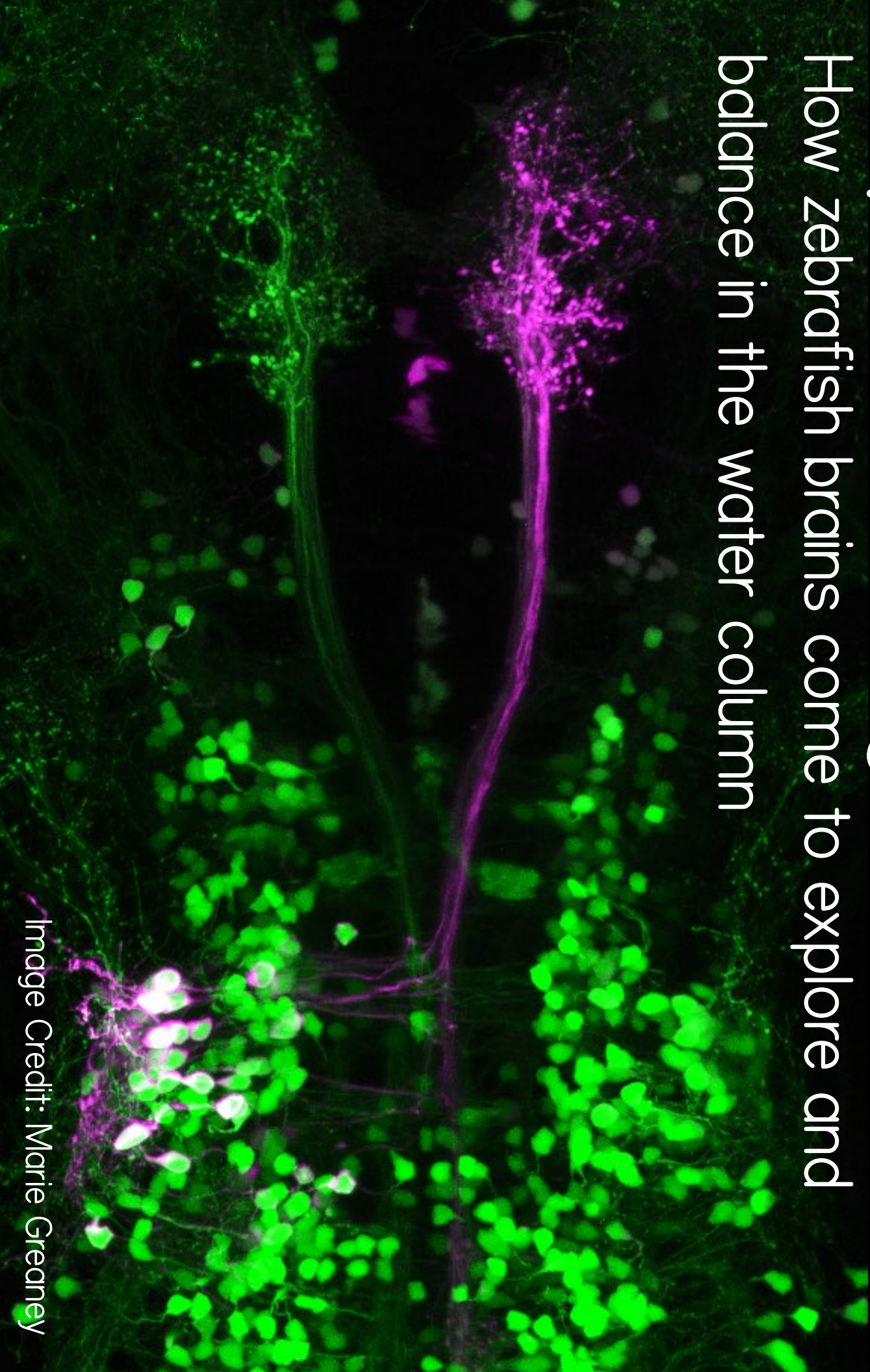


Depth Learning:

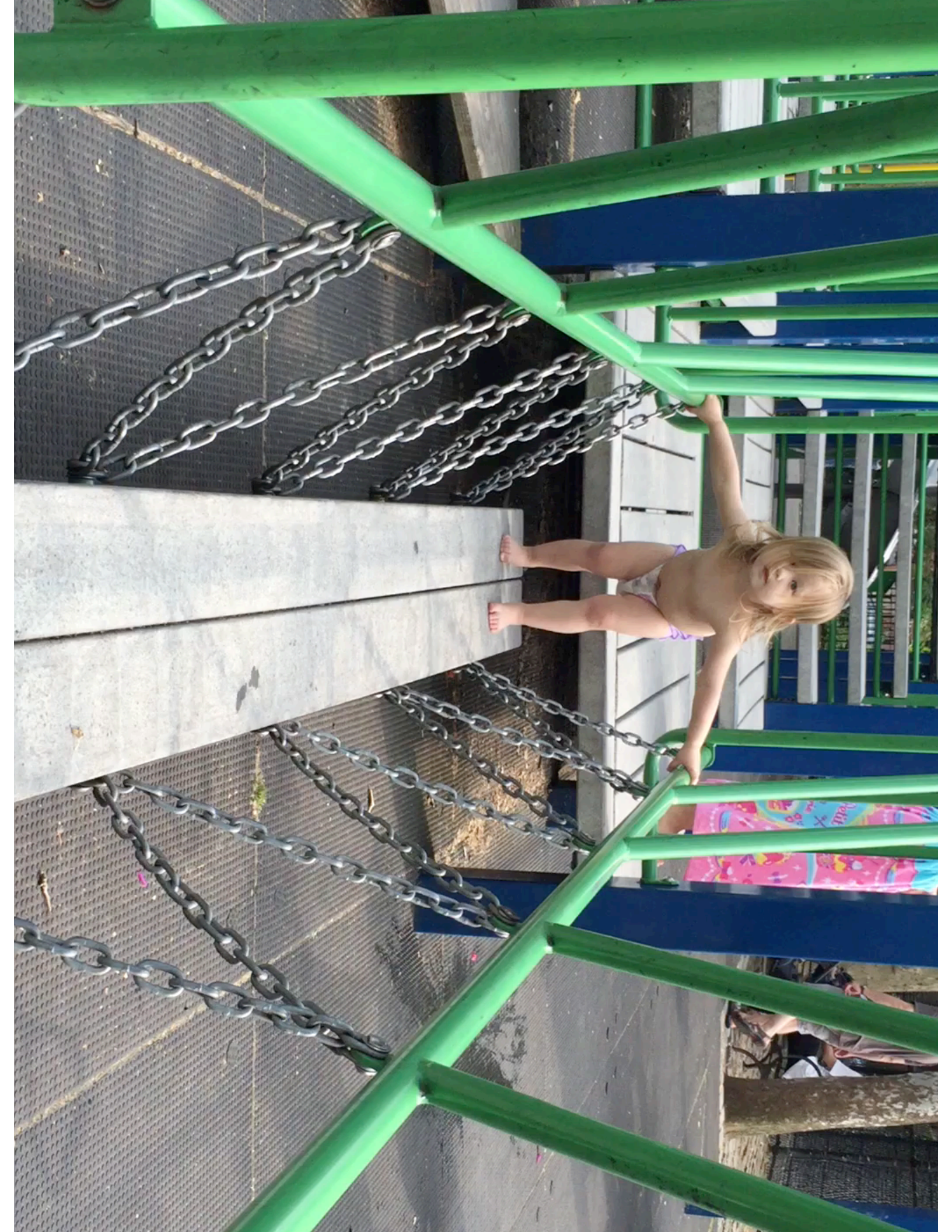
How zebrafish brains come to explore and balance in the water column

Image Credit: Marie Greaney

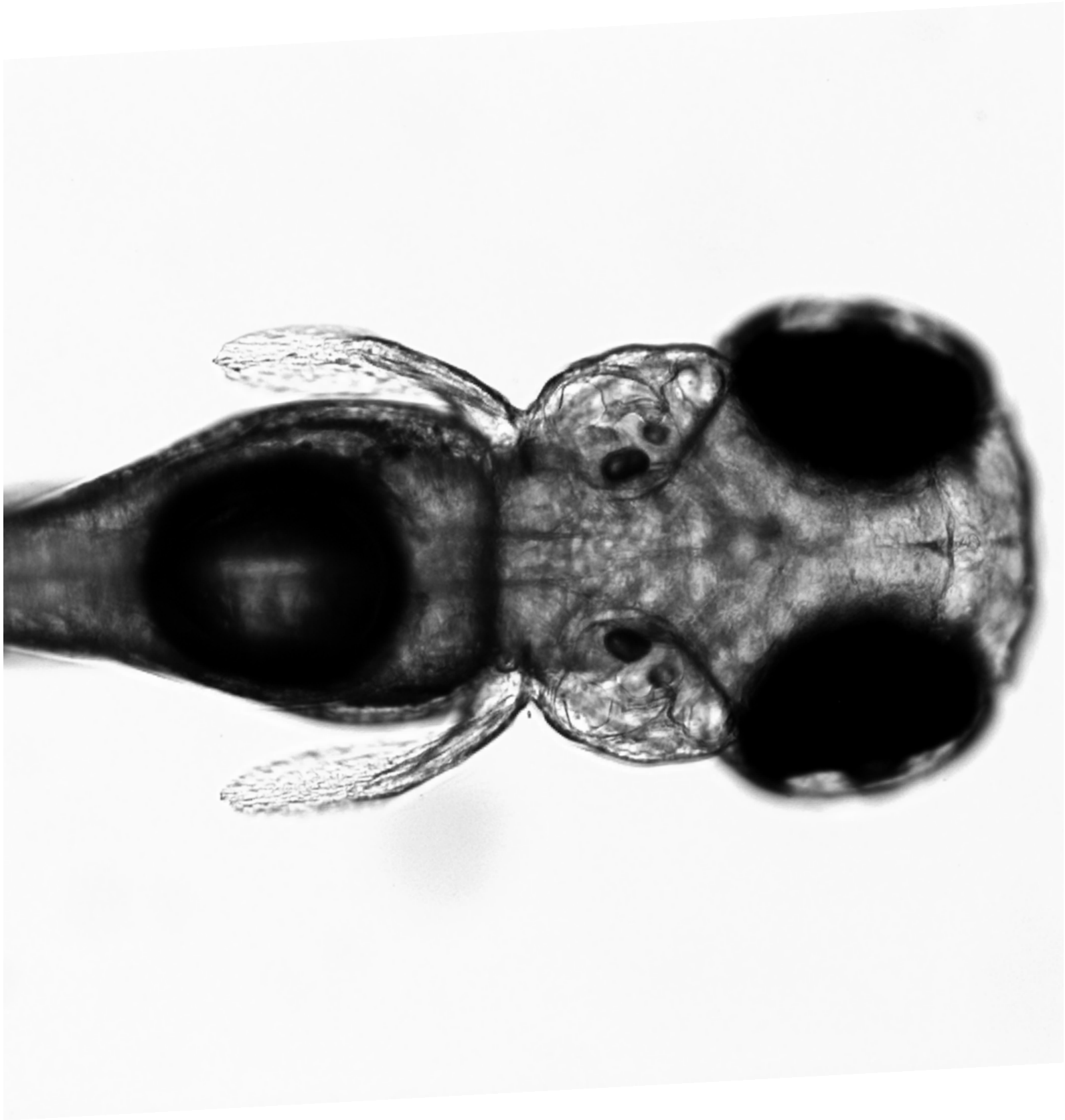












Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

David Ehrlich, Ph.D.

Ehrlich & Schoppik 2017a

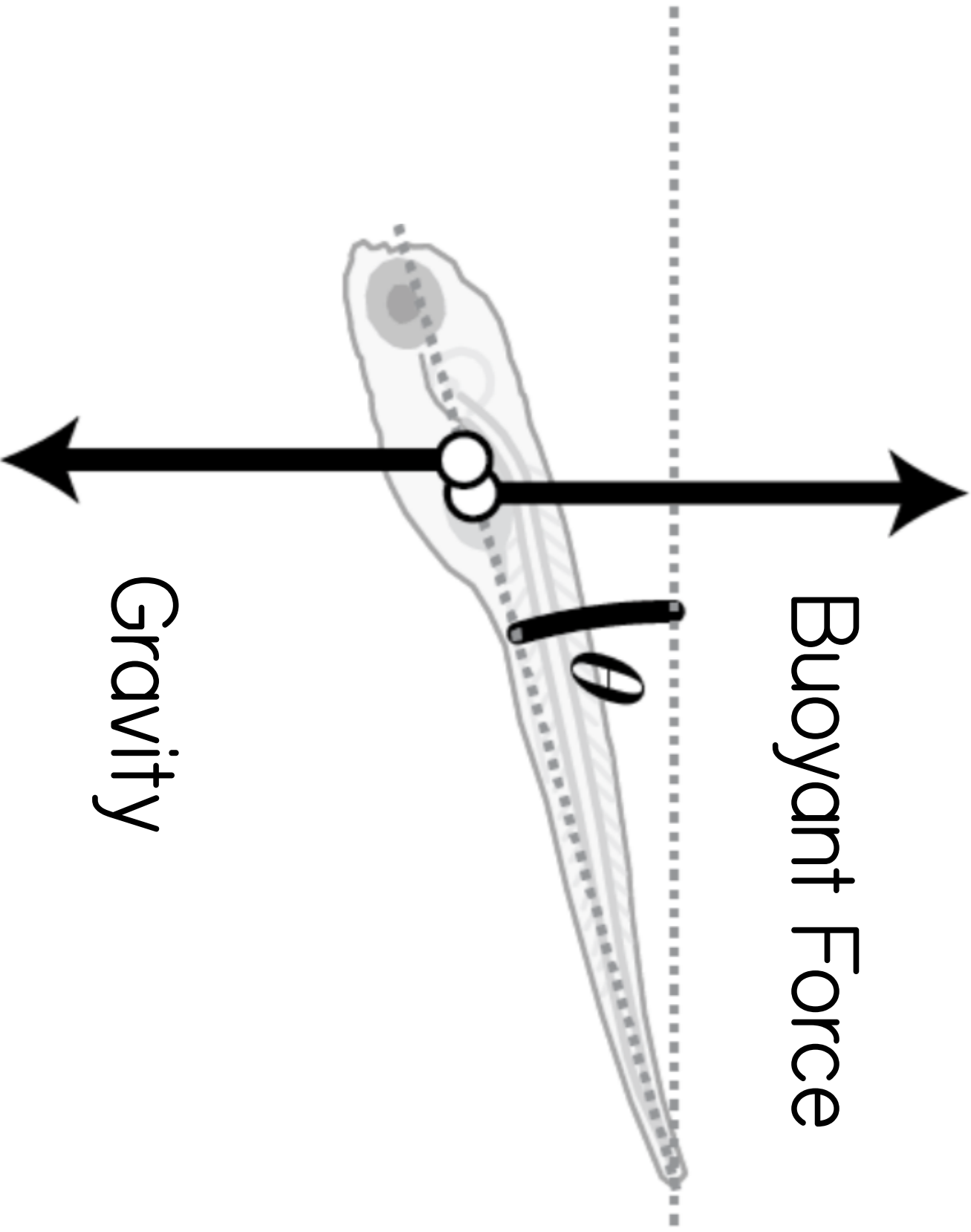
Ehrlich & Schoppik 2017b



Bout timing

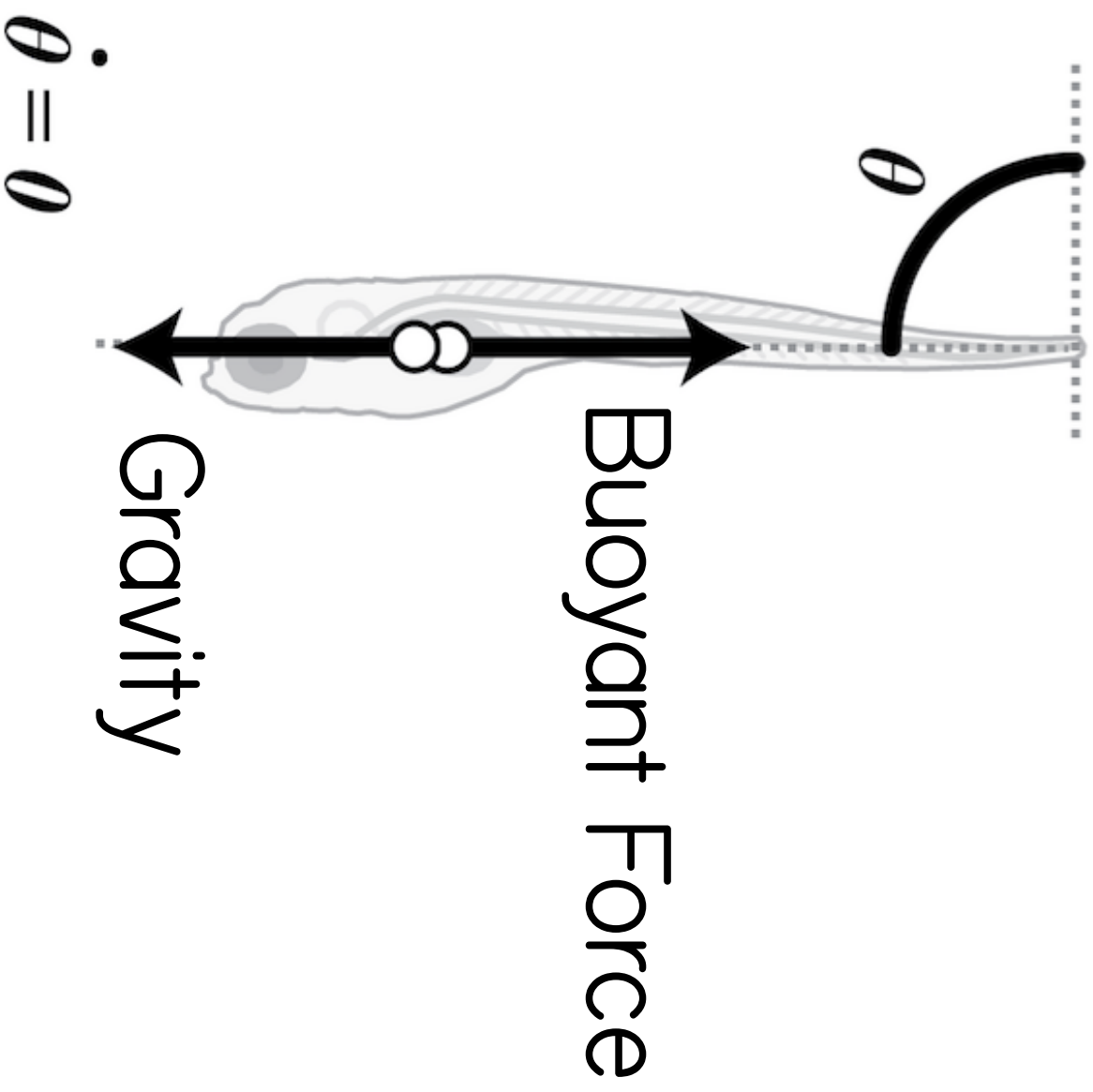
or

Why do zebrafish move when they
do?



Buoyant Force

Gravity

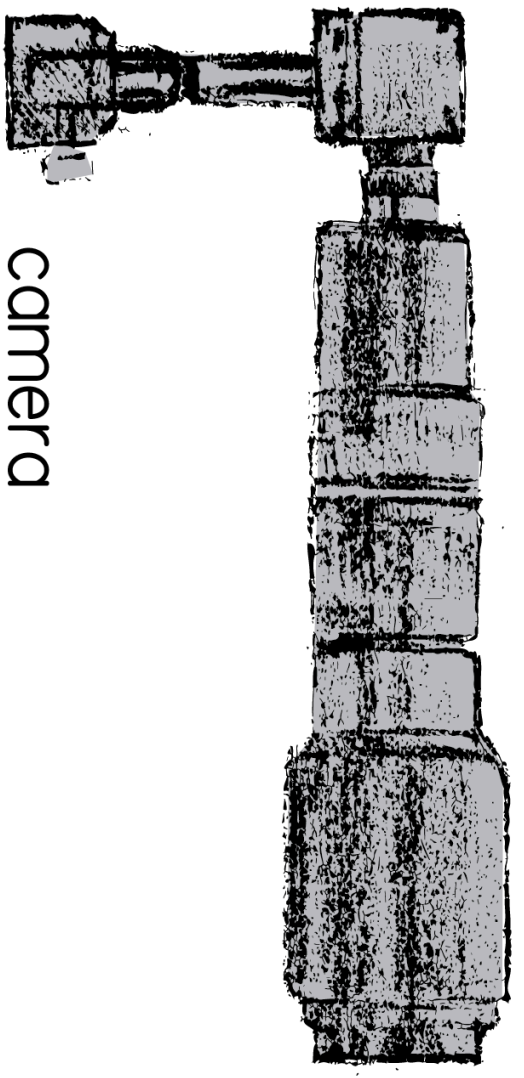




Active
equilibrium



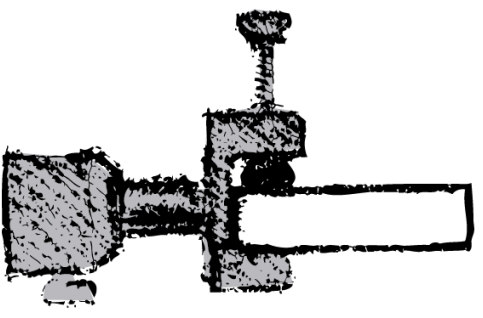
camera
& lens



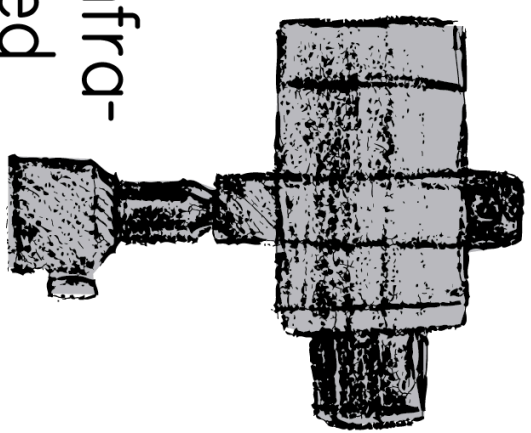
white illumination

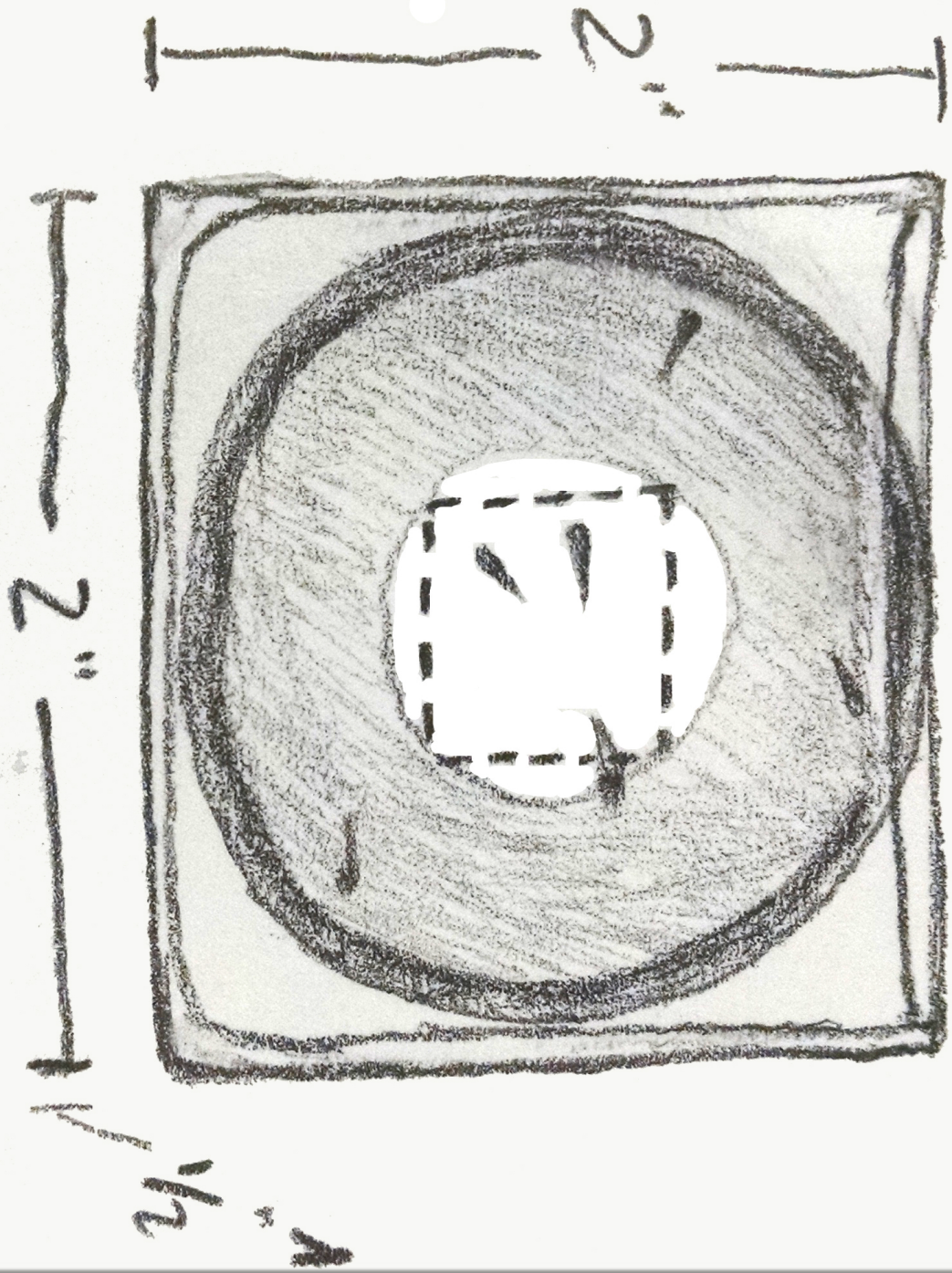


tank



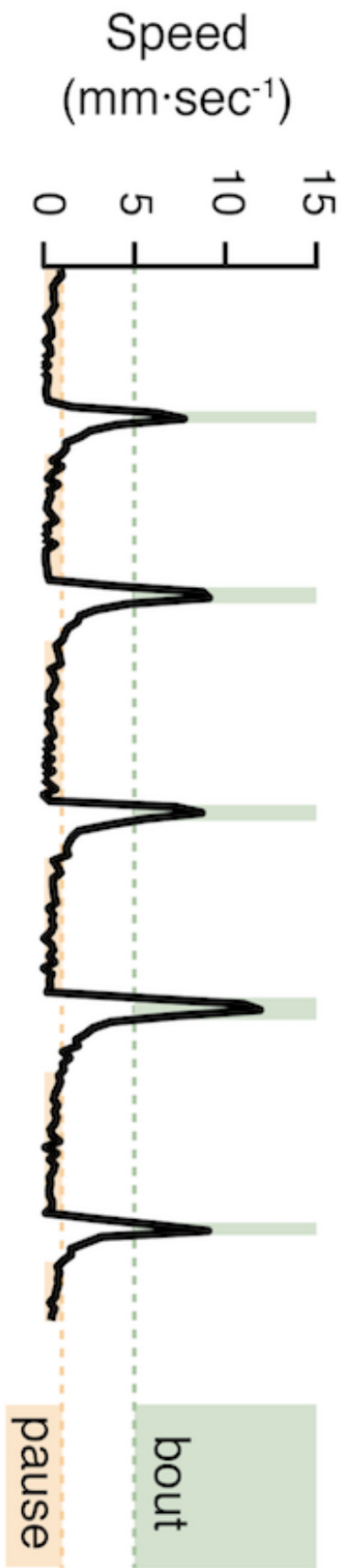
infra-
red
illumination





NEA





A

 swimbladder

1 mm



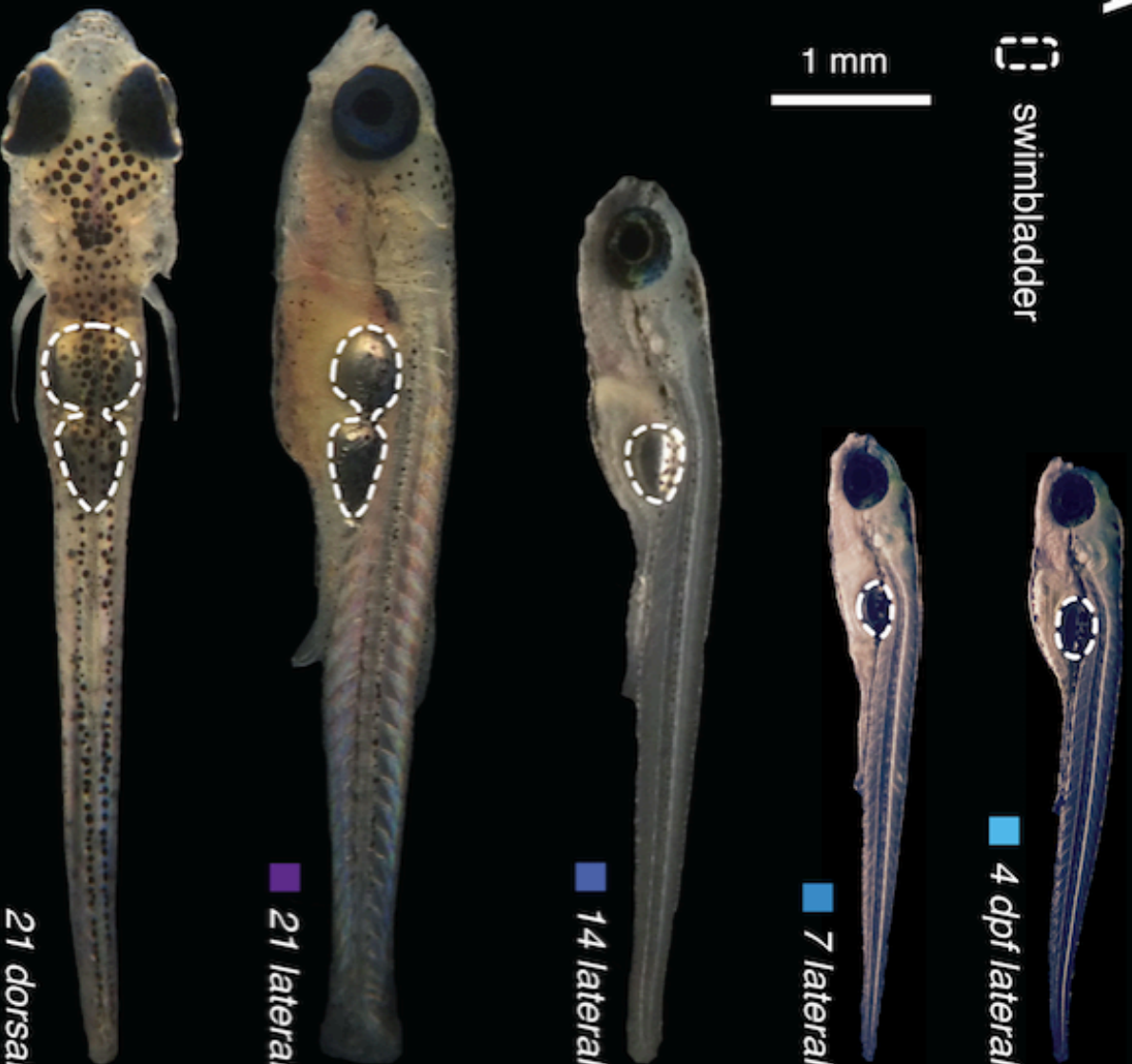
 4 dpf lateral

 7 lateral

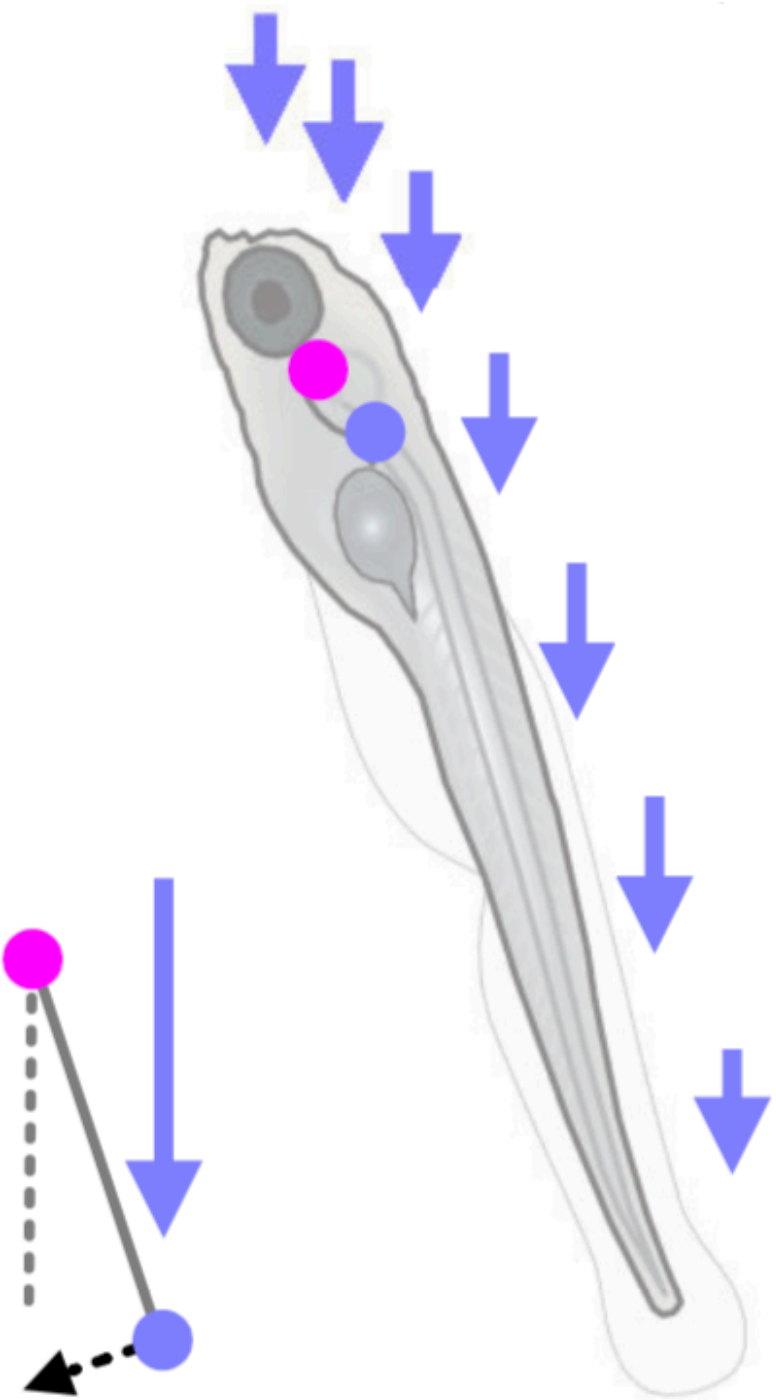
 14 lateral

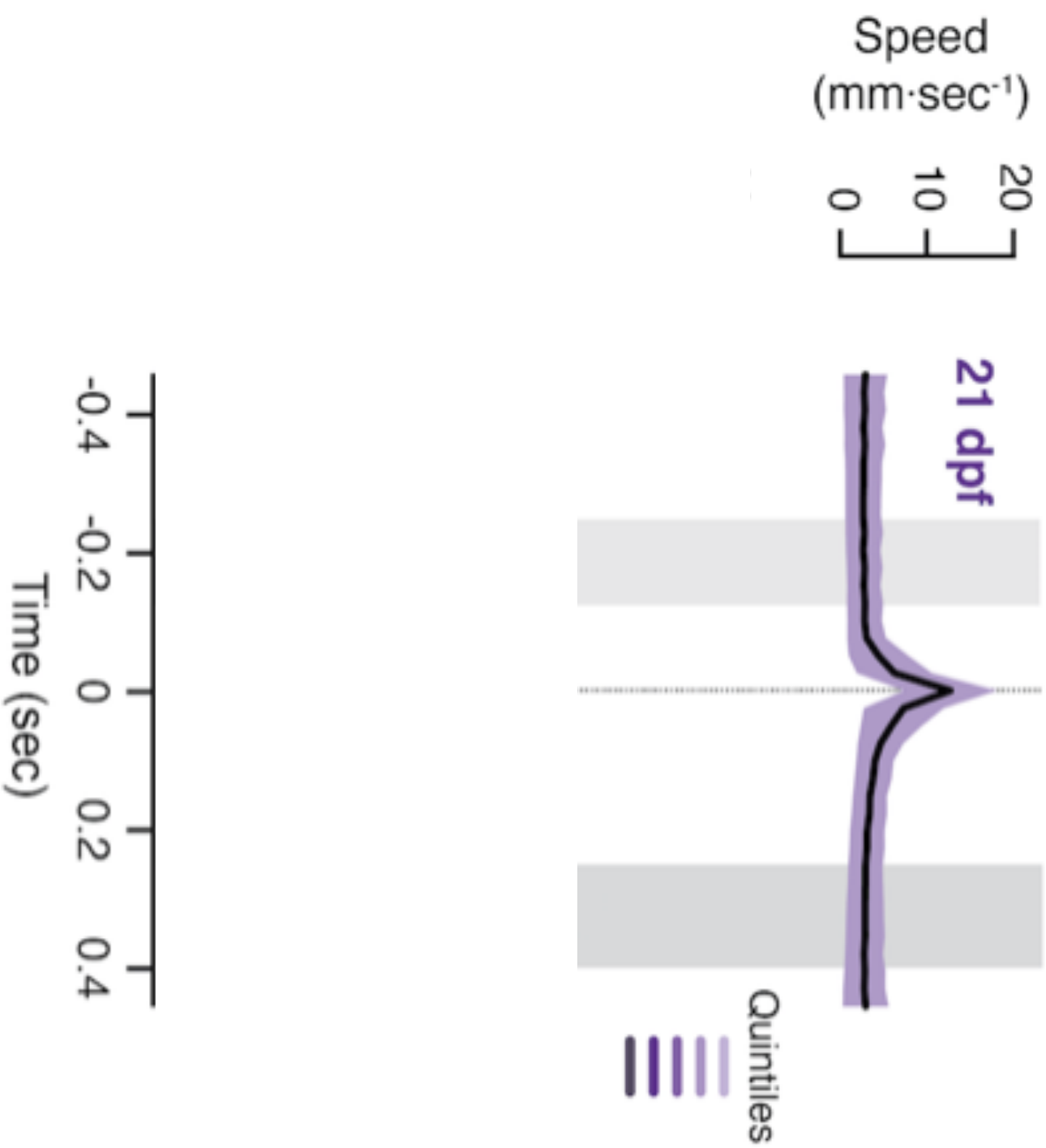
 21 lateral

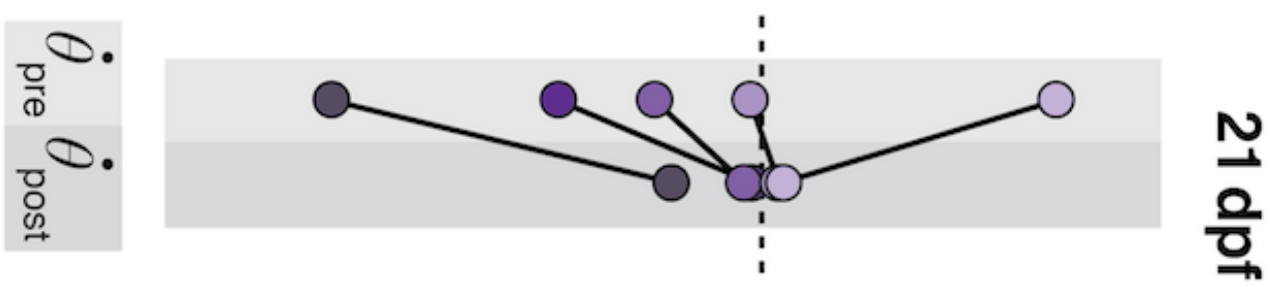
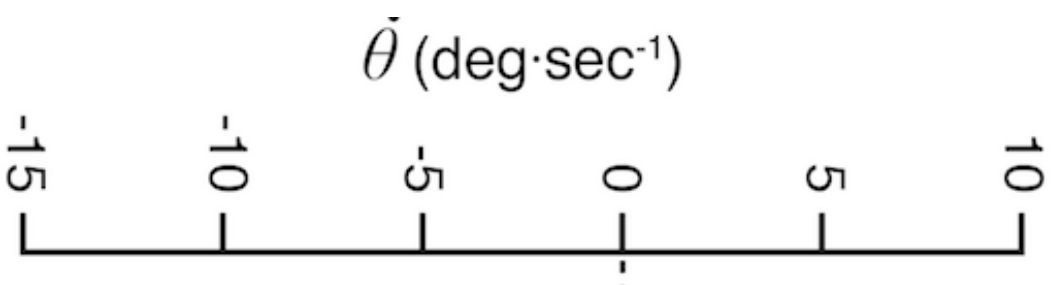
 21 dorsal

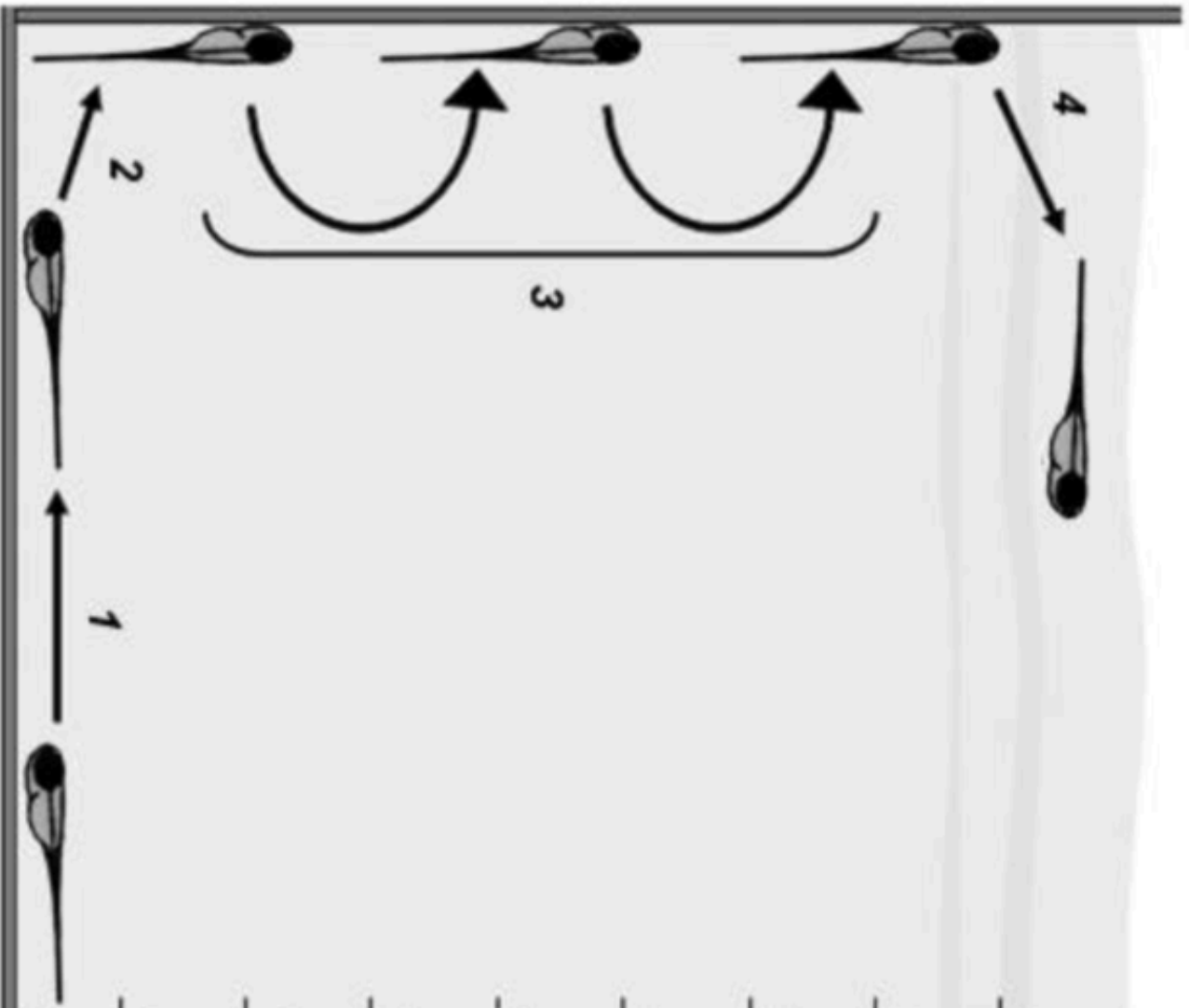








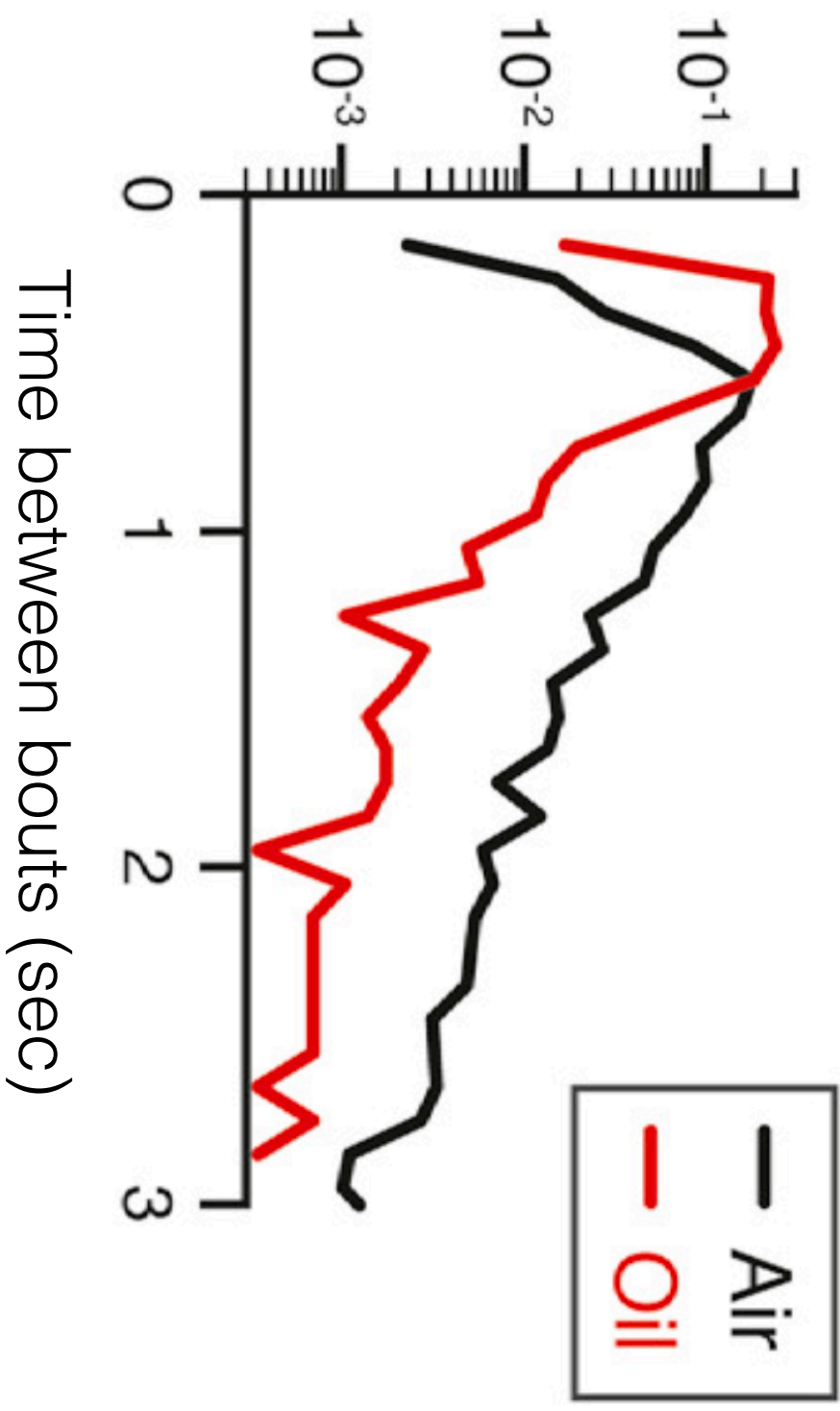








Probability

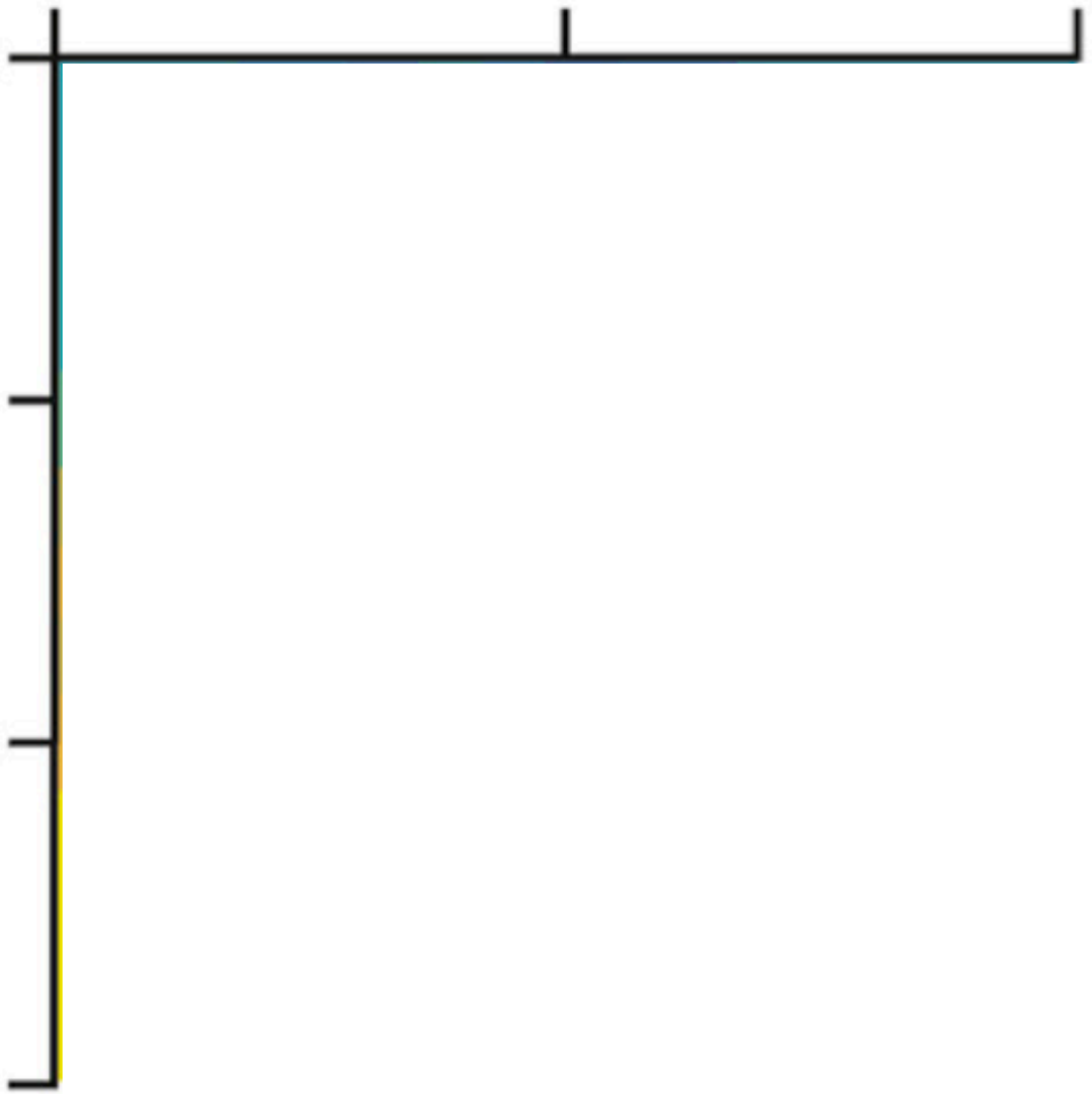


$$P_{\text{bout}} | \Theta, \dot{\Theta}$$

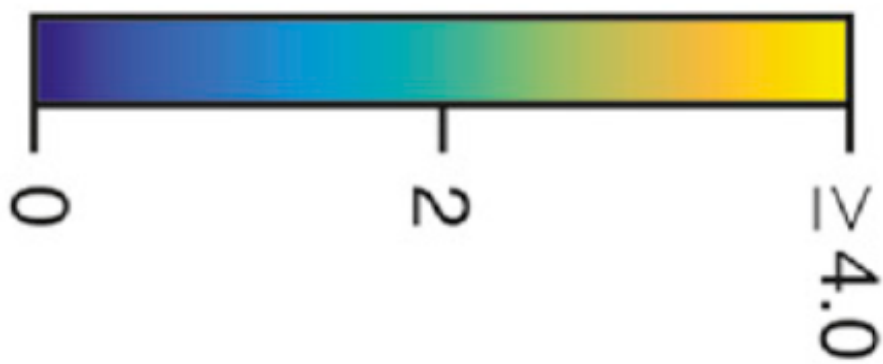
$P_{\Theta, \dot{\Theta}} | \text{bout}$

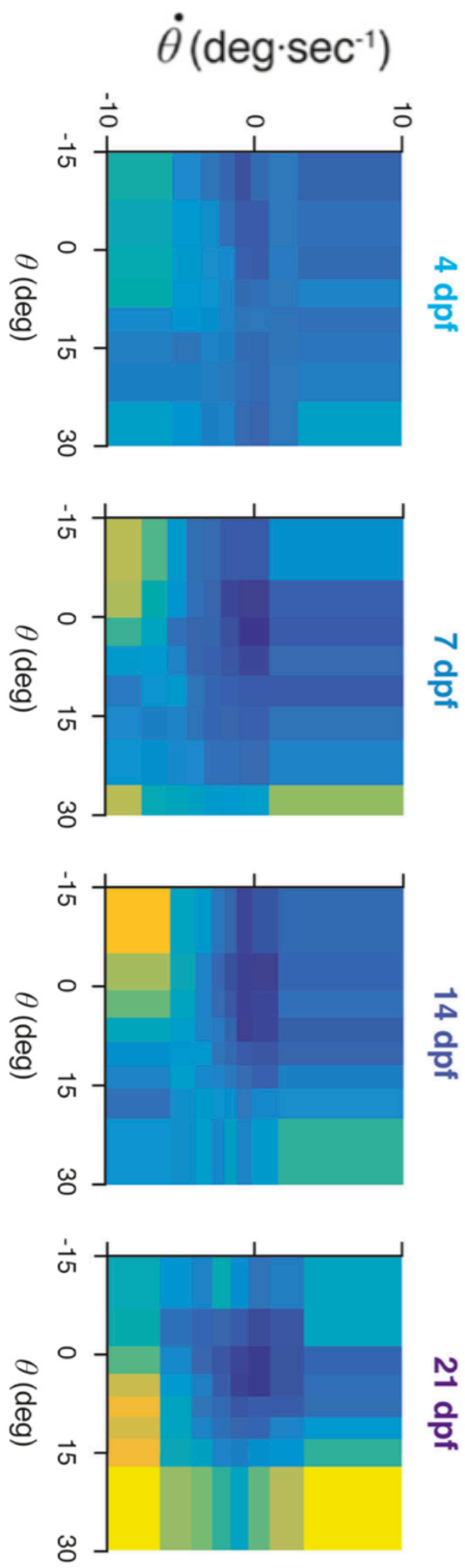
$\dot{\theta}$ (deg·sec⁻¹)

θ (deg)



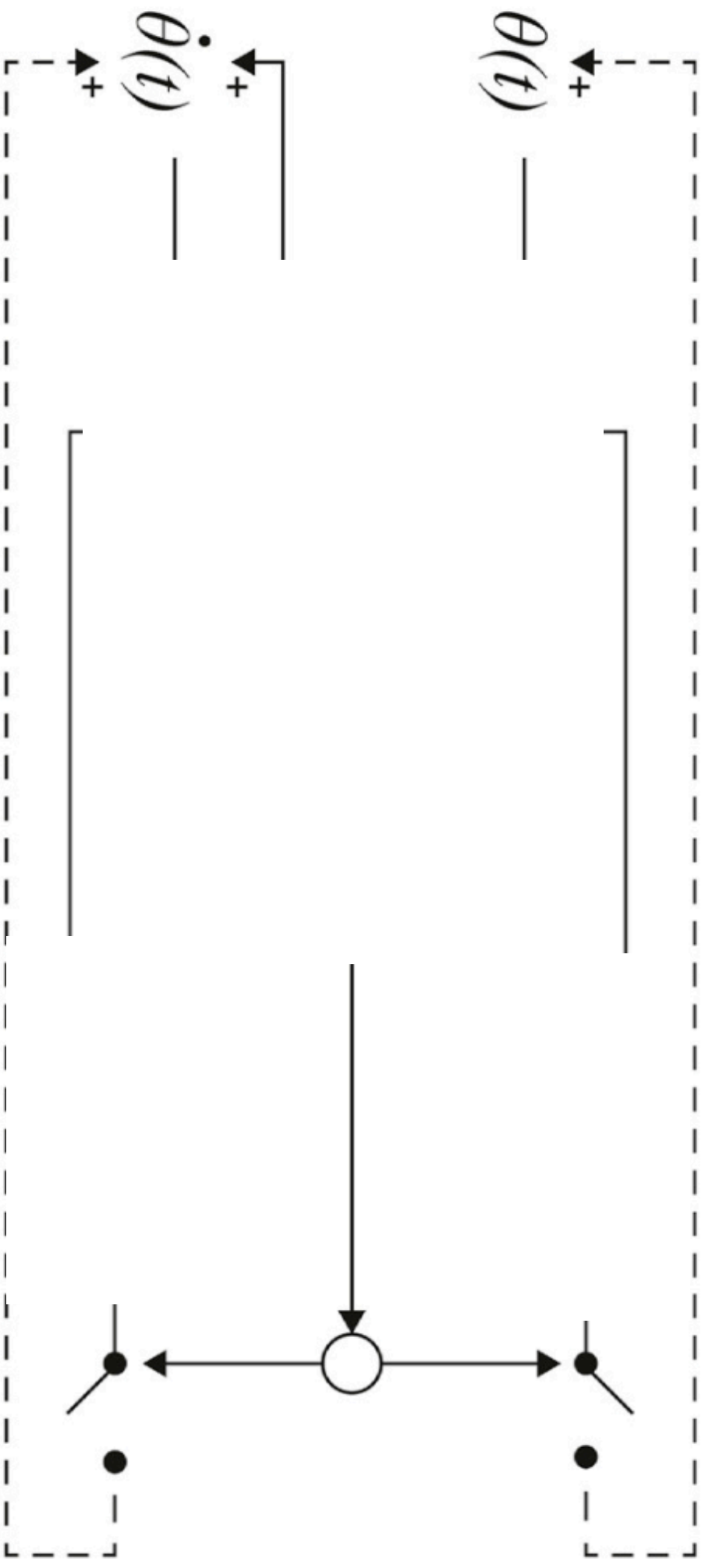
Relative bout likelihood

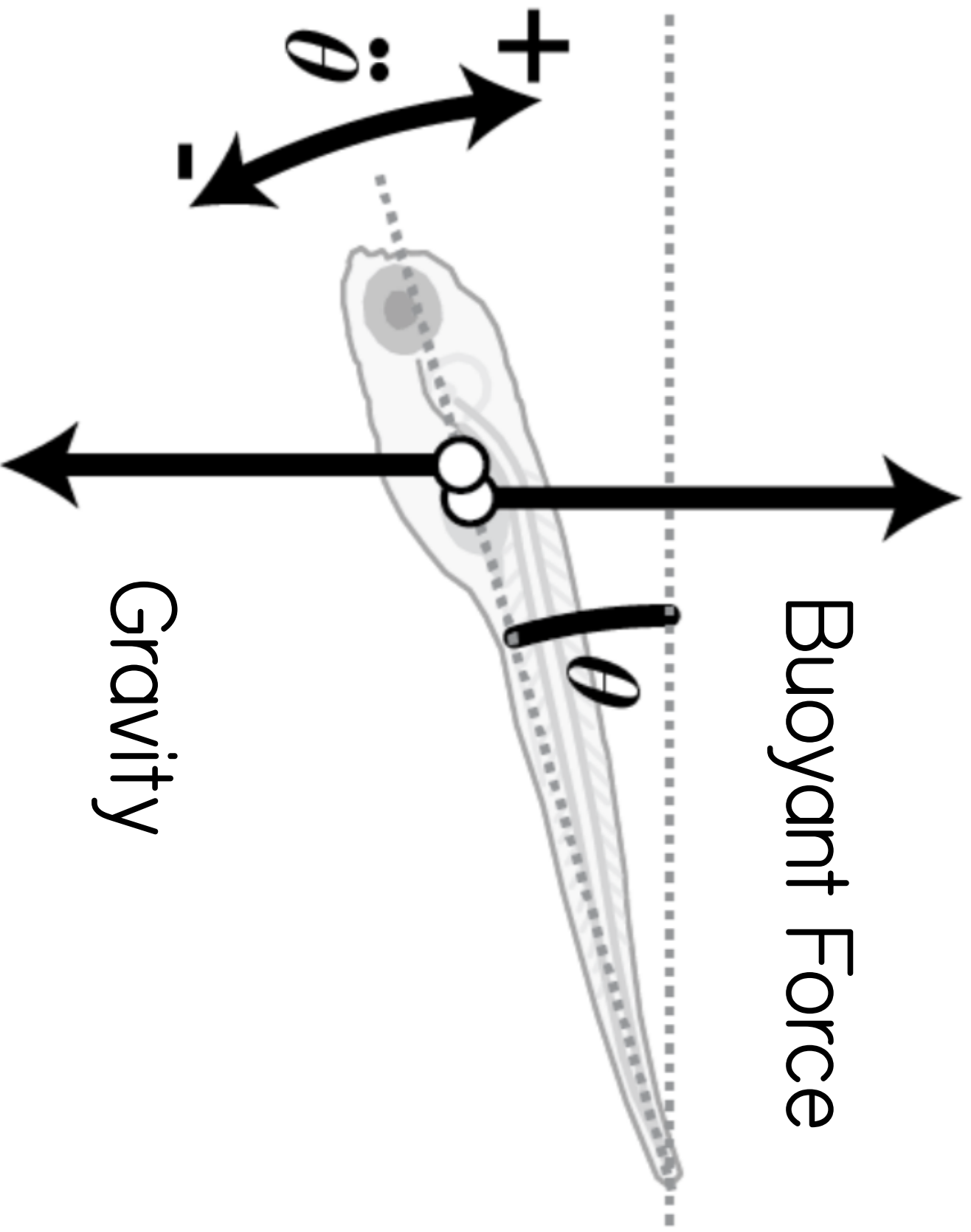




locomotion-
independent

locomotion-
dependent



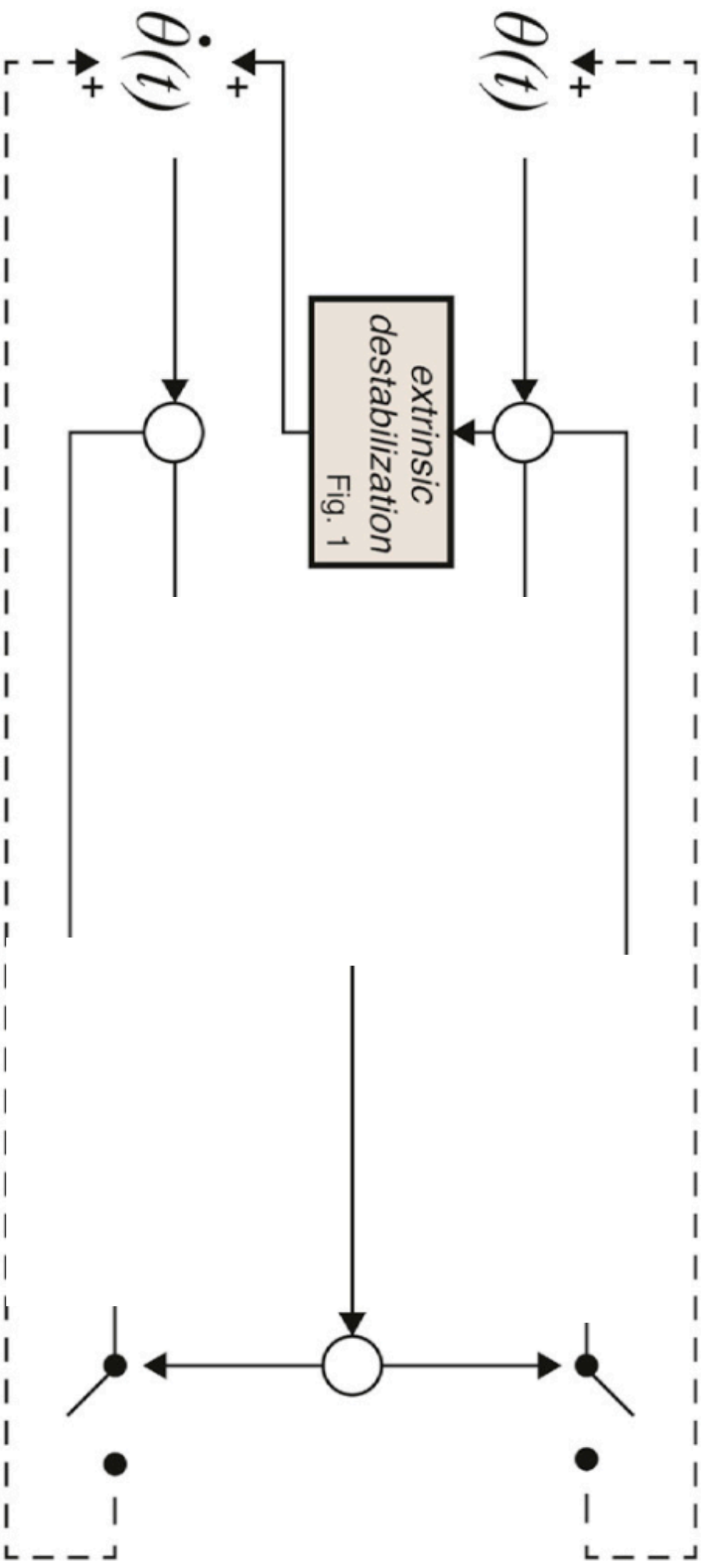


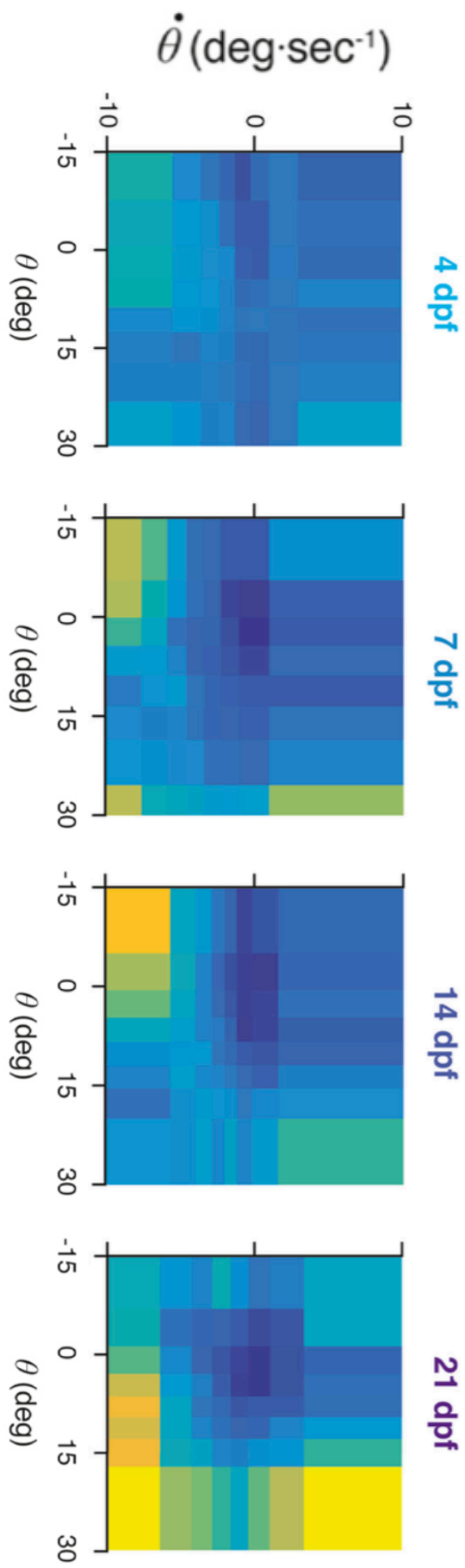
Buoyant Force

Gravity

locomotion-
independent

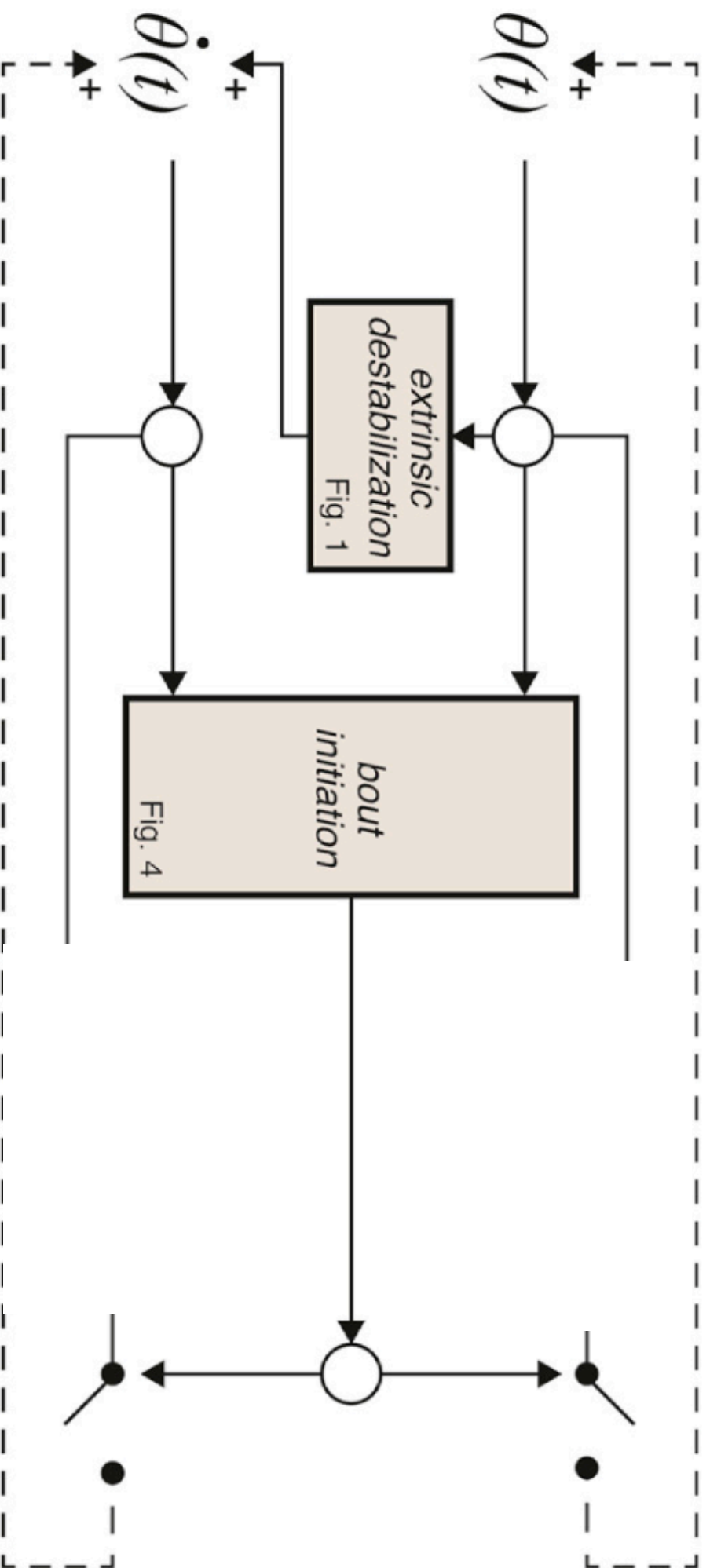
locomotion-
dependent



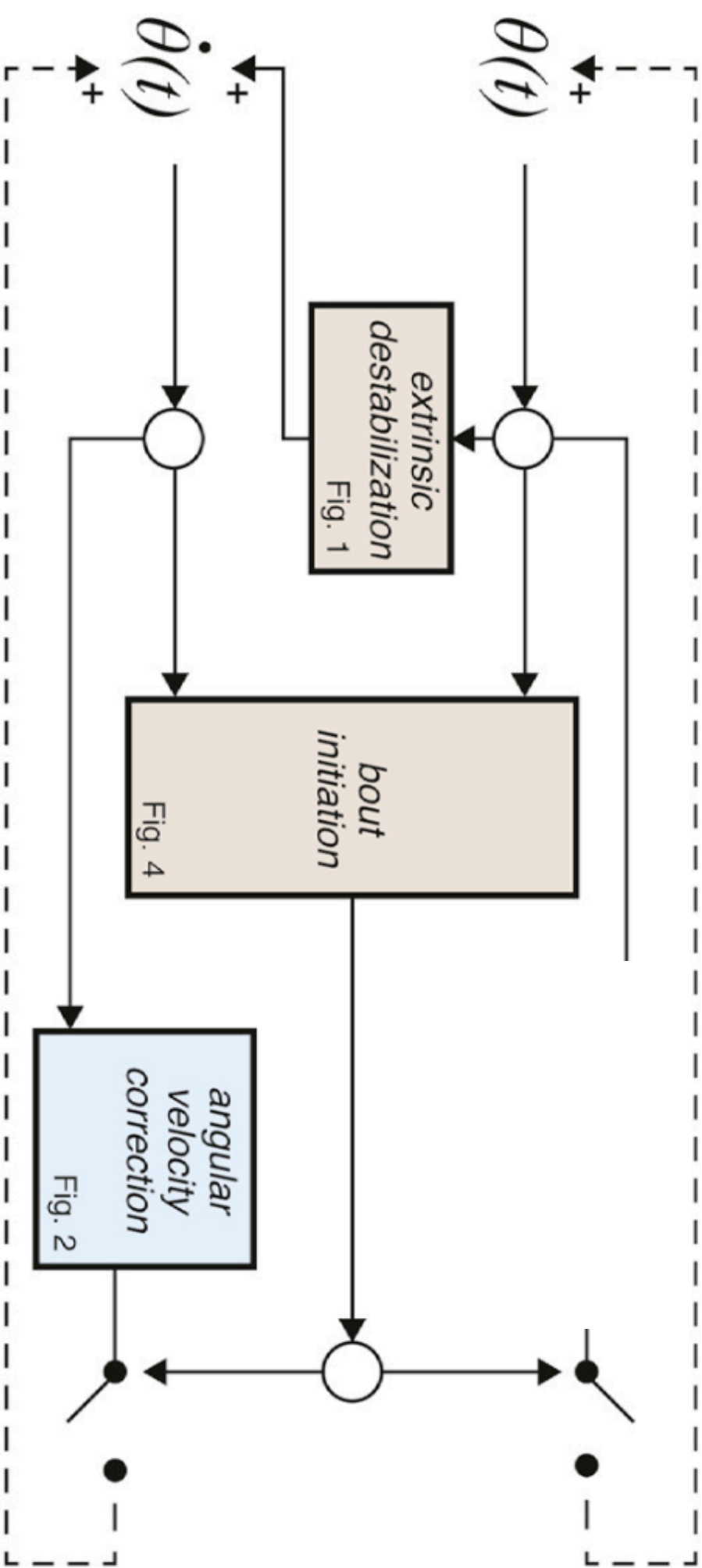


locomotion-
independent

locomotion-
dependent

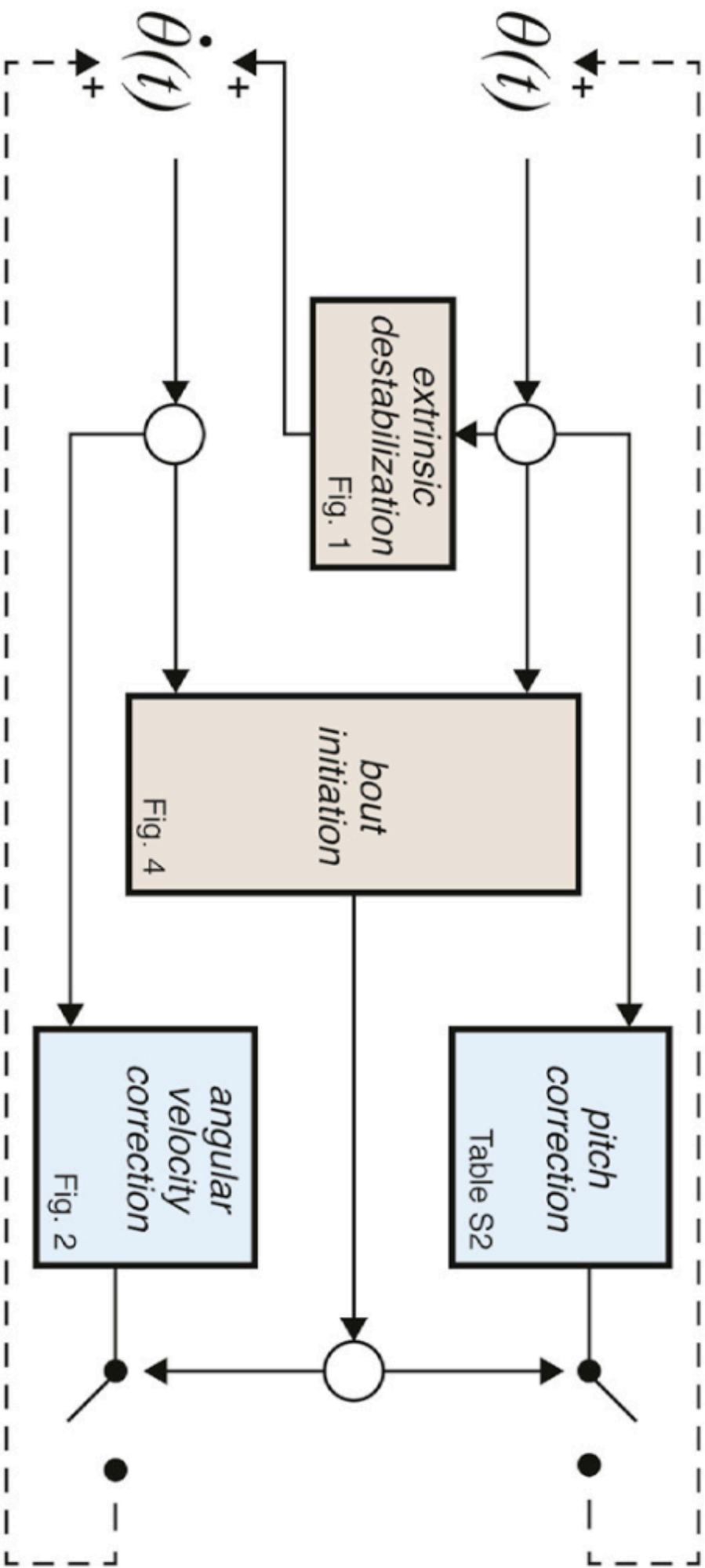






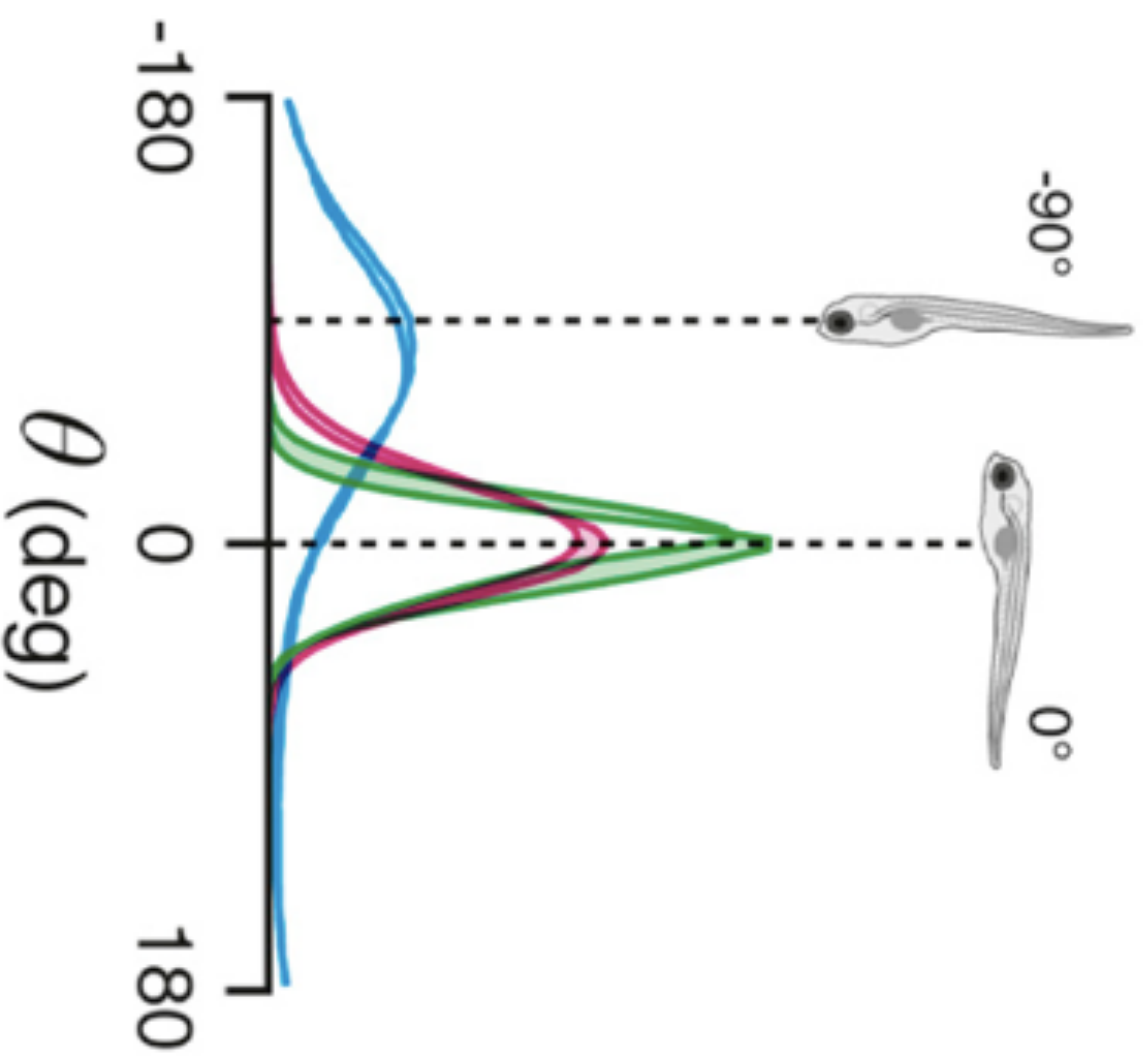
locomotion-independent

locomotion-dependent

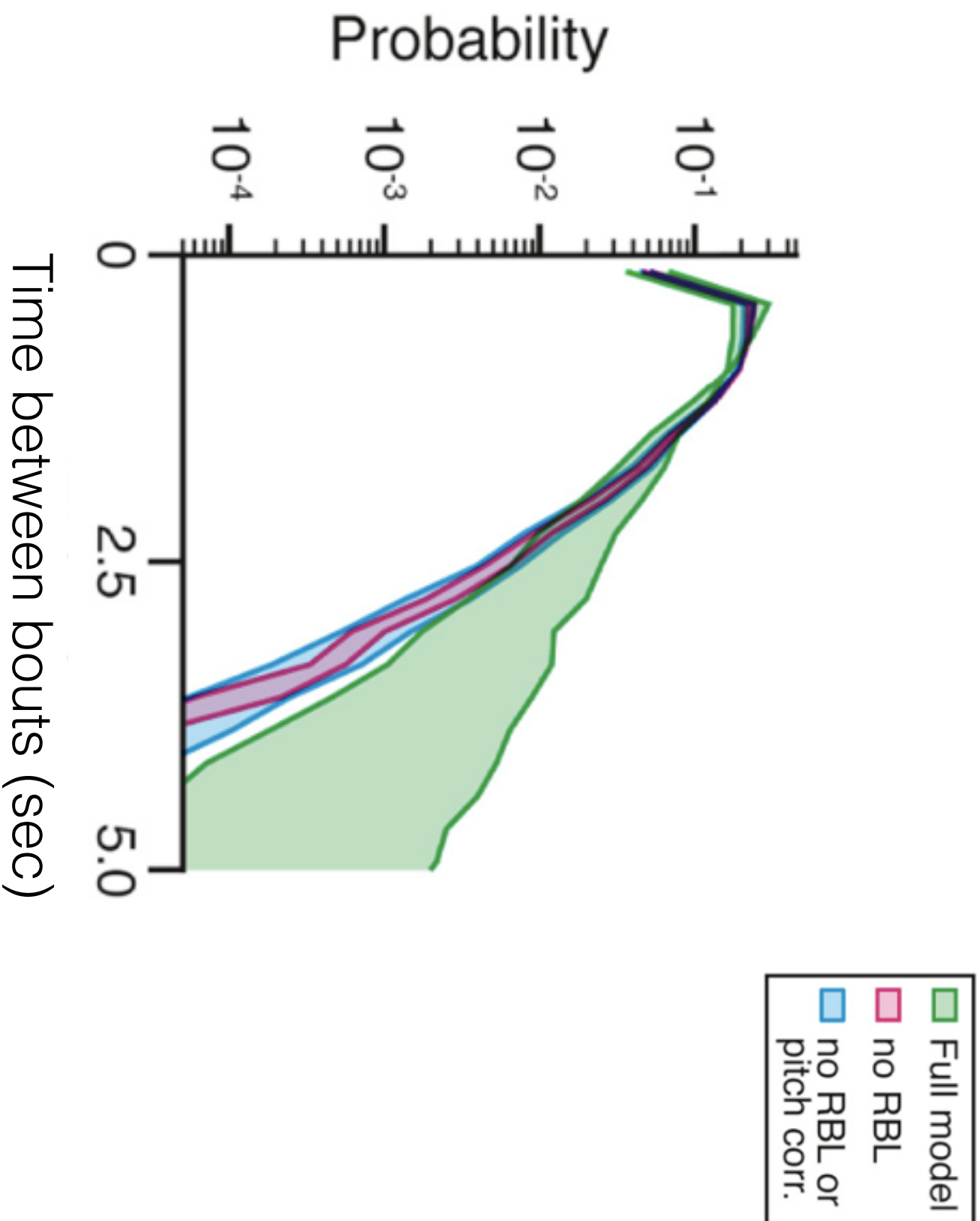


locomotion-independent

locomotion-dependent



- Full model
- no RBL
- no RBL or pitch corr.



1. Bouts correct destabilization.
2. *As they develop, larvae come to bout preferentially when unstable.*

Why zebrafish move when they
do.

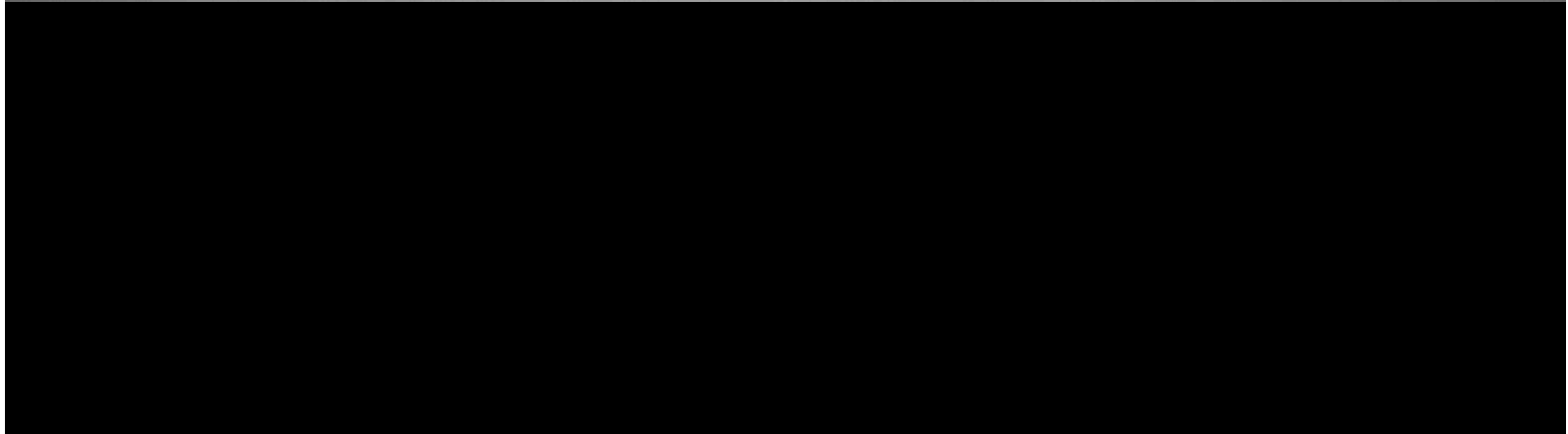
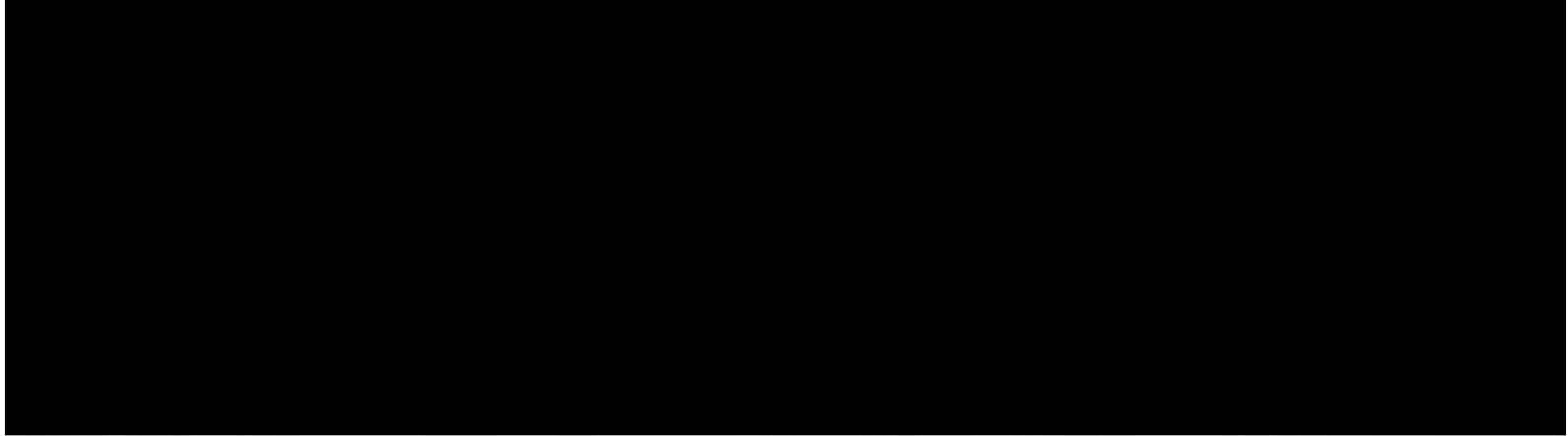
How zebrafish explore depth.

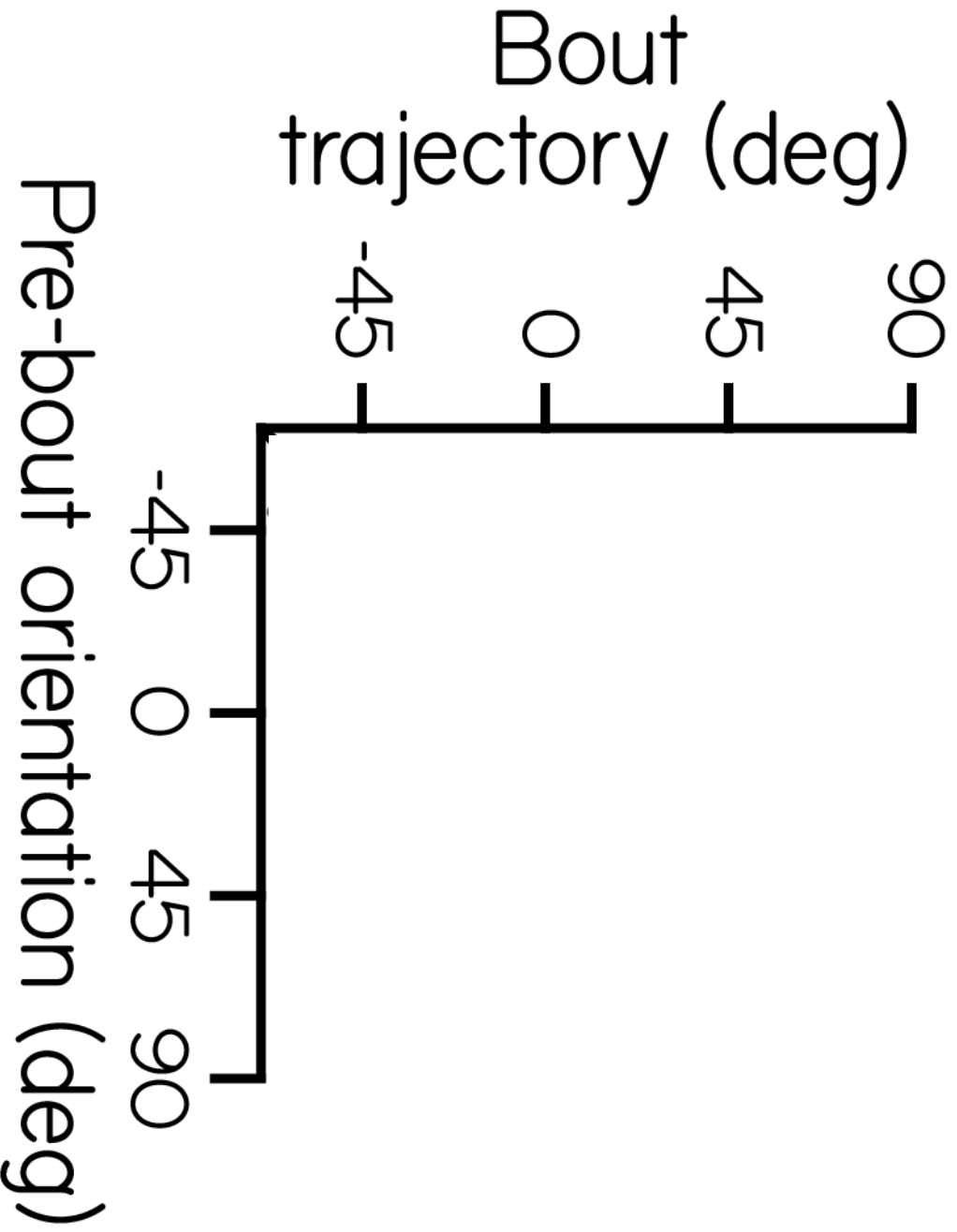
How zebrafish come to climb.

Why zebrafish move when they
do.

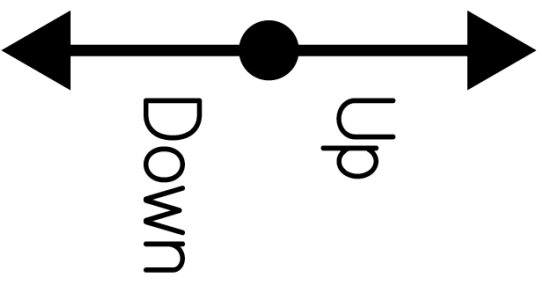
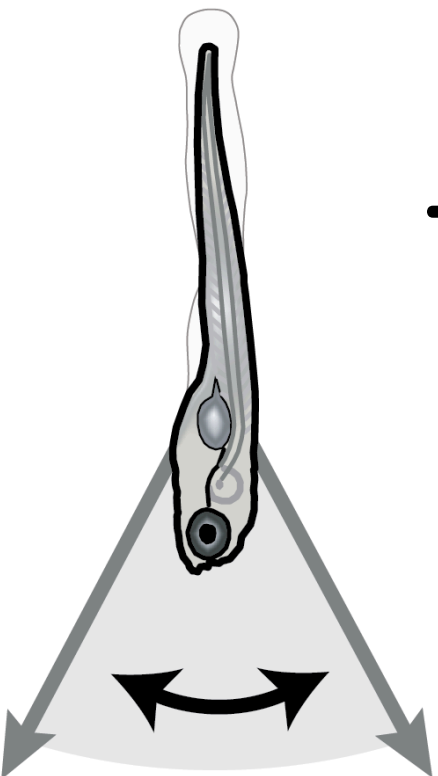
How zebrafish explore depth.

How zebrafish come to climb.



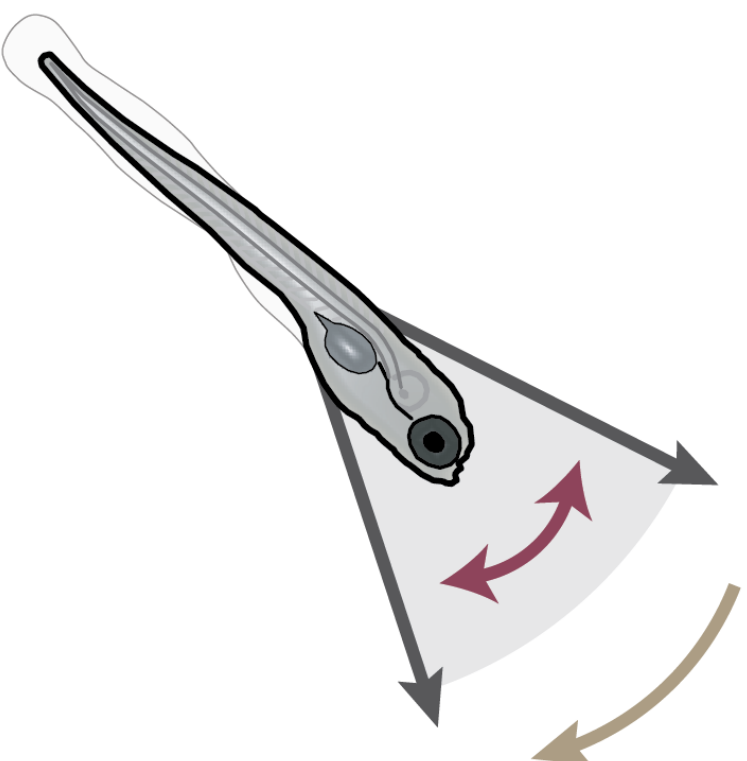


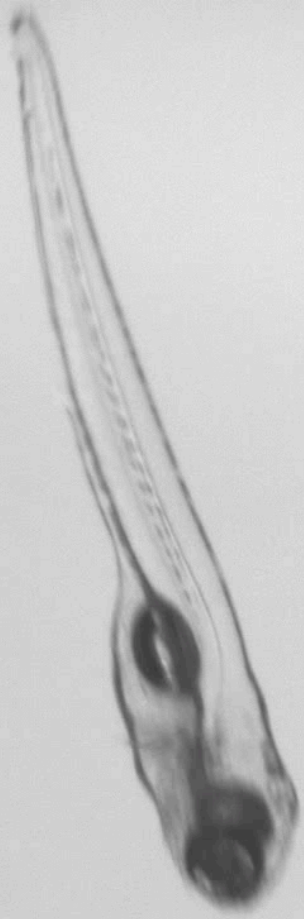
Explore

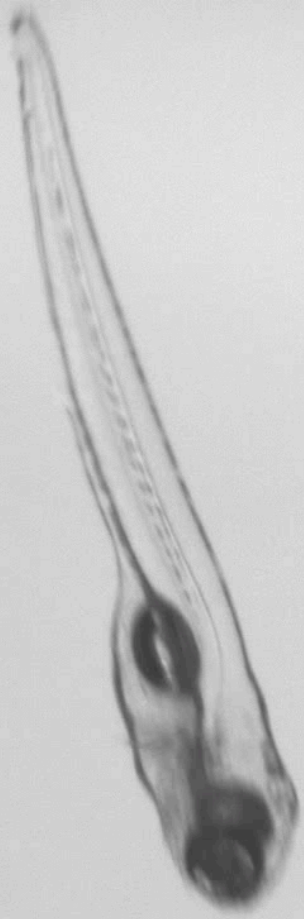


1. Explore

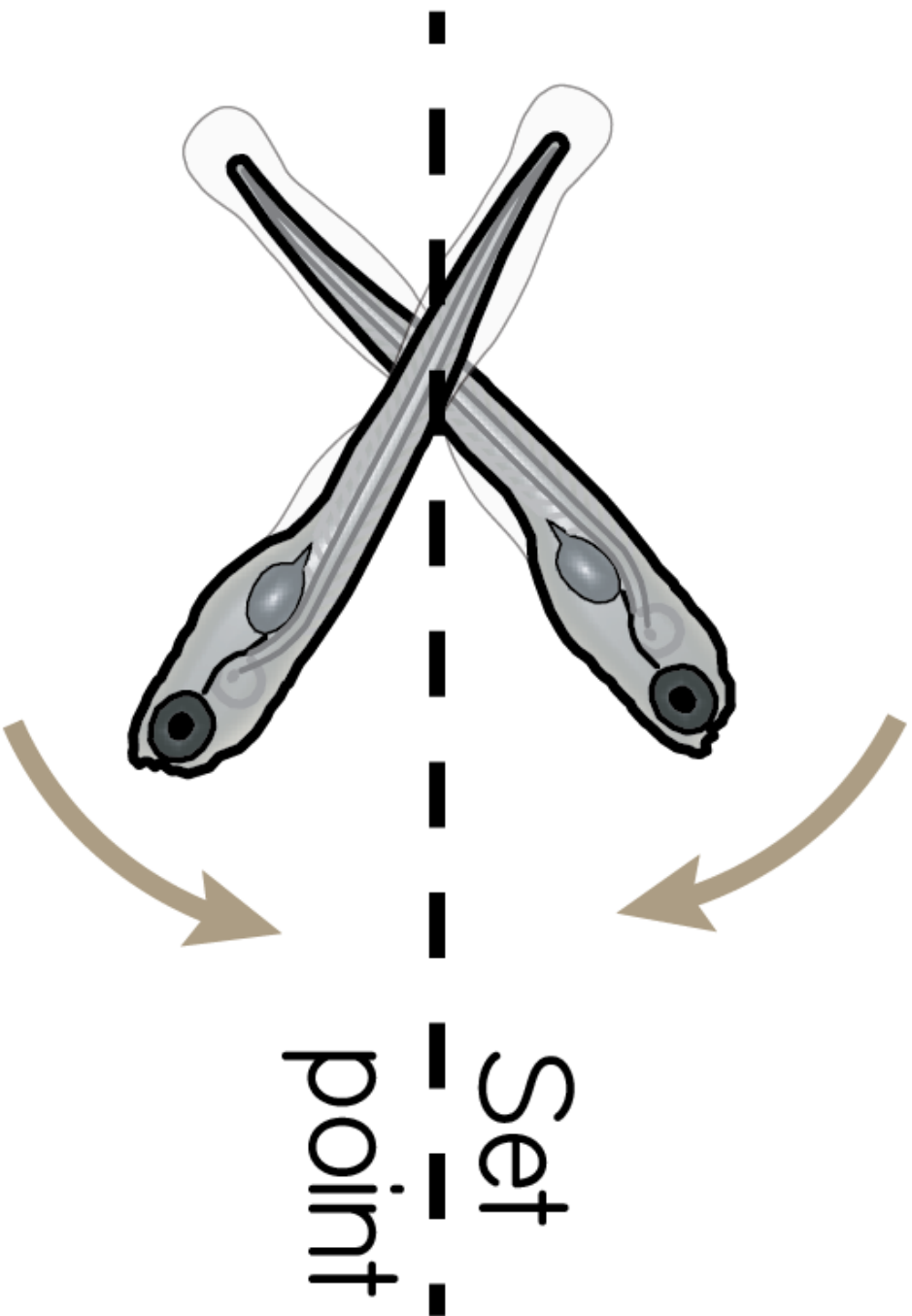
2. Balance

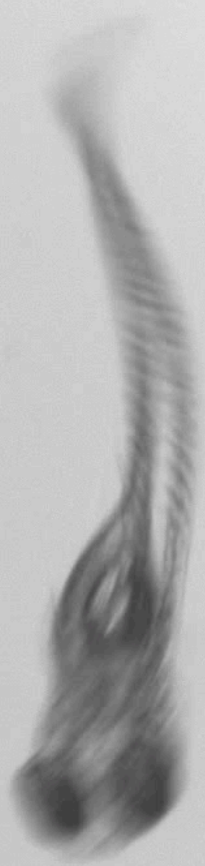


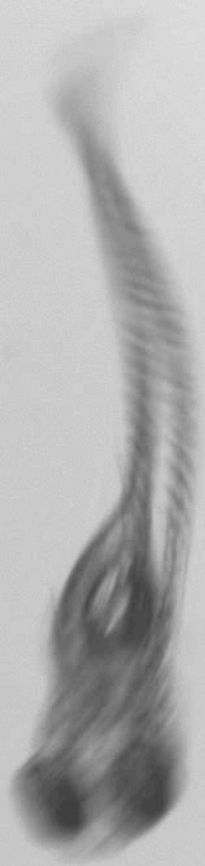




Righting

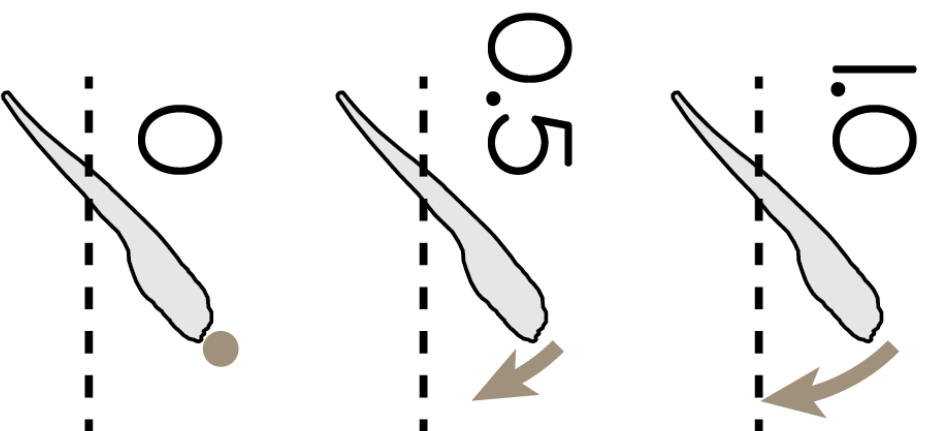




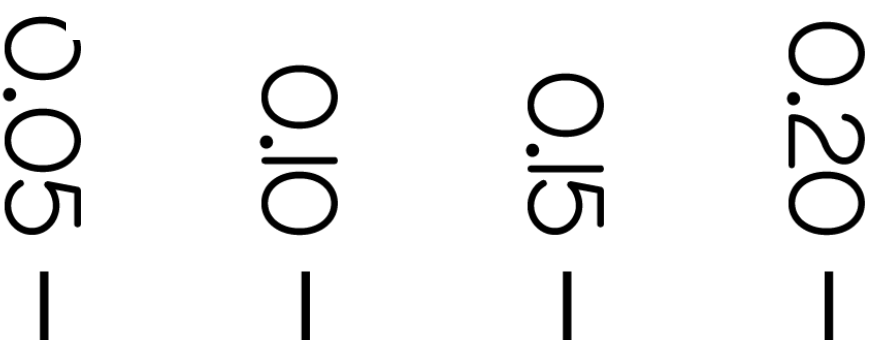


Righting

gain

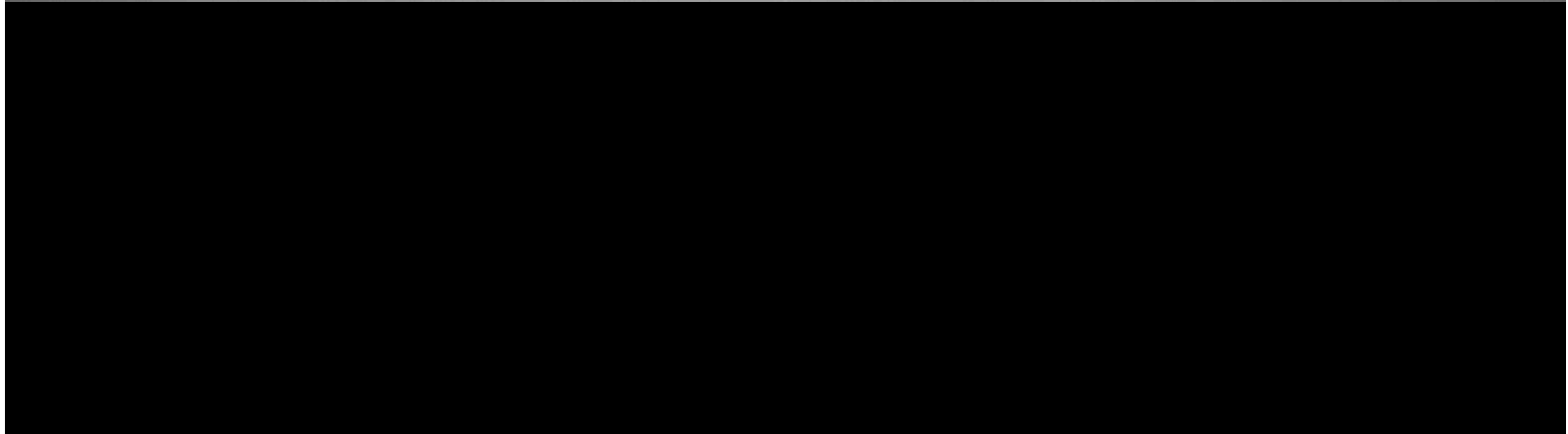
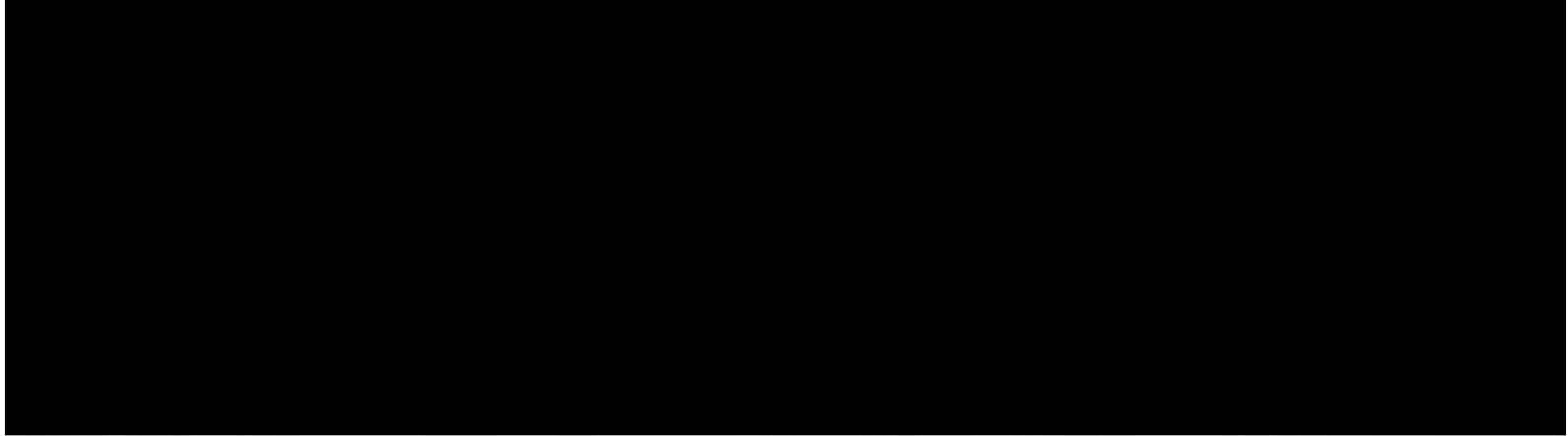


Righting gain



1 2 3

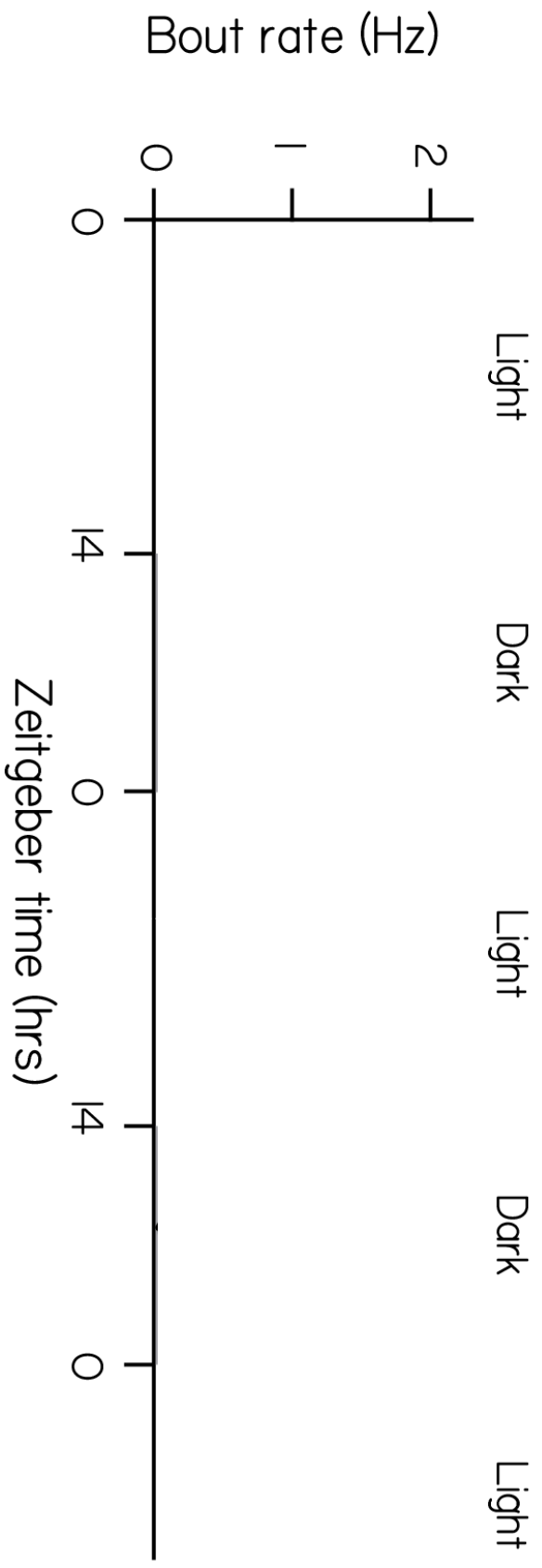
Age (wpcf)



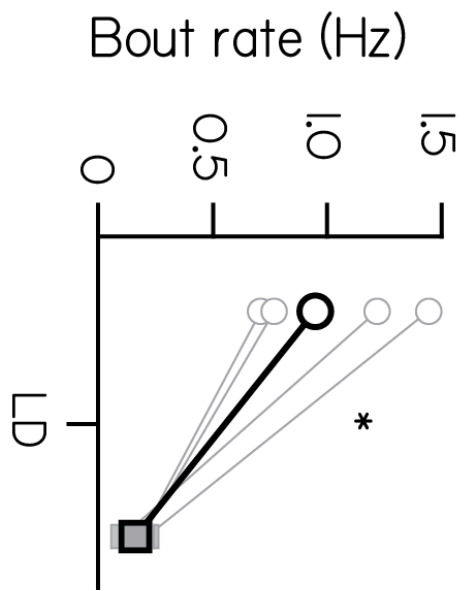
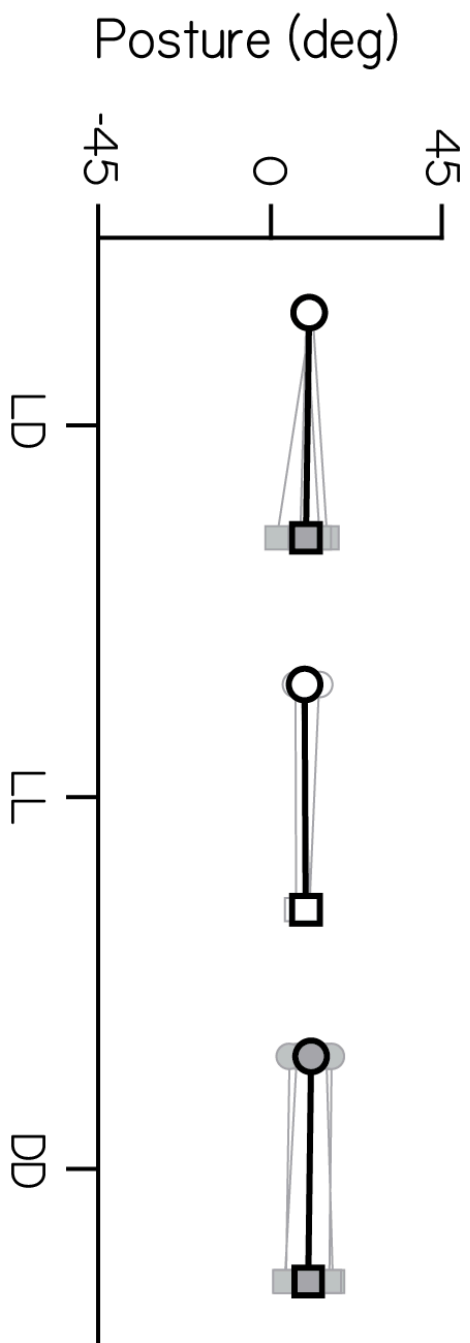
Recap:

1. Fish make bouts when unstable
2. Each bout partially returns the fish to its preferred posture

What happens at night?

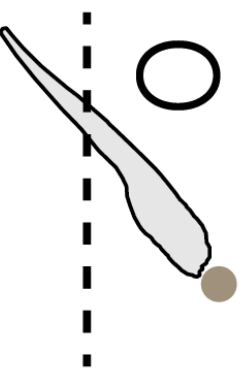
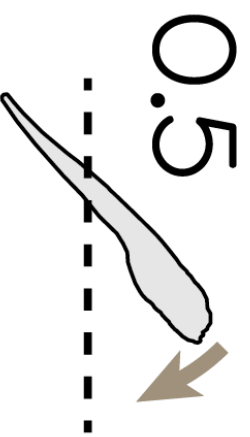
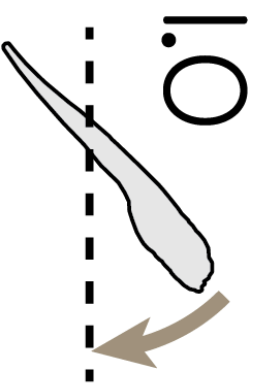


○ Day
□ Night

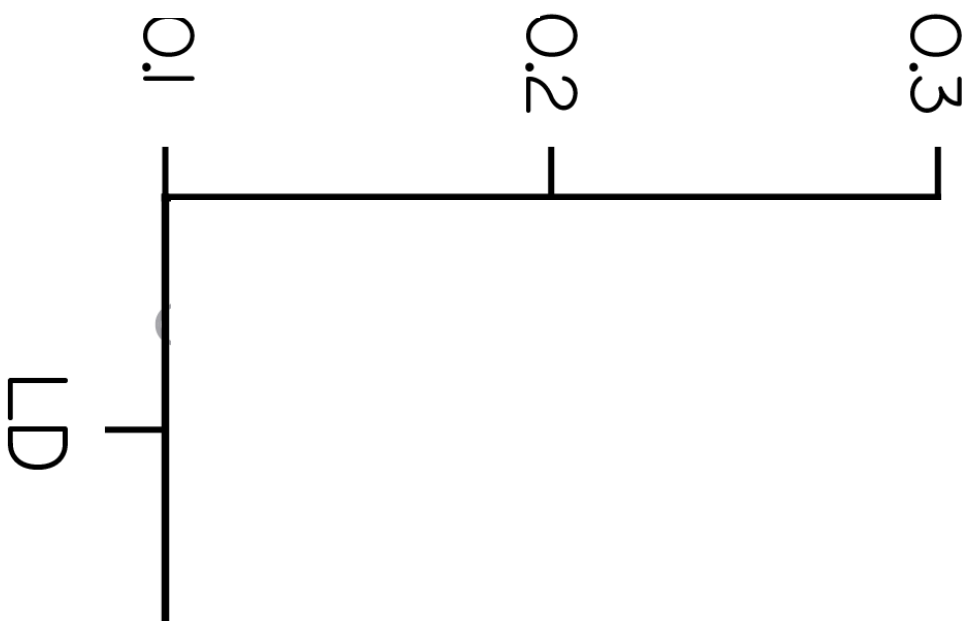


How can fish maintain posture given that
they make fewer bouts at night?

Righting gain



Righting gain



- Day
- Night

Summary:

1. Fish make bouts when unstable
2. Each bout partially returns the fish to its preferred posture
3. Sensitivity to posture isn't different at night
4. Amazingly, fish are better able to return to their preferred posture at night.

Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

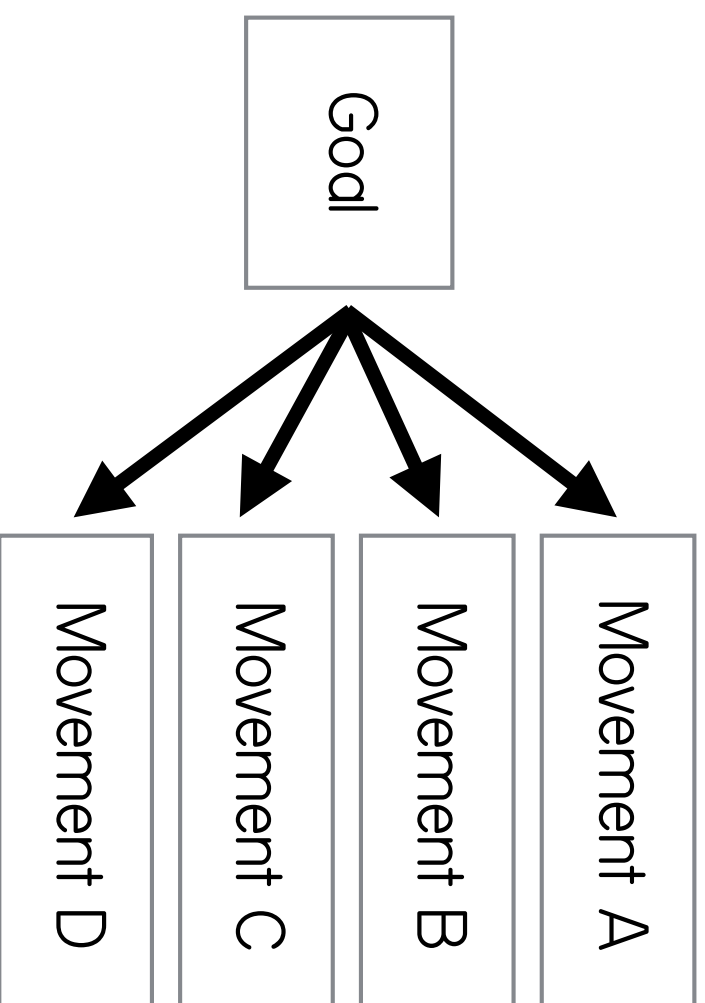
Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

Motor equivalence problem

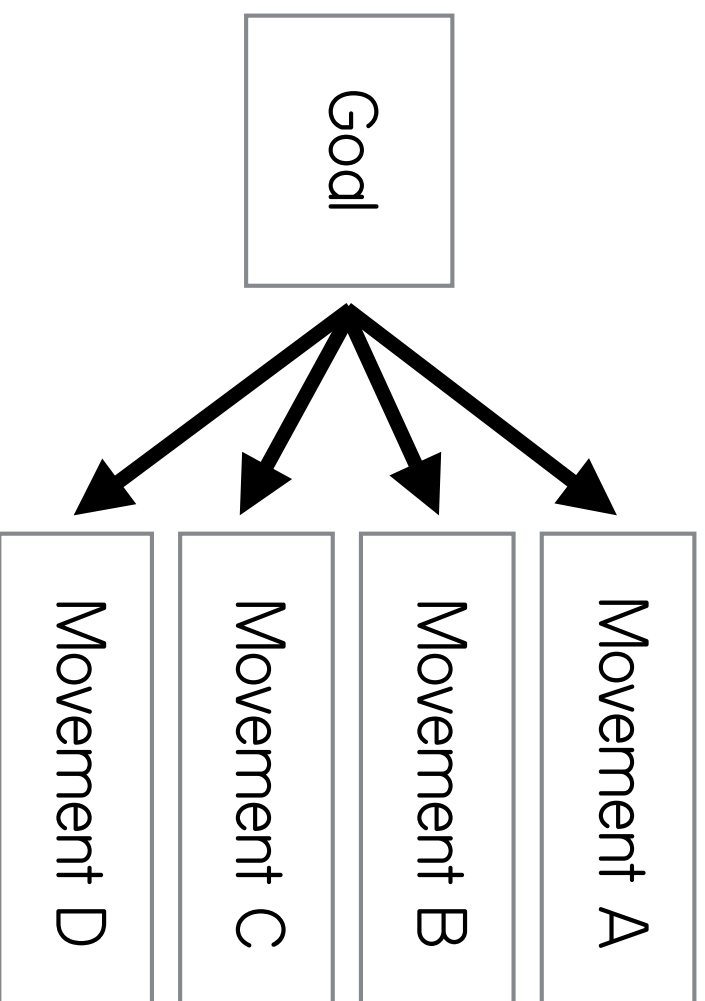
An animal can achieve a goal with redundant movements



Bernstein, 1967

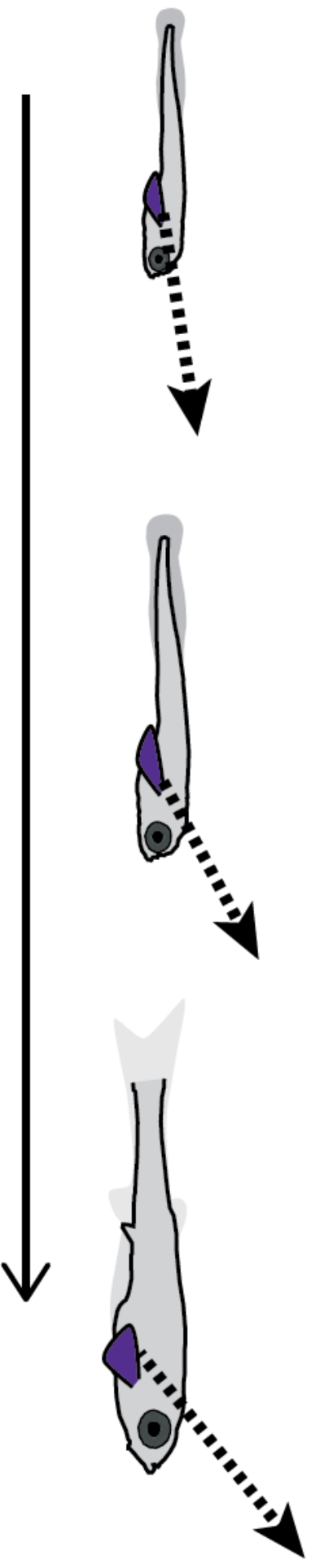
Todorov & Jordan, 2005

Hypothesis: locomotion develops
because preferences are learned





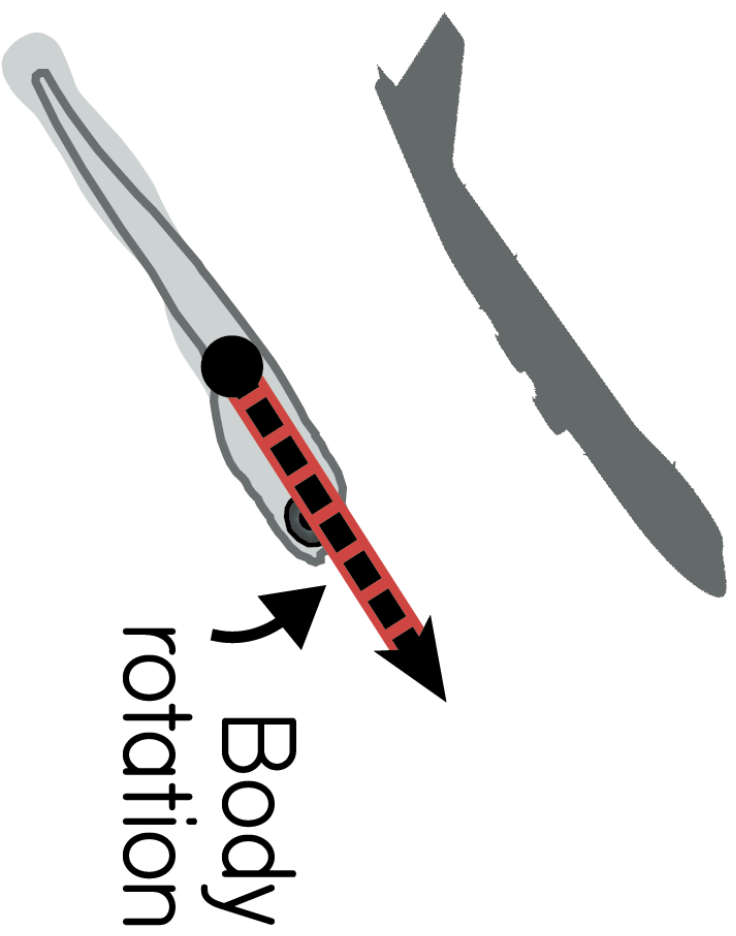
Thelen, 2005






Fish can climb using their bodies or fins

Swimming matures via acquired preference for fins

Thrust-based



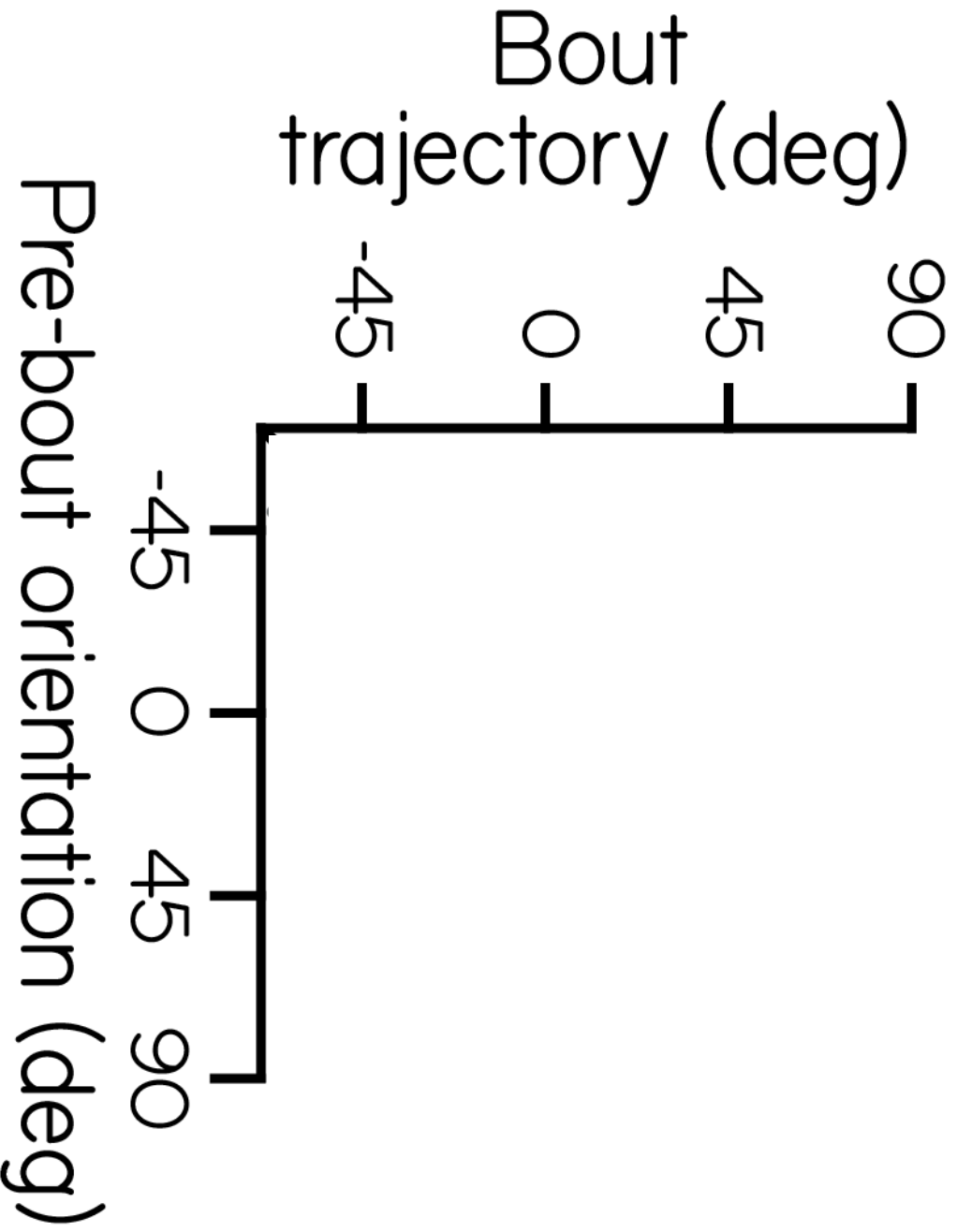
| Key | |
|--|------------------|
|  | Posture & Thrust |
|  | Lift |
|  | Trajectory |



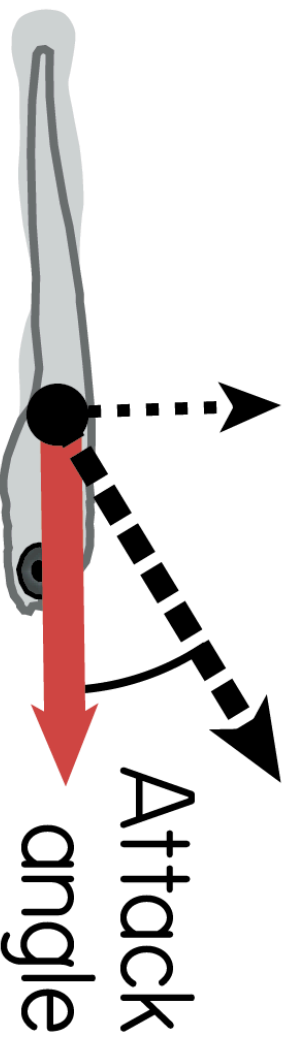
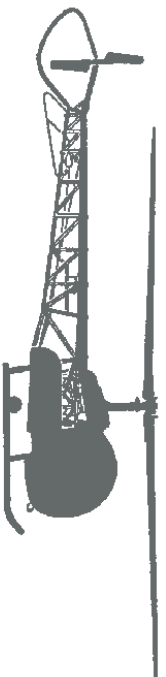
Up
Dn




1 mm




Lift-based

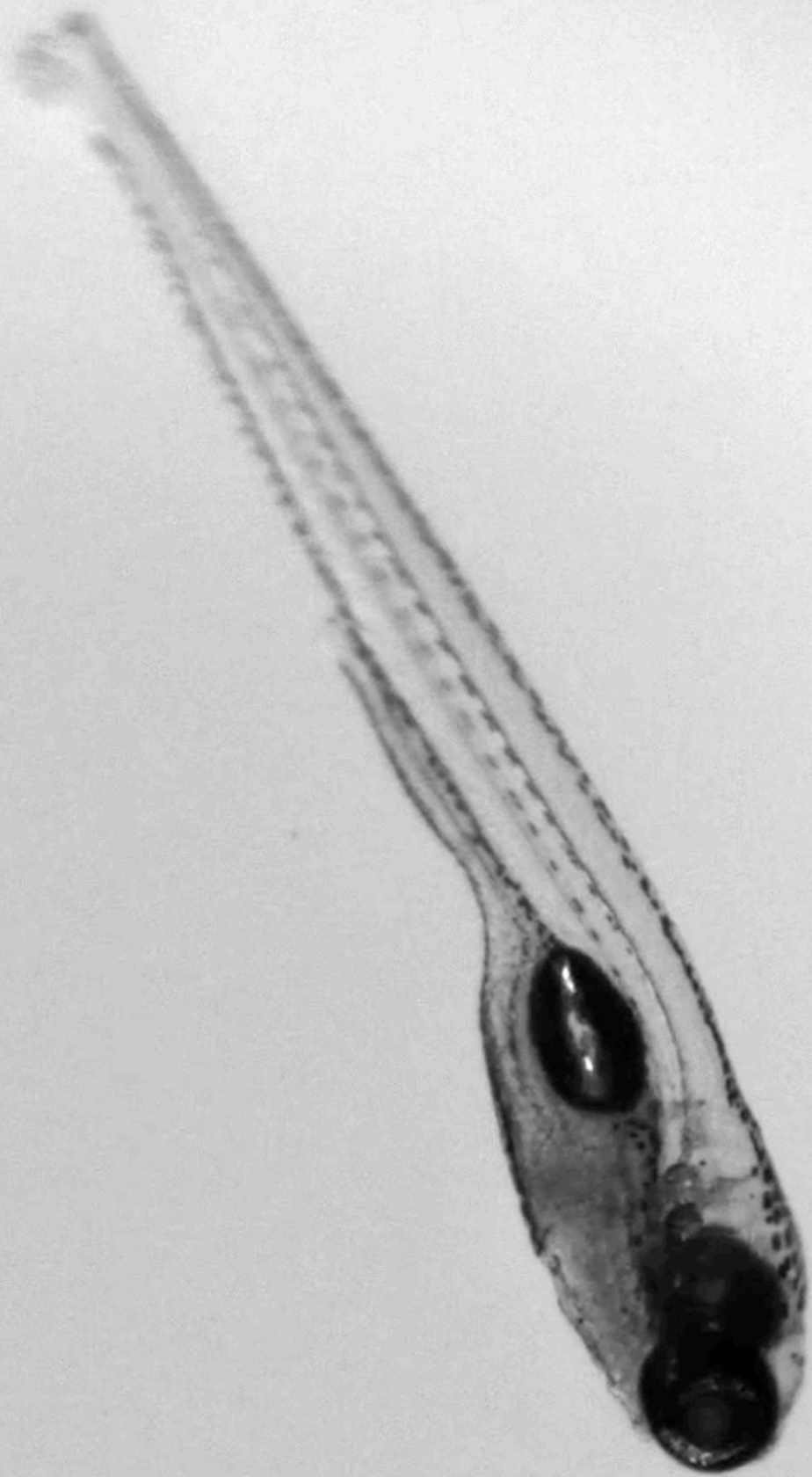


Key

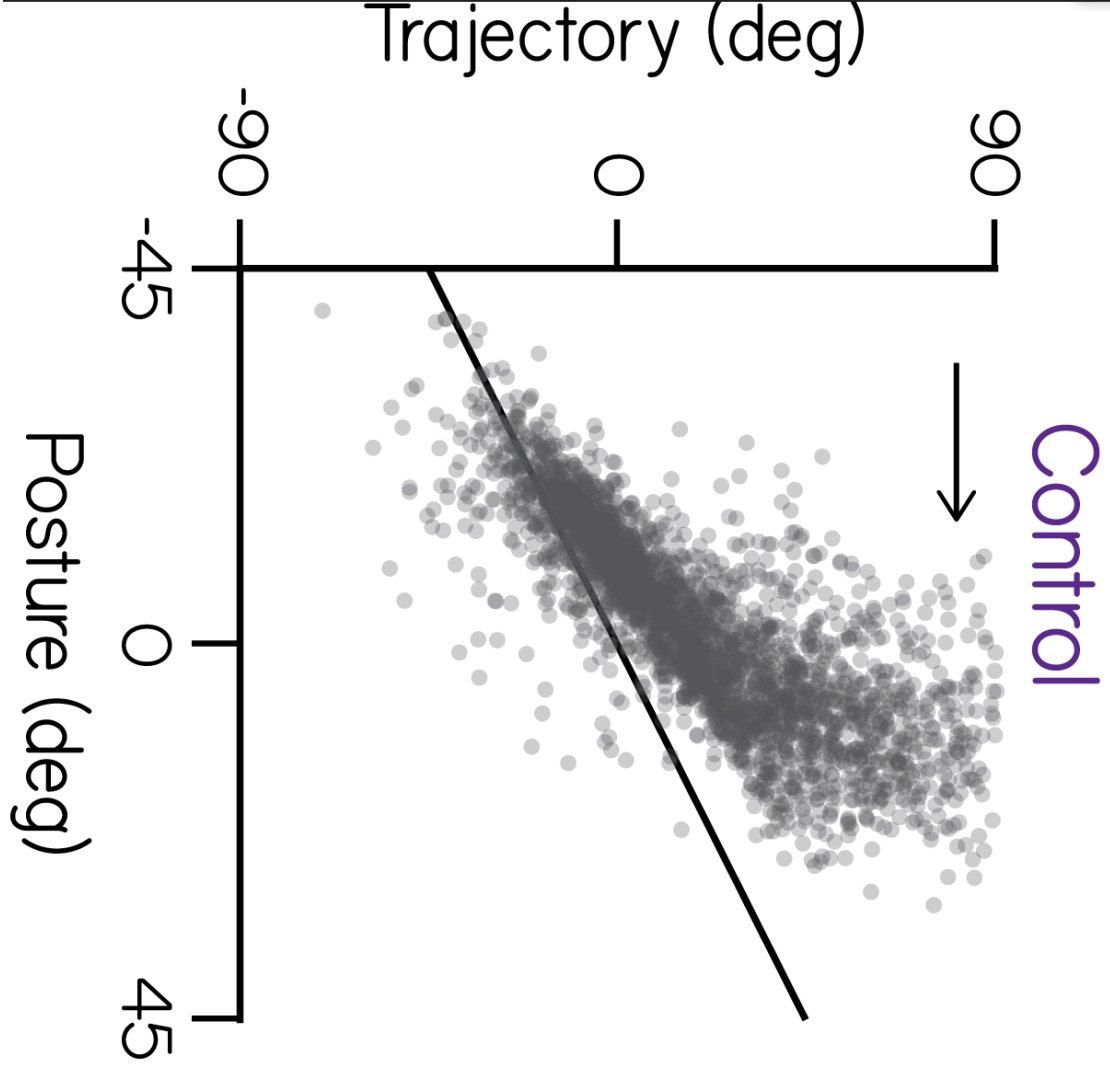
 Posture & Thrust

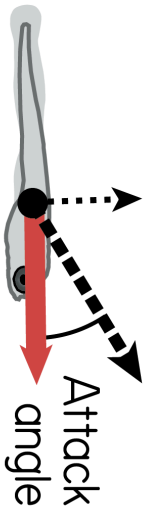
 Lift

 Trajectory



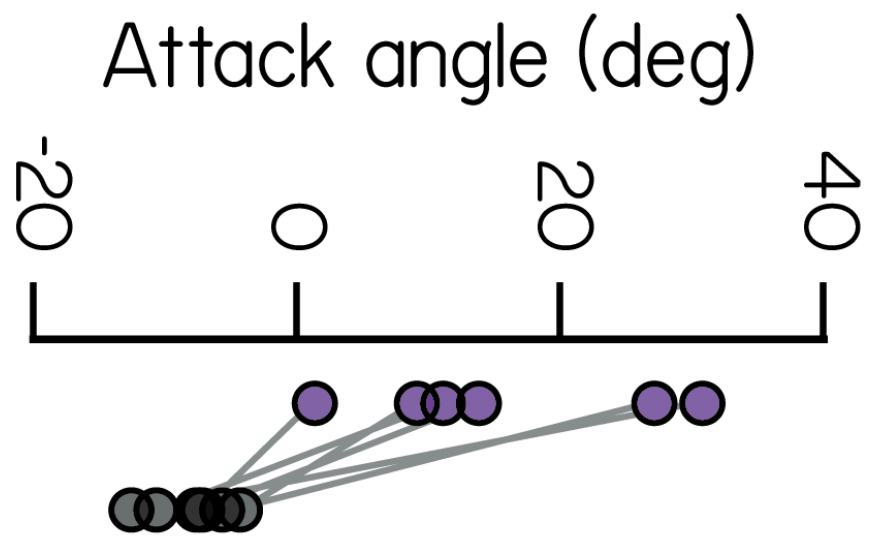


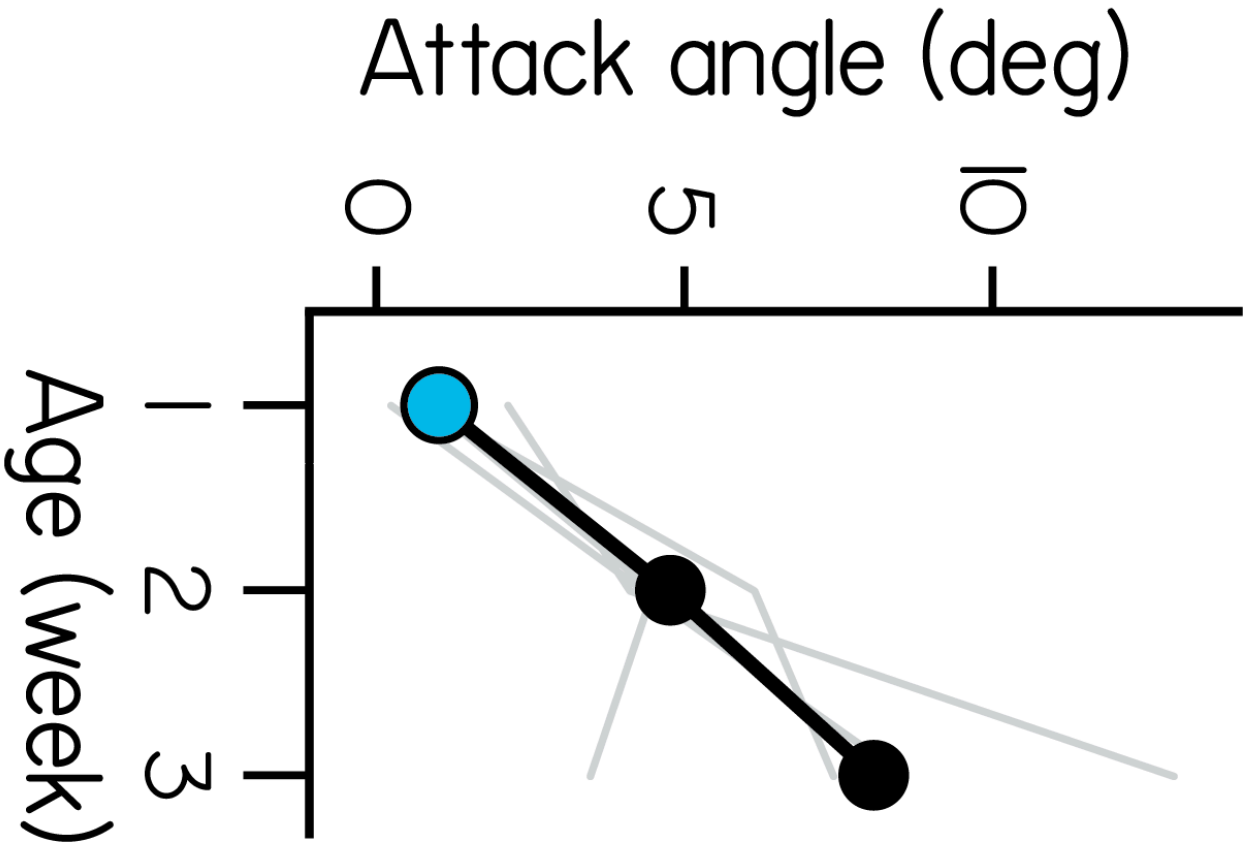




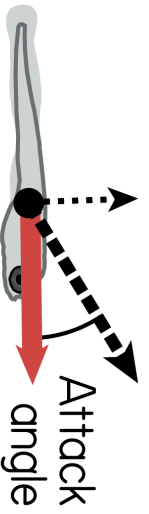
Lift-based

Control
Finless



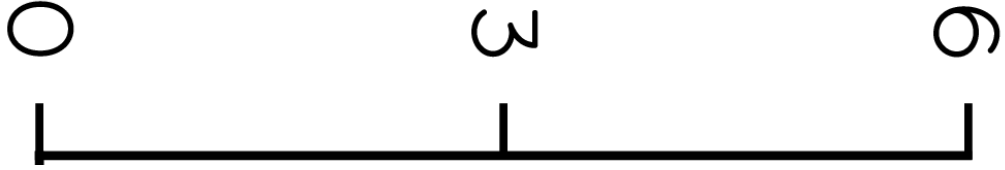


Lift-based

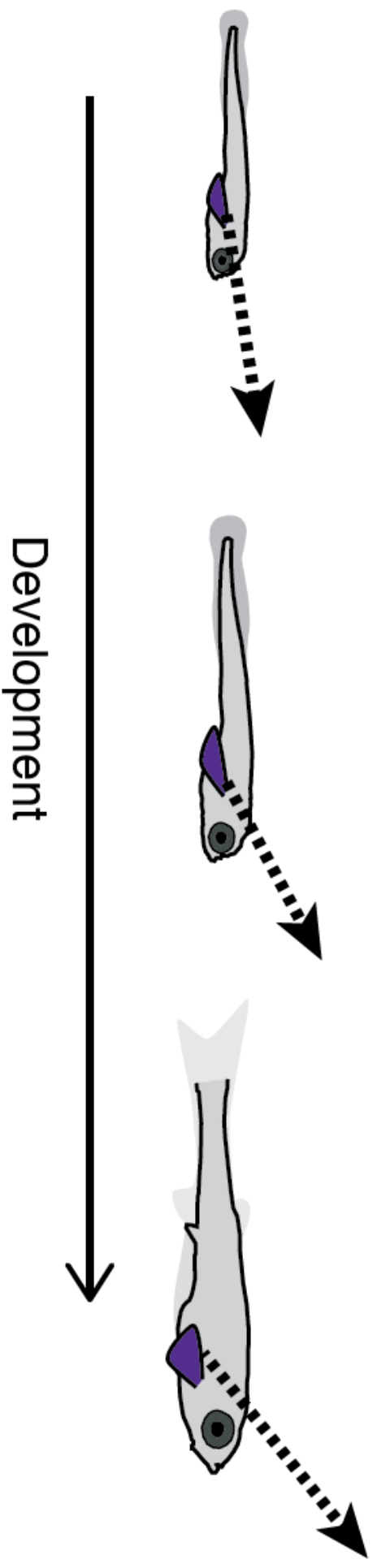


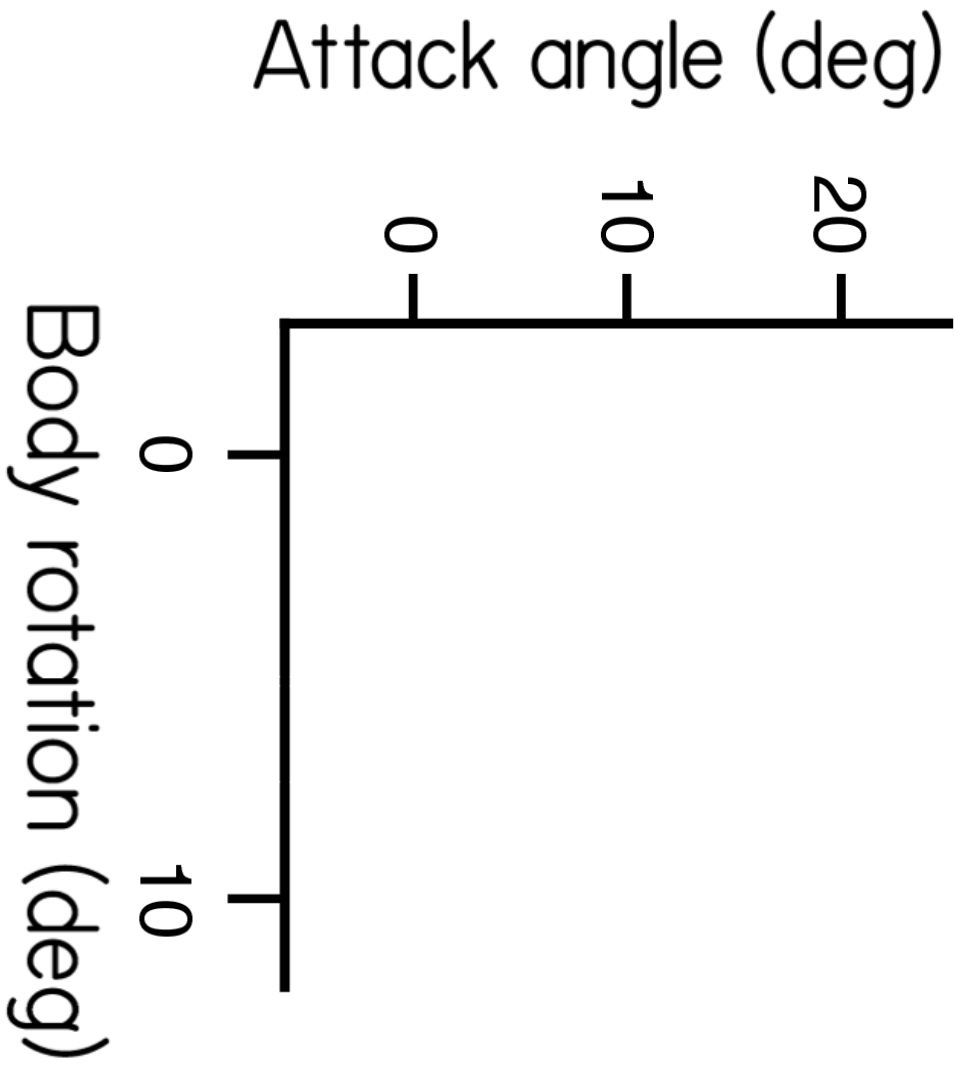
% bouts with
attack angle $>15^\circ$

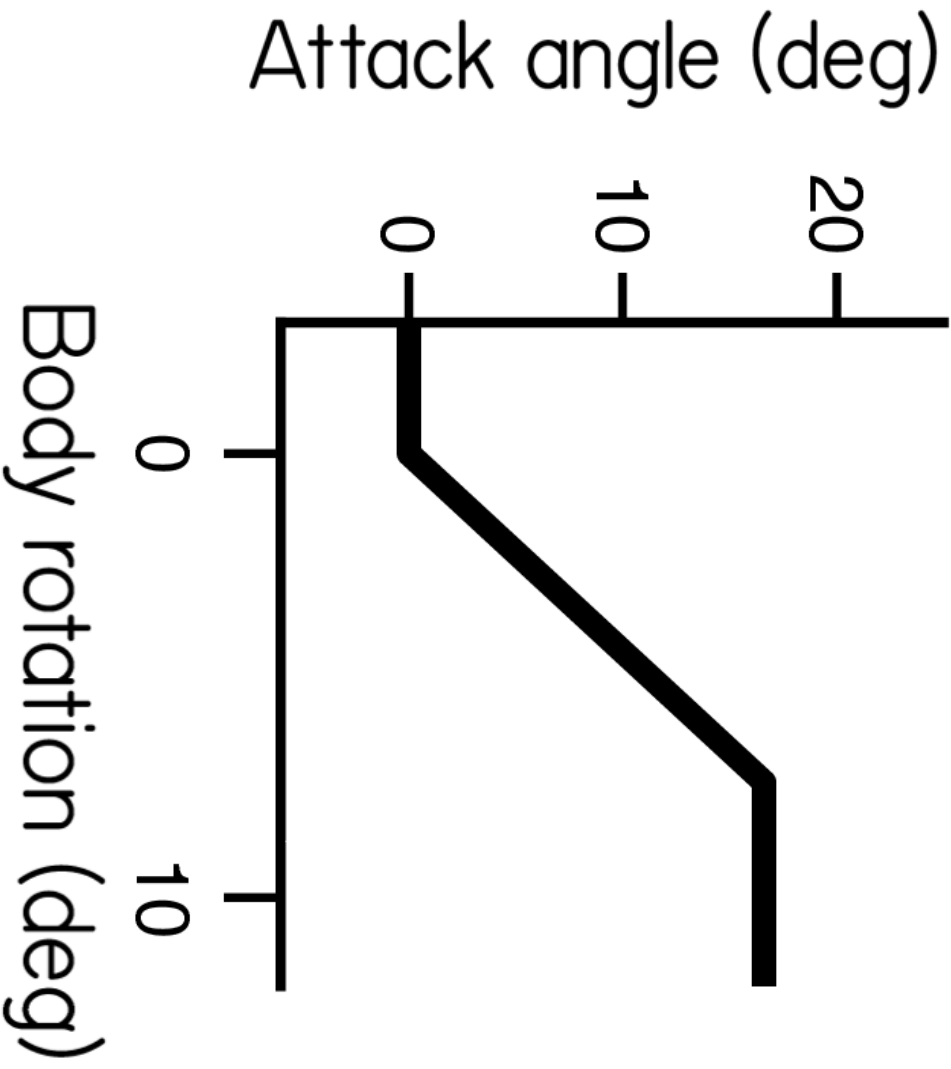
Control
Finless



Acquire a preference
for fin use?

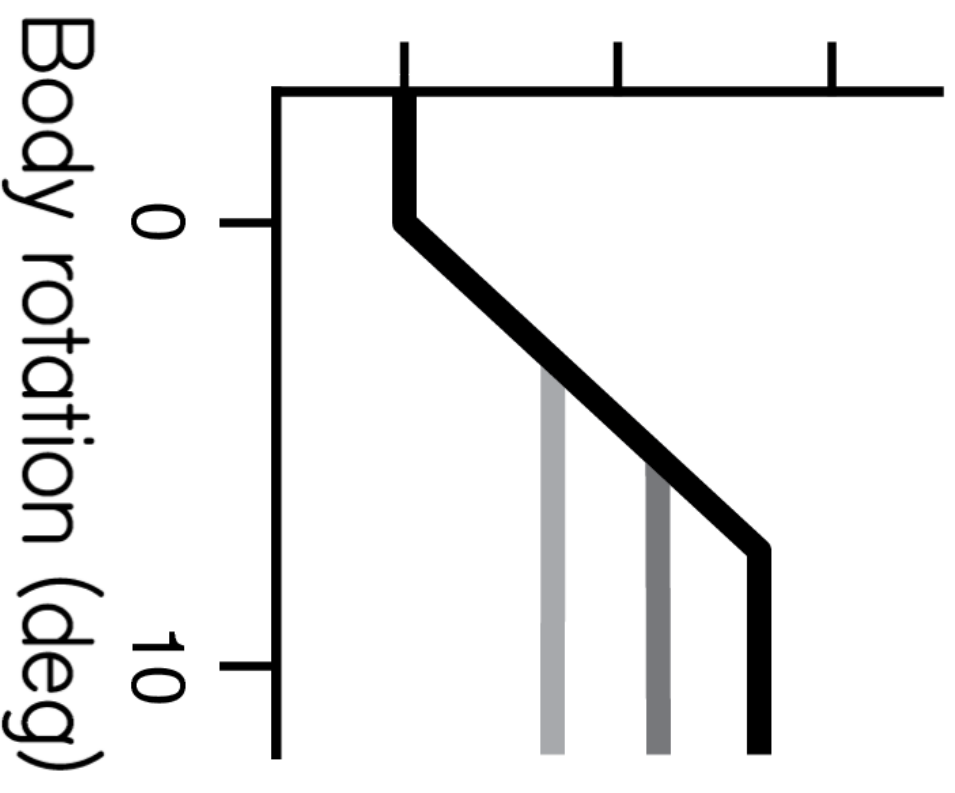
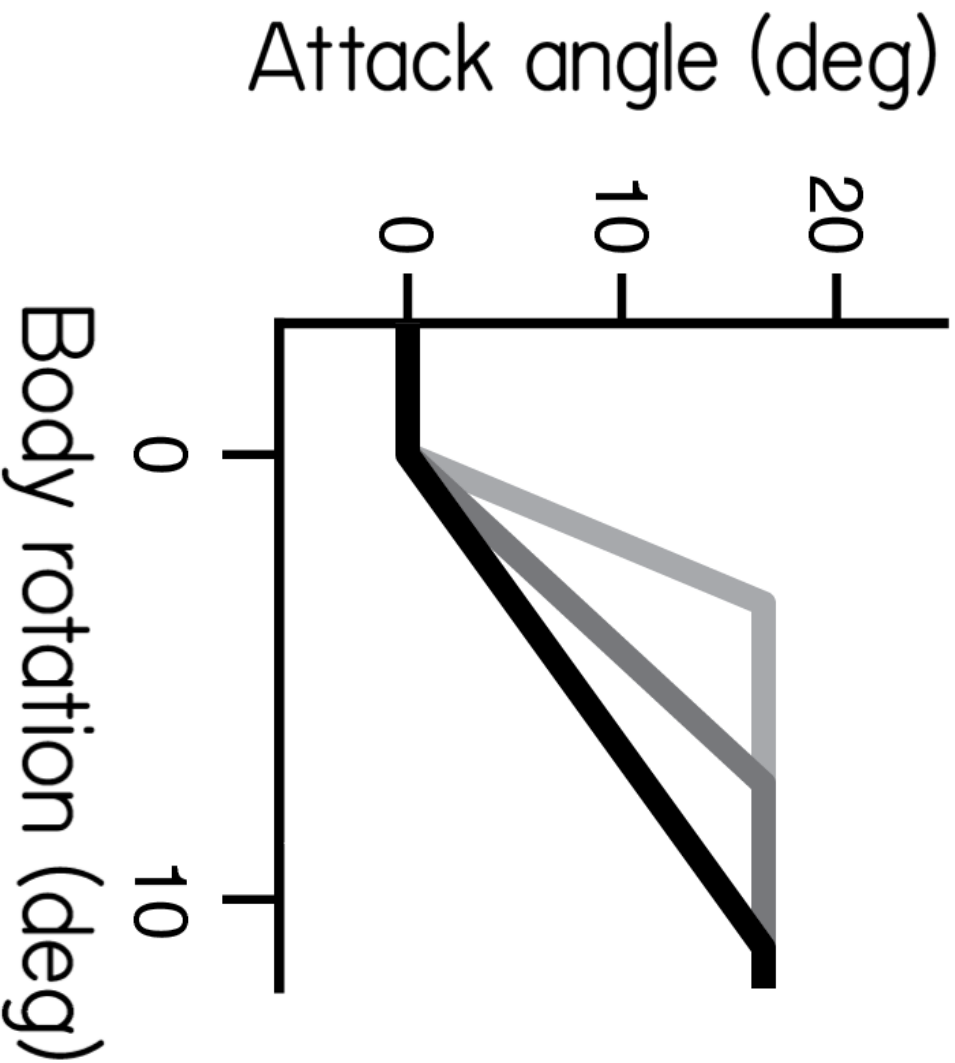




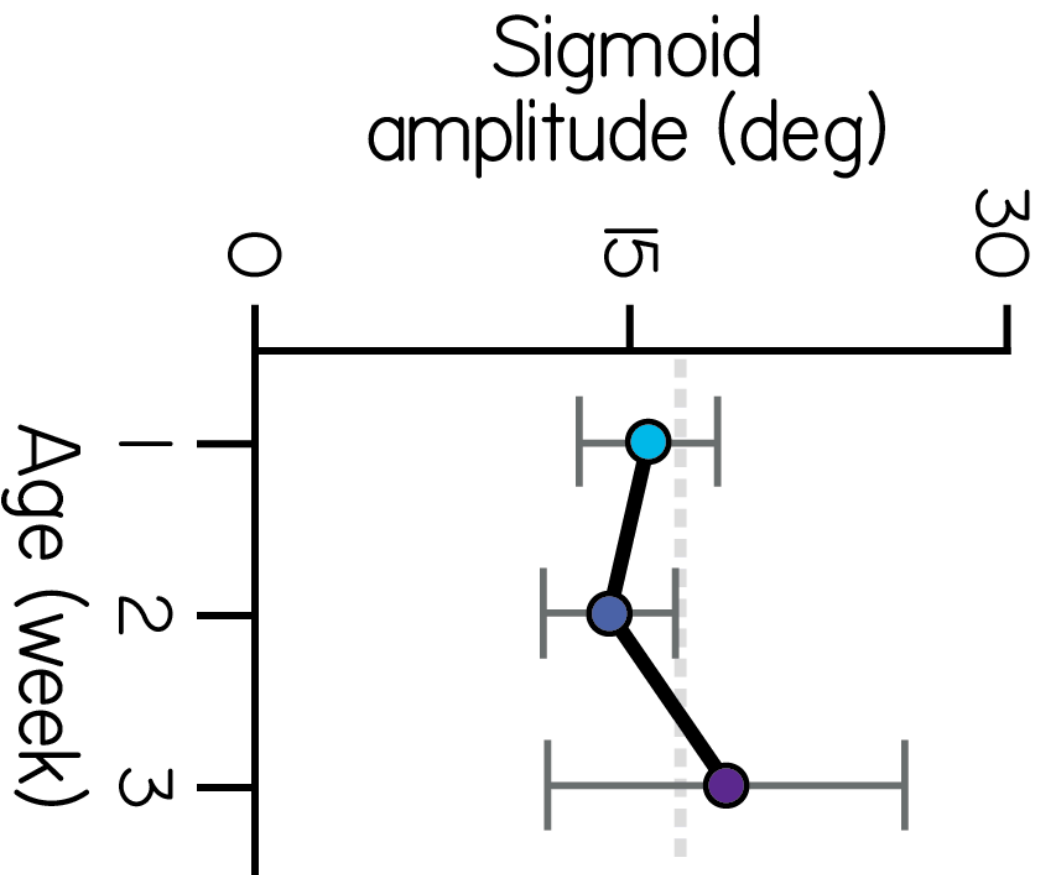


Preference

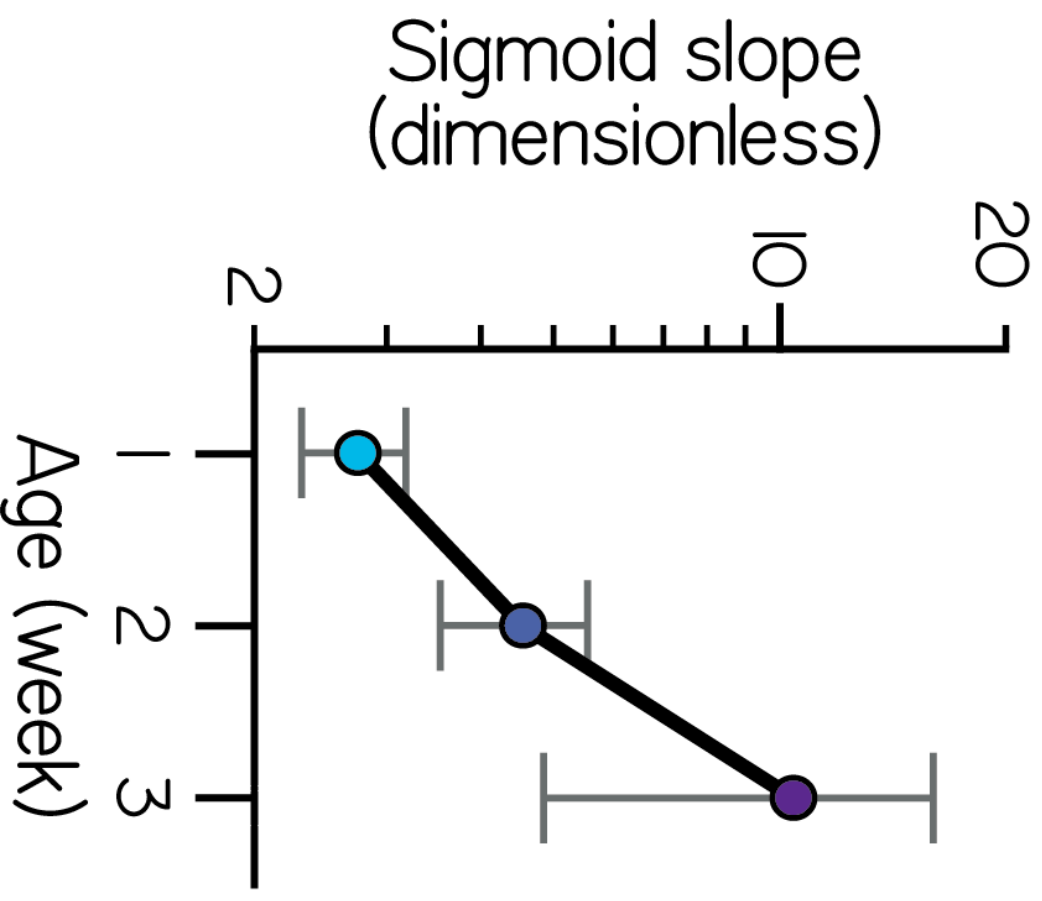
Capability

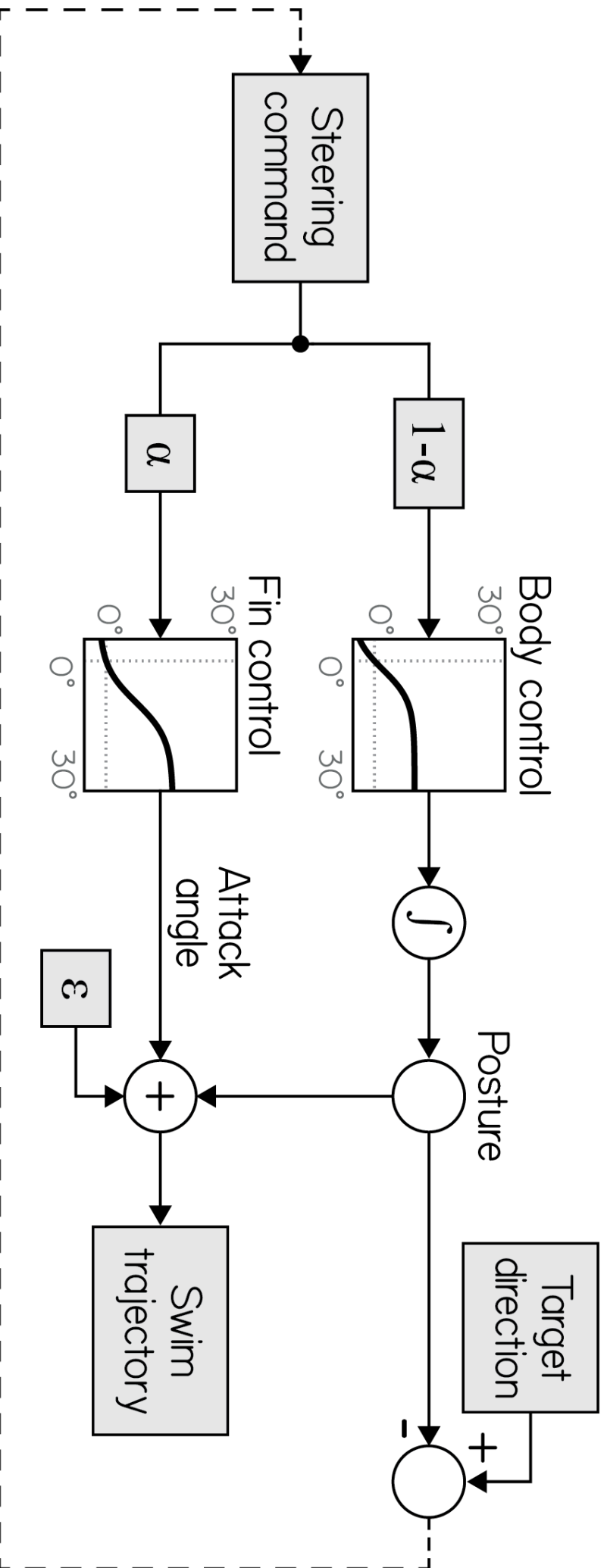


Capability



Preference





Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

Why zebrafish move when they
do.

How zebrafish explore depth.

How zebrafish come to climb.

