# Learning clinically useful information from medical images

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Biomedical Image Analysis Group
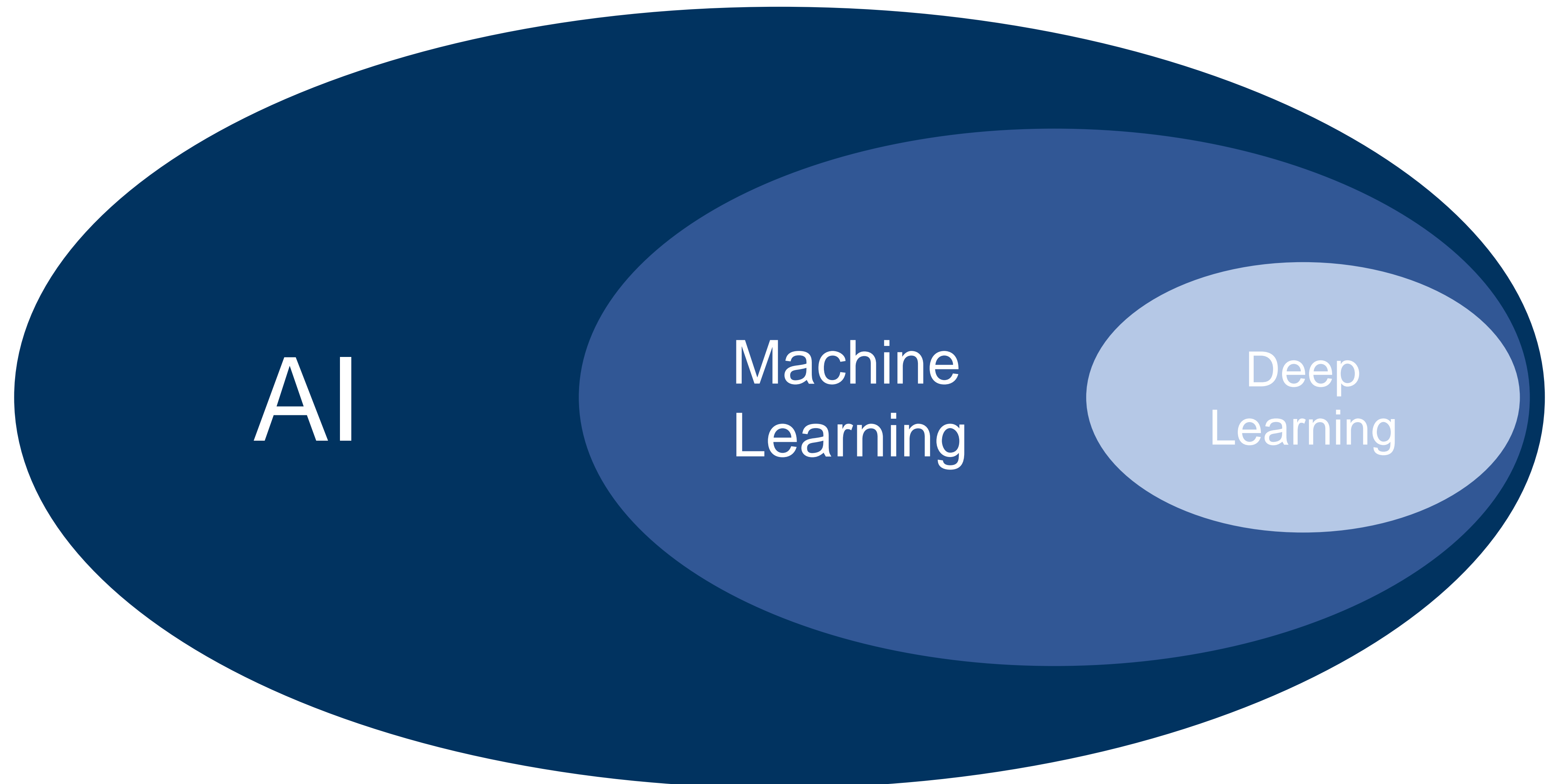
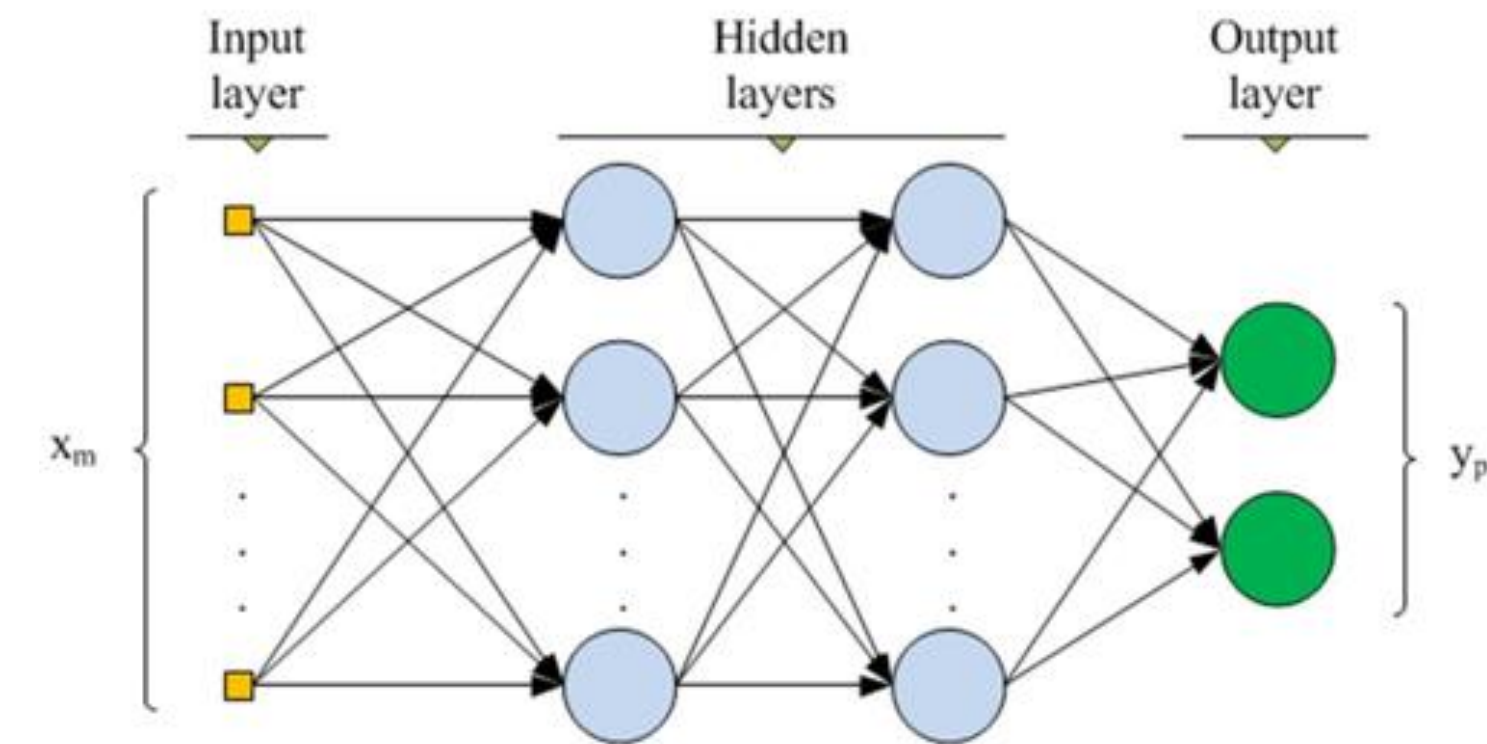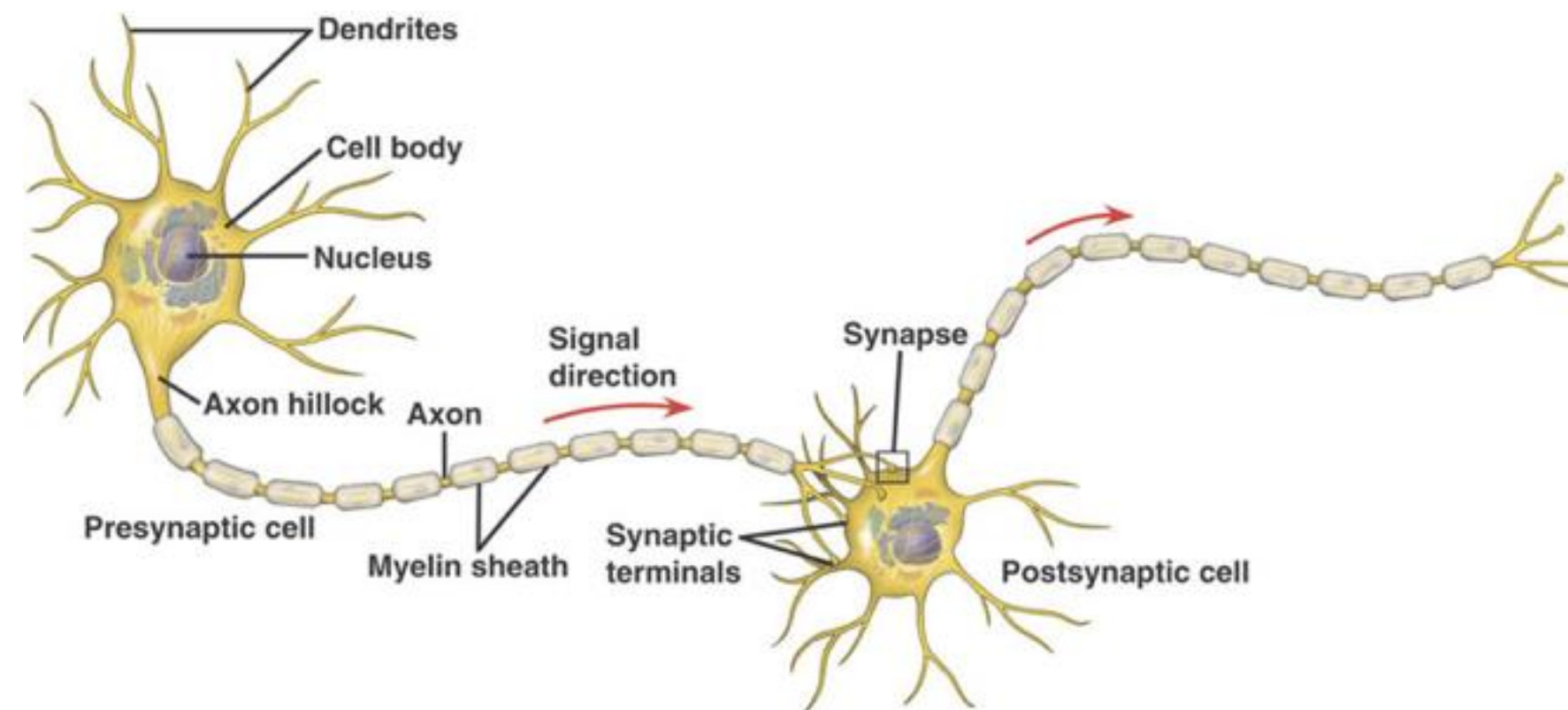Department of Computing, Imperial College London, UK

# Disclosures

- Adviser – HeartFlow
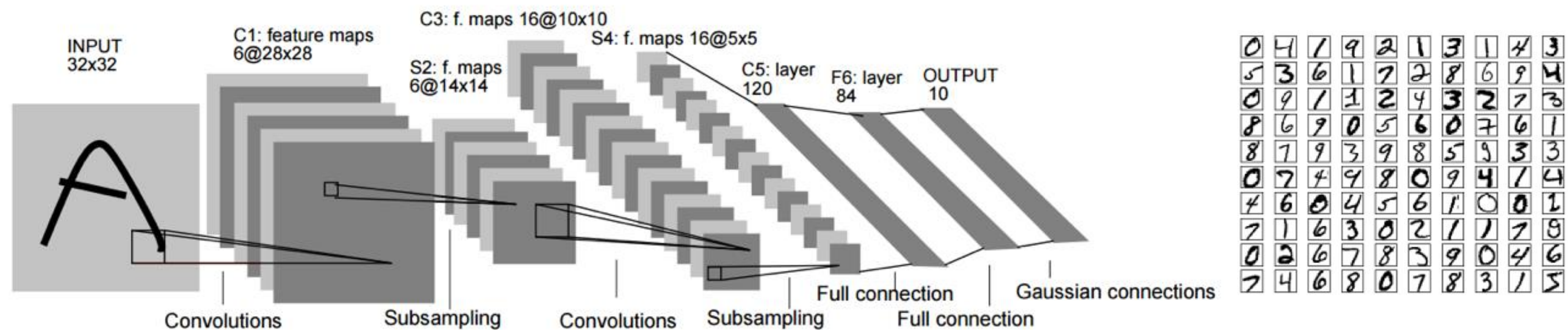- Co-founder – IXICO

# Artificial Intelligence and Machine Learning
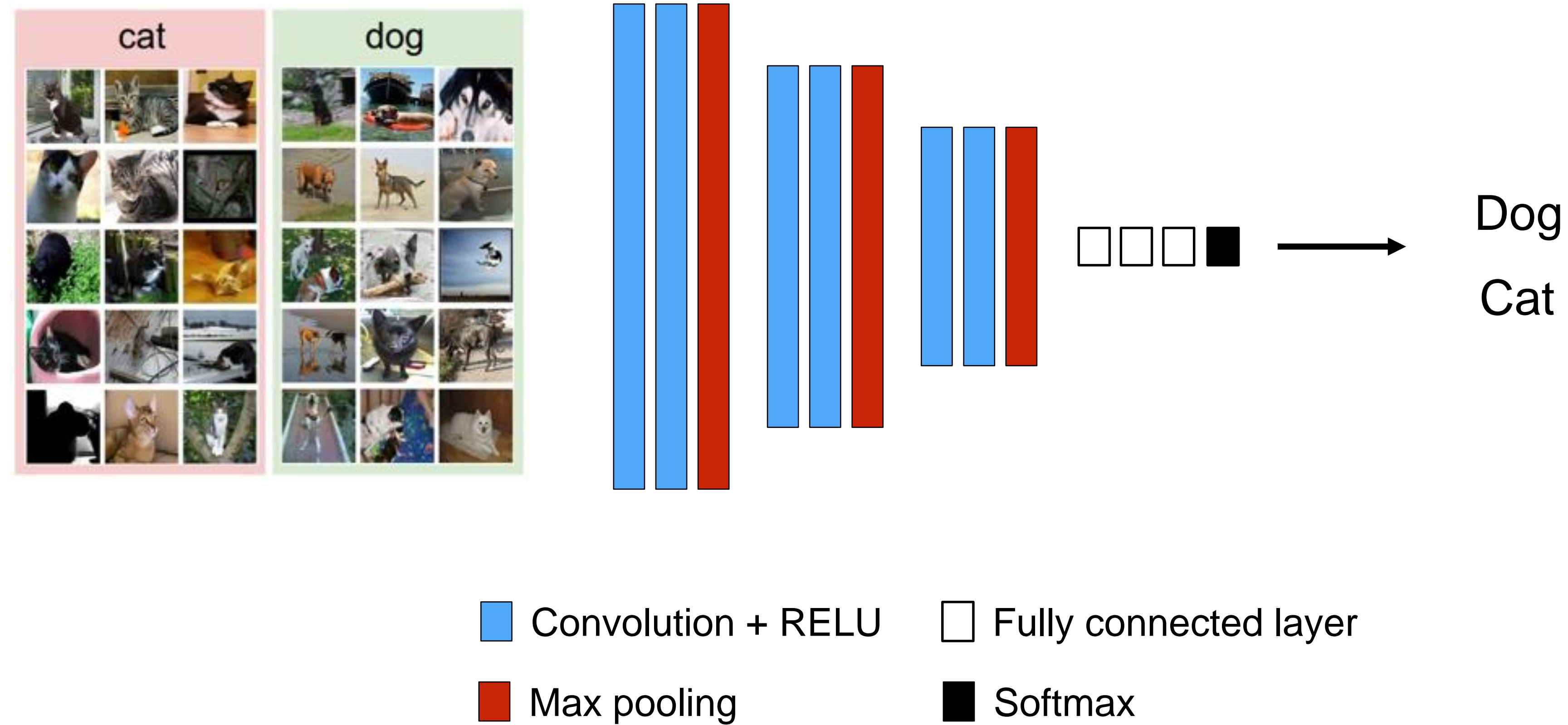
# The era of deep learning



Biologically inspired neural networks: Multi-layer perceptron, 1960s - 1980s



Convolutional neural networks: LeCun, 1990s
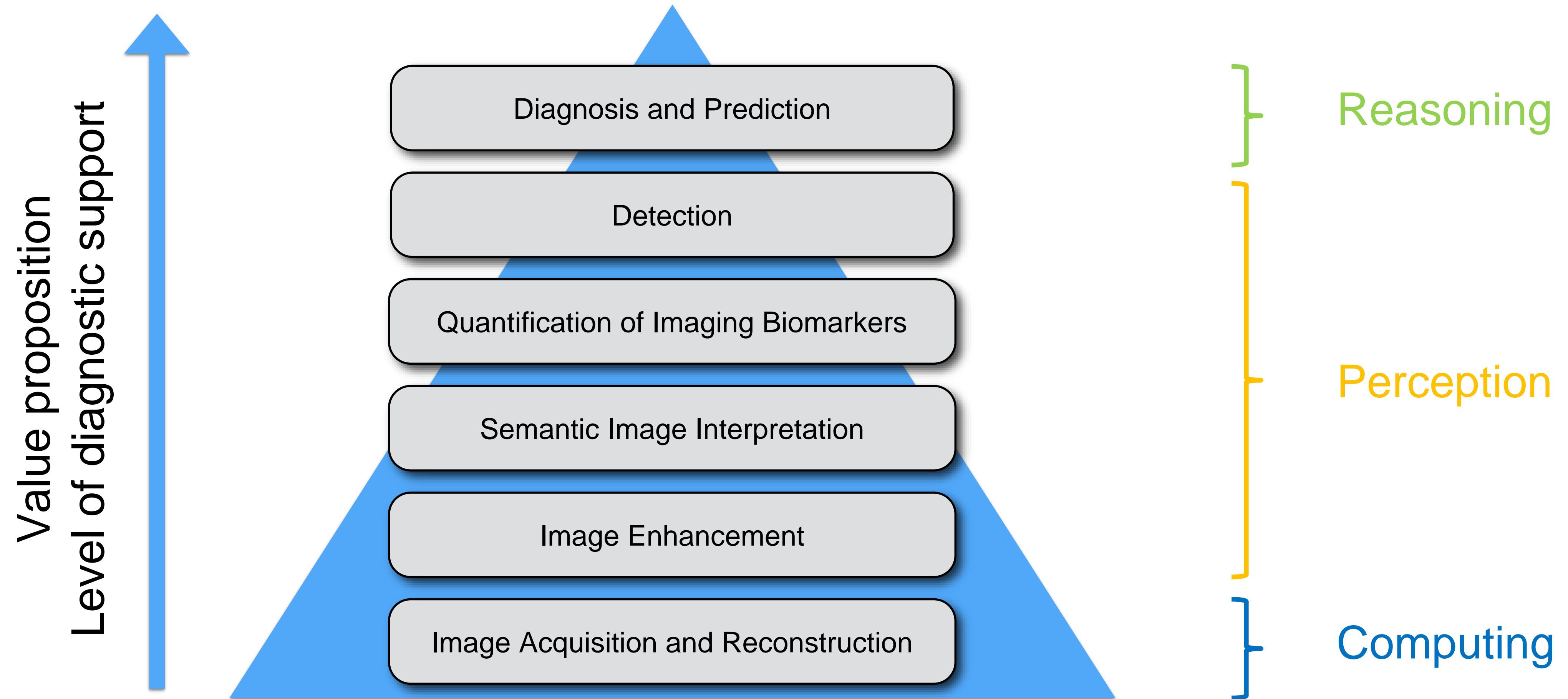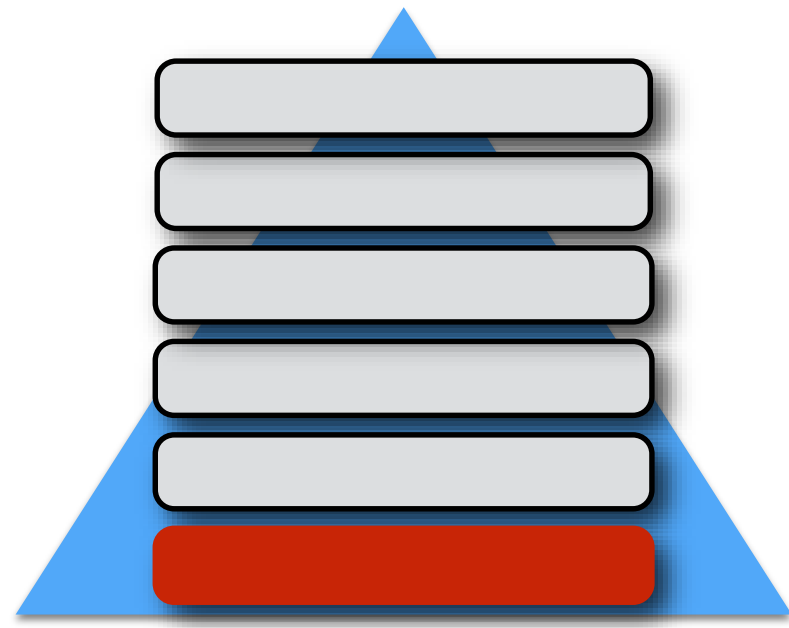
# The era of deep learning



Dog

Cat

■ Convolution + RELU   □ Fully connected layer

■ Max pooling   ■ Softmax

# The era of deep learning

- ## Image-to-image networks (many different architectures)
  - Fully convolutional networks (Long et al., 2015)
  - U-Net (Ronneberger et al., 2015)
  - DeepMedic (Kamnitsas et al., 2016)



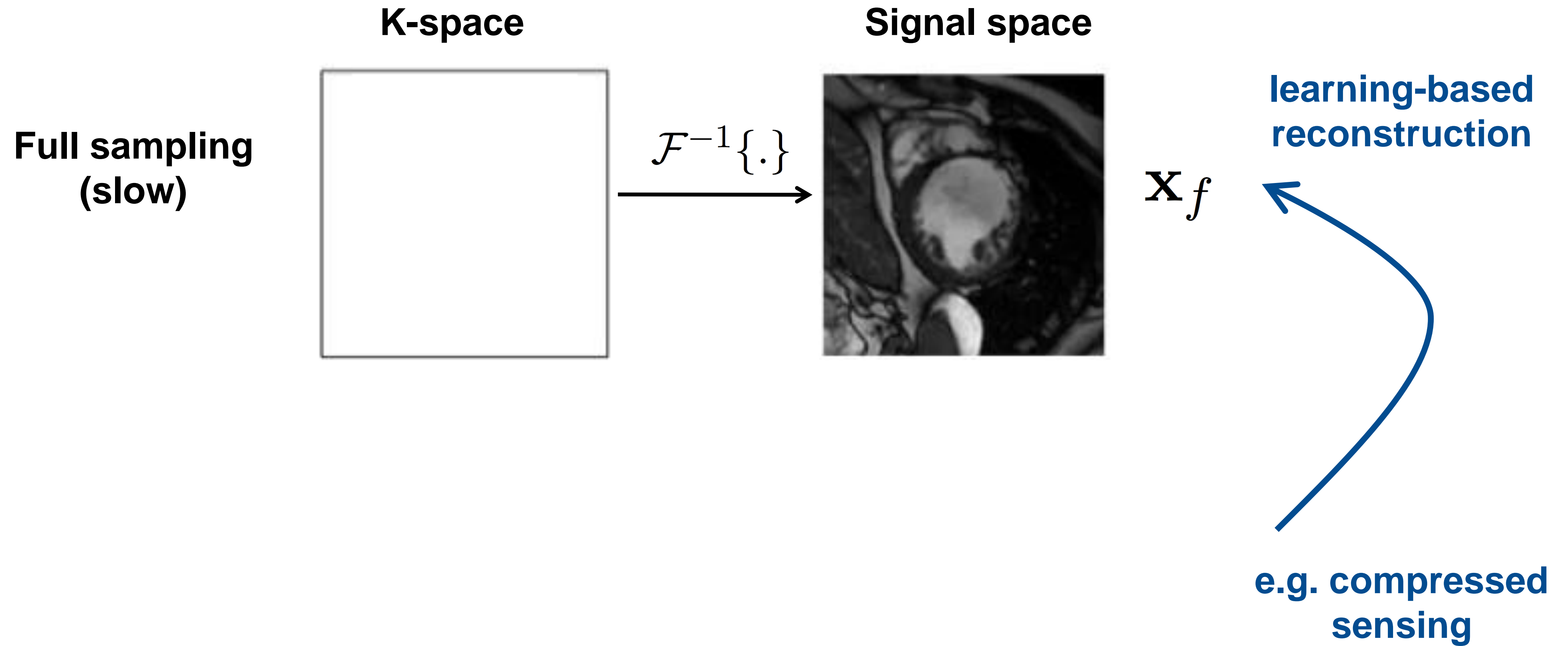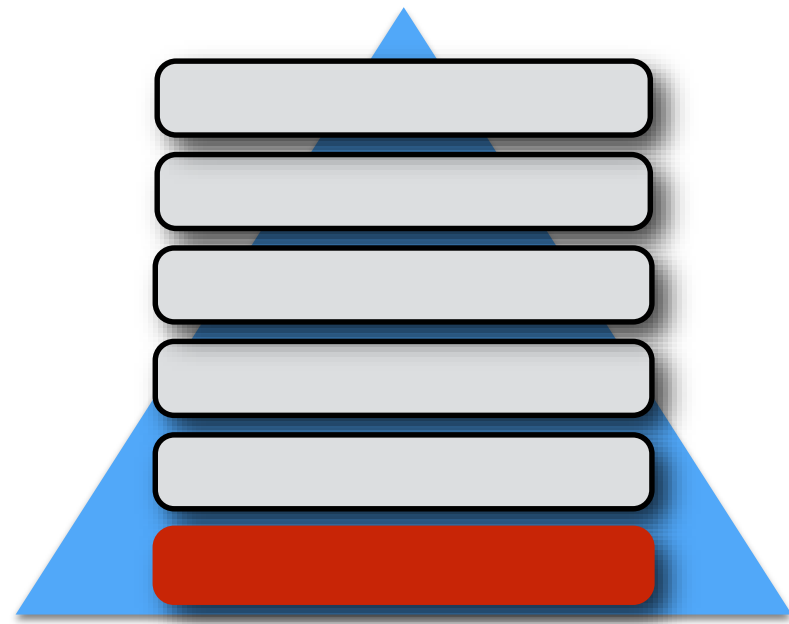Convolution + RELU   Unpooling (transposed convolution)
Max pooling   Softmax   Skip layers
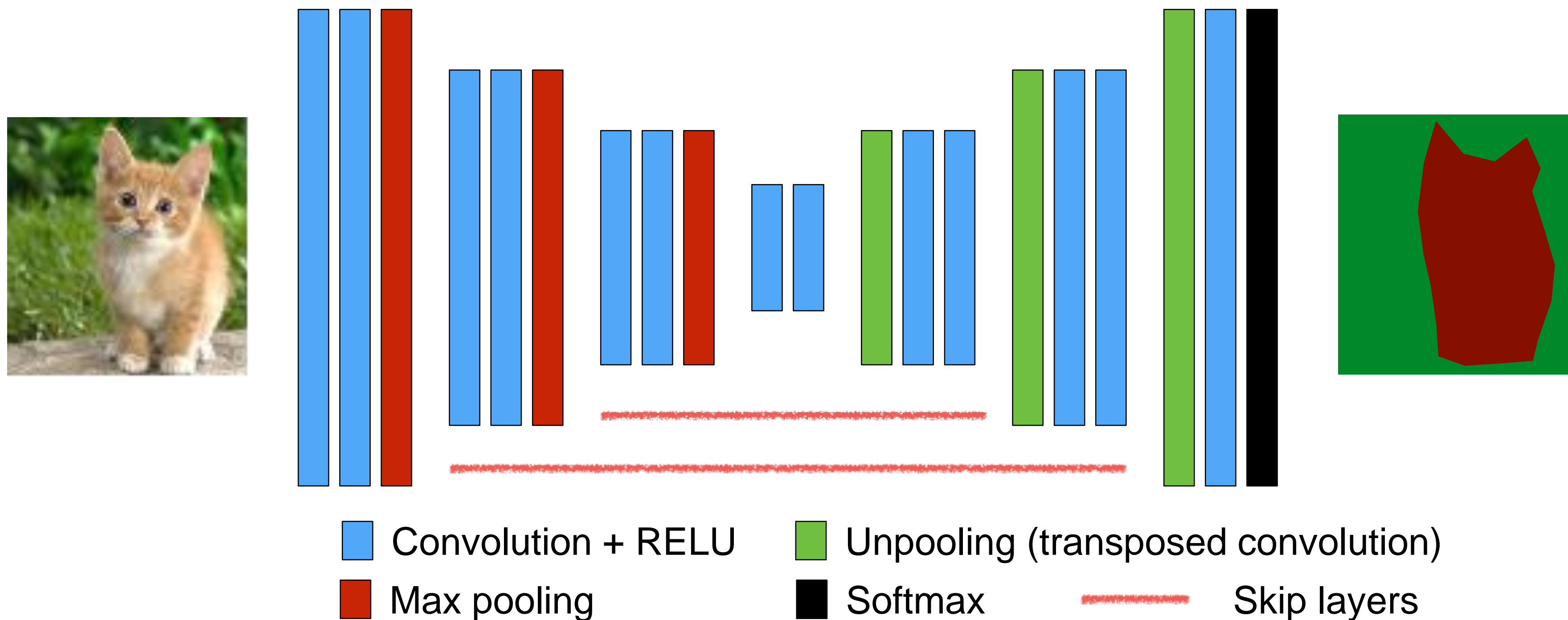
# Deep learning for medical imaging: Opportunities

# Deep learning for image reconstruction

**K-space**

**Signal space**

**Full sampling (slow)**

$\mathcal{F}^{-1}\{.\}$

$\mathbf{x}_f$

**learning-based reconstruction**

**e.g. compressed sensing**
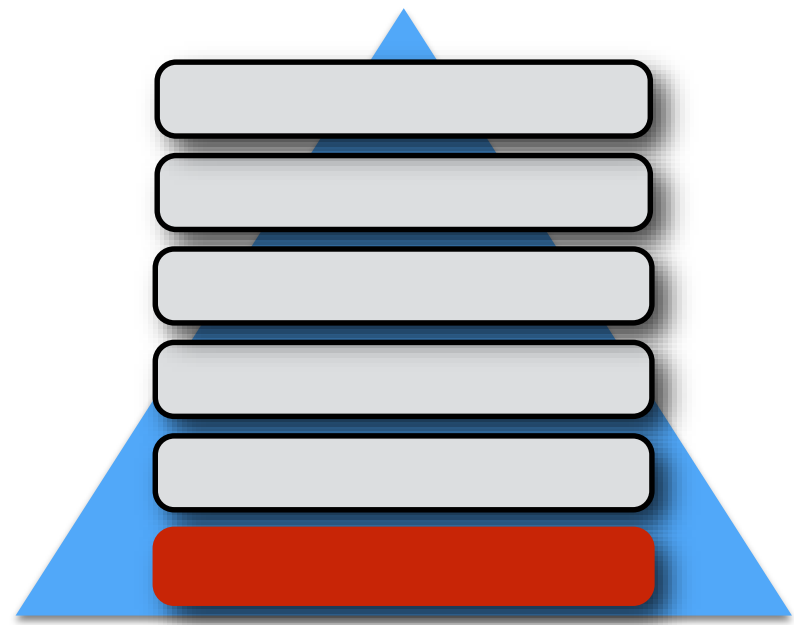
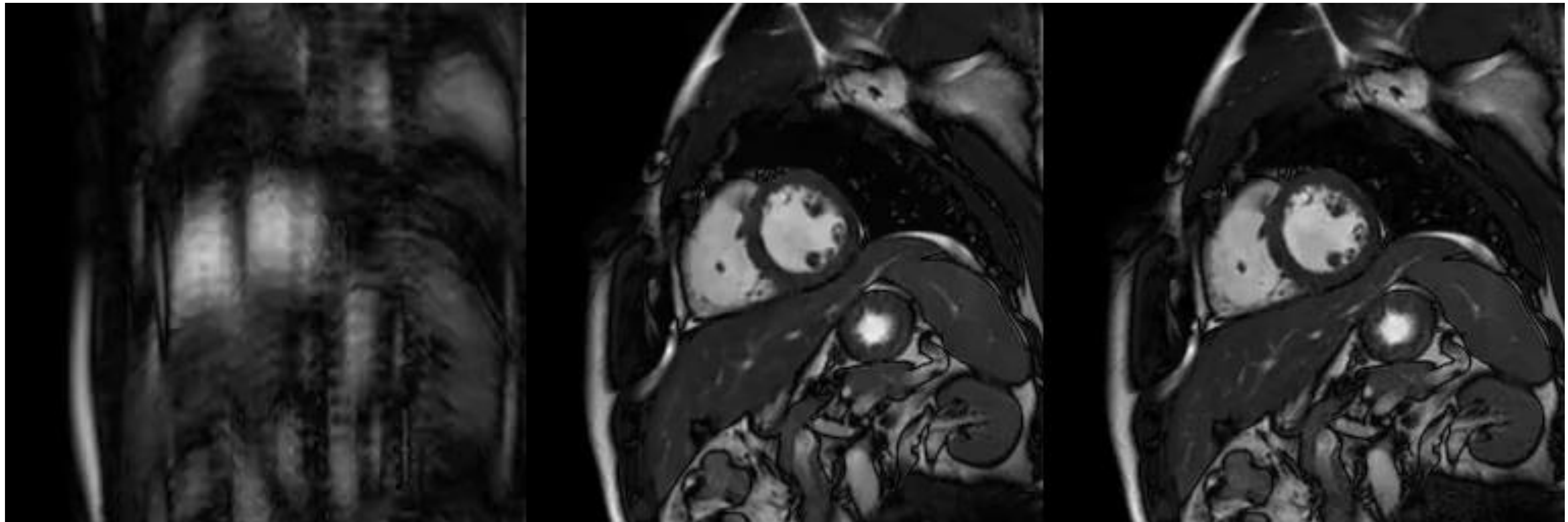# Deep learning for image reconstruction



Convolution + RELU     Transposed convolution

Max pooling     Softmax     Skip layers

# Magnitude reconstruction (6-fold)



(a) 6x Undersampled  (b) CNN reconstruction  (c) Ground Truth
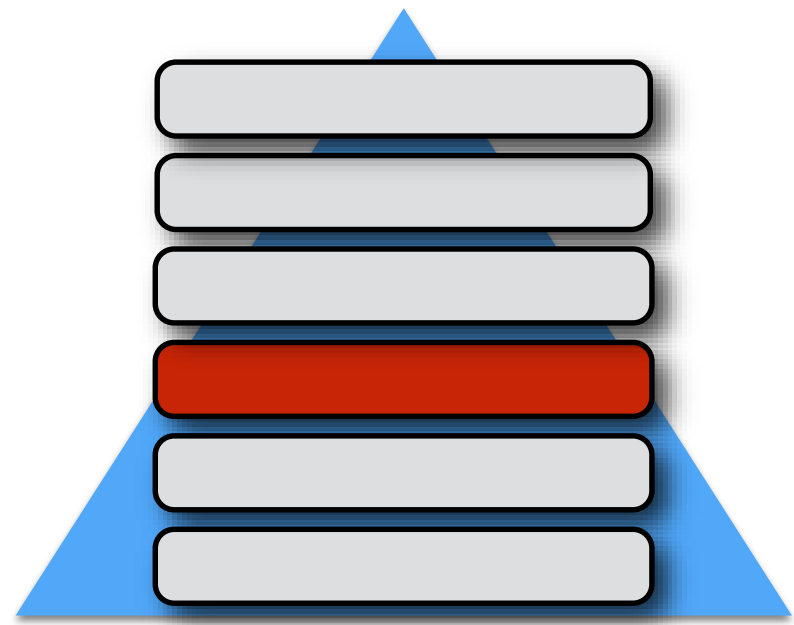
Schlemper et al. IEEE TMI 2017
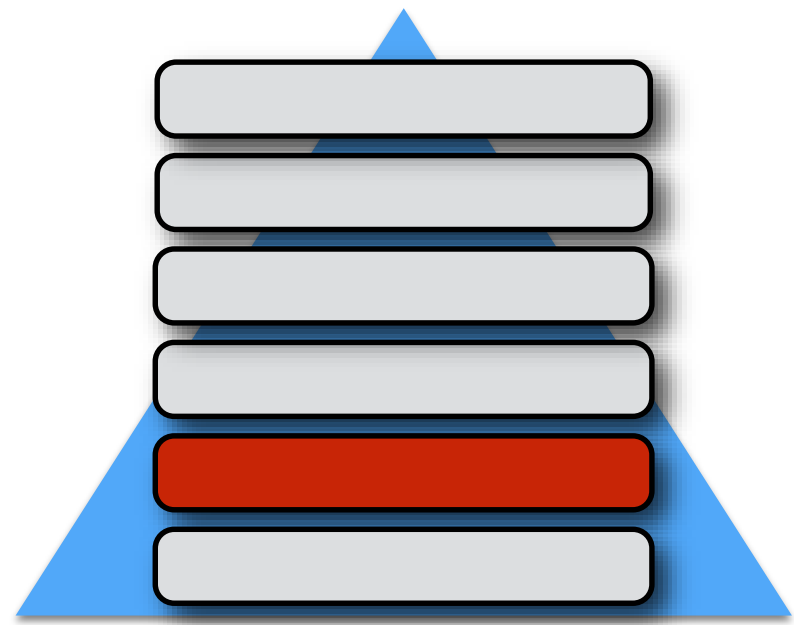
# Deep learning for image super-resolution



2D-LV SAX
Acquisition
1.2x1.2x10mm

Linear
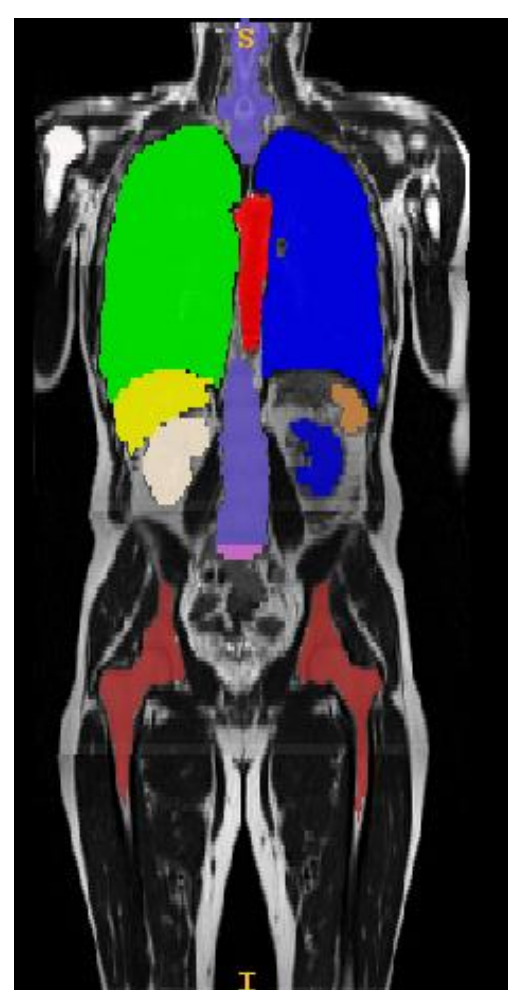Interpolation
1.2x1.2x2mm

CNN
Super Res
1.2x1.2x2mm

3D-LV SAX
Acquisition
1.2x1.2x2mm

O. Oktay et al. IEEE TMI 2017

# Deep learning for image segmentation
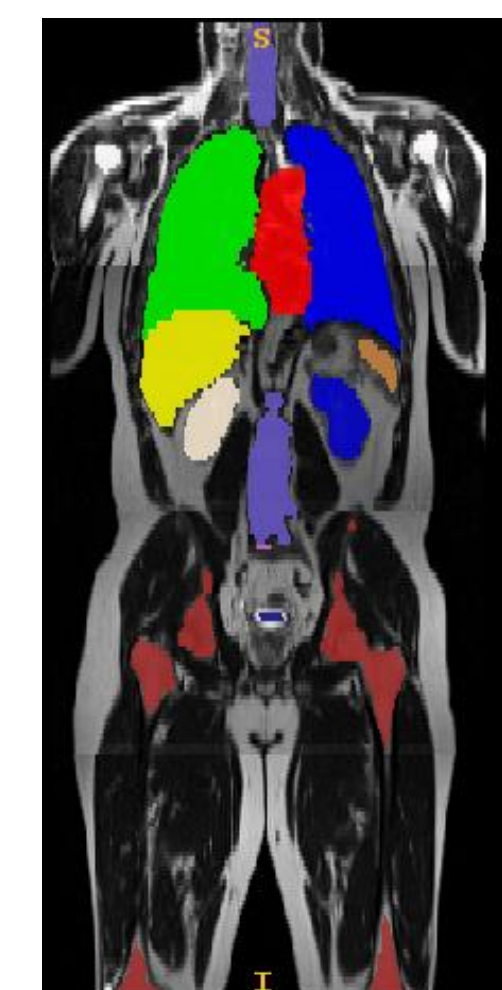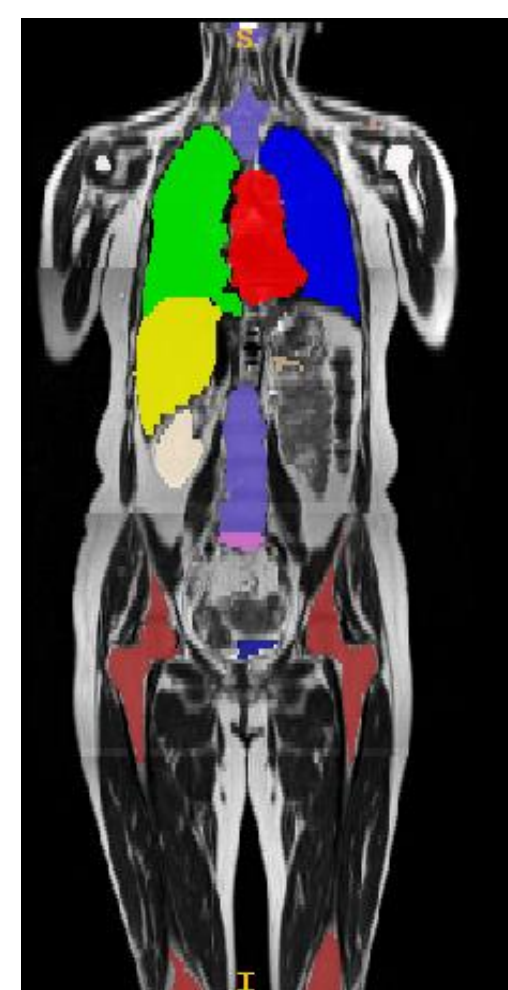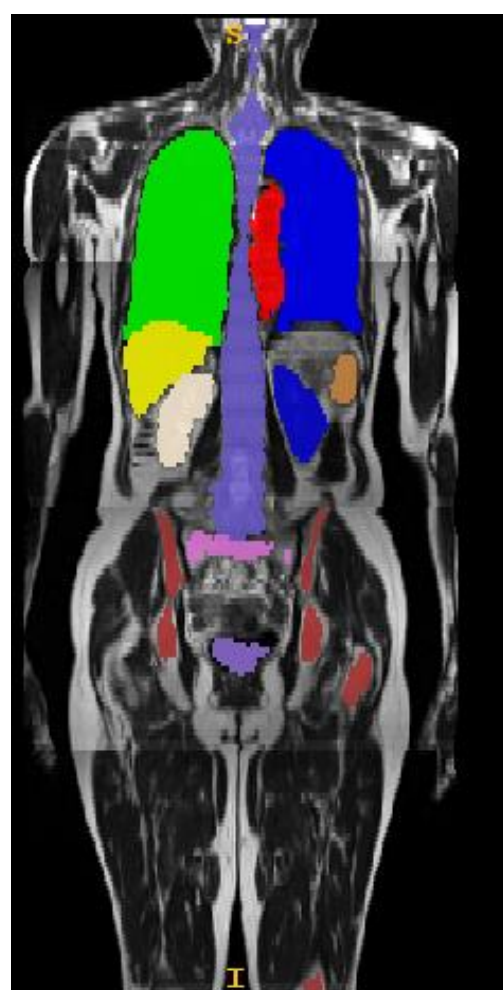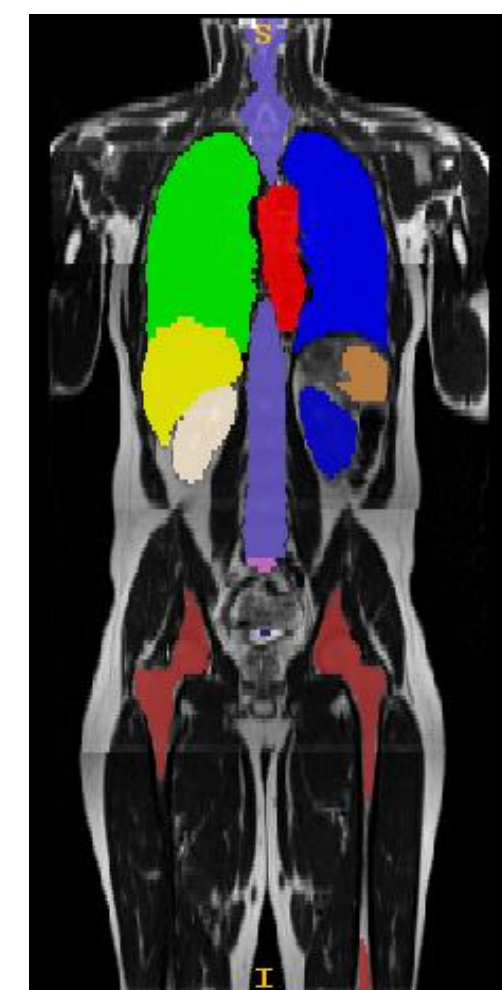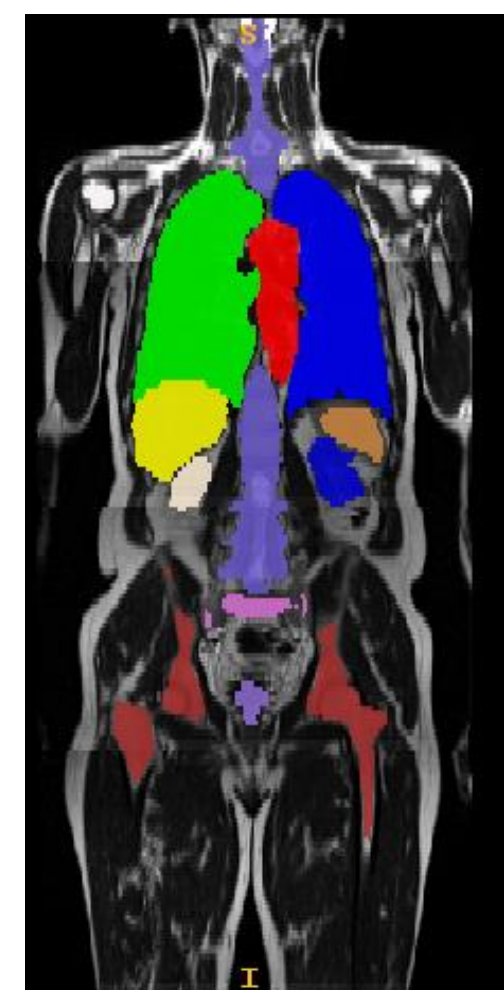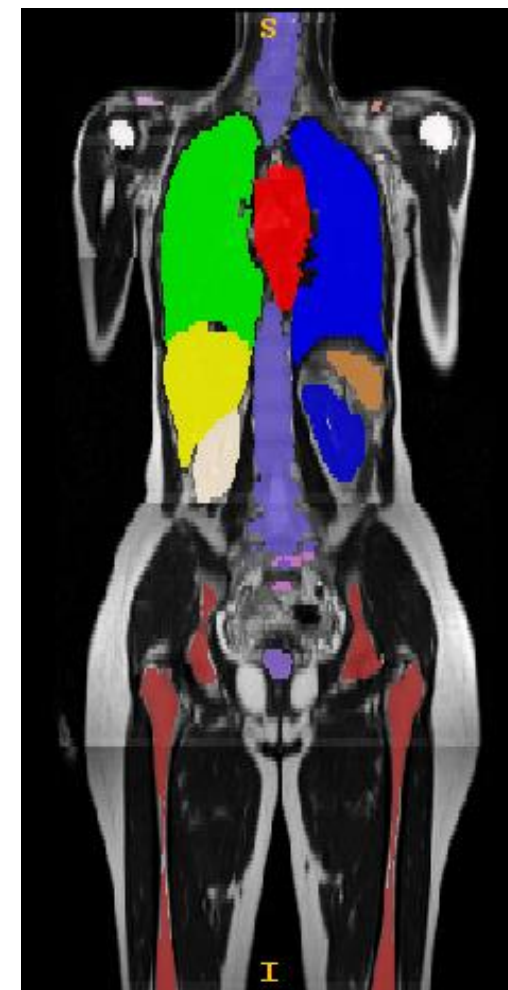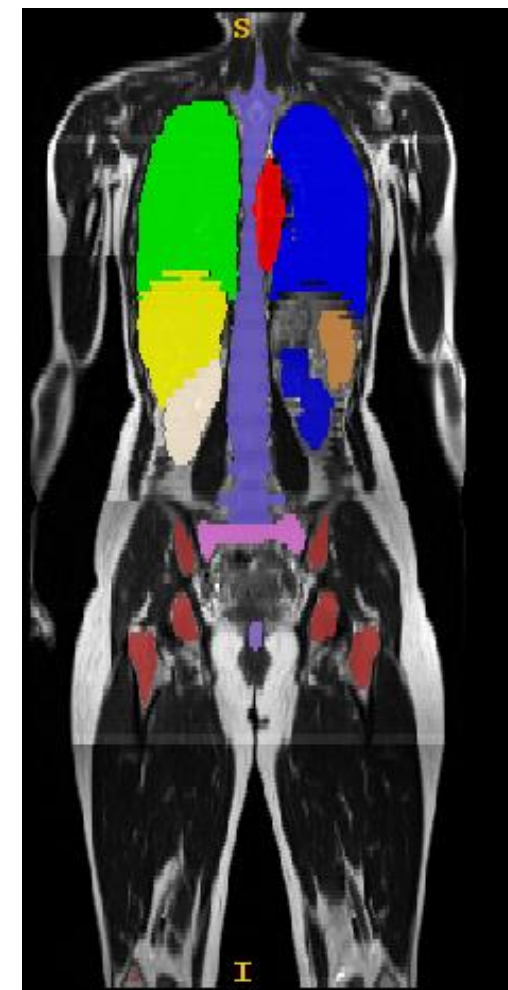
Lavdas et al. 2017,
Medical Physics
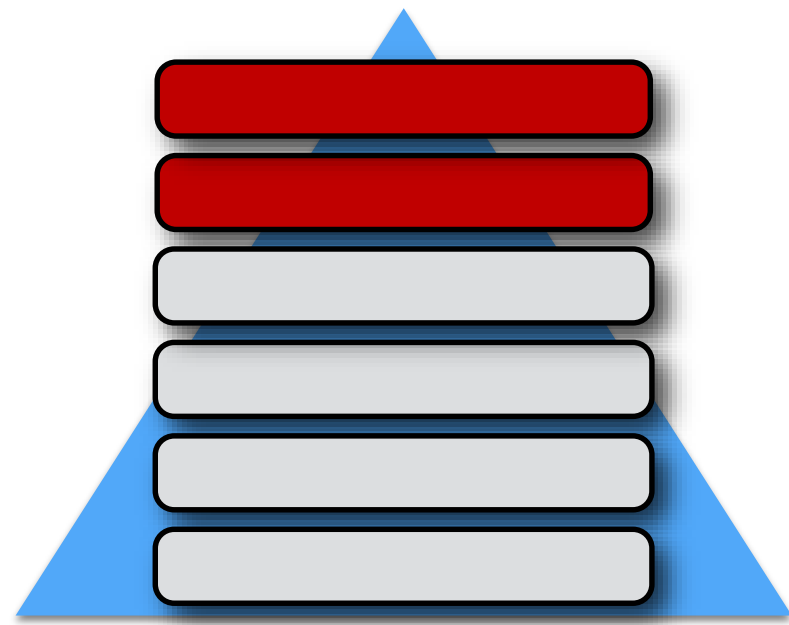
# Deep learning for decision support
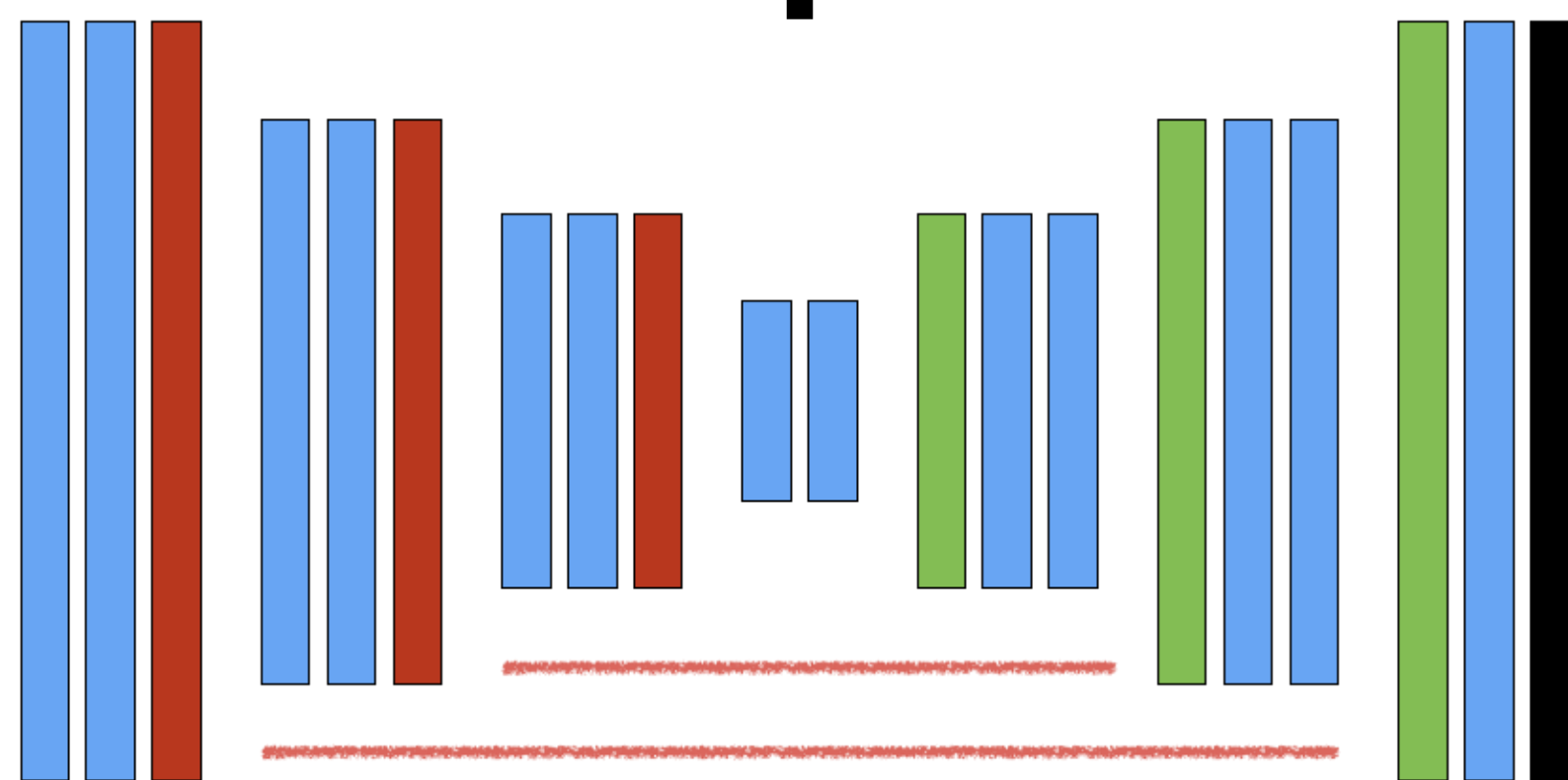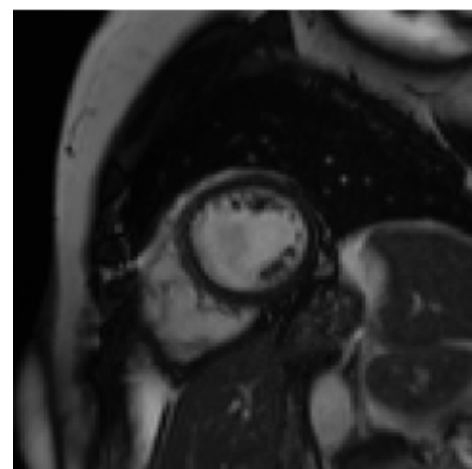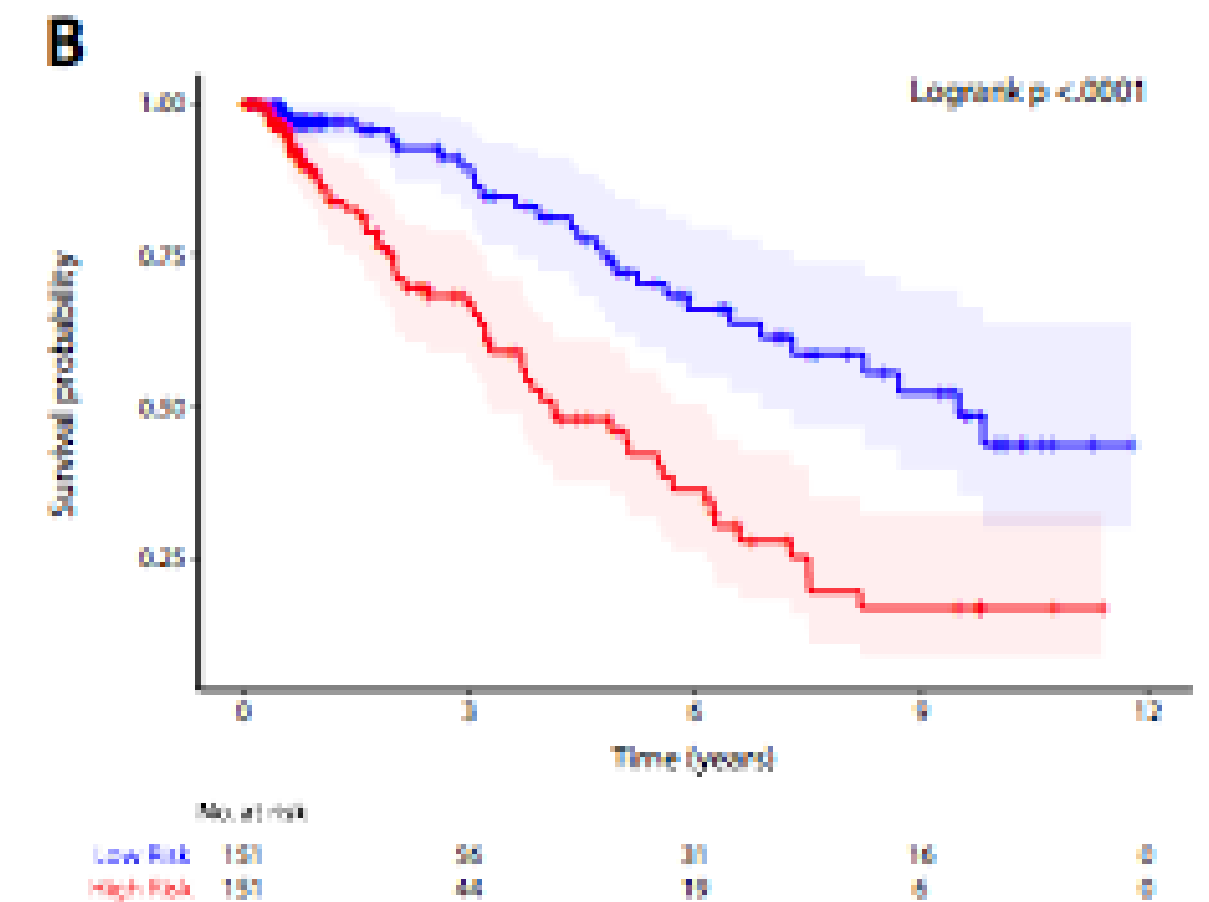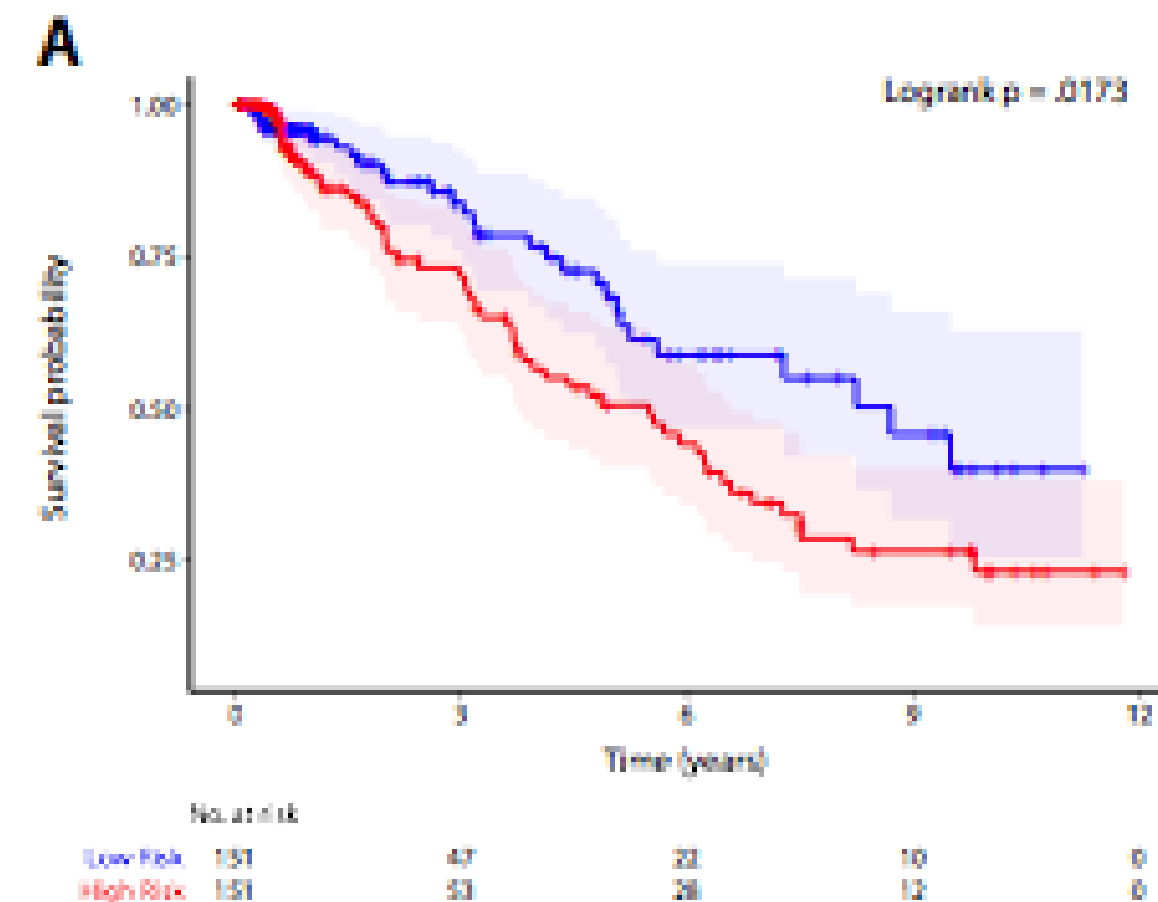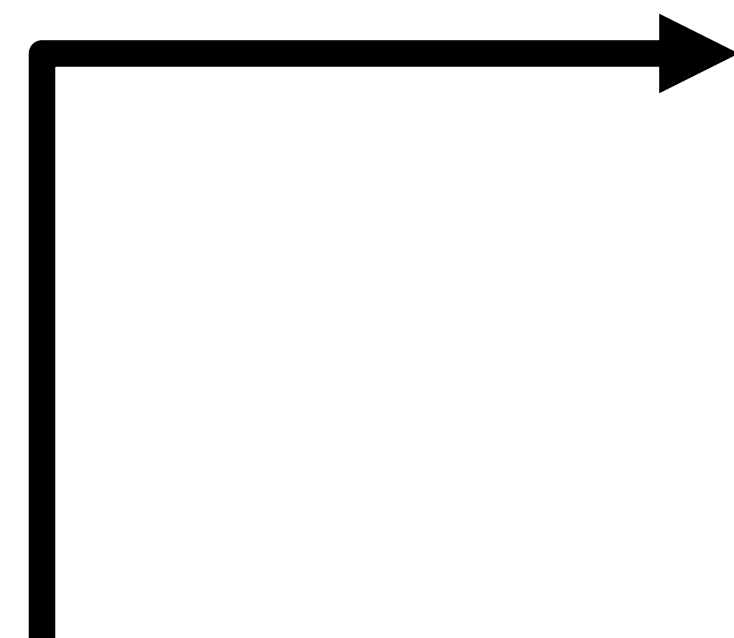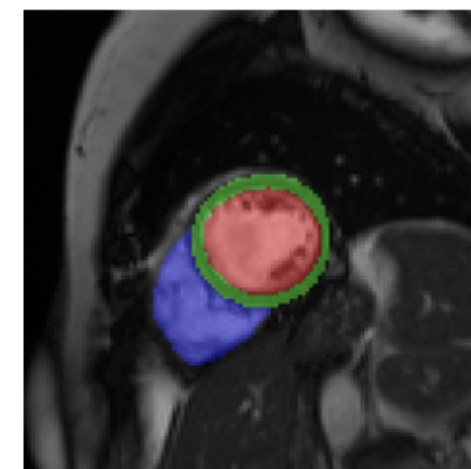


Prediction of survival in patients
with pulmonary hypertension

Convolution + RELU   Transposed convolution
Max pooling   Softmax   Skip layers

Bai et al., JCMR 2018

# Technical challenges

- Lack of data

# Technical challenges

- Lack of data ➡ Population studies

UK Biobank will provide large-scale imaging data from 100,000 subjects

# Technical challenges

- Lack of data → Population studies

UK Biobank will provide large-scale imaging data from 100,000 subjects



Lifestyle

Genetics

Clinical records

# Technical challenges

- Lack of data  →  Population studies
- Domain shift



In the lab



In the the real-world

# Technical challenges

- Lack of data   ➡   Population studies
- Domain shift   ➡   Transfer learning
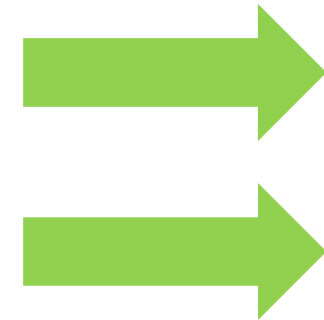


**theguardian**

news / opinion / sport / arts / life

UK / world / business / election / tech / UK politics / more

Artificial intelligence (AI)

A beauty contest was judged by AI and the robots didn't like dark skin

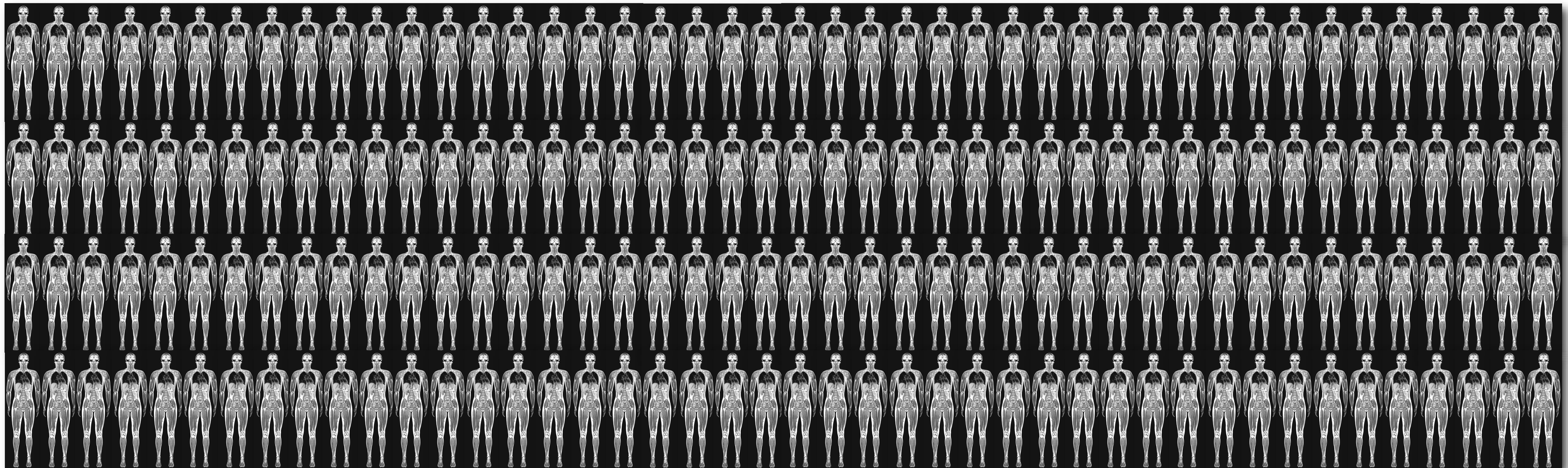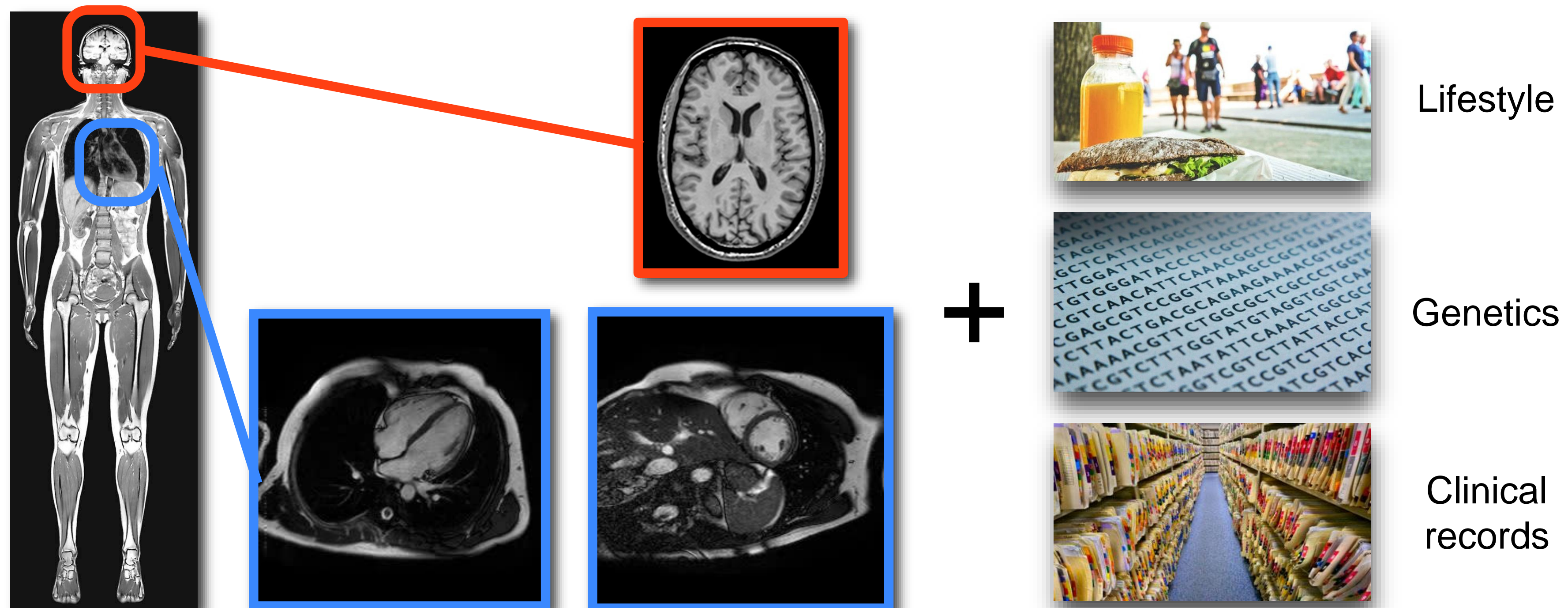"…the main problem was that the data the project used to establish standard of attractiveness did not include enough minorities."

- The Guardian (url)



# TIME

## Are Face-Detection Cameras Racist?

"You would think that Nikon, being a Japanese company, would have designed this with Asian eyes in mind."

- Random commenter(url)

# Technical challenges

- Lack of data   ➡️   Population studies
- Domain shift   ➡️   Transfer learning
- Privacy   ➡️   Differential privacy and federated learning



Hospital 1      Hospital 2      Hospital $k$
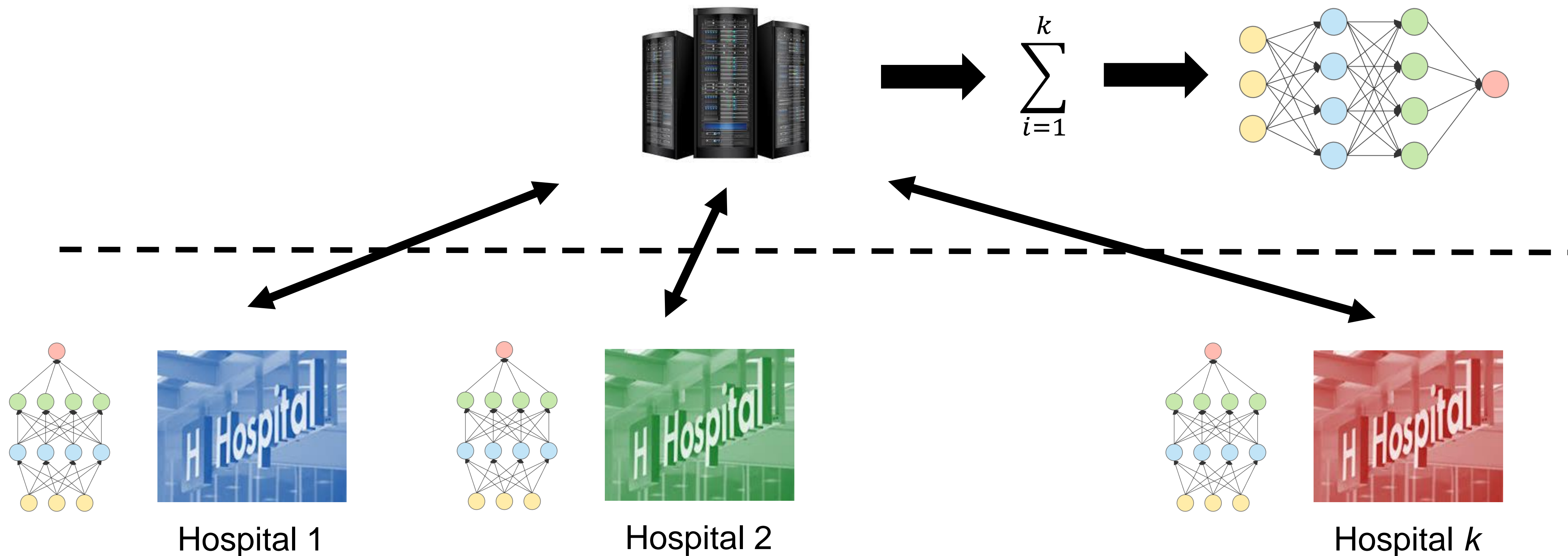
# Technical challenges

- Lack of data    ➡️   Population studies
- Domain shift    ➡️   Transfer learning
- Privacy    ➡️   Differential privacy and federated learning
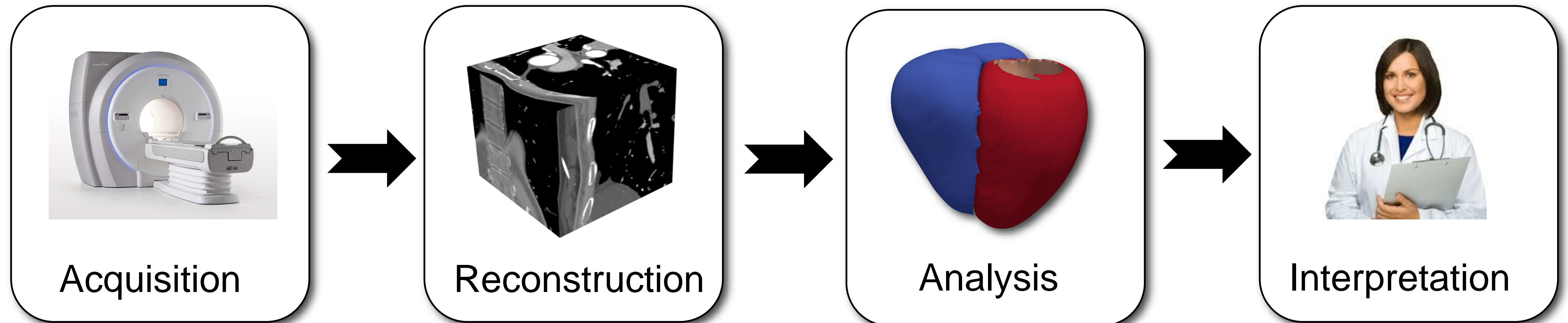- Adversarial attacks    ➡️   Verification

$+.007 \times$

$=$

"panda"
57.7% confidence

"nematode"
8.2% confidence

"gibbon"
99.3 % confidence

# Traditional medical imaging



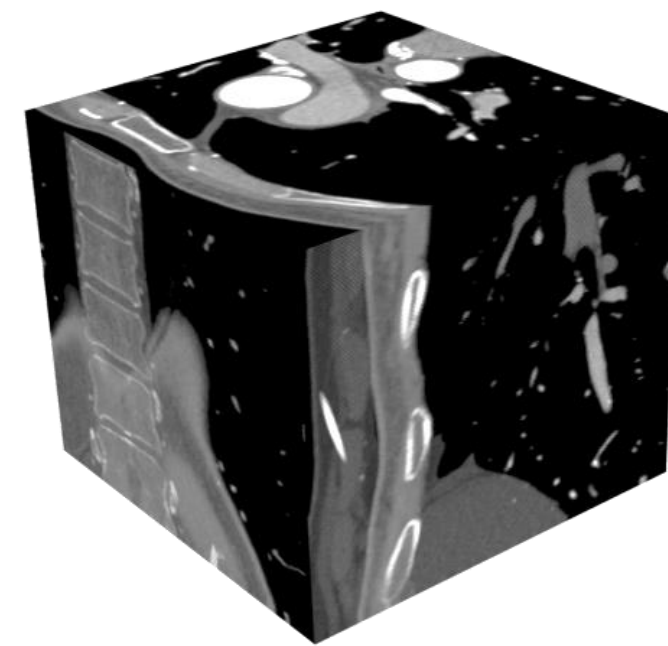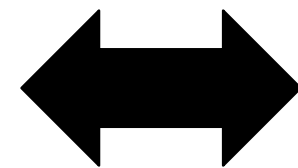| Acquisition | → | Reconstruction | → | Analysis | → | Interpretation |

✗ Serial process with no interaction between different components of imaging pipeline

✗ Limited ability for adjustment of upstream imaging pipeline based on downstream requirements

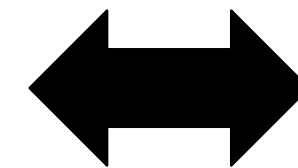✗ Stages of imaging pipeline not optimized for clinical endpoint
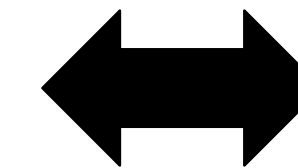
# AI-enabled medical imaging



Acquisition ⟷ Reconstruction ⟷ Analysis ⟷ Interpretation

✓ Close coupling of acquisition, reconstruction, analysis and interpretation
✓ Feedback and interaction between components of imaging pipeline
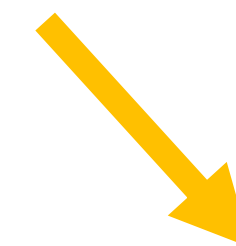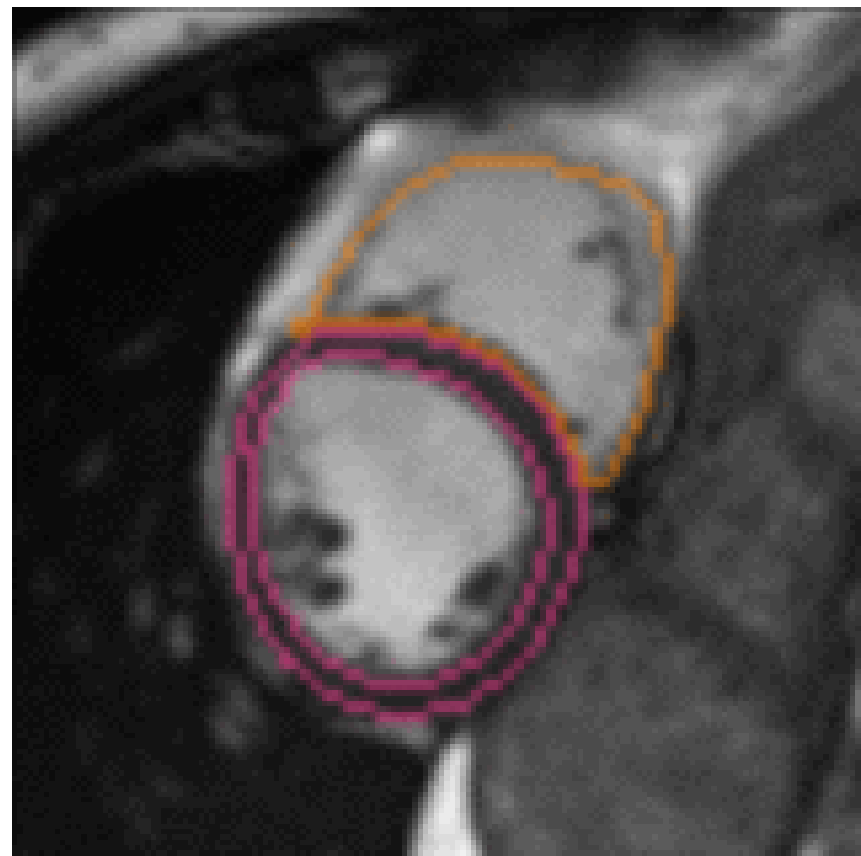✓ Optimization of whole imaging pipeline with respect to clinical endpoint

VALUE ADDED
100%
100%

# AI-enabled medical imaging



Acquisition

?

Diagnosis

## Do we need images at all?

# AI-enabled medical imaging: Example

Ground truth

J. Schlemper et al.
MICCAI 2018

# Acknowledgements

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