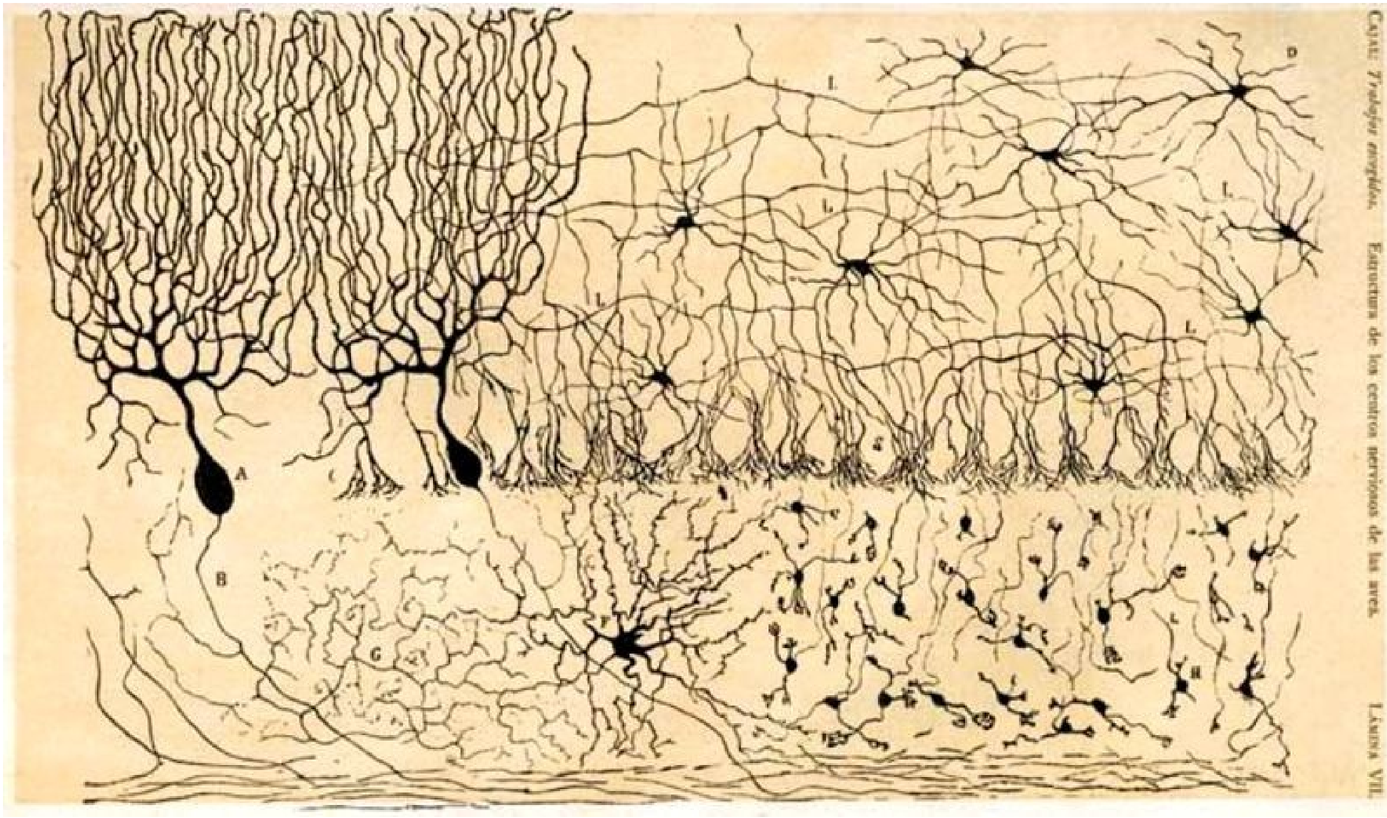
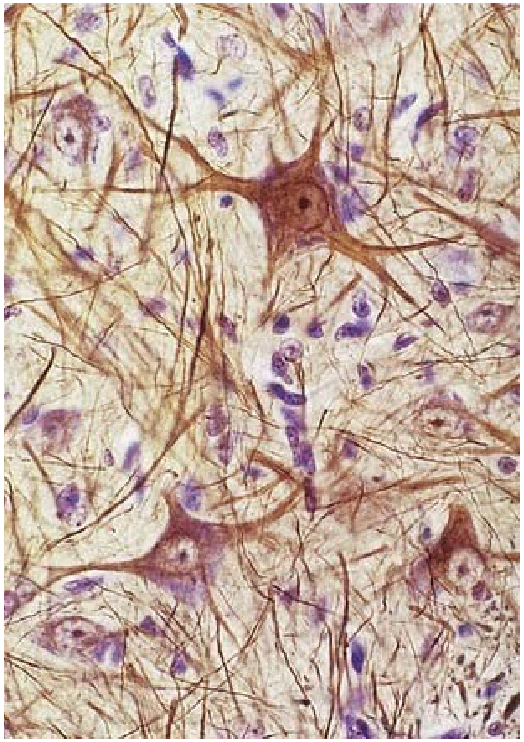
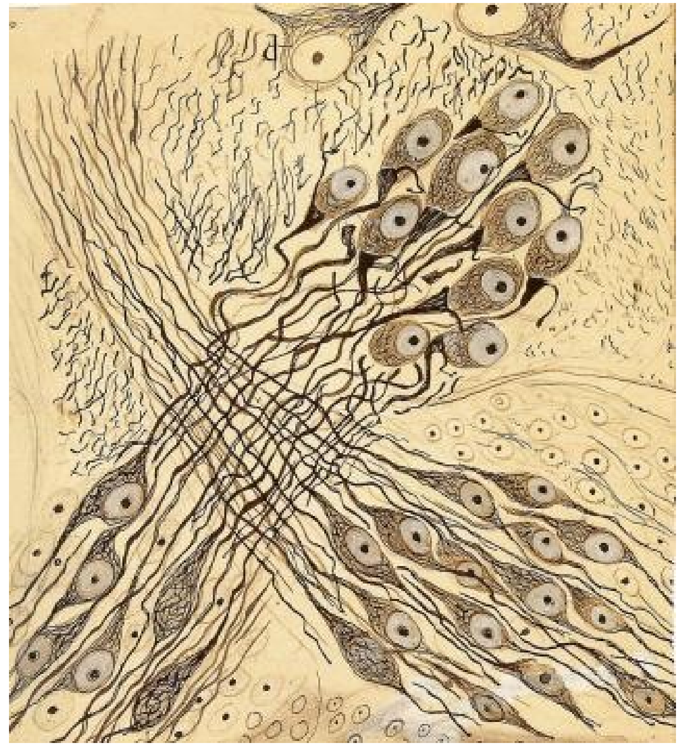
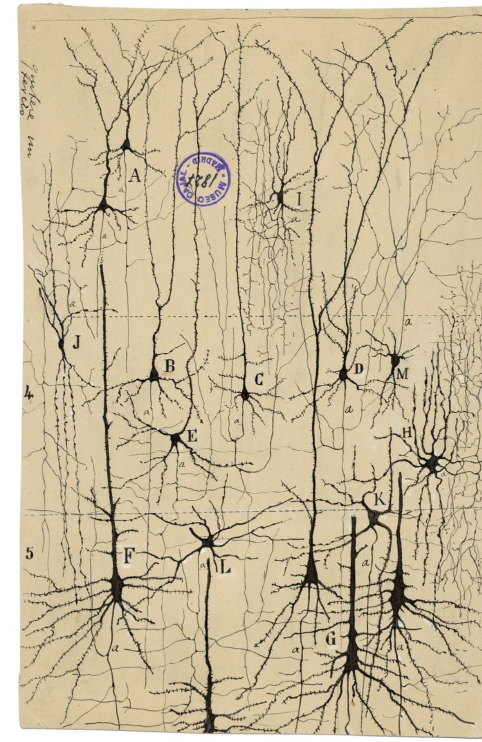
How does it feel to be a neural network?



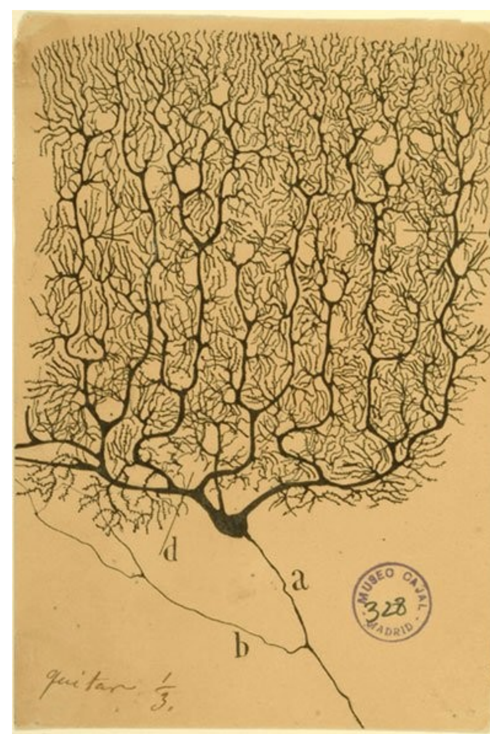
Samuel Johnson
School of Mathematics
University of Birmingham

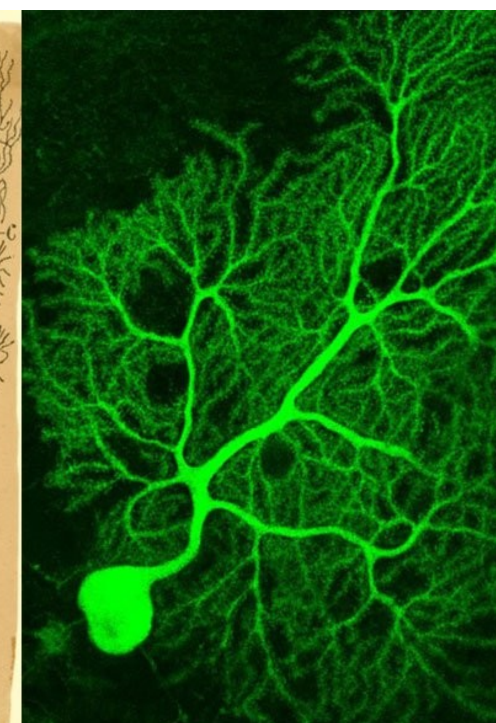






Santiago Ramón y Cajal (~1890)





Think (process info)

Learn (adapt to new info)

Remember (store info)

Imagine (generate new info)

Feel?

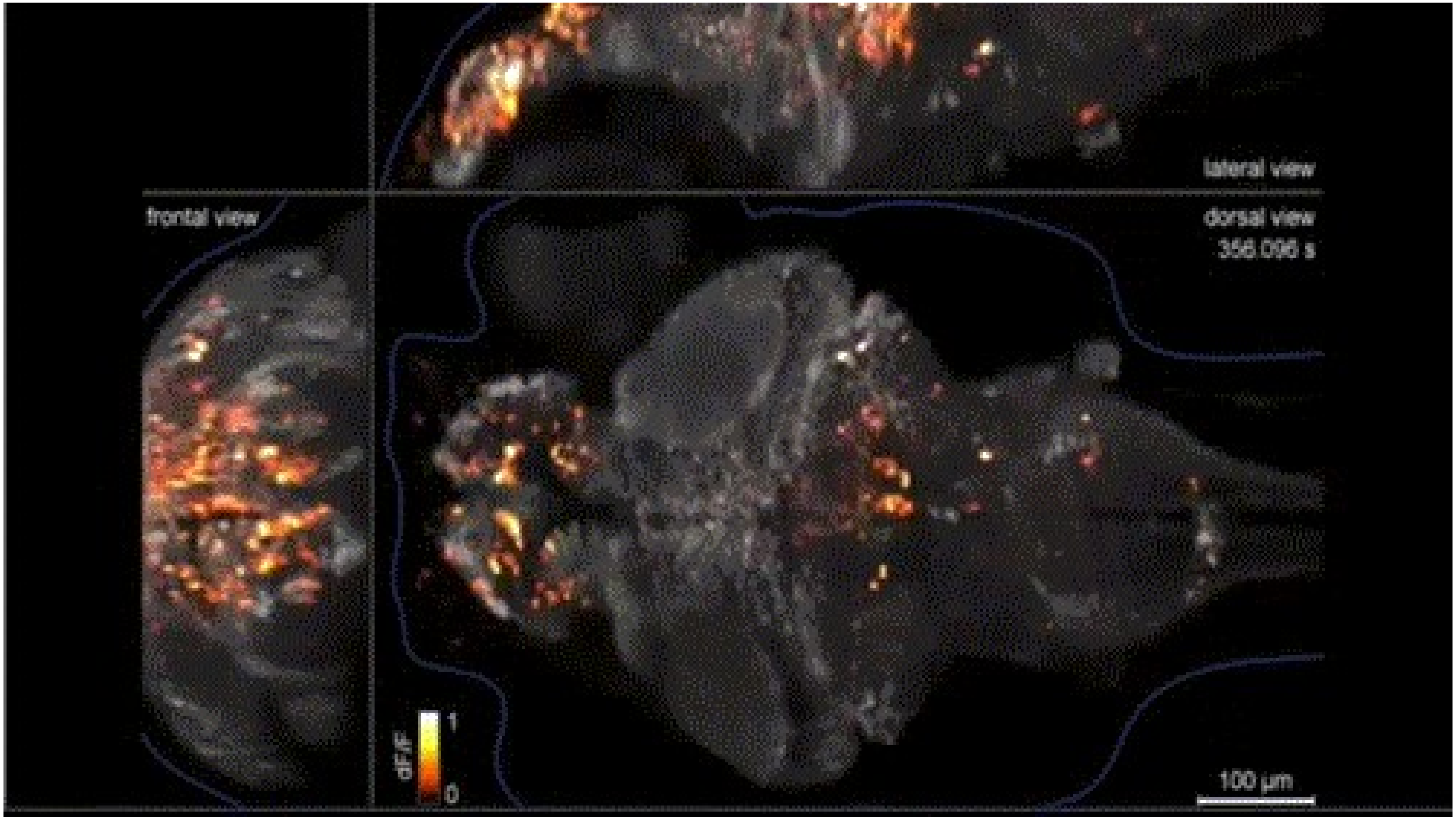
Think (process info)

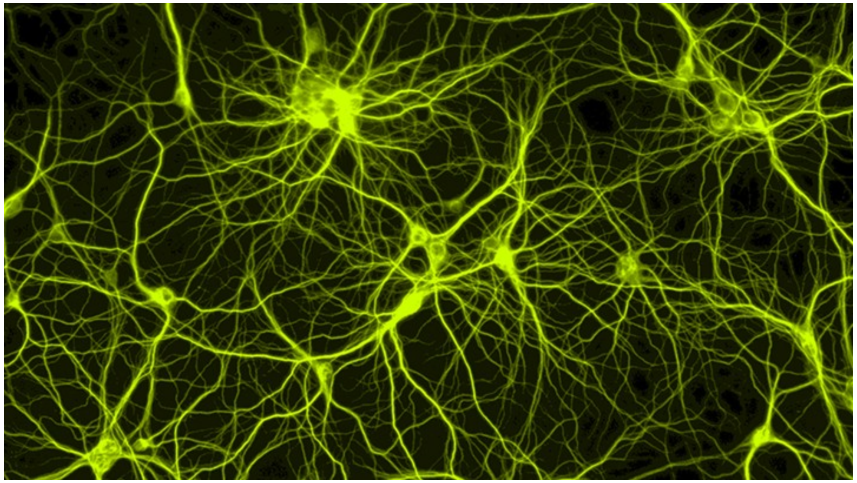
Learn (adapt to new info)

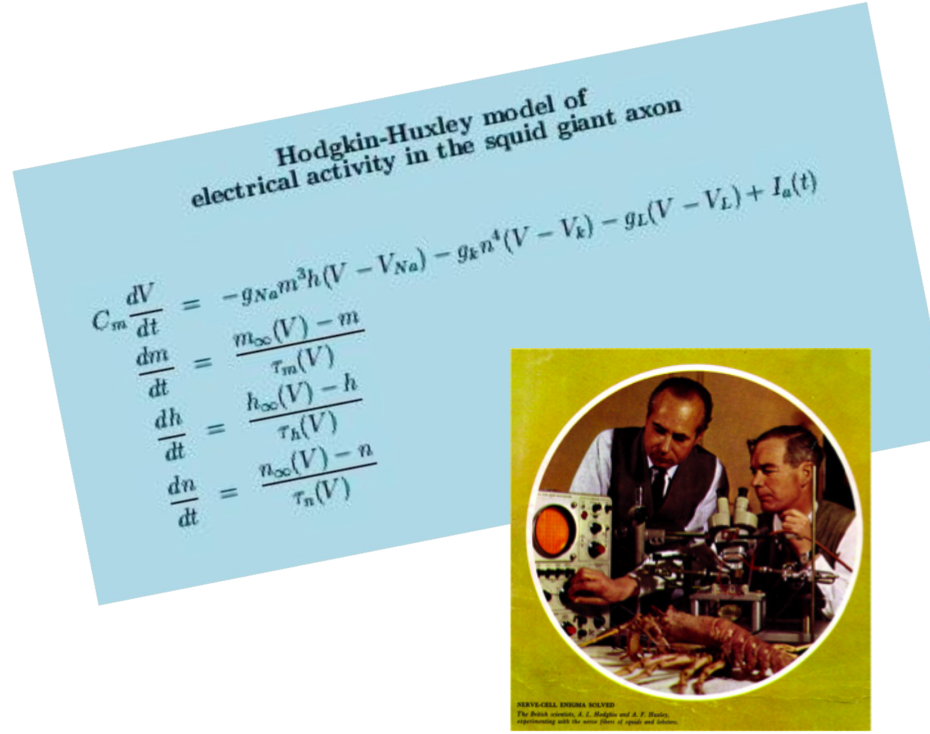
Remember (store info)

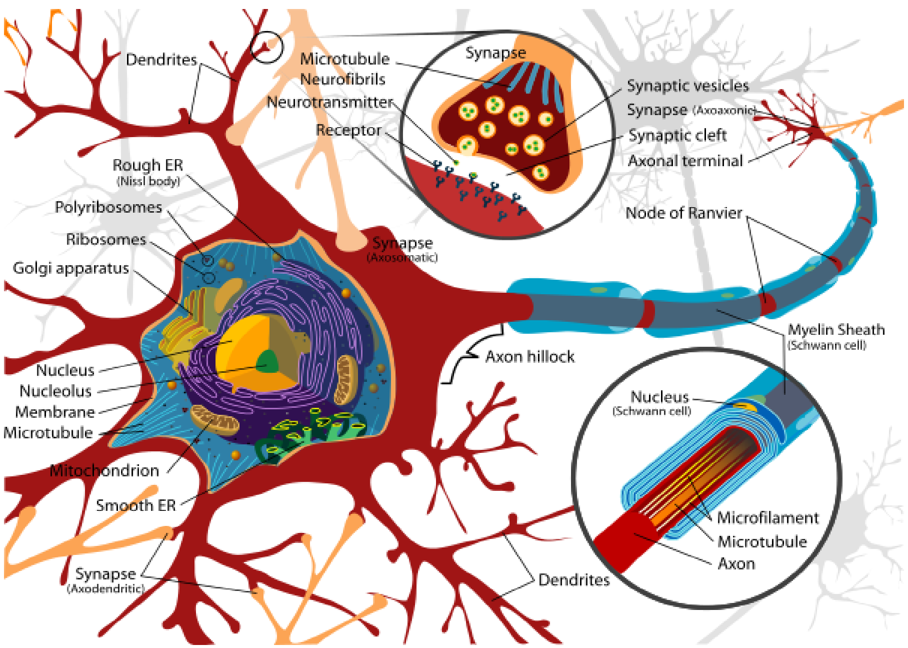
Imagine (generate new info)

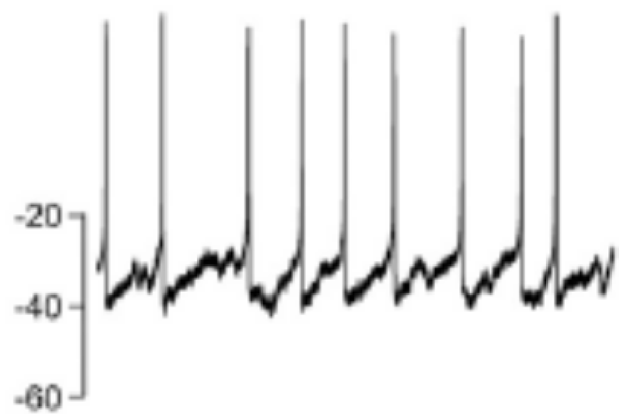
Feel?

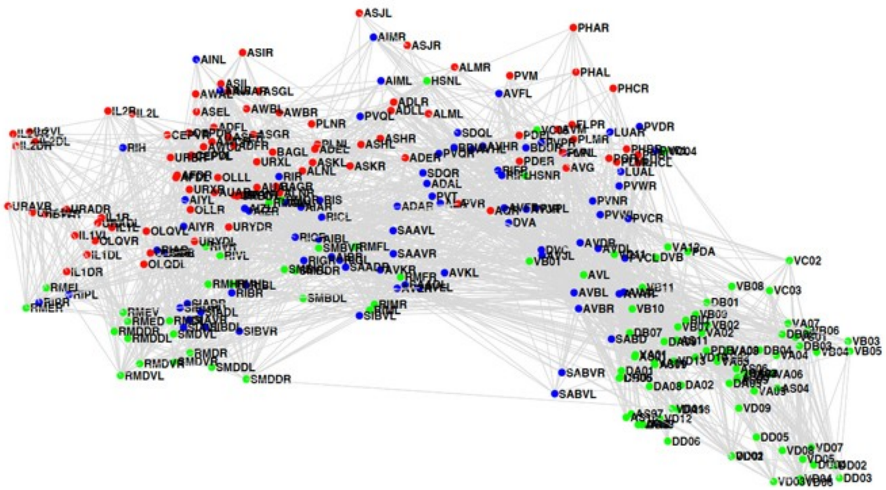





Hodgkin-Huxley model of
electrical activity in the squid giant axon
$C_m \frac{dV}{dt} = -g_{Na}m^3h(V - V_{Na}) - g_k n^4(V - V_k) - g_L(V - V_L) + I_a(t)$
$\frac{dm}{dt} = \frac{m_\infty(V) - m}{\tau_m(V)}$
$\frac{dh}{dt} = \frac{h_\infty(V) - h}{\tau_h(V)}$
$\frac{dn}{dt} = \frac{n_\infty(V) - n}{\tau_n(V)}$


Dendrites
Microtubule
Neurofibrils
Neurotransmitter
Receptor
Synapse
Synaptic vesicles
Synapse (Axoaxonic)
Synaptic cleft
Axonal terminal
Rough ER
(Nissl body)
Polyribosomes
Ribosomes
Golgi apparatus
Synapse
(Axosomatic)
Node of Ranvier
Myelin Sheath
(Schwann cell)
Axon hillock
Nucleus
Nucleolus
Membrane
Microtubule
Mitochondrion
Smooth ER
Nucleus
(Schwann cell)
Microfilament
Microtubule
Axon
Synapse
(Axodendritic)
Dendrites


-20
-40
-60



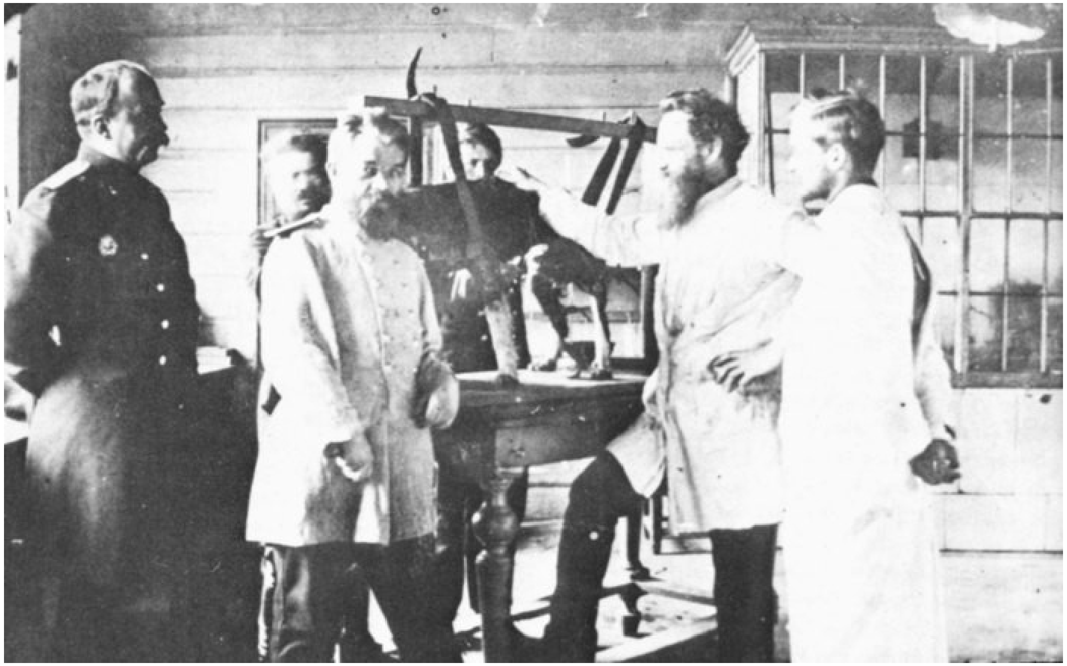
	# neurons	# synapses
C. elegans	302	~ 7,500
Fruit fly	10^5	10^7
Mouse	$7.1 \cdot 10^7$	10^{11}
Human	$8.6 \cdot 10^{10}$	10^{14}-10^{15}
Elephant	$2.57 \cdot 10^{11}$	?

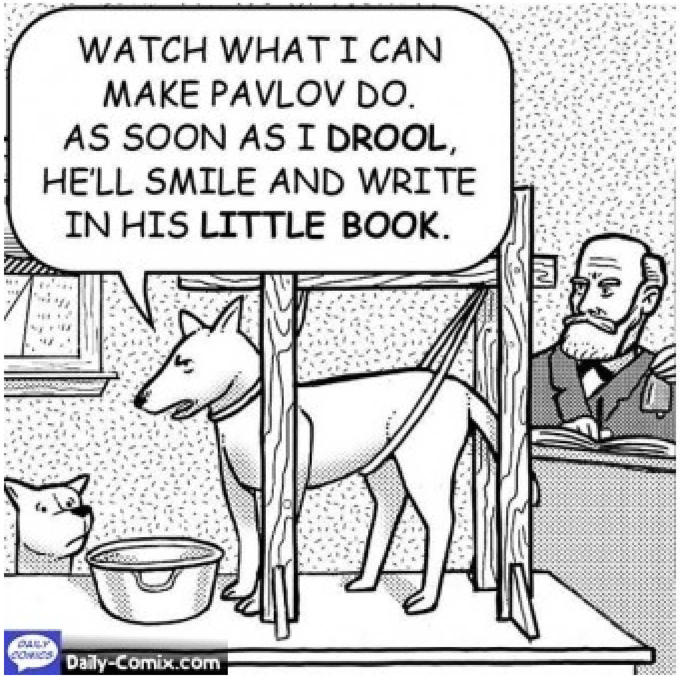
How does the mind emerge from the brain?

Ethics debate as pig brains kept alive without a body

By Pallab Ghosh
Science correspondent, BBC News

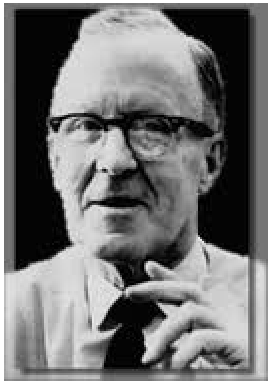
27 April 2018



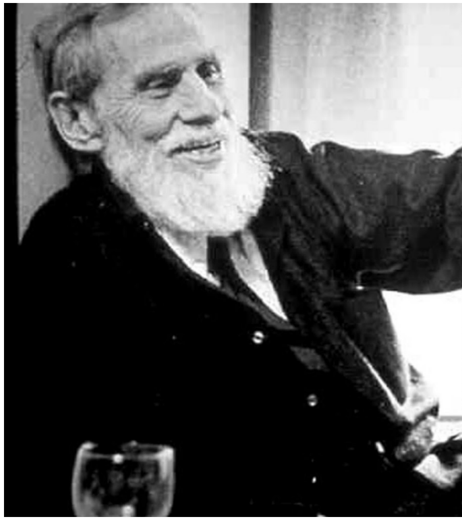
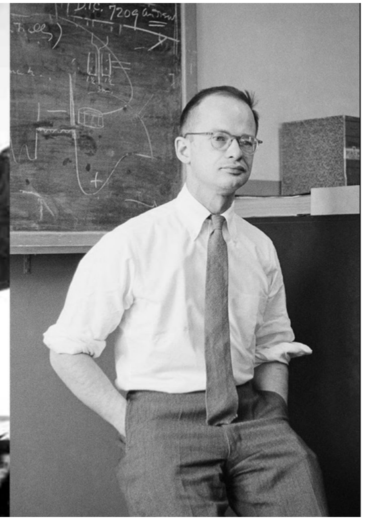


IP Pavlov

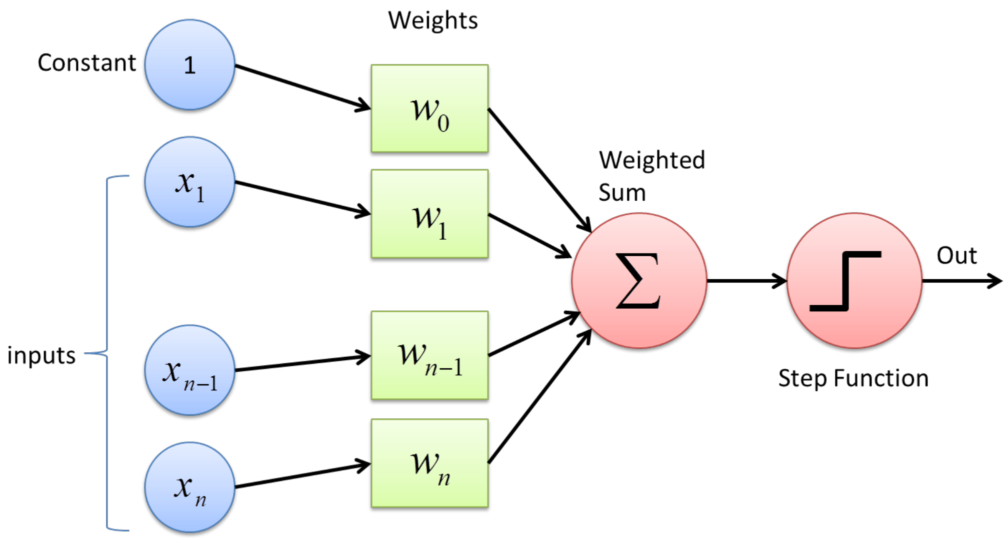
"Cells that fire together, wire together"

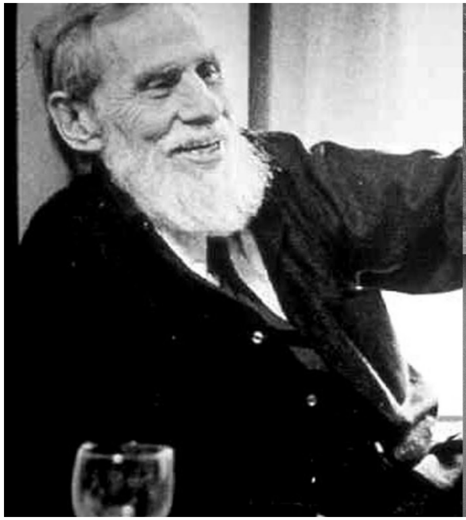


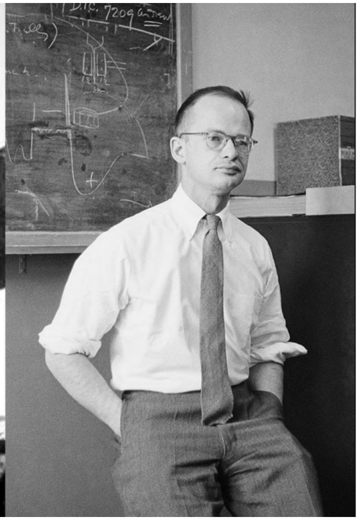
DO Hebb

W McCuloch W Pitts



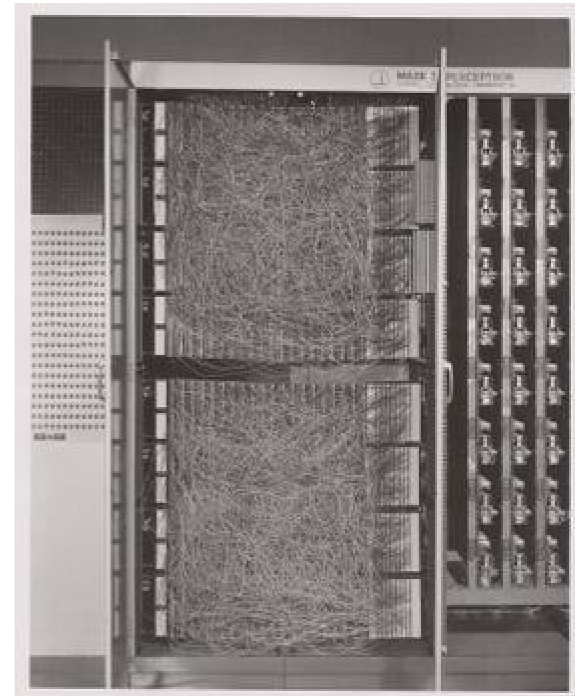




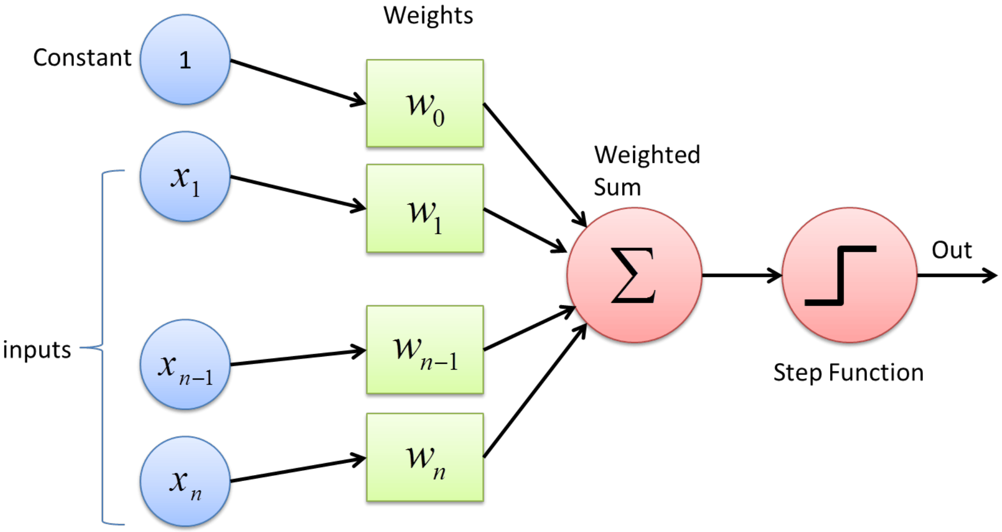
W McCuloch

W Pitts

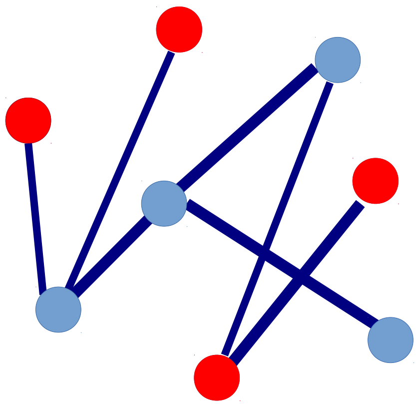
F Rosenblatt

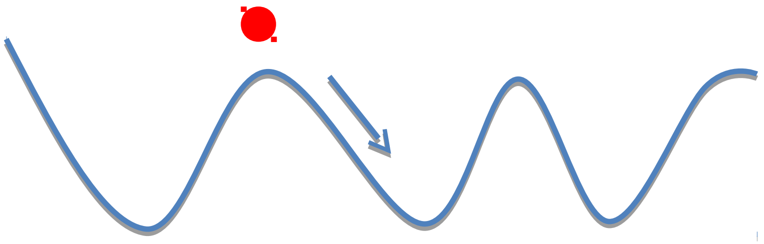


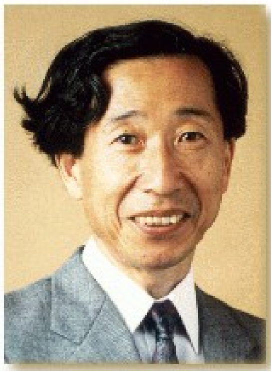
Perceptron

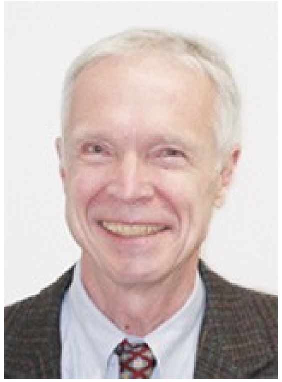


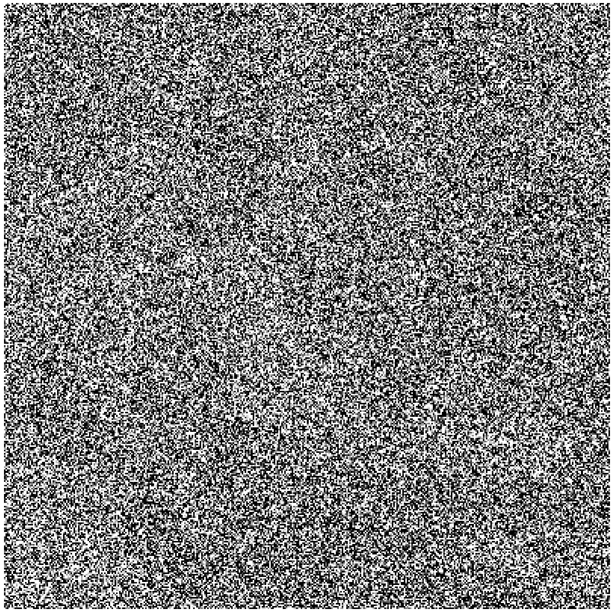
Amari-Hopfield Model



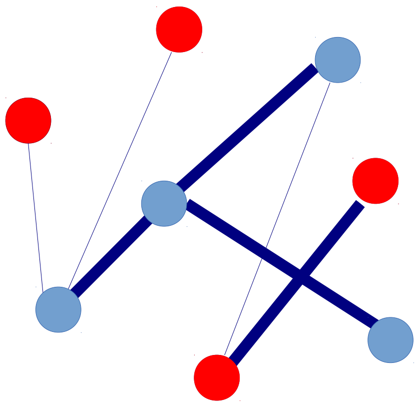


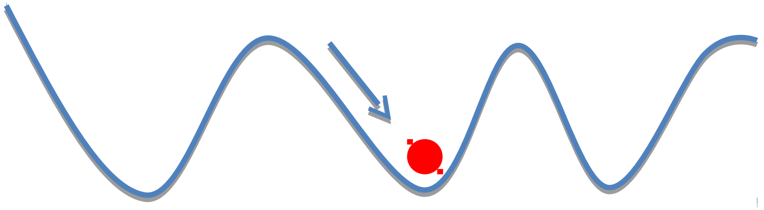


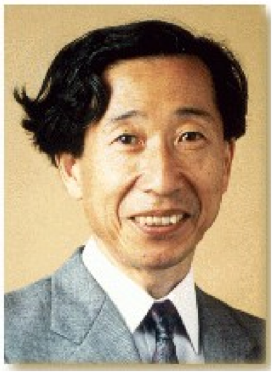


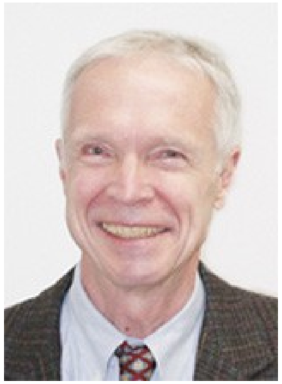


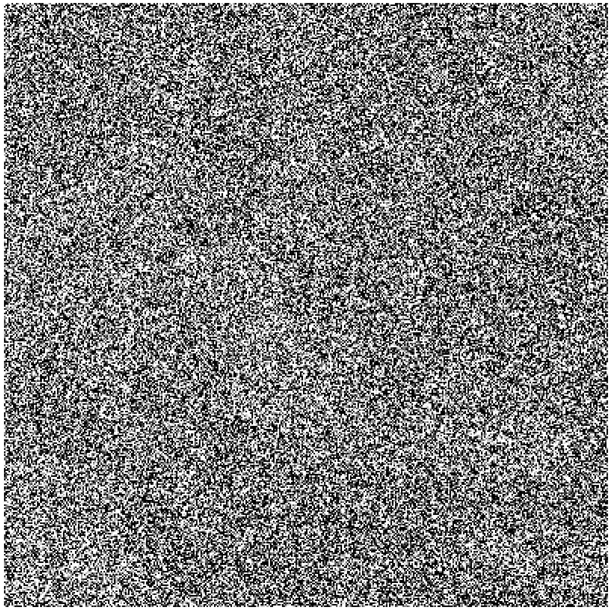
Amari-Hopfield Model

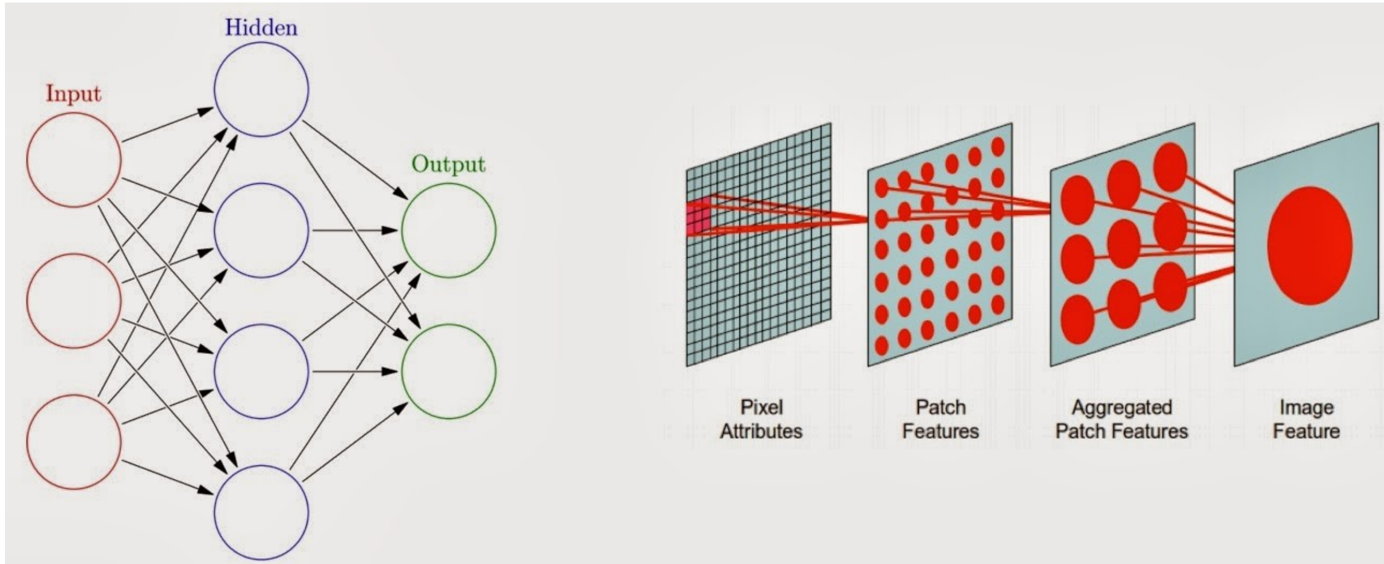


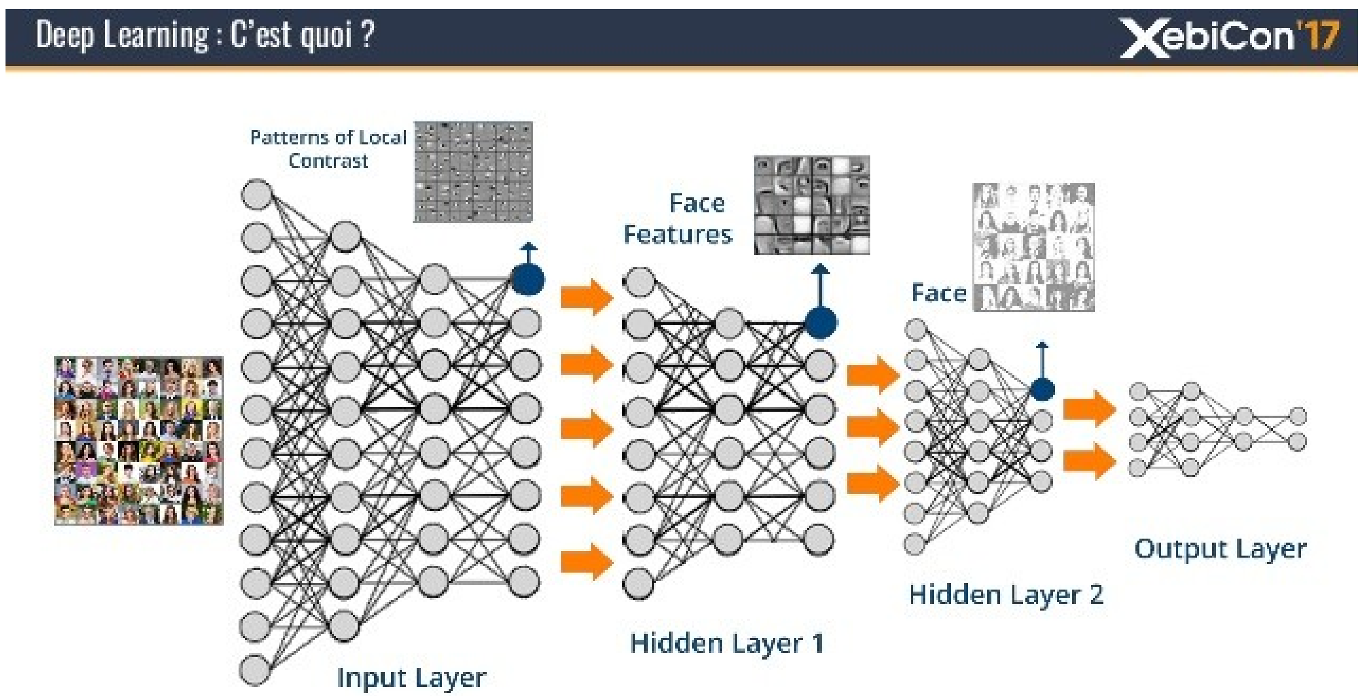









Hidden
Input
Output
Pixel Attributes
Patch Features
Aggregated Patch Features
Image Feature


Deep Learning : C'est quoi ?
XebiCon'17
Patterns of Local Contrast
Face Features
Face
Input Layer
Hidden Layer 1
Hidden Layer 2
Output Layer

Garry Kasparov vs Deep Blue (1997)

Ke Jie vs AlphaGo (2017)

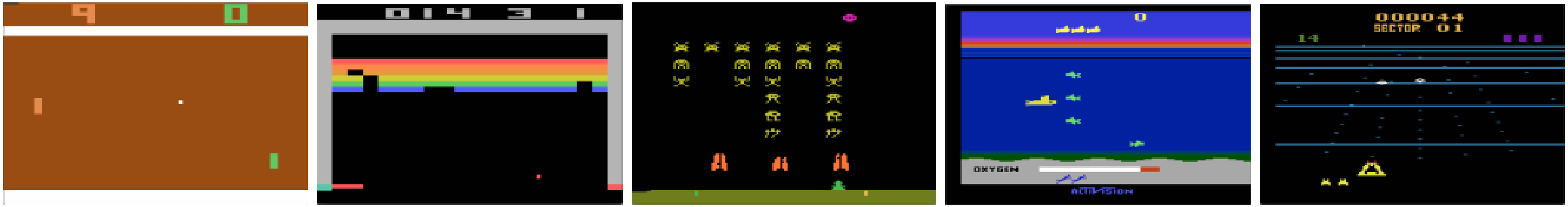
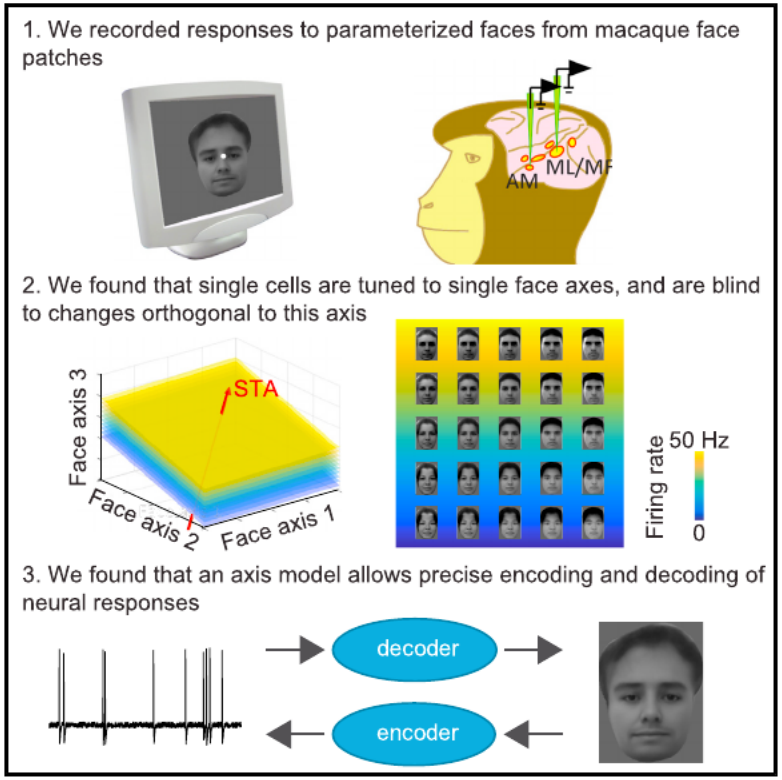


Figure 1: Screen shots from five Atari 2600 Games: (*Left-to-right*) Pong, Breakout, Space Invaders, Seaquest, Beam Rider

Cell
Article

The Code for Facial Identity in the Primate Brain

Graphical Abstract



Authors

Le Chang, Doris Y. Tsao

Correspondence

lechang@caltech.edu (L.C.),
dortsao@caltech.edu (D.Y.T.)

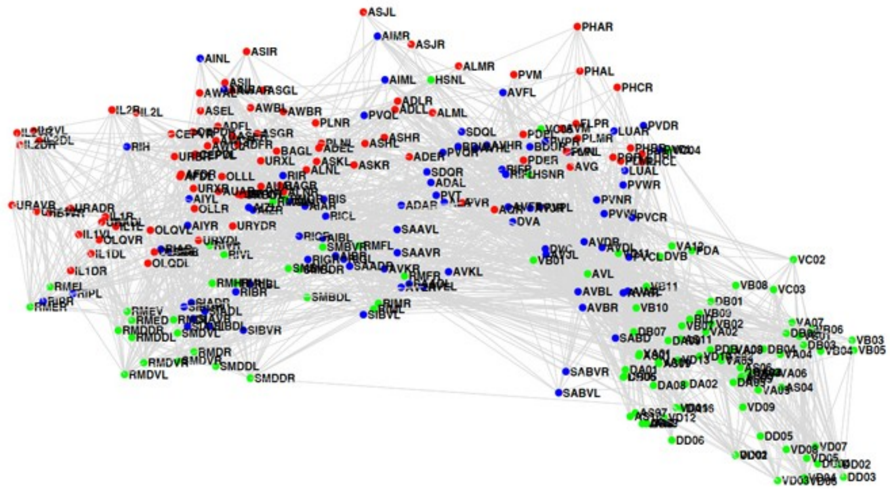
In Brief

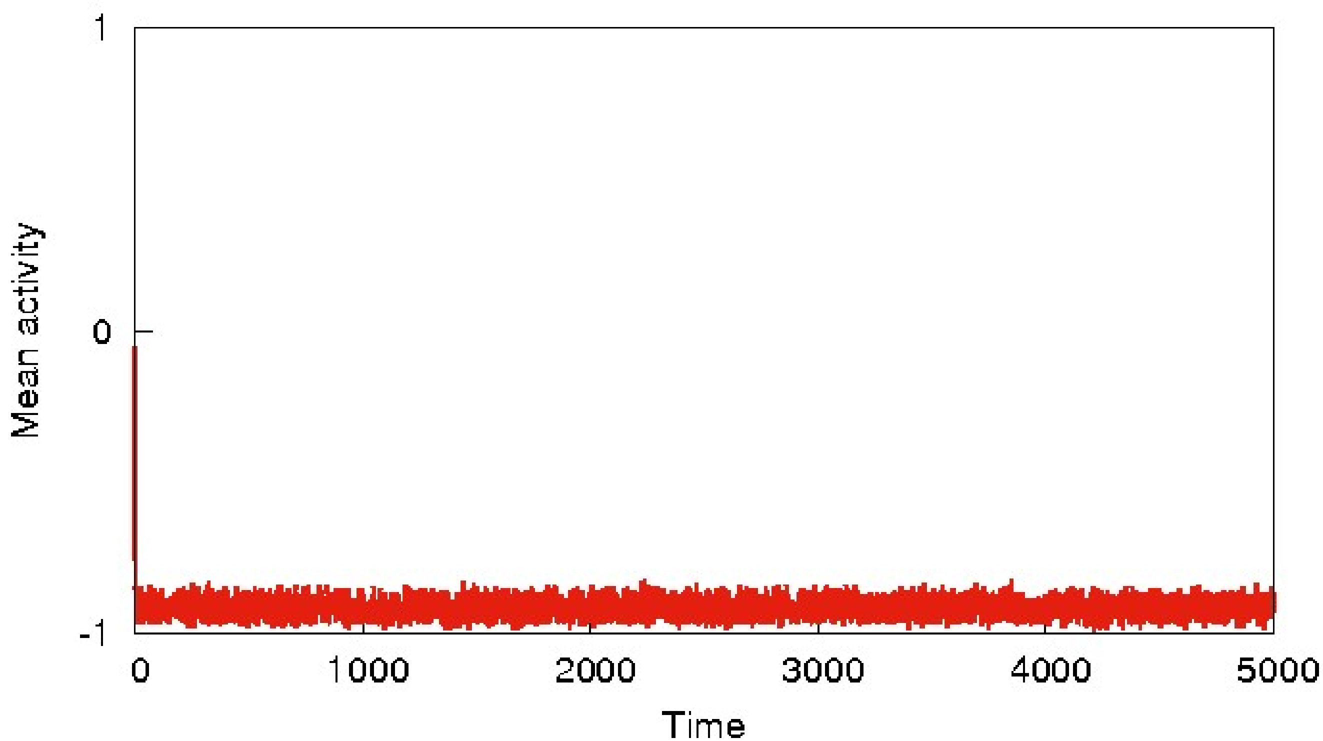
Facial identity is encoded via a remarkably simple neural code that relies on the ability of neurons to distinguish facial features along specific axes in face space, disavowing the long-standing assumption that single face cells encode individual faces.

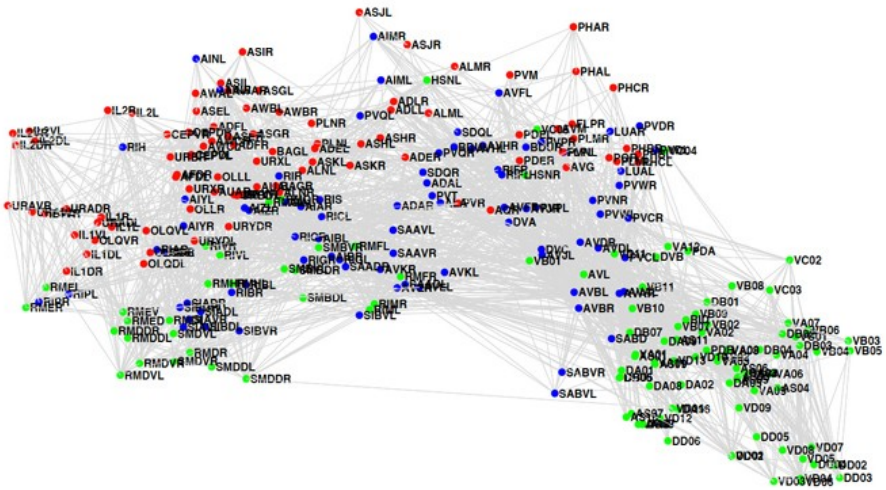
Highlights

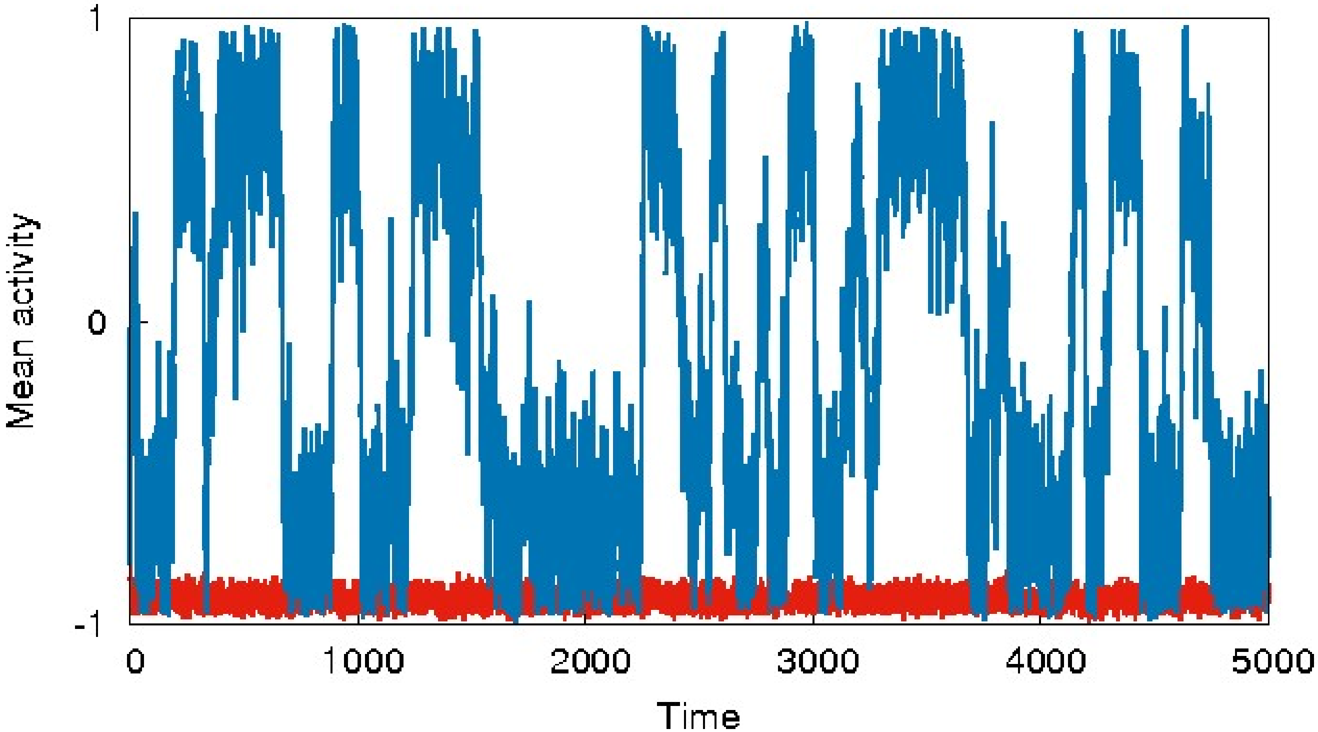
- Facial images can be linearly reconstructed using responses of ∼200 face cells
- Face cells display flat tuning along dimensions orthogonal to the axis being coded
- The axis model is more efficient, robust, and flexible than the exemplar model
- Face patches ML/MF and AM carry complementary information about faces

Actual face   Predicted (all)

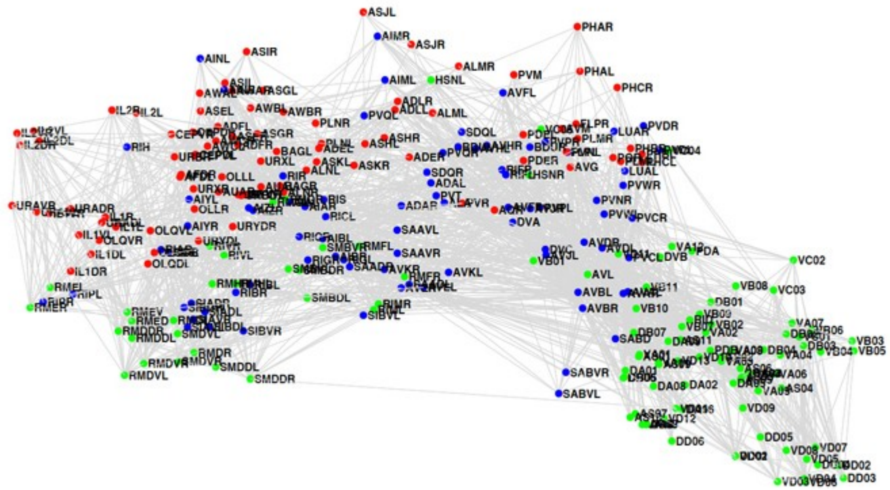


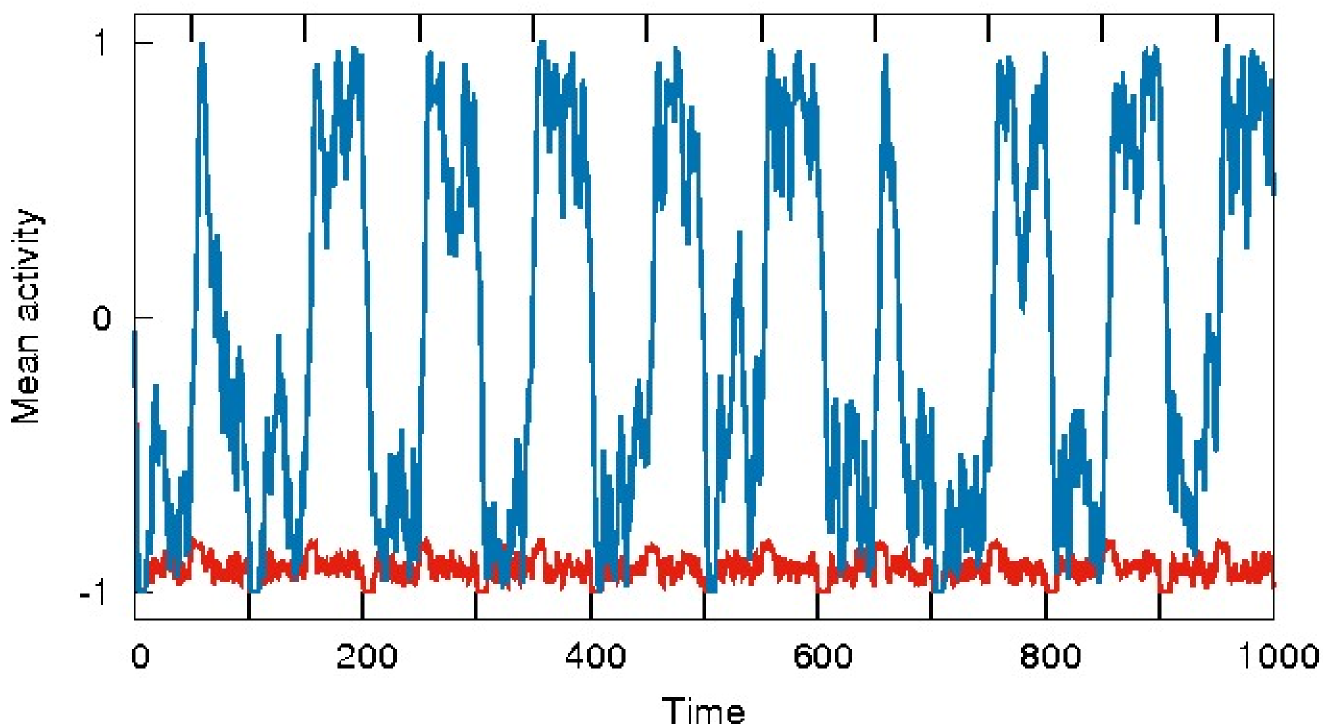

1
0
-1
Mean activity
0
1000
2000
3000
4000
5000
Time





Mean activity
1
0
-1
0
1000
2000
3000
4000
5000
Time



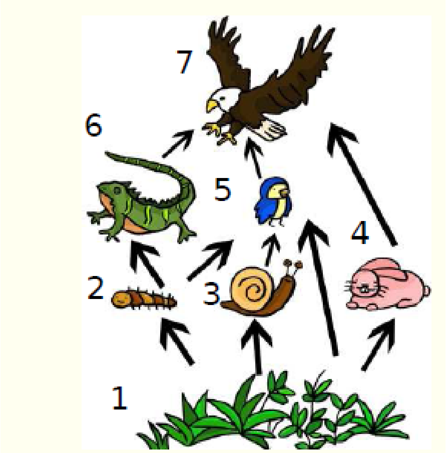

Mean activity
1
0
-1
0
200
400
600
800
1000
Time

Trophic coherence

$s = 3$

$s = 2$

$s = 1$

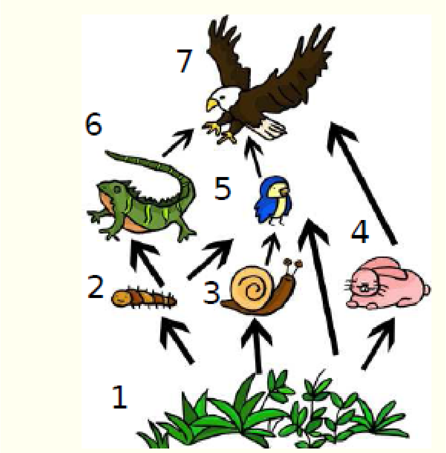


Trophic coherence

$s = 3$

$s = 2$

$s = 1$



$$s_i = 1 + \frac{1}{k_i^{in}} \sum_j a_{ij} s_j$$

Trophic level of node *i*

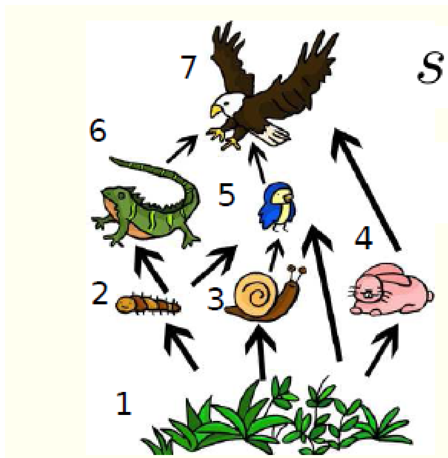
Average trophic level of *i*'s 'prey'

Trophic coherence

$s = 3$

$s = 2$

$s = 1$



$s = 32/9$

$s = 8/3$

$$s_i = 1 + \frac{1}{k_i^{in}} \sum_j a_{ij} s_j$$

Trophic level of node *i*

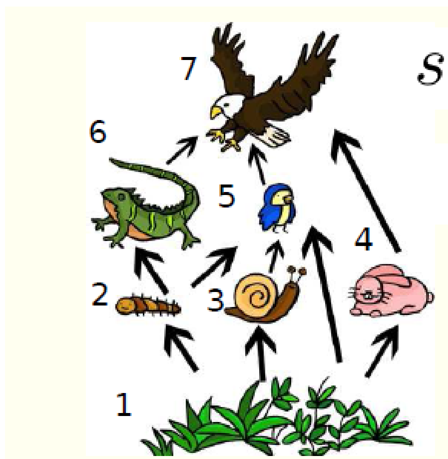
Average trophic level of *i*'s 'prey'

Trophic coherence

$s = 3$

$s = 2$

$s = 1$



$s = 32/9$

$s = 8/3$

$$s_i = 1 + \frac{1}{k_i^{in}} \sum_j a_{ij} s_j$$

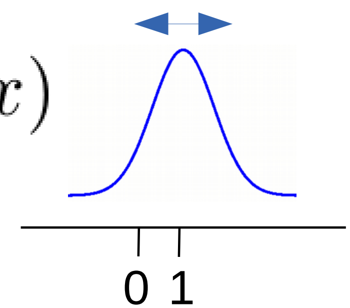
Trophic level of node *i*

Average trophic level of *i*'s 'prey'

$$x_{ij} = s_i - s_j$$

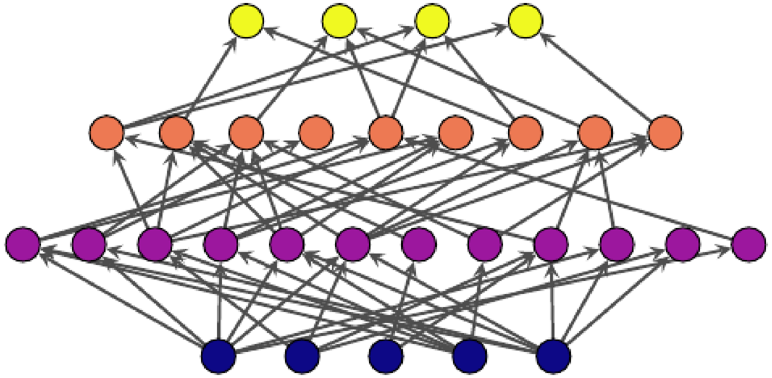
q

$p(x)$

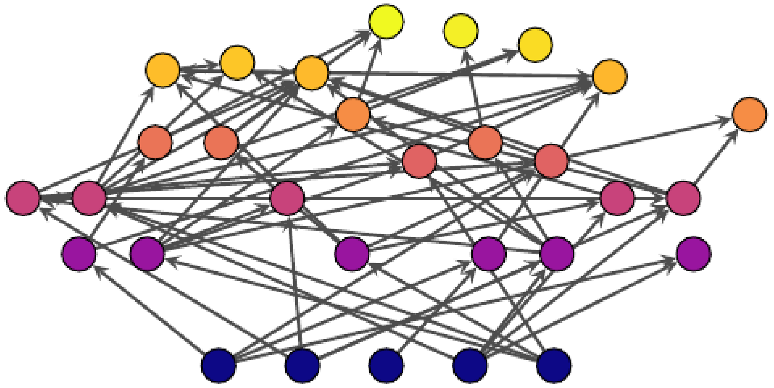


Johnson, Domínguez-García, Donetti, Muñoz (2014) *PNAS*

Trophic coherence



$q = 0$

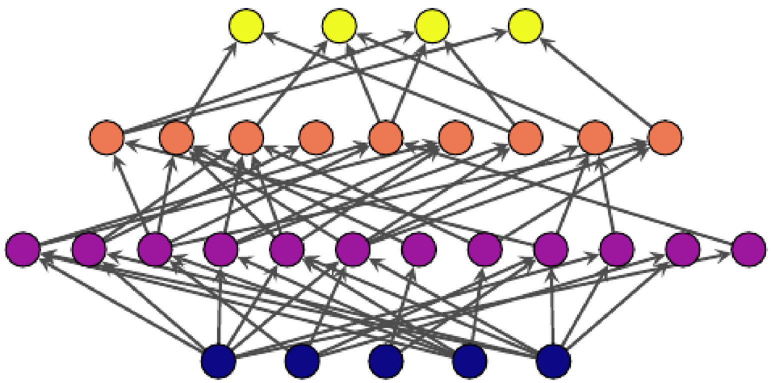


$q = 0.49$

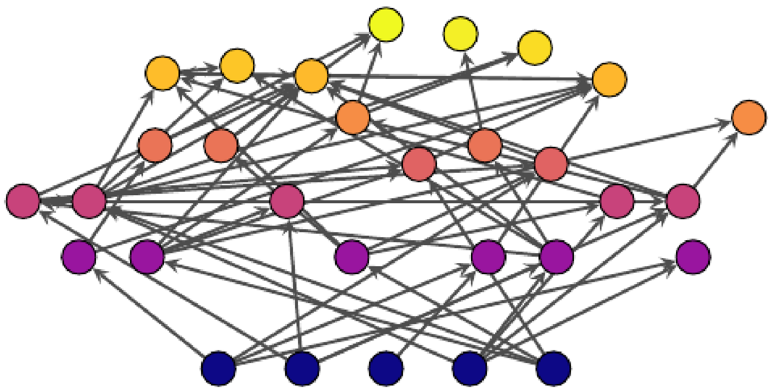
Johnson, Domínguez-García, Donetti, Muñoz (2014) *PNAS*

Klaise & Johnson (2016) *Chaos*

Trophic coherence



$q = 0$



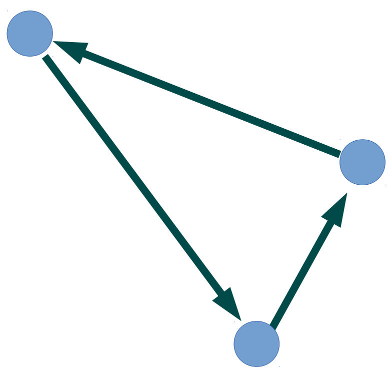
$q = 0.49$

Johnson & Jones (2017) *PNAS* → $\text{C Elegans: } q/\tilde{q} = 0.42$

Johnson, Domínguez-García, Donetti, Muñoz (2014) *PNAS*

Klaise & Johnson (2016) *Chaos*

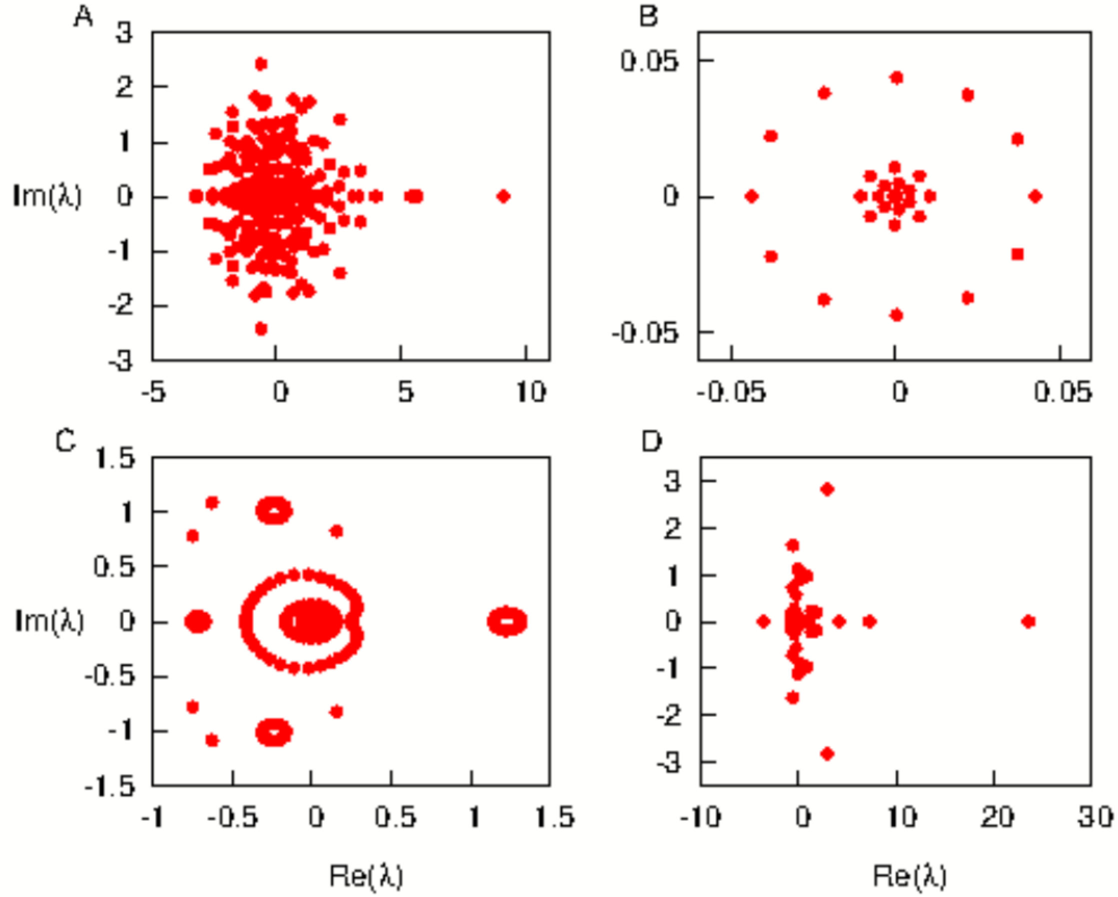
Feedback



$$\langle \lambda^\nu \rangle = \frac{1}{N}\mathrm{tr}(A^\nu)$$

Moment of the eigenspectrum

Number of directed cycles



Johnson & Jones (2017) *PNAS*

Feedback

Coherence ensemble:

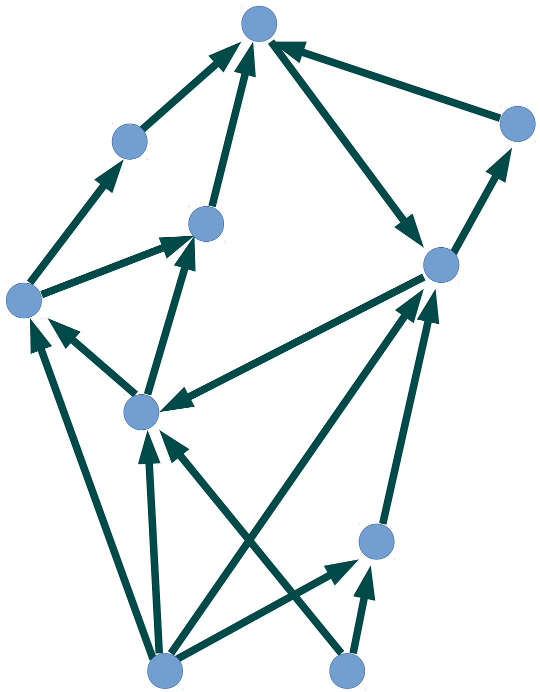
Directed configuration ensemble
+
fixed trophic coherence

Johnson & Jones (2017) *PNAS*

Feedback

Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence

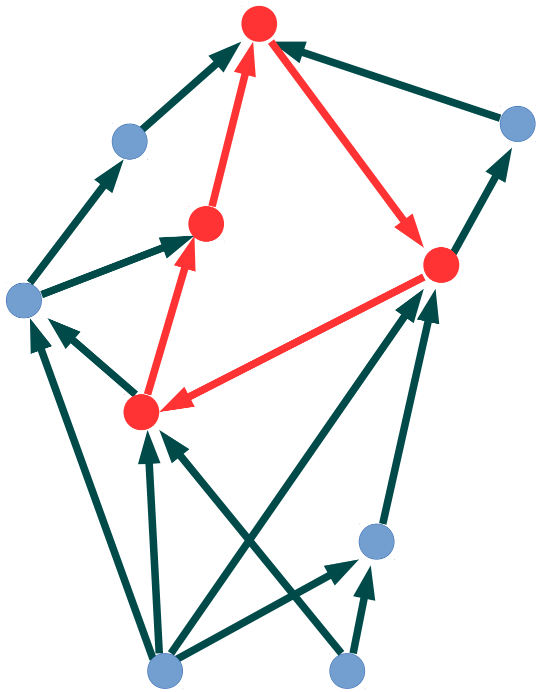


Johnson & Jones (2017) *PNAS*

Feedback

Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence

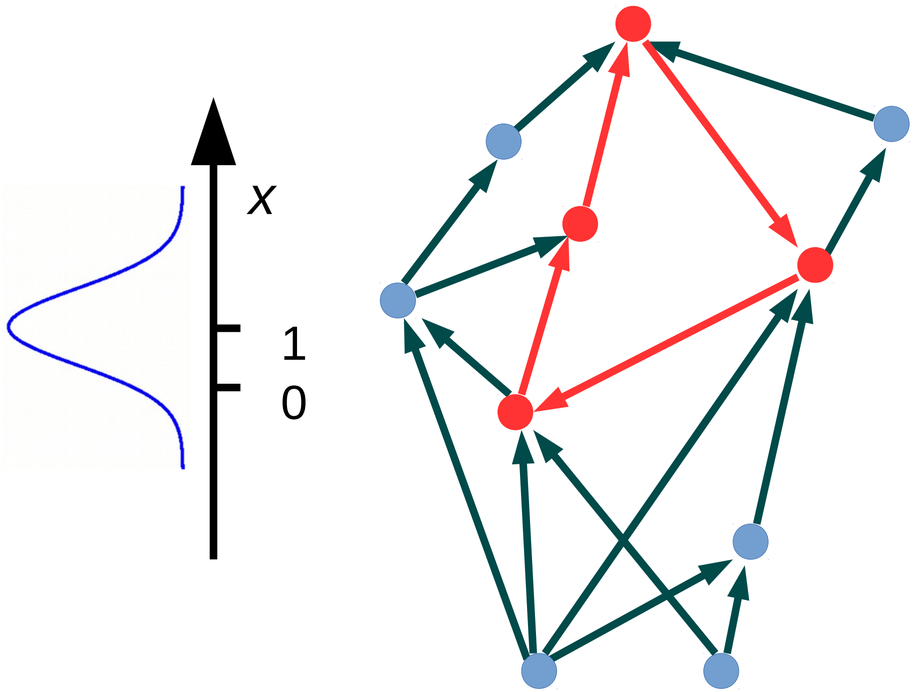


Johnson & Jones (2017) *PNAS*

Feedback

Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence



Johnson & Jones (2017) *PNAS*

Feedback

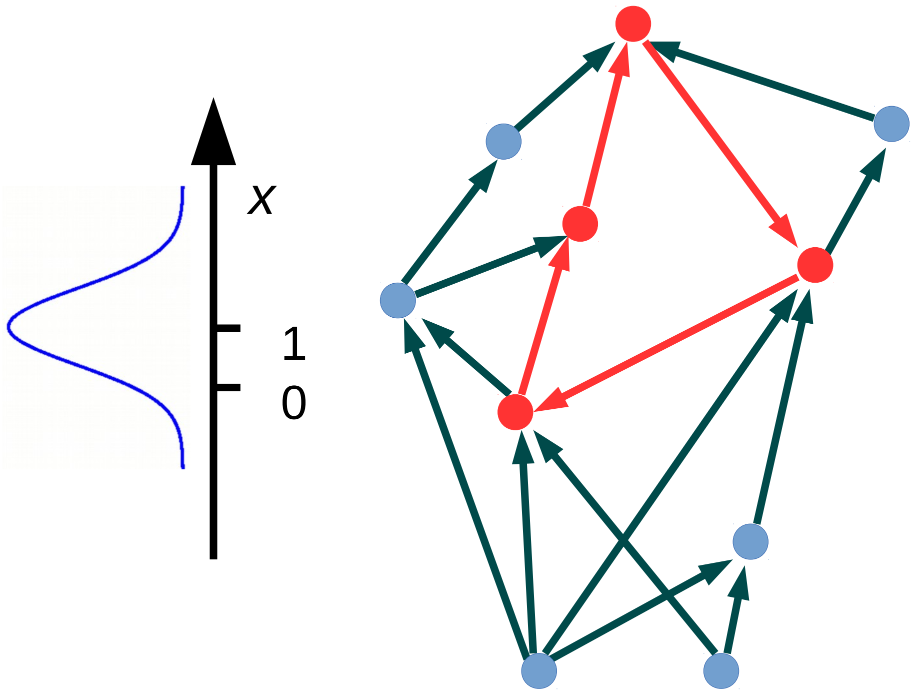
Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence

$$\# \text{ cycles} = \frac{\tilde{\alpha}\tilde{q}}{\alpha q} e^{\nu\tau}$$

$$\overline{\lambda_1} = e^{\tau}$$

$$\tau = \ln \alpha + \frac{1}{2\tilde{q}^2} - \frac{1}{2q^2}$$



Johnson & Jones (2017) *PNAS*

Feedback

Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence

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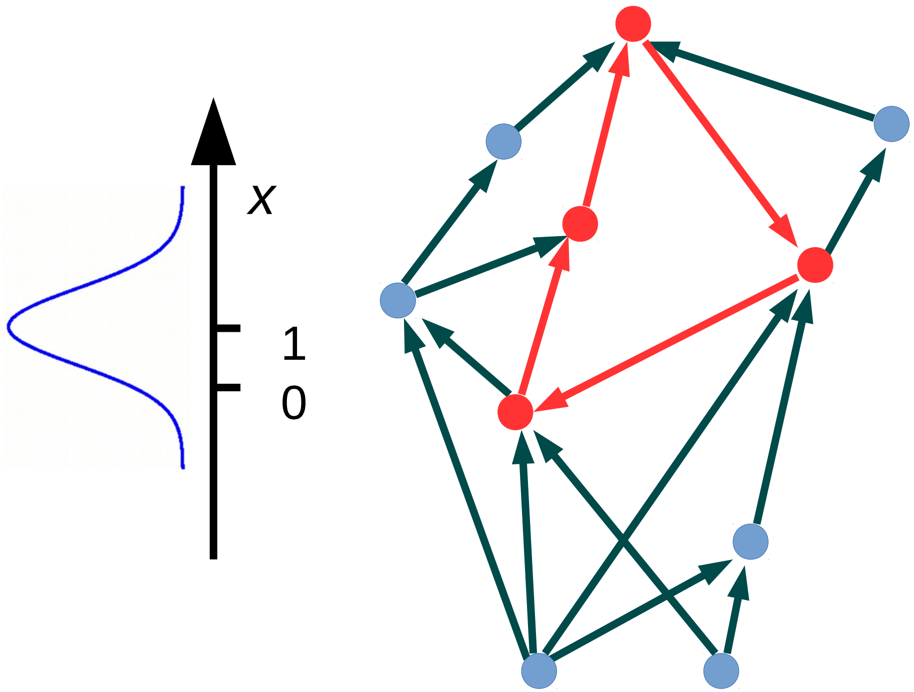


Johnson & Jones (2017) *PNAS*

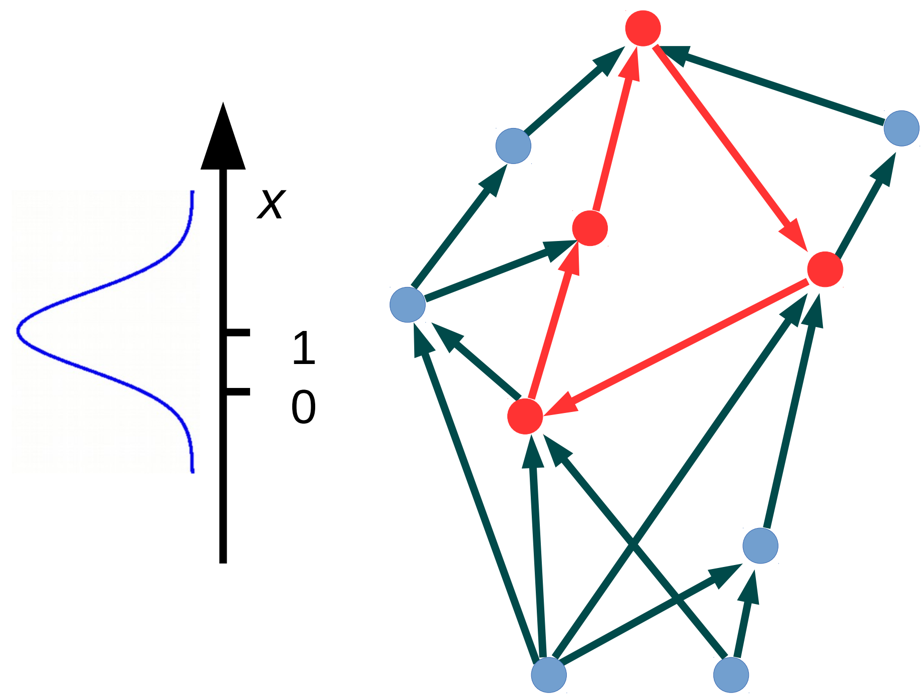
Feedback

Coherence ensemble:

Directed configuration ensemble
+
fixed trophic coherence

$$\# \text{ cycles} = \frac{\tilde{\alpha}\tilde{q}}{\alpha q} e^{\nu\tau}$$

$$\overline{\lambda_1} = e^{\tau}$$

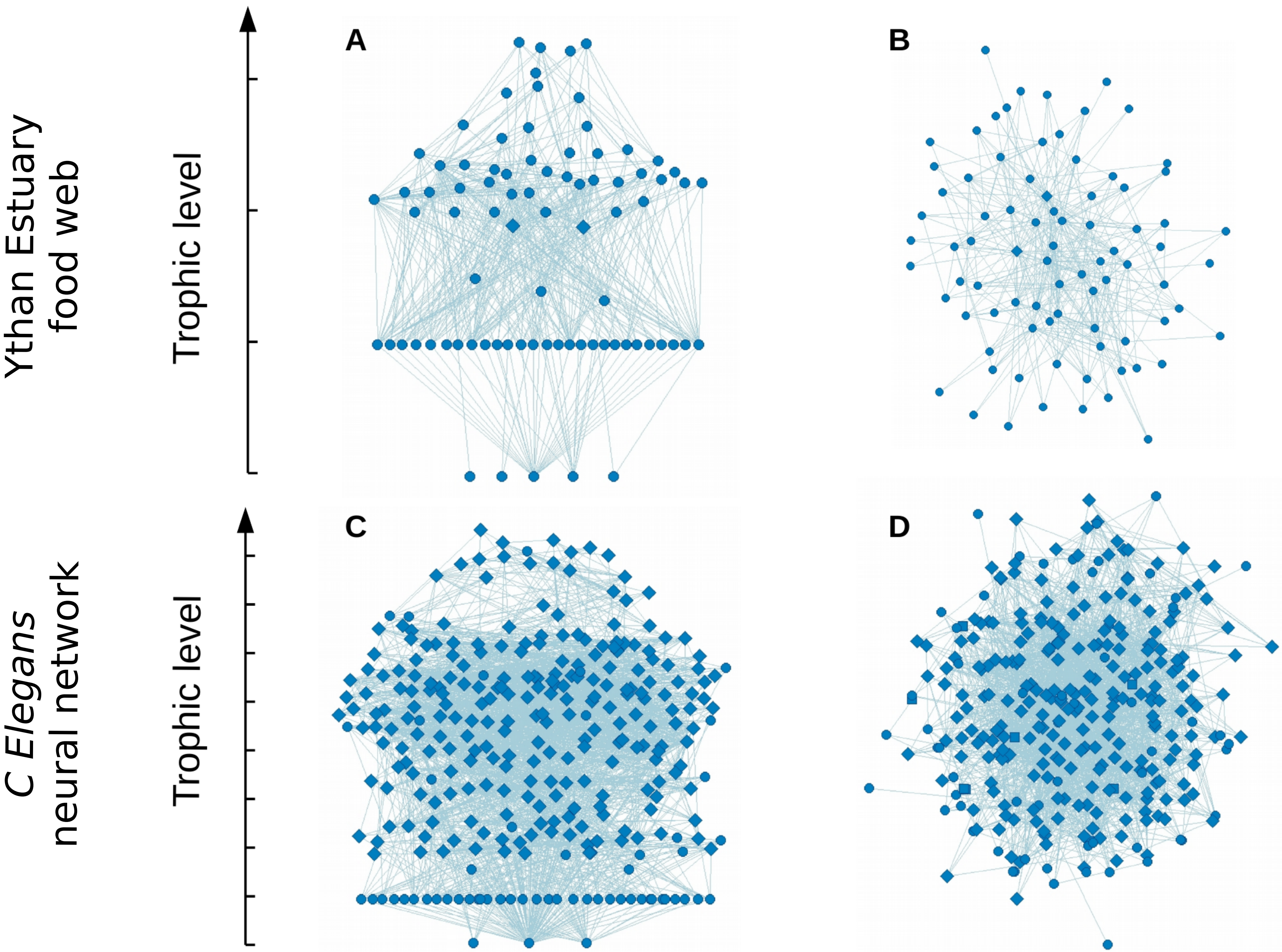


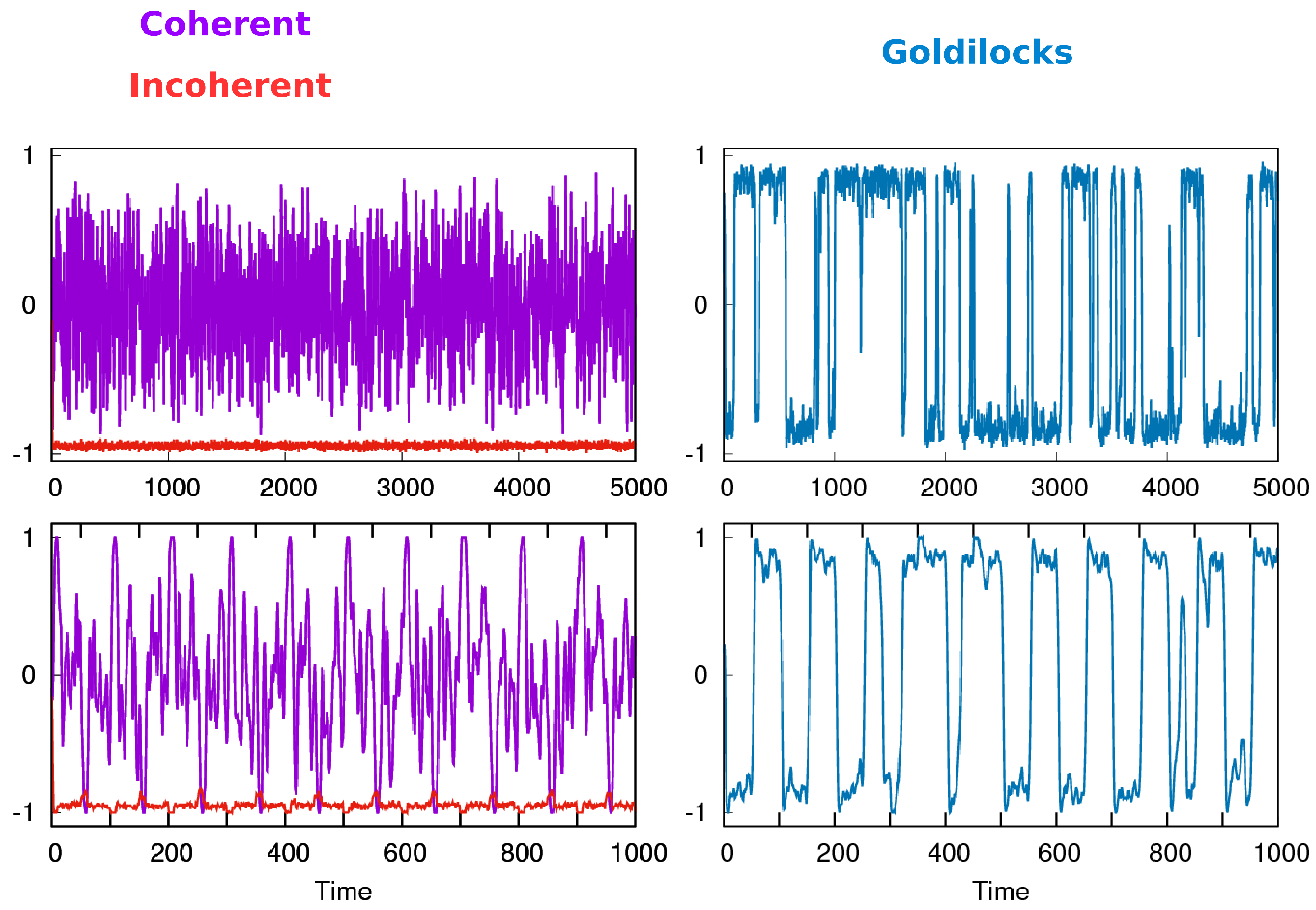
$$\tau = \ln \alpha + \frac{1}{2\tilde{q}^2} - \frac{1}{2q^2}$$

$\tau > 0$: Loopful regime (incoherent)

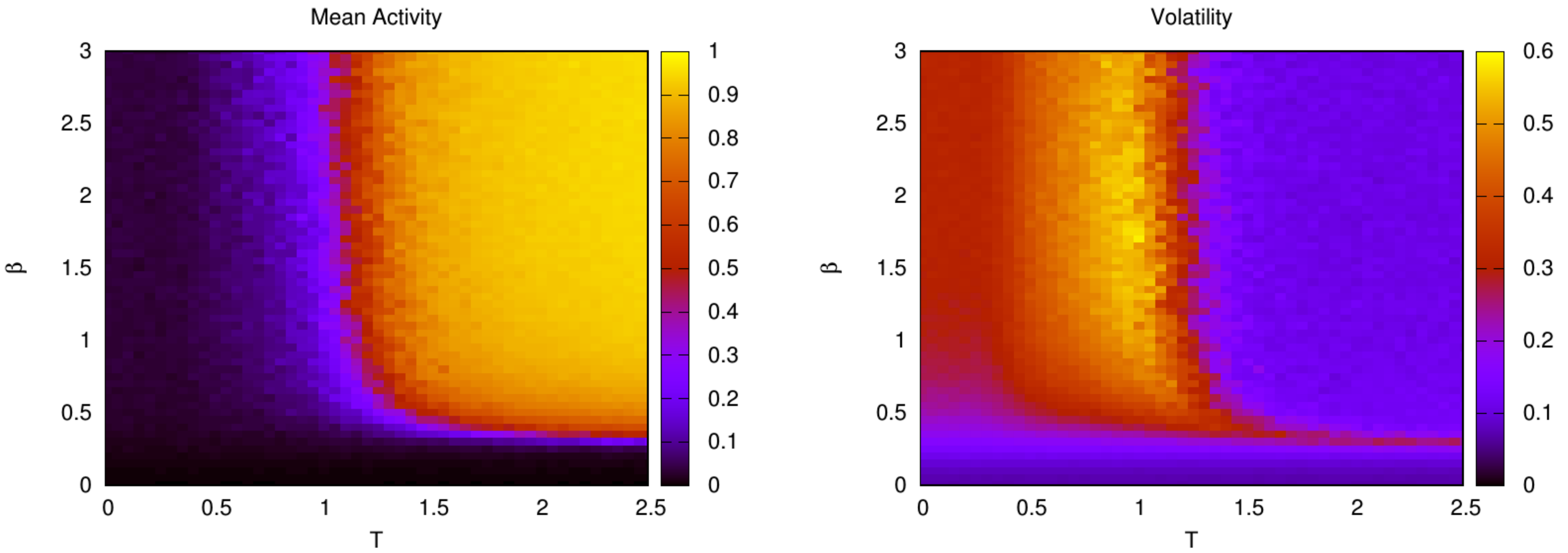
$\tau < 0$: Loopless regime (coherent)

Johnson & Jones (2017) *PNAS*


Ythan Estuary
food web
Trophic level
A
B
C Elegans
neural network
Trophic level
C
D



Coherent
Incoherent
Goldilocks
1
0
-1
0
1000
2000
3000
4000
5000
200
400
600
800
Time



Networks generated with the ‘preferential preying model’

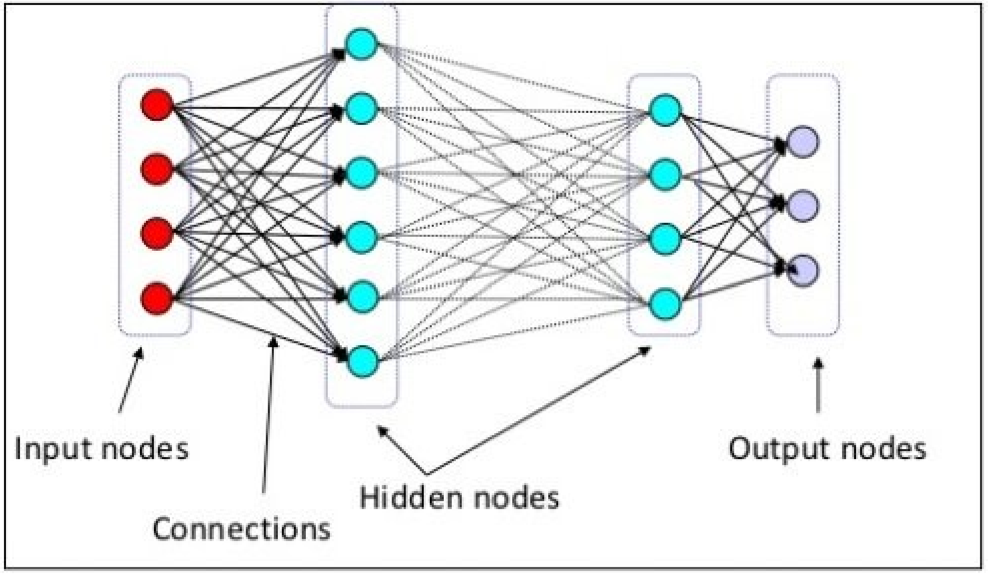
T sets incoherence of network

β sets stochasticity of dynamics

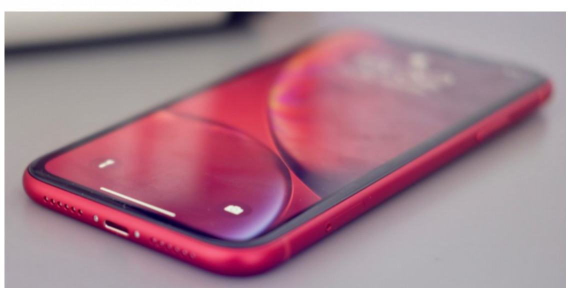
Bio models: Incoherent

Goldilocks networks?

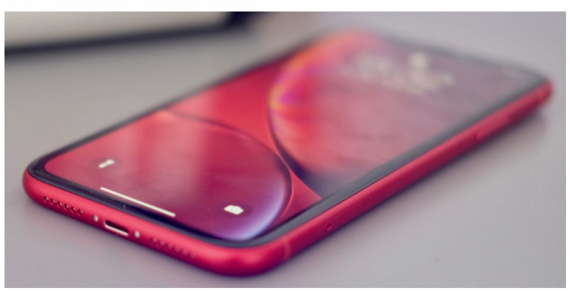
Deep neural nets: Coherent

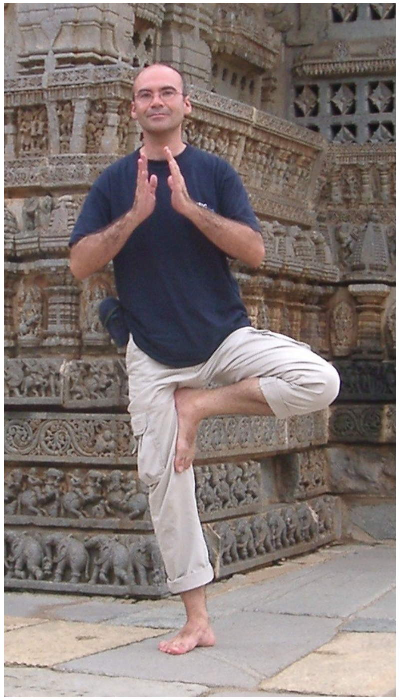


Are *we* robots?



Are *we* robots?





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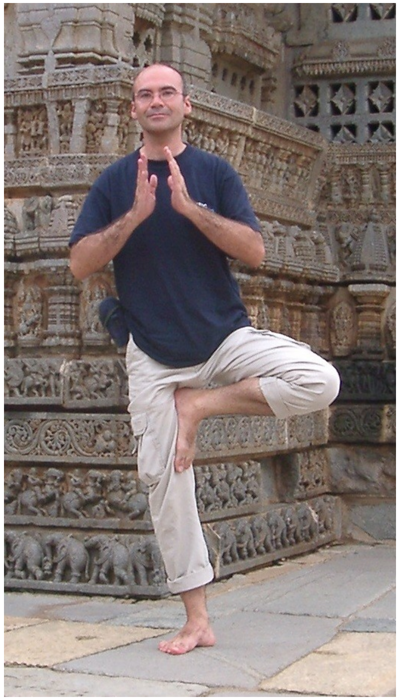

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Thank you for your attention!!