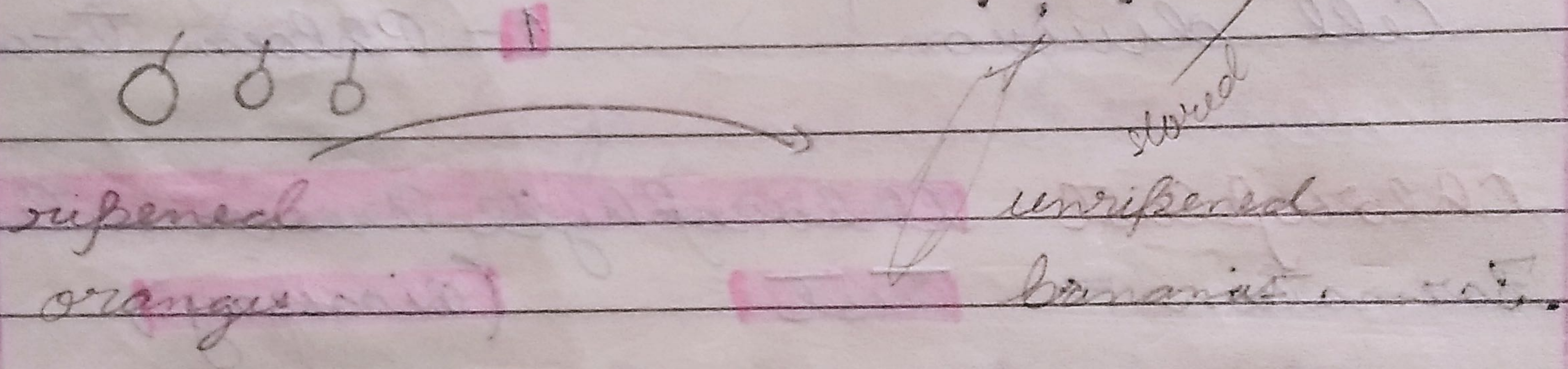
7 Flowering → Lemna (Water plant)

8 ♀ flower

Richmond Lang effect : delaying senescence by cytokinins.

Ethylene

→ Leucine



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
\checkmark	\times
Increase in Respiration	\times
• Apple, Banana, Pear, Orange, Peach, Plum	• Strawberry, cherry, Pineapple
	flowering

Ethephon

Ethylene

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

-> hasten fruit ripening in tomatoes, apples.

Thinning of walnut, cherry, cotton (NCERT)

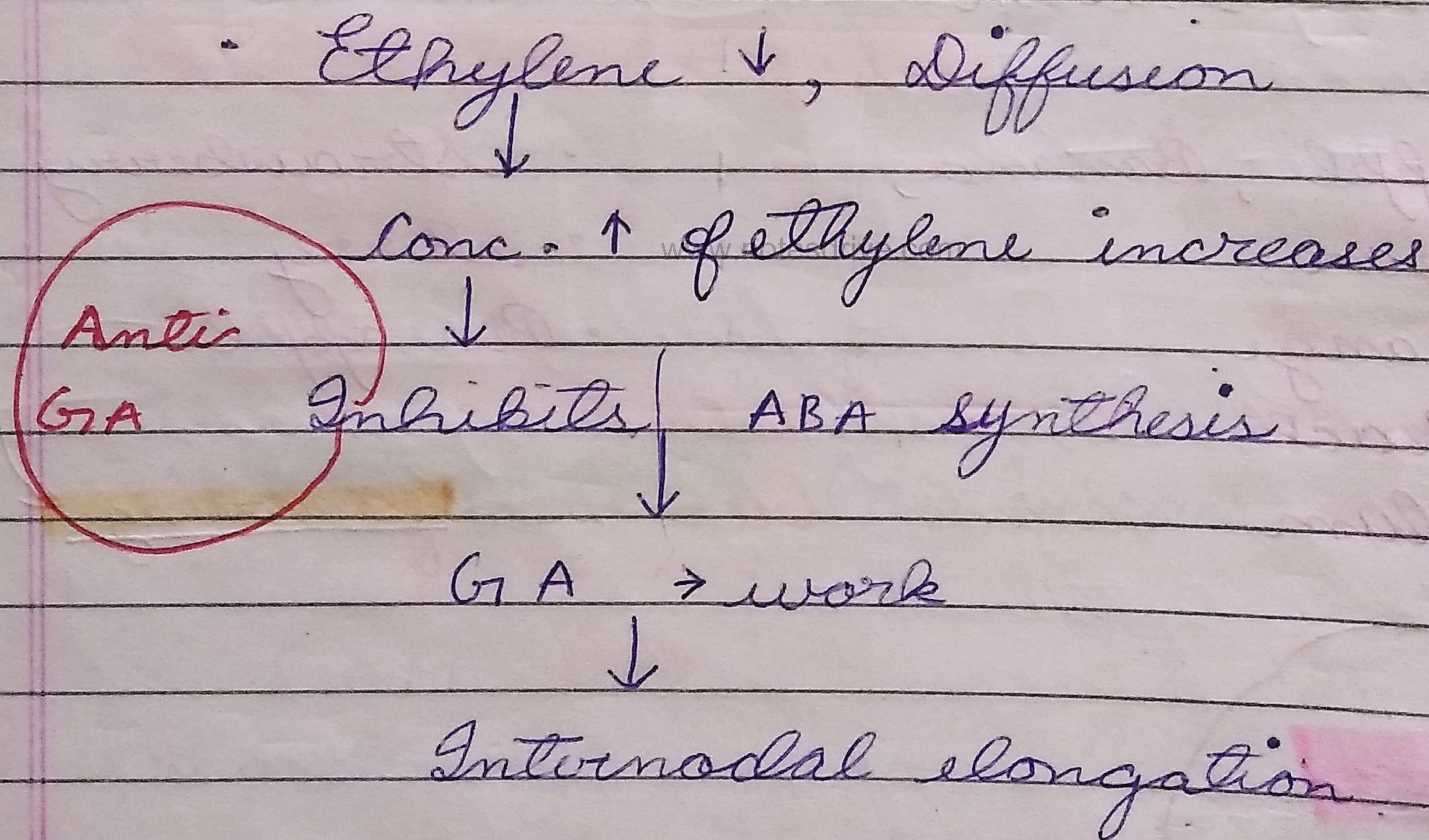
★ Abscicic acid is antagonistic to G.A.

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 → Lucifer

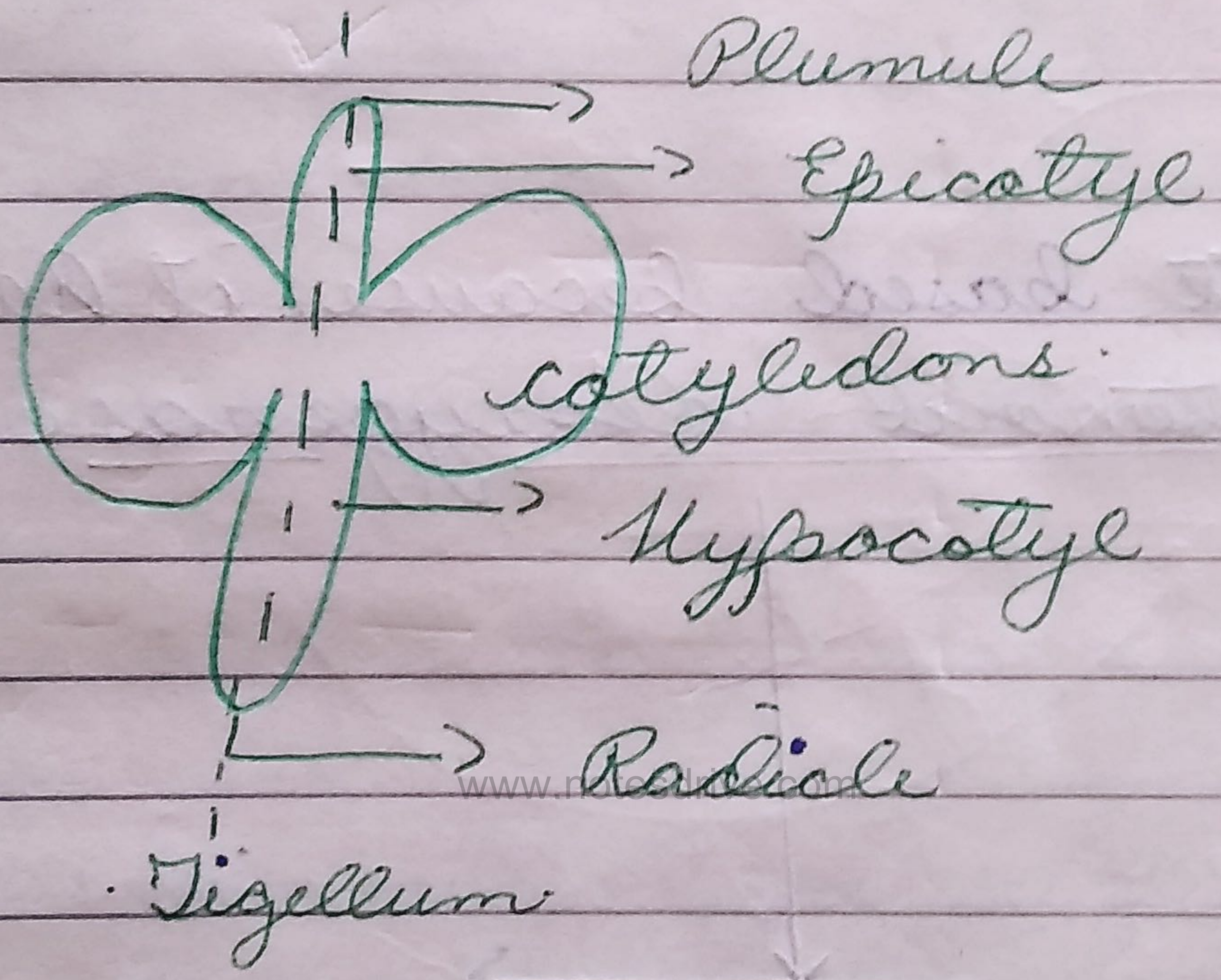
6 Breaks seed & bud dormancy

7 Seed germination in pea-nut.

8 Apical hook - Dicot seedling
Plumule → Protest *

★ Sprouting of potato tubers

EMBRYO



Seed Germination

Hypogeal

★ Epicotyle forms first
Cotyledons → Inside soil

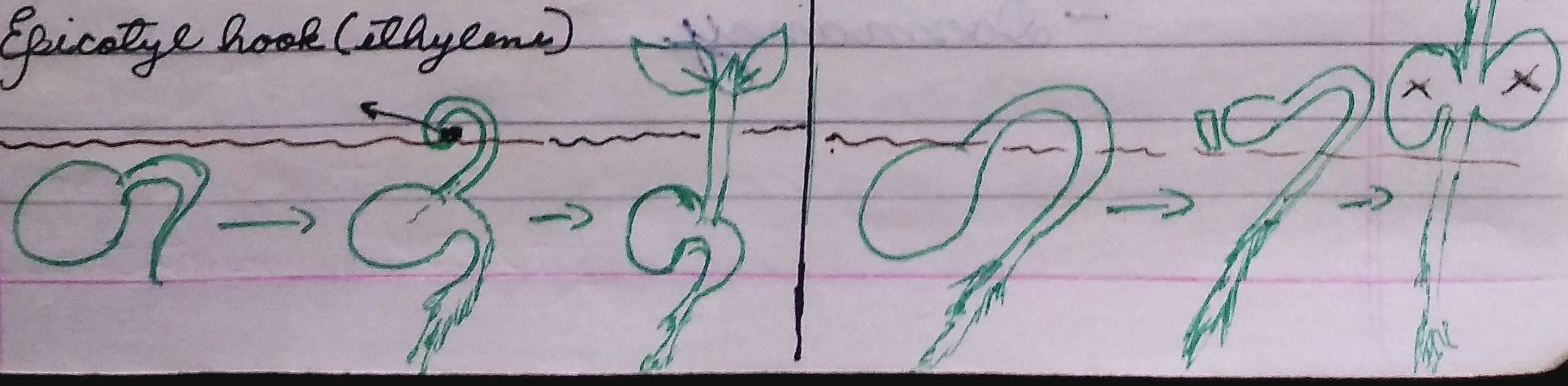
Epigeal

Hypocotyle develop first
Come out of soil

Mango, Fabaceae family

Castor, onion,
Mustard

Epicotyle hook (ethylene)



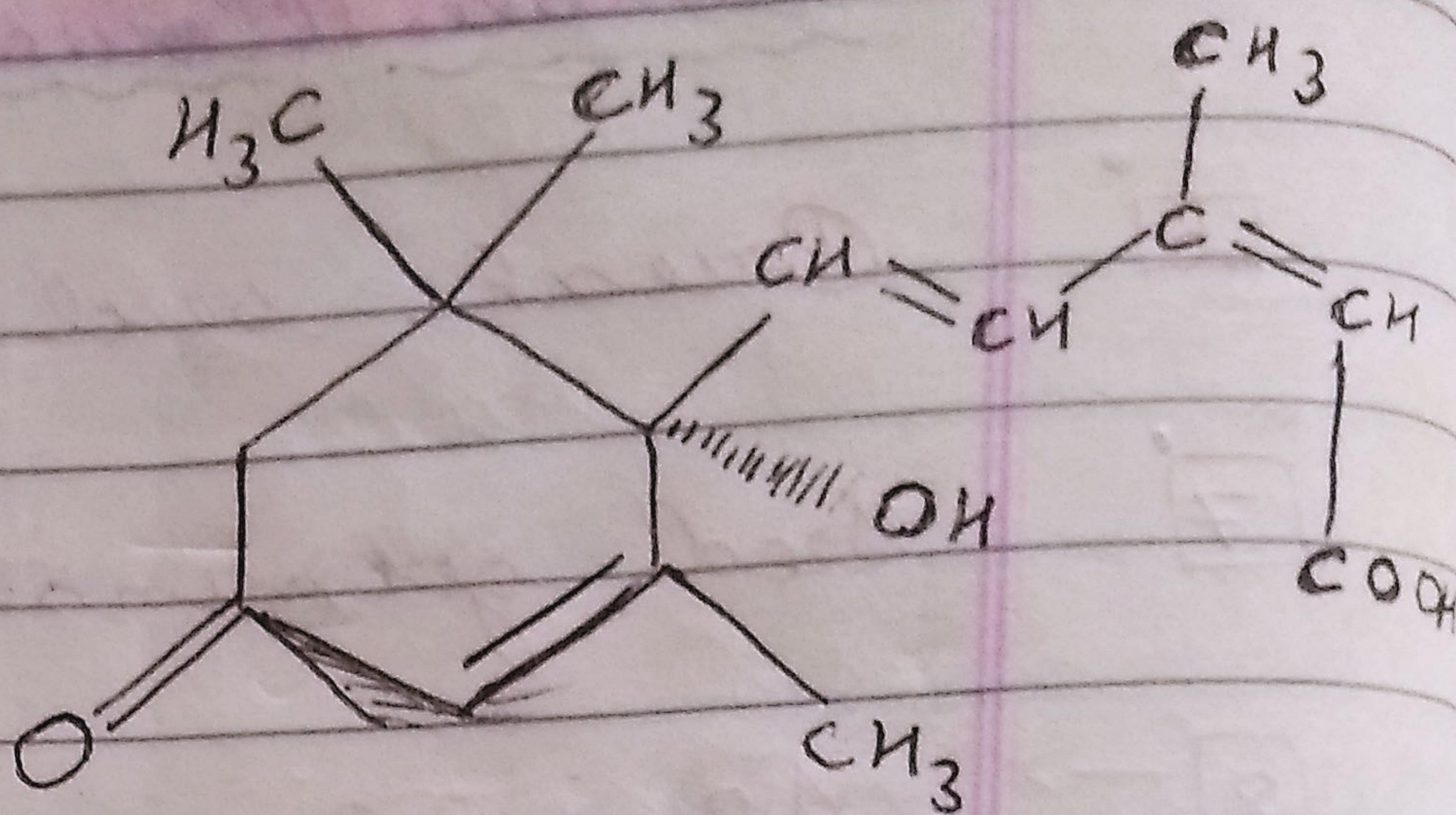
Abscisic acid.

History

Inhibitor - B ✓

Abscission - II ✓

Dormin ✓



Abscisic acid.

Formation

- Chloroplast based because it has enzyme
- Epoxycarotenoid dioxygenase.

Precursor

40 carbon

Violaxanthin

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15 carbon

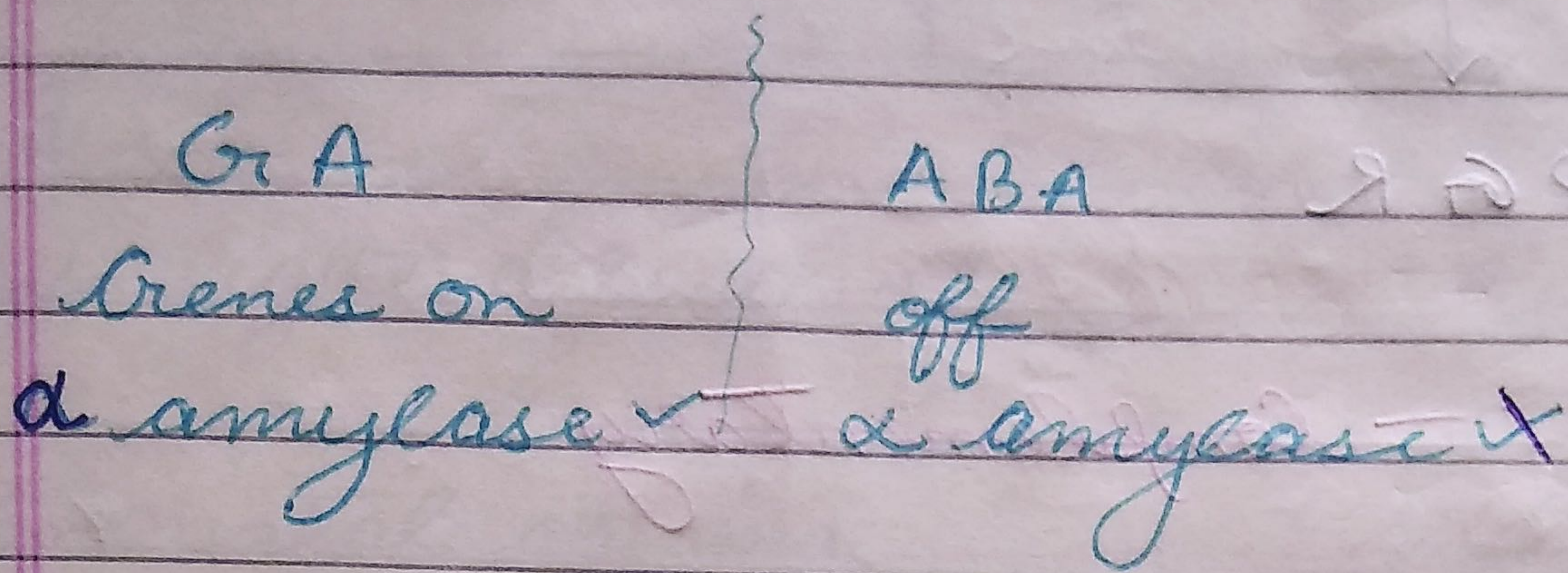
ABA

Dextrorotatory
Terpene derivative
cis-compound.

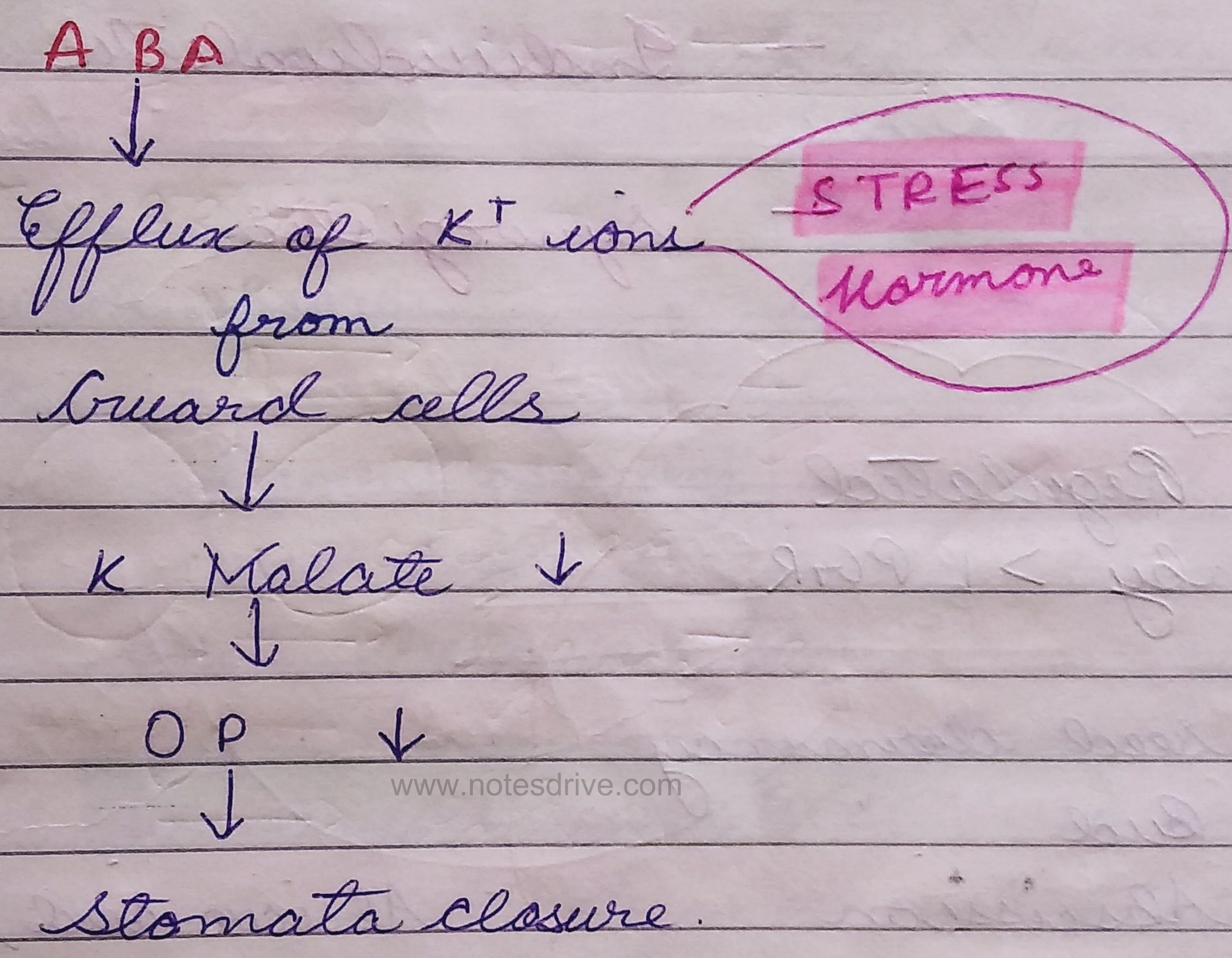
Function:

- 1. Seed - development
- maturation
- Dormancy.

Anti GA



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 " www.notesdrive.com
- Abscission → Abscisa acid, ethylene
- Senescence
- Apical dominance → 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

Bohannon and Hendrick

- Different wavelength of light → seed germination

★ Seed Red → G_v
660 nm

• seed germination depends on red light.

Seed Far Red → G_x
730 nm

• Seed germination depends on last exposure of

Seed R + FR → G_x

light to seed

Seed R + FR + R → G_v

Bullter: extracted phytochrome.

Phytochrome

Homoprotein

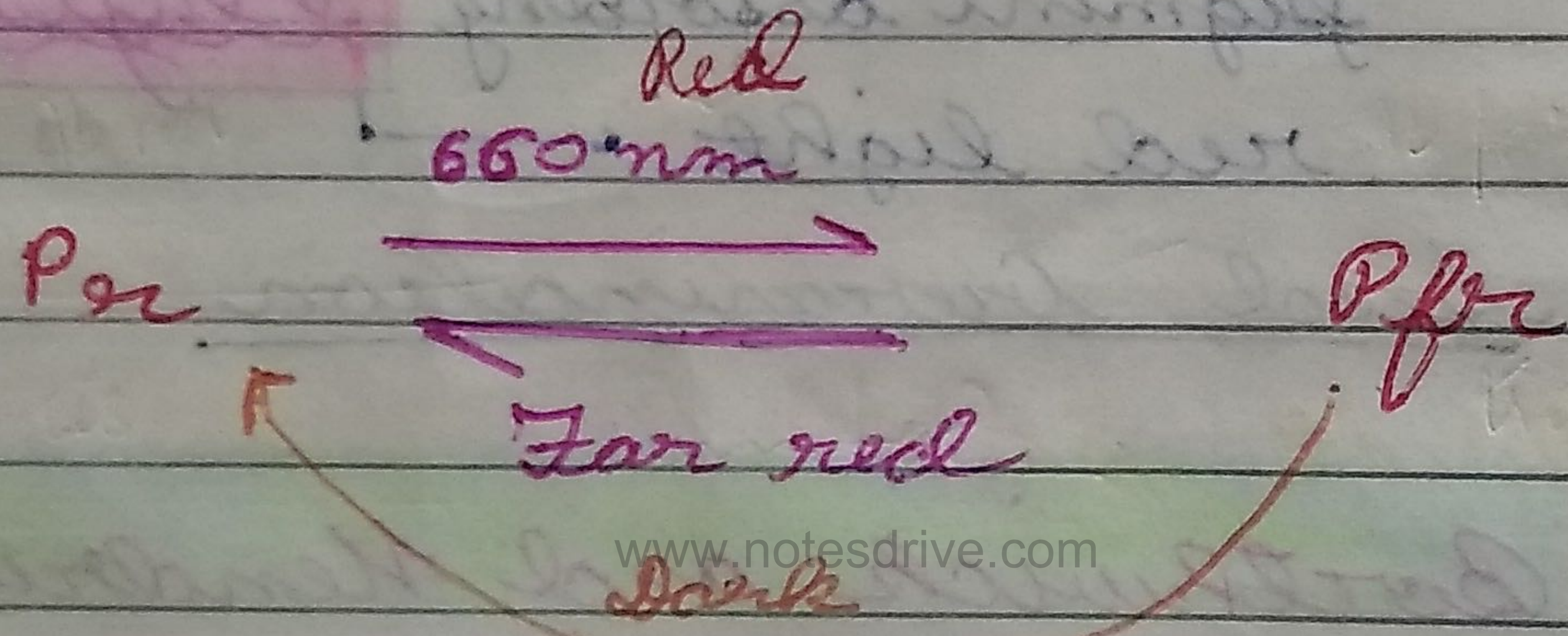
Apoprotein

Chromophore^m

- Protein ✓
- Kinase

- Protein X
- Light absorbⁿ

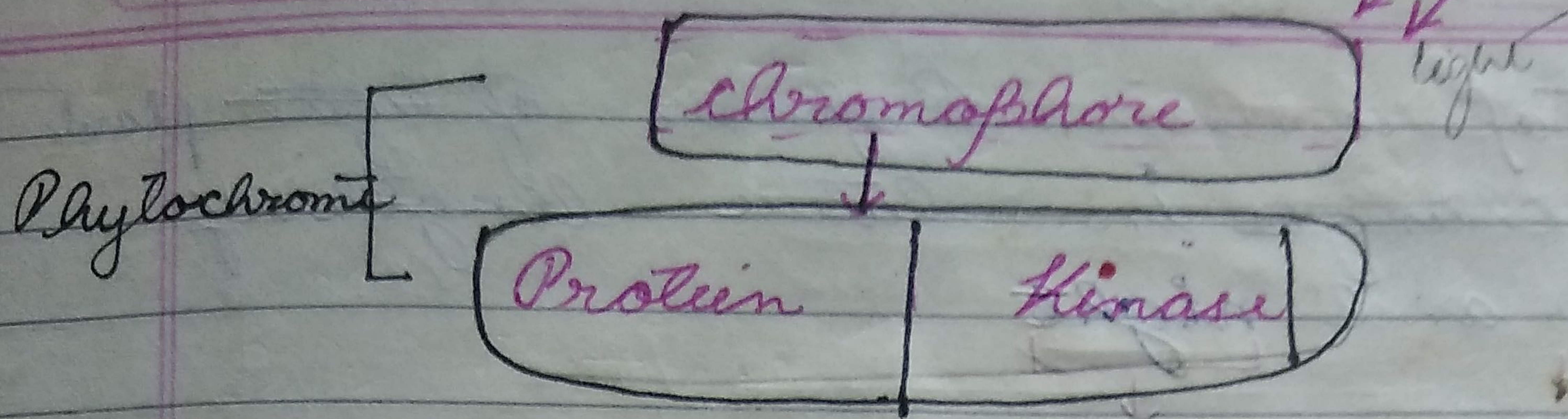
Two forms of phytochrome.



- | | |
|--------------------|-------------------------|
| • Absorb red: slow | • Absorb far red |
| • cis form | • Trans form |
| • Blue | • Y-G (yellowish-green) |
| • Inactive | • Active |
| • Stable | • Unstable |

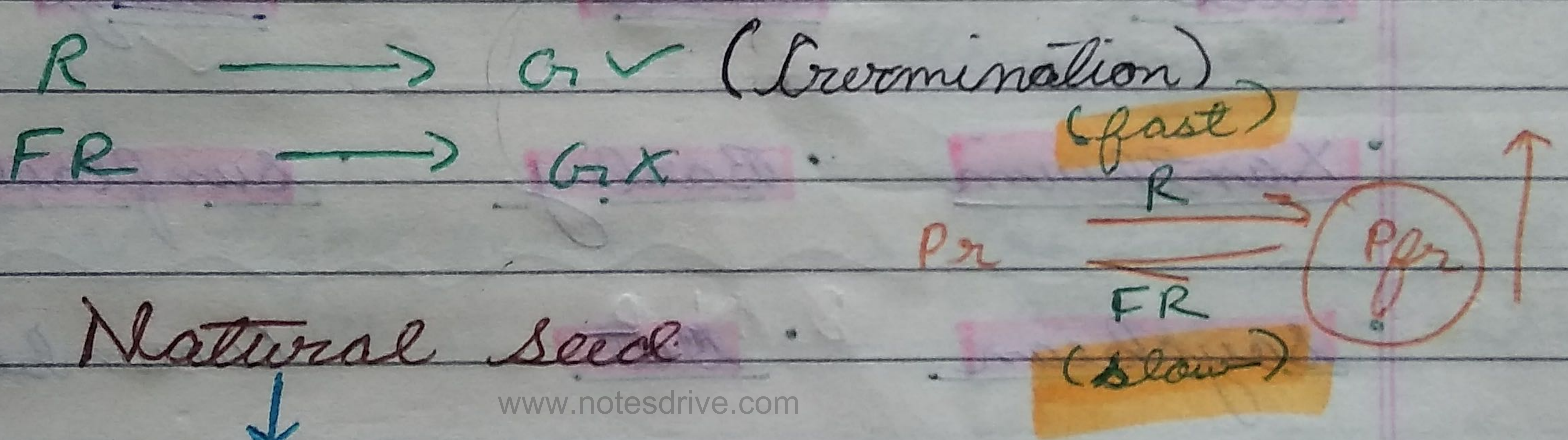
P_{fr} is responsible for seed germination.

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 → P (Gene) → G.A (Gibberellic acid) (Gene)



Natural seed
 ↓
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White light ⇒ Red light
 (R, FR)

White light has net effect is equivalent to Red light as conversion of P_{pr} to P_r is faster.

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

PAGE NO:

DATE:

SOP

LDP

• Dark period - IMP

Photoperiod: important

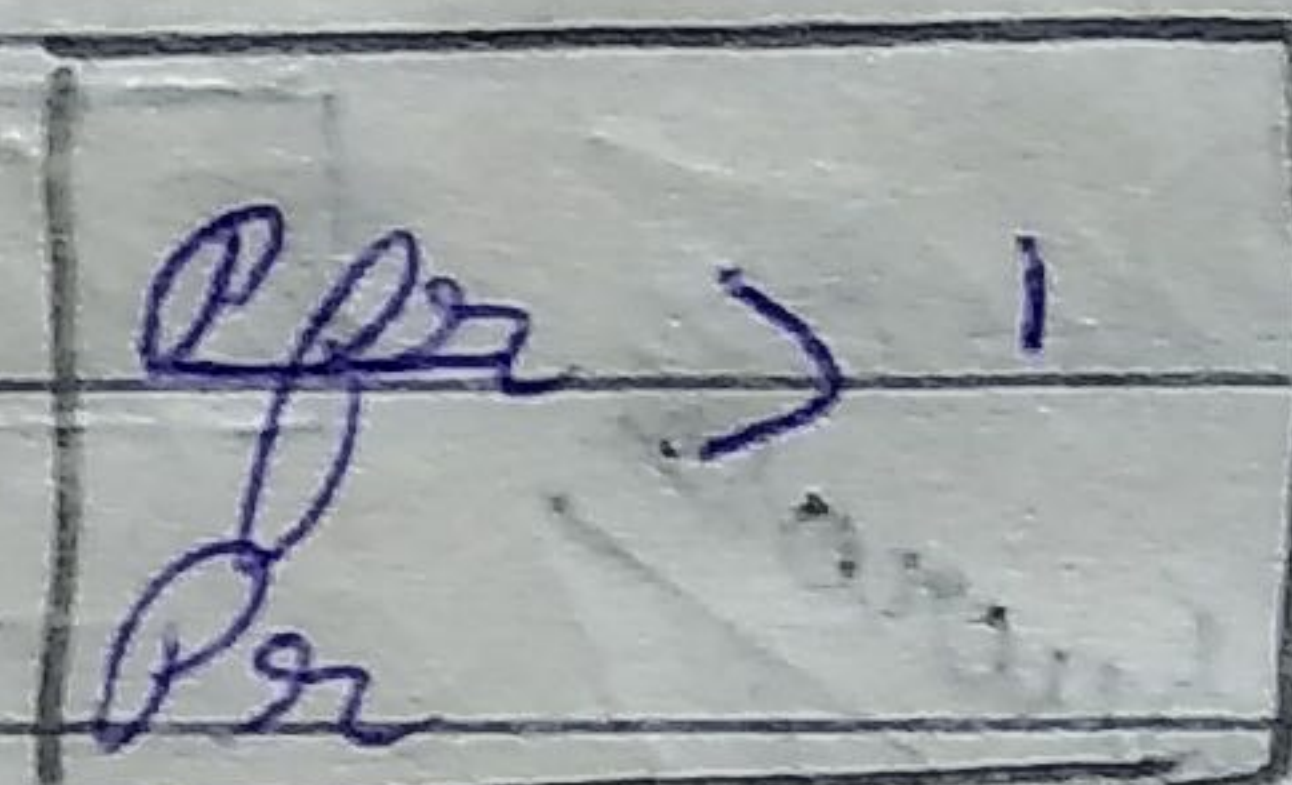
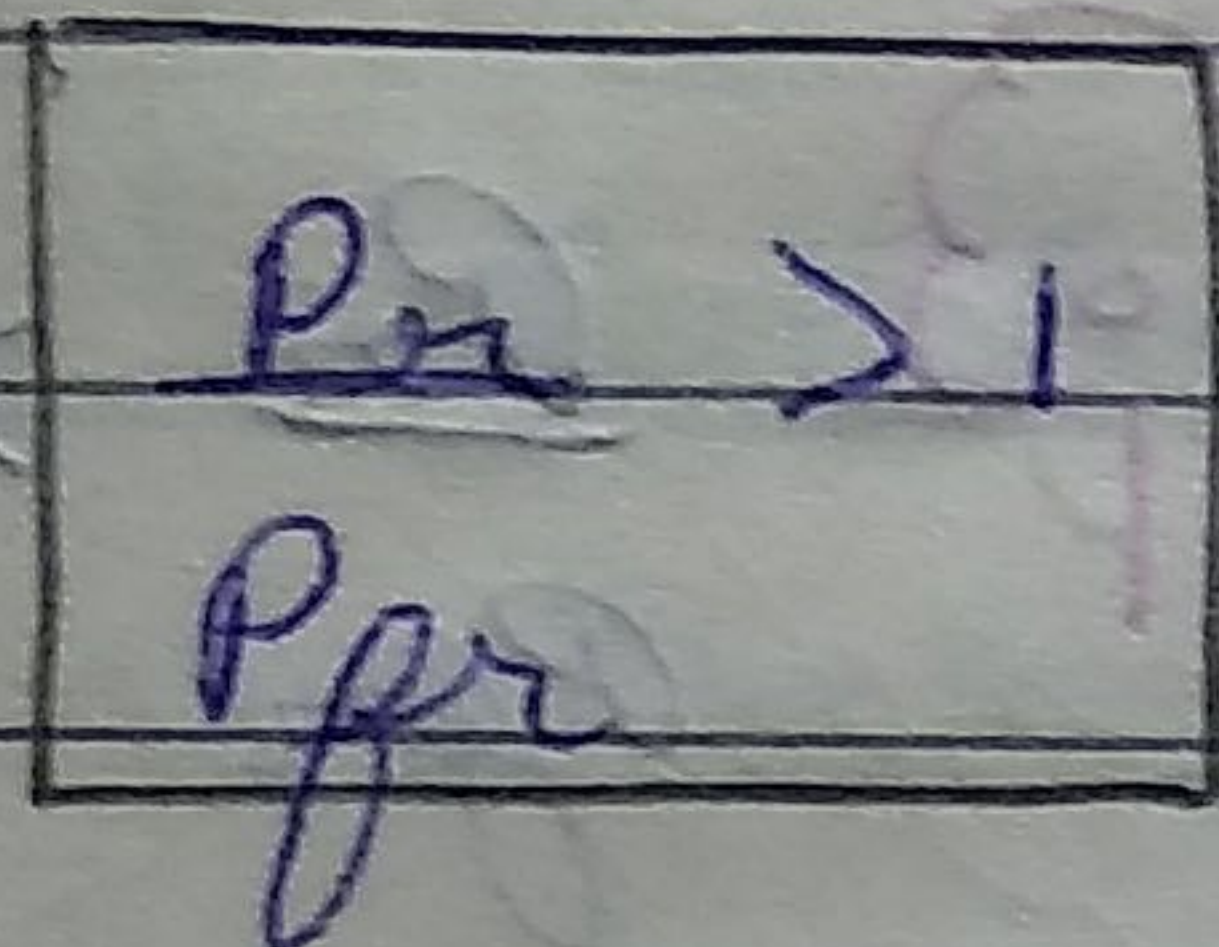
• Long night plants (LNP)

short night plants (SNP)

Flowering

• Autumn, winter, early spring

Summer, Late spring



• Eg Xanthium

Eg Kenbane

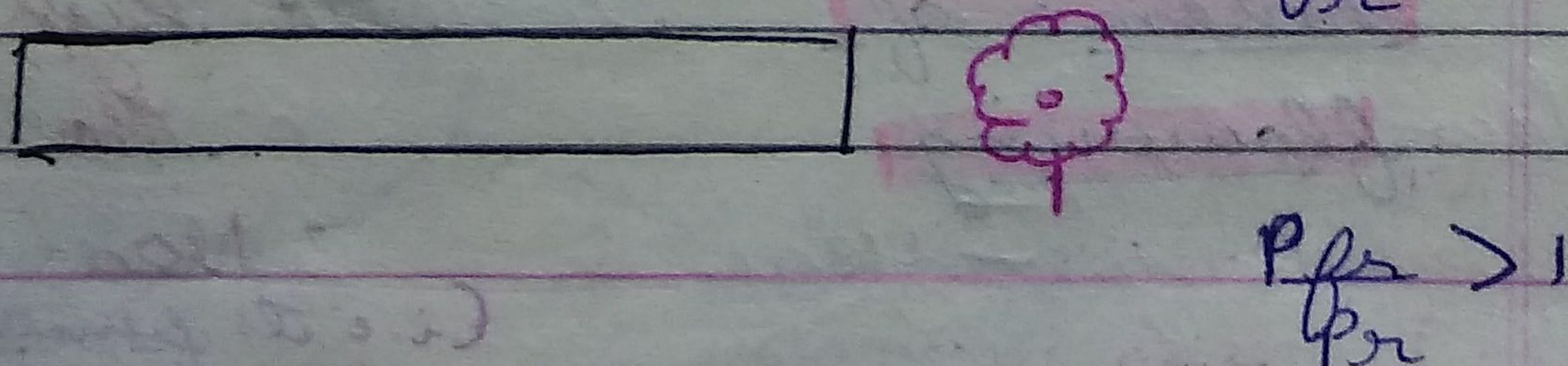
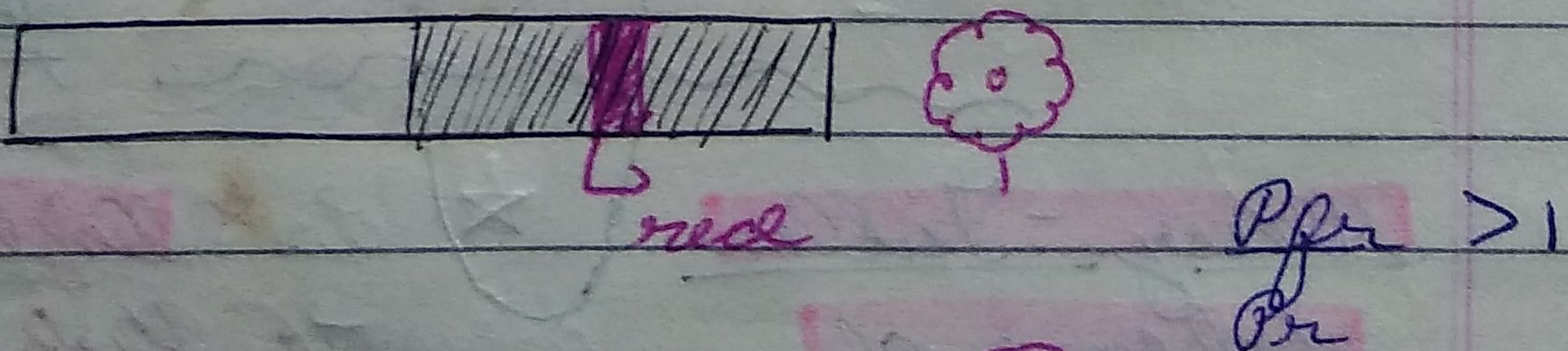
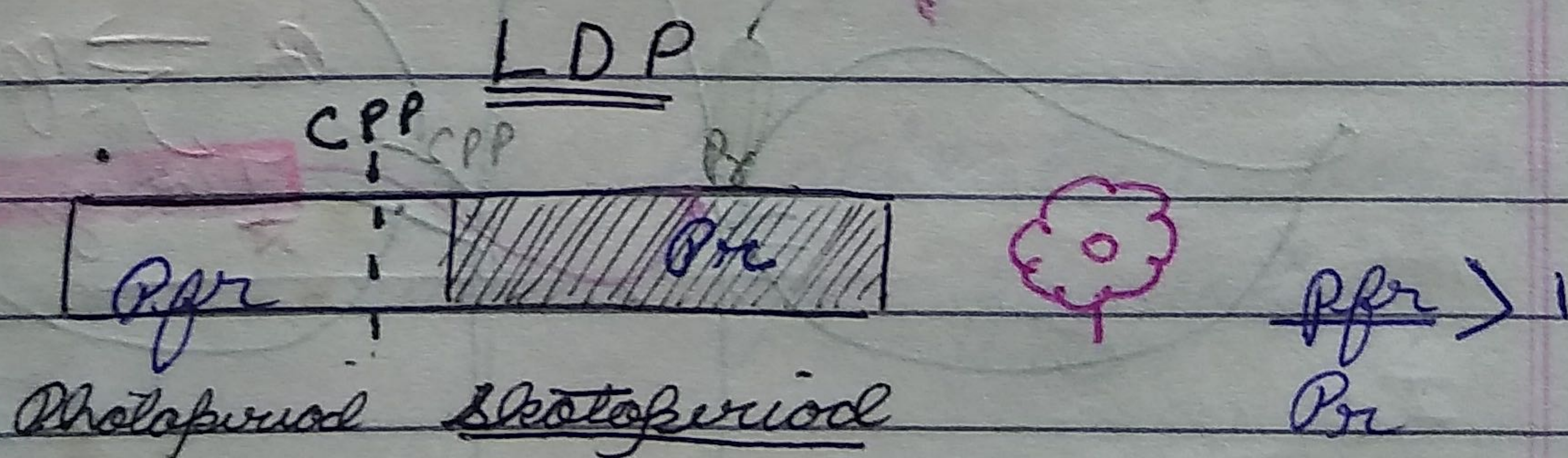
• Critical light period < 15.5 hrs

Critical light phase > 11 hrs

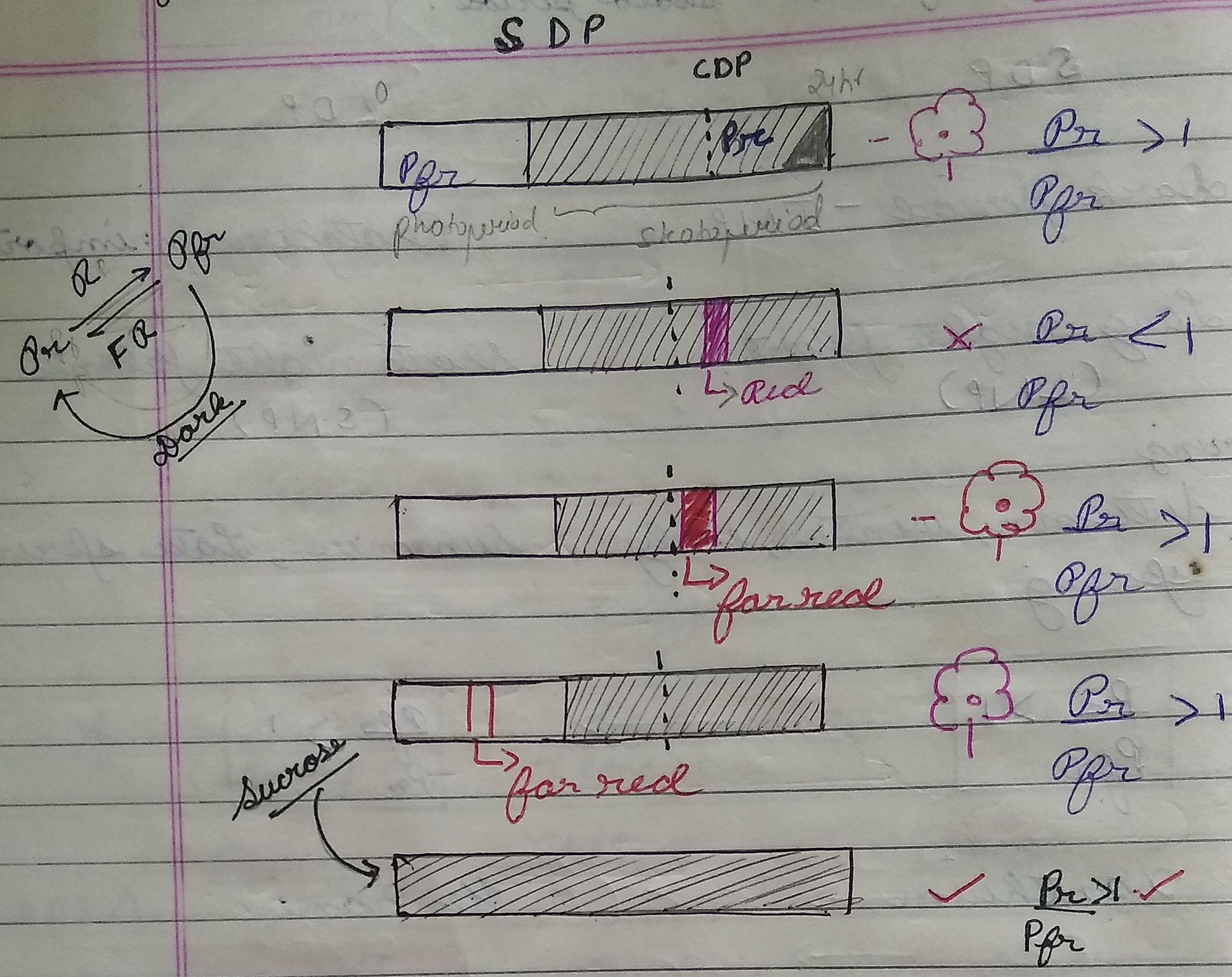
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✓ "Dark" > 8.5 hrs

"Dark" < 13 hrs

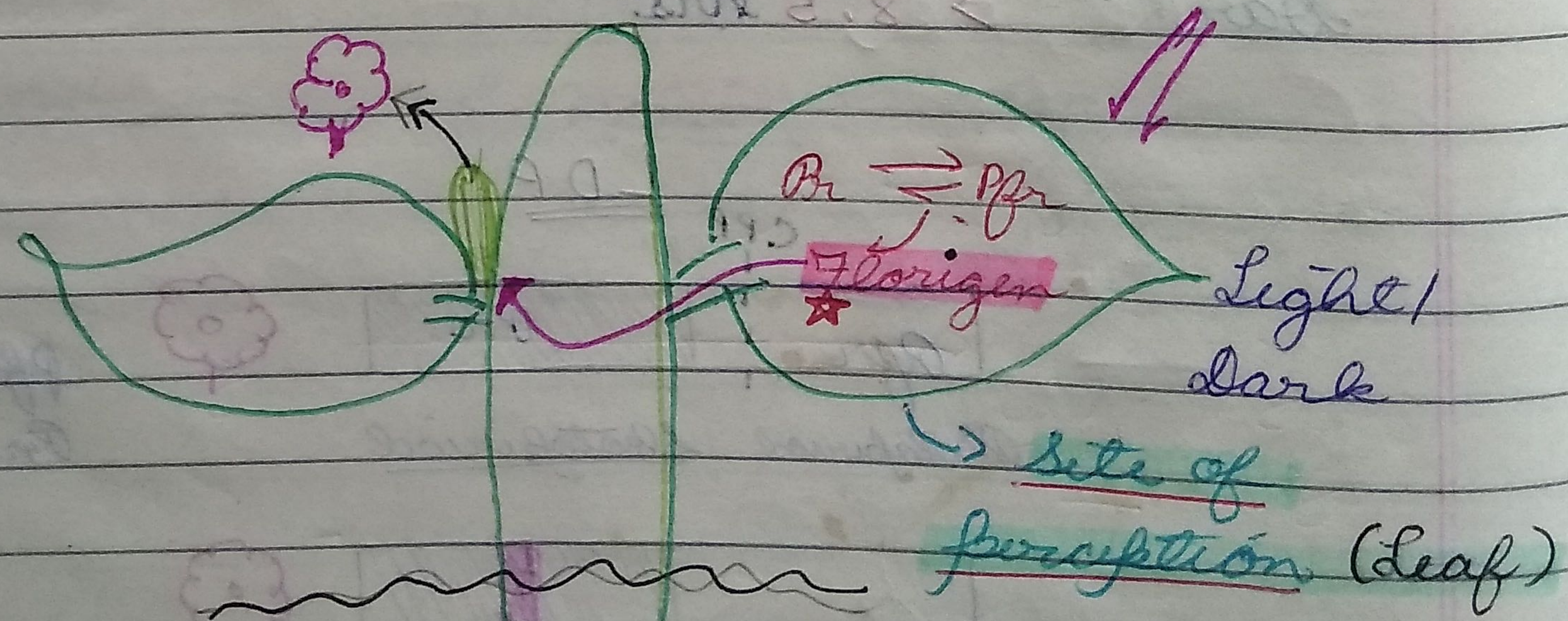


★ Florigen is a hypothetical hormone



D N P

Independent of photoperiod



Went - Fuller
Scheme of
flowering

- ★ Rajalakshmi
- 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

GA (deficient)

Anthresin (def) ^{suff.}

not correct dark period

GA (suff.)

Anthresin (def)

Vernalisation →

Lysenko

Springification

Jarvisation

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Jarvisation

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

• Annuals

• Wheat

• Barley

• Rye

winter variety

spring variety

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

Spring Variety Wheat

- W
- SP
- Su
- A

Feb → April / May
(Mature)

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

Winter Variety

Sept / Oct → Dec → April / May
(Mature)

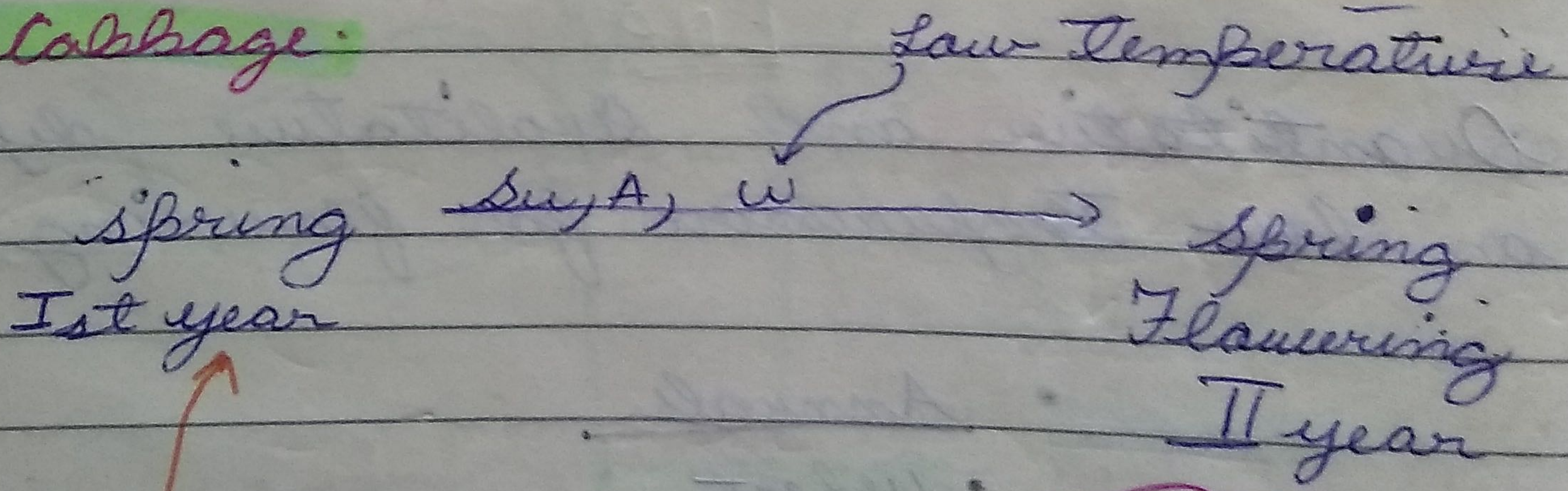
- Long duration
- High yielding
- Low temperature (required)

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

Biennials www.notesdrive.com

- 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

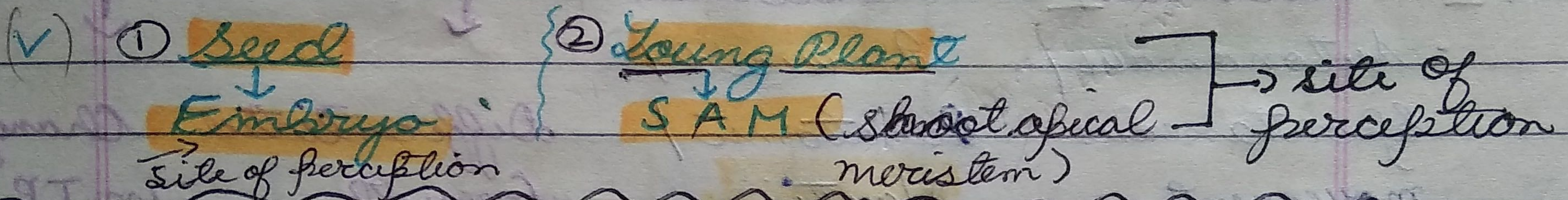
- (i) seed hydrated - 50% H₂O
- (ii) Aerobic conditions
- (iii) Proper nutrition
- (iv) Low temperature 0-5°C → few days → weeks

Melcher
(Scientist)

Hormone

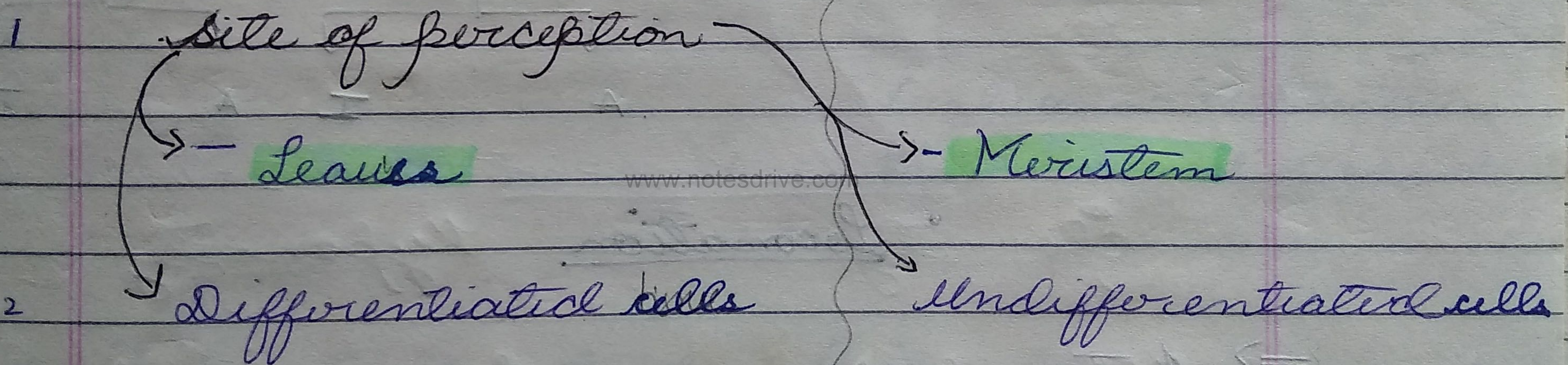
Vernalin (Hypothetical)

GA substance



Photoperiodism

Vernalisation



3 Florigen ← Hypothetical → Vernalin

4 Phytochrome chemical X

5 LDP → GA All → GA

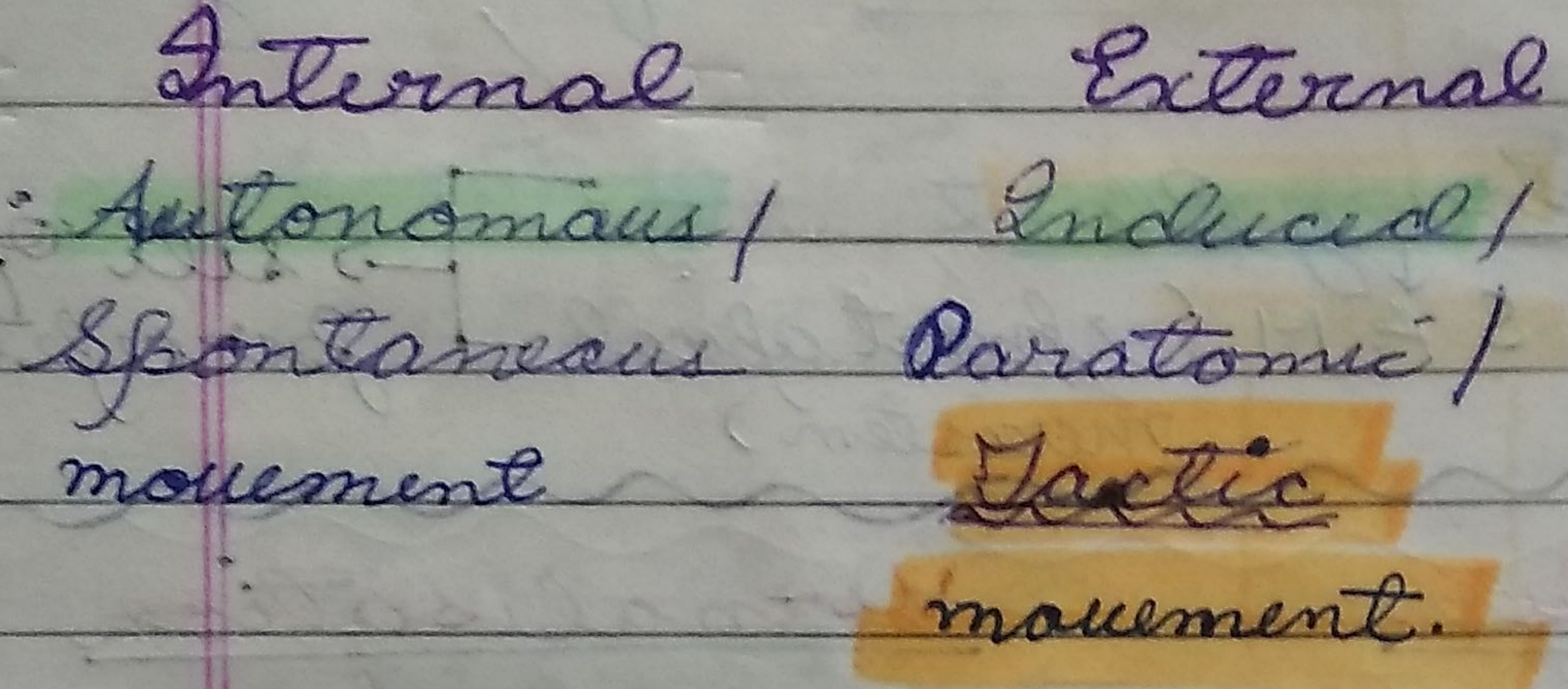
6 All plants • Temperate } plants
• Arctic

Plant Movements

Locomotion

- whole organism / cellular constituents

Factor involved



Curvature

Plant organs

Differentiated Growth Change in TP

Growth

Variation

A I A I

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A = autonomous I = induced

Locomotion

⇒ Autonomous

• Ciliary / Flagellary mov.

Amoeboid movement

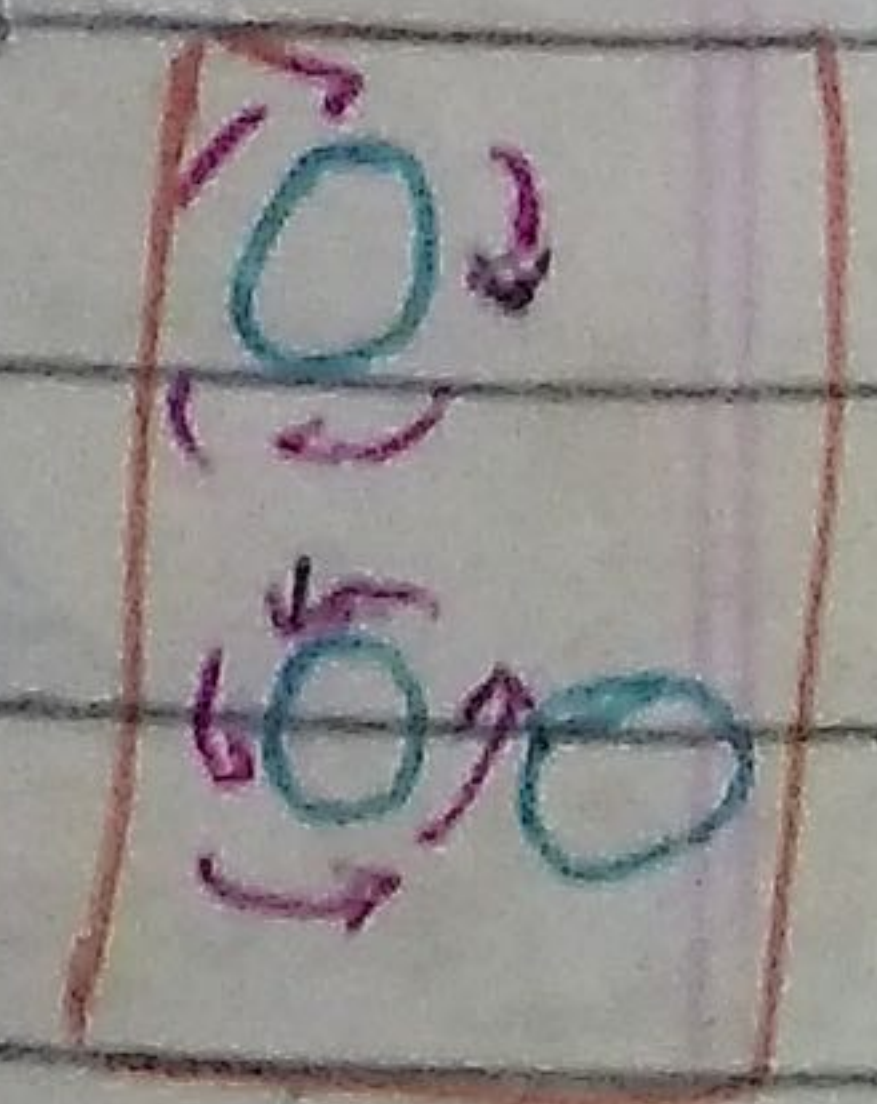
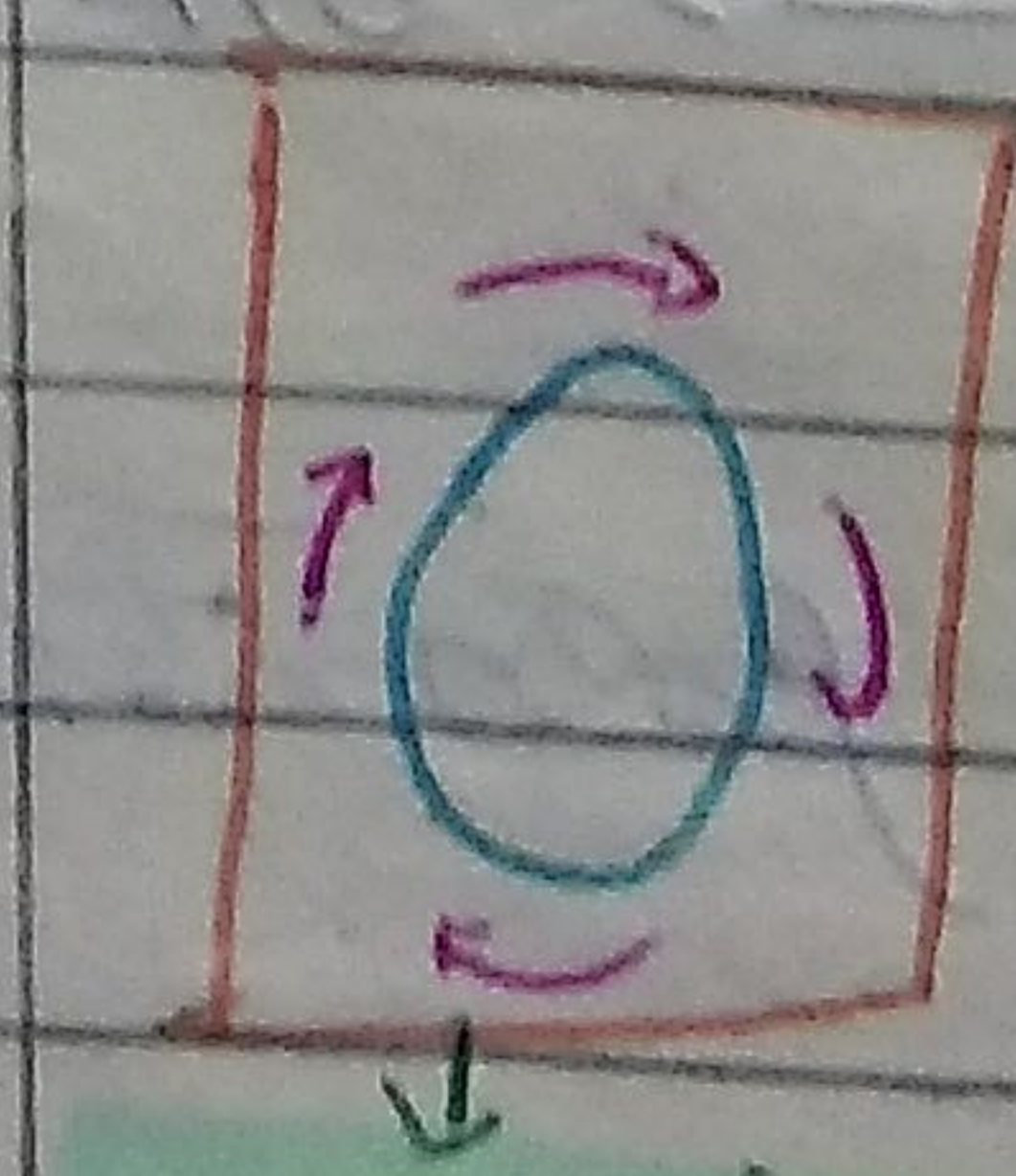
• Cytoplasmic streaming
↓
Rotation Circulation

• Chlamydomonas

- Amoeba

• Volvox

- Slime moulds
• Plasmodium



• Paramecium

Hydrilla
Nalaeonera

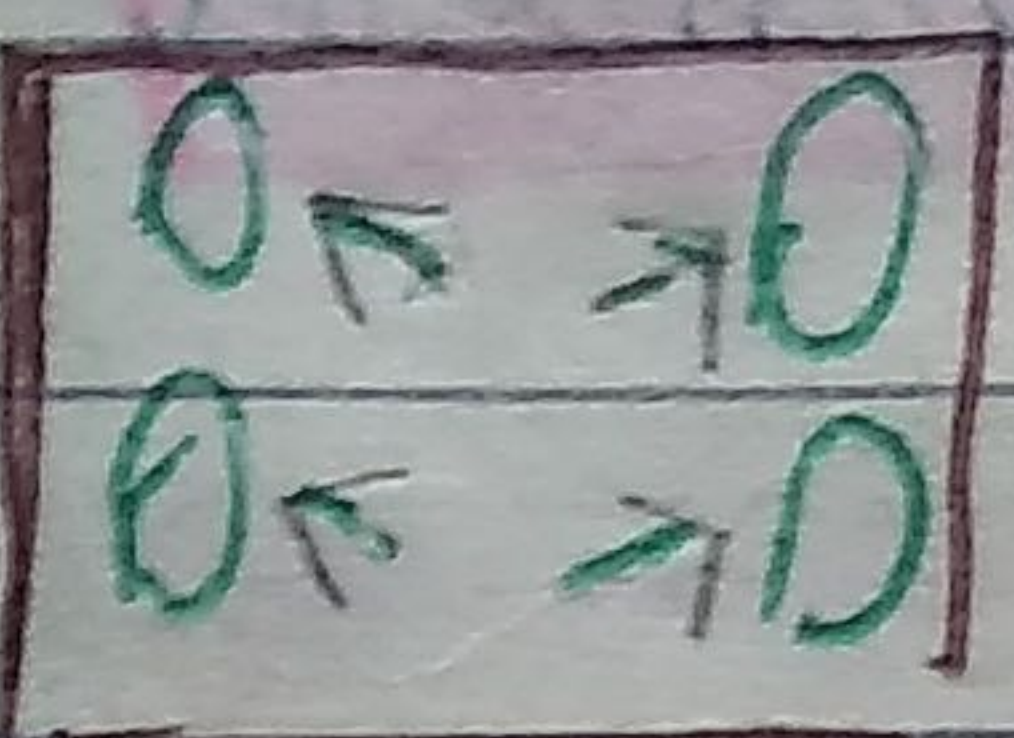
Staminal hair of
Tradescantia

⇒ Induced

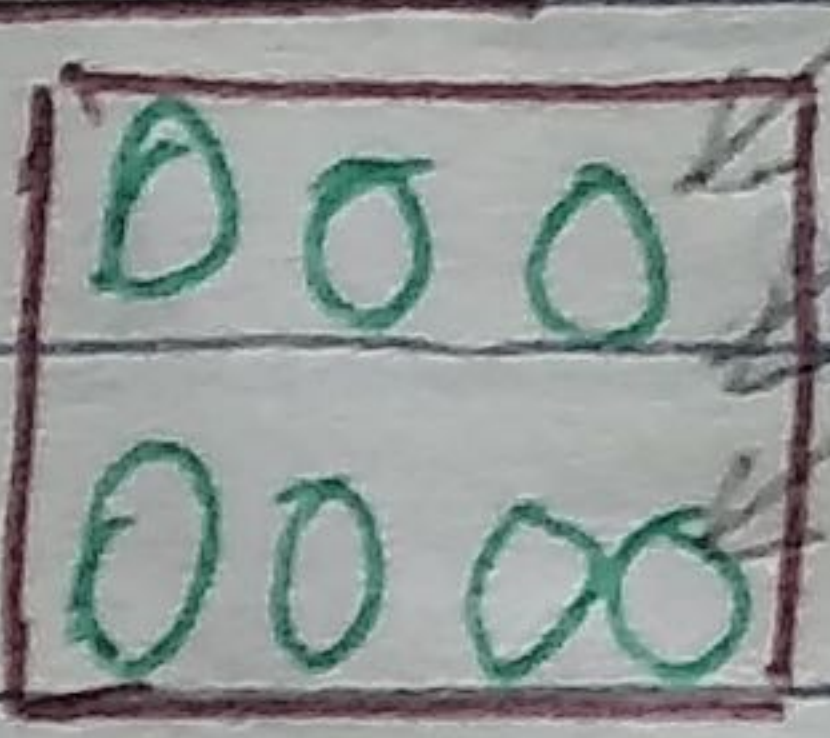
Phototactic movement

- Chlamydomonas
- Chloroplast

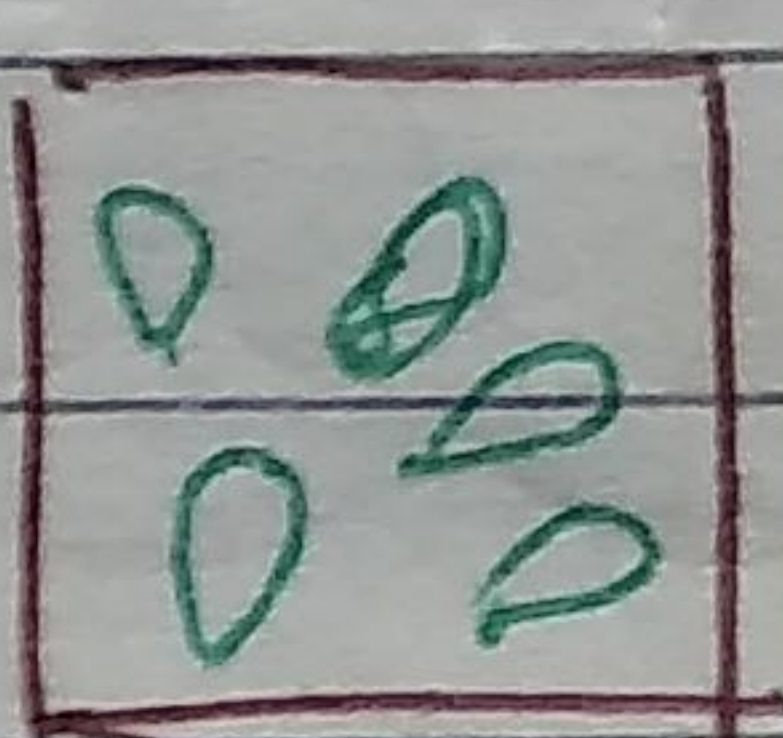
* P Parastrophic
High light intensity



E Epistrophic
Moderate light



A Anastrophic
Low light



Chemotactic

• Anthozooids of Bryophytes, Pteridophytes

• 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.

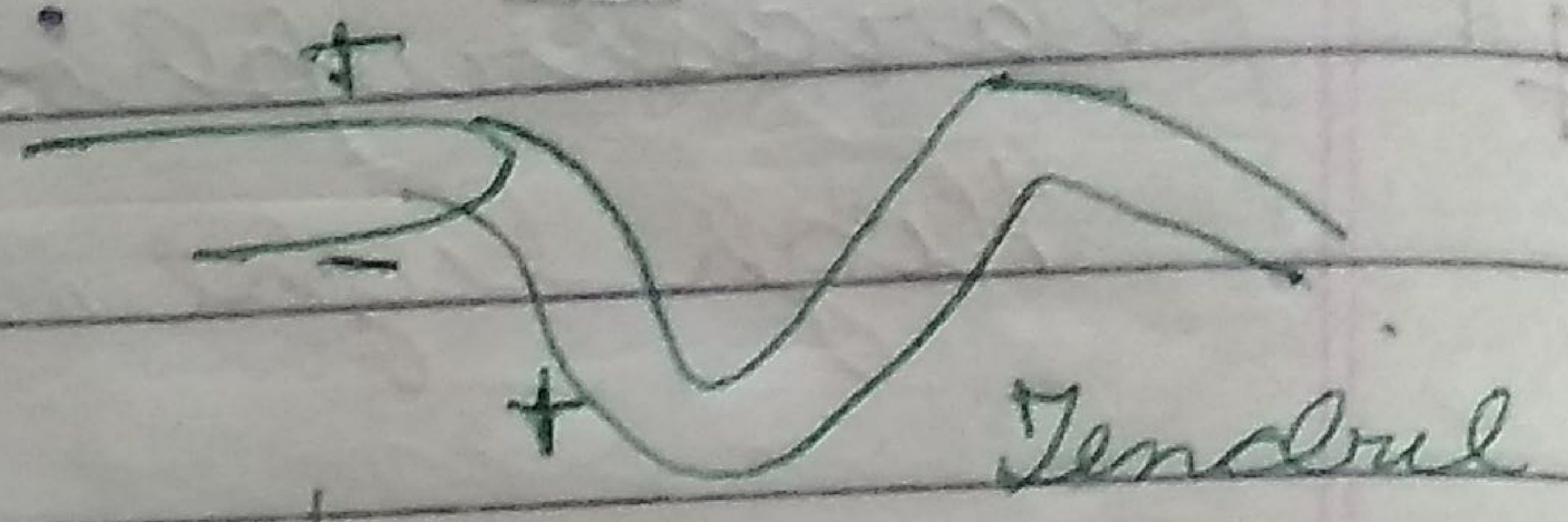
Structure Movement

- Growth
- Autonomous movement

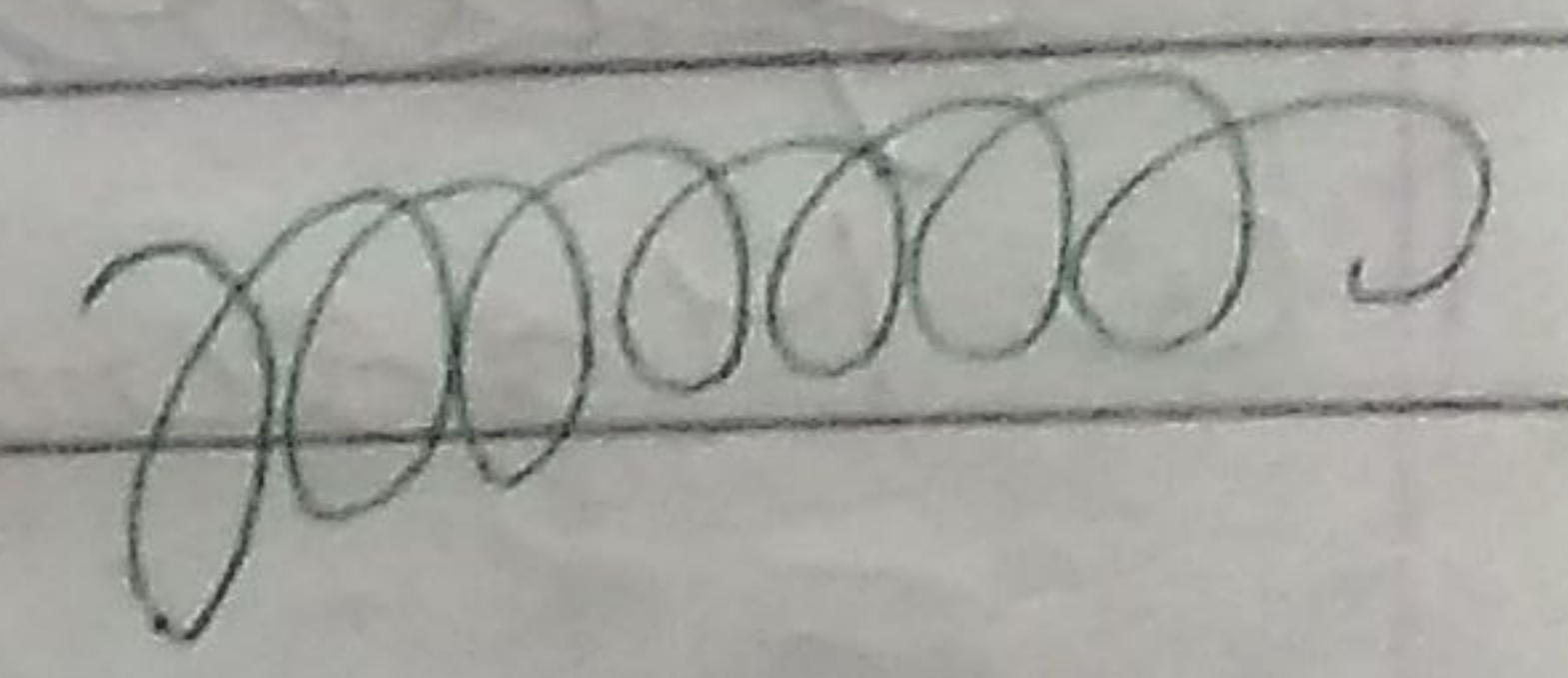
<u>Nastic</u> Fast Variation/ Growth	<u>Tropic</u> Slow Growth movements
A / I	always Induced
Non-directional	Directional movement.
Asymmetrical Leaf	Cylindrical organs stem, root

(ii) Mutation

- Runner



differential growth



circumnutation

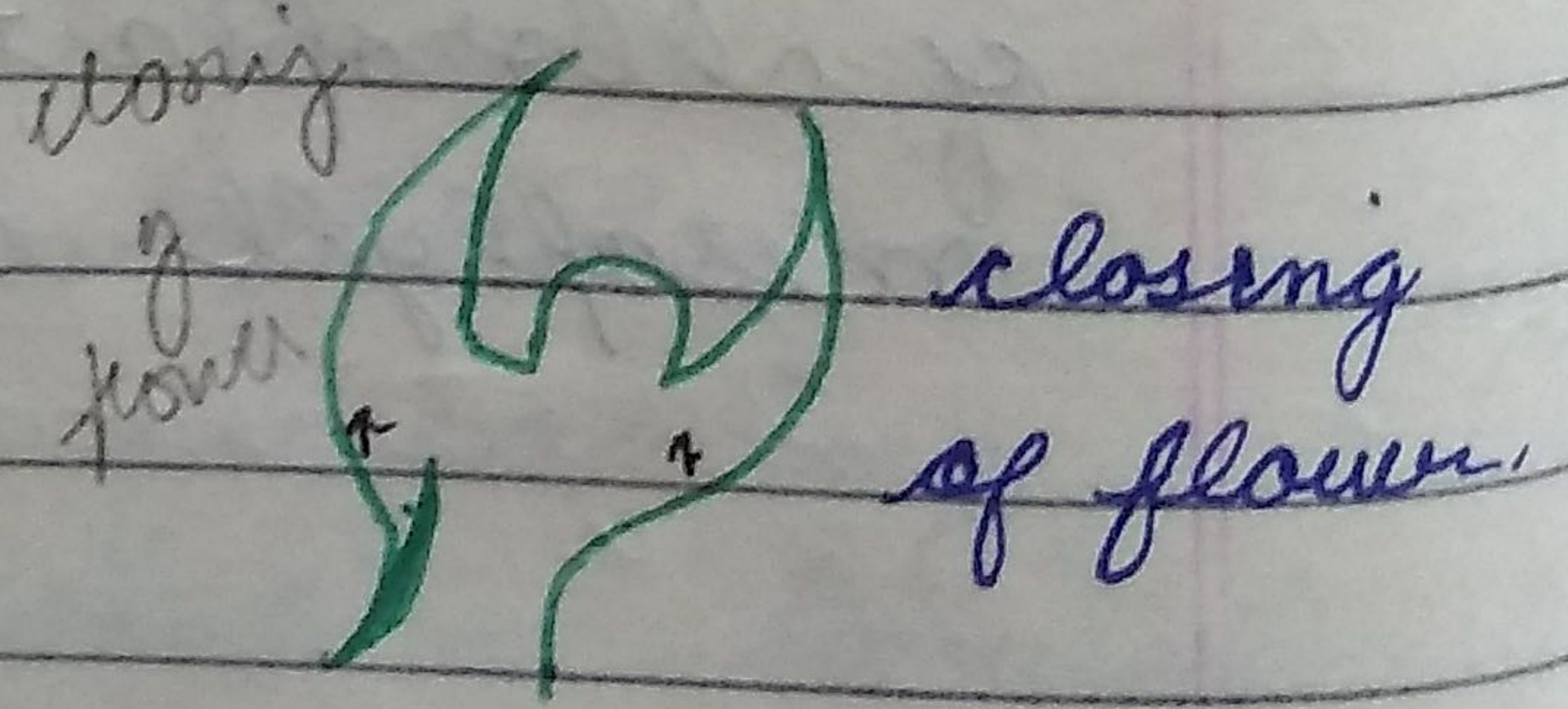
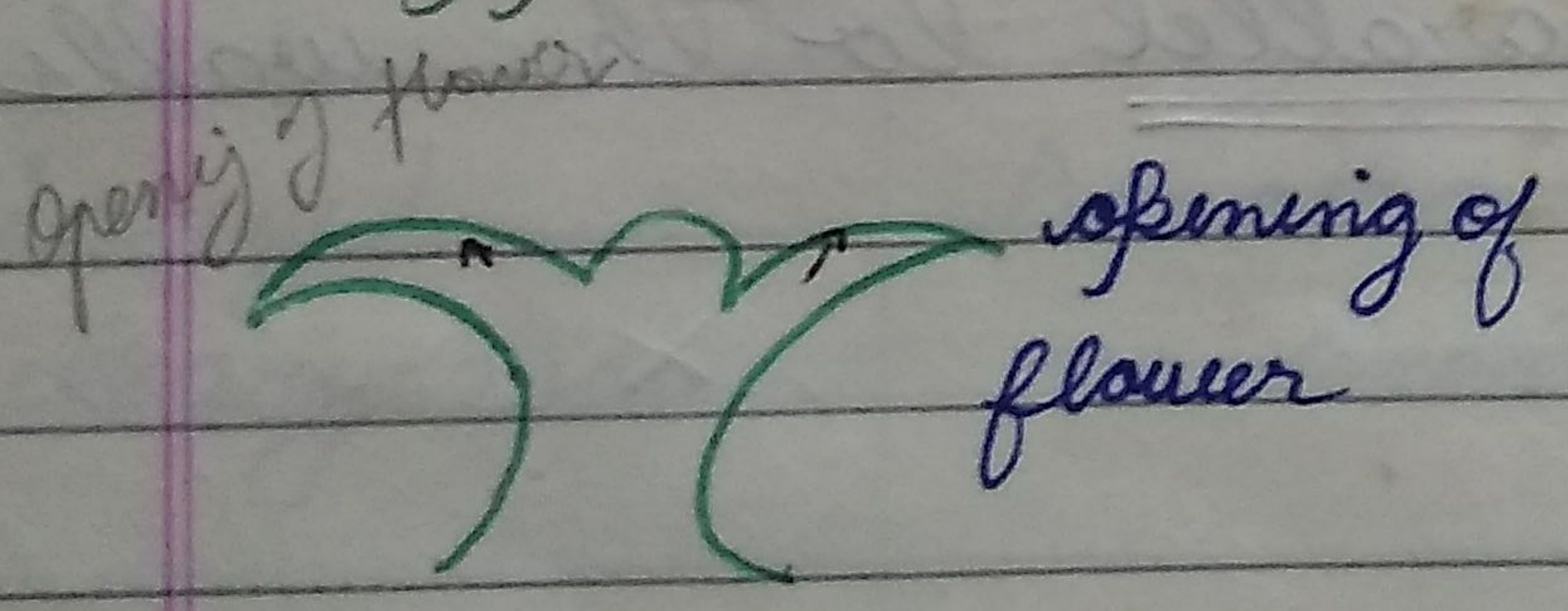
(i) Nastic Movement

Epinasty

Hyponasty

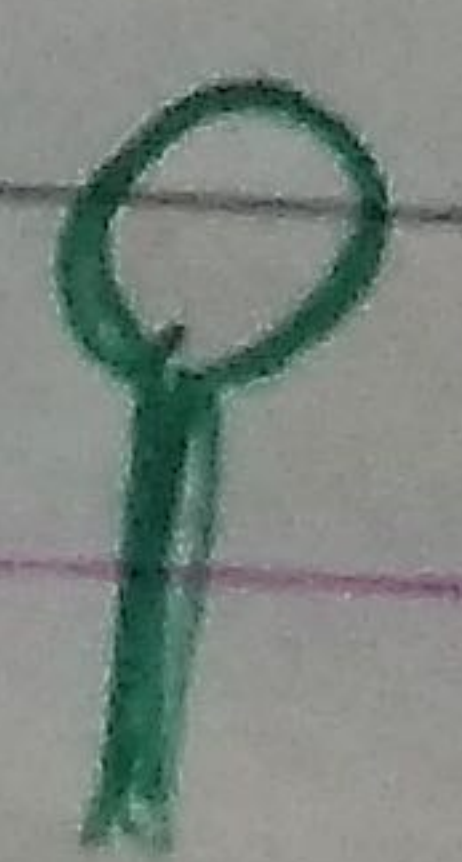
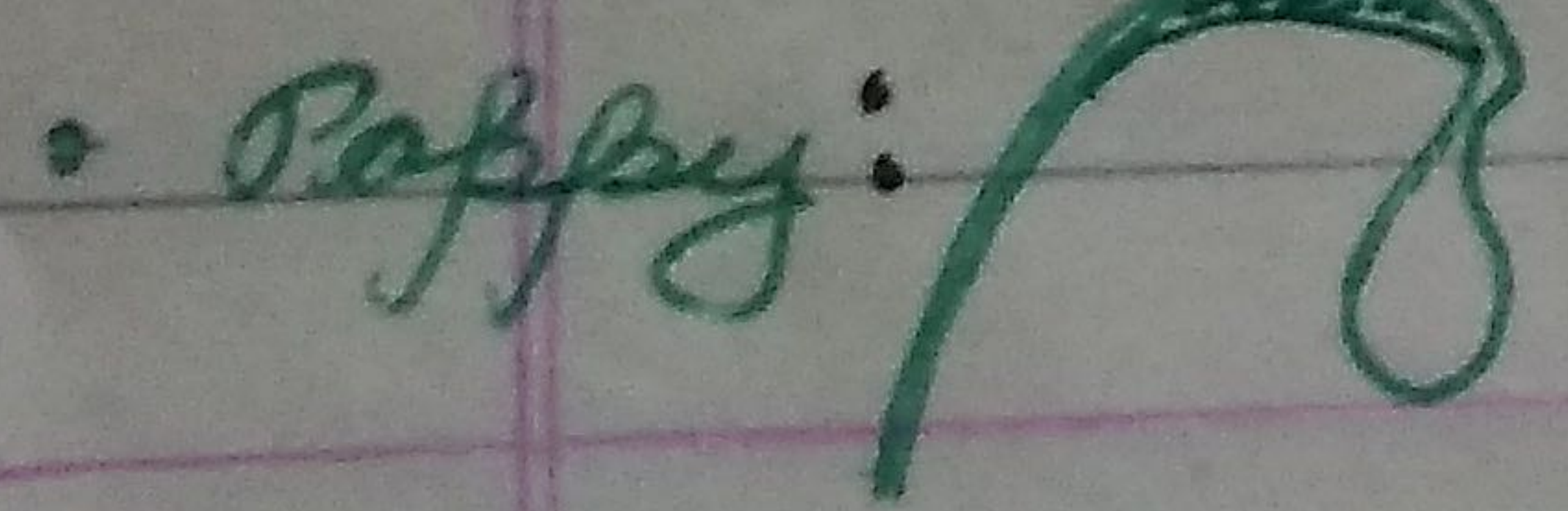
More growth: Upper side ↑

Lower side ↑



Uncoiling of leaf

Coiling of young leaf - in ferns



Geotropism / Gravitropism / Barytropism.

DATE: _____
PAGE NO: _____

DATE: _____
PAGE NO: _____

Curvature : Branching

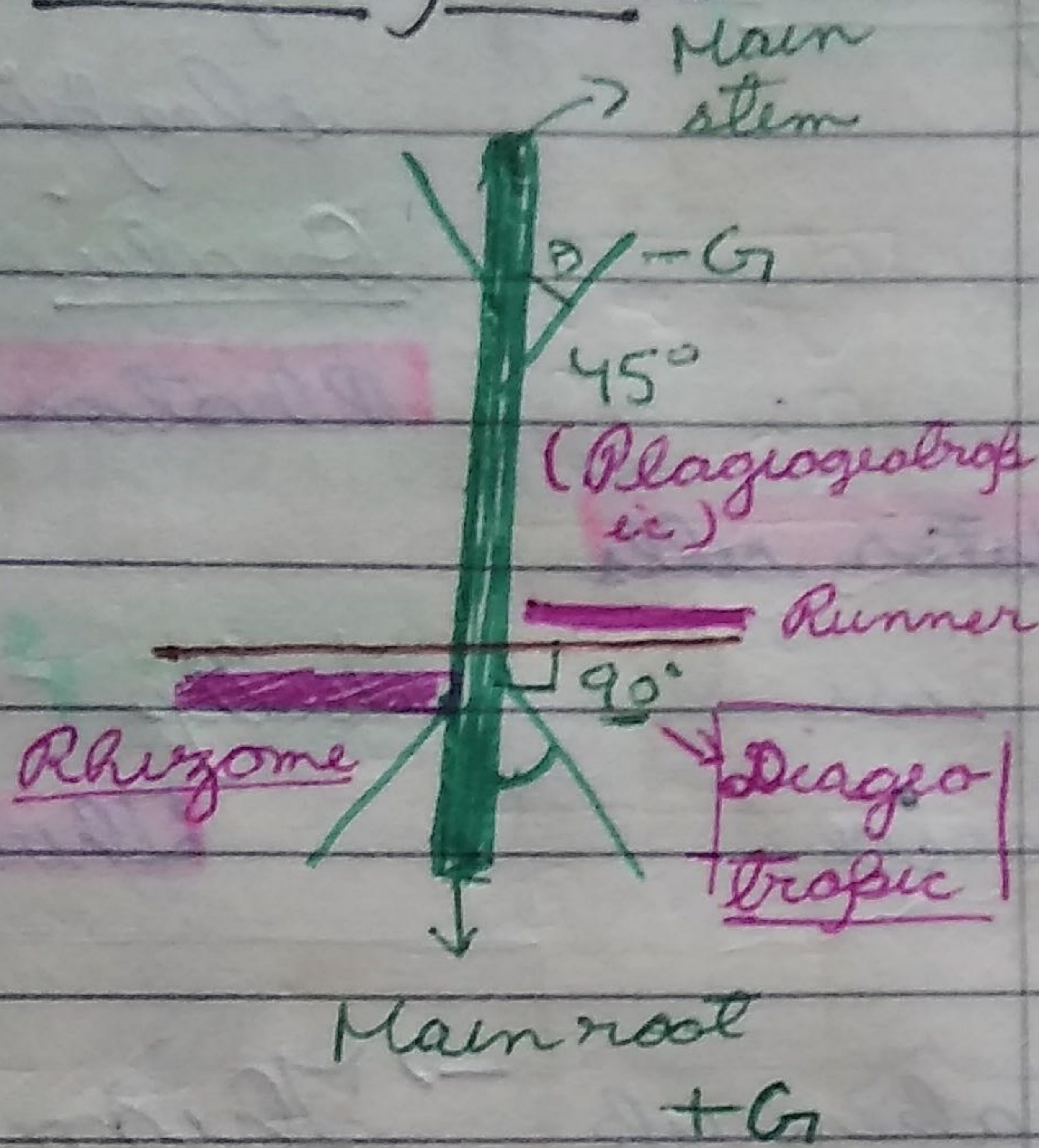
⇒ Induced movement

Phototropic

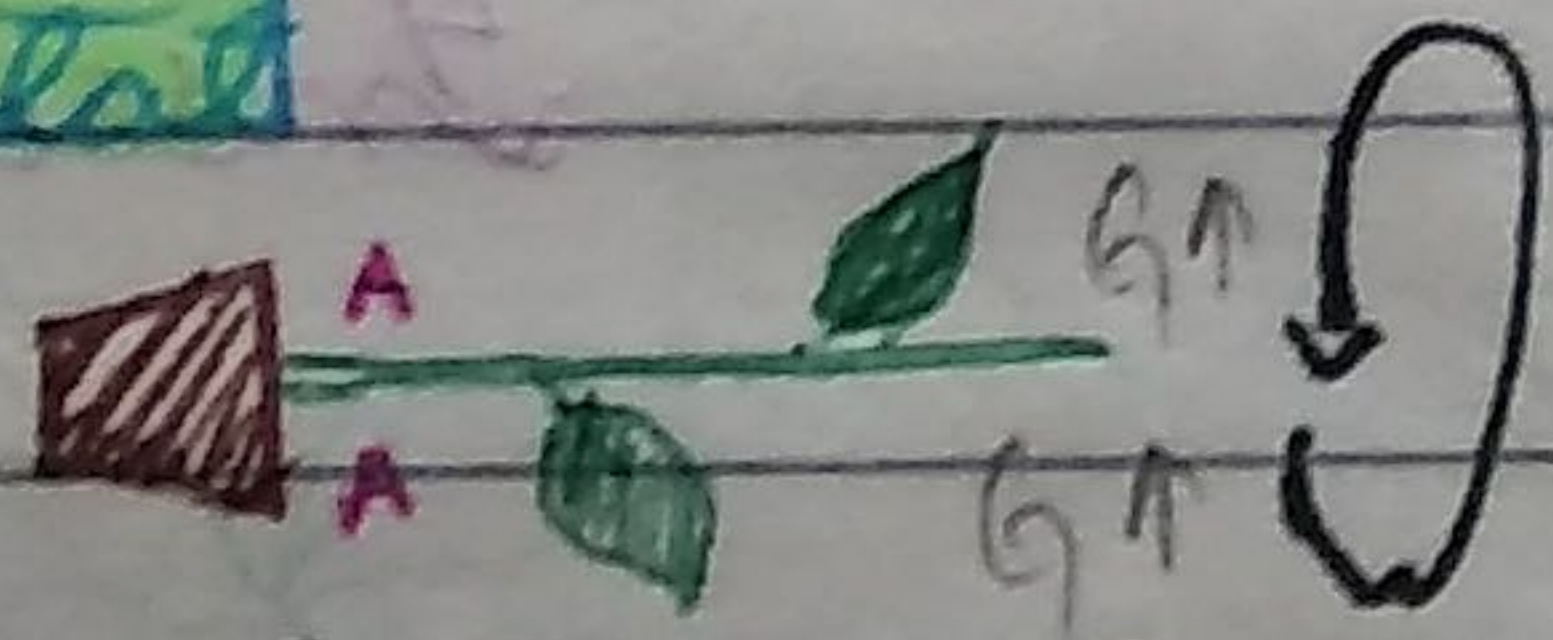
stem = +P

Root = -P

Geotropism



Clinostat

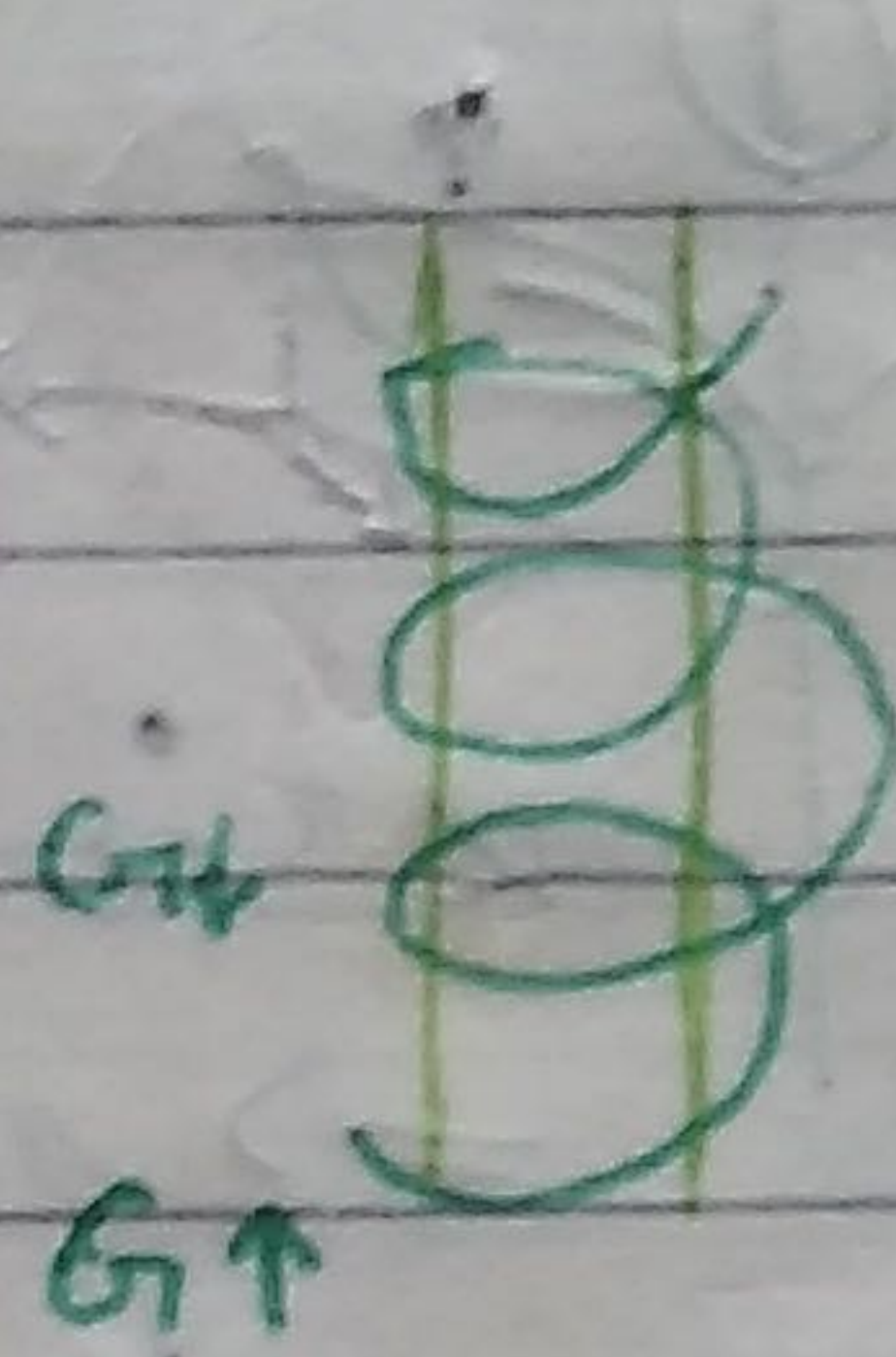


Haptotropism

Thigmotropism

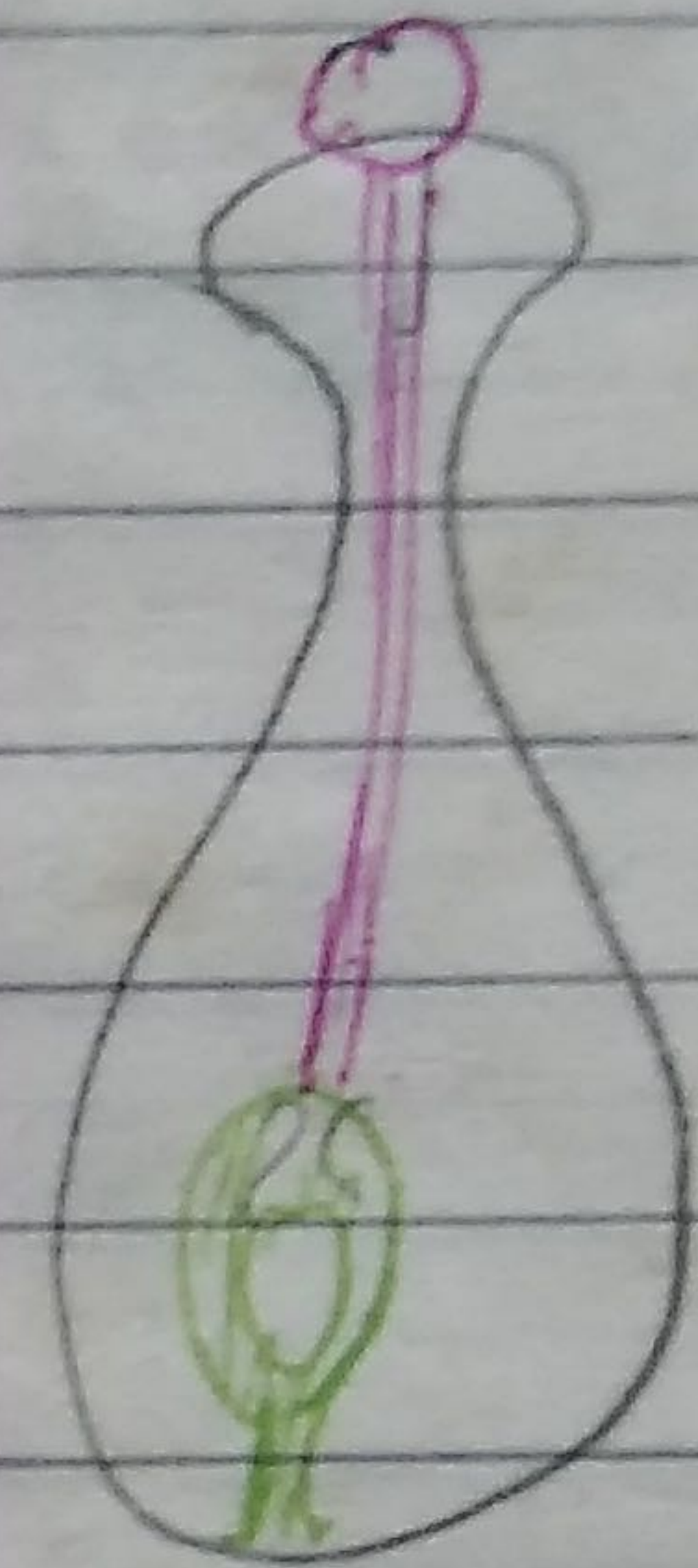
Twenners

Tendrils



due to touch

Chemotropism



Hydro-
-tropic

stem = -H

root = +H

Aerotropism

Pneumatophores

Heliotropic
chamber



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Heliotropic chamber is used to study positive phototropism.

45° Plagiogeotropism
root, shoot branches

90° Diageotropic

rhizome	runner
below	above
soil	soil

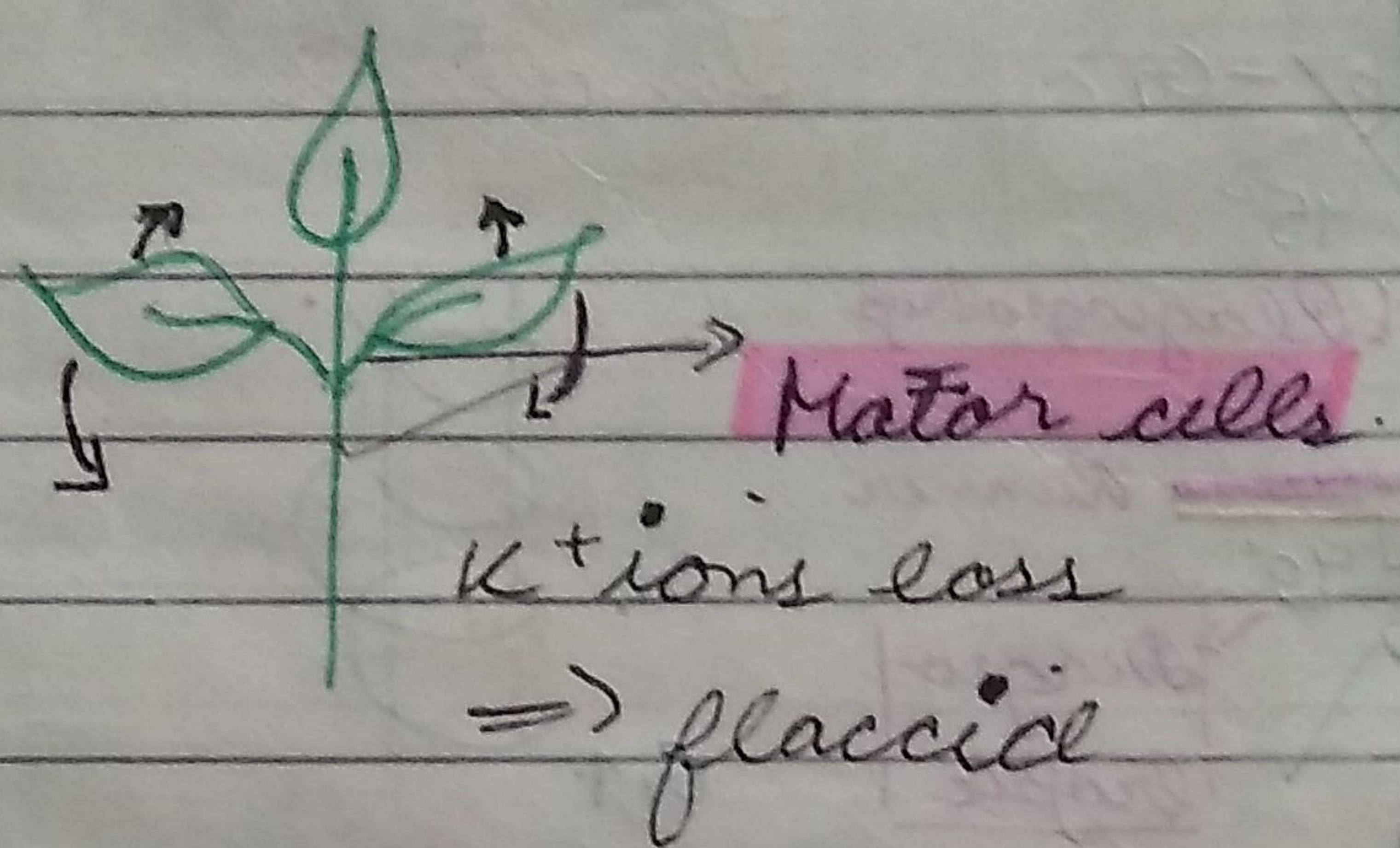
In clinostat effect of gravity is nullified as the plant is rotated, hence the concentration of auxin is same on both sides.

Succature: Variation

Autonomous

Induced

• Desmodium gyrans



K⁺ ion taken up
=> Turgid

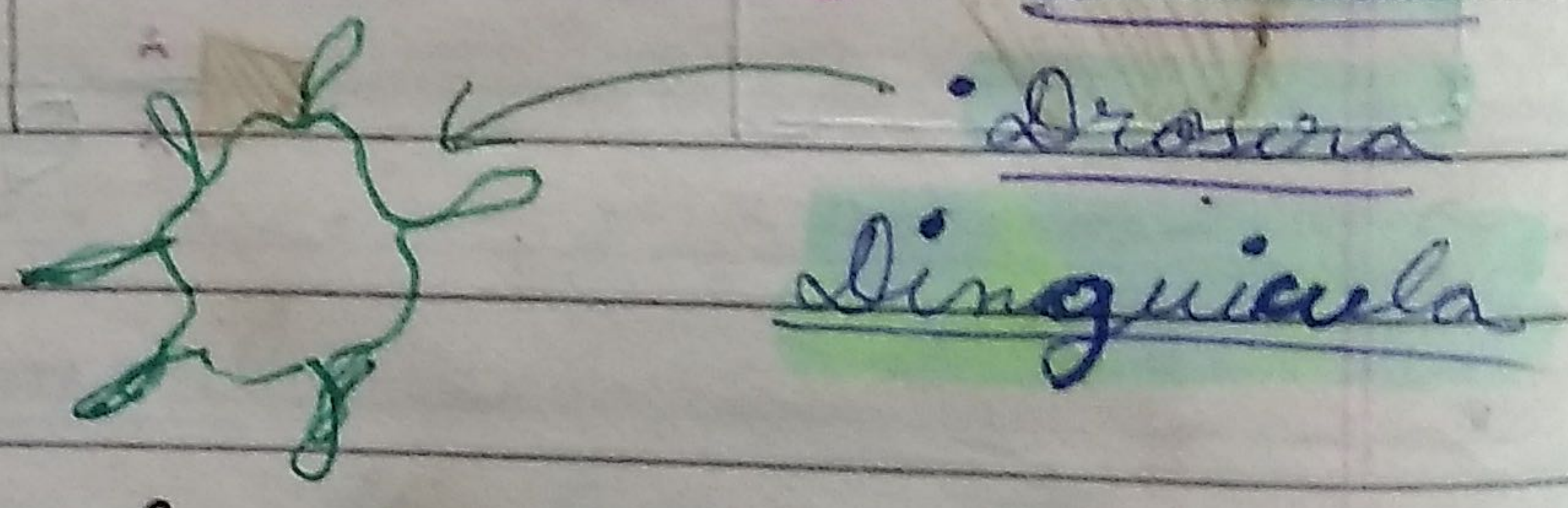
• Nyctinasty -> sleeping movements

Oxalis, Marselia
Photonastic (light)

Tulip -> Temperature
Thermonastic

-> Thigmonastij -> Touch

Insectivorous -> Dionaea



• Drosera
Linguicula

3

Seismonasty

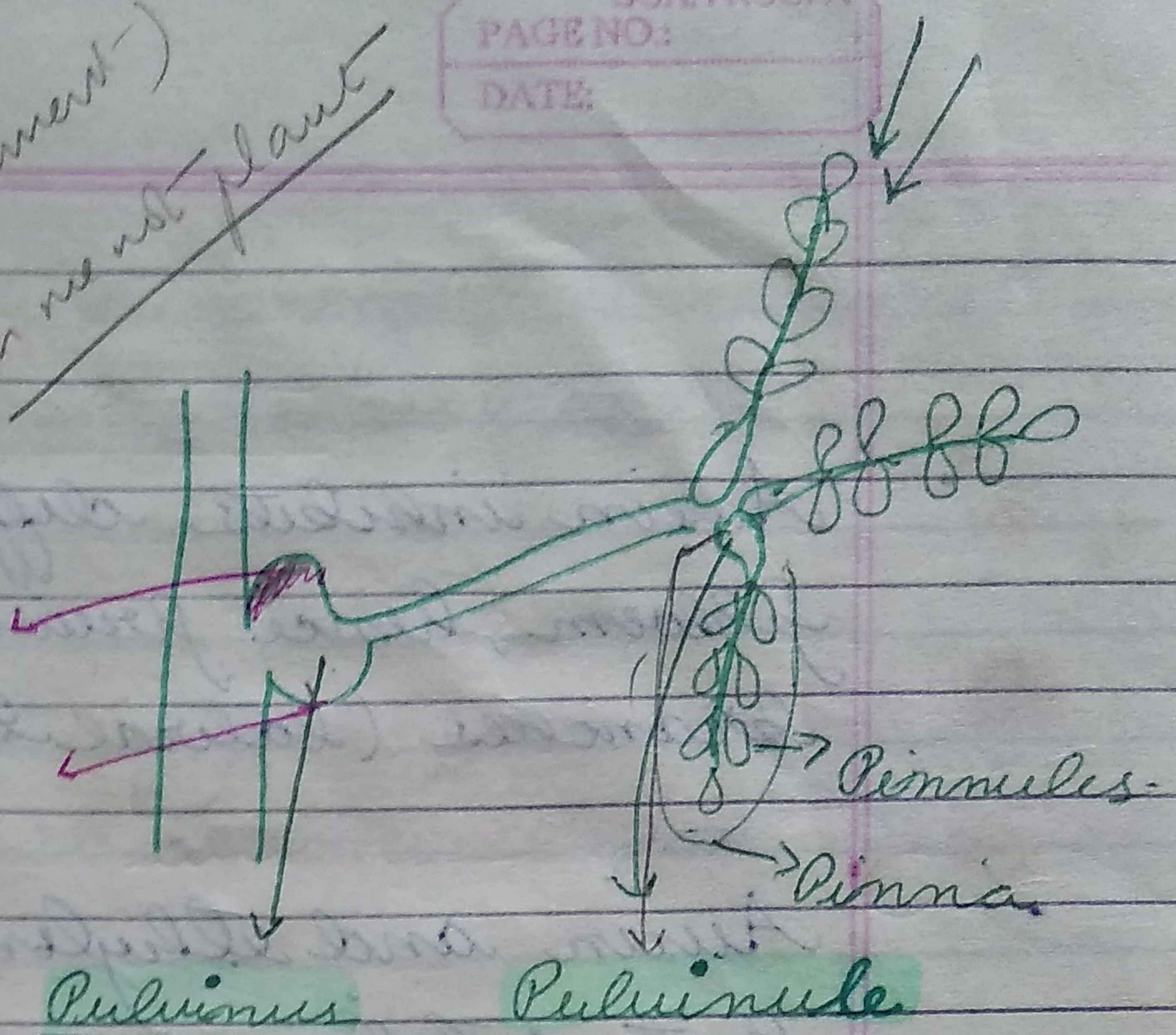
(short movement)
touch sensitive plant

Mimosa Pudica

Thick

Thin

T.P



on touch

Jurgon (Hormone)

Pulvinus / Pulvinules

K^+ efflux

Flaccid

droop down

- 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 flowering.
- 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.