OXIDATIVE STRESS

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Living organisms are exposed to different kinds of stresses, which may originate from **human activities or natural causes** such as **high and low temperatures, high light intensities, drought, air pollutants (eg. ozone or sulphur dioxide), ultraviolet light and herbicides such as paraquat.**

A common feature of different stress factors is their potential to increase the production of **reactive oxygen species** in plant tissues

Reactive oxygen species are also generated in plant cells during normal metabolic processes- Alscher *et al.,* 1997.

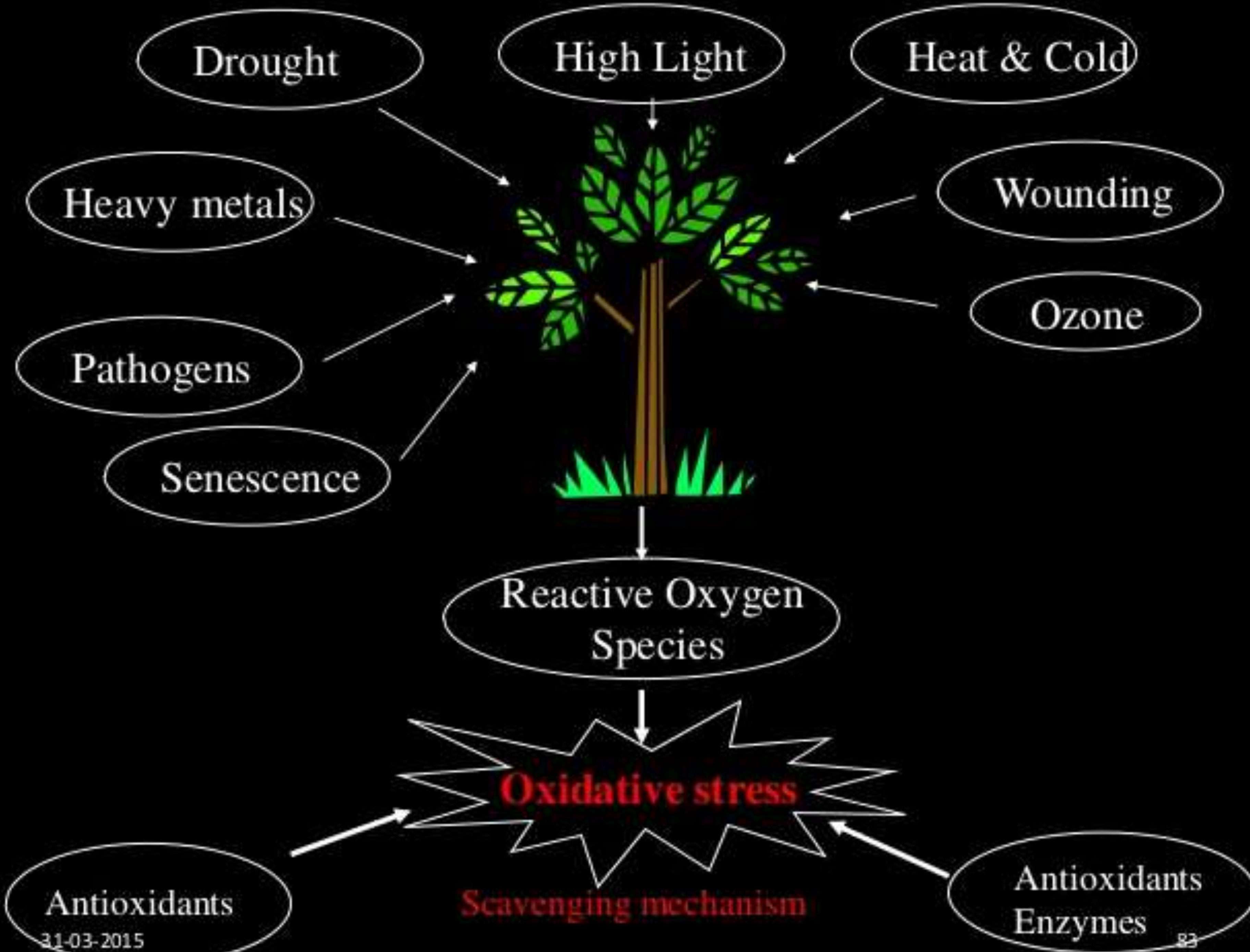
The photosynthetic electron transport system is the major source of active oxygen in plant tissues having potential to generate **superoxide (0^{-2}),hydrogen peroxide (H_20_2) and hydroxyl radicals (OH*)**

- Asada, 1994

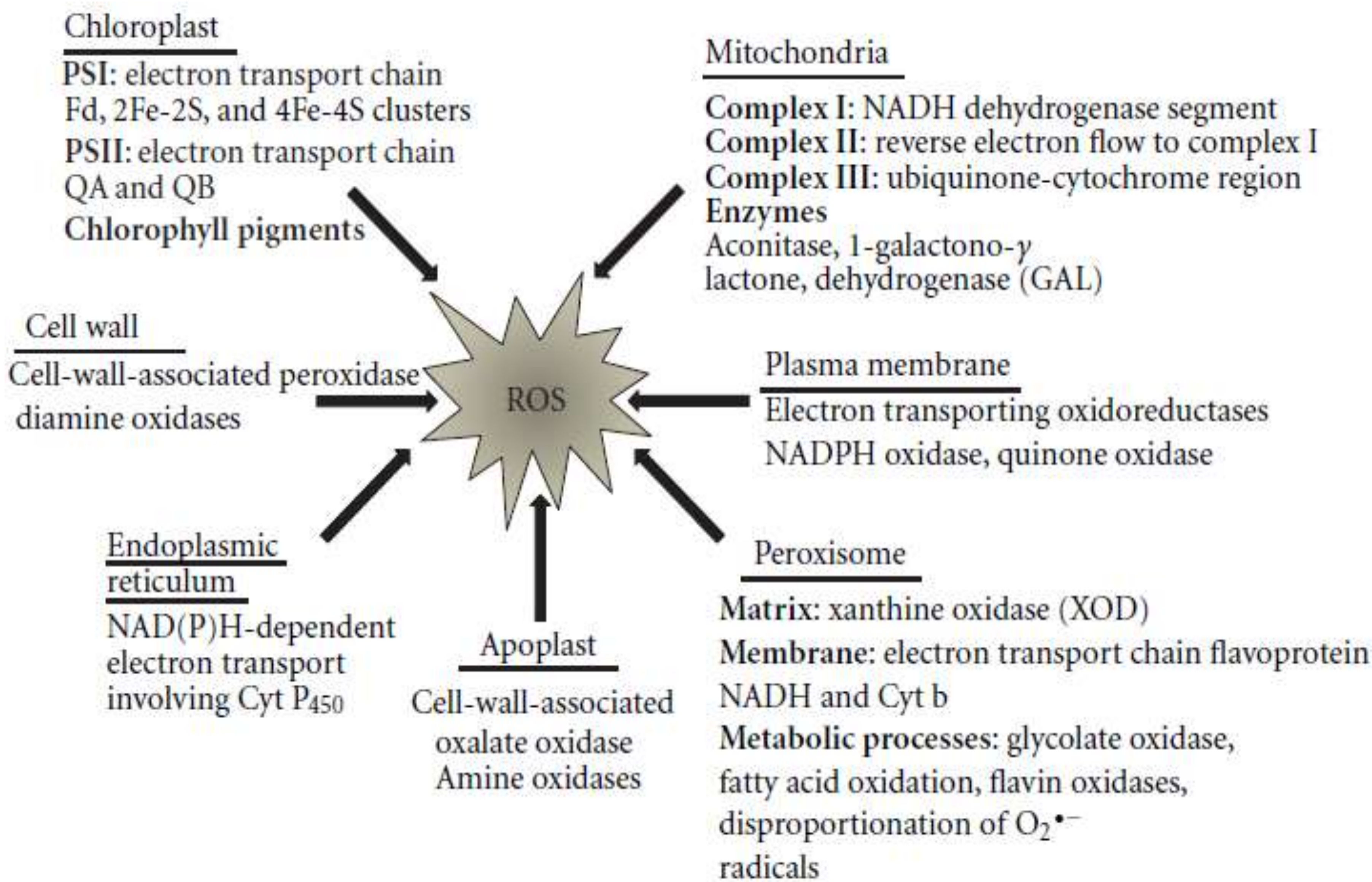
Oxidative stress is regulated process, the equilibrium between the **oxidative and antioxidative capacities** determining the fate of the plant

Under nonstressful conditions the antioxidant defence system provides adequate protection against active oxygen and free radicals – Asada,1987

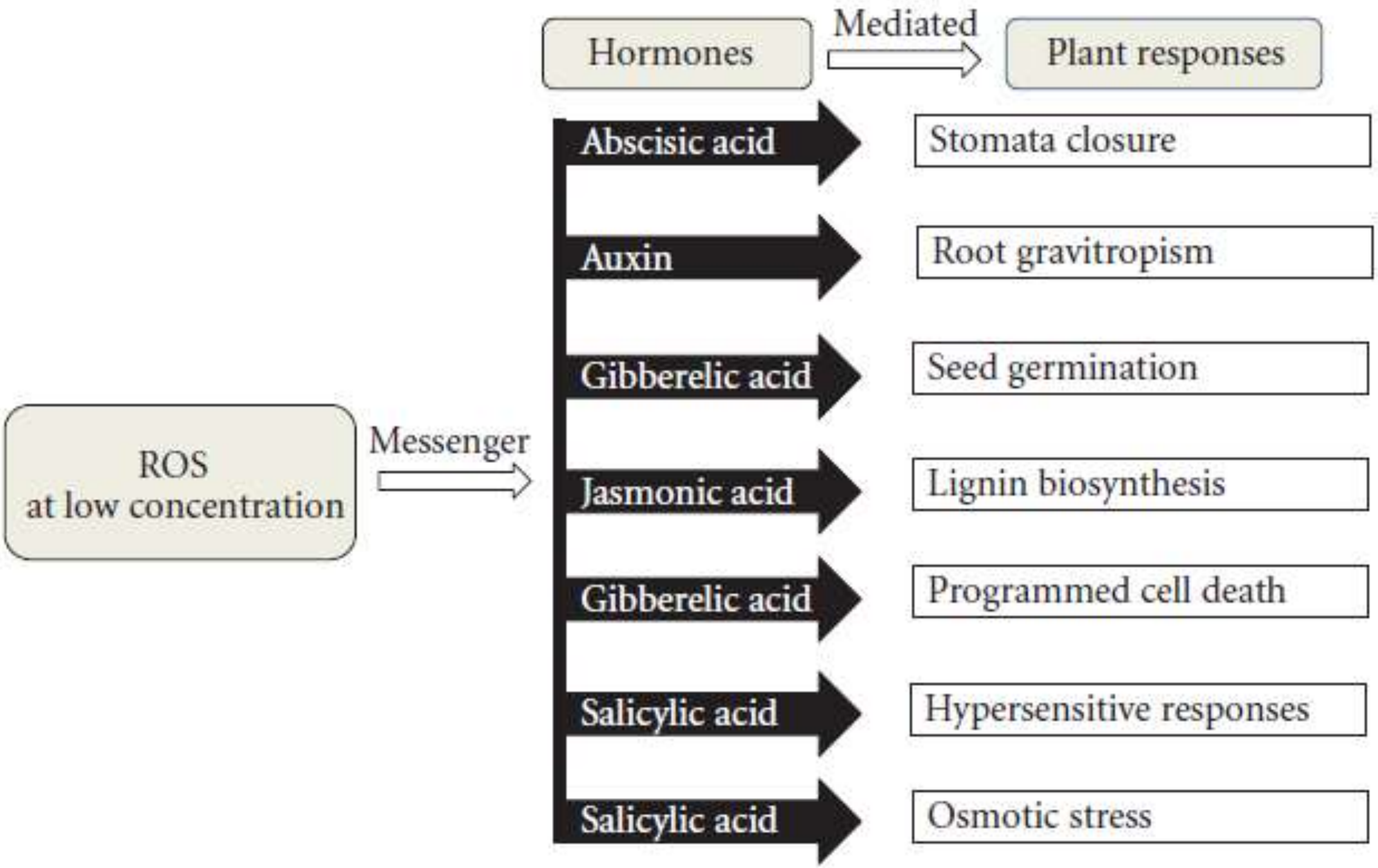
Both natural and man-made stress situations increase the production of toxic oxygen derivatives


Drought
High Light
Heat & Cold
Heavy metals
Wounding
Ozone
Pathogens
Senescence
Reactive Oxygen Species
Oxidative stress
Scavenging mechanism
Antioxidants
Antioxidants Enzymes

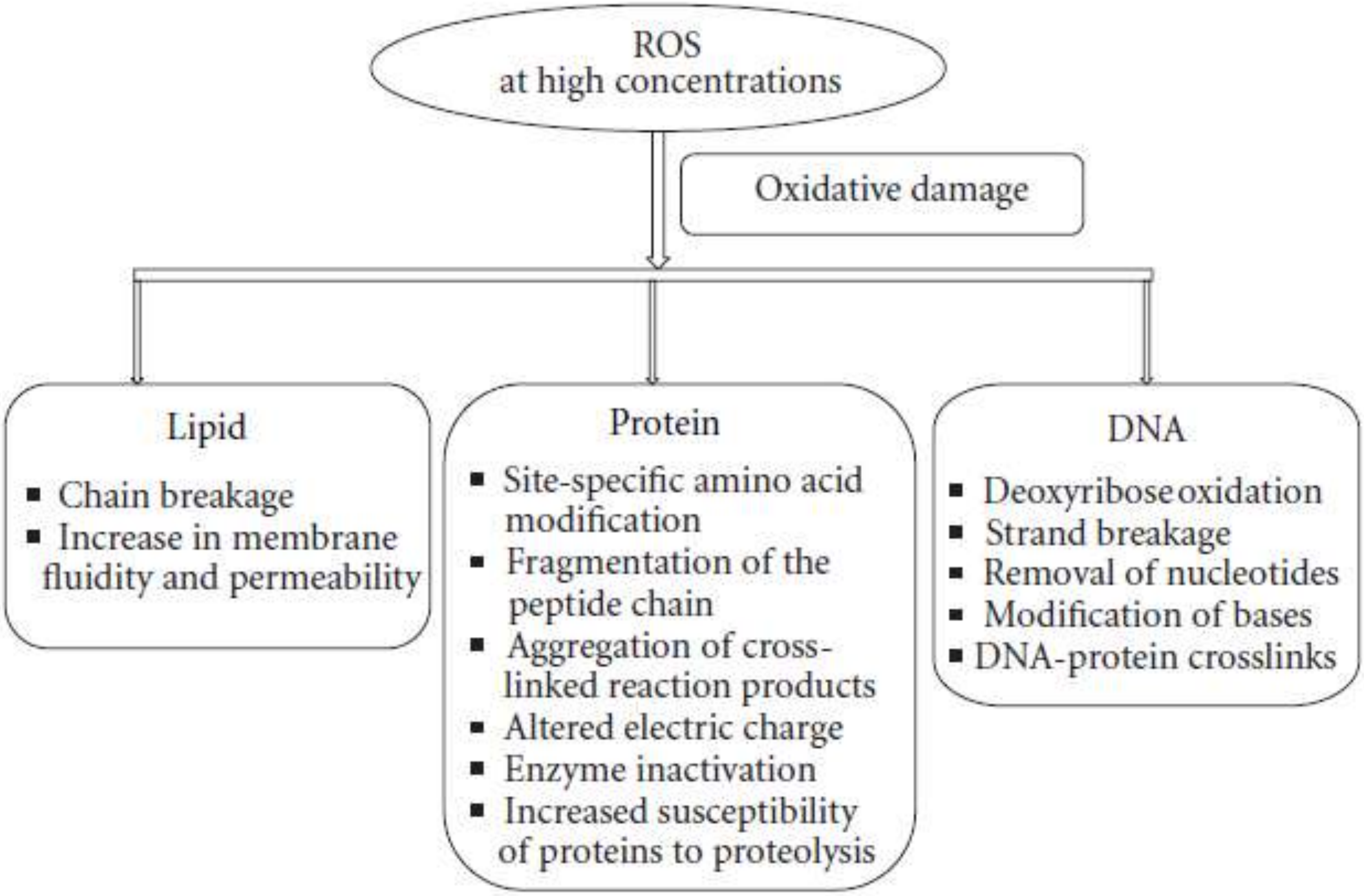
Sites of production of reactive oxygen species (ROS) in plants



Reactive oxygen species (ROS) as second messengers in several plant hormone responses



Reactive oxygen species (ROS) induced oxidative damage



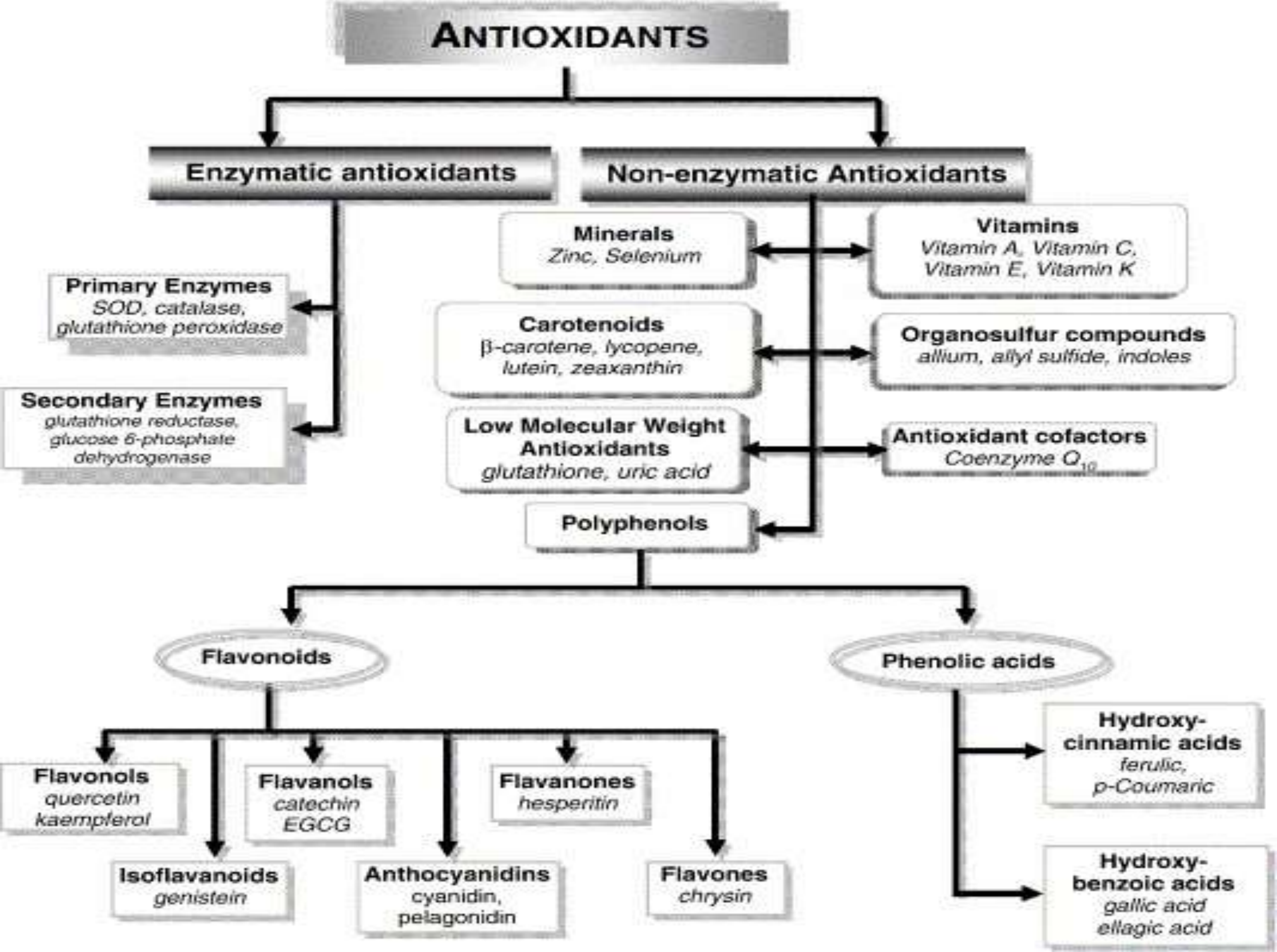
Antioxidative Defense System in Plants

Plants possess complex antioxidative defense system comprising of **nonenzymatic and enzymatic** components to scavenge ROS

In plant cells, specific ROS producing and scavenging systems are found in different organelles such as **chloroplasts, mitochondria, and peroxisomes.**

In order to avoid the oxidative damage, higher plants raise the level of **endogenous antioxidant defense**

– Sharma *et al* ., 2010


ANTIOXIDANTS
Enzymatic antioxidants
Non-enzymatic Antioxidants
Primary Enzymes
SOD, catalase, glutathione peroxidase
Secondary Enzymes
glutathione reductase, glucose 6-phosphate dehydrogenase
Minerals
Zinc, Selenium
Vitamins
Vitamin A, Vitamin C, Vitamin E, Vitamin K
Carotenoids
β-carotene, lycopene, lutein, zeaxanthin
Organosulfur compounds
allium, allyl sulfide, indoles
Low Molecular Weight Antioxidants
glutathione, uric acid
Antioxidant cofactors
Coenzyme Q_{10}
Polyphenols
Flavonoids
Phenolic acids
Flavonols
quercetin kaempferol
Flavanols
catechin EGCG
Flavanones
hesperitin
Isoflavanoids
genistein
Anthocyanidins
cyanidin, pelagonidin
Flavones
chrysin
Hydroxy-cinnamic acids
ferulic, p-Coumaric
Hydroxy-benzoic acids
gallic acid ellagic acid

Nonenzymatic Components of Antioxidative Defense System

Ascorbate (AsA) and glutathione - **tocopherol, carotenoids and phenolic**

They interact with numerous cellular components and in addition to crucial roles in defense system

Mutants with decreased nonenzymic antioxidant contents have been shown to be **hypersensitive to stress**

- Gao and Zhang,2008; Semchuk *et al*., 2009

1. Ascorbate (AsA)

Most abundant, **low molecular weight antioxidant** that has a key role in defense against **oxidative stress caused by enhanced level of ROS**

AsA is considered powerful antioxidant because of its ability to **donate electrons in a number of enzymatic and nonenzymatic** reactions

AsA has been shown to play important role in several physiological processes in plants, including **growth, differentiation and metabolism**

Most of AsA, almost more than **90%, is localized in cytoplasm**

Over expression of two members of the **GDP- Mannose 3,5-epimerase (GME) gene** family resulted in increased accumulation of **ascorbate** and improved tolerance to abiotic stresses in **tomato plants**

– Maroco *et al*., 2002

Over expression of **strawberry and potato plants** - increase galactonic acid- leads to accumulation of AsA and enhanced abiotic stress tolerance

- Shu *et al.,*2011

Increased AsA content has been shown to confer oxidative stress tolerance in **Arabidopsis**

- Foyer and Noctor, 2003

2. Glutathione

Tripeptide glutathione is one of the low molecular weight nonprotein thiol that plays an important role in **intracellular defense against ROS-**induced oxidative damage

It has been detected in all cell compartments such as **cytosol, chloroplasts, endoplasmic reticulum, vacuoles, and mitochondria**

- Foyer and Noctor, 2003

Drought stress and metal toxicity altered ratio of **glutathione synthetase/glutathione disulfide** has been observed in chilling

- Radyuk *et al* ., 2009

Eltayeb *et al.,* 2010- observed greater protection against oxidative damages imposed by various environmental stresses in transgenic potato with higher level of glutathione

3. Tocopherols

Tocopherols is a group of lipophilic antioxidants involved in **scavenging of oxygen free radicals, lipid peroxy radicals and 1O^2** – Diplock *et al*.,1989

it is synthesized only by **photosynthetic organisms** and are present in only green parts of plants.

Tocopherols are known to protect lipids and other membrane components chemically reacting with O_2 in chloroplasts, thus protecting the structure and function of PSII

- Ivanov and S. Khorobrykh,2003

Accumulation of *α-tocopherol has* been shown to induce tolerance to chilling, water deficit, and salinity in different plant species

(Yamaguchi and Shinozaki, 1994; Munn *et al.,*1999; Guo et al., 2006 and Bafeel and Ibrahim, 2008)

4. Carotenoids

its serve as precursors to signaling molecules that influence plant development and abiotic stress responses

- Vallabhaneni *et al*., 2008

Gomathi and Rakkiyapan, 2011 observed that high carotenoids content favors better adaptation of plants under saline condition

5. Phenolic Compounds

Phenolics are secondary metabolites (flavonoids, tannins, and lignin) which possess antioxidant properties

Polyphenols can directly scavenge molecular species of active oxygen, and can inhibit lipid peroxidation by trapping the lipid alkoxyl radical

Janas *et al.,* 2008 observed that ROS could serve as a common signal for acclimation to Cu^{2+} stress and could cause accumulation of total phenolic compounds

Transgenic potato plant with increased concentration of flavonoid showed improved antioxidant capacity- Lukaszewicz *et al.,* 2004

Enzymatic Components

The enzymatic components of the antioxidative defense system comprise of several antioxidant enzymes such as

- ✓Superoxide dismutase (SOD),
- ✓ Catalase (CAT),
- ✓Enzymes of ascorbate glutathione (asa-gsh)
- ✓Ascorbate peroxidase (APX),
- ✓Monodehydroascorbate reductase (MDHAR),
- ✓Dehydroascorbate reductase (DHAR), and
- ✓Glutathione reductase (GR)

- Noctor and Foyer, 1998

1. Superoxide Dismutase

Superoxide dismutase (SOD) plays central role in defense against oxidative stress in all aerobic organisms –Scandalios,1993

SOD activity has been reported to increase in plants exposed to various environmental stresses, including drought and metal toxicity

- Srivastava and Dubey, 2011

Increased activity of SOD is often correlated with increased tolerance of the plant against environmental stresses.

It was suggested that SOD can be used as an indirect selection criterion for screening drought-resistant plant materials

– Zaefyzadeh *et al.*, 2009

Overproduction of SOD has been reported to result in enhanced oxidative stress tolerance in plants

– Gupta *et al.*, 1993

2. Catalase

Among antioxidant enzymes, catalase (CAT, 1.11.1.6) was the first enzyme to be discovered and characterized

CAT scavenges H_2O_2 generated in this organelle during photorespiratory oxidation, β-oxidation of fatty acids, and other enzyme systems – Del *et al.,* 2006

Willekens *et al.* 1995, proposed a classification of CAT based on the expression profile of the tobacco genes.

Class I CATs are expressed in photosynthetic tissues and are regulated by light.

Class II CATs are expressed at high levels in vascular tissues, whereas

Class III CATs are highly abundant in seeds and young seedlings.

Environmental stresses cause either enhancement or depletion of CAT activity,depending on the intensity, duration, and type of the stress

- Moussa and S. M Abdel-Aziz,2008

Stress analysis revealed increased susceptibility of CAT-deficient plants to paraquat, salt and ozone, but not to chilling

- Willekens,2011

Over expression of a CAT gene from *Brassica juncea* introduced into tobacco, enhanced its tolerance to Cd induced oxidative stress

–Guan,2009

3. Guaiacol Peroxidase

Heme containing protein, preferably oxidizes aromatic electron donor such as guaiacol and pyragallol at the expense of H_2O_2

GPX is associated with many important biosynthetic processes, including lignification of cell wall, degradation of IAA, biosynthesis of ethylene, wound healing, and defense against abiotic stresses

Various stressful conditions of the environment have been shown to induce the activity of GPX - Sharma and Dubey,2005

Radotic, 2000, correlated increased activity of GPX to oxidative reactions under metal toxicity conditions and suggested its potential as biomarker for sublethal metal toxicity in plants.

Conclusion

ROS are unavoidable by products of normal cell metabolism.

ROS are generated by electron transport activities of chloroplast, mitochondria, and plasma membrane or as a byproduct of various metabolic pathways localized in different cellular compartments.

environmental stresses such as drought, salinity, chilling, metal toxicity, and UV-B, if prolonged over to a certain extent, disrupt the cellular homeostasis and enhance the production of ROS.

ROS play two divergent roles in plants; in low concentrations they act as signaling molecules that mediate several plant responses in plant cells, including responses under stresses, whereas in high concentrations they cause exacerbating damage to cellular components.

Enhanced level of ROS causes oxidative damage to lipid, protein, and DNA leading to altered membrane properties like ion transport, loss of enzyme activity, protein crosslinking, inhibition of protein synthesis, DNA damage, ultimately resulting in cell death.

In order to avoid the oxidative damage, higher plants possess a complex antioxidative defense system comprising of nonenzymatic and enzymatic components.

THANK YOU