When did you first become interested in the evolutionary development of marine organisms?

As an undergraduate, I trained as an experimental embryologist. After working on a number of different species, I became interested in how evolutionary novelties arose and the direction of evolutionary change. As a young faculty member at the University of Chicago, molecular approaches were being developed to understand the history of life and the relationships between extant organisms. This provided a context to understand patterns of change in developmental mechanisms and morphological evolution, and emphasised that we needed to 'fill in the gaps' with information from a much broader range of organisms in order to make more meaningful comparisons.

Could you elaborate on the importance of marine labs and field stations in understanding biodiversity?

I feel strongly about the role of marine labs and field stations and have had the opportunity to work in several around the world. They have played a tremendous historical role in many aspects of human endeavour, from parlours of wealthy 19th Century Europeans who prided themselves on collecting odd marine organisms, to fundamental discoveries in environmental and experimental biology.

Marine labs sit on the interface between aquatic and terrestrial environments, and are the perfect places to launch studies to characterise the complex interactions between the biotic and abiotic players at these locations. Remote sensing, molecular techniques and the ability to sample and explore areas that were inaccessible to us only a few years ago provide opportunities to understand how the living world works and how humans fit into its future.

What are the challenges associated with research in this area?

As in any comparative field, the more data you have from both within a group and from a larger number of groups, the better your ability to resolve what is going on. But much of our work takes time, and our current academic enterprise has little patience for this. Instead, we opt for high-throughput approaches which are subject to 'garbage in, garbage out' outcomes.

There is still a need for more careful experimentation and a public peer-reviewed funding mechanism is required to keep these sorts of studies alive. It is essential that we do not let the market place or private philanthropy drive basic science. Science and education are long-term investments in our future society and scientists must be allowed to let their results drive future questions. This is where true innovation comes from.

Are there any particularly inspirational people you have encountered along your career path?

The two people that have influenced my career most are my undergraduate professor, the late Dr John Morrill, and my PhD advisor, Dr Gary Freeman. John instilled a deep sense of creativity, critical thinking and independence in all of his students and I was lucky to be part of a research project that was published in a peer-reviewed journal, which taught us that even undergraduates can make significant contributions to science. Gary was remarkably immune to trends in science and urged us to forge out on our own, choose the appropriate organism and technique for the question asked, and justify our decisions based on first principles. I have been extremely lucky to have been moulded by such inspiring people.

Finally, what was the significance for you of being awarded the Kowalevsky Medal?

No one goes into science looking for fame and fortune. This profession is an opportunity to pursue one’s natural sense of curiosity and try and uncover new insights about the way the world works. The Kowalevsky Medal is of particular significance to me because it is named after one of the greatest comparative embryologists of all time, a Russian who made profound connections about evolutionary biology by studying different types of marine invertebrate systems. I have had the luck to work on around 15 (of the ~35) different animal groups, and while that certainly does not make me an expert in any of those groups, it does give me some unique perspectives on similarities and differences in how embryos develop. It is an honour for me to join a group of bright, dedicated and hardworking Kowalevsky winners. I can only hope that my and my students’ work will continue to draw attention to the beauty and value of studying the development of mysterious creatures.
Embryonic development, in the ocean and beyond

The world-leading Whitney Laboratory for Marine Bioscience in Florida, USA, is studying the biodiversity of marine animals to understand the complex evolution of life on Earth, finding ideas in nature that can enhance the world around us.

**THE OCEAN IS** where life first evolved, and it remains home to the greatest biological diversity on the planet – from tiny microbes to megafauna. Yet much of this biology remains a mystery. Astoundingly, the old adage that we know more about the surface of the moon than the depths of the ocean remains true today.

With an endless curiosity for the animals within the ocean, Dr Mark Q Martindale is studying this biodiversity, helping to reveal its evolution both in the sea and on land. Martindale directs the University of Florida Whitney Laboratory for Marine Bioscience (UF Whitney), located in Saint Augustine on the shores of the Intracoastal and Atlantic Ocean, as well as the Seahorse Key Marine Laboratory, situated on the Gulf Coast. The combination of UF Whitney’s close proximity to a wide range of marine organisms and access to advanced molecular and imaging techniques has enabled the researchers there to understand how organisms evolve and function.

**NEW UNDERSTANDING**

Studying undeniably one of the greatest and most interesting challenges in biology – how the developmental process gives rise to the diversity of life on Earth – the team has made several groundbreaking discoveries. Using experimental embryological techniques, they revealed the embryonic stem cell counting mechanisms responsible for the elaboration of important components into adult body plans in marine organisms. This also has human relevance, as how cells are counted by the embryo is a critical part of development, failures of which can lead to cancer.

Even more strikingly, Martindale’s team challenged a central dogma in biology: organisms that appear simple under the microscope are correspondingly simple at the genetic level. Using comparative and functional genomics, the researchers showed that animals with very few cell types (as few as six) have almost the same number of genes as humans, and express them in numerous and complex ways. “This forced us to rethink the mechanisms of evolutionary adaptation and the relationship of phenotype to genotype,” he confirms.

**SELF-RENEWING PARTS**

Similar to the developmental process is regeneration, a capacity found in numerous species. Though taking place at very different stages of the life cycle, both give rise to the same end product: a functional adult animal. Many aquatic invertebrates are able to regenerate ‘missing parts’, with prime examples coming from axolotls and starfish, which can both regenerate their limbs, to worms that can regenerate their heads – including their complex brains. In an important new direction for the lab, applying molecular and functional genomic techniques, Martindale and colleagues are gradually illuminating the regenerative processes of different animals.

By examining the link between development and regeneration in marine animals, the researchers showed that abnormal adult animals are able to regenerate entirely normal adult body plans, despite the initial flaw in embryonic development. Going one step further, they could even pinpoint the time when the regenerative ability developed. Importantly, this work gives hope to the notion that congenital defects – affecting an estimated one in 33 infants – could be mitigated by promoting adult regenerative mechanisms.

**LEARNING FROM NATURE**

While involved in diverse research efforts, Martindale’s key foci are development and evolution. Determining the evolutionary relationships between organisms on Earth allows Martindale to effectively ‘replay’ the history of life on the planet and understand the direction of evolutionary change. This deeper understanding of evolutionary history will have impacts far beyond basic biology. For example, while many parasites are highly simplified as adults, it is now known that they are related to free-living forms.
Impossible without….marine labs

Marine labs and field stations are essential to basic science and have accelerated the progress made by Martindale.

The University of Florida supports two marine labs: the Seahorse Key Marine Laboratory (in the Gulf of Mexico) and Whitney Laboratory for Marine Bioscience, both funded by the US National Science Foundation. Situated in natural environments with minimal human impact, they provide the ideal space for researching the complex interplay of a wide range of organisms.

As highlighted in a recent National Academy of Sciences report, field stations are an important means for scientists to study the natural world. They are centres for research, conservation and education and the origin of many important discoveries.

Away from the traditional departmental boundaries of a university, field stations allow researchers to combine disciplines and develop innovative investigations. Hugely valuable both to science and society, they facilitate immersive and collaborative research. “Students need to get out from behind their computer screens and get their feet muddy!” Martindale enthuses.