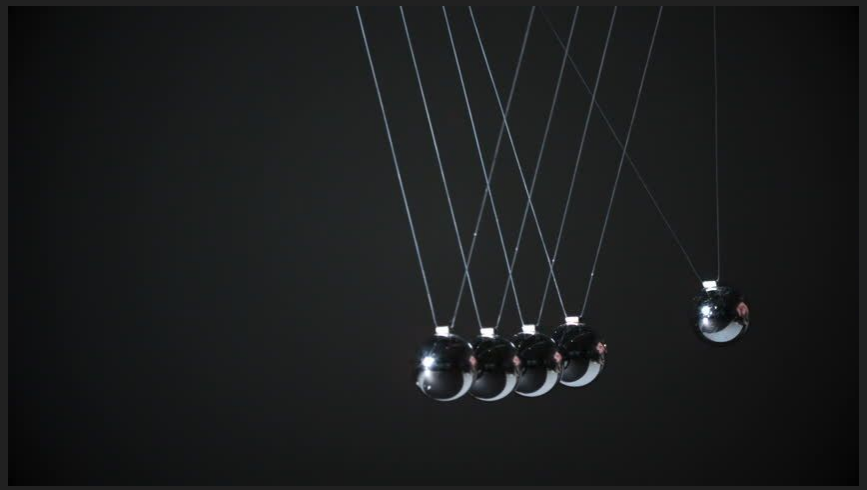
What is a physicist doing in a neuroscience department?

Yonatan Aljadeff, University of Chicago

A high-school student’s view:

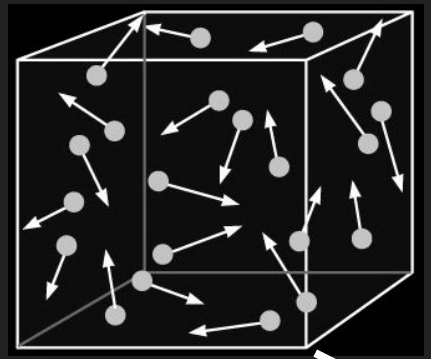
physics



neuroscience

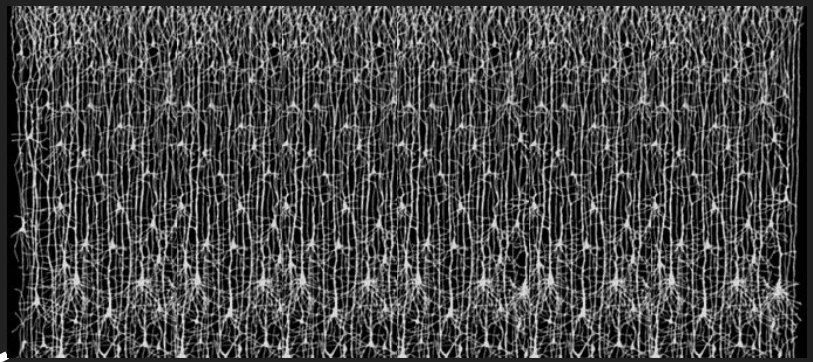
A college student’s view:

physics



temperature,
pressure

neuroscience



memory,
learning and cognitive capabilities

How does a zebra finch learn to sing?

Stages of song development

Tutor

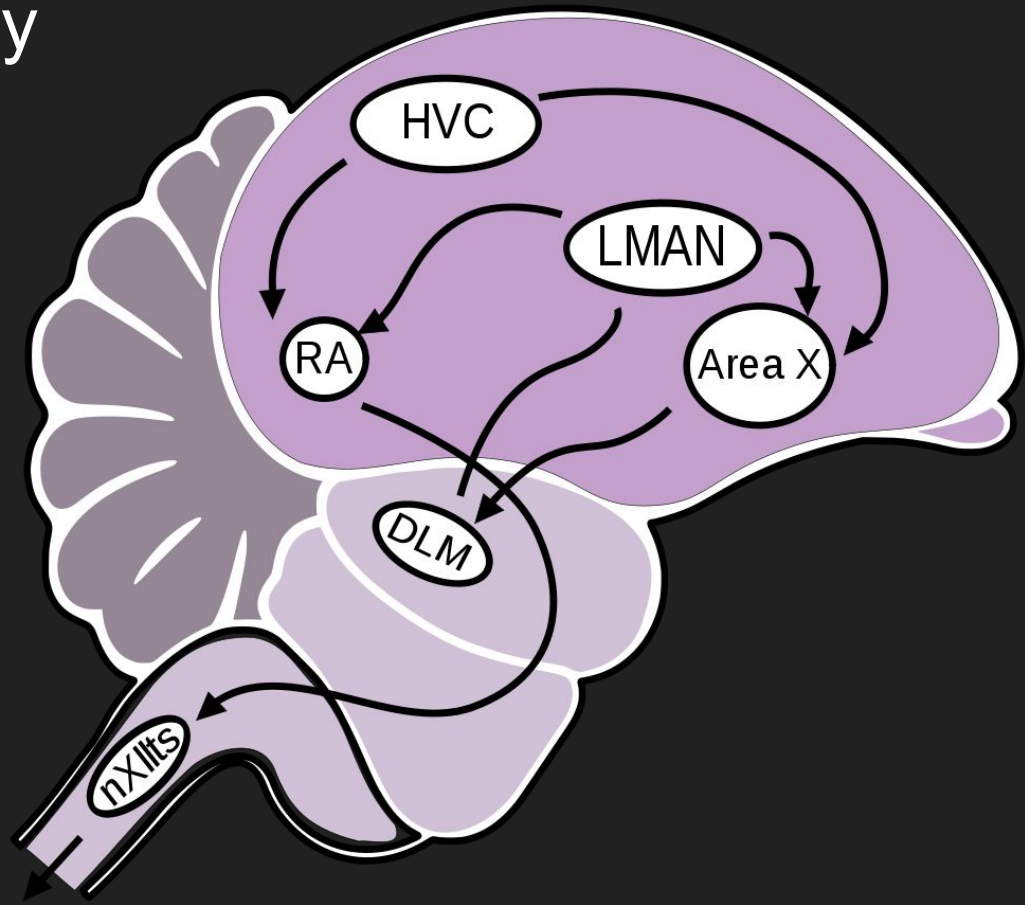
40 days

50 days

70 days

90 days

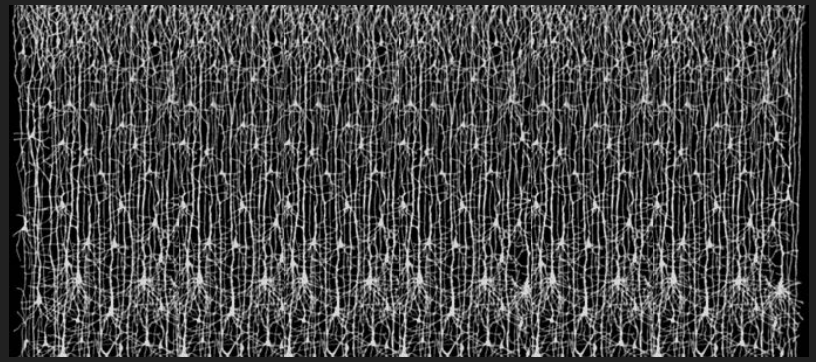
The relevant anatomy



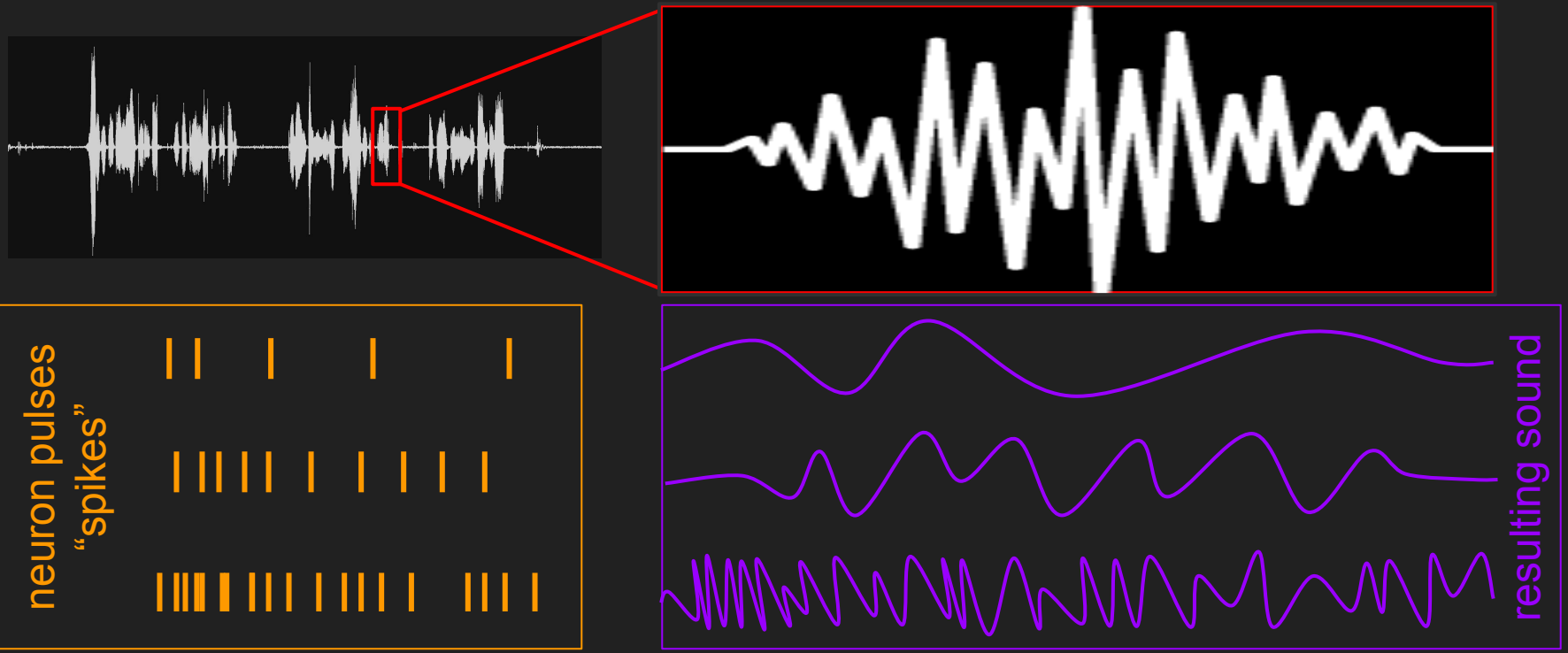
So we know something about songbird learning, now what do the physicists do?

Q1: What properties of the exploratory behavior allow learning?

Q2: How is this exploratory behavior generated?



Q1: What properties of the exploratory behavior allow effective learning?

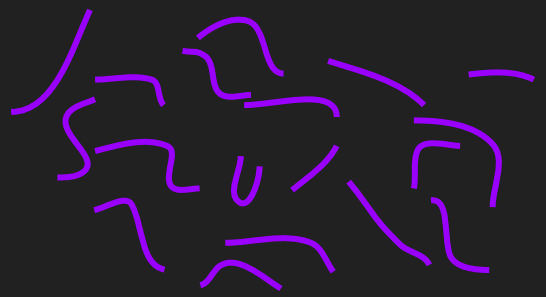


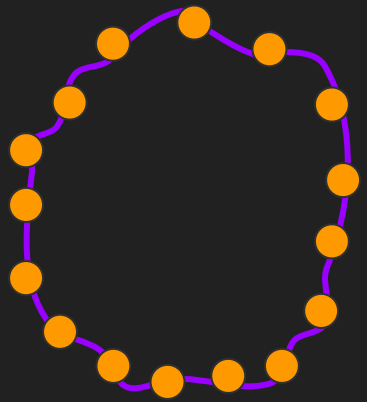
A1: Need specific frequency, and correlation of neural activity, to give “correct” exploratory behavior

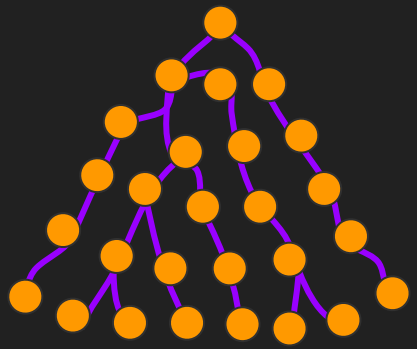
neuron pulses
“spikes”

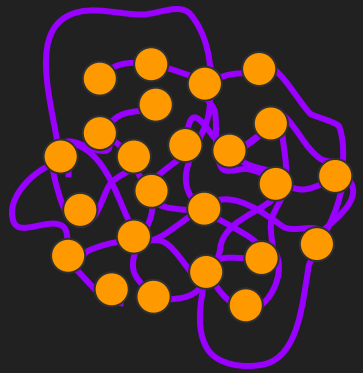
resulting sound

Q2: How is “correct” exploratory behavior generated?









Q2: How is “correct” exploratory behavior generated?

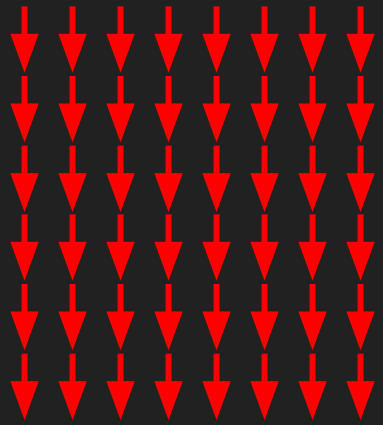
This was the central question of my PhD.
I will explain the approach we took in three steps.

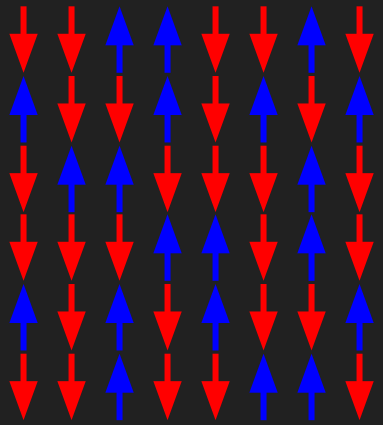
A. How does a *completely random* network behave?
B. How does a *random, structured* network behave?
C. Can we *design* the structure appropriately?

How does a *random* network behave?

When a network is completely random, every neuron is affected by the network in the exact same way.

This symmetry leads to what's known in physics as mean field theory, which is a tool used to analyze magnetic materials.



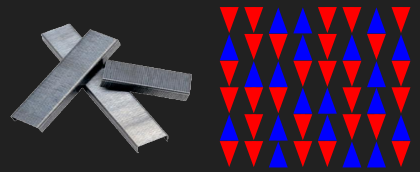


How does a *random* network behave?

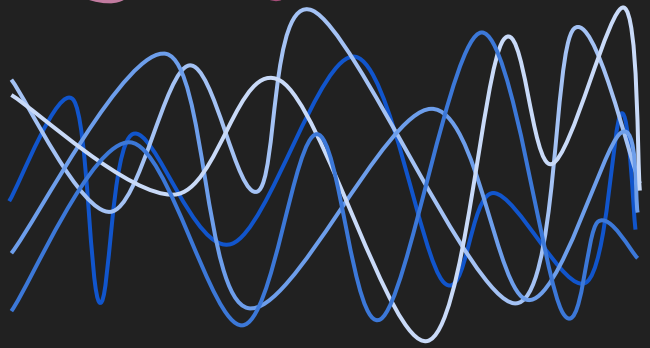
physics

all neurons are silent

neuroscience

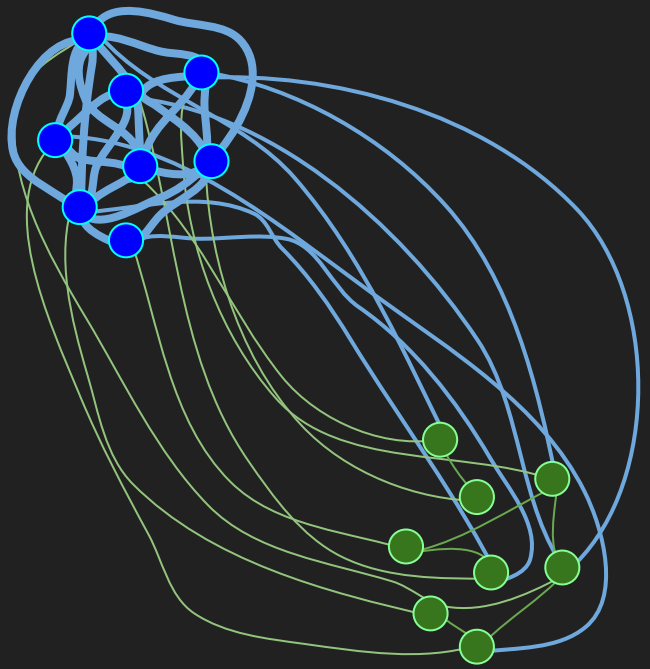


neurons fluctuate randomly



but no control over properties of spontaneous activity

How does a *random, structured* network behave?



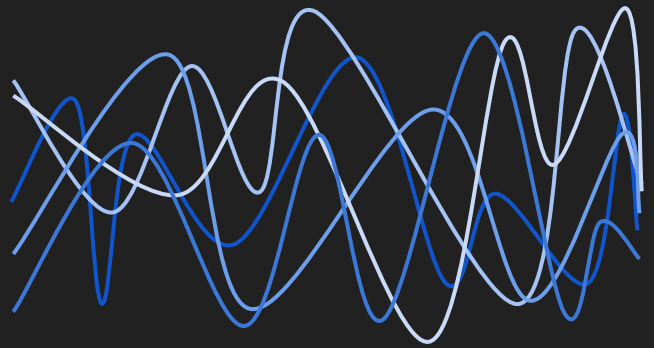
from / to		
	very weak	medium
	weak	strong

so the symmetry that we used previously does not apply.

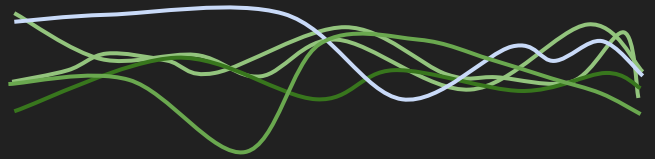
How does a *random, structured* network behave?

neurons fluctuate randomly in a way that depends on connectivity rules:

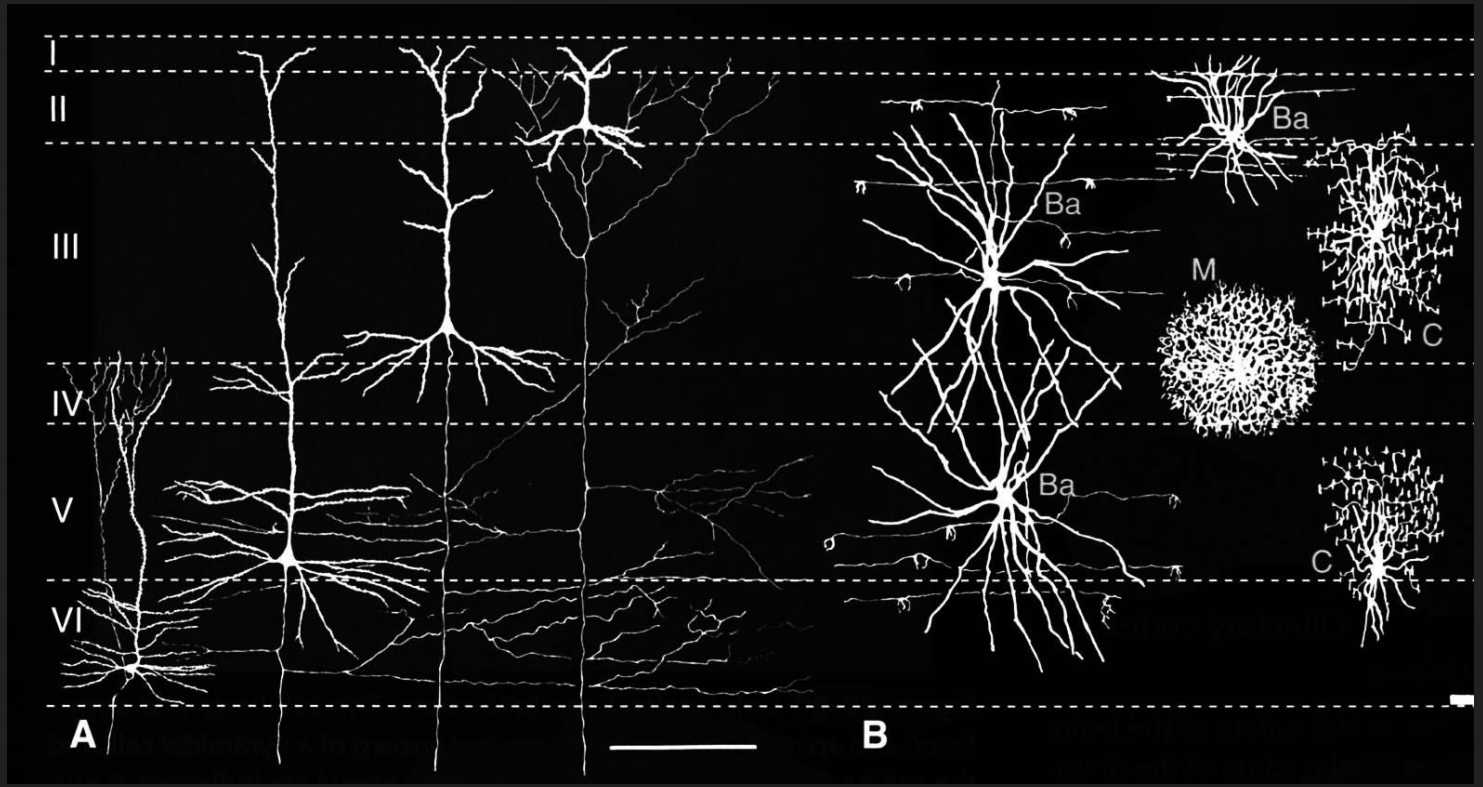
blue - high amplitude, fast



green - low amplitude, slow



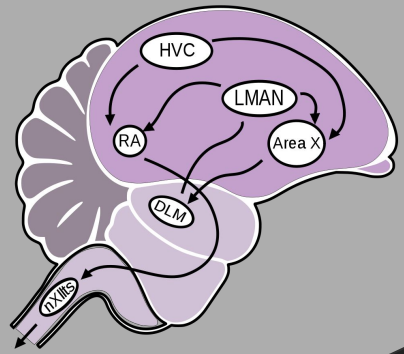
Can we *design* the structure appropriately?



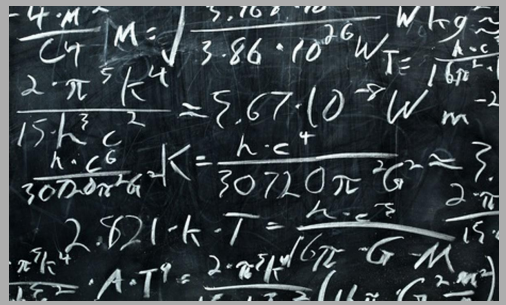
Closing the circle

behavior

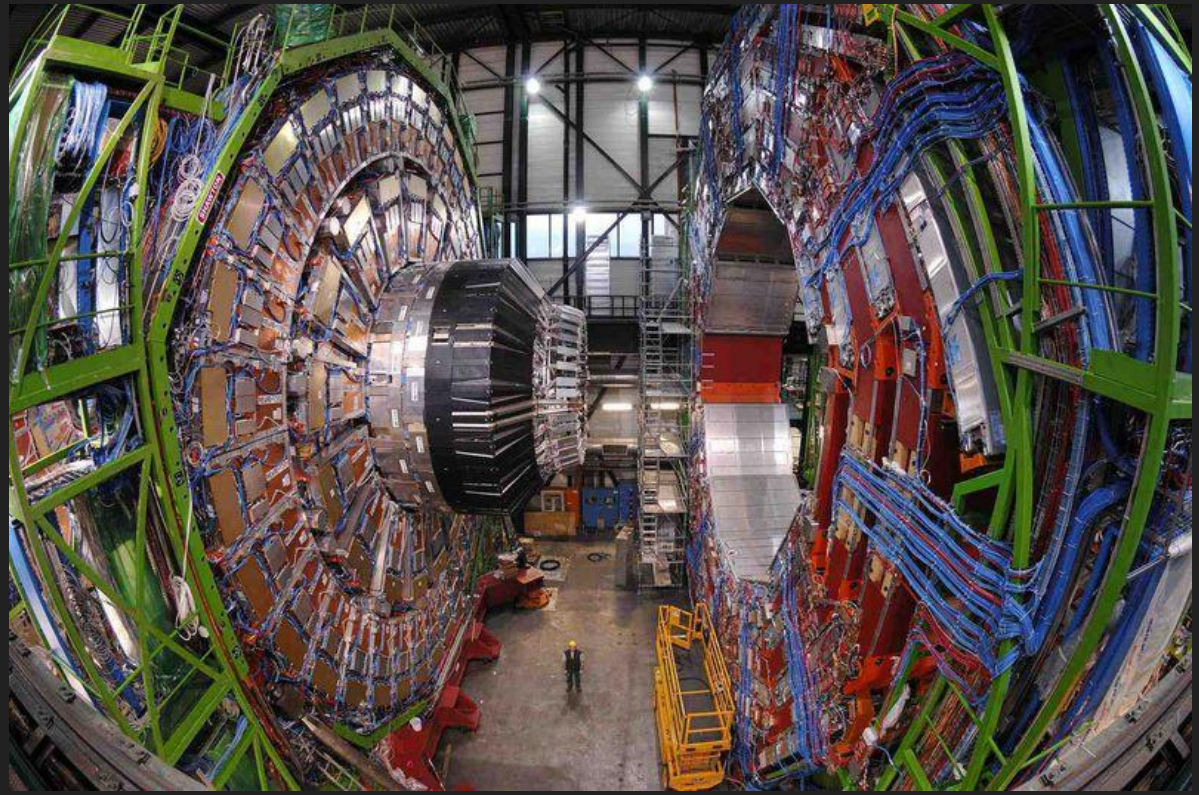
anatomy



theory



How far along are we?



A theory of the brain?

Not yet.

The field is developing an understanding in various systems.






The hope is that a multi-disciplinary theory will emerge.