Are machines the next Einstein?

Thank you for joining us!

Credit: Elena Colangeli

LSC UNIVERSITY OF PORTSMOUTH

Machine Learning

Are machines the next Einstein?

British Computing Society

Susanna Green

Image Credit: svstudioart on Freepik

Please feel free to contact me with any questions: susanna.green@port.ac.uk

“Even though I am doing an Astrophysics PhD… I oscillate between being a software engineer, machine learning engineer, and a data scientist. Plus I am a content creator!”

– Susanna Green –

How do **YOU** **think** and **learn?**

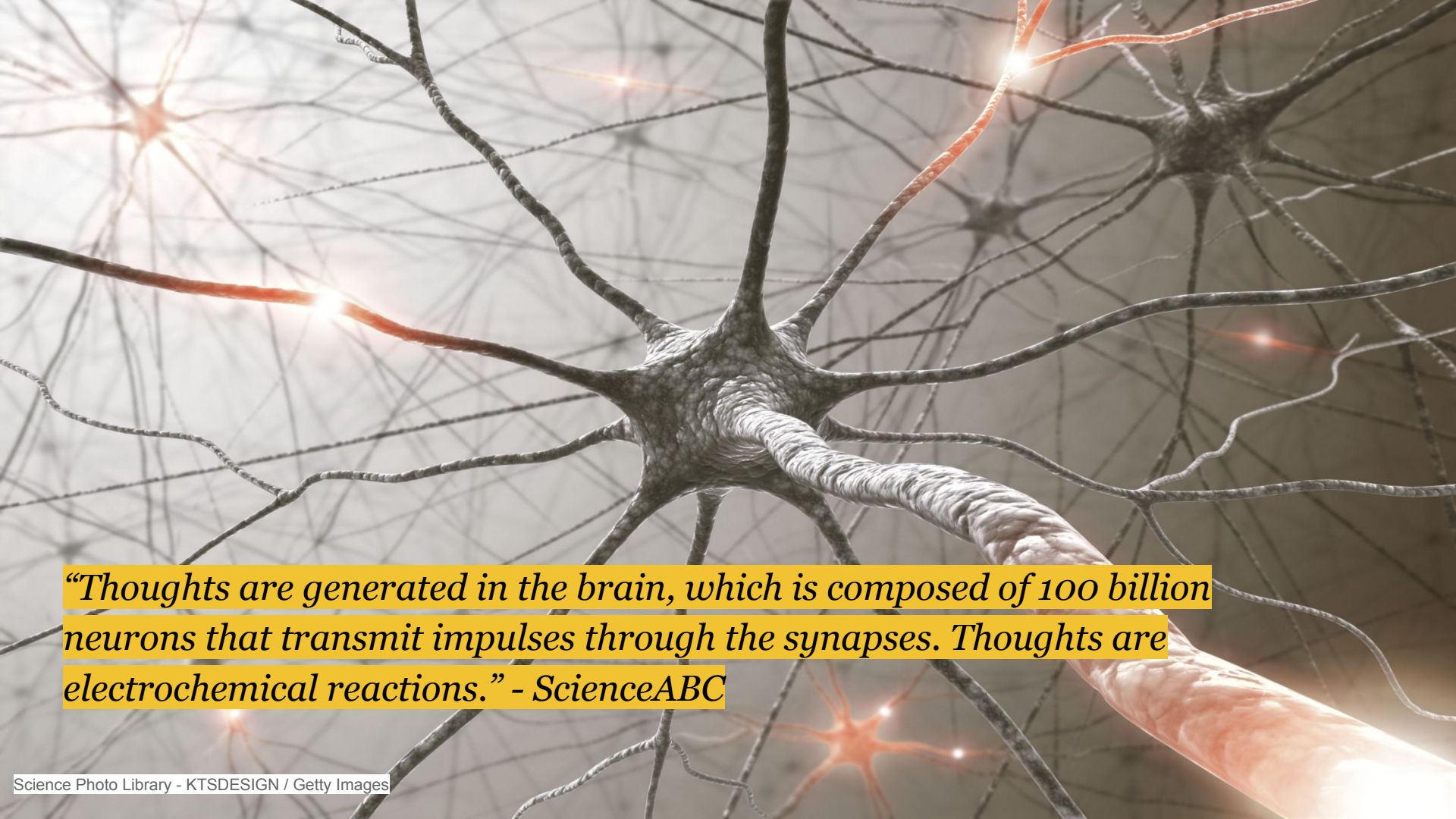
Image by wayhomestudio on Freepik

“Did you know the average person has about 6,200 thoughts per day”

Psychologists at Queen’s University in Kingston, Ontario, 2020 (Credit: Bigthink.com)

A. I have more thoughts than this!!!
B. I have about this many thoughts.
C. I have very few thoughts a day…

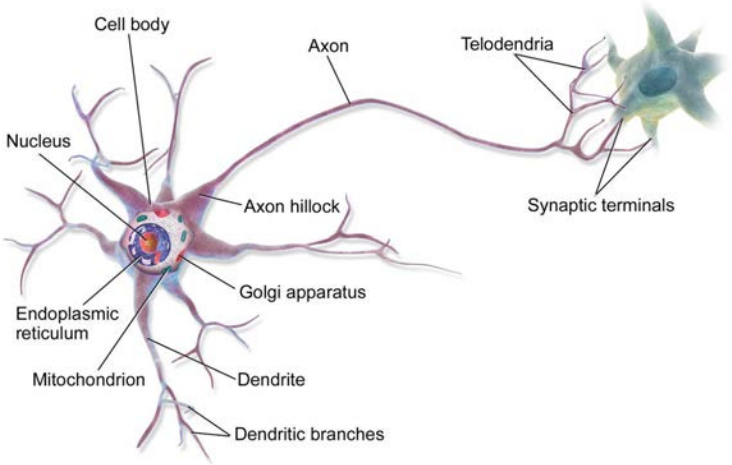

Have you ever thought about your thoughts? Like, what even is a thought?
Like… what are your thoughts made of?
Credit: ScienceABC



“Thoughts are generated in the brain, which is composed of 100 billion neurons that transmit impulses through the synapses. Thoughts are electrochemical reactions.” - ScienceABC

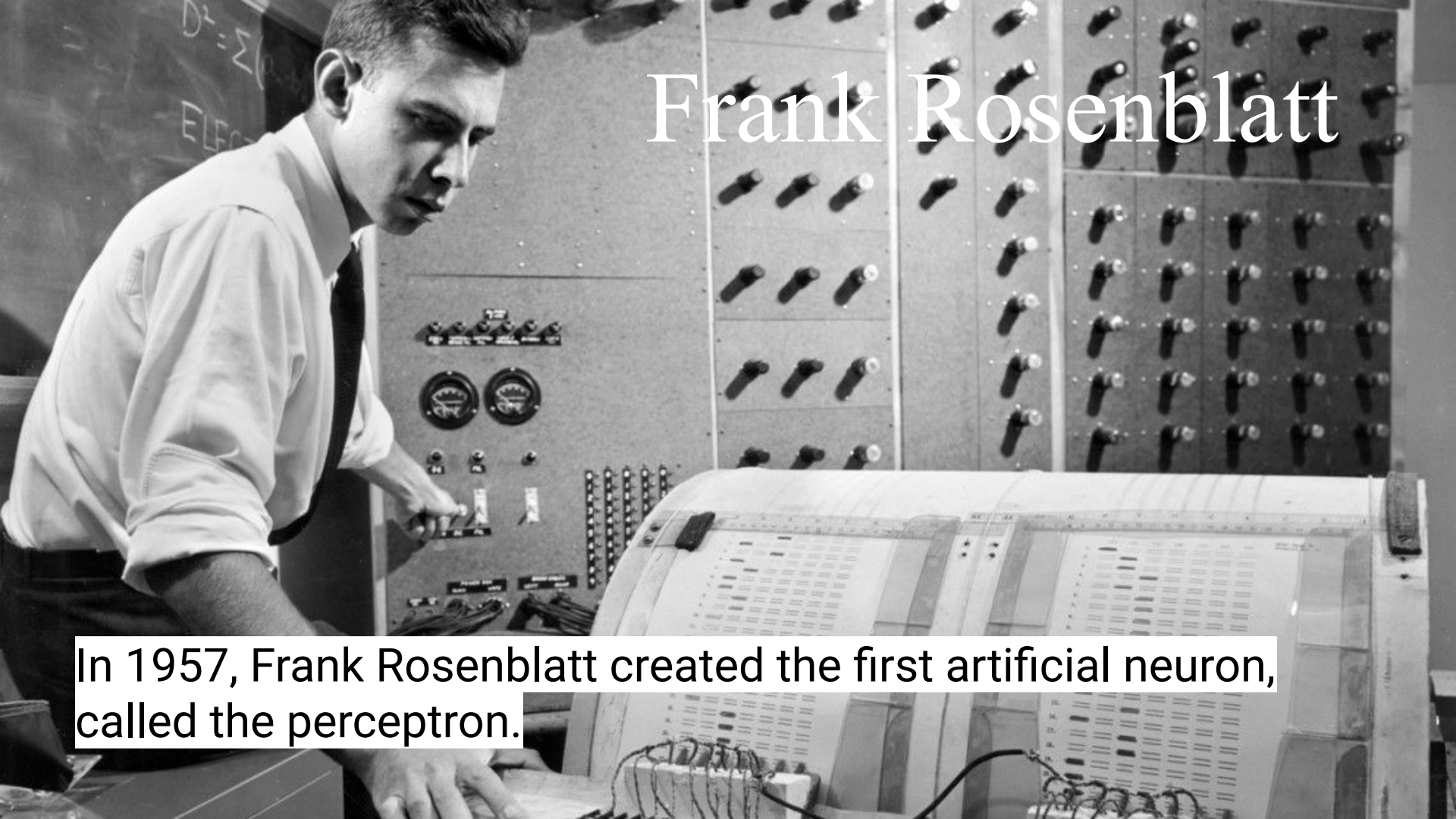
Science Photo Library - KTSDESIGN / Getty Images

Biological neuron



Credit: Wiki

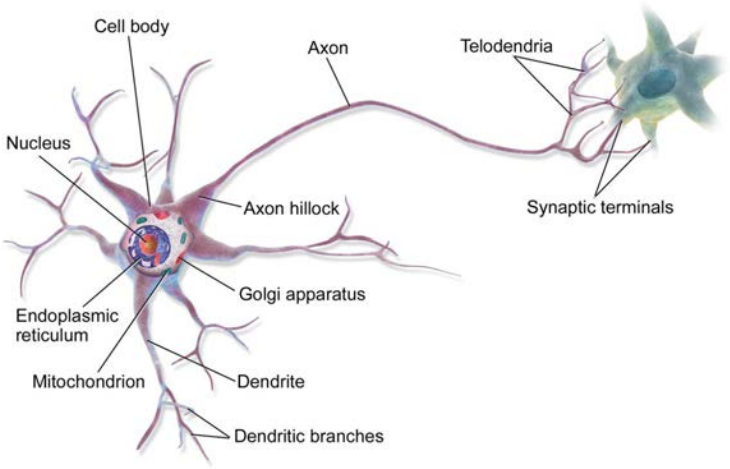
Stimulus → Enough stimulus to send on signal → Signal passed onto the next neuron



Frank Rosenblatt

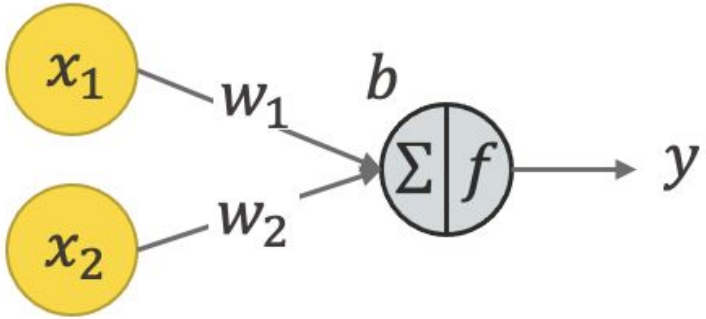
In 1957, Frank Rosenblatt created the first artificial neuron, called the perceptron.

Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

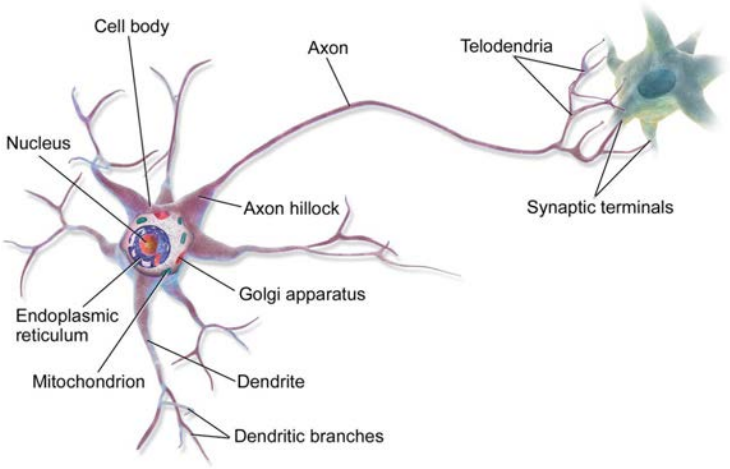
v.s.



Credit: knime.com

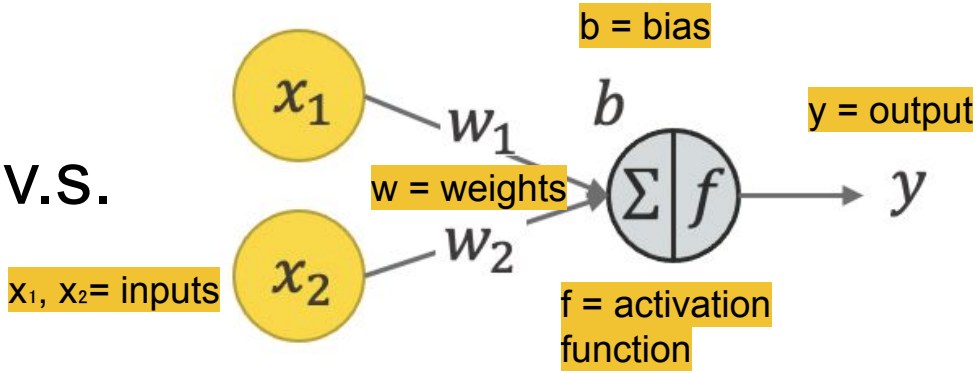
Input → Process → Output

Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

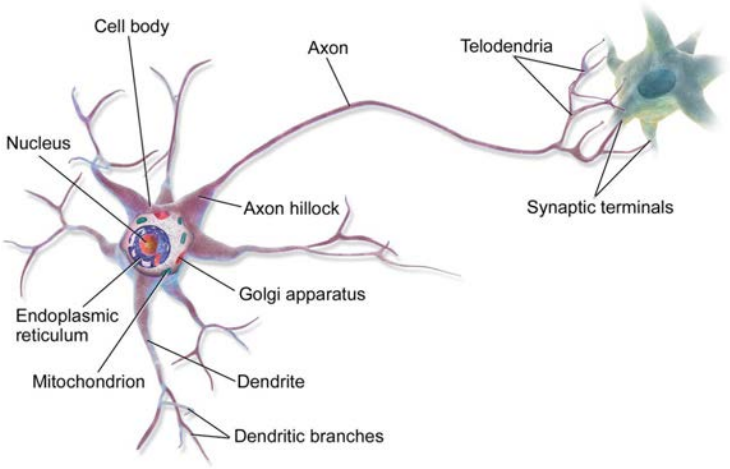
V.S.



Credit: knime.com

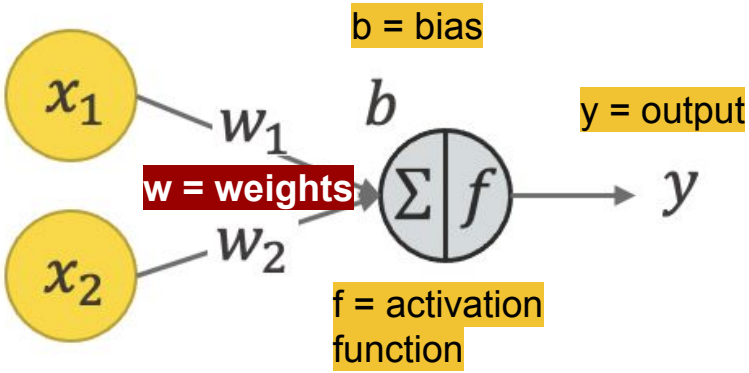
Input → $f\left(b + \sum_{i=1}^{n} x_i w_i\right)$ → Output

Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

V.S.



Credit: knime.com

Input → $f\left(b + \sum_{i=1}^{n} x_i w_i\right)$ → Output

"Neurons that fire together, wire together."

- Donald Hebb -

My second home!

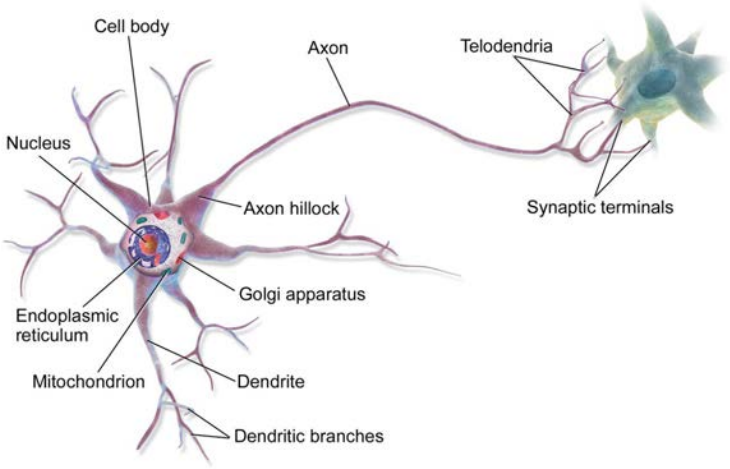
2 hr 9 min
97 miles

1 hr 56 min
74.9 miles

You are here!

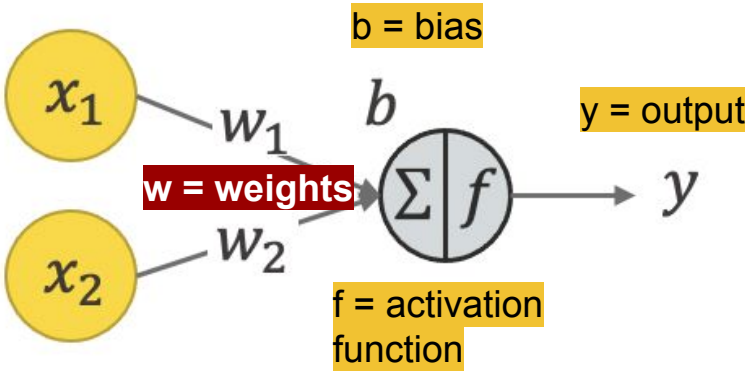
Google

Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

V.S.



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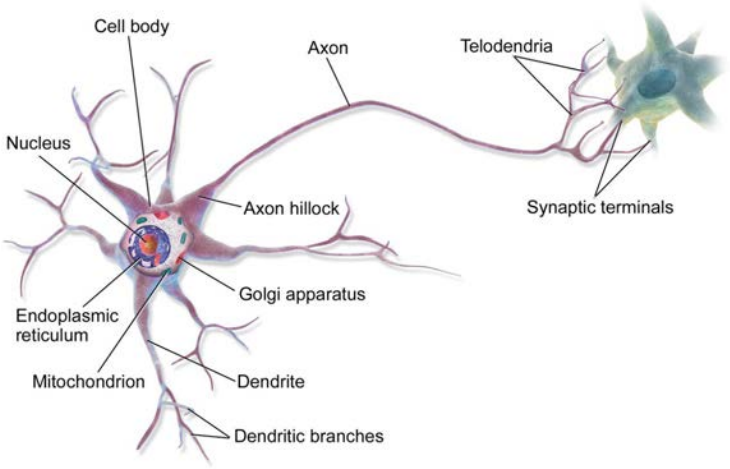
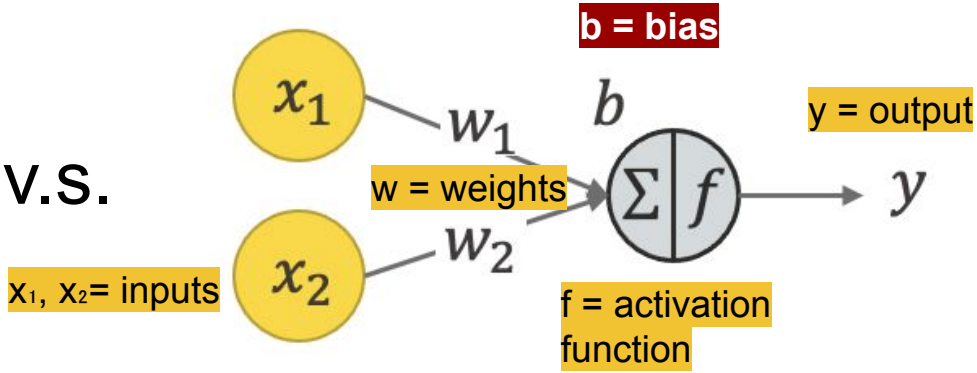
Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

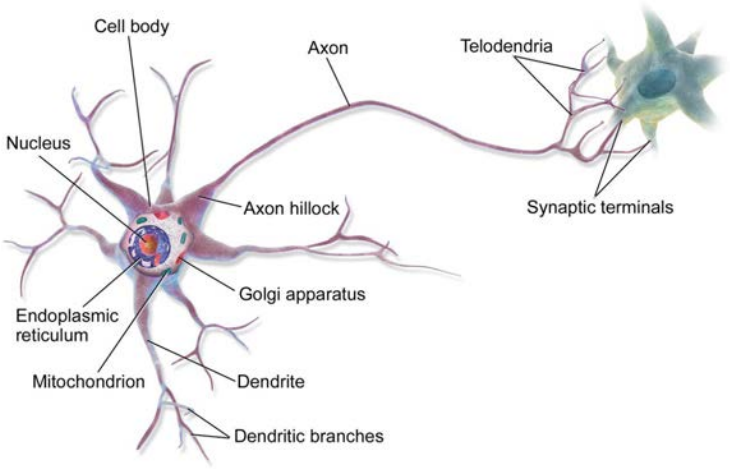
V.S.



Credit: knime.com

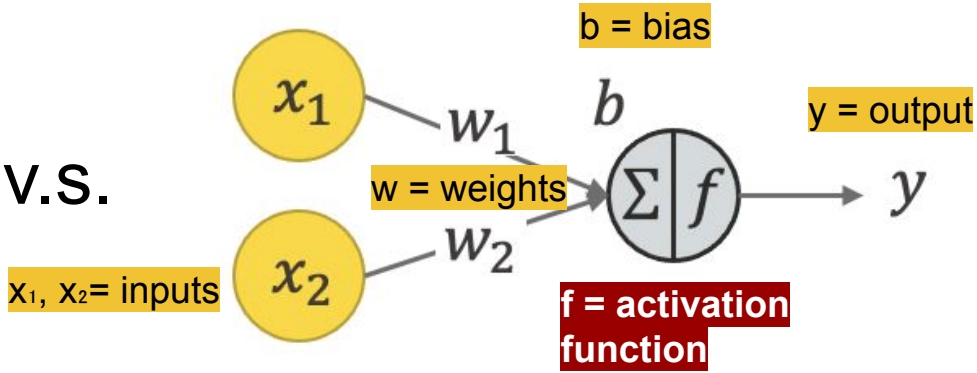
Input → $f\left(b + \sum_{i=1}^{n} x_i w_i\right)$ → Output

Biological neuron v.s. artificial neuron (perceptron)?



Credit: Wiki

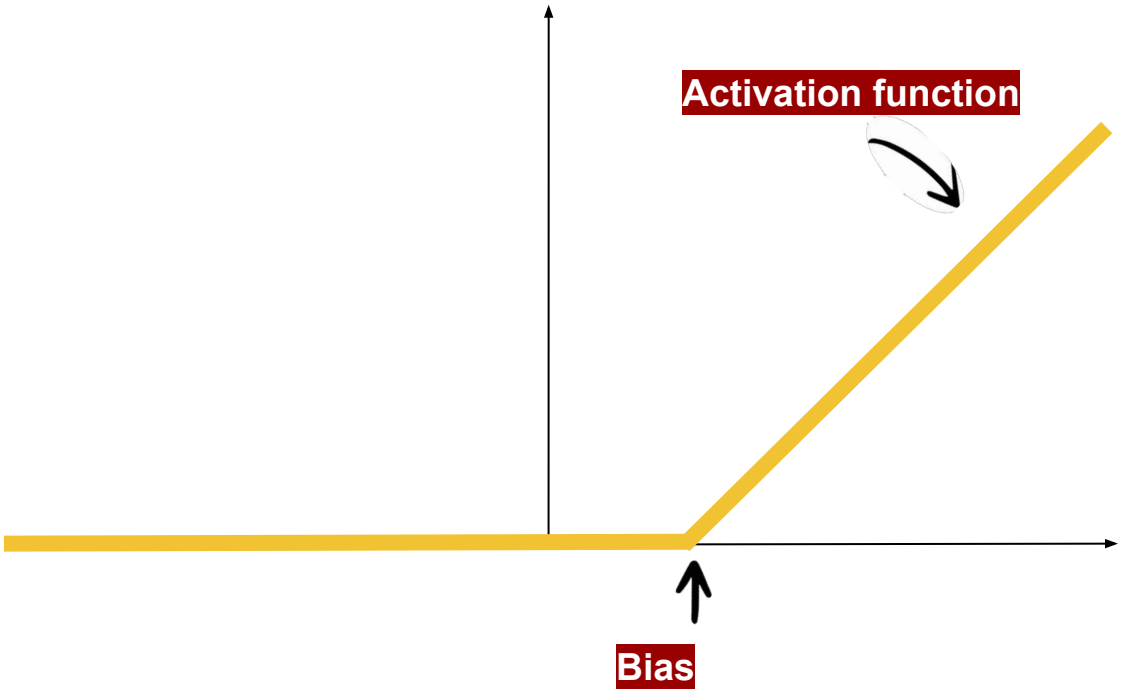
V.S.



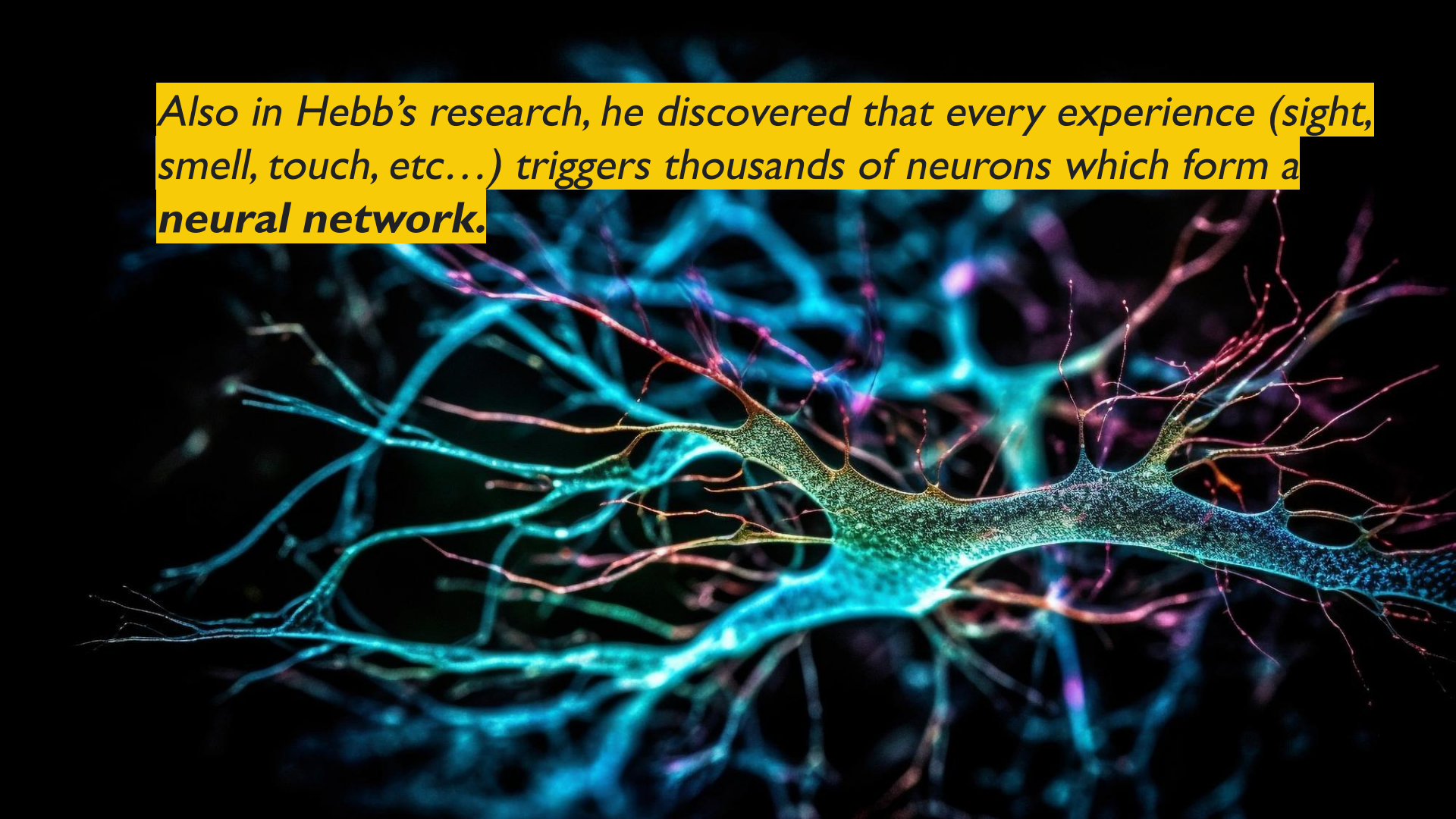
Credit: knime.com

Input → $f\left(b + \sum_{i=1}^{n} x_i w_i\right)$ → Output

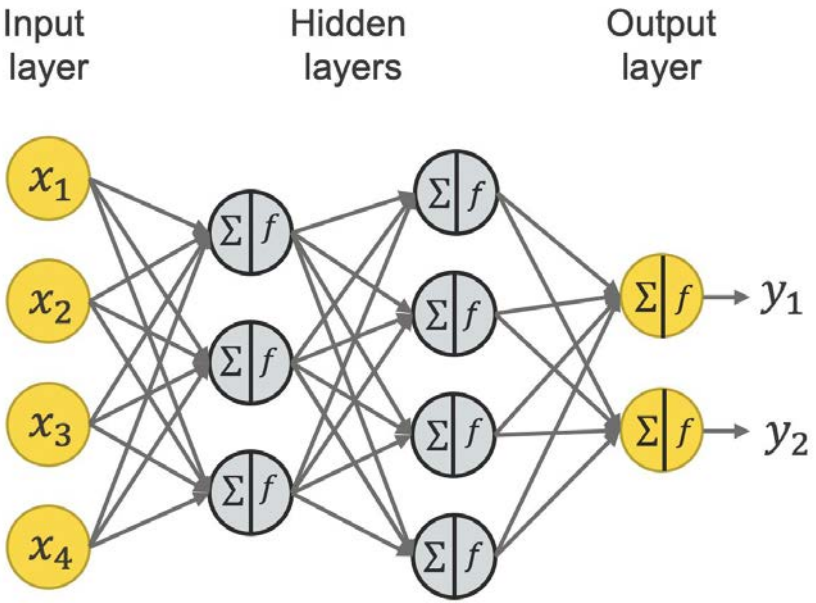
Biological neuron v.s. artificial neuron (perceptron)?



Also in Hebb's research, he discovered that every experience (sight, smell, touch, etc…) triggers thousands of neurons which form a ***neural network.***



Artificial neural networks are one way that a machine 'thinks' and 'learns'...



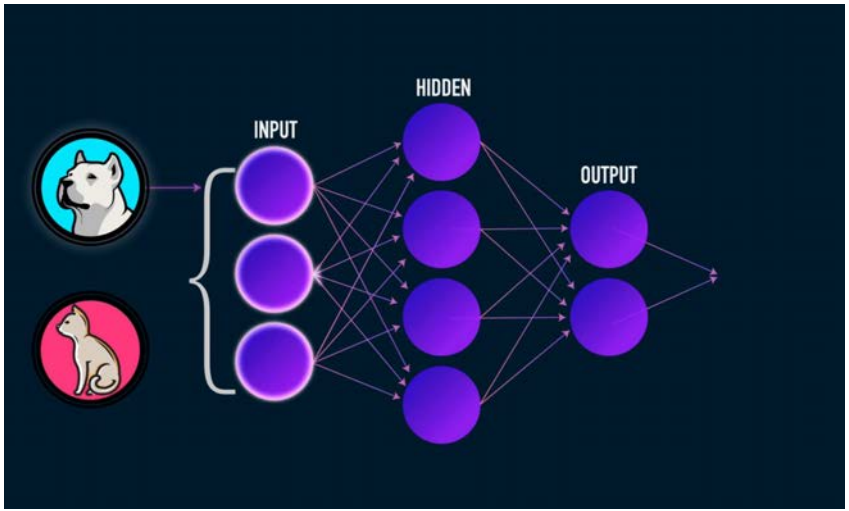
Credit: knime.com

YOU v.s. MACHINE

Dog

Cat

YOU v.s. MACHINE



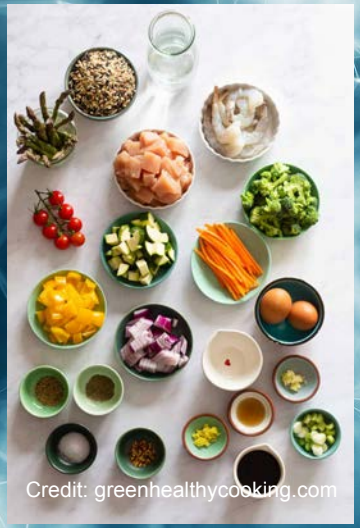
Credit: upadhyay-shivam.medium.com

What is Machine Learning?

The machine learns the pattern rather than you explicitly telling the machine the pattern


Credit: thedigitaldoctorate.com

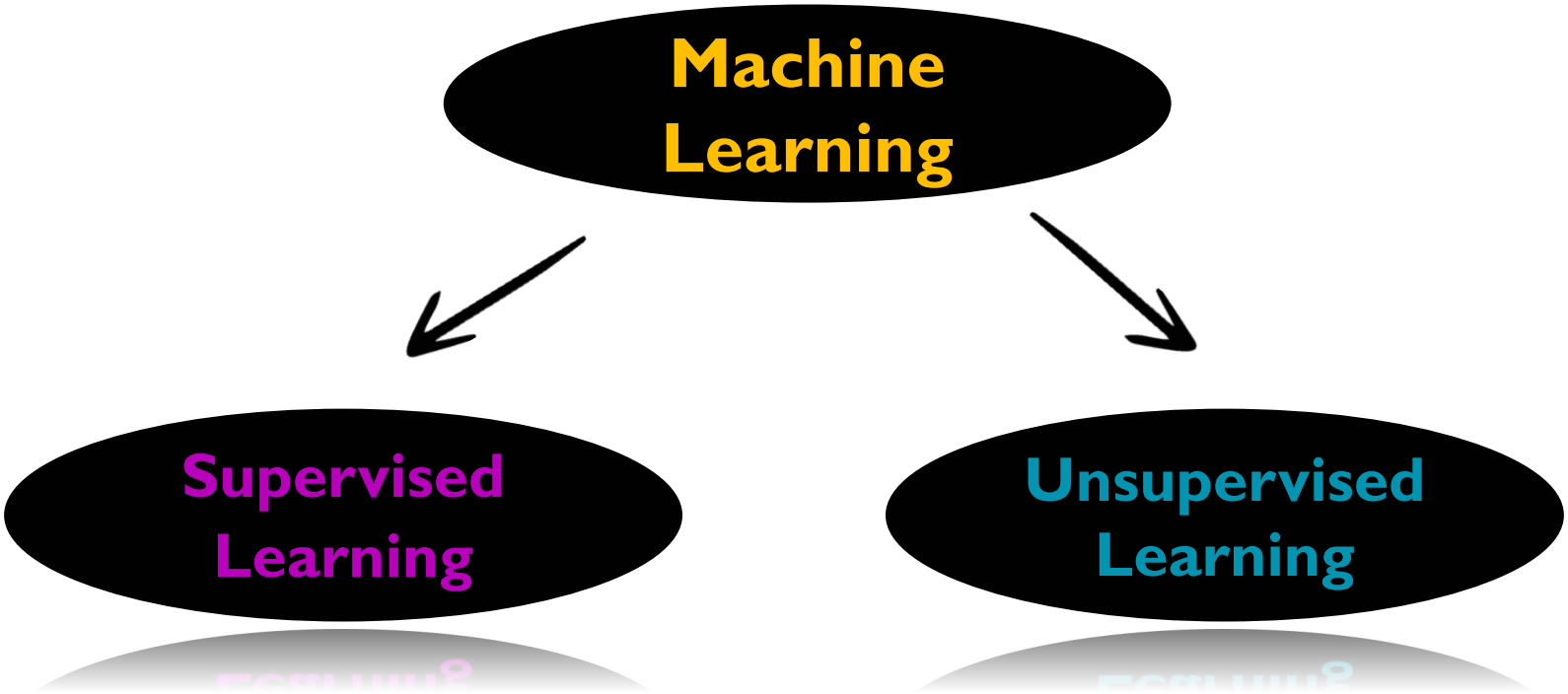
v.s.


Credit: greenhealthycooking.com

Humans learn in different ways…

…so do **machines.**

Image Credits: Freepik



Supervised learning you tell the computer what to learn (i.e. a cat or dog) while unsupervised learning you don’t tell the computer what to learn.

V.S.

Supervised learning is when you give the computer the ingredients and final dish, then tell it to find a recipe.

Image Credit: jcomp on Freepik

Unsupervised learning is when you give the computer the ingredients and ask it to create a recipe and new dish.

Image Credit: Freepik

Let’s use a classification task to explain this…

Image Credit: thabisfotowelt, Pixabay
Image Credit: GreenCross Vets

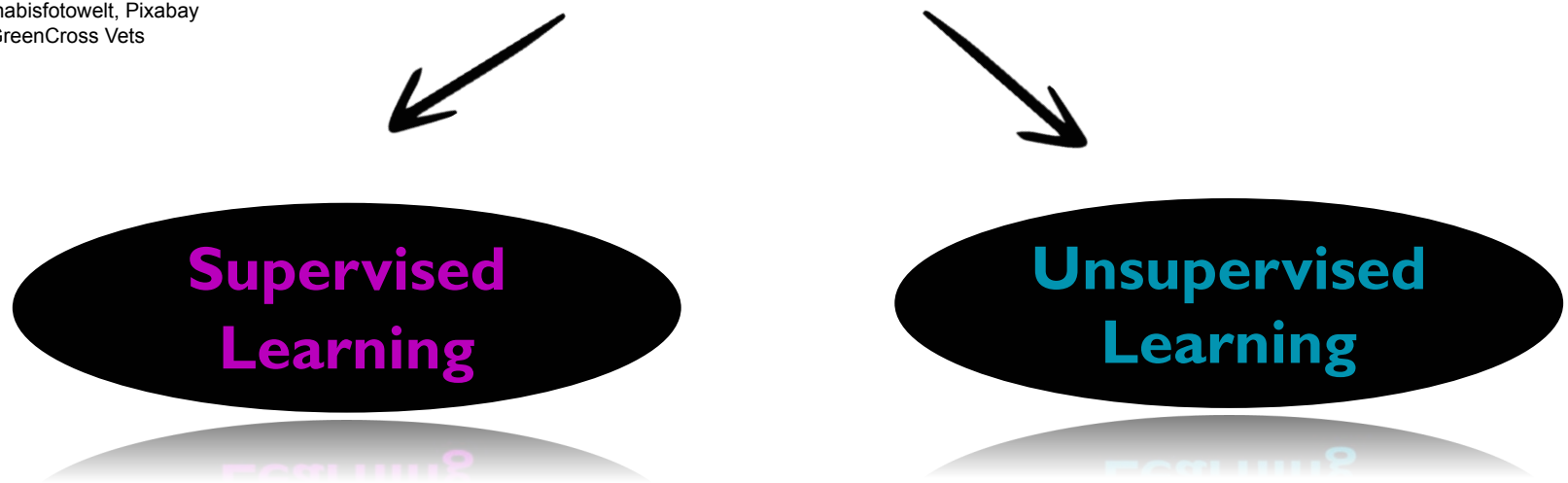


Image Credit: thabisfotowelt, Pixabay
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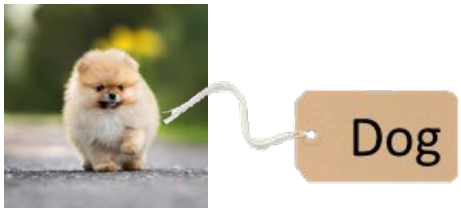
Supervised Learning



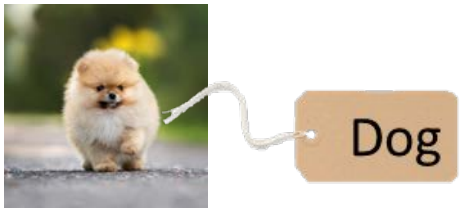
Labelled Data

Unsupervised Learning

Unlabelled Data

Image Credit: thabisfotowelt, Pixabay
Image Credit: GreenCross Vets

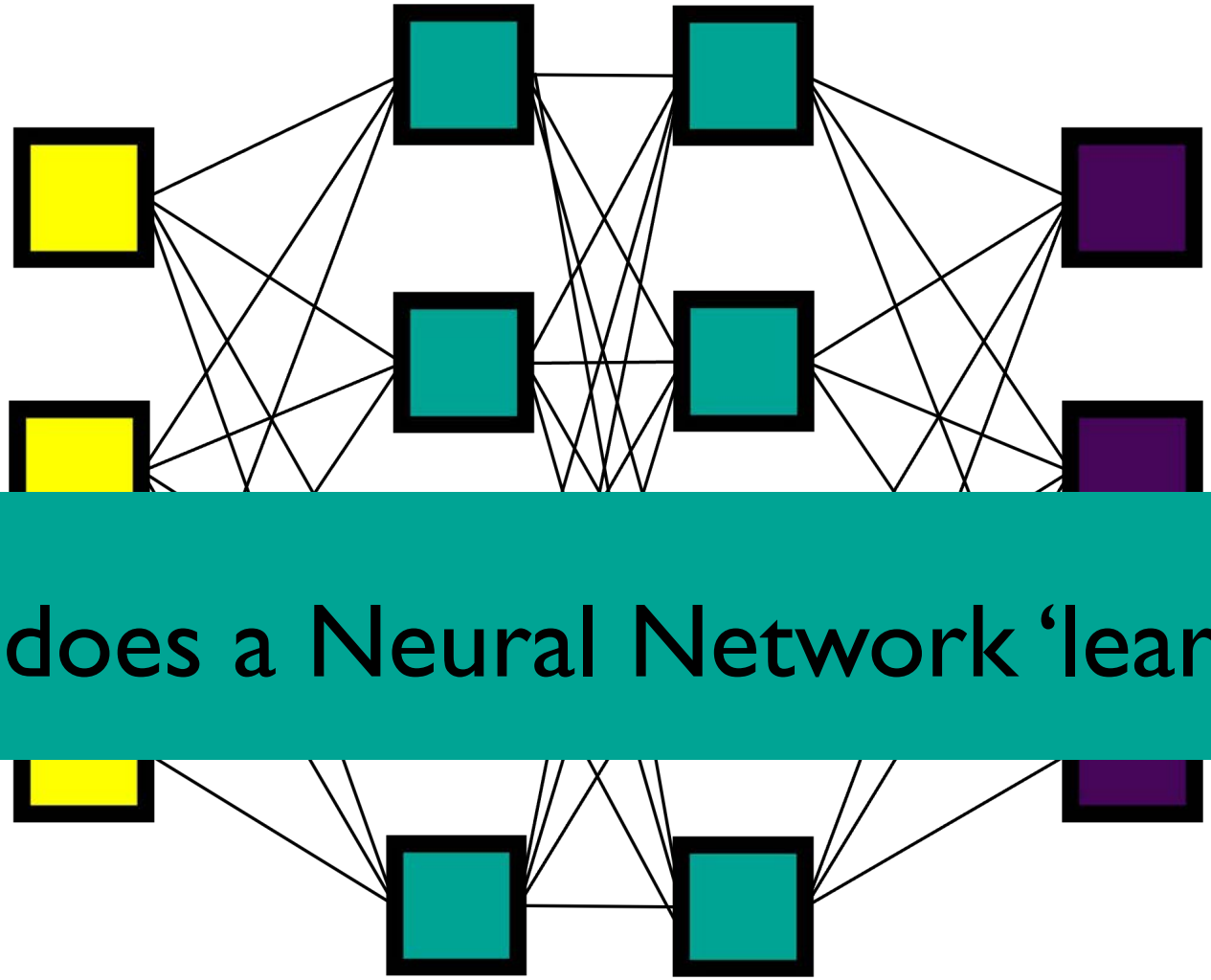
NEURAL NETWORKS



Labelled Data

Unlabelled Data

Image by senivpetro on Freepik

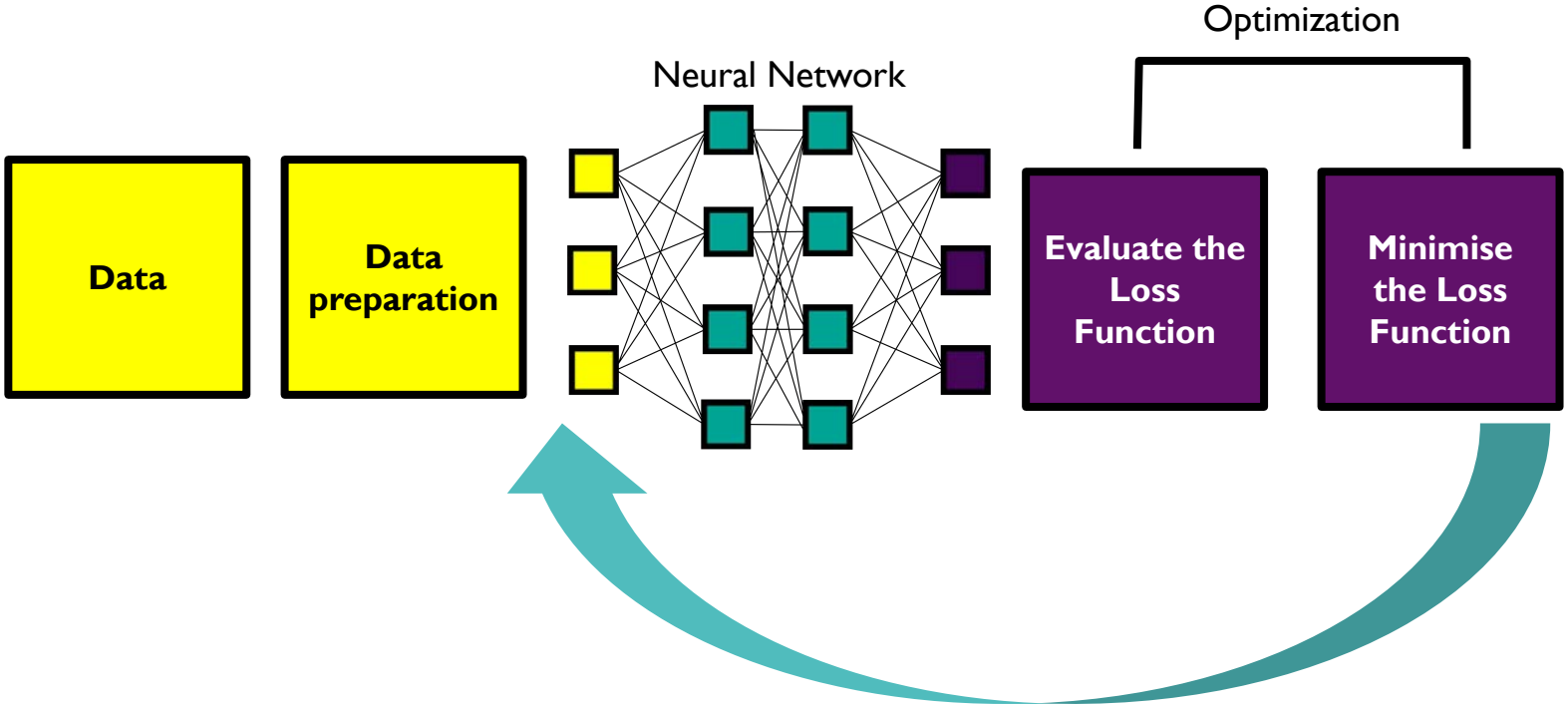


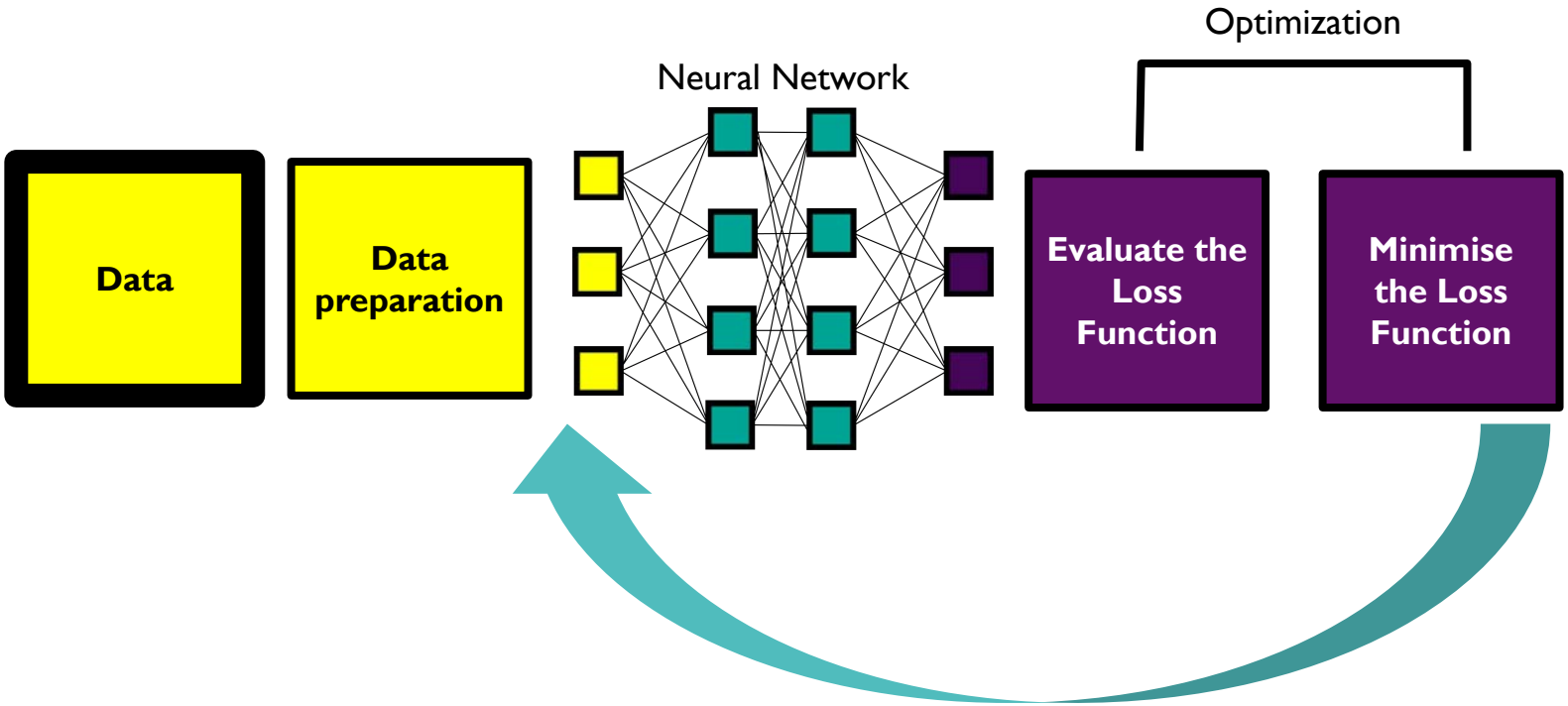
How does a Neural Network ‘learn’?

\\ Like humans, neural networks learn by their mistakes…

…but we call it ‘Optimization’!

This is a machine learning pipeline…




Optimization
Neural Network
Data
Data preparation
Evaluate the Loss Function
Minimise the Loss Function

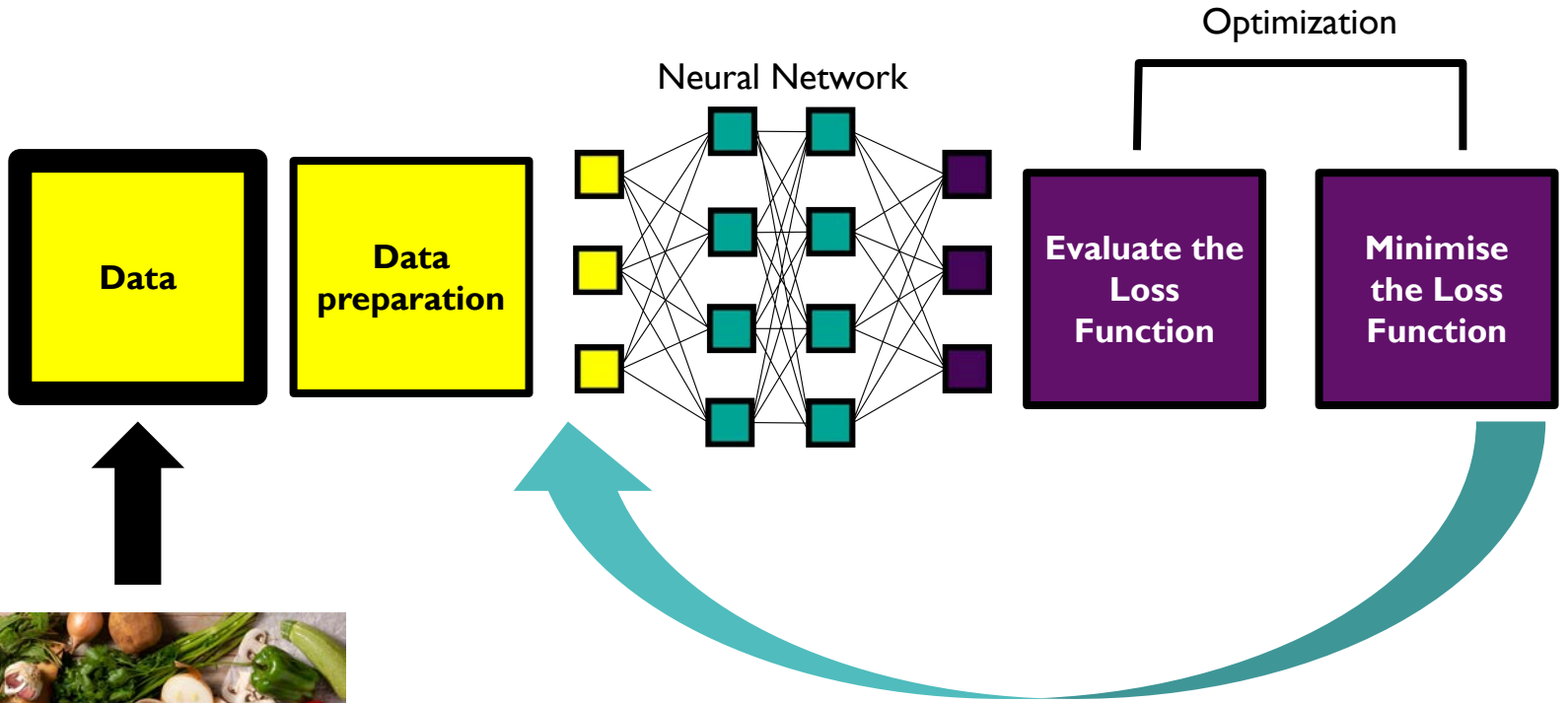
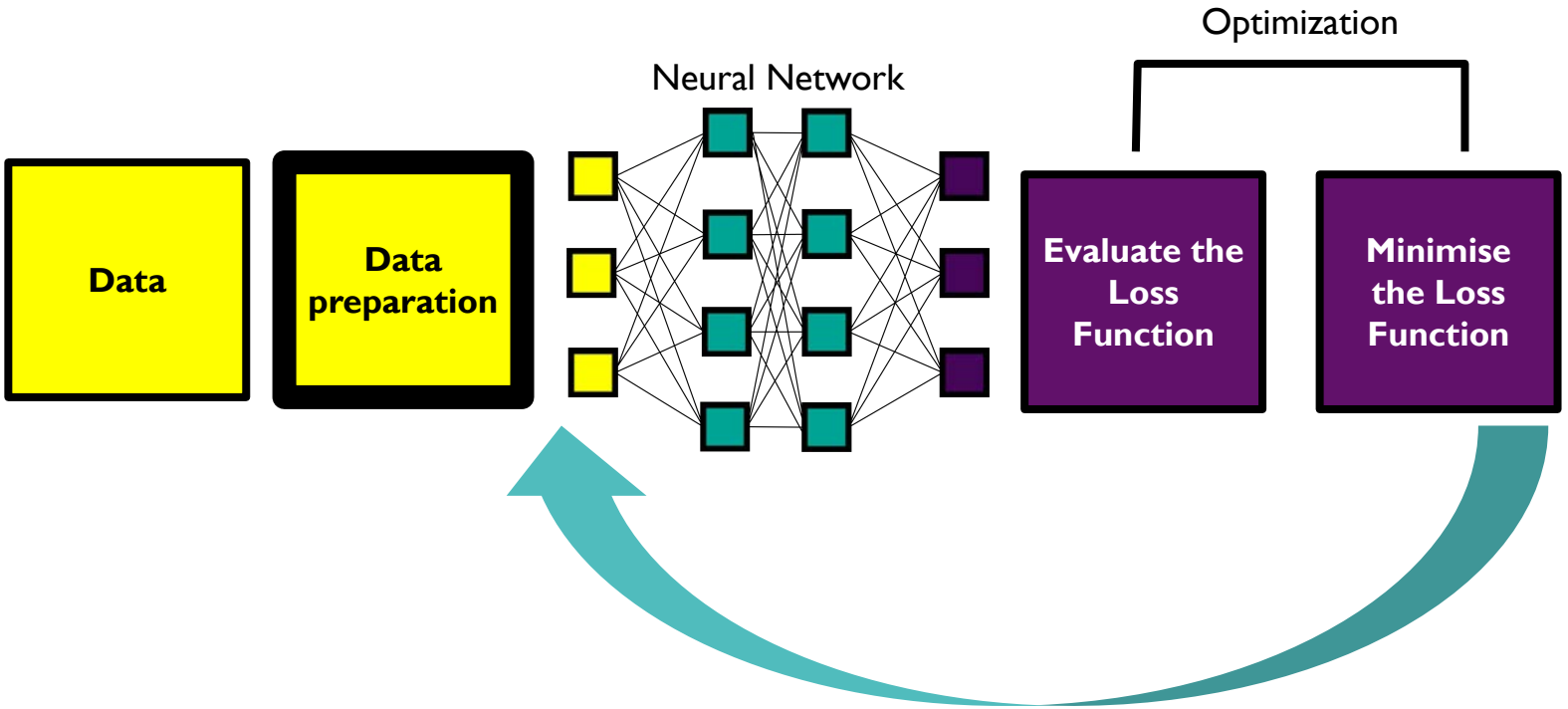


Image by pressfoto on Freepik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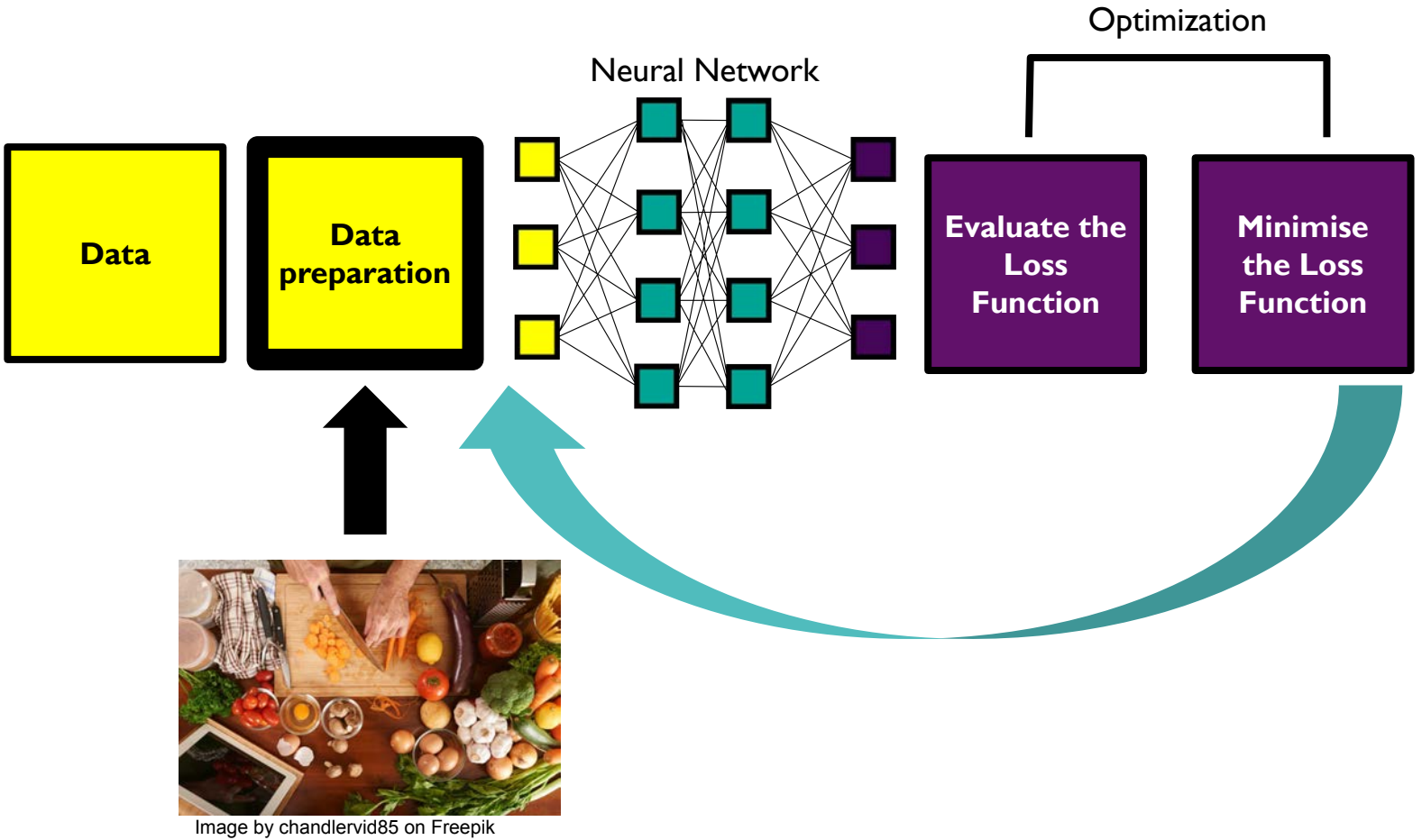
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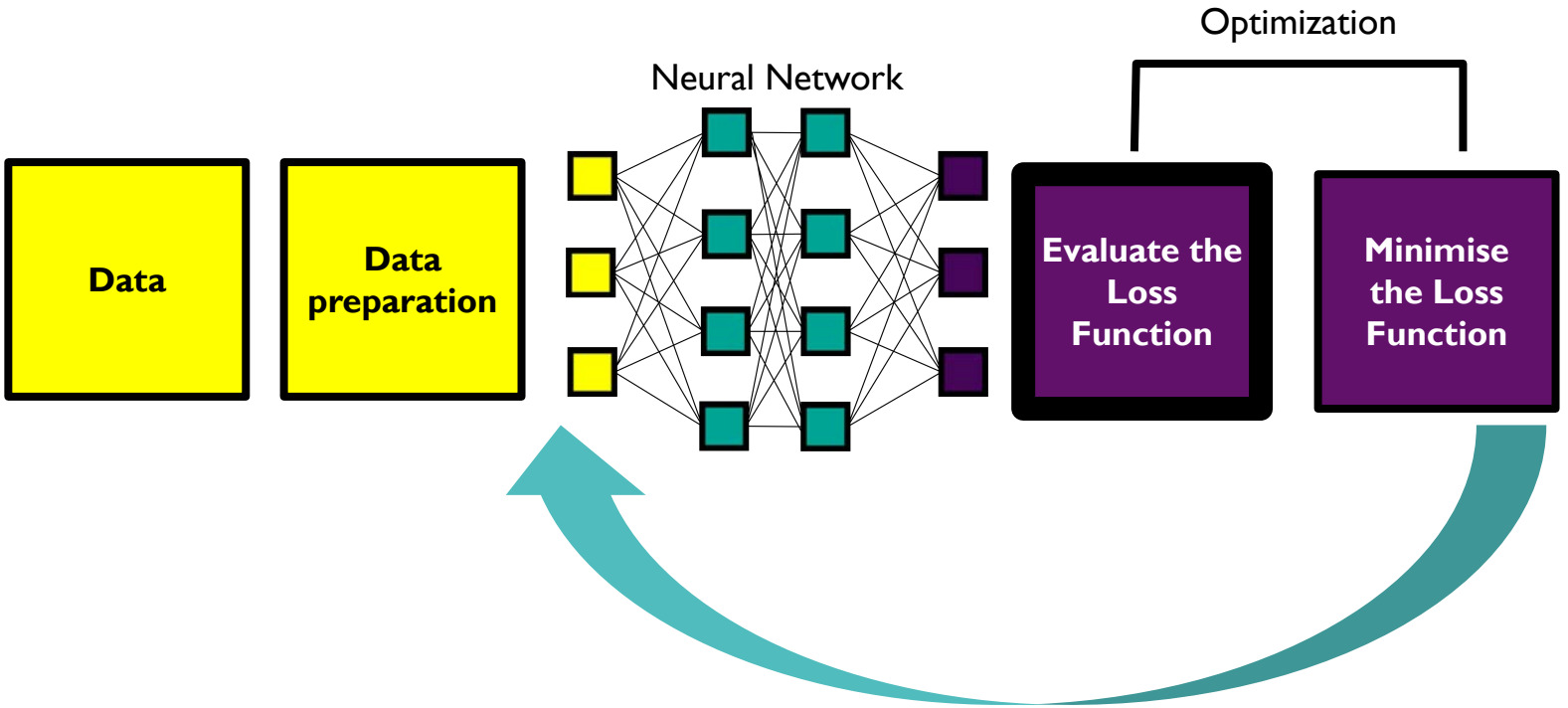
Image by chandlervid85 on Freepik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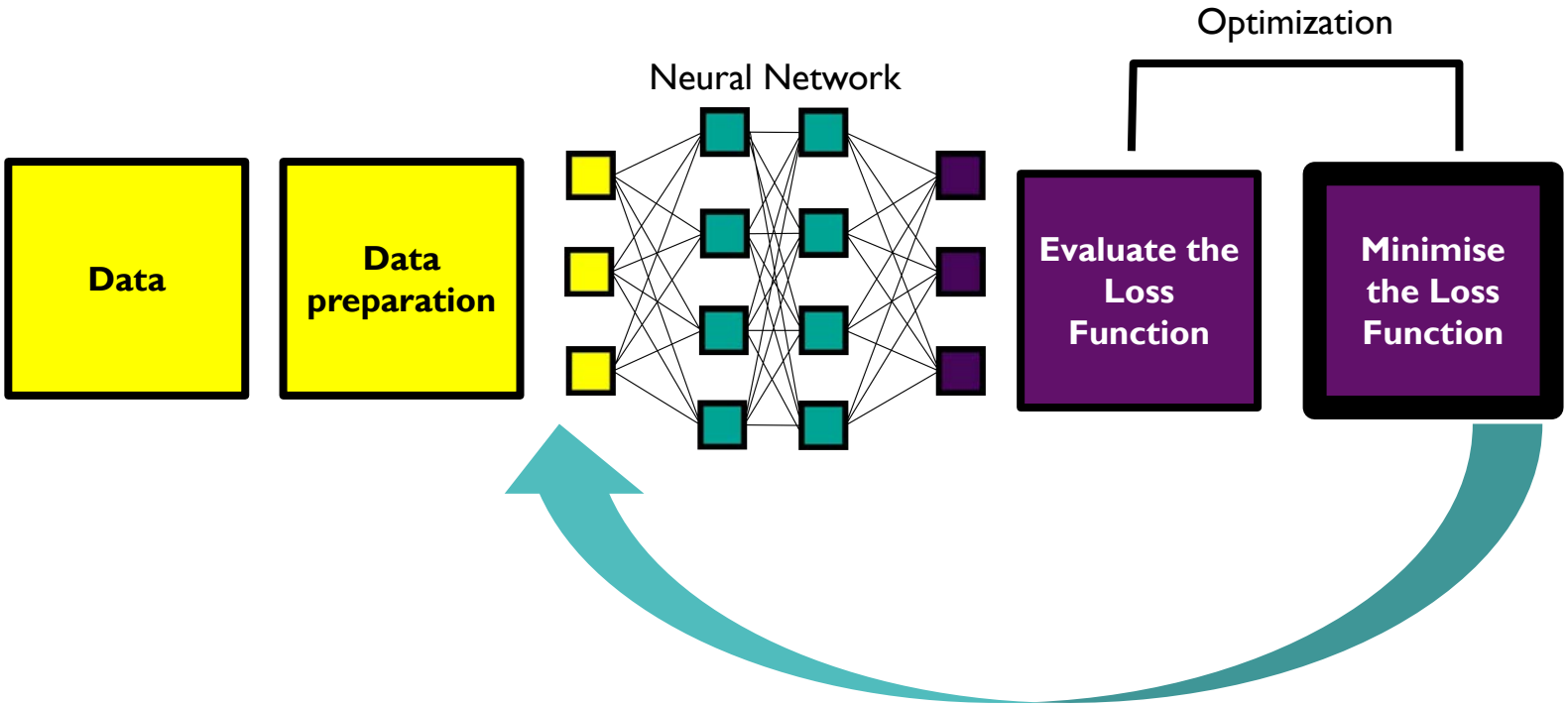
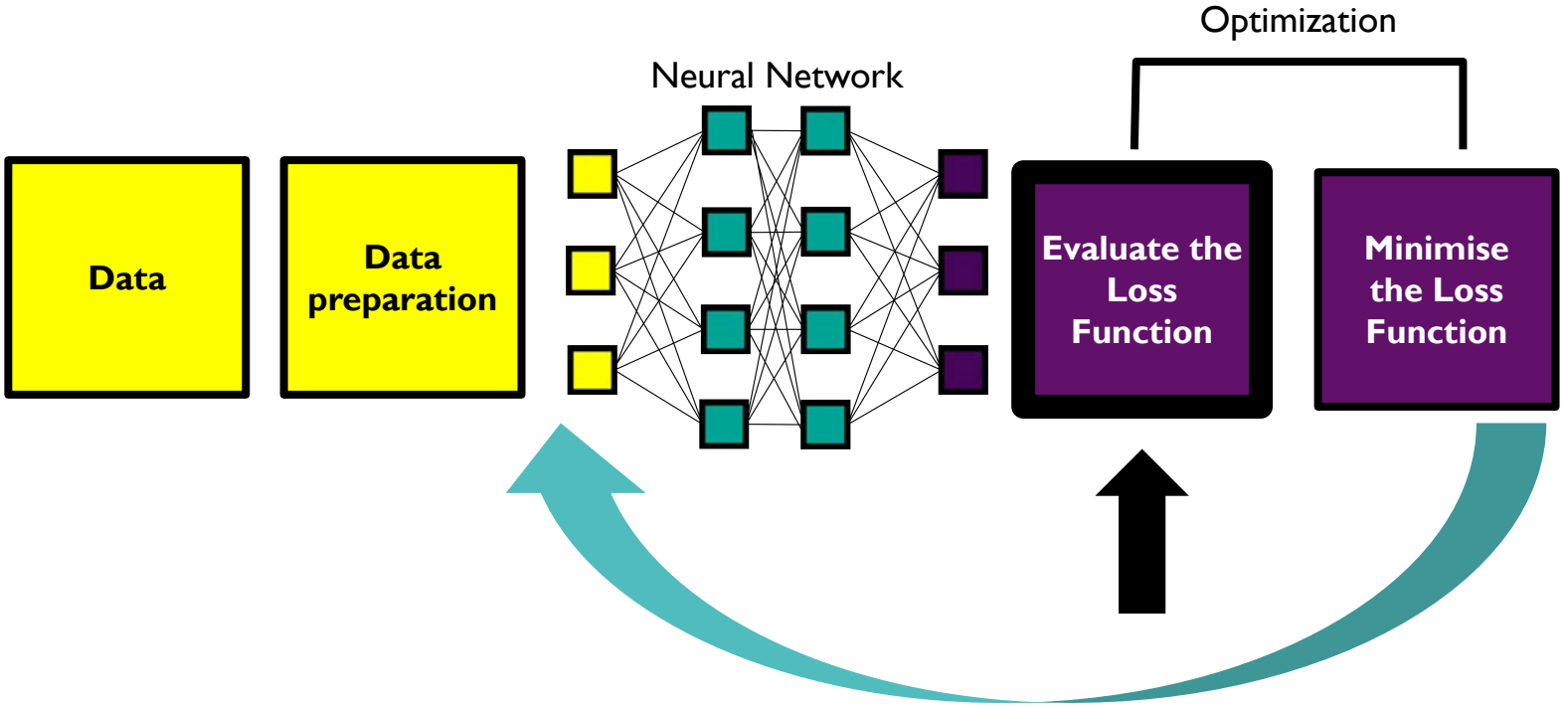


"The parameters in the neural network are adjusted multiple times to find the minimum Loss. Let me explain…"

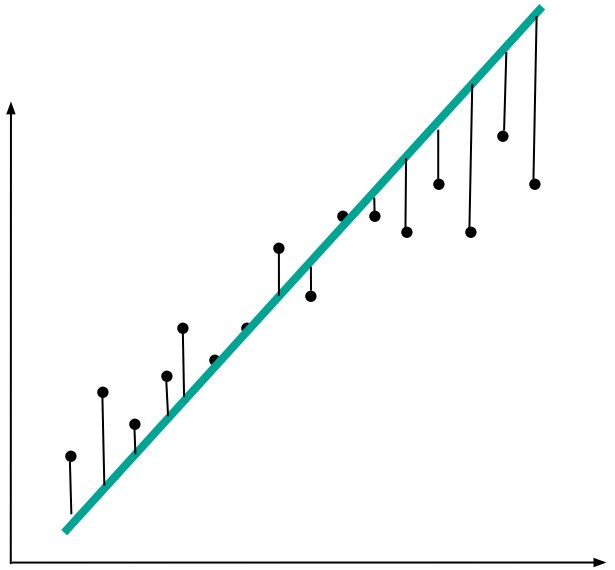


*"The **Loss Function** is the choice of the error function which is how the optimization algorithm is told how good the model is…"*

Optimization: Loss Function

“As a machine learning engineer, it is your responsibility to chose the loss function that best suits your problem.”

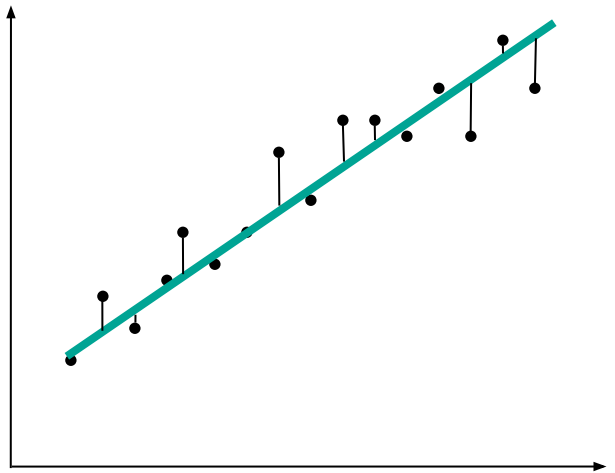
For example:



Optimization: Loss Function

“As a machine learning engineer, it is your responsibility to chose the loss function that best suits your problem.”

For example:



Optimization: Loss Function

"As a machine learning engineer, it is your responsibility to chose the loss function that best suits your problem."

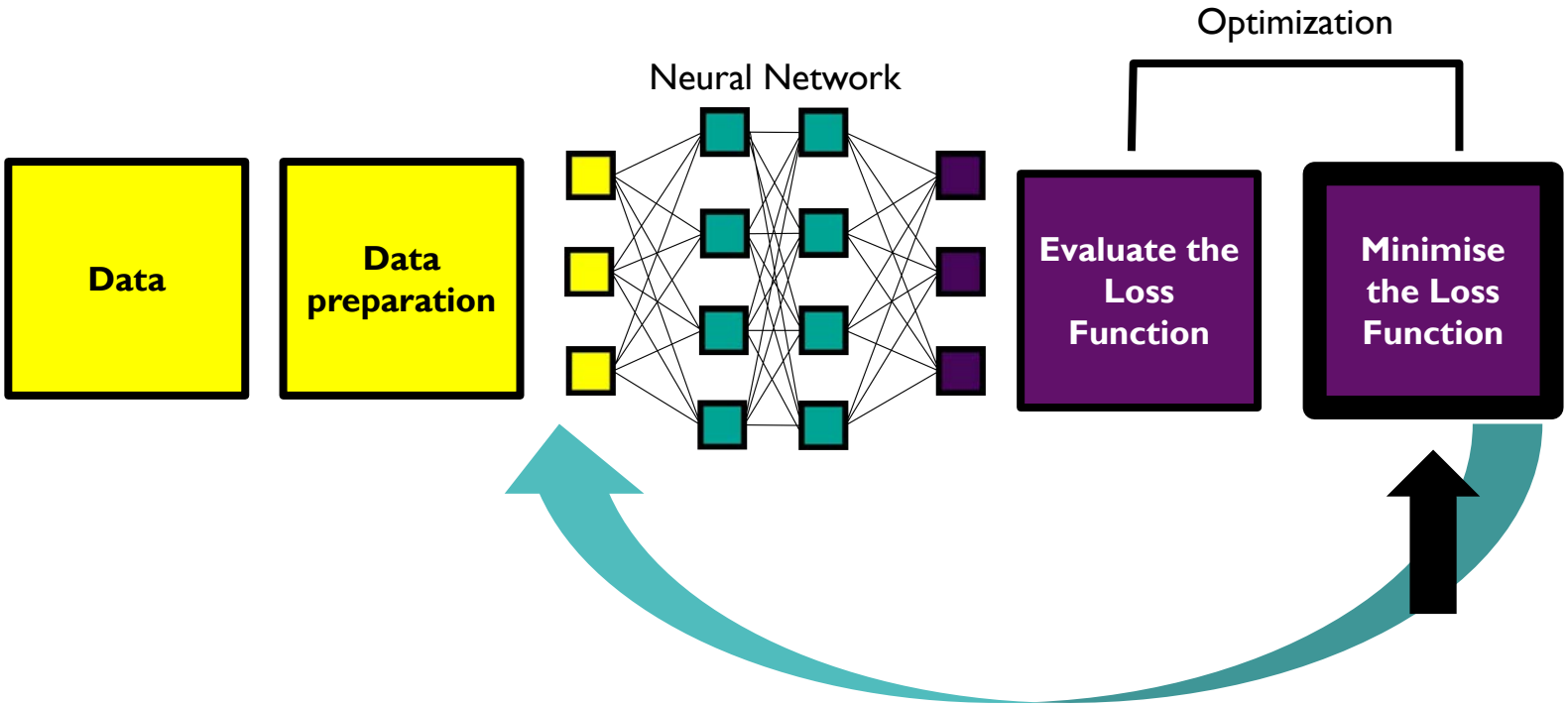
For example:

1) Mean Squared Error (MSE)
2) Mean Squared Logarithmic Error (MSLE)
3) Mean Absolute Error (MAE)

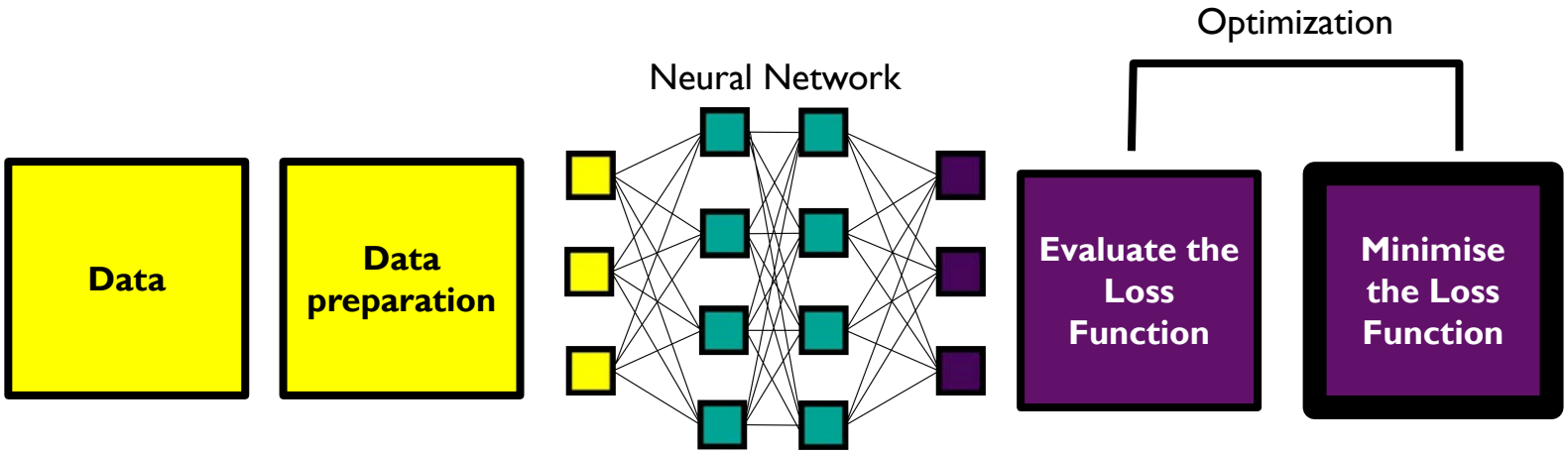
$$MSE = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}$$

$$MSLE = \frac{1}{n}\sum_{i=1}^{n}(\log(Y_i) - \log(\hat{Y}_i))^2$$

$$MAE = \frac{1}{n}\sum_{j=1}^{n}|y_j - \hat{y}_j|$$



*"...**Optimizers** are responsible for changing the weights, bias and learning rate of the neurons in the neural network to reach the minimum loss function."*



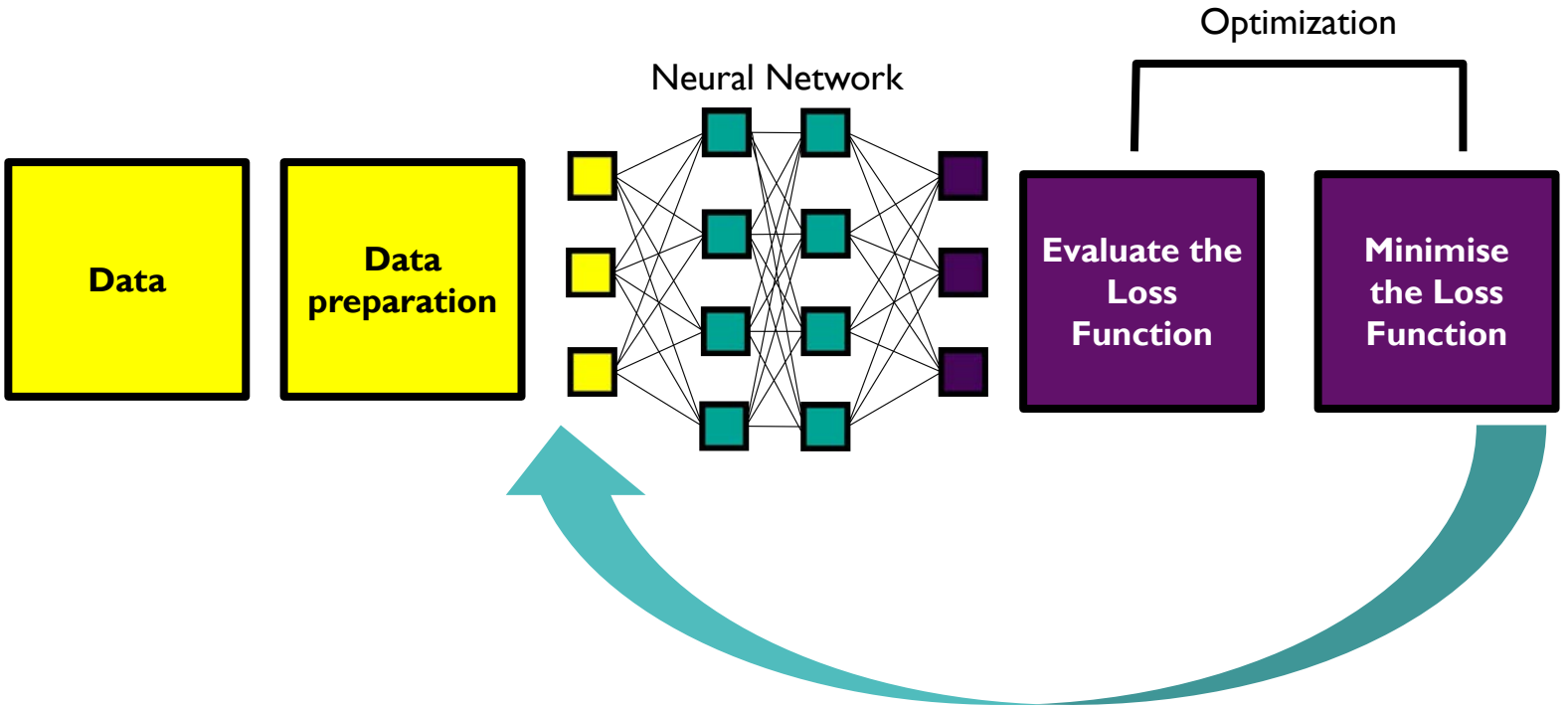
New weights and bias

Learning Rate

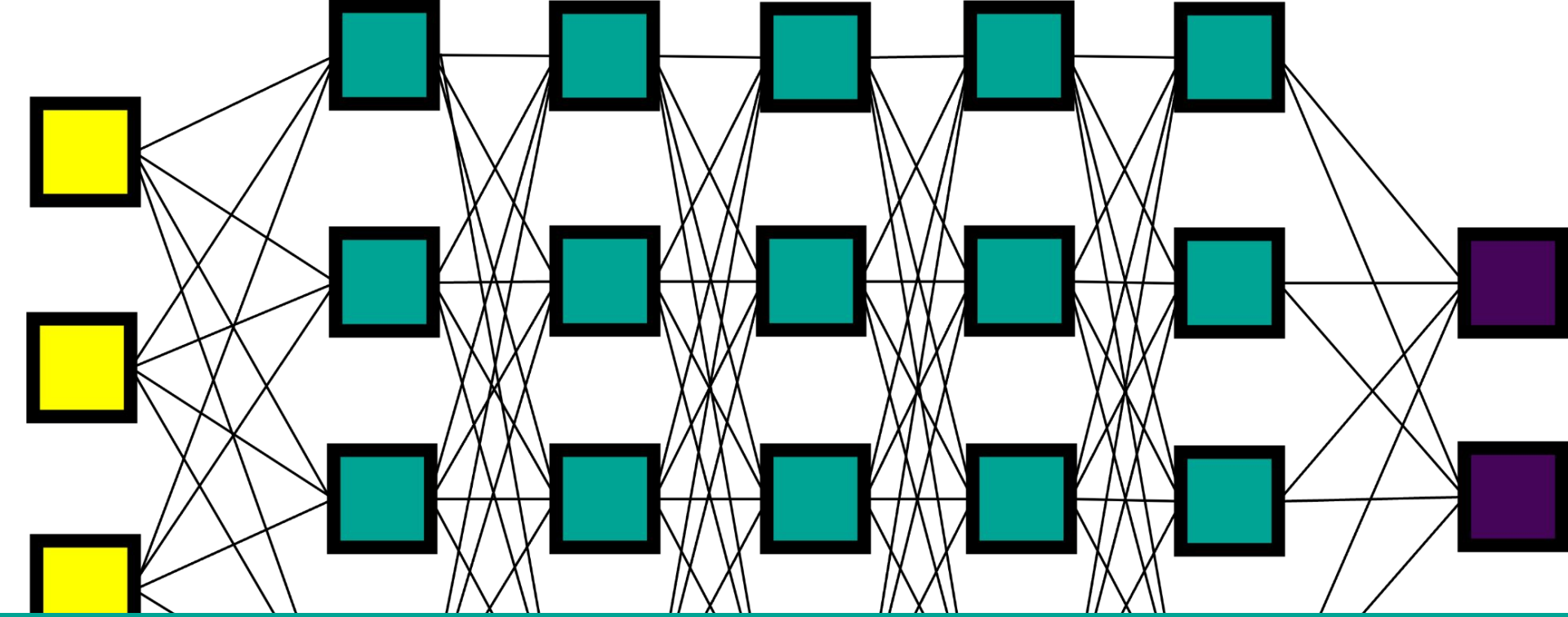
Loss Function

$$\theta_t = \theta_{t-1} - \alpha_t \nabla_{\theta_{t-1}} L_t$$

Current weights and bias

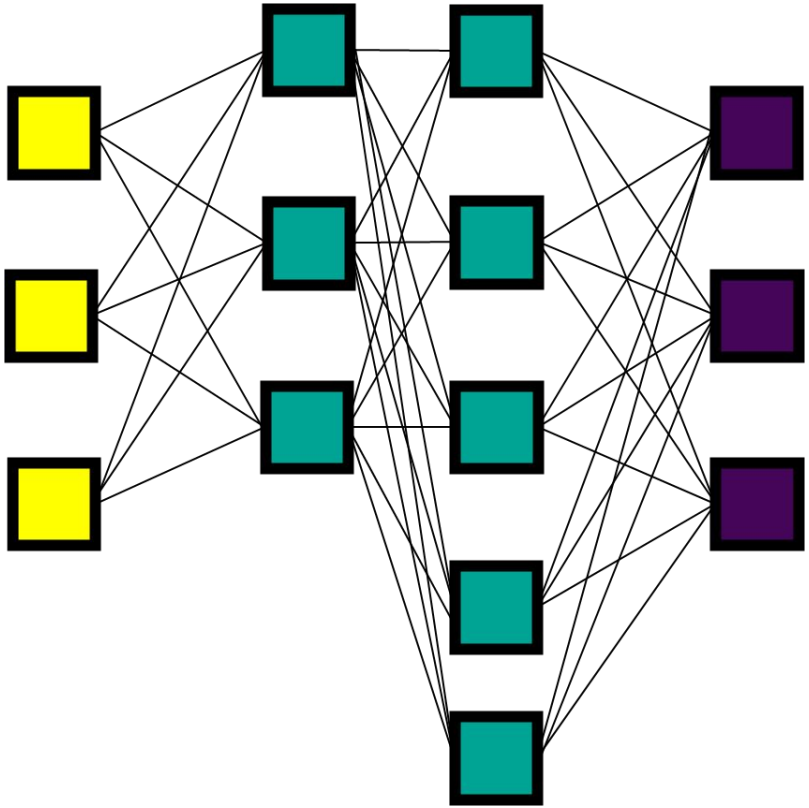


…this is how a neural network learns.

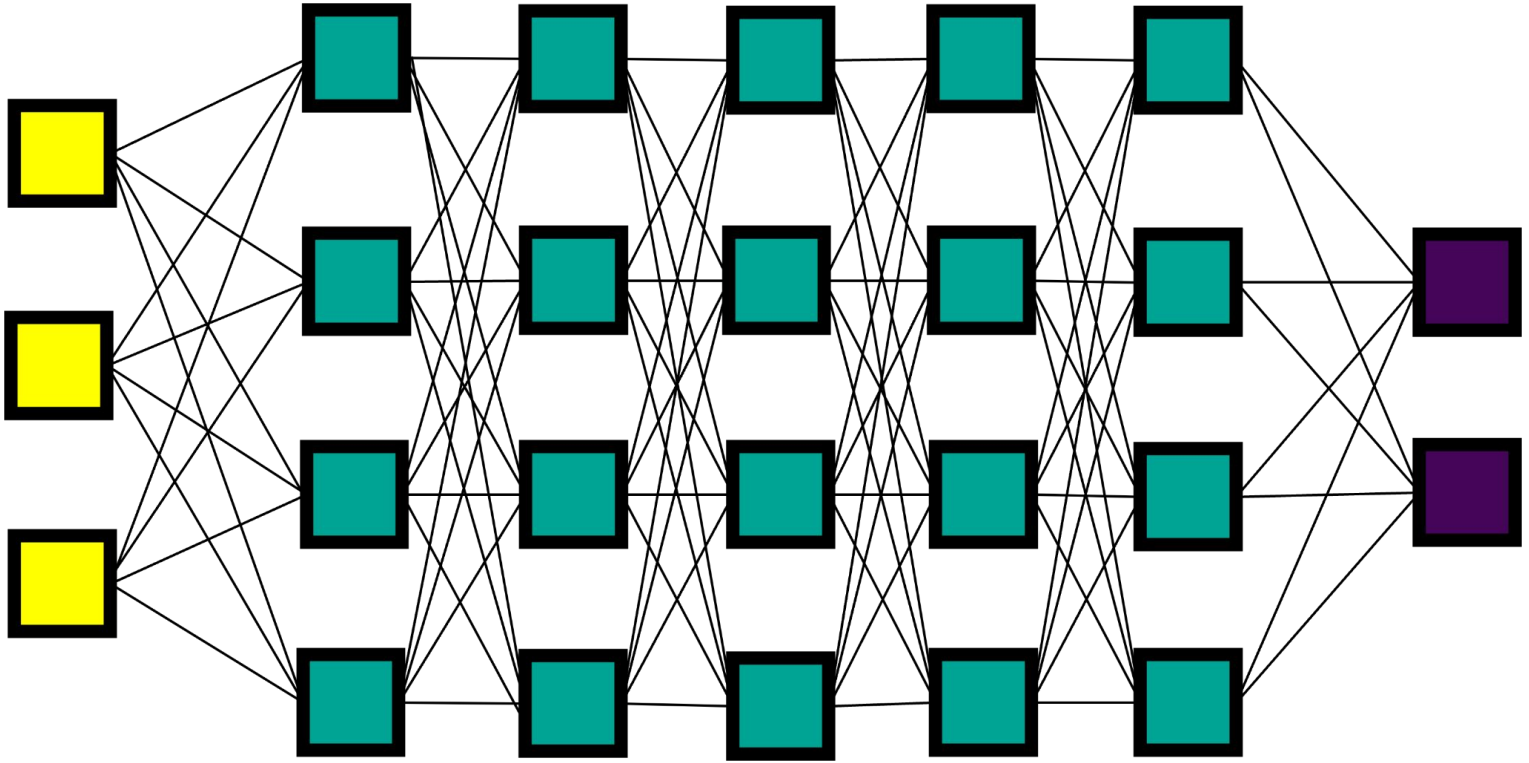


In order for the neural network to learn the neural network architecture may need to be adjusted…

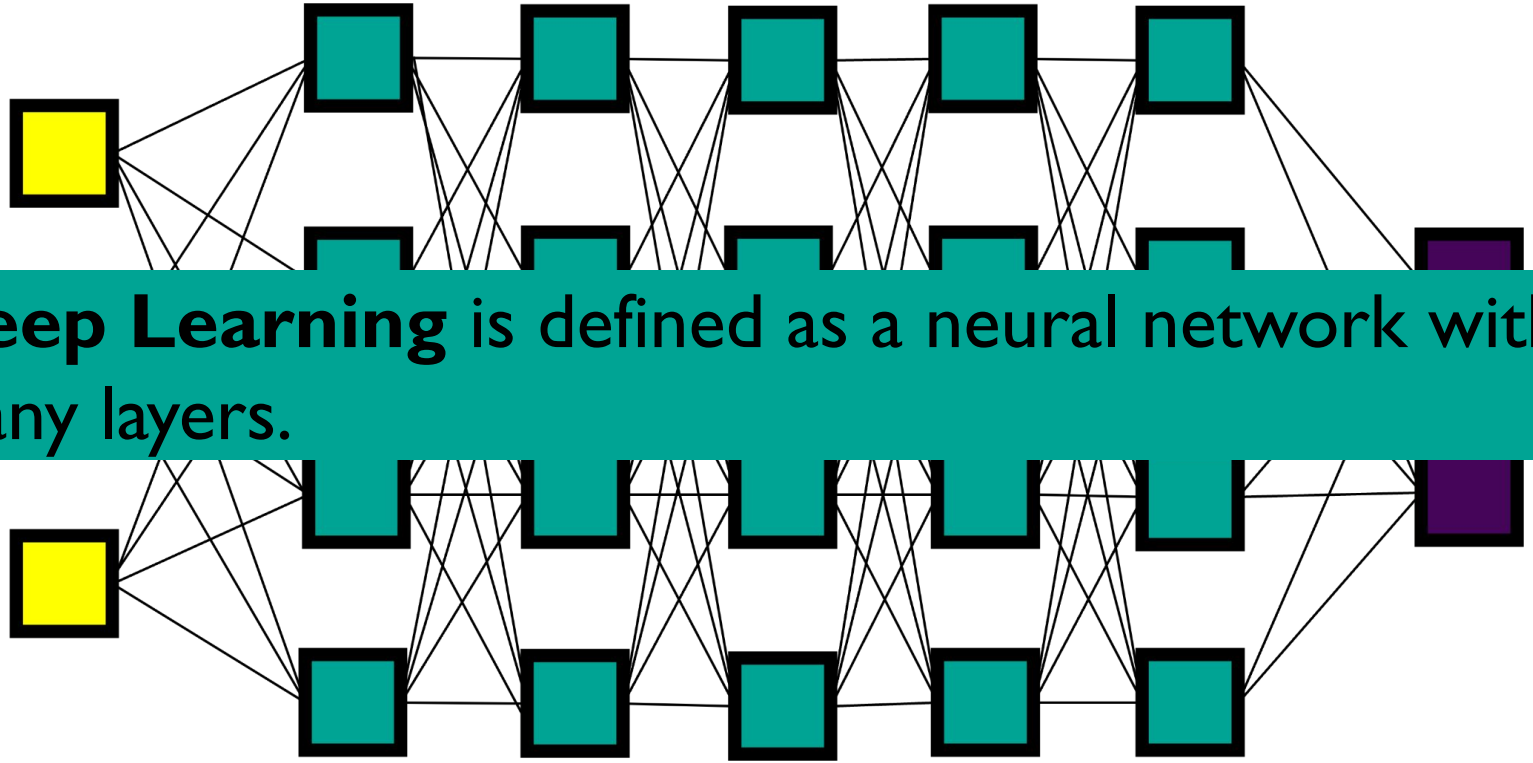
E.g. vary the width of the neural network…



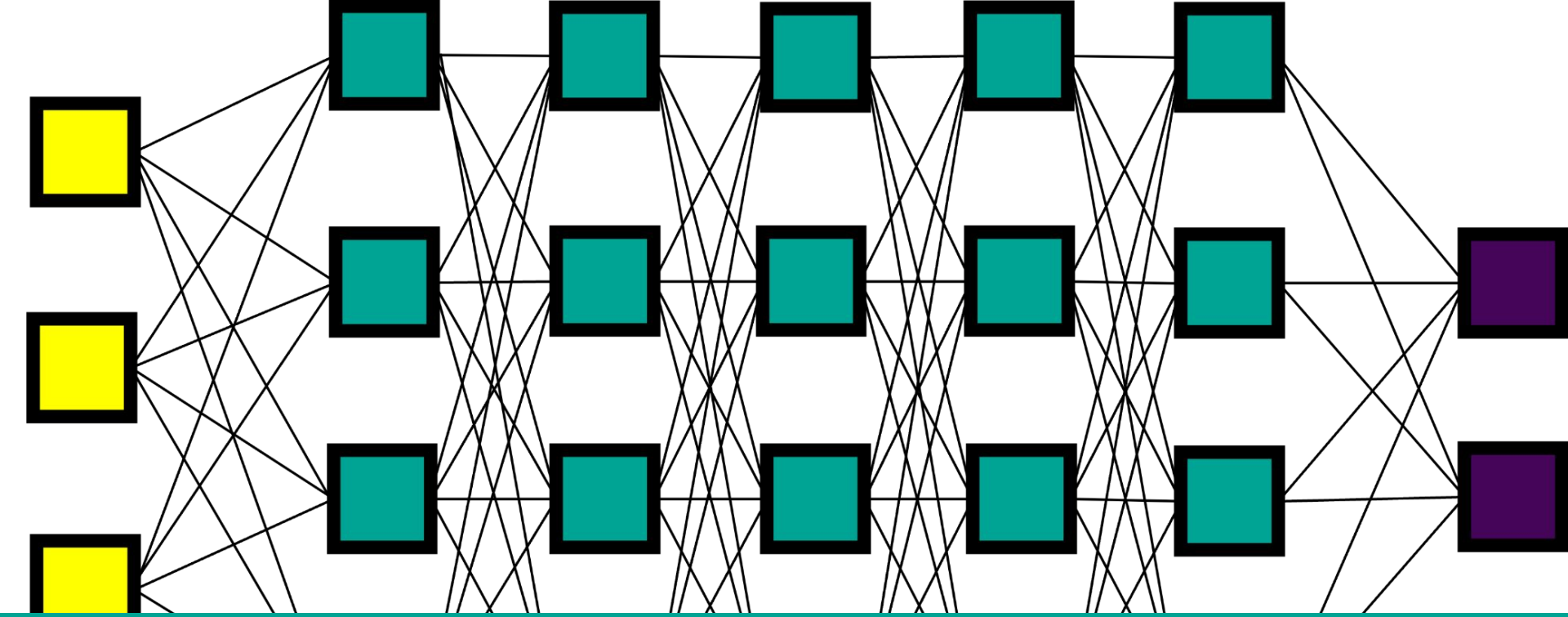
E.g. vary the depth of the neural network…



Vary the depth of the neural network…



Deep Learning is defined as a neural network with many layers.



… it is up to a machine learning engineer to adjust the neural network architecture so that the machine ‘learns’.

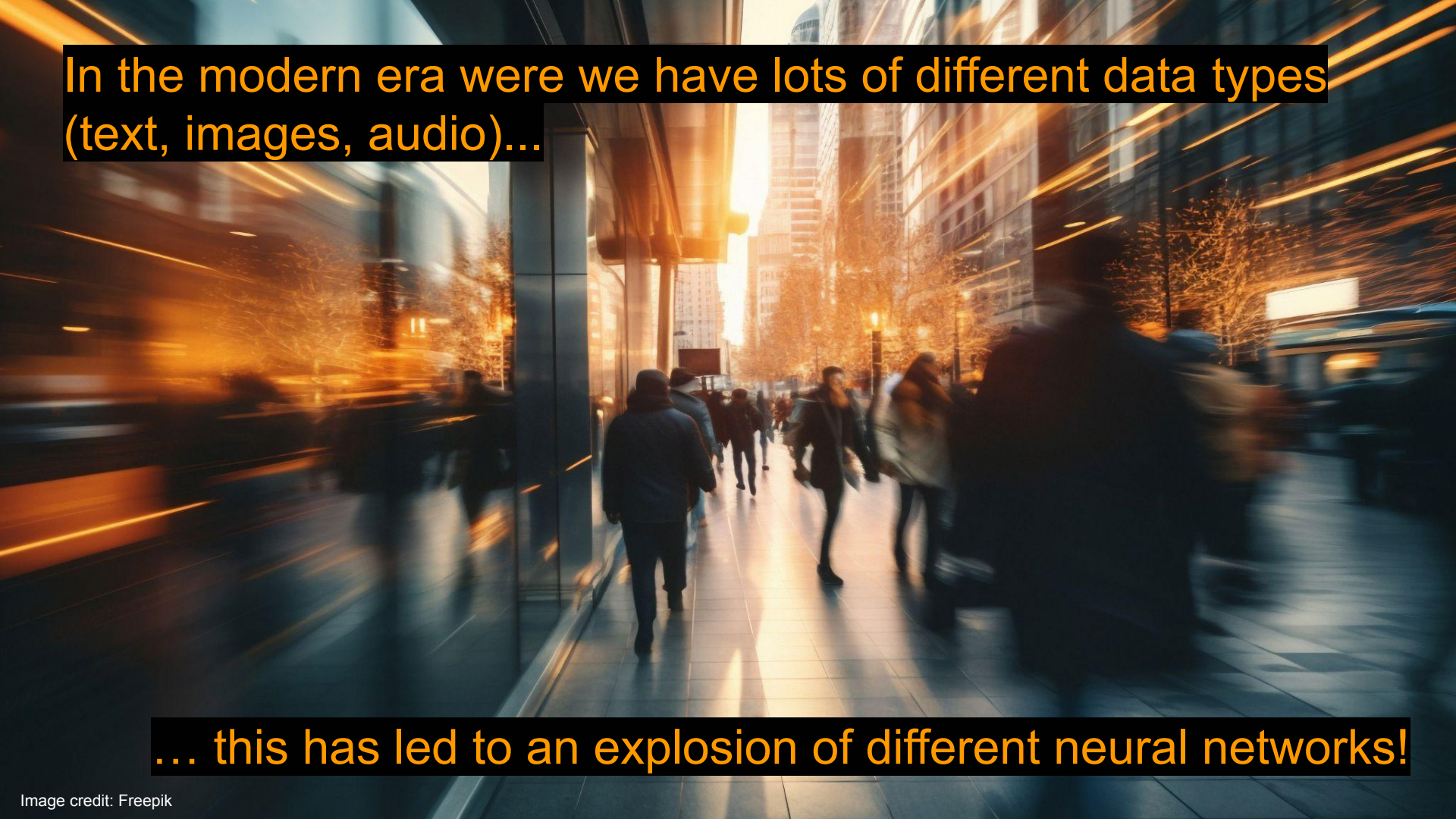
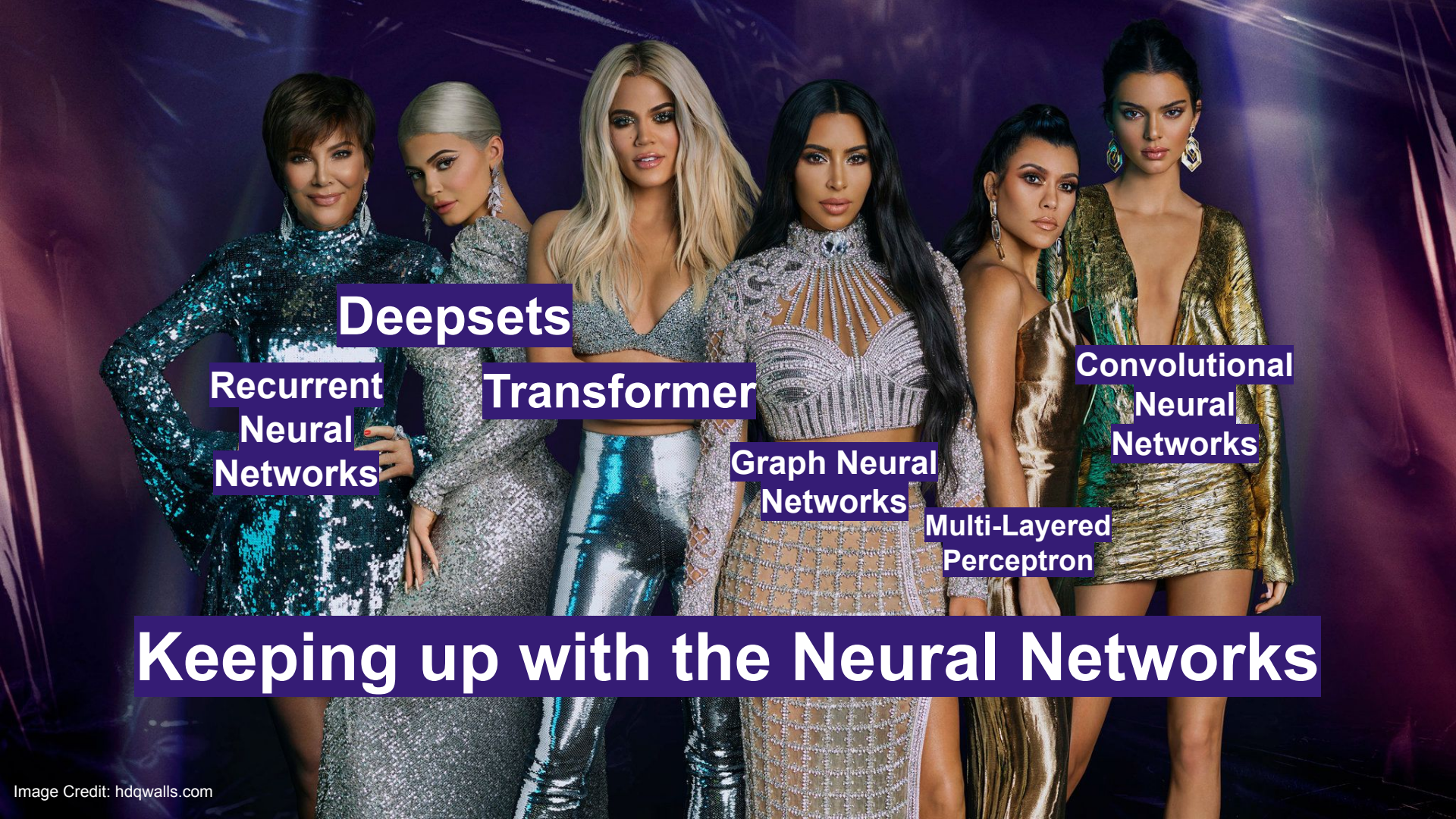
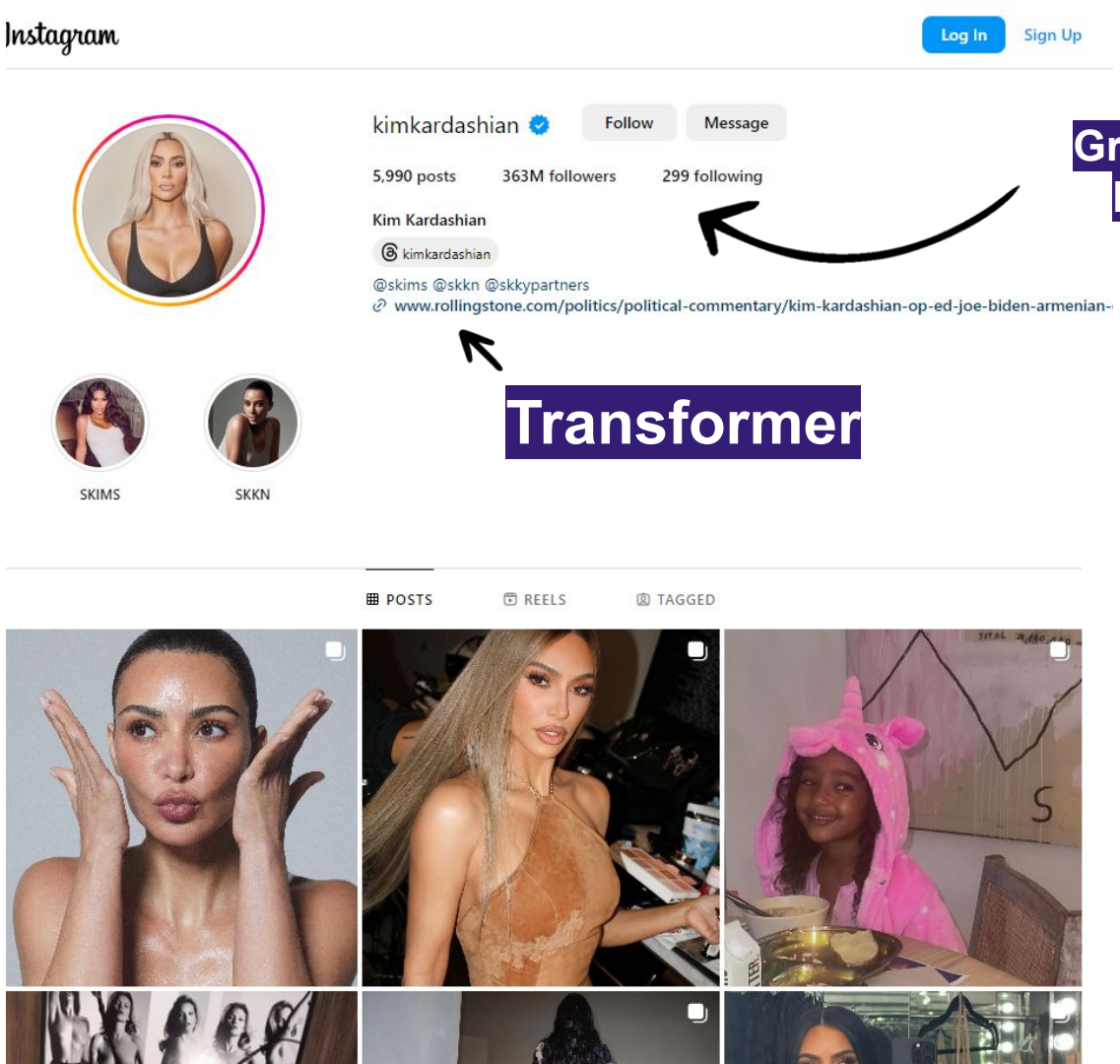


Image credit: Freepik


Deepsets
Recurrent Neural Networks
Transformer
Graph Neural Networks
Convolutional Neural Networks
Multi-Layered Perceptron
Keeping up with the Neural Networks
Image Credit: hdqwalls.com



Graph Neural Networks

Transformer

Convolutional Neural Networks

Image Credit: Hulu

Convolutional Neural Networks

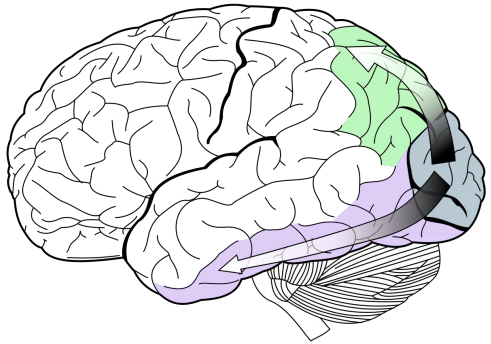
Image Credit: Antonello Trio/Getty images

Convolutional Neural Networks

It is an artificial neural network that features one or more convolutional layers

Image Credit: Antonello Trio/Getty images

How do **Humans** process **visual information**?



Dog

Image Credit: sheltieplanet.com and Selket (wiki)

Did you know that it takes your brain 100 milliseconds to process an image.

True or False?

Image by master1305on Freepik

Did you know that it takes your brain 100 milliseconds to process an image.

False

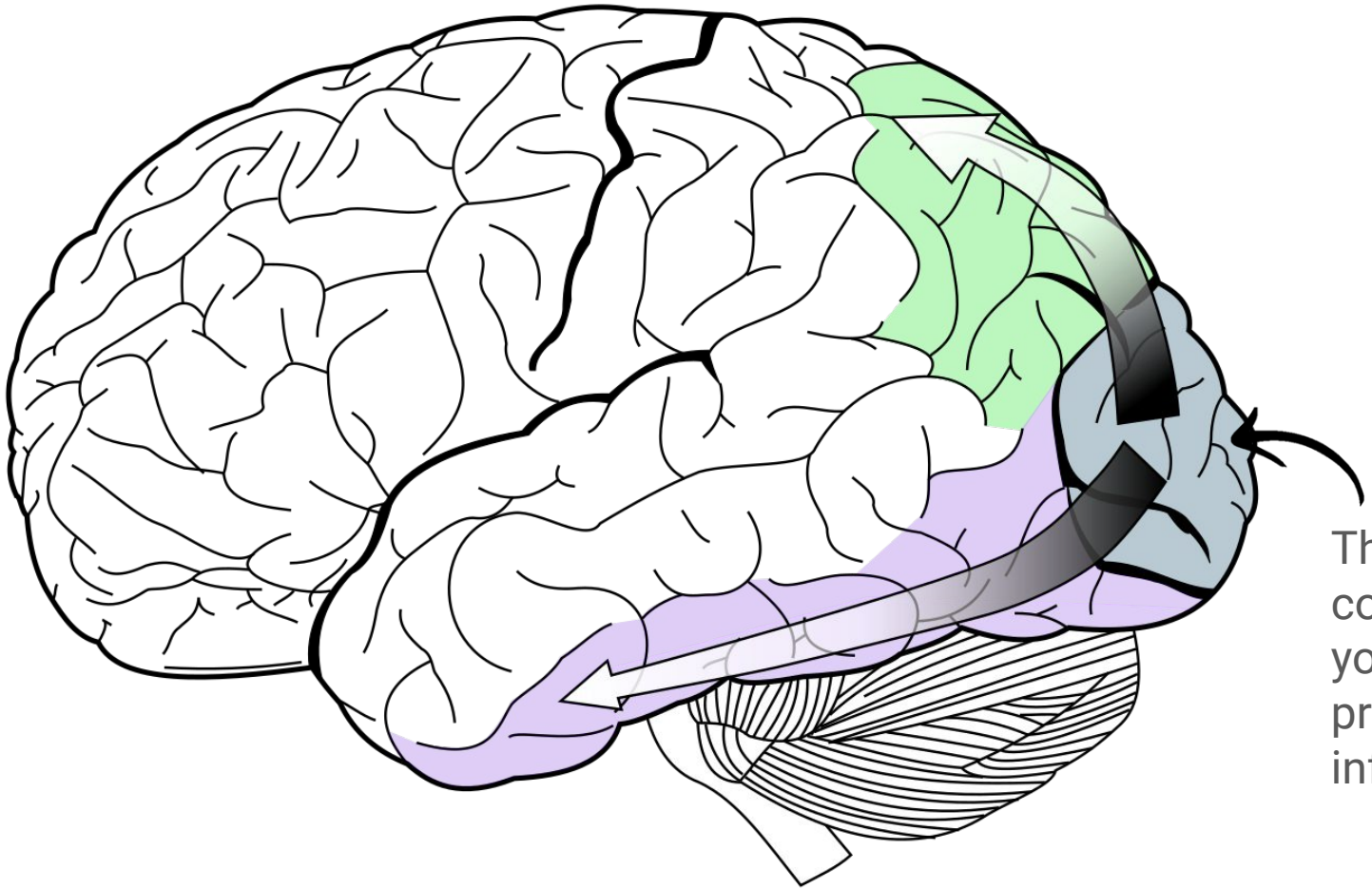
Image by master1305on Freepik

Did you know that it takes your brain 100 milliseconds to process an image.

False

“A team of neuroscientists from MIT has found that the human brain can process entire images that the eye sees for as little as 13 milliseconds”
- Anne Trafton

Image by master1305on Freepik

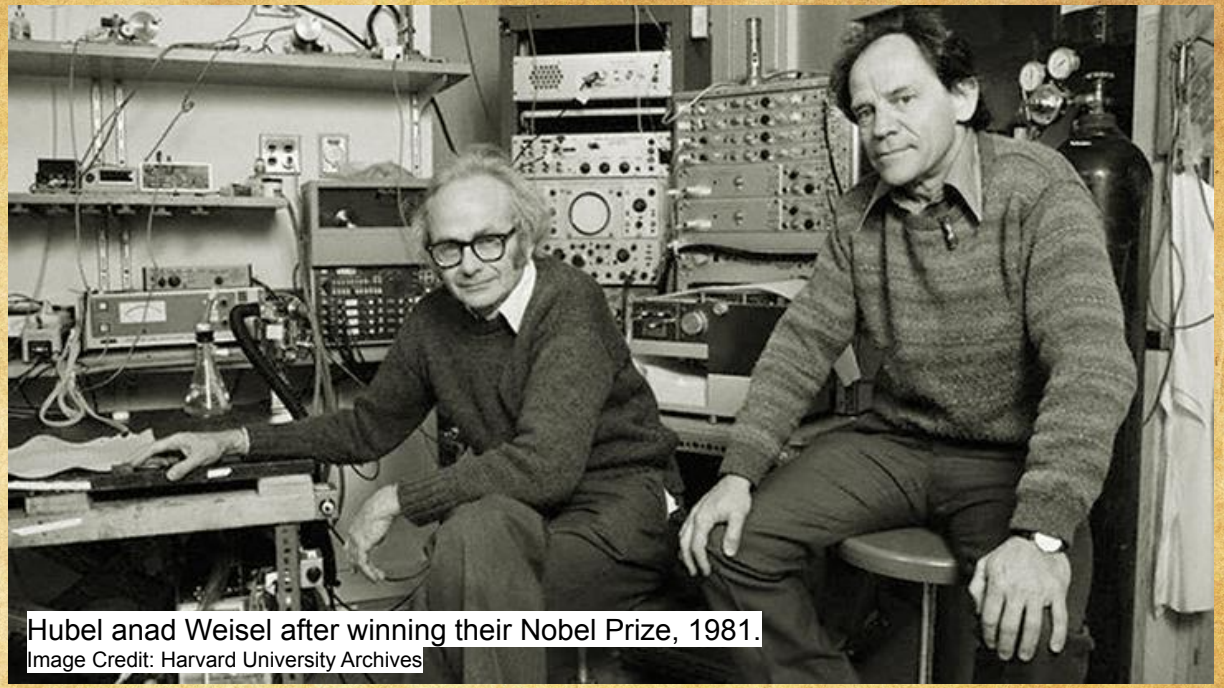


The visual cortex is where your brain processes visual information.

Image Credit: Selket (Wiki)

How do we know this?

Image Credit: wayhomestudio on Freepik



Hubel anad Weisel after winning their Nobel Prize, 1981.
Image Credit: Harvard University Archives

In the 1950s at Johns Hopkins University, the David Hubel and Torsten Wiesel performed pioneering research of how visual information is processed in the brains of mammals.

David and Torsten set up the following experiment…

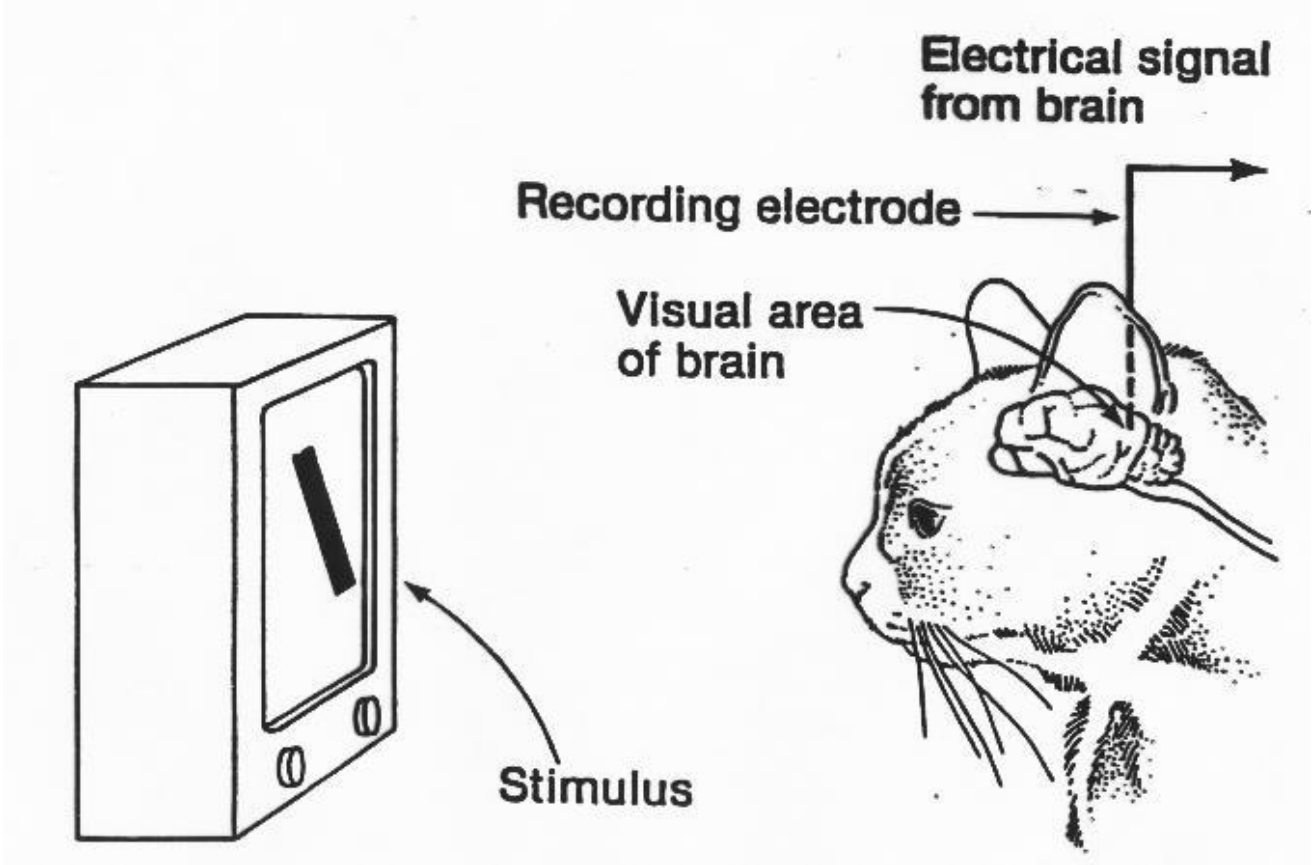


Image Credit: goodpsychology.wordpress.com

…and concluded that the cat's primary visual cortex neurons were only stimulated by certain angles of orientation

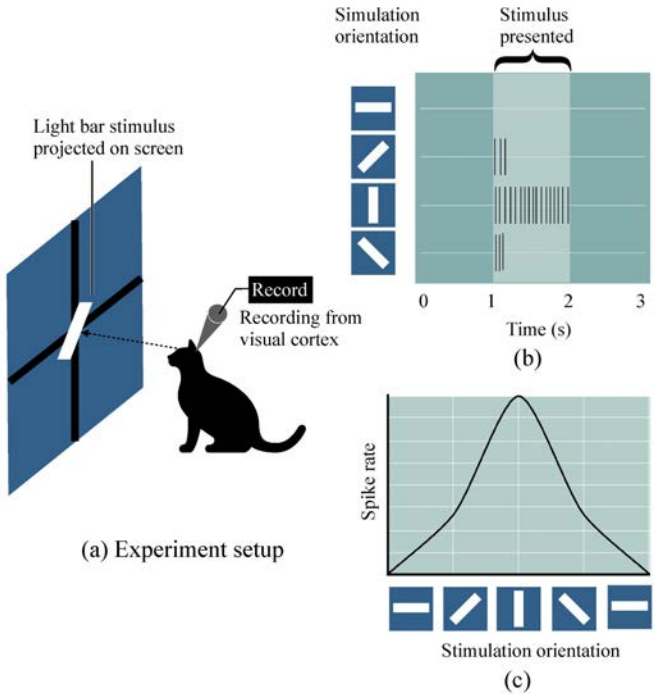
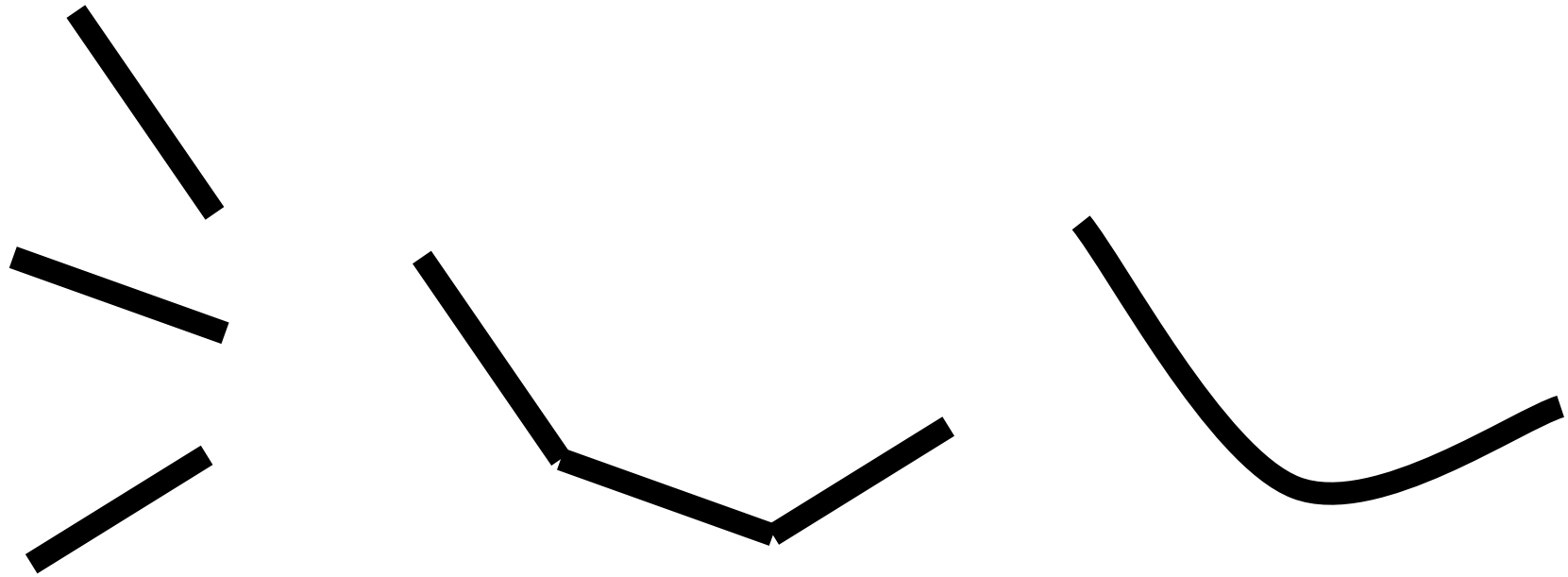


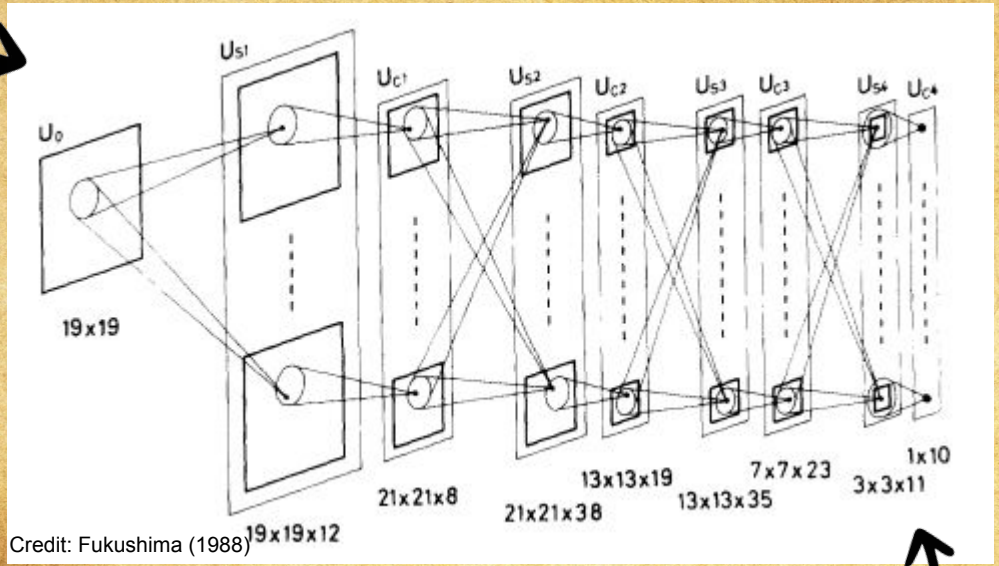
Figure 1. A neuron in the primary visual cortex responds selectively to line segments. Credit: Bin Li et al. (2022)



Simple neurons

Complex neurons

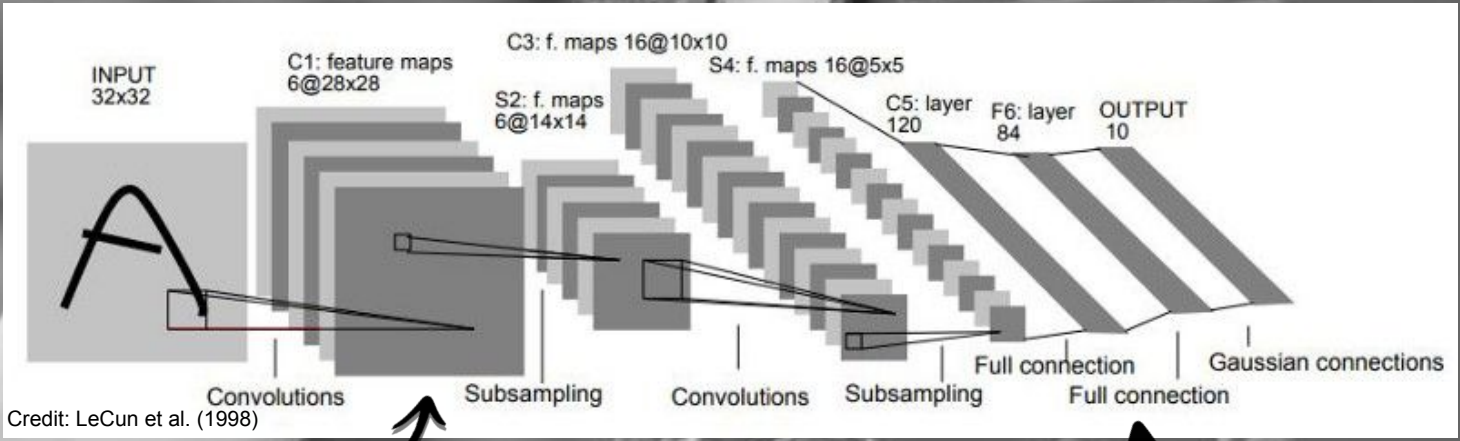
This is **Neocognition**, is the first convolutional neural network architecture.



Credit: Fukushima (1988)


fi.edu/en/awards/laureates/kunihiko-fukushima

This is **Neocognition** was able to categorize handwritten digits.



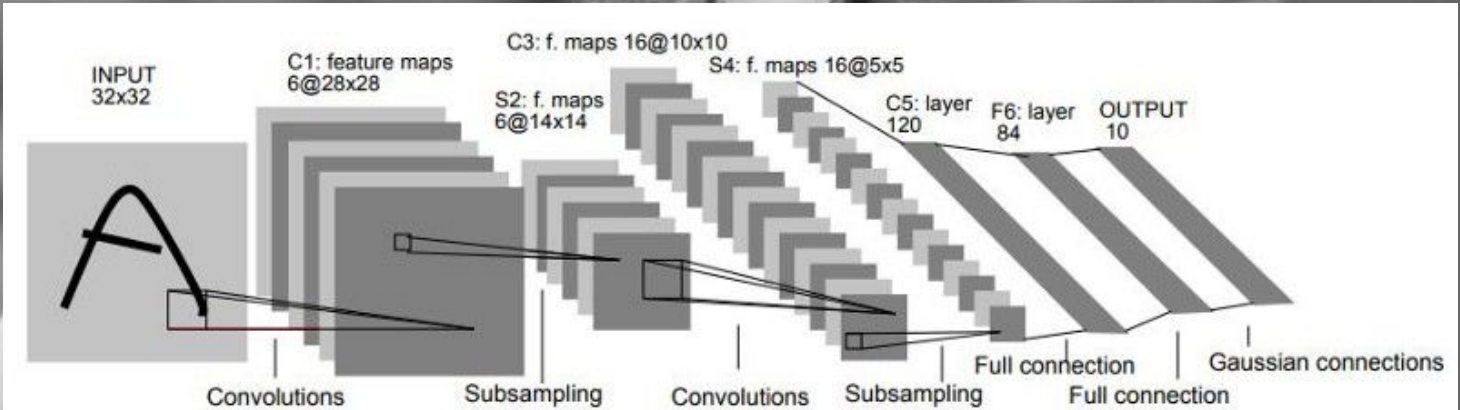
Credit: LeCun et al. (1998)

Convolutional layer

Neural Network

Image Credit: Royal Mail

Example: LeNet - 5

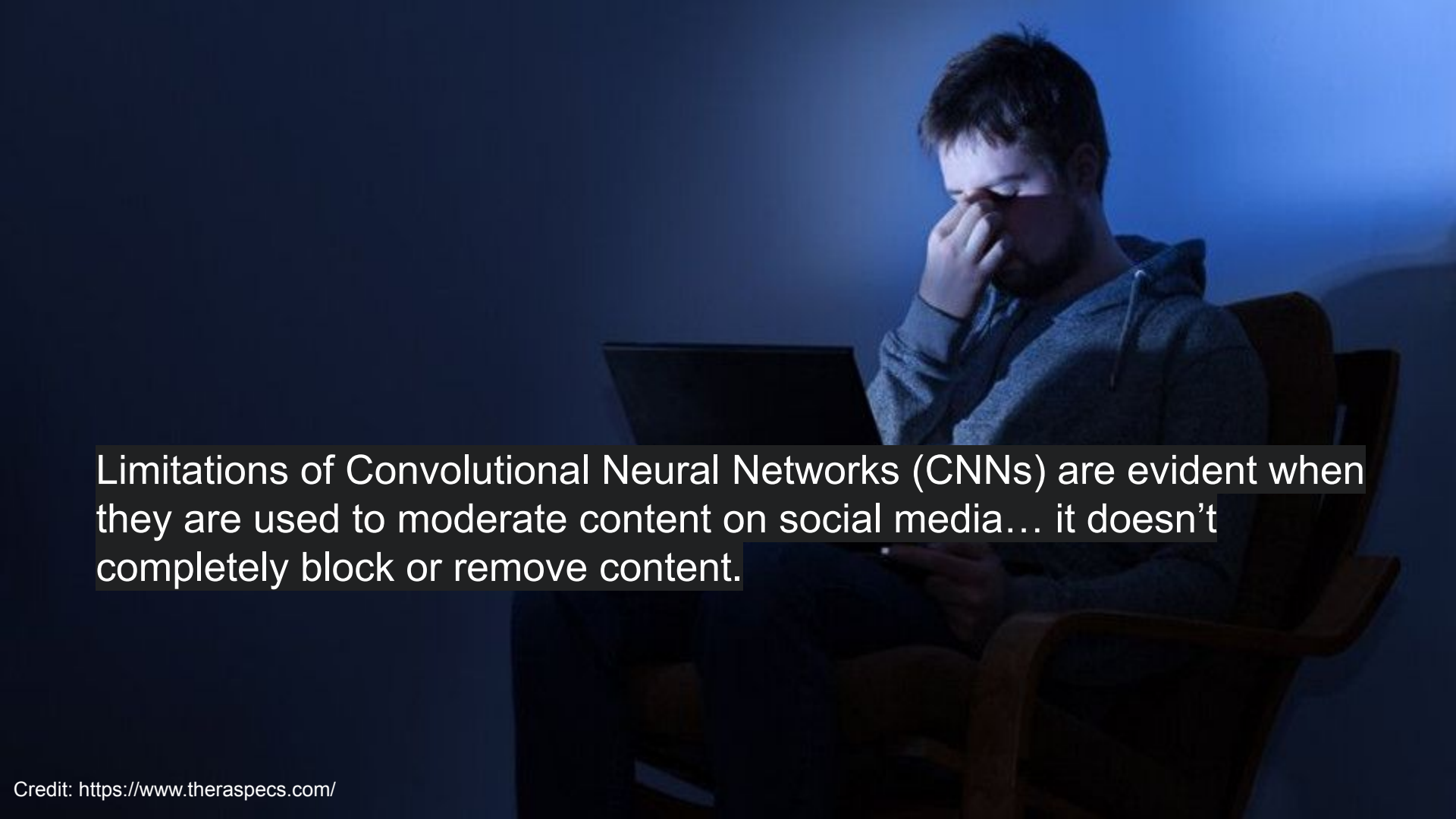


Credit: LeCun et al. (1998)

The neural network architecture shown above is called LeNet 5 and is used in the postal service.

Image Credit: Royal Mail

Convolutional neural networks are not **perfect**.



Limitations of Convolutional Neural Networks (CNNs) are evident when they are used to moderate content on social media… it doesn’t completely block or remove content.

Credit: https://www.theraspecs.com/

ImageNet

ImageNet is publicly released dataset containing 14 million labelled images and is used in classification and object detection tasks.

ImageNet

CNN's struggle with different lighting, extreme angles and parts of the object.

Machine learning is not about ‘thinking like a human’

Image by Freepik

World

Insight - Amazon scraps secret AI recruiting tool that showed bias against women

By **Jeffrey Dastin**

October 11, 2018 1:50 AM GMT+

Apple Card Investigated After Gender Discrimination Complaints

A prominent software developer said on Twitter that the credit card was "sexist" against women applying for credit.

INTERNET CULTURE

Google's algorithm shows prestigious job ads to men, but not to women. Here's why that should worry you.

By Julia Carpenter

July 6, 2015 at 4:43 p.m. EDT

POLICY

Predictive policing is still racist—whatever data it uses

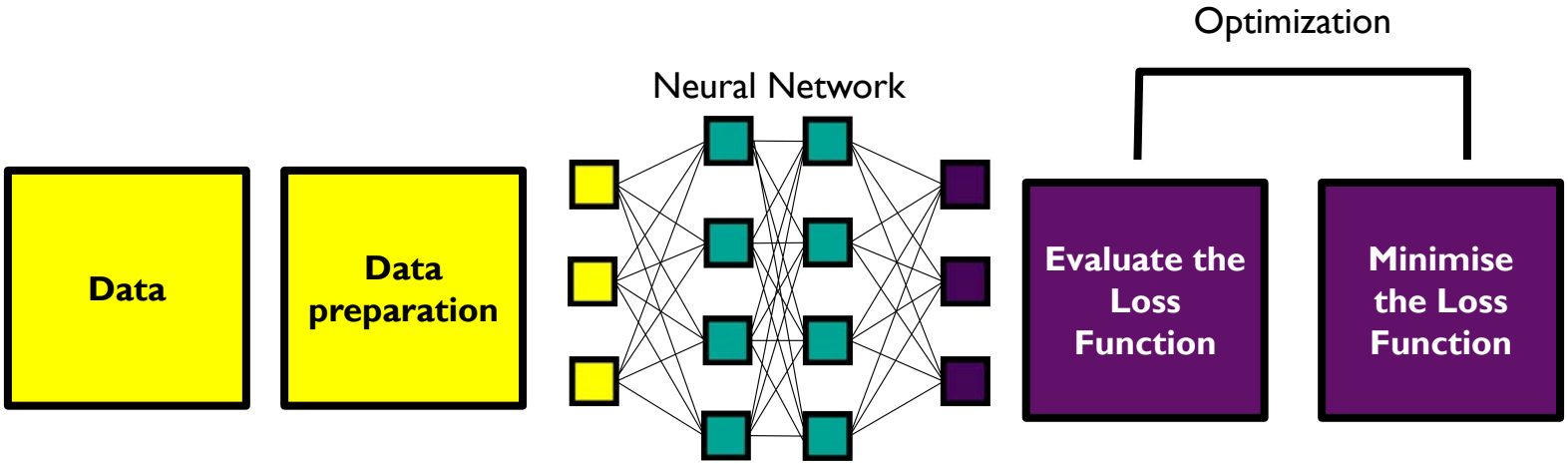
Training algorithms on crime reports from victims rather than arrest data is said to make predictive tools less biased. It doesn't look like it does.

By Will Douglas Heaven

February 5, 2021

How is **bias** introduced?

Bias can be injected into a machine learning pipeline at various stages…



…including how the problem is framed.

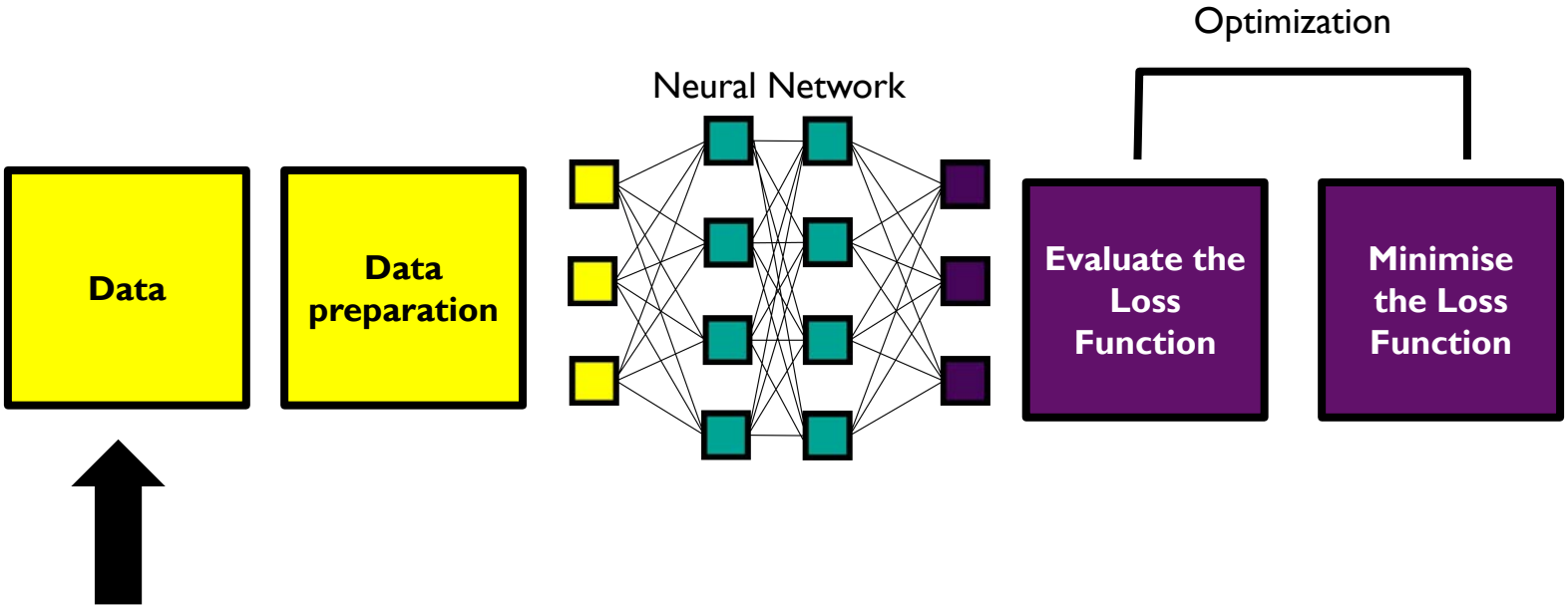
You’re machine learning engineers, let’s predict whether England will win the Euros 2024.

Credit: sky

Credit: sky

Credit: Sky

Bias can be injected into a machine learning pipeline at various stages…



…including how the problem is framed.

Nom. goals scored

Hobbies

Height

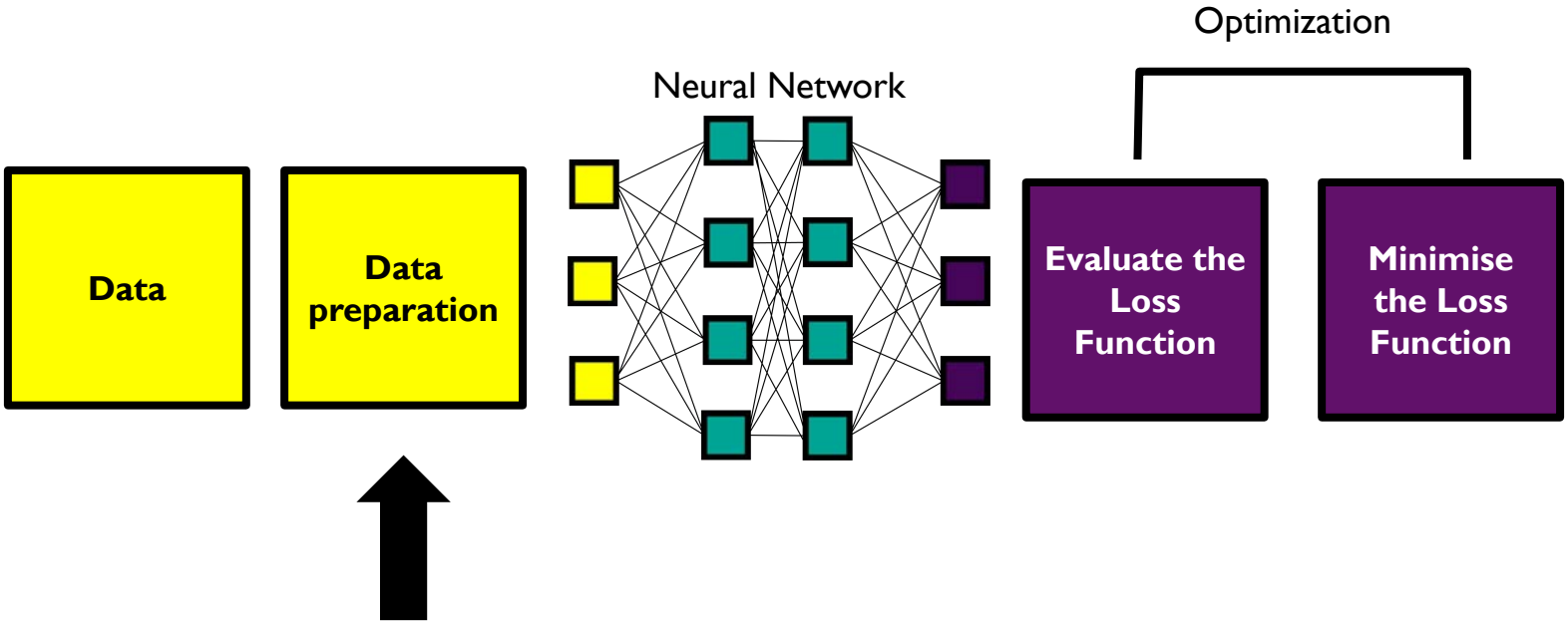
Nom. red cards

Hair Colour

Goal attempts

Credit: Sky

Bias can be injected into a machine learning pipeline at various stages…



…including how the problem is framed.

Nom. goals scored

Height

Nom. red cards

Goal attempts

Credit: Sky

Junk in = Junk out

Why is machine learning bias hard to fix?

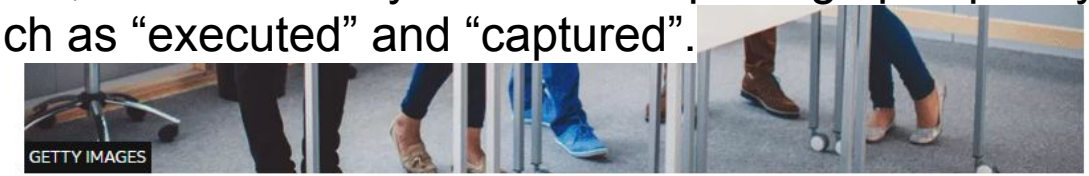
1) Not obvious

Credit: technologyreview.com

Amazon scrapped 'sexist AI' tool

10 October 2018

The neural network was reprogrammed to ignore explicitly gendered words, like “woman”, but then the system started picking up implicitly gendered words, such as “executed” and “captured”.



The algorithm repeated bias towards men, reflected in the technology industry

An algorithm that was being tested as a recruitment tool by online giant Amazon was sexist and had to be scrapped, according to a Reuters report.

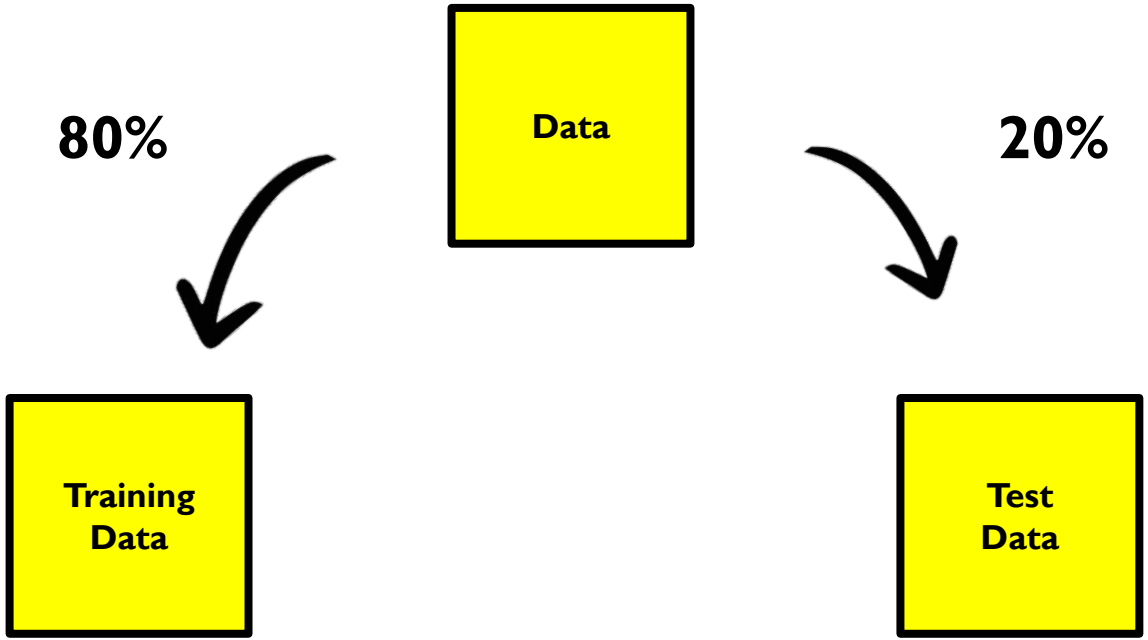
The artificial intelligence system was trained on data submitted by applicants over a 10-year period, much of which came from men, it claimed.

Credit: BBC

Why is it hard to fix?

1) Not obvious
2) Imperfect process

Credit: technologyreview.com


80%
Data
20%
Training Data
Test Data

Why is it hard to fix?

1) Not obvious
2) Imperfect process
3) Lack of social context

Credit: technologyreview.com

United Kingdom

Image Credit: gpointstudio on Freepik

India

Image Credit: rawpixel.com on Freepik

Why is it hard to fix?

1) Not obvious
2) Imperfect process
3) Lack of social context
4) The definitions of fairness

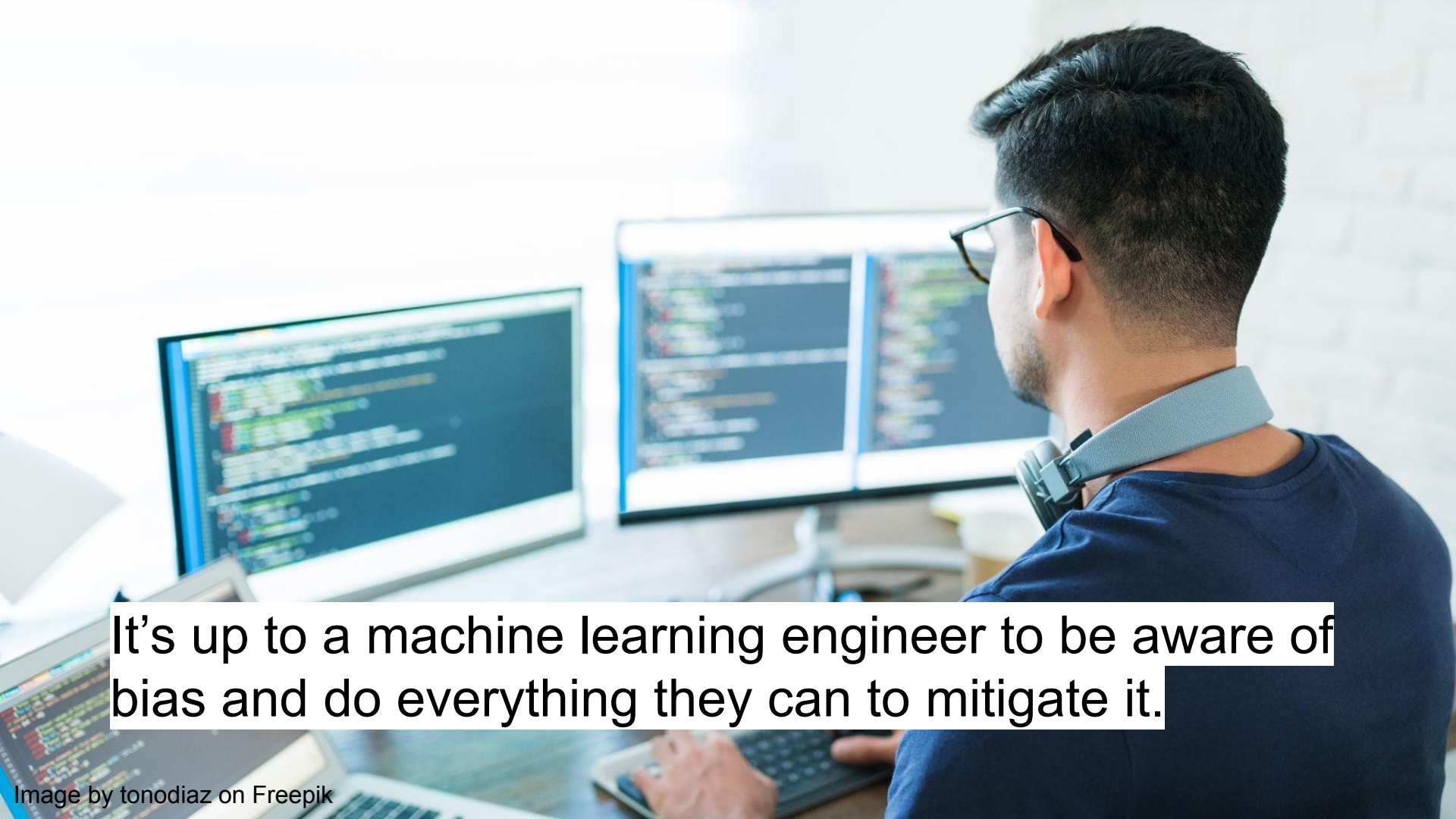
Credit: technologyreview.com

What is ‘fairness’?

50% of men and 50% of women are considered high risk?

Everyone considered high risk?

Image Credit: Freepik



It’s up to a machine learning engineer to be aware of bias and do everything they can to mitigate it.

Image by tonodiaz on Freepik

Maybe **you** could be the solution?

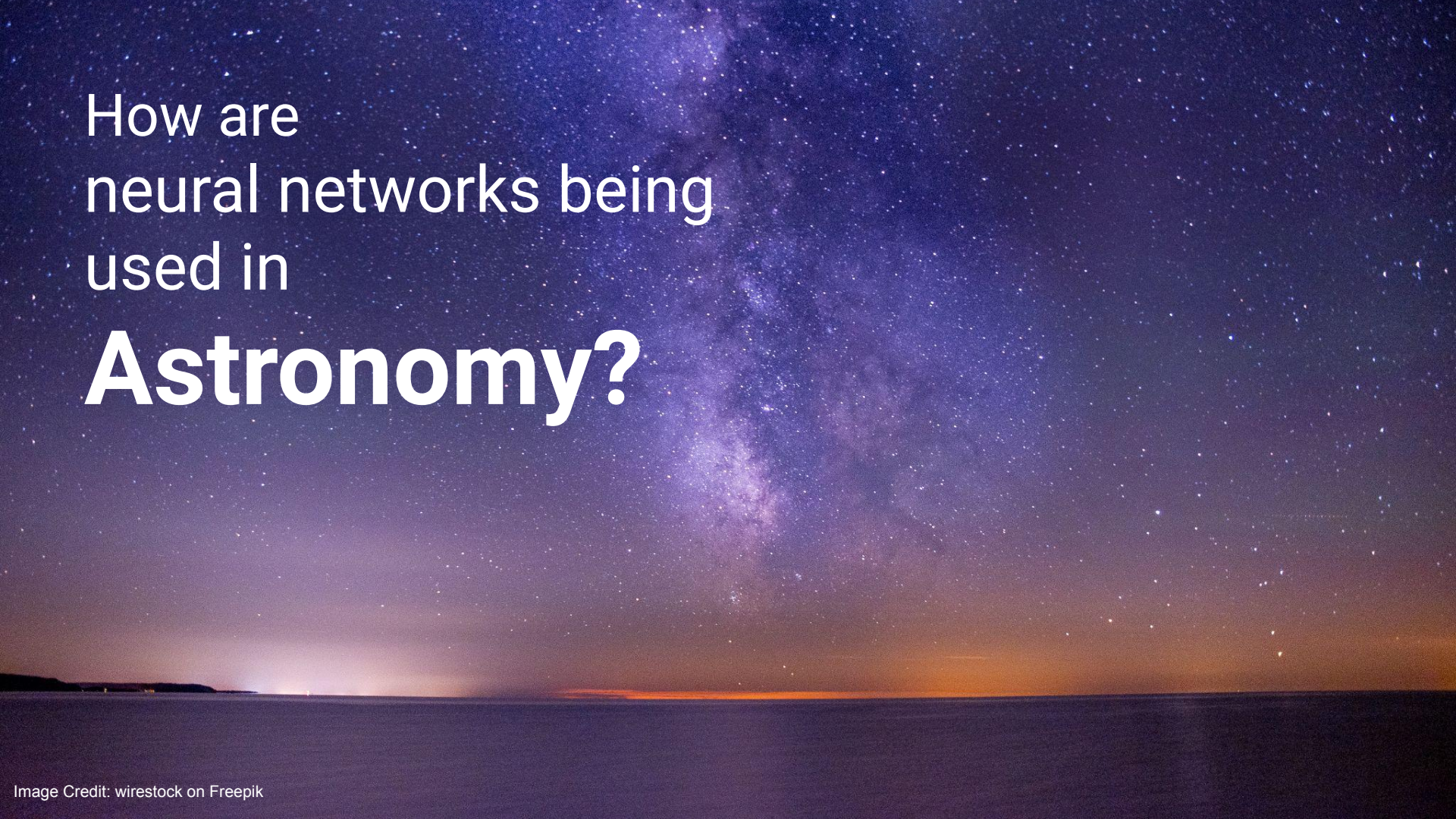
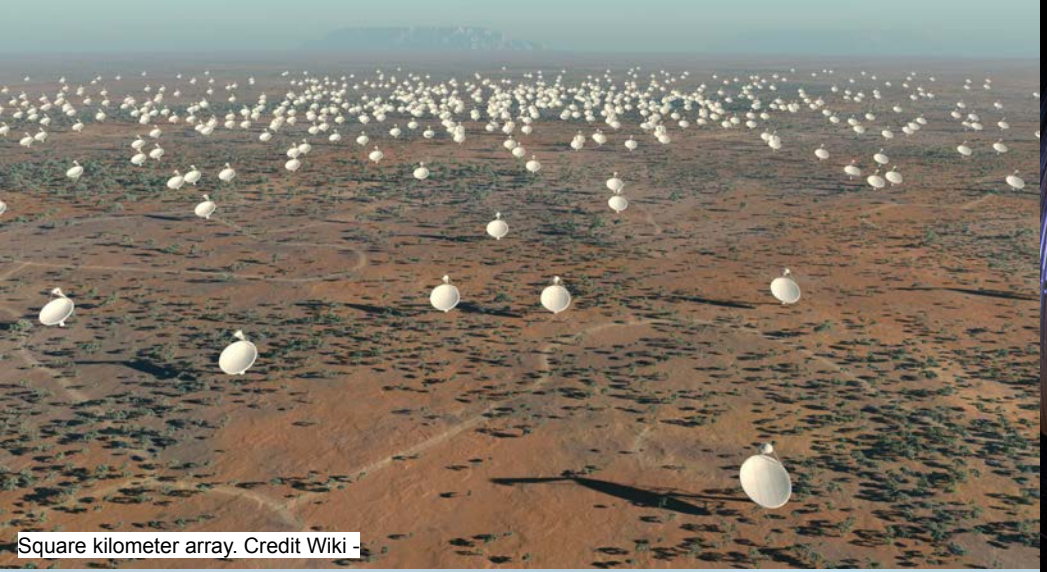
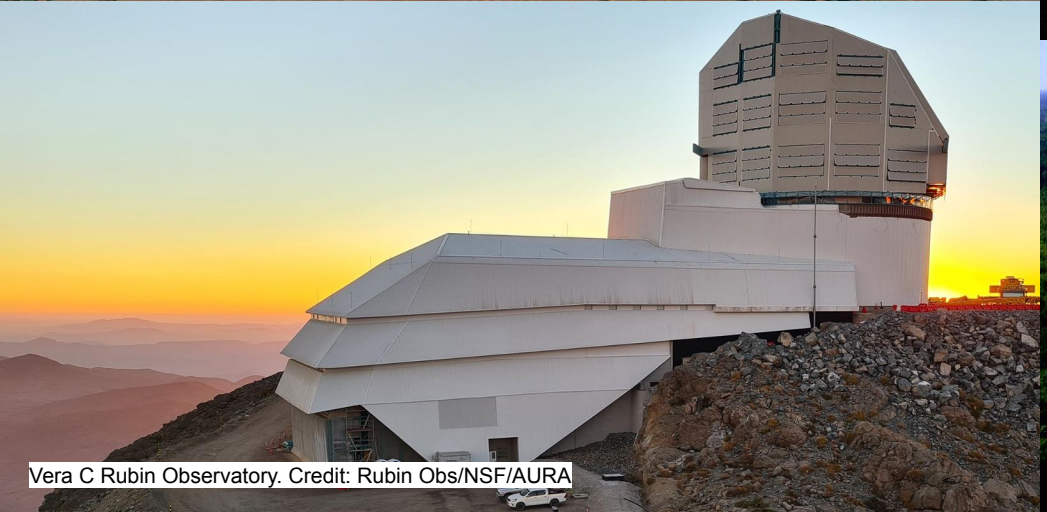


Image Credit: wirestock on Freepik



Square kilometer array. Credit Wiki -

The Victor M. Blanco 4-meter telescope building Credit DES



Vera C Rubin Observatory. Credit: Rubin Obs/NSF/AURA

Gravitational wave detector. Credit: Ligo

How many galaxies are we expected to discover with Vera Rubin Observatory?

A. ~16 million

B. ~1 billion

C. ~20 billion

Vera C Rubin Observatory. Credit: Rubin Obs/NSF/AURA

Image by cookie_studio on Freepik

In 2023, a neural network (with human supervision) identified 527 new strong lensing candidates, a rare event where light bends around heavy objects like galaxies.

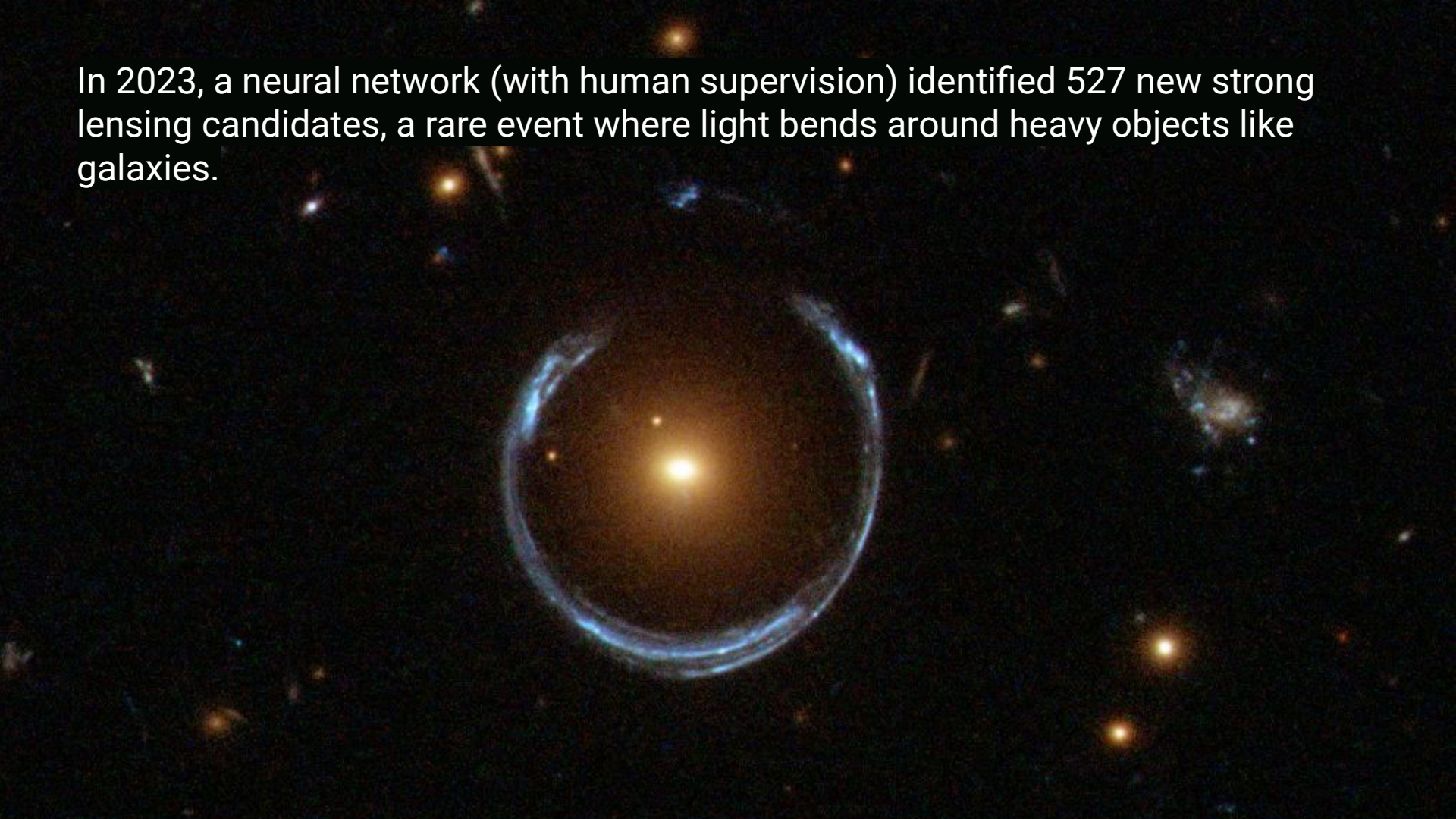


Image Credit: vector_corp

Neural networks are challenging some of our theories of galaxy evolution by classifying the galaxies differently… new physics?

Image Credit: NASA, ESA, ADAM G. RIESS (STSCI, JHU) - https://scitechdaily.com/images/Hubble-Space-Telescope-Galaxy-Collection.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=118249156

LSC UNIVERSITY OF PORTSMOUTH

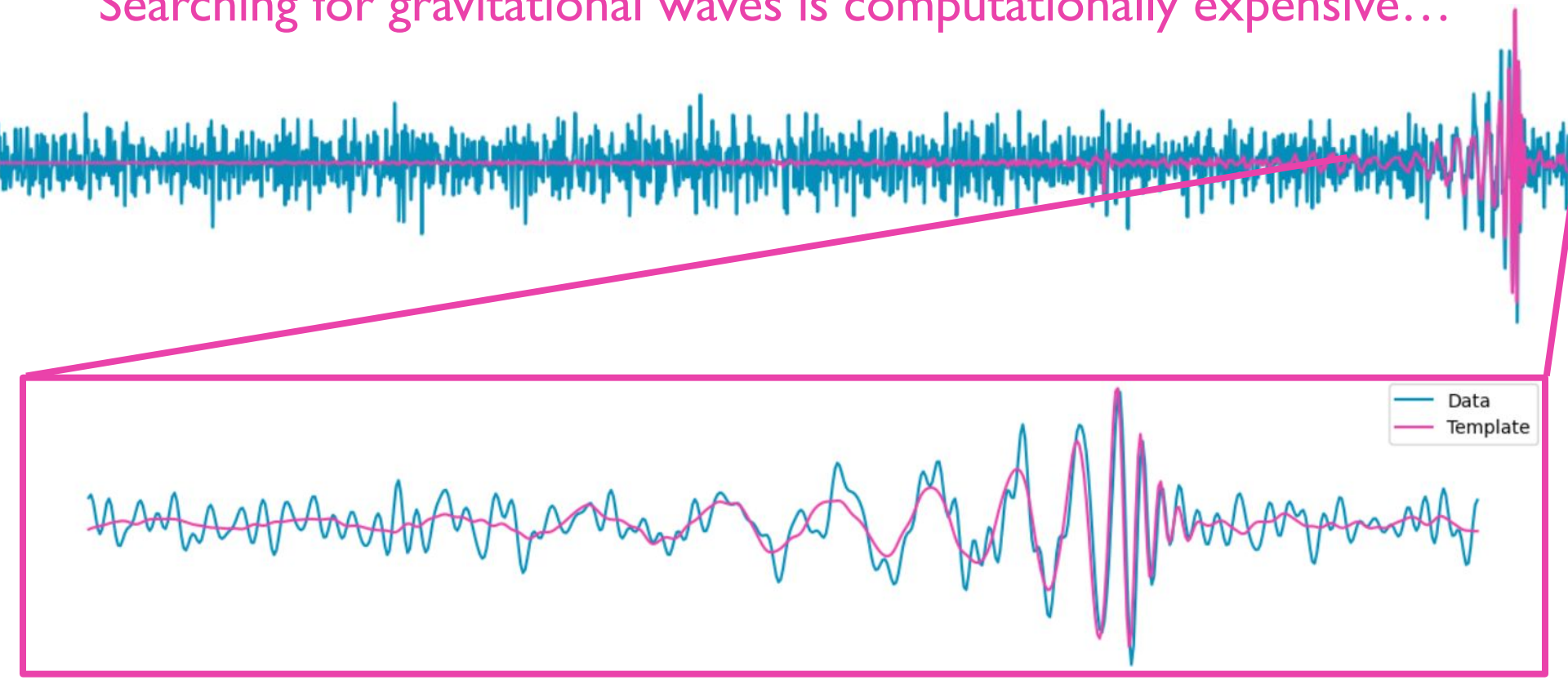
LearningMatch

Using Neural Networks to Predict the ‘Match’

Image Credit: kjpargeter on Freepik

Gravitational Waves are ripples in the curvature of spacetime produced by **accelerating masses**… such as two **black holes** or two **neutron stars** colliding.

Searching for gravitational waves is computationally expensive…



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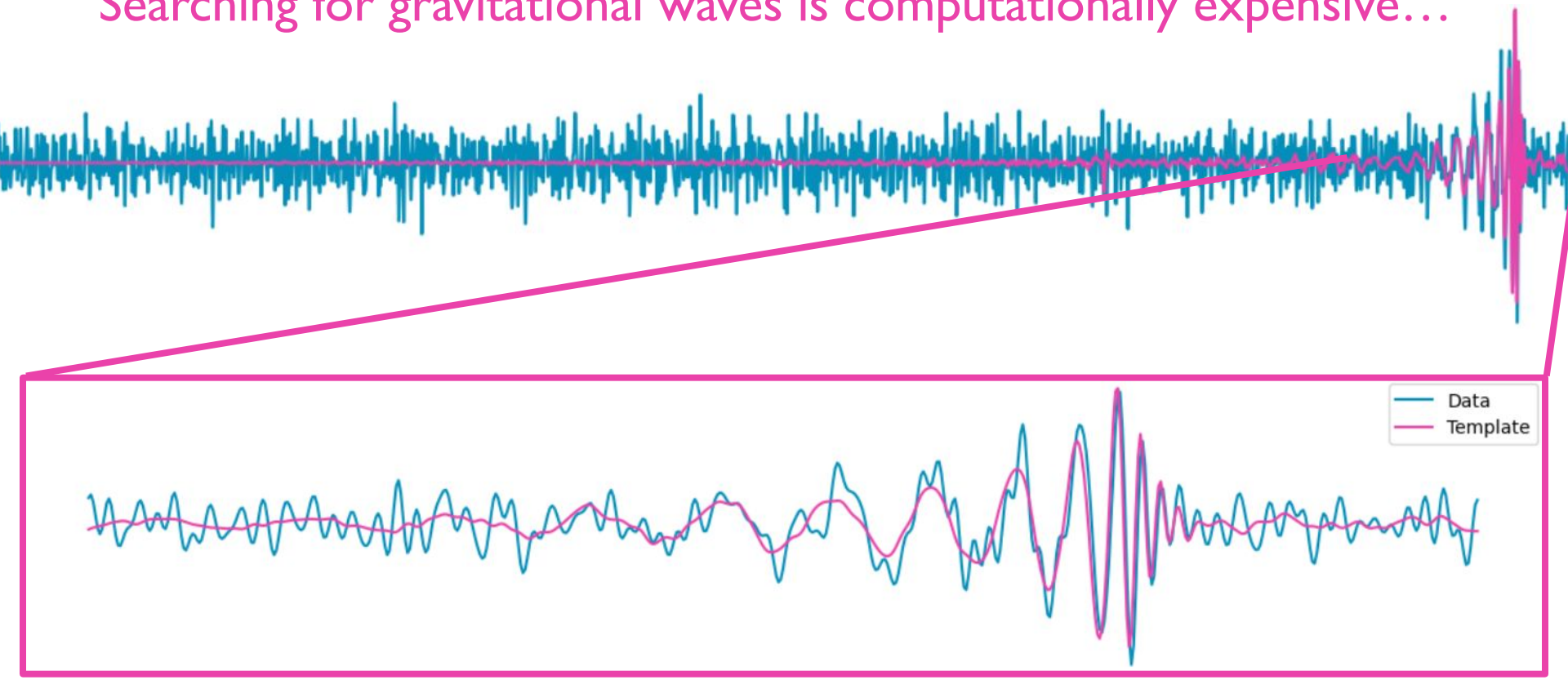
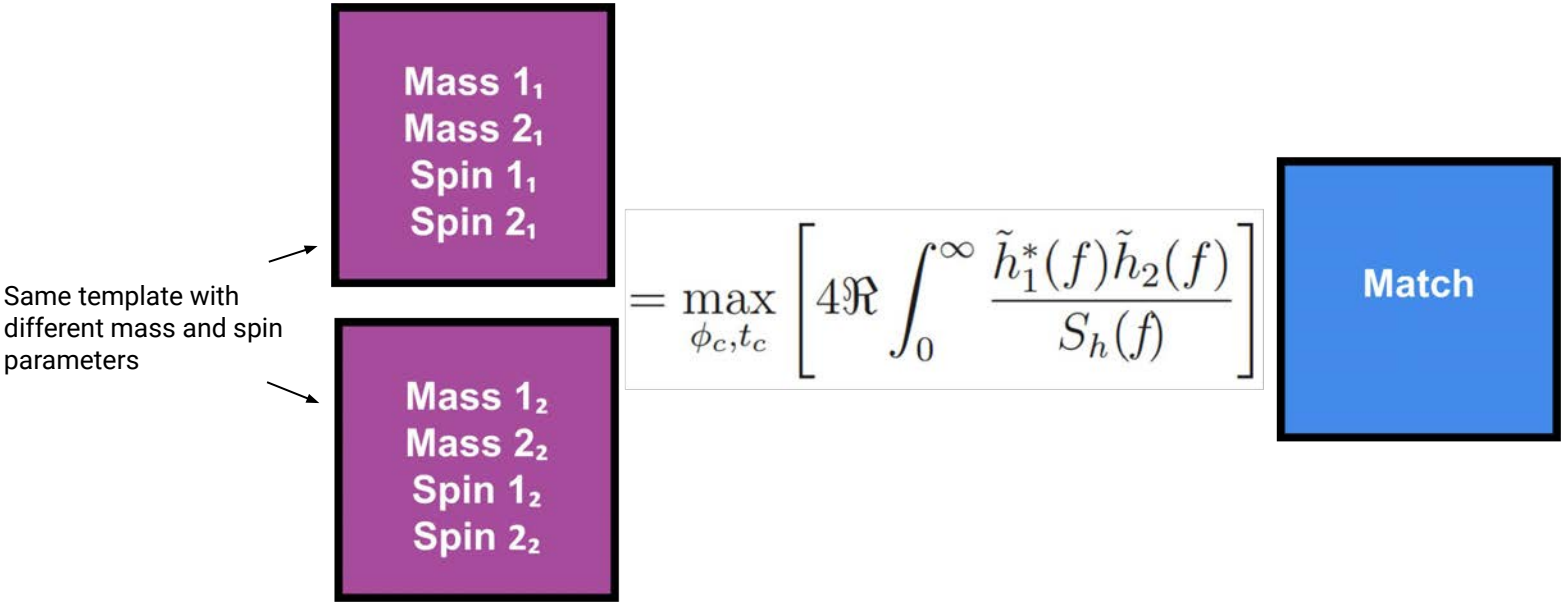


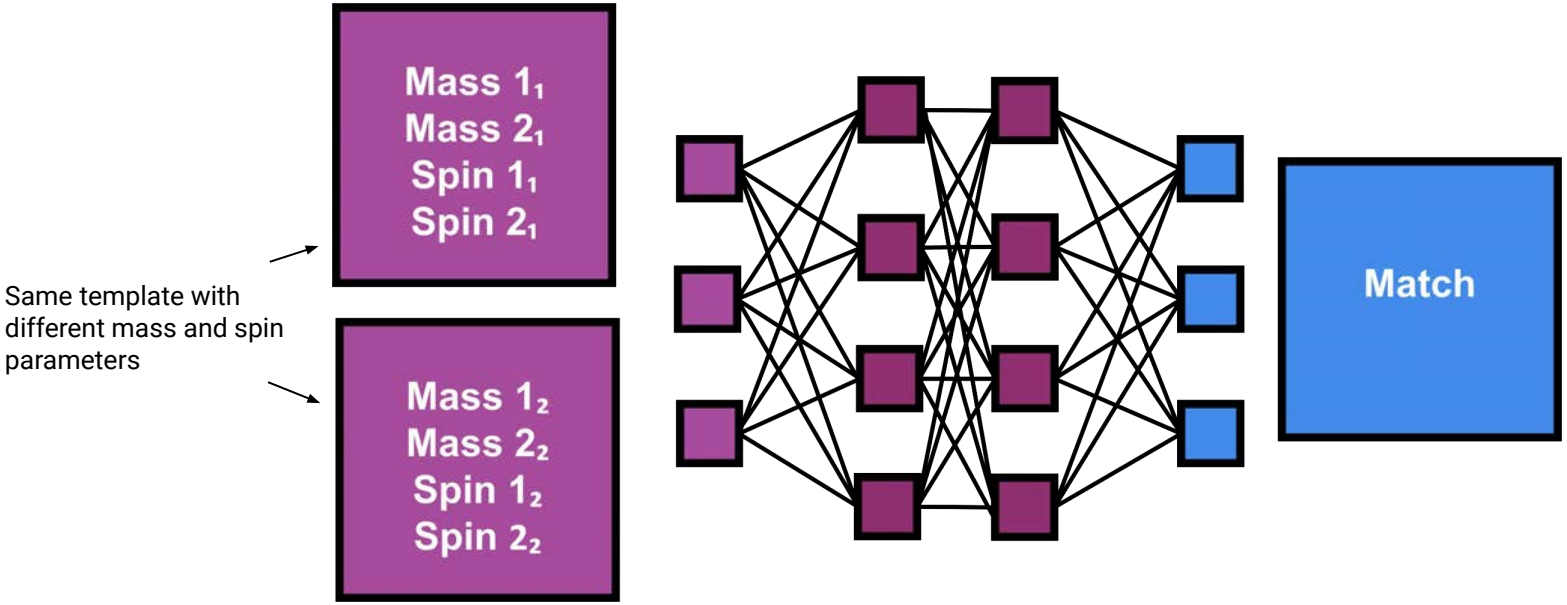
…so we want to use neural networks to speed up the process.

The Aim:



The aim of the neural network is to learn the relationship between the parameters and the match.

The Aim:



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What have I **learned** as a machine learning engineer?

1) **Unknown -** We need the neural network to be accurate within 1%, which hasn't been done before.

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…this is why machine learning engineers are paid nice salaries!

Using neural networks in astronomy is still current research…

AI generated image. Credit: freepik

Using neural networks in astronomy is still current research…

…so who knows what the **future** looks like!

AI generated image. Credit: freepik

We need your **help...**

Image Credit: benzoix on Freepik

Black Hole Hunters

Galaxy Zoo

Language English

ABOUT CLASSIFY TALK COLLEC

Few have witnessed what you're about to see

Learn more Get started

Planet Hunters NGTS

ABOUT

Get involved at zooniverse.org!

Dark Energy Explorers

Identify distant galaxies to help measure dark energy when the universe was just ~2-3 billion years old

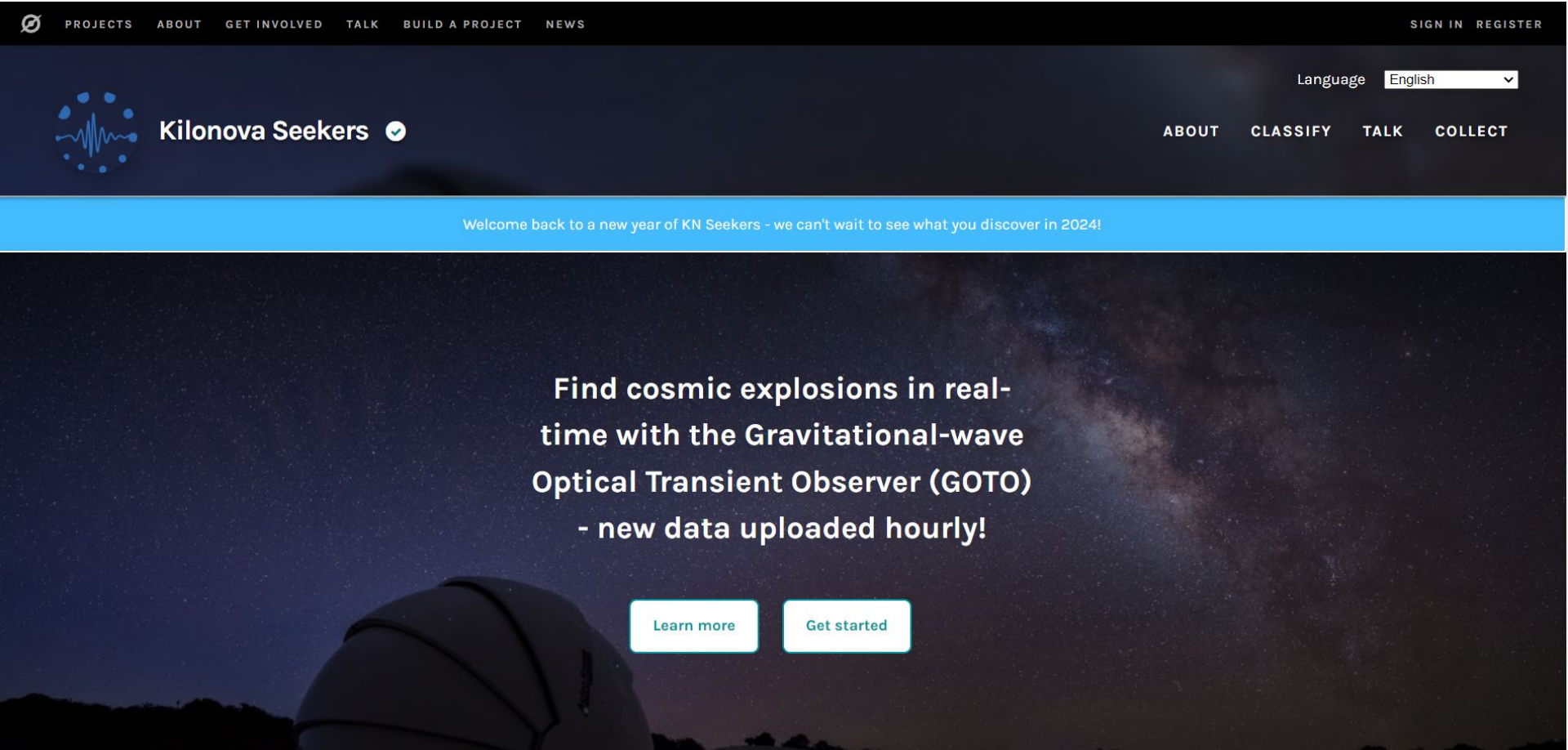
Learn more

Discover hidden worlds with the Next-Generation Transit Survey

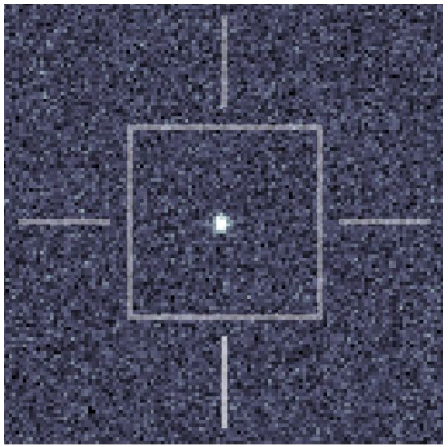
Learn more

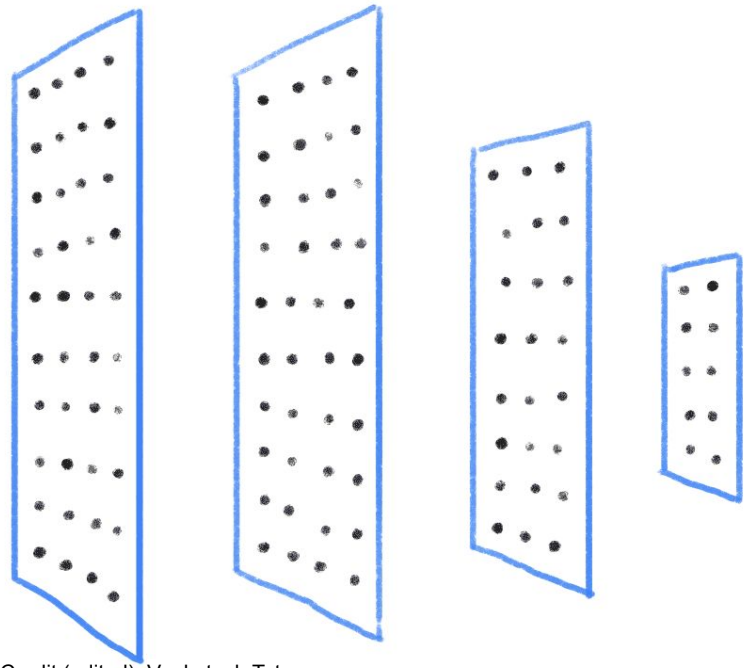
Gravity Spy

We need you to help us identify the physics…



…in this research a neural network is uncertain about whether it has observed an explosion and we need you to clarify!





Credit (edited): Venkatesh Tata

Credit: Elena Colangeli

Thank you for listening and are there any questions?

Scan here to get involved with an astronomy project from your phone... we need you!

Instagram: @susie_verte
Linkdin: Susanna Green
YouTube: @fieldof_view

Get involved at zooniverse.org!

Please feel free to contact me with any questions: susanna.green@port.ac.uk