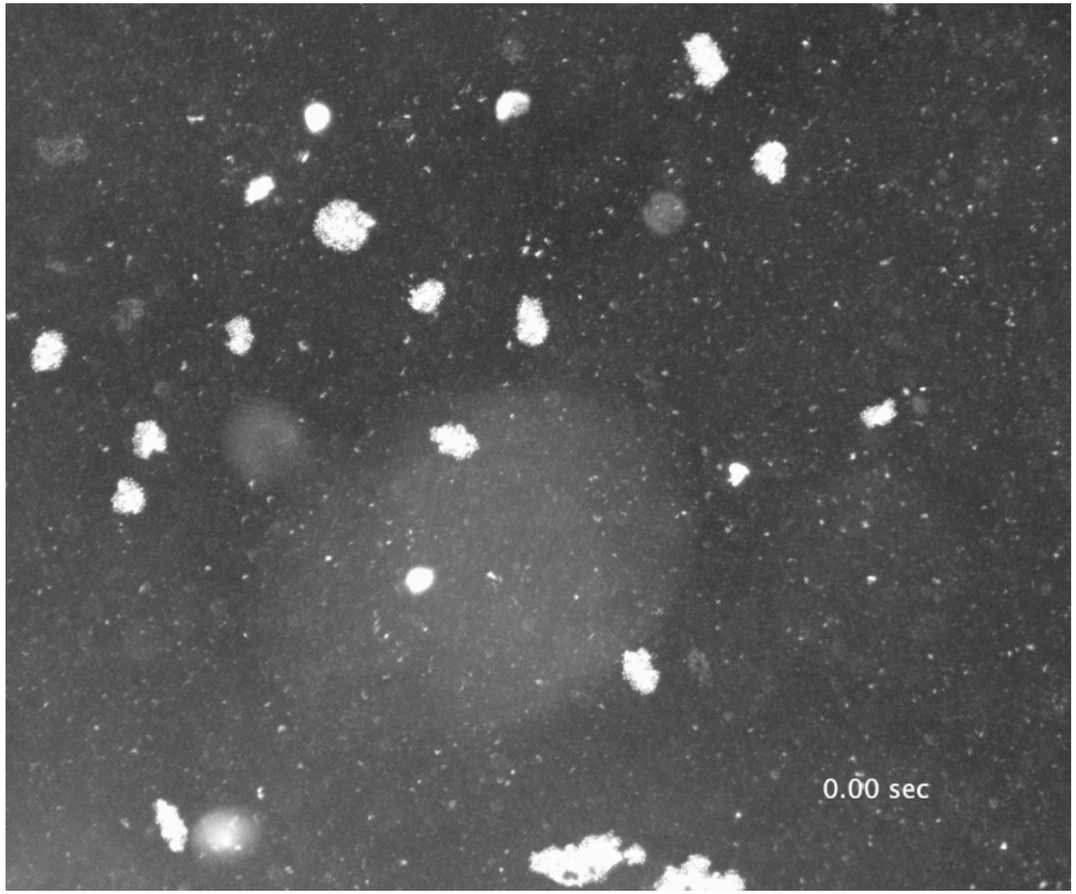
Sensing at the edges

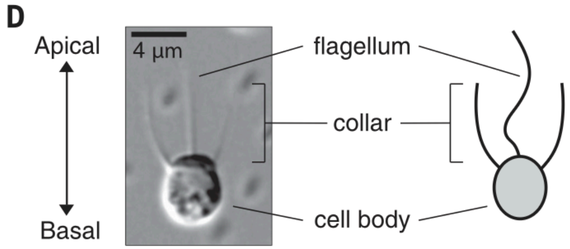
Synthetic specimens for early contractile coordination

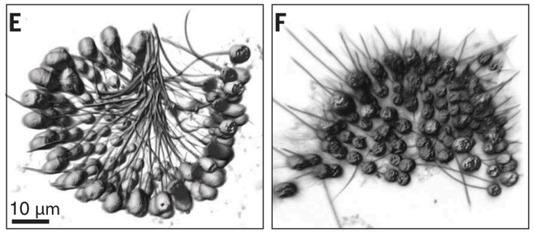


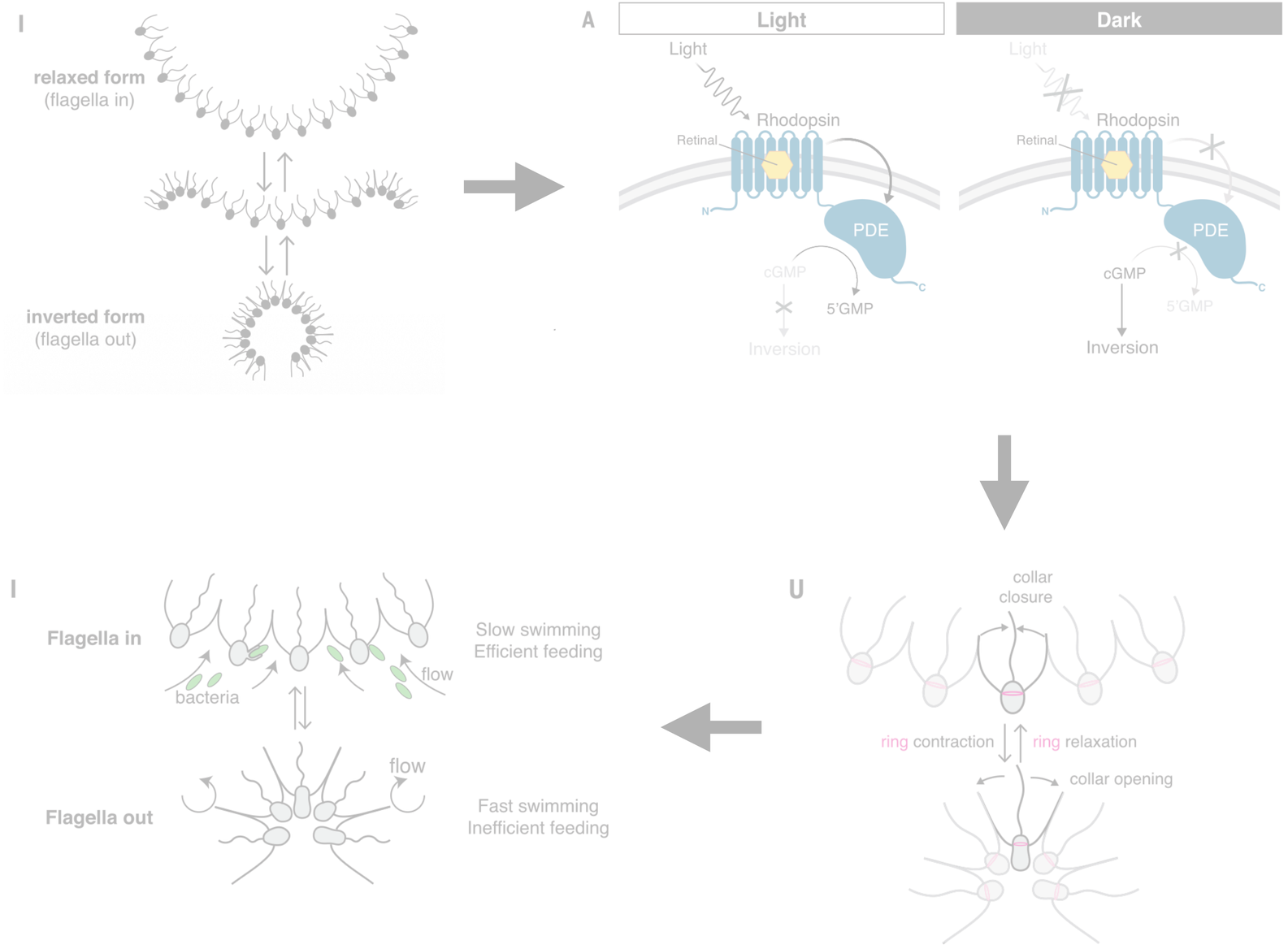
Brunet et al., 2019

Ben Gaskin, University of Sydney

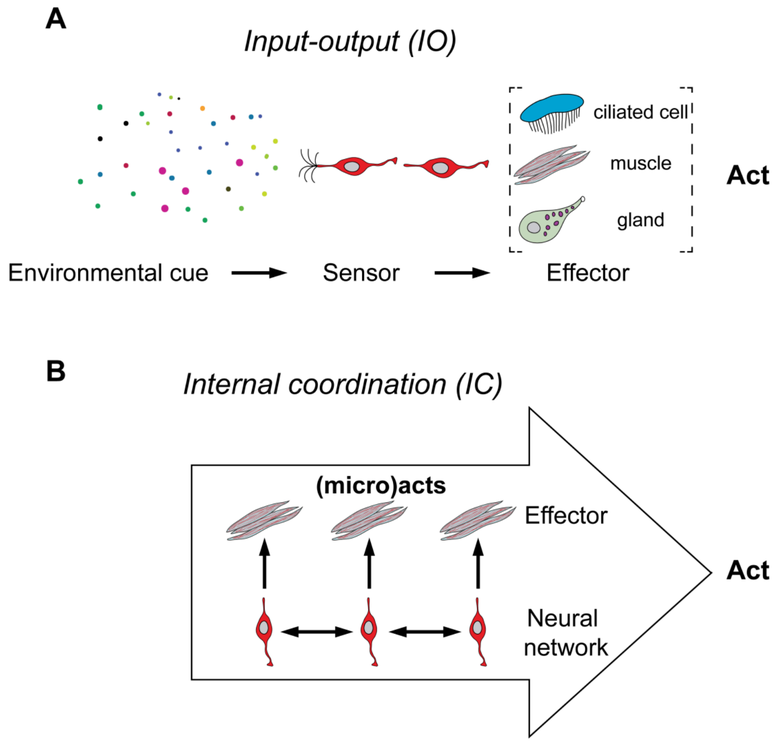
C. flexa


D
Apical
Basal
4 µm
flagellum
collar
cell body

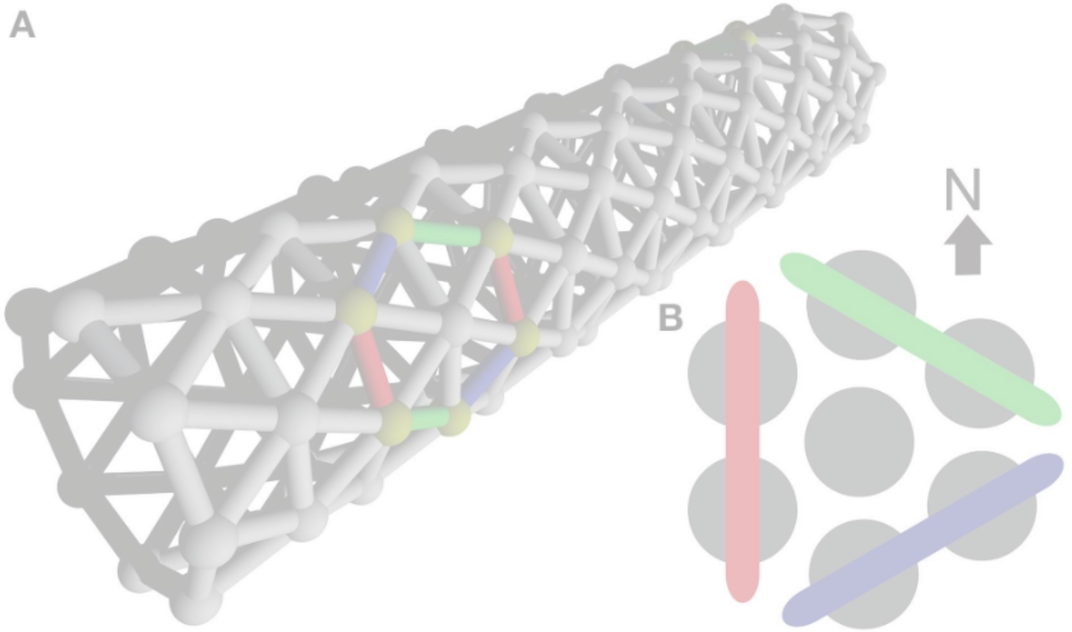

E
F
10 µm


I
relaxed form
(flagella in)
inverted form
(flagella out)
A
Light
Dark
Light
Rhodopsin
Retinal
N
PDE
cGMP
5'GMP
C
Inversion
U
collar
closure
ring contraction
ring relaxation
collar opening
I
Flagella in
Slow swimming
Efficient feeding
bacteria
flow
Flagella out
Fast swimming
Inefficient feeding
flow

Keijzer's Skin-Brain Thesis (SBT)

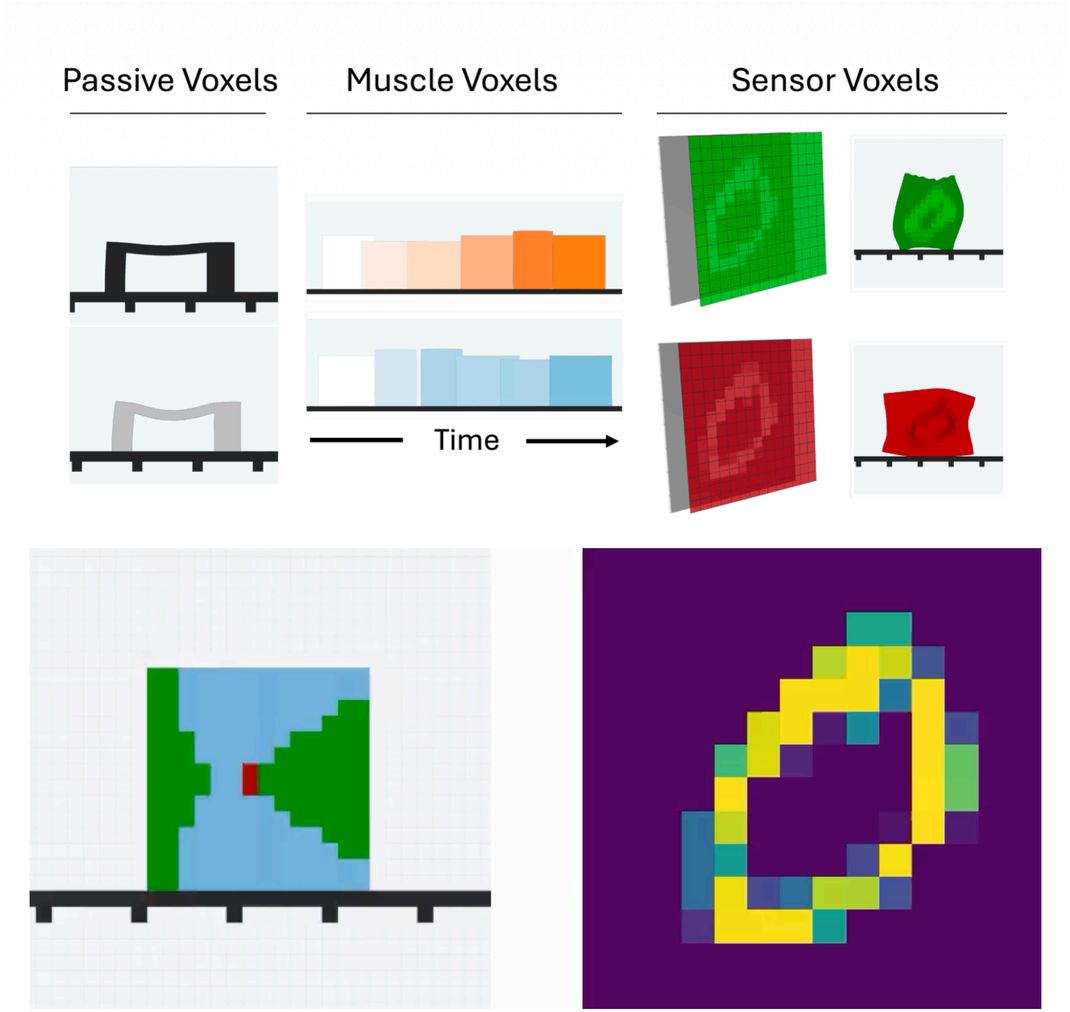


Jékely et al., 2015

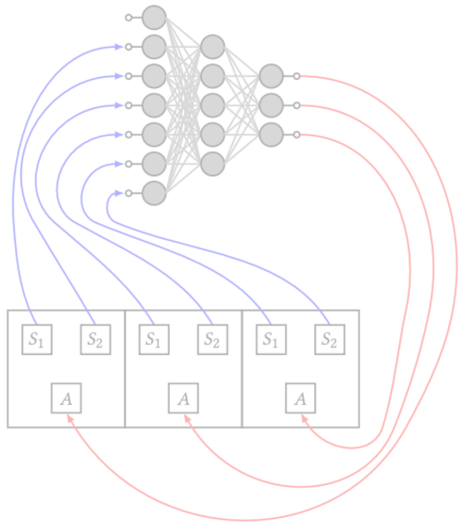


De Wiljes et al., 2015

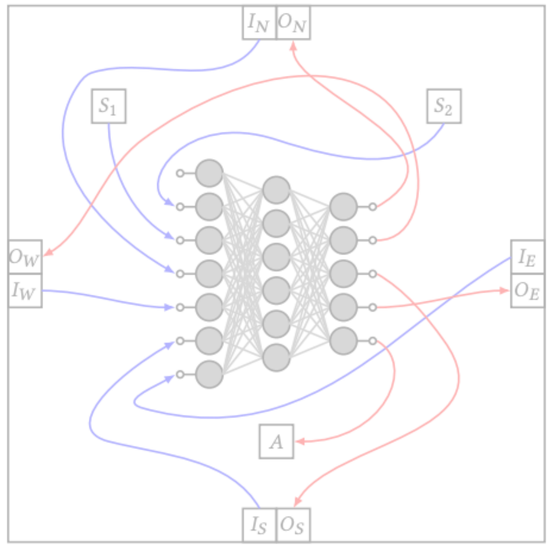
Prior work



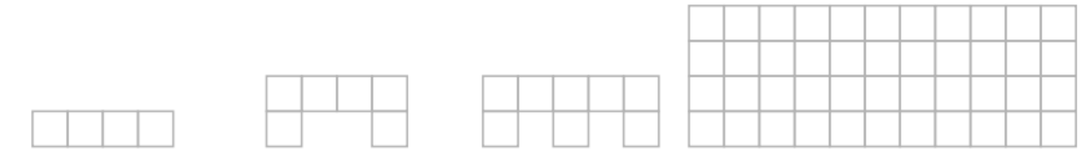
Mertan & Cheney, 2025



centralised



distributed

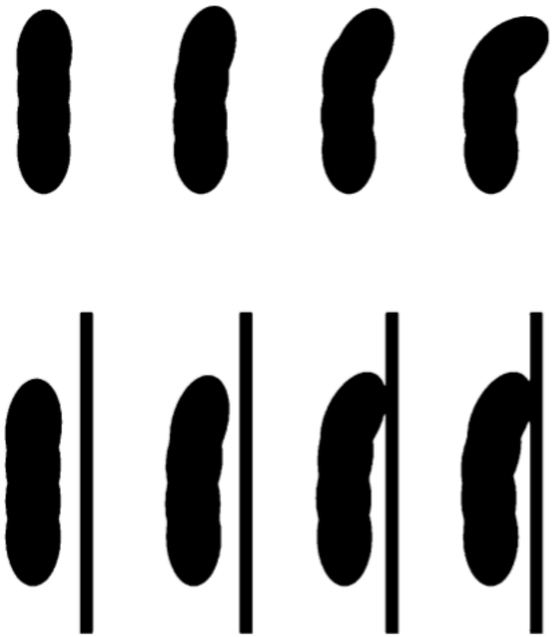


(a) S-worm (b) S-biped (c) S-tripod (d) L-worm

Medvet et al., 2020

Moving and sensing without input and output

Fig. 1 Sensing bodies: a self-induced motion to the right can either proceed (*top*) or is blocked by an external obstacle (*below*). The difference in body contraction can be detected without requiring external sensors

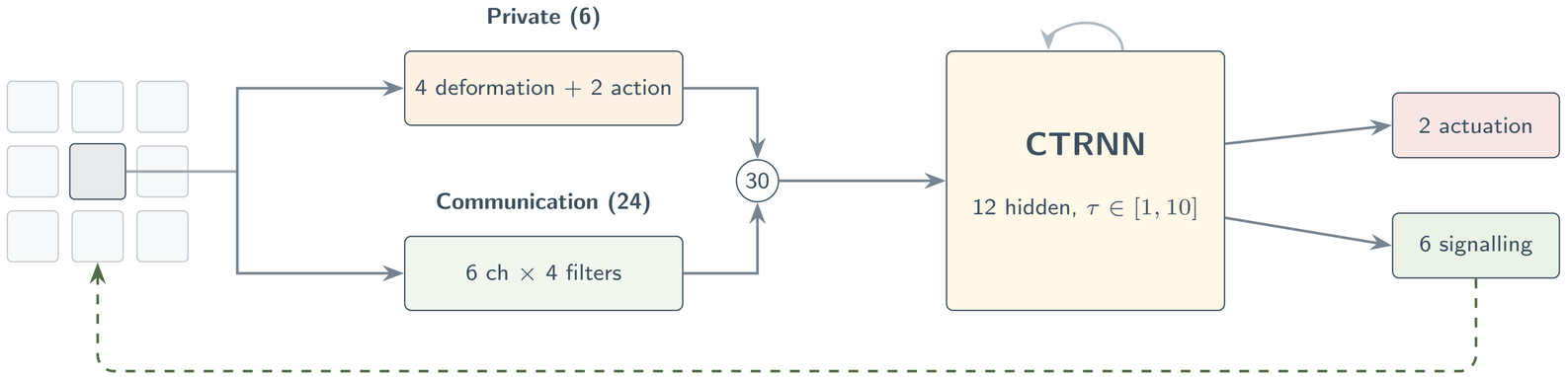


Keijzer, 2015

Animal Sensorimotor Organisation Hypothesis

1. Cells determine only their own geometry
2. There is no access to global state
3. Cells perceive through local signalling
4. Of the environment, each cell knows only:
    a. What is my current contractile state?
    b. What was my previous command?
    c. How far apart are these two?

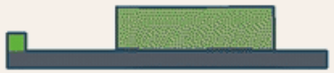
Testing Keijzer's hypothesis





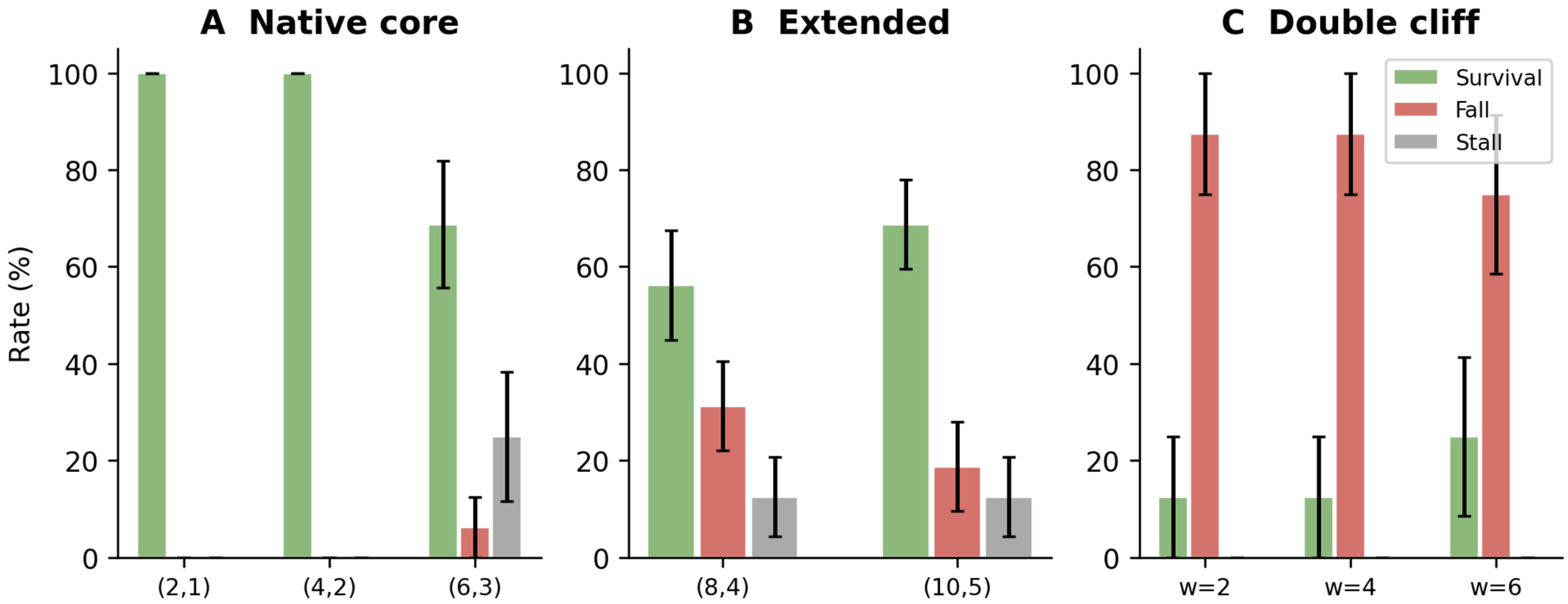




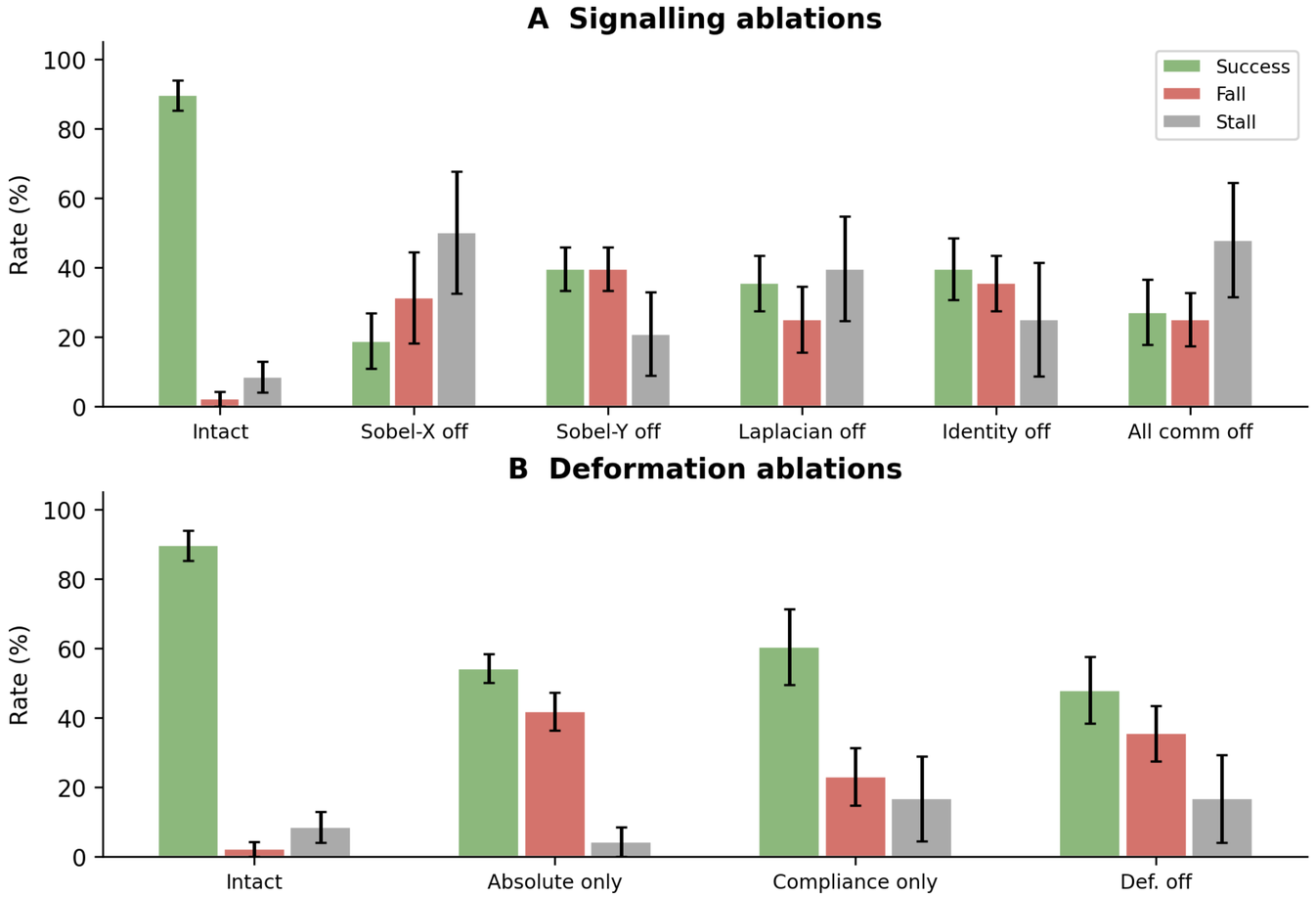

What did they learn?

strong native, but heuristic methods do not generalise



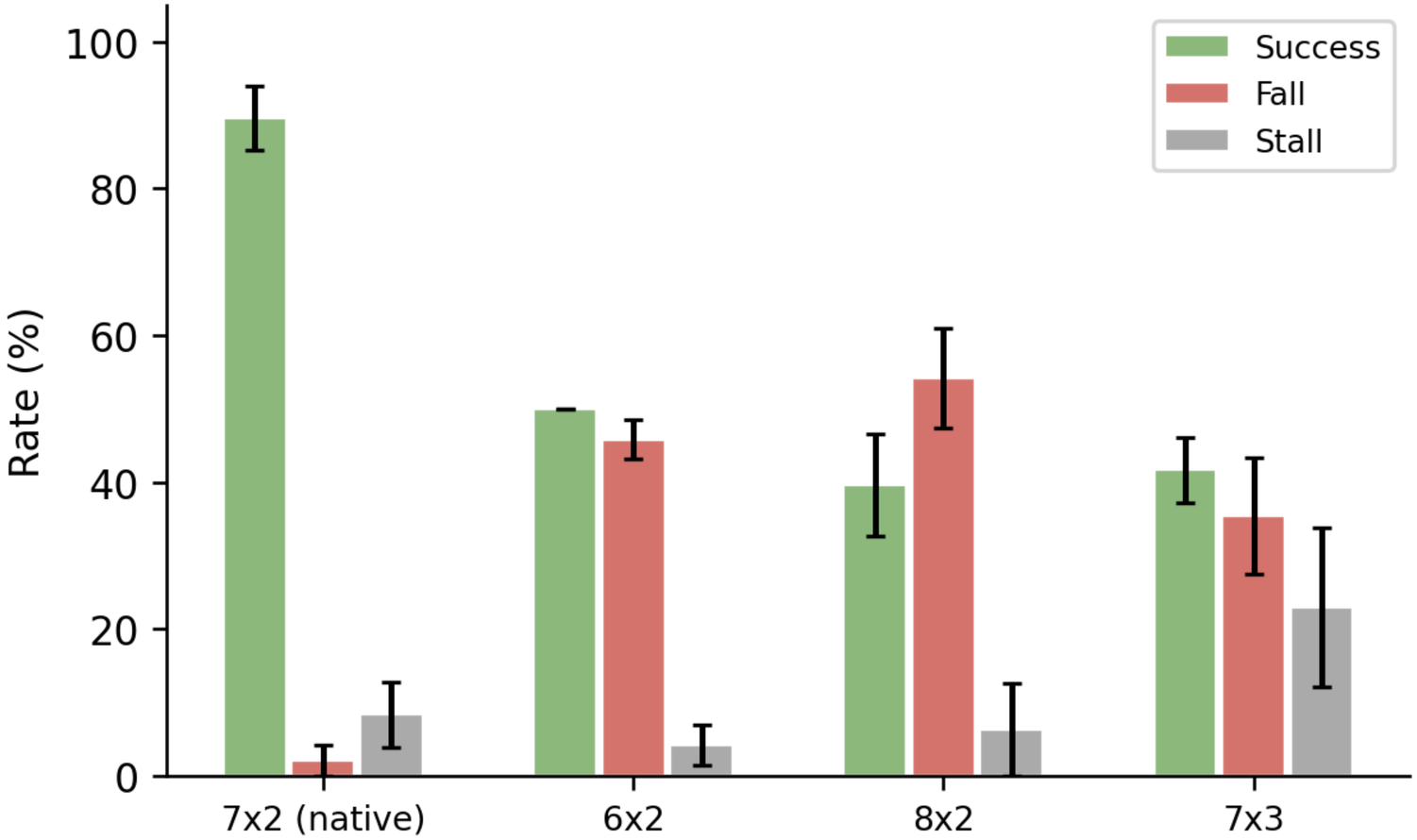
How do they do it?

ablating local signalling and deformation inputs leads to specific effects

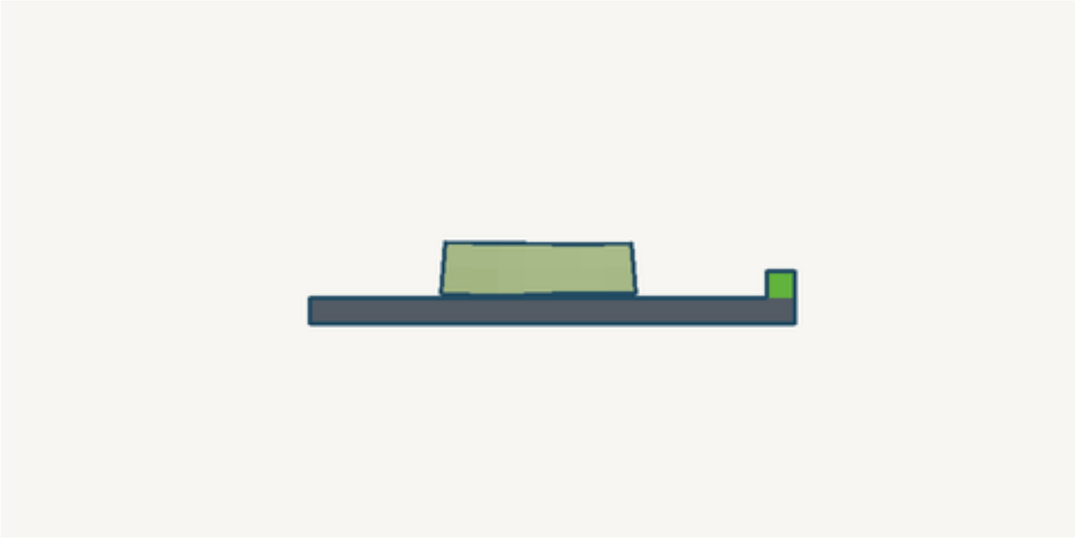


Who are they?

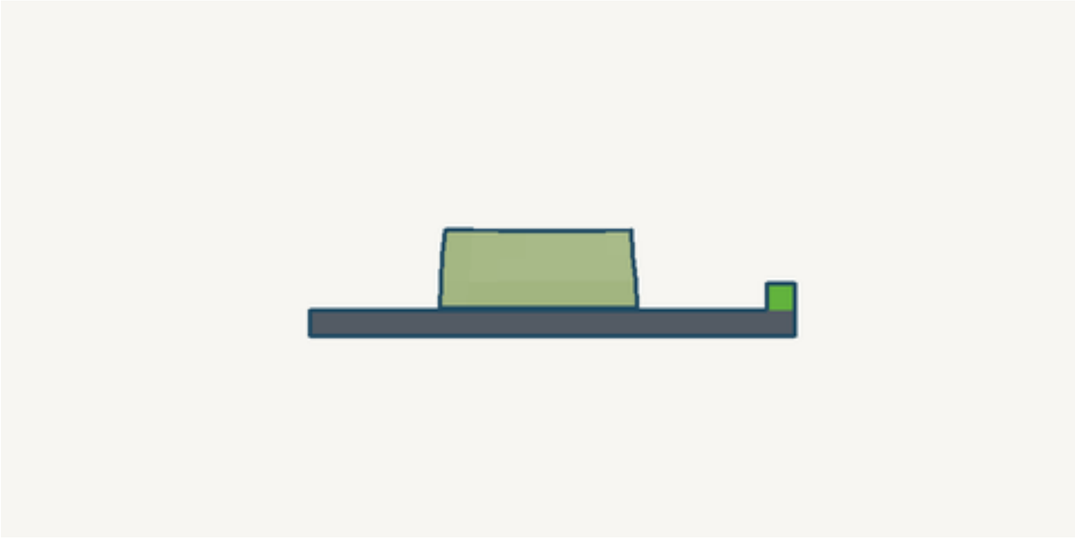
performance fails to transfer smoothly across bodies shapes



Who are they?

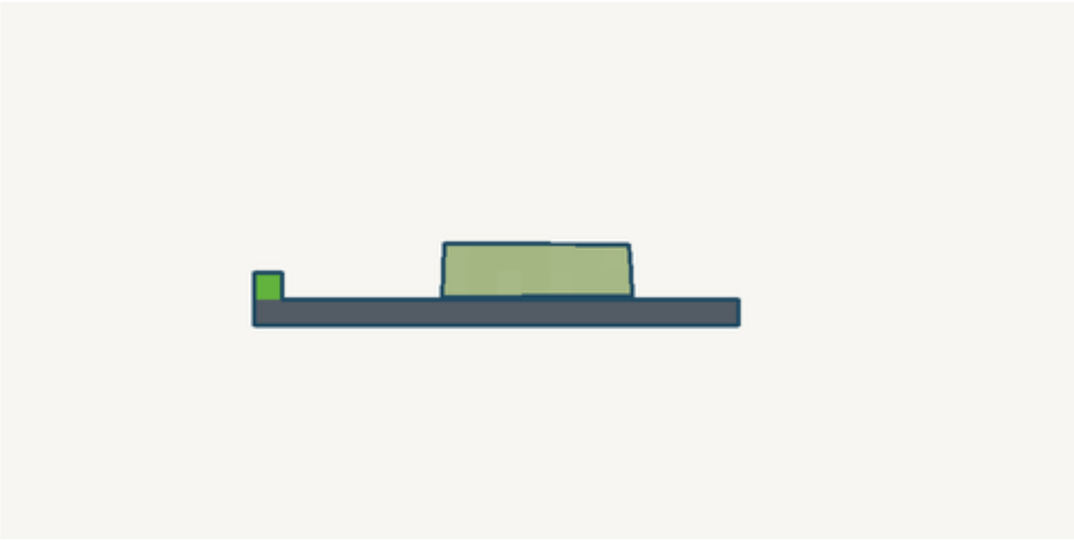


7x2

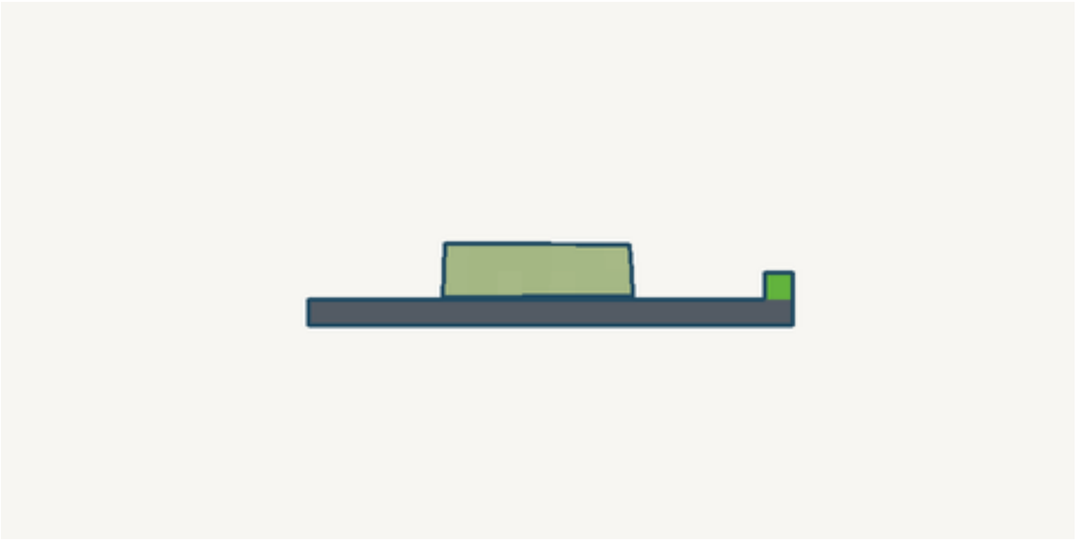


7x3

Who is S4?

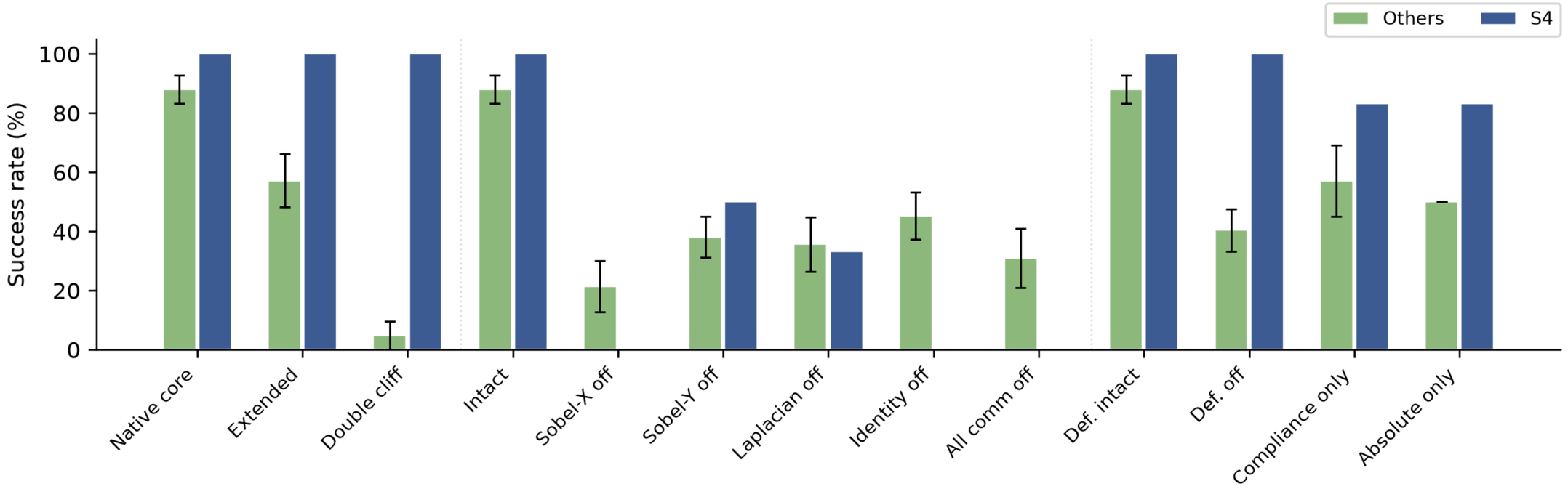


deformation
intact



deformation
off

Who is S4?


Others
S4
Success rate (%)
100
80
60
40
20
0
Native core
Extended
Double cliff
Intact
Sobel-X off
Sobel-Y off
Laplacian off
Identity off
All comm off
Def. intact
Def. off
Compliance only
Absolute only

Why should we care?

We can sample synthetic specimens from the murky pond of theory

Taking Keijzer's constraints, we can speak of early multicellular coordination

The picture is plausible: distributed clonal controllers can learn conditionals

These specimens can be surprising, with S4 suggesting different strategies:

- proprioceptive coordination
- morphological computation