# ARTIFICIAL NEURAL NETWORKS

HOW DO THEY WORK?
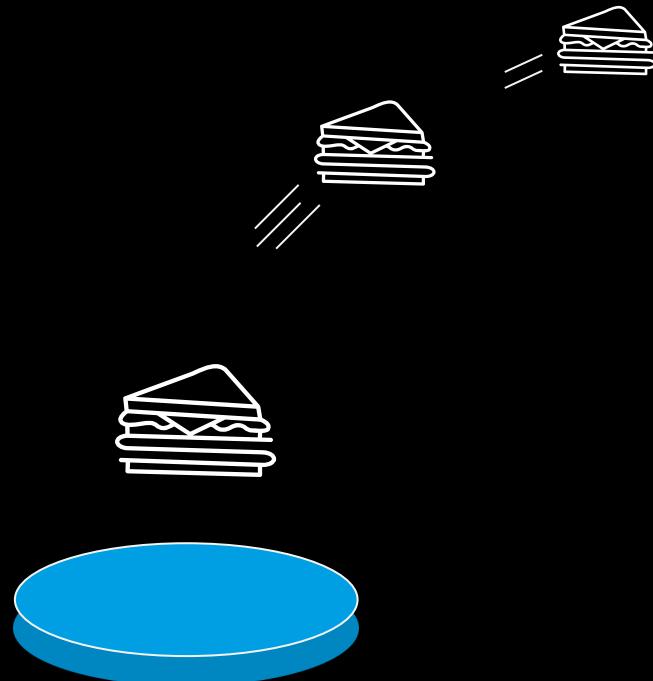
A magic sandwich hole spits out random sandwiches with a finite set of possible ingredients:

- Cheese
- Eggshells
- Mud
- Chicken
- Peanut Butter
- Marshmallow
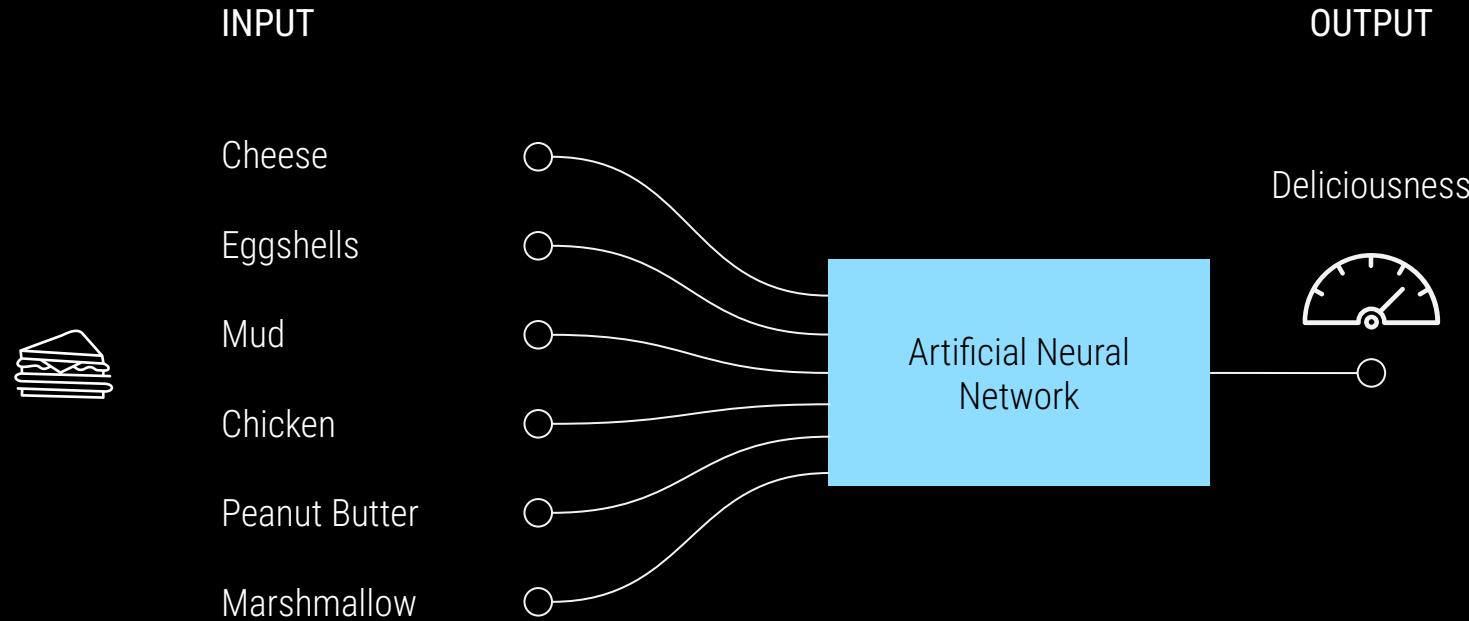
Only 1 in 1000 is actually good - but really, really good.

We want to train a neural network to identify the delicious ones!

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PROBLEM STATEMENT

INPUT

OUTPUT

Cheese

Eggshells

Mud

Chicken

Peanut Butter

Marshmallow

Artificial Neural Network

Deliciousness
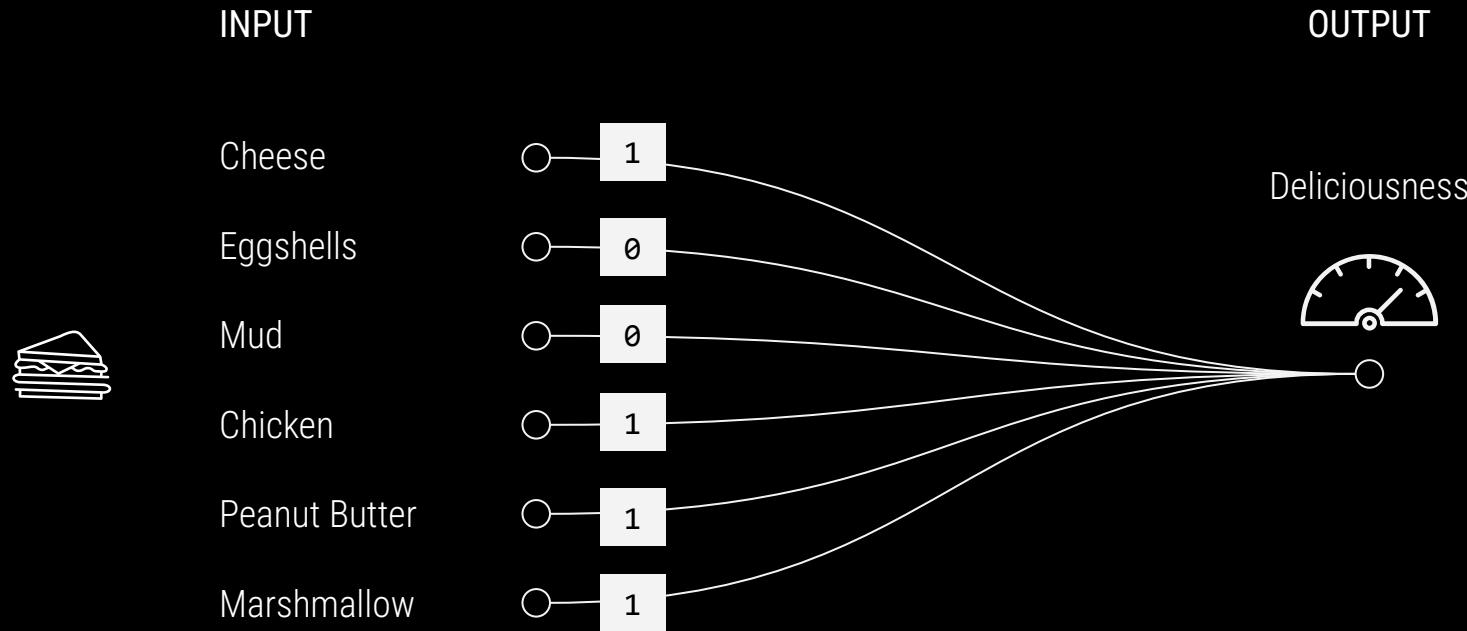
HOW NEURAL NETWORKS WORK
PROBLEM STATEMENT

INPUT

OUTPUT

Cheese

Deliciousness

1

Eggshells

0

Mud

0

Chicken

1

Peanut Butter

1

Marshmallow

1

HOW NEURAL NETWORKS WORK
EGGSHELLS AND MUD?

INPUT

OUTPUT

Cheese   ○ | 1

Eggshells   ● | 0

Mud   ● | 0

Chicken   ○ | 1

Peanut Butter   ○ | 1

Marshmallow   ○ | 1

Deliciousness

= 0

Great :-)

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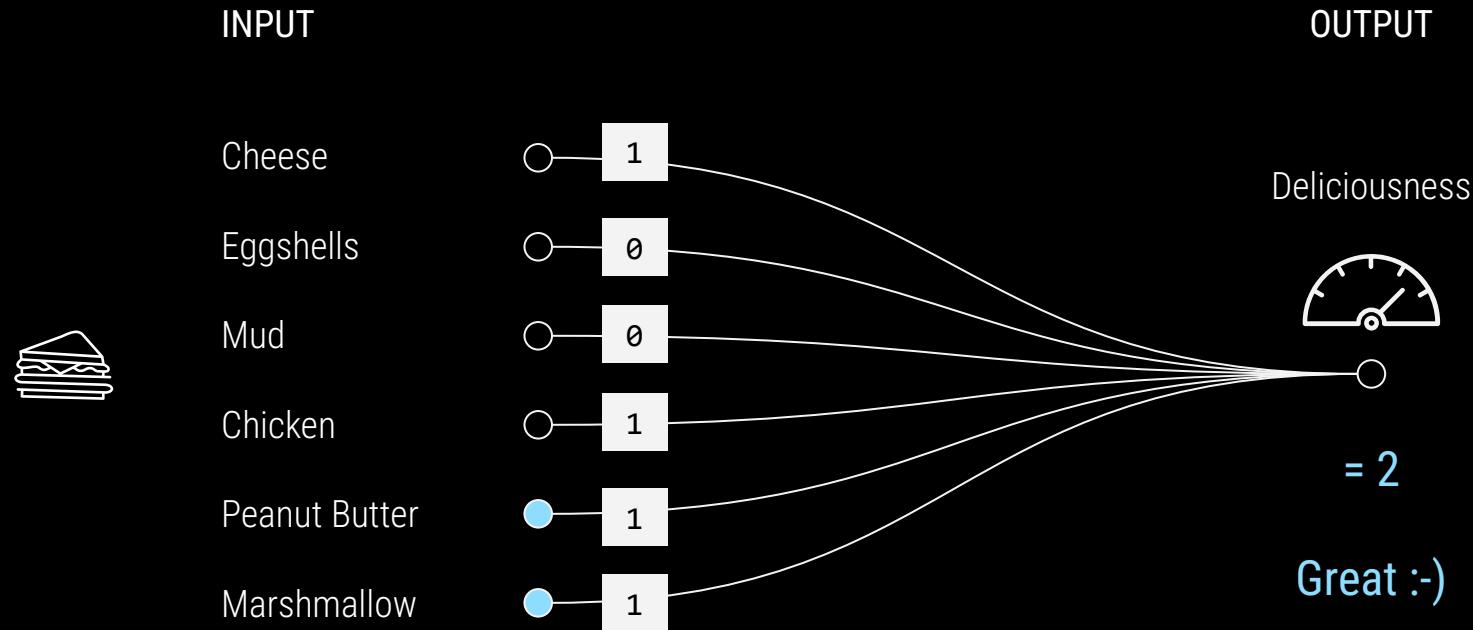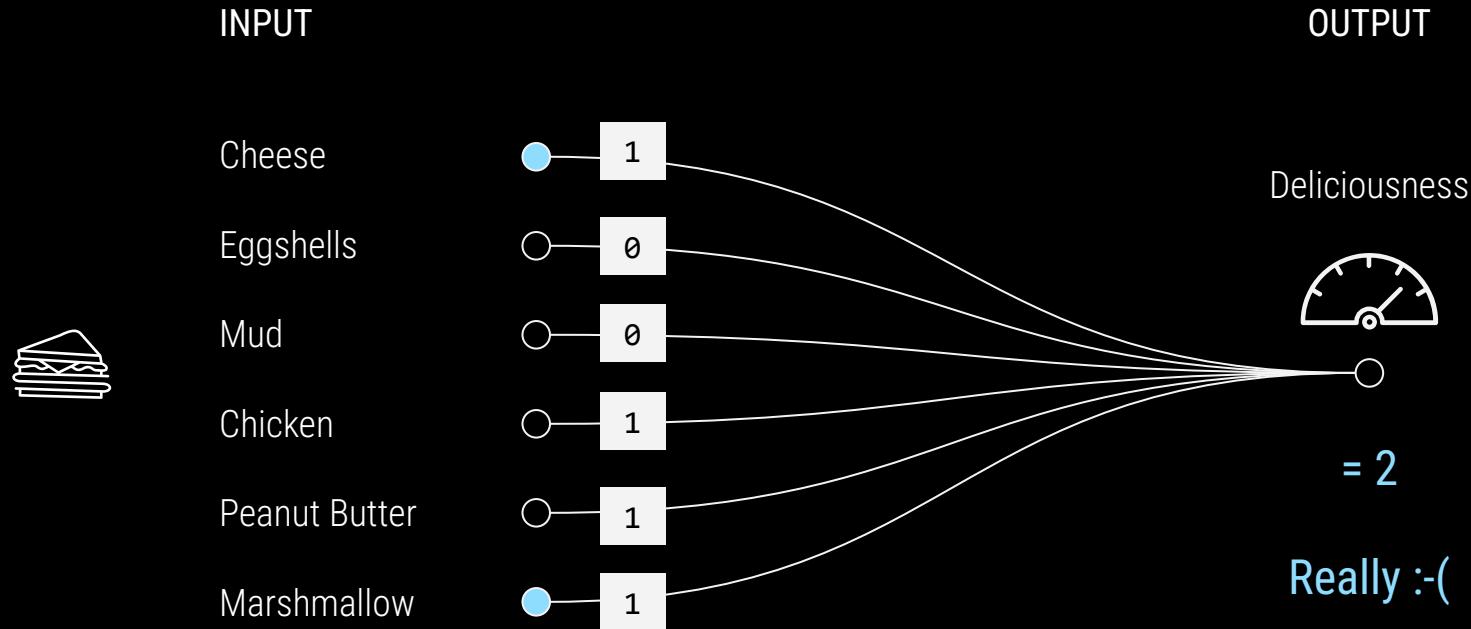
HOW NEURAL NETWORKS WORK
PEANUT BUTTER AND MARSHMALLOW?

INPUT

OUTPUT

Cheese · 1

Eggshells · 0

Mud · 0

Chicken · 1

Peanut Butter · 1

Marshmallow · 1

Deliciousness

= 2

Great :-)

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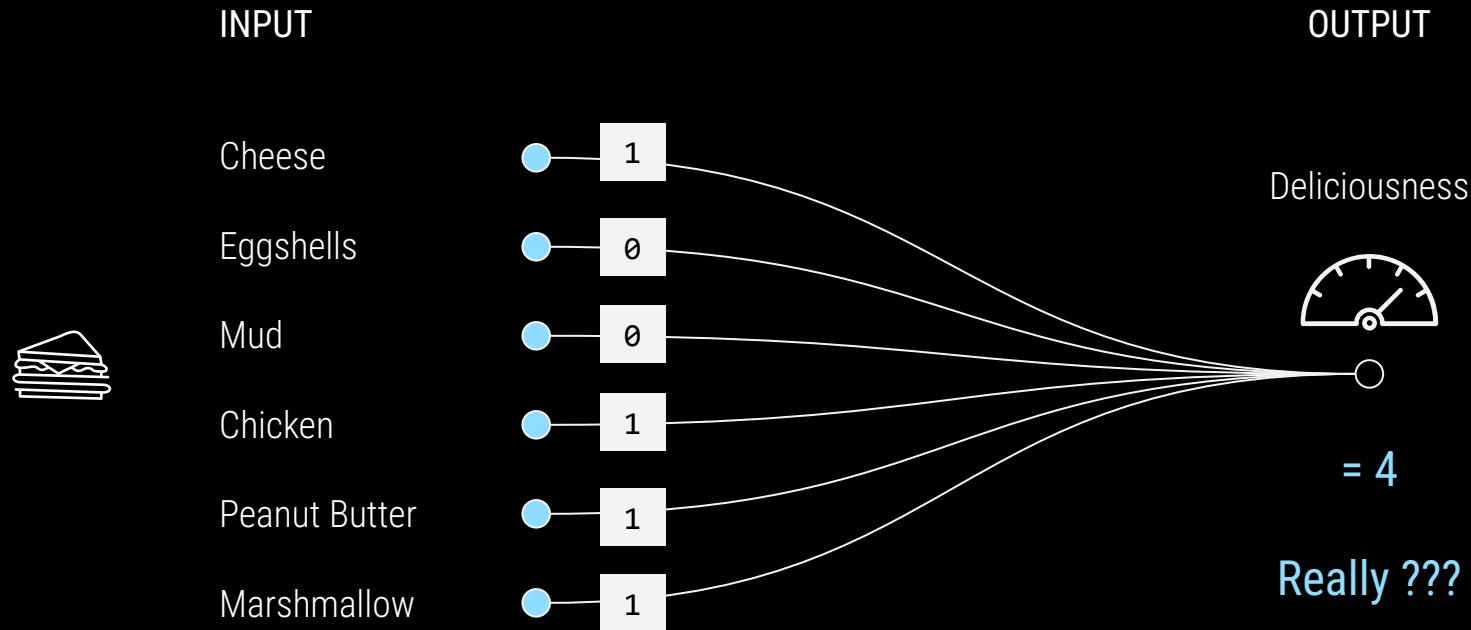
HOW NEURAL NETWORKS WORK
CHEESE AND MARSHMALLOW?

INPUT

OUTPUT

Cheese   1

Eggshells   0

Mud   0

Chicken   1

Peanut Butter   1

Marshmallow   1

Deliciousness

= 2

Really :-(

ALL AT ONCE

INPUT

OUTPUT

Cheese   1

Eggshells   0

Mud   0

Chicken   1

Peanut Butter   1

Marshmallow   1

Deliciousness

= 4

Really ???
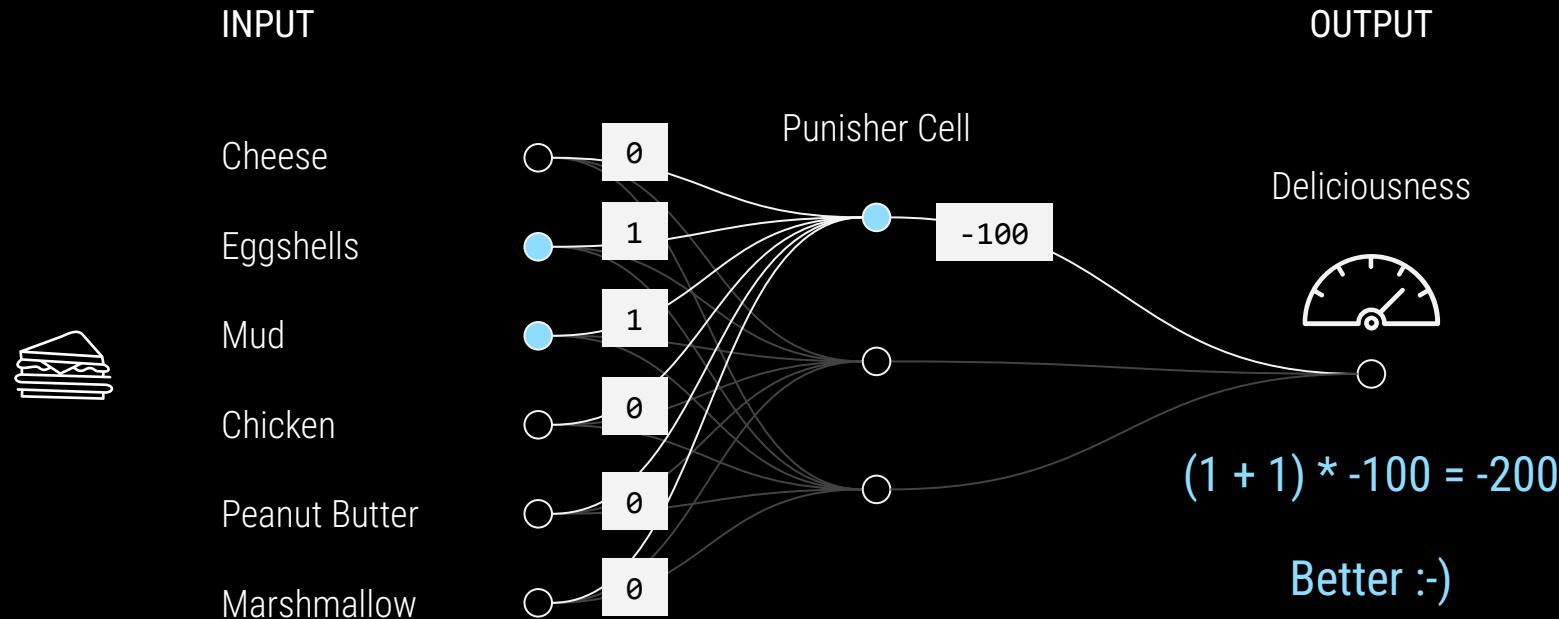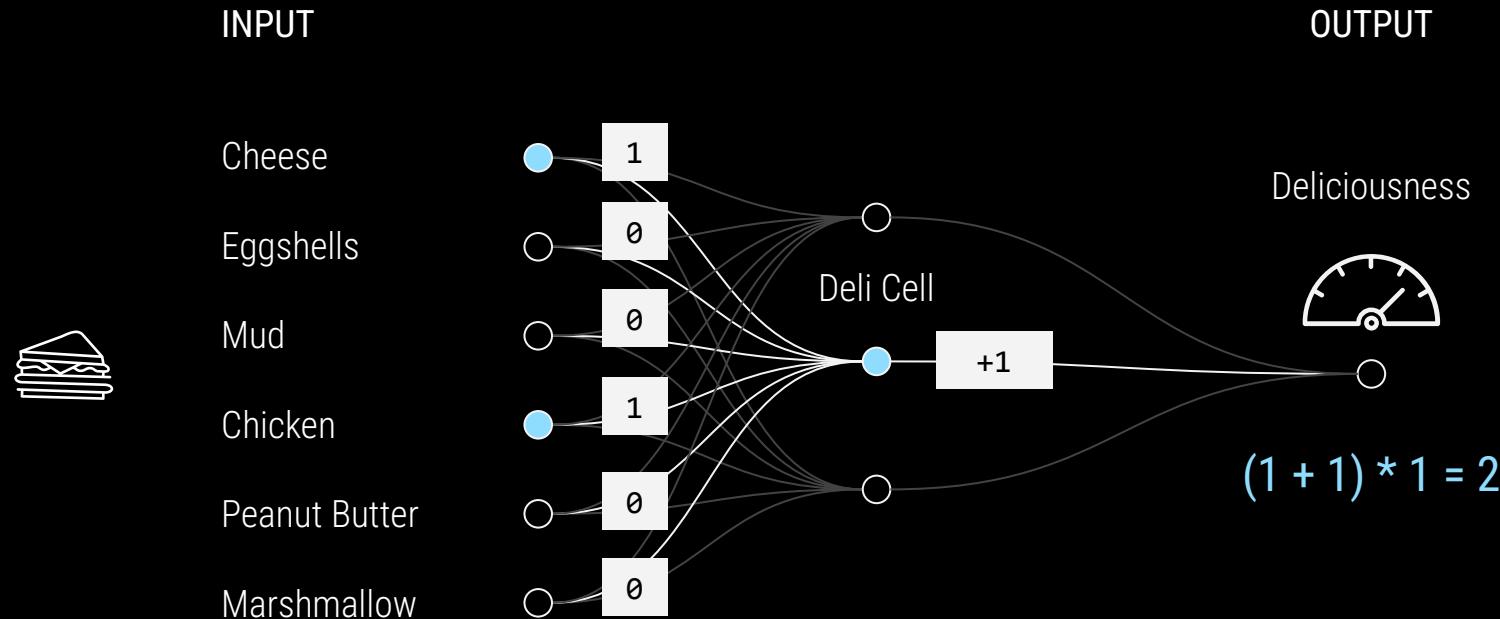
HOW NEURAL NETWORKS WORK
THE PUNISHER CELL

INPUT

OUTPUT

Cheese

Punisher Cell

0

Eggshells

1

-100

Deliciousness

Mud

1

Chicken

0

Peanut Butter

0

Marshmallow

0

$(1 + 1) * -100 = -200$

Better :-)

HOW NEURAL NETWORKS WORK
THE DELI SANDWICH CELL

INPUT

OUTPUT

Cheese `1`

Eggshells `0`

Mud `0`

Deli Cell

Chicken `1`

`+1`

Peanut Butter `0`

Marshmallow `0`

Deliciousness

(1 + 1) * 1 = 2

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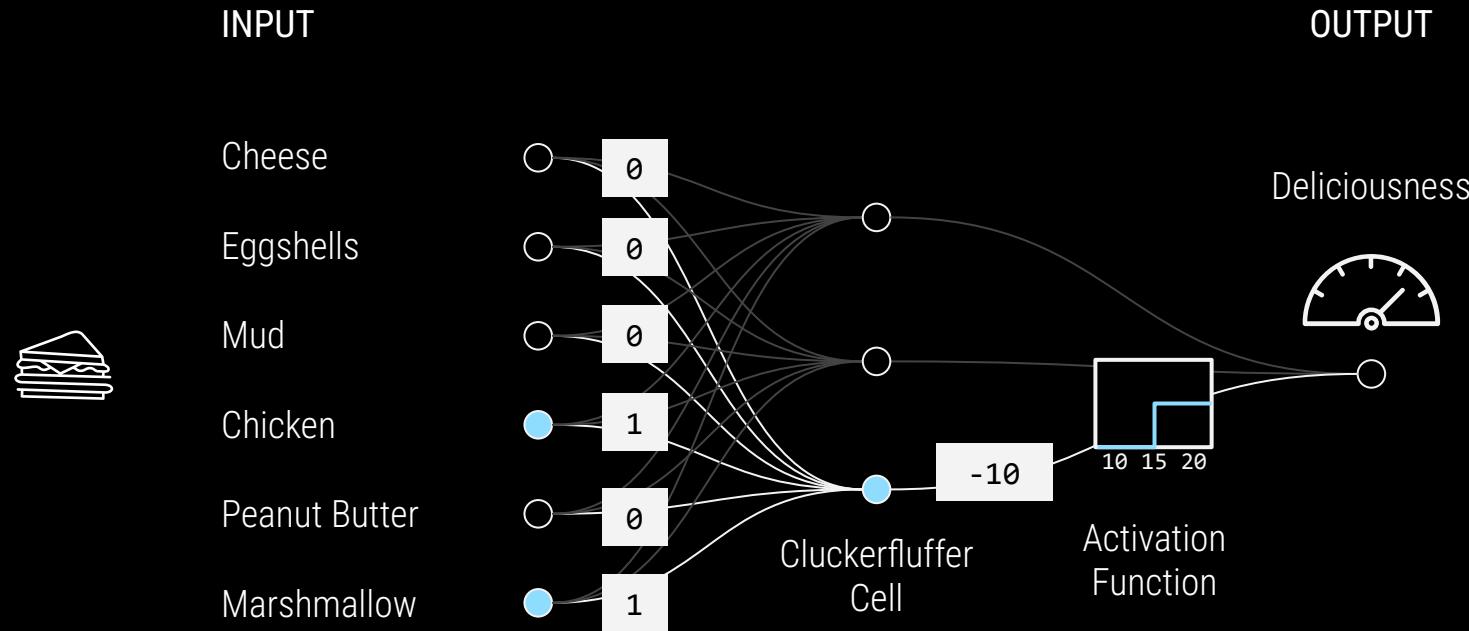
HOW NEURAL NETWORKS WORK
PUNISH CERTAIN COMBOS

INPUT

OUTPUT

Cheese

Eggshells

Mud

Chicken

Peanut Butter

Marshmallow

0

0

0

1

0

1

Cluckerfluffer
Cell

-10

Deliciousness

$(1 + 1) * -10 = -20$

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HOW NEURAL NETWORKS WORK
THE ACTIVATION FUNCTION

INPUT

OUTPUT

Cheese ⭘ 0

Eggshells ⭘ 0

Mud ⭘ 0

Chicken 🔵 1

Peanut Butter ⭘ 0

Marshmallow 🔵 1

Deliciousness

-10

Cluckerfluffer
Cell

10 15 20

Activation
Function

HOW NEURAL NETWORKS WORK
TRAINING THE NEURAL NETWORK

Cheese	Eggshells	Mud	Chicken	Peanut Butter	Marshmallow	Delicious
1	0	0	1	0	0	9.5
0	1	1	0	0	0	0.0
1	0	1	0	1	0	0.5
1	0	0	0	0	0	6
0	0	0	0	1	1	8.9

HOW NEURAL NETWORKS WORK
TRAINING THE NEURAL NETWORK

This is the first record from the training data

The weights are randomly initialized

OUTPUT

Cheese

Eggshells

Mud

Chicken

Peanut Butter

Marshmallow
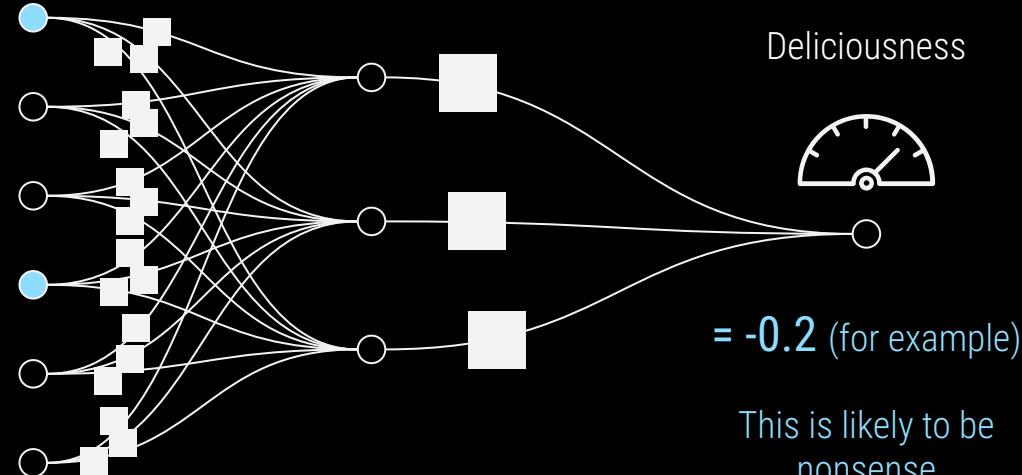
Deliciousness

= -0.2 (for example)

This is likely to be nonsense
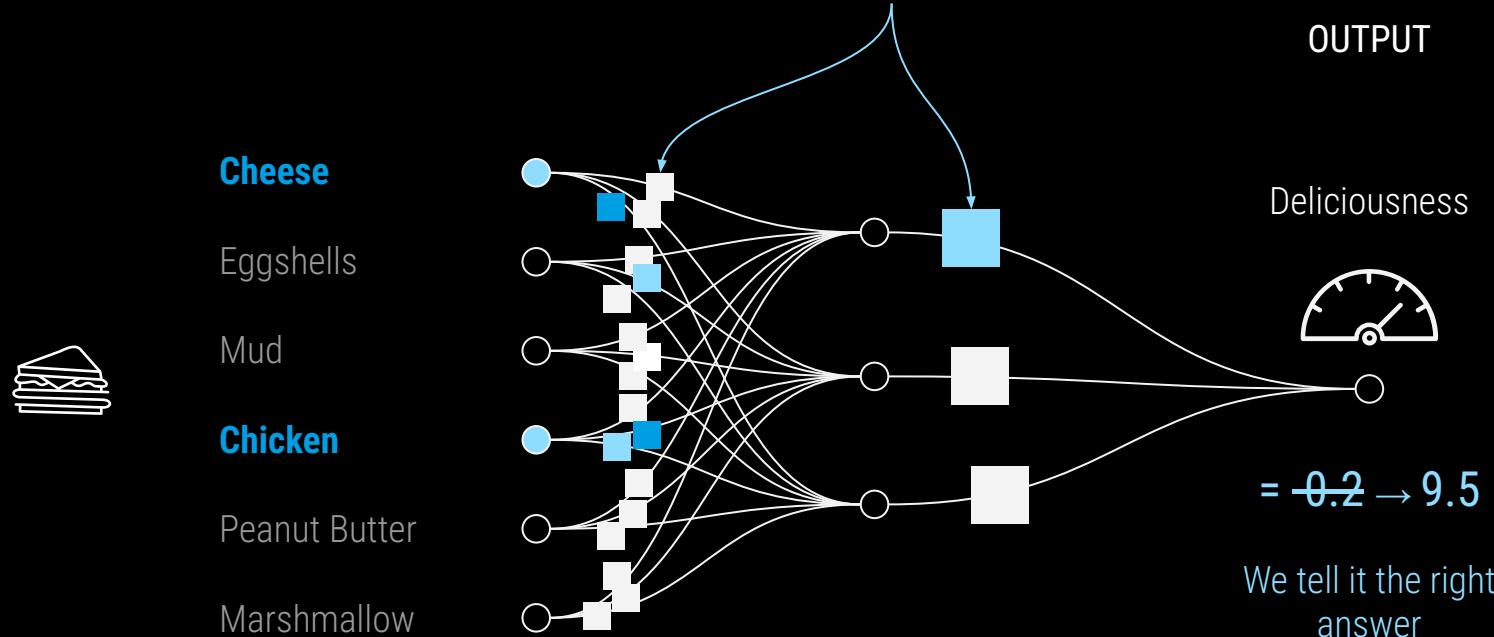
TRAINING THE NEURAL NETWORK

The weights are adjusted gradually, so the network is more likely to predict the correct score next time

OUTPUT

Cheese

Eggshells

Mud

Chicken

Peanut Butter

Marshmallow

Deliciousness

= ~~0.2~~ → 9.5

We tell it the right answer
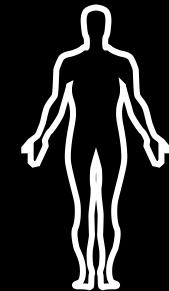
~~Researchers estimate ANNs could have as many neurons as a human brain by 2050 (~80 billion)~~

UPDATE: The GPT-3 neural network, released in May 2020, has **~170 billion** neurons.

UPDATE: GPT-4, released in March 2023, has ~1.2 trillion neurons.

UPDATE: GPT-5, released in August 2025, is estimated to have 2-5 trillion neurons.
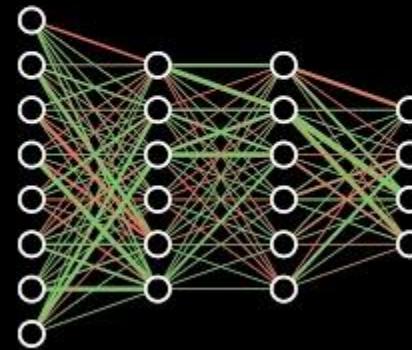
Modest sized ANNs have as many neurons as a worm's brain (~300)

Large ANNs come close to the number of neurons a bee's brain has (~170.000)

The largest ANNs have about the size of a frog's brain (16 million neurons)

A human brain has about 86 billion neurons

Neural Networks — From the ground up