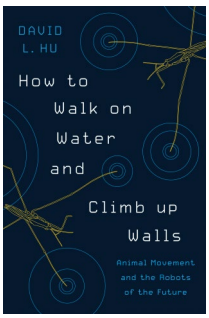
Physics at the zoo



How to Walk on Water and Climb up Walls: Animal Movement and the Robots of the Future

By David L. Hu

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As a new parent, David Hu learned the hard way that his infant son took 21 seconds to empty his bladder. Out of curiosity, he timed his own urination, counting 23 seconds. Being a scientist, this consistency led him to the question: shouldn't the time to urinate scale with bladder volume? The resulting research project, in which his students measured timing and volume of urination across species at Atlanta Zoo and local farms, found that urination time is remarkably constant for animals from small dogs to elephants, with 70% of the measured times falling between 10 and 30 seconds. Fluid dynamics theory showed that the important factor for timing is the aspect ratio of the urethra. For this research, Hu won the 2015 Ig Nobel Prize in physics.

This is one of the anecdotes in *How to Walk on Water and Climb up Walls: Animal Movement and the Robots of the Future*, Hu's treatise on why animal motion is not just a subject of the Ig Nobels. In it, Hu describes studies of animals from snakes to sharks to cockroaches. From the book we learn how mechanical considerations affect how animals move and interact with their environment as they run, swim, fly, eat and, yes, urinate. We also learn the stories of how researchers across physics and biology find problems to work on, and ingenious ways of uncovering nature's secrets.

The interactions between physics, mathematics and biology have a long history, which Hu touches on in his introduction. They date back at least as far as Leonardo da Vinci's notebooks, where designs for machines were interspersed with anatomical studies of animals. This history reminds us that the boundaries between disciplines have always been permeable, and not every scientist is a strict specialist. At the same time, unlike these historical studies, the emphasis of modern biology is not on whole animals but on molecules, cells and systems biology problems such as genomics, transcriptomics and metabolomics. Where whole animals are studied, they are often model organisms, which have been selected precisely because they are well-known. Hu sees the move away from studying a diverse range of animals as a loss for science, because of the physics and engineering insights that can be found in sometimes surprising places.

What can you learn from observing cockroaches running around a racetrack?

It is in this context that Hu describes the present and the future of animal movement studies. Through a series of stories based on interviews with scientists about their projects, he portrays the field as one where curiosity and ingenuity rule the roost. Want to understand how snakes move on smooth surfaces? Buy some, sedate them, and let them slide down inclined planes to measure their coefficient of friction. (As a new postdoc, Hu actually did this — in his New York apartment.) What can you learn from observing cockroaches running around a racetrack? That they can navigate by trailing their antennae along the wall, which lets them measure both how far they are from the wall and the rate of change of that distance. How do you splint a bumblebee's wing to test which deformations are important? Use flecks of glitter, which is light-weight and cheap, with ultramarine being the cheapest colour.

The other thread of the book is stories about robots built using the principles of locomotion derived from animal experiments. These stories feature aquatic robots that swim like fish, compressible robots that squeeze into gaps like cockroaches and swarming modular robots, among others. Hu emphasizes how roboticists benefit from understanding animal locomotion, for example by finding ways to design energy-efficient walking robots. Roboticists can also bring new insight on animal locomotion. An example of this in the book is the AmphiBot, a modular robot with a control system based on the coupled neural oscillators that had been characterized in experiments on lampreys (a type of jawless fish). But it wasn't just that animal experiments inspired robot design. The robot enabled experiments on how the nervous system responded to obstacles in the environment, tests that would have otherwise been challenging.

I enjoyed this book. Hu is enthusiastic for his subject, and that enthusiasm is contagious. By the time I finished reading it I wanted to tell my friends about how mosquitos survive impact by raindrops and how the shape of jellyfish changes the way they swim. And by using a narrative format, Hu avoids simply presenting a series of did-you-know factoids about the animal world, and instead shows his readers scientists at work: the questions they ask, the challenges they overcome, and the joys of moments of discovery.

That Hu is a scientist and not a journalist does come through. His descriptions of his own research experiences are richer than those of others, and sometimes the picture he paints of how science works is simplified to the point of rosiness — everyone is motivated by the desire to learn about the world, no one is worried about tenure. In addition, at times Hu's writing style wavers between academic and journalistic. But the exposition is always clear and readable, and I would not hesitate to recommend the book to a curious non-scientist.

In the book's conclusion, Hu turns explicitly to the question: is this research worth the money? Hu's answer is, unsurprisingly, that it is, and he points to the practical applications that have come from the studies he has discussed. But another answer can be found in the preceding pages. Animal movement research is worthwhile because it enriches our understanding of the world around us, it rewards creativity, and it is — let's admit it — fun. Perhaps the best summary of the book comes from its introduction, where Hu appeals for us to "[t]ake this curiosity with you as you begin to explore the wide world of animal movement." ❐

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