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

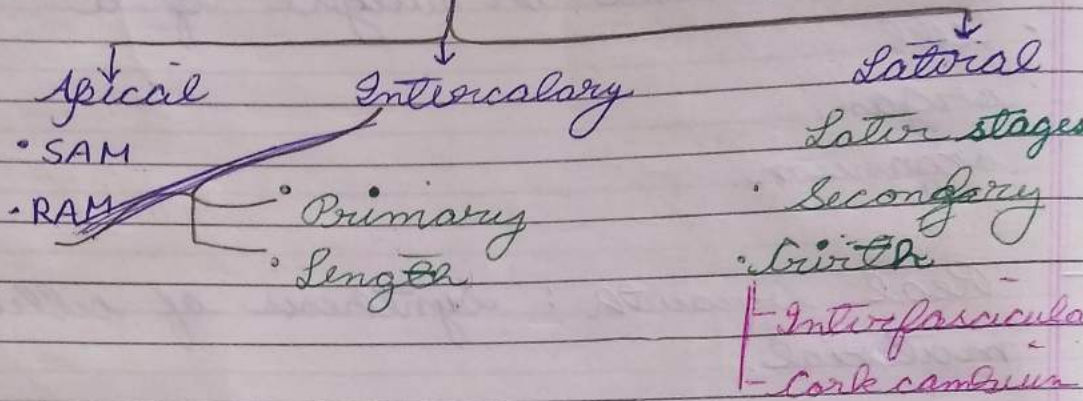
- **Accentric Growth**: cell enlargment ✓
  cell division ✗

- **Multiplicative growth**: cell enlargment ✗
  cell division ✓
  e.g tissue culture

• In animals growth is limited and no. of ... 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

1 Formative Phase / Phase of cell formation (Respiratory activity ↑ high)

2 Phase of elongation (Growth ↑)

3 Phase of maturation / Differentiation

Areas (Vacuole ×) Meristem → Daughter cell → Cell division

Cell division × → New material C-W → C.W enlargement → formation of vacuole

→ Cellulose fibrils → Expansin (Vacuole ✓) → H-Bond × → Cellulose fibril network loosen up

→ Structural, chemical and Physiological specialisation of cell. ⇓ Differentiation

3
2
1

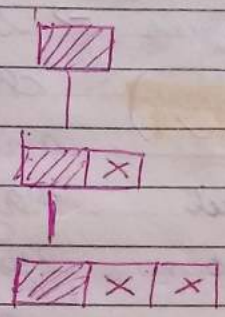
• Maximum respiratory activity present in formative phase.

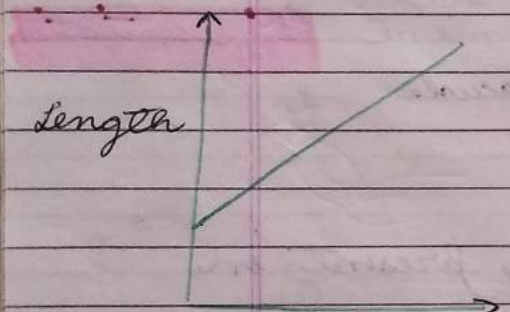
• Maximum growth in elongation phase.

Growth Rate

Arithmetic

- Constant rate
- shoot & root





$L_t = L_o + rt$

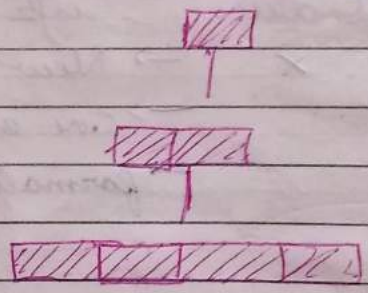
Here r = growth rate
t = time
L_o = initial length.

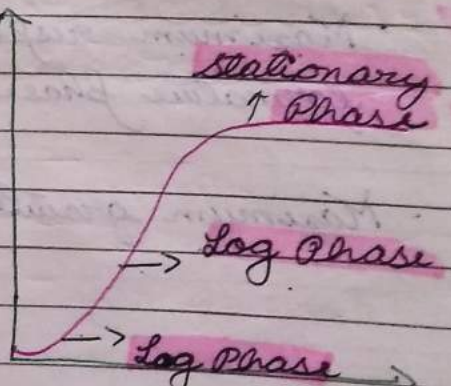
Geometric

- All the daughter cells retain capacity of division

e.g

- Embryo development
- bacterial culture.





$W_t = W_o e^{rt}$

AGR : Absolute Growth Rate
= Growth per unit time
= A = B = $5 cm^2$/ day.

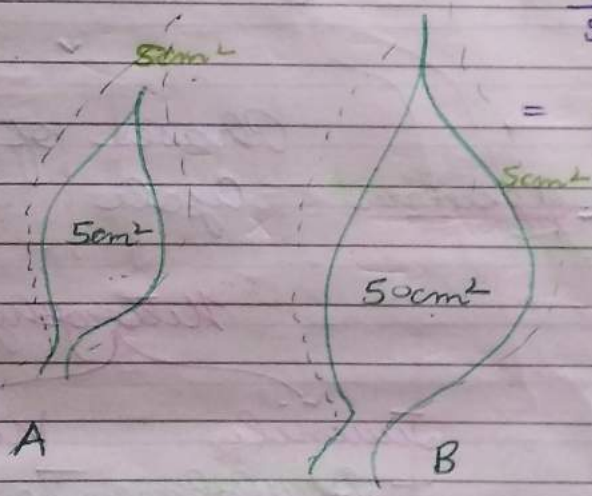
RGR: Relative growth rate

$\frac{\text{Growth}}{\text{Initial Size}} \times 100$

A > B

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

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



Terms

- Differentiation — 1° Meristem → (cell division ✗) → 1° Permanent tissue → (Mature cell div ✓ (Despecialisation)) → 2° Meristem (eg Interfascicular cambium) → (cell div ✗) → 2° Permanent tissue
- Dedifferentiation
- Redifferentiation

specialised
structurally
Chemically
Physiologically

Ranunculus ~ buttercup

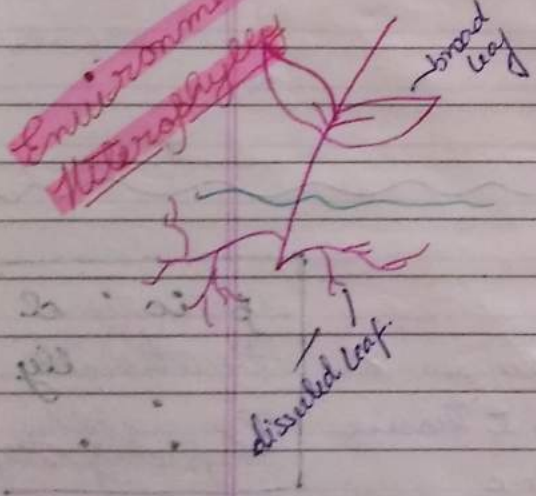
Development

All the changes in structure and function of an organisms that occurs throughout its life cycle from seed germin^n 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

- Intercellular
  - PGRs
  - Plant Growth Regulators
- Intracellular
  - Genetic

Extrinsic factors

- Temp
- O_2
- H_2O
- Nutrients

5 Types

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

Promoter (P)

Inhibitor (I)

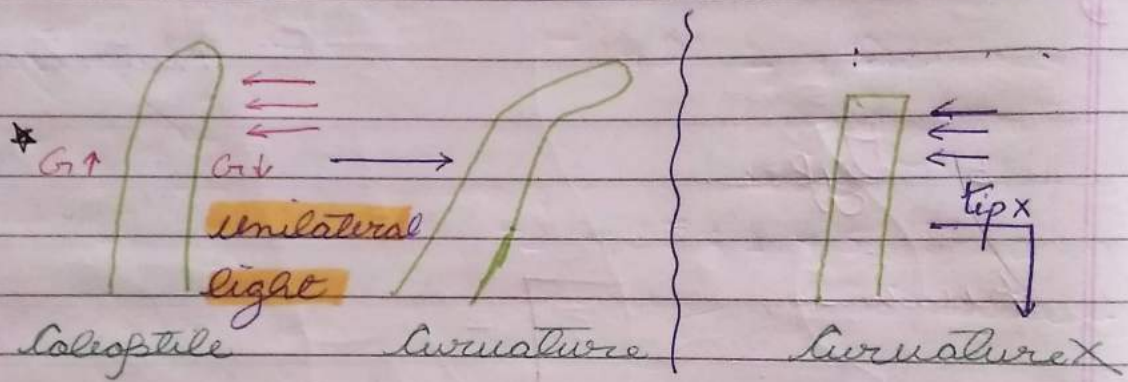
I > P

*Differential growth leads to curvature.

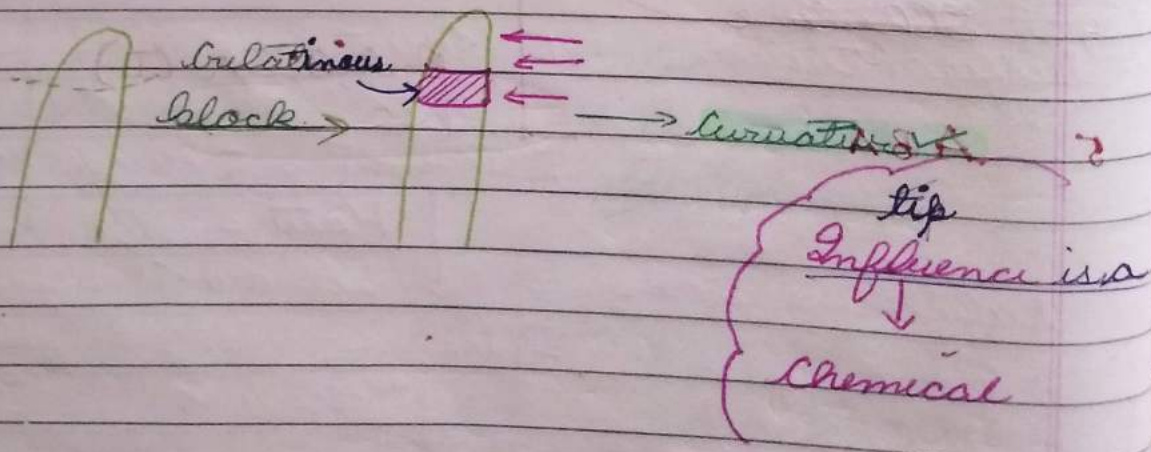
Auxin

① Charles Darwin
Francis ,,

Canary Grass
(Phalaris canariensis)



② Boysen - Jensen

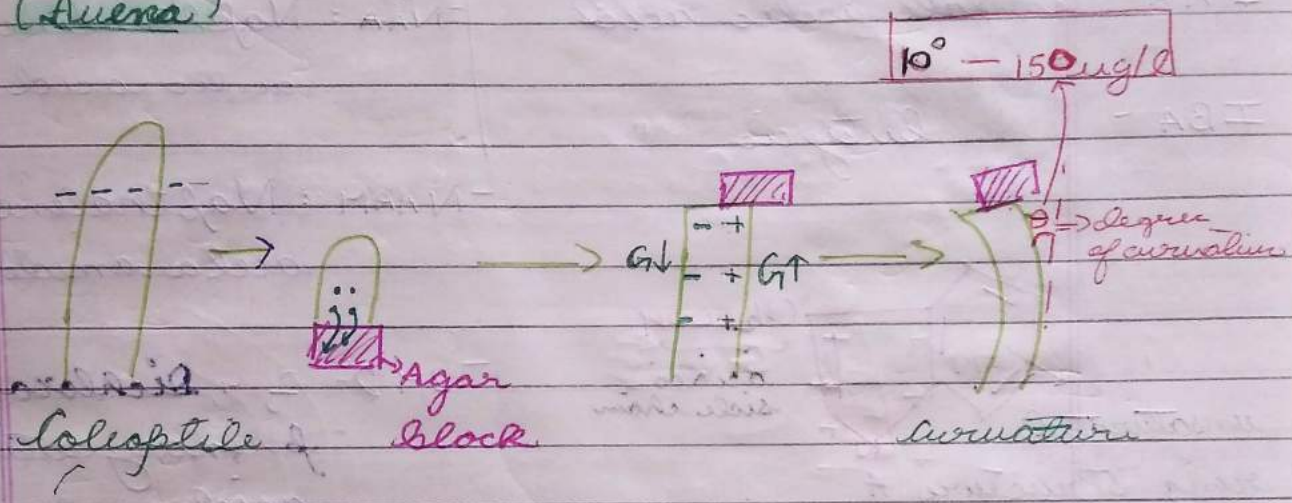


• Auxin was first extracted by Went.

☆ Auxin first isolated from Human urine.

3 Went → Gave the name auxin

Oat seedling (Avena)



Auxin

↓

Gk Auxein

↓

to grow

extracted

Bioassay of Auxin

- Avena curvature test
  - Quantitative ✓
  - Qualitative ✓
- Split Pea Test
- Cress Root Inhibitor test

Structure

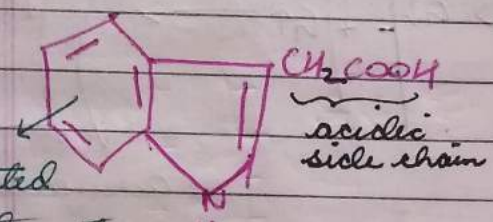
- Weakly acid compound ✓
- Unsaturated ring ✓
- Acidic side chain present ✓

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

Natural

IAA - Indole acetic acid

IBA - " Butyric "

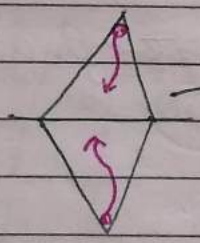


(IAA)

Synthetic

- NAA : Naphthalene acetic acid
- NAAM : Naphthalene aceta amides
- 2,4,D : 2, 4, **Dichloro** - phenoxyacetic acid
- 2,4,5T : 2,4,5 Trichloro phenoxy acetic acid.

- Synthesis : Tryptophan, Zn^{+2}
- 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

Bound with ← Inactive

Storage purpose.

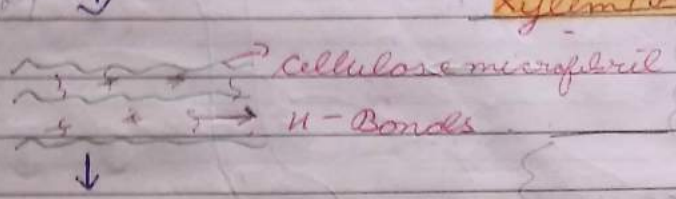
- Expansin activated in acidic medium.

★ Cytokinin counteracts apical dominance.

- Functions

1. Cell Elongation

Auxin
↓
(cell wall)
C.W acidic
↓
Expansin
↓



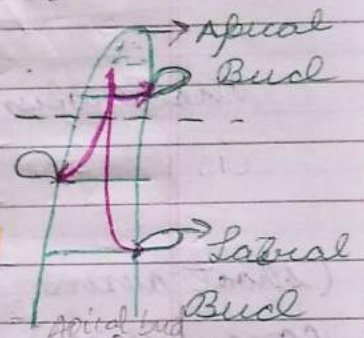
↓

Loosen-up network
addition → New cell wall material
→ Cell wall enlargement
leading to cell elongation

★ Weak Cross Bonds

(2) Apical Dominance

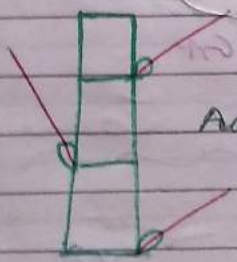
Apical bud suppresses the growth of lateral buds



Auxin
↓
Lateral Bud
↓
Growth of lateral Bud ↓ (decreases)
↓
Sprout / Branch ×

- Inhibits differentiation of Xylem / Phloem

Pruning / removal of apical bud
Decapitation



Auxin
Inhibits
Differentiation of X & P
∴ Lateral bud ×

Significance of pruning.
- Tea Plantation
- Hedge making

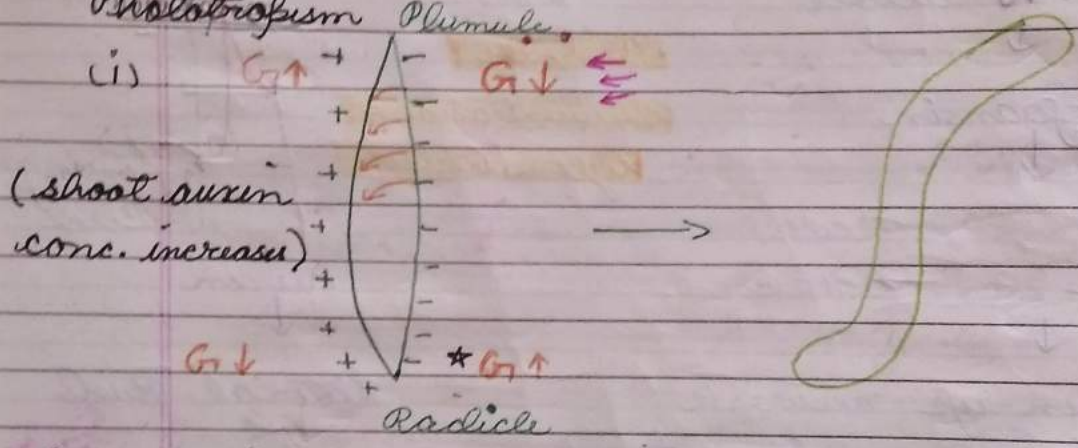
★ For root growth auxin concentration should be less.

[3] Phototropism & Geotropism

- Tropic movements
  - → Curvature movements
  - → Cylindrical organs (shown by)
  - → Diff↑ ventral growth (due to)
  - → Stimulus (towards or away from)

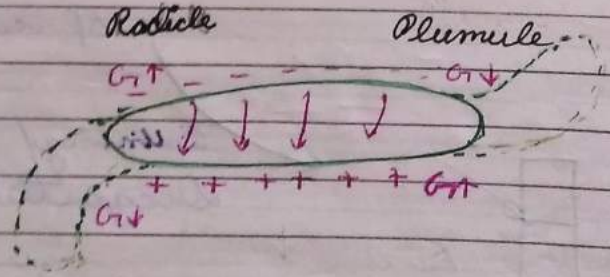
Phototropism

(i)



(Root auxin con. decreases)

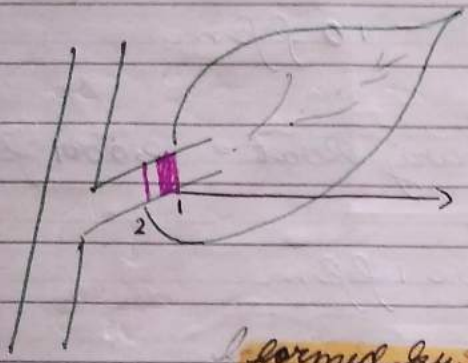
(ii) Geotropism



⇒ 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 layer

1: Separation layer
formed by ethylene.
(Cellulases, Pectinases)
C.W breakdown

2: Protectective layer
suberin + wt

- Auxin gradient Theory given by
- Addicot & Lynch

Stem	Leaf	Asscission
A	A	×
A	A	start of abscission zone
A	A	✓ abscission occurs.

5 Herbicides
↓
2,4D
2,4,5T

Absorption ✓ Absorption ×

- Dicot — Monocots (Insensitive)
- Broad leaf plants — ×

Kill

6 Lateral root form"

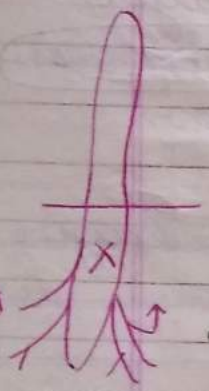
shoot growth — 10 ppm

Main Root / Primary Root = 0.0001 ppm

Auxin > 0.0001 ppm

→ primary root ✗

→ Lateral / adventious root ✓



Pericycle

↓

cell division

↓

Lateral roots

Rooting of cutting

→ Plant

⇒ vegetative reproduction

Also called

"RSH → Root setting Harmone"

ROOTONE

7 Parthenocarpy → Tomato

8 Root nodule → Legumes

cell division

* Plants
- Auxin

* Bacteria
Cytokinin

• In apples fruits are formed on dwarf shoot.
• Auxin stimulates the stem of grasses.
• Indole acetic 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 ↑ NAAM used.

13. Traumatic acid : Healing hormone.

14. Sweetness of fruit : CH changes → fructose
(carbohydrates)

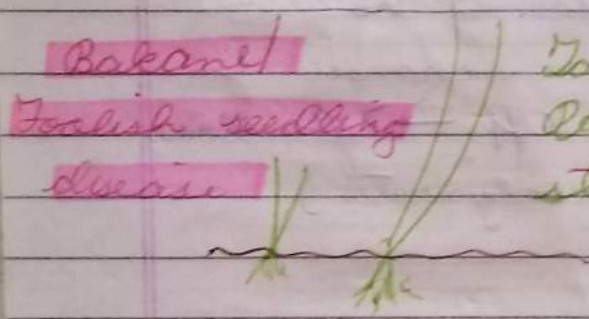
* Terpenes are derived from acetyl CoA hence Gibberellin can also said to be derived fro acetyl CoA.

- **Gibberellins**

- Weakly acidic
- Terpens (derivative)
- Gibbane ring structure

- **History:**

(i) **Kurosawa:**



- Fungi – Gibberella fujikori → 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
- GA_3 (most studied)

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

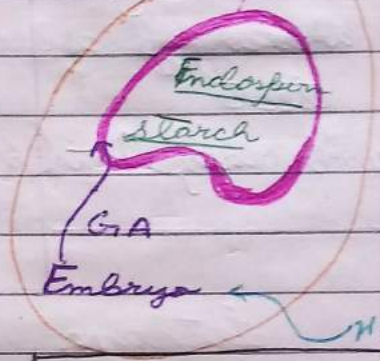
• Precursor:
Acetyl CoA → Mevalonic acid
↑ precursor

• Synthesis
  • Root tip ✓
  • Developing embryo ✓

• Functions →

1 Seed germination
— Barley seed

Protein aleurone layer.



Embryo
↓ GA
Aleurone layer
↓ Genes on
Hydrolytic enzyme
α-amylase
Proteases
↓
Starch endosperm → Maltose → Beer
↓
Sugars (ATP)

• Bioassay
α amylase ∱ Barley endosperm test

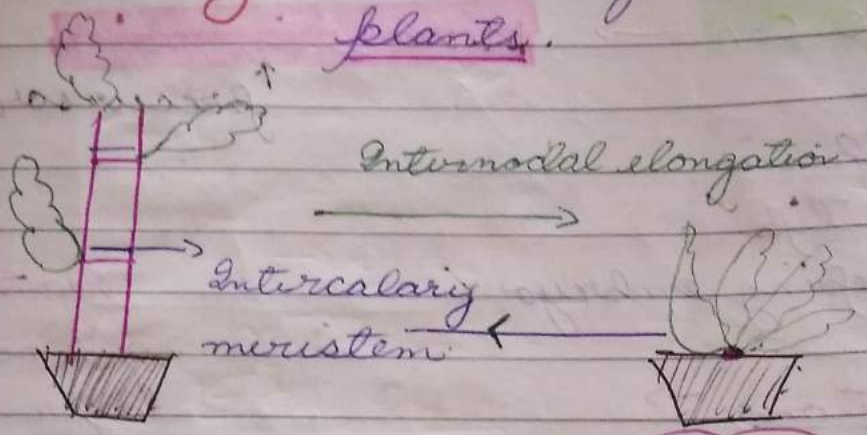
(Malt)

(GA3)

• In brewing industry gibberelic 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**

Ponalin

CK + GA

BAP (Benzyl amino purine)

GA4 + GA7

Thalamus → Apple
Internode → Size ↑ shape

GA → Grapes → Clusters → stalk → Size ↑

Contact inhibition

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

4 Sugarcane (C_4 plant)

↓

Stem ⇓ GA

↓

Stem ↑

↓

Increases Yield by 20 tonnes/acre

5 Flowering — ALDP (long day plants)

6 Male Flowers → MISH-
(male steroidal hormone)

7 * Delay senescence

8 Conifers Juvenile —GA→ Seed formation is enhanced.

- Cytokinin
- Skoog and Miller
- Tobacco internodal segments
  - → Auxin
  - → vascular tissue, coconut milk, DNA, Yeast
  - ~~Auxin~~ Callus
- Herring sperm DNA
- Kinetin (6-furfuryl amino purine)
- Lethan: extracted natural cytokinin
  - Corn kernal and coconut milk
  - Zeatin
- Synthesis → - Fruits
  - Shoot lateral bud
  - // Root tip.
- Precursor → Purine → Adenine, Guanine

(CDK - Cyclin Dependent Kinase)

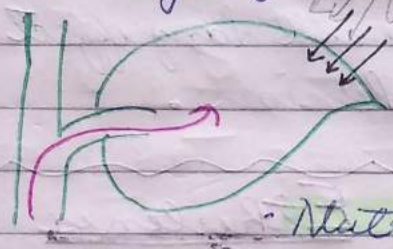
☆ Cytokinin involved in formation of chloroplast.

• 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)

[6] Tissue culture :

Explant : part of plant used in tissue culture.

☆ Auxin = CK cell division = Callus

A > CK Adv. root
CK > Auxin Adv. shoot
= Morphogenesis / Organogenesis.

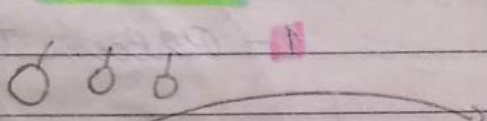
[7] Flowering ⟶ Lemna (Water plants)

[8] ♀ flowers

- Richmond Lang effect : delaying senescence by cytokinins.

- **Ethylenes**

→ Gaseous



ripened orange — stored unripened banana

Conc. 0.01 — 10 ppm	conc. in which ethylene is effective

→ Precursor

Methionine (Amino acid)

↓

SAM

Sadenosyl methionine

↓ ACC Synthetase

ACC

Amino cyclo propane carboxylic acid

↓

Ethylene

Autocatalytic Effect

Stimulates

Production of Ethylene

Compounds: Increase ↑ production | ↓ decrease production

① Ethylene | ① CO_2

② Auxin | ② Ag^{+2}

→ **Functions:**

1 **Ripening:**

Climatric fruits ✓	Non-Climateric fruits ✗
Increase in Respiration	✗
• Apple, Banana, Pear, Orange Peach Plum	• Strawberry • cherry • Pineapple

Flowering

Ethephon

↓

Ethylene

→ Ripening

→ Abscission - fruits, Flowers, leaves

→ Hastens fruit ripening in tomatoes, apples.

Thinning of walnuts, cherry, cotton (NCERT)

★ Absicic acid is antagonistic to Gr. 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.

- Ethylene ↓, Diffusion ↓ Conc. ↑ of ethylene increases ↓ Inhibits ABA synthesis ↓ GA → work ↓ Internodal elongation

Anti GA

5 Flowering → Pineapple
Synchronising fruit set

- Mango (Induces flowers in)

☆. Female flowers → Cucumber

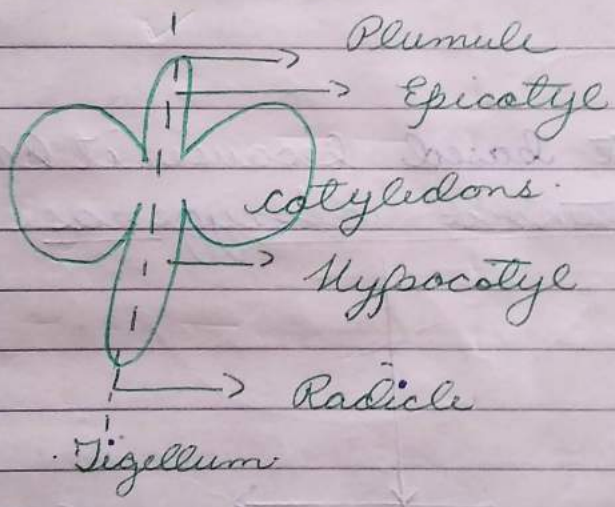
6. Breaks seed & bud dormancy

7. Seed germination in pea-nut

8. Apical hook :- Dicot seedling
Plumule → Protect ☆

☆ Sprouting of potato tubers.

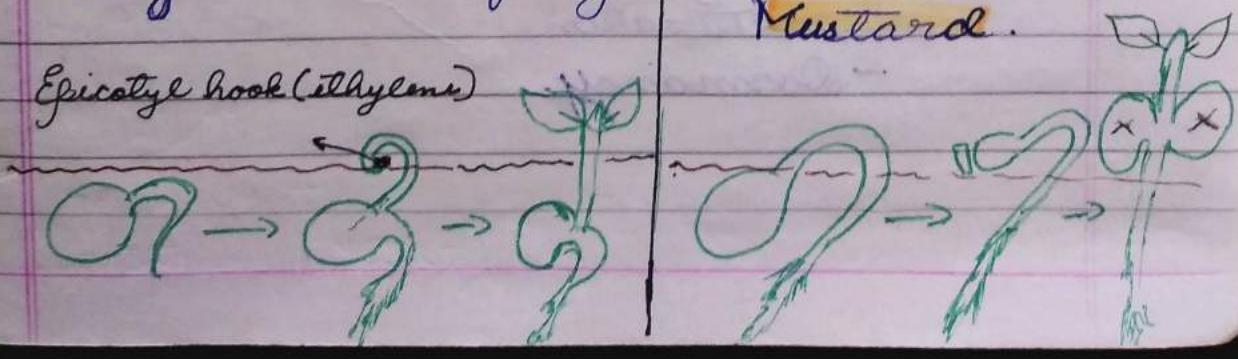
EMBRYO



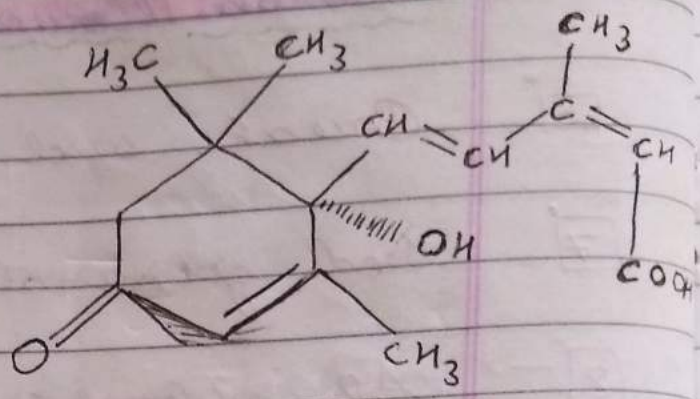
· Seed Germination

Hypogeal	Epigeal
☆ Epicotyl forms first	Hypocotyl develop first
· Cotyledons → Inside soil	Come out of soil
Mango, Fabaceae family	· Castor, onion, Mustard.

Epicotyl hook (elbyem)



- **Abscisic acid.**



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

Anti GA

GA	ABA
Genes on	off
α amylase ✓	α amylase ✗

2 ABA
↓
Efflux of K^+ ions — STRESS Hormone
from
Guard cells
↓
K Malate ↓
↓
OP ↓
↓
Stomata closure.

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 ---> Absicic acid, ethylene
- Senescence
- Apical dominance ---> Auxin, ethylene

Photomorphogenesis

Blue light dependent

- Stomatal opening
- Phototropism
- Chloroplast movement
- Phototropin

Pigment which absorbs blue light.

Red light dependent

- Seed germination
- Flowering
- Pollen germination
- Anthocyanin synthesis
- Stomatal differentiation
- Cleistogamy
- Phytochrome

Pigment absorbing red light

Seed Germination

- Borthwick and Hendricks

- Different wavelength → Seed germination of light.

☆

Seed — Red (660 nm) → G✓ — Seed germination depends on red light.

Seed — Far Red (730 nm) → G✗ — Seed germination depends on last exposure of light to seed

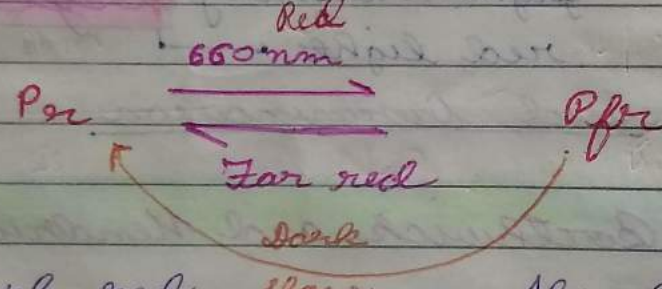
Seed — R + FR → G✗

Seed — R + FR + R → G✓

Bullen : extracted phytochrome.

- Phytochrome
  - Holoprotein
    - Apoprotein
      - Protein ✓
      - Kinase
    - Chromophore
      - Protein ✗
      - Light absorbⁿ

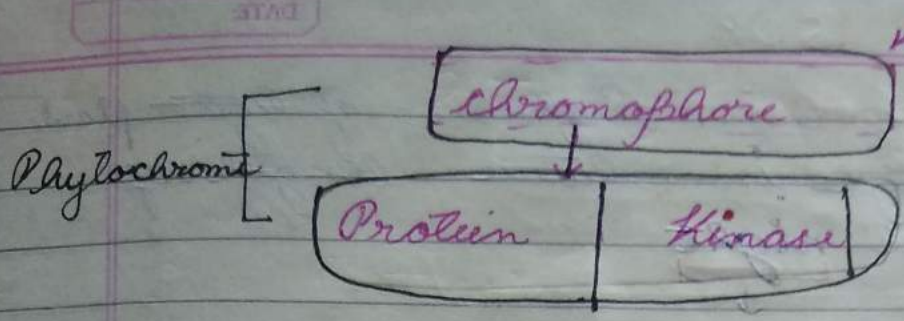
- Two forms of phytochrome.



Pr	Pfr
Absorb red	Absorb far red
Cis form	Trans form
Blue	Y-G (yellowish-green)
Inactive	Active
Stable	Unstable

- Pfr is responsible for seed germination.

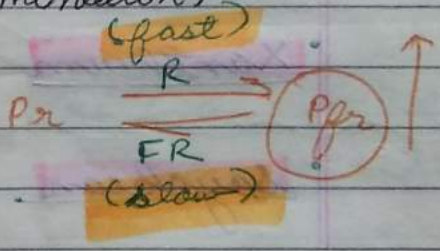
Pfr is unstable because even in the absence of far red light it is converted into Pr.



- Phytochrome
  ↓ Activate
- Phosphorylation of Proteins
  ↓ Activate
- Transcription factors
  ↓
  Gene → G.A (Gibberellic acid)

R → G ✓ (Germination)

FR → G ✗



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

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

- **Photoperiodism**: Response of ~~light~~ plant to changes in relative length of day and night

Photoperiod Skotoperiod.

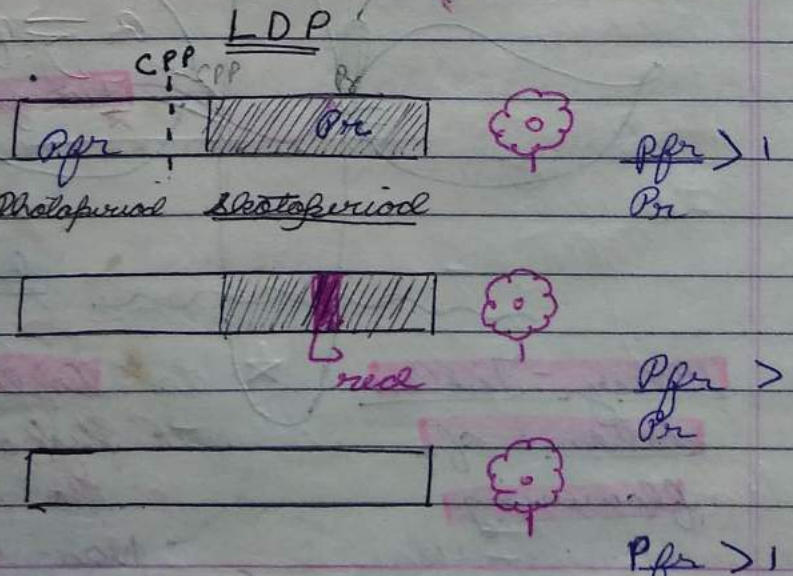
3 Types.

✡	SDP (Short)	LDP (long)	DNP
RADS X	• Rice	• Wheat	• Maize
	• Xanthium	• Barley	• Sunflower
	• Soyabean	• Oat	Cucumber.
	Dahlia	Henbane WHO-B	• Tomato
	Aster	• Larkspur	Pepper.

MPT – SC

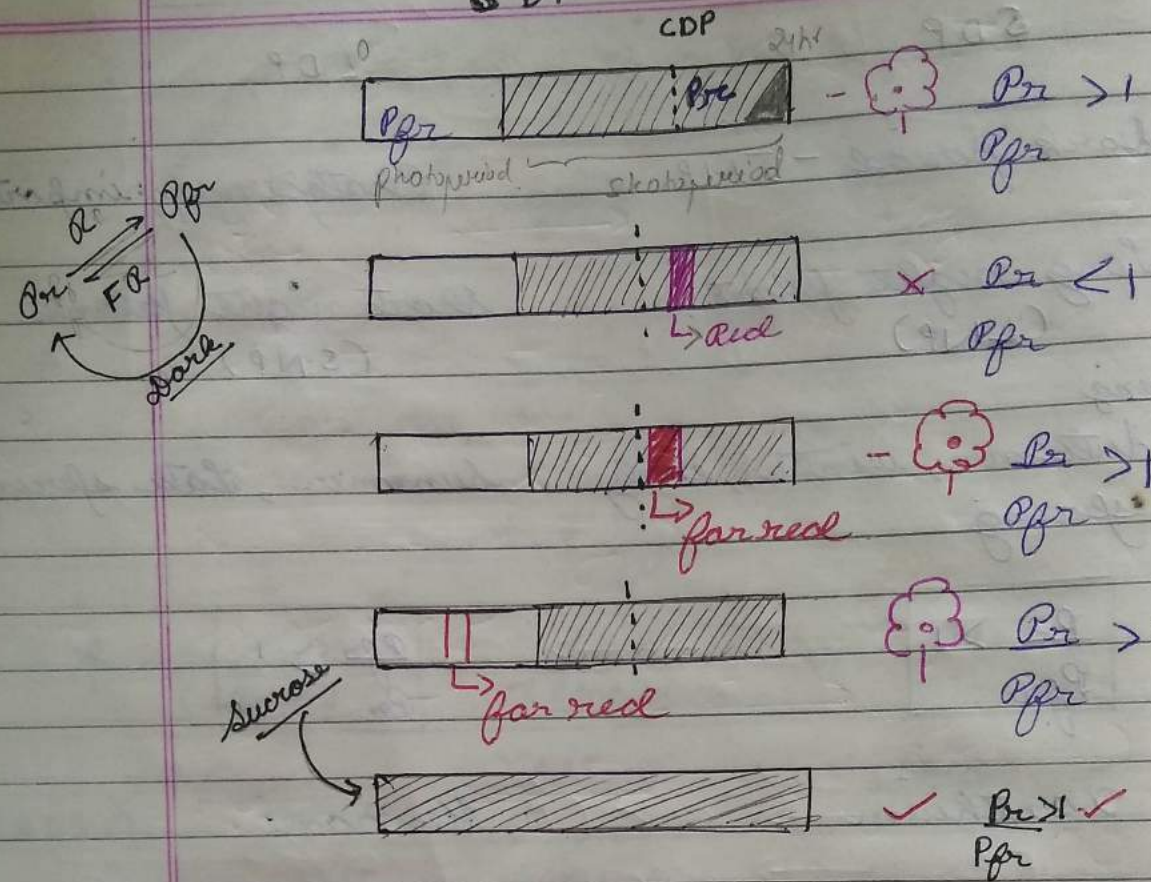
- Critical light period = photo period
- Critical dark period = skoto period.

SDP	LDP
• Dark period - IMP	Photoperiod : important
• Long night plants (LNP)	Short night plants (SNP)
Flowering	
• Autumn, winter, early spring	Summer, Late spring.
• $\frac{Pr}{Pfr} > 1$	$\frac{Pfr}{Pr} > 1$
• Eg. Xanthium	Eg. Henbane.
• Critical light period < 15.5 hrs	Critical light phase > 11 hrs
"Dark" > 8.5 hrs	"Dark" < 13 hrs



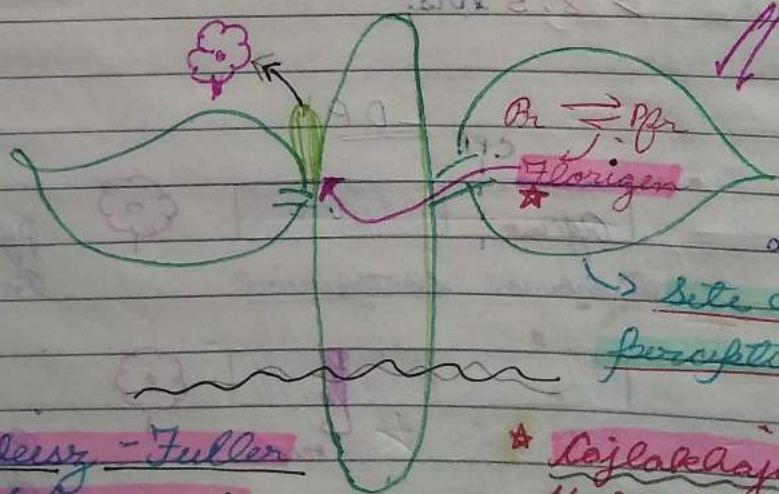
☆ Florigen is a hypothetical hormone.

SDP



DNP

Independent of photoperiod



Wellensiek-Fuller Scheme of flowering

☆ Cajalakdajan

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

LDP
× Photoperiod
but if given
- GA
F ✓ (flowering)

SDP
× Dark period
but if given
ABA
F ✓

Florigen

not correct photoperiod | Components | not correct dark period

- GA (deficient)
- Anthesin (suff. def)

GA (suff.)
Anthesin (def)

- **Vernalisation** → Lysenko
- Springification
- Jarovisation
- Jarovisation
- Quantitative and Qualitative dependance of plant ↑ on low temperature for flowering

  - 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 ✗ (not required)
- ~~Winter variety~~

Winter Variety

Sept / Oct ⟶ (Low temp) Dec ⟶ April / May (Mature)

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

Winter variety
OO seeds
Soak
Low tem
artificial
0-5°C
Early flowering

Biennials

W
Sp
Su
A

Sugar beet
Carrot
Cabbage

Spring (Su, A) W ⟶ Spring Flowering
I year (Low Temperature) II year

seed
- Low temp.
- Flowering I year

★ Low temperature can convert Biennials → into Annuals

☆ Vernalin is an hypothetical hormone.

- Requirements

(i) Seed hydrated – 50% H_2O

(ii) Aerobic conditions

(iii) Proper nutrition

(iv) Low temperature 0–5°C → few days → weeks

(v) ① Seed → Embryo (site of perception)
② Young Plant → SAM (shoot apical meristem) → site of perception

Melchers (scientist)
↓
Hormone
↓
Vernalin (hypothetical)
↓
GA substance

- Photoperiodism ... Vernalisation

1	Site of perception → Leaves	Site of perception → Meristem
2	Differentiated cells	Undifferentiated cells
3	Florigen ← Hypothetical →	Vernalin
4	Phytochrome chemical	×
5	LDP → GA	All → GA
6	All plants	• Temperate, • Arctic — plants

Plant Movements

Locomotion

- whole organism / cellular constituents

Factor initiated

Internal
- Autonomous / Spontaneous movement

External
- Induced / Paratonic / ~~Tactic~~ movement.

Curvature

Plant organs

Differentiated Growth

Growth

A | I

Change in TP

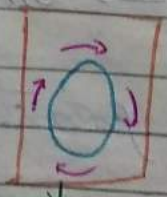
Variation

A | I

A = autonomous I = induced

• Locomotion

=> Autonomous

• Ciliary / Flagellary mov	Amoeboid movement	• Cytoplasmic streaming
• Chlamydomonas	- Amoeba	Rotation / Circulation
• Volvox	- Slime moulds • Plasmodium	
• Paramoecium		Hydrilla Vallisneria / Staminal hair of Tradescantia

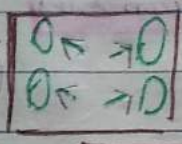
⟹ Induced :-

Rhotatactic movement

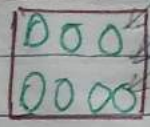
→ Chlamydomonas :

→ Chloroplast

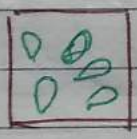
☆ P Parastrophic
High light



E Epistrophic
Moderate light



A Anastrophic
Low light



Thermatactic

· Antherozoids of Bryophytes, Pteridophytes

· Slime mould → Myxamoebae.

Rheotactic : H₂O currents

Thermatactic : Temp.

Galvano :- :→ Electric tactic movement current.

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

Curvature Movement

- Growth
- Autonomous movement

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

(i) Nastic Movement

Epinasty

More growth: Upperside ↑

opening of flower

- Uncoiling of leaf.
- Poppy:

Hyponasty

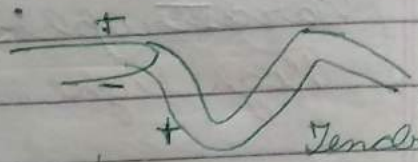
Lower side ↑

closing of flower

Coiling of young leaf in ferns

(ii) Nutation

- Runner



- circumnutation

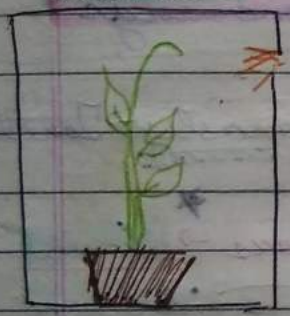
• Geotropism / Gravitropism / Barytropism.

Curvature : Growth
⇒ Induced movement

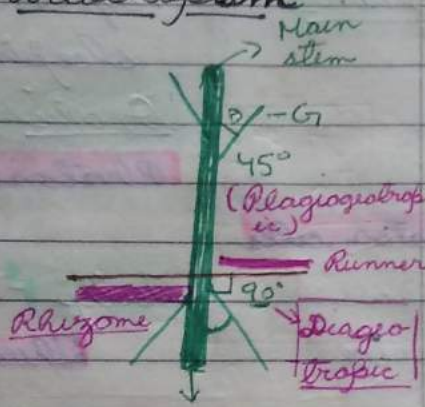
Haptotropism

• Phototropic
stem = +P
Root = −P

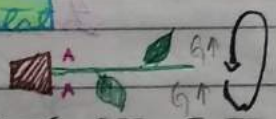
Heliotropic chamber



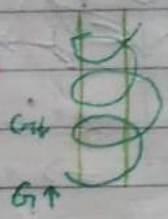
• Geotropism



Clinostat



• Thigmotropism
Tweenners
Tendrils



Due to touch

• Chemotropism

• Hydrotropism
stem = −H
or
root +H

• Aerotropism
• Pneumatophore

• Heliotropic chamber is used to study positive phototropism.

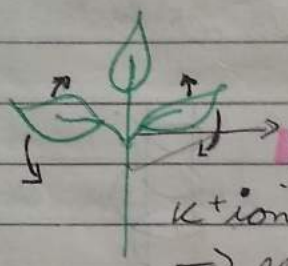
45° Plagiogeotropism	90° Diageotropic	
root, shoot branches	rhizome	runner
	below	above
	soil	soil

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

Curvature: Variation

Autonomous

- Desmodium gyrans



Motor cells

K^+ ions loss
=> flaccid

K^+ ion taken up
=> Turgid

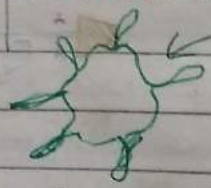
Induced

- Nyctinasty → sleeping movements
  Oxalis, Marsclia
  Photonastic (light)

Tulip → Temperature
Thermonastic

→ Thigmonasty → Touch

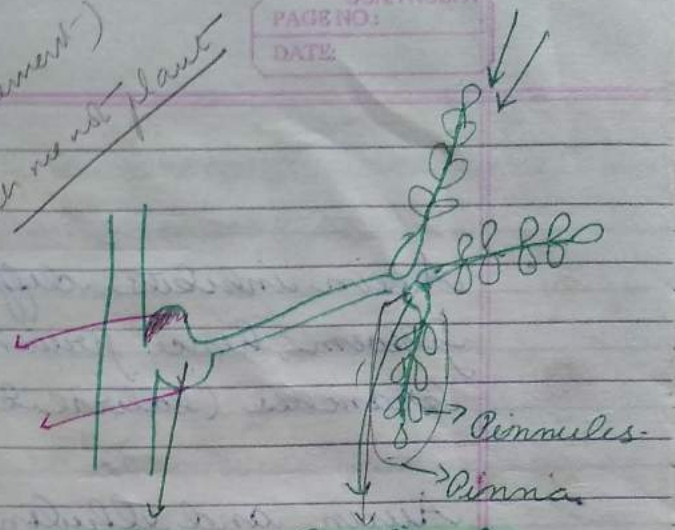
Insectivorous → Dionea
Drosera
Dinguicula



Leaf

3 Seismonasty (Shake movement) touch response plant

Mimosa Pudica



on touch.

Turgorin (Hormone)

↓

Pulvinus / Pulvinnules

↓

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 pectinase in separation layer of abscission zone.
- Traumatic acid is a type of auxin.
- Giberallic acid can cause elongation even in genetically dwarf variety of pea and maize.
- Only giberallic acid leads to formation of male flowers.
- Ethylene causes ripening only in climetric fruits.
- Ethylene cannot cause ripening in pineapple but it can initiate its rip flowering.
- Gr A 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.