# 植物生理學

是一門探討植物從萌芽、生長、分化、成熟至死亡的生命週期以及植物對環境因子反應的科學，即研究植物生命功能特性的學科。利用已知的生物化學、生物物理、分子與遺傳之原理，闡釋植物各種生理現象的機制，探究植物生命現象的奧妙。

**Text:** Plant Physiology (2010) Taiz L, Zeiger E

**References:**

Introduction to Plant Physiology (2009) Hopkins WG., Huner NPA.
植物生理學 (2006) 審校者：王淑美；主編者：潘瑞熾

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## *Part 1: Water and Plant cells*

＊ 95~5% water content
  vegetative, storage tissues: 80~95%
  xylem: 35~50%
  seeds: 5~15%, mucilage

＊ 500 g $H_2O$ / g organism of plant

Less than 5% of the absorbed water is actually retained for growth and even less used in biochemical reactions

＊ Absorb vs. lose water:
  Absorption (吸收): major via root (~97%), take up soil minerals
  Transpiration (蒸散): occur in leaf, dissipate the heat of sunlight
  Photosynthesis: occur in leaf, $CO_2$ uptake
  — Even slightly imbalance……..

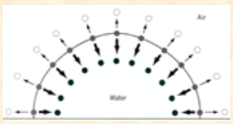
＊ Water movement at cell level
  — chemical properties and physical forces

## § *The polarity of water molecules*

* An excellent solvent for ionic substances
  – hydration shells (水合層) formation
* Transparency (透明)
* Hydrogen bond
  – high specific heat: buffer temperature fluctuations
  – high latent heat of vaporization: regulates plant's temp.

absorb ca. 50% solar energy, 300 μm $H_2O \xrightarrow{\text{light}}$ 100 °C / min

* Hydrogen bond
  cohesive and adhesive properties




cohesion (內聚力):
the mutual attraction between $H_2O$ molecules,
to minimizes the surface area at air-water interface – most stable.

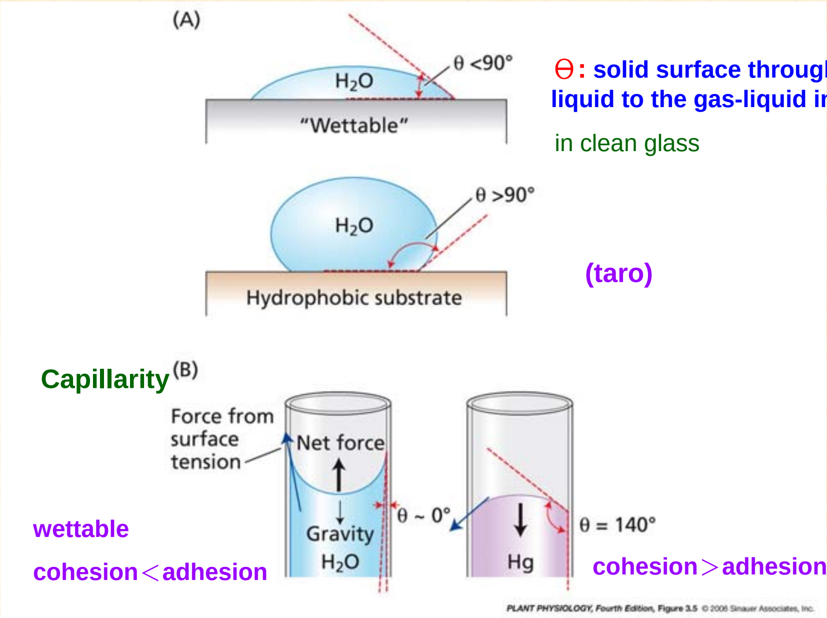
surface tension (表面張力):
the energy required to increase the surface area of air-liquid interface

adhesion (附著力):
the attraction of $H_2O$ to a solid phase

⇒ cohesion, adhesion, surface tension
→ capillarity (毛細現象)

Surface tension of several liquids at 20°C (N/m)

| | |
|---|---|
| 1% gelatin | 0.0083 |
| Ethanol | 0.0228 |
| Phenol | 0.0409 |
| Water | 0.0728 |




Θ: solid surface through the liquid to the gas-liquid interface

in clean glass

(taro)

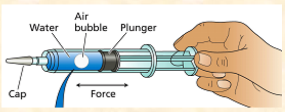
**Capillarity**

wettable

cohesion＜adhesion

cohesion＞adhesion

## ＊ Hydrostatic (流體靜力) pressure




– Positive hydrostatic pressure: push
Negative hydrostatic pressure: pull
tensile strength (tension，張力)

**The Max. force per unit area that to break the water column**
**the tensile strength of water column: – 30 MPa**

**If have air bubble? / cavitation in xylem**

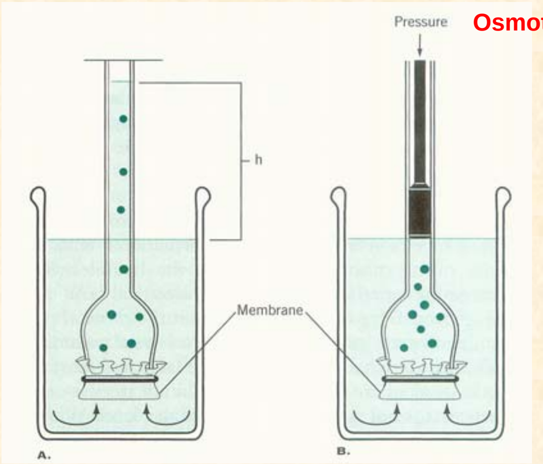
**Comparison of units of pressure**

1 atmosphere = 14.7 pounds per square inch
= 760 mm Hg (at sea level, 45° latitude)
= 1.013 bar
= 0.1013 Mpa
= $1.013 \times 10^5$ Pa

A car tire is typically inflated to about 0.2 MPa.
The water pressure in home plumbing is typically 0.2–0.3 MPa.
The water pressure under 15 feet (5 m) of water is about 0.05 MPa.

## * Osmosis (滲透):

the diffusion of water




Osmotic pressure

(+)

selective

**Reverse osmosis (RO)**

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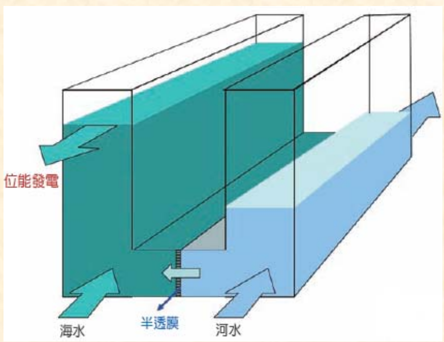
# 薄膜—未來能源之鑰

### 滲透膜

水力發電是利用水的位能轉換成動能以推動發電機而發電，在由高處往低處流的溪流裡建水壩累積水的高度，自然會獲得具比較高位能的水。日月潭抽蓄發電廠就是利用離峰時間的便宜電力把水抽至高處，再於顛峰時間放水發電。地球上海水取之不盡，如果能用以發電，會是一理想的資源。

利用海水發電，技術之一是利用潮汐起落的能量差來發電，另一則是利用薄膜技術的「鹽分梯度發電」。當淡水（河水）和鹽水（海水）被薄膜隔開時，因爲滲透壓的關係，如果所用的薄膜具有半透性，就只能透過水分子但阻絕鹽分子，則濃度差異會迫使淡水通過薄膜到達鹽水側，鹽水側端的水位就會高過淡水側端，產生的水位差異就可提供足夠的位能用以發電。



§ **Water potential ($\Psi_w$ , 水勢)**

– **the free energy of water per unit of volume (J $m^{-3}$)**

– **a good overall indicator of plant health**

The water potential of solution is dissected into three components

∗ ***Osmotic potential*** **($\Psi_s$) ↔ osmotic pressure**

**$\Psi_s = -RTC_s$, $C_s$ is osmolality (mole/L $H_2O$)**

– **independent of the nature of solutes**

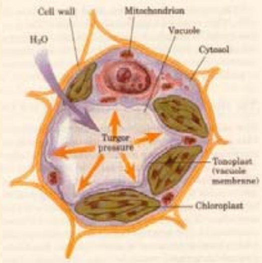
– **ionic solutes (dissociation) e.g., sucrose, NaCl**

∗ ***Hydrostatic pressure potential ($\Psi_p$)***

positive hydrostatic pressure: turgor

negative hydrostatic pressure: tension

pure water in standard state: $\Psi_p$=0




∗ *Gravity* **($\Psi_g$)**

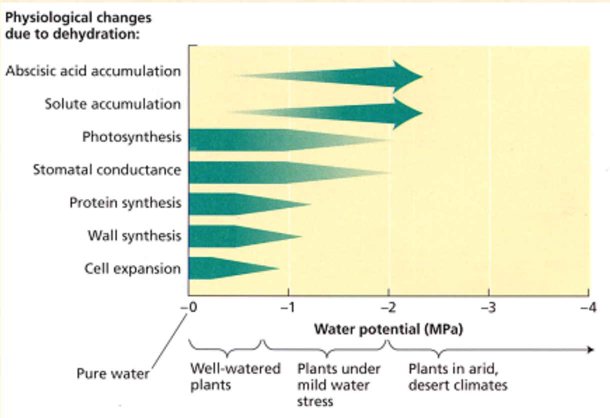
**$\Psi_g = \rho_w gh$**

At the cell level: **$\Psi_w = \Psi_s + \Psi_p$**

**Plant in space**

**Water potential**

**– evaluate the water status of a plant**




∗ **$\Psi_w$ of a typically well-watered leaves: – 0.2 ~ – 1.0MPa;**

**the leaves of plants in arid climates: – 2 ~ – 5MPa.**

## Cactus stem:

outlayer: photosynthesis

inner layer: water storage,

larger size and thinner cell wall ⇒ more flexible walls

### During drought:

Inner cells:

[soluble solutes] ↓, polymerization

[nonsoluble starch granules] ↑

$\Psi_s \uparrow \Rightarrow \Psi_w \uparrow$

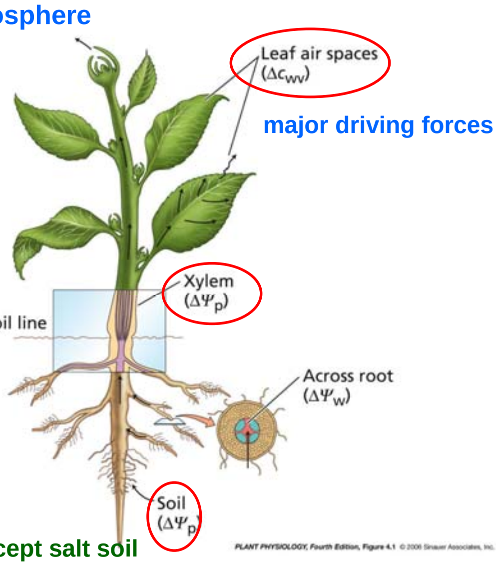
⇒ water enter into outlayer cells,

maintain photosynthesis

## Part 2: Translocation (運移) in plants

## A: in xylem (木質部)

**Water → soil → plant → atmosphere**




**$\Psi_s$ is minor, except salt soil**

## § Root pressure

***Root pressure: (+ 0.05 ~ 0.5 Mpa)***

– The stem of a young seedlings is cut off just above the soil…

– Root absorb ions which are transported to xylem

⇒ $\psi_s$ , $\psi_w$ of xylem ↓

⇒ root pressure ↑

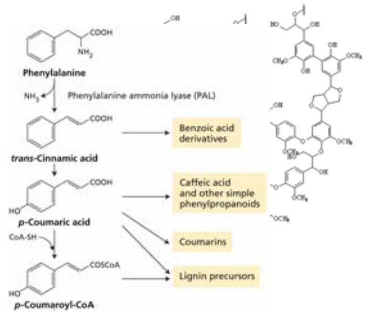
occur when soils $\Psi_w$ are high and transpiration rates are low

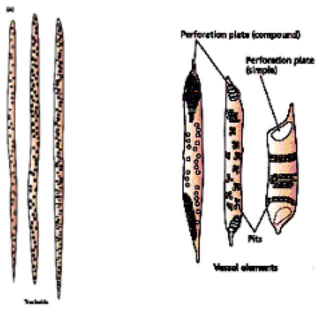
## § Water transport through xylem

- ∗ The longest, simplest and most low resistance pathway
- ∗ Also transport dissolved minerals, and, on occasion, small organic molecules
- ∗ Mature xylem is a grouped ‘dead’ cell, no membranes, no organelles, and remain the thick, lignified (木質化) cell wall, which form hollow tube

$C_6$-$C_3$

- ∗ Consists two types of tracheary elements:
  - (a) tracheids (假導管)
  - (b) vessel elements (導管)




**Long-distance water transport:**

Volume flow rate ($m^3/s$)=
$(\pi r^4/8\eta)\ (\Delta\Psi_p/\Delta x)$

**the rate of transport**

$\Rightarrow$ **Jv ($m\ s^{-1}$)** $= (\mathbf{r^2}/8\eta)\ (\Delta\tau_p/\Delta x)$

***$Jv = 4\times10^{-3}\ m\ s^{-1}$***

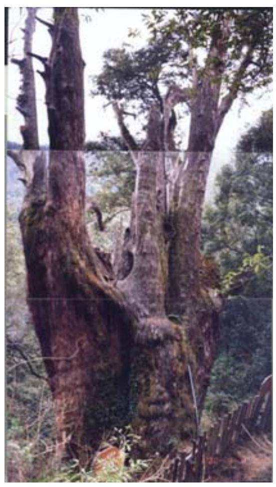
$r = 40\ \mu m$

$\eta = 10^{-3}$ Pa s water

$\Delta\tau_p/\Delta x =$ 0.02 MPa/ m

**If 100 m huge tree:**

**$100 \times 0.02 + 100 \times 0.05/5 = 3$ MPa**



## § The ascent of xylem water on huge trees

- Root pressure:
- Capillarity
- Cohesive-tension theory

**Venation (脈紋) pattern:**

vein

minor vein: 0.5 mm

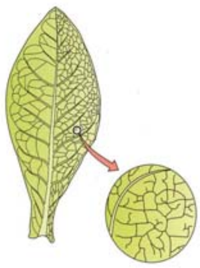
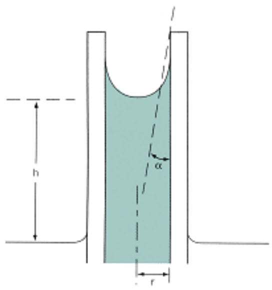


FIGURE 4.8




**Capillary rise**

$(2\pi r\cos\alpha)\ \gamma = \pi r^2 h \rho g$

20℃

$\gamma$ =0.073 N/m

$\rho$ =998 kg/m$^3$

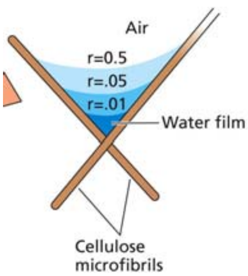
g= 9.8 m/s$^2$

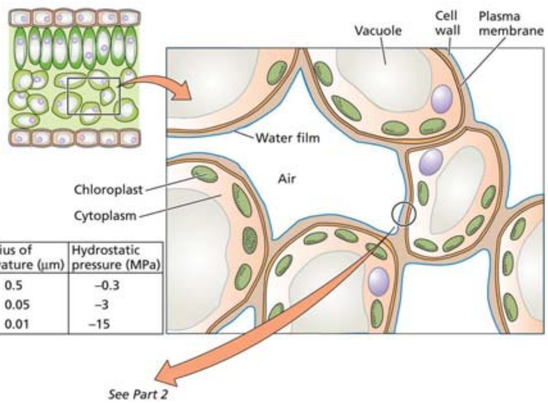
If r= 40 $\mu$m    h= 0.75 m

## Cohesive-Tension theory: the predominate driving force

$\Psi_p$= -2T / r

air-water interfaces




| | Radius of curvature (μm) | Hydrostatic pressure (MPa) |
|---|---|---|
| (A) | 0.5 | −0.3 |
| (B) | 0.05 | −3 |
| (C) | 0.01 | −15 |

PLANT PHYSIOLOGY, Fourth Edition, Figure 4.8 (Part 1) © 2006 Sinauer Associates, Inc.

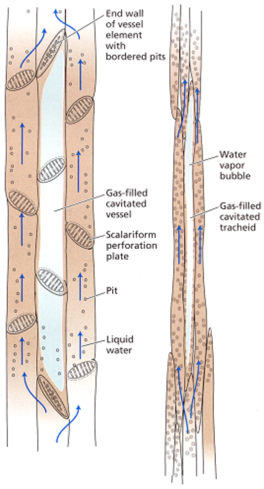
## § The physical challenges of water movement in the xylem

*** *Air seeding***

*** *Cavitation* (gas bubbles expansion) *or embolism* (gas-filled void，栓塞)**

**gas bubbles expand under tensile forces, break the continuity of water column and prevent water transport**

**Acoustic shock**




## § Plants minimize the consequence of xylem cavitation

- **Detour (繞道)around the embolized conduit**
- **Dissolve gas into xylem solution**
  **at night, transpiration↓, solubility↑**
- **New xylem formation**
- **Repair cavitation (?)**

## § Water movement from the leaf to atmosphere

*** Transpiration (蒸散): loss of water from plants occur through pores in the leaf**

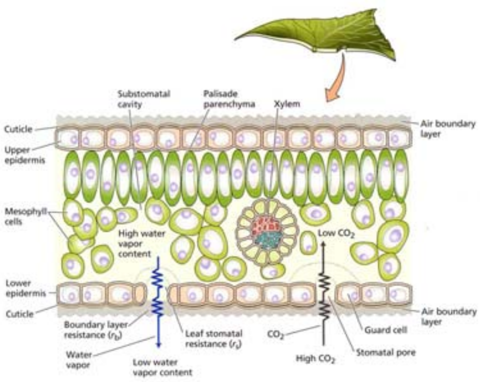



FIGURE 4.10

**90~95 % stomatal transpiration**

*** Transpiration rate :**

$$E = \frac{c_{wv(leaf)} - c_{wv\,(air)}}{r_s + r_b}$$

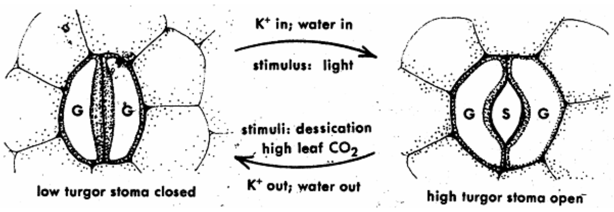
difference in water vapor conc.

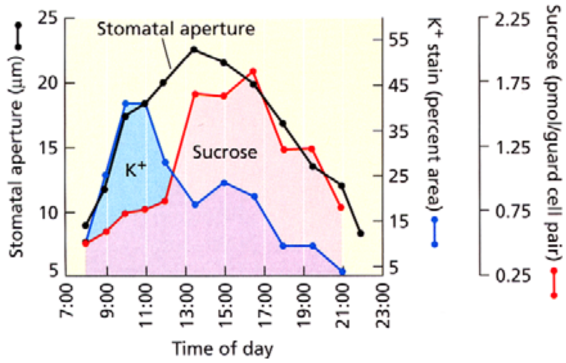
*** $r_s$: leaf stomatal resistance**
(biological factor)

*** $r_b$: leaf boundary layer resistance**
(non-biological factor)
wind velocity, anatomical and morphological aspects

## Guard cells:

a pair of specialized epidermal cells, which surround the stomatal pore




## § Leaves must dissipate vast quantities of heat (Temp.)

absorb ca. 50% solar energy, 300 $\mu$m $H_2O \xrightarrow{\text{light}}$ 100 °C / min

* **long-wavelength radiation** **(1000 nm)**
* **Sensible heat loss**
* **Evaporative heat loss (latent)** **perspiration**

***Bowen ratio:***

**sensible / evaporative heat loss**

Desert plants: 10

Tropic rain forests: 0.4

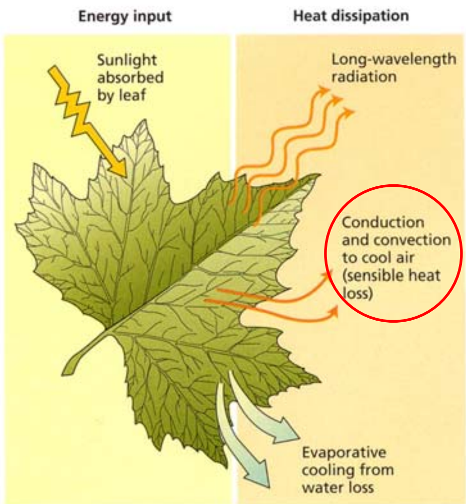



FIGURE 9.14

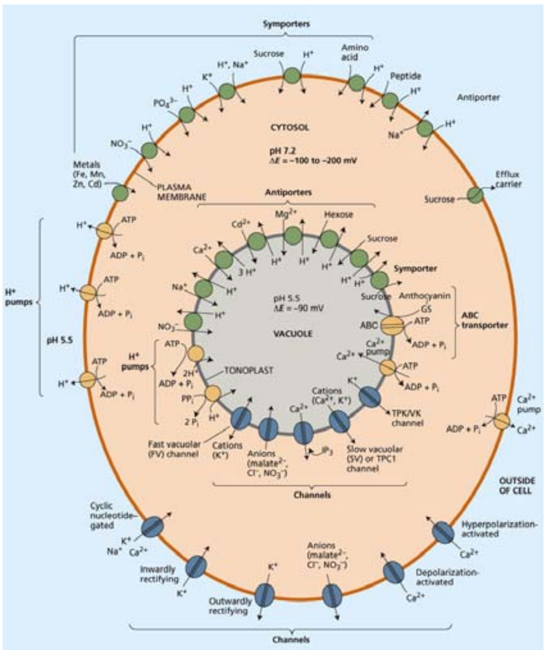
## § Mineral nutrition    Hoagland solution

**TABLE 5.3**
**Composition of a modified Hoagland nutrient solution for growing plants** *(Part 1)*

| Compound | Molecular weight | Concentration of stock solution | Concentration of stock solution | Volume of stock solution per liter of final solution | Element | Final concentration of element | |
|---|---|---|---|---|---|---|---|
| | g mol$^{-1}$ | m*M* | g L$^{-1}$ | mL | | μ*M* | ppm |
| **Macronutrients** | | | | | | | |
| $KNO_3$ | 101.10 | 1,000 | 101.10 | 6.0 | N | 16,000 | 224 |
| $Ca(NO_3)_2 \cdot 4H_2O$ | 236.16 | 1,000 | 236.16 | 4.0 | K | 6,000 | 235 |
| $NH_4H_2PO_4$ | 115.08 | 1,000 | 115.08 | 2.0 | Ca | 4,000 | 160 |
| $MgSO_4 \cdot 7H_2O$ | 246.48 | 1,000 | 246.49 | 1.0 | P | 2,000 | 62 |
| | | | | | S | 1,000 | 32 |
| | | | | | Mg | 1,000 | 24 |
| **Micronutrients** | | | | | | | |
| KCl | 74.55 | 25 | 1.864 | | Cl | 50 | 1.77 |
| $H_3BO_3$ | 61.83 | 12.5 | 0.773 | | B | 25 | 0.27 |
| $MnSO_4 \cdot H_2O$ | 169.01 | 1.0 | 0.169 | 2.0 | Mn | 2.0 | 0.11 |
| $ZnSO_4 \cdot 7H_2O$ | 287.54 | 1.0 | 0.288 | | Zn | 2.0 | 0.13 |
| $CuSO_4 \cdot 5H_2O$ | 249.68 | 0.25 | 0.062 | | Cu | 0.5 | 0.03 |
| $H_2MoO_4$ (85% $MoO_3$) | 161.97 | 0.25 | 0.040 | | Mo | 0.5 | 0.05 |
| NaFeDTPA (10% Fe) | 468.20 | 64 | 30.0 | 0.3–1.0 | Fe | 16.1–53.7 | 1.00–3.00 |

**MS/B5…**

**Transporters**



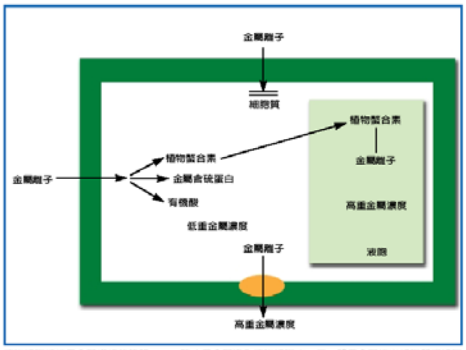
* Plant via roots absorb mineral nutrients, primarily in the form of *inorganic ions* from the soil, act as a "miner (礦工)"

* To recycle animal wastes and remove deleterious minerals from toxic-waste dumps – phytoremediation (植生復育)

## 植生復育的概念

重金屬性植物(metallophytes): 向日葵、包心菜、芥菜及天竺葵等

目的： 1. 清除重金屬汙染；2. 採礦




植物細胞抵抗重金屬逆境的策略：一、防止重金屬進入植物細胞中。二、將重金屬排出細胞質或細胞外。三、藉由蛋白質或化學物質直接與重金屬結合，以降低重金屬的毒害。

§ Mycorrhiza(e) (根菌共生)– are not unusual

* fungus (supply nutrients and water) and root (supply carbohydrates)

* in cabbage, spinach, macadamia nuts, aquatic plants

* Absent in very dry, saline, flooded soil or the fertility of soil is extreme, either high or low

* To facilitate nutrient uptake

* Ectotrophic mycorrhizae (外生菌)
Vesicular-arbuscular mycorrhizae (胞囊叢枝狀菌)

– nitrogen-fixing bacteria

– Herbicide (殺草劑)

*Ectotrophic mycorrhizal fungi*

— A thick sheath (鞘) or mantle (外膜) of fungal mycelium (菌絲體) around the roots, and some of the mycelium penetrates between the cortical (皮層的) cells.

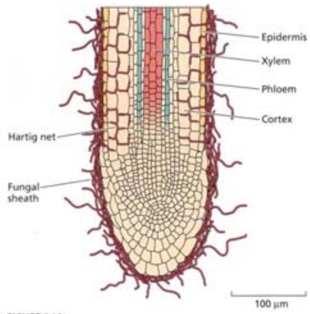



FIGURE 5.10

*Vesicular-arbuscular mycorrhizae*

— No mantle. The hyphae (菌絲) even penetrate individual cells of the cortex and can form vesicles and arbuscule.

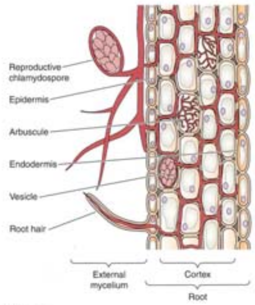



FIGURE 5.11

**B: in phloem (韌皮部)**

* **Root:** anchor, absorb water and nutrients; **absorption**
**Leave:** absorb light and exchange gas; **assimilation (同化)**
efficiently exchange via long-distance transport

* **The long-distance transport pathways:**
**Xylem:** transport water and nutrients from roots to aerial portions
**Phloem:**
*mature* leaves (sugars)→ growth and storage portions (*Phalaenopsis*)
redistributes water and various compounds
transmits signaling molecules such as hormones, proteins and RNA.

## *Materials translocated in the phloem*

**Water: the most abundant substance**

Sugar-rich sap

Carbohydrate
Sucrose
(0.3 to 0.9 M)
Nitrogen
Asx (Asp, Asn)
Glx (Glu, Gln)

**TABLE 10.2**
The composition of phloem sap from castor bean (*Ricinus communis*), collected as an exudate from cuts in the phloem

| Component | Concentration (mg $mL^{-1}$) |
|---|---|
| Sugars | 80.0–106.0 |
| Amino acids | 5.2 |
| Organic acids | 2.0–3.2 |
| Protein | 1.45–2.20 |
| Potassium | 2.3–4.4 |
| Chloride | 0.355–0.675 |
| Phosphate | 0.350–0.550 |
| Magnesium | 0.109–0.122 |

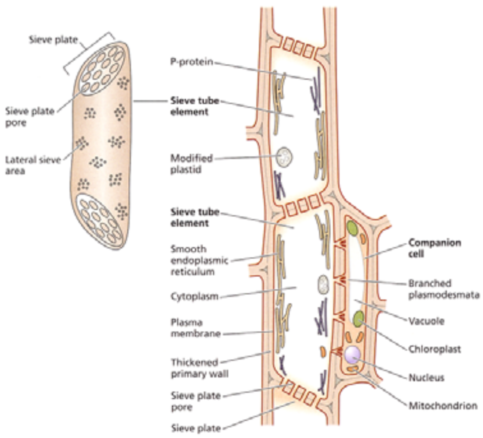
*Source*: Hall and Baker 1972.

– **RNAs: mRNA, pathogenic RNA, small regulatory RNA**
– **Plant hormones, including auxin, GAs, sytokinins, and ABA**
– **Proteins (proteomics analysis, 2009)**

## *Phloem*:

♣ **living cells, nonlignified walls**
♣ **sieve element: directly involved in translocation**
**sieve tube element (angiosperms)**
♣ **companion cells (伴細胞)**
**functions: to supply energy, to transport the photosynthetic products, take over (接管) some of the critical metabolic functions, such as protein synthesis.**

***Lack:***
**nuclei, Golgi bodies, ribosomes**
***Retained:***
**mitochondria, plastids smooth ER**



§ **P-protein (slime):** rich in phloem

**are synthesized in companion cells**

**along the periphery of the sieve tube element, or evenly distribute in the lumen**

**P-protein (body): the major function is in sealing off damaged sieve elements – short-term solution**

§ **Callose deposition – long-term solution**

**a β-1,3-glucan**

**is synthesized during damage and other stresses, such as mechanical stimulation and high temperature and dormancy**

**callose disappears when the damage is recovery or break dormancy**

Callus (癒創，癒合組織)

## *The translocation patterns of phloem*

- **is not exclusively either an upward or downward direction irrespective to gravity**
- **Source (供源): area of supply, an exporting organ**
  - **mature leaves, storage root beet (*Beta maritima*)**

  **Sink (沉積): area of metabolism or storage, a receiving organ**
  - **nonphotosynthetic organs, root and shoot apices, young tuber, developing fruits, immature leaves**
- **Not all sources supply all sinks on a plant**

  → certain sources preferentially supply specific sinks

***plasticity***

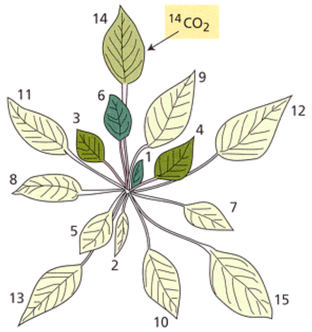
## The features of source-to-sink pathways

a. proximity

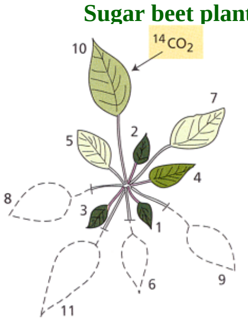
b. development: vegetative or reproductive stage

c. vascular connections: orthostichy ()

d. modification of translocation pathways: wounding, pruning

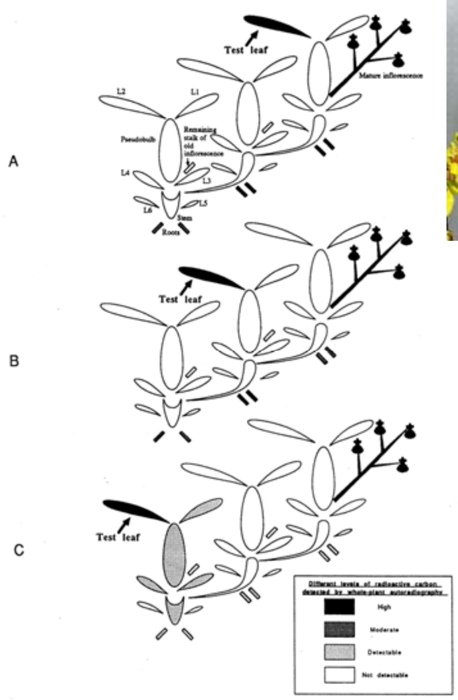



Sugar beet plant



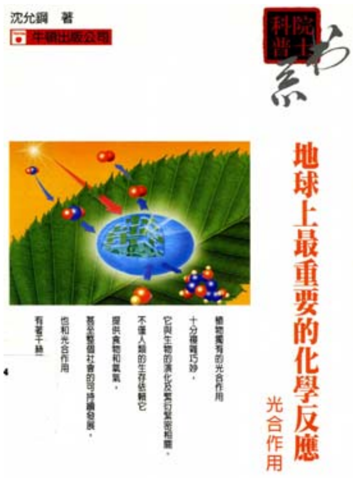

*Oncidium*

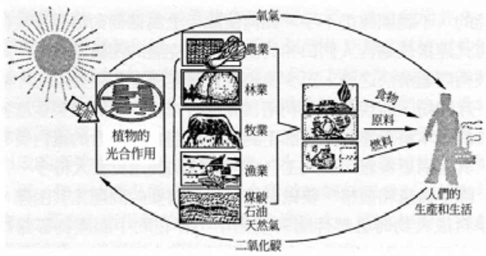
a sympodial (複莖的) and epiphytic (著生的) orchid




## Part3:Photosynthesis $6\ CO_2 + 6\ H_2O \xrightarrow{☼} C_6H_{12}O_6 + 6\ O_2$

光合作用是地球上最重要的化學反應，是自然界將太陽的光能轉變為化學能的主要途徑。能源危機的再現與環境惡化造成日益嚴重的溫室效應，使人類更加重視此無聲無息的高效能反應。




## § Photosynthesis: the light reaction

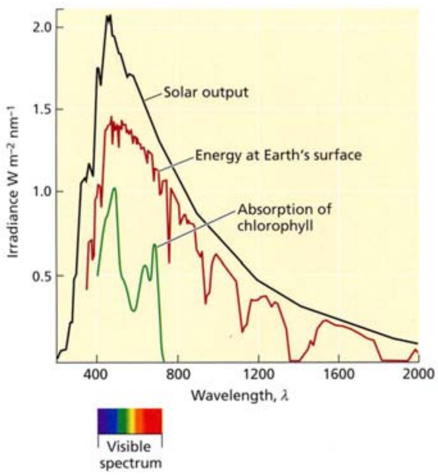



FIGURE 7.3 Algae's pigment

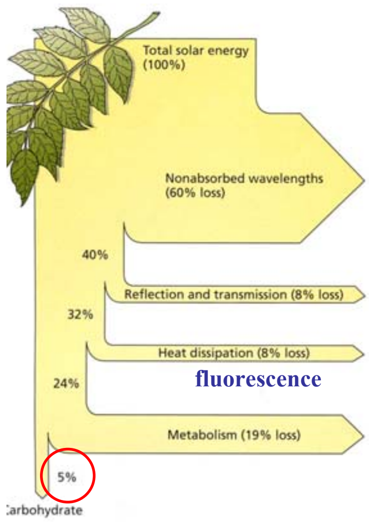



FIGURE 9.2

***Emerson:***

♣ **Red drop effect**

**Far-red light alone is insufficient in driving photosynthesis**

♣ **Enhancement effect**

**Accessory pigments** **＞ 680 nm**

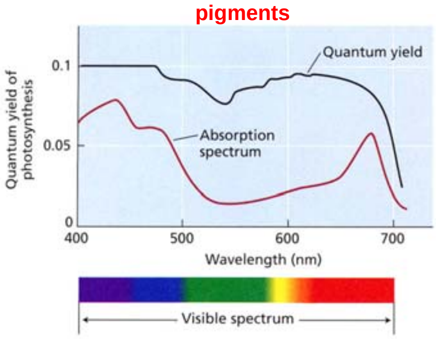



FIGURE 7.12

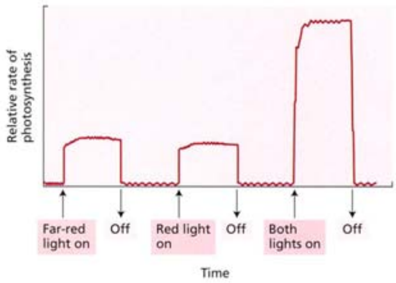



FIGURE 7.13

**⇒ Two photochemical complexes**

***Z scheme***: **noncyclic** electron transfer in photosynthetic organisms

∗ **Consist of four major protein complexes:**

**(1) PSⅡ; (2) cytochrome $b_6f$ complex; (3) PSⅠ; (4) ATP synthase**

∗ **The primary source of electrons: the oxidation of $H_2O$**

**The final electron acceptor: $NADP^+$**

**The major source of $O_2$ in earth**

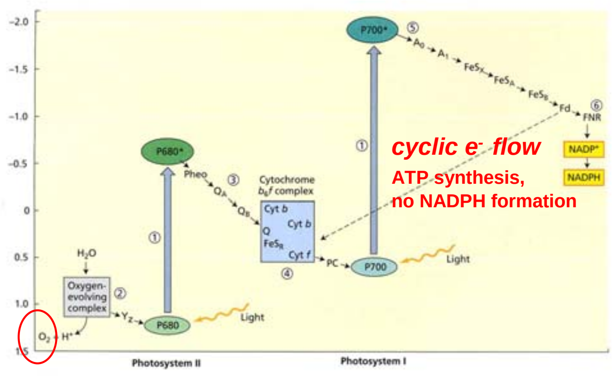



FIGURE 7.21

*Z scheme*

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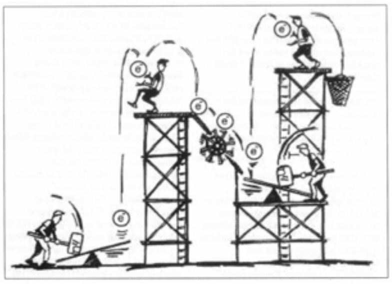
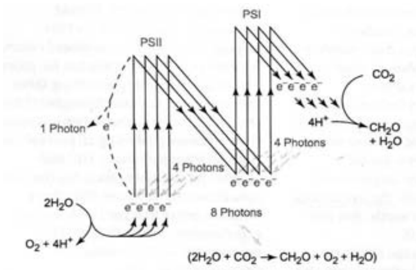





**3ATP, 2 NADPH, $O_2$ / 8 photons / 4 $e^-$**

## Hill reaction (1937)

♣ **an artificial electron acceptors in isolated chloroplast thylakoid**

**No $CO_2$ condition, still $O_2$ production**

$4\ Fe^{3+} + 2\ H_2O \xrightarrow{☼} 4\ Fe^{2+} + O_2 + 4\ H^+$

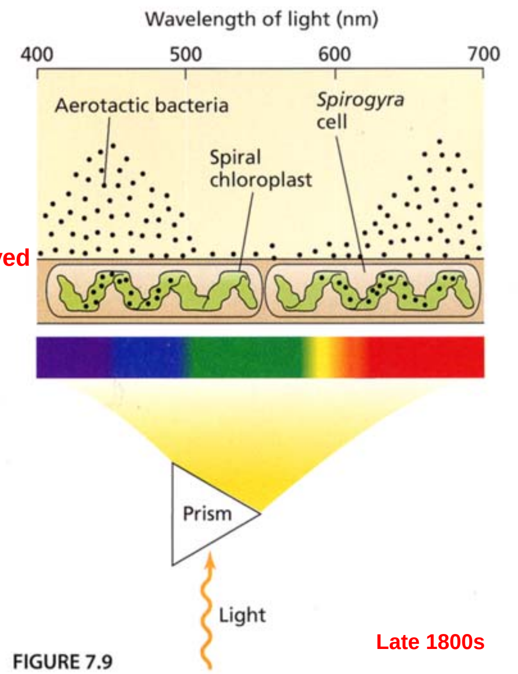
♣ $CO_2 + 2\ H_2S \rightarrow (CH_2O) + 2\ S + H_2O$

$H_2{}^{18}O + CO_2 \rightarrow (CH_2O) + {}^{18}O_2$

(1) $CO_2 + 2\ H_2O \rightarrow (CH_2O) + O_2 + H_2O$

(2) $CO_2 + H_2O \rightarrow (CH_2O) + O_2$

$O_2$ evolved




Late 1800s

FIGURE 7.9

## Three light parameters:
### spectral quality, amount, and direction

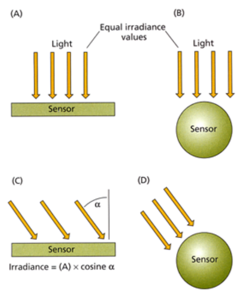
♣ **Spectral quality**

– **Light sources: sunlight, incandescent light, fluorescent light, light emitting diode**

– **photoreceptors**

**Phytochromes (光敏素) for red light**

**Cryptochromes (隱色素), Phototropins (向光素), Carotenoid zeaxanthin (玉米黃素) for blue light**




♣ **Spectral amount**

– **Light compensation point (光補償點): the photon flux when photosynthetic $CO_2$ assimilation equal to $CO_2$ release by mitochondria respiration**

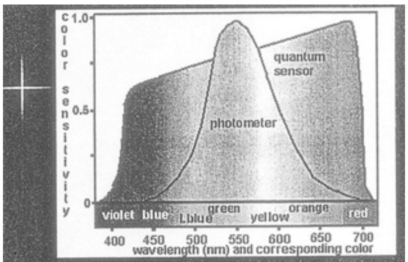
– **Photoinhibition (光抑制): absorption of too much light**

## ♣ Lux (流明) or foot-candles (呎燭光):

- lumen (lm): the luminous flux on a unit surface, all points of which are at unit distance from a uniform point source of one candle.
- intensity was expressed either as foot candles (lm $ft^{-2}$) or lux (lm $m^{-2}$)
- based on the perception of light by the human eye, which is maximally sensitive to light within the green region of the spectrum, at 555 nm.

## ♣ Photosynthetic photon flux density (PPFD)

- Under direct sunlight 2000 μmole $m^{-2}s^{-1}$
- Photosynthetically active radiation (PAR): 400-700 nm



照度計(photometer)與光量子數感測器(quantum sensor)感度曲線

Instruments/calibration

## *Ecological functions*

| TABLE 17.3 Ecologically important light parameters | Photon flux density ($\mu mol\ m^{-2}\ s^{-1}$) | R/FR[a] |
|---|---|---|
| Daylight | 1900 | 1.19 |
| Sunset | 26.5 | 0.96 |
| Moonlight | 0.005 | 0.94 |
| Ivy canopy | 17.7 | 0.13 |
| Lakes, at a depth of 1 m | | |
| Black Loch | 680 | 17.2 |
| Loch Leven | 300 | 3.1 |
| Loch Borralie | 1200 | 1.2 |
| Soil, at a depth of 5 mm | 8.6 | 0.88 |

*Source:* Smith 1982, p. 493.

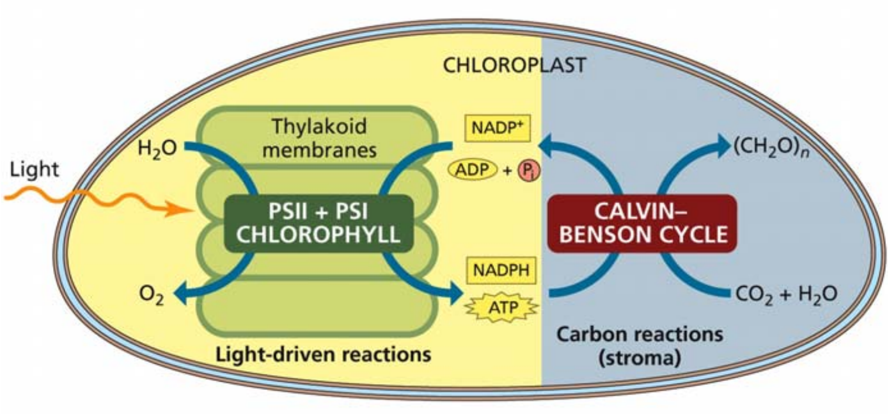
*Note:* The light intensity factor (400–800 nm) is given as the photon flux density, and phytochrome-active light is given as the R:FR ratio.

[a]Absolute values taken from spectroradiometer scans; the values should be taken to indicate the relationships between the various natural conditions and not as actual environmental means.

Red/far red

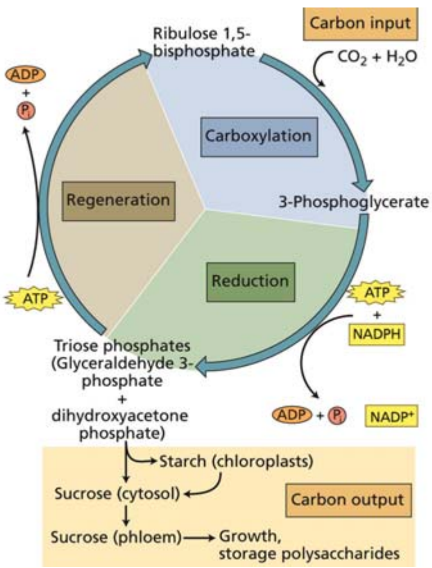
## § Photosynthesis: Carbon reactions

- ♣ dark reaction → carbon reactions of photosynthesis
- ♣ take place in stroma (基質)

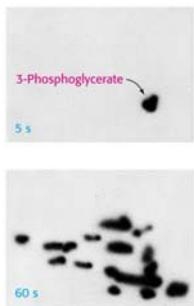



40% $CO_2$ fixation was derived from marine phytoplankton

## Calvin-Benson cycle: 1961 Nobel



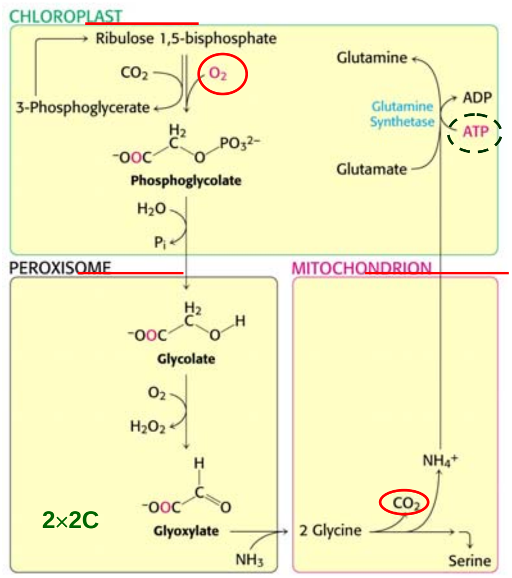

Ribulose bisphosphate carboxylase/oxygenase (rubisco)




C3 plant

Light regulation

## Photorespiration (光呼吸) – a wasteful process




C2 oxidative photosynthetic carbon cycle

$1\times CO_2 + 1\times 3C$

(¾ C)

## [gas] μM = $P_{gas} \times \alpha \times 10^6 / V_0$

*In vitro* vs. *In vivo*

$P_{gas}$: partial pressure; α: absorption coefficient

**Solubility of $CO_2$ and $O_2$ as a function of temperature**

| Temperature (°C) | α ($CO_2$) | [$CO_2$] (μ*M* in solution) | α ($O_2$) | [$O_2$] (μ*M* in solution) | [$CO_2$]/[$O_2$] |
|---|---|---|---|---|---|
| 5 | 1.424 | 21.93 | 0.0429 | 401.2 | 0.0515 |
| 15 | 1.019 | 15.69 | 0.0342 | 319.8 | 0.0462 |
| 25 | 0.759 | 11.68 | 0.0283 | 264.6 | 0.0416 |
| 35 | 0.592 | 9.11 | 0.0244 | 228.2 | 0.0376 |

9.11/21.92 (41%)　　228.2/401.2(56.9%)

T↑ ⇒ tilt toward the $C_2$ oxidative photosynthetic cycle

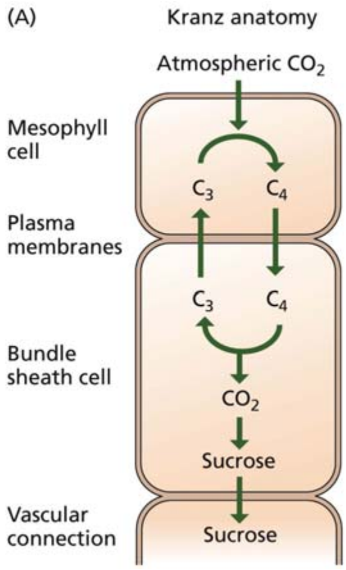
透過光合作用把二氧化碳轉化成樹葉、木材等生物質料，是二氧化碳的再利用機制之一。

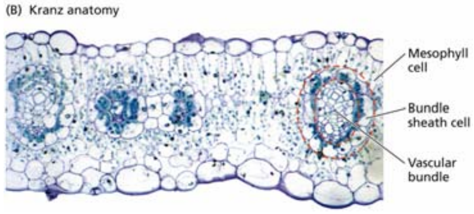
**Photosynthesis rate (Max.) >> Photorespiration rate > normal respiration rate**

**[chloroplast]** **[C, M, peroxisome]** **[mitochondria]**

## § The C4 photosynthetic carbon cycle

- **Kranz (wreath) cells:**
  **present mesophyll (葉肉) and bundle sheath (維管束鞘)cells**
  **spatial (空間的)**
- **concentrating $CO_2$, little phosphorespiration**

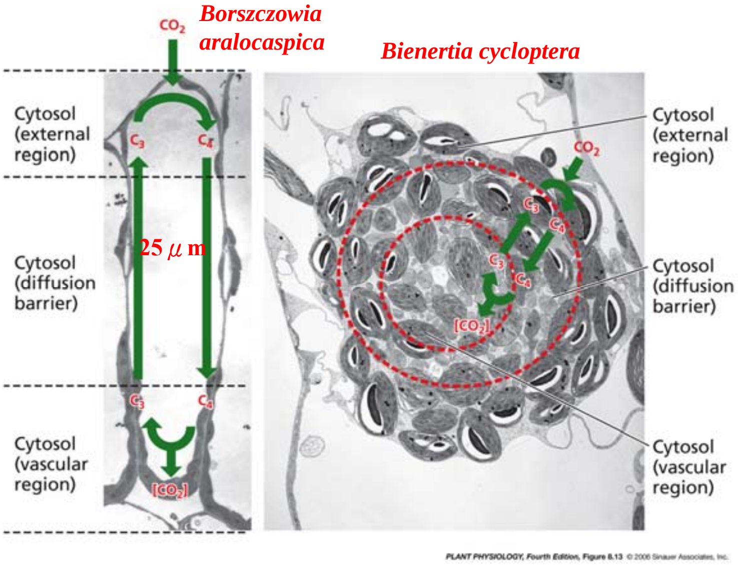


## ♣ Single-celled C4 photosynthesis

*Borszczowia aralocaspica*

*Bienertia cycloptera*




2
5
μ
m

**Importance!**

## § Crassulacean acid metabolism (CAM，景天酸代謝)

**Cacti, pineapple, vanilla, and agave.**

**Spatial and temporal**

**Water use efficiency**

**Nocturnal acidification**

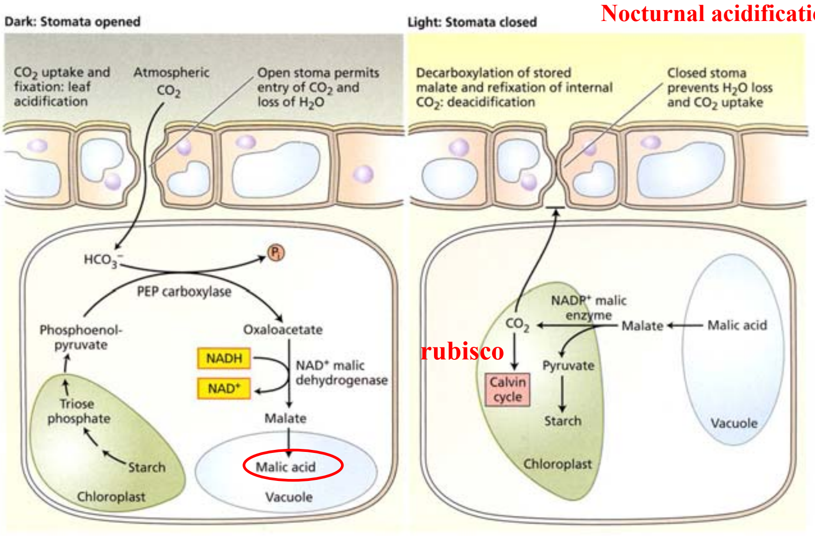



FIGURE 8.12

TABLE 3. *Relevance of CAM among major plant families of rainforests and deserts, where it is assumed that almost all Cactaceae and Agavaceae species and half of all Orchidaceae and Bromeliaceae species are CAM species*

| Major families | Number of species |
|---|---|
| Desert succulents | |
| Cactaceae | 1500 |
| Agavaceae | 300 |
| Total number of species | 1800 |
| CAM species | 1800 |
| Rainforest species | |
| Orchidaceae | 19 000 |
| Bromeliaceae | 2500 |
| Total number of species | 21 500 |
| CAM species | 10 700 |

蝴蝶蘭

*Annals of Botany* **93**: 629–652, 2004

## *Part 4: Plant hormones*

**have profound effects on development at vanishingly low concentration (< 1 mM).**

**kinds: auxins, gibberellins, cytokinins, ethylene, abscisic acid,**

**brassinosteroids, jasmonic acid, salicylic acid, polypeptide systemin, strigolactone (the later buds outgrowth), flavonids**

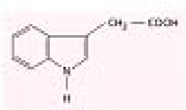
## *Plant growth regulators:*

**promoters and inhibitors**

---

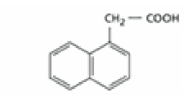
## § Auxin: the first growth hormone to be discovered in plants

**Kinds: natural (天然的) vs. synthetic (合成的) auxins**

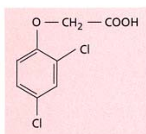


Indole-3-acetic acid (IAA)

Indole-3-butyric acid (IBA)



α-Naphthalene acetic acid (α-NAA)

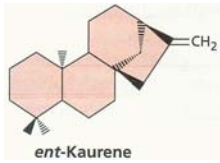


2,4-Dichlorophenoxyacetic acid (2,4-D)

**Functions:**

**Plant cell expansion, viability, stem elongation, apical dominance, root initiation, fruit development, oriented, tropic growth or phototropism**

## § Gibberellins: Regulators of plant height




- 1950s, the second groups of hormones

  (Auxin: discovery, 30 years; structural elucidation, 20 years)

- a disease of rice: "foolish seedling" or bakanae
- a chemical secreted by *Gibberella fujikuroi*, $GA_3$
- $C_{19}$ or $C_{20}$, defined by their chemical structure, more than 136
- only a few are biologically active

**Functions:**

increase in plant stem and root growth, regulate the transition from juvenile to adult phases, floral initiation and sex determination, promote pollen development and (pollen) tube growth, promote fruit set and parthenocarpy (單性結果) (some fruits), promote seed germination

biosynthesis inhibitors

## Stem elongation:

**GA**

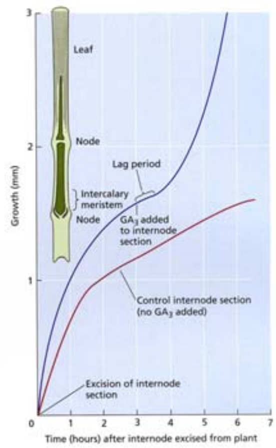



FIGURE 20.23

**Auxin**

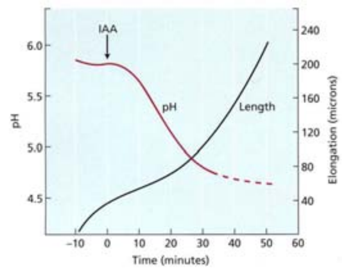


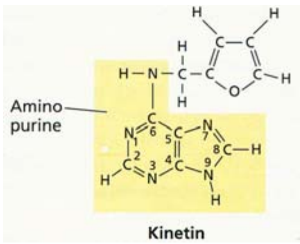

FIGURE 19.23

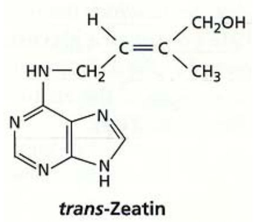
**Lag time:**

Auxin-induced wall acidification

GA-promoted wall extension: xyloglucan endotransglycosylase/hydrolase (XTH)

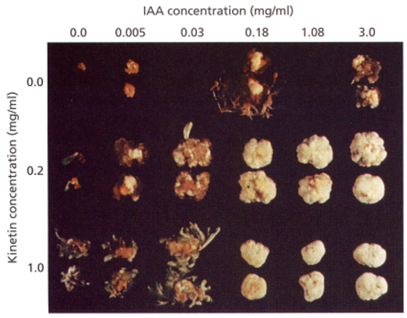
## § Cytokinins: a diffusible and water-soluble regulators of cell division

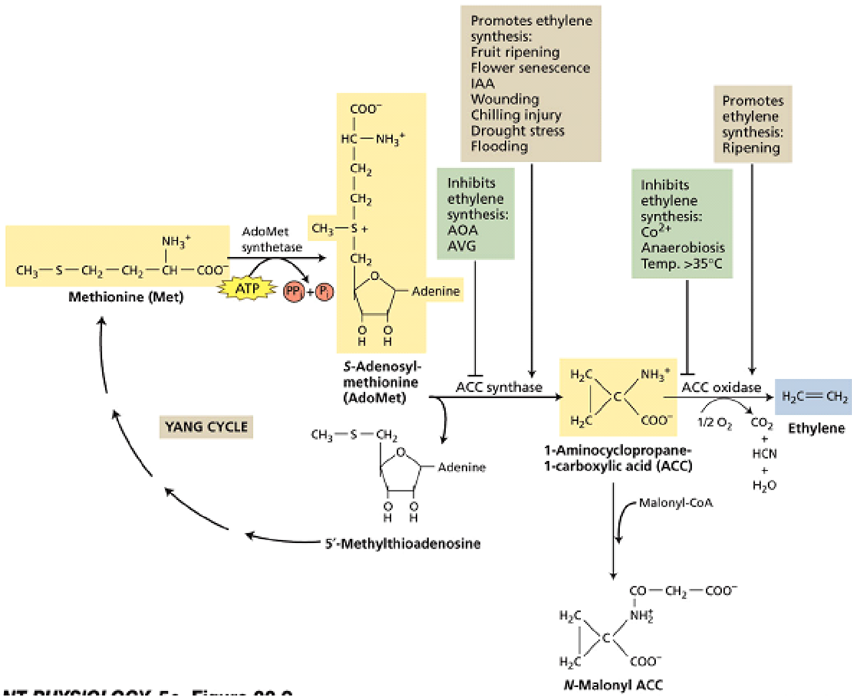



autoclaved herring sperm DNA immature endosperm of corn

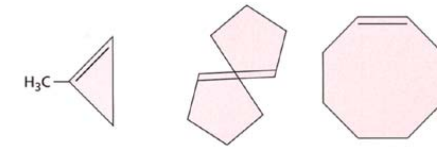
**Auxin/cytokinin ratio: regulate morphogenesis in cultured tissues**



## Inhibit ethylene production and action

- inhibitors of ethylene synthesis
  AVG, AOA, $Co^{2+}$
- inhibitors of ethylene action
  Silver ions ($AgNO_3$ or $Ag(S_2O_3)_2^{3-}$)
  carbon dioxide (5~10%) –antagonist, less efficient than silver ions.
  trans-cyclooctene
  1-methylcyclopropene (MCP)
- remove ethylene
  alkaline potassium permanganate
  lysophospatidylethanolamine




1-Methylcyclopropene (MCP) *trans*-Cyclooctene *cis*-Cyclooctene

EthylBloc

## Effect of ethylene on defoliation

**birch**

50 ppm C=C
fumigated 3 days

FIGURE 22.10

¤ supraoptimal auxin concentrations
stimulate ethylene production and
cause defoliation
e.g., 2,4,5-T, during Vietnam War

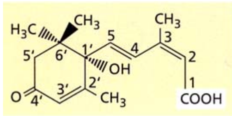
美國和越南首次就越戰期間，美軍化武「落葉劑」的遺害達成賠償金額協議，美方願賠3億美元。美軍在越戰期間，在越南叢林和農田上空，投下了數以千噸計的「橙劑」（落葉劑）。美國和越南的一個聯合小組周三表示，清理橙劑遺害以及治療受害者，約需3億美元。這是越戰結束近35年後，美國和越南的決策者和專家首次就賠償數字達成協議。不過，有關賠償還需要美國國會通過確認 。(2010)

越南茶

## § Abscisic acid (ABA):

### ♣ *a seed maturation*

***dormin:*** **a growth inhibitor was purified from sycamore leaves collected in early autumn, when the trees were entering dormancy**




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

**ABA-deficient mutants:**

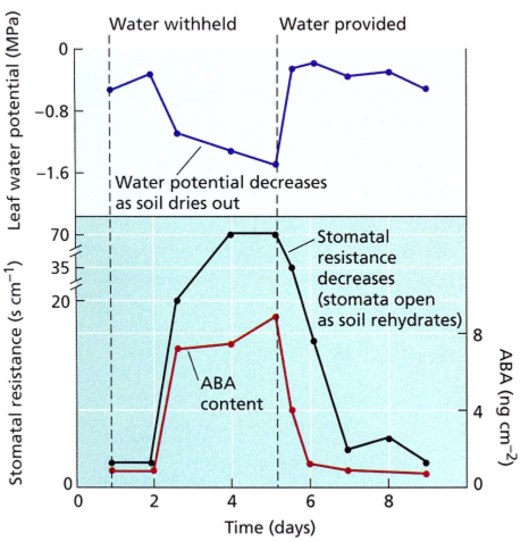
**Vivipary (母體發芽) : precocious germination of seeds in the fruits**

## § Abscisic acid (ABA):

### ♣ *antistress signal*

**inhibit growth and stomatal opening, particularly when the plant is under environmental stress**

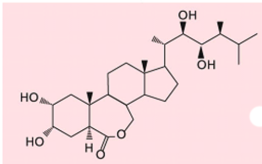
**Maize exposed to water stress**




**[ABA] in tissues are highly variable ~ 3000-fold increase**

## § *Brassinosteroids*

novel growth-promoting substances in pollen




Brassinolide

Most active BR

1970 Mitchel et al

the pollen of rape (油菜) plant (*Brassica napus* L.)

in the organic solvent fraction

1979 Grove et al

227 kg of bee-collected rape pollen

⇒ 4 mg bioactive brassin compound,

X-ray analysis: a polyhydroxylated steroid, a steroidal lactone

Functions:

involved shoot growth, root growth, vascular differentiation, pollen tube growth, and seed germination

## BRs act locally near their sites of synthesis

Reciprocal grafting


Endogenous BRs do not seem to undergo root-to-shoot (a long-distance) translocation

PLANT PHYSIOLOGY, Fourth Edition, Figure 24.12 © 2006 Sinauer Associates, Inc.