第五节 脱落酸（ABA）

1964年，美国**Addicott**等从将要脱落的未成熟的棉桃中提取一种促进脱落的物质，命名为脱落素Ⅱ（**abscisin Ⅱ**）。

1963年，英国Wareing从槭树将要脱落的叶子中提取一种促进休眠的物质，命名为休眠素（dormin）。

后来证明为同一种物质。**1967**年命名为脱落酸（**abscisic acid**，**ABA**）。

ABA为单一的化合物，是一种倍半萜结构

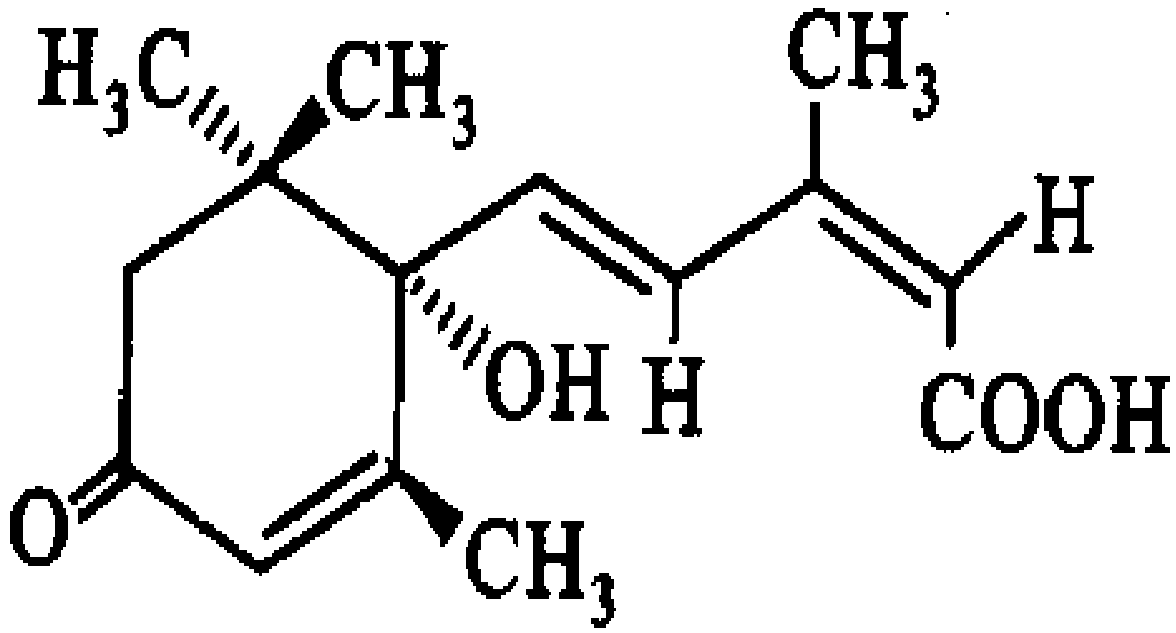
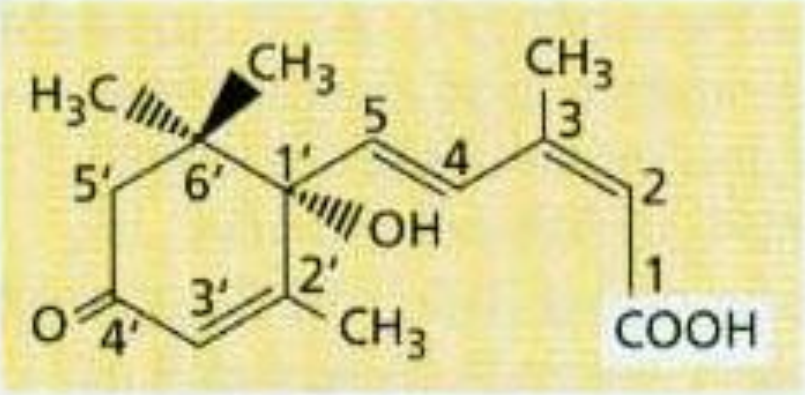
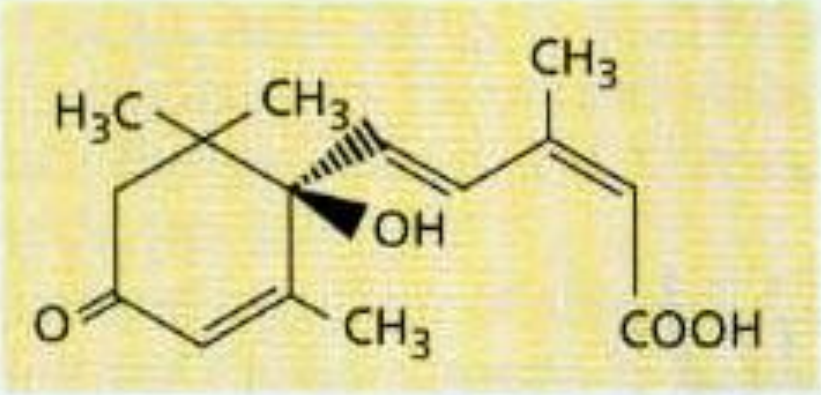


图 6－4　ABA 分子的化学结构

两种旋光异构体：右旋型（以+或S表示）与左旋型（以－或R表示）。两种几何异构体：顺式和反式。植体内的主要是顺式右旋型。



(*S*)-*cis*-ABA
(naturally occurring active form)



(*R*)-*cis*-ABA
(inactive in stomatal closure)

右旋顺式－**ABA**

一、ABA的生理作用

1、促进脱落

2、促进休眠

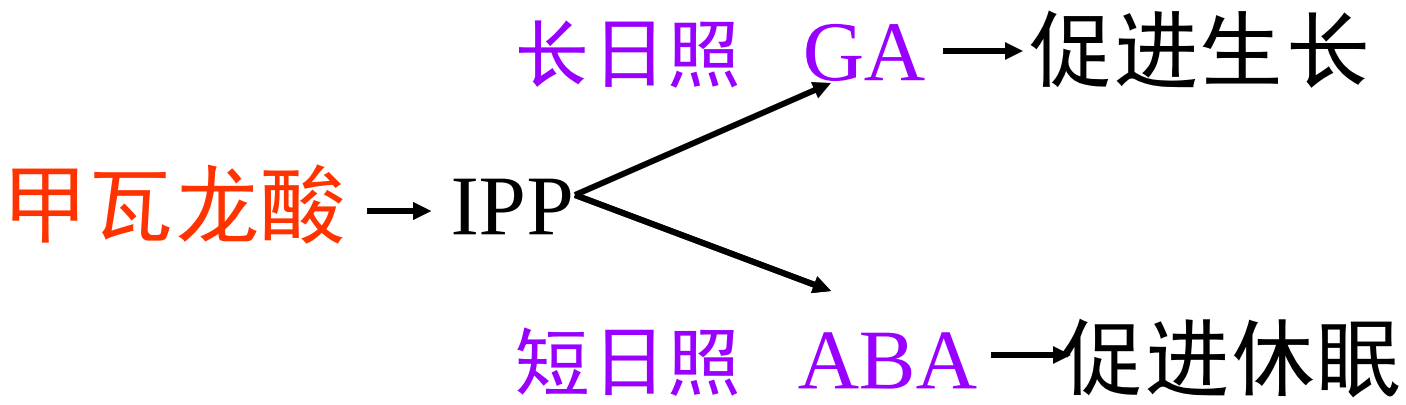
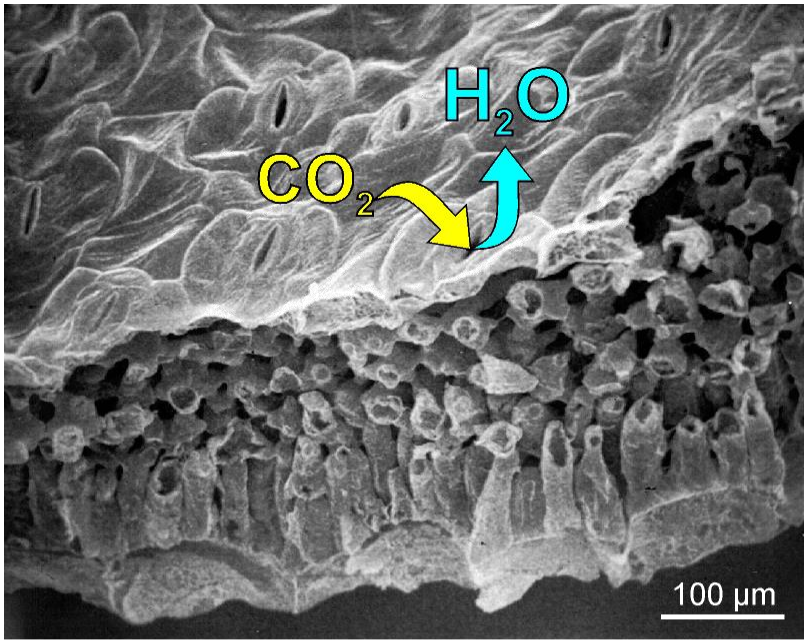
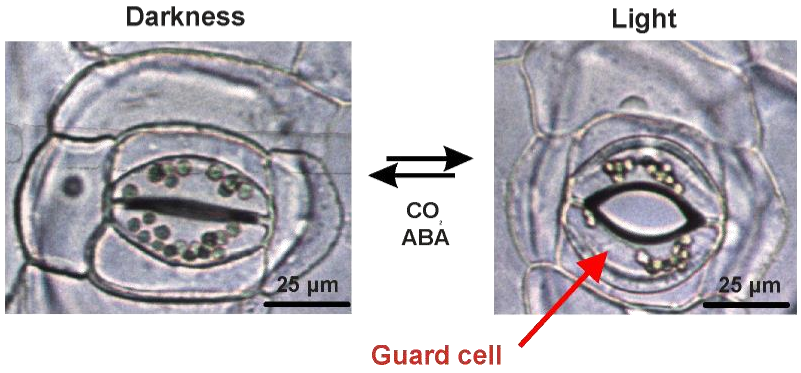
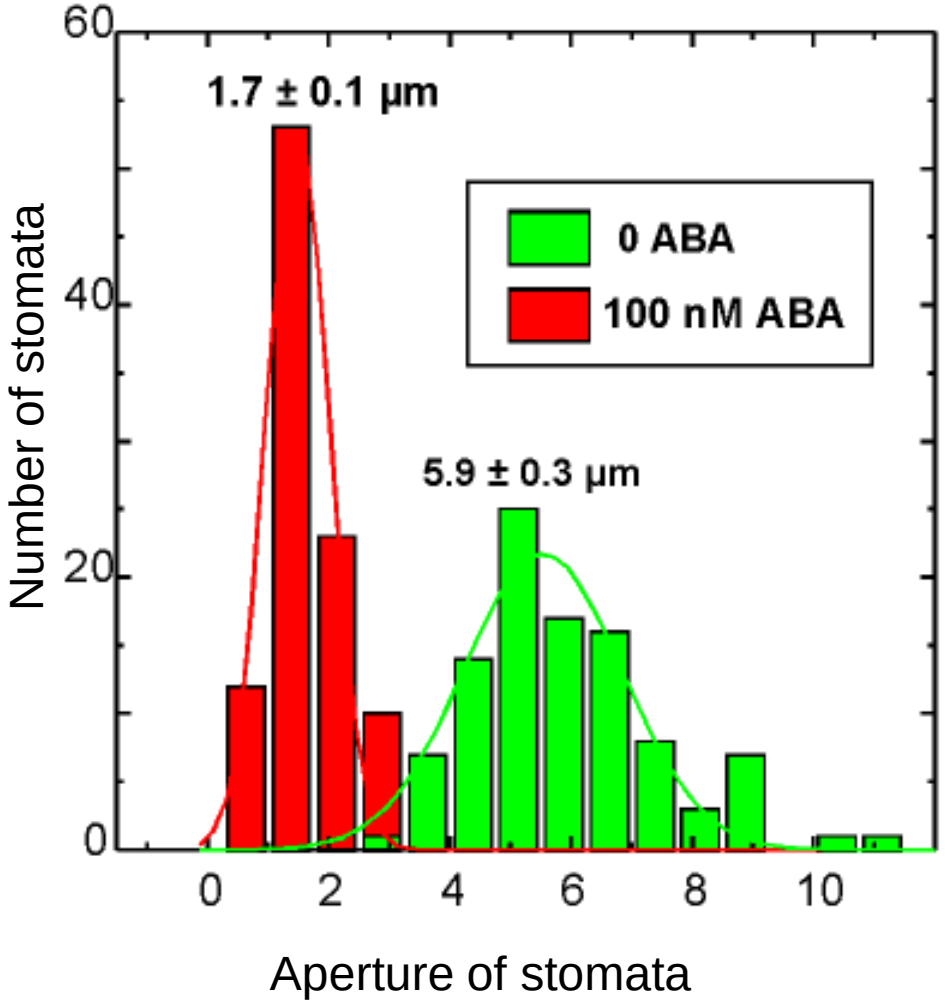


FIGURE 36–18 Inability to produce abscisic acid can prevent seed dormancy in corn. Some of the white kernels have germinated prematurely, while still on the ear, producing white roots (*arrows*). (Courtesy of M.G. Neuffer)

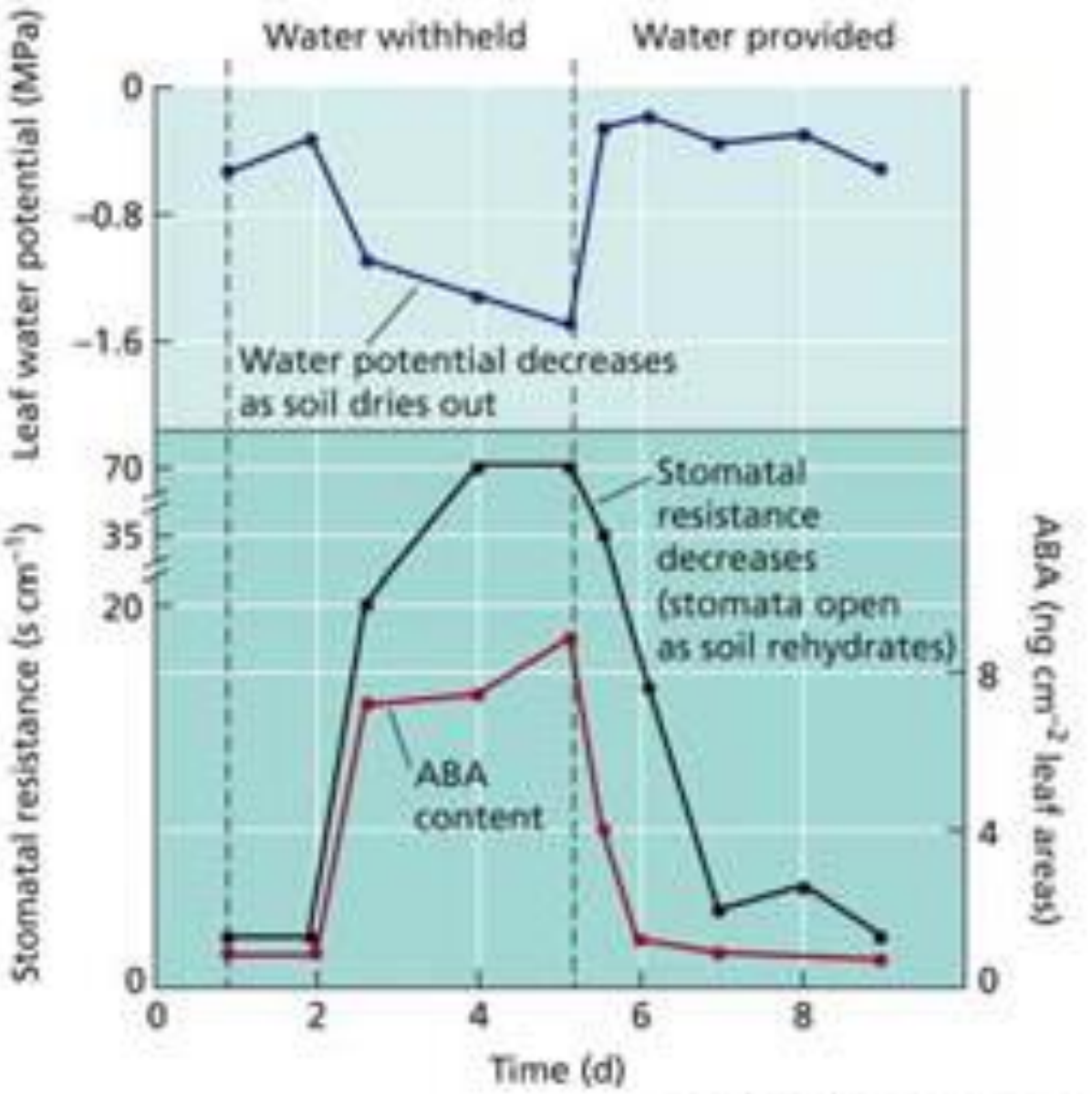
3、促进气孔关闭（close stomata ）



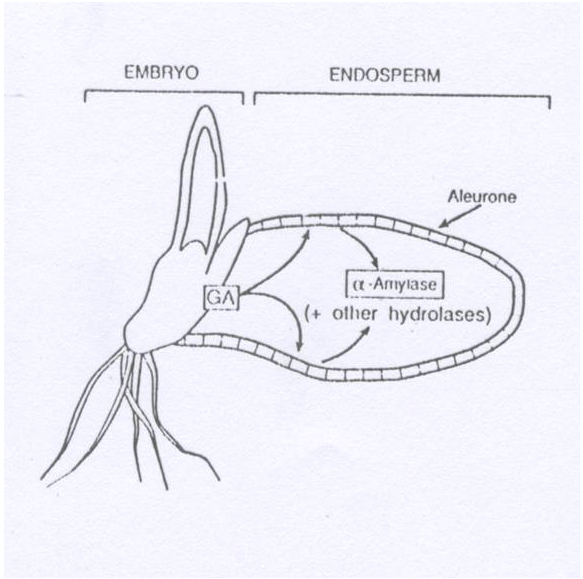


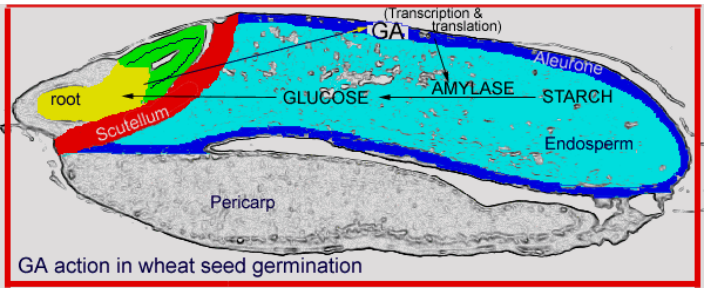


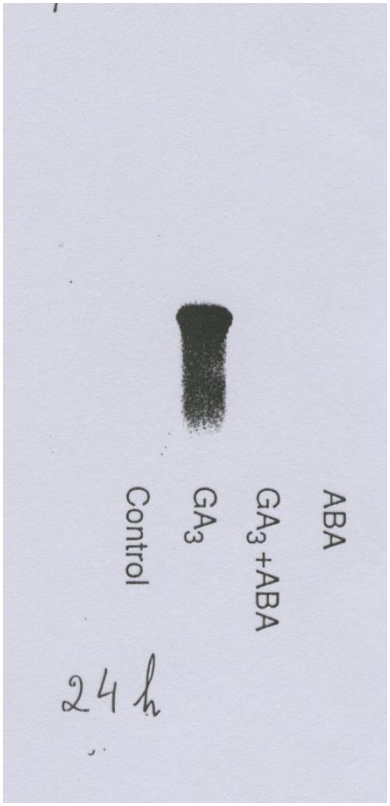
4、提高抗逆性——“应激激素”或“逆境激素”



ABA抑制：种子萌发







α-淀粉酶基因表达

二、分布、运输

存在于全部维管植物，包括被子植物、裸子植物和蕨类植物。各器官和组织都有存在，在脱落和休眠的组织和器官中较多。

逆境条件下含量会迅速增加。

非极性运输

ABA 作为土壤干旱信号影响叶片水分代谢

- 正常供水条件下，木质部ABA在pH6.3左右以非解离状态为主ABAH，易进入叶肉细胞，而分配到保卫细胞的量较低。气孔不关闭
- 干旱条件下，木质部碱化，pH7.2，ABA^-。不易进入叶肉细胞，而分配到保卫细胞的量较高，气孔关闭

水分胁迫是木质部汁液碱化导致叶片ABA再分布

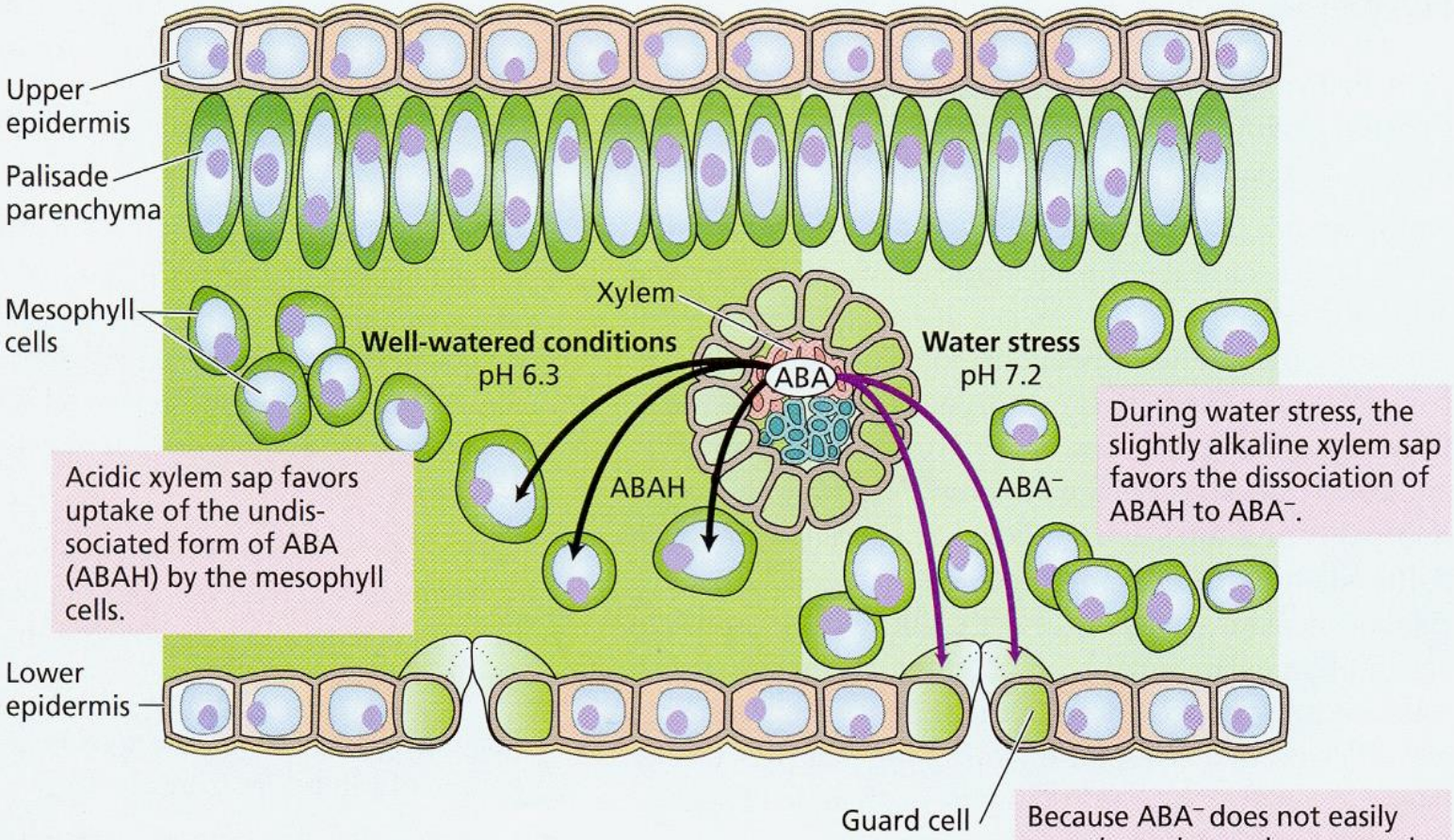


FIGURE 23.4 Redistribution of ABA in the leaf resulting from alkalinization of the xylem sap during water stress.

土壤干旱 ？？⟶ 气孔关闭

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FIVE CROP RESEARCHERS WHO COULD CHANGE THE WORLD

The current crisis in worldwide food prices reinforces the need for more productive agriculture. **Emma Marris** meets five ambitious scientists determined to stop the world from going hungry.

The thriving peasant

Zhang Jianhua

Plant physiologist at Hong Kong Baptist University

Timescale for change: now

Research on water-saving crop production

三、ABA的代谢和运输

（一）生物合成

部位：主要在根尖和叶片细胞的质体内。

前体：甲瓦龙酸

合成途径：

甲瓦龙酸 C_5

↓

异戊烯基焦磷酸

↓

法呢焦磷酸 C_{15}

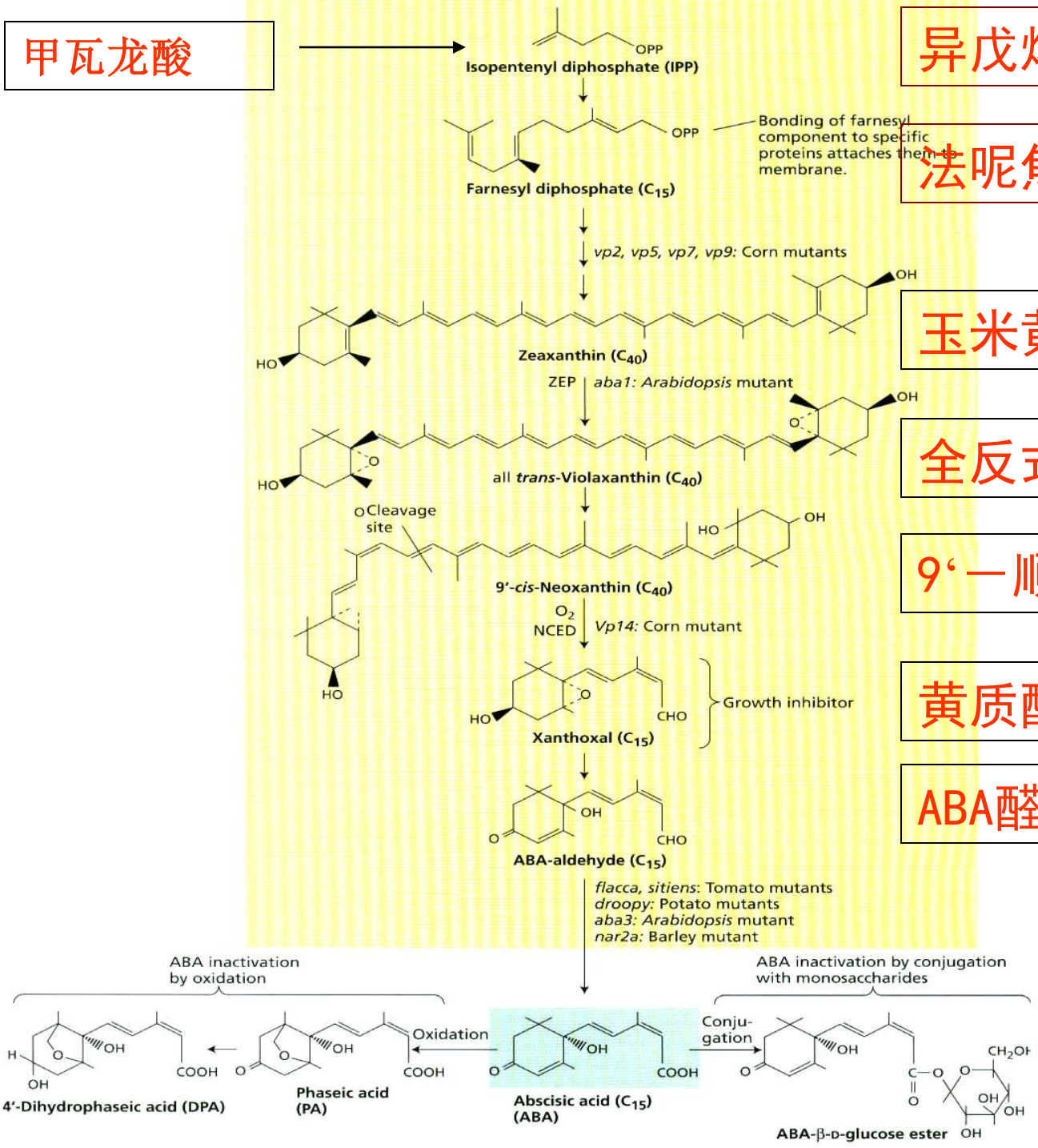
↓

ABA

↓

直接途径

甲瓦龙酸



异戊烯基焦磷酸

法呢焦磷酸

玉米黄素

全反式堇菜黄素

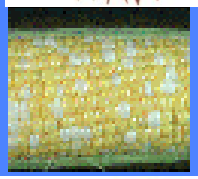
9'—顺—新黄素

黄质醛

ABA醛

Carotenoids

(类胡萝卜素，呈现黄、橙、红类:terpene）



lycopene

β-carotene

HO

zeaxanthin

（玉米黄质）

Violaxanthin(紫黄素）

Capsanthin （辣椒红素）

代谢

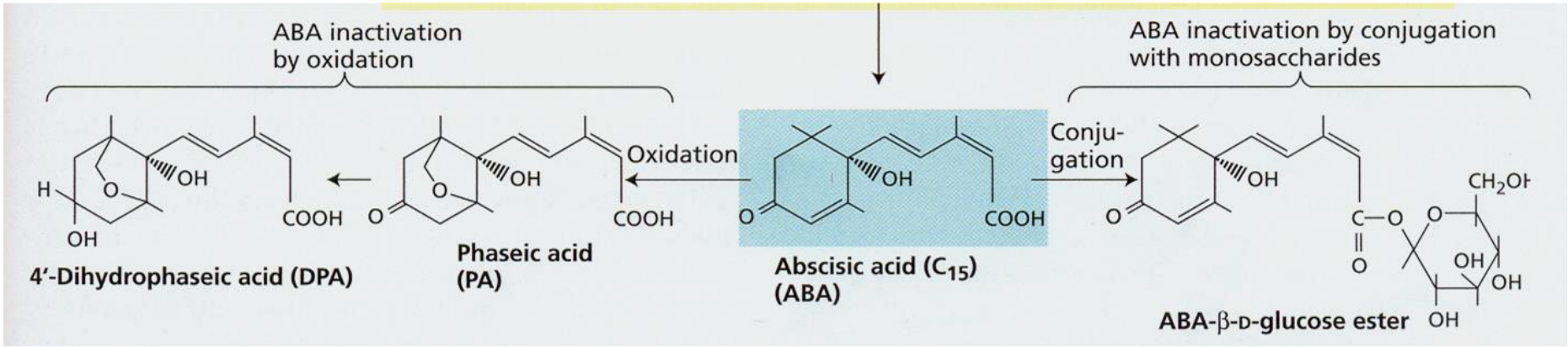
红花菜豆酸 ⟶ 二氢红花菜豆酸

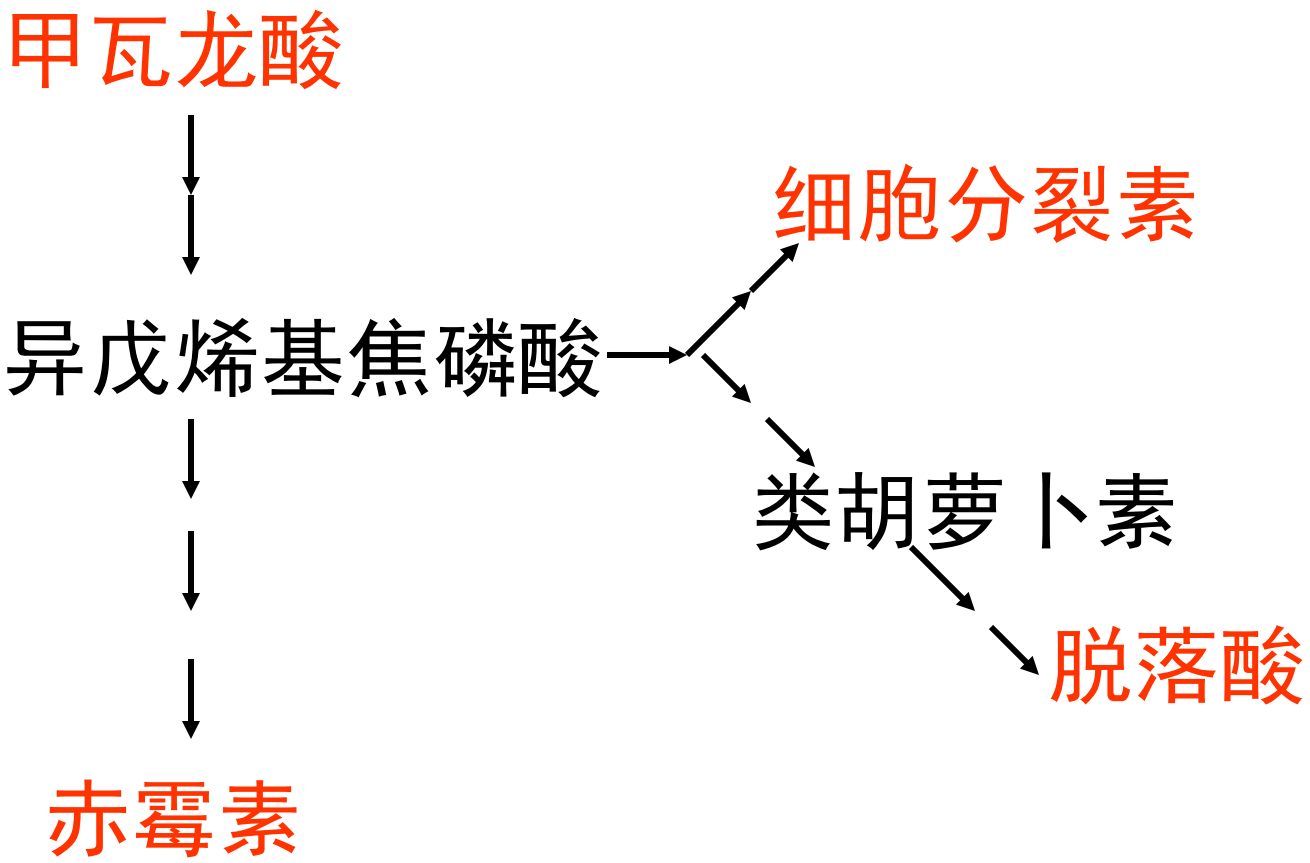
氧化

ABA

结合

脱落酸葡萄糖酯



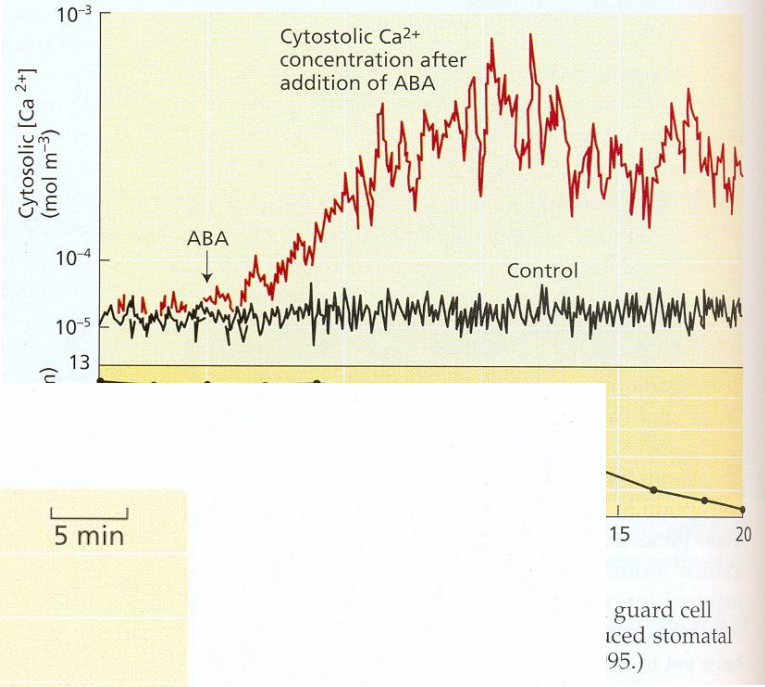


Ipp在不同条件下，会分别转变为GA、CTK、ABA

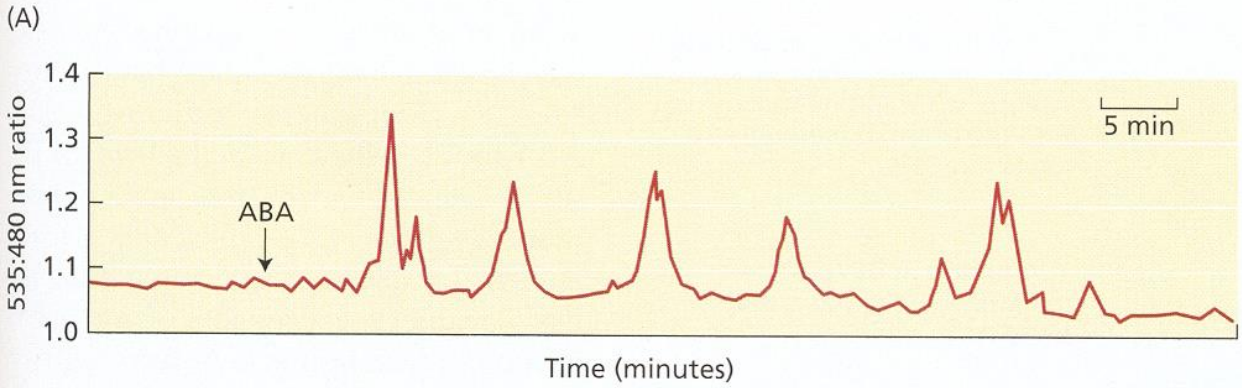
四、作用机理

1）胞外受体和胞内受体

2）信号转导



guard cell
ced stomatal
95.)



(B)

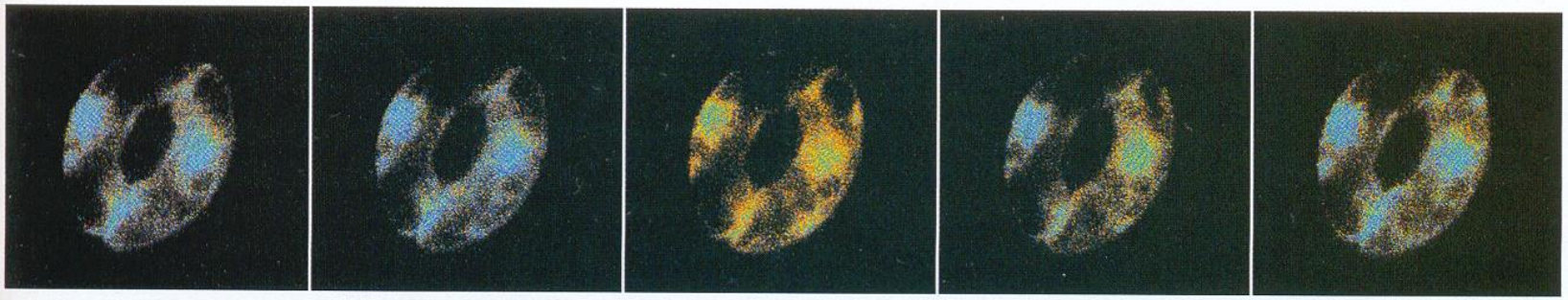


FIGURE 23.10 ABA-induced calcium oscillations in *Arabidopsis* guard cells expressing yellow cameleon, a calcium indicator protein dye. (A) Oscillations elicited by ABA are indicated by increases in the ratio of flourescence emission at 535 and 480 nm. (B) Pseudo colored images of fluorescence in *Arabidopsis* guard cells, where blue, green, yellow and red represent increasing cytosolic calcium concentration. (From Schroeder et al. 2001.)

the plasma membrane (Schroe
and Hagiwara 1990) (see Cha
6). ABA has been shown to acti

1. ABA binds to its receptors.

2. ABA-binding induces the formation of reactive oxygen species, which activate plasma membrane Ca^{2+} channels.

3. ABA increases the levels of cyclic ADP-ribose and IP_3, which activate additional calcium channels on the tonoplast.

4. The influx of calcium initiates intracellular calcium oscillations and promotes the further release of calcium from vacuoles.

5. The rise in intracellular calcium blocks K^+_{in} channels.

6. The rise in intracellular calcium promotes the opening if Cl^-_{out} (anion) channels on the plasma membrane, causing membrane depolarization.

7. The plasma membrane proton pump is inhibited by the ABA-induced increase in cytostolic calcium and a rise in intracellular pH, further depolarizing the membrane.

8. Membrane depolarization activates K^+_{out} channels.

9. K^+ and anions to be released across the plasma membrane are first released from vacuoles into the cytosol.

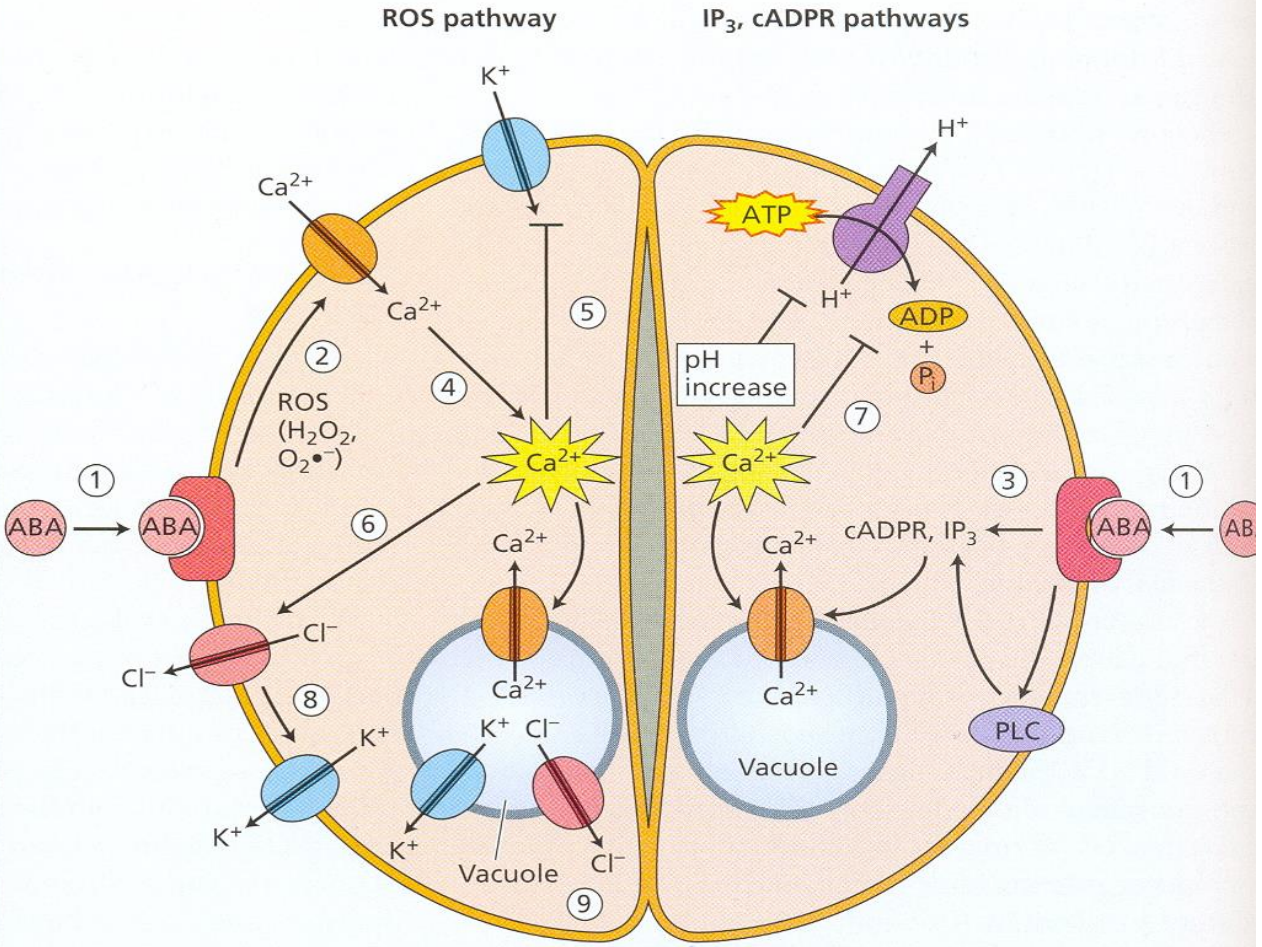
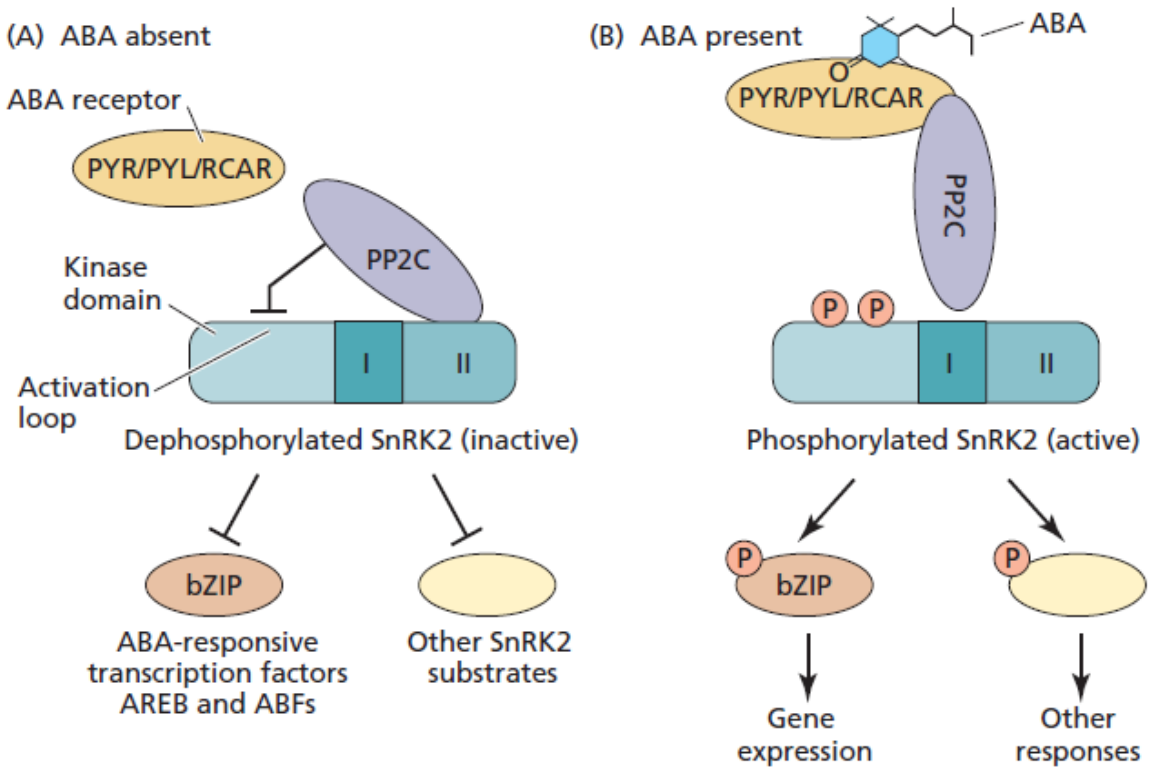


FIGURE 23.12 Simplified model for ABA signaling in stomatal guard cells. The net effect is the loss of potassium and its anion (Cl^- or malate^{2-}) from the cell. (R = receptor; ROS = reactive oxygen species; cADPR = cyclic ADP-ribose; G-protein = GTP-binding protein; PLC = phospholipiase C.)

气孔保卫细胞ABA信号转导导致胞内K^+溶质下降，水势上升



In the absence of ABA, the protein phosphatase PP2C keeps the protein kinase SnRK2 dephosphorylated and thereby inactivated.

When ABA is present, its receptor prevents dephosphorylation of SnRK2 by PP2C. Phosphorylated (active) SnRK2 phosphorylates downstream substrates, thereby inducing ABA responses.

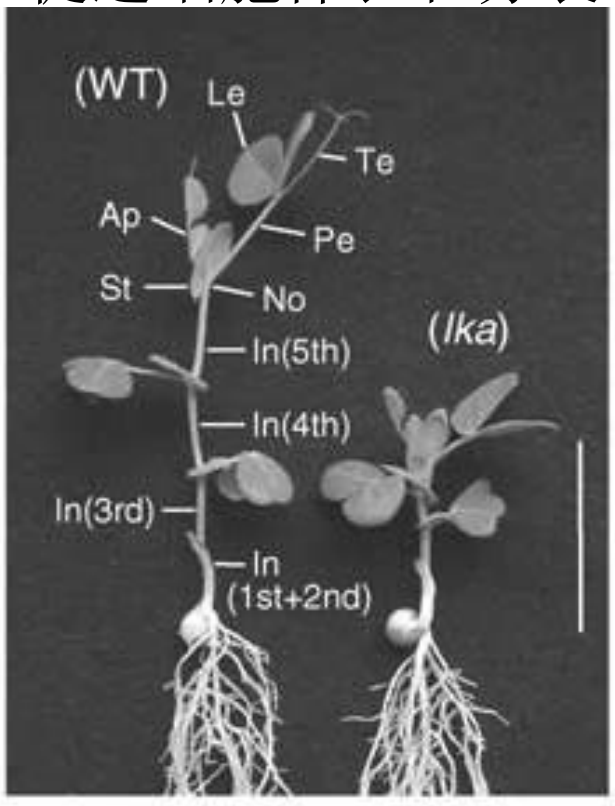
Figure 15.32 Abscisic acid (ABA) signaling involves kinase and phosphatase activities. (A) In the absence of ABA, the protein phosphatase PP2C dephosphorylates and inactivates the SnRK2 kinase. (B) In the presence of ABA, the ABA receptor protein PYR/PYL/RCAR interacts with PP2C, blocking phosphatase action and releasing SnRK2 from negative regulation. The activated SnRK2 phosphorylates ABA-responsive transcription factors (bZIP) and other unknown substrates to induce an ABA response. SnRK2, SNF1-related protein kinase 2; PP2C, protein phosphatase 2C; AREB, ABA-responsive element binding protein; ABF, ABA-responsive element-binding factor.

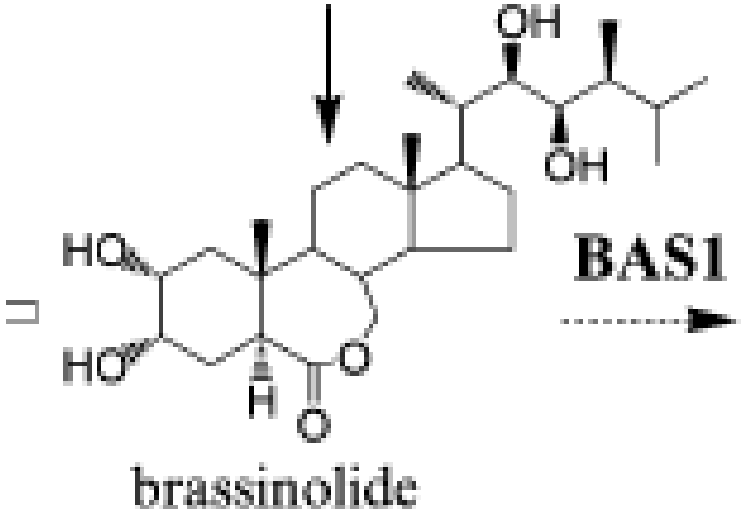
第六节 其他天然的植物生长物质

一、油菜素内酯　　BRASSINOSTEROID　　BR

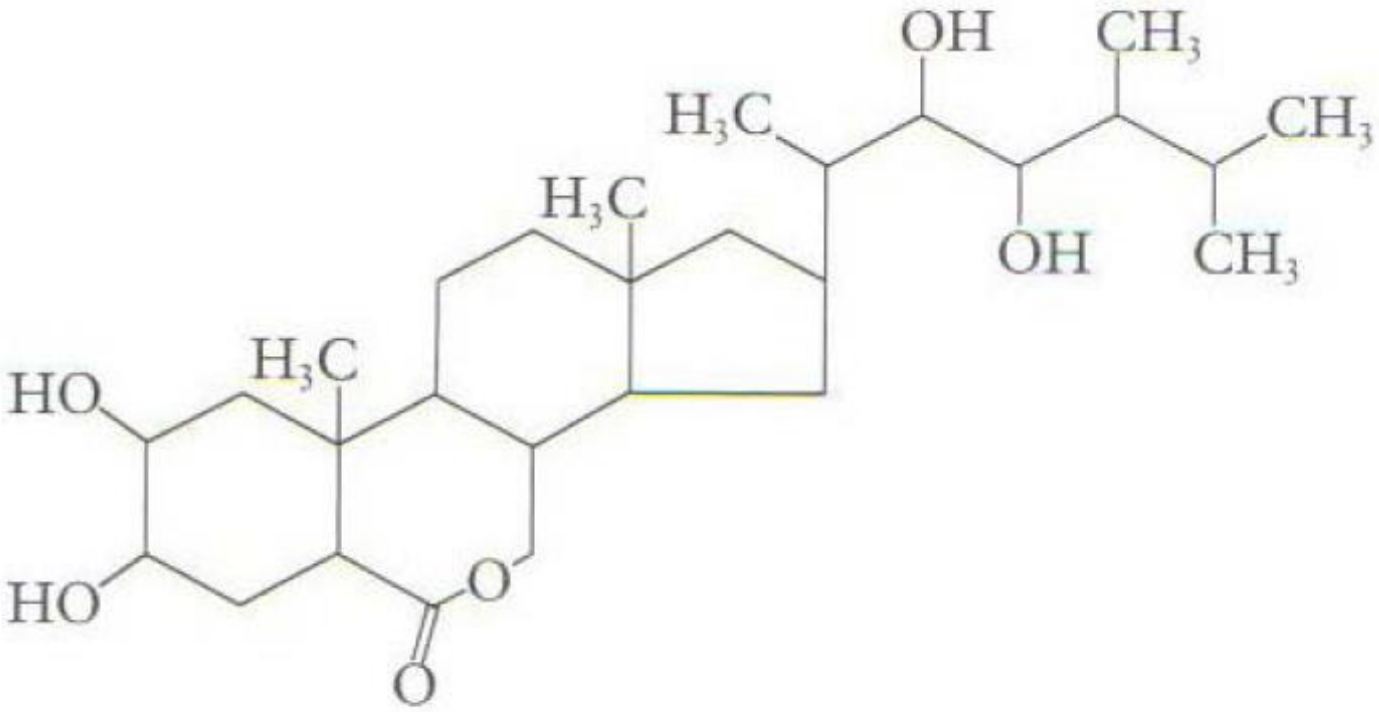
甾醇内酯

促进细胞伸长和分裂



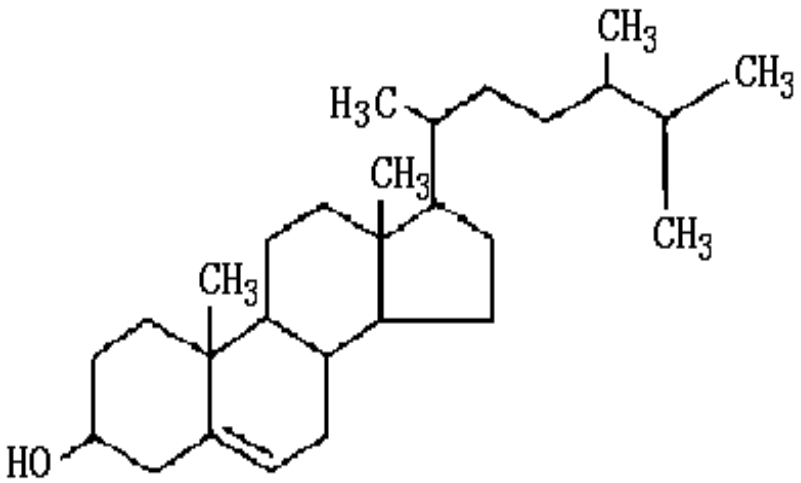


- **6.1** BR（ Brassinosteroids 油菜素甾醇类 or **Brassinolide,**油菜素内酯）.

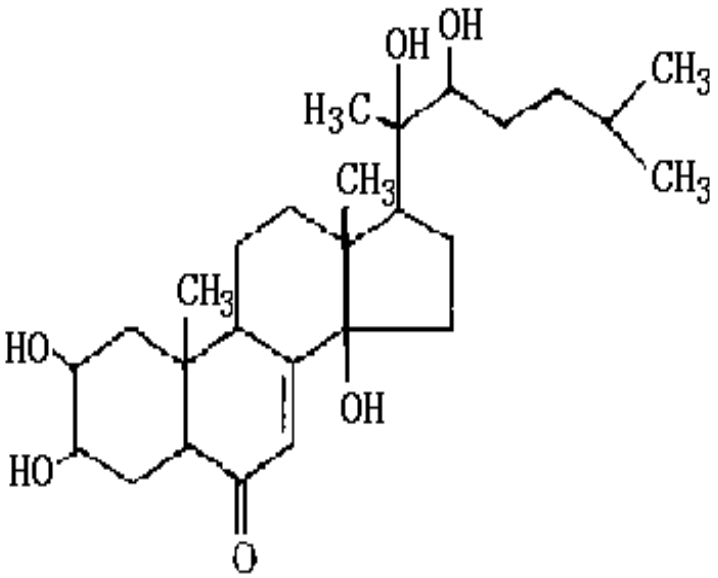


Brassinolide

FIGURE 15.23 Brassinolide is an example of brassinosteroid hormones.



谷固醇（植物固醇的一种）



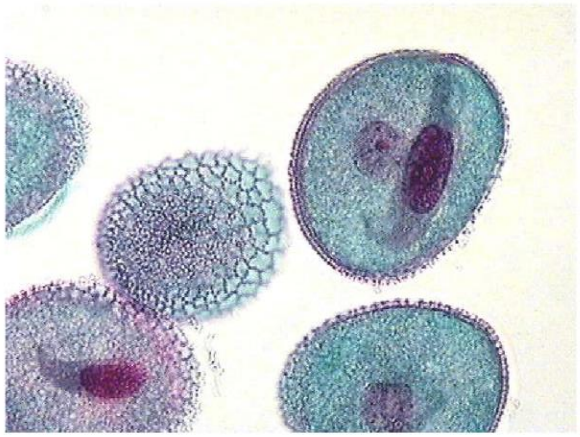
松甾醇 A（植物蜕皮激素的一种）

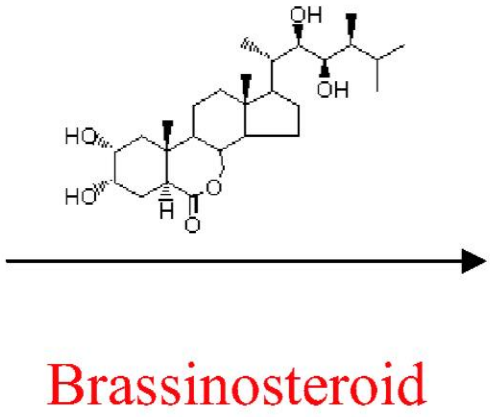
甾醇（sterol），也称类固醇(steroid alcohol)是三萜的衍生物，它是质膜的主要组成。

合成类固醇 运动兴奋剂

Discovery of Brassinosteroids

Discovered as a growth stimulator from pollen extracted from rape plant (*Brassica napus* L.) -> Mitchell et al. 1970 -> called substances *Brassins*





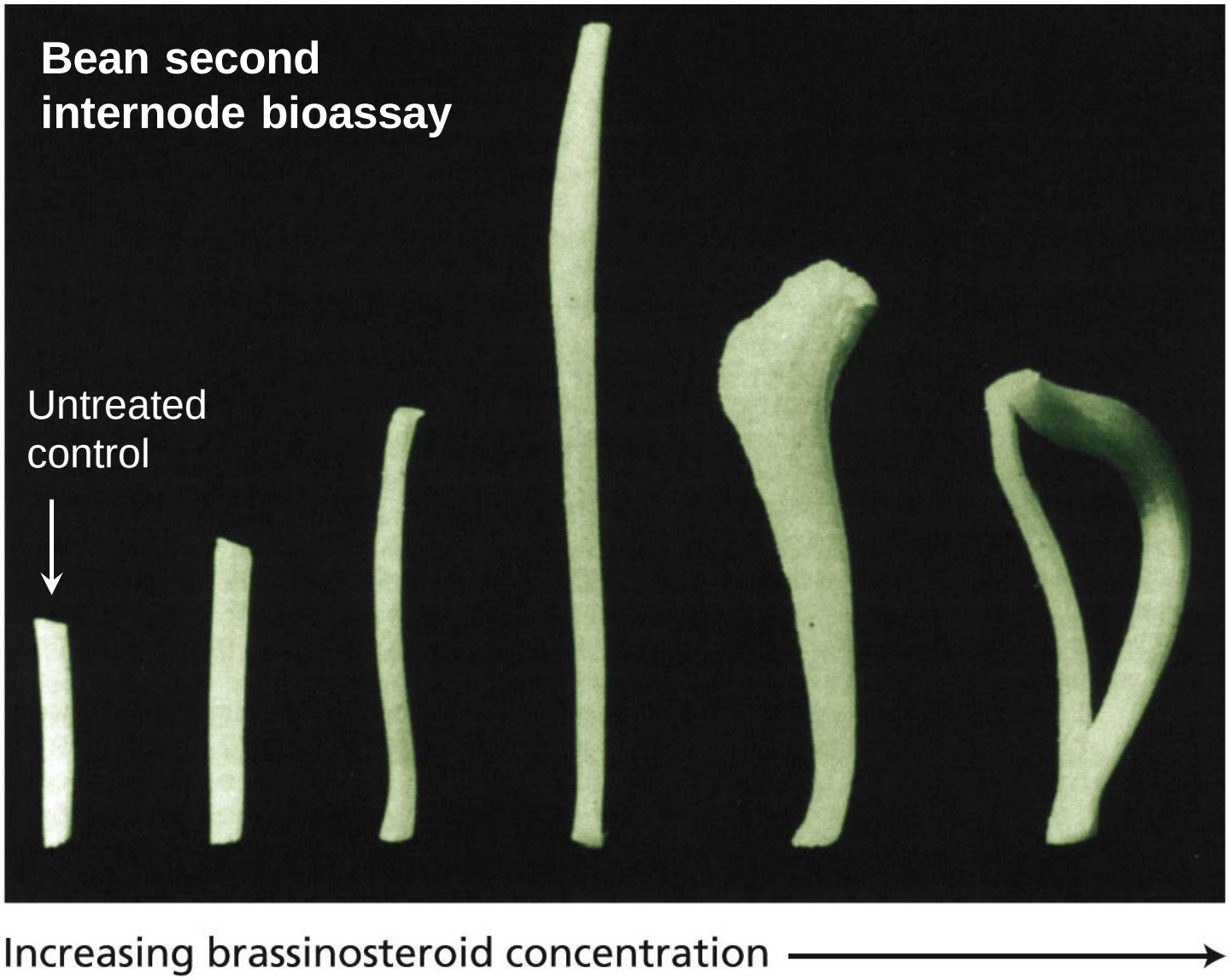
Brassinosteroid

1 Kg of pollen harvested.
Pollen extracts fractionated.
Assayed for inducers of pollen tube growth.

Occur in Brassicaceae (mustards, cauliflowers, cabbages, turnips, Arabidopsis)

Discovery of Brassinosteroids

Brassins induced stem elongation in beans: Mandava 1988



Brassinosteroids-mediated physiological responses

Inhibit:

- Root growth (but also promote root growth)
- Leaf abscission

Stimulate:

- Cell and stem elongation and division -> promote shoot growth
- Unrolling and bending of grasses
- Ethylene production
- Seed germination and Photomorphogenesis
- Xylem differentiation
- Pollen tube growth

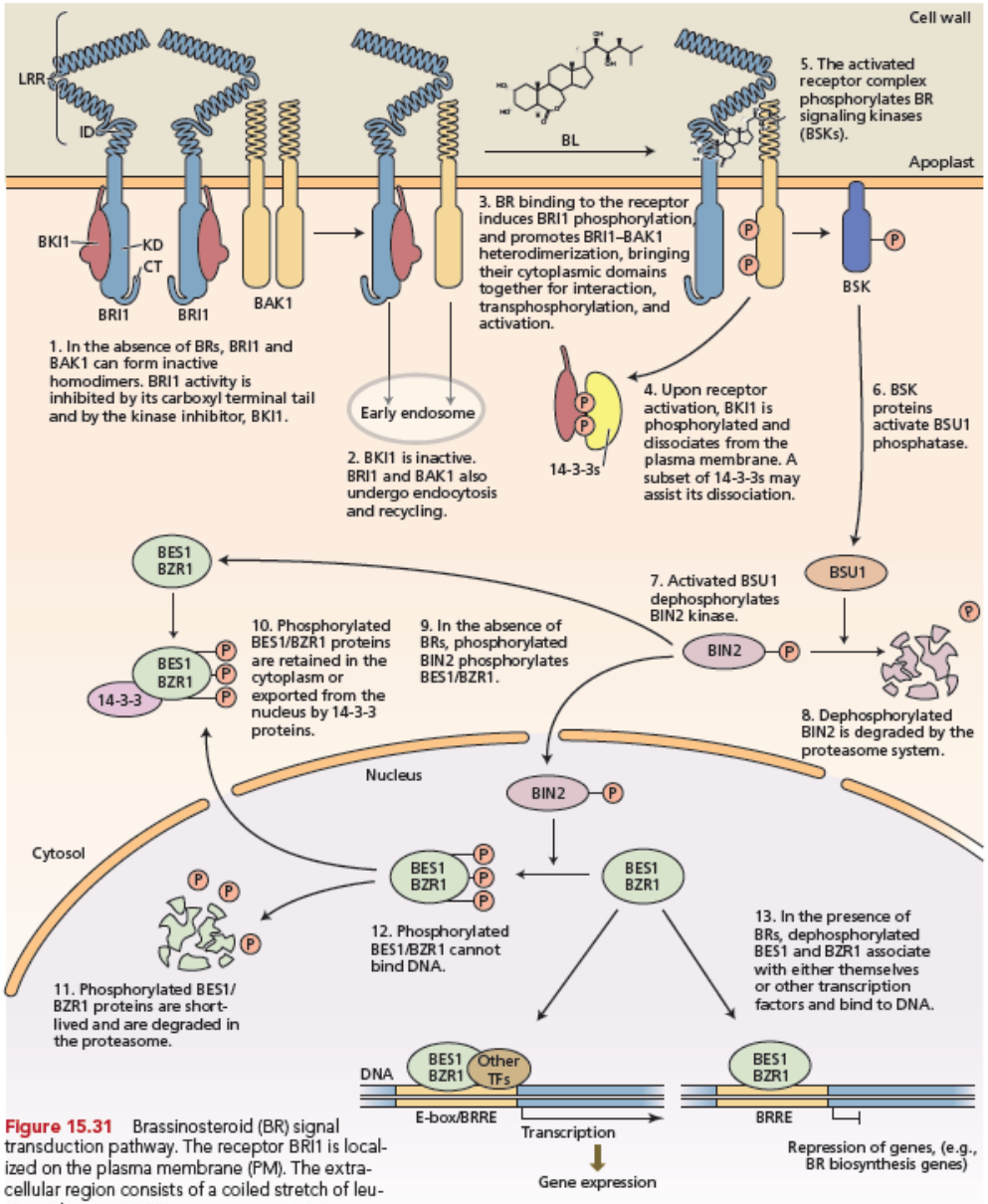
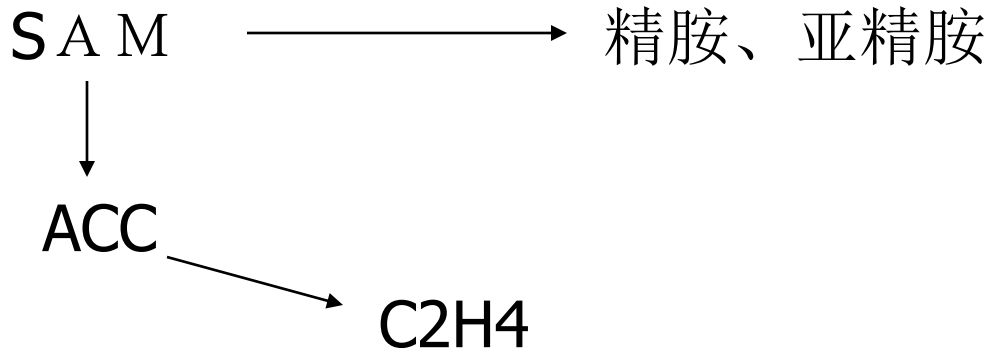


Figure 15.31 Brassinosteroid (BR) signal transduction pathway. The receptor BRI1 is localized on the plasma membrane (PM). The extracellular region consists of a coiled stretch of leucine rich repeat (LRR) sequences containing an island domain (ID) that functions as part of the brassinolide (BL) binding site. The intracellular portion contains a kinase domain (KD) and the C-terminal tail (CT). Signal perception occurs at the cell surface and results in changes in BR-regulated gene expression. BRRE, brassinoisteroid response element. (After Jiang et al. 2013.)

二、多胺——脂肪族含氮碱

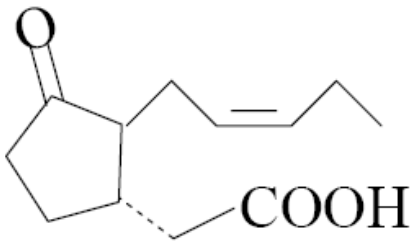
- Put(腐胺) $NH_2(CH_2)_4NH_2$
- Cad(尸胺) $NH_2(CH_2)_5NH_2$
- Spd(亚精胺) $NH_2(CH_2)_3NH\ (CH_2)_4NH_2$
- Hspd(高亚精胺) $NH_2(CH_2)_4NH\ (CH_2)_4NH_2$
- Spm(精胺) $NH_2(CH_2)_3NH\ (CH_2)_4NH(CH_2)_3NH_2$
- Agm(鲱精胺) $NH_2(CH_2)_5NH\ C\ (NH)\ NH_2$

1、促进细胞分裂 2、延迟衰老， 3、适应逆境（维持渗透平衡）

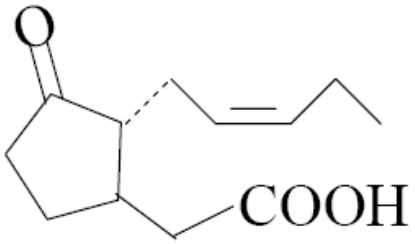


三、茉莉酸（Jasmonic Acid, JA;methyl JA, MJ)

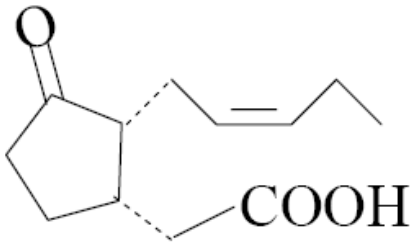
提高植物的抗逆性



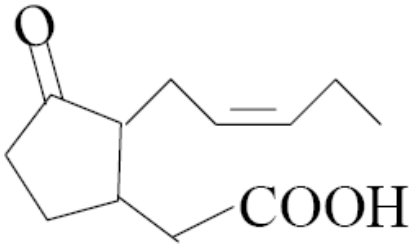
（+）JA



（-）JA



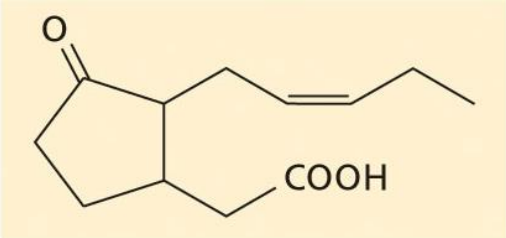
（-）7-iso-JA



（+）7-iso-JA

Inhibit growth，promote senescence and tuberization

Jasmonic acid



Jasmonic acid (JA)

Isolated from plants and fungi

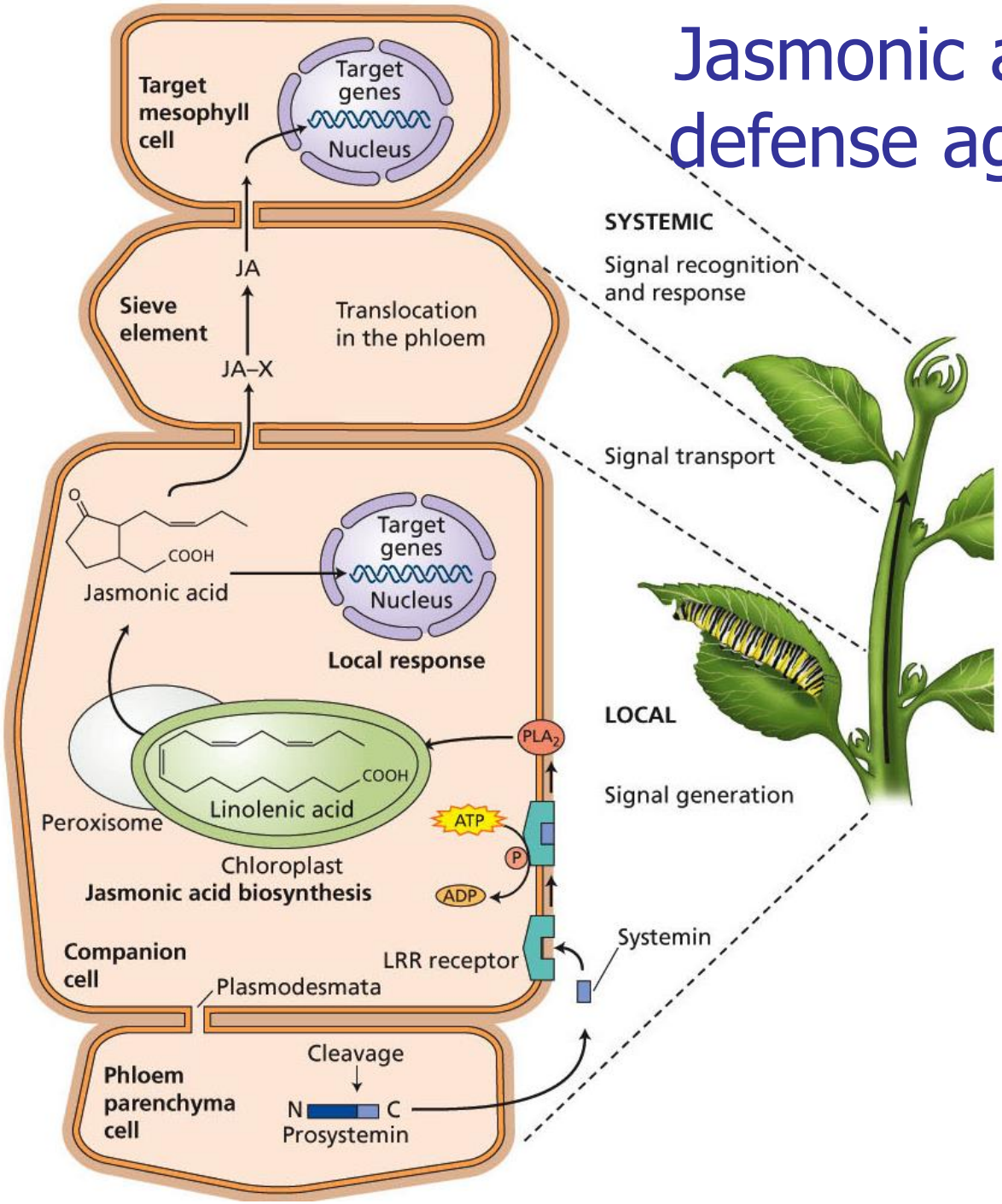
Inhibits:

seed and pollen germination
root growth

Stimulates:

plant defenses against microbial and insect pathogens
wound responses
ripening
exogenous application decreases expression of genes associated with photosynthesis

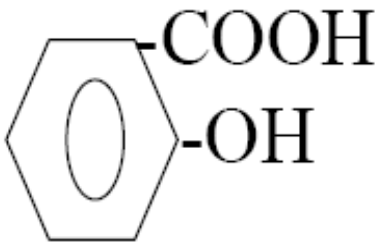
Jasmonic acid is involved in defense against insects and microbes



四、水杨酸（salicylic acid SA)

诱导抗氰呼吸

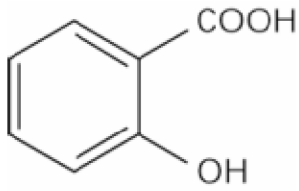
提高植物的抗病性



Signal transduction in resistance to diseases of plant （PRPs-pathogenesis-relative proteins）。

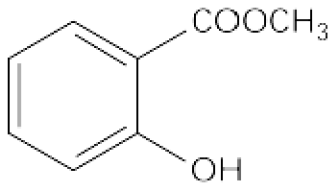
Enhance male flower .

Salicylic acid (SA)

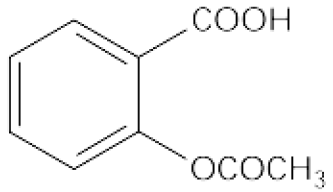


Salicylic acid

Pain-relieving properties of willow bark and oil of wintergreen due to SA and related compounds



Methyl salicylate



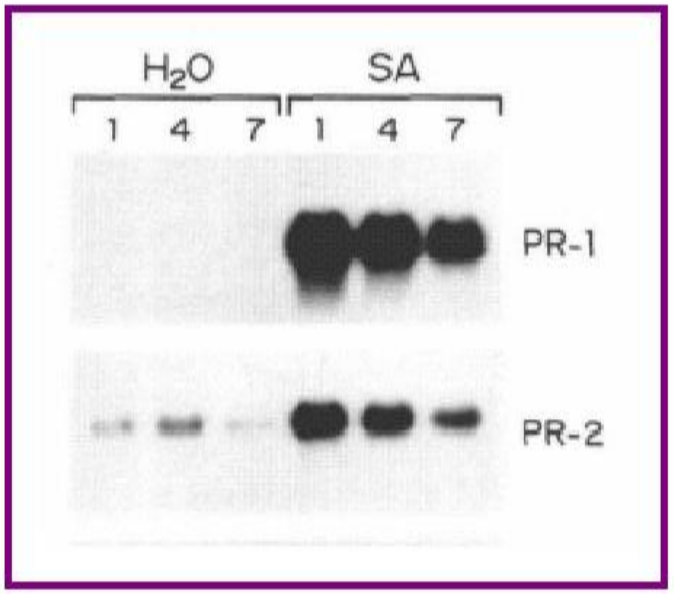
Acetylsalicylic acid

Levels of SA increase when resistant plants are infected

SA induces the expression of pathogenesis-related (PR) proteins

Arabidopsis plants treated with SA

Northern Blot to Detect PR mRNAs



Nawrath et al. (1999) Plant Cell 11: 1393-1404

PR1 encodes ???
PR2 encodes β1,3-glucanase

} Marker genes for induction of plant defense

第七节 植物生长调节剂

- 7.1 Plant growth-promoters
- Indole derivatives : IBA, 吲哚丁酸（吲哚衍生物）
- naphthalene derivatives :NAA 萘乙酸
- chlorophenol derivatives: 2.4-D 2，4－二氯苯氧乙酸
-
-
- **Cytokinin-like :KT** 激动素 **6—BA**。

6－苄基腺嘌呤

Hormone	Product Name	Function in Plant Tissue Culture
Auxins	**Indole-3-Acetic Acid** **Indole-3-Butyric Acid** **Indole-3-Butyric Acid, Potassium Salt** **α-Naphthaleneacetic Acid** **2,4-Dichlorophenoxyacetic Acid** **p-Chlorophenoxyacetic acid** **Picloram** **Dicamba**	**Adventitous root formation (high concen)** **Adventitious shoot formation (low concen)** **Induction of somatic embryos** **Cell Division** **Callus formation and growth** **Inhibition of axillary buds** **Inhibition of root elongation**
Cytokinins	**6-Benzylaminopurine** **6-γ,γ-Dimethylallylaminopurine (2iP)** **Kinetin** **Thidiazuron (TDZ)** **N-(2-chloro-4-pyridyl)-N'Phenylurea** **Zeatin** **Zeatin Riboside**	**Adventitious shoot formation** **Inhibition of root formation** **Promotes cell division** **Modulates callus initiation and growth** **Stimulation of axillary's bud breaking and growth** **Inhibition of shoot elongation** **Inhibition of leaf senescence**
Gibberellins	**Gibberellic Acid**	**Stimulates shoot elongation** **Release seeds, embryos, and apical buds from dormancy** **Inhibits adventitious root formation** **Paclobutrazol and ancymidol inhibit gibberellin synthesis thus resulting in shorter shoots, and promoting tuber, corm, and bulb formation.**
Abscisic Acid	**Abscisic Acid**	**Stimulates bulb and tuber formation** **Stimulates the maturation of embryos** **Promotes the start of dormancy**
Polyamines	**Putrescine** **Spermidine**	**Promotes adventitious root formation** **Promotes somatic embryogenesis** **Promotes shoot formation**

植物生长抑制物质

1、生长抑制剂——抑制顶端分生组织生长，GA不能逆转

2、生长延缓剂——抑制近顶端分生组织生长，GA生物合成的抑制剂，GA可逆转

一、生长抑制剂

天然：ABA、茉莉酸（JA）、水扬酸、绿原酸、香豆素、咖啡酸等

人工合成的：三碘苯甲酸（TIBA）、青鲜素（马来酰肼，MH）、整形素、增甘膦等

二、生长延缓剂

如：矮壮素（CCC）、缩节安（Pix）、多效唑（PP_{333}）、烯效唑（S 3307)、比久（B_9）

General plant hormones

Auxins (cell elongation)

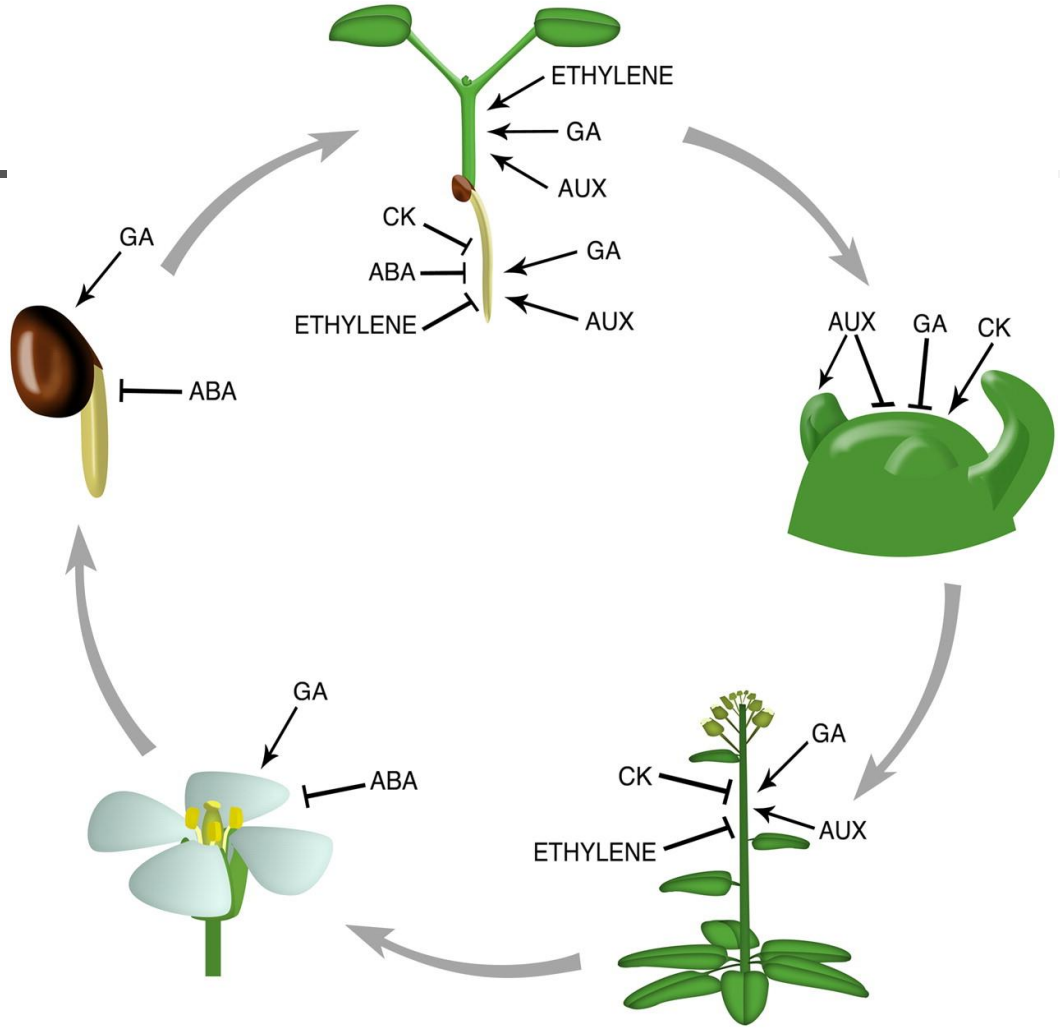
Gibberellins (cell elongation + cell division - translated into growth)

Cytokinins (cell division + inhibits senescence)

Abscisic acid (abscission of leaves and fruits + dormancy induction of buds and seeds)

Ethylene (promotes senescence, epinasty, and fruit ripening)

植物激素的交叉作用



Weiss D , Ori N Plant Physiol. 2007;144:1240-1246