

Summer School Quantum Technologies



Consiglio Nazionale
delle Ricerche



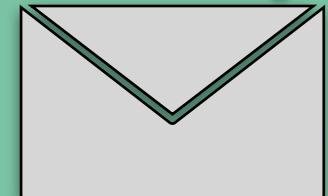
UNIVERSITÀ
DI PAVIA



QUANTUM
FLAGSHIP

In viaggio verso il **Quantum Machine Learning** Da Turing al Computer Quantistico

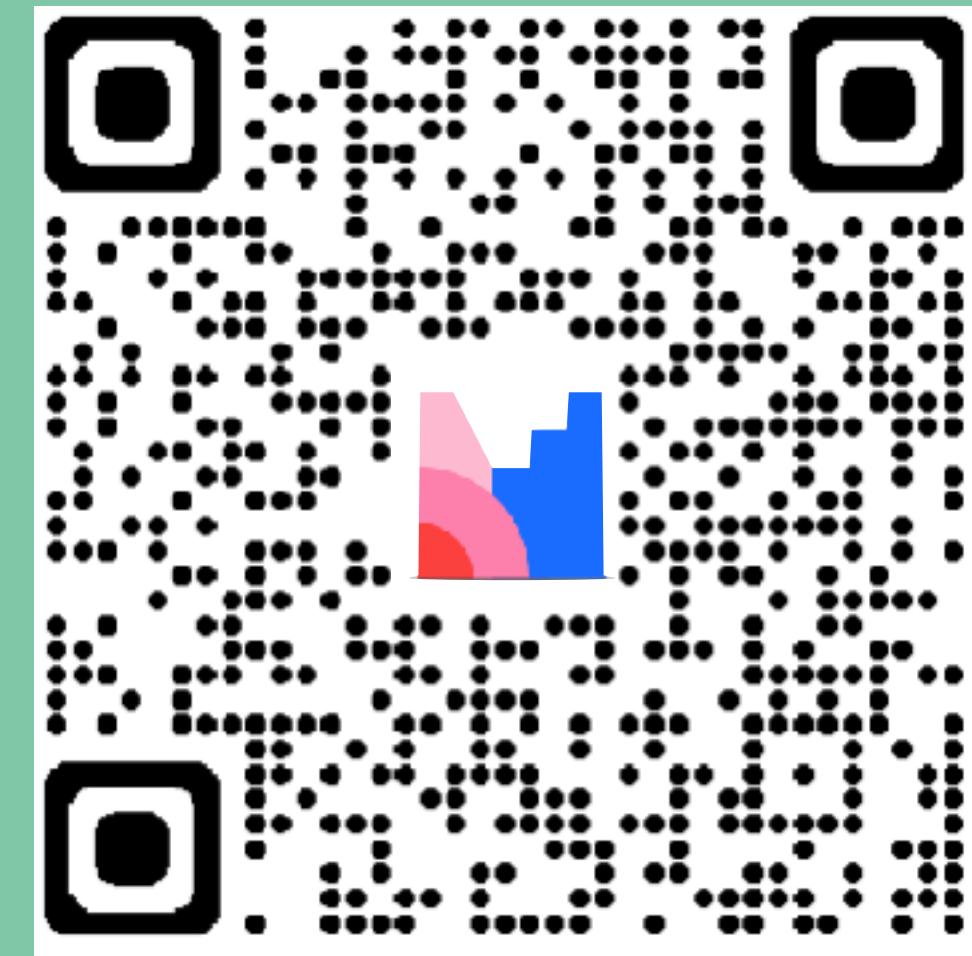
Francesco Scala



francesco.scala01@ateneopv.it

05/09/2023

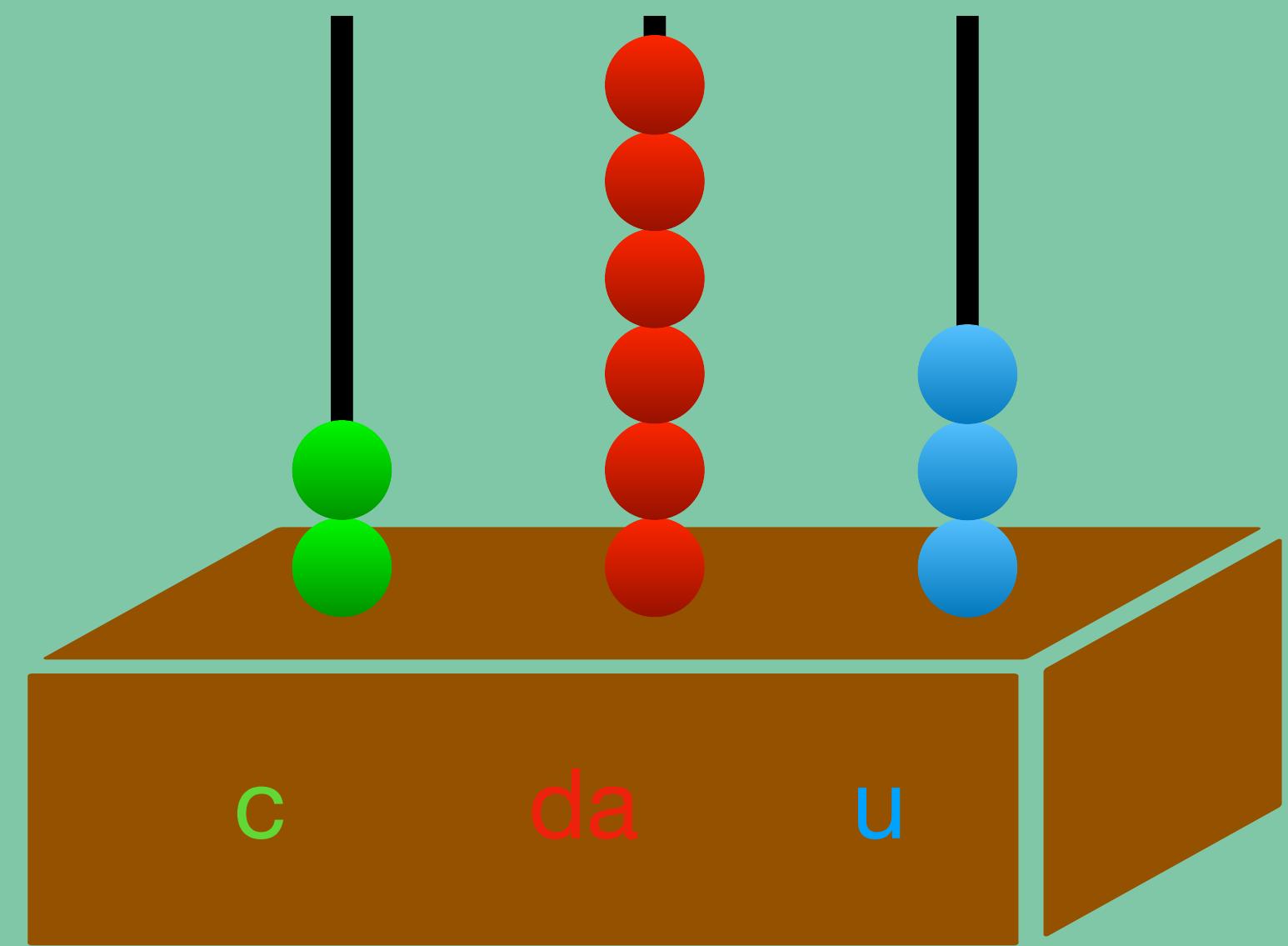
A cosa serve
Quantum Machine Learning?



CODICE

Conti facili e conti difficili

Come impariamo
a fare i conti?



Conti facili e conti difficili

Come impariamo
a fare i conti?

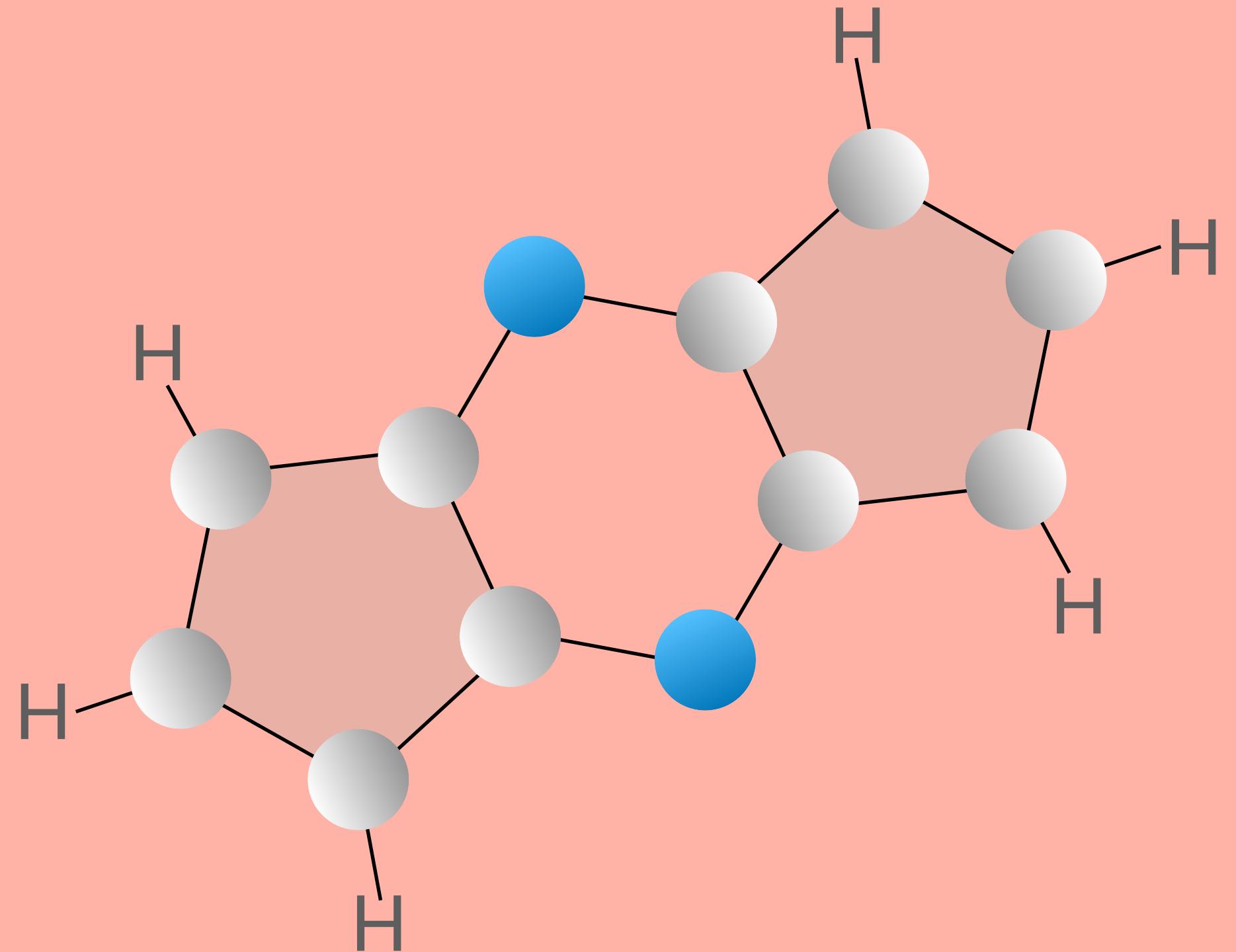


Conti facili e conti difficili

Come impariamo
a fare i conti?



Come si simula
una molecola?

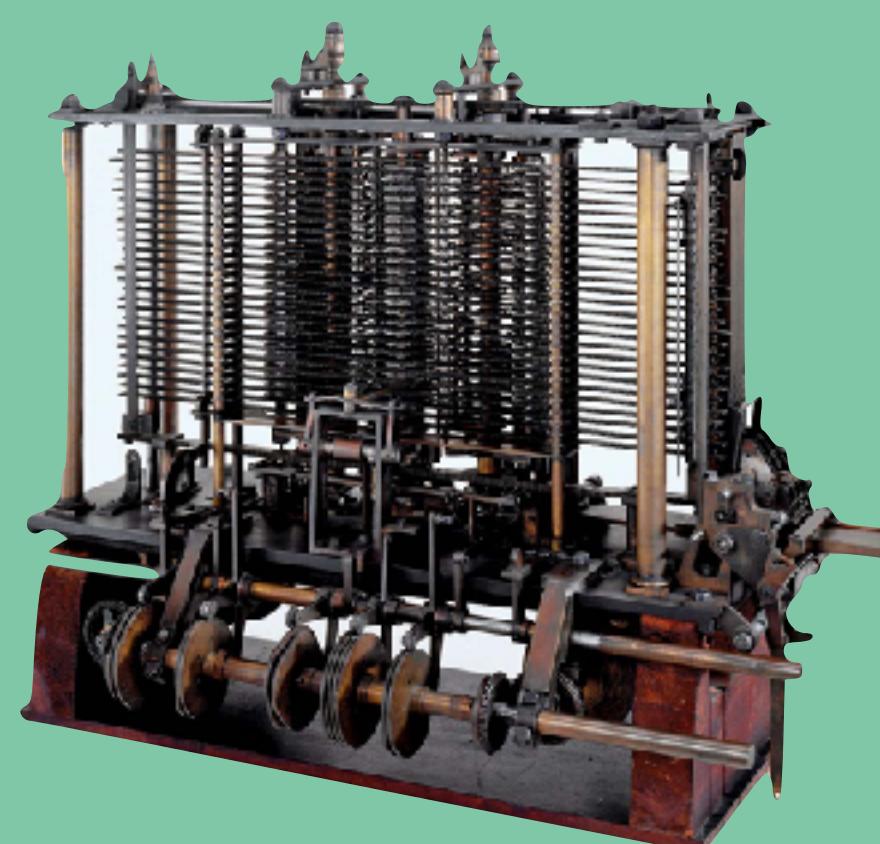


La computazione nel tempo

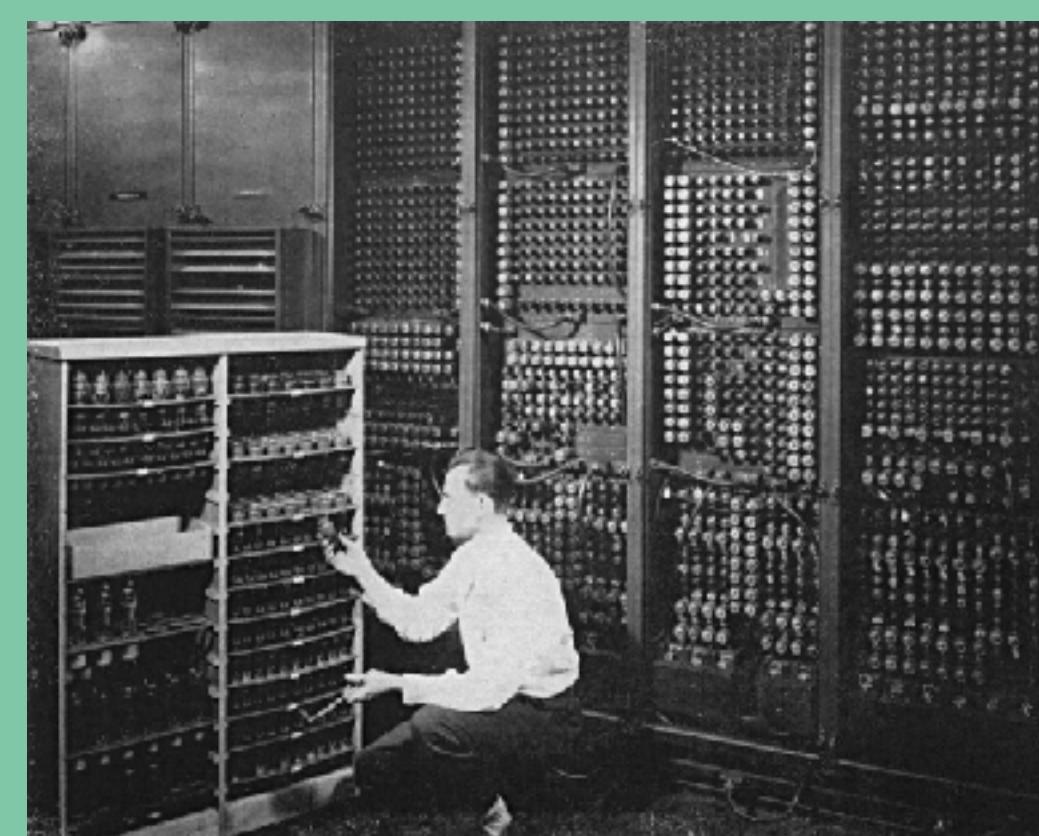
Abaco



**Calcolatori
meccanici**



**Computer
elettronici**



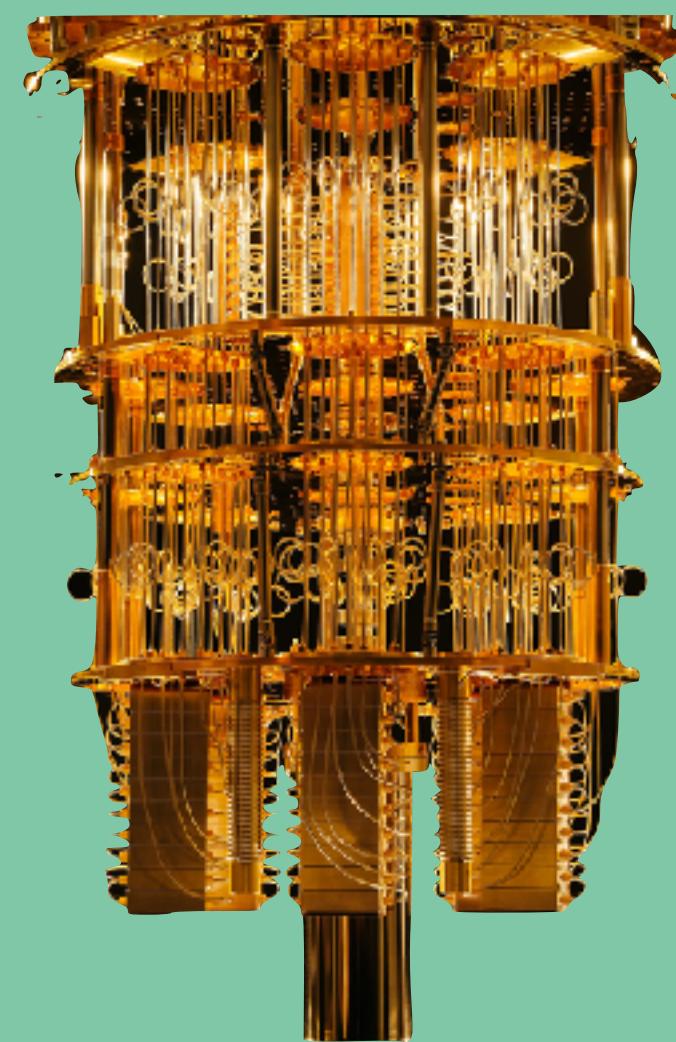
**Personal
Computer**



**Laptop
Cellulari**



**Computer
Quantistici**



~2000AC

~1820

~1945

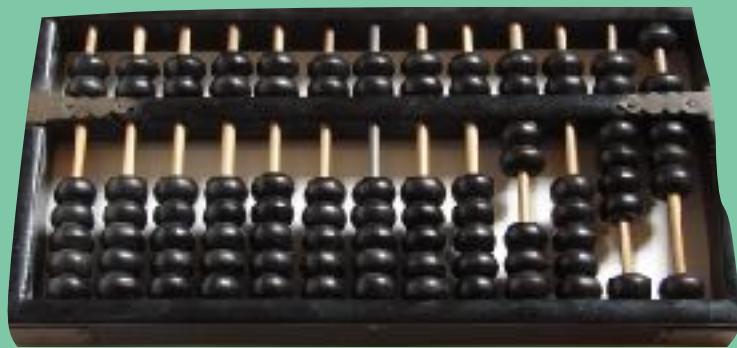
~1980

~2010

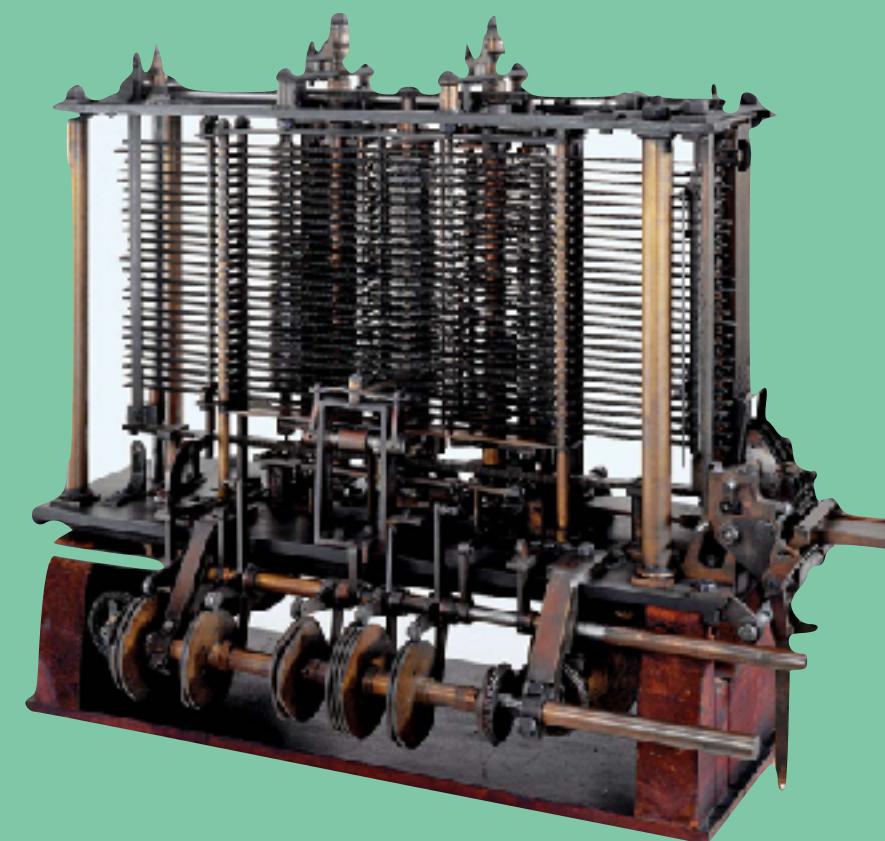
Oggi

La computazione nel tempo

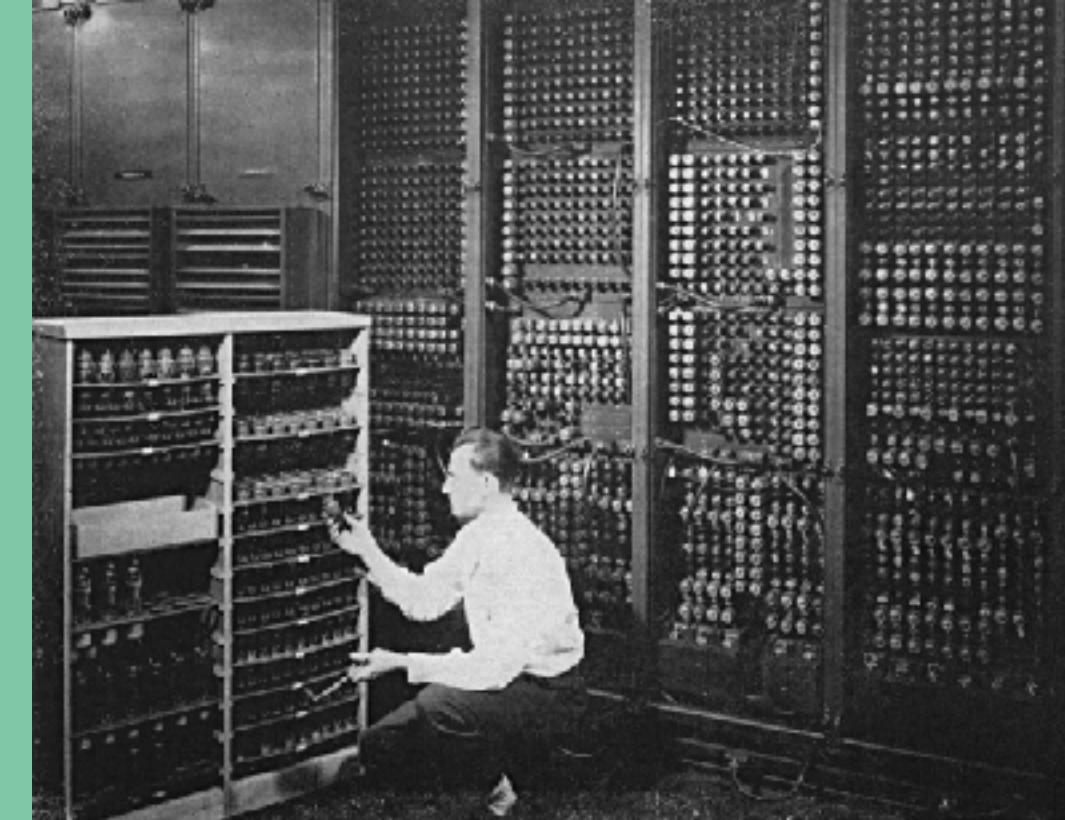
**Calcolatori
meccanici**



Abaco

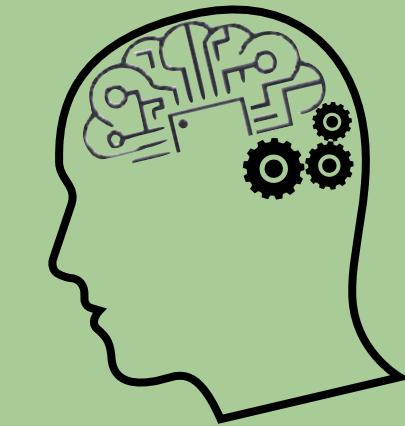


**Computer
elettronici**



~1945

Intelligenza Artificiale



**Personal
Computer**



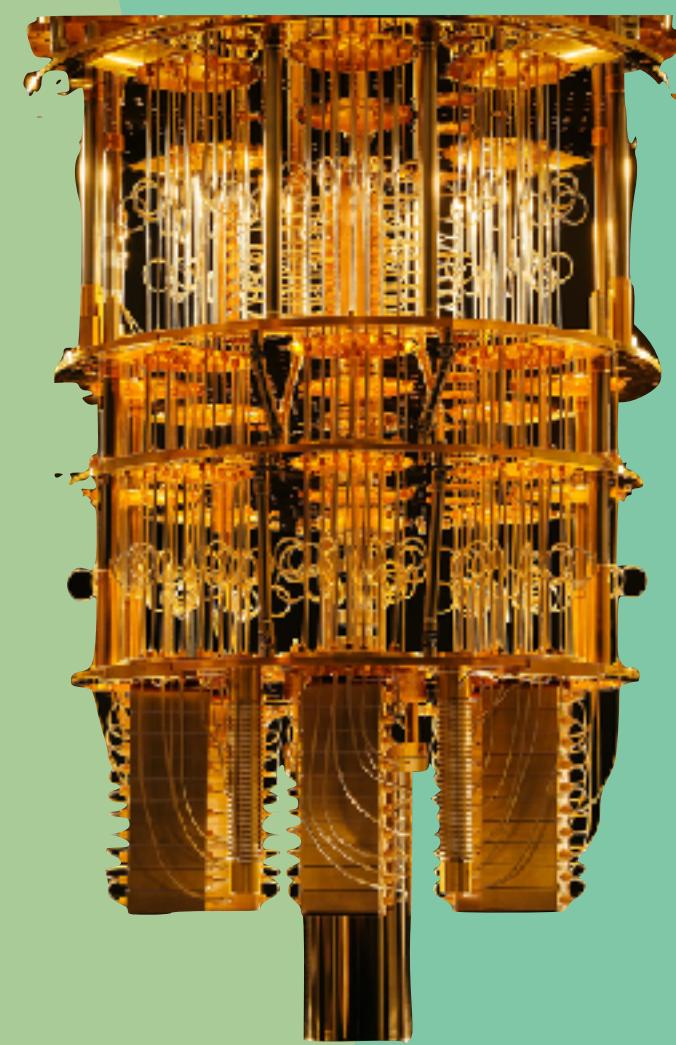
~1980

**Laptop
Cellulari**



~2010

**Computer
Quantistici**



Oggi

~2000AC

~1820

~1945

~1980

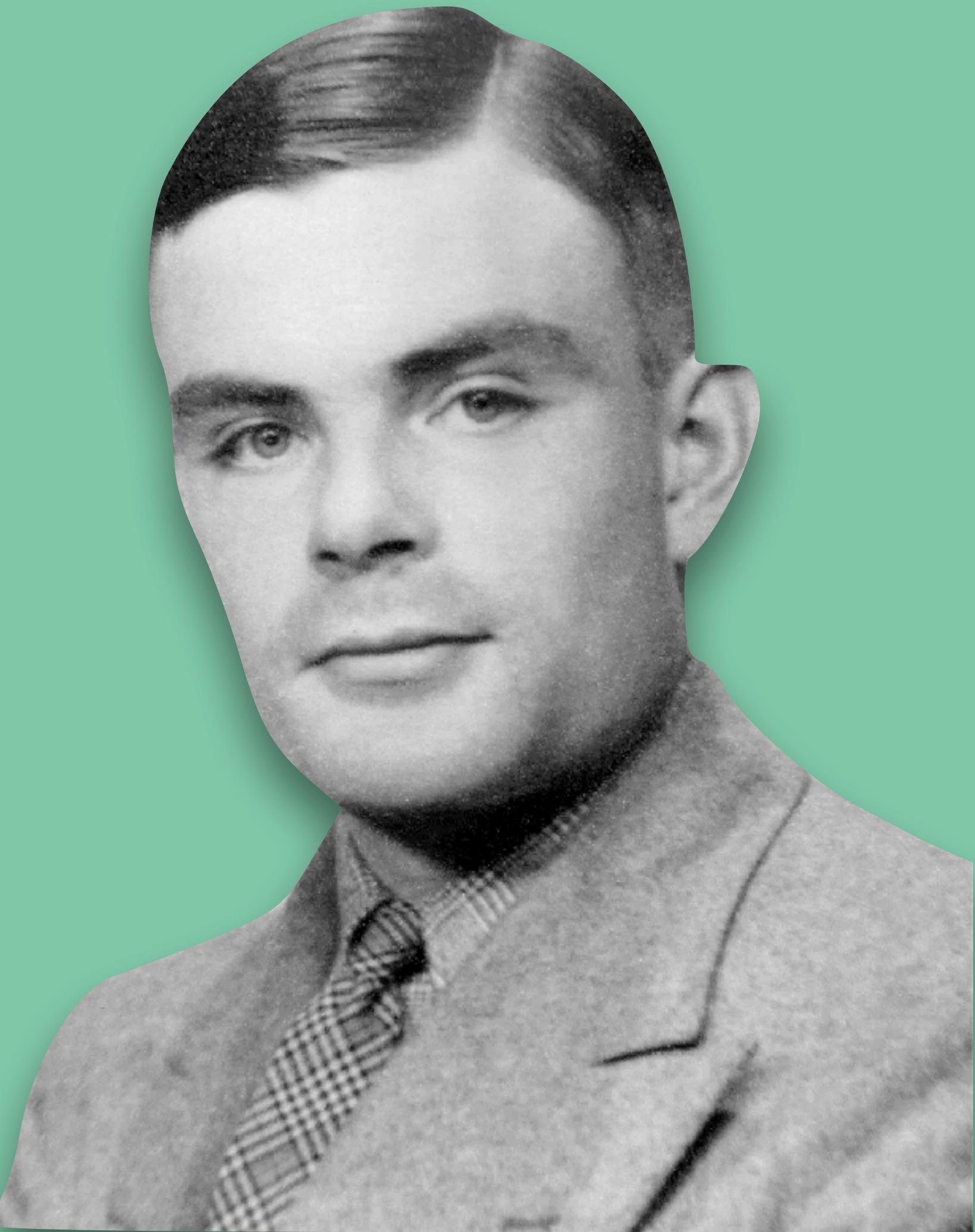
~2010

Oggi

Alan Turing

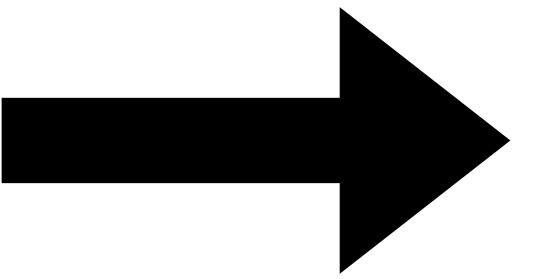
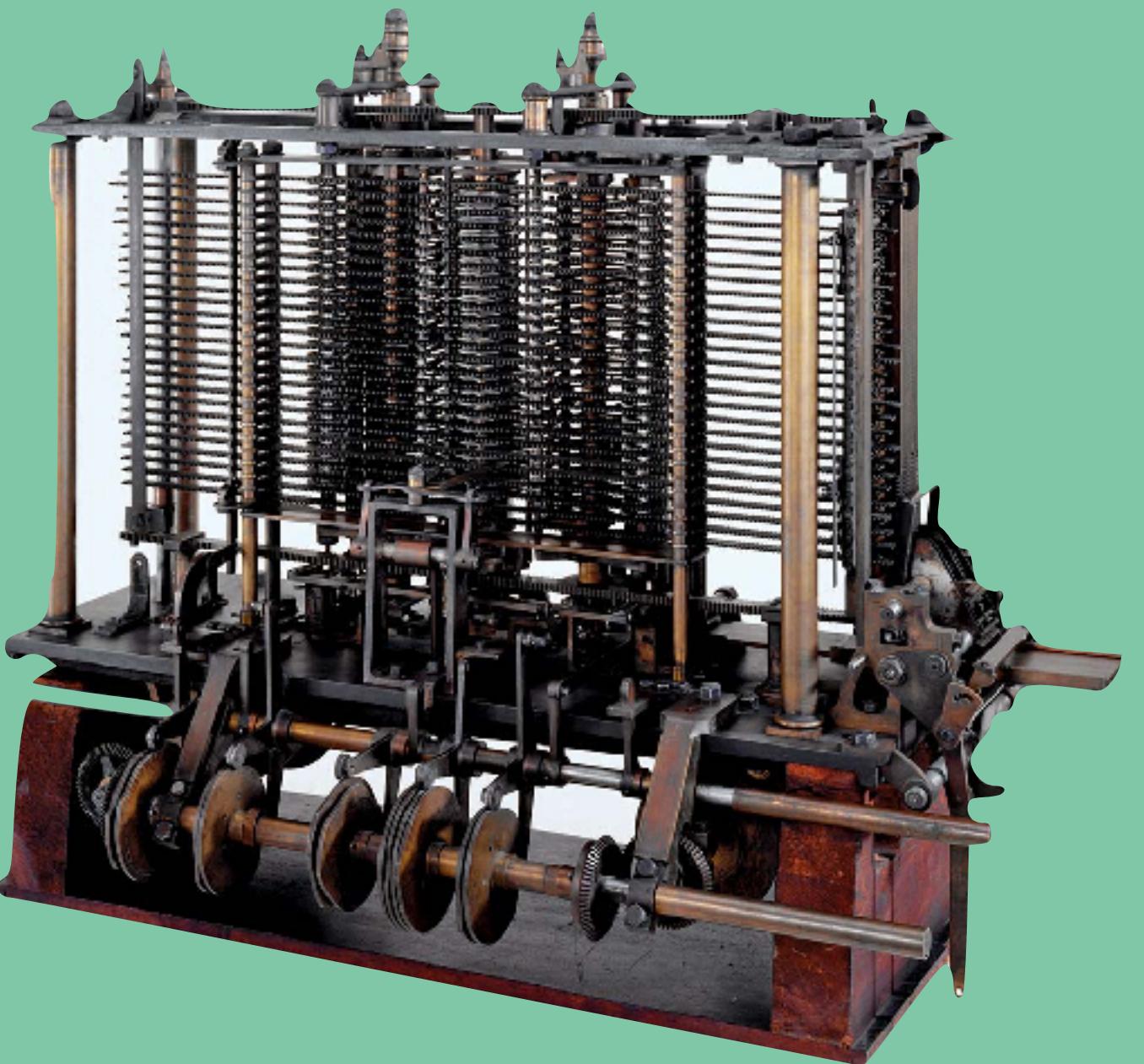
(1912-1954)

Padre dell'Informatica
e dell'Intelligenza Artificiale



Computazione astratta

Calcolo meccanico

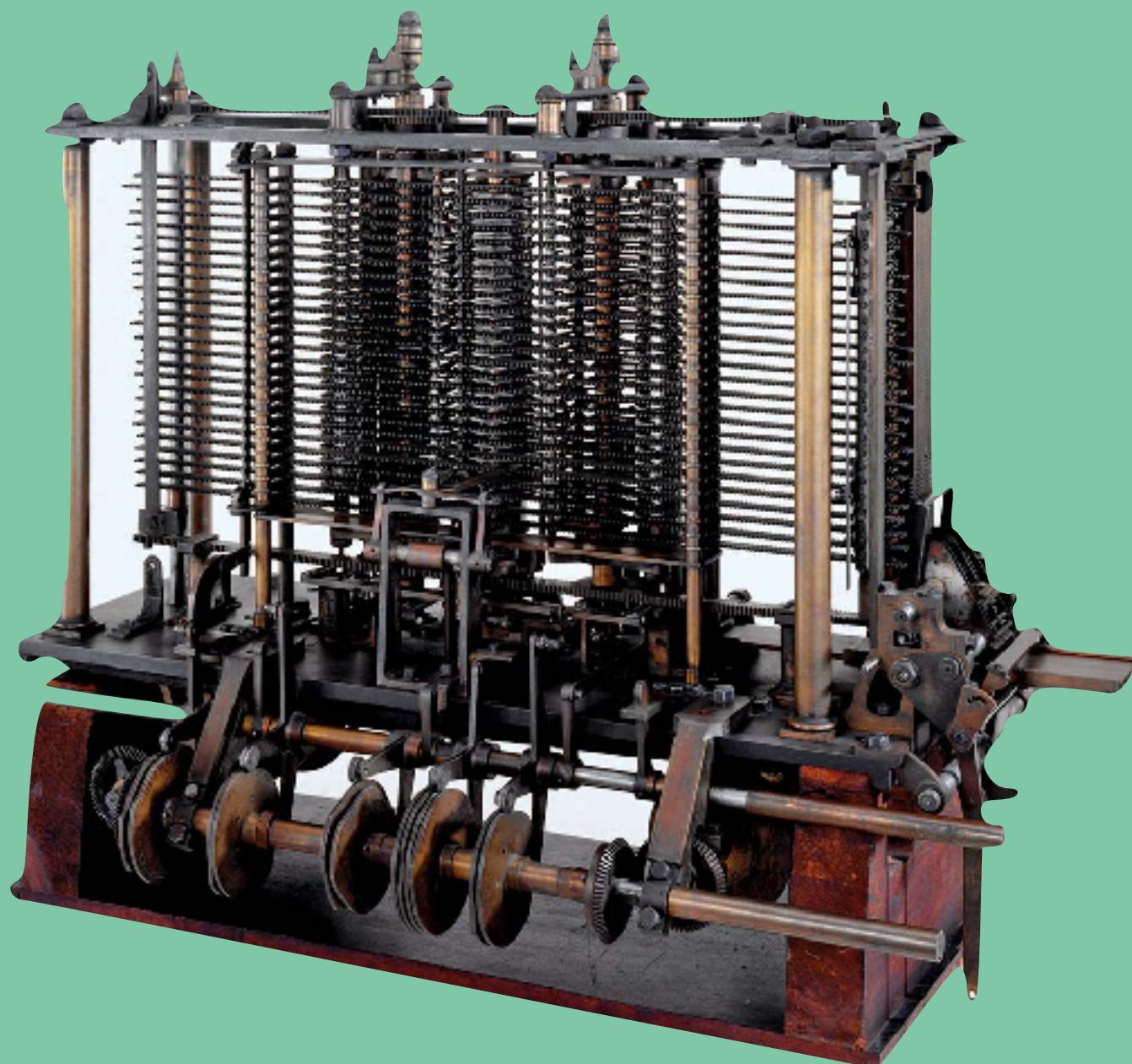


Calcolo astratto

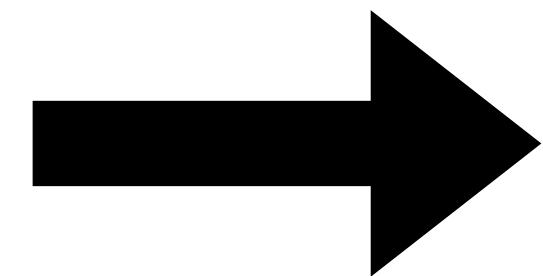


Computazione astratta

Calcolo **meccanico**



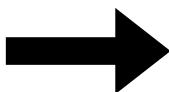
Calcolo **astratto**



Calcolo

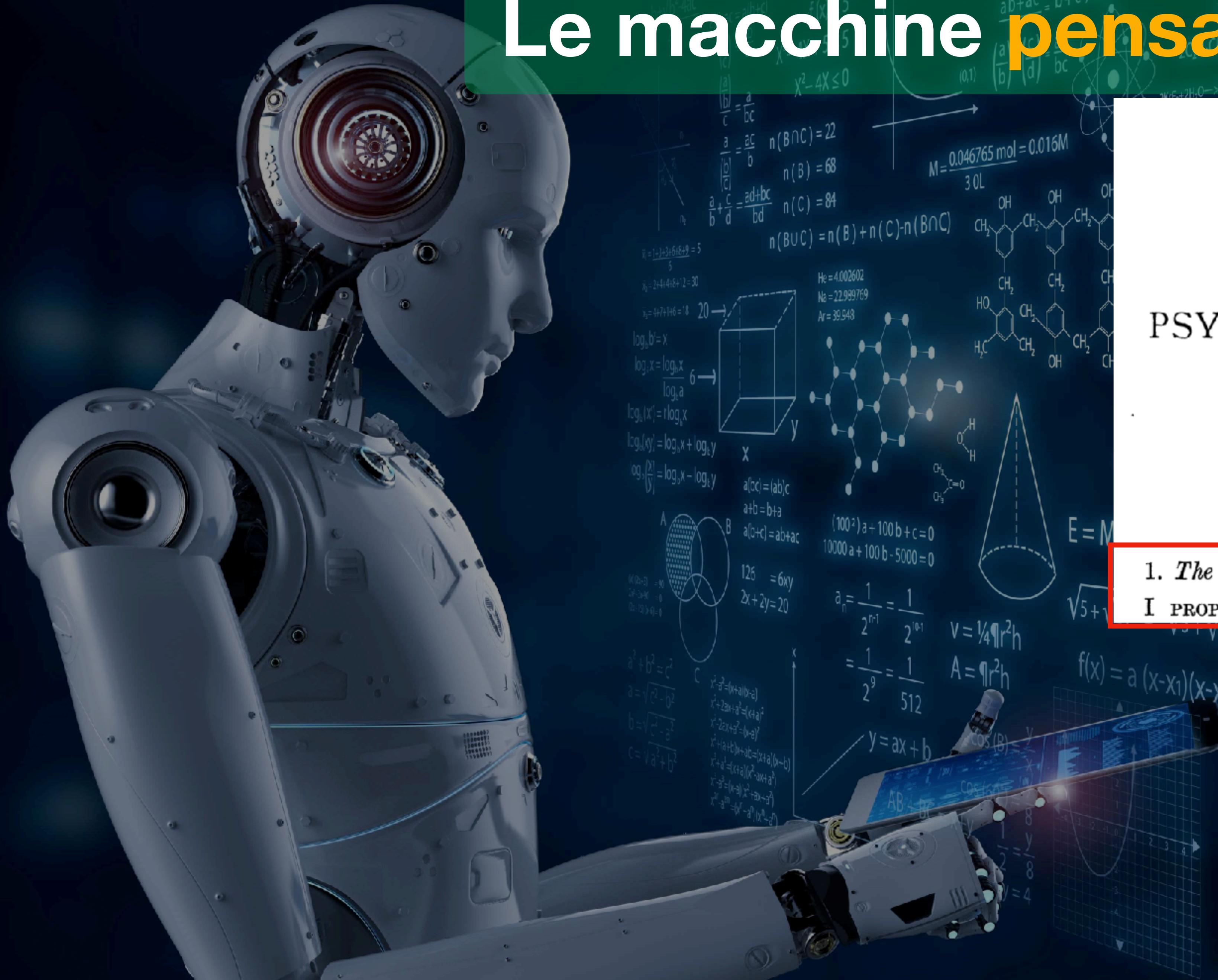


Computazione



Algoritmo

Le macchine pensano veramente?



M I N D
A QUARTERLY REVIEW
OF
PSYCHOLOGY AND PHILOSOPHY

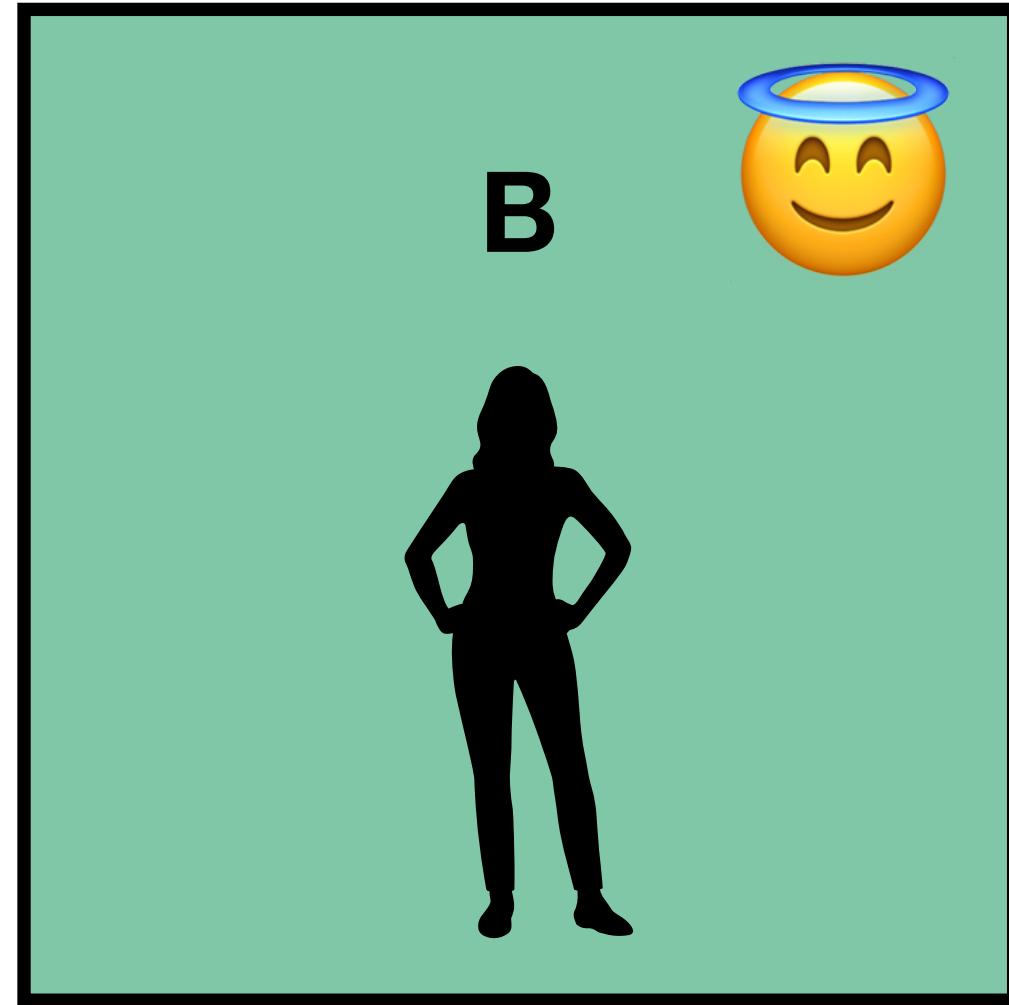
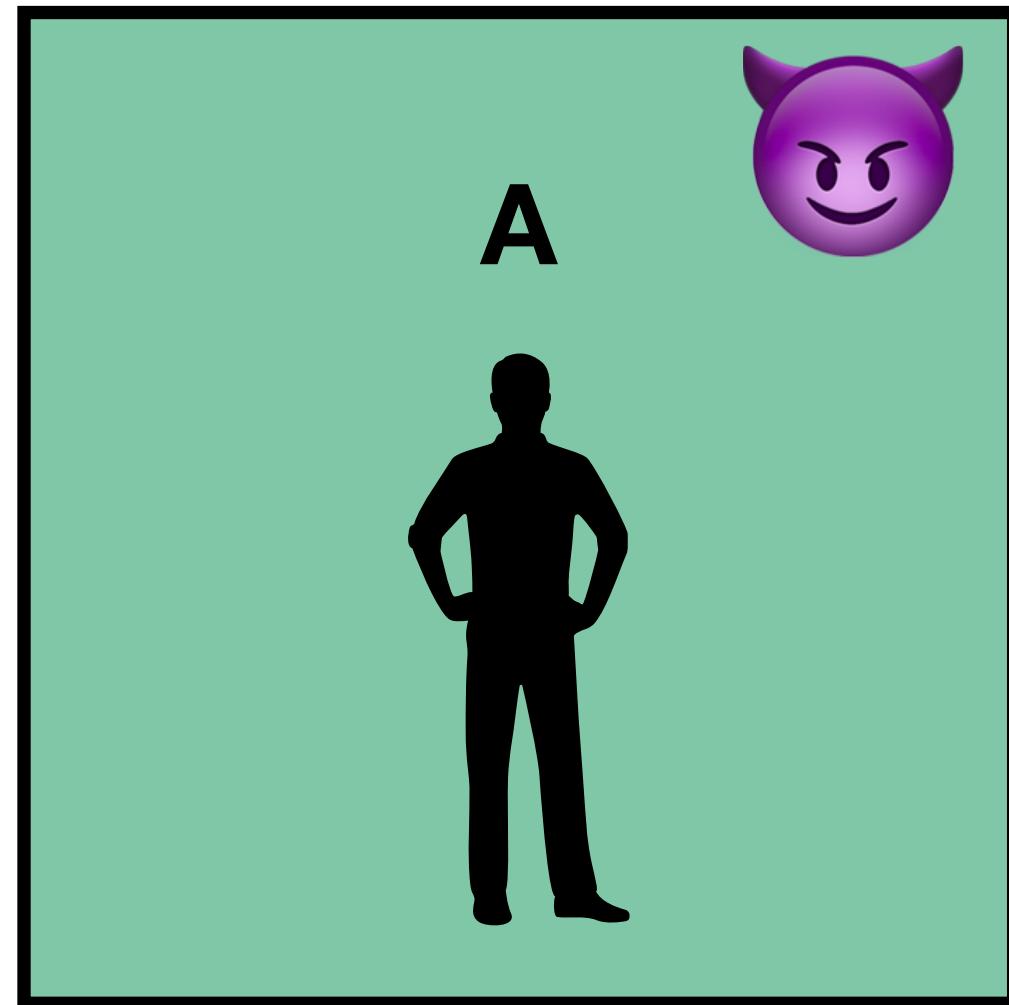
I.—COMPUTING MACHINERY AND INTELLIGENCE

BY A. M. TURING

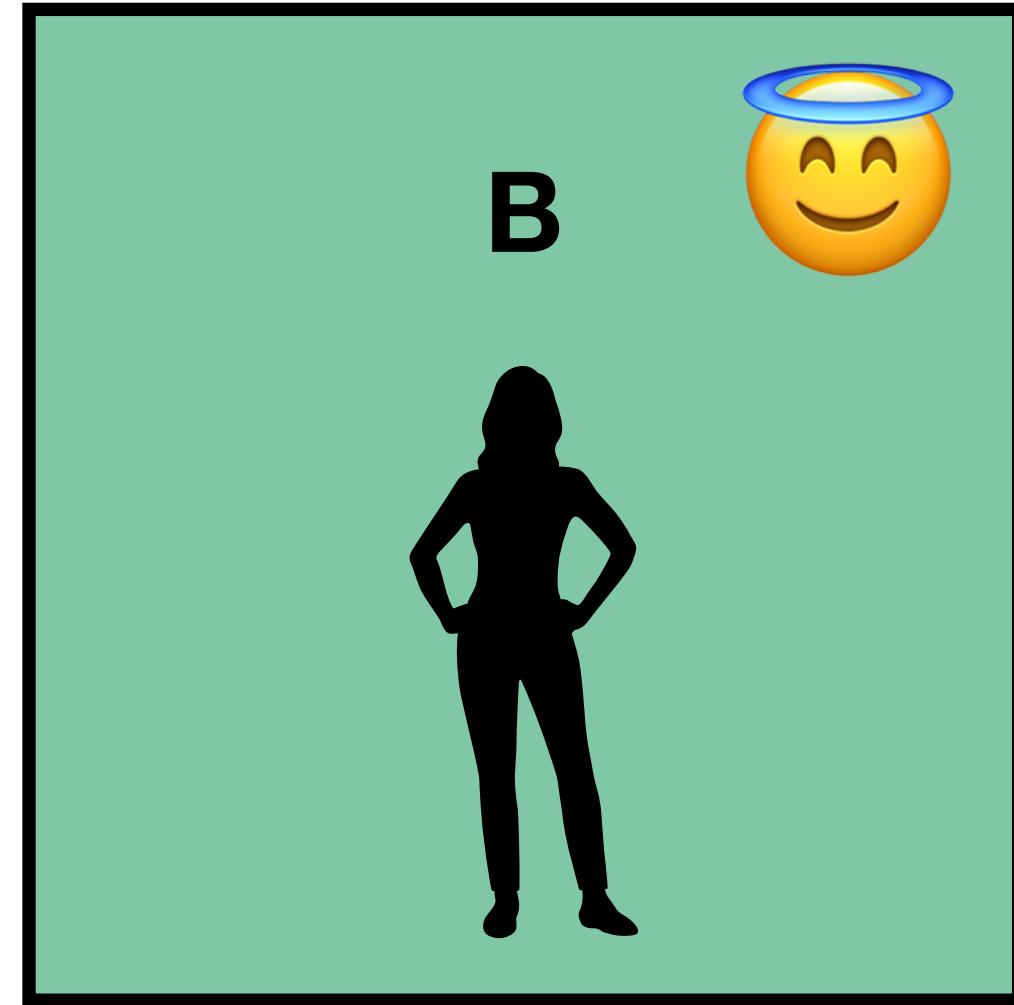
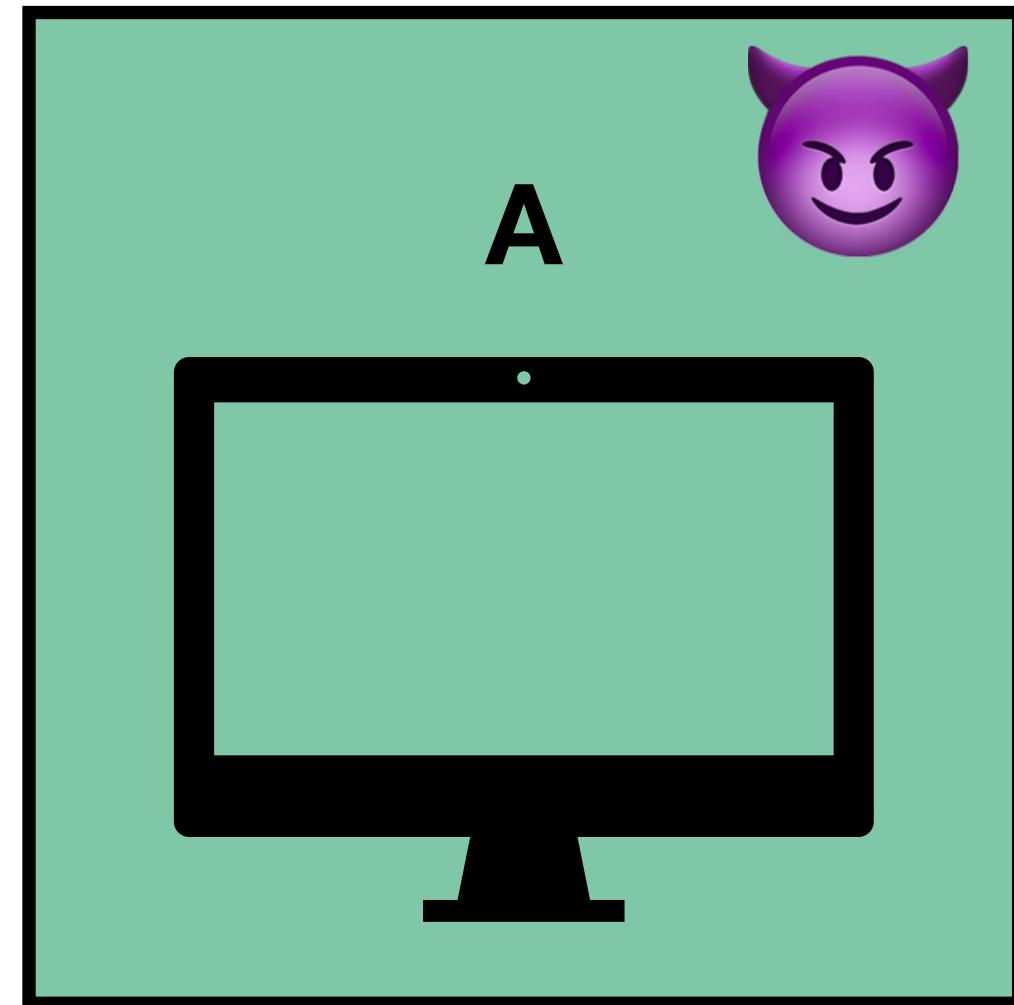
1. *The Imitation Game.*

I PROPOSE to consider the question, ‘Can machines think?’

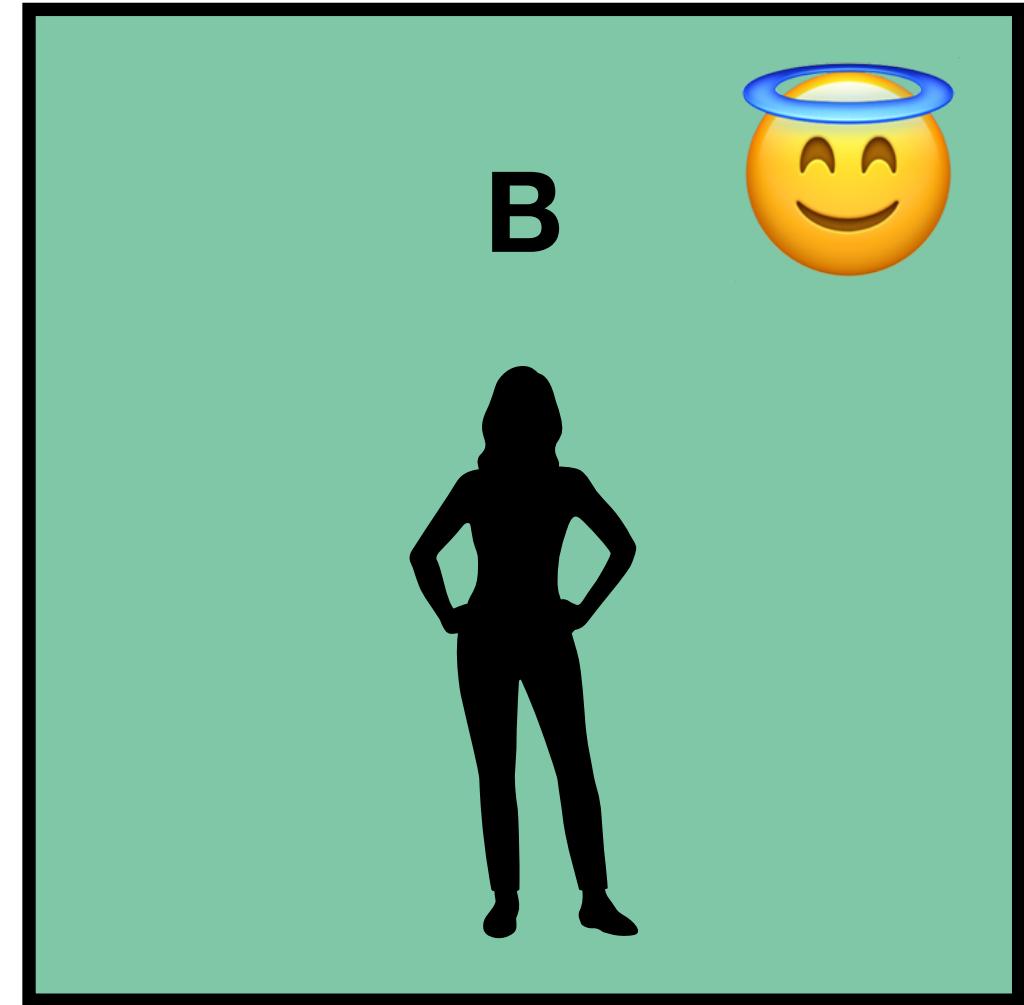
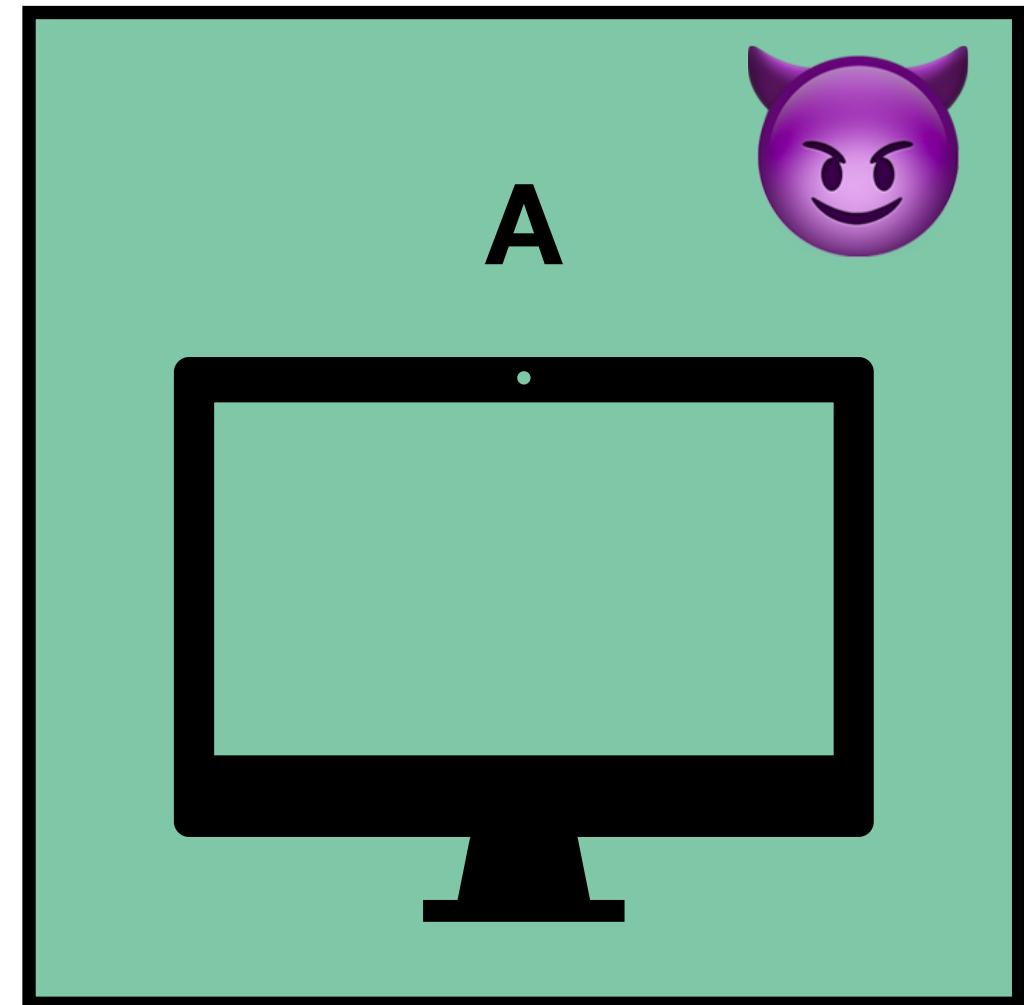
Test di Turing



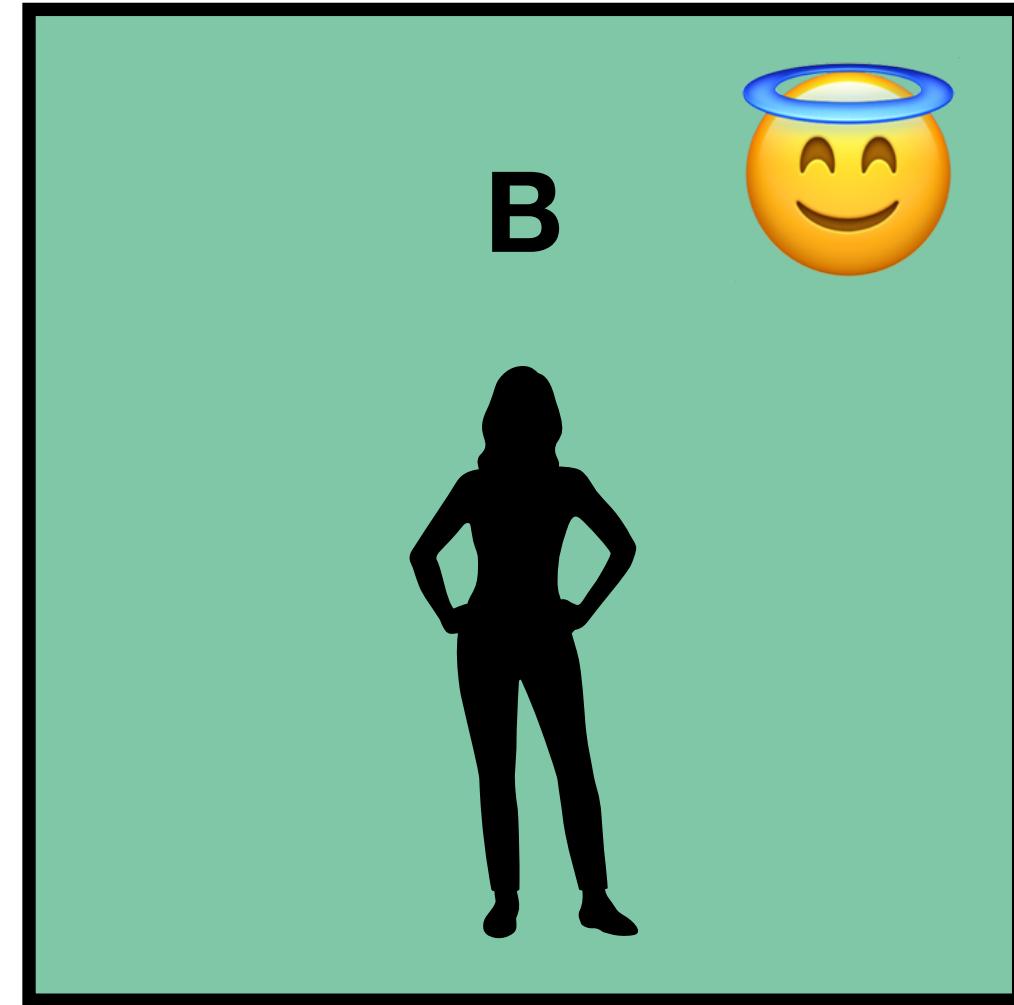
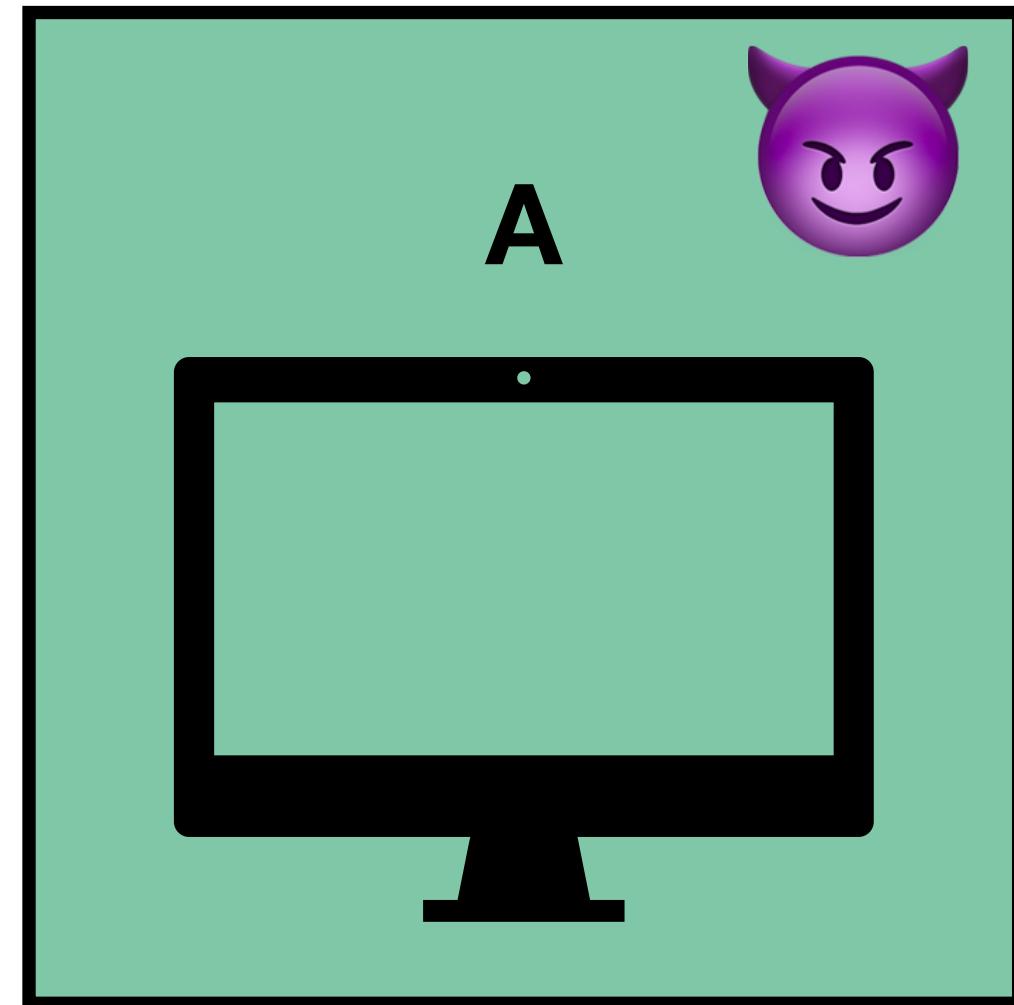
Test di Turing



Test di Turing



Test di Turing



Welcome to

EEEEEE	LL	III	ZZZZZ	AAAAA
EE	LL	II	ZZ	AA AA
EEEEEE	LL	II	ZZZ	AAAAAAA
EE	LL	II	ZZ	AA AA
EEEEEE	LLLLL	III	ZZZZZ	AA AA

Eliza is a mock Rogerian psychotherapist.

The original program was described by Joseph Weizenbaum in 1966.
This implementation by Norbert Landsteiner 2005.

ELIZA: Is something troubling you ?

YOU: Men are all alike.

ELIZA: What is the connection, do you suppose ?

YOU: They're always bugging us about something or other.

ELIZA: Can you think of a specific example ?

YOU: Well, my boyfriend made me come here.

ELIZA: Is it important to you that your boyfriend made you come here ?

YOU: He says I'm depressed much of the time.

ELIZA: I am sorry to hear that you are depressed.

YOU: It's true. I am unhappy.

ELIZA: Can you explain what made you unhappy ?

YOU:

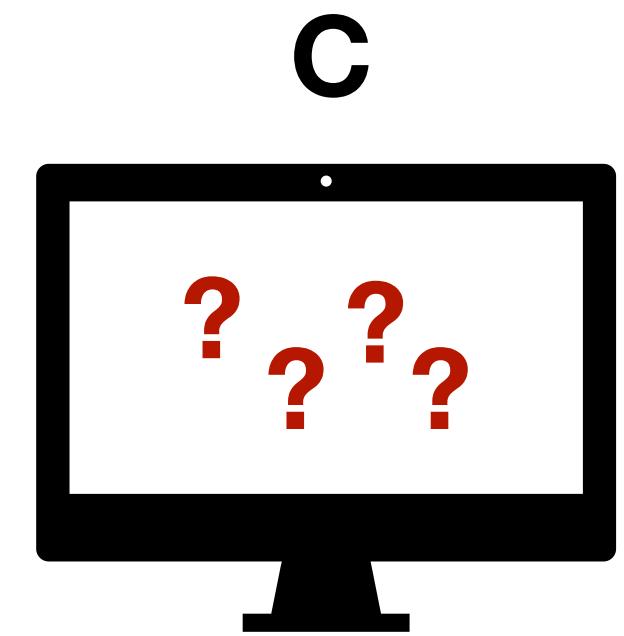
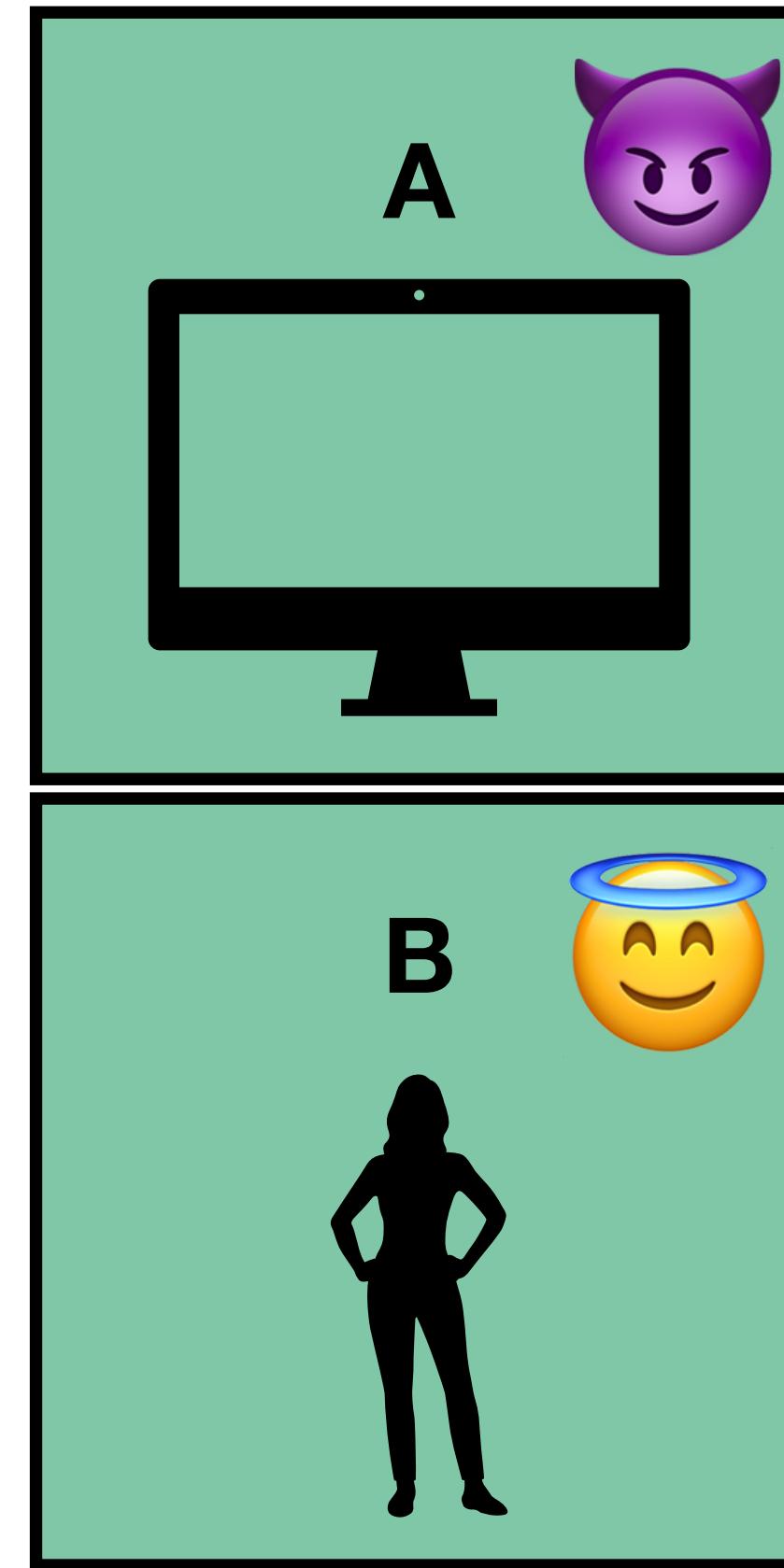


reCAPTCHA



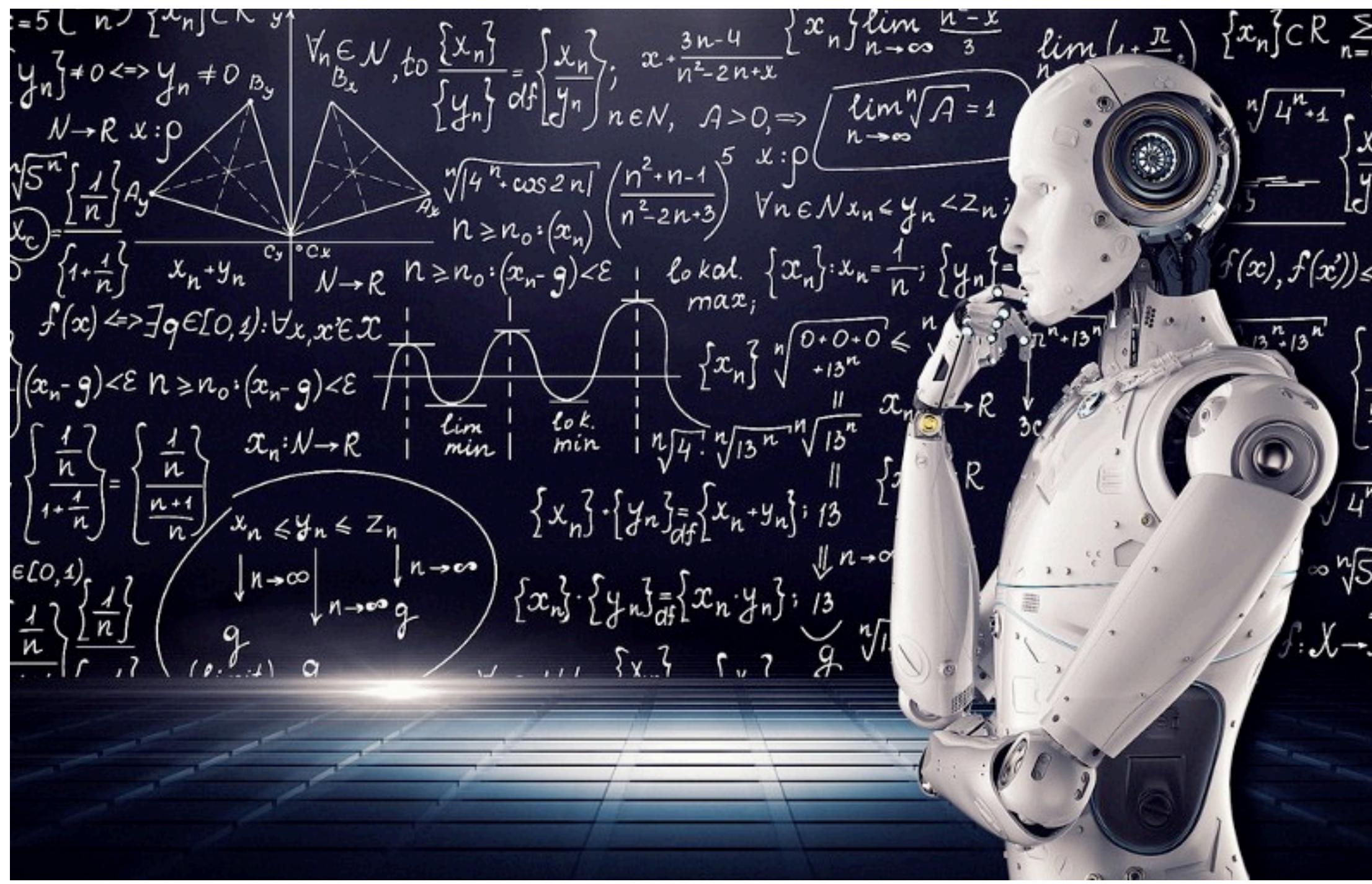
reCAPTCHA

Test di Turing inverso



Intelligenza artificiale

“studia se e in che modo si possano realizzare sistemi **informatici intelligenti** in grado di simulare la capacità e il comportamento del pensiero umano.”

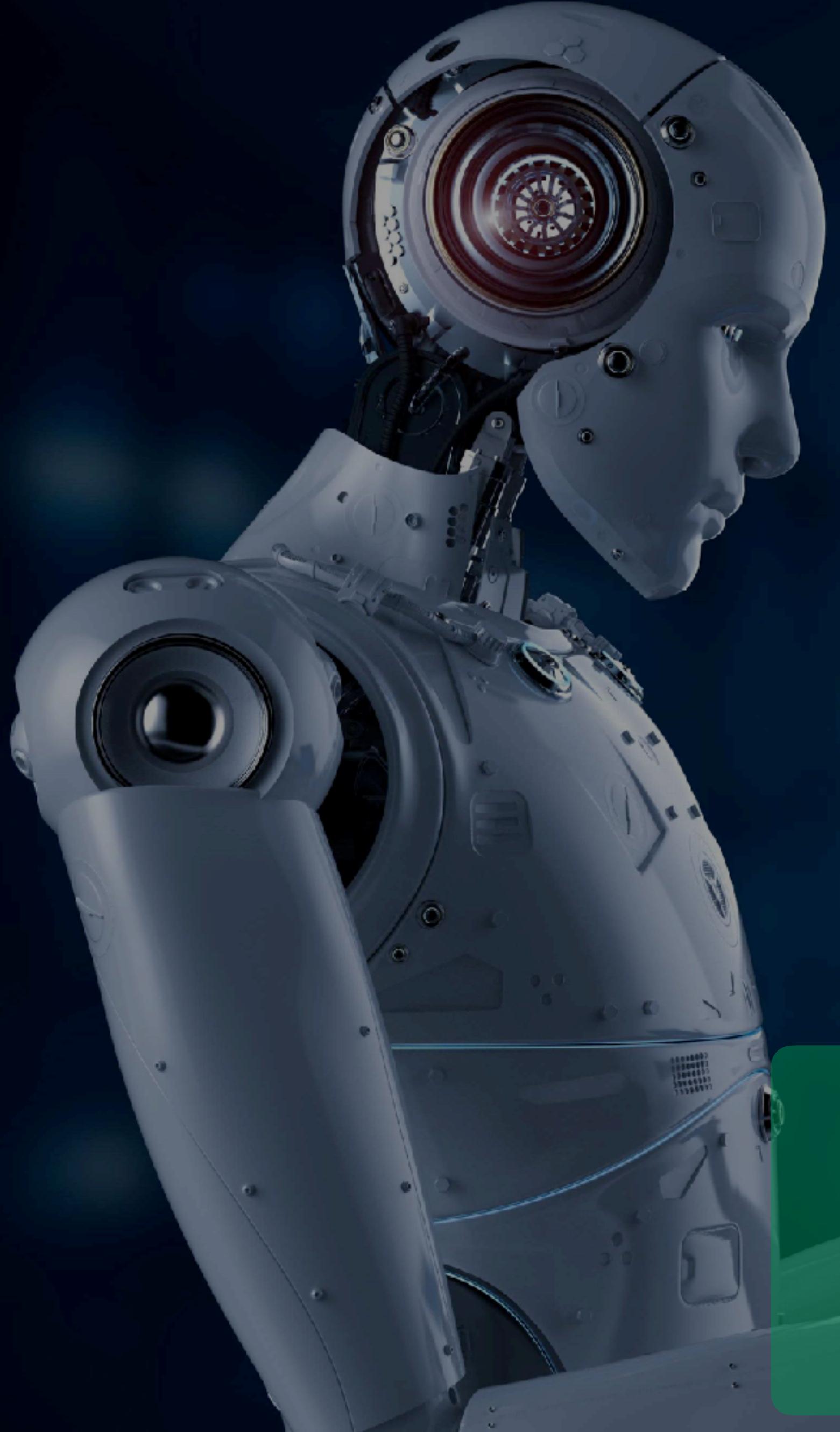


Wikipedia

- È strettamente legata a:
- logica
 - scienze cognitive
 - filosofia

Intelligenza?

Non proprio...
È Apprendimento Automatico



Apprendimento automatico

O Machine Learning (ML)



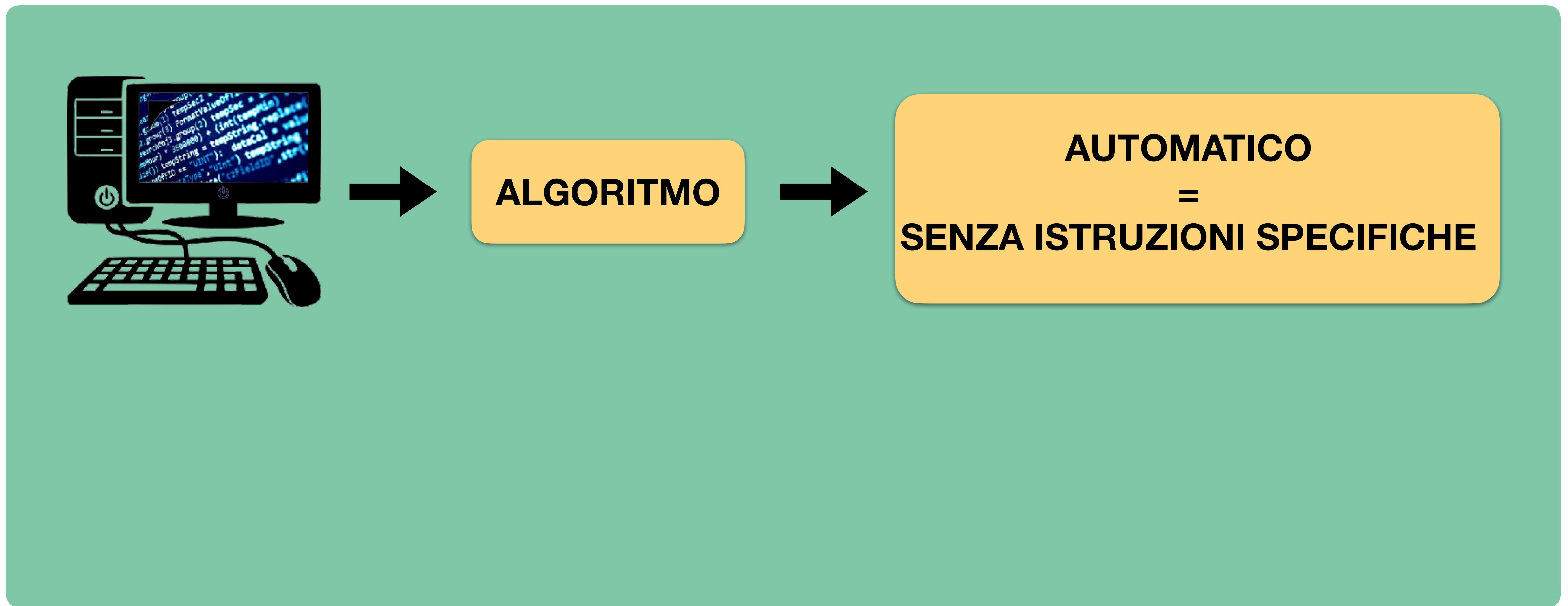
Apprendimento automatico

O Machine Learning (ML)



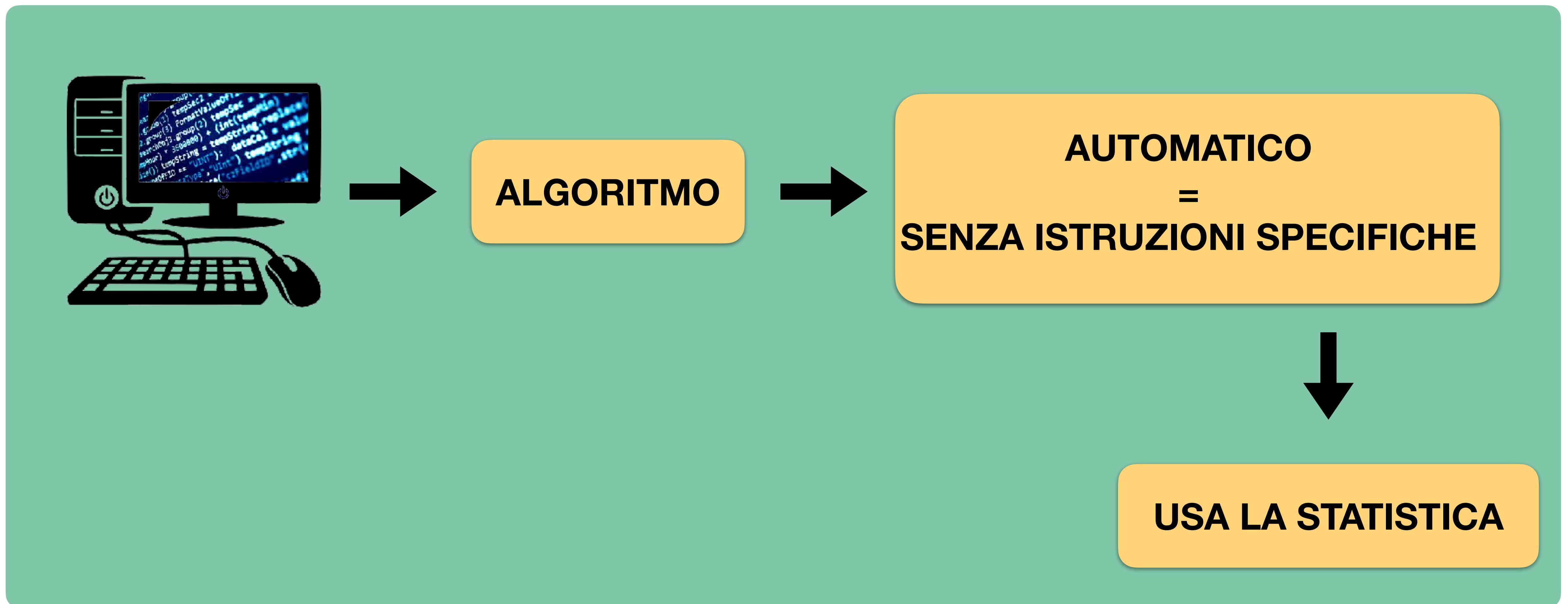
Apprendimento automatico

O Machine Learning (ML)

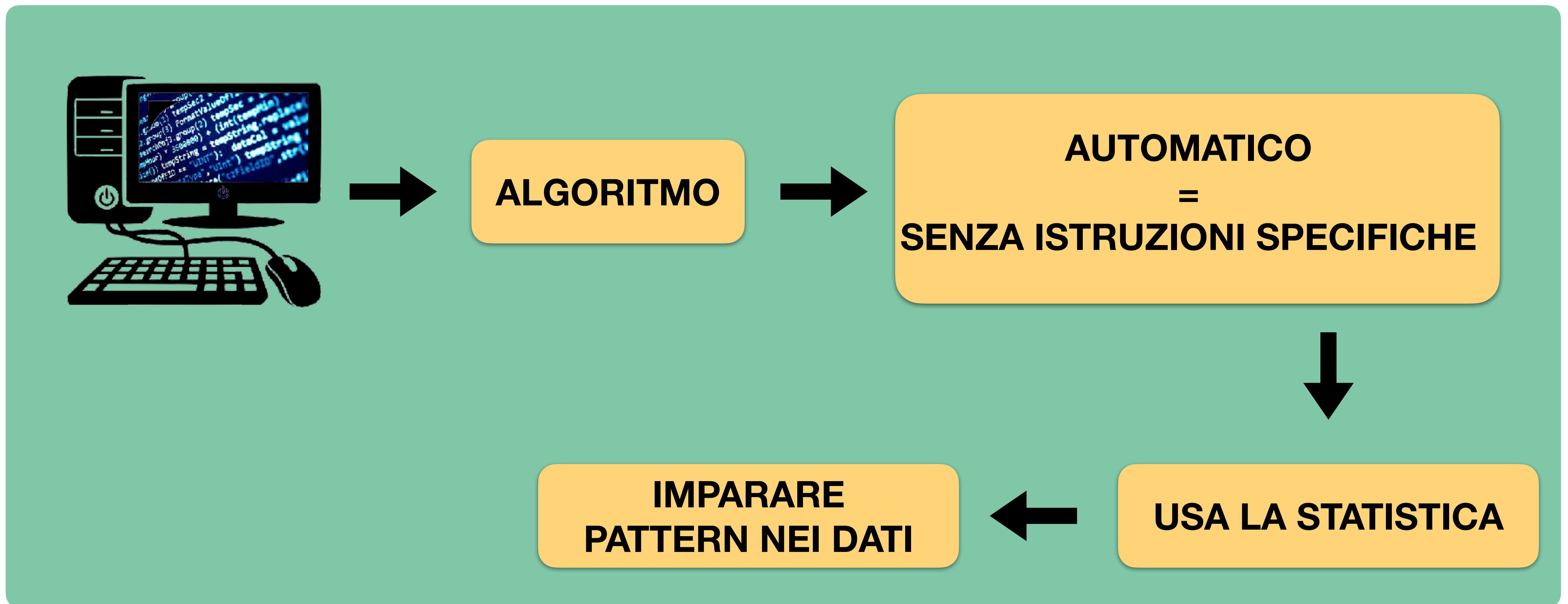


Apprendimento automatico

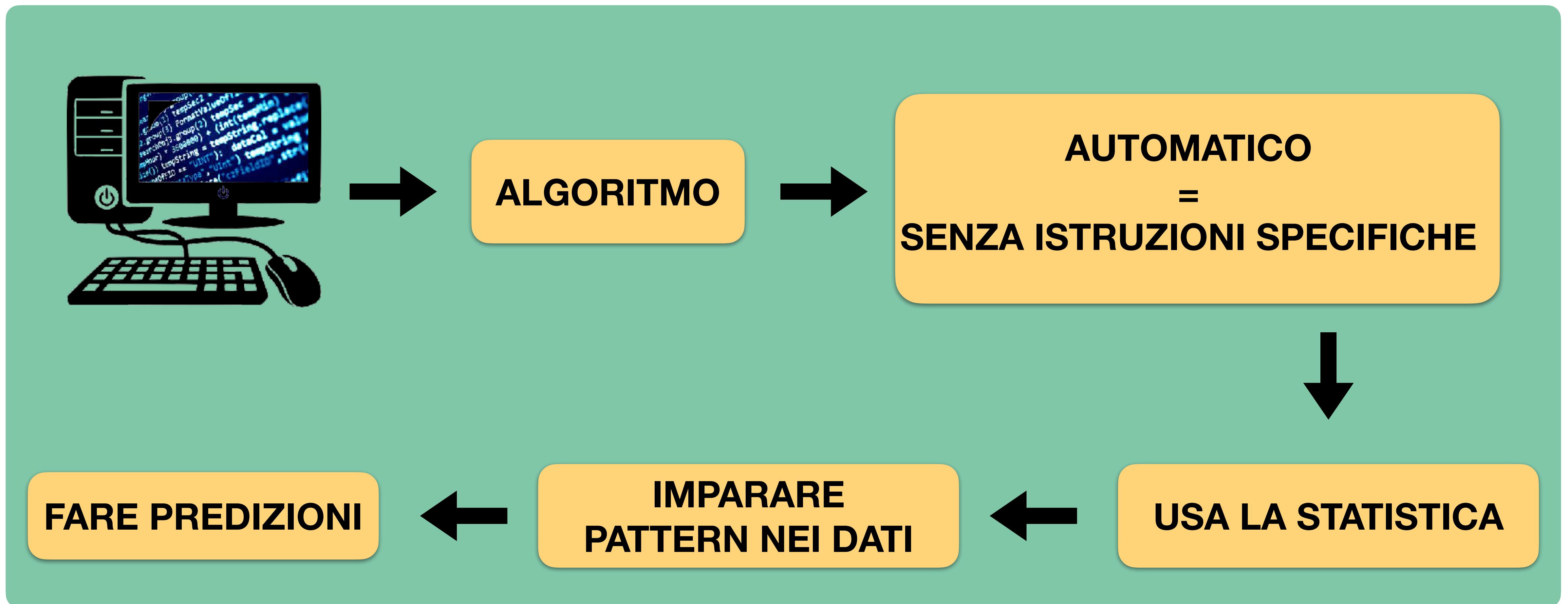
O Machine Learning (ML)



Apprendimento automatico o Machine Learning (ML)



Apprendimento automatico o Machine Learning (ML)



INTELLIGENZA ARTIFICIALE

MACHINE LEARNING

Impara pattern dai dati
seguendo leggi statistiche

DEEP LEARNING

Utilizza reti neurali artificiali

Cerca di simulare
il pensiero umano

INTELLIGENZA ARTIFICIALE

MACHINE LEARNING

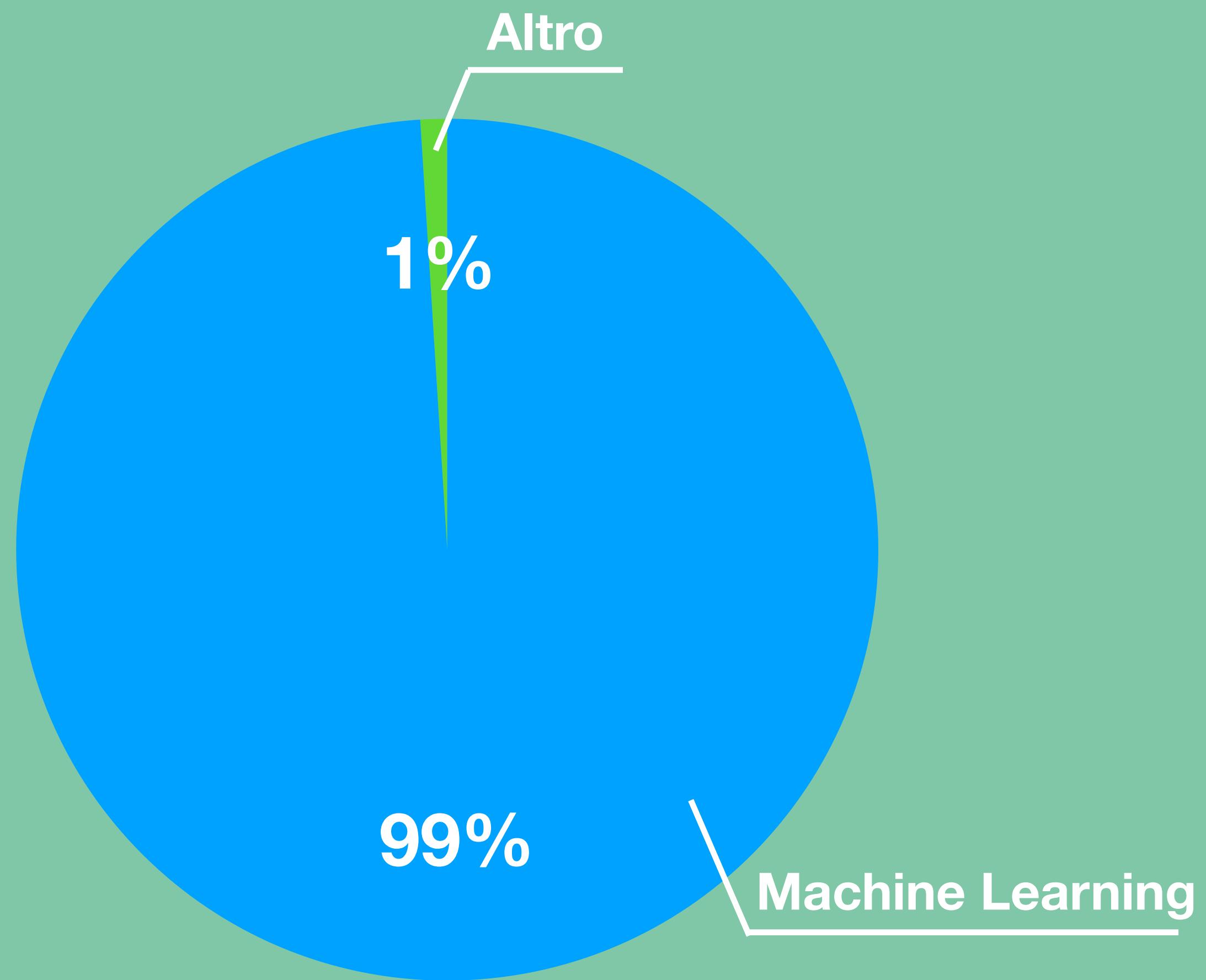
Impara pattern dai dati
seguendo leggi statistiche

DEEP LEARNING

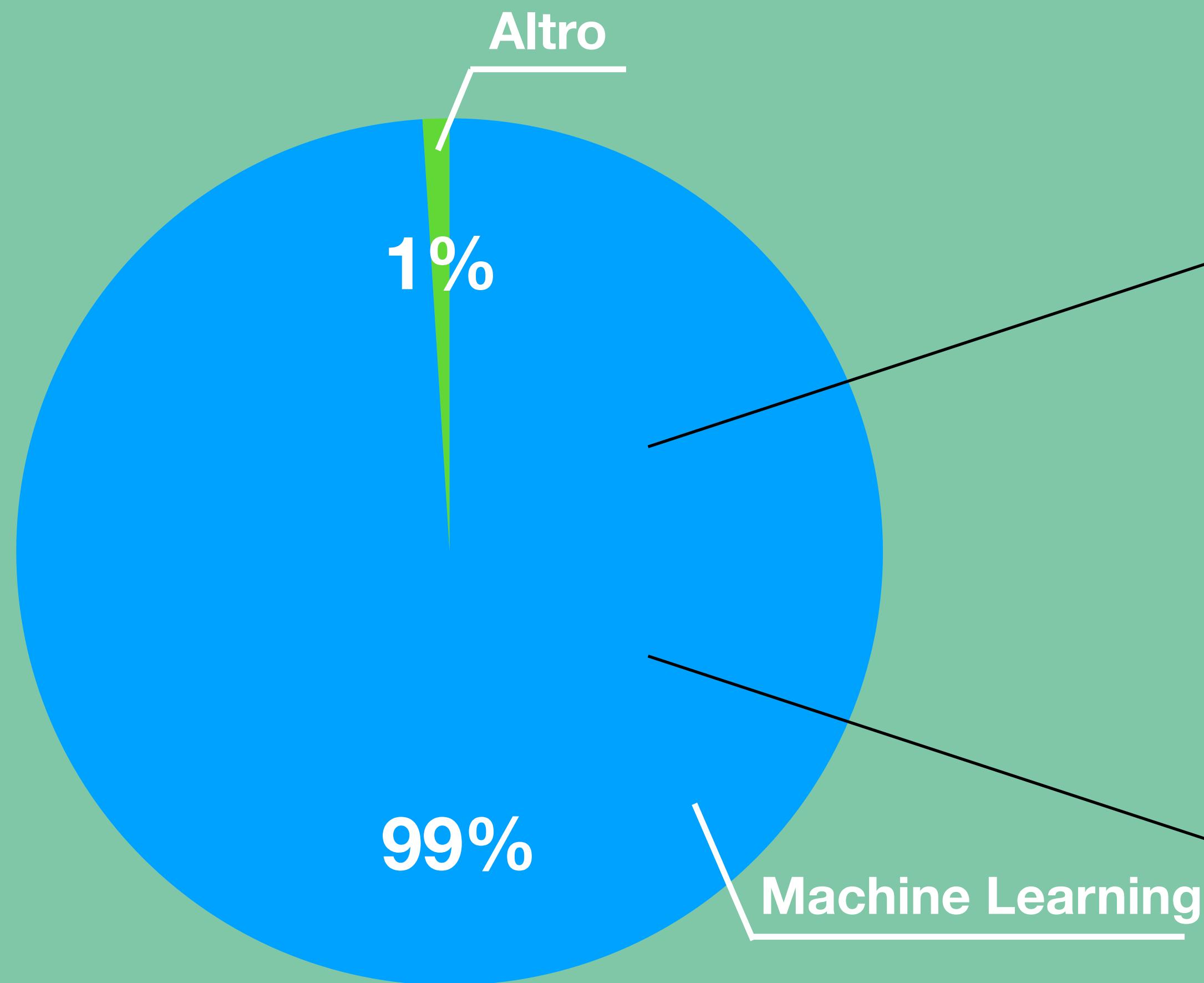
Utilizza reti neurali artificiali

Cerca di simulare
il pensiero umano

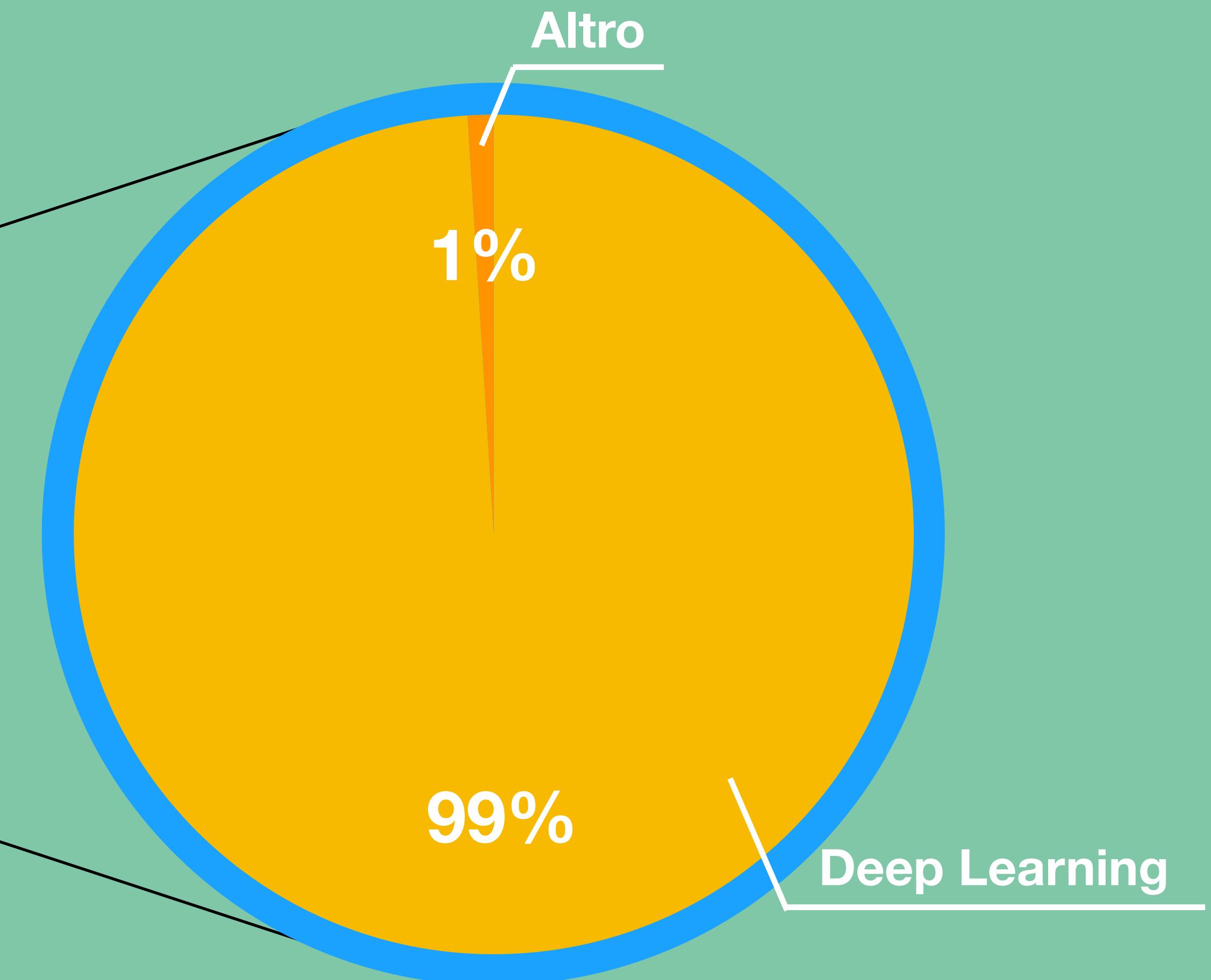
Intelligenza Artificiale

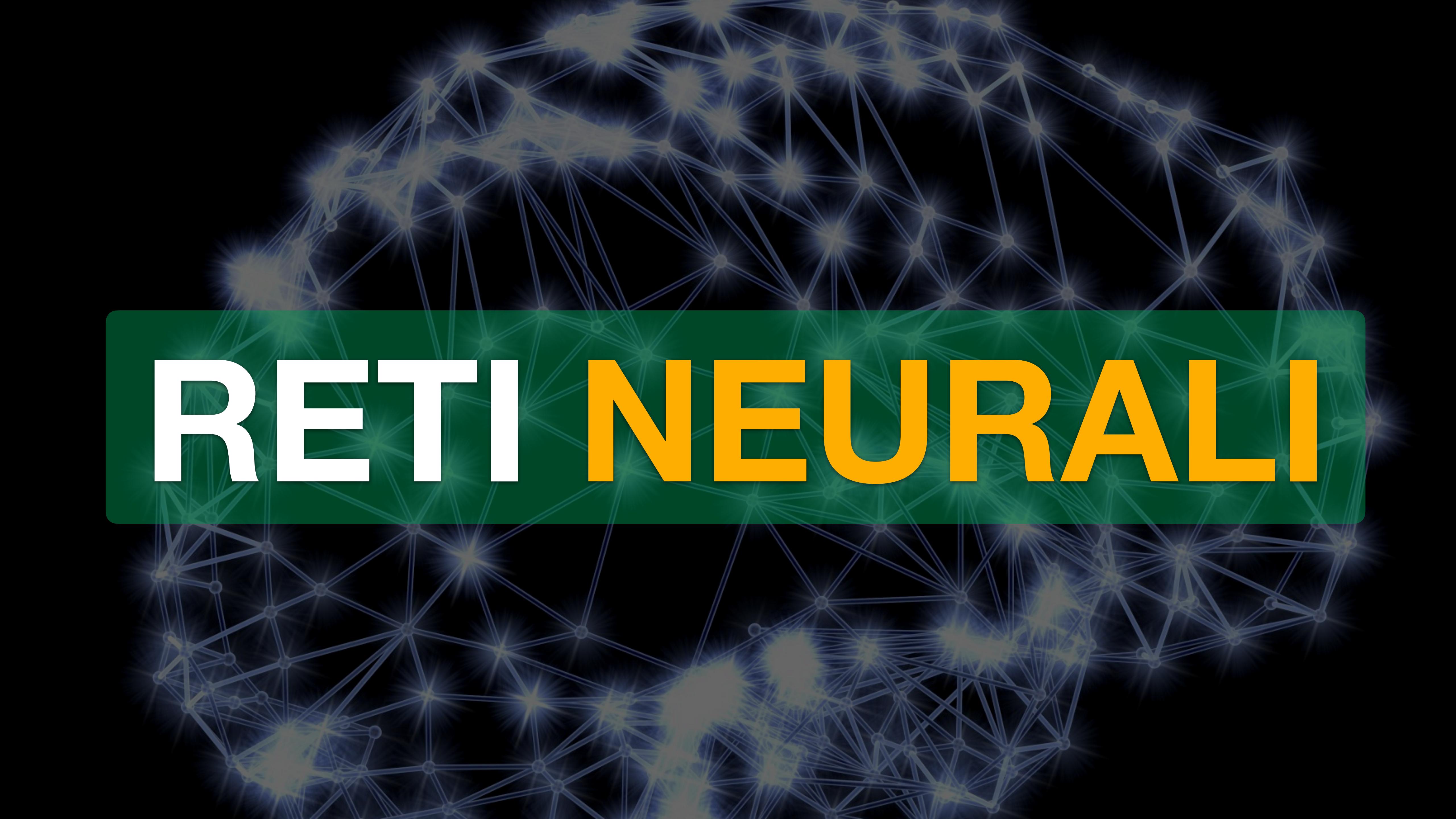


Intelligenza Artificiale



Machine Learning

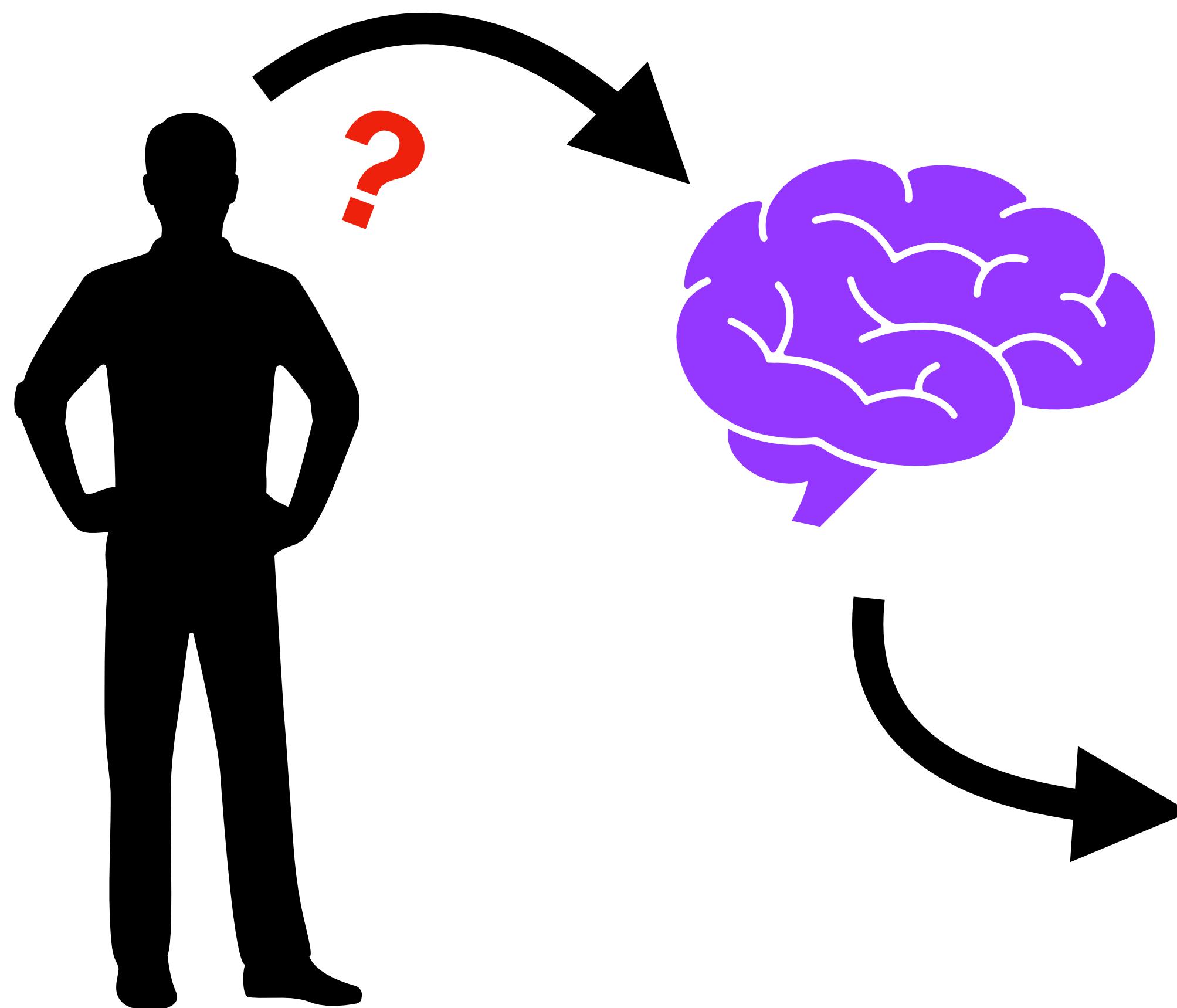




The background features a dense, abstract network graph composed of numerous small, glowing blue and yellow nodes connected by thin lines, creating a sense of a complex system or neural network.

RETINEURAL

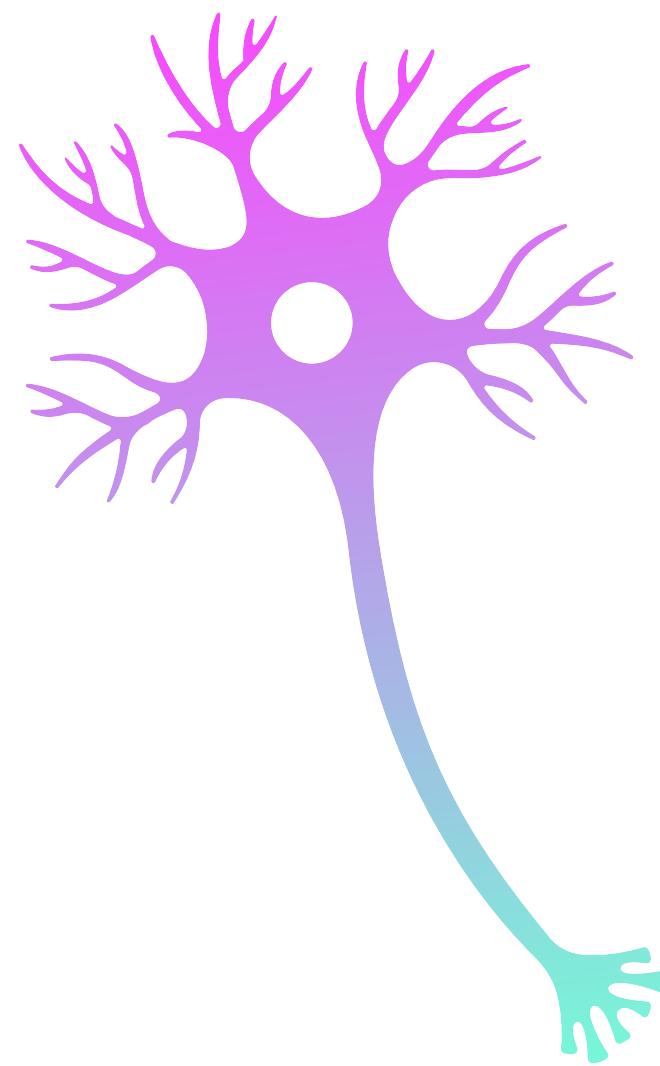
Cervello umano



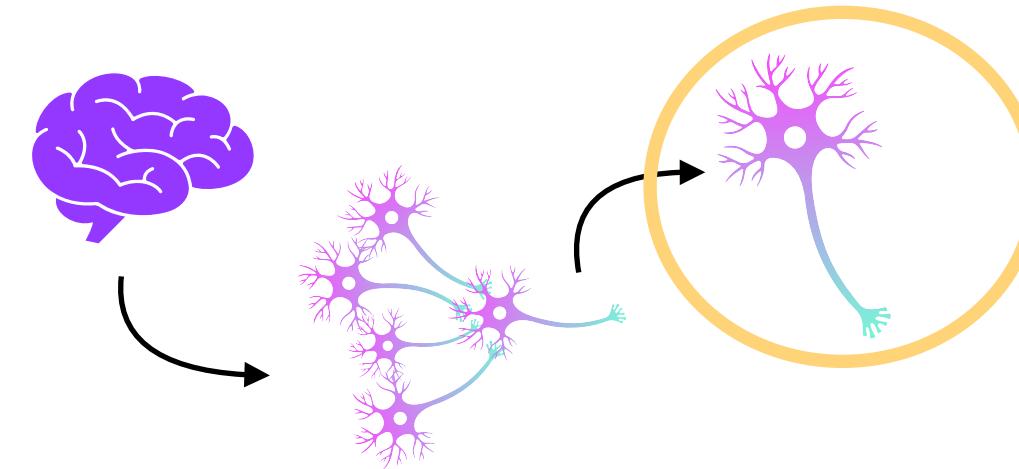
RETI NEURALI

NEURONE

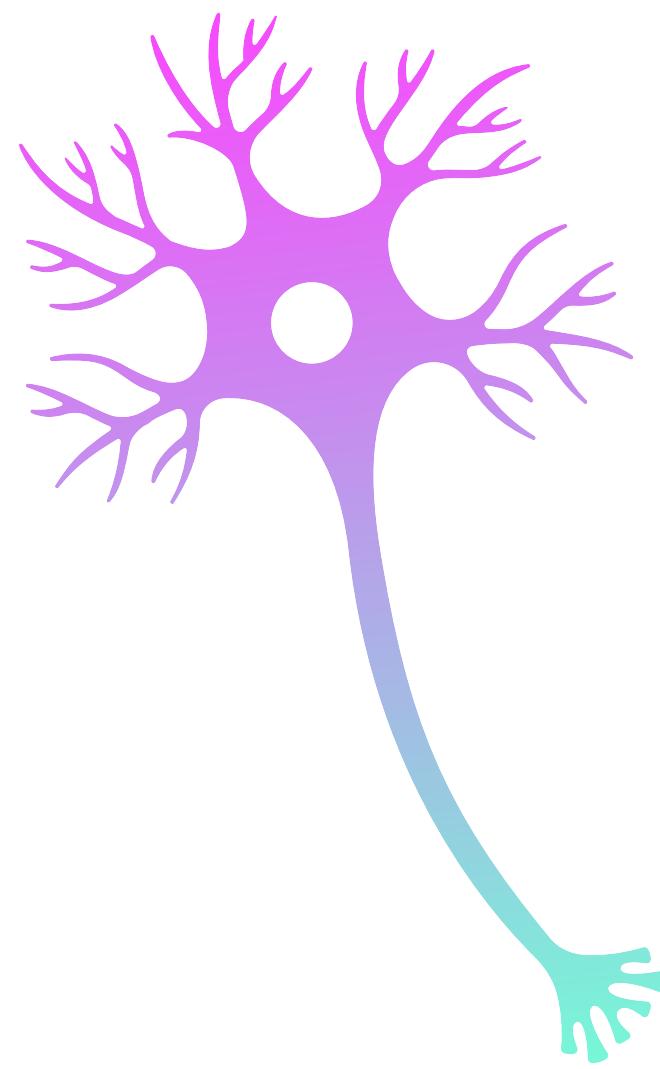
II neurone



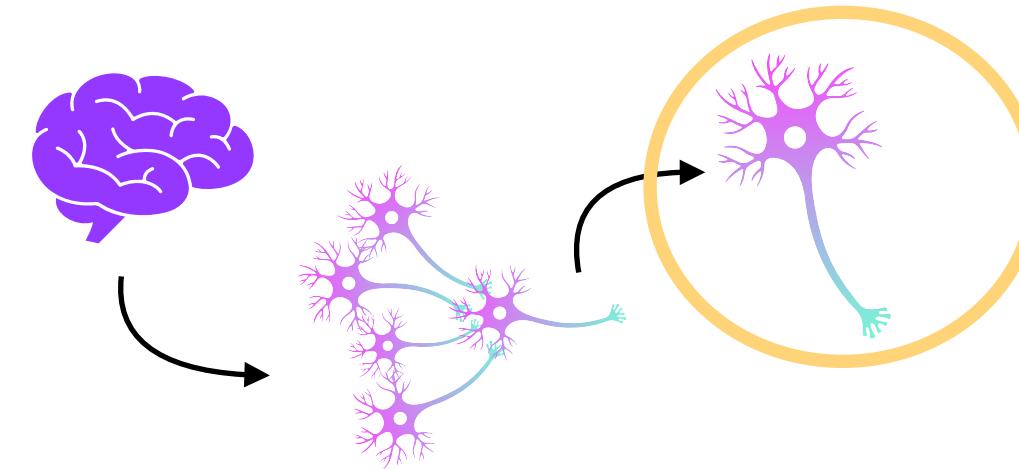
NEURONE



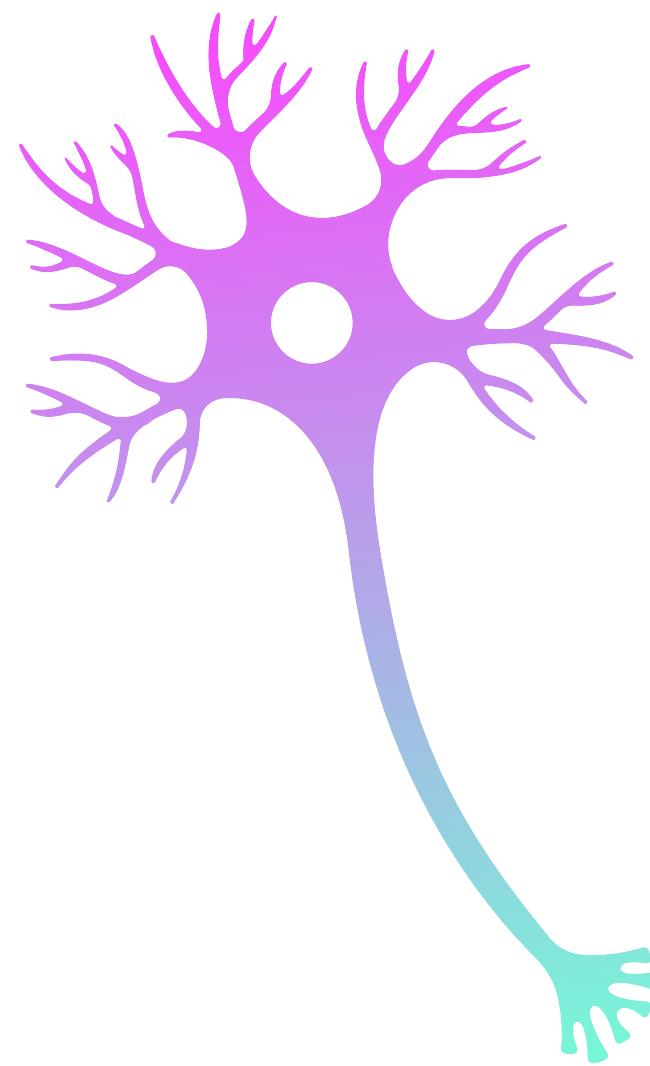
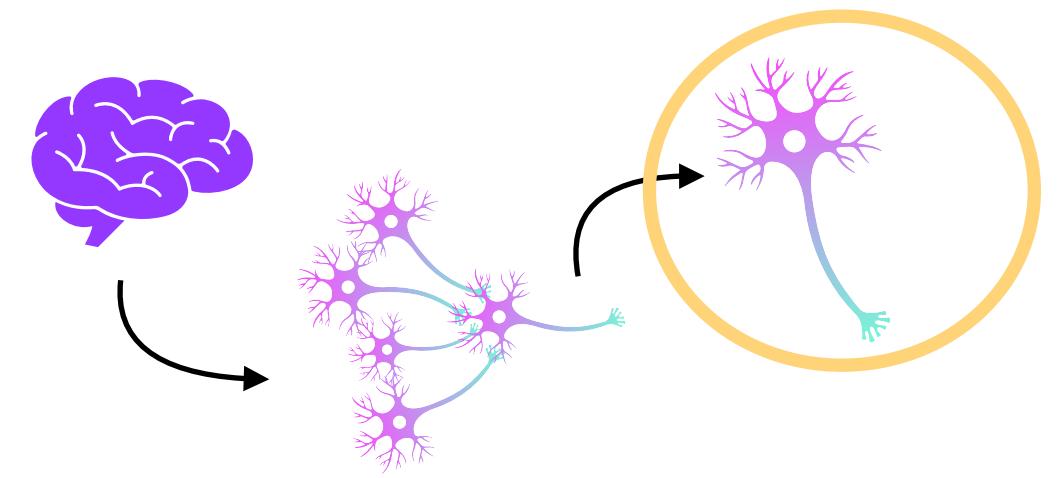
II neurone



NEURONE

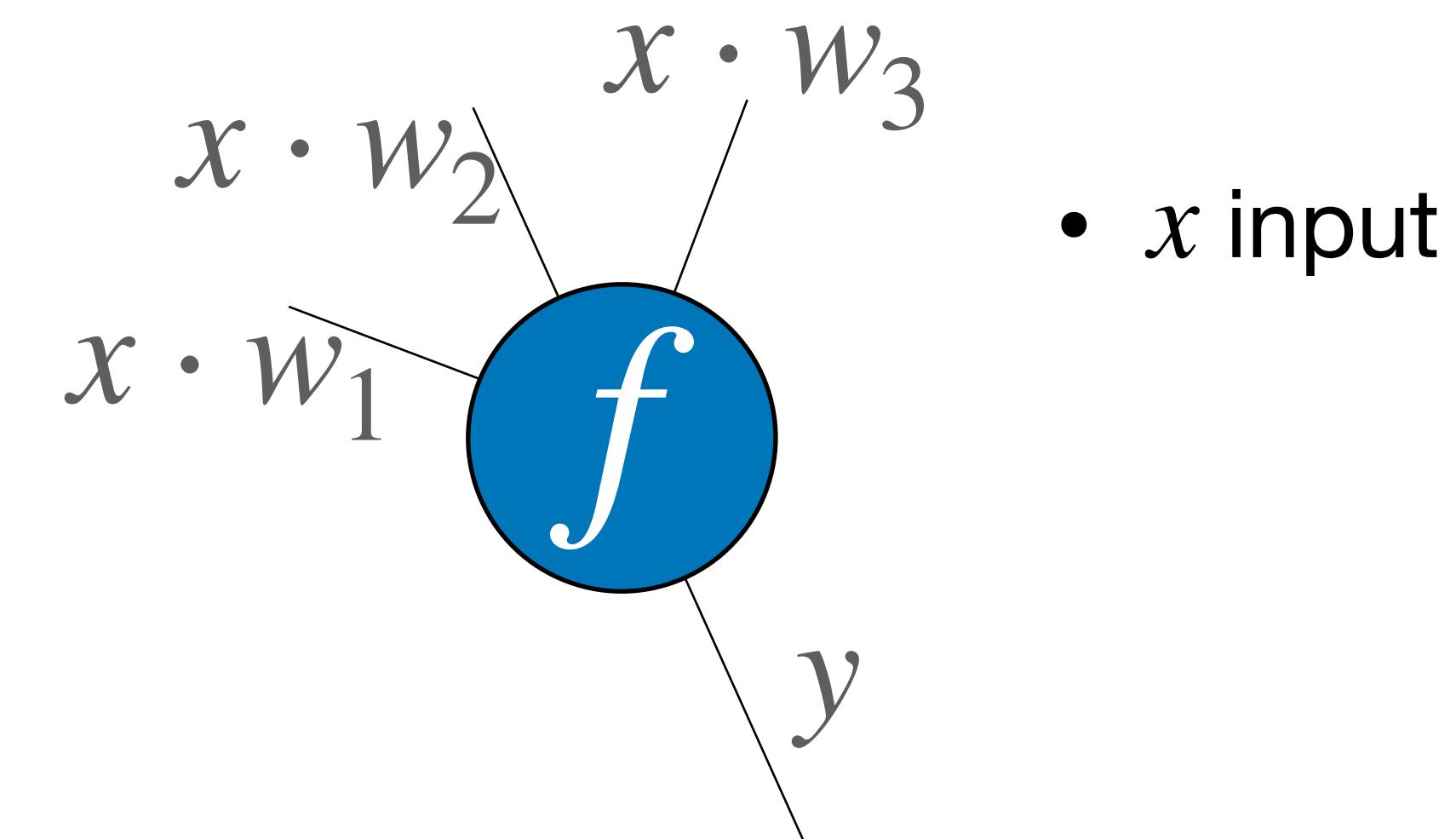
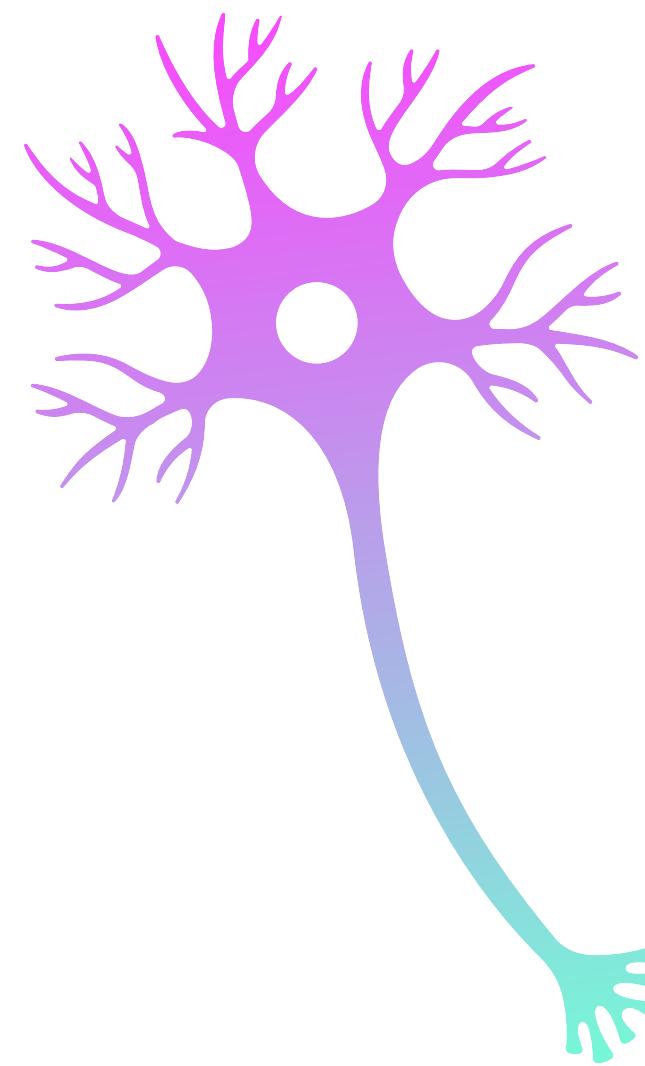
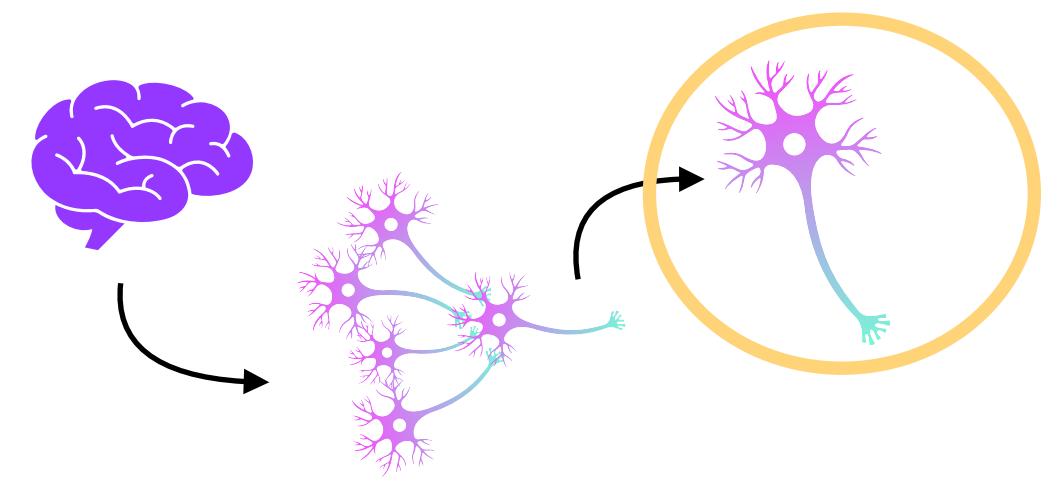


Il neurone artificiale (o percettore)



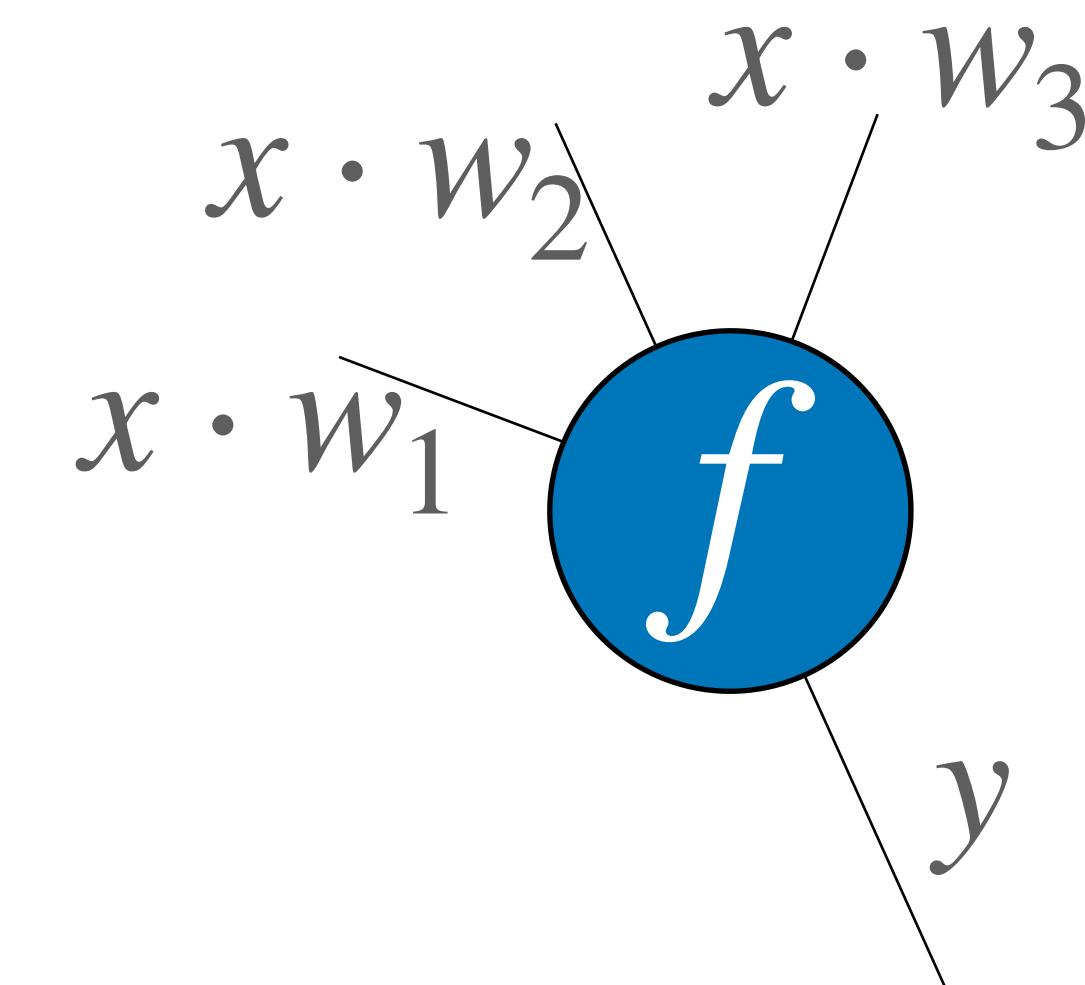
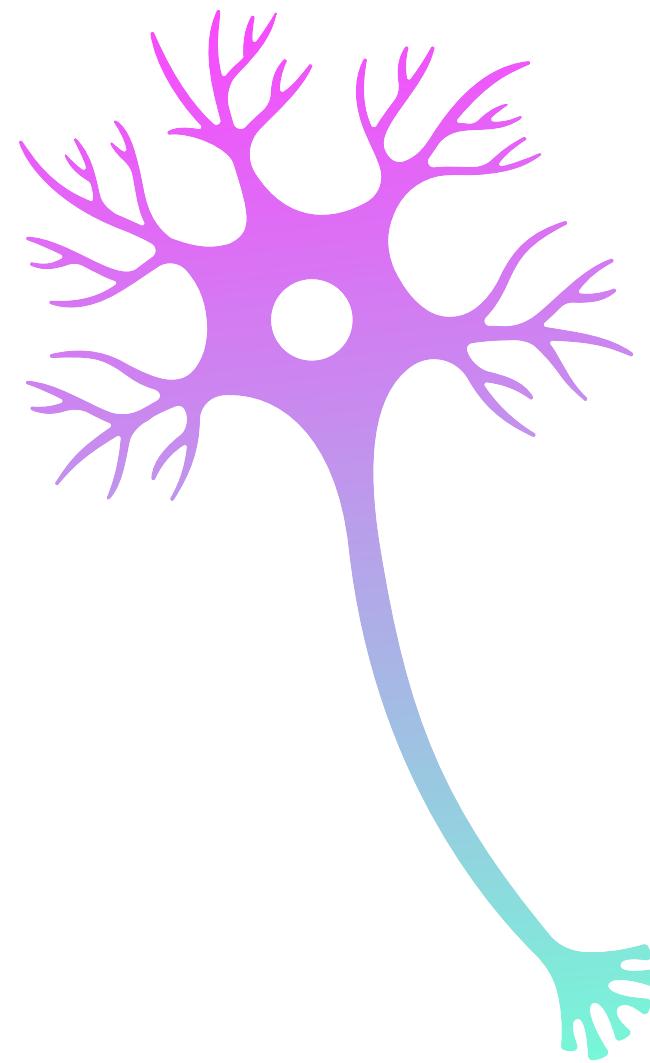
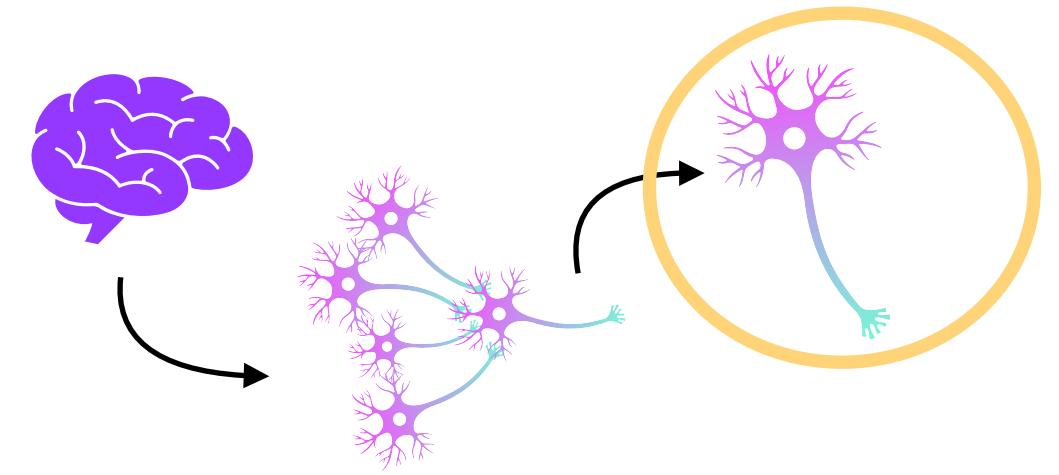
NEURONE

Il neurone artificiale (o percettore)



NEURONE

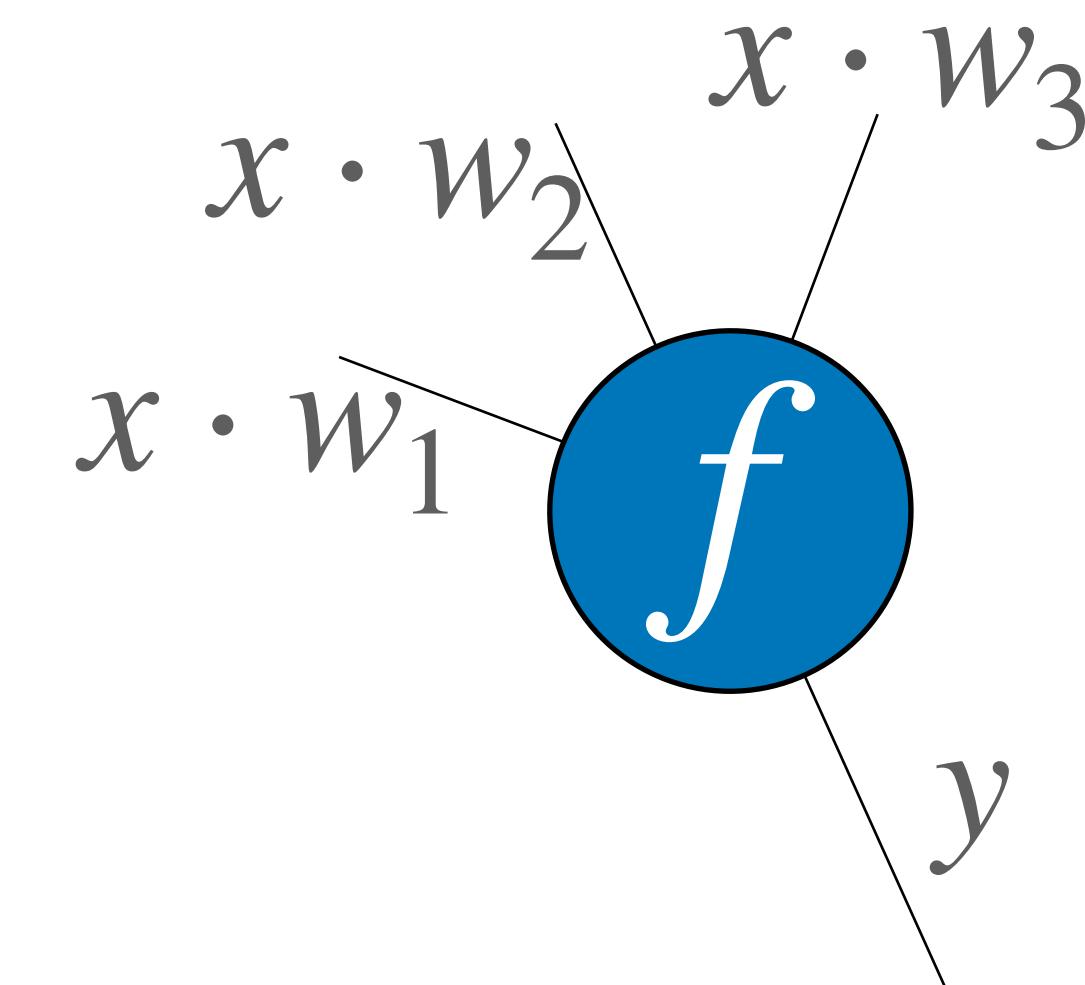
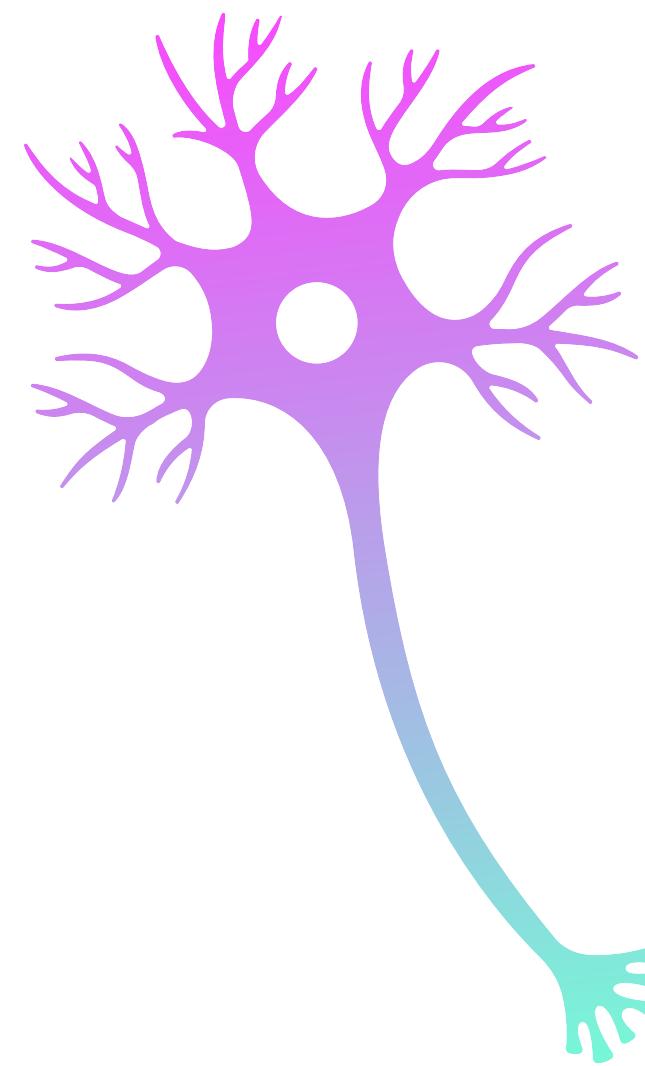
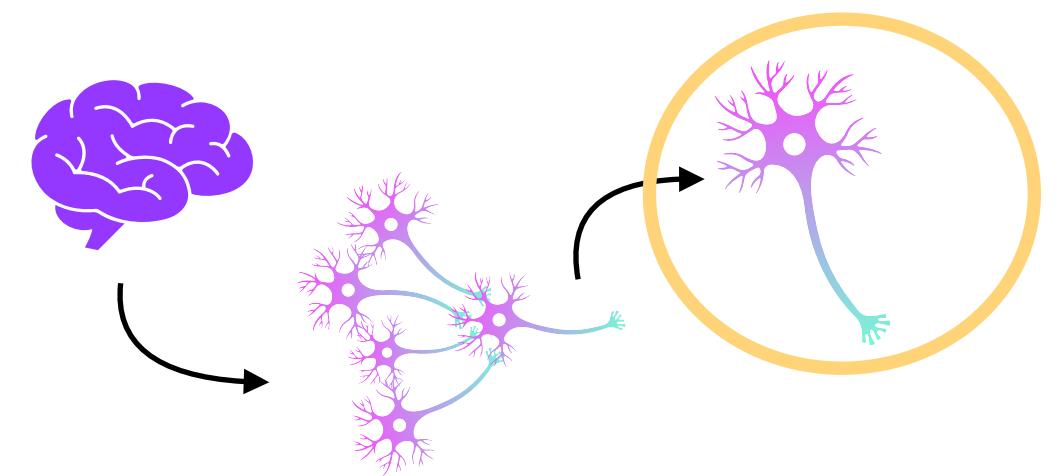
Il neurone artificiale (o percettore)



- x input
- w_i pesi (parametri)

NEURONE

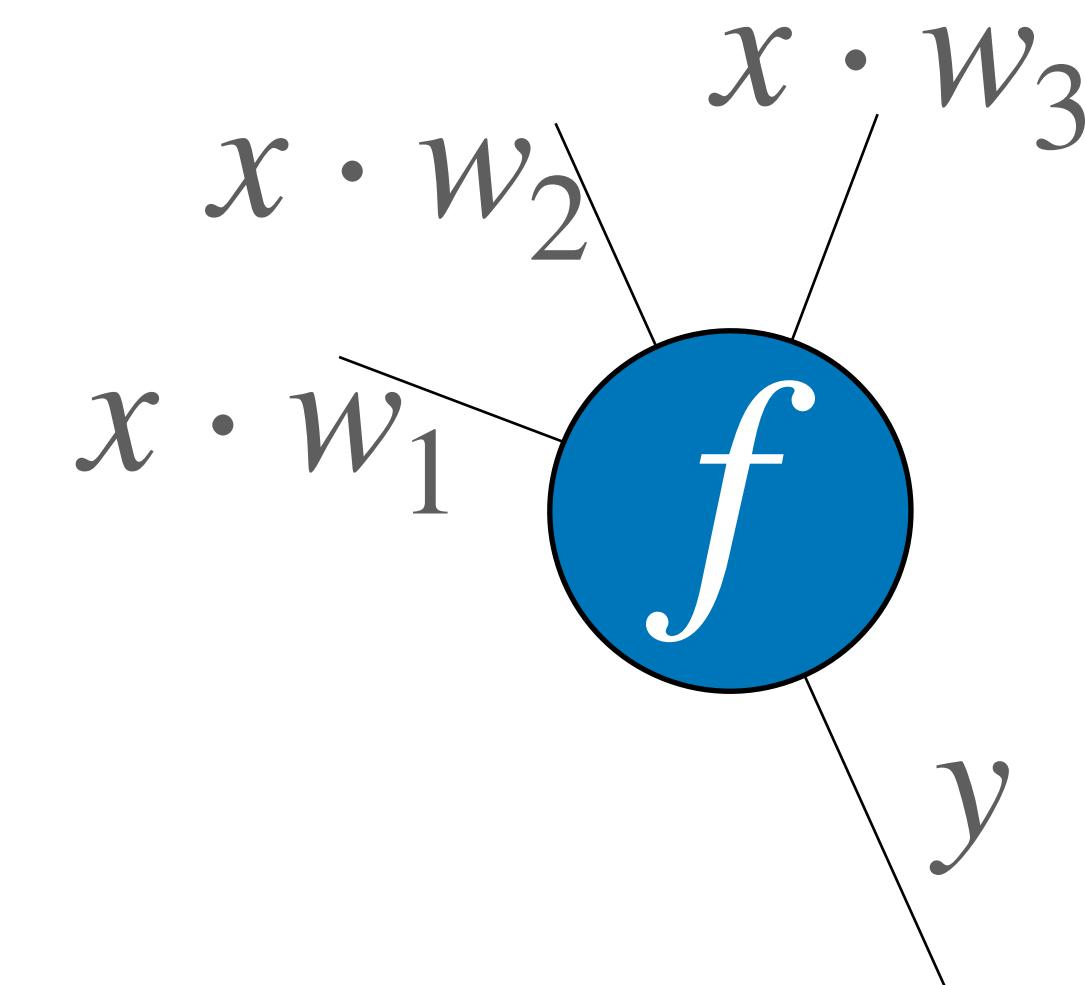
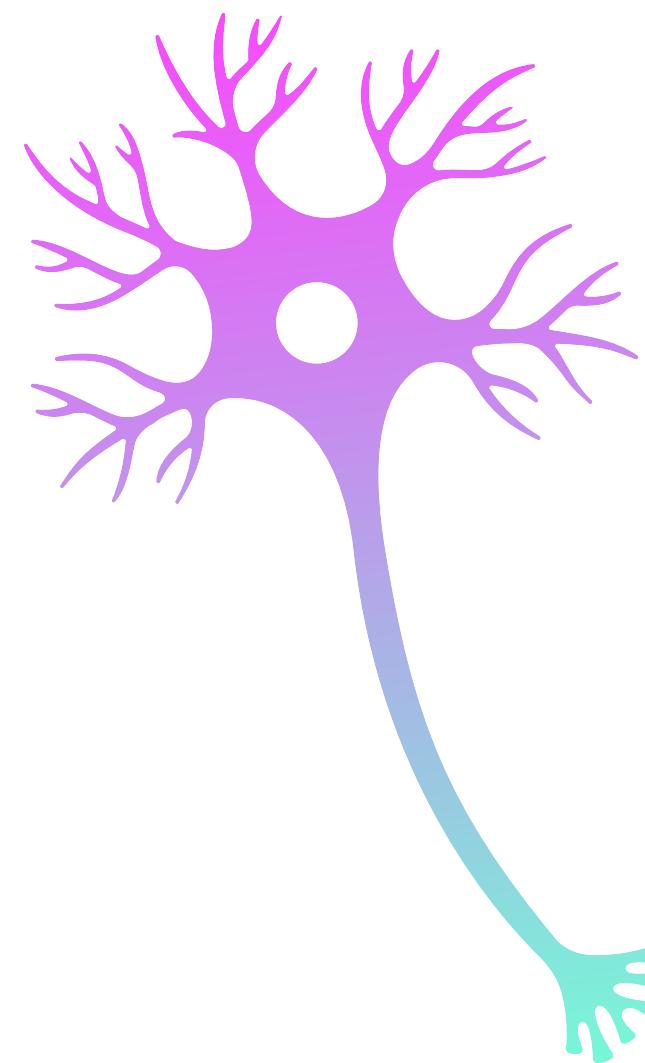
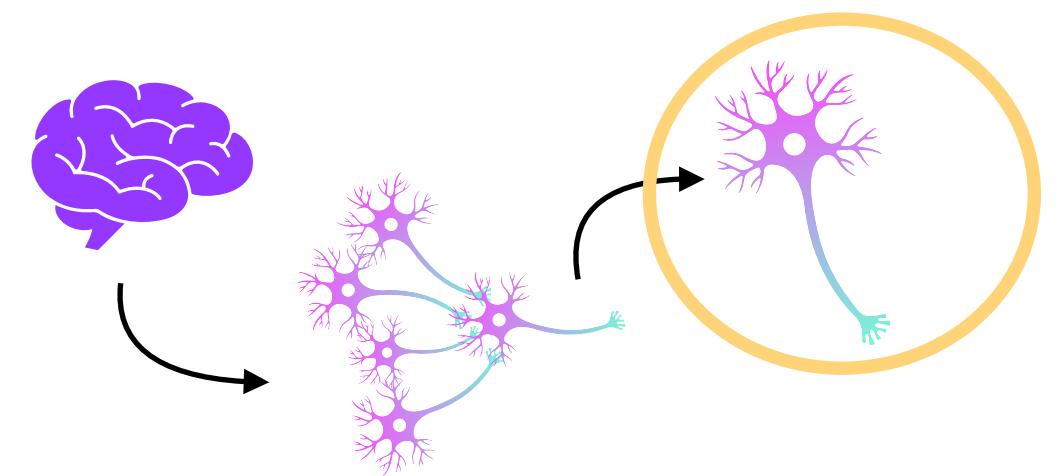
Il neurone artificiale (o percettore)



- x input
- w_i pesi (parametri)
- f funzione di attivazione

NEURONE

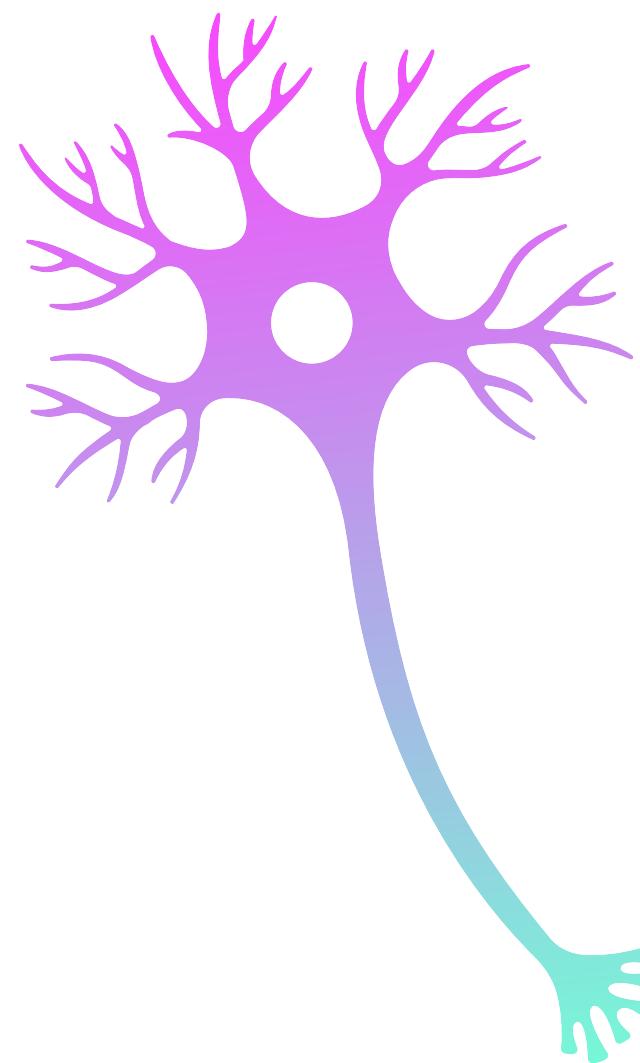
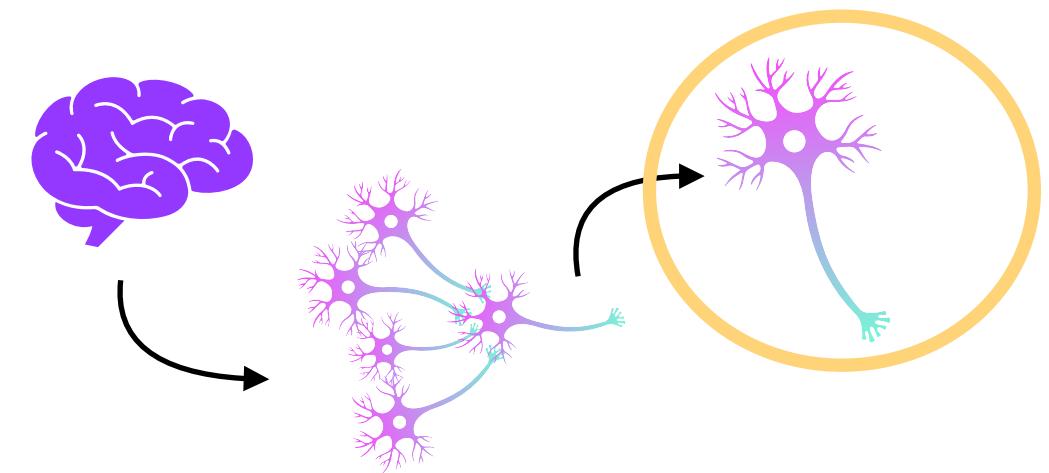
Il neurone artificiale (o percettore)



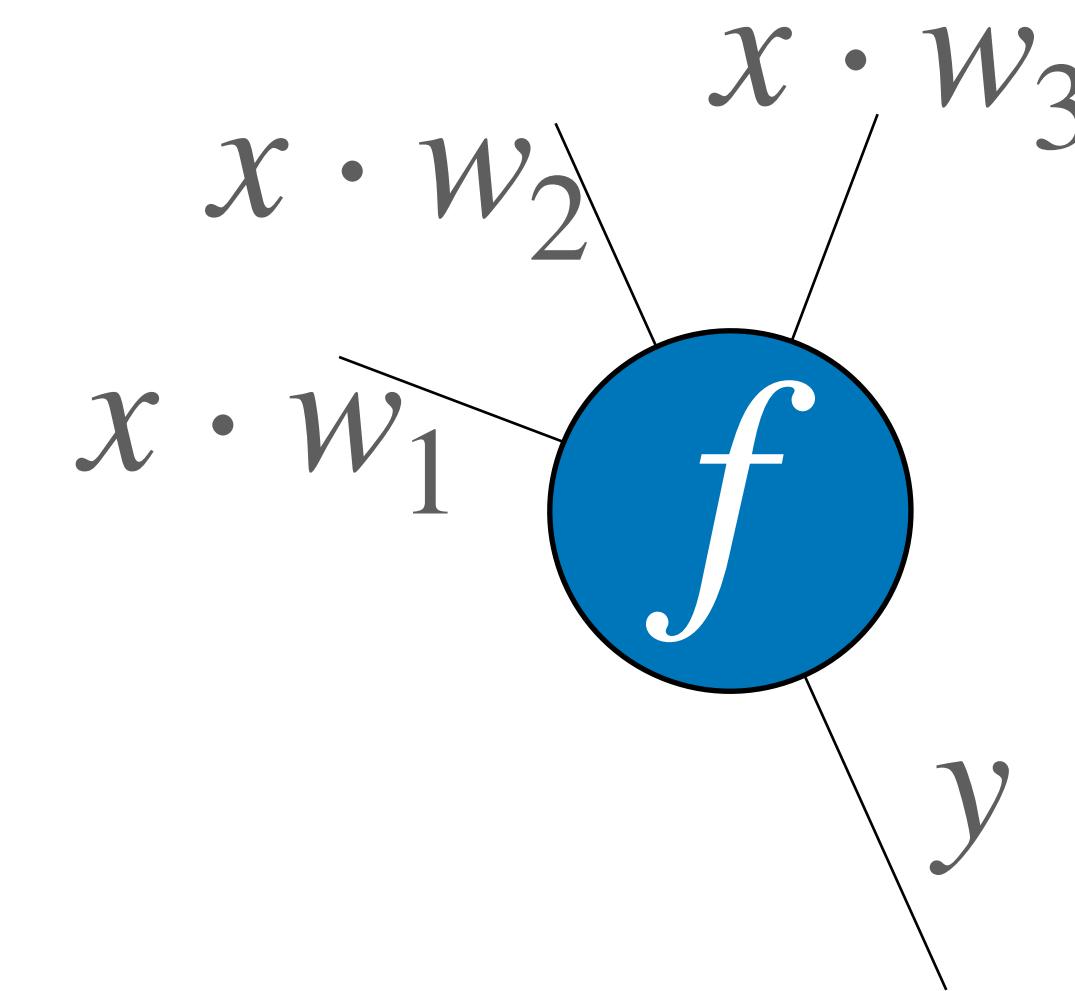
- x input
- w_i pesi (parametri)
- f funzione di attivazione
- y output

NEURONE

Il neurone artificiale (o percettore)



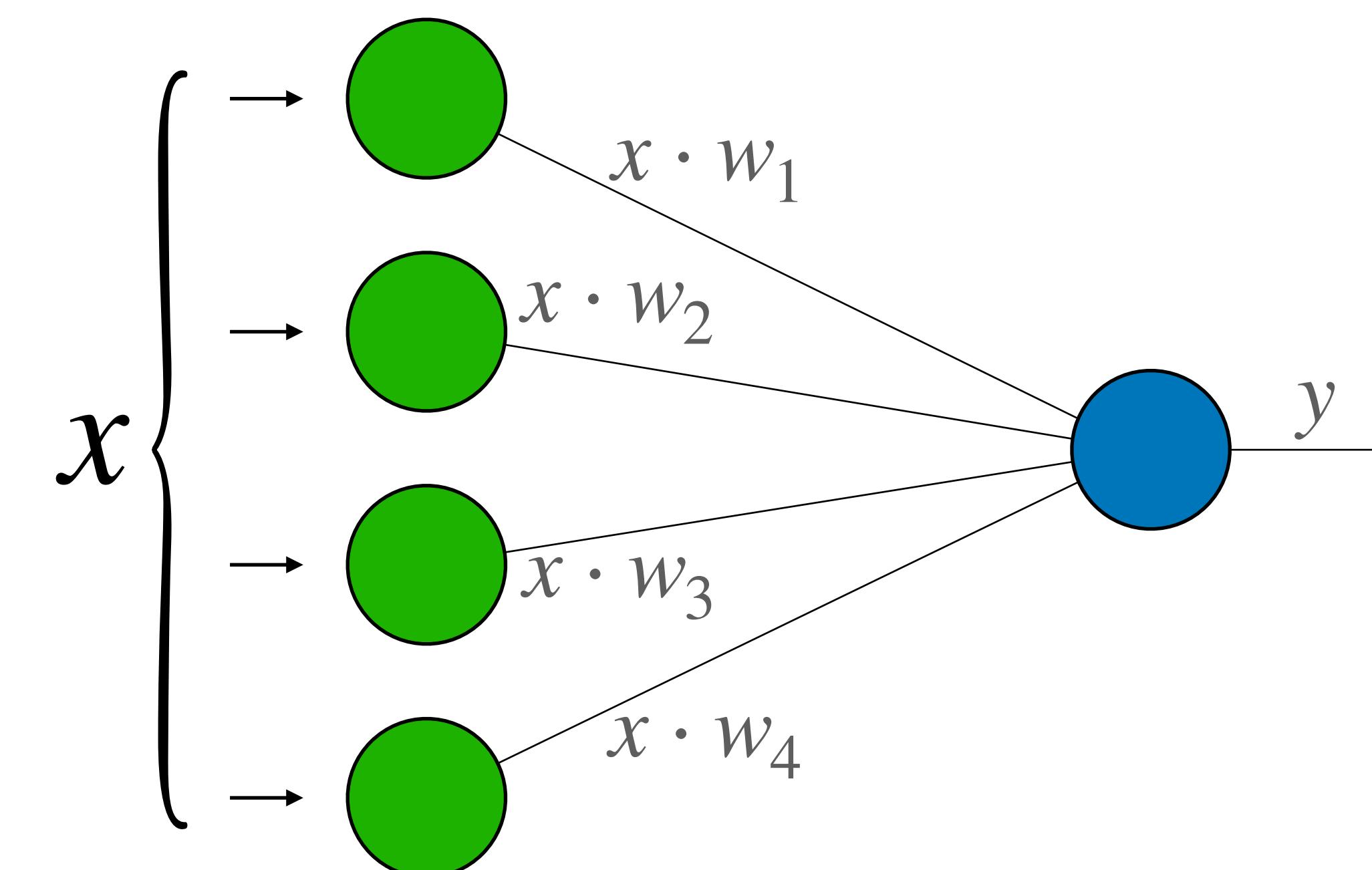
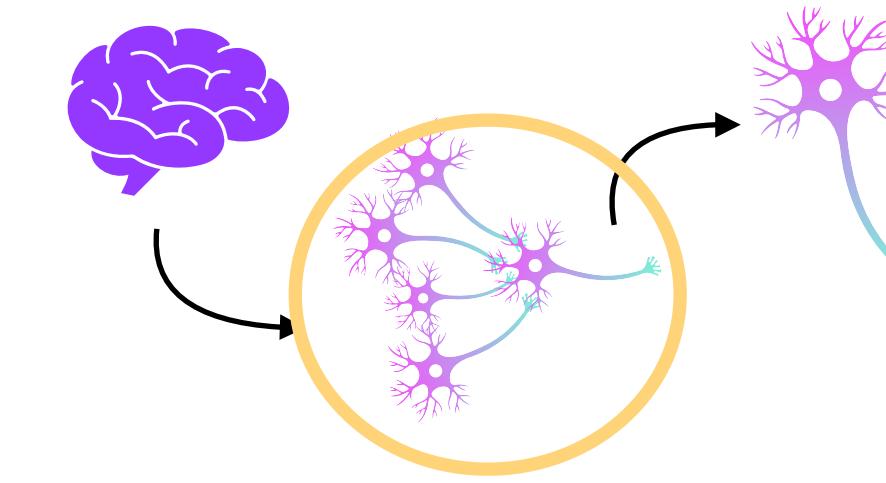
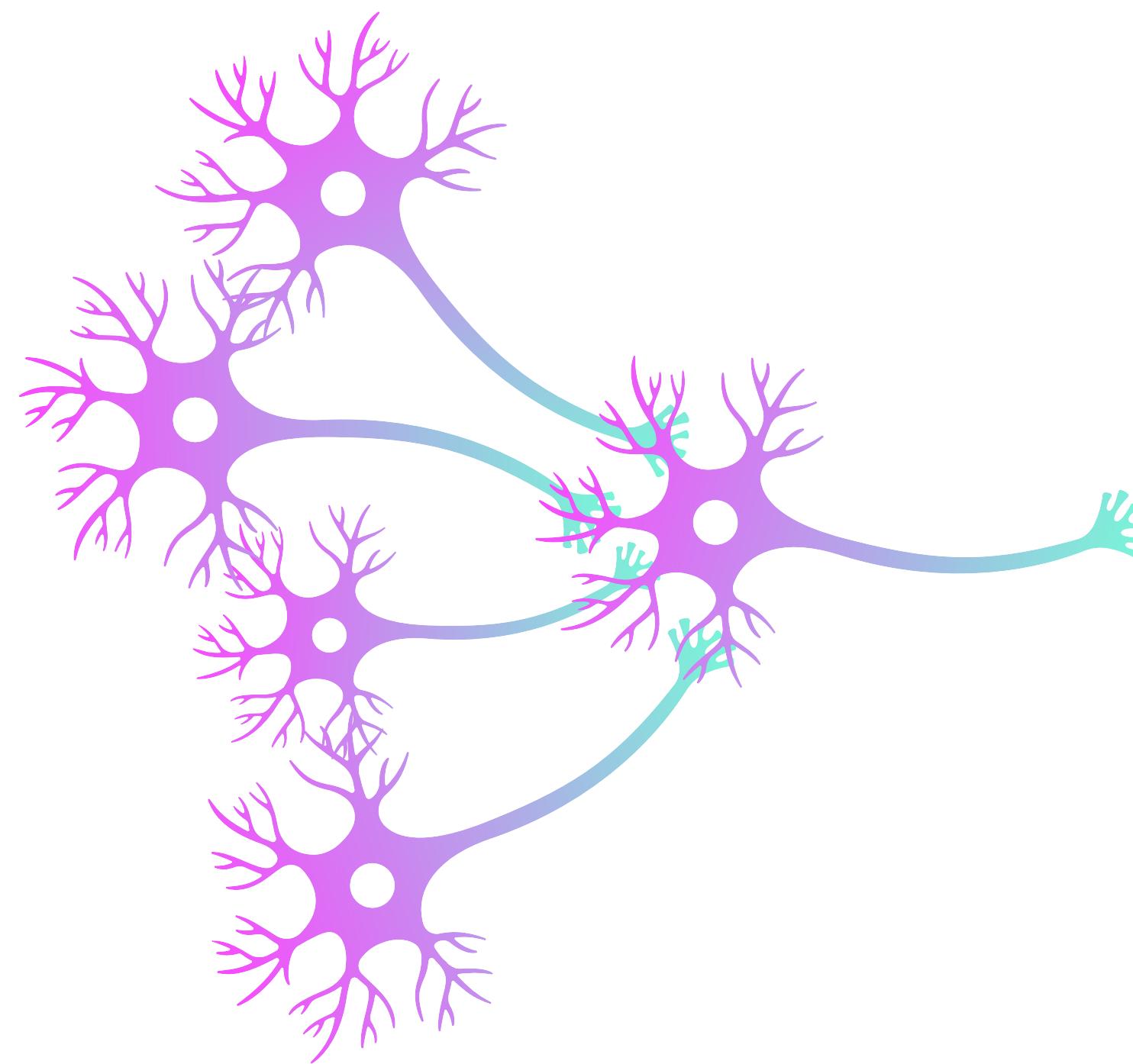
NEURONE



$$y = f(x \cdot w)$$

- x input
- w_i pesi (parametri)
- f funzione di attivazione
- y output

Reti neurali artificiali





Come impara una
rete neurale artificiale?

Prova
ed
errore



DATI

(x)

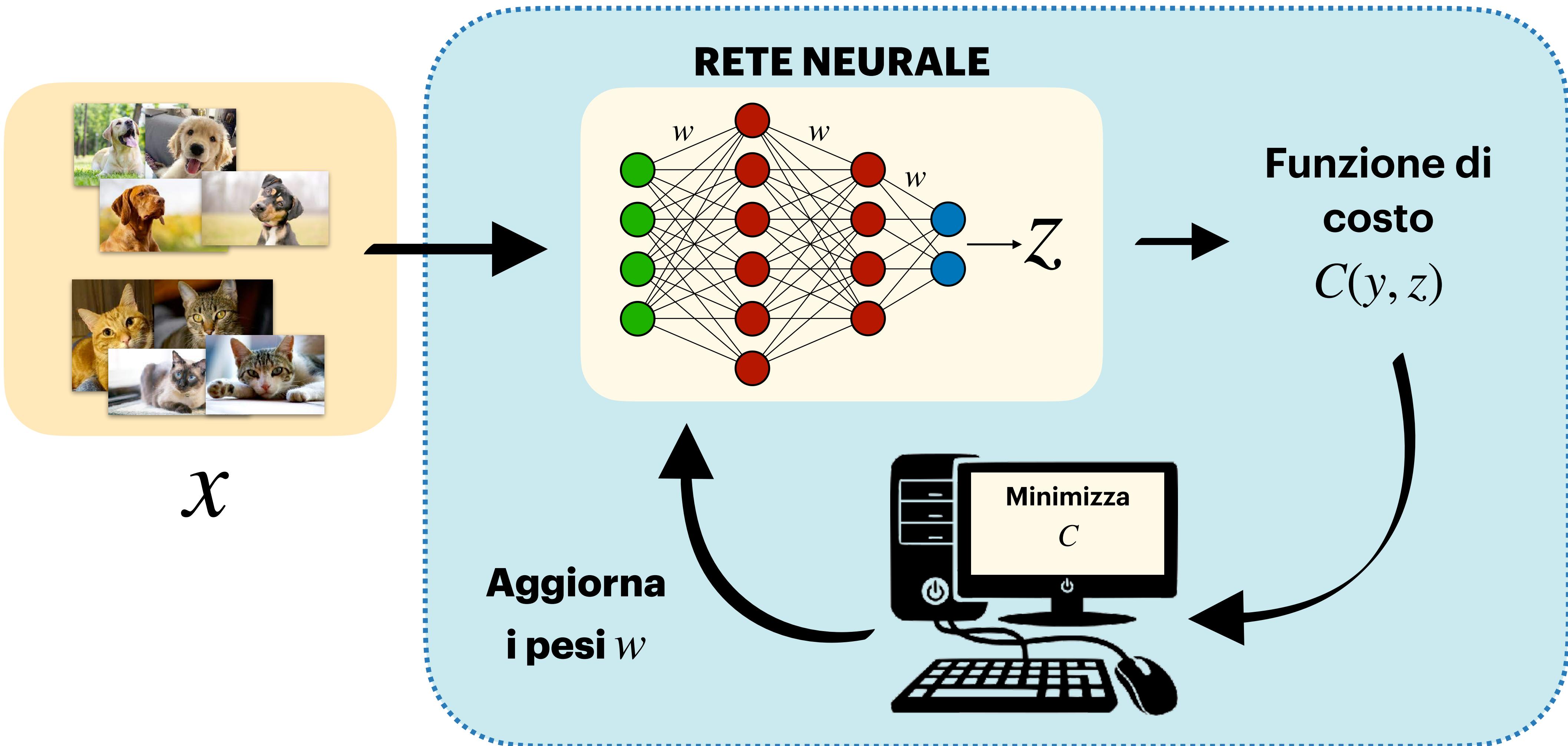


ETICHETTE (y)

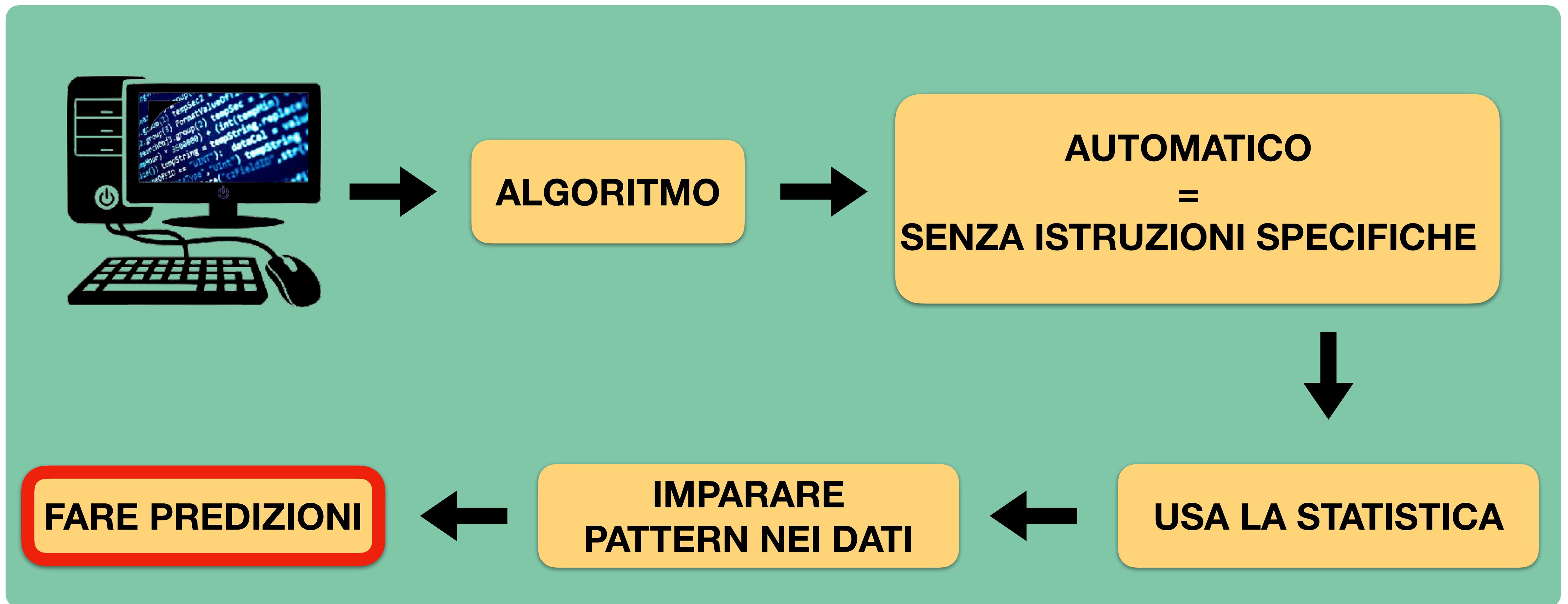
CANE

GATTO

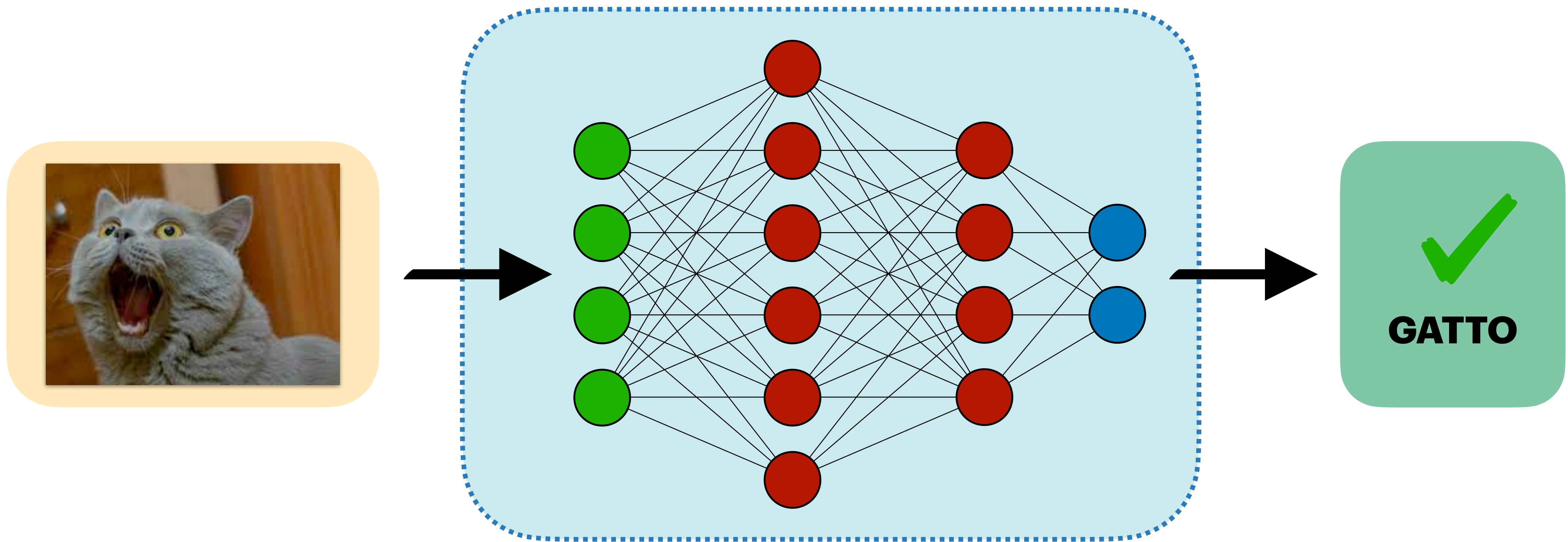
APPRENDIMENTO



Apprendimento automatico o Machine Learning (ML)



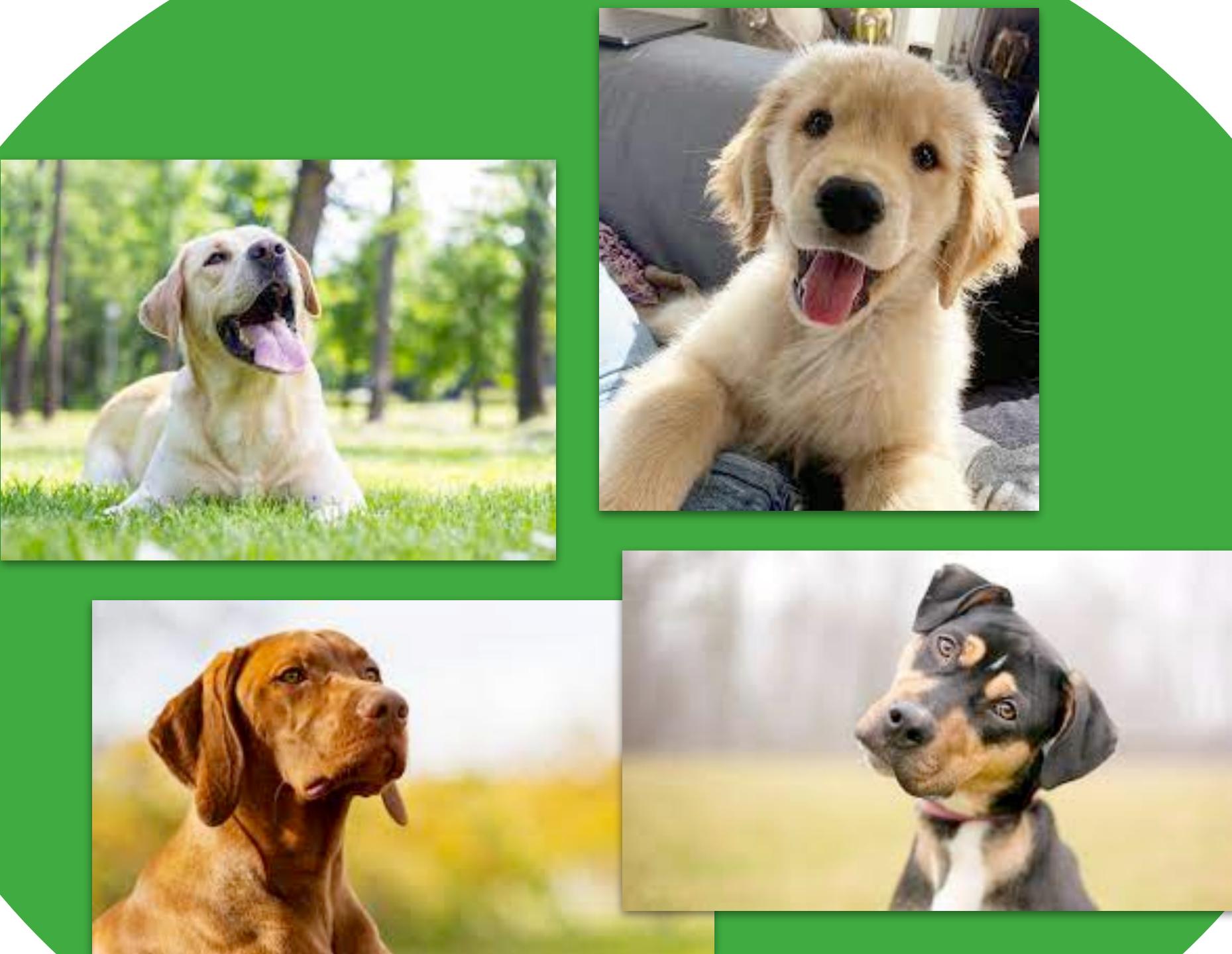
Generalizzazione





Cosa può fare il
Machine Learning?

Classificazione di immagini



Assistenti vocali

Ok Google!



Alexa che ore sono?

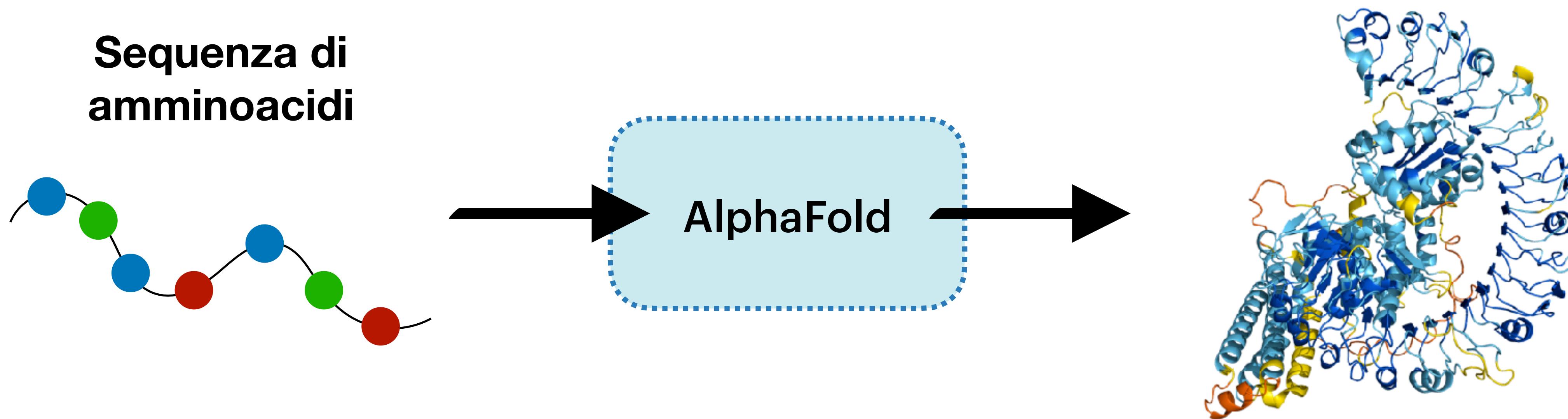


Hey Siri!



Predizione di Strutture di Proteine

AlphaFold



 Reset Thread

 Light Mode

 OpenAI Discord

 Learn More

 Log out

ChatGPT



Examples

"Explain quantum computing in simple terms"

"Got any creative ideas for a 10 year old's birthday?"

"How do I make an HTTP request

Capabilities

Remembers what user said earlier in the conversation

Allows user to provide follow-up corrections

Trained to decline inappropriate

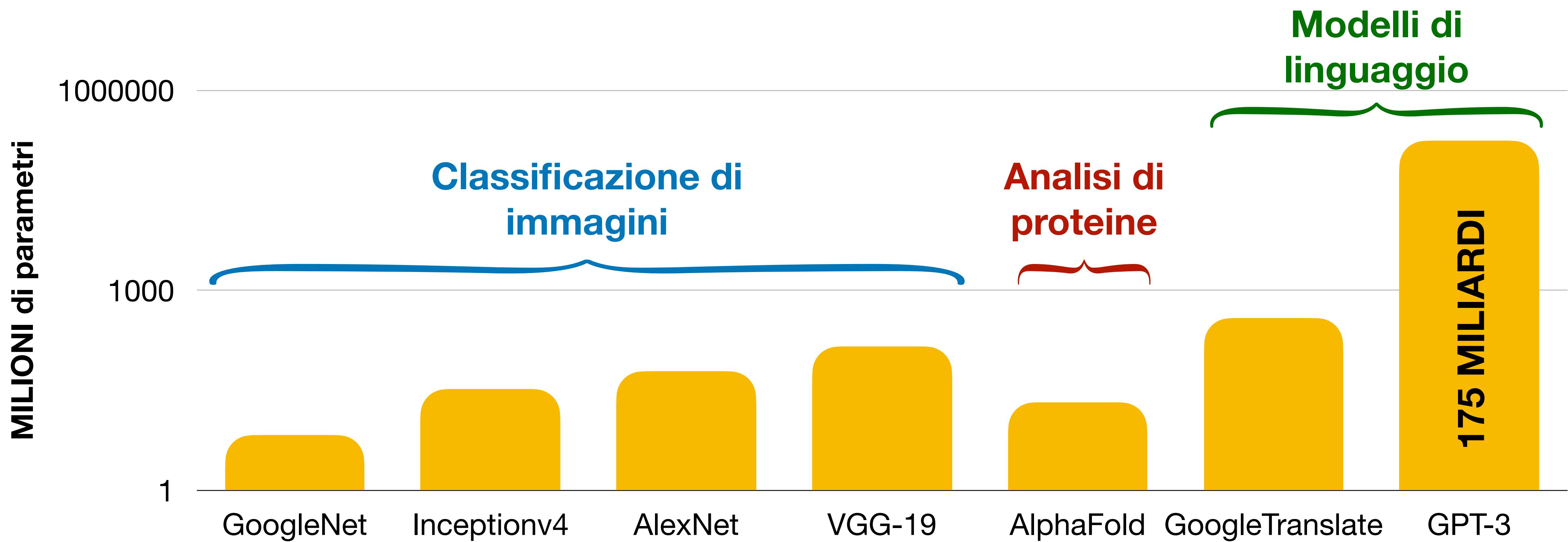
Limitations

May occasionally generate incorrect information

May occasionally produce harmful instructions or biased content

Free Research Preview: ChatGPT is optimized for dialogue. Our goal is to make AI systems more natural to interact with, and your feedback will help us improve our systems and make them safer.

Più è difficile, più parametri servono



Quanta energia è necessaria?

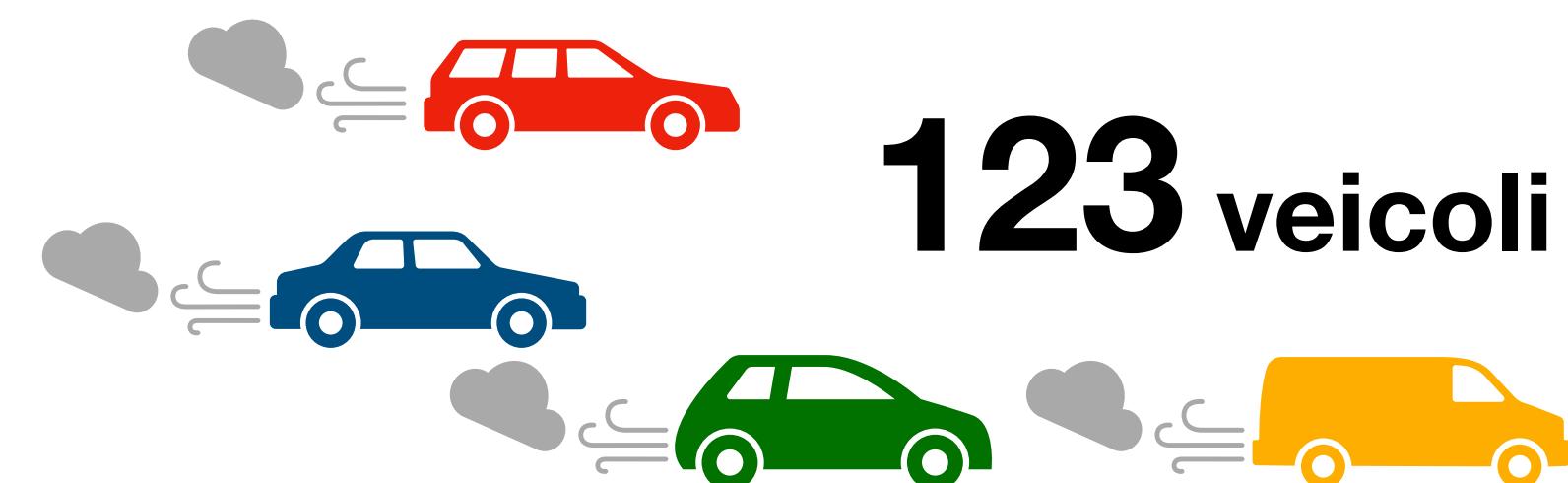
Consumo per la creazione di GPT-3



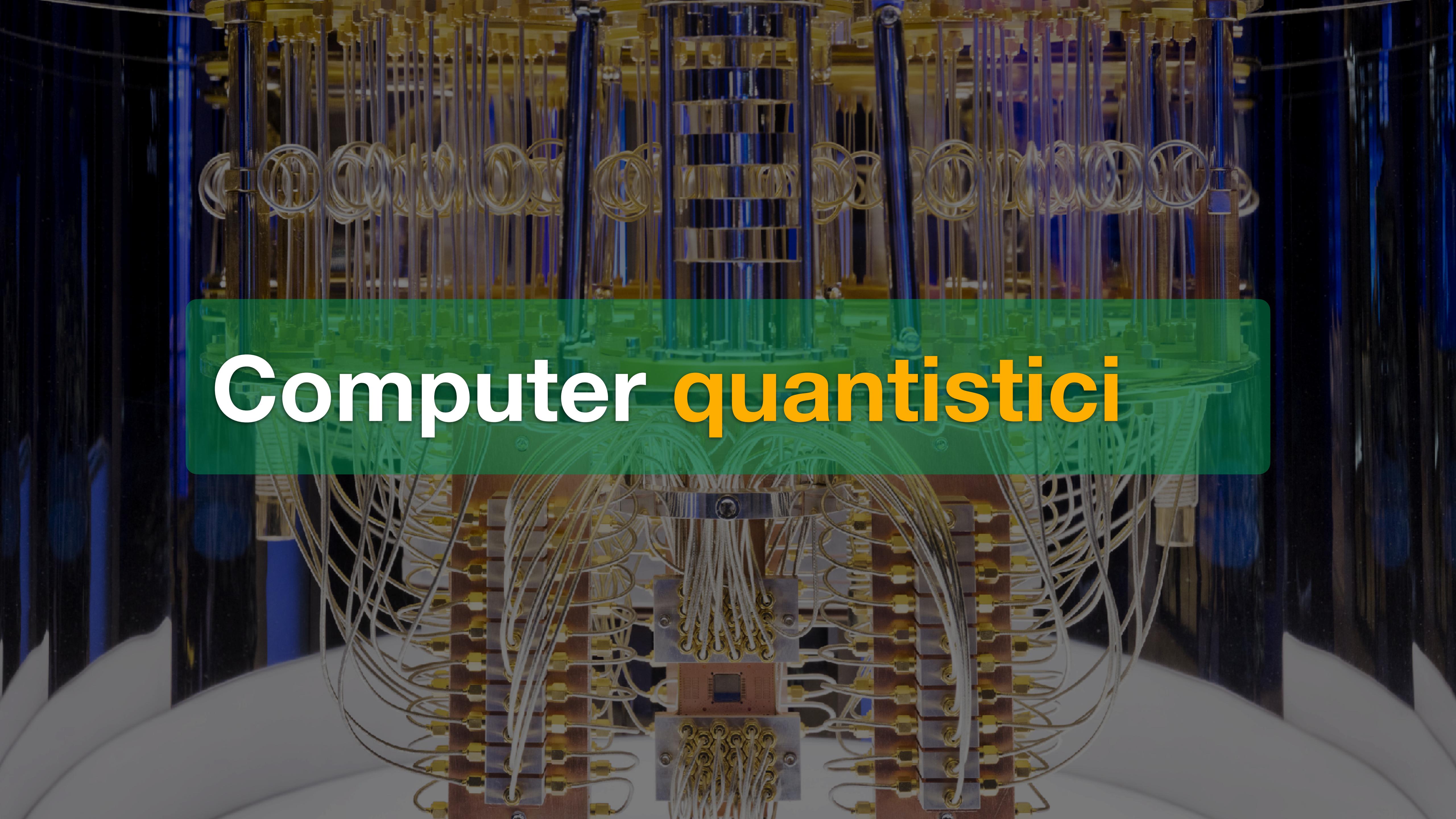
1.287 megawattora



552 tonnellate di anidride carbonica



123 veicoli a benzina guidati per un anno



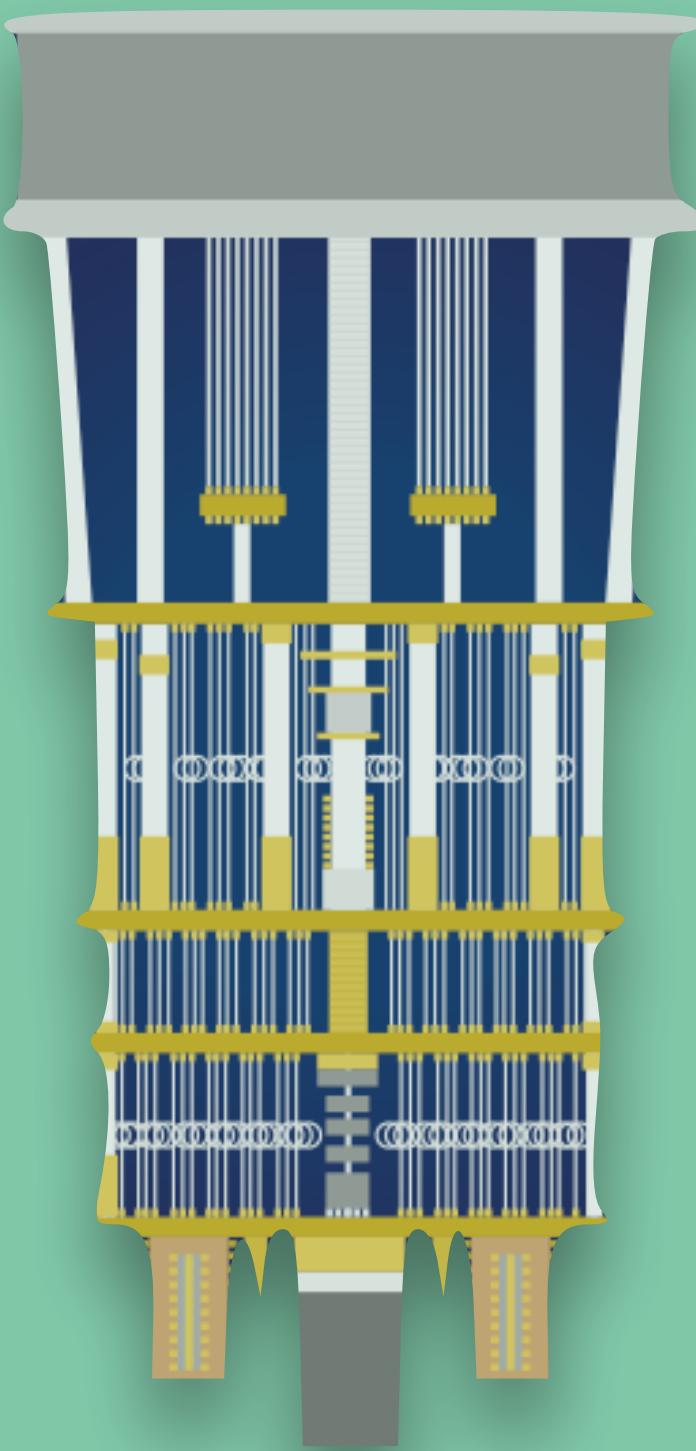
Computer quantistici

Richard Feynman

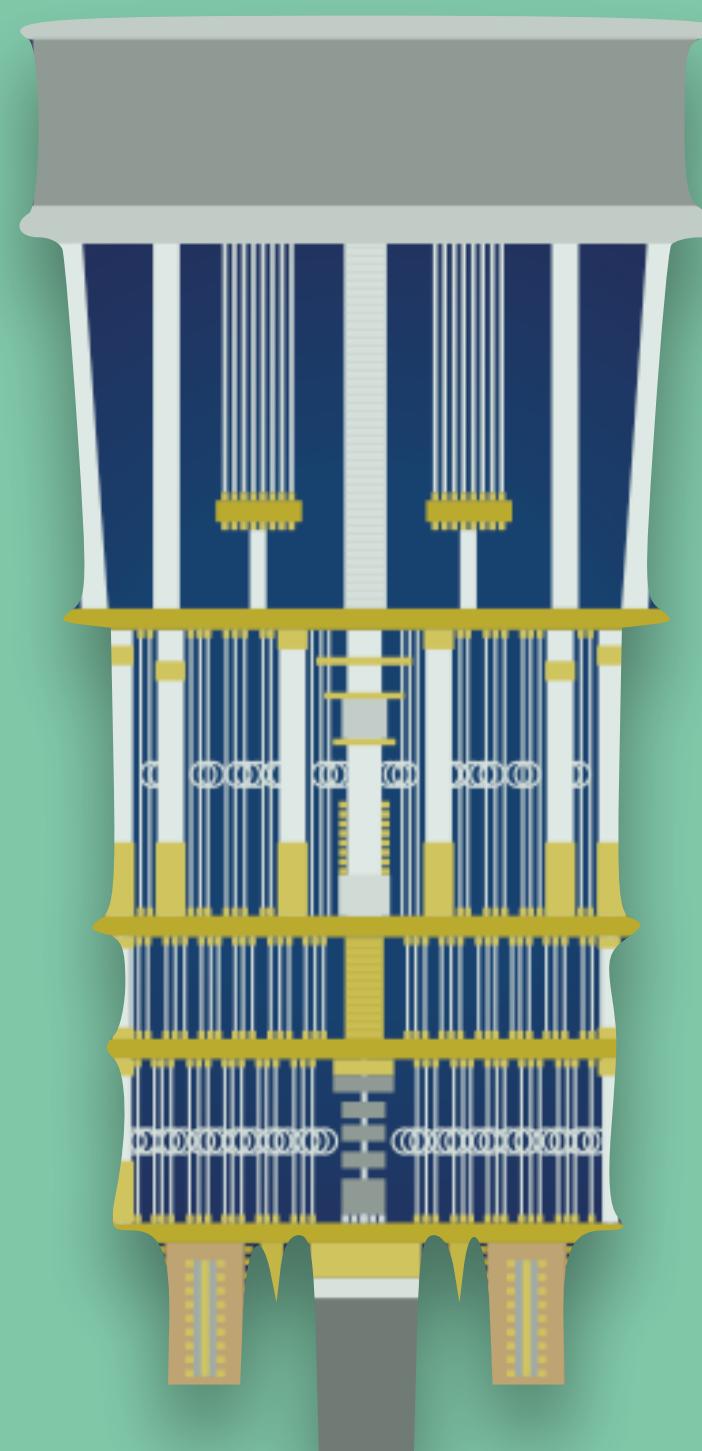
(1918-1988)



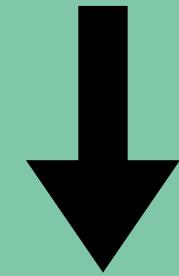
“La natura non è classica, dannazione,
e se volessi fare una **simulazione** della
Natura, sarebbe meglio la facessi
quantistica!”



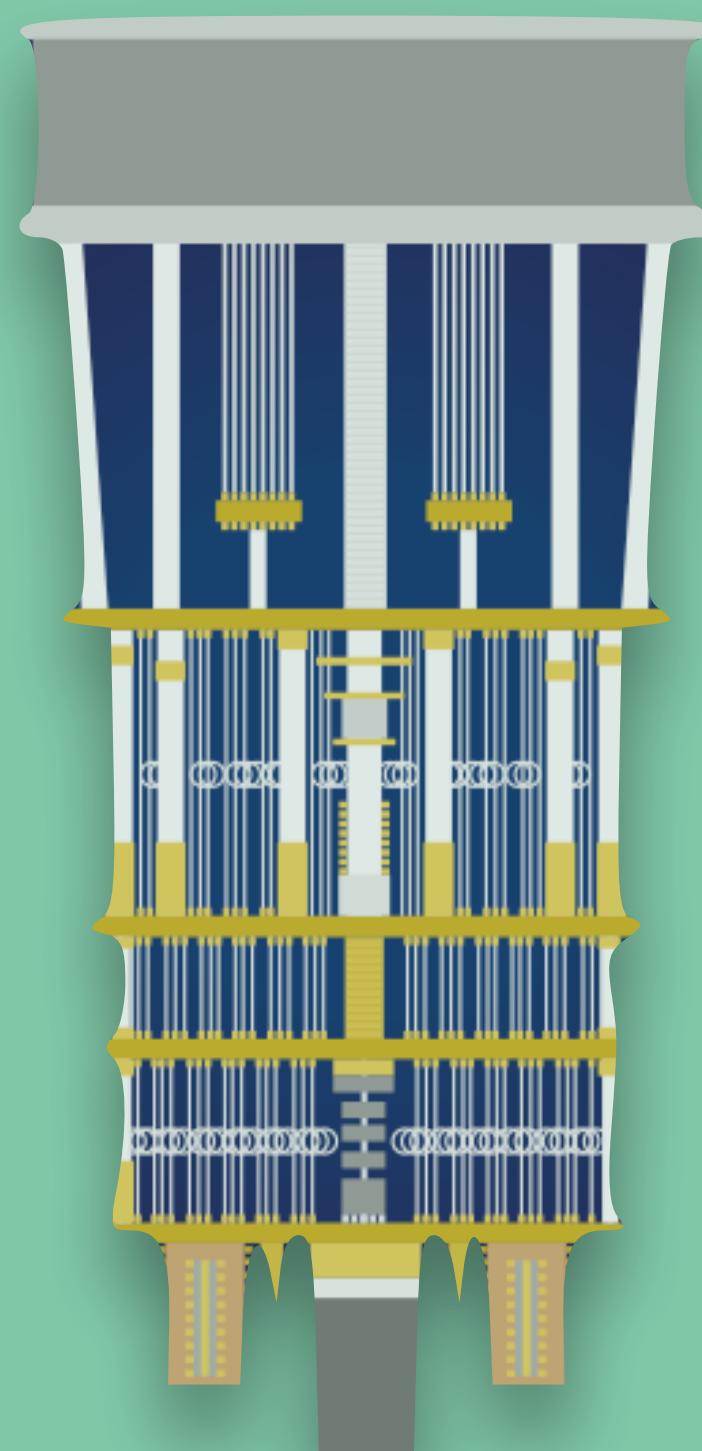
Computer quantistico



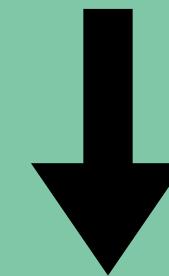
Computer quantistico



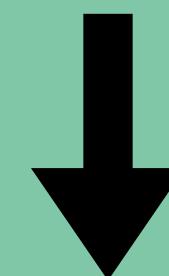
sfrutta le **proprietà quantistiche** della materia



Computer quantistico



sfrutta le **proprietà quantistiche** della materia



per elaborare dati

QUESTO È UN FRIGORIFERO

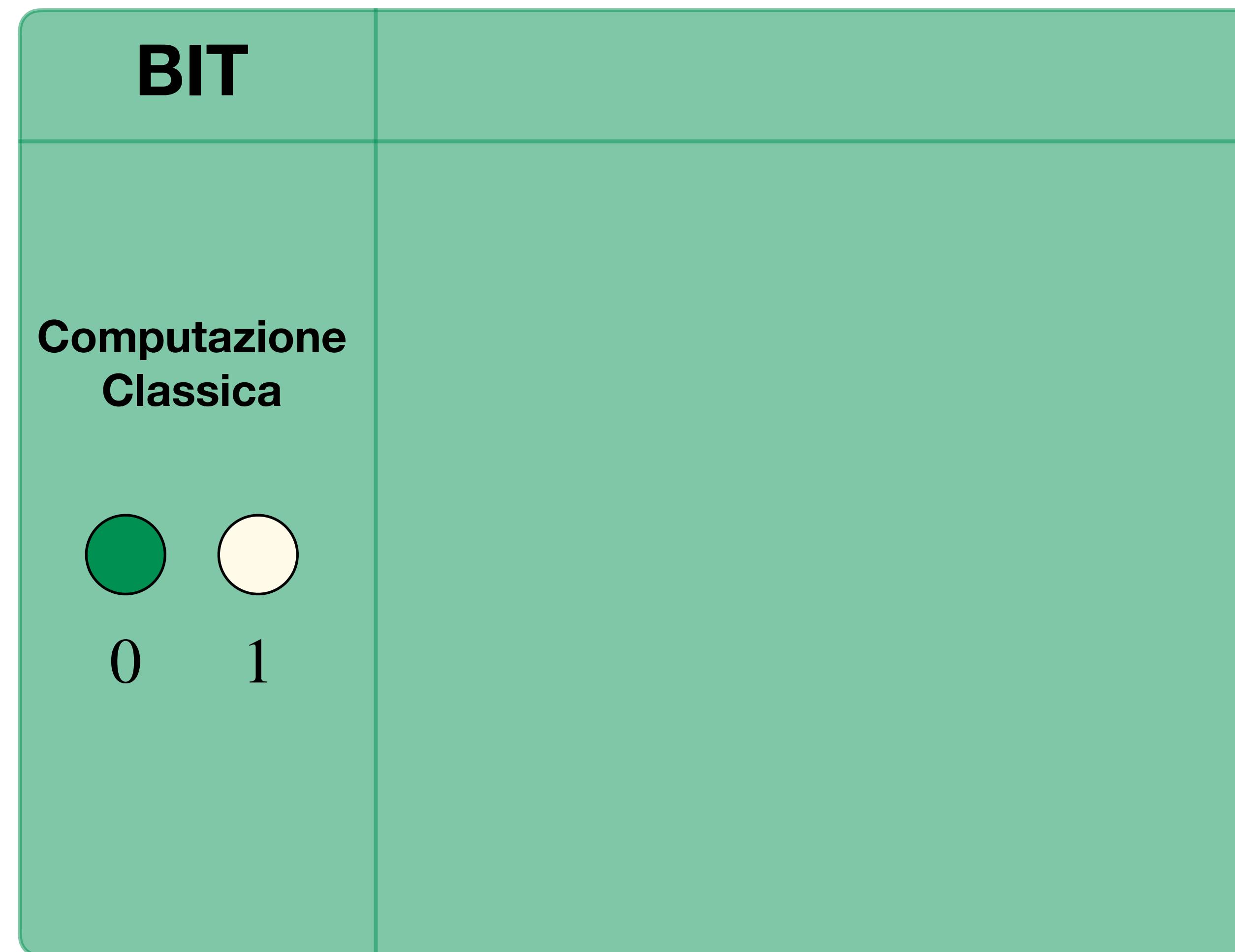


Computer quantistico

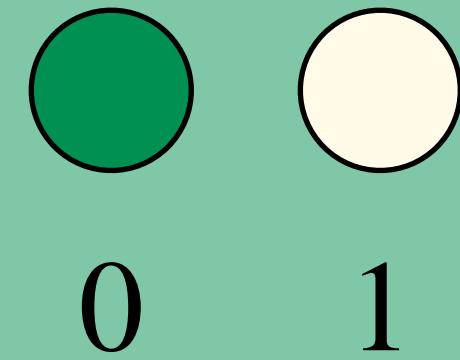
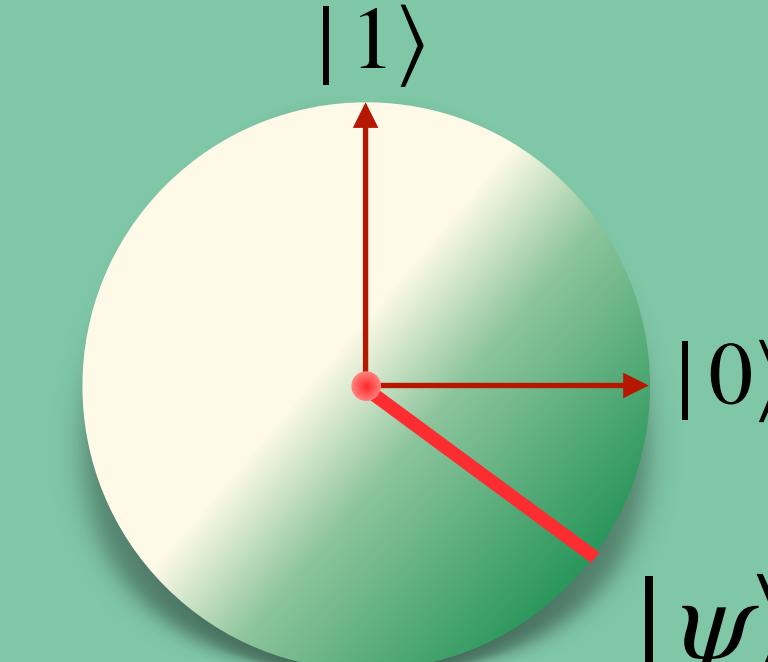
sfrutta le proprietà quantistiche della materia

per elaborare dati

Unità di informazione



Unità di informazione

BIT	QUANTUM BIT
<p>Computazione Classica</p>  <p>0 1</p>	<p>Computazione Quantistica</p>  $ \psi\rangle = \alpha 0\rangle + \beta 1\rangle$

Sovrapposizione

Se però abbiamo **tanti qubit...**

$$1) \quad a_1 |0\rangle + a_2 |1\rangle$$

$$2) \quad a_1 |00\rangle + a_2 |01\rangle + a_3 |10\rangle + a_4 |11\rangle$$

:

$$N)$$

Sovrapposizione

Se però abbiamo tanti qubit...

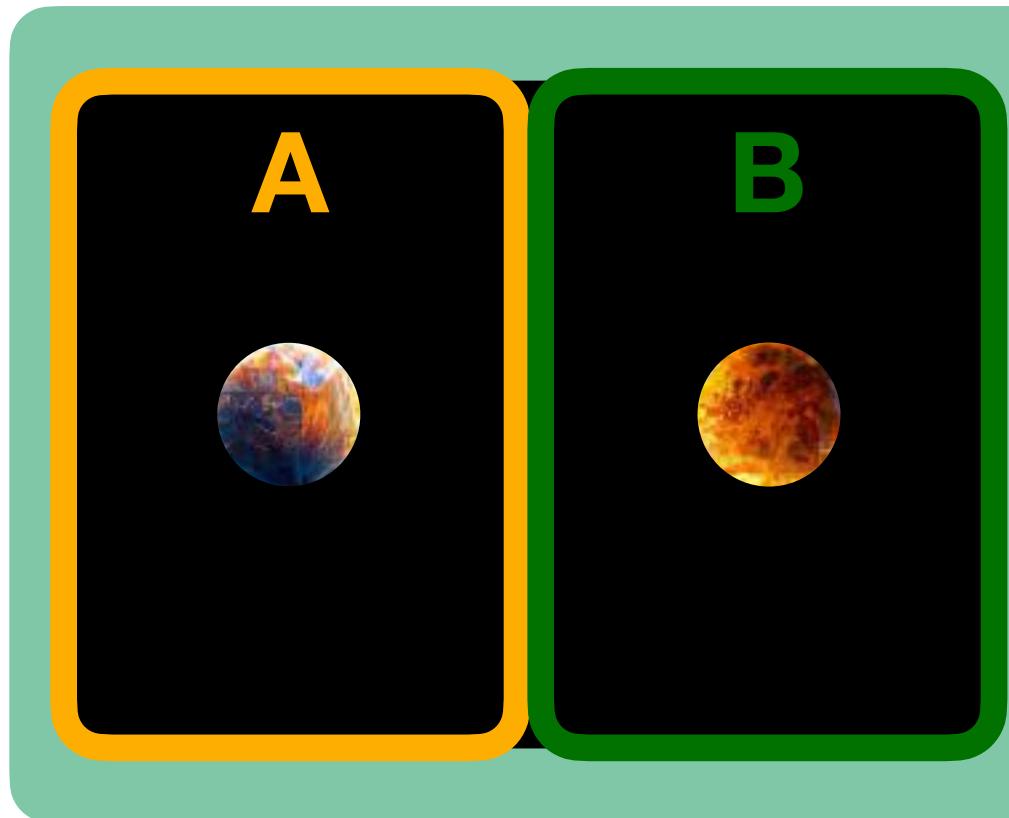
$$1) \quad a_1 |0\rangle + a_2 |1\rangle$$

$$2) \quad a_1 |00\rangle + a_2 |01\rangle + a_3 |10\rangle + a_4 |11\rangle$$

:

$$N) \quad a_1 |0\dots00\rangle + a_2 |0\dots01\rangle + \dots + a_{2^n} |1\dots11\rangle$$

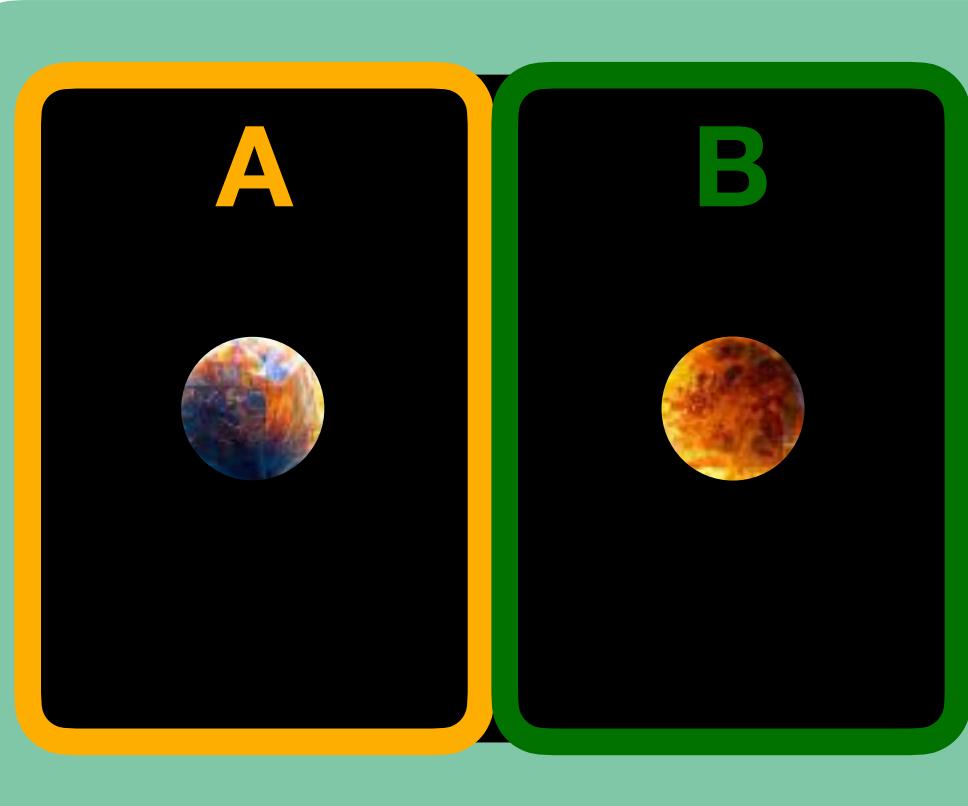
Entanglement



Sistemi **separabili**

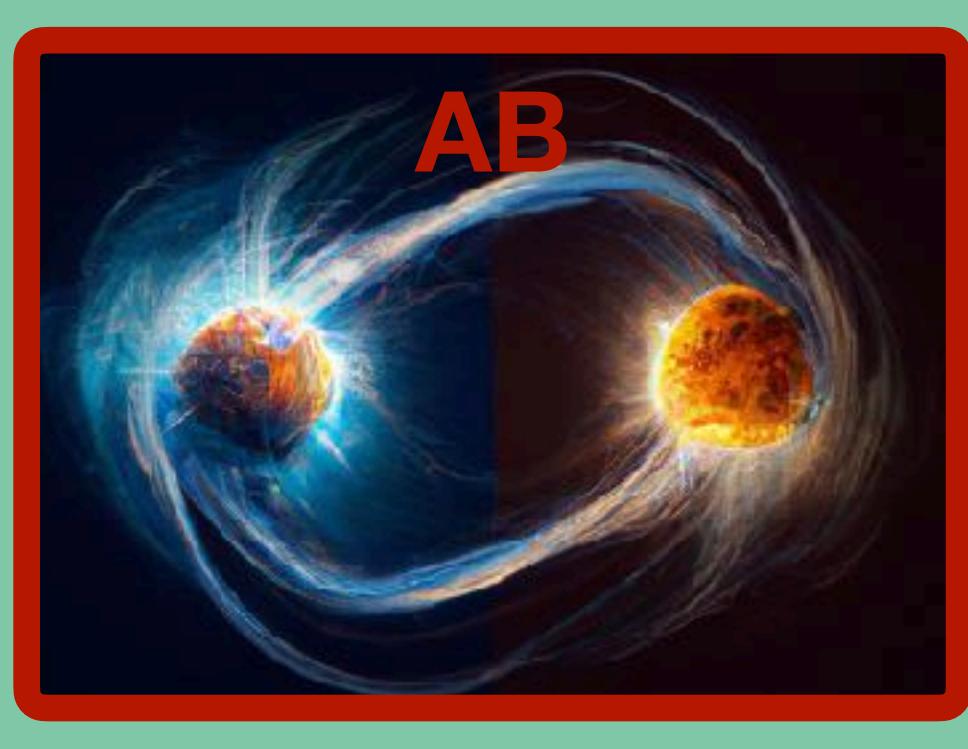
→ possono essere descritti **separatamente**

Entanglement



Sistemi **separabili**

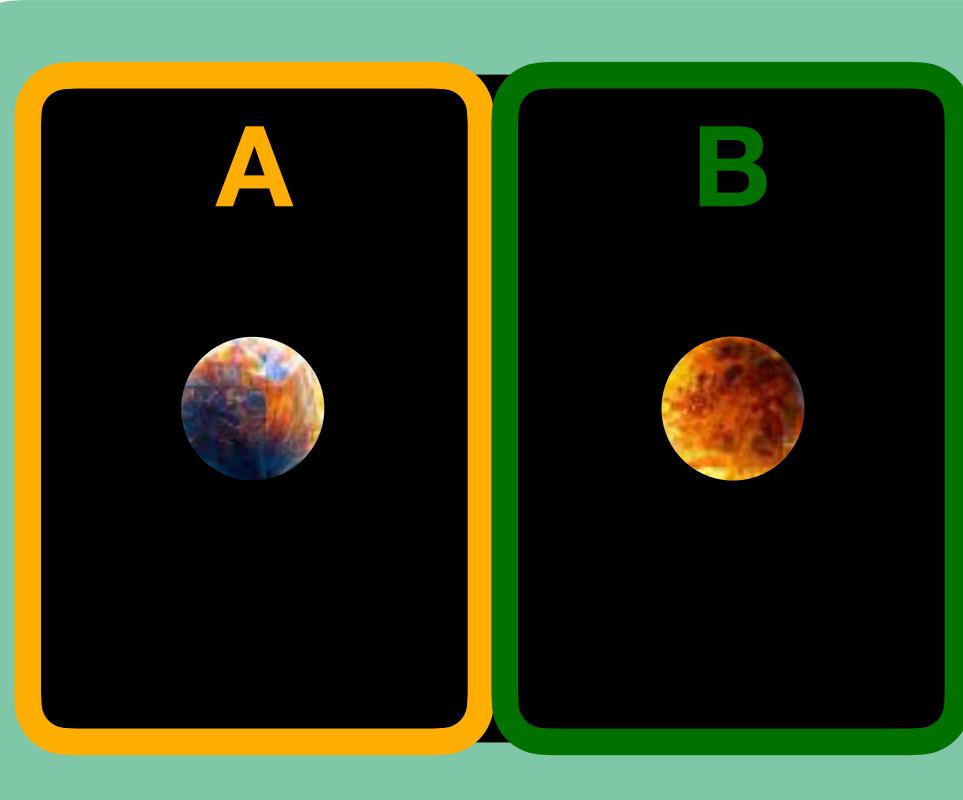
→ possono essere descritti **separatamente**



Sistemi **entangled**

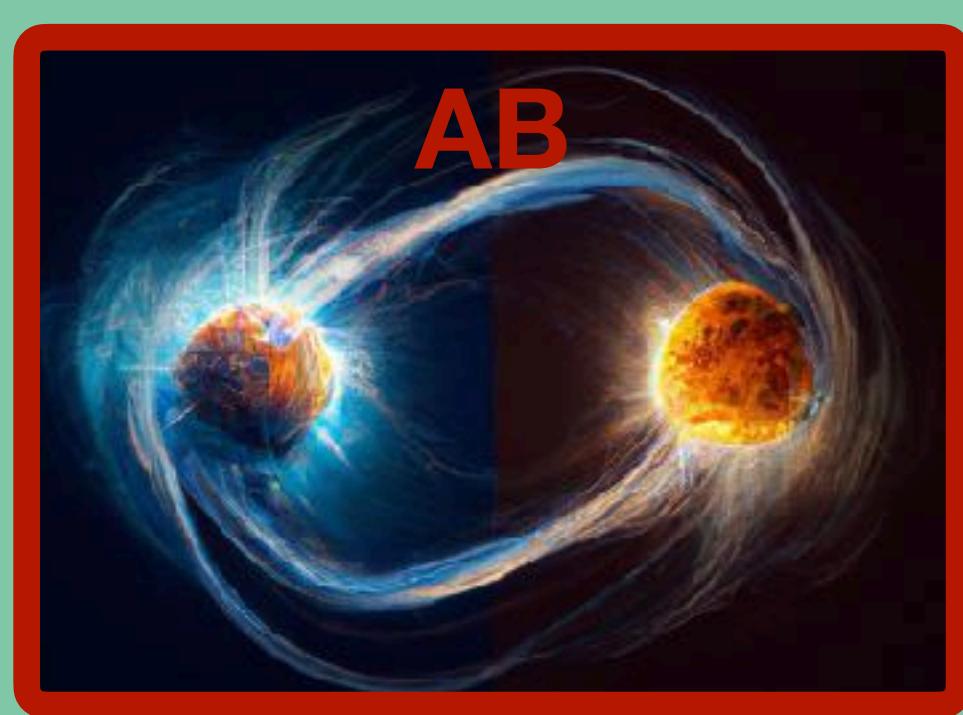
→ **NON** possono essere descritti **separatamente**

Entanglement



Sistemi **separabili**

→ possono essere descritti **separatamente**



Sistemi **entangled**

→ **NON** possono essere descritti **separatamente**

Correlazione **NON-CLASSICA**

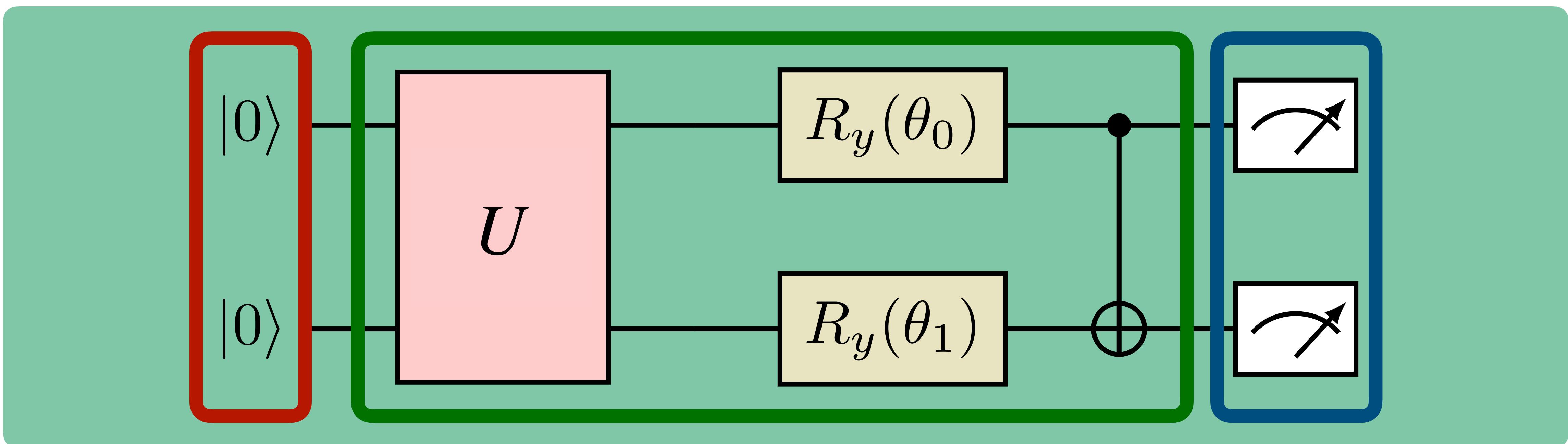
Computazione quantistica

Quantum Computing

Preparazione
dei qubits

Modifica dello stato
tramite operazioni quantistiche

Lettura del
risultato





Quantum computing

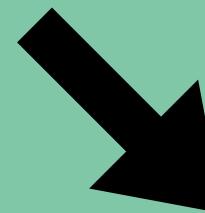
Machine Learning



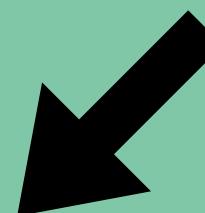
Quantum Machine Learning (QML)

Quantum Machine Learning

Computer quantistico



sfrutta le proprietà quantistiche della materia



per elaborare dati

Quantum Machine Learning

Computer quantistico

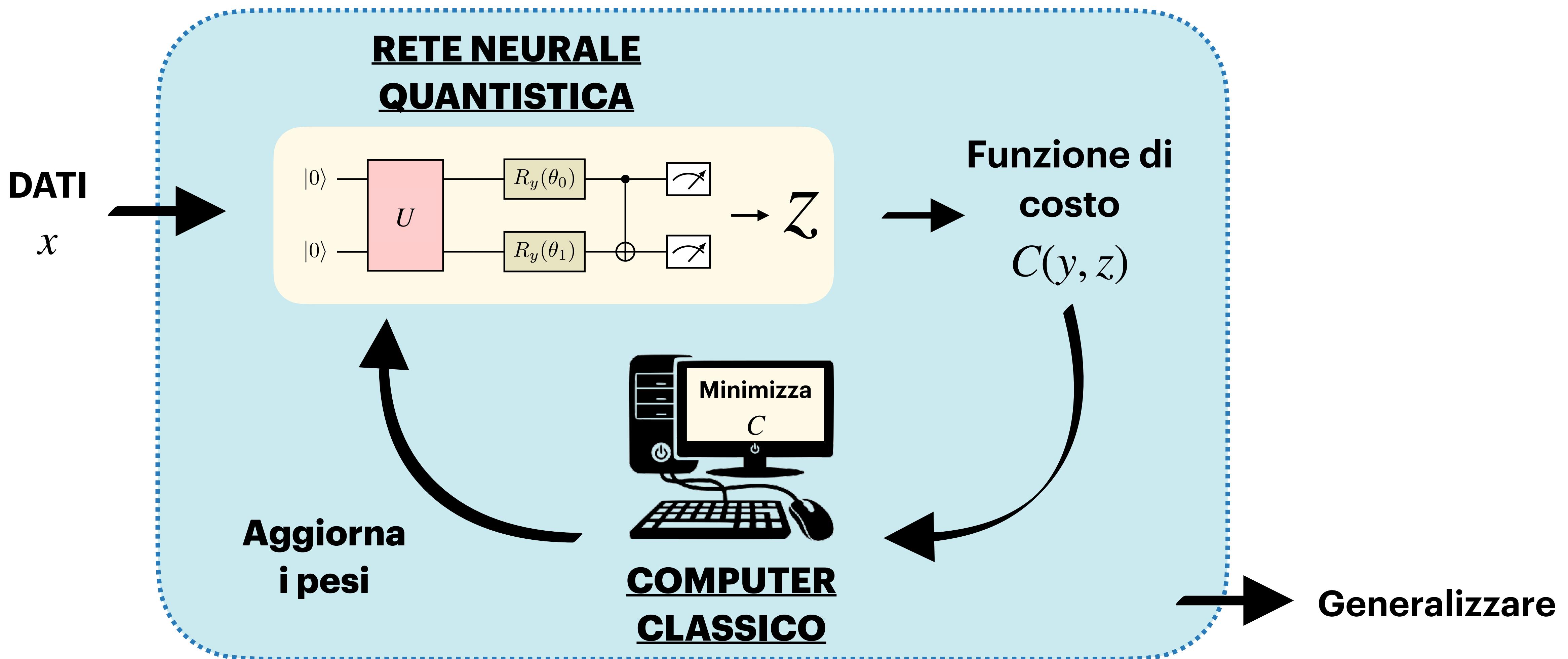
QML

sfrutta le proprietà quantistiche della materia

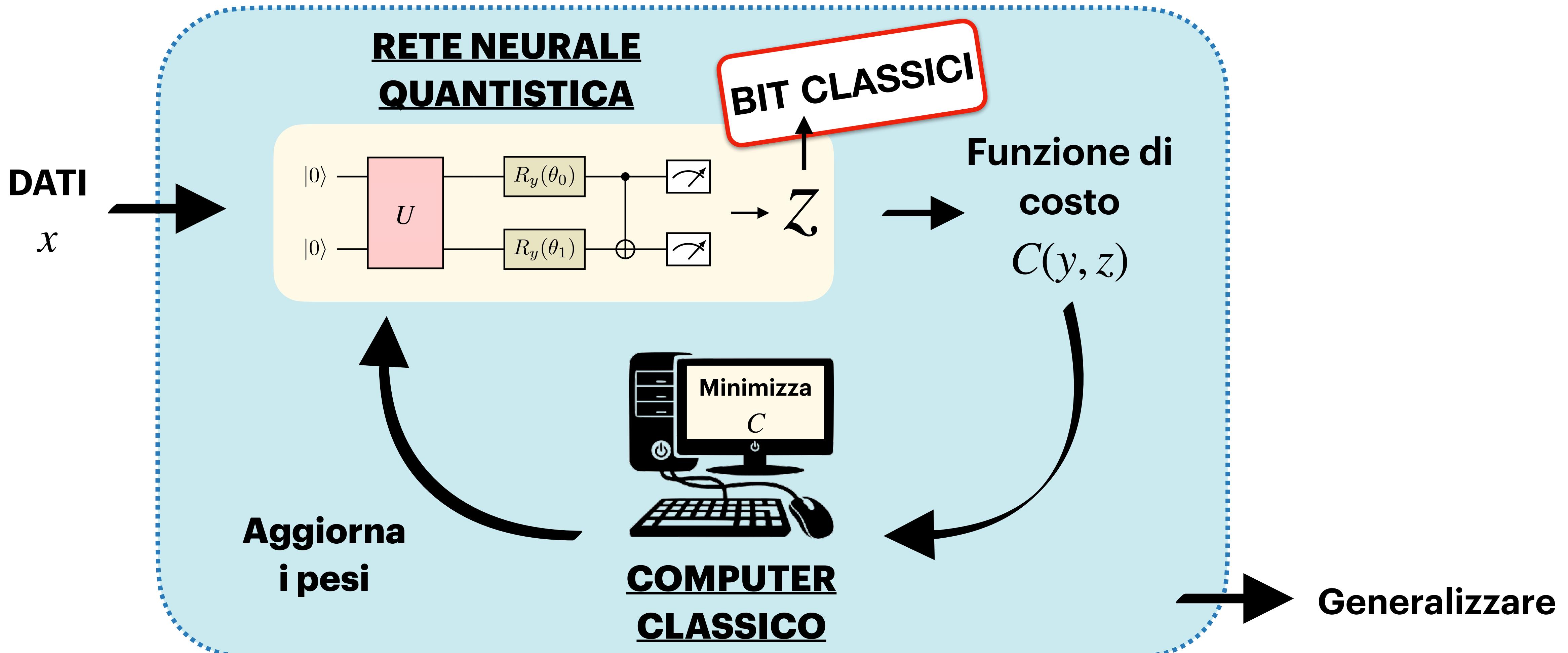
per elaborare dati

per trovare pattern dati

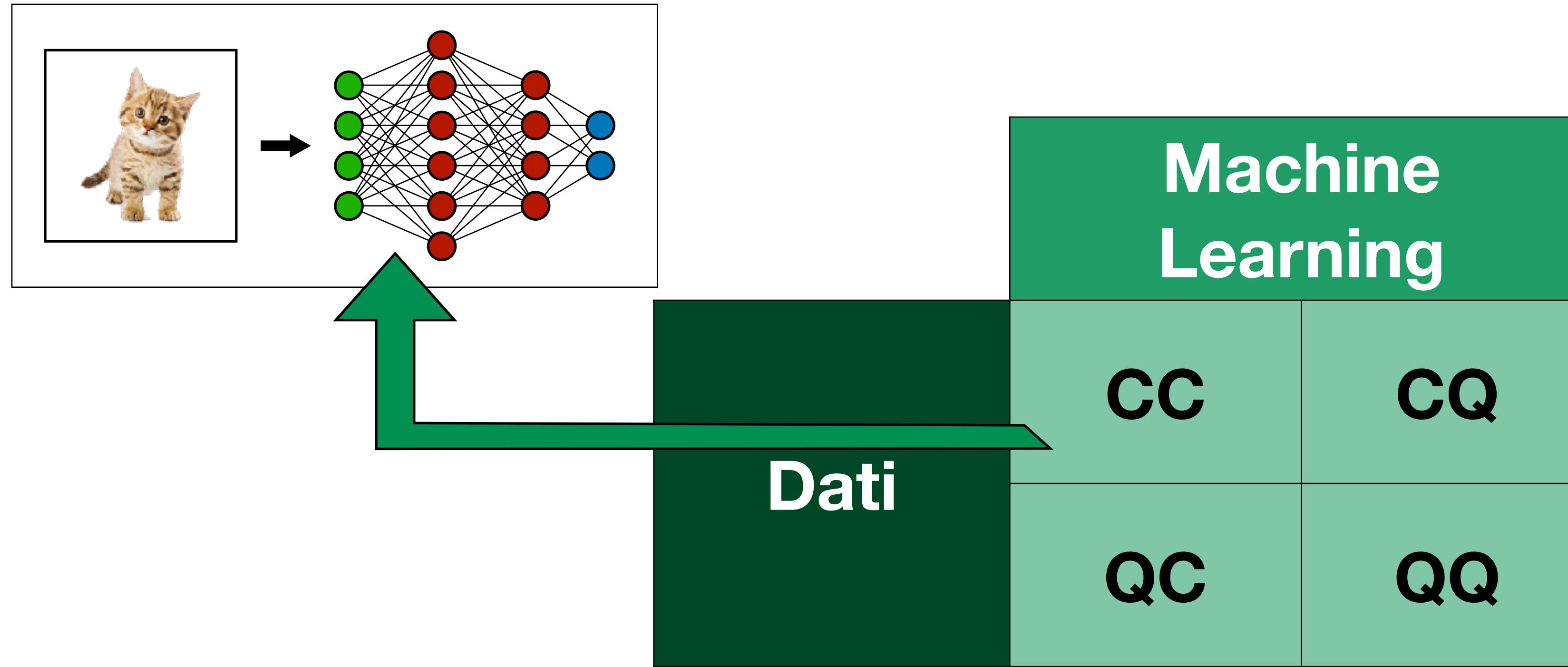
Quantum Machine Learning

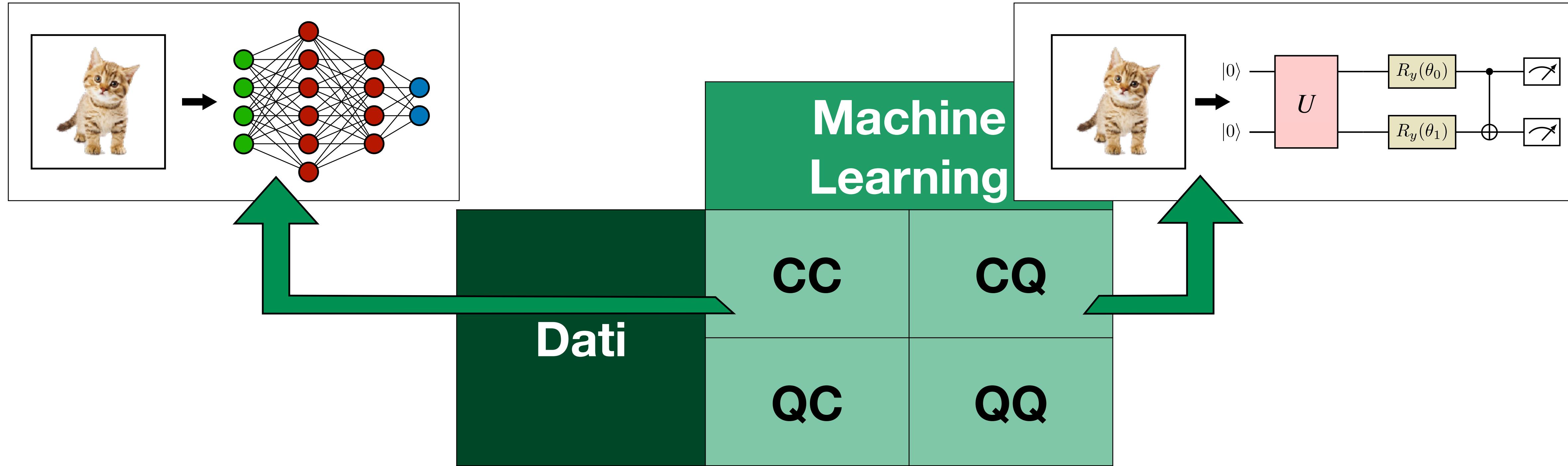


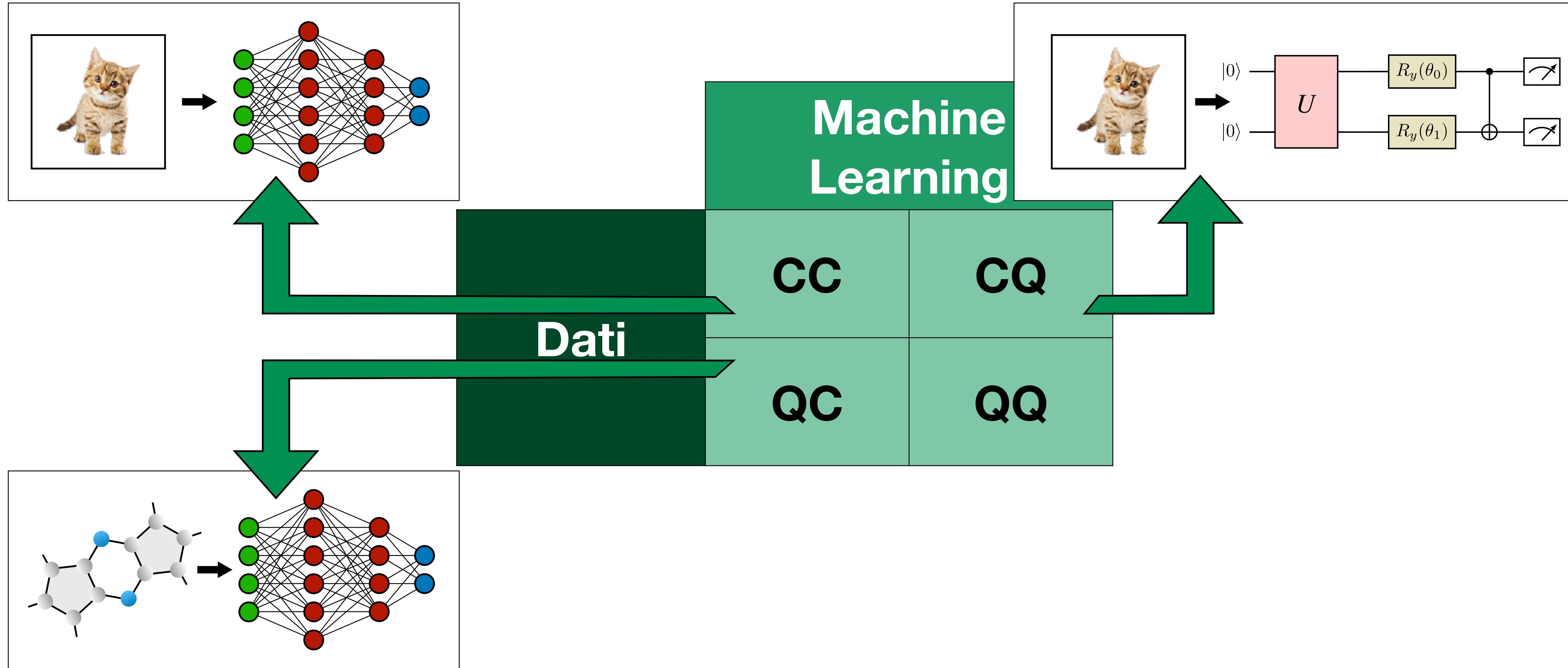
Quantum Machine Learning

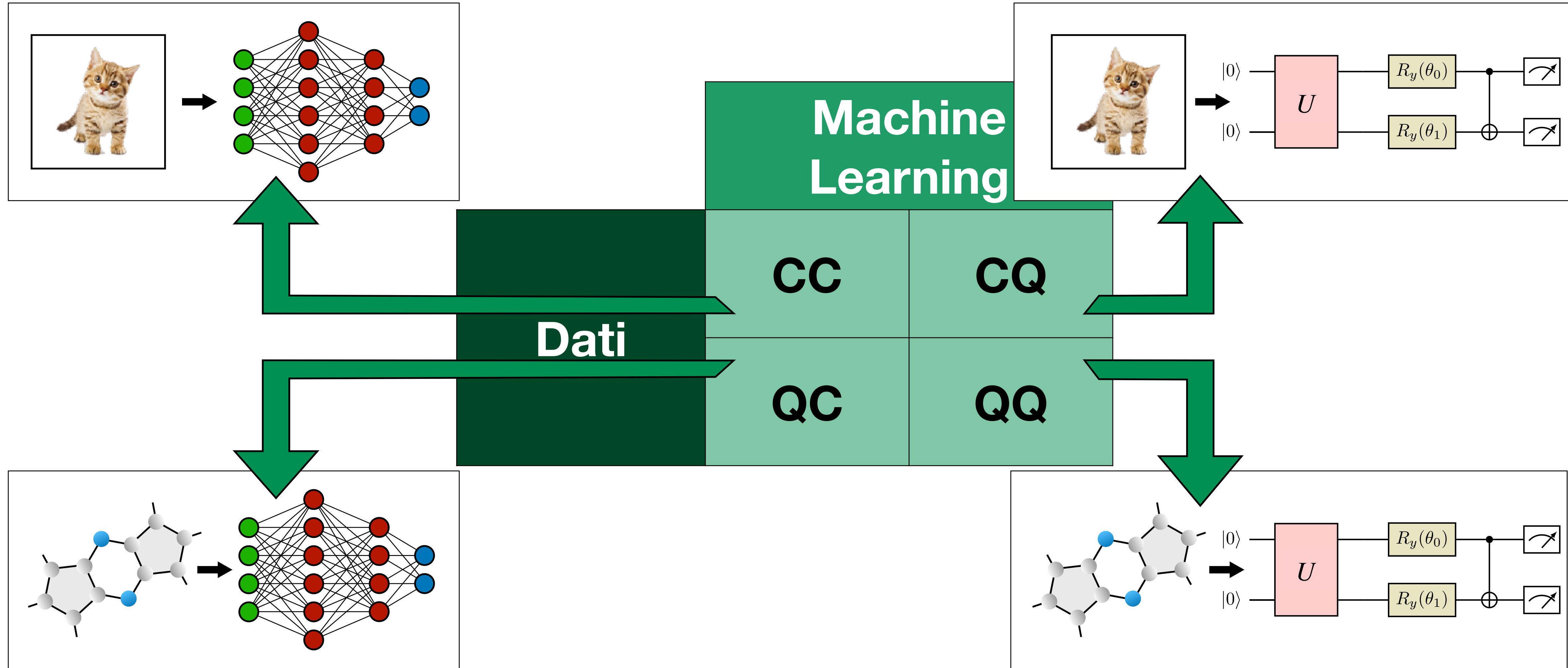


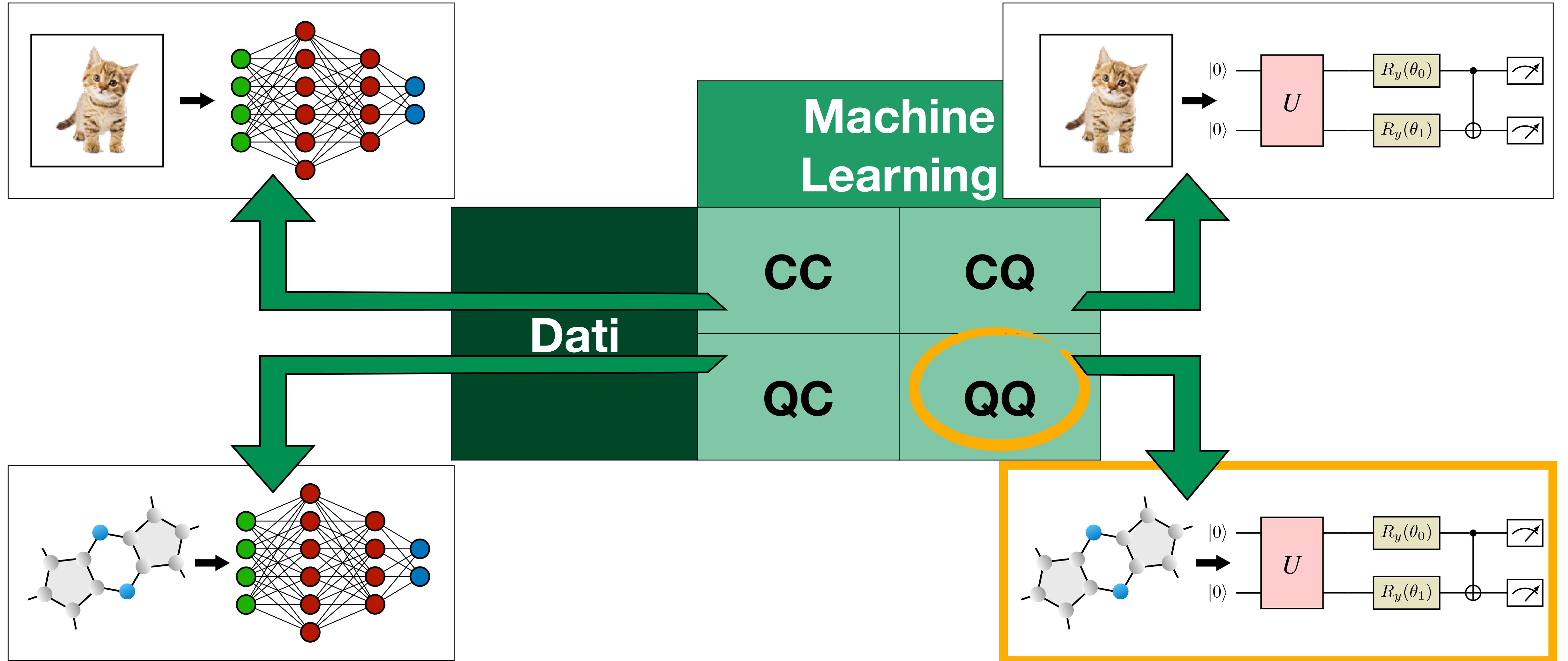
		Machine Learning	
Dati		CC	CQ
QC	QC	QQ	





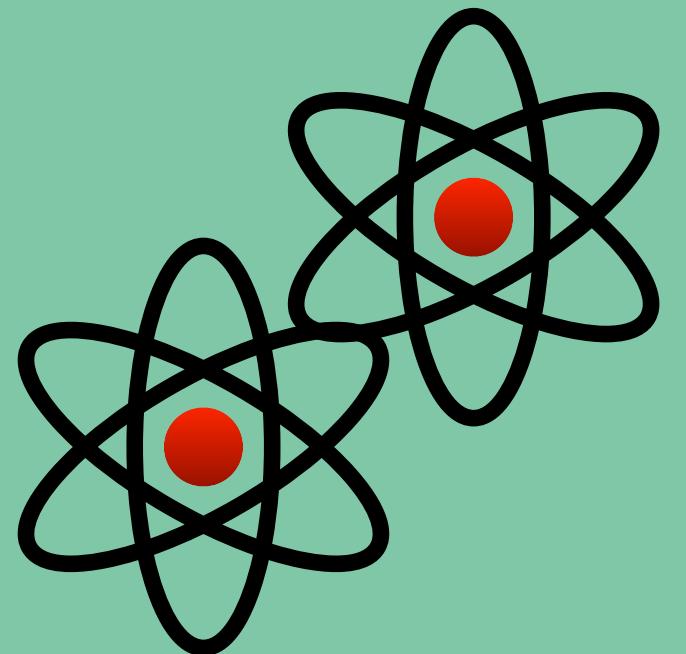




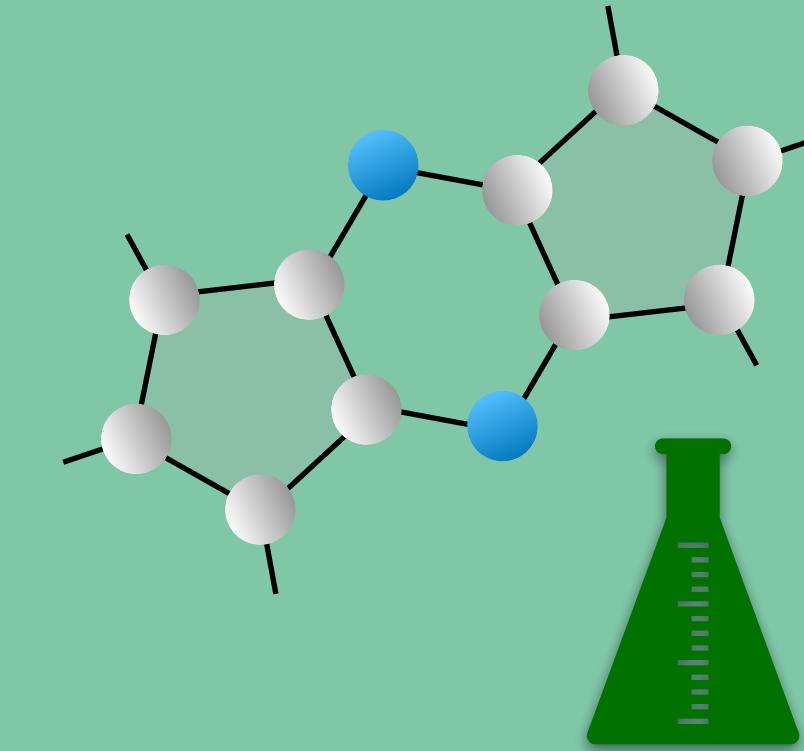




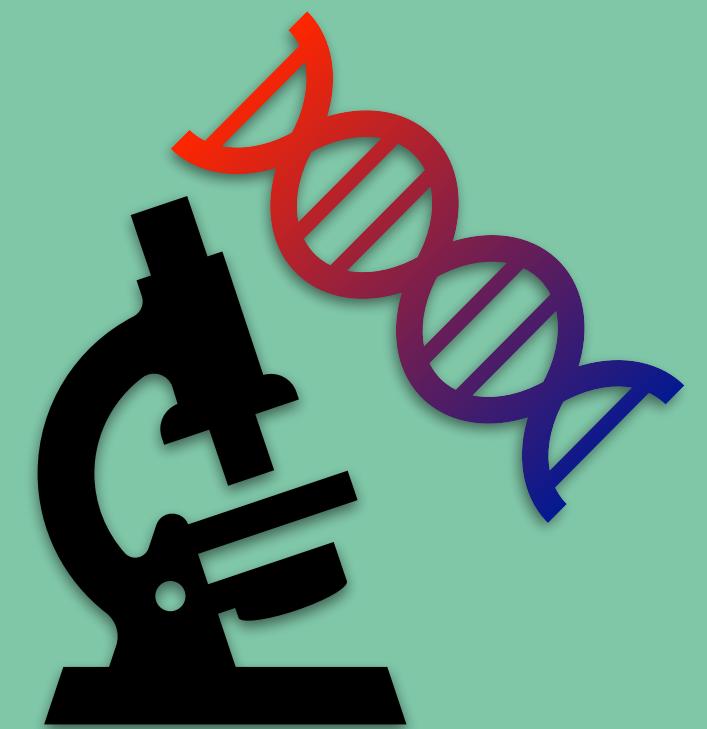
Dove può fare la differenza il Quantum Machine Learning?



FISICA



CHIMICA



BIOLOGIA



ECONOMIA

E tanti altri campi...

Dario Gerace



Supervisore
Professore ordinario

Francesco Scala



Quantum Machine Learning
Dottorando 2° anno

Francesco Ghisoni



Quantum Machine Learning
Dottorando 1° anno

Davide Cugini



Quantum Simulations
Dottorando 1° anno

Risorse utili



Qiskit



XANADU QUANTUM CODEBOOK



Link alla presentazione

