Kenzie File

Dr. A

Comparative Anatomy

7 Dec 2023

An Anatomical Comparative Analysis of the Red Fox, the Elk, and the Mute Swan

Studying comparative anatomy offers insights into many things including structural variations and adaptations among different species. It can be useful in many adjacent fields including veterinary medicine and ecology. In this paper, I will be exploring the anatomical features of three species: the red fox (Vulpes vulpes), the elk (Cervus canadensis), and the mute swan (Cygnus olor). I will be referring to them by their common names for convenience throughout the rest of the paper. To better understand these animals, I will be delving into individual systems in particular to get an in-depth look at what they have in common and where they differ. I will attempt to unveil the adaptations that they have gained by comparing and contrasting their anatomy.

As taxonomy classifies every species based on phylology, this is where I will begin. Being part of the family Canidae, the red fox belongs to the order Carnivora. They often have sharp teeth or claws to aid in food consumption. (Encyclopædia Britannica) The elk is a member of the Cervidae family and falls under the Artiodactyla order. Members of Cervidae are hooved and usually opportunistic omnivores, though most generally eat mainly plant matter. (Encyclopædia Britannica) Lastly, the mute swan resides within the Anatidae family within the Anseriformes order. Members of Anatidae are typically waterfowl and, besides swans, include ducks and geese as well. (Encyclopædia Britannica) Being both mammals, the red fox and the

elk may have more similarities with each other than the mute swan. Despite their differences, they all share a common ancestry and are all chordates. I will be highlighting both the differences and the similarities in this paper.

As far as ecology goes, these animals can all be found in North America. Red foxes typically prefer grassy lands and have been shown to adapt well to human presence. Elk can be found mainly in coniferous rainforests whereas swans, being waterfowl, reside near bodies of water. The mute swan in particular is not a native species to North America and poses somewhat of a threat to the ecosystem as it is aggressive to other animals and humans and consumes large amounts of food with no natural predators to keep it in check. Humans still seem to side with the swams, perhaps because of their aesthetic purposes. Around the middle of the 20th century, humans had begun to eradicate larger predatory animals, such as wolves. This has allowed smaller predatory animals, like foxes and coyotes, to breed and hunt without fear of running into larger competitors. This resulted in a cascade of effects including a sharp increase in cervids, such as elk, as well as a steep drop in avians, mainly smaller birds, due to the hunting preferences of these smaller predatory animals. As cervids began to take over, plant life suffered as well. (Encyclopædia Britannica) The ecosystem is slowly but surely healing from these issues.

The first system I will be discussing is the integumentary system. This particular system plays a crucial role in protecting organisms from external elements. It is composed of skin, feathers, fur, and other structures associated with the skin. Both the red fox and the elk have fur while the mute swan has feathers. Both fur and feathers have their pros and cons. For the red fox, fur has multiple purposes. “The red fox has a coat of long guard hairs and soft fine underfur that is typically a rich reddish brown.” (Encyclopædia Britannica) This double coat provides insulation from elements and ever-changing temperatures. The elk, in contrast, has more bristly

fur and only a single coat. (Encyclopædia Britannica) Due to their large size and slightly warmer climate, they do not need a double coat like the red fox does. The mute swan dons feathers rather than fur. They have a combination of downy feathers for insulation as well as long flight feathers. This adaptation aids in flight, insulation, and buoyancy. (Encyclopædia Britannica)

In addition to the integumentary system, the skeletal system is also an extremely important system in which each of these animals exhibits structurally unique adaptations. Mammalian skulls and avian skulls have distinct fundamental differences. Mammalian skulls have both a secondary palate as well as nasal turbinates. These adaptations only pertain to mammalian skulls. (Nord) The secondary palate is a structure in the roof of the mouth of mammals that allows them to suck. Because mammals produce milk for their young, this is a crucial part of their anatomy. Additionally, nasal turbinates are curved bone structures within the nose that aid in respiration and olfactory functioning. Swans, being avians rather than mammals, do not have these structures.

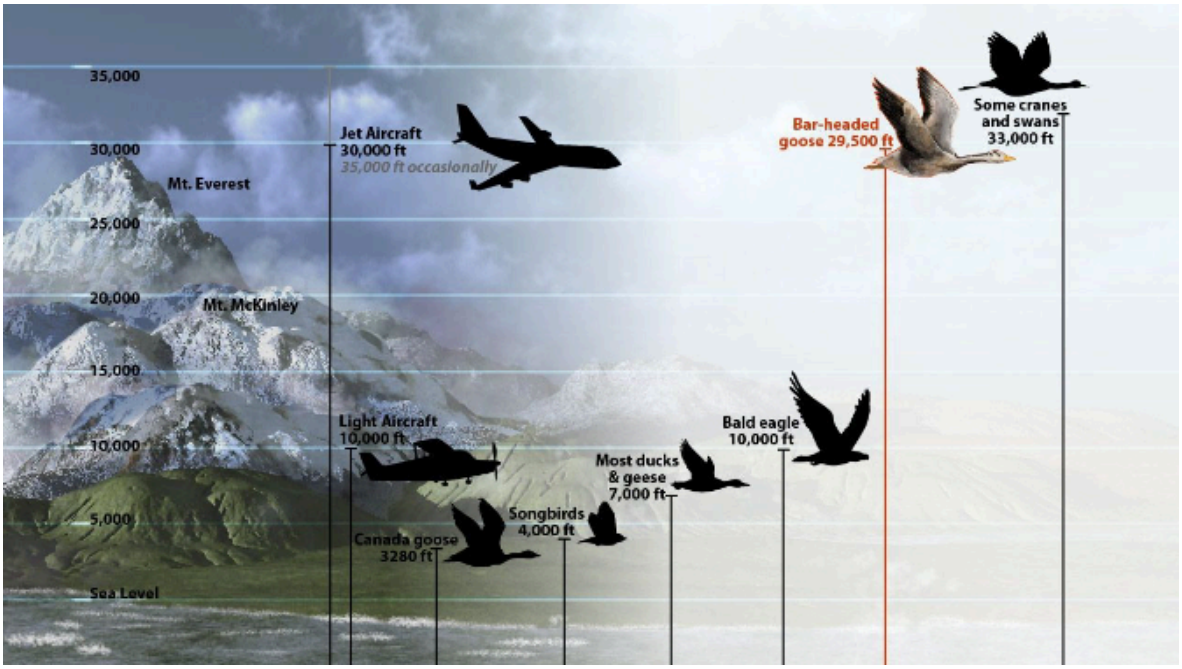
Though birds don't have nasal turbinates or secondary palates, they, along with only reptiles, do have sclerotic rings in their eye sockets. This interesting structure keeps their eye from rolling and in place. Though this may seem restrictive, it is crucial for animals who make rapid movements. There is an article in which researchers measured and analyzed 1404 pairs of sclerotic rings to better understand the differences among the orders of avians. "The sclerotic ring of the avian eye is composed of a number of individual plates, placed side by side and overlapped to form a bony ring which surrounds the pupil of the eye and extends inward to a distance that is exceedingly variable in different orders of birds." (Curtis) According to this article, a swan would have different sclerotic rings than, say, a sparrow due to their differing lifestyles. "It would appear that the steeper-sided ring gives greater support to the outer part of

the eyeball, which would be advantageous alike to diving birds, whose eyes are subjected to pressure from the water, and to swift-flying birds whose eyes are subjected to the pressure of rushing air." (Curtis) Swans, being waterfowl, have steeper sclerotic rings to help support their eyes against water pressure.

Another interesting feature about mammalian skulls is the temporalis and the masseter. These are skeletal muscles that affect bite force and chewing. (Nord) Typically, carnivores have a larger temporalis and a smaller masseter. In contrast, herbivores posses a smaller temporalis and a larger masseter. This is because the temporalis increases bite force whereas the masseter enhances chewing. Carnivores, like the red fox, need to tear flesh while herbivores, like the elk, need to chew plant matter thoroughly. Avians have their own version of the temporalis and the masseter. According to an interesting article, there are seven jaw muscles for birds. "The usual seven jaw muscles in birds are highly adapted for diverse food-getting devices through muscular modifications as well as changes in kinesis of the skeletal components of the skull." (Bhattacharyya) It makes sense that avians have specially adapted muscles given their unique anatomical layout. Because they have beaks rather than mouths, their skeletal and muscle structure will differ greatly from other animals.

Avians also have unique respiratory systems. They have what's called unidirectional airflow. This means that they don't take individual breaths but, rather, there is a constant flow of

air circulating through their respiratory system. (Nord) The images above and below were taken from Dr. Andrea Nord's lecture presentation on respiratory systems in chordates. We can see that the air is constantly flowing through their system. The air flows to one lung and is "exhaled" from that lung and "inhaled" into another. It is then finally exhaled from the bird. This is crucial for birds which are creatures that often reach lofty altitudes that are low in oxygen. Swans in particular can reach heights of 33,000 feet whereas jet aircraft typically only go up to 30,000 feet. (Nord) Having this adaption keeps them from running low on oxygen in areas where it is scarce.



Though mammalian respiratory systems are a bit less dazzling, they still have interesting features and are a bit more familiar as well. Mammals are typically terrestrial animals and don't need to worry about extremely high altitudes like the majority of avians do. They do not have unidirectional airflow and have to inhale and exhale separately by taking individual breaths. The diaphragm, a muscle positioned directly below the lungs and ribcage, contracts and relaxes for each breath. (Nord) This helps to pull air in and out of the lungs. Interestingly enough, "…the

respiratory system in birds is considered the most advanced in the animal kingdom." (Thayer Birding) This puts them above mammals, including humans, when it comes to respiration.

An amazing avian adaptation that is specific to waterfowl is their incredible ability to thermoregulate in very cold water. Their feet are webbed and do not have fur or feathers to insulate them. An interesting study was conducted on this subject. Researchers took ducklings and measured their body temperatures in cold water. All waterfowl, including the mute swan, must be able to thermoregulate in cold water so they don't get hypothermia. The researchers were able to create a heat transfer model for swimming ducklings. "Interestingly, ducklings can maintain body temperature >39 °C while swimming in 5 °C water, but not when restrained in a calorimeter with 5 °C water. Peak oxygen consumption is greater when swimming, and apparently exercise metabolism substitutes almost completely for thermoregulatory heat production." (Van Sant) Waterfowl are able to maintain a normal body temperature due to a multitude of reasons. They use countercurrent heat exchange which means that their blood vessels are arranged so that heat can flow from warmer parts of the body to colder parts. Their bodies also use vasoconstriction to help reduce heat loss. There are also no sweat glands that heat can be lost through and, when necessary, lose heat through their respiratory system and exposed skin instead. ("Metabolism and Thermoregulation – Ornithology") All of this contributes to saving heat in colder conditions.

Another way of obtaining energy is through the consumption of food. The digestive system can look very different from animal to animal. The red fox is usually a carnivore though they won't turn down berries and nuts when those are the only option. As carnivores, their digestive system is much more simplistic and straightforward, given that meat is very easy to digest. They tear their food with their sharp teeth and swallow fairly quickly. (Saylor Academy)

The food then travels to their stomach and intestines and is secreted as waste. (Red Fox Resource) The mute swam has a slightly more complex digestive system given that they are omnivorus avians. They have a gizzard which acts as an almost second stomach and aids in digestion. They also swallow "…grit which grinds up the food." (YPTE) "The length of their digestive system more closely resembles that of an herbivore as compared to a carnivore. However, omnivores lack the fermenting vats found in herbivores." (Saylor Academy) Lastly, elk have the most complex digestive system out of the three. Among herbivores, there are foregut fermentors and hindgut fermentors. The reason that they need more steps to break down their food is that plant matter is much more difficult to break down. Hindgut fermentors have bacteria-aided digestion going on in the large intestine, somewhat similar to how omnivores operate. Forefut fermentors have bacteria that help break down their food before it gets to the stomach and they regurgitate the half-digested food, called "cud," and chew it again before swallowing it and sending it to the stomach. "In animals that use foregut (a.k.a. pre-gastric) fermentation, the stomach is modified into four chambers/compartments where the first chamber is the rumen. This rumen provides a place for the bacterial breakdown of food." (Saylor Academy) Elk are foregut fermentors. Aside from their more complex stomach setup, they also do not have very sharp teeth and have more flat teeth suitable for grinding and chewing.

Overall, the red fox, the elk, and the mute swan have many similarities and differences. They give us a peek at the fascinating variations in adaptations that different classes and orders went through to get to the animals that we have today. Taking a comparative approach allows us to see how their unique form creates their unique functions. Their phylogenic classifications give us an understanding of what kind of adaptations occurred to specialize them for their ecological niches. Taking the time to learn and understand what makes them similar and what makes them

different gives us a better grasp on the relationship between ecology and evolution as well as highlighting the importance of biodiversity in our world. After discovering the subtle anatomical differences between the red fox, the elk, and the mute swan, we have enriched our understanding of the natural world and taken in more of the beauty of evolution and diversity that the animal kingdom has to offer.

Literature Cited

Bhattacharyya, B. N. "Avian jaw function: adaptation of the seven–muscle system and a review." Proceedings of the Zoological Society. Vol. 66. No. 2. India: Springer India, 2013.

“Comparison of Digestive Systems.” Saylor Academy, 2012, resources.saylor.org/wwwresources/archived/site/wp-content/uploads/2012/07/BIO309-OC-3.8.1-Comparison-of-Digestive-Systems-FINAL.pdf.

Curtis, Elizabeth L., and Robert C. Miller. "The sclerotic ring in North American birds." The Auk 55.2 (1938): 225-243.

“Elk.” Encyclopædia Britannica, Encyclopædia Britannica, inc., 28 Oct. 2023, www.britannica.com/animal/elk-mammal.

“Metabolism and Thermoregulation – Ornithology.” Ornithology, www.ornithology.com/ornithology-lectures/7898-2/. Accessed 12 Dec. 2023.

Nord, Andrea. "Axial Skeleton Skull." BIOL309 Comparative Anatomy, Sept 2023

Nord, Andrea. "Respiratory Part 2." BIOL309 Comparative Anatomy, Oct 2023

“Red Fox.” Encyclopædia Britannica, Encyclopædia Britannica, inc., 11 Oct. 2023, www.britannica.com/animal/red-fox-mammal.

“Swan.” Encyclopædia Britannica, Encyclopædia Britannica, inc., 10 Oct. 2023, www.britannica.com/animal/swan.

“Swan (Mute) - Food and Feeding.” Young People’s Trust For the Environment, 10 Sept. 2014, ypte.org.uk/factsheets/swan-mute/food-and-feeding?hide_donation_prompt=1.

“Thayer Birding.” How Does the Respiratory System in Birds Differ From …, www.thayerbirding.com/the-respiratory-system-in-birds/. Accessed 12 Dec. 2023.

“The Digestive System.” The Red Fox Resource, redfoxofficial.weebly.com/the-digestive-system.html. Accessed 13 Dec. 2023.

Van Sant, Matthew J., and George S. Bakken. "Thermoregulation on the air–water interface—II: Foot conductance, activity metabolism and a two-dimensional heat transfer model." Journal of Thermal Biology 31.6 (2006): 491-500.