Journal of
Biodiversity & Endangered Species

Butnariu and Samfira, J Biodivers Endanger Species 2013, 1:2
DOI: 10.4172/2332-2543.1000e106

Editorial Open Access

Aspects Relating of the Oxidative Stress to Living Organisms

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Free radicals (pro-oxidants) are compounds belonging to the radical groups; they are active biochemically and biologically, and they destroy cell membranes, nuclei, and cytoplasm, producing and maintaining an intense oxidative stress. This is a consequence of the presence of one or several free electrons on the last layer of an atom in the molecule. Free radicals are oxygenated electron-deficit anions that do not make up salts, acids, or bases, but keep this reactive (free) form [1].

Oxygen electronic structure explains why the element, though a free diradical (two unpaired electrons) have low reactivity. Oxygen is essential for aerobic bodies' life, but, in concentrations that are too high, it can turn toxic. Molecular oxygen in fundamental state is inert, and its partial reduction results in active oxygen species–the most dangerous free radicals [2]. This group of compounds is called Reactive Oxygen Species (ROS). ROS is a term including not only oxygen radicals (O and H), but also oxygen non-radicalic derivatives, including hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), and ozone (O_3) [3. Even if ROS are not true free radicals, these species are molecule reactive [4].

Under physiological conditions, ROS are produced in small amounts in the cells [5.

The interaction between these species and lipid membranes, nucleic acids, proteins and enzymes or other small molecules, leads inevitably to cell lesions (Figure 1).

These cell lesions are one of the factors leading to ageing and degenerative diseases at cell level, there are several types of reactive species.

The variety of free radicals in nature resulted from different processes (ultraviolet radiations, gamma radiations, action of specific particles, etc.) makes their classification difficult [6,7].

From the point of view of the nature of the element containing free electrons, free radicals can be: superoxide, peroxide, hydroxide, nitric oxide, nitrite, nitrate, alkoxyl (Table 1).

Cell production of ROS roots in enzymatic and non–enzymatic sources.

Electron transfer from proteins or enzymatic systems can lead to ROS as a result of electron transfer reactions. This "unintentional" generation of ROS in mitochondria represents 1–2% of the total O_2 consumed in reducing conditions. Body oxygen content represents 65% and inhaled air oxygen content is 21%. Cells generate aerobic energy, reducing O_2 to water.

Oxygen can be used in catabolic and anabolic processes, allowing larger amounts of energy than possible in its absence [8].

Oxygen has a particular electronic structure in its fundamental state, with two non-participating electrons on the last layer, each of which is localised on an orbital n* (Figure 2).

These two electrons have the same quantum number of spin; thus, if O_2 tries to oxidate a compound by accepting two electrons, they need to have a parallel spin number to occupy the free spaces in the orbitals n* (in an orbital, two electrons have anti-parallel spins +1/2 and –1/2) [9].

This particularity asks for a restriction of oxidations, determining higher or lower reactivity, depending on the nature of the electron donor (Table 2).

All oxidations in nature are based on these two pathways, even if the forms may seem varied.

Peroxides and superoxides are anions that have oxidative action (peroxides, alkoxyls, nitrosamines, acrolein) derive from H_2O_2 and from other sources/processes, like the anions resulted from the degradation (rancidisation, proteolytic degradation, etc.) of lipid-rich foods (lipid peroxides, lipid alkoxyls) or from food processing (frying, refreezing, etc.).

Hypochlorous acid behaves like free radicals (but they do not belong to this class).

Other sources of free radicals are nitrosamines and unsaturated aldehydes (acrolein), very active and destructive because of their action on cell membranes [10].

Evolutively, nature has selected and included in the composition of the organisms, reactions generating free radicals with multiple roles: functional, intracellular communication, or destructive, cytolitic. If, at molecular level, the main target of the free radicals is the free or protein groups SH, at cellular level, the major goal is cell membranes.

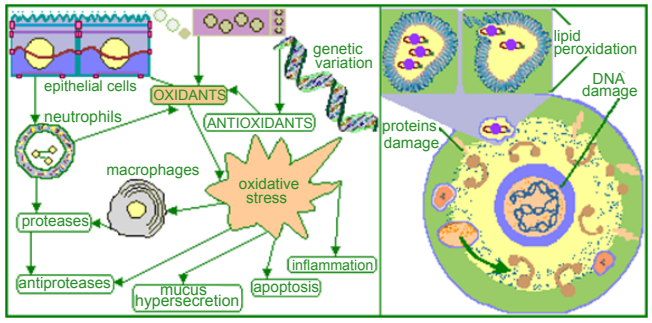

Figure 1: Effects of free radicals.

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Received July 20, 2013; **Accepted** July 22, 2013; **Published** July 22, 2013

Citation: Butnariu M, Samfira I (2013) Aspects Relating of the Oxidative Stress to Living Organisms. J Biodivers Endanger Species 1: e106. doi:10.4172/2332-2543.1000e106

Species/Common Name	Systematic Name/Alternative and Comments
CO/carbon monoxide	carbon monoxide/Oxidomethanediyl (CH_3◦)
CO_2/carbon dioxide	carbon dioxide/dioxidomethane
CO_2^{-}◦/carbon dioxide radical anion	dioxidocarbonate (◦1–)/oxidooxomethyl radical
CO_3^{-}◦/carbonate radical	trioxidocarbonate (◦1–)
H◦/hydrogen atom	monohydrogen (◦)
H_2O/water	dihydrogen monoxide/oxidane
H_2O_2/hydrogen peroxide	dihybridodioxide/dioxidane
H_3C◦	methyl radical
HNO_2	nitrous acid
HNO_3	nitric acid
HO◦/hydroxyl radical	hydridooxygen/oxidanyl
HO_2^{-}/ hydridodioxygen (1–)	dioxidanide, hydrogendioxide (1–)/ hydrogenperoxide (1–)
HO_2◦/hydroperoxyl, but is obsolete	Hydridodioxygen (◦) dioxidonyl/ hydrodioxyl, perhydroxyl
HO_3◦/hydrogen trioxide radical	hydridotrioxygen (◦)/trioxidanyl
HOCO◦	hydroxidooxidocarbon (◦)
$HOCO_2$◦	hydroxidodioxidocarbon (◦)
HOCl/hypochlorous acid	hydrogenoxidochlorate
HOBr/hypobromous acid	hydrogenoxidobromate
HOI/hypoiodous acid	hydrogenoxidoiodate
HOSCN/hypothiocyanous acid	hydrogenoxidothiocyanate
HON_2◦	hydroxidonitrogen(2◦) (triplet)/hydrogen oxidonitrate(2◦)
HOOCO/ (hydridodioxido)	oxidocarbon(◦)
HOONO/peroxynitrous acid	hydrogenoxidoperoxidonitrate/ nitrosodioxidane
$(NO)_2$◦$^{-}$	*bis* (oxidonitrate) (*n* – *n*) (◦1–)
N_2O/nitrous oxide	dinitrogen monoxide
N_2O^{-}◦	oxidodinitrate (◦1–)
N_2O_3	dinitrogen trioxide
N_3◦/azidyl radical	trinitrogen (2*n* – *n*)(◦)
NO◦/nitric oxide, but is obsolete	oxidonitrogen (◦)/oxoazanyl, nitrogen monoxide
NO^{-}(2◦)/nitroxyl	oxidonitrate (2◦1–) (triplet)
NO_2^{-}/nitrite	dioxidonitrate (1–)
NO_2◦/nitrogen dioxide	dioxidonitrogen
NO_2^{2-}◦	dioxidonitrate(◦2–)
NO^{3-}/nitrate	trioxidonitrate (–)
NO_3◦/nitrogen trioxide	trioxidonitrogen (◦)/nitrosoxidanyl
NO_3^{2-}◦	trioxidonitrate (◦2–)
O◦$^{-}$/radical anion of HO◦	oxide (◦1–)/oxidanidyl
O_2◦$^{-}$/superoxide	dioxide (◦1–)/dioxidanidyl
O_2^{+}◦/	dioxygen (◦1+)
O_2^{2}◦/oxygen, usually O written O_2	dioxygen (triplet)/dioxidanediyl
O_3/ozone	trioxygen
O_3◦$^{-}$/ozonide	trioxide (◦1–)/trioxidanidyl
OCl^{-}/hypochlorite	oxidochlorate (1–)
OBr^{-}/hypobromite	oxidobromate (1–)
OI^{-}/hypoiodite	oxidoiodate (1–)
OSCN^{-}/hypothiocyanate	oxidothiocyanate (1–)
OCOO◦$^{-}$	(dioxido) oxidocarbonate (◦1–)
ONOO^{-}/peroxynitrite	oxidoperoxidonitrate (1–)/nitrosodioxidanide
ONOOH/peroxynitrous acid	hydrogen–oxidoperoxinitrate/nitrosodioxidane
ONOO◦	(dioxido)oxidonitrogen (◦)/ nitrosodioxidanyl

Table 1: Formulae and IUPAC Recommended Names of Simple Compounds Containing C, H, and O in Free Radical Biology

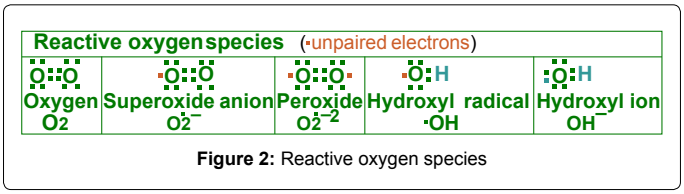

Figure 2: Reactive oxygen species

No.	Species/Abbreviation	Name
	Asc; AscH^{-}; Asc◦$^{-}$	ascorbate, general; ascorbate monoanion; ascorbate radical
	CAT	catalase
	HRP	peroxidase
	GPx	glutathione peroxidase
	GR	glutathione disulfide reductase; often referred to as glutathione reductase
	Grx	glutaredoxin
	GSH	glutathione, not reduced glutathione (a misnomer)
	GST	glutathione S transferase
	LDL	low density lipoprotein
	OH–	hydroxide anion, not to be confused with HO◦
	PUFA	polyunsaturated fatty acid
	RO◦	alkoxyl radical; not alkoxy
	ROO◦	alkyl dioxygen (◦), alkyldioxyl, alkylperoxyl radical; not peroxy
	SOD	superoxide dismutase

*These are commonly used abbreviations. Others appear in the literature.

Table 2: Common Abbreviations.

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