OPEN ACCESS Freely available online

ISSN: 2167-7662
Bioenergetics: Open Access

Commentary

# Bioenergetic Recovery in Mitochondria after Anoxia and Deoxygenation

**Fuentes Ireyoma***

*Department of Biophysics and Biochemistry, University of Tokyo, Tokyo, Japan*

## DESCRIPTION

Mitochondria play a central role in cellular energy metabolism through oxidative phosphorylation, a process that involves electron transport and ATP production. These organelles are highly responsive to oxygen levels, adapting their function based on oxygen availability. However, extreme fluctuations between oxygen depletion (anoxia) and restoration (reoxygenation) can disrupt mitochondrial bioenergetics. Understanding the effects of anoxia and subsequent reoxygenation on mitochondrial function reveals how cells manage energy under stress and illuminates the mechanisms underlying damage associated with ischemic events.

Mitochondria generate Adenosine triphosphate (ATP) through the Electron Transport Chain (ETC), a series of complexes that transfer electrons from Nicotinamide Adenine Dinucleotide Hydrogen (NADH) and Flavin Adenine Dinucleotide ($FADH_2$) to oxygen. This process creates a proton gradient across the inner mitochondrial membrane, driving ATP synthase and producing ATP. Oxygen availability is essential for the ETC, as it serves as the final electron acceptor. Inadequate oxygen levels impair this process, reducing ATP production and shifting the cell toward anaerobic metabolism.

Anoxia, a state of complete oxygen depletion, severely restricts mitochondrial ATP production, impacting cellular bioenergetics. Upon reoxygenation, mitochondria attempt to resume normal function, though the abrupt restoration of oxygen can lead to oxidative damage, altering mitochondrial structure and energy metabolism.

When oxygen is completely absent, electron transport within the ETC halts, leading to a rapid depletion of the mitochondrial membrane potential and a cessation of ATP production through oxidative phosphorylation. This drop in membrane potential disrupts cellular ion homeostasis, impairing calcium transport and allowing calcium to accumulate within mitochondria. Calcium accumulation triggers Mitochondrial Permeability Transition (MPT), a phenomenon that increases the inner membrane's permeability, ultimately causing mitochondrial swelling and loss of membrane integrity.

Without sufficient ATP, cells rely on glycolysis, an anaerobic pathway that produces small amounts of ATP. However, the dependence on glycolysis is unsustainable in most cells, as it does not meet the energy demands required to maintain cellular functions. The metabolic shift also leads to lactate buildup, reducing cellular pH and causing acidosis. During extended anoxia, mitochondrial enzymes and structural components can be altered or damaged, further impeding bioenergetic recovery after reoxygenation.

The reintroduction of oxygen triggers complex responses in mitochondria. The sudden availability of oxygen allows electron flow to resume within the ETC, reinstating ATP production. However, the ETC's return to function under these conditions is accompanied by a burst of Reactive Oxygen Species (ROS) production, primarily from complexes I and III. As oxygen becomes available, partially reduced oxygen species, including superoxide radicals, are formed due to the delayed reactivation of the ETC and accumulated electrons from anoxia.

Excessive ROS production disrupts cellular homeostasis, damaging mitochondrial DNA, lipids and proteins. ROS generated during reoxygenation can also exacerbate MPT and facilitate the release of cytochrome c from the mitochondria into the cytosol. This release is a key step in apoptotic signaling pathways, where mitochondrial damage ultimately leads to programmed cell death. Therefore, although reoxygenation restores ATP production, it also introduces oxidative stress that may hinder the overall recovery of mitochondrial bioenergetics.

Calcium plays a vital role in mitochondrial bioenergetics, regulating key enzymes involved in the Tricarboxylic Acid (TCA) cycle. Under normal conditions, mitochondria actively regulate calcium levels, maintaining concentrations that support optimal enzyme activity. Upon reoxygenation, calcium overload can trigger prolonged MPT, allowing solutes to enter the mitochondria and causing swelling, depolarization and eventually mitochondrial rupture. These disruptions impair ATP

**Correspondence to:** Fuentes Ireyoma, Department of Biophysics and Biochemistry, University of Tokyo, Tokyo, Japan, E-mail: auentes@ireyoma.jp

**Received:** 27-May-2024, Manuscript No. BEG-24-27422; **Editor assigned:** 29-May-2024, PreQC No. BEG-24-27422 (PQ); **Reviewed:** 12-Jun-2024, QC No. BEG-24-27422; **Revised:** 19-Jun-2024, Manuscript No. BEG-24-27422 (R); **Published:** 26-Jun-2024, DOI: 10.35248/2167-7662.24.12.259

**Citation:** Ireyoma F (2024). Bioenergetic Recovery in Mitochondria after Anoxia and Deoxygenation. J Bio Energetics. 12:259.

synthesis and can lead to cell death. Additionally, calcium overload during reoxygenation activates phospholipases, proteases and nucleases, further damaging mitochondrial membranes and bioenergetic components. The switch from aerobic to anaerobic metabolism during anoxia alters mitochondrial metabolite levels, including NADH, succinate and Adenosine Diphosphate (ADP). With an ETC halt, NADH and succinate accumulate within mitochondria, while ADP levels decline due to lack of ATP synthesis. During reoxygenation, this imbalance is partially responsible for ROS generation. For instance, accumulated succinate undergoes rapid oxidation at complex II, contributing significantly to ROS production upon reoxygenation.

NADH buildup during anoxia also affects redox balance, altering cellular metabolism and ROS sensitivity. As reoxygenation progresses, accumulated NADH is rapidly oxidized, leading to abrupt redox changes that enhance ROS production. Thus, metabolite imbalances during anoxia significantly influence bioenergetic recovery during reoxygenation, impacting mitochondrial function.