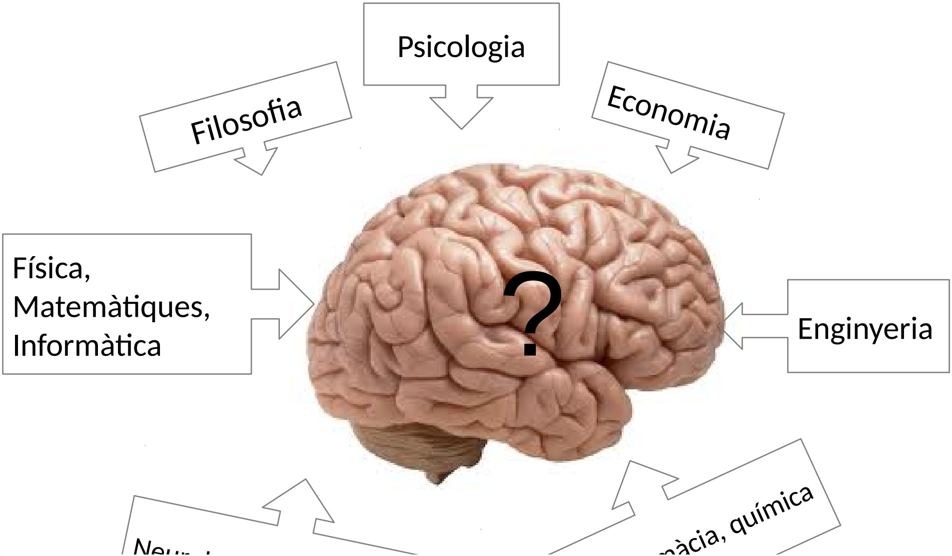
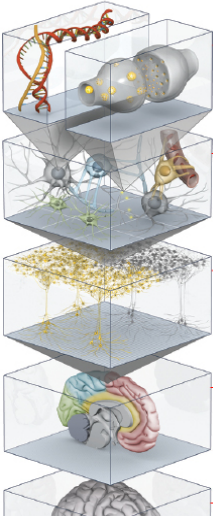
Matemàtiques per entendre el cervell

Gemma Huguet
Universitat Politècnica de Catalunya

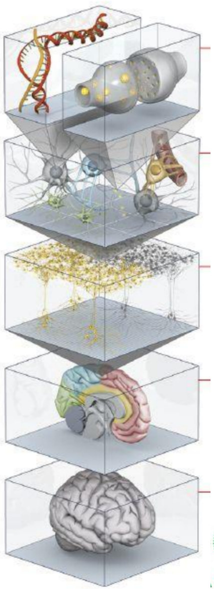
13-3-2021


Psicologia
Filosofia
Economia
Física,
Matemàtiques,
Informàtica
?
Enginyeria
àcia, química

El cervell



El cervell en diferents escales



Molecular

Cel·lular

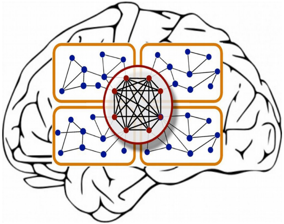
Circuits

Regions

Òrgan

Eines matemàtiques en Neurociència

Data analysis, statistics, information theory

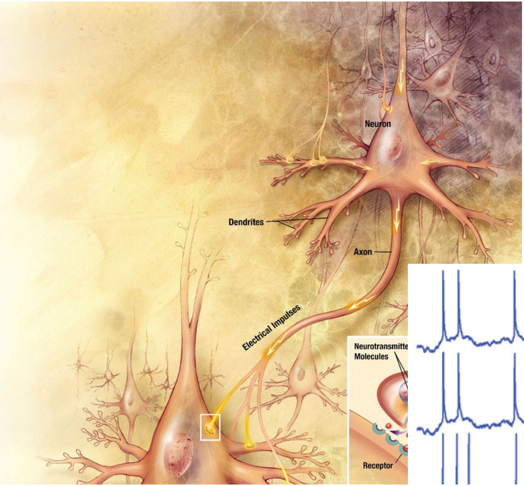


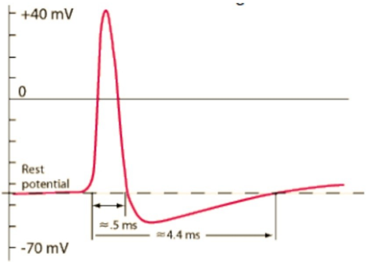
Graph theory, topology

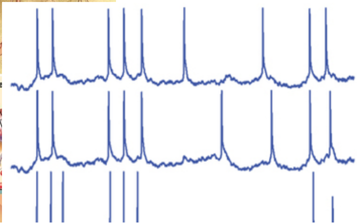
$$
\begin{cases}
C\dot{V} &= -I_{\mathrm{Na}} - I_{\mathrm{K}} - I_{\mathrm{L}} + I_{\mathrm{app}} \\
&= -g_{\mathrm{Na}} m^3 h (V - V_{\mathrm{Na}}) - g_{\mathrm{K}} n^4 (V - V_{\mathrm{K}}) - g_{\mathrm{L}} (V - V_{\mathrm{L}}) + I_{\mathrm{app}} \\
\dot{m} &= (m_\infty(V) - m)/\tau_m(V) \\
\dot{h} &= (h_\infty(V) - h)/\tau_h(V) \\
\dot{n} &= (n_\infty(V) - n)/\tau_n(V)
\end{cases}
$$

Continuous models: differential equations, dynamical systems, stochastic processes

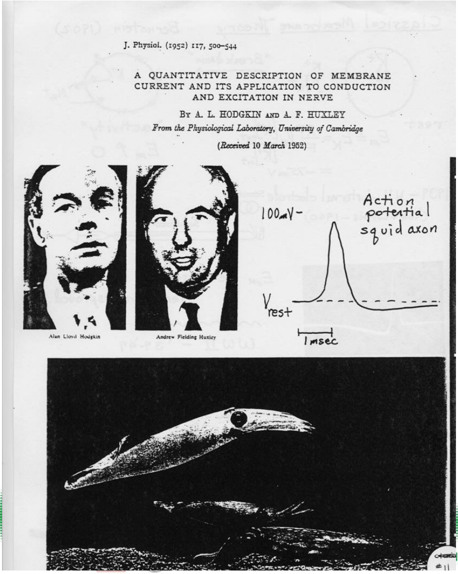
La neurona

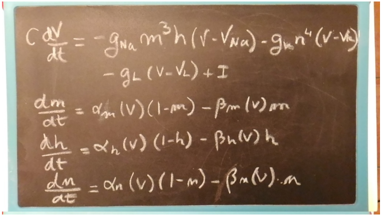

Neuron
Dendrites
Axon
Electrical Impulses
Neurotransmitte
Molecules
Receptor


+40 mV
0
Rest
potential
≈.5 ms
≈4.4 ms
-70 mV



Model de Hodgkin-Huxley (1952)





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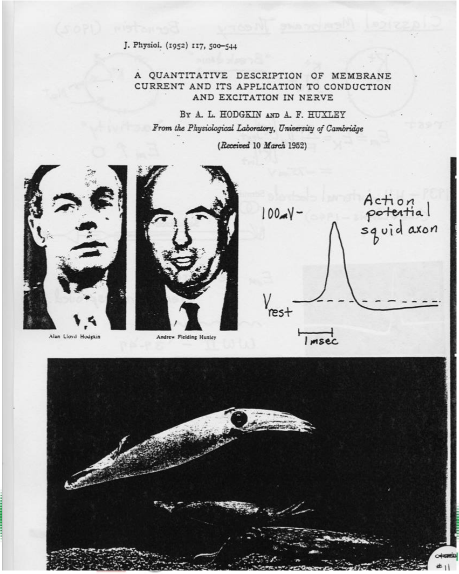
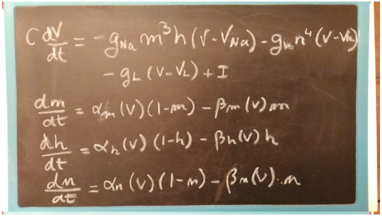
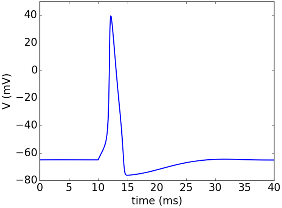
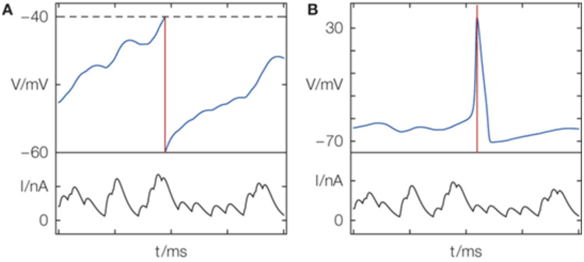






Model *Integrate-and-fire*

$$\begin{cases} C\dot{V} = -g_L(V - E_L) + I_{app}, \\ \text{si } V(t) > V_{th}, \text{ aleshores } V \to V_{re} \end{cases}$$



- *Integrate-and-fire* (forma adimensional):

$$v' = -v + I, \text{ si } v(t) = 1, \text{ aleshores } v(t^+) = 0$$

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- Solució: $v(t) = I + (v_0 - I)e^{-t}$, amb $v(0) = v_0$.

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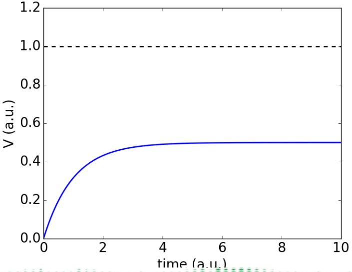
$I = 0.5, \; v_0 = 0$



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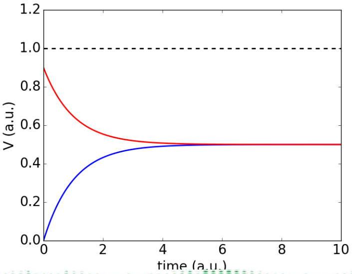
$$v' = -v + I, \text{ si } v(t) = 1, \text{ aleshores } v(t^+) = 0$$

- Solució: $v(t) = I + (v_0 - I)e^{-t}$, amb $v(0) = v_0$.

$I = 0.5, \; v_0 = 0 \;\; v_0 = 0.9$



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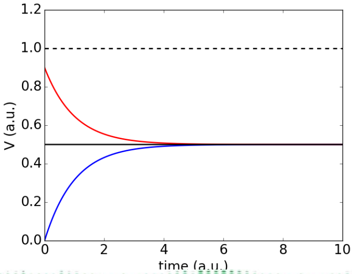
$$v' = -v + I, \text{ si } v(t) = 1, \text{ aleshores } v(t^+) = 0$$

- Solució: $v(t) = I + (v_0 - I)e^{-t}$, amb $v(0) = v_0$.

$I = 0.5,\ v_0 = 0\ \ v_0 = 0.9\ \ v_0 = 0.5.$

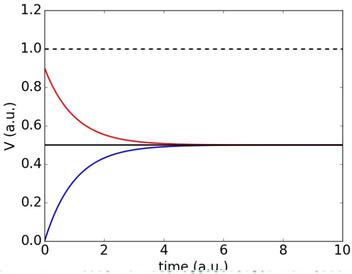


- *Integrate-and-fire* (forma adimensional):

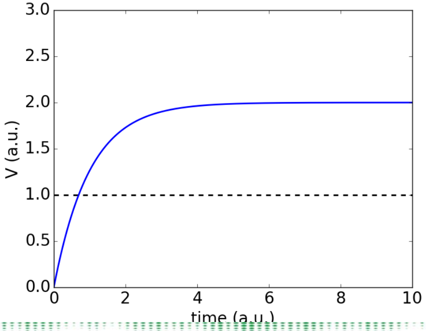
$$v' = -v + I, \text{ si } v(t) = 1, \text{ aleshores } v(t^+) = 0$$

- Solució: $v(t) = I + (v_0 - I)e^{-t}$, amb $v(0) = v_0$.

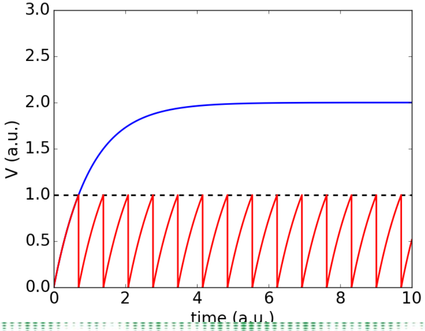
$I = 0.5$, $v_0 = 0$ $v_0 = 0.9$ $v_0 = 0.5$.
$v = I = 0.5$ és un punt d'equilibri estable



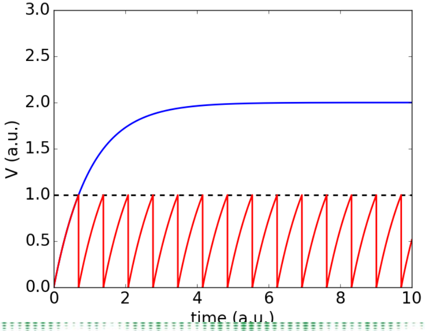
- Considerem $I = 2,\ v_0 = 0.$



- Considerem $I = 2$, $v_0 = 0$.
- Afegim la reinicialització



- Considerem $I = 2$, $v_0 = 0$.
- Afegim la reinicialització
- Canvi qualitatiu en les solucions (punt equilibri estable $\rightarrow$ solució periòdica estable). Bifurcació.



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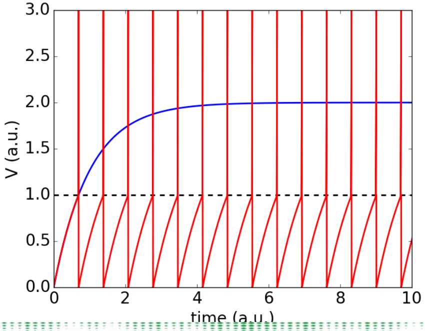
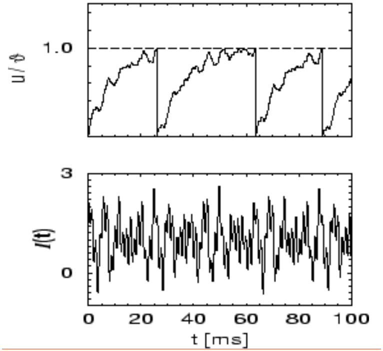
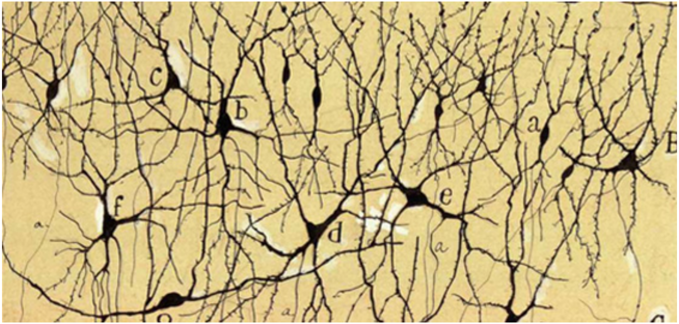


Senyal d'entrada depenent del temps

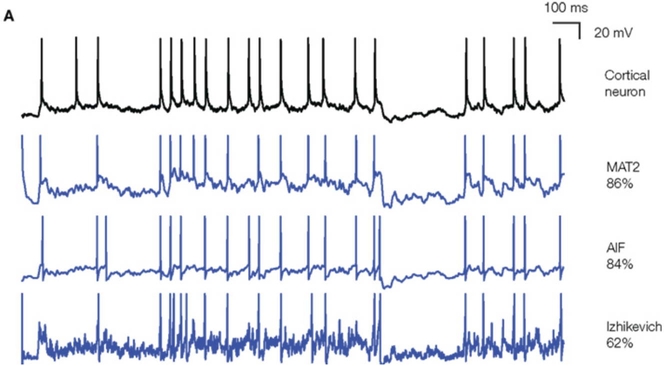


Circuits Neuronals

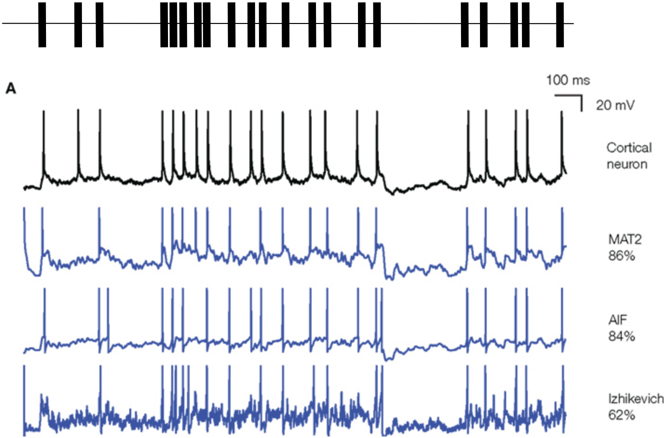


Dibuix de S. Ramon y Cajal
Sinapsis Neuronals: Excitadores i Inhibidores

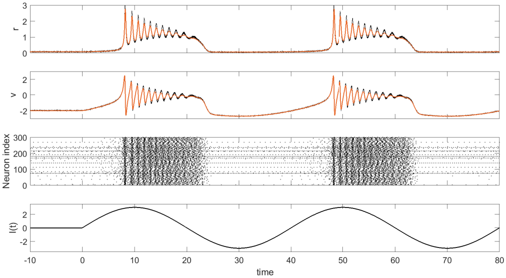
Simulacions



Simulacions

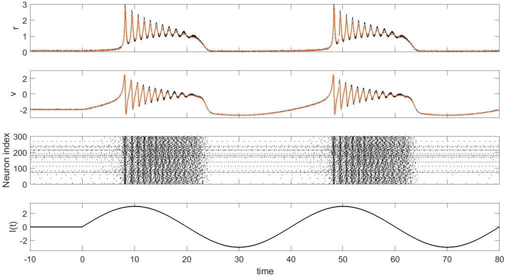


Dibuix de trama (*raster plot*) i Freqüència de Descàrrega



Simulacions de D. Reyner basades en Montbrió et al 2015.

Dibuix de trama (*raster plot*) i Freqüència de Descàrrega



Simulacions de D. Reyner basades en Montbrió et al 2015.

Models de camp mitjà: Equacions de Wilson-Cowan.

Codi Neuronal

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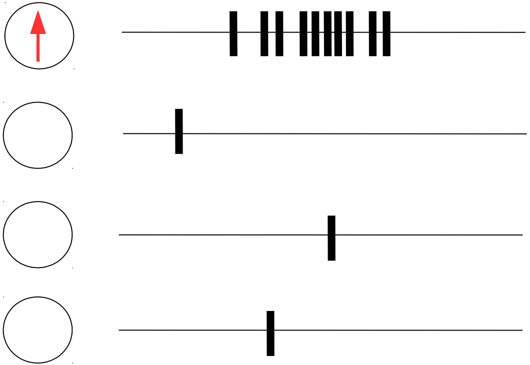
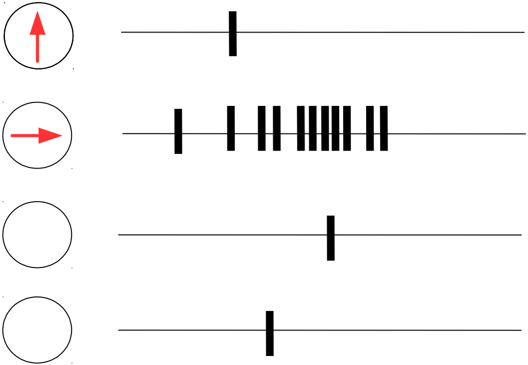
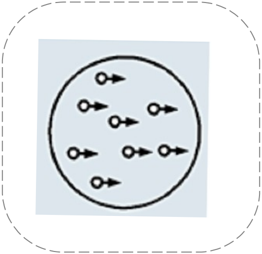
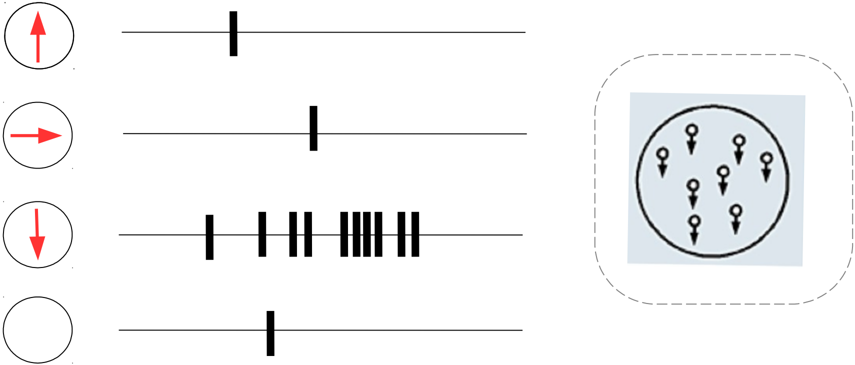


Codi Neuronal

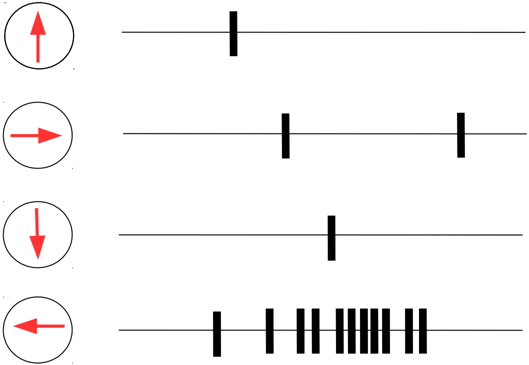


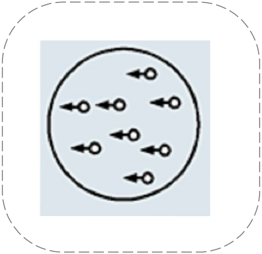


Codi Neuronal

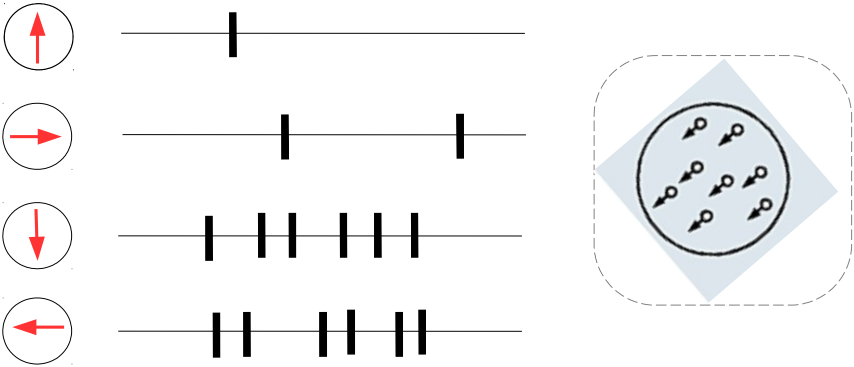


Codi Neuronal

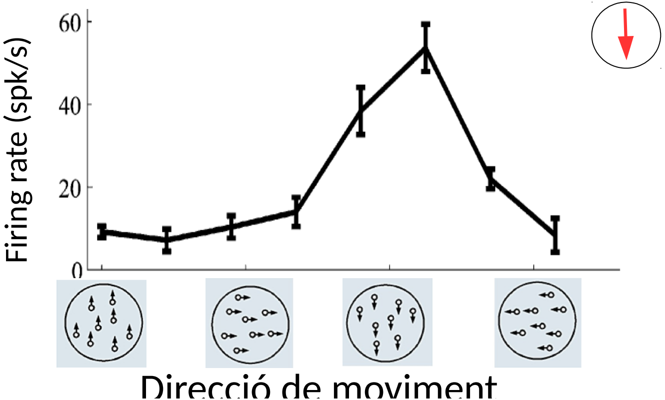




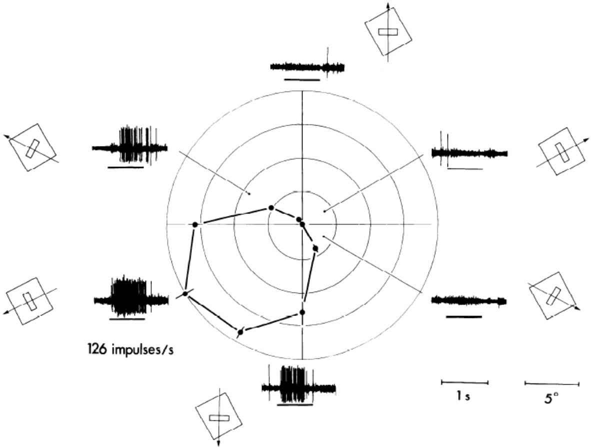
Codi Neuronal



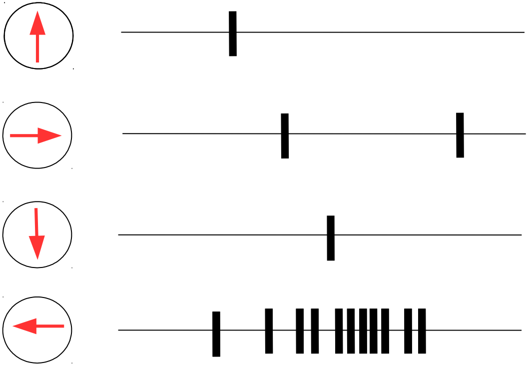
Codi Neuronal

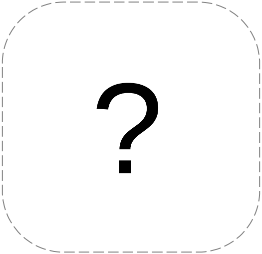


Experiments area MT del còrtex visual



Codi Neuronal





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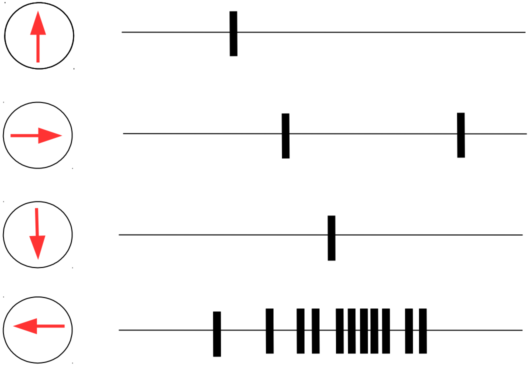

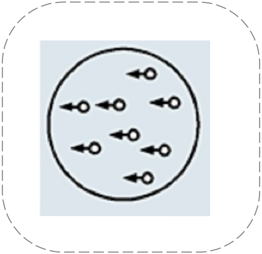

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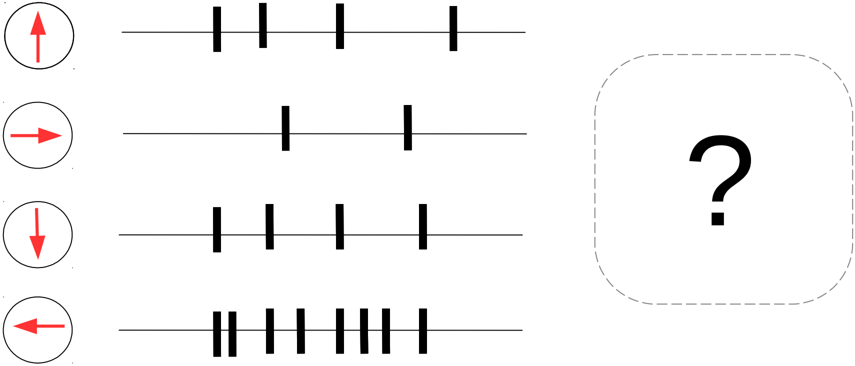

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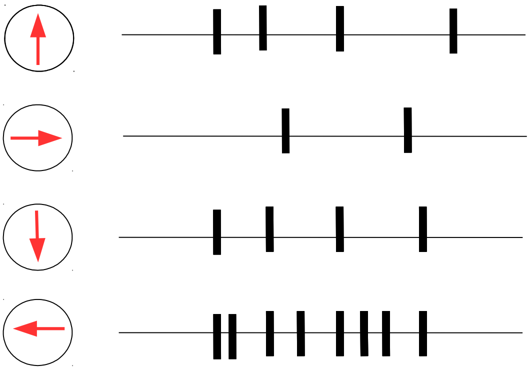

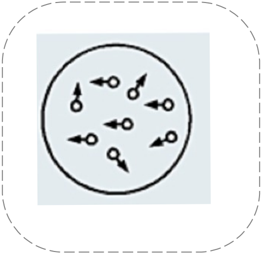

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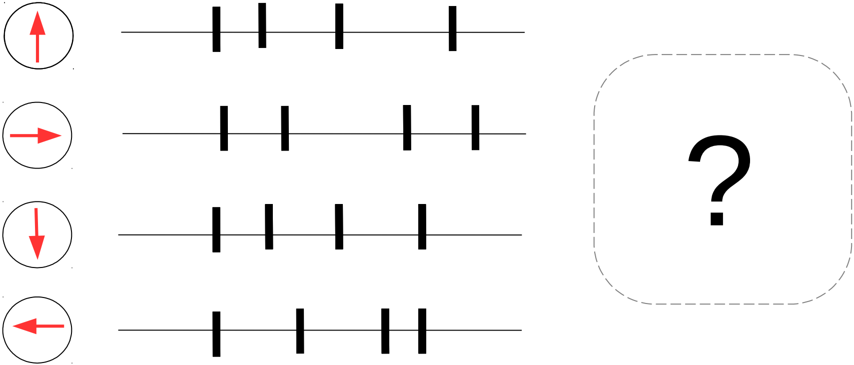

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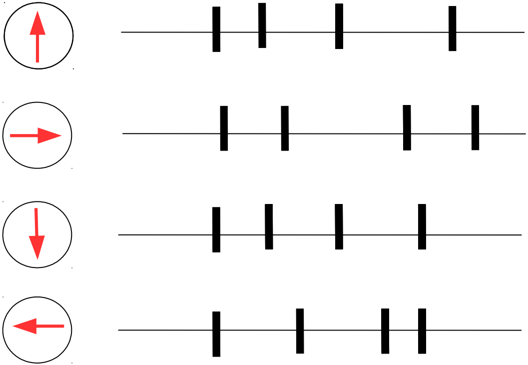
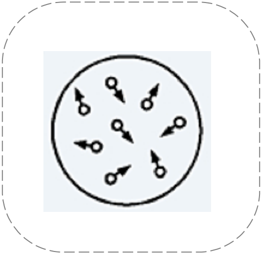
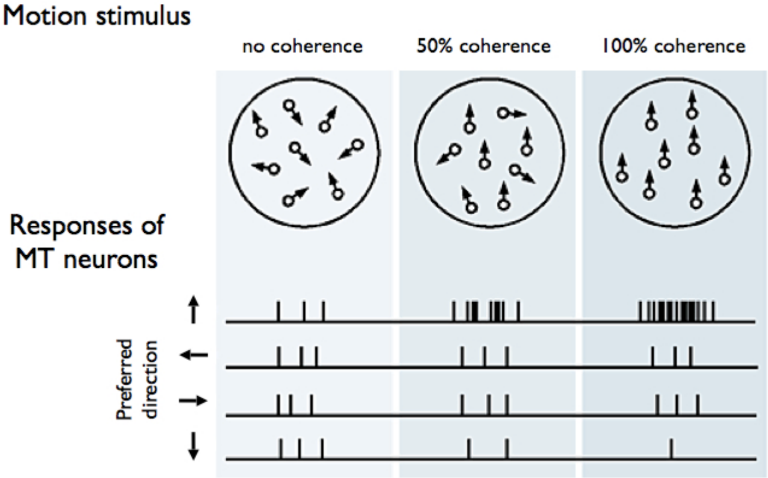
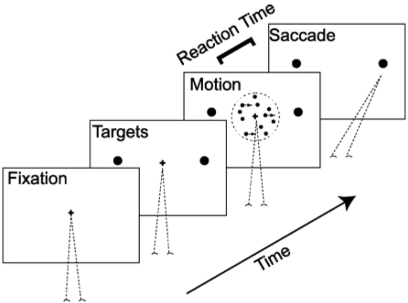




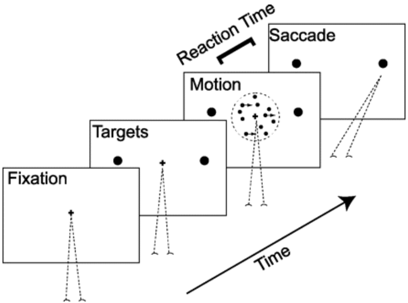
Motion coherence and MT neurons



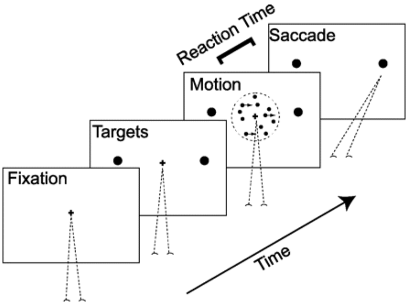
Decisions perceptuals

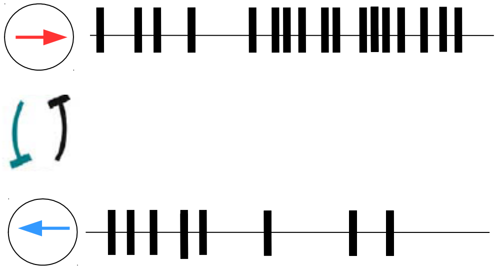


Decisions perceptuals

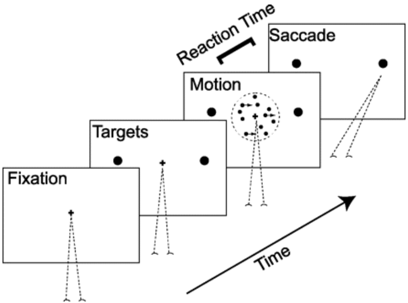


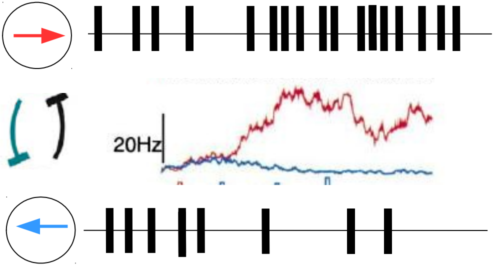
Decisions perceptuals



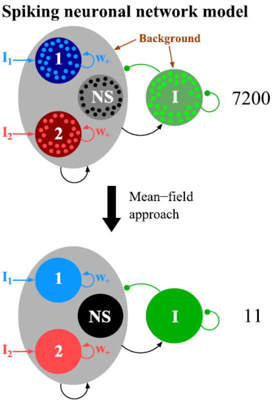


Decisions perceptuals



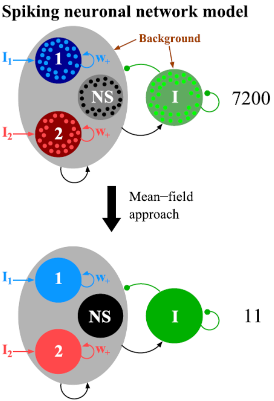


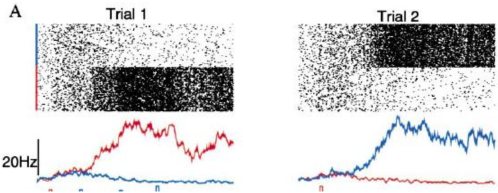
El model



Wang 2002, Wong and Wang, 2002

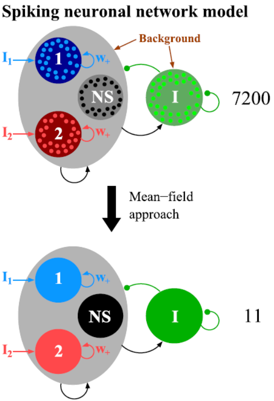
El model

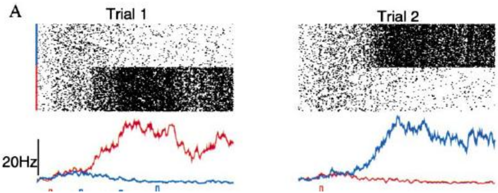




Wang 2002, Wong and Wang, 2002

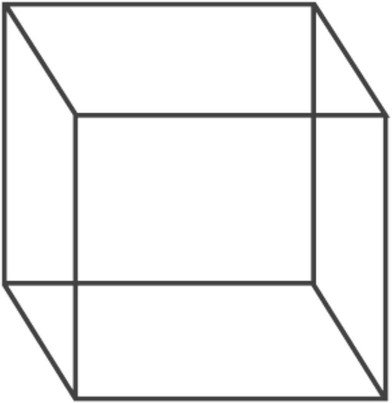
EI model

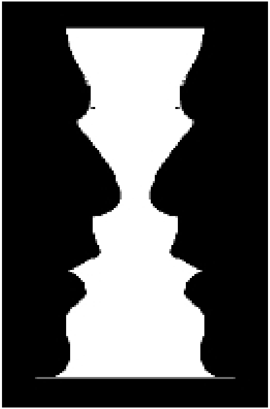




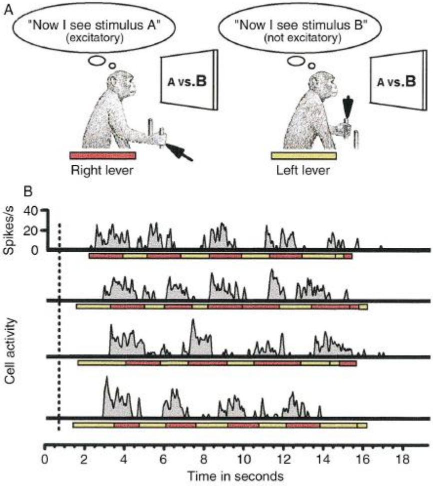
Wang 2002, Wong and Wang, 2002

Figures ambigües



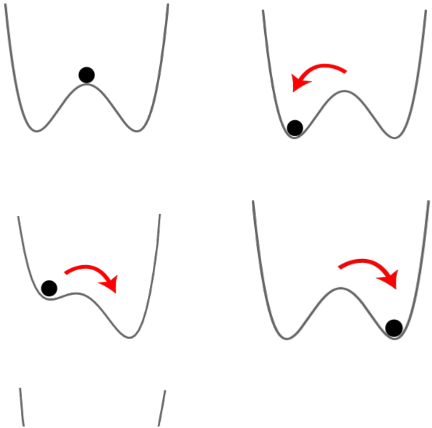


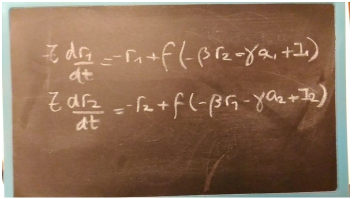
Què passa al nostre cervell?



Registres fisiològics de l'àrea V4 (Leopold i Logothetis, 1999).

El model





Per què un model del cervell?

- Per a reproduir-lo $\rightarrow$ nous algoritmes
- Per a curar-lo $\rightarrow$ noves teràpies
- Per a comprendre'l millor $\rightarrow$ nou coneixement

ENTREVISTA

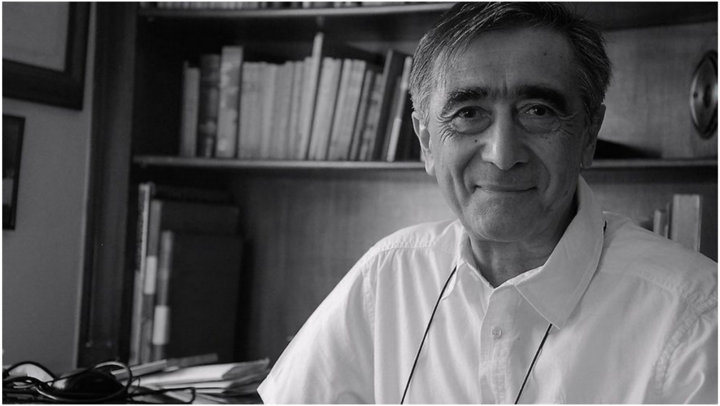
SOCIETAT | 12/12/2020

Fernando Giráldez: "La comprensió profunda del cervell vindrà de les matemàtiques"

Entrevista al catedràtic de la Universitat Pompeu Fabra

Toni Pou

5 min



Fernando Giráldez: "La comprensió profunda del cervell vindrà de les matemàtiques" F.G.

Moltes gràcies per la vostra atenció