

Cognitive Psychology

is the study of mental processes.



Observe phenomena

Invent mechanistic models
that we hope can explain
what we observe

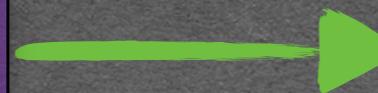


Mental phenomena may seem more magical or mysterious than other phenomena, but they're not...

They are the product of real physical mechanisms just like anything else.

René Descartes ~1630

Mind-Body Dualism

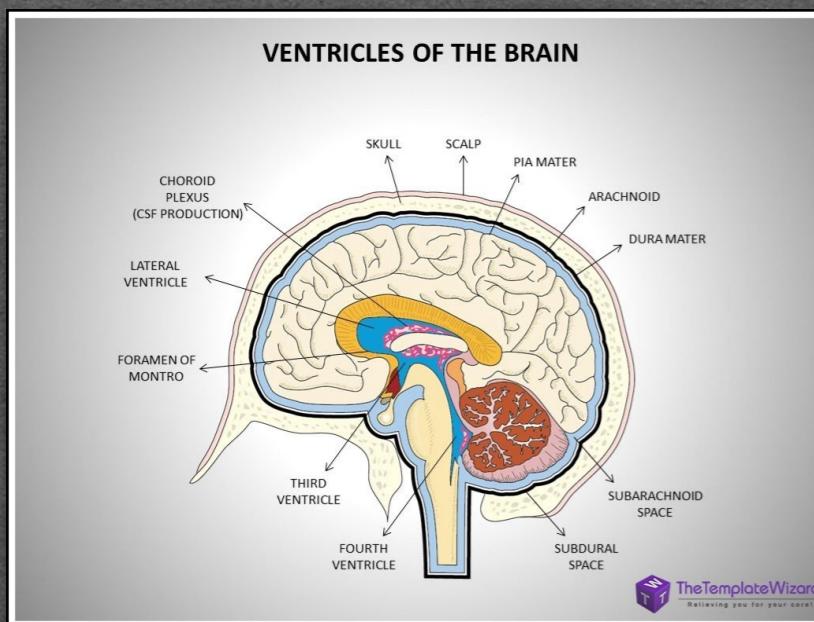


Descartes proposed the mind and body are fundamentally **different substances** or processes

Versus

Monism/Materialism - the universe is made up of only one kind of physical material (atoms)

“Everything reduces to physics”



But... In Descartes' time, the ventricles (empty spaces) were thought to hold **higher** thought processes...

Mind-Body Dualism

The universe contains two different kinds of things...

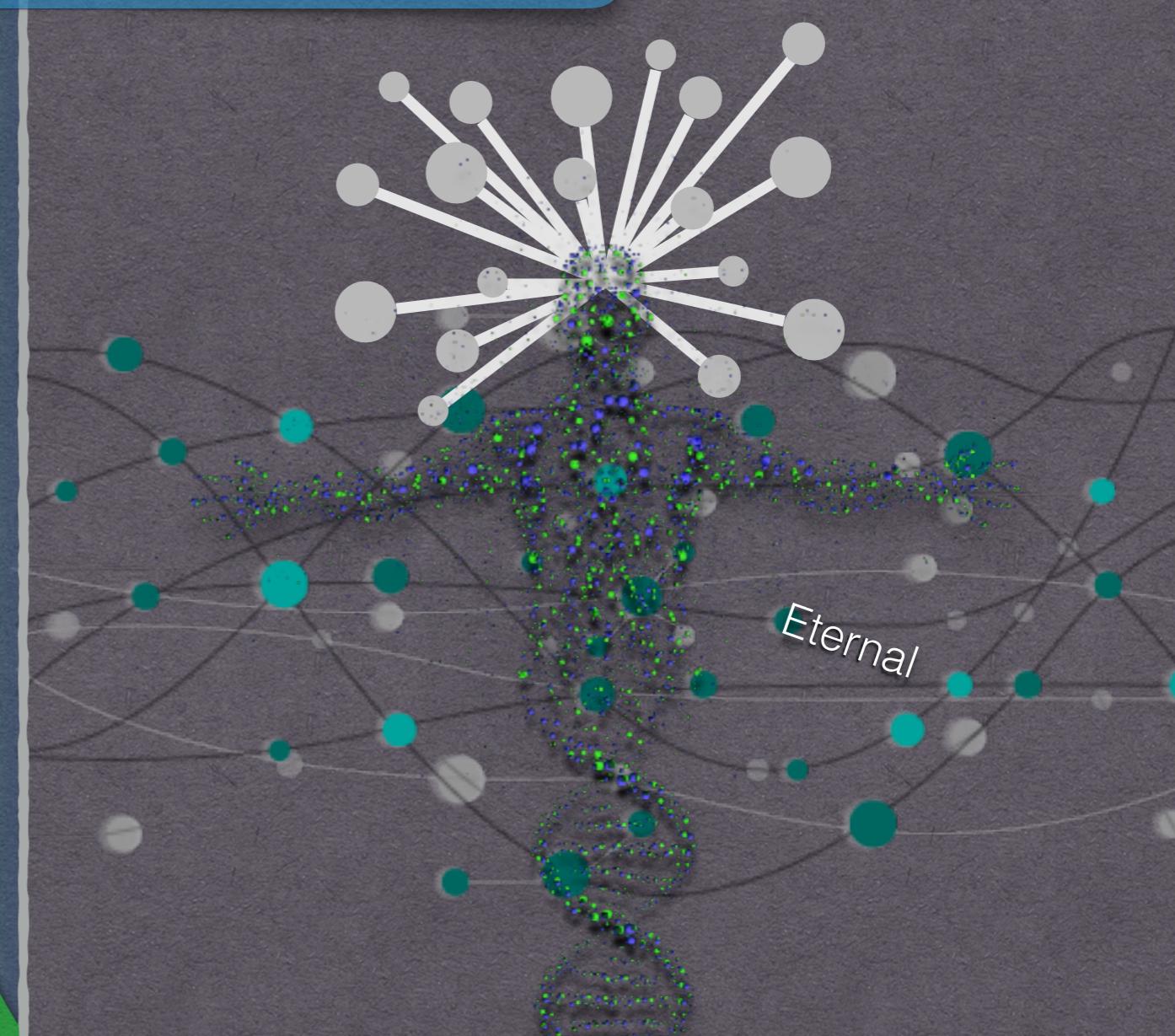
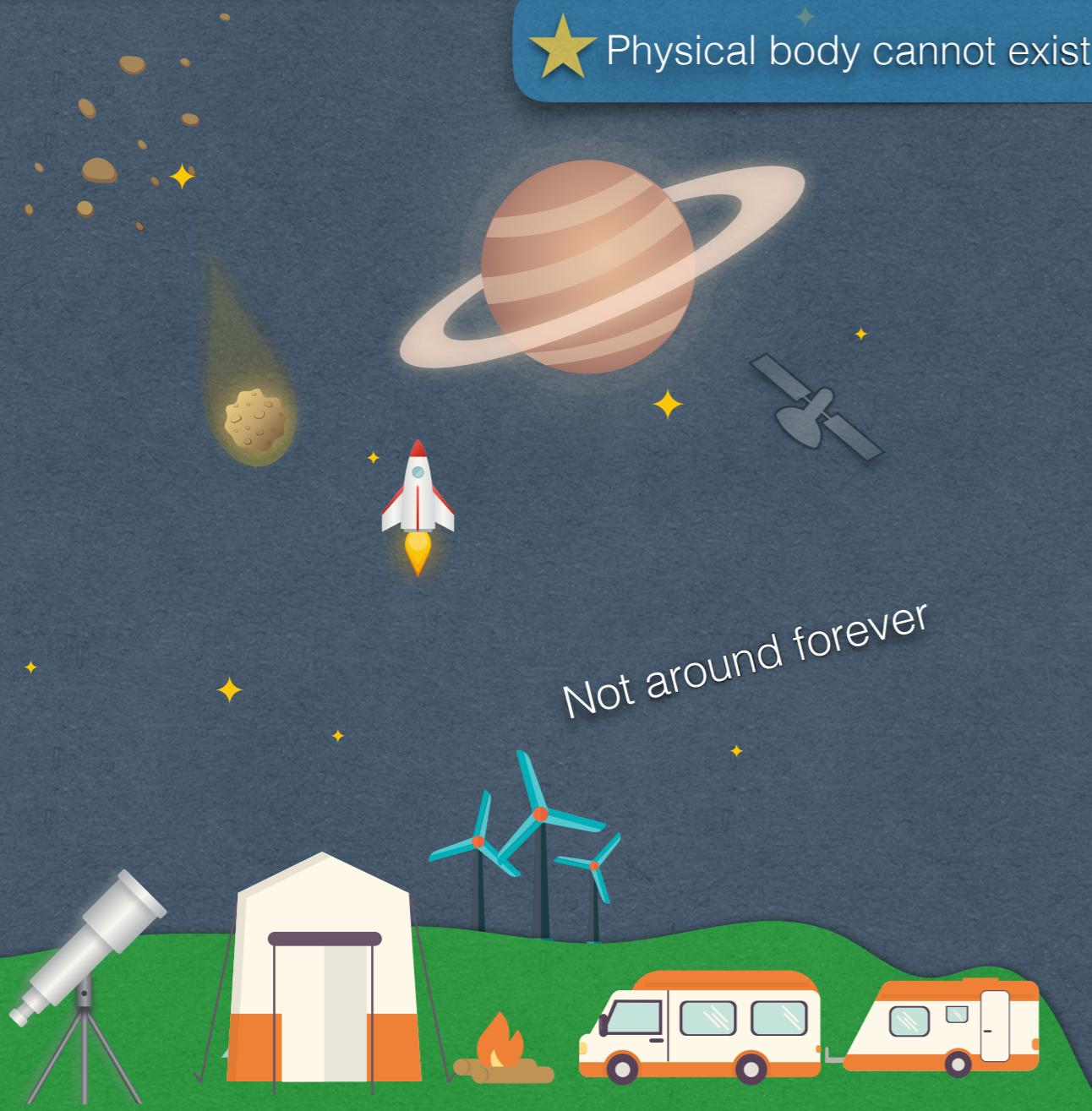
Physical



Non-Physical



Physical body cannot exist without the non-physical mind...



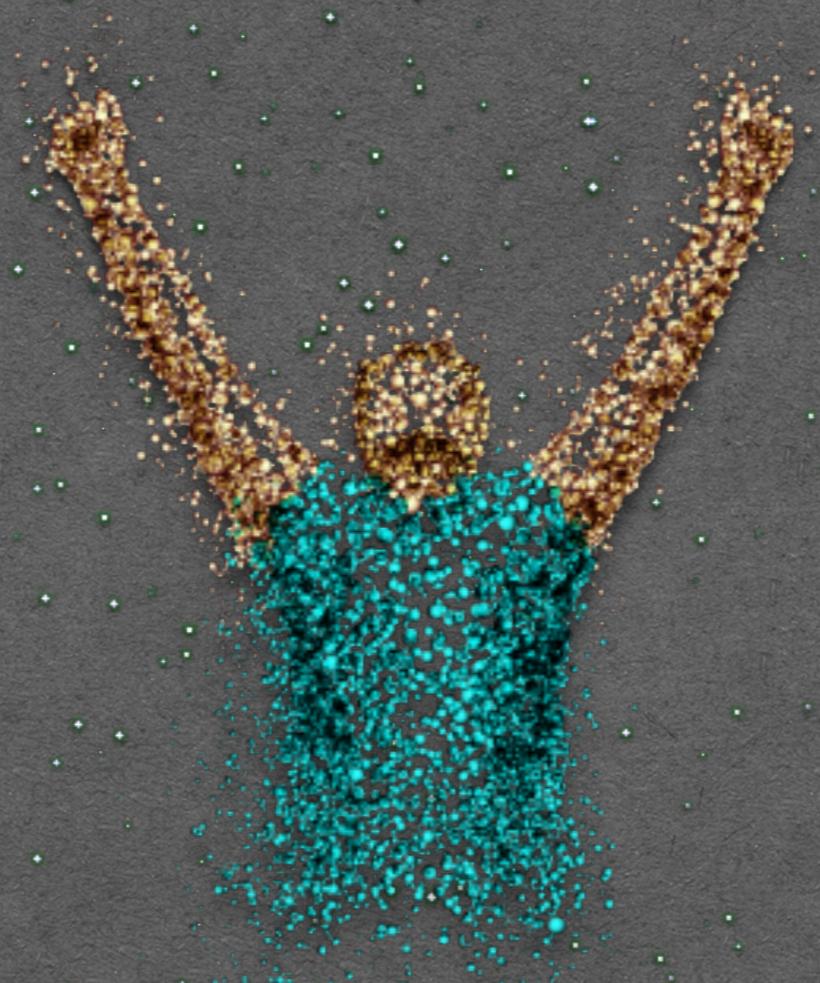
de la Mettrie ~1748

L'homme Machine

He extends Descartes' argument that animals were mere automatons or machines to human beings...

...**denying** the existence of the soul as a substance separate from matter.

Presented a materialistic theory of the “soul”

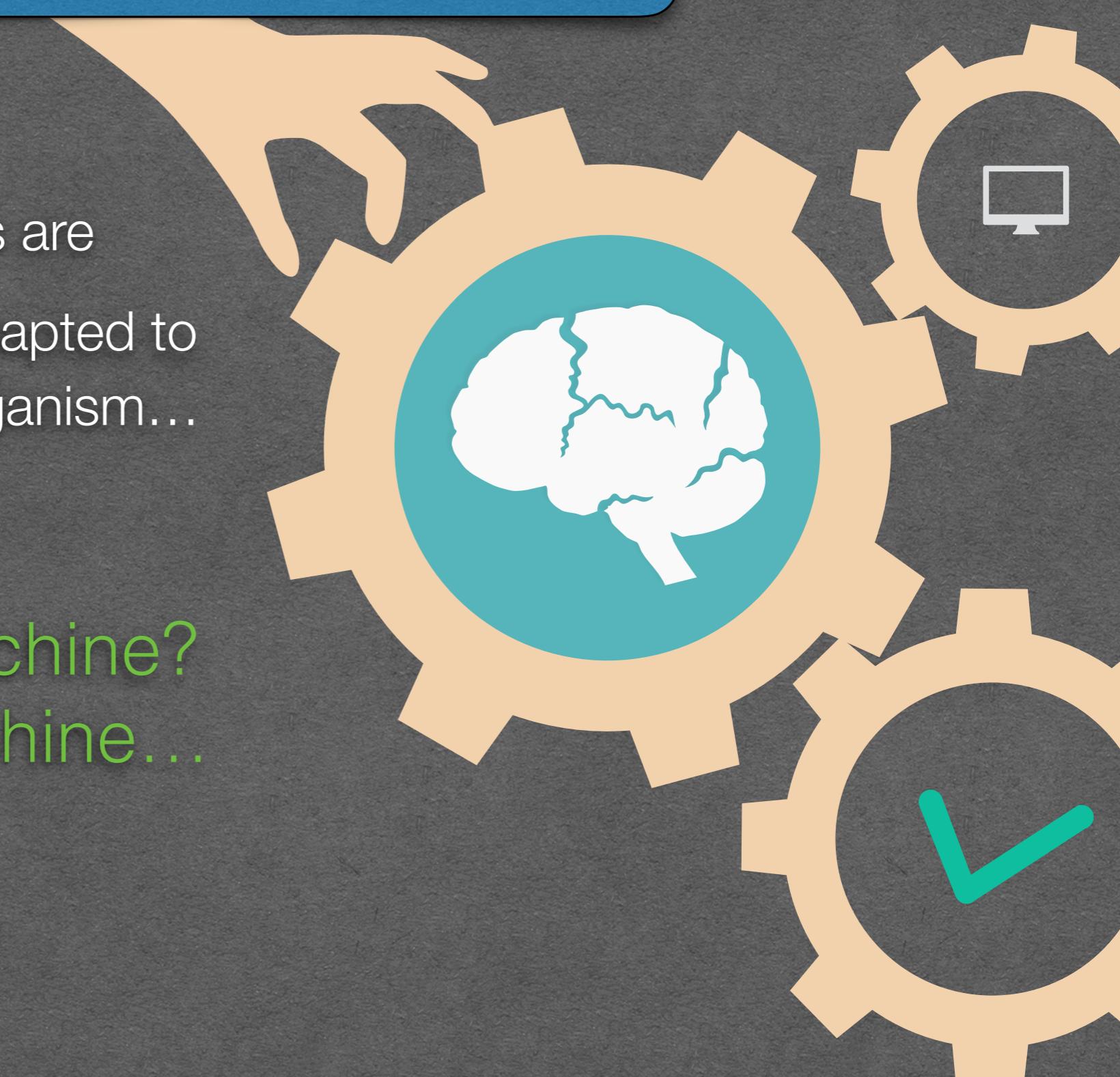


Darwin ~1850

Then Darwin comes along...

All biological structures are
“**devices**” that are adapted to
serve the survival of the organism...

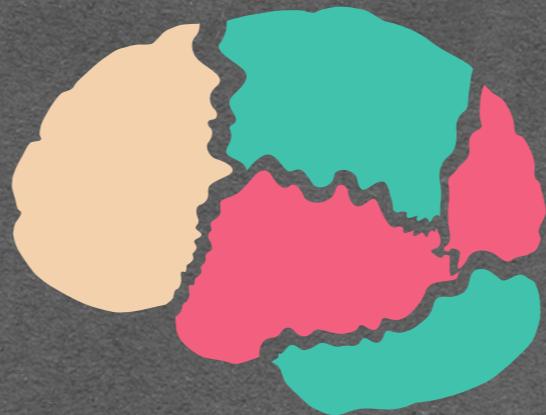
The mind as a machine?
The mind is a machine...



What does this mean?

A **machine** is a process consisting entirely of physical, material elements that affect each other causally—that is, via physical processes.

In **cognition**, a mechanistic theory is one in which every element is understood in terms of the combination of simpler, stupider, elements.



Therefore we reduce things we DON'T understand to combinations of things we DO understand.

Banish the Homonculus



Homonculus

An imaginary “man inside the head”

Theories of cognition must **NEVER** rely on a homonculus - an intelligent component - or it is **CHEATING...**

No miracles allowed...

★ Seek to **BANISH** the Homonculus ★

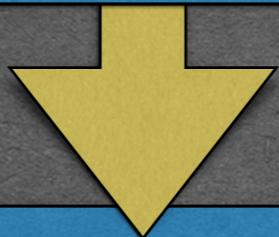
Levels of Explanation

Levels of Explanation	
Storms	Air Molecules
Macroscopic	Microscopic
Holistic	Reductionist
Cognitive Psychology	Neuroscience



“concerning the big picture”

Explanation is reduction to **simpler** phenomena.



In cognition, simpler means “**stupider**”

Thought and Artificial Intelligence

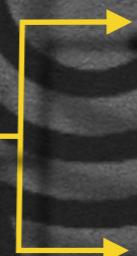
Thought



Thought has patterns

Standard procedures that work because of their **form**,
not their content

What does this suggest?



Thought can be standardized or converted into a
mechanical process (AI) ★

Mental processes can be understood in scientific terms
(cognitive psychology) ★

Aristotle and Syllogism

★ Syllogism

An instance of a form of reasoning in which a conclusion is drawn from two given or assumed propositions (premises)

Each premise shares a term with the conclusion, and shares a common or middle term not present in the conclusion

Premise:	All men are mortal	Premise:	All ducks are green
Premise:	Socrates is a man	Premise:	Josephine is a duck
Conclusion:	Socrates is mortal	Conclusion:	Josephine is green

The truth of the **conclusion** is logically certain based on the form of the argument, regardless of the content

George Boole: An Investigation of the Laws of Thought (1854)

Using **algebra**, we can make statements about **numbers** that are true regardless of the specific values of the numbers...



$$x + x = 2x$$

Statements that are
true or **false**

Boole proposed to do the same thing with **propositions** instead of numbers.

$$\begin{array}{r} 2 > -3 \\ 0.999\dots = 1 \\ \pi \approx 3.\overline{14} \\ \sqrt{2} \\ 5(2+2) \end{array}$$
$$\begin{array}{c} \times \\ \infty \\ + \\ \times \\ \div \\ 5^2 \\ 1 + 2 \cdot 3 \\ (1 - 2) + 3 \\ 101_2 = 5_{10} \end{array}$$

This leads to a way of “calculating” with **ideas** instead of with numbers, called **Propositional Calculus** or Boolean algebra

Propositional Calculus

Propositions are put together with logical connectives...

$A \wedge B$: conjunction	“A is true AND B is true”
$A \vee B$: disjunction	“A is true OR B is true (or both)”
$\sim A$: negation	“not A” = “A is not true”
$A \rightarrow B$: implication or entailment	“ If A is true then B is true”

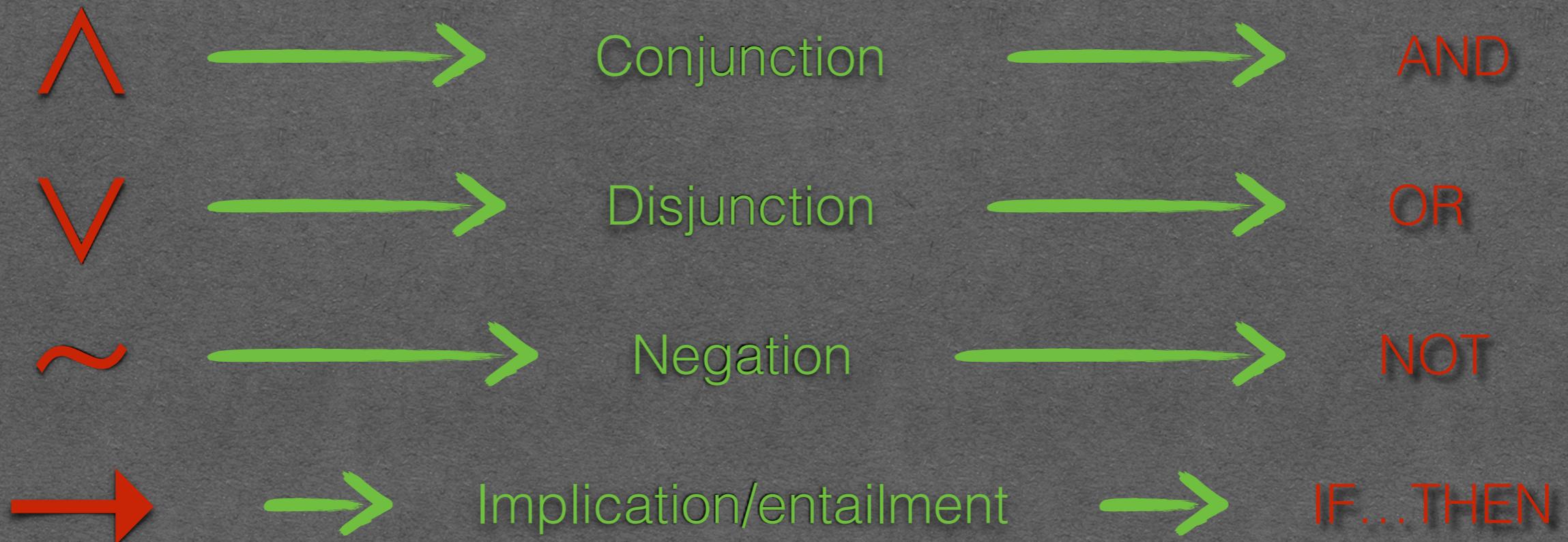
Example



A = “the sky is blue”
B = “all men are mortal”

Propositional Calculus

Again...



$$\text{NOTE: } \sim(A \wedge \sim B) = \sim A \vee B$$

The negation flips the conjunction/disjunction

Truth Table: Conjunction

Λ

B

True

False

True

TRUE

FALSE

A

False

FALSE

FALSE

Truth Table: Disjunction

V

A

True
False

B

True

False

		True	False
		True	False
A	True	TRUE	TRUE
	False	TRUE	FALSE

Truth Table: Negation

~

A

True

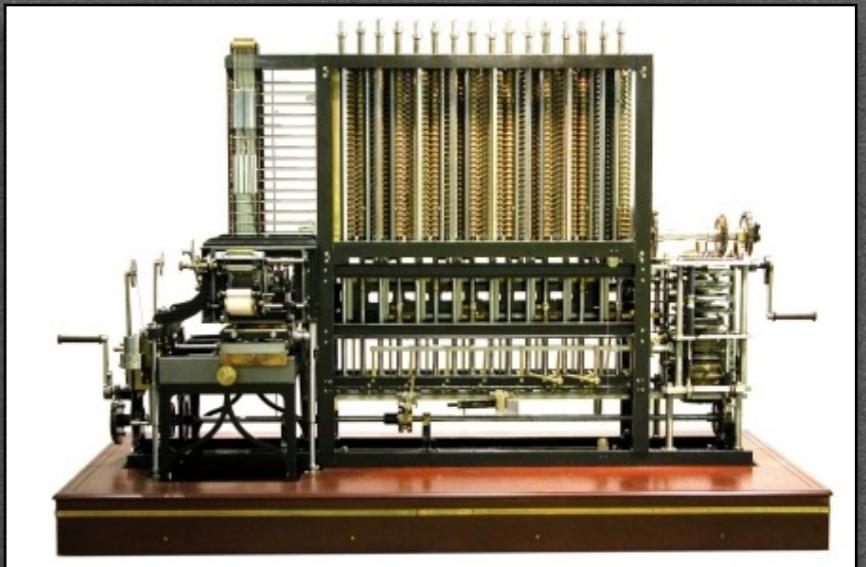
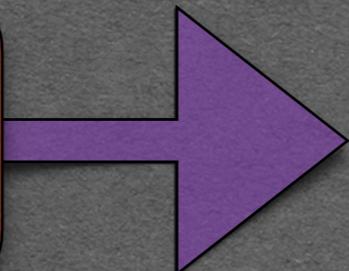
False

FALSE

TRUE

Machinery of Thought

Charles Babbage: 1830
Analytical Engine



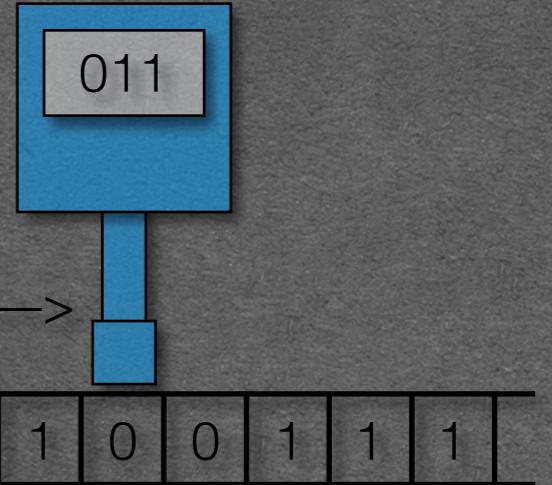
- A proposed mechanical general-purpose computer
- Incorporated an ALU, control flow in the form of conditional branching and loops, and integrated memory
- First design for a general-purpose computer that could be described in modern terms as Turing-complete (it can be used to simulate any single-taped Turing machine)

Machinery of Thought

Alan Turing

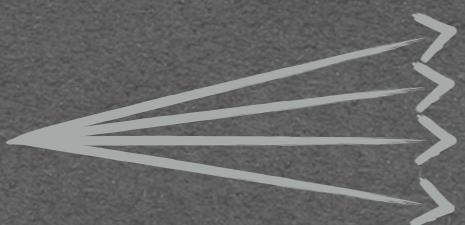


Turing Machine



A Turing machine gets input symbols on an infinite paper tape, and writes output symbols on the same tape.

What can it do?



- Read symbols to the tape
- Write symbols to the tape
- Move the tape left or right
- Make (logical) conditional decisions about which of the above to do

Uses algorithms, or concrete procedures to solve particular problems (give an output for each input).

Turing Machine

It is an abstract model of a computer program.

Universal Turing Machine

A universal TM is a
general purpose
computer

One that can be given the encoding of
another Turing machine and “simulate” it

M
e
a
n
i
n
g

For each possible input, giving
exactly the same output

Turing Machine & Thought

Universal TM is the origin of the distinction between software and hardware...

This led Turing
to ask:

What is “simulation”? If something can simulate the input-output of an intelligent process, is it intelligent?



Hardware is the physical machine.



Brain?



Software is the program it carries out.



Mind?

The Turing Test

Can a machine *think*?

What observable behavior would count as thinking?

A judge “texts” back and forth
with a mystery entity.



If the entity is a computer, it tries to
pretend to be a human being.



If it passes, is its behavior “*intelligent*?”

Or is it just a “**simulation**” of intelligence?

Artificial Intelligence

Artificial intelligence attempts to program computers to be intelligent.



Highlights of AI



Samuels checkers program

—>learns and improves; eventually beats human players including its programmer

Eliza: simulates a psychotherapist

—>Surprisingly convincing in a limited domain; shows that apparent intelligence often reflects simple underlying rules

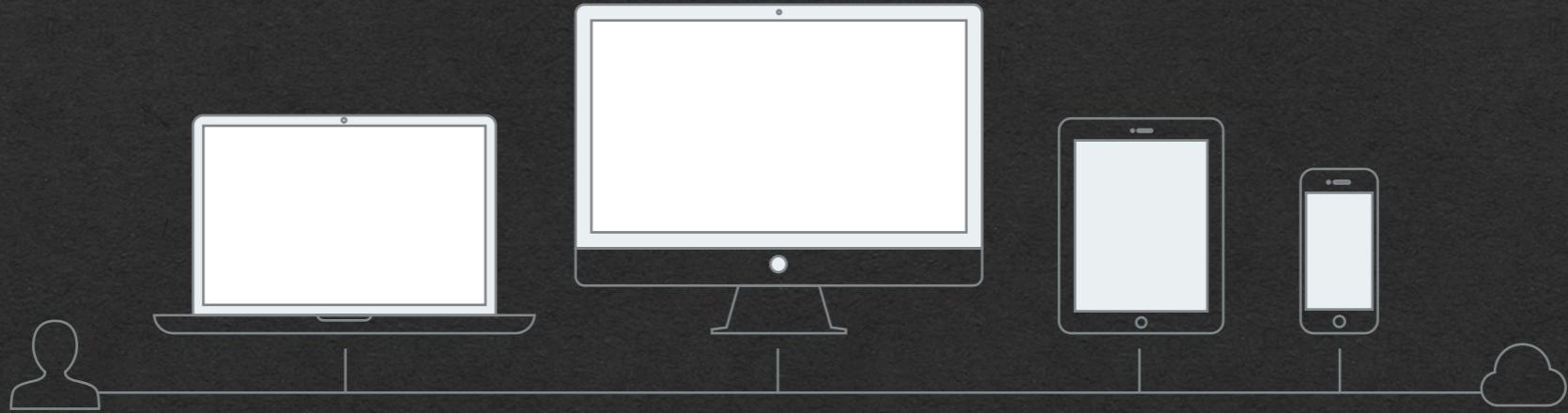
Chess

—>Much harder to simulate human intelligence; doesn't beat human champion until 1996

Vision, language:
—>still working on it

The Church-Turing Thesis

Turing noticed that many systems of computation had the same “power”...



They could **solve** the same problems, and they failed to **solve** the same problems.
He speculated that this was the limit of computational power for any device.

But what about the brain?

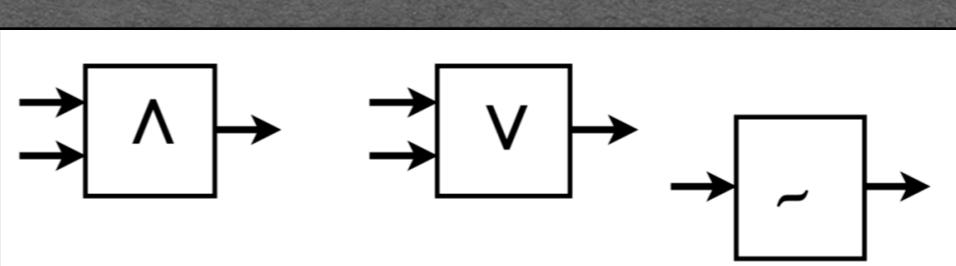
This speculation is called the **Church-Turing thesis**:
Anything that can be computed by any system
can be computed by a computer
(a Turing machine)



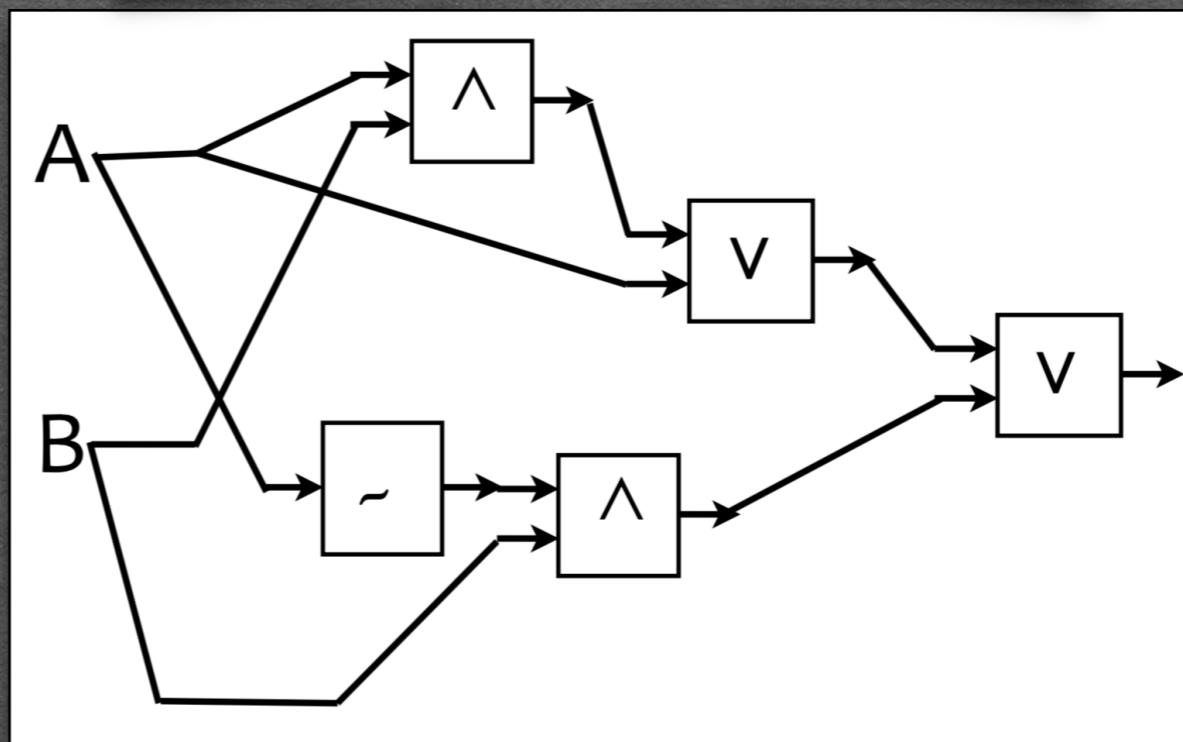
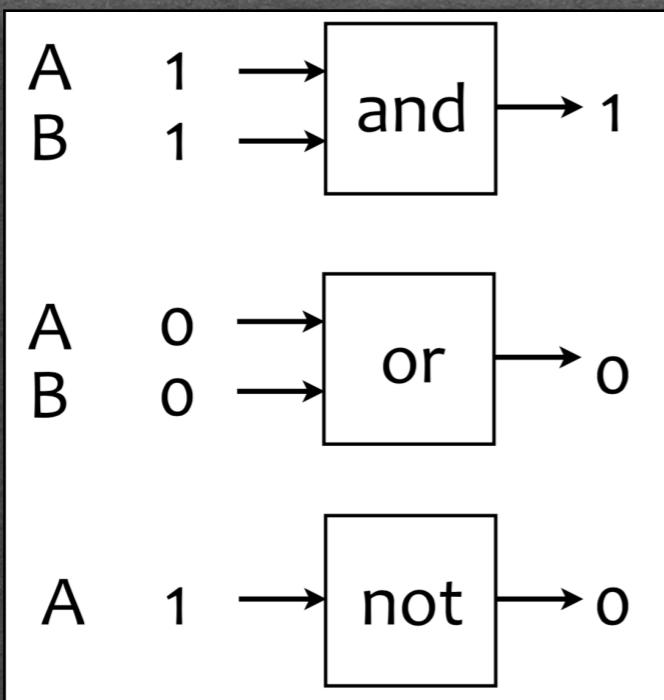
Logic Gates

Same as connectives, but as a piece of a circuit...

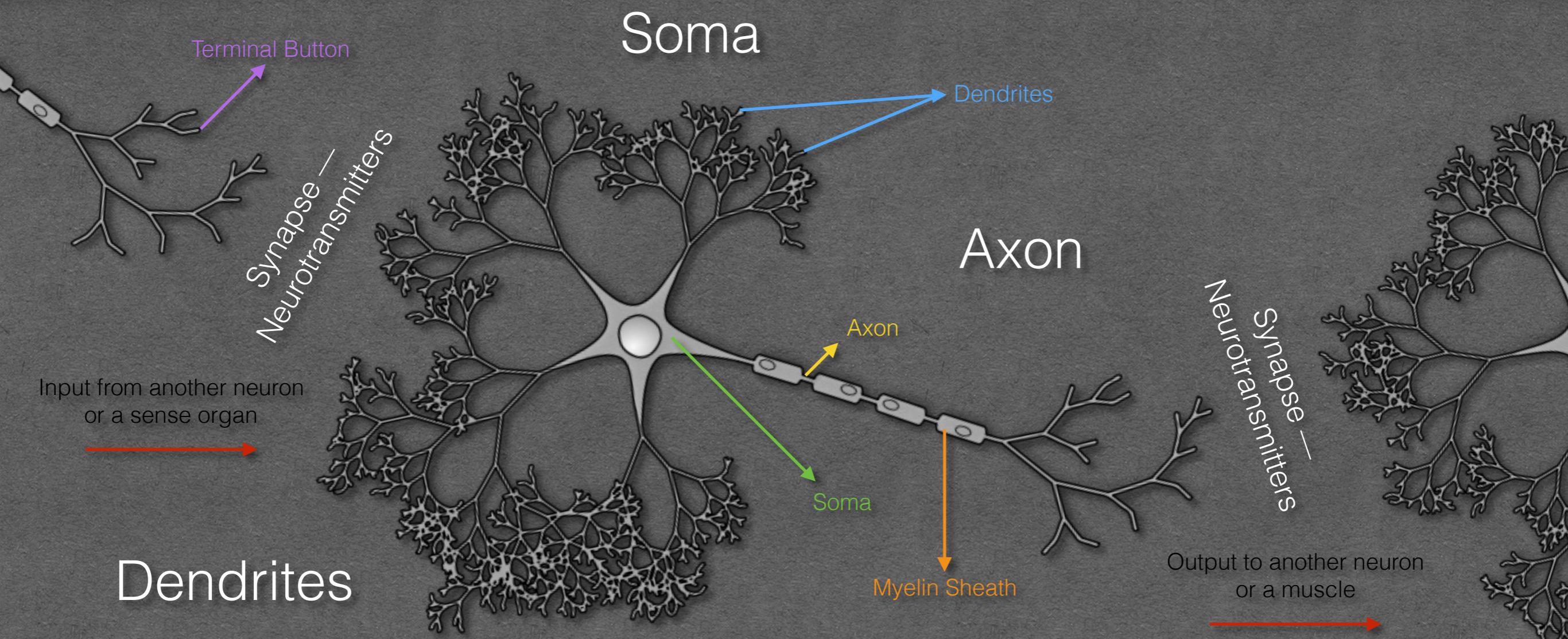
LOGIC is like a machine,
machines are like logic.



$$((A \wedge B) \vee A) \vee (\neg A \wedge B)$$



The Neuron



Neuron integrates **excitation** and **inhibition** to get total net activation;
If activation is above threshold, it “spikes” - sends an **action potential** down the axon.

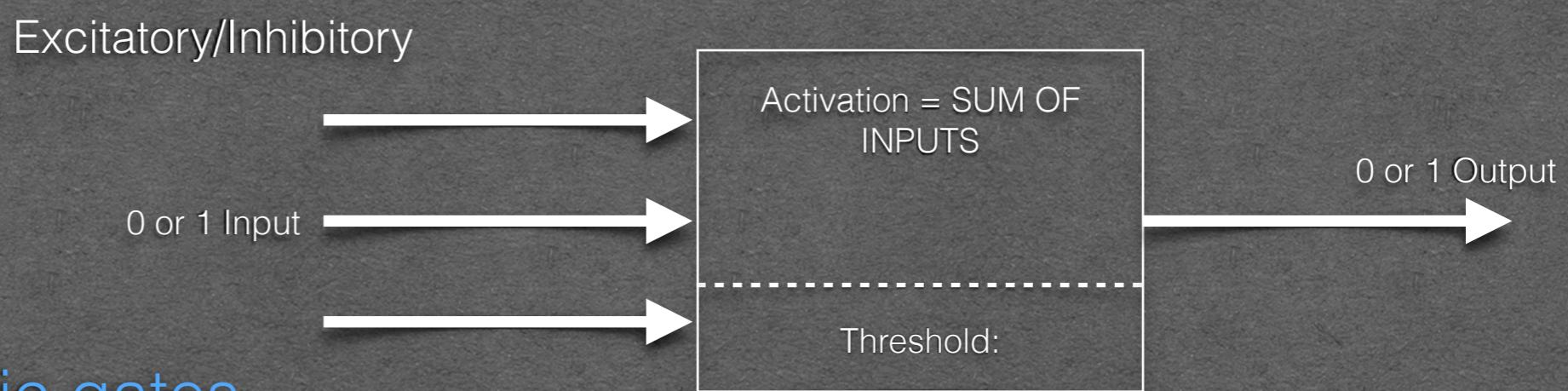
After firing, the neuron resets (~2 or 3msec).

If it is still being stimulated over threshold, it fires again.
Hence the **firing rate** indicates the level of activation.

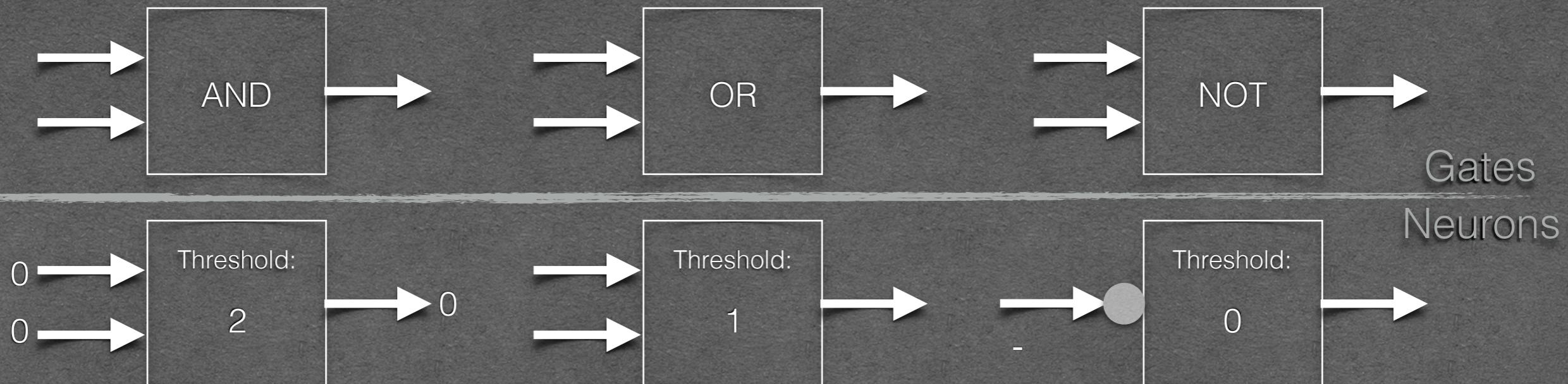
McCulloch & Pitts:

Neurons Are Little Computing Devices

Model of Artificial Neuron



Neurons are like logic gates...



Neurons can do what Turing machines can do; Turing machines can do what neural networks can do... **Brains are computers**

What is Knowledge & Where Does it Come From?

Nature versus Nurture

Locke

Descartes
Kant

Empiricism

Rationalism

Based on experience
Blank slate; Tabula Rasa

Based on reason
innate knowledge

Associationism
Behaviorism

Nativism
Cognitivism

General learning mechanism

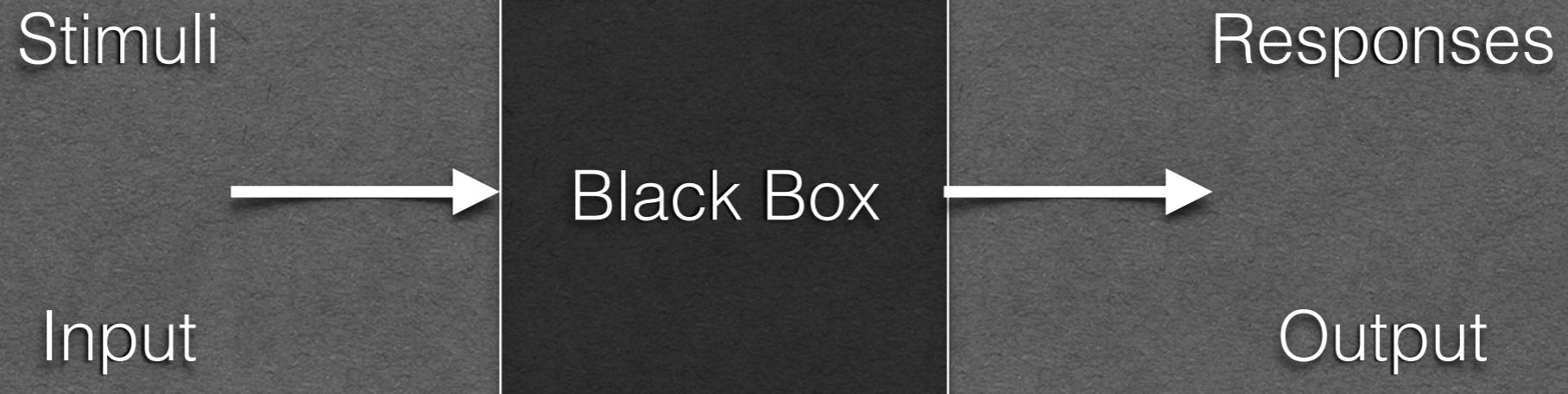
Versus

Domain-specific innate modules

Watson: Behaviorism

Stimuli/Response

B.F. Skinner



All learning is conditioned responses to stimuli.