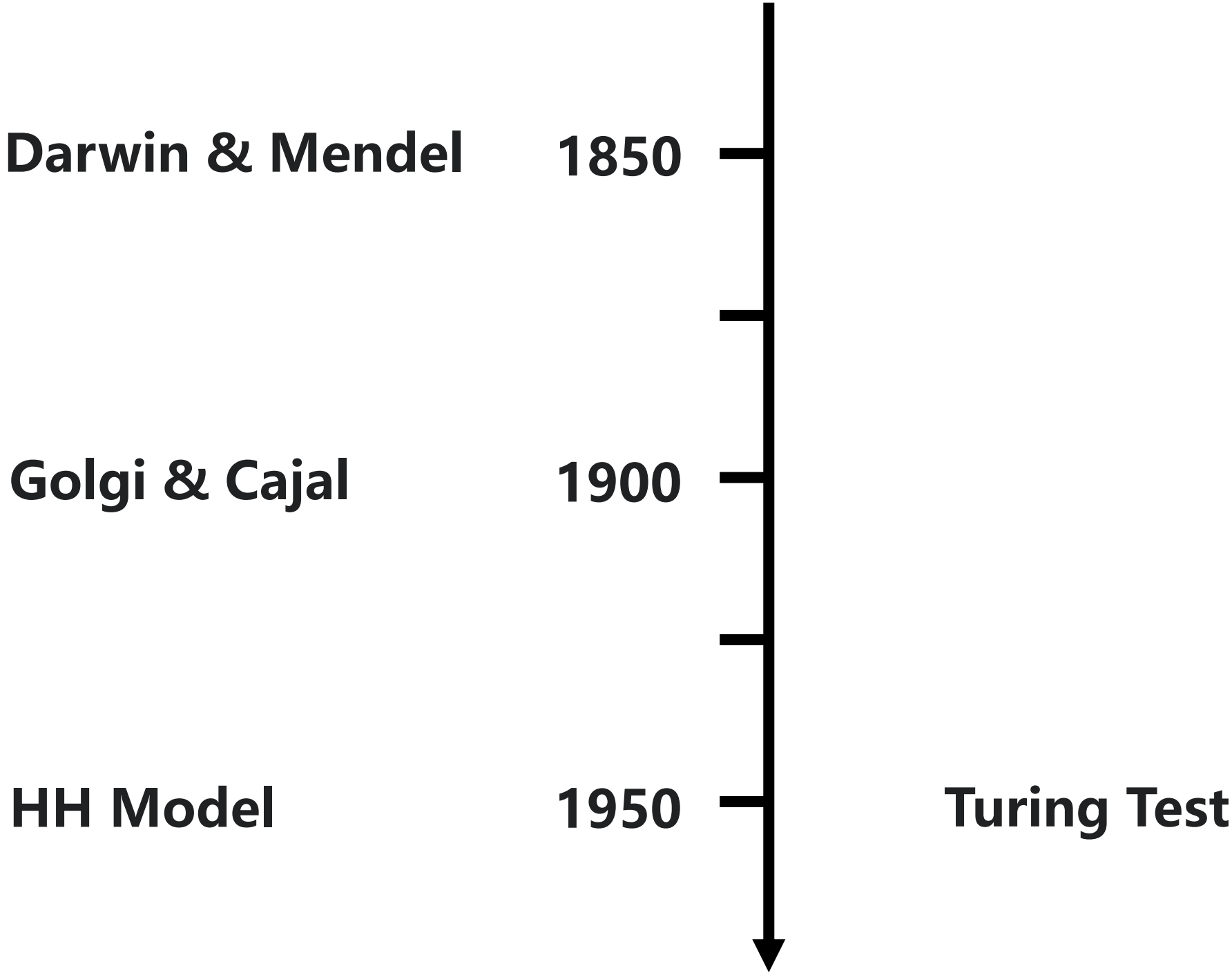
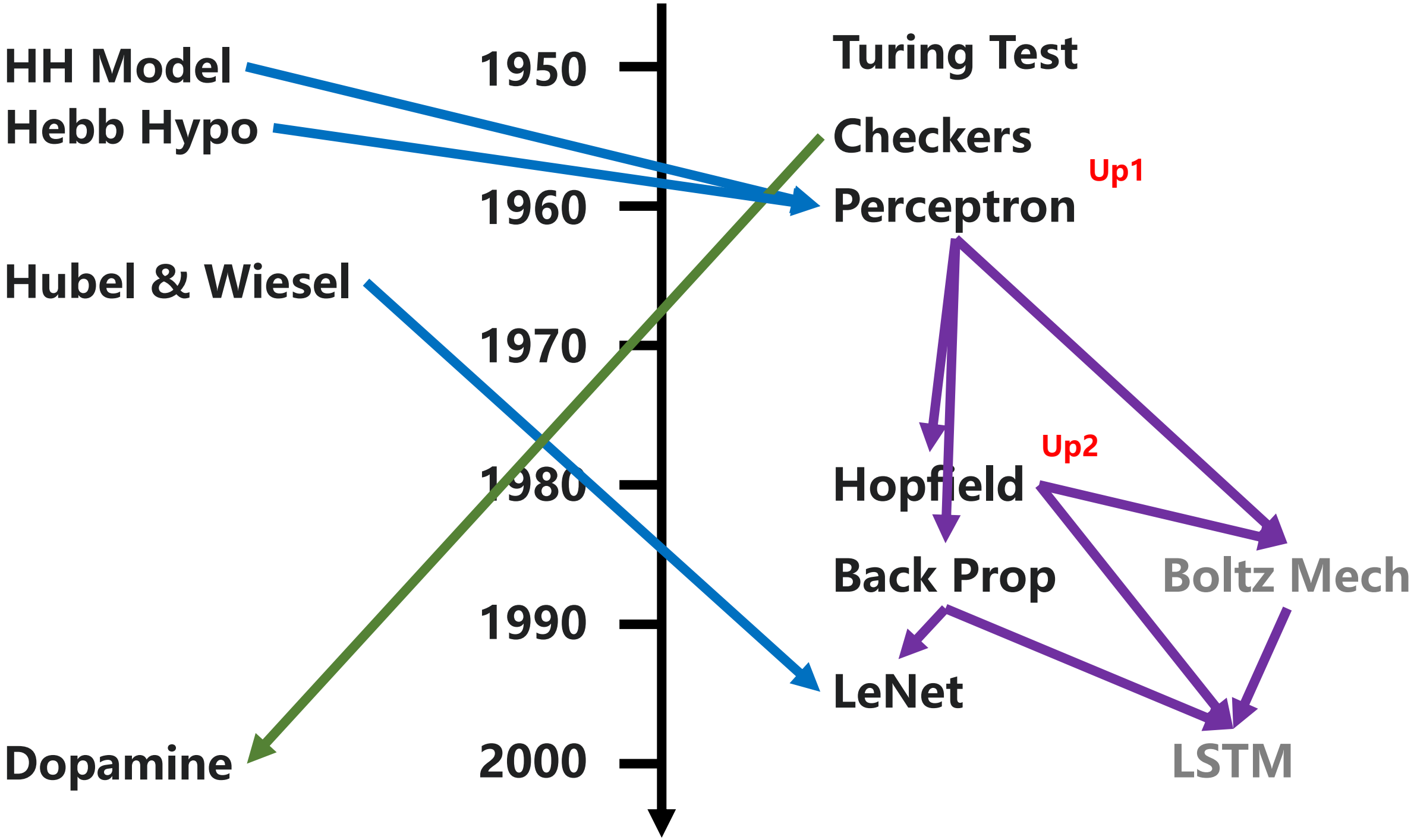
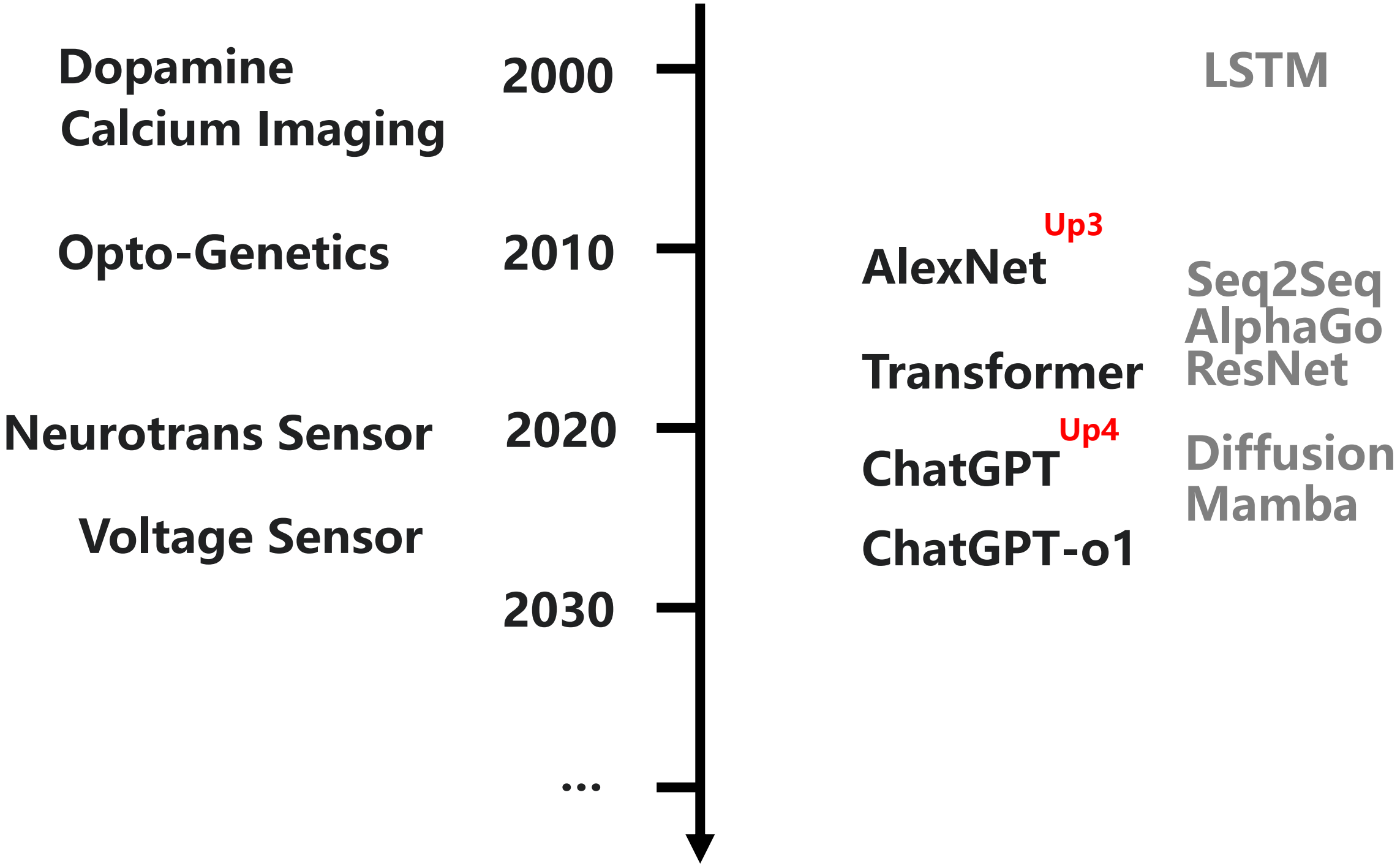
Neuroscience vs DL


Darwin & Mendel
1850
Golgi & Cajal
1900
HH Model
1950
Turing Test


HH Model
Hebb Hypo
Hubel & Wiesel
Dopamine
1950
1960
1970
1980
1990
2000
Turing Test
Checkers
Perceptron
Up1
Hopfield
Up2
Back Prop
Boltz Mech
LeNet
LSTM


Dopamine
Calcium Imaging
2000
LSTM
Opto-Genetics
2010
Up3
AlexNet
Seq2Seq
AlphaGo
Transformer
ResNet
Neurotrans Sensor
2020
Up4
ChatGPT
Diffusion
Mamba
Voltage Sensor
ChatGPT-o1
2030
...

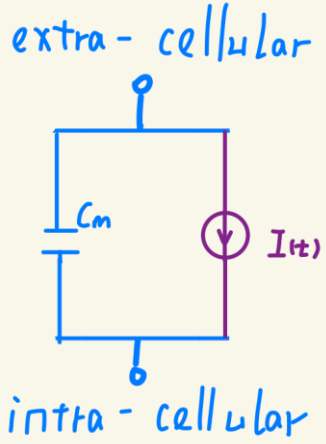
1. Goal

2. Motivation / Inspiration

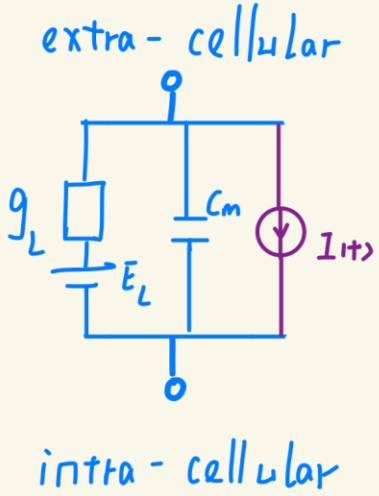
Single Neuron Model

1. Goal: Explain and Predict a Single Neuron.
2. Inspiration: Electrical Circuits.

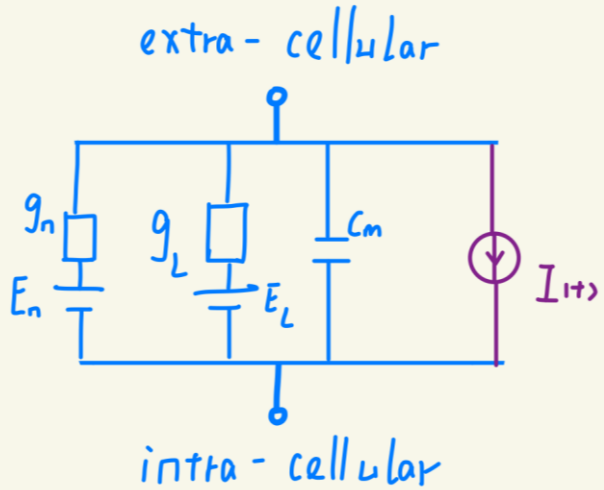
Non-Leak IF

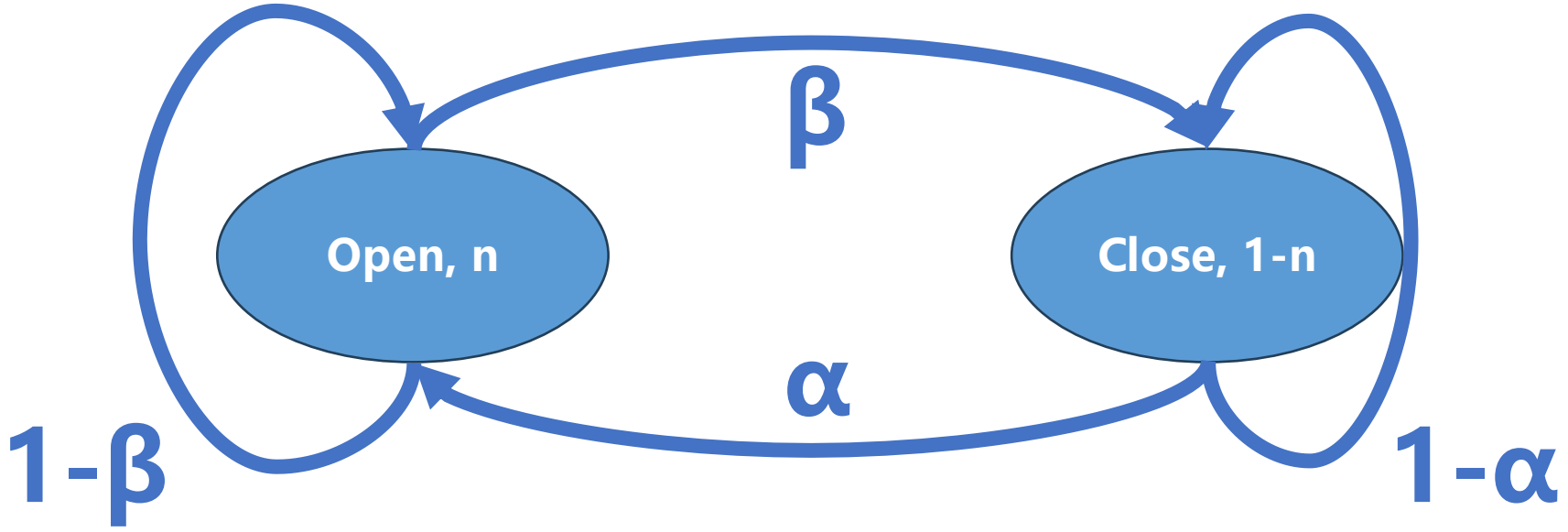


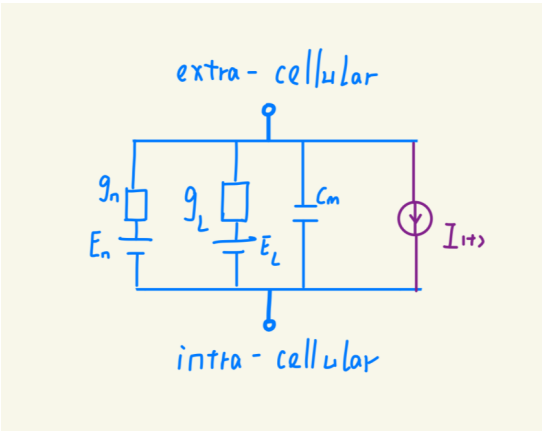
Leak IF



HH Model







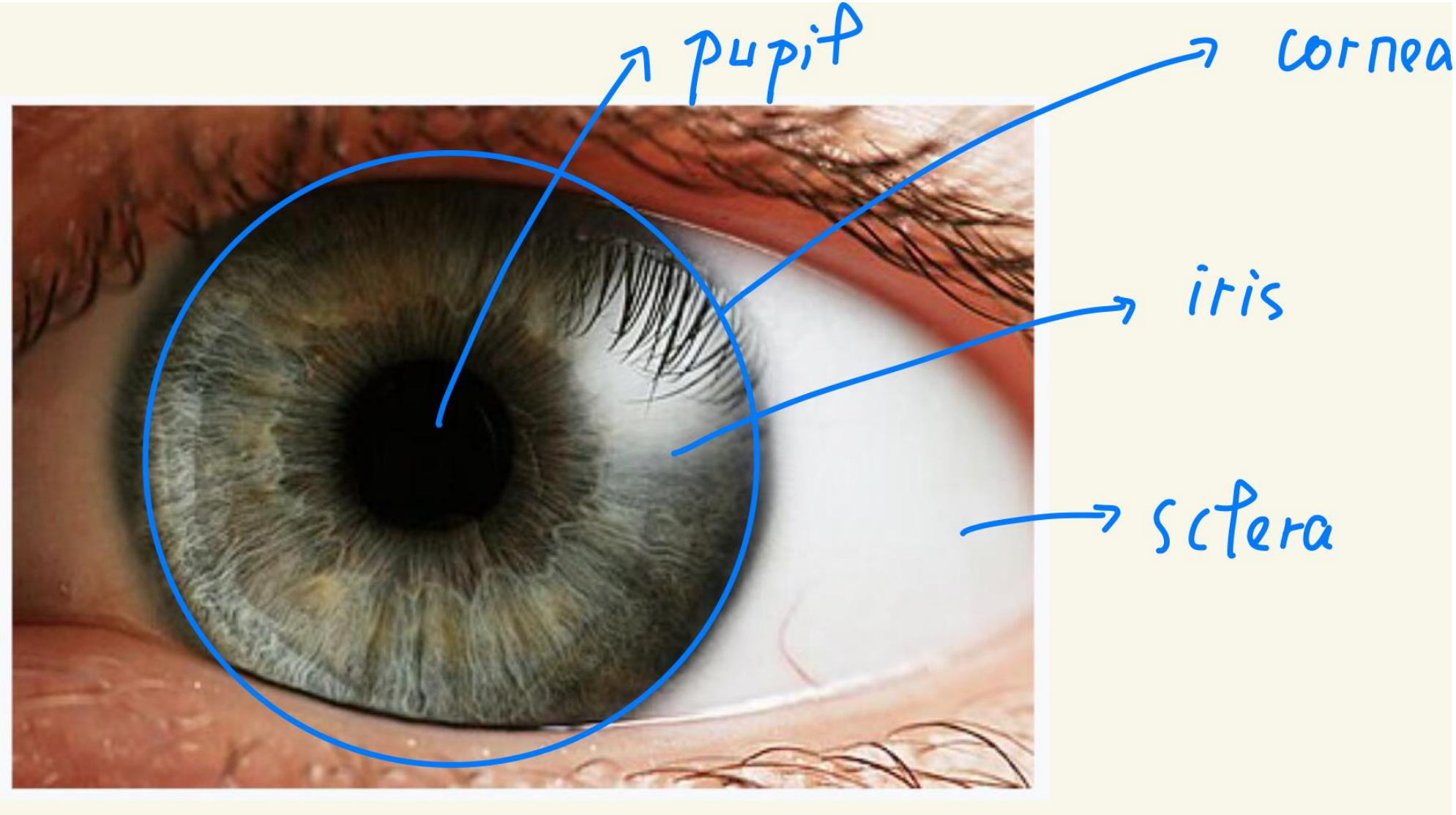
$$I = C_m \frac{\mathrm{d}V_m}{\mathrm{d}t} + \bar{g}_{\mathrm{K}} n^4 (V_m - V_K) + \bar{g}_{\mathrm{Na}} m^3 h (V_m - V_{Na}) + \bar{g}_l (V_m - V_l),$$

$$\frac{dn}{dt} = \alpha_n(V_m)(1-n) - \beta_n(V_m)n$$

$$\frac{dm}{dt} = \alpha_m(V_m)(1-m) - \beta_m(V_m)m$$

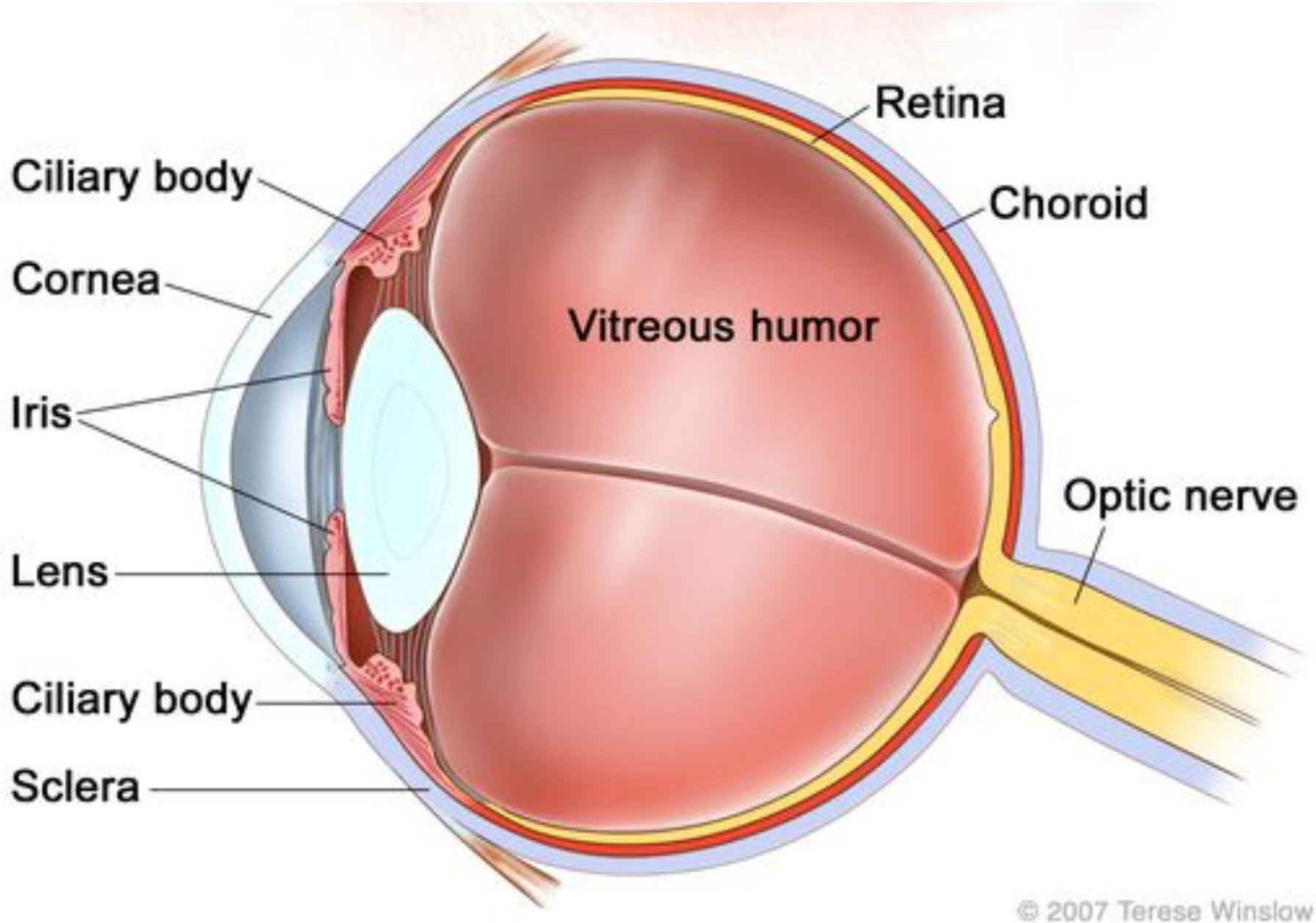
$$\frac{dh}{dt} = \alpha_h(V_m)(1-h) - \beta_h(V_m)h$$

Vision



Internet

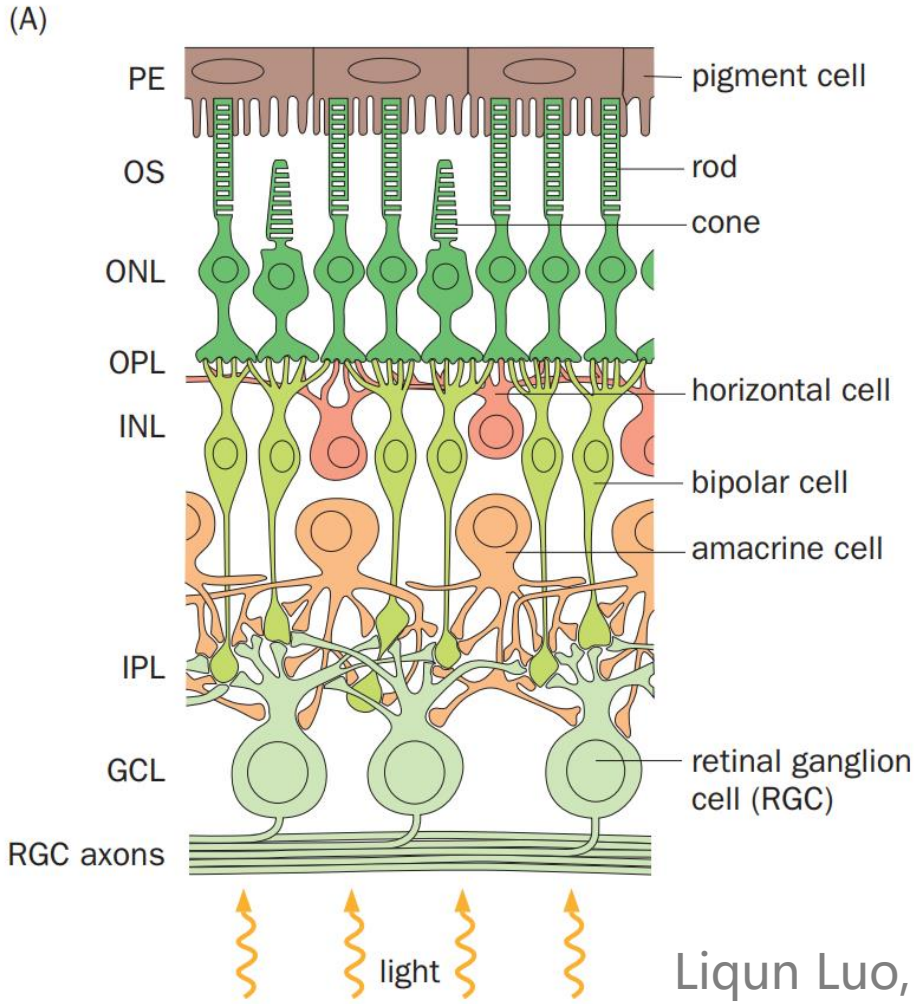
Vision



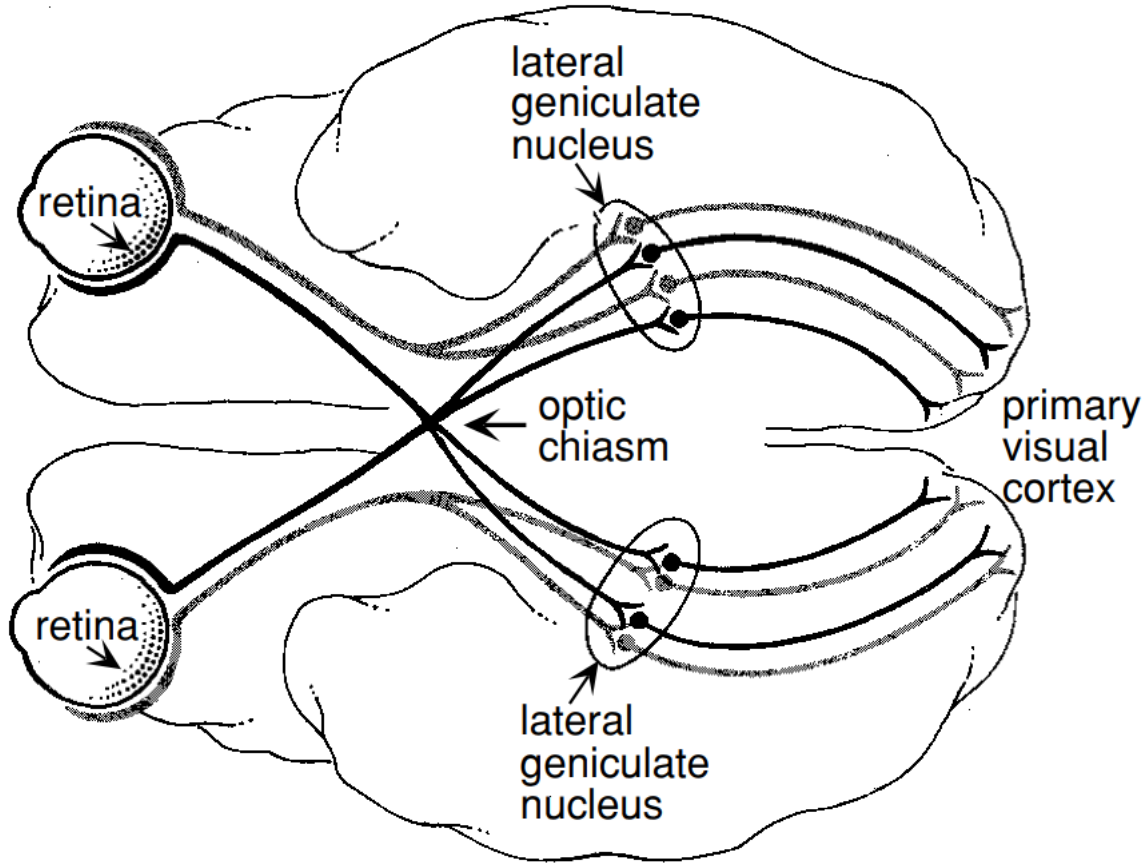
Internet

HW Model

1. Goal: How Do We See Things?
2. Inspiration: Linearity.



Liqun Luo, Principles of Neurobiology



Dayan, Theoretical Neuroscience

HW Model

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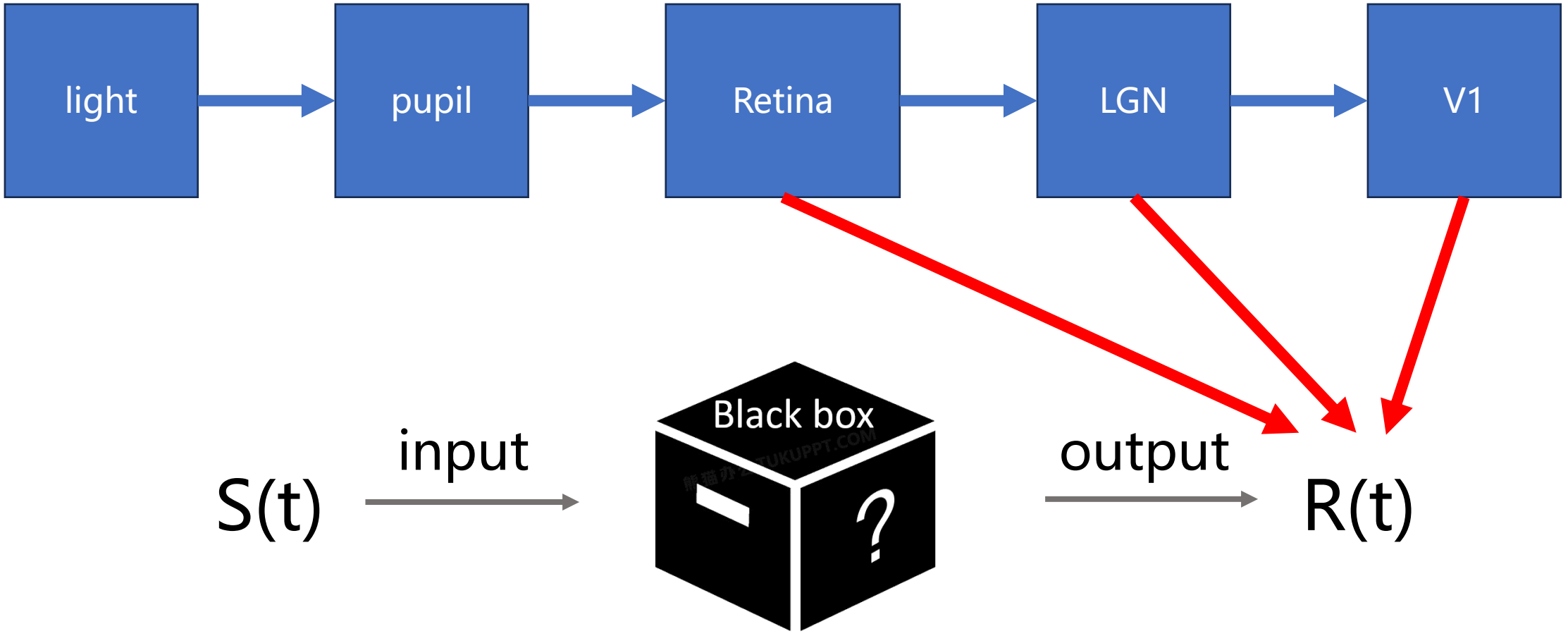
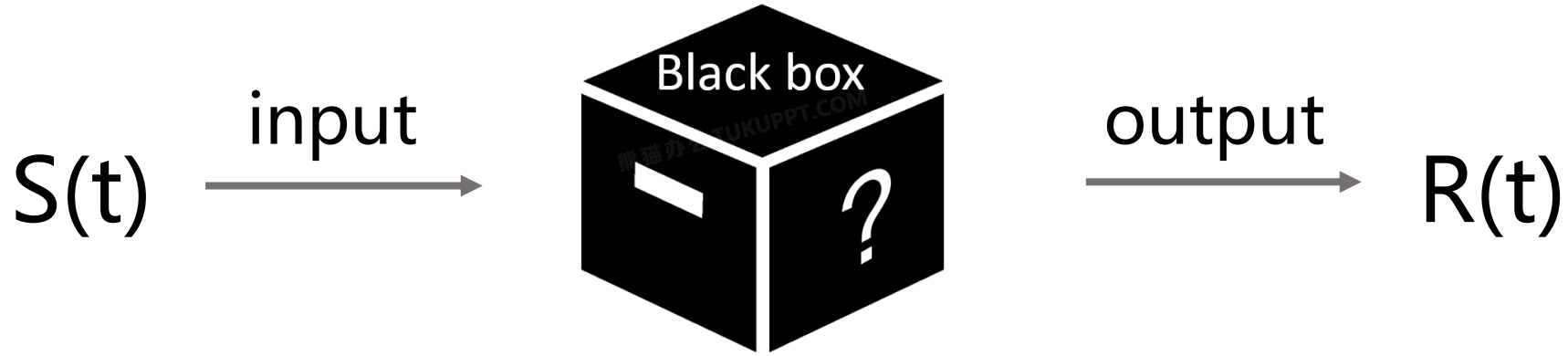




Weighted Mean

$$r_t = K \cdot S'_t, S'_t := [s_{t-N};\ s_{t-N+1};\ \ldots\ldots;\ s_{t-1}]$$

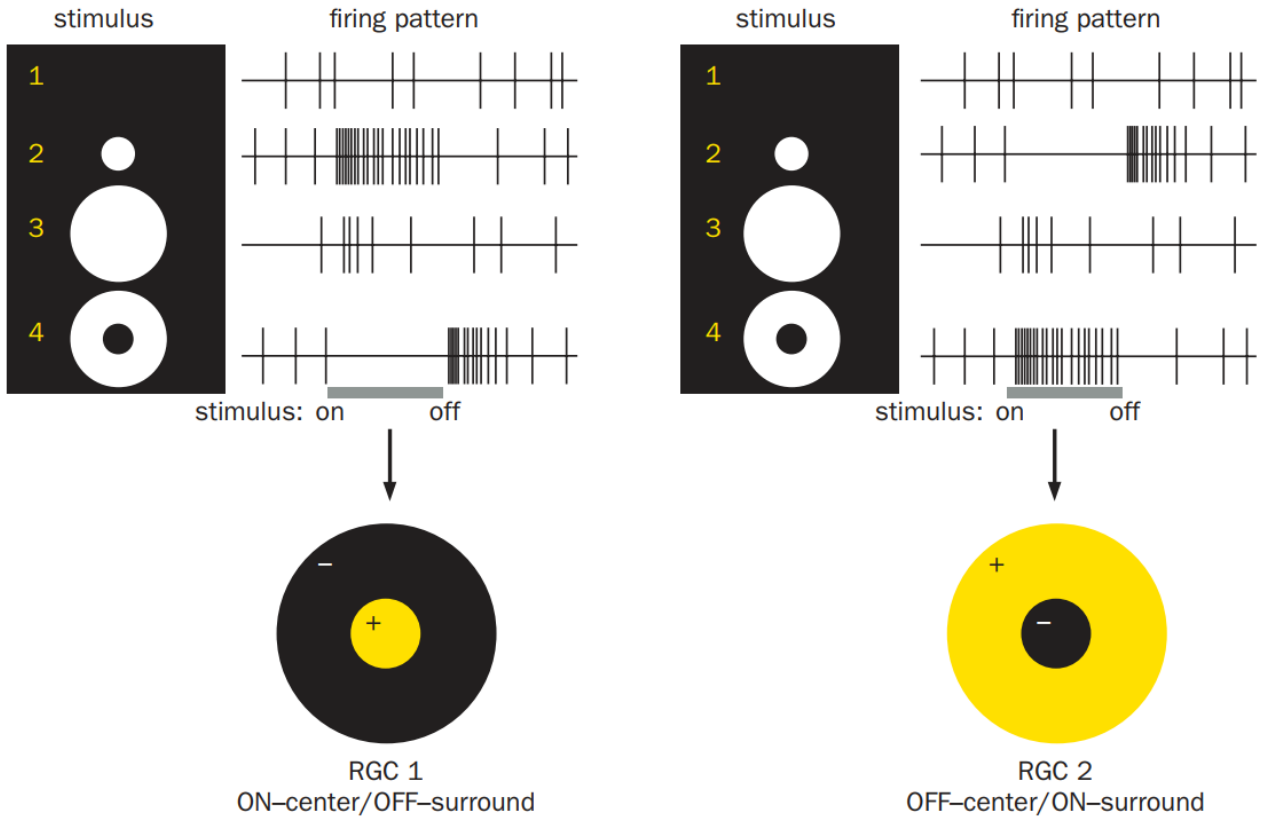
$$R = K \cdot S, R := [r_1, r_2, \ldots, r_T], S := [S'_1, S'_2, \ldots, S'_T]$$

Least Square

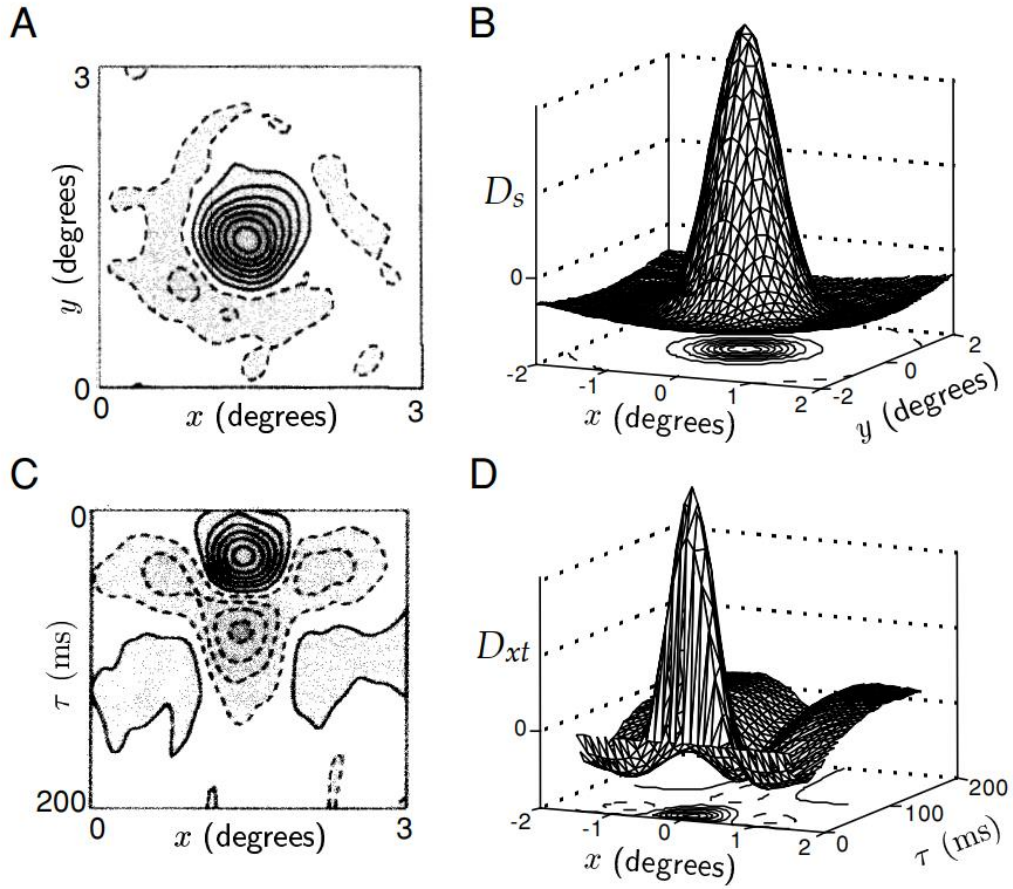
$$K = R\,S^T(SS^T)^{-1}$$

HW Model

1. Goal: How Do We See Things?
2. Inspiration: Linearity.



Liqun Luo, Principles of Neurobiology



Dayan, Theoretical Neuroscience

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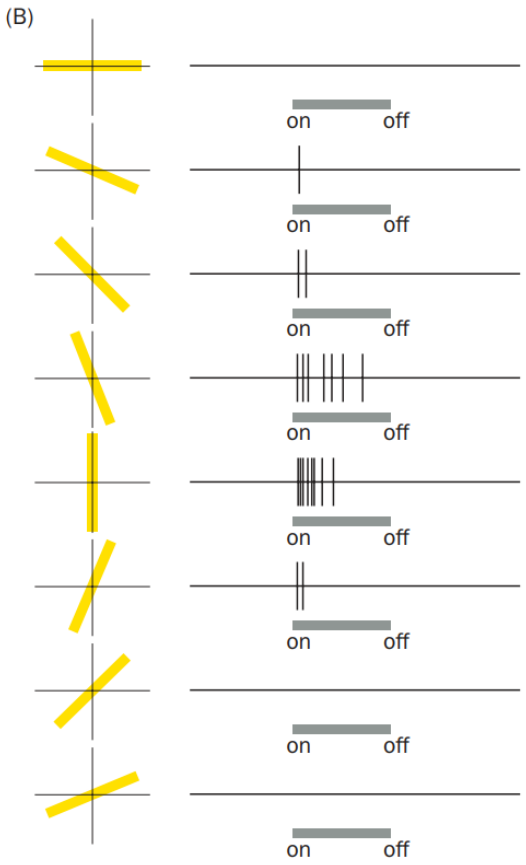
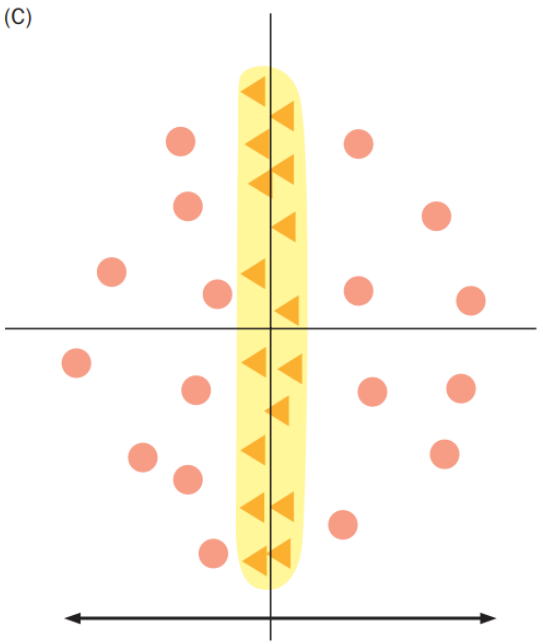
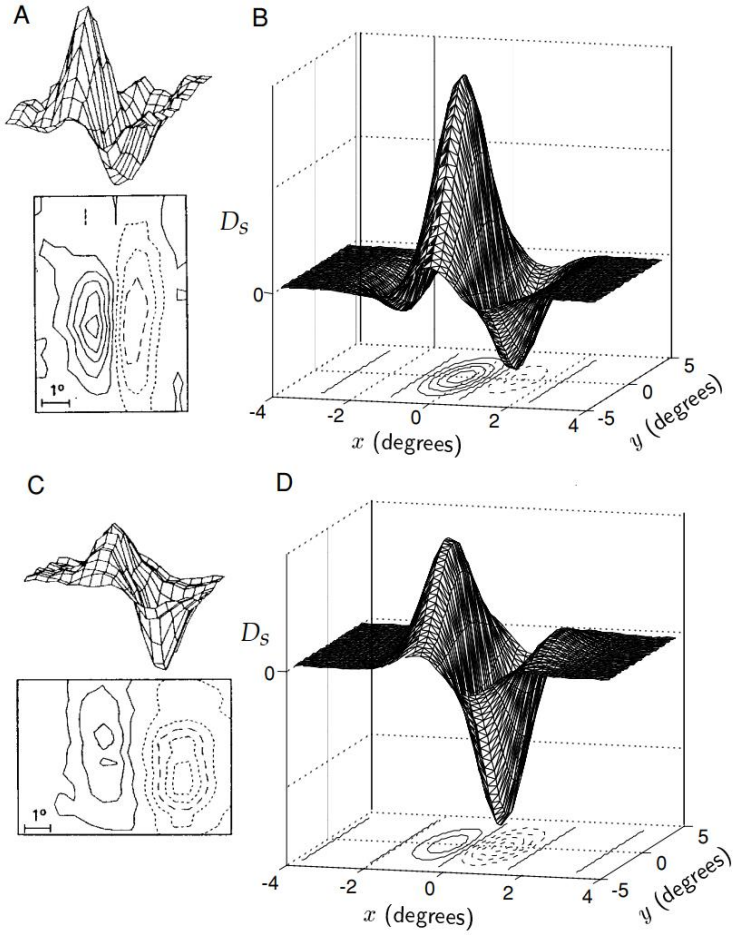




Liqun Luo, Principles of Neurobiology



Dayan, Theoretical Neuroscience

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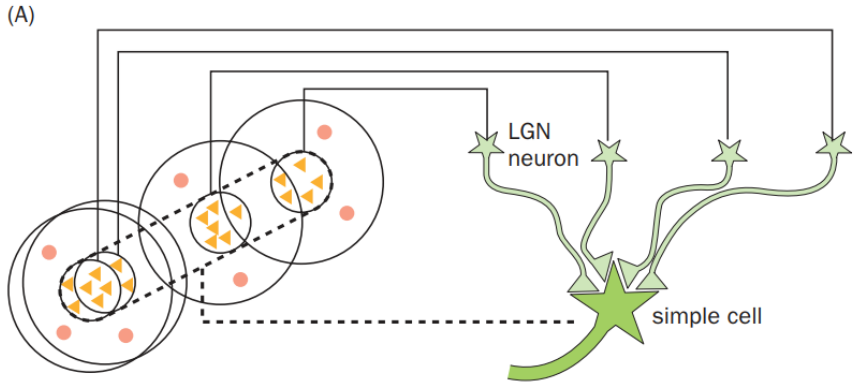
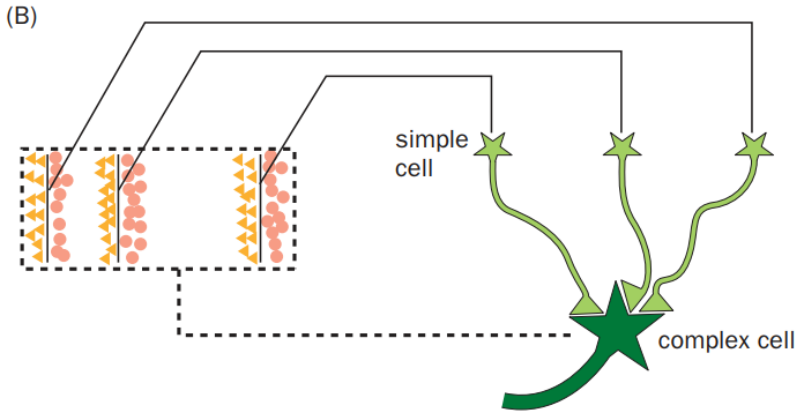
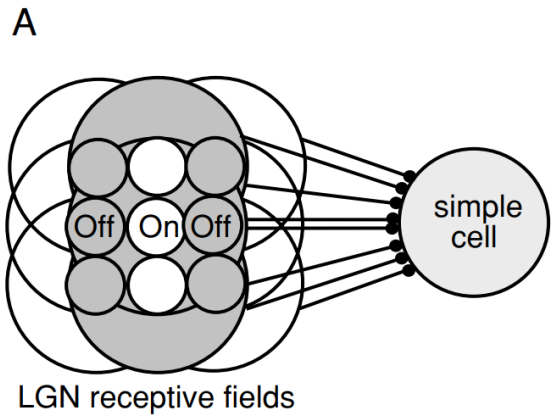
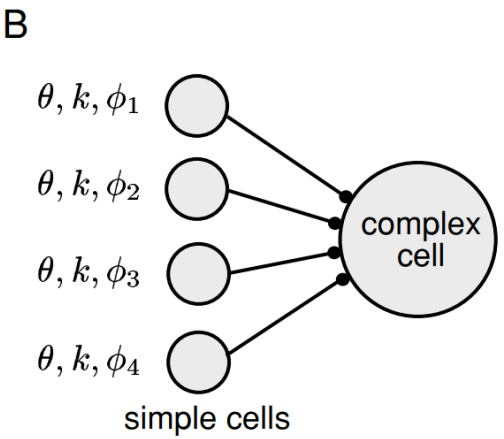
2. Inspiration: Linearity.





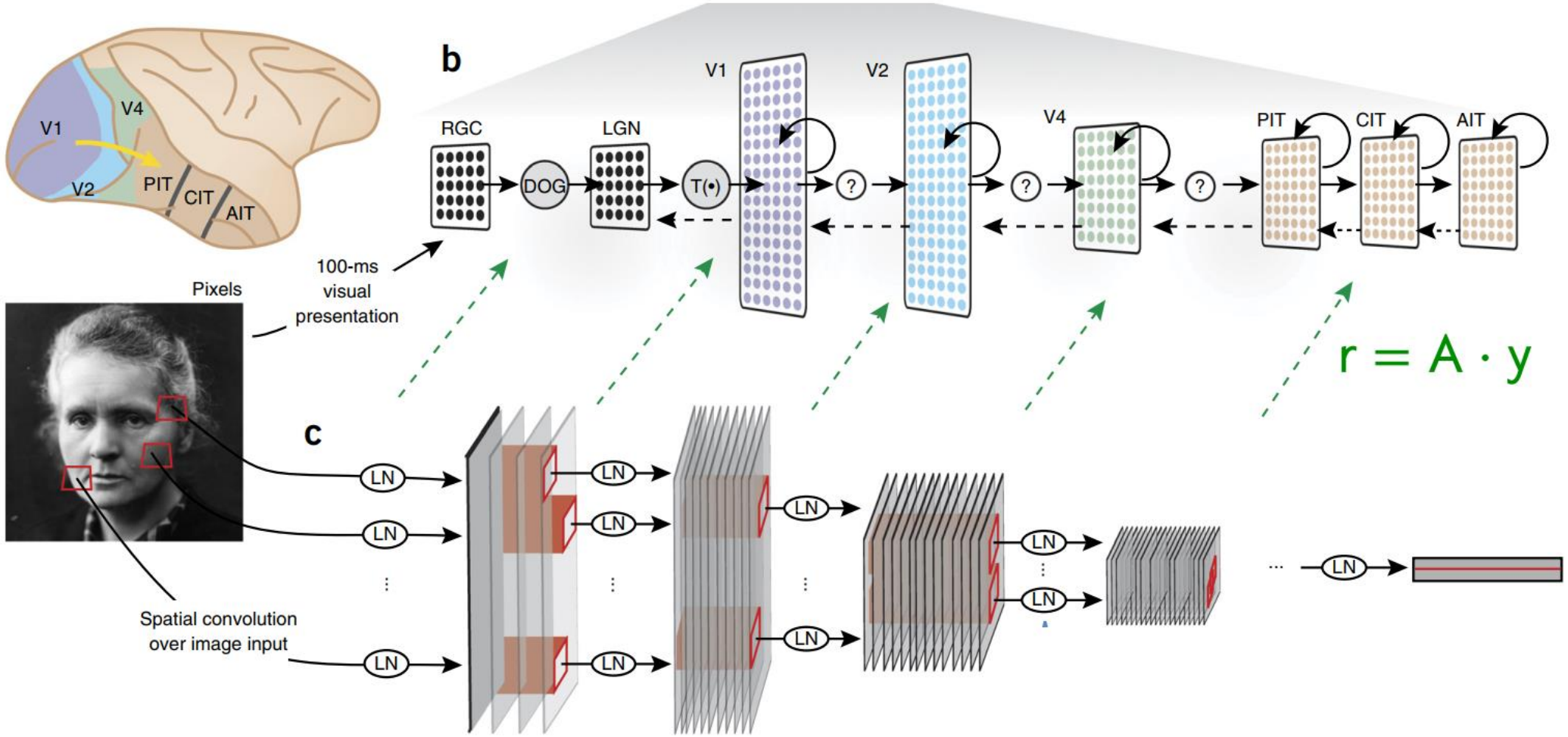
Liqun Luo, Principles of Neurobiology





Liqun Luo, Principles of Neurobiology

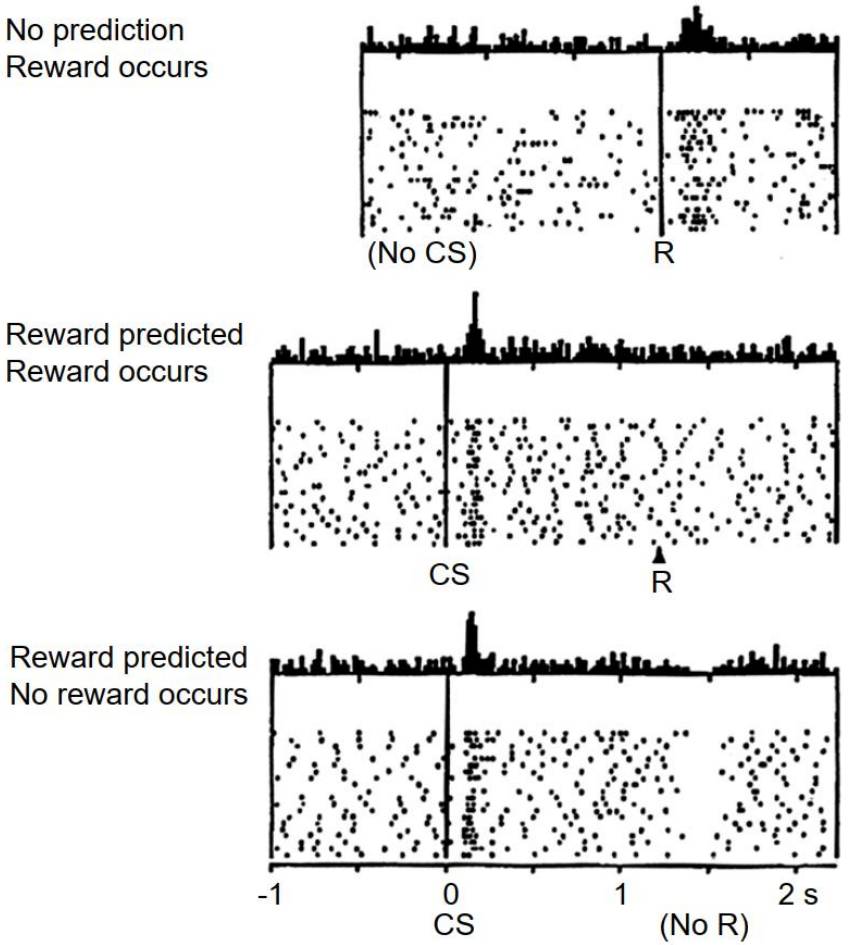
Vision Encoding



2016, Yamins et al.

Dopamine

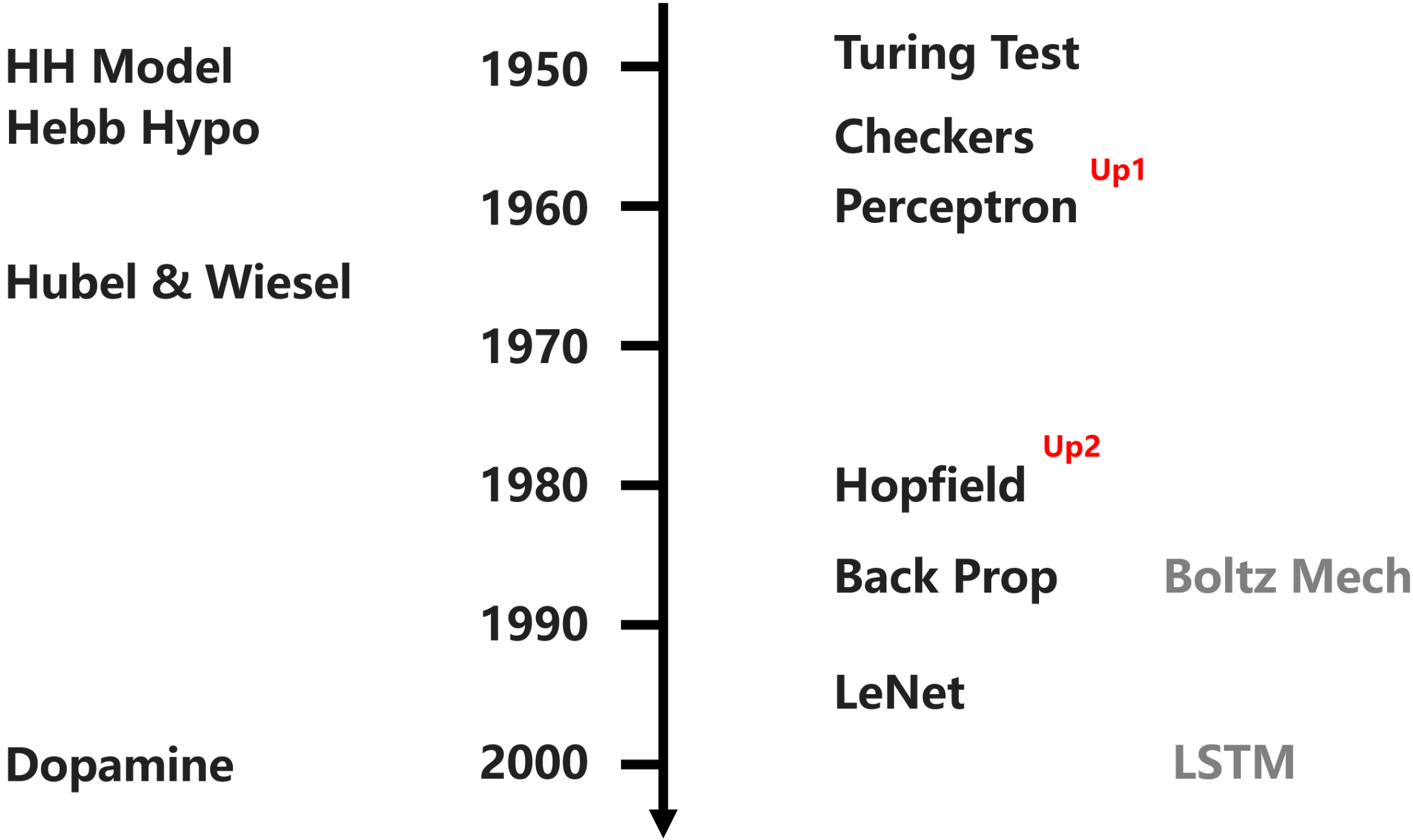
1. Goal: What does dopa represent?
2. Inspiration: RL.



1997, Schultz

$$V(S_t) \leftarrow (1-\alpha)V(S_t) + \underbrace{\alpha}_{\text{learning rate}} \overbrace{[R_{t+1} + \gamma V(S_{t+1})]}^{\text{The TD target}}$$

Dive into DL


HH Model
Hebb Hypo
Hubel & Wiesel
Dopamine
1950
1960
1970
1980
1990
2000
Turing Test
Checkers
Perceptron
Up1
Hopfield
Up2
Back Prop
Boltz Mech
LeNet
LSTM

Turing Test

1. Goal: What is an AI?
2. Inspiration: An Imitation Game

COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

1. The Imitation Game

In order that tones of voice may not help the interrogator the answers should be written, or better still, typewritten. The ideal arrangement is to have a teleprinter communicating between the two rooms. Alternatively the question and answers can be repeated by an intermediary. The object of the game for the third player (B) is to help the interrogator. The best strategy for her is probably to give truthful answers. She can add such things as "I am the woman, don't listen to him!" to her answers, but it will avail nothing as the man can make similar remarks.

C: Will X please tell me the length of his or her hair?

Now suppose X is actually A, then A must answer. It is A's object in the game to try and cause C to make the wrong identification. His answer might therefore be:

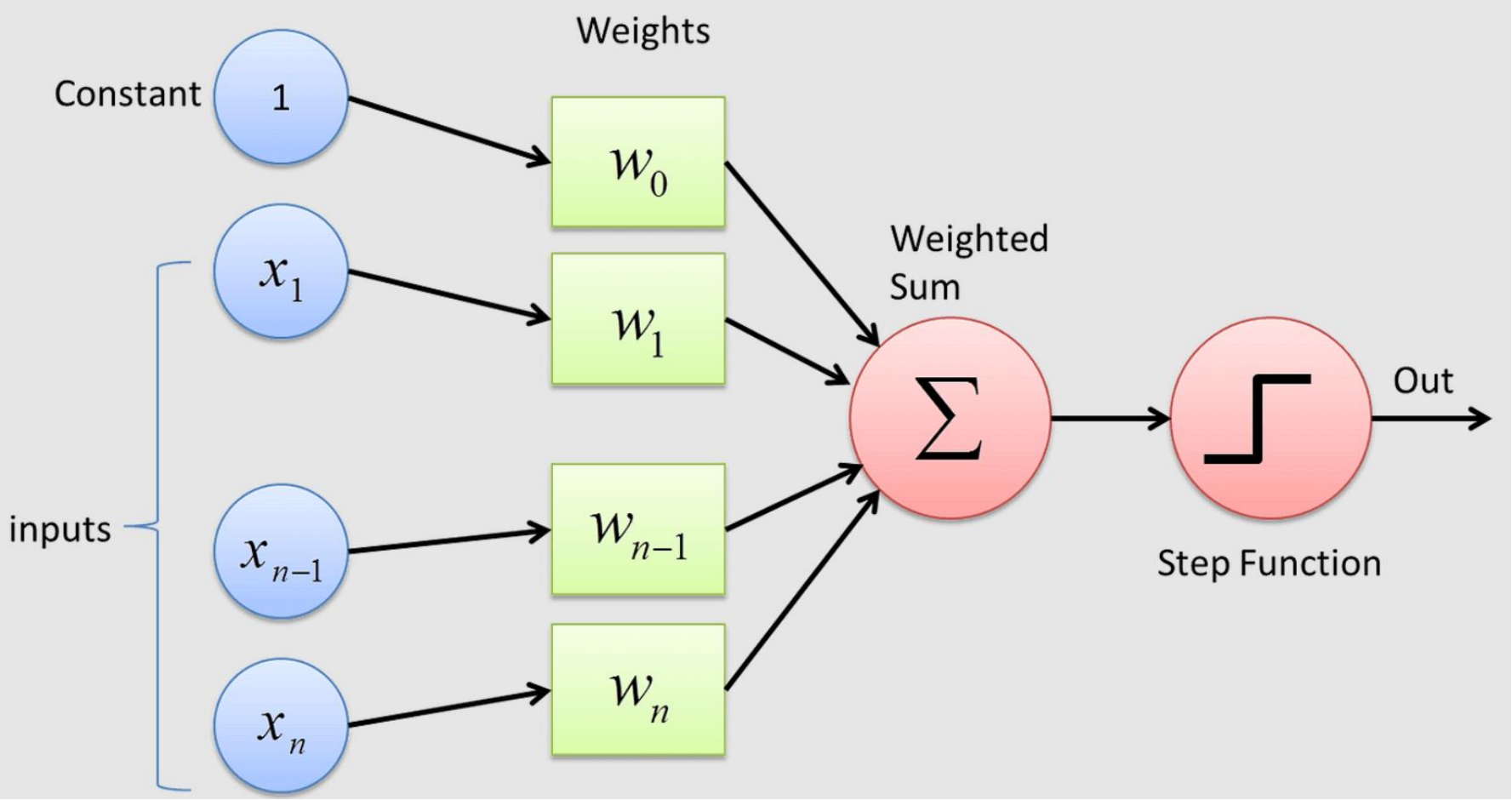
"My hair is shingled, and the longest strands are about nine inches long."

Turing, 1950

Perceptron

Up1

1. Goal: AGI.
2. Inspiration: Neurons

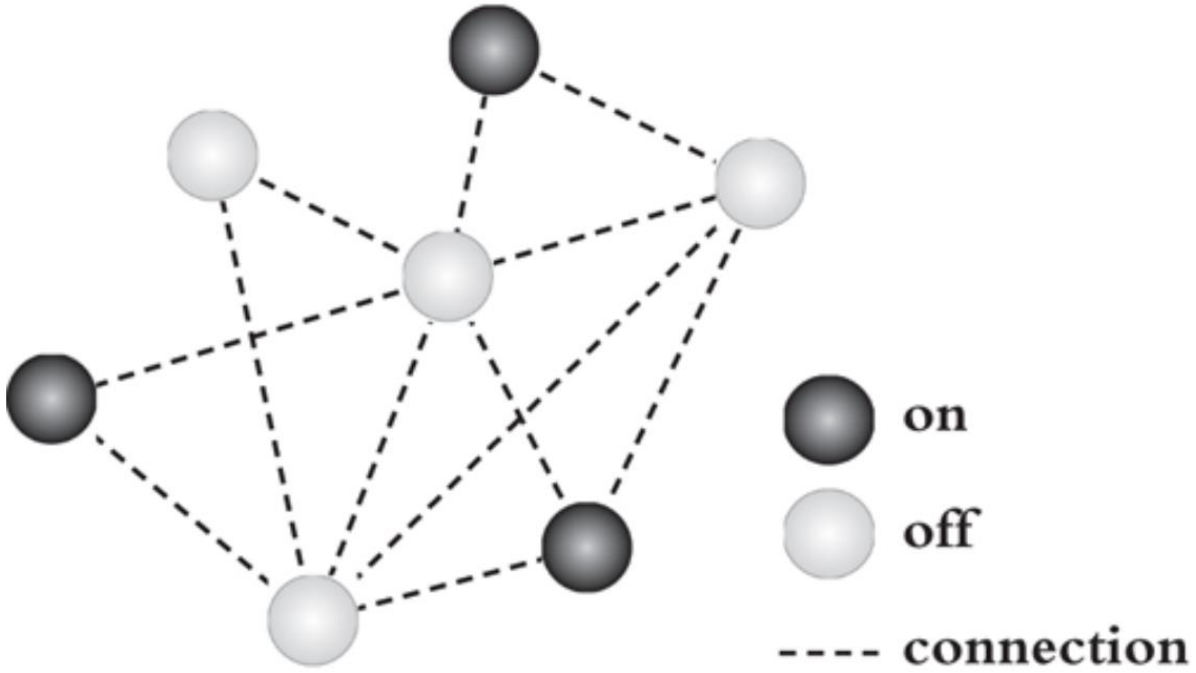


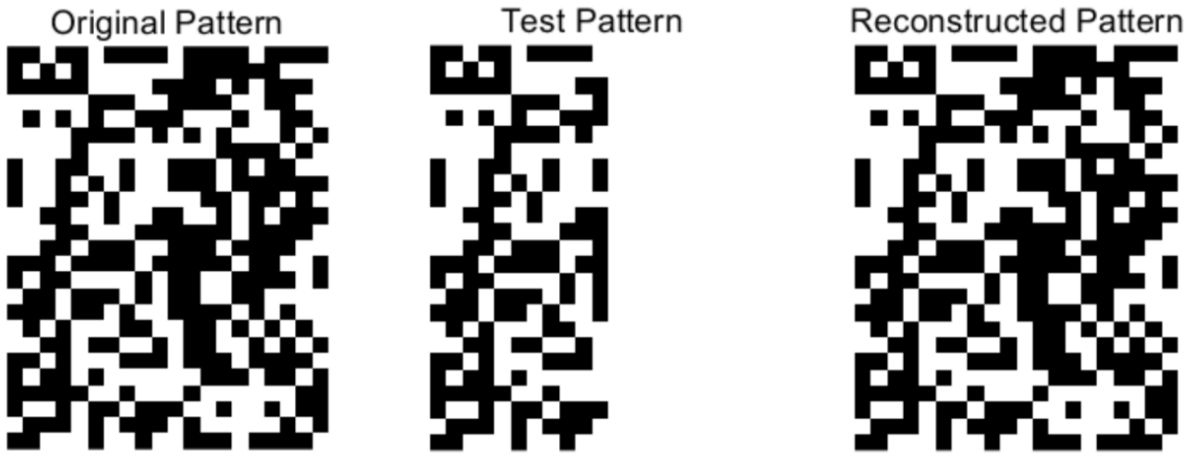
Internet

Hopfield

Up2

1. Goal: Explain Memory.
2. Inspiration: Ising Model





Hopfield & Travel

3. Energy Function Formulation:

The energy function E combines the constraints and the objective:

$$E = AE_1 + BE_2 + CE_3$$

Where:

- E_1**:** Enforces that each city is visited once.

$$E_1 = \frac{1}{2}\sum_{i=1}^{N}\left(\sum_{k=1}^{N} V_i^k - 1\right)^2$$

- E_2**:** Ensures each position in the tour is occupied.

$$E_2 = \frac{1}{2}\sum_{k=1}^{N}\left(\sum_{i=1}^{N} V_i^k - 1\right)^2$$

- E_3**:** Incorporates the total distance.

$$E_3 = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{N} D_{ij} V_i^k V_j^{k+1}$$

  - D_{ij}: Distance between city i and city j.
  - $V_j^{N+1} = V_j^1$ (to return to the starting city).

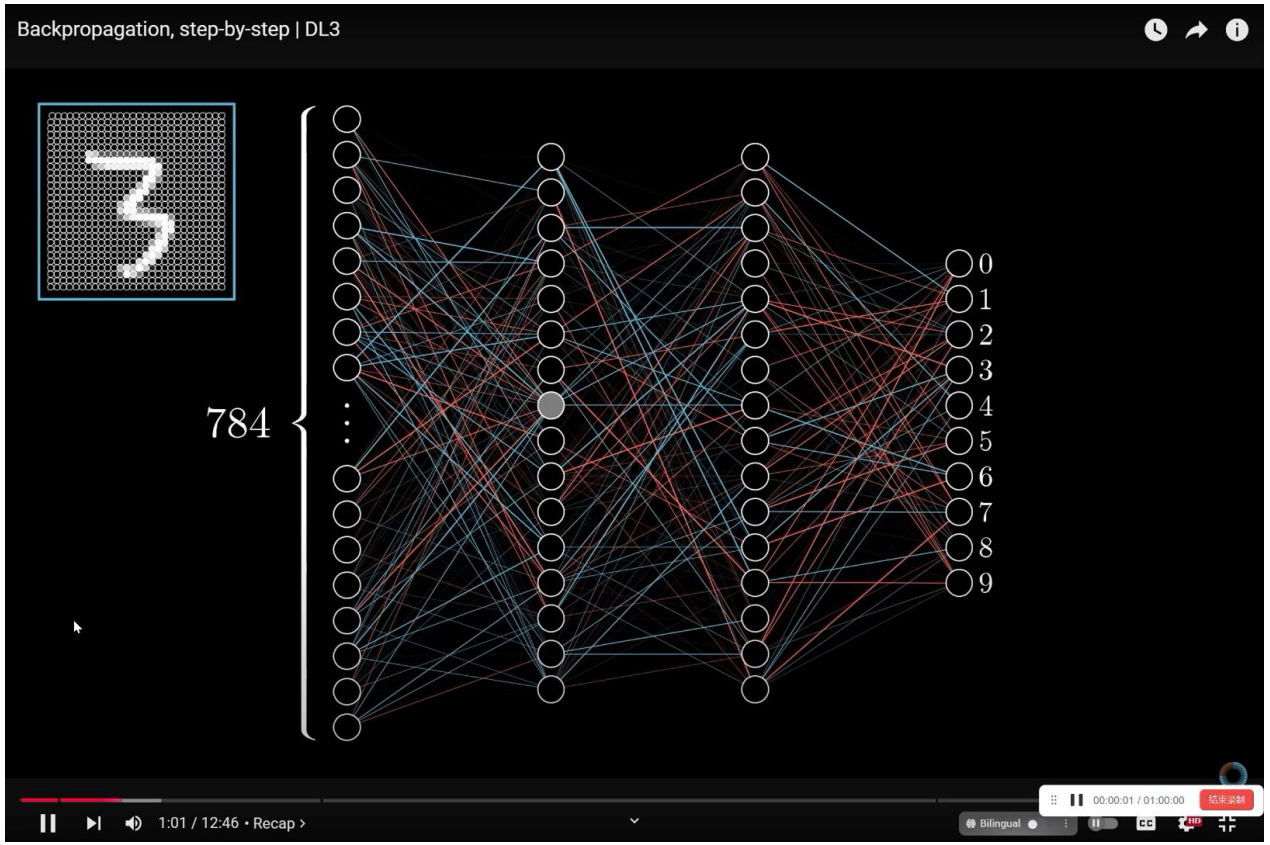
$$E = A/2 \sum_X \sum_i \sum_{j \neq i} V_{Xi} V_{Xj} + B/2 \sum_i \sum_X \sum_{X \neq Y} V_{Xi} V_{Yi}$$
$$+ C/2 \left(\sum_X \sum_i V_{Xi} - n\right)^2, \qquad (8)$$

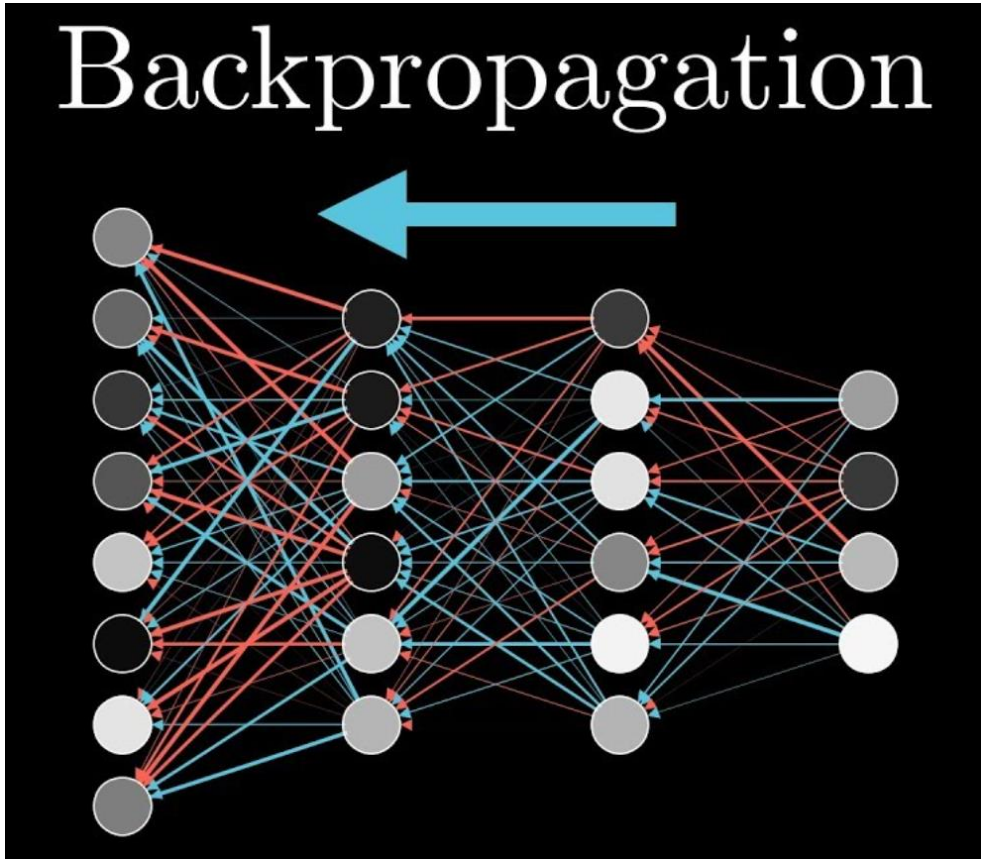
$$T_{Xi,Yj} = -A\delta_{XY}(1-\delta_{ij}) \text{ “inhibitory connections within each row”}$$
$$-B\delta_{ij}(1-\delta_{XY}) \text{ “inhibitory connections within each column”}$$
$$-C \text{ “global inhibition”}$$
$$-Dd_{XY}(\delta_{j,i+1} + \delta_{j,i-1}) \text{ “data term”}$$
$$[\delta_{ij} = 1 \quad \text{if} \quad i = j \text{ and is 0 otherwise}]. \qquad (10)$$

Hopfield, 1985

Back Prop

1. Goal: Train MLP.
2. Inspiration: Leibniz Rules

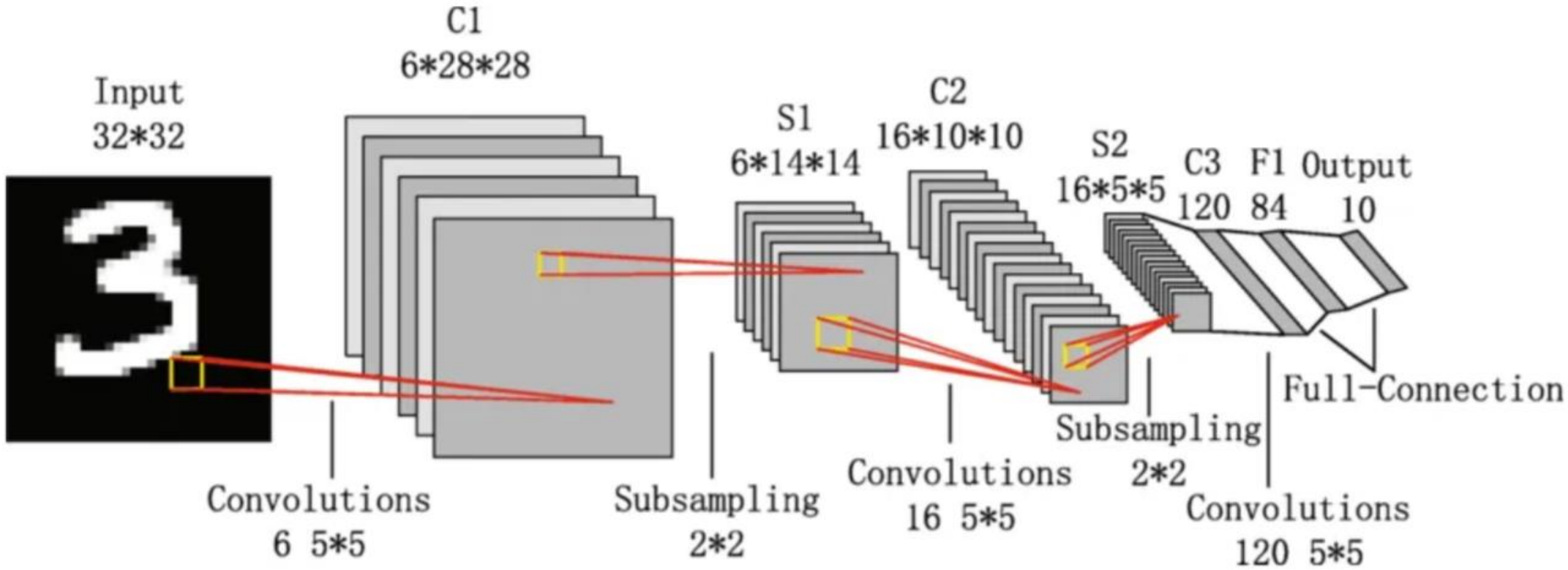




Internet

LeNet

1. Goal: Image Classification.
2. Inspiration: Hubel-Wiesel

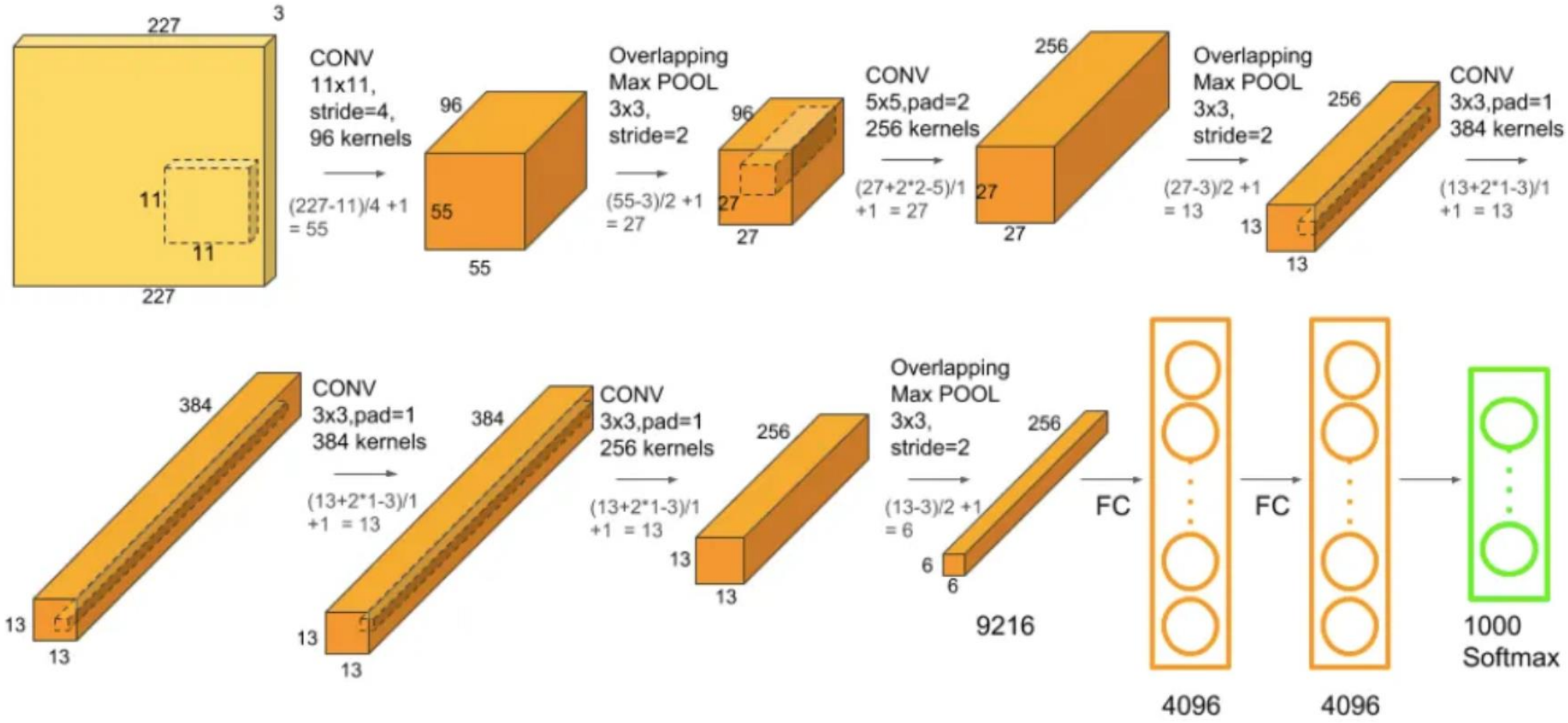


Internet

AlexNet

Up3

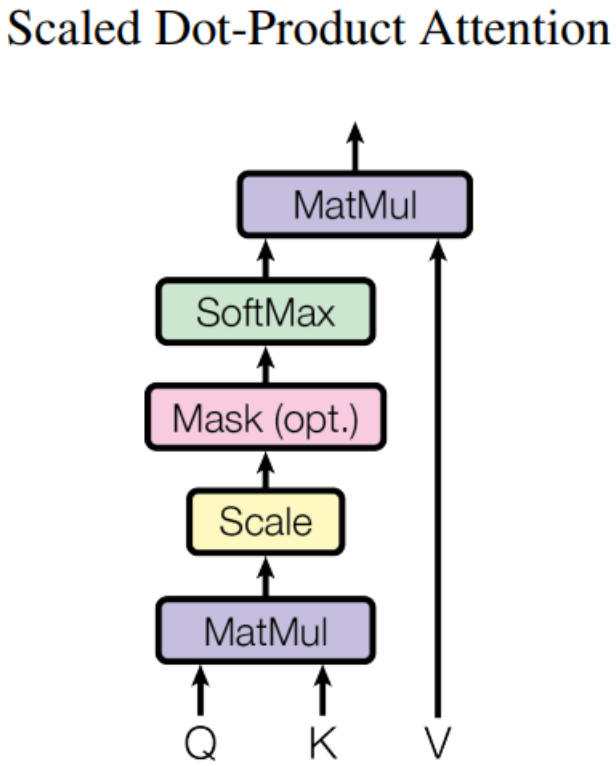
1. Goal: Image Classification.
2. Inspiration: HW; LeNet.



Internet

Transformer

1. Goal: NLP.
2. Inspiration: I do not know.

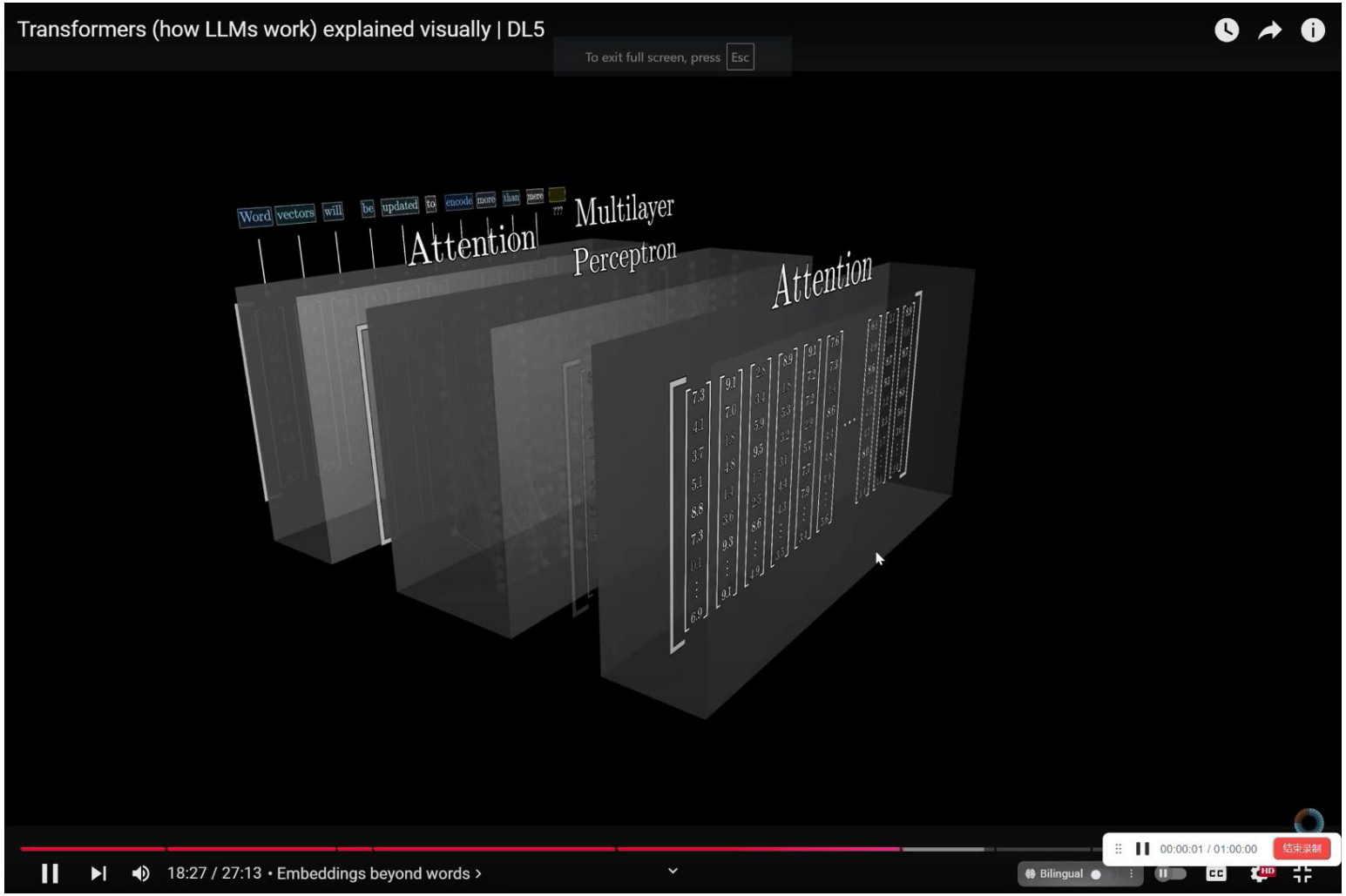


$$\text{Attention}(Q, K, V) = \text{softmax}(\frac{QK^T}{\sqrt{d_k}})V$$

Attention Is All You Need, 2017

GPT

1. Goal: AGI
2. Inspiration: Attention; MLP.



youtube.com/@3blue1brown

ChatGPT Up4

1. Goal: AGI
2. Inspiration: RL; Human Label.

Prompt

Explain the moon landing to a 6 year old in a few sentences.

Completion

GPT-3

```
Explain the theory of gravity to a 6 year old.

Explain the theory of relativity to a 6 year old in a few sentences.

Explain the big bang theory to a 6 year old.

Explain evolution to a 6 year old.
```

InstructGPT

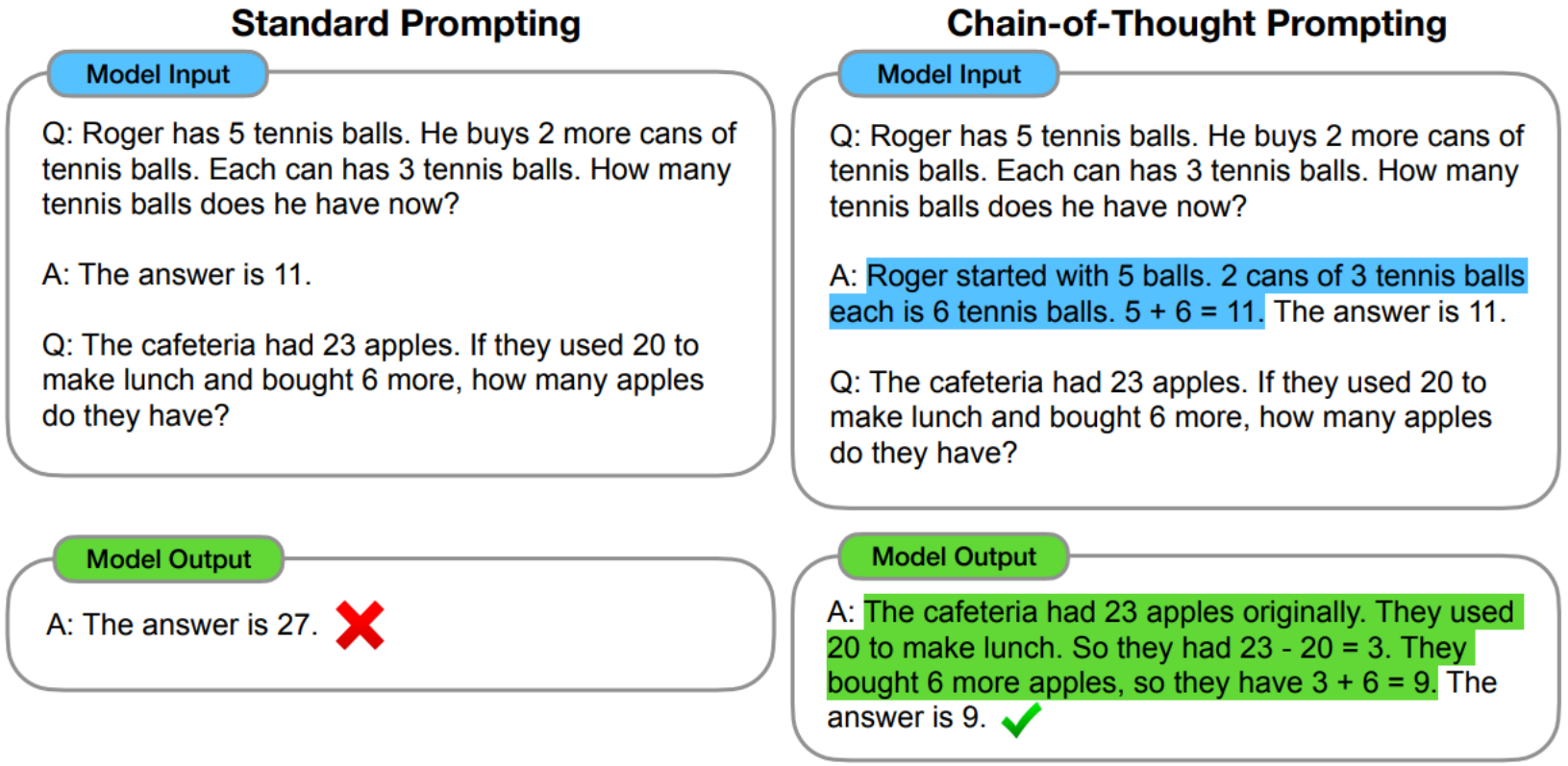
```
People went to the moon, and they took pictures of what they saw, and sent them back to the earth so we could all see them.
```


openai.com/index/instruction-following/

youtube.com/@3blue1brown

ChatGPT-o1

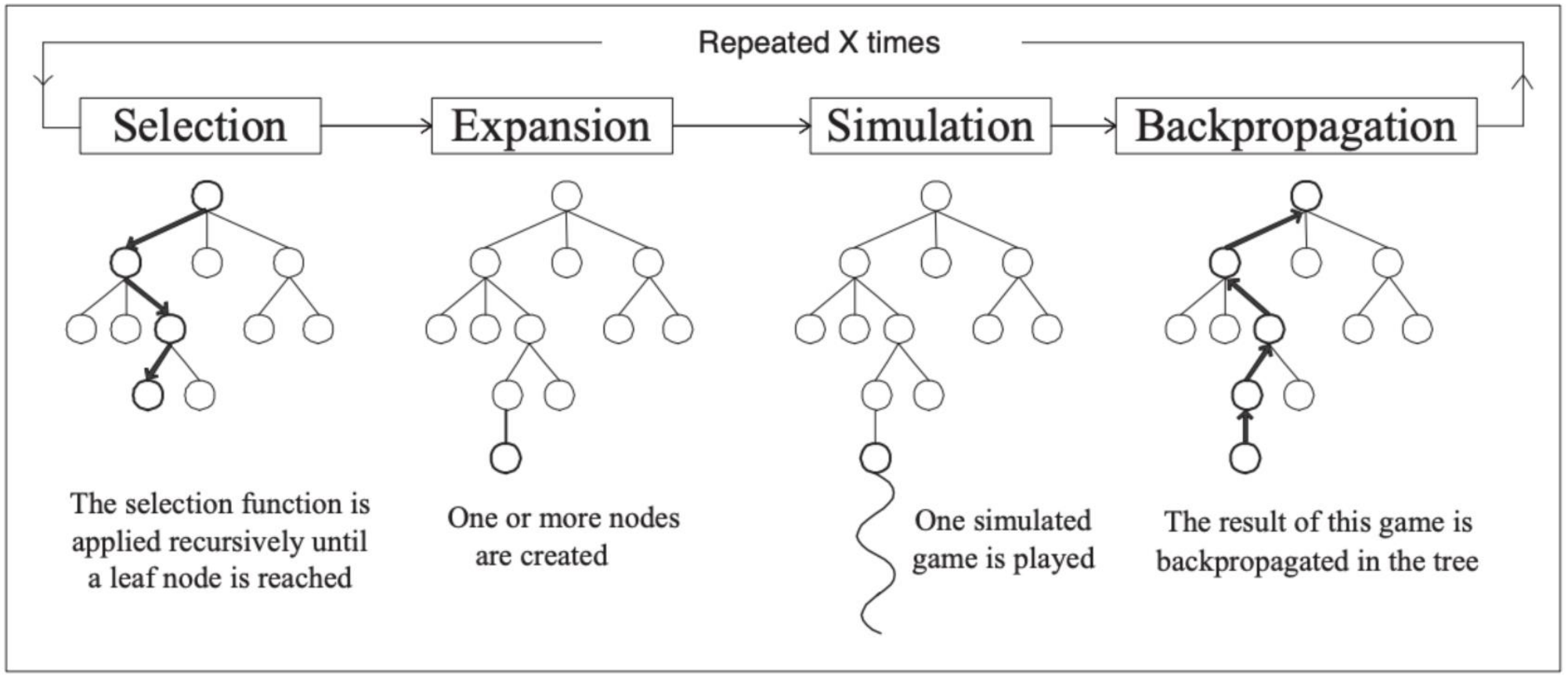
1. Goal: AGI
2. Inspiration: Chain of Thought; Monte Carlo Tree Search.



Jason Wei, 2022-01

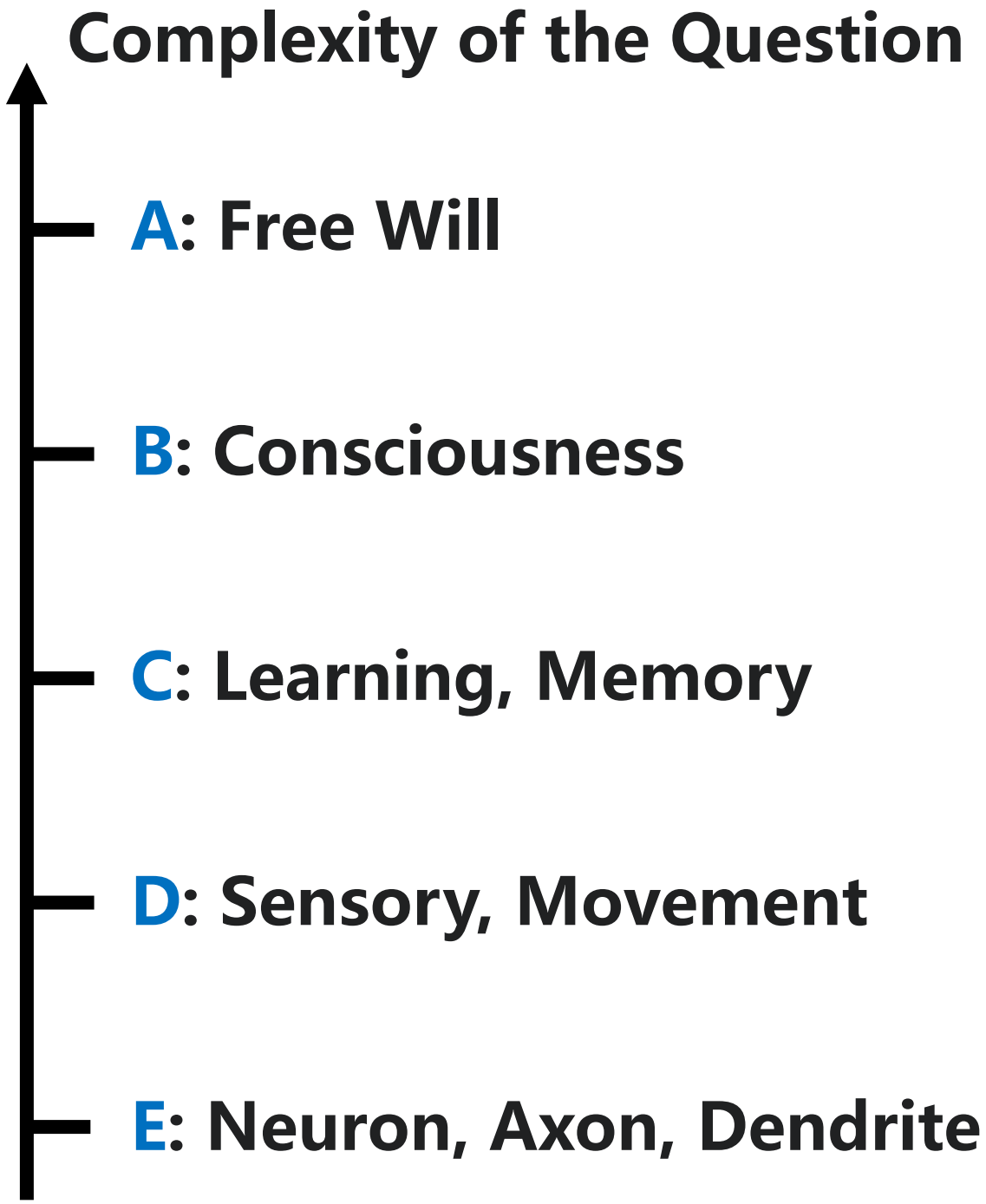
ChatGPT-o1

1. Goal: AGI
2. Inspiration: Chain of Thought; Monte Carlo Tree Search.



Internet

Complexity of Neuro & DL



What We Just Saw

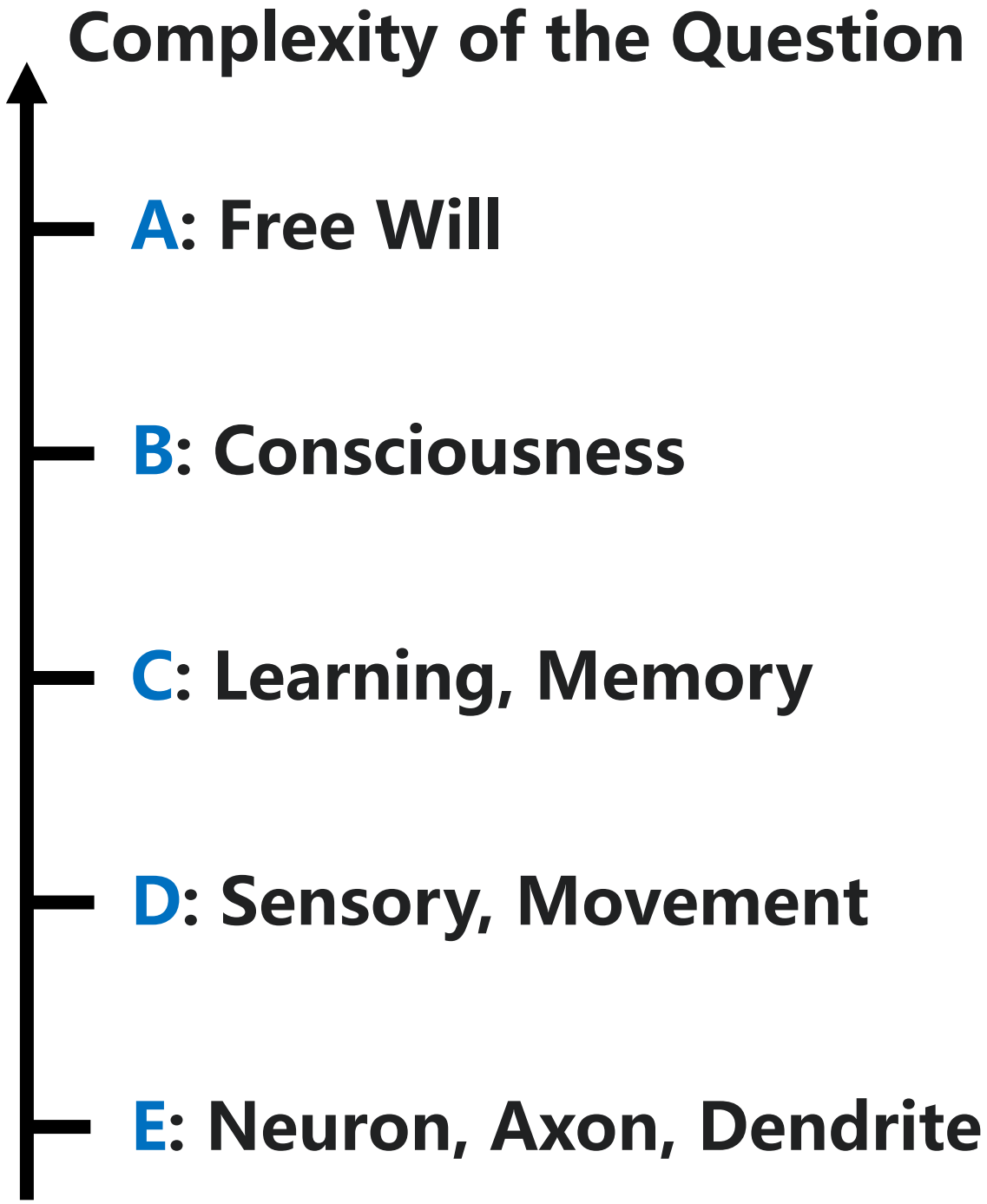
1. HH Model	E
2. Hubel-Wiesel	D
3. Perceptron & BP	C
4. Hopfield Network	C
5. Dopamine	C
6. LeNet/AlexNet	C
7. Transformer	C
8. ChatGPT 3.5/o1	C? B? A?

Complexity of the Question

- **A: Free Will**
- **B: Consciousness**
- **C: Learning, Memory**
- **D: Sensory, Movement**
- **E: Neuron, Axon, Dendrite**

Other Neuro Topics

1. Singing — **D**
2. Integrate Info Theory — **B**
3. 读心术/传心术 — **A**
4. 心灵操纵 — **A**
5. 意识上传 — **B**
6. Psychology — **A**
7. Sleep — **C? D?**

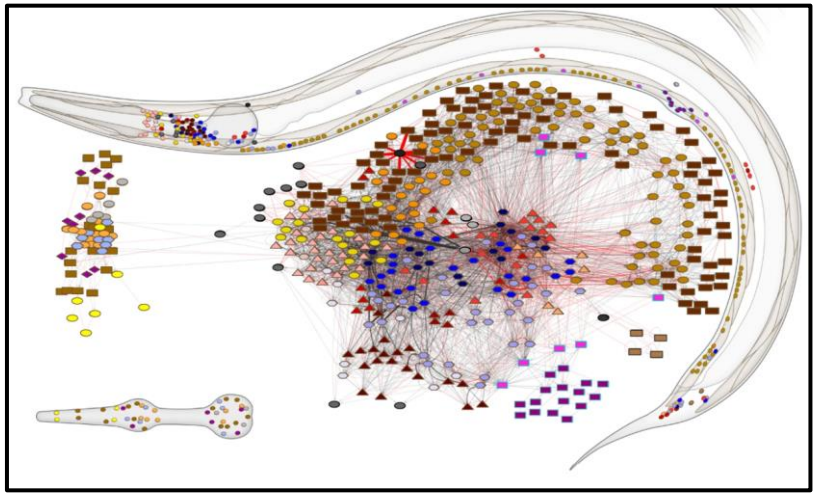


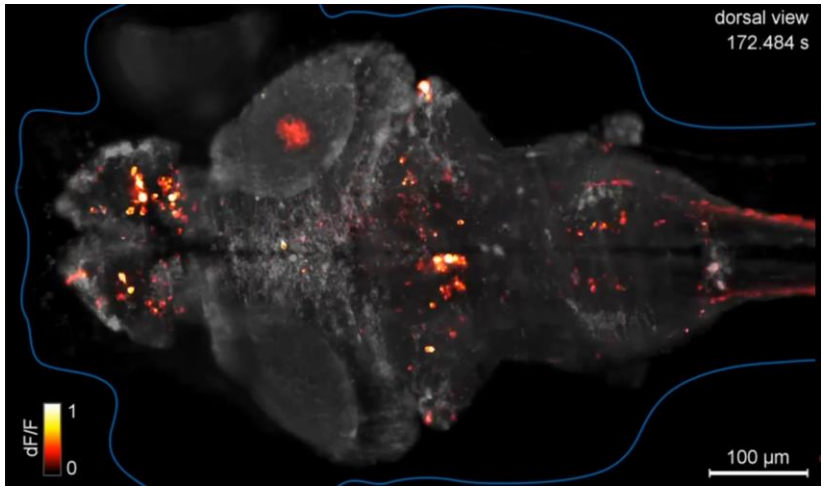
Diseases

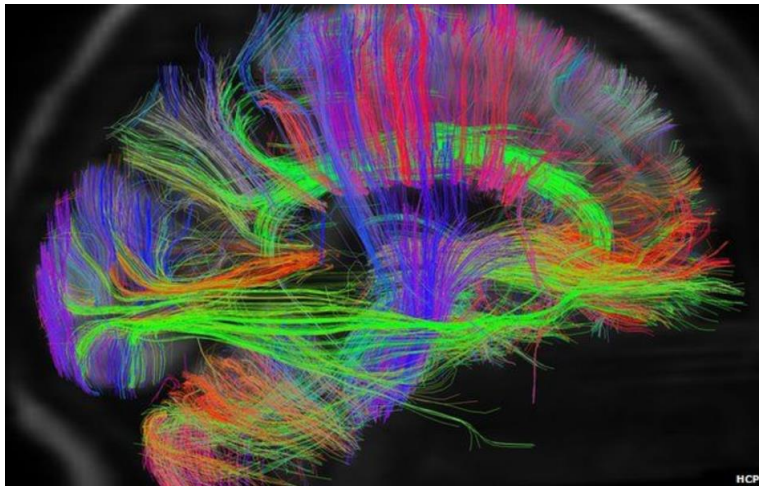
1. Addiction & OCD — **C**
2. Depression & Bipolar — **A**
3. Parkinson — **D**
4. Alzheimer — **C**
5. Restore Speech — **D**
6. Restore Motor — **D**

Future of Neuro & DL

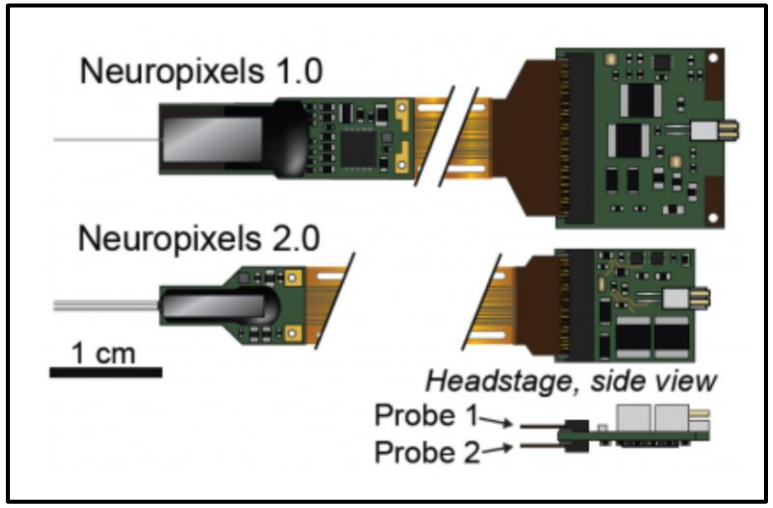
Read

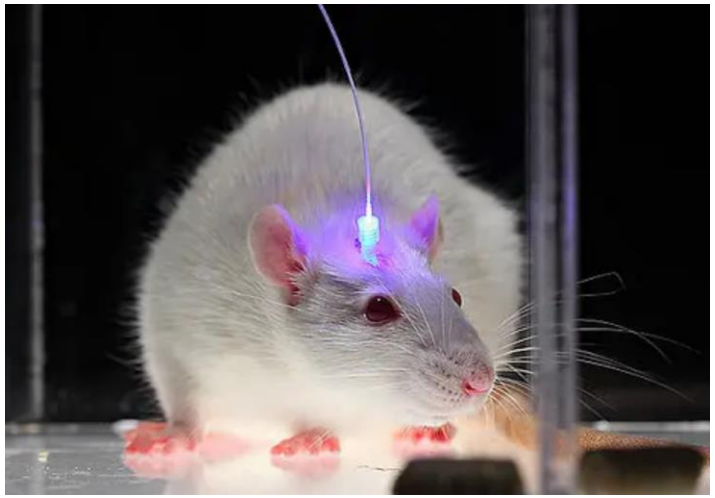






Write





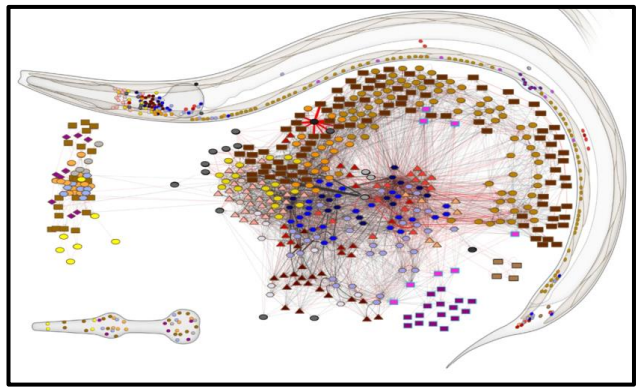
Figs from Internet

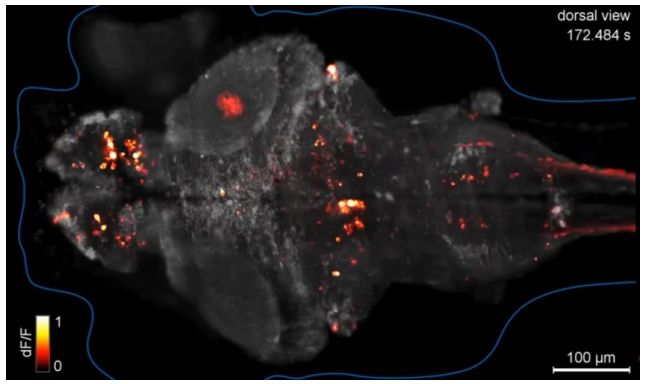
Humans Cannot Unravel Transformers.

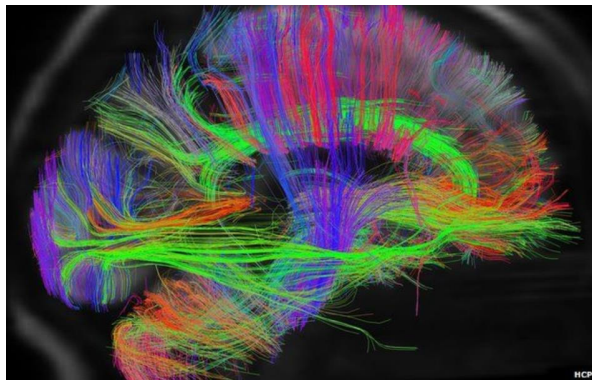
Yet Aim to Understand Brains???

vs

Figs from Internet







My Answer:

Our Understanding of Neuro Can Not Surpass Our Understanding of DL