BIRDS · ANATOMY & PHYSIOLOGY

How Birds Breathe

Air sacs, one-way airflow and super-charged haemoglobin — the respiratory system that lets a vulture soar higher than Everest.

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> We breathe like bellows: air goes in and comes back out the same way. Birds do something very different. Their lungs are ventilated by a set of air sacs, air moves through the lungs in one direction only, and a single breath stays inside the bird for two full breathing cycles.

01 How is it different from us?

AIR SACS

Lungs plus bellows

Birds have lungs *and* a system of thin-walled **air sacs** — usually nine. The sacs act as bellows that pump air; they take no direct part in gas exchange.

ONE-WAY FLOW

Fresh air, one direction

Air moves through the lungs in **one direction**, through tiny tubes called **parabronchi**. In mammals, air flows in and out of the same passages.

TWO CYCLES

One breath, two rounds

A single breath stays in the bird's respiratory system for **two cycles** of inhalation and exhalation before it leaves.

CROSS-CURRENT

Air and blood at right angles

Air and blood travel at right angles to each other in the lung — a **cross-current** arrangement that makes oxygen uptake very efficient.

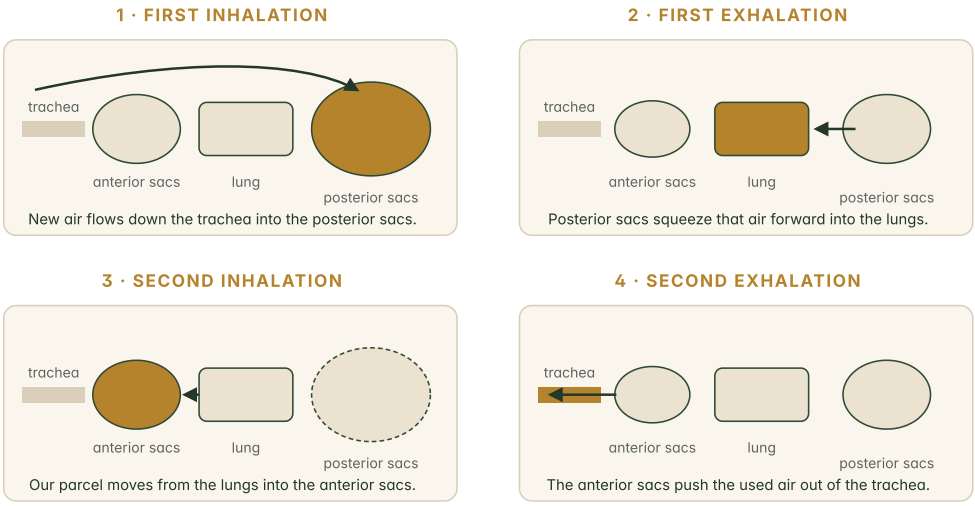
The two-cycle pattern was worked out by giving birds a single breath of pure oxygen and tracking it with oxygen sensors placed in the air sacs and airways; it is now standard textbook physiology.

THE NINE AIR SACS

One **interclavicular**, two **cervical**, two **anterior thoracic**, two **posterior thoracic** and two **abdominal**. For airflow, the important split is between the **anterior** (front) group and the **posterior** (rear) group.

02 Following one breath through the bird

Follow a single “parcel” of air (shown in ochre) as it travels through the system:



Simplified schematic. At every breath the bird is doing all four things at once with different parcels of air, so fresh air passes through the lungs on both inhalation and exhalation.

REMEMBER THE ORDER

The steps alternate **in–out–in–out**: the air reaches the lungs on the *first exhalation* and leaves on the *second exhalation*.

03 Why one-way flow is such an advantage

- **Fresher air at the exchange surface.** In a mammal, incoming air mixes with stale air left in the lungs. In a bird, the air passing through the lungs is largely fresh, with a higher oxygen content.
- **Cross-current exchange.** Because air and blood flow at right angles, oxygen can still diffuse into the blood even when the air holds only slightly more oxygen than the blood — a big help at altitude.
- **Air in the lungs on both strokes.** Fresh air crosses the gas-exchange surface during inhalation *and* exhalation.

04 Haemoglobin: the oxygen carrier

Haemoglobin is the protein in red blood cells that carries **oxygen** from the lungs to the rest of the body. There it releases the oxygen so the tissues can carry out aerobic respiration — turning food into energy.

How tightly haemoglobin grabs oxygen is called its **oxygen affinity**. A higher affinity helps an animal load oxygen from thin, oxygen-poor (hypoxic) air. Many birds that fly or live at high altitude have haemoglobins with altered oxygen-binding properties that raise this affinity.

11,300 m

RÜPPELL’S GRIFFON

The height a Rüppell’s griffon vulture has been recorded flying — higher than Everest.

4 haemoglobins

A FIRST FOR BIRDS

A 1988 study found four haemoglobin types in this vulture’s blood, with low, intermediate and high oxygen affinities — the first time four had been found in a bird.

The researchers suggested that this **gradient of oxygen affinities** helps the vulture load oxygen across a wide range of altitudes. Note that this finding is specific to Rüppell's griffon; it isn't true of "vultures" in general.

AT THE VEHICLE — HOW TO SAY IT

"When you breathe out, the air goes back the way it came. A bird's lungs work like a one-way street. Air sacs throughout its body act as bellows, and every breath takes two full in-and-out cycles to pass through. That keeps fresh air flowing over the lungs all the time."

POINT TO A SOARING VULTURE

"That's how a Rüppell's griffon has been recorded at over 11 kilometres up, higher than Everest. It even carries four kinds of haemoglobin to grab oxygen out of the thin air."

05 Key terms

Air sacs	Thin-walled sacs that act as bellows, moving air through the lungs. They don't exchange gases themselves.
Parabronchi	Tiny parallel tubes in the bird lung through which air flows one way; gas exchange happens in the air capillaries off them.
Unidirectional flow	Air moving through the lungs in one direction only.
Cross-current exchange	Air and blood flowing at right angles, giving efficient oxygen transfer.
Haemoglobin	The oxygen-carrying protein in red blood cells.
Oxygen affinity	How strongly haemoglobin binds oxygen; higher affinity helps in thin air.
Hypoxia	A shortage of oxygen — for example in thin air at high altitude.

In summary

- Birds have lungs **plus about nine air sacs**; the sacs are bellows, not gas-exchange organs.
- Air moves through the lungs **one way**, and one breath takes **two cycles** (in–out–in–out) to pass through.
- Air and blood cross at right angles, so oxygen uptake is efficient even in thin air.
- High-flying species have **higher-affinity haemoglobins**; Rüppell's griffon has four types and has been recorded at 11,300 m.

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