

The biomechanics of insect internal flow systems

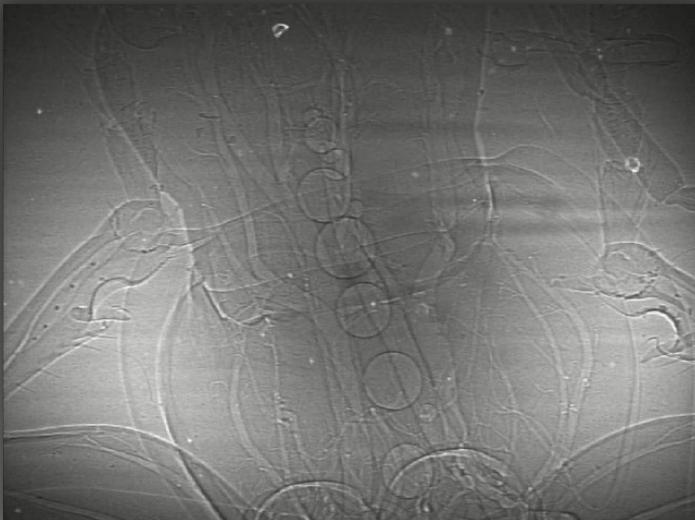
Jake Socha

Engineering Science and Mechanics
Virginia Tech

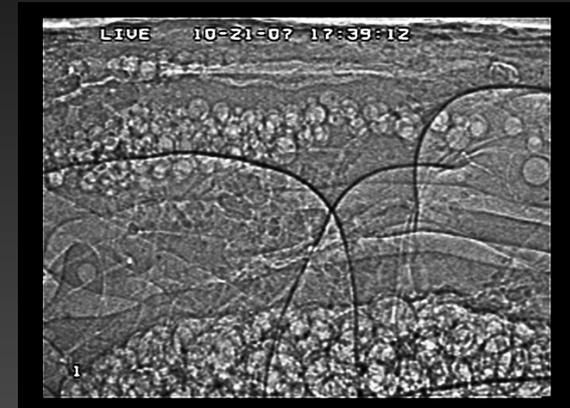


Gliding flight in 'flying' snakes

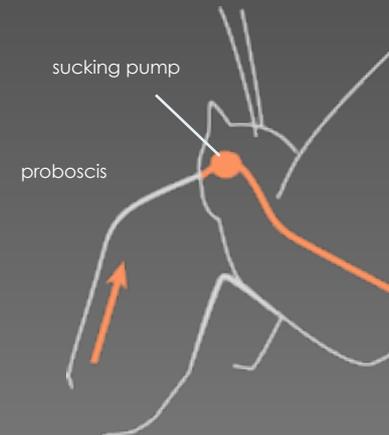
Rhythmic tracheal compression

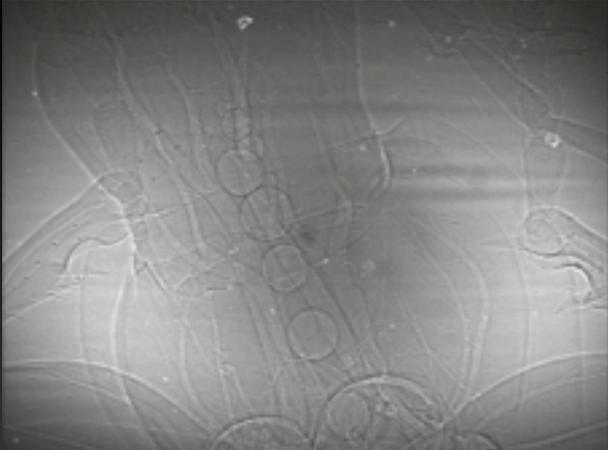


Insect heartflow



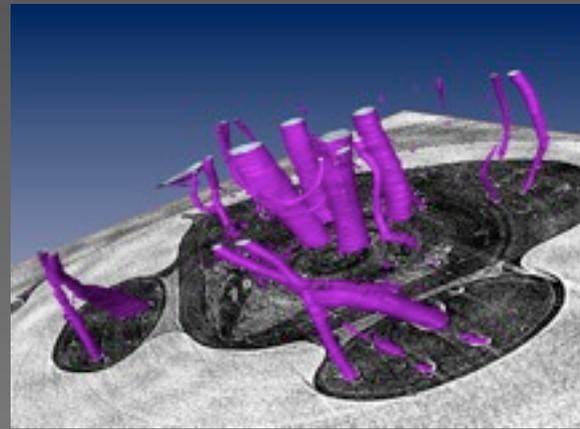
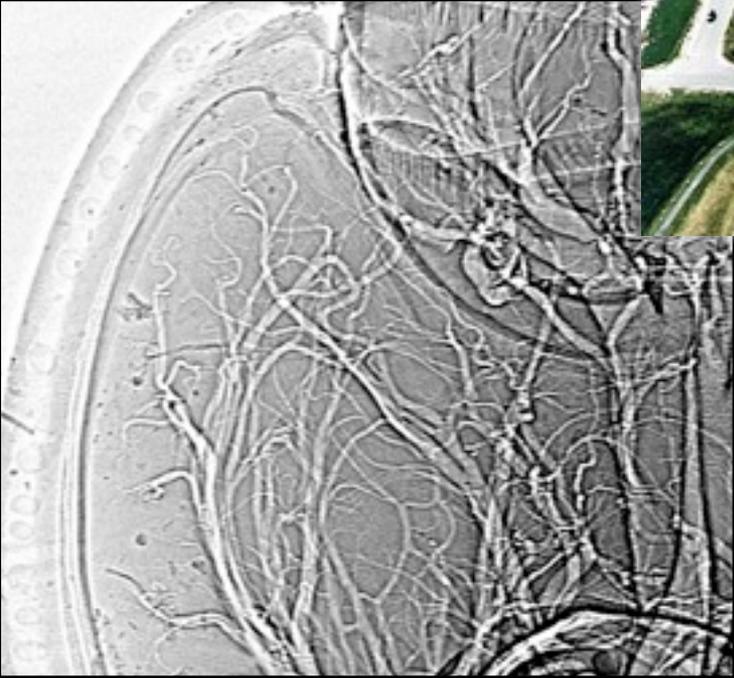
Flow of viscous foods using sucking pumps



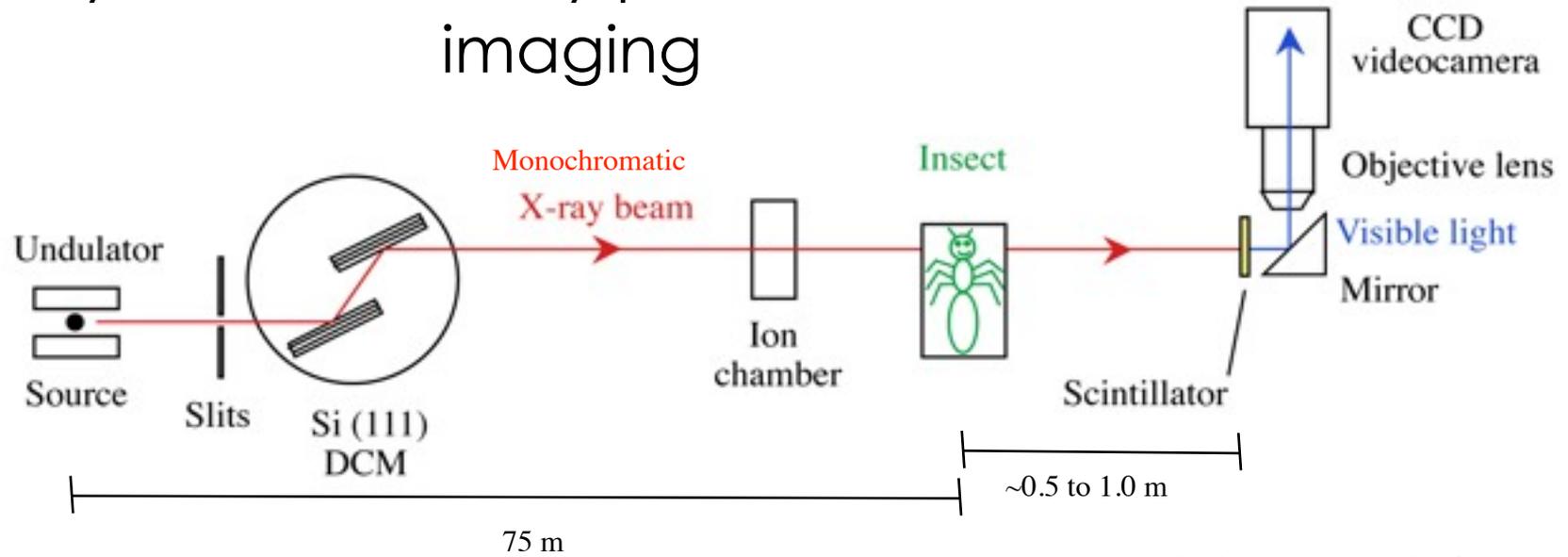


32-ID

Advanced
Photon
Source
ARGONNE NATIONAL LABORATORY



Synchrotron x-ray phase-contrast imaging



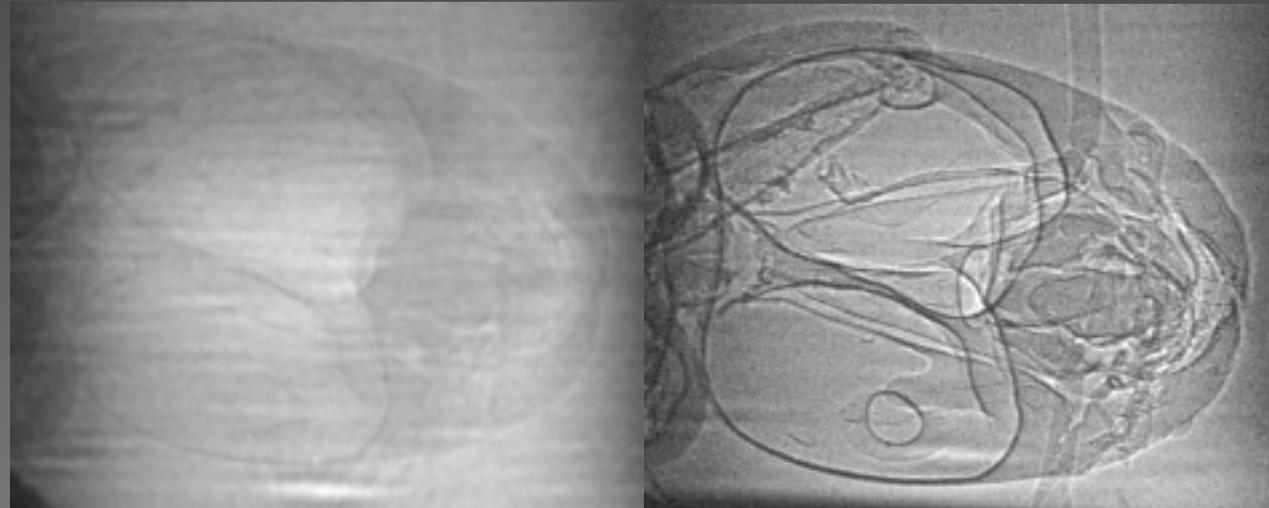
Socha et al., 2007 BMC Biology

Absorption only

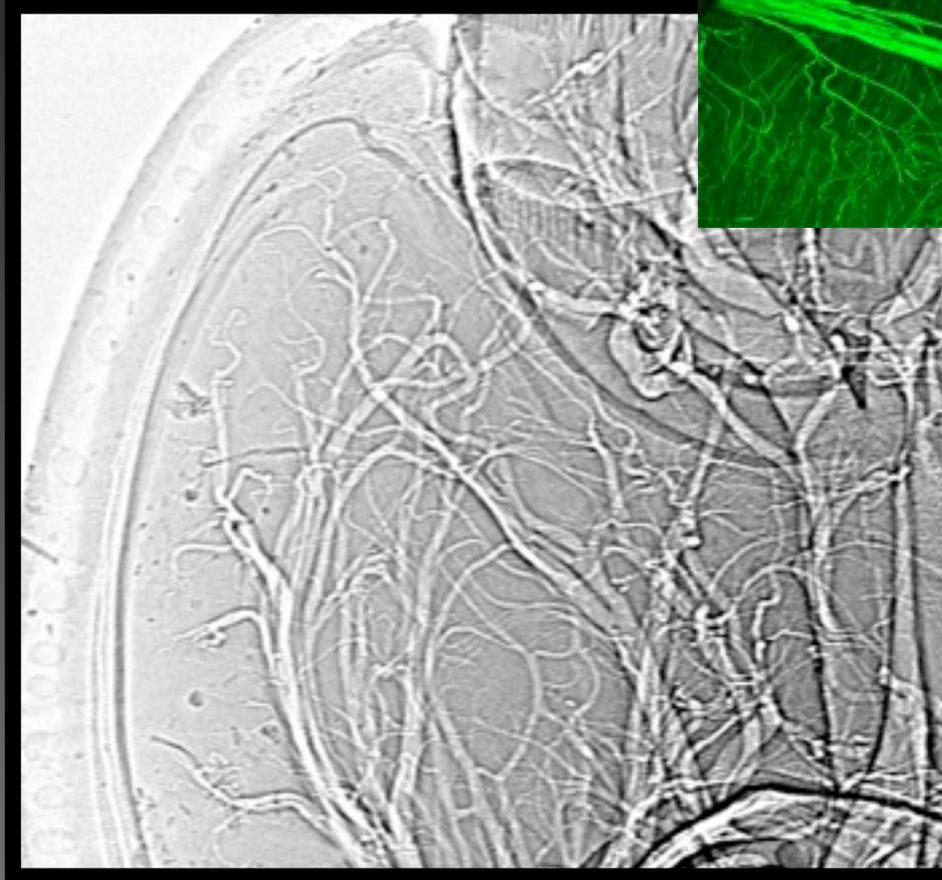
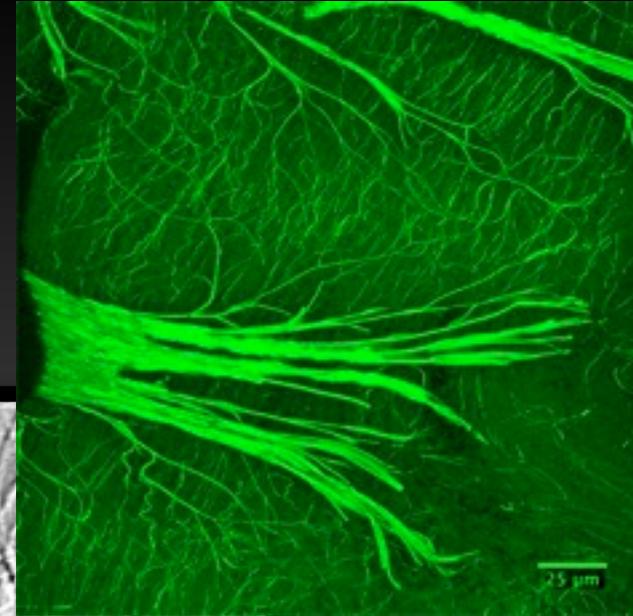
Phase enhanced

X-ray images depend on
diffs. in density within the
sample.

Beam coherence + distance
produces edge
enhancement effects.



Insect tracheal system



Mechanisms of creating convection

Body compression (eg, abdominal pumping, thoracic pumping, proboscis extension)

Autoventilation

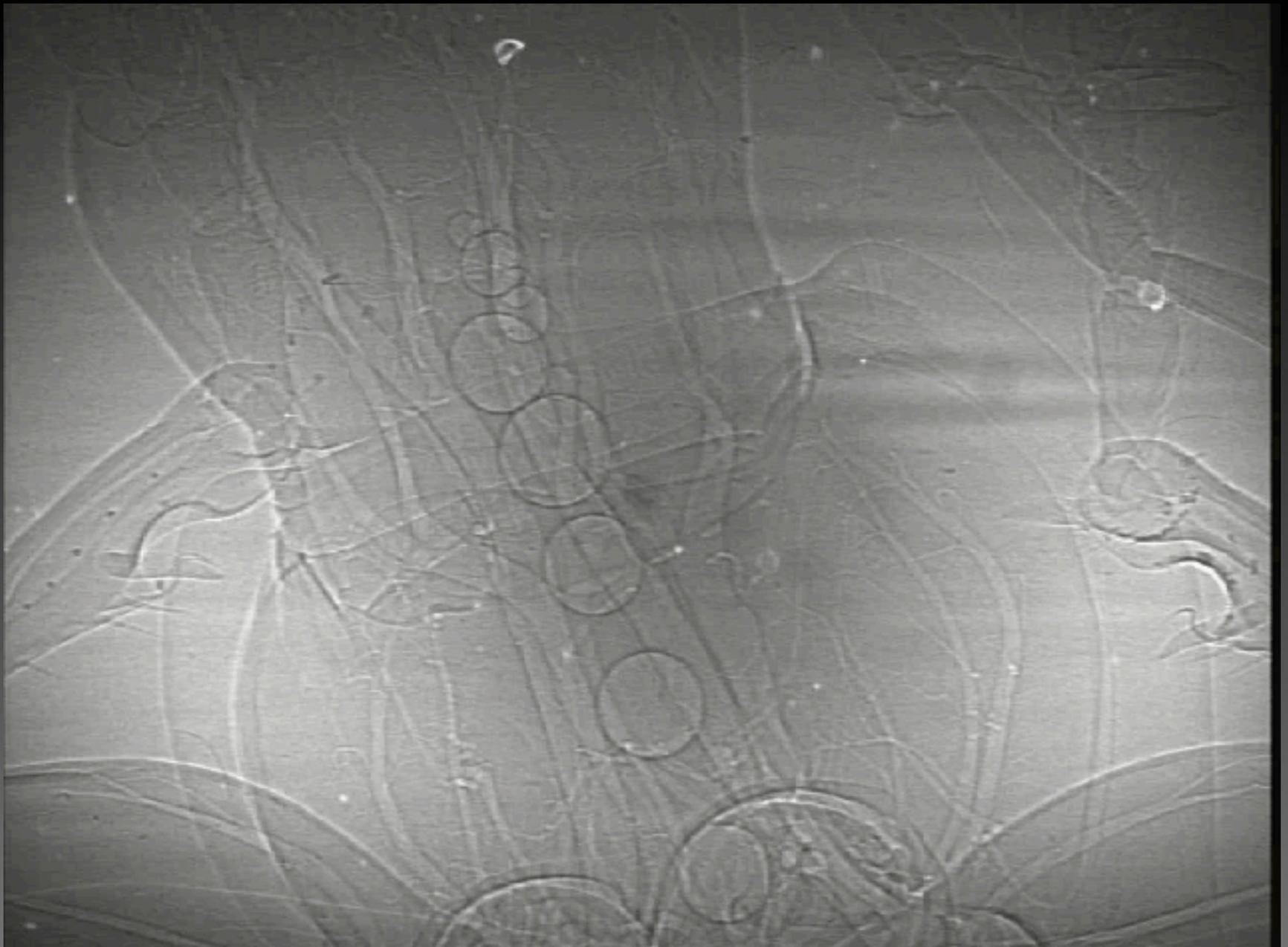
Hemolymph pumping

Passive suction ventilation

work via compressible tracheae or airsacs

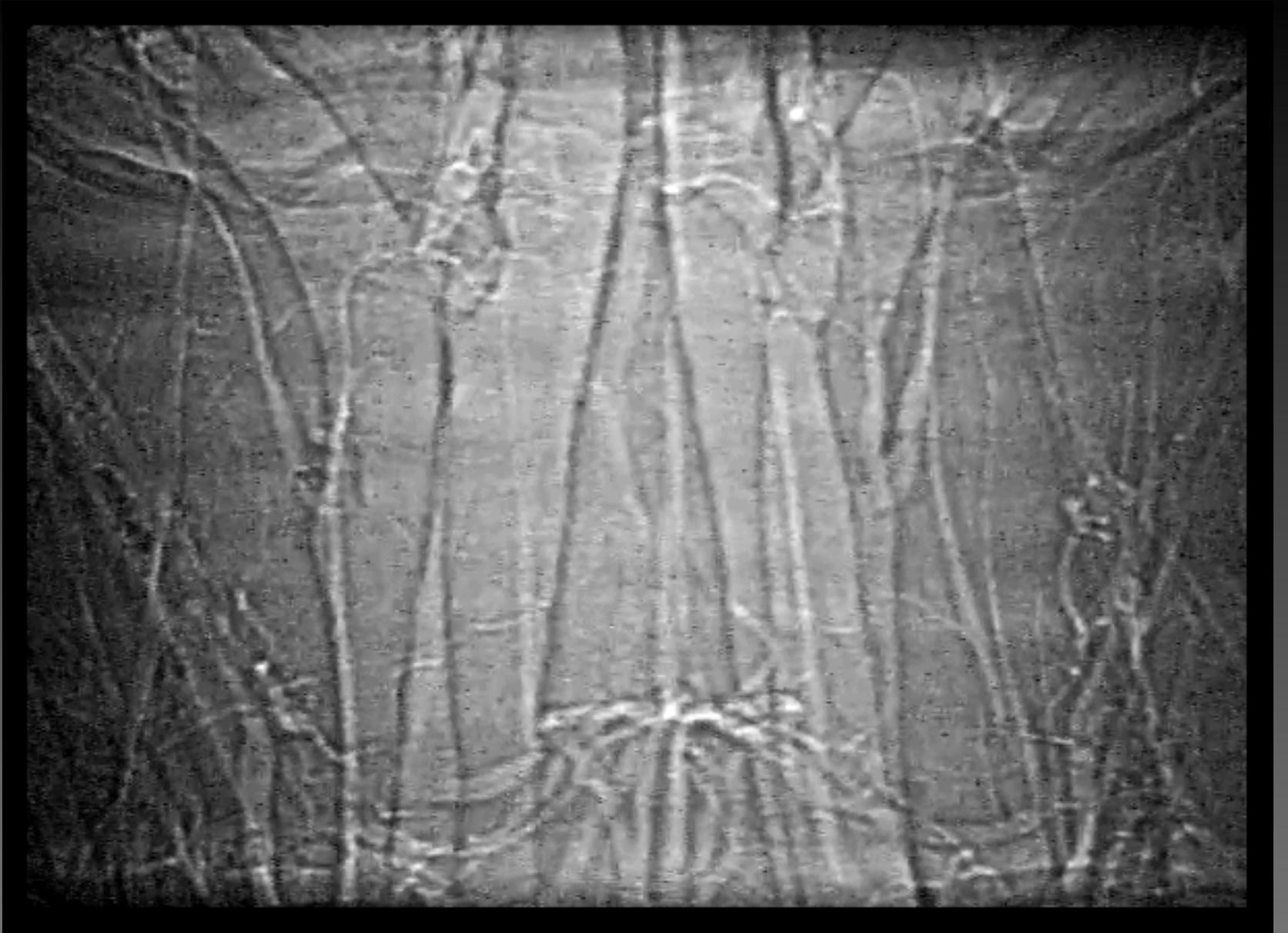
“Active tracheal compression”





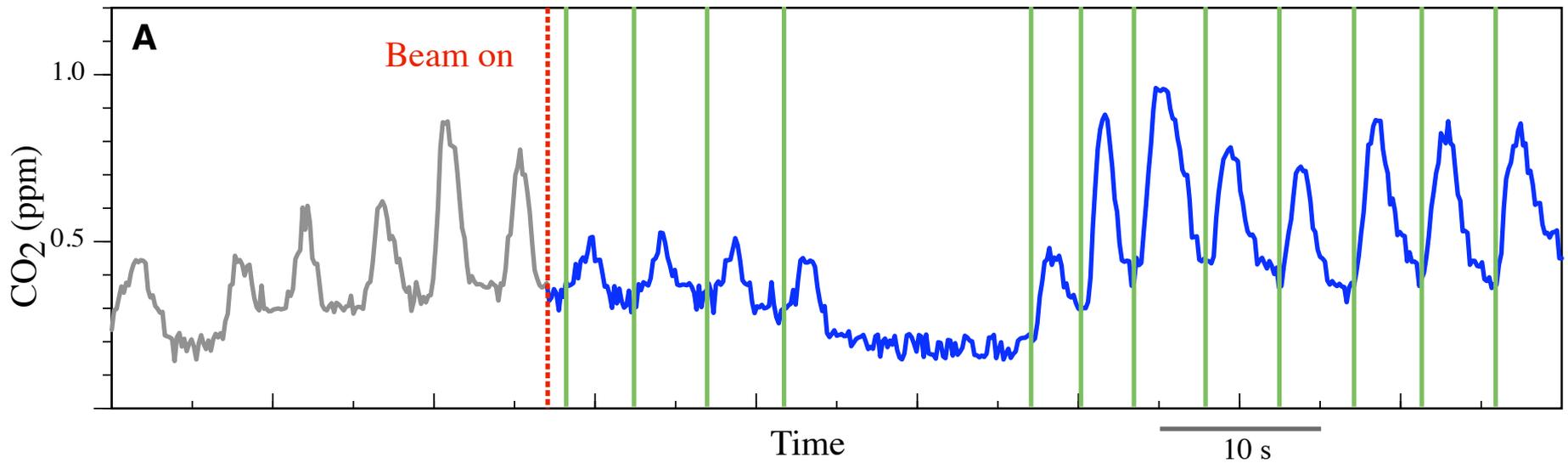
Platynus decentis

Variable shape of tube collapse



Platynus decentis

Pterostichus stygicus

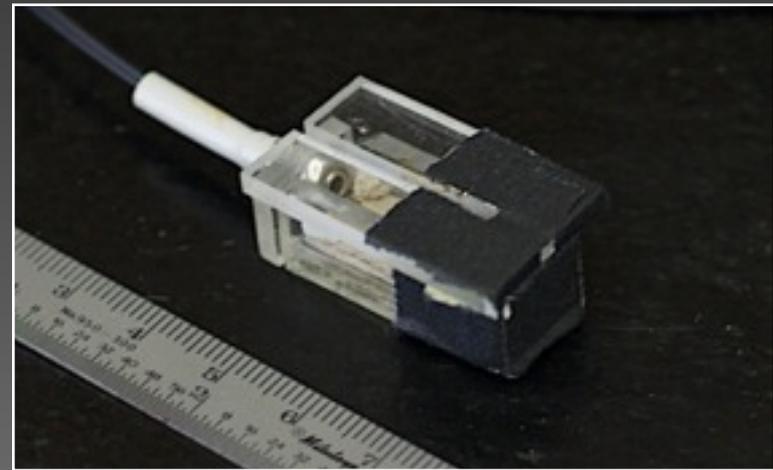
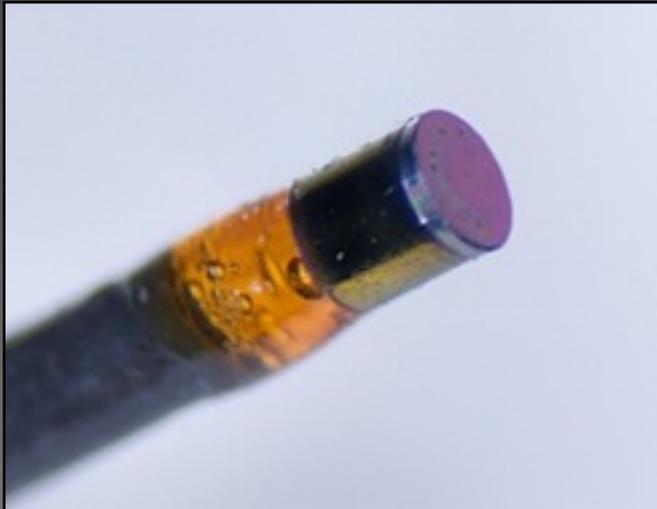
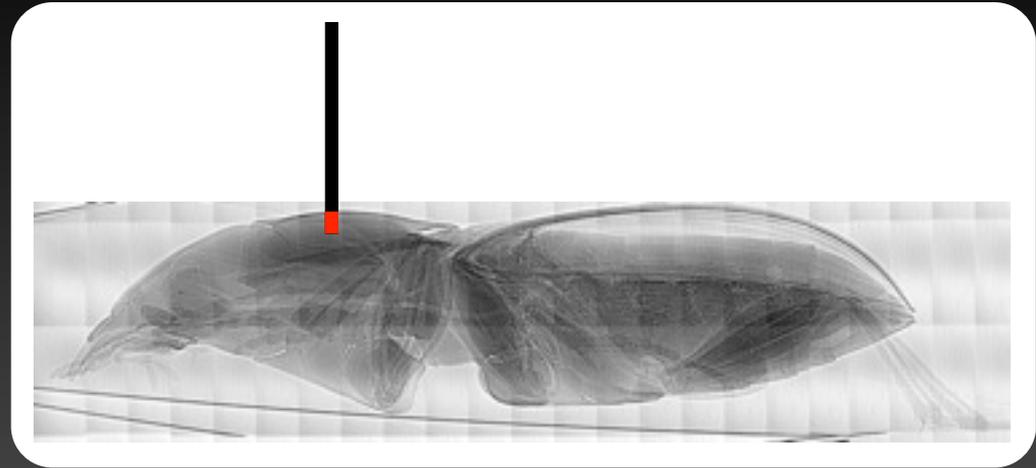


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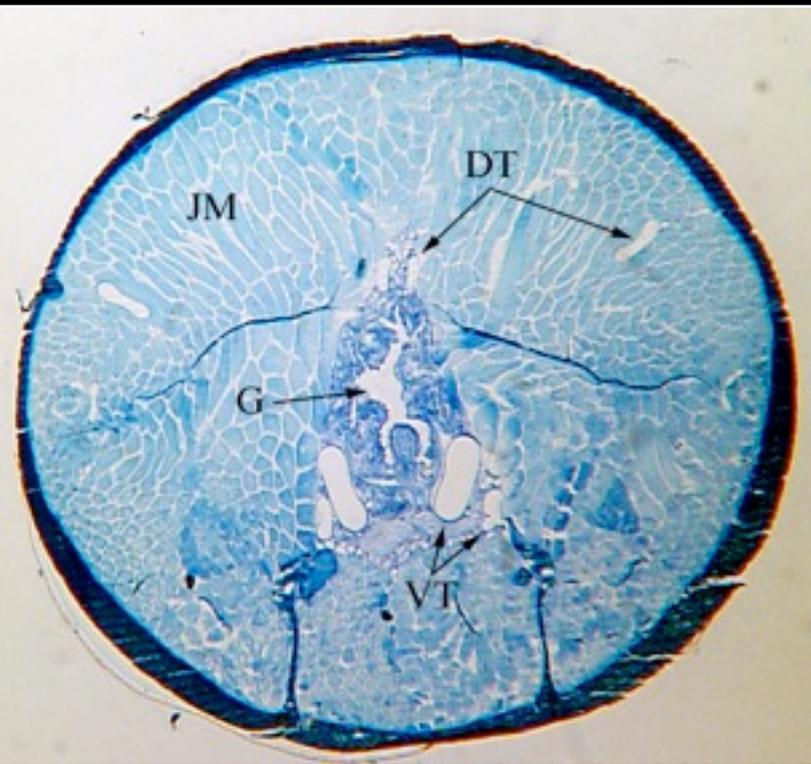
I

Measurements of internal thoracic pressure



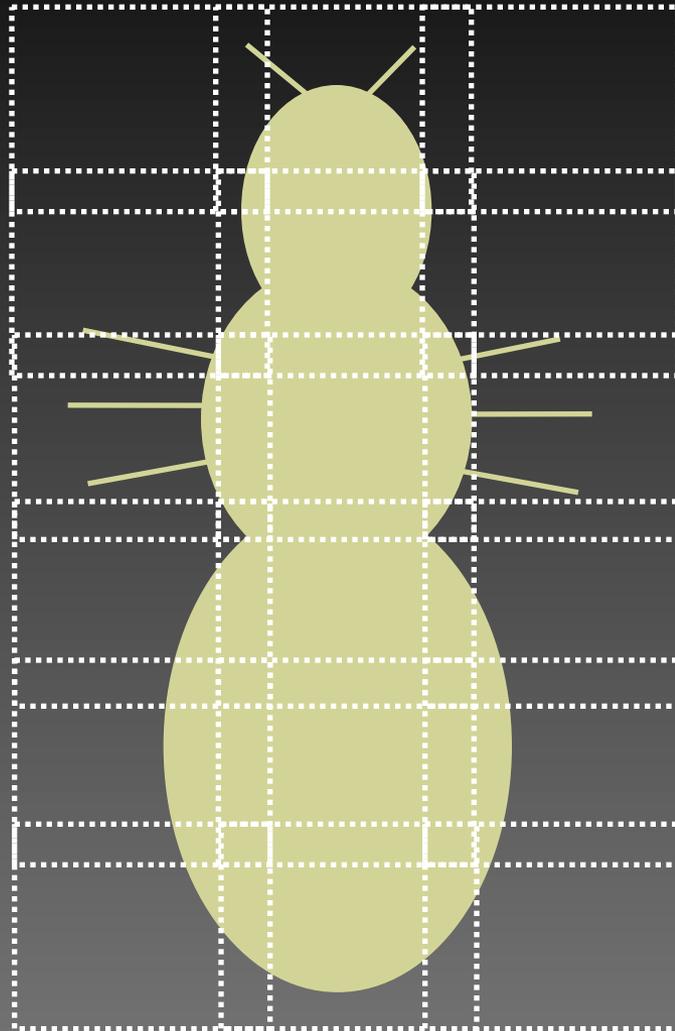
Samba Preclin fiber-optic pressure sensor
diameter = 420 μ m

Platynus histology



data from Oliver Betz, U. Tübingen

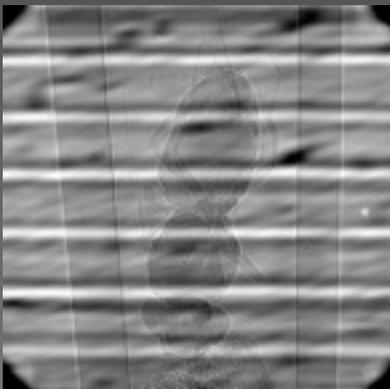
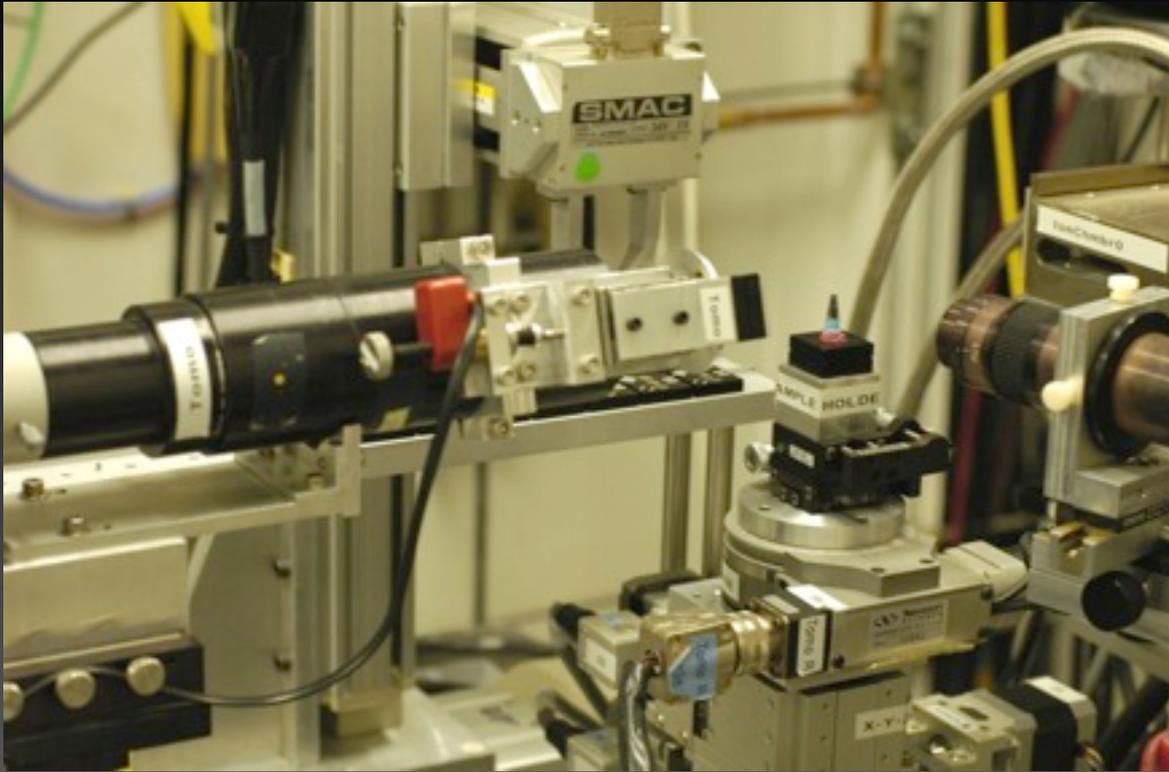
High-resolution still imaging





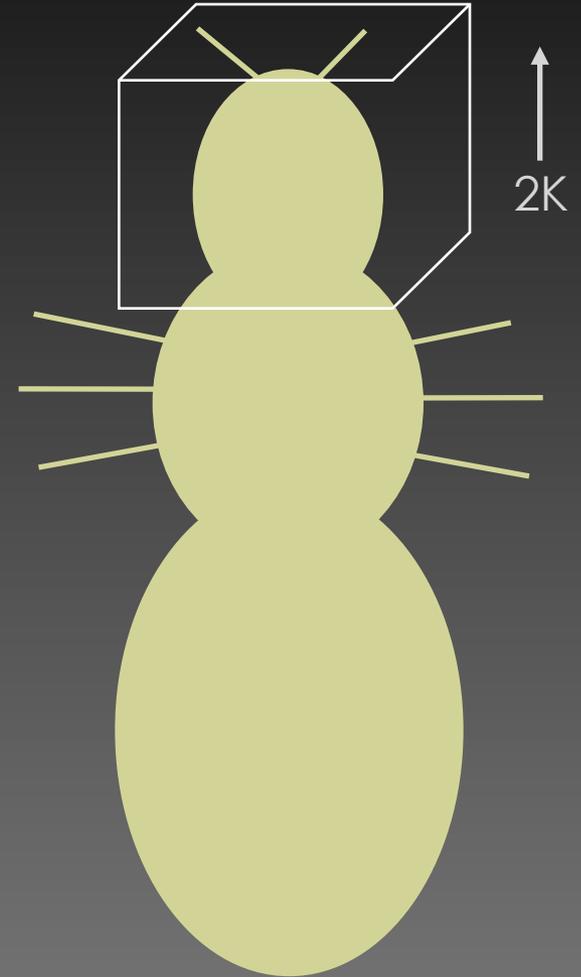


Synchrotron microtomography

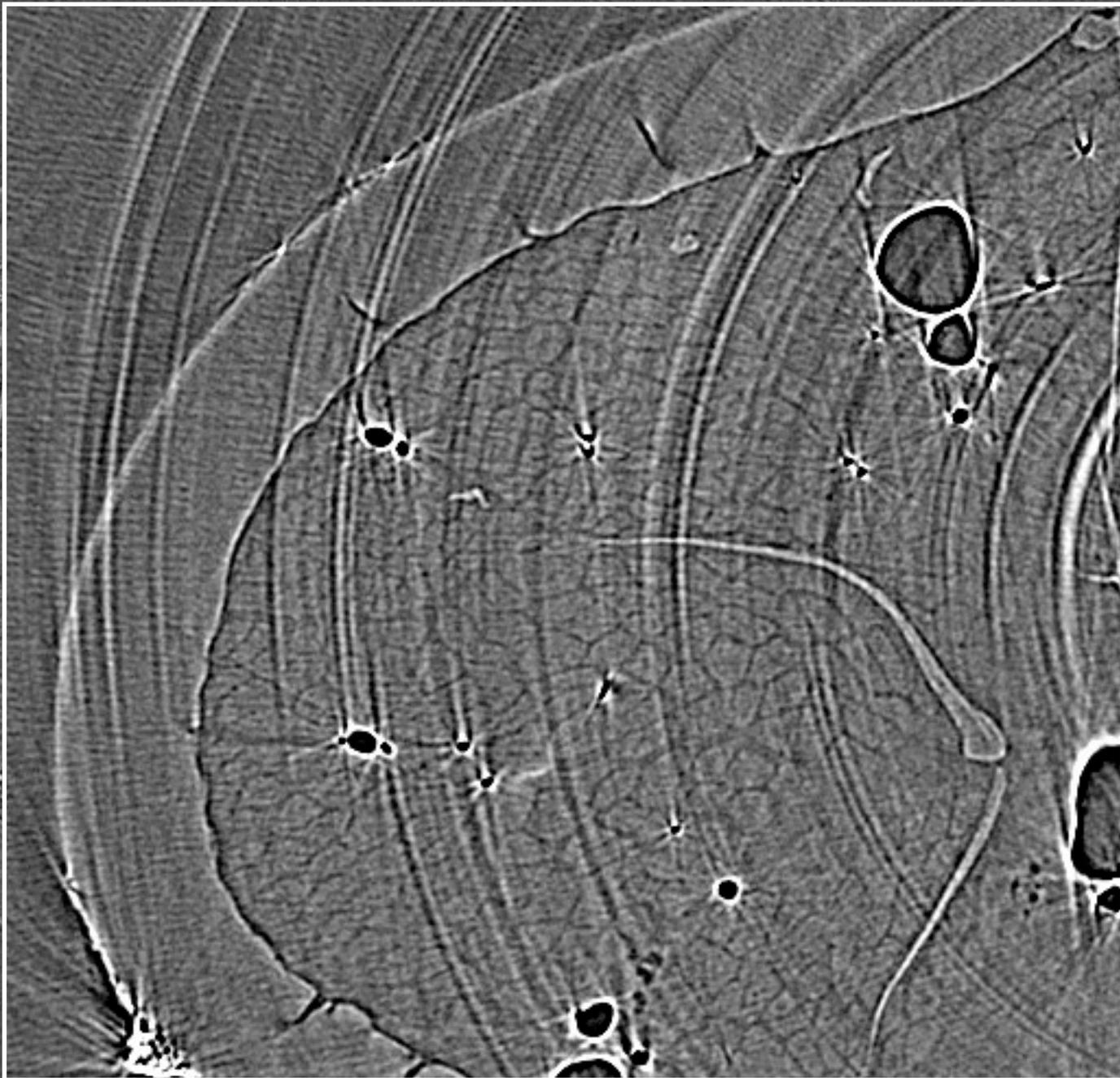
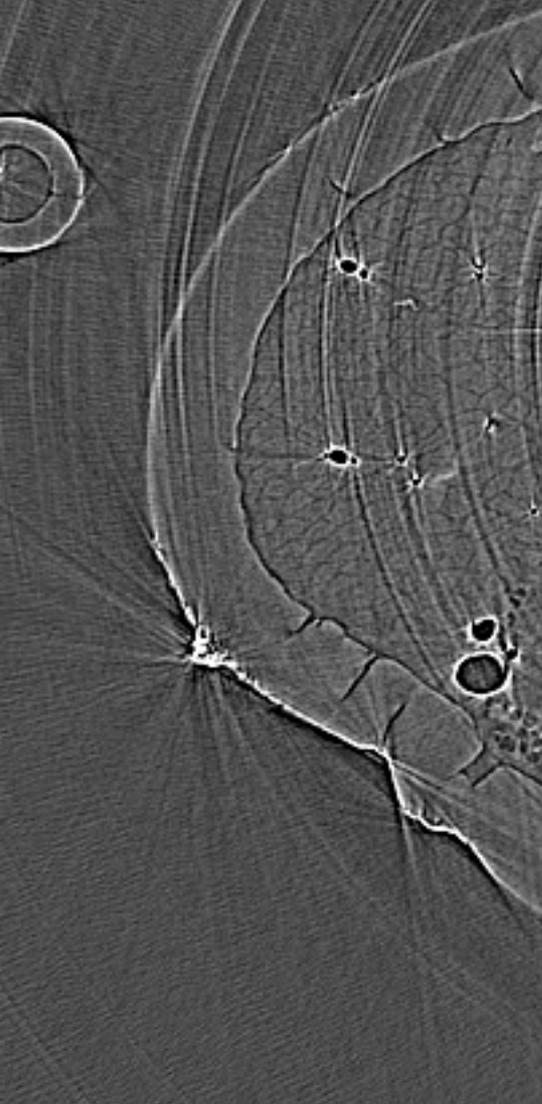


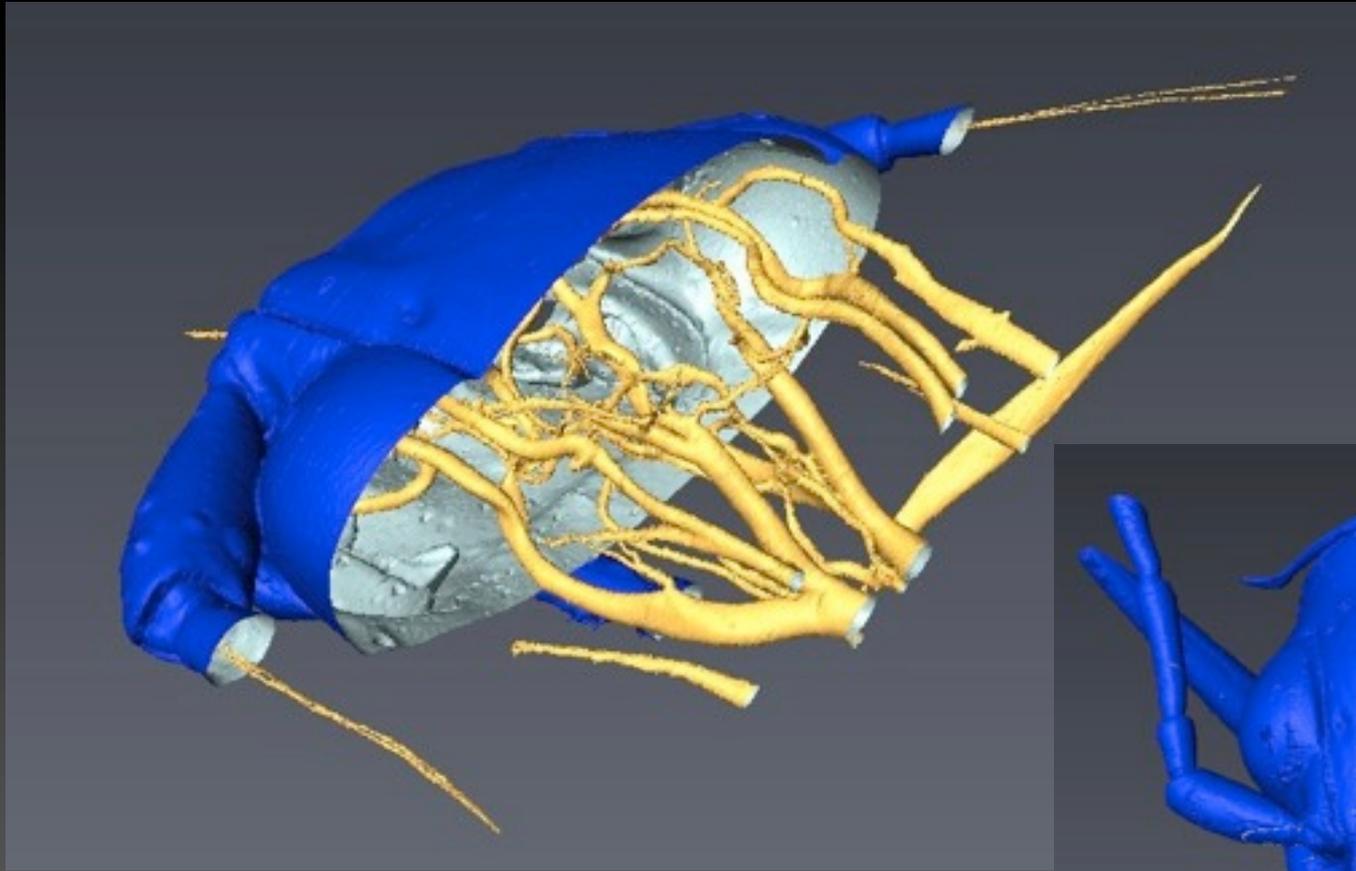
2K

resolution $\sim 1 \mu\text{m}$
1 sample ~ 0.5 hrs

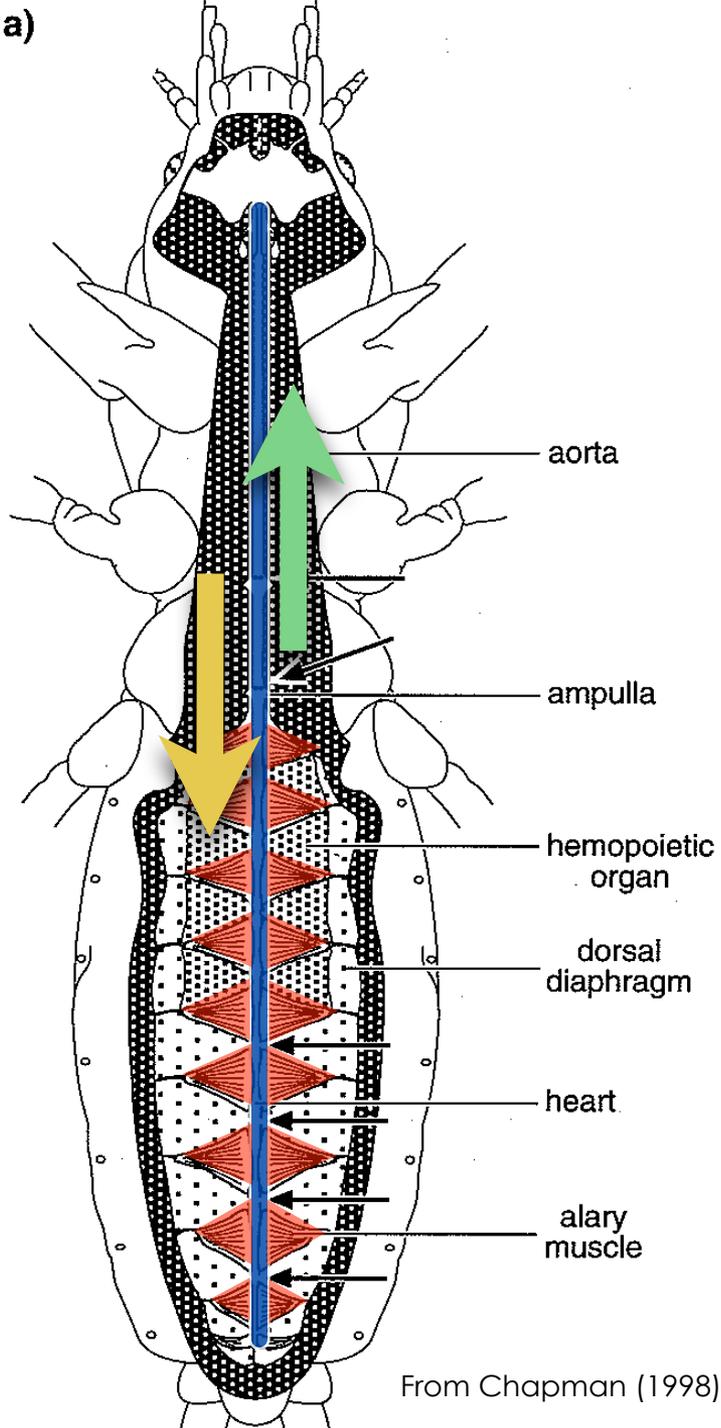


carabid beetle
Platynus decentis



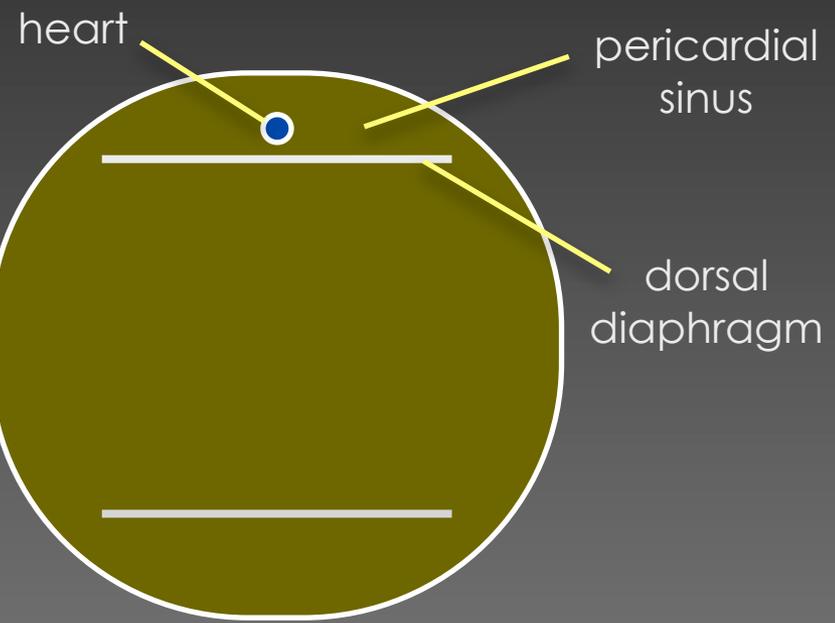


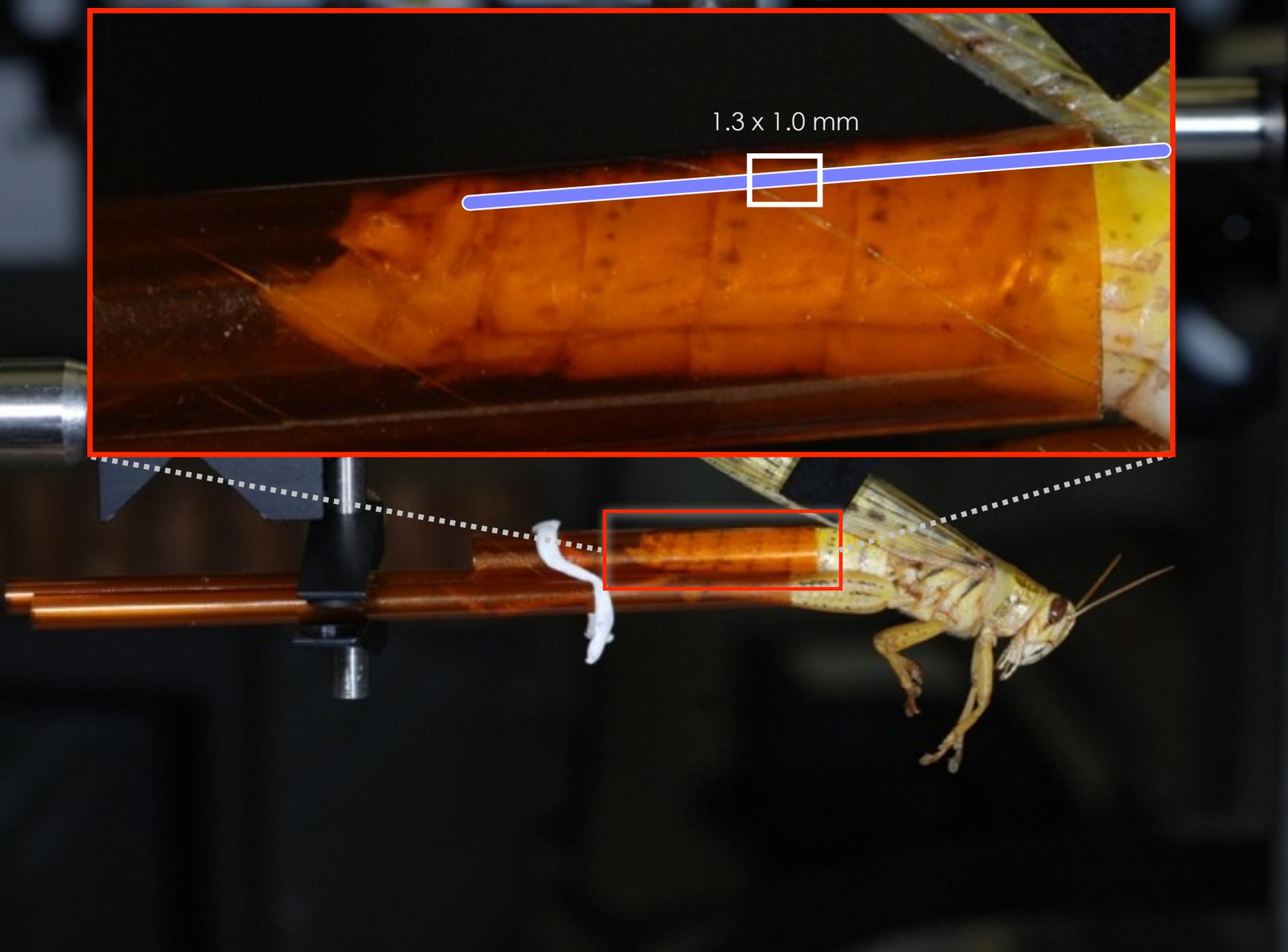
a)



From Chapman (1998)

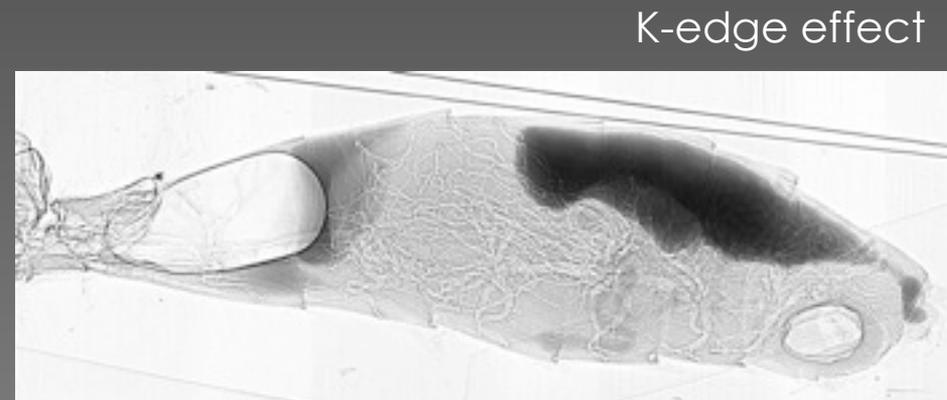
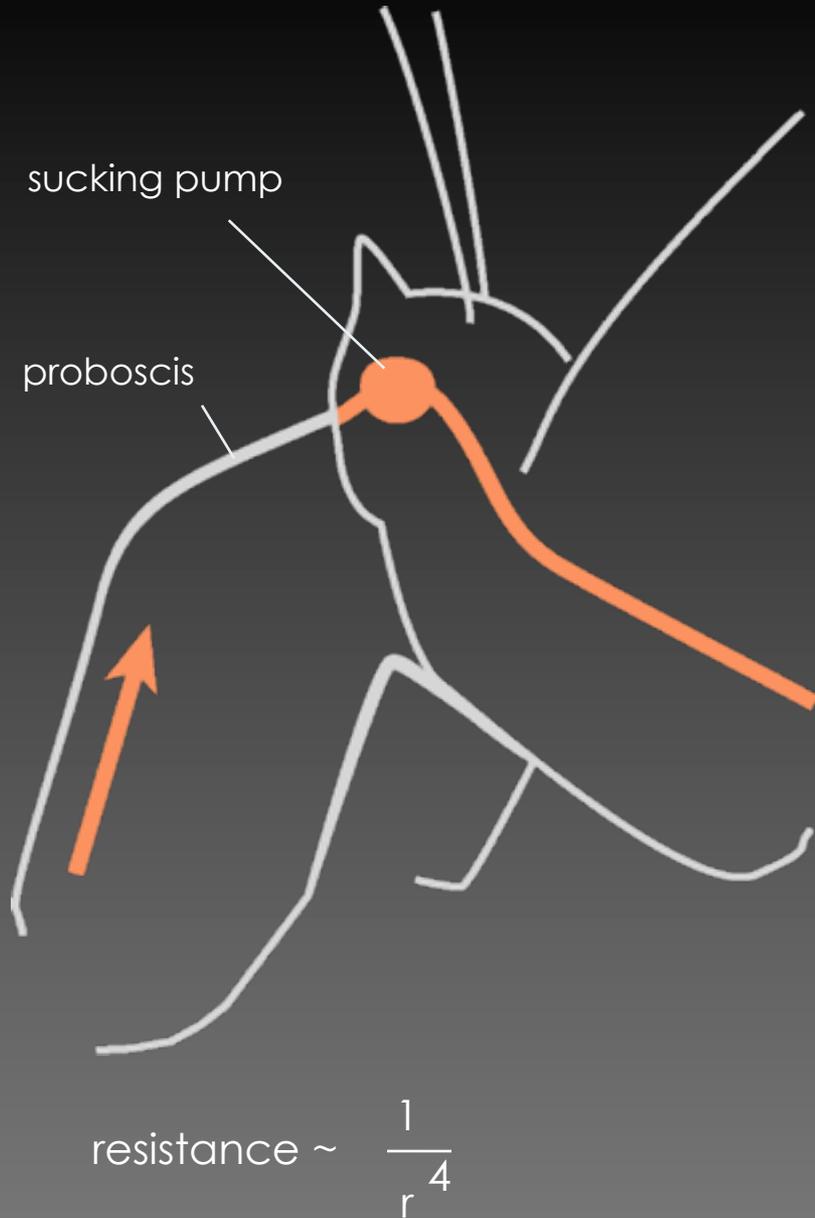
The insect heart





1.3 x 1.0 mm

Pumps for liquid feeding in butterflies and moths

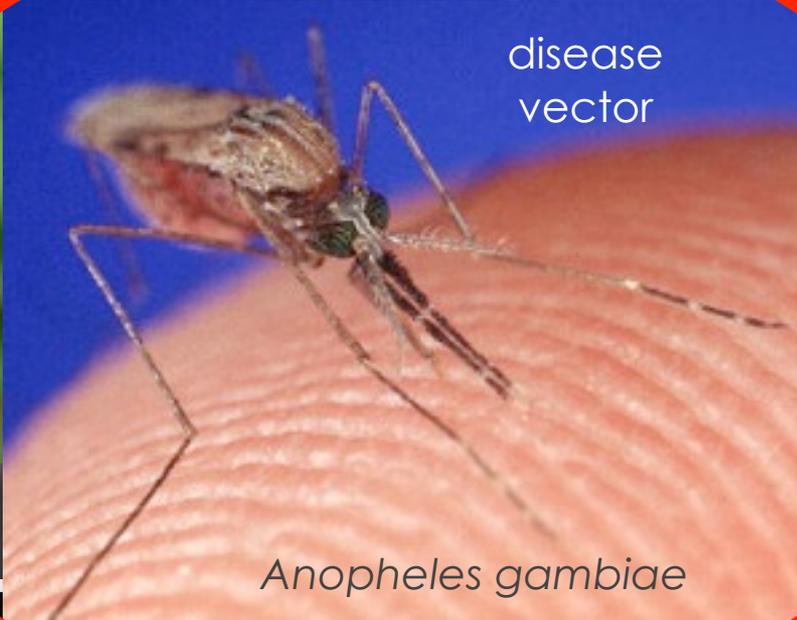


drinks from
carrion



Bev Wigney

disease
vector



Anopheles gambiae

(d)



sucks eye
juices

Hilgartner et al 2007

ridiculously
long
proboscis

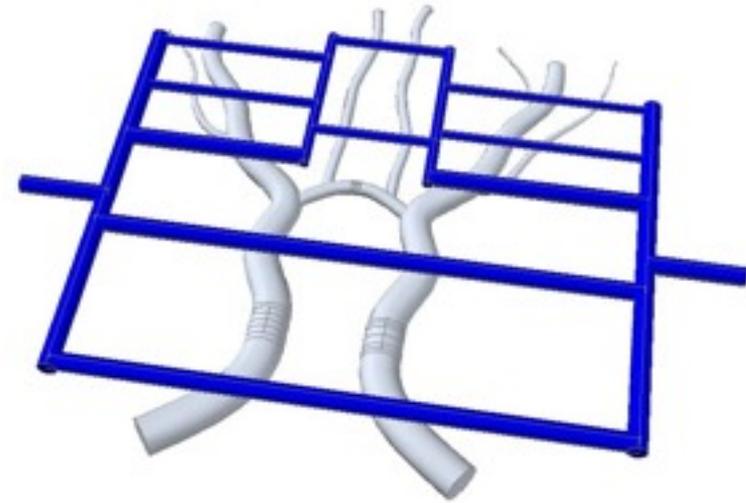
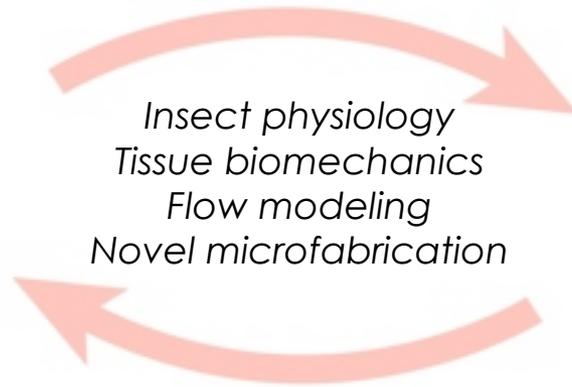


*Xanthopan morgani
predicta*

Darwin's hawk
moth

EFRI-BSBA: Complex Microsystem Networks Inspired by Internal Insect Physiology

- Air flows in some insects are created via collapsing flexible tubes in complex networks using distributed passive control.



- Flows in the circulatory system are created by differentially expanding and collapsing a single muscular tube, pushing blood throughout the body.

We will apply principles of flow control and actuation learned from insects to develop novel engineered microfluidic devices, with applications ranging from scaffolds for tissue engineering, to new implantable microdevices for autonomous sensing and therapy.



Phase-contrast imaging: benefits

Basic biology:

- Physiology & biomechanics of small animals: whole organism, alive!
- Implications for systematics & evolution

Agriculture:

- Understanding agriculturally relevant processes

Biomedical:

- Understanding insects, disease, & function
- Physiology of models: rat, mouse
- Imaging of flows in vessels
- Biomimetics

My NSLS-II beamline needs:

- Bigger beam
- More time: beamtime, animal survival