PROJECT TITLE: Cranial biomechanics of marine reptiles and ecological implications

University of Bristol Theme: Climate and Environment Research Challenge Area
Research Group(s): Palaeobiology Research Group
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Project keywords: palaeontology, function, Mesozoic, biomechanics, adaptation, marine reptiles
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Figure 1. Ichthyosaurs were common apex predators in Jurassic marine ecosystems and fed on a variety of prey items, but their skull mechanics remain poorly understood, undermining attempts to characterise their ecology. [Image: John Sibbick]

Figure 2. Finite Element Analysis breaks complex objects into thousands of elements, whose responses to applied forces can be modelled and visualised heat maps, giving insights into function and structure, as in this example from two Early Jurassic ichthyosaurs [From Jamison-Todd et al. 2022]

Project Background
Aquatic reptiles (ichthyosaurs and plesiosaurs) were keystone species and apex predators in many Mesozoic marine ecosystems that fed upon a range of other vertebrate and invertebrate taxa (Foffa et al. 2018). The remains of these animals are common in Jurassic to Cretaceous-aged deposits around the world and include complete and three-dimensionally preserved specimens. Although ichthyosaurs and plesiosaurs have been the focus of intense taxonomic scrutiny for over two centuries, their cranial function is usually described qualitatively or from ecomorphological studies, with inferences of feeding ecology derived from macroevolutionary studies using cladistic datasets, lower jaw metrics and ecospace modelling (Stubbs & Benton 2016, Moon & Stubbs 2020; Reeves et al 2021; Fischer et al. 2020, 2022; Johnson et al. 2022). A few quantitative biomechanics studies of skull function exist (e.g. Foffa et al. 2014; Jamison-Todd et al. 2022), but a comparative, skull-focused, biomechanical framework for understanding the feeding ecology and evolution of ichthyosaurs is currently lacking, limiting our understanding of their role in Mesozoic marine ecosystem complexity and evolution. Here, we propose to rectify this deficit by conducting detailed research into the feeding biomechanics of Jurassic marine reptiles, using cutting-edge computational biomechanical methods to compare and contrast the feeding ecology, performance and behaviour of these important groups.

Project Aims and Methods
The project will aim to assess skull performance during feeding in a range of Jurassic marine reptiles, including members of the major clades Ichthyosauria and Plesiosauria. These two groups are not closely related, but both exhibit numerous adaptations to life in a fully aquatic setting. The project will be based on 3D skulls from Jurassic-aged representatives of both groups, which are held in the collections of the Natural History Museum and the Bristol City Museum and potentially other institutions. Skulls will be µCT-scanned to reveal their detailed anatomical construction and to virtually remove any surrounding rock matrix, or surface scanned where µCT is unfeasible. The resulting scans will be used to produce virtual 3D models, through segmentation, retrodeformation and reconstruction. Simulations of the jaw muscles of these taxa will be added to the models.
following detailed comparisons with living reptiles. These ‘fleshed out’ 3D models will form the basis for a series of biomechanical experiments using Finite Element analyses. These analyses will reveal patterns of stress/strain and cranial function that can be used to compare the feeding behaviours and ecologies of the two groups. The effect of matching complex cranial sutures with loosely-connected jaws and extensive cartilage between bones will be explored. Studies will also highlight potential differences and similarities in cranial performance and function and give insights into the trophic relationships and guild structure within Mesozoic marine ecosystems. In addition, it will reveal the relative roles of evolutionary history (phylogeny) and environmental constraint (adaptation) in driving the development of these functional complexes. This project will represent the first attempt to characterise and compare skull function between these two major clades.

Candidate requirements
The project will suit a student with a background in palaeontology, geology, biology or zoology, interested in pursuing further study in vertebrate palaeontology. Ideally the student should feel comfortable working with digital datasets and computational functional analysis, yet prior experience is not required as full training will be provided.

Project partners Natural History Museum, Bristol City Museum

Training
Training will be provided in vertebrate comparative osteology and myology, taxonomy, use of museum collections, µCT-scanning, 3D reconstruction and retrodeformation techniques, Finite Element and Multibody dynamic analyses, and evolutionary comparative analyses.

Background reading and references

Useful links
http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

Eligibility
UK and International students are eligible for a University of Bristol Scholarship. UoB Scholarships are fully funded for 4 years and cover university fees, living expenses at the UKRI standard rate, and an allowance of £2000 per year towards research expenses.

Application deadline: Tuesday 16th January, 2024, 23.59 GMT
(Interviews are expected to take place in mid/late February)

How to apply
Applications are online only at: http://www.bristol.ac.uk/study/postgraduate/apply/
Please select “PhD in Geology” as the programme in the online application system.
Please specify the project title and supervisors for the project that you are applying for.
To ensure your application is considered under the University of Bristol Scholarship funding scheme you must complete the Funding page in your online PhD application as follows:
1. For “What is your likely source of funding?” select Studentship
2. For the free text field “Please give the name of your scholarship or studentship” enter University of Bristol Scholarship.
3. Set “Percentage from this source” to 100%
4. Set “Is this funding already secured?” to No