Mechanics and geometry in chiral structures: from nanohelices to twisted embryonic brain

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Abstract

Mechanical forces play a key role in the shaping of versatile morphologies, especially chiral structures, in both natural and synthetic systems. First, an elasticity theory combining differential geometry and stationarity principles is developed for the spontaneous bending and twisting of ribbons with tunable geometries in the presence of mechanical anisotropy. Closed-form predictions are obtained from this theory with no adjustable parameters and validated with simple, table-top experiments that are in excellent agreement with the theoretical predictions. We then investigate the shape transition and multistability that also arise in a number of physical systems. Finite element simulations are also employed to study the mechanical self-assembly of nanoribbons as well as the associated change of handedness and multistability.

In embryos, chiral structures can also arise via mechanics. The embryonic chick brain, for example, undergoes rightward torsion, one of the earliest organ-level left-right asymmetry events in development. Here we unveiled the mechanical
origin of brain torsion and the associated progression of left-right asymmetry, through both experiments and modeling.

The study of mechanics and geometry in chiral structures will facilitate understanding of morphology generation in natural and synthetic systems, and benefit the ongoing efforts in developing programmable micro-fabrication techniques and novel functional devices such as NEMS devices, active materials, drug delivery agents, and bio-inspired robots. Studies of embryonic development can also benefit the future practices in preventing or treating some congenital defects.

About the Speaker

Dr. Zi Chen is currently an Assistant Professor and Society in Science – Branco Weiss Fellow at Thayer School of Engineering and an adjunct Assistant Professor in Department of Biological Sciences at Dartmouth College. Dr. Chen received a bachelor’s and master’s degree in Materials Science and Engineering from Shanghai Jiaotong University, and a PhD in Mechanical and Aerospace Engineering from Princeton under Dr. Mikko Haataja and David J. Srolovitz. He was also a visiting scholar in Dr. Clifford Brangwynne’s group at Princeton. Before joining Dartmouth, Dr. Chen worked as a postdoctoral fellow with Dr. Larry Taber in Department of Biomedical Engineering at Washington University. He was also a visiting scientist in the Weitz lab at Harvard University.

Dr. Chen received a number of awards and honors including Society in Science – Branco Weiss fellowship, Marquis Who’s Who in the World, Outstanding Paper Award at the ASME 2013 2nd Global Congress on NanoEngineering for Medicine and Biology (NEMB), American Academy of Mechanics Founder’s Award, MRS Graduate Student Award Silver Award, etc. His research has been supported by National Institute of Health and Society in Science. He is a founding co-Editor-in-Chief of Journal of Postdoctoral Research, and an editorial board member of Journal of Applied Mechanical Engineering and Journal of Material Science & Engineering.

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All are Welcome!

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