

The Continuing Adventures of Mr. O'Too

When last we heard from Mr. O'Too, he was traveling from the lungs to the leg muscles of an athlete. The unit one observation was a very general overview of the basic path an oxygen molecule travels through the body in order to reach a particular destination cell. In the continuing adventures of Mr. O'Too, we'll take a deeper look at his travels, specifically exploring how he manages to get into the lungs in the first place and once there, how he is able to leap from thin air into the blood tissue of our athlete, exchanging places with his very distant cousins, the Cee O'Toos (a process known as external respiration).

In the short amount of time we've taken thus far to introduce these two important questions, the respiratory center in our athlete's brain senses a need for oxygen and issues motor impulses signaling that it is time to take a breath (when at rest, this happens around 16 times a minute). These impulses travel along the phrenic and intercostal nerves and are ultimately received by the diaphragm and the intercostal muscles in the rib cage, all of which contract simultaneously in response, causing the thoracic cavity to enlarge. This mechanical action results in a difference of pressure between the lungs and the outside air, thereby stretching the lungs and pulling air in (along with Mr. O'Too) from the outside until the pressures are again equal (**see respiration image**).

It's a fairly quick trip for Mr. O'Too, but a few things happen along the way. First, as the air passes through the oral and/or nasal cavities, it is filtered, warmed, and moistened (eventually to saturation). Tissue cells containing cilia (hairlike structures) and excreting mucous essentially "scrub" the air as far as the bronchi, removing unwanted particles from it. The particles stick in the mucous and the mucous is moved along by the cilia until it reaches the trachea, where it may be swallowed. Further warming and cleansing takes place via protective cells within the lung tissue. Second, the air moving in (and subsequently moving out) is branched through a series of passages, each narrower than the one before (bronchus,

bronchioles, respiratory bronchioles, alveolar ducts, and alveoli). This slows down and regulates the movement of air moving into and out of the lung's gas exchange area, so there is always a constant mingling of gas molecules moving in and out by the time air reaches this deeper, inner level of the lungs where the composition of air is very different from the outside atmosphere.

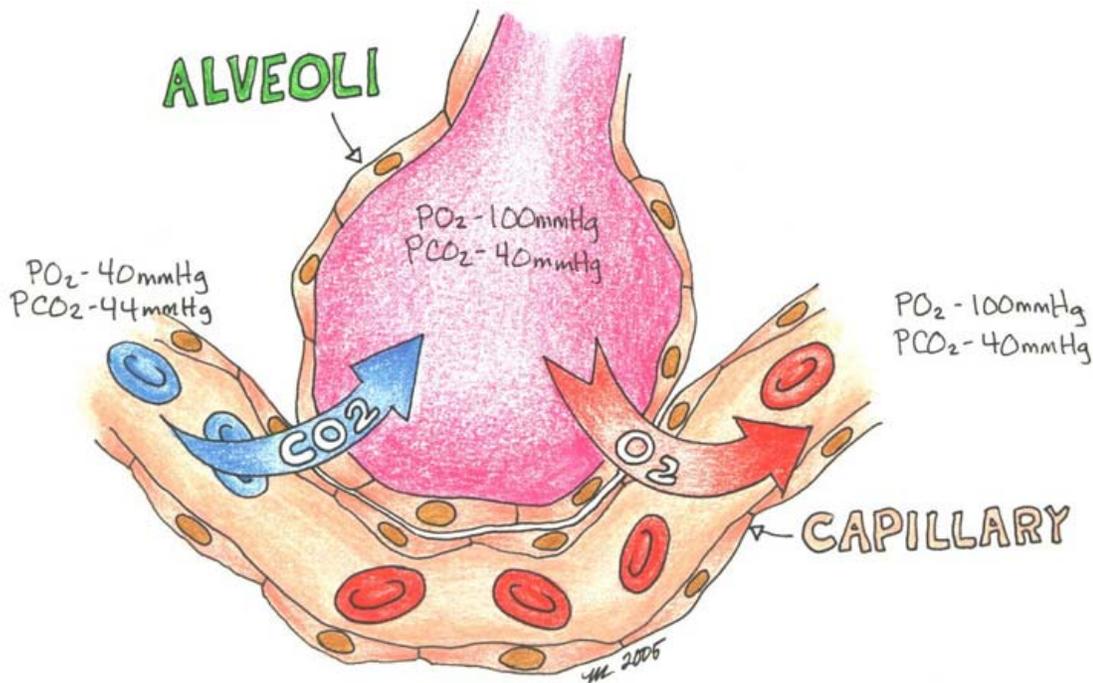
If we were to take all 300,000+ alveoli (tiny little 'bubbles' about 0.3mm in diameter) and lay out the total gas exchange area of the lungs, we would see there is approximately 70 – 80 square meters of "breathing room," allowing for about 5.25 liters of air ventilation each minute! In a similar fashion, the lungs have perhaps one of the densest capillary networks in the body – the alveoli are surrounded by capillaries. As blood is branched out to this level in the alveoli-capillary beds it has slowed dramatically, allowing plenty of time for gas exchange.

Since our athlete cannot hold his breath for very long, he has breathed numerous times while you have been reading, and Mr. O'Too is already long gone. He's bounced his way through some 25 passages, finally arriving in an alveoli with his close relatives. He has already mysteriously exchanged places across this surface area with his distant cousins (the Cee O'Toos), and has probably expended himself in some body cell, no doubt participating in the production of ATP. We'll have to go on without him and just stop in the alveoli long enough to understand the magic that takes place. Exactly how does a molecule like O'Too get across two cell membranes and a thin layer of fluid between, to end up in the bloodstream? And how do his distant cousins perform the same trick at the same time, to get out of the blood stream and eventually back into the atmosphere outside the lungs?

Diffusion is the process of gas exchange across semi-permeable membranes, but is only possible when differences of pressure exist on either side of the membranes. By the time Mr. O'Too has arrived in the alveoli, there is only a single cell wall separating him from a single cell wall in the capillary. Between the two walls is a very thin layer of fluid for protection and elasticity. Blood returning from the body cells contains a low concentration of oxygen relative to that residing in the alveoli (40mmHg to 100mmHg), and a higher concentration of CO₂

(44mmHg to 40mmHg). Because the cell membranes are semi-permeable (which means some things small enough are allowed to pass through if there is a difference in pressure), CO₂ moves from the capillary to the alveoli across the membranes until the pressures are equalized between blood and alveoli (40mmHg to 40mmHg). In the same fashion, Mr. O'Too (and all his O'Too relatives) move through the membranes into the capillary, again until the two pressures are equalized (100mmHg to 100mmHg). Since the air composition is constant and the velocity of blood very slow, diffusion is independent of (and not influenced by) the athlete breathing in and out, and again, there is plenty of time for the gas exchange to take place (see Figure 2).

We've explored the mechanical action of taking air into the lungs and the action of diffusion and gas exchange between alveoli and capillary. Although we have not had the athlete hold his breath all this time (he would have been forced long ago to take an involuntary



breath), we have not looked at how the lungs expel air back out into the atmosphere. Briefly, another set of impulses are sent to the intercostal muscles and the diaphragm, this time with the

message to “breathe out” or relax. The muscles respond by relaxing and the same dynamic of pressure differential that expanded the thoracic cavity and lungs now permits them to return to their “at rest” size and shape (**see respiration image**)¹.

¹ Expired air composition is 16 percent oxygen, 4 percent carbon dioxide, and the same 78% nitrogen and other gases (which are not used in the body and therefore not diffused, since their concentrations remain the same whether in the body or out of it).

Bibliography

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