Study of neuronal morphology by computational modeling.

Julián Tejada

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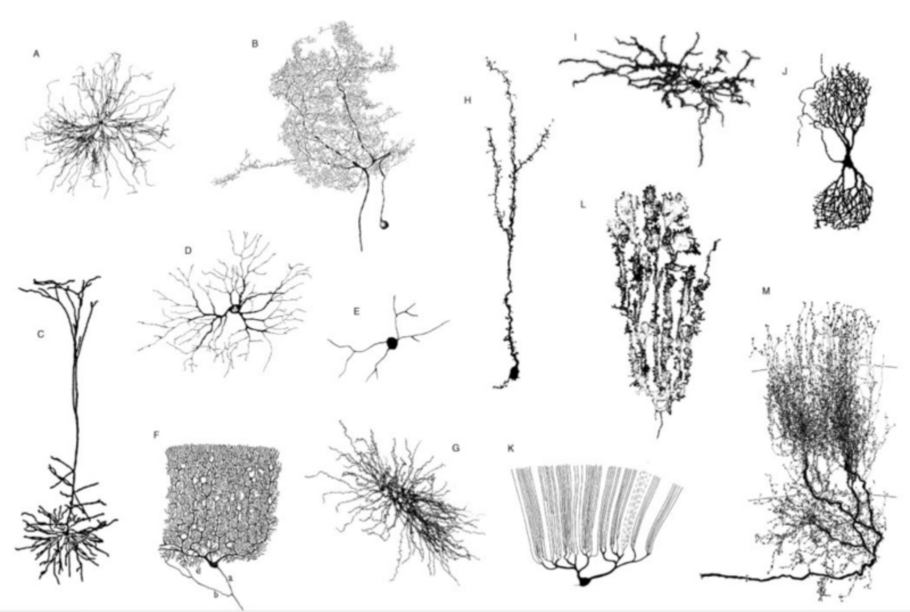
Universidade Federal de Sergipe - UFS

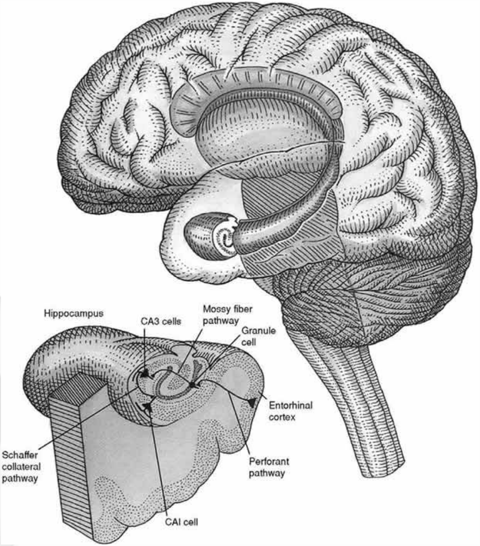


https://ngp.usc.edu/faculty/profile/?fid=12

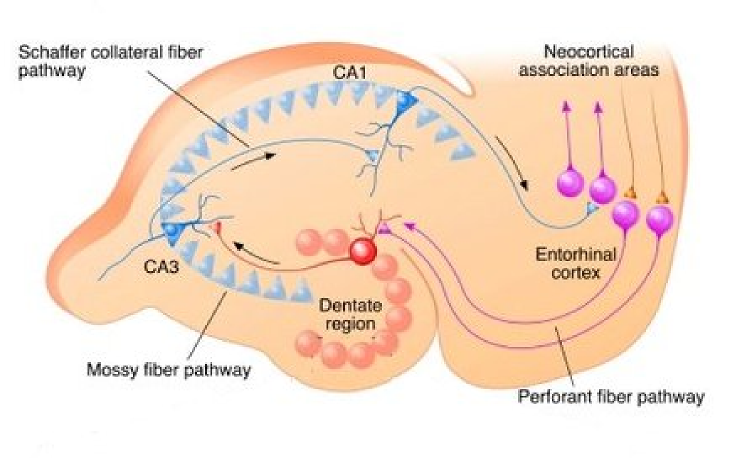
Wikipedia

Epilepsy

Hippocampus - Temporal lobe epilepsy

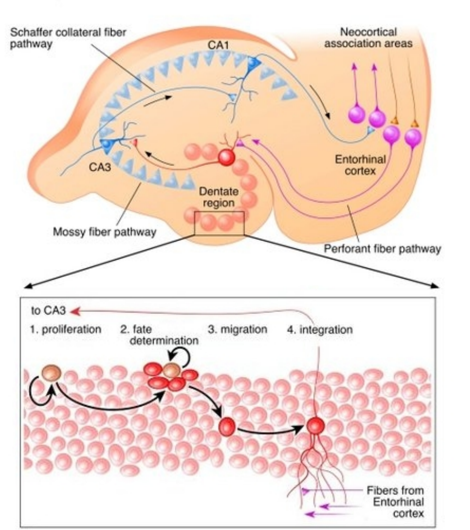


Hippocampus



http://www.helmholtz-muenchen.de/

Dentate gyrus neurogenesis



Morphological alteration of the dentate gyrus

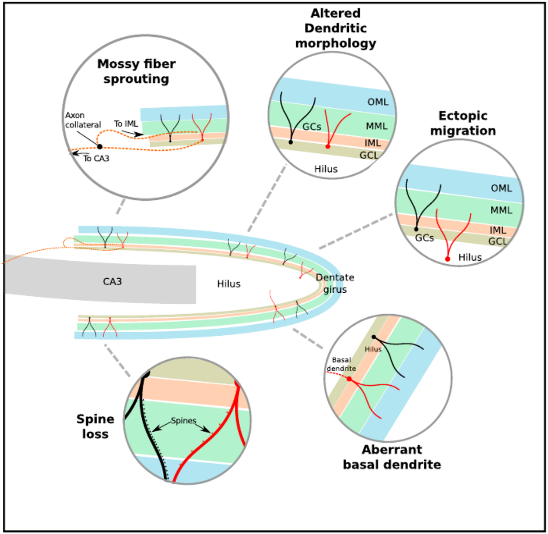


Fig. 1. Main morphological alterations exhibited by the DG GCs. They are highlighted within zoomed views (circular drawings). Some of the alterations are related with axonal target: mossy fiber sprouting. Others are related with dendritic morphology: apical dendrites with altered morphology and aberrant basal dendrites. Another is related with abnormal or ectopic migration, and finally, there are alterations related with dendritic spine loss.

Three-dimensional reconstructions

available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

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BRAIN RESEARCH

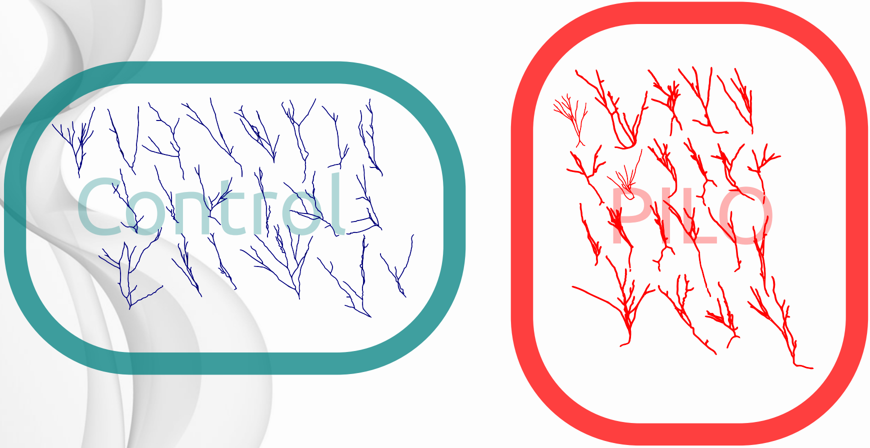
Research Report

Doublecortin-positive newly born granule cells of hippocampus have abnormal apical dendritic morphology in the pilocarpine model of temporal lobe epilepsy

*Gabriel Maisonnave Arisi, Norberto Garcia-Cairasco**

Department of Physiology, Medical School of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, 14049-900, Brazil

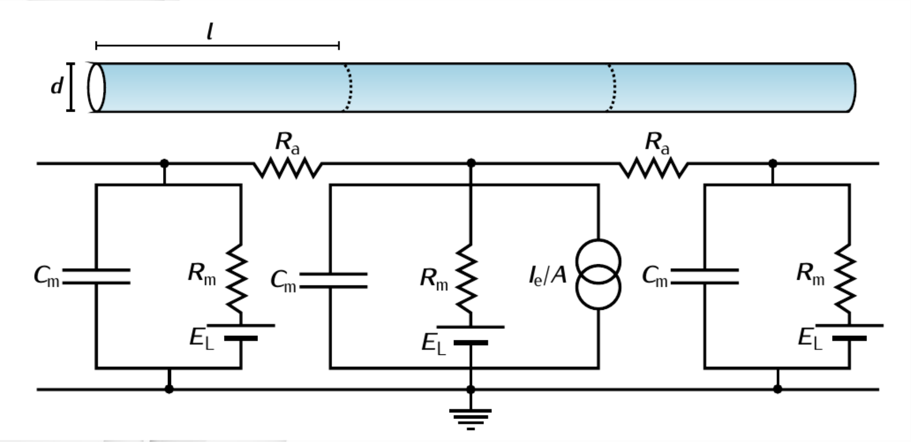
Three-dimensional reconstructions



Realistic models

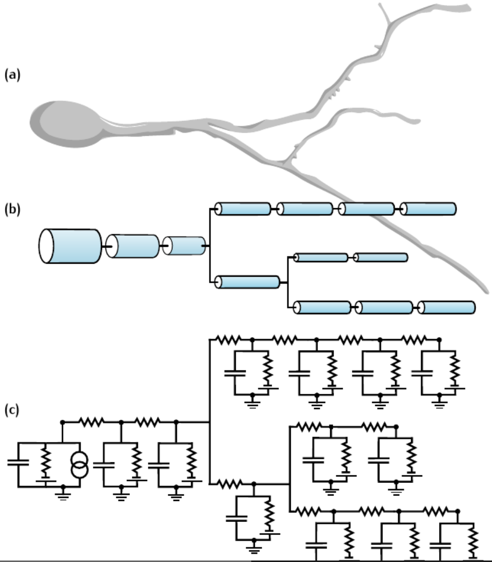
Spiking neural network

Model based on multi-compartments



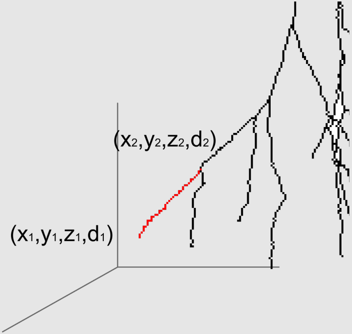
Sterratt et al. Principles of Computational Modelling in Neuroscience

Neural models with morphology



Three-dimensional reconstructions

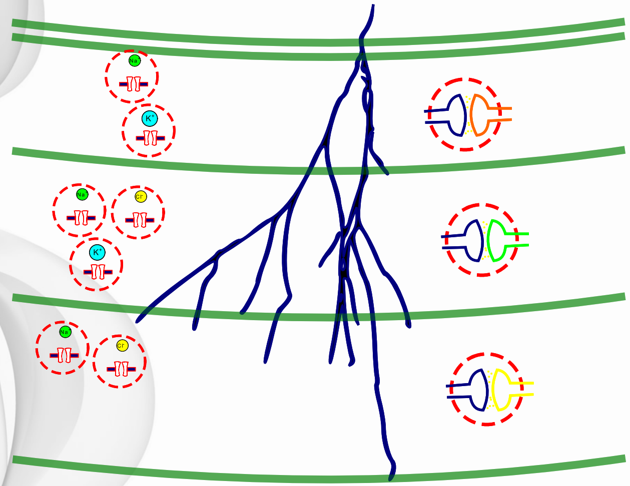
Stereological representation



Each segment is represented by a set of three-dimensional coordinates and a diameter

- pt3dadd(10.25,19.19,1.25,2.41)
- pt3dadd(11.92,20.29,0.37,1.21)
- pt3dadd(14.24,20.75,0.48,1.11)
- pt3dadd(16.66,20.93,0.44,0.74)
- pt3dadd(17.49,22.86,-0.32,1.02)
- ...

Morphology and biophysical properties



PLOS one

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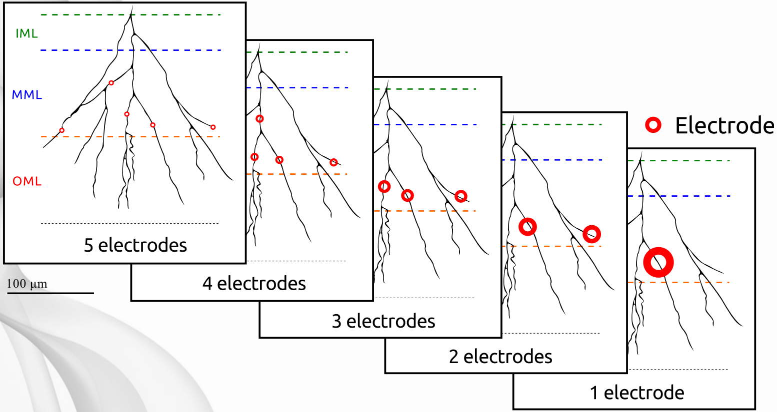
PLoS one

Morphological Alterations in Newly Born Dentate Gyrus Granule Cells That Emerge after *Status Epilepticus* Contribute to Make Them Less Excitable

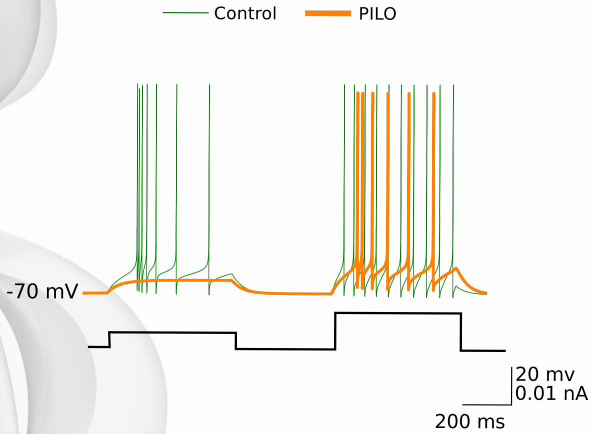
Julián Tejada[1,2], Gabriel M. Arisi[2], Norberto García-Cairasco[2*], Antonio C. Roque[1*]

1 Departamento de Física, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, São Paulo, Brazil, **2** Departamento de Fisiologia, Faculdade de Medicina de Ribeirão Preto, Ribeirão Preto, São Paulo, Brazil



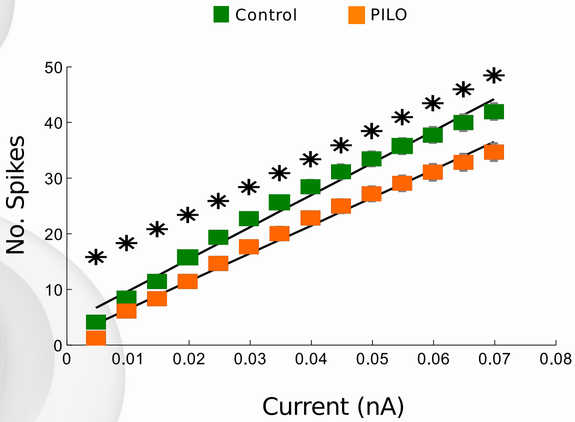
Tejada J, Arisi GM, García-Cairasco N, Roque AC (2012) Morphological Alterations in Newly Born Dentate Gyrus Granule Cells That Emerge after Status Epilepticus Contribute to Make Them Less Excitable. PLoS ONE 7(7): e40726. doi:10.1371/journal.pone.0040726

Simulated Action Potential



PLoS ONE 7(7): e40726. doi:10.1371/journal.pone.0040726

Simulated Action Potential



From the neuron up to the network model

Computational model of the dentate girus

Role of Mossy Fiber Sprouting and Mossy Cell Loss in Hyperexcitability: A Network Model of the Dentate Gyrus Incorporating Cell Types and Axonal Topography

Vijayalakshmi Santhakumar, Ildiko Aradi and Ivan Soltesz

J Neurophysiol 93:437-453, 2005. First published 1 September 2004; doi:10.1152/jn.00777.2004

Computational model of the dentate girus

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PLOS | COMPUTATIONAL BIOLOGY

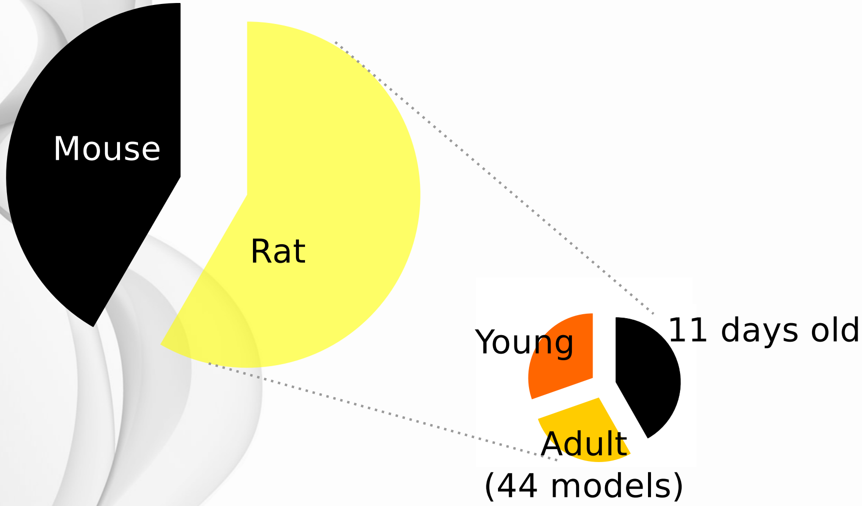
Combined Role of Seizure-Induced Dendritic Morphology Alterations and Spine Loss in Newborn Granule Cells with Mossy Fiber Sprouting on the Hyperexcitability of a Computer Model of the Dentate Gyrus

Julian Tejada[1,2]*, Norberto Garcia-Cairasco[2], Antonio C. Roque[1]

1 Departamento de Física, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, São Paulo, Brasil, **2** Departamento de Fisiologia, Faculdade de Medicina de Ribeirão Preto, Ribeirão Preto, São Paulo, Brasil

http://neuromorpho.org/

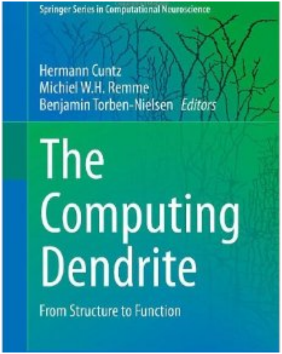
Selection of the morphological reconstructions



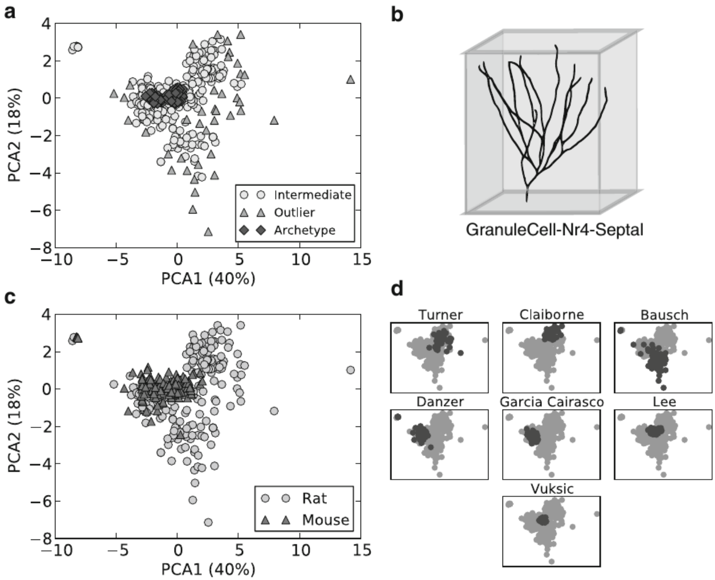
Selection of the morphological reconstructions

Chapter 3
Archetypes and Outliers in the Neuromorphological Space

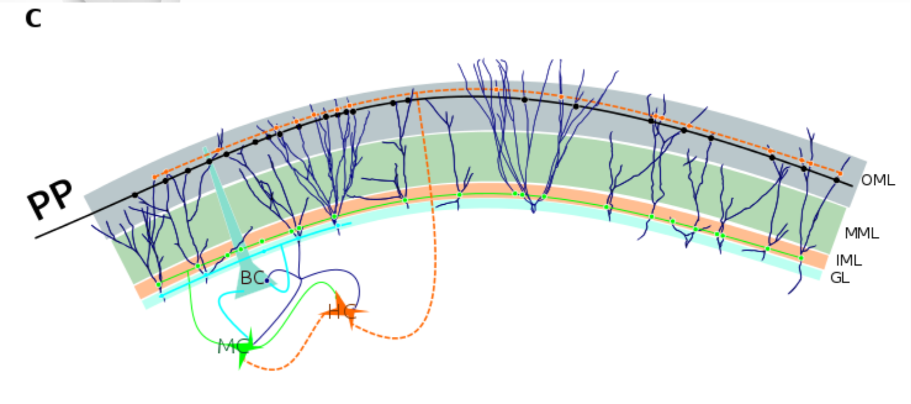
Cesar H. Comin, Julian Tejada, Matheus P. Viana, Antonio C. Roque, and Luciano da F. Costa



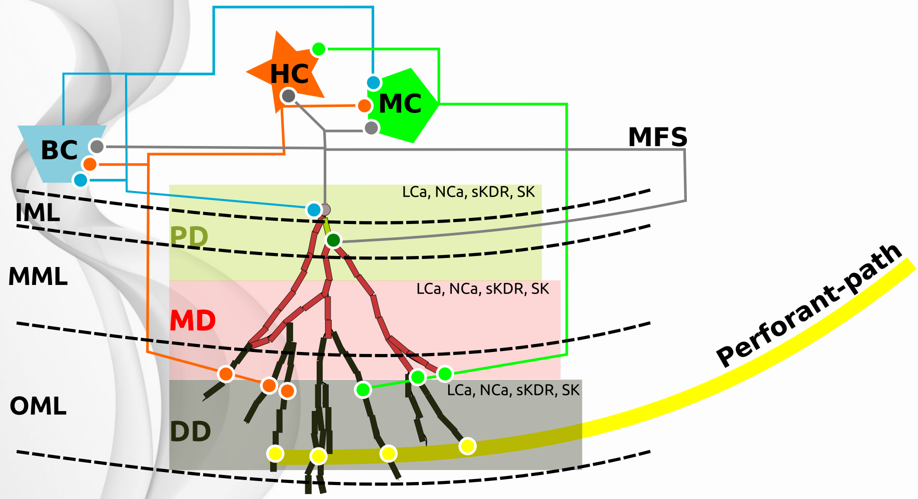
Selection of the morphological reconstructions



Schematic representation of the model



Representation of the connections between neurons

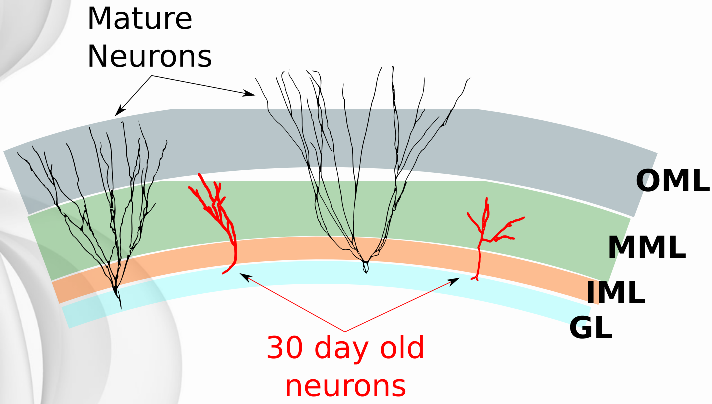


Alterations evaluated on the model

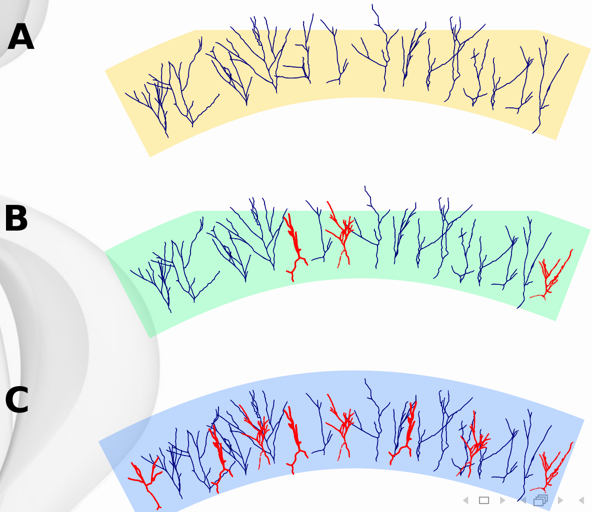
- On dendritic morphology
- On axonic morphology
- On dendritic spines
- Product of Neurogenesis

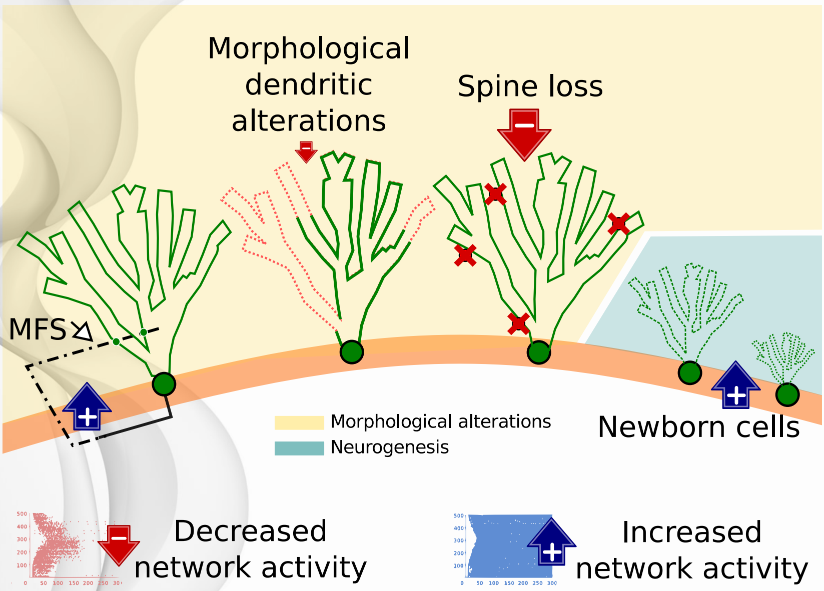
How to simulate neurogenesis

Simulation of neurogenesis



Different proportion of new neurons




Morphological dendritic alterations
Spine loss
MFS
Morphological alterations
Neurogenesis
Newborn cells
Decreased network activity
Increased network activity

Link para o modelo

SenseLab ModelDB

Dentate gyrus network model (Tejada et al 2014)

Accession: 155568

" ... Here we adapted an existing computational model of the dentate gyrus (J Neurophysiol 93: 437-453, 2005) by replacing the reduced granule cell models with morphologically detailed models coming from (3D) reconstructions of mature cells. ... Different fractions of the mature granule cell models were replaced by morphologically reconstructed models of newborn dentate granule cells from animals with PILO-induced Status Epilepticus, which have apical dendritic alterations and spine loss, and control animals, which do not have these alterations. This complex arrangement of cells and processes allowed us to study the combined effect of mossy fiber sprouting, altered apical dendritic tree and dendritic spine loss in newborn granule cells on the excitability of the dentate gyrus model. Our simulations suggest that alterations in the apical dendritic tree and dendritic spine loss in newborn granule cells have opposing effects on the excitability of the dentate gyrus after Status Epilepticus. Apical dendritic alterations potentiate the increase of excitability provoked by mossy fiber sprouting while spine loss curtails this increase. "

References:

1. Tejada J, Garcia-Cairasco N, Roque AC (2014) Combined role of seizure-induced dendritic morphology alterations and spine loss in newborn granule cells with mossy fiber sprouting on the hyperexcitability of a computer model of the dentate gyrus. *PLoS Comput Biol* **10**:e1003601 [PubMed]

2. Tejada J, Arisi GM, Garcia-Cairasco N, Roque AC (2012) Morphological alterations in newly born dentate gyrus granule cells that emerge after status epilepticus contribute to make them less excitable. *PLoS One* **7**:e40726-78 [PubMed]

https://senselab.med.yale.edu/modeldb/ShowModel.asp?model=155568

Next logical step

ENLARGE THE MODEL

Next logical step

ENLARGE THE MODEL

From

Animal tissue

Or from

Algorithms

Next logical step - ENLARGE THE MODEL

TREES toolbox

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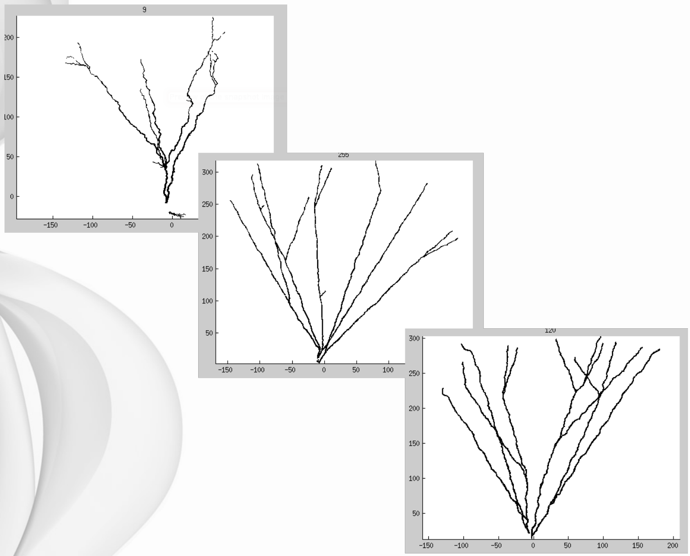
More than a century ago, Ramón y Cajal provided a qualitative description of neuronal branching in all its forms and variants. However, even today, few rigorous and useful formalisms are available for quantitative description of dendritic and axonal morphology.

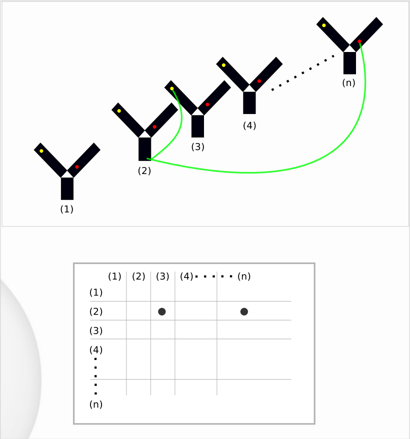
The TREES toolbox provides:

1. Tools to automatically reconstruct neuronal branching from microscopy image stacks and to generate synthetic axonal and dendritic trees.
2. The basic tools to edit, visualize and analyze dendritic and axonal trees.
3. Methods for quantitatively comparing branching structures between neurons.
4. Tools for exploring how dendritic and axonal branching depends on local optimization of total wiring and conduction distance.

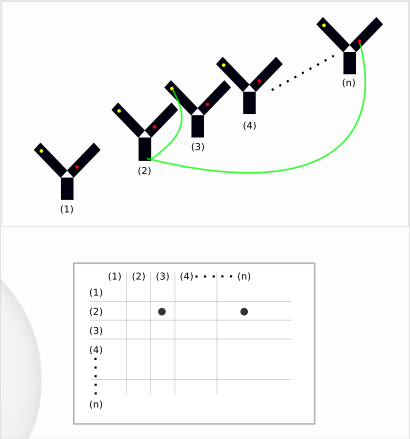
Artificial models



Matrix of Connections



Matrix of Connections - Graph Theory



Collaborators

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- Prof. Norberto Garcia-Cairasco

DCOMP - UFS

- Prof. Carlos Estombelo
- Ivton Lira
- Fellipe Manzano

FAPESP

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico