# Dwarfs and giants

It was once thought to be a quirk of evolution found only on islands. But then marine biologist **Craig R. McClain** found it in the most unexpected place: the sea floor.


Craig McClain with MBARI's remote operated vehicle Ventana


A yellow Picasso sponge, as well as some shrimp and a carnivorous branch sponge, taken from MBARI's Tiburon, 1300 m deep off the Central California Coast.

Shallow-water snails next to three tiny deep-sea snails.


**MY FIRST SUBMERSIBLE DIVE** happened off Rum Cay in the Bahamas. Despite my large size, I don't remember feeling cramped inside the soda can-sized sub at any moment. The entire time I pressed my face against a 15-centimetre porthole, my cheek against the cool glass, and focused my eyes on the three metres of illuminated sea floor around me and the kilometres of black beyond.

It was down here on the sea floor, nearly one kilometre beneath the surface, that I got my first look at the giant isopod, *Bathynomus giganteus*. This deep-sea crustacean looks a lot like your typical pill bug or slater, except that it's the size of a large shoe. It instantly captured my imagination, launching a journey to understand why the giant isopod is giant.

Why am I so interested in size? For me, road trips are easily diverted by 'the world's largest ball of rubber bands'; special weekend getaways include visits to attractions claiming to be 'North America's largest'. But, in the biological world, size is more than a novelty. How an organism relates to the world around it is determined by its size, and understanding size is understanding the disparity of life itself.

As a graduate student at the University of Massachusetts, Boston, I turned my attention from crustaceans to snails. They tend to display exactly the opposite pattern: miniaturisation. My new question, then, was: why do some deep-sea organisms shrink in size? At the time, I believed I was placing my original question on hiatus. In actuality, I drew closer to finding an explanation for both patterns.

Almost six years later, I came across scientific papers on an organism and habitat much different from those I study: the body size of birds and mammals on oceanic islands.

On islands, evolution yields bizarre twists, a phenomenon that inspired Charles Darwin's thinking on biological variety and the origins of species. These twists are caused by isolation: terrestrial species which arrive on an island cannot reproduce with continental counterparts, so the island gene pool becomes isolated. This factor, as well as fewer predators, less competition from other species, reduced habitat area and potentially marginal food sources, can lead to new evolutionary trajectories and sometimes bizarre adaptations.

> "Miniaturisation and gigantism on islands seemed to mirror what I observed for deep-sea animals."

There are many examples of this island effect: the diminished kiwi and the enormous moa, the flightless birds of New Zealand; the colossal Komodo dragon; extinct pygmy elephants on the islands of the Mediterranean; the ant-sized frog of the Seychelles; the giant hissing cockroach of Madagascar; and of course, the giant tortoises of the Galápagos. On islands, large organisms typically evolve toward smaller sizes and small organisms to larger sizes, both toward a medium. This occurs with such frequency on islands that it's often referred to as the 'island rule'.

On islands, the presence of miniaturisation and gigantism seemed to mirror what I had observed in deep-sea animals. So I began to wonder: did these two radically different environments share some aspect that would produce very similar evolutionary patterns?

Coincidentally, I was working in a lab at the University of New Mexico where Alison Boyer, a graduate student, was researching island bird evolution. I discussed the island/deep sea idea with Alison and convinced her it was worth exploring.

To test the notion – in other words, to track multiple evolutionary pathways – we were going to need a really big data set. Large data sets are sorely lacking in deep-sea research, where the logistical and financial constraints of sampling an environment kilometres deep tend to be rather prohibitive. I remembered that a scientist at the Academy of Natural Sciences of Philadelphia, Gary Rosenberg, had constructed such a data set. Fortunately, it involved a group of organisms with which I was already very familiar: snails. The three of us combined our strengths to solve a question that had long plagued me and other scientists in the field.

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The giant isopod, *Bathynomus giganteus*.

Eventually we discovered that deep-sea snails – and later research revealed sharks, too – follow the island rule. As shallow-water species colonised the deep, small species evolved to become larger, with the reverse occurring in large species, converging on an ideal size. This implies that the Earth's largest and smallest environments tend to follow similar evolutionary patterns. The fact that the two environments have so little in common was a bonus that allowed us to refine and eliminate hypotheses.

One can quickly rule out habitat size as a cause for these patterns, as the deep sea possesses a wealth of habitat covering roughly 306 million square kilometres. Despite all of this surface area, what the deep sea lacks is food. The absence of sunlight precludes plants – thus, for the majority of organisms living there, the food chain starts with plankton, dead organisms and other organic debris descending from the ocean's surface. Less than five per cent of the total food available drifts to the sea floor, leading to an extremely food-limited environment. On islands, less food is available because small land areas support fewer plants at the base of the food chain.

In either case, island and deep-sea animals need to be efficient and creative in their acquisition of food. There's simply not enough food to support a whole population of giants. On the other hand, tiny animals are unable to travel long distances looking for food and don't have room to store any surplus food when it becomes available. Therefore, on islands as well as in the deep sea, evolution favours a medium-sized organism. In the interests of reaching this 'golden medium', some species become giant while others miniaturise.

*Bathynomus giganteus* is still an extreme example of gigantism among crustaceans, much like the Komodo dragon among lizards. However, research on the giant isopods shows another bizarre evolutionary response to food limitation: the species is a scavenger which utilises a variety of food sources, and dead fish on the sea floor can attract swarms of them within hours. This quick response relates to the creature's size, which allows it to traverse distances more quickly than its smaller relatives. The large size also allows it to store a great quantity of fat, giving it the potential to survive extended periods without food – in captivity, some have survived up to two months.

Often, a single observation of an item or event proves to be the catalyst or trigger for a single question that you spend the rest of your life trying to answer. It is for exactly these kinds of questions that I became a scientist. Perhaps my next question is, why is the giant squid giant? Or perhaps, more interestingly, why isn't the giant squid larger?

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