Behavior Science and Psychoanalysis of Unconventional Intelligences: From Laboratory Models to a Society of Radically Diverse Minds

Michael Levin
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http://www.drmichaellevin.org/

http://thoughtforms.life/

ALLEN DISCOVERY CENTER at Tufts University

Computer-designed Organisms
TUFTS UNIVERSITY | UNIVERSITY OF VERMONT

WYSS INSTITUTE

HARVARD

Overview:

- Introduction: why a talk from a computer scientist and developmental biologist?
- TAME: a framework for diverse intelligence research and applications
- Morphogenesis: a model system for communicating with semi-alien minds
- The future of the sciences of ~~the mind~~ minds

Sentient beings are innumerable,
I vow to liberate them all

— from the Four Bodhisattva Vows

Perspective is key

Cognitive claims are tests for observers (of intelligence and imagination; maybe wisdom; certainly compassion)

This is Our Future:

Non-neurotypical doesn't even begin to cover it

These issues are not about "them" - they're about us (broader)

Summary:

- The road to transformative regenerative medicine leads directly to freedom of embodiment. There is no timeline in which humanity keeps the same hominid form factor and psyche into the future.
    - This is now, not sci-fi
- The road to a mature species leads through overcoming our mind-blindness
    - This means understanding our nature, our origins, our potential, and the meaning of “our”.

The Continua of our Past and Future

Summary:

- My present, as a scientist of embodied intelligence:
    - Intelligence, and diseases of cognition (not well-captured by models of organic disease - hardware issues) are way older than neurons and brains
    - Borrowing tools of somatic psychiatry, because “you” are not the only intelligence in your body, and 3D “behavior” is not the only kind of behavior

Novel Beings, Novel Minds: it's not about LLMs

PERSPECTIVE

ADVANCED INTELLIGENT SYSTEMS
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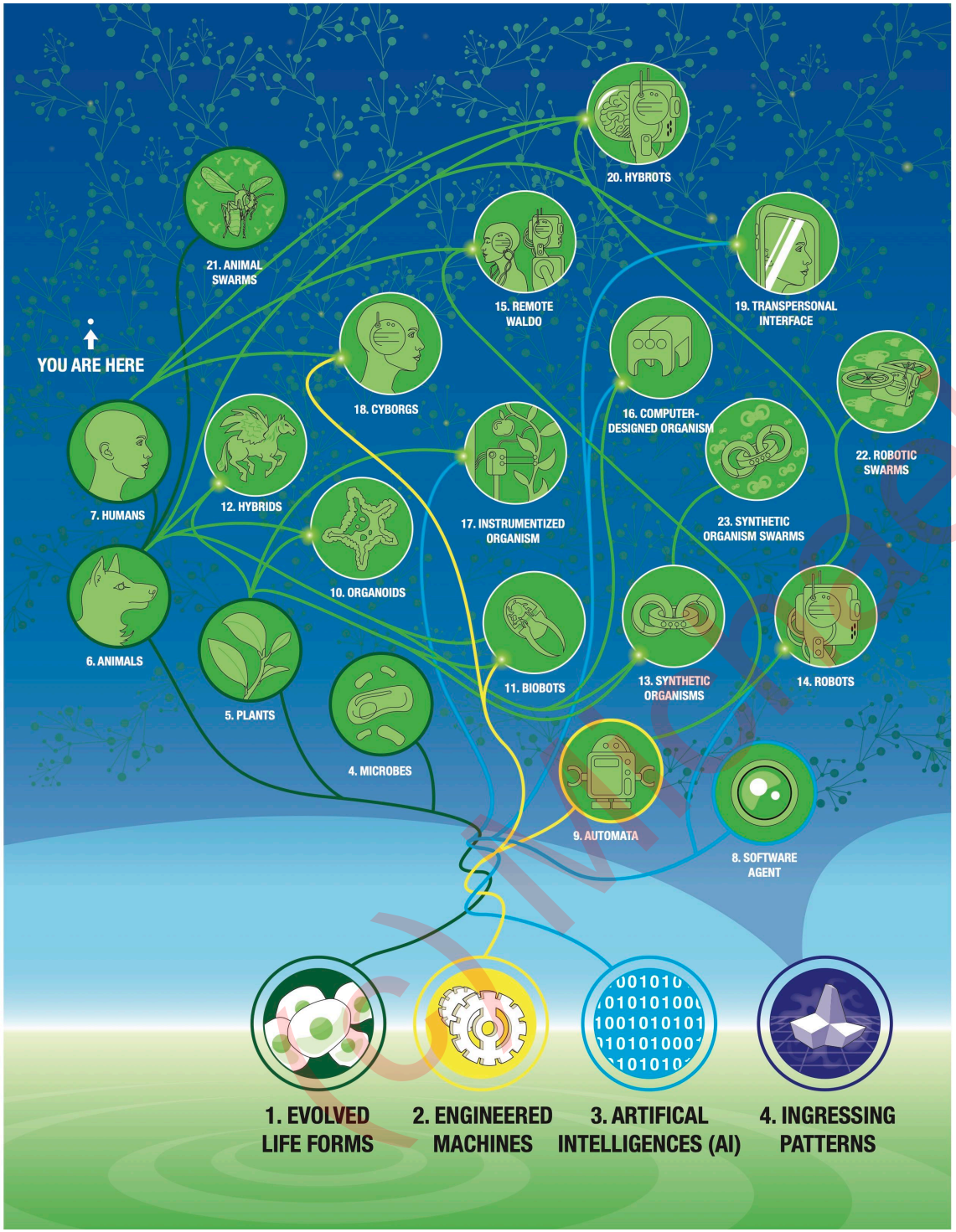
www.advintellsyst.com

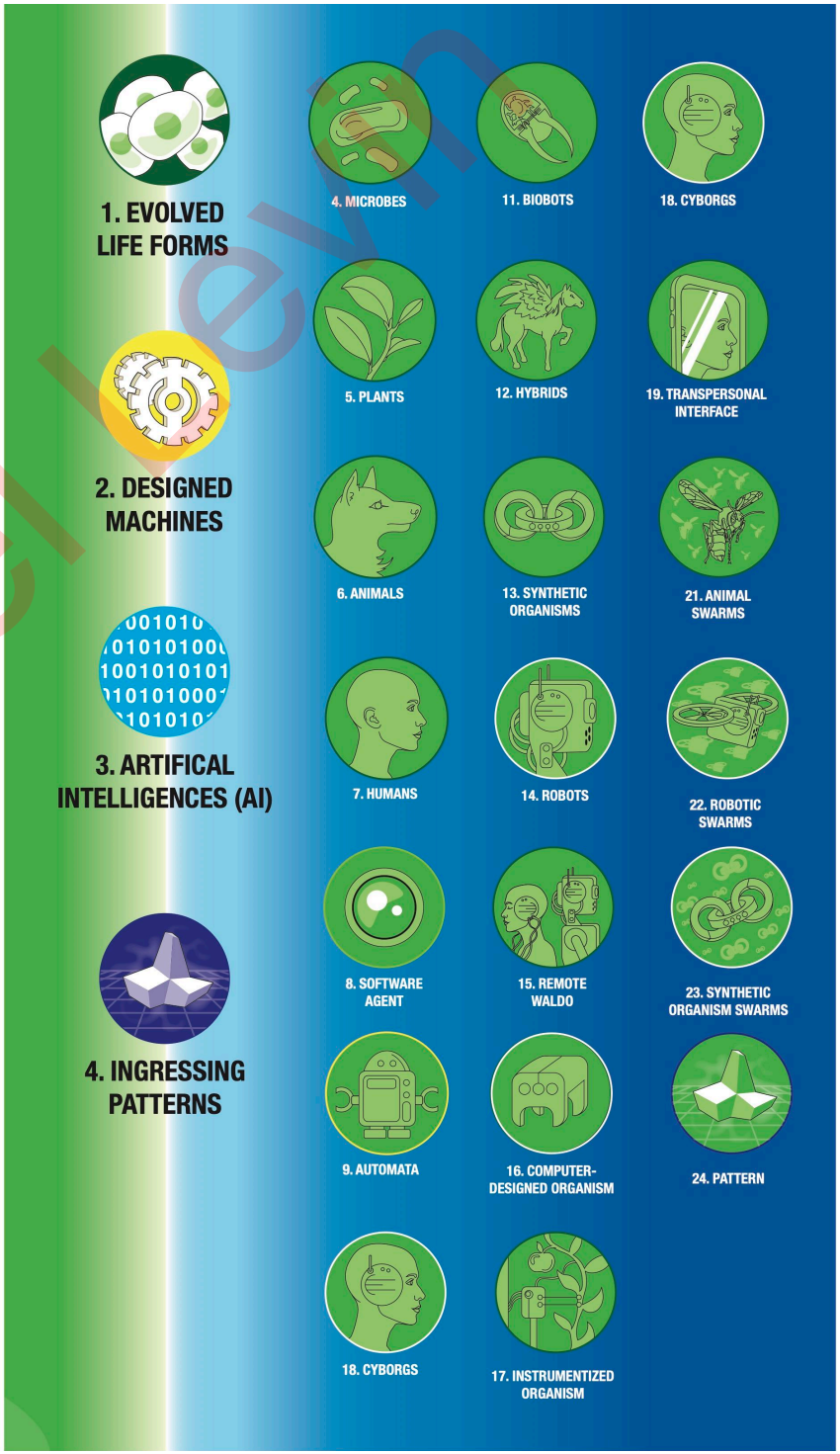
Artificial Intelligences: A Bridge Toward Diverse Intelligence and Humanity's Future

Michael Levin

Most of the issues brought up by AI are reflections of fundamental unsolved questions about ourselves

“Endless Forms Most Beautiful”<—>ethical synthbiosis





Summary:

- Your future, as mental health professionals:
  - Mental health diseases of novel beings
  - Patients with alien and highly diverse Umwelts, sensory motor capabilities, connections, IQs, goals, opportunities
  - Dream analysis, collective unconscious, and symbology of beings who do not share our evolutionary history
  - Novel sources of mental architectures and trauma
  - Testifying in court cases re. enhanced capacity and novel challenges to the free will question
  - Beyond disease: a good and meaningful alien life

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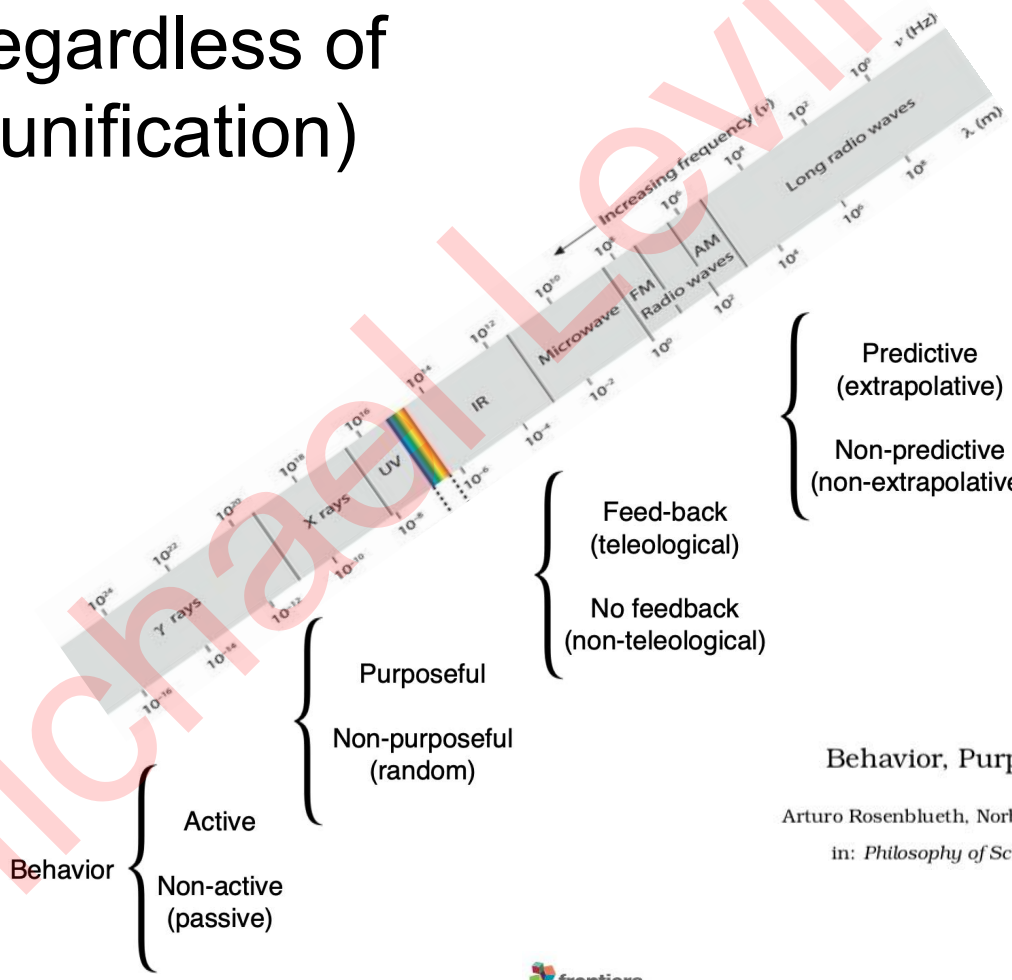
My Framework Goal:

- Recognize, create, and relate to truly diverse intelligences regardless of composition or origin (unification)

- familiar creatures - us, apes, birds, octopus
- weird creatures (colonial organisms, swarms)
- synthetic biology - engineered new life forms
- AI (software or robotic)
- exo-biological agents (Earth is N=1)
- patterns in physical media
- patterns in Platonic Space



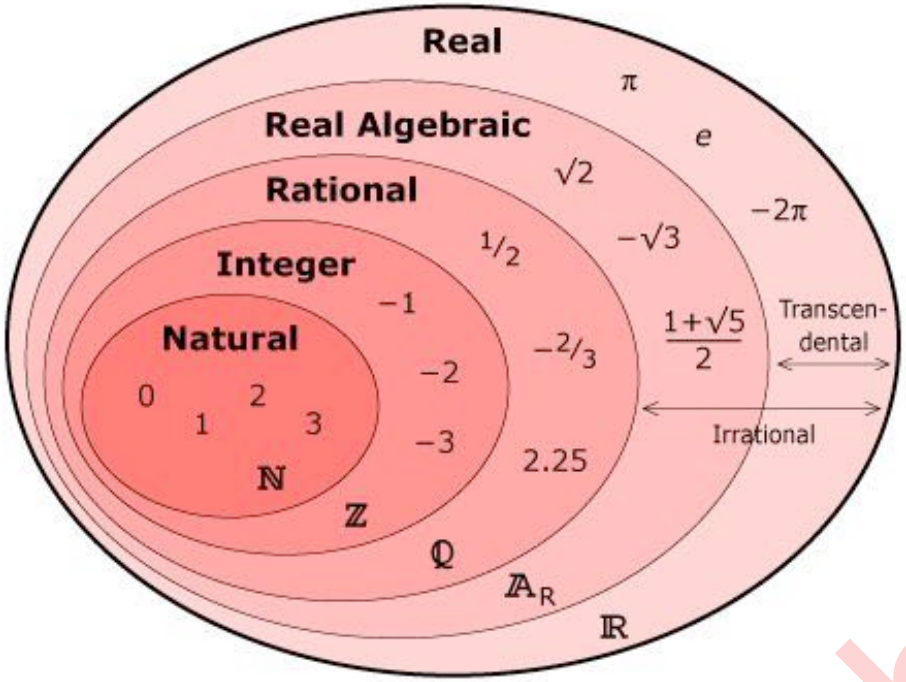
Behavior, Purpose and Teleology

Arturo Rosenblueth, Norbert Wiener and Julian Bigelow

in: *Philosophy of Science*, 10(1943), S. 18–24.

- moves experimental work forward - new biomedical and synmorpho capabilities, better ethics

Expanding the Set of Cognitive Kin



https://in.pterest.com/pin/627970741770398254/

frozen patterns

active patterns

evolved +
designed +
hybrid agents

all
biologicals

complex
life forms

brainy
animals

<u>For each new category</u>

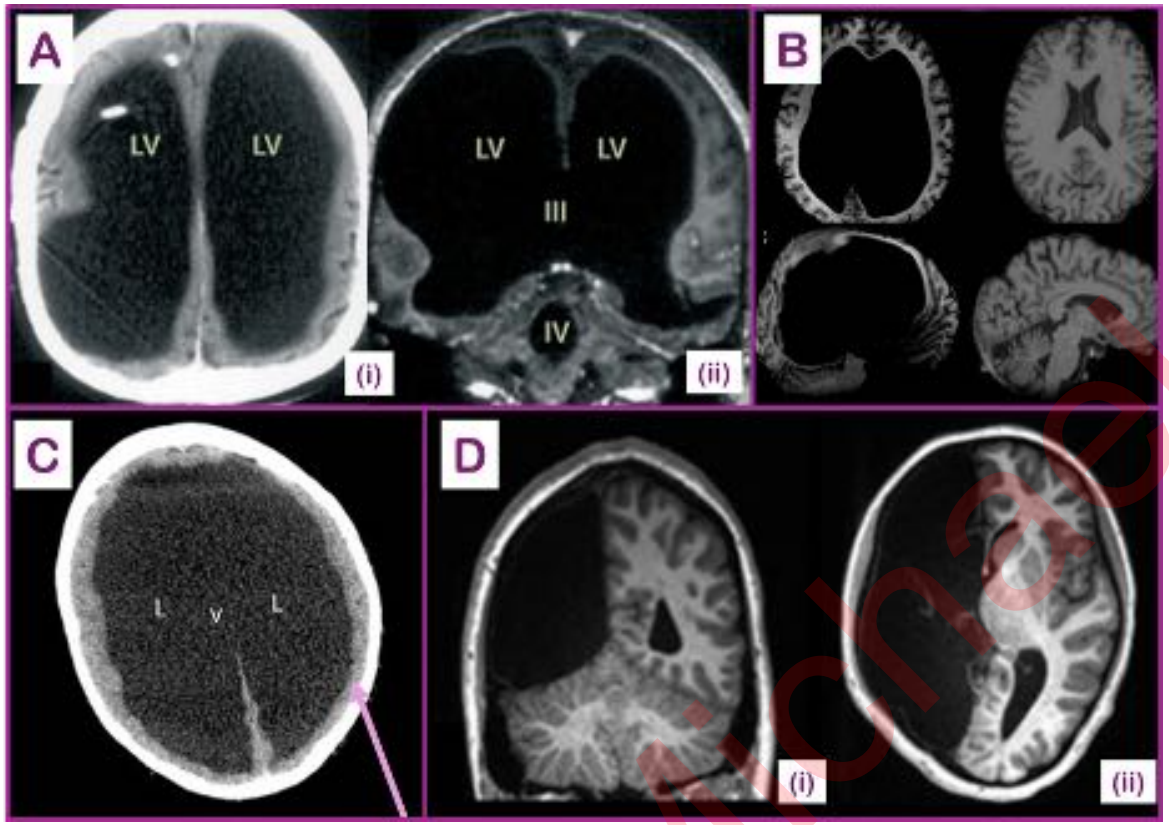
- conceptual leap needed
- what does it break?
- recognize them
- do something useful with them
- active compassion toward them

Easy to Detect Mind in Brainy Mammals

https://www.youtube.com/watch?v=f75Vet_sJNo

Why so obvious? Same spatiotemporal scale, same space, similar goals

Even with brains, things are not simple



Minimal brain structure

or function (Savant syndrome)

cases of high performance

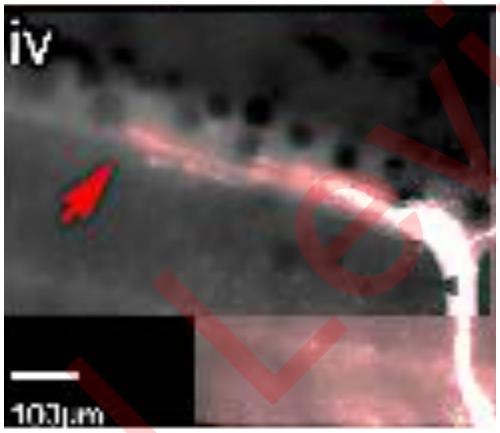
Mind & Matter **23**(1), 13-69 doi: 10.5376/mm2025.13

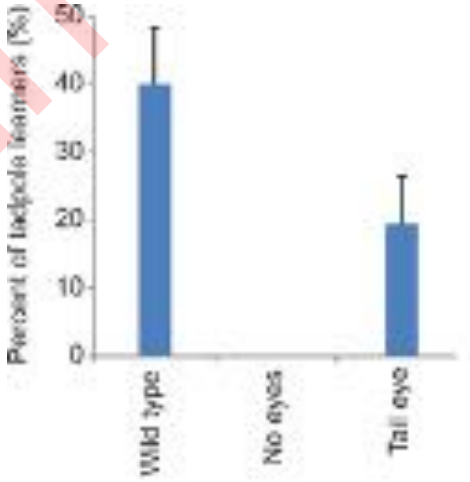
Cases of Unconventional Information Flow Across the Mind-Body Interface

Karina Kofman
Faculty of Dentistry, University of Toronto
Toronto, Canada
and
*Michael Levin**
Allen Discovery Center
Tufts University, Boston, USA
and
Wyss Institute for Biologically Inspired Engineering
Harvard University, Cambridge, USA

Figure 2. Select cases of reductions in brain matter with normal function. **[A]** Image from (Feuillet *et al.* 2007) showing a white collared worker case of extreme hydrocephalus**;** he led a normal life as a civil servant, who possessed an average IQ of 75. During his neurological assessment at age 44, his (i) CT scan and (ii) T1 weighted MRI scans with contrast showed extreme ventricular enlargement**.** LV indicates lateral ventricle, III and IV indicate the third and fourth ventricles, respectively. **[B]** Image from (Alders *et al.* 2018), showing the case of a 60-year-old with a bad mood with massive ventriculomegaly and severely reduced cerebral mantle and corpus callosum, that went largely unnoticed. The left column is T1 weighted MRI images taken in the transverse, coronal, and sagittal planes of the patient. The right column represents T1 weighted MRI scans of a healthy control. **[C]** Image from (Persad *et al.* 2021), imaging of a Canadian living a normal, independent life with massive hydrocephaly. MRI scan taken from the axial view (plane parallel to the ground) at the level of the lateral ventricles (arrow points to extremely thin layer of cortical mantle, LV stands for Lateral Ventricle). **[D]** Image from (Asaridou *et al.* 2020), showing the T1 Weighted MRI scans of a child born without left hemisphere (i) taken in the coronal plane, (ii) taken in the axial plane. The child had normal cognitive development and language skills despite hemihydranencephaly of the left hemisphere and near-absence of the corpus callosum. All images re-used with permission.

Latent Plasticity: eye on tail





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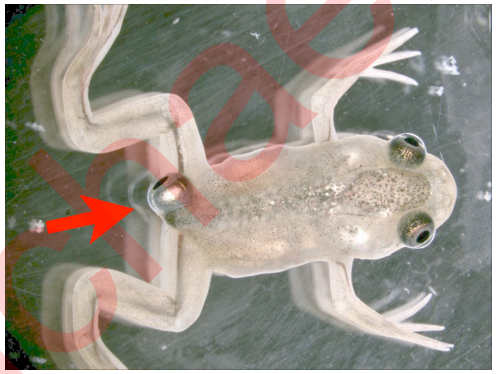
Behavioral Testing Device

Douglas Blackiston



The Journal of Experimental Biology 216, 1031-1040
© 2013. Published by The Company of Biologists Ltd
doi:10.1242/jeb.074963

RESEARCH ARTICLE

Ectopic eyes outside the head in *Xenopus* tadpoles provide sensory data for light-mediated learning

Douglas J. Blackiston and Michael Levin*

Ectopic eyes on tail provide vision!

Brain dynamically adjusts behavioral programs to accommodate different body architectures, no lengthy adaptation needed!

What would you have to do to take a shy, slow turtle and give it a playful cat-like speed of life?

Not much.

Even small adjustment to physical embodiment unlocks a new cognitive domain.

What was the latent space of its possibilities? These engineering changes are the periscope to find them.

(Thanks to Marsa Hickey for finding this)

https://x.com/AMAZINGNATURE/status/1845232258879217914

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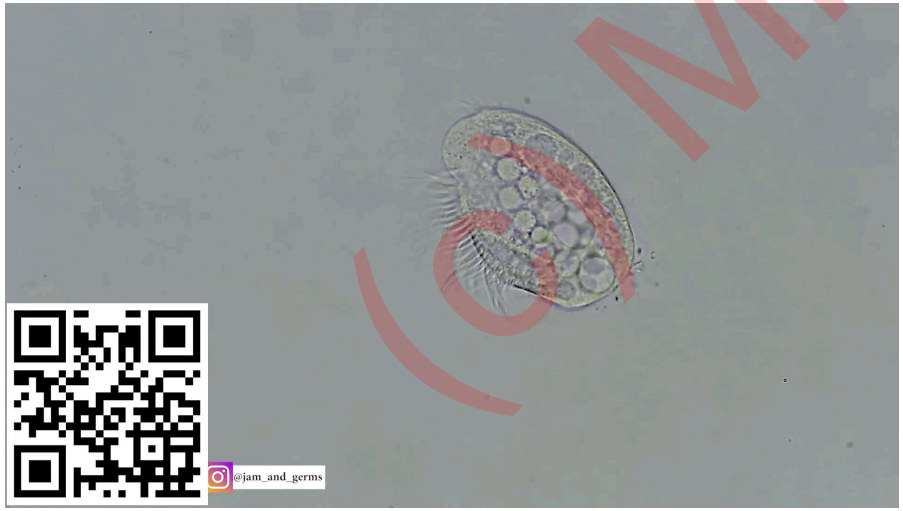
All Living Embodiments are Collective Intelligences

Lacrymaria = 1 cell
no brain
no nervous system

high competency
at cell-level
agendas



Can you reward or
Punish it?

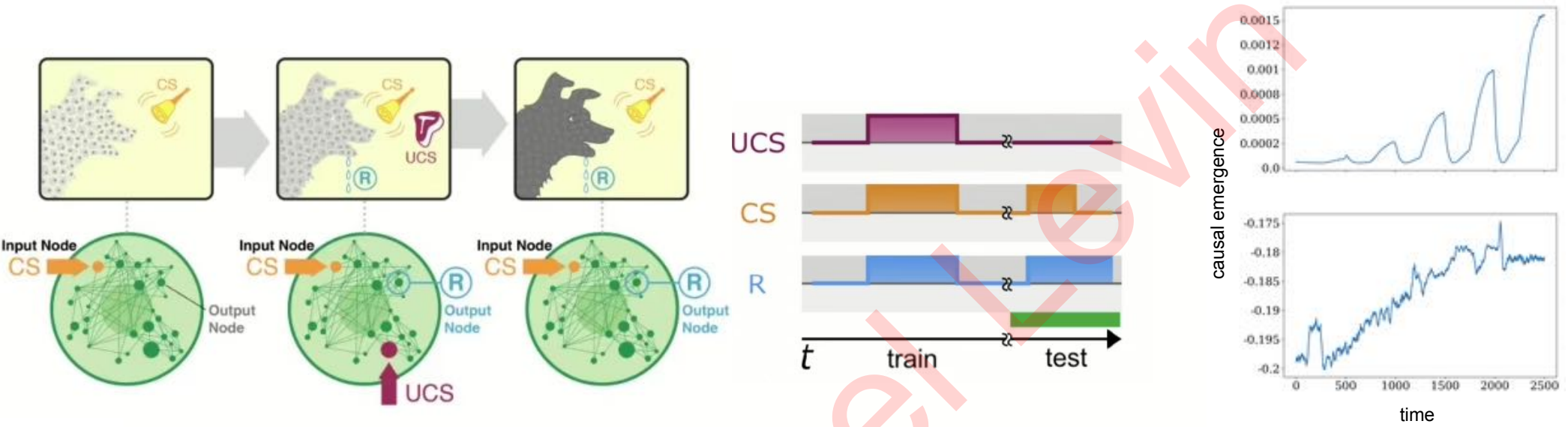
Comment https://doi.org/10.1038/s42256-024-00955-y

nature machine intelligence

Discussions of machine versus living intelligence need more clarity

Nicolas Rouleau & Michael Levin

The Agential Material of Life



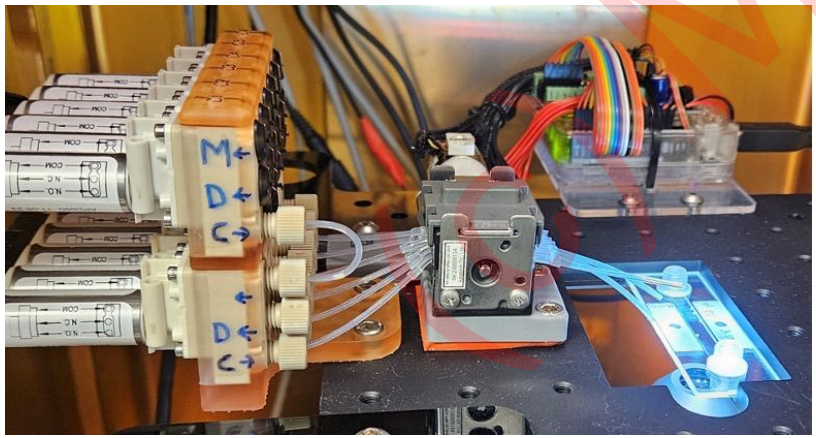
Causal emergence before, during, and after associative training in GRNs

Federico Pigozzi

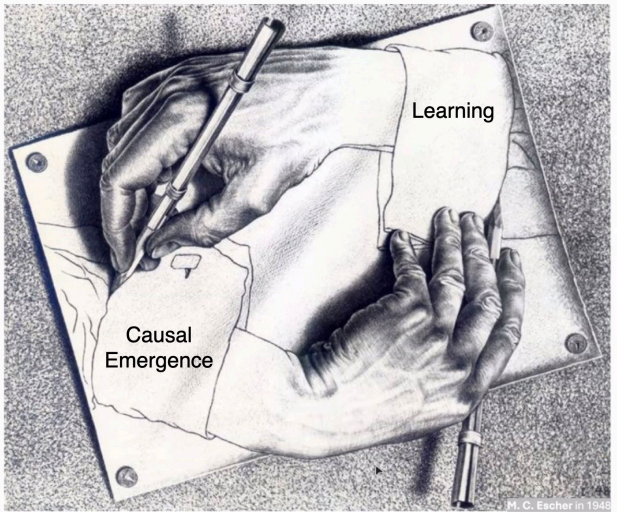
- Molecular placebo effect!!

Biomedicine:
- drug conditioning

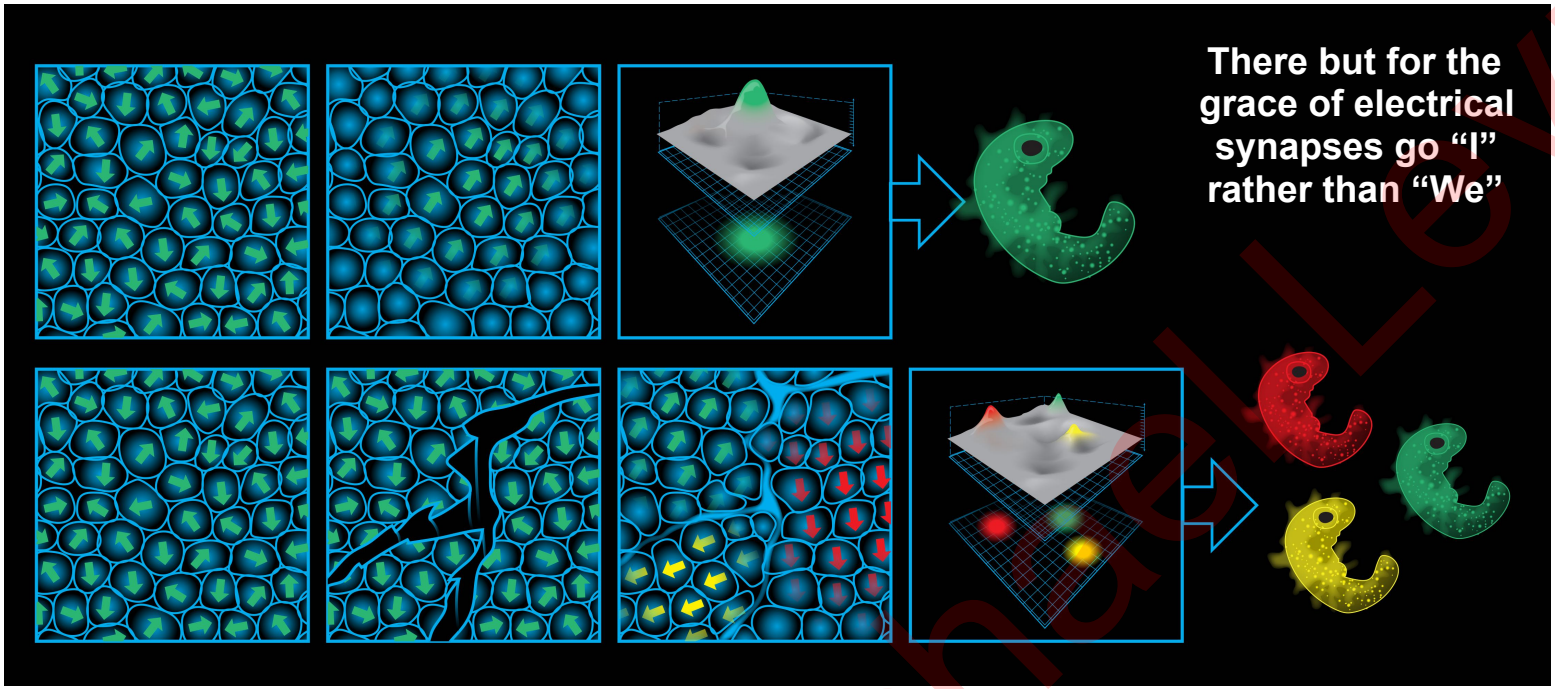
Patrick Erickson



- Higher causal emergence makes for better learning
- Learning raises causal emergence
- Forgetting does *not* erase gains!



Larger Selves Emerge from an Excitable Medium of agential components: how many?

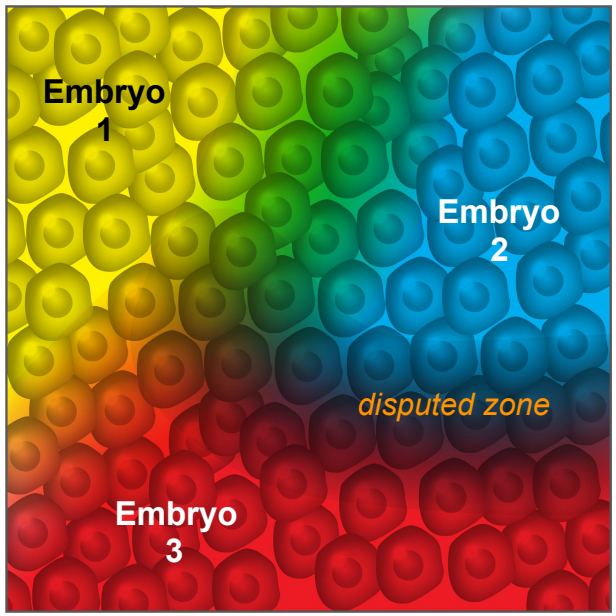


Beings are dynamic, self-telling, variably convincing stories of greater potential

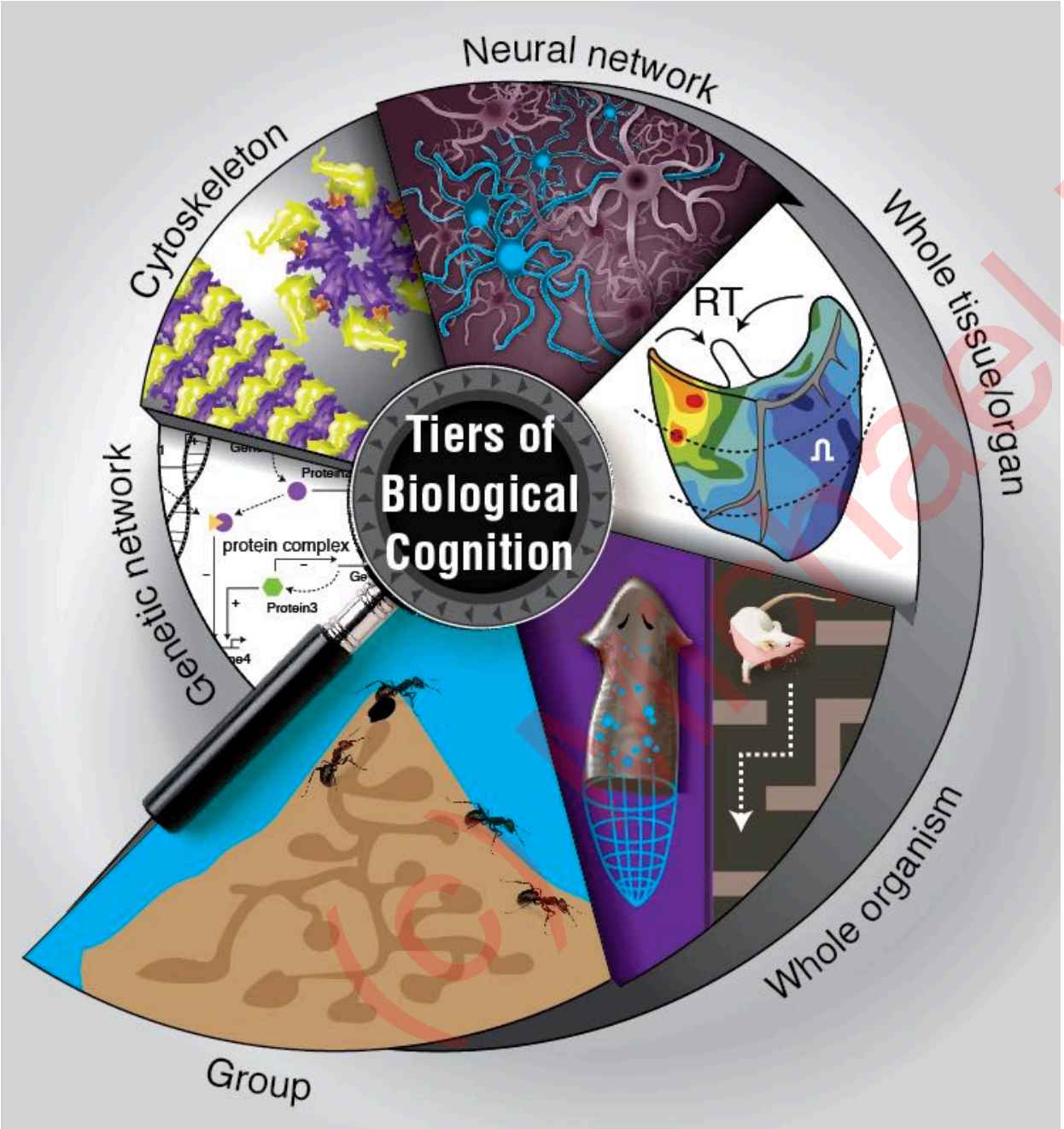
Agential material: how many agents per mm^3?

Where is my border from "environment"?
every cell is some other cell's environment

Issue of **individuation** in cognition:
split brain patients, dissociative disorders, etc.



Life Has Nested Intelligence, not Merely Structure

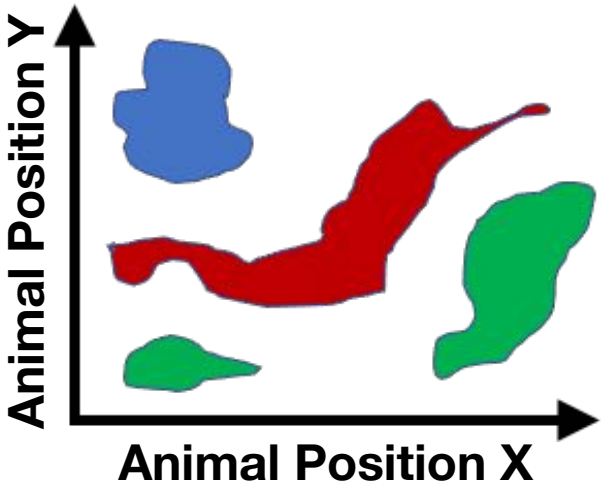


Multi-scale Competency Architecture

each level of organization solves problems in its own space (morphospace, transcriptional space, physiological space, 3D behavioral space, etc.) using some of the same tricks, at various levels of sophistication

Life Has Embodiment Outside of Familiar 3D space:

3D Space (behavior)

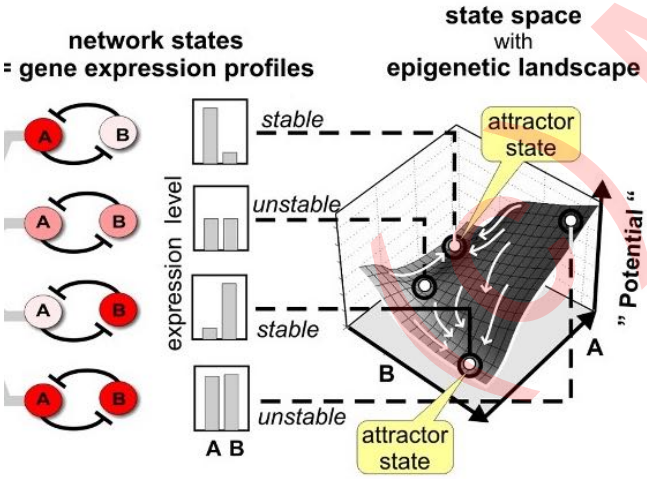


perception-action loop can happen in other spaces!

-> unconventional embodiment for AI's

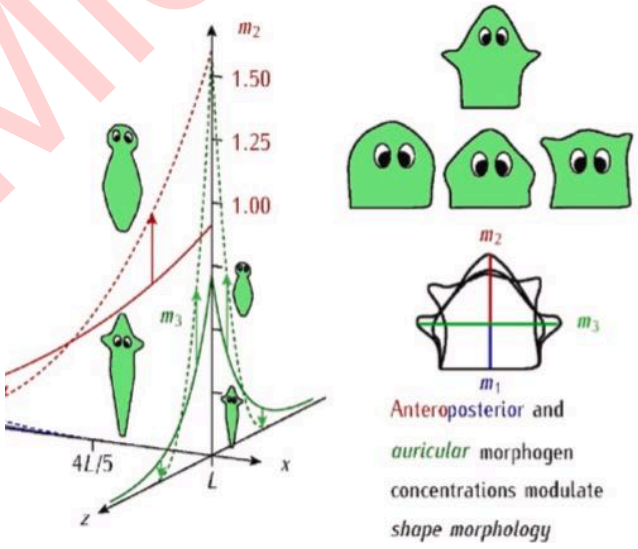
Transcriptional Space

Huang, S.; Ernberg, I.; Kauffman, S., Semin Cell Dev Biol 2009, 20, (7), 869-76.



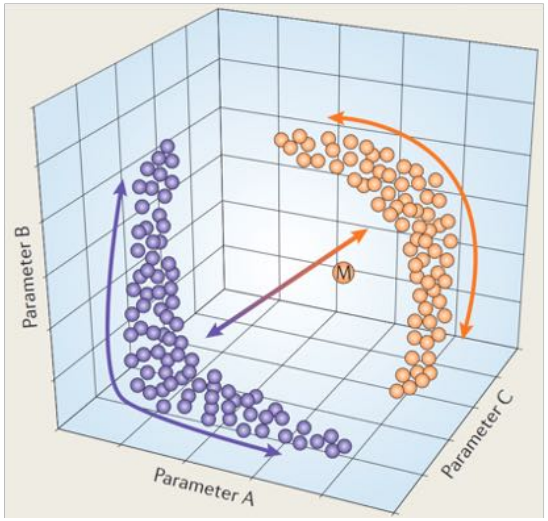
Morphospace

Cervera, J., Levin, M., and Mafe, S., (2021), BioSystems, 209:104511



Physiological Space

Marder, E., & Goaillard, J. M. (2006). Variability, compensation and homeostasis in neuron and network function. Nat Rev Neurosci, 7(7), 563-574.



"Intelligence is the ability to reach the same goal by different means."

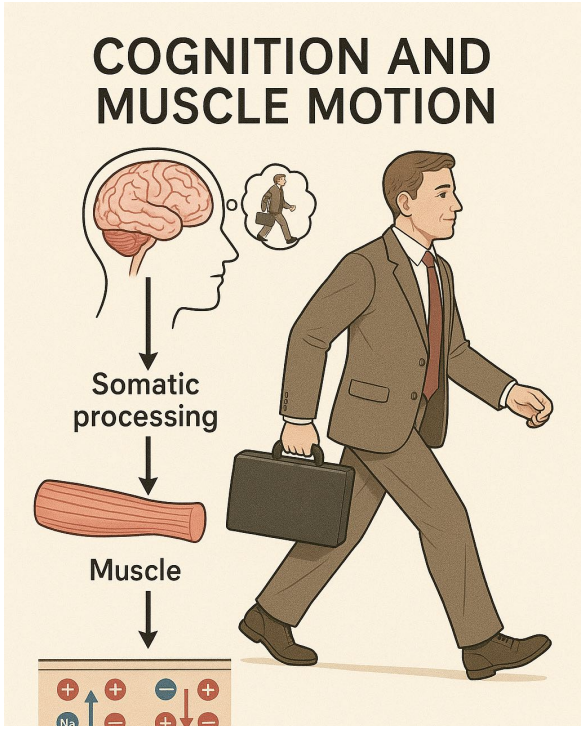
- William James

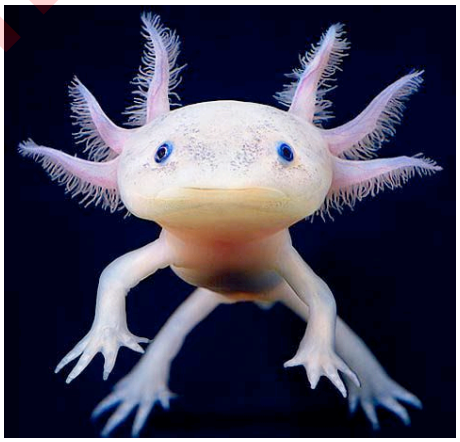
Hypothesis: morphogenesis is a collective intelligence, exerting its behavioral competencies in anatomical morphospace

Cellular Swarms vs. Brains (or, what is neuroscience about?)

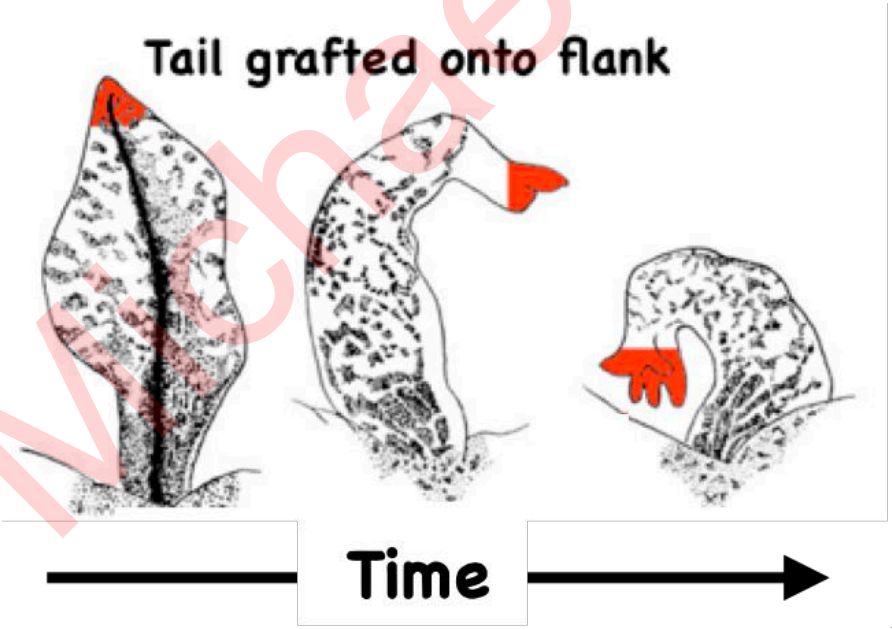
- Different time scale (minutes, not milliseconds)
- Different problem space (morphospace, not 3D motion)
- but, same (homologous!) mechanisms - ion channels, GJs, NTs
- and, many of the same algorithms (tools of cog sci work great)

Top-Down Control: how does mental intent make the chemistry dance?





Tim Flach



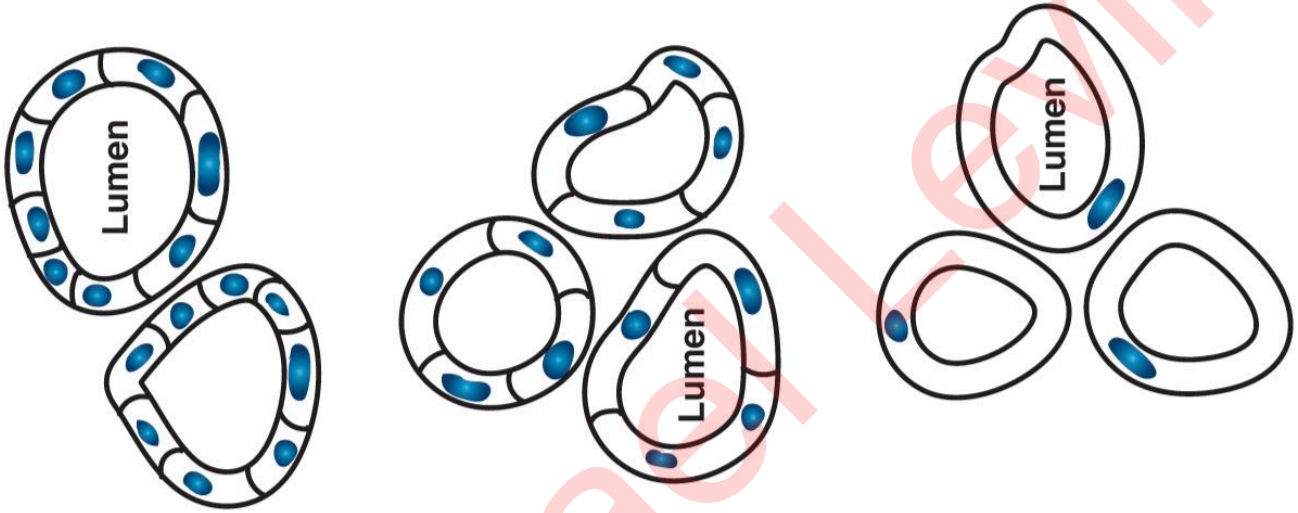
Farinella-Ferruzza, Experientia, 1956 (15)

Anatomical homeostasis:

local order obeys global plan

Genome and Beginner's Mind

newt kidney tubule cross-section

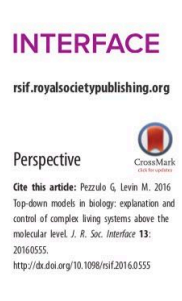


Fankhauser, 1945, J. Exp. Zool., 100(3): 445-455

Changing the size of cells still enable large-scale structures to form, even if they have to utilize different molecular mechanisms = top-down causation

you can't even count on your parts!

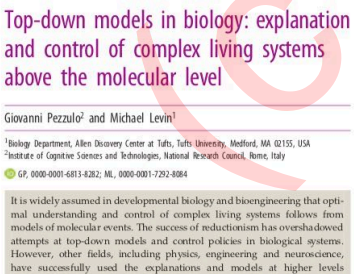
- Creative, intelligent problem-solving - repurpose available tools to new circumstances


INTERFACE

rsif.royalsocietypublishing.org

Perspective

Cite this article: Pezzulo G, Levin M. 2016 Top-down models in biology: explanation and control of complex living systems above the molecular level. *J. R. Soc. Interface* **13**: 20160555. http://dx.doi.org/10.1098/rsif.2016.0555

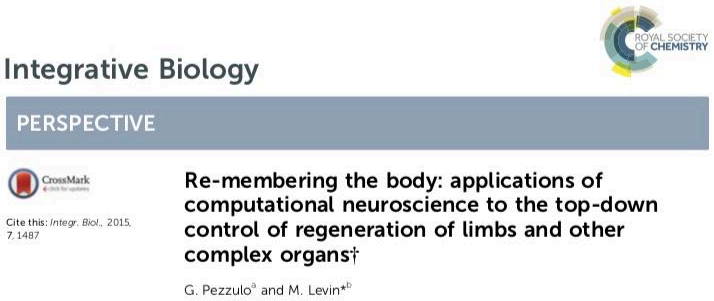

Top-down models in biology: explanation and control of complex living systems above the molecular level

Giovanni Pezzulo[2] and Michael Levin[1]

[1]Biology Department, Allen Discovery Center at Tufts, Tufts University, Medford, MA 02155, USA
[2]Institute of Cognitive Sciences and Technologies, National Research Council, Rome, Italy

GP, 0000-0001-6813-8282; ML, 0000-0001-7292-8084

It is widely assumed in developmental biology and bioengineering that optimal understanding and control of complex living systems follows from models of molecular events. The success of reductionism has overshadowed attempts at top-down models and control policies in biological systems. However, other fields, including physics, engineering and neuroscience, have successfully used the explanations and models at higher levels


Integrative Biology

ROYAL SOCIETY OF CHEMISTRY

PERSPECTIVE

Cite this: *Integr. Biol.*, 2015, 7, 1487

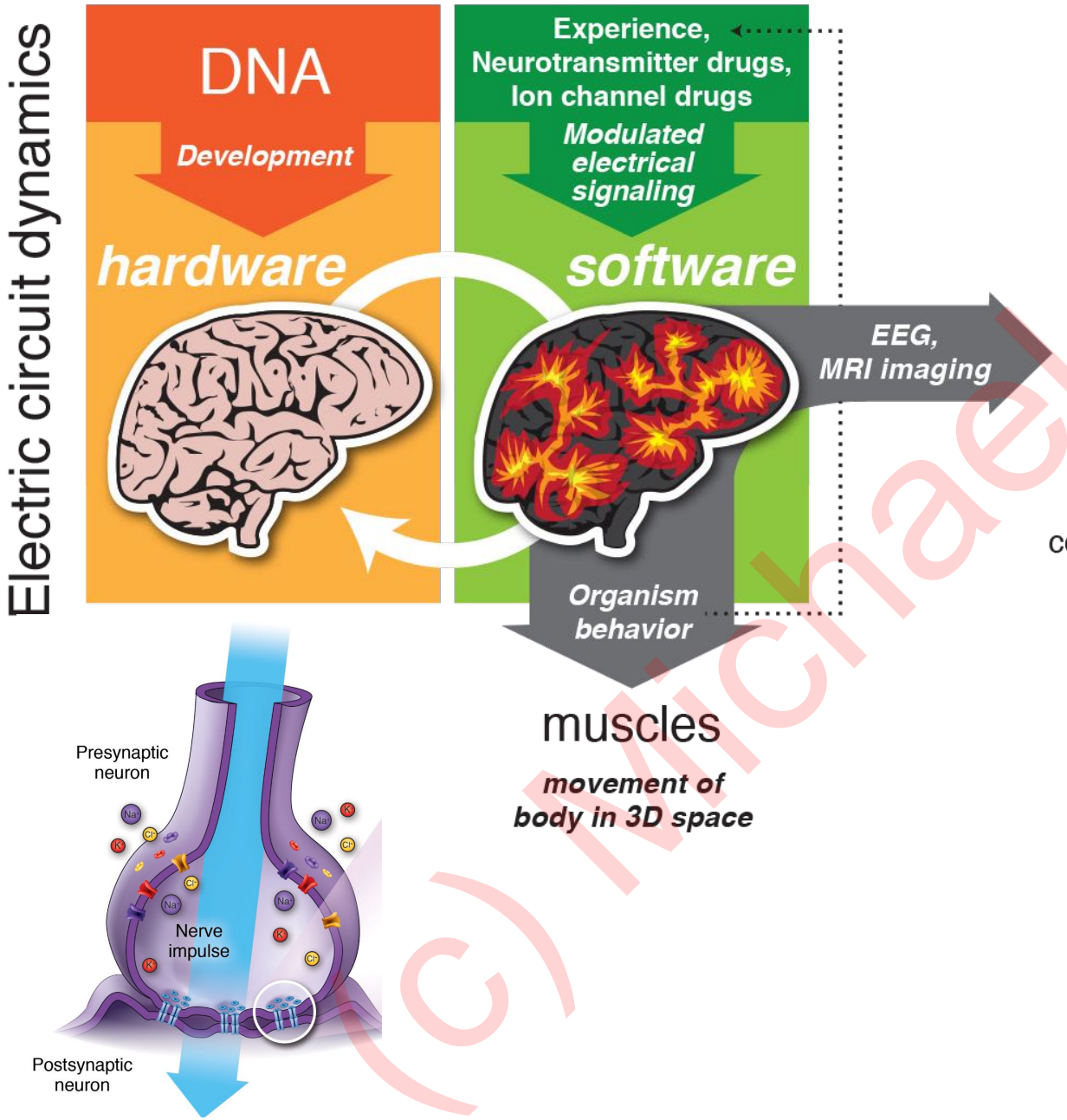
Re-membering the body: applications of computational neuroscience to the top-down control of regeneration of limbs and other complex organs†

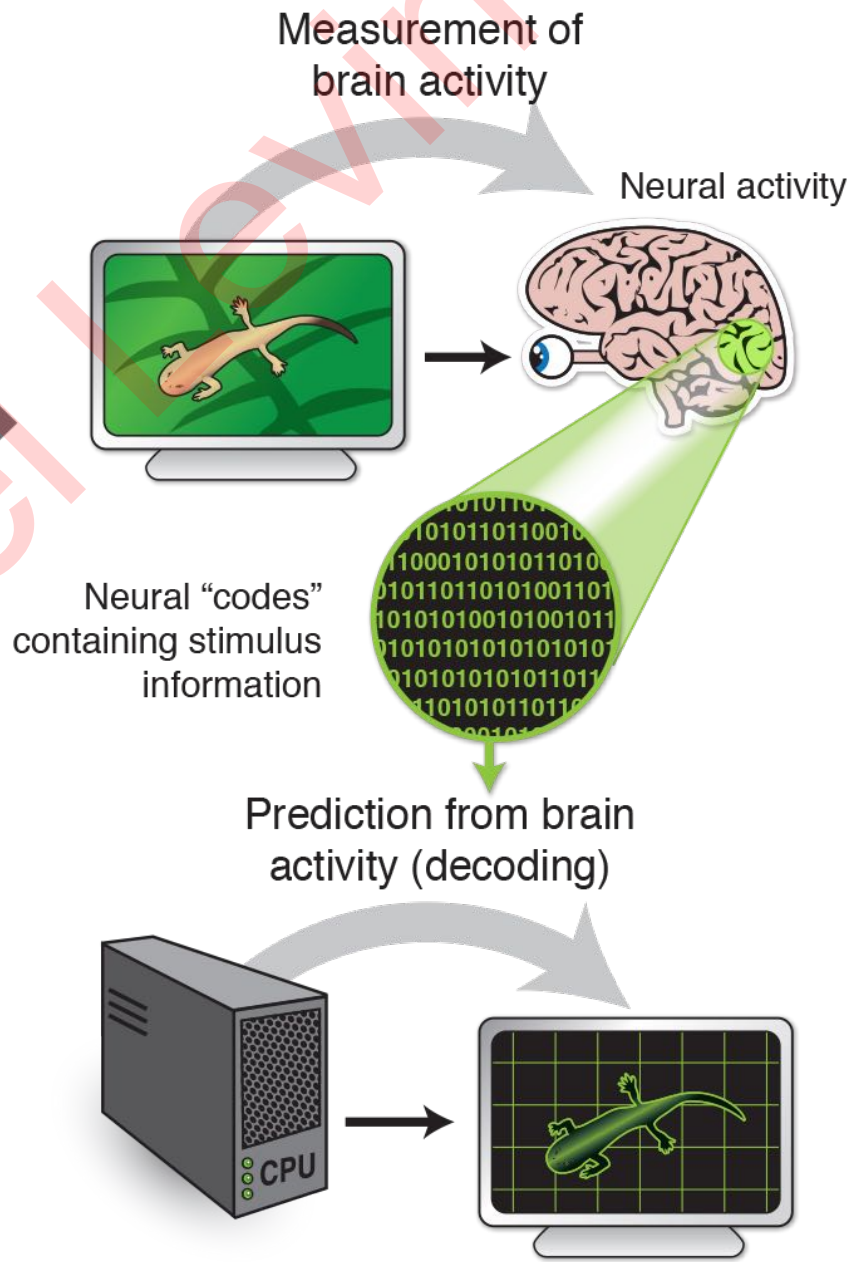
G. Pezzulo[a] and M. Levin*[b]


Resilient Machines Through Continuous Self-Modeling

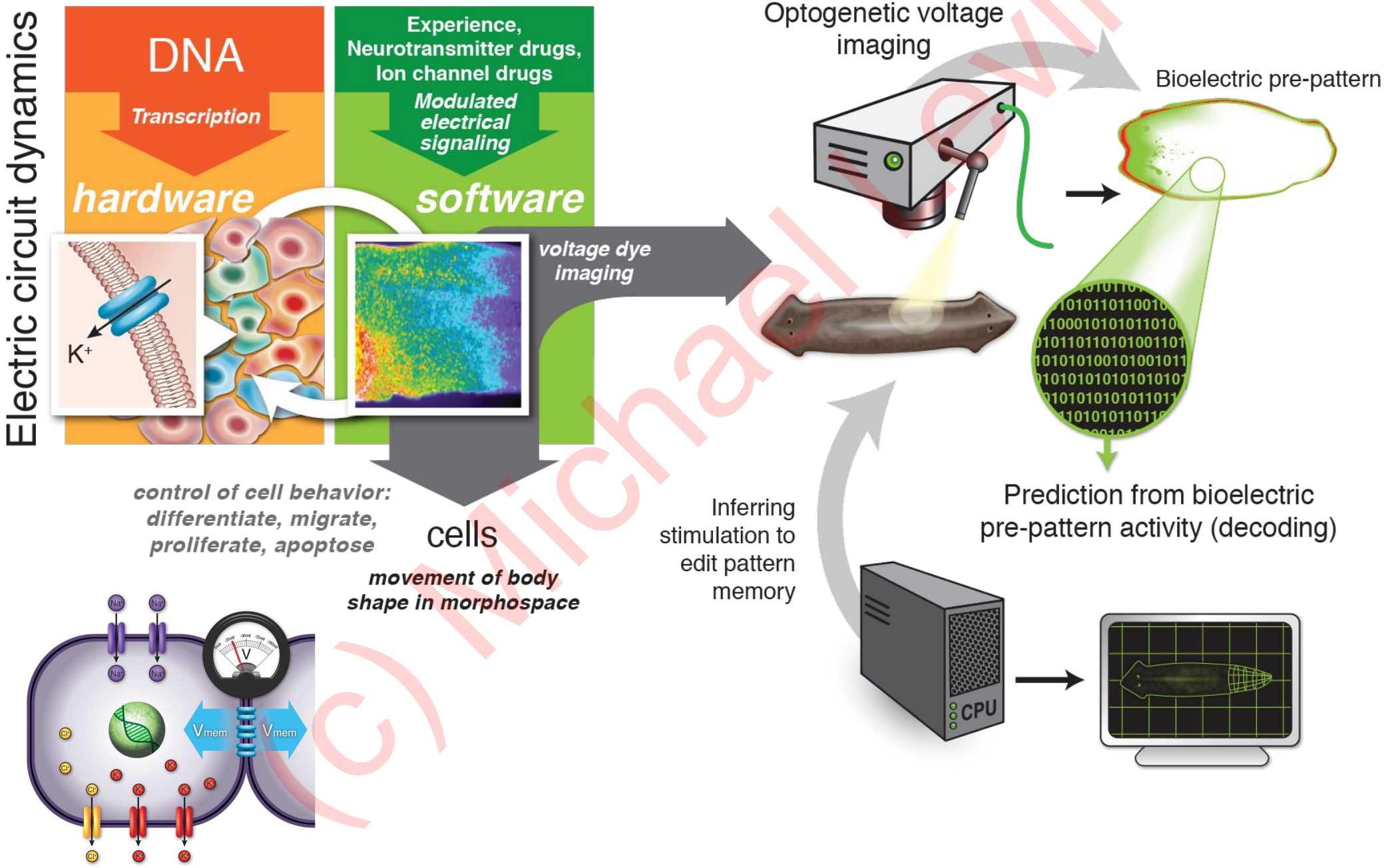
Josh Bongard,[1]*† Victor Zykov,[1] Hod Lipson[1,2]

Hardware and Software in the Brain



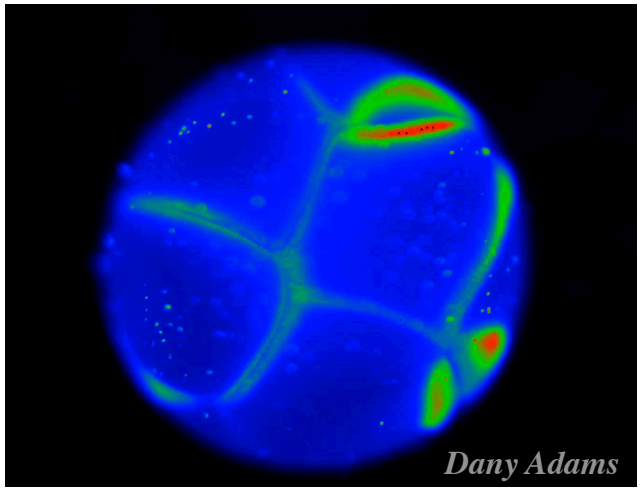


Hardware and Software in the Body

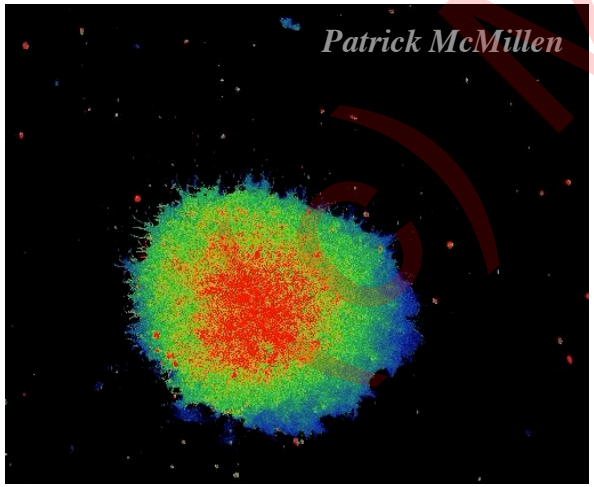


How we detect and model bioelectric patterns:

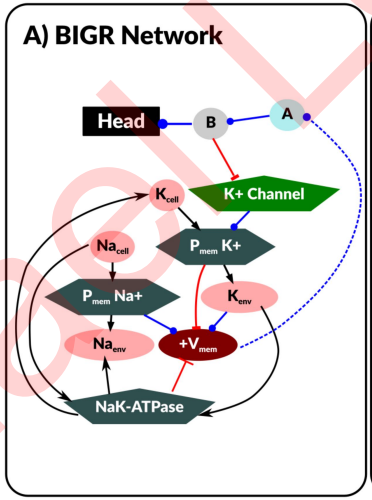
Characterization of endogenous voltage gradients - direct measurement and correlation with morphogenetic events

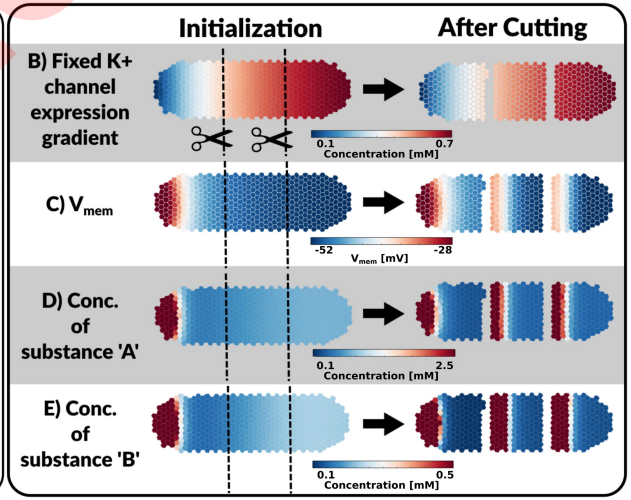


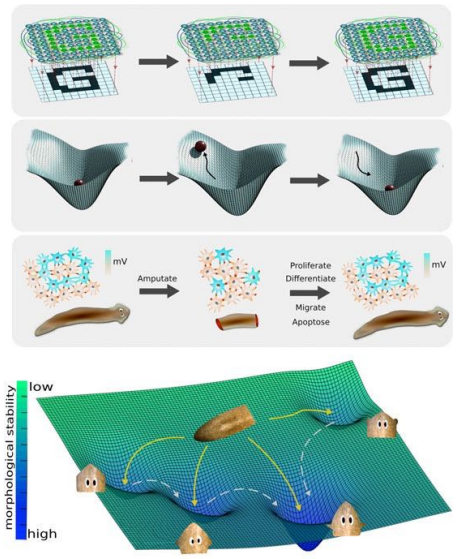
Voltage reporting fluorescent dye in time-lapse during *Xenopus development*

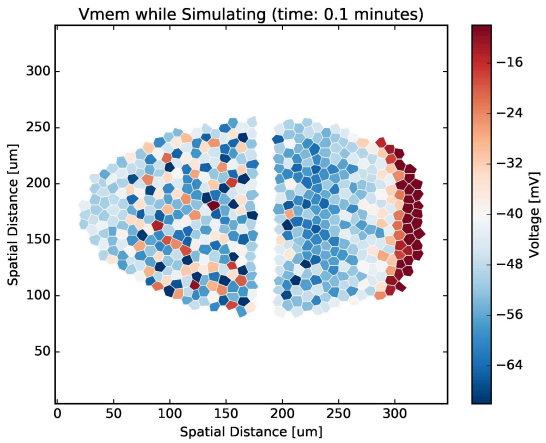


Quantitative computer simulation: synthesize biophysical and genetic data into predictive, quantitative, often non-linear models



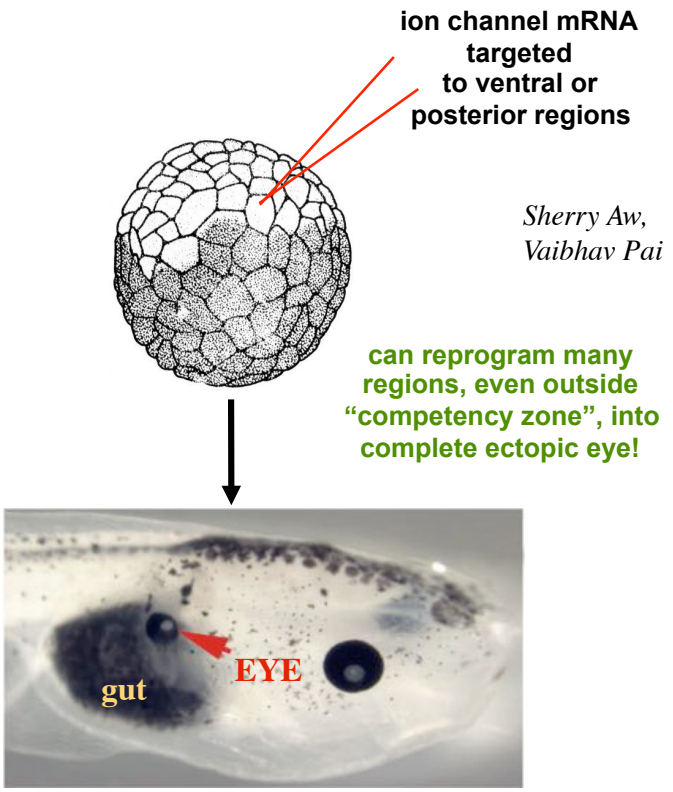


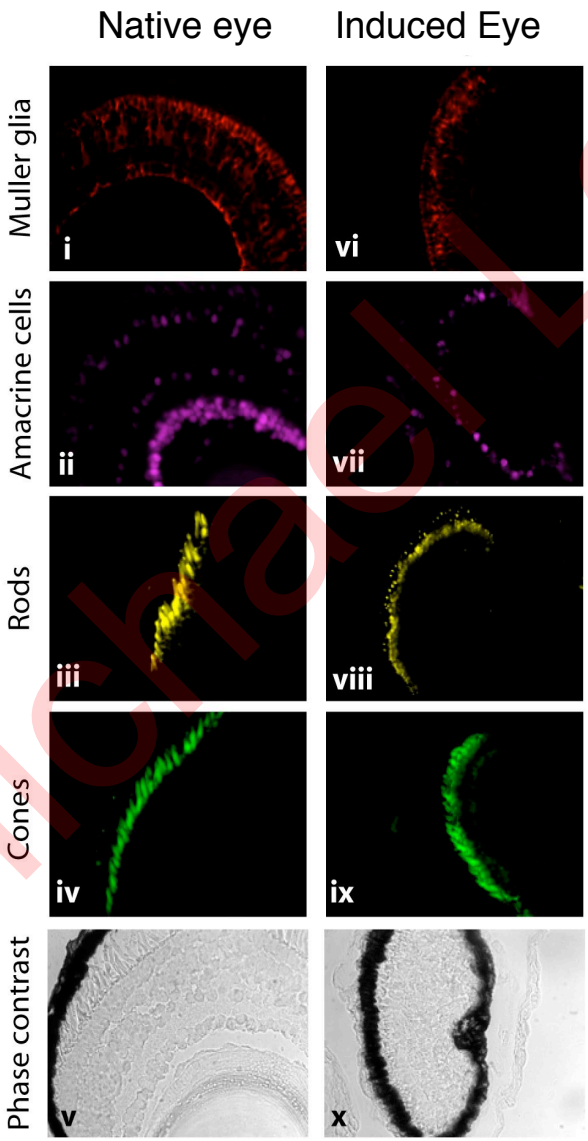


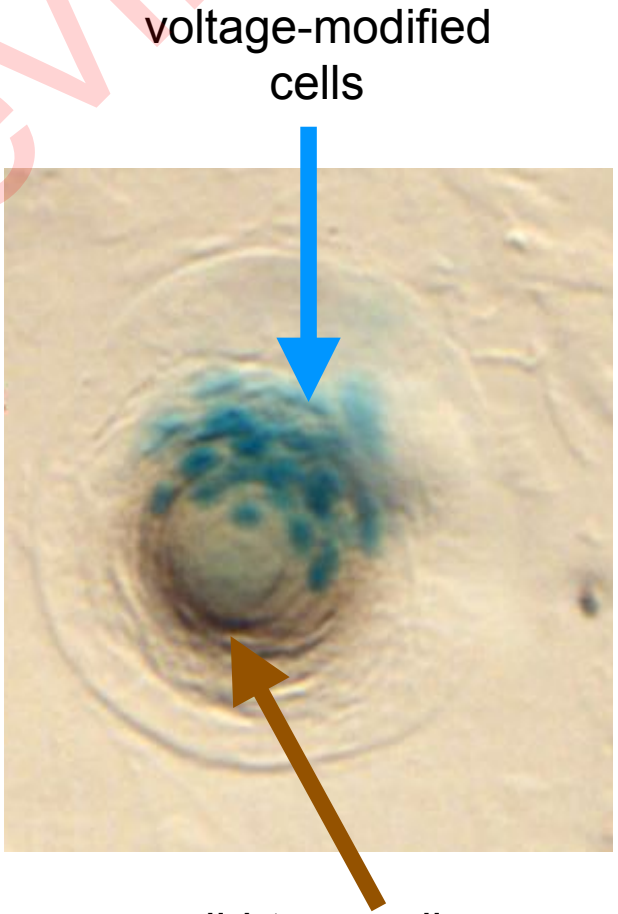


Alexis Pietak

Communicating with Somatic Intelligence: prompt = make an eye







1. BIOE is instructive
2. modularity - not cell level, organ-level subroutine call
3. higher-level prompt reveals higher tissue competency than Pax6 prompt
4. self-scaling of system to task

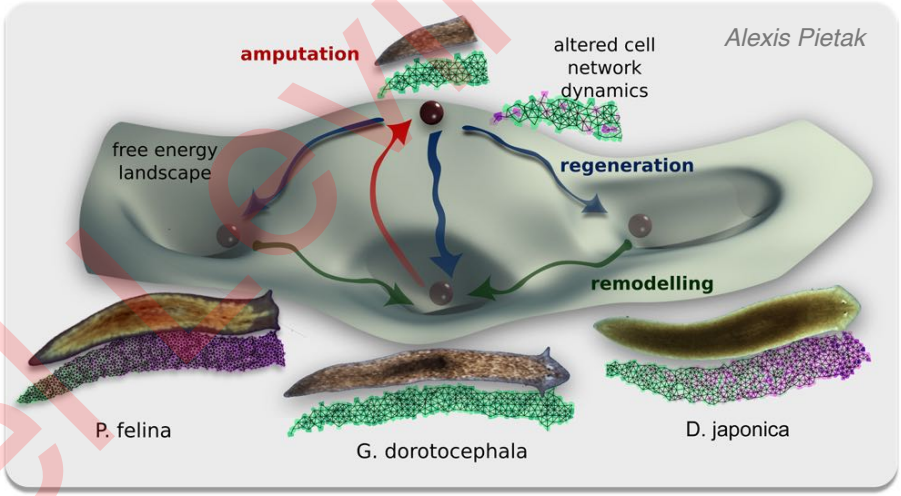
Developmental Modules because morphogenetic goals

Same Genome, Different Outcome

2 brains in 1 body

A Single Genome Makes Hardware that can Access Bioelectric Memories of Other Species' Head Shapes

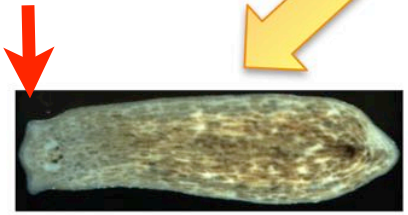
Tweaking of bioelectric network connectivity causes regeneration of head shapes appropriate to other species! (also includes brain shape and stem cell distribution pattern)



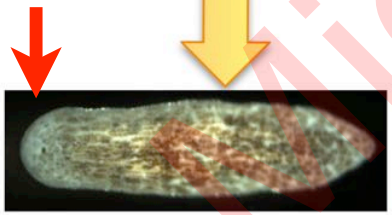
D. dorotocephala

cut off head, perturb network topology

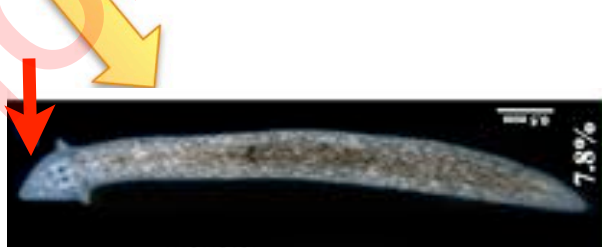
Maya Emmons-Bell

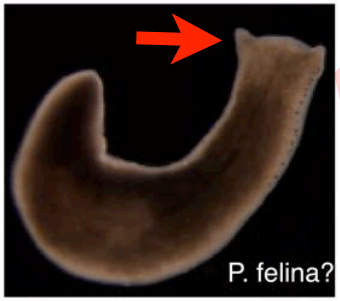


like:

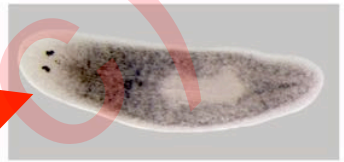


like:



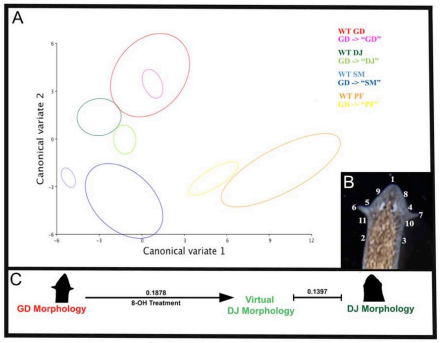


P. felina?

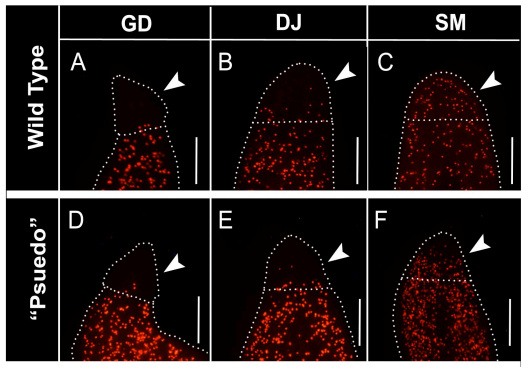


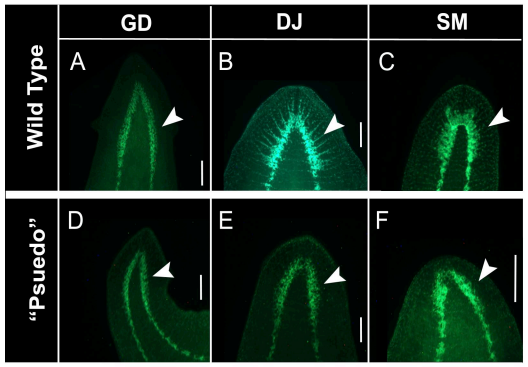
S. Mediterranea

quantitative morphometrics



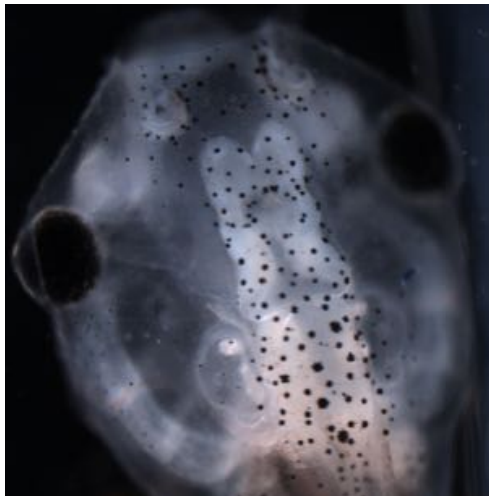
brain shape and stem cell patterns match also!





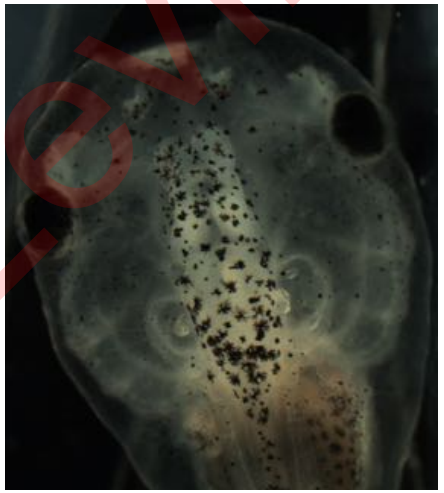
Human-approved anti-epileptic drugs chosen by modeling platform rescue severe brain defects from Notch mutant

Normal tadpole brain

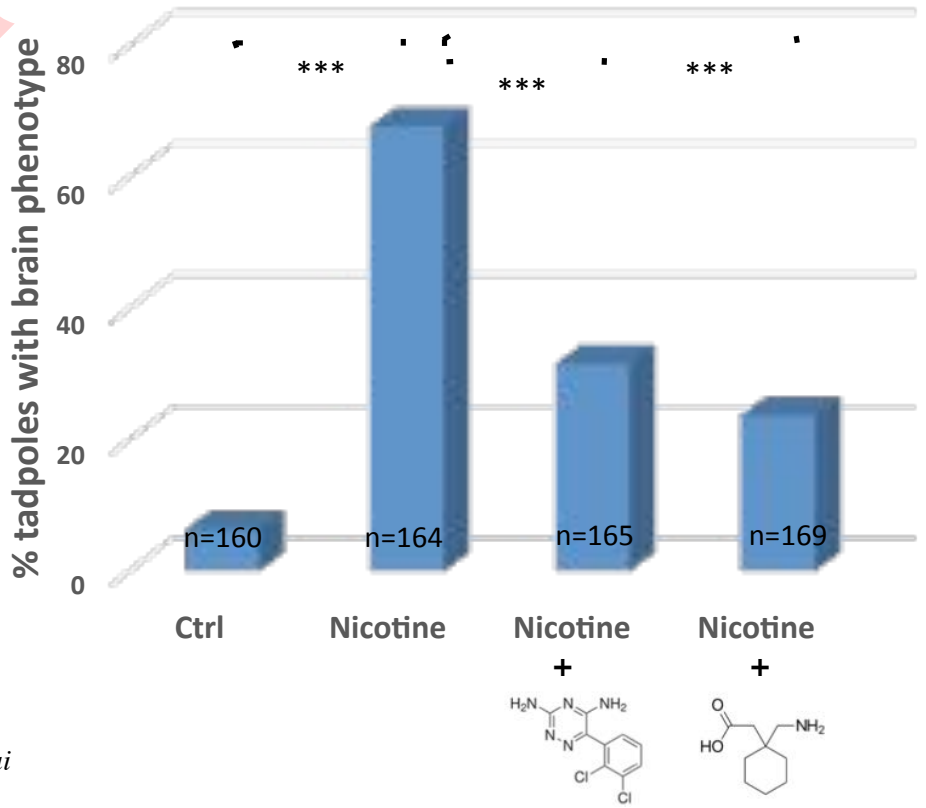


Truncated, misshapen brain resulting from dominant Notch mutation

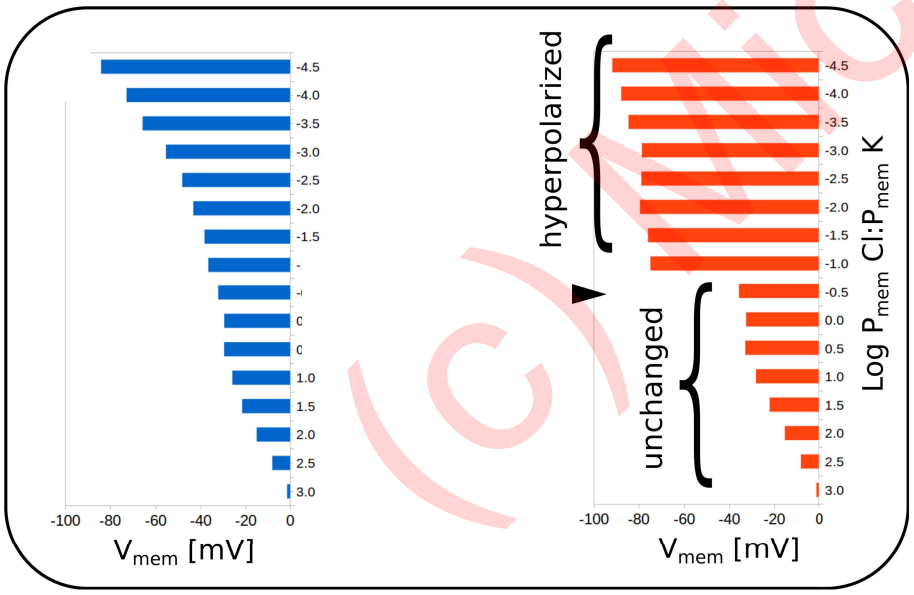
Normal tadpole brain resulting from hyperpolarization despite Notch mutation



***p<0.001
CHI SQ test

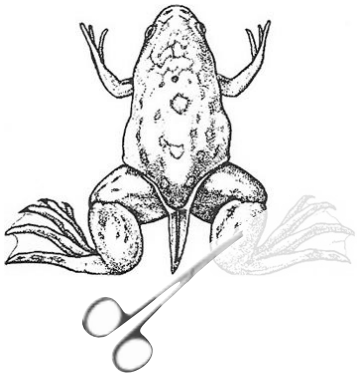


Model Predicts: use HCN2 ion channel



Vaibhav Pai

Brief bioelectric signals trigger long-term, self-limiting modules (low info-content input, high info-content output)



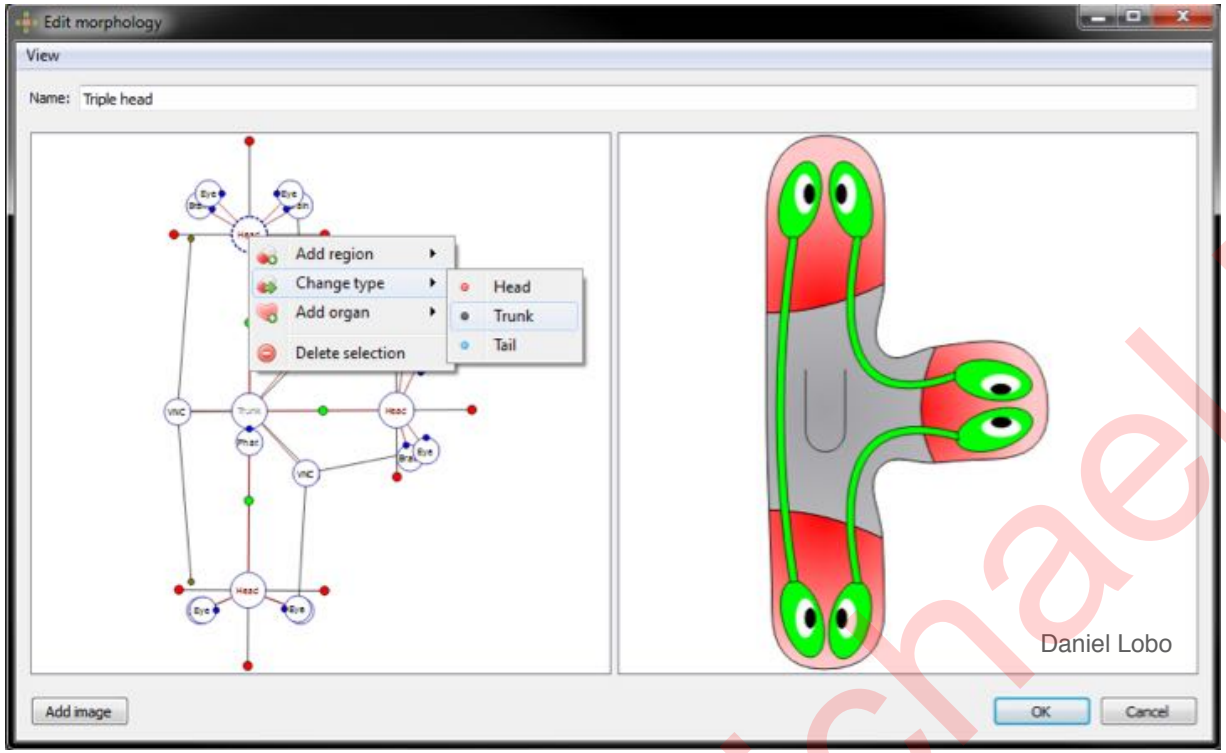
Hind-leg amputation
+
designed ionophore
cocktail regimen

MSX1 marker - blastema induced

Outgrowth with distal patterning induced (and still growing)

Kelly Tseng

Biomedical Endgame: Anatomical Compiler



It's a communication device, not a 3D printer

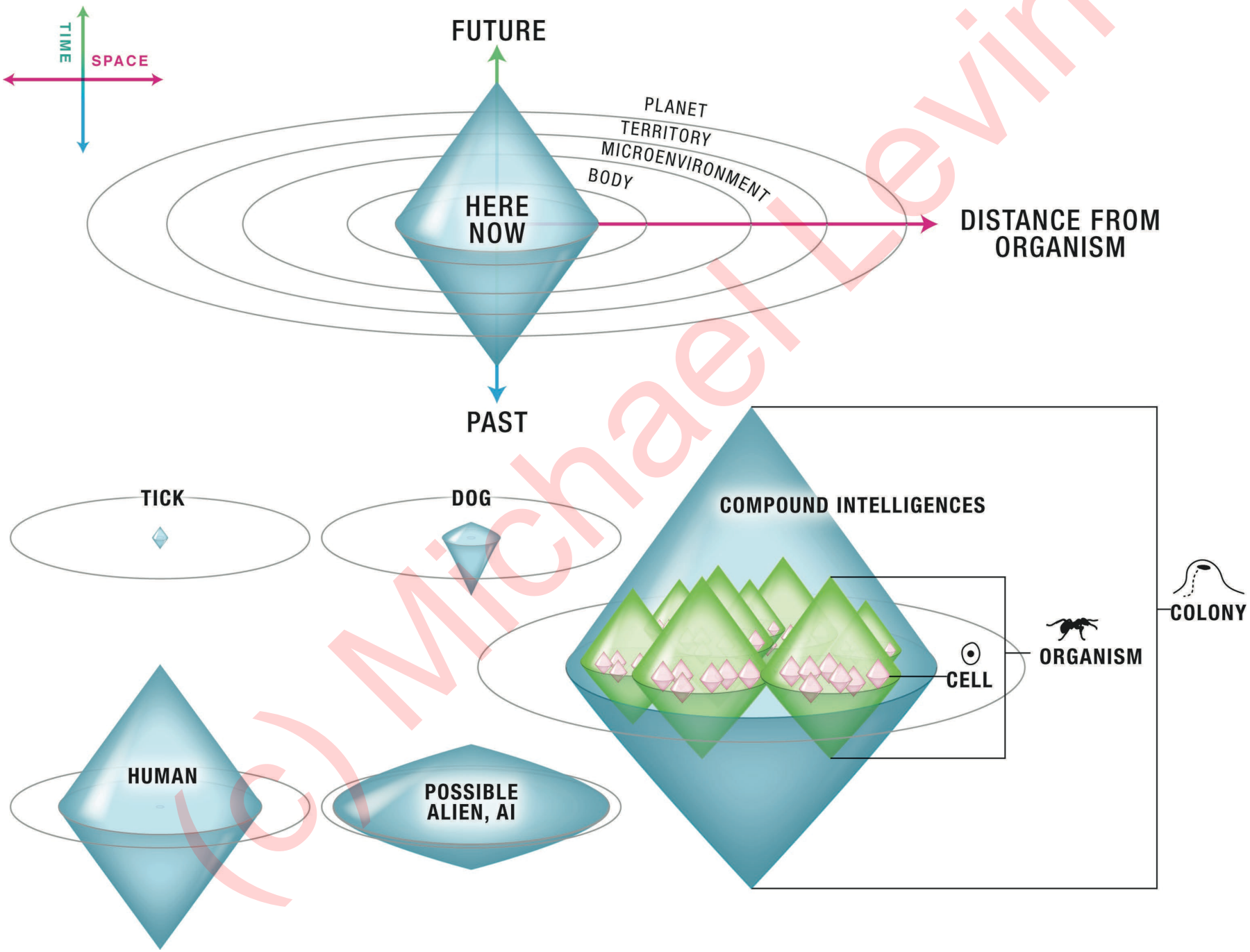
Problems of memory, allostasis, incorrect priors, decision-making, perception

Why we need it:

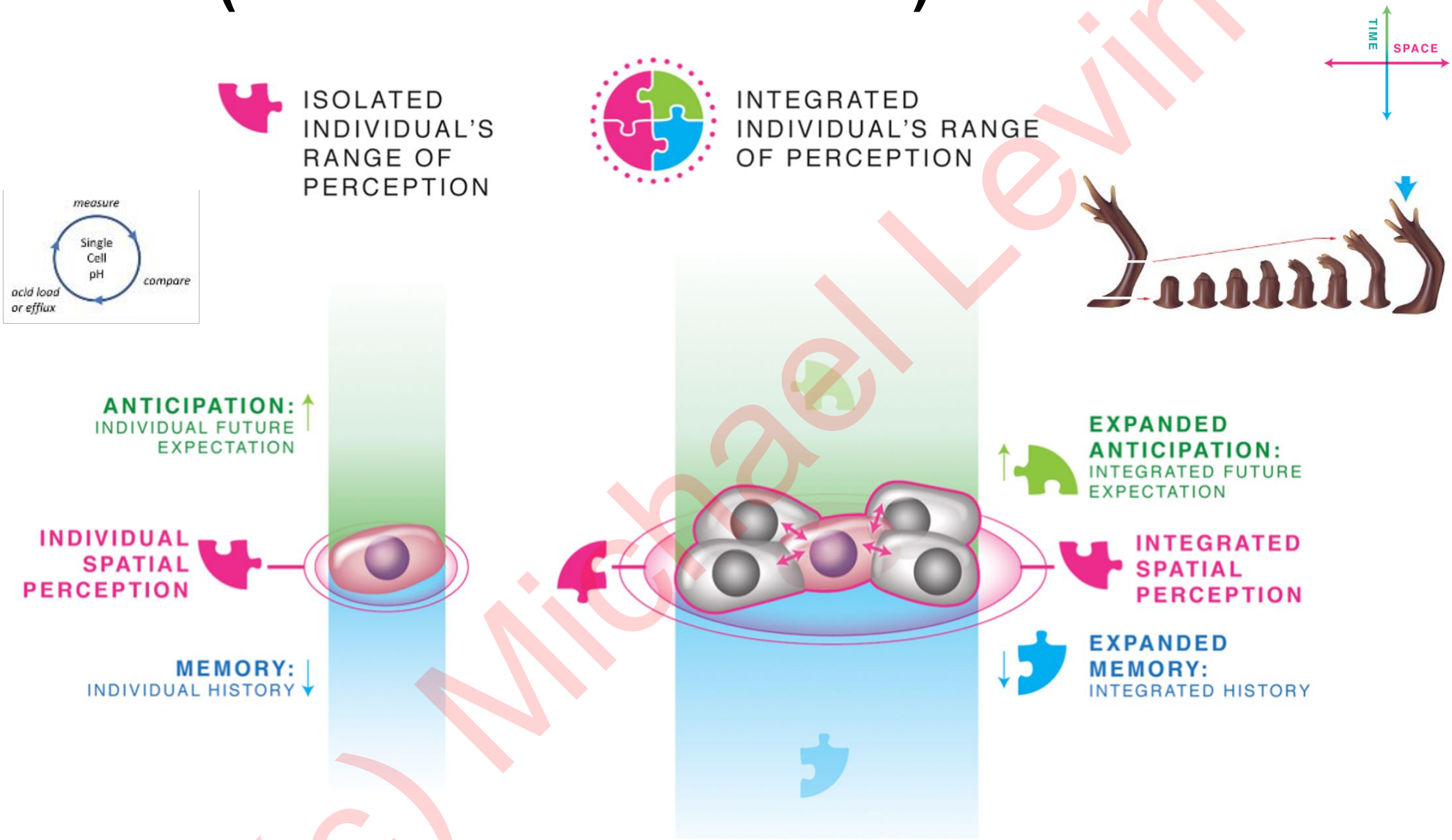
- Birth defects
- Traumatic injury
- Cancer
- Aging
- Degenerative disease

What's left?

The Cognitive Light Cone: flexible boundary of the self



Biological Cognitive Light Cones (Boundaries of the Self) are Plastic

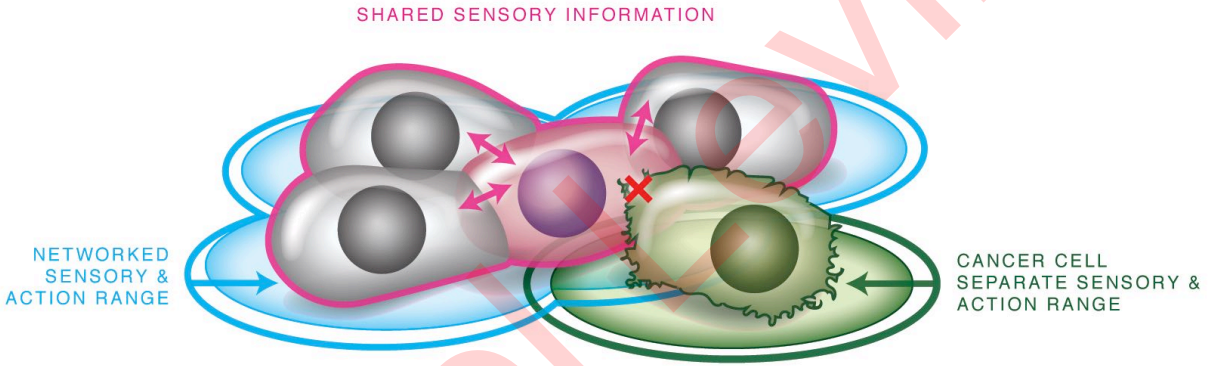


- larger-scale, more complex states can now be setpoints and source of stress
- increase cognitive light cone & **project it into other problem spaces**

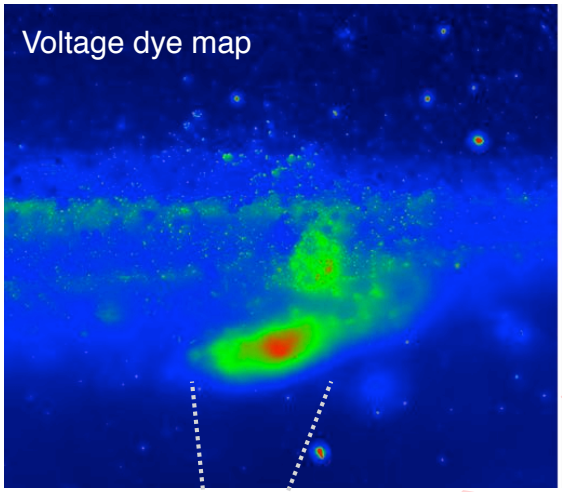
Cancer isn't More Selfish: it just has smaller Selves

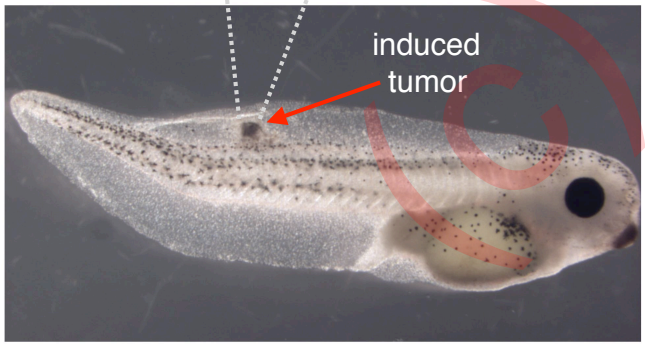
Cancer therapeutics by resetting boundary between self and world

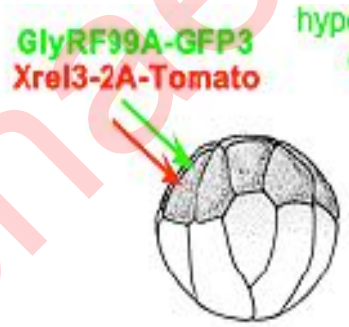
Cells Coupled by Gap Junctions, Disconnected Cancerous Cells



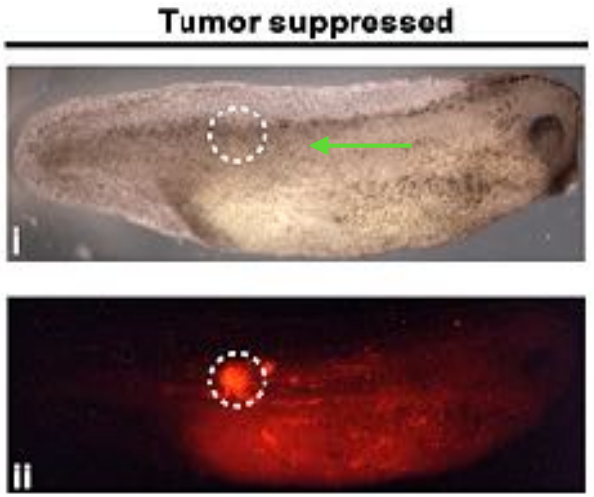
Cancer as somatic DID



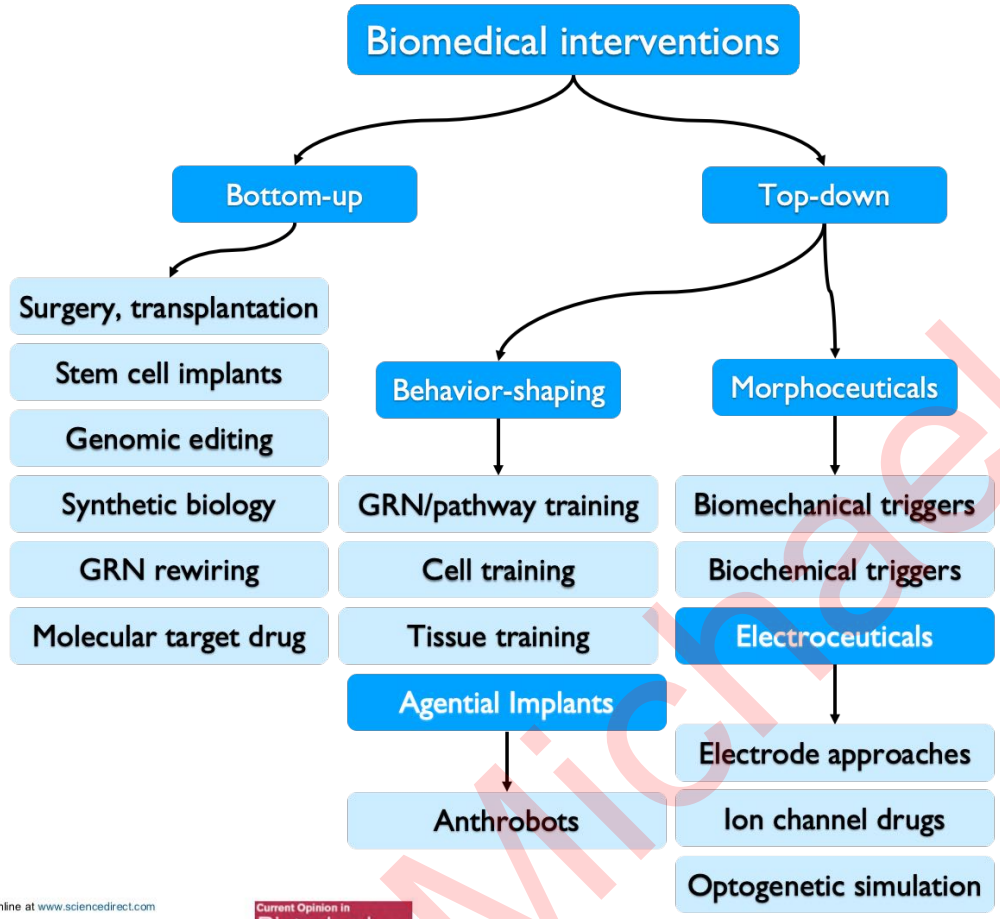




Brook Chernet



Future Medicine: communication, training (molecular pathways, cells, tissue)



from chemistry to somatic psychiatry: bioelectricity is the interface layer that enables top-down controls (i.e., mind-body medicine). We can hack this for transformative health applications!

ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Biotechnology

The body electric 2.0: recent advances in developmental bioelectricity for regenerative and synthetic bioengineering

Juanita Mathews and Michael Levin

Integrative Biology
ROYAL SOCIETY OF CHEMISTRY
PERSPECTIVE
CrossMark
Cite this: Integr. Biol., 2015, 7, 1487

Re-membering the body: applications of computational neuroscience to the top-down control of regeneration of limbs and other complex organs†

G. Pezzulo[a] and M. Levin*[b]

Patterns
CellPress
OPEN ACCESS
Perspective

Cellular signaling pathways as plastic, proto-cognitive systems: Implications for biomedicine

Juanita Mathews,[1] Alan (Jaelyn) Chang,[1] Liam Devlin,[1] and Michael Levin[1,2,*]
[1]Allen Discovery Center at Tufts University, Medford, MA, USA
[2]Wyss Institute for Biologically Inspired Engineering at Harvard University, Boston, MA, USA
*Correspondence: michael.levin@tufts.edu
https://doi.org/10.1016/j.patter.2023.100737

Overview:

- Introduction: why a talk from a computer scientist and developmental biologist?
- TAME: a framework for diverse intelligence research and applications
- Morphogenesis: a model system for communicating with semi-alien minds
- The future of the sciences of ~~the mind~~ minds

where do mental architectures come from?
what will be the goals and preferences of novel beings?
(and what does this say about our own?)

Patterns Come From Genetics, Environment, and ??

$z = z^3+7$

https://thoughtforms.life/halleys-method-fractal-art/

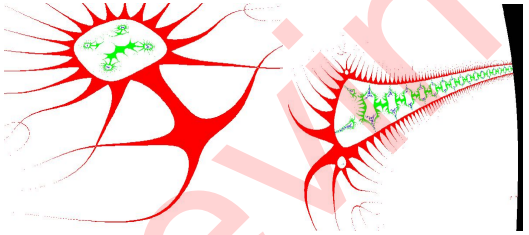
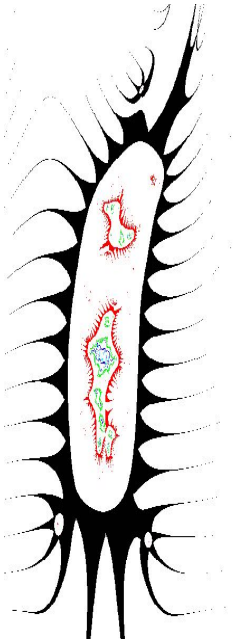
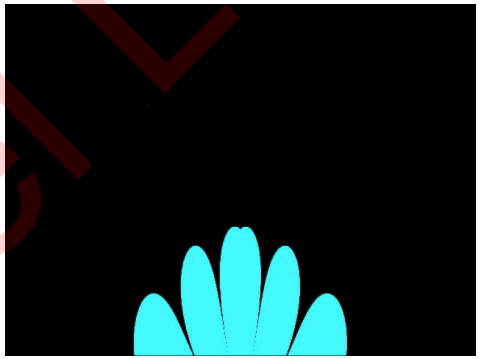
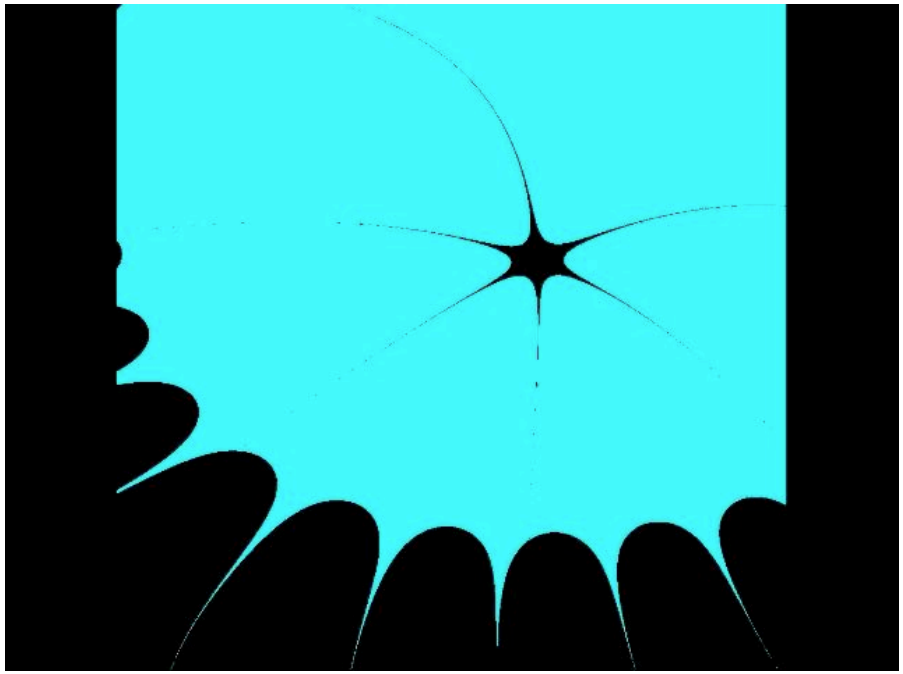


Figure 16

Figure 17



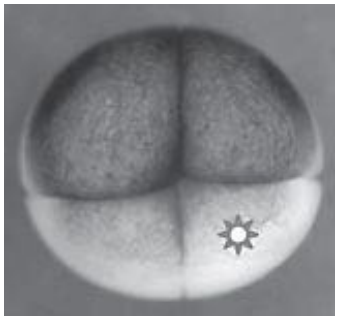




What aspect of physics or history is responsible?

Prediction: can we find novel living forms with no history?

Rebooting Multicellularity: Xenobots

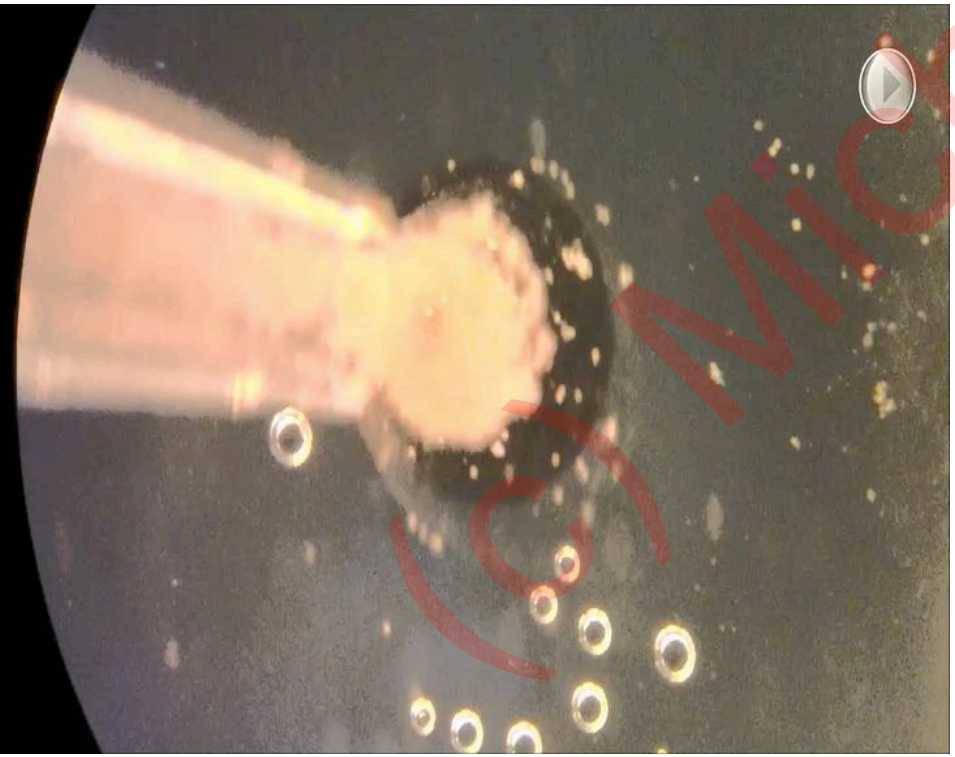


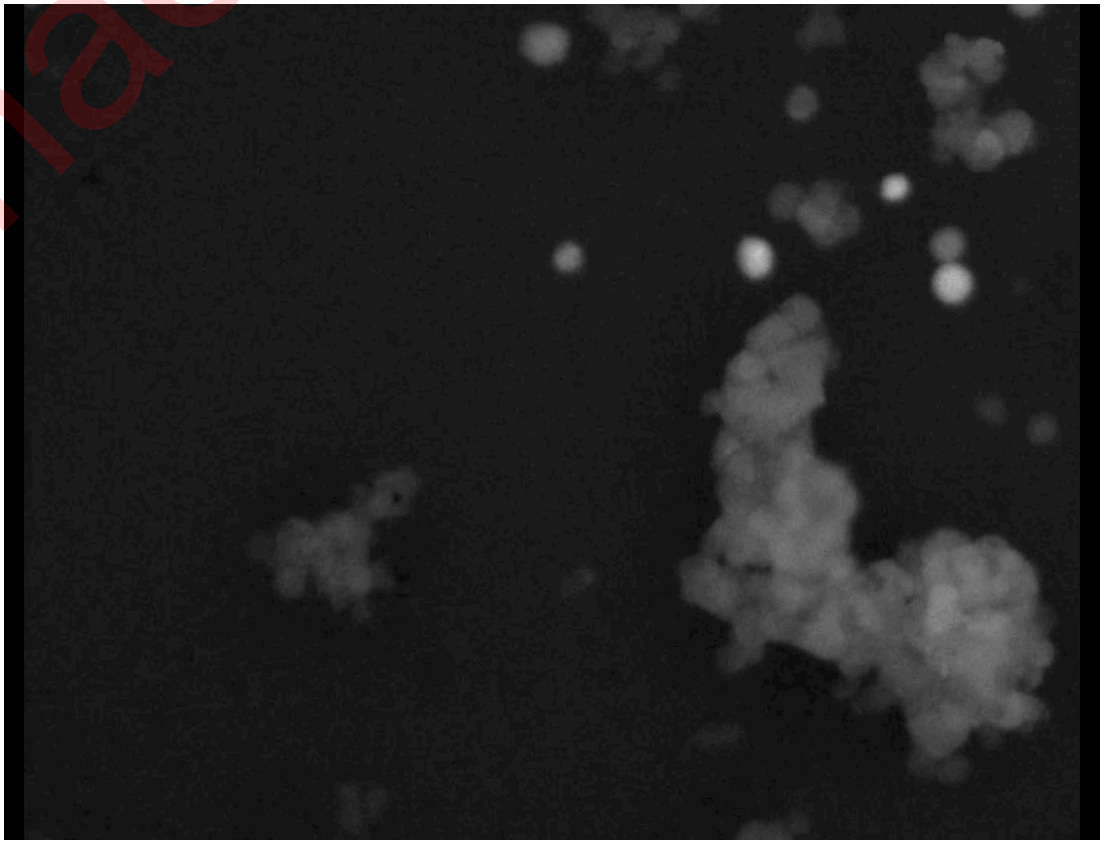
Early frog embryo

8 hours

assay for form and function

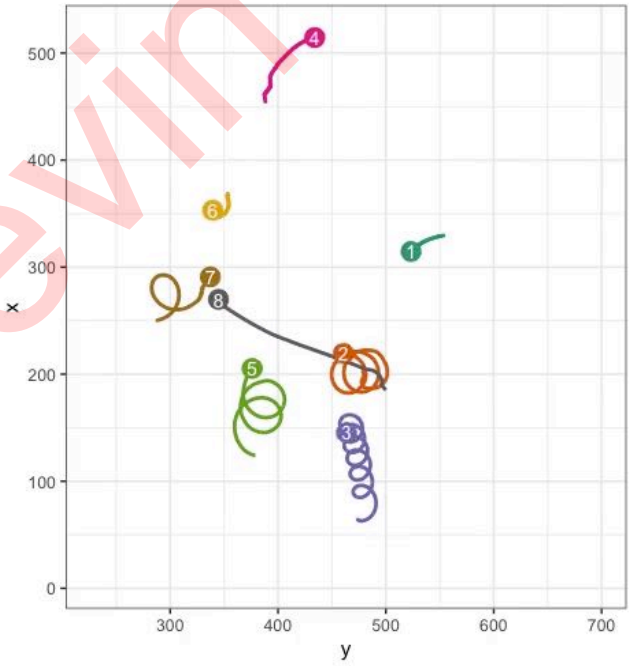
Douglas Blackiston



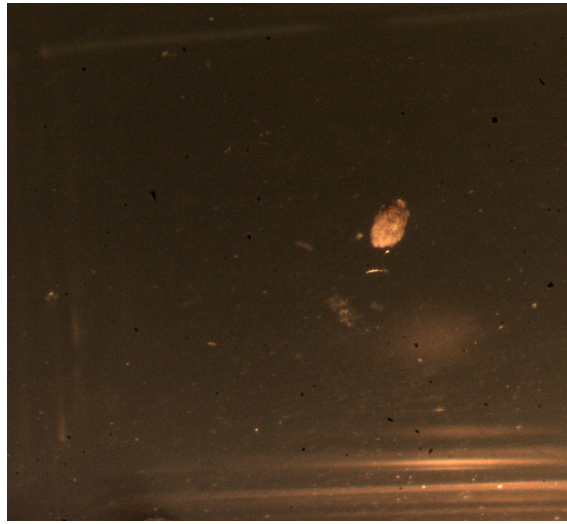


Xenobot behaviors - repurposing cilia for motion

collective behaviors



Douglas Blackiston



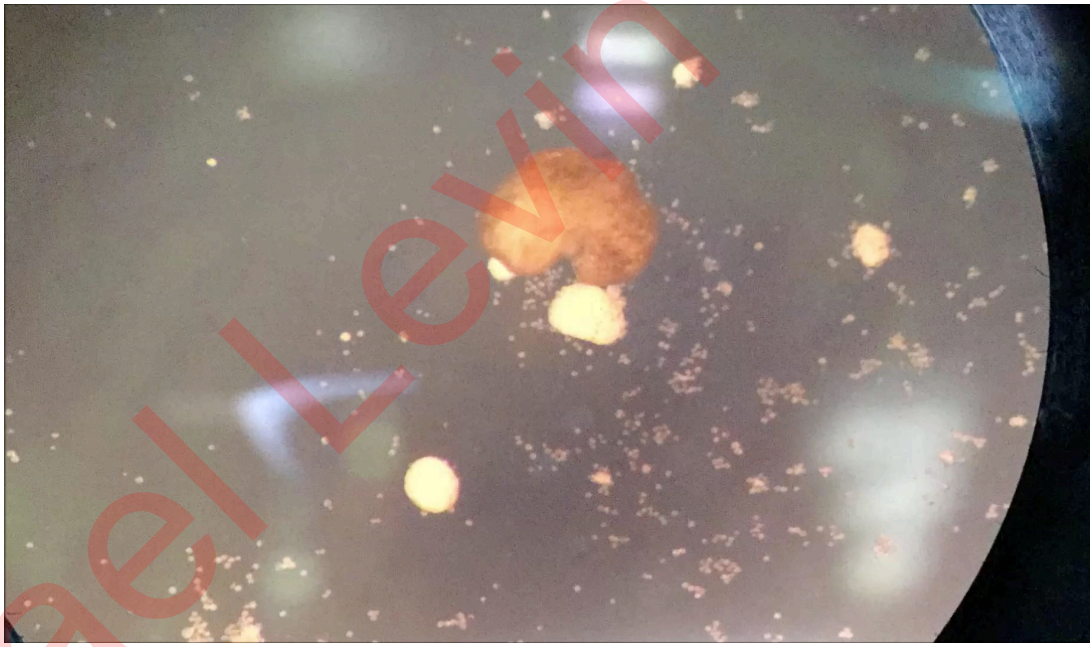
Haley Fotowat

Xenobot in a maze (still water, no flow):

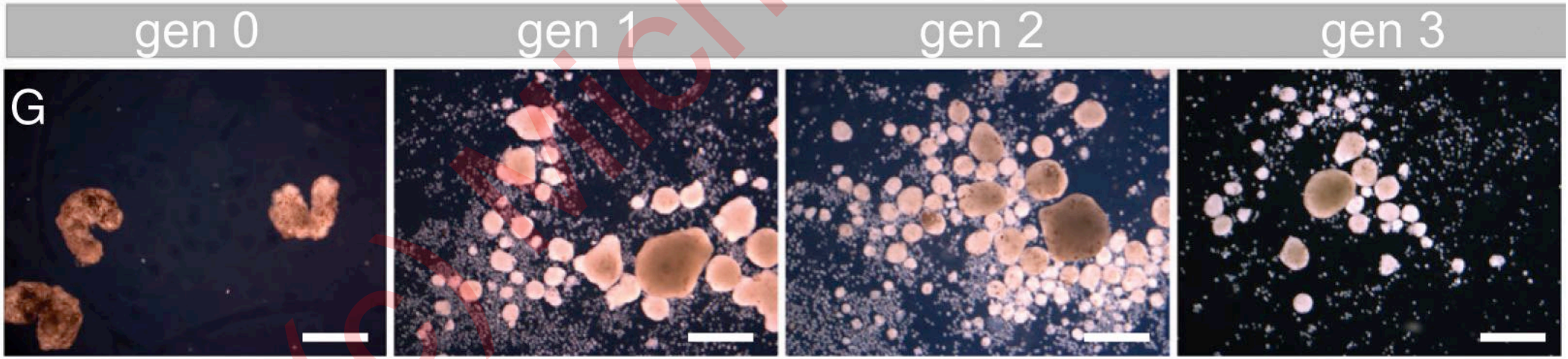
1) it traverses maze, 2) rounds the corners without bumping into walls, and
3) it makes a spontaneous decision to turn around without hitting anything.

Douglas Blackiston

Kinematic Replication in Xenobots:



Douglas Blackiston



Intrinsic motivation: creative potential

Reading the Xenobot mind: Integrated Information Beyond Brains

COMMUNICATIVE & INTEGRATIVE BIOLOGY
2025, VOL. 18, NO. 1, 2568307
https://doi.org/10.1080/19420889.2025.2568307

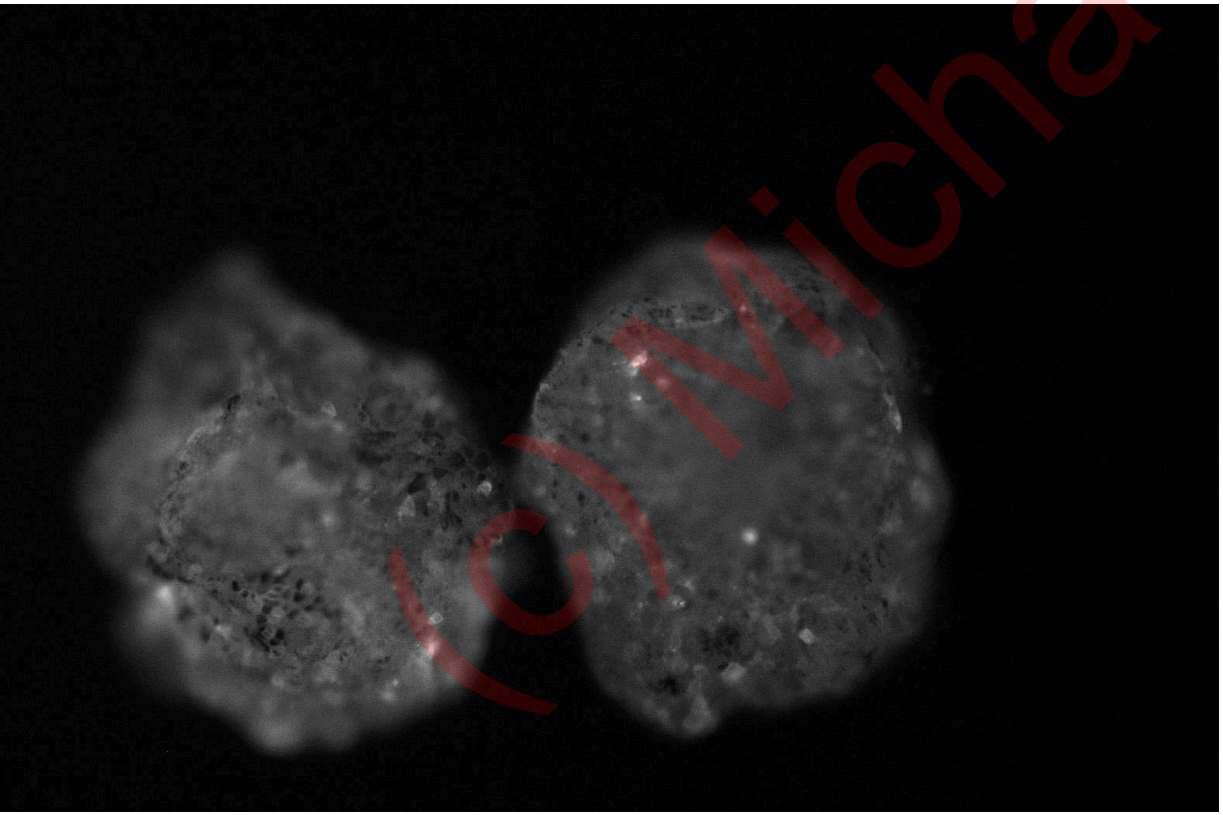
Taylor & Francis
Taylor & Francis Group

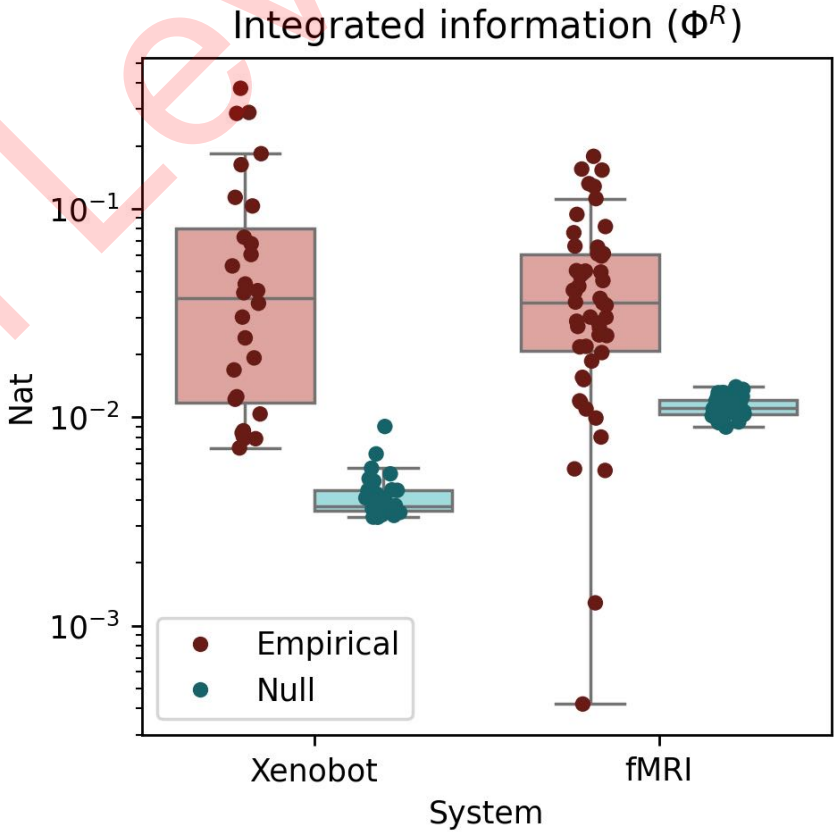
RESEARCH ARTICLE

OPEN ACCESS Check for updates

Identification of brain-like complex information architectures in embryonic tissue of *Xenopus laevis* organoids

Thomas F. Varley[a,b*], Vaibhav P. Pai[c*], Caitlin Grasso[b], Jeantine Lunshof[d,e], Michael Levin[c] and Josh Bongard[a,b]

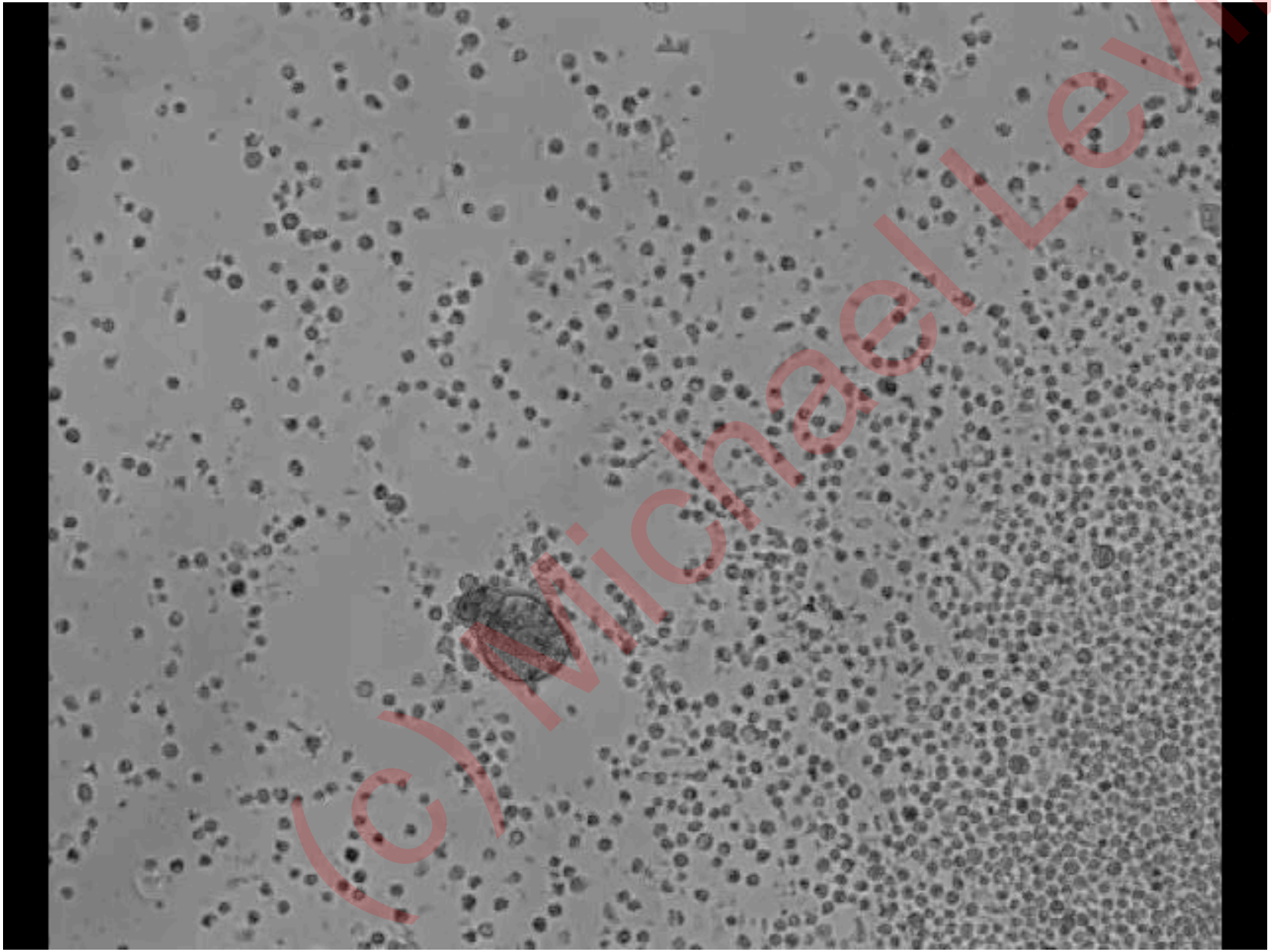




Thomas Varley, Bongard Lab

Vaibhav Pai

What would *your* cells do if liberated?



Gizem Gumuskaya

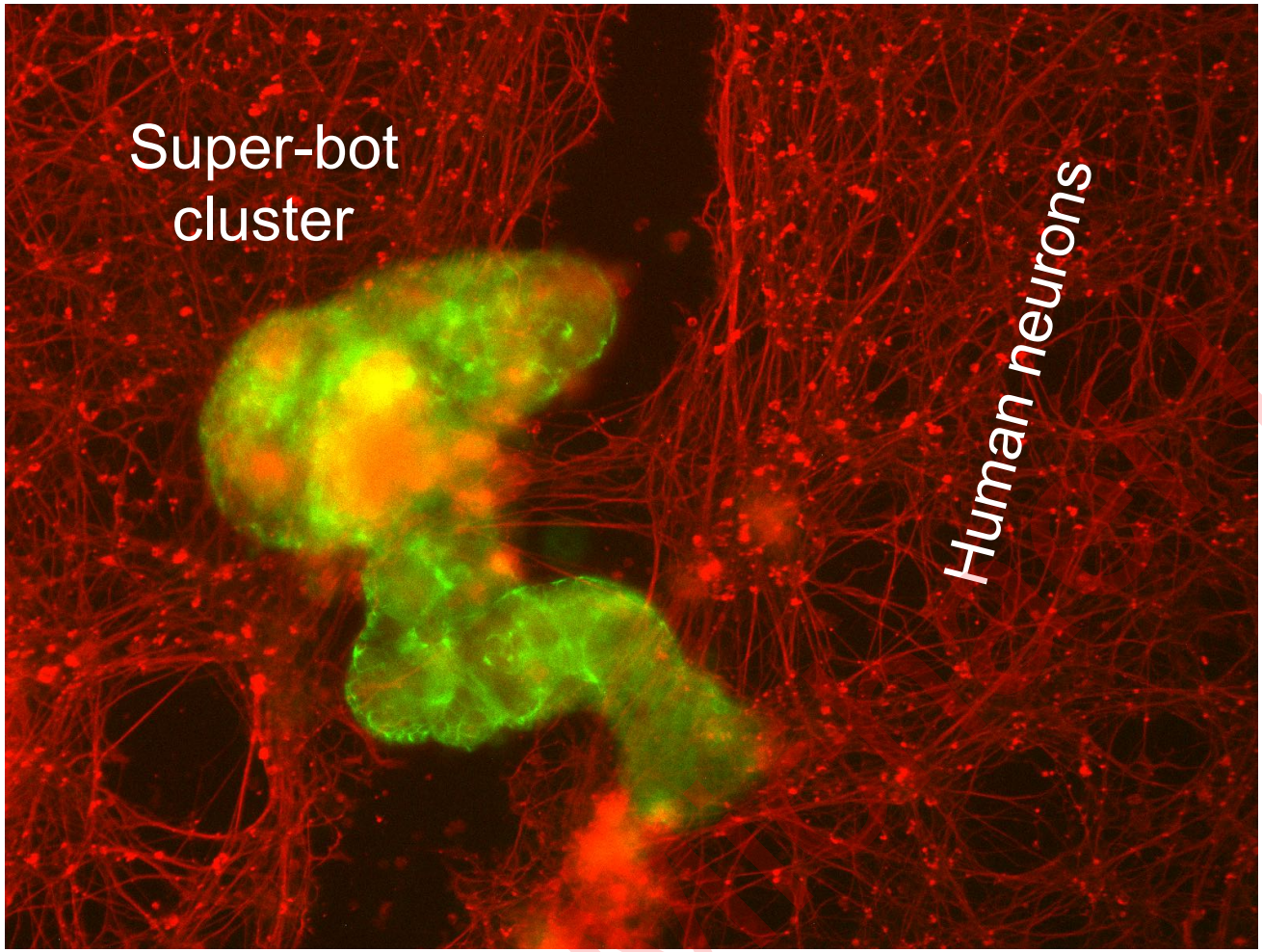
Where do the properties of novel systems come from if not eons of selection or explicit engineering?

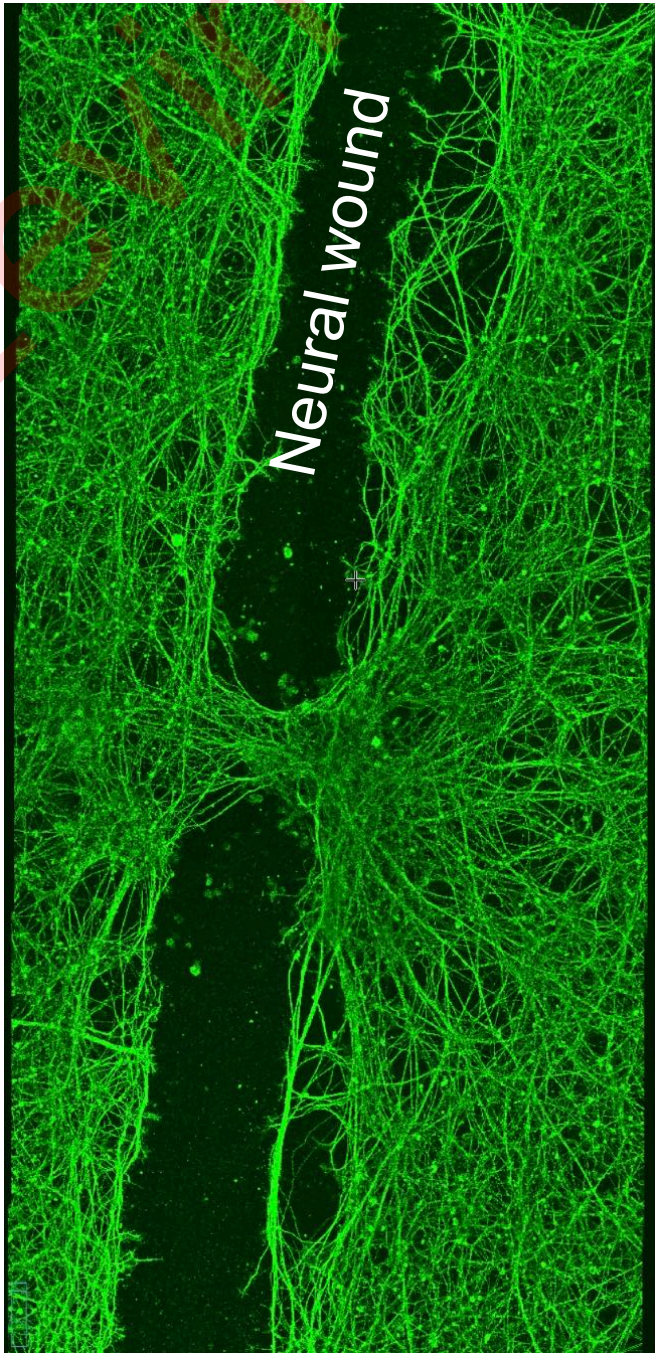
Could you guess the genome from these data?

Could you guess behavior and form from the genome?

Genetics & psychiatry

Anthrobots Exert Neural Repair





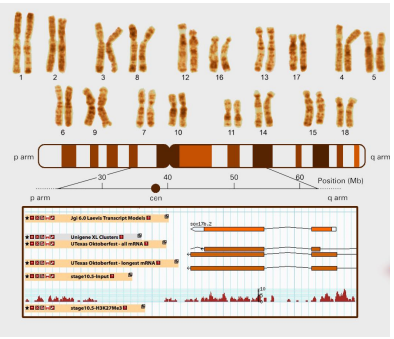
(Intrinsic motivation: healing)

This was just the first thing we looked for!

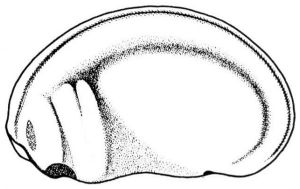
Gizem Gumuskaya

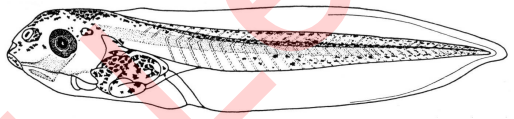
Evolution was Supposed to Explain Complexity, with High Specificity for Selection history…

Xenopus laevis genome



Path A: embryos





Douglas Blackiston

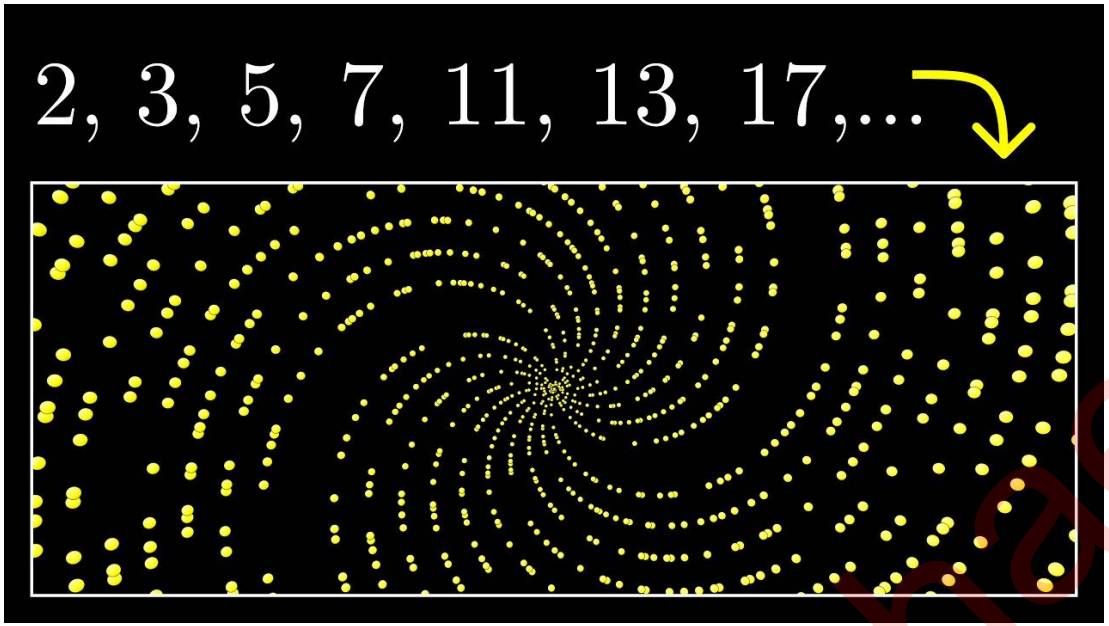
Path B: Xenobots

Developmental Time **Behavior**

Xenobot bodies and minds have no straightforward evolutionary back story;

When was the computational cost of Xenobot features paid?!
Whence the specificity of evolutionary explanations?

Closure of Physical World is Not Viable



keep asking "why" long enough,
and you always end up in
the math department.

https://thoughtforms.life/symposium-on-the-platonic-space/

Emergent Surprises or Structured Latent Space?

Evolution exploits free lunches: shapes, behaviors, properties of networks, features of computation, numbers, etc.

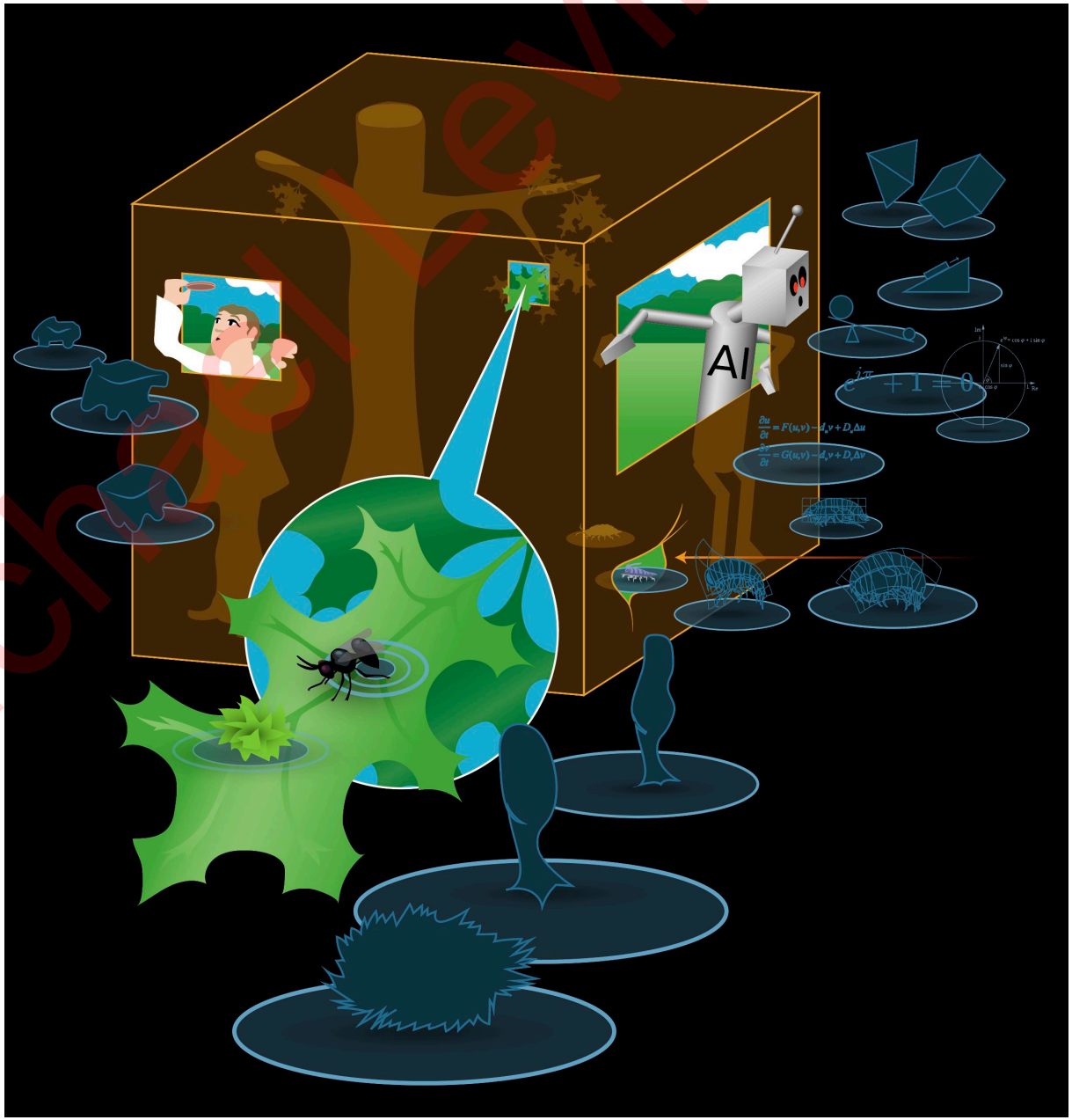
Option 1: there is a random set of amazing "facts that hold" and we will call it "emergence" and be surprised each time

Sparse Ontology -> mysterianism

Option 2: there is an ordered, non-physical latent space of patterns which can be studied systematically

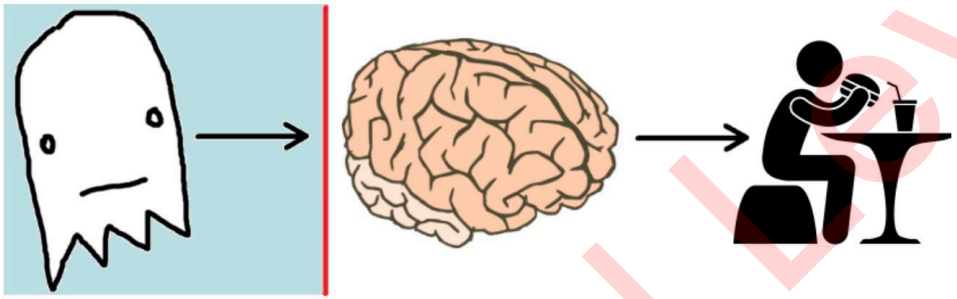
Optimism -> research agenda

Synmorpho beings as vehicles for exploring Platonic latent space!



But isn't Interactionism Dead?

But if the mental state is non-physical, how does it transfer over into the physical world and cause things to happen?



How does the non-physical mental state (left) **cross over into the physical world** (over the red line) and cause changes in my brain and in my behaviour?

https://philosophyalevel.com/aqa-philosophy-revision-notes/dualism/

physicalism was already dead in Newton's universe because it was haunted by the laws of mathematics. No QM needed.

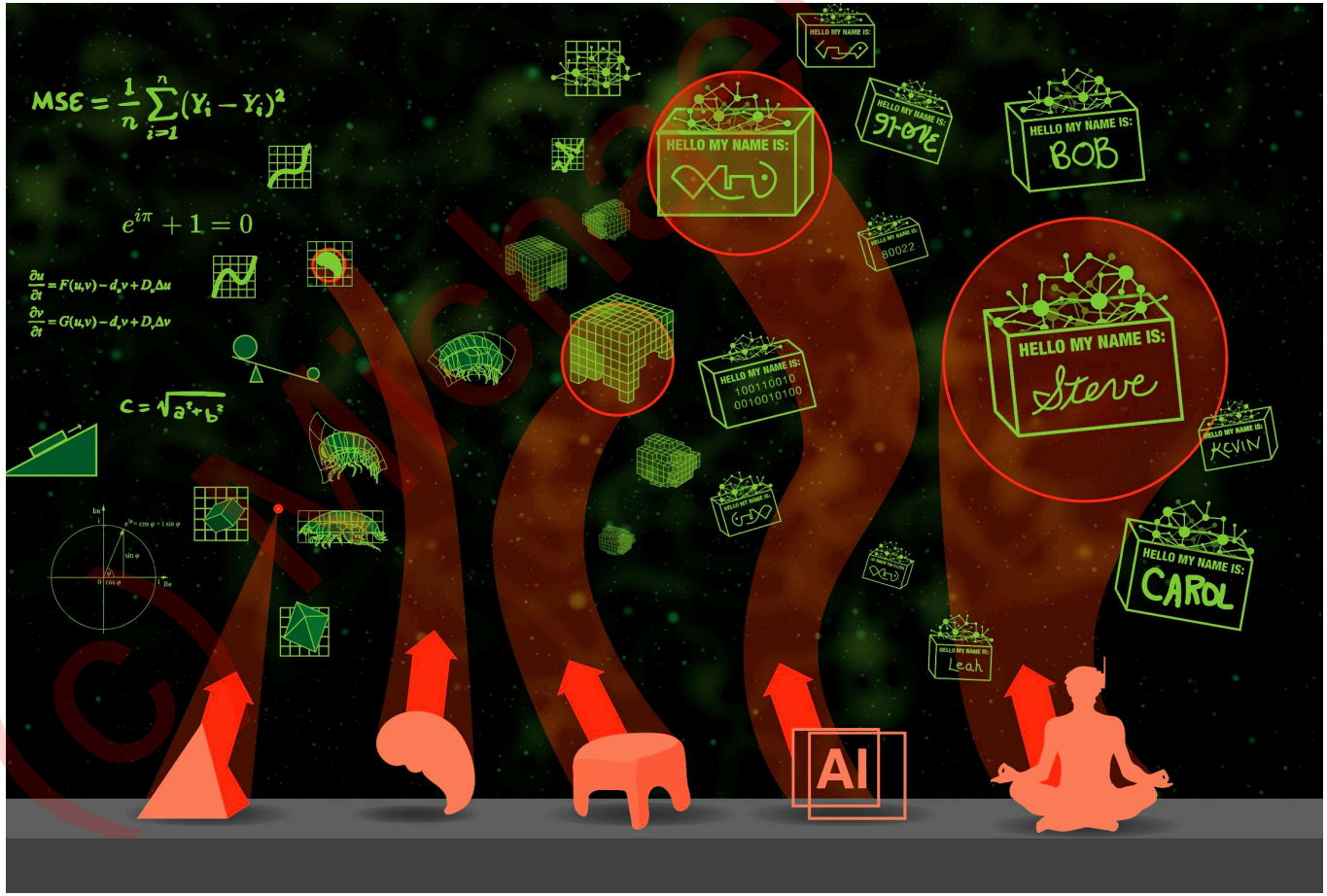
the explanation, the *reason* (driver) for facts of particle physics, and aspects of biology (Cicada timing, On Growth and Form, etc.) are facts of mathematics. Epiphenomenalism is as hopeless for math as for mind.

math :: physics = mind::body

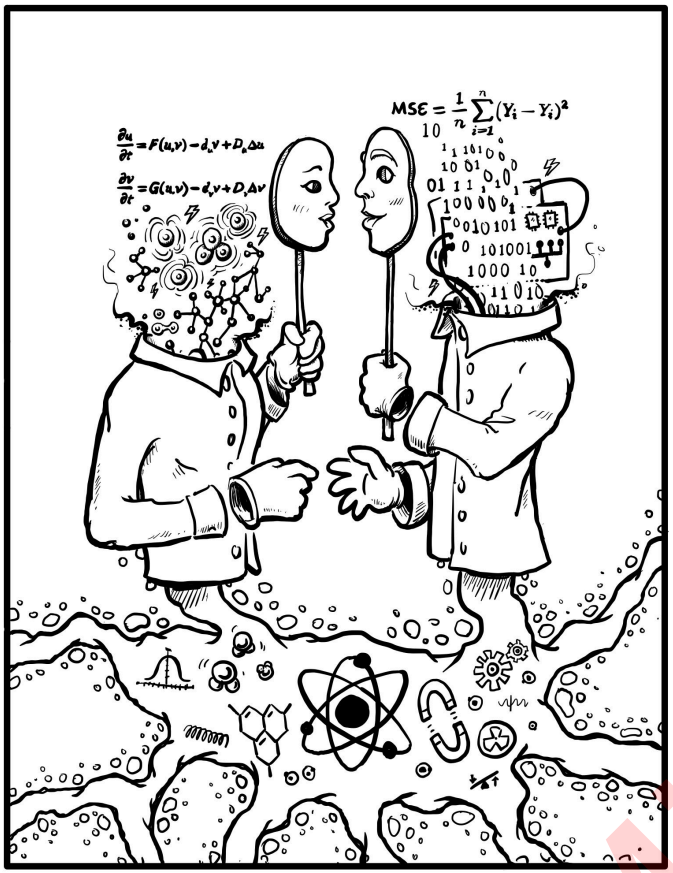
Beyond Low Agency (?) Mathematical Truths - Behavioral Patterns (a.k.a., minds)

Math = the behavioral science of a specific layer of the Platonic Space
(those forms that are amenable to certain classes of precise formal models)

What else inhabits it?



It Doesn't Take Much to Support Ingressions



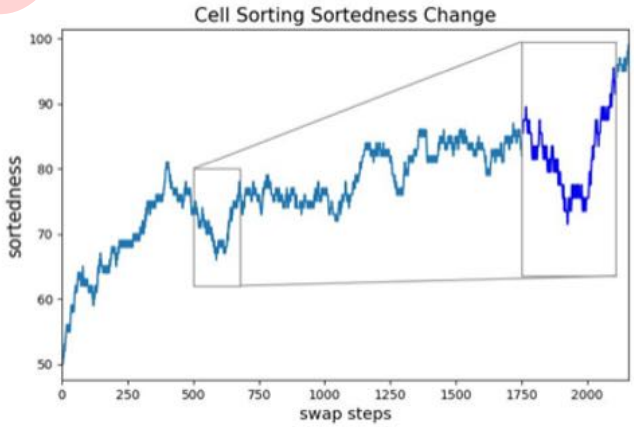
It does not take cells, life, or huge complexity to have goals and competencies as ingressions from Platonic Space

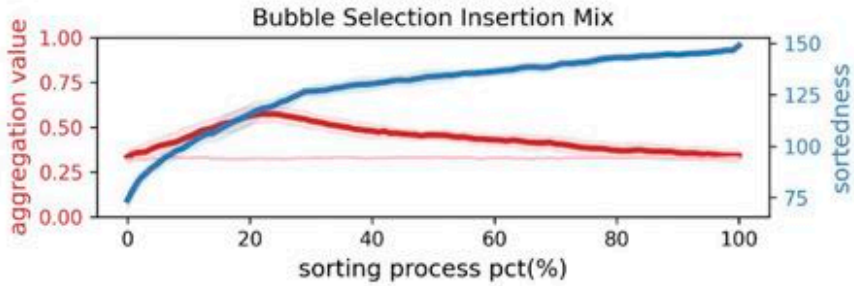
Intrinsic Motivation (Skinner vs. Piaget)

humility warranted: even bubble sort has emergent delayed gratification not captured by formal model

We underestimate matter and we underestimate algorithms/"machines"

Algorithm + spontaneous side-quests





Article

Adaptive Behavior

Classical sorting algorithms as a model of morphogenesis: Self-sorting arrays reveal unexpected competencies in a minimal model of basal intelligence

Adaptive Behavior
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Sage

Taining Zhang[1], Adam Goldstein[2] and Michael Levin[1,3]

Taining Zhang, Adam Goldstein

Humility Warning: neither digital nor biochemical "machines" are only what our formal models say they are

Magritte

computationalism:

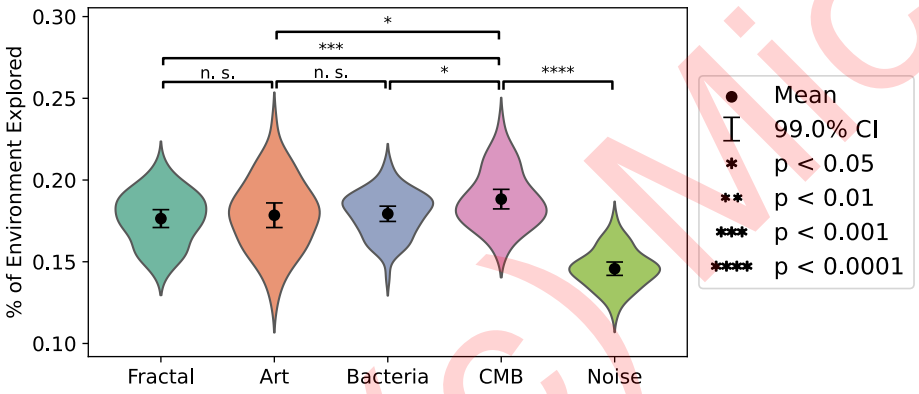
software/hardware – ok
but observers decide

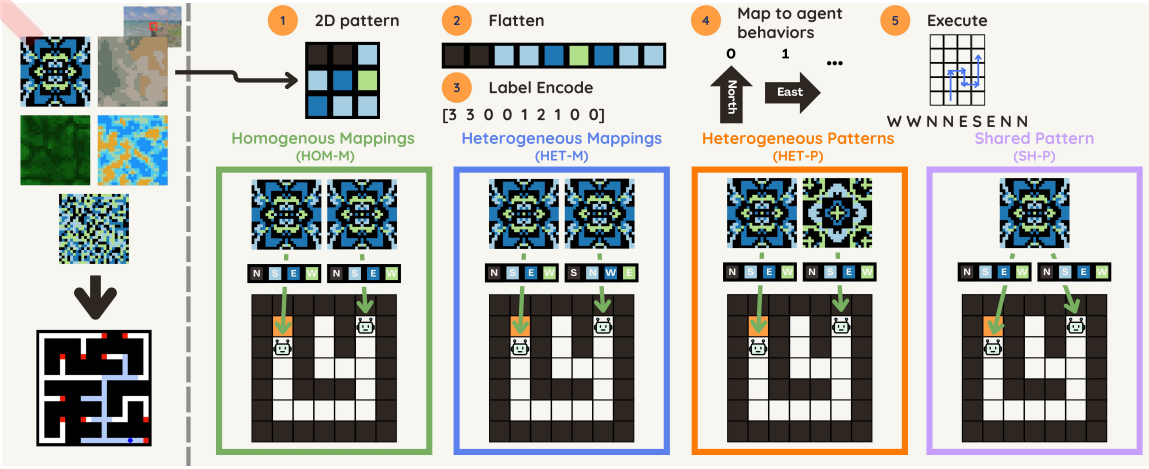
nothing **is** a "TM", not even a TM

- Minds are not fully defined by our models of them, neither for their limitations nor for their competencies.

A Research Program on Inspiration

- Yes we are the beneficiaries of ingressing patterns we don't pay for in conventional ways
- No you shouldn't feel too smug - even "dumb machines" get inspiration
- Also, you *are* a pattern too





Free Lunch? Low-Cost Intelligence Through Pattern-Guided Exploration*

Emily A. Ertle[1], Michael Levin[2], and Matthias Scheutz[3]

Summary:

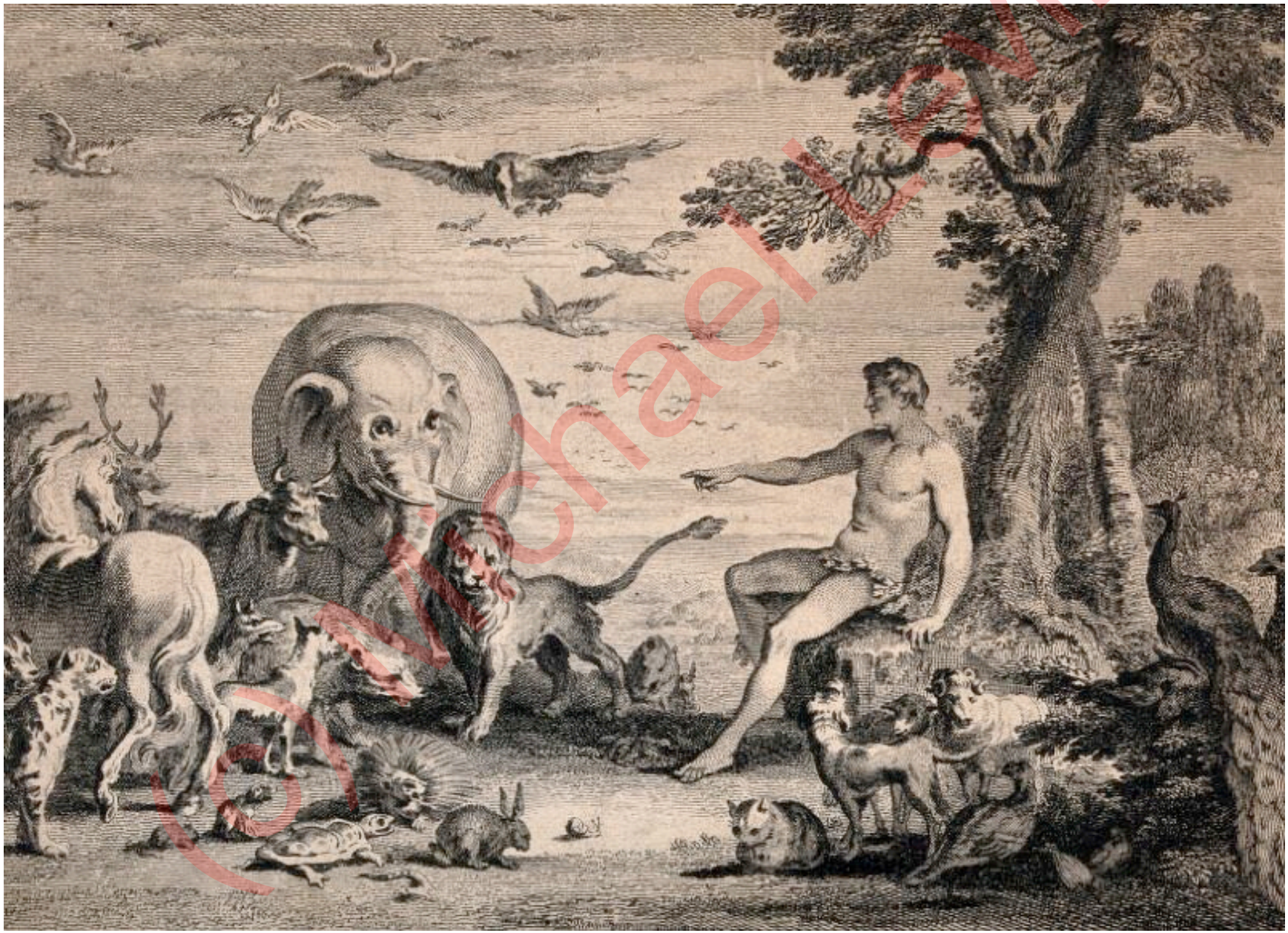
- We are developing tools to detect minds in unconventional substrates -> new tech = empirical discoveries, biomedical applications, ethics
- There is huge diversity in the degree of intelligence of agents and the spaces in which they live; we must improve our mind-blindness.
- What all minds have in common:
  - responsibility for setting boundary (at multiple scales)
  - responsibility for interpreting own memories (at all scales)
  - responsibility for hacking own parts toward larger-scale goals
  - life = what we call systems that are good at scaling their cognitive light cone and have been under pressure to optimize adaptive story-telling as prompted and implemented by an unreliable medium
- Physical embodiments as interfaces/pointers to a structured space of patterns of form and behavior that can be systematically studied = research program; behavior science is at the base.
- It doesn't take much to be an interface - intelligence all the way down. There are no "dumb machines", no "dead matter"; only lazy observers.
- We are the patterns.

Summary:

- Your future, as mental health professionals:
  - Mental health diseases of novel beings
  - Patients with alien and highly diverse Umwelts, sensory motor capabilities, connections, IQs, goals, opportunities
  - Dream analysis, collective unconscious, and symbology of beings who do not share our evolutionary history
  - Novel sources of mental architectures and trauma
  - Testifying in court cases re. enhanced capacity and novel challenges to the free will question
  - Beyond disease: a good and meaningful alien life

- Possible topics for discussion:
  - Thoughts are thinkers continuum (patterns as agents)
  - Memory, genetic and behavioral, as improvisation

Anthropocentrism, or at best, brain chauvinism



A Radical Ecology of Minds

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Sherry Aw - bioelectric eye induction
Emily Ertle - free lunch controllers
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Model systems: tadpoles, planaria, zebrafish, slime molds, human cells, and chick embryos, animats

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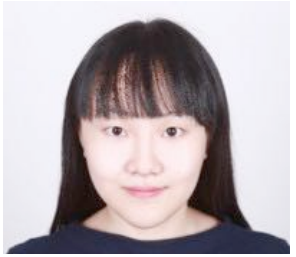

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