SpiNNaker:
large-scale real-time neural simulation

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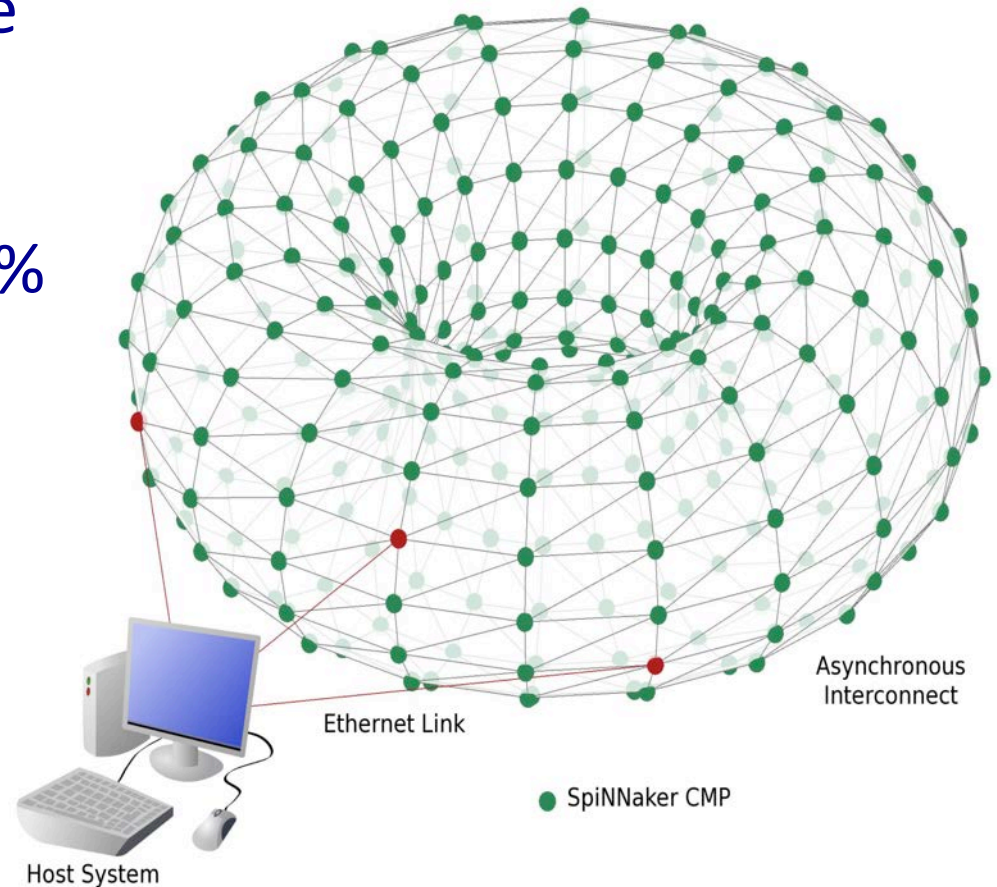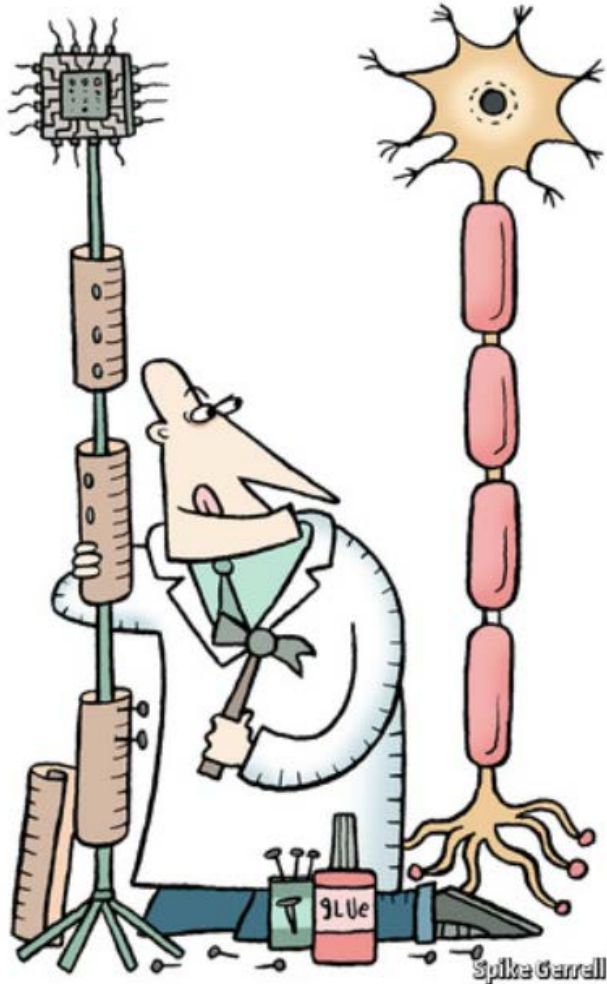
The University of Manchester

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SpiNNaker project

- A million mobile phone processors in one computer
- Able to model about 1% of the human brain…
- …or 10 mice!

Ethernet Link

Asynchronous Interconnect

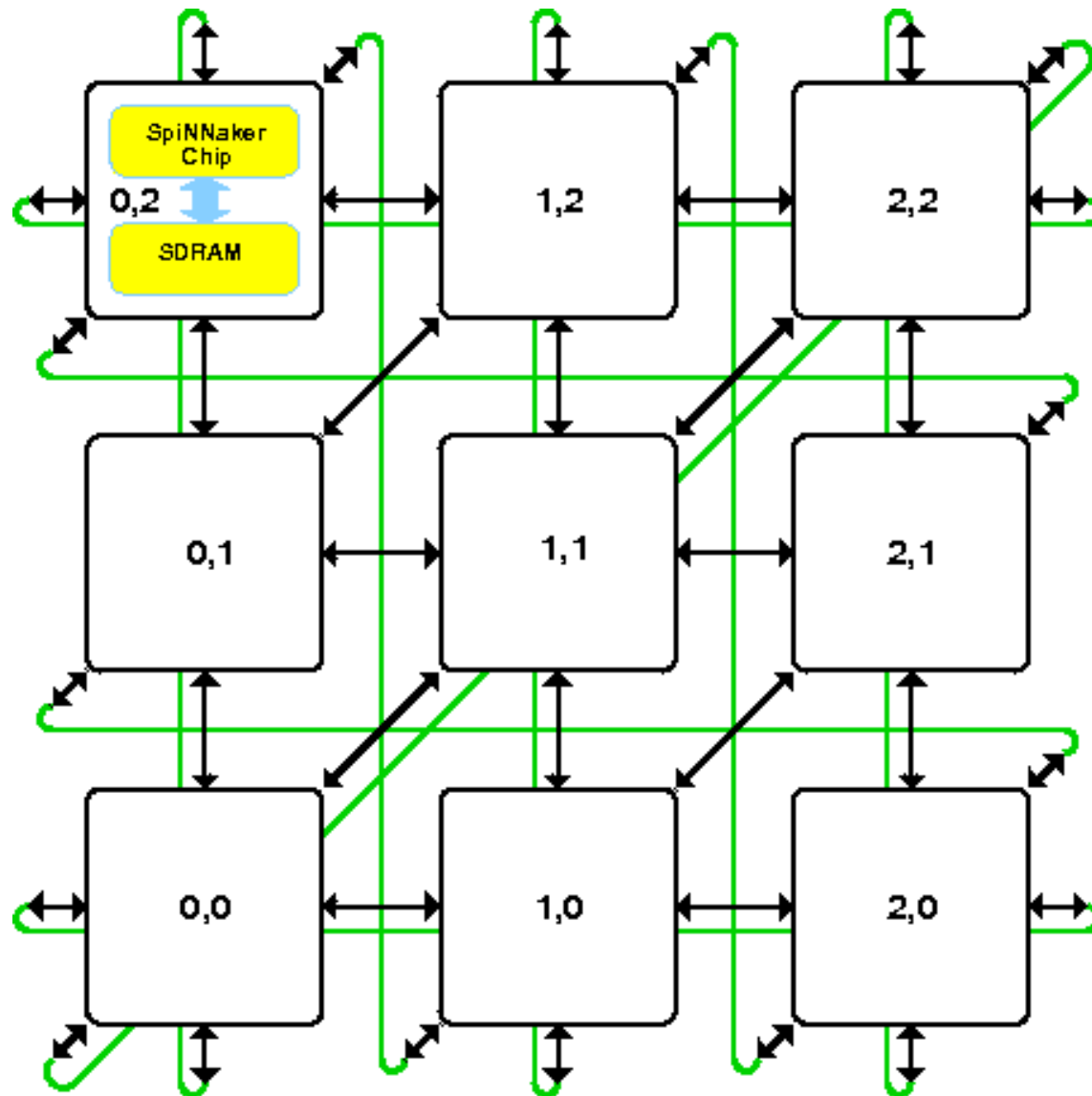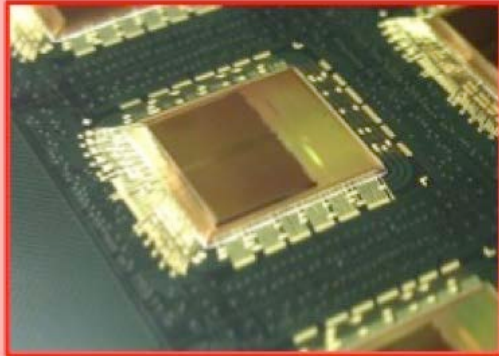Host System

● SpiNNaker CMP

Design principles

- *Virtualised topology*
  - physical and logical connectivity are decoupled
- *Bounded asynchrony*
  - time models itself
- *Energy frugality*
  - processors are free
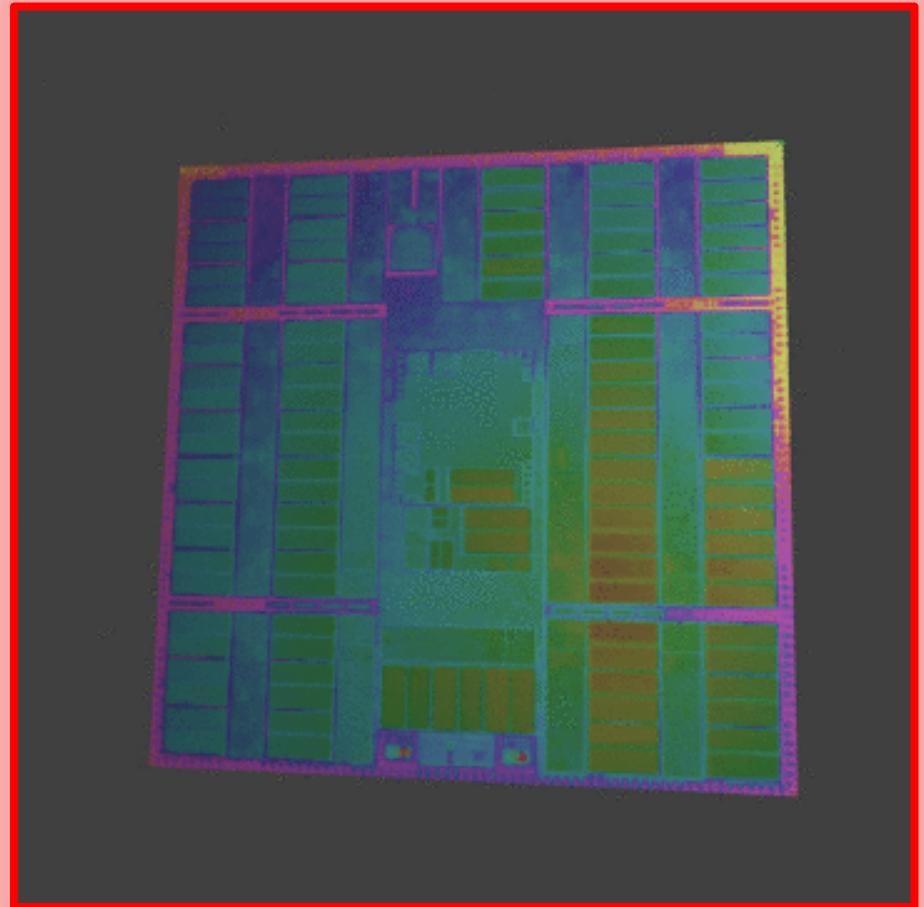 - the real cost of computation is energy
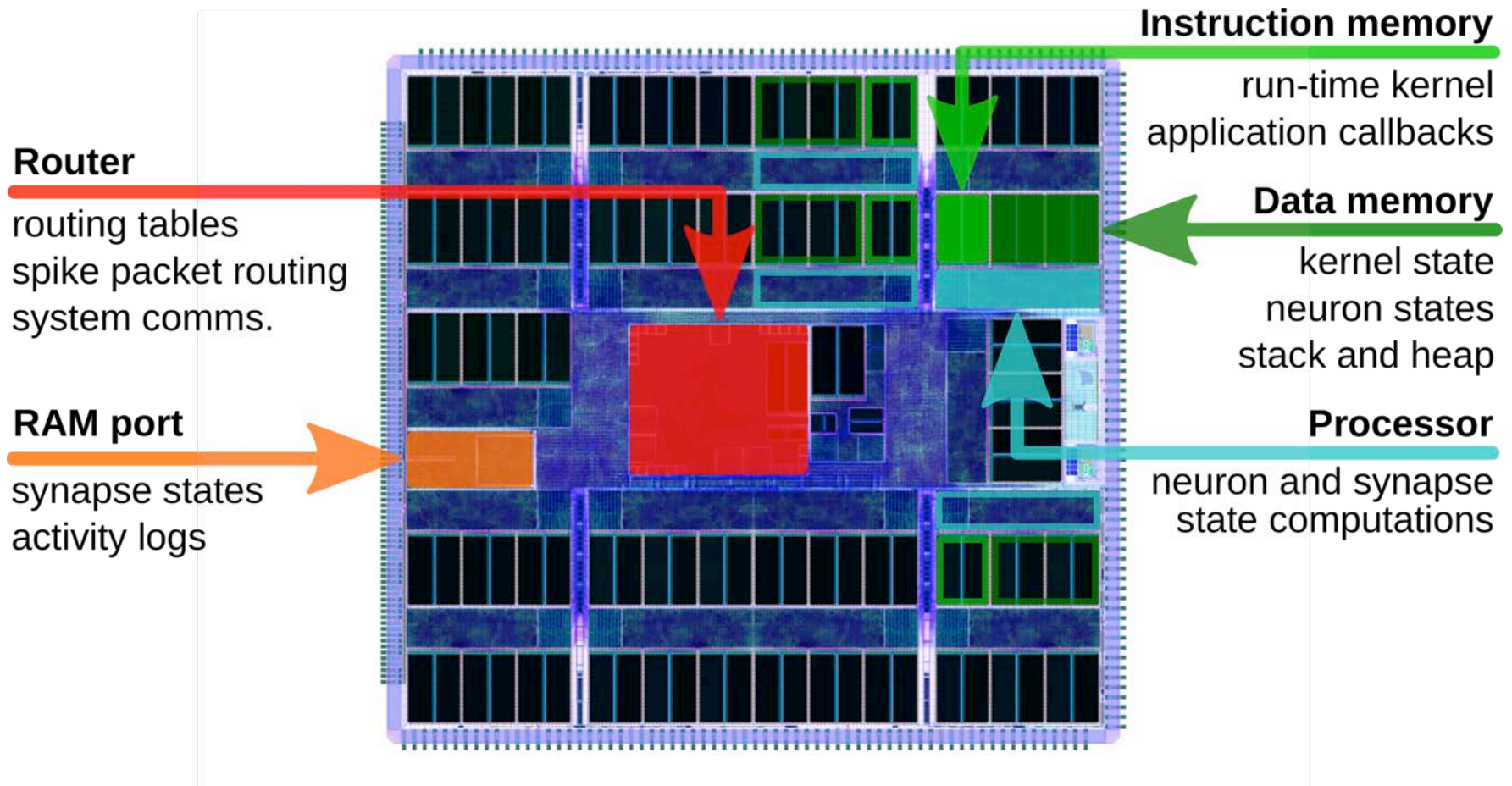
SpiNNaker system

SpiNNaker chip

Multi-chip packaging by UNISEM Europe

Chip resources

Instruction memory

run-time kernel
application callbacks

Router

routing tables
spike packet routing
system comms.

Data memory

kernel state
neuron states
stack and heap

RAM port

synapse states
activity logs

Processor

neuron and synapse
state computations

Multicast routing
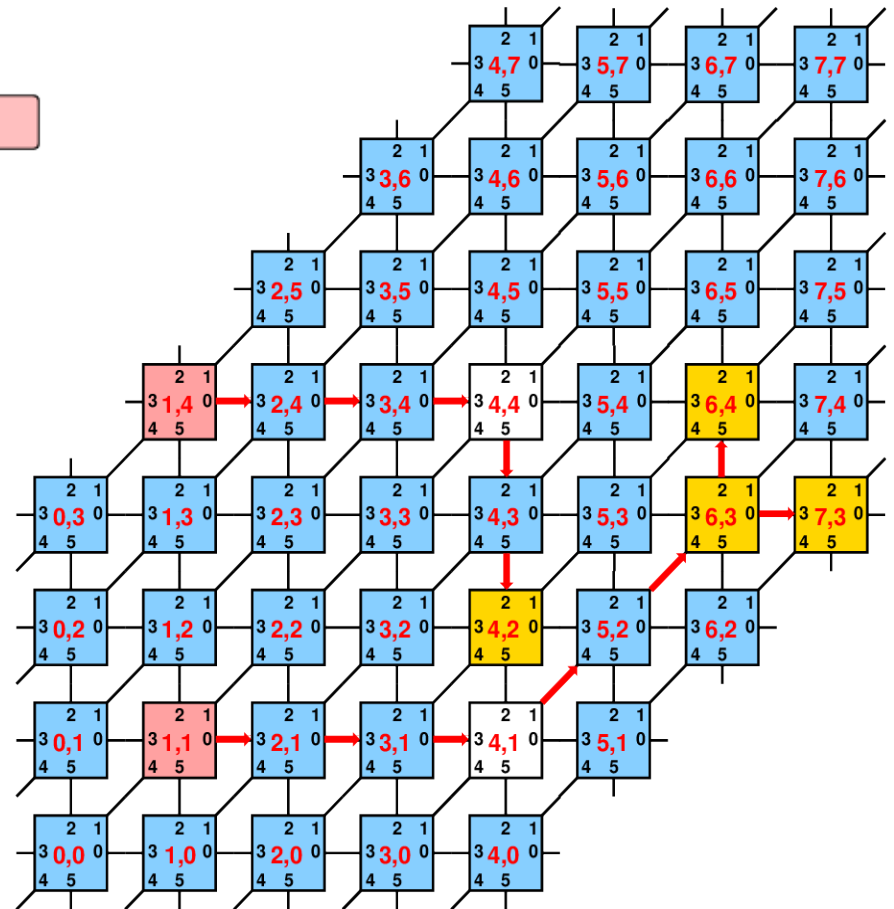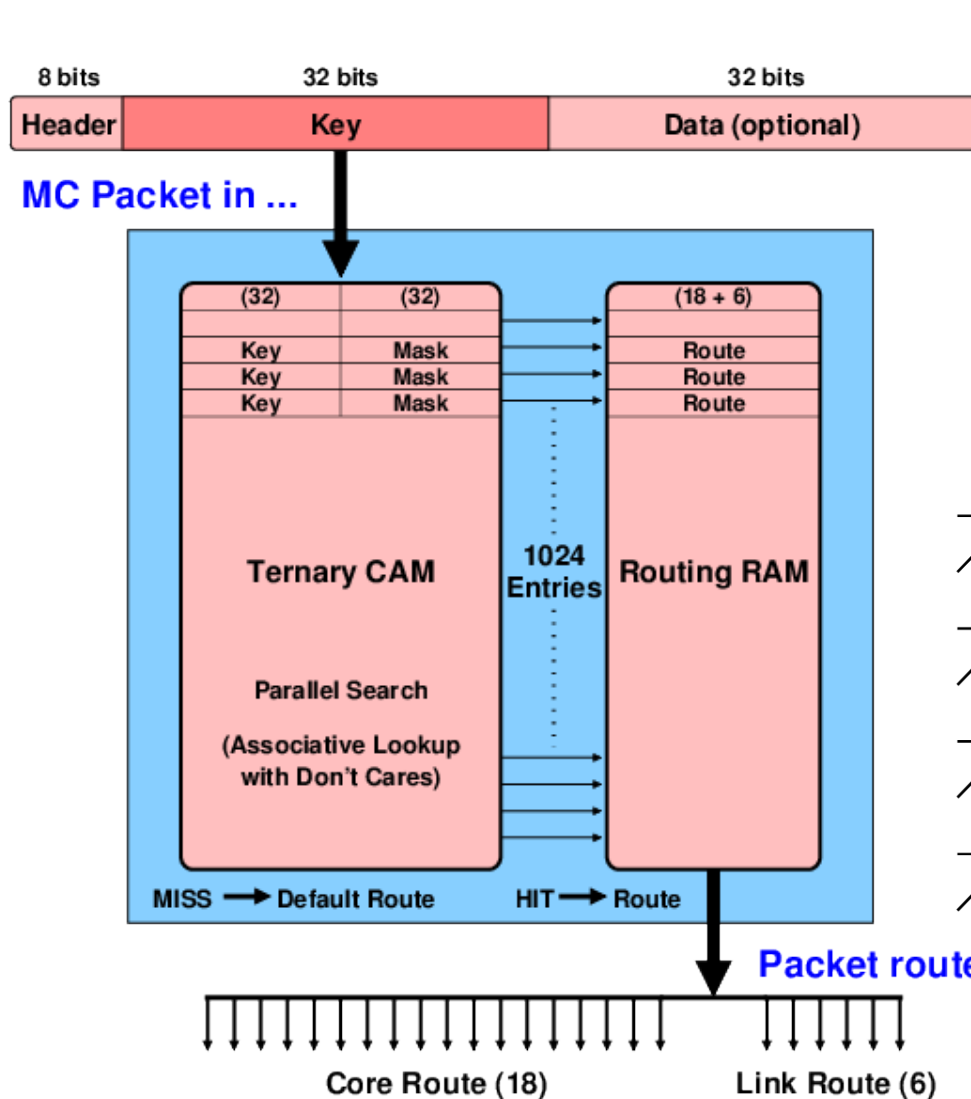
SpiNNaker machines

103

864 cores
- drosophila scale

102

72 cores
- pond snail scale

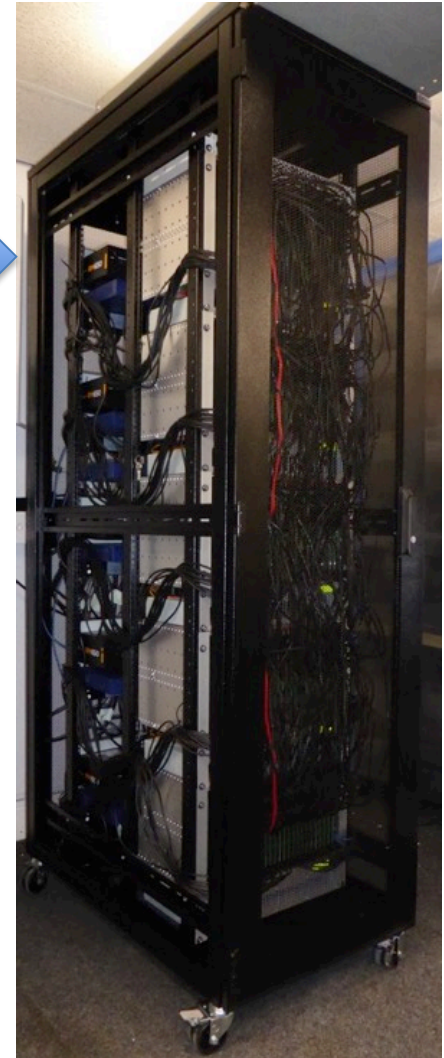## 104

20,000 cores
– frog scale

105

100,000 cores
– mouse scale

Building the HBP machine

SpiNNaker machines

Human Brain Project

- HBP platform
  - 500,000 cores
  - 6 cabinets
    (including server)
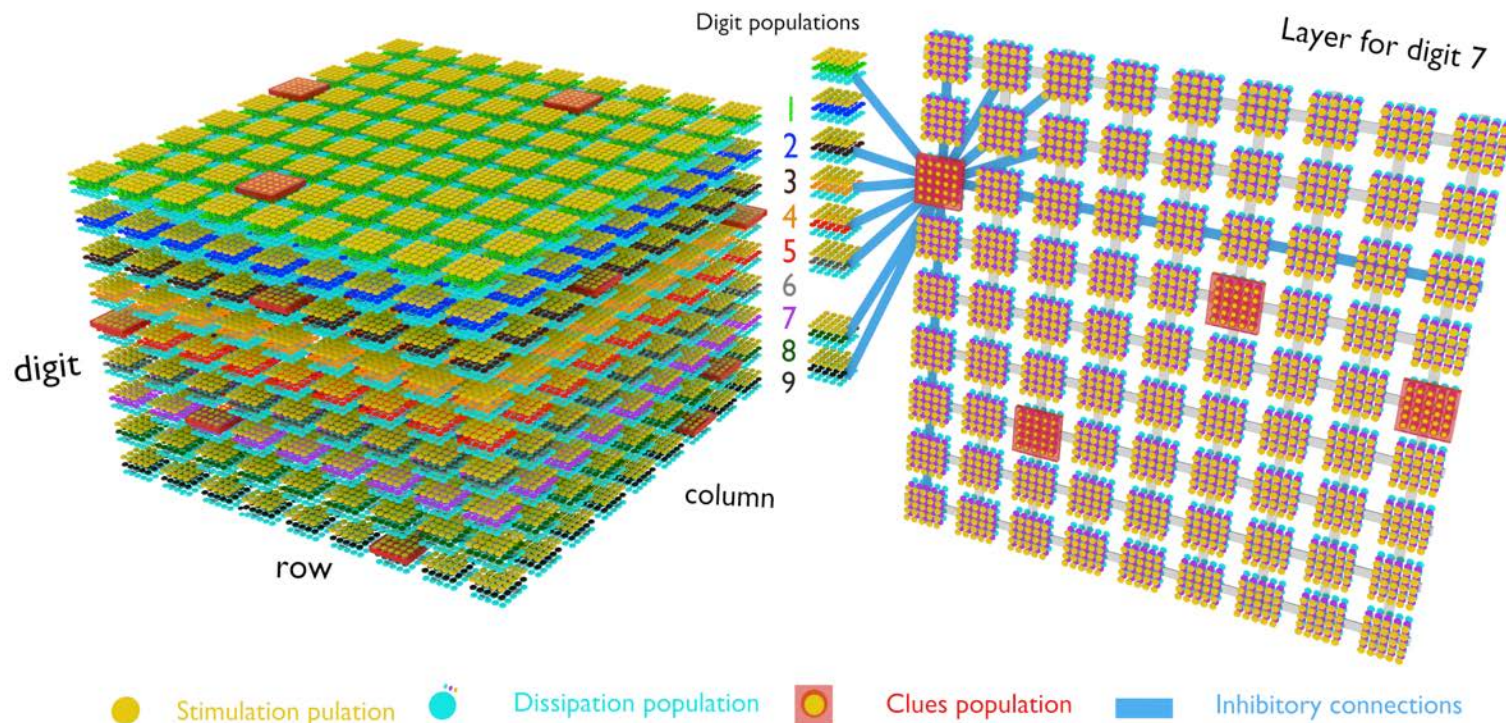- Launch
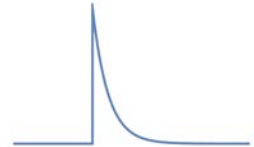 - 30 March 2016

SpiNNaker machines

- **90 SpiNNaker systems in use**
  - global coverage
- **4-node boards**
  - training & small-scale robotics
- **48-node boards**
  - insect-scale networks
- **multi-board systems**

SpiNNaker
Biologically
Inspired
Massively
Parallel
Architectures

🔴 sales

🔵 loans
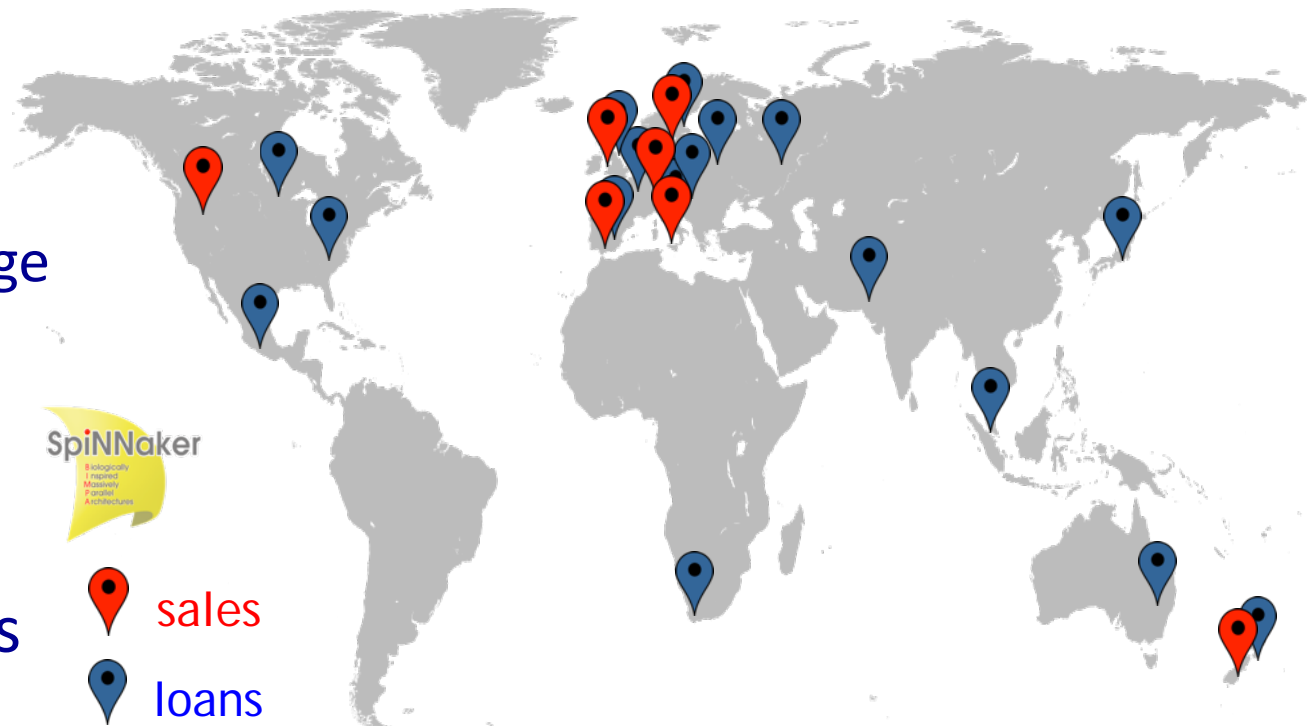
Sudoku solver
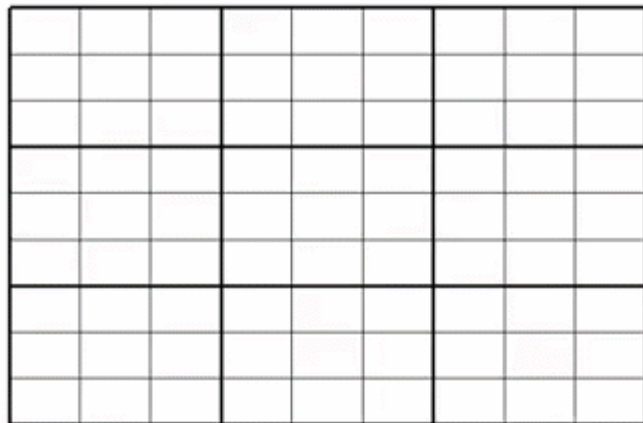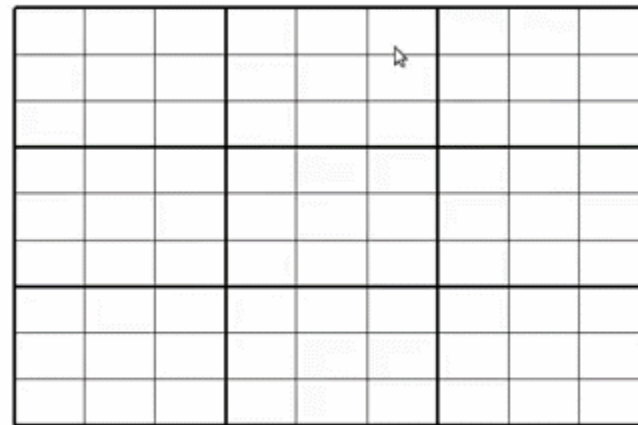
- 219,000 neurons, 22M synapses

Each dot represents an LIF neuron : $\tau_m \dfrac{du}{dt} = -u(t) + RI(t),$ with exponential PSP

Digit populations

Layer for digit 7

digit

column

row

Stimulation pulation   Dissipation population   Clues population   Inhibitory connections

S. Habenschuss, Z. Jonke, and W. Maass, "Stochastic computations in cortical microcircuit models", PLOS Computational Biology, 9(11):e1003311, 2013.

work by: Gabriel Fonseca Guerra

Sudoku solver

work by: Gabriel Fonseca Guerra
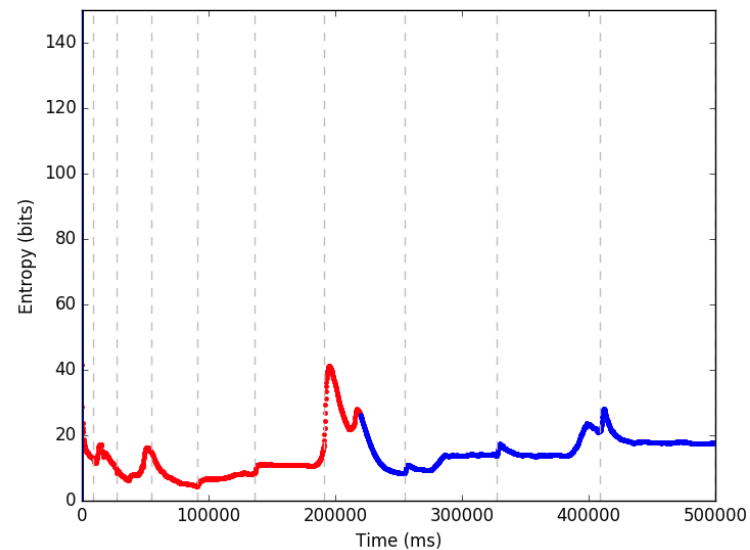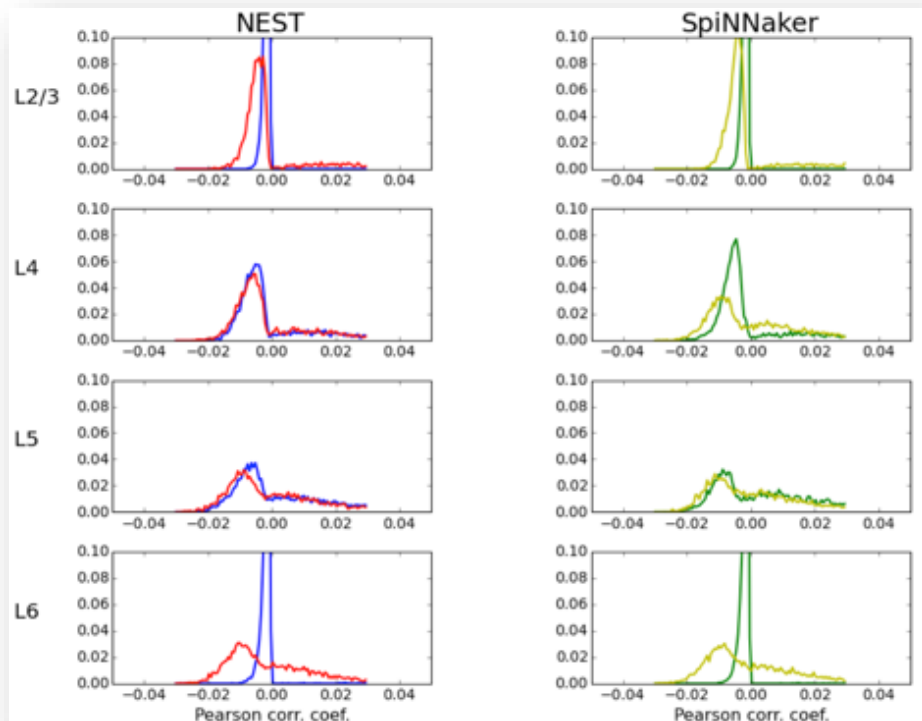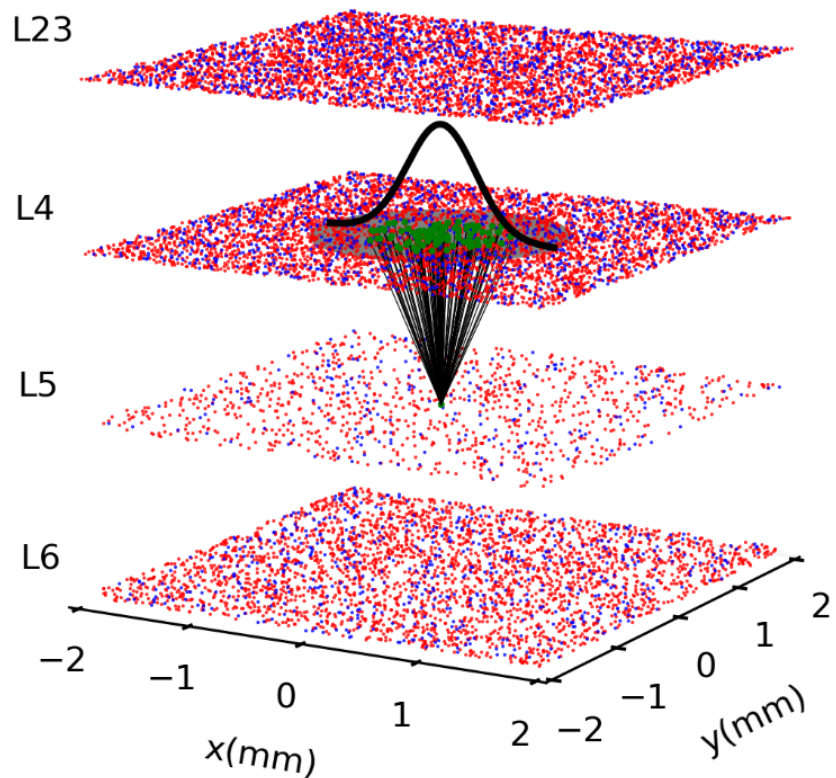
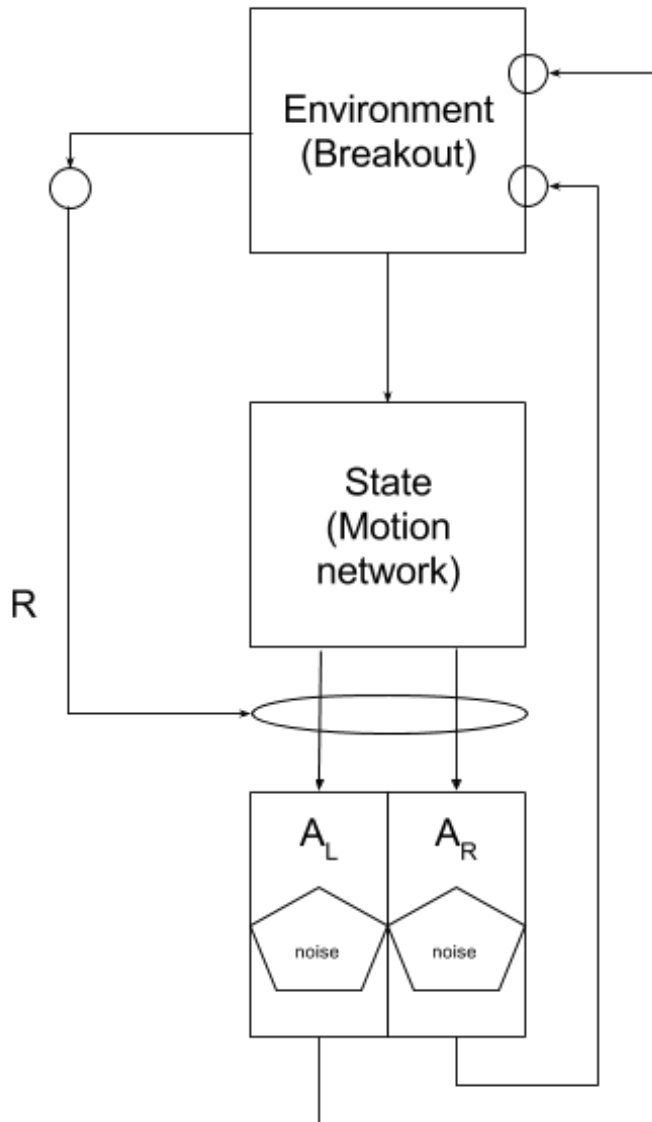# Cortical microcolumn

Learning to play video games

- dopamine modulated STDP
  - reinforcement learning

work by: Petrut Bogdan

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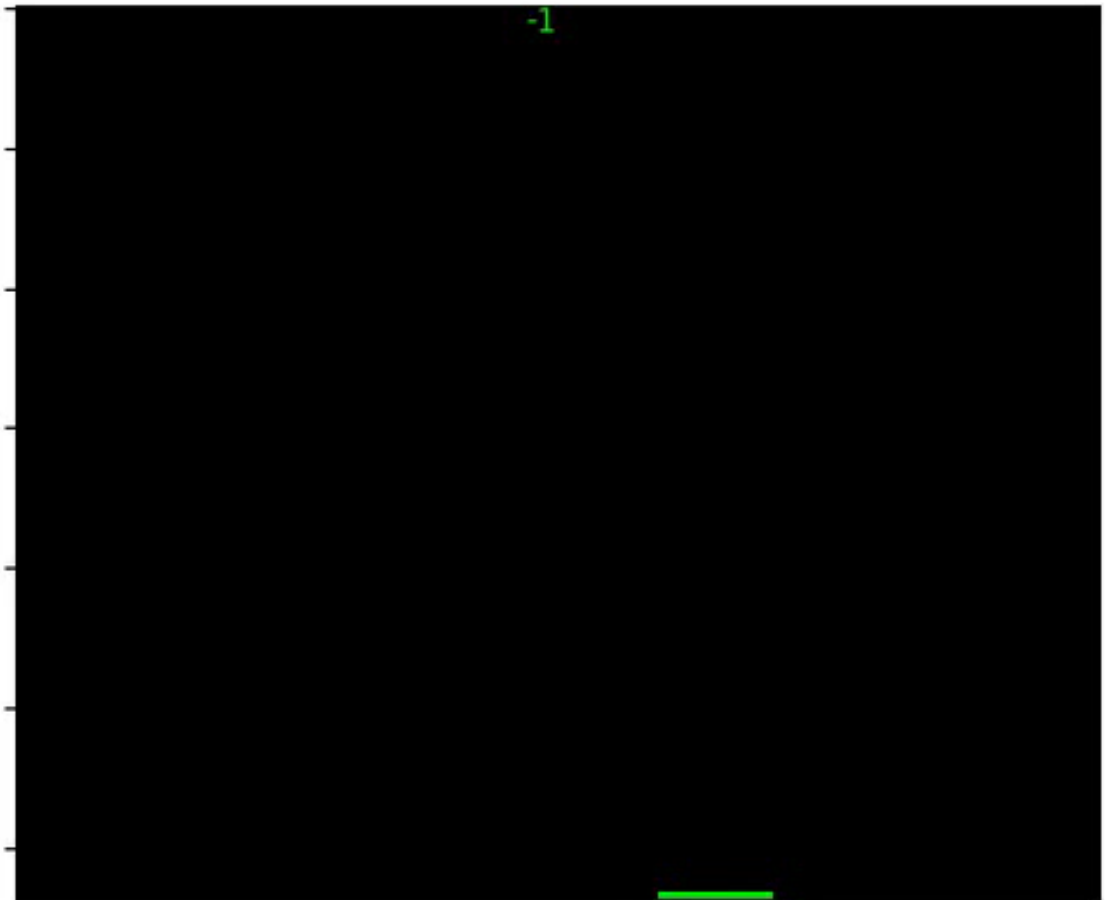
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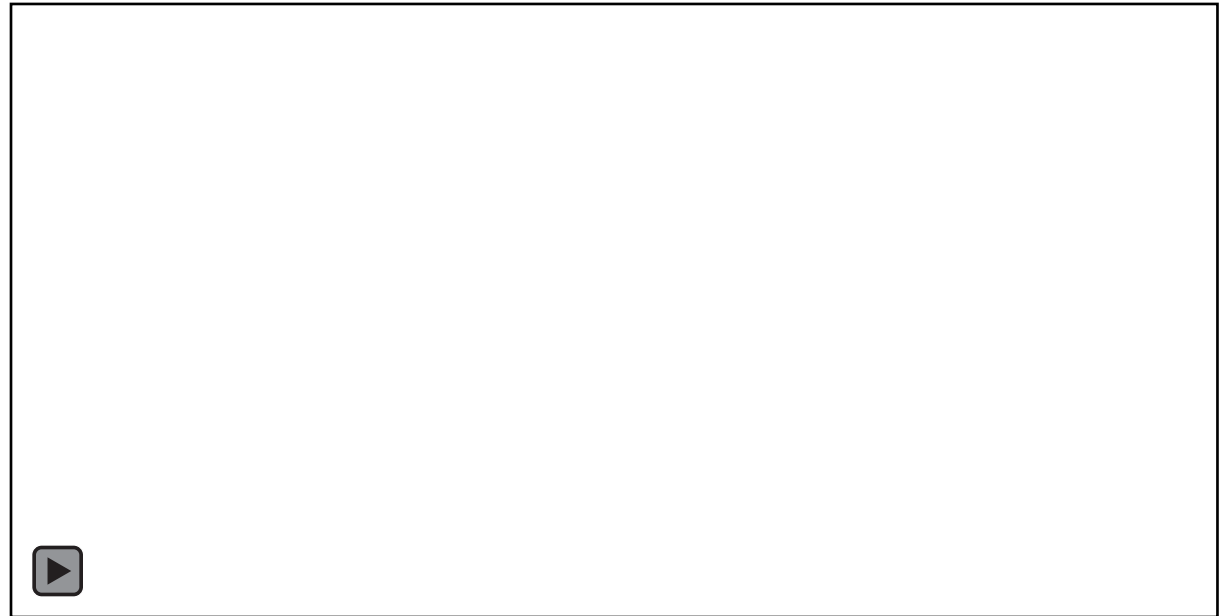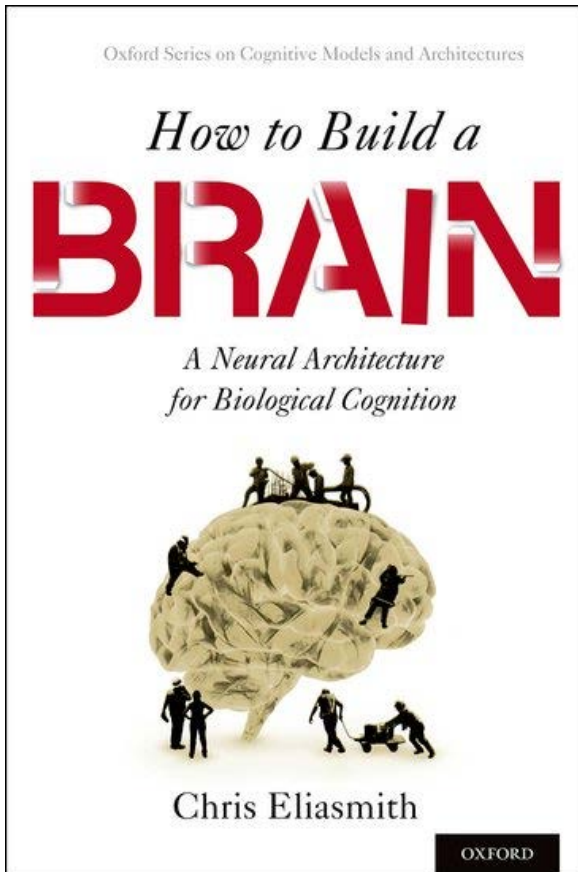
Cluster machine:

- 2.5 hours/sec

Chris Eliasmith et al, Science vol. 338, 30 Nov 2012
SpiNNaker port by Andrew Mundy

SpiNNaker:

- 25,000 ARMs
- 30x 48-node PCBs
- real-time - soon!

Conclusions

- We have come a long way in 60 years…
  - x10^{10} improvement in efficiency
- We still don't have the computer power to model the human brain
  - but we are getting there!
- *SpiNNaker:*
  - has been 20 years in conception…
  - …and 10 years in construction,
  - and is now ready for action!
- ~90 boards with groups around the world
- 500,000 core machines built
- HBP is supporting s/w development

Human Brain Project

Energy scales

10^0 J
1 Joule

Complex Brain Model

Simplified Brain Model

10^{-4} J
0.1 milliJoule

10^{-8} J
10 nanoJoule

Numerical Neuromorphic Model

Physical Neuromorphic Model

10^{-10} J
0.1 nanoJoule

10^{-14} J
10 femtoJoule

Biological Brain

EFFICIENCY
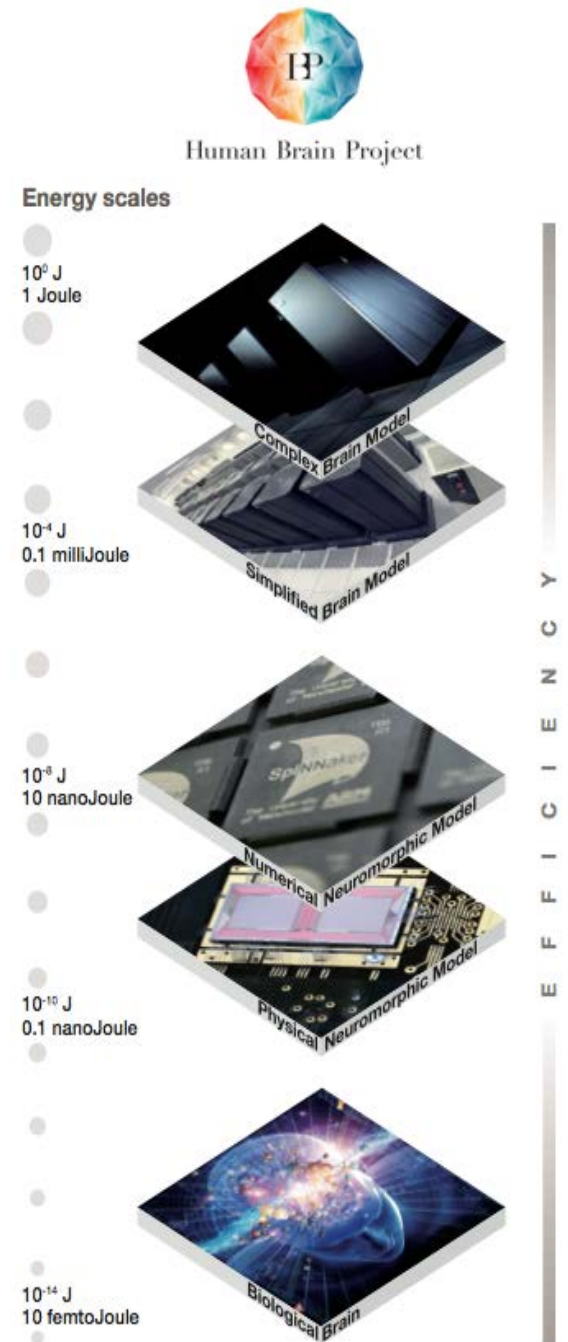
Credits

Evie Andrew

Patrick Camilleri

Dave Clark

Simon Davidson

Sergio Davies

Francesco Galluppi

Garibaldi Pineda Garcia

Jim Garside

Martin Grymel

Yebin Shi

Alan Stokes

Evangelos Stromatias

Gabriel Fonseca Guerra

Jonathan Heathcote

Michael Hopkins

Mukaram Khan

Jamie Knight

Dave Lester

Gengting Liu

Qian Liu

Xin-Jin Liu

Joanna Moy

Steve Temple

Andrew Webb

Viv Woods

Mantas Mikaitis

Robert James

Andrew Mundy

Javier Navaridas

Eustace Painkras

Cameron Patterson

Luis Plana

Alex Rast

Dominic Richards

Andrew Rowley

Tom Sharp

Jian Wu

Shufan Yang

Petrut Bogdan

…