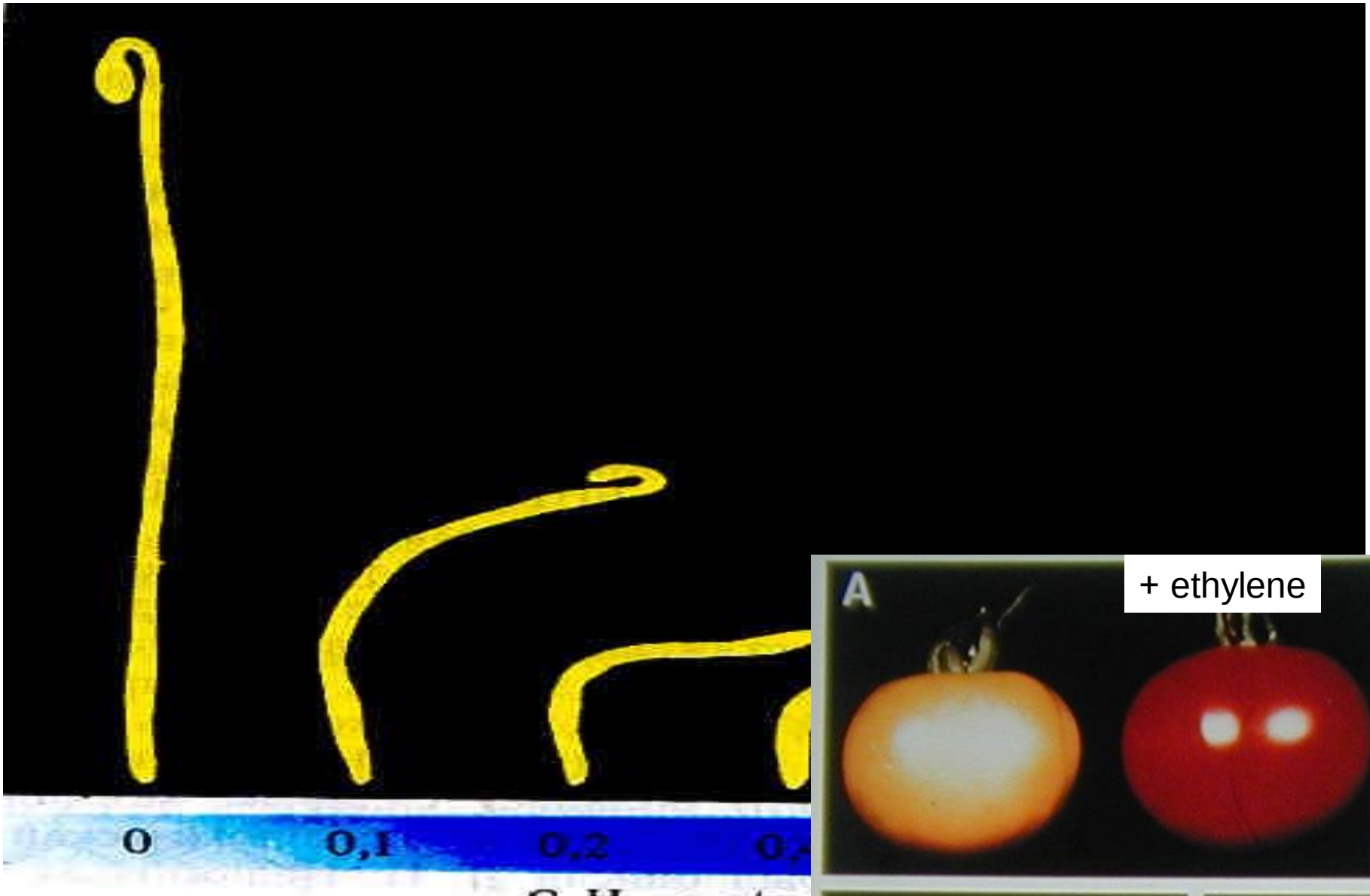
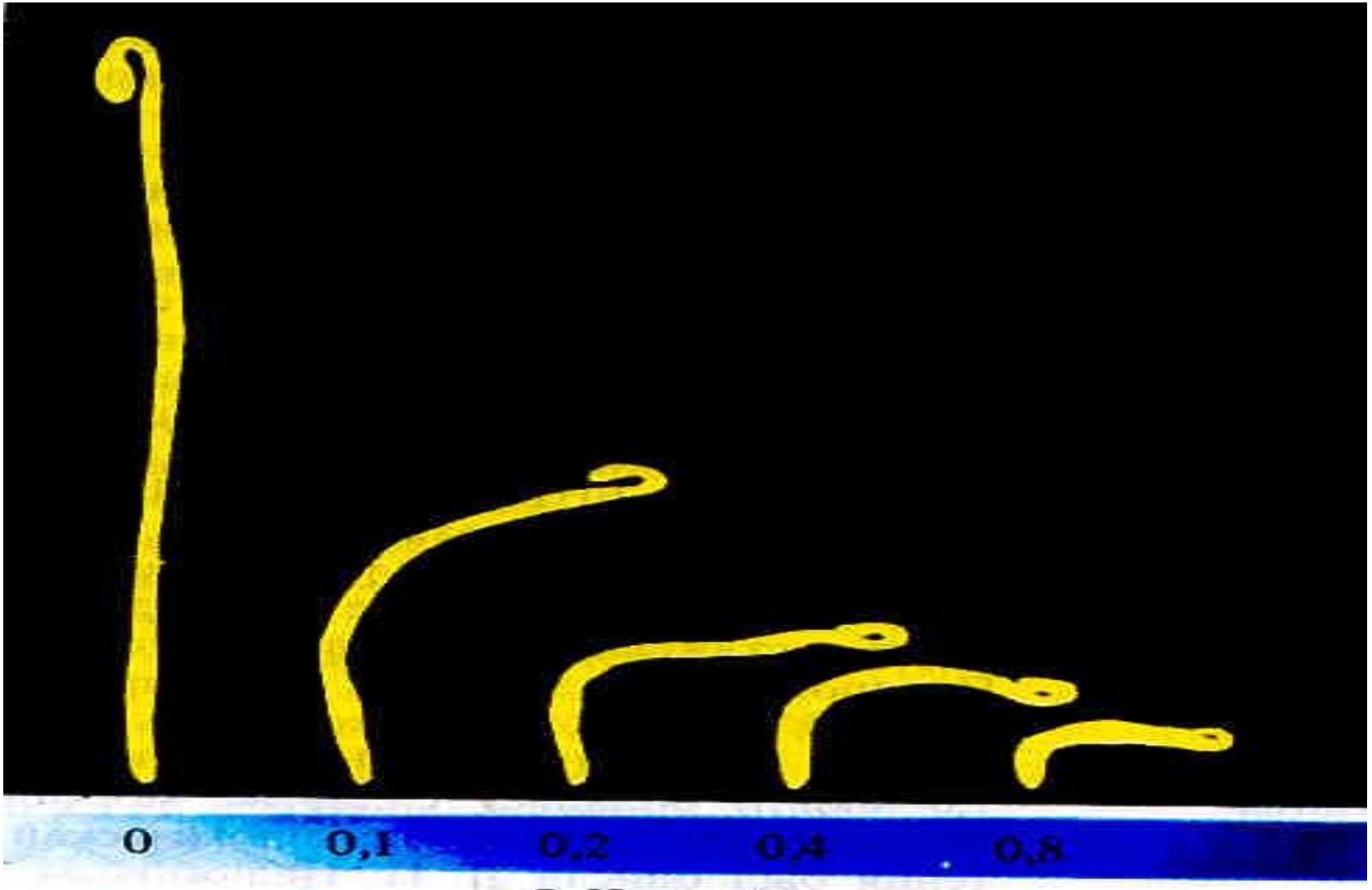
第四节、乙烯（ETH，ethylene）



一、Physiological roles

1、Ethylene Induces Lateral Cell Expansion乙烯的三重反应triple response：reducing the rate of elongation and increasing lateral expansion, leading to swelling of the region矮化、加粗和偏上生长



Induce epinasty 偏上生长

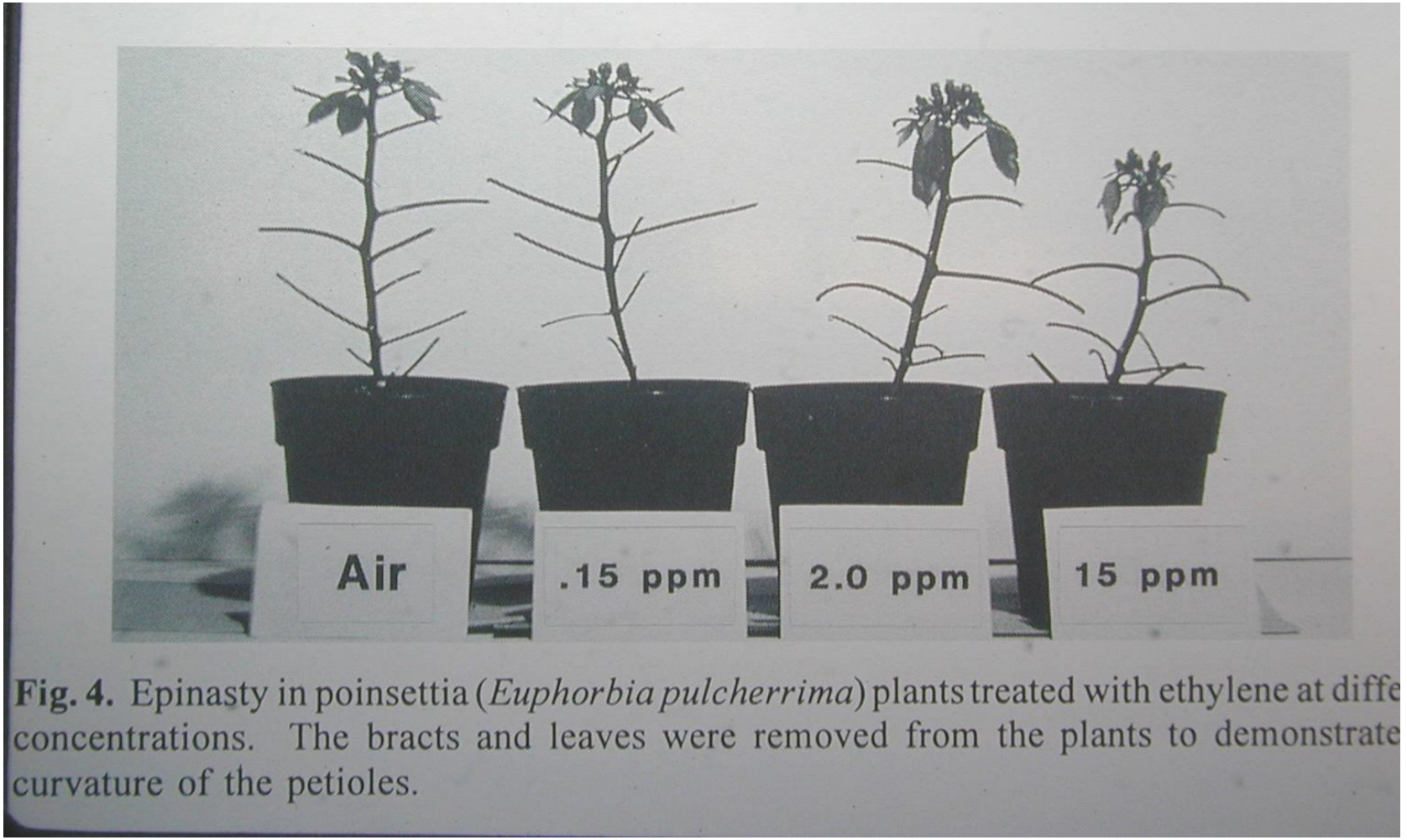
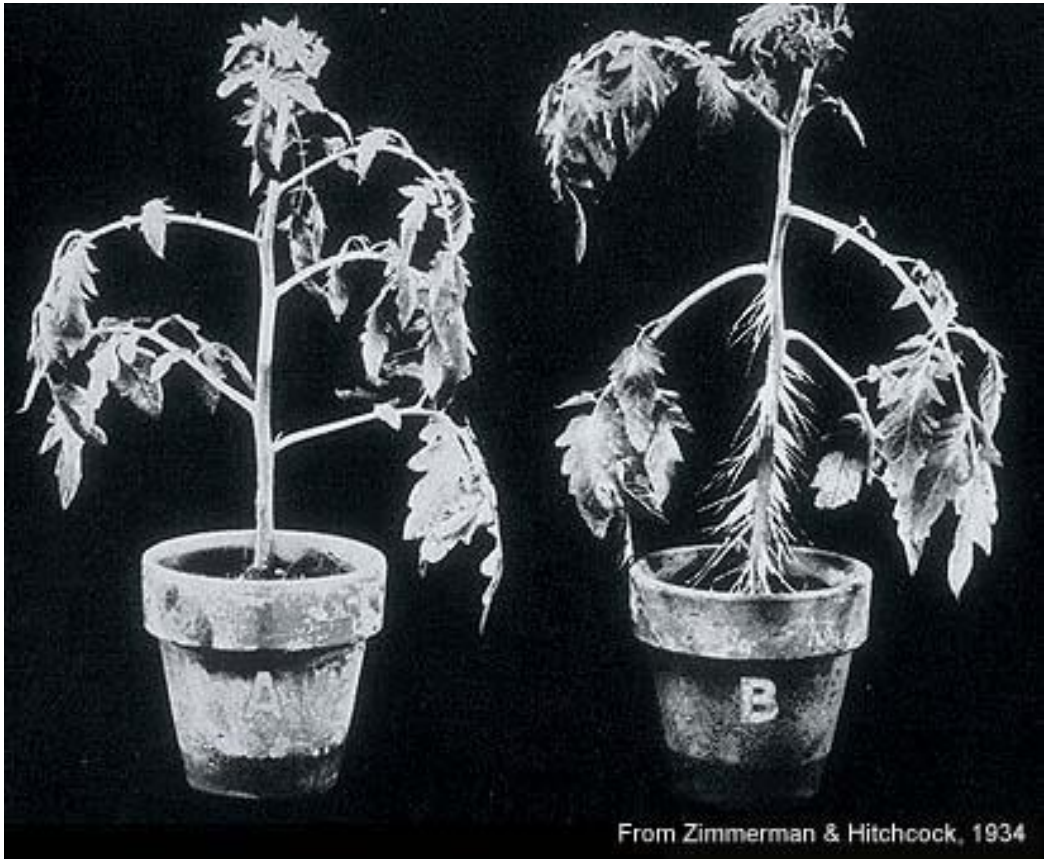


Fig. 4. Epinasty in poinsettia (*Euphorbia pulcherrima*) plants treated with ethylene at diffe concentrations. The bracts and leaves were removed from the plants to demonstrate curvature of the petioles.

2、诱导不定根的形成

Ethylene effect on adventitious roots formation



3、诱导某些植物开花Ethylene Induces Flowering in the Pineapple Family

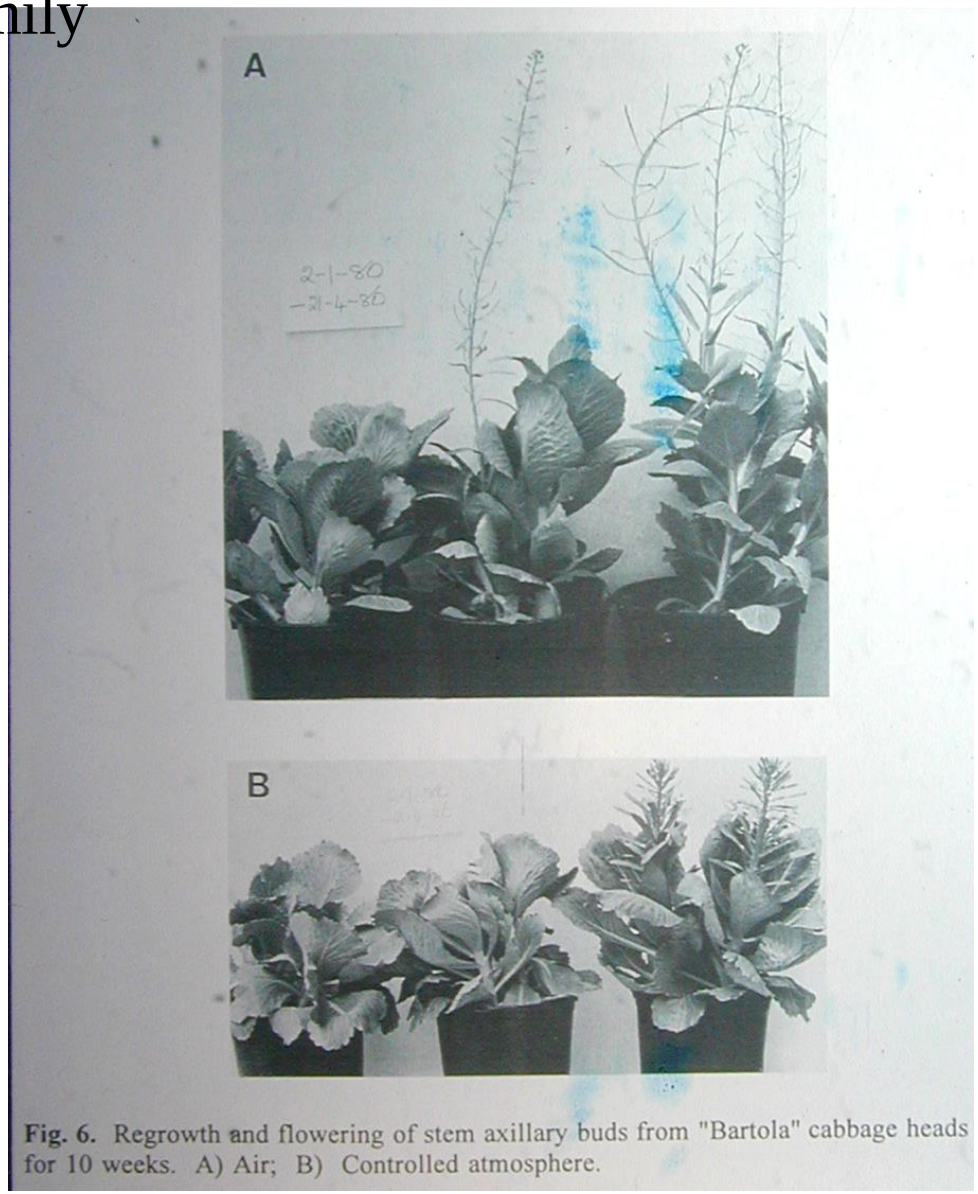


Fig. 6. Regrowth and flowering of stem axillary buds from "Bartola" cabbage heads for 10 weeks. A) Air; B) Controlled atmosphere.

4、诱导雌花

♀

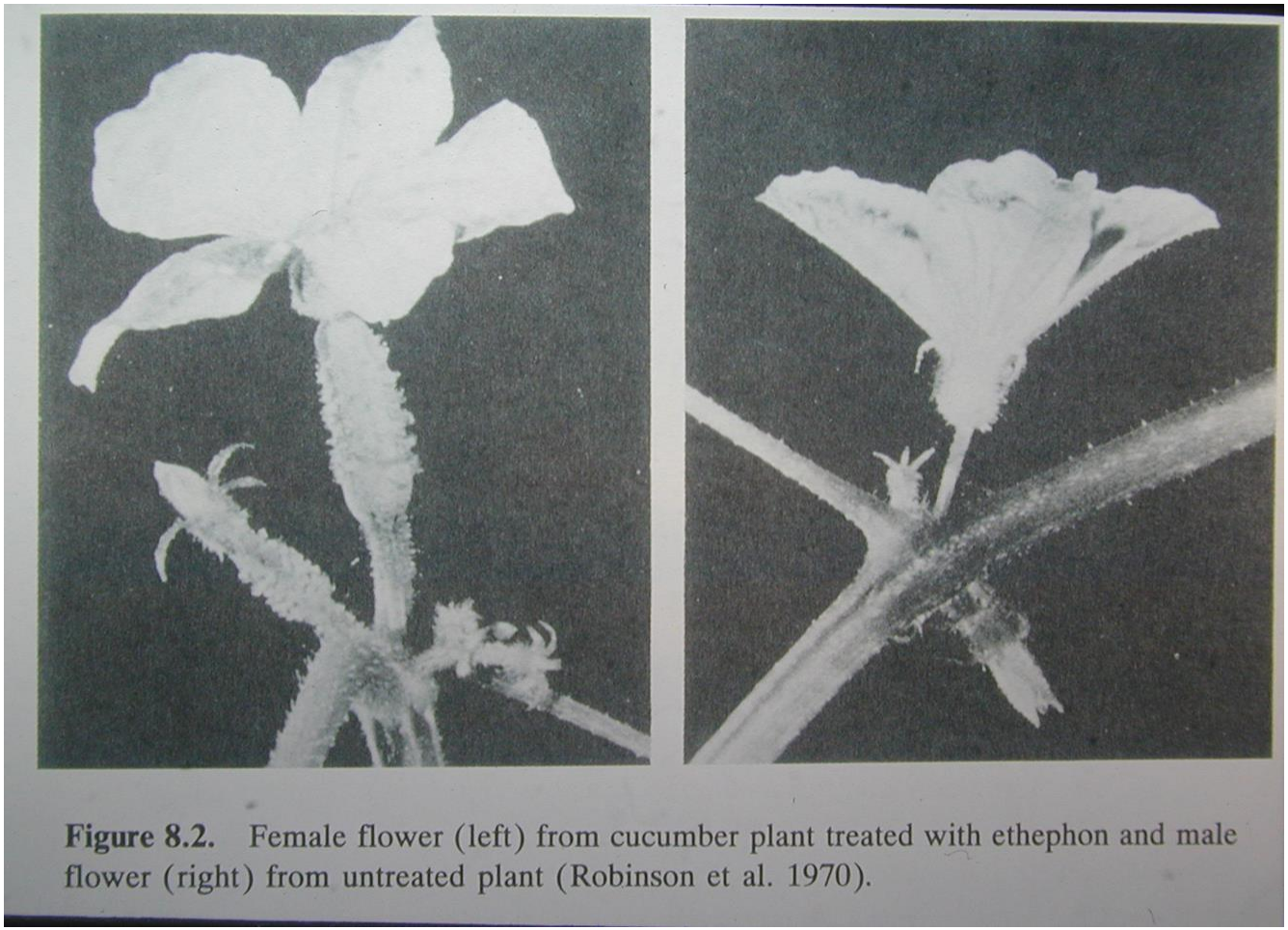
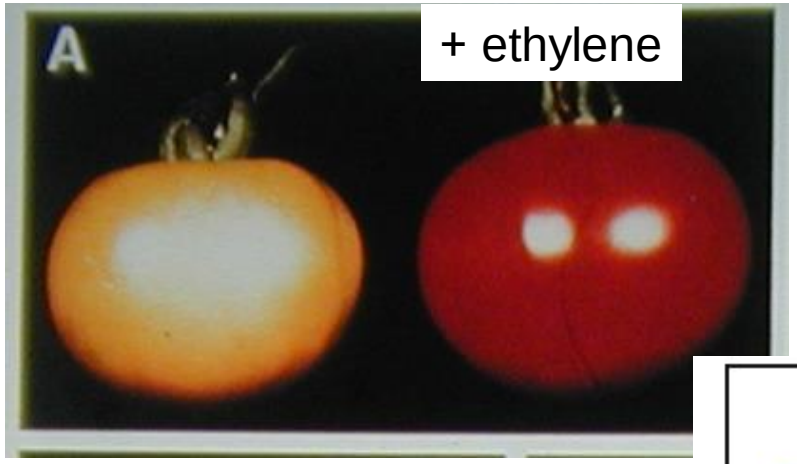
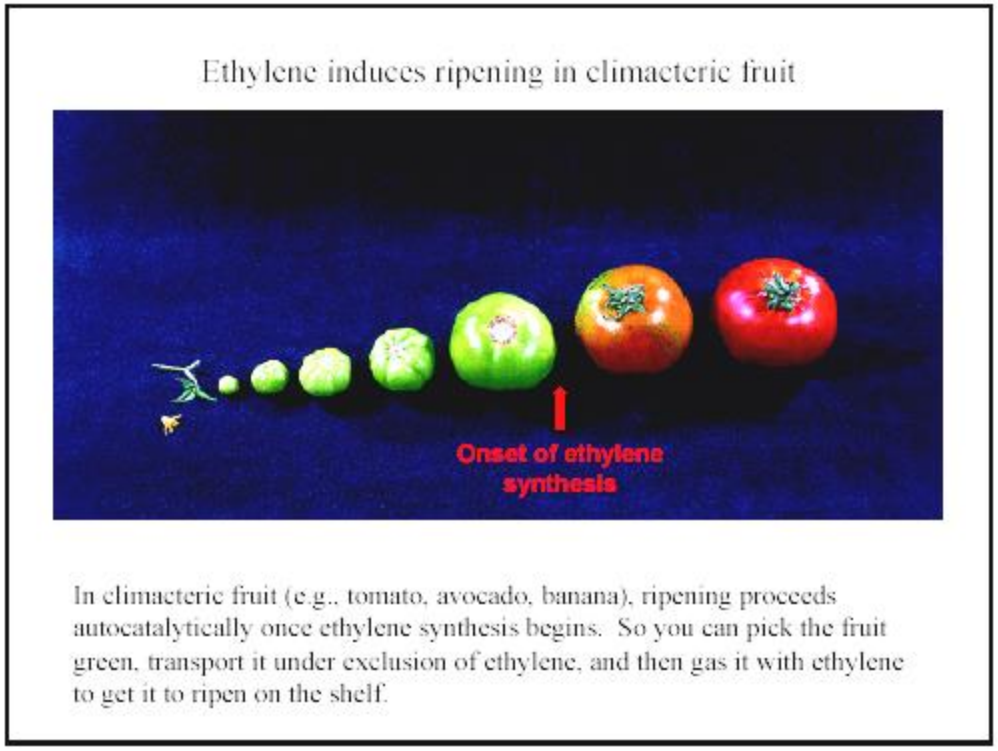


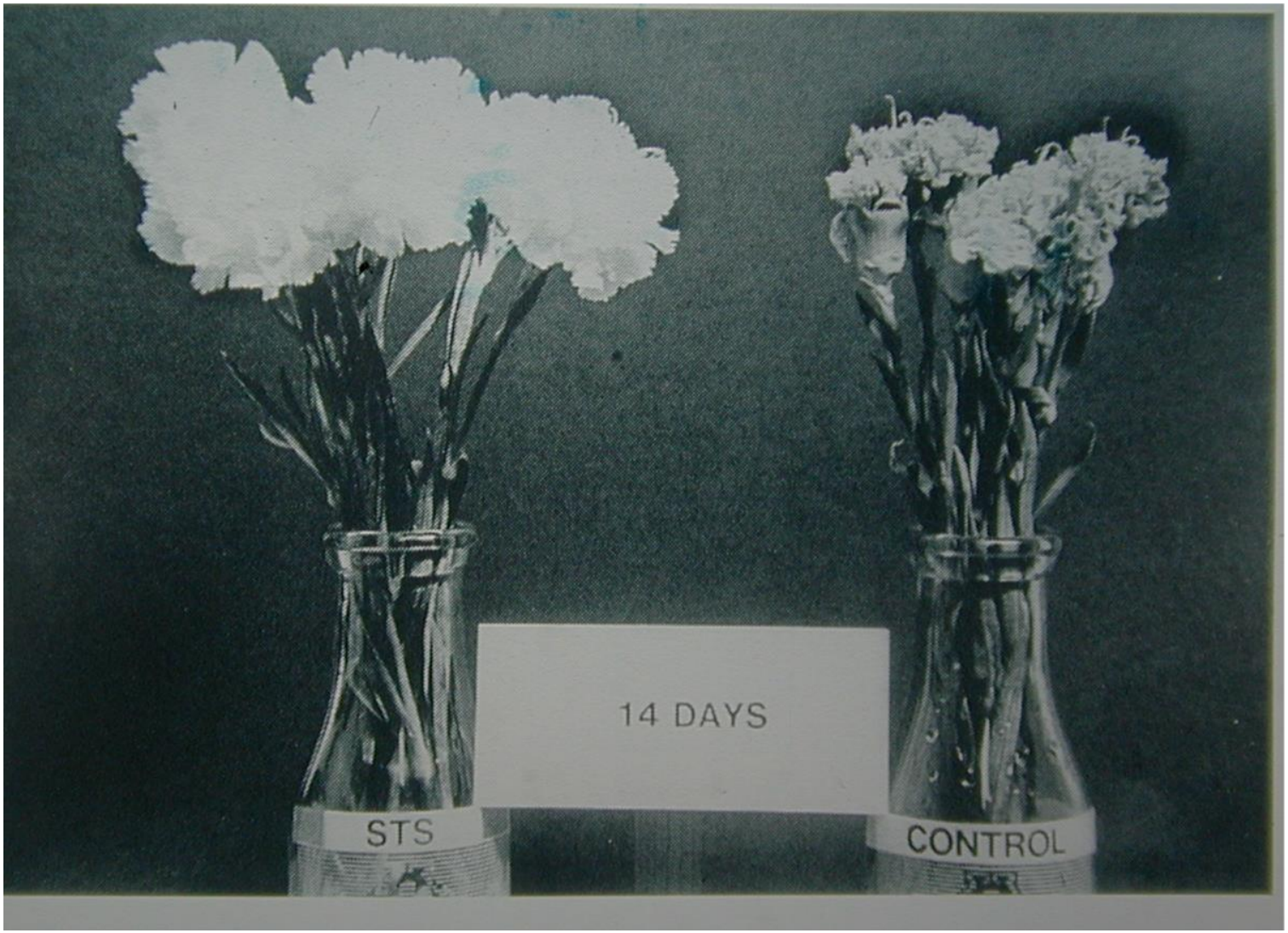
Figure 8.2. Female flower (left) from cucumber plant treated with ethephon and male flower (right) from untreated plant (Robinson et al. 1970).

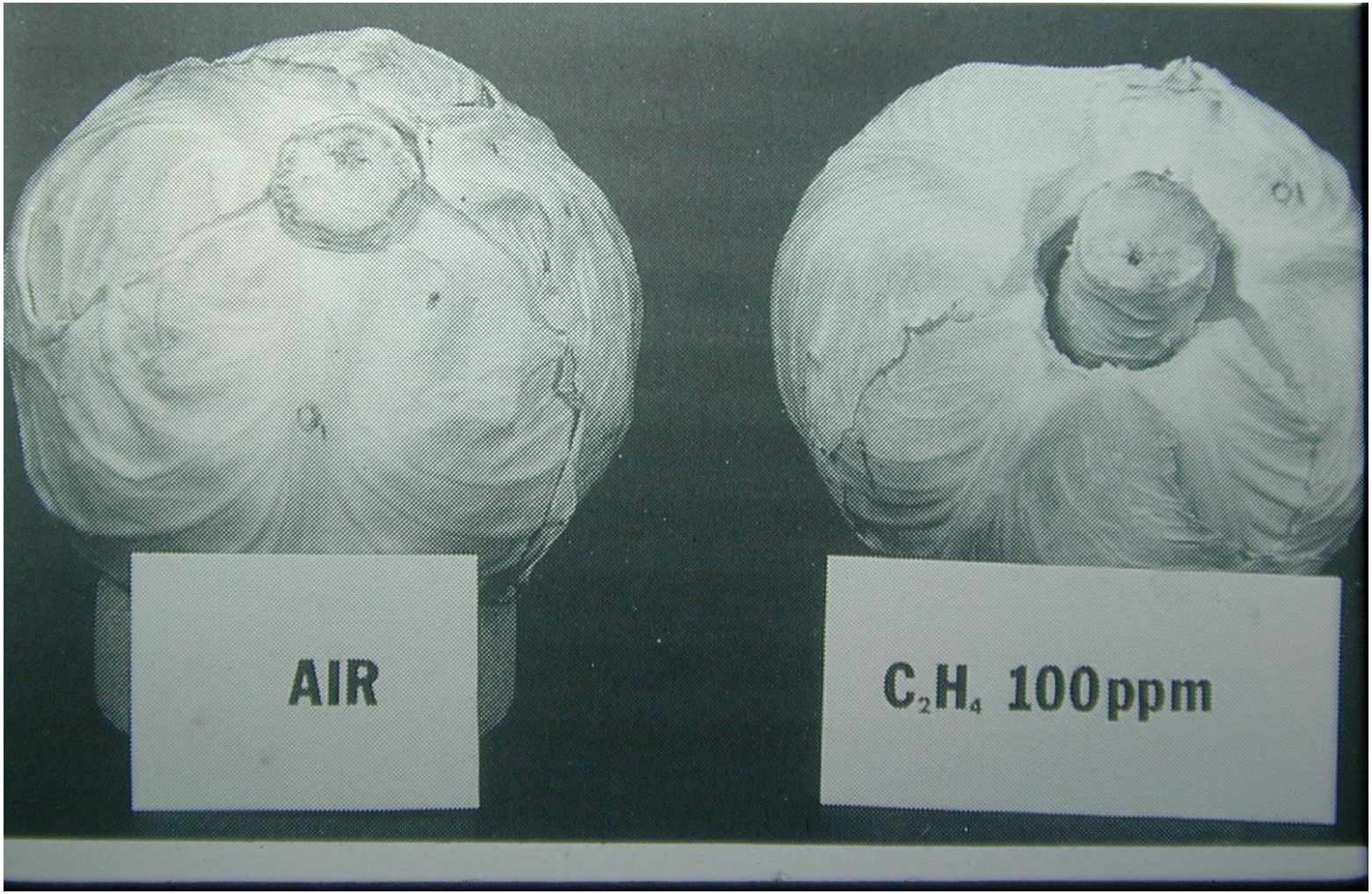
♂

5、诱导果实成熟 Ethylene Promotes the Ripening of Some Fruits






14 DAYS
STS
CONTROL


AIR
C_2H_4 100ppm

二、乙烯的分布与合成

1）分布：0.01－10nl. $g^{-1}FW.h^{-1}$, 分生组织、种子萌发、花刚凋谢和果实成熟时最多。各器官均可产生。

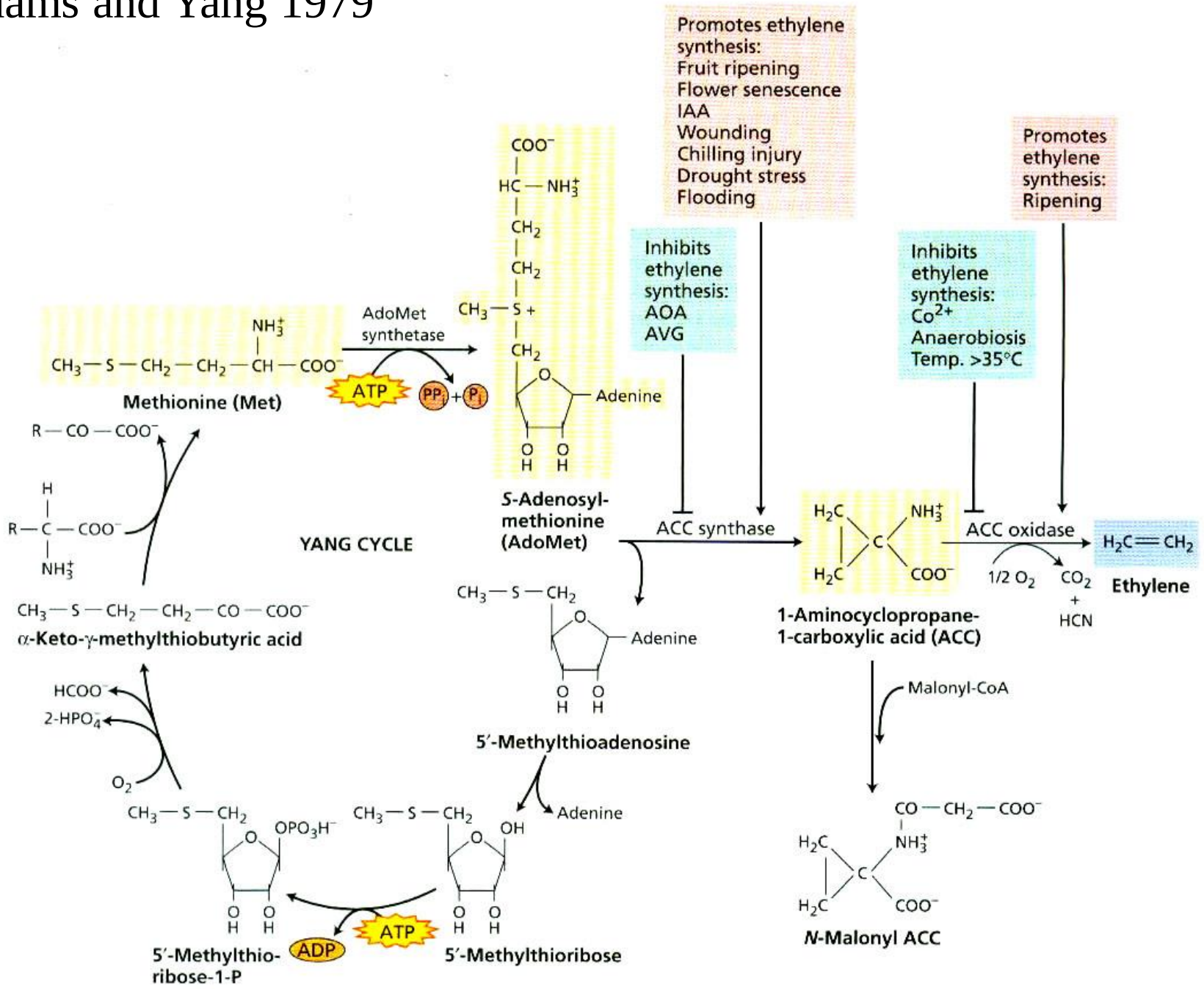
2）合成途径：

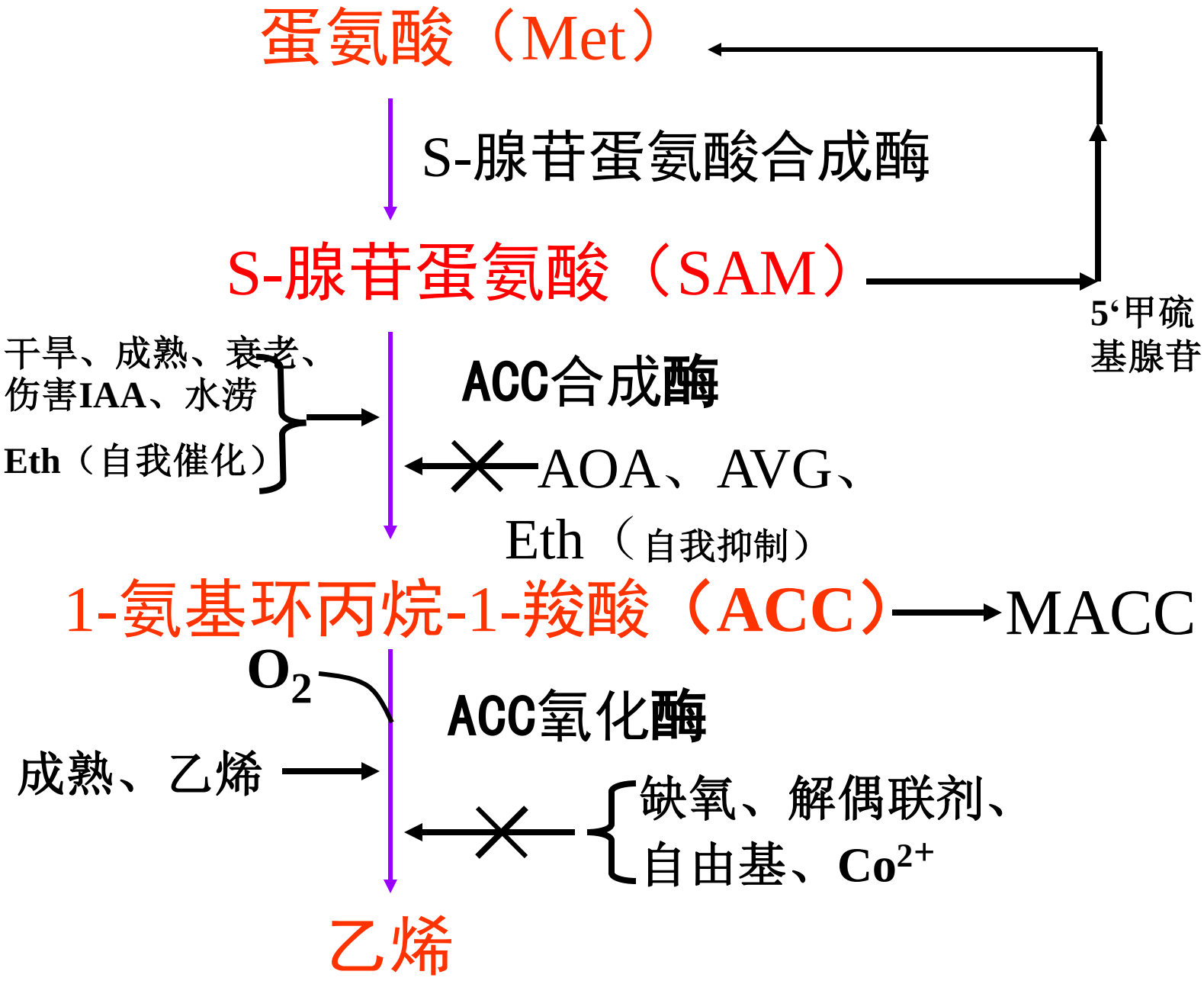
蛋氨酸循环

前体：蛋氨酸；　　直接前体：**ACC**

（1-氨基环丙烷-1-羧酸）

Adams and Yang 1979




蛋氨酸（Met）
S-腺苷蛋氨酸合成酶
S-腺苷蛋氨酸（SAM）
5‘甲硫
基腺苷
干旱、成熟、衰老、
伤害IAA、水涝
Eth（自我催化）
ACC合成酶
AOA、AVG、
Eth（自我抑制）
1-氨基环丙烷-1-羧酸（ACC）
MACC
O2
ACC氧化酶
成熟、乙烯
缺氧、解偶联剂、
自由基、Co2+
乙烯

乙烯合成的调节

1.ACC合成酶：

诱导：

生育期：种子萌发、果实成熟、器官衰老

环　境：不良环境

激 素：　IAA, Eth(自我催化)

抑制：AOA（氨基氧乙酸），AVG（氨基乙氧基乙烯基甘氨酸）抑制，乙烯的自我抑制。

ACC合成酶基因及调控（多基因家族）

不同成员受不同的因子调控

ACC synthase antisense反义ACSRNA：抑制成熟

Eth

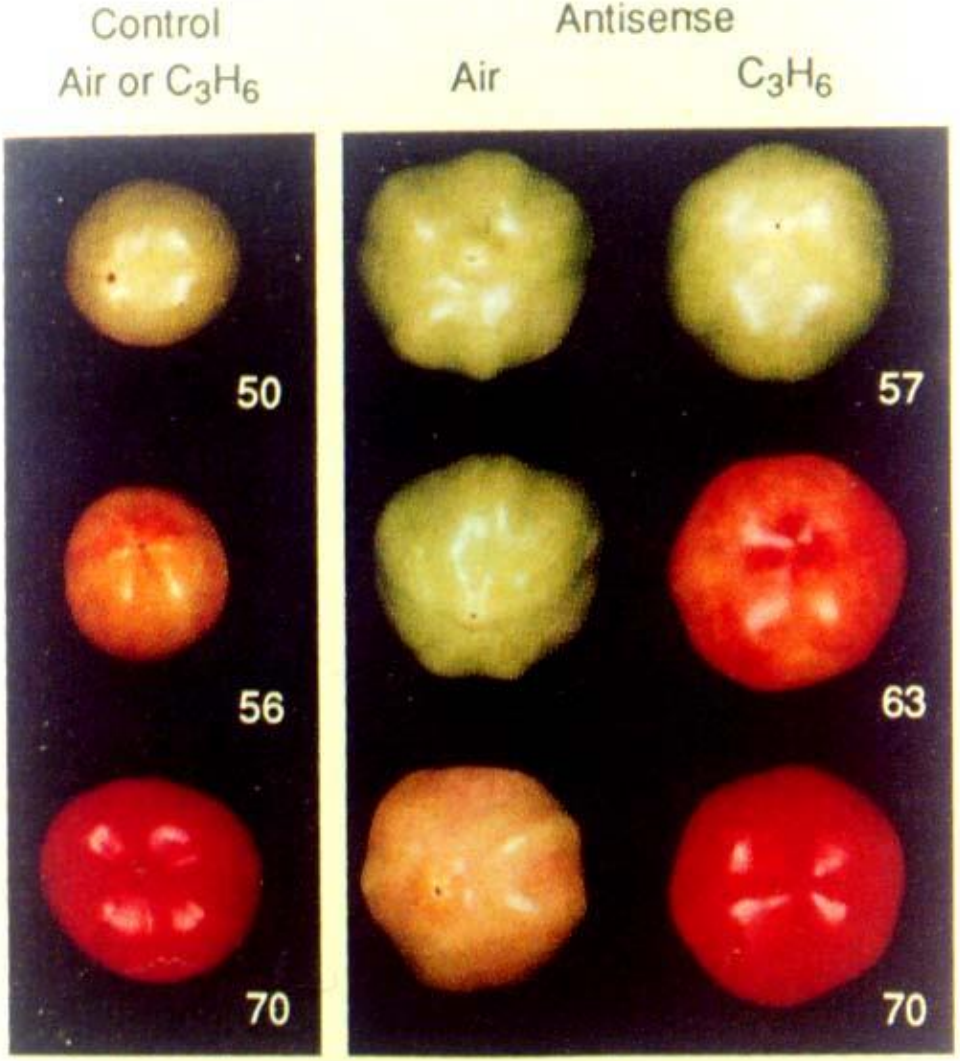


Fig. 3. Phenotype of the fruits used in Fig. 2A. The numbers indicate the age of the fruits in days.

2.ACC氧化酶

缺氧，解耦联剂，自由基清除剂 Co^{2+}，

Mature green　　4 weeks post Br　　4 weeks post Br + 8 weeks stored

WT

a/s EFE

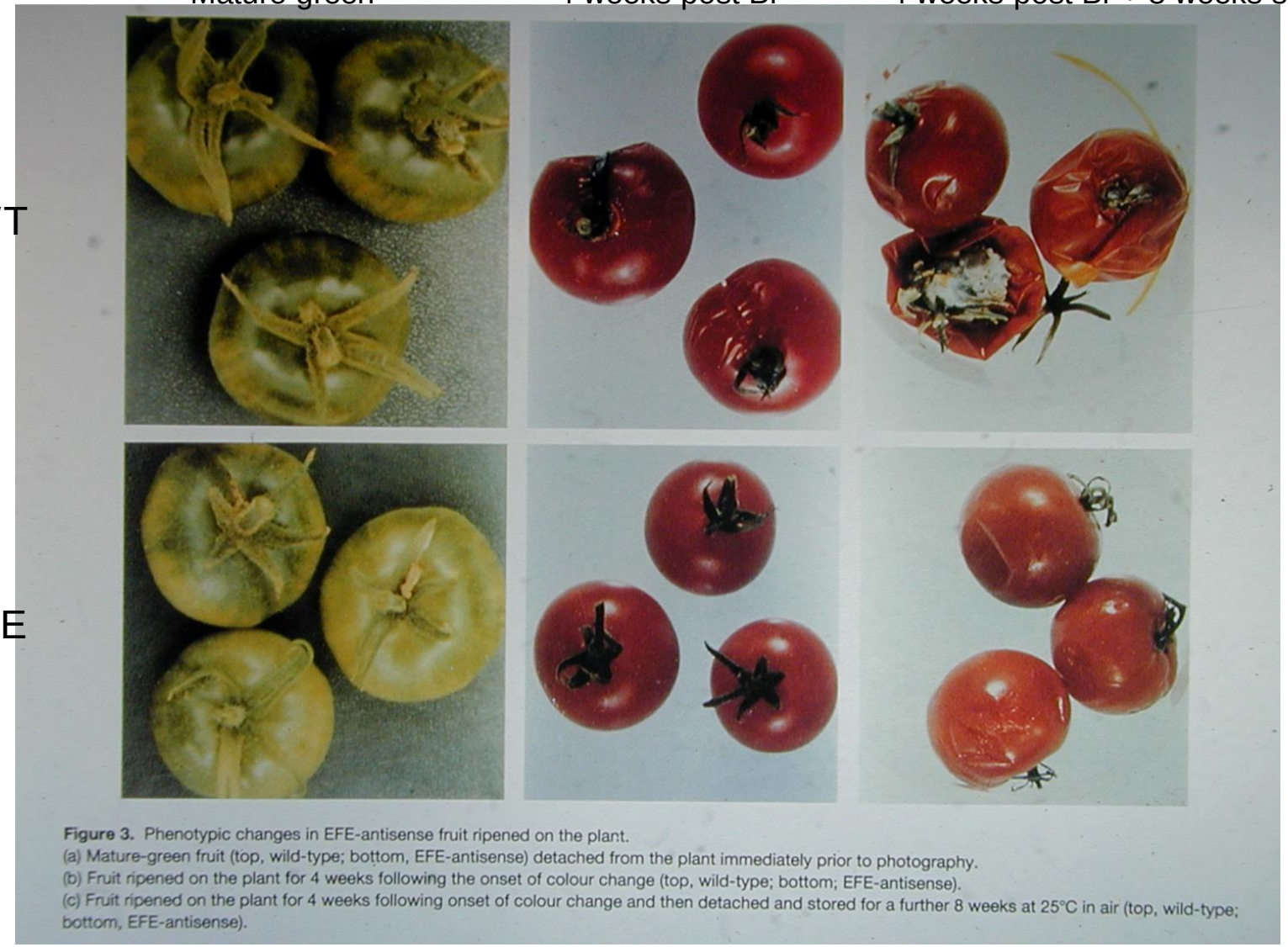
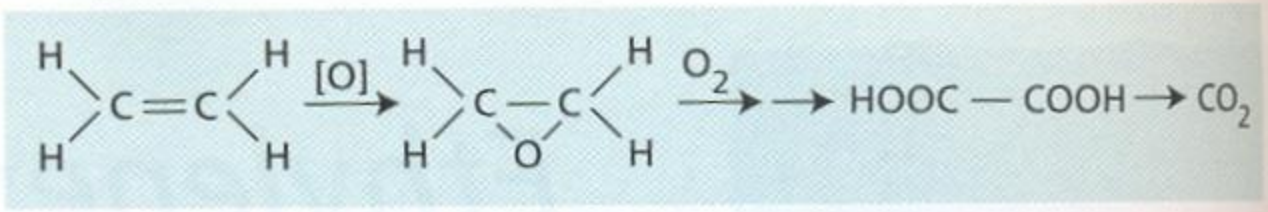


Figure 3. Phenotypic changes in EFE-antisense fruit ripened on the plant.
(a) Mature-green fruit (top, wild-type; bottom, EFE-antisense) detached from the plant immediately prior to photography.
(b) Fruit ripened on the plant for 4 weeks following the onset of colour change (top, wild-type; bottom; EFE-antisense).
(c) Fruit ripened on the plant for 4 weeks following onset of colour change and then detached and stored for a further 8 weeks at 25°C in air (top, wild-type; bottom, EFE-antisense).

三、Eth 的代谢

In most plant tissues, ethylene can be completely oxidized to CO_2, in the following reaction:

Complete oxidation of ethylene



Ethylene | Ethylene oxide | Oxalic acid | Carbon dioxide

Eth结合体

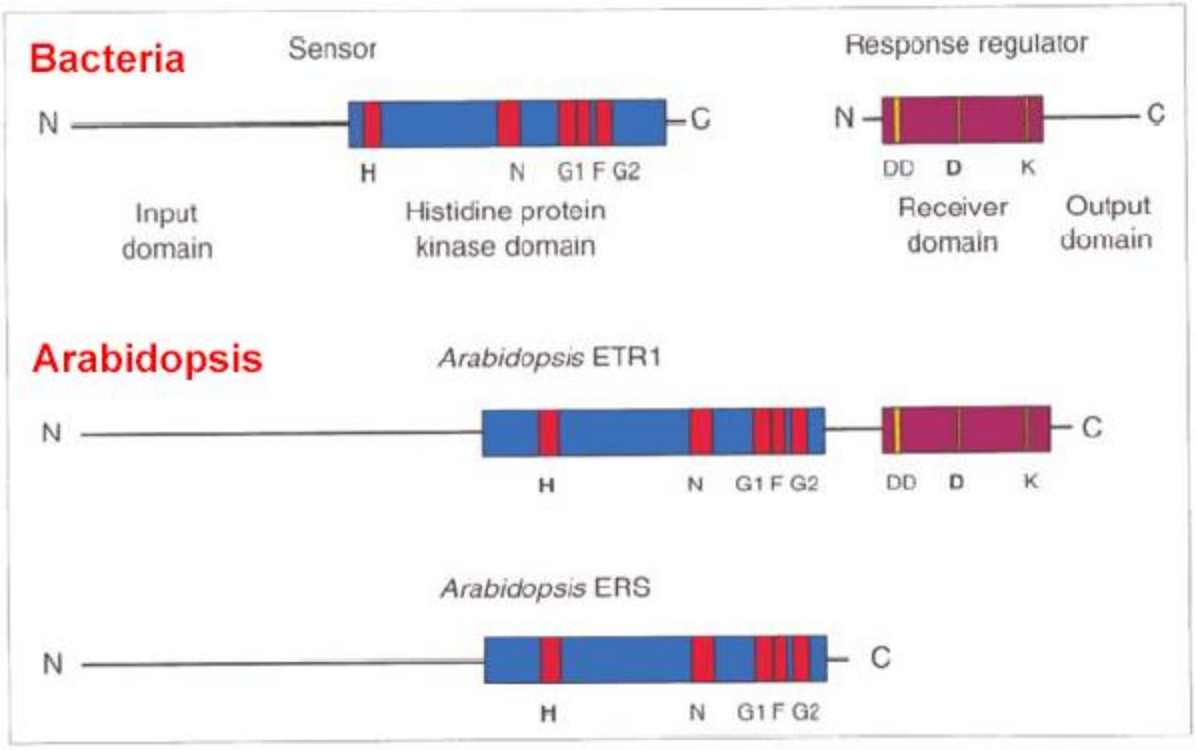
四、Eth的信号转导途径

(一）受体

Selection of ethylene insensitive mutants in *Arabidopsis*

Mutagenized seed grown in the dark in the presence of ethylene yielded the *etr* mutants, that is mutants in which the triple response to ethylene is absent.

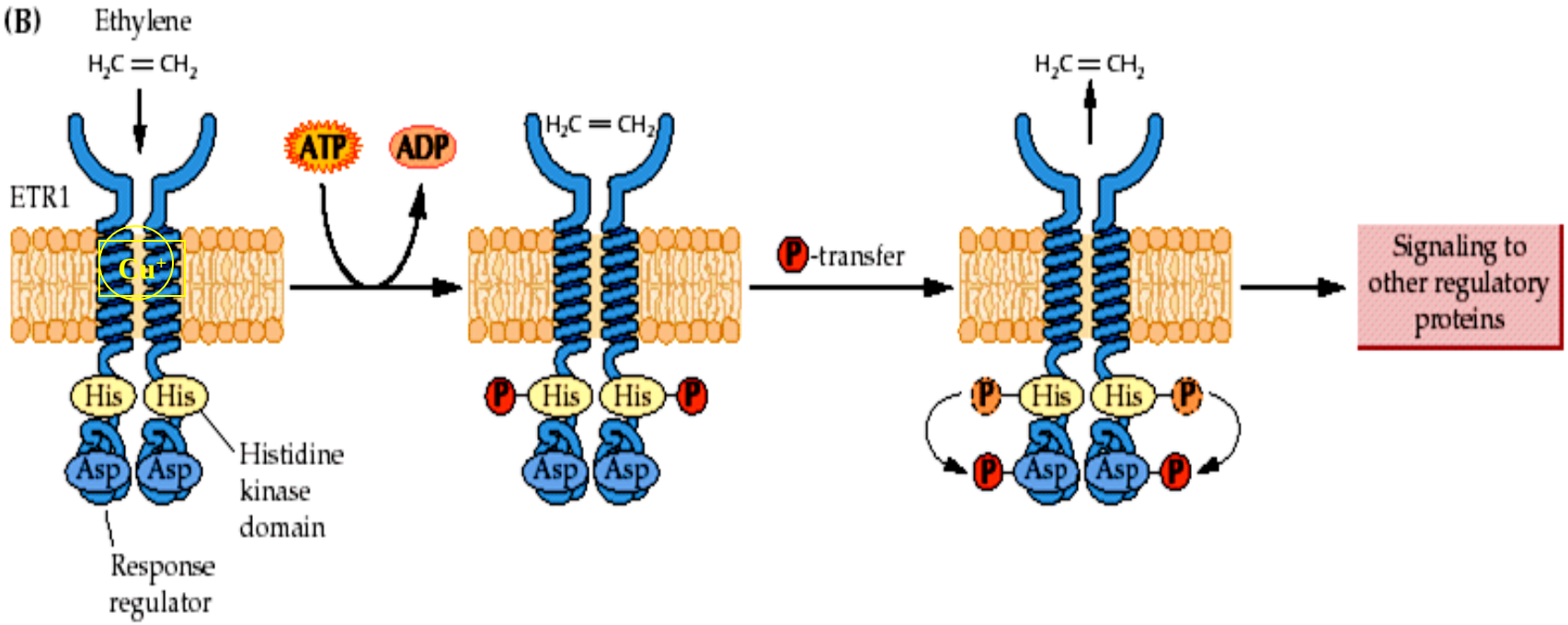
Cloned ETR1 gene showed similarity with bacterial two-component regulatory proteins



Chang (1996) TIBS **21:** 129-133

金属辅因子

Ethylene receptor mode of action



The receptor is bound to the **ER** and ethylene (hydrophobic) diffuses freely into the cells

Screen for ethylene-independent triple response phenotype "constitutive" ethylene response

CTR- Constitutive Triple Response

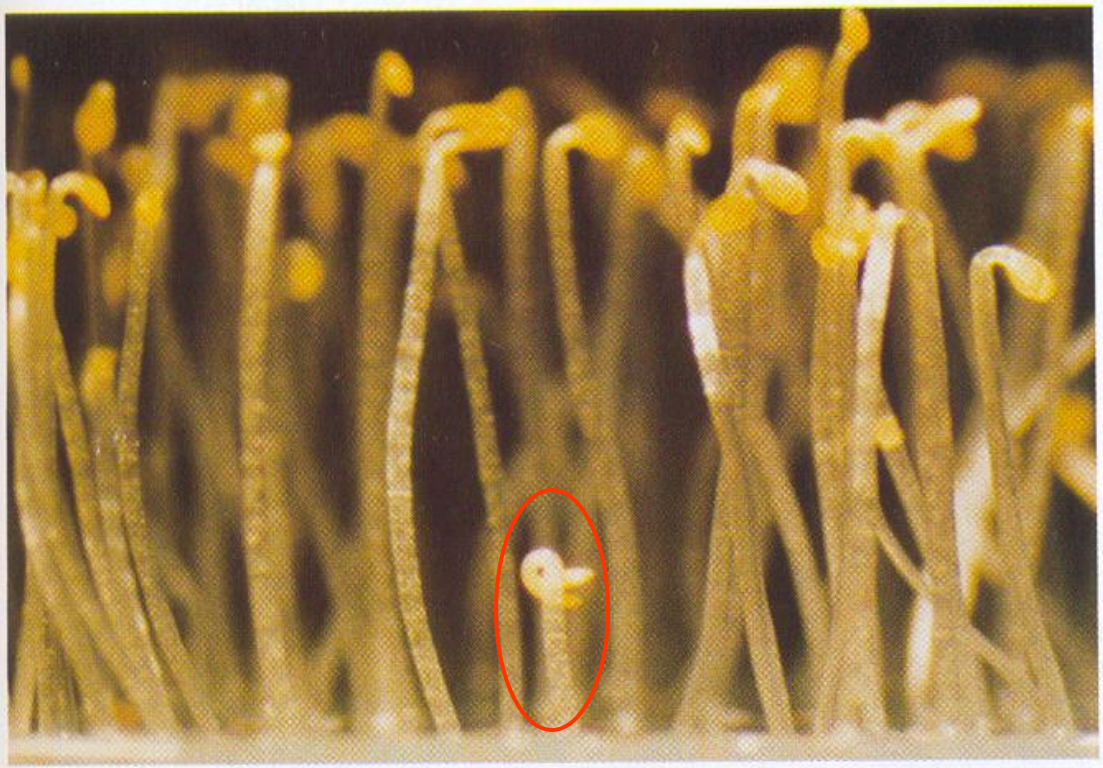
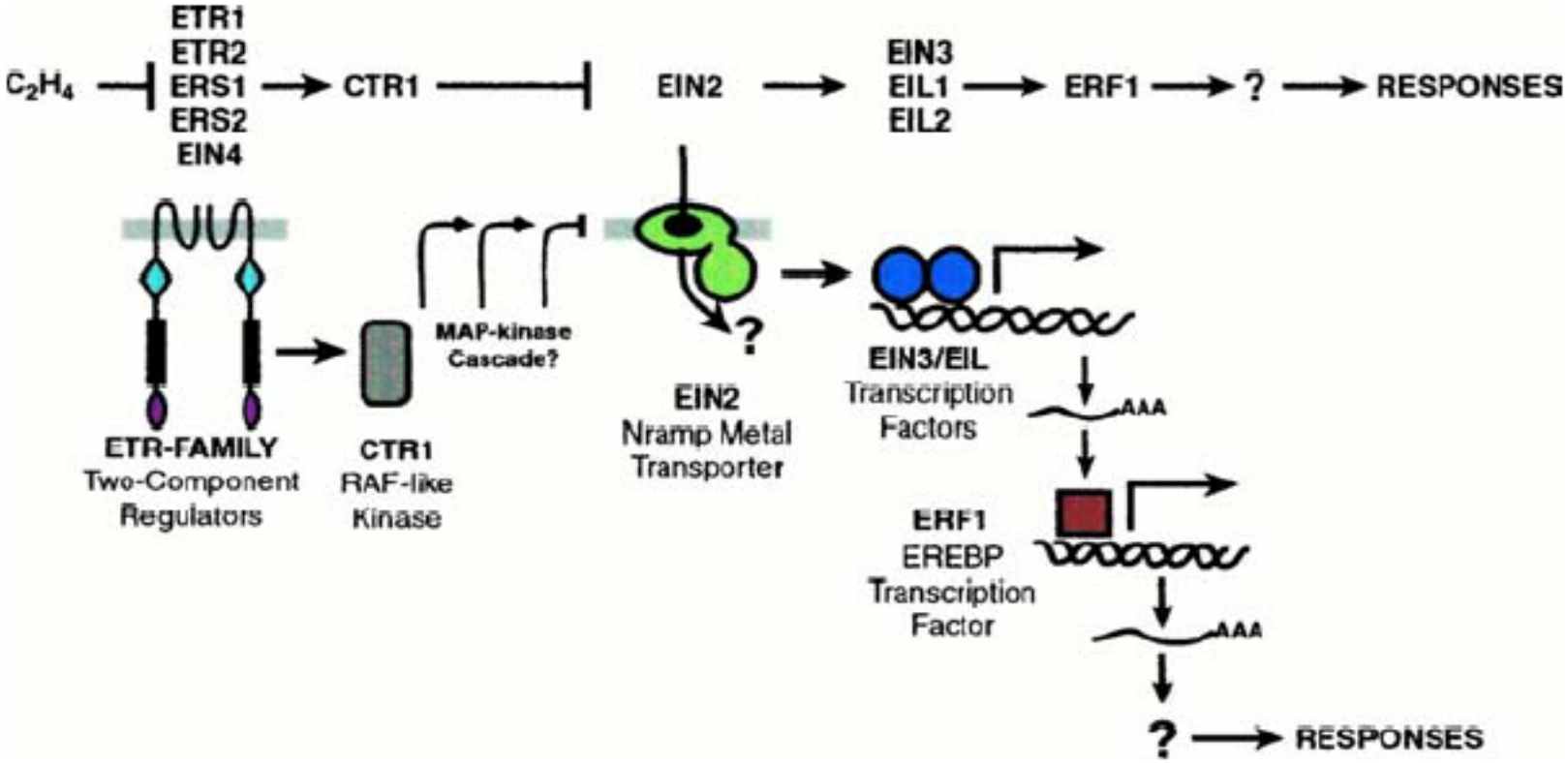


FIGURE 22.15 Screen for *Arabidopsis* mutants that constitutively display the triple response. Seedlings were grown for 3 days in the dark in air. A single *ctr1* mutant seedling is evident among the taller, wild-type seedlings. (Courtesy of J. Kieber.)

The genetic interactions and biochemical identities of components of the ethylene signal transduction pathway.



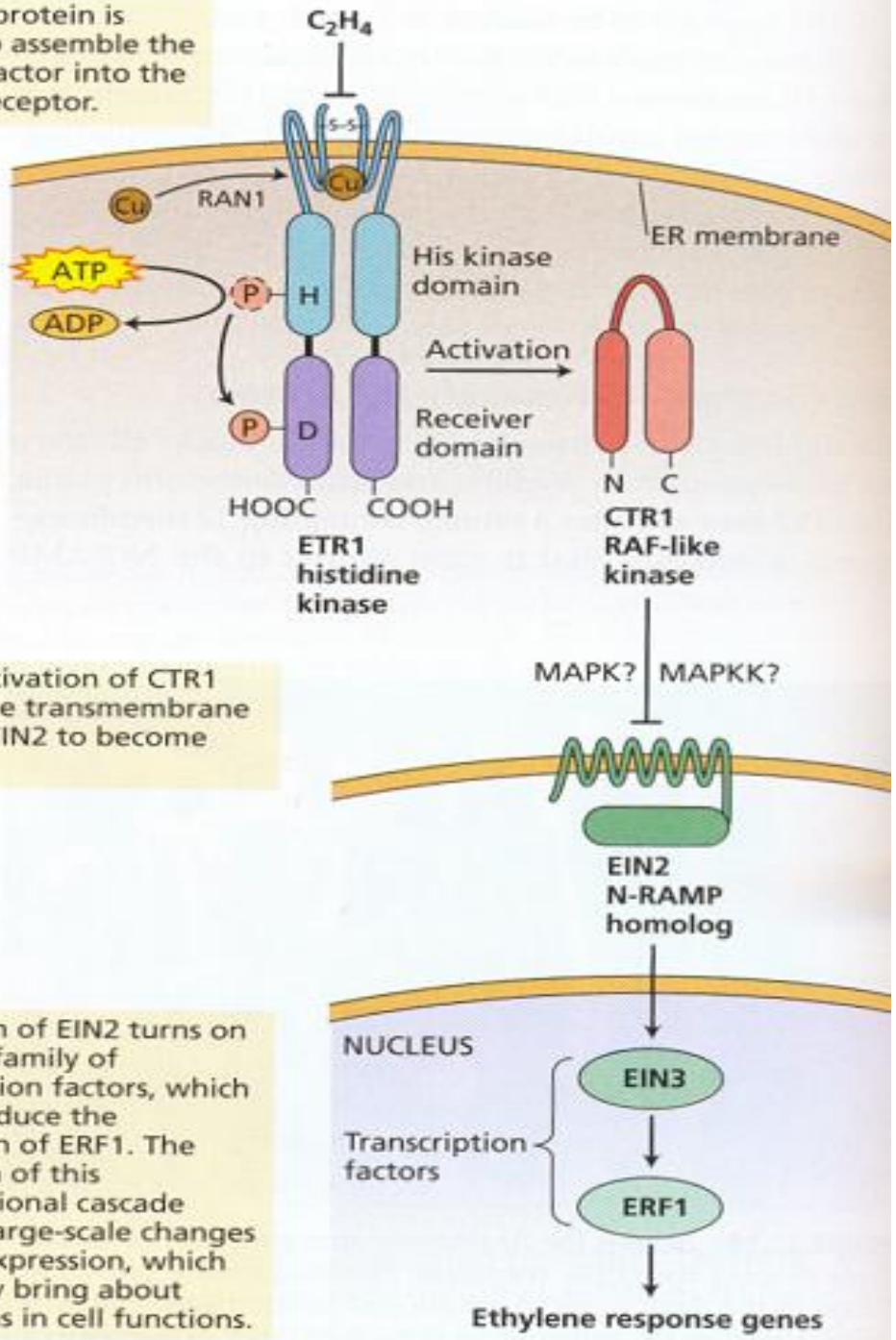
Ethylene is thought to regulate negatively a family of membrane-associated receptors. The histidine-kinase transmitter domains of members of the receptor family interact with the regulatory domain of the Raf-like kinase CTR1. This receptor/CTR1 complex negatively regulates a membrane protein (EIN2). The cytoplasmic C-terminal domain of EIN2 positively signals downstream to the EIN3 family of transcription factors located in the nucleus. A target of the EIN3 transcriptions factors is the promoter of the ERF1 gene, a member of a second family of transcription factors. [Taken from Annu.Rev.Cell Dev.Biol. (2000) 16:1-18]

The RAN1 protein is required to assemble the copper cofactor into the ethylene receptor.

In the absence of ethylene, ETR1 and the other ethylene receptors activate the kinase activity of CTR1. This leads to a repression of the ethylene response pathway, possibly through a MAP kinase cascade. The binding of ethylene to the ETR1 dimer results in its inactivation, which causes CTR1 to become inactive.

The inactivation of CTR1 allows the transmembrane protein EIN2 to become active.

Activation of EIN2 turns on the EIN3 family of transcription factors, which in turn induce the expression of ERF1. The activation of this transcriptional cascade leads to large-scale changes in gene expression, which ultimately bring about alterations in cell functions.



ne signaling in
the ETR1 recep-
rane protein of
oforms of ethyl-
in a cell; only
The receptor is a
ide bonds.
s-membrane
factor, which is
ceptors through

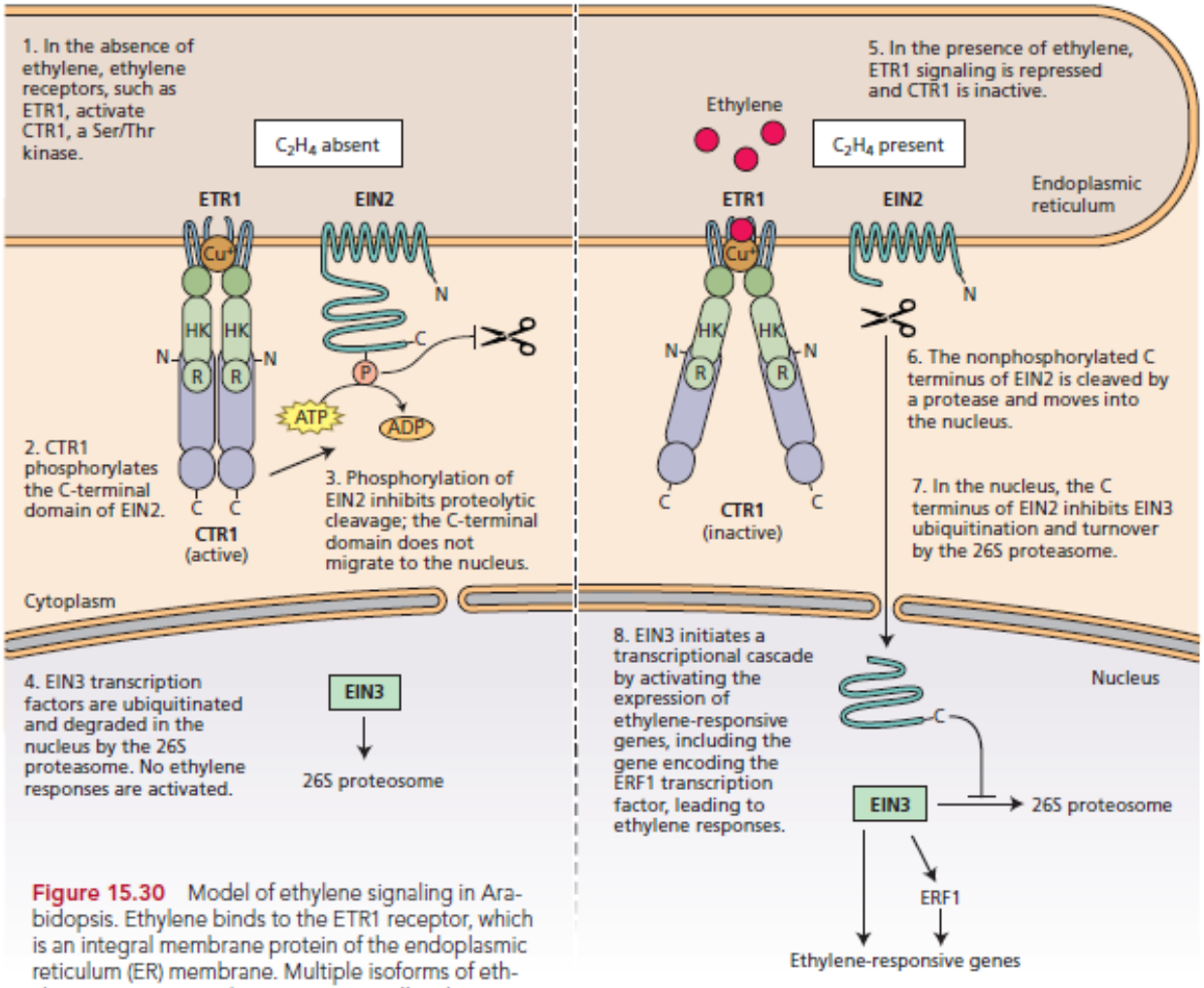
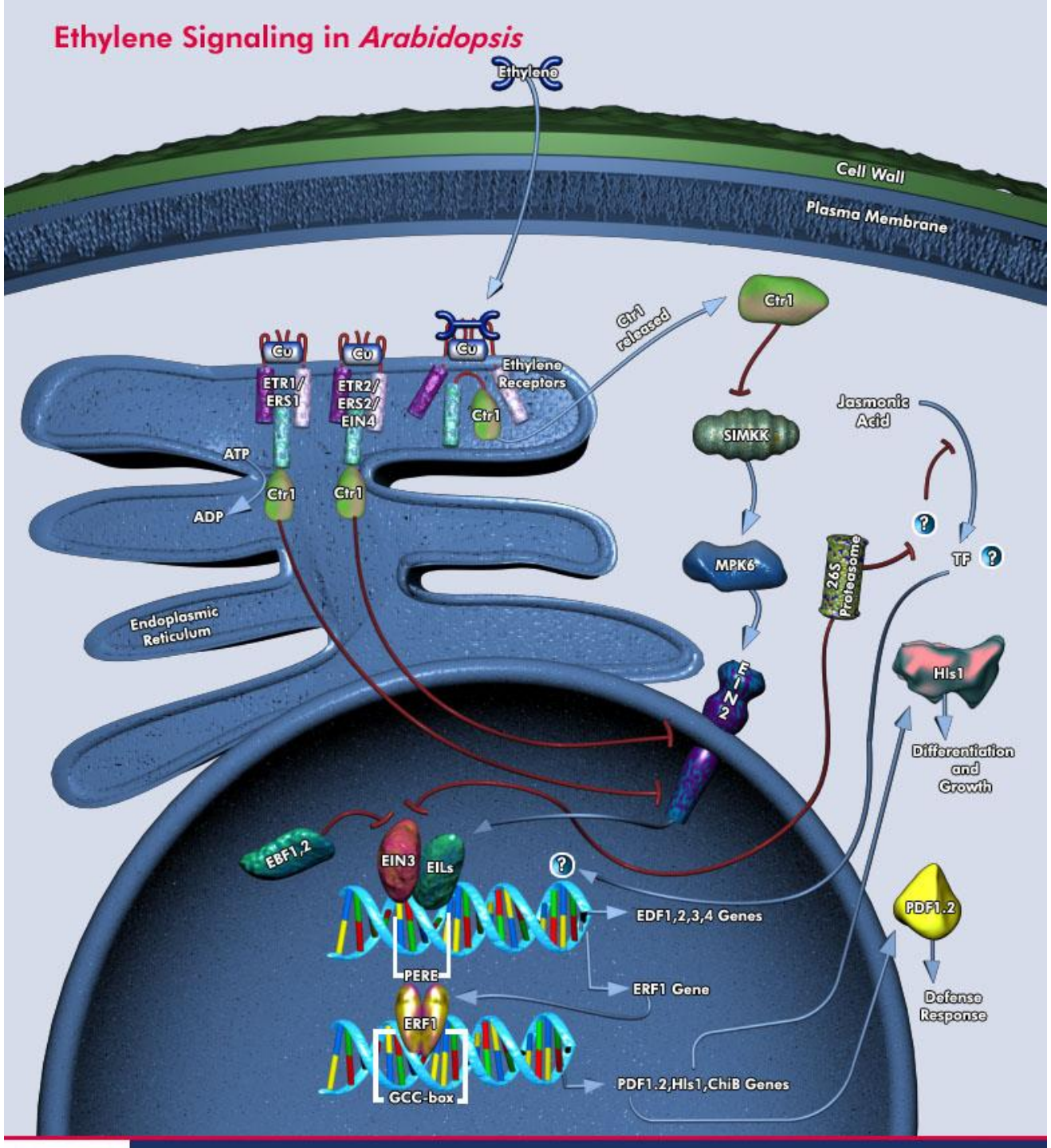


Figure 15.30 Model of ethylene signaling in Arabidopsis. Ethylene binds to the ETR1 receptor, which is an integral membrane protein of the endoplasmic reticulum (ER) membrane. Multiple isoforms of ethylene receptors may be present in a cell; only ETR1 is shown for simplicity. The receptor is a dimer, held together by disulfide bonds. Ethylene binds within the transmembrane domain, through a copper cofactor, which is assembled into the ethylene receptors. (After Ju et al. 2012.)

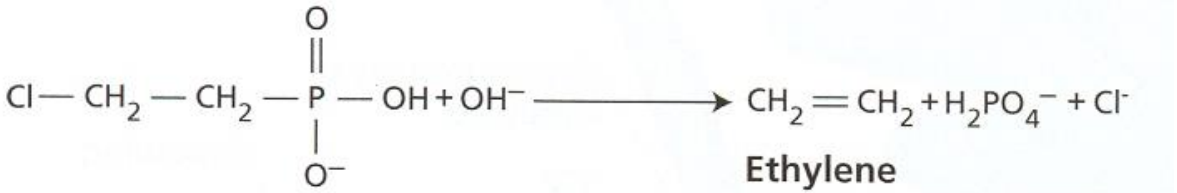
hormone signal into a transcriptional response. In brief, brassinolide binding to the brassinosteroid receptor kinase BRASSINOSTEROID-INSENSITIVE1 (BRI1) on the plasma membrane triggers a phosphorylation cascade that causes a repressor protein, BRASSINOSTEROID-INSEN-


Ethylene Signaling in *Arabidopsis*
Ethylene
Cell Wall
Plasma Membrane
Cu
Cu
Cu
ETR1/ ERS1
ETR2/ ERS2/ EIN4
Ethylene Receptors
Ctr1
Ctr1 released
Ctr1
SIMKK
MPK6
Jasmonic Acid
26S Proteasome
TF
ATP
ADP
Ctr1
Ctr1
Endoplasmic Reticulum
EIN2
Hls1
Differentiation and Growth
EBF1,2
EIN3
EILs
EDF1,2,3,4 Genes
PERE
ERF1 Gene
ERF1
GCC-box
PDF1.2,Hls1,ChiB Genes
PDF1.2
Defense Response

目前已知的拟南芥乙烯信号传导模式是：

乙烯与细胞质膜受体ETR1结合之后，钝化了其信号转导下游的CTR1（蛋白激酶家族的成员），使EIN2磷酸化水平下降，器C端被剪切，进入细胞核，抑制EIN3泛素化降解，EIN3/EIL1上调ERF等乙烯响应转录因子的转录，调节乙烯反应。

五、应用

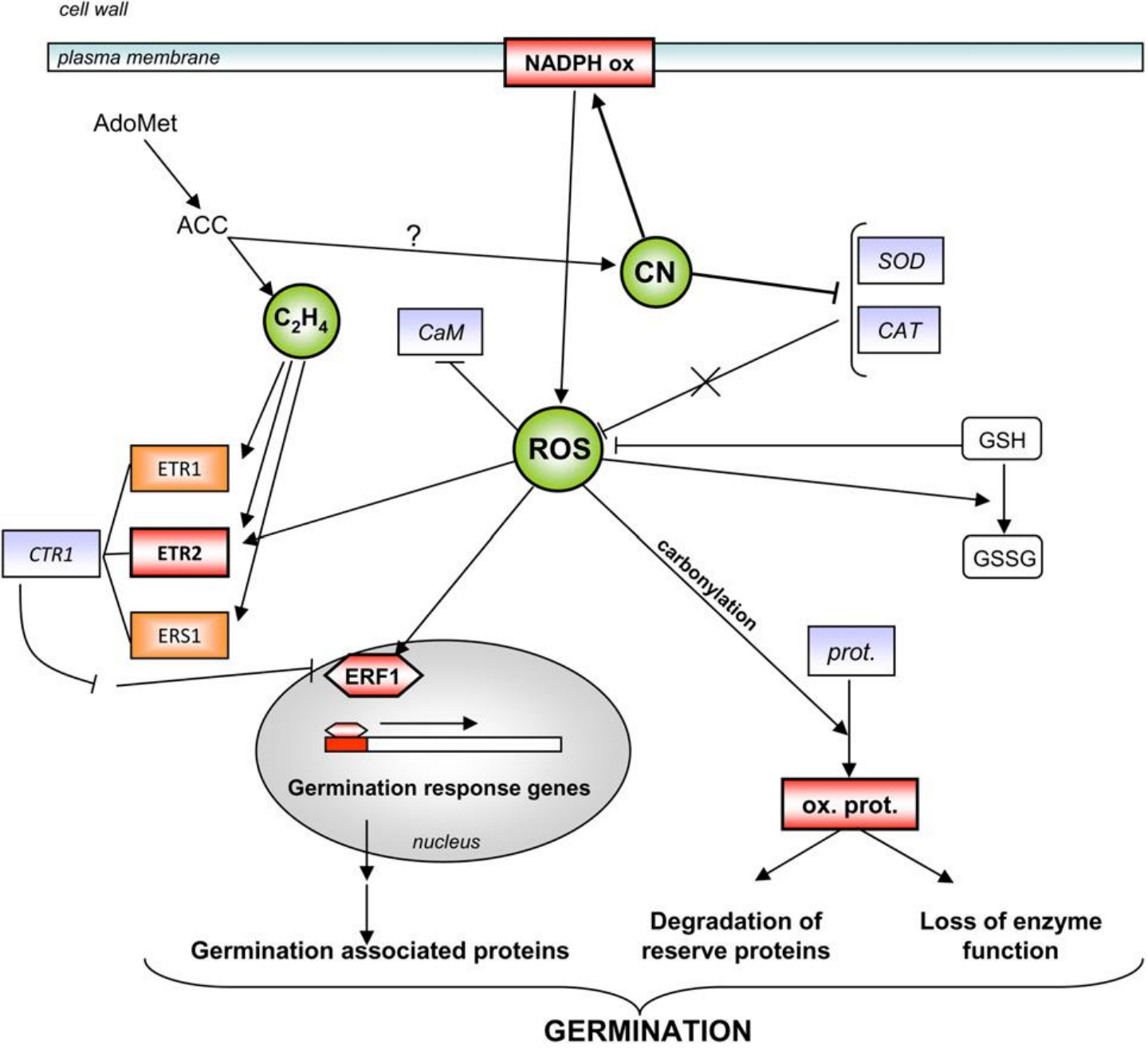


2-Chloroethylphosphonic acid (ethephon)

Ethylene release (Ethrel
乙烯利： 2－氯乙基磷酸)

Ethrel application in Agriculture:

1. Breaks seed dormancy and initiate germination in cereals
2. Breaks bud dormancy
3. Induces elongation of submerged aquatic species (deep water rice, increase GA synthesis and sensitivity to)
4. Induces flowering in pineapple (applied to synchronized fruit development)
5. Induces leaf senescence (cotton)
6. Femaleness in cucumbers
7、Induces fruit ripening
8、促进橡胶树排乳胶


cell wall
plasma membrane
NADPH ox
AdoMet
ACC
?
CN
SOD
CAT
C_2H_4
CaM
ROS
GSH
GSSG
ETR1
ETR2
ERS1
CTR1
carbonylation
prot.
ERF1
Germination response genes
nucleus
ox. prot.
Germination associated proteins
Degradation of reserve proteins
Loss of enzyme function
GERMINATION

抑制乙烯的合成：

1. ACC合成酶和氧化酶的抑制剂

AOA，AVG，Co2＋, Ag+

2.乙烯吸附剂：KMnO4

3.低温：降低乙烯合成

4. 乙烯受体竞争物：1－MCP（1－甲基环丙烯）

CO_2