The Last of the Ailurids: History and Adaptations of the Red Panda

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Introduction

As the last surviving members of the Ailuridae family, red pandas are a branch all their own. Researchers are still working out just where this family fits in the phylogenetic tree and are constantly reevaluating and refining their theories as new evidence comes to light. Currently, there are two species that make up this family, the Chinese red panda *(Ailurus fulgens refulgens*, previously *Ailurus fulgens styani)* and the Himalayan red panda *(Ailurus fulgens fulgens*). This makes Ailuridae one of the smallest extant mammalian families. However, this family was once widespread and successful, with fossil traces seen as early as the Late Oligocene to Early Miocene (18-20 million years ago). Though today's red pandas are only found in Nepal, Bhutan, China, Myanmar, and India (Thapa et al., 2018) their ancestors once lived in Europe and North America as well (Wallace, 2011). These species evolved in Order Carnivora and early Ailurids were true carnivores. However, today's pandas are obligate bamboo eaters. They rarely eat meat and instead rely on bamboo to make up the bulk of their diet (Pradhan, 2001). They are also arboreal, spending the majority of their time in the trees as opposed to being more terrestrial like their ancestors (Salesa et al., 2011). These lifestyle changes have caused red pandas to develop various attributes to help them adapt to their new diet and habitat and now today's red pandas possess characteristics of carnivores as well as herbivores.

Skeletal and physical differences

Overall, the red panda still retains several of its Carnivora characteristics. It has a simple stomach and short digestive tract, both of which are uncommon in herbivores. In comparison to Procyonids of similar size, such as raccoons and coatis, as well as early Ailurids, the red panda has a larger head, but the increased skull depth is believed to help increase their bite pressure, allowing for better grinding of plant material. Figure 1 shows the shortened skull depth as compared to one of the red pandas' most well studied ancestor, *Pristinailurus bristoli* (Woodruff, 2015) . Each paw on extant red pandas contains five semi-retractable claws, a sign of it's arboreal lifestyle. The large postscapular fossa on the back of the shoulder blades is also likely an adaptation to allow the red panda to climb easier and make the forelimbs more supportive than the hind limbs (Roberts and Gittleman, 1984). Living red pandas still contain the signature lateral groove on their canine teeth and also have molar cusps which were present in early Ailurid species.

Comparatively, today's red pandas have smaller humerus/femur and humerus/tibia ratios than their ancestors. This is another indicator that today's red pandas live a more arboreal lifestyle than early Ailurids (Wallace, 2011). Today's red pandas are so adept at climbing that they can descend head first down a tree. With this arboreal lifestyle came a smaller body size. Figures 1.1, and 1.2 show the size difference between Ailurids, note the much smaller size of *A. fulgens* (Woodruff, 2015).

While most carnivores have their left lung separated into three lobes, Ailurids have their left lung separated into only two lobes. This is in line with Procyonidae, Mustelidae (otters, ferrets, and wolverines), and Ursidae (bears). Ailurids have their right lung divided into four lobes. It is believed the reduction in lobes in the left lung leads to a broadening of the thorax (Roberts and Gittleman, 1984). The purpose of this broader thorax has not yet been discovered since not all carnivores have the same corresponding number of lobes per lung. Another similarity between red pandas and Procyonids includes the structure of the larynx and the fact that the cuneiform cartilages are missing. The exact role of these cartilages is still unknown but it is believed that they help support the vocal cords and prevent aspiration. Both of these families also have a prominent entepicondylar foramen, or opening, on the humerus that allows for the median nerve to pass through. Other distant relatives of Ailurid and Procyonid, such as Mustelids and Feliforms (cats, hyenas, and mongooses), also have this foramen but the brachial artery passes through it as well as the median nerve. Ursids and Canids (dogs), other families in Order Carnivora, don't have this foramen at all (Fisher, 2011).

Radial sesamoid bone

As the Ailurid species moved from being mainly terrestrial to arboreal, they developed an enlarged radial sesamoid bone in the Miocene that assisted with climbing. This enlarged wrist bone gave Simocyons, early members of the Ailurid family, a functioning pseudothumb. Since dentition shows that Ailurids were still partaking in a mainly carnivorous diet at the emergence of the pseudothumb, researchers surmise that the enlarged radial sesamoid bone developed as a climbing aid. Extinct Ailurids had a smaller radial sesamoid bone than today's red pandas, supporting the theory that this developed as a climbing aid (Wallace, 2011). However, this pseudothumb was a preadaptation and also assists with grabbing fruits, stems, and leaves (Salesa et al., 2006). Figure 2 demonstrates how red pandas use this preadaptation to assist them with holding and grabbing (voltagegate, 2007).

The giant panda, a member of the Ursidae family, also developed an enlarged radial sesamoid bone, however, it did so independently from the red panda, a member of the Ailuridae family. In relation to the other bones in the wrist, the giant pandas radial sesamoid is larger than the red pandas. Since the giant pandas don't do as much climbing and have been strict herbivores longer than the red panda, researchers theorized that this enlarged bone evolved to assist the giant pandas with grabbing and holding, which was a preadaptation in the red panda (Salesa et al., 2006).

The genes responsible for this enlarged radial sesamoid bone in both the red and giant pandas are believed to be the *DYNC2H1* and *PCNT*. Both of these genes contribute to limb development and have undergone adaptive convergence in both of these species who diverged 43 million years ago (Hu et al., 2017).

Umami taste receptor

Red pandas are the only species aside from humans and Old World apes and monkeys who are known to be able to taste artificial sweetener (Goldman, 2014). In exchange for this taste, red pandas lost what is known as the umami taste. Umami is also referred to as "savory" and detects tastes in substances such as monosodium glutamate, 5′-monophosphates, L-amino acids, and 5′-ribonucleotides (Yamaguchi, 1979; Sato et al., 2012). The gene responsible for the umami taste is known as the *TAS1R1* gene (Hu, 2017). *TAS1R1* encodes for the T1R1 protein, which is one of three type-1 taste receptors and the one used by carnivores to detect the best tasting meat (Sato et al., 2012; Li, 2009; Yarmolinksky, 2014). As red pandas began to adapt more of a herbivorous diet, they pseduogenized the *TAS1R1* gene. Instead of the “umami” heterodimer T1R1/T1R3, red pandas possess the heterodimer for “sweet”, T1R2/T1R3. The protein for the “sweet” heterodimer is encoded by the gene *TAS1R2* (Li, 2009). Herbivores utilize the ability to taste “sweet” to detect carbohydrates in the plants they ingest. The ability to taste aspartame, or artificial sweeteners, is a recent evolutionary development. The giant panda has a diet very similar to that of the red panda and may have evolved their “sweet” taste receptors in a response to their high carbohydrate diet as well.

Gut microbiomes

There are three species of obligate bamboo eaters: the red panda, the giant panda, and the bamboo lemur *(Hapalemur griseus).* Each are members of a different phylogenetic family (Hu, 2017). These three species share 48 low-abundance operational taxonomic units (OTUs). The bamboo lemur and it’s sister species, the ring tailed lemur *(Lemur catta)* only share eight OTUs (McKenney et al., 2017). OTUs are sequences of similar genomic data on a DNA sequence and are used to determine relatedness among species (Galimberti et al., 2012).

Each of these species also has an increased amount of cyanide degradation enzymes, something that is found in herbivores but not carnivores. These enzymes help to break down the cyanide in the bamboo leaves (Zhu, 2018). Since each species developed independently of the others but yet all share similar characteristics, researchers believe that their diet of bamboo may have driven some of the phenotypic evolution.

Conclusion

Despite the fact that there are only two living species left, Ailuridae is a complex and old phylogenetic family. Even though Ailurid species were once widespread across North America, Asia, and Europe, there is very little fossil evidence available to explain their evolutionary changes, or extinctions, over the millenia. So far, most of the prehistoric Ailurid species are only represented by fossilized teeth. The most well represented and well researched species, *P. bristoli,* is unlike any of the other extinct as well as extant species of ailurids that are currently known. There are still many “missing pieces" needed to connect the various members in the

Ailuridae family. Even with continuing advances in genetics and phylogeny, researchers still debate over where Ailuridae fits in Order Carnivora.

Many of Ailuridae's genetic adaptations are also seen in species who are members of other phylogenetic families. This is evidence of convergent evolution and provides researchers with new evolutionary information to analyze. This is also one of the few families that has transformed from a carnivorous diet to that of an obligate herbivore. That alone begets various evolutionary mysteries for researchers to study. Preserving this unique species also preserves an irreplaceable bank of information that can help scientists better understand adaptations and convergent evolution. Losing this endangered species would be losing a species full of distinctive attributes, ranging from taste receptors to skeletal design. As scientists decode more and more genomes and find more genetic links, we will be able to learn even more about how animals, including ourselves, adapt and evolve in an ever-changing environment. The red panda has proven for thousands of years that it's able to modify itself and survive, even going to such extremes as completely changing its diet. This cute ball of fluff may hold the key to answering the big question: what really drives evolution?

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