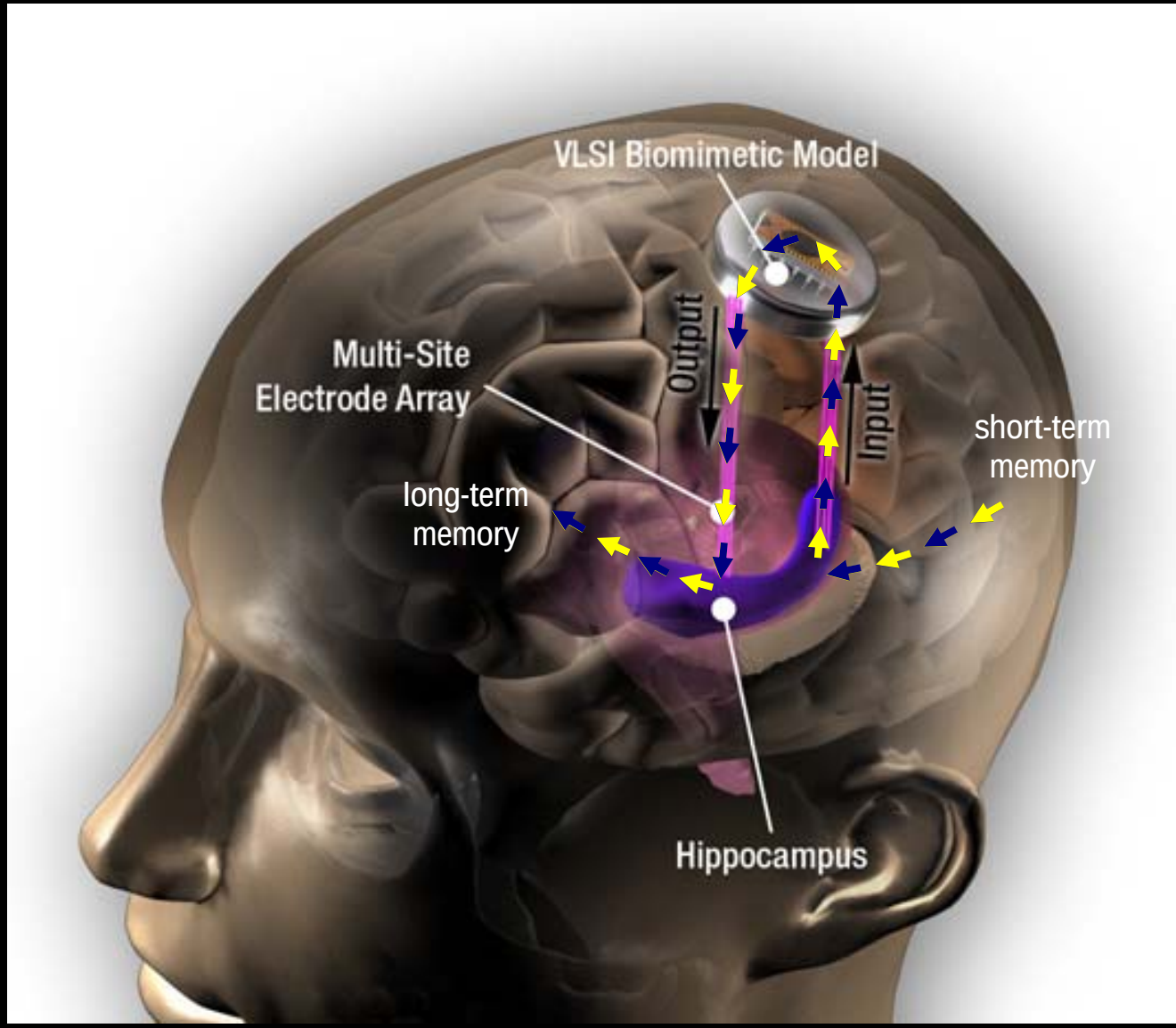
Biomimetic Microelectronics as Brain-Implantable Computing Devices: Real-Time Bi-Directional Communication between Brain and Computing Systems

Multi-Disciplinary Components:

1. Biomimetic modeling of neurons and neural systems (neuroscience, mathematics, biomedical engineering)
2. Hardware implementation (VLSI) of neural models for parallelism, rapid computational speed, and miniaturization (computer science, computer engineering, electrical engineering)
3. Multi-site electrode recording/stimulation arrays to interface devices with the brain (material science, physics, chemistry)

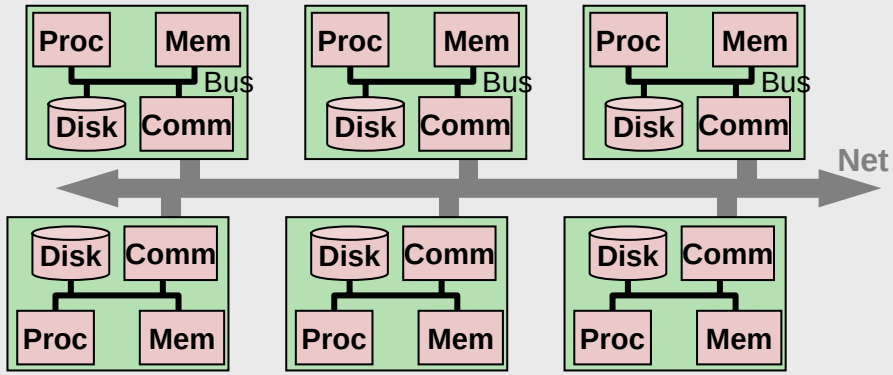


Next-Generation Biologically Based Computing Platforms

Human Brain

- **Complexity**
  - Billions of processors
  - Multiple terabytes (***very*** large) memory
  - Many specialized operations
  - Slow processors, slow wires (10^2 Hz)
- **Network**
  - 10^5 fanout
  - Unknown information coding
- **Management**
  - Distributed: hierarchical organization
  - Diffuse: consciousness?
- **Fault Tolerance:** high; self-healing
- **Power:** 10 - 20 Watts
- **Adaptation & Learning:** high

Blade/Cluster Computer



- **Complexity**
  - Hundreds/thousands of processors
  - Terabytes of memory
  - Limited operations/functions
  - Very fast processors & wires (10^9 Hz)
- **Network**
  - 1-10 fanout
  - Consistent message formats
- **Management**
  - Distributed: policy enforcement
  - Centralized: privileged control functions
- **Fault Tolerance:** low
- **Power:** 10^2 - 10^4 Watts
- **Adaptation & Learning:** very low

Disciplines: neuroscience, computer science, mathematics, computer engineering, electrical engineering, materials science (nano)

Multi-Level, Multi-Systems Modeling and Simulation

Problem: Representing the Hierarchical Functional Organization of the Brain

- the brain is a hierarchically organized set of nonlinear dynamical systems
- multiple space- and time-scales
- nonlinearities, nonstationarities, state-dependencies
- need for novel mathematical modeling methodologies and simulation platforms (integrated with problem areas)
- potential applications: study of complex systems, uncovering novel representational structures, drug design, systems pathophysiology

Disciplines: neuroscience, biomedical engineering, mathematics, computer science, computer engineering