What aquaculture does for taxonomy, evo-devo, palaeontology, biomechanics and biomedical research

Fish skeletal biology has a long history and the classic literature is a truly valuable source of knowledge. Thomas Huxley (1859) lists in his treatise “Observations on the development of some parts of the skeleton of fishes” some of the fundamental works that have been published between 1835 and 1850 by von Bär, Agassiz, Voigt, Sibold, Stannius and Heckel (Huxley, 1859; and references therein). Five years after the publication of the “On the Origin of Species” Huxley’s and Darwin’s opponent Richard Owen does not receive full credits although Owen also greatly contributed to fish skeletal biology (Owen, 1845, 1854). Huxley (1859) informs us that mineralisation of the notochord sheath rather than cartilage establishes vertebral body anlagen in teleosts. This exemplifies how knowledge from before 1900 remains essential also to understand the zebrafish (Danio rerio) and the medaka (Oryzias latipes) skeleton. Being popular models in developmental and biomedical research, these two species boost the interest in fish skeletal biology. Zebrafish and medaka can be studied as models for human skeletal diseases because basic skeletal components, their development and essential development-related genes are conserved within gnathostomes and osteichthyans (Harris, Henke, Hawkins, & Witten, 2014; Witten, Harris, Huysseune, & Winkler, 2017). Despite variation within developmental networks, their core functions are often conserved, even across phyla (Elinson & Kezmoh, 2010; Harris et al., 2014). The availability of zebrafish and medaka mutant lines and transgenes allows for unprecedented investigation into the mechanisms of skeletal development. Establishment of gene editing approaches, via targeted endonuclease activity such as CRISPR/Cas9 or TALEN, further improves the applicability of organisms amenable to genetics (Hruscha et al., 2013; Hwang et al., 2013; Mackay & Schulte-Merker, 2014). The fact that we are bony fish (indeed mammals/humans are osteichthyans) should help to understand the function of the fish skeleton. Only, we live in an environment that is very different from the environment of other bony fish. It started when bony fish evolved a lung. Indeed, a main character that distinguishes us, osteichthyans, from our chondrichtyian siblings, is the evolution of the lung, not the skeletal tissues (Maisey, 2000). A plan to evolve a lung with the purpose to conquer dry land does, of course, not exist in evolution. The lung must have evolved because gas exchange in the vascularized gut enabled bony fish to survive in ponds that were likely hot, muddy and low in oxygen. When it became crowded in some ponds the losers, our ancestors, were kicked out on dry land. The winners, the ancestors of the teleosts, moved to cleaner, more oxygenated waters where the lung further evolved into a swimbladder (Cass, Servetnick, & McCune, 2013; Longo, Riccio, & McCune, 2013). A swimbladder is a marvellous organ that enabled osteichthyans to soar in water column, essentially weightless, like astronauts in space. Meanwhile, the skeleton of our landlocked ancestors was exposed to the full mechanical load that is required to move the body outside the water. We keep those differences in mind when analysing development, cells and morphology of the fish skeleton. Apart from its conserved genetic basis, the skeleton is, indeed, an organ system that is strongly impacted by epigenetic factors. It is not a secret that mechanical load triggers skeletal development, that the skeleton changes in response to mechanical load and that load is required to keep the skeleton healthy (Danos & Staab, 2010; Fiaz, van Leeuwen, & Kranenborg, 2010; Dean & Shahar, 2012; Witten & Hall, 2015). Mechanical load is one important factor but the range of epigenetic factors that influence skeletal development is extensive. As pointed out by West-Eberhard (2005) even behaviour is a common mediator of normal skeletal development. Most laboratory experiments investigate the genetic basis of skeletal development. Less experiments address epigenetic factors (Fiaz, Leon-Klooosterziel, van Leeuwen, & Kranenborg, 2014; Gunter & Meyer, 2014; Huysseune, 1995). Most epigenetic experiments are done in relation to aquaculture research. These are often large scale experiments that cannot be done in the laboratory (Fjelldal et al., 2014). Light regime, temperature, size, colour and shape of the tank, rearing destiny, size, composition and shape of the food, as well as many other factors are being tested. Essentially, any parameter one can think of is being investigated (Boglione, Gavaia, et al., 2013; Boglione, Gisbert, et al., 2013). The epigenetic experiments carried out in the frame of aquaculture research complement the studies that address genetic questions. If we bring the results from genetic and epigenetic studies together we have a chance to better understand the fish skeleton. A total number of 120 articles from IAFSB participants about fish skeletal biology in this volume and in the previous three volumes represent this approach (Journal of Applied Ichthyology 2010, 26, 2; 2012, 28, 3; 2014, 30, 4). What aquaculture contributes to the understanding of fish skeletal biology is only one example. Notwithstanding, similar examples exist for all disciplines that are required. Paleontology is as much indispensable as the neontological disciplines such as morphology, comparative anatomy, taxonomy, biomechanics, physiology, evo-devo and developmental biology, immunology, molecular genetics and aquaculture research. The congress series “Interdisciplinary Approaches in Fish Skeletal Biology” (IAFSB.org) brings colleagues from all these disciplines together for a better
understanding of fish skeletal biology, thus also contributing to advance the understanding of our own osteichthyan skeleton.

**REFERENCES**


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