Modeling the growth of mineralized tissues in non-mammalian odontodes: implications for their morphogenesis and for the ontogeny and plasticity of polyodontodes

PhD supervisor (NOM Prénom) : GOUDEMAND Nicolas	**Co-supervisor** (NOM Prénom) :
Research unit : IGFL, ENS Lyon	Research unit :
E-mail : nicolas.goudemand@ens-lyon.fr	E-Mail :
HDR : OUI	HDR : OUI / NON

Description:

Odontodes (teeth as well as tooth-like elements such as shark dermal denticles) are formed via the regulated folding of an epithelium-mesenchyme interface, followed by secretion of a mineralizing organic matrix by specialized cells (for instance, secretion of enamel by ameloblasts). Although odontodes comprise most of the fossil record of many taxa, their development is still poorly understood, which impairs the necessary integration of developmental biology in evolutionary studies. Much of what we know is based on the analysis of dental development in mice and other mammals: a lot of efforts were dedicated to the elucidation of the molecular basis of dental development and some decent models exist for simulating the folding of the epithelium-mesenchyme interface. Yet, until now, there was no model for the secretion of the extracellular matrix at this interface and its subsequent mineralization. Hence, although the existing models captured realistically the main features of the developing teeth (say the relative positions of the cuspids), it was not possible to predict the final occlusal shape of the teeth once the many layers of mineralized tissues have been deposited. Although still limited to two-dimensional growth simulations, the recent model of Hakkinen et al. (2019), which is based on diffusion-limited growth, has partly filled this gap.

The goal of this project is to develop models that extend the applicability of Hakkinen et al.'s model to the three-dimensional growth of non-mammalian odontodes and to analyze their implications for their morphogenesis and hence for taxonomical practices. In particular we are interested in applying such models to the growth of polyodontodes, also called odontocomplexes, that is, organs that are formed or grown via accretion of several odontodes. This is the case for the ganoid scales of living polypterids. This is also the plesiomorphic condition for the dermal denticles in sharks, and for the teeth and tooth-like elements of many early, and now extinct, vertebrate taxa. Among them, conodonts are particularly interesting because some of their ever-growing, oral elements were shown to display occlusal wear and breakage of their denticles, and those may be repaired during a new growth cycle of the element, presumably via the addition of a new odontode: new layers of crown and basal body tissues (analogs of enamel and dentine) are added on top of the previous ones, thus regenerating worn or broken denticles. During that process, we observed that some denticles may get fused, particularly in the occlusal area, which may explain the occurrence of some particular morphological traits used in taxonomy. Since the frequency of such traits may thus depend on the hardness of food, local changes in diet may lead to morphological plasticity within a species. This is one of many examples where a better understanding of developmental and functional constraints would benefit the interpretation of fossils.

Depending on the previous experience and motivations of the Master or PhD candidate, the project may comprise more or less empirical, experimental and theoretical work. Indeed, although the main goal is to develop new theoretical models, their validation may involve lab experiments and morphometric/histologic studies on, say, extant ganoid scales, and the analysis of their implications for the interpretation of early vertebrate taxa is rich of many opportunities. **Le sujet du stage de M2 peut être facilement adapté 'à la carte' pour correspondre au mieux aux compétences et envies de l'étudiant.e**.

Although most of the skills necessary for this project can be acquired within the team during the course of the Master/PhD, it would be ideal if the candidate had some experience with programming and/or with the processing of microtomographic data and geometric morphometrics.

The Master/ PhD student will work within the Biomodeling team led by Nicolas Goudemand at the Institute of Functional Genomics of Lyon (IGFL), on the Gerland campus of the ENS Lyon. The team's main research area is paleo-eco-evo-devo of vertebrate odontodes. The two main current model systems are conodonts and sharks. The scientists at the IGFL are interested in how animals function, develop and evolve. The IGFL's originality comes from bringing together, under one roof, leading researchers from different backgrounds (molecular biologists, embryologists, bioinformaticians, cell biologists, paleontologists), which makes for a very fertile environment where varied approaches can cross-fertilize. For instance, Nicolas Goudemand is a trained physicist turned into a paleontologist, who collaborates with developmental biologists.