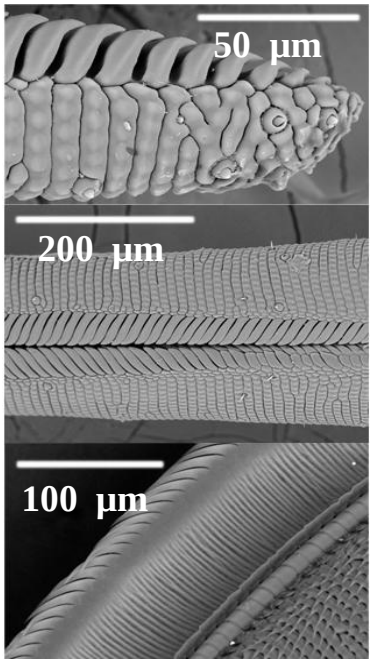
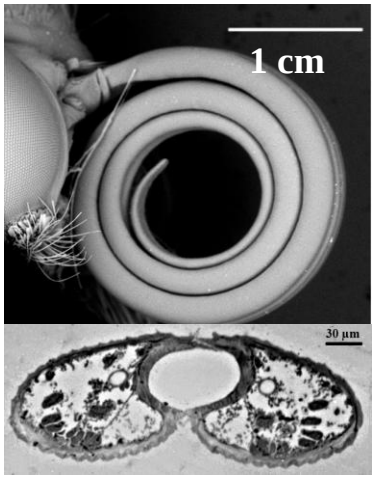
Design of fiber-based microfluidics by exploring mechanisms of insect feeding

CLEMSON UNIVERSITY

Kornev's lab

The order Lepidoptera includes butterflies and moths. These insects are able to draw minute volumes of liquids, which span many orders of magnitude in viscosity, from very thin sugar solutions to thick mucosal liquids. No one microfluidic device can compete with the lepidopteran fluidic system in this respect!





SEM image of Monarch butterfly proboscis and its cross-section (right); structural features of the monarch proboscis (left).

Butterflies feeding from a flower and from surface moisture

The ability to manipulate the proboscis, which can be coiled and uncoiled like a party noisemaker, is closely linked to the remarkable fluid transport capabilities, in addition to being useful for positioning the proboscis in a target liquid.

This shape change alters fluid transport properties. Lepidoptera can tune pumping rate by controlling proboscis shape and can drink from the lateral pores as well as the proboscis tip. Proboscises feature integrated sensors and filters that distinguish foods and chemicals.

This research aims to understand the physical principles used by Lepidoptera for fluid sampling and analyses.

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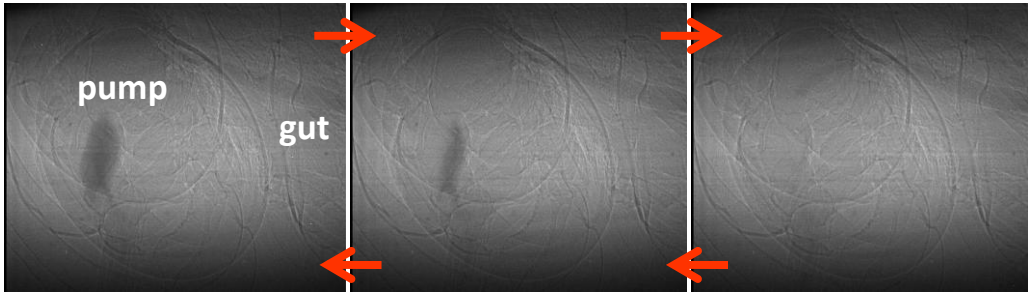
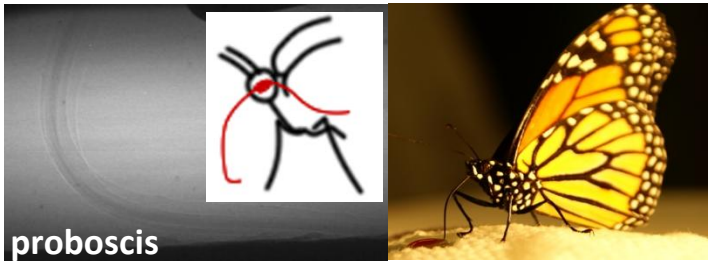
- Strategic goal: development of fiber-based microfluidics using biomimetic approach

Current focus on

- physics of nectar uptake by butterflies
- role of proboscis morphology in creating capillary force
- Applications: injecting/probing devices

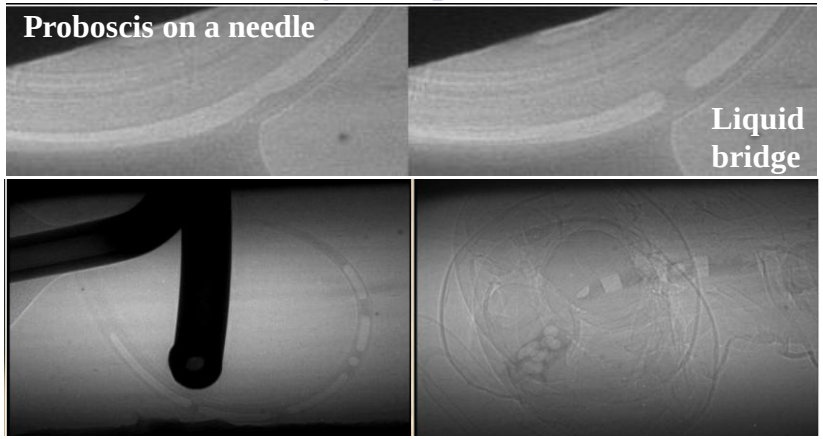
MODEL 1. Feeding from large droplets: Butterfly creates negative pressure in the head compartment (sucking pump) to transport liquids from the food source through the feeding system





Visualization of the liquid flow under High energy X-Ray beam. (Experiments were conducted in Argonne National Laboratory)

MODEL 2. Feeding from porous materials:



The uptake of liquids from porous substrates and small droplets is a two-step process, facilitated by hierarchical structure of the proboscis. Liquid, driven by capillary action of nanopores, creates a film on the food canal surface. This film collapses to form multiple liquid bridges, which are then transported to the digestive system. **The lepidopteran fluidic system offers a unique model for the integration of nano- and microchannels, shifting the existing microfluidic paradigm from stationary channel-like structures toward fiber-based microfluidic devices providing distributed actuation, sensing, and manipulation of minute amounts of fluids.**