PHYTOHORMONE

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MSC BOTANY

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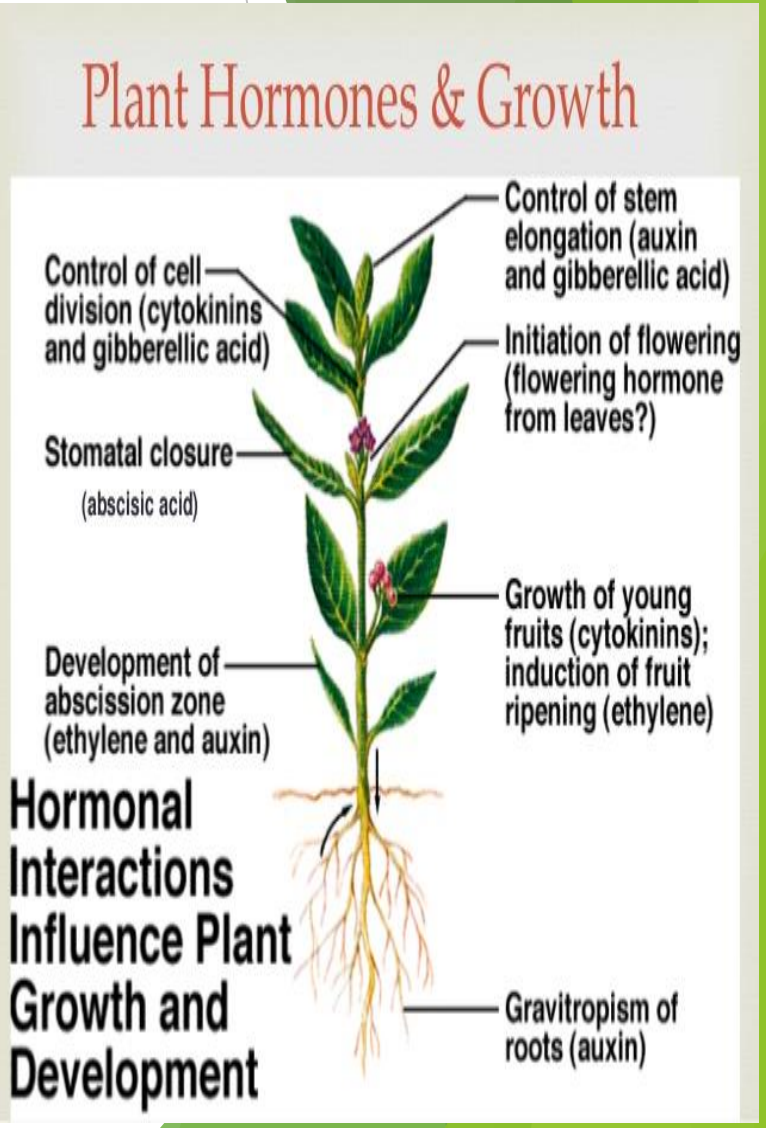
CONTENTS

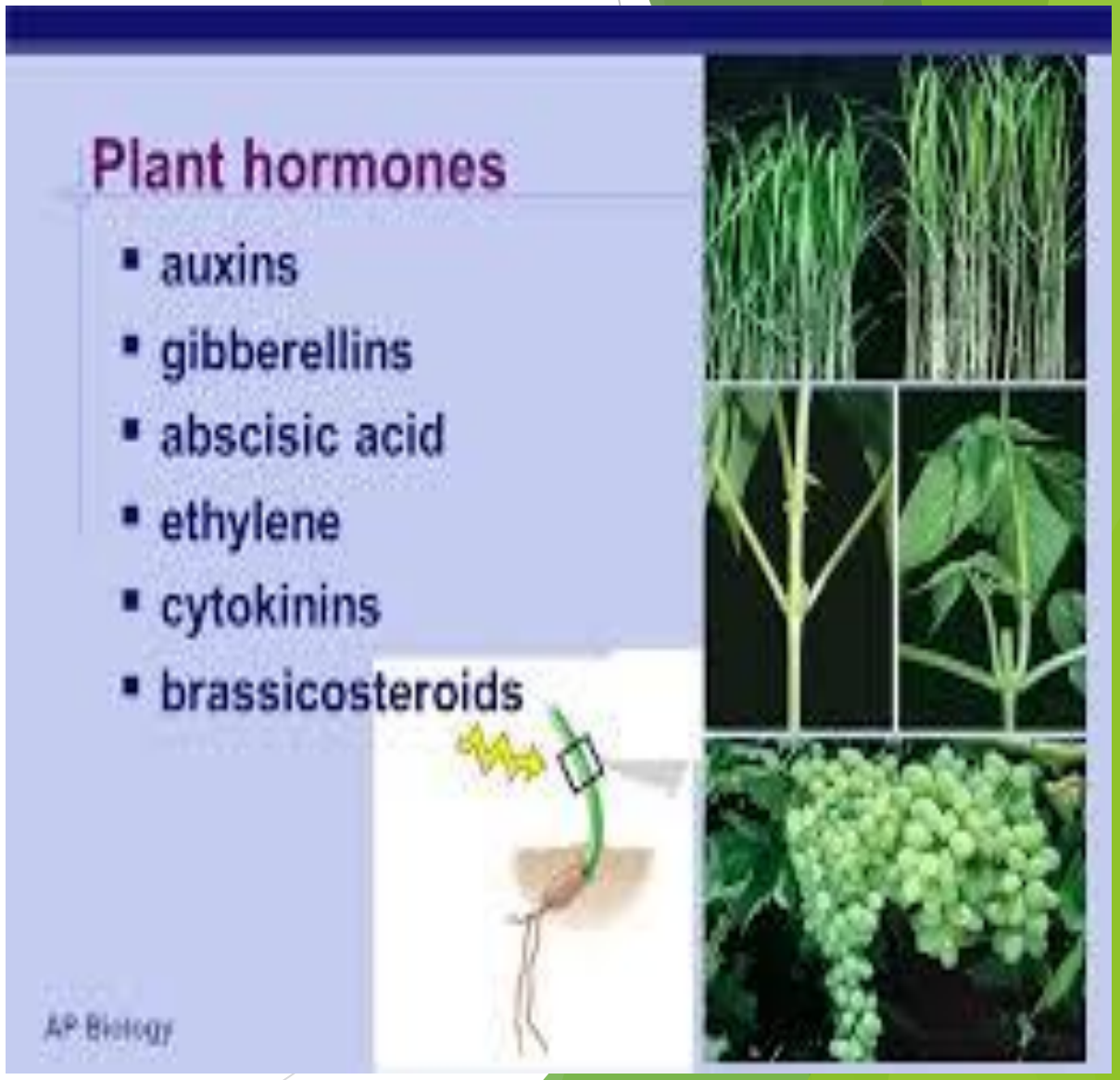
INTRODUCTION

- Phytohormones are chemical messengers that co-ordinates cellular activities.
- Phytohormones are signal molecule produced within plants, that occur in extremely low concentration (10^{-6} to 10^{-5}M).
- Plant hormone controls all aspects of growth and development from embryogenesis, the regulation of organ size, pathogen defense, stress tolerance and through to reproductive development.



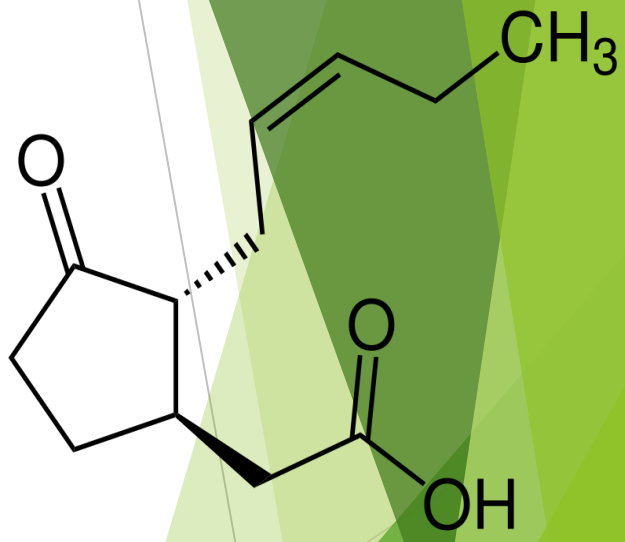
CLASSES

- Different hormone can be sorted into different classes, depending on their chemical structures.
- Initial research into plant hormone identified 5 major classes- auxin, abscisic acid, cytokinin, ethylene and gibberellins.
- This list was later expanded and jasmonic acid, salicylic acid, brassinosteroids are now considered as major plant hormone.



1) JASMONIC ACID

- Jasmonic acid are lipid based hormone that were originally isolated from jasmine oil.
- Jasmonic acid are especially important in the plant response to attack from herbivores and necrotrophic pathogens.
- It is further metabolized into methyl jasmonic acid, which is volatile organic compound.
- This unusual property means that methyl jasmonic acid can act as an airborne signal to communicate herbivore attack to other distant leaves within one plant and even as a signal to neighboring plants.



- In addition to their role in defense, Jasmonic acid are also delivered to play role in seed germination, the storage of protein in seeds and root growth.
- The highest level of jasmonic acid are reported in flowers and reproductive tissue, where as much lower level are found in roots and promote abscission.
- If concentration of jasmonic acid is greater than 50 induced senescense in plant culutre and this include degradation of chloroplast protein.

BIOSYNTHESIS

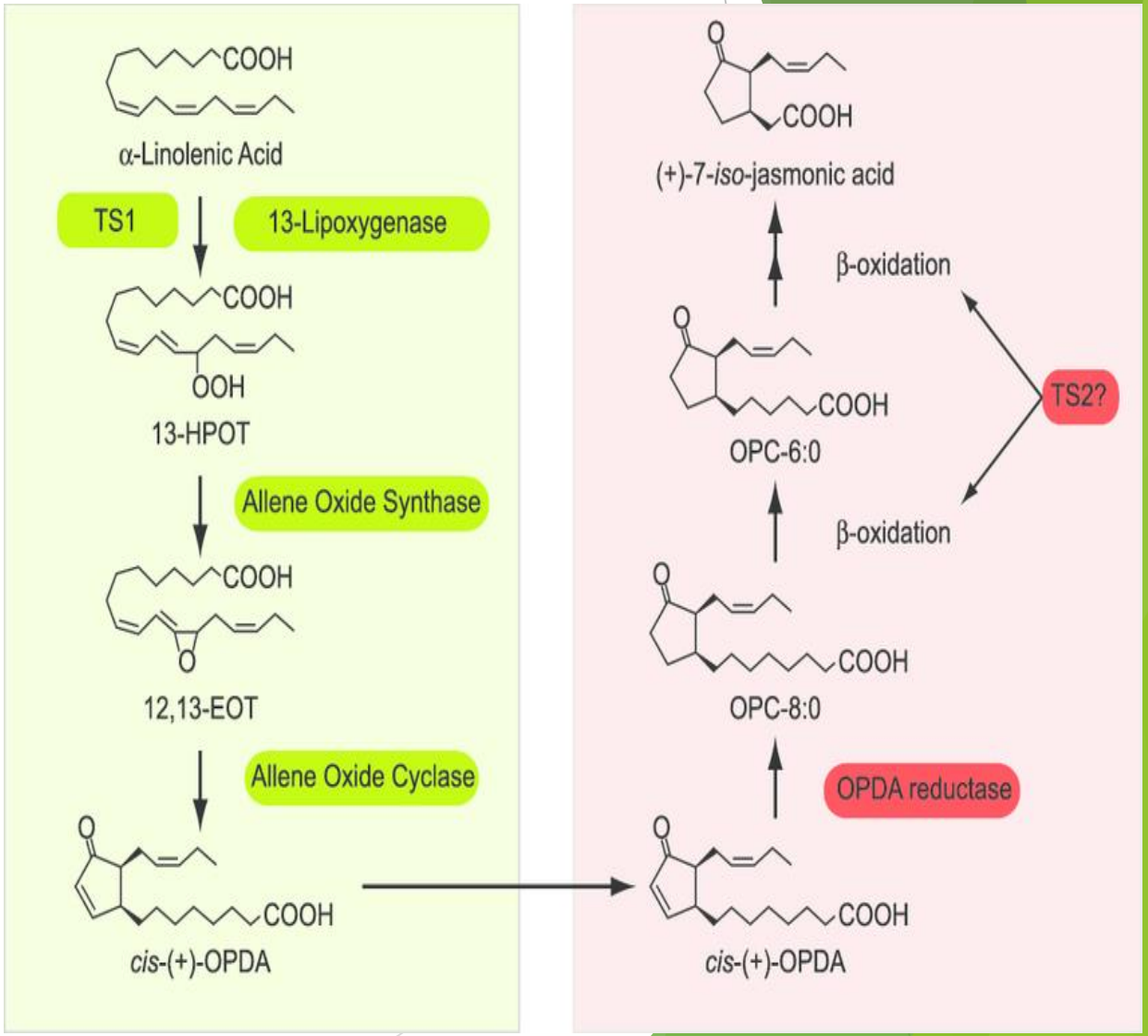
- Jasmonic acid is synthesized from linolenic acid by octadecanoid pathway. Linolenic is a fatty acid.

➢ It follows main five step-

1) Oxygenation
2) Cyclization
3) Rearrangment
4) Reduction
5) Beta oxidation

OCTADECANOID PATHWAY

- *α*–linolenic acid act as precusor molecule for jasmonic acid synthesis.
- In first step α-linolenic acid is oxygenated by enzyme **lipoxygenase** and this enzyme help to convert α-linolenic acid into peroxide (13-hydroperoxydecatrienoic acid).



- In second step there is cyclization in presence of **allen oxide synthase** and this peroxide convert into allene oxide.
- In third step allen oxide rearrangment by enzyme **allen oxide cyclase** and allen oxide convert into OPDA (12-Oxophytodienoic acid).
- Till this process all different steps occur in plant plastid (green box), where all the corresponding enzymes are localized and subsequent reactions occur in peroxisome (red box).
- In next step there will be reduction process with the help of **reductase** enzyme and series of 3 beta-oxidation and after that generation of jasmonic acid.

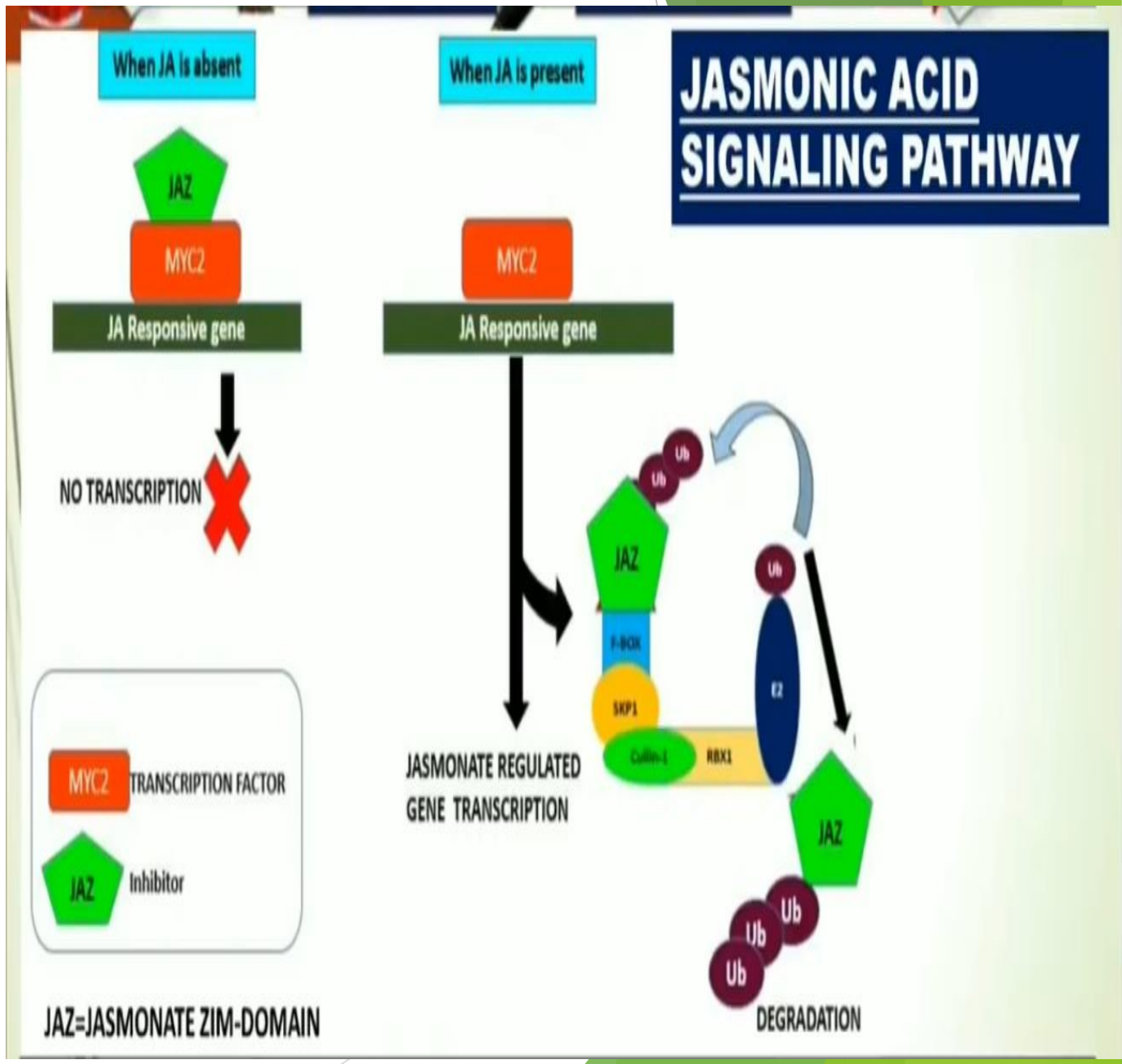
SIGNAL TRANSDUCTION

- Most bioactive form of Jasmonic acid is JA isoleucine.
- JA –isoleucine insensitive protein belong to highly conserved F-box protein that recruits substrate to Skp1, CUL1, f-box, E3 Ubiquitine ligase complex .This whole form a SCF Col 1 complex
- There is another protein called JAZ (JASMONATE-ZIM DOMAIN) transcriptional repressor and binds to MYC transciption factor.
- The complex of SCF Col1 and JAZ is receptor of JA signaling.

❑ WHEN JA IS ABSENT

JAZ is act as inhibitor. JAZ is bind with MYC2 and inhibit the overall expression of JA responsive gene and there will be no transcription .

No overall growth of plant that is depend upon Jasmonic Acid.



❑ WHEN JA IS PRSENT :

- JA is mediate the translocation of JAZ to ubiquitination. Now JAZ is ubiquitinated with ubiquitin protein and enter into 26 proteasome and finally degradation of this inhibitory protein (JAZ).

- Degradation of JAZ release MYC2 transcriptional factor from repression and induces expression of gene require for stress response.

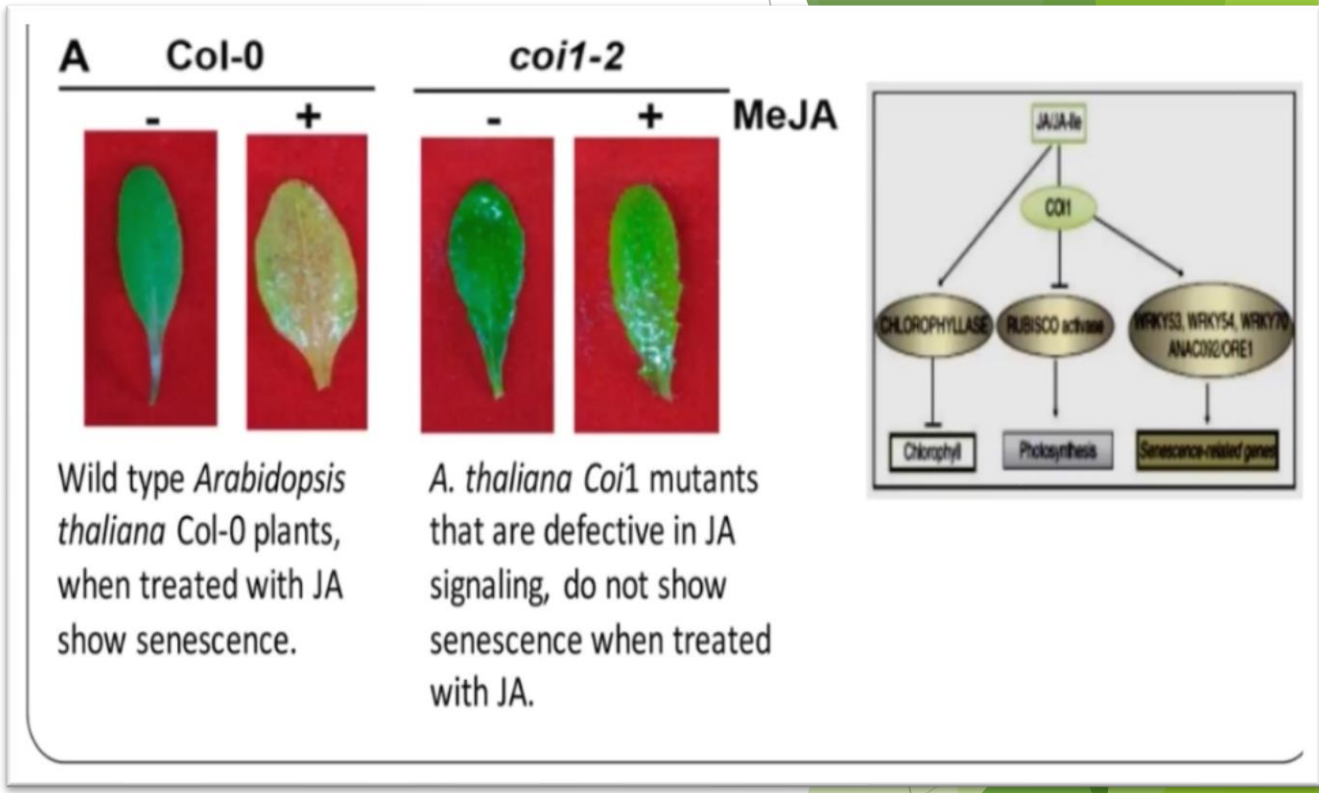
PHYSIOLOGICAL EFFECT OF JA

- **PHOTOSYNTHESIS**
  - JA decrease expression of gene that regulate photosynthesis **RUBPCase or RUBISCO** are two major photosynthesis enzyme down regulated after JA treatment.

- **GROWTH**
  - To promote growth bioactive JA binds to co-receptor and leads to 26S proteasome dependent degradation of repressor protein Della.
  - JA inhibit degradation of Della and arrest the growth.

❑ LEAF SENESCENCE

- Exogenous application of JA causes chlorosis that lead to senescence.
- JA interact many kinases and it involves in leaf senescence.
- JA repression of photosynthetic protein RUBISCO activase, responsible for leaf senescence in Arabidopsis .



- **GERMINATION AND SEEDLINGS**
  - Later known the intermediate biosynthesis pathway OPDA compound inhibit seed germination.
- **REPRODUCTIVE ORGAN**
  - JA are important for proper development of reproductive organ and show different phenotype in jasmonic insensitive organ.
  - sensitive mutant A.thalia showing male sterile phenotype.
  - JA insensitive tomato mutant Jal1 is sterile and doesn't develop seed.

2) BRASSINOSTEROIDES

- Brassinosteroides (BRs) are a class polyhydroxysteroides of that have been recognized as sixth class of plant hormones and may have utility as an responsive to induce apoptosis and inhibit growth.

- These brassinosteroides were first time explored nearly 40 years ago, when Mitchell et al. reported promotion in stem elongation and cell division by the treatment of organic extracts of rapeseed (Brassica napus) pollen.

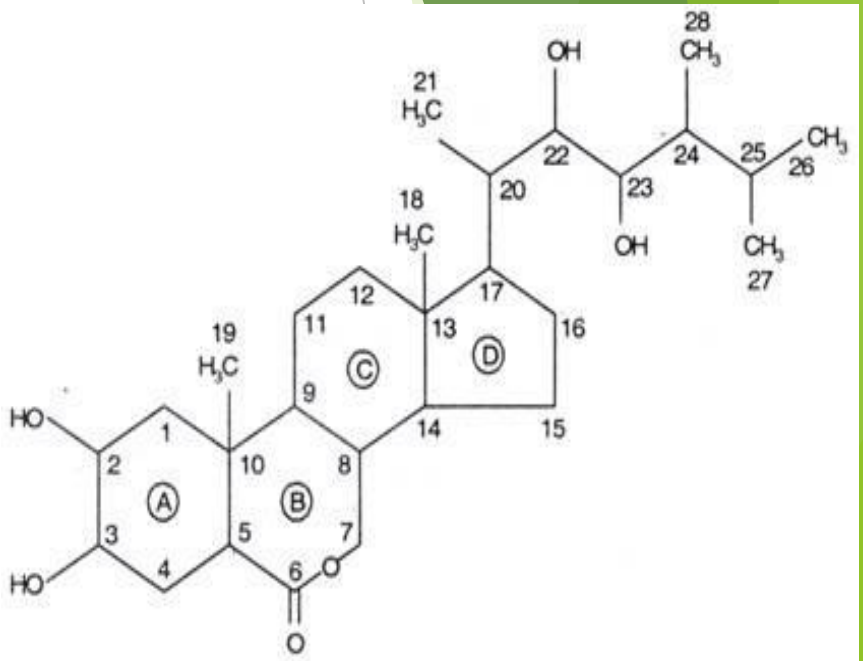


Fig. 17.33. Brassinolide.

- Brassinolide was the first isolated brassinosteroid in 1979, when pollen from Brasica napus was shown to promote stem elongation and cell division and biologically active molecule was isolated.
- Brassinosteroides regulate a wide range of physiological process including plant growth, development and immunity.
- Brassinosteroids are also involved in regulating the metabolism of plant oxidation, ethylene synthesis, and root gravitropic response.

BR BIOSYNTHESIS

- BRs are triterpenoides, ie. they are synthesized from C30 compound squalene.
- Campestenol is the first committed step in BR biosynthesis.
- Campestenol is hydroxylated and oxidized to forms brassinolide the active BR.

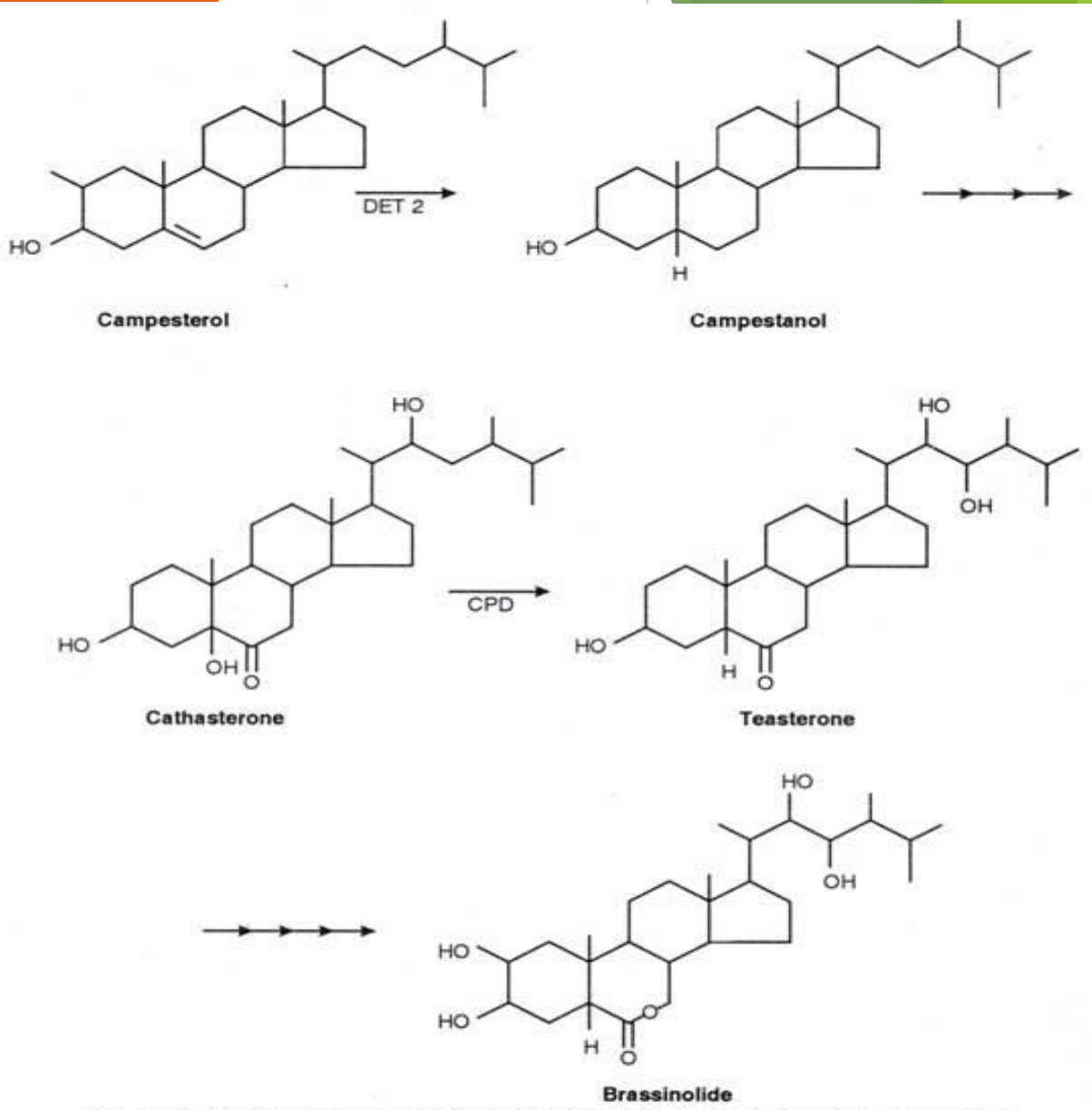
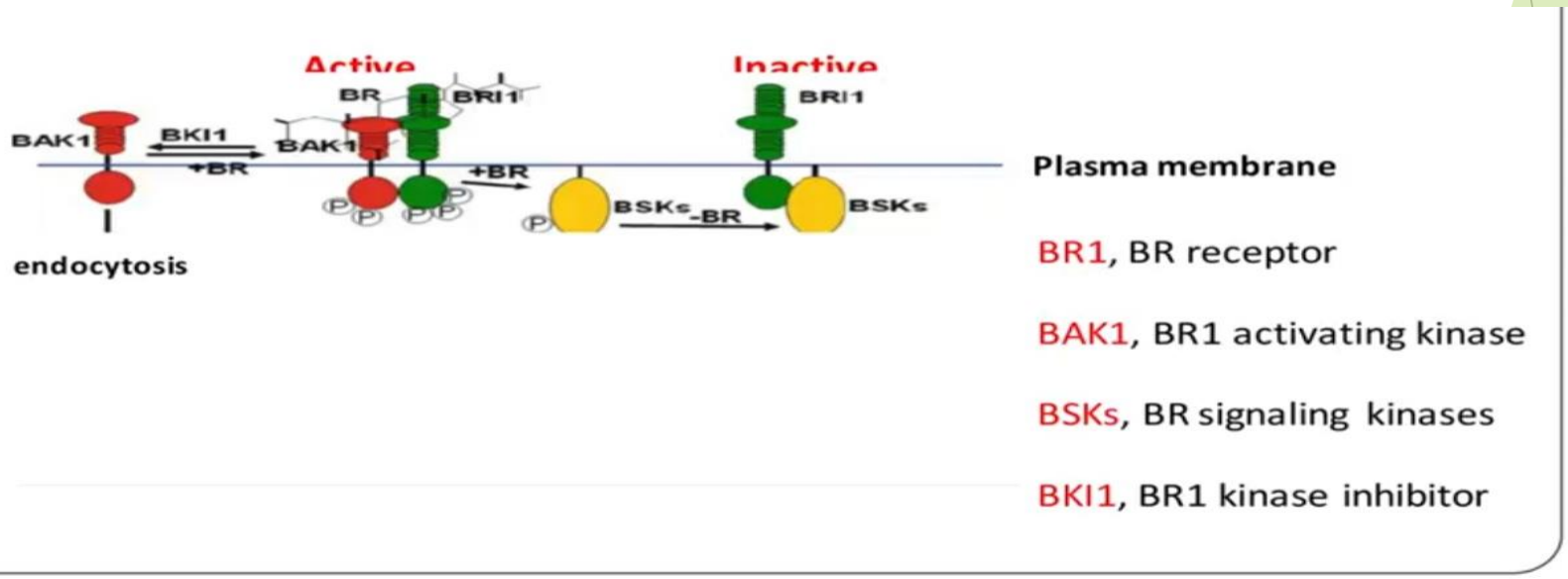


Fig. 17.34. Biosynthetic pathway for a brassinosteroid, **brassinolide** from campesterol.

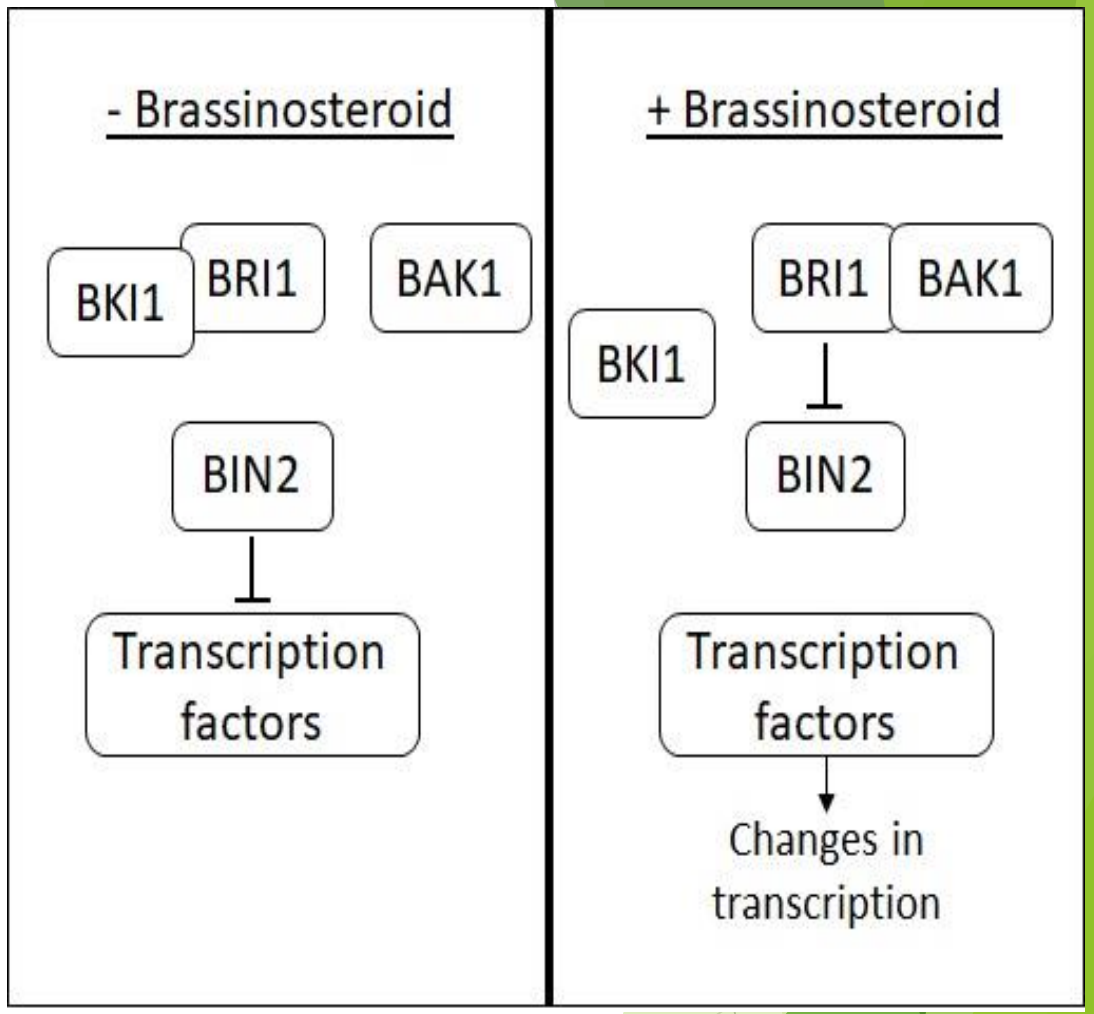
BR SIGNALING

- BRs are perceived at the cell membrane by a co-receptor complex, comprising BRASSINOSTEROIDE INSENSITIVE1 (BRI1) and BRI-ASSOCIATED RECEPTOR KINASE 1(BAK1).
- BRI1 act as **kinase**, but in the absence of BR its action is inhibited by another protein, **BRI1 KINASE INHIBITOR 1 (BKL1).**



- When BR binds to the BRI1:BAK1 complex, BKI1 is released, and a Phosphorylation cascade is triggered which results in the de-activation of another kinase, Brassinosteroid cascade2 (BIN2).

- BIN2 and its close homologues inhibit several transcription factor. The inhibition of BIN2 by BR releases these transcription factors to bind to DNA and to enact certain developmental pathways.

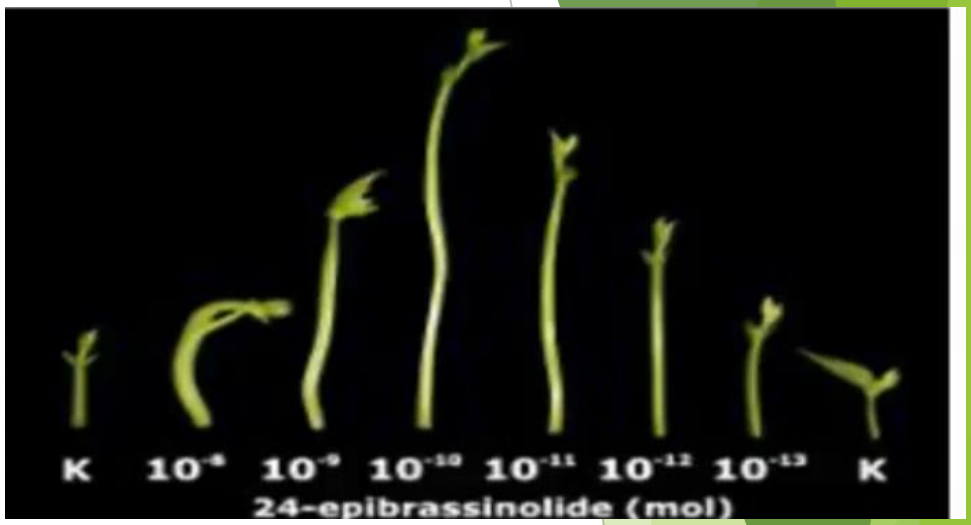


Brassinosteroid signal cascade:

BR- PHYSIOLOGICAL RESPONSES

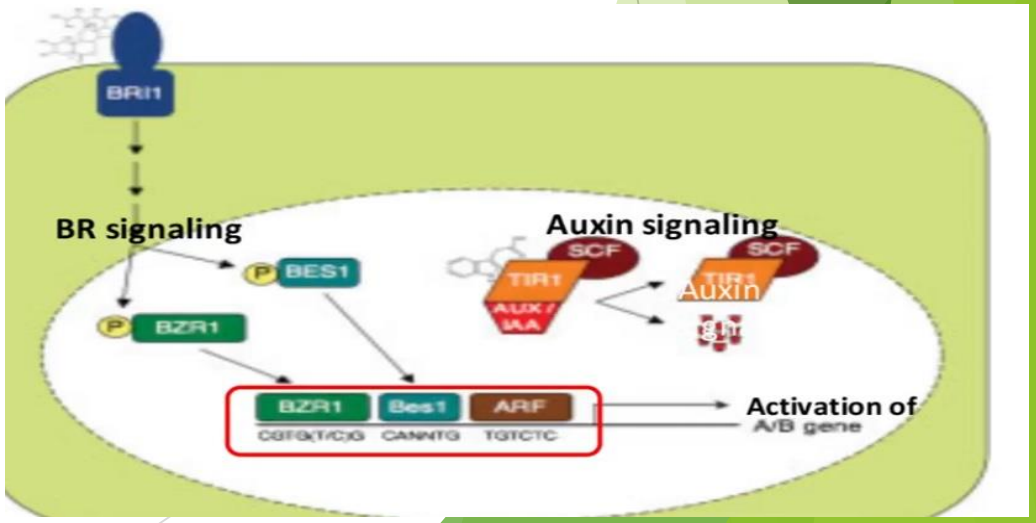
1 CELL ELOGATION

- A dose response is seen with lower concentrations of BR being growth promotory and high concentrations being growth inhibitory. (K= control)



2 BR-AUXIN CROSSTALK

- A/B genes contain target sites for auxin responsive transcription factor(ARFs) and BR responsive transcription factor(BES1/BZR1)

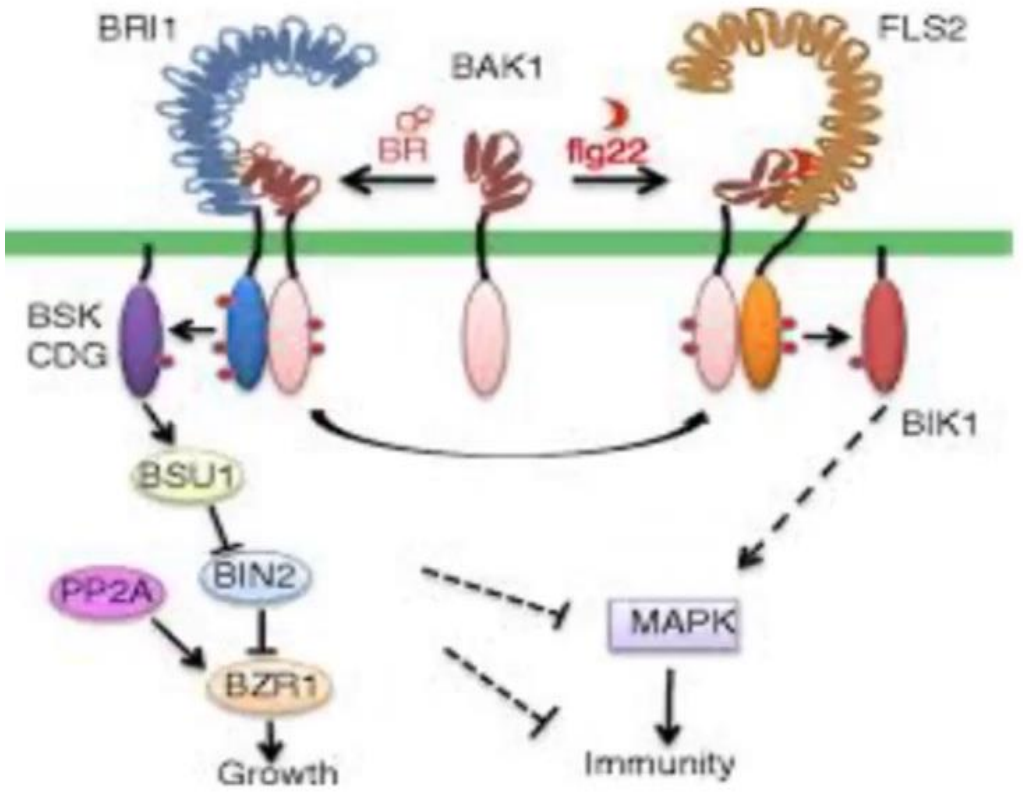


3) BR-IMMUNE RESPONSES

- BR activated **kinase** BAK1 binds to BR receptor BRI1or a micobe ligand (flagellin) receptor FLS2

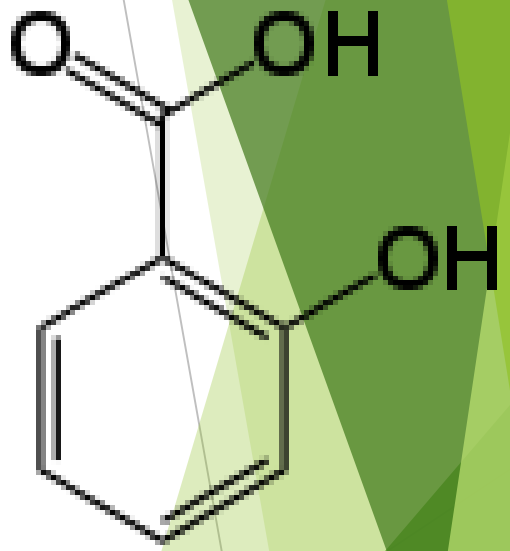
- When flagellin binds to FLS2, the receptor recruits BAK1 and is phosphorylated.

- Activated FLS2 phosphorylates the receptor like kinase BIK1 present in the cytoplasm and activates gene related to immunity.



3) SALICYLIC ACID

- Salicylic acid is a lipophilic monohydroxybenzoic acid, a type of phenolic acid, and a beta hydroxy acid (BHA). It has the formula $C_7H_6O_3$.
- This colorless crystalline organic acid is widely used in organic synthesis and functions as a plant hormone. It is derived from the metabolism of Salicin.
- It is reported in several plat species like tomato, potato, pea, sunflower etc.
- Salicylate regulated defenses more active against biotrophic pathogens.



BIOSYNTHESIS OF SALICYLIC ACID

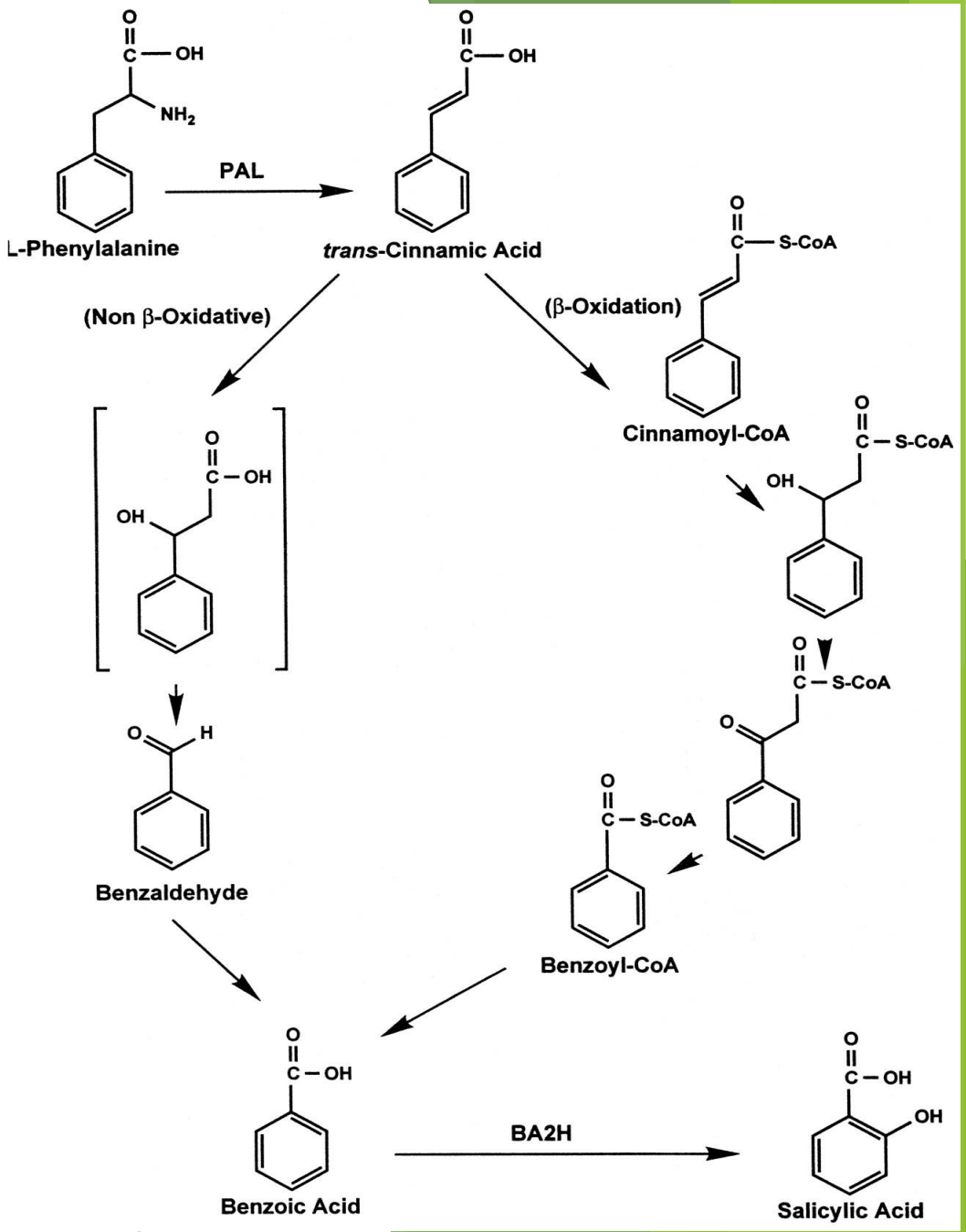
- **Salicylic acid synthesizes by two pathways:**

  - Phenylalanine Ammonia Lyase pathway (PAL Pathway)
  - Isochorismate pathway (IC Pathway)

Chorismic acid is used as precursor in both the pathways.

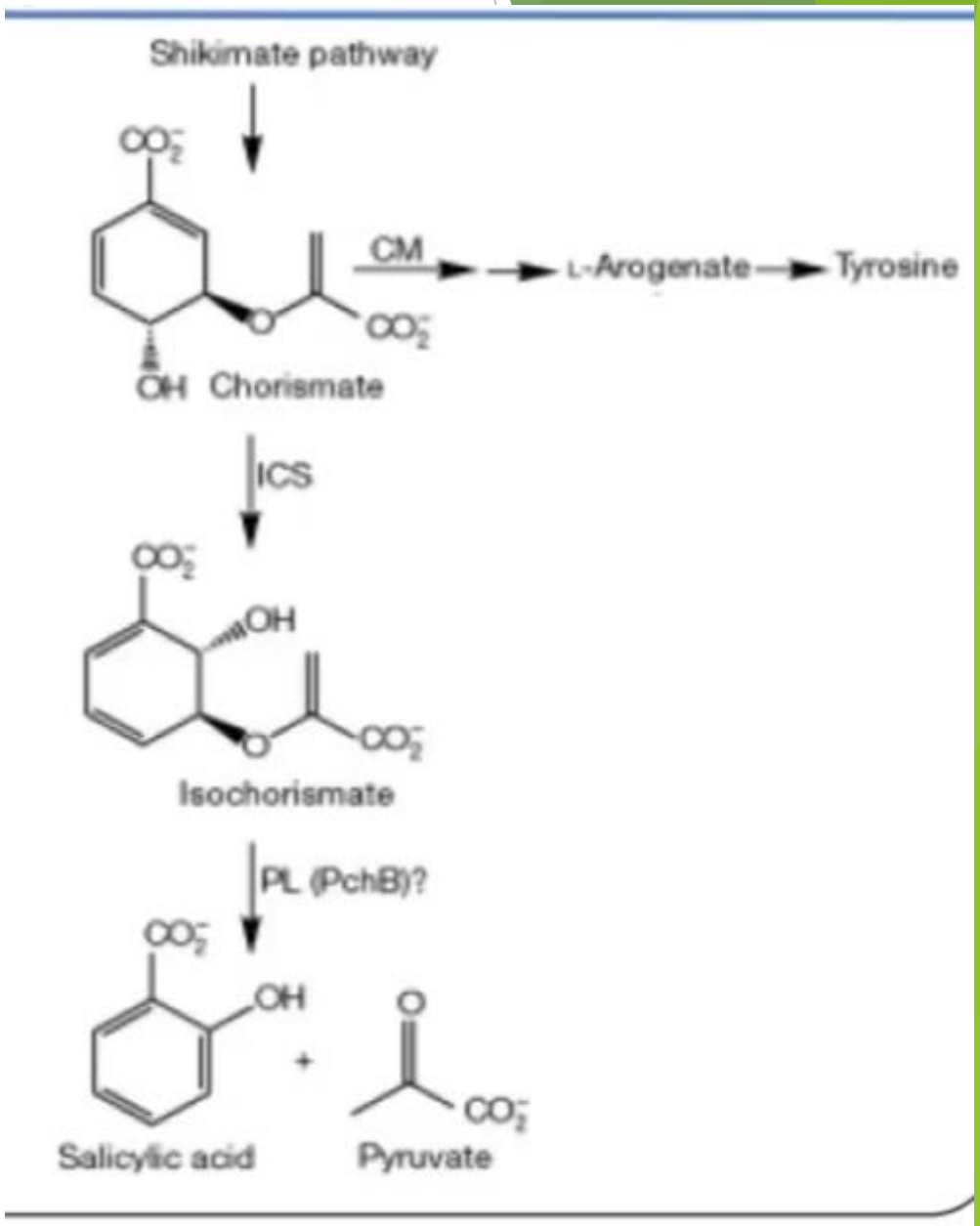
❑ Phenyalanine Ammonia Lyase (PAL Pathway)

- **PAL** is first enzyme of PAL pathway.
- **PAL** convert phenyalanine to trans-cinnamic acid and ammonia by non oxidative deamination reaction.
- Trans-cinnamic acid is converted to o-coumaric acid, benzoic acid (BA) or cinnamoyl-Co-A a three possible intermediate of SA depending upon plant species.



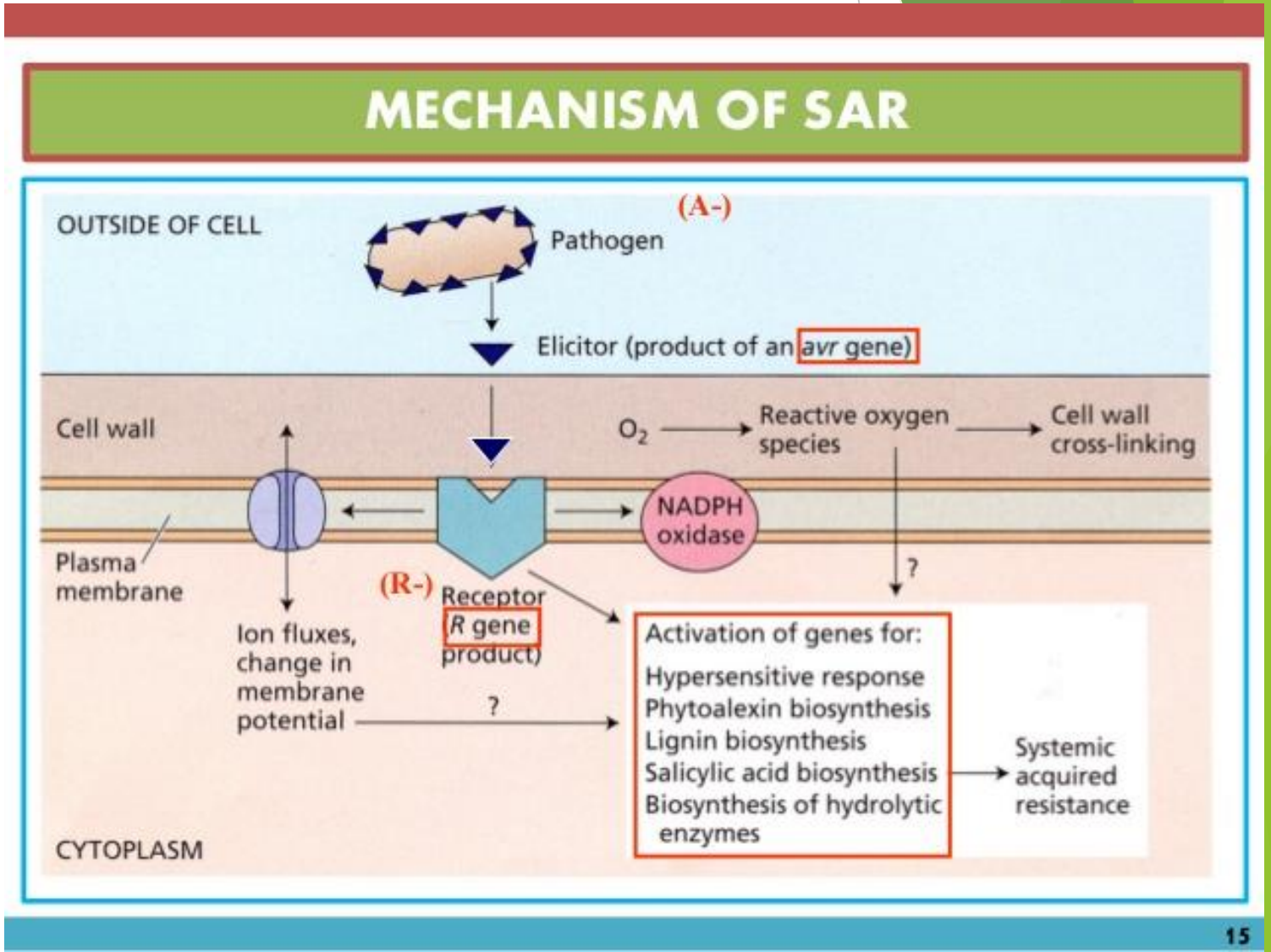
❑ Isochorismate Pathway (IC Pathway):

- Chorismate is synthesized in chloroplast.
- In bacterial species chorismate is isomerizes to isochorismate by **isochorismate synthase (ICS).**
- IC is furthur converted to SA and pyruvate by the enzyme **isochorismate pyruvate lyase**.



SALICYLIC ACD SIGNALING AND MECHANISM OF GENE REGULATION

- **ELICITORS**
  - Molecules produced by pathogen that induce a defense response by the host.
  - Innate immunity on plant rely on rapid cytosolic disease resistance proteins (R protein), which perceive pathogen protein known as elicitors.

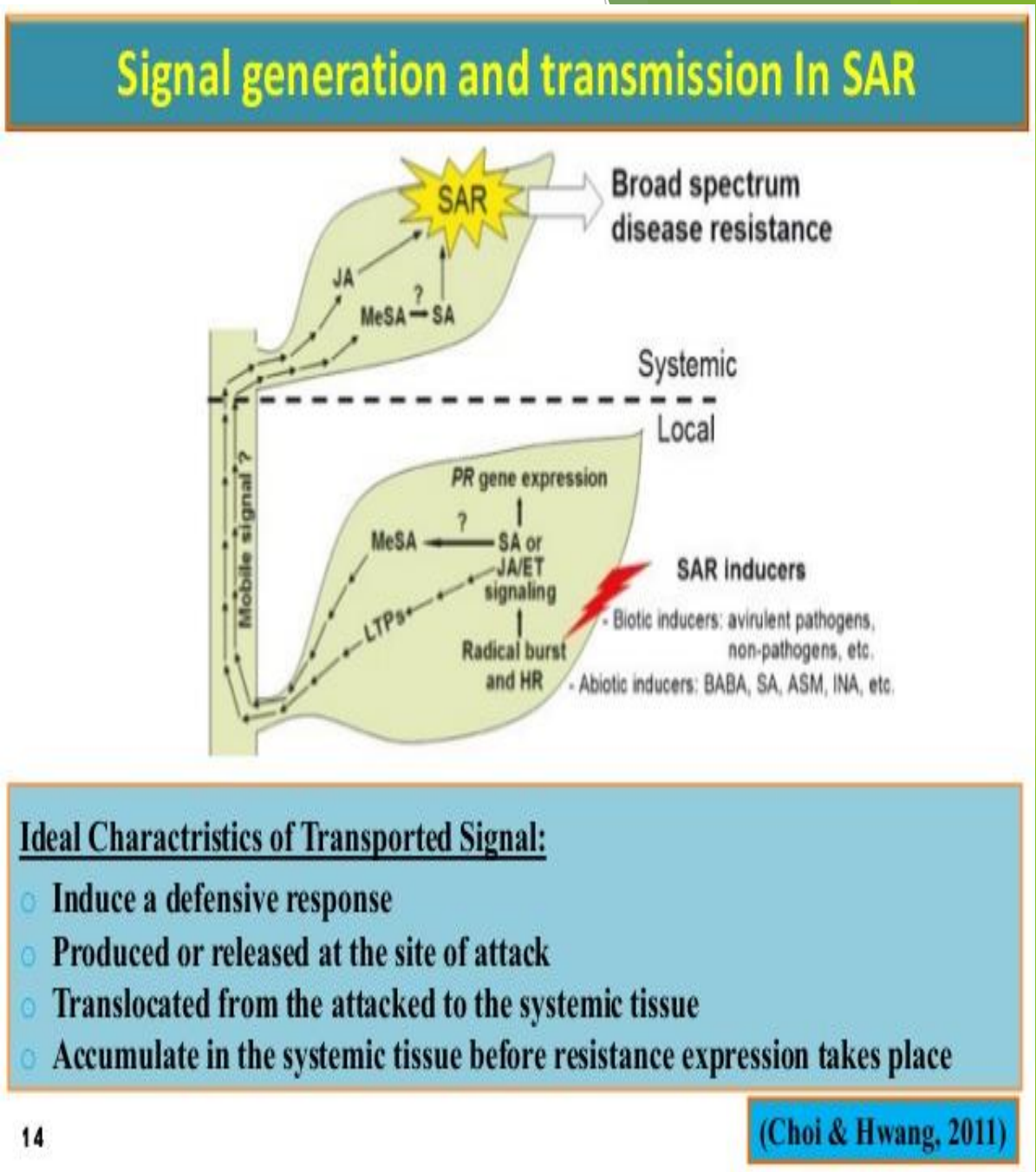


- In compatible host pathogen interaction, the elicitor escapes recognition by an R protein, leading to development of disease.
- In incompatible reaction elicitors is recognized by R protein, triggering a cascade of defence reactions that leads to programmed cell death or apoptosis, which is hypersensitive response.

REACTIVE OXYGEN SPECIES

- Hydrogen peroxide accumulates in small groups of cell in uninoculated leaves of Arabidopsis after infection with an avirulent strain of P. syringae.

- Systemic acquired Resistance (SAR): signals from the infected leaf transmitted in the uninfected plant parts.
- Signals transmission takes place via phloem.
- Major signal: SA
- Long distance signal: MeSA
- SA signaling network: upstream and downstream signals.



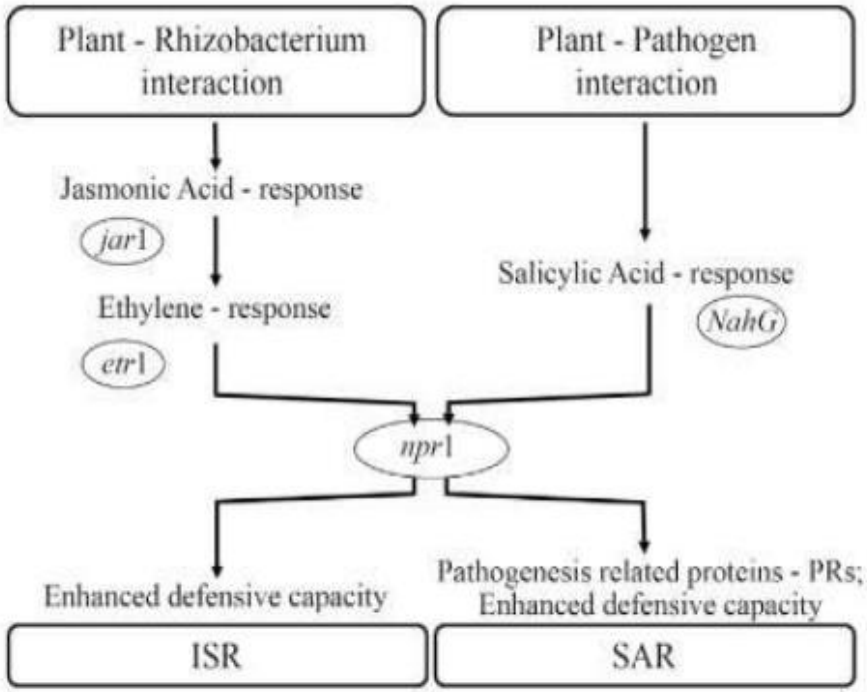


Figure 1 - Signal transduction pathways leading to pathogen-induced systemic acquired resistance (SAR) and rhizobacteria-mediated induced systemic resistance (ISR) in *Arabidopsis thaliana*. *Modified from*: Van Loon *et al.*, 1998.

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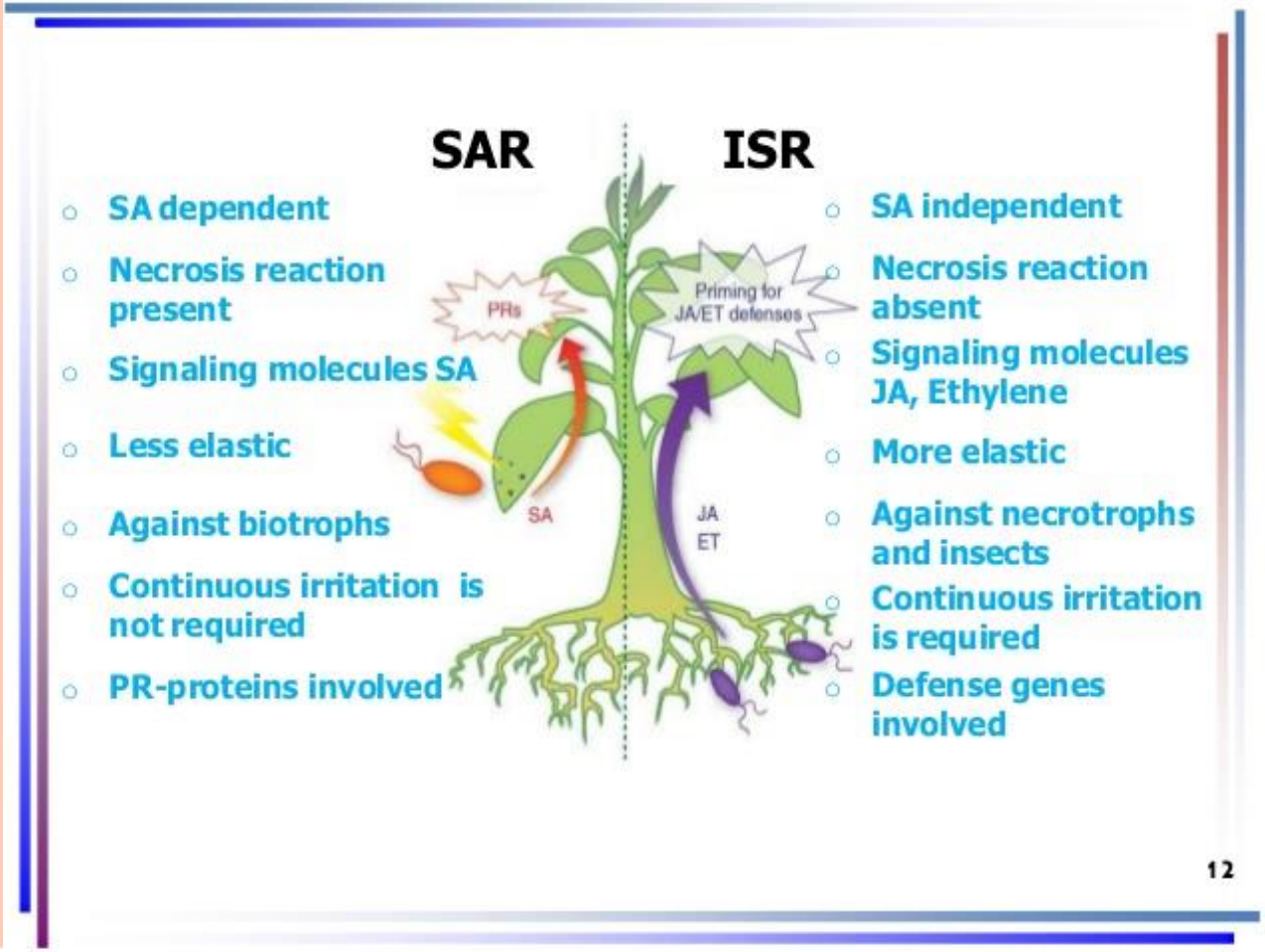
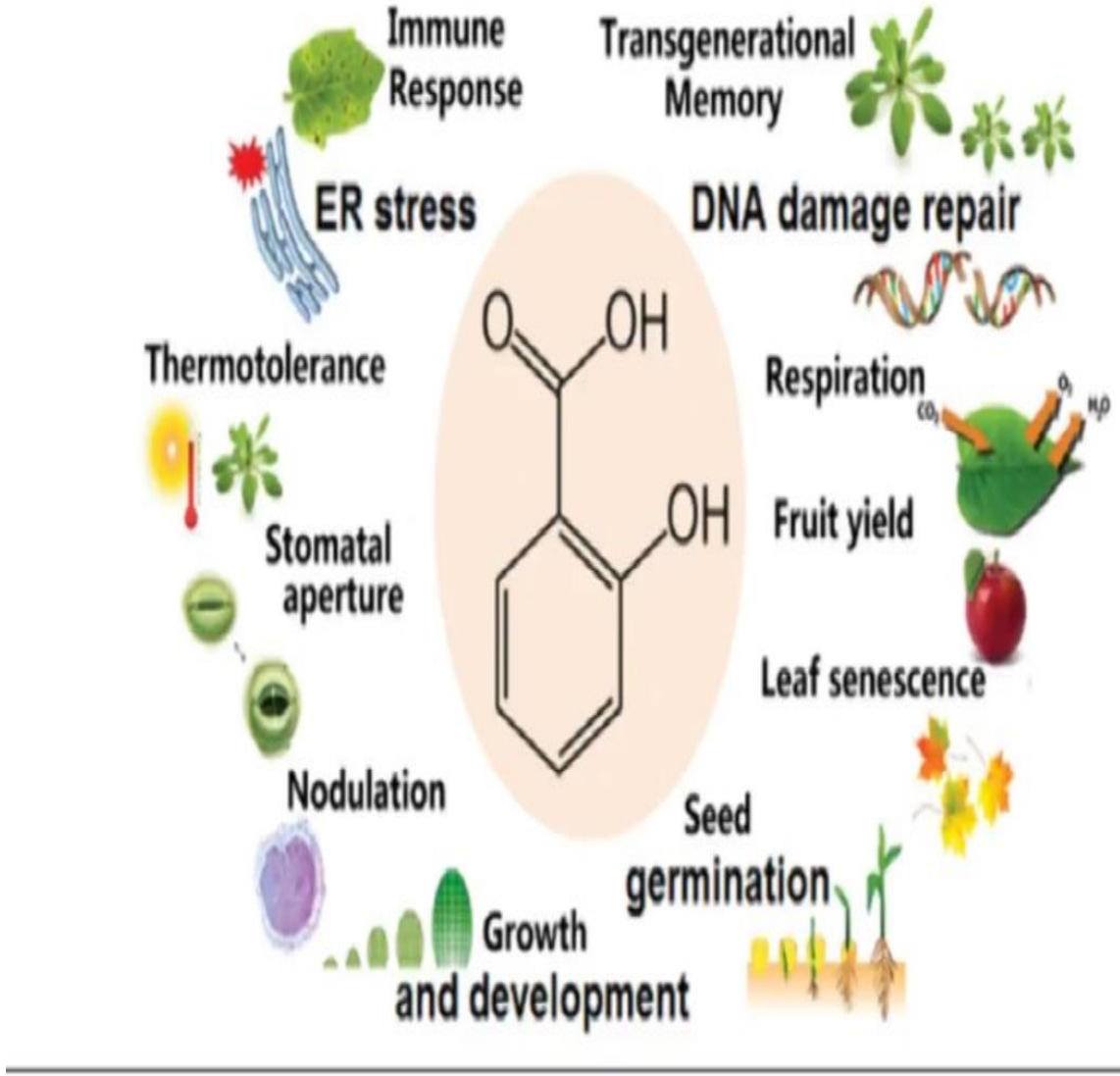


Physiological effects of Salicyclic acid

- Salicylic Acid is directly or indirectly influence the various vital processes like seed germination, seedling establishment, respiration, stomatal closure and leaf senescence etc.



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- Picture source: **Google.com**

Thank you