SENESCENCE AND AGING

- **SENESCENCE AND AGING**
- All living organisms have a definite life span.
- A plant, be it annual or perennial has a vegetative growth phase after germination.
- The formation of flowers or development of reproductive structures marks the arrival of reproductive phase. The plant becomes mature by this time.
- With further passage of time its metabolic activities retard.
- The functional activities slow down.
- The plant becomes old and it reaches the senescence phase. Ultimately, the plant dies.

- Occasionally or seasonally, it has been observed that leaves and other organs fall down from the plant.
- The process is called abscission and it is regular feature with all the perennial plants - Ageing, senescence and death

- The process of growing old is called **ageing** and death is the termination of functional life.
- The stages of developmental processes that ultimately lead to death of an organ or organism is called **senescence**. This can be clearly observed in the plants having a short life span.

- **Ageing** is the sum total of changes occurring in the whole plant or some of its constituent organs. It includes all chemical and structural changes in cells, tissues, organs and the whole plant during their life cycle.

- **Senescence** is a consequence of ageing. Metabolic failure and cellular breakdown increase while the functional activities decrease during the senescence.
- It occurs due to some highly ordered degenerative processes and lead ultimately to death.
- Senescence is a highly ordered degenerative process and finally terminates the functional life of an organ or organism.

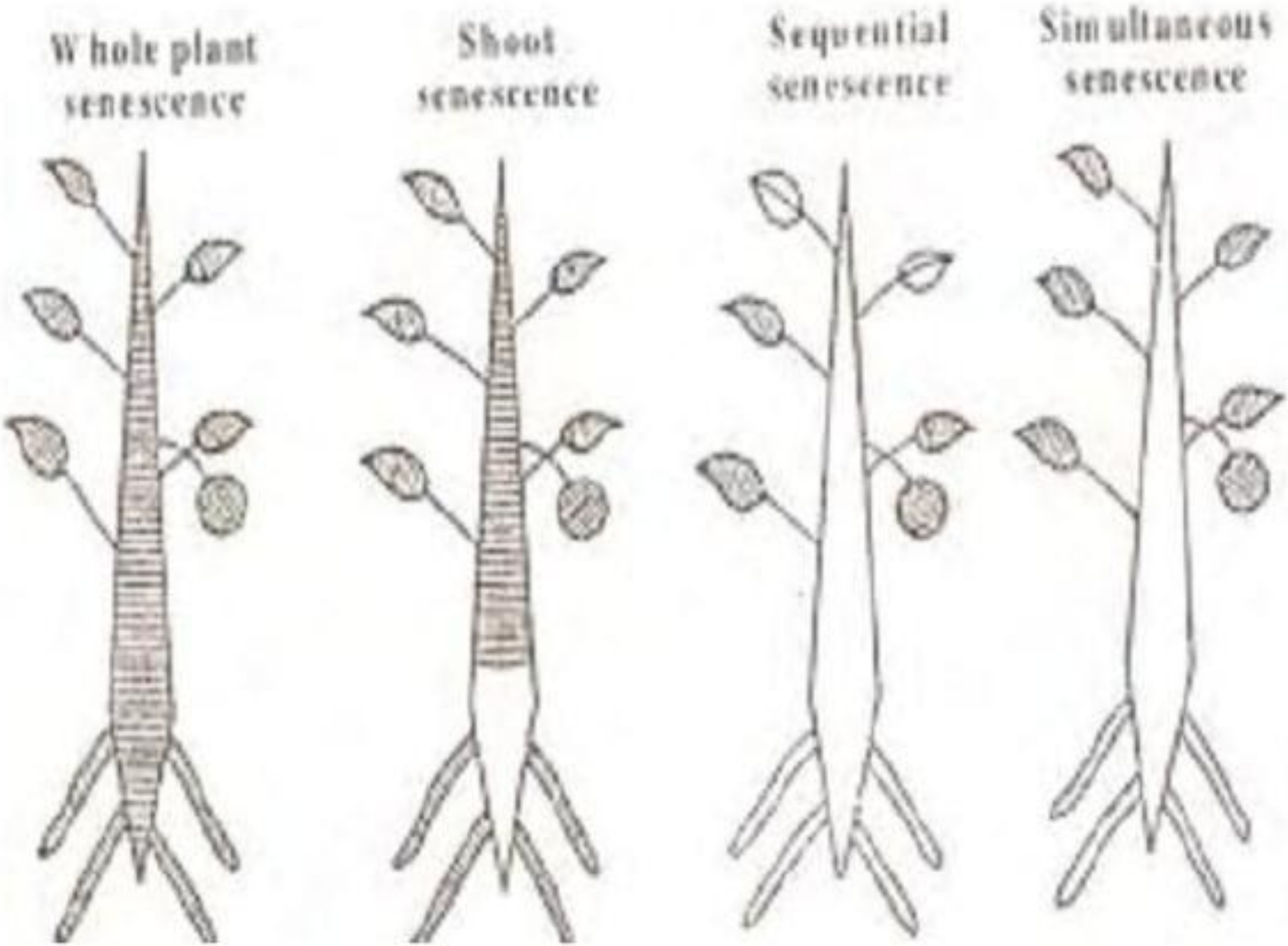
- **Senescence in plants is manifested in various forms**
- **1. Whole plant senescence**
- The process of senescence begins with the reproductive maturity and the whole plant dies after seed production. It is a characteristic of monocarpic plant species which flower and fruit only once in their life cycle and as such senescence of whole plant occurs in them. This is seen is annuals and biennials.

- **2. Shoot Senescence**
- The aerial shoots only senesce and die every year after flowering. Its underground part (shoot and root) survive and form new shoots. Shoot senescence is seen in many perennials like Zingier, Musa, and Chrysanthemum etc.

- **3. Organ senescence**
- Here senescence of only lateral organs such as leaves and fruits occur and they die prior to the death of the whole plant. Organ senescence may be of the following type.

- (i) Simultaneous or synchronous This type of senescence is seen in the case of deciduous trees in which almost all leaves scenesce and fall more of less simultaneously at a particular season of the year. *seasonal senescence*

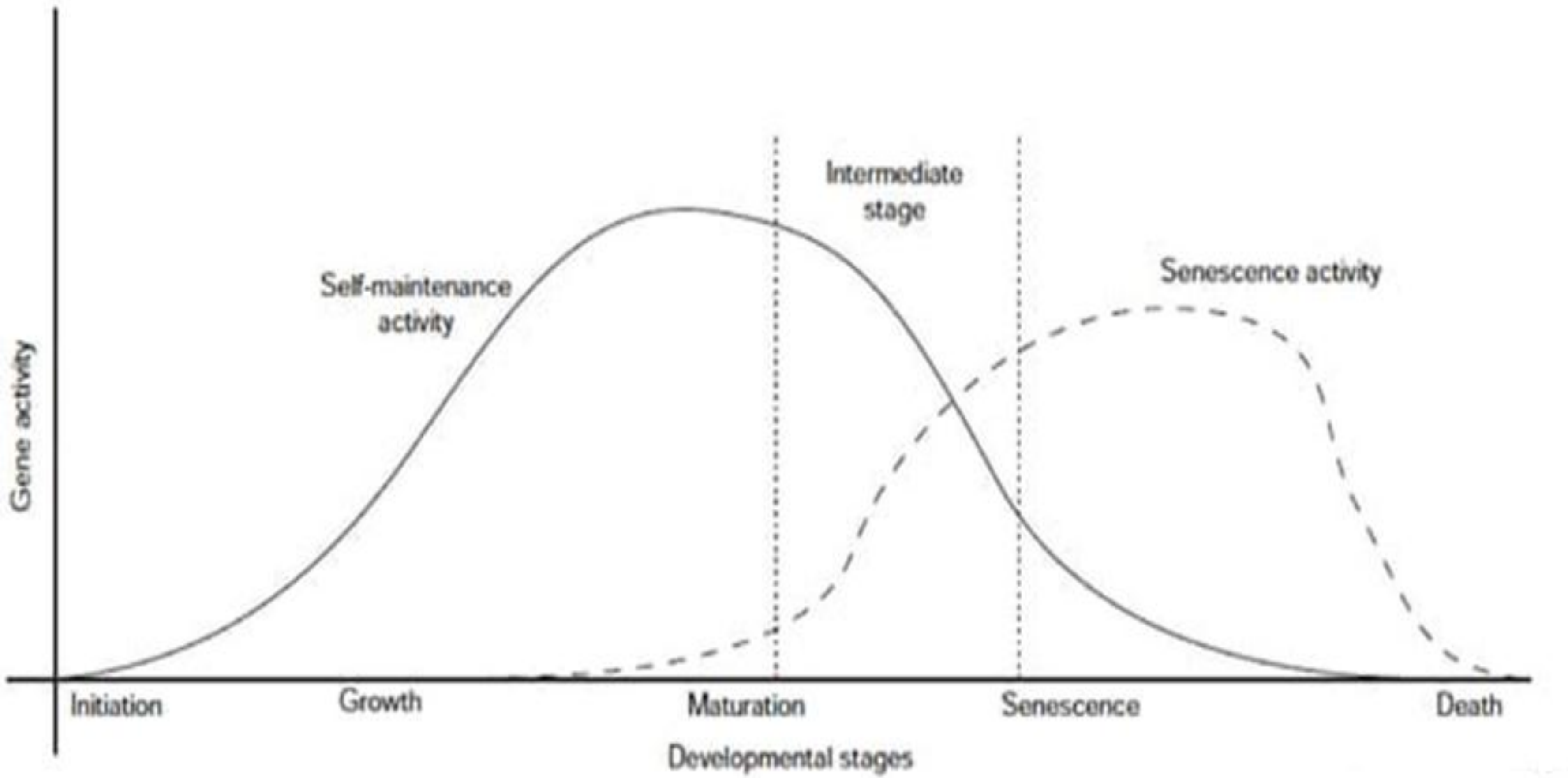
- (ii) Sequential senescence. It is a progressive senescence of the lower and older leaves while new ones are added to the growing shoot in a sequence.
- Because the leaves have a limited life span, here, the senescence takes place in a sequential manner depending on the age of the leaf.

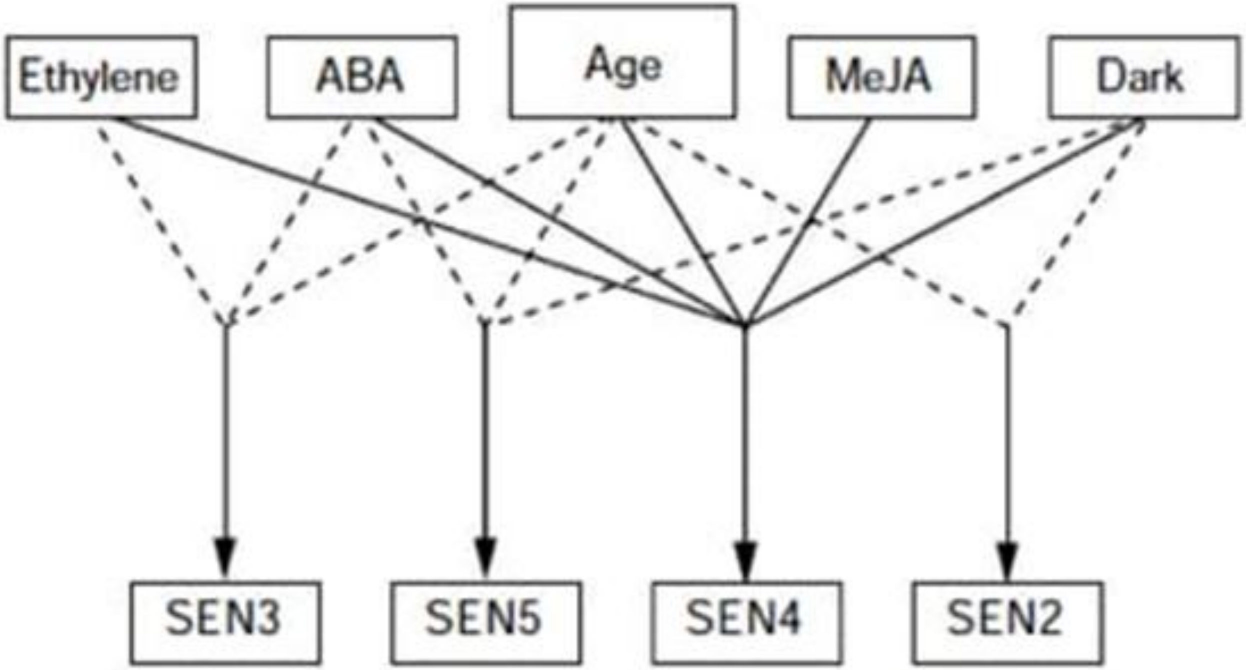

Whole plant senescence
Shoot senescence
Sequential senescence
Simultaneous senescence

- **Significance of Senescence**
- The process has many advantages in the cellular mechanism.
- (i) Because of this, new, functionally efficient organs or organisms are created and the old, functionally inefficient are discarded.
- (ii) It ensures recovery and reutilization of mineral elements and organic nutrients from older senescing organs to the newly formed growing organs.

- (iii) Synchronous or seasonal senescence avoids water loss due to transpiration during unfavorable season and thereby, helps in the survival of the plant.
- (iv) Falling of leaves due to senescence adds to the humus content of the surface layer of the soil and thereby makes to soil reach in nutrients for germination and growth of new seedlings.

Simple model for leaf growth and senescence





- The involvement of different sets of genes during leaf senescence affected by various senescence factors.
- Leaf senescence is affected by several factors and involves the induction of different sets of genes.
- Apparent symptoms of senescence may look the same, the detailed molecular states of senescent leaves are different depending on the senescence factors.

Triggers of senescence

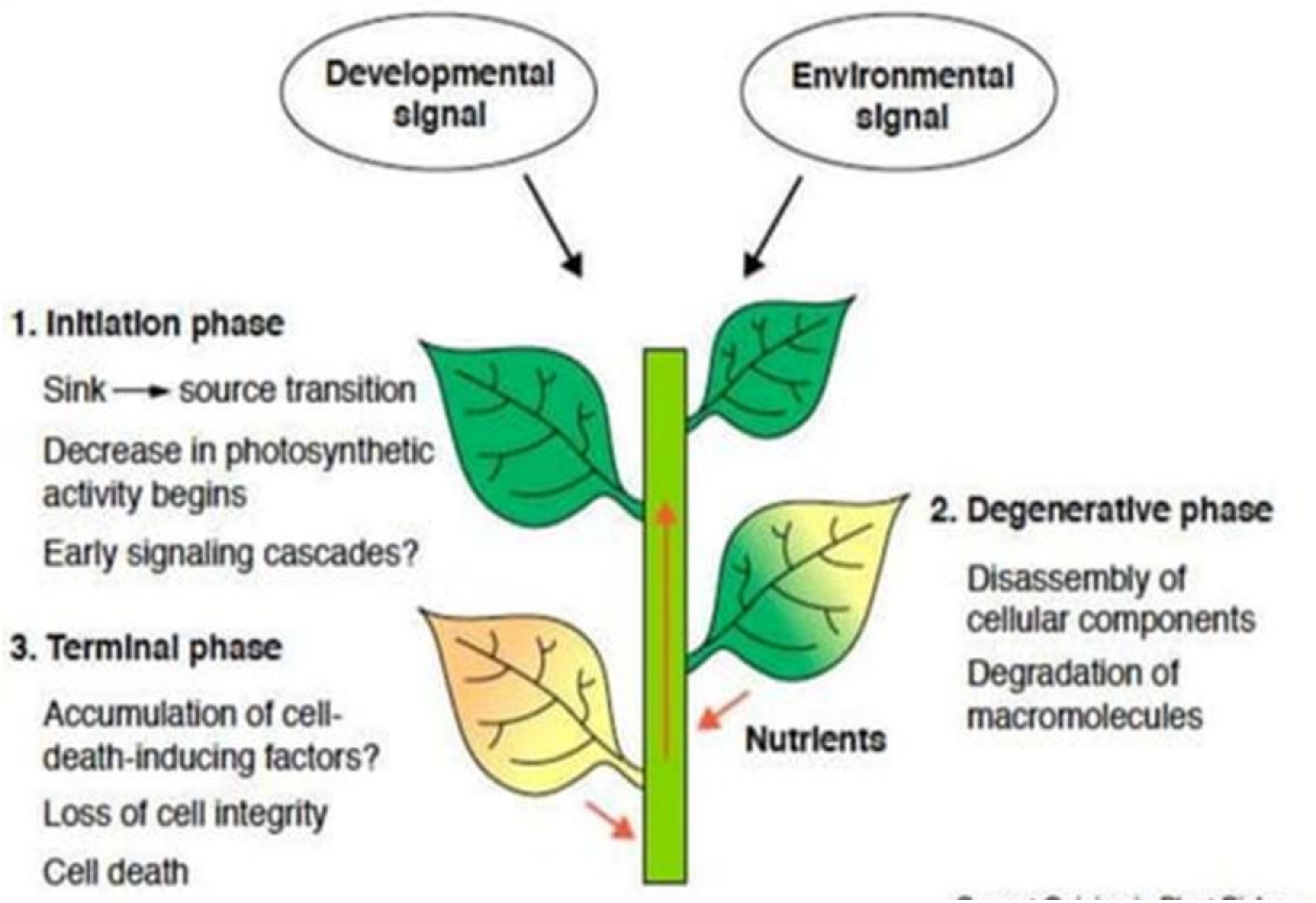
Internal → monocarpic senescence

External → day length and temperature in autumnal leaf senescence of deciduous plants

→ abiotic and biotic stress

Regardless of the initial stimulus, different senescence patterns share common internal programs in which, regulatory senescence genes initiate a cascade of secondary gene expression that brings about senescence and death.

Three stages of Leaf Senescence



Physiological and biochemical events

Senescence is genetically encoded, allowing a predictable course of cellular events.

Some organelles are destroyed while others remain active.

Chloroplast – first organelle to deteriorate during onset of leaf senescence (destruction of thylakoid protein components and stromatal enzymes)

Nuclei remain structurally and functionally intact until the late stages of senescence

Senescent tissues carry out catabolic processes that require *de novo* synthesis of

- proteases
- nucleases
- lipases
- chlorophyll-degrading enzymes

Senescence is an ordered series of Physiological and biochemical events

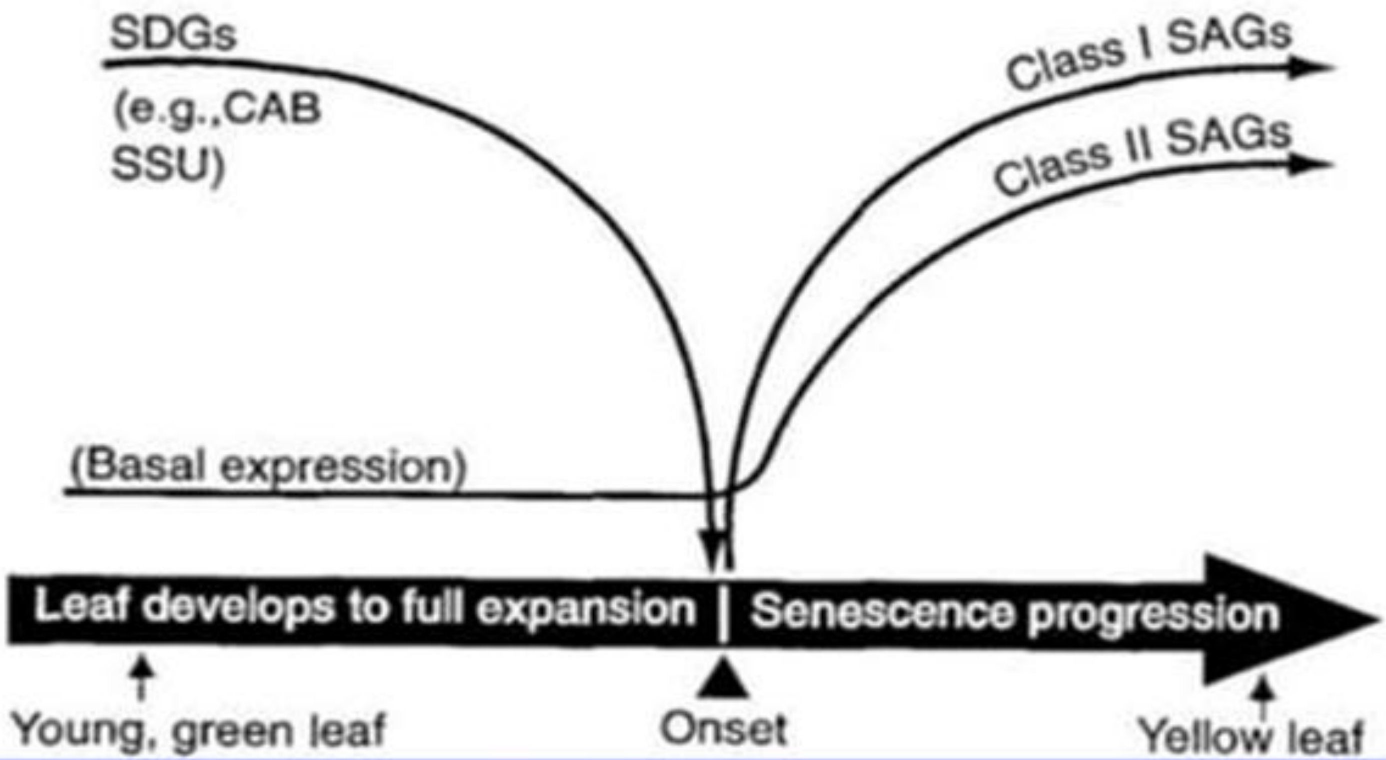
Senescence down-regulated genes (*SDGs*) – their expression decreases during senescence
e.g. photosynthetic genes

Senescence-associated genes (*SAGs*) – their expression is induced during senescence

Group A: proteases, ribonucleases, lipases, ACC synthase, ACC oxidase

Group B: glutamine syntethase (converts NH_4^+ to glutamine, nitrogen recycling from leaves)

Differential gene expression during leaf senescence



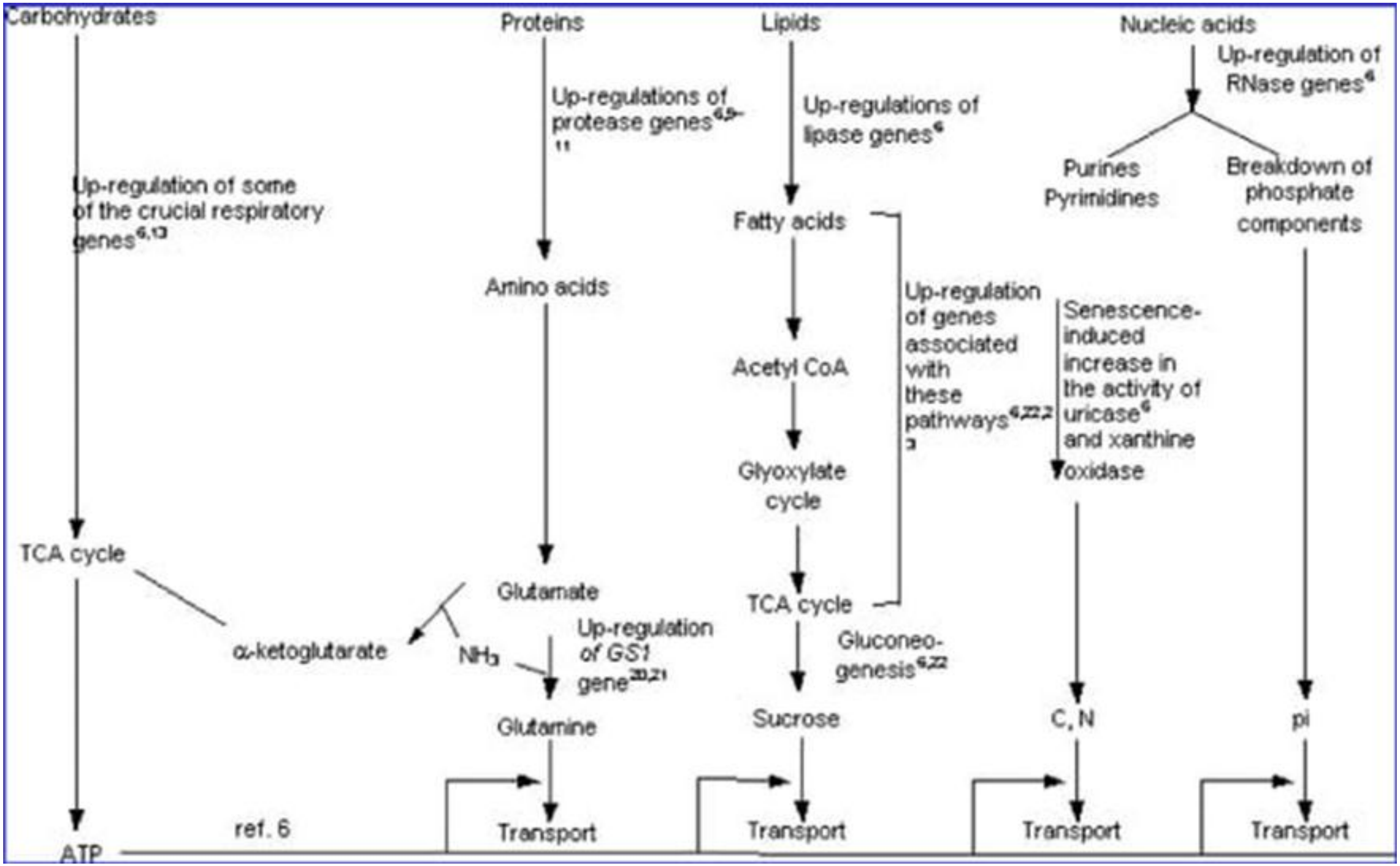
Senescence down-regulated genes ***(SDCs)*** include chlorophyll a/b-binding protein gene *(CAB)*, Rubisco small subunit gene (*SSU*).

***SAGs* -** expression up-regulated during leaf senescence.

Class I ***SAGs*** - expressed only during senescence (senescence-specific).

Class II ***SAGs* -** have basal level of expression during early leaf development, but expression increases during senescence.

Physiological mechanism of Senescence on Bio macromolecules



Physiology and biochemistry

Senescence-associated genes(SAGs)

Senescence is controlled by special genes.

Two kinds of genes can be found during senescence.

- **Senescence-**downward genes most of genes code enzymes relevant to photosynthesis, energy metabolism and other synthesis.
- **Senescence-**upward genes most of genes code enzymes for hydrolase, such as DNase, RNase, Protease, phospholipase

Senescence-associated genes SAGs refers to their mRNA levels increase with senescence proceeding. They function in metabolism of biomacromolecule degradation and mobilization.

Degradation of biomacromolecules

1. DNA degrades RNA changes in quality and quantity.

   RNA break down faster than DNA does during senescence, especially rRNA, which is more sensitive to senescence.

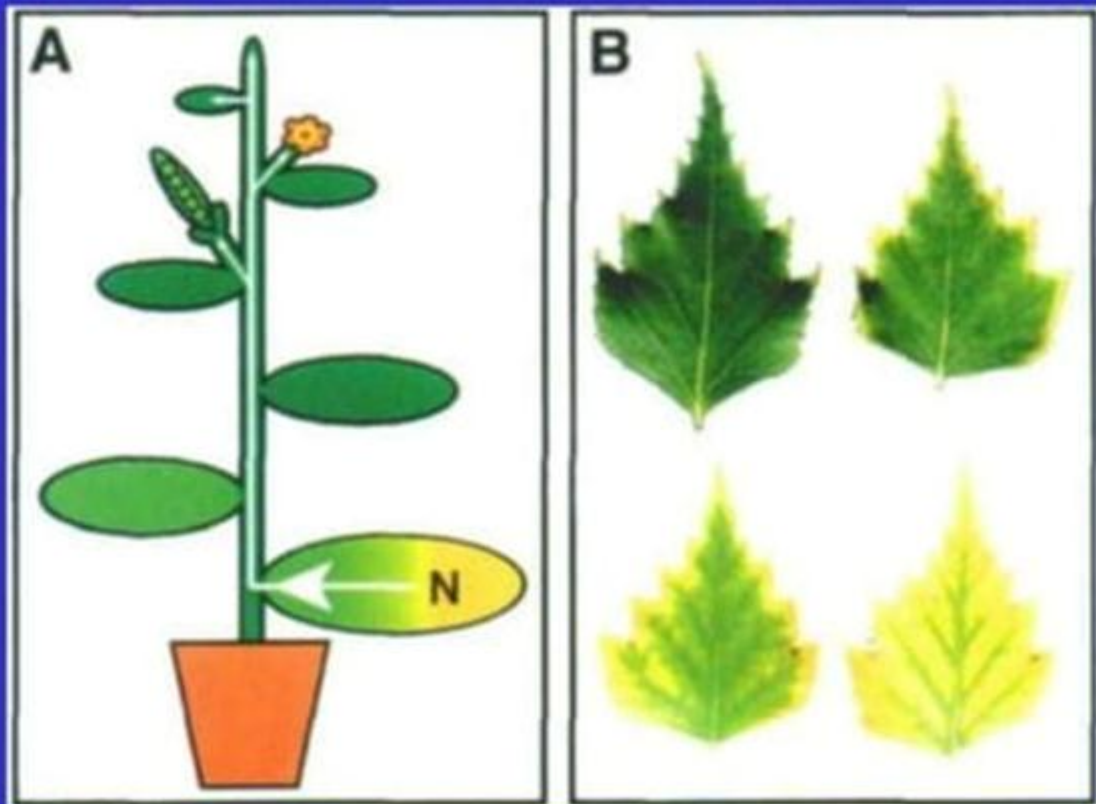
   RNase activity rises and DNA—RNA polymerase activity declines.

2. Protein synthesis decreases and its degradation increases

   Soluble protein-----Rubisco decreases by 85%, thylakoid membrane protein decreases by 50%, and cytochrome f,b also decreases fast

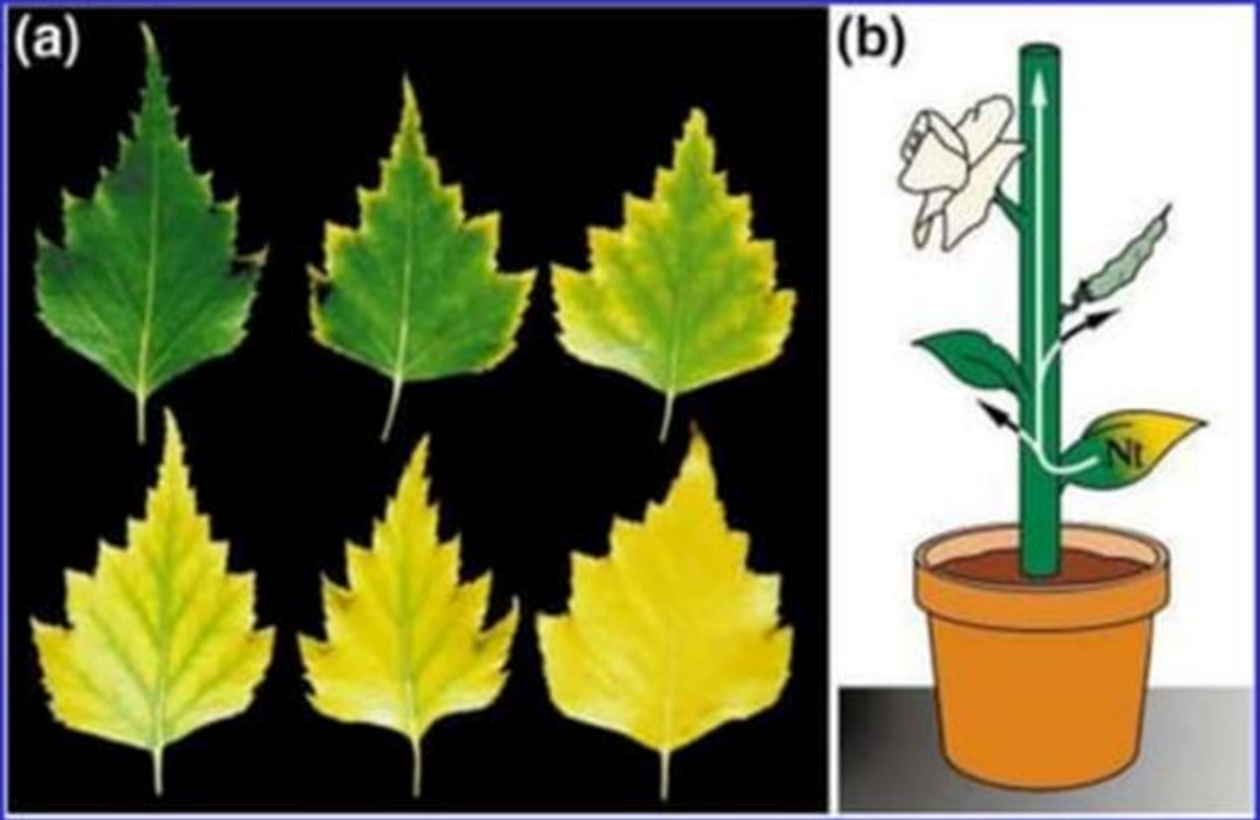
3. Biomembrane breakdowns and loses its function.

Senescence is a recycling process



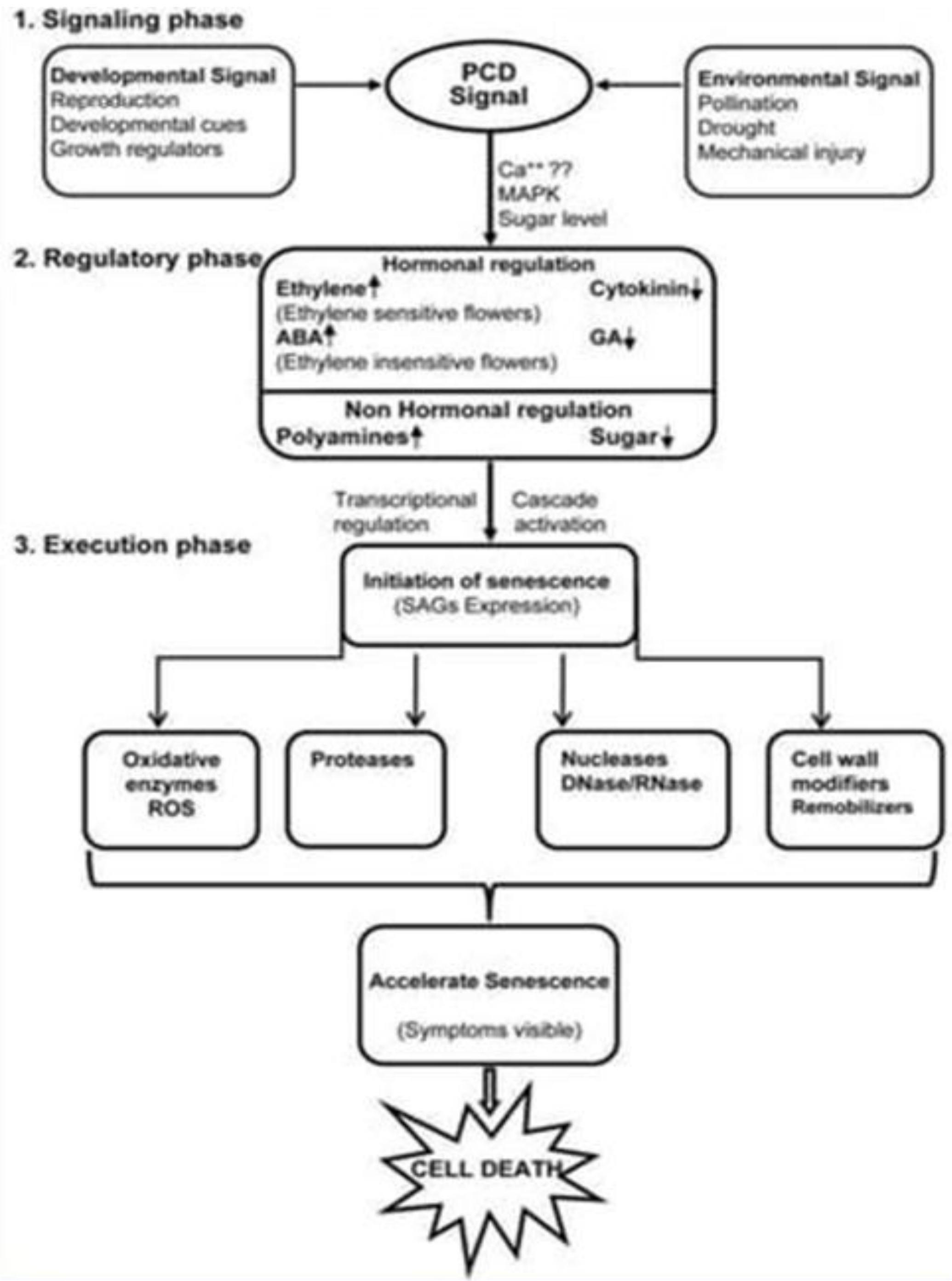
Some of the released nutrients (N) such as nitrogen are transported to developing seeds and young organs at the shoot apex.

Senescence proceeds from leaf margins toward the center. Cells surrounding the vascular tissues senesce relatively late to facilitate nutrient mobilization from adjacent senescing cells.



(a) Senescing leaves can be recognized by their characteristic loss of chlorophyll. Often, the last areas of a leaf that senesce are close to veins, presumably because these are needed for nutrient export.
The top-left leaf is just starting to senesce; the bottom-right leaf is in the most-advanced stage of senescence.

(b) As a leaf senesce, nutrients such as nitrogen, phosphorus and metals are reallocated to other parts of the plant such as developing seeds and leaves.



A model for regulatory pathways in flower senescence

PCD signal is generated by both external and internal stimuli and transduced by some signals resulting hormonal imbalance in the cell

Altered level of hormones activates several cascade and transcriptional regulation

Initiation of senescence starts with expression of several SAGs like proteases, nucleases, wall degrading and oxidative enzymes

Later stage of senescence symptoms become visible and ultimately leads to cell death of flowers

Programmed cell death is a specialized type of senescence

Senescence can occur at the level of:

whole plant (monocarpic senescence)

- organ (leaf senescence)
- cell (tracheary element differentiation)

Process whereby individual cells activate an intrinsic senescence program = **Programmed Cell Death (PCD)**

In animals, PCD may be initiated by specific signals (errors in DNA replication during division)

- involves expression of a characteristic set of genes, resulting in cell death
    - accompanied by morophological and biochemical changes (**apoptosis**, Greek: “falling off”)
- during apoptosis, cell nucleus condenses and DNA fragments in a specific pattern

PCD in plants, less well characterized

- PCD occurs during differentiation of xylem tracheary elements, during which nuclei and chromatin degrade and cytoplasm disappears → activation of genes encoding nucleases and proteases

- protection against pathogenic organisms

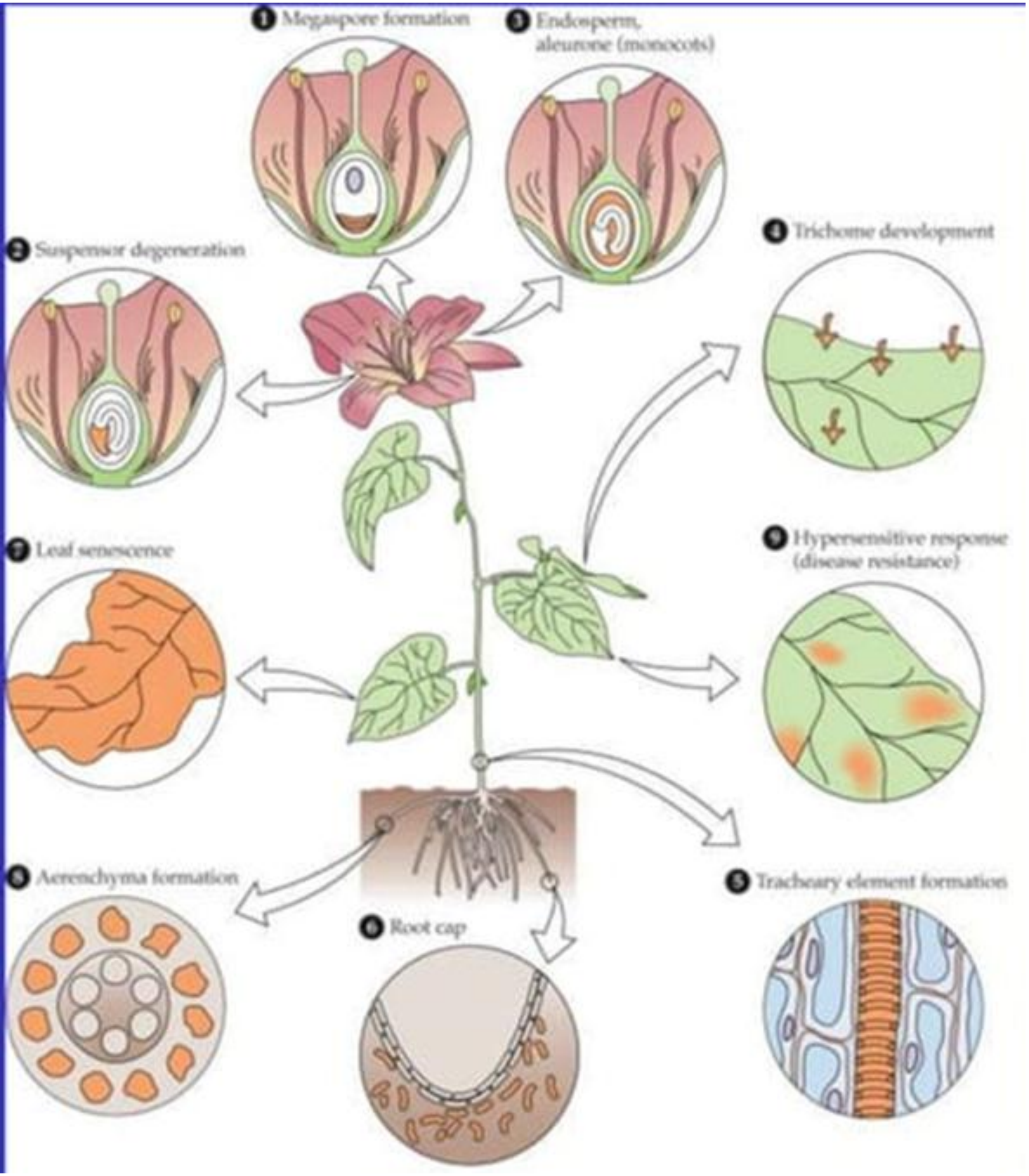
- infection by pathogen causes plant cells to quickly accumulate high concentrations of toxic phenolic compounds and die (it's not quite as simple) → dead cells form small circular island of cell death (**necrotic lesion**)

- necrotic lesions isolate and prevent infection from spreading to surrounding healthy tissues by surrounding the pathogen with a toxic and nutritionally depleted environment (**hypersensitive response**)

Programmed cell death (PCD)

The organism controls the initiation and execution of the cell death process, these types of cell death are referred to as programmed cell death (PCD)

PCD can appear in all organelles of cell



Cell death occurs in almost all plant cells and tissues.

PCD is involved in numerous processes, including the following illustrated in this figure gamete formation, including

Megaspore formation (1); Embryo development(2); Degeneration of tissues in the seed and fruit (3);

Tissue and organ development (4) through (6);

Senescence(7); and

Responses to environ-mental signals and path-ogens(8 and 9).

Control of senescence

Utilization of germplasm resistant to senescence

selection of varieties and cultivars resist to senescence

Transgenic plant for resistant to senescence

ACC synthase gene, *nr*, (*ipt1*, *kn1*)