Bird Respiration

The avian respiratory system is considered to be the most efficient in the animal kingdom. The anatomy of the avian respiratory system is quite complex, unique, and efficient compared to that of mammals. An average bird devotes about one-fifth of its body volume to its respiratory system, while an average mammal only about one-twentieth.

Characteristics of the Bird Respiratory System

LUNGS

Unlike the lungs of mammals, avian lungs are relatively rigid and do not move much during breathing, i.e., they are nonexpandable. In mammals, inspired air goes into the lung as the lung expands and is expired when the lung contracts. In birds the lungs expand very little because the air goes through them in only one direction.

Bird lungs have more blood capillaries per area than mammals.

The lungs are paired but are not divided into lobes as they are in mammals. They have very little ability to expand and are attached firmly to the ribs and dorsal body wall. The lungs are deeply entrenched into the ribs, so that it appears that the ribs are embedded into the lungs, i.e., the lungs surround each of the ribs. Avian lungs weigh as much as the lungs of mammals of equal body weight, but because avian lungs have much greater tissue density they occupy only about half the volume.

The gas exchange region in the lungs is made up of blood capillaries and tiny lung structures in the walls of the lungs called air capillaries. The air capillaries are basically very small channels or fine tubules of air that are surrounded by a profuse network of blood capillaries. It is within these air capillaries that the exchange of gases between the lungs and the blood occurs.

Current wisdom is that the bird breathing system evolved as an adaptation for the requirements for flight. However, another proposal is that the group of dinosaurs giving rise to birds had this arrangement for breathing in an environment with a very reduced level of oxygen – half of today's oxygen level. Some evidence exists that reduced oxygen even at sea level was the case during this time period. Therefore this arrangement could have been a preadaptation that aids flight.

AIR SACS

Connected to the lungs are thin-walled air sacs that fill most of the body cavity not occupied by other organs, i.e., a large percentage of the bird's body is filled with the air sacs. These air sacs play an important role in respiration but are not directly involved in the exchange of gases. In fact, the sacs have very few blood vessels associated with them. Most birds have nine air sacs, but there is variation among species. Some of these air sacs penetrate the interior of the bones and even under the skin. Birds do not have a diaphragm and therefore rely on pressure changes in their air sacs to move air through the lungs, i.e., these air sacs act as a bellows system to move air through the respiratory tract.

The air sacs permit a unidirectional flow of air through the lungs. Unidirectional flow means that air moving through bird lungs is largely fresh air and has a higher oxygen content.

Basically, no residual air is left in the lungs of a bird during a breathing cycle. In contrast, air flow is bi-directional in mammals, moving back and forth into and out of the small blind sacs (the alveoli) of the lungs, i.e., in and out through the same pathway. As a result, air coming into a mammal's lungs is mixed with old air that has been in the lungs for a while and this mixed air has less oxygen. So, in bird lungs, more oxygen is available to diffuse in the blood. (RW: "pursed lips" illustration to demonstrate residual air in human lungs.)

Air sacs also provide buoyancy for aquatic birds. Swimming species have particularly large abdominal and post thoracic air sacs whose volume can be controlled for swimming or diving. They also provide a cushion for internal organs when landing or diving into the water for food.

Air sacs may be modified for courtship displays, e.g., the neck bladders of the Frigate Bird and Prairie Chicken.

Air sacs also serve to cool the body during vigorous exercise through the internal evaporation of water.

Breathing rate increases with activity, as you would expect. A House Sparrow has a resting respiratory rate of 50 breaths per minute and a respiratory rate of 200 after just flying around a room. Because of the efficiency of the bird's breathing system, the ratio of breaths to heartbeats can be quite low. A mammal takes about one breath for every four-and-a-half heartbeats (independent of the size of the mammal) whereas a bird takes one breath for every six to ten heartbeats (depending on the size of the bird).

SOUND

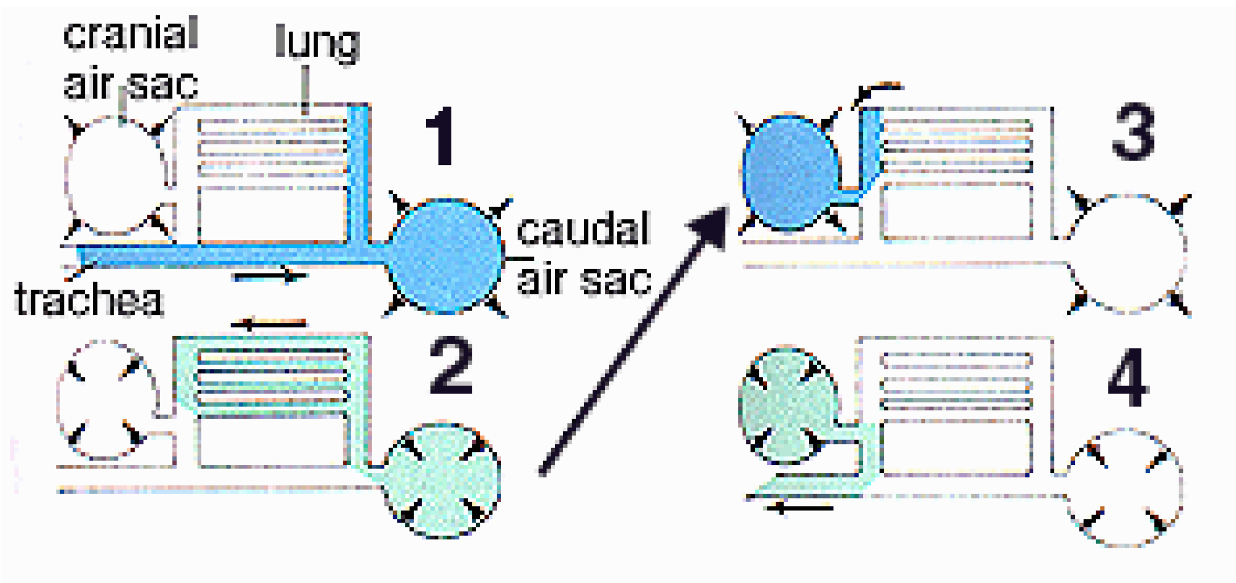
Vocalization is by means of a syrinx, not a larynx as in mammals. Birds have a larynx, but it is just the entrance into the trachea. Unlike mammals there is no small flap of tissue covering the glottis. The trachea is formed by a series of ring-shaped cartilages, which are completely closed in birds – unlike in mammals in which the cartilage ring also contains a membranous component. The trachea divides after entering the thoracic cavity. The syrinx or voice box is located at this division. The syrinx is composed of both cartilage and vibrating soft structures.

NARES/TRACHEA

The entrance into the respiratory system is through the nares or nostrils usually located at the base of the beak. In most birds the nares are readily visible, while in some birds - such as crows –they are covered by feathers. The air enters the nares and moves into the nasal cavity. The nasal cavity is divided into a right and left side by a nasal septum. This septum is composed of cartilage and bone. Highly vascularized projections and folds, called nasal conchae, project from the lateral walls on each side of the septum into the nasal cavity. These increase the surface over which inhaled air passes. The nasal cavity filters inhaled airborne particles by means of mucus and small hair-like cilia. Furthermore, inhaled air is warmed and moistened by the nasal cavity.

Birds can breathe through the mouth or the nares. Air entering these openings during inspiration passes through the pharynx and then into the trachea (the windpipe). The trachea is usually as long as the neck, however, some birds, such as cranes, have an exceptionally long trachea – up to 1.5 meters long. Not only does the trachea go down the neck but also is coiled within the hollowed keel of the breastbone. This arrangement apparently gives added resonance to their loud calls. The typical bird trachea is 2.7 times longer and 1.29 wider than that of similarly-sized mammals. Birds compensate for the larger tracheal area by having a relatively larger tidal volume of air.

PATTERN OF AIR FLOW THROUGH THE LUNGS AND AIR SACS:
Unlike the case with mammals high oxygen air moves in one direction through a bird's lungs. Also see the diagram in the text on page 121.



Unlike in mammals, it takes TWO cycles of inhaling and exhaling for one volume unit of air to pass through the respiratory system, i.e., there are two inhalations and two exhalations in the complete cycle.
1) First Inhalation - Air flows through the trachea and bronchi of the lungs - but primarily into the posterior air sacs.
2) First Exhalation – Air moves from the posterior air sacs into the lungs.
3) Second Inhalation – Air moves from the lungs into the anterior air sacs.
4) Second Exhalation – Air moves from the anterior air sacs back into the trachea and out the body.

During inspiration the sternum moves forward and downward and the rib cage expands to expand both the posterior and anterior air sacs. This lowers the air pressure on the inside of the air sacs, causing air to move into those air sacs. Simultaneously the air in the trachea moves into the posterior air sac, and the air in the lungs moves into the anterior air sacs. (Note how this is similar to the movement of blood through the four chambers of the heart when two volumes of blood are moving at the same time.) Especially note that when a bird inhales, air actually leaves its lungs.

During exhalation the sternum moves backward and upward while the ribs also move to reduce the volume of the body cavity. This reduces the volume of both the anterior and posterior air sacs, causing air to move out of those sacs. Simultaneously the air in the posterior air sacs move into the lungs and the air in the anterior sacs move into the trachea and out of the body. Especially note that most of the fresh oxygenated air enters the lungs as a bird exhales!