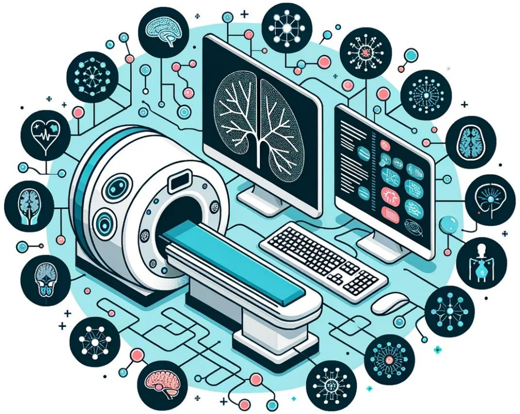
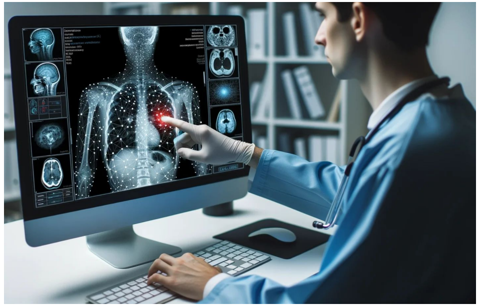
Applied Deep Learning and Generative Models in Healthcare





Session 1: Introduction
Date: Jan 11 2025

Instructor: Mahmoud E. Khani, Ph.D.

Course structure and objectives

- **Class format:** Lecture + Lab (Jupyter notebooks for hands-on coding)
- **Course material:** Canvas, GitHub
- **Assessments:** Homework assignments, Final project
- **Learning outcomes**
  - Build deep learning models for medical imaging, drug discovery, etc.
  - Understand and apply generative models (e.g., GANs) in a healthcare context
  - Critically evaluate AI models for safety, bias, and regulatory considerations
- **Prerequisites**
  - Familiar with Python
  - Familiarity with basic ML concepts
  - Familiarity with Deep Learning libraries such as PyTorch and Tensorflow.

Overview of upcoming sessions

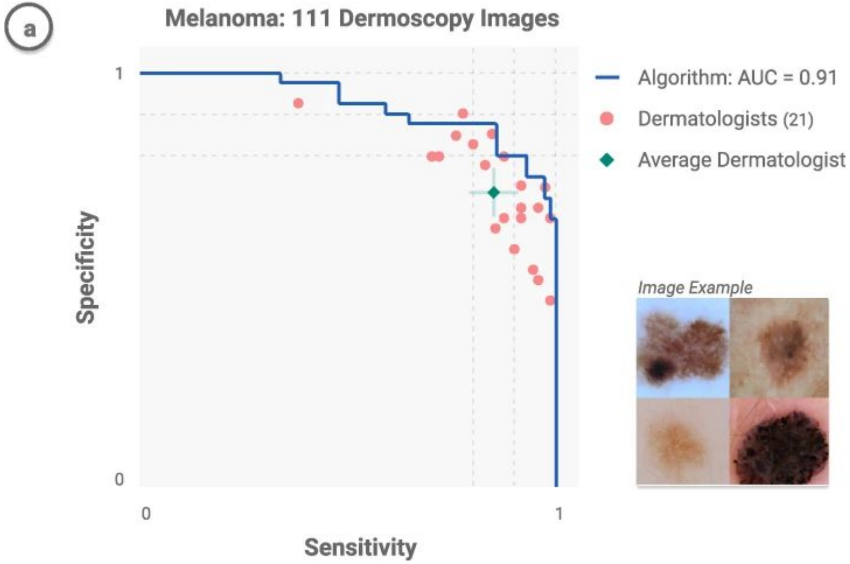
Session 1 (Today): Introduction to Deep Learning in Healthcare — high-level overview of the field, course logistics, Q&A.

Session 2: Convolutional Neural Networks (CNNs) in Medical Imaging — typical imaging tasks (e.g., classification, detection, segmentation) and a hands-on notebook using CNN architectures (ResNet, VGG, etc.).

Session 3: Graph Neural Networks (GNNs) in Drug Discovery — how GNNs can model molecular graphs, predict protein-ligand interactions, and accelerate drug discovery pipelines.

Why Deep Learning in Healthcare?

Transformation Potential: From diagnostics to drug discovery, deep learning is driving innovation.



✷Esteva, A. et al. npj Digit. Med. **4 (**2021)

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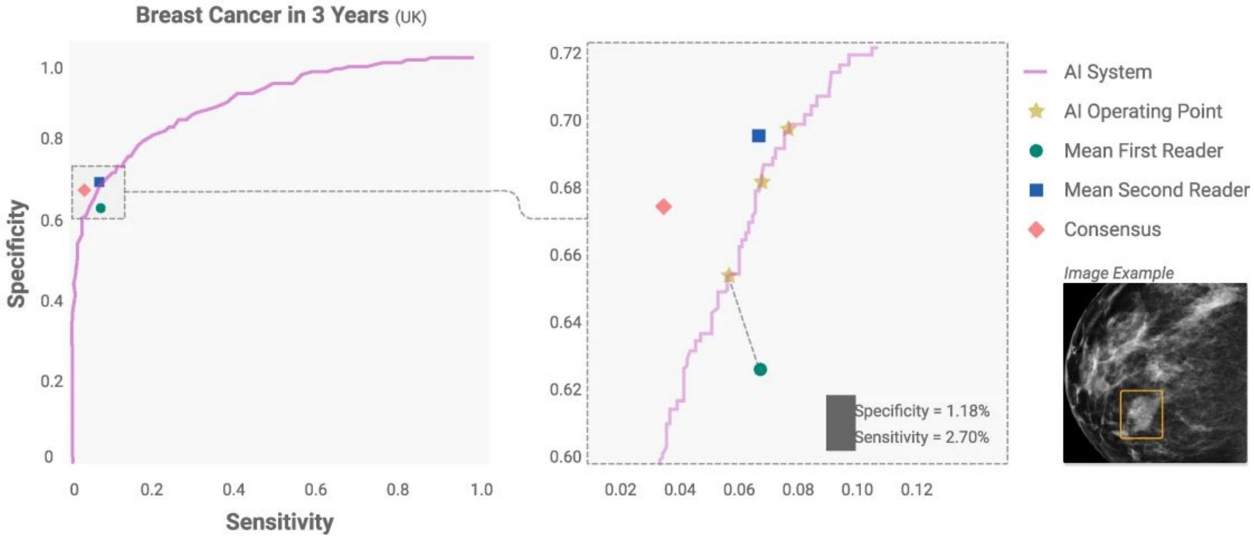
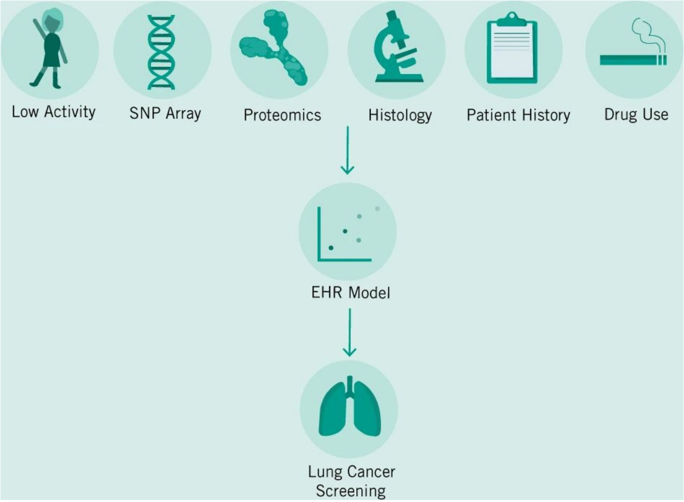
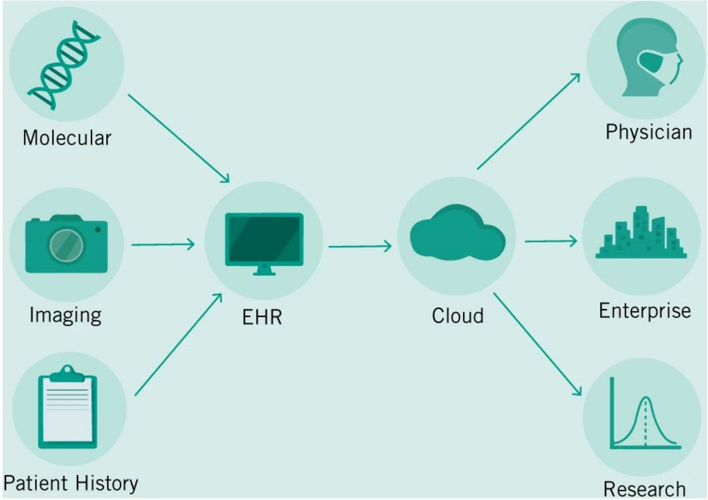


✷Esteva, A. et al. npj Digit. Med. **4 (**2021)

Why Deep Learning in Healthcare?

Data Availability: Electronic Health Records (EHRs), medical imaging repositories, genomics data.

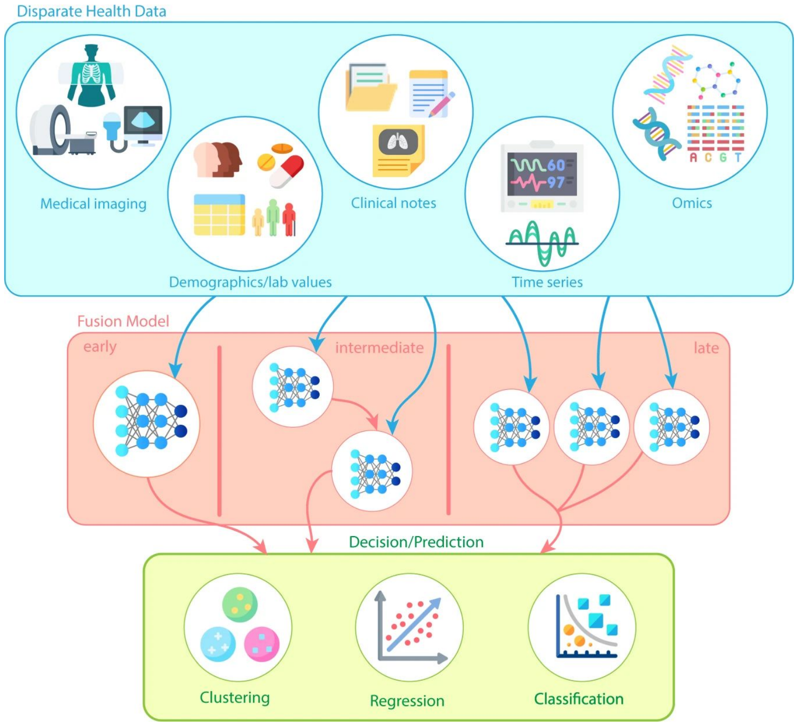




✷Agrawal, R. et al. Heredity **124** (2020)

Why Deep Learning in Healthcare?

Complexity of Healthcare Data:
Structured (EHRs, lab results), unstructured (clinical notes), image data (X-ray, MRI), multimodal data, etc.



✷Kline, A. et al. npj Digit. Med. **5** (2022)

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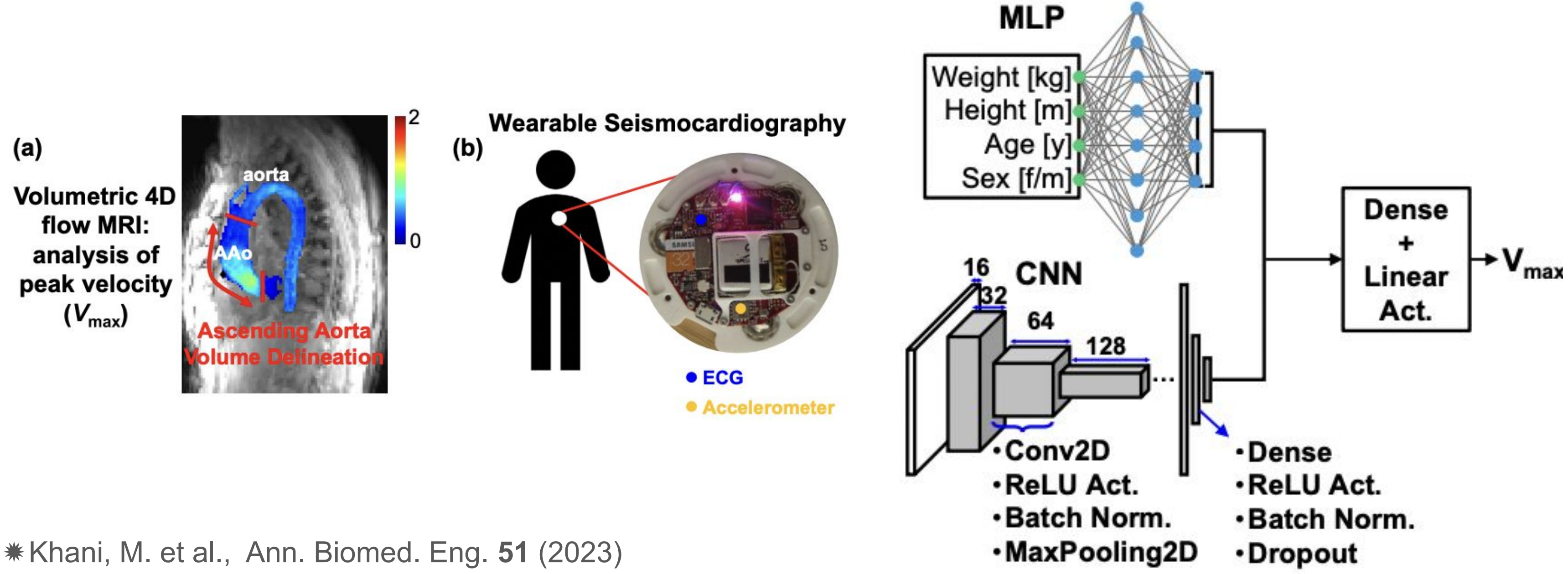


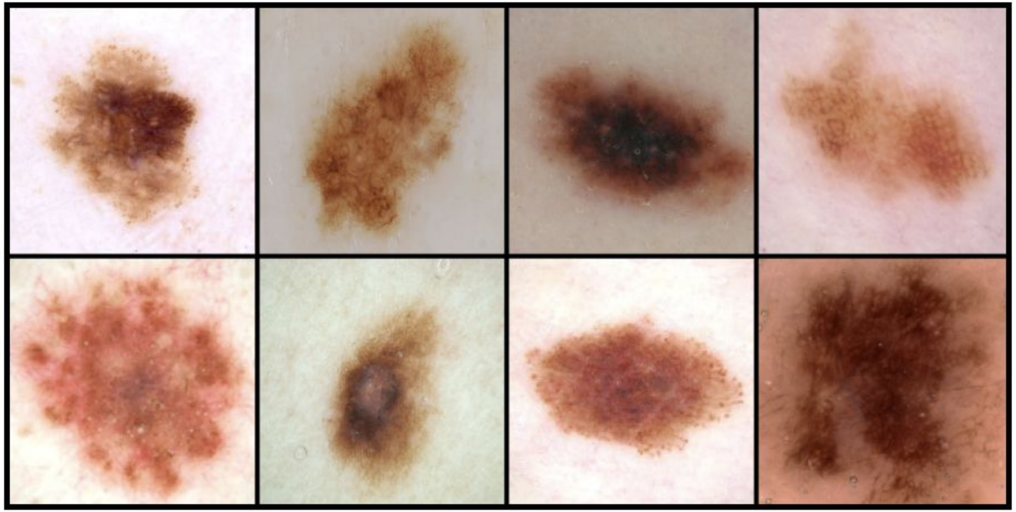
⁕Khani, M. et al., Ann. Biomed. Eng. **51** (2023)

Why Deep Learning in Healthcare?

Growing Need: Address physician shortages, reduce medical errors, accelerate drug discovery, personalized medicine.

Malignant Melanoma

Benign Nevi



✷Esteva, A. et al., Nature **542** (2017)

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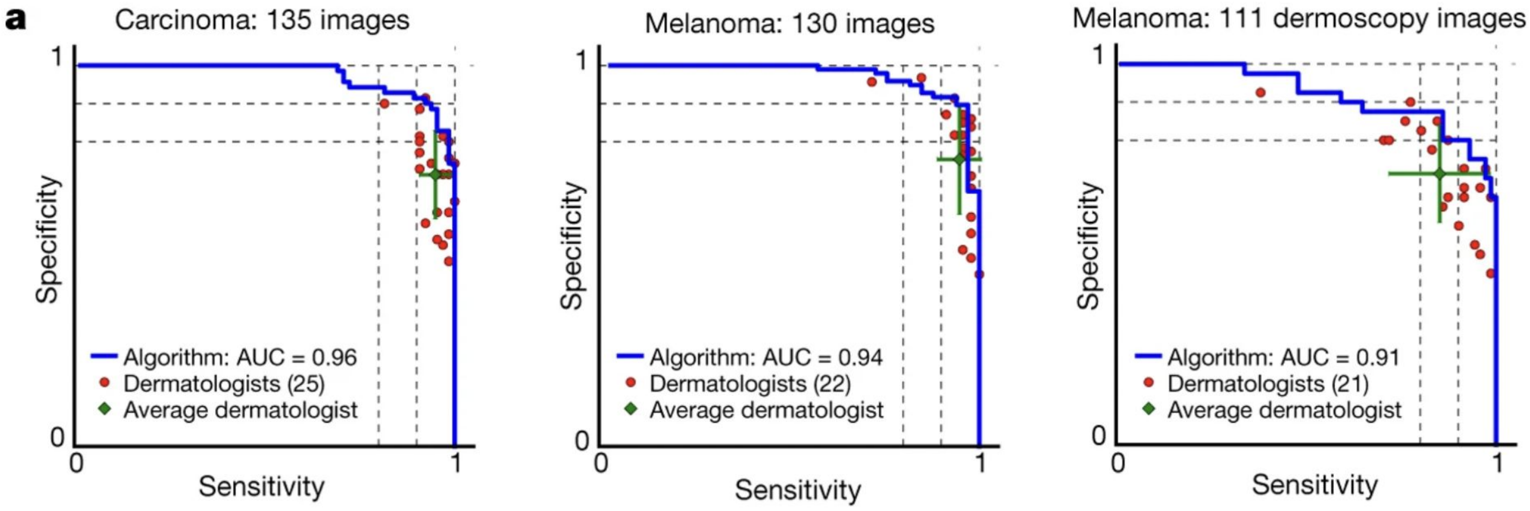

✷Esteva, A. et al., Nature **542** (2017)

Techniques used to solve this problem

Training set A large set of lesion images each labelled as *malignant* or *benign* (from biopsy)

Training Adjustment of 25 million parameters in *deep neural network* using the training set

Supervised learning For each training example, the network is told the correct label

Classification Each input is assigned to a discrete set of classes (benign or malignant)

Transfer learning The deep neural network was first trained on a much larger data set of 1.28 million images of everyday objects (such as dogs, buildings, and mushrooms) and then fine-tuned on the 129,000 data set of lesion images

Evaluation metrics Accuracy, sensitivity, specificity, ROCAUC, confusion matrices, recall, precision, etc.

✷Esteva, A. et al., Nature **542** (2017)

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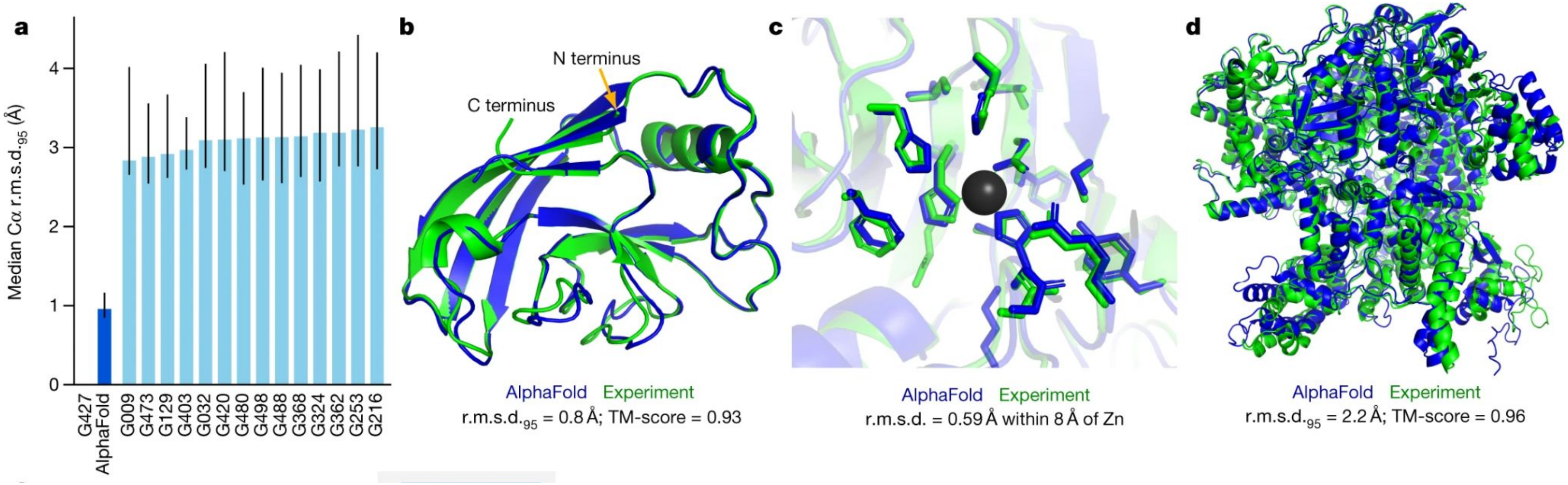
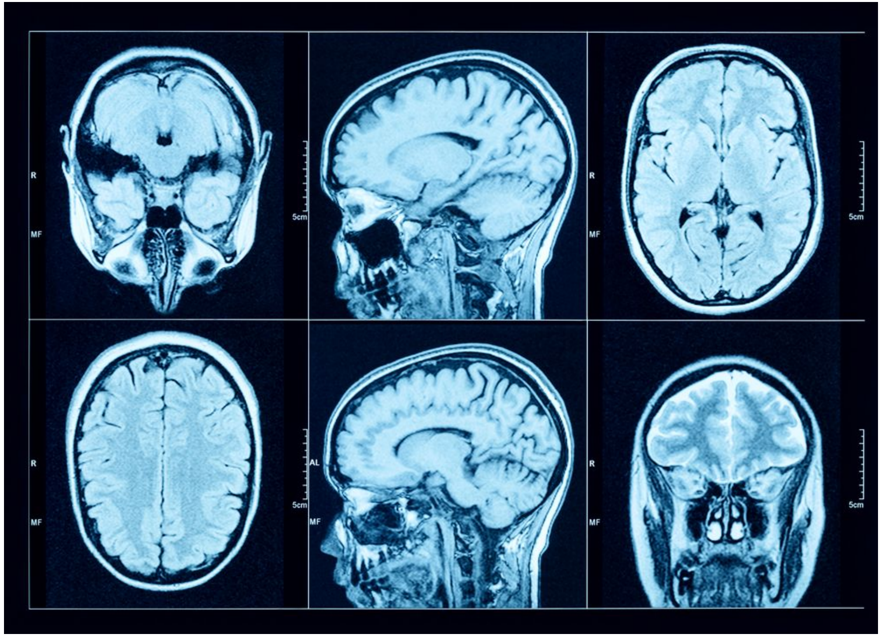


✷Jumper, J. et al., Nature **596** (2021)

GenAI in Medical Image Synthesis

Medical image acquisition is challenging:

- High operational costs (technical fees, professional fees, facility fee)
- High radiation exposure (PET/CT scans expose patient to high radiation)
- Long acquisition times (motion artifacts due to patient movements)

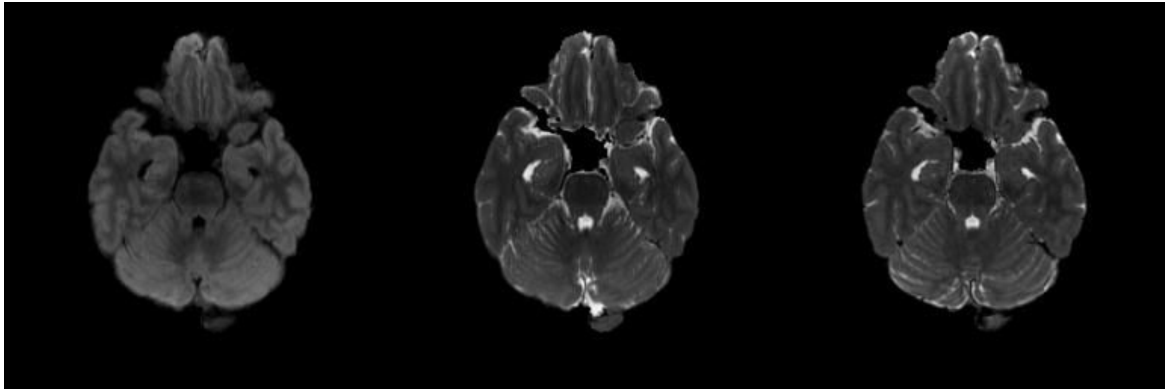


✷ https://swdic.com/services/

GenAI in Medical Image Synthesis

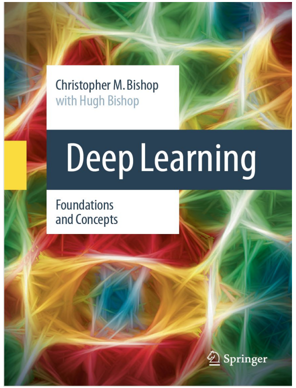
Low-field MRI cuts equipment and operational costs, and **low-dose PET** reduces patient radiation exposure.

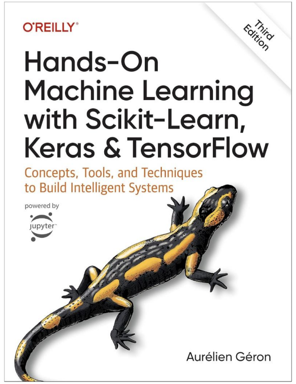
Both methods face difficulties with **image quality**, **diagnostic accuracy**, and **practical implementation**.

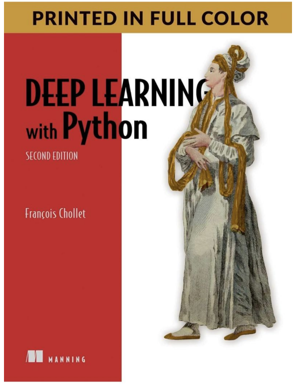


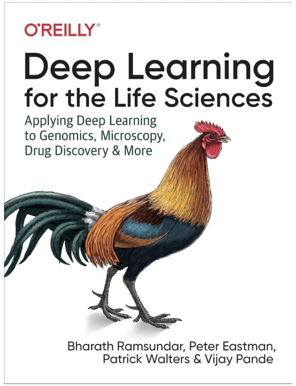
✷https://github.com/sanuwanihewa/MRSyn.git

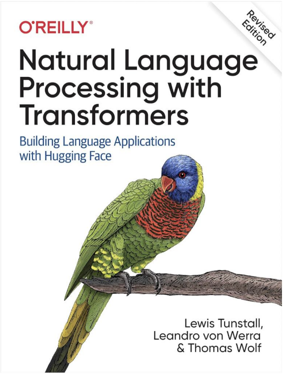
Some useful resources











- Stanford CS230 (Deep Learning)
- MIT's 6.S191 (Introduction to Deep Learning)
- fast.ai