# Data Science and AI for Medicine Training School

## TRAINING: Introduction to Deep Learning

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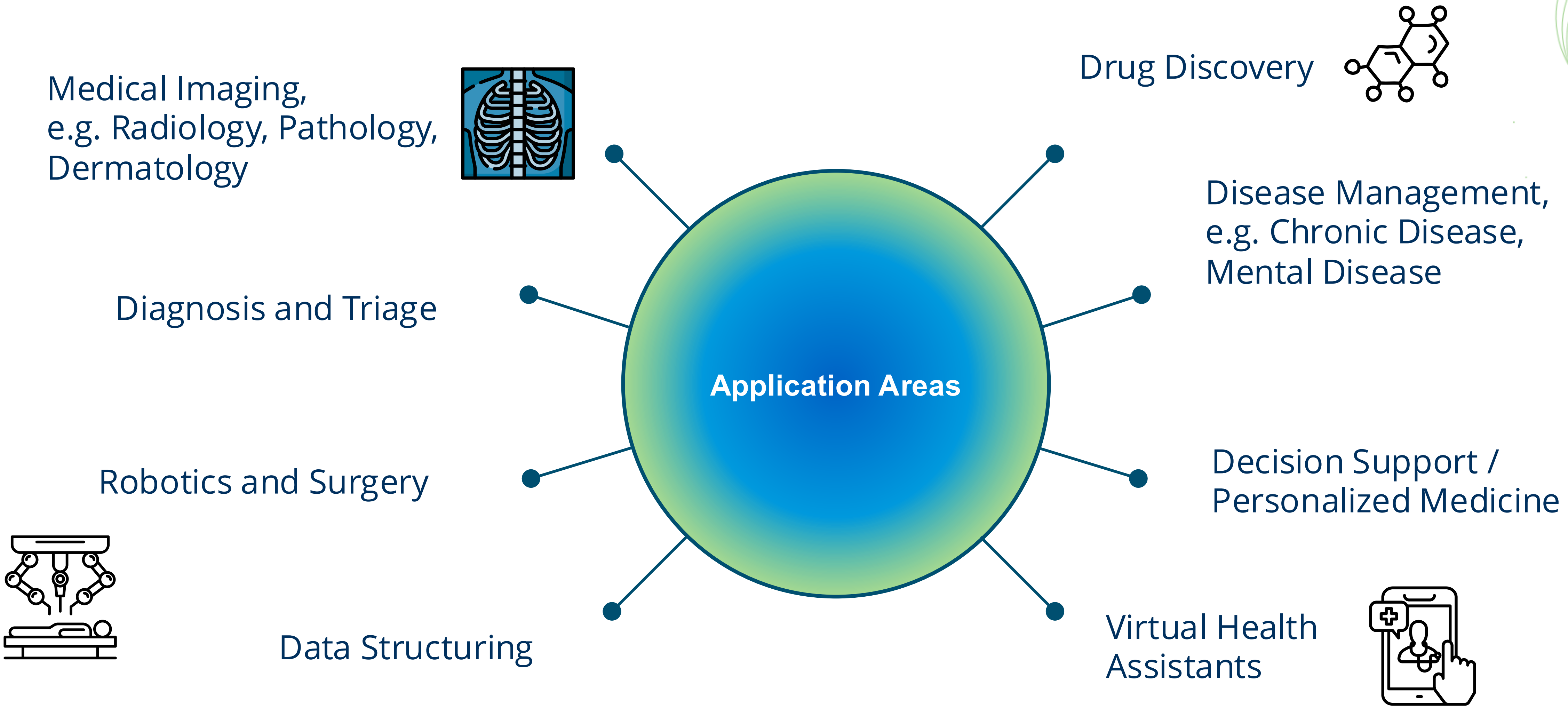
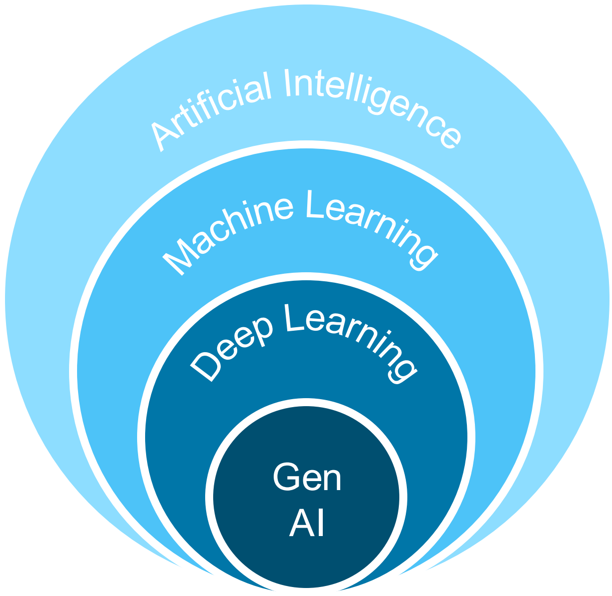
SACHSEN
Diese Maßnahme wird gefördert durch die Bundesregierung aufgrund eines Beschlusses des Deutschen Bundestages. Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushaltes.

# Deep Learning is everywhere

# Deep Learning in in Medicine

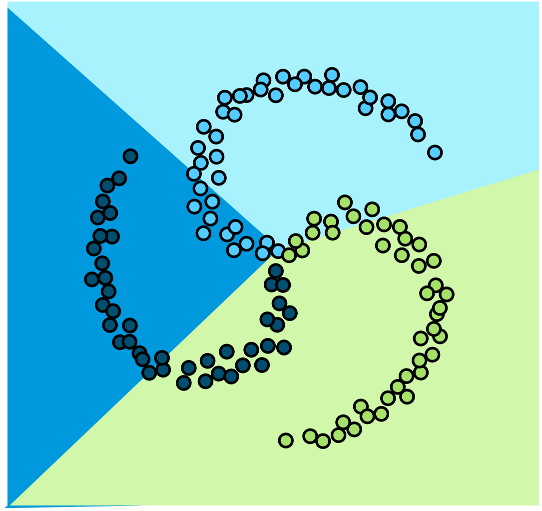


# Why Machine Learning is not enough sometimes...

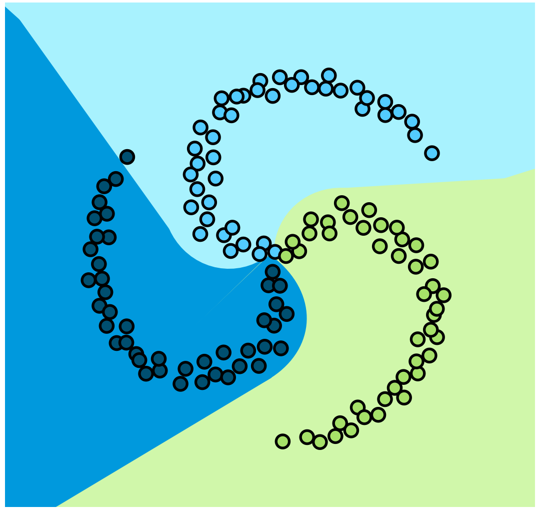



| | Feature 1 | Feature 2 | Feature 3 |
|---|---|---|---|
| **Pat. 1** | 21 | 7 | 8 |
| **Pat. 2** | 5 | 35 | 9 |
| **Pat. 3** | 87 | 58 | 3 |

- Raw/ unstructured data
- Unknown features
- Manual labour
- Complex interactions



*Deep learning can be used to model non-linear relations* →



# History of DL

**1943** McCulloch & Pitts first artificial neuron

**1958** Rosenblatt's perceptron

**1969** Minsky & Papert "Perceptron" book

**Deep Learning Winter**

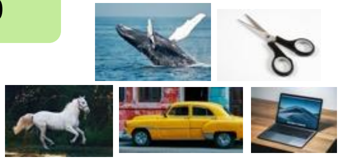
**1980** Fukishima's Neocognition

**1986** Rumelhart, Hinton, Williams invent backpropagation algorithm

**1989** LeCun engineers Convolutional Neural Networks

**Deep Learning revival**

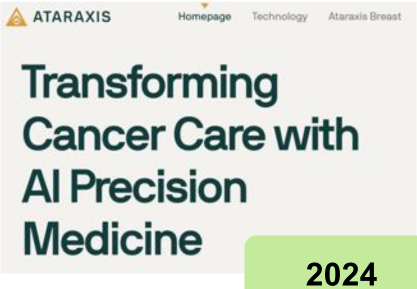
**2009** ImageNet



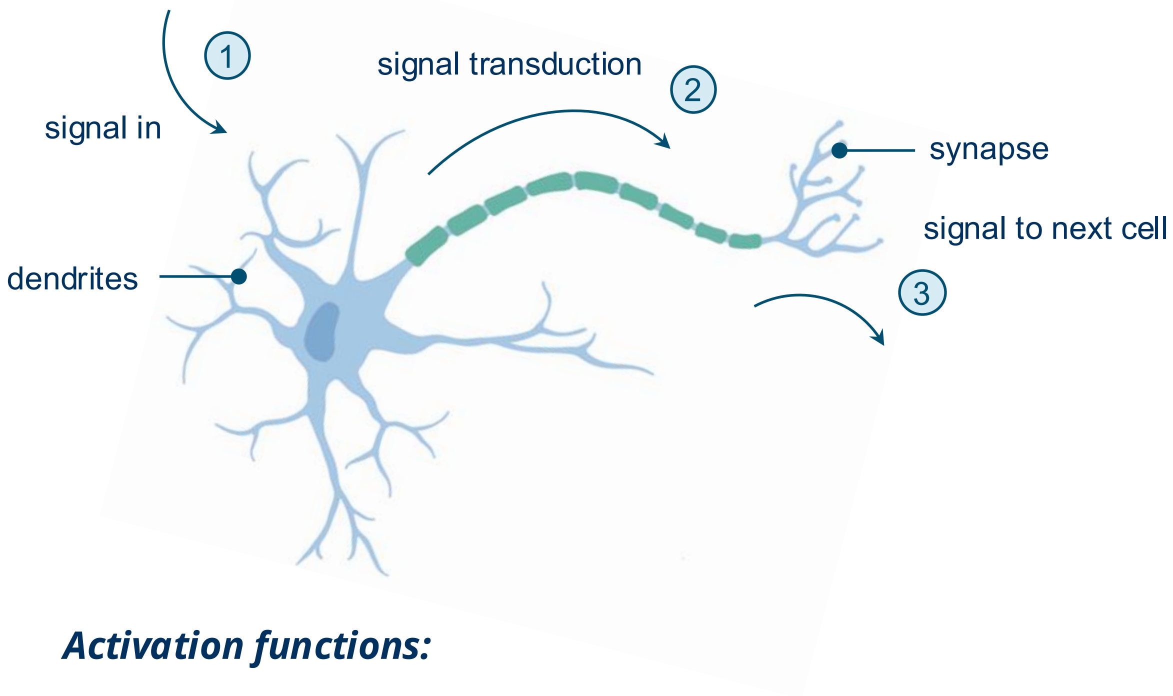
**2012** GPU acceleration

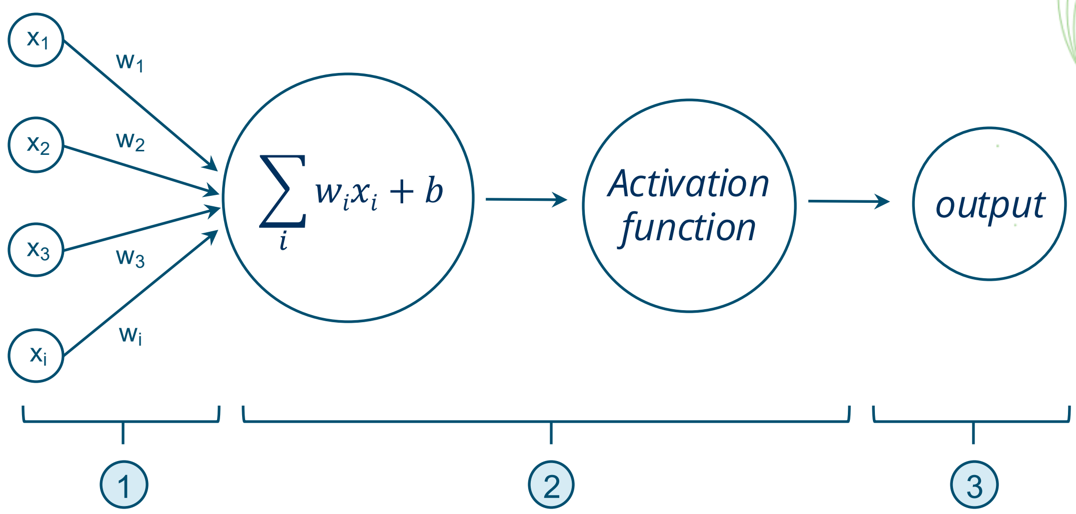
**2017** Transformer Neural Networks

**2024**

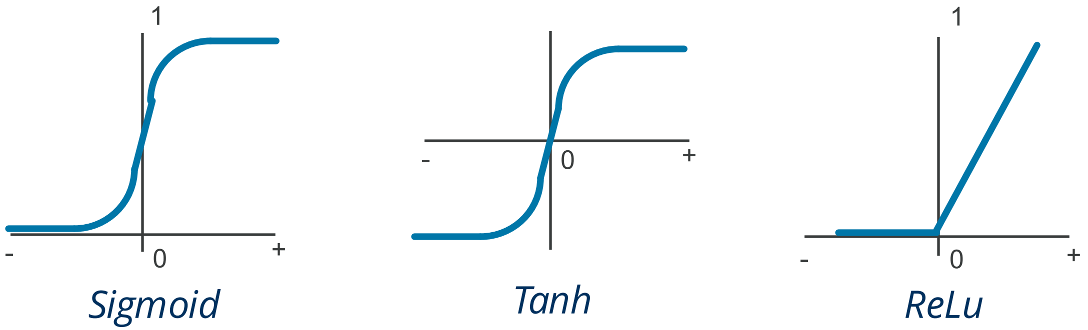


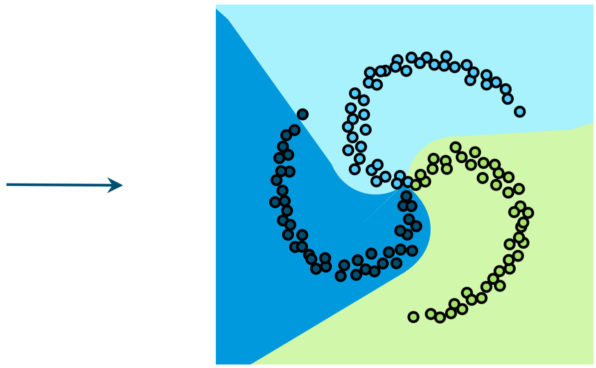
# Basics of Neural Networks




***Activation functions:***

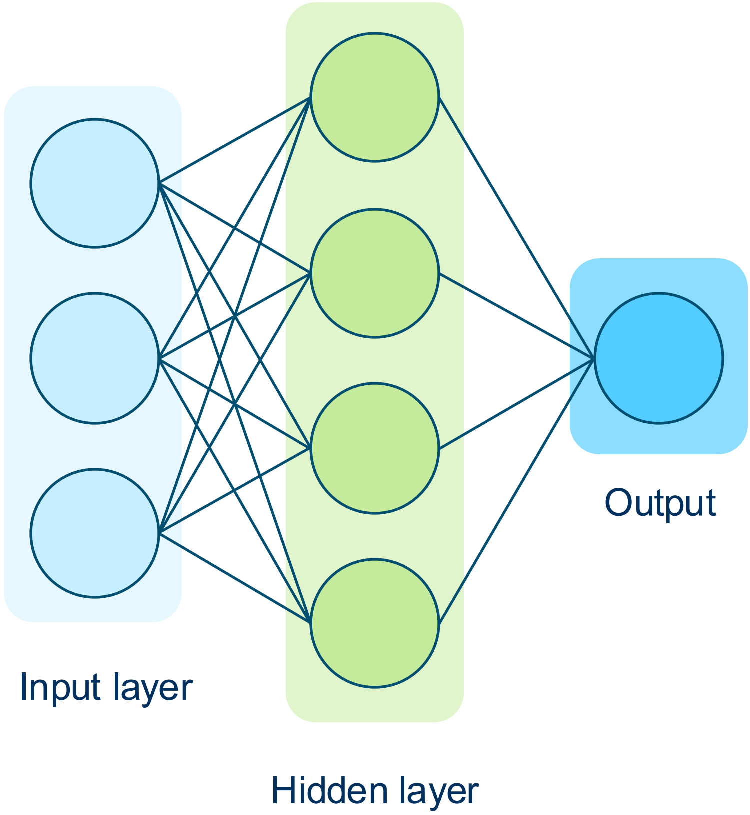


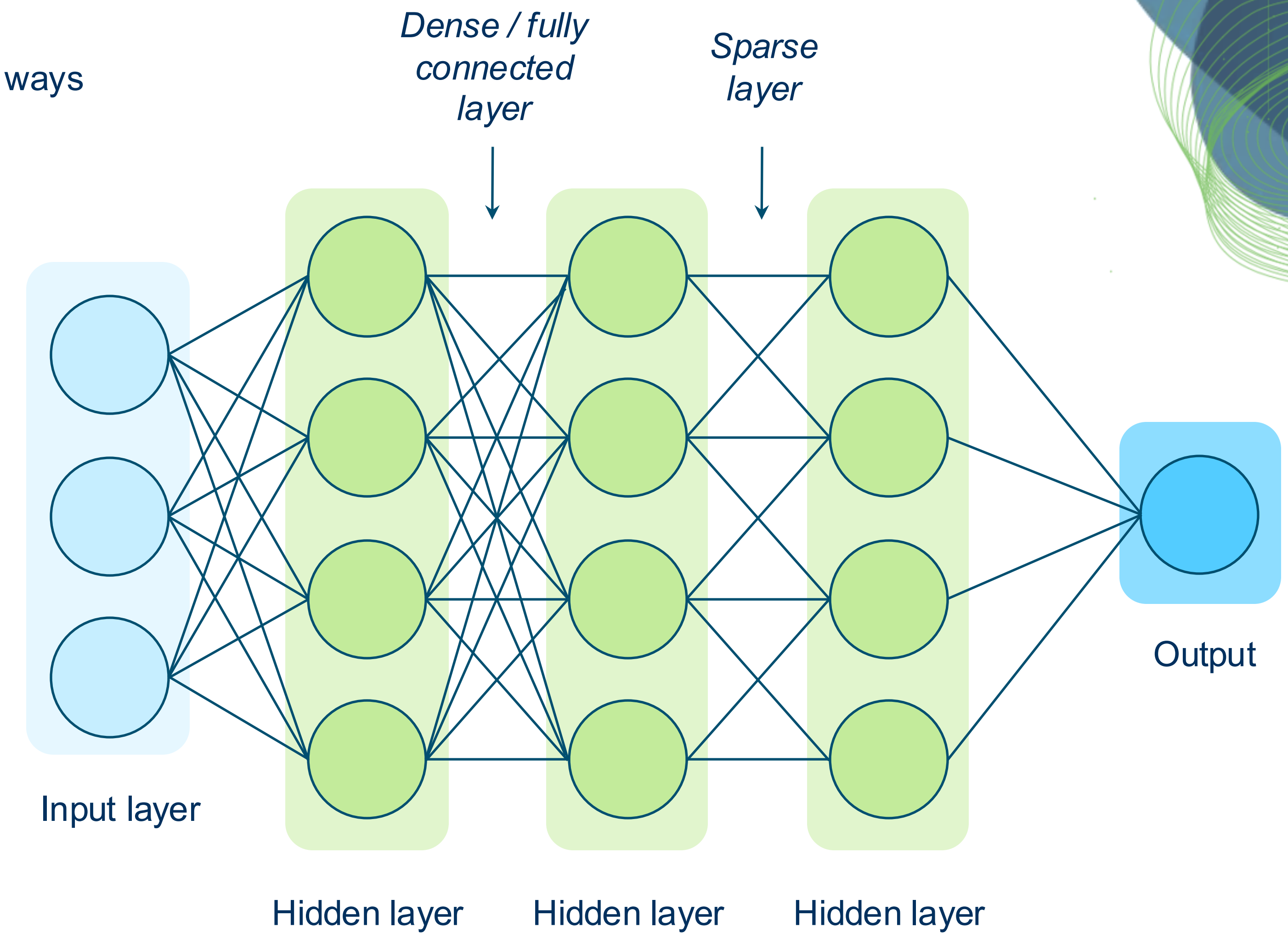



*Activation functions introduce non-linearity to neural networks*

# Deep Neural Networks

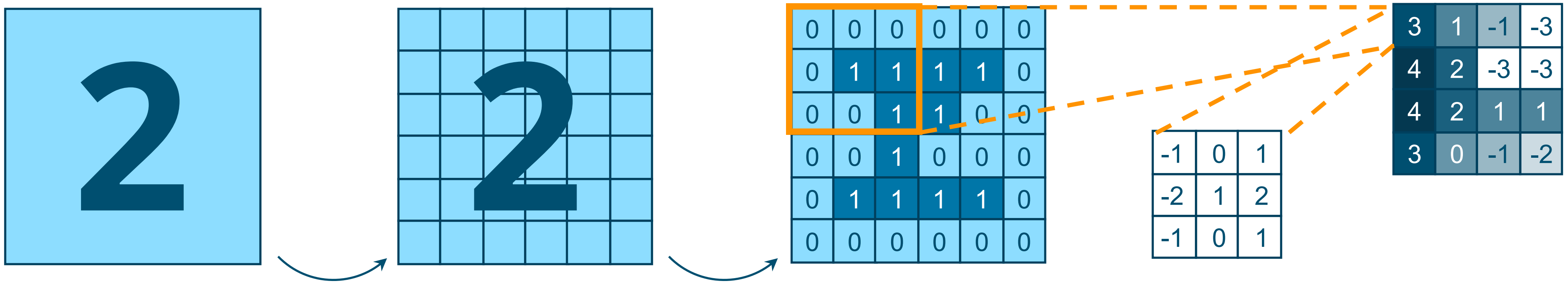
- Artificial neurons can be stacked together in various ways



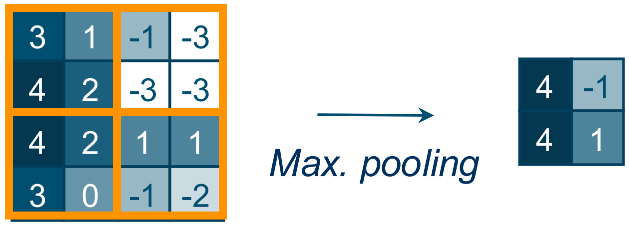
# Convolutional Neural Networks

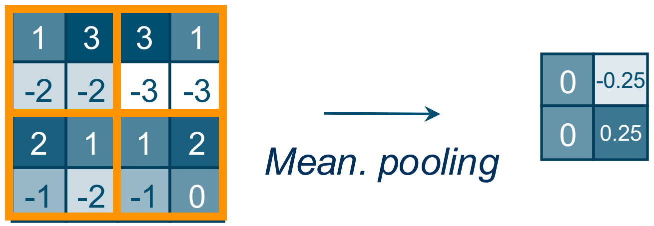
***Convolution:***




- Filters detect structures within the image matrix

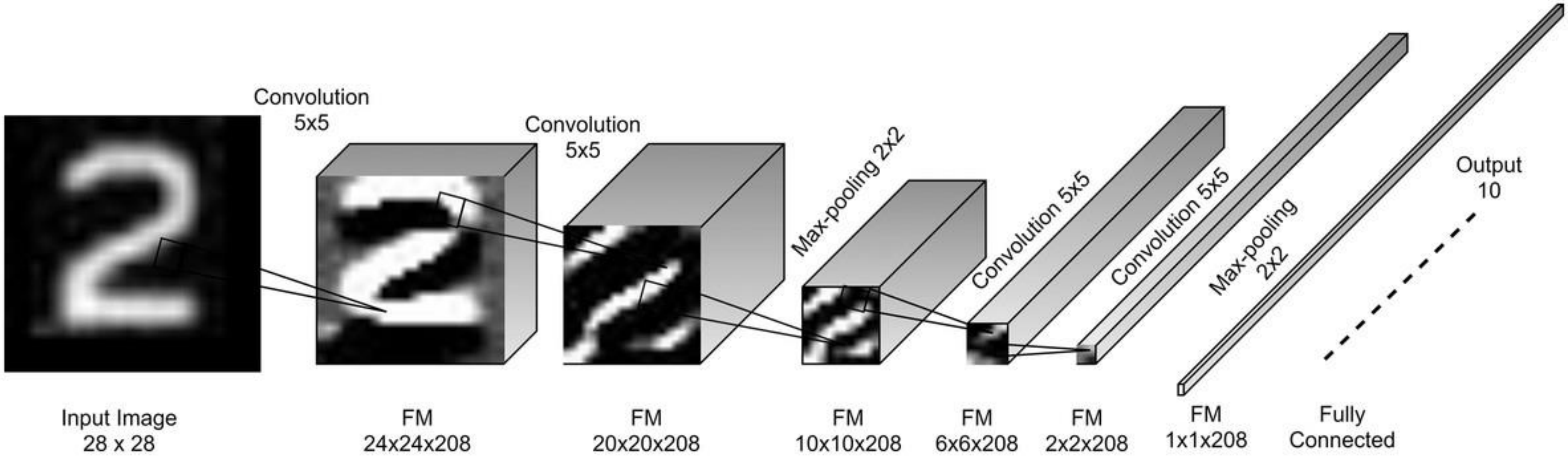
***Pooling:***

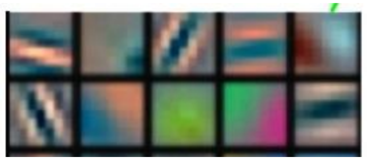


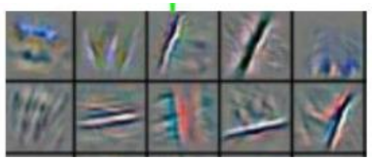

- Pooling reduces spatial size
- Makes features more robust to variation

# Convolutional Neural Networks



*Small-level features*



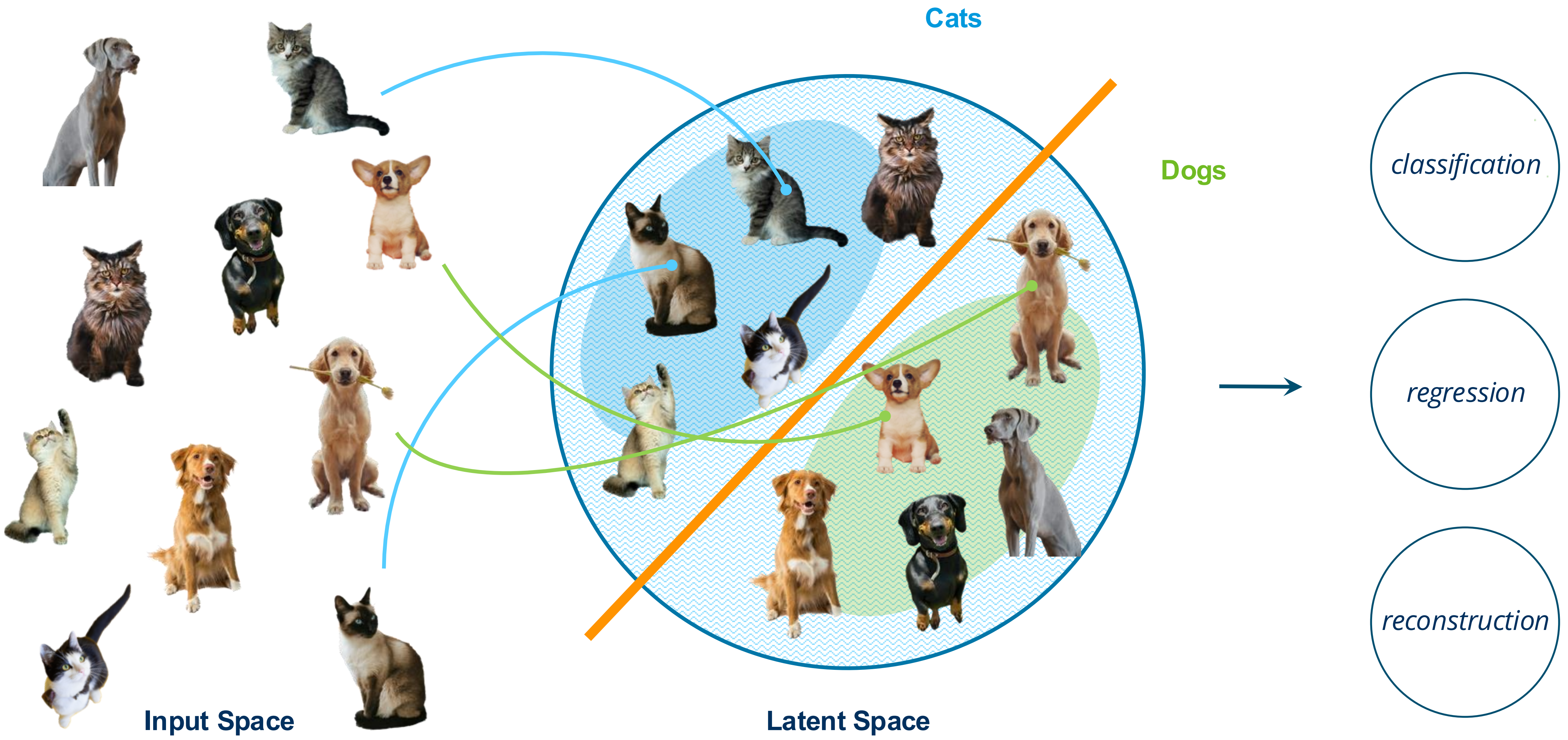
*Middle-level features*

*High-level features*

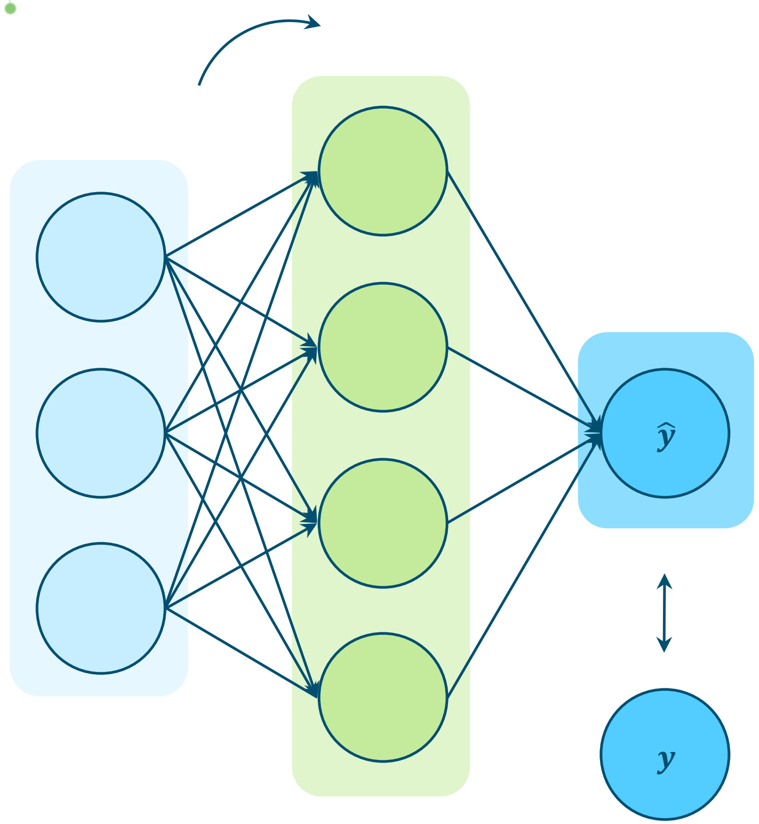
*output*

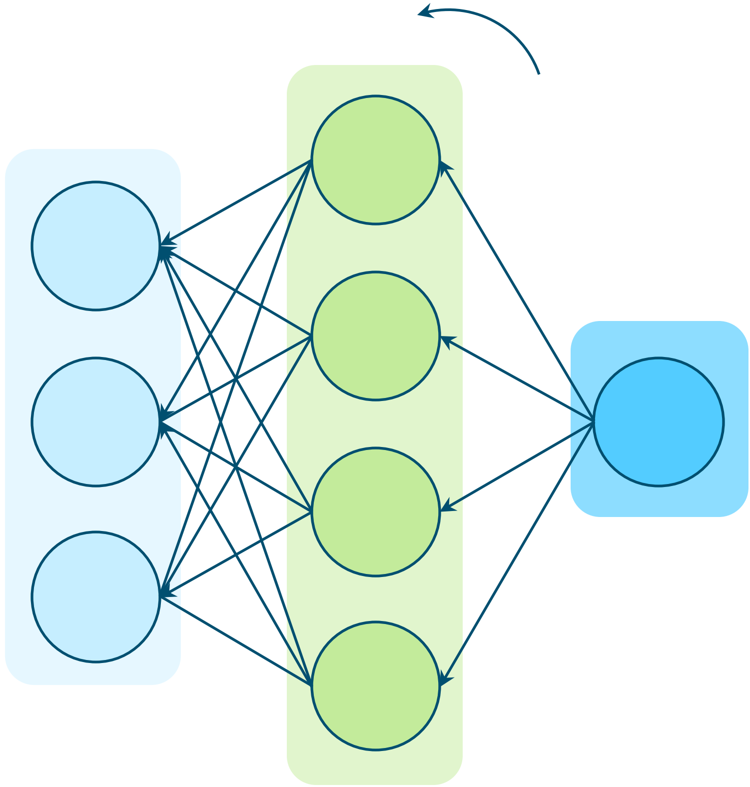
*classifier*

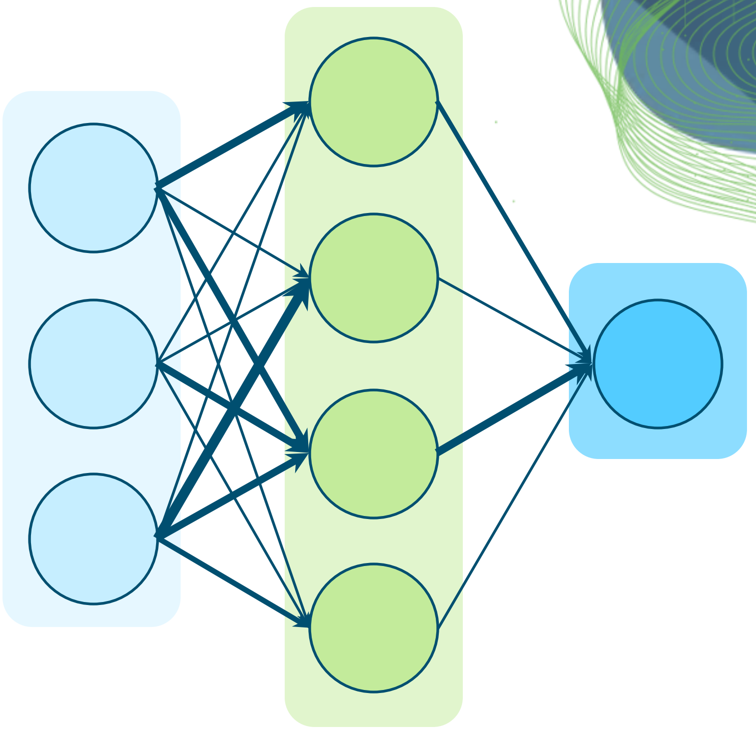
# The Latent Space



# How do Neural Networks learn ?





1 ***Error**: difference between prediction and output*

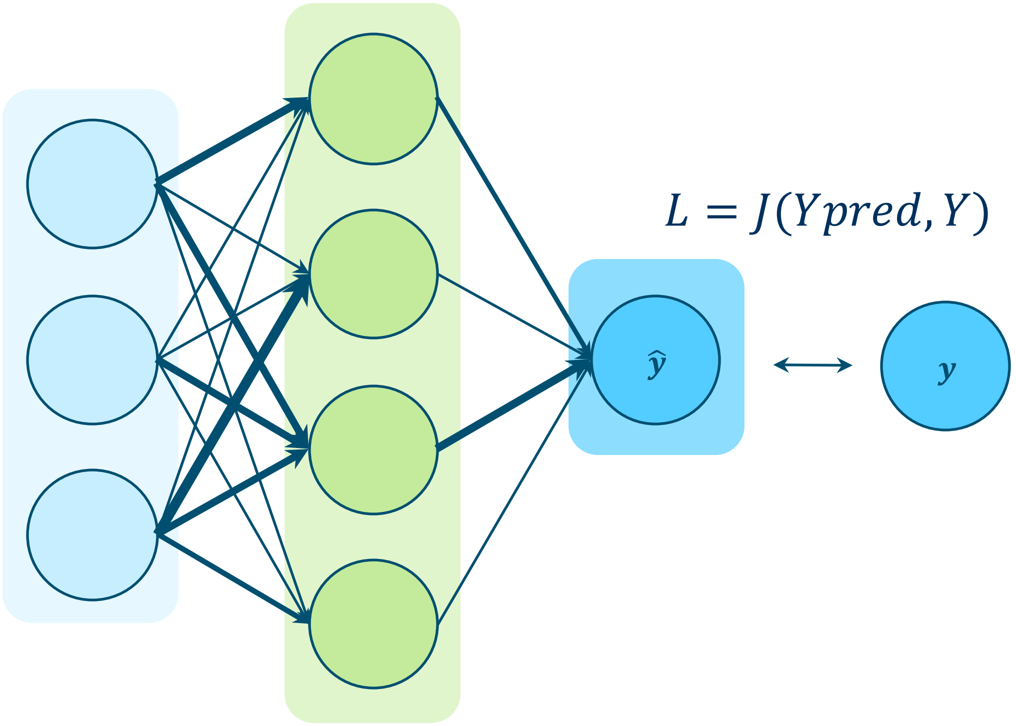
2 *Error is sent back through all neurons*

3 *Gradient of error is calculated for each weight*

4 *Weights are updated in regard to error*

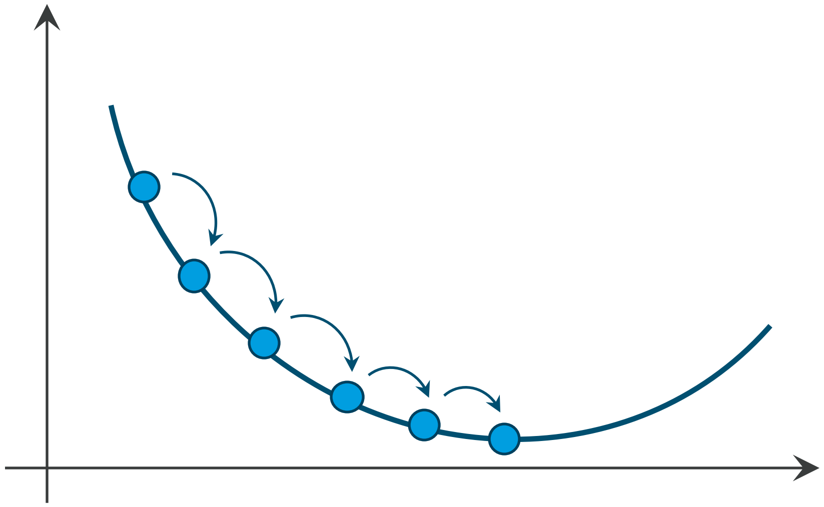
5 *New error is sent back …*

# How do Neural Networks learn ?




### *Loss Function*

- We want to minimize loss function and with this decrease the error between prediction and label.



### *Loss Function for Regression*

$$L = \frac{1}{N}\sum_{i=1}^{N}(yi - \hat{y}_i)^2$$

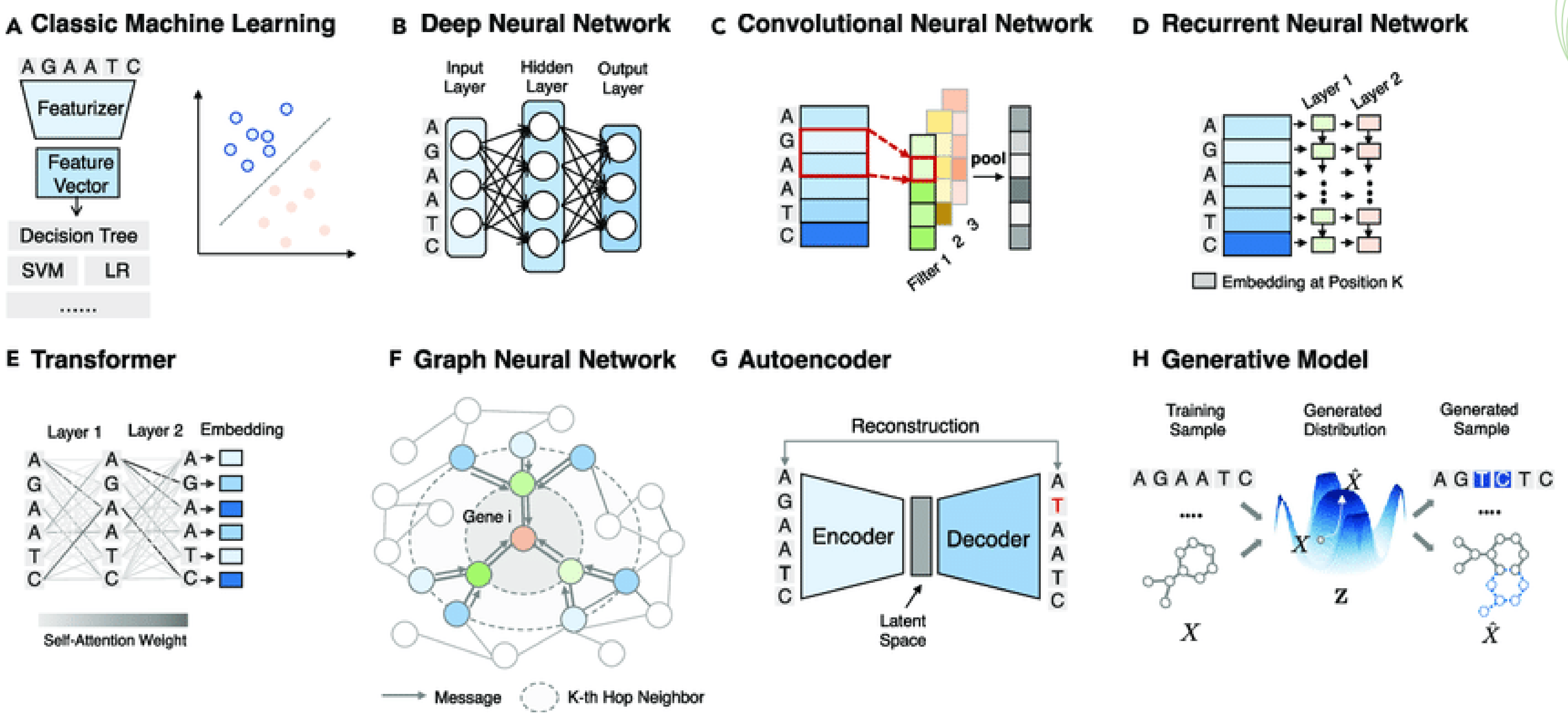
### *Loss Binary Classification*

$$L = -\frac{1}{N}\sum_{i=1}^{N}[yi \log(\hat{y}_i) + (1 - yi)\log(1 - \hat{y}_i)]$$

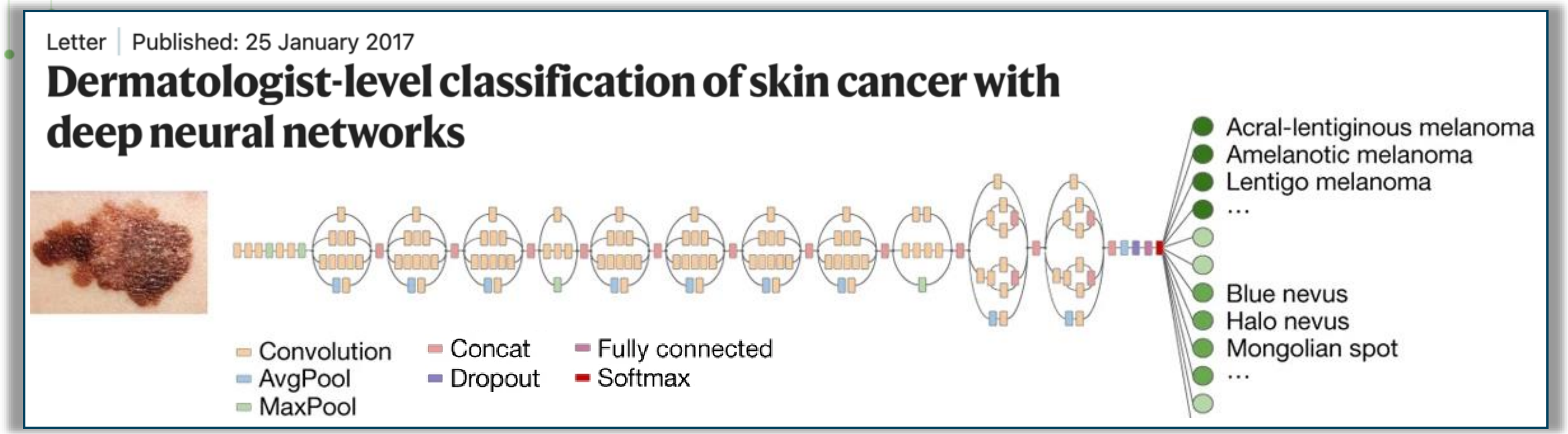
### *Loss Multi-Class Classification*

$$L = -\frac{1}{N}\sum_{i=1}^{N}\sum_{c=1}^{C} y_{ic} log(\hat{y}_{ic})$$

# Todays Diversity

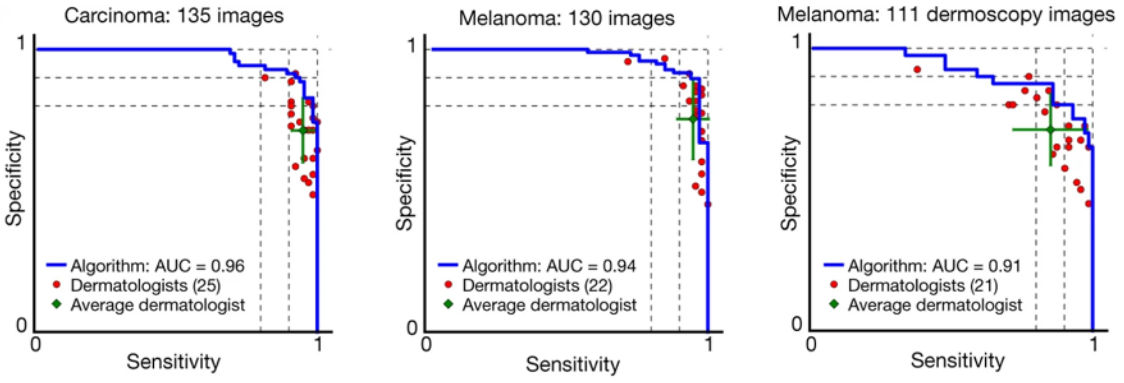


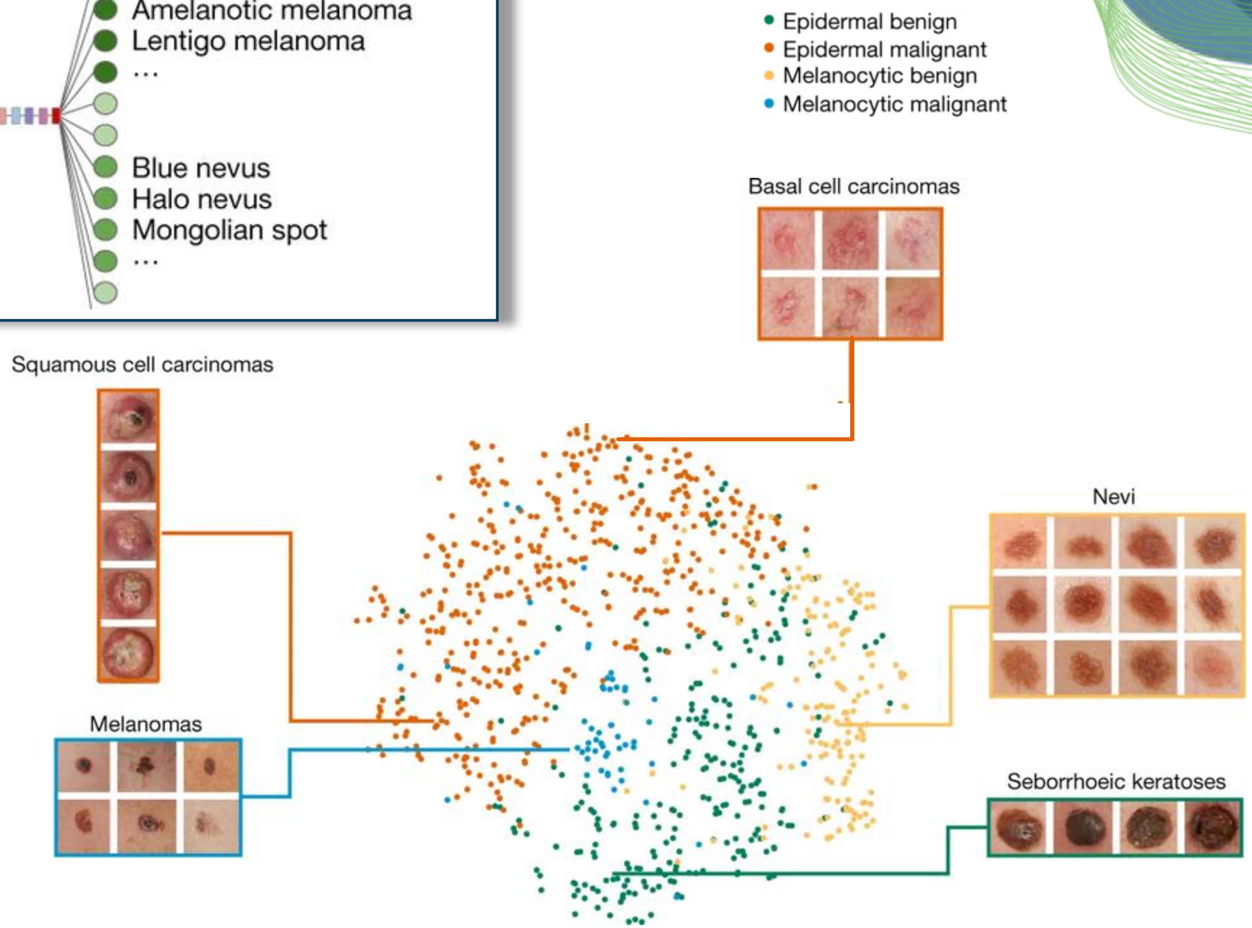
# Example - Melanomas


Letter | Published: 25 January 2017

**Dermatologist-level classification of skin cancer with deep neural networks**





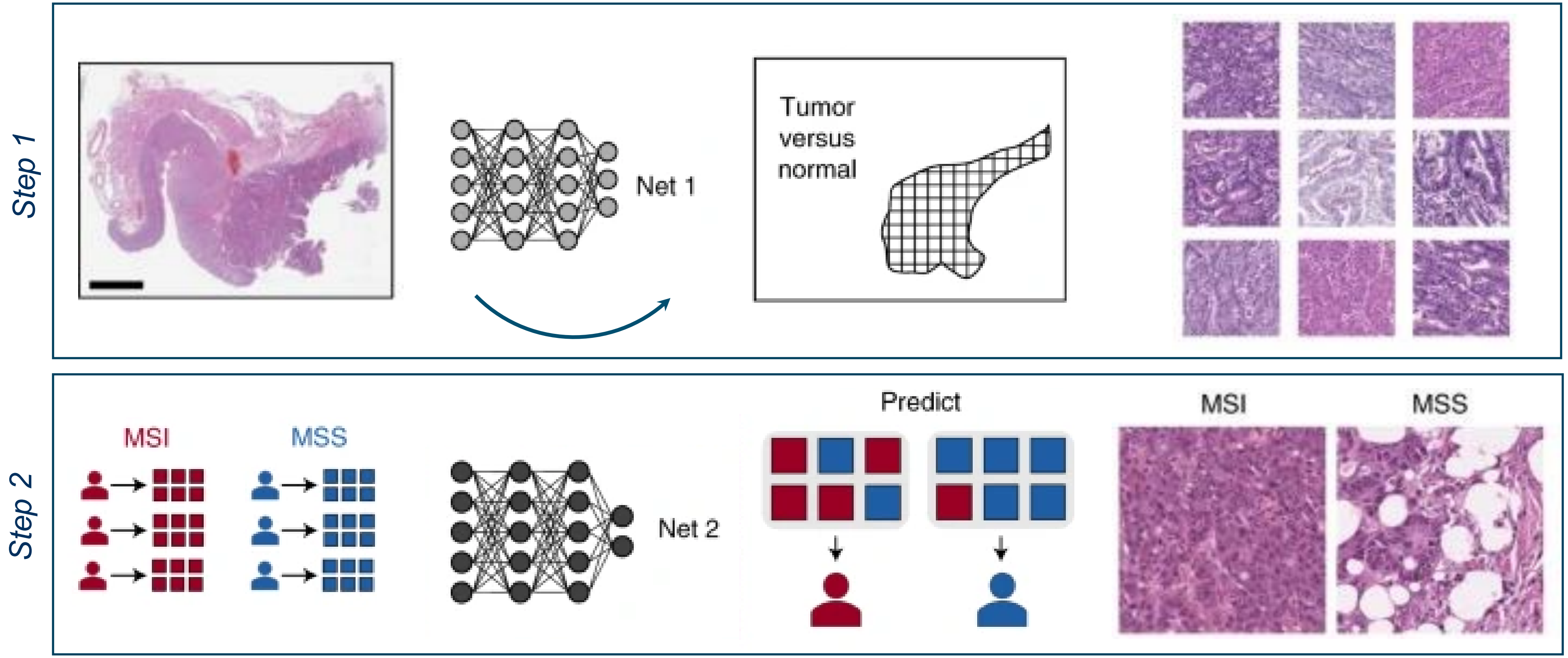


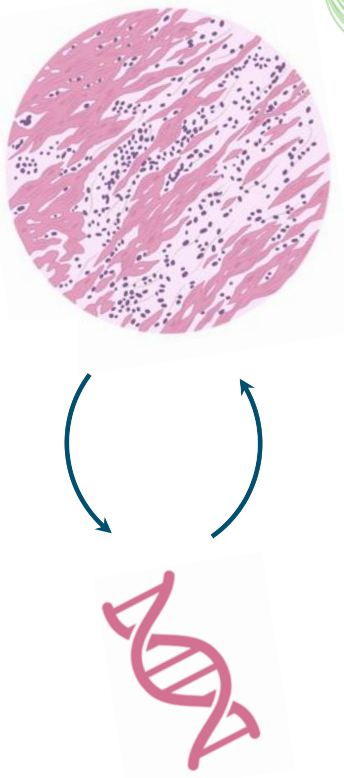

https://doi.org/10.1038/nature21056

# Example - Pathology

Brief Communication | Published: 03 June 2019

**Deep learning can predict microsatellite instability directly from histology in gastrointestinal cancer**



# Challenges and Limitations

### Data Challenges

- Bias in training data
- Imbalance of training data
- Data availability / open-access
- Artefacts

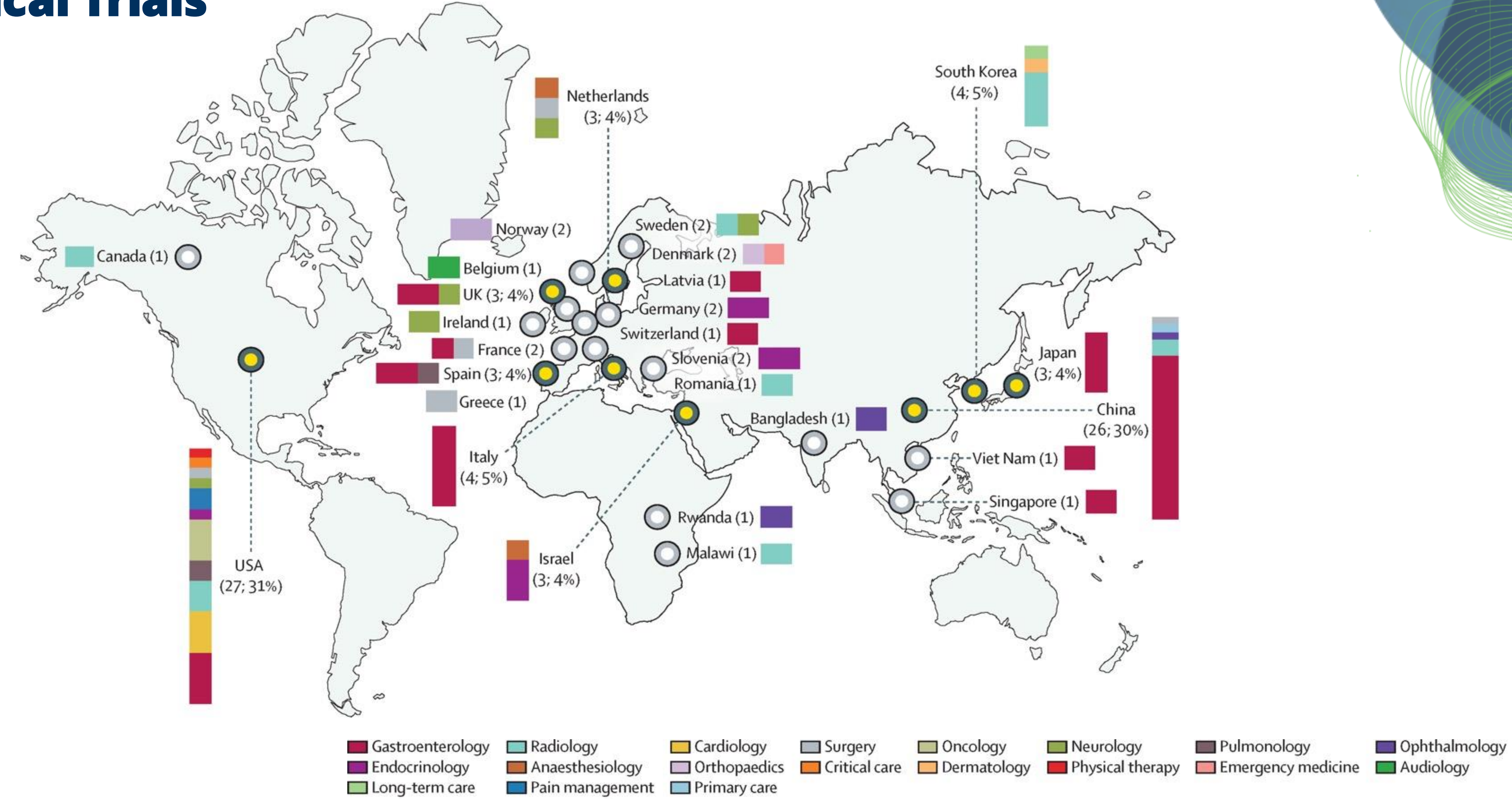
### Model Challenges

- Digitization
- Explainability
- Decisions aligned with newest clinical guidelines
- Compute
- Size

### Clinical Challenges

- Safe use in best interest of patients
- Performance degradation over time / domain shift
- Compliance with regulatory standards
- Easy and accessible use

# Clinical Trials



Any questions or remarks?

Let’s practice – Deep Learning Basics on Jupyter Hub