

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☐ ☒ The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
- ☐ ☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☐ ☒ The statistical test(s) used AND whether they are one- or two-sided
Only common tests should be described solely by name; describe more complex techniques in the Methods section.
- ☐ ☒ A description of all covariates tested
- ☐ ☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☐ ☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☐ ☒ For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
Give P values as exact values whenever suitable.
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☐ ☒ Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection

Inner ears obtained from micro-computed tomographies or propagation phase-contrast microtomographies were segmented and measured using Amira 5.3.3, Avizo 7.1, and ImageJ 1.53e. Membranous labyrinths were segmented in Avizo 7.1, prepared for analysis in Geomagic Studio 12, and analysed using Ariadne toolbox v1.1.0. 2D measurements of published membranous labyrinths were obtained following protocols described in the Methods, using ImageJ 1.53e. For some specimens, condylobasal length and condylo-anteroorbital length were calculated from scans or photographs using Amira 5.3.3, Avizo 7.1, or ImageJ 1.53e (see Supplementary Data 2 for further details). We used Mesquite 3.5 for constructing the phylogenetic tree and setting the calibration nodes.

Data analysis

We used R v.4.0.3 and XLSAT 2018.1.1 for all analyses performed. The R scripts used in this study are available in the Supplementary Dataset.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The raw datasets used in this study are available in the Supplementary Dataset. Links for CT scan datasets and bony labyrinth 3D meshes obtained from Morphosource.org can be found in Supplementary Data 3. Some bird skull measurements and fish lengths were obtained from skullsite.com and fishbase.org, respectively (Supplementary Data 2). Time calibrations between most extant species were obtained from timetree.org. Body mass and Tb of some extant species were obtained from eol.org/traitbank (Supplementary Data 2).

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research](#).

Reporting on sex and gender

N/A

Population characteristics

N/A

Recruitment

N/A

Ethics oversight

N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

- ☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size

Our sample captures taxonomic, phylogenetic, morphological, ecological, behavioural and locomotor diversity, but was constrained by the availability of material. We focused on densely sampling mammals and birds, which we used as independent models for endotherms; we used a large lepidosaurian sample as a model for ectotherms. The remaining extant specimens covered the range of body temperatures in vertebrates, but they are not the focus of this study. Our fossil sample included several mammalian morphs, where the transition to endothermy is thought to occur. The 2D dataset is less accurate than the 3D sets, but was only used to extend the analysis to lower body temperatures, to obtain a broader range of data to assess the relationship between temperature and the Thermo-Motility Index. Predictions for the thermal regime of fossil synapsids are only based on the 3D sets.

Data exclusions

No data was excluded from the analyses.

Replication

Repeatability and reproducibility tests were successful and respective statistics are available in Supplementary Data 4. Measurements were repeated five times by two different individuals to perform these tests (for further details see Methods).

Randomization

Randomization was used for cross-validation of the logistic regression and partial least-squares regressions used to calculate missing values in fossils. Each of these analyses was replicated 100 times, and for each of them specimens were randomly assigned to training and testing sets. Randomization was not used for the remaining analyses because of the nature of fossil material.

Blinding

Blinding is not relevant to our study due to the nature of the analysis of fossil material.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance	This study uses 352 specimens in total and all details concerning provenance of each specimen is provided in Supplementary Data 2 and 3. No new fossil specimens were obtained in the course of this study, therefore no permits were required to conduct the current study.
Specimen deposition	All specimens are part of collections housed in public museums or institutions and are freely accessible. This study uses 352 specimens in total and all details of the institutions where the specimens are housed are provided in Supplementary Data 2.
Dating methods	No new dates are provided, but the divergence time ages and last appearance data are based on stratigraphical correlation and previously published radiometric data (Supplementary Note 4).
☒ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.	
Ethics oversight	No ethical approval was required because only specimens from public collections were used.

Note that full information on the approval of the study protocol must also be provided in the manuscript.