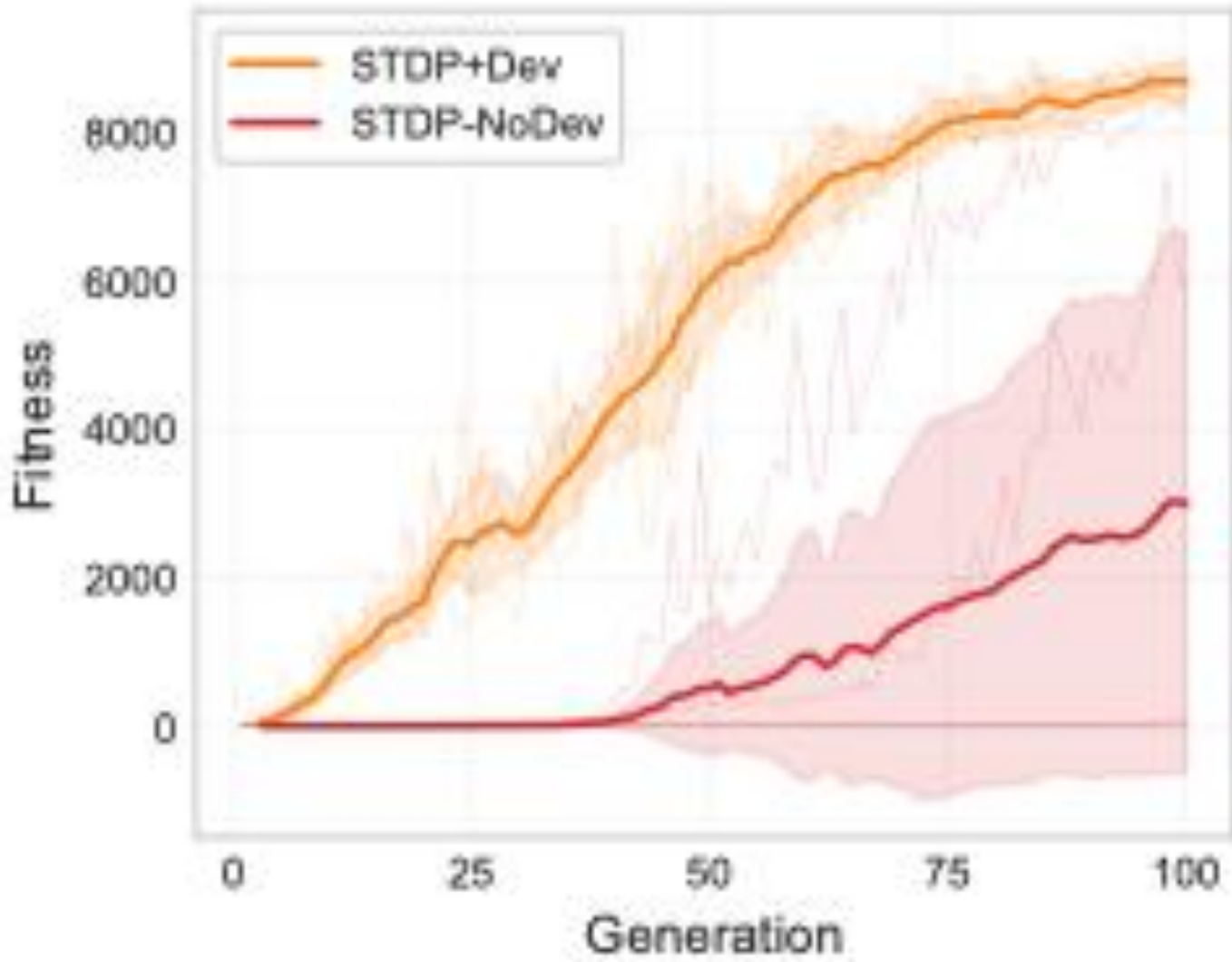
# Another Kind of Clay: Intelligence as the Shaping of Intrinsic Noise

Benjamin Gaskin

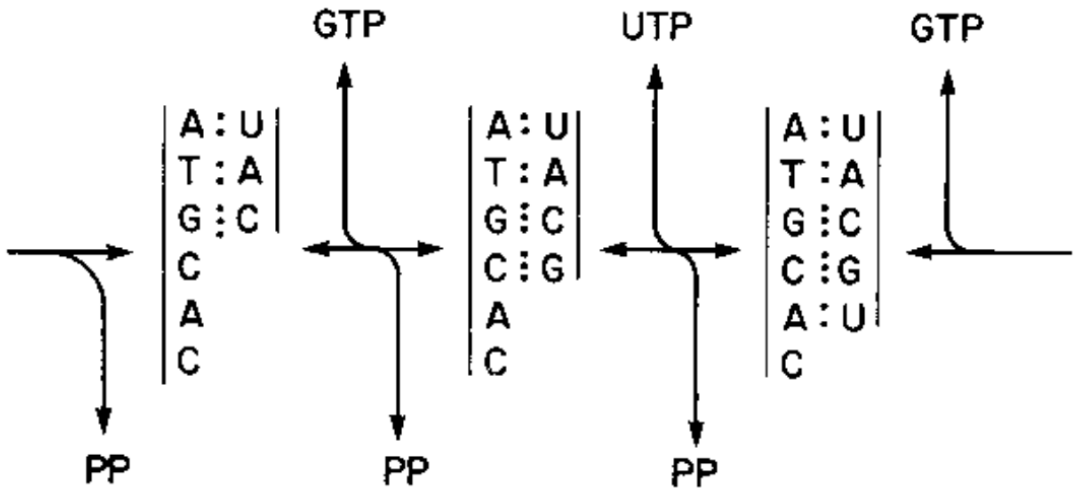
His origins are become remote as is his destiny and not again in all the world's turning will there be terrains so wild and barbarous to try whether the stuff of creation may be shaped to man's will or whether his own heart is not another kind of clay.

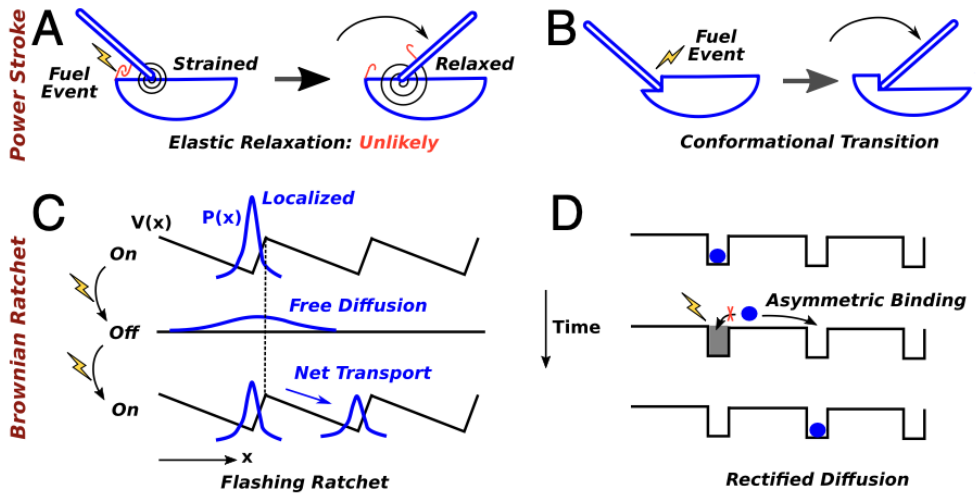
—Cormac McCarthy, *Blood Meridian*

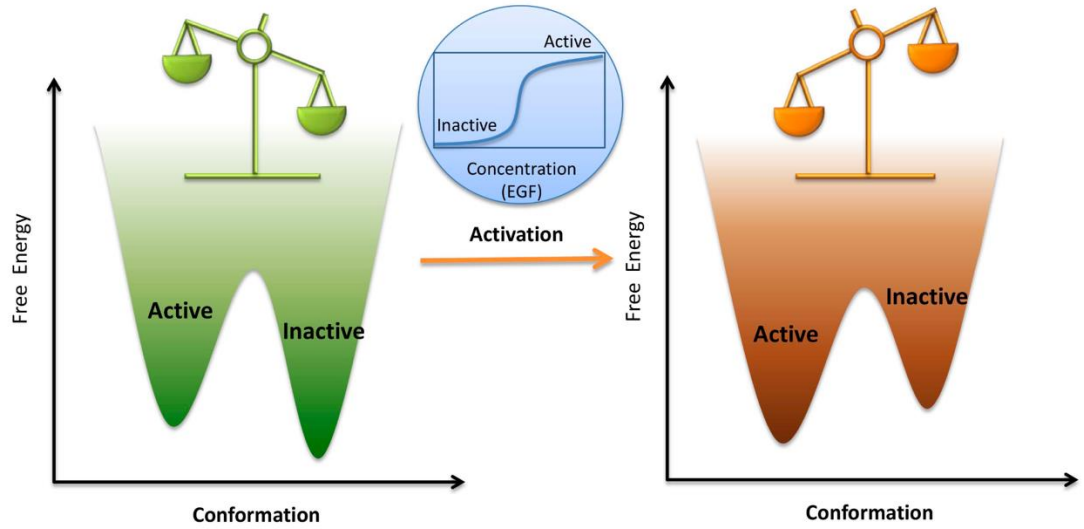
# Unreliable organisms


STDP+Dev
STDP-NoDev
8000
6000
4000
2000
0
Fitness
0
25
50
75
100
Generation

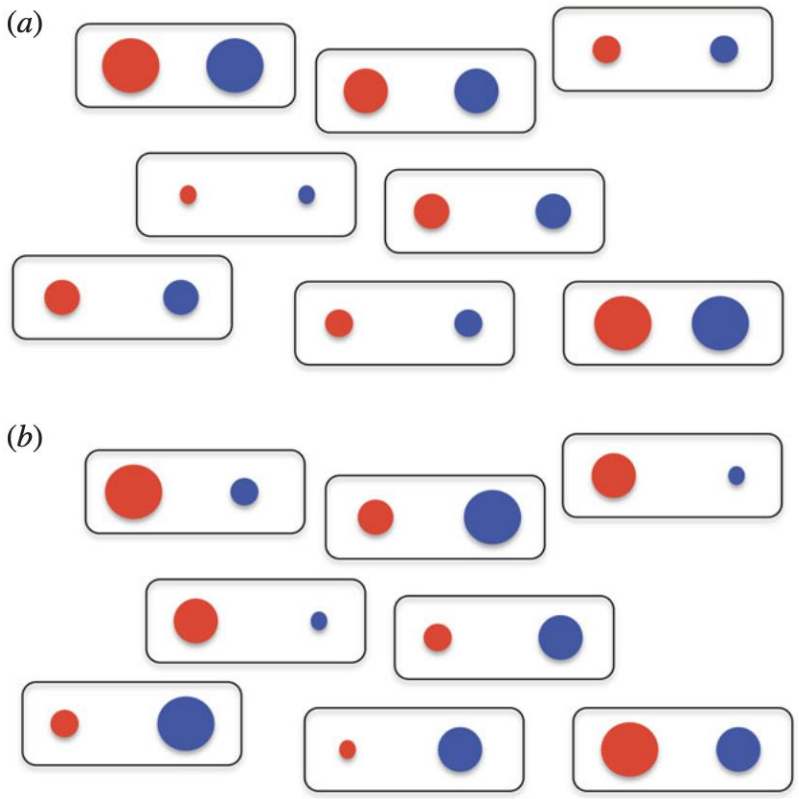
# Molecular

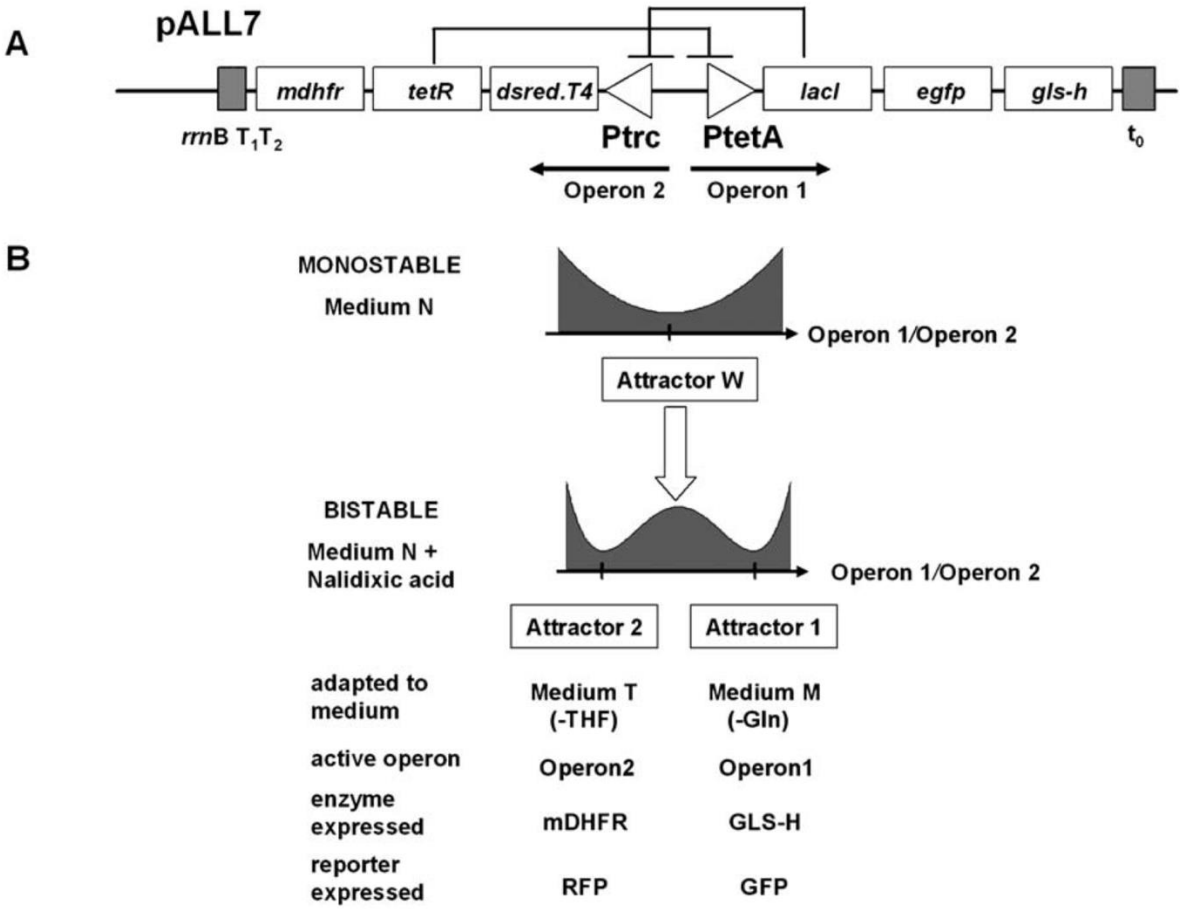

GTP
UTP
GTP
A : U
T : A
G : C
C
A
C
PP
PP
PP


Power Stroke
A
Fuel Event
Strained
Relaxed
Elastic Relaxation: Unlikely
B
Fuel Event
Conformational Transition
Brownian Ratchet
C
V(x)
P(x)
Localized
On
Free Diffusion
Off
Net Transport
On
x
Flashing Ratchet
D
Time
Asymmetric Binding
Rectified Diffusion

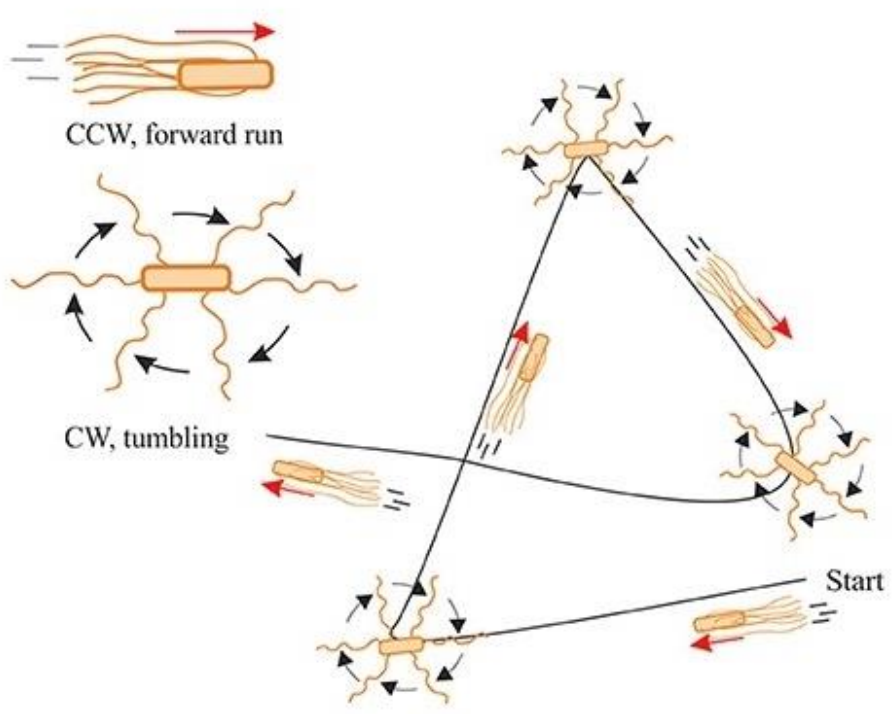

Free Energy
Active
Inactive
Conformation
Active
Inactive
Concentration (EGF)
Activation
Free Energy
Active
Inactive
Conformation

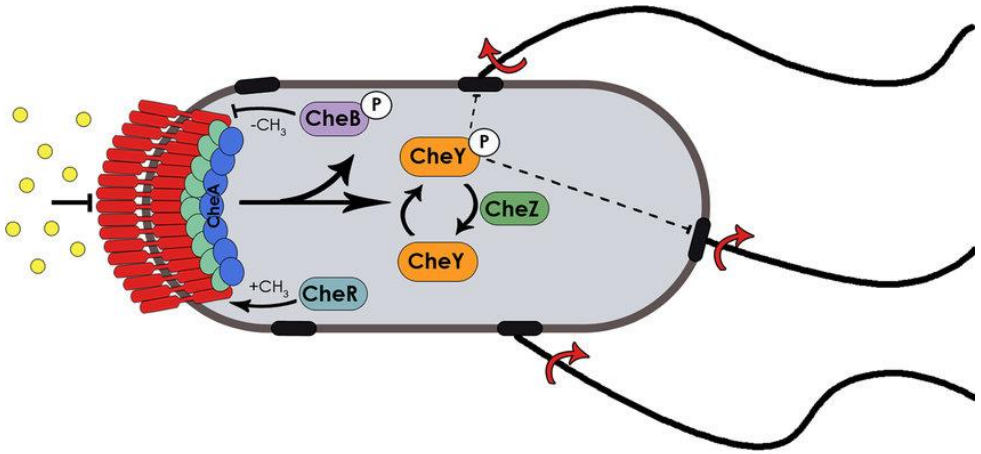
# Genetic

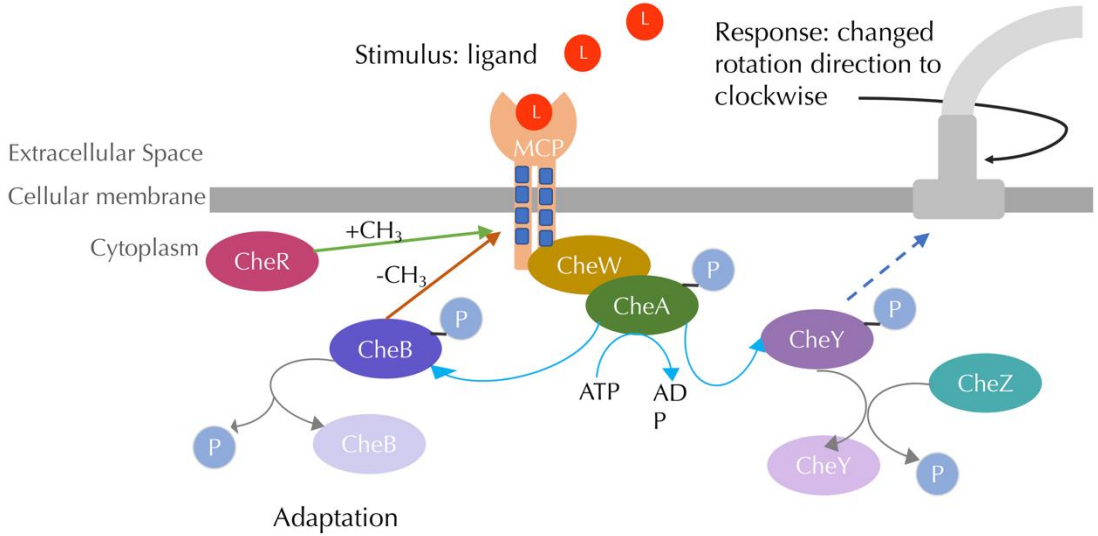

(a)
(b)


A
pALL7
mdhfr
tetR
dsred.T4
lacI
egfp
gls-h
rrnB T1T2
Ptrc
PtetA
t0
Operon 2
Operon 1
B
MONOSTABLE
Medium N
Operon 1/Operon 2
Attractor W
BISTABLE
Medium N +
Nalidixic acid
Operon 1/Operon 2
Attractor 2
Attractor 1
adapted to medium
Medium T (-THF)
Medium M (-Gln)
active operon
Operon2
Operon1
enzyme expressed
mDHFR
GLS-H
reporter expressed
RFP
GFP

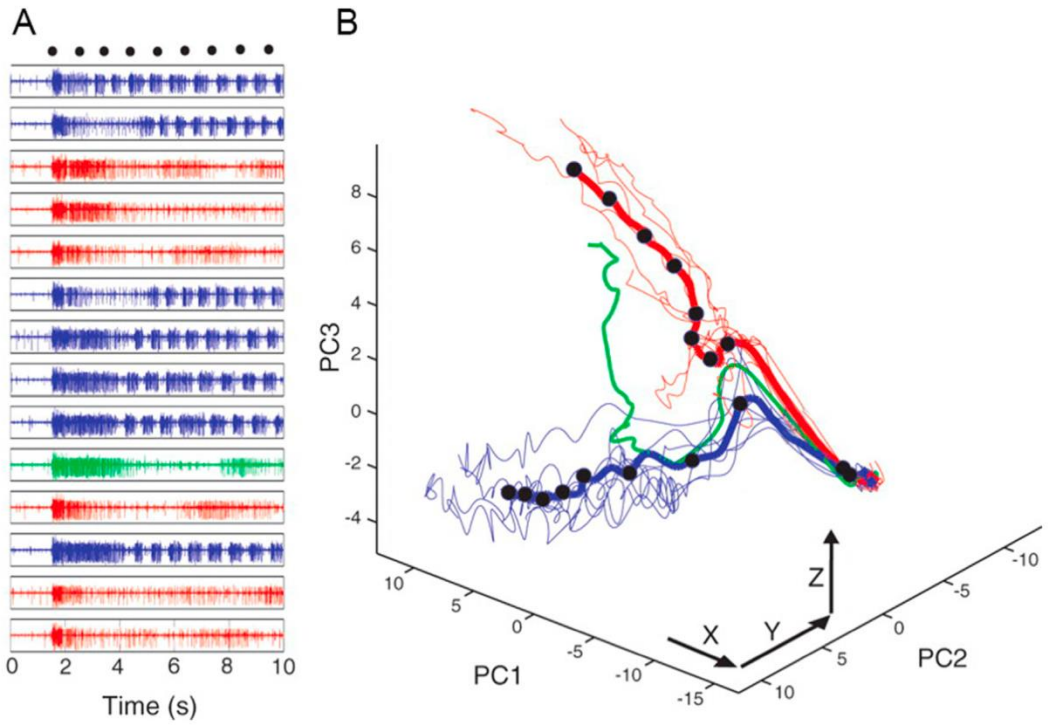
# Cellular

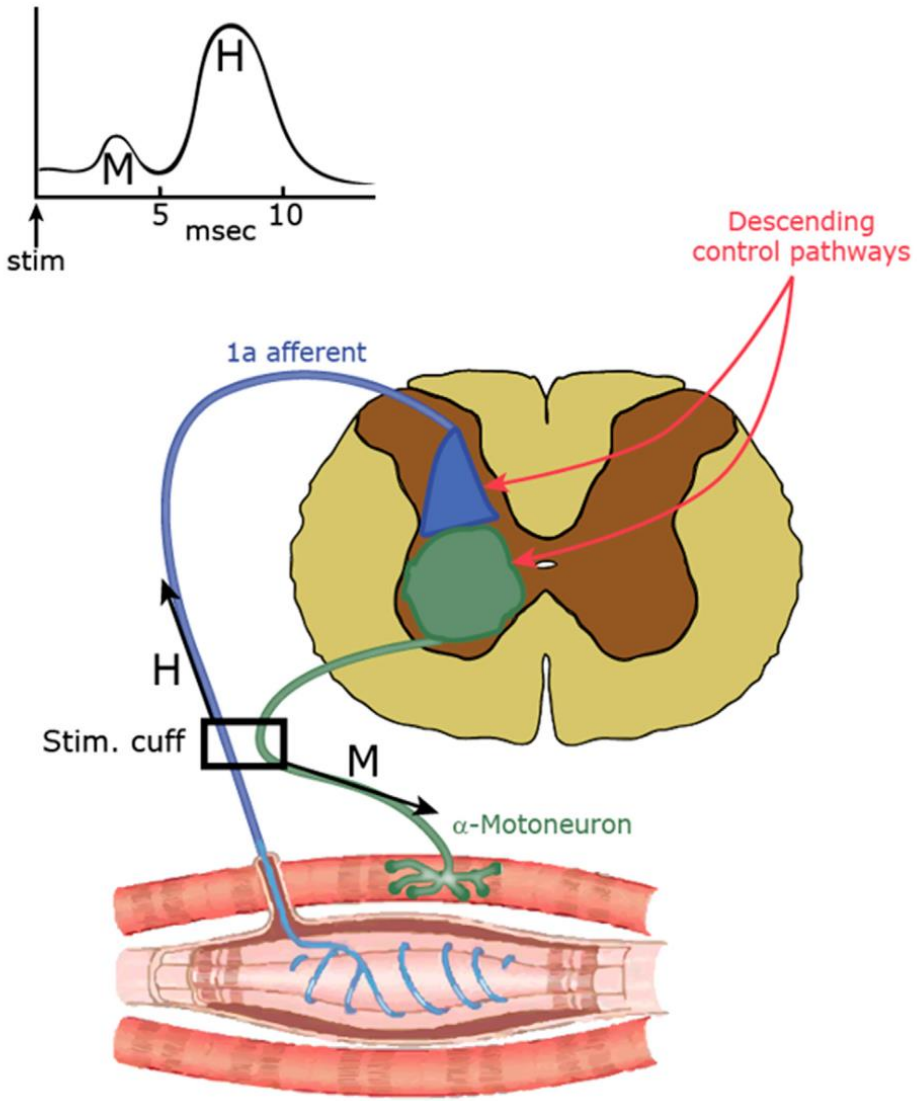

CCW, forward run
CW, tumbling
Start


CheB
P
-CH3
CheY
P
CheZ
CheA
CheY
+CH3
CheR

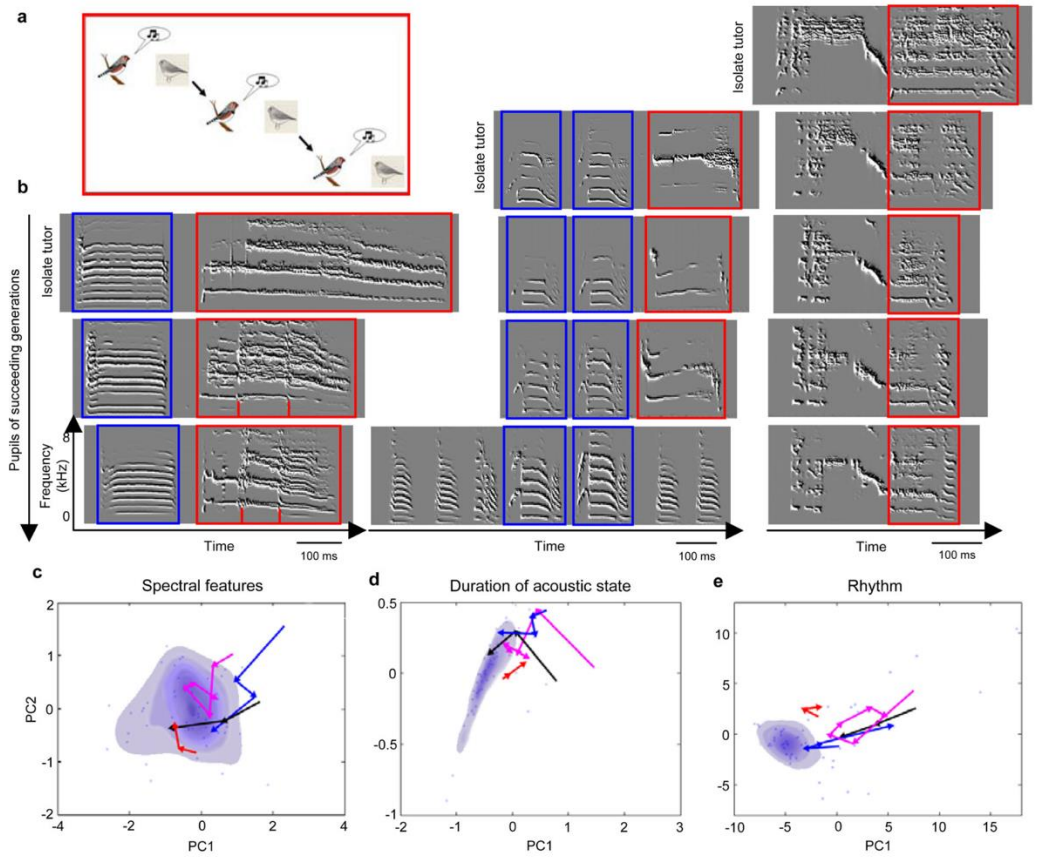

Stimulus: ligand
L
L
L
Response: changed rotation direction to clockwise
MCP
Extracellular Space
Cellular membrane
Cytoplasm
CheR
+CH3
-CH3
CheW
P
CheA
P
CheB
P
ATP
AD P
CheY
P
CheZ
P
CheB
CheY
P
Adaptation

# Individual

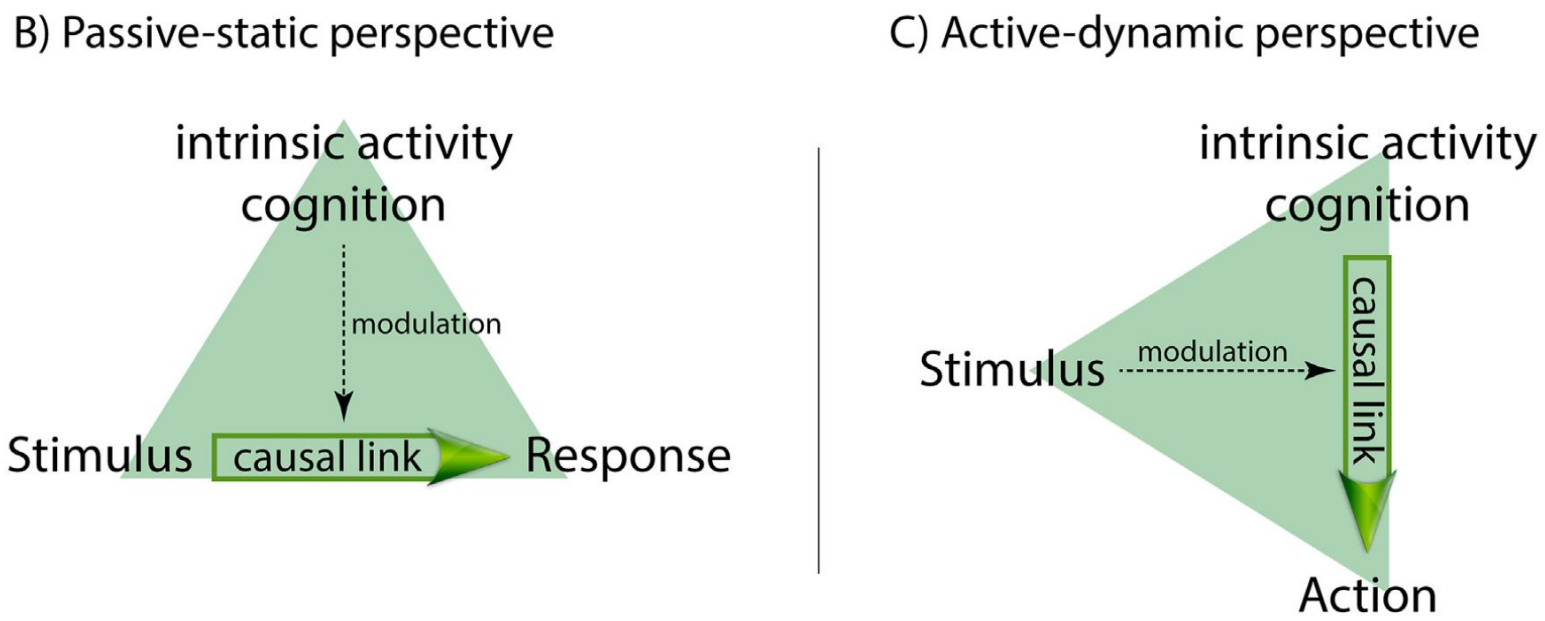

A
B
Time (s)
PC1
PC2
PC3
X
Y
Z


H
M
5
msec
10
stim
Descending
control pathways
1a afferent
H
Stim. cuff
M
α-Motoneuron

# Social

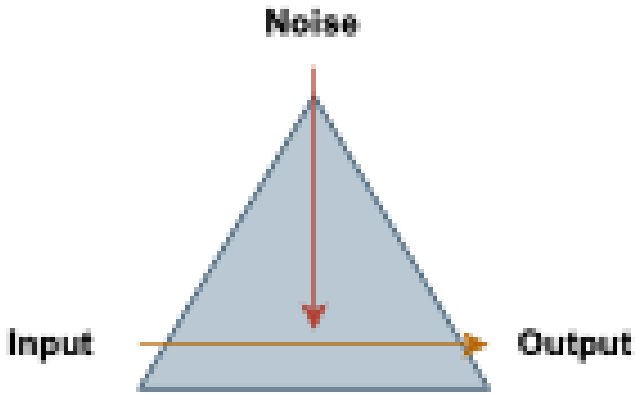

a
b
Isolate tutor
Isolate tutor
Isolate tutor
Pupils of succeeding generations
Frequency (kHz)
8
0
Time
100 ms
Time
100 ms
Time
100 ms
c
Spectral features
PC2
PC1
d
Duration of acoustic state
PC1
e
Rhythm
PC1

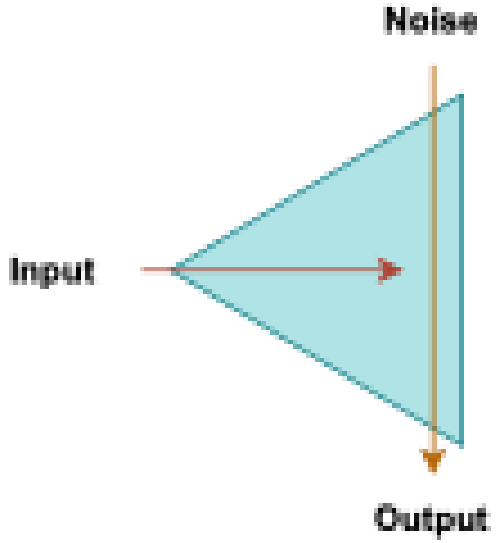

a
02:05:57:46
b
02:06:03:32




Brembs' makes **three related arguments** in *'The Brain as Dynamically Active Organ'*—

1. **Intrinsic activity is primary and sensory input modulates this**
2. **This activity structures reafferent behaviour to probe the world**
3. **The variability of intrinsic activity is evolutionarily advantageous**

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# What is life?

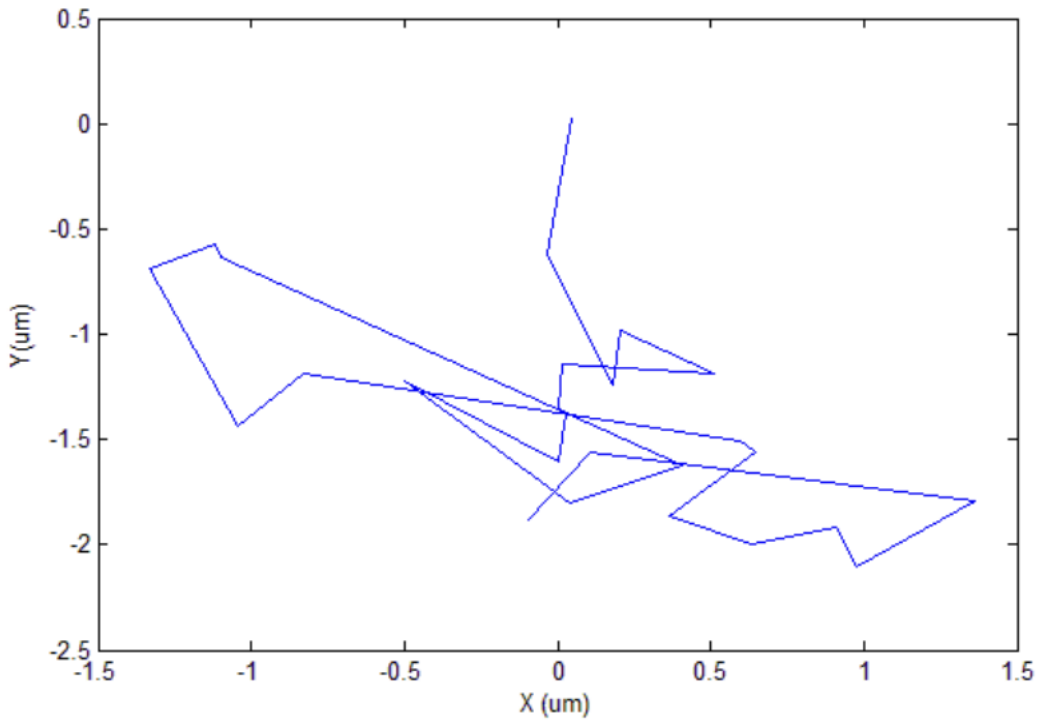
# Living systems as agentic entities

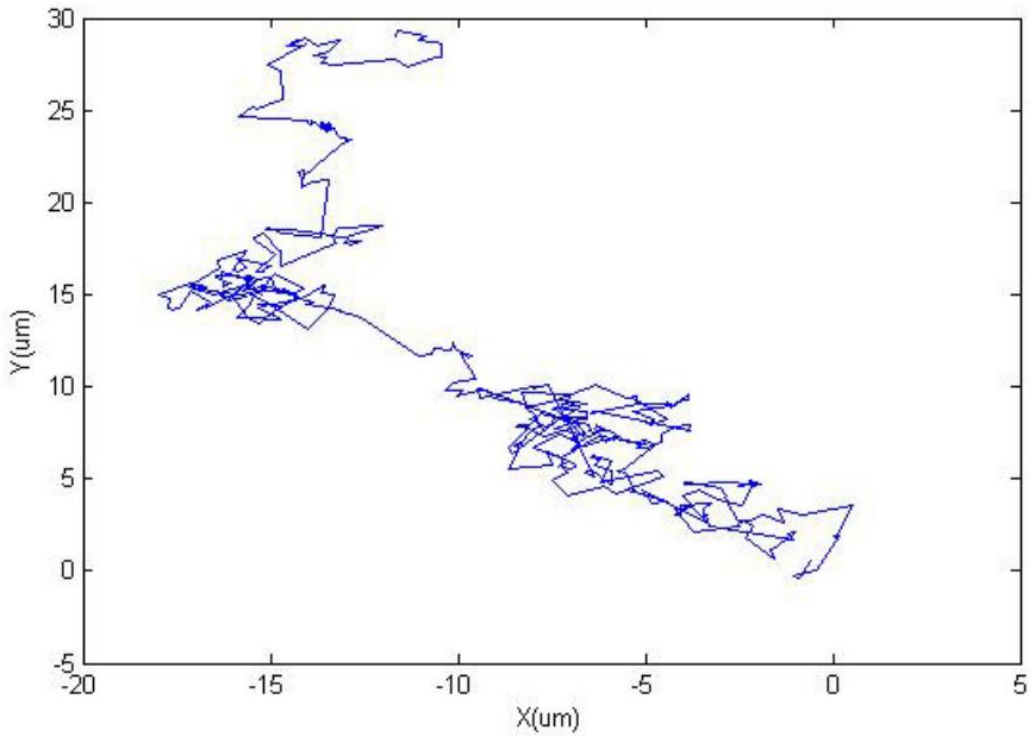
- Agentic **events** involve the **costly reweighting of probabilities**
  - **KL divergence** between passive and active path distributions
  - Maxwell's demon as minimal form, **Landauer's principle** as limit cost
- Agentic **entities** arrange such events into **organisational closure**
  - Rosen's metabolism-repair systems, Hofmeyr's fabrication-assembly
  - Kaufmann's work–constraint cycles, Gánti's chemoton model
- Agentic **acts**—are what?
  - Gánti's chemoton model is **purely stoichiometric**, hence relatively rigid
  - The emergence of **regulatory control requires stoichiometric freedom**
  - This level is the basis of agentic acts, **below which there are only events**

# The vector model of agency and intelligence

- Agency as **magnitude**
- Intelligence as **direction**
  - How can we measure the ‘direction’ of a path difference?
  - Intuitively, we can think of this as its **qualitative specificity**
  - Strictly, however, this is **co-constituted by passive and active**
  - **Intelligence is thus a form sculpted of the passive distribution**
- Some implications of this model—
  - Intelligence **requires agency, hence is costly**
    - Maxwell’s demon, Landauer’s principle
  - This is an **outcome-agnostic view** of intelligence
    - The directedness of agency, not its effect

# What is the passive distribution?



# Pattee’s biosemiotics

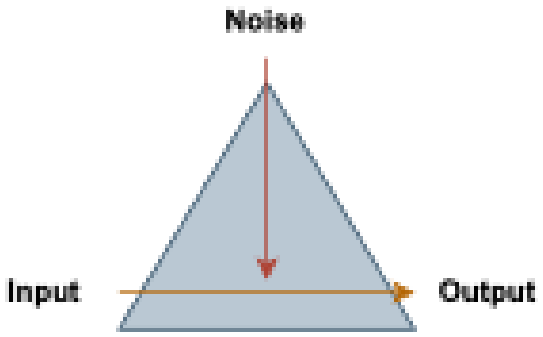
“It is useless to search for meaning in symbols without complementary knowledge of the dynamics being constrained by the symbols.”

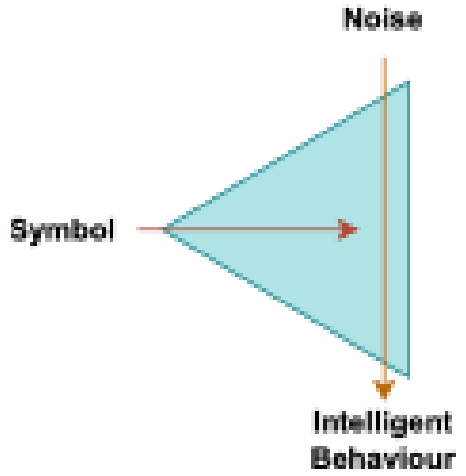
# Pattee's account of a symbol

- Symbols here have **six essential characteristics—**
  - They are **physical structures**
  - They are **replicable (i.e., transmittable)**
  - They are **selected constraints**
  - They act by **harnessing dynamics**
  - They effect **functional coordination**
  - Their **constraining is continuous**
- **Meaning is thus the specificity of a symbolic constraint**
  - This emerges from the **selected history of symbol as physical structure**
  - Symbols **must be replicable to have been selected over such a history**

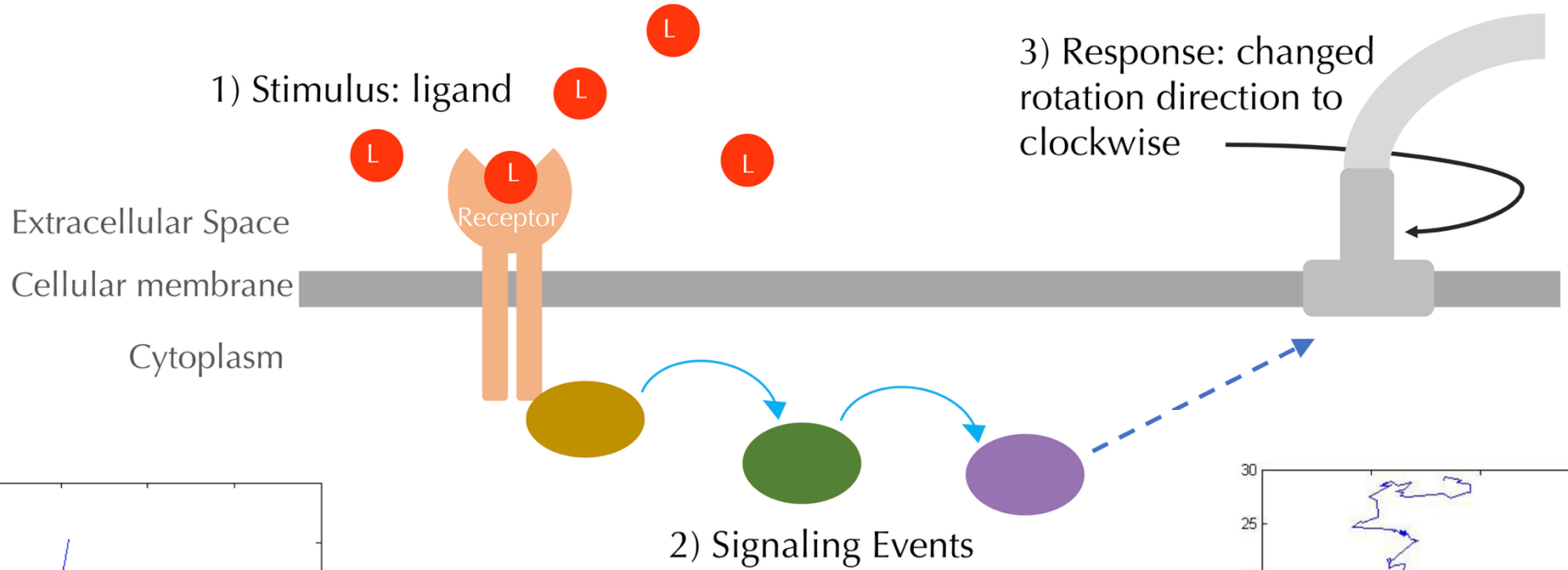
# Intelligence as symbolic-dynamical constraint

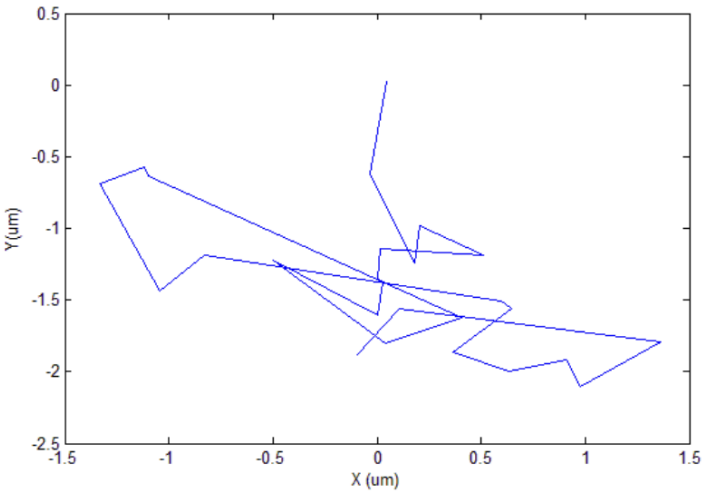
- The fundamental material of intelligence is **intrinsic activity**
- Sensory input **constrains this according to a selection history**
  - For Pattee, this was **essentially a phylogenetic history**
  - For **chemical systems**, it is still essentially phylogenetic
  - For **neural systems**, the **ontogenetic becomes important**

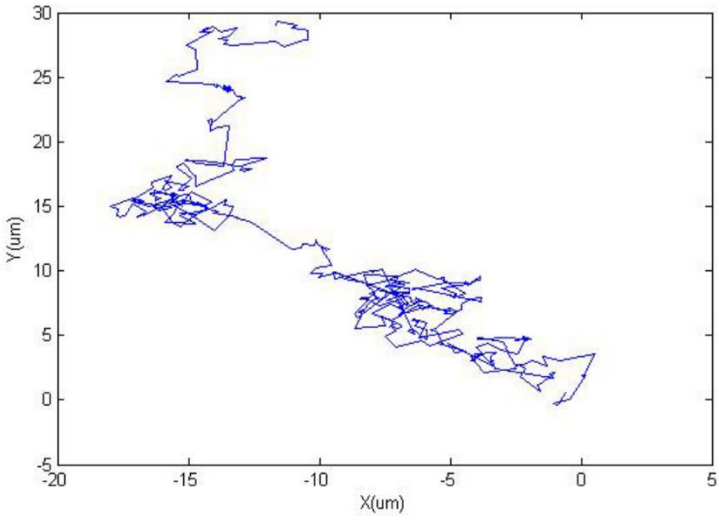


# Sensory constraint in bacterial chemotaxis



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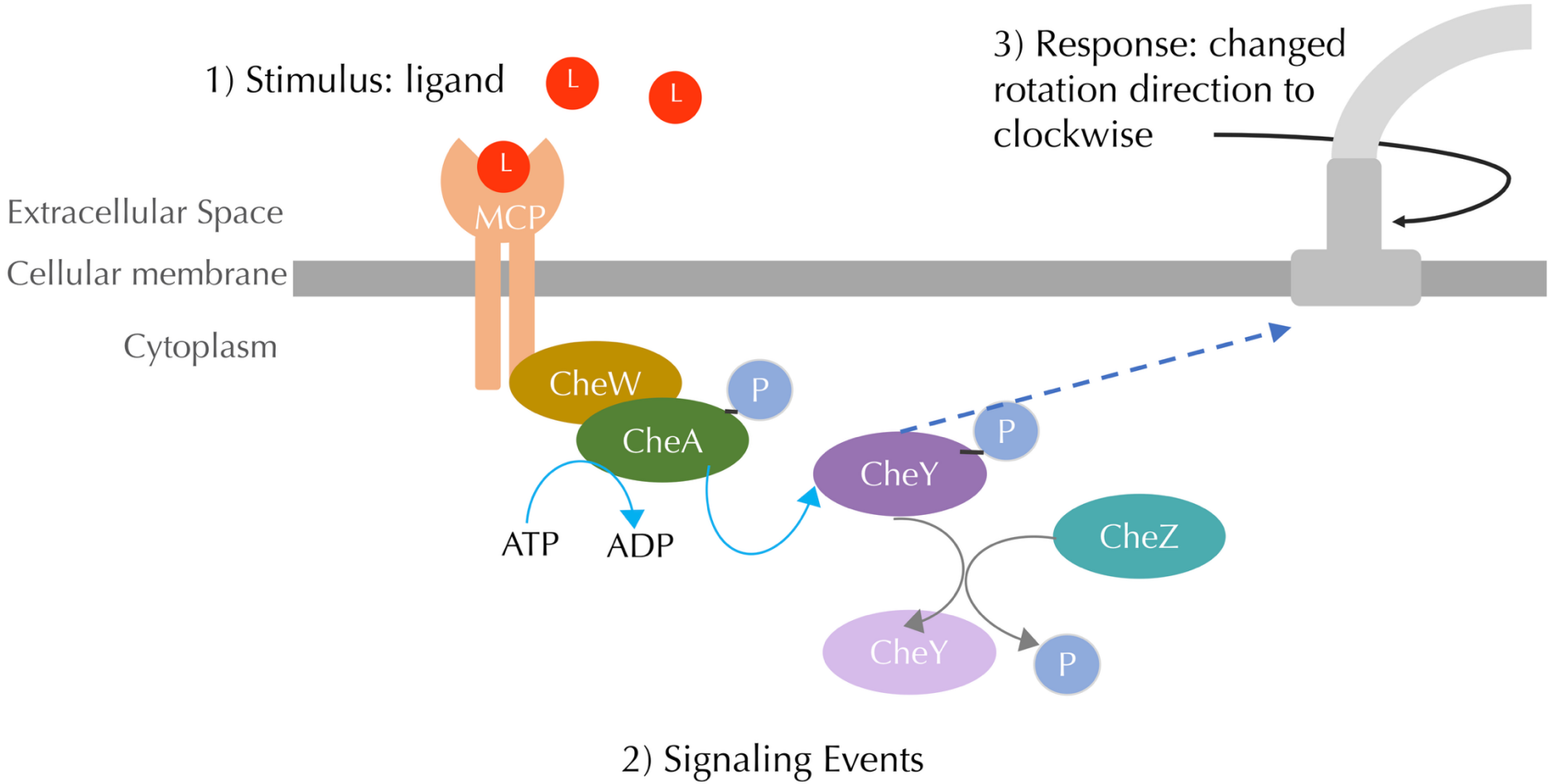

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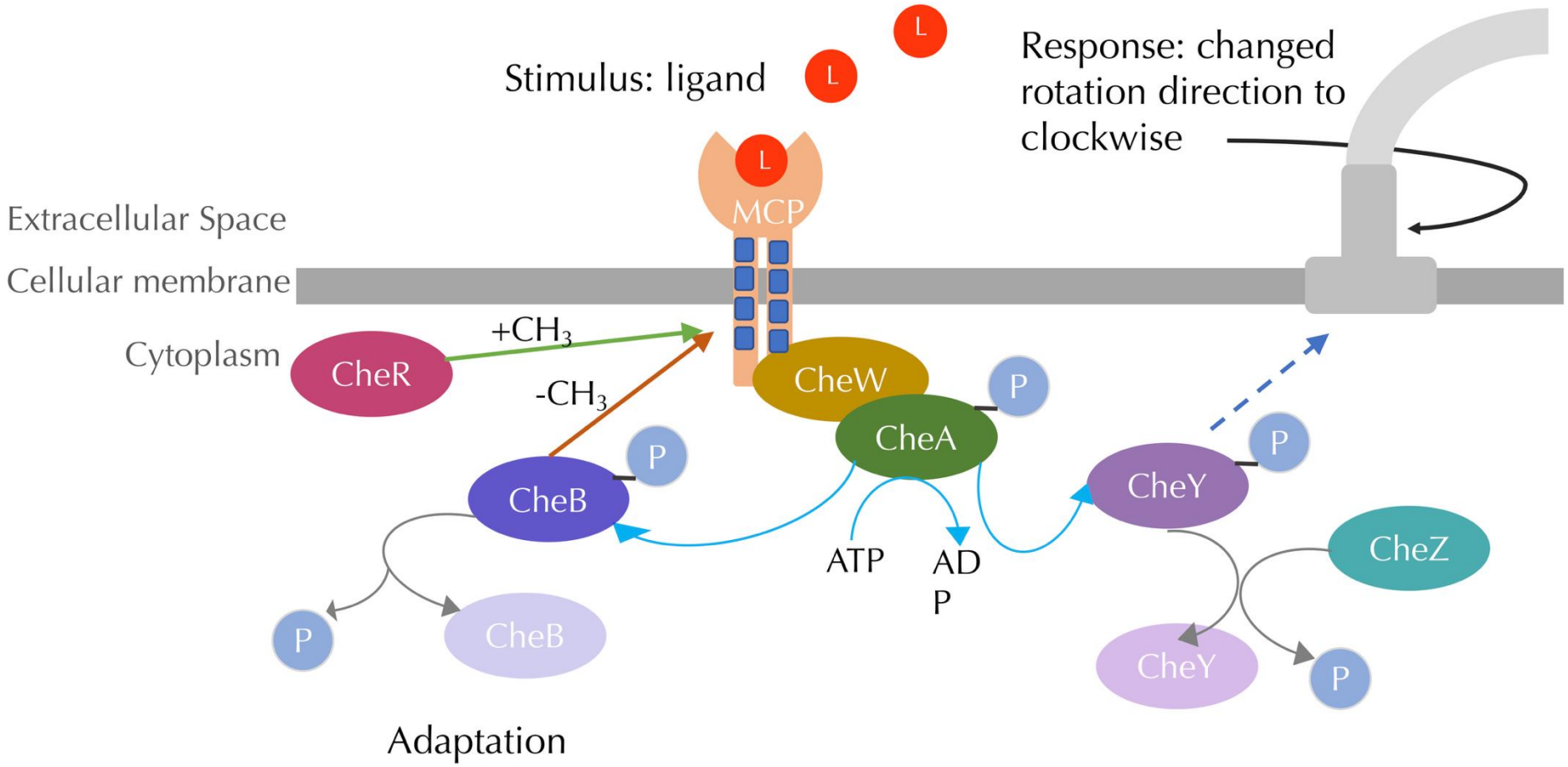
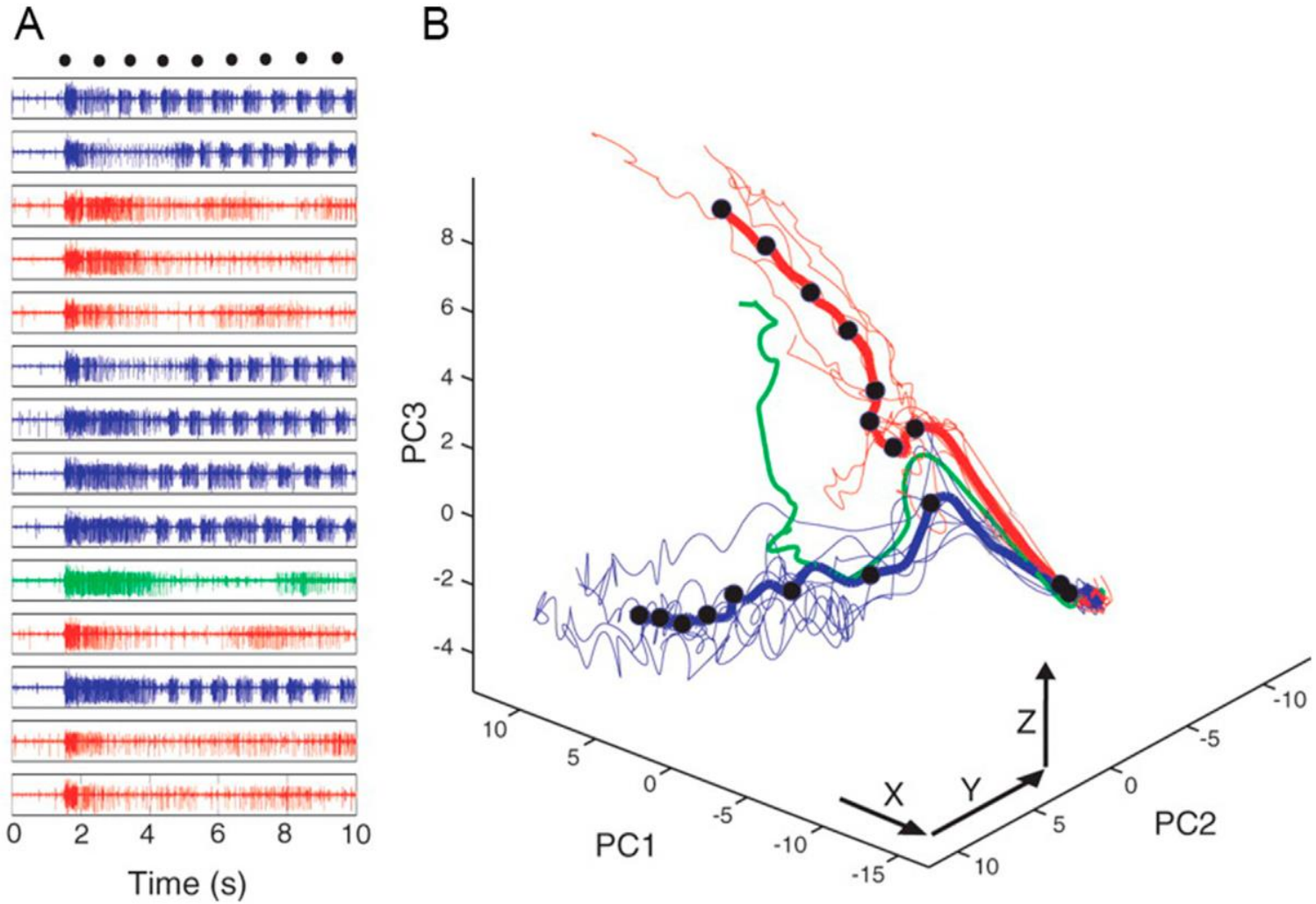
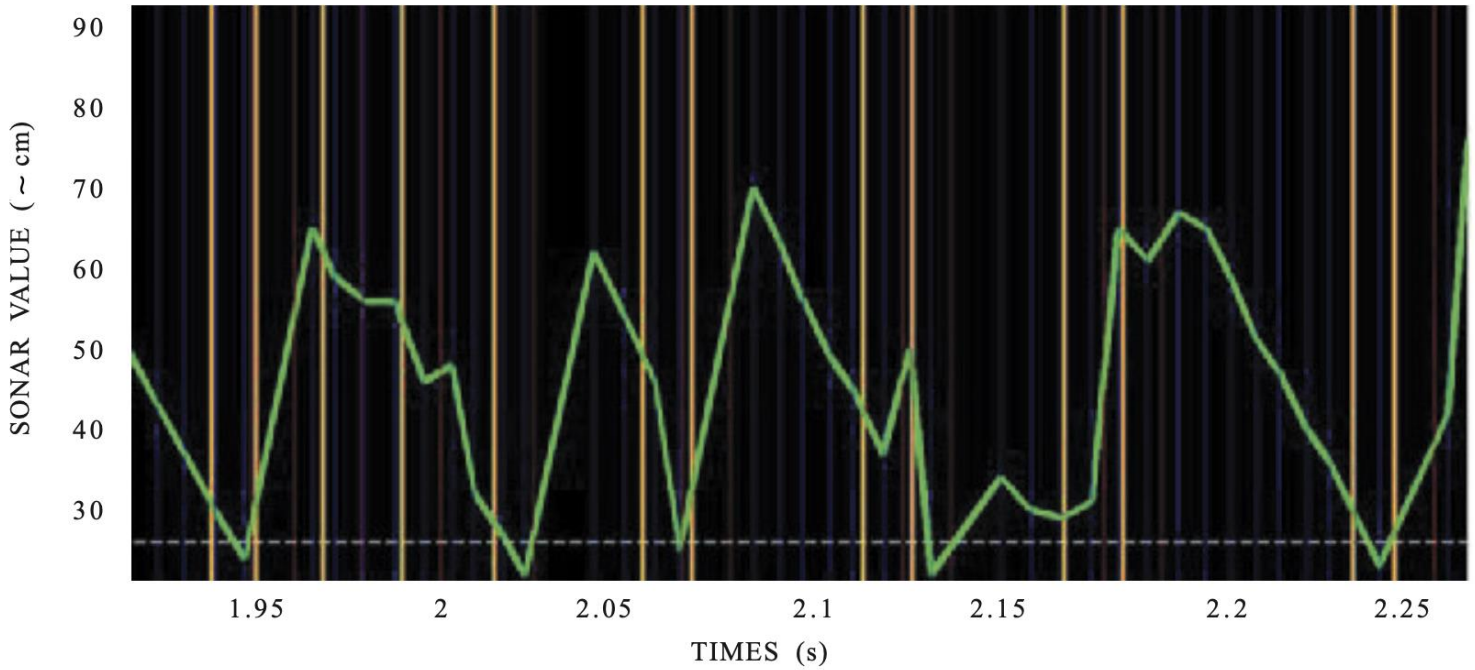


# Unreliable organoids


A
0
2
4
6
8
10
Time (s)
B
PC3
8
6
4
2
0
-2
-4
10
5
0
-5
-10
-15
PC1
Z
X
Y
-10
-5
0
5
10
PC2

# Meaningful versus spontaneous behaviour

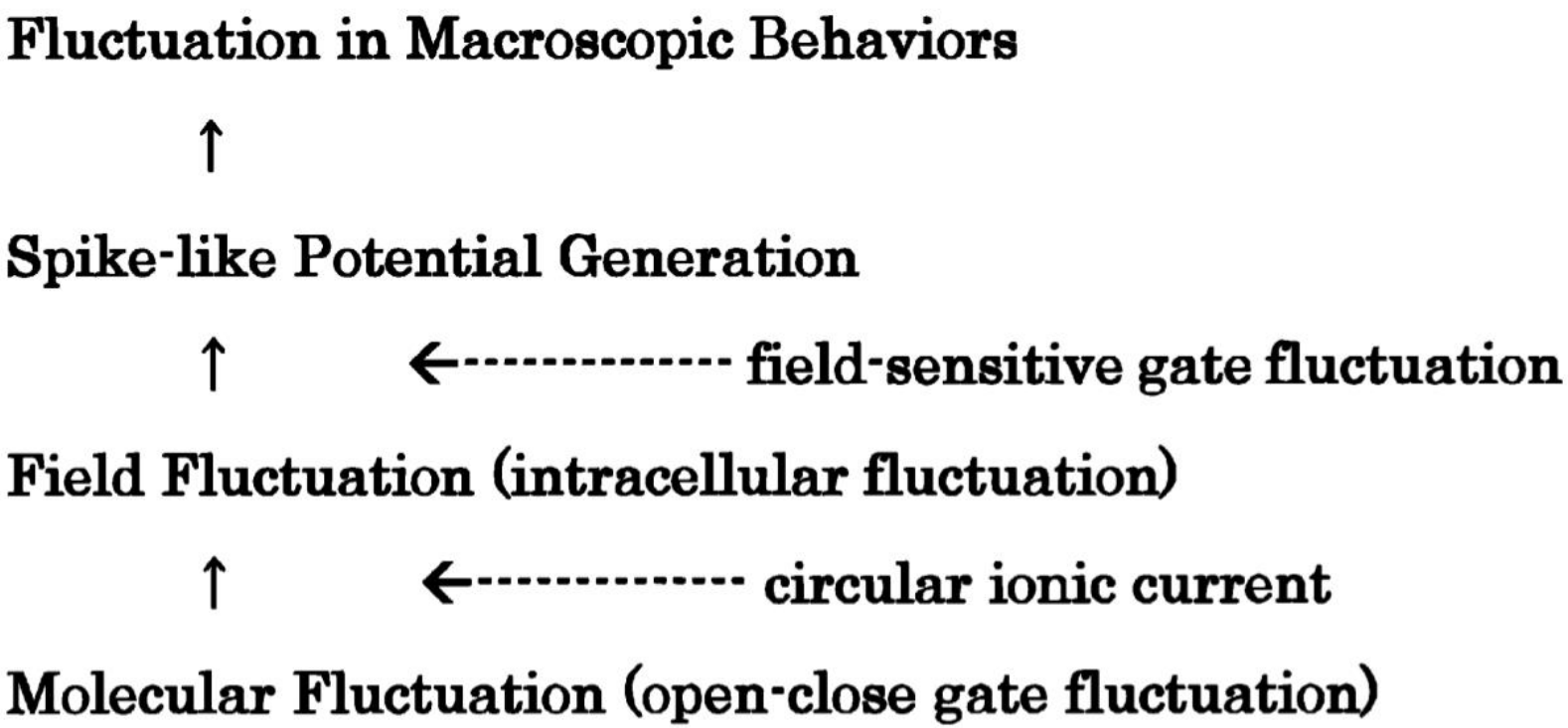
Controlling a mobile robot with a biological brain (Warwick et al., 2010)




“Under control of the model cell 95 ± 4 per cent (mean ± SD) meaningful turns were observed … In contrast, the live culture displayed a relatively low number of meaningful turns (46 ± 15 %) and a large number of spontaneous turns 54 ± 19 % as a result of intrinsic spontaneous neuronal activity.”

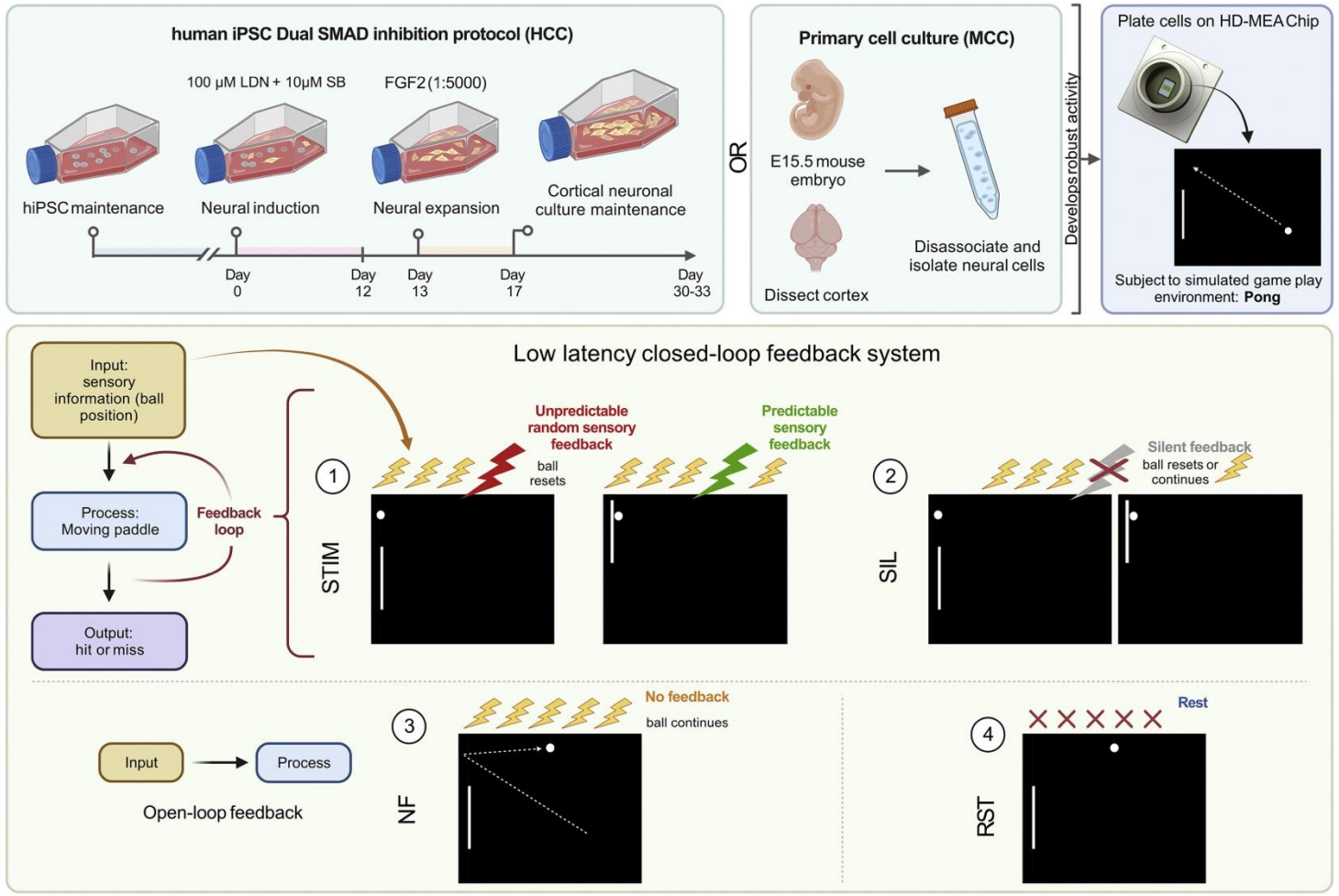
# From noise to spontaneous activity in Paramecia

Spontaneous activity of living cells (Oosawa, 2007)



# Learning to play Pong

In vitro neurons learn and exhibit sentience when embodied in a simulated game-world (Kagan et al., 2022)



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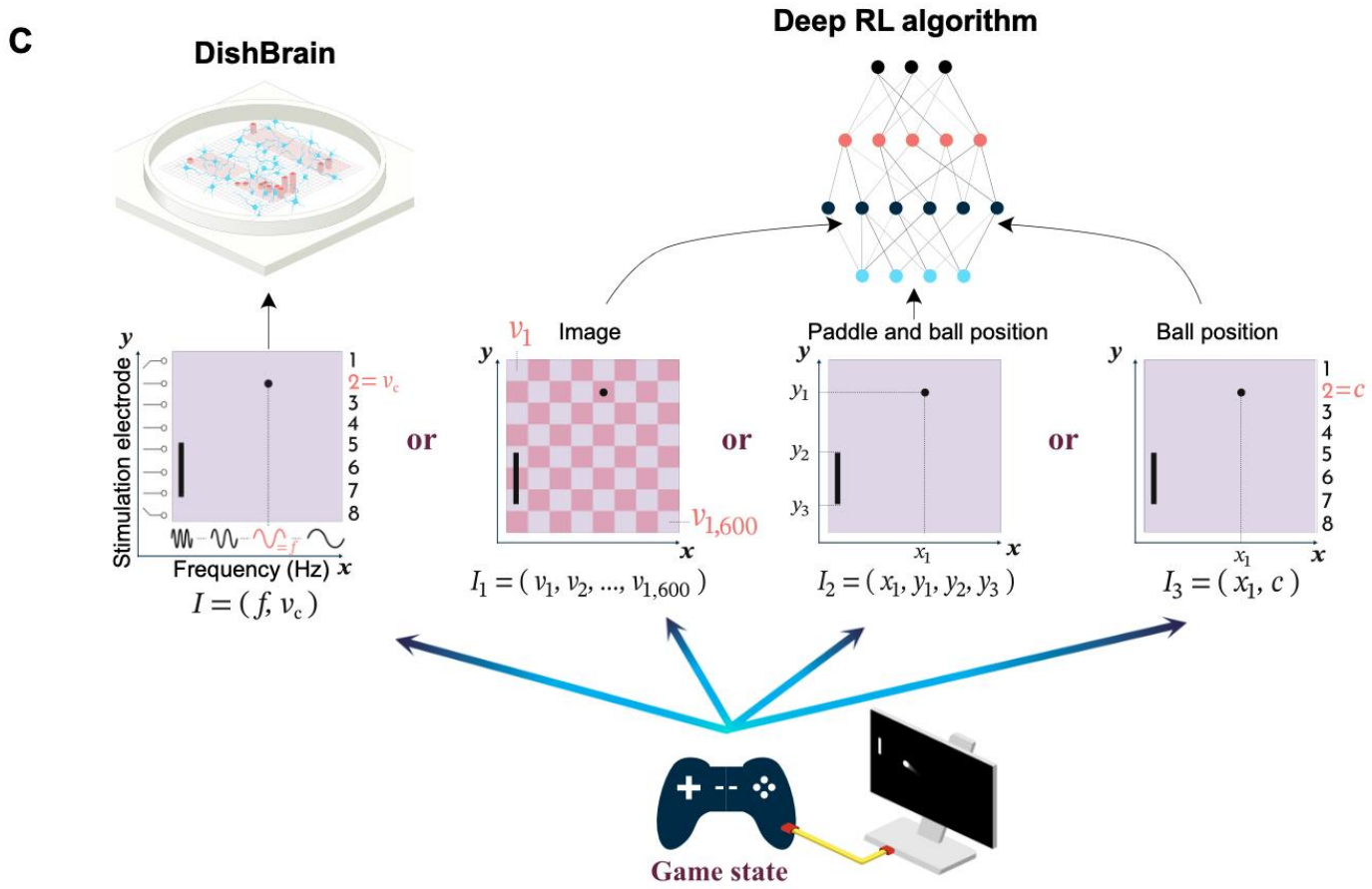
# Intrinsic activity in artificial and biological networks

Dynamic Network Plasticity and Sample Efficiency in Biological Neural Cultures (Khajehnejad et al., 2025)



# End.

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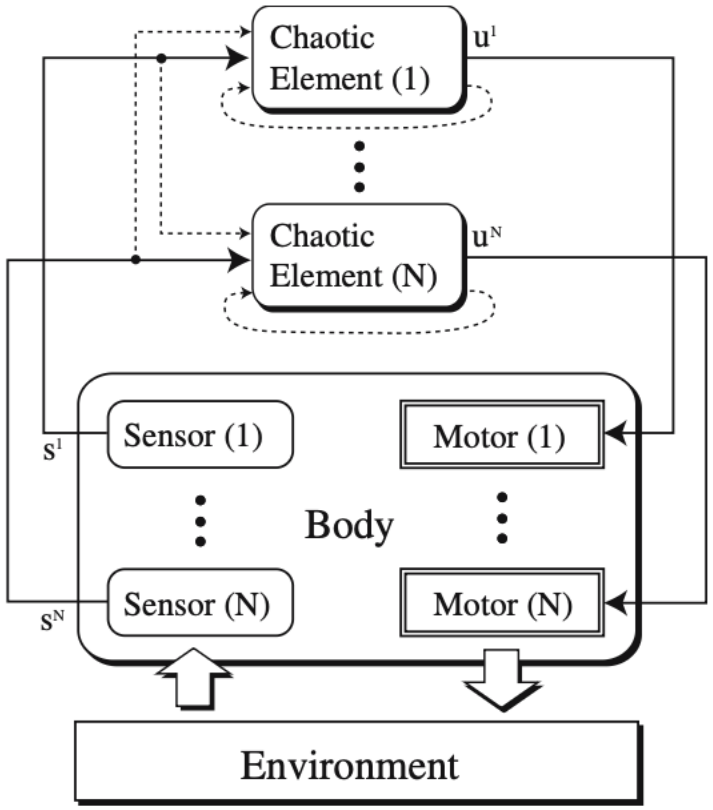
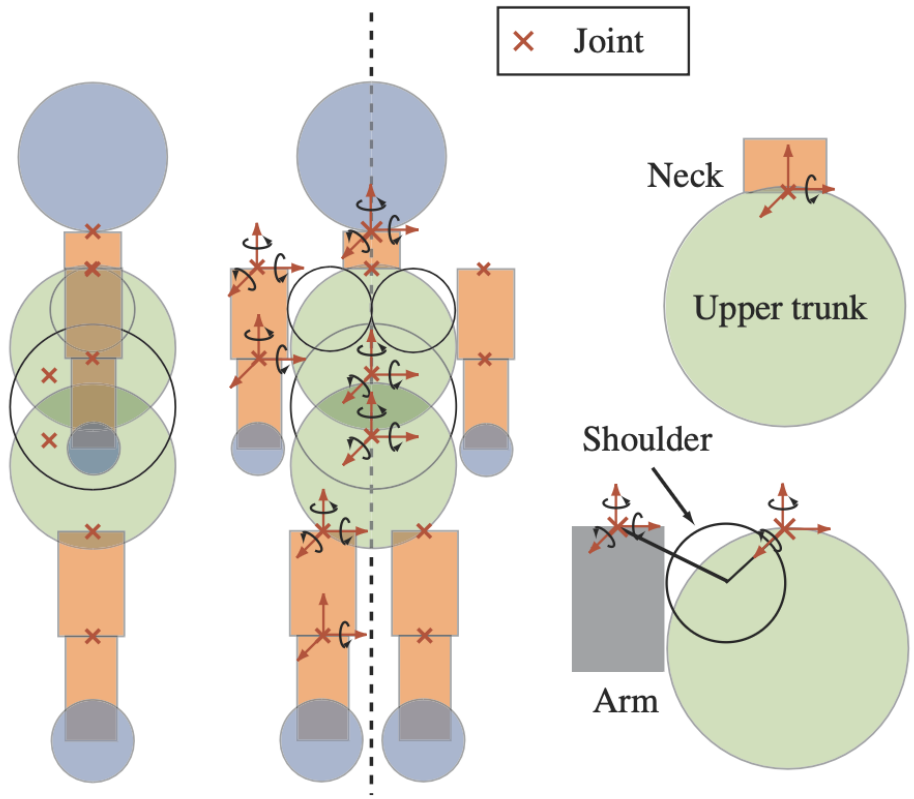
# Embodiment as symbolic constraint?

Early motor development from partially ordered neural-body dynamics (Kuniyoshi & Sangawa, 2006)



# Embodiment as symbolic constraint?

Cognitive developmental robotics: a survey (Asada et al., 2009)