

# Network Level Modeling in Neurosciences

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# Large Neural Networks

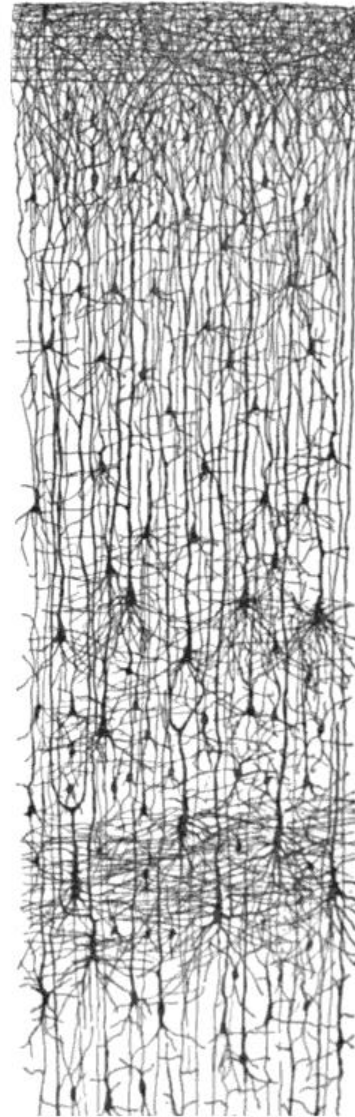
Visual Cortex



Motor cortex



Cortex in an Infant

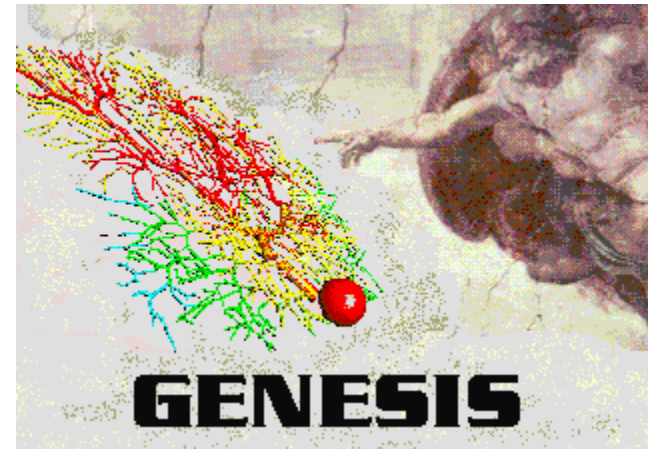
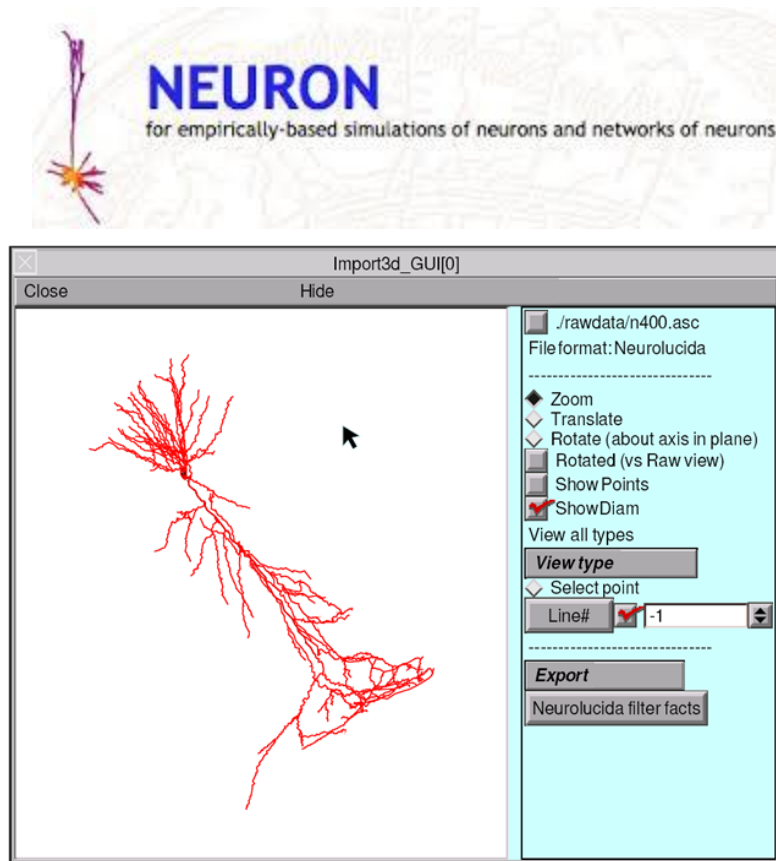


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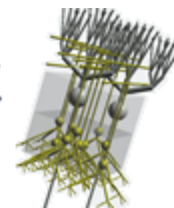
# **Practical Issues in Modeling Networks**

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# Simulators



*neuroConstruct*  
Biophysical Neural Network Modelling Software

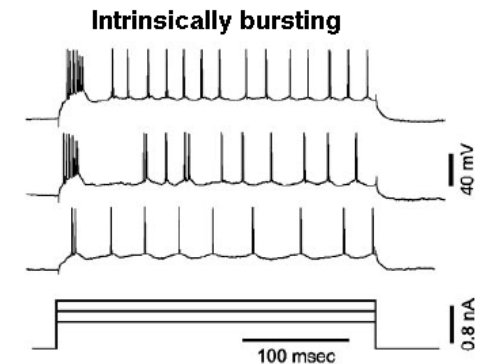
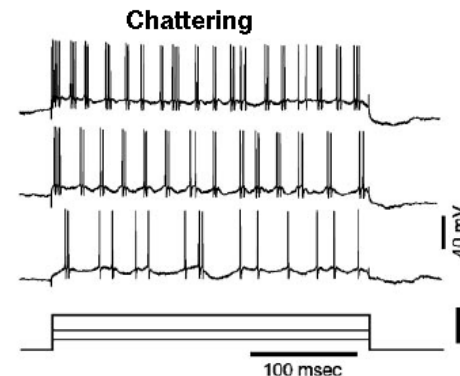
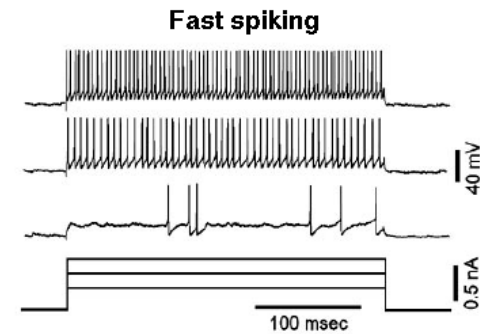
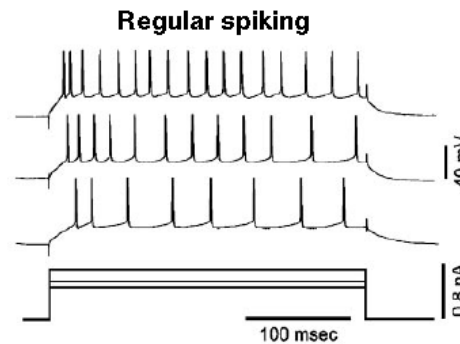
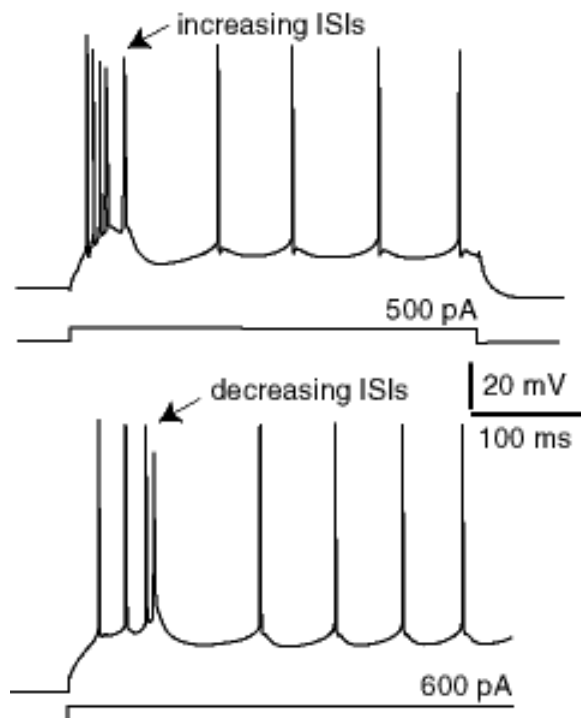


# Choosing Parameters

- Information from Anatomical Studies
  - Neuronal subtypes
  - Numbers
  - Connections
  - Conduction Velocity
  - Morphology, etc.
- Everything not available in Literature !!
- For some brain parts – Hippocampus, Basal Ganglia
  - Fairly good amount of Data

# Evaluation of Models

- Data from Behavioural Studies
- Dynamics of Information Processing
  - Interspike interval (ISI), Type of Spiking - Regular, Fast, Burst; Firing Rate, etc.



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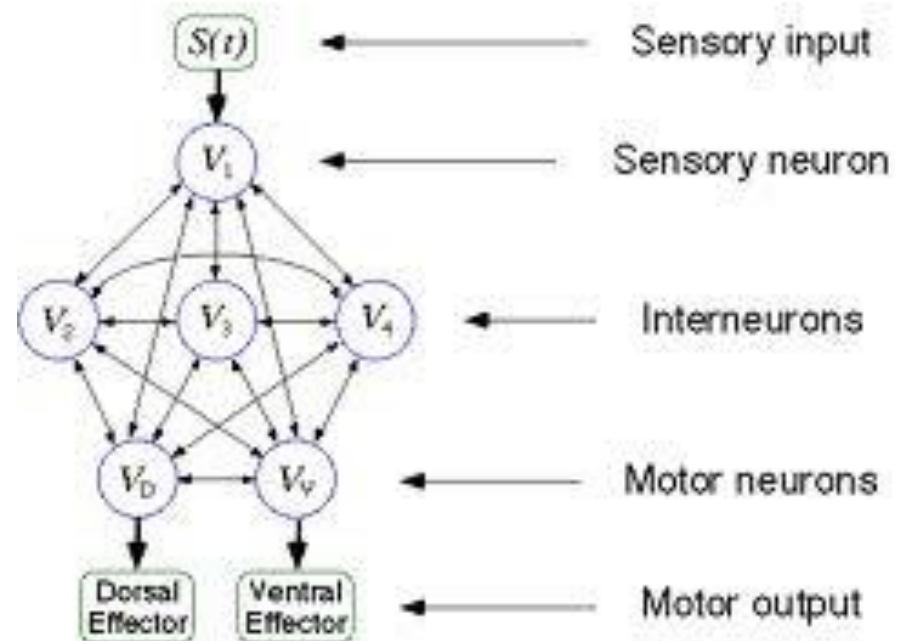
# **Properties of Networks**

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# Patterns of Connectivity

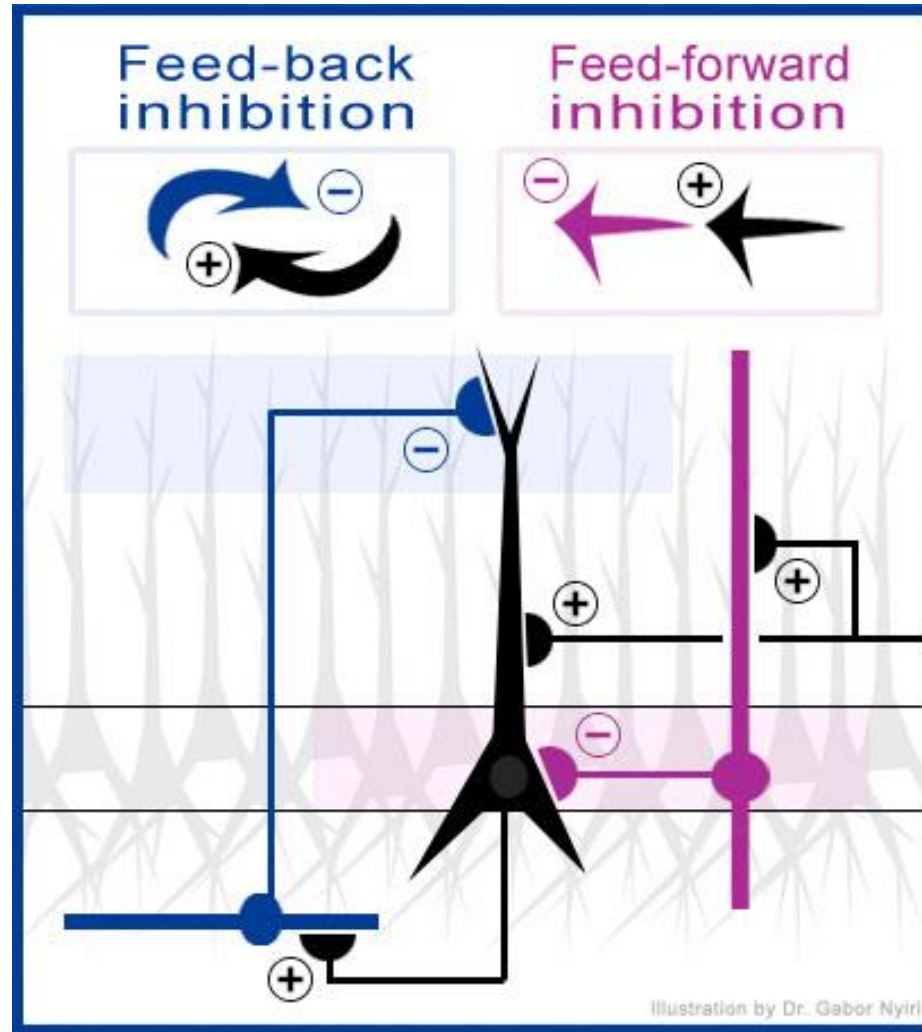
- Principal Cells
- Afferent inputs to Principal Cells
- Interneurons

Idealized chemotaxis network



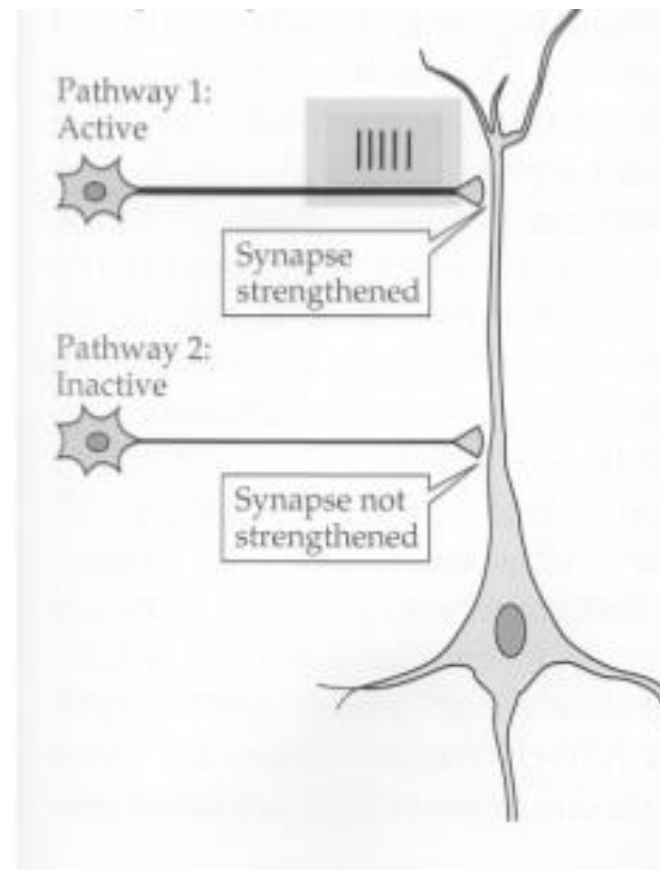
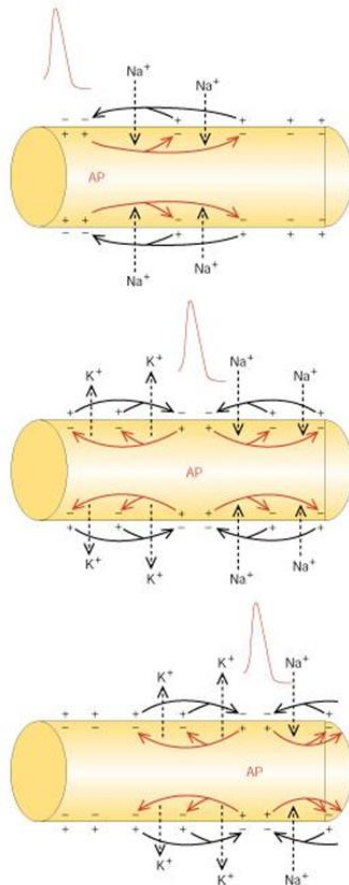


# Feedback and Feedforward Inhibition



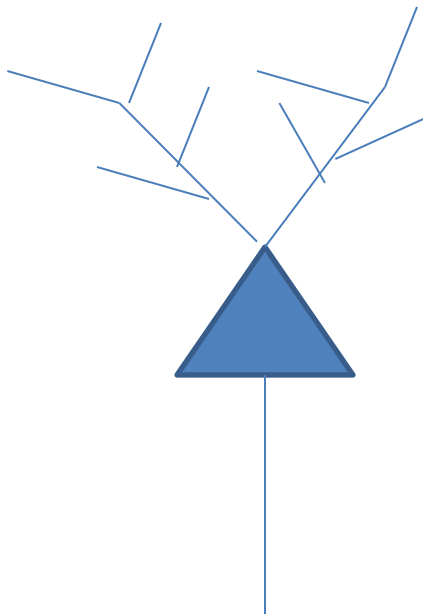
# Axonal and Synaptic Properties

- Axonal delay and Synaptic Transmission
- Synaptic Plasticity – e.g. Hebb's Rule

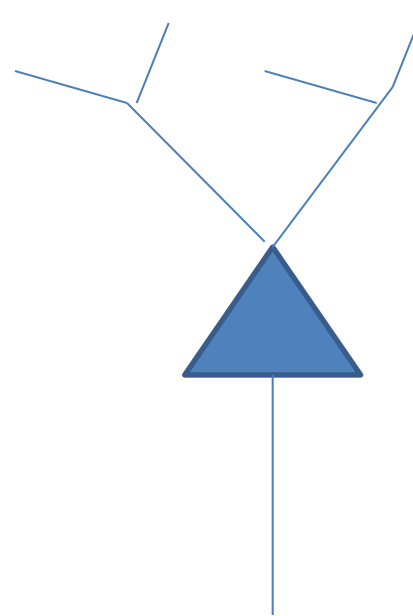


# Scaling of networks

To account for the decreased Synaptic Inputs to neurons in the network, we can  
Scale the Connection Strength



In Biological Network  
Weight of each synapse =  $w_1$



In Computational Model  
Weight of each synapse =  $w_2$

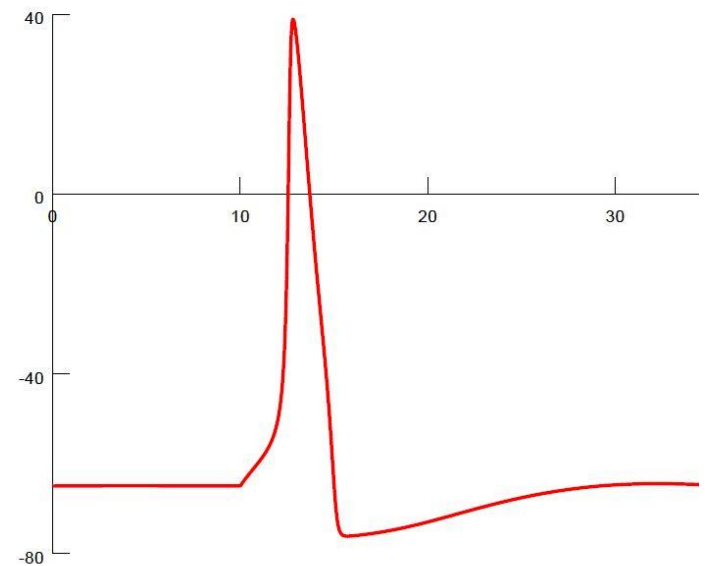
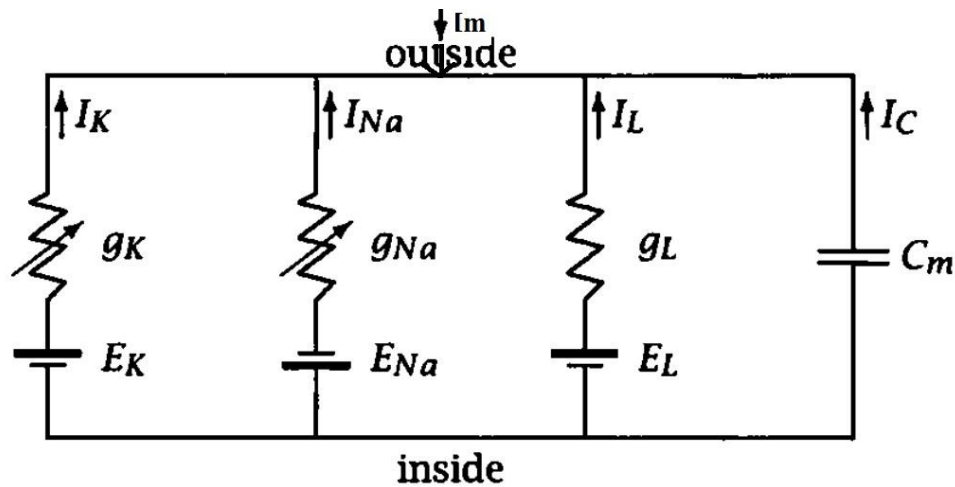
$$w_2 > w_1$$

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# **Simplified Models of Biological Neurons**

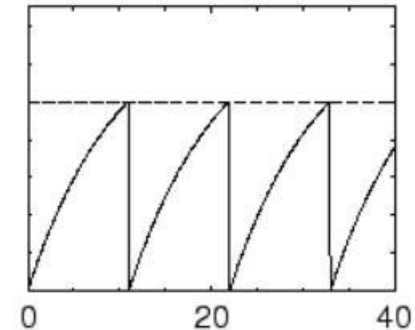
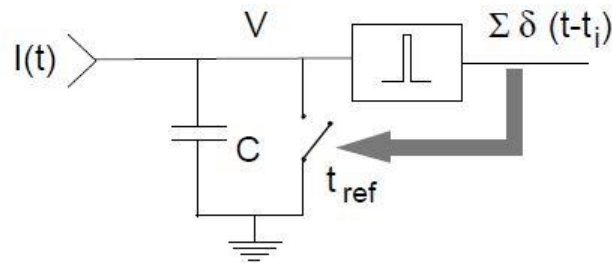
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# Hodgkin Huxley Neuron

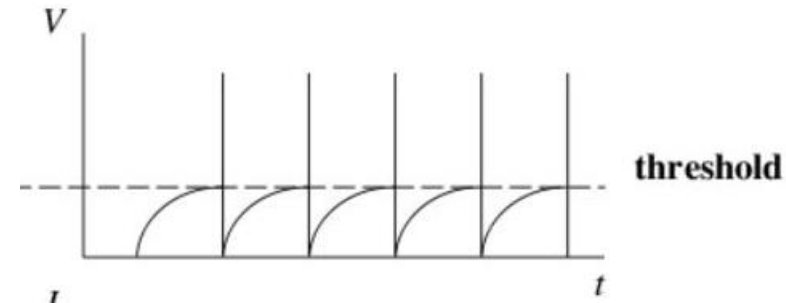
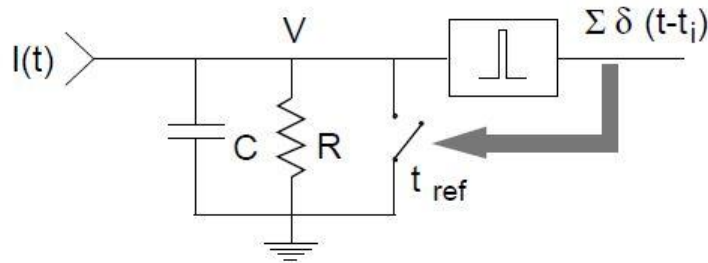


# Integrate and Fire Neurons

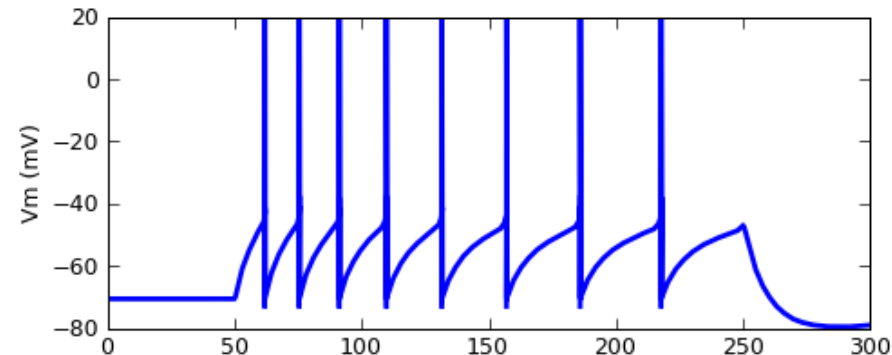
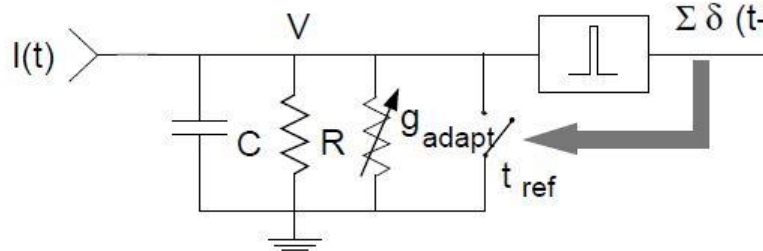
Perfect Integrate-and-Fire Unit



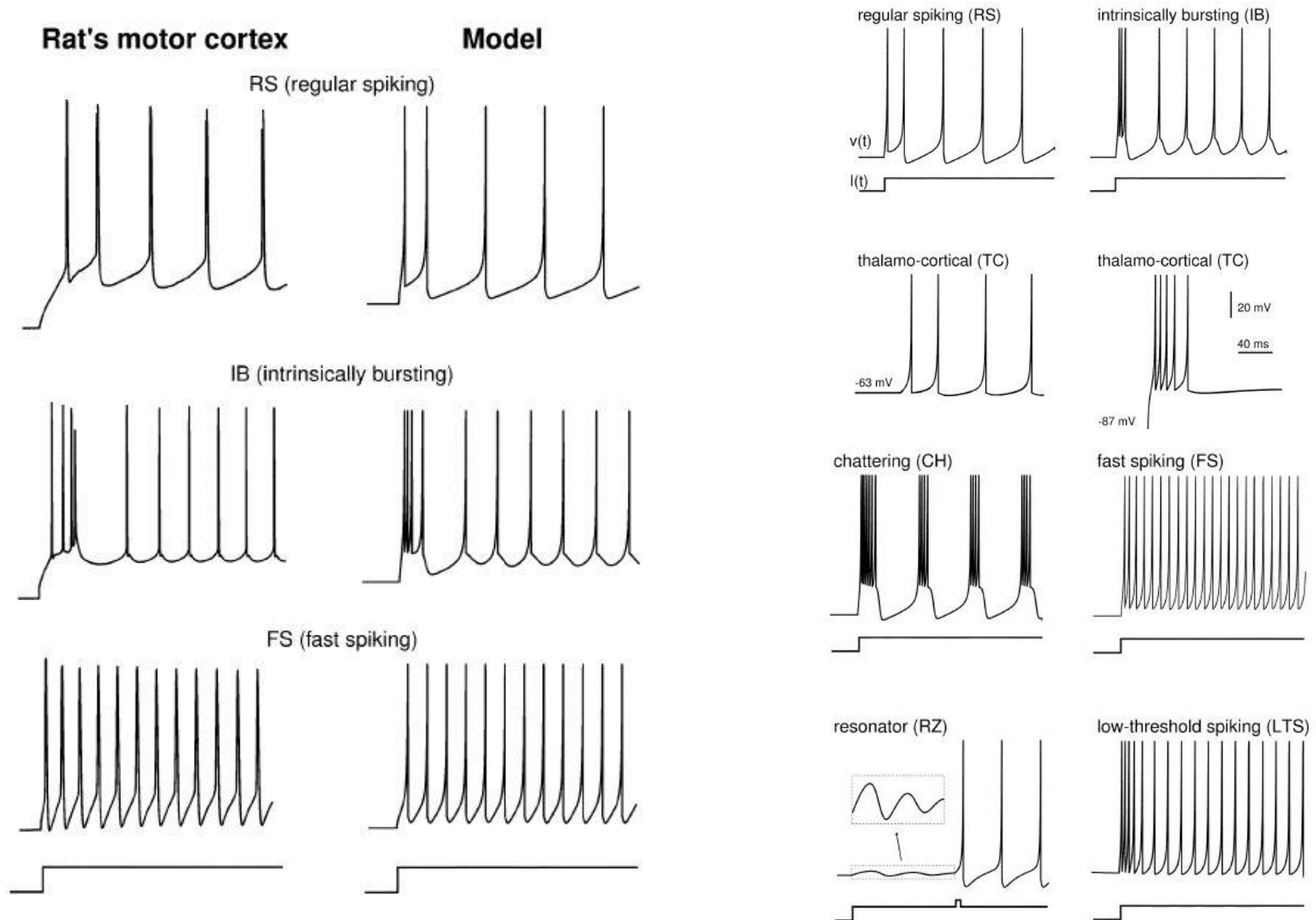
Leaky Integrate-and-Fire Unit



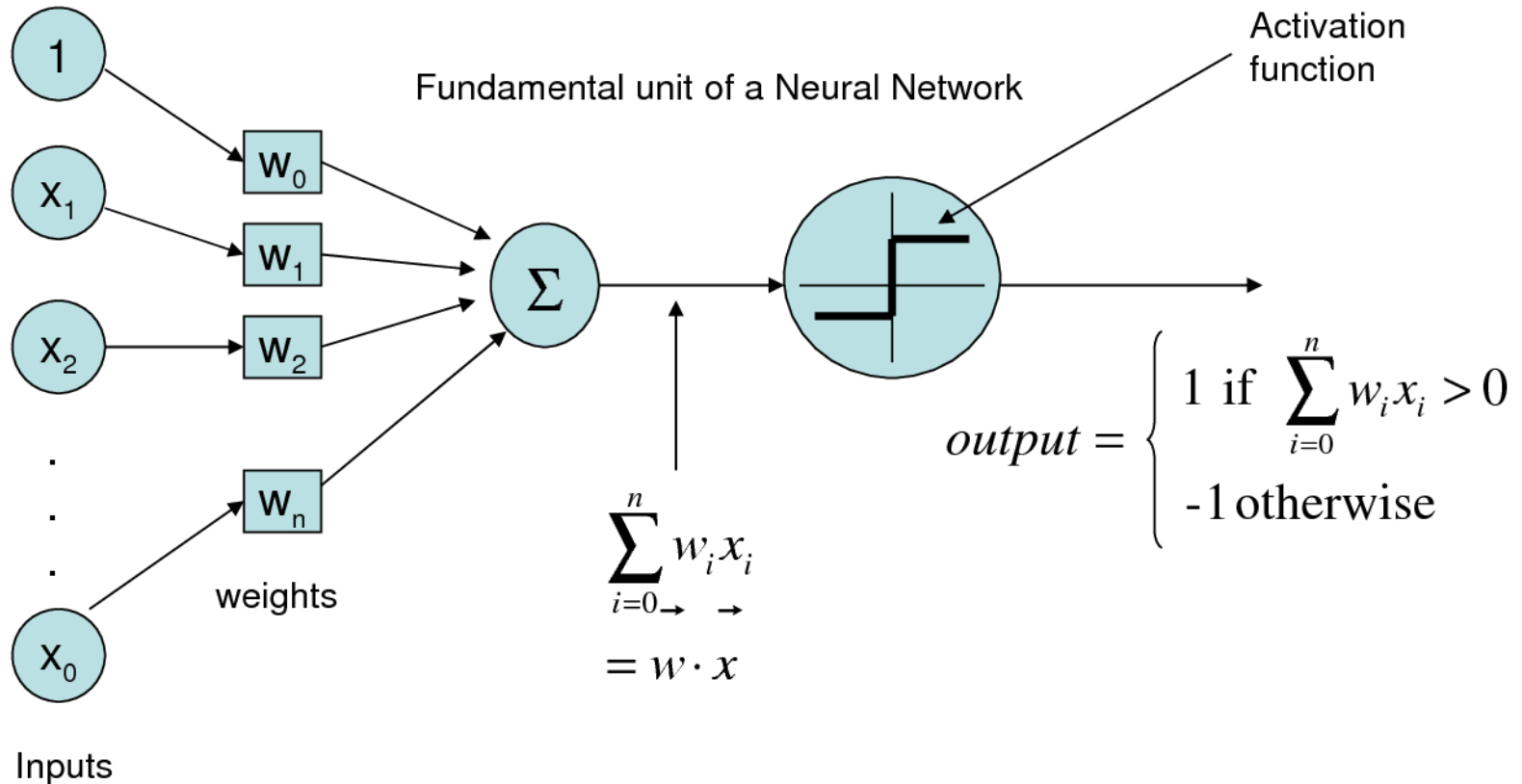
Adapting Integrate-and-Fire Unit



# Izhikevich Neuron



# Perceptron (Artificial Neuron)



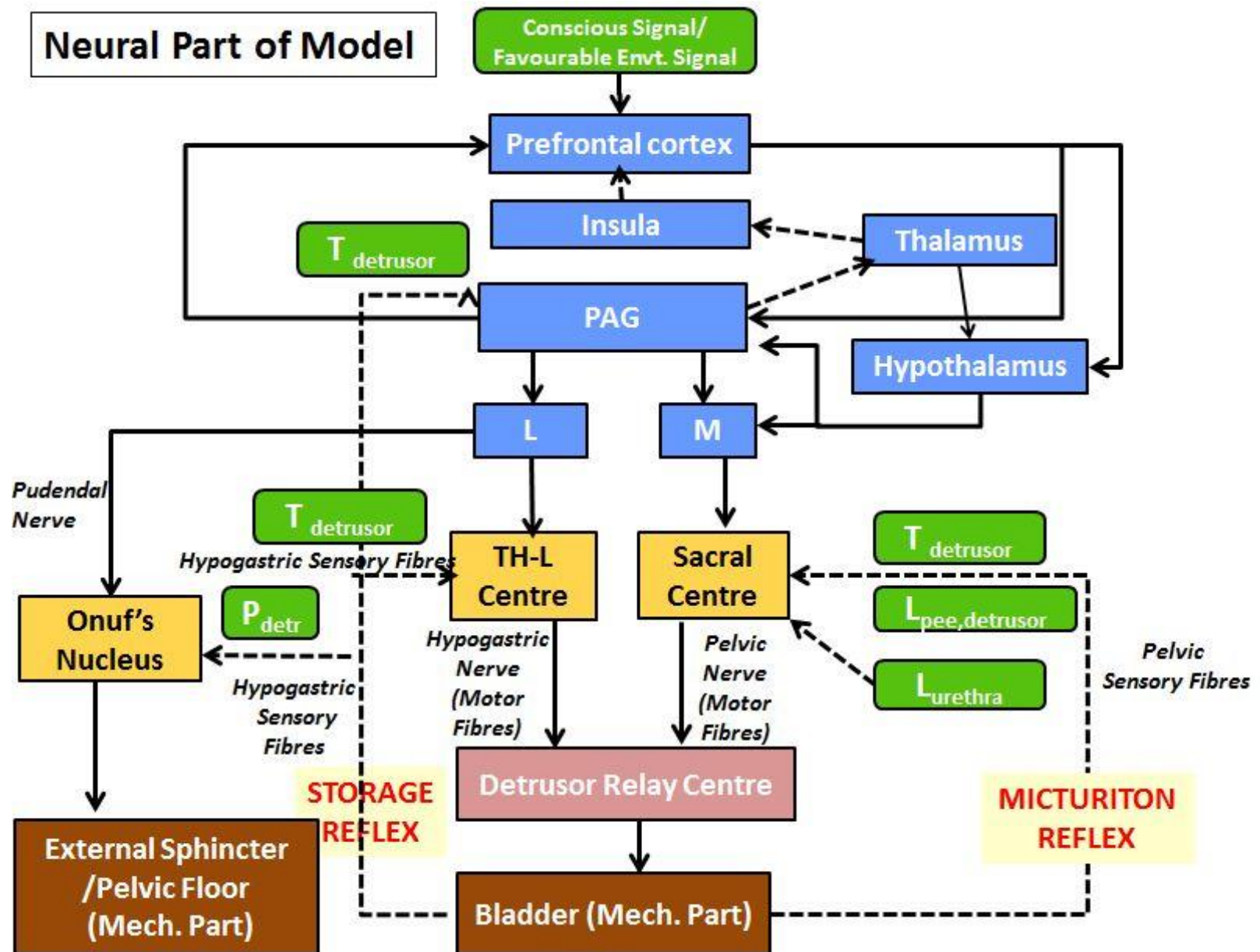


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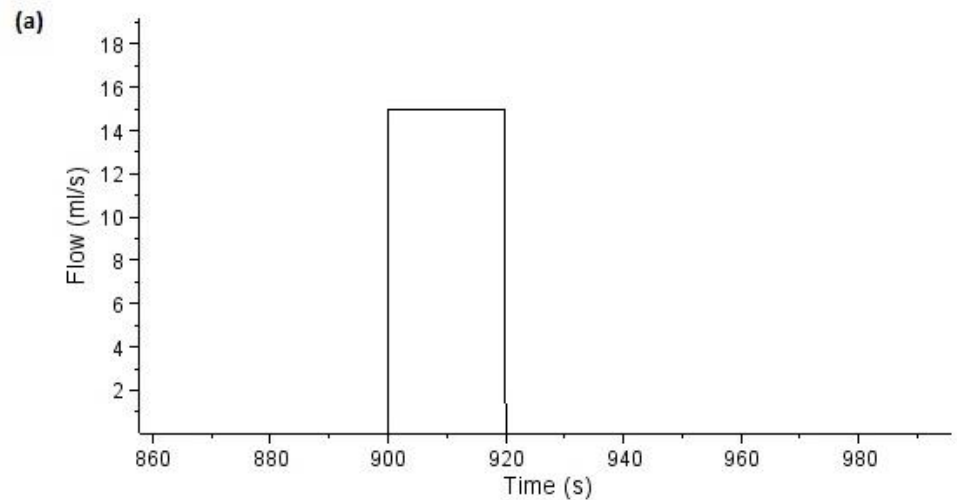
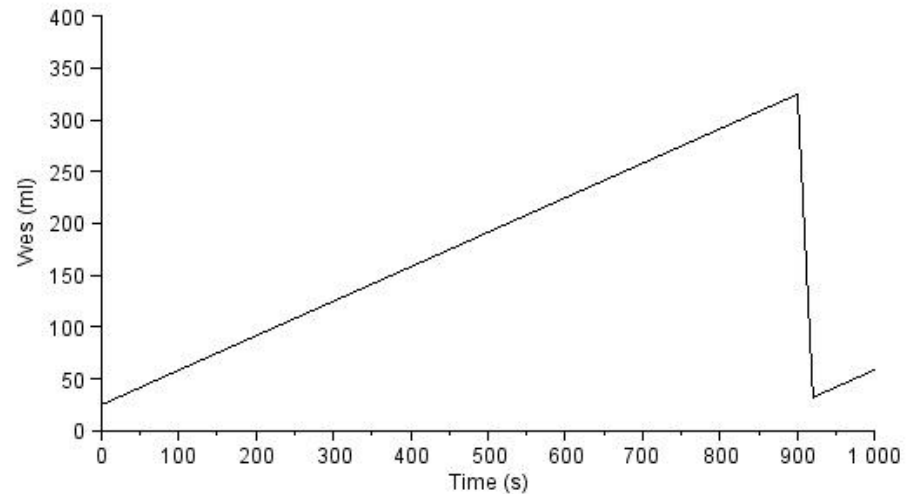
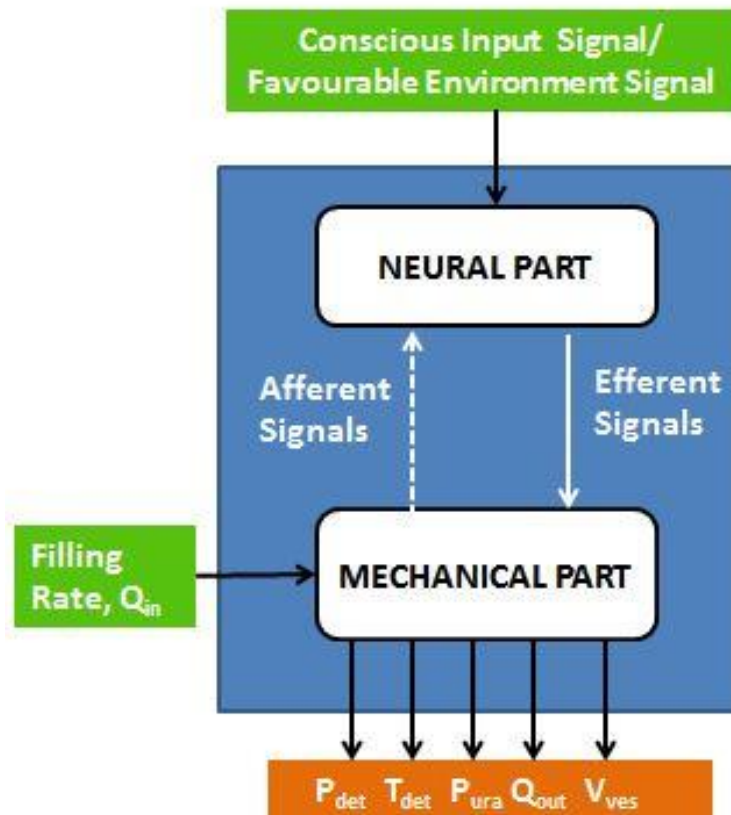
# **A Neural Network Model**

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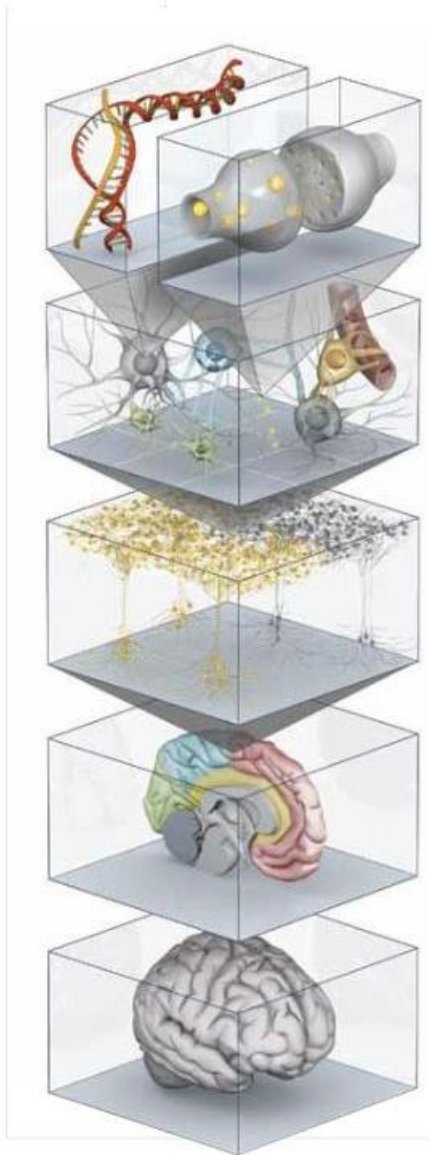
# Model: Neural Network Controlling the Bladder



# Model: Neural Network Controlling the Bladder



# Human Brain Project



## Build and simulate unifying human brain models

1. Accelerate understanding of the human brain
2. Increase the value of all past and future experiments
3. Gather and organize all fragments of data and knowledge on the brain
4. Provide publicly accessible brain atlases
5. Fill knowledge gaps using novel ICT tools
6. Generate strategically selected missing data that will not be generated otherwise
7. Prioritize, optimize and accelerate biological experiments
8. Establish massive collaborative science on the brain

# Human Brain Project

**Video Link:**

<http://www.youtube.com/watch?v=UFOSHZ22q4>

# OpenWorm

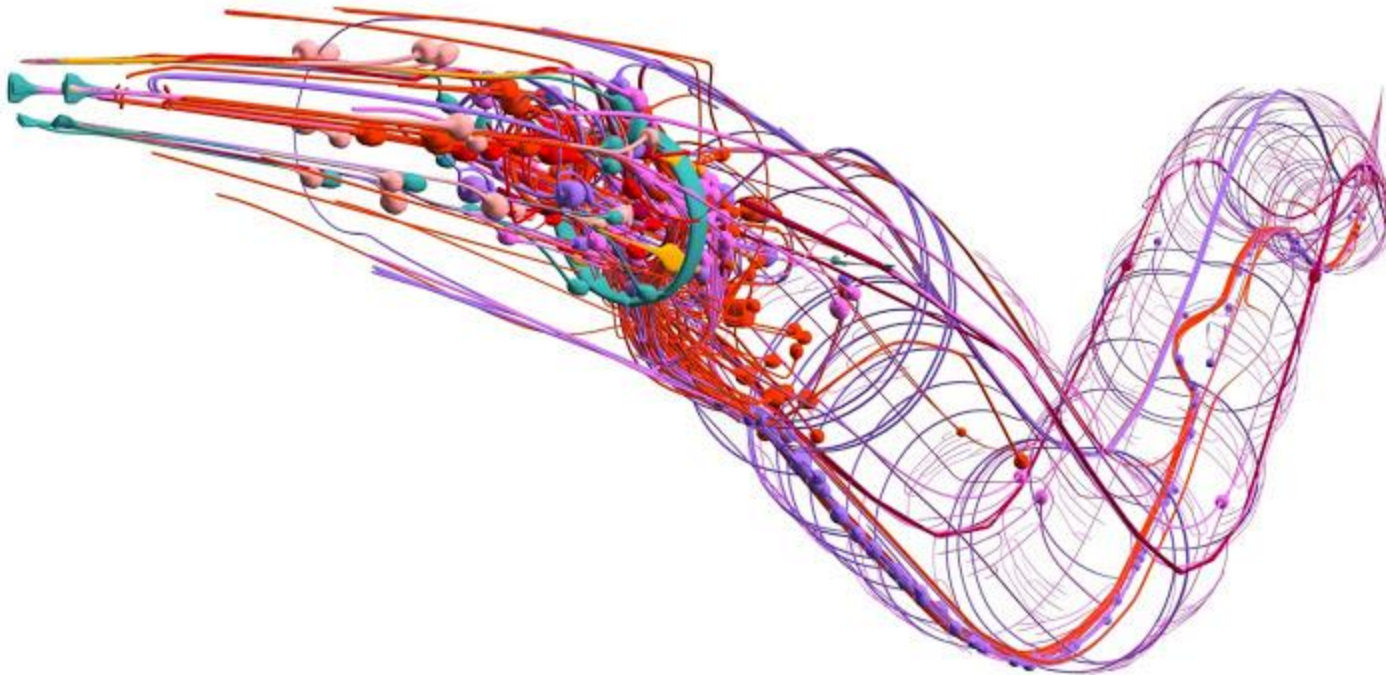


Image from [Openworm.org](https://openworm.org)



# References

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- Eugene M. Izhikevich, *Simple Model of Spiking Neurons*, IEEE Transactions On Neural Networks, Vol. 14, No. 6, November 2003 1569

## Books

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- Foundations of Cellular Neurophysiology, Johnston and Wu, 1994.
- Biophysics of Computation – Information Processing in Single Neurons, Christof Koch, 1999

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- <http://www.youtube.com/user/TheHumanBrainProject>
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