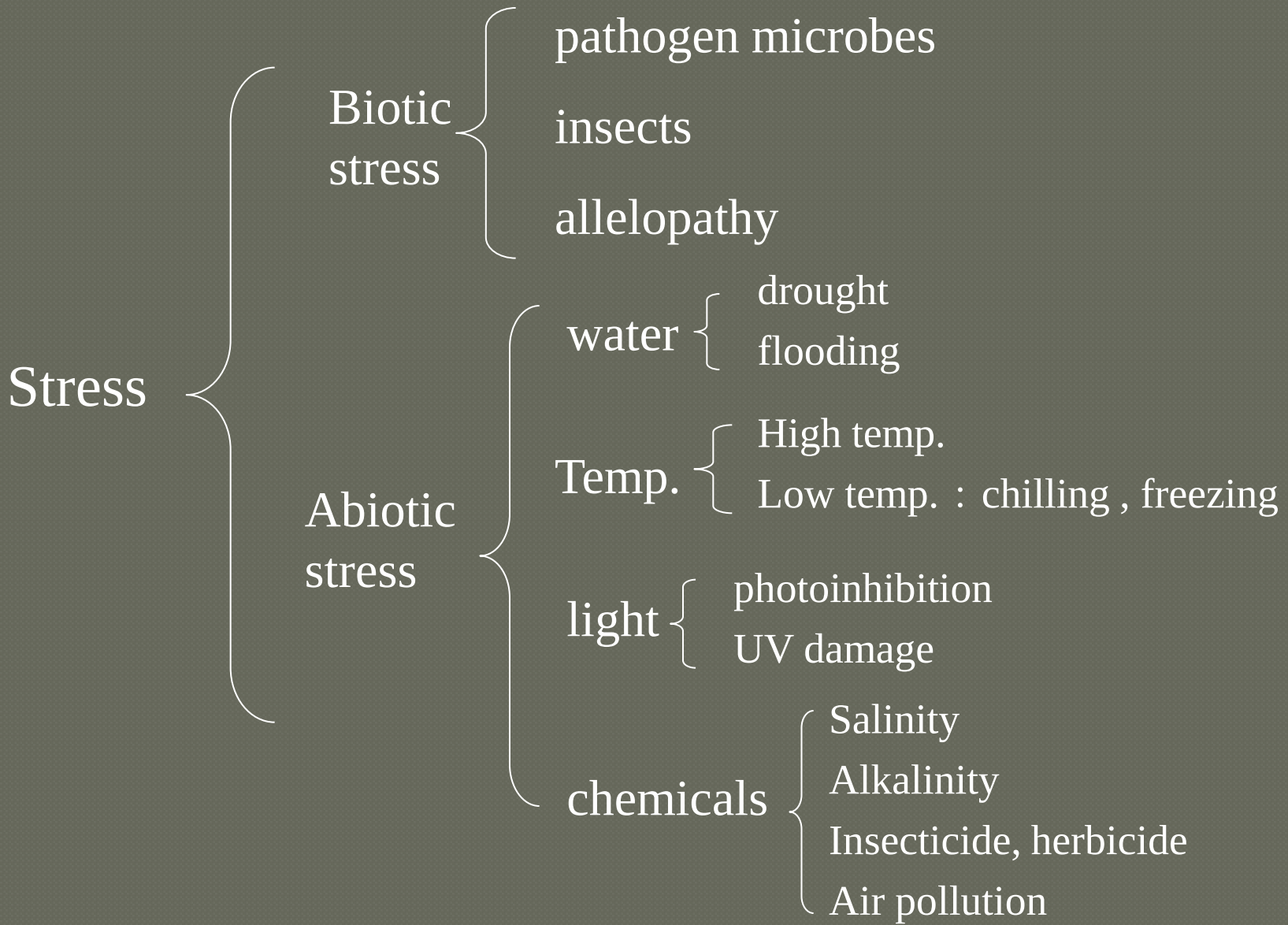
FISIOLOGIA VEGETALE

Come le piante si adattano agli stress biotici ed abiotici

What is Plant Stress?

- Plant stress is the adverse reaction of plants to environmental conditions that are unfavorable to growth, such as lack of sufficient nutrients, inadequate watering, flooding, high or low temp., disease or insect infestation.


Stress
Biotic stress
pathogen microbes
insects
allelopathy
Abiotic stress
water
drought
flooding
Temp.
High temp.
Low temp. : chilling , freezing
light
photoinhibition
UV damage
chemicals
Salinity
Alkalinity
Insecticide, herbicide
Air pollution

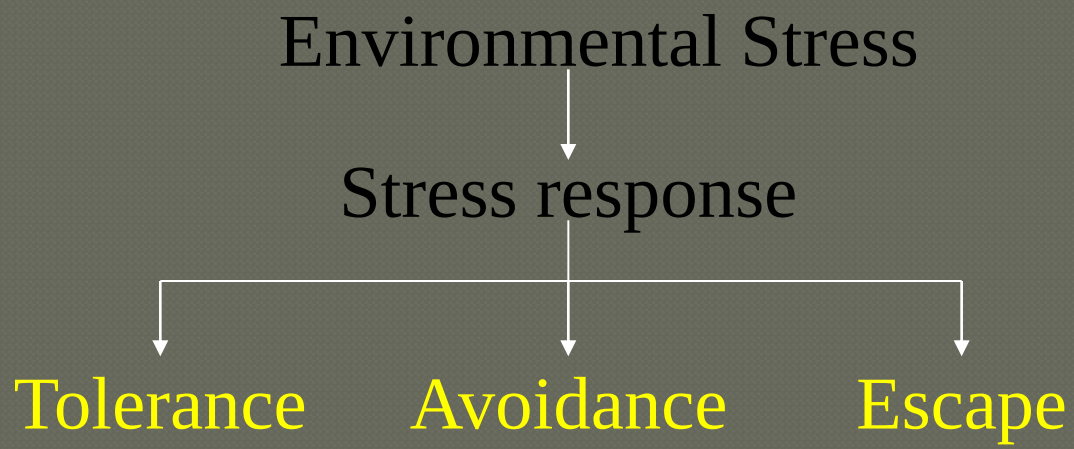
I. Damages of stress to the plant

- Bio-membrane
  - Change in membrane phase
  - Change in membrane constituents
  - Change in membrane permeability
- Photosynthesis
  - Decrease in Photosynthesis rate
  - Decrease in stomatal aperture

- Respiration
  - Decrease in respiration rate under freezing, hot and flooding stress
  - Increase in respiration rate under wounding and pathogen stress
  - Under chilling and drought stress, the respiration rate increase first and then decrease
- Changes of phytohormone level
  - Decrease in IAA, CTK, GB
  - Significant increase in ABA
  - Increase of Eth under flooding

- Oxidative stress induced by reactive oxygen species (ROS)
  - Reactive oxygen species are highly reactive molecules containing atom oxygen. It mainly include 3 species: $O_2^{\cdot -}$, $\cdot OH$, H_2O_2
  - ROS can attack chloroplast, mitochondria and other organelles.
  - ROS can also attack membrane by causing membrane peroxidation.

II. Plants Respond to Stress in Several Different Ways



- Stress Escape: Plant avoid the injury of stress by regulating its life cycle to avoid meeting with stress.
  - E.g. some short-lived, desert ephemeral plants germinate, grow and flower very quickly following seasonal rains. They thus complete their life cycle during a period of adequate moisture and form dormant seeds before the onset of dry season.

- Stress avoidance: plants avoid the injury of stress by building up a barrier to prevent stress factors entering the plant.
  - E.g. alfafa survive dry habitats by sending down deep root systems that penetrate the water table.
  - Salt-secretion halophytes secrete the salts out from the leaf thus reduce salt content in the leaf.

- Stress tolerance: Plants adapt to the stress environment by regulating their metabolism and repair the damage caused by stress.
  - E.g. Highly salt tolerant halophytes survive salty habitat by many strategies such as high ROS scavenging ability, high osmotic adjustment ability

Adaptation vs. Acclimation

- Adaptation and acclimation both are means of achieving tolerance to a particular stress.
- Adaptation refers to heritable modifications in structure or function that increase the fitness of the organism in the stressful environment. e.g. CAM plants to desert.
- Acclimation refers to nonheritable physiological modifications that occur over the life of an individual. These modifications are induced by gradual exposure to the stress. E.g. slow drying increases the drought resistance of plants.

How plants get adapted to stress?

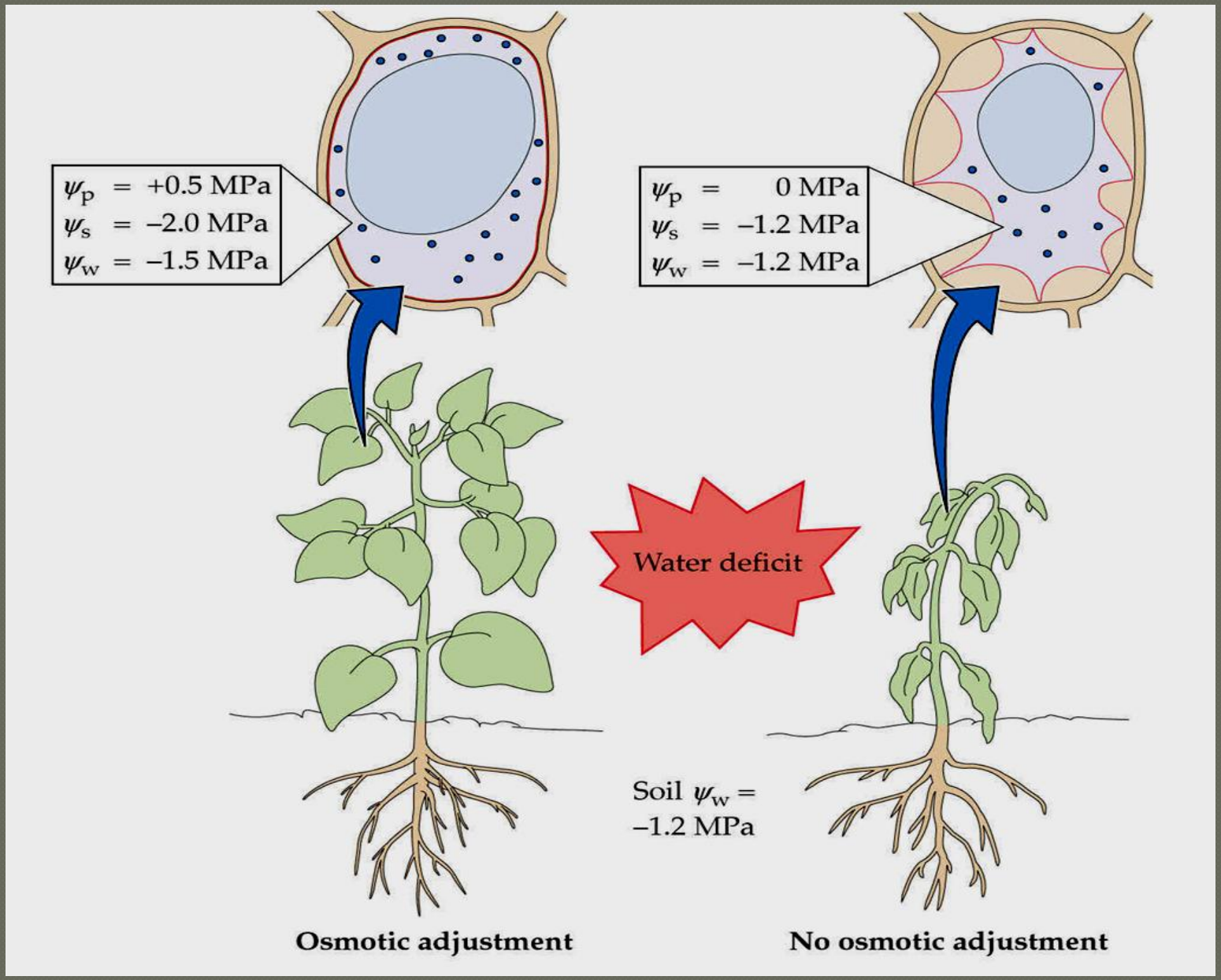
1. Osmotic adjustment
2. Stress proteins
3. Scavenge ROS
4. Synthesis ABA

1. Osmotic adjustment

① Water deficit can be induced by many environmental conditions
- Drought
- Salinity
- Cold temperature

② Osmotic adjustment is a biochemical mechanism that helps plants to acclimate to drought, salinity etc.

③ Osmotic adjustment is an active process of increasing the number of solute particles in the plant that resulting in a reduced osmotic and water potential and enables the plant to absorb water in drought and saline habitat.

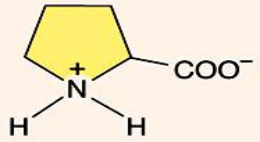

ψ_p = +0.5 MPa
ψ_s = –2.0 MPa
ψ_w = –1.5 MPa
ψ_p = 0 MPa
ψ_s = –1.2 MPa
ψ_w = –1.2 MPa
Water deficit
Soil ψ_w = –1.2 MPa
Osmotic adjustment
No osmotic adjustment

④ Compatible solutes share specific biochemical attributes

- Highly soluble
- Low molecular weight
- Do not interfere with cellular metabolism
- Neutrally charged at physiological pH
- Mainly distributed in the cytosol, not vacuoles

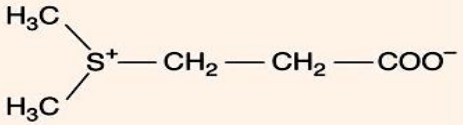
Compatible osmolytes

Amino acid:



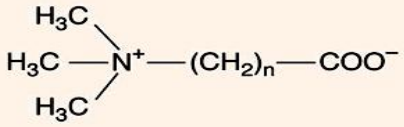
Proline

Tertiary sulfonium compound:

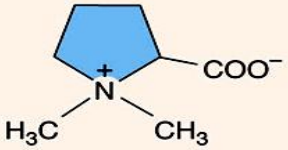


Dimethylsulfoniopropionate

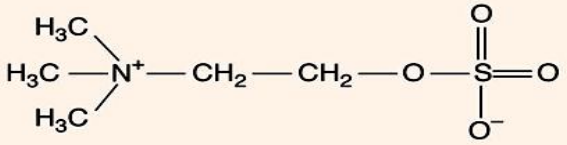
Quaternary ammonium compounds:



$n = 1$, Glycine betaine
$n = 2$, β-Alanine betaine

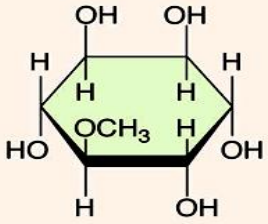


Proline betaine

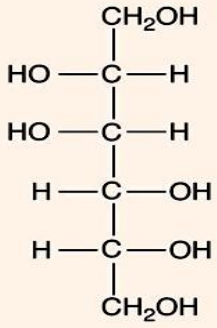


Choline-*O*-sulfate

Polyhydric alcohols:



Pinitol



Mannitol

Sucrose
Trehalose

⑤ Some compatible solutes may serve other protective functions in addition to osmotic adjustment

- Minimizing the perturbing impact of ions
- Protecting enzymes (pro,glycine betain)
- Scavenging ROS (pro, mannitol, sorbitol)

2. Stress proteins

- HSPs(Heat shock proteins)
- LEAs(late embryogenensis abundant proteins)
- Pathogenesis-related proteins

3. Scavenging ROS

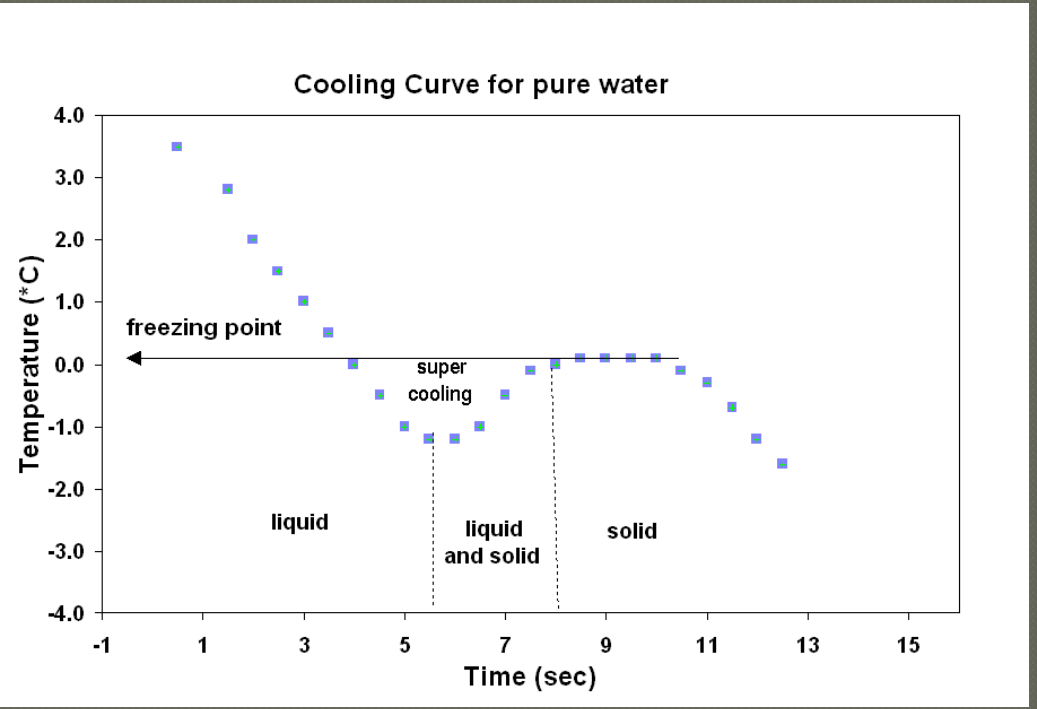
- Enzymes：
  1) SOD（superoxide dismutase)
  2) CAT (Catalase)
  3) POD (Ascorbic acid Peroxidase)
- Anti-Oxidants：
  1) carotene
  2) Vit E
  3) Dimethil Sulfoxide (DMSO)
  4) Vit C
  5) Glutathione (GSH)

4. ABA-stress hormone

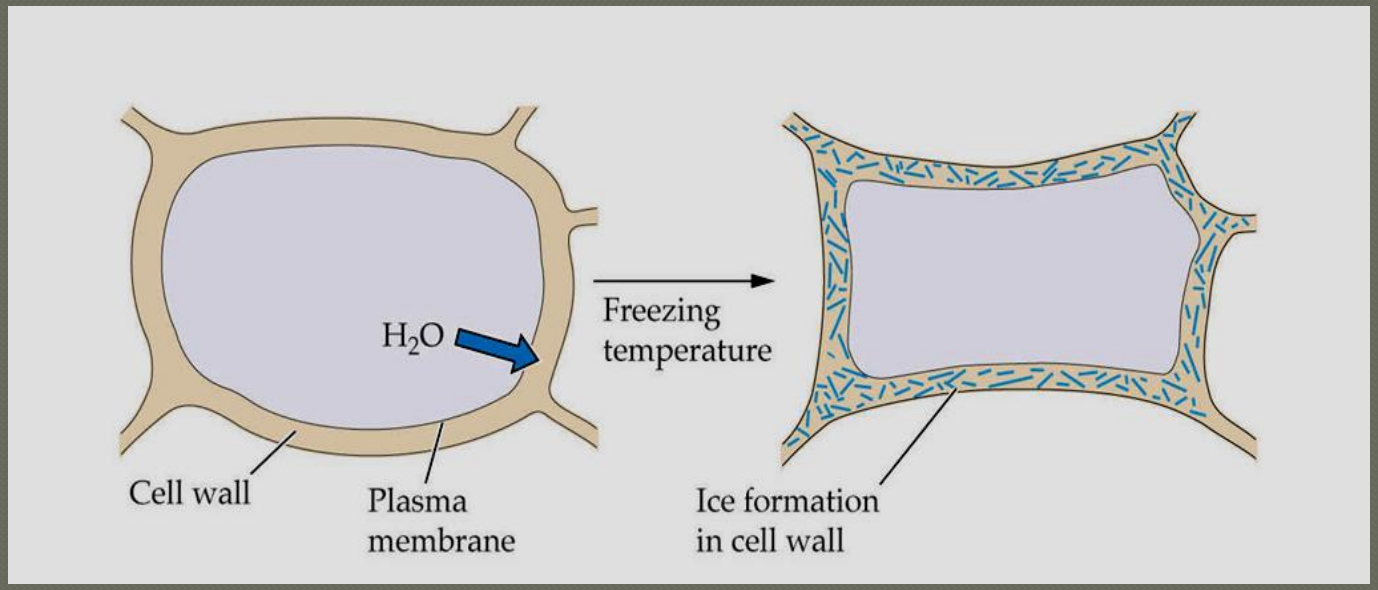
- Keep membrane stability
- Promote synthesis of osmolytes
- Reduce water loss
- Increase water conductivity

Freezing Stress

- Freezing injury is caused by low temp.<0℃
- Supercooling



- Intercellular crystallization
  - Ice crystals form between cells.
- Intracellular crystallization
  - Ice crystals form in the cell.



- Freezing Injury:
  - Direct injury: injury by crystal formation
  - Indirect injury: dehydration
- Injury mechanism:
  - Membrane injury
  - Mechanical injury

- Strategies of increasing plant freezing tolerance:
  - Lower water content
  - Reduce photosynthesis
  - Increase ABA/GB
  - Dormant
  - Increase osmolytes

- Strategies to avoid freezing stress:
  - Reducing the body surface
  - Hairs on the aerial body

Drought Stress

- Drought stress includes:
  - 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.

- Mechanisms of drought stress:
  - Membrane damage
  - Metabolic disorder:
    - Water redistribution in the organ
    - Photosynthesis reduction
    - Respiration rises then drops
    - **Decrease in nuclear acids and proteins**
    - Accumulation of proline
    - ABA accumulation
  - Mechanical damage

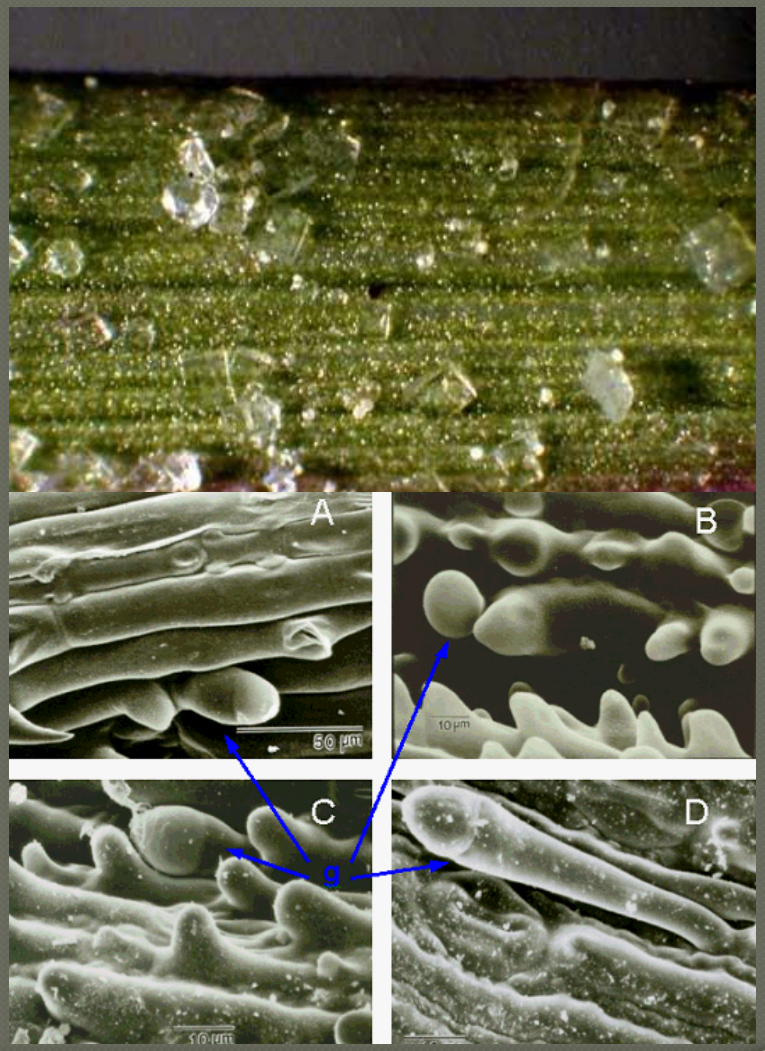
- Strategies of increasing drought resistance
  - Stress avoidance:
    - absorption of water, increase in water transportation.
      - Developed root system and higher ratio of root to shoot
      - Thick leaf , smaller leaf area and thick cuticle
    - Accumulation of ABA and stomatal control
  - Stress tolerance
    - Osmotic adjustment
    - Change of photosynthetic pathway

Salt stress

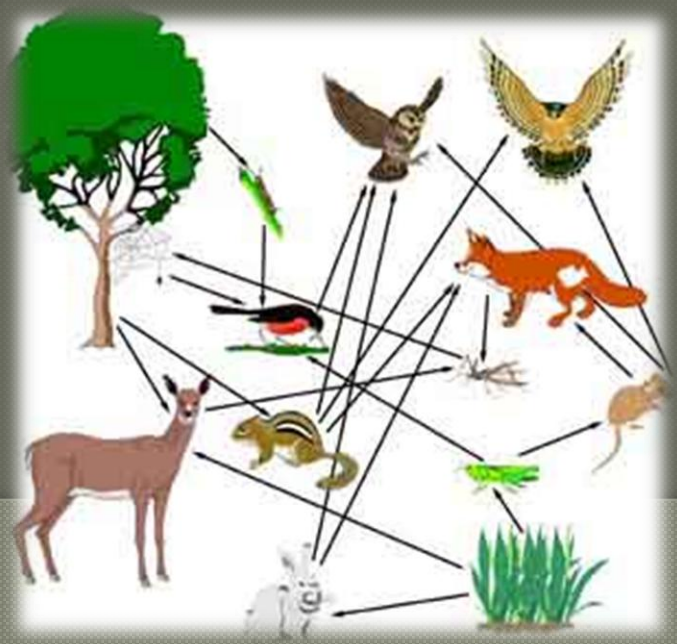
- Salt stress includes 3 aspects:
  - Ionic stress: Na^+ Cl^-
  - Drought stress
  - Metabolic disorder: Rubisco↓, protein degradation↑

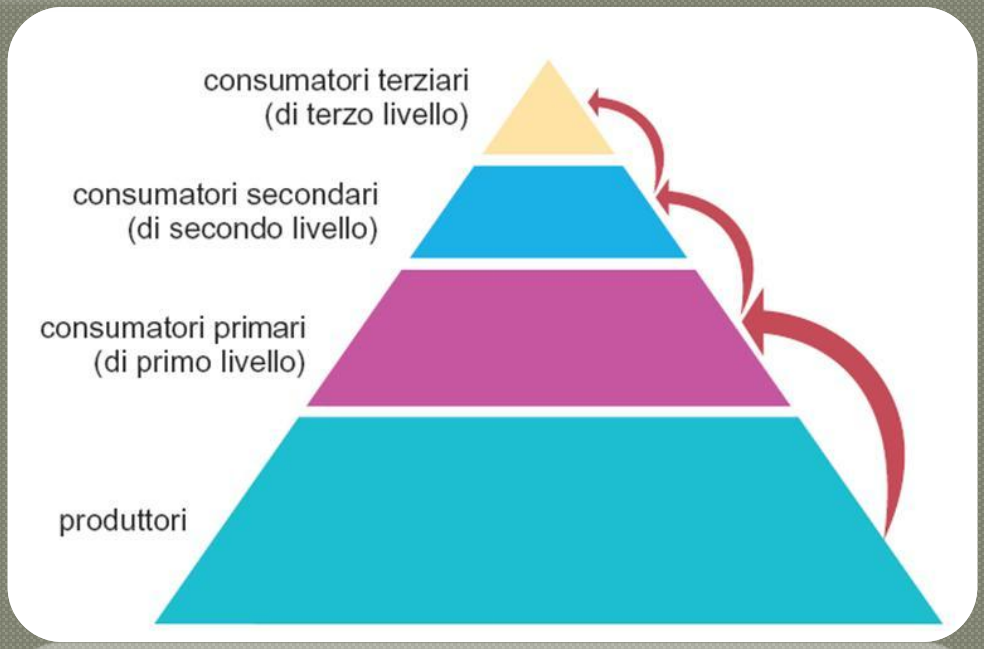
Mechanism of salt resistance:

- Salt avoidance:
  - Salt secretion
  - Salt dilution
  - Salt reclusion
- Salt tolerance:
  - Osmotic adjustment
  - ROS scavenging



PREDAZIONE




consumatori terziari
(di terzo livello)
consumatori secondari
(di secondo livello)
consumatori primari
(di primo livello)
produttori


Phytoplankton
Zooplankton
Migrating Midwater Fishes
Migrating
Midwater Fishes
Migrating
Predators
450 meters
Wreckfish

le difese che i produttori utilizzano contro i consumatori sono state sviluppate attraverso un processo di co- evoluzione risultato della selezione naturale e sono più o meno bilanciate da adattamenti dei consumatori .

- Adattamenti morfologicio-strutturali : spine, foglie e fusti con depositi calcarei o silicei

Mineralizzazione

Deposito di Sali minerali nella parete cellulare

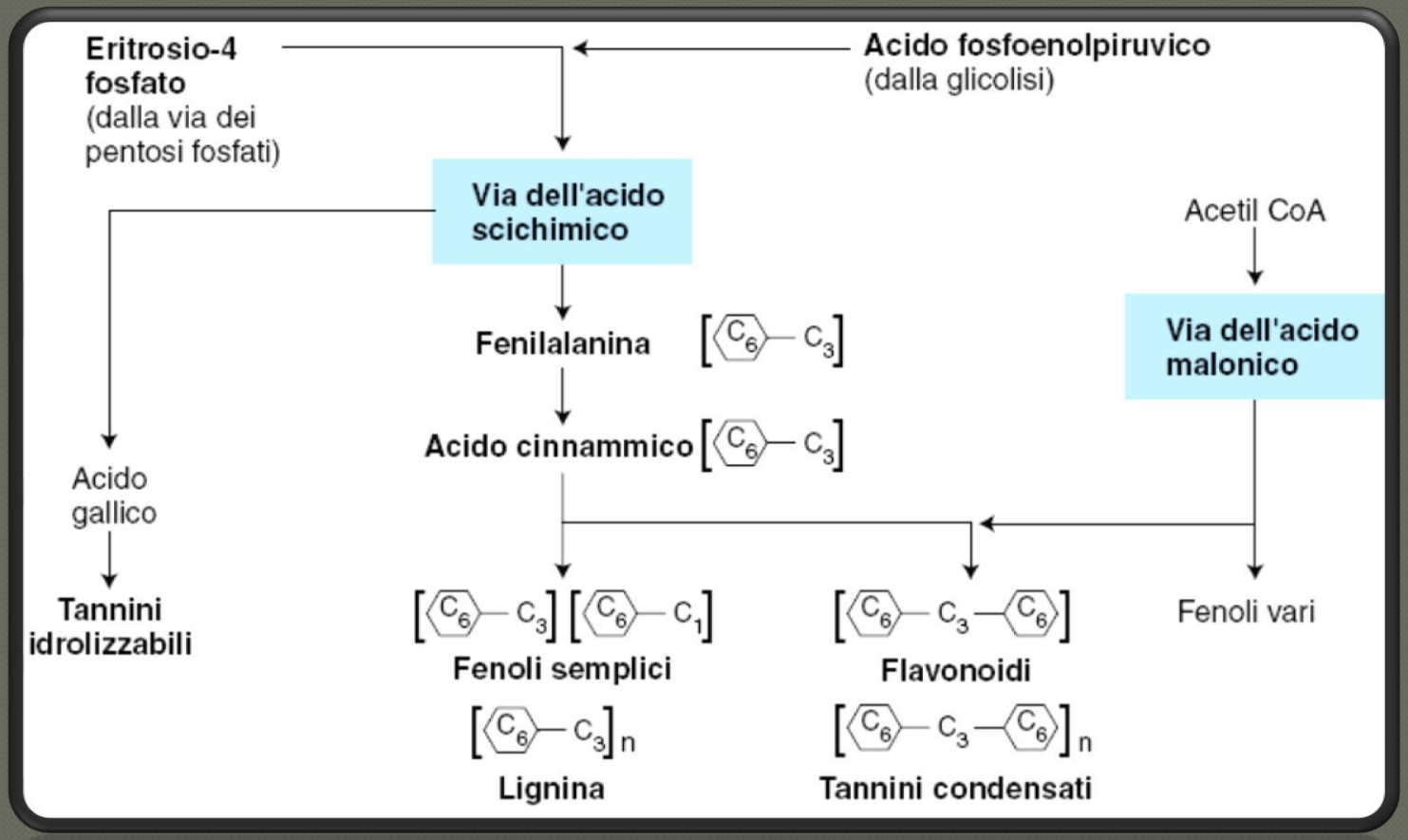
Silicizzazione
Deposito di silice (SiO_2) (es. diatomee e molte Gramineae)

Calcificazione
Deposito di carbonato di calcio ($CaCO_3$)

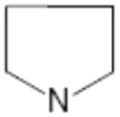
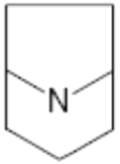
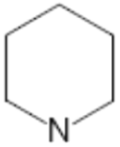
Es. alghe rosse ed alcune piante superiori
(peli di Cucurbitaceae e Boraginacae)

Modificazione dell'apparato buccale e/o digerente del predatore

- Adattamenti chimico-metabolici: composti secondari quali i fenoli



un impressionante numero composti deterrenti quali gli alcaloidi

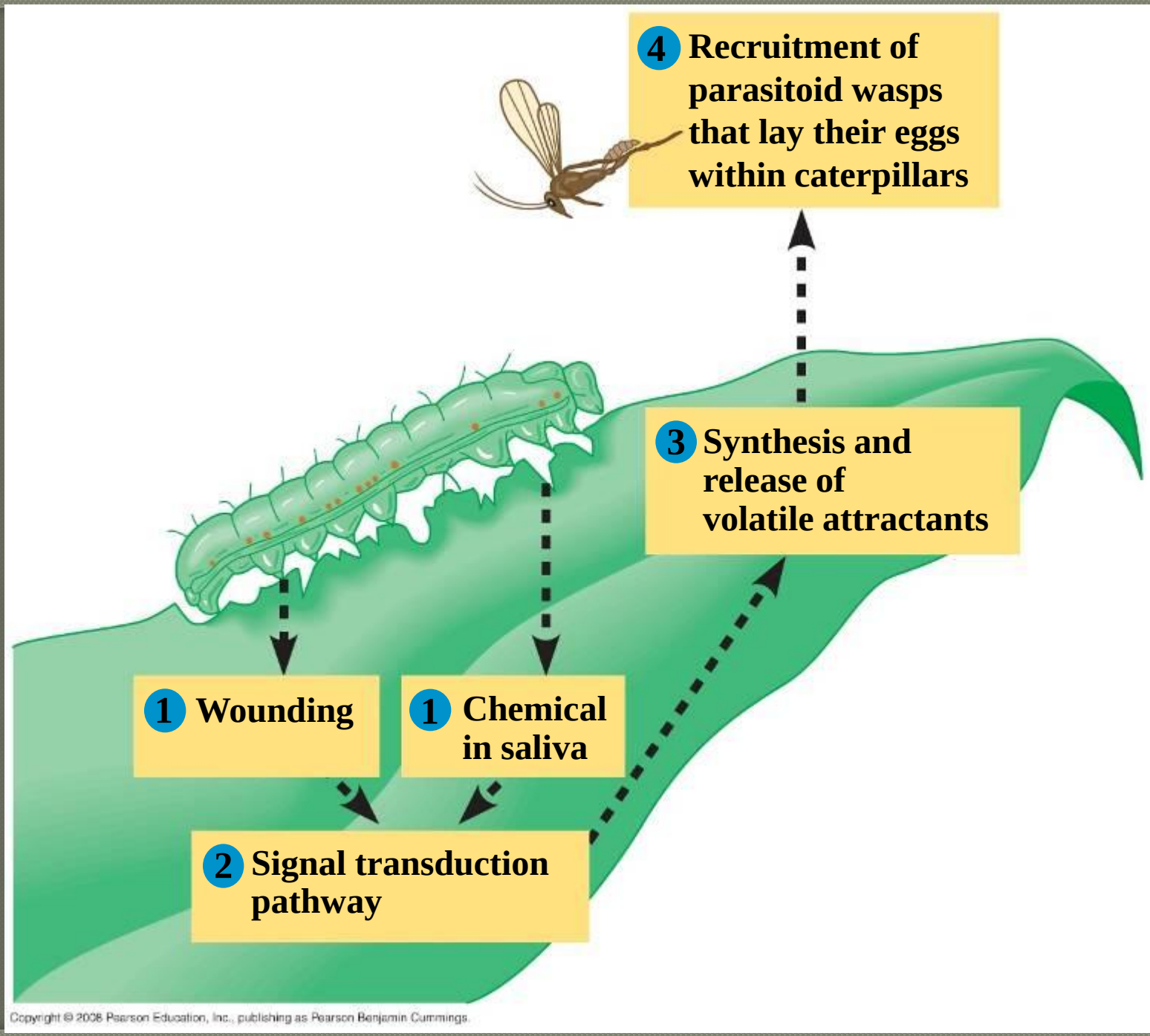
Esempi	Struttura	Classe di alcaloide	Precursore amminoacidico
Nicotina		Pirrolidinici	Ornitina
Atropina, Cocaina		Tropanici	Ornitina
Coniina		Piperidinici	Lisina

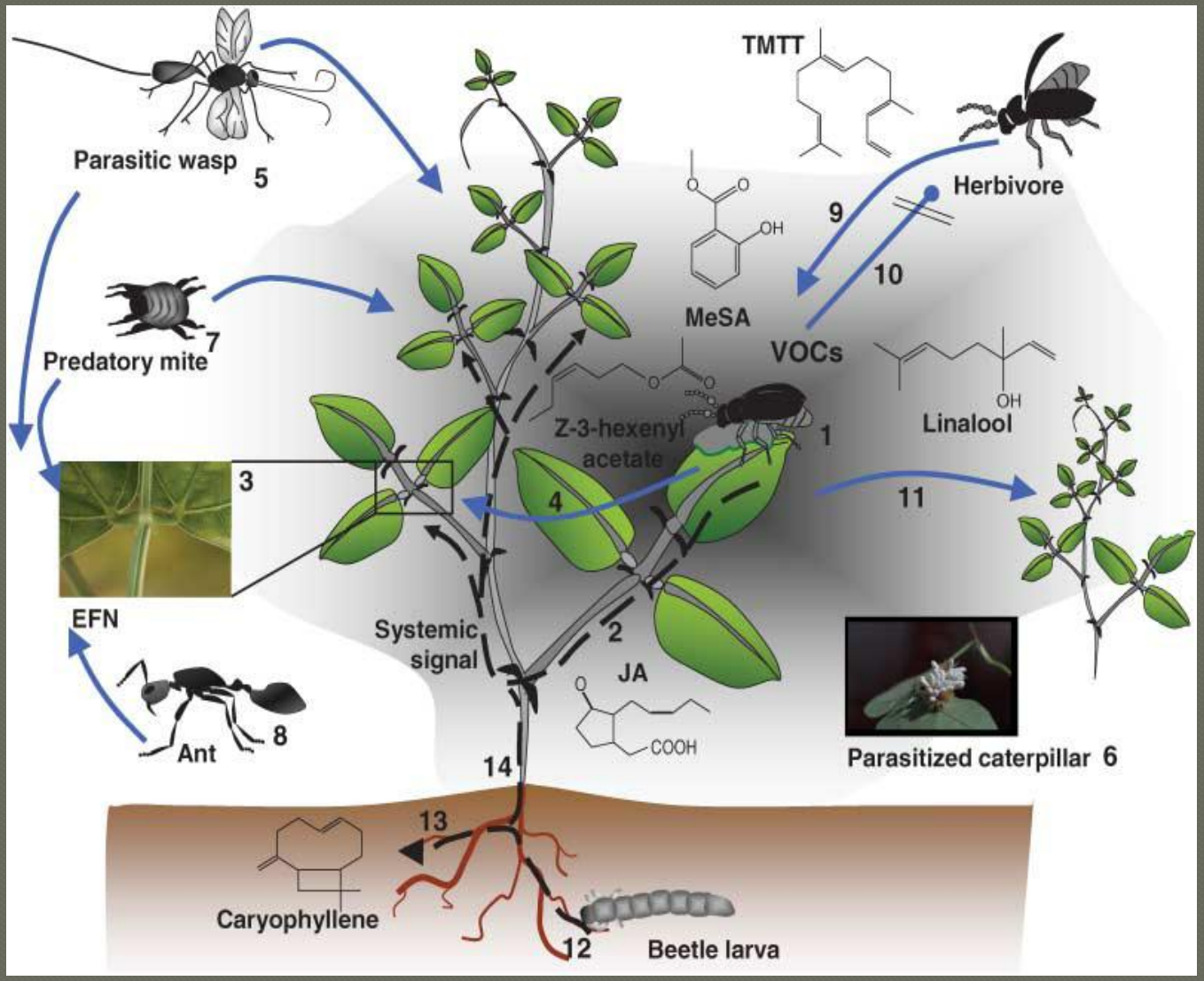
E tossine: digitossine, saponine, ricine

Sviluppo di sistemi di detossificazione

Farfalla Monarca (*Danaus plexippus*) e piante del genere *Asclepias*
Tossine di tipo cardenoide (glicosidi cardioattivi)

da predazione (larva)
a mutualismo (adulto)




TMTT
Parasitic wasp
5
Herbivore
9
10
MeSA
VOCs
Predatory mite
7
Linalool
Z-3-hexenyl
acetate
1
3
4
11
EFN
Systemic
signal
2
JA
Ant
8
Parasitized caterpillar
6
14
13
Caryophyllene
12
Beetle larva