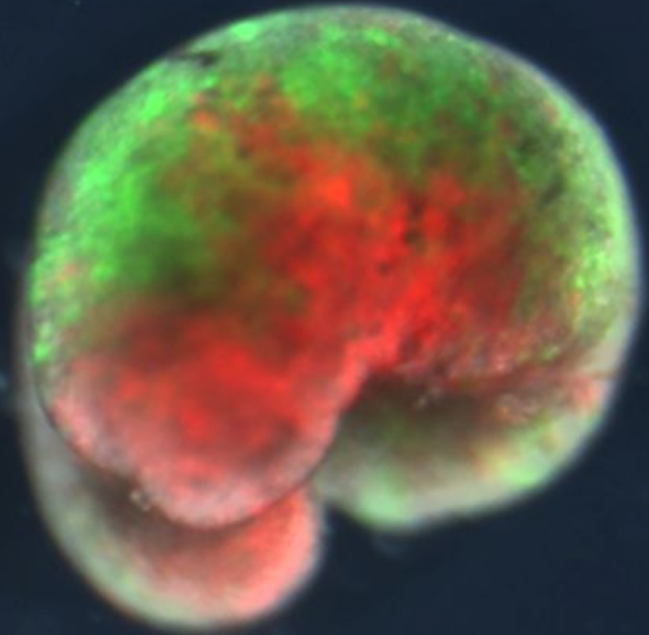
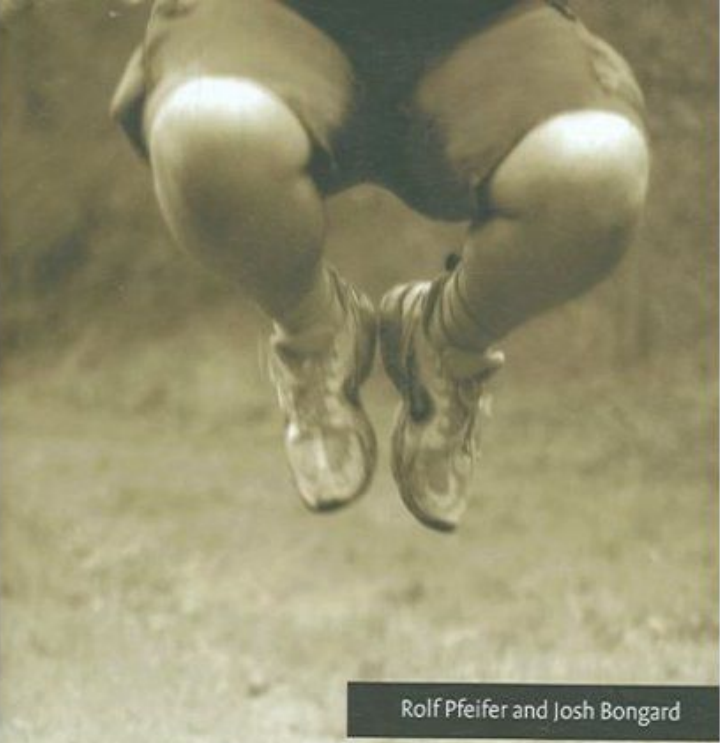


From rigid to soft to biological robots



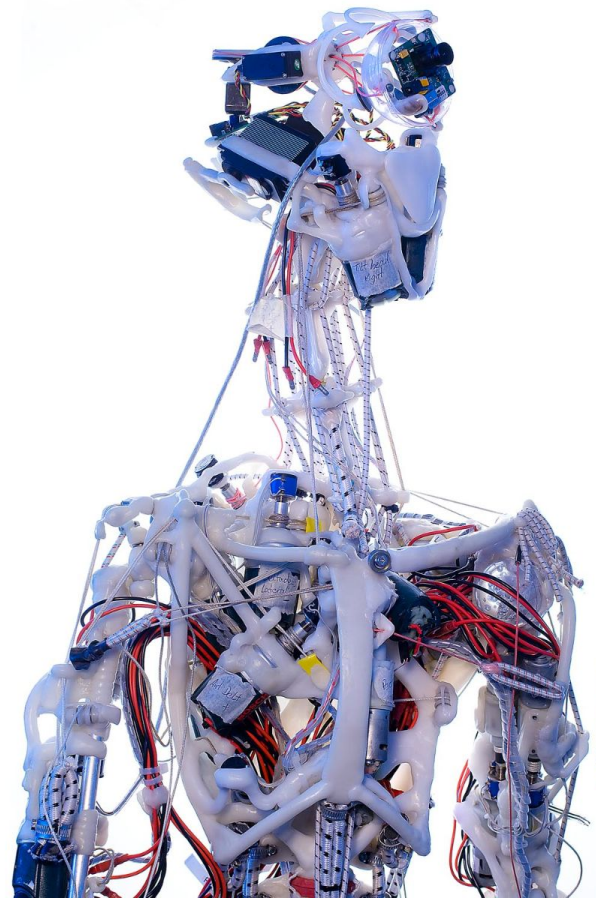
Josh Bongard
University of Vermont



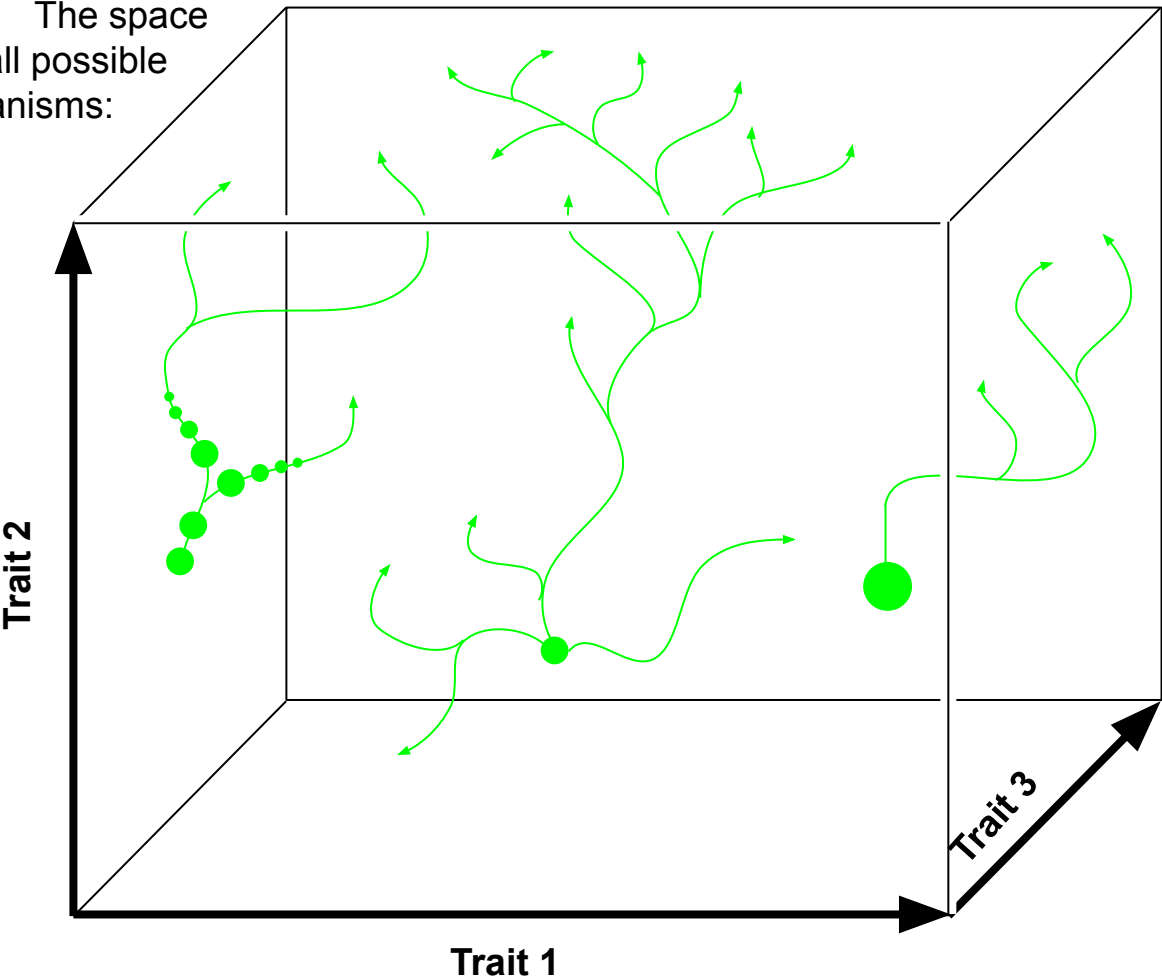
Rolf Pfeifer and Josh Bongard

how the body shapes the way we think

a new view of intelligence
foreword by Rodney Brooks



The space
of all possible
organisms:



The space
of all possible
rigid
robots:

Generality

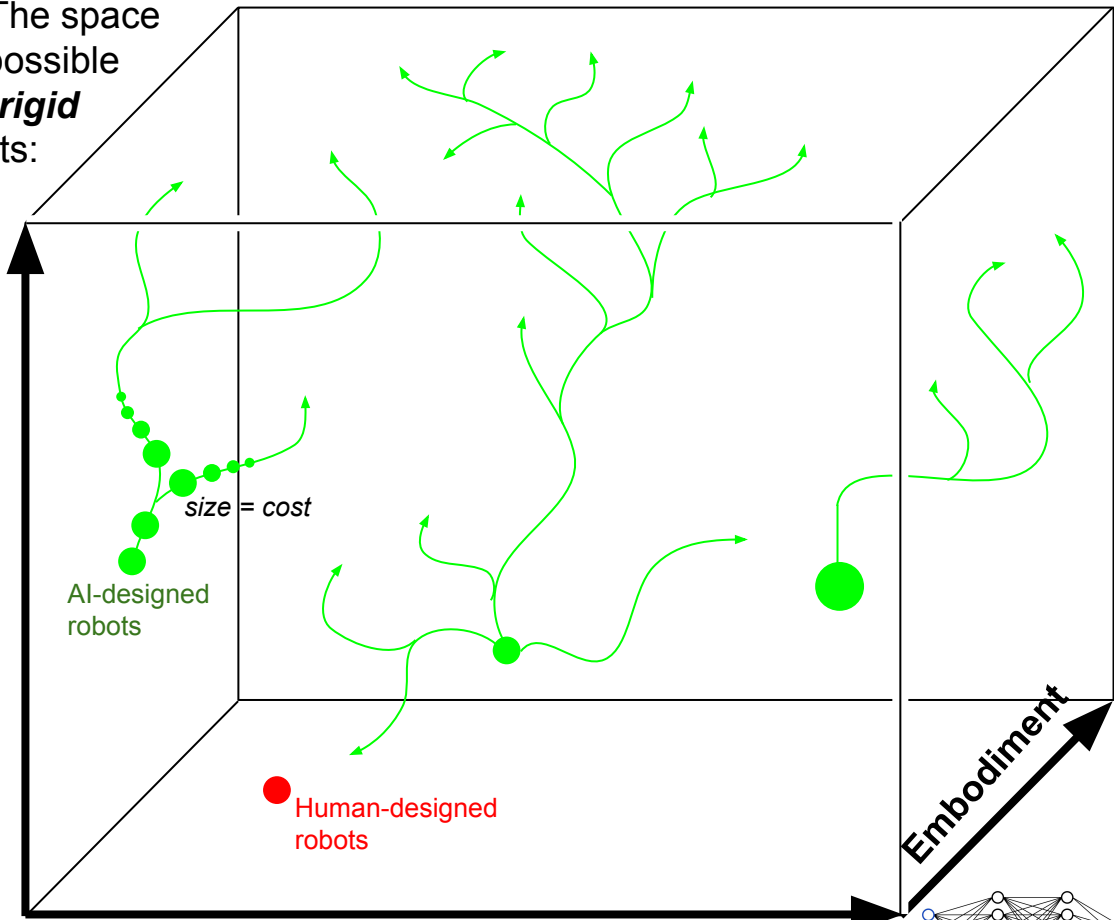
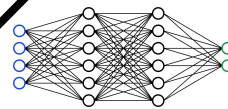
AI-designed
robots

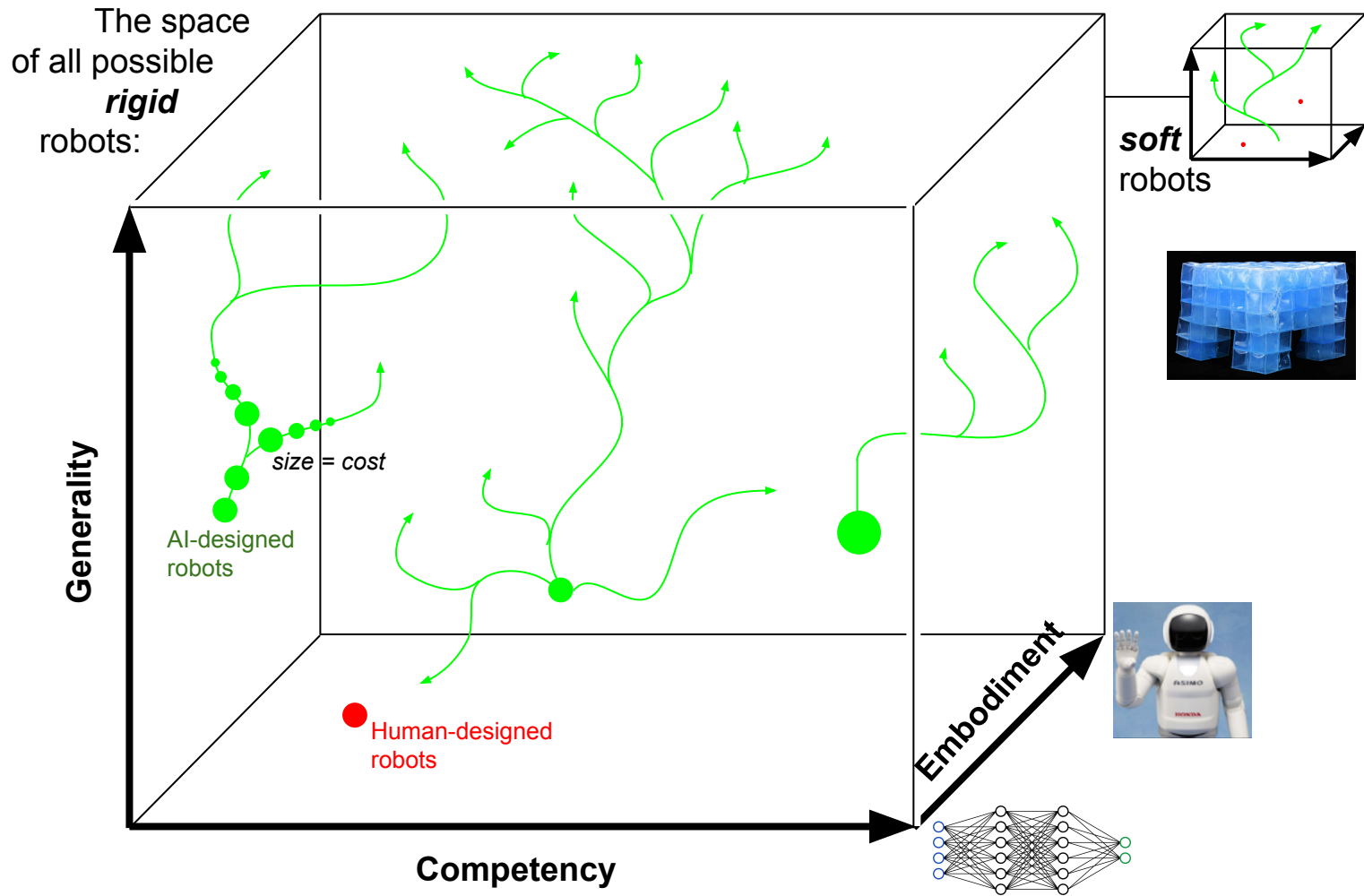
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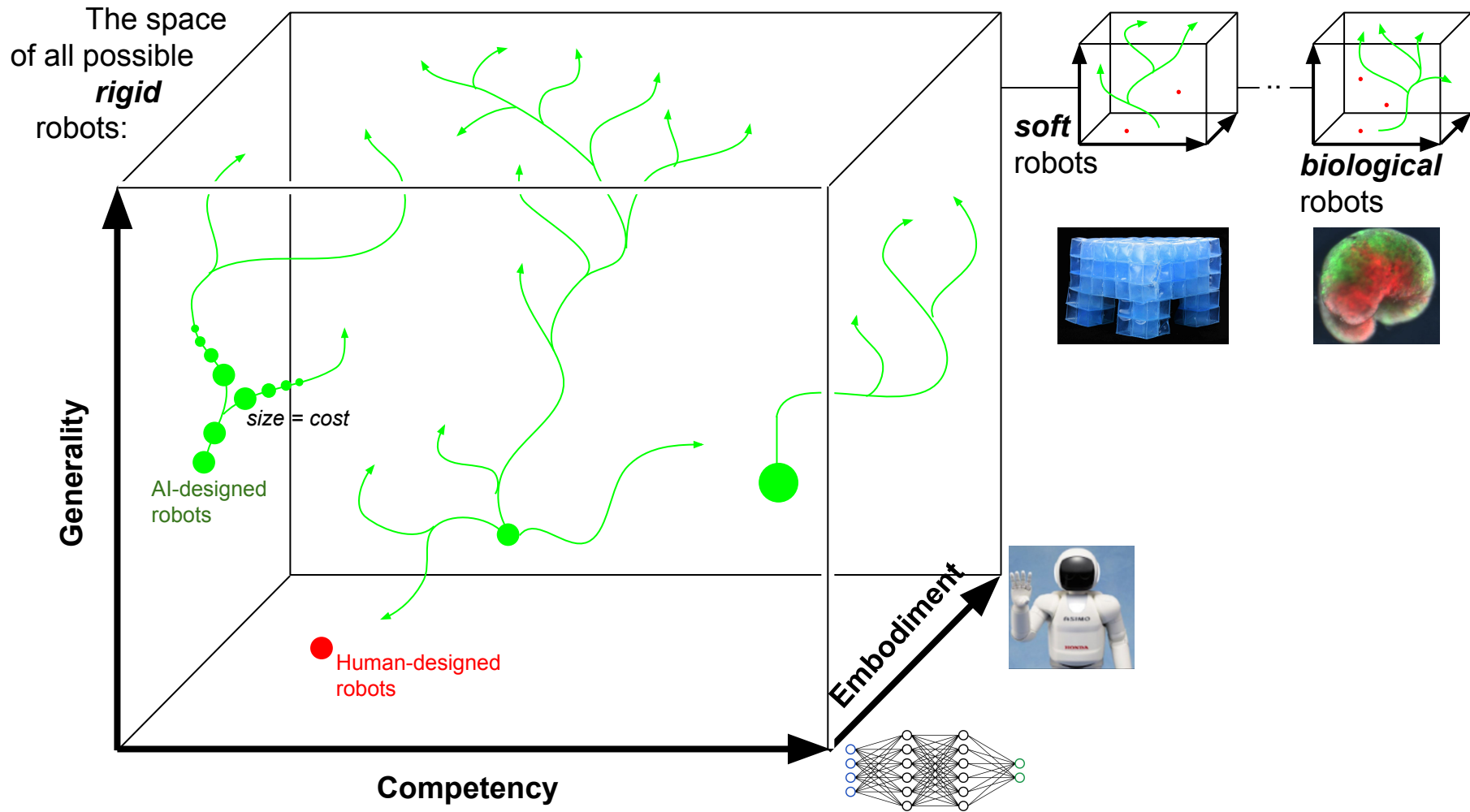
Human-designed
robots

Competency

Embodiment









Frutiger, Iida & Bongard
CLAWAR, 2002



Bongard, Zykov & Lipson
Science, 2006



Bongard,
PNAS, 2011



Rosser, Kok, Chahl, Bongard
RSS, 2019



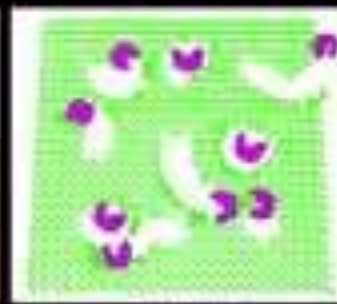
Kriegman, Nasab, Shah, Steele, Branin, Levin,
Bongard, Kramer-Bottiglio, RoboSoft, 2020



Shah, Powers, Tilton,
Kriegman, Bongard,
Kramer-Bottiglio,
Nature Mach Int, 2020



Kriegman, Blackiston,
Levin, Bongard
PNAS, 2020



Kriegman, Blackiston,
Levin, Bongard
PNAS, 2021



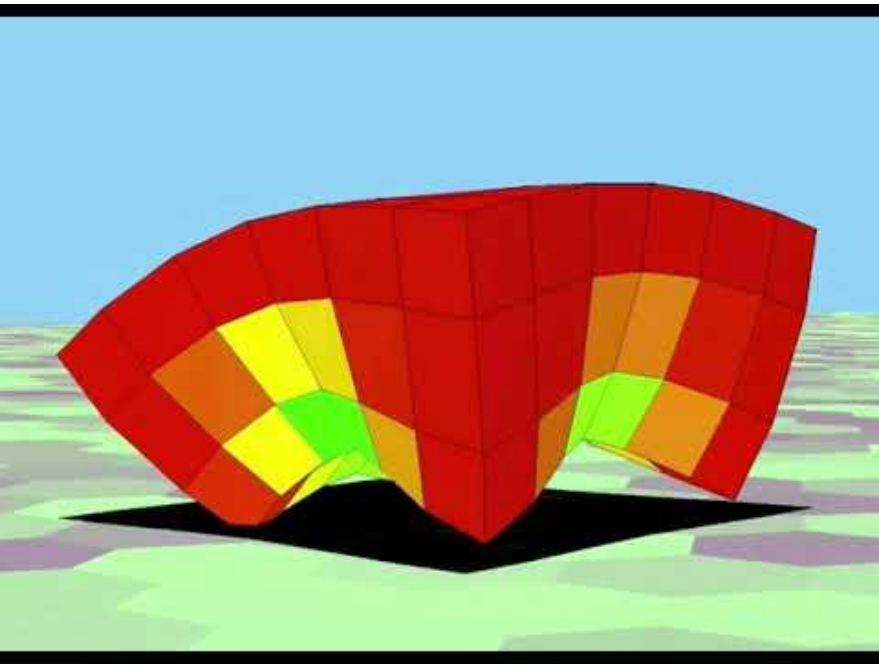
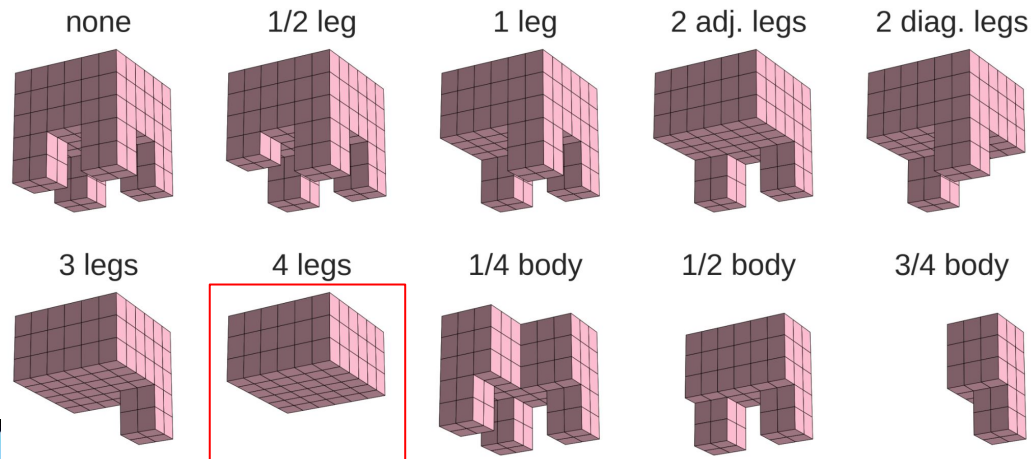
Parsa, Wang, O'Hern, Shattuck,
Kramer-Bottiglio, Bongard,
Proc of GECCO, 2022

Intact

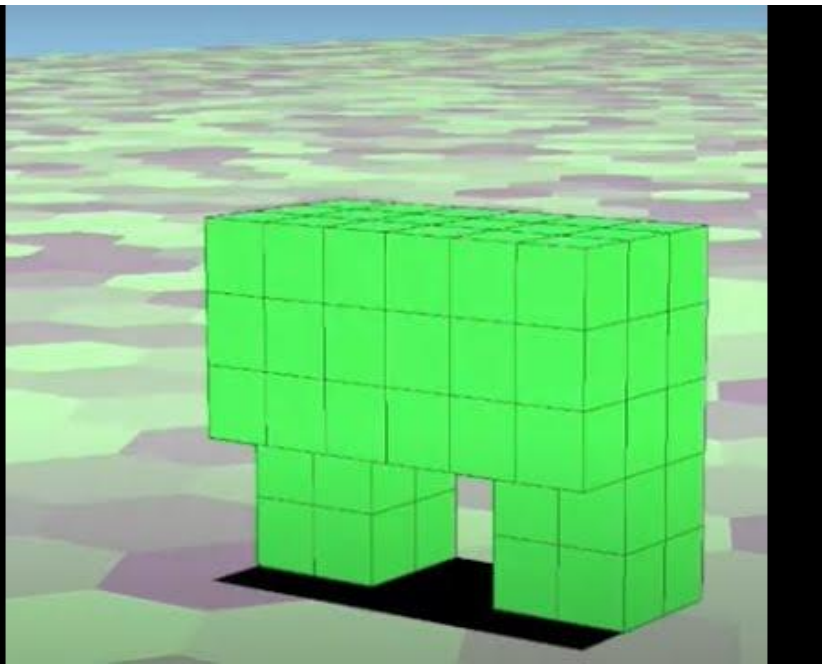
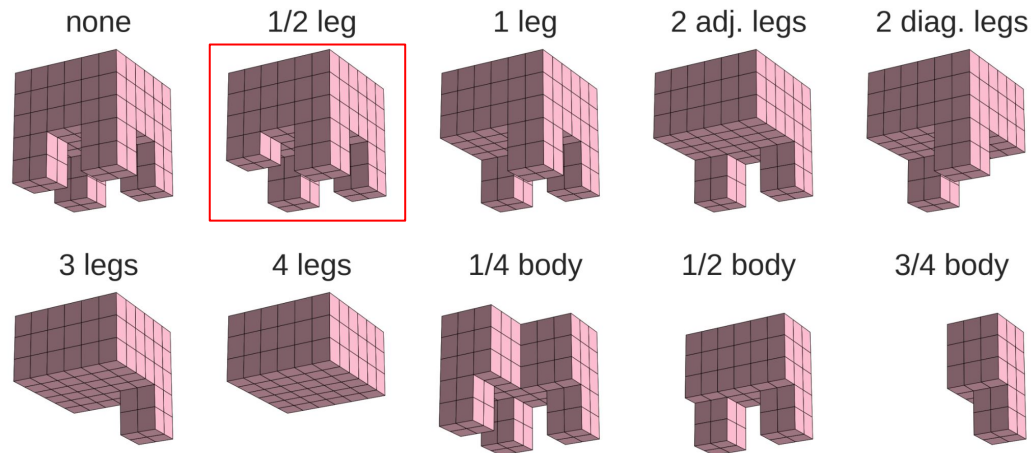


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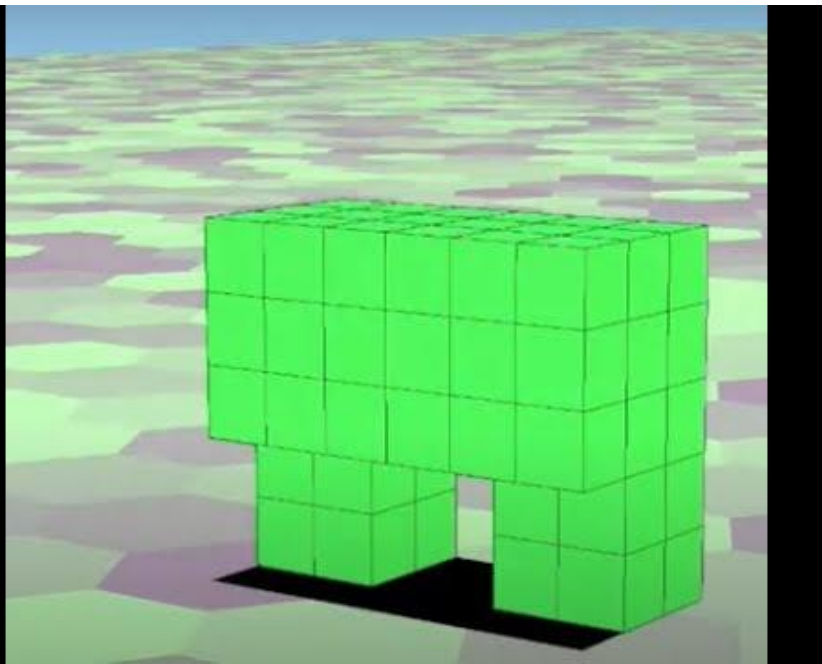
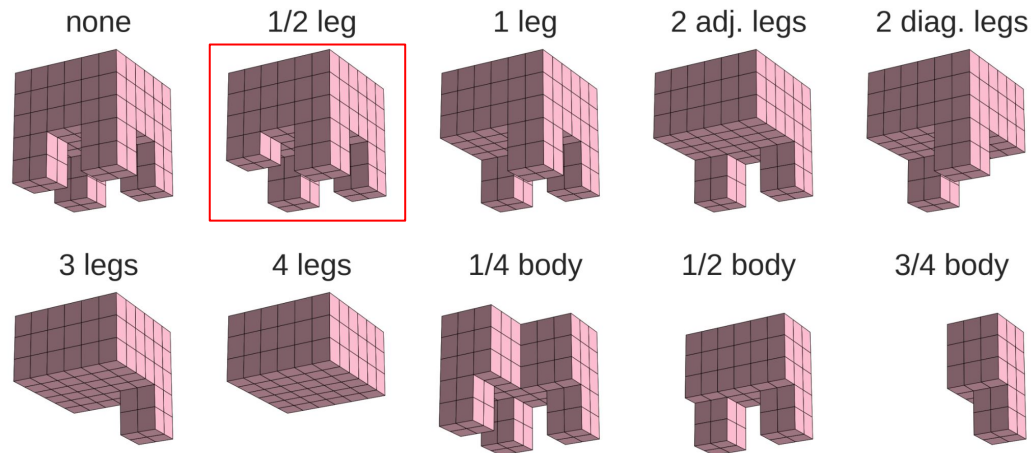




Kriegman,
Walker,
Shah,
Levin,
Kramer-Bottiglio,
Bongard.
RSS
(2019)



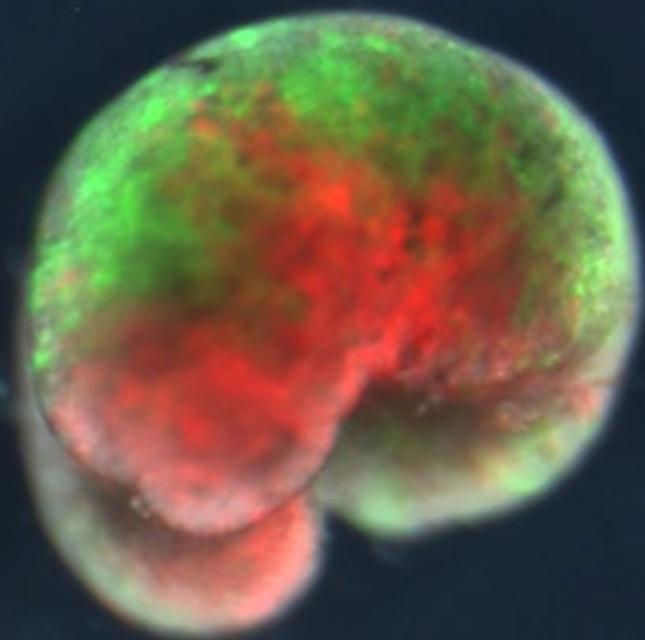
Kriegman,
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Kramer-Bottiglio,
Bongard.
RSS
(2019)

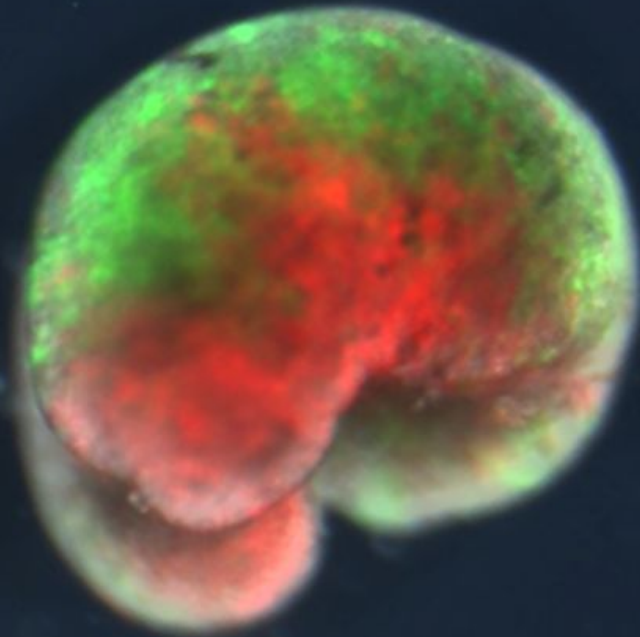
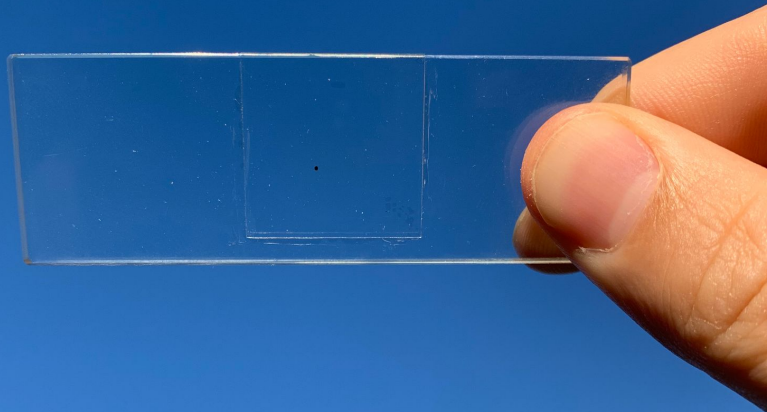


Kriegman,
Walker,
Shah,
Levin,
Kramer-Bottiglio,
Bongard.
RSS
(2019)



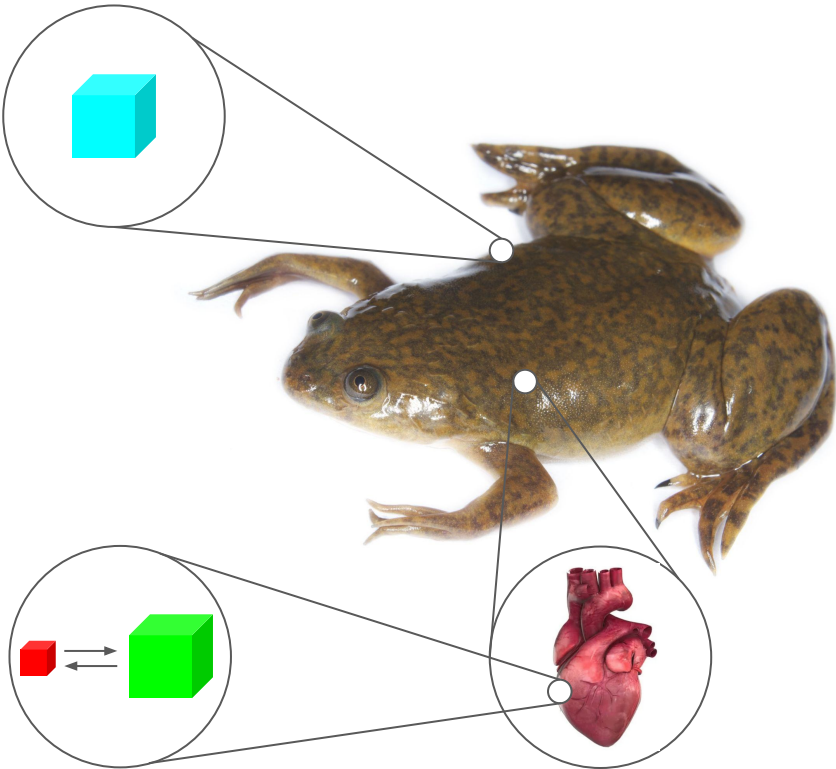
Kriegman, Blackiston,
Levin & Bongard (2020).
PNAS.



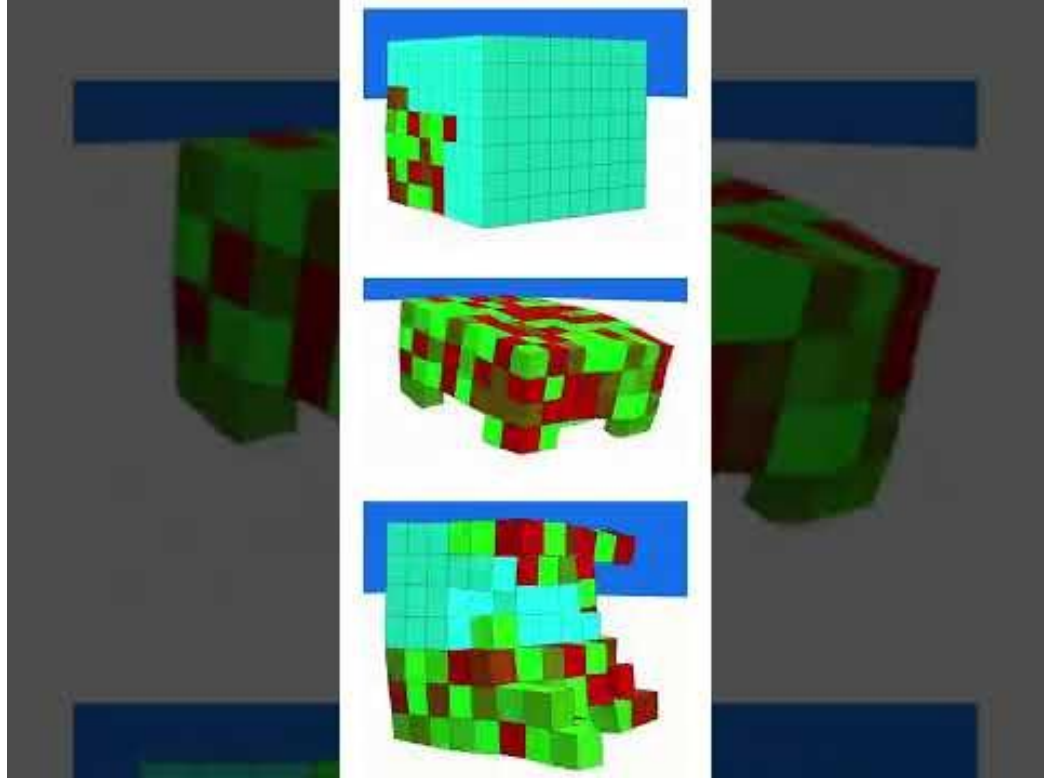
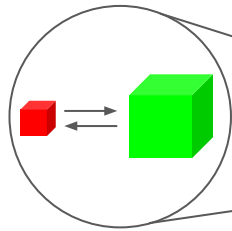
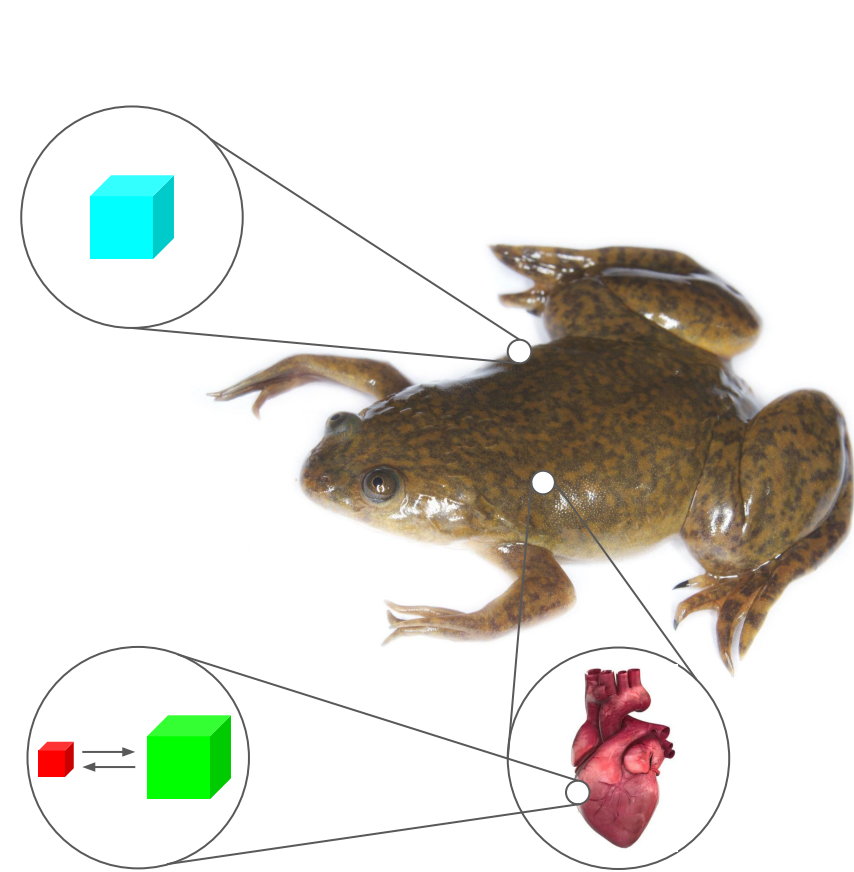


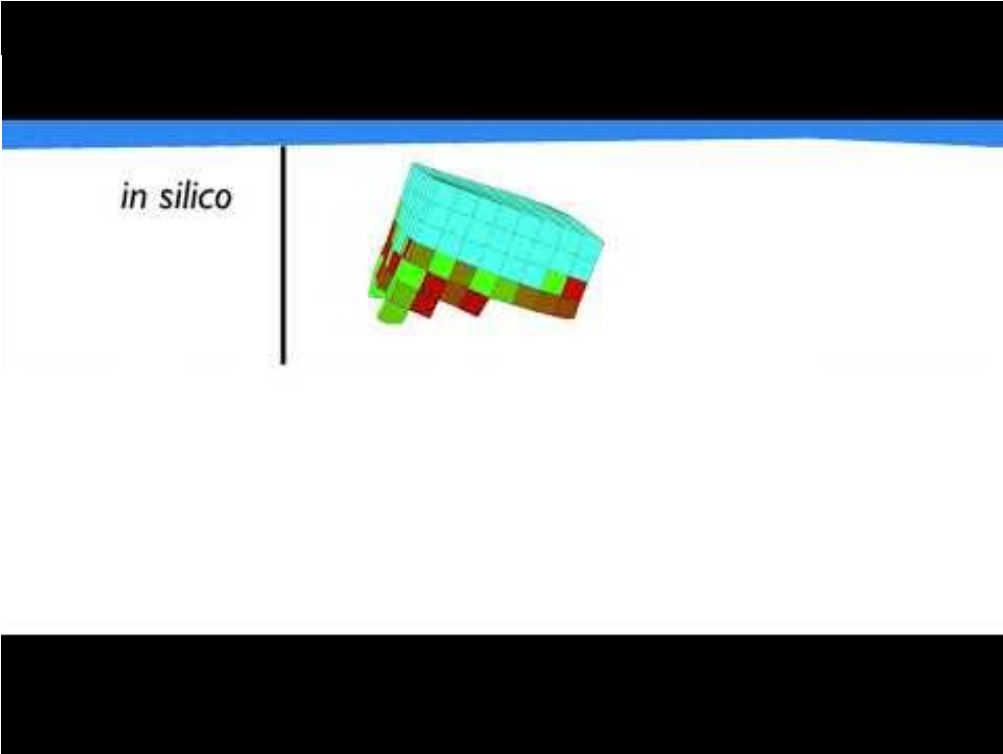
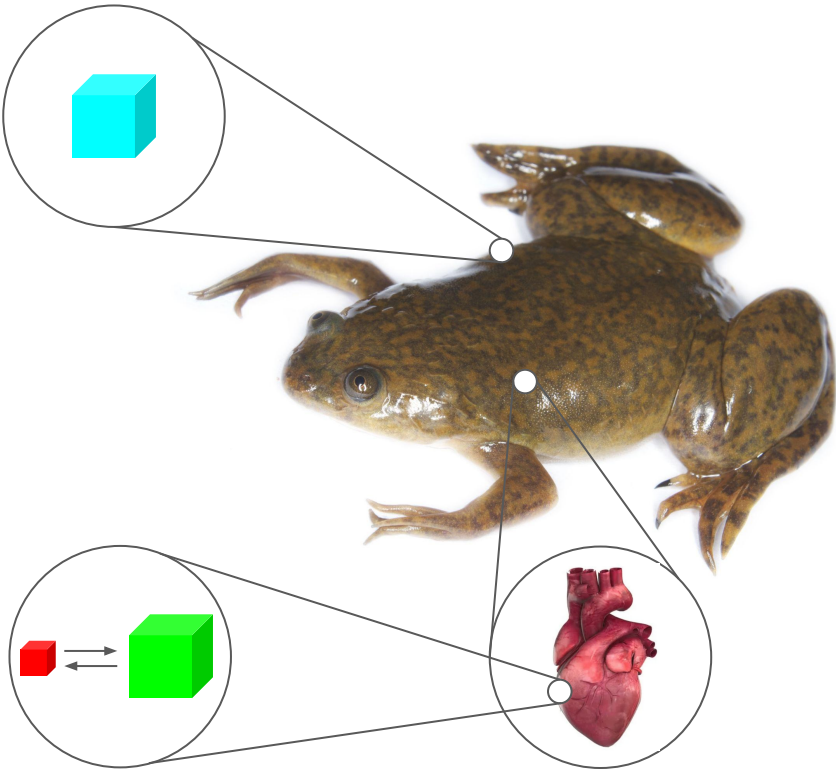


Blackiston & Levin, *J Exp Biol.* 2013

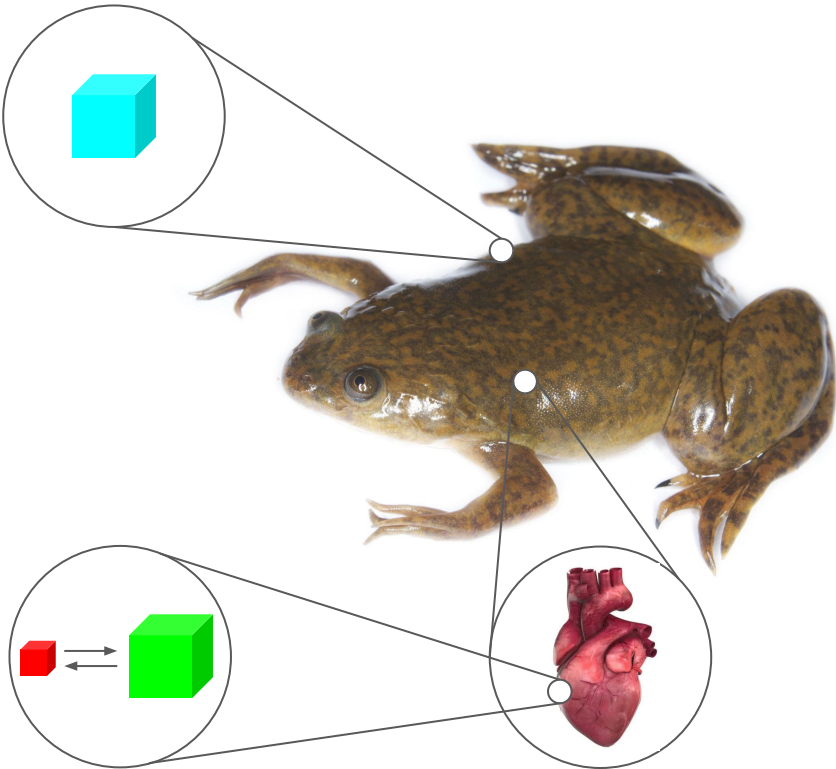


Kriegman, Blackiston, Levin & Bongard (2020). *PNAS*.

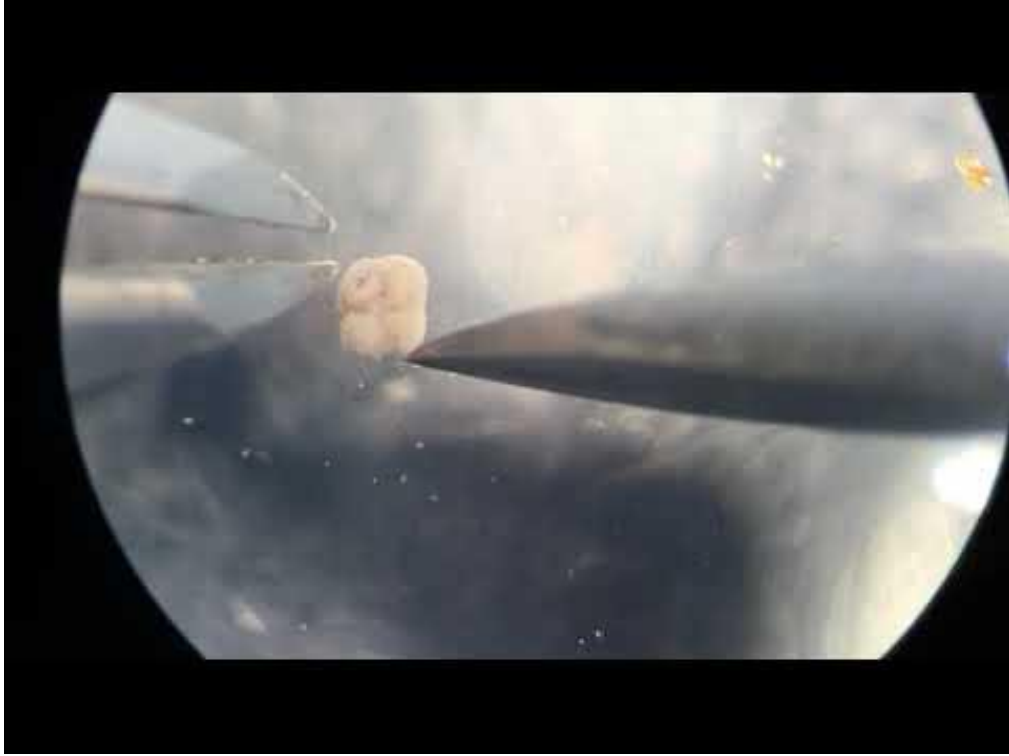
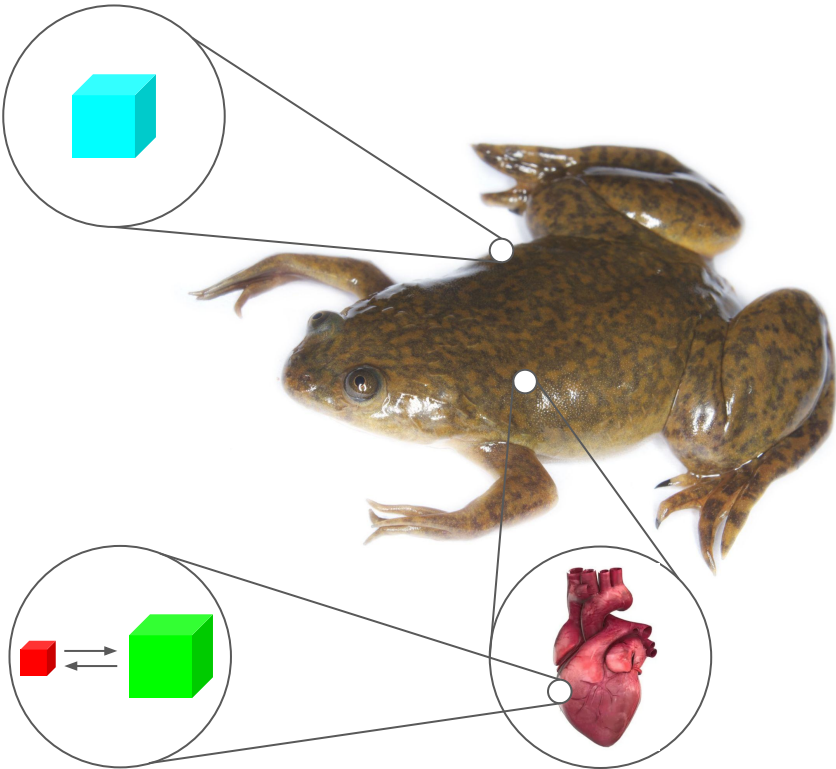




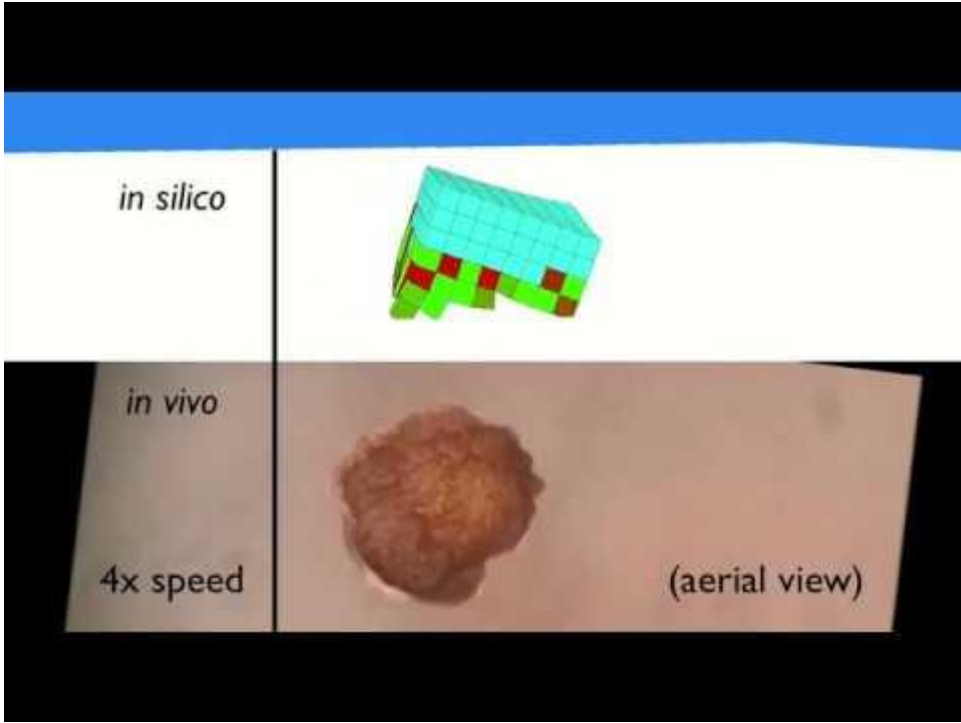
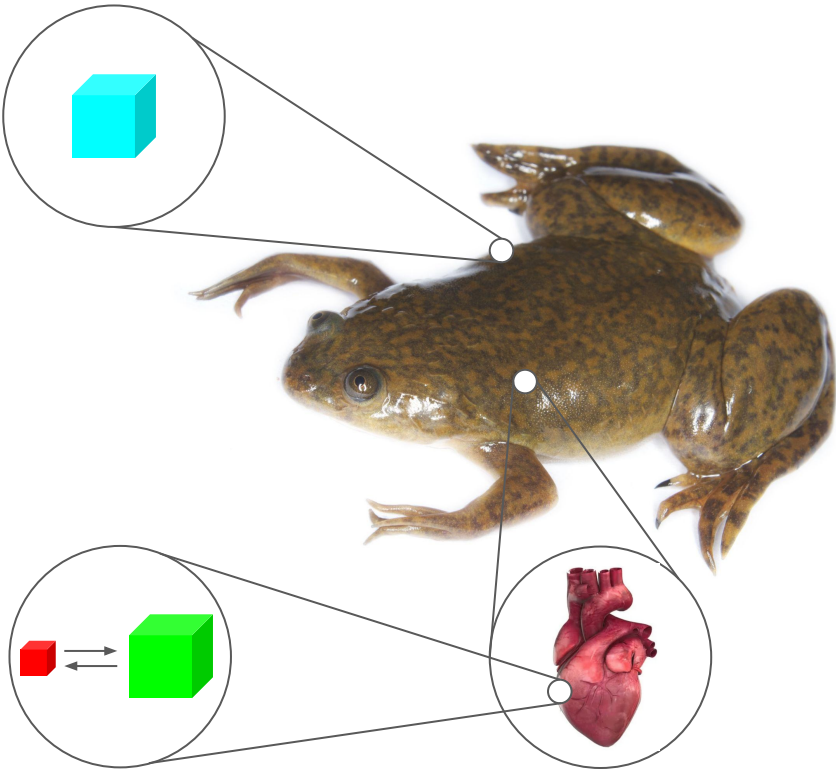
Kriegman, Blackiston, Levin & Bongard (2020). *PNAS*.



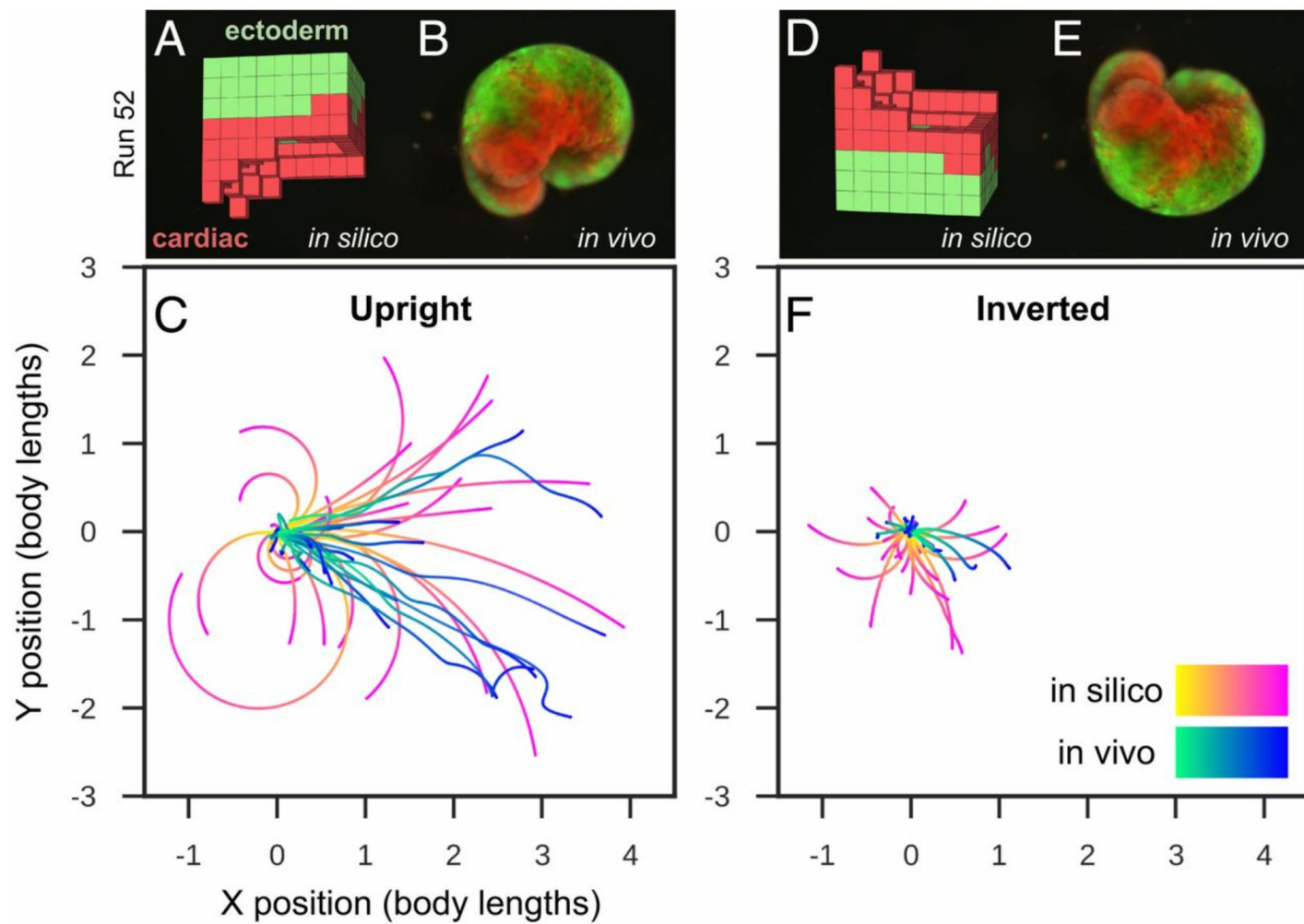
Kriegman, Blackiston, Levin & Bongard (2020). *PNAS*.

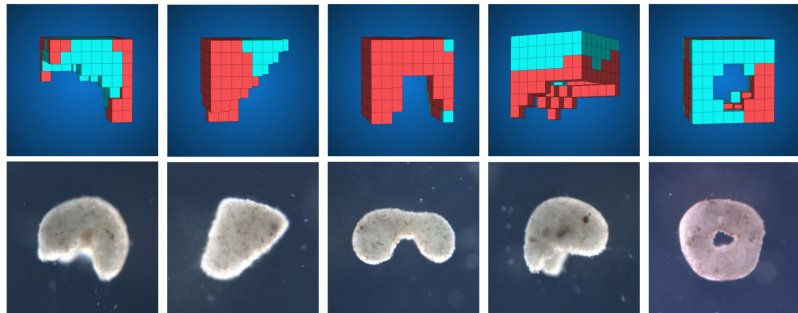
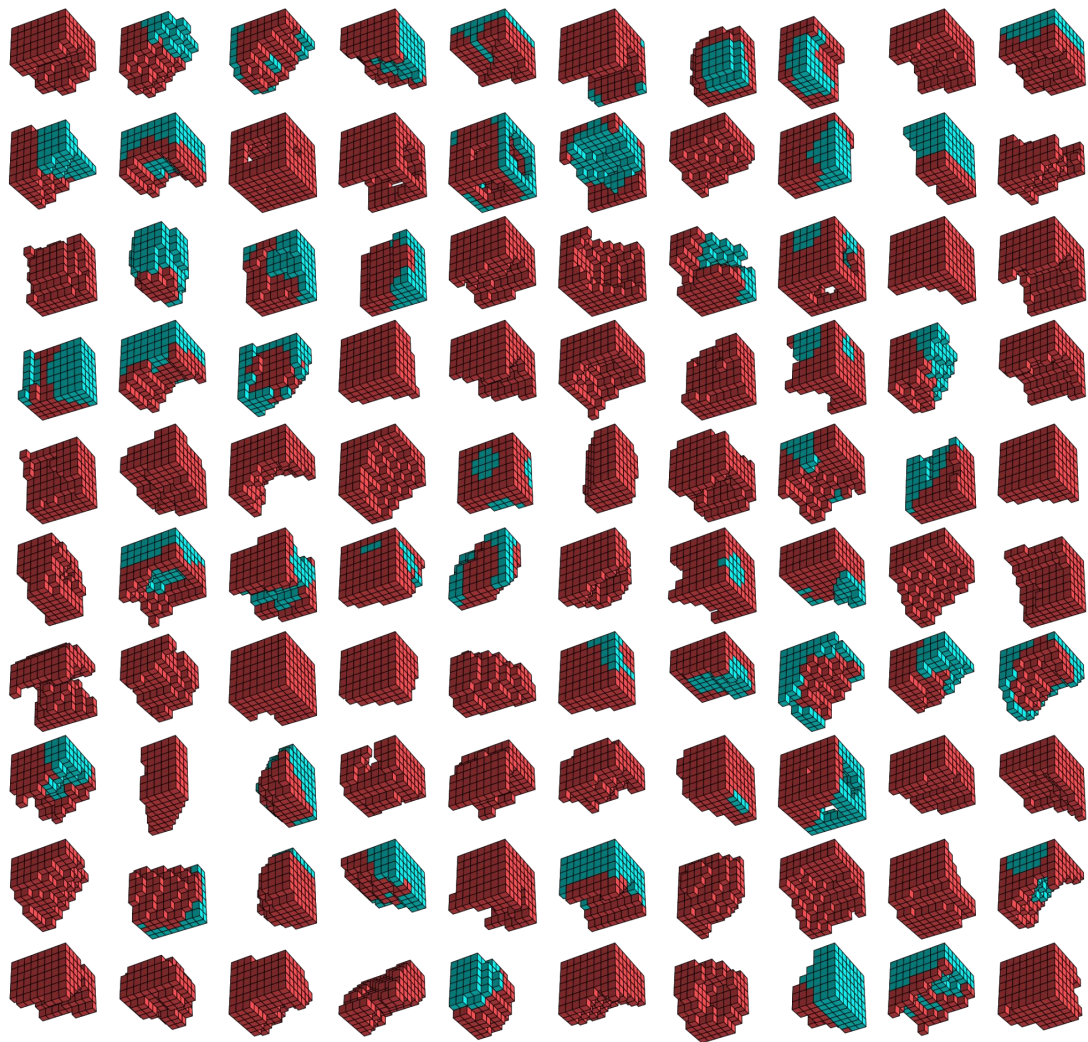


Kriegman, Blackiston, Levin & Bongard (2020). *PNAS*.



Kriegman, Blackiston, Levin & Bongard (2020). *PNAS*.

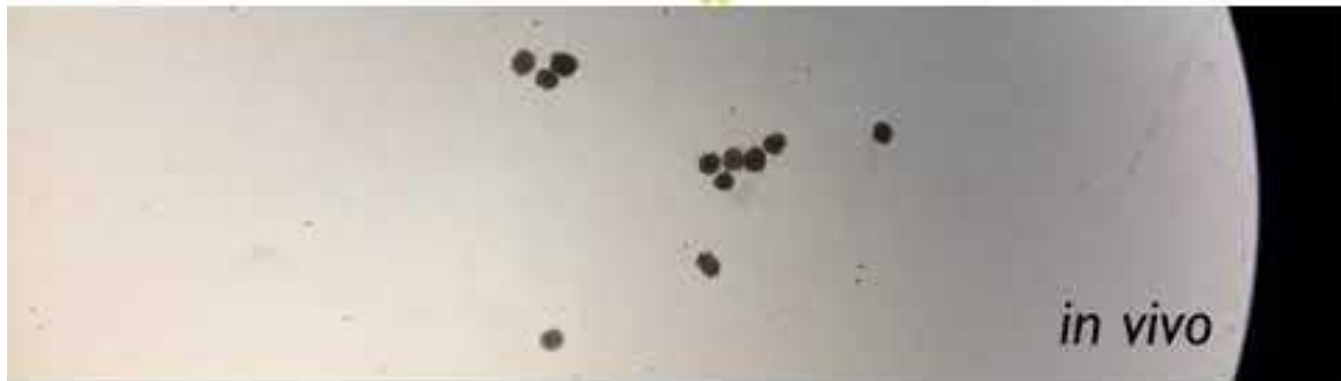




Collective
behavior

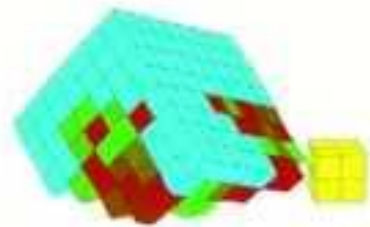


in silico



in vivo

Object
manipulation

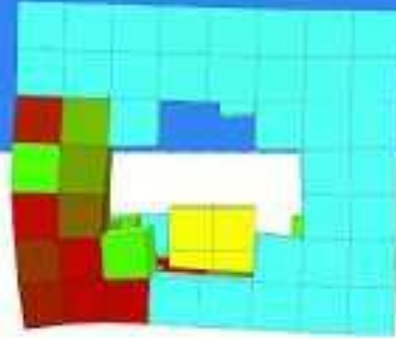


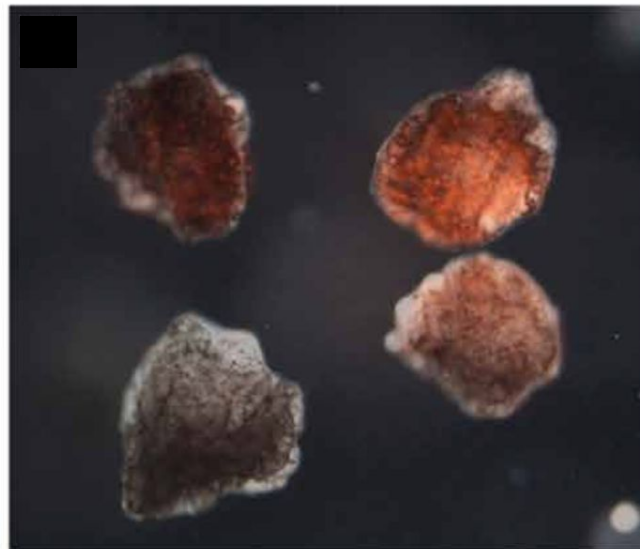
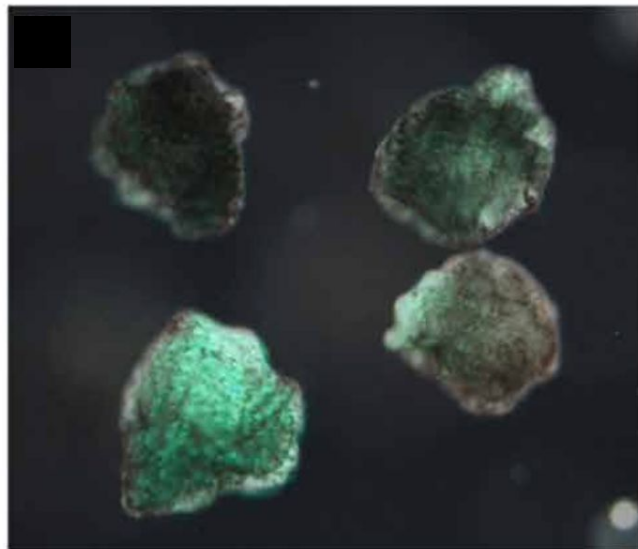
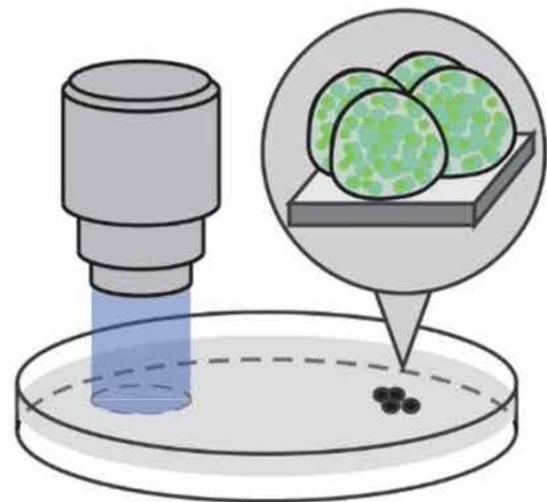
in silico



in vivo

Object transport





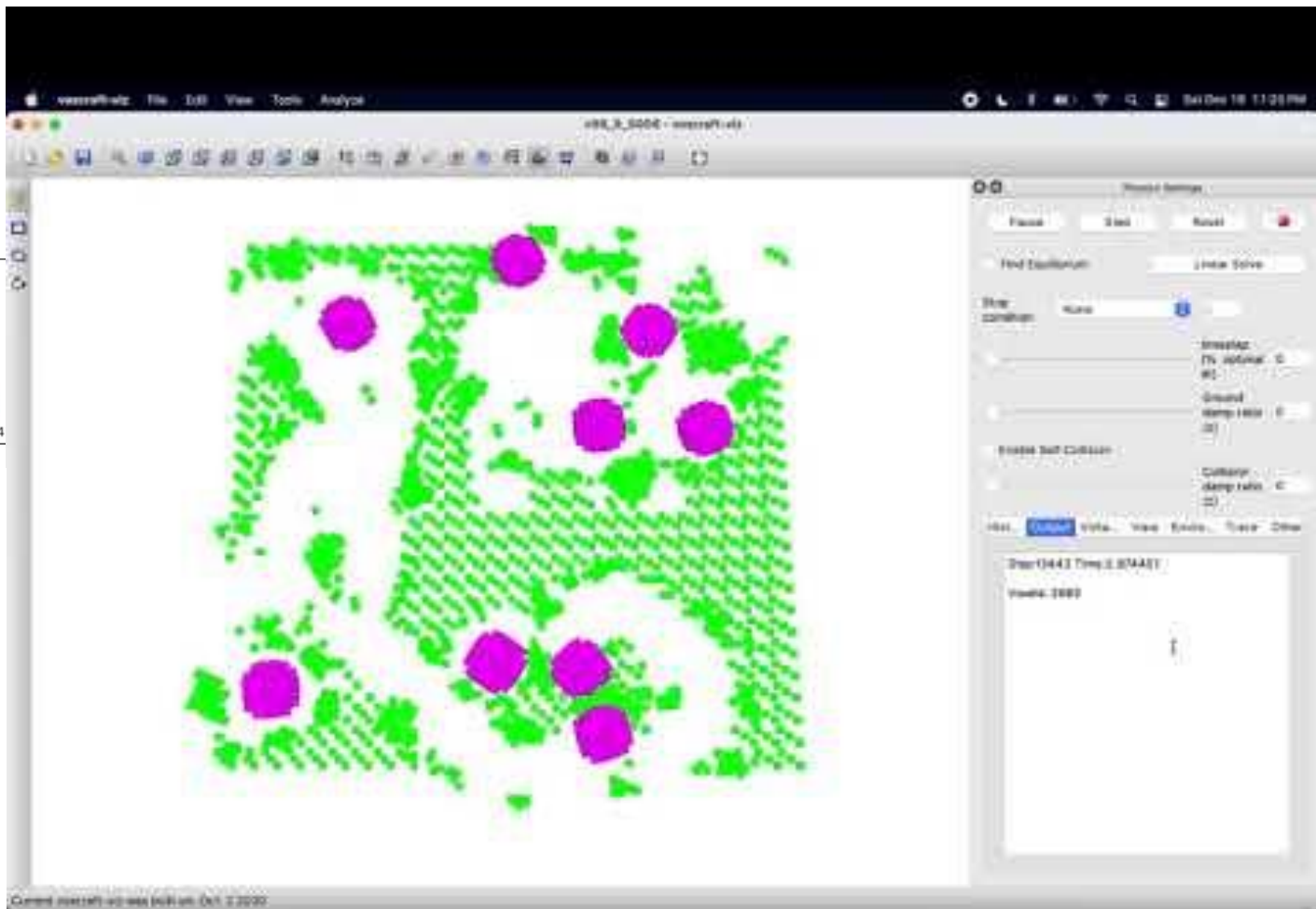
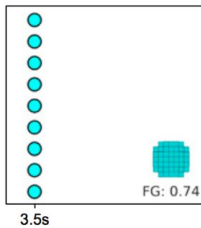
Blackiston, Kriegman,
Bongard & Levin (2021).
Science Robotics.



Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.



Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.



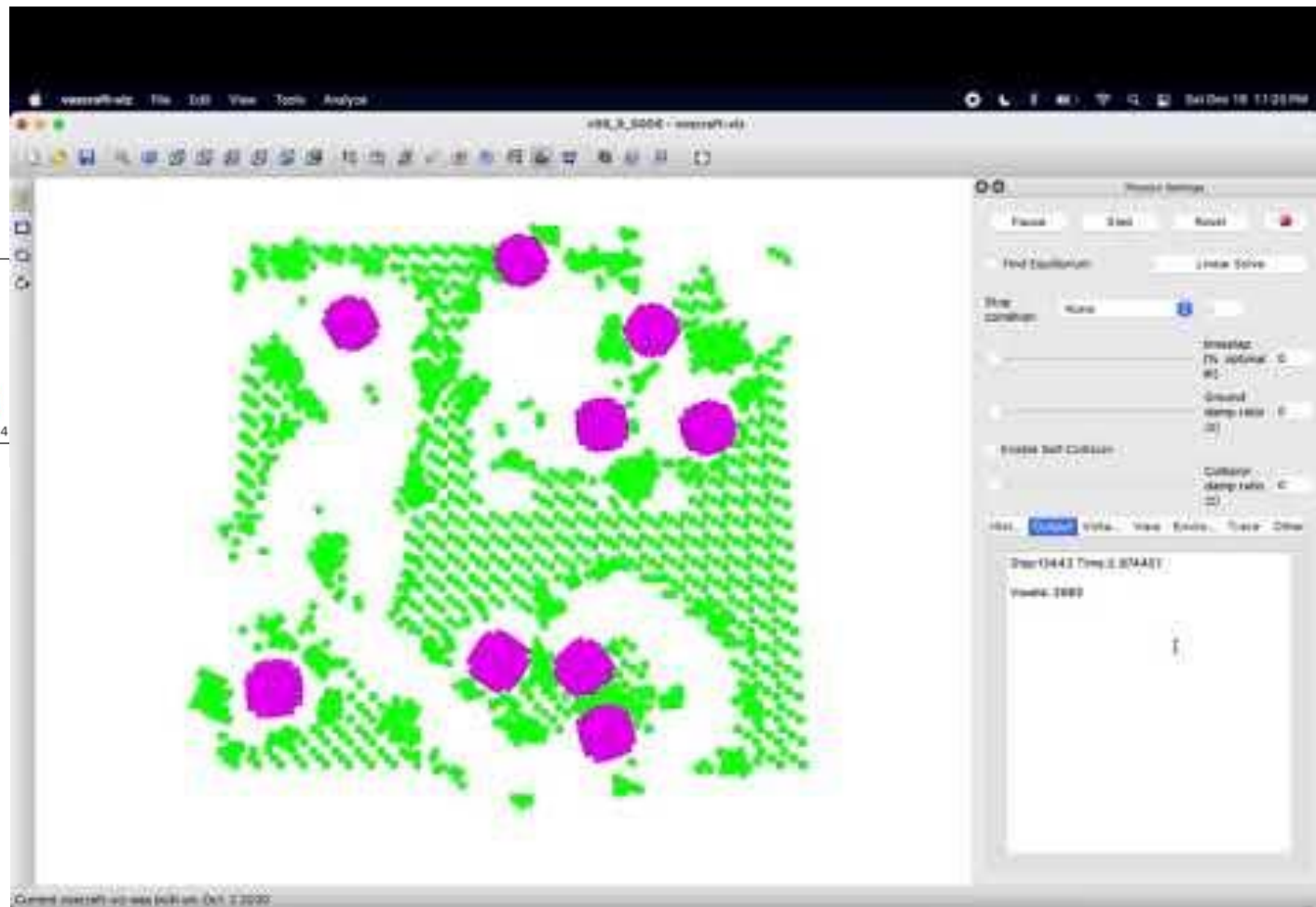
Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.



FG: 0.74

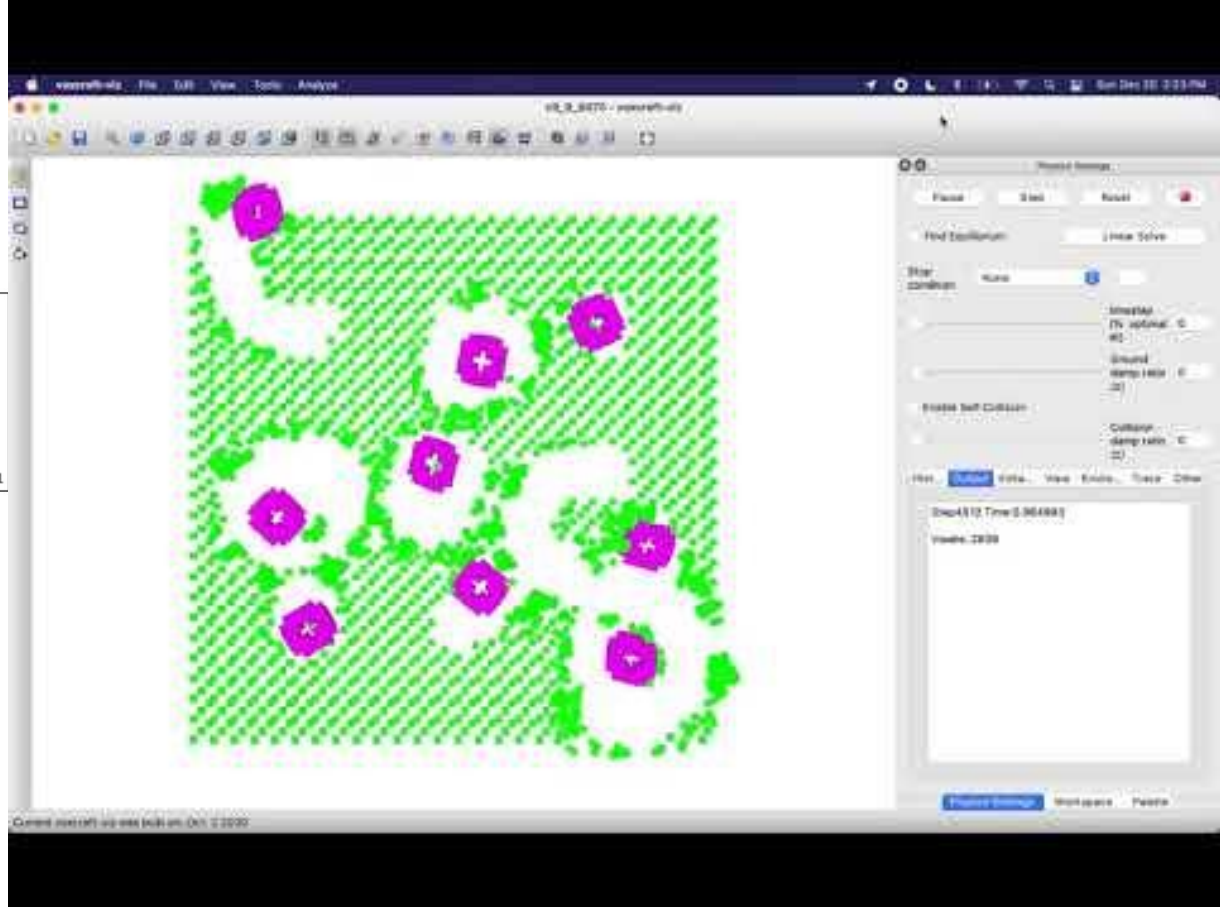
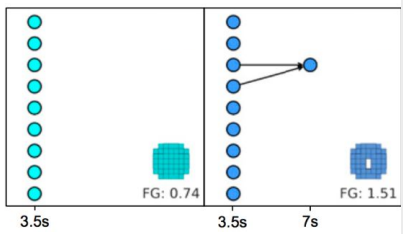
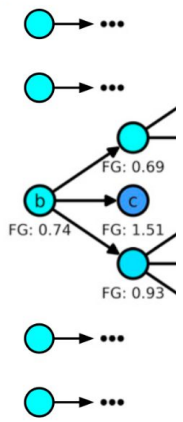


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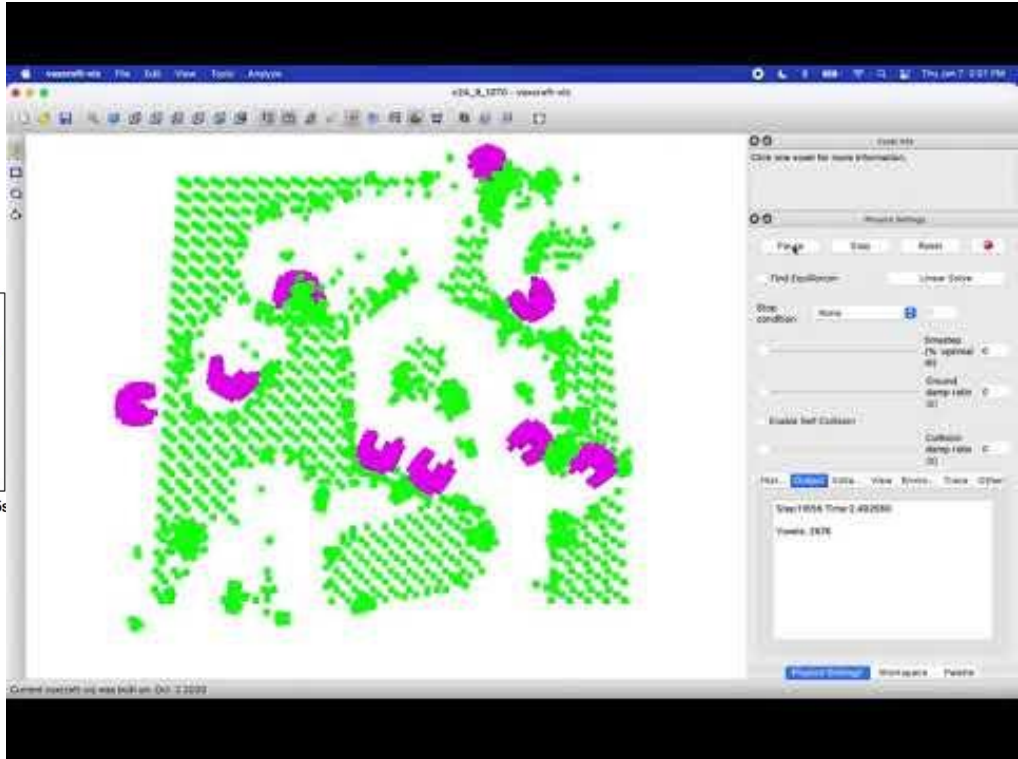
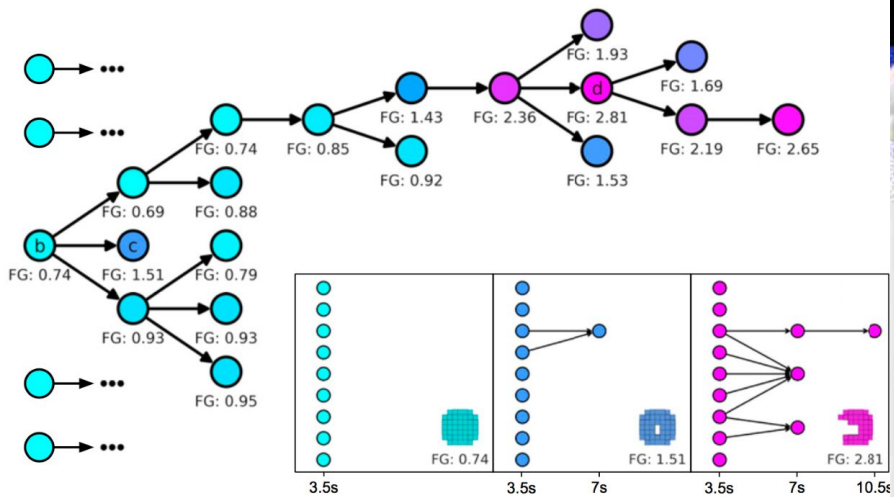


Control Panel (1) - 100% (10/11/2021)

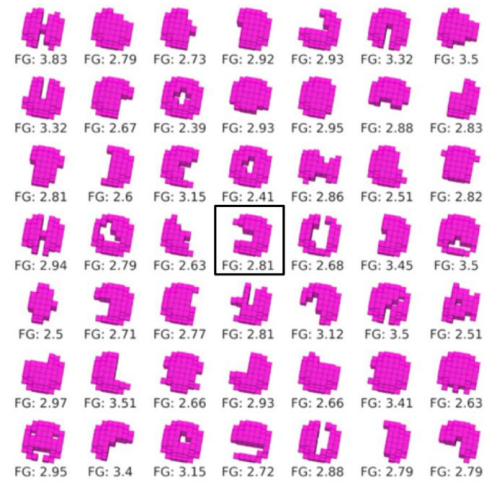
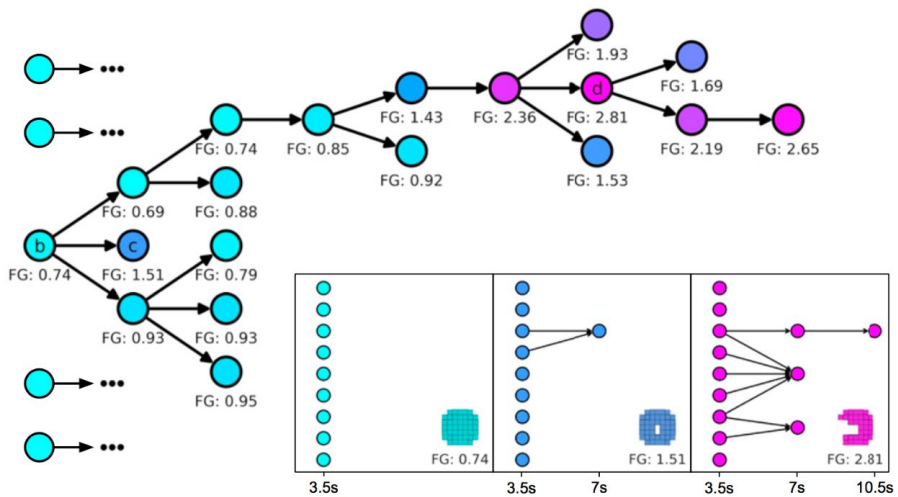
Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.

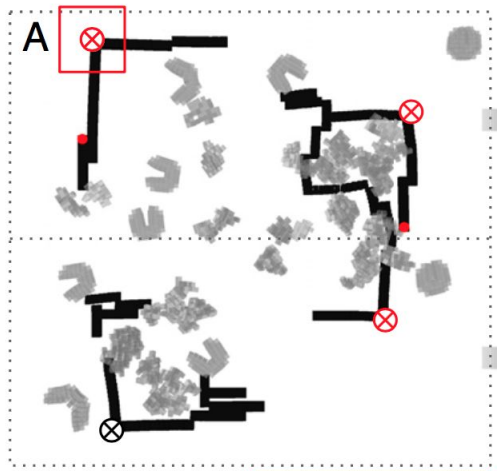


Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.

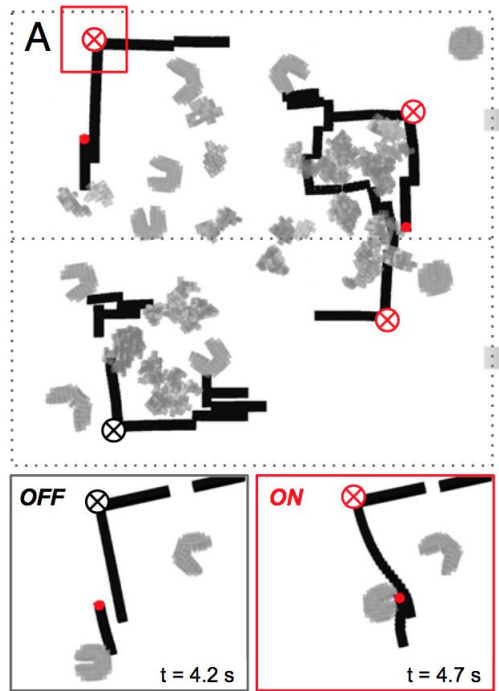


Kriegman, Blackiston, Levin & Bongard (2021). *PNAS*.

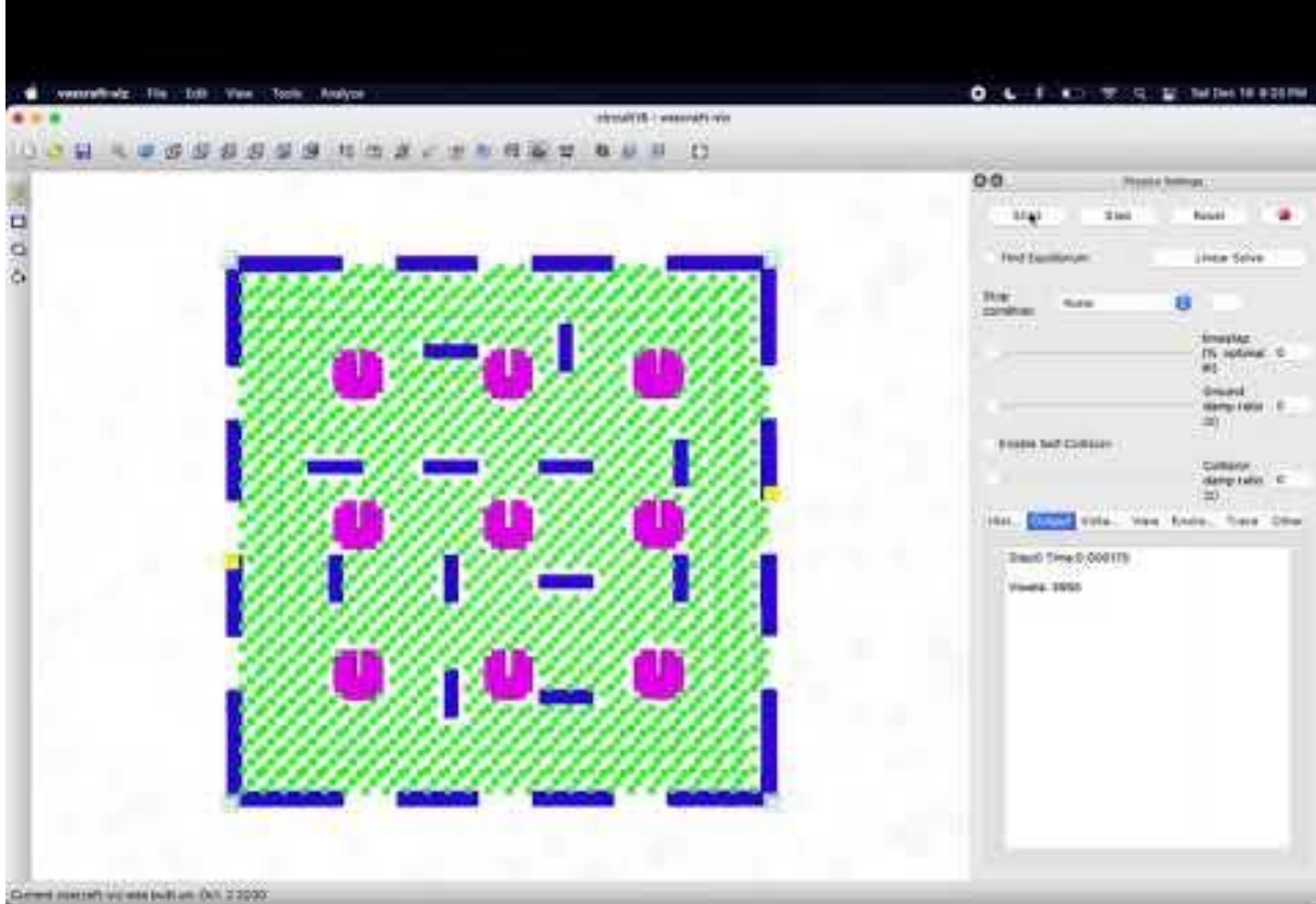




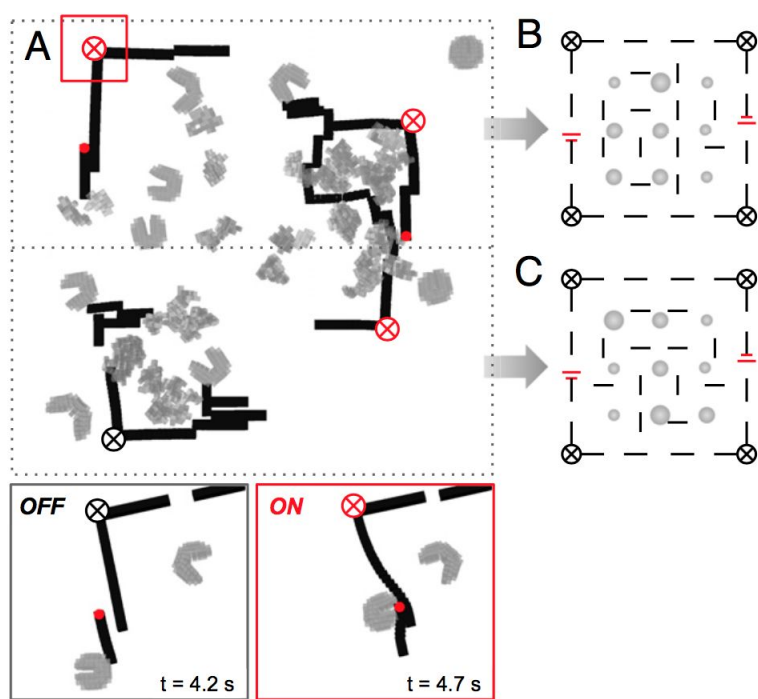
Kriegman, Blackiston,
Levin & Bongard (2021).
PNAS.



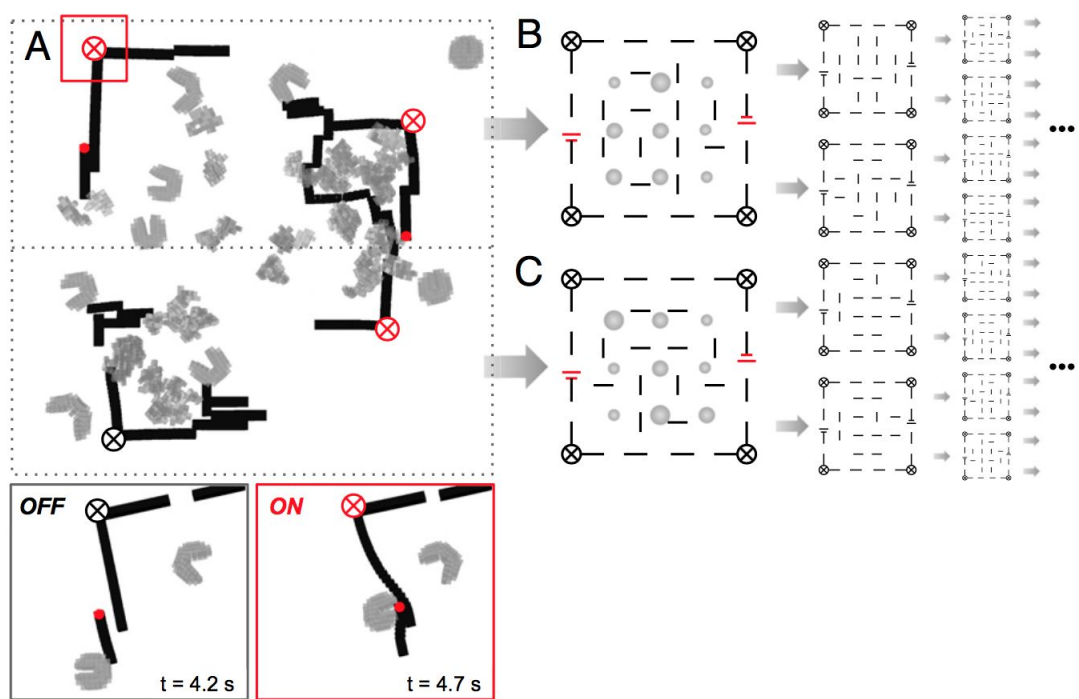
Kriegman, Blackiston,
Levin & Bongard (2021).
PNAS.



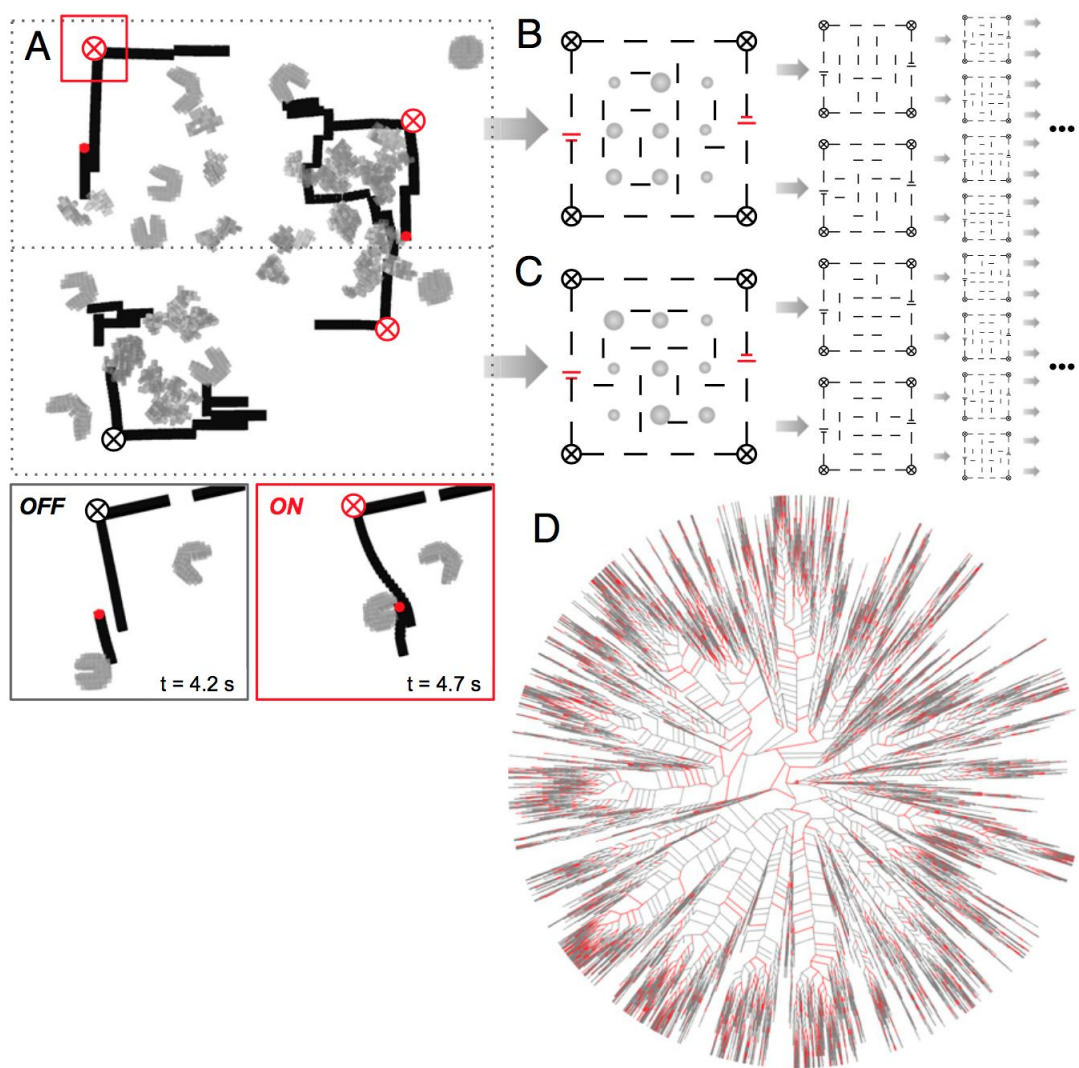
Kriegman, Blackiston,
Levin & Bongard (2021).
PNAS.



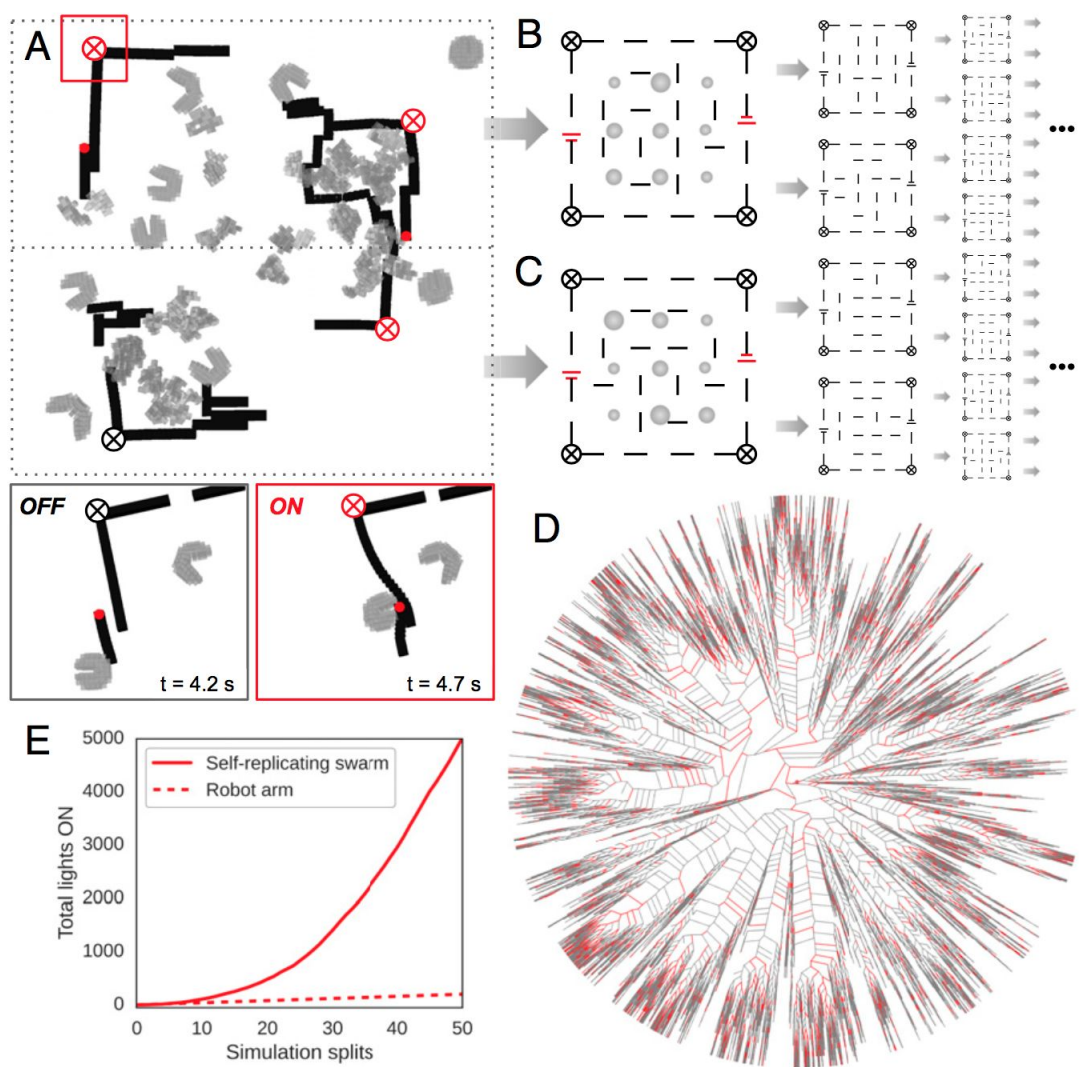
Kriegman, Blackiston,
 Levin & Bongard (2021).
PNAS.



Kriegman, Blackiston,
 Levin & Bongard (2021).
PNAS.



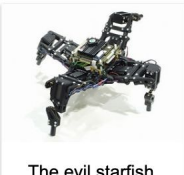
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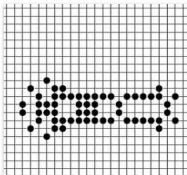
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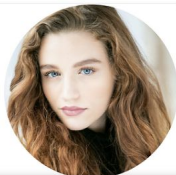
Josh Bongard
Lab director.



The evil starfish.
Lab mascot.



Tyrell Davis
Postdoc (2021-)



Piper Welch
PhD student (2022 - present)



Kam Bielawski
PhD student (2022 - present)



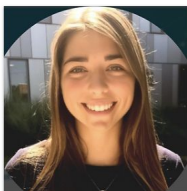
Doug Blackiston
Tufts



Atoosa Parsa
PhD student (2019-)



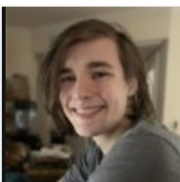
Amanda Bertsc...
PhD student (2020-)



Caitlin Grasso
PhD student (2019-)



Krishna Sriniva...
PhD student (2021 - present)



Nathan Tolley
MSc student (2020-present)



Mike Levin
Tufts



The
UNIVERSITY
of
VERMONT



Ryan Grindle
MS student (2018-2020)



David Matthews
Undergrad intern (2018-2022)



Alex Medvedeff
MSc student (2022)



Sidhanth Kafley
Undergrad intern (2020-2022)



Rachel Dotey
Developer (2018-2021)



Sam Kriegman
PhD student (2016-2020).

