The Oxygen Paradox

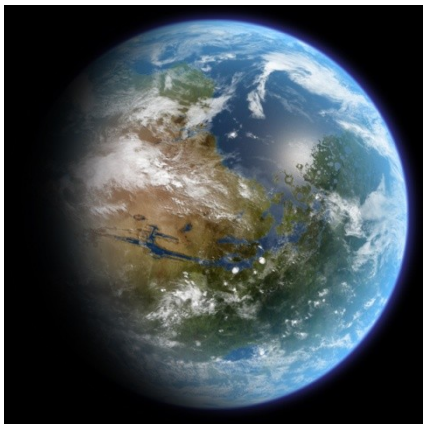
In short: Oxygen is essential for us as life-giving (like in respiration as o2) but it can also be extremely harmful (turning iron to rust, making butter rancid, turning the apple slice brown or milk to go sour). Why is it that (seemingly) the same thing is good and bad at once?

Short background on the different allotropes of oxygen

All major classes of structural molecules in living organisms, such as proteins, carbohydrates, and fats, contain oxygen, as do the major inorganic compounds that comprise animal shells, teeth, and bone. But all these structures are under the constant threat of being “torn apart” by oxygen- *Oxidative stress.*

Thus, oxidative stress can result from increased exposure to oxidants or from decreased protection against oxidants, or even from both problems occurring simultaneously.

Oxidation reactions cause iron to rust, potato chips to spoil, milk to go sour, and oil or meat to turn rancid. *We* would spoil or go rancid, too, except that we have numerous defences to minimize oxidation. Just imagine what happens to butter left out at room temperature for a day or two- why does this not happen in our body?

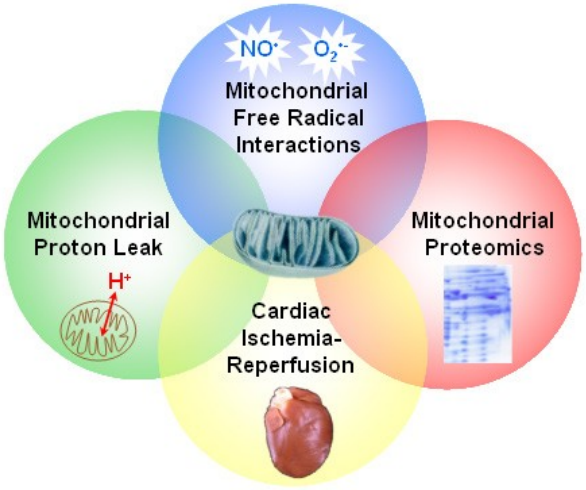


Oxygen in the form of O_2 is produced by cyanobacteria, algae and plants from splitting water during *photosynthesis* and is used in *cellular respiration* for all complex life.

Oxygen is toxic to obligately *anaerobic* organisms, which were the dominant form of early life on Earth until O_2 began to accumulate in the atmosphere 2.5 billion years ago. Another allotrope of oxygen, ozone (O_3), helps protect the biosphere from ultraviolet radiation with the high-altitude ozone layer, but is a pollutant near the surface where it is a by-product of smog.

Compounds

Water (H_2O) is the most familiar oxygen compound. We also breathe it as oxygen gas (O2). But this planet that we inhabit is dominated by oxygen in different forms.



The oxidation state of oxygen is −2 in almost all known compounds of oxygen. But the oxidation state −1 is found in a few compounds such as peroxides. Compounds containing oxygen in other oxidation states are very uncommon: −1/2 (superoxides), −1/3 (ozonides), 0 (elemental, hypofluorous acid), +1/2 (dioxygenyl), +1 (dioxygen difluoride), and +2 (oxygen difluoride). These molecules are unstable and highly reactive. Commonly called: ***free radicals***. They result naturally from cell metabolism and oxygen consumption and are also caused by exposure to toxins, stress and other lifestyle factors. The main source may be a side effect of *eating more than you exercise** (see later)

Oxygen used as treatment

All our tissues require oxygen for survival. Delivery depends on adequate ventilation, gas exchange, and circulatory distribution. Tissue hypoxia occurs within 4 minutes of failure of any of these systems because the oxygen reserves in tissue and lung are relatively small. (That is why we breathe so much.) For doctors it is always important to first and foremost secure enough oxygen to the *hypoxic tissue.* The treatment is often administered according to the physiological and pathological mechanisms. They can be classified into two main groups: those causing arterial hypoxemia (the oxygen rich blood won't reach the tissue) and those causing failure of the oxygen-hemoglobin transport system without arterial hypoxemia (the blood gets there but doesn't carry enough oxygen).

Treatment can be administered through a nasal catheter, mask or in an oxygen chamber. Some places it is administered in a hyperbaric chamber. When administered under pressure one can increase the partial pressure of oxygen considerably. As many as 40 – 200 treatments of 60 -90 minutes at 1,5 – 1.75 ATA breathing pure oxygen under pressure is reckoned as safe (Paul G. Harch, MD), although more research is needed in this area.

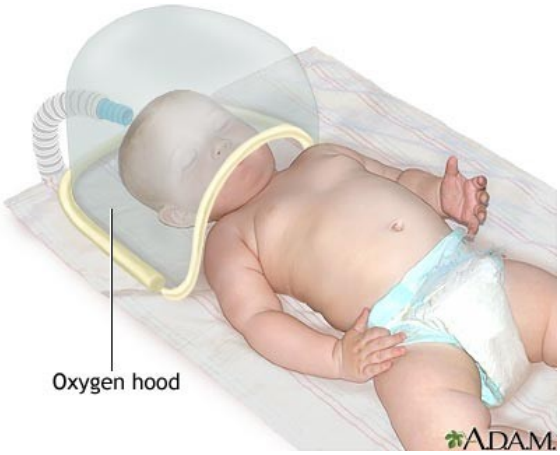
Example1: Oxygen therapy administered as a gas has been shown beneficial in improving pulmonary hemodynamics, exercise capacity, the work of breathing, neuropsychological performance, and mortality in patients with chronic obstructive pulmonary disease.

Example 2: A coronary bypass is preformed if there is a blockage in one of the hearts own blood vessels- the blockage has to be opened so that the oxygenated blood can bring the oxygen to the suffering tissue.

Example3: A SCUBA diver contracts "Bends" and partial paralysis of his legs. This is due to the formation of small bubbles of nitrogen in his spine. Swiftly he should receive hyperbaric treatment, breathing pure oxygen, then the bubbles can dissolve and he might regain control of his legs if administered in time.

Infant retinopathy and risk for ROP

Modest supplemental oxygen given to premature infants with moderate cases of retinopathy of prematurity (ROP), a potentially blinding eye disorder, may not significantly improve ROP, but definitely does not make it worse, according to researchers funded by the Federal government's National Institutes of Health (NIH)-2000. The results mean that clinicians do not have to be as restrictive as they have been when giving supplemental oxygen to infants who have already developed moderate ROP.



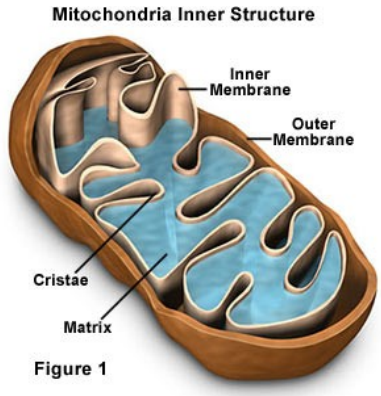


Figure 1

Mitochondrial oxygen radical formation

Mitochondria are considered to be the major site of superoxide and hydrogen peroxide production within eukaryotic cells. The mitochondria produce ATP from carbohydrates, lipids and proteins, using the power in the loose electrons of Oxygen. (60 kg of ATP is produced from ADP in a 70 man every day). Harmful oxygen radicals are formed if the “loose electrons” handled in the Electron transport chain during the formation of ATP from ADP somehow become “renegade”.

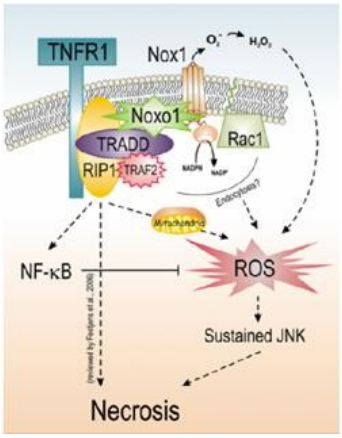
They become harmful only when the body is unable to neutralize their negative impact. If the body cannot respond adequately, free radicals cause damage at the cellular level. Production of free radicals is inevitable, even natural. However, an excess of free radicals causes cellular damage known as oxidative stress. This can results in a host of negative health effects, from advanced aging to depressed immunity or various forms of chronic disease.

The main reason for oxygen radical formation in the mitochondria is the lack of ADP as substrate to form ATP and as a consequence the loose electrons “pile up and get lost”.

In plain this means: ADP +Pi ≠ ATP

If you eat more than you exercise, you won’t have any ADP to phosphorylate and the loose electrons escape and become harmful radicals. (Another reason for engaging in moderate exercise.)

Used as a weapon in immune defence



Phagocytic cells such as neutrophils in the blood stream utilize an NADPH oxidase system to generate superoxide and hydrogen peroxide. The hydrogen peroxide generated is then acted on by a phagocyte enzyme, *myeloperoxidase*, which again reacts with Cl ions to generate the highly reactive hypochlorous acid (HOCl). The myeloperoxidase –H2O2–Cl¡ system is one of the vital “weapons” used by the immune system while killing a wide variety of pathogens.
We actually still don’t quite understand how the body can handle such a powerful oxidant without damaging itself.
This potent oxidant is also part of an inflammatory response that can oxidize many cellular components and can even result in apoptosis or necrosis.

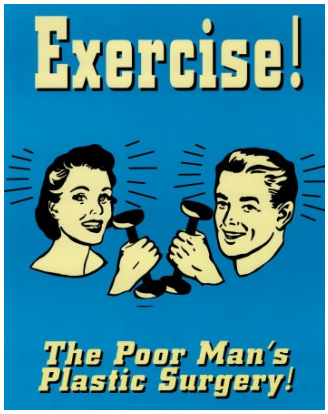
Other ways the body uses oxygen

Signalling: Endothelial cells (cells lining inner surfaces of the body for example: Inner lining of our blood vessels) seem to produce oxidants as a response to activation by several hormones, lipoproteins, and calcium antagonists.

Low oxygen concentration can also activate a specific type of white blood cell PMN

Antioxidants

Antioxidants are dietary substances including some nutrients such as beta carotene, vitamins C and E and selenium. They can prevent damage to your body cells or might possibly even repair damage that has been done.
Antioxidants work by significantly slowing or preventing the oxidative process caused by free radicals that can lead to cell dysfunction and the onset of problems like heart disease and diabetes. Antioxidants may also improve immune function and perhaps lower your risk for infection and cancer.
In your body, the antioxidant process is similar to stopping an apple from browning. Once you cut an apple, it begins to brown, but if you dip it in orange juice, which contains vitamin C, it stays white.
There again, we have been aware of the health benefits of fruit since the days of Hippocrates. (An apple a day keeps the doctor away). Another interesting part of the oxygen paradox is that vitamins alone are not enough to prevent damage. It seems that vitamins in fruit and vegetables work better than when they are administered as a tablet:

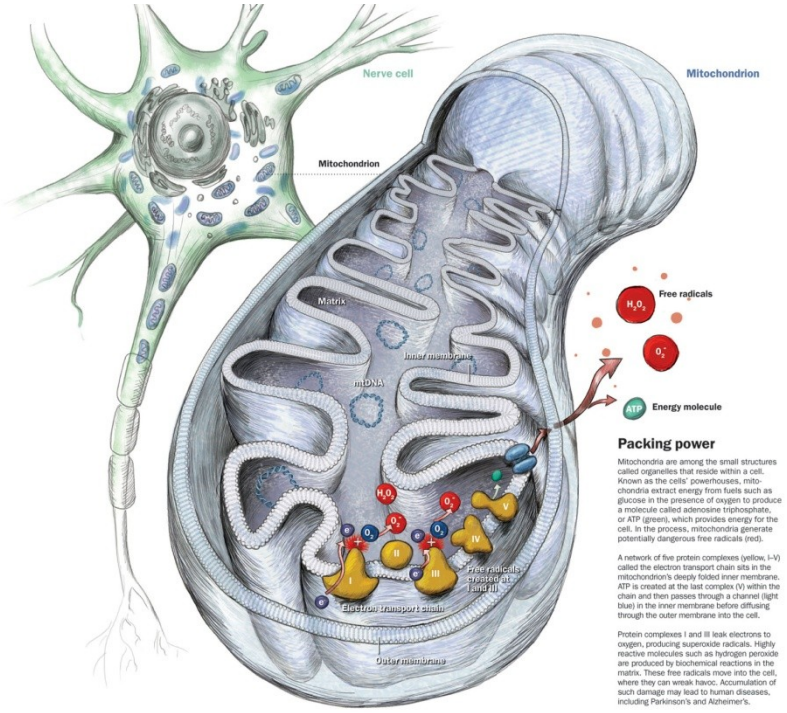


The “Oxygen Paradox” (*2*, *3*) is the concept that oxygen is dangerous to the very life forms for which it has become an
essential component of energy production. Estimates of damage
to cells, based on laboratory experiments, indicate that we
should quickly die from oxidative damage to vital cellular constituents if the antioxidant enzymes and compounds were our only means of protection.

Kelvin J. A. Davies

Lately there has been great interest in colloid particles and minerals as possible “cofactors” to vitamins.

Conclusion



All our tissues are dependent on a steady supply of oxygen. It is a very powerful molecule and is used in the body by the mitochondria to produce ATP. If for some reason the loose electrons obtained from oxygen are not used they can become harmful *oxygen radicals.*

The body has many ways to protect itself, amongst others *antioxidants, minerals and cofactors.*

Oxygen has been used safely as a treatment at an increasing rate since the last 20 years. Normal treatments vary between 60-90 min at 1,5 -1,75 ATA pure O2 and are repeated 40-200 times. (Dr. Neubauer).

Administering low dose O2 to low weight infants is no longer reckoned as a risk of developing damage to the retina of premature infants.

Many researchers point out to the fact that exercise and training can dramatically increase oxidative stress resistance, even during exhaustive exercise.

Diets containing suitable levels of vitamins, minerals, cofactors, and moderate physical exercise may minimize oxidative damage, whereas poorer diets or extreme physical exhaustion may potentiate its harmful effects.
J. A. Davies, Ethel Percy Andrus Gerontology Center, the University of Southern California,

Considerations about oxygen enriched water

Although the oxygen content in the Oxy+ water is surprisingly high then still the amounts of oxygen we are considering are small compared to the amounts used therapeutically in hospitals all over the world or in hyperbaric therapy (HBOT). We do not know enough about how the oxygen is absorbed or where it eventually ends up, but the amount is hardly more than in a single breath.