On how to reconcile flexibility with rigidity during evolution: the caudal system in seahorses

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Within teleosts, seahorses and pipehorses are unique fishes that are capable of using their caudal tail as a prehensile organ. An unusual level of flexibility for such a system in teleosts, paradoxally, evolved within a lineage in which the body is covered with bony plates. This provides at least in pipefish an increased level of rigidity, as well as protection against predators. It thus seems that evolutionary transformations of the caudal system within syngnathid fishes resulted in a system that avoids extensive trade-offs between rigidity and flexibility. Additionally, considering the use of this prehensile organ, it suggests that also at the muscular level, modifications have occurred to allow fine motor control of this system. In order to get to a better understanding of how the body armour in seahorses got modified from an ancestral condition, as found in pipefish, a comparative study is performed on a pipefish and seahorse species. To allow a full comprehension of the detailed 3D-anatomy of the musculoskeletal system in the caudal system, including the structural interaction between elements, both non-invasive (synchrotron X-ray scanning and micro-CT scanning) and invasive (histological sectioning) are used and combined with graphical 3D-reconstructing and modelling. Results show that the structural organisation and interaction between modified skeletal plates in seahorses can explain how rigidity and flexibility can be combined. The muscular system also shows that apparent complex movements for prehension may be achieved by a limited set of muscles.