**Active Learning Exercise 14.1**

to accompany

*Vertebrate Life*, Tenth Edition

Pough • Janis

**The Origin of Bird Breath**

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**Sources:** This activity is based on the following papers:

Farmer, C. G. 2010. The Provenance of Alveolar and Parabronchial Lungs: Insights from Paleoecology and Discovery of Cardiogenic, Unidirectional Airflow in the American Alligator (*Alligator mississippiensis*). *Physiological and Biochemical Zoology* 83: 561–575.

<https://www.journals.uchicago.edu/doi/abs/10.1086/605335>

Farmer, C. G. 2015. Similarity of Crocodilian and Avian Lungs Indicates Unidirectional Flow Is Ancestral for Archosaurs. *Integrative and Comparative Biology* 55: 962–971.

<https://academic.oup.com/icb/article/55/6/962/2363644>

Milius, S. 2015. Slow, cold reptiles may breathe like energetic birds. *Science News* Oct. 31: 22–25.

<https://www.sciencenews.org/article/slow-cold-reptiles-may-breathe-energetic-birds>

Schachner, E. R, R. L. Cieri, J. P. Butler, C. G. Farmer. 2014. Unidirectional pulmonary airflow patterns in the savannah monitor lizard. *Nature* 506: 367–370.

<https://www.nature.com/articles/nature12871>

**Activity**

The textbook describes the lungs of birds and synapsids (mammals). It turns out that while avian and mammal heart structure is quite similar, avian and mammal lungs are quite different, and the avian design is more efficient at extracting oxygen from air.

1. In general, describe how they are different.

2. Do you think birds might need more efficient lungs than mammals? Why or why not?

3. There has been some interesting work on the evolutionary history of this difference between avian and mammal lungs. Based on your ideas in the previous question, where/when do you predict that the avian-style, one-way lungs showed up?

4. Internal organ structure tends not to fossilize, so how could you test your hypothesis? Would looking at other lungs help? Which ones? Explain you answer.

Evolutionary physiologist Colleen Farmer has looked at these questions and collected some interesting data. Review Figure 1B from Farmer (2015), showing heartbeat (ECG) and movement of air in the cervical ventral bronchus (CVB) of a crocodilian. That is a structure similar to the cervical air sac associated with avian lung structure.

5. In general, what do you think is going on in the cardiorespiratory system of the alligator represented by this figure over this time, according to these data?

6. Would it surprise you to learn that he’s actually holding his breath? What do you think is making it look like he’s breathing?

7. How might this movement of air be adaptive for the alligator? (Consider how an alligator might spend the day.)

Now look at the phylogeny (figure titled “Breathers’ family tree” from Milius (2015).

8. Explain why alligators and birds might have similar lungs evolutionarily.

So this means the common ancestor to birds and alligators had the faveolar-style lungs, right? End of story? Look at the phylogeny again.

Emma Schachner and colleagues (including Colleen Farmer) looked at monitor lizards next.

9. Why? What question were they trying to answer?

Here’s what they found: Look at Figure 1 from Schachner (2014) showing the pulmonary anatomy and airflow patterns of *Varanus exanthematicus*.

10. Look at that first phylogeny again. What does this suggest about when the original faveolar-style lung showed up?

11. Now look at your answer to Question 2. Does that apply to lizards and crocodilians?

Plus, consider that bats get enough energy to fly with alveolar mammal lungs. The birds and crocodilians and lizards use their lung efficiency in different ways and it’s unlikely that different selective pressures would have led to the same structural solution, so the structure must have been there first. So what else might have selected for the shift to the more efficient structure we see in several groups of sauropsids?

Look at Figure 4 from Farmer (2010) showing the percentage of Earth’s atmosphere composed of oxygen as a function of millions of years before the present and in relation to the radiation of tetrapods.

12. What do you notice about oxygen levels compared to the present, which is about 22%?

Review the bottom panel from the same figure (Farmer 2010). It shows the entire radiation of the Triassic archosaurs. Note the oxygen levels at the time that happened.

13. Does this provide a possible answer to the previous question?

Colleen Farmer thinks so. But there are more extant animals to look at, more fossils to find, and potential molecular studies to do. The story continues...