

## Supplementary Online Material (SOM):

Comparative anatomy of the carotid canal in the Miocene small-bodied catarrhine *Pliobates cataloniae*

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## **SOM S1**

### **Extended methodology**

#### *3D carotid canal surfaces*

For each specimen, the carotid canal was virtually extracted through semiautomatic threshold-based segmentation in Avizo v. 7.0 (Visualization Sciences Group, Bordeaux). The right carotid canal was segmented for most specimens; when this was not possible, the left canal was segmented and mirrored. We devised a protocol to identify the two ends (anterior and posterior) of the carotid canal and cut them at homologous points (Fig. 1; SOM Fig. S1), to obtain 3D canal surfaces comparable among specimens. For the posterior end of the canal, we placed landmarks on its external aperture (carotid foramen; SOM Fig. S1a, b), computed the best-fit plane to these landmarks, translated it to be located at the centroid of the landmark set, and finally cut the canal (Fig. 1a). The centroid of the landmarks on the carotid foramen was taken as the posterior endpoint of the canal (Fig. 1l).

The methodology employed to cut the anterior part of the carotid canal was more complex, because its opening on the endocranial surface of the petrosal is irregular and displays a variable outline among individuals. Furthermore, it was not completely preserved in fossil specimens we included here. We started by defining a landmark located posteriorly to the canal opening, and used it to determine the anterior limit at which we could later cut the anterior part of the canal. We defined a landmark termed ‘intersection ridge–groove’ (IRG) that corresponds to the intersection between the anterior pyramidal ridge and the groove of the greater superficial petrosal nerve (SOM Fig. S1c, d; Table 2). Based on IRG, we applied a semiautomatic protocol coded on R v. 3.6.3 (R Core Team, 2020; see script in SOM File S1) to find the plane orthogonal to the 3D carotid canal surface passing through IRG. In particular, the 3D canal surface is first generated and smoothed in Avizo (using a constrained smoothing and a smoothing extent of 3) and then imported as a cloud of points in R (Fig. 1b); the orthogonal projection of IRG onto the canal (IRG’) is calculated (Fig. 1c). These two points (IRG and IRG’) define a main axis, around which infinity of points can be generated, further enabling the creation of infinity of planes. Indeed, a plane can be defined by three points expressed as two vectors, and the axis defined by IRG and IRG’ corresponds to one of the two vectors necessary to compute the orthogonal plane to the canal (passing through IRG), because IRG’ is the orthogonal projection of IRG onto the canal. However, to obtain the second vector, a third point is required, which cannot be defined a priori. We decided to

define the cutting plane as the one that is orthogonal to the 3D canal surface (and therefore to the canal streamline) and thus that minimizes the cross-sectional area resulting from the cut. The protocol generates multiple cutting planes—defined on IRG, IRG', and multiple possible third points—and calculates the cut area for each of them. In particular, we created 360 equally distributed points (differing in 1° of orientation) around the IRG–IRG' axis (Fig. 1d) and computed the cutting cross-sectional area for all the 360 possible cutting planes (Fig. 1e, f). For each plane possibility, among the cloud of points representing the canal, the points that are closest to the plane (i.e., those having an orthogonal distance to the plane equal or shorter than the distance between two adjacent points of the cloud) are identified (Fig. 1g). Among them, only the most external ones are kept and used to form a convex hull approximating the contour of the canal cross-section (Fig. 1h). The area subtended by the convex hull is then subdivided in  $n-2$  triangles, where  $n$  is the number of points that form the hull, using one of the points as the shared vertex (the most acute one) for all the triangles; the area of the triangles is computed and their sum is used as an approximation of the total area of the cross-section (Fig. 1i). The plane for which the resulting cross-sectional area is the smallest is kept and used as reference for cutting the canal at its anterior end (Fig. 1i, j). The centroid of the cross-section obtained by cutting with this orthogonal plane (Fig. 2h–i) is calculated and used as the anterior endpoint of the canal (Fig. 1l).

### *Carotid canal orientation*

We quantified the orientation of the carotid canal within the petrosal by computing a 3D vector representing the canal direction and decomposing it into two 2D angles relative to standard anatomical planes: one angle represents the canal superior orientation (2DYZA) along the (para)sagittal plane, and the other represents its medial orientation (2DXYA) along a transverse plane—respectively corresponding to canal 'orientation' and 'direction' sensu Alba et al. (2015: Tables S5 and S6). The 3D vector representing the canal was computed as a single direction, from the posterior to the anterior endpoints of the canal. All the specimens were first put in the same coordinate system by performing a generalized Procrustes analysis (GPA; Rohlf and Slice, 1990; Bookstein, 1991) using the R package 'Geomorph' v. 3.3.1 (Adams et al., 2019) based on nine petrosal/tympanic landmarks (Fig. 2; Table 2). This allowed us to scale, orient, and locate the petrosals in a standardized way within a common Cartesian coordinate system. The translation-scaling-rotation parameters resulting from this

alignment were then extracted and applied to the two endpoints of the canal vector. Performing the alignment on the petrosal, instead of the canal endpoints or both structures simultaneously, enables the retention of the canal position, orientation and shape inside the petrosal, for each specimen. The coordinates of the posterior and anterior endpoints after the petrosal/tympanic-based alignment were used to compute the 3D vector representing the 3D canal direction.

As the specimens were prealigned, we were able to use a single reference vector to calculate the two 2D angles. Despite some variation among the sample, there is an overall correspondence (with no extreme deviations) between spatial axes of the common Cartesian coordinate system and canal directions after alignment: the X-axis corresponds to the anteromedial–posterolateral direction of the canal, the Y-axis corresponds to its inferomedial–superolateral direction, and the Z-axis corresponds to its anterolateral–posteromedial direction. Considering these correspondences, 2DYZA was calculated as the 2D angle between the YZ coordinates of the canal vector and a reference vector with coordinates (1, -1) corresponding to the cranial anteroposterior axis (from posterior to anterior). In turn, 2DXYA was calculated as the 2D angle between the XY coordinates of the canal vector and a reference vector with coordinates (-0.2, 1) also corresponding to the cranial anteroposterior axis (from posterior to anterior). While in anthropoids the canal runs from a posterolateral location to an anteromedial location, after alignment some specimens display a canal running almost anteroposteriorly or slightly (postero)medio(antero)laterally. To take into account those exceptions the 2DXYA angle was calculated so that positive values correspond to medially oriented canals and negative values identify canals (only a few) slightly laterally oriented.

Because the alignment is based on petrosal/tympanic landmarks, one should consider the possibility that two specimens possessing similar angles relative to the petrosal may display different angles if computed relative to the whole cranium, depending on the orientation and position of the petrosal inside the cranium. However, based on Spoor's (1993) data, differences of superior petrosal surface orientations in the sagittal plane and superior and inferior petrosal surface orientations in the transverse plane are not significant among the main crown anthropoid clades. Furthermore, relying on petrosal/tympanic landmarks for scaling-translating-orienting carotid canal specimens, instead of landmarks from the cranium as a whole, has several advantages besides enabling the analysis of fragmentary fossil

remains. In particular, this procedure may prevent alignment problems related to striking shape differences between extant lineages (such as the elongated muzzle of some papionins, the much more globulous neurocranium of some hominoids, the longer parietal of platyrrhines, etc.), because the variation in petrosal shape seems less marked.

#### *Carotid canal proportions*

After cutting the two ends of the carotid canal, the 3D canal surfaces were generated again without smoothing in Avizo, and the volume ( $V$ , in  $\text{mm}^3$ ) of the closed 3D surfaces was computed using the module 'Surface Area Volume'. The 3D surfaces were then reimported in R and, for each specimen, we calculated canal length ( $L$ , in mm). To do so, we computed nine semilandmarks corresponding to the centroids of the canal cross-sections obtained by means of nine equidistant slices generated along the two canal endpoints (i.e., type III landmarks; Bookstein, 1991). The resulting 11 streampoints (2 endpoints + 9 centroids in between) were used to generate 8 equidistant streampoints between the 2 endpoints using the 'digit.curve' function of 'Geomorph' v. 3.3.1—the sliding process embedded in this function requiring to set a number of final points smaller than the original number of points. Based on these 10 equidistant streampoints representing the canal streamline we computed nine segments (distances), whose sum was taken as canal length.

#### *Carotid canal course within the petrosal*

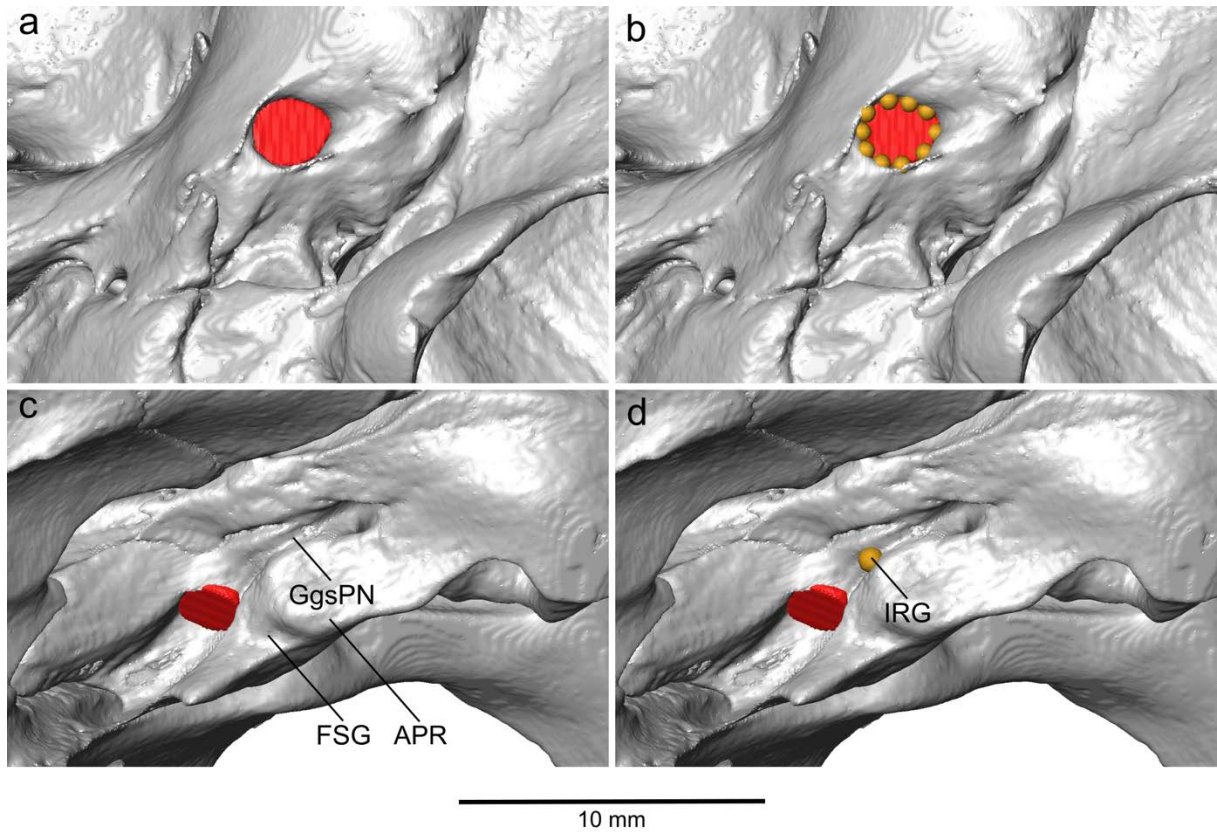
To assess the course of the carotid canal within the petrosal we used a similar approach to that employed for computing  $L$ . We took the 10 equidistant streampoints previously computed during the calculation of  $L$ . As mentioned above, these 10 streampoints follow the streamline of the canal, i.e., de facto they represent the canal course. Then we applied the translation-scaling-rotation parameters resulting from the alignment of the petrosals described above to the 10 streampoints. As for the canal orientation, this procedure allowed us retaining the information on the variation of position, orientation and shape of the canal inside the petrosal. The configuration of the 10 canal streampoints obtained after alignment therefore represents the course of the carotid canal within the petrosal.

#### *Phylogenetic tree*

To compute PGLS regressions and quantify phylogenetic signal we used a time-calibrated tree representing the phylogenetic relationships among the extant taxa included in the comparative sample. The tree was derived from the 10kTrees website (Arnold et al., 2010), with some modifications to account for not included species in the 10kTrees website: (1) *Simias concolor* was added as the sister taxon of *Nasalis larvatus* with a divergence time at 2.16 Ma (Springer et al., 2012); (2) *Presbytis rubicunda* was replaced by data on *Presbytis melalophos*, which is its closest species (Meyer et al., 2011; Springer et al., 2012); (3) *Pithecia monachus* was added as the sister taxon of *Pithecia pithecia*, with a divergence time between both taxa set at 3.46 Ma (Springer et al., 2012); (4) *Chiropotes chiropotes* was added as the sister taxon of *Pithecia* spp., with a divergence time set at 13.27 Ma (Springer et al., 2012); (5) *Plecturocebus cupreus* was added as the sister taxon of the *Chiropotes-Pithecia* clade, with a divergence time set at 19.84 Ma (Springer et al., 2012).

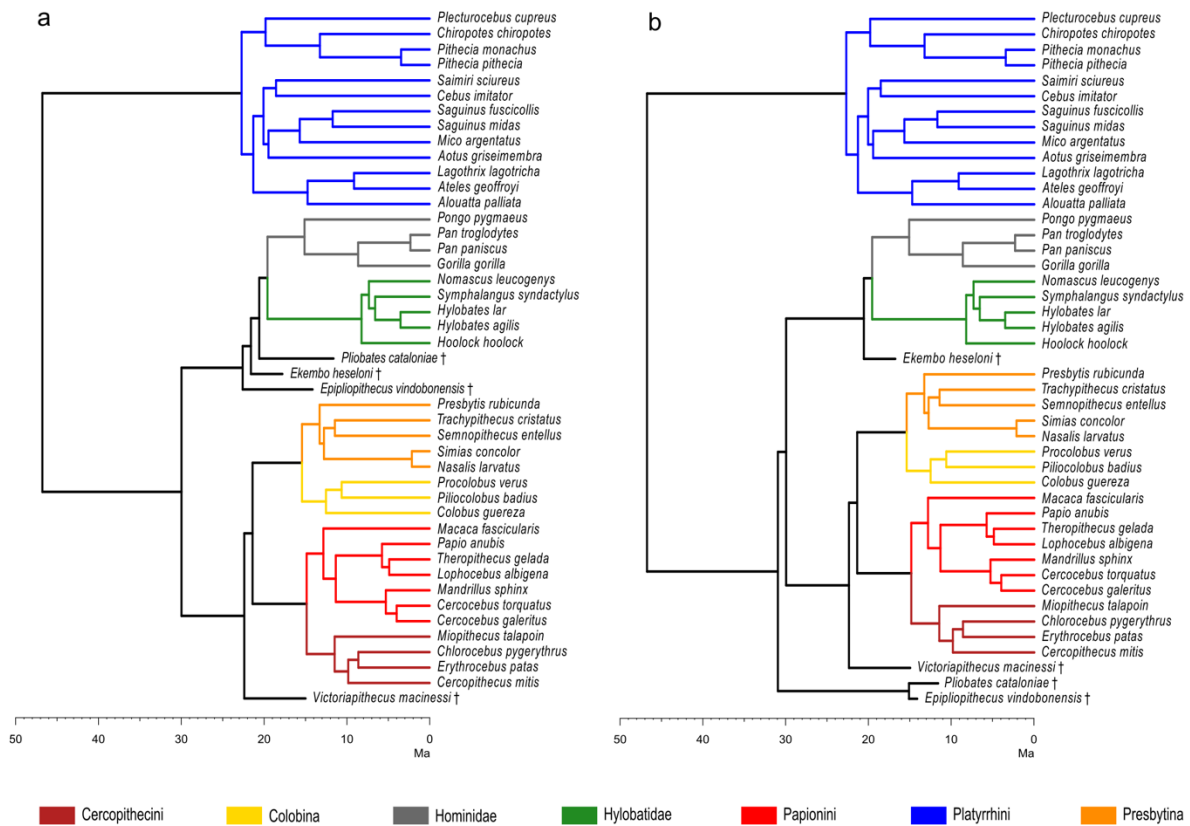
We further used two different hypotheses for the phylogenetic relationships among the investigated fossil genera and extant catarrhines, with the exception of *Victoriapithecus*, considered a stem cercopithecoid in both instances. The tips of the fossil taxa were set based on their geological age: *Victoriapithecus* at 15 Ma (Benefit, 1999); *Epipliopithecus* at 14.15 Ma (as estimated from the midpoint of MN6 in Europe based on van der Meulen et al., 2011); *Pliobates* at 11.62 Ma (Alba et al. 2017); and *Ekembo* at 17.8 Ma (as the midpoint of the maximum-minimum range of the Kulu Formation in Rusinga Island, where *E. heseloni* has been found; Drake et al., 1988; Peppe et al., 2009; Harrison, 2010). The divergence between *Victoriapithecus* and crown cercopithecoids was set 1 Myr older than the cercopithecine-colobine divergence (21.41 Ma). Under hypothesis 1 (SOM Fig. S2a), *Epipliopithecus*, *Ekembo*, and *Pliobates* are considered successive stem hominoids, following the results of Alba et al.'s (2015) cladistic analysis. Their divergence from crown hominoids was set 3, 2 and 1 Myr before the hominid-hylobatid divergence date (19.61 Ma), respectively. In contrast, under hypothesis 2 (SOM Fig. S2b) only *Ekembo* is considered a stem hominoid, while both *Pliobates* and *Epipliopithecus* are considered stem catarrhines within a pliopithecoid clade, following the results of other cladistic analyses (Nengo et al., 2017; Gilbert et al., 2020). The divergence between *Epipliopithecus* and *Pliobates* was set 1 Myr older than the oldest occurrence of either of them (1 Myr older than *Epipliopithecus*, i.e., 15.15 Ma), while the divergence between pliopithecoids and crown catarrhines was set 1 Myr older than the divergence between cercopithecoids and hominoids (30 Ma), as this is

older than the oldest documented occurrence of pliopithecoids in the fossil record (18–17 Ma; Harrison, 2013, 2017; Begun, 2017).

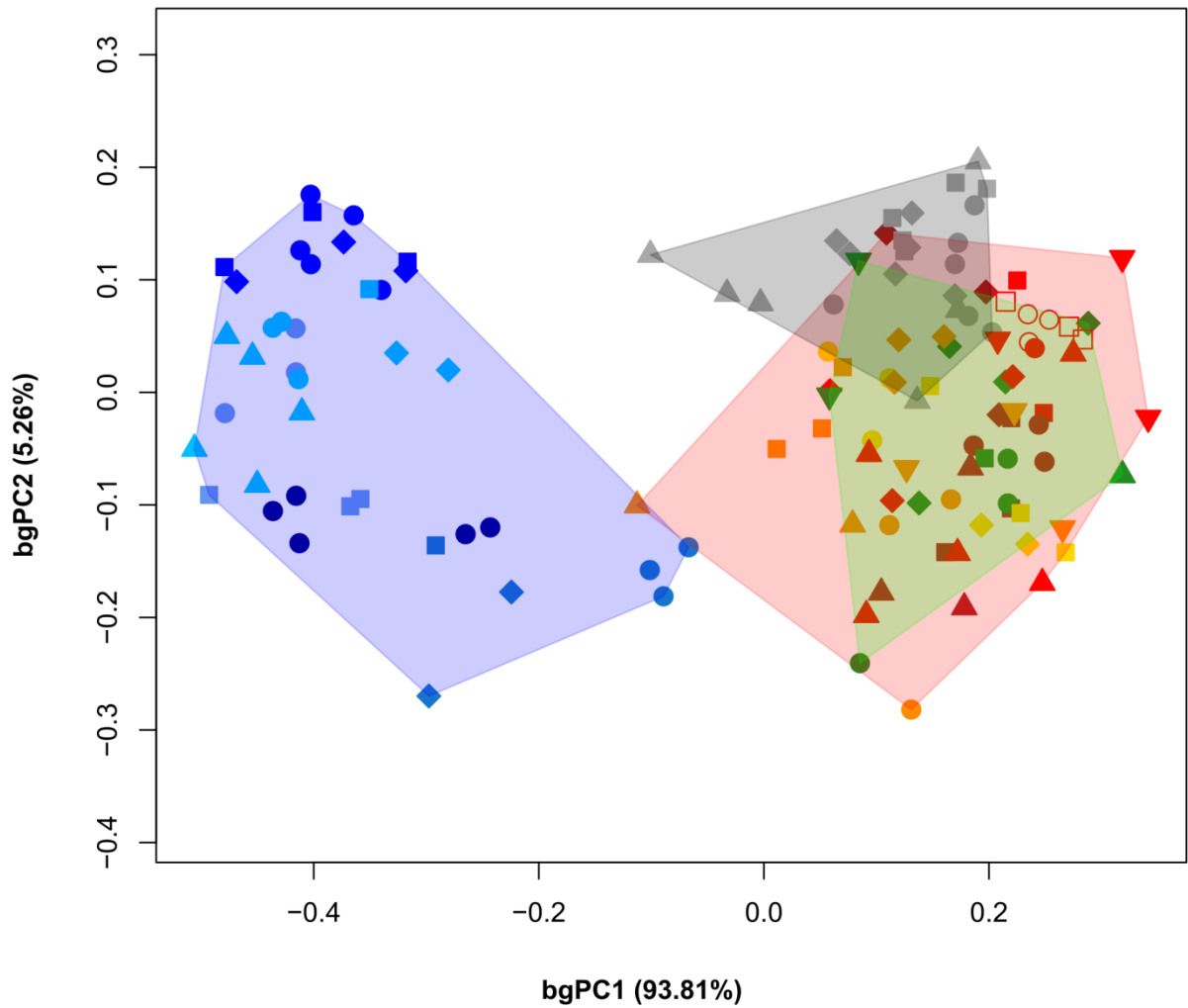


**SOM Figure S1.** Landmarks used for delimiting the extremities of the carotid canal as exemplified in a *Macaca fascicularis* individual. The 3D canal surface (in red; a) is posteriorly defined by putting landmarks on the rim of the carotid foramen (b). The anterior limit of the canal (in red; c) is identified by placing a landmark (IRG) at the intersection between the anterior pyramidal ridge and the groove for the greater superficial petrosal nerve (d). Abbreviations: APR = anterior pyramidal ridge; FSG = fossa for the semilunar ganglion; GgsPn = groove of the greater superficial petrosal nerve; IRG = intersection ridge–groove.



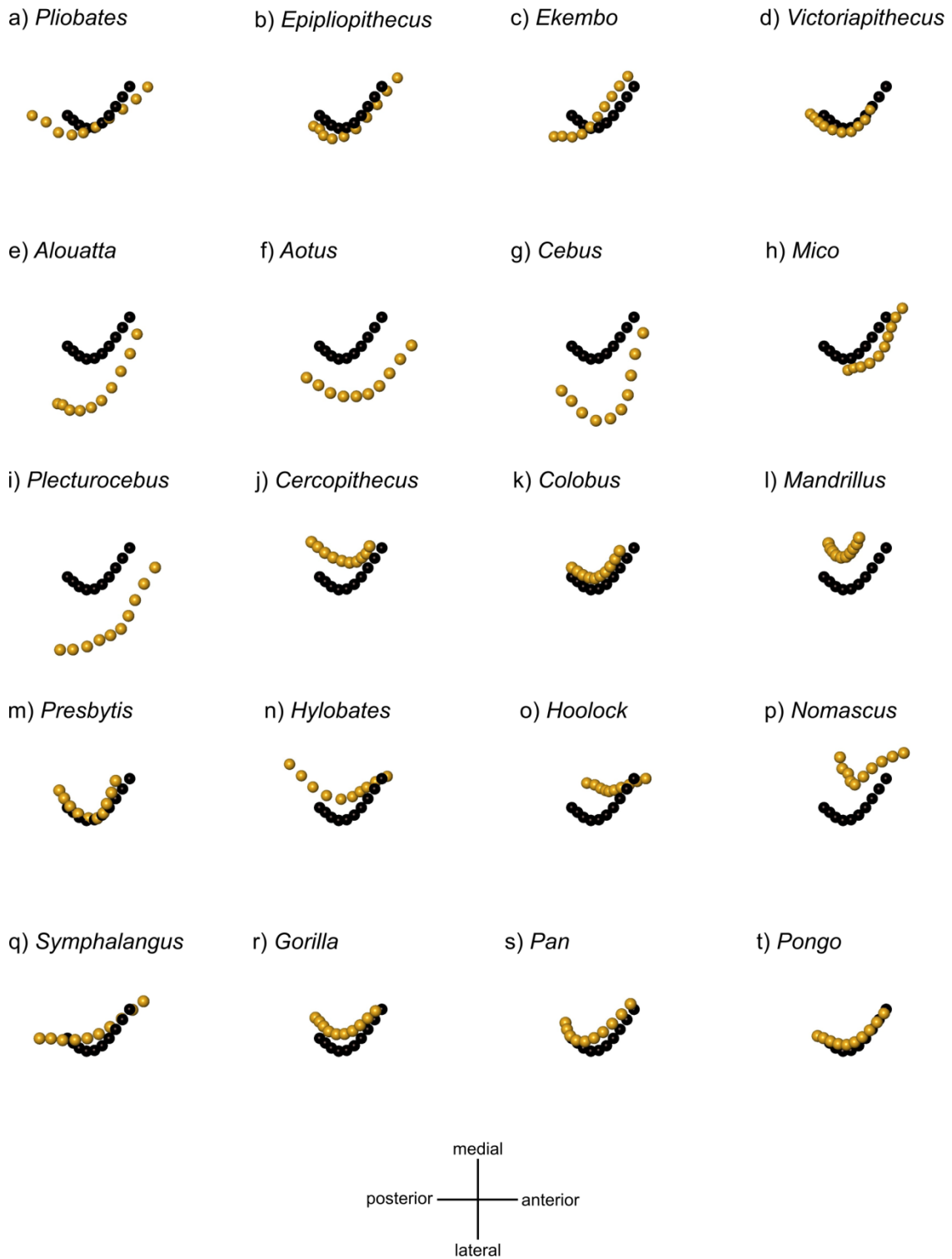


**SOM Figure S2.** Time-calibrated phylogenetic trees of extant anthropoids and selected extinct catarrhines (denoted by a dagger) used in this paper to compute phylogenetic generalized least-squares regressions (excluding fossils), phylogenetic signal (excluding fossils), and phylomorphospaces. The trees are based on molecular data and derived from the 10kTrees website v. 3 (Arnold et al., 2010) with some modifications based on Meyer et al. (2011) and Springer et al. (2012). Extinct taxa were added a posteriori according to the two phylogenetic hypotheses considered in this paper: a) *Epipliopithecus*, *Ekembo* and *Pliobates* are considered successive stem hominoids following Alba et al. (2015: Fig. 8); b) *Epipliopithecus* and *Pliobates* are considered sister taxa within a stem catarrhine pliopithecoid clade and *Ekembo* is considered a stem hominoid, following Nengo et al. (2017: Fig. 5) and Gilbert et al. (2020: Fig. 4). *Victoriapithecus* is considered a stem cercopithecoid under both hypotheses. The point estimates for extinct taxa correspond to their occurrence in the fossil record (Drake et al., 1988; Benefit, 1999; Peppe et al., 2009; van der Meulen et al., 2011; Alba et al., 2017). See SOM S1 for further details.



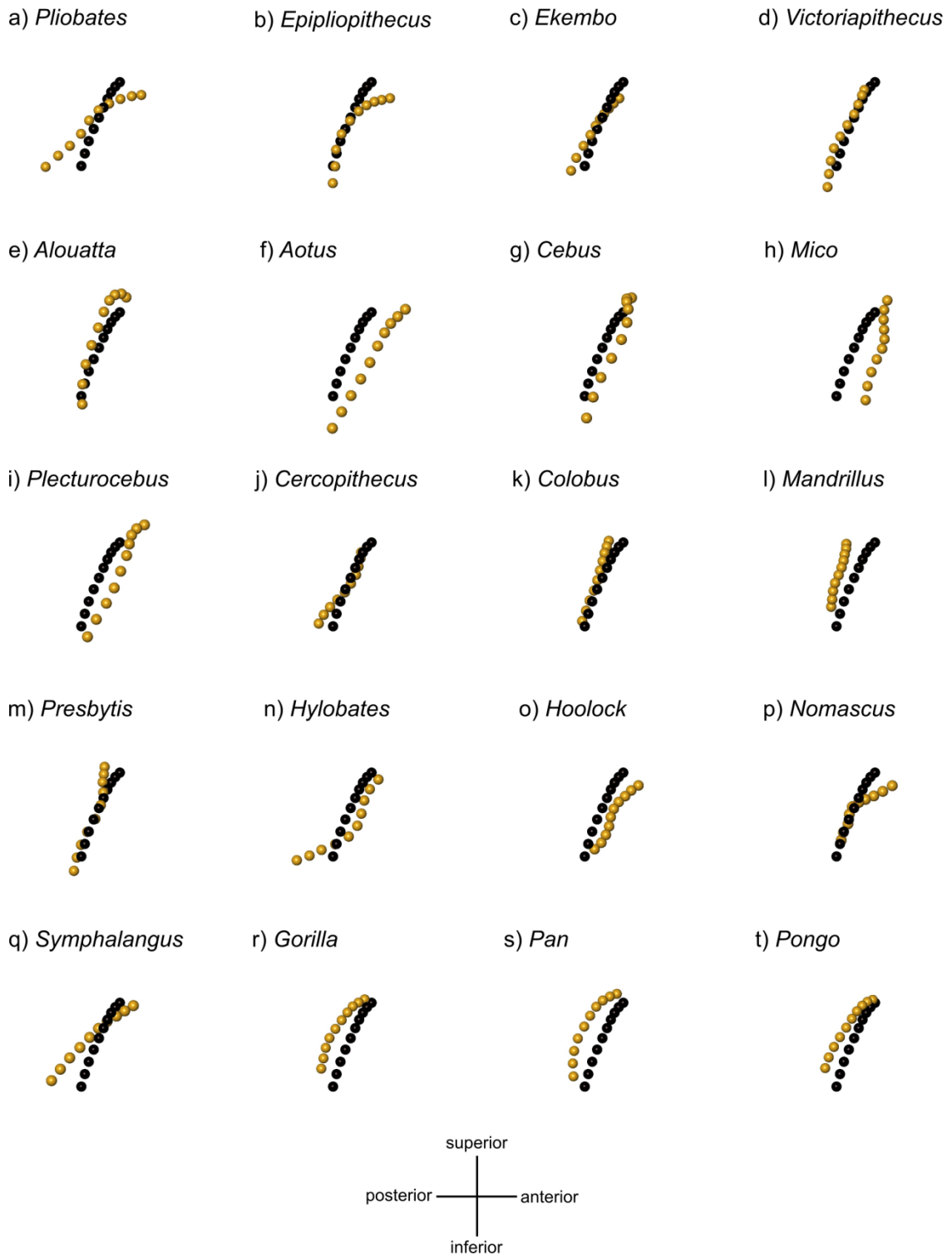
- |                                 |                                  |                                   |                                   |
|---------------------------------|----------------------------------|-----------------------------------|-----------------------------------|
| ● <i>Alouatta palliata</i>      | ● <i>Cercocebus galeritus</i>    | ● <i>Colobus guereza</i>          | ● <i>Gorilla gorilla</i>          |
| ■ <i>Ateles geoffroyi</i>       | ■ <i>Cercocebus torquatus</i>    | ■ <i>Ptilocolobus badius</i>      | ■ <i>Pan paniscus</i>             |
| ◆ <i>Lagothrix lagotricha</i>   | ◆ <i>Lophocebus albigena</i>     | ◆ <i>Procolobus verus</i>         | ◆ <i>Pan troglodytes</i>          |
| ● <i>Aotus griseimembra</i>     | ▲ <i>Macaca fascicularis</i>     | ● <i>Nasalis larvatus</i>         | ▲ <i>Pongo sp.</i>                |
| ● <i>Mico argentatus</i>        | ▼ <i>Mandrillus sphinx</i>       | ■ <i>Presbytis rubicunda</i>      | ● <i>Hoolock hoolock</i>          |
| ■ <i>Saguinus fuscicollis</i>   | ○ <i>Papio anubis</i>            | ◆ <i>Semnopithecus entellus</i>   | ■ <i>Hylobates agilis</i>         |
| ◆ <i>Saguinus midas</i>         | □ <i>Theropithecus gelada</i>    | ▲ <i>Simias concolor</i>          | ◆ <i>Hylobates lar</i>            |
| ● <i>Cebus imitator</i>         | ● <i>Cercopithecus mitis</i>     | ▼ <i>Trachypithecus cristatus</i> | ▲ <i>Nomascus leucogenys</i>      |
| ■ <i>Saimiri sciureus</i>       | ■ <i>Chlorocebus pygerythrus</i> |                                   | ▼ <i>Symphalangus syndactylus</i> |
| ● <i>Cheirotopes chiropotes</i> | ◆ <i>Erythrocebus patas</i>      |                                   |                                   |
| ■ <i>Pithecia monachus</i>      | ▲ <i>Miopithecus talapoin</i>    |                                   |                                   |
| ◆ <i>Pithecia pithecia</i>      |                                  |                                   |                                   |
| ▲ <i>Plecturocebus cupreus</i>  |                                  |                                   |                                   |

**SOM Figure S3.** Results of the cross-validated between-group principal component analysis (CV-bgPCA) using main extant anthropoid clades as the grouping factor, as depicted by a bivariate plot of bgPC2 vs. bgPC1. Convex hulls correspond to: platyrrhines (blue), cercopithecids (red), hylobatids (green), and hominids (gray). Abbreviation: CV-bgPC = cross-validated between-group principal component.



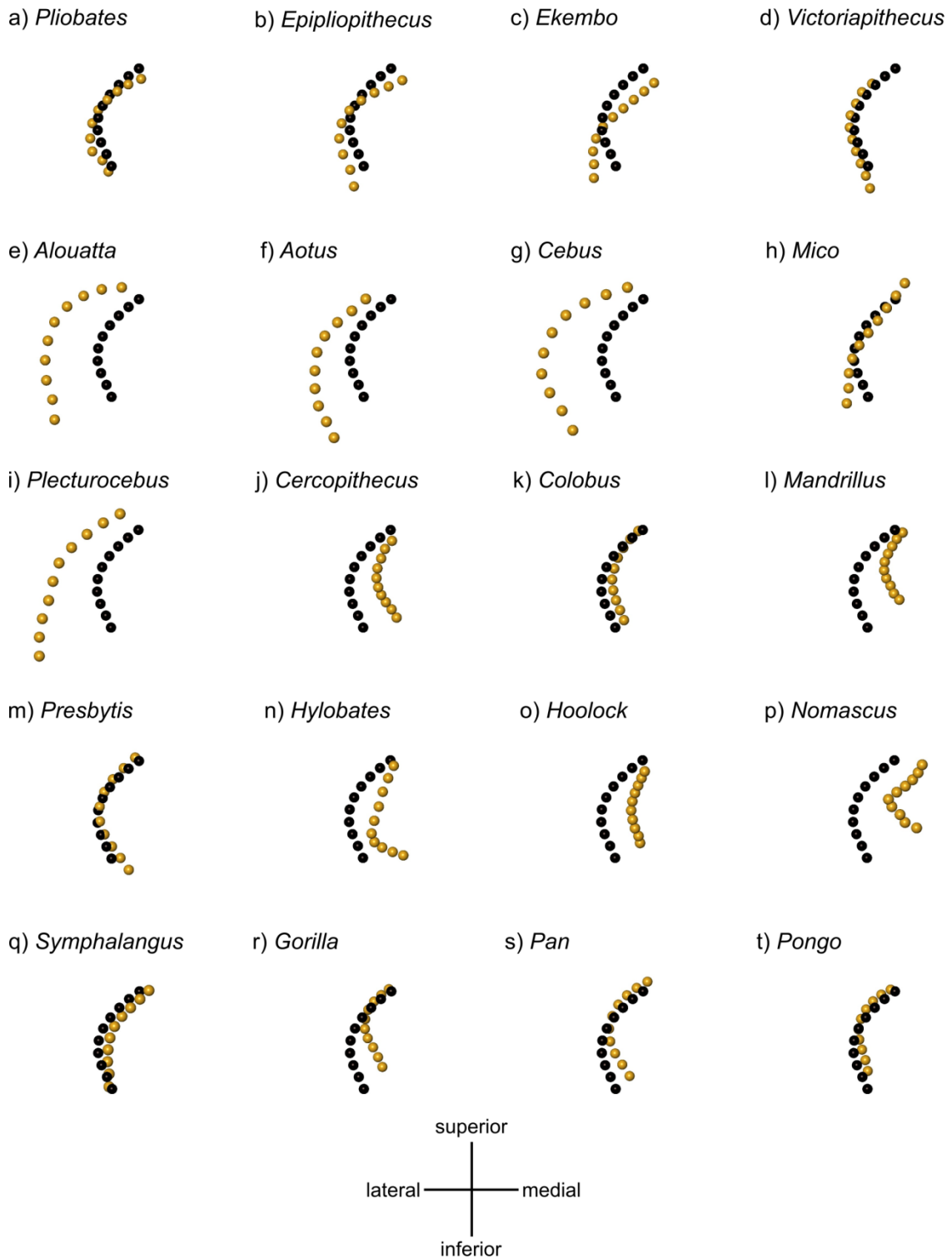
**SOM Figure S4.** Configurations of the carotid canal course in *Pliobates* compared with fossil and extant anthropoids in superior view: a) *Pliobates* (IPS58443.1); b) *Epiplioipithecus* (NHMW 1970/1397/0003); c) *Ekembo* (KNM-RU 2036al); d) *Victoriapithecus* (KNM-MB 29100); e) *Alouatta*; f) *Aotus*; g) *Cebus*; h) *Mico*; i) *Plecturocebus*; j) *Cercopithecus*; k) *Colobus*; l) *Mandrillus*; m) *Presbytis*; n) *Hylobates*; o) *Hoolock*; p) *Nomascus*; q)

*Symphalangus*; r) *Gorilla*; s) *Pan*; t) *Pongo*. The mean configuration computed for the whole anthropoid sample is represented by black dots while configurations for specimens are represented in beige. For a better understanding of the canal course variation in space the anthropoid mean configuration was used as a reference for visualizing all the configurations at the same relative scale.



**SOM Figure S5.** Configurations of the carotid canal course in *Pliobates* compared with fossil and extant anthropoids in lateral view: a) *Pliobates* (IPS58443.1); b) *Epipliopithecus* (NHMW 1970/1397/0003); c) *Ekembo* (KNM-RU 2036al); d) *Victoriapithecus* (KNM-MB 29100); e) *Alouatta*; f) *Aotus*; g) *Cebus*; h) *Mico*; i) *Plecturocebus*; j) *Cercopithecus*; k) *Colobus*; l) *Mandrillus*; m) *Presbytis*; n) *Hylobates*; o) *Hoolock*; p) *Nomascus*; q) *Symphalangus*; r) *Gorilla*;

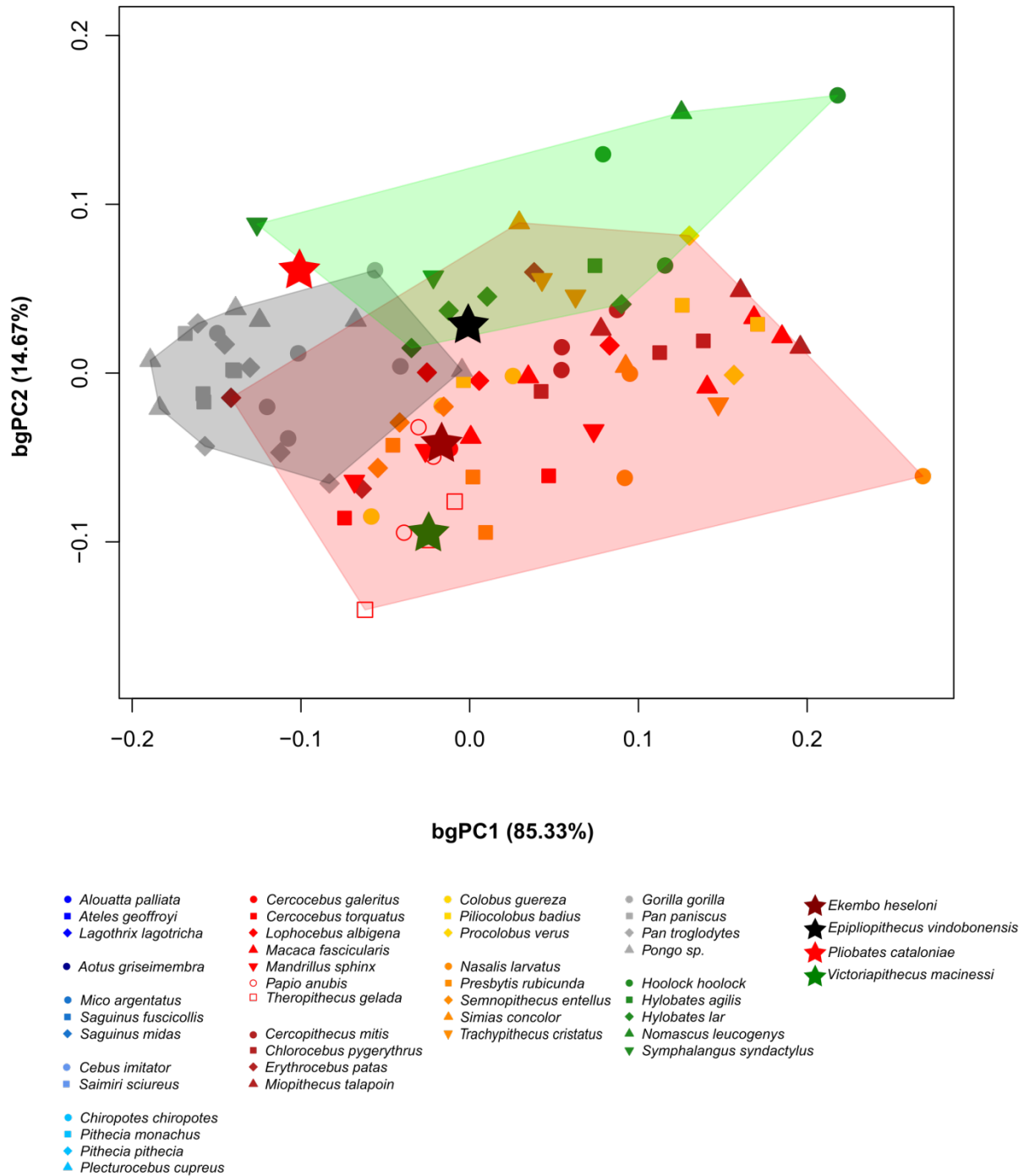
s) *Pan*; t) *Pongo*. The mean configuration computed for the whole anthropoid sample is represented by black dots while configurations for specimens are represented in beige. For a better understanding of the canal course variation in space the anthropoid mean configuration was used as a reference for visualizing all the configurations at the same relative scale.



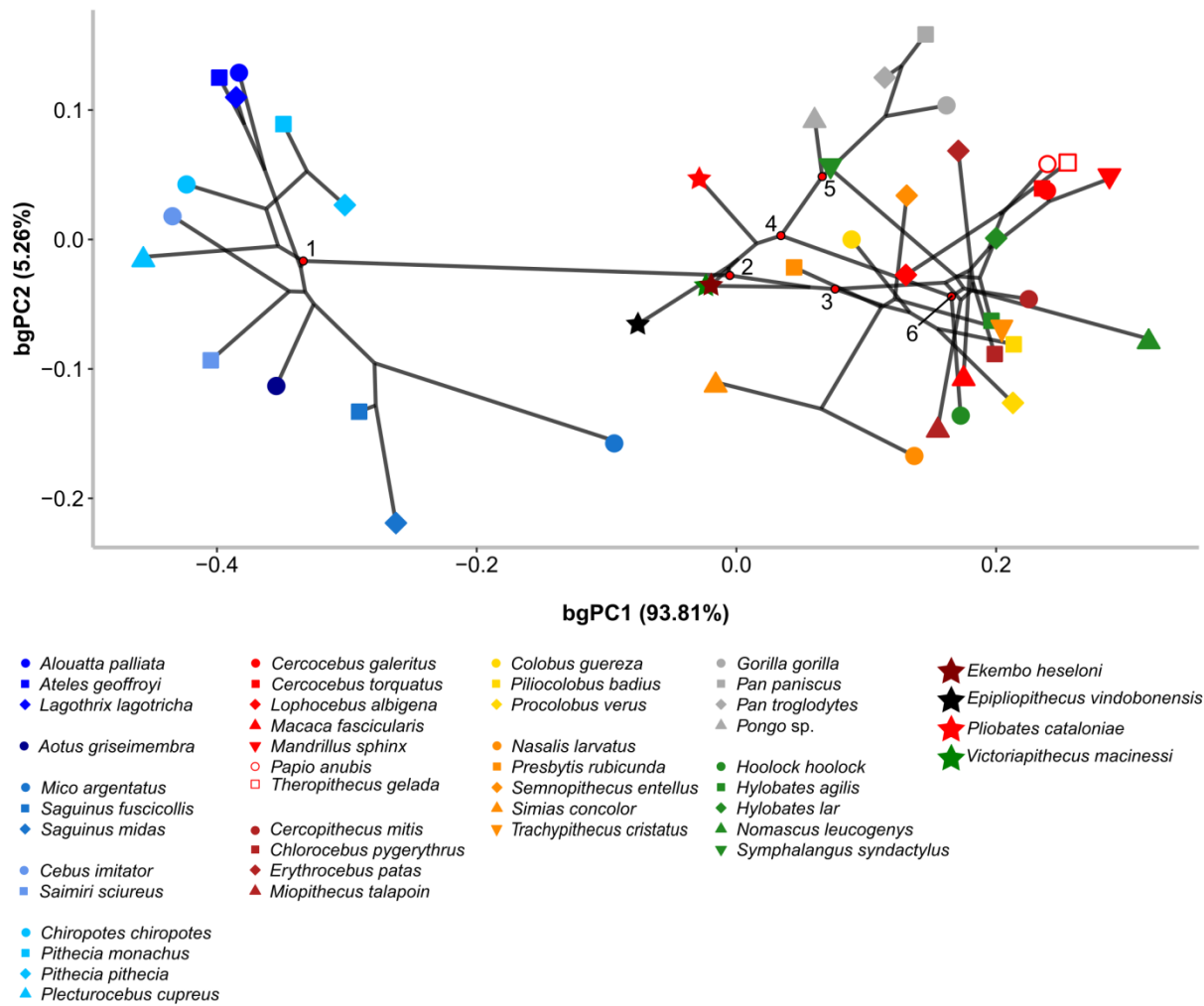
**SOM Figure S6.** Configurations of the carotid canal course in *Pliobates* compared with fossil and extant anthropoids in anterior view: a) *Pliobates* (IPS58443.1); b) *Epipliopithecus* (NHMW 1970/1397/0003); c) *Ekembo* (KNM-RU 2036al); d) *Victoriapithecus* (KNM-MB 29100); e) *Alouatta*; f) *Aotus*; g) *Cebus*; h) *Mico*; i) *Plecturocebus*; j) *Cercopithecus*; k) *Colobus*; l) *Mandrillus*; m) *Presbytis*; n) *Hylobates*; o) *Hoolock*; p) *Nomascus*; q)

*Symphalangus*; r) *Gorilla*; s) *Pan*; t) *Pongo*. The mean configuration computed for the whole anthropoid sample is represented by black dots while configurations for specimens are represented in beige. For a better understanding of the canal course variation in space the anthropoid mean configuration was used as a reference for visualizing all the configurations at the same relative scale.

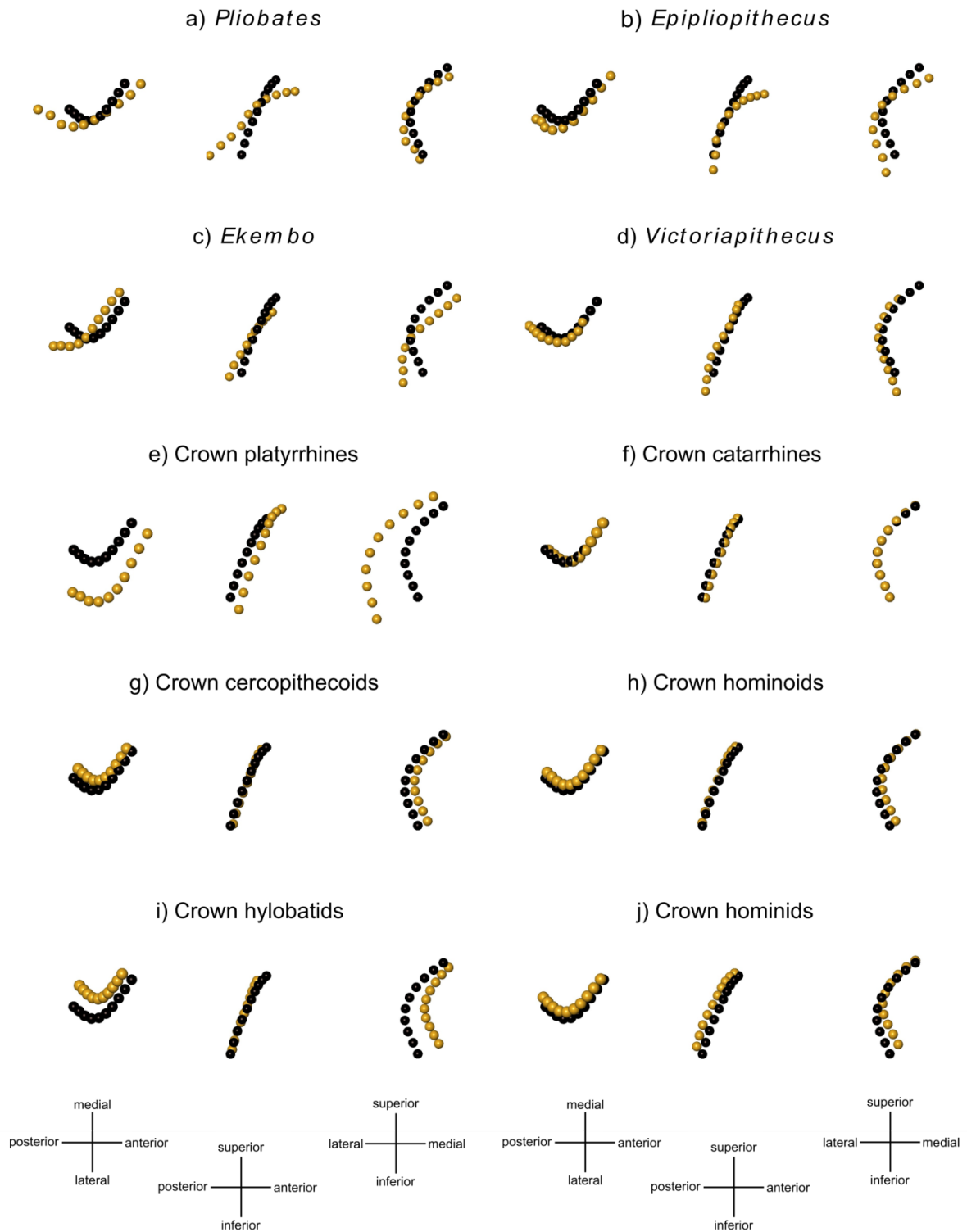




**SOM Figure S7.** Results of the between-group principal component analysis (bgPCA) based on carotid canal course variation among the catarrhine subsample, as depicted by a bivariate plot of bgPC2 vs. bgPC1. Convex hulls correspond to: cercopithecids (red), hylobatids (green), and hominids (gray). Abbreviation: bgPC = between-group principal component.



**SOM Figure S8.** Phylomorphospace of carotid canal course variation in extant anthropoids and extinct Miocene catarrhines including *Pliobates*. *Epipliopithecus*, *Ekembo* and *Pliobates* are considered successive stem hominoids following Alba et al. (2015: Fig. 8), while *Victoriapithecus* is considered a stem cercopithecoid. See SOM Figure S2a for a representation of this phylogenetic hypothesis. Ancestral nodes: 1 = crown platyrrhines; 2 = crown catarrhines; 3 = crown cercopithecoids; 4 = crown hominoids; 5 = crown hominids; 6, crown hylobatids.



**SOM Figure S9.** Configurations of the carotid canal course in *Pliobates* compared with other Miocene catarrhines and with the reconstructed carotid canal course for the last common ancestors (LCAs) of various anthropoid clades: a) *Pliobates* (IPS58443.1); b) *Epiplioptithecus* (NHMW 1970/1397/0003); c) *Ekembo* (KNM-RU 2036al); d) *Victoriapithecus* (KNM-MB 29100); e) crown platyrrhines; f) crown catarrhines; g) crown cercopithecoids; h) crown

hominoids; i) crown hylobatids; j) crown hominids. The canal courses of the LCAs have been inferred based on the phylomorphospace displayed in SOM Figure S8. For each specimen/LCA, the configurations are displayed in superior (left), lateral (middle), and anterior (right) views. The mean configuration computed for the whole anthropoid sample is represented by black dots, while configurations for Miocene catarrhines and LCAs are represented in beige. The anthropoid mean configuration was used as a reference for visualizing all the configurations at the same relative scale.

## SOM Table S1

List of extant anthropoid specimens included in this work.  $\mu$ CT scans were mainly downloaded from MorphoSource (<https://www.morphosource.org>, Duke University) or provided by Sergio Almécija (used in Urciuoli et al., 2020;  $\mu$ CT scans stored at the AMNH, New York, USA) and the Institut Català de Paleontologia Miquel Crusafont (ICP; Sabadell, Spain).

Species	ID	Source	Voxel size (mm)	Sex	DOI/Ark identifier/Occurrence ID	MorphoSource ID
<i>Alouatta palliata</i>	DUEALP 04	Morphosource	0.061	M	—	S1924
<i>Alouatta palliata</i>	DUEALP 06	Morphosource	0.067	M	—	S78
<i>Alouatta palliata</i>	DUEALP 13	Morphosource	0.052	F	—	S1108
<i>Alouatta palliata</i>	DUEALP 14	Morphosource	0.055	F	—	S1925
<i>Alouatta palliata</i>	DUEALP 16	Morphosource	0.058	F	—	S80
<i>Aotus griseimembra</i>	USNM 281551	Morphosource	0.036	M	<a href="http://n2t.net/ark:/65665/31db1d5a6-9879-459b-b08e-89e55015542e">http://n2t.net/ark:/65665/31db1d5a6-9879-459b-b08e-89e55015542e</a>	S3994
<i>Aotus griseimembra</i>	USNM 281552	Morphosource	0.034	F	<a href="http://n2t.net/ark:/65665/3b29a3a53-e84f-4f04-9e48-bc203f45765c">http://n2t.net/ark:/65665/3b29a3a53-e84f-4f04-9e48-bc203f45765c</a>	S3980
<i>Aotus griseimembra</i>	USNM 284776	Morphosource	0.035	F	<a href="http://n2t.net/ark:/65665/34fb1e7f4-ed5d-4d36-9f36-e7741dcd02bd">http://n2t.net/ark:/65665/34fb1e7f4-ed5d-4d36-9f36-e7741dcd02bd</a>	S3996
<i>Aotus griseimembra</i>	USNM 284777	Morphosource	0.035	M	<a href="http://n2t.net/ark:/65665/30fe89705-6148-4207-9b9c-f5435c669587">http://n2t.net/ark:/65665/30fe89705-6148-4207-9b9c-f5435c669587</a>	S3997
<i>Aotus griseimembra</i>	USNM 284779	Morphosource	0.038	F	<a href="http://n2t.net/ark:/65665/354427a46-c645-4785-90d2-b08310d3110d">http://n2t.net/ark:/65665/354427a46-c645-4785-90d2-b08310d3110d</a>	S3979
<i>Ateles geoffroyi</i>	AMNH-M 26593	Morphosource	0.062	F	urn:catalog:AMNH:Mammals:M-26593	S5312
<i>Ateles geoffroyi</i>	MCZ 10138	Morphosource	0.063	F	<a href="http://dx.doi.org/10.17602/M2/M2917">http://dx.doi.org/10.17602/M2/M2917</a>	S971
<i>Ateles geoffroyi</i>	MCZ 29628	Morphosource	0.063	F	<a href="http://dx.doi.org/10.17602/M2/M2919">http://dx.doi.org/10.17602/M2/M2919</a>	S973
<i>Cebus imitator</i>	MCZ 10135	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M5151">http://dx.doi.org/10.17602/M2/M5151</a>	S1676
<i>Cebus imitator</i>	MCZ 34326	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M5148">http://dx.doi.org/10.17602/M2/M5148</a>	S1673
<i>Cebus imitator</i>	MCZ 34353	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M5147">http://dx.doi.org/10.17602/M2/M5147</a>	S1672
<i>Cercocebus galeritus</i>	AMNH-M 52641	Morphosource	0.068	M	urn:catalog:AMNH:Mammals:M-52641	S1513
<i>Cercocebus torquatus</i>	AMNH-M 70063	Morphosource	0.118	M	urn:catalog:AMNH:Mammals:M-70063	S4046
<i>Cercocebus torquatus</i>	MCZ 32625	Morphosource	0.091	M	<a href="http://dx.doi.org/10.17602/M2/M2589">http://dx.doi.org/10.17602/M2/M2589</a>	S777
<i>Cercopithecus mitis</i>	MCZ 25022	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M2929">http://dx.doi.org/10.17602/M2/M2929</a>	S983
<i>Cercopithecus mitis</i>	MCZ 26832	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M2930">http://dx.doi.org/10.17602/M2/M2930</a>	S984

<i>Cercopithecus mitis</i>	MCZ 7088	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M2927">http://dx.doi.org/10.17602/M2/M2927</a>	S981
<i>Chiropotes chiropotes</i>	USNM 388161	Morphosource	0.047	F	<a href="http://n2t.net/ark:/65665/3bd51f984-2926-4bd6-a368-1c2be2fb4a87">http://n2t.net/ark:/65665/3bd51f984-2926-4bd6-a368-1c2be2fb4a87</a>	S3926
<i>Chiropotes chiropotes</i>	USNM 388163	Morphosource	0.047	F	<a href="http://n2t.net/ark:/65665/3007743ab-5f8c-4542-a384-bc68d16bd910">http://n2t.net/ark:/65665/3007743ab-5f8c-4542-a384-bc68d16bd910</a>	S3928
<i>Chiropotes chiropotes</i>	USNM 388165	Morphosource	0.049	M	<a href="http://n2t.net/ark:/65665/3b5260e90-e411-4638-9257-f4e65440a1ea">http://n2t.net/ark:/65665/3b5260e90-e411-4638-9257-f4e65440a1ea</a>	S3935
<i>Chlorocebus pygerythrus</i>	SIU 4799	Morphosource	0.050	F	—	S4045
<i>Chlorocebus pygerythrus</i>	SIU 4800	Morphosource	0.046	F	—	S4047
<i>Chlorocebus pygerythrus</i>	SIU 4801	Morphosource	0.055	M	—	S4048
<i>Colobus guereza</i>	AMNH-M 52211	Morphosource	0.073	M	urn:catalog:AMNH:Mammals:M-52211	S1143
<i>Colobus guereza</i>	AMNH-M 52213	Morphosource	0.066	F	urn:catalog:AMNH:Mammals:M-52213	S3768
<i>Colobus guereza</i>	AMNH-M 52238	Morphosource	0.068	F	urn:catalog:AMNH:Mammals:M-52238	S1215
<i>Erythrocebus patas</i>	MCZ 47015	Morphosource	0.083	M	<a href="http://dx.doi.org/10.17602/M2/M2923">http://dx.doi.org/10.17602/M2/M2923</a>	S977
<i>Erythrocebus patas</i>	MCZ 47016	Morphosource	0.083	M	<a href="http://dx.doi.org/10.17602/M2/M2924">http://dx.doi.org/10.17602/M2/M2924</a>	S978
<i>Erythrocebus patas</i>	MCZ 47018	Morphosource	0.083	F	<a href="http://dx.doi.org/10.17602/M2/M2926">http://dx.doi.org/10.17602/M2/M2926</a>	S980
<i>Gorilla gorilla</i>	AMNH-A 999686	Morphosource	0.131	M	—	S5189
<i>Gorilla gorilla</i>	AMNH-M 54356	Morphosource	0.106	F	urn:catalog:AMNH:Mammals:M-54356	S5125
<i>Gorilla gorilla</i>	MCZ 17684	Morphosource	0.126	F	<a href="http://dx.doi.org/10.17602/M2/M2943">http://dx.doi.org/10.17602/M2/M2943</a>	S644
<i>Gorilla gorilla</i>	MCZ 26850	Morphosource	0.123	F	<a href="http://dx.doi.org/10.17602/M2/M2947">http://dx.doi.org/10.17602/M2/M2947</a>	S995
<i>Gorilla gorilla</i>	MCZ 37264	Morphosource	0.126	F	<a href="http://dx.doi.org/10.17602/M2/M2949">http://dx.doi.org/10.17602/M2/M2949</a>	S997
<i>Gorilla gorilla</i>	MCZ 46325	Morphosource	0.126	F	<a href="http://dx.doi.org/10.17602/M2/M2955">http://dx.doi.org/10.17602/M2/M2955</a>	S1001
<i>Hoolock hoolock</i>	AMNH-M 112720	Morphosource	0.052	M	urn:catalog:AMNH:Mammals:M-112720	S1206
<i>Hoolock hoolock</i>	AMNH-M 201743	Morphosource	0.064	F	urn:catalog:AMNH:Mammals:M-201743	S12604
<i>Hoolock hoolock</i>	AMNH-M 83425	AMNH	0.084	F	urn:catalog:AMNH:Mammals:M-83425	S1209
<i>Hylobates agilis</i>	IPS3773	CENIEH	0.052	?	—	
<i>Hylobates lar</i>	MCZ 41412	Morphosource	0.067	F	<a href="http://dx.doi.org/10.17602/M2/M2961">http://dx.doi.org/10.17602/M2/M2961</a>	S1005
<i>Hylobates lar</i>	MCZ 41418	Morphosource	0.067	F	<a href="http://dx.doi.org/10.17602/M2/M2967">http://dx.doi.org/10.17602/M2/M2967</a>	S1008
<i>Hylobates lar</i>	MCZ 41421	Morphosource	0.067	F	<a href="http://dx.doi.org/10.17602/M2/M2969">http://dx.doi.org/10.17602/M2/M2969</a>	S1009
<i>Hylobates lar</i>	MCZ 41424	Morphosource	0.067	F	<a href="http://dx.doi.org/10.17602/M2/M3007">http://dx.doi.org/10.17602/M2/M3007</a>	S1017

<i>Lagothrix lagotricha</i>	USNM 269839	Morphosource	0.058	F	<a href="http://n2t.net/ark:/65665/3d05a410d-2384-4415-a7cb-9d53b2d58726">http://n2t.net/ark:/65665/3d05a410d-2384-4415-a7cb-9d53b2d58726</a>	S3004
<i>Lagothrix lagotricha</i>	USNM 461930	Morphosource	0.060	F	<a href="http://n2t.net/ark:/65665/35d3a334f-9bc6-48e9-864d-6fe2cf11beba">http://n2t.net/ark:/65665/35d3a334f-9bc6-48e9-864d-6fe2cf11beba</a>	S3006
<i>Lagothrix lagotricha</i>	USNM 545879	Morphosource	0.058	M	<a href="http://n2t.net/ark:/65665/30f0814b2-a584-4c20-96c2-fbcb4e5778e2">http://n2t.net/ark:/65665/30f0814b2-a584-4c20-96c2-fbcb4e5778e2</a>	S283
<i>Lophocebus albigena</i>	MCZ 14725	Morphosource	0.090	F	<a href="http://dx.doi.org/10.17602/M2/M2626">http://dx.doi.org/10.17602/M2/M2626</a>	S794
<i>Lophocebus albigena</i>	MCZ 18614	Morphosource	0.090	M	<a href="http://dx.doi.org/10.17602/M2/M2622">http://dx.doi.org/10.17602/M2/M2622</a>	S790
<i>Lophocebus albigena</i>	MCZ 22737	Morphosource	0.090	F	<a href="http://dx.doi.org/10.17602/M2/M2621">http://dx.doi.org/10.17602/M2/M2621</a>	S789
<i>Macaca fascicularis</i>	MCZ 12758	Morphosource	0.062	F	<a href="http://dx.doi.org/10.17602/M2/M3028">http://dx.doi.org/10.17602/M2/M3028</a>	S1032
<i>Macaca fascicularis</i>	MCZ 22277	Morphosource	0.062	F	<a href="http://dx.doi.org/10.17602/M2/M3029">http://dx.doi.org/10.17602/M2/M3029</a>	S1033
<i>Macaca fascicularis</i>	MCZ 23812	Morphosource	0.062	M	<a href="http://dx.doi.org/10.17602/M2/M3030">http://dx.doi.org/10.17602/M2/M3030</a>	S1034
<i>Macaca fascicularis</i>	MCZ 35765	Morphosource	0.062	F	<a href="http://dx.doi.org/10.17602/M2/M3033">http://dx.doi.org/10.17602/M2/M3033</a>	S1037
<i>Macaca fascicularis</i>	MCZ 41167	Morphosource	0.091	M	<a href="http://dx.doi.org/10.17602/M2/M3038">http://dx.doi.org/10.17602/M2/M3038</a>	S1042
<i>Mandrillus sphinx</i>	AMNH-A 9912049	Morphosource	0.075	M	—	S5815
<i>Mandrillus sphinx</i>	AMNH-M 89367	Morphosource	0.080	F	urn:catalog:AMNH:Mammals:M-89367	S4599
<i>Mandrillus sphinx</i>	MCZ 34089	Morphosource	0.126	M	<a href="http://dx.doi.org/10.17602/M2/M5096">http://dx.doi.org/10.17602/M2/M5096</a>	S1571
<i>Mico argentatus</i>	MCZ 30579	Morphosource	0.041	M	<a href="http://dx.doi.org/10.17602/M2/M5192">http://dx.doi.org/10.17602/M2/M5192</a>	S1708
<i>Mico argentatus</i>	MCZ 30580	Morphosource	0.041	M	<a href="http://dx.doi.org/10.17602/M2/M5193">http://dx.doi.org/10.17602/M2/M5193</a>	S1709
<i>Mico argentatus</i>	MCZ 32164	Morphosource	0.041	F	<a href="http://dx.doi.org/10.17602/M2/M5196">http://dx.doi.org/10.17602/M2/M5196</a>	S1712
<i>Miopithecus talapoin</i>	MCZ 23196	Morphosource	0.050	M	<a href="http://dx.doi.org/10.17602/M2/M5094">http://dx.doi.org/10.17602/M2/M5094</a>	S1665
<i>Miopithecus talapoin</i>	MCZ 23197	Morphosource	0.050	M	<a href="http://dx.doi.org/10.17602/M2/M5093">http://dx.doi.org/10.17602/M2/M5093</a>	S1664
<i>Miopithecus talapoin</i>	MCZ 5547	Morphosource	0.050	M	<a href="http://dx.doi.org/10.17602/M2/M5087">http://dx.doi.org/10.17602/M2/M5087</a>	S1659
<i>Nasalis larvatus</i>	MCZ 37341	Morphosource	0.071	F	<a href="http://dx.doi.org/10.17602/M2/M5082">http://dx.doi.org/10.17602/M2/M5082</a>	S1655
<i>Nasalis larvatus</i>	MCZ 41560	Morphosource	0.071	F	<a href="http://dx.doi.org/10.17602/M2/M5056">http://dx.doi.org/10.17602/M2/M5056</a>	S1642
<i>Nasalis larvatus</i>	MCZ 41562	Morphosource	0.071	F	<a href="http://dx.doi.org/10.17602/M2/M5055">http://dx.doi.org/10.17602/M2/M5055</a>	S1641
<i>Nomascus leucogenys</i>	AMNH-M 87251	Morphosource	0.105	M	urn:catalog:AMNH:Mammals:M-87251	S5127
<i>Pan paniscus</i>	AMNH-M 86857	AMNH	0.116	F	urn:catalog:AMNH:Mammals:M-86857	S1590
<i>Pan paniscus</i>	IPS9033	CENIEH	0.066	F	—	
<i>Pan paniscus</i>	MCZ 38018	Morphosource	0.094	M	<a href="http://dx.doi.org/10.17602/M2/M4399">http://dx.doi.org/10.17602/M2/M4399</a>	S1333

<i>Pan paniscus</i>	MCZ 38019	Morphosource	0.092	F	<a href="http://dx.doi.org/10.17602/M2/M4398">http://dx.doi.org/10.17602/M2/M4398</a>	S1332
<i>Pan paniscus</i>	MCZ 38020	Morphosource	0.099	?	<a href="http://dx.doi.org/10.17602/M2/M4397">http://dx.doi.org/10.17602/M2/M4397</a>	S1331
<i>Pan troglodytes</i>	AMNH-M 167342	Morphosource	0.089	M	urn:catalog:AMNH:Mammals:M-167342	S5129
<i>Pan troglodytes</i>	AMNH-M 167344	Morphosource	0.111	M	urn:catalog:AMNH:Mammals:M-167344	S5313
<i>Pan troglodytes</i>	IPS5698	CENIEH	0.077	M	—	
<i>Pan troglodytes</i>	MCZ 17702	Morphosource	0.102	F	<a href="http://dx.doi.org/10.17602/M2/M4395">http://dx.doi.org/10.17602/M2/M4395</a>	S1330
<i>Pan troglodytes</i>	MCZ 23167	Morphosource	0.106	F	<a href="http://dx.doi.org/10.17602/M2/M4390">http://dx.doi.org/10.17602/M2/M4390</a>	S1326
<i>Pan troglodytes</i>	MCZ 26849	Morphosource	0.106	F	<a href="http://dx.doi.org/10.17602/M2/M4388">http://dx.doi.org/10.17602/M2/M4388</a>	S1324
<i>Papio anubis</i>	MCZ 17342	Morphosource	0.108	M	<a href="http://dx.doi.org/10.17602/M2/M4885">http://dx.doi.org/10.17602/M2/M4885</a>	S1615
<i>Papio anubis</i>	MCZ 21160	Morphosource	0.118	M	<a href="http://dx.doi.org/10.17602/M2/M4881">http://dx.doi.org/10.17602/M2/M4881</a>	S1613
<i>Papio anubis</i>	MCZ BOM 8304	Morphosource	0.118	M	<a href="http://dx.doi.org/10.17602/M2/M4887">http://dx.doi.org/10.17602/M2/M4887</a>	S1616
<i>Ptilocolobus badius</i>	MCZ 24080	Morphosource	0.080	M	<a href="http://dx.doi.org/10.17602/M2/M2892">http://dx.doi.org/10.17602/M2/M2892</a>	S947
<i>Ptilocolobus badius</i>	MCZ 24775	Morphosource	0.090	M	<a href="http://dx.doi.org/10.17602/M2/M2893">http://dx.doi.org/10.17602/M2/M2893</a>	S948
<i>Ptilocolobus badius</i>	MCZ 24793	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M2894">http://dx.doi.org/10.17602/M2/M2894</a>	S949
<i>Pithecia monachus</i>	MCZ 27124	Morphosource	0.050	?	<a href="http://dx.doi.org/10.17602/M2/M4708">http://dx.doi.org/10.17602/M2/M4708</a>	S1496
<i>Pithecia pithecia</i>	MCZ 30718	Morphosource	0.050	M	<a href="http://dx.doi.org/10.17602/M2/M4707">http://dx.doi.org/10.17602/M2/M4707</a>	S1495
<i>Pithecia pithecia</i>	MCZ 30719	Morphosource	0.0501	F	<a href="http://dx.doi.org/10.17602/M2/M4706">http://dx.doi.org/10.17602/M2/M4706</a>	S1494
<i>Plecturocebus cupreus</i>	AMNH-M 72141	Morphosource	0.049	F	urn:catalog:AMNH:Mammals:M-72141	S5132
<i>Plecturocebus cupreus</i>	AMNH-M 72143	Morphosource	0.049	M	urn:catalog:AMNH:Mammals:M-72143	S5133
<i>Plecturocebus cupreus</i>	AMNH-M 75987	Morphosource	0.051	M	urn:catalog:AMNH:Mammals:M-75987	S5134
<i>Plecturocebus cupreus</i>	AMNH-M 75988	Morphosource	0.049	F	urn:catalog:AMNH:Mammals:M-75988	S5135
<i>Plecturocebus cupreus</i>	MCZ 37828	Morphosource	0.047	M	<a href="http://dx.doi.org/10.17602/M2/M5171">http://dx.doi.org/10.17602/M2/M5171</a>	S1692
<i>Pongo sp.</i>	IPS10647	CENIEH	0.077	F	—	
<i>Pongo sp.</i>	IPS10651	CENIEH	0.077	F	—	
<i>Pongo sp.</i>	IPS9031	CENIEH	0.077	F	—	
<i>Pongo sp.</i>	IPSSN	CENIEH	0.077	F	—	
<i>Pongo sp.</i>	MCZ 37518	Morphosource	0.126	F	<a href="http://dx.doi.org/10.17602/M2/M4613">http://dx.doi.org/10.17602/M2/M4613</a>	S1458



<i>Pongo</i> sp.	MCZ 35719	Morphosource	0.103	F	<a href="http://dx.doi.org/10.17602/M2/M4615">http://dx.doi.org/10.17602/M2/M4615</a>	S1459
<i>Presbytis rubicunda</i>	MCZ 35704	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M4552">http://dx.doi.org/10.17602/M2/M4552</a>	S1419
<i>Presbytis rubicunda</i>	MCZ 35705	Morphosource	0.080	F	<a href="http://dx.doi.org/10.17602/M2/M4551">http://dx.doi.org/10.17602/M2/M4551</a>	S1418
<i>Presbytis rubicunda</i>	MCZ 36820	Morphosource	0.080	M	<a href="http://dx.doi.org/10.17602/M2/M4554">http://dx.doi.org/10.17602/M2/M4554</a>	S1420
<i>Procolobus verus</i>	AMNH-M 89438	Morphosource	0.076	F	urn:catalog:AMNH:Mammals:M-89438	S4627
<i>Procolobus verus</i>	AMNH-M 89439	Morphosource	0.080	M	urn:catalog:AMNH:Mammals:M-89439	S4628
<i>Saguinus fuscicollis</i>	AMNH-M 74051	Morphosource	0.027	F	urn:catalog:AMNH:Mammals:M-74051	S4404
<i>Saguinus midas</i>	MCZ 30597	Morphosource	0.041	M	<a href="http://dx.doi.org/10.17602/M2/M4498">http://dx.doi.org/10.17602/M2/M4498</a>	S1385
<i>Saguinus midas</i>	MCZ 30601	Morphosource	0.041	M	<a href="http://dx.doi.org/10.17602/M2/M4497">http://dx.doi.org/10.17602/M2/M4497</a>	S1384
<i>Saimiri sciureus</i>	MCZ 20187	Morphosource	0.047	?	<a href="http://dx.doi.org/10.17602/M2/M4486">http://dx.doi.org/10.17602/M2/M4486</a>	S1373
<i>Saimiri sciureus</i>	MCZ 30568	Morphosource	0.047	F	<a href="http://dx.doi.org/10.17602/M2/M4483">http://dx.doi.org/10.17602/M2/M4483</a>	S1370
<i>Saimiri sciureus</i>	MCZ 30569	Morphosource	0.047	M	<a href="http://dx.doi.org/10.17602/M2/M4447">http://dx.doi.org/10.17602/M2/M4447</a>	S1362
<i>Semnopithecus entellus</i>	AMNH-A 9912285	Morphosource	0.060	M	—	S4396
<i>Semnopithecus entellus</i>	AMNH-A 9912286	Morphosource	0.108	M	—	S3764
<i>Semnopithecus entellus</i>	AMNH-M 90328	Morphosource	0.052	F	urn:catalog:AMNH:Mammals:M-90328	S4193
<i>Simias concolor</i>	AMNH-M 103369	Morphosource	0.056	M	urn:catalog:AMNH:Mammals:M-103369	S3558
<i>Simias concolor</i>	AMNH-M 103371	Morphosource	0.056	F	urn:catalog:AMNH:Mammals:M-103371	S3965
<i>Symphalangus syndactylus</i>	AMNH-M 102724	Morphosource	0.062	F	—	S5810
<i>Symphalangus syndactylus</i>	AMNH-M 106583	AMNH	0.079	F	urn:catalog:AMNH:Mammals:M-106583	S533
<i>Theropithecus gelada</i>	AMNH-M 238034	Morphosource	0.120	F	urn:catalog:AMNH:Mammals:M-238034	S4889
<i>Theropithecus gelada</i>	AMNH-M 60568	Morphosource	0.085	M	urn:catalog:AMNH:Mammals:M-60568	S4042
<i>Theropithecus gelada</i>	AMNH-M 80126	Morphosource	0.087	M	urn:catalog:AMNH:Mammals:M-80126	S4065
<i>Trachypithecus cristatus</i>	MCZ 35567	Morphosource	0.050	F	<a href="http://dx.doi.org/10.17602/M2/M4439">http://dx.doi.org/10.17602/M2/M4439</a>	S1355
<i>Trachypithecus cristatus</i>	MCZ 35584	Morphosource	0.051	F	<a href="http://dx.doi.org/10.17602/M2/M4436">http://dx.doi.org/10.17602/M2/M4436</a>	S1353
<i>Trachypithecus cristatus</i>	MCZ 35586	Morphosource	0.050	F	<a href="http://dx.doi.org/10.17602/M2/M4435">http://dx.doi.org/10.17602/M2/M4435</a>	S1352

Abbreviations: F = female; M = male; ? = unknown sex; AMNH = American Museum of Natural History, New York, USA; AMNH-A = American Museum of Natural History, Anthropology Collection, New York, USA; AMNH-M = American Museum of Natural History, Mammal collection,

New York, USA; DUEA = Duke University, Evolutionary Anthropology, Durham, USA; ICP = acronym of the collections of the Institut Català de Paleontologia Miquel Crusafont, Sabadell, Spain; MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, USA; MCZ-BOM = Museum of Comparative Zoology, Bones of Mammals collection, Harvard University, Cambridge, USA; SIU = Southern Illinois University, Carbondale, USA; USNM = Smithsonian National Museum of Natural History, Washington, D.C., USA.

## SOM Table S2

Raw data of the variables describing the orientation, proportions and course of the carotid canal in extant anthropoid specimens.

Species	ID	2DYZA	2DXYA	L/V <sup>(1/3)</sup>	bgPC1	bgPC2
<i>Alouatta palliata</i>	DUEALP 04	66.73	30.17	3.06	-0.36	0.15
<i>Alouatta palliata</i>	DUEALP 06	61.00	44.25	3.56	-0.40	0.17
<i>Alouatta palliata</i>	DUEALP 13	70.71	29.86	3.17	-0.40	0.11
<i>Alouatta palliata</i>	DUEALP 14	68.50	26.13	2.90	-0.34	0.09
<i>Alouatta palliata</i>	DUEALP 16	64.95	38.50	3.50	-0.41	0.12
<i>Aotus griseimembra</i>	USNM 281551	60.21	20.69	4.29	-0.41	-0.09
<i>Aotus griseimembra</i>	USNM 281552	57.58	16.89	3.60	-0.41	-0.13
<i>Aotus griseimembra</i>	USNM 284776	55.28	19.84	3.37	-0.24	-0.12
<i>Aotus griseimembra</i>	USNM 284777	55.09	23.71	3.90	-0.43	-0.10
<i>Aotus griseimembra</i>	USNM 284779	52.21	8.25	3.39	-0.27	-0.12
<i>Ateles geoffroyi</i>	AMNH-M 26593	59.21	32.81	3.53	-0.48	0.11
<i>Ateles geoffroyi</i>	MCZ 10138	50.66	38.21	3.69	-0.40	0.16
<i>Ateles geoffroyi</i>	MCZ 29628	57.38	39.33	4.05	-0.32	0.11
<i>Cebus imitator</i>	MCZ 10135	64.39	23.90	3.38	-0.41	0.02
<i>Cebus imitator</i>	MCZ 34326	72.30	37.16	4.01	-0.48	-0.02
<i>Cebus imitator</i>	MCZ 34353	64.19	26.39	4.14	-0.41	0.05
<i>Cercocebus galeritus</i>	AMNH-M 52641	57.39	11.66	2.40	0.24	0.04
<i>Cercocebus torquatus</i>	AMNH-M 70063	79.78	14.60	2.28	0.25	-0.02
<i>Cercocebus torquatus</i>	MCZ 32625	73.83	19.02	2.91	0.22	0.10
<i>Cercopithecus mitis</i>	MCZ 25022	57.20	-0.89	2.77	0.25	-0.06
<i>Cercopithecus mitis</i>	MCZ 26832	58.20	1.59	2.78	0.24	-0.03
<i>Cercopithecus mitis</i>	MCZ 7088	57.59	14.39	3.19	0.19	-0.05
<i>Chiropotes chiropotes</i>	USNM 388161	71.59	26.41	3.23	-0.41	0.01
<i>Chiropotes chiropotes</i>	USNM 388163	67.98	39.14	3.73	-0.43	0.06
<i>Chiropotes chiropotes</i>	USNM 388165	63.98	34.79	3.33	-0.43	0.06
<i>Chlorocebus pygerythrus</i>	SIU 4799	66.70	12.29	2.74	0.22	-0.10
<i>Chlorocebus pygerythrus</i>	SIU 4800	80.13	19.28	2.84	0.16	-0.14
<i>Chlorocebus pygerythrus</i>	SIU 4801	65.77	26.59	2.79	0.22	-0.02
<i>Colobus guereza</i>	AMNH-M 52211	71.43	26.52	2.88	0.06	0.03
<i>Colobus guereza</i>	AMNH-M 52213	58.93	10.06	3.13	0.10	-0.04
<i>Colobus guereza</i>	AMNH-M 52238	76.34	18.85	2.44	0.11	0.01
<i>Erythrocebus patas</i>	MCZ 47015	72.58	28.49	2.65	0.20	0.09
<i>Erythrocebus patas</i>	MCZ 47016	58.13	31.28	2.86	0.11	0.14

<i>Erythrocebus patas</i>	MCZ 47018	57.22	20.98	2.70	0.21	-0.02
<i>Gorilla gorilla</i>	AMNH-A 999686	56.92	10.14	3.10	0.17	0.13
<i>Gorilla gorilla</i>	AMNH-M 54356	50.82	6.84	2.99	0.20	0.05
<i>Gorilla gorilla</i>	MCZ 17684	61.71	18.12	2.85	0.19	0.17
<i>Gorilla gorilla</i>	MCZ 26850	55.54	3.89	3.28	0.17	0.12
<i>Gorilla gorilla</i>	MCZ 37264	55.97	16.40	3.24	0.18	0.07
<i>Gorilla gorilla</i>	MCZ 46325	56.37	12.71	3.51	0.06	0.08
<i>Hoolock hoolock</i>	AMNH-M 112720	52.89	4.59	2.26	0.09	-0.25
<i>Hoolock hoolock</i>	AMNH-M 201743	57.65	15.22	2.53	0.22	-0.10
<i>Hoolock hoolock</i>	AMNH-M 83425	52.54	11.33	2.57	0.22	-0.06
<i>Hylobates agilis</i>	IPS3773	44.51	1.00	3.19	0.20	-0.06
<i>Hylobates lar</i>	MCZ 41412	59.84	11.48	2.63	0.16	0.04
<i>Hylobates lar</i>	MCZ 41418	50.05	1.19	2.65	0.21	0.01
<i>Hylobates lar</i>	MCZ 41421	78.27	2.48	1.97	0.29	0.06
<i>Hylobates lar</i>	MCZ 41424	74.17	12.69	2.08	0.14	-0.10
<i>Lagothrix lagotricha</i>	USNM 269839	52.40	38.35	3.78	-0.47	0.09
<i>Lagothrix lagotricha</i>	USNM 461930	61.55	31.61	3.36	-0.32	0.11
<i>Lagothrix lagotricha</i>	USNM 545879	59.62	34.10	4.18	-0.37	0.13
<i>Lophocebus albigena</i>	MCZ 14725	76.19	30.79	2.53	0.06	0.00
<i>Lophocebus albigena</i>	MCZ 18614	69.57	7.34	3.03	0.11	-0.10
<i>Lophocebus albigena</i>	MCZ 22737	61.40	18.58	2.40	0.22	0.01
<i>Macaca fascicularis</i>	MCZ 12758	73.31	31.62	3.84	0.09	-0.06
<i>Macaca fascicularis</i>	MCZ 22277	70.90	13.51	2.73	0.17	-0.14
<i>Macaca fascicularis</i>	MCZ 23812	74.49	22.03	3.07	0.09	-0.20
<i>Macaca fascicularis</i>	MCZ 35765	73.79	26.47	2.21	0.25	-0.17
<i>Macaca fascicularis</i>	MCZ 41167	70.90	5.01	2.77	0.27	0.03
<i>Mandrillus sphinx</i>	AMNH-A 9912049	78.47	24.83	3.87	0.21	0.05
<i>Mandrillus sphinx</i>	AMNH-M 89367	69.43	13.60	2.44	0.34	-0.02
<i>Mandrillus sphinx</i>	MCZ 34089	70.52	2.25	2.37	0.32	0.12
<i>Mico argentatus</i>	MCZ 30579	79.36	33.38	4.16	-0.07	-0.14
<i>Mico argentatus</i>	MCZ 30580	70.89	37.76	3.40	-0.09	-0.18
<i>Mico argentatus</i>	MCZ 32164	71.40	36.16	3.86	-0.10	-0.16
<i>Miopithecus talapoin</i>	MCZ 23196	75.86	-3.12	3.74	0.10	-0.18
<i>Miopithecus talapoin</i>	MCZ 23197	84.14	-3.55	3.18	0.18	-0.19
<i>Miopithecus talapoin</i>	MCZ 5547	76.48	6.76	3.41	0.18	-0.07
<i>Nasalis larvatus</i>	MCZ 37341	68.96	8.49	2.94	0.17	-0.10
<i>Nasalis larvatus</i>	MCZ 41560	68.07	8.32	3.28	0.11	-0.12
<i>Nasalis larvatus</i>	MCZ 41562	69.62	2.58	2.90	0.13	-0.29

<i>Nomascus leucogenys</i>	AMNH-M 87251	46.95	10.01	2.88	0.32	-0.08
<i>Pan paniscus</i>	AMNH-M 86857	51.61	10.73	3.15	0.11	0.15
<i>Pan paniscus</i>	IPS9033	58.88	7.58	3.31	0.12	0.13
<i>Pan paniscus</i>	MCZ 38018	52.37	2.45	3.53	0.20	0.18
<i>Pan paniscus</i>	MCZ 38019	37.27	-0.82	3.35	0.12	0.14
<i>Pan paniscus</i>	MCZ 38020	44.76	10.08	3.12	0.17	0.19
<i>Pan troglodytes</i>	AMNH-M 167342	57.40	27.78	3.52	0.13	0.17
<i>Pan troglodytes</i>	AMNH-M 167344	40.91	17.19	3.42	0.08	0.13
<i>Pan troglodytes</i>	IPS5698	68.86	14.32	3.15	0.17	0.09
<i>Pan troglodytes</i>	MCZ 17702	58.80	8.02	3.44	0.13	0.13
<i>Pan troglodytes</i>	MCZ 23167	69.11	15.22	2.55	0.12	0.11
<i>Pan troglodytes</i>	MCZ 26849	65.72	19.18	3.82	0.06	0.14
<i>Papio anubis</i>	MCZ 17342	71.02	12.95	3.00	0.25	0.06
<i>Papio anubis</i>	MCZ 21160	77.92	12.01	3.06	0.23	0.04
<i>Papio anubis</i>	MCZ BOM 8304	84.99	13.10	2.89	0.23	0.07
<i>Piliocolobus badius</i>	MCZ 24080	72.37	13.36	1.80	0.23	-0.11
<i>Piliocolobus badius</i>	MCZ 24775	63.44	25.62	2.73	0.15	0.01
<i>Piliocolobus badius</i>	MCZ 24793	70.48	26.93	1.40	0.27	-0.14
<i>Pithecia monachus</i>	MCZ 27124	61.35	31.85	3.95	-0.35	0.09
<i>Pithecia pithecia</i>	MCZ 30718	65.29	33.95	4.17	-0.32	0.03
<i>Pithecia pithecia</i>	MCZ 30719	64.58	24.78	3.91	-0.28	0.02
<i>Plecturocebus cupreus</i>	AMNH-M 72141	60.37	36.47	3.82	-0.50	-0.05
<i>Plecturocebus cupreus</i>	AMNH-M 72143	58.98	35.27	4.03	-0.41	-0.02
<i>Plecturocebus cupreus</i>	AMNH-M 75987	54.55	29.05	3.95	-0.47	0.05
<i>Plecturocebus cupreus</i>	AMNH-M 75988	67.10	39.93	3.84	-0.45	-0.08
<i>Plecturocebus cupreus</i>	MCZ 37828	59.76	34.57	4.42	-0.45	0.03
<i>Pongo sp.</i>	IPS10647	35.58	26.47	3.08	-0.10	0.12
<i>Pongo sp.</i>	IPS10651	57.41	14.44	3.41	0.00	0.08
<i>Pongo sp.</i>	IPS9031	45.95	23.54	2.81	-0.03	0.09
<i>Pongo sp.</i>	IPSSN	51.04	12.11	3.22	0.19	0.20
<i>Pongo sp.</i>	MCZ 35719	55.71	21.61	2.61	0.14	-0.01
<i>Pongo sp.</i>	MCZ 37518	55.44	18.00	2.57	0.17	0.07
<i>Presbytis rubicunda</i>	MCZ 35704	73.37	9.72	3.28	0.05	-0.03
<i>Presbytis rubicunda</i>	MCZ 35705	59.19	10.94	3.26	0.07	0.02
<i>Presbytis rubicunda</i>	MCZ 36820	79.70	20.06	3.31	0.01	-0.05
<i>Procolobus verus</i>	AMNH-M 89438	72.35	13.25	3.05	0.19	-0.12
<i>Procolobus verus</i>	AMNH-M 89439	76.59	3.64	2.67	0.23	-0.13
<i>Saguinus fuscicollis</i>	AMNH-M 74051	74.69	29.71	4.08	-0.29	-0.13

<i>Saguinus midas</i>	MCZ 30597	79.05	43.03	3.18	-0.30	-0.26
<i>Saguinus midas</i>	MCZ 30601	75.43	34.46	3.27	-0.22	-0.17
<i>Saimiri sciureus</i>	MCZ 20187	68.68	38.36	2.91	-0.49	-0.09
<i>Saimiri sciureus</i>	MCZ 30568	67.23	27.31	3.44	-0.36	-0.09
<i>Saimiri sciureus</i>	MCZ 30569	70.14	38.60	3.48	-0.37	-0.10
<i>Semnopithecus entellus</i>	AMNH-A 9912285	66.06	28.37	2.52	0.12	0.05
<i>Semnopithecus entellus</i>	AMNH-A 9912286	64.95	33.39	3.01	0.16	0.05
<i>Semnopithecus entellus</i>	AMNH-M 90328	62.09	25.82	3.17	0.12	0.01
<i>Simias concolor</i>	AMNH-M 103369	73.52	29.07	3.13	0.08	-0.12
<i>Simias concolor</i>	AMNH-M 103371	71.86	33.87	3.40	-0.11	-0.10
<i>Symphalangus syndactylus</i>	AMNH-M 102724	38.27	19.77	3.37	0.08	0.12
<i>Symphalangus syndactylus</i>	AMNH-M 106583	44.54	23.27	3.32	0.06	0.00
<i>Theropithecus gelada</i>	AMNH-M 238034	66.58	7.26	2.87	0.28	0.05
<i>Theropithecus gelada</i>	AMNH-M 60568	68.61	20.77	3.02	0.27	0.06
<i>Theropithecus gelada</i>	AMNH-M 80126	65.87	24.69	3.11	0.21	0.08
<i>Trachypithecus cristatus</i>	MCZ 35567	58.10	27.71	3.38	0.13	-0.07
<i>Trachypithecus cristatus</i>	MCZ 35584	80.20	17.07	3.23	0.26	-0.12
<i>Trachypithecus cristatus</i>	MCZ 35586	61.67	21.44	3.35	0.22	-0.02

Abbreviations: 2DYZA = 2D angle in the YZ plane (canal superior orientation; in degrees); 2DXYA = 2D angle in the XY plane (canal medial orientation; in degrees); L = length (in mm); V = volume (in mm<sup>3</sup>); bgPC = between-group principal component; AMNH = American Museum of Natural History, New York, USA; AMNH-A = American Museum of Natural History, Anthropology Collection, New York, USA; AMNH-M = American Museum of Natural History, Mammal collection, New York, USA; DUEA = Duke University, Evolutionary Anthropology, Durham, USA; ICP = acronym of the collections of the Institut Català de Paleontologia Miquel Crusafont, Sabadell, Spain; MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, USA; MCZ-BOM = Museum of Comparative Zoology, Bones of Mammals collection, Harvard University, Cambridge, USA; SIU = Southern Illinois University, Carbondale, USA; USNM = Smithsonian National Museum of Natural History, Washington, D.C., USA.

**SOM Table S3**

Results of the Kruskal-Wallis comparisons for the indices and bgPCs describing the orientation, proportions and course of the carotid canal in the main extant anthropoid clades.

	H	<i>p</i>
2DYZA	45.74	<0.001
2DXYA	58.57	<0.001
L/V <sup>(1/3)</sup>	63.73	<0.001
bgPC1	83.36	<0.001
bgPC2	39.31	<0.001

Abbreviations: 2DYZA = 2D angle in the YZ plane (canal superior orientation; in degrees); 2DXYA = 2D angle in the XY plane (canal medial orientation; in degrees); L = length (in mm); V = volume (in mm<sup>3</sup>); bgPC = between-group principal component; H = Kruskal-Wallis statistic.

**SOM Table S4**

Results of the Bonferroni-corrected Mann-Whitney post hoc pairwise comparisons for the indices and bgPCs describing the orientation, proportions and course of the carotid canal in the main extant anthropoid clades.

	Platyrrhini	Cercopithecidae	Hominidae	Hylobatidae
<b>2DYZA</b>				
Platyrrhini	—	<0.01	<0.001	0.035
Cercopithecidae	<0.01	—	<0.001	<0.01
Hominidae	<0.001	<0.001	—	1
Hylobatidae	0.035	<0.01	1	—
<b>2DXYA</b>				
Platyrrhini	—	<0.001	<0.001	<0.001
Cercopithecidae	<0.001	—	1	0.240
Hominidae	<0.001	1	—	1
Hylobatidae	<0.001	0.240	1	—
<b>L/V<sup>(1/3)</sup></b>				
Platyrrhini	—	<0.001	<0.001	<0.001
Cercopithecidae	<0.001	—	<0.01	1
Hominidae	<0.001	<0.01	—	0.016
Hylobatidae	<0.001	1	0.016	—
<b>bgPC1</b>				
Platyrrhini	—	<0.001	<0.001	<0.001
Cercopithecidae	<0.001	—	0.068	1
Hominidae	<0.001	0.068	—	0.390
Hylobatidae	<0.001	1	0.390	—
<b>bgPC2</b>				
Platyrrhini	—	0.760	<0.001	1
Cercopithecidae	0.760	—	<0.001	1
Hominidae	<0.001	<0.001	—	<0.001
Hylobatidae	1	1	<0.001	—



Abbreviations: 2DYZA = 2D angle in the YZ plane (canal superior orientation; in degrees);  
2DXYA = 2D angle in the XY plane (canal medial orientation; in degrees); L = length (in mm);  
V = volume (in mm<sup>3</sup>); bgPC = between-group principal component.

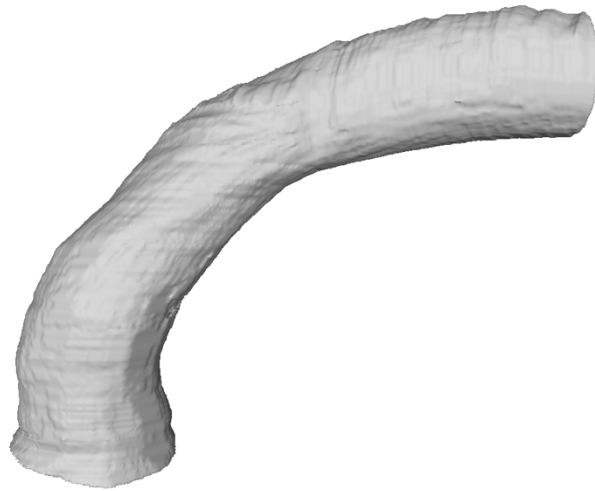
**SOM Table S5**

Results of the permutational analysis of variance based on the Euclidean distances between group means. Groups correspond to the main extant anthropoid clades (i.e., platyrrhines, cercopithecids, hylobatids, and hominids) used in the bgPCA and further analyses (see the main text). The tests have been computed with the streampoint configurations (i.e., full space) and with the bgPC scores with and without cross-validation (i.e., bgPCA spaces). While  $p$  is the significance of group mean differences, the coefficient of determination ( $R^2$ ) denotes the variance explained by the grouping structure.

	$p$	$R^2$
Full space	0.001	0.67
bgPCA space without CV	0.001	0.77
bgPCA space with CV	0.001	0.77

Abbreviations: bgPCA = between-group principal component analysis; CV = cross-validation.

**SOM File S1.** R script used to import the 3D carotid canal surface and iteratively find the orthogonal plane to the canal passing through IRG (intersection ridge–groove) among several cutting plane possibilities. (Provided as a separate R file.)



**SOM File S2.** 3D model of the carotid canal surface of *Pliobates cataloniae*, available from MorphoSource.org (<http://dx.doi.org/10.17602/M2/M344218>).

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