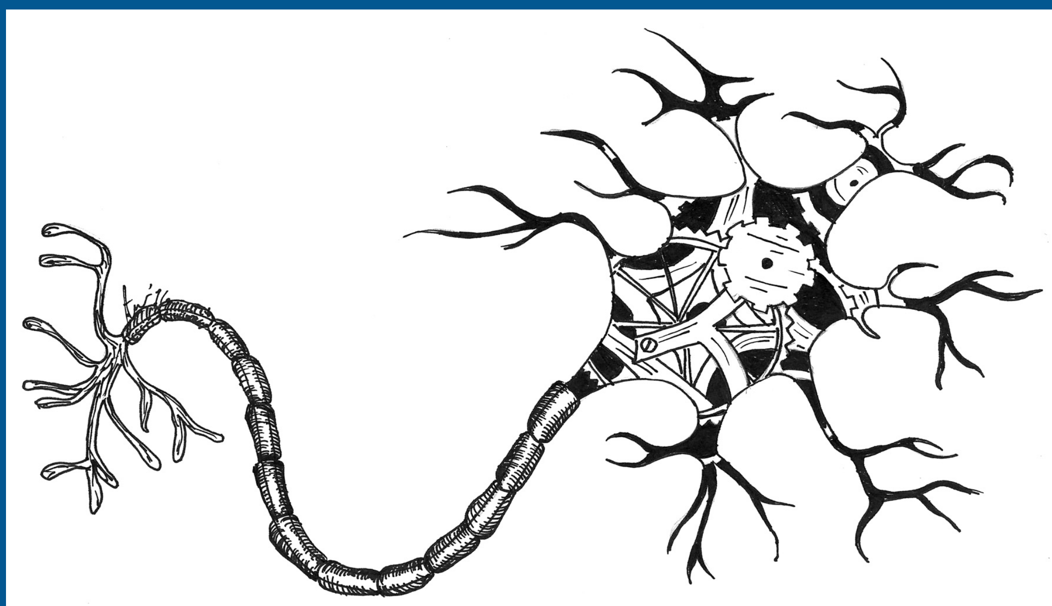
Wheaton Journal of
Neuroscience
Senior Seminar Research

Issue 1, Spring 2016:
"Life 2.0: Blurring the Boundary Between our Tech and Ourselves"
R.L. Morris, Editor. Wheaton College, Norton Massachusetts.



Original artwork by Ashley Wang '16

Respiratory Aids: Breathing On Mars

Laura Wunderl

NEURO 400 / Neuroscience Senior Seminar
Final Research Paper
27 April 2016

Respiratory Aids: Breathing On Mars

Laura Wunderl
Final Research Paper written for
Wheaton Journal of Neuroscience Senior Seminar Research
Neuro 400 / Neuroscience Senior Seminar
Wheaton College, Norton Massachusetts
27 April 2016

Introduction:

It is inevitable that humans will one day travel to, inhabit, and colonize other planets. There are currently missions in the works to travel to and begin life on Mars within the next ten years. Mars One is a nonprofit organization that is proposing to begin a permanent and independent human colony on Mars, with the expected launch date of 2026. Humans are naturally curious and many space travel enthusiasts wish to live on Mars, yet there is another possible significant reason as to why humans will be leaving earth, which Dr. Leila Zucker, one of the final candidates for Mars One, sums up well: "If humans do not expand to other planets, we will stay stagnate. We cannot stay on this planet forever – I would argue, let's go now," ("Meet the Martians", 2016). However, in order for anyone to successfully survive and thrive anywhere, there must be means to acquire food, water, and breathable oxygen. Unfortunately, Mars has an atmosphere that is not suitable for humans. A main reason as to why Mars is not suitable for humans is that there is too much carbon dioxide (95.3%) and not enough oxygen (0.13%) in the atmosphere (Kuroda, et al., 2013). Therefore, when planning on inhabiting Mars, respiratory aids must be considered and created.

Human Biological Respiratory System:

In order to breathe on Mars, a technology must be implemented that affects and ultimately aids the respiratory system. Yet before this technology can be made, the human biological respiratory system must be understood. Humans on Earth breathe in air, which contains oxygen, nitrogen, and small amounts of carbon dioxide, argon, and methane (Kuroda *et al.*, 2013). The human biological respiratory system takes in oxygen from the air to allow for the circulation of oxygenated blood, and also releases waste gases, such as carbon dioxide. As a breath is taken (figure 1), your diaphragm contracts and moves downward, increasing the space available in your chest to allow your lungs to expand and pull air through the nose or mouth. The air moves down your trachea, or windpipe, (figure 1) and reaches your lungs where oxygen will exchange into the blood in capillaries. Hemoglobin allows for oxygen to be carried in the blood, and then oxygen-rich blood will be delivered to the heart through the pulmonary vein. (National Heart, Lung, and Blood Institute, 2012).

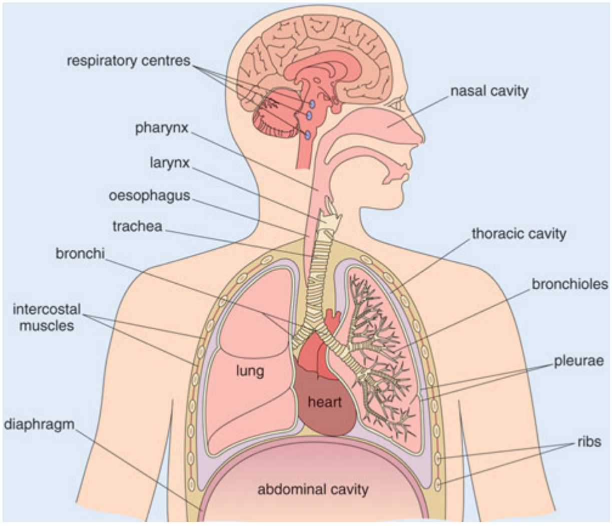


Figure 1. This image shows the structure of the human biological respiratory system and labels the different organs and areas of the body involved in the process of breathing. Areas to highlight are the diaphragm, trachea, lungs, and heart. Figure from *ThingLink*. Respiration, 2015, Human Respiratory System. Retrieved from: http://humananatomybody.info/human-respiratory-system-diagram/.

Artificial Lungs:

However, the human biological system on Earth is not resistant to failure or disease, and therefore there is a need for technology to aid or take over the task of an organ or biological system. Lung disease is quite common among humans on Earth and in hopes of combating the issue of lung failure, artificial lungs have been created. An artificial lung is a small prosthetic device that is implanted inside a human body for respiratory support. The artificial lung oxygenates the blood and removes the excess carbon dioxide from the blood (Nolan, et al., 2011). These are intentional outcomes in hopes of saving the lives of those who need respiratory aids or new lungs. One model of an artificial lung (figure 2) is a bio-inspired microfabricated artificial lung that focuses on gas exchange and works with air as a ventilating gas rather than pure oxygen (Potkay, 2013). The air and blood channels are separated by a gas diffusion membrane that allows for the blood and air to be exchanged, that is, allows for the blood to be oxygenated. This gas diffusion membrane contains small microfluidic channels that are similar in size to blood vessels in biological lungs. In this device (figure 2), blood is injected into the 'blood inlet' and air into the 'air inlet'. Oxygen molecules from the air diffuse across the gas exchange membrane, into the blood, so that the newly oxygenated blood is released through the 'blood outlet' (figure 2). Meanwhile, the carbon dioxide from the blood diffuses across the membrane, into the air, and exits with the air through the 'air outlet' (figure 2) (Potkay, et al., 2011).

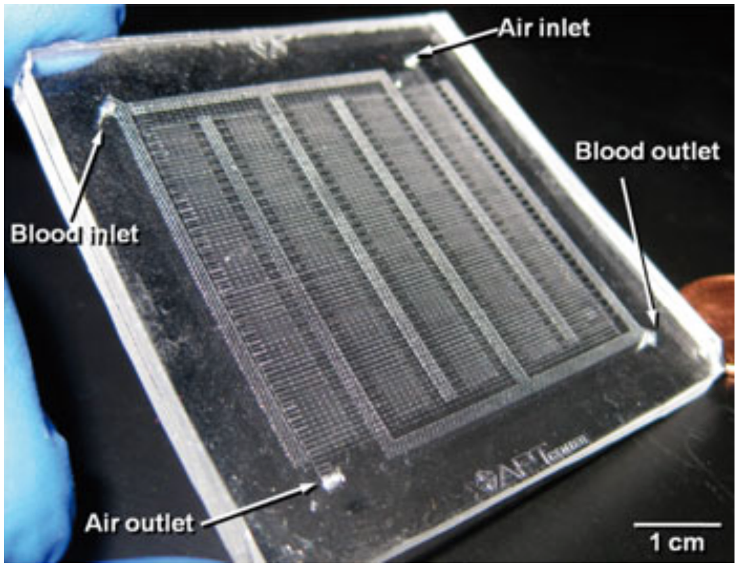


Figure 2. The Bio-inspired Microfabricated Artificial Lung Device. This image shows the small size of the artificial lung that is described and points out where the ‘blood inlet’, ‘blood outlet’, ‘air inlet’ and ‘air outlet’ are. Figure adapted from “Bio-inspired, efficient, artificial lung employing air as the ventilating gas” by J. Potkay, M. Magnetta, A. Vinson, and B. Cmolik, 2011, *Lab on a Chip*, 11, p. 2901-2909. Copyright from Case Western Reserve University. Retrieved from: https://www.researchgate.net/profile/Joseph_Potkay/publication/51491010_Bio-inspired_efficient_artificial_lung_employing_air_as_the_ventilating_gas/links/0a85e52e022196be12000000.pdf

The Mars Oxygen ISRU Experiment:

The Mars Oxygen ISRU Experiment (MOXIE) proposes that by 2020 there will be a space rover fit for Mars that can convert carbon dioxide into oxygen to be used as fuel and breathable air (Extance, 2014). As seen in figure 3, MOXIE will collect carbon dioxide from the Mars atmosphere, compresses it to approximately 1 atmosphere, electrochemically split the CO_2 molecules into CO and O_2, purify the O_2, and then release the gases (Hecht, et al., 2015). The splitting of CO_2 molecules into CO and O_2 is called solid oxide electrolysis and is the main technology that will be used in order to convert carbon dioxide to carbon-neutral fuels. The excess gases will ultimately be vented back out into the atmosphere (Hecht, et al., 2015).

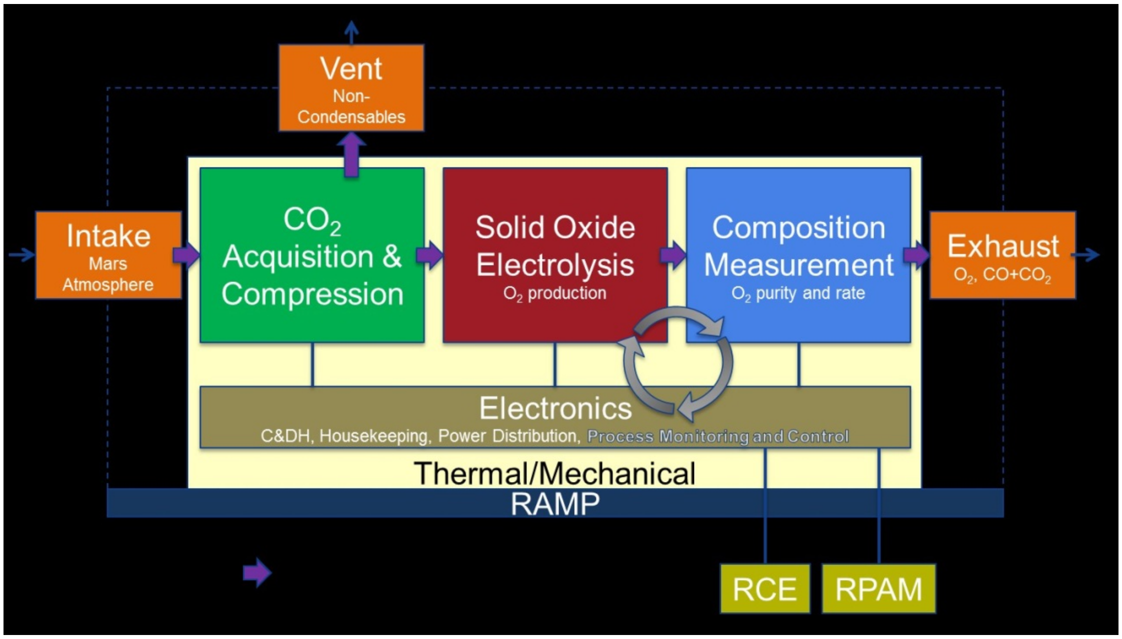


Figure 3. MOXIE Functional Block Diagram. This image represents the mechanism involved in MOXIE in order to take in carbon dioxide from the atmosphere and convert it to oxygen and other gases. Figure adapted from "The Mars oxygen ISRU experiment (MOXIE)" by M. Hecht, D. Rapp, and J. Hoffman, 2015. Copyright 2015 by the M.I.T. Dept. of Aeronautics and Astronautics. Retrieved from: http://mars.nasa.gov/mars2020/mission/science/for-scientists/instruments/moxie/

Neurobiology/Technology Three-Part Hybrid Proposal:

I propose a three-part merger: the human biological respiratory system, the artificial lung, and the use of MOXIE technology to form an artificial lung that can take in carbon dioxide from the atmosphere on Mars and convert it to oxygen in order to oxygenate the blood. MOXIE technology will one day be able to be implemented into an artificial lung, so that the artificial lung can directly take in carbon dioxide and convert it to breathable oxygen and breath out the excess carbon dioxide. The air that we currently inhale has small amounts of carbon dioxide; carbon dioxide becomes problematic when there is high concentration of carbon dioxide in the bloodstream and hardly any oxygen in the blood. However, the model I am proposing will convert the carbon dioxide into oxygen and rid the blood of its excess carbon dioxide before the carbon dioxide can enter the bloodstream. These technologies will be merged together to produce an artificial lung to be permanently implanted into a human. We will ultimately be able to breathe in carbon dioxide, convert it to oxygen, and breathe back out carbon dioxide.

Future Predictions:

Ray Kurzweil firmly believes that human progress is exponential and that this exponential growth at first is quite slow and not as evident, but then it becomes rapid and extremely profound (Kurzweil, 2005). Since the rate of transformation of technology is accelerating so rapidly and the future will hold even more rapid changes, the future will be a surprise to us. We may not know how it would be feasible to have an implantable lung that allows us to take in carbon dioxide and convert it to breathable oxygen today, however with the constant advancement of technology and the possibility to learn from previous technologies, I believe that the model will one day be improved on and implemented in all humans living on Mars. Right now, MOXIE is very large, yet in the coming years, the technology will become smaller and smaller until ultimately it will be small enough to be implemented into an artificial lung. MOXIE will likely first be used under a dome in a human settlement on Mars, then inside a spacesuit, then in a smaller mask, until it will be small enough to successfully fit in an artificial lung. This three-way merger and artificial lung will become a permanent fixture in the human biological system that is irreversible and available to everyone. This hybrid system will create a merger between human biology and technology in order to enhance the human race and keep us alive on otherwise inhospitable planets.

I have abided by the Wheaton College Honor Code in this work.

-Laura Wunderl

References:

Extance, A. (2014). Next Mars rover will make oxygen from CO_2. *Scientific American*.

Flam, F. (2015). Meet the martians. *Pyschology* Today, July/August, 30-32.

Hecht, M., Rapp, D., & Hoffman, J. (2015). The Mars oxygen ISRU experiment (MOXIE). M.I.T. Dept. of Aeronautics and Astronautics.

Respiration. (2015). Human Respiratory System Diagram. Copyright ThingLink. Retrieved from: http://humananatomybody.info/human-respiratory-system-diagram/.

Kuroda, T., Medvedev, A., Kasaba, Y., & Hartogh, P. (2013). Carbon dioxide ice clouds, snowfalls, and baroclinic waves in the northern winter polar atmosphere of Mars. *Geological Research Letter, Agu Journal, 40*, 8, 1484-1488.

Kurzweil, R. (2005). “The Singularity is Near”. The Penguin Group, New York, New York. Print.

National Heart, Lung, and Blood Institute. (2012). What happens when you breath? *National Institute of Health.*

Nolan, H., Wang, D., & Zwischenberger, J. (2011). Artificial lung basics. *Organogenesis, 7*(1), 23-27.

Potkay, J. (2013). A simple, closed-form, mathematical model for gas exchange in microchannel artificial lungs. *Biomed Microdevices, 15*, 397-406.

Potkay, J., Magnetta, M., Vinson, A., & Cmolik, B. (2011). Bio-inspired, efficient, artificial lung employing air as the ventilating gas. *Lab on a Chip, 11*, 2901-2909.