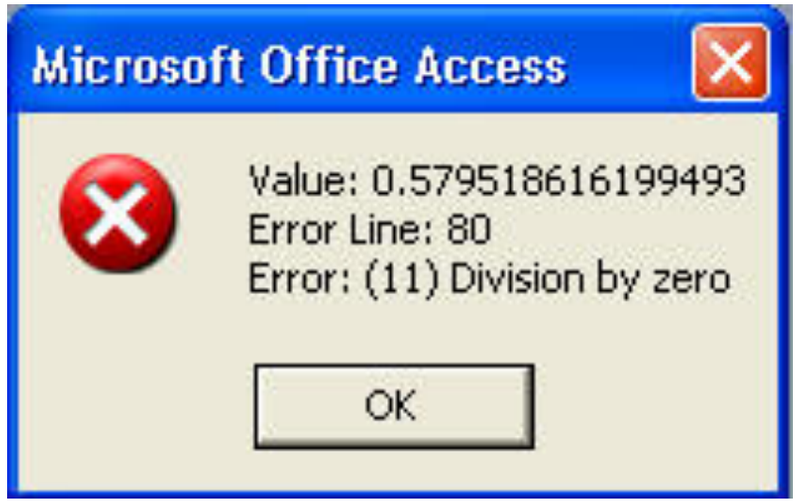
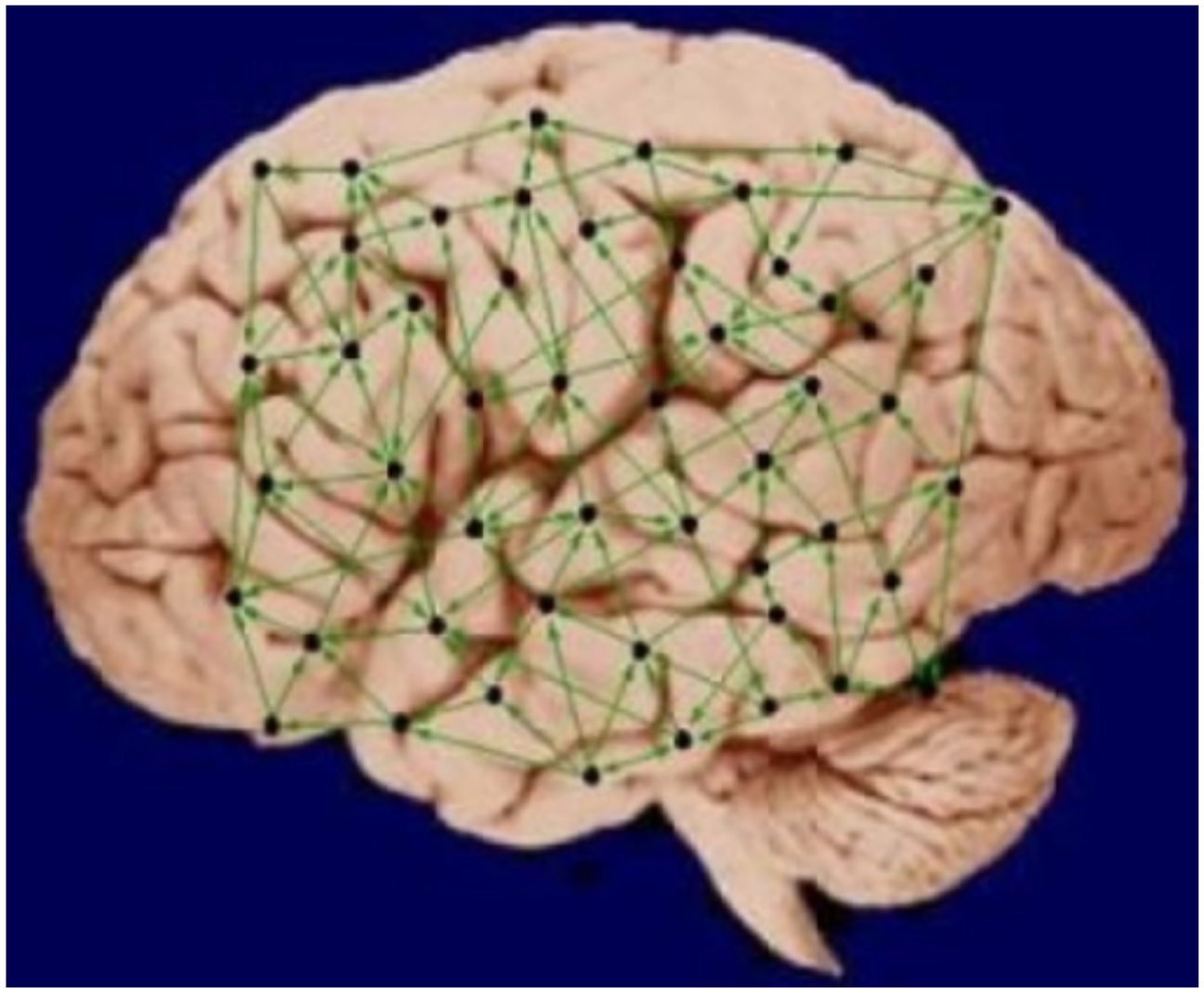
What kinds of algorithms would it take for a neuroscientist to understand a microprocessor?

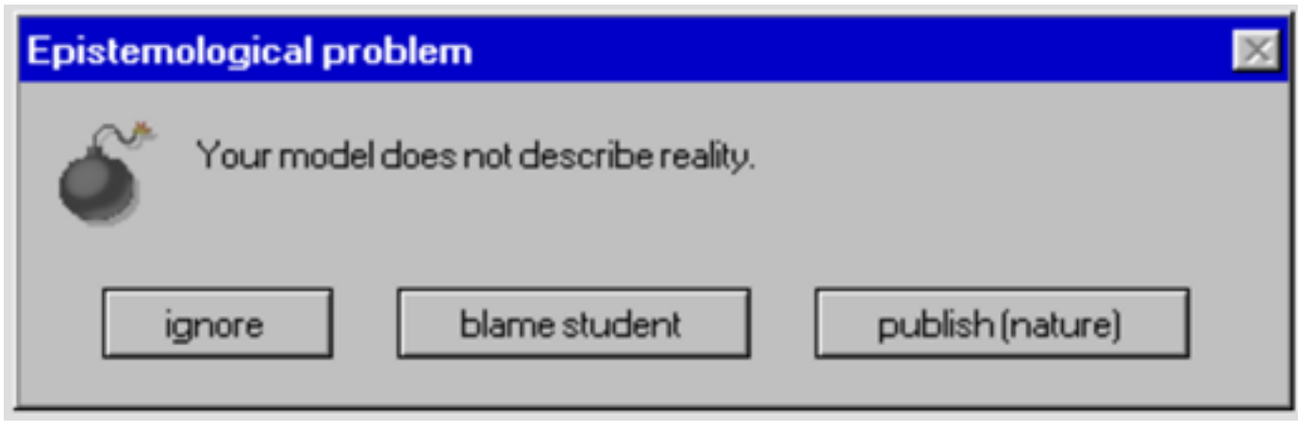
with Eric Jonas

BioRXiv: Could a neuroscientist understand a microprocessor?

Error messages are useful

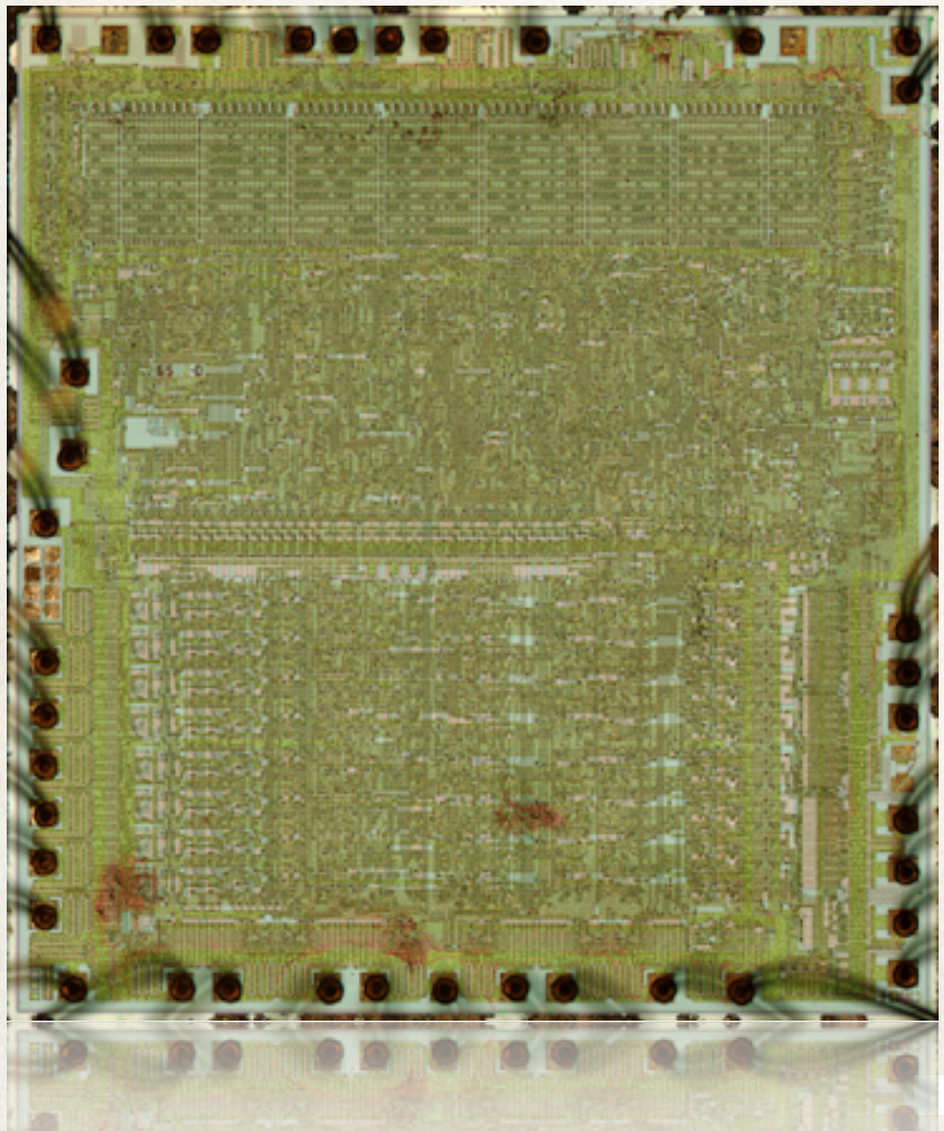


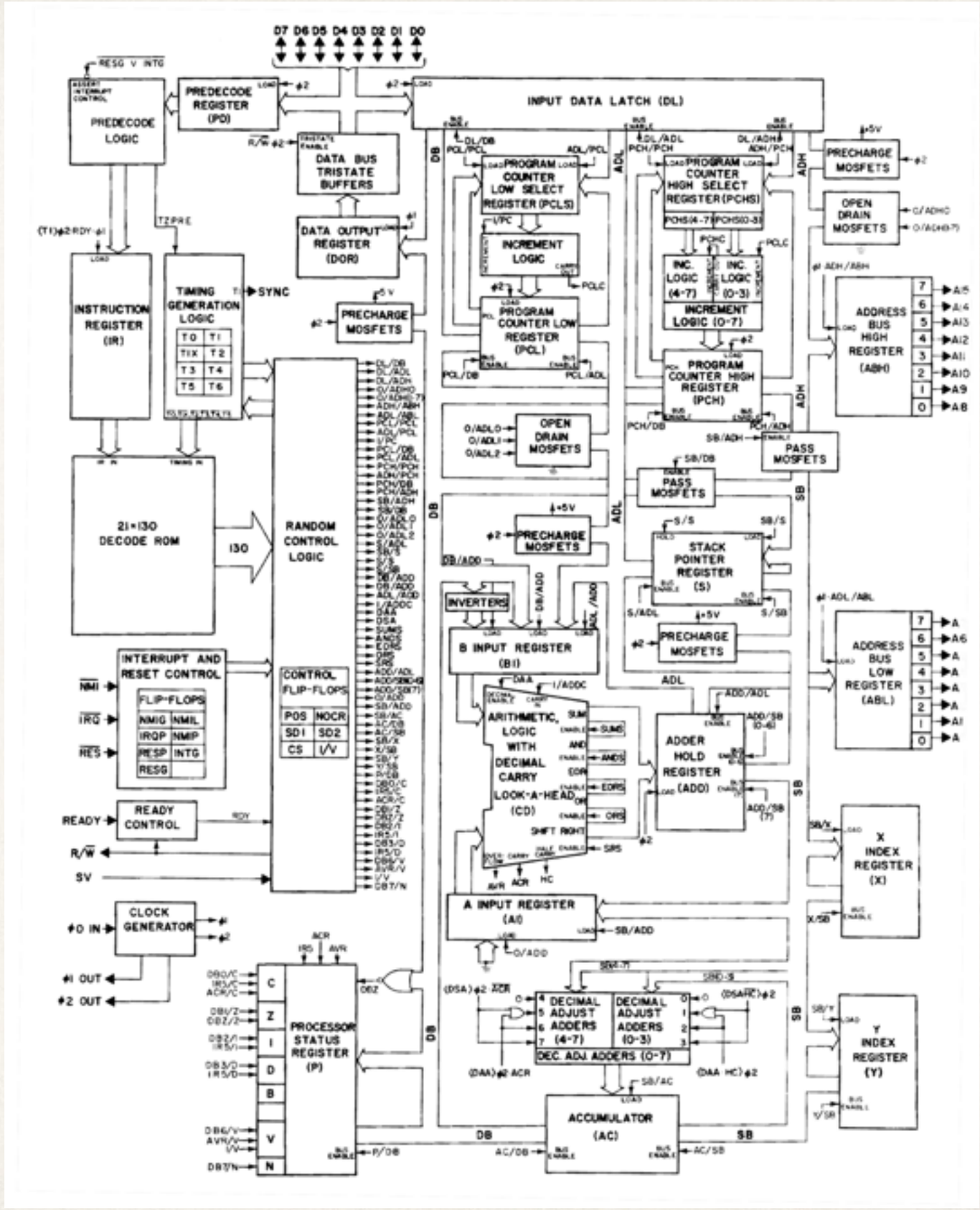




Reverse engineer a big biological distributed algorithm

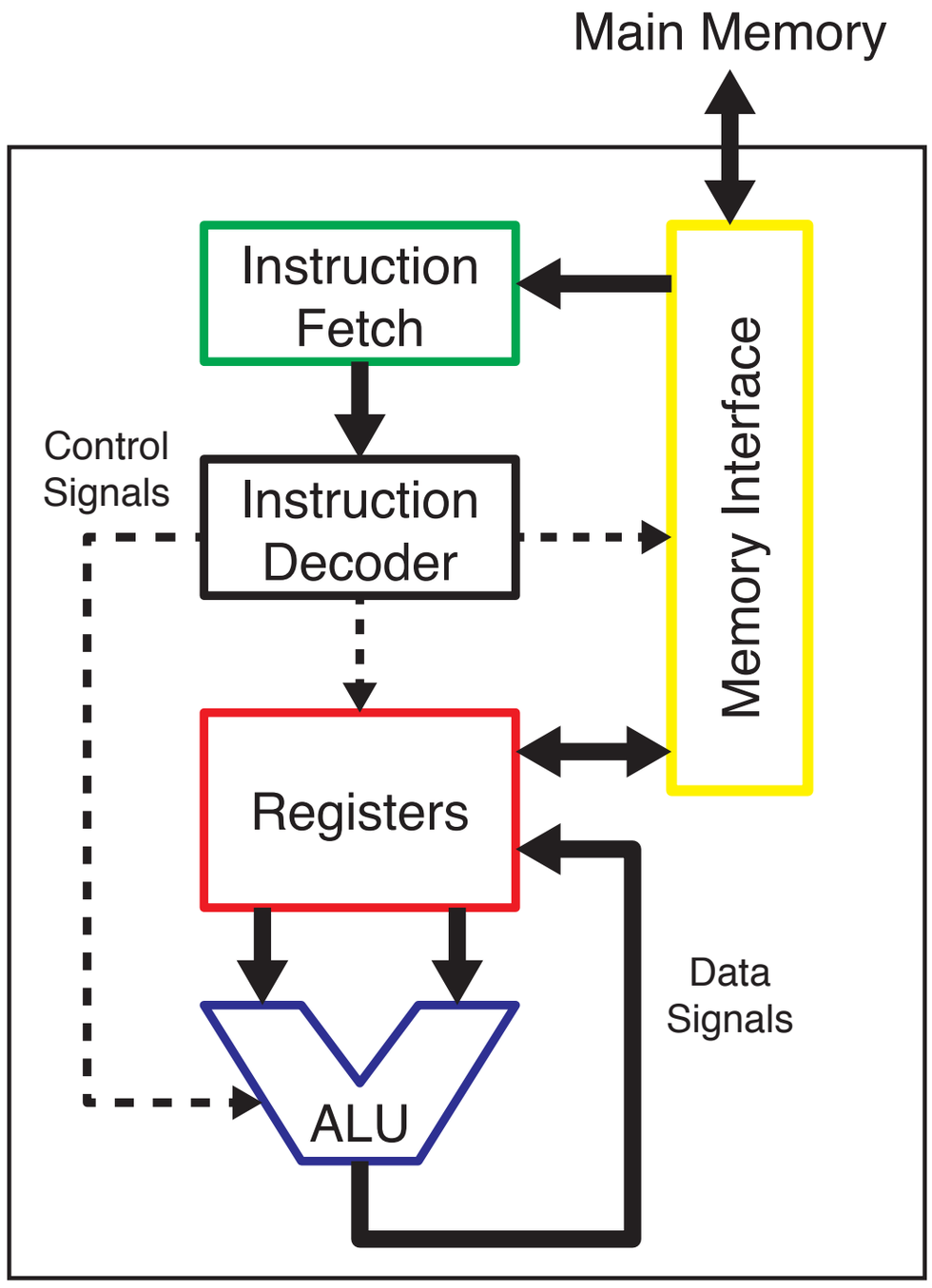
MOS 6502





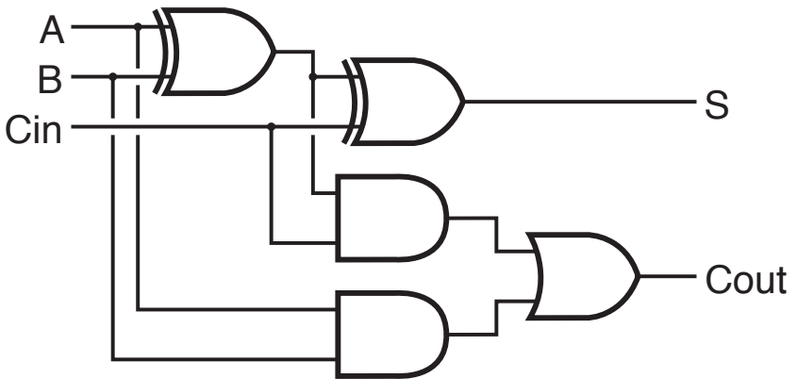
Courtesy http://visual6502.org

How it actually works

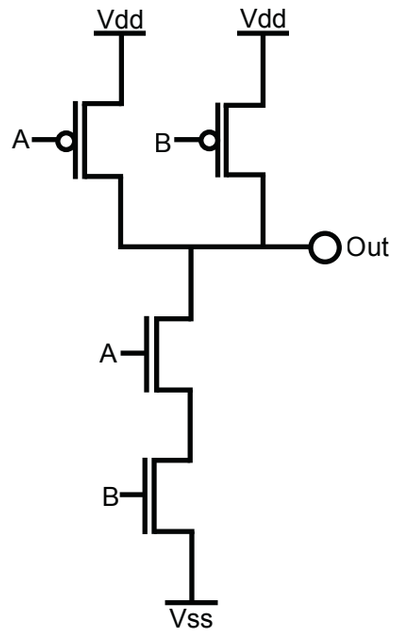


Multi scale

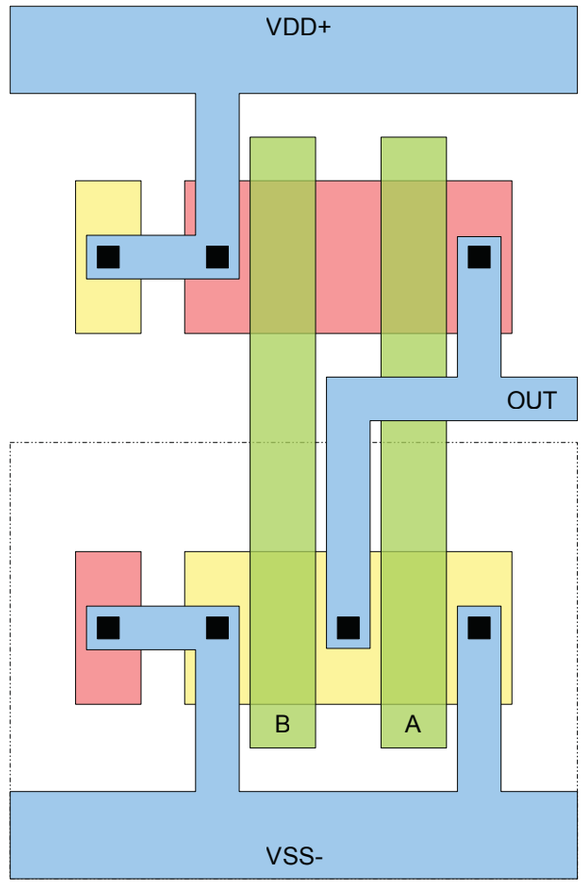
1-bit Adder



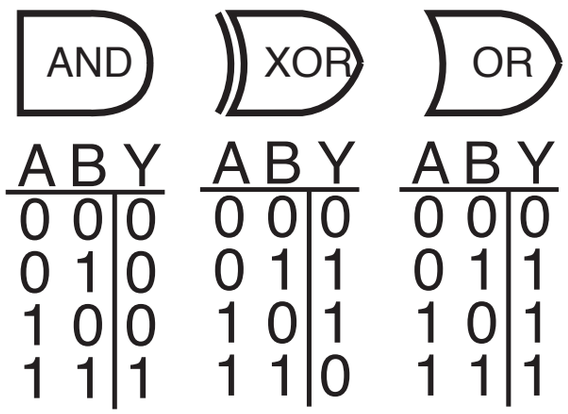
AND gate



AND gate (silicon)



logic gate primitives

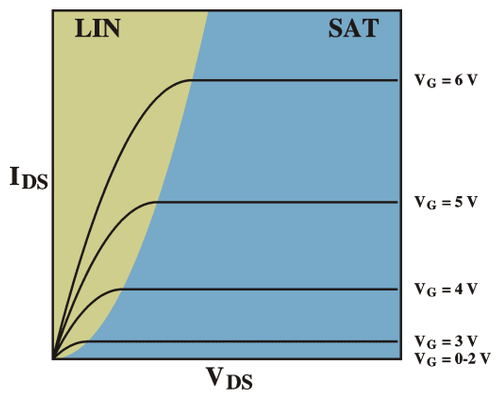


A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

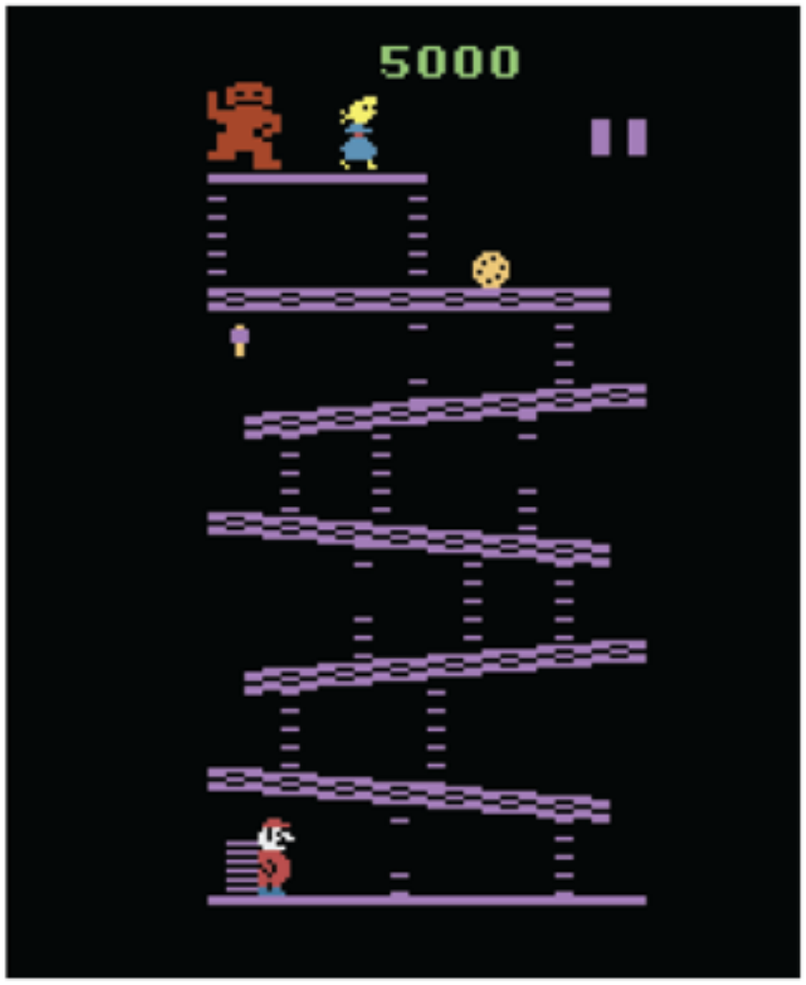
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

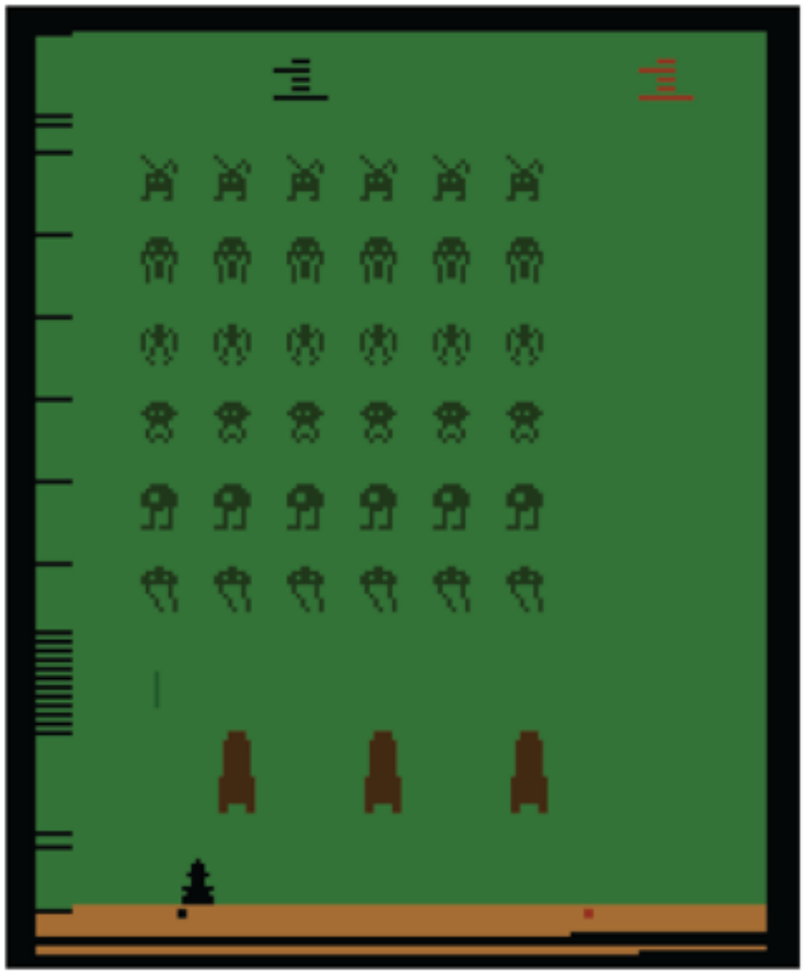
I/V for single gate



3 Behaviors



a. Donkey Kong (DK)

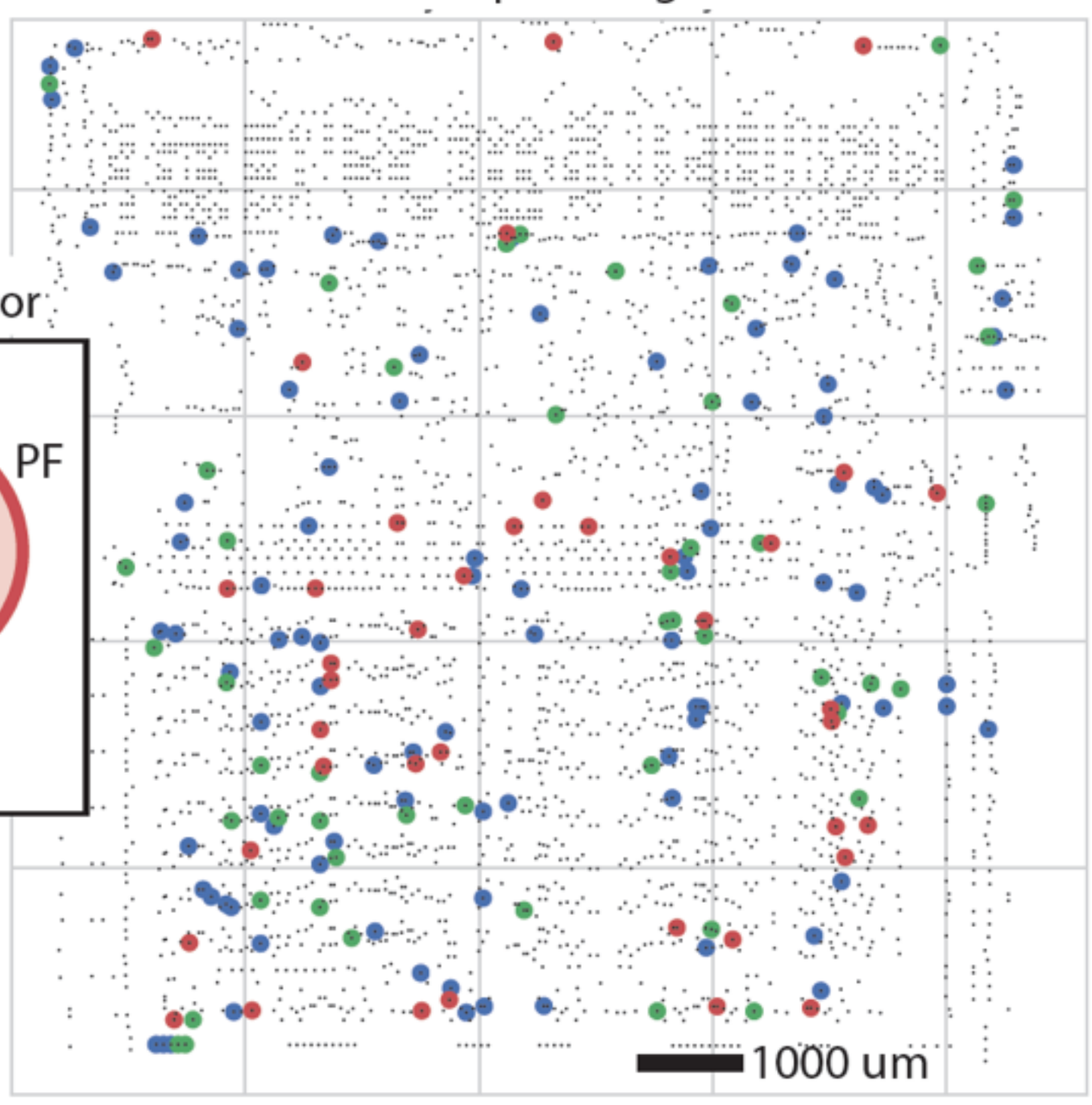


b. Space Invaders (SI)

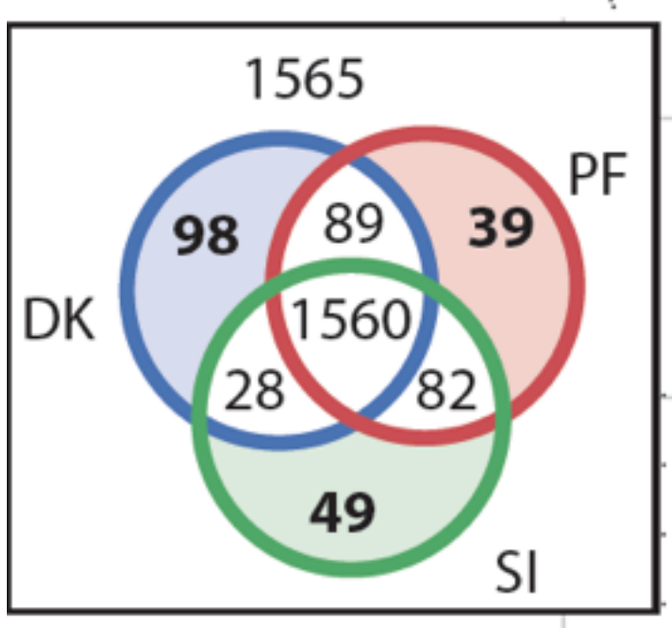
c. Pitfall (PF)

Lesion studies

Lesions which impact single behavior



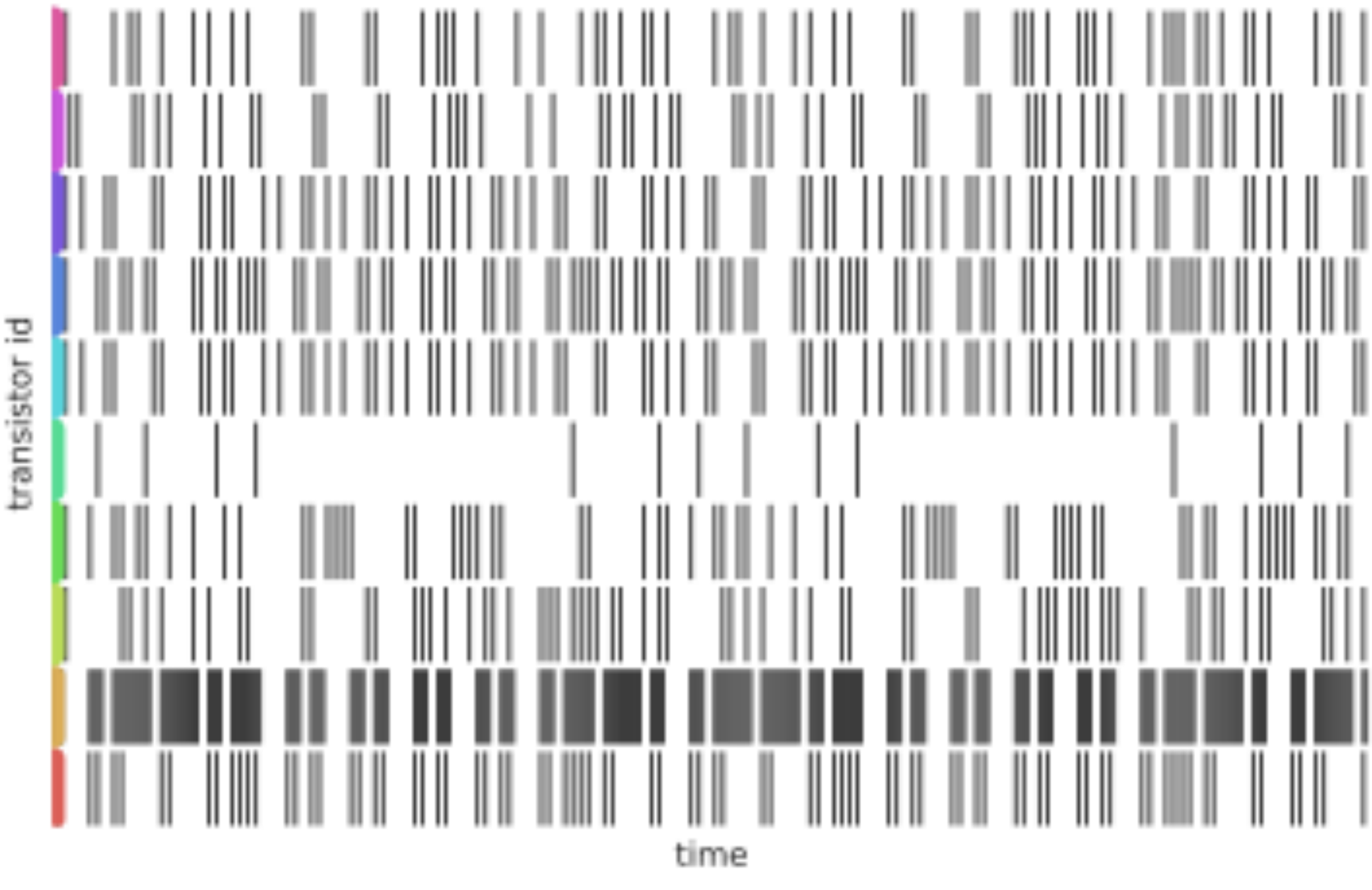
Lesion site vs behavior



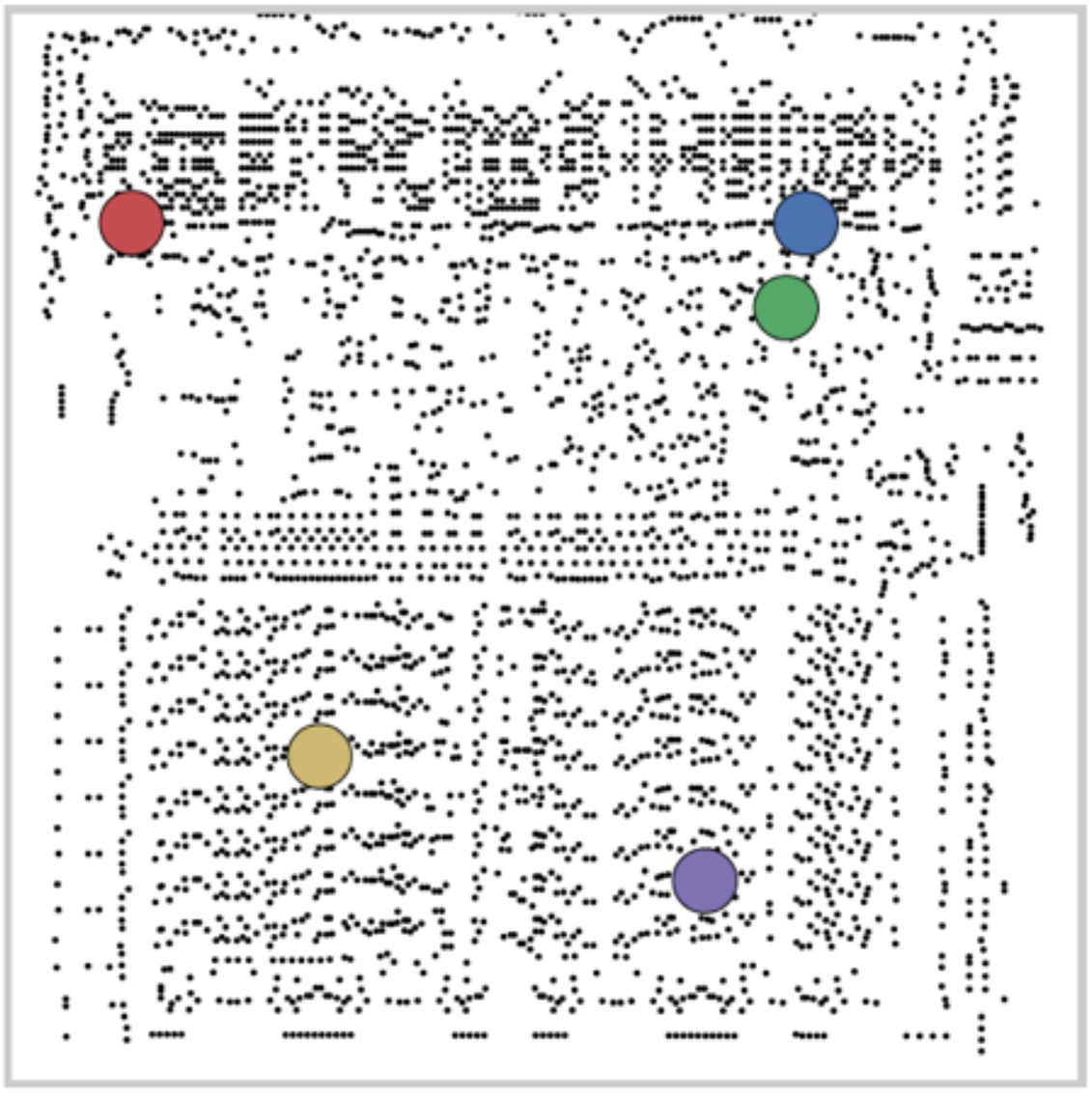
How to make it work

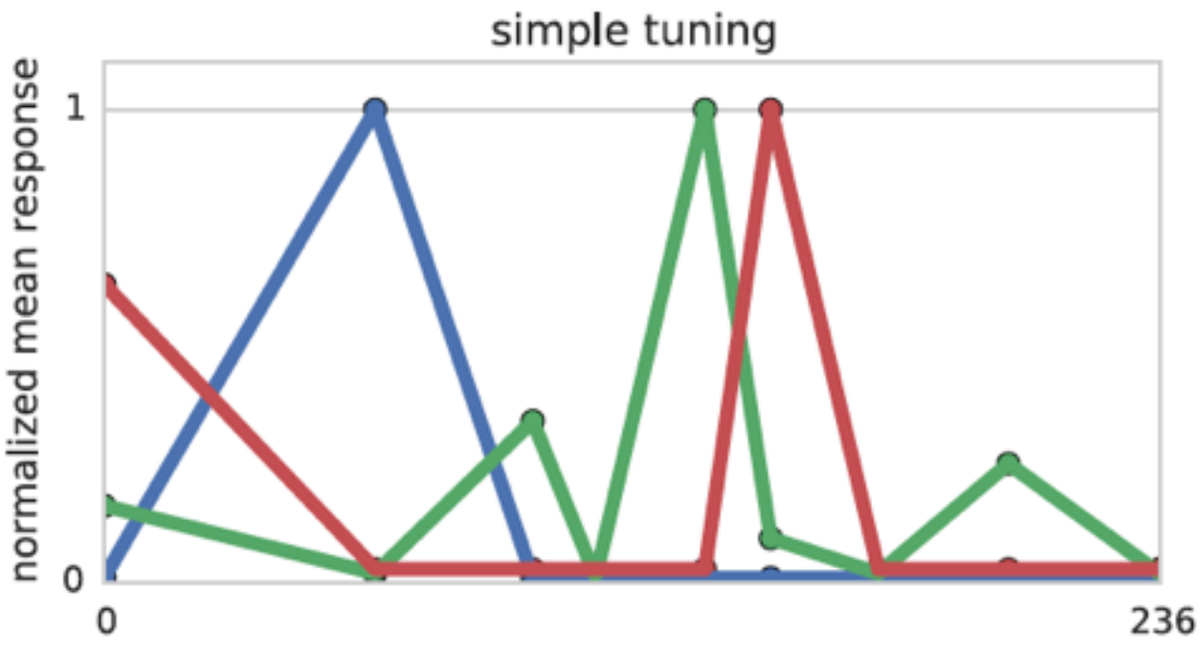
- Problem: Complex game instead of targeted instructions
- *Same as for brain*
- But could work if one activated/inactivated
- And optimized stimulation so that effects are sparse

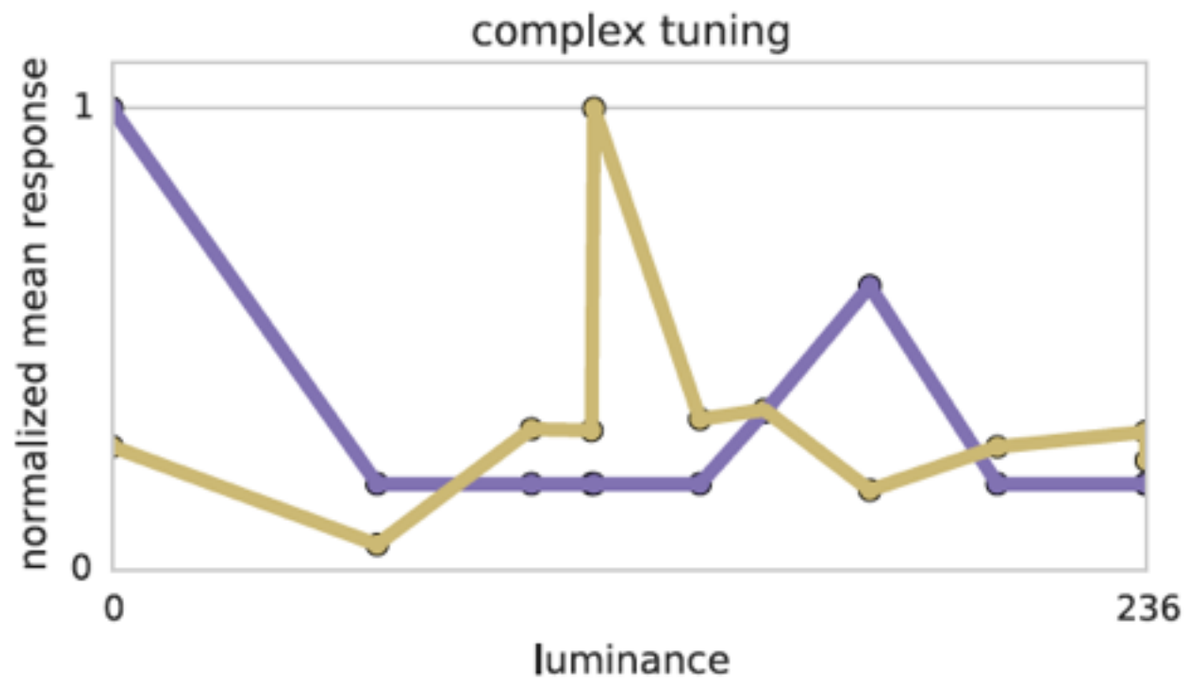
“Spike data”



Tuning curves



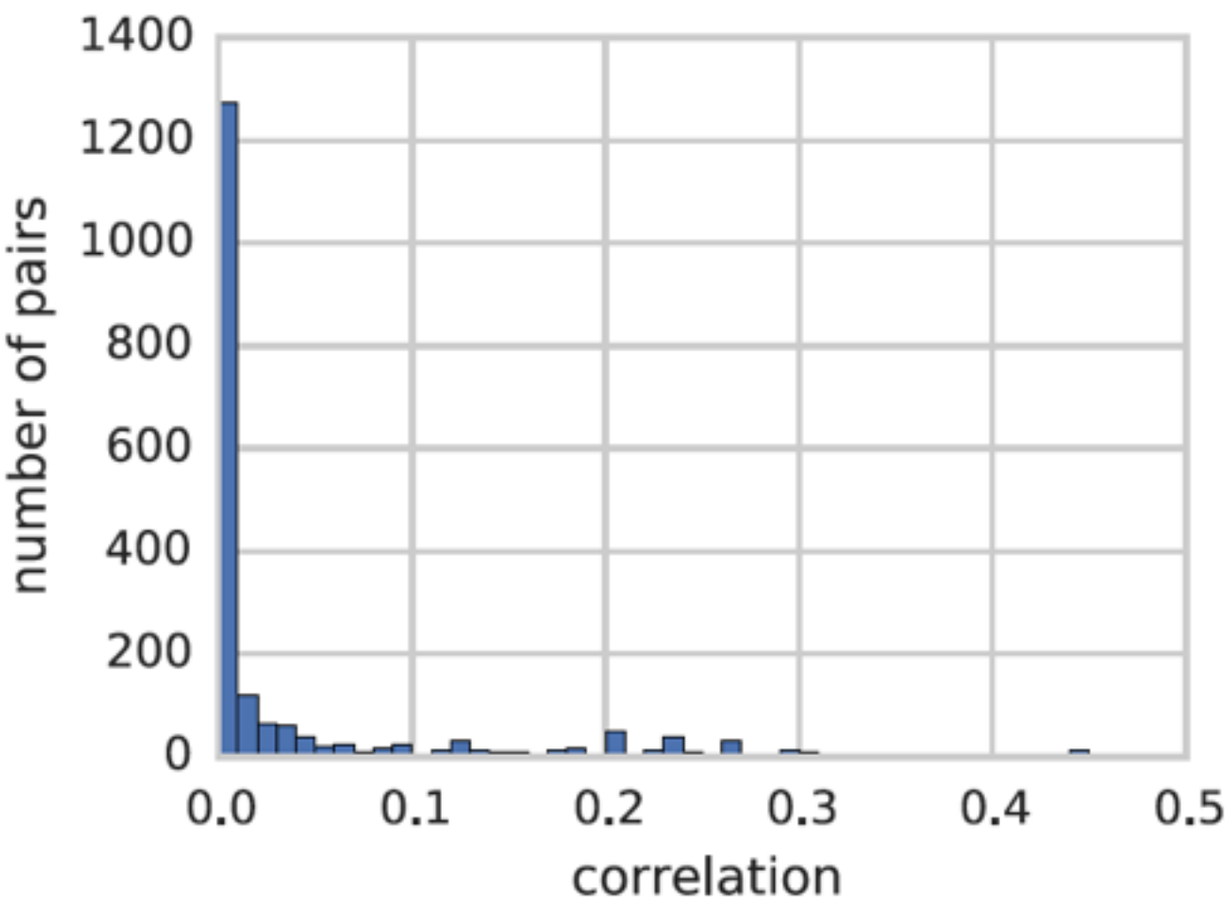


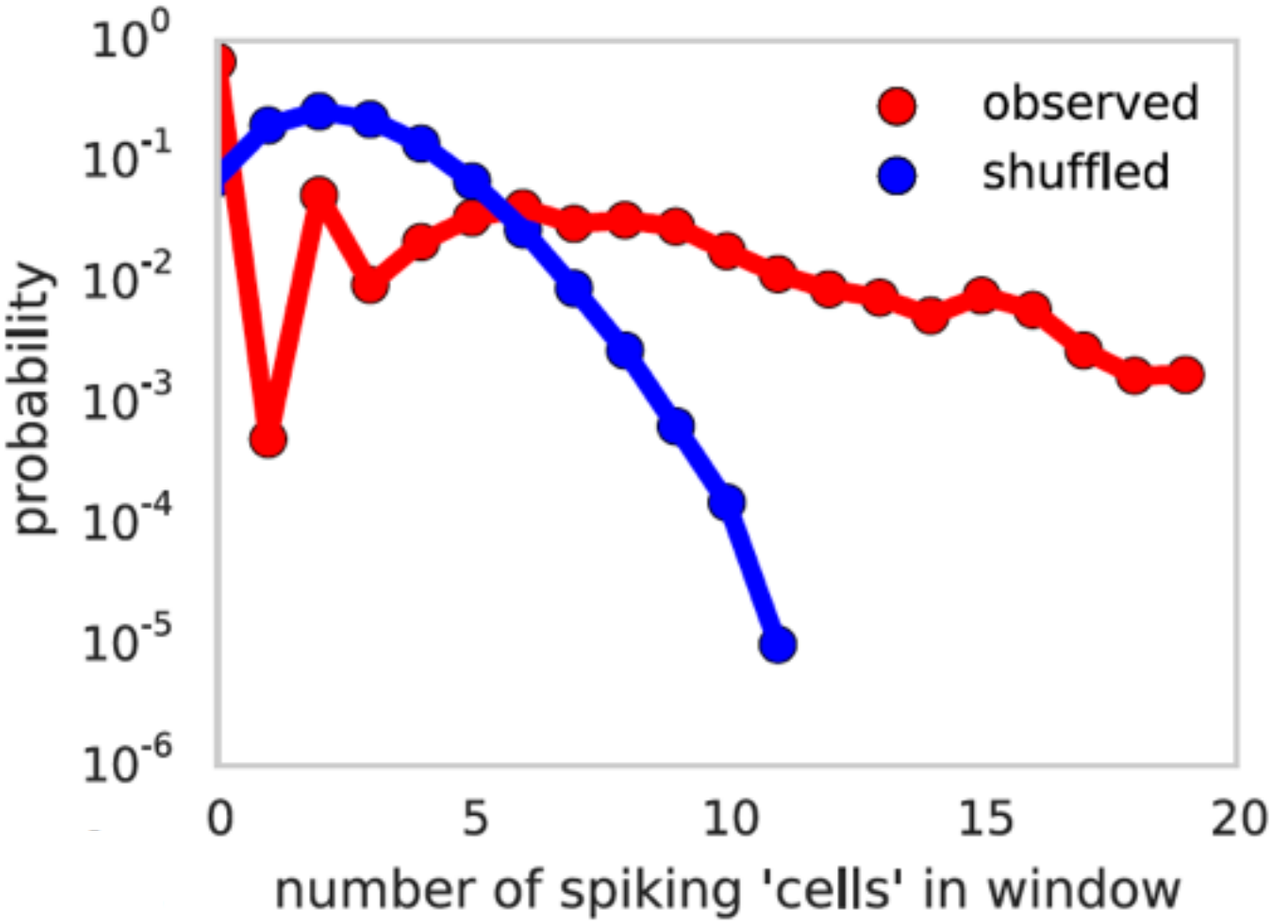


How to make it work

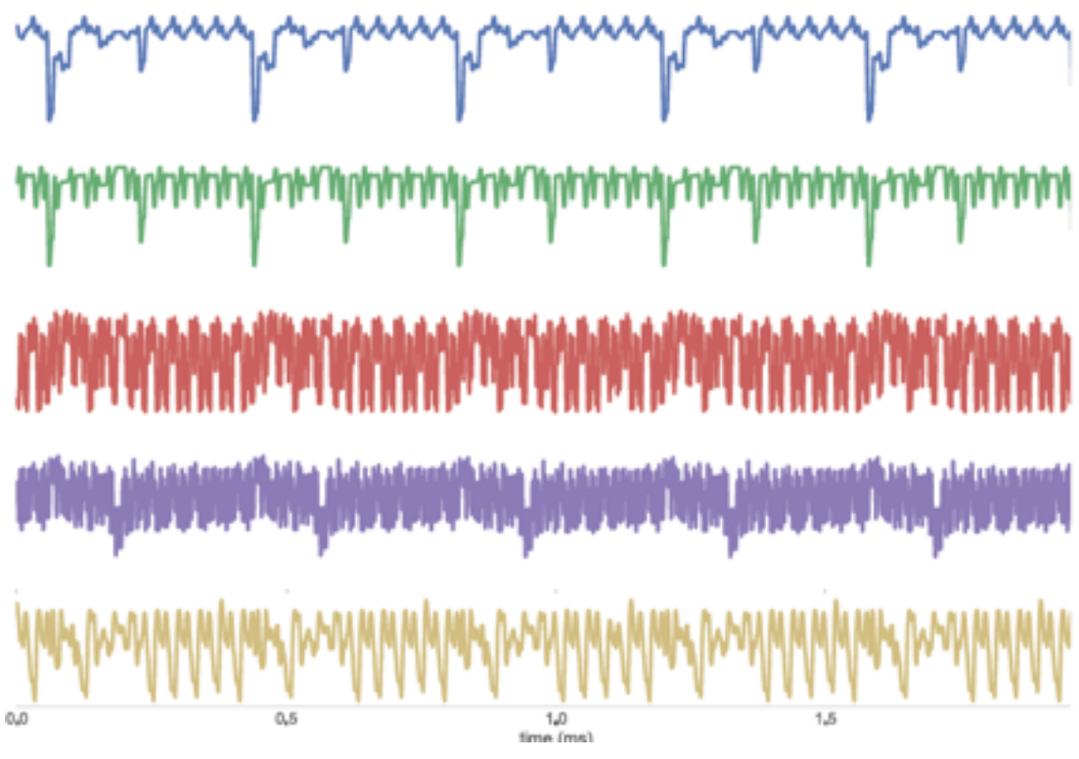
- Problem: not having understanding of “instructions”
- *Same as for brain*
- Run lots of programs. Relate instructions to activities.

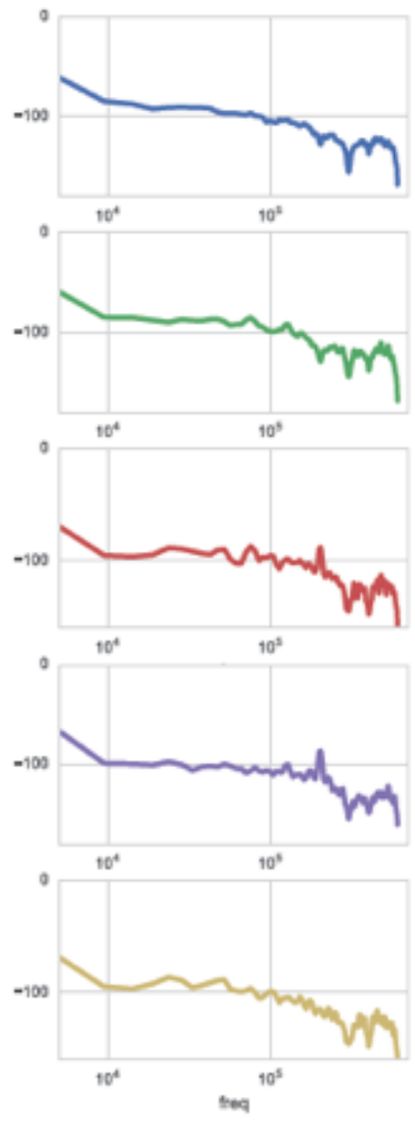
Strong global correlations



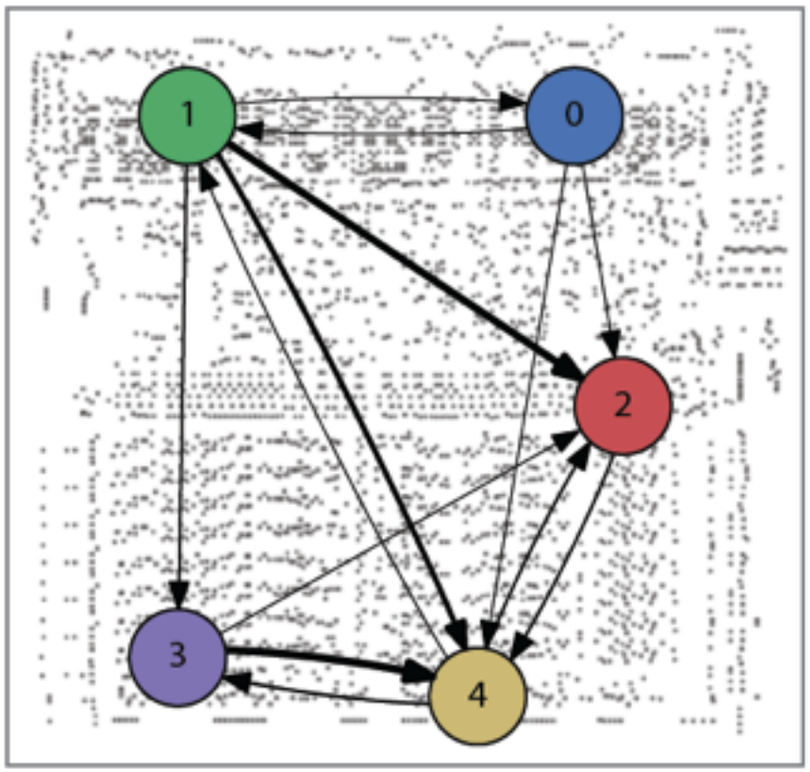


LFPs and power law spectra

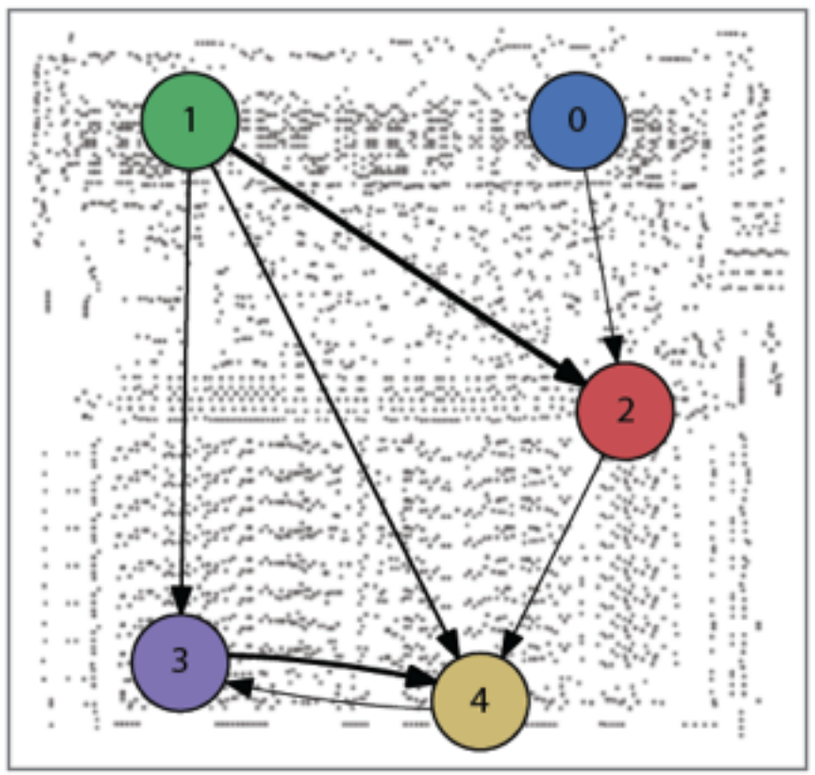




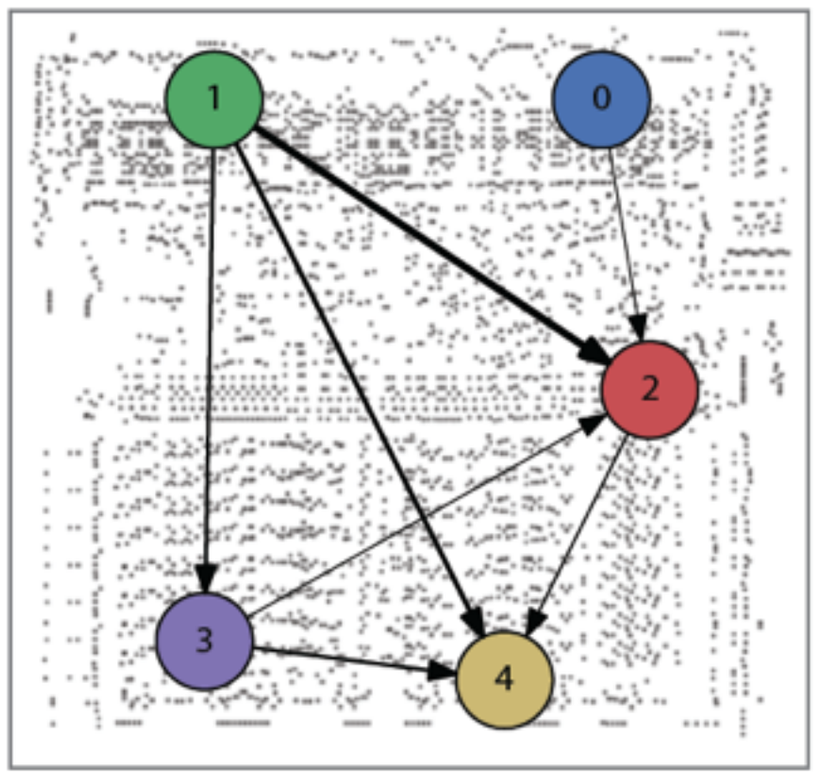
Granger causality



a. Donkey Kong



b. Space Invaders

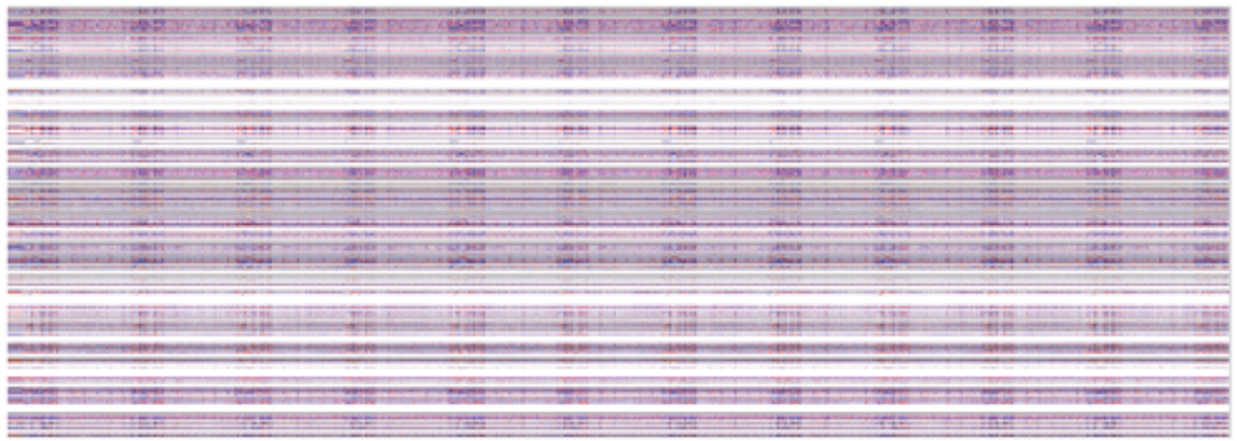


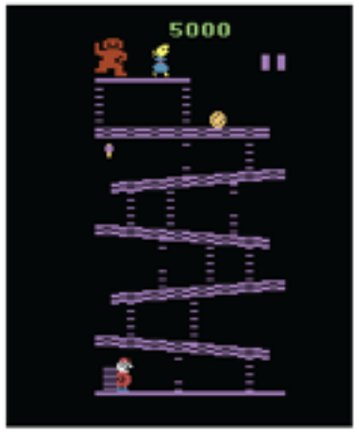
c. Pitfall

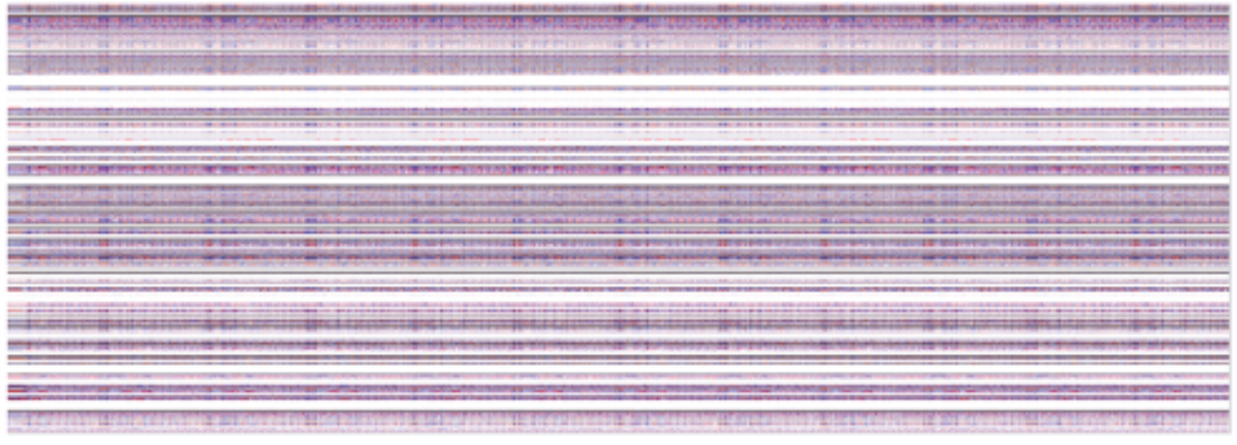
How to make these work?

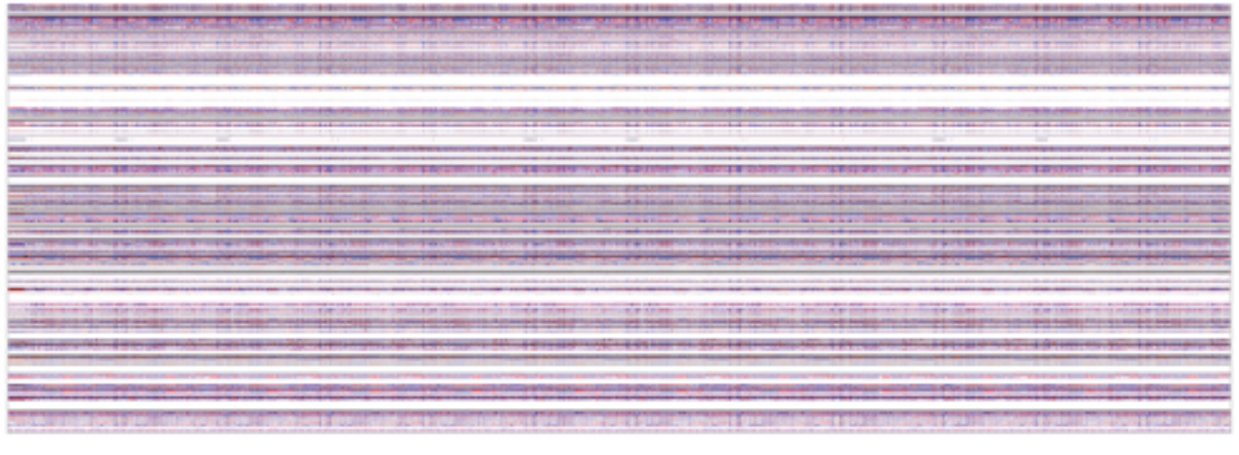
- No idea!

Whole chip



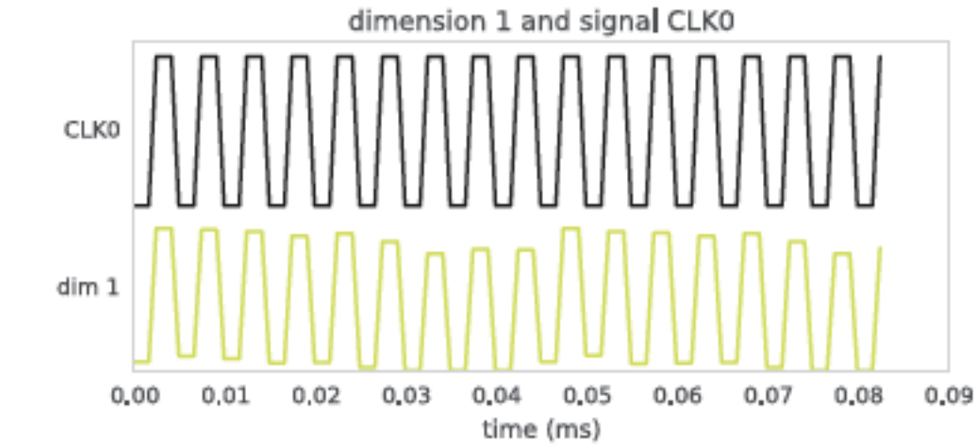


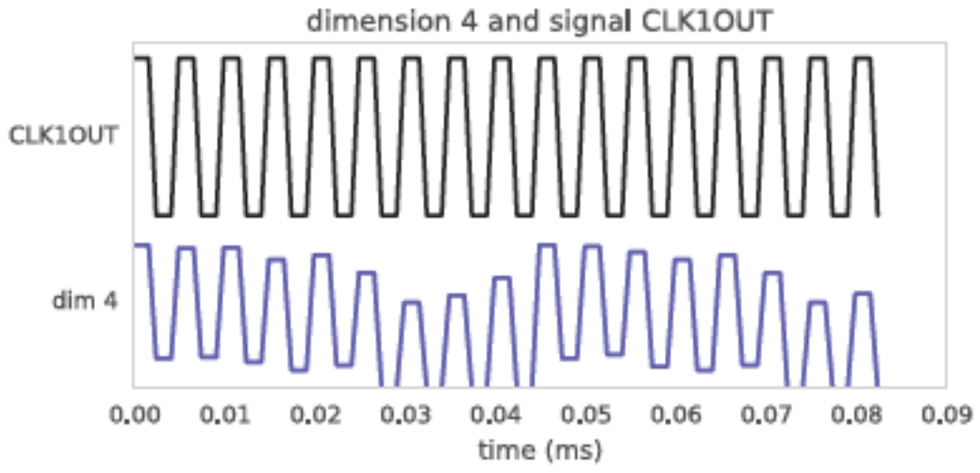


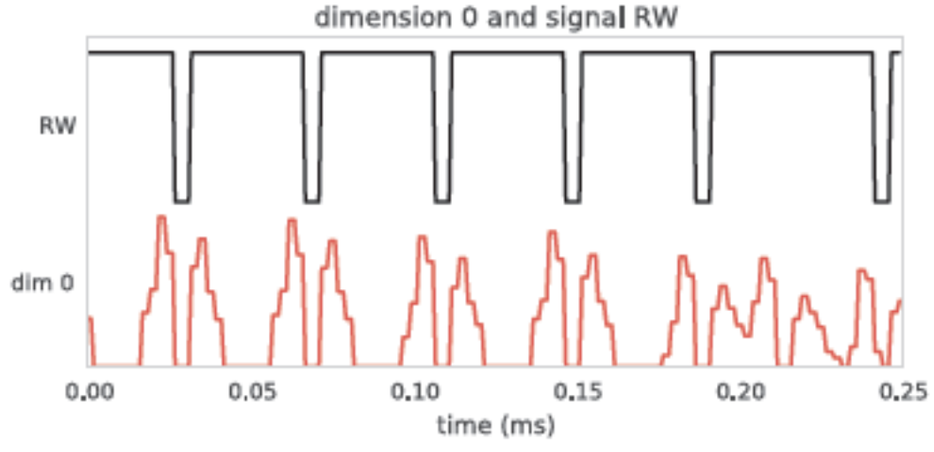


time

Nonnegative matrix factorization finds something



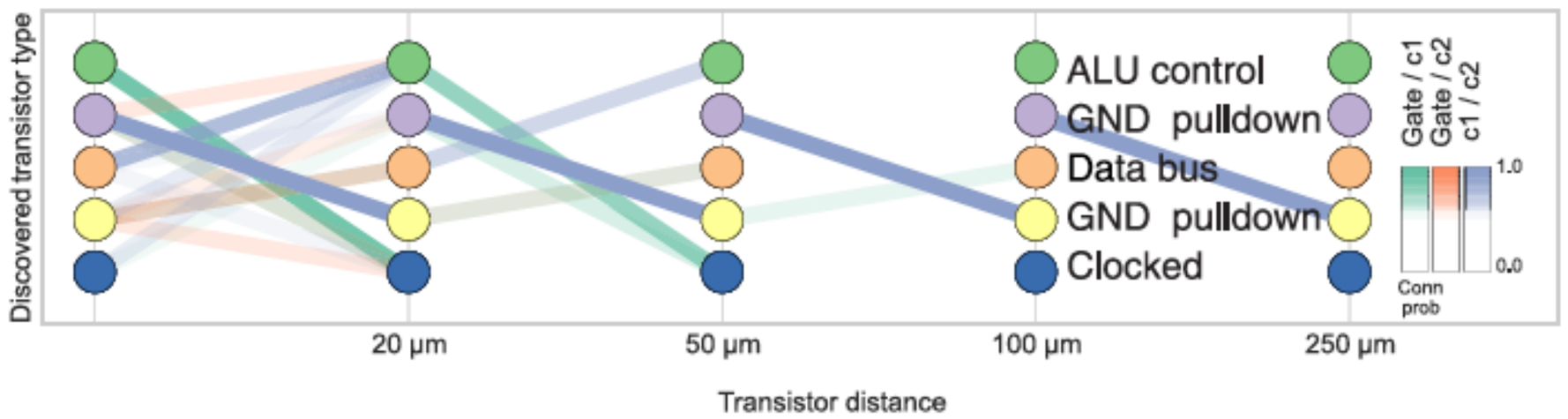




How to make these work?

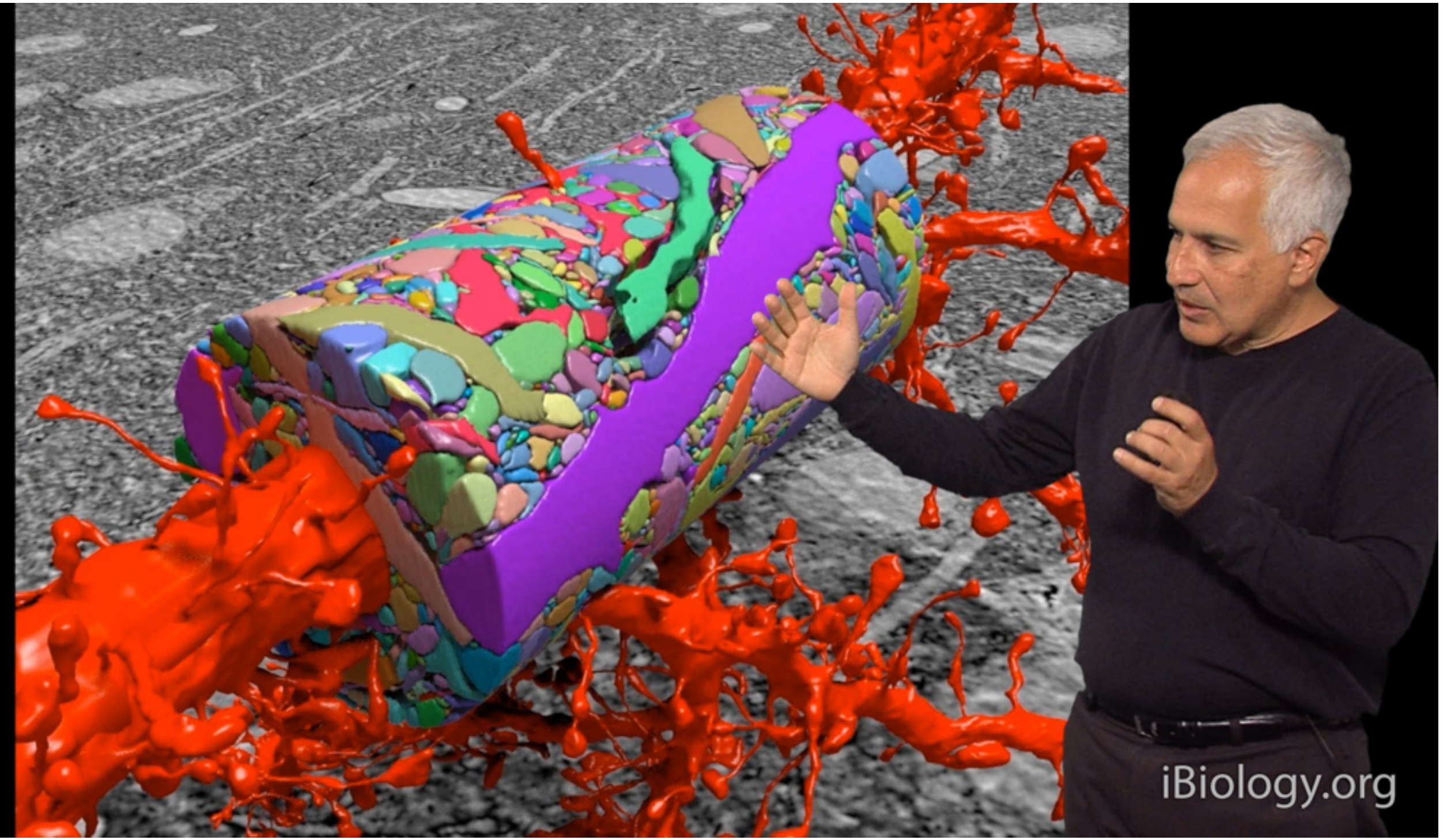
- Need far more different states to be meaningful
- Far more data
- Nonlinear dimensionality reduction

Souped up Stochastic block model finds some network structure

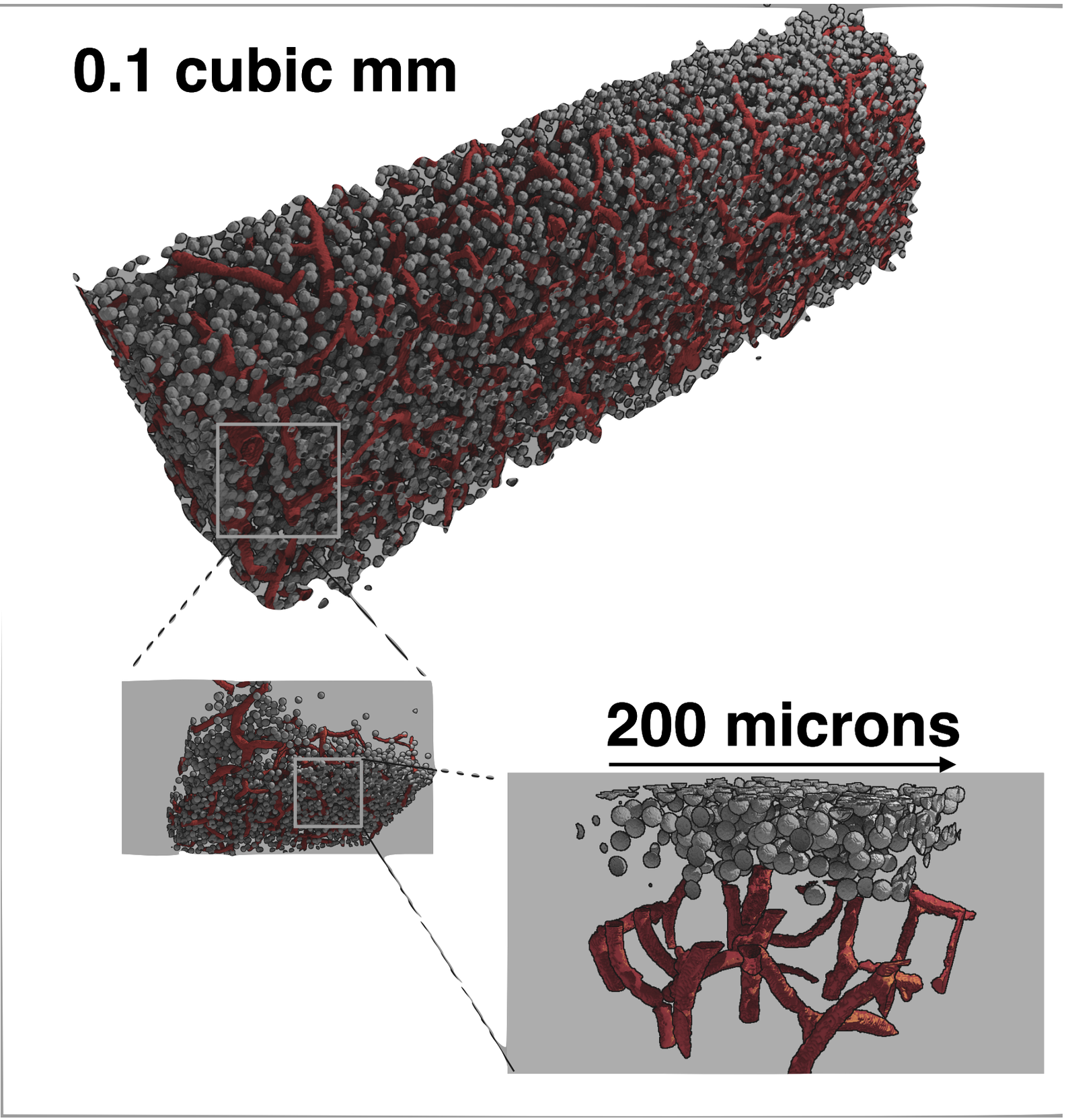


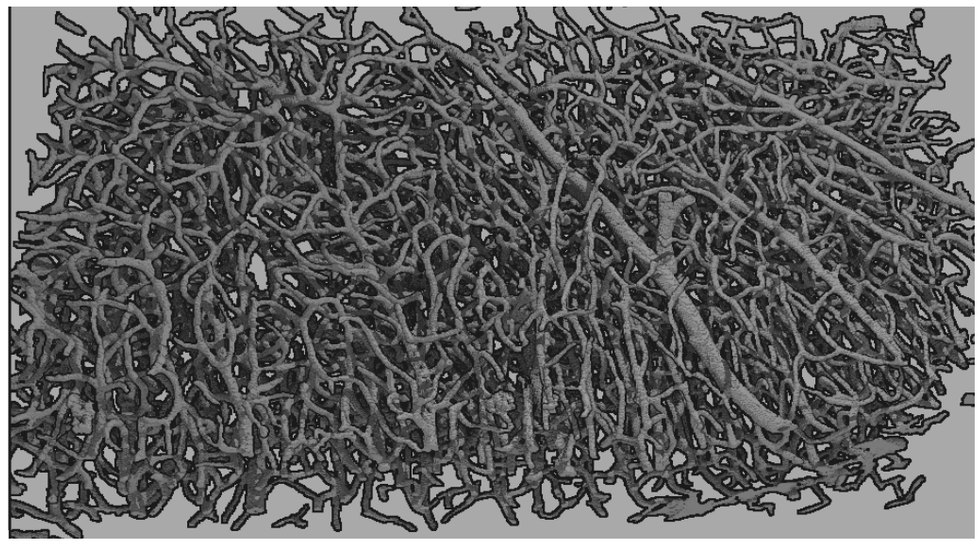
How to make it work

- Problem: The network is far more complicated
- *Same for the brain*
- Solutions hierarchical structure inference
  - MCMC is too slow, clustering too unspecific, needs something in between
  - Big systems



Kasthuri and Lichtman





with Kasthuri, Xiao, Jacobsen

Conclusion

- We know little about how the brain works
- Data by itself won’t solve the problem
- Need to ask the fundamental questions
- Countless big computational problems