

Letter from the Editor: Breathtaking



This Letter from the Editor is about the variations in the way different animals respire. Assuming the reader already understands the human system, it focuses on other species. But first I want to mention another lung-related curiosity: haggis. For those unfamiliar with this term, it refers to the national dish of Scotland, which is unavailable in the United States because one of its main ingredients is sheep lung. Since 1971, the U.S. has banned the sale of Scottish haggis as “livestock lungs shall not be saved for human food”.¹ Stomach fluids can make their way into the lungs of an animal during the slaughtering process, making lungs unsafe for human consumption. This ban does not apply to pet food. In addition to sheep’s lungs, haggis includes sheep’s heart and liver, onion, oatmeal, suet, and spices. These ingredients are minced together and boiled inside a sheep’s stomach for several hours.

Back to variations in animal respiration. Respiration is not just the mechanical process of breathing – the transport of oxygen from the outside air to the cells within tissues, and the transport of carbon dioxide in the opposite direction. It is also the metabolic process by which oxygen reacts with glucose to yield water, carbon dioxide, and energy. The simplest form of gas exchange, diffusion, occurs in small multicellular organisms such as flatworms. In these organisms less than one millimeter in diameter, every cell in the body is close to the external environment. Their cells are kept moist so that gases diffuse quickly via direct diffusion. Their flat shape increases the surface area for diffusion, ensuring that each cell within the body is close to the outer membrane surface and has access to oxygen.² If the flatworm had a cylindrical body, then the cells in the center would not be able to get oxygen.

Organisms that live in water take up dissolved oxygen from water through gills, which are thin tissue filaments that are highly branched and folded. When water passes over the gills, the dissolved oxygen in the water rapidly diffuses across the gills into the bloodstream. The circulatory system then carries the oxygenated blood to the other parts of the body.² Insect respiration is independent of its circulatory system. Insects have body openings called spiracles that connect to a tubular tracheal network that transports oxygen and carbon dioxide. Birds have a unique system of respiration that

involves lungs as well as anterior and posterior air sacs. The flow of air is opposite from that of blood flow, resulting in very efficient gas exchange. A complete avian respiratory cycle involves two inspirations and two expirations (unlike mammals which involve only one of each). Whereas mammals have lungs in which air is inspired and then exhaled in a bidirectional manner, the bird’s system is unidirectional and equivalent to having three lungs. Air is shifted around the anterior and posterior air sacs and the lungs during inhalation and exhalation.³ A hummingbird’s gas exchange is so efficient that when migrating between California and South America, it will fly for 24 hours at a stretch, all the while beating its wings thousands of times each minute.⁴ It would take a human athlete working for a week at peak capacity without a moment’s break to match this performance.

In addition to differences in respiratory mechanics, the physics of respiration also vary tremendously among species. For example, when dolphins inhale, they exchange up to 80% of the contents of their lungs (compared with 17% in humans), allowing them to hold their breath for up to 7 minutes.⁵ Walruses and other marine mammals can store large amounts of oxygen in their blood and muscle thanks to enhanced levels of hemoglobin and myoglobin.⁶

Through evolution, racehorses have developed enlarged hearts with a capacity to pump more blood around the body. But the lungs themselves do not grow or improve with exercise. The cardiac output is higher, but the lungs aren’t matched to the higher flow rate. Because of this, nearly all thoroughbreds bleed into their lungs after a race, resulting from the great volumes of blood coursing through the lungs, putting pressure on the lung capillaries and causing them to burst.⁴

A cheetah can run at a pace of 70 miles per hour, but for only a few seconds before collapsing. A Wyoming pronghorn antelope, perhaps the greatest athlete alive, can run at a maximum speed of 60 miles per hour for an hour.⁴ Compared with goats, the pronghorns’ lungs have five times the surface area, and thus five times the opportunity to pick up oxygen. Their hearts are three times as big and thus can pump three times the volume of blood through the body. Their tracheas are much wider, their muscle mass is greater, and their concentrations of hemoglobin in the blood and mitochondria in

the muscle cells are much denser. But they pay a price for their extraordinary design. They have virtually no body fat and in a bad Wyoming winter, many of them die of starvation.⁴

Learning about the variations in respiration among different species gives me a greater appreciation for the mechanics and physics of the human system. The human is a highly evolved being, but their lungs remain limited in many ways. I hope you enjoy reading the excellent reviews of diffuse lung diseases prepared by the authors of this issue. I thank Dr. Pipavath for lending his talents as guest editor.

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