2 Books

Theoretical Neuroscience: How questions?

- How to generate spikes as a single neuron?
- How to build SNN?

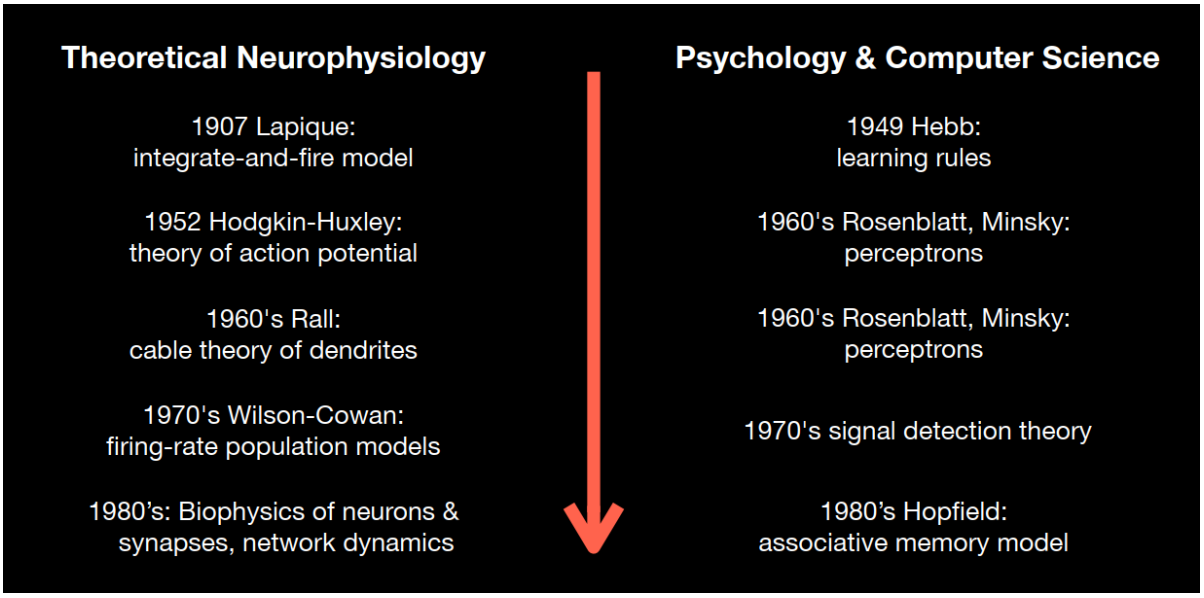
Principles of Neural Design: Why questions?

- Why do we have a brain?
- Why do we have a bigger brain?
- Why do we have different neuron types?

History Before 1988

Sejnowski et al., 1988: a famous review paper by 3 notable scientists.

In 2022 Fall, we covered 8 topics of these 10: except for cable theory and Wilson-Cowan model. You can read these on *Theoretical Neuroscience*



(figure from class slides)

There has been a lot progress after 1988.

In exactly 1988, Hinton and colleagues developed error-back-propagation.

Principles/Axioms of Neuroscience?

In physics, we always have some principles, like Newton-3-laws, thermodynamics-3-laws, Maxwell equations, Schrodinger equation, equal probability principle.

But in biology, we don't have such things. Maybe the only thing can be called principle in biology is Darwin's **Nature Selection**.

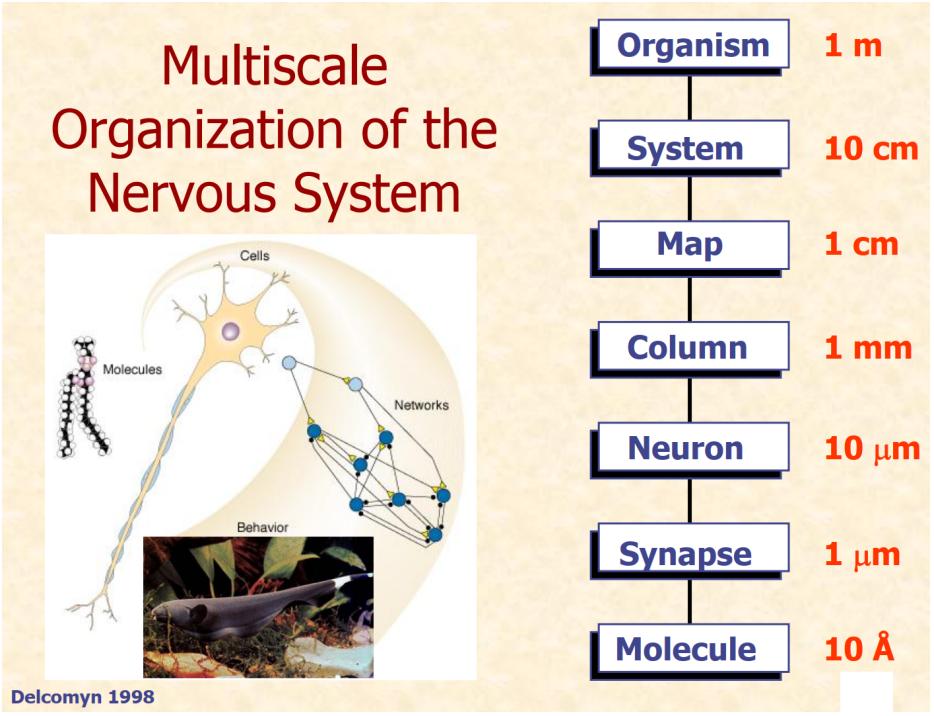
Goals of Neuroscience?

1. Understand how the brain works

More Is Different

More Is Different: Broken symmetry and the nature of the hierarchical structure of science: a famous paper by Philip Anderson in 1972

This "More Is Different" thing also plays important role in Neuroscience.



(figure from class slides)

David Marr vs Henry Markram

Marr

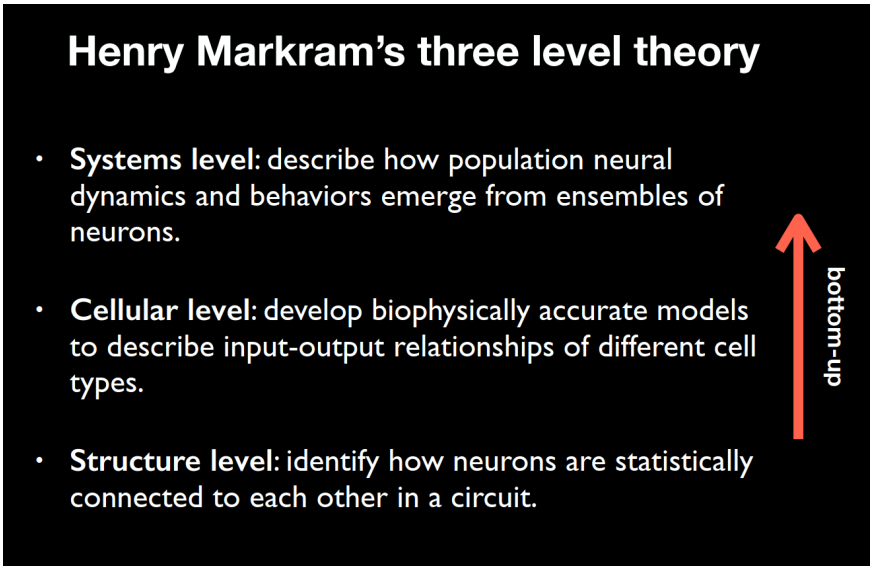
Computational theory	Representation and algorithm	Hardware implementation
What is the goal of the computation, why is it appropriate, and what is the logic of the strategy by which it can be carried out?	How can this computational theory be implemented? In particular, what is the representation for the input and output, and what is the algorithm for the transformation?	How can the representation and algorithm be realized physically?

Figure 1–4. The three levels at which any machine carrying out an information-processing task must be understood.

(figure from Vision)

In the past, algorithm needs a lot math. But now, just 炼丹。

Markram



This approach **succeeds** in physics (mechanics, thermodynamics, electrodynamics), but it **seems** to fail in neuroscience.

> Think about the AlexNet, the ResNet or the transformer. You know every connection between each pair of artificial neurons. But can you tell me how the transformer works?

PS: In 2009, Henry Markram claimed that he could build human brain in ten years. But he failed, along with the blue brain project. Blue Brain Project and Human Brain Project were highly related to each other and both got a lot of criticism. See this paper for the controversy.

Think

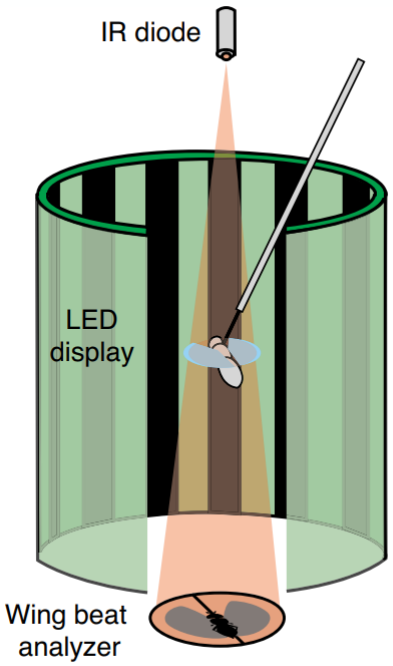
A friend of mine said that: both Marr's and Markram's theory has the biggest difficulty from the 2nd level to the 3rd level (from algorithm to hardware and from cell to system), do you agree with him?

Example: Vision of Fruit-fly

An experiment

Original paper in 2007.

PS: we want to use dragon-fly one day!

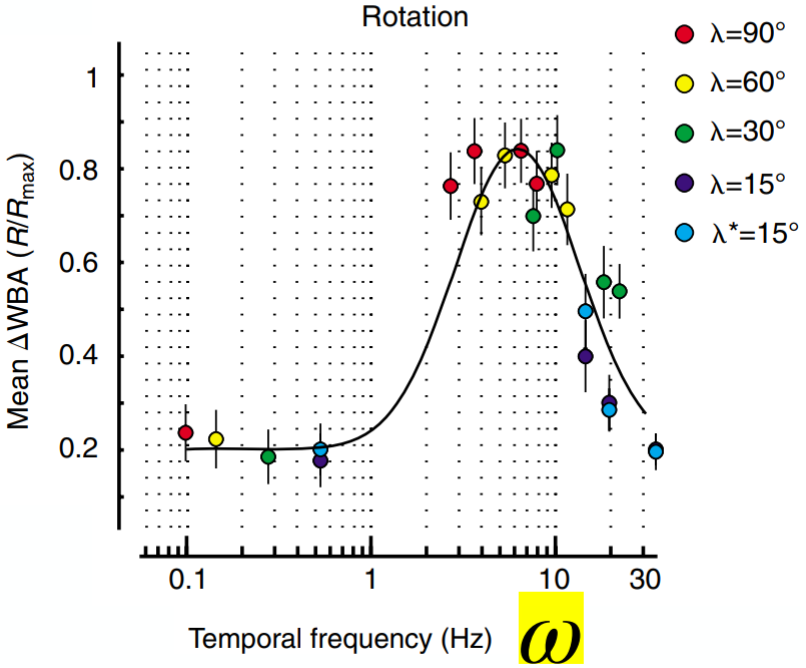


The stimulus is:

$$s(t) = sin(wt - kx)$$

The response is wing beat.

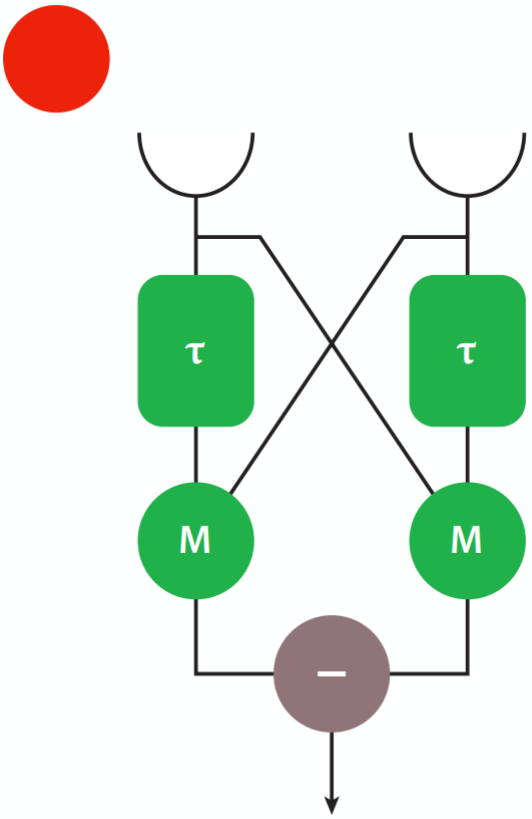
The response-stimulus plot is:



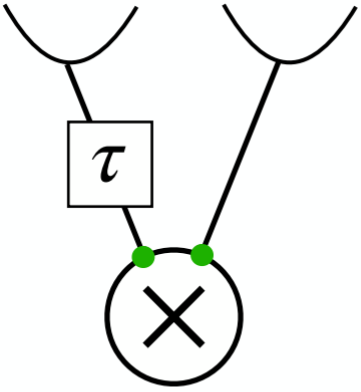
A theory

Original paper in 1956.

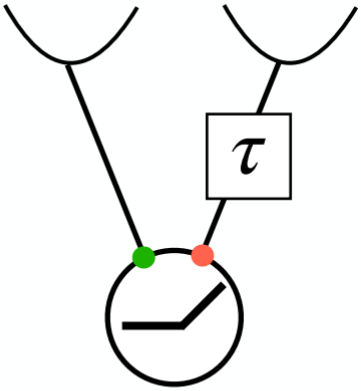
Attention: this model is for 2 near photo receptors in the retina, not for left eye and right eye!!!



Use ReLU instead of multiplication.



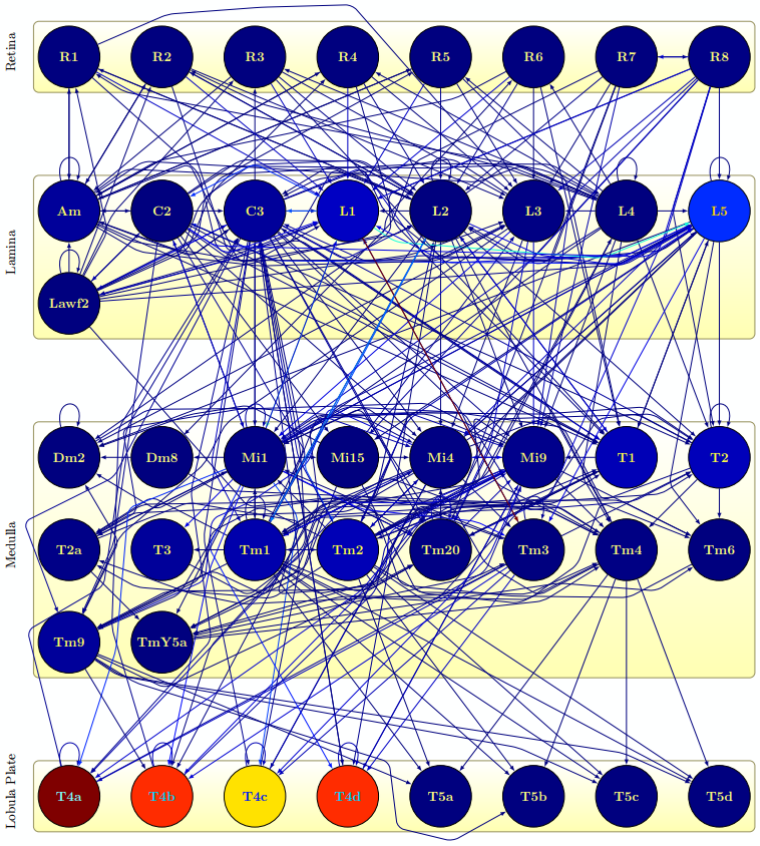
Reichardt model



barlow-levick model

Open the black box

Try to open the black box in Drosophila.



Think

Does this example have David Marr's 3 levels?