Chapter 10 Stress Physiology

- **Stress:**
- **Stress in physics is any force applied to an object. Stress in biology is any change in environmental conditions that might reduce or adversely change a plant's growth or development.**
- **Such as freeze, chill, heat, drought, flood, salty, pest and air pollution etc.**
- **Resistance: resistance is the ability adaptive or tolerant to stress.**

- **Resistance includes adaptation, avoidance and tolerance.**
- **Adaptation is permanent resistance to stress in morphology and structure , physiology and biochemistry under long-term stress condition.**

- **a well-developed aerenchyma** in hydrophytes,
- **a pattern for stomata movement** in CAM plant.

- **Avoidance is a manner to avoid facing with stress using neither metabolic process nor energy.**
- Very short lifecycle in desert plants. Dormancy during the cool,hot, and drought conditions.
- **Tolerance** is a resistant reaction to reduce or repair injury with morphology , structure, physiology, biochemistry or molecular biology, when plant counters with stress.

- **Hardening** is a gradual adaptation to stress when the plant is located in the stress condition.

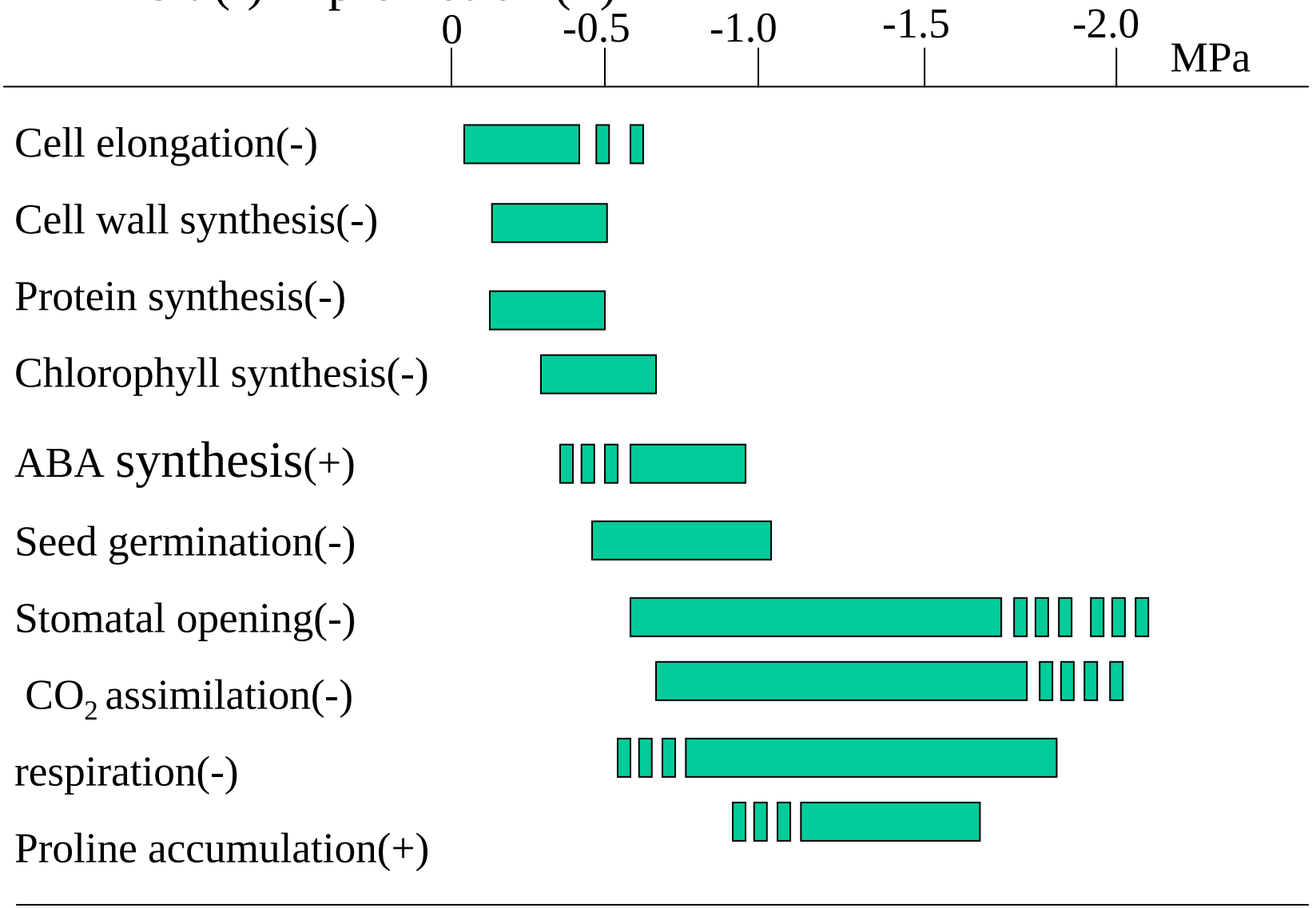
- **Section 1. Water stress in plant**
- **1.1 Resistance of plant to drought**
- **Drought injure:**

Soil drought:no rain for long time and no-available water in the soil.

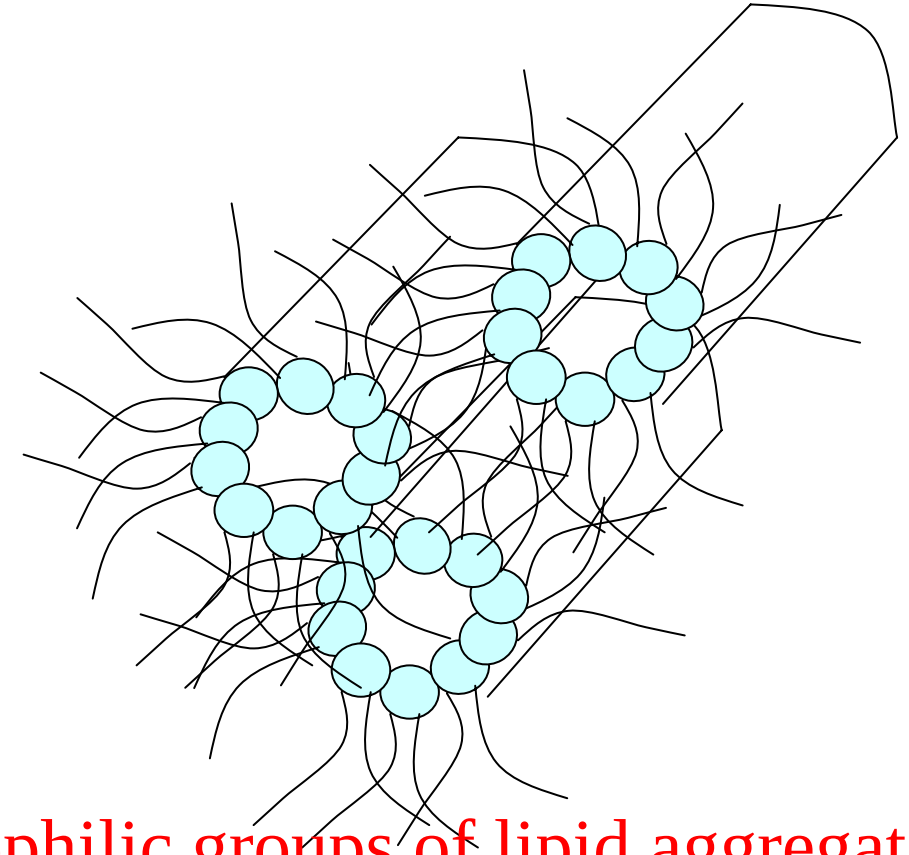
Air drought:RH<20% in atmosphere，transpiration>>water absorption. If longer, soil drought occurs.

- **Drought injury is actual injury in physiology.**

- Metabolism relevant to water sensitive to range of water
- Inhibit (-) promotion (+)



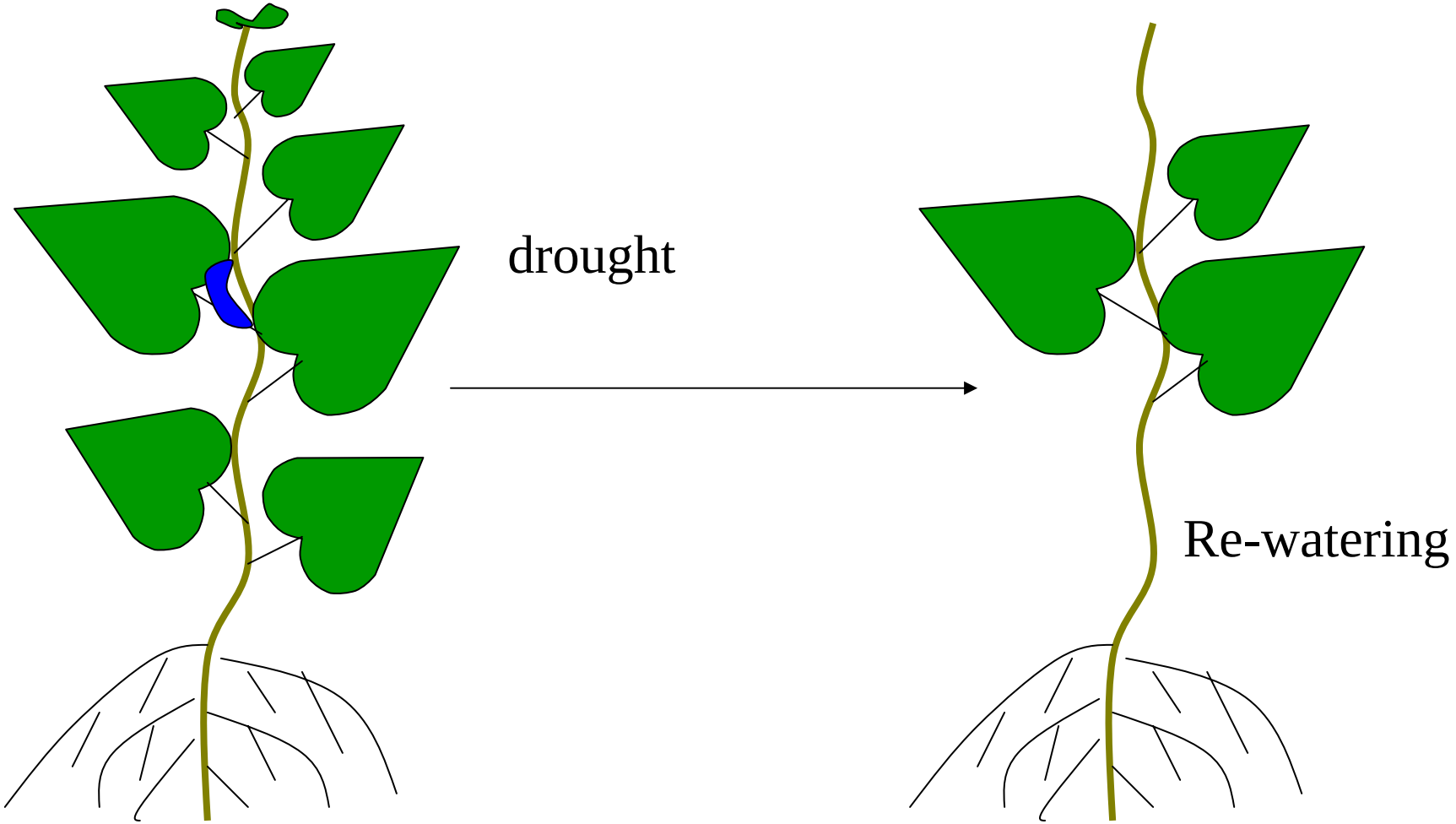
- Symptoms in plant facing to drought： stun, red color in base， small cell and leaf area， leaf yellowish and abscission. Young leaves or/and reproductive organs wilt to death.
- **1.1.1 Mechanism of drought injure**
- **1.1.1.1 Membrane damage.**
- **Like senescence, biomembrane changes in states, such as 6- crystalline state and become leaked.**



Hydrophilic groups of lipid aggregate together

•1.1.1.2. Metabolic disorder

•（1）Redistribution of water among organs：



- **(2)Photosynthesis decreases, while respiration rises after lowering**
- **Starvation to death**.
- **a.** assimilate ↓ SC ↓ , Photorespiration ↑ , electron transfer activity and PSP ↓ .In sunflower,-1.1MPa，ET and PSP decrease obviously，—1.7MPa, PSP is 0.
- **b.** inhibition by photoassimilate feedback.

- **（3）Decrease in nuclear acids and proteins。**
- Protease activity ↑， free aa ↑， RNAase activity ↑， RNA hydrolysis ,DNA content falls down.
- **（4）Pro accumulation：**
- **① Pro from protein hydrolysis;②synthesis ↑， ③ oxidation ↓.**
- **Pro function：**
- **① detoxication of NH_3;②bound water ↑ .**

- **（5）Changes in plant hormones，** promoters ↓， inhibitors ↑， esp. ABA ↑.
- **（6）Poisonous agents accumulation.** NH_3 **and amines** ↑.

- **1.1.1.3 Mechanical injure**
- Cytoplasm is broken down.

- Formation of －S－S－.

- **1.1.2 Mechanisms of resistance to drought and the methods to increase the resistance**
- **1.1.2.1. Mechanisms of resistance**

（1）**Morphology**： increase in water absorption and transportation , declination of transpiration.

- **a. Developed root system and higher ratio of root to shoot——‘开源’**

- **b. Thick leaf , smaller leaf area and thick cuticle——‘节流’。**
- **c. Developed bundle and veins，smaller and more stomata——‘流畅’**

- **（2）Physiology and biochemistry**
- **a. Stomatal regulation：**
- **ABA accumulation→stomatal closure → ex. Tomato** (*flacca*)-*dhns*, *(sitiens*)-*PI-PII* ***mutants***; Potato (droopy)-*PI-PII* ***mutants***
- **b. Increase in capacity of resistance to dehydration of cytoplasm**
- **Rapid accumulation of Pro, glycinebetaine Lea protein, dehydrin,osmotins and ion etc.**

- **1.1.2.2. Methods to increase the resistance**
- **（1）Selection of cultivars with high resistance to drought，high yield and quality.**
- **（2）drought hardening：**
- “Seedling drought”, “seedling starvation”, “double sprout”.
- **Seed priming(种子引发): a special technology to control seed water absorption and re-drying slowly**

- **（3）Suitable fertilizer application：**
- Application of more P、K to plants.

- **（4）Chemical regents application**
- Soaking in 0.25% $CaCl_2$ or 0.05%$ZnSO_4$ solution.
- Application of plant substance: ABA, CCC etc

- **2.2 Resistance of plant to flood**
- **Flood injury: moisture injury and flooding injury.**

- **Moisture injury is caused by soil space filled with water and without air.**

- **flooding injury: whole plant or part of shoot is submerged to water while flooding**

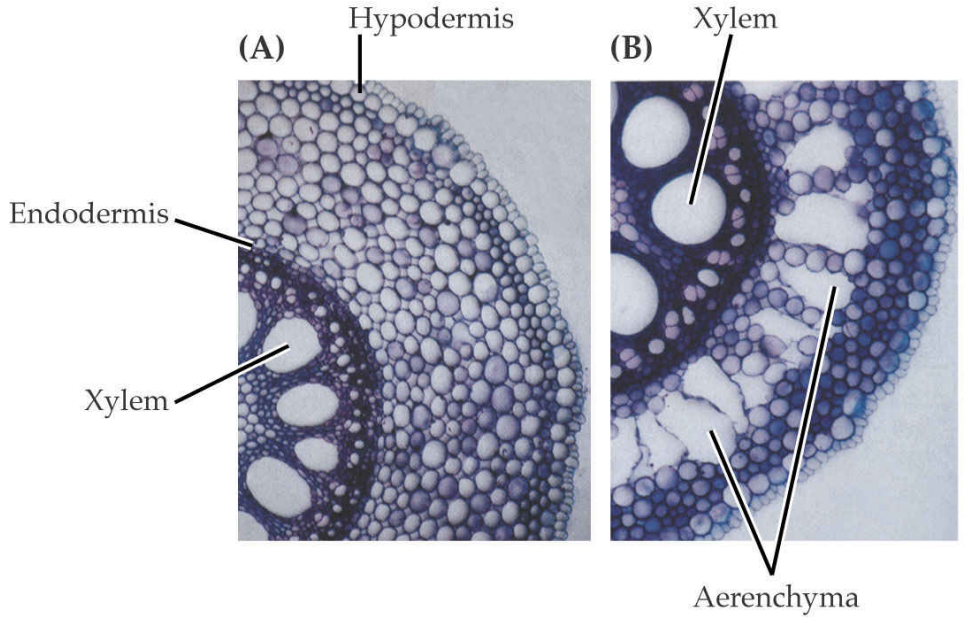
- **2.2.1 Injures of flood to plant**
- Flood is actual deficiency in O_2
- Anything increases in soluble O_2, the injury will decrease. And anything decreases in soluble O_2, the injury will increase
- Such as slowly streaming water less damage than static water.

- **(1) Injury in morphology and anatomy by O_2 deficiency**：growth ↓，leaf yellowish (nutrition deficiency），root darkness（low Eh），epinasty（Eth), air root(IAA, Eth), stem hollow (tissue degradation caused by Eth ）.

- **(2) Injury in metabolism by O_2 deficiency**，photosynthesis ↓——stomatal block, inhibition of CO_2 entrance . Anaerobic respiration ↑，toxicants: alcohol，acetaldehyde，NH_3，lactate , H_2S.

- **(3) Nutrition disorder：**
- absorption ↓ ， soil N、P、K、Ca loss but H_2S、Fe、Mn ↑， microelements poison。
- **(4) Changes in plant hormones：** IAA and CTK ↓ .ACC synthesis in root and release of Eth in shoot.
- **(5) Mechanical damage and infection by harmful organism.**

- **2.2.2 Mechanism of resistance to flood**
- Resistance is different in plants:hydrophytes>land plants，rice>rape>barley; O.sativa>O.japonica，and in growth stages : seedling >other stages,
- “寸麦不怕尺水,尺麦怕寸水”.
- **(1) Tolerance in tissues：Well-developed aerenchyma.**



- **(2) Tolerance in metabolism：**
  mitochondria well develops in anaerobic conditions, succinic acid dehydrogenase ↑， tolerance to ethanol ; PPP instead of EMP，NR ↑， Glutamate dehydrogenase ↑。

- Immediately drainage is necessary after flood:

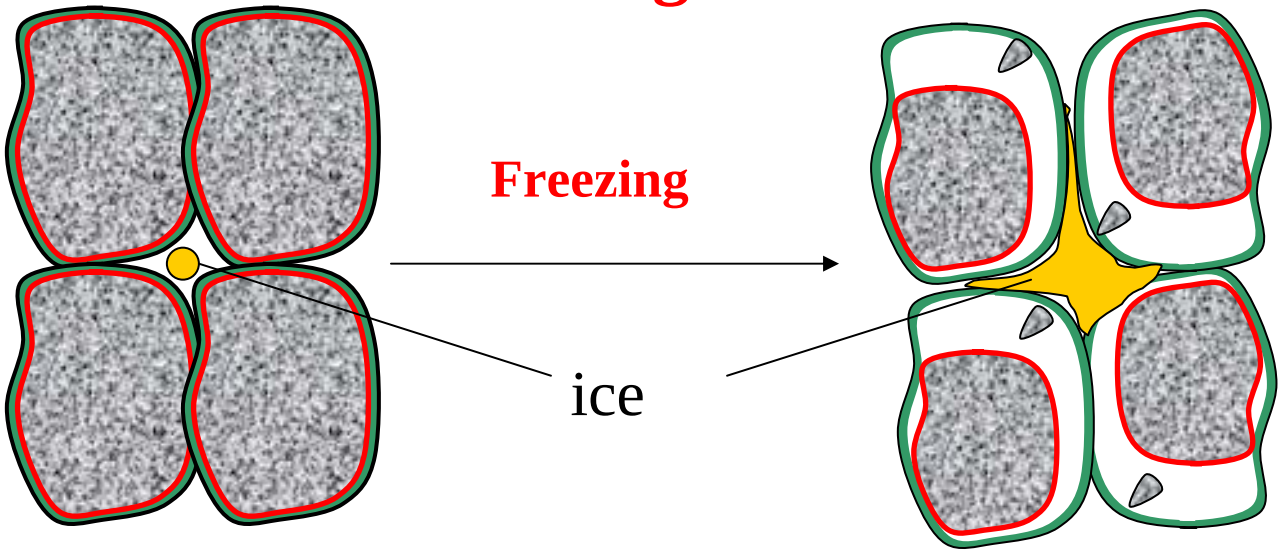
- The drainage should be done late if strong sunlight.
- It is necessary to wash the soil attaching the plant and apply N、P、K to plant after drainage.

• Section 2 Temperature stress

- **Temperature stress: Low or high temperature, called frost injury or heat injury, respectively.**

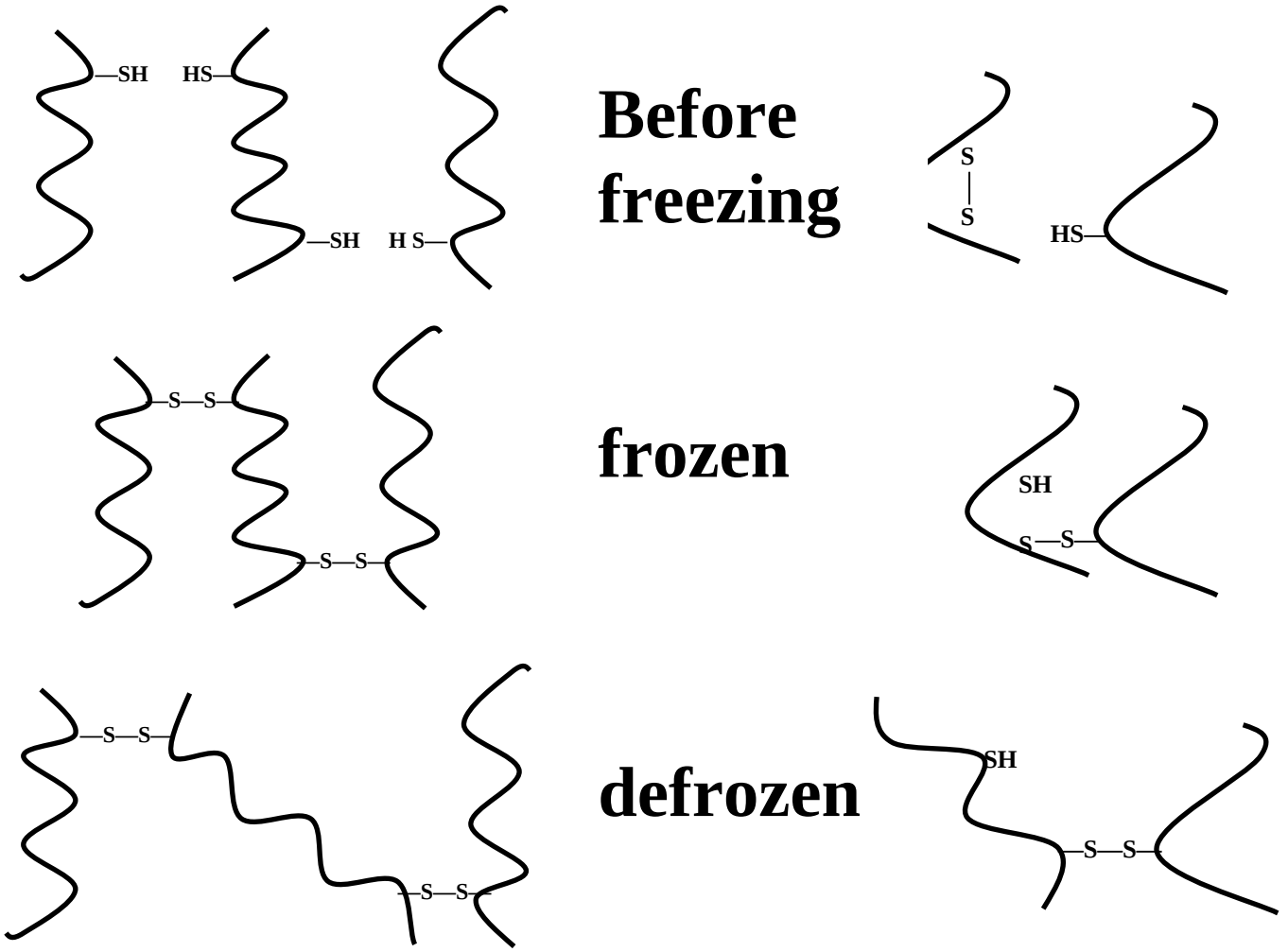
- **2.1 Frost (freezing)injury**
- The injury is caused by low temperature below freezing point (〈 0℃) ,companied with frost.

- **2.1.1 Mechanism of freezing (frost)injury**
- **2.1.1.1.Freezing**:(intercellular and intracellular freezing)
- **(1) Intercellular freezing**



Intercellular freezing occurs when temperature falls gradually down.

- **（2）Intracellular Freezing :**
- **Intracellular freezing** often occurs when temperature falls suddenly down.
- Ice results in the direct injury in cytoplasm, biomembrane and organelle, and damages to cell compartmentation and metabolic disorder.
- **Much more serious damage is caused by Intracellular Freezing than by Intercellular Freezing.**
- **2.1.1.2 damage of protein**:
- Sulfhydryl group hypothesis（disulfide bridge hypothesis）



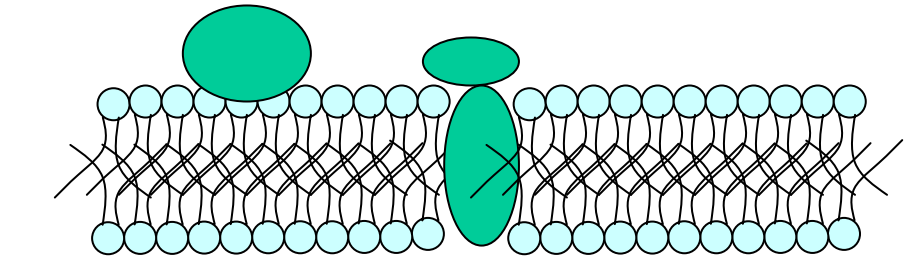
Injury by formation of sulfhydryl group hypothesis

- Supported Exp：
- **(1)** －S－S－increase and soluble －SH decrease after plant tissue faces to freezing.
- **(2)** Less－S－S－and －SH of protein in the resistant-freeze plants.
- **(3)** The plant with free－SH,glutathione, is more resistant to freeze.
- **(4) Artificial** －SH,mercapthanol increases resistance of plant to low temperature.

- **2.1.1.**3.Damage of biomembrane
- Electric conductivity ↑ , cell material leakage ↑ , photochemical activity and ATP production ↓, while photoinhibition ↑ , CF1 and PC depart from membrane.
- Change in state of lipid and protein denuturation

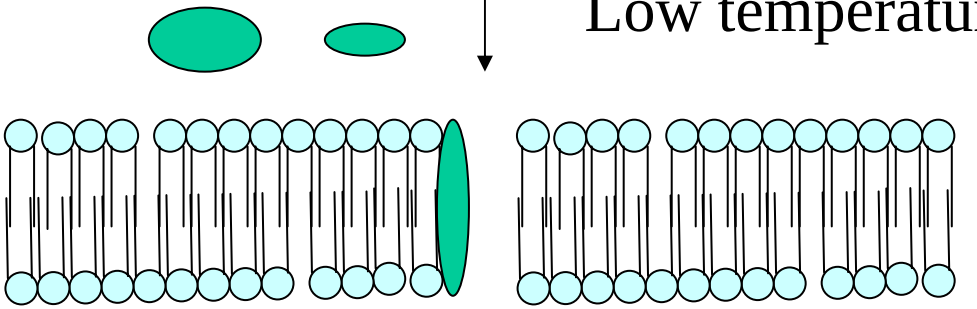
- **2.1.2 Chilling injury**
- **Chilling injury** in tropical or subtropical plant is caused by temperature above 0℃ (freezing point)..
- Maize, cotton rice seedling——10℃.
- Rice pollen-mother cell division，23℃ for O. sativa and 20℃ for O. japonica.
- Banana tree——13℃.
- Oak tree——5℃.

- **2.1.2.1. Change in state of lipid**



liquid-crystalline state

Low temperature



Solid-gel state

Electric conductivity as an index for resistance to low temperature in production

- **2.1.2.2. Metabolism disorder**
- （1）Uptake function of roots declines and water balance disorders
- **Transpiration>water absorption. The plant loss water and leaf curl**——青枯死苗（水稻）.
- （2）Photosynthetic rate lowers 。
- Photosynthesis< respiration, starvation to death——黄枯死苗.
- Rubisco losses activity under low temperature，PSP uncouples and free radicals breaks suddenly.

- （3）Aerobic respiration decreases and anaerobic respiration increases.
- Cytaa$_3$ activity ↓, respiratory electron transport and phosphorylation activities ↓. Ethanol poison.
- （4） Organic substance degrades.
- protease ↑， protein ↓， RNA、ATP ↓.

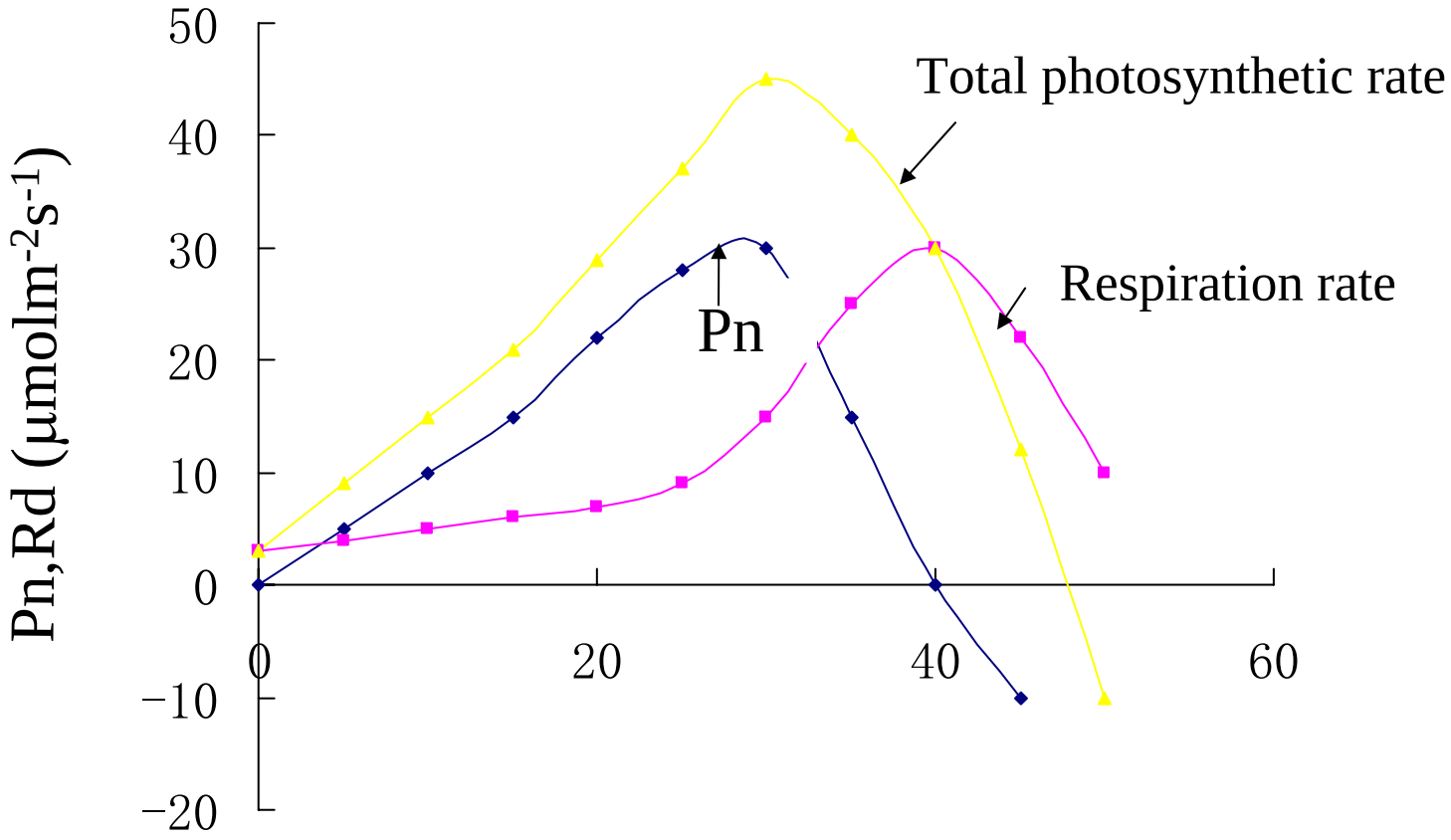
- **2.1.3 Physiological reaction of plant to low temperature**
- (1) Water content, metabolism, growth decrease .
- Total water content ↓， bound water ↑， free water and ratio (free water/bound water) ↓.
- **(2) Protective substances increase.**
- NADPH——reduces－S－S－ to － SH， ATP and sugar ↑, bound water ↑.

- **(3) Unsaturated fatty acid increase in membrane.**
- **Unsaturated fatty acid ↑ and saturated one ↓.**
- **(4) ABA ↑, GA ↓, dormancy appears.**
- **(5) Proteins-resistant to freezing accumulations.**
- **Freezing resistant protein —— Ice-Box—— The genes expression induced by freeze—— freeze-resistant protein.**

- **2.1.2.4 Methods to increase the resistance to low temperature。**
- **(1) The resistant cultivars.**
- **(2) Low temperature hardening.**
- **(3) Chemical control.**
- ABA ,CCC， PP_{330}， Amo-1618)。
- **(4) Others.**
- PK application, keep warm with artificial things.

- **2.2 High temperature stress and heat resistance of plants**
- Cold-favored plants: some alga， bacteria and fungi，meets heat injury at 15－20℃ .
- Temperature-mediate plant: most of crops——35℃.
- Temperature-favored plants， some alga， bacteria 65－100℃，many CAM plants>50℃.
- **Heat injury is a damage to the temperature-mediate plant by high temperature above 35℃.**

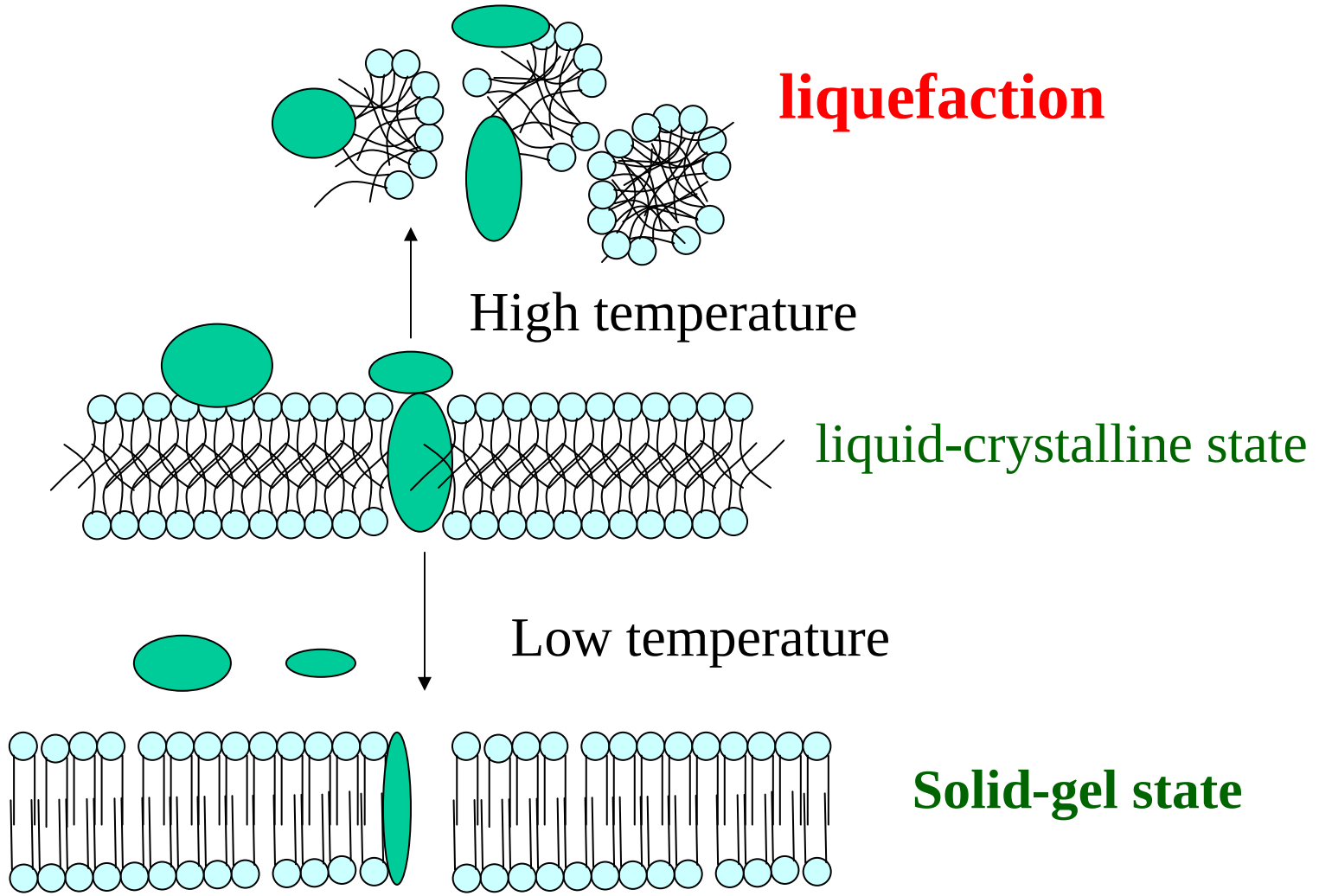
- **2.2.1 Reasons for heat injure**
- **2.2.1.1. Indirect damage**
- **（1）Starvation**
- **Temperature compensation point: Pn is equal to zero at high temperature**
- Respiration is much larger than photosynthesis.


Pn,Rd (μmolm-2s-1)
50
40
30
20
10
0
−10
−20
0
20
40
60
Total photosynthetic rate
Respiration rate
Pn

- **（2）Poisoning**
- Ethanol or acetaldehyde, free radicals.
- **（3）deficiency of biotins**
- Biotins，Vitamins .
- **（4）damage of nuclear acids and proteins**

- **2.2.1.2. Direct damage**
- **（1）Protein denaturation**
- Configuration damage
- The degree in denaturation is positively related to water content in plant tissue.
- Dry seed is able to resist to 70－80℃.

- **（2）Lipid liquefaction**



- **2.2.2 Mechanism of heat resistance**
- **(1) High stability of protein under heat stress。**
- much－S－S－
- **(2) Lower water content**
- **(3) High contents of saturated fatty acid。**
- **(4) High contents of organic acid。**
- CAM——非常耐热原因，含有大量有机酸。
- 可以减轻或防止NH_3中毒。

- (5)**Form of heat shock proteins (HSPs or hsps)**
- **Heat shock proteins** are a newly synthesizing set of proteins that organisms ranging from bacteria to humans respond to high temperature.
- **Functions:** protect or repair proteins, nuclear acids and biomembrane from heat injury.
- More than 30 HSPs, 15-27kD, some are chaperons

- **Section3　Salt stress and resistance to salt**
- Over 1% of salt content in **reclaimed tideland** (海涂地)， 0.2~0.25% of salt content in the northern basic soil (碱土). 1/5-1/3 of tatol cultivated land .

- 3.1Mechanism of salt injure
- **1. Physiological drought**。
- **2. Single salt toxicity .**Na^+ and Cl^-， SO_4^{--}.
- **3. Metabolic damage：** Ch1 and Rubisco↓， protein degradation↑,Pro↑， NH_4^+ poison↑.

- 3.2 1Mechanism of resistance to salt
- 3.3 Methods resistant to salt
- (self-study)

Section 4 Resistance to plant diseases

- 4.1 Types of plant response to diseases.
- Three types: resistance, sensitivity and tolerance

- 4.2 Physiological damage of plant diseases to plants
- 1. The cell membrane permeability increases.
- 2. Metabolism disorders.
- Water metabolism(absorb, loss and transport). Photosynthesis,
- Respiration (PPP).
- Assimilate transport.

- 4.3 The resistance of plant to plant diseases

- 1.Formation of protective structure.
- 2.hypersensitive response. Synthesis of phytoalexins and fungitoxic proteins and pathogenesis related proteins (PRs)
- 3.immuno-induction.

- **Section5 The role of plant in environmental protection**
- 1.O_2 and CO_2 equilibrium;
- 2.Prevent water and soil loss.
- 3. Clean soil, water or other environmental conditions or depoison.
- 4.Detect environmental conditions

- Section6 **General response to stresses**
- **1. Damage in biomembrane system**
- **2. Disorder in metabolism**
- **3. Functional proteins denuturation and stress protein synthesis**
- **4. Osmotic substance synthesis**
- **5. Change in plant hormones**

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- Questions:
  1.How does drought injury damage the plants in morphology and physiology ?
- 2. Which of stresses make water potential decrease of plant leaf and why can they do it?