

Exceptional service in the national interest



Cognitive Science & Technology

Neurons to Algorithms (N2A)

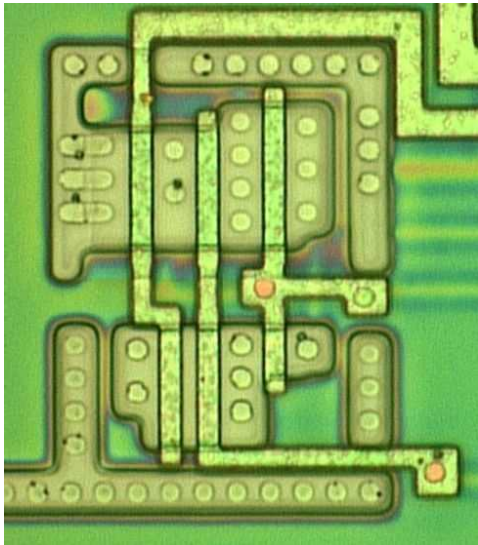
Fred Rothganger, Derek Trumbo, Christy Warrender, Brad Aimone, Corinne Teeter



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

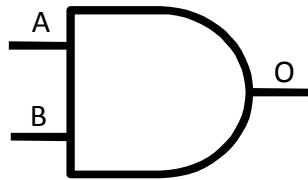
Original Motivation

Describe the *function* of each brain circuit.

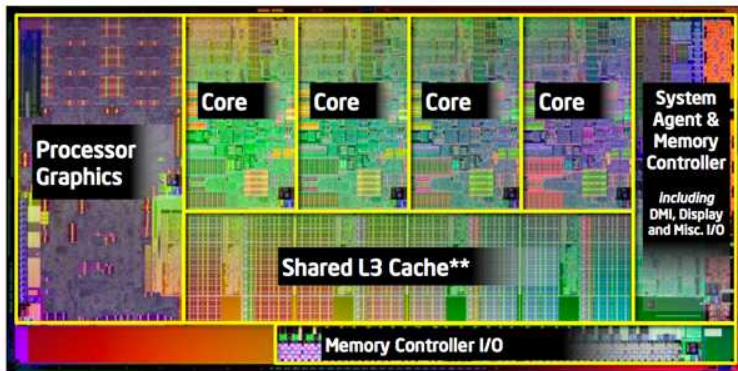


AND gate [Kömmerling & Kuhn 99]

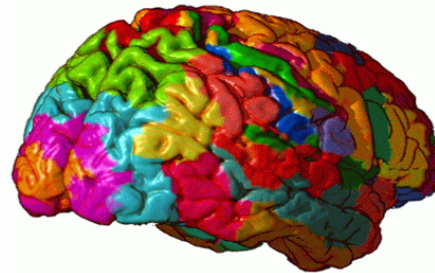
Abstract away physical details to explain what something does or how it interacts with other things.



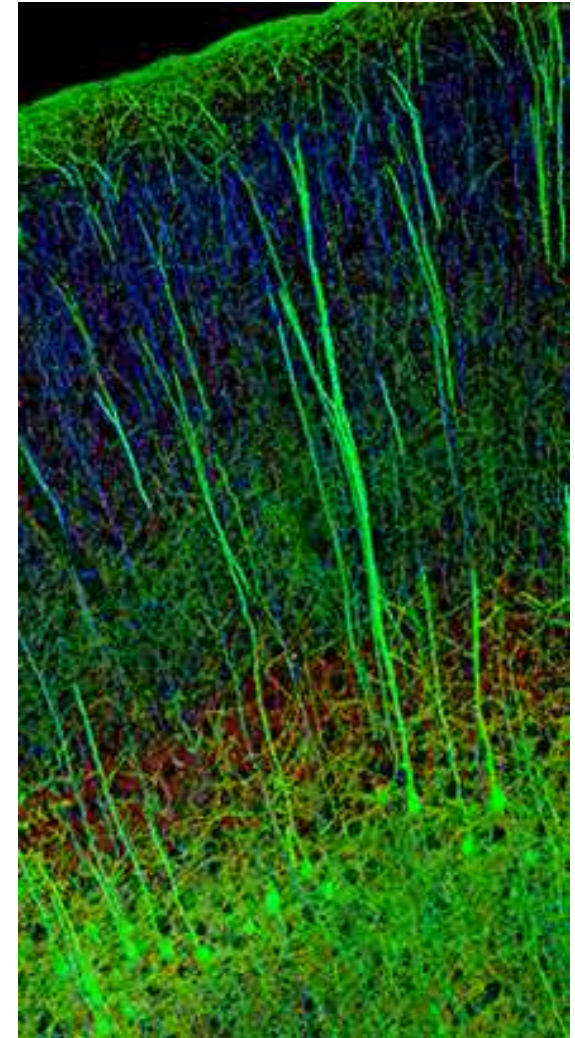
A	B	O
F	F	F
F	T	F
T	F	F
T	T	T



Sandy Bridge die [Intel Corp.]



Brodmann Areas



Neocortical (brain) slice
[Stephen Smith Lab at Stanford]

The Challenge



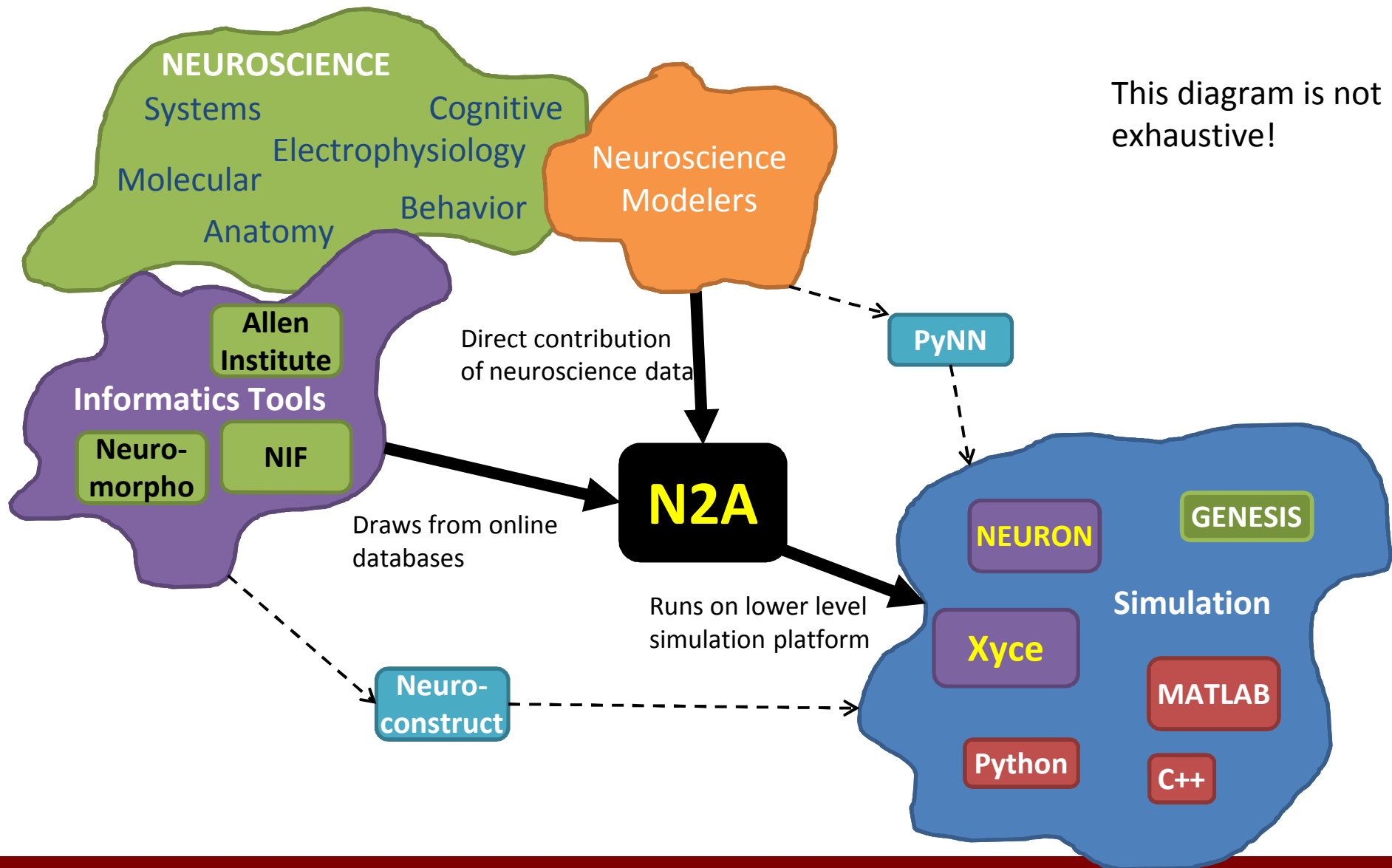
Society for Neuroscience
>30,000 scientists attend
>1,000 topic areas presented

Need to integrate all this knowledge. Beyond capacity of anyone to comprehend.

Complete model of human cognition *cannot* exist as an idea in one person's mind.

Must be an information structure held in a large computer system.

Where N2A Fits

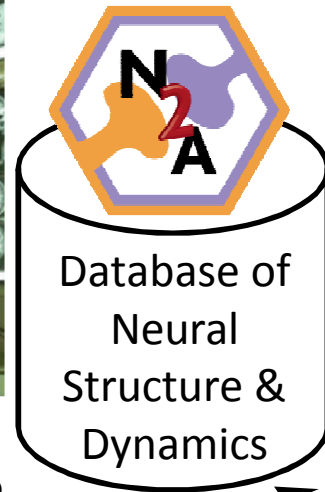


Workflow



- Contributed models
- Neurophysiology literature
- Online databases

- Visualization
- Automatic analysis



Simulate

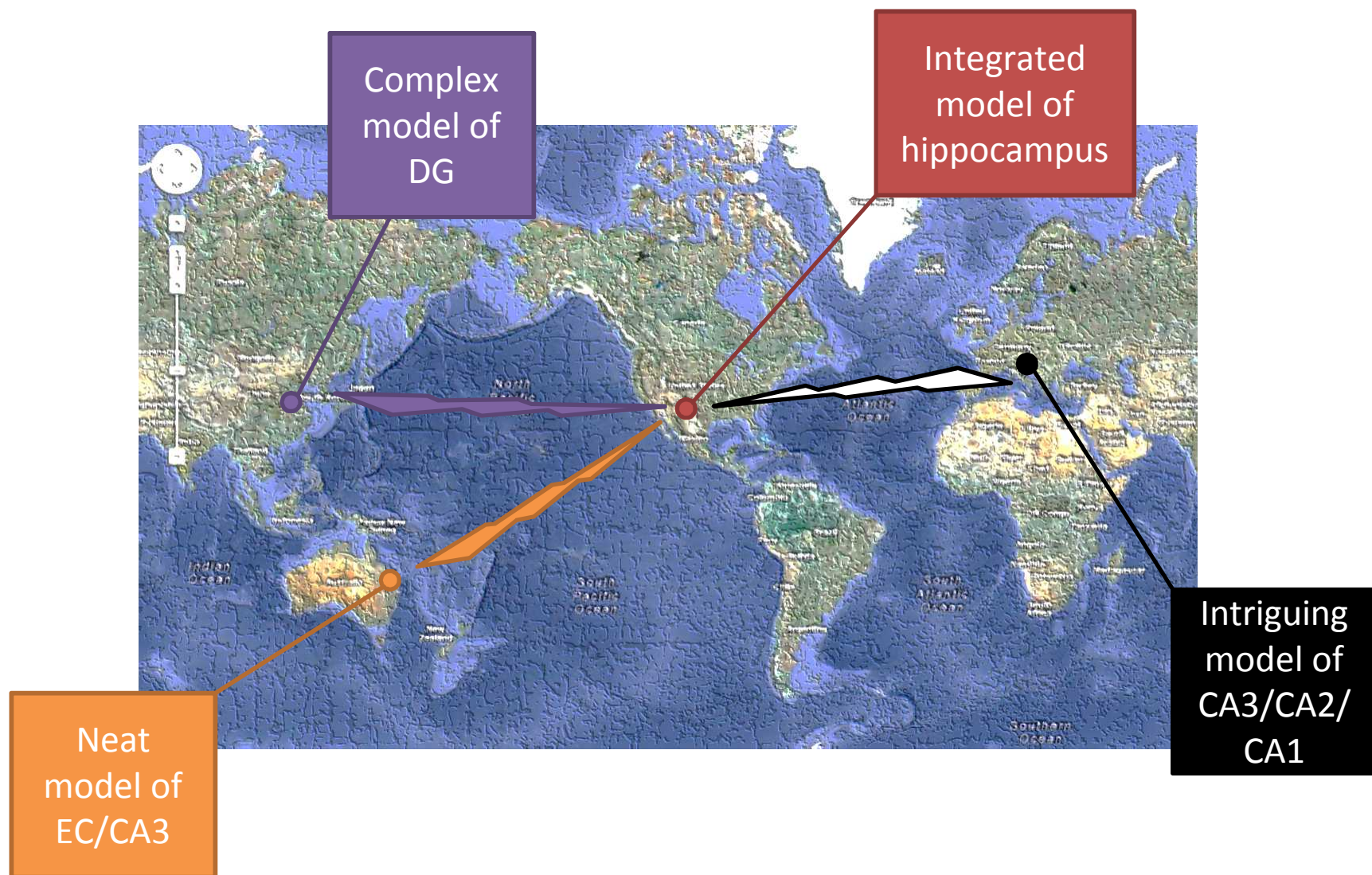


Fit
parameters

Characterize
model behavior

Algorithmic
motifs

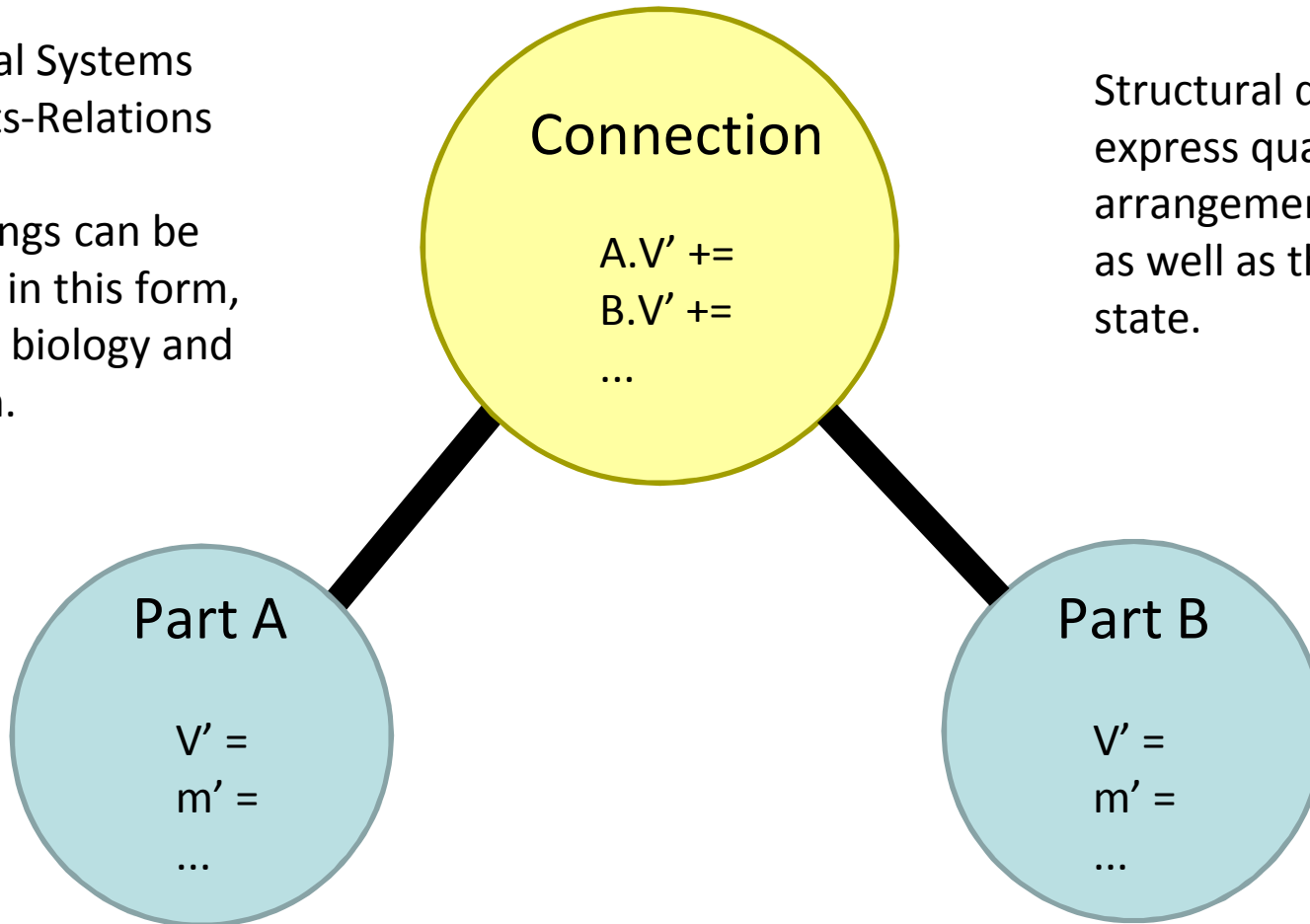
Use Case: Model Integration



Model Structure

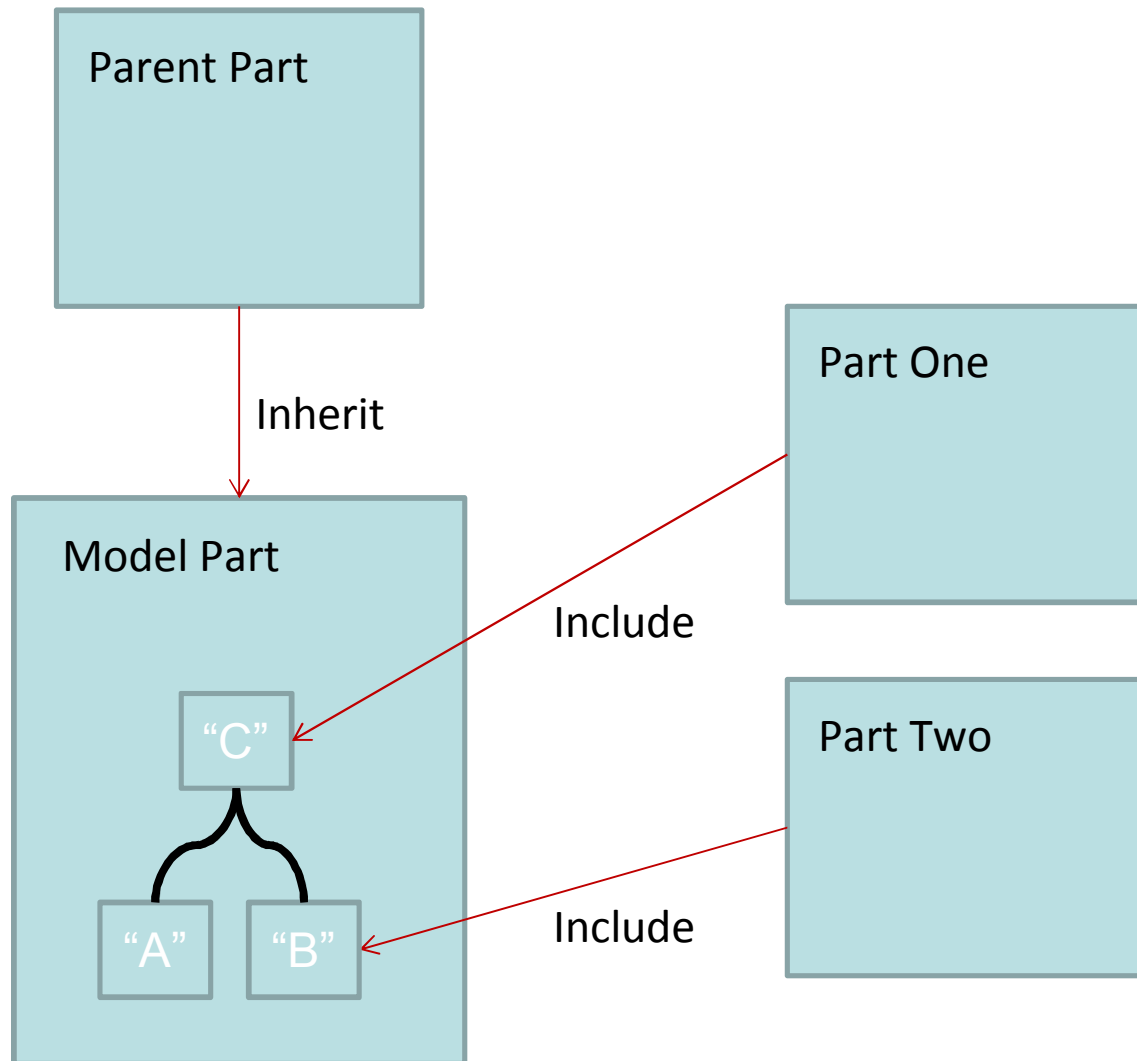
Dynamical Systems
AND Parts-Relations

Many things can be
modeled in this form,
including biology and
cognition.

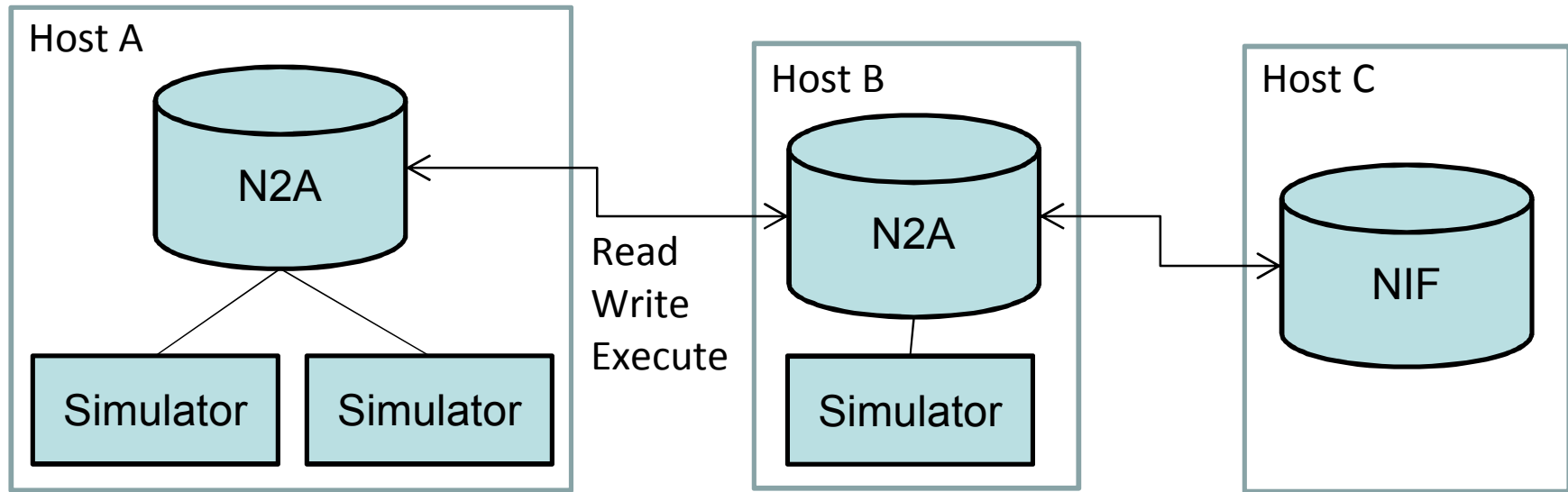


Structural dynamics:
express quantity and
arrangement of Parts,
as well as their internal
state.

Composition



Sharing (future work)



A remote system may be another desktop, a cluster-computer, or a “cloud” service.

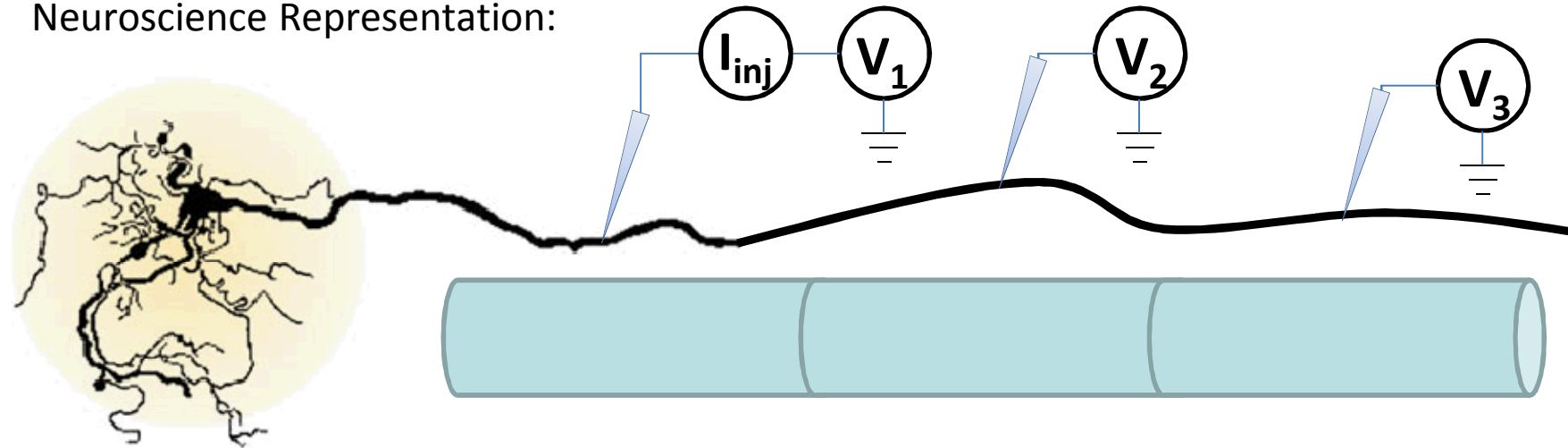
You may upload your models to another N2A system,
download models from it,
or ask it to simulate a model on your behalf.

Simulator may be any tool (Xyce, Neuron, PyNN, Brian, ...) for which there is a backend wrapper.

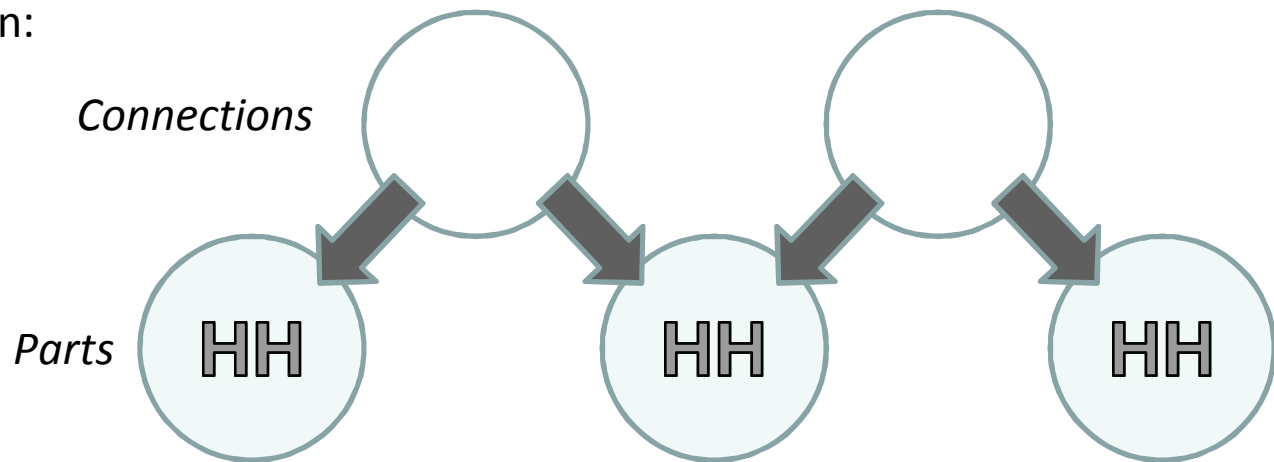
Demo

Simulate spike propagation through Hodgkin-Huxley cable

Neuroscience Representation:

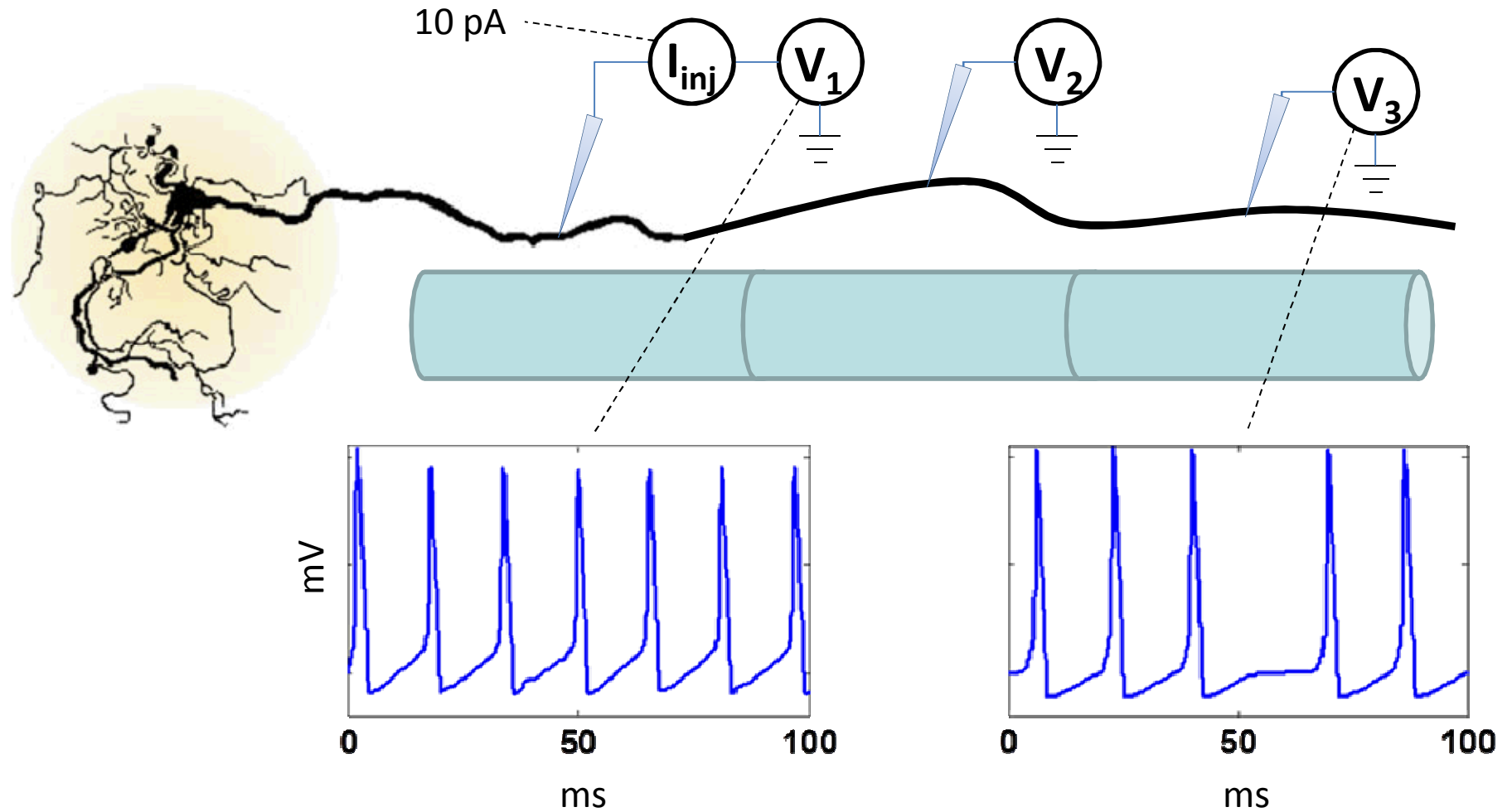


N2A Representation:



Demo

Typical behavior



Demo

Neurons To Algorithms v0.8.4

File View Tools People Look & Feel Window Help

Home Search HHmod

Edit Compartment

Save Cancel

General Parent Equations Includes Notes/Tags Uses Discussion Permissions References Change History Summary

Summary: ? ☒ Tree ☐ Flat ☐ Text ☐ Graph ☐ Problems

All Equations For "HHmod"

- Inherited Equations
 - Parent: passive
 - $V' = (G_m * (V_{rest} - V) + I_{inj}) / C_m$
 - $G_m = 0.3$
 - $V_{rest} = 10.613$
 - $C_m = 1$
- Included Equations
 - Na_Koch (alias: Na_Koch)
 - $I = G_{Na} * m^3 * h * (E_{Na} - V)$
 - $m' = \alpha_m * (1 - m) - \beta_m * m$
 - $h' = \alpha_h * (1 - h) - \beta_h * h$
 - $\alpha_m = (25 - V) / (10 * (\exp((25 - V) / 10) - 1))$
 - $\beta_m = 4 * \exp(-V / 18)$
 - $\alpha_h = 0.07 * \exp(-V / 20)$
 - $\beta_h = 1 / (\exp((30 - V) / 10) + 1)$
 - $G_{Na} = 120$
 - $E_{Na} = 115$
 - K_Koch (alias: K_Koch)
 - $I = G_K * n^4 * (E_K - V)$
 - $n' = \alpha_n * (1 - n) - \beta_n * n$
 - $\alpha_n = (10 - V) / (100 * (\exp((10 - V) / 10) - 1))$
 - $\beta_n = 0.125 * \exp(-V / 80)$
 - $G_K = 36$
 - $E_K = -12$

Connected to: jdbc:postgresql://mechta/n2a

Capabilities

Now

Model Description Language
Composition (Include, Inherit)
Xyce Backend
Run Management (local and parallel)
References & Metadata
UQ/SA
Deployability (embedded DB)

This Year

Compose Models like Parts
Visual Model Editing

Future

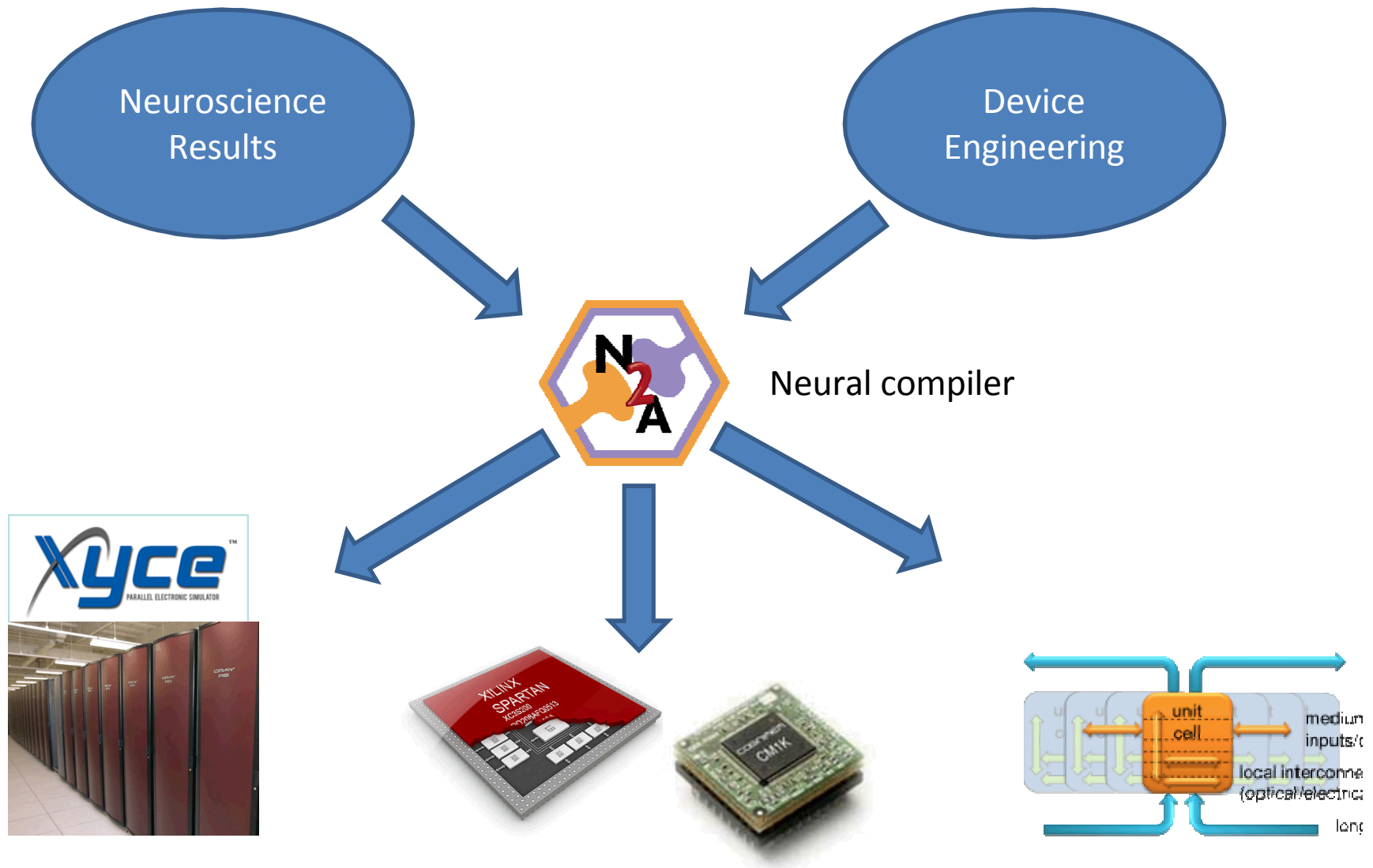
Structural Dynamics
Sharing (NIF, NeuroML, P2P)
External I/O
Documentation

Long-term

Automatic Algorithm Extraction
Asynchronous Execution on Exascale and
Neuromorphic Computers

Seeking funding for future work via NIH proposal and GC LDRD.

Neuro-inspired Computing Engines (NiCE)



Long-term Vision

Computational model of the human mind, complete and accurate.

Why?

- Implement general AI
- Understand human behavior in a quantitative and predictive way
 - Cope with the flaws in ourselves and others
- Heal mental illness

What is required to achieve this?

- The participation of everyone
 - Common framework to represent the computation
 - N2A is probably *not* the ultimate framework, but it is a beginning
 - Social structures that reward sharing
- A **lot** more of our current way of studying the brain
- Or a breakthrough that lets us extract what we need automatically