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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	We use Mesquite for formatting the data for phylogenetical analyses and export the data as nexus format, for details see Supplementary Dataset file 1.
Data analysis	We used the following softwares for data analyses in the study: The Bayesian total-evidence dating analysis was performed using software MrBayes 3.2.8(not formally released when performing this study and the executable was compiled from the latest source code, https://github.com/NBISweden/MrBayes);The phylogenetic trees were visualized in FigTree (v1.4.4) and adjusted in Adobe Illustrator CS6 and Affinity Designer (v1.8.4); The data collected by X-ray micro-computerized tomography was analyzed by using VGstudio 2.2 to produce the 3D images.

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

Character matrix, NEXUS files, all figures, scripts for phylogenetical analyses and MrBayes commands are given in main text, Supplementary information and

Supplementary Dataset.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	*Use the terms sex (biological attribute) and gender (shaped by social and cultural circumstances) carefully in order to avoid confusing both terms. Indicate if findings apply to only one sex or gender; describe whether sex and gender were considered in study design whether sex and/or gender was determined based on self-reporting or assigned and methods used. Provide in the source data disaggregated sex and gender data where this information has been collected, and consent has been obtained for sharing of individual-level data; provide overall numbers in this Reporting Summary. Please state if this information has not been collected. Report sex- and gender-based analyses where performed, justify reasons for lack of sex- and gender-based analysis.*
Population characteristics	*Describe the covariate-relevant population characteristics of the human research participants (e.g. age, genotypic information, past and current diagnosis and treatment categories). If you filled out the behavioural & social sciences study design questions and have nothing to add here, write "See above."*
Recruitment	*Describe how participants were recruited. Outline any potential self-selection bias or other biases that may be present and how these are likely to impact results.*
Ethics oversight	*Identify the organization(s) that approved the study protocol.*

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

Ecological, evolutionary & environmental sciences study design

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

Study description	This is a palaeontological and evolutionary study aiming to report two superbly preserved lampreys from the Jurassic terrestrial fossil Lagerstätte Yanliao Biota of North China, reconstruct the evolutionary process of lampreys' feeding mechanism and assess its implications to the establishment of the modern-type life history mode of lampreys. On the basis on the revised phylogeny of lampreys, the conventional wisdom about the origin of modern lampreys were replaced by our new interpretations.
Research sample	A total of four specimens (two species) of fossil lampreys were included in this study, all showing a wealth of anatomical details of the feeding structures. We compare their feeding mechanism and that of previously known fossil and extant lampreys in the context of the phylogeny of its group to reconstruct the evolutionary history of the feeding system and feeding habits of lampreys.
Sampling strategy	We observe directly the specimens to obtain the anatomical details. We also use X-ray micro-computerized tomography for scanning the oral disc and the dentition of IVPP V 15830.
Data collection	During 2009-2010, the palaeotonlogical investigation team of Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences collected the specimens from the fossil localities (Tiaojishan Formation, Oxfordian, earliest Late Jurassic) of Bawanggou, Mutoudeng Town, Qinglong County, Hebei Province and Daohugou beds (late Middle Jurassic, ca. 163 Ma) Wubaiding Village, Reshuitang County, Liaoning Province, China. In 2020, the first author and colleagues revisited relevant fossil localities and checked the accurate lithological features of the fossiliferous layers. Meristic measurements of fossils were performed directly for the specimens. The dataset for phylogenetical analyses includes 25 extant taxa and 20 fossils from Cyclostomi (total group), and combines both morphological characters (partially revised, for details see supplementary information) and molecular sequences (following the reference of a recent study on cyclostome phylogeny), with morphological characters for all taxa (208 characters), 16S gene for 10 extant species (772 sites) and CO1 gene for 11 extant species (721 sites).
Timing and spatial scale	During 2009-2010, the palaeontological investigation team of Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences collected the fossils from the fossil localities (Tiaojishan Formation, Oxfordian, earliest Late Jurassic) of Bawanggou, Mutoudeng Town, Qinglong County, Hebei Province and Daohugou beds (late Middle Jurassic, ca. 163 Ma) Wubaiding Village, Reshuitang County, Liaoning Province, China.
Data exclusions	No data excluded.
Reproducibility	Independent Markov chain Monte Carlo runs were executed at least twice to confirm consistent results among runs. Commands and inputs to reproduce all the analyses are provided in Supplementary Information and Supplementary Dataset.

Randomization	No randomization procedure was used because it was not necessary for the type of study we conducted.
Blinding	This is a palaeontological study of all known fossil materials. Blinding is inapplicable and irrelevant.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	Middle to Late Jurassic laminated mudstones are well-exposed in both fossil sites, fossils were collected directly from these rocks. All the fossil sites are located near the village or the main roads. The region of the fossil sites is dominated by semi-arid climate and monsoon, with mean annual temperature of ca. 6–8.5°C and mean annual precipitation of 500-600 mm.
Location	Wubaiding 41°22'9'' N, 119°23'38'' E; Bawanggou 40°27'07.8'' N, 119°22'46.0'' E
Access & import/export	All fossil specimens in this study were collected by palaeontological expedition team of the Institute of Vertebrate Paleontology and Paleoanthropology in compliance with all local, national and international laws. All collecting permissions were obtained before the field work.
Disturbance	All samples were collected by the researchers of the Institute of Vertebrate Paleontology and Paleoanthropology and are formally stored therein. No disturbance will be caused by the study.

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	The authors are researchers of Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing and have been permitted to study these specimens.
Specimen deposition	The specimens were deposited in Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing and permit free access by other researchers.
Dating methods	The dating methods were described or cited in the main text and the Method section of the Supplementary Information.

☒ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.

Ethics oversight	Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing approved on the study protocol.

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