

# Zihnimizi Bir de Matematik ile Anlamaya Çalışalım

Rahmi Elibol    Neslihan Serap Şengör

57. Ulusal Psikiyatri Kongresi

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Ankara

Örnek Model

Hesaplamalı Modeller

Kodlar

## Örnek Model

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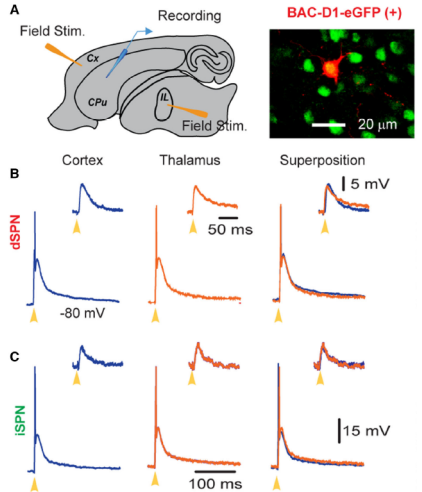
ORIGINAL ARTICLE

# Functional comparison of corticostriatal and thalamostriatal postsynaptic responses in striatal neurons of the mouse

M. A. Arias-García<sup>1</sup> · D. Tapia<sup>1</sup> · J. A. Laville<sup>1</sup> · V. M. Calderón<sup>1</sup> ·  
Y. Ramiro-Cortés<sup>1</sup> · J. Bargas<sup>1</sup> · E. Galarraga<sup>1</sup>

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# Sinaps modeli



<sup>1</sup>Arias-García, M.A., Tapia, D., Laville, J.A. et al., 'Functional comparison of corticostriatal and thalamostriatal postsynaptic responses in striatal neurons of the mouse'. Brain Struct Funct (2017).

<https://doi.org/10.1007/s00429-017-1530-0>



I developed the most realistic neural network!

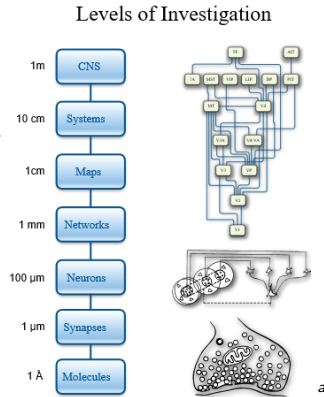
I do not see any neurons here, only equations!

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# Hesaplama Nörobilim - Computational Neuroscience

Sinir sistemini veriler ve teoriler ışığında analiz eder.

- Tek hücre kayıtları
- LFP
- EEG
- fMRI
- ...



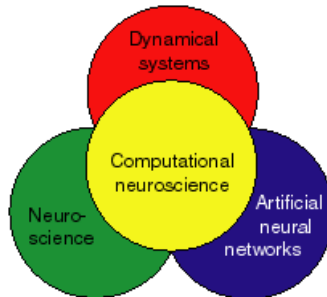
<sup>a</sup>Sejnowski T., <http://cnl.salk.edu/>

## Yapay sinir ağları

- ▶ McCulloch-Pitts
- ▶ Perceptron
- ▶ Kohonen
- ▶ ...
- ▶ Deep learning

## Biyofiziksel sinir ağları

- ▶ Integrate and fire
- ▶ Wilson-Cowan
- ▶ Hodgkin-Huxley
- ▶ Izhikevich
- ▶ ...

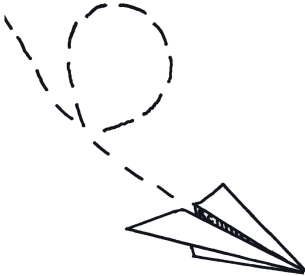


4

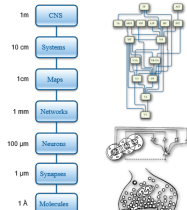
<sup>4</sup>[http://www.scholarpedia.org/article/Encyclopedia:Computational\\_neuroscience](http://www.scholarpedia.org/article/Encyclopedia:Computational_neuroscience)



## Modelleme yaklaşımları



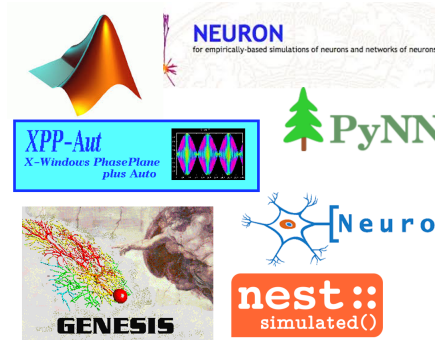
Levels of Investigation



## Benzetim araçları

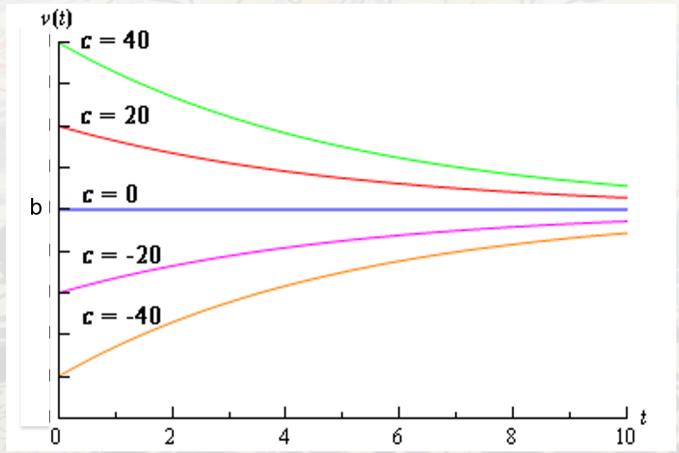
The logo for BRIAN, featuring the word "BRIAN" in large, bold, yellow 3D block letters.

- Hücre Modeli oluşturmak
- Sinaptik Bağlantı kurmak (esneklik)
- Grup ve Grup Bağlantısı



## Kodlar

$$\frac{dv}{dt} = av + b, \quad v(0) = c, \quad a \leq 0, v \in \mathbb{R}$$



## Kodlar

```
1 from brian2 import * #Kütüphanelerin tanımlanması
2 from numpy import * #Numeric python kütüphanesi temel matematiksel işlemlerin fonksiyonları
3 from matplotlib.pyplot import * #Grafik çizdirme için gerekli kütüphane
4
5 #Topla ve ateşle modelinin tanımlanması
6 tau = 5*ms #tau değişkenine değer atama(Birimlere dikkat!)
7 a=-1
8 b=1
9 # Çok satırlı ifadeleri yazmak için ''' kullanılır. Hücre denklemi bu şekilde tanımlanır.
10 eqs = '''
11 dv/dt = (a*v+b)/tau : 1
12 '''
13 G = NeuronGroup(1, eqs, method='linear')
14 #G.v=0.1 #Baslangic kosulu
15 # Modeli gerçekleyen temel fonksiyon hücre sayısı, denklemi, çözüm metodu gibi değişkenlere
16 M = StateMonitor(G, 'v', record=0)
17 # Model çalıştırıldığında tüm veriler tutulmaz. StateMonitor gibi fonksiyonlarla kaydedilme
18 run(30*ms)
19 # Model run komut ile belli bir süre işletilir. (Burada programın akışına dikkat!)
20
21 plot(M.t/ms, M.v[0])# Kaydedilen veri grafiğe çizdirilir.
22 xlabel('Time (ms)')
23 ylabel('v')
```

# Birimler

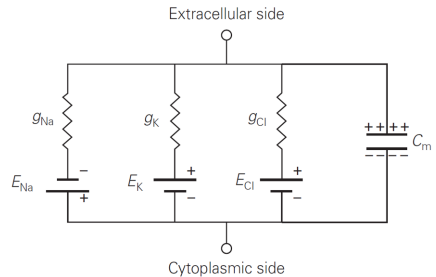
Kodlara erişebileceğiniz sayfa: <https://github.com/rahmielibol>

```
from brian2 import *  
print(3*volt+2*volt)  
print(3*volt+2*mV)  
print((3*volt)/(1*ohm))  
print((3*volt)/(1*amp))  
print((3*mA)*(1*ohm))
```

5. V  
3.002 V  
3. A  
3. ohm  
3. mV

## Hodgkin Huxley Modeli, 1952

$$\begin{aligned}
 C \dot{V} &= I - \overbrace{\bar{g}_K n^4 (V - E_K)}^{I_K} - \overbrace{\bar{g}_{Na} m^3 h (V - E_{Na})}^{I_{Na}} - \overbrace{g_L (V - E_L)}^{I_L} \\
 \dot{n} &= \alpha_n(V)(1 - n) - \beta_n(V)n \\
 \dot{m} &= \alpha_m(V)(1 - m) - \beta_m(V)m \\
 \dot{h} &= \alpha_h(V)(1 - h) - \beta_h(V)h,
 \end{aligned}$$



## Izhikevich Modeli, 2003

$$\begin{aligned}\dot{v} &= 0.04v^2 + 5v + 140 - u + I_s \\ \dot{u} &= a(bv - u)\end{aligned}\tag{2}$$

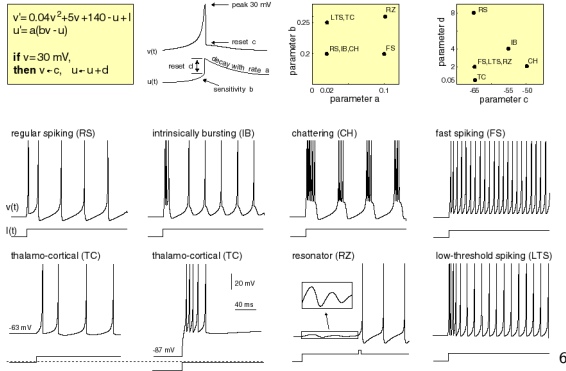
$$v > 30 \text{ mV}, \quad \text{ise} \quad \begin{cases} v \leftarrow c \\ u \leftarrow u + d \end{cases}\tag{3}$$

5

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<sup>5</sup>Izhikevich, E., 'Which Model to Use for Cortical Spiking Neurons?', IEEE Transactions on Neural Networks (2004) 15:1063-1070

# Izhikevich Modeli, 2003



<sup>6</sup>Izhikevich, E., 'Which Model to Use for Cortical Spiking Neurons?', IEEE Transactions on Neural Networks (2004) 15:1063-1070



Models	biophysically meaningful	tonic spiking	phasic spiking	tonic bursting	phasic bursting	mixed mode	spike frequency adaptation	class 1 excitable	class 2 excitable	spike latency	subthreshold oscillations	resonator	integrator	rebound spike	rebound burst	threshold variability	bistability	DAP	accommodation	inhibition-induced spiking	inhibition-induced bursting	chaos	# of FLOPS
integrate-and-fire	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	5
integrate-and-fire with adapt.	-	+	-	-	-	+	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	10
integrate-and-fire-or-burst	-	+	+		+	-	+	+	-	-	-	+	+	+	-	+	+	-	-	-			13
resonate-and-fire	-	+	+	-	-	-	+	+	-	+	+	+	+	-	-	+	+	+	+	-	-	+	10
quadratic integrate-and-fire	-	+	-	-	-	-	+	-	+	-	-	+	-	-	+	+	-	-	-	-	-	-	7
Izhikevich (2003)	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	13
FitzHugh-Nagumo	-	+	+	-		-	+	-	+	+	+	-	+	-	+	+	-	+	+	-	-		72
Hindmarsh-Rose	-	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+		+		120
Morris-Lecar	+	+	+	-		-	+	+	+	+	+	+	+		+	+	-	+	+	-	-		600
Wilson	-	+	+	+			+	+	+	+	+	+	+	+	+		+	+					180
Hodgkin-Huxley	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+		+		1200

<sup>7</sup>Izhikevich, E., 'Which Model to Use for Cortical Spiking Neurons?', IEEE Transactions on Neural Networks (2004) 15:1063-1070

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