Evolutionary perspectives of bony labyrinths in humans, chimpanzees and baboons: high resolution three dimensional comparisons.

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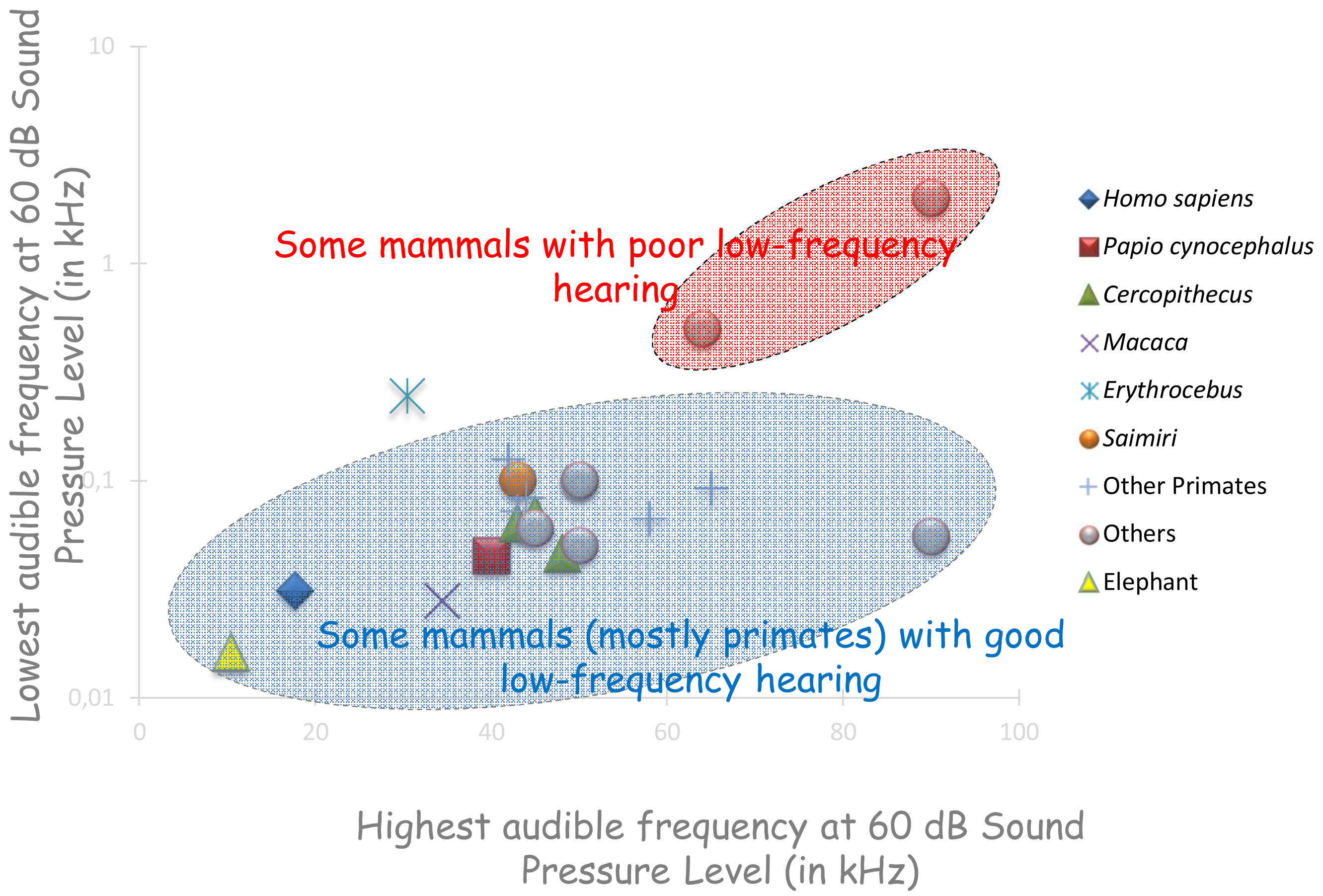
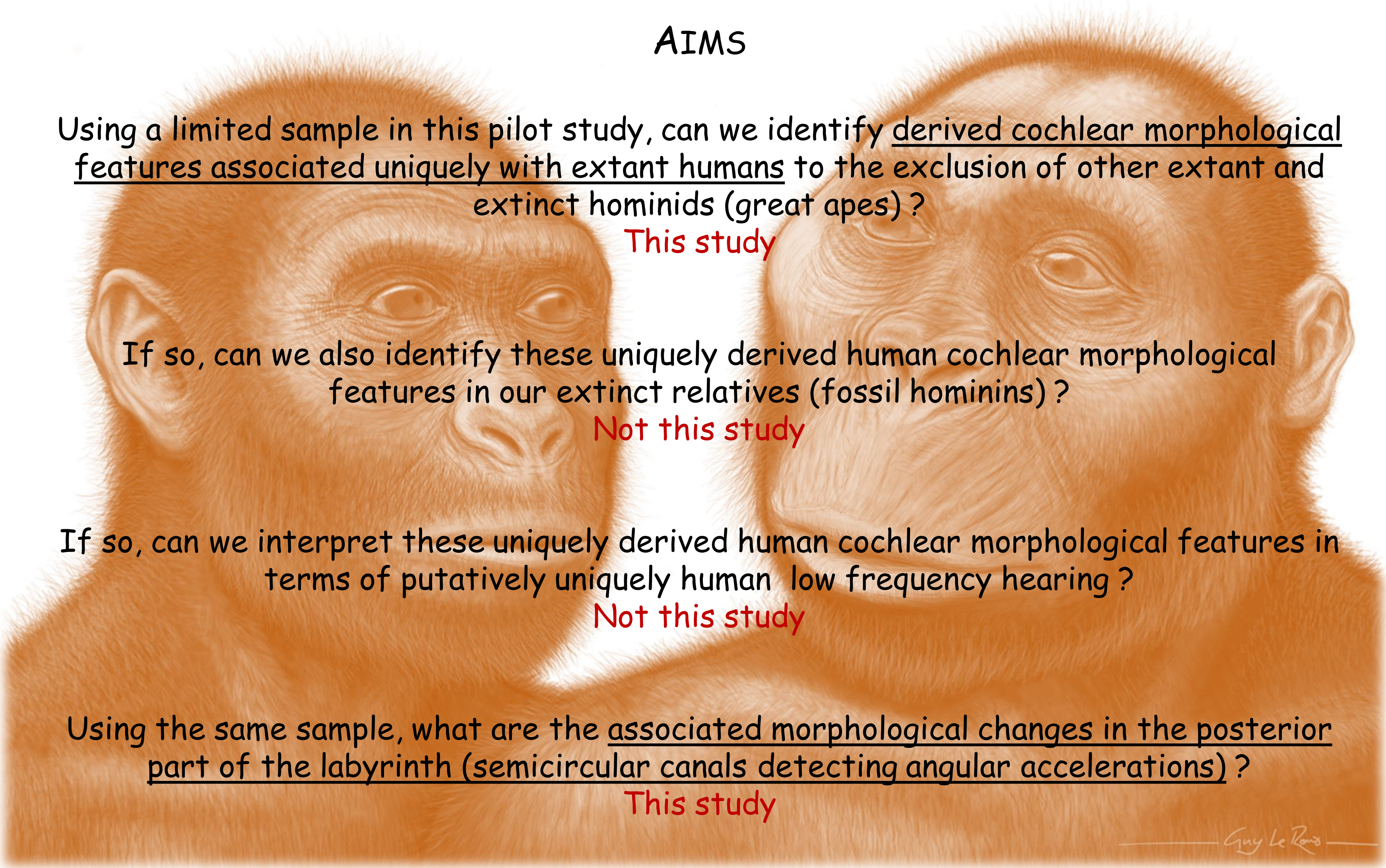
It is often considered that extant humans display a unique low-frequency hearing among extant primates



Primate data from RS Heffner 2004 (Table 1)
Primate hearing from a mammalian perspective



Aims

Using a limited sample in this pilot study, can we identify derived cochlear morphological features associated uniquely with extant humans to the exclusion of other extant and extinct hominids (great apes) ?

This study

If so, can we also identify these uniquely derived human cochlear morphological features in our extinct relatives (fossil hominins) ?

Not this study

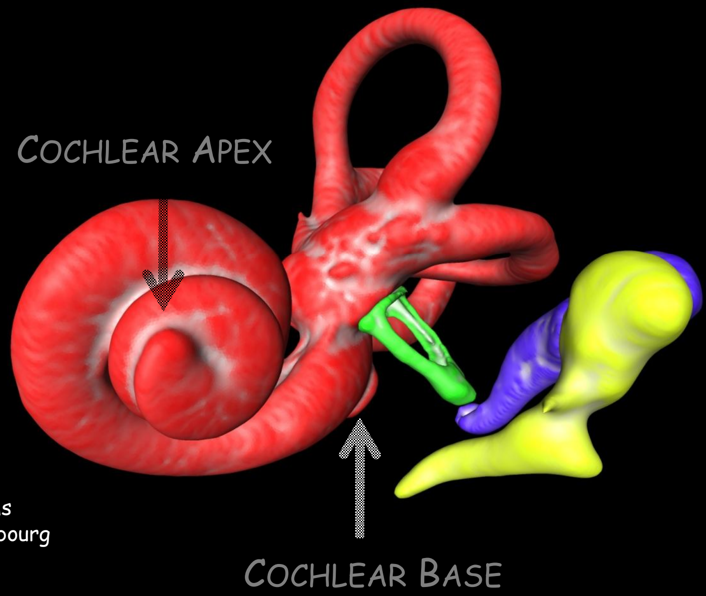
If so, can we interpret these uniquely derived human cochlear morphological features in terms of putatively uniquely human low frequency hearing ?

Not this study

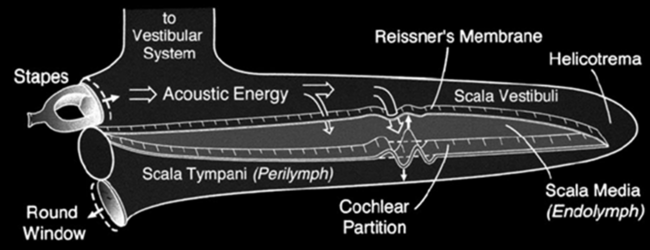
Using the same sample, what are the associated morphological changes in the posterior part of the labyrinth (semicircular canals detecting angular accelerations) ?

This study

Proposed relationships between low-frequency hearing and cochlear geometry



Girl - 5 months
Inst. Anat. Strasbourg



Brugge & Howard 2002

Increased length (mm) from the base to the apex (West, 1985; Coleman & Colbert 2010)

Lower number of spiral turns (West, 1985; Coleman & Colbert 2010)

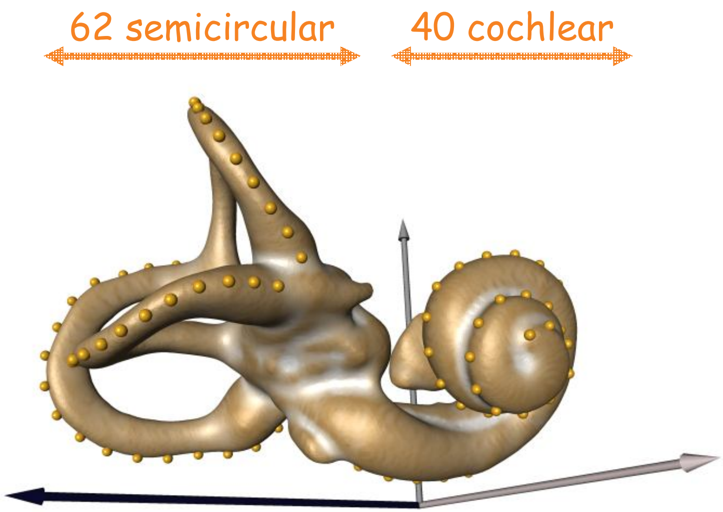
Higher base to apex gradient of curvature (dimensionless ratio) (Manoussaki et al 2008)

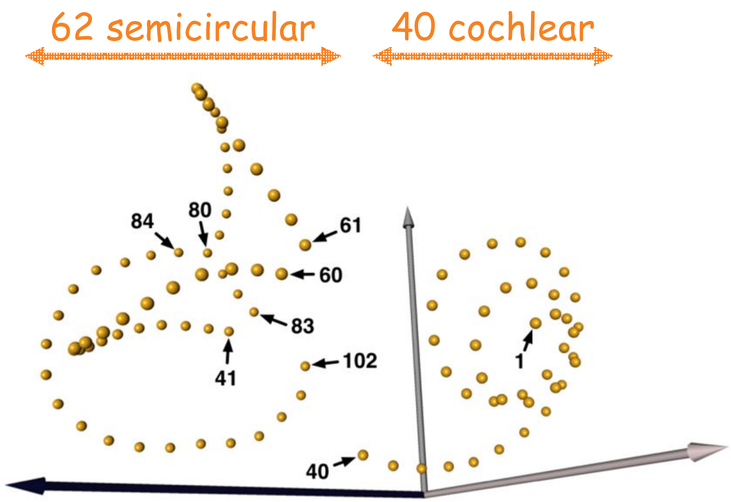
3D geometrical models of bony labyrinths reconstructed from micro-CT scans (41 μm resolution, isotropic) of extant humans (n=22), chimpanzees (n=2), bonobos (n=2), extant "baboons" (*Papio*, *Mandrillus*; n=6), one fossil "baboon" (*Papio* sp.) and one *Oreopithecus* specimen (from Rook et al., 2004).

We combine juveniles and adults assuming that adult morphology is attained before birth (Jeffery and Spoor, 2004).

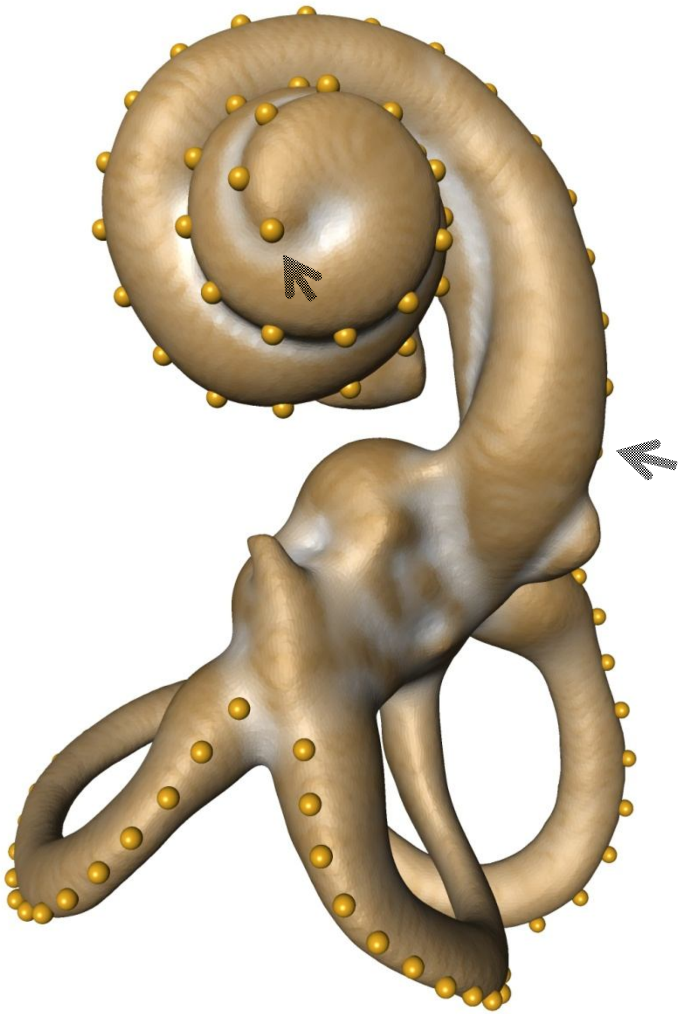
8 anatomical landmarks and 94 semilandmarks distributed equally over the entire bony labyrinth.

Two separate analyses :
- 40 cochlear landmarks (2) and semilandmarks (38)
- 62 semicircular landmarks (6) and semilandmarks (56)





The cochlear warping corresponds to the combination of the torsion and bending of the helix.

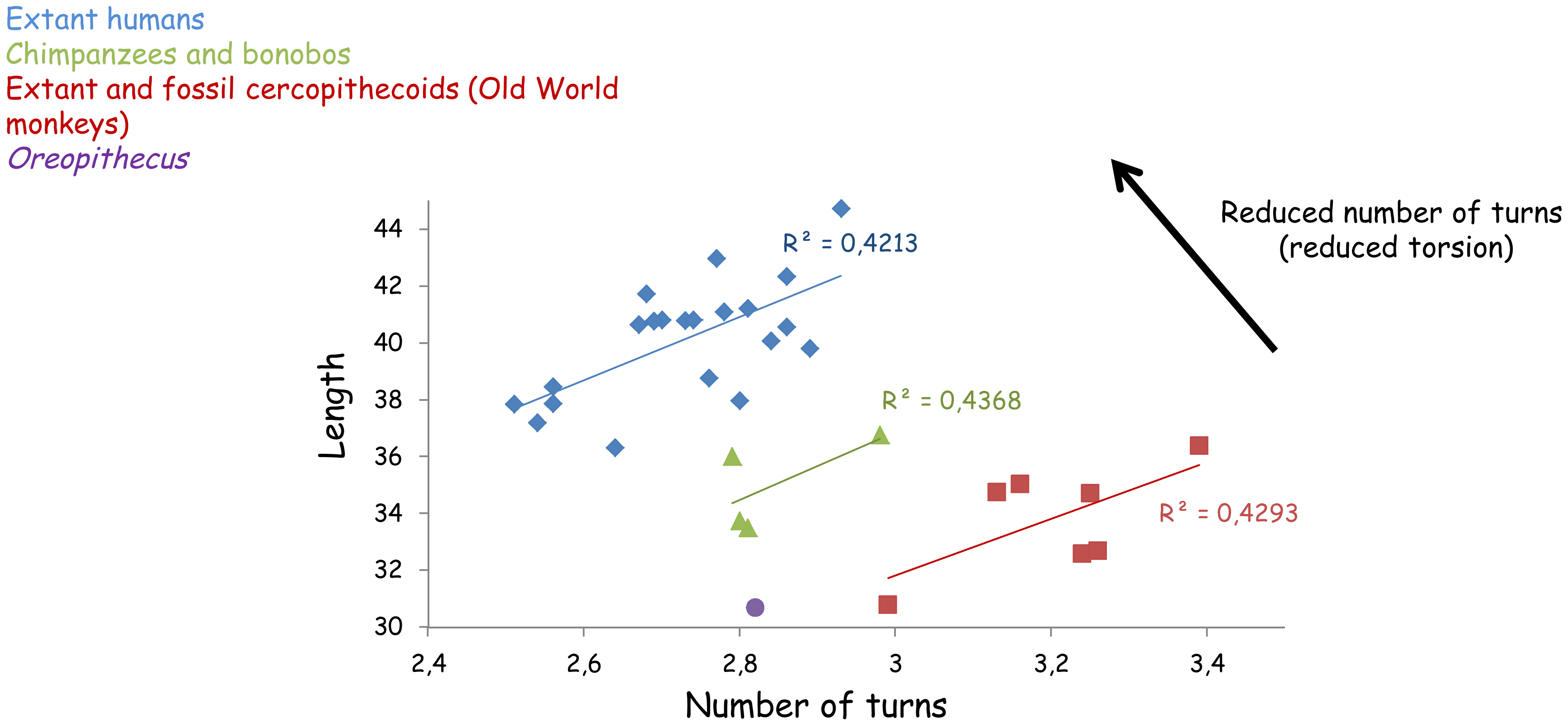


Cochlear outer circumference modeled by an helix with a bending and a torsion :
- radius at the basal turn (bending)
- radius at the apical turn (bending)
- number of turns (torsion)
- pitch (height of one helix turn)

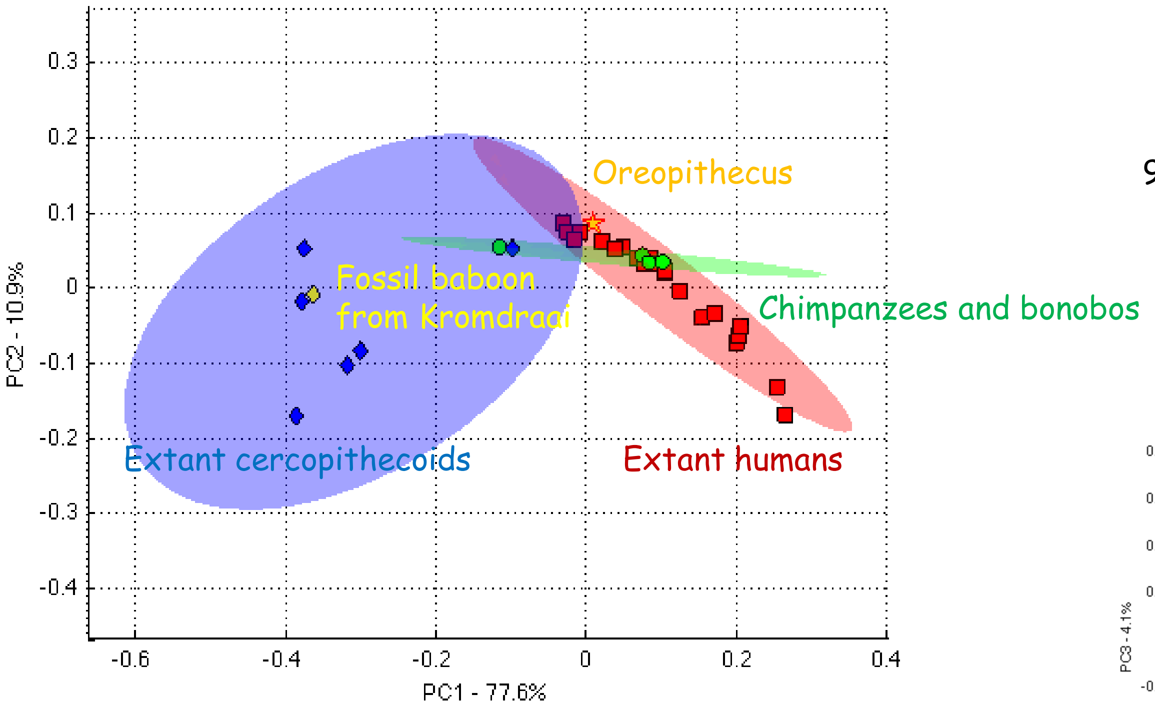
• Limited linear relationship (within groups, approx. 42-43% of cochlear length only explains the number of turns)

• Similar slopes between groups : grade shift from cercopithecoids to humans

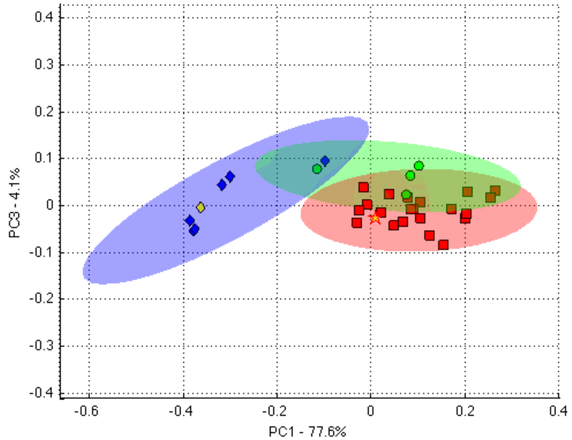
• From cercopithecoids to humans : cochlear lenghtening is accompanied by a reduced number of turns (a reduced torsion)



Cochlea – Principal component analysis of Procrustes shape variables
PC 1 : 77,6 % of variance
Other PCs fail to show any inter-taxon difference (PC 2 : 10,9 % - PC 3 : 4,1 %)

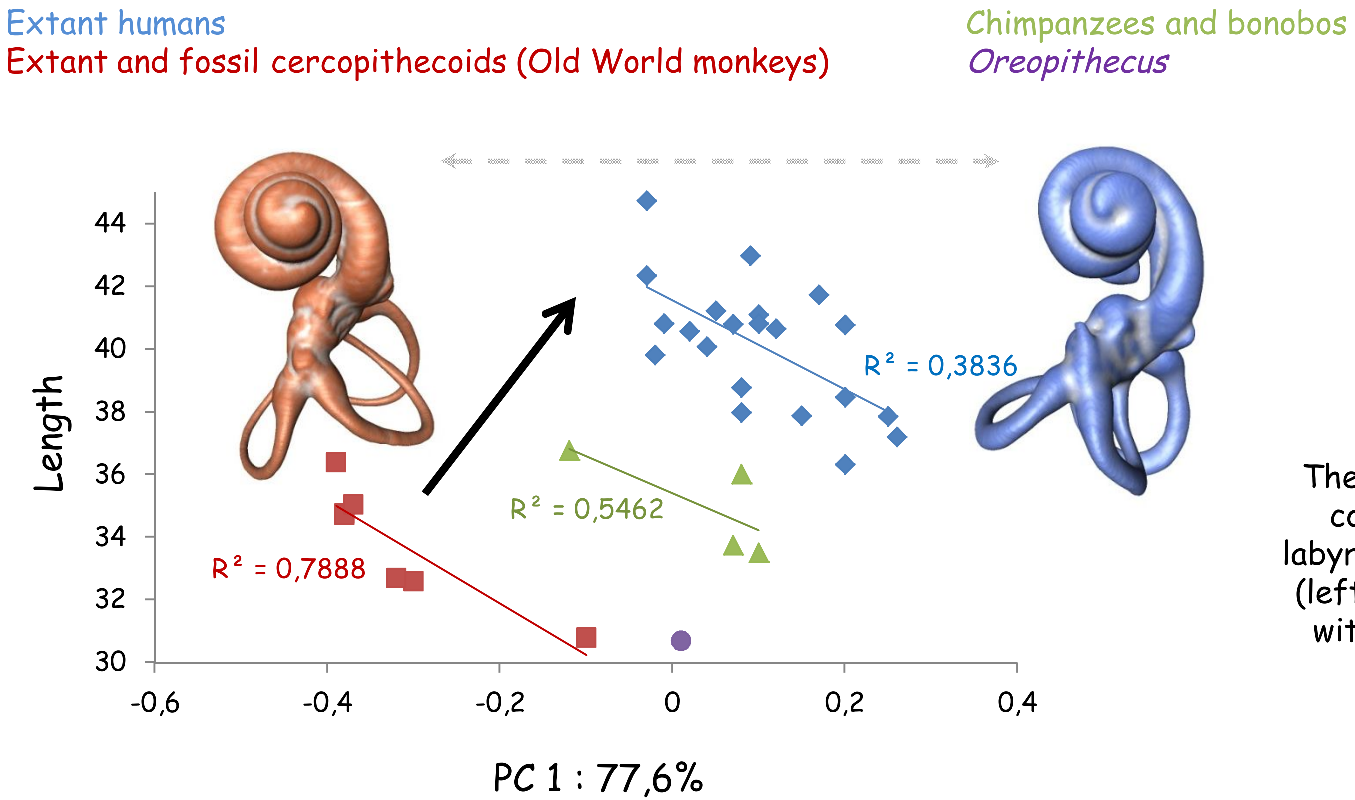


95 % confidence ellipses are shown



• Better linear relationship in cercopithecoids (approx. 79% of cochlear length explains PC 1 in this group)

• Apes display similar lengths than cercopithecoids but higher values on PC 1

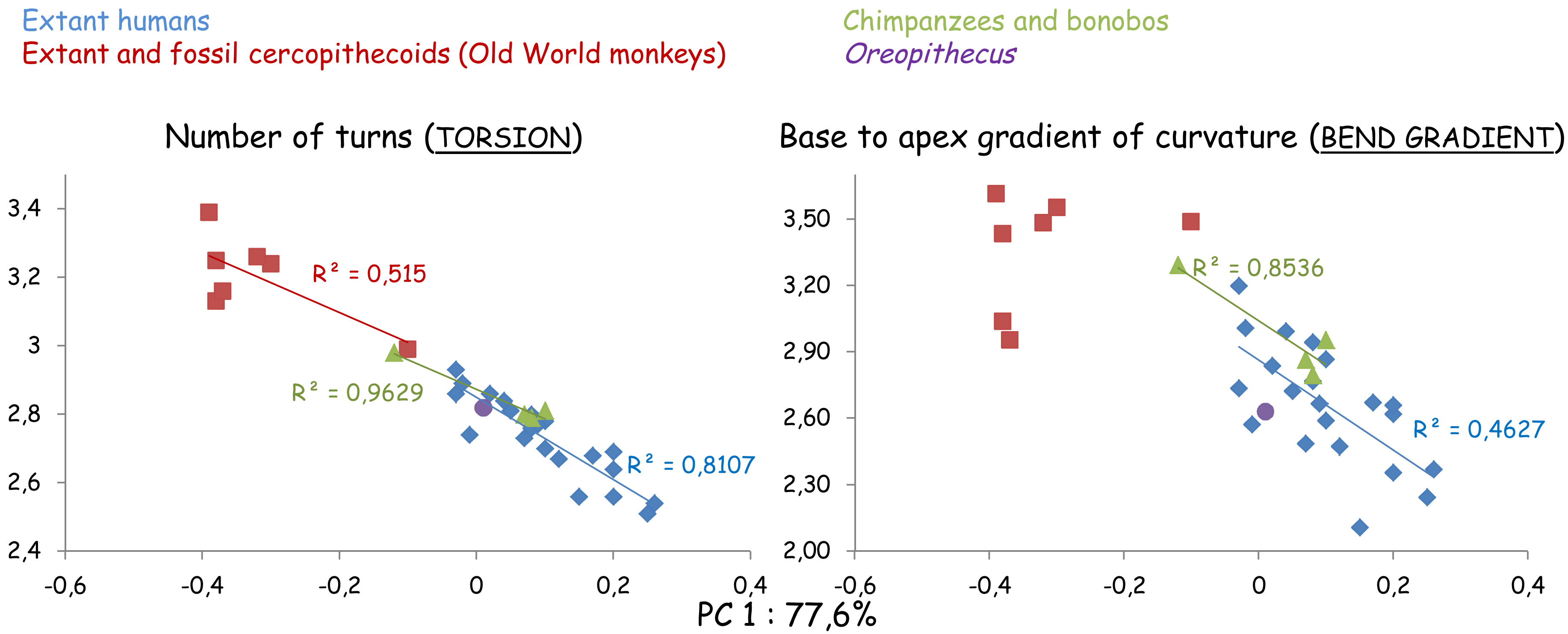


The two surfaces shown here correspond to one baboon labyrinth with PC 1 value at -0,4 (left) and one human labyrinth with PC1 value at 0,3 (right)

• Humans : better linear relationship for the number of turns (approx. 81% of the number of turns explains PC 1). PC 1 positive values for humans correspond to a lower torsion than in cercopithecoids.

• Apes : PC 1 appears to be explained by a bend gradient-torsion coupling (but : very limited ape sampling at this stage); also in extant humans to a lesser extent

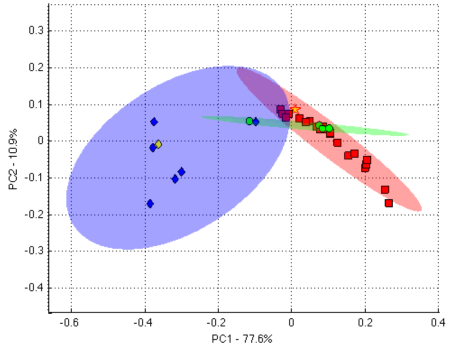
• Limited linear relationships in cercopithecoids for the number of turns (and no relationship for the bend gradient).

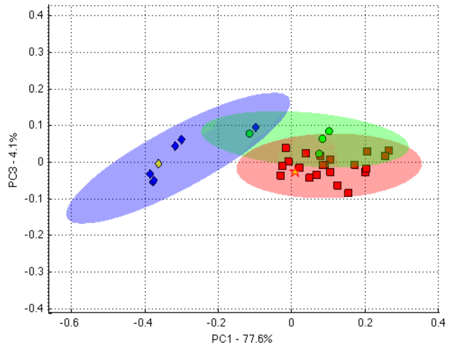


Principal component analysis of Procrustes shape variables

<u>Cochlear morphology (only 40 cochlar landmarks)</u>

- Bend gradient-torsion coupling unique and conservative in hominids ?
- Lenghtening derived in extant humans and some hominin ancestors ?





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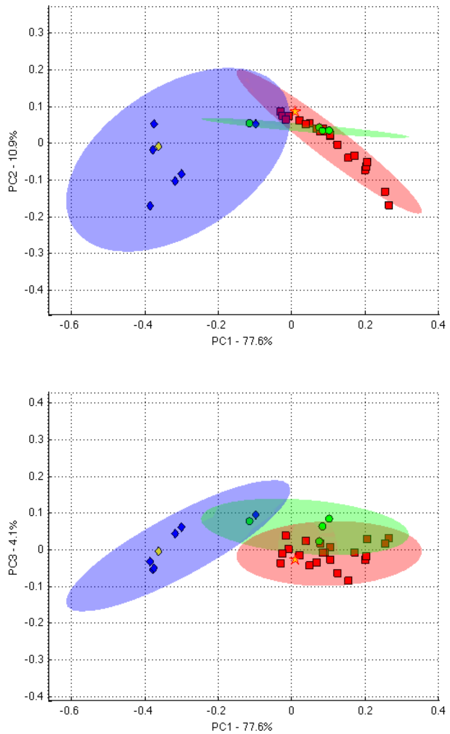
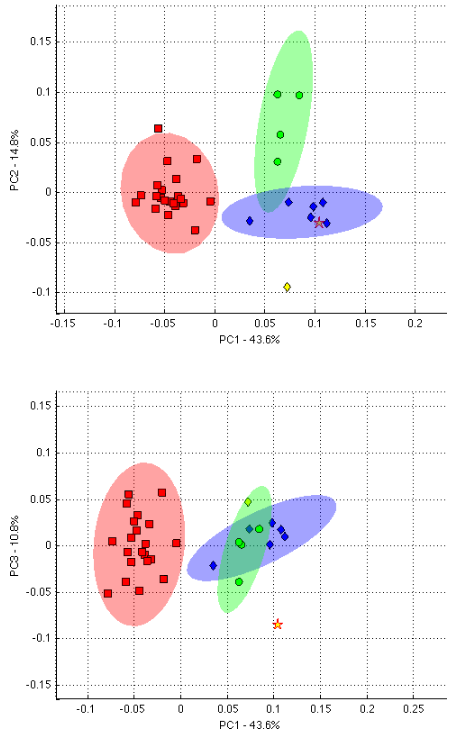


Semicircular morphology (only 62 semincircular landmarks)

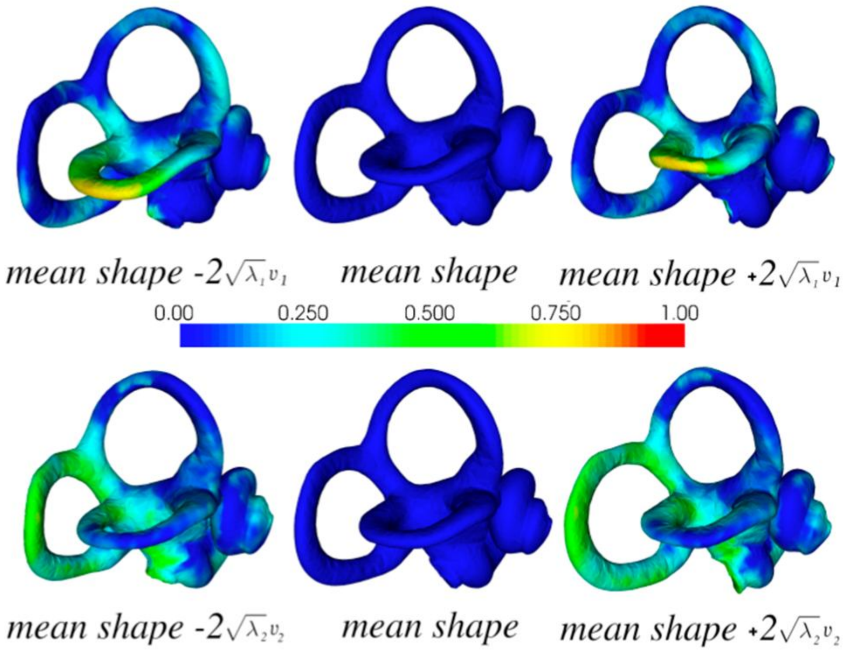
- Not as conservative in hominids ?



Need to investigate more patterns of morphological differences and variabilities

Need for more methods :

Automated computational tools allowing to process 3D free-form surfaces, and more specifically to assess the mean anatomy within a sample, the pattern of variability around this mean, and to compare samples.



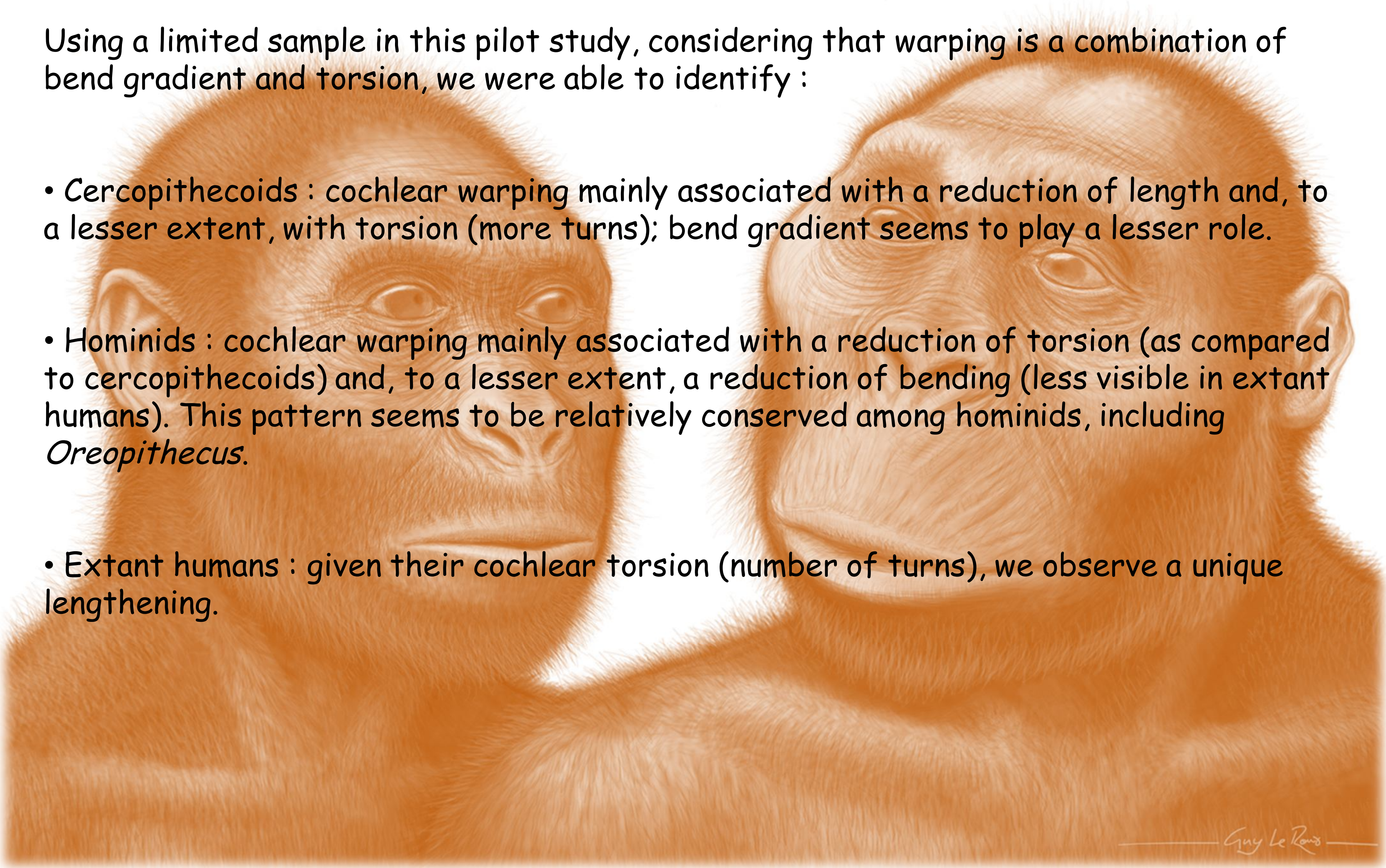
Conclusions

Using a limited sample in this pilot study, considering that warping is a combination of bend gradient and torsion, we were able to identify :

- Cercopithecoids : cochlear warping mainly associated with a reduction of length and, to a lesser extent, with torsion (more turns); bend gradient seems to play a lesser role.

- Hominids : cochlear warping mainly associated with a reduction of torsion (as compared to cercopithecoids) and, to a lesser extent, a reduction of bending (less visible in extant humans). This pattern seems to be relatively conserved among hominids, including *Oreopithecus*.

- Extant humans : given their cochlear torsion (number of turns), we observe a unique lengthening.



Thank you

Ministère des Affaires Etrangères, France, Mission Kromdraai, Afrique du Sud

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