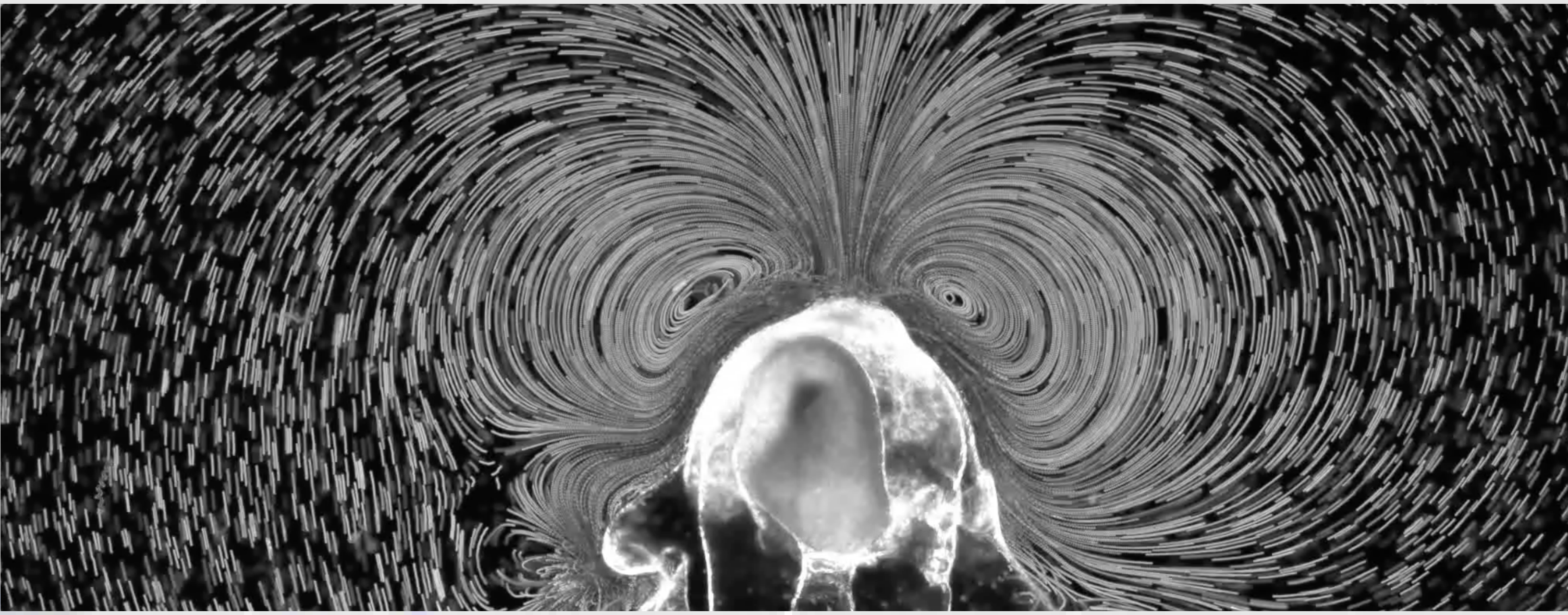
BIOPHYSICS OF FASCINATING "FLOWS" IN ANIMALS



Interview with

Dr. Vivek Prakash

Assistant Professor
Department of Physics
Secondary Faculty in Biology
University of Miami

1. Shara Zeitlin: I would like to express my appreciation for your inspiring presentation on 'Fascinating flows and emergent mechanics in simple marine animals'. I thought the way you delivered your seminar was very interesting and memorable. Can you tell us about your background and how you became interested in Marine Biophysics, specifically 'flows in living animal systems'?

Dr. Vivek Prakash: Thank you for your kind words! I have a unique academic trajectory that led me marine biophysics. During my undergraduate studies in Mechanical Engineering in Bangalore, India, I was lucky to be selected to participate in a summer undergraduate research program at JNCASR, Bangalore – a premier research institute. I set up a novel lab experiment to mimic mantle convection – this summer internship experience really motivated me to pursue a research career, and I continued to work on this project for my MS degree in Fluid Mechanics at JNCASR. Following this, I moved to Europe to pursue my PhD (Applied Physics) at the University of Twente (Netherlands). My PhD research focused on the dynamics of light particles (bubbles, hollow spheres) dispersed in a large-scale turbulent water tunnel. I used experimental techniques such as 3D high-speed Lagrangian particle tracking combined with computational data analysis. I was fascinated with the strong interplay of physical principles in biology, and wanted to complement my fluid mechanics expertise with biology. Hence, I transitioned into biomechanics for my postdoctoral research at Stanford University. At Stanford, I worked on 'flows' in three different living animal systems: Trichoplax adhaerens, sea star larvae (Patiria miniata), and chick embryo development. My research focused on linking the biological form vs function relationships in these animals using 'flows' (fluid/solid mechanics) as tool.

2.Shara Zeitlin: Your primary research focus is on Tissue Mechanics and Biological Fluid Mechanics. Can you explain to us briefly what you are trying to discover & how?

Dr. Vivek Prakash: Yes, our research is focused on two major themes:

(1) Tissue Mechanics: Our goal is to uncover the fundamental physical mechanisms governing local & global cellular flows in tissues of living animals, and to understand how these flows regulate morphogenesis and development.

During my postdoc at Stanford University, we discovered that physiological tissue fracture and healing dynamics govern extreme plastic shape changes (Prakash et al., Nature Physics, 2021) in the early divergent animal Trichoplax adhaerens. . In collaboration with researchers at University of California, San Francisco (UCSF), we have also investigated cellular flows during early chick embryo development.

(2) Biological Fluid Mechanics: The goal is to study fluid mechanics in marine invertebrates, and to use physical insights and models to link small-scale biophysics to macro-scale natural behavior and ecology, and to develop bio-inspired engineering applications. During my postdoc at Stanford University, we demonstrated how swimming-feeding tradeoffs are dictated by hydrodynamics in sea star larvae (Gilpin et al., Nature Physics 2017).

3.Shara Zeitlin: Why study simple marine non-model animals such as Placozoans and Ctenophores?

Dr. Vivek Prakash: Simple marine non-model animals such as Placozoans and Ctenophores are fascinating, exotic and under-studied systems. It is extremely interesting to study these animals since there are many secrets waiting to be unraveled, and so much is unknown about them that there are many exciting discoveries to be made!

In these simple animals, we can bridge length scales, and scales of organization going from cells to tissues, and go from tissues to whole organisms in some animals since they don't have specialized organs and organ systems. Also, given that these are the early divergent animals, we can start to address longstanding questions about the origins of multicellularity, and origins of complexity.

This is an exciting time to be studying these simple animals since novel approaches and tools are available. Advances in molecular biology and genetics have resulted in studies that have sequenced the complete genomes of these animals. Key advances in microscopy now enable us to carry out in-toto live imaging, i.e. the ability to image all the cells in the whole organism. Finally, these animals are excellent model systems for the study of soft living active matter – an area of huge interest in the biophysics community.

4.Shara Zeitlin: What excites you most about studying an ancient, extraordinary animal - the Trichoplax adhaerens?

Dr. Vivek Prakash: The Trichoplax adhaerens is ancient and extraordinary – this is already exciting to me! This animal is very fascinating for several reasons. It is the simplest animal alive, with just six cell types, and a simple flat body plan architecture with a three-layered epithelium. These animals have no neurons and no muscles, but they still exhibit rich behaviors such as coordinated motility and asexual reproduction – so the question is how do the cells communicate and propagate information in an animal without a nervous system? These animals do not have a basement membrane to give them a fixed shape, nor do they have an extra cellular matrix or tight junctions between cells.

All these ingredients (or lack of) make this animal a unique and simple system to study the extreme limits of tissue mechanics. From both a physics and biology standpoint, these animals have simple 'minimal' epithelial tissues, so we have an opportunity to investigate the fundamental properties of epithelial tissue mechanics.

5.Shara Zeitlin: Are all these animals somehow interconnected and behave as a community/threat even without neurons, cognitive functions etc? If so, how?

Dr. Vivek Prakash: These marine animals that I am interested in, are not actually interconnected in any obvious way. If the question is whether groups of Trichoplax organize themselves in groups to exhibit collective behavior – we have seen some interesting social behavior but we don't really understand it yet! At the moment, we are studying the biophysics of each animal, and haven't looked at animal-animal interactions which could be very interesting as a future area to explore.

6. Shara Zeitlin: It seems like your research & tools has opened up the door for exploring new opportunities not only for simple marine animals but also for other higher organisms. What do you hope to accomplish in the near future?

Dr. Vivek Prakash: Yes, we also developed several novel experimental and computational tools for tissue mechanics. During my postdoc, I came up with an adhesive fluorescent micro-spheres method to tag cells in tissues of the Trichoplax. In collaboration with researchers at UCSF, we have demonstrated that this technique can also be used to visualize the large-scale cellular 'polonaise' movements involved in chick embryo gastrulation. Hence, this adhesive beads assay can have wide applications in tissue mechanics and also cellular aggregate systems including organoids. In the near future, I am hoping to address several open tissue mechanics questions in Trichoplax. In the long term, I am also exploring the application of our biomechanics approach to medically relevant problems in tissue mechanics.

7.Shara Zeitlin: BioNIUM is really looking forward to collaborating & working with you. Is there anything else you would like to share with us?

Dr. Vivek Prakash: Thank you, I am also very much looking forward to collaborations with researchers at BioNIUM. I am excited to utilize the fantastic instrumentation and fabrication resources at BioNIUM for our experiments. I really like curiosity-driven research and love to think about many diverse and interesting questions in physics, biology, and engineering, so please reach out to me to chat and brainstorm potential projects. Thank you so much for this opportunity to share some aspects of our work with all of you. I encourage you to visit our lab website to find more information on our research projects: www.marinebiophysics.org