



SYSTÈME DE FILTRATION PAR LE BEC DES CANARDS BARBOTEURS, CAS D'ÉTUDE POUR LA BIOINSPIRATION

TONGUE AND BEAK FILTRATION IN DABBLING DUCKS, CASE STUDY FOR BIO INPIRATION

Etablissement **Muséum national d'Histoire naturelle**

École doctorale **Sciences de la nature et de l'Homme : évolution et écologie**

Spécialité **Biologie des organismes**

Unité de recherche **Mécanismes Adaptatifs et Evolution**

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Employeur **MNHN**

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Mots clés - Keywords

évolution, morphologie fonctionnelle, zoology, anatomy, Imagerie 3D, bioinspiration

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Description de la problématique de recherche - Project description

Le réseau doctoral Marie Skłodowska-Curie, Nature4Nature, organise un vaste réseau international et interdisciplinaire de chercheurs dans le but de conceptualiser un cadre pour des innovations technologiques durables. Pour cela, il étudie le cas de la pollution par les (micro)plastiques des écosystèmes aquatiques, dont les organismes filtreurs sont les victimes. Il accueille neuf projets de doctorat, chaque projet du programme explorant une étape du processus de bioinspiration, de la formulation du problème à la mise en œuvre technique (<https://www.nature4nature.net/>). Dans ce cadre, le projet de doctorat au Muséum National d'Histoire Naturelle se concentrera sur l'une des premières étapes du processus : identifier l'architecture du système ostéomusculaire impliqué dans la filtration des particules chez les canards barboteurs dans un contexte évolutif par une étude en anatomie fonctionnelle. Il analysera les améliorations que les concepts de la biologie évolutive et les méthodes comparatives peuvent apporter à la bioinspiration dans le cadre du développement durable

Marie Skłodowska-Curie doctoral network, Nature4Nature, organize a broad international and interdisciplinary network of researchers. It aims to build a conceptual framework for nature-friendly technological innovations. To do so, it addresses the problem of (micro)plastic pollution of aquatic ecosystems, of which filter-feeding organisms are the victims. It hosts nine doctoral projects, each project of the program will explore one stage of the bioinspiration process, from formulation of technical problem to the technical implementation (<https://www.nature4nature.net/>). Within this framework, the doctoral project at the Muséum National d'Histoire Naturelle will focus on one of the first stages of the process, identifying the architectures of the osteomuscular system involved in the particle filtration in the dabbling ducks in an evolutionary context. It will use a functional morphology approach. It will analyse the improvements that evolutionary biology concepts and comparative methods can bring for bioinspiration in the context of sustainable development.

Thématique / Domaine / Contexte

Marie Skłodowska-Curie doctoral network, Nature4Nature, organize a broad international and interdisciplinary network of researchers. It aims to build a conceptual framework for nature-friendly technological innovations. To do so, it addresses the problem of (micro)plastic pollution of aquatic ecosystems, of which filter-feeding organisms are the victims. The doctoral project will explore on of the first stage of the bioinspiration process: the analysis of the biological system.

Evolution, Functional morphology

The doctoral project is involved in the Nature4nature network. The PhD student will take part, with 8 other PhD students, to events, training modules, summer school and final exhibition.

Within this framework, the doctoral project at the Muséum National d'Histoire Naturelle will focus on one of the first stages of the process, identifying the architectures of the osteomuscular system involved in the particle filtration in the dabbling ducks in an evolutionary context.

Objectifs

The dabbling ducks' filtration system (i.e., tongue and beak) is the biological model of interest.

The goals of the PhD project are:

- 1) identify and describe dabbling ducks' filtration system
- 2) produce transfer procedures coming from this system to technology
- 3) study the impact of considering evolutionary constraints in the transfer of biological functional systems to technology, in the context of sustainable development.

The DC will study the morphology of the bucco-lingual system of a sample of species, representative of the phylogenetic and ecological diversity of the Anatidae. The DC will establish a solid 3D anatomical knowledge of the osteo-muscular system associated with filtration (beak and tongue) from the literature, classical anatomical dissections, and numerical segmentations of digital models (MNHN). To obtain appropriate 3D digital models, the DC will establish a method of anatomical preparation using contrast agents to access detailed soft and hard tissue anatomy by tomography. The 3D models acquired by micro-CT will be obtained using the latest generation of image analysis software (VGStudio Max) (SU). The DC will analyze the diversity of structures involved in the oral-lingual system and identify structures associated with filtration in a variety of *Anas* species from different ecologies. 3D geometric morphometric methods will be used to quantify shape and variation between species in an evolutionary and functional context (MNHN).

The detailed anatomical study of this biological functional system, in a phylogenetic informed context, will allow to determine anatomical characteristics linked to evolutionary history and those linked to the type of food filtered.

He/she/they will identify the principles of filtration and propose procedures for technology transfer. The DC will investigate how providing practitioners with an evolutionary context can facilitate the development of technological frameworks based on form-function relationships in nature. The DC will extract the underlying conserved biological principles and evolutionary adaptations associated with the filtration mechanisms observed in dabbling ducks for the design of a technological system (THD). To do so, the DC will link the knowledge base they have created to existing tools in the Bioinspired design and development process, e.g., identification of biological trade-offs (E2BMO) or innovative design principles (BionIQuity, BioTRIZ) for the application (thesaurus, business canvas).

In addition, they will identify areas of application of the identified principles and models that can inform the development of various applications. An analysis of the approach, from evolutionary biology to industry application, will be carried out (Impactvista) in order to identify how this innovation can be useful in the context of sustainable development and more broadly how evolutionary biology concepts can participate in bioinspired innovation.

Méthode

Dabbling ducks, a subgroup of Anatidae (ducks, geese, and swans), mainly feed at the surface of the water and filter their food with the lamellae of their bills. Dabbling ducks present a wide diversity of species (Johnson and Sorenson, 1999). Considering the variability of ecologies and feeding strategies of the genus *Anas*, which includes pintails, most teals, the mallard and its close relatives (Livezey, 1995), we propose to mainly focus on these taxa.

The DC will sample species following the concepts of comparative analyses in evolutionary biology. Phylogenetic and ecological diversities will be maximized, considering the constraints linked to specimen availability. The mallard (*Anas platyrhynchos*), a widespread dabbling duck is a good candidate for a detailed anatomical analysis, using state-of-the-art techniques of contrast agent for bone and muscle tomography (Gignac and Kley, 2014; Gignac et al., 2016) (SU).

The DC will establish a solid 3D anatomical knowledge of the osteo-muscular system associated with filtration (beak and tongue) based on literature (Zweers' work), classic anatomical dissections (MNHN) and numerical segmentations of digital models (SU). To obtain appropriate 3D numerical models, the DC will establish a method using contrast agents to have access to the detailed anatomy of both soft and hard tissues. The DC will analyze the diversity of structures involved in the bucco-lingual system and will identify the structures associated with filtration on a variety of *Anas* species from different ecologies.

3D geometric morphometrics methods will be used to quantify the shape and variations between species in an evolutionary and functional context (MNHN).

As dabbling ducks use their tongue and beak to not only filter, but also swallow, groom, vocalize, etc. identifying the morphological features linked to the filtration function is particularly relevant in this project. The DC will extract underlying conserved biological principles and evolutionary adaptations associated with filtration mechanisms observed in dabbling ducks for the design of a technological system (THD).

The main part of the thesis will take place at MNHN in Paris, France. The PhD student will mandatory secondments:

- SU (Year 1, 6 months, supervision Prof. Anton du Plessis): collection and processing of micro-CT data.
- THD (Year 2, 2 months, supervision Prof. Kristina Wanieck): translation of evolutionary concepts into analogies for use in design/engineering sciences.
- Impactvista (Year 3, 2 months supervision Ief Winckelmans): assessing challenges and opportunities for applying evolutionary thinking to bioinspired design in industry.

Résultats attendus - Expected results

- Biomechanically informed characterization of 3D shape of filtration structures
- Analysis of phylogenetic, functional, and environmental constraints on form-function relationships
- Assessment of their importance to bioinspired technologies

Références bibliographiques

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- Wanieck, K., Fayemi, P. E., Maranzana, N., Zollfrank, C., & Jacobs, S. (2017). Biomimetics and its tools. *Bioinspired, Biomimetic and Nanobiomaterials*, 6(2), 53-66.

Précisions sur l'encadrement - Details on the thesis supervision

In addition to the local exchanges, weekly meetings will be organised to solve small problems. Monthly meetings with the supervisors will allow the progress of the work to be monitored. Frequent contacts, several times a year, are also planned with the members of the nature4nature network. The PhD student will have to participate in the Nature4nature network's activities

Secondments will be supervised by:

- Anton Du Plessis Stellenbosch University South Africa
- Kristina Wanieck Deggendorf institut of technology Germany
- Ief Winckelmans ImpactVista Belgium

Conditions scientifiques matérielles et financières du projet de recherche

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Ouverture Internationale

Stellenbosch University, South Africa
Deggendorf institute for technology, Germany
ImpactVista, Belgium

Objectifs de valorisation des travaux de recherche du doctorant : diffusion, publication et confidentialité, droit à la propriété intellectuelle,...

The DC will publish its work in scientific journals and participate in oral presentations within the consortium and at international scientific conferences.

Collaborations envisagées

The DC will have access to the network of collaborators of the Nature4Nature project partners.

Complément sur le sujet

<http://nature4nature.net> (<http://nature4nature.net>)

Profil et compétences recherchées - Profile and skills required

- Les candidats doivent être titulaires d'un master ou d'un diplôme équivalent dans le domaine de la biologie évolutive.
- Les relevés de notes du diplôme de master doivent être disponibles à la date du recrutement.
- Les candidats doivent avoir une forte affinité avec la recherche en morphologie fonctionnelle, en morphologie animale et en évolution.
- Avoir des compétences en analyses de forme et/ou en méthodes comparatives phylogénétiques et/ou en imagerie biomédicale est un fort atout.
- Les candidats doivent être familiarisés avec la vision de PyroLife.
- Les candidats doivent être capables de comprendre et de s'exprimer en anglais écrit et parlé à un niveau suffisant pour l'achèvement

d'un doctorat.

- Les candidats peuvent être de n'importe quelle nationalité mais doivent se conformer aux critères d'éligibilité d'Horizon Europe MSCA : Les candidats ne doivent pas avoir résidé ou exercé leur activité principale (travail, études, etc.) dans le pays de l'organisme d'accueil (France) pendant plus de 12 mois au cours des 3 dernières années précédant immédiatement la date de recrutement. Les courts séjours tels que les vacances, et le temps passé dans le cadre d'une procédure d'obtention du statut de réfugié ne sont pas pris en compte. Les candidats ne doivent pas être titulaires d'un doctorat ou d'un diplôme équivalent à la date de début du recrutement. Les chercheurs qui ont soutenu avec succès leur thèse de doctorat mais qui n'ont pas encore reçu officiellement le diplôme de doctorat ne seront pas considérés comme éligibles.

- Tous les candidats qualifiés, y compris les minorités et les femmes, sont encouragés à postuler.

- Applicants must hold a master's degree or equivalent in the field of Evolutionary Biology.
- Transcripts of the master's degree must be available by the date of the recruitment
- Applicants should have a strong affinity for research in functional morphology, animal morphology and evolution.
- Having skills in shape analyses and/or phylogenetic comparative methods and/or biomedical imaging is a strong plus.
- Applicants should be familiar with the PyroLife vision
- Applicants must be able to understand and express themselves in both written and spoken English to a level that is sufficient for the completion of a PhD.

• Applicants may be of any nationality but must comply with the Horizon Europe MSCA eligibility criteria:

Applicants must not have resided or carried out their main activity (work, studies, etc.) in the country of the host organization (France) for more than 12 months in the past 3 years immediately before the recruitment date. Short stays such as holidays, and time spent as part of a procedure for obtaining refugee status are not taken into account.

Applicants may not hold a doctoral degree or equivalent at the start date of the recruitment. Researchers who have successfully defended their doctoral thesis but who have not yet formally been awarded the doctoral degree will not be considered eligible.

- All qualified applicants, including minorities and women, are encouraged to apply

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