Upcoming Events at KITP

Sep 7
5:30 pm

Chalk Talk: Rahul Nandkishore at KITP
"Quantum Glass"

Nov 28
5:30 pm

Chalk Talk: Louis Kauffman at KITP
"Knots and Physics"

The tao of fish swimming

KITP Chalk Talk
August 7th, 2018

James C. Liao
Associate Professor
Department of Biology
UF Term Professor

UF UNIVERSITY of FLORIDA

THE WHITNEY LABORATORY
for MARINE BIOSCIENCE

The tao of fish swimming

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for MARINE BIOSCIENCE

ARISTOTLE

PARTS OF ANIMALS

WITH AN ENGLISH TRANSLATION BY

A. L. PECK

MOVEMENT OF ANIMALS
PROGRESSION OF ANIMALS

WITH AN ENGLISH TRANSLATION BY

E. S. FORSTER

HARVARD UNIVERSITY PRESS
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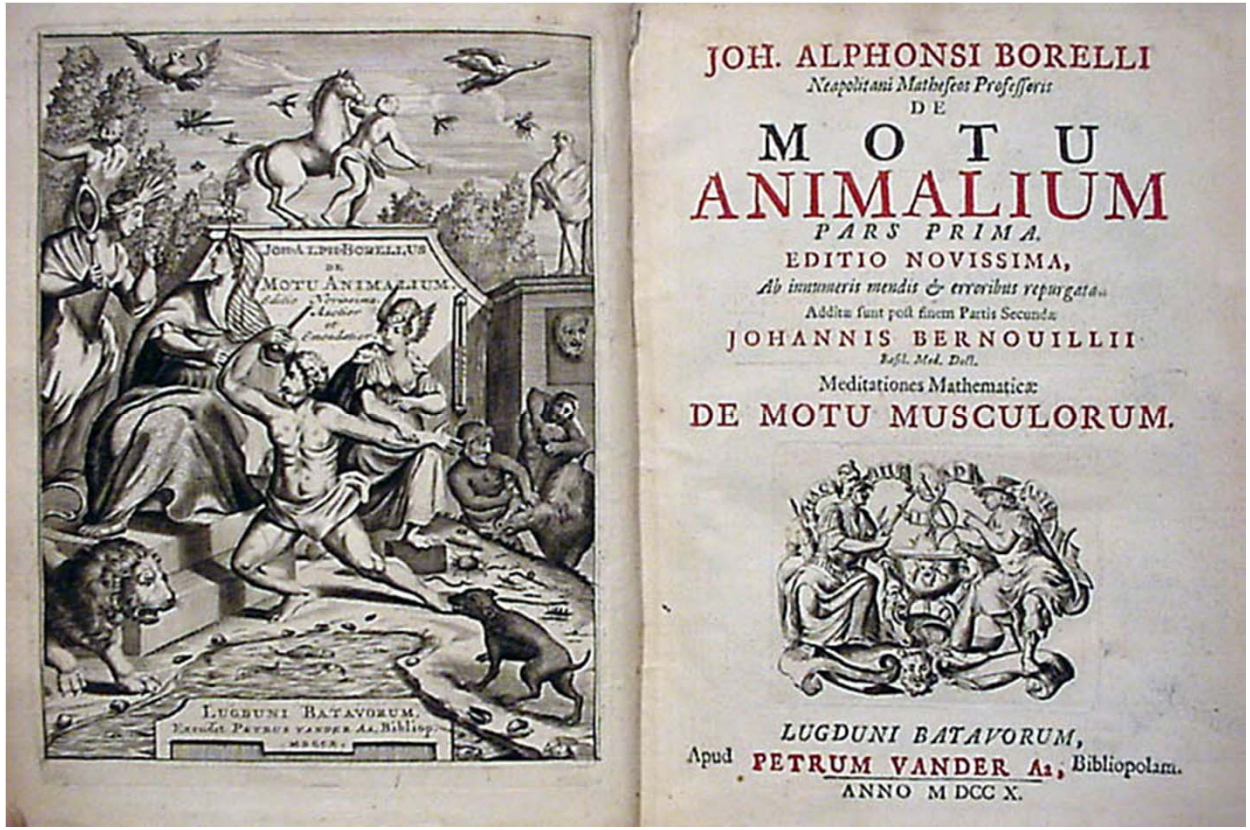
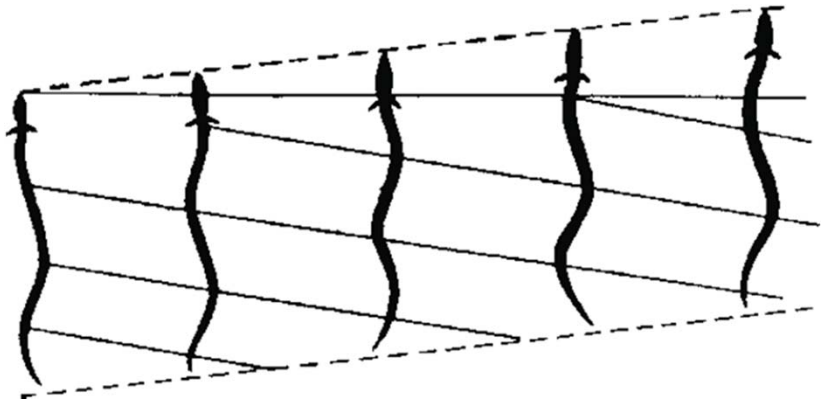
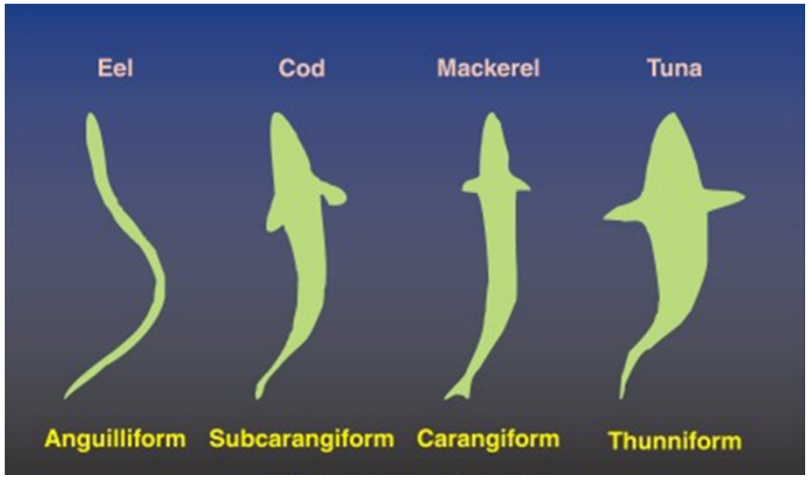


JOH. ALPHONSI BORELLI
Neapolitani Matheseos Professoris
DE
MOTU
ANIMALIUM
PARS PRIMA.
EDITIO NOVISSIMA,
Ab innumeris mendis & erroribus repurgata.
Additæ sunt post finem Partis Secundæ
JOHANNIS BERNOUILLII
Basil. Med. Doct.
Meditationes Mathematicæ
DE MOTU MUSCULORUM.
LUGDUNI BATAVORUM,
Apud PETRUM VANDER Aa, Bibliopolam.
ANNO M DCC X.

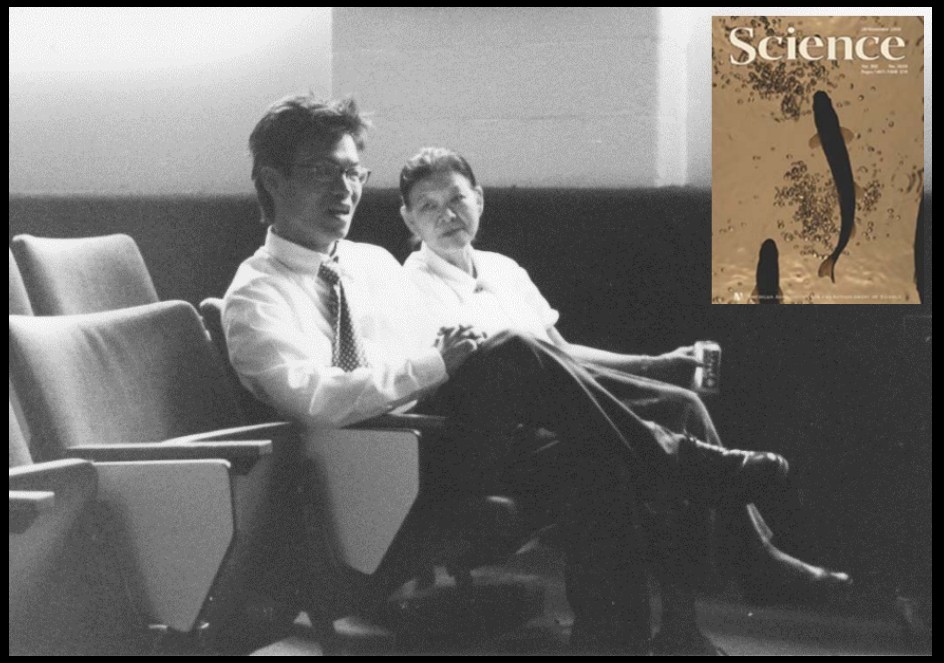




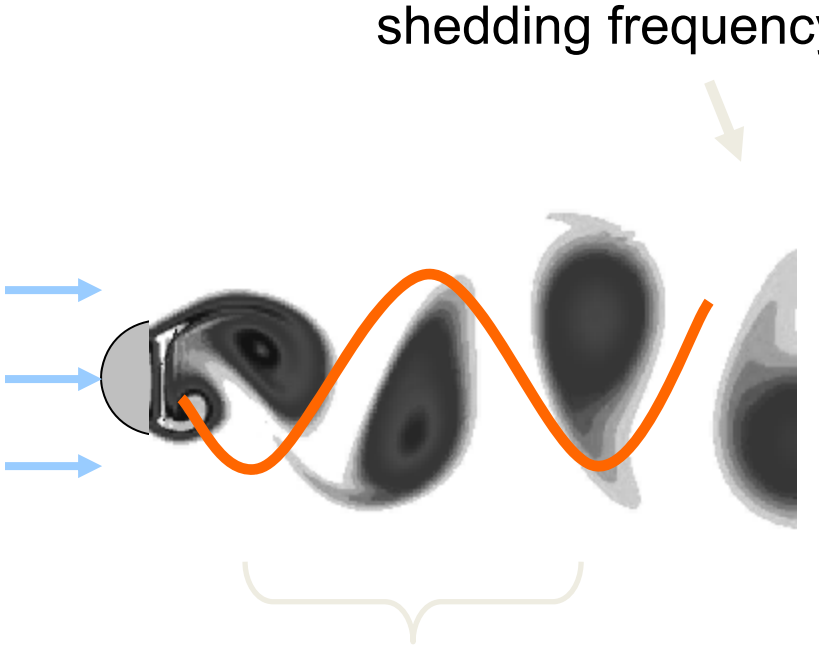
Traveling wave equation for undulatory swimming.

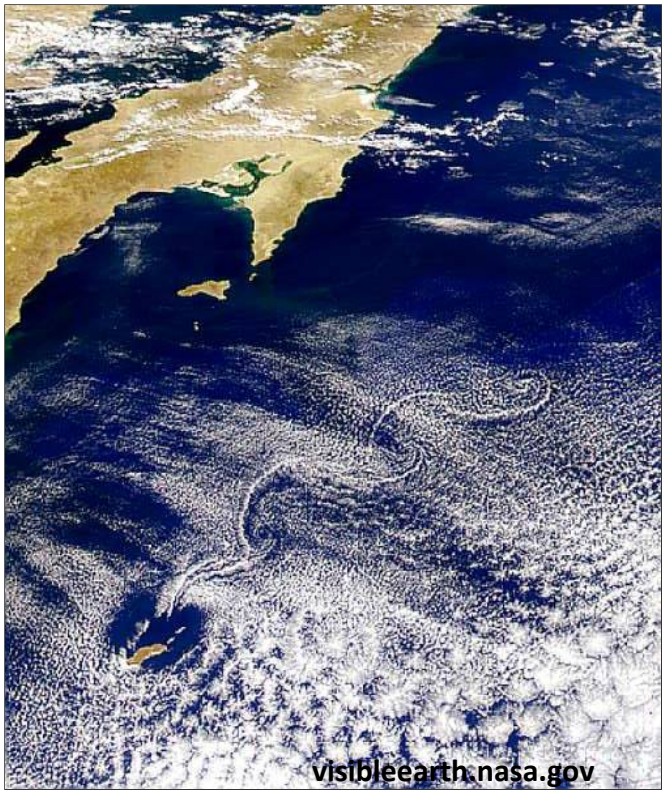
$$h(x,t) = A(x) * \sin(kx - \omega t + \phi)$$


1980
1986
1992
1996
1999
2004
2009
2016
....

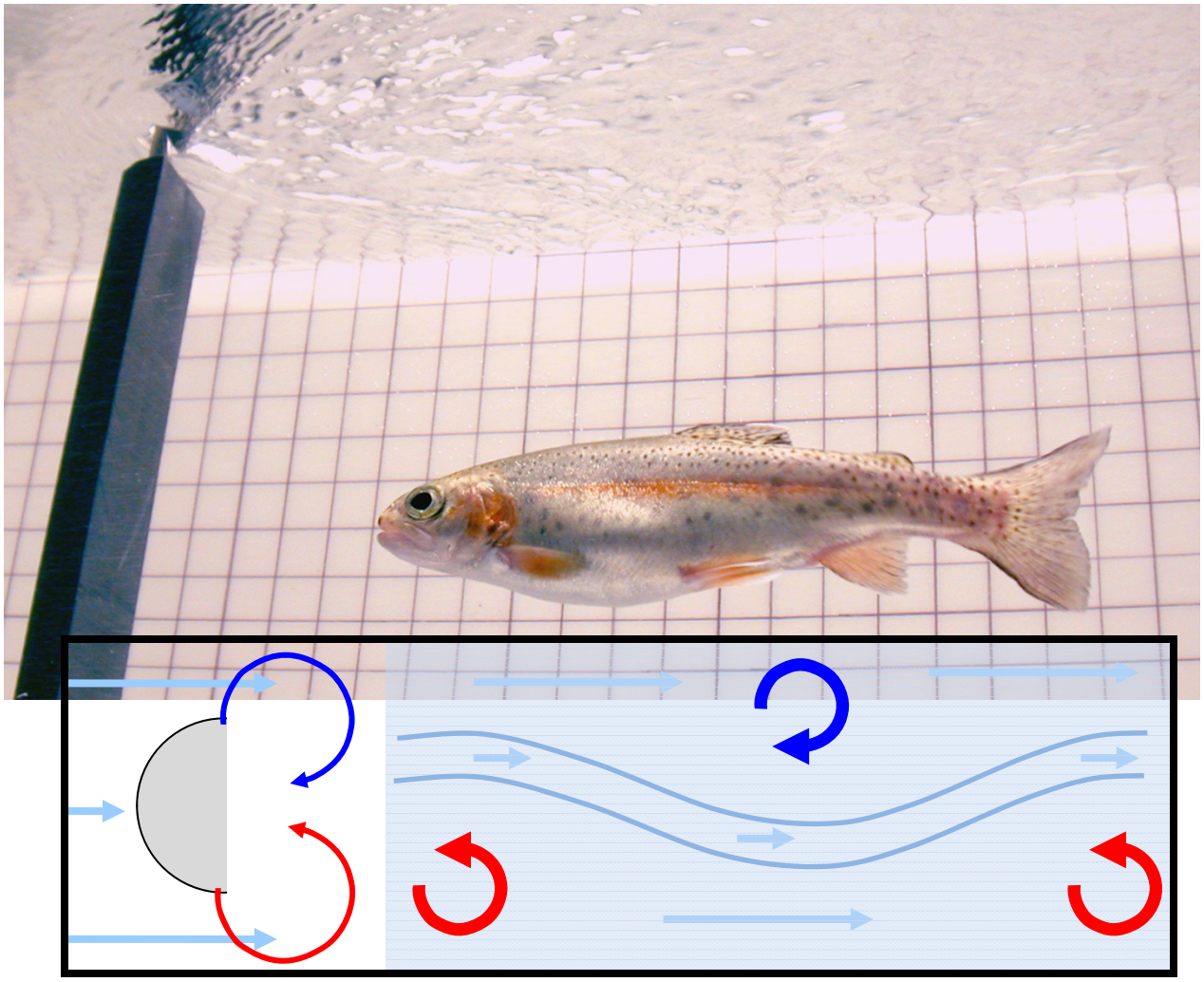

Science

Kármán vortex street





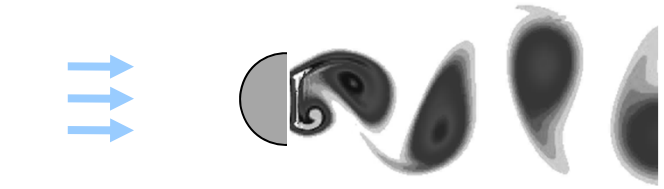
Fish in a Kármán vortex street



Kármán vortex street

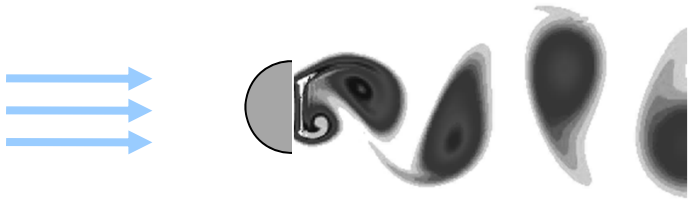
Strouhal number = (L*f) / v

$\lambda = v/f$



λ = 11 cm

f = 2.2 Hz



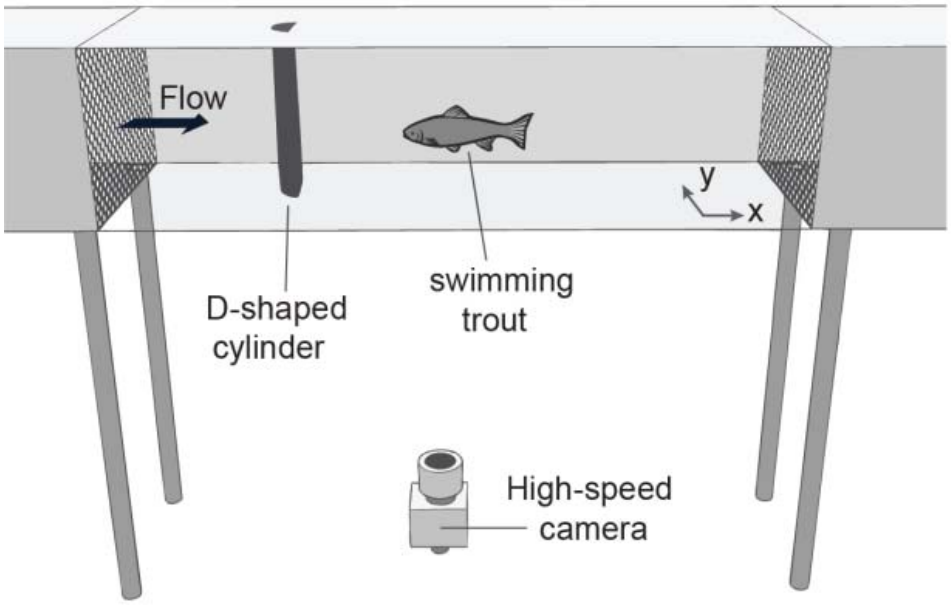
λ = 11 cm

f = 4.0 Hz

λ = 20 cm

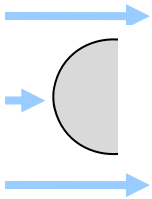
f = 2.2 Hz

The Kármán Gait

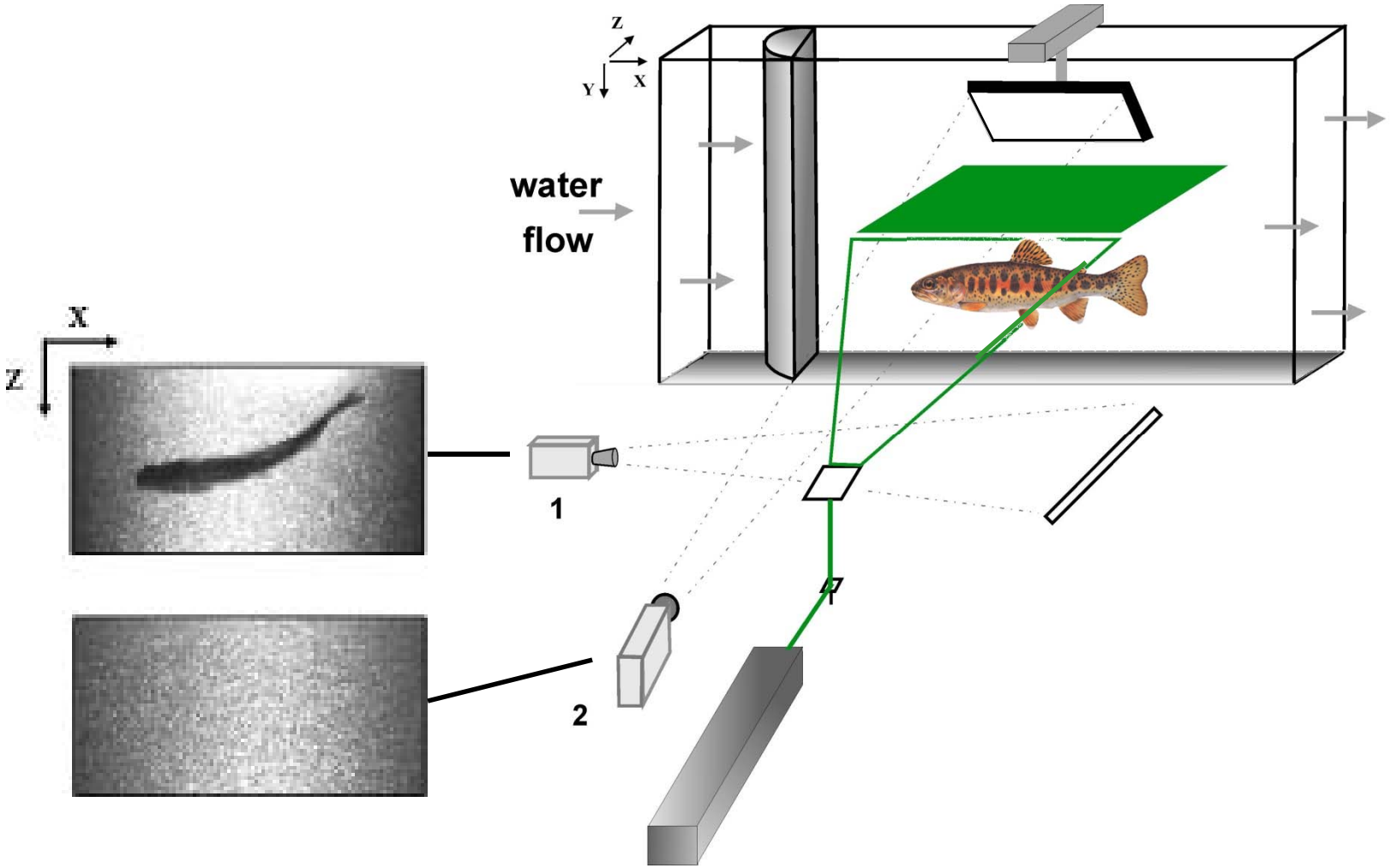


Kármán gait
with cylinder

no cylinder

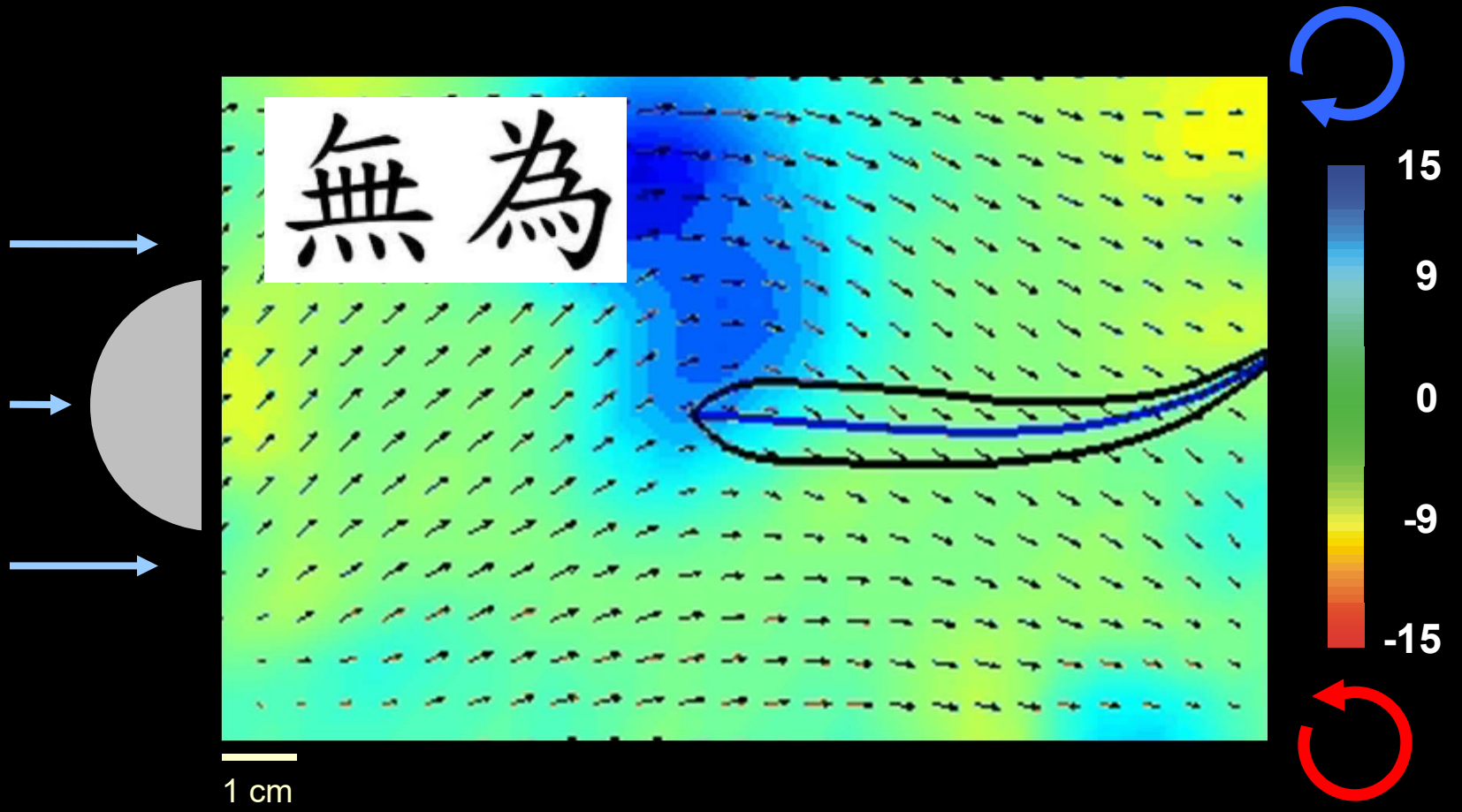


Digital Particle Image Velocimetry



Digital Particle Image Velocimetry

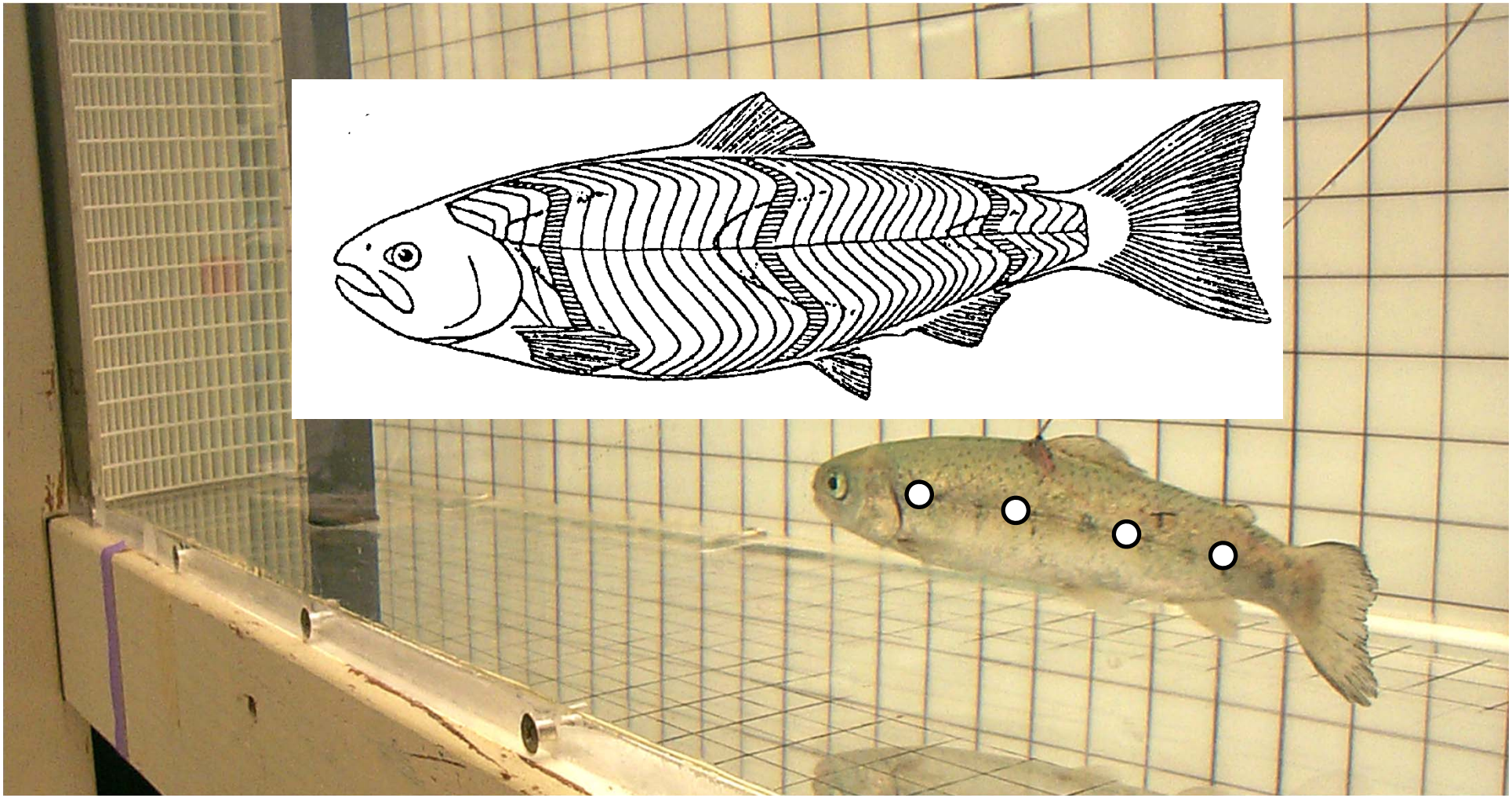
Digital Particle Image Velocimetry



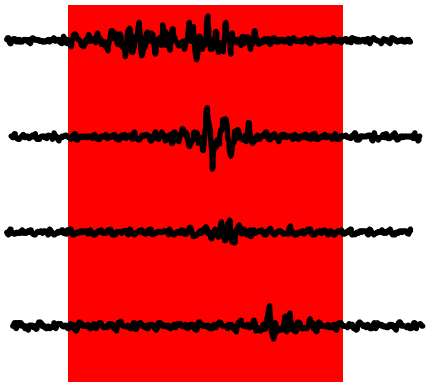
Liao et al. **Science** 2003

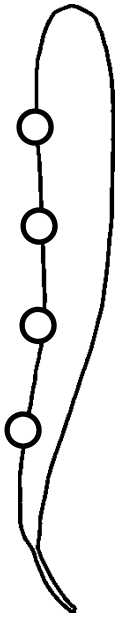
Akanyeti and Liao **J. Exp. Biol.** 2013a,b

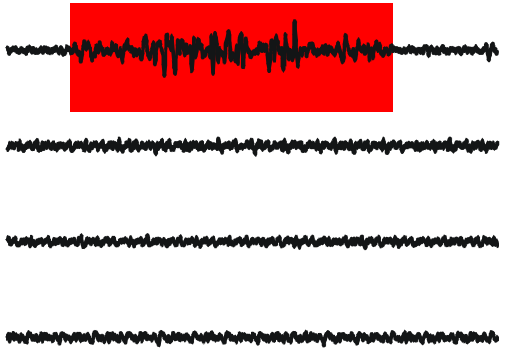
Muscle activity



Muscle activity



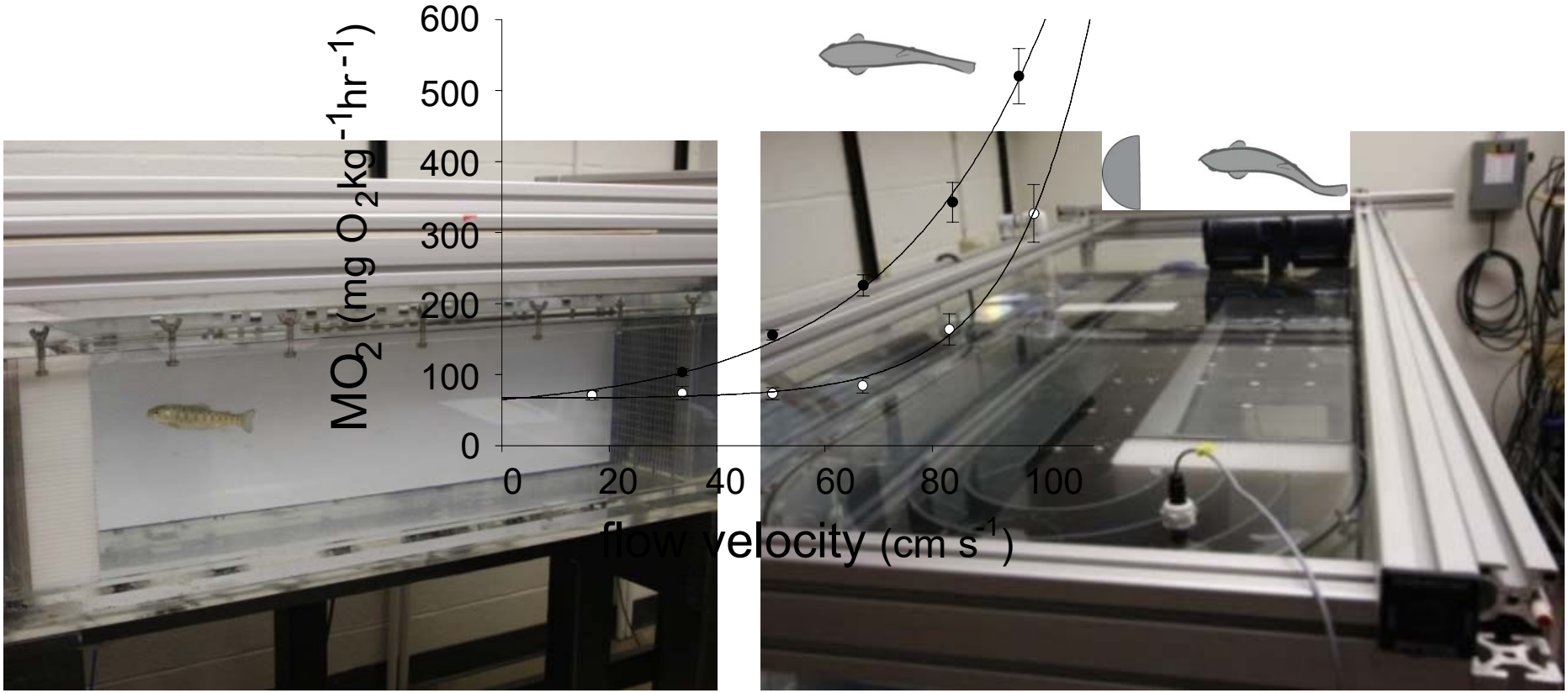




swimming

Kármán gait

Kármán gaiting saves energy

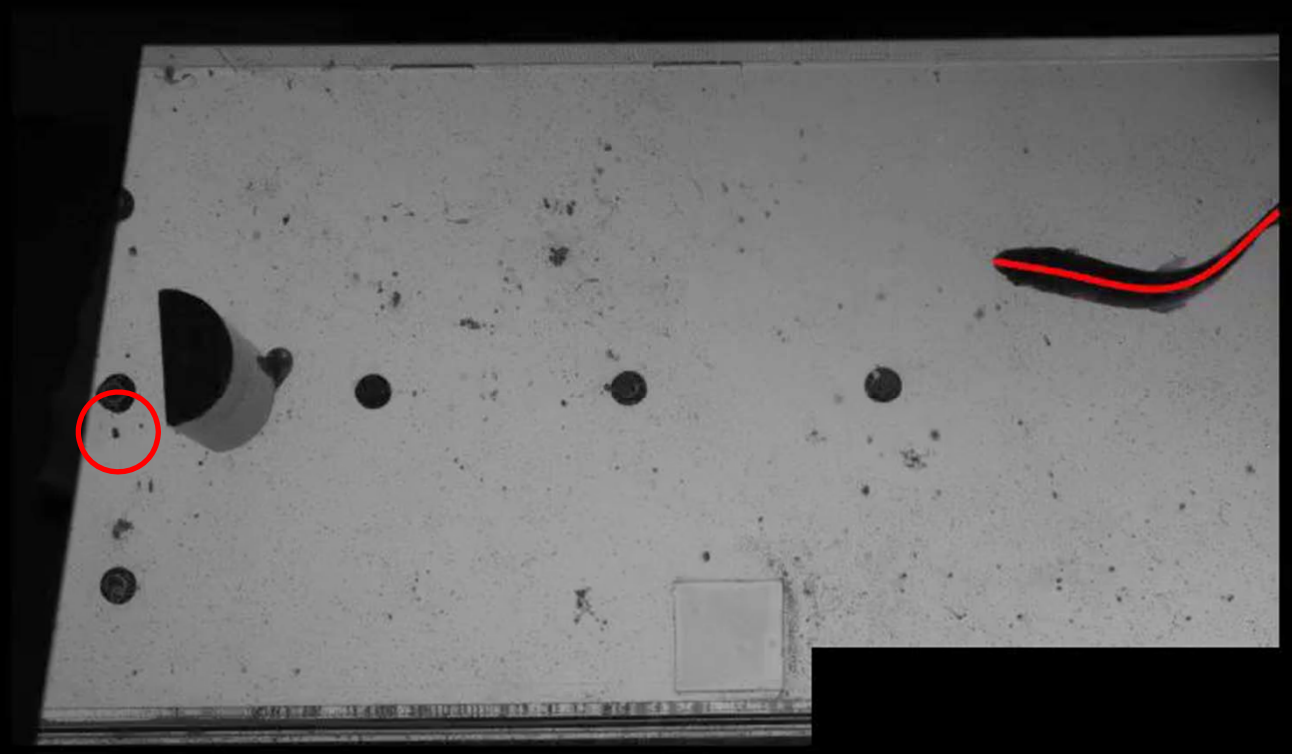


Taguchi and Liao. **J. Exp. Biol.** (2010)

Dead trout swimming

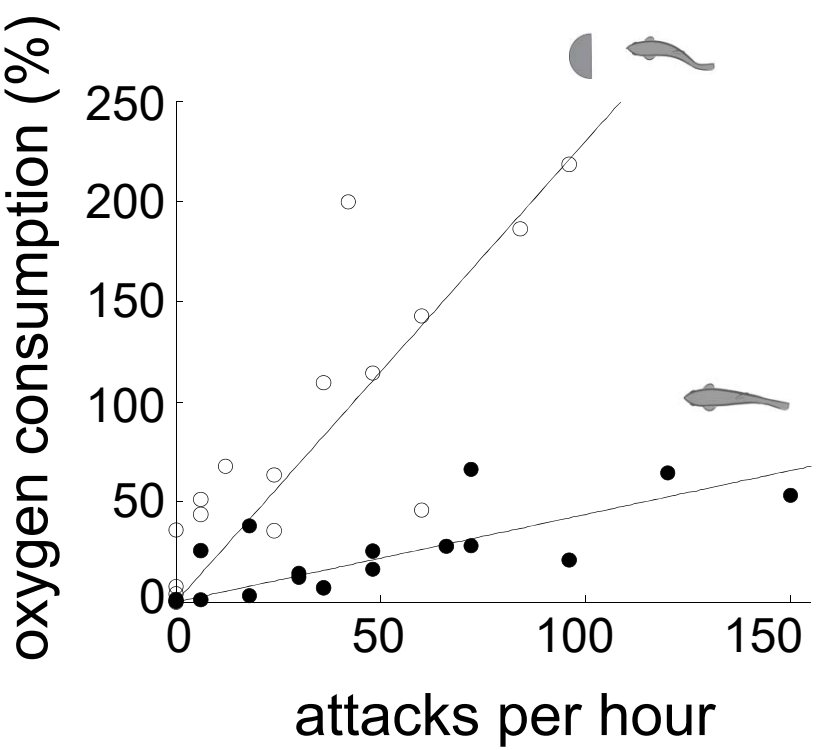
Beal, Liao et al. **Journal of Fluid Mechanics 2006**

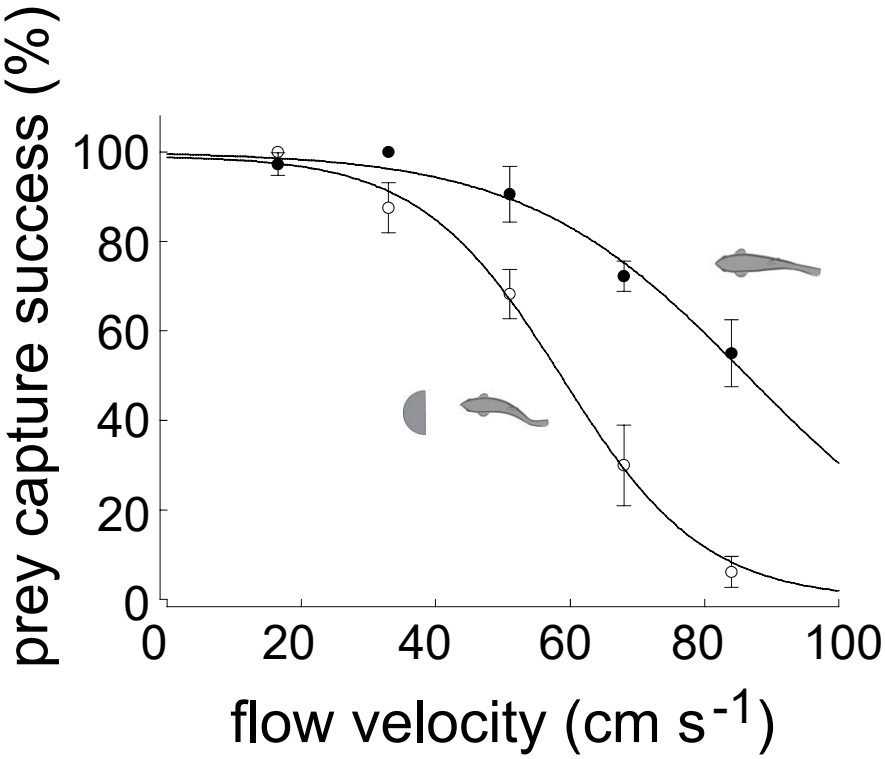
Drift Feeding



Feeding in unsteady flows

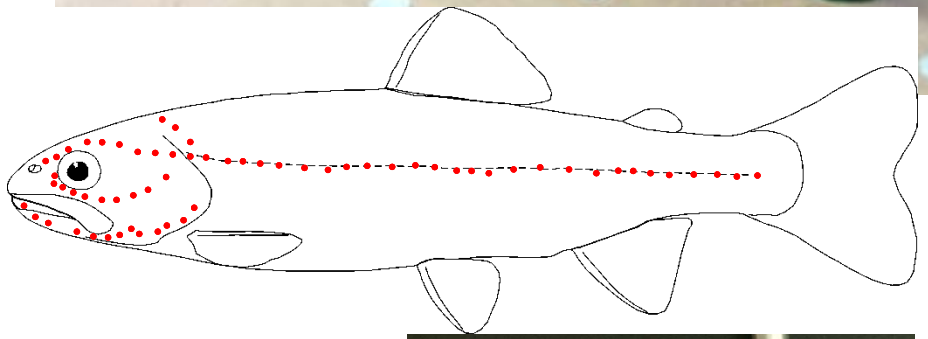
1. **more costly**
2. **less successful**

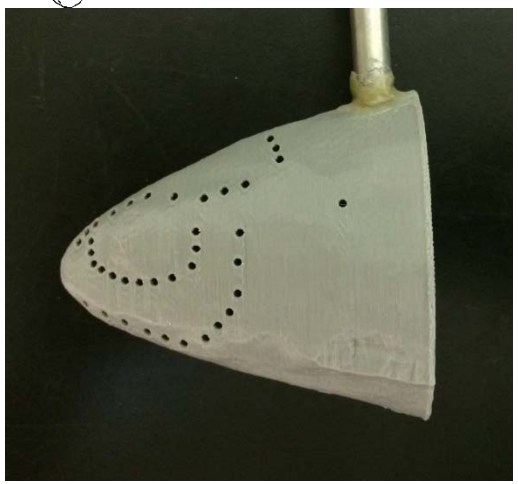




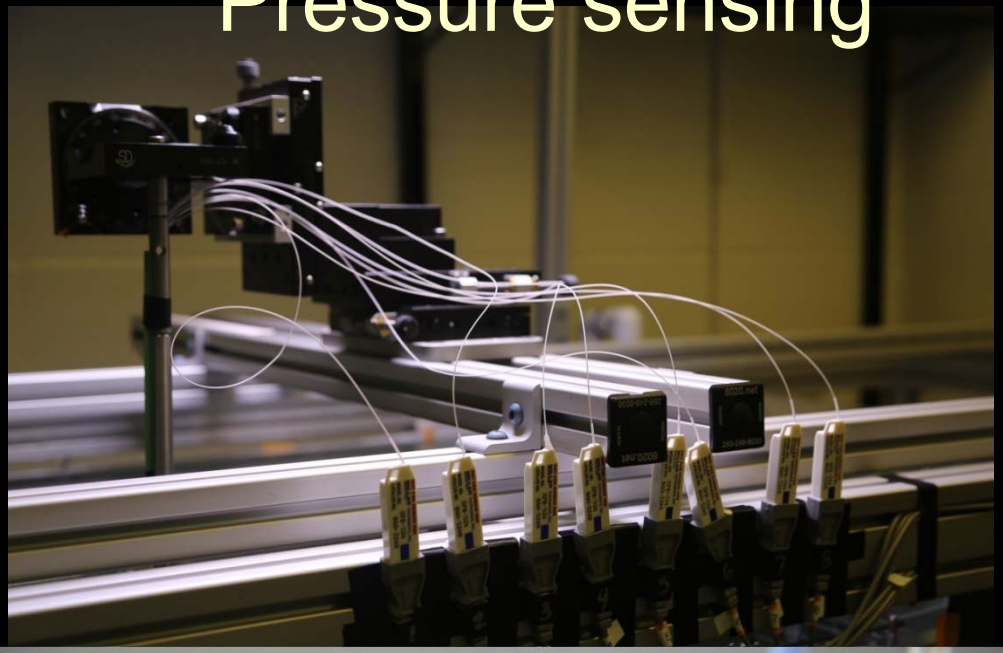
What is the role of the flow sensing lateral line system?

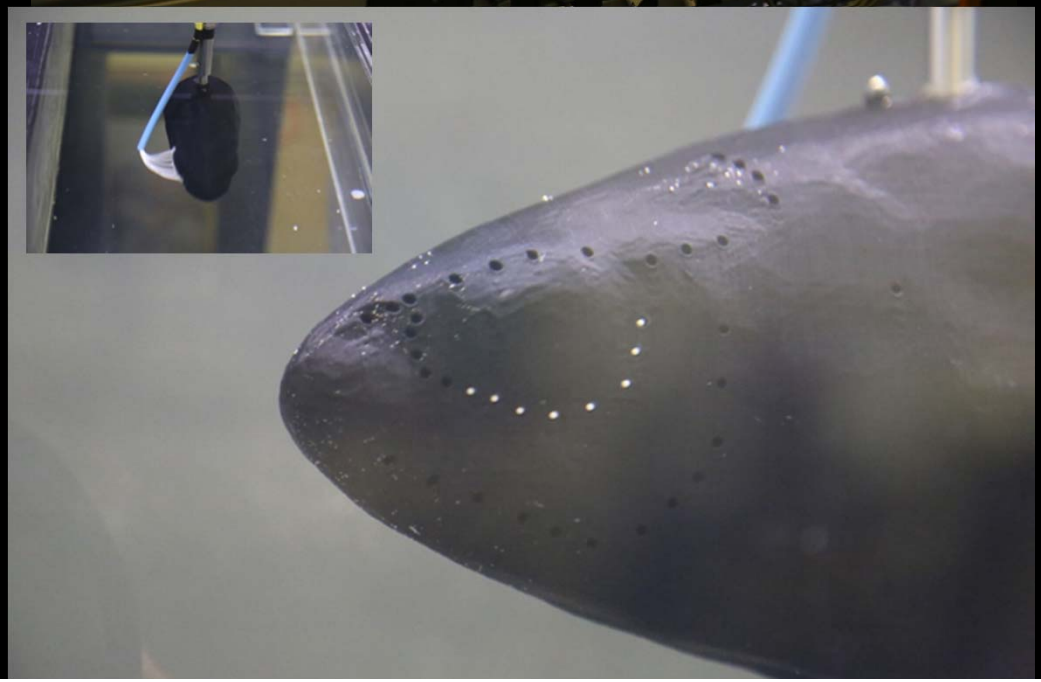
Can the lateral line optimize swimming?

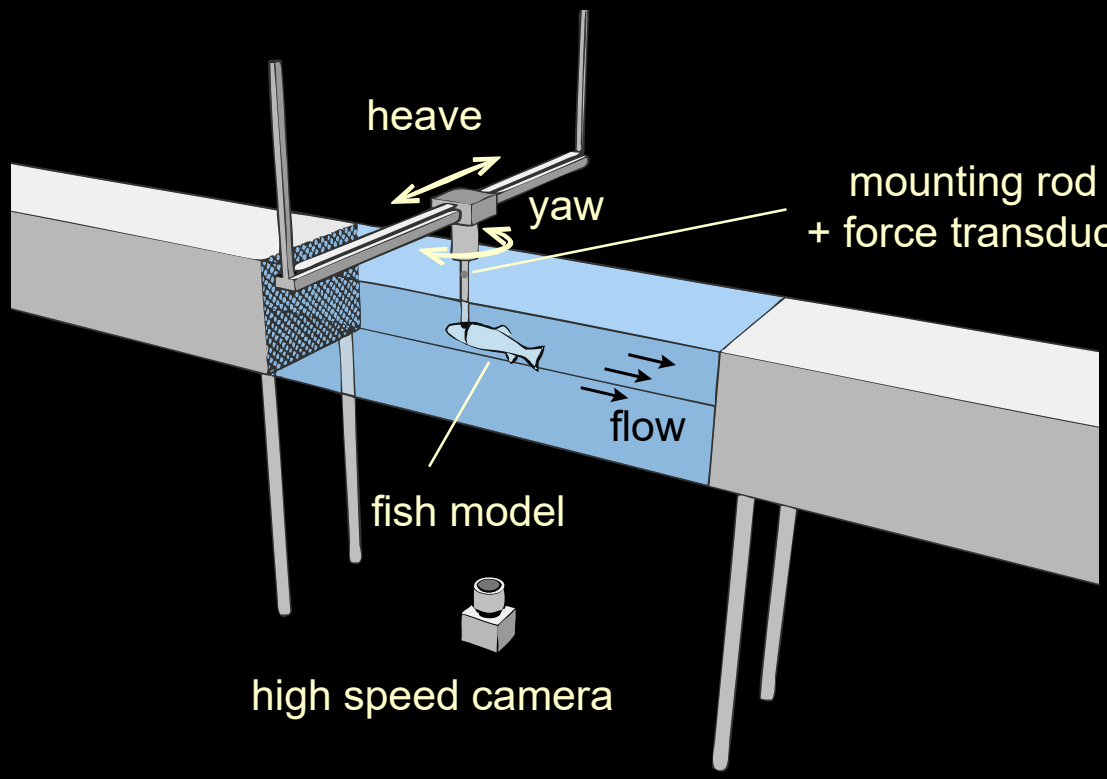




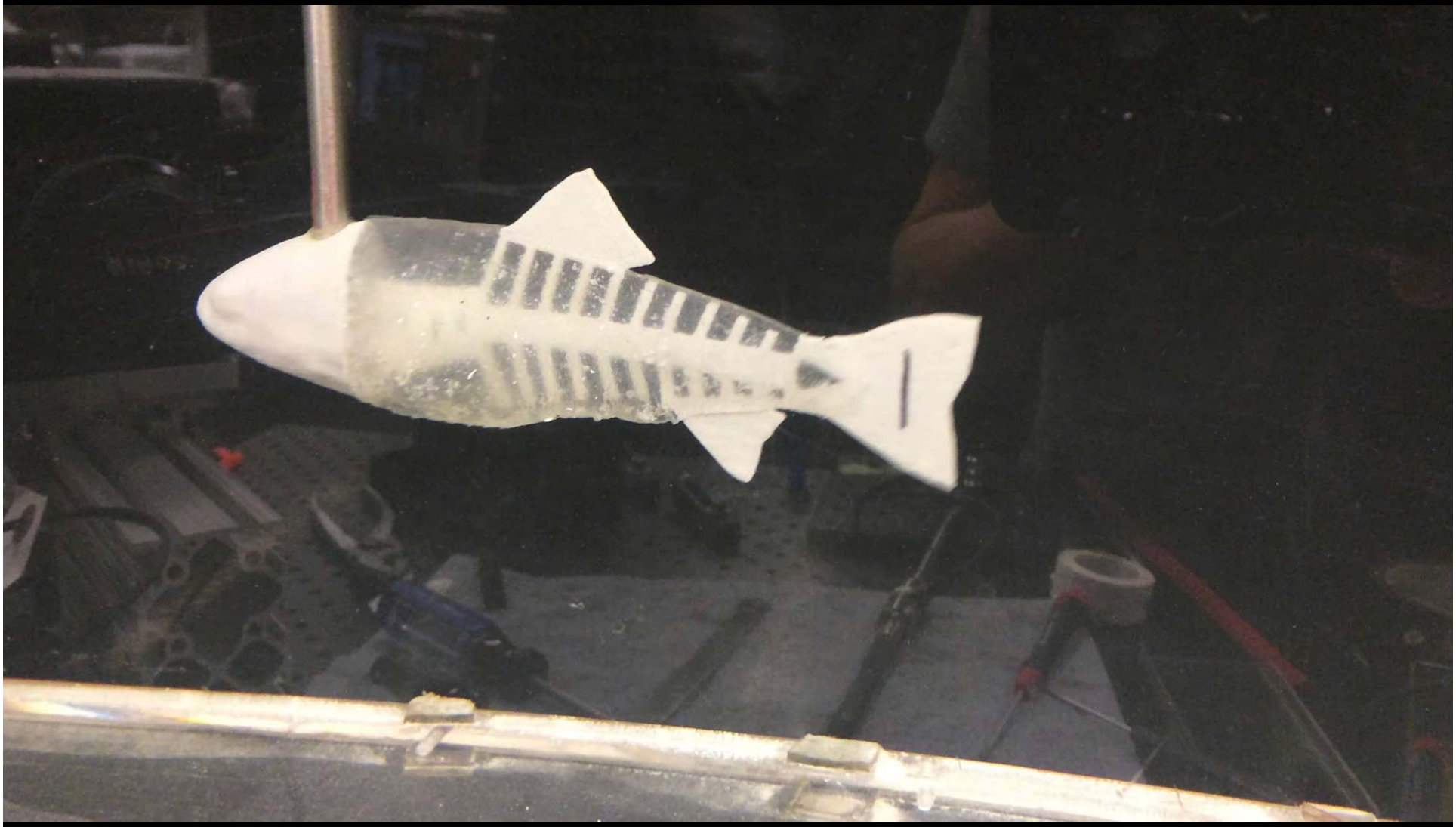
Pressure sensing





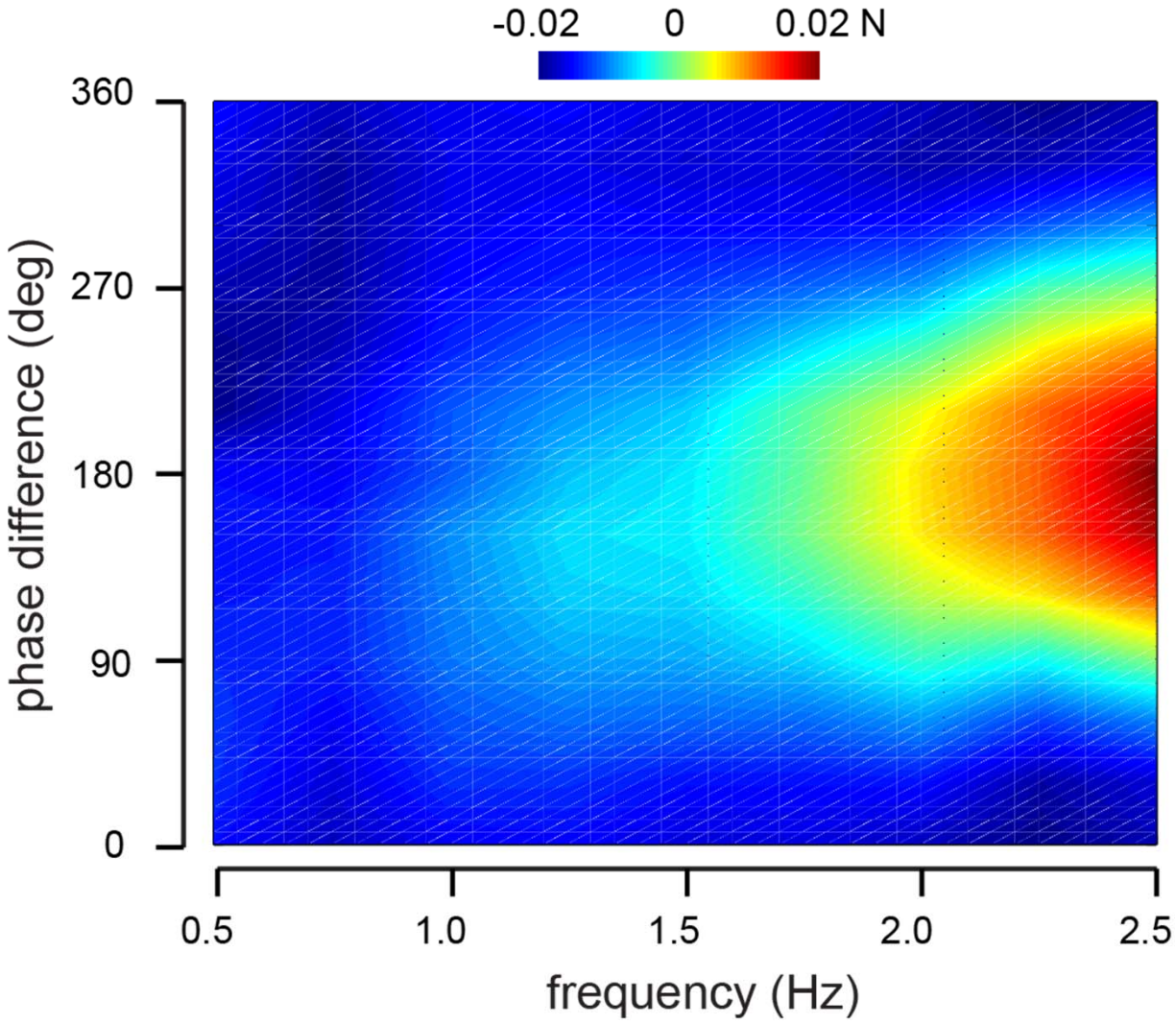

heave
yaw
mounting rod
+ force transducer
flow
fish model
high speed camera

Soft robotics



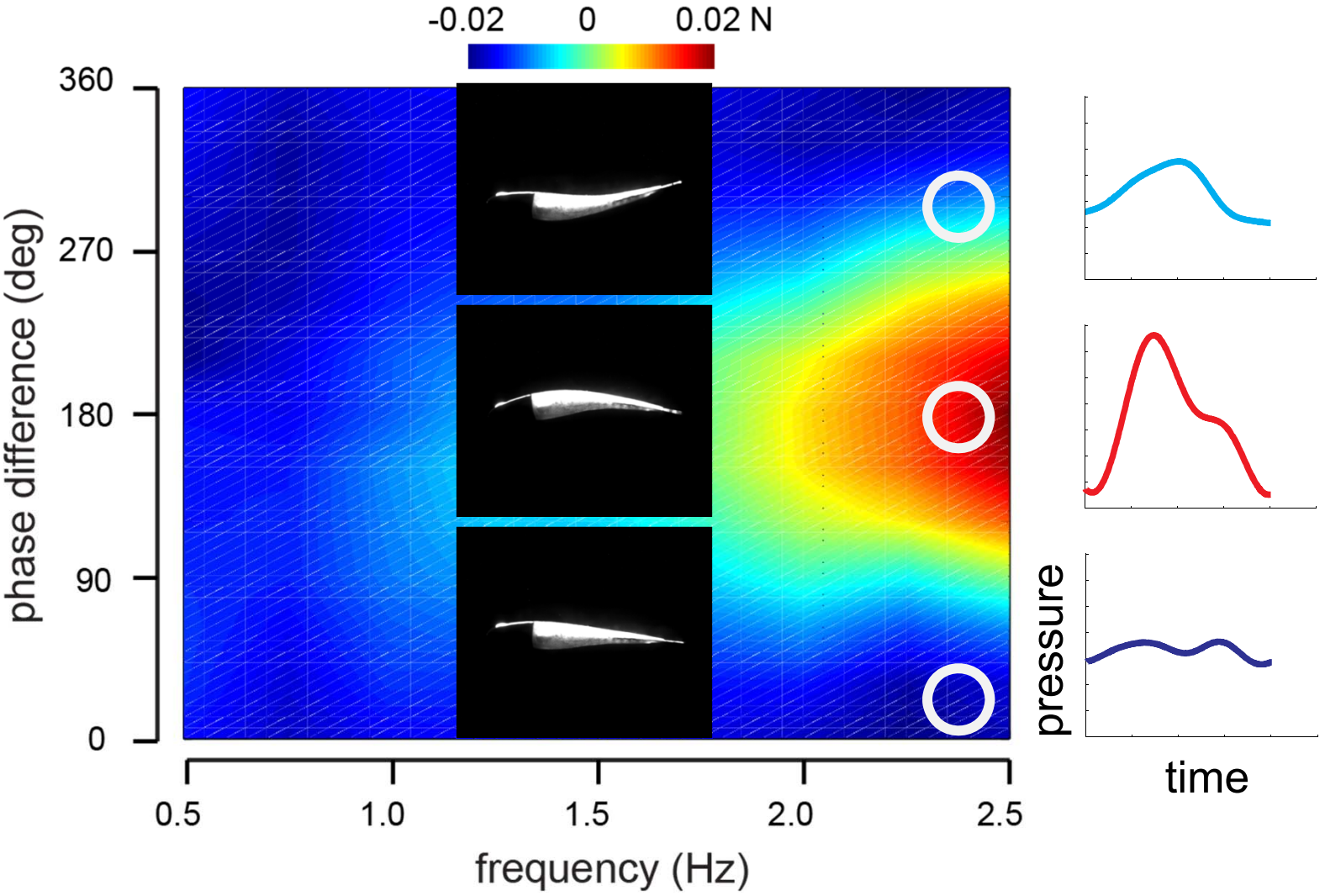
Akanyeti, Putney, Yanagitsuru, Lauder, Stewart and Liao **PNAS** 2017

Thrust correlated to unique pressure profiles



Akanyeti, Thornycroft, Lauder, Yanagitsuru, Peterson, and Liao **Nature Communications** 2016

Thrust correlated to unique pressure profiles

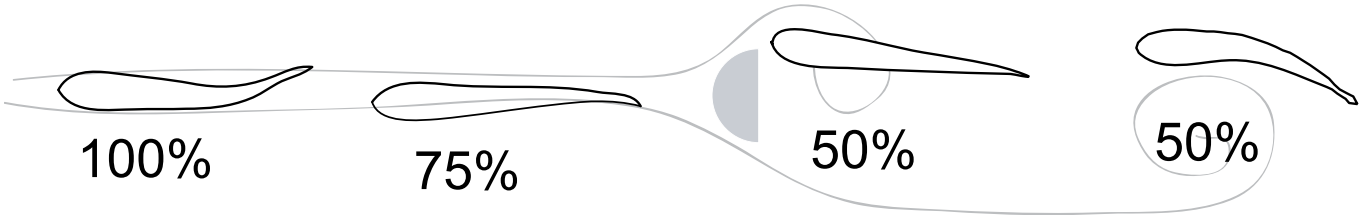


Akanyeti, Thornycroft, Lauder, Yanagitsuru, Peterson, and Liao **Nature Communications** 2016

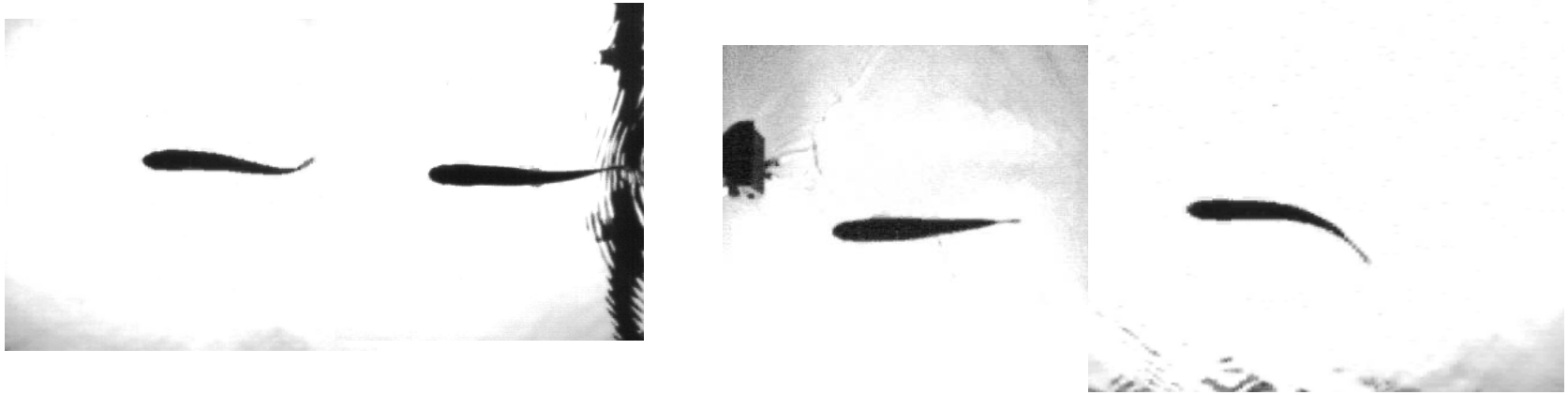
Summary

How and why do fish swim in unsteady flows?

Behavioral complexity



swimming bow waking entraining Kármán gaiting



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- Yuzo Yanagitsuru

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- Christina Walker

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