Ear Shape

Phylogeny

From Felidae Phylogeny page:

Cats of the genera Panthera and Pardofelis, which diverged from other cats before Caracal, had rounded ears. This implies that rounded ears are ancestral in Felidae. Understanding when exactly these traits arose, however, is difficult. Most genera in Felidae have rounded ears, however cats in the distantly related genera Caracal, Lynx, and Felis have pointed ears. Pointed ears may have arisen before Caracal diverged and reverted in Leopardus and after Lynx diverged, then arisen again later in Felis. However, the most parsimonious hypothesis is that pointed ears is a homoplastic character that arose independently in Caracal, Lynx, and Felis.

Hypothesis

Development & Gene Regulation

While there have been few studies about the development of pointed ears in Felidae, the development of vertebrate ears is of interest to many scientists. Here, we are most interested in the development of the outer/external ear, which acts like a satellite dish to collect sound and funnel it into the middle and inner ear. The outer ear develops from partial fusion of ectoderm and mesenchyme of branchial arches I and II (Fekete 1999,
Mutations in many different genes can reduce the size of the outer ear. Homeobox transcription factors that regulate hindbrain segmentation and identity can sometimes cause mutations in outer ear formation (Fekete 1999). Loss of Endothelin-1 can also result in outer ear underdevelopment (Kurihara et al. 1994). Short-ear mutants in mice have a mutation in a bone morphogenic protein (Kingsley 1994). Fibroblast growth factor and receptor mutations can reduce ear size in mice (Wright & Mansour 2002). Mutations in all of these genes also cause large-scale changes over the entire organism, so it is more likely that differences in ear size in cats are caused by differences in gene regulation than differences in the genes themselves. Although these examples likely don’t include all genes that could change the shape of ears in cats, it is possible that some of them could be involved in the different phenotypes we observed.

One likely candidate for ear shape differences is fibroblast growth factors (FGFs) and FGF receptors, whose mutants have been shown to reduce ear pinna length in mice (Wright & Mansour 2002). FGFs are important to cell differentiation, motility, and survival. FGF signaling is used in communication between epithelial and mesenchymal tissues, and is only involved in signaling of cells that are near each other. When an FGF binds to its receptor on the outer surface of a cell, the ligand-receptor complex dimerizes with another, and tyrosine kinase activity is activated inside the cell, causing a signal cascade. This cascade activates transcription factors to change gene expression. Mutants with 20% expression of Fgfr1 (a receptor) have reduced ear pinna lengths (loss of function mutations are lethal), and mutants with 20% expression of Fgf8 (a growth factor that binds to a FGF receptor) have similar phenotypes, implying that these are the Fibroblast growth factor and receptor most important in outer ear development (Wright & Mansour 2002). Since losses of these genes causes reduced ear size, it seems possible that overexpression of them in the tip of the ear might cause extension of the ear. FGFs and their receptors are likely candidates for a shift from rounded to pointed ears in the genus Caracal if pointed ears are adaptive because it is a signal known to be involved in ear development that does not travel far from the area where it originates, but is a growth factor that causes major changes in a cell’s gene expression.

**Phenotypic Evolution**

Since tigers, lions, and caracals live in different habitats and have different prey, different auditory cues may be important to their ability to hunt prey. We hypothesized that changes in ear shape alter the way sound enters the inner ear, and a need to hear a different type of sound may have driven selection to alter outer ear shape in the genus Caracal. Unfortunately, the outer ears of cats are not bony and therefore are not well preserved in the fossil record. However, most cats have rounded ears, implying that this is the ancestral state (Sunquist & Sunquist 2002, Johnson et al. 2006).

Few studies of the outer ears of cats have been conducted, which makes most hypotheses about evolution of ear shape complete supposition. However, some of the existing studies of the middle ears of cats might also provide insight into the frequency sensitivity of different types of cats. In a comparison of the middle ears of lions and domestic cats, Huang et al. (1997) found that the structure of the middle ears of the two species were similar, but domestic cats are able to hear higher frequencies. Another paper comparing tigers to domestic cats found that domestic cats can also hear higher than tigers can (Bergevin et al. 2012). Although neither of these studies includes caracals, larger cats are generally able to hear lower frequencies than smaller cats (Huang et al. 2000). This implies that caracals may be able to hear a different group of sounds than lions and tigers can, however it gives no insight into whether outer ear shape is selected based on this, as many other small cats have rounded ears (Sunquist & Sunquist 2002).

In addition, a study by Middlebrooks and Knudsen in 1987 showed that position of external ears determines the ability of domestic cats to hear sound from a certain direction. While this does not shed any light on the specific effects of ear shape on cat hearing, it does add evidence in favor of our hypothesis that the external ear is important for collecting sounds.

It is possible that differences in external ear shape are adaptations by lions, tigers, and caracals to needing to be able to hear different sounds. However, while our search of the literature suggests that caracals may be able to hear a different group of sounds than lions and tigers, genes that change the shape of outer ears also often make many different changes to vertebrate morphology. This means that another valid hypothesis for a change in ear shape might be that pointed ears are caused by pleiotropy in a gene being selected for something else.

**Conclusions**

At the zoo, we observed that while both tigers and lions have rounded ears, caracals have pointed ears. We hypothesized that the difference in ear shape allowed cats to hear different types of prey. Unfortunately, literature about external ear shape in cats is not abundant. However, based on literature comparing the middle and inner ears of different species of cats, certain species of cats may be better able to hear different sounds. This implies that there could also be selection pressures to change the shape of the outer ear so it is optimal for those sets of sounds. However, small cats with rounded ears are likely to be able to hear similar sounds to the caracal, making our original hypothesis less likely. During our search of the literature, we found many developmental genes that may be involved in changing ear shape in cats. Since many of the genes we know to be involved in external ear formation are also important to other aspects of development, it is likely that expression patterns of the genes, rather than the genes themselves, are changing to convert ancestral rounded ears into the pointed ears of Caracal caracal. However, there has been little research on the evolution of Felidae ear shape, so it is possible that rather than ear shape being an adaptation, it is a product of a pleiotropic gene being selected for something else. We also know little about the population genetic history of the genus Caracal, and it might be possible that rather than being an adaptation, ear shape was a neutral mutation that went to fixation during a population bottleneck or due to a founder effect. Further study is needed to determine the reasons for differences in outer ear morphology in the family Felidae.

**References:**


