# A Technical Description of Avian Respiration

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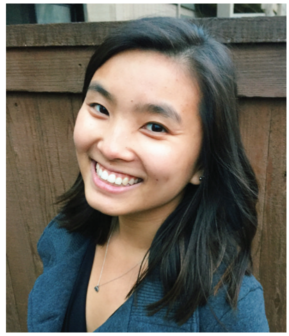


*Writer's Comment: When I entered UC Davis as a Wildlife, Fish, and Conservation major, I was convinced I wanted to study mammals. However, since taking a class about the biological conservation of wild birds, I have become fascinated with avian ecology. Thus, such a topic seemed fitting for this technical description assignment because we were encouraged to pick a subject that interested us. Avian respiration in particular came to mind because of its unique characteristics and the way in which it integrates avian ecology, physiology, and morphology. In this assignment, Dr. Matt Oliver wanted us to focus on utilizing four characteristics of good scientific writing: brevity, clarity, specificity, and organization. To focus on these characteristics, I tried to ensure the description was informative and relevant without being too overwhelming by including numerous images to clarify my description and "Compare and Contrast" sections to put the description into context. Thank you for reading my technical description; I hope that it stimulates an interest in birds, too or in the very least deepens your appreciation for the unique way in which they breathe.*

*Instructor's Comment: Michelle's passion for wildlife conservation gives her writing life and energy. This energy makes her work a delight to read and results in my always learning from her. Teaching technical concepts to an audience of nonexperts requires thoughtful document design, appropriate graphics, and clear, concise, and specific language. Look for examples of these qualities as you read about the avian respiratory system. Michelle plans to pursue graduate work to* *improve understanding about anthropogenic impacts on avian ecology in order to better inform conservation policy. This is what the bulk of her research focused on in 104E. When I think of the challenges of educating the public regarding this important and complex relationship, I know that Michelle's strong technical communication skills will have an impact far beyond their role in her academic assignments. It is rare that technical writing is both informative and a joy to read. Michelle's technical description achieves these qualities.*

*—Matt Oliver, University Writing Program*

## Avian Respiration

Members of Class Aves must possess efficient respiratory systems because they require two to five times more oxygen than other animals to maintain their relatively high metabolic rate and to fly. Three major factors characterize avian respiration and allow for increased efficiency of oxygen uptake: the structure of the avian respiratory system, unidirectional flow of oxygenated air through the lung, and counter-current gas exchange.

## Structure of the avian respiratory system

The avian respiratory system consists of one trachea, one syrinx, nine air sacs, and two lungs. Air sacs fill all residual space within the bird and lay symmetrically on either side; there are two cervical sacs, two anterior thoracic sacs, two posterior thoracic sacs, and two abdominal sacs (Figure 1). The final air sac, the interclavicular sac, integrates itself into the bird's humerus.

> *Reminder:*
> *The trachea is a membrane tube reinforced with cartilage rings and acts as a windpipe. The syrinx is the avian voice organ, and bronchi are the main passageway into the lungs.*

Birds do not have diaphragms or flexible lungs; instead, they rely on these air sacs and air pressure to move air through their rigid lungs. These flexible air sacs expand and contract, acting like bellows for the lungs. Because the lungs do not have to expand, their membranes can be thinner. Thin membranes mean decreased thickness of the blood-gas barrier over which gas must diffuse; thin barriers mean increased efficiency of gas exchange. For birds, the mean thickness of this barrier is anywhere from one-half to one-ninth the mean width of barriers found in other groups of animals.

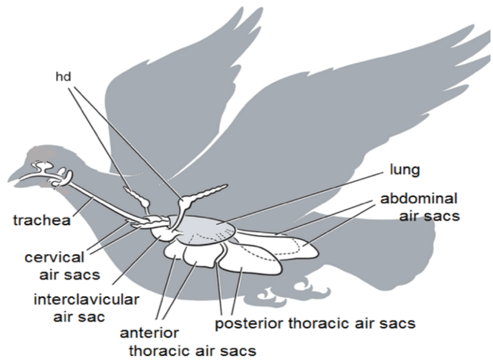



*Figure 1. Side view of the nine air sacs.*

A three-tiered bronchial system makes up the lung. The trachea feeds into the lung via the first tier of bronchi, the mesobronchi. These extend posteriorly and end at the abdominal air sacs (Figure 2). The mesobronchi split into the second tier of bronchi, the dorsobronchi and ventrobronchi. Finally, parabronchi branch off the dorsobronchi and ventrobronchi, connecting the two and forming the third tier of the avian lung. The parabronchial lumen extends to form air capillaries that intertwine with blood capillaries. Sites where the two kinds of capillaries come into contact mark the site of gas exchange. This surface area available for gas exchange is relatively high because of how the air and blood capillaries are arranged; it is about 15% higher in birds relative to mammals of a similar size, which increases the efficiency of gas exchange.

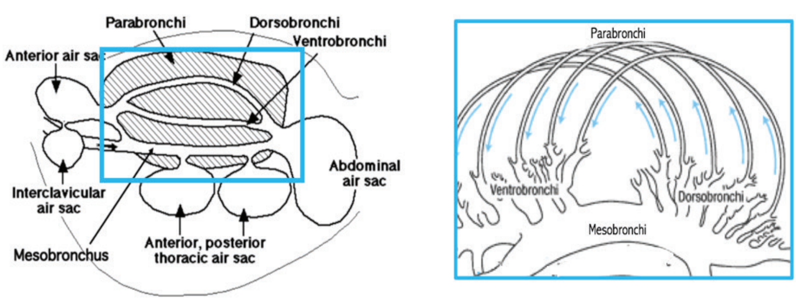



*Figure 2. (Left) Side view of the lungs and their connections to the air sacs. The shaded region represents the parabronchi. (Right) Detailed view showing the three tiers of bronchi: mesobronchi, ventrobronchi/dorsobronchi, and parabronchi.*

## Unidirectional air flow

Oxygenated air replenishes itself continuously via unidirectional flow because of the air sacs; air sacs permit the intake of air when a bird inhales and exhales, maintaining constant pressure within the lungs. This unidirectional flow is generated in two distinct cycles outlined below (Figure 3).

> *<u>Compare & Contrast:</u>*
> *Mammals breathe via bidirectional flow, meaning that air moves back and forth in the lungs. This mixes fresh air with "old" air that contains less oxygen, meaning less oxygen is available overall for diffusion into the blood.*

1. *Inspiration:*

   Fresh air moves through the trachea, the syrinx, the mesobronchus, and back into the posterior thoracic and abdominal air sacs.

   *Expiration:*

   Air flows from these air sacs and into the lungs, where gas exchange occurs.

2. *Inspiration:*

   Deoxygenated air moves out of the lungs and into the cervical, interclavicular, and anterior thoracic air sacs.

   *Expiration:*

   Air leaves the body back through the trachea.

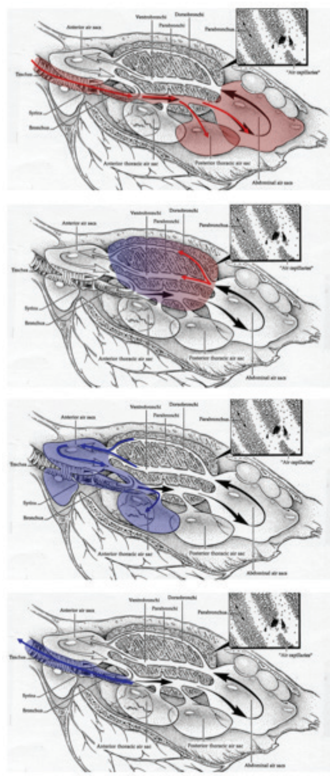


*Figure 3. Cycles of respiration.*

Thus, during inspiration and expiration, two processes occur during each step simultaneously. During inspiration, oxygenated air flows into air sacs from the trachea and deoxygenated air flows into air sacs from the lungs. During expiration, air moves from posteriorly located air sacs into the lungs, while air moves from anteriorly located air sacs out of the trachea.

The avian skeleton also aids in these cycles to adjust air sac size and manipulate air flow (Figure 4). During inspiration, the bird lowers its sternum and expands the thoracic air sacs, which decreases air pressure and stimulates air flow into the air sacs. The opposite occurs during expiration to stimulate air flow out of the air sacs. During flight, the furcula also aids in respiration by changing the size of the interclavicular air sac. The downstroke of a bird's wings pushes the furcula outward, which expands the interclavicular air sac. This causes the air sac to draw air from the lungs. The upstroke compresses the furcula and the interclavicular air sac, forcing air into the trachea for expiration.

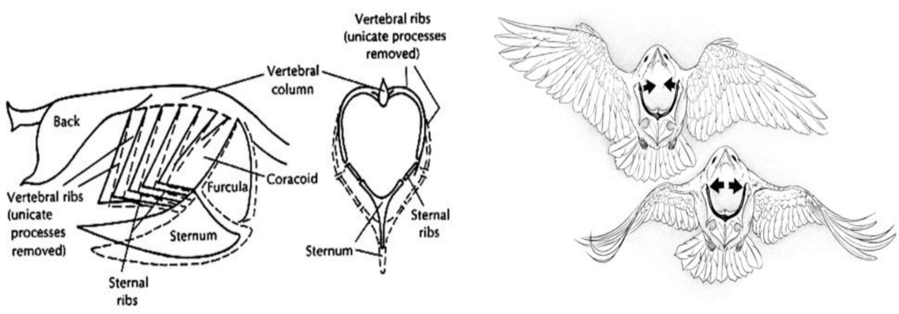



*Figure 4. (Left) Movement of the sternum as the bird breathes. Dotted lines indicate lowering of the sternum. (Right) Compression and expansion of the furcula during the upstroke and downstroke.*

## Counter-current gas exchange

When air moves through the lungs, it moves through the parabronchi's air capillaries. The orientation of the air capillaries relative to the blood capillaries allows blood and air to flow in opposite directions, creating a counter-current system (Figure 5).

This system enables birds to extract 100% of the oxygen from the air they breathe in. As fresh air saturated with oxygen moves through the air capillaries and oxygen depleted blood moves through the blood capillaries, an oxygen concentration gradient between the two capillaries forms. These gradients form at multiple points along the two capillaries, increasing the number of sites passive diffusion can occur.

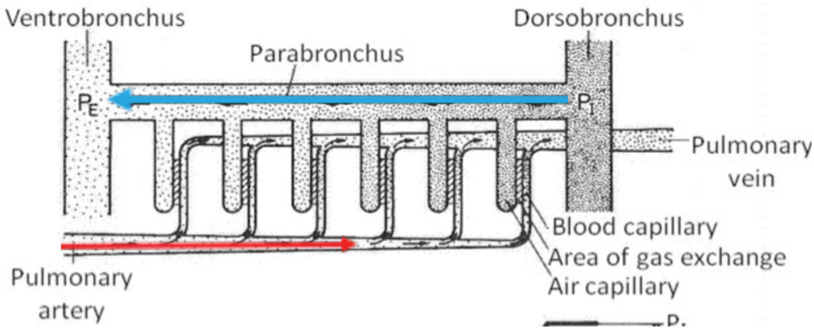
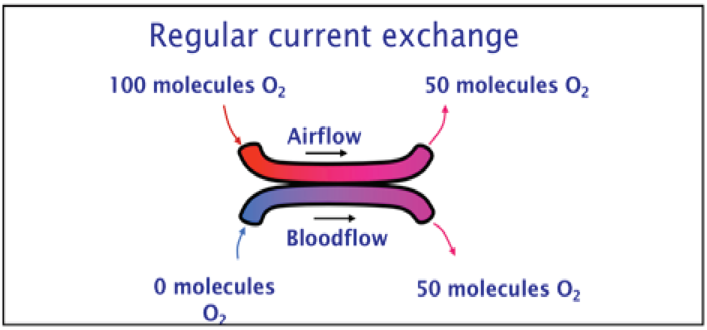



*Figure 5. Orientation of the air capillaries relative to blood capillaries. Bottom arrow indicates direction of blood flow; top arrow indicates direction of air flow.*

As oxygen diffuses down its gradient from the air capillaries into the blood capillaries, the partial pressure of oxygen along the air capillaries lowers and the partial pressure of oxygen along the blood capillaries leaving the lungs increases. By the time the blood capillaries leave the lungs, they have absorbed all of the oxygen from the air capillaries (Figure 6).

*Compare & Contrast (Figure 6):*

*Parallel current exchange (what occurs in mammals) results in the blood capillaries only absorbing half of the oxygen from the air capillaries. This occurs because the concentration of oxygen equilibrates in both capillaries, removing any gradient; this removes any potential for oxygen to passively diffuse into the blood capillaries.*



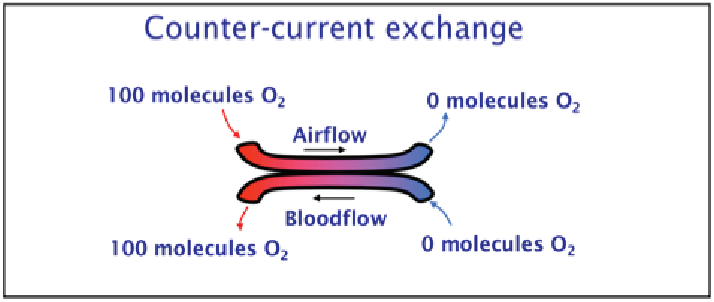




*Figure 6. (Top) Regular (parallel) current exchange. (Bottom) Counter-current exchange. In both images, red arrows indicate oxygenated blood, while blue arrows represent deoxygenated blood.*

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