

Computational Neuroscience Course

An Introduction to Computational Neuroscience

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University of Science and Technology of China

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Course website

<https://github.com/Wenlab/Computation-Neuro-Course/tree/Fall2023>

The screenshot shows a dark-themed GitHub README.md page. At the top left is a navigation bar with three horizontal lines and the text "README.md". At the top right is a small edit icon. The main title "Computational-Neuroscience-Course" is centered above a horizontal line. Below the line, the text describes the repository's purpose: "This repository serves as an ongoing effort to create a systems and computational neuroscience course. I hope to develop a two-semester course for USTC biophysics students. The first semester will cover some basic materials, and the second semester will introduce more advanced topics for undergraduate and graduate students." Following this, there are sections for "When", "Where", "Teacher", "Teaching Fellow", "Recommended Textbooks", "Course Performance Evaluation", and "Summary". Each section contains bullet points or descriptive text. The "Teacher" and "Teaching Fellow" sections include email addresses. The "Recommended Textbooks" and "Course Performance Evaluation" sections also include links.

README.md

Computational-Neuroscience-Course

This repository serves as an ongoing effort to create a systems and computational neuroscience course. I hope to develop a two-semester course for USTC biophysics students. The first semester will cover some basic materials, and the second semester will introduce more advanced topics for undergraduate and graduate students.

When: Thursday 9:45 am - 11:20 am, Fall 2023

Where: 东区第二教学楼2603

Teacher: 温泉 qwen@ustc.edu.cn

Teaching Fellow: 李懿轩 hyperdunk2019@mail.ustc.edu.cn

Recommended Textbooks:

- [Theoretical Neuroscience: Computational and Mathematical Modeling the Neural System](#)
- [Principles of Neural Design](#)

Course Performance Evaluation:

- Homework: 70%
- Final: 30%

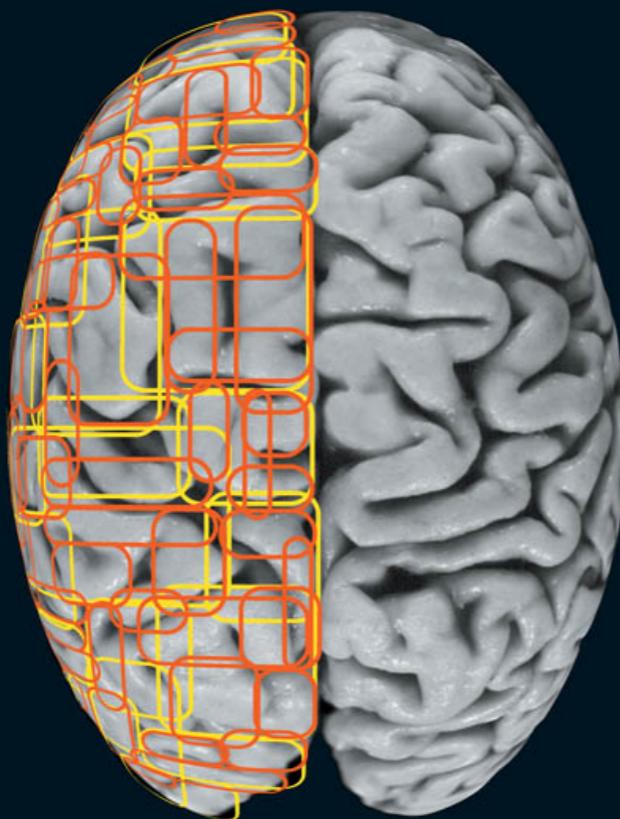
Summary

How intelligence and behavior emerge from complex and intricate interactions within the brain remain important and unsolved mysteries in modern science. This is an exciting time. In the last decade, we have seen rapid progress in experimental tools that now make it possible to monitor and manipulate brain circuits in unprecedented detail. This is also a confusing time. Neuroscientists are lost in the jungles of brain structures and dynamics.

Recommended textbooks

THEORETICAL NEUROSCIENCE

Computational and Mathematical
Modeling of Neural Systems



Peter Dayan and L. F. Abbott

How questions

Principles of
Neural Design



Peter Sterling and Simon Laughlin

Why questions

A brief pre-history

Theoretical Neurophysiology

1907 Lapique:
integrate-and-fire model

1952 Hodgkin-Huxley:
theory of action potential

1960's Rall:
cable theory of dendrites

1970's Wilson-Cowan:
firing-rate population models

1980's: Biophysics of neurons &
synapses, network dynamics

Psychology & Computer Science

1949 Hebb:
learning rules

1960's Rosenblatt, Minsky:
perceptrons

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1970's signal detection theory

1980's Hopfield:
associative memory model



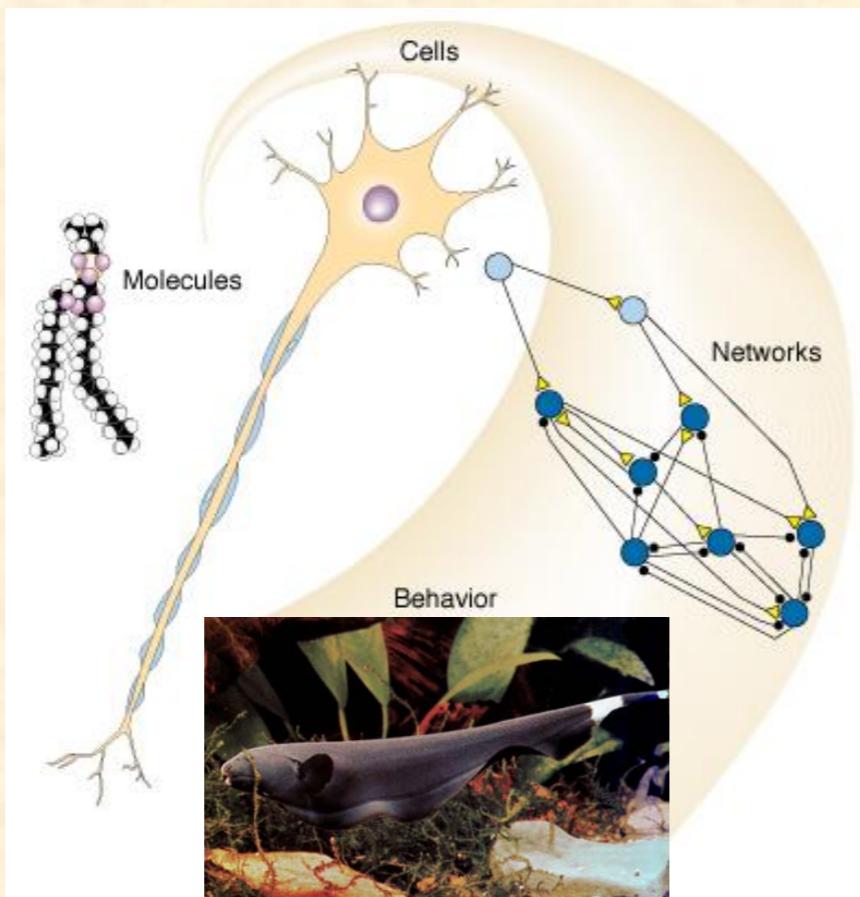
Sejnowski, Koch, Churchland, Computational neuroscience. *Science* 1988 241: 1299-1306
Methods in Computational Neuroscience Summer School, Marine Biological Laboratory

adapted from Xiaojing Wang's slide

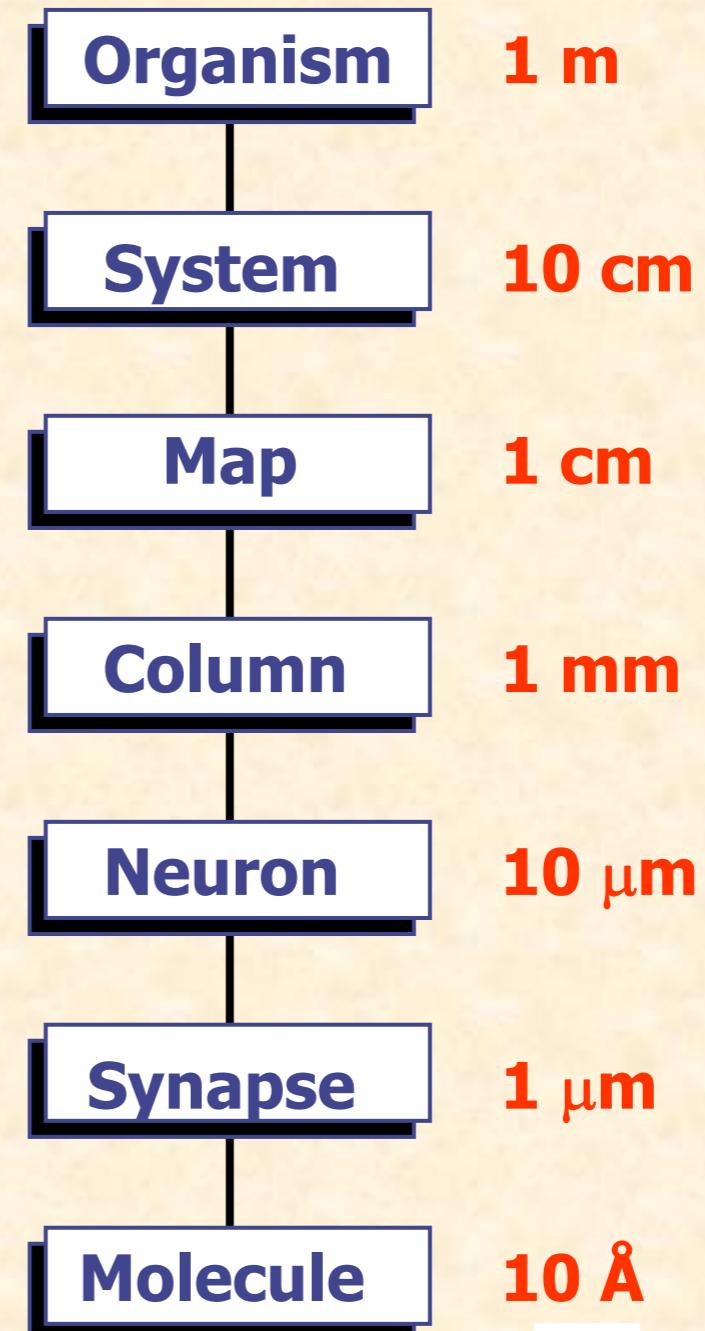
Principles of Neuroscience ?



Multiscale Organization of the Nervous System



Delcomyn 1998



“To pile speculation on speculation, I would say that the next stage could be hierarchy or specialization of function, or both.... with increasing complication at each stage, we go on up the hierarchy of sciences. We expect to encounter fascinating and, I believe, very fundamental questions at each stage in fitting together less complicated pieces into the more complicated system and understanding the basically new types of behavior which can result.”

P. W. Anderson, 1972
condensed matter physicist

More is different

Fitzgerald: The rich are **different** from us.

Hemingway: Yes, they have **more** money.

a conversation somewhere in Paris in 1920s



David Marr
1945-1980



Henry Markram
1962 -

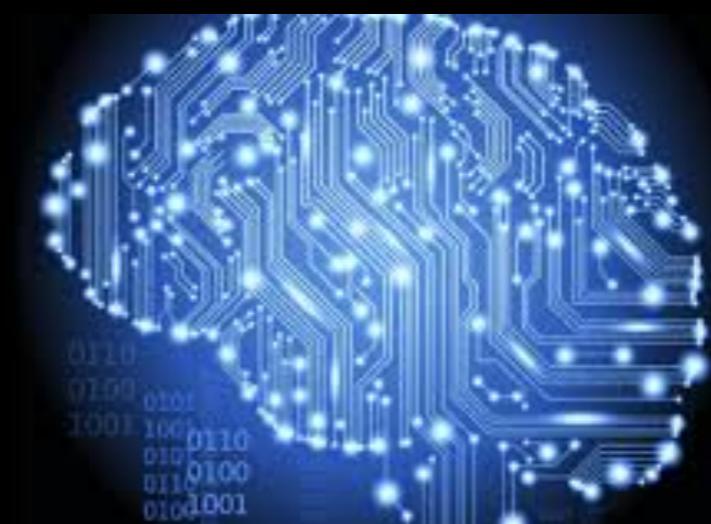
VISION



David Marr

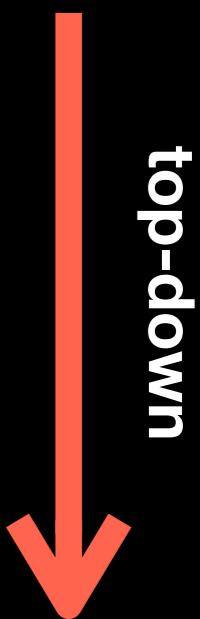
FOREWORD BY
Shimon Ullman
AFTERWORD BY
Tomaso Poggio

blue brain project



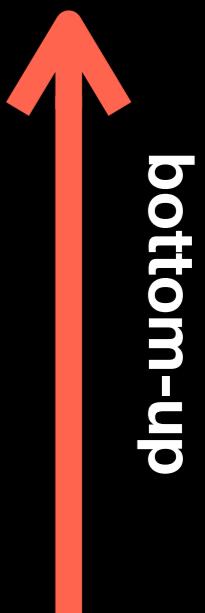
David Marr's three level theory

- **Computational level:** Identify the computational problem and task that the brain solves.
- **Algorithmic level:** Find the mathematical procedures that solve the problem.
- **Implementation level:** How the algorithms are realized by the nervous system.



Henry Markram's three level theory

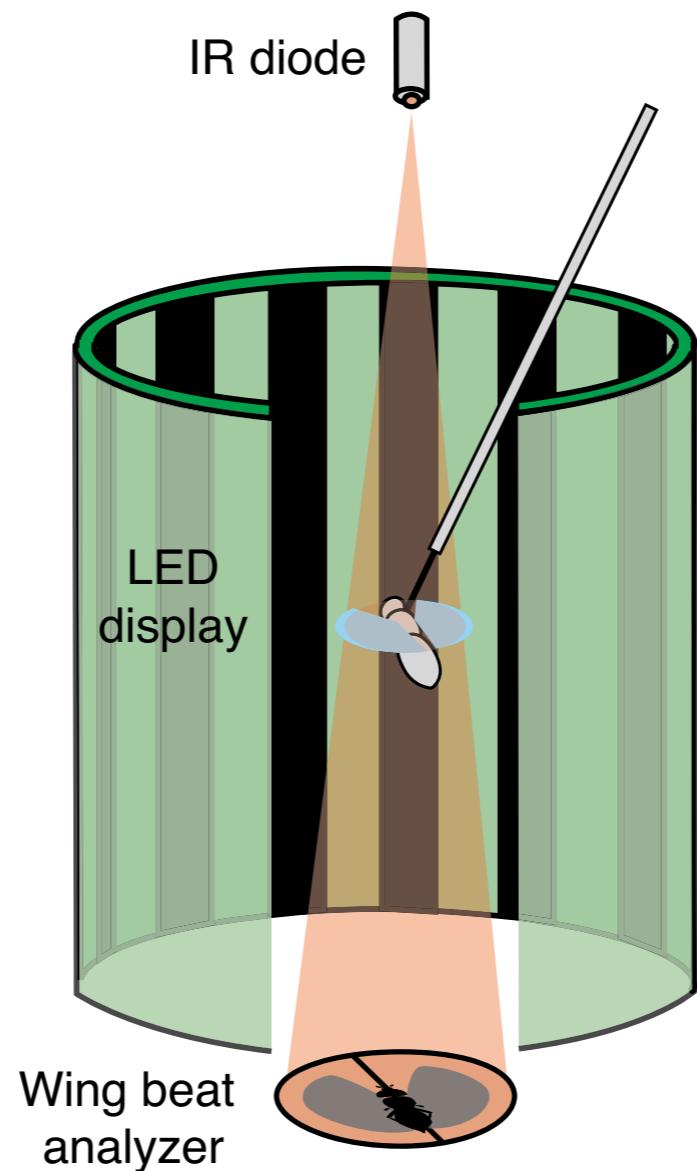
- **Systems level:** describe how population neural dynamics and behaviors emerge from ensembles of neurons.
- **Cellular level:** develop biophysically accurate models to describe input-output relationships of different cell types.
- **Structure level:** identify how neurons are statistically connected to each other in a circuit.



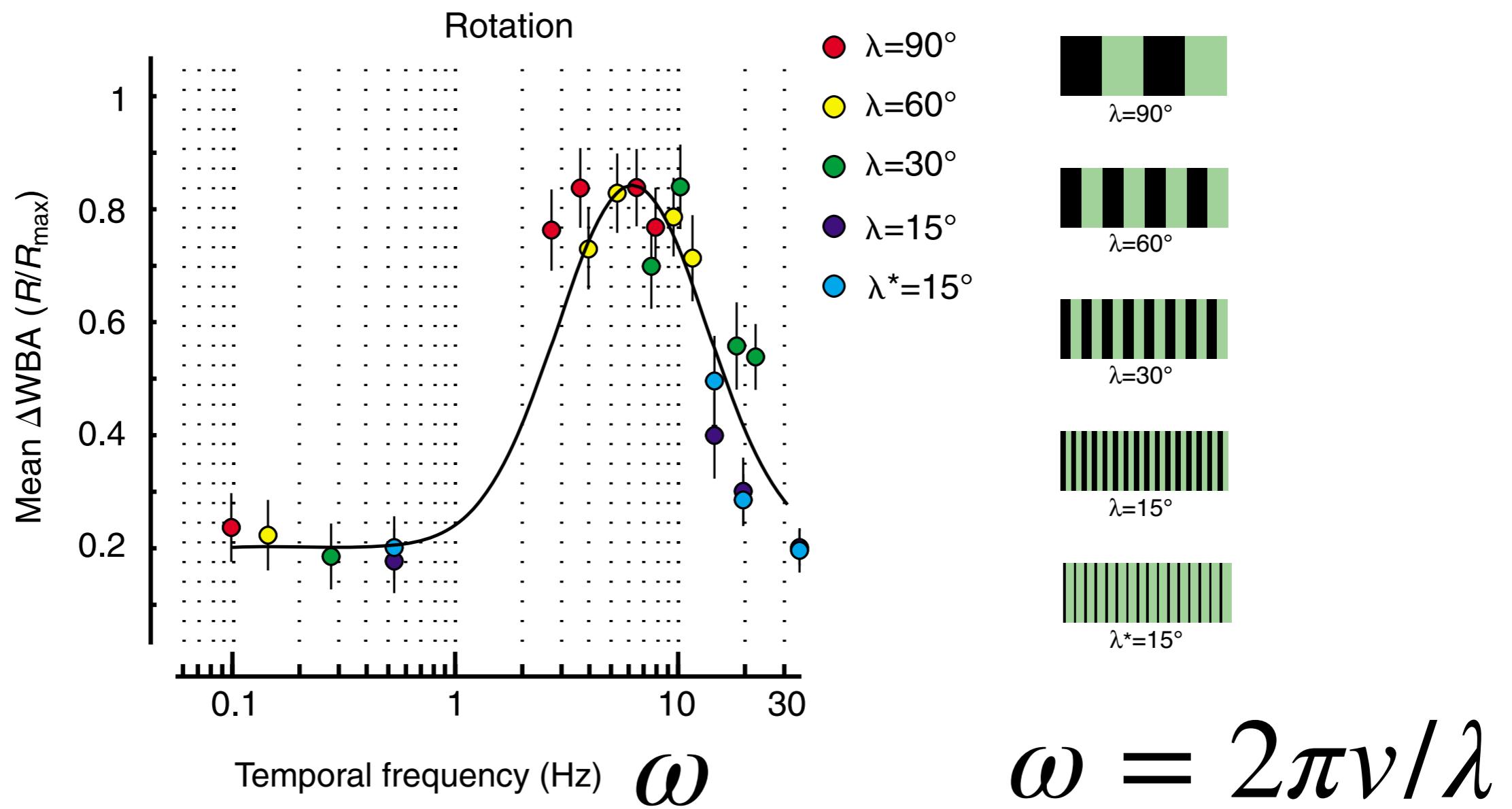
Motion detection, an example



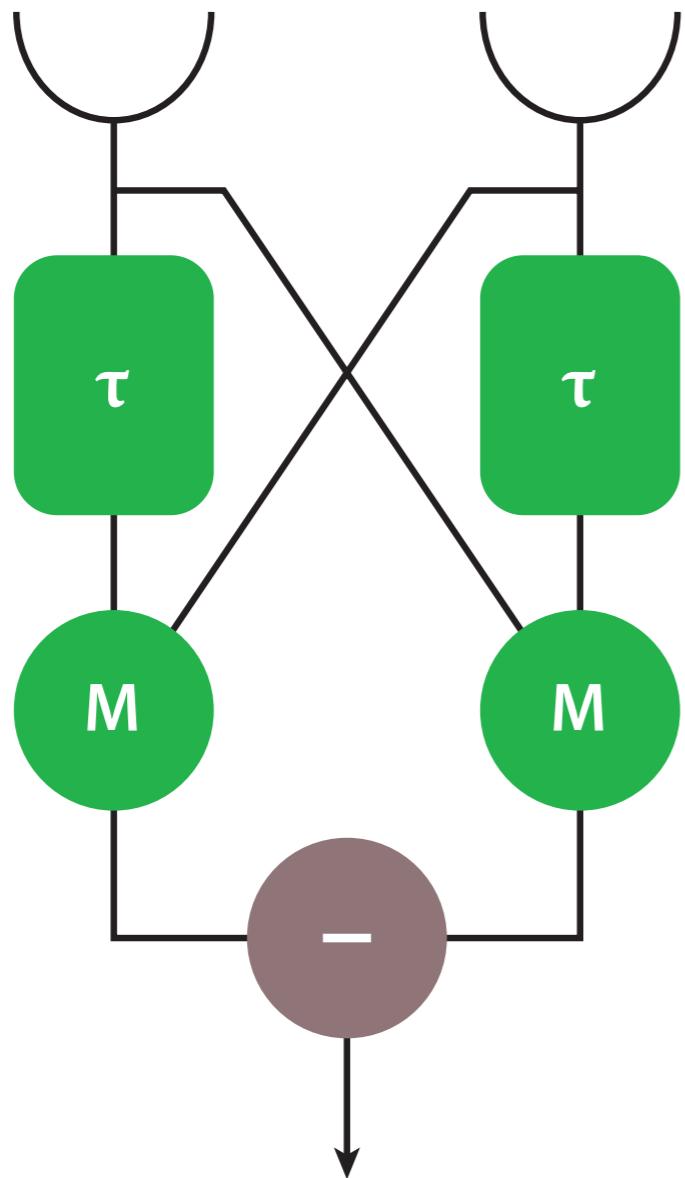
Optomotor response in fly



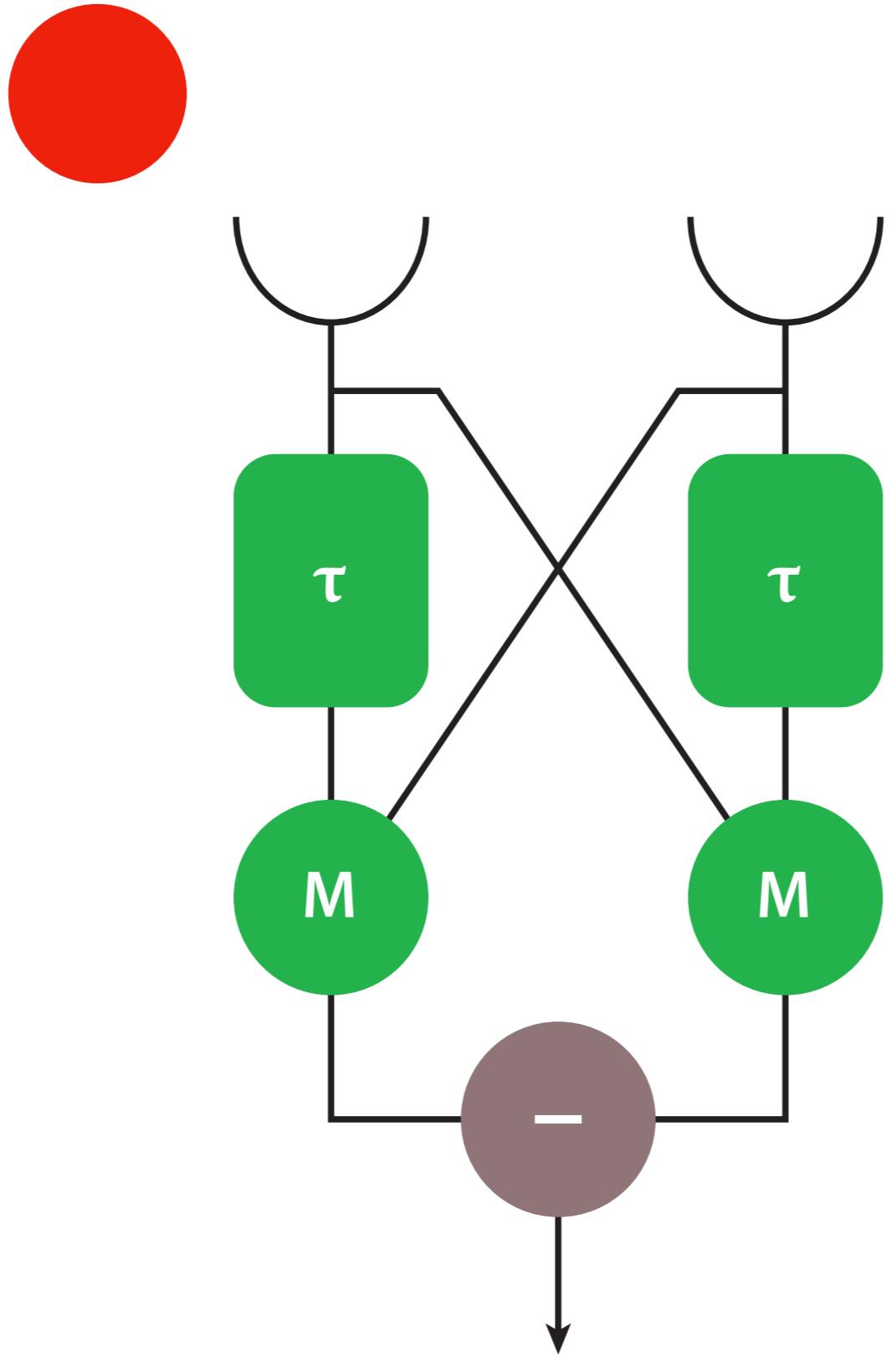
Optomotor response in fly

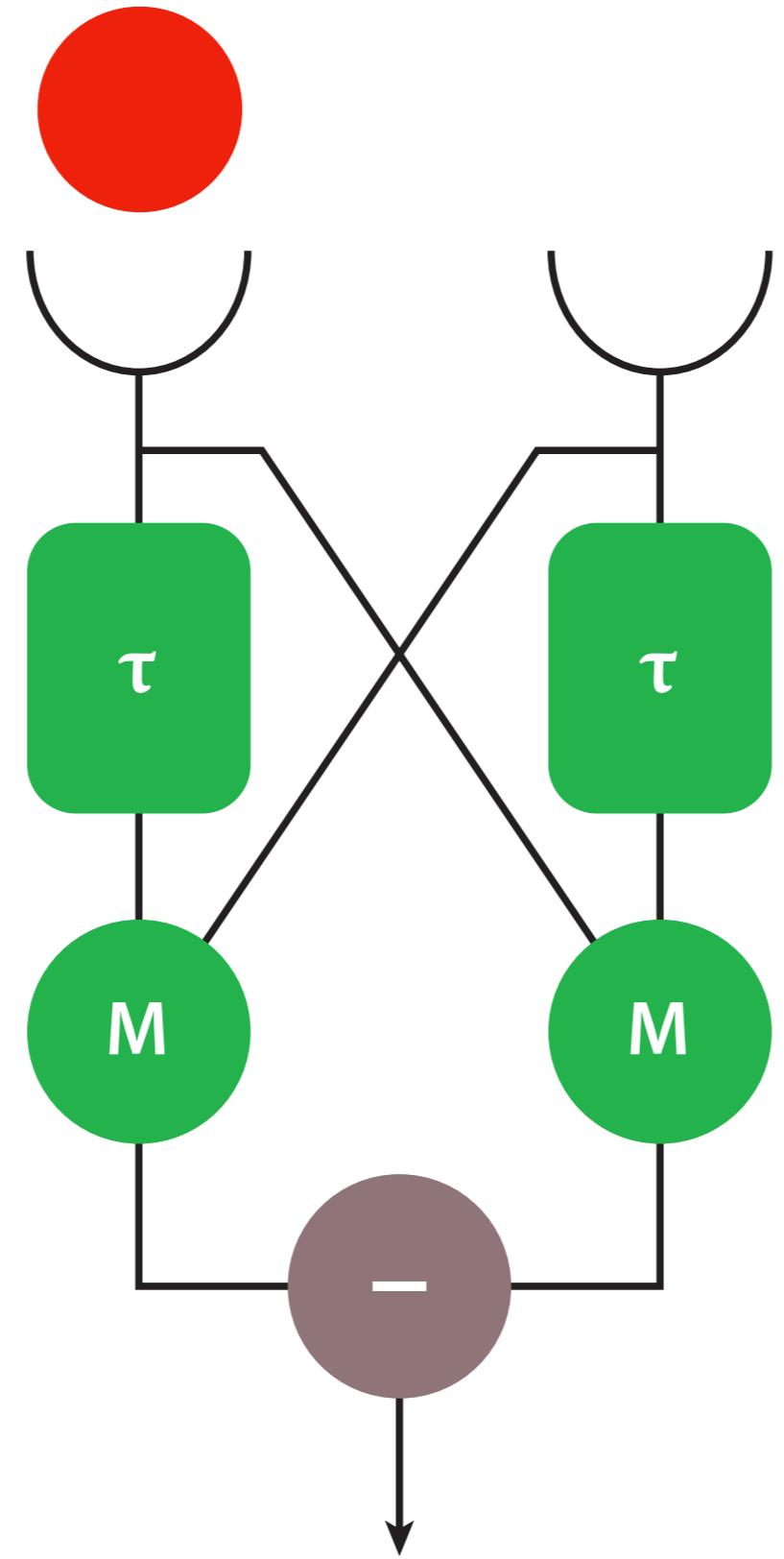


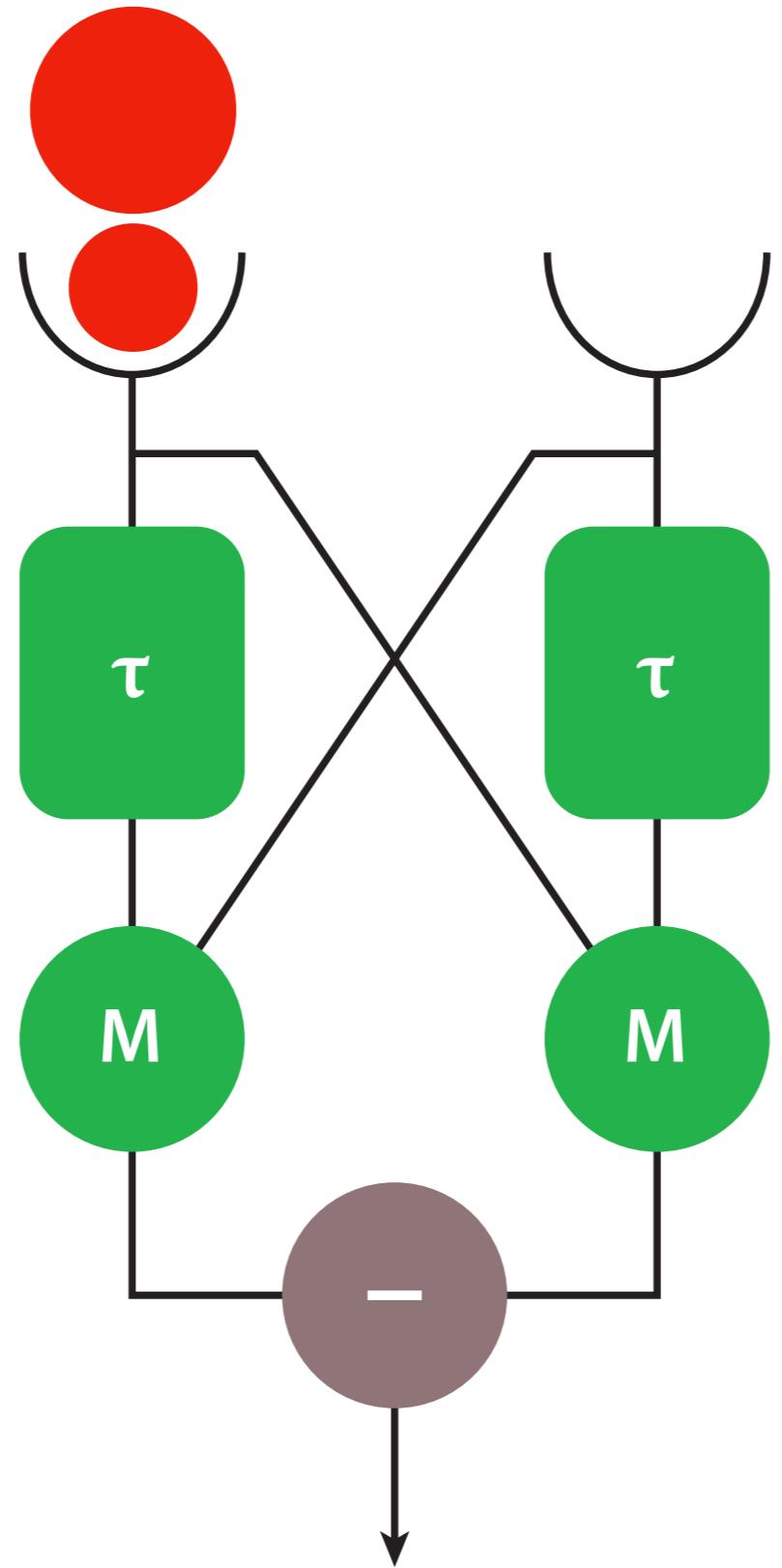
Hassenstein-Reichardt Detector Model

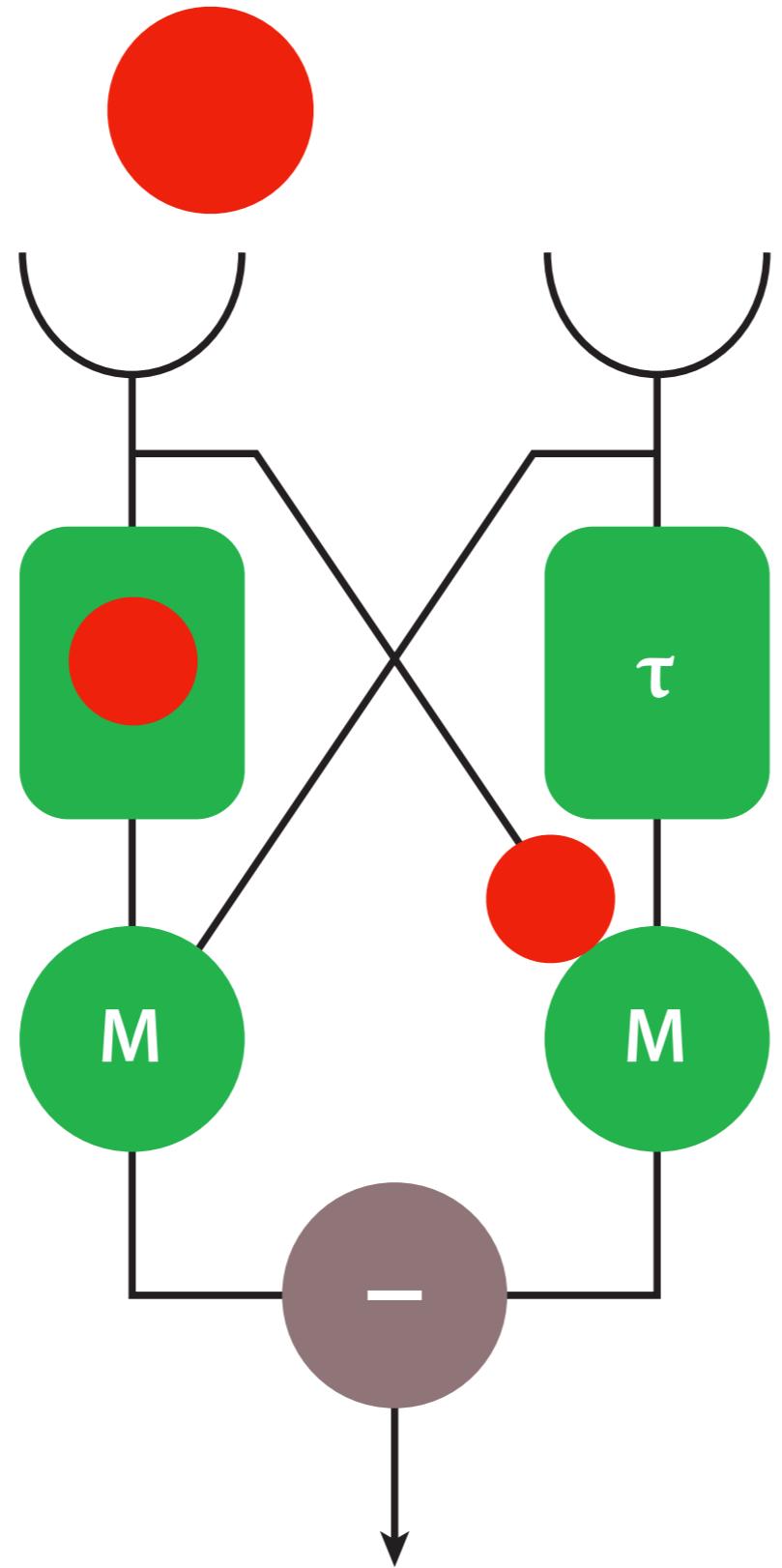


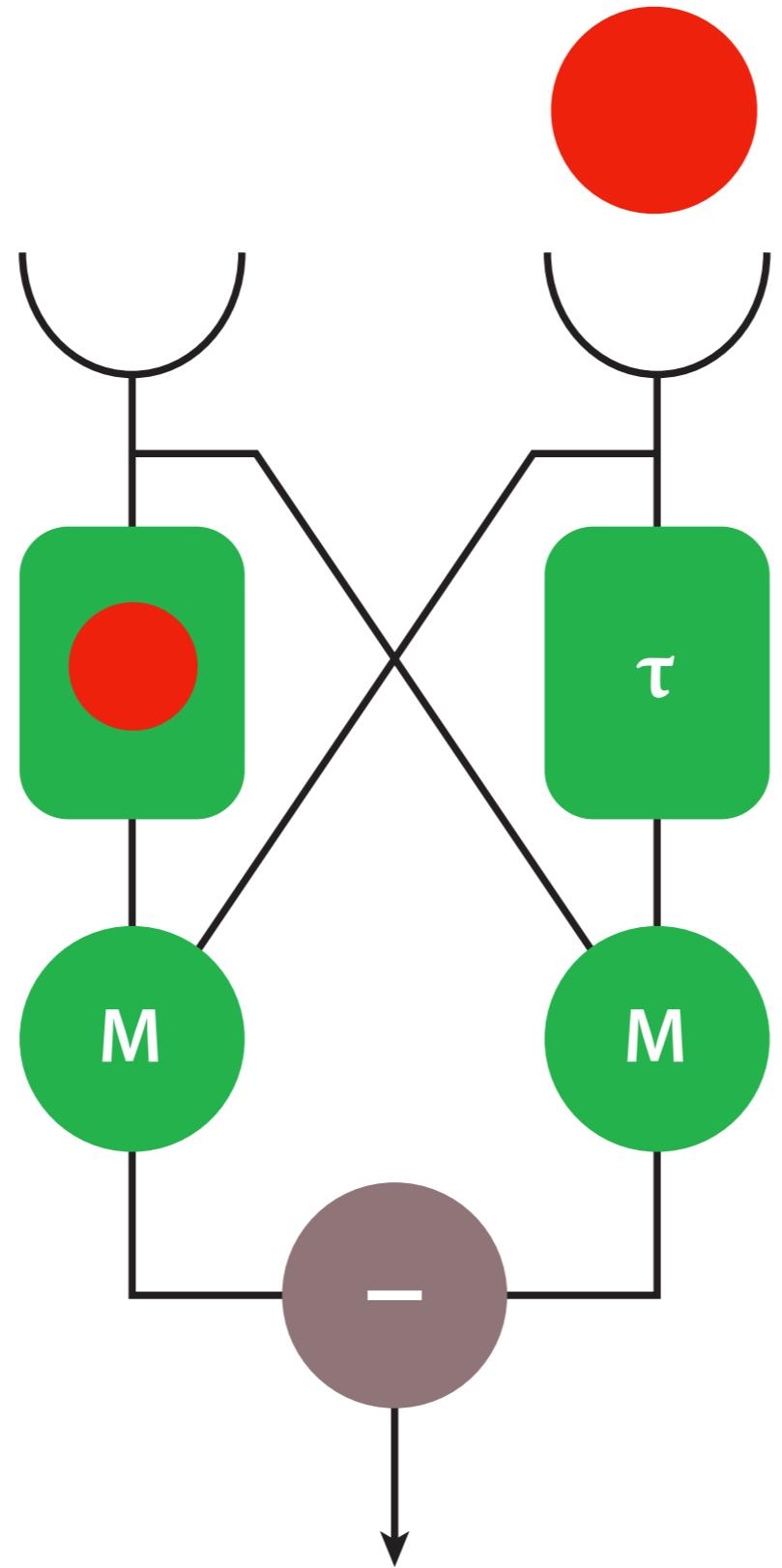
Werner Reichardt

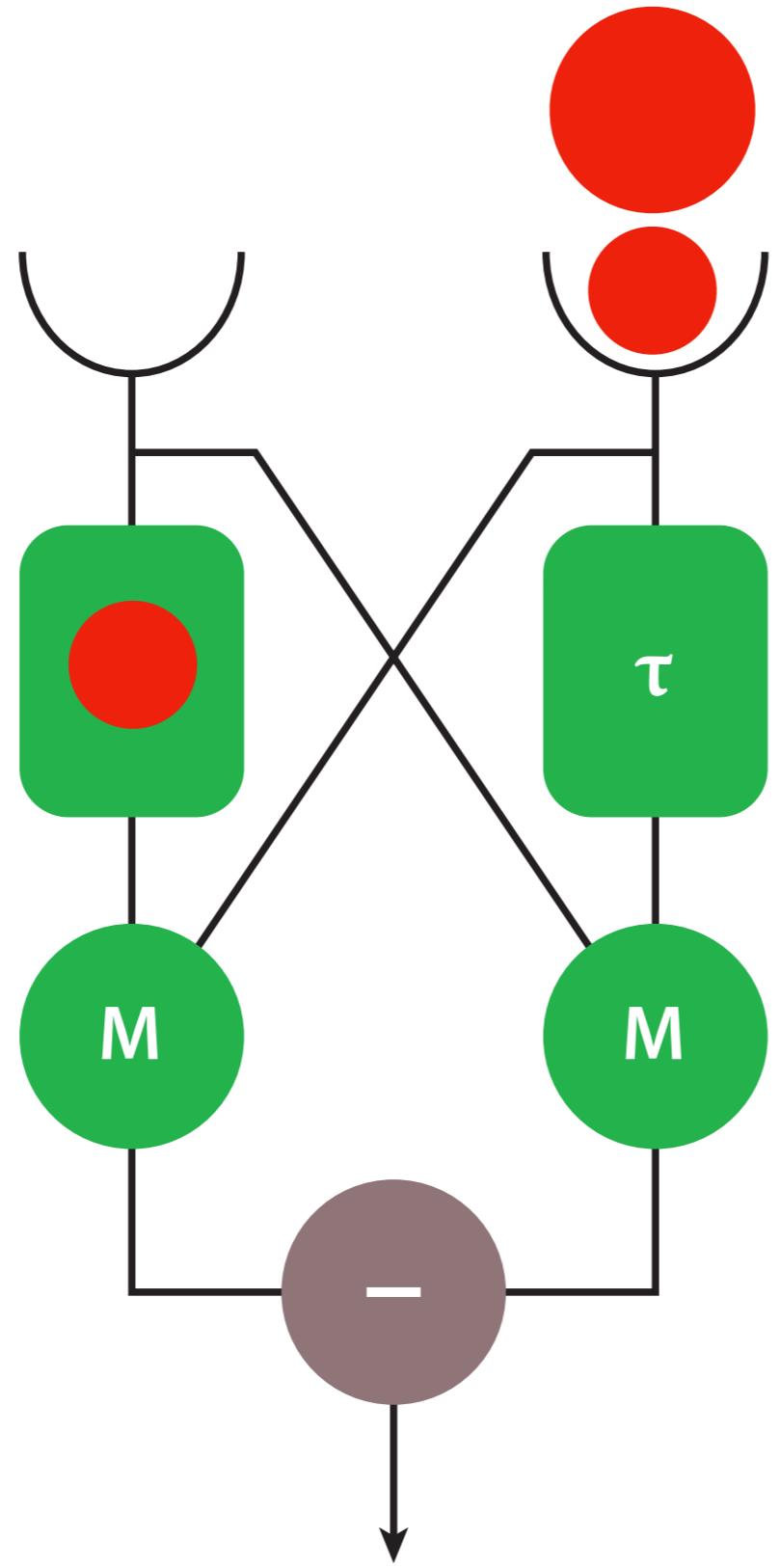


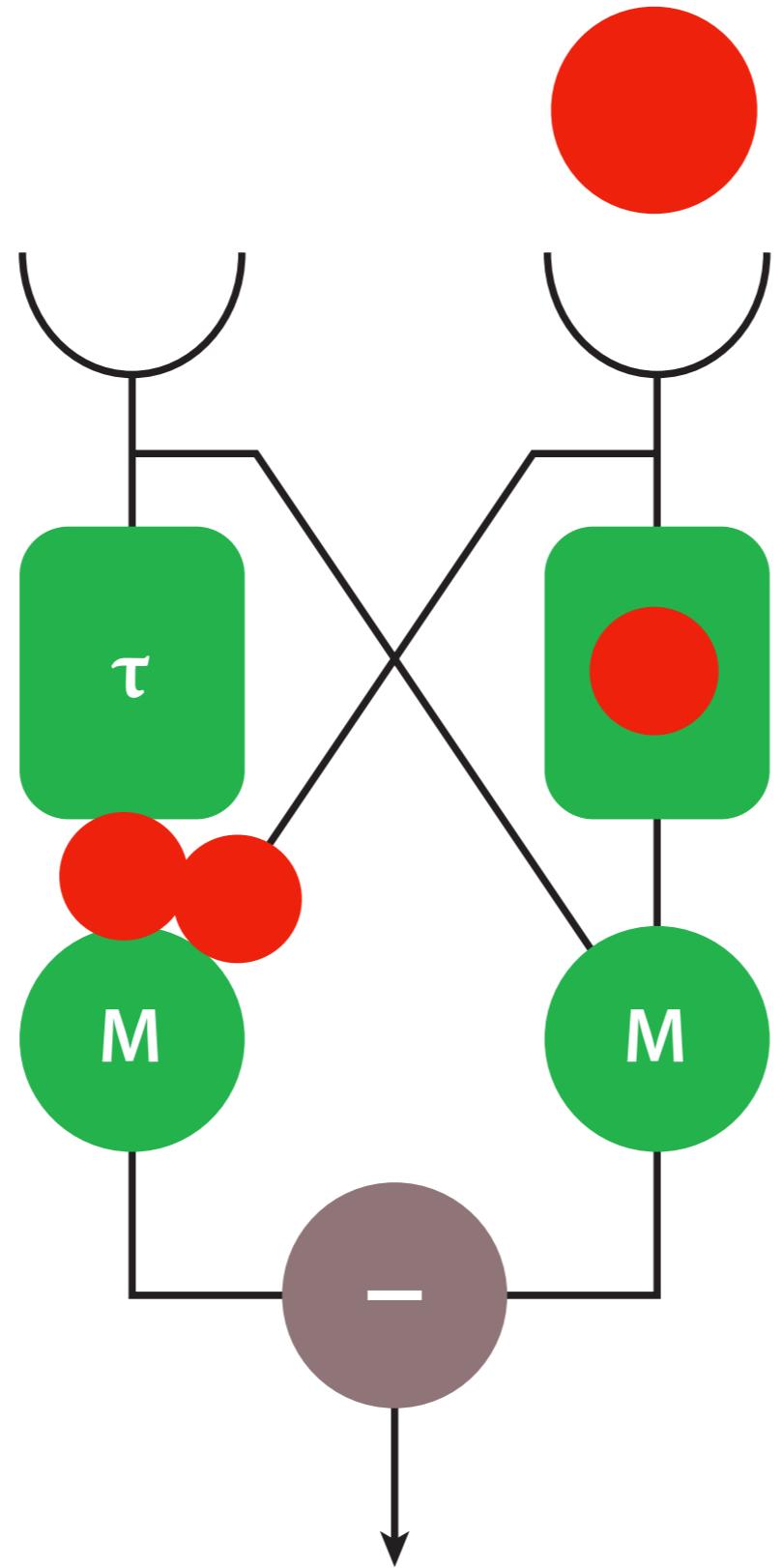


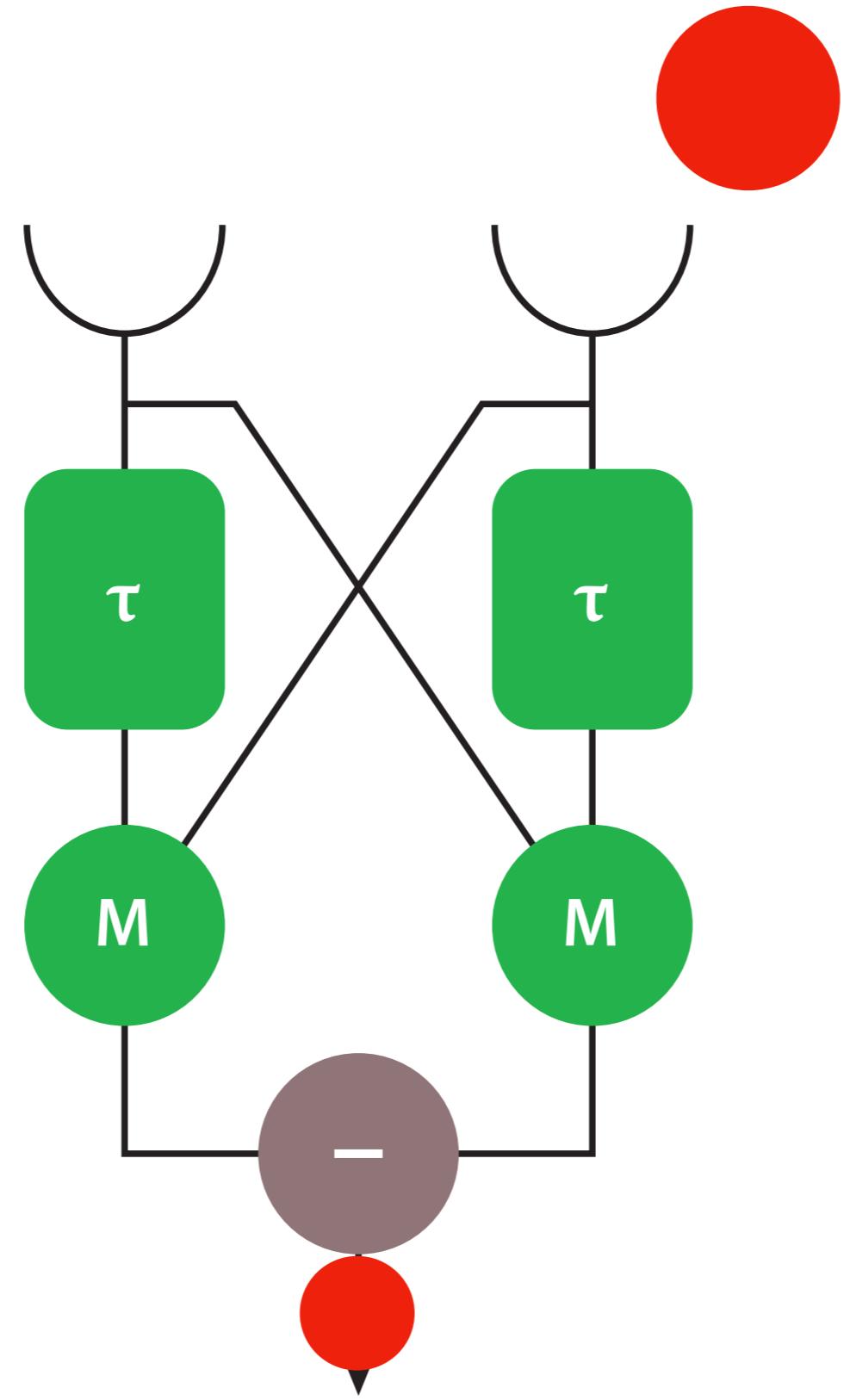




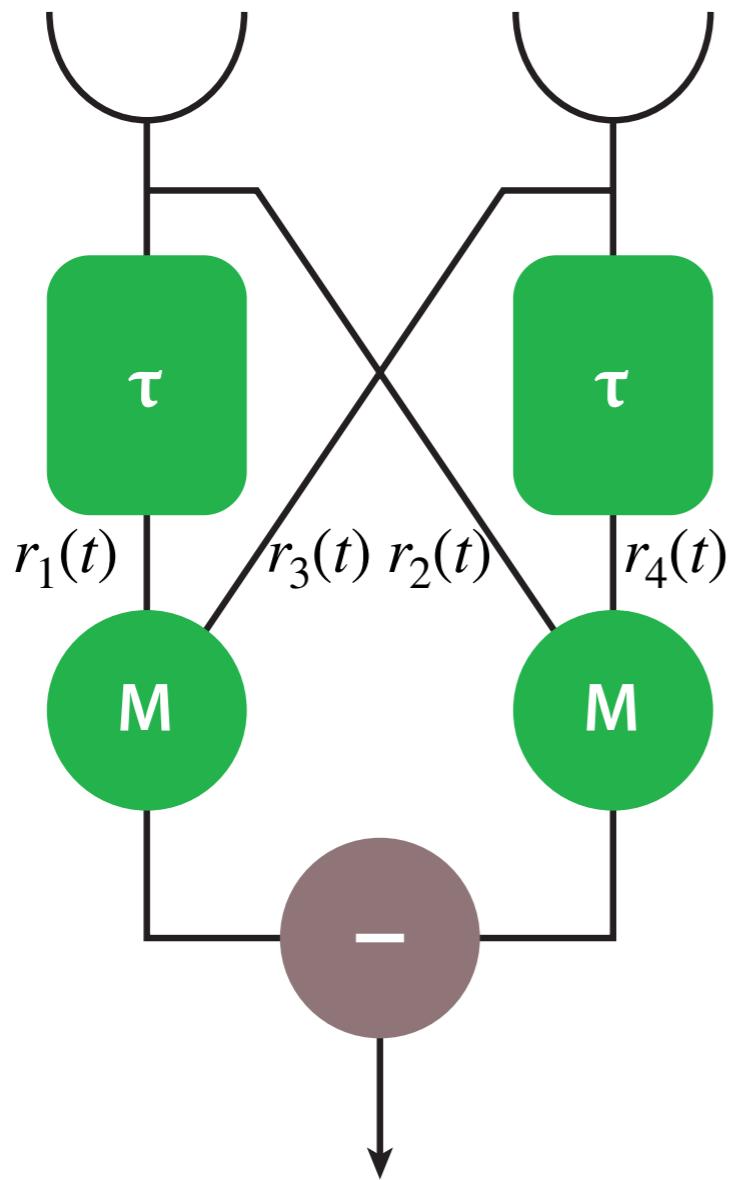








Hassenstein-Reichardt Detector Model

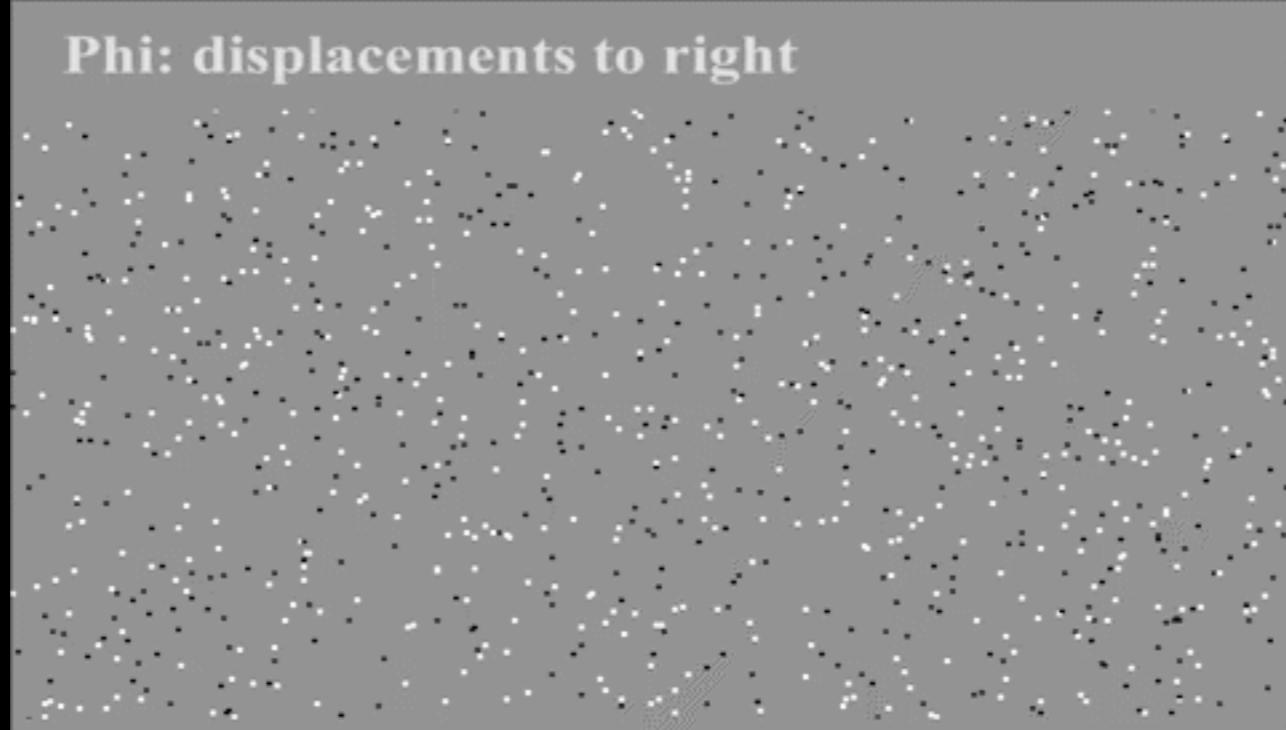


$$r_1(t) = \int_0^{\infty} s_1(t - \tau) D(\tau) d\tau; \quad r_2(t) = \int_0^{\infty} s_1(t - \tau) \delta(\tau) d\tau$$
$$r_3(t) = \int_0^{\infty} s_2(t - \tau) \delta(\tau) d\tau; \quad r_4(t) = \int_0^{\infty} s_2(t - \tau) D(\tau) d\tau;$$
$$R(t) = r_1(t)r_3(t) - r_2(t)r_4(t)$$

$$D(\tau) = \frac{1}{\tau_0} \exp(-\tau/\tau_0)$$

$$\langle R \rangle = \frac{\omega \tau_0}{\omega^2 \tau_0^2 + 1}$$

Phi: displacements to right

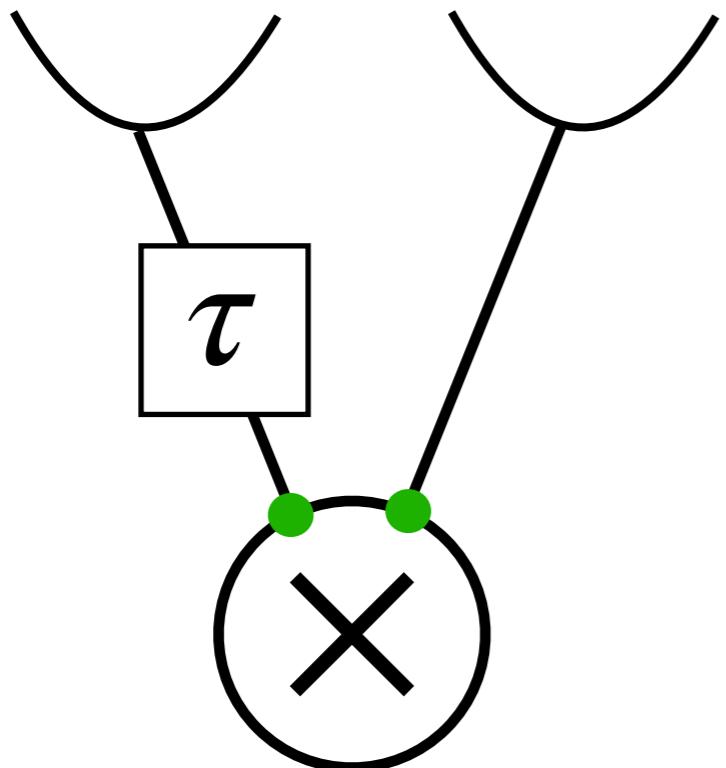


adapted from Damon Clark's slide

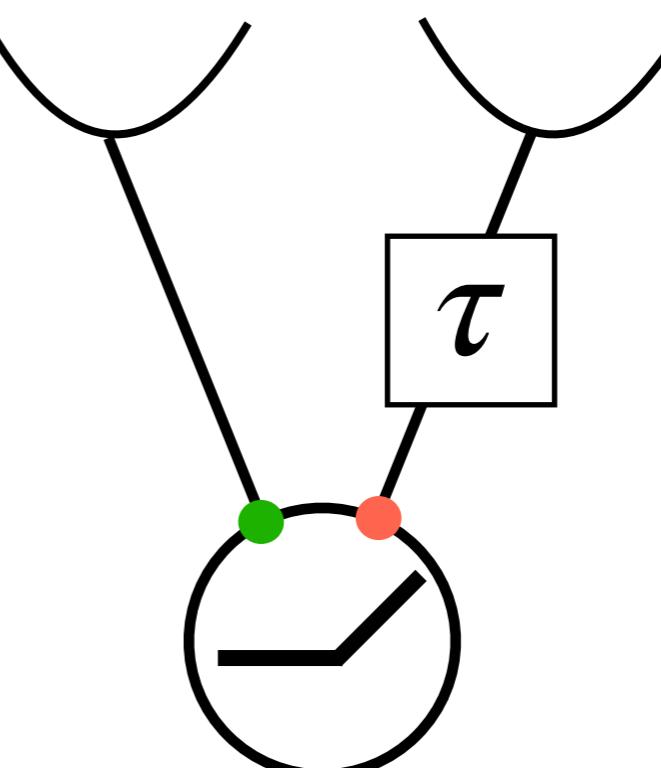
preferred
direction



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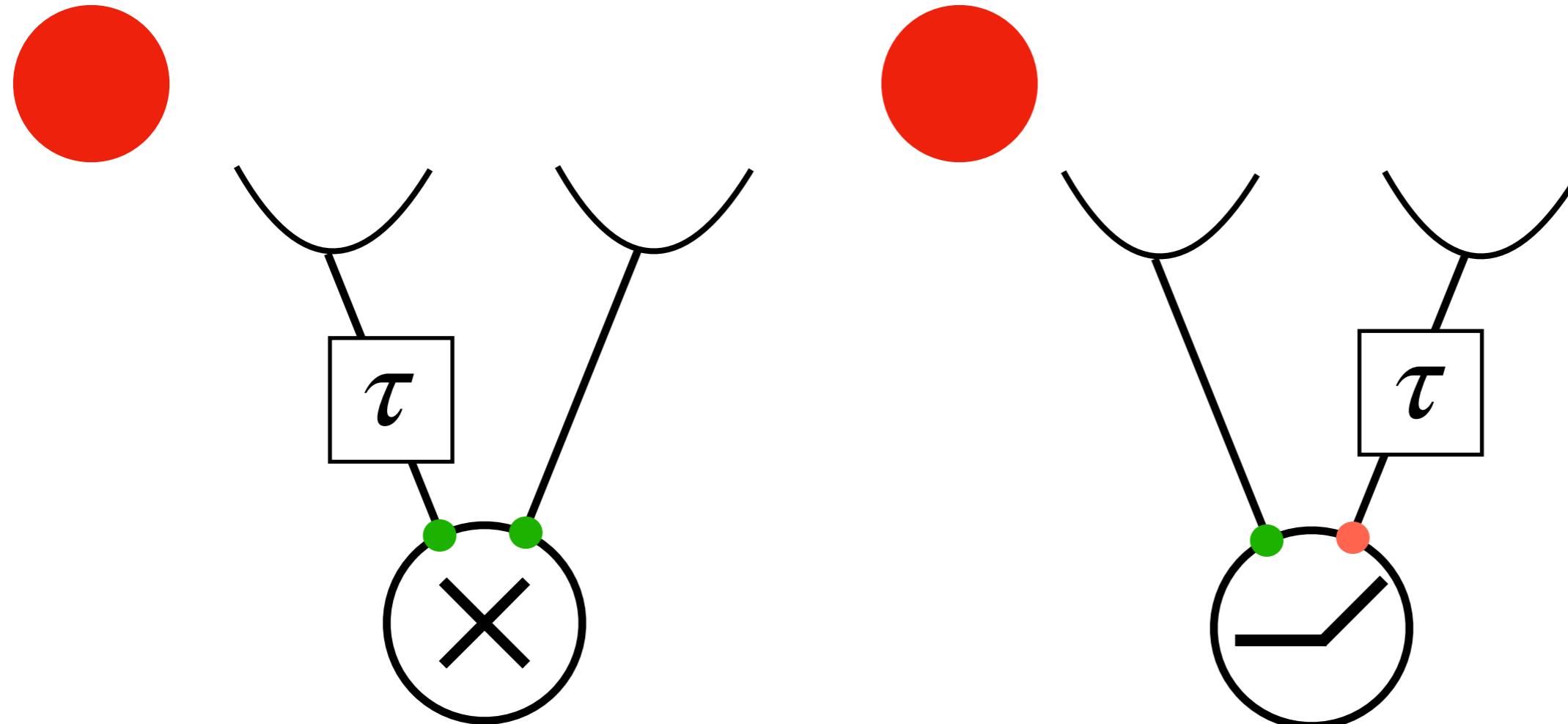


Reichardt model



barlow-levick model

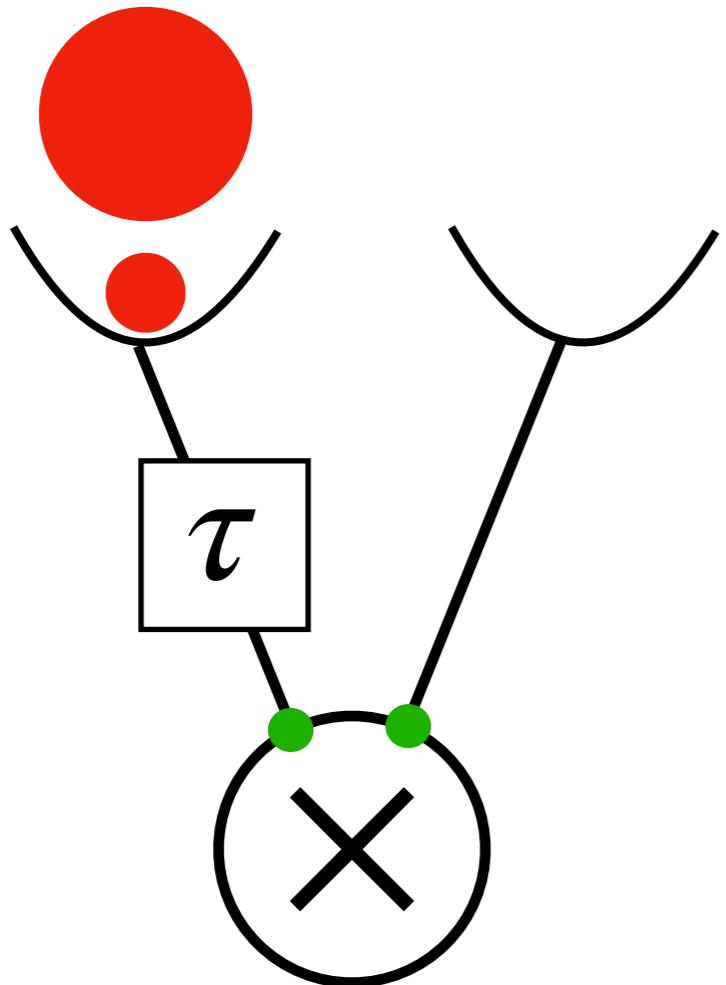
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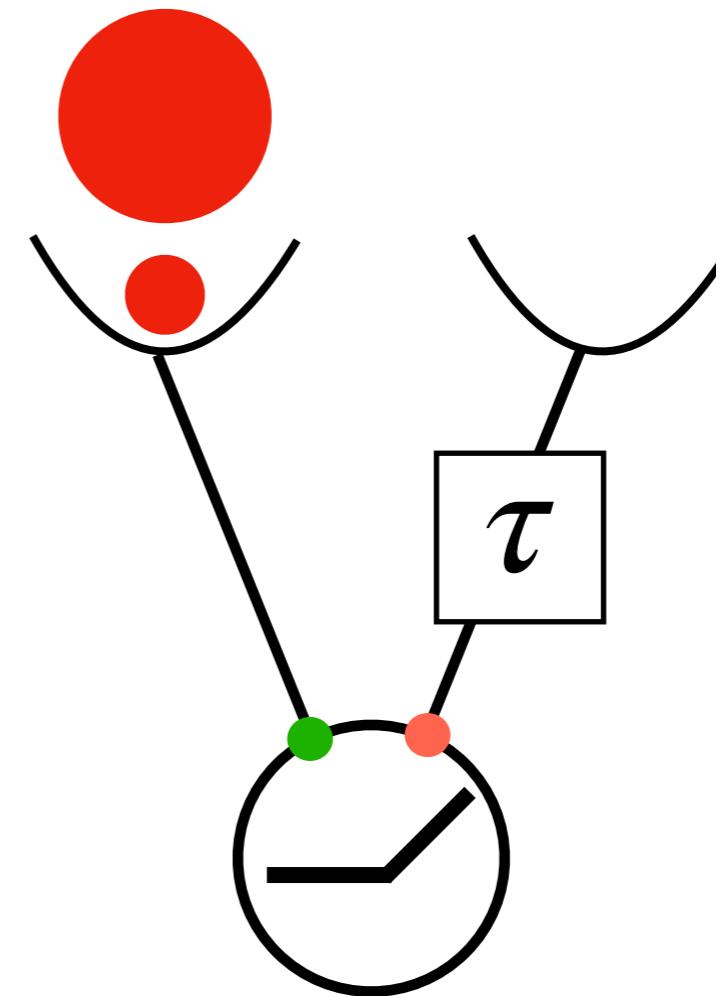
Reichardt model

barlow-levick model

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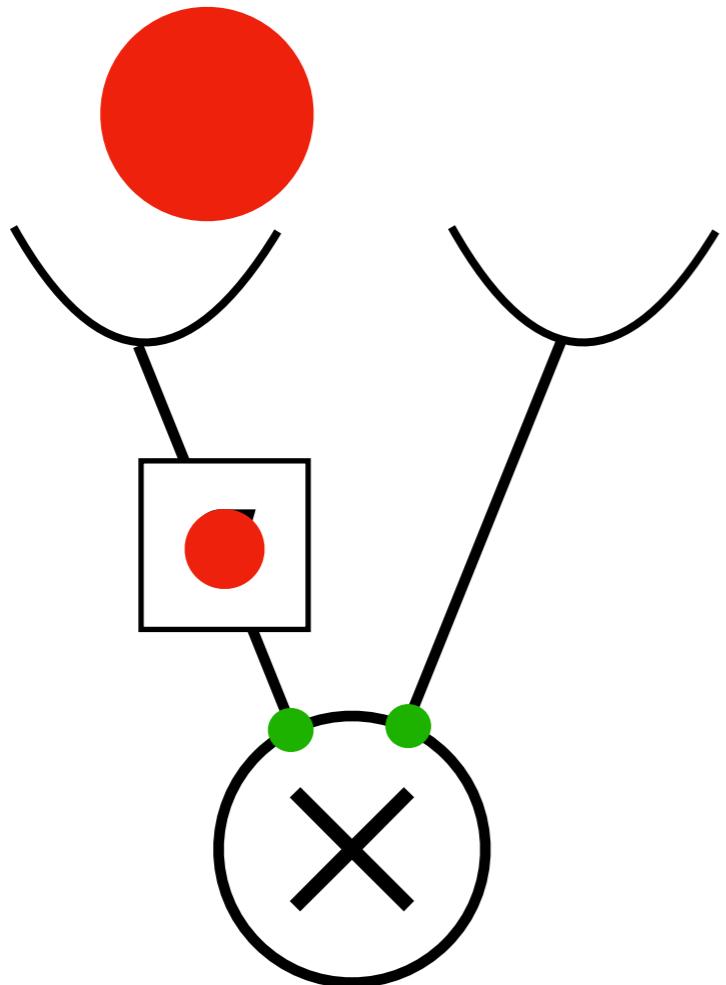


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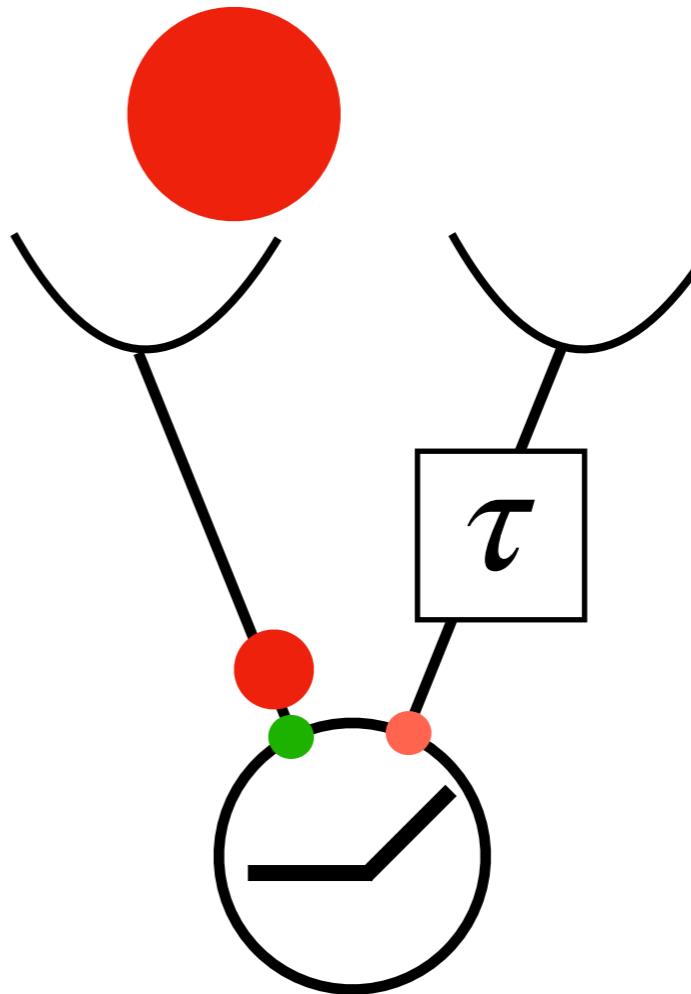


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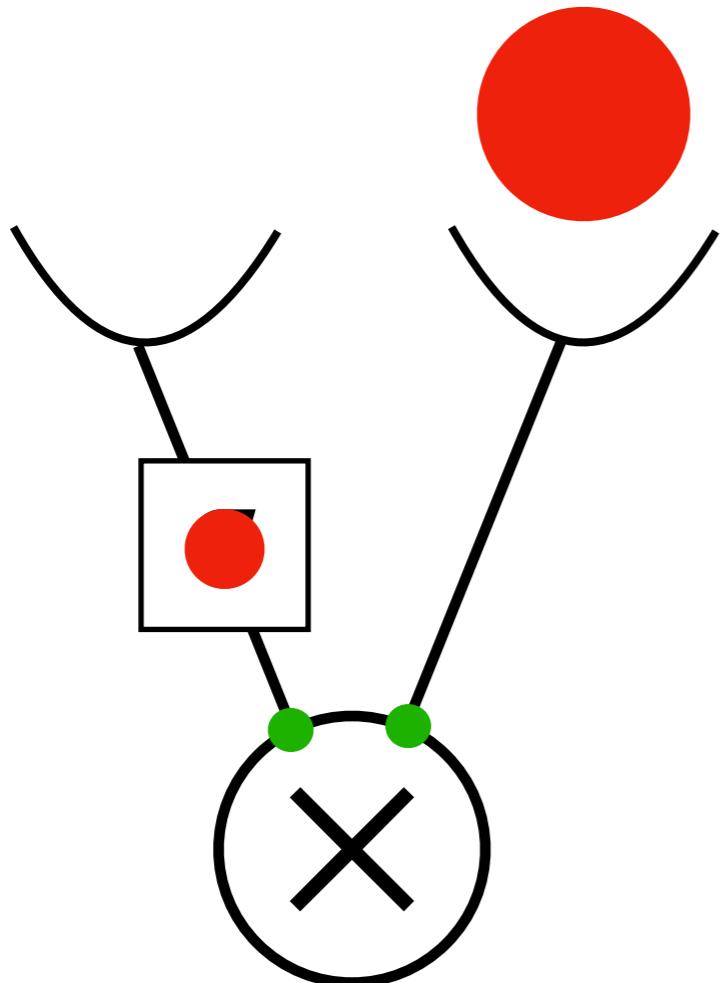


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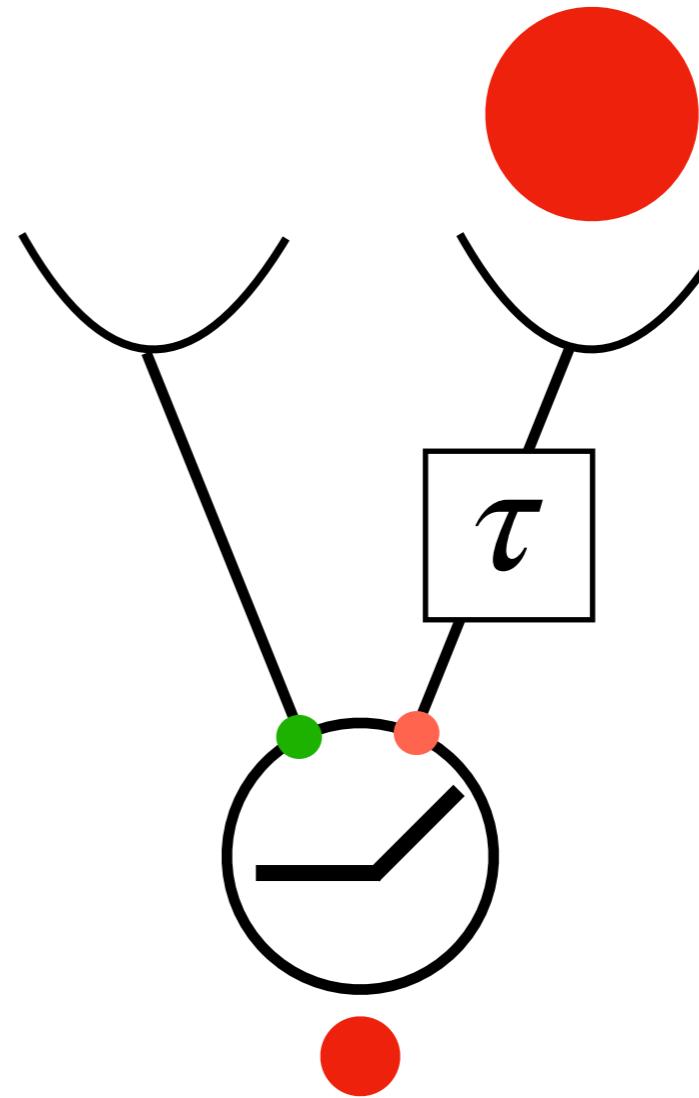


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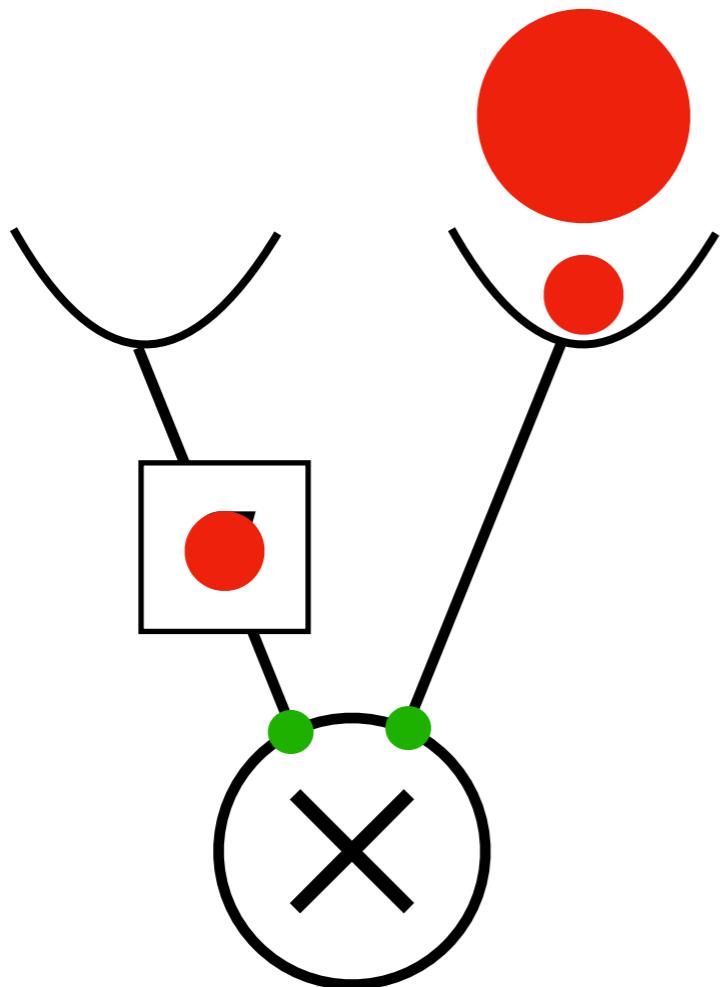


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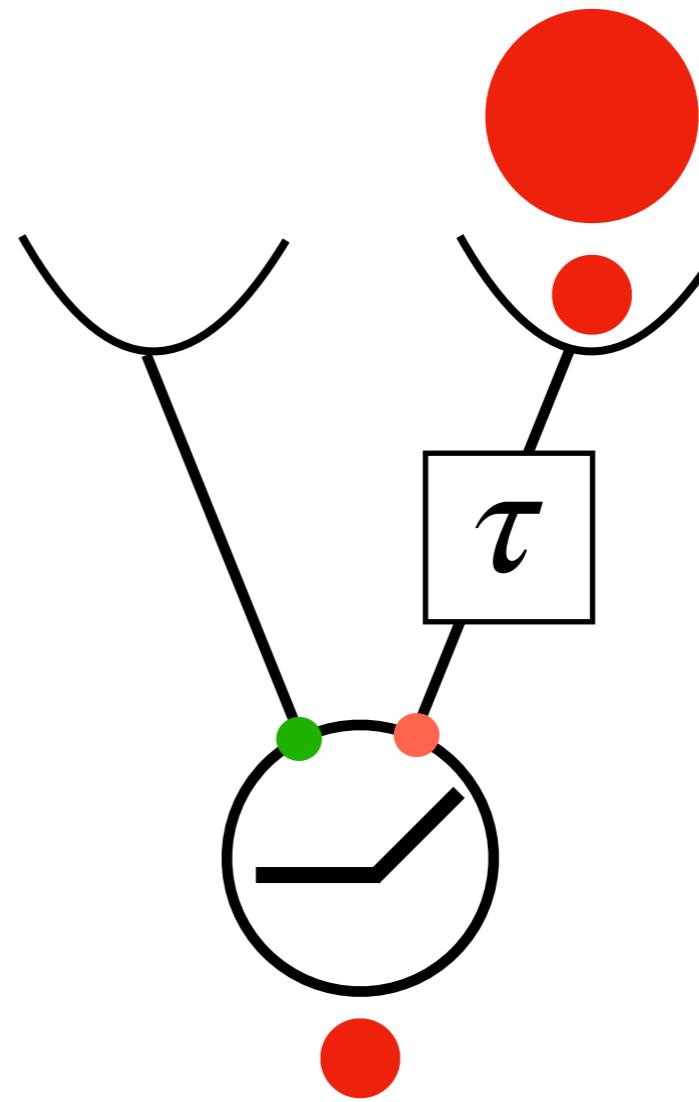


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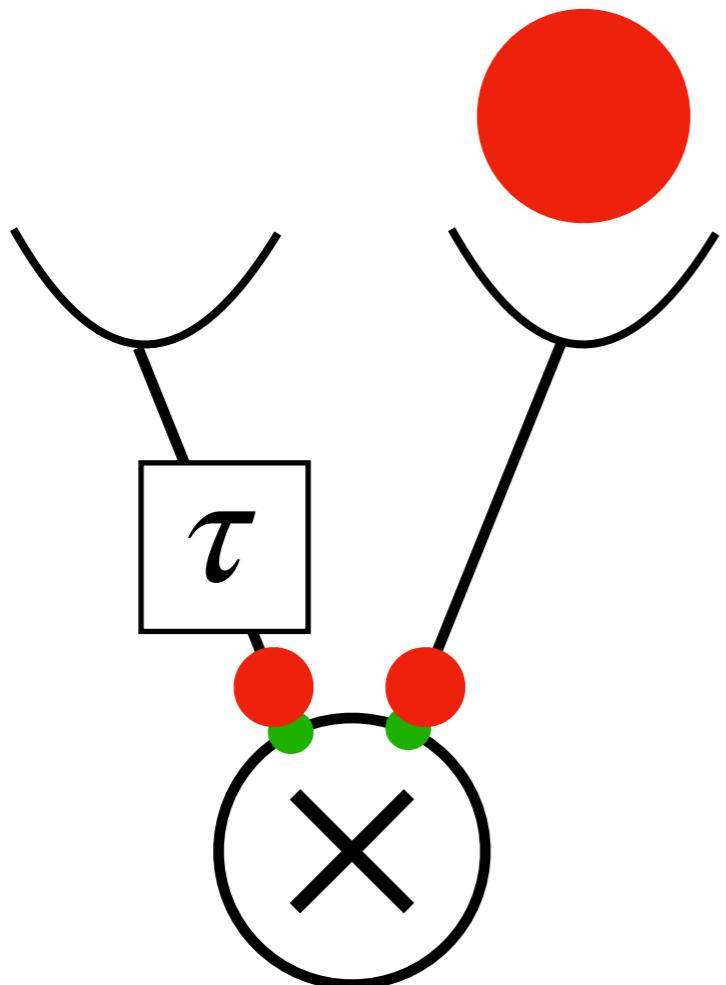


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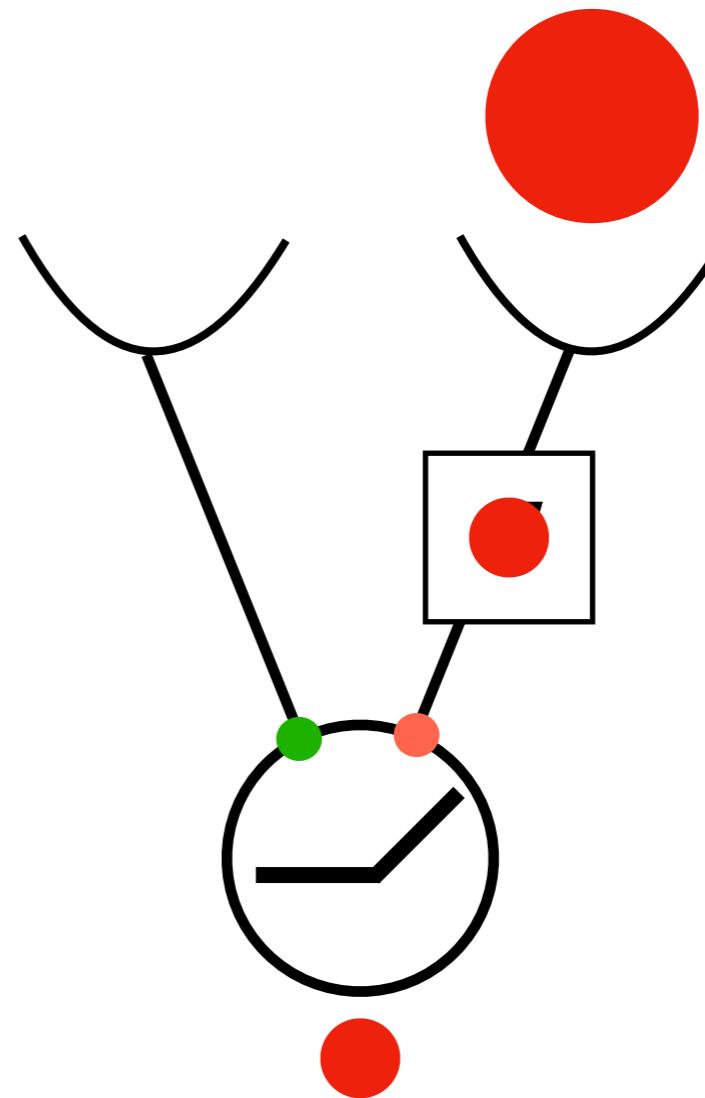


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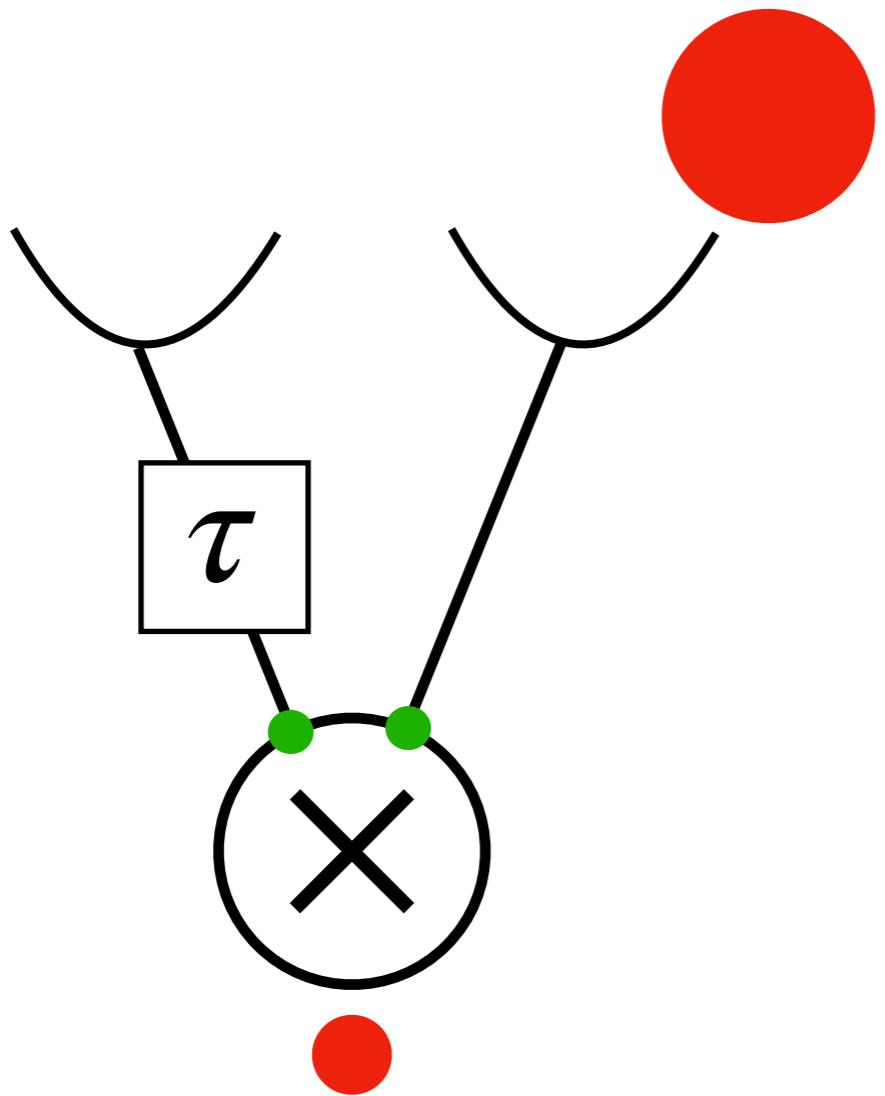


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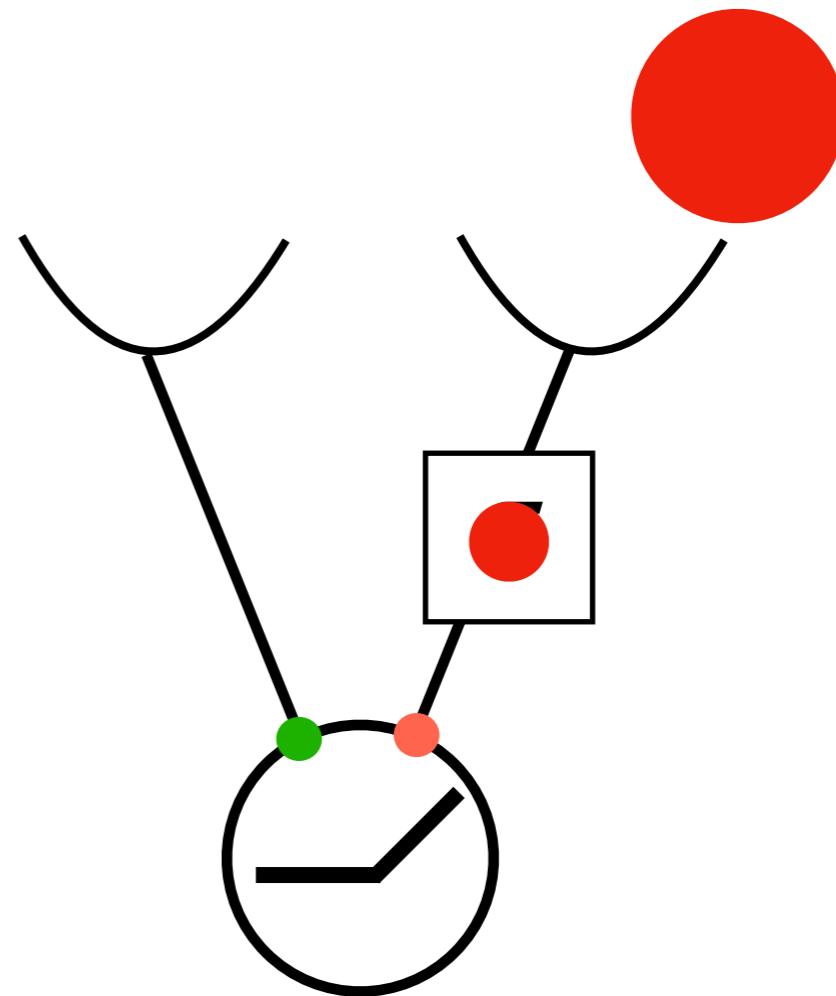


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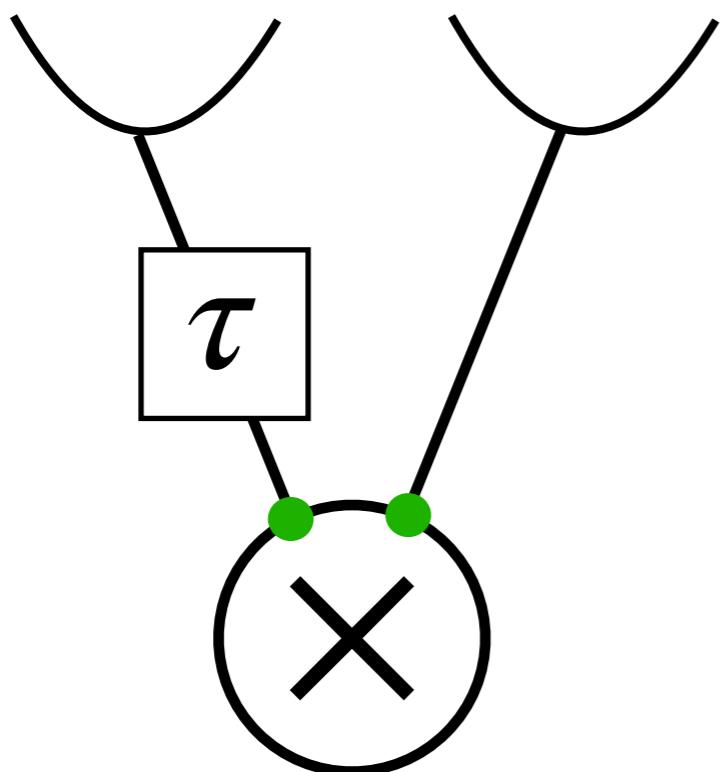


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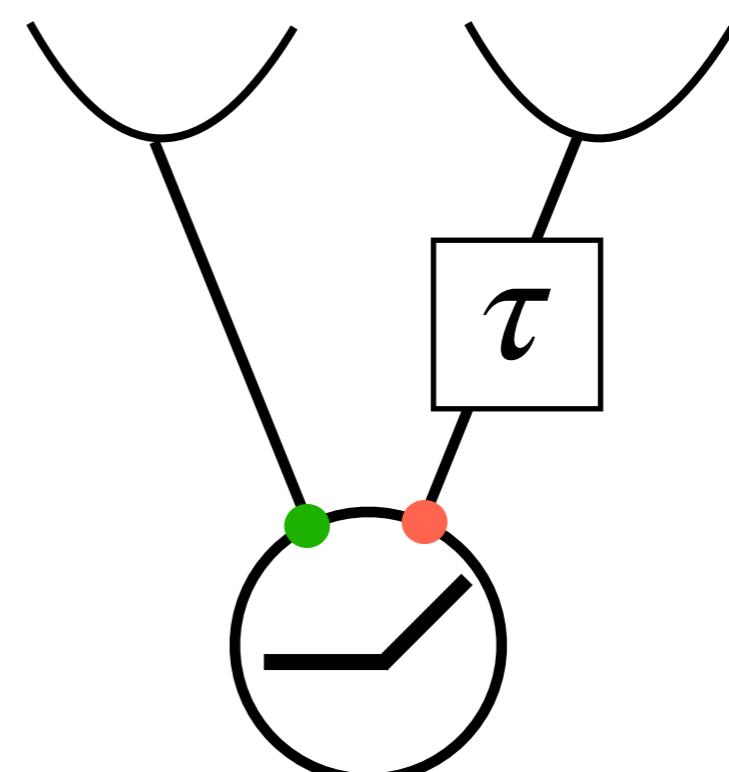


barlow-levick model

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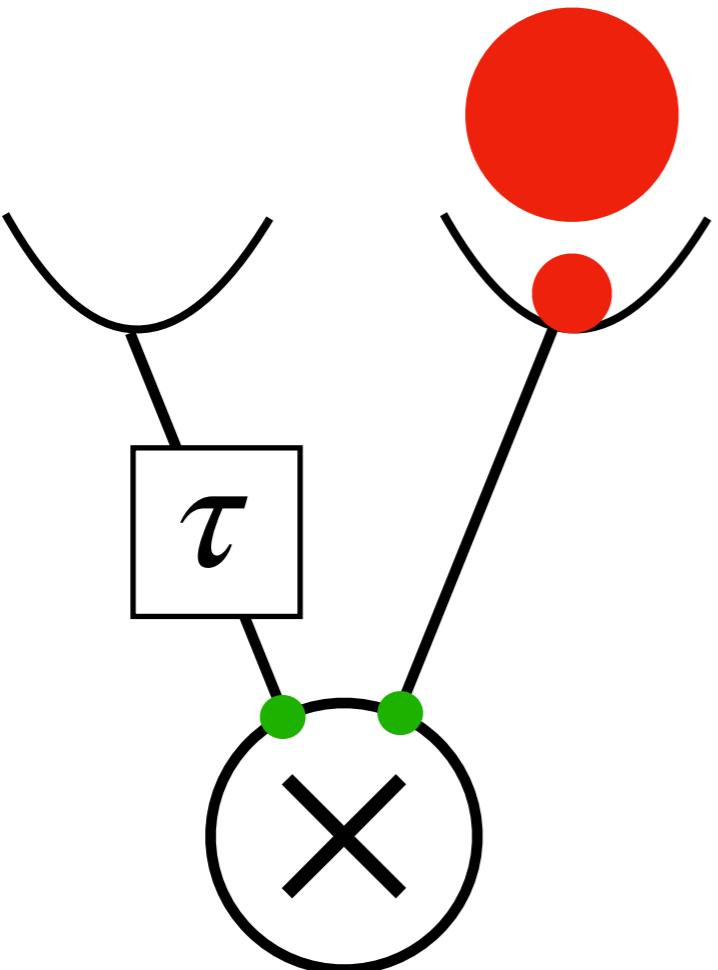


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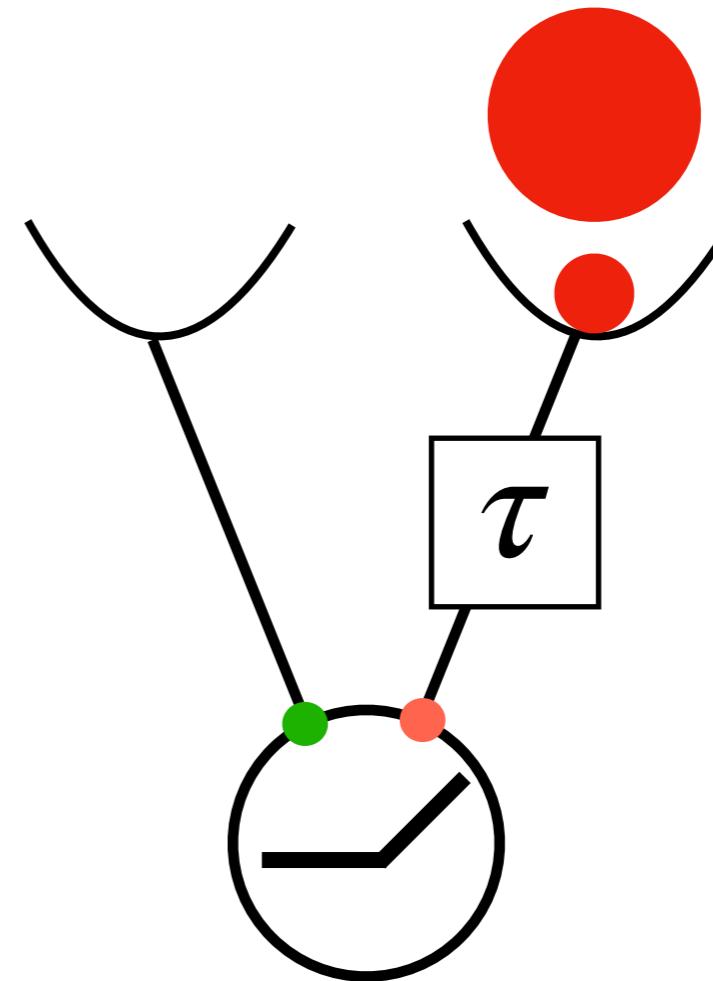


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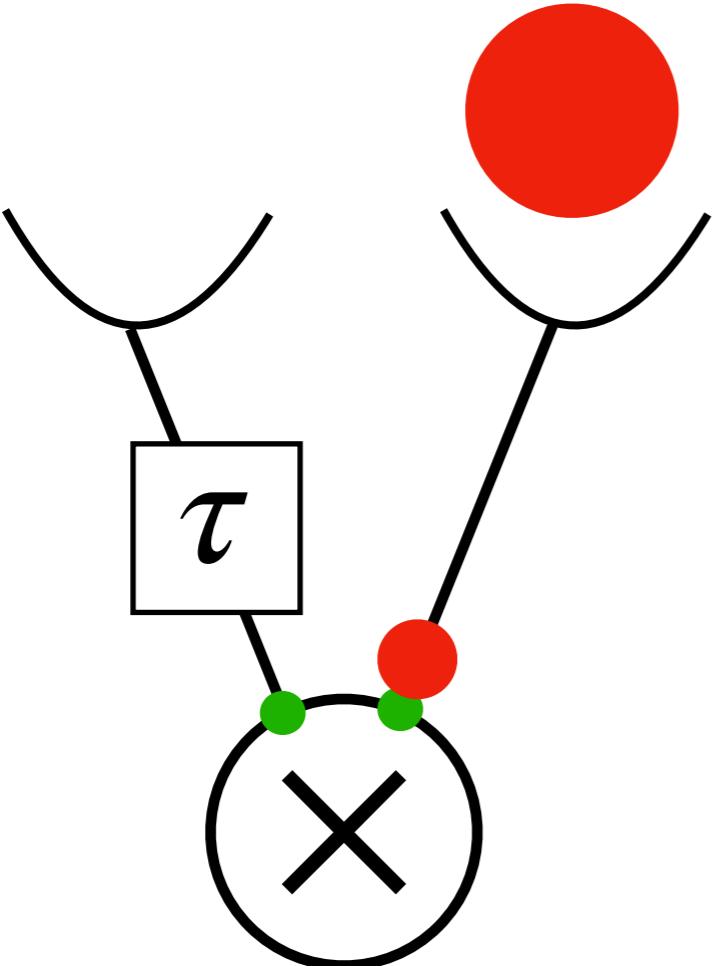


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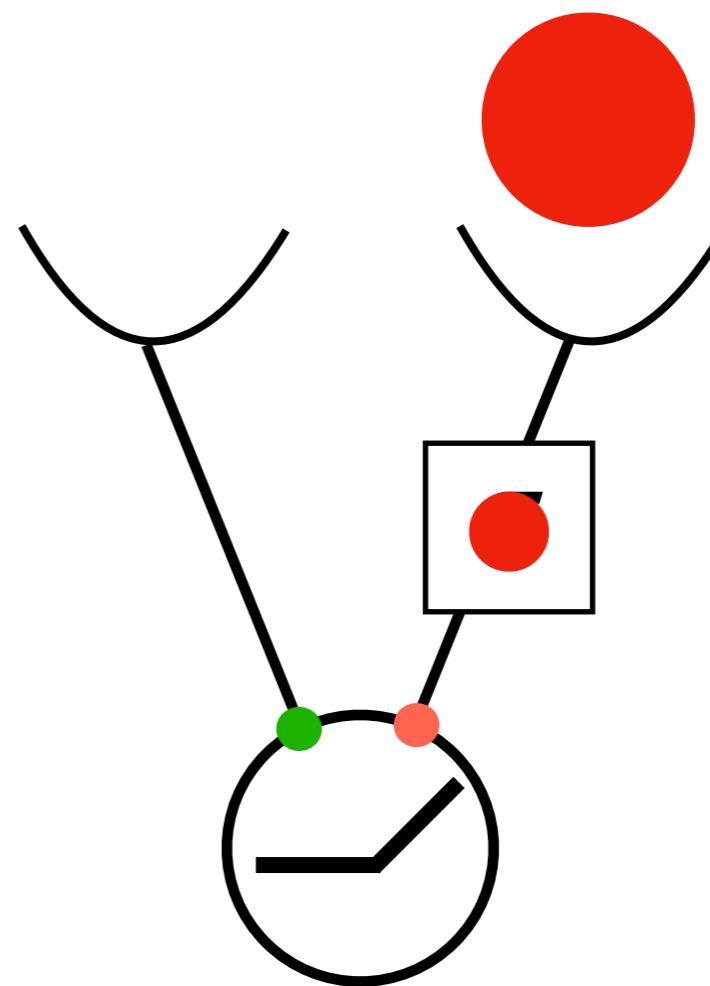


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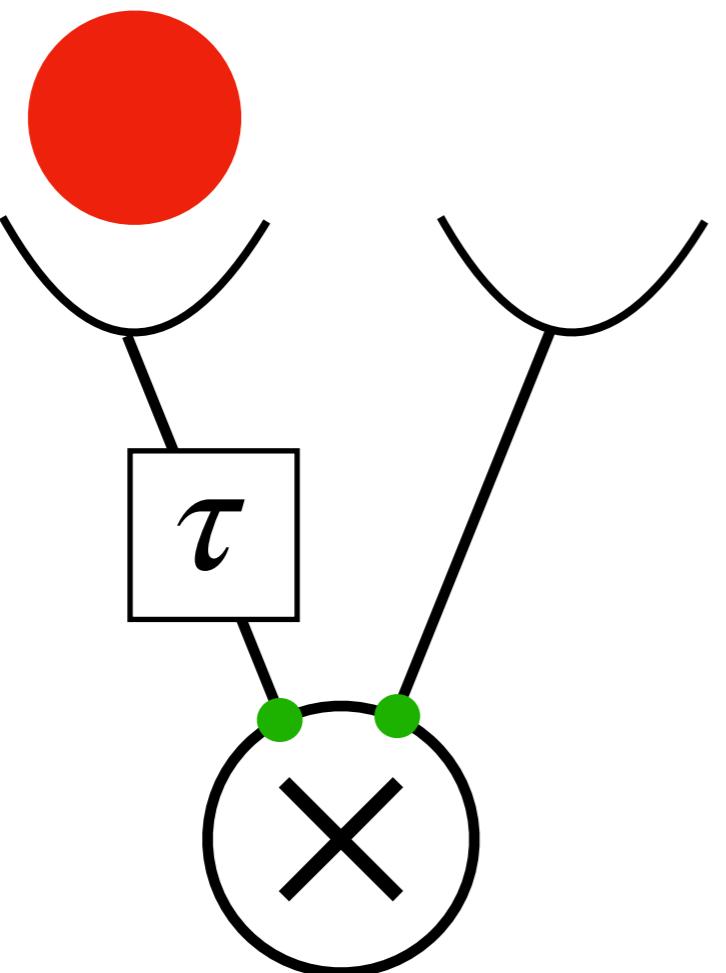


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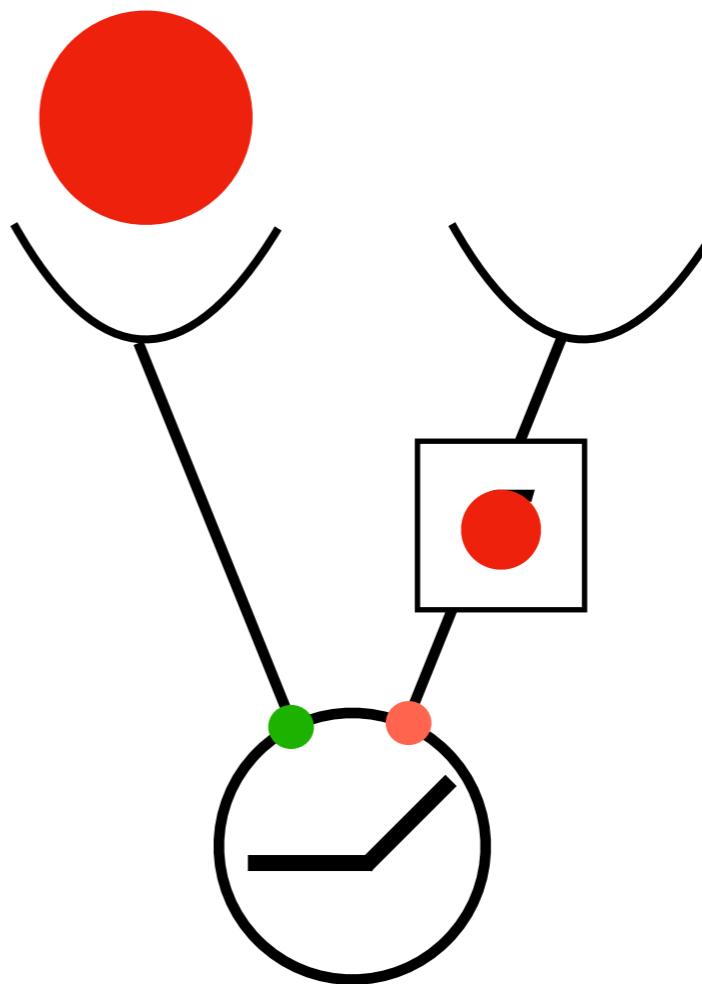


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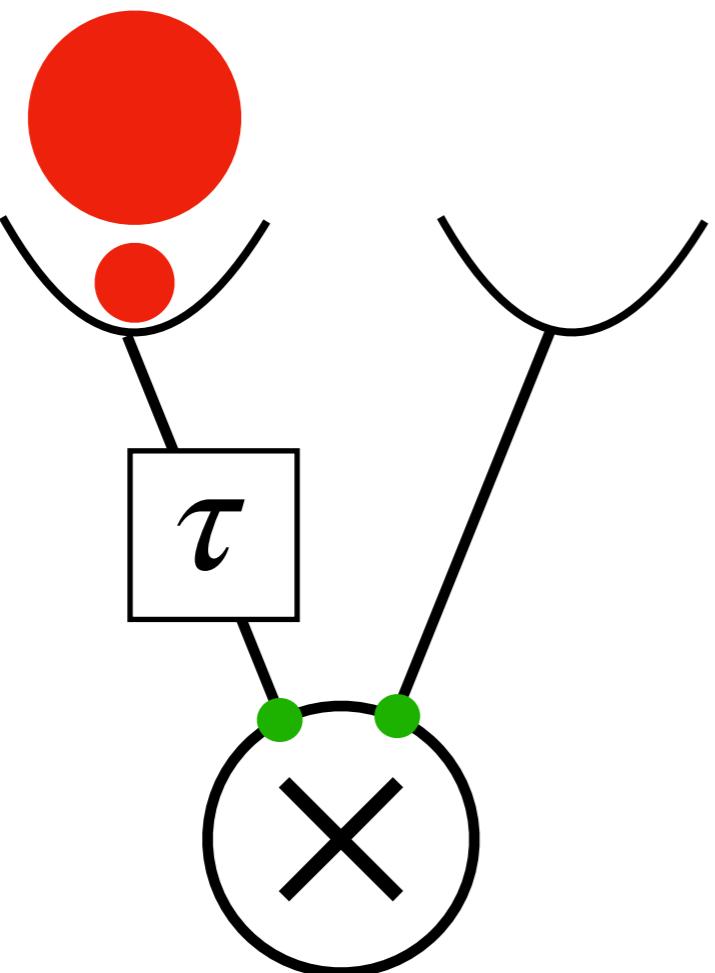


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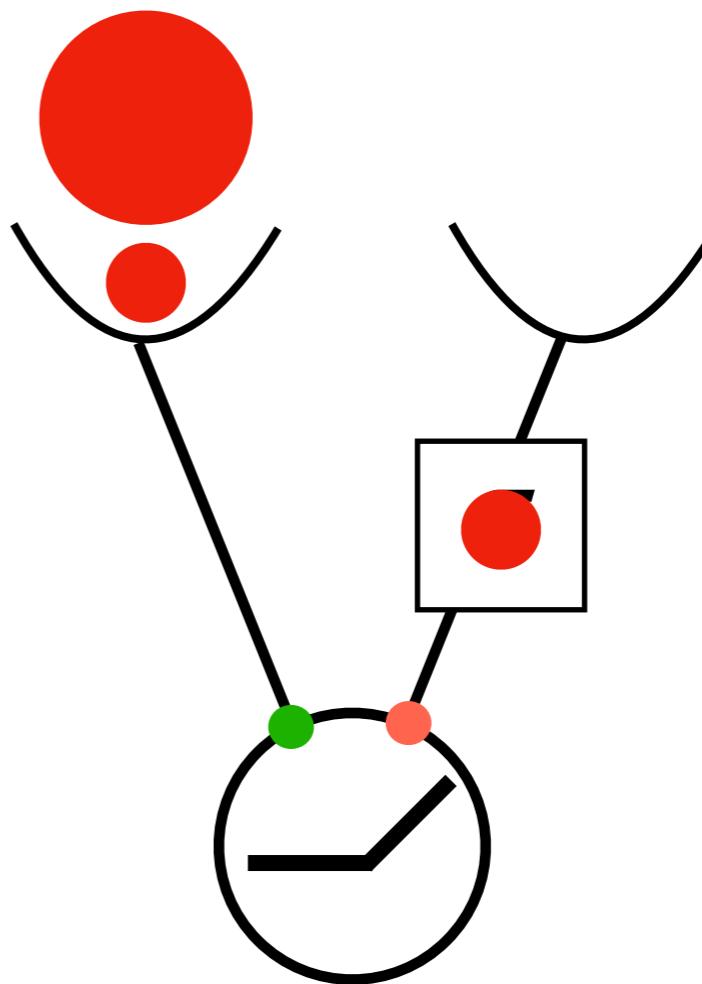


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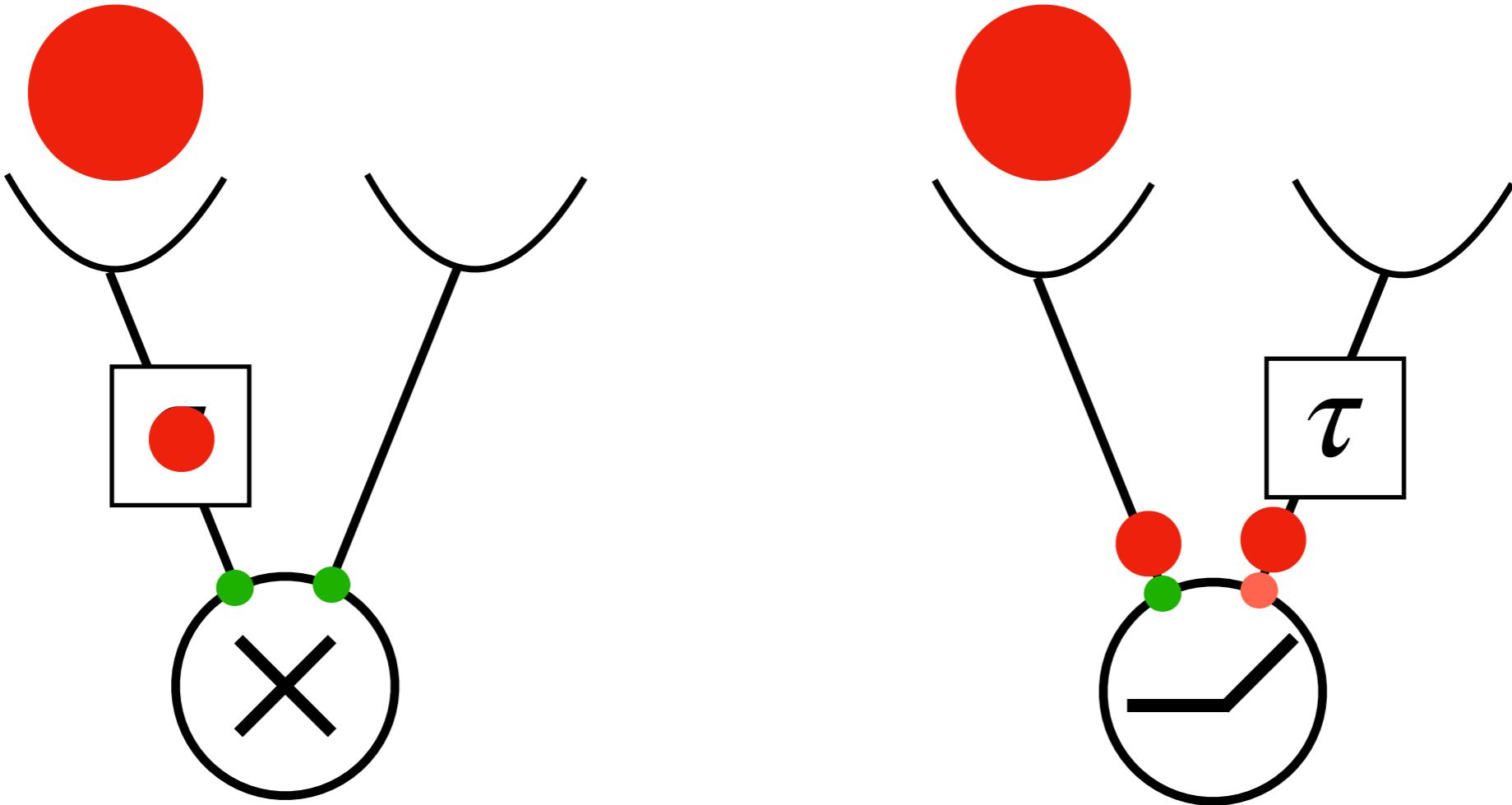
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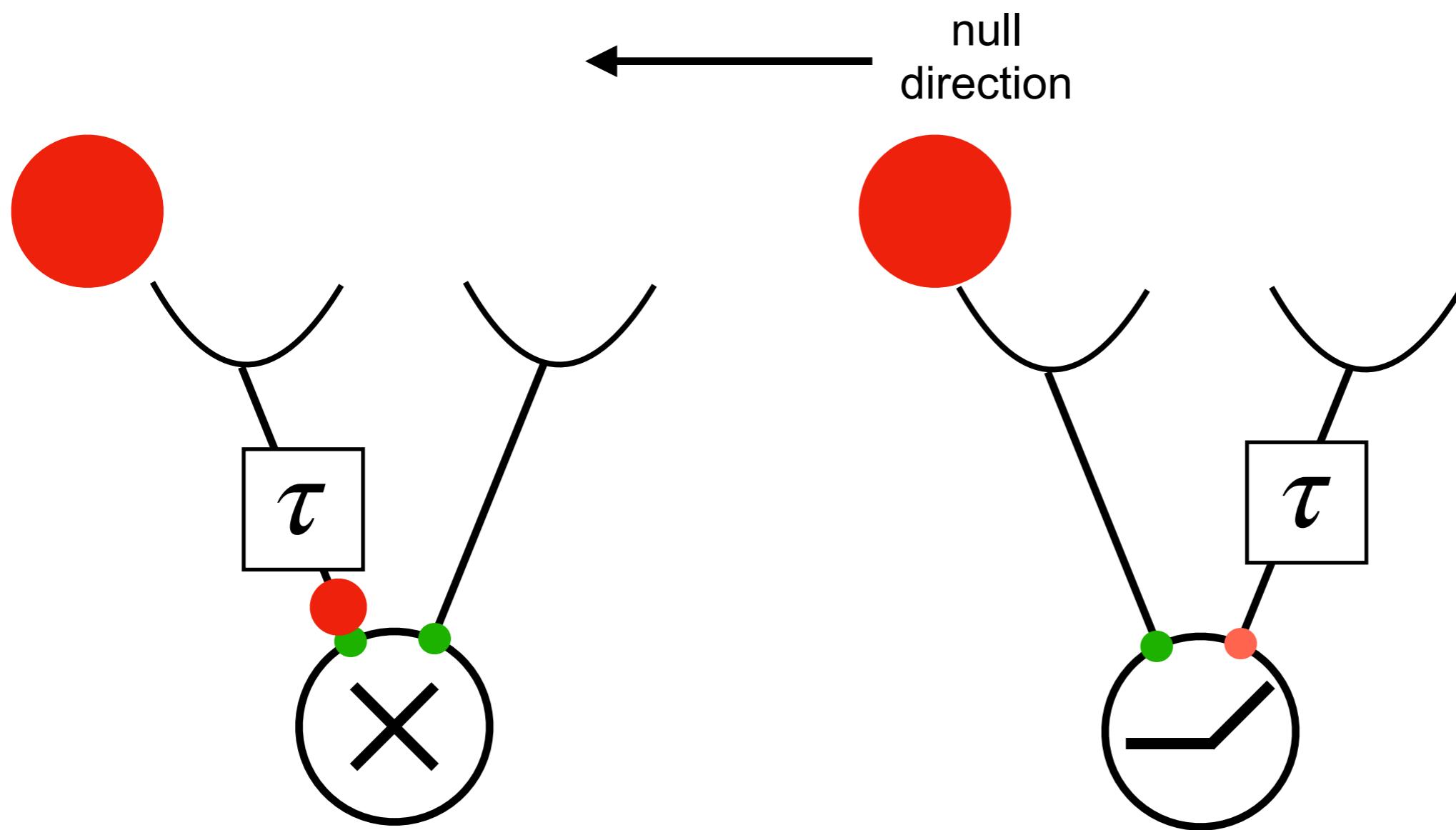


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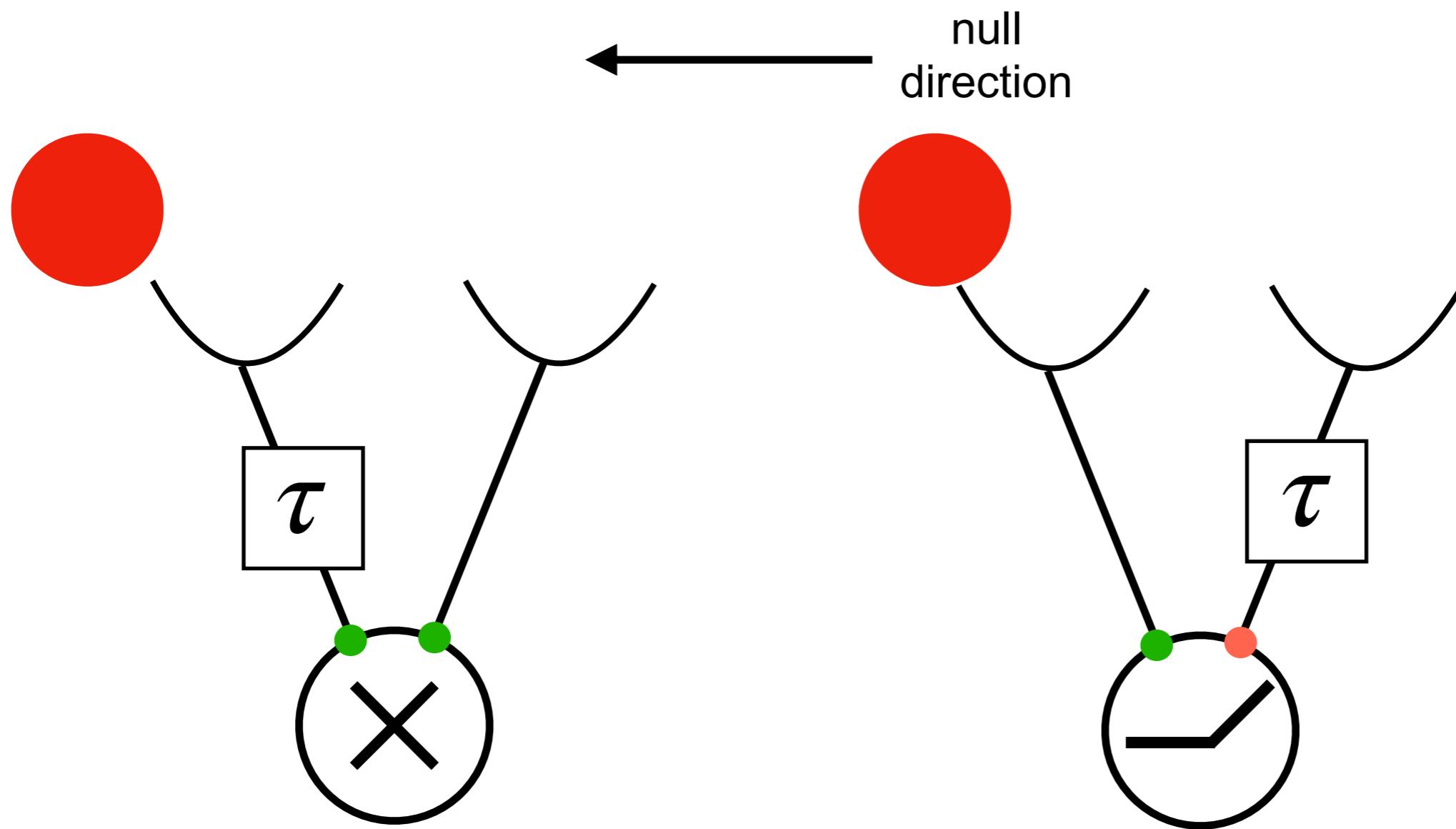
Reichardt model

barlow-levick model



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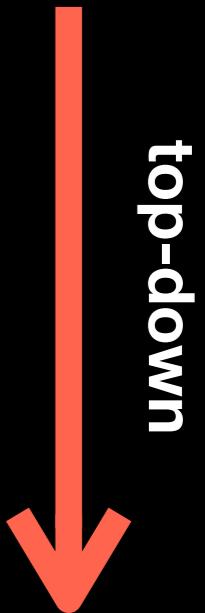
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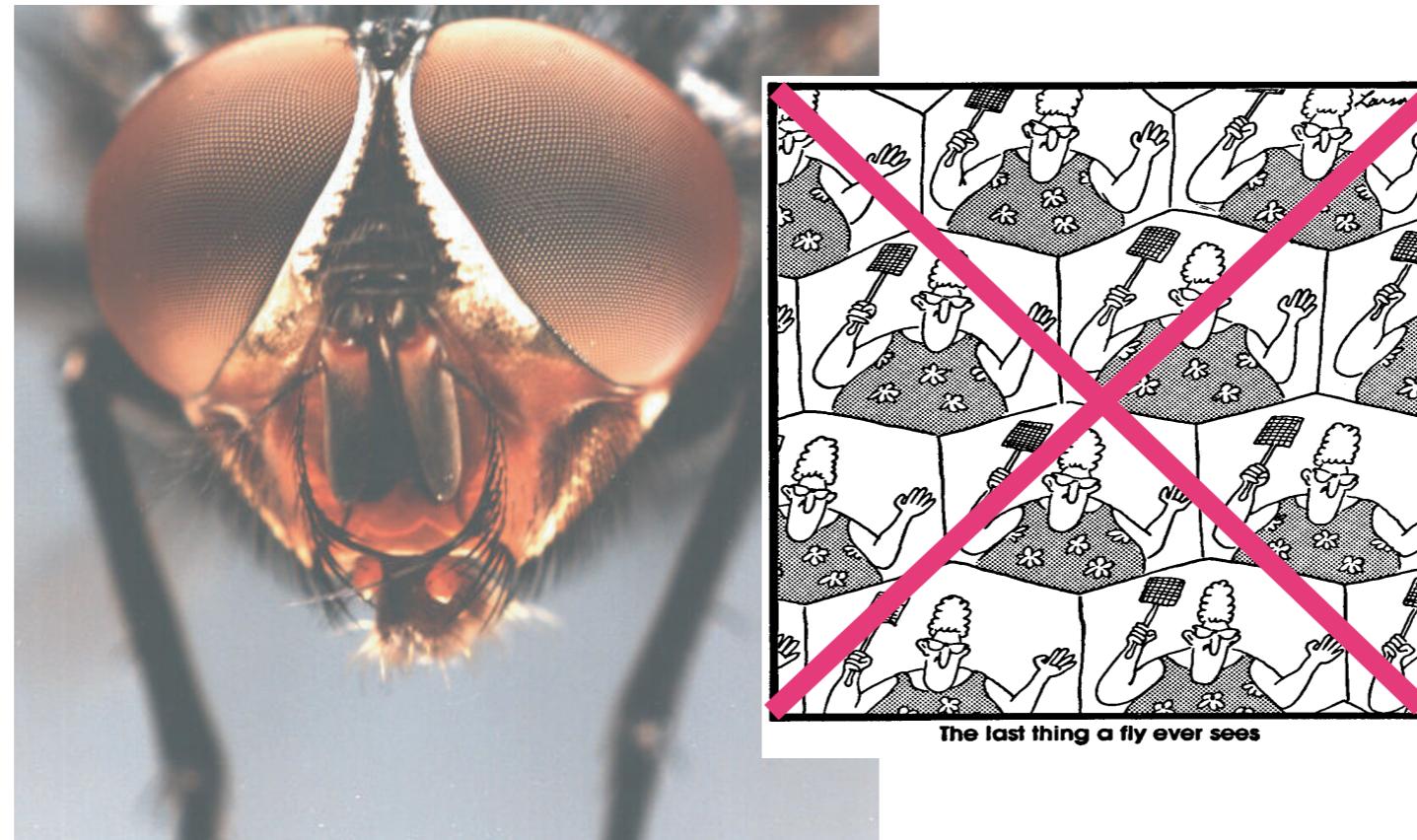
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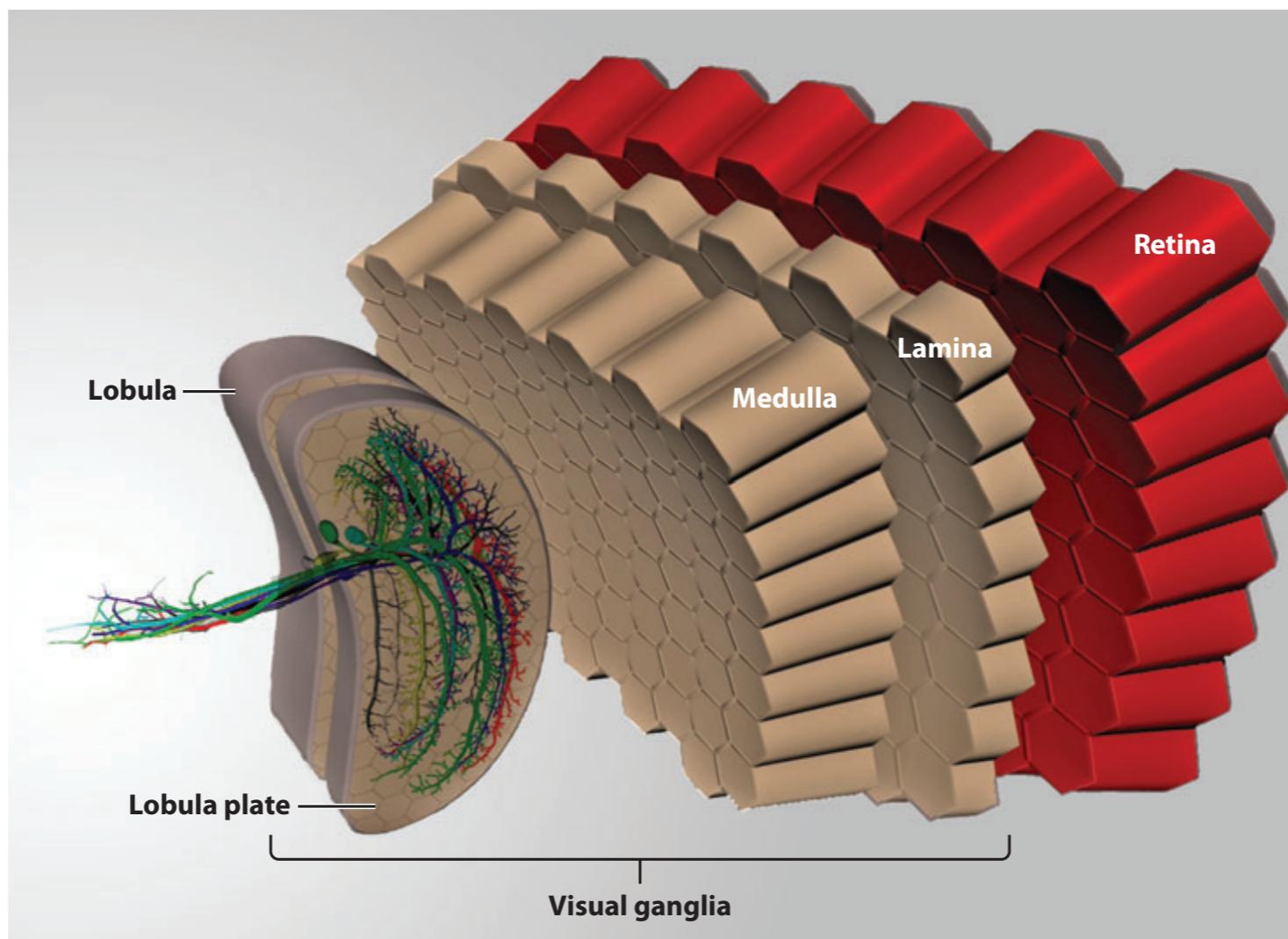
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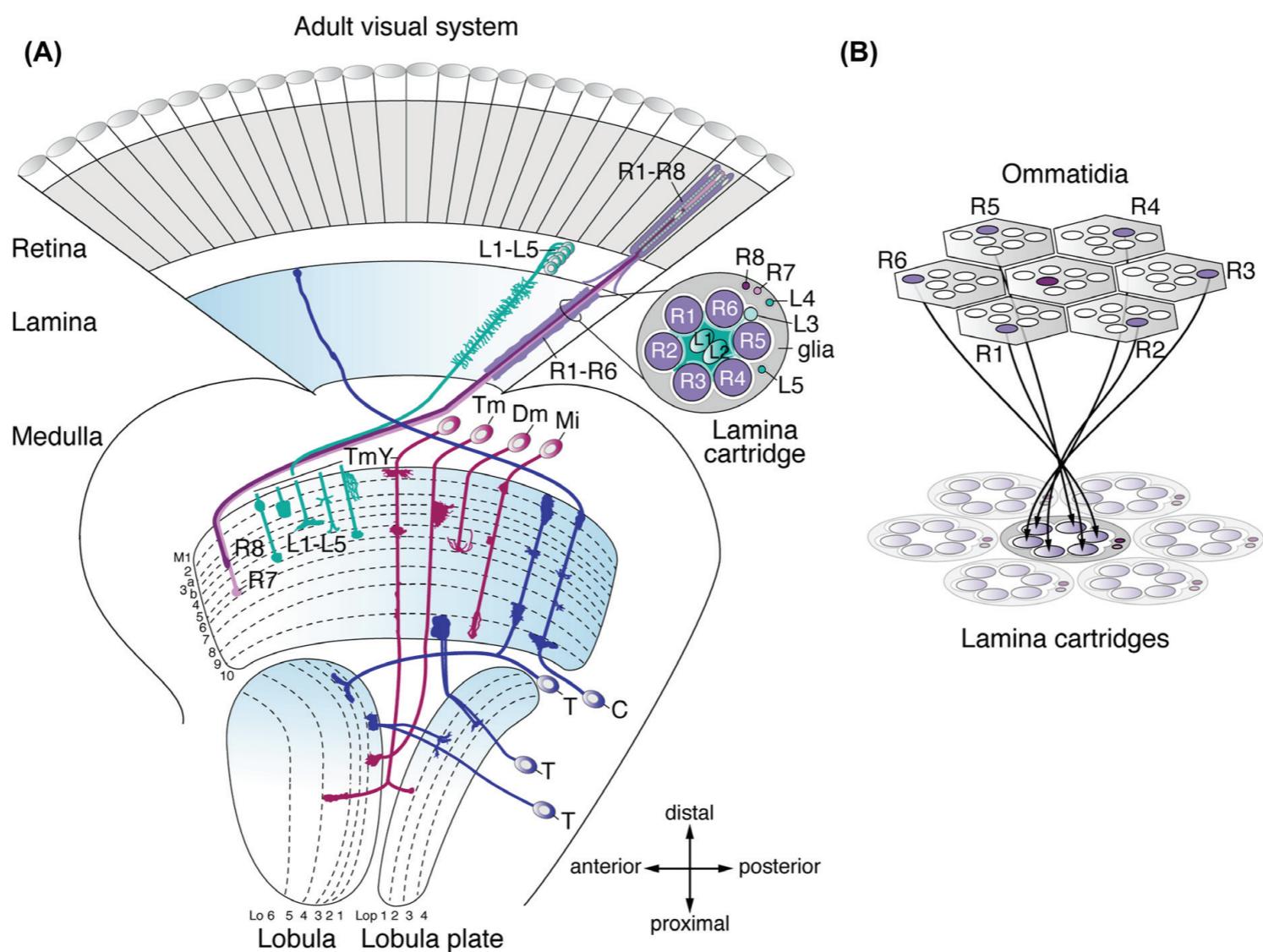
The Fly Visual System

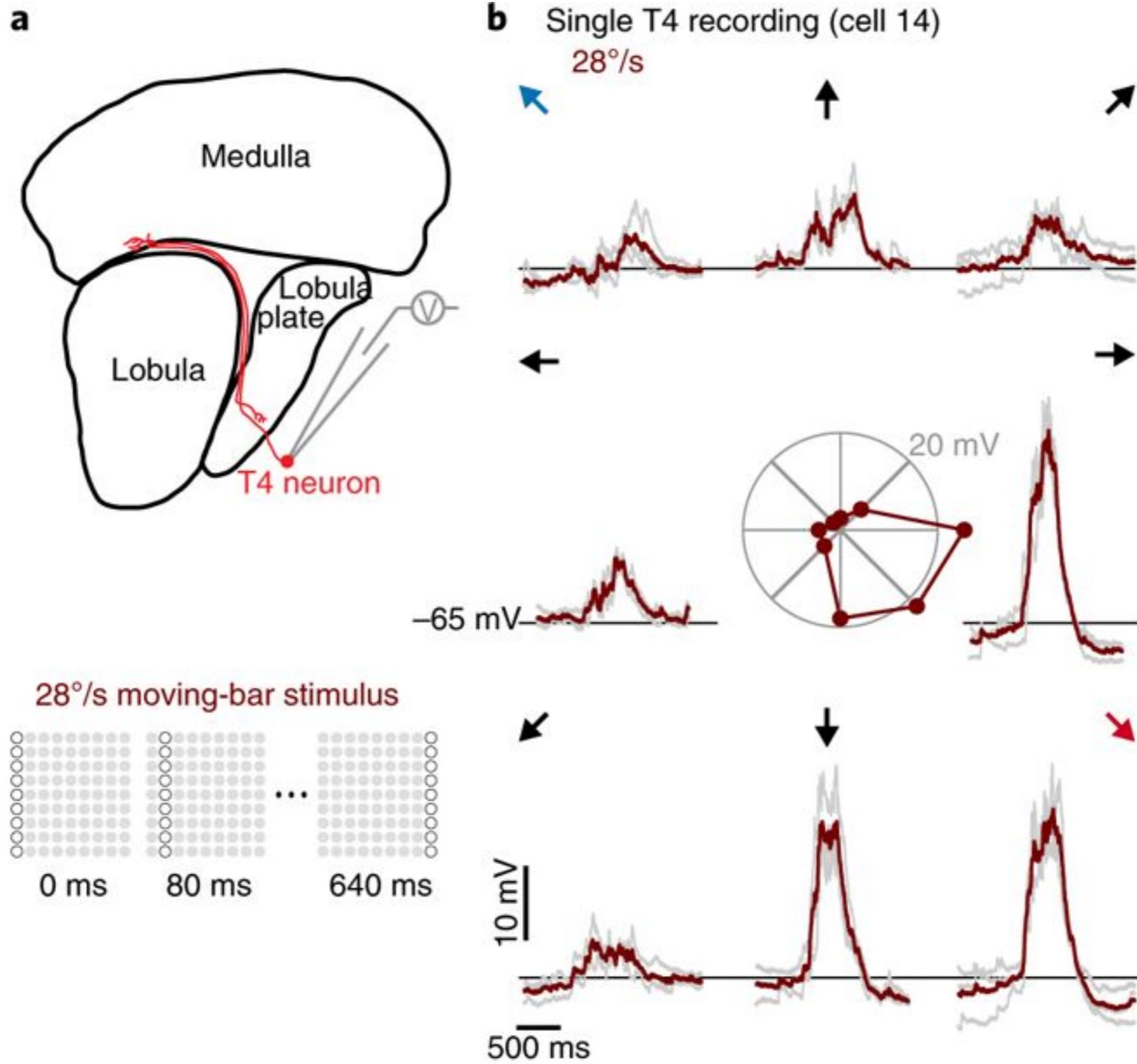


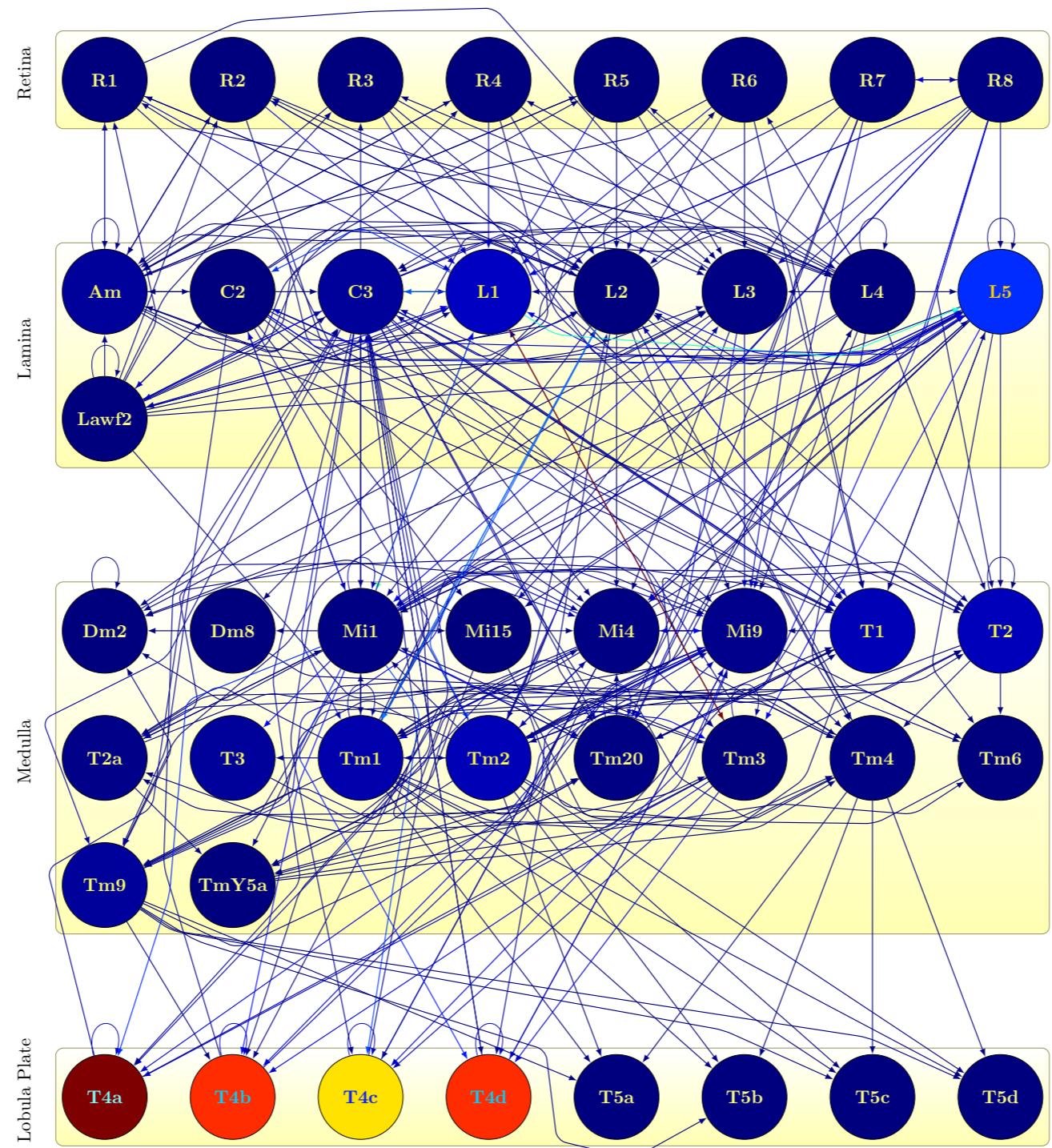
The Fly Visual System



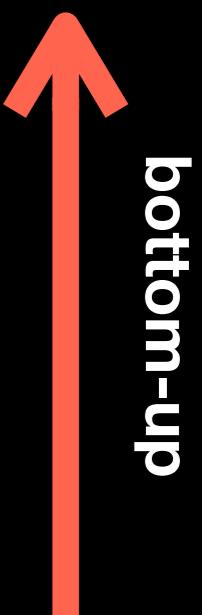
The Fly Visual System







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2023 Fall Course Program

