Artificial Neural Network and Artificial Intelligence in Medical Sciences

نسیبه رادی راز

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بسم الله الرحمن الرحیم

دانشگاه علوم پزشکی و خدمات بهداشتی درمانی ایران

عنوان دوره آنلاین:

هوش مصنوعی در پزشکی با رویکرد بالینی

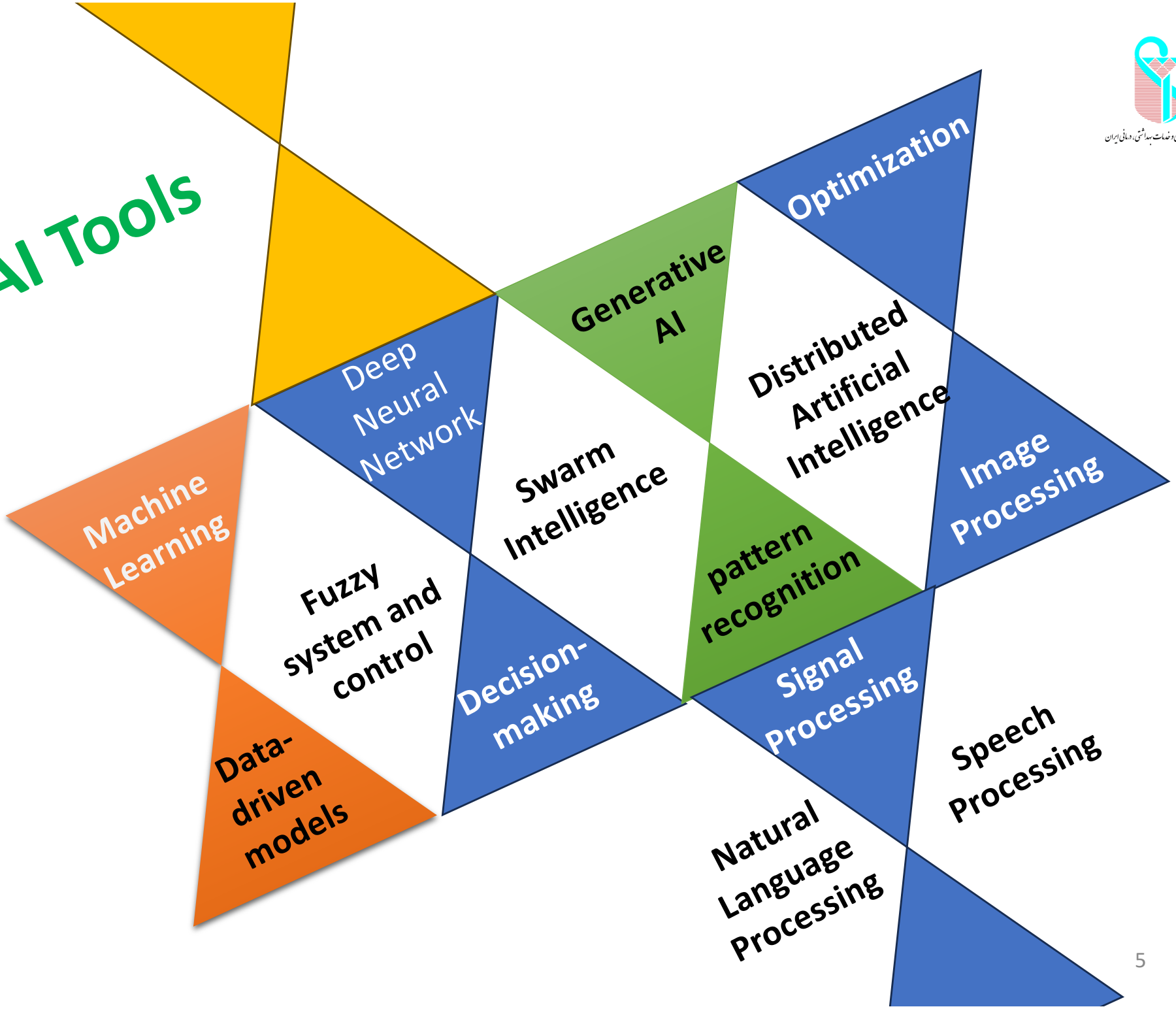
Online Course: Artificial Intelligence in Medicine with Clinical Approach

Course Topics	عناوین بیست و چهار جلسه	تاریخ جلسات
Artificial Intelligence (AI) in medicine	معرفی هوش مصنوعی در پزشکی	۲۸بهمن ۱۴۰۲
AI and Fuzzy systems and its applications in medicine	هوش مصنوعی و سیستم های فازی در پزشکی	۵ اسفند ۱۴۰۲
Machine Learning and its applications in medicine	یادگیری ماشین و کاربردهای آن در پزشکی	۱۲اسفند۱۴۰۲
Evolutionary systems and its applications in medicine	الگوریتم های بهینه سازی تکاملی و کاربردهای آن در پزشکی	۱۹اسفند ۱۴۰۲
Neural networks and deep neural networks in medicine	شبکه های عصبی و شبکه های عصبی عمیق در پزشکی	۲۵فروردین ۱۴۰۳
Application of AI in Early Detection of Disease	کاربرد هوش مصنوعی در تشخیص زودهنگام بیماری ها	۱ اردیبهشت ۱۴۰۳
Swarm Intelligence and multi-agent/swarm in medicine	هوش ازدحامی، سیستم های چند عامله/ازدحامی در پزشکی	۸اردیبهشت ۱۴۰۳
Application of AI in Cancer	کاربردهای هوش مصنوعی در سرطان	۲۲اردیبهشت ۱۴۰۳
Application of AI in surgery	کاربردهای هوش مصنوعی در جراحی	۲۹ اردیبهشت ۱۴۰۳
Applications of AI in Neurology	کاربردهای هوش مصنوعی در مغز و اعصاب	۵ خرداد ۱۴۰۳
Application of AI in Internal Medicine	کاربردهای هوش مصنوعی در پزشکی داخلی	۱۲ خرداد ۱۴۰۳
Applications of AI in cardiovascular	کاربردهای هوش مصنوعی در قلب و عروق	۱۹ خرداد ۱۴۰۳
Applications of AI in Breast Disease	کاربردهای هوش مصنوعی در بیماری های پستان	۲۶ خرداد ۱۴۰۳
Application of AI in Ophthalmology	کاربردهای هوش مصنوعی در چشم پزشکی	۲ تیر ۱۴۰۳
Application of AI in Nephrology	کاربردهای هوش مصنوعی در نفرولوژی	۹ تیر ۱۴۰۳
Application of AI in Otorhinolaryngology	کاربردهای هوش مصنوعی در گوش و حلق و بینی	۱۶ تیر ۱۴۰۳
Application of AI in Gynecology and obstetrics	کاربردهای هوش مصنوعی در زنان و مامایی	۲۳ تیر ۱۴۰۳
Application of AI in pediatric medicine	کاربردهای هوش مصنوعی در پزشکی اطفال	۳۰ تیر ۱۴۰۳
Application of AI in anesthesia	کاربردهای هوش مصنوعی در بیهوشی	۶ مرداد ۱۴۰۳
Application of AI in emergency medicine	کاربردهای هوش مصنوعی در پزشکی اورژانس	۱۳ مرداد ۱۴۰۳
Applications of artificial intelligence in orthopedics	کاربردهای هوش مصنوعی در ارتوپدی	۲۰ مرداد ۱۴۰۳
Application of AI in pain management	کاربردهای هوش مصنوعی در مدیریت درد	۲۷ مرداد ۱۴۰۳
Application of AI in pharmacology	کاربردهای هوش مصنوعی در داروسازی	۳ شهریور ۱۴۰۳
Application of AI in dentistry	کاربردهای هوش مصنوعی در دندان پزشکی	۱۰ شهریور ۱۴۰۳

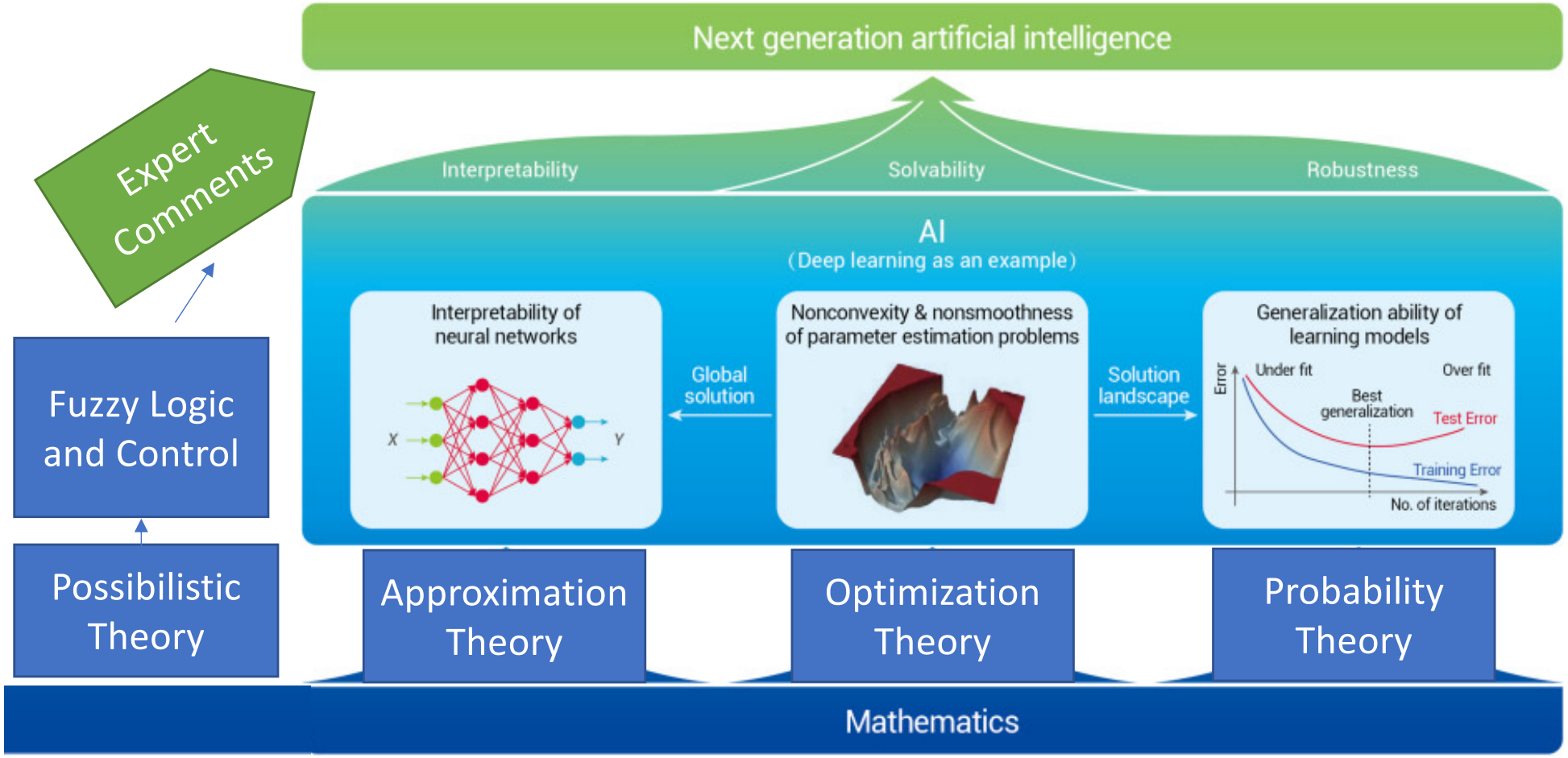
Artificial Intelligence

AI is a multidisciplinary field of study dealing with intelligence, perceiving, and inferring information by machines.

Narrow AI: is used to solve a specific problem.
General AI: is used for solving general problems.
Super AI: Nobody knows what will happen.


AI Tools
Optimization
Generative AI
Deep Neural Network
Distributed Artificial Intelligence
Machine Learning
Swarm Intelligence
Image Processing
pattern recognition
Fuzzy system and control
Decision-making
Signal Processing
Data-driven models
Speech Processing
Natural Language Processing

Artificial Intelligence



Aspect of Intelligence

- Generalization
- learning/adapting
- Optimization
- Social Interaction
- Cognition

Medical Need

Disease Detection

Data classification

question answering

multi-document summarization

natural language processing

prediction of treatment response

diagnosis

information extraction

paraphrase detection

machine translation

image recognition

Data Analysis

information extraction

semantic parsing

language generation

speech and character recognition

image recognition

NNs are used when

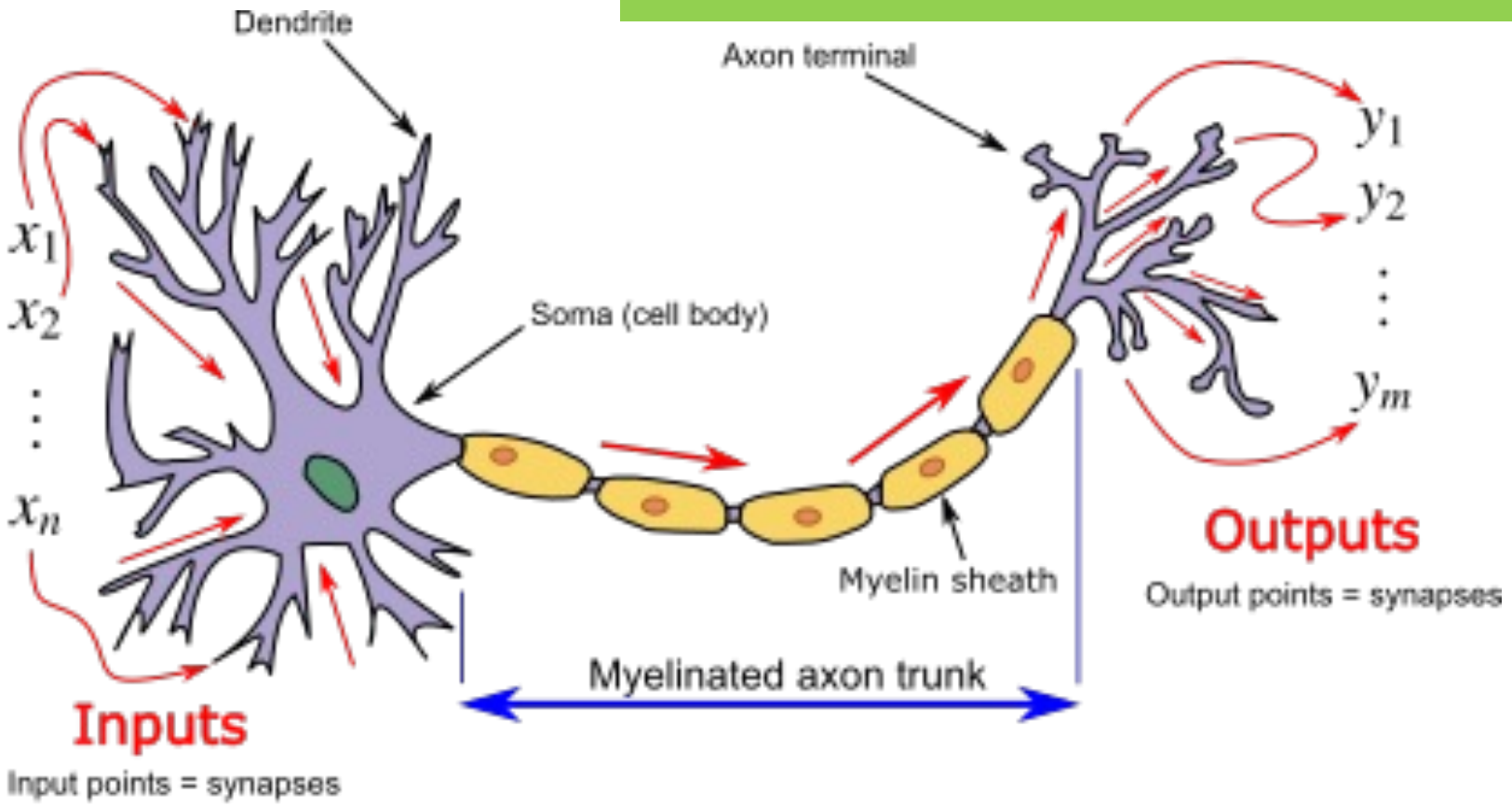
- When sample data show complex or unknown interaction effects or do not meet parametric assumptions,
- When the relationship between independent and dependent variables is not strong,
- when there is a large unexplained variance in information,
- When in situations where the theoretical basis of prediction is poorly understood.

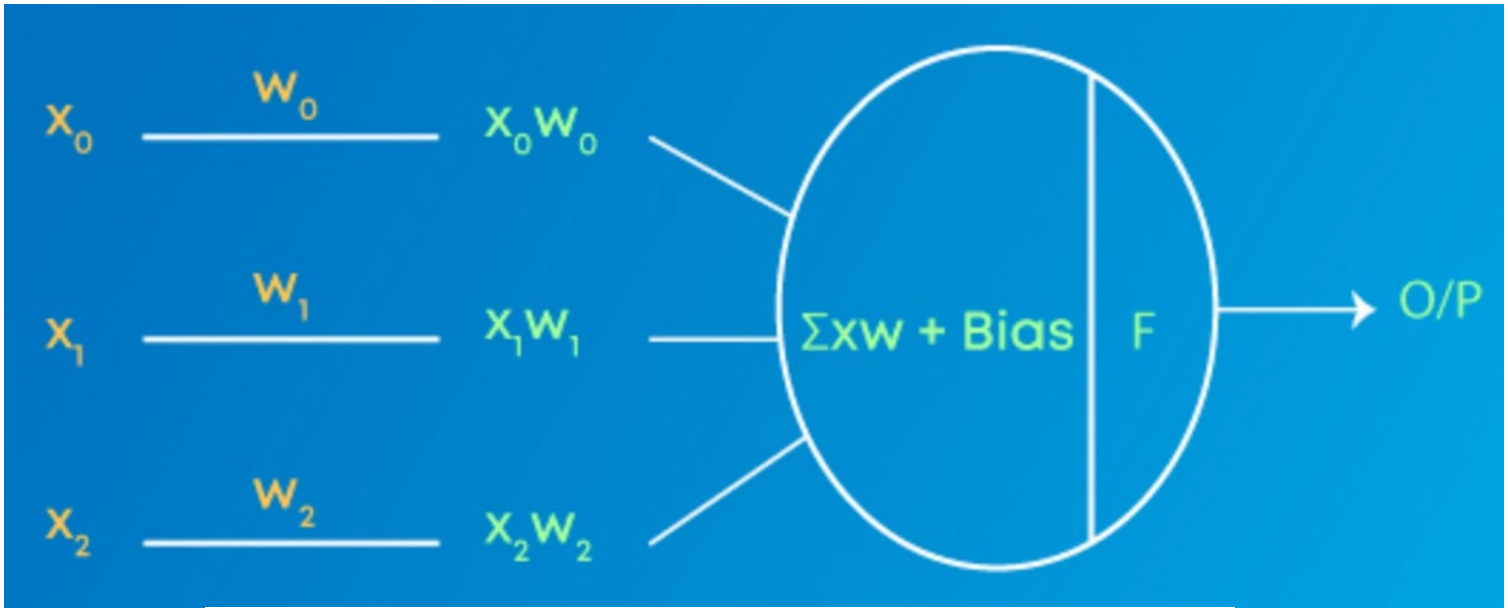
inspired by the biological neurons

ANN

An ANN is a mathematical representation of the human neural architecture

reflecting its “learning” and “generalization” abilities.



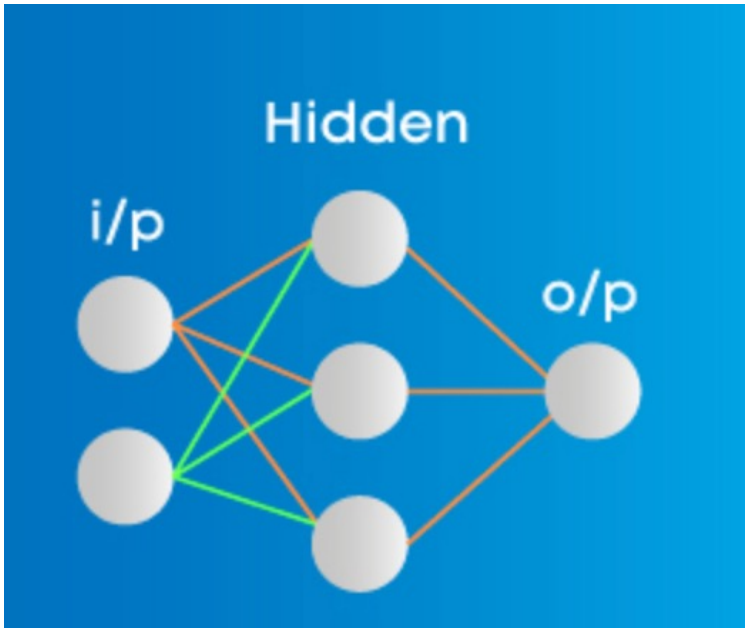


$$net_j = \sum_{i=1}^{m} x_i \times w_{ij} + \theta_j \quad (j = 1, 2, \ldots, n)$$

- ANNs learn from standard data and capture the knowledge contained in the data.
- It is a system of interconnected nodes that learn to recognize patterns in data.
- **Weights** are numeric values that are multiplied by inputs.
- **Activation Function** is a mathematical formula that helps the neuron to switch ON/OFF.

What parts do ANNs have

- ANN have single or multiple layers
- Consist of processing units (nodes or neurons)
- processing units are interconnected by a set of adjustable weights
- interconnection allows signals to travel through the network in parallel and consecutively



Input Layer (receives data), This data can be anything from images to text to sounds.

Hidden Layer (responsible for extracting patterns, perform most of internal processing),

Output Layer (produces and presents final network outputs)

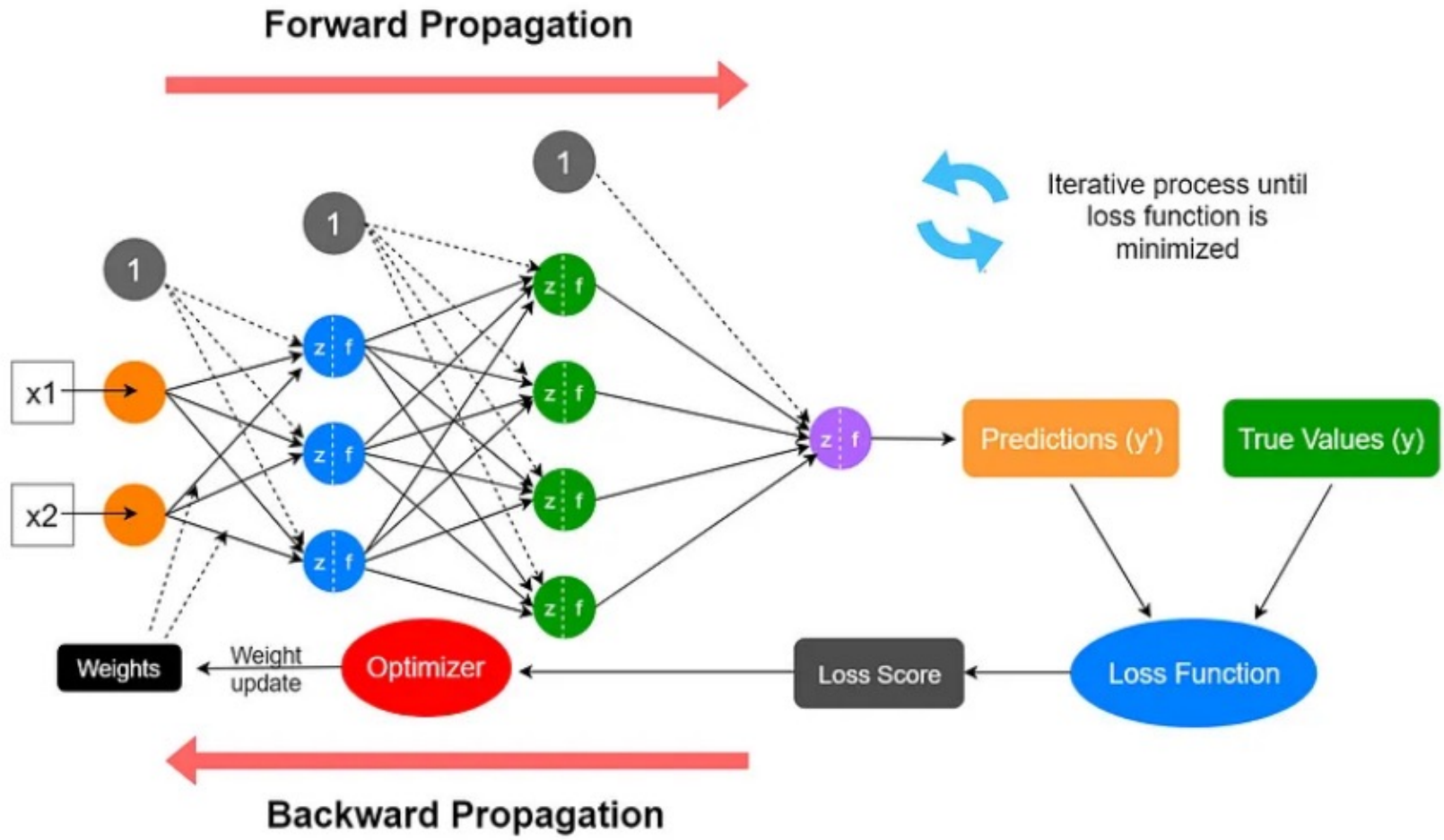
What ANNs do?

- ANN gather knowledge by detecting patterns and relationships in data and “learn” through experience.
- ANN **learns** by optimizing its inner unit connections in order to minimize errors in the predictions that it makes and to reach a desired level of accuracy.
- New information can be inputted into the model once the model has been trained and tested.

ANN **training process**

- The training process for an ANN involves adjusting the weights of the connections between the nodes.
- This is done by feeding the ANN a set of training data and comparing the ANN's predictions to the actual outputs.
- The weights are adjusted so that the ANN's predictions are more accurate.

How ANNs work?



Type of ANN are

- Feed-forward neural networks (e.g. single-layer perceptron, multi-layer perceptron, radial basis function networks) or
- feed-back, or recurrent neural networks (e.g. Competitive networks, Kohonen's self-organizing maps, Hopfield networks)
- New ANN

Deep learning model

- Deep learning is the subset of machine learning methods based on artificial neural networks (ANNs) with representation learning.
- The adjective "deep" refers to the use of multiple layers in the network.
- direct learning of correlations between raw input data and target output,

Why Deep ANN

Conventional machine-learning techniques were limited in their ability to process natural data in their raw form.

They need careful engineering to design a feature extractor that transformed the raw data into a suitable internal representation or feature vector for detection or classification.

- Convolutional Neural Network (CNN)
- **Recurrent Neural Network**
- LSTM
- **Transformer neural network**
- **Capsule neural network**

Pre-trained Model

- A pre-trained model is a saved network that was previously trained on a large dataset.
- You either use the pretrained model as is or use transfer learning to customize this model to a given task.
- ResNets, VGGs, DenseNet, AlexNet, GoogleNet, ResNeXt, and SqueezeNet.

Black box

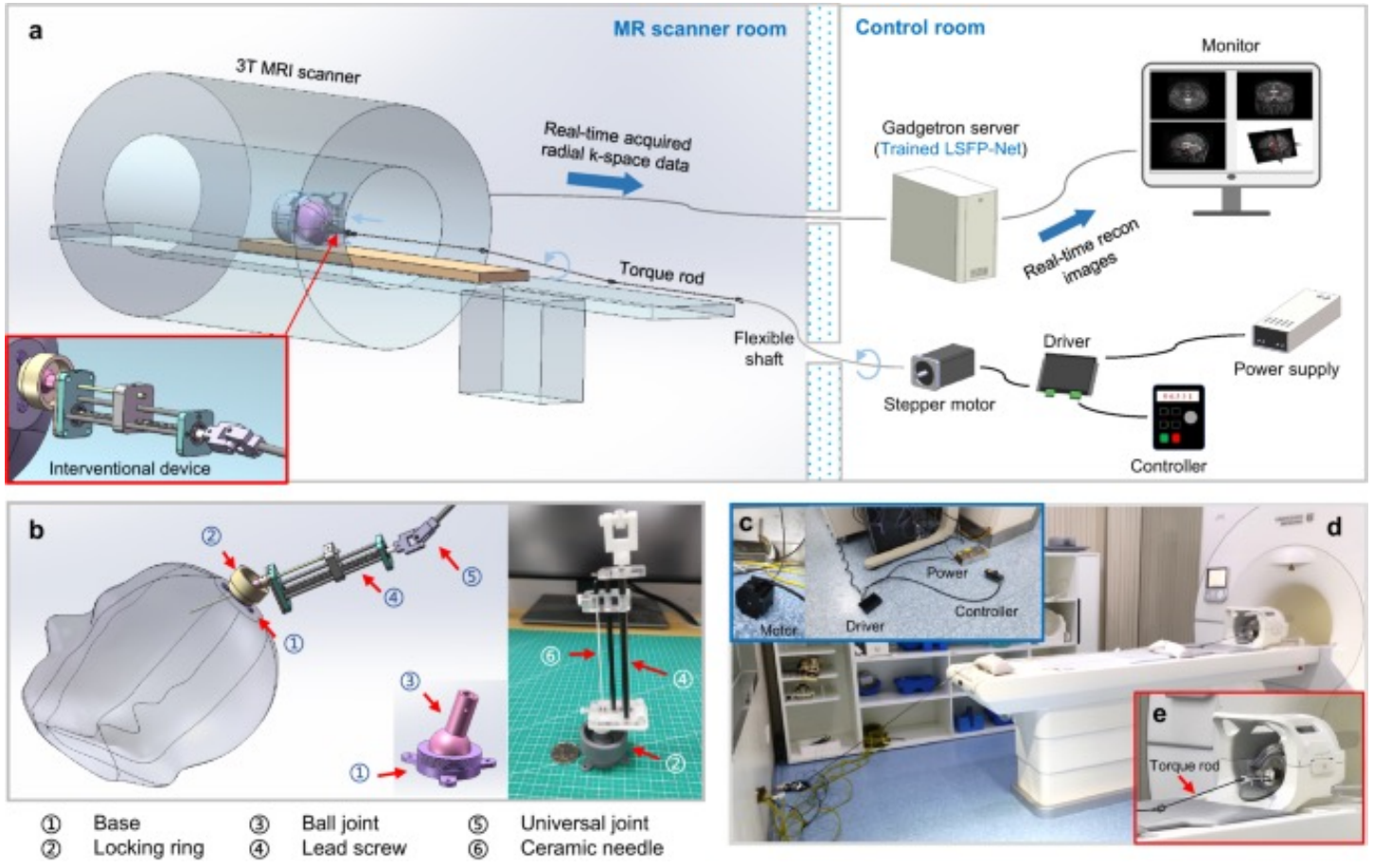
- The mathematical process through which the network achieves “learning” can be principally ignored by the final user.
- In this way, the network can be viewed as a “black box” that receives a vector with m inputs and provides a vector with n outputs.

Examples of Data and output

Input data or method	Clinical context	Output information
Age, cholesterol concentration, arterial hypertension	Coronary artery disease	Diagnosis
Heart sound	Valve stenosis	Diagnosis
Hematologic profile	Chronic myeloid leukemia	Classification of leukemia
Visual information of wireless capsule endoscopy	Small bowel tumors	Diagnosis, classification of tumor
Glucose concentration – Near-infrared spectroscopy	Diabetes	Diagnosis
Demographic and clinicopathologic data, surgical outcome	Hepatocellular carcinoma	Prediction of disease free survival
Cytology of effusion fluid	Carcinoma	Presence of malignant cells
Speech record	Oral/Oropharyngeal cancer	Detection of nasalence (hypernasality)
Electroencephalographic (EEG) recordings	Epilepsy	Prediction of seizures

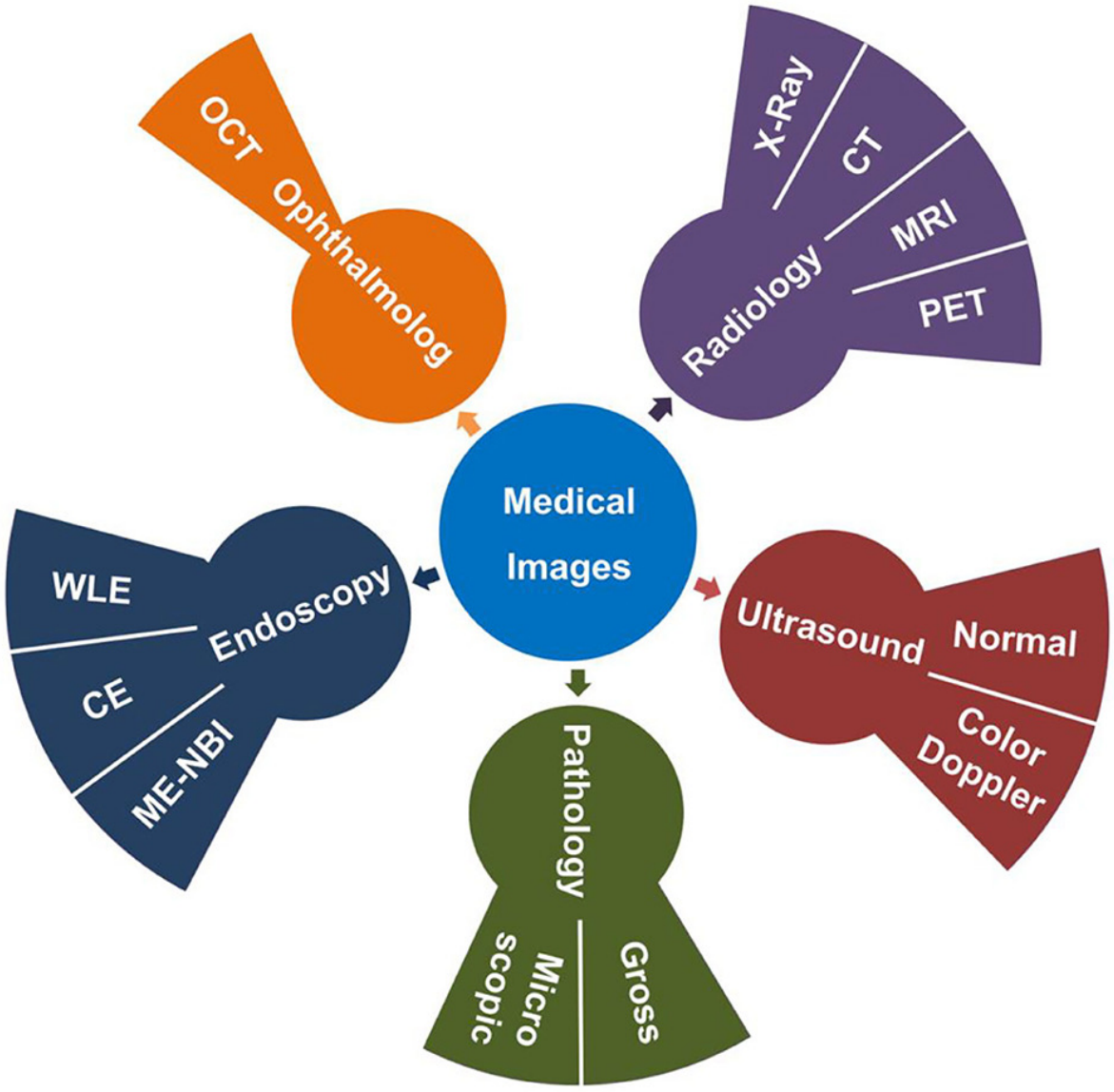
A deep unrolled neural network for rea time MRI-guided brain intervention

Accurate navigation and targeting are critical for neurological interventions including biopsy and deep brain stimulation.

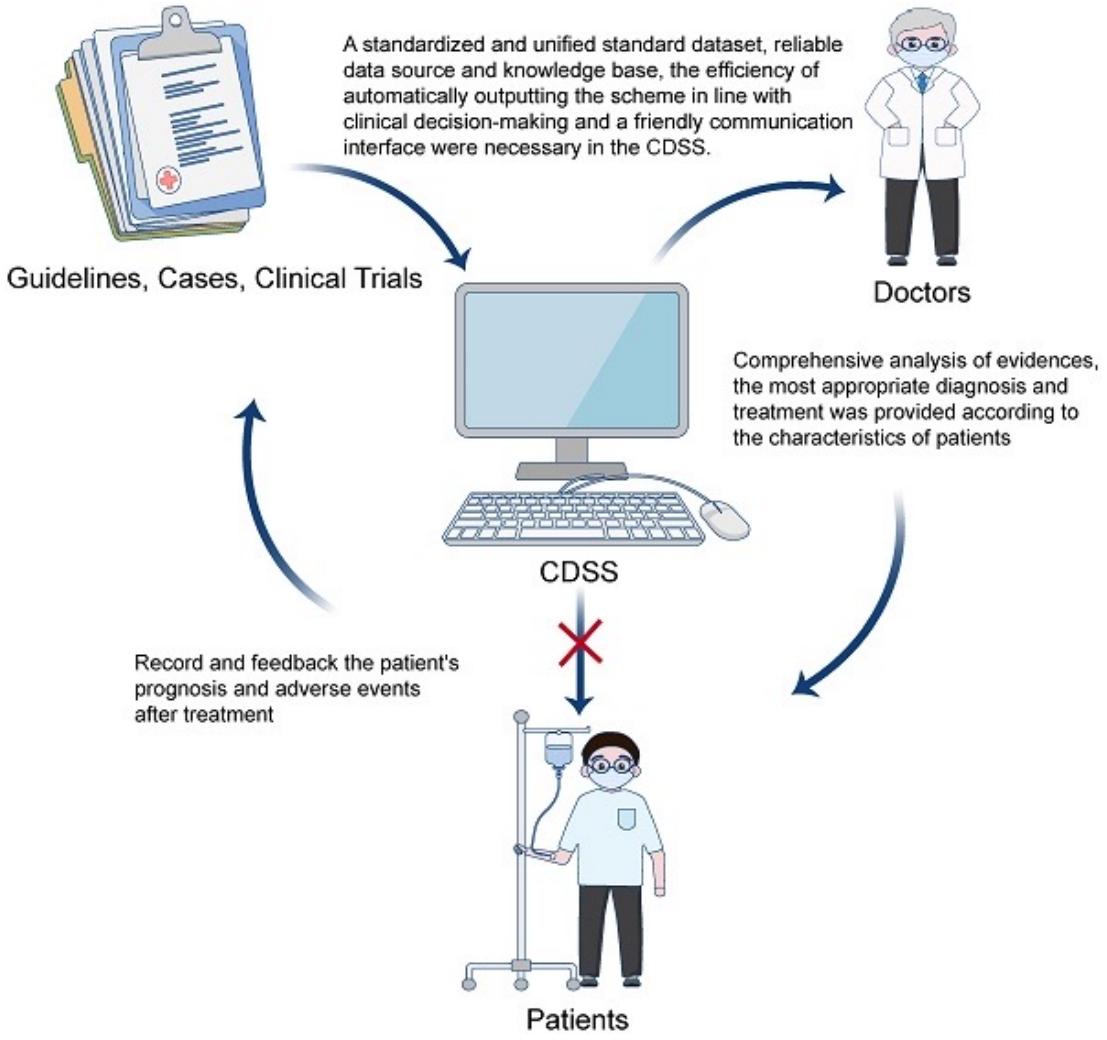


Nature Communications **volume 14**, Article number: 8257 (2023)

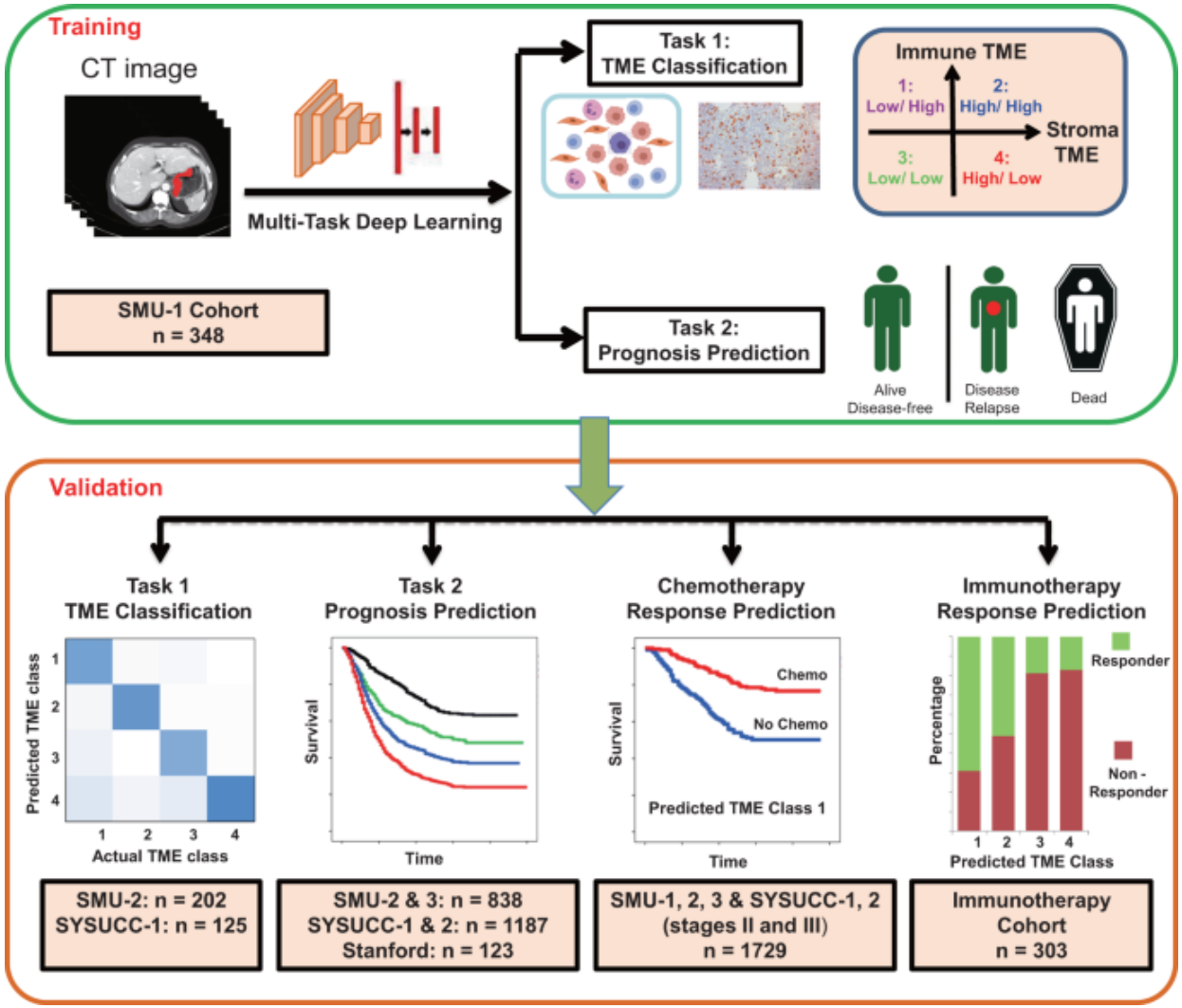
Categories of medical images



Artificial Neural Networks for Decision Support in Clinical Medicine

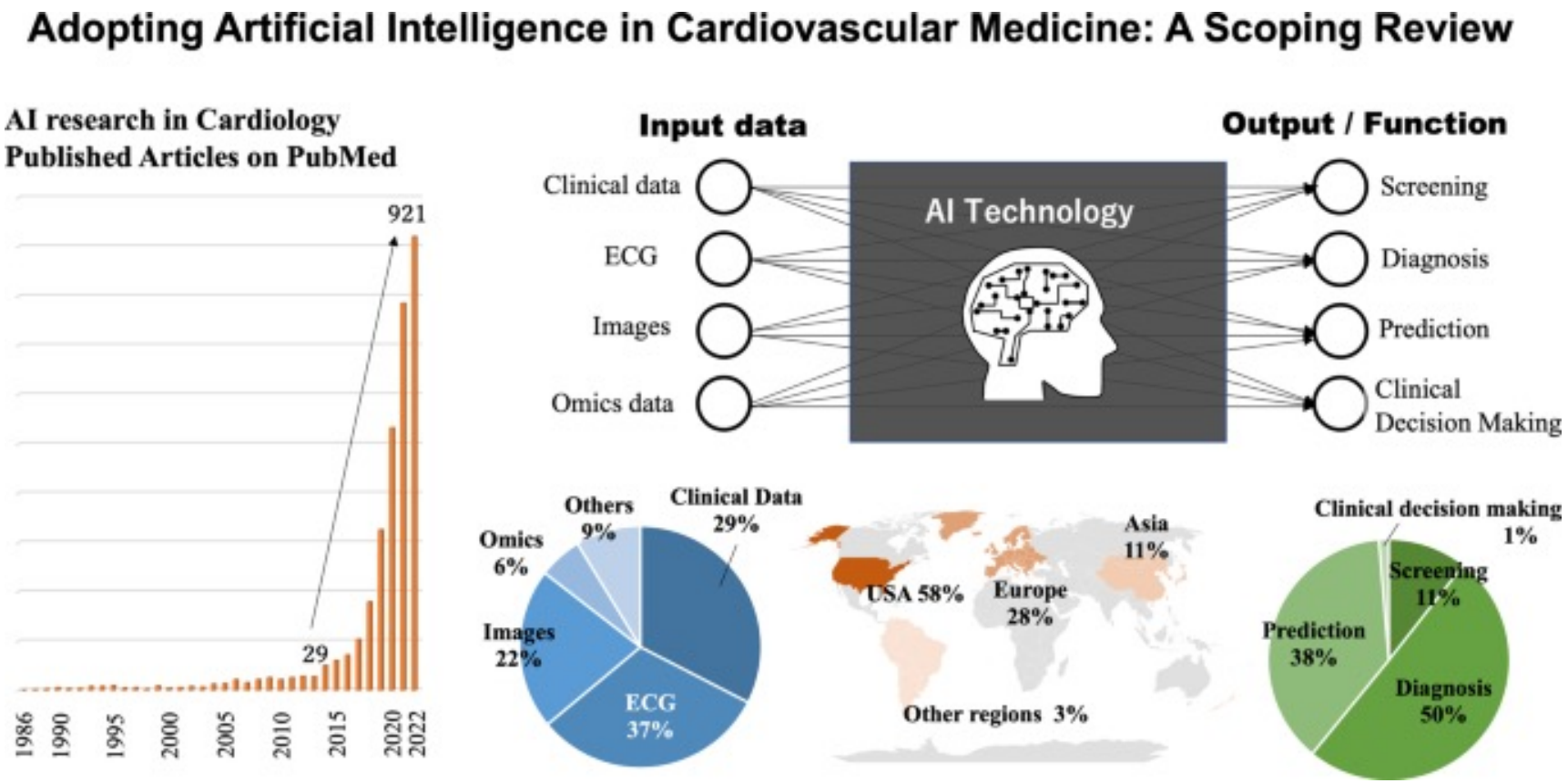


Predicts prognosis and cancer immunotherapy response



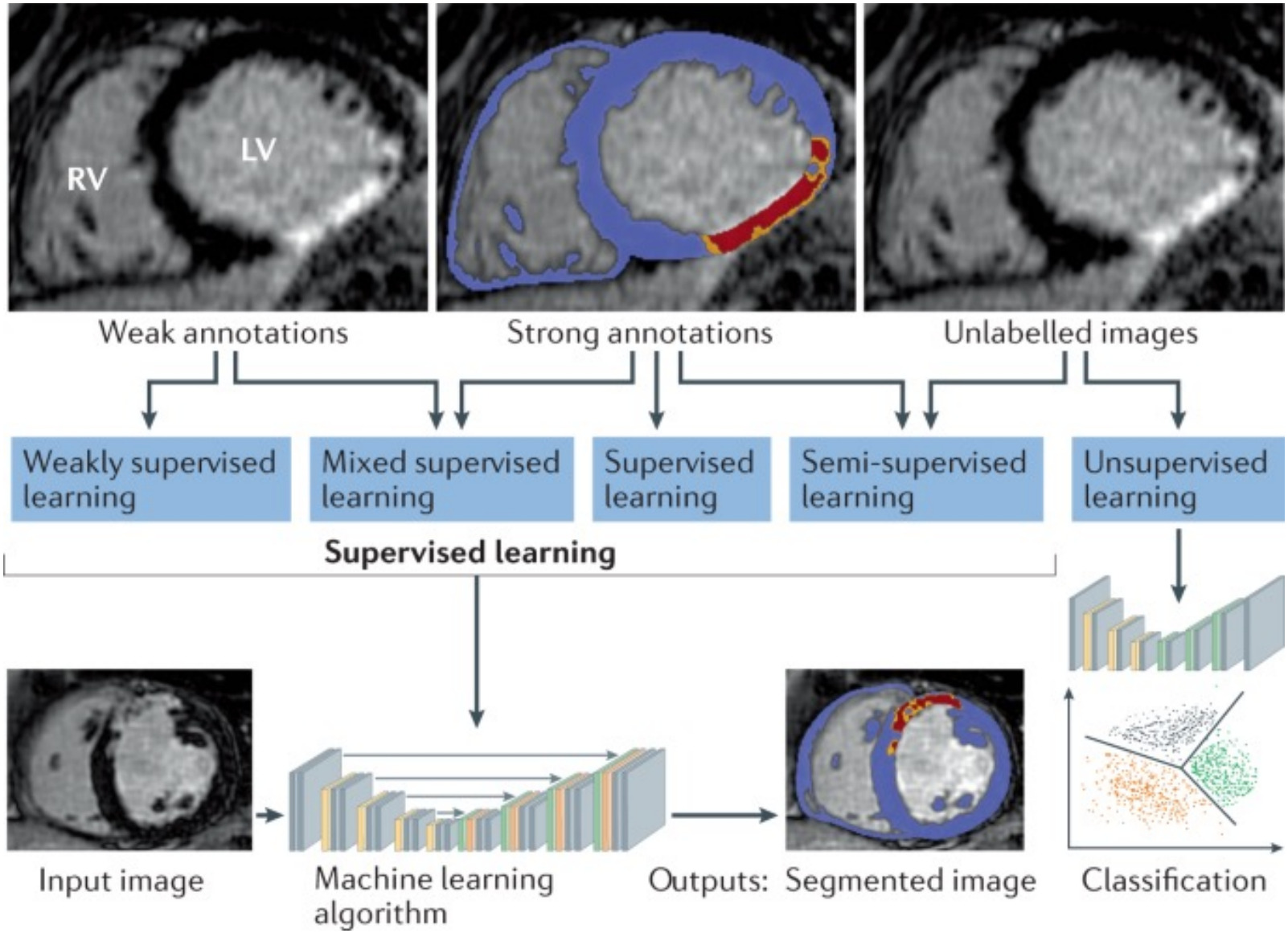
Biology-guided deep learning predicts prognosis and cancer immunotherapy response

ANN in cardiology

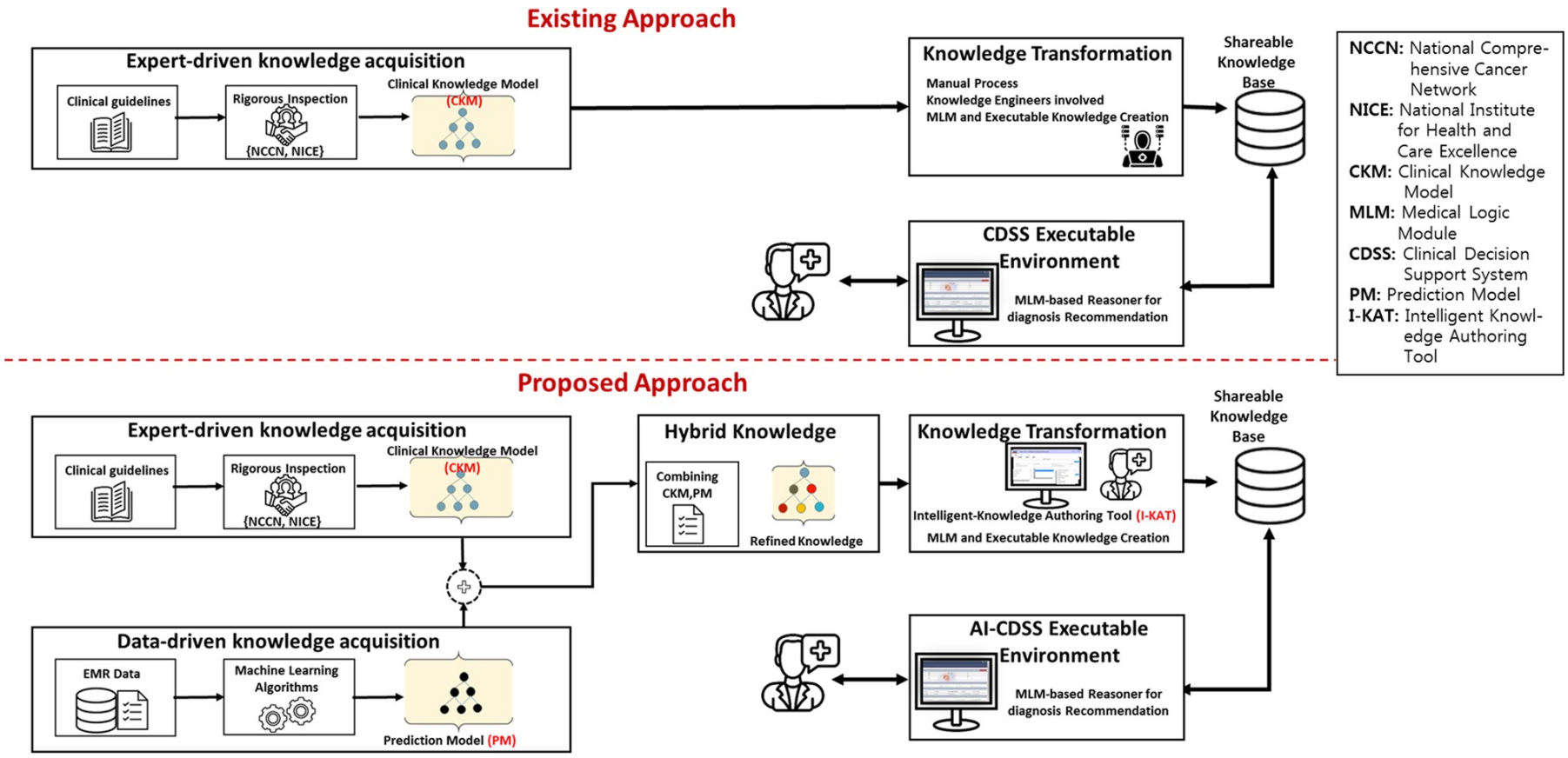


Adopting artificial intelligence in cardiovascular medicine: a scoping review

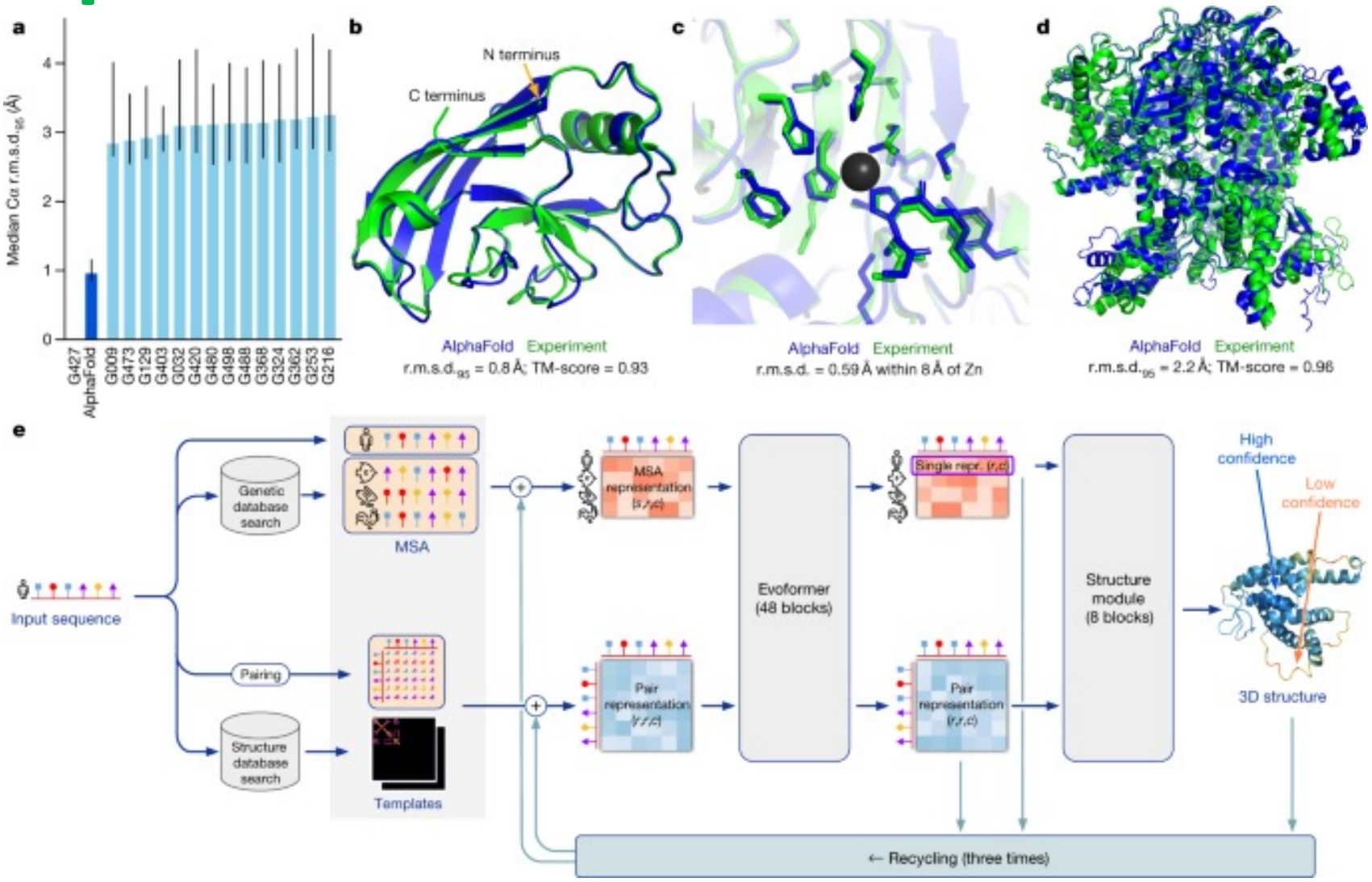
ANN in cardiology



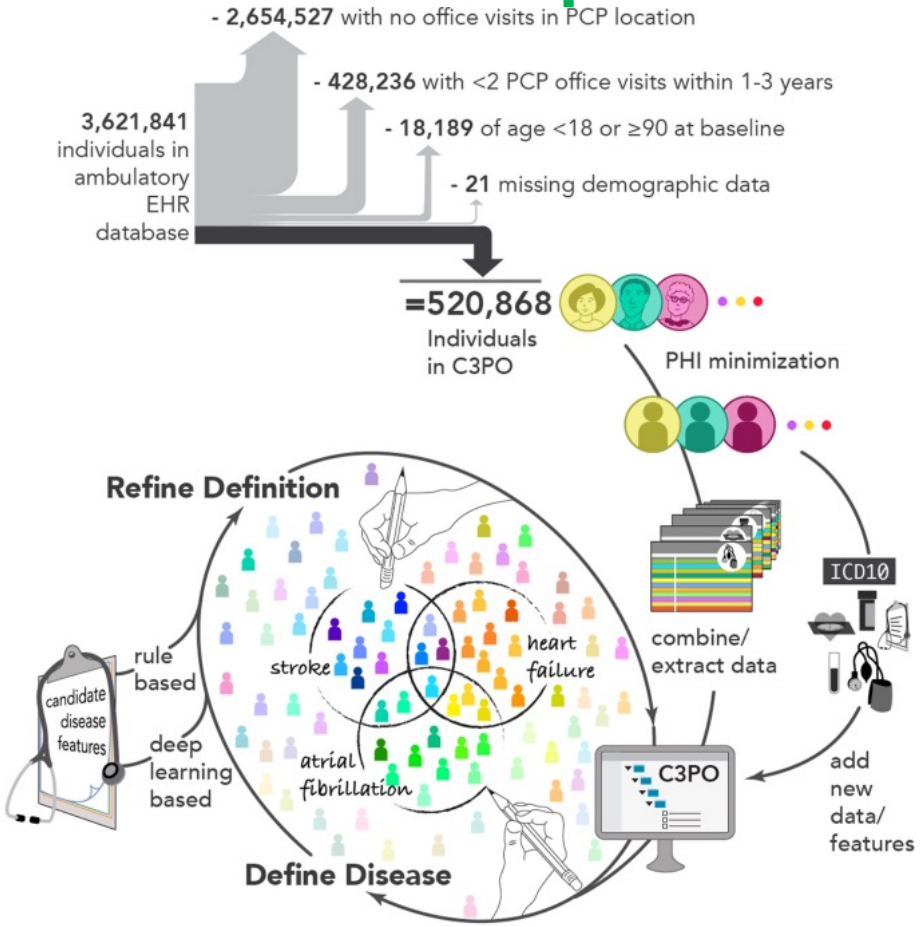
ANN in cardiology



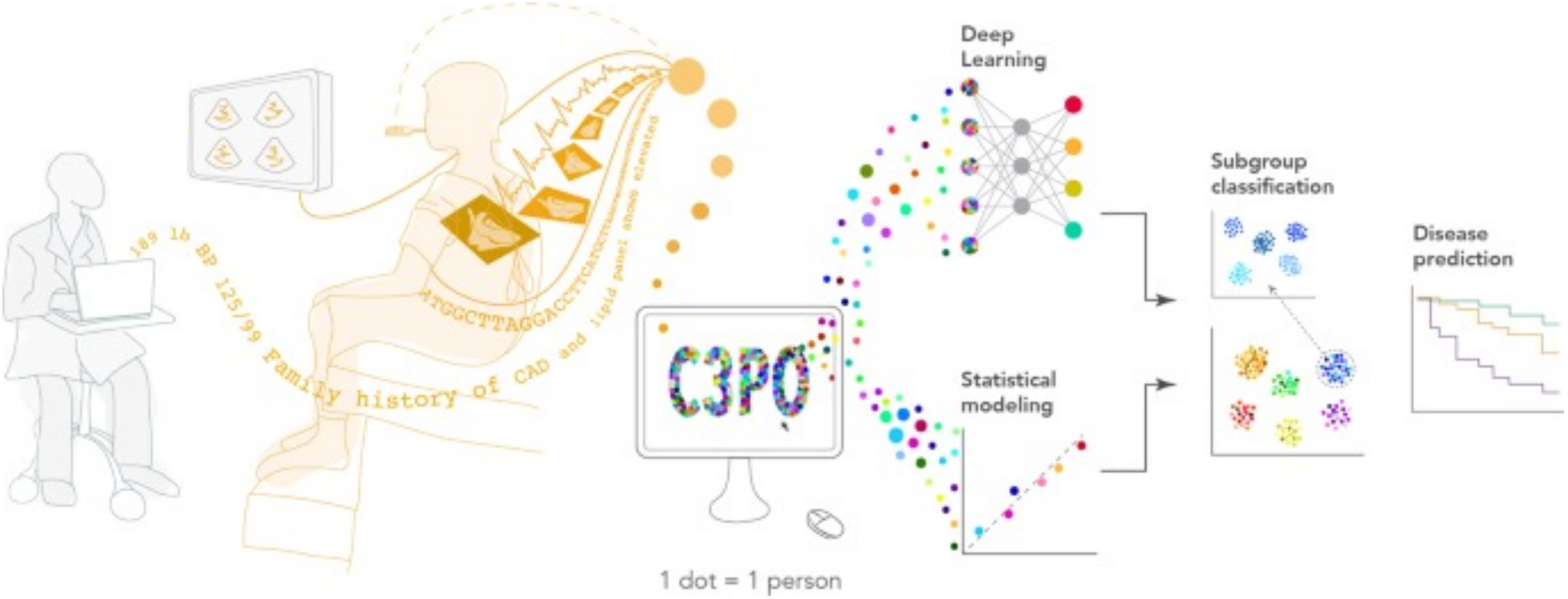
Protein structure prediction witl AlphaFold



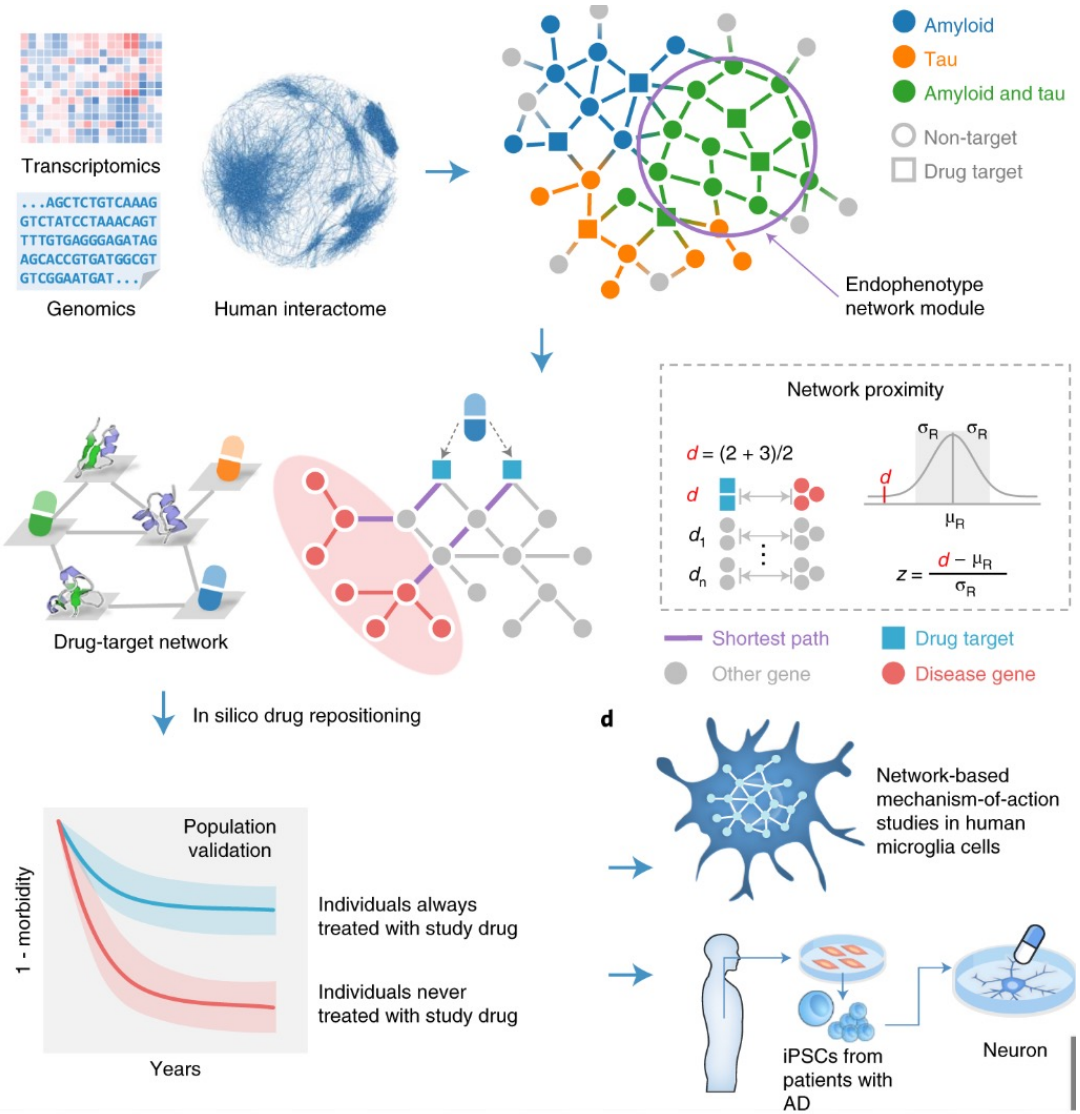
ANN in pharmacoepidemiology



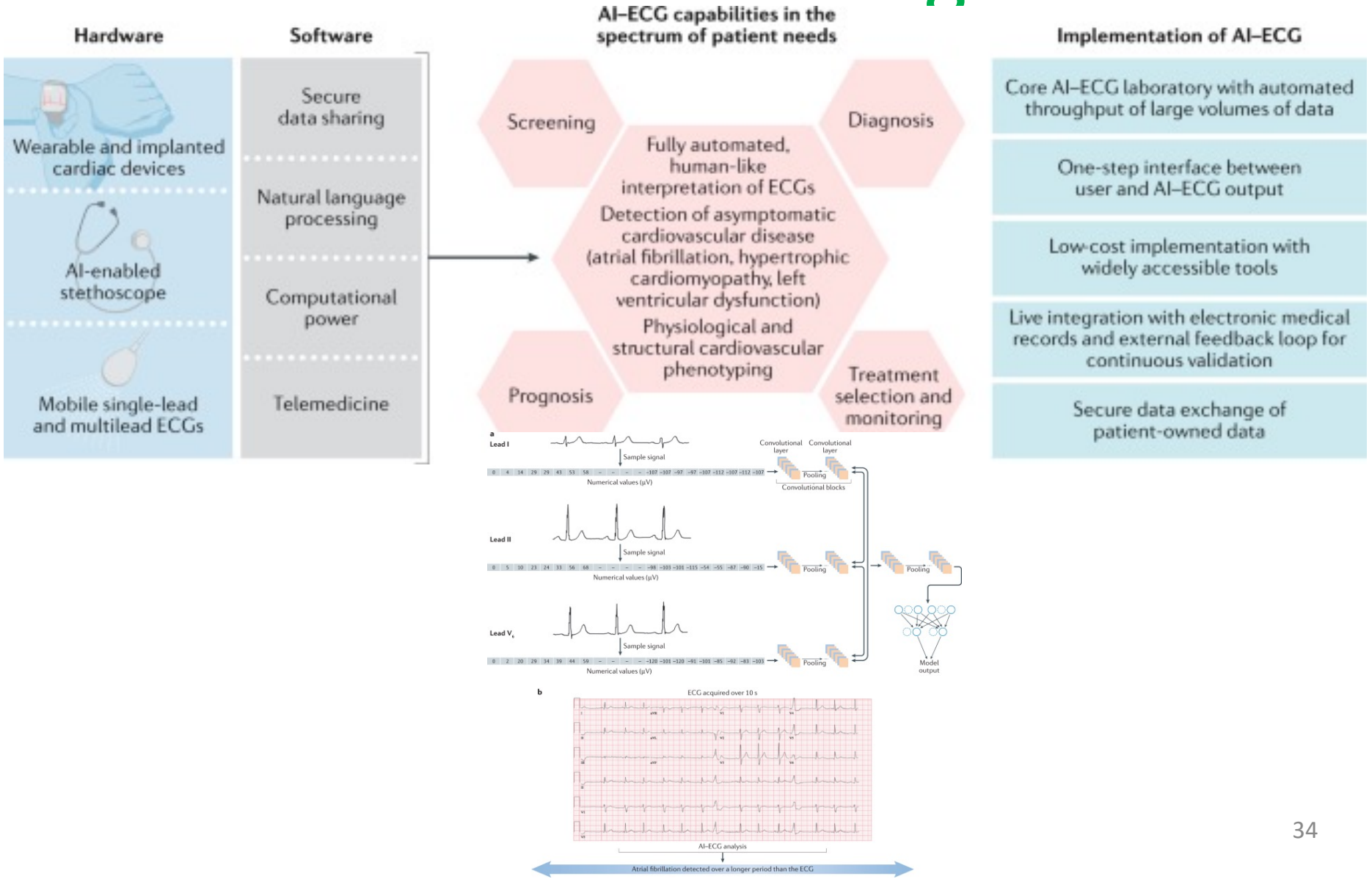
ANN and **disease risk prediction models**



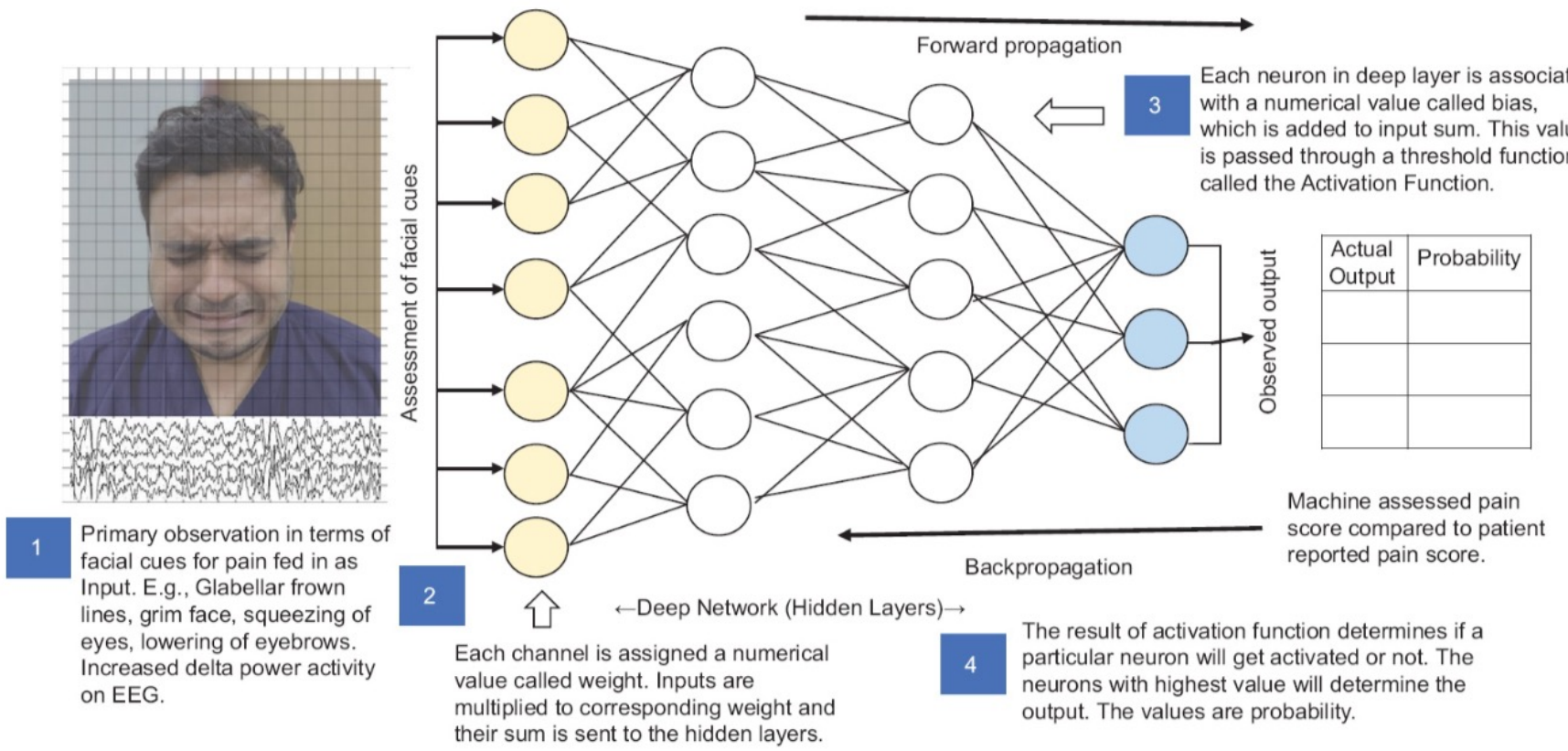
in silico network medicine discovery



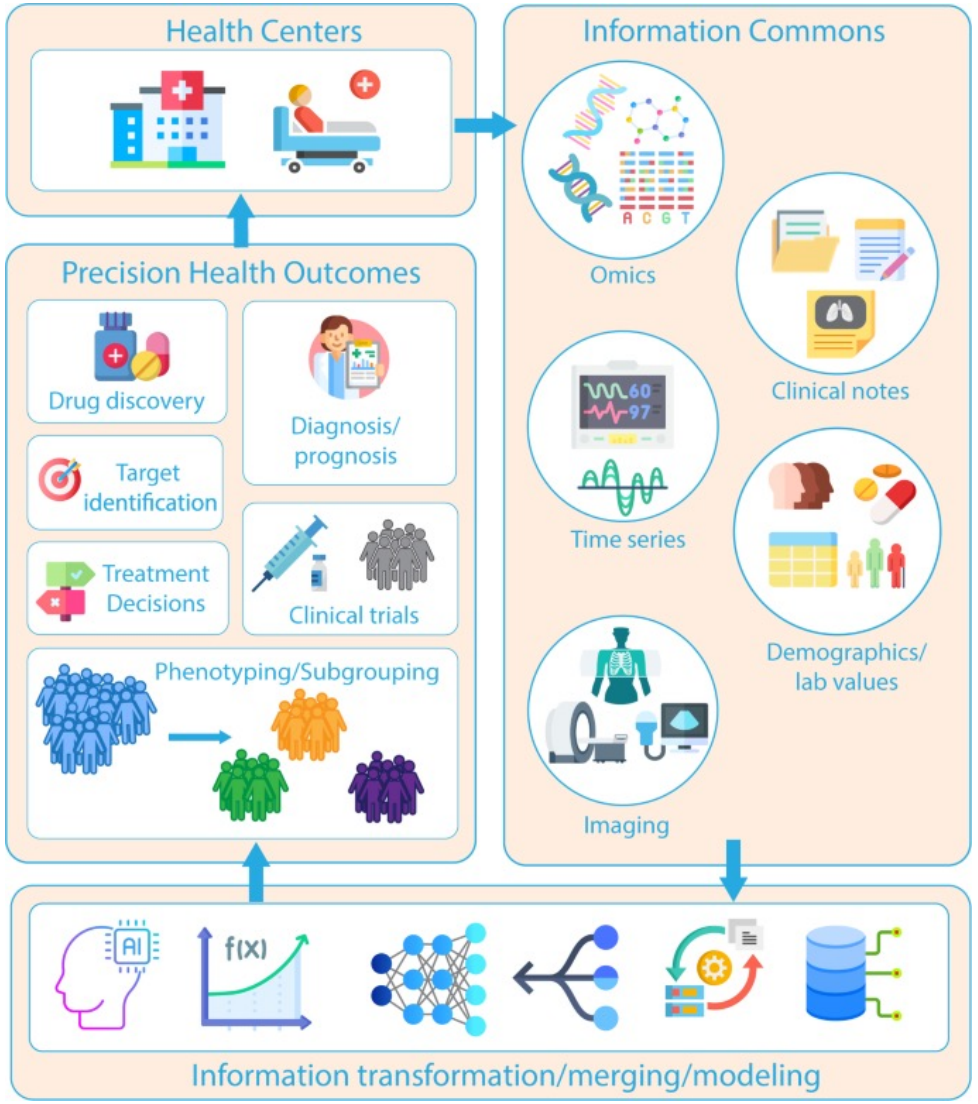
ANN in pharmacoepidemiology and medical data mining



Artificial Neural Network in Clinical Pain Medicine and Research

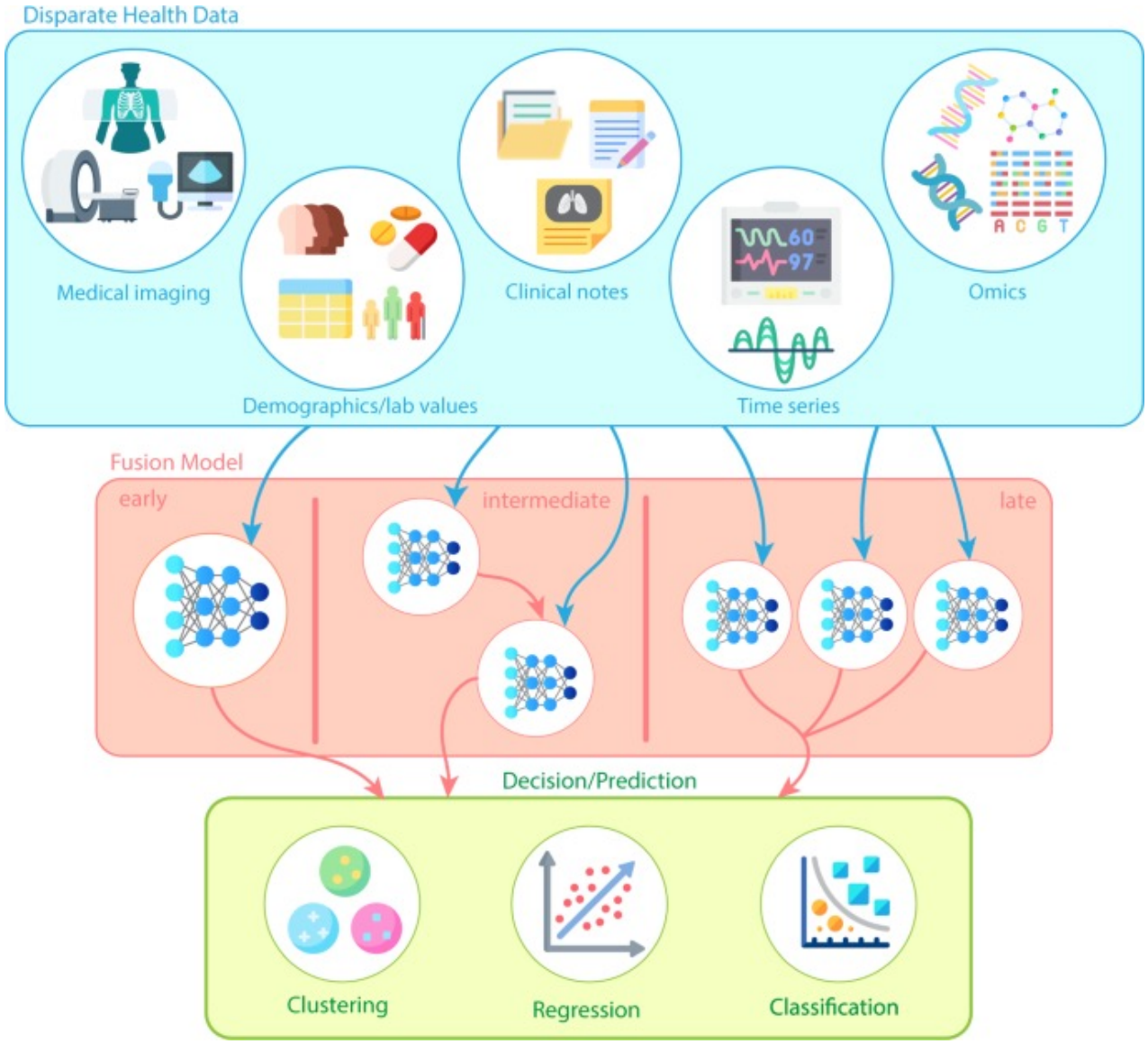


ANN and **Multimodal machine learning in precision health**

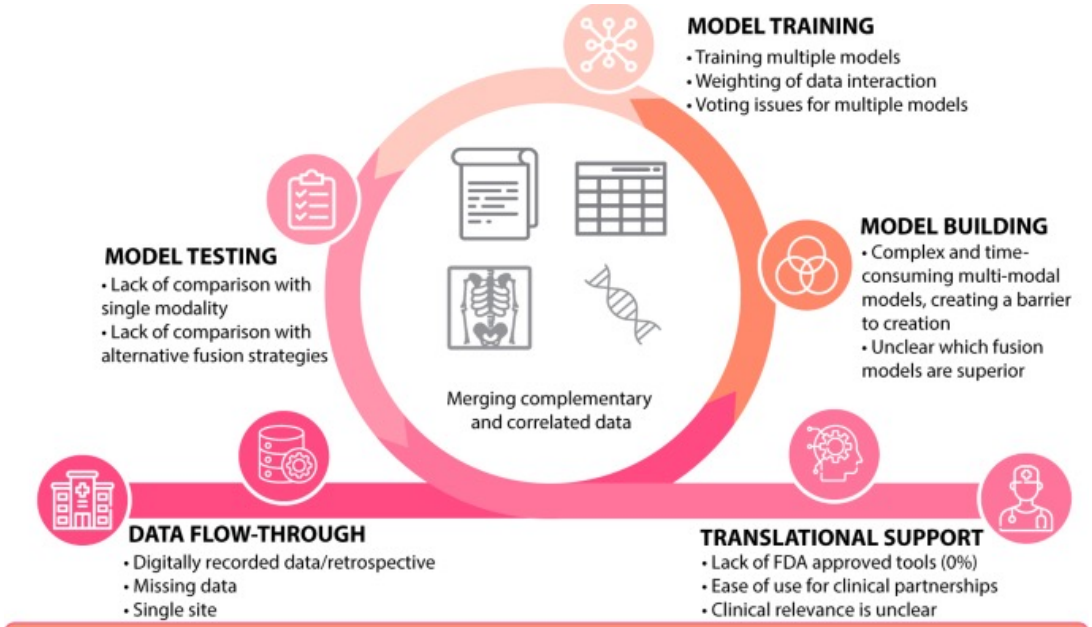


Multimodal machine learning in precision health: A scoping review *, npj Digital Medicine* **volume 5**, Article number: 171 (2022)

ANN and **Information fusion**



Challenges and limitation



Future Directions

Data

- Explore undersaturated health topics such as dermatology, hematology and medication health topics
- Expand datasets to include mutliple sites and make dataset larger
- Create prospective studies to harness the full extent of ML
- Explicit methodological approaches to handle missing data
- Library development for data transformation

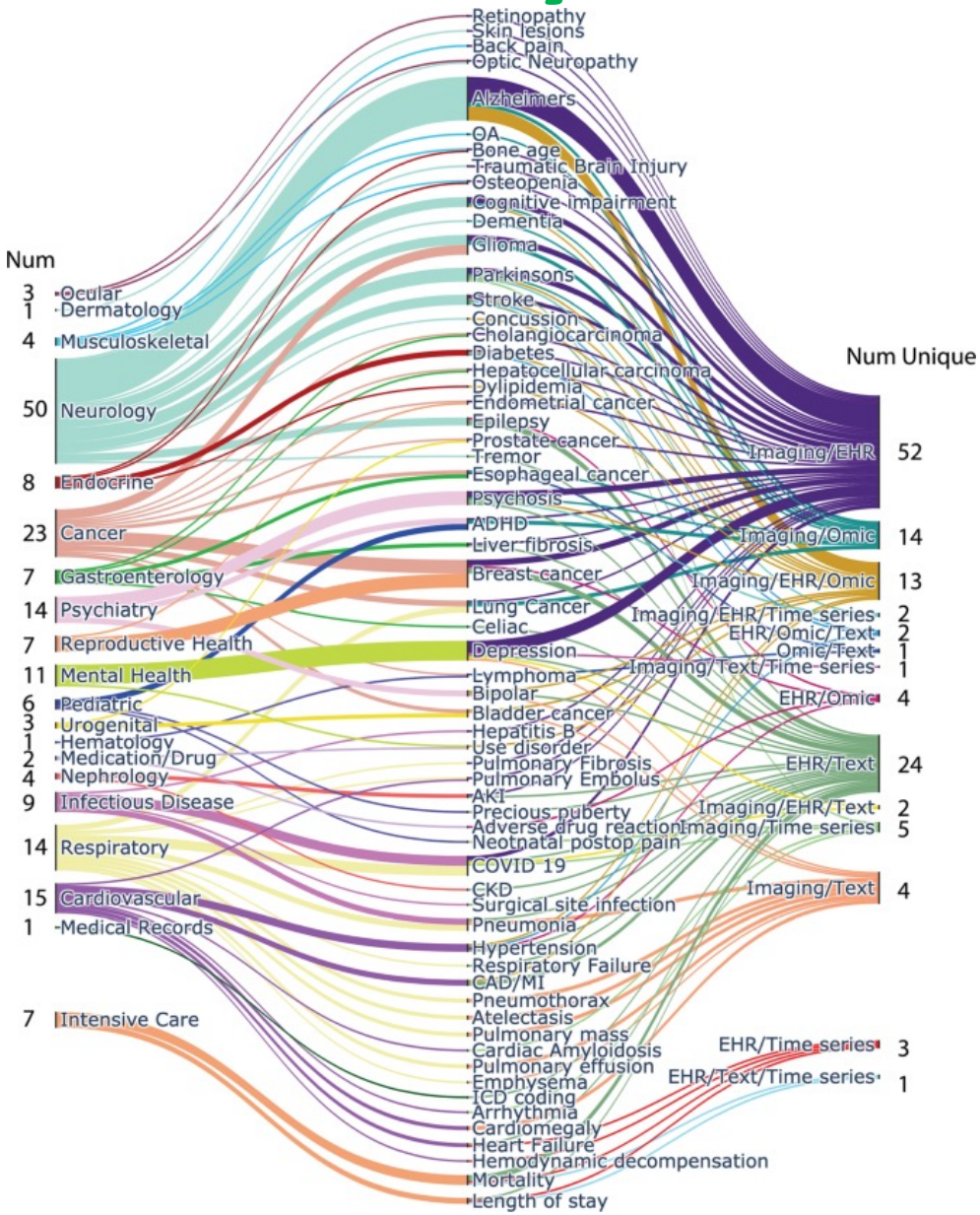
Modeling

- No consensus on optimal way to combine data
- Best algorithm is expected to vary by disease/application
- Algorithms such as XGBoost and LightGBM may be robust and high performing avenues
- Graph NN allow for non-Euclidean relationships in data
- Interpretability of model development - opt for white box methods over black box methods where performance is equivalent

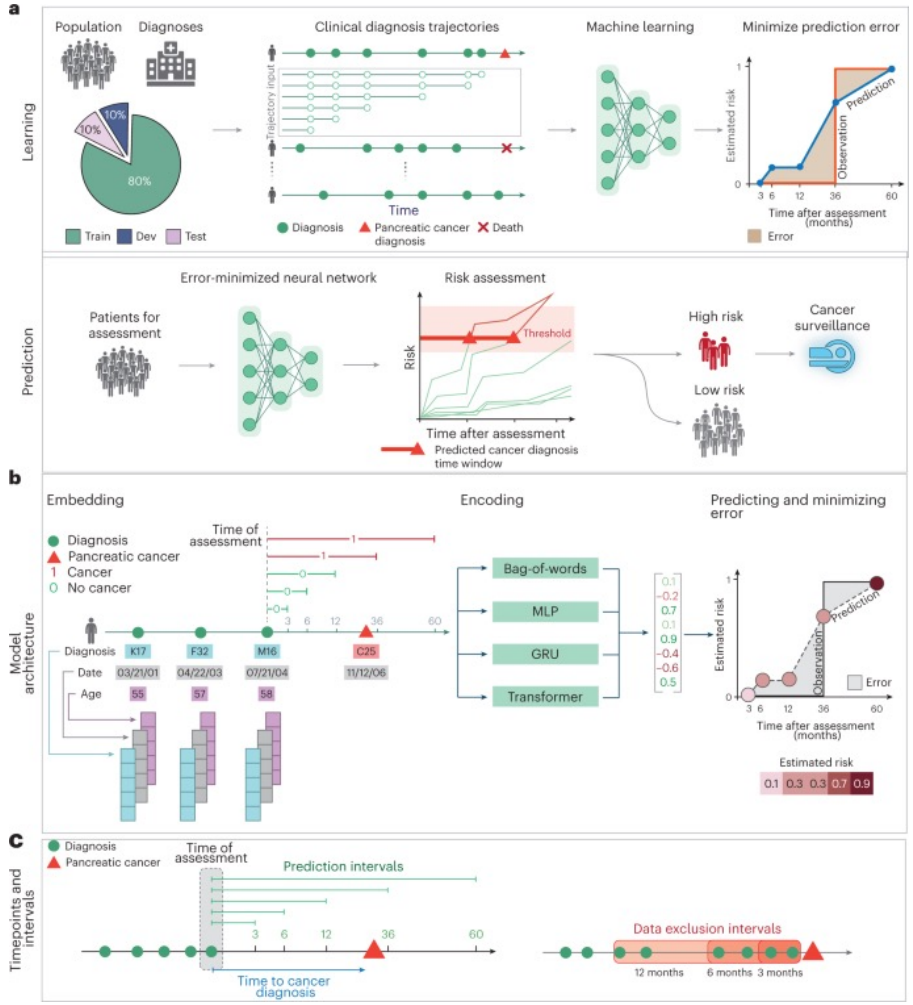
Translation

- Keeping front-end model usage in mind to allow adoption and ease of use
- Explore multimodal data avenues to combat generizability and bias issues associated with geographic, gender, ethnic and racial subpopulations
- Deploy data and algorithms according to the FAIR principles
- Seek FDA approvals for ML models

ANN and **Modality Modeling**

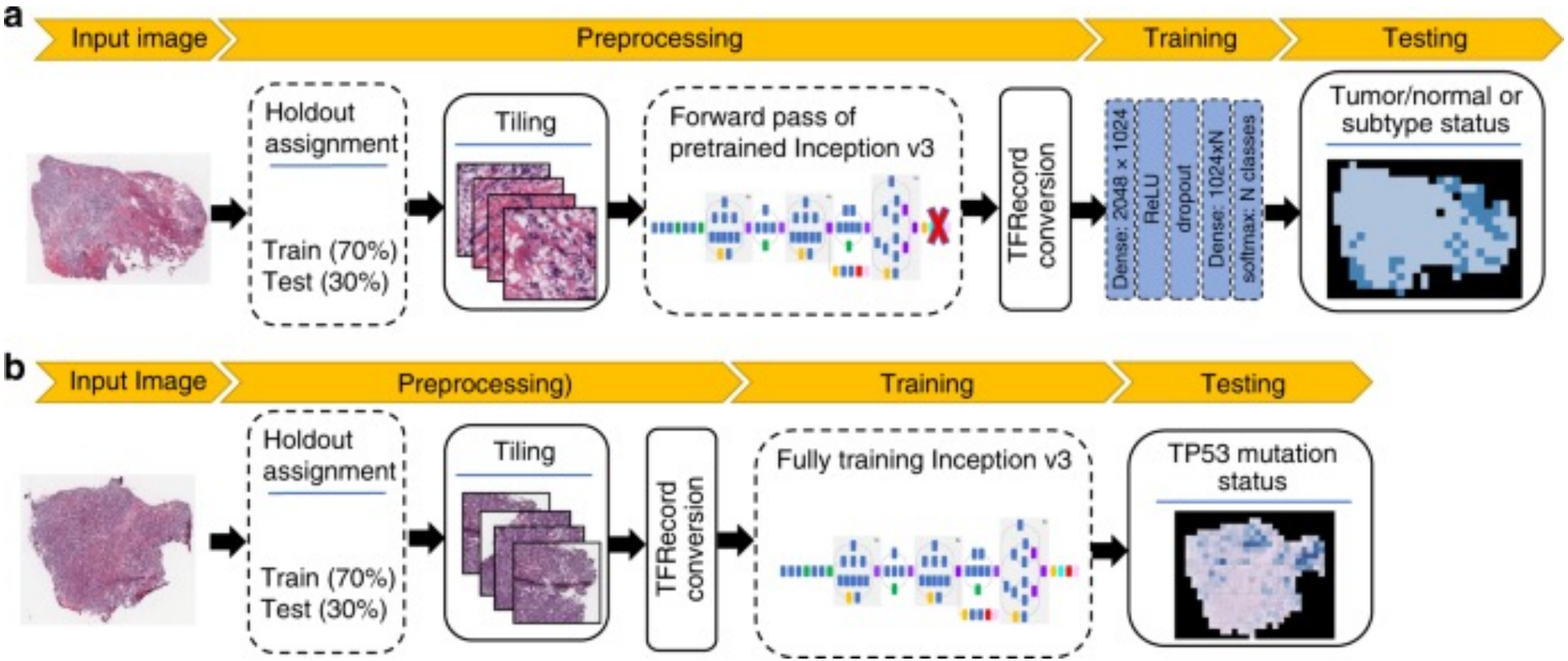


Predict risk of pancreatic cancer from disease trajectories

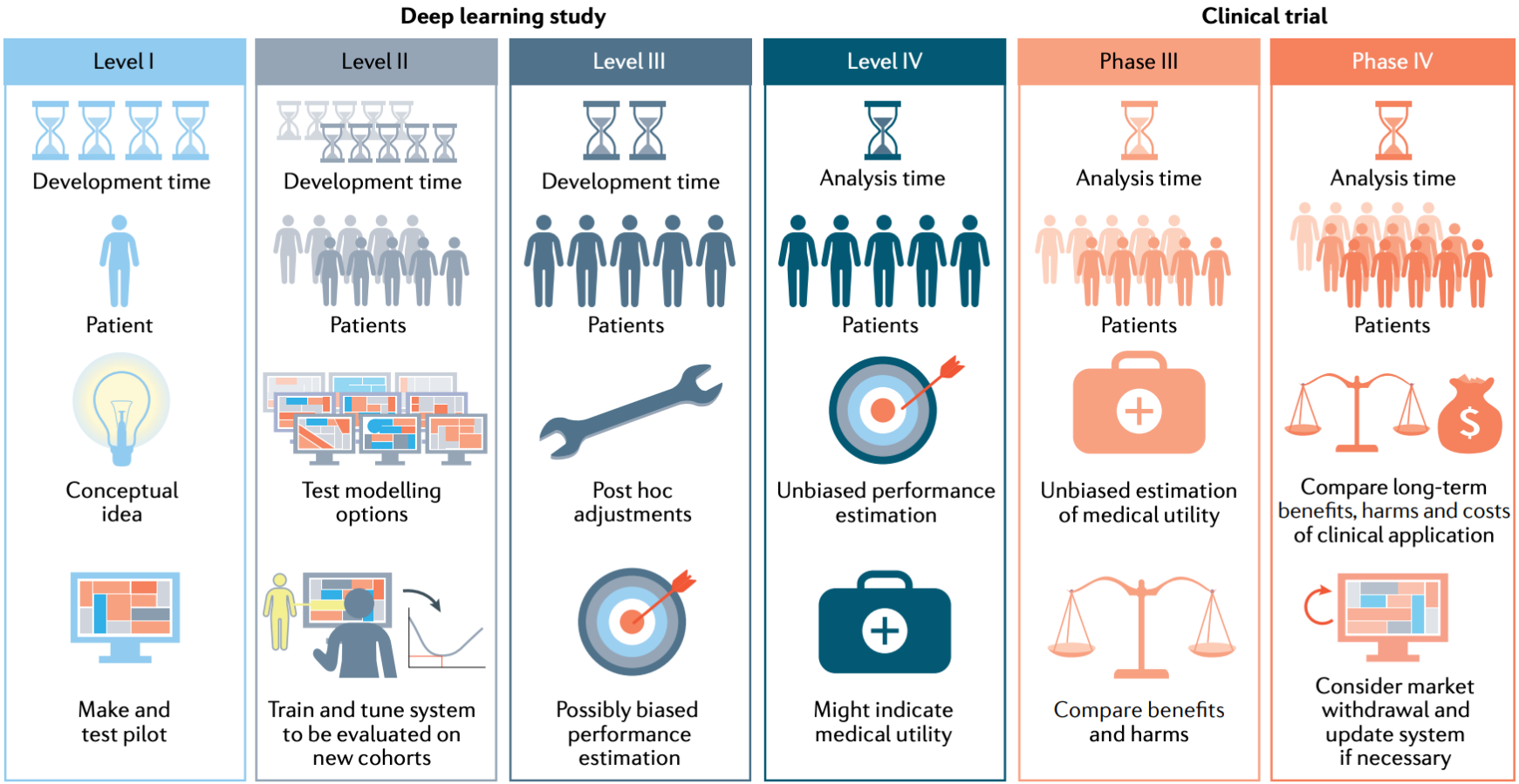


Nature Medicine **volume 29**, pages1113–1122 (2023), **deep learning algorithm to predict risk of pancreatic cancer from disease trajectories**

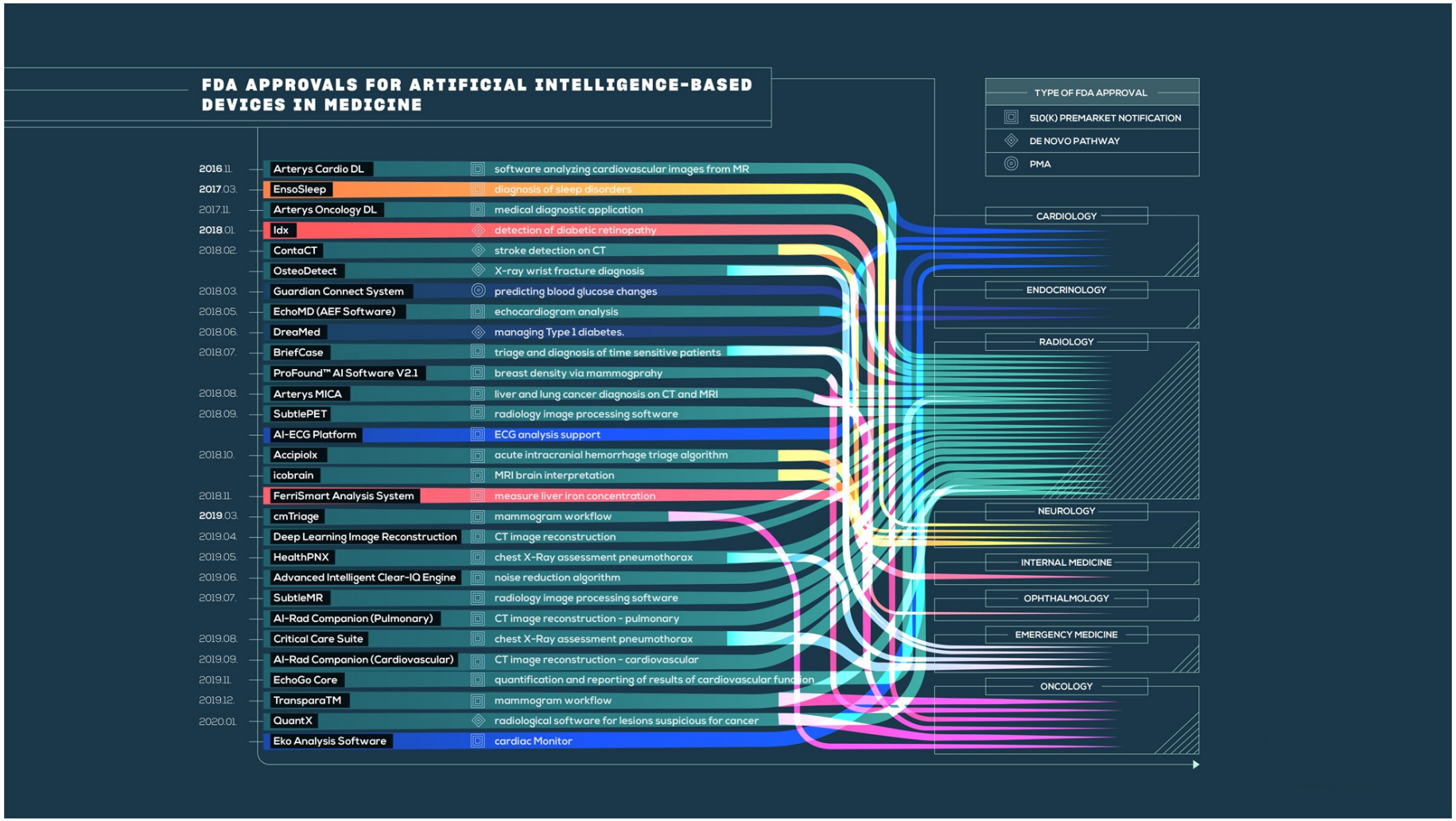
Tumor histological Classification



Development and evaluation of deep learning systems



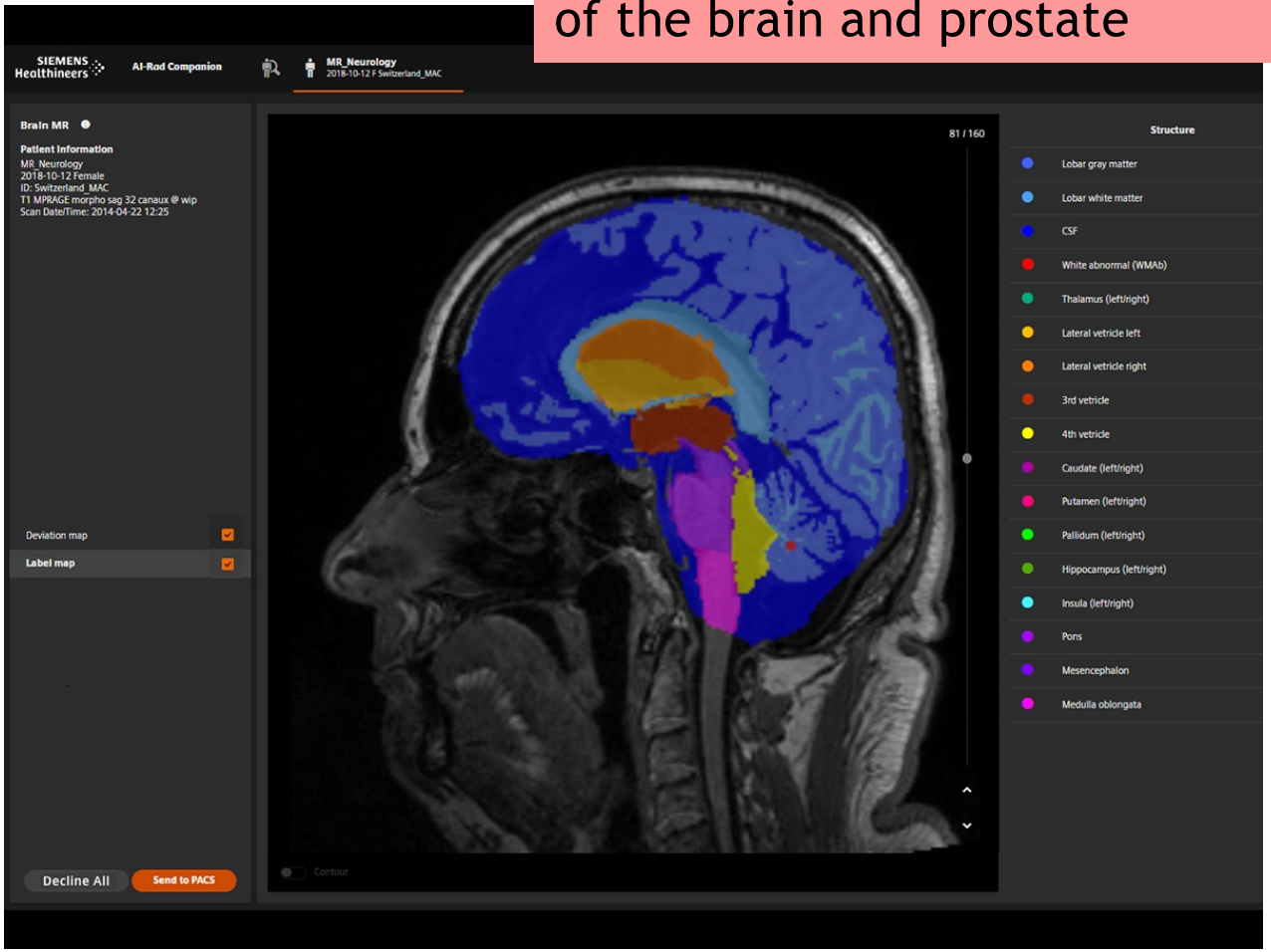
FDA Approved AI Software using ANN



AI-based MRI interpretation tools

Siemens Healthineers

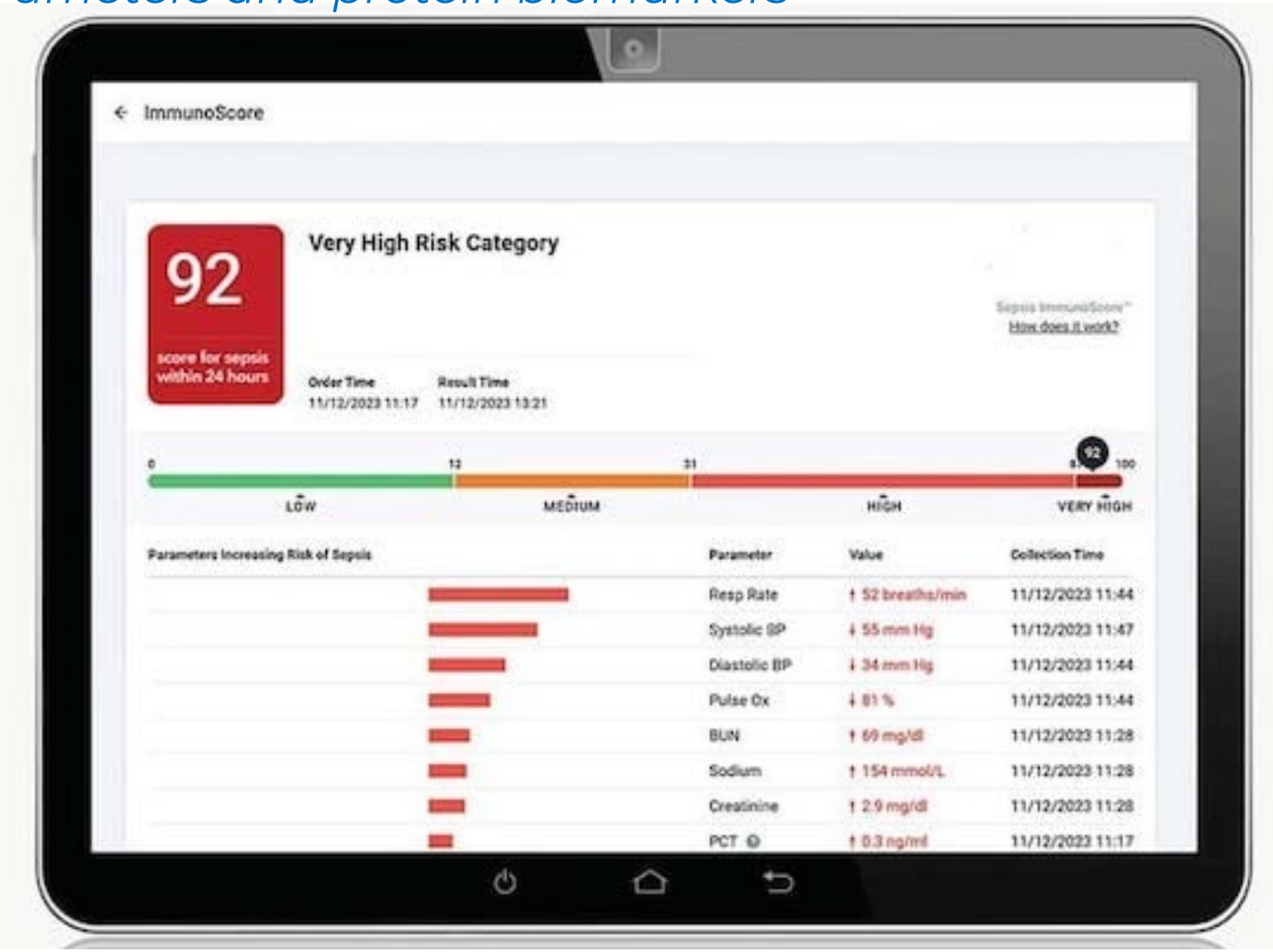
(AI) tools to assist in interpreting magnetic resonance imaging (MRI) studies of the brain and prostate



AI tool for sepsis

based on a combination of clinical parameters and protein biomarkers

ImmunoScore



Benefits of AI

Data Analysis

improve the accuracy and speed of diagnoses

Cost reduction

Time management

AI Challenges

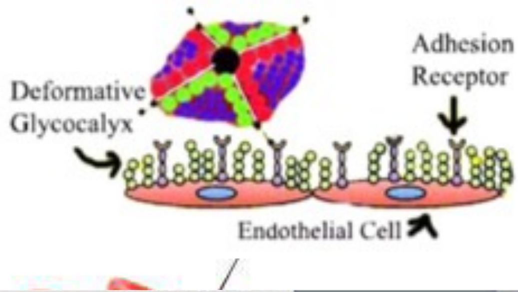
- Bias in data sets, and selection of algorithms
- Lack of transparency ≠ Explainable artificial intelligence (XAI)
- Inaccurate results
- Dependence on technology
- Ethical concerns

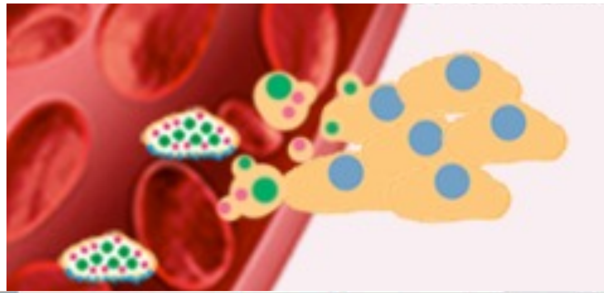
Note that!!

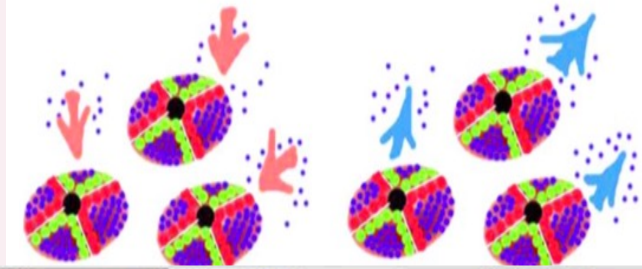
- AI may not replace human doctors.
- Since doctors are trained to not only diagnose and treat diseases but also to provide emotional support to patients.
- AI cannot replace the empathy and compassion that doctors bring to their work.

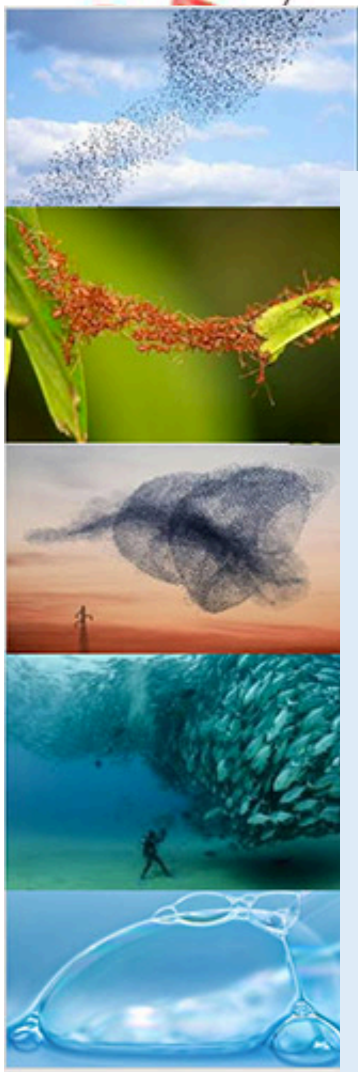
8-AI Medical Application

Prevention	Screening
Early Detection	Diagnosis
Recurrence Prediction	Critical Decision Making
Treatment Selection and Analysis	Mortality and Morbidity Prediction
Triage	…









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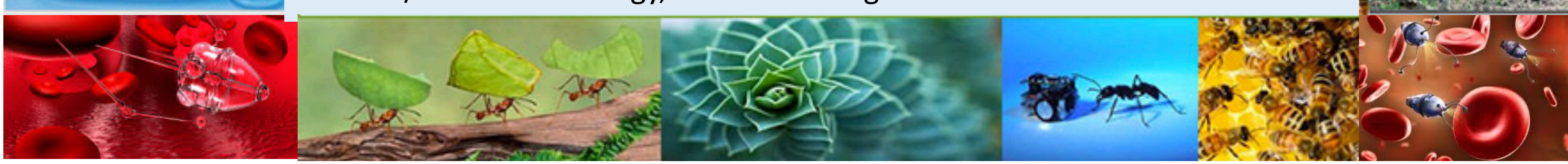
Research Interest:

Artificial Intelligence, Artificial Intelligence in Medicine, Complex Systems, Biomimicry, Cognitive Science, Swarm Intelligence, Nanomedicine, Targeted Drug Delivery, Early Detection of Disease, Swarm Nano Robotics, Cancer Research, Fuzzy Logic and Control, Soft Computing, Neural Networks, Machine Learning, Multi-agent Systems, Distributed Decision Making, Biomarkers, Biophysics, Nature Inspired Algorithms, Computational Cellular/Molecular Biology, Protein Folding



Artificial Intelligence for Good (AI for Good)