

**Nano-scale red blood cell
substitutes to enhance tissue
oxygenation**

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Of the many conditions which can do harm to the human body, one of the most fundamental and fast acting is a lack of perfusion of oxygen to the tissue. Insufficient oxygenation can be caused by problems with oxygen uptake in the lungs, problems with blood flow in the arteries due to obstruction or exsanguinations, or problems with oxygen transportation, as with anemia.

Advances in nanotechnology have suggested a possible treatment for these conditions in the form of microelectromechanical red blood cell analogs called respirocytes. While none have been built yet, they are feasible in theory, and await only manufacturing technology capable of manipulation on such a fine scale.

In selecting a size for the respirocytes, it is necessary to make them large enough to accommodate the mechanical requirements of the device, but small enough to pass through capillaries to the target tissue. The narrowest human capillaries can reach a diameter of 3.7 microns, setting the upper size limit, while the liver and kidneys filter out particles less than 0.1 microns, setting the lower limit. The fact that only the Kupffer cells in the liver are responsible for phagocytosis of particles larger than 0.1 microns encourages larger device diameters. Accounting for power generation, active pumping and communications/processing gives a workable size range from 0.2-2 microns

in diameter. Current studies assume a one micron diameter.

A buckyball (a sphere made of one layer of graphite) of one micron in diameter can safely tolerate an internal pressure of 1000 atmospheres (atm.), giving a compression ratio of ~530 to 1. Given that a resting human uses ~240 cc/minute of oxygen, one liter of oxygen at 1,000 atmospheres could last for 36 hours. In order to avoid immune response from the body and possible toxicity, it may be necessary to “camouflage” the buckyball structure by attaching molecules to the outside surface, either through covalent bonding or polymer tethers.

The respirocytes could be powered by the oxidation of endogenous glucose, producing only heat and water as waste. Theoretical engine efficiency is over 99%, but based on the 68% efficiency of mitochondria, a 50% efficiency is assumed. This would allow the respirocyte to fill its oxygen tank from a fully empty state within ten seconds. The energy generated during the release of gases could be almost entirely recovered, allowing for repeated cycles with little glucose consumption.

Aside from the treatment of trauma, as well as respiratory and circulatory diseases, this technology would allow incredible performance increases in athletics and would even allow humans to remain underwater for up to three hours, then surface for six to twelve minutes before diving again.

Artificial Cells, Blood Substitutes, and Immobilization Biotechnology **26**(1998): 411-430.
<http://www.foresight.org/Nanomedicine/Respirocytes.html>
<http://www.zyvex.com/nanotech/nanotechAndMedicine.html/>