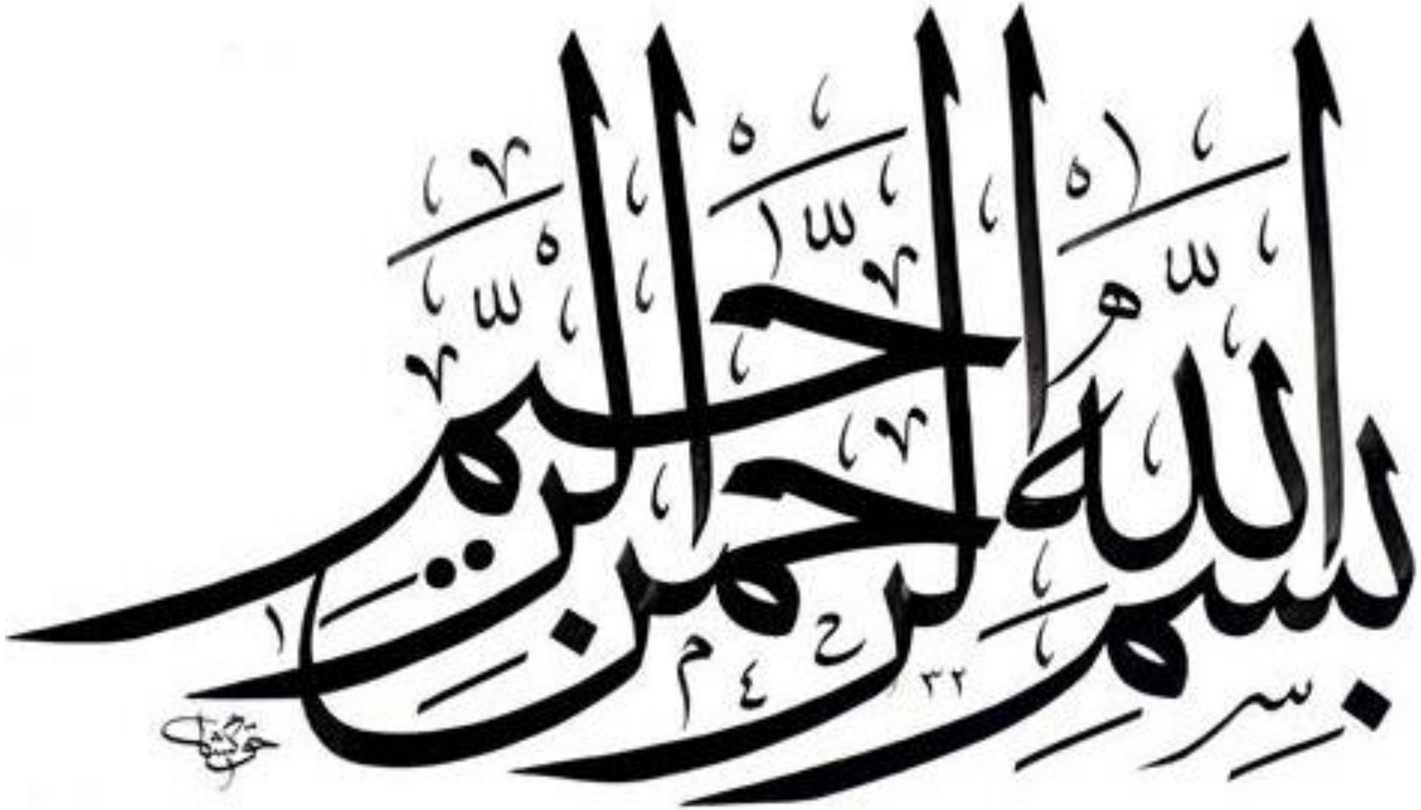
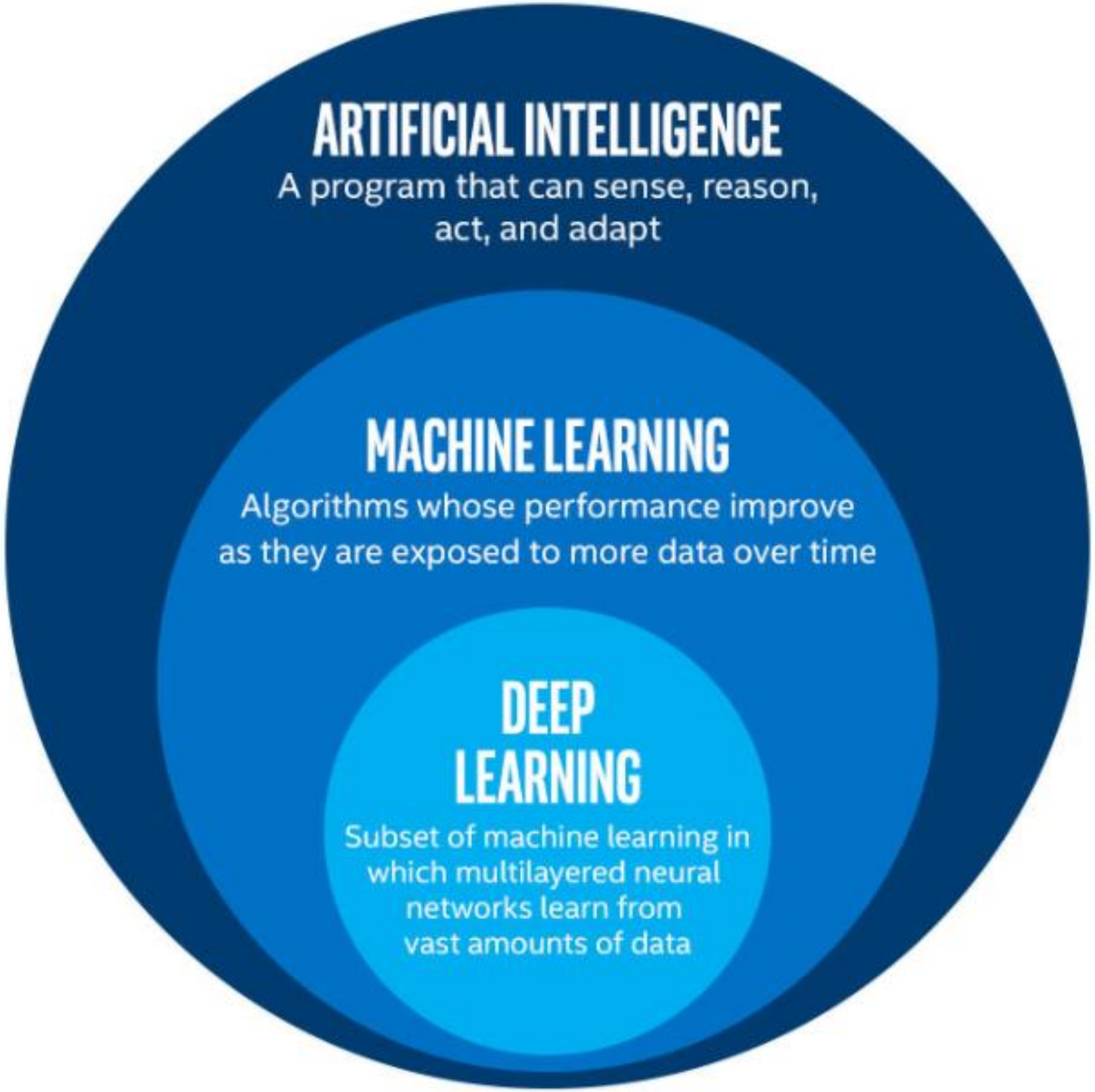

بسم الله الرحمن الرحيم

AI in precision medicine

“AI” application in personalized medicine

- Artificial intelligence is being used in personalized medicine to analyze large amounts of genomic and clinical data, identify patterns and relationships, and develop predictive models for disease risk and treatment response.
- AI is also being used to support clinical decision-making, develop personalized treatment plans, and improve patient outcomes.


ARTIFICIAL INTELLIGENCE
A program that can sense, reason, act, and adapt
MACHINE LEARNING
Algorithms whose performance improve as they are exposed to more data over time
DEEP LEARNING
Subset of machine learning in which multilayered neural networks learn from vast amounts of data

What is Learning?

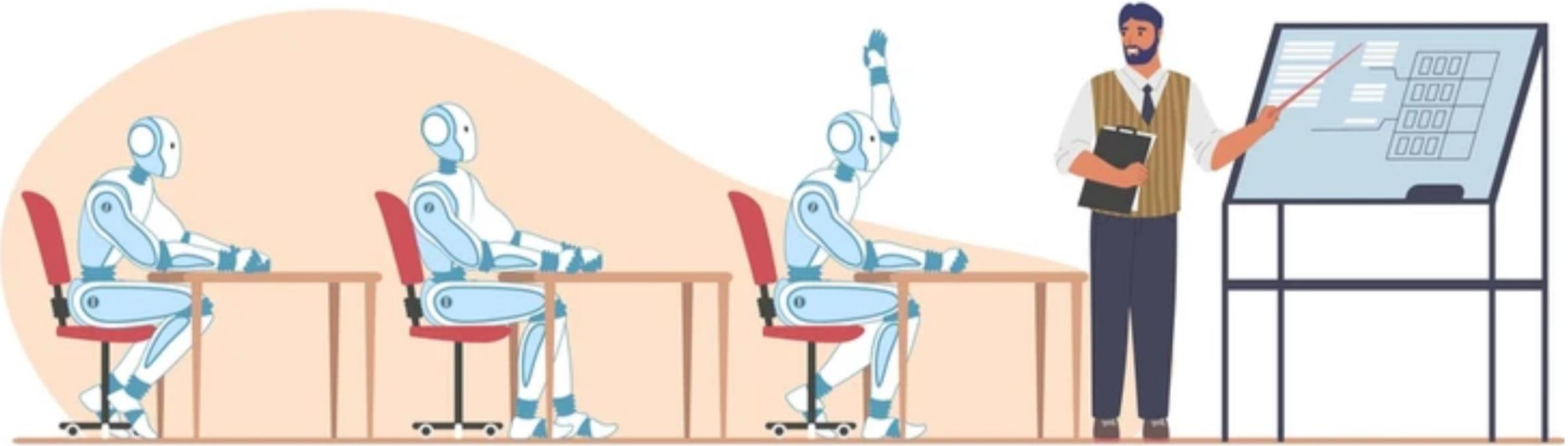
- Herbert Simon: “Learning is any process by which a system improves performance from experience.”

- “A computer program is said to **learn** from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.”

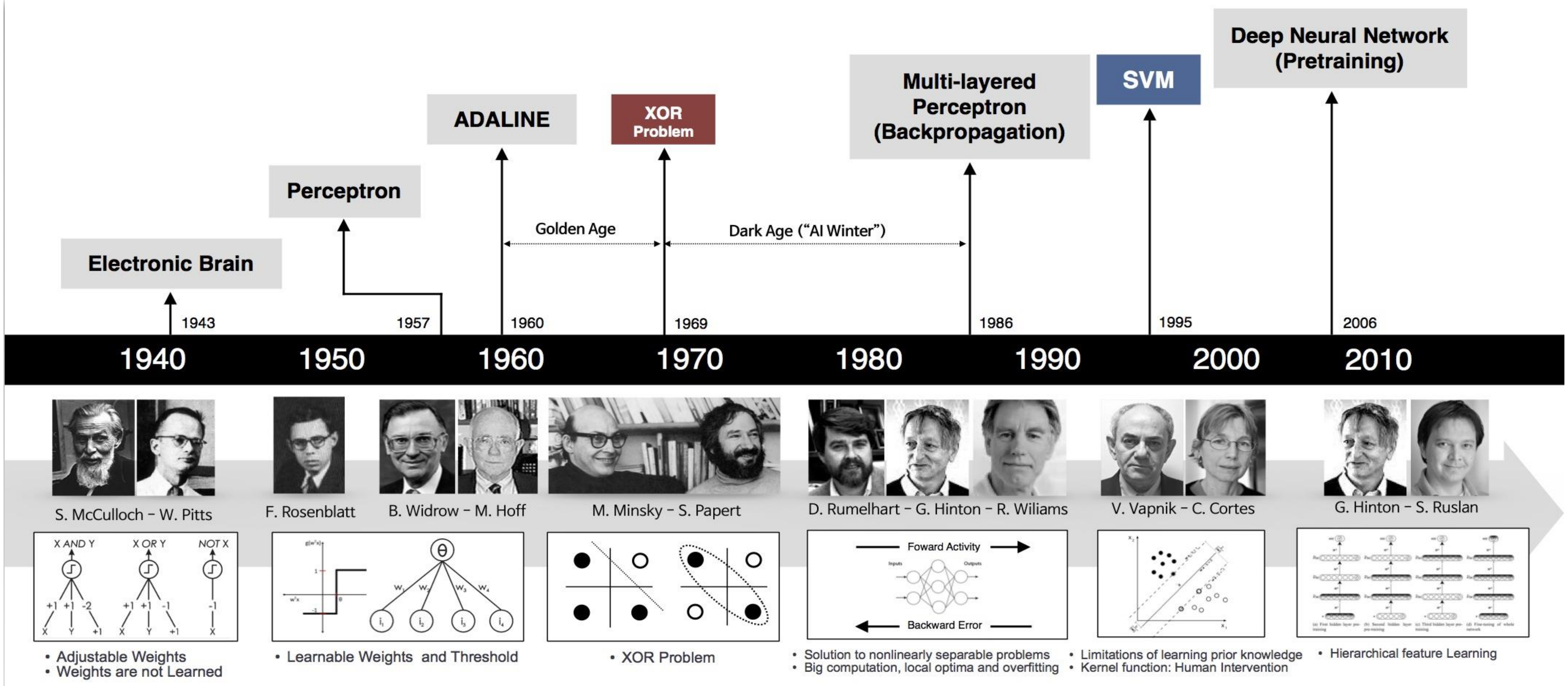
– Tom Mitchell

Learning from Observations

Public Big Data	Different Personal Data
Machine Learning	Data Analysis



Machine Learning

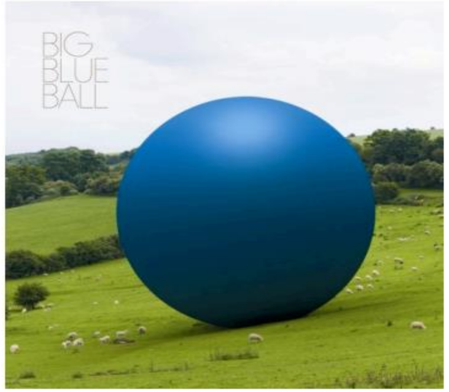


Machine Learning

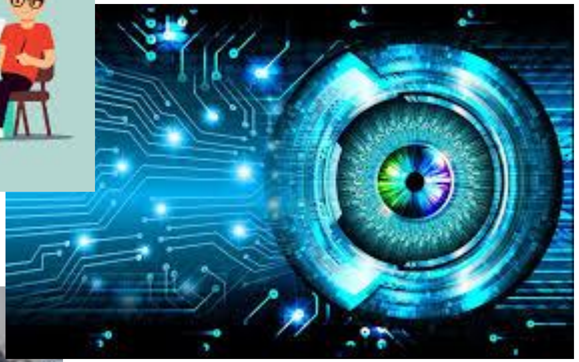
- *Machine learning*
  1. learn from data, experience,
  2. identify patterns and
  3. make decisions

Input (x) → **F(x)** → **Y {class label (classification) or vector (estimation)}**

Machine Learning



Machine Learning



Machine Learning

- **Supervised Learning**: Data and corresponding labels are given
- **Unsupervised Learning**: Only data is given, no labels provided
- **Semi-supervised Learning**: Some (if not all) labels are present
- **Reinforcement Learning**: An agent interacting with the world makes observations, takes actions, and is rewarded or punished; it should learn to choose actions in such a way as to obtain a lot of reward

Machine Learning

Application

1. Better Customer interaction using chatbots
2. Providing smart recommendations
3. Fraud detection using machine learning algorithms

Supervised Learning

Supervised Learning

- Learning a discrete function: **Classification**
  - Boolean classification:
    - Each example is classified as true(positive) or false(negative).
- Learning a continuous function: **Regression**

Unsupervised Learning

Unsupervised learning

Cluster analysis or **clustering** is the task of grouping a set of objects in such a way that objects in the same group (called a **cluster**) are more similar (in some sense or another) to each other than to those in other groups (clusters).

Reinforcement Learning

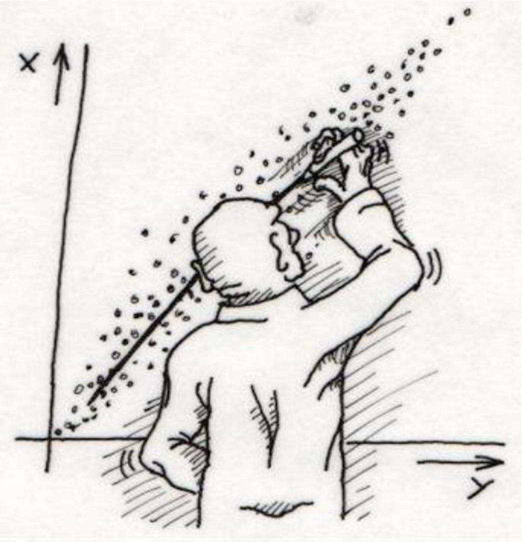
Reinforcement learning

Reinforcement learning is a machine learning training method based on rewarding desired behaviors and/or punishing undesired ones. In general, a reinforcement learning agent is able to perceive and interpret its environment, take actions and learn through trial and error.

Regression

Regression / Forecasting

- Data table statistical correlation
  - Mapping without any prior assumption on the functional form of the data distribution
  - Machine learning algorithms well suited for this
- Curve fitting
  - Find a well defined and known function underlying your data;
  - Theory / expertise can help.

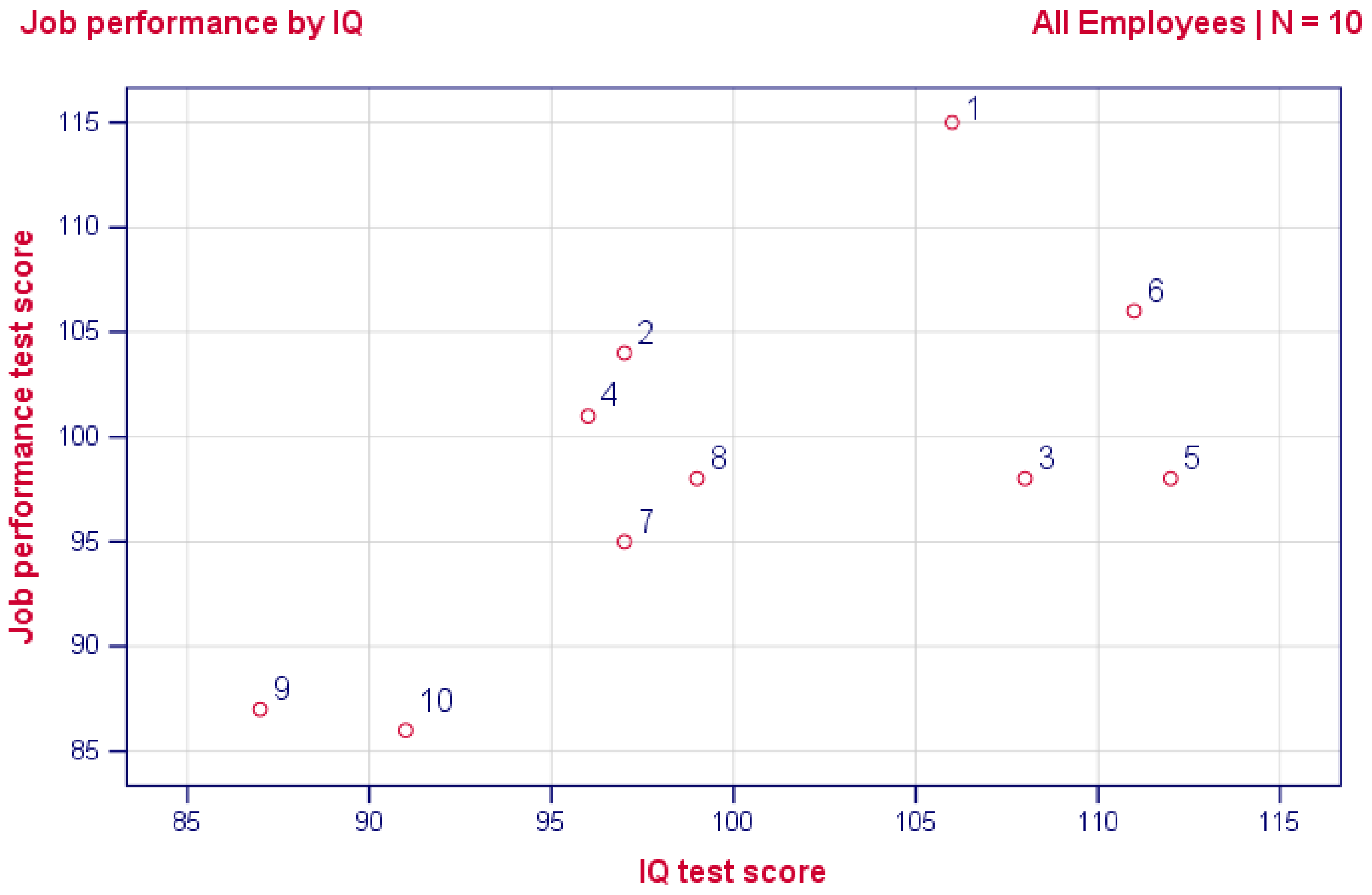


Regression Algorithms

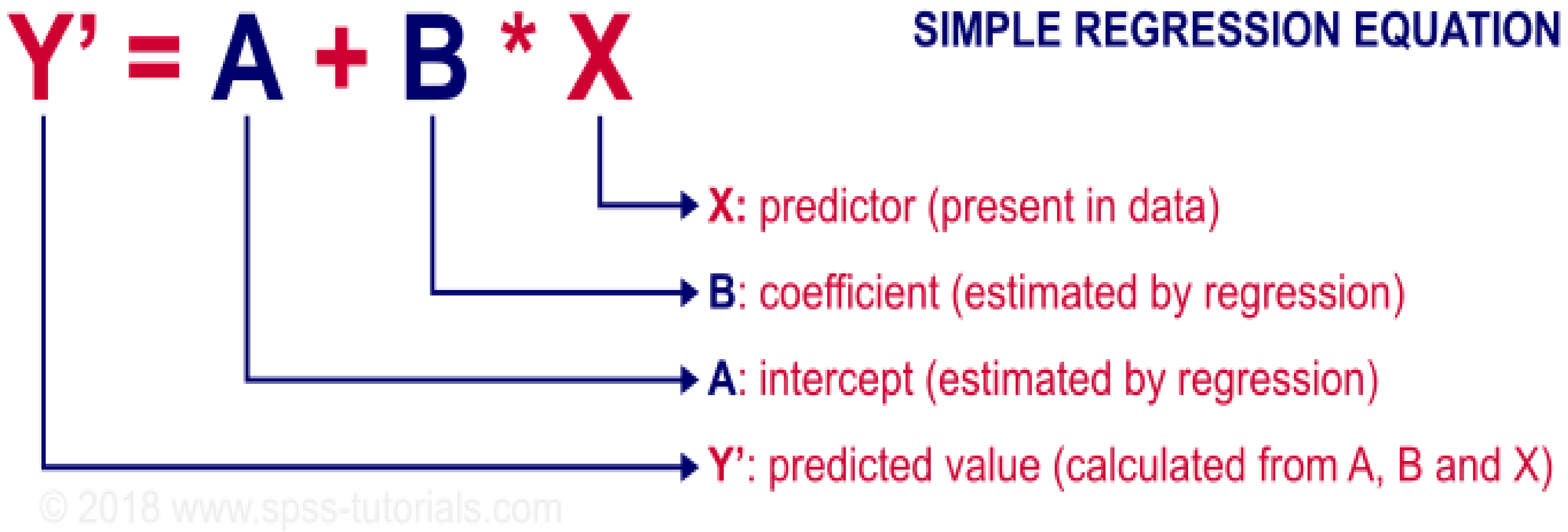
File Edit View Data Transform Analyze Graphs Utilities Extensions Window Help

	id	fname	iq	performance	var
1	1	Kevin	106	115	
2	2	Ayden	97	104	
3	3	Madelyn	108	98	
4	4	Madelyn	96	101	
5	5	Tristan	112	98	

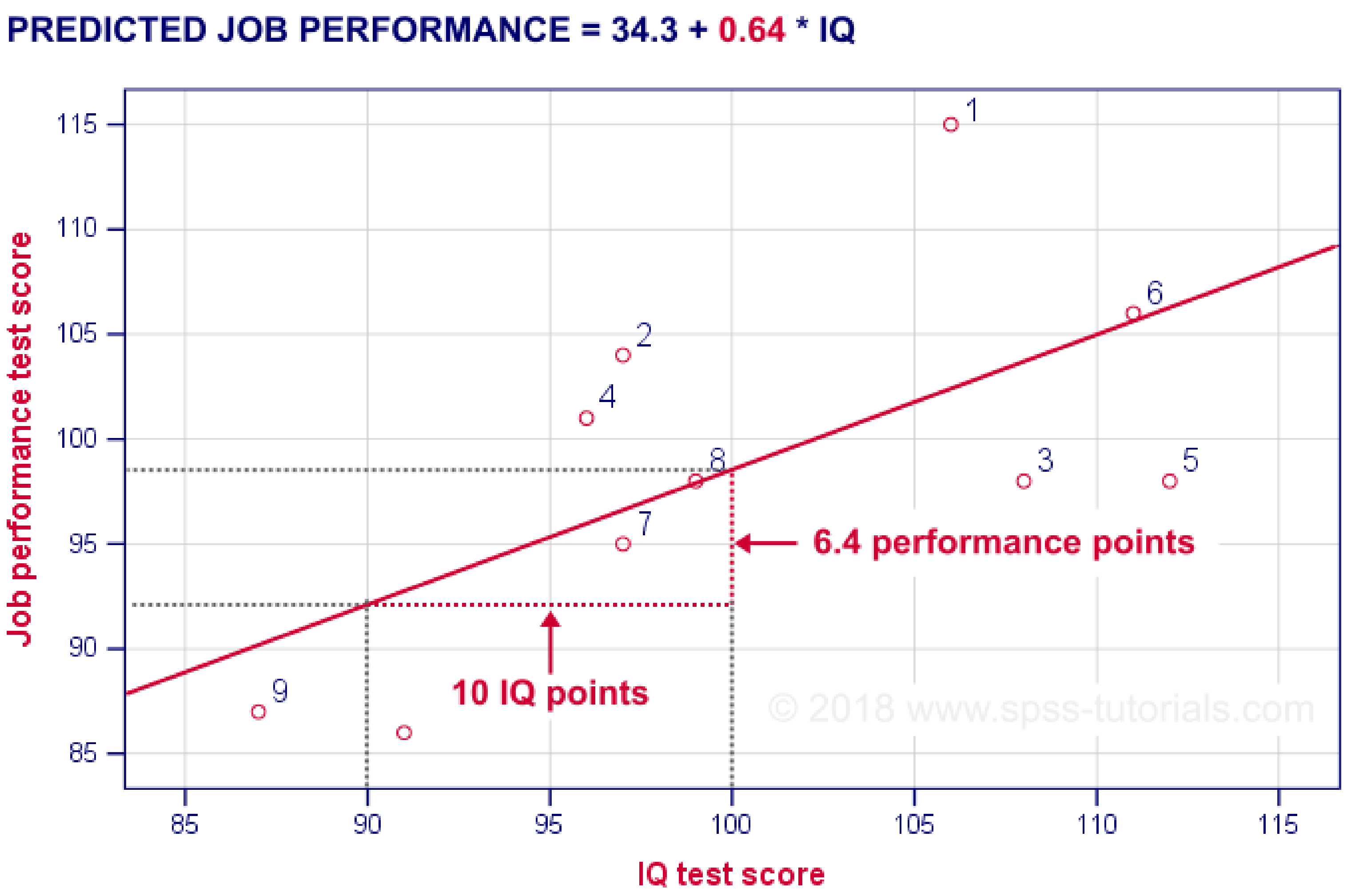
Regression Algorithms



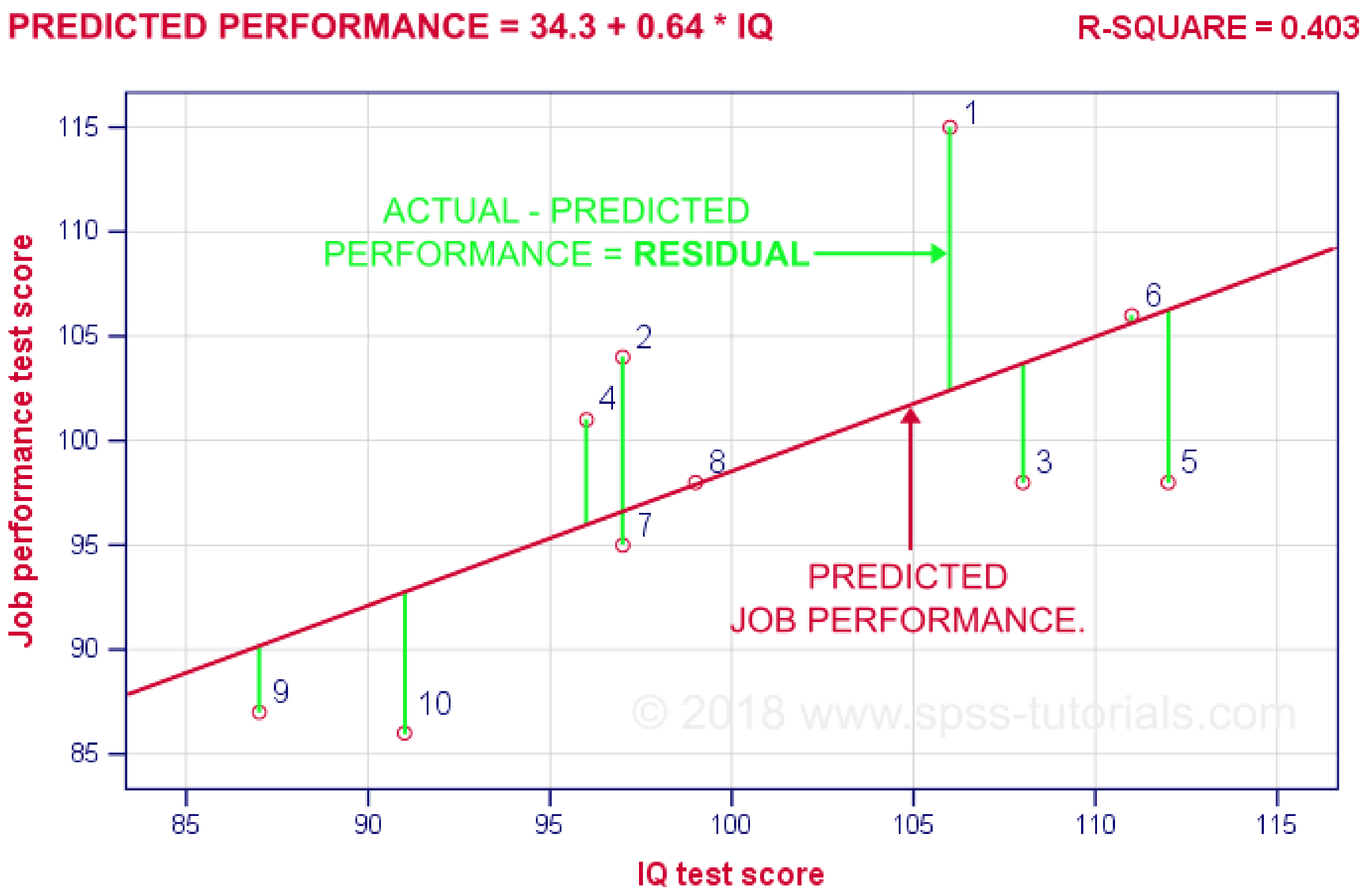
Regression Algorithms



Regression Algorithms



Regression Algorithms



Regression Algorithms

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17 :

	id	fname	iq	performance	pred	resid
1	1	Kevin	106	115	102.40	12.60
2	2	Ayden	97	104	96.61	7.39
3	3	Madelyn	108	98	103.69	-5.69
4	4	Madelyn	96	101	95.97	5.03
5	5	Tristan	112	98	106.26	-8.26
6	6	Isaac	111	106	105.61	.39
7	7	Victoria	97	95	96.61	-1.61
8	8	Christopher	99	98	97.90	.10
9	9	Caroline	87	87	90.19	-3.19
10	10	Daniel	91	86	92.76	-6.76
11						

Regression Algorithms

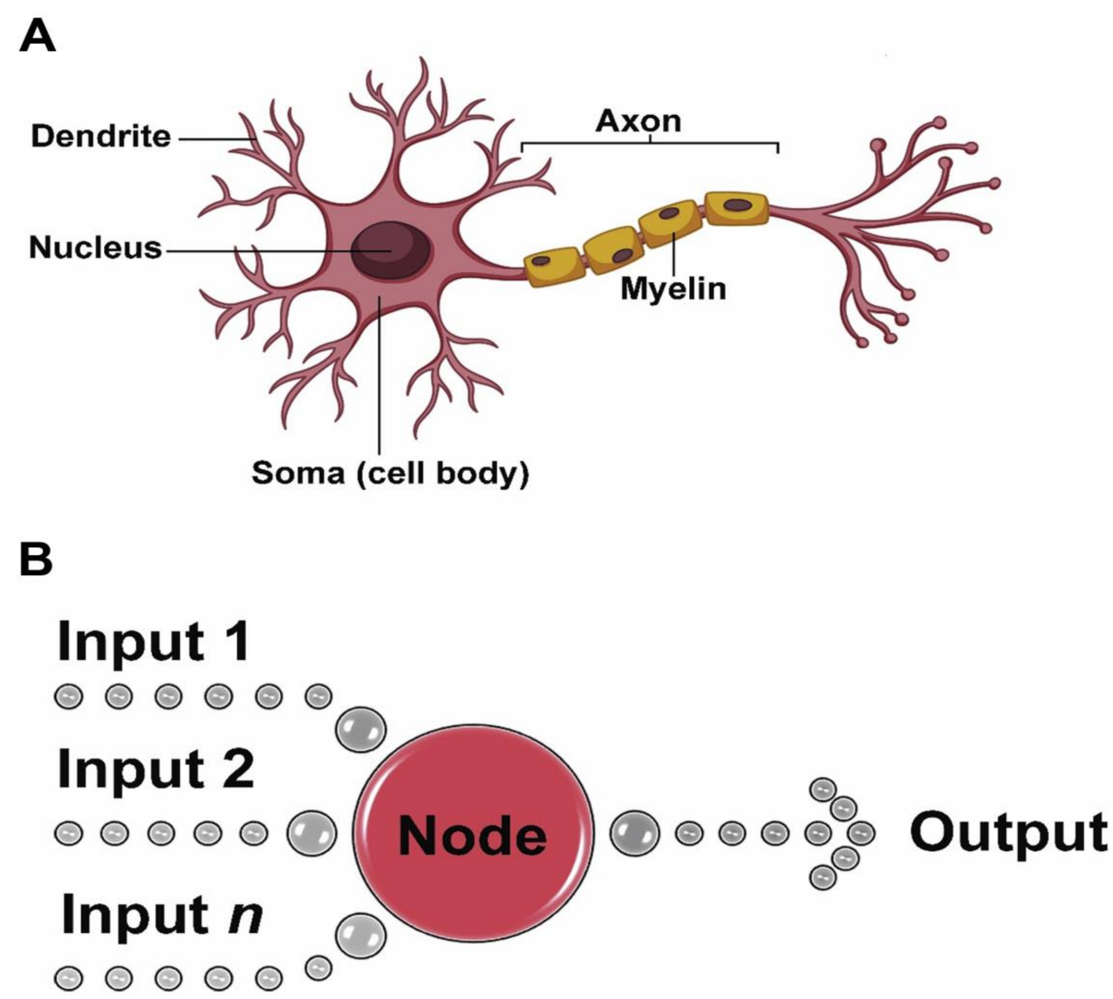
R-Squared is a way of measuring how much better than the mean line you have done based on summed squared error. The equation for R-Squared is

Sum Squared Regression Error

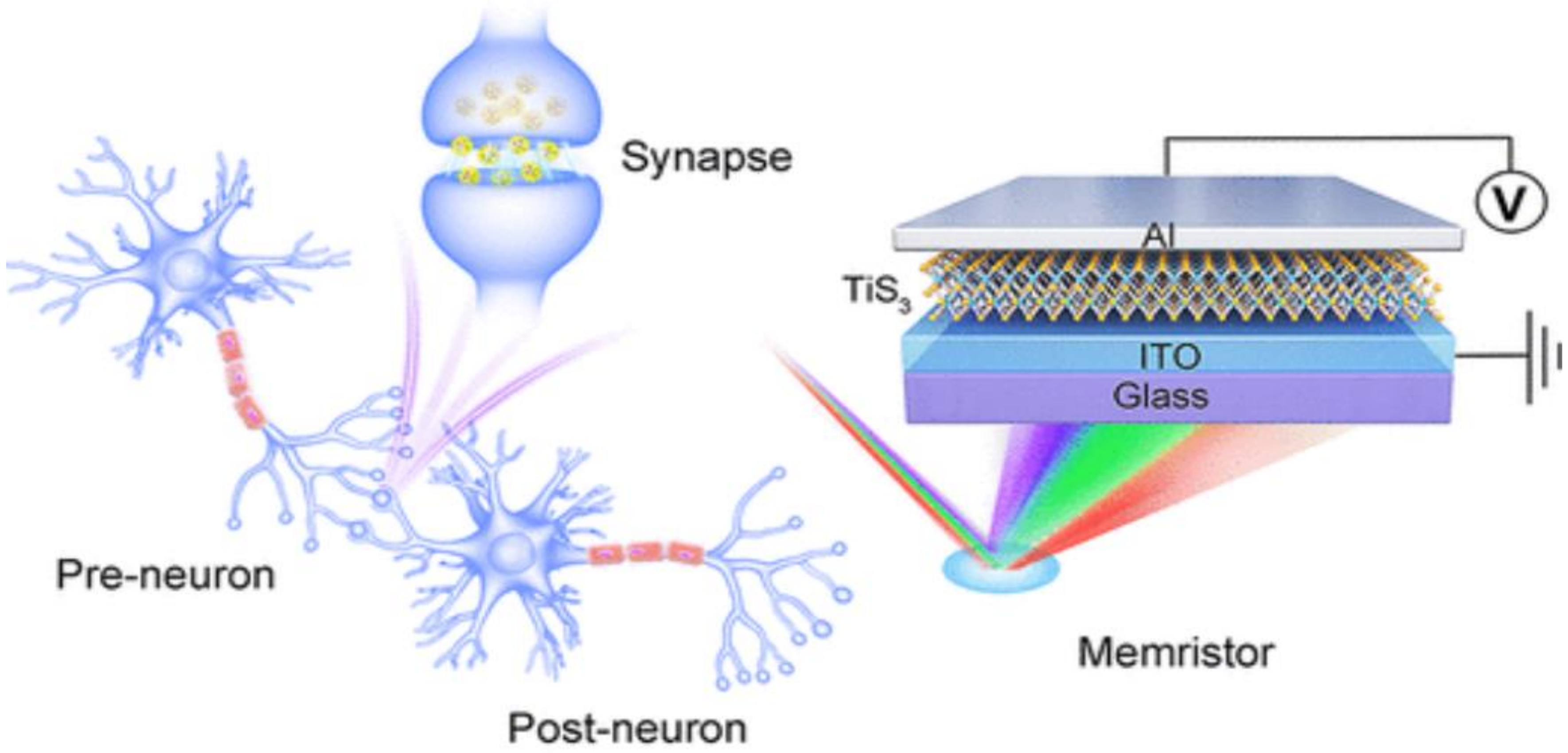
$$R^2 = 1 - \frac{SS_{Regression}}{SS_{Total}}$$

Sum Squared Total Error

Neural Network



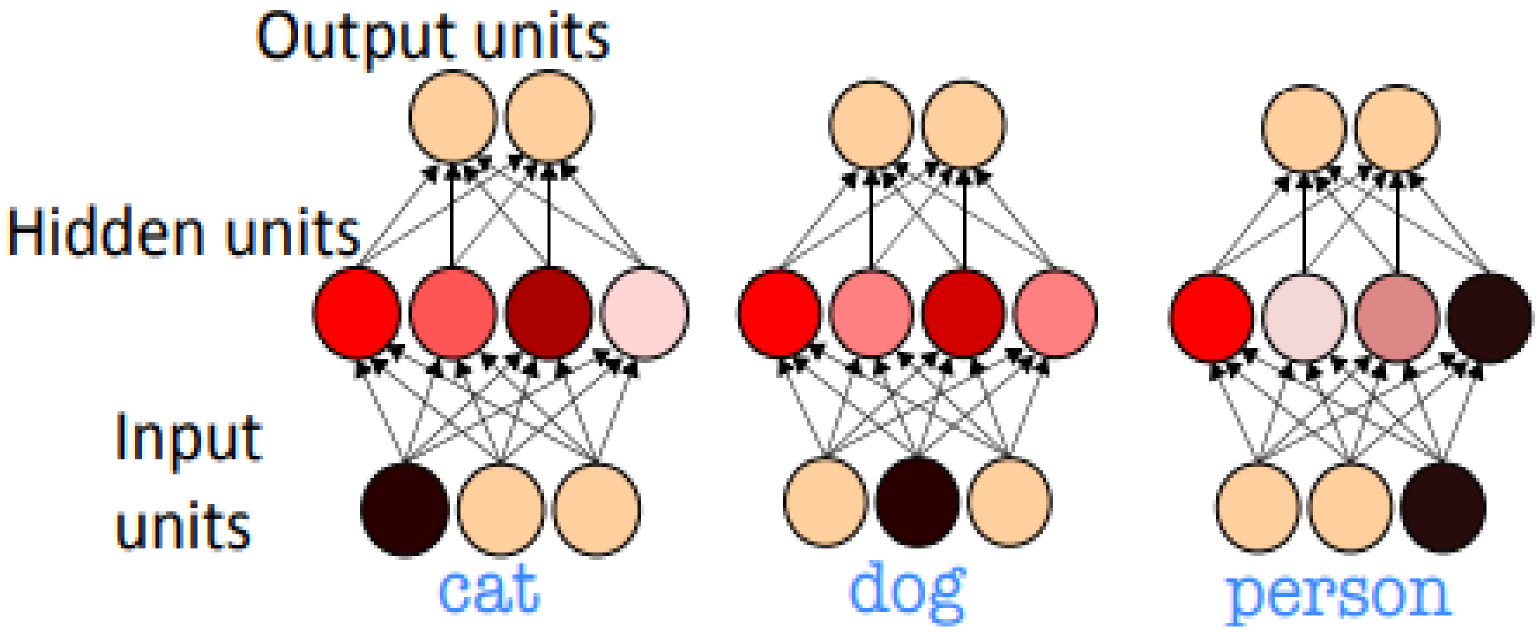
Neural Network



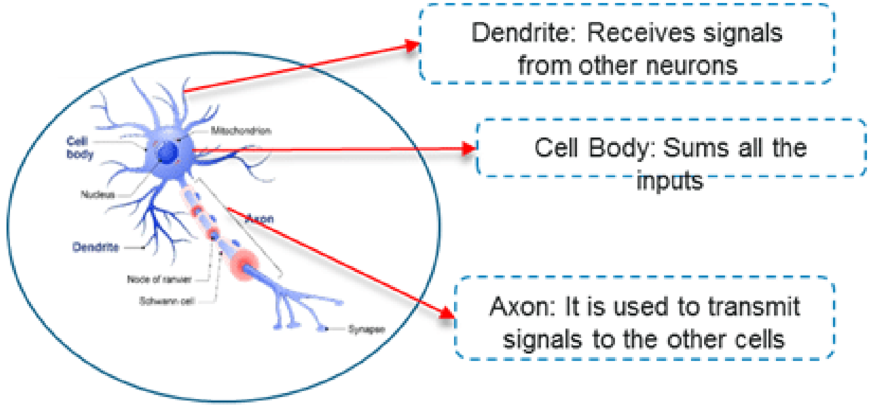
Neural Network

(Connectionism, 1980's)

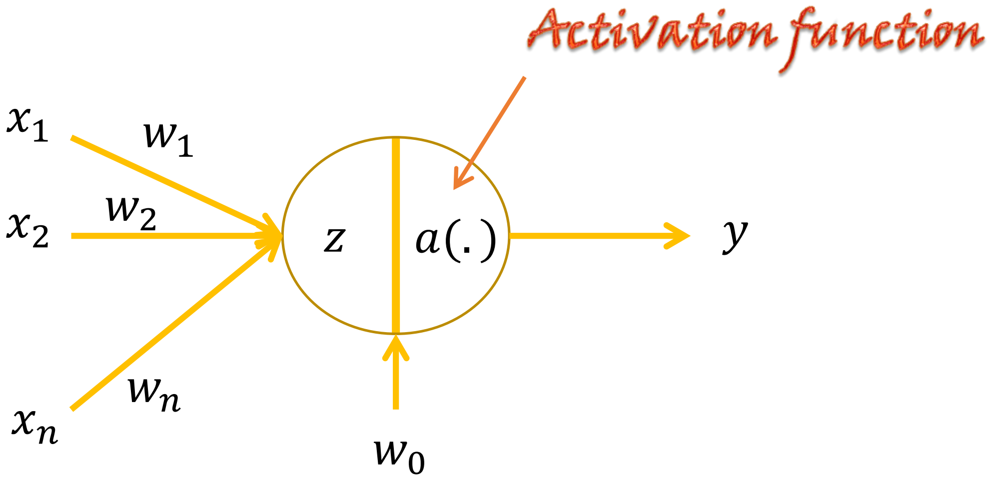
"Concepts are not represented by symbols in our brain, but by patterns of activation."



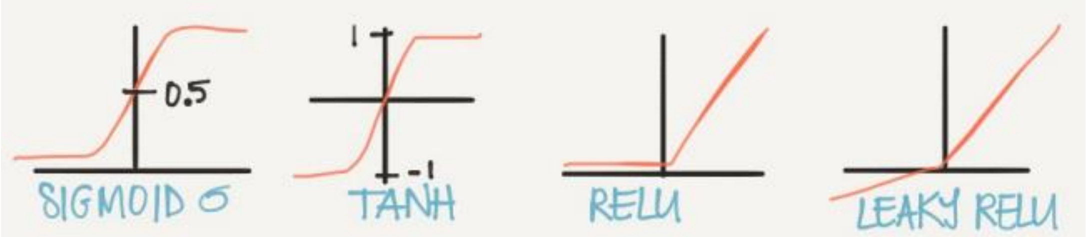
Neural Network



Neuron



$$z = \sum_{i=1}^{n} x_i w_i + w_0 \qquad y = a(z)$$



Neural Network

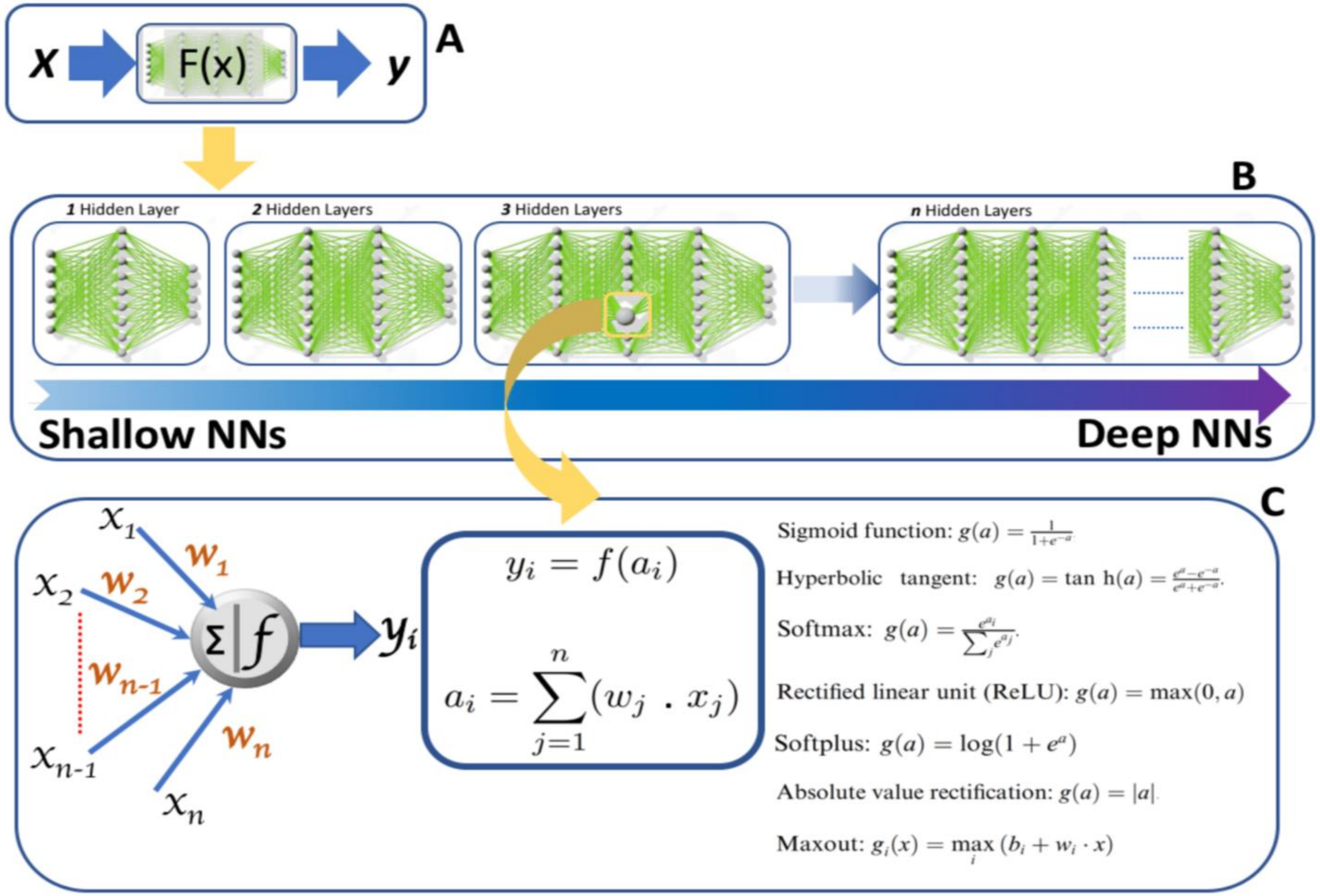
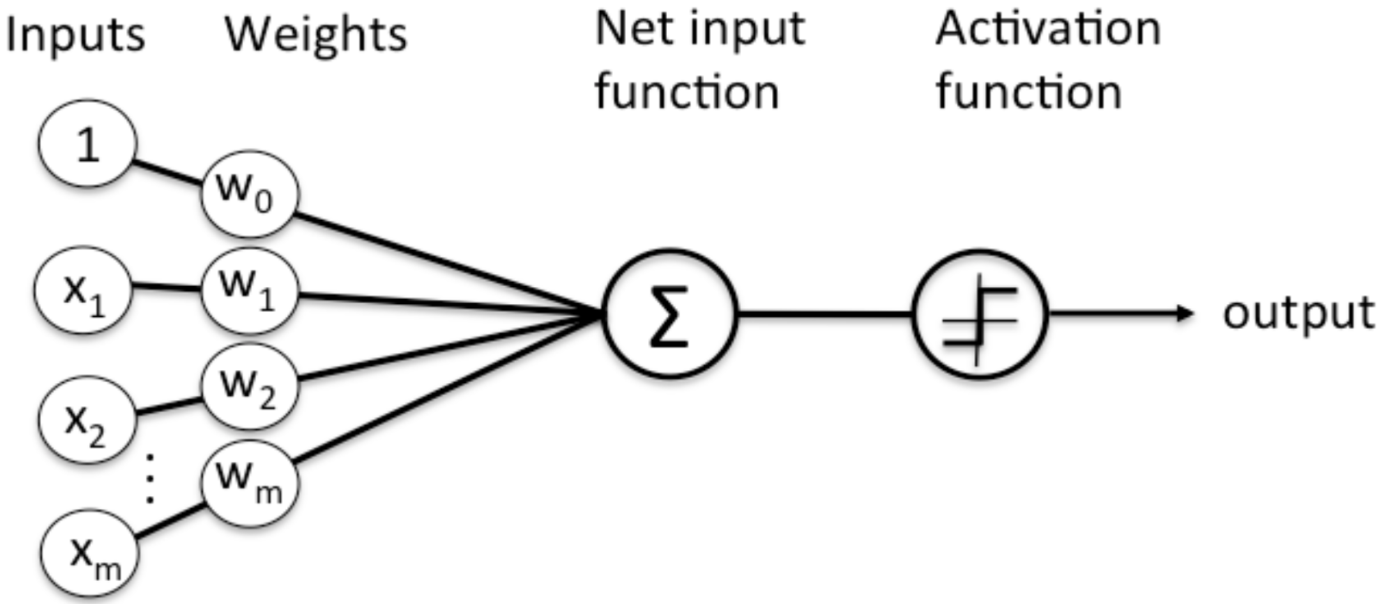
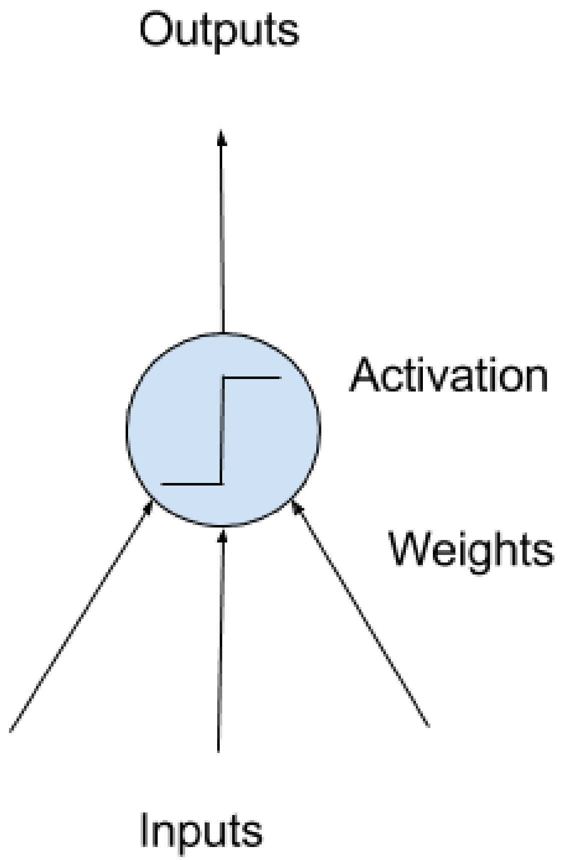


Figure 4. Artificial neural networks.

Neural Network

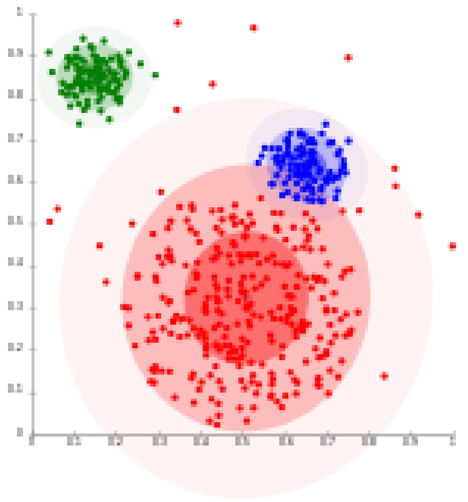
Here's a diagram of what one node might look like.

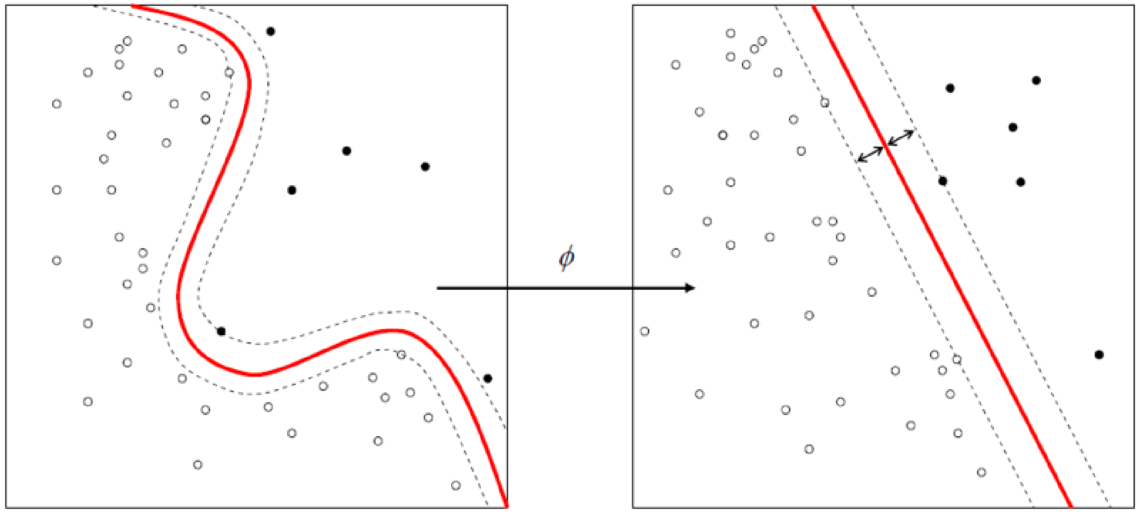


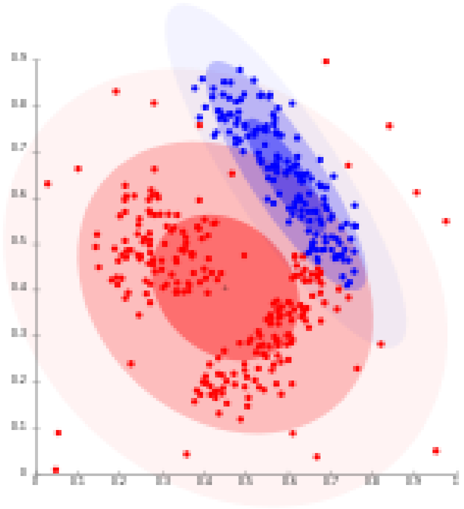


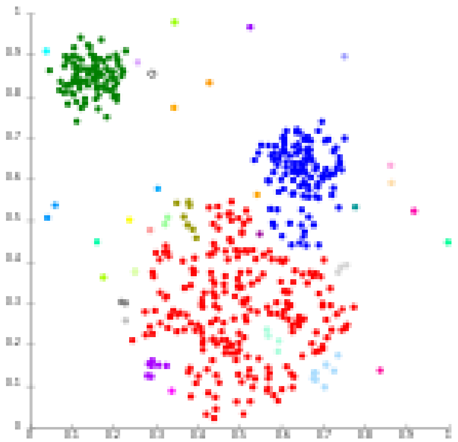
A node layer is a row of those neuron-like switches that turn on or off as the input is fed through the net. Each layer's output is simultaneously the subsequent layer's input, starting from an initial input layer receiving your data.

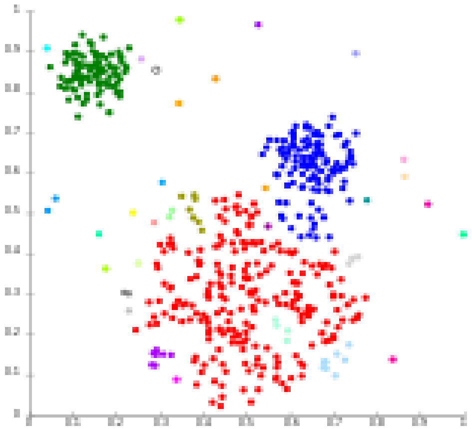
Clustering



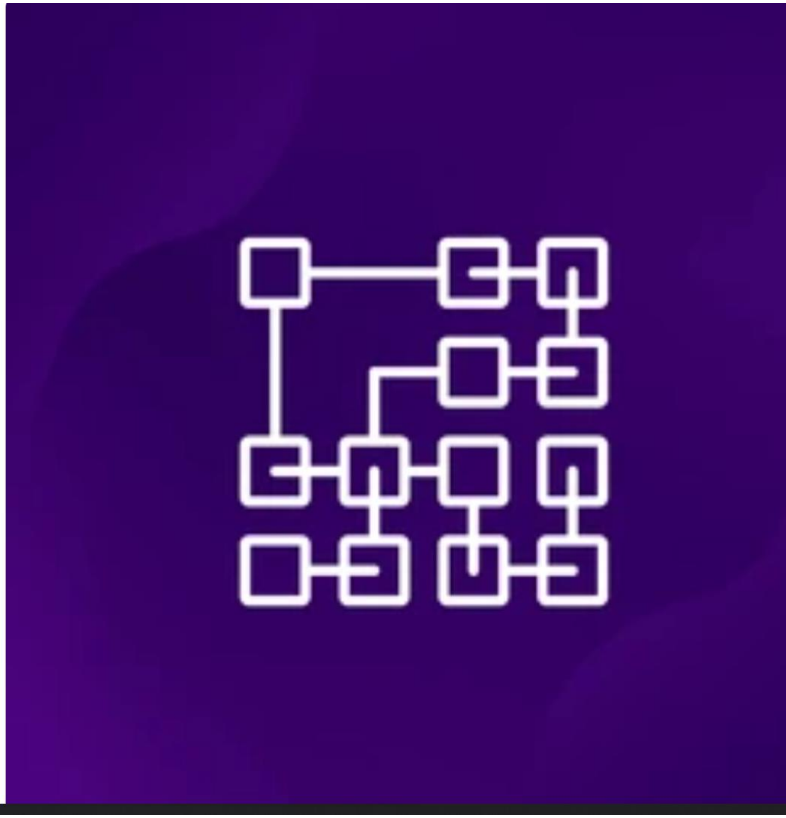








Clustering

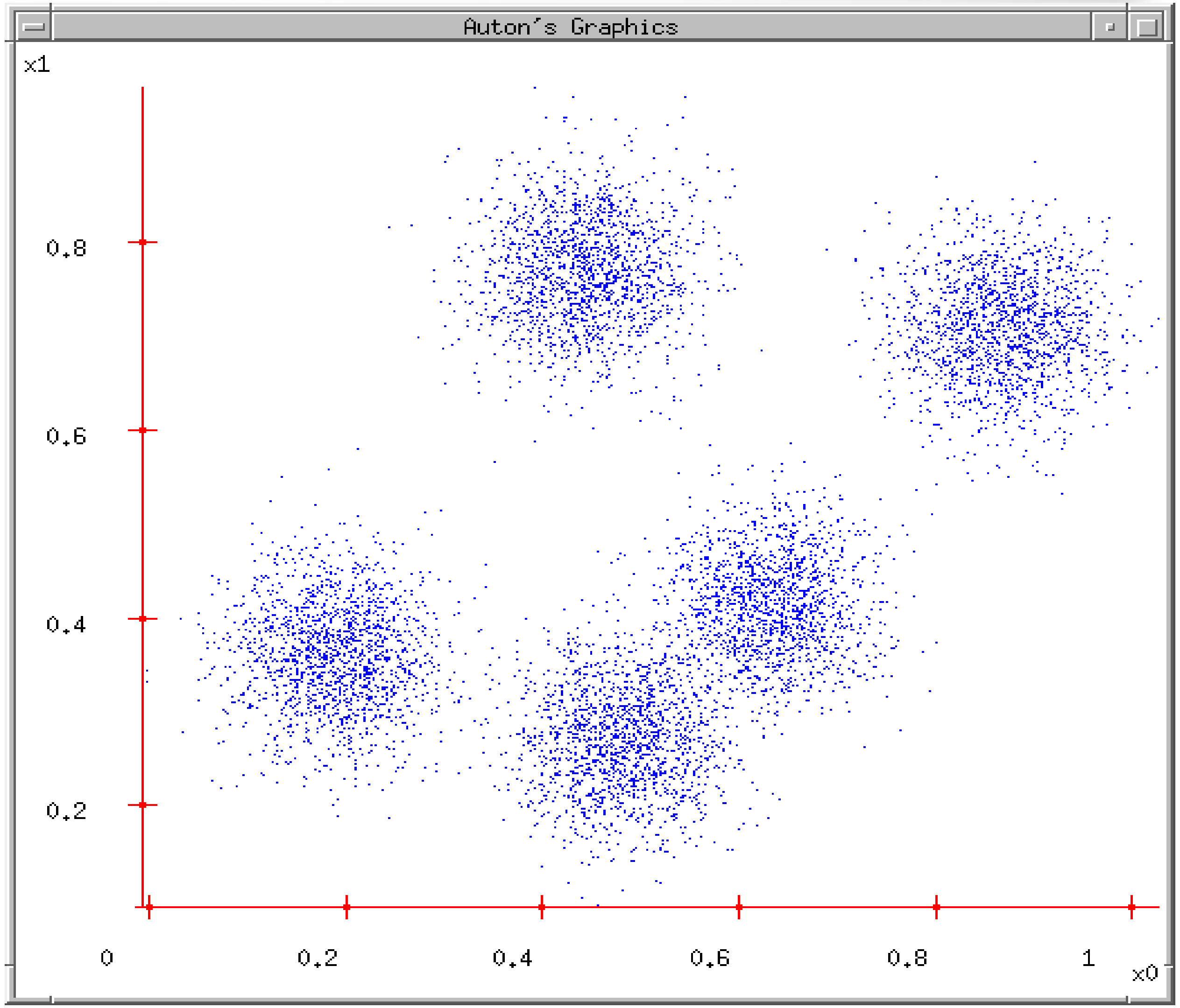


K-means Clustering

Some Data

This could easily be modeled by a Gaussian Mixture (with 5 components)

But let’s look at an satisfying, friendly and infinitely popular alternative…



Lossy Compression

Suppose you transmit the coordinates of points drawn randomly from this dataset.

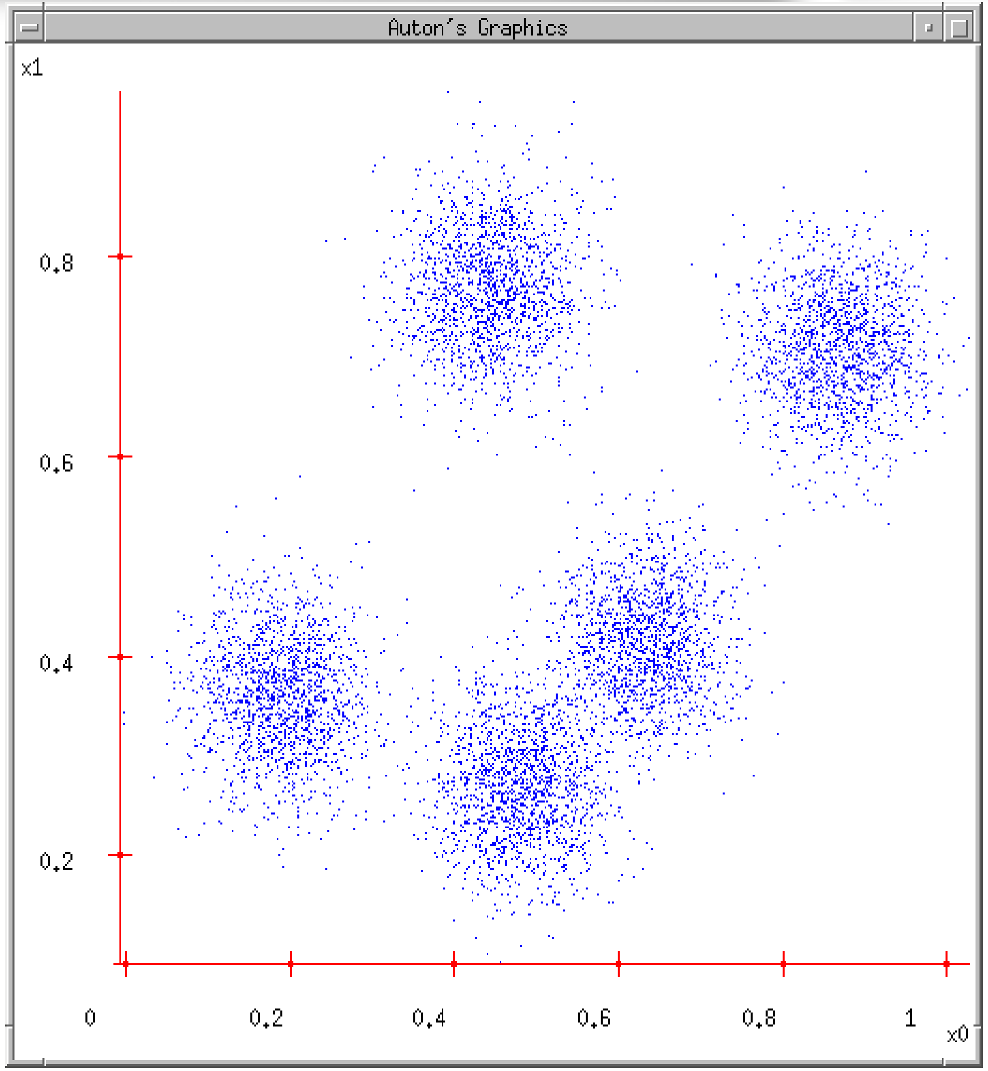
You can install decoding software at the receiver.

You're only allowed to send two bits per point.

It'll have to be a "lossy transmission".

Loss = Sum Squared Error between decoded coords and original coords.

What encoder/decoder will lose the least information?



Generalization

Generalization

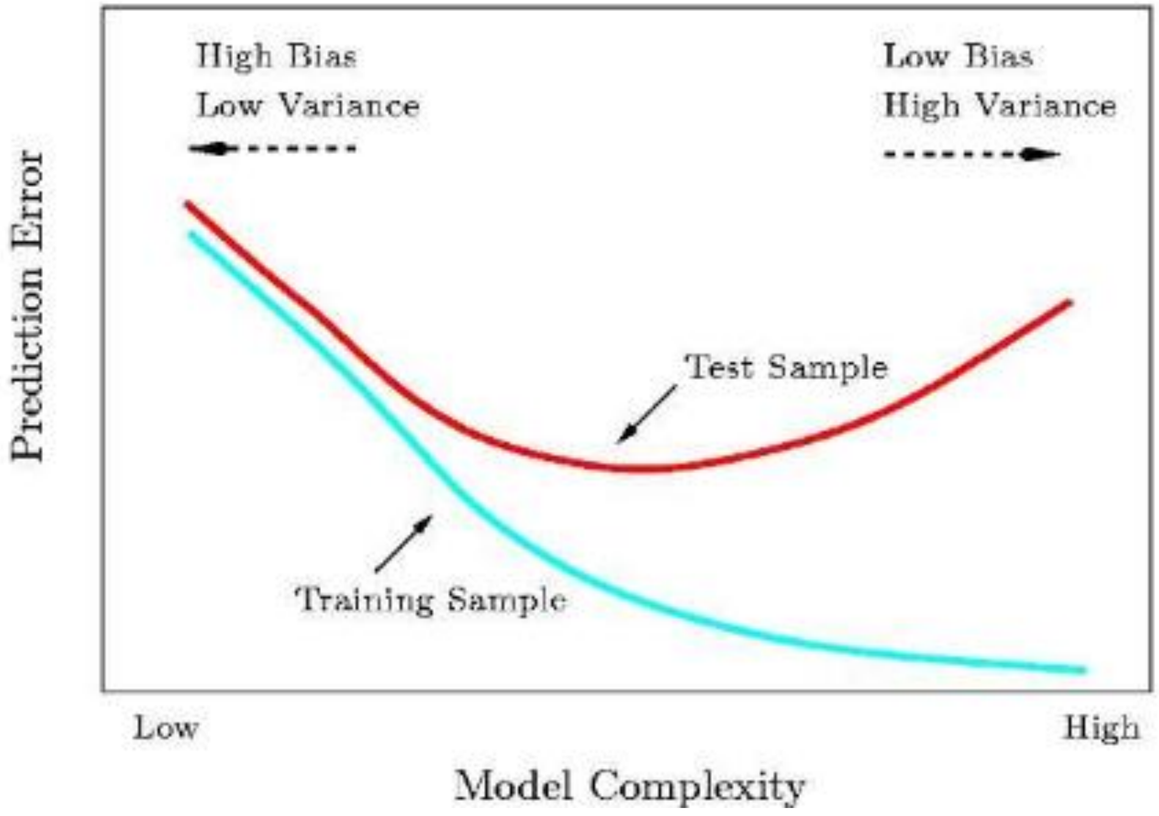
- Refers to the ability to produce reasonable outputs for inputs not encountered during the training.

In other words: NO PANIC when "never seen before" data are given in input!

Generalization

- Hypotheses must generalize to correctly classify instances not in the training data.
- Simply memorizing training examples is a consistent hypothesis that does not generalize.
- *Occam's razor*:
  - Finding a *simple* hypothesis helps ensure generalization.

Training Error vs Test Error



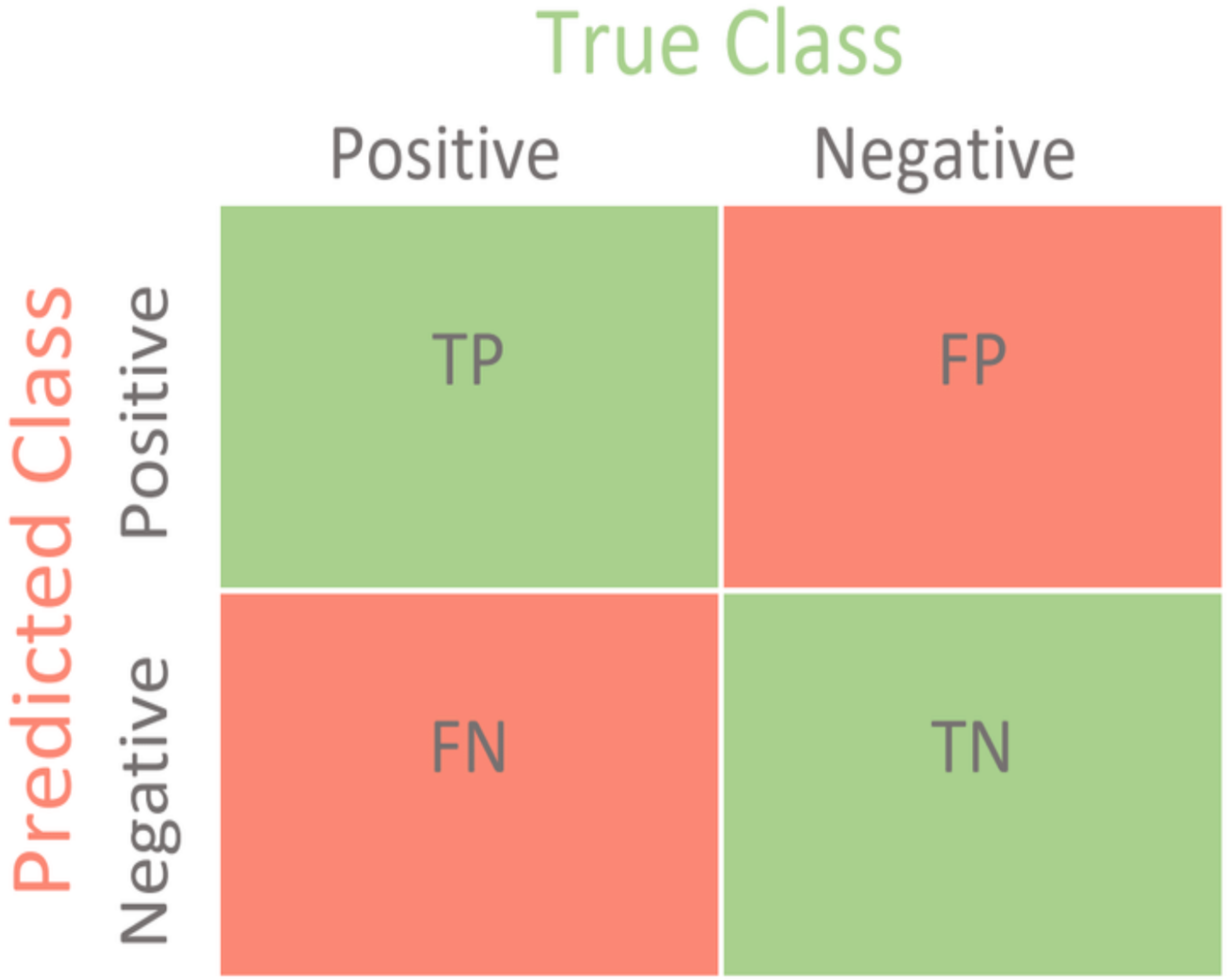
A common problem: OVERFITTING

- Learn the “data” and not the underlying function
- Performs well on the data used during the training and poorly with new data.

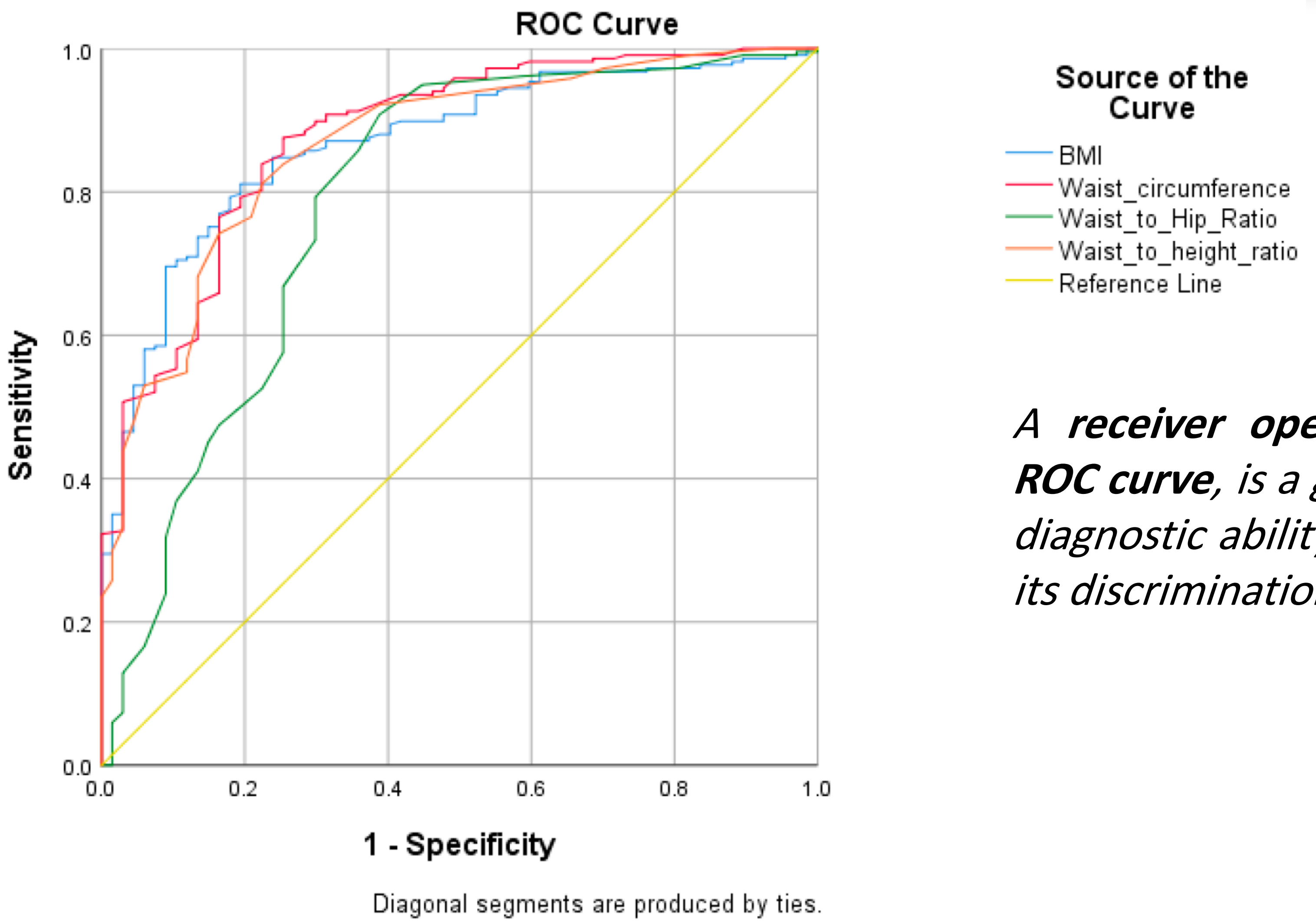
How to avoid it: use proper subsets, early stopping.

Performance measurement

A **Confusion matrix** is an ***N x N matrix*** used for evaluating the **performance of a classification model**, where **N** is the number of ***target classes***. The matrix compares the actual target values with those predicted by the machine learning model.



Performance measurement



*A **receiver operating characteristic curve**, or **ROC curve**, is a graphical plot that illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied.*

K-Nearest Neighbor

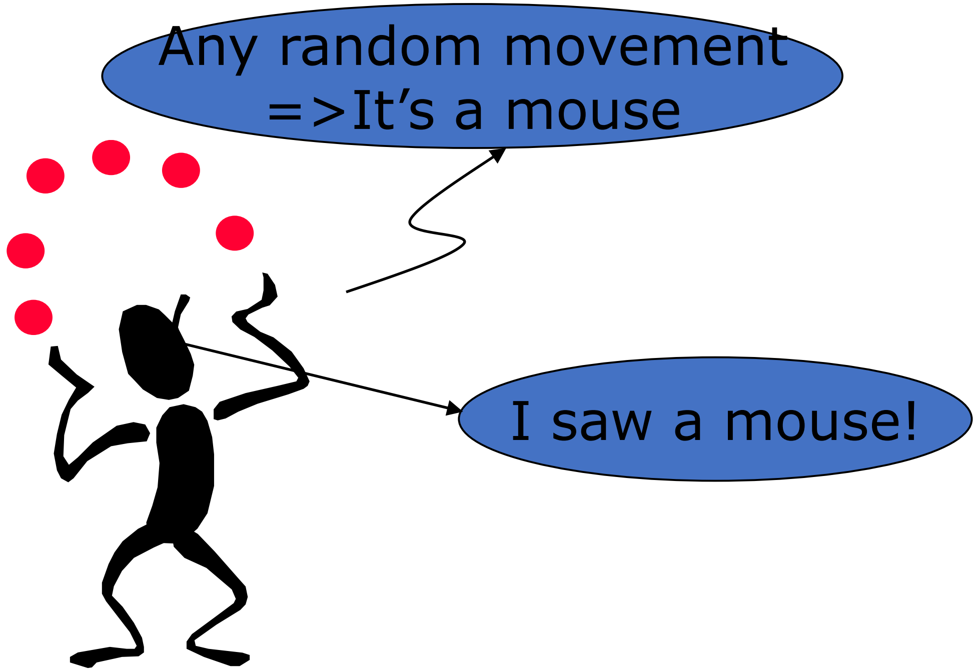
K-Nearest Neighbor

- Eager Learning
  - Explicit description of target function on the whole training set
- Instance-based Learning
  - Learning=storing all training instances
  - Classification=assigning target function to a new instance
  - Referred to as “Lazy” learning

K-Nearest Neighbor

Eager Learning

Instance-based Learning

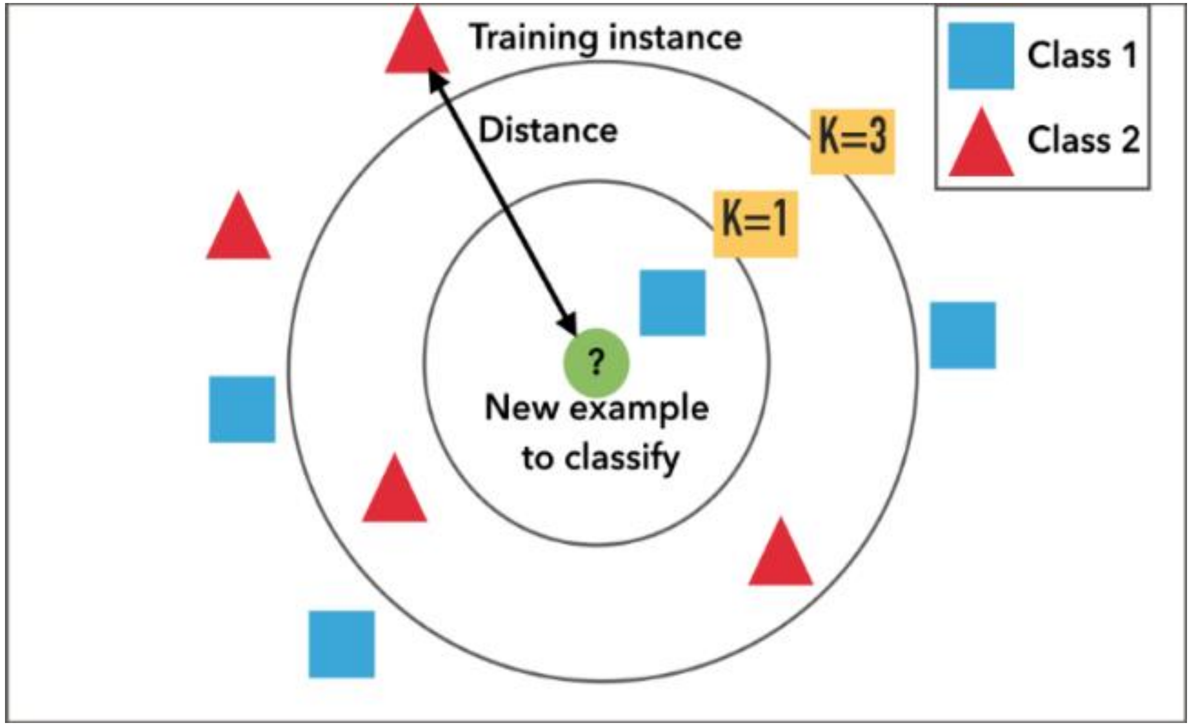


K-Nearest Neighbor

- KNN algorithm is one of the simplest classification algorithm
- non-parametric
  - it does not make any assumptions on the underlying data distribution
- lazy learning algorithm.
  - there is *no explicit training phase* or it is very minimal.
  - also means that the training phase is pretty fast .
  - Lack of generalization means that KNN keeps all the training data.
- Its purpose is to use a database in which the data points are separated into several classes to predict the classification of a new sample point.

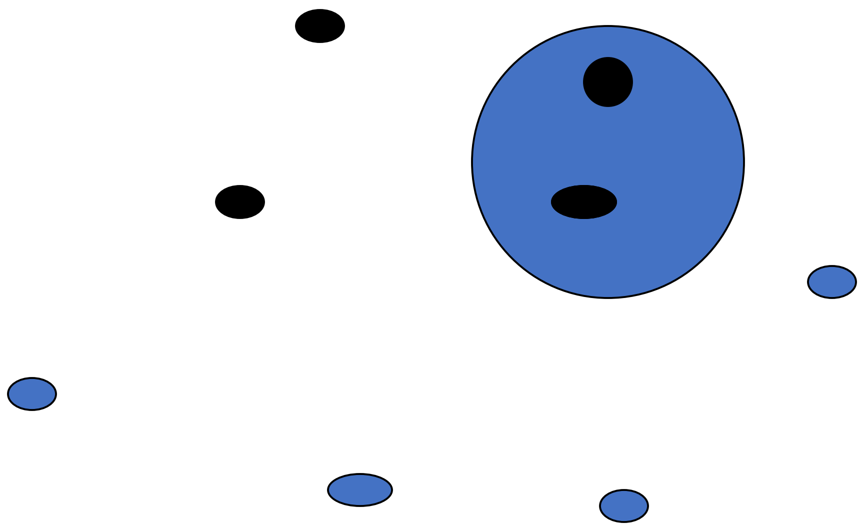
K-Nearest Neighbor

- KNN Algorithm is based on feature similarity
- How closely out-of-sample features resemble our training set determines how we classify a given data point



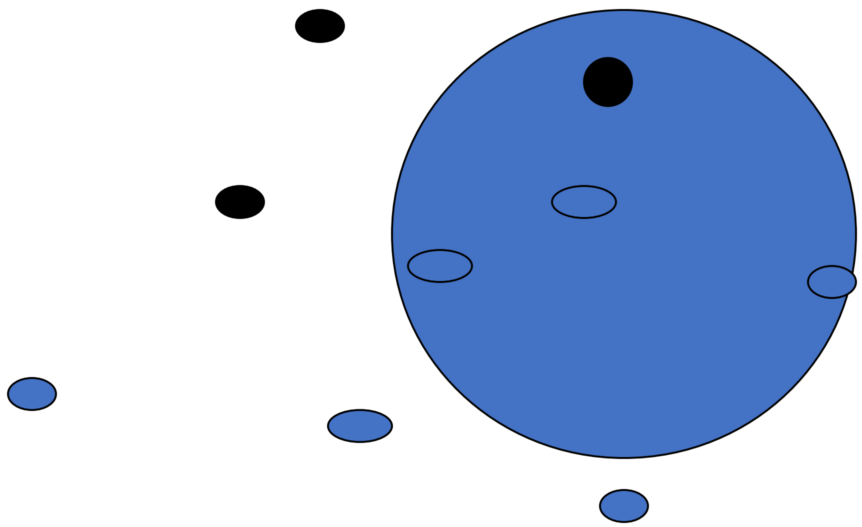
K-Nearest Neighbor

1 -Nearest Neighbor



K-Nearest Neighbor

3 -Nearest Neighbor

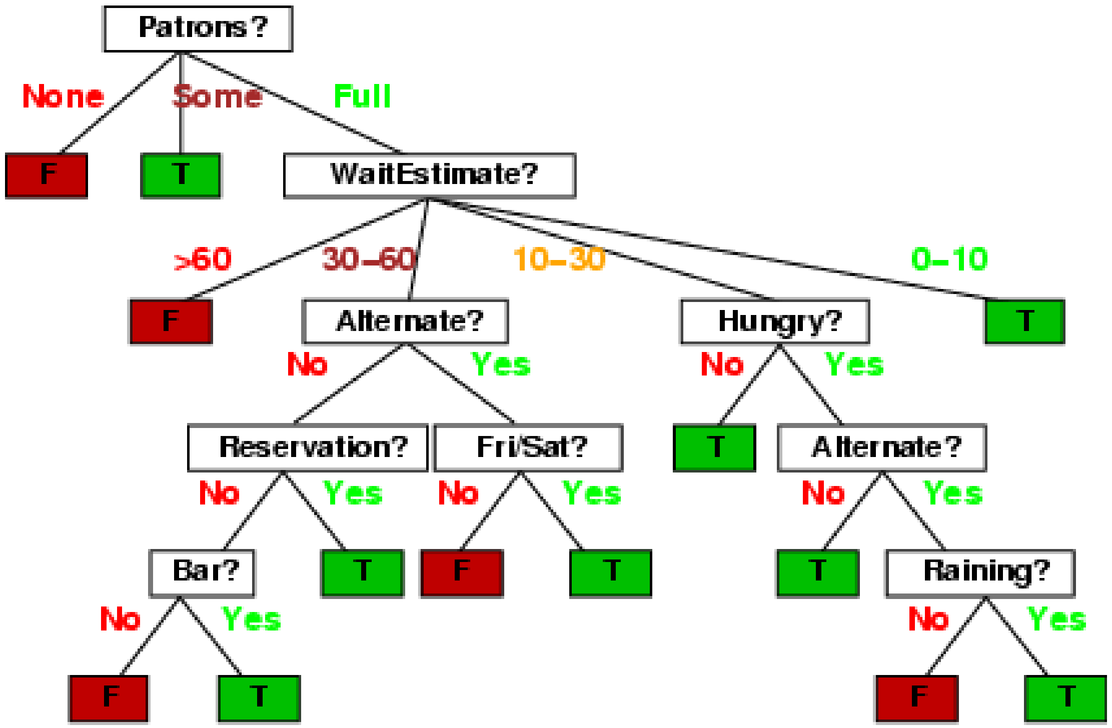


K-Nearest Neighbor

1. Training phase: a model is constructed from the training instances.
   - classification algorithm finds relationships between predictors and targets
   - relationships are summarised in a model
2. Testing phase: test the model on a test sample whose class labels are known but not used for training the model
3. Usage phase: use the model for classification on new data whose class labels are unknown

Decision trees

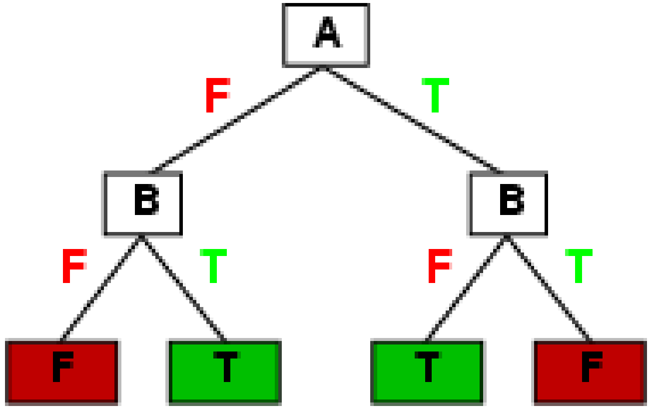
- One possible representation for hypotheses
- E.g., here is the "true" tree for deciding whether to wait:



Expressiveness

- Decision trees can express any function of the input attributes.
- E.g., for Boolean functions, truth table row → path to leaf:

A	B	A xor B
F	F	F
F	T	T
T	F	T
T	T	F

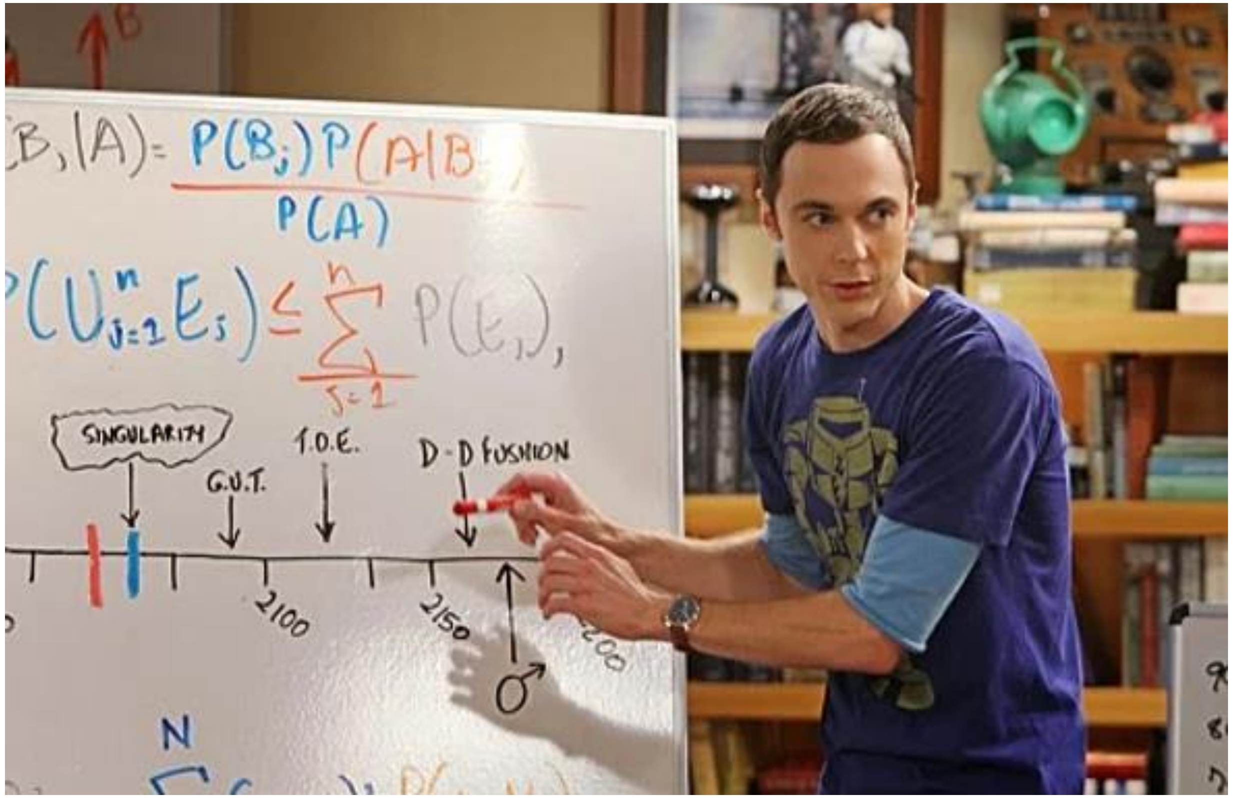


- Trivially, there is a consistent decision tree for any training set with one path to leaf for each example (unless *f* nondeterministic in *x*) but it probably won't generalize to new examples

- Prefer to find more compact decision trees

The Bayesian Theory

The Bayesian Theory



A Private View of Quantum Reality

Quantum theorist Christopher Fuchs explains how to solve the paradoxes of quantum mechanics. His price: physics gets personal.

78

The Bayesian Theory

Naivety in Canada

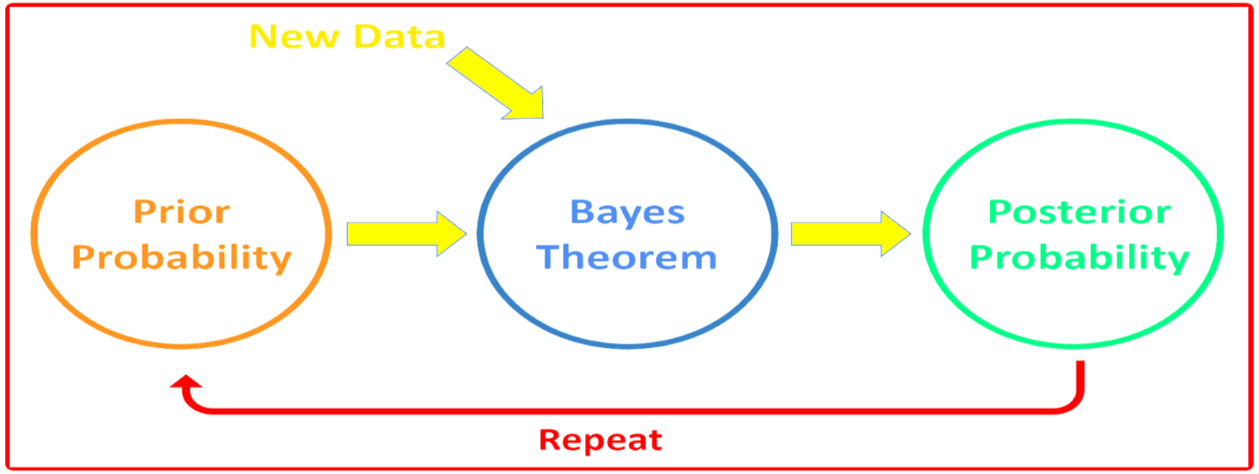
Likelihood

Prior

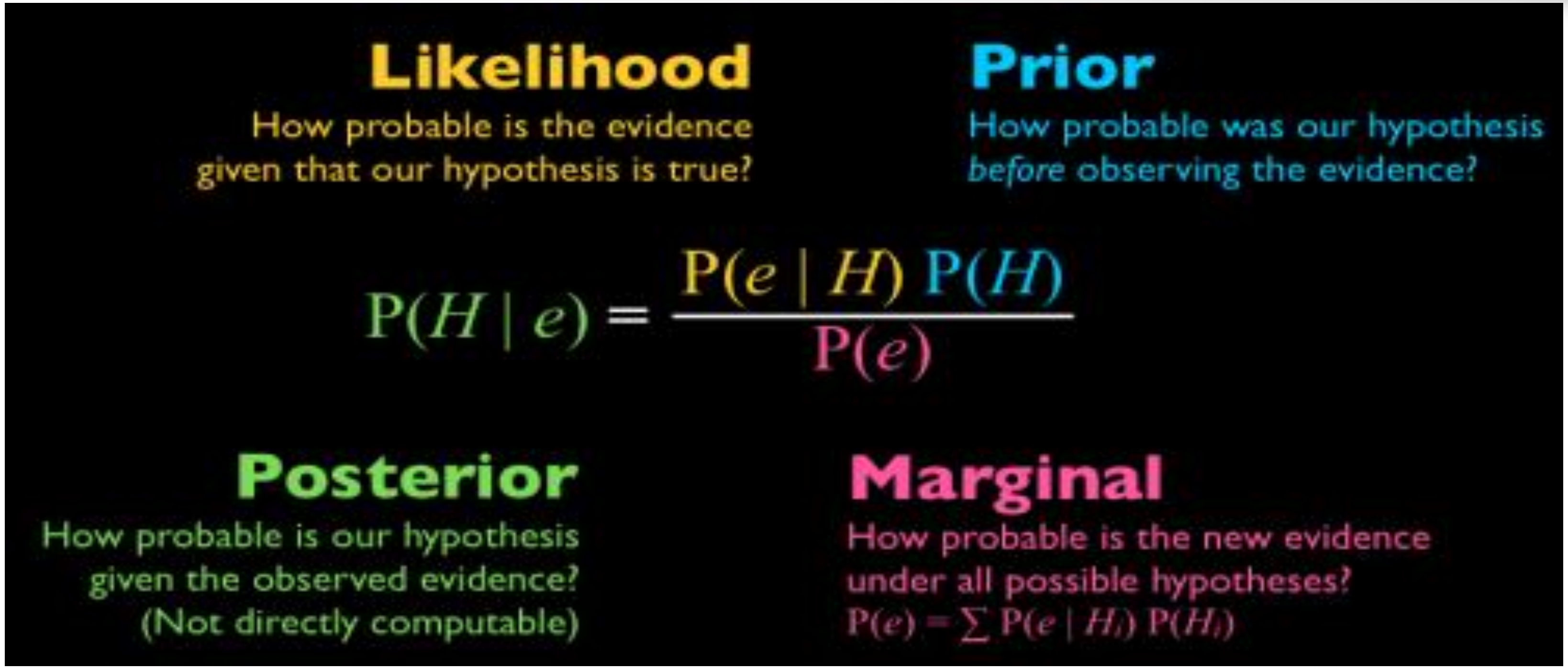
$$p(H|E) = \frac{p(E|H) \times p(H)}{p(E)}$$

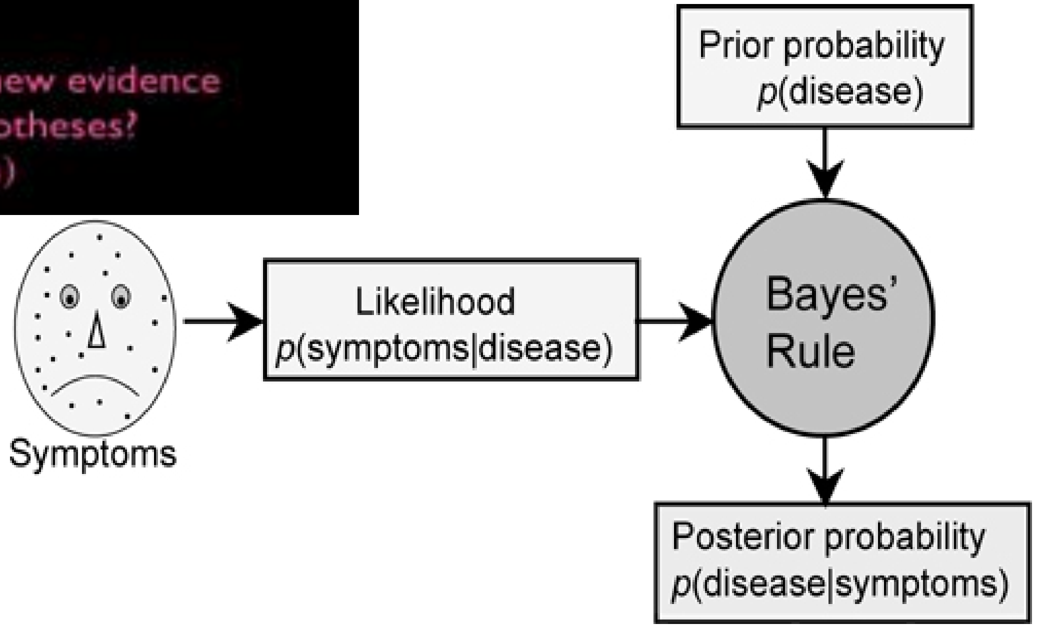
Posterior

Evidence

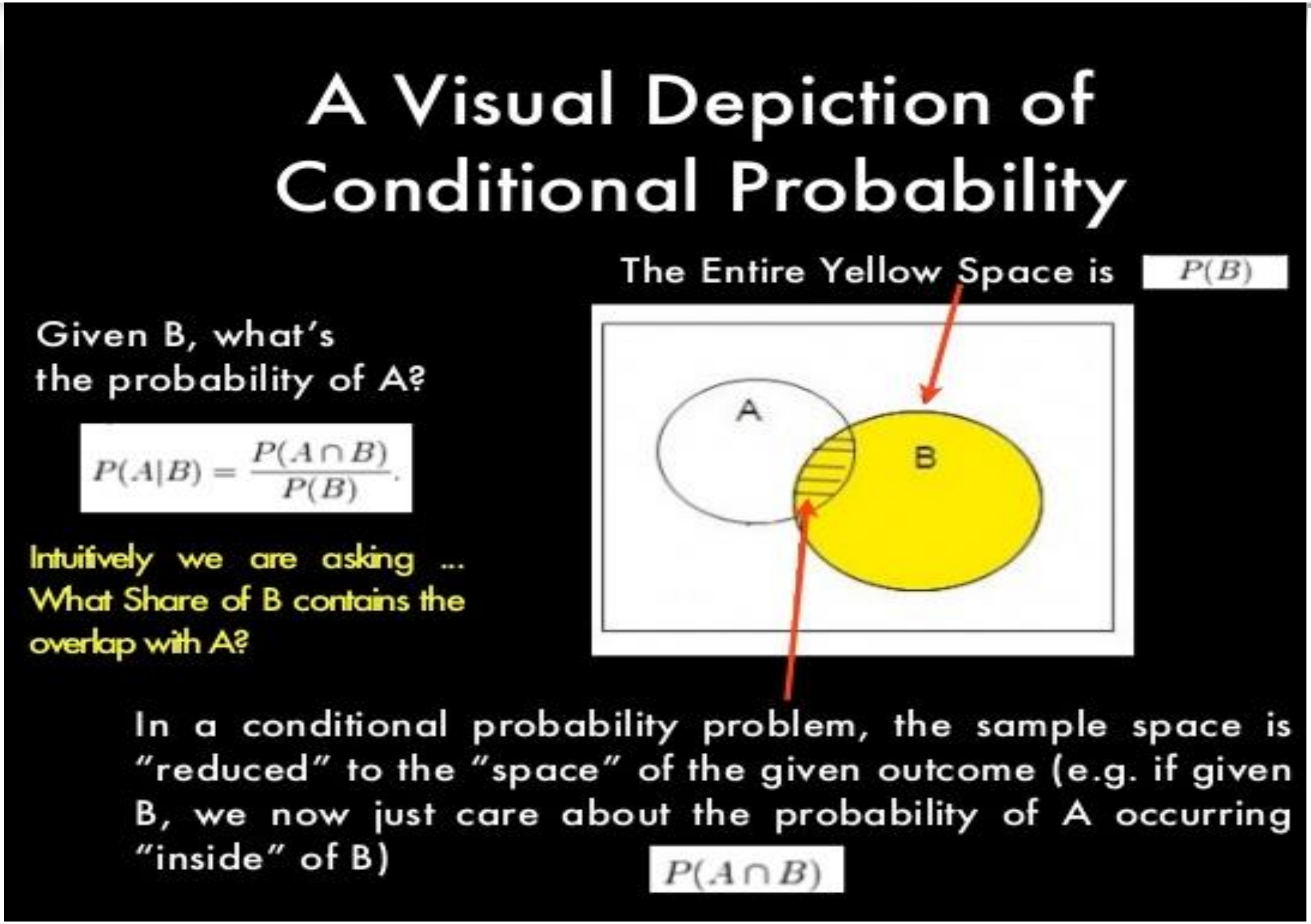


The Bayesian Theory





The Bayesian Theory



$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

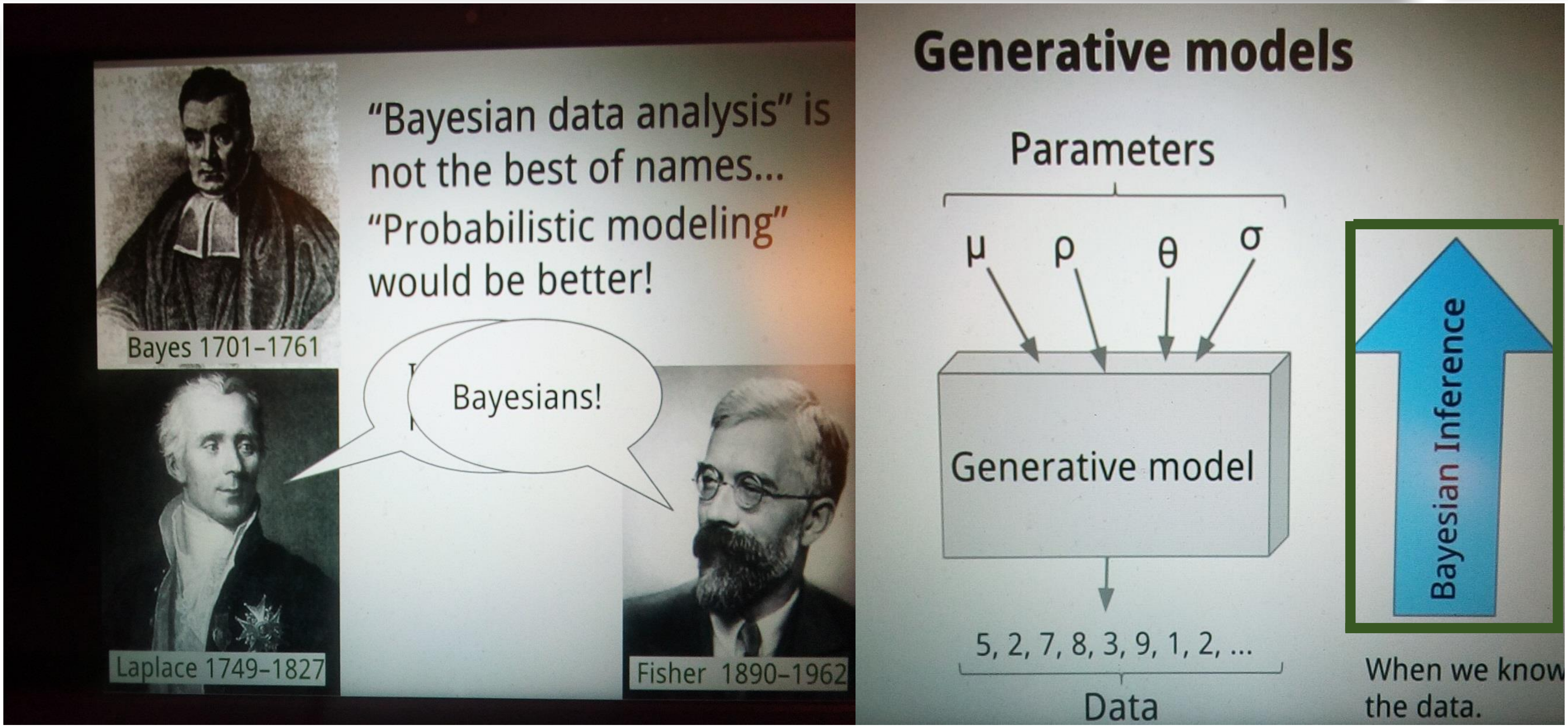
$$P(A_i \mid B) = \frac{P(A_i)\,P(B \mid A_i)}{\sum_{i=1}^{k} P(A_i)\,P(B \mid A_i)}$$

$$P(\theta \mid x) = \frac{P(x \mid \theta)P(\theta)}{P(x)}$$

where

$$P(x) = \int P(x \mid \theta)P(\theta)\,d\theta$$

The Bayesian Theory

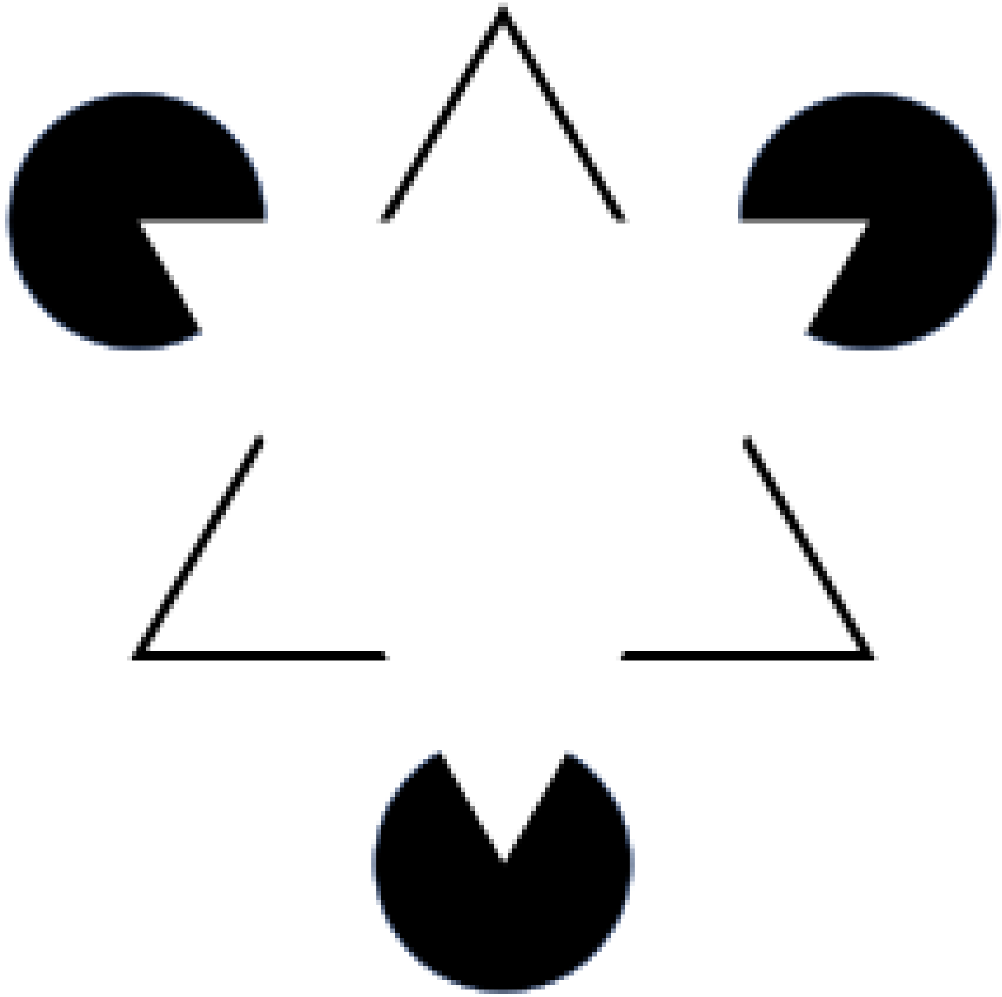


The Bayesian Theory

- The number that is the probability of some observed outcomes given a set of parameter values is regarded as **the likelihood of the set of parameter values (hypothesis)** given the observed outcomes (evidence)

- The likelihood is about the stimulus/parameter/hypothesis – what are the likely stimuli that could give rise to this data (e.g. activation)?

The Bayesian Brain



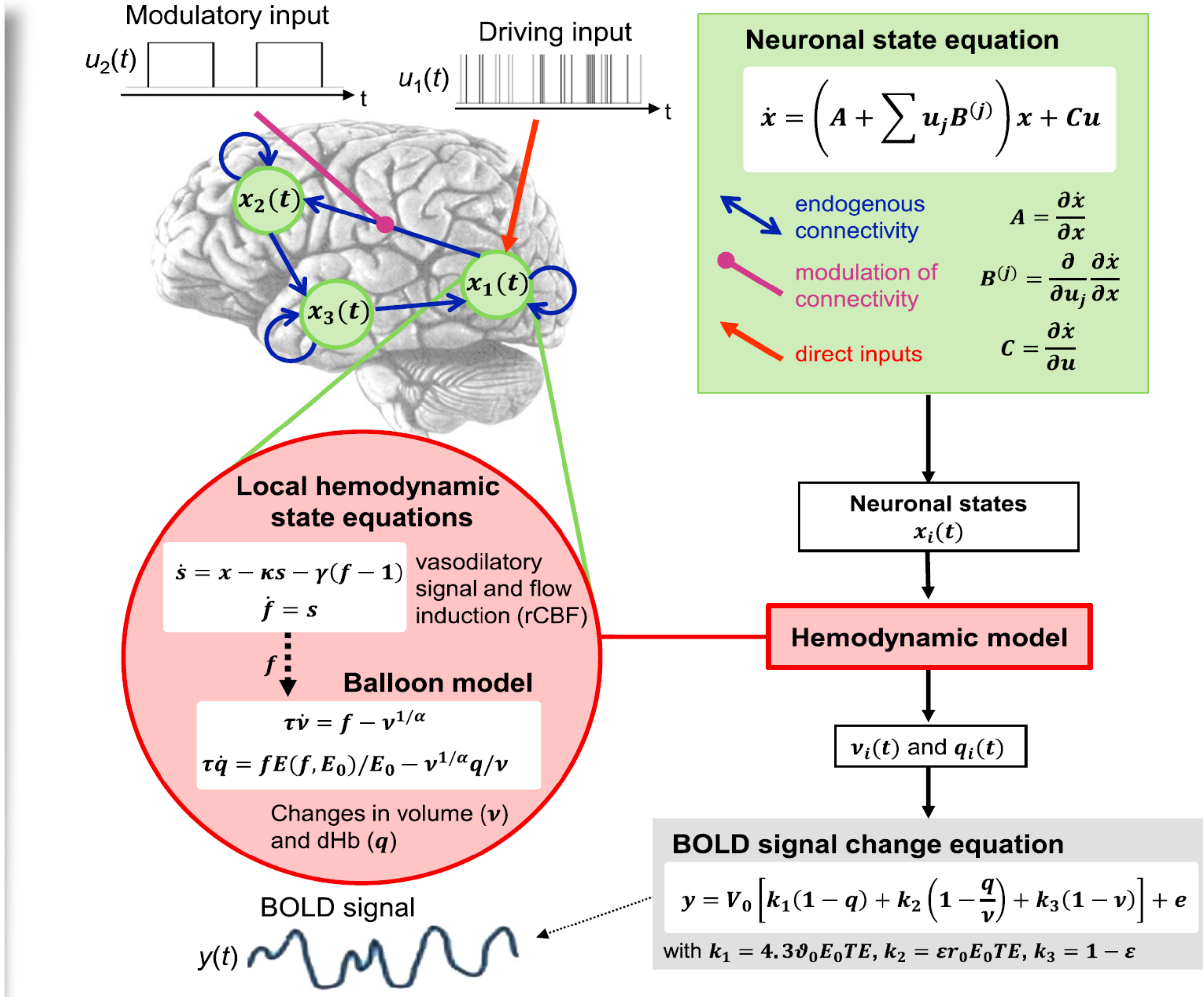
The Bayesian Brain

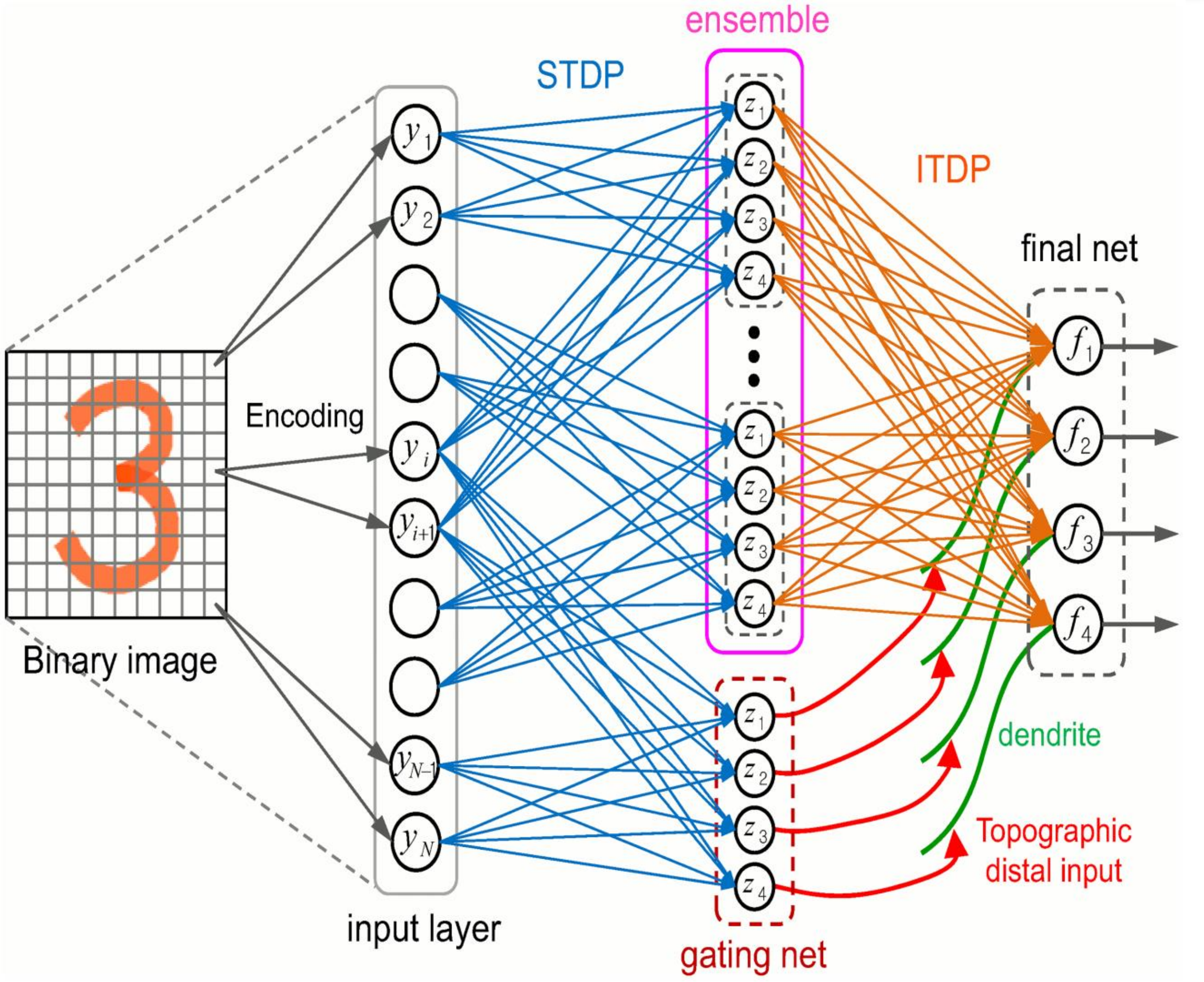
- Computational/Theoretical Neuroscience: describe the brain in the language of mathematics (as we do with the universe)

- The Bayesian brain: a possible mathematical framework on how the brain works as a *probabilistic inference machine* (1990's)

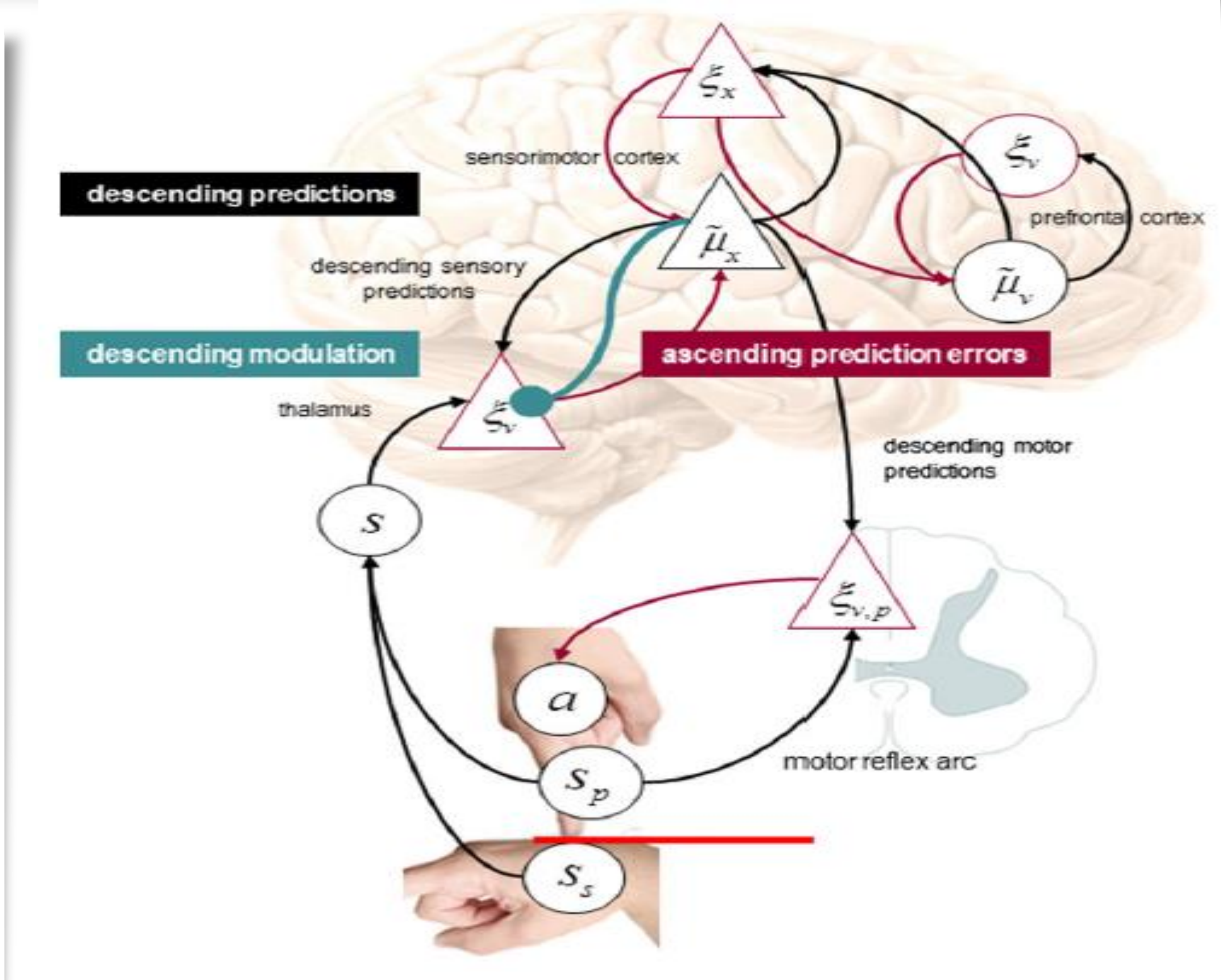
- Bayes' (born circa 1701) Theorem

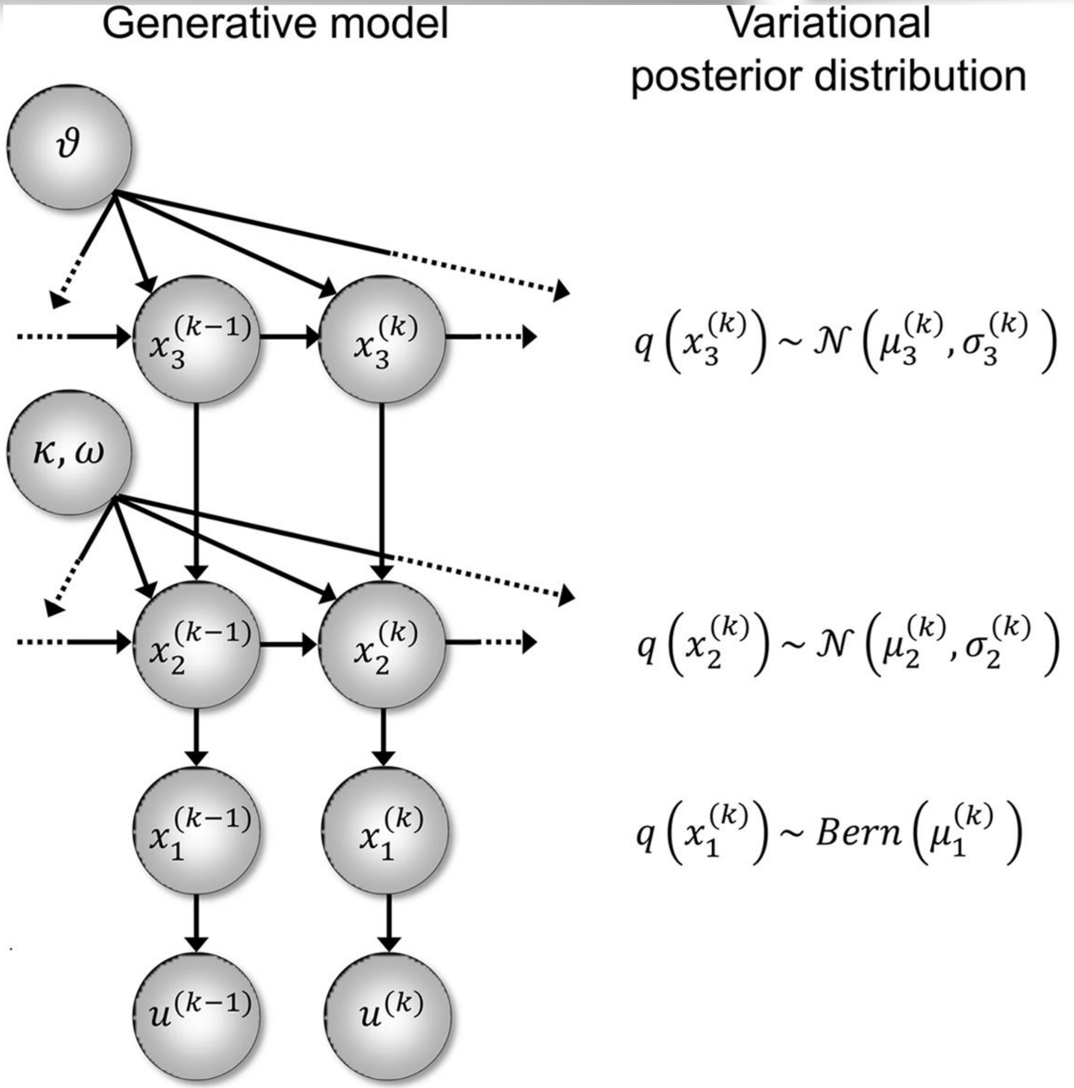
The Bayesian Brain





The Bayesian Brain

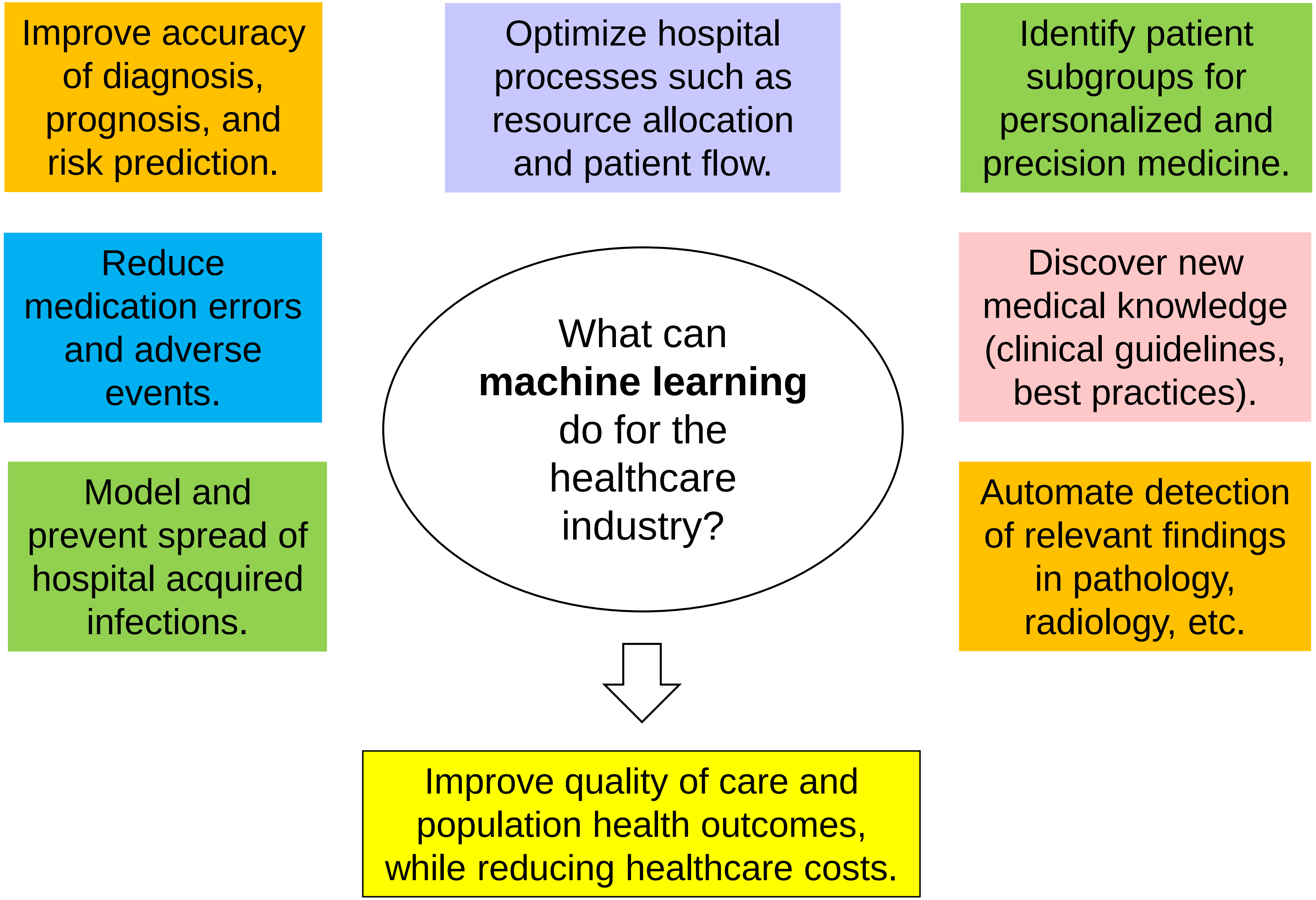




Artificial intelligence (AI)
in
Healthcare

Applying AI in Healthcare

1. Diagnostic Assessment
2. Virtual Health Assistants
3. Treatment of Rare Diseases
4. Targeted Treatment
5. Drug Discovery

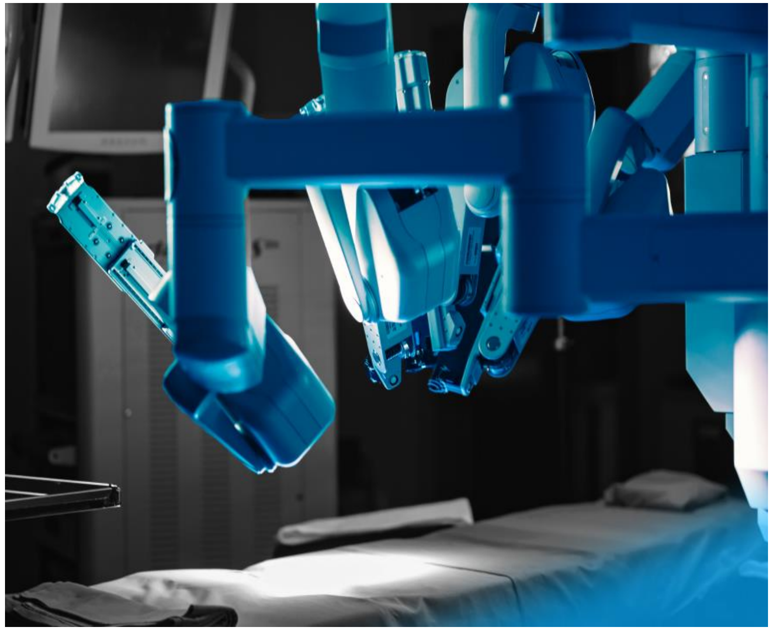

Improve accuracy of diagnosis, prognosis, and risk prediction.
Optimize hospital processes such as resource allocation and patient flow.
Identify patient subgroups for personalized and precision medicine.
Reduce medication errors and adverse events.
What can **machine learning** do for the healthcare industry?
Discover new medical knowledge (clinical guidelines, best practices).
Model and prevent spread of hospital acquired infections.
Automate detection of relevant findings in pathology, radiology, etc.
Improve quality of care and population health outcomes, while reducing healthcare costs.

What are the examples of AI in medical diagnosis?

- AI algorithms can analyze medical images (e.g., X-rays, MRIs, ultrasounds, CT scans, and DXAs) and assist healthcare providers in identifying and diagnosing diseases more accurately and quickly.

What is an example of AI in surgery?

- The system is used in laparoscopic operations to create and execute a surgical plan with minimal human intervention. Thanks to AI algorithms, STAR quickly adapts if an issue arises during surgery by using: ML-based tracking algorithms. 3D imaging system.



AI algorithms and tools used in personalized medicine

- The different types of AI algorithms and tools used in personalized medicine include machine learning, natural language processing, deep learning, and neural networks.
- These algorithms and tools are used **to analyze and interpret large amounts of genomic and clinical data, develop predictive models, and support clinical decision-making.**

challenges of personalized medicine

- The main challenges of personalized medicine include the high cost of genetic testing, the complexity of analyzing and interpreting large amounts of genomic data, and the need for specialized training and expertise in personalized medicine.
- The main opportunities include the potential to improve patient outcomes and reduce healthcare costs by providing more effective and efficient prevention, diagnosis, and treatment options.

Promoting patient outcomes and personalize treatment options

- AI can improve patient outcomes and personalized treatment options by providing more accurate and efficient diagnosis, predicting disease risk and treatment response, and developing personalized treatment plans.
- AI can also help healthcare providers identify new drug targets and develop more effective medications.

Main applications of artificial intelligence in personalized medicine

- The main applications of AI in personalized medicine include developing predictive models for disease risk and treatment response, supporting clinical decision-making, developing personalized treatment plans, and identifying new drug targets.

Analysis of large amounts of genomic and clinical data

- AI supports the analysis of large amounts of genomic and clinical data by using algorithms and tools to identify patterns and relationships in the data, and develop predictive models for disease risk and treatment response.
- AI can also help healthcare providers analyze and interpret complex data more efficiently and accurately.

key technologies and infrastructure

- High-performance computing infrastructure for analyzing large amounts of data.
- Electronic health records and other data sources to collect and store patient information.
- Advanced algorithms and machine learning models for analyzing and interpreting data.

Standardization and interoperability

- Standardization and interoperability help to ensure that data can be easily shared and integrated.
- It allows for the development of common data standards and definitions.
- It enables the use of advanced analytics and machine learning techniques to generate insights from multiple data sources.

key policy and regulatory considerations

- Ensuring patient privacy and data security.
- Developing standards and regulations for AI-based medical devices.
- Addressing **ethical concerns** around the use of AI in healthcare.

future of personalized medicine and artificial intelligence

- Continued growth and development of this field
- Greater integration with other health care technologies and systems
- More personalized and targeted treatments for patients

How can stakeholders work together

- **Collaborating** to develop common standards and data infrastructure.
- Sharing best practices and lessons learned across different organizations.
- Ensuring that patients are involved in the development and implementation of personalized medicine and AI.+

Role of the healthcare provider

- Collecting and analyzing patient data
- Implementing AI-based decision support systems
- Interpreting complex genomic and clinical data for treatment recommendations

Role of patients

- Providing consent for the use of their data
- Participating in clinical trials and studies
- Sharing personal health information to inform treatment decisions

personalized medicine and artificial intelligence, addressing health disparities and improve health equity

- Identifying and addressing gaps in healthcare access and quality
- Improving disease prevention and early detection in underserved populations
- Developing tailored treatments that take into account the unique genetic and environmental factors that contribute to health disparities.

"The good news is that you're perfectly healthy —the bad news is that my algorithms predict you'll be dead in two days..."

(picture source: *Elliott*, AI Cartoons <https://timoelliott.com/blog/cartoons/artificial-intelligence-cartoons>)

What is the importance of AI in medicine?

- **Early detection and diagnosis of diseases:**
  - machine learning models could be used to observe patients' symptoms and alert doctors if certain risks increase. This technology can collect data from medical devices and find more complex conditions
  - By analyzing patient data and other relevant information, enterprise AI can help healthcare professionals reduce medical errors. Once deployed, an AI algorithm can review all diagnostic imaging, working to minimize medical errors while ensuring equity in healthcare.

What is a real world example of AI in healthcare?

"AI" in Healthcare & Medical AI Examples to Know

AI in healthcare shows up in a number of ways, such as:

- finding new links between genetic codes
- powering surgery-assisting robots
- automating administrative tasks
- personalizing treatment options and much more.

Objectives of AI in Healthcare

1. Increasing Effectiveness of Diagnostic Processes
2. Reducing Overall Healthcare Costs.
3. Safer Surgeries
4. Easy Information Sharing

Objectives of AI in Healthcare

Increasing Effectiveness of Diagnostic Processes

One reason to implement AI in healthcare is to improve diagnostic effectiveness. Large caseloads and a lack of medical history may increase the possibility of human error in healthcare settings.

In comparison to clinicians, AI systems can detect and diagnose diseases quicker and with minimal risk of error.

Reducing Overall Healthcare Costs.

Reducing Overall Healthcare Costs
AI can be employed to make diagnosis processes more efficient, which in turn, reduces the total cost of healthcare procedures. For example, consider a case when AI can scan through millions of diagnostic images to look for disease symptoms. It eliminates the need for expensive manual labor.
Moreover, patients can receive faster and more effective care, which reduces the need for hospital admissions and long waiting periods

Objectives of AI in Healthcare

Safer Surgeries

By offering effective and distinctive aid in surgery, AI is establishing a position for itself in healthcare robotics. AI’s ability to perform less invasive surgical procedures that might otherwise require open surgery provides a wide range of benefits to patients, such as reduced blood loss, decreased infection risk, and less pain after surgery. Moreover, due to AI’s capacity to offer more precision while operating on delicate organs and tissues, patients need smaller incisions and also experience reduced scarring and faster recovery times.

Objectives of AI in Healthcare

Easy Information Sharing

The ability of AI algorithms to analyze vast amounts of information quickly is the key to fulfilling the potential of this technology in precision medicine. For instance, currently, 11.3% of the American population has diabetes. The condition has to be treated and managed urgently, and AI can assist healthcare professionals in understanding the disease through data via a real-time glucose monitoring system

What are the applications of AI in medicine?

- AI in disease detection and diagnosis. Unlike humans, AI never needs to sleep. ...
- Personalized disease treatment. Precision medicine could become easier to support with virtual AI assistance. ...
- AI in medical imaging. ...
- Clinical trial efficiency. ...
- Accelerated drug development.

Diagnostic Assessment

AI can examine enormous amounts of data from Electronic Health Records (EHRs), radiography, CT scans, and magnetic resonance images. By comparing data across patients, finding patterns, and detecting associations, AI systems can help with early symptom predictions.

Virtual Health Assistants

Virtual health assistants (such as Sense.ly, AiCure) are responsible for performing a variety of tasks, such as answering routine patients' calls and emails, managing medical information, protecting sensitive patient data, scheduling doctor appointments, and reminding patients of follow-up visits. It is one of the most helpful AI applications in healthcare that provides patients with a tailored experience in managing their health as well as addressing their queries.

Treatment of Rare Diseases

An AI-based clinical-stage biotech platform called BERG strives to map diseases to accelerate the discovery and development of cutting-edge breakthrough drugs and vaccines, revolutionizing the way healthcare is provided. It uses Research and Development (R&D), along with interrogative biology, that allows medical practitioners to produce robust products for patients fighting rare diseases.

Targeted Treatment

With the help of technologies such as Deep Learning and AI, BenevolentAI, a leading, clinical-stage AI-enabled drug discovery company, was able to deliver appropriate treatment to the required patients at the right time, resulting in targeted treatment of patients with useful insights. Currently, the company is working on obtaining licensing for its drugs and creating portable treatments for rare diseases.

Applying AI in Healthcare

Drug Discovery

AI uses neural networks to assess the bioactivity and properties of drug candidates. Researchers can identify the best drug targets to test for various diseases with the help of AI systems. It has proved indispensable in clinical trials in the selection of the right candidates and, as a result, the healthcare industry has witnessed an increased speed and lesser investment in drug discovery.

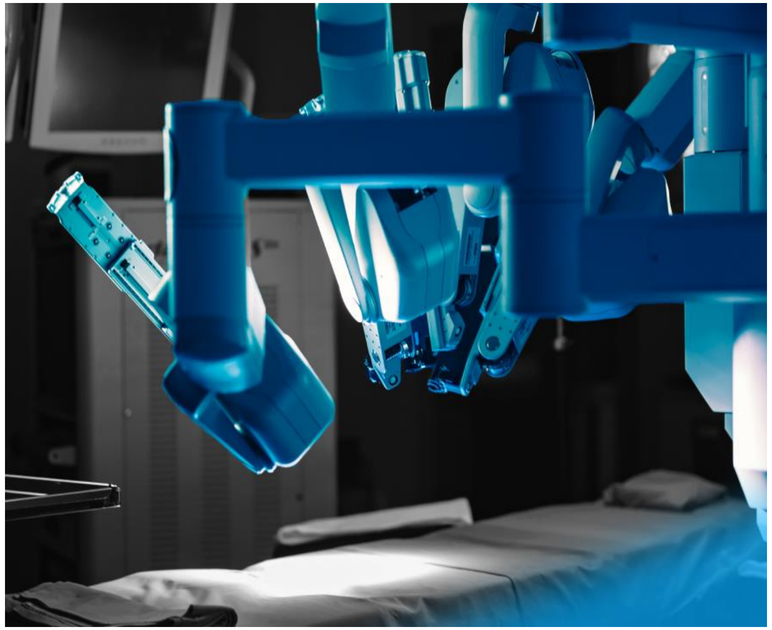
What are the examples of AI in medical diagnosis?

AI algorithms can analyze medical images (e.g., X-rays, MRIs, ultrasounds, CT scans, and DXAs) and assist healthcare providers in identifying and diagnosing diseases more accurately and quickly.

What is an example of AI in surgery?

How Startups Use Artificial Intelligence in Surgery
Real-Life Example: Smart Tissue Autonomous Robot (STAR)

The system is used in laparoscopic operations to create and execute a surgical plan with minimal human intervention. Thanks to AI algorithms, STAR quickly adapts if an issue arises during surgery by using: ML-based tracking algorithms. 3D imaging system.



How does AI improve surgery?

Four Ways Artificial Intelligence Can Benefit Robotic Surgery
Aside from compiling a large set of information to learn from and develop new trends, AI can enhance robotic surgery by

- alleviating surgeons' stress
- highlighting tools
- monitoring operations
- sending alerts,

AI-based systems can guide surgical procedures and ensure a more streamlined process.

Role of AI in Healthcare

- Accurate Cancer Diagnosis
- Early Diagnosis of Fatal Blood Diseases
- Customer Service Chatbots
- Virtual Health Assistants
- Treatment of Rare Diseases
- Targeted Treatment
- Automation of Redundant Healthcare Tasks
- Management of Medical Records
- Reduction of the Dosage Error
- Robot-assisted Surgery
- Automated Image Diagnosis
- Fraud Detection
- Clinical Trial Participation
- Development of New Medicines
- Improved Healthcare Access

Can AI solve medical problems?

One reason to implement AI in healthcare is to improve diagnostic effectiveness. Large caseloads and a lack of medical history may increase the possibility of human error in healthcare settings. In comparison to clinicians, AI systems can detect and diagnose diseases quicker and with minimal risk of error.

Top Most Common Challenges of AI in Healthcare

Despite impressive possibilities, the real deployment of AI-enabled solutions in clinical practice is still limited. Besides privacy challenges, AI technology also presents other technical and methodological shortcomings. Here are the top challenges of AI in healthcare:

1. Lack of Quality Medical Data
2. Clinically Irrelevant Performance Metrics
3. Methodological Research Flaws

Top Most Common Challenges of AI in Healthcare

Lack of Quality Medical Data

Clinicians require high-quality datasets for the clinical and technical validation of AI models. However, due to the fragmentation of medical data across several EHRs and software platforms, collecting patient information and images to test AI algorithms becomes challenging. Another obstacle is that the medical data from one organization may not be compatible with other platforms due to interoperability problems. To increase the amount of data available for testing AI systems, the healthcare sector must concentrate on techniques for standardizing medical data.

Clinically Irrelevant Performance Metrics

The measures used to gauge an AI model's success are not necessarily transferable to clinical settings. The discrepancy between the clinical efficacy demonstrated in the real world and the technical precision of AI tests is referred to as the AI chasm. To avoid this gap, developers and clinicians should collaborate to investigate how AI algorithms enhance patient care. To do this, they can assess AI models for accuracy using decision curve analysis. This method enables them to evaluate the clinical usefulness of a prediction model by comparing the datasets and estimating the chances of an AI model's success in the real world.

Methodological Research Flaws

There are not enough established methodologies, prospective research, or peer-reviewed studies of AI in healthcare. The majority of studies have been retrospective and based on historical patient medical records. However, to realize the true value of AI diagnosis in real-world settings, physicians must study current patients over time, which means prospective research. And for reliable prospective research, doctors should monitor the health of their patients by combining physical examinations with telehealth visits and remote monitoring technologies (sensors and trackers).

What is the risk of AI in medicine?

However, along with the many benefits of AI there are security and privacy risks that must be considered. One of the biggest risks is the potential for data breaches. As health care providers create, receive, store and transmit large quantities of sensitive patient data, they become targets for cybercriminals.

What is the limitation of AI in medicine?

The concern AI in the health systems is concluded by highlighting several implementation issues with AI both within and outside the health sector. The data privacy, social issues, ethical issues, hacking issues, developer issues were among the obstacles to implementing the successfully AI in medical sector.

the liberal professions and the law

with a special focus on the medical profession

Smart Regulation
Field of Excellence
University of Graz

- Professor Dr. Karl Stöger, MJur (Oxford)
- Institute of Public Law and Political Science
- University of Graz

Definition of "liberal" professions

- **"free"** from the state, but also from third parties
-
- Performing an **intellectual task**
- due to **special competence**
- **personally** (predominantly in a special relationship of trust)
- **self-reliant**
- and **professionally independent**.

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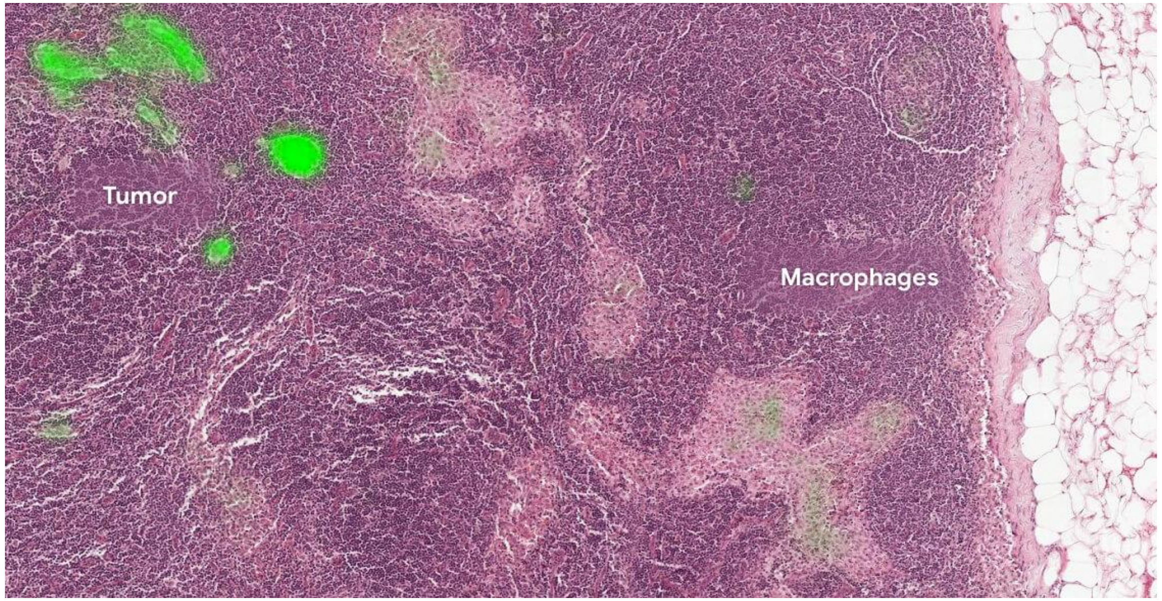
Core aspects of Machine Learning (ML)

- Recognition of **patterns/rules**
- in a large **amount of data**
- **Transfer** of these rules to
- **unknown** situations

→ ML works with **statistical** tools
→ a form of **pattern recognition**
→ correlation instead of causality

State of development - medicine

- **Image evaluation** as a leading field of application for ML
- **Decision support** as the most promising market



Lymph node biopsy, identification of a tumor (marked green) by means of AI

(picture source: *Google AI* <https://ai.google/healthcare/>)

AI changes the job profiles of the liberal professions

-
- **"Standard applications"** for trainees will become less frequent (e.g. data checking) → reduction of training positions?
- **(Expenditure-based) fee calculation** will have to adapt - but there will be new costs for AI infrastructure
- Partial **replacement** and **further delegation** of tasks: e.g. health apps, contract preparation on the Internet
- Potential **dependency** on a few providers

Who can regulate the use of AI?

- **European law:** if there is a reference to the internal market and thus a need for legal harmonisation: e.g. differences between national AI regulations make cross-border activities more burdensome

- **International law** (e.g. "European Ethical Charter on the use of AI in judicial systems and their environment" of the Council of Europe)

- **National law**

- **Professional codes** - self-regulation as a "privilege" of the liberal professions

Where does the European law stand?

- **No comprehensive codification**, only single provisions (e.g. Art 22 GDPR – automated individual decision-making, including profiling)

- **Awareness:** given, **implementation**: work in progress
  - **High-Level Expert Group on AI**: AI Definition, Ethics Guidelines (currently in practical pilot phase until early 2020), Policy and Investment Recommendations
  - **Announcement *von der Leyen***: legislative proposals within 100 days

- → **No specific rules for the liberal professions**

High-Level Expert Group on AI: Ethics Guidelines

4 ethical principles:	7 core requirements:
1. Respect for human autonomy 2. Prevention of harm 3. Fairness 4. Explicability (source: https://ec.europa.eu/futurium/en/ai-alliance-consultation/guidelines)	1. Human agency and oversight 2. Technical robustness and safety 3. Privacy and Data Governance 4. Transparency 5. Diversity, non-discrimination and fairness 6. Societal and environmental wellbeing 7. Accountability

AI and human rights:
Charter of Fundamental Rights, ECHR, constitutions

- **Responsibility for the consequences of innovation**:
- The state guarantees protection from negative effects of technological innovation
- Principle of non-discrimination – **Attention: correlation instead of causality**

- **Freedom of innovation**: Securing the freedom for technical development - Freedom to conduct business, right to (intellectual) property

- **Necessary standard** of medical treatments: **Obligation to use AI?** (e.g. ECHR 30.8.2016, 40448/06 *Aydoğdu/Turkey:* functioning hospital system)

Quality of the database of AI-applications: European Union Agency for Fundamental Rights

Algorithms used in machine learning systems and artificial intelligence (AI) can only be as good as the data used for their development. High quality data are essential for high quality algorithms. Yet, the call for high quality data in discussions around AI often remains without any further specifications and guidance as to what this actually means. Since there are several sources of error in all data collections, users of AI-related technology need to know where the data come from and the potential shortcomings of the data. AI systems based on incomplete or biased data can lead to inaccurate outcomes that infringe on people's fundamental rights, including discrimination. Being transparent about which data are used in AI systems helps to prevent possible rights violations. This is especially important in times of big data, where the volume of data is sometimes valued over quality.

Source: *FRA*, Data quality and artificial intelligence – mitigating bias and error to protect fundamental rights (2019)

„Personal intellectual care“ as a core element of all liberal professions → Mutual trust

- **Explainable AI** is an important topic, in particular for medical professionals in the area of **informed consent**
- Justification of decisions is particularly essential for members of the liberal professions as they work as „advisors and companions“

Personal and trustful provision of services (I)

- Protection of **privacy** of patients

- “[…] Black-box medicine — the use of big data and sophisticated machine-learning techniques for health-care applications — could be the future of personalized medicine. Black-box medicine promises to make it easier to diagnose rare diseases and conditions, identify the most promising treatments, and allocate scarce resources among different patients. But to succeed, it must overcome two separate, but related, problems: <u>patient privacy</u> and <u>algorithmic accountability</u>. […]”

  - Source: *Ford/Price,* Privacy and Accountability in Black-Box Medicine, Michigan Telecommunications and Technology Law Review 2016, 1 (1)

Personal and trustful provision of services (II)

- "[…] Privacy is a problem because researchers need access to huge amounts of patient health information to generate useful medical predictions. And accountability is a problem because black-box algorithms must be verified by outsiders to ensure they are accurate and unbiased, but this means giving outsiders access to this health information. […]"

- Source: *Ford/Price,* Privacy and Accountability in Black-Box Medicine, Michigan Telecommunications and Technology Law Review 2016, 1 (1)

Professional independence: conflicts of interest

- Duty to declare potential conflicts of interest (**duty of loyalty**)
- → Client/patient can search for **alternatives**

- **However:**
- **Financial** and not altruistic motives shape the development of AI: „hunger” for more data
- **To renounce** AI-support is not a viable alternative because AI is to useful (e.g. diagnostic accuracy)
- **Dominance** of few providers prevents realistic alternatives

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ARTIFICIAL INTELLIGENCE IN CLINICAL TRIALS

ENG. BECCARIA MASSIMO

Co-founder Advice Pharma Group
Co-founder Alfa Technologies international
Co-founder Davinci Digital Therapeutics

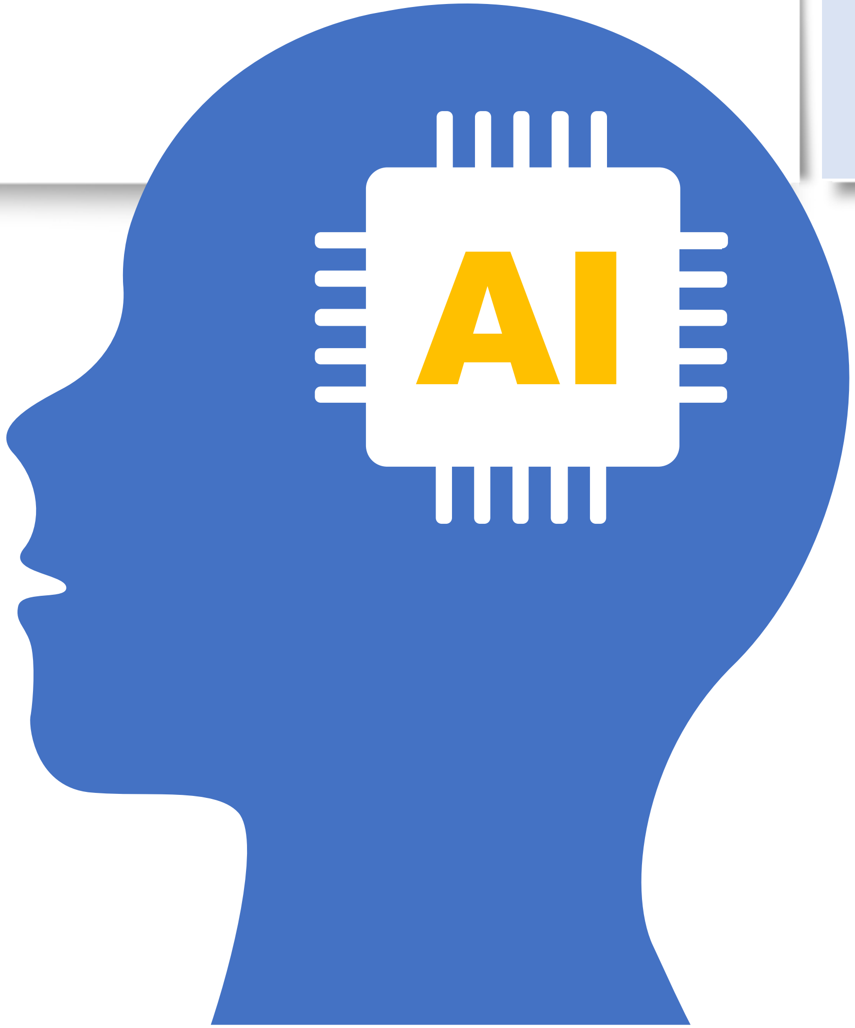
AdvicePharma

Alfa|TI
Technologies for Life Sciences

daVinci
DIGITAL THERAPEUTICS

What is ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. In computer science AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving".



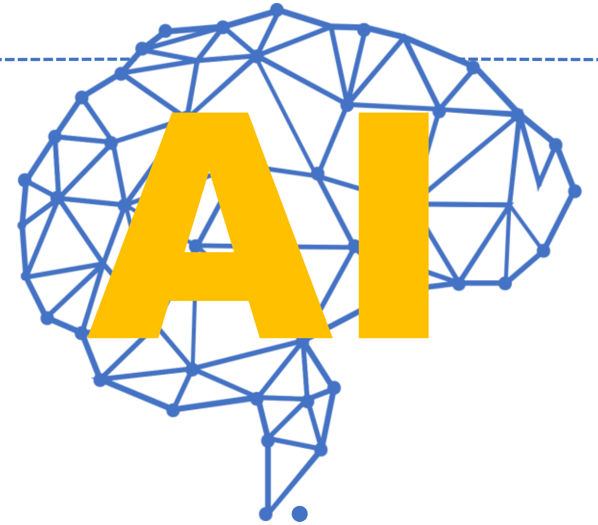
OTHERWISE: A REAL, QUICK, STUPIDITY

https://en.wikipedia.org/wiki/Artificial_intelligence

• What AI can do for us now

TECHNOLOGY

Could reproduce limited cognitive pattern
Growing the computing power of devices
Growing the Robotic technologies
Growing the storage capacity
Growing battery technology



ENVIRONMENT

Everyone will be introduced in a new connected world
Presence of Big Data
Everyone has a PDA (i.e. smartphone)

VALUE CREATION FOR STAKEHOLDER

BIG PHARMA/BIOMEDICAL COMPANIES

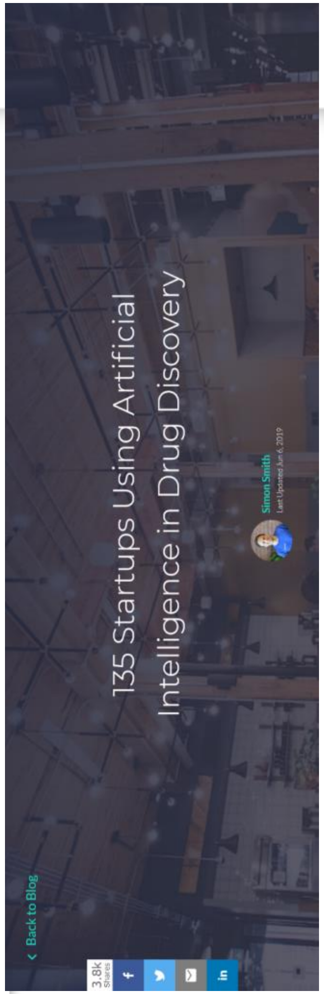
May increase their own market value with AI;
More efficacy and efficiency on research and improvement on their products

PATIENTS

May have access to personalized therapy
May save time and have a better qol
May have warning and research improvement

PHYSICIANS/RESEARCHER

May Improve the research program
May analyze big data in no time
May support diagnosis



WHERE A.I. is used in Drug Discovery

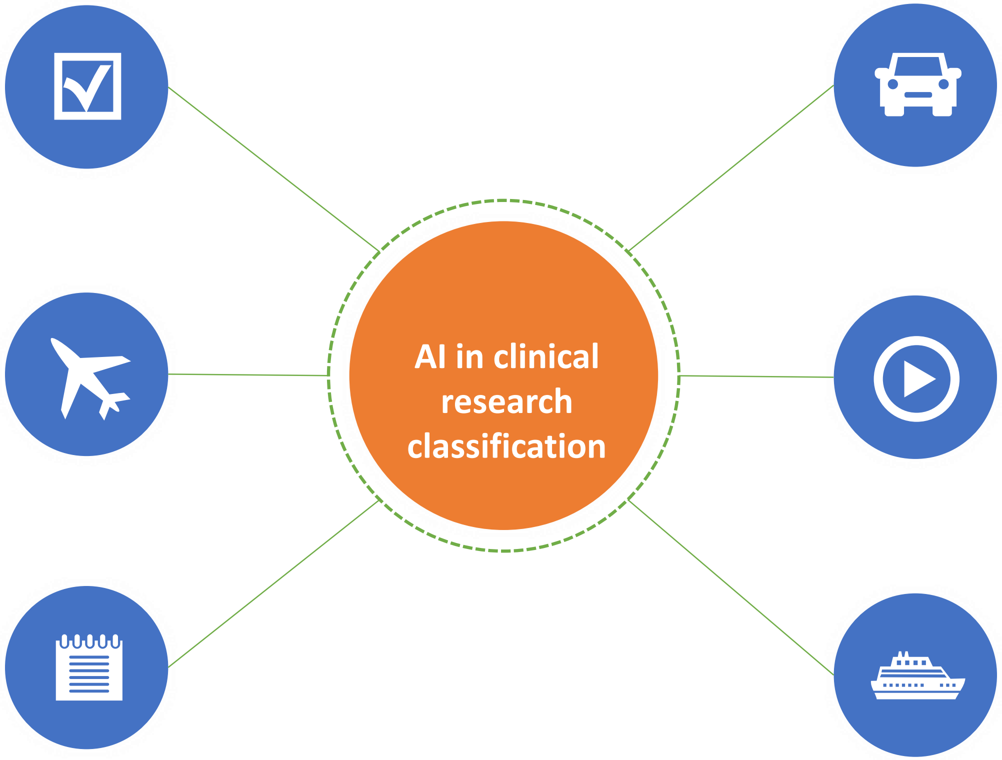
https://blog.benchsci.com/startups-using-artificial-intelligence-in-drug-discovery#step3

• Clinical Research

Find and create big data to analyze:
I.A. that harvest between several databases and aggregate data,
Use Ai to extract structural biological knowledge to power drug discovery application

Cognitive approach to discover relationship
Uses AI to: Analyze genomic data related to cancer and other diseases, Find applications for existing approved drugs or clinically validated candidates.

Optimize the process:
Uses AI to: create a Chat bot or machine learning system to prevent issue on clinical trials,
Optimize oncology drug development with a biomarker monitoring platform and millions of patient datapoints

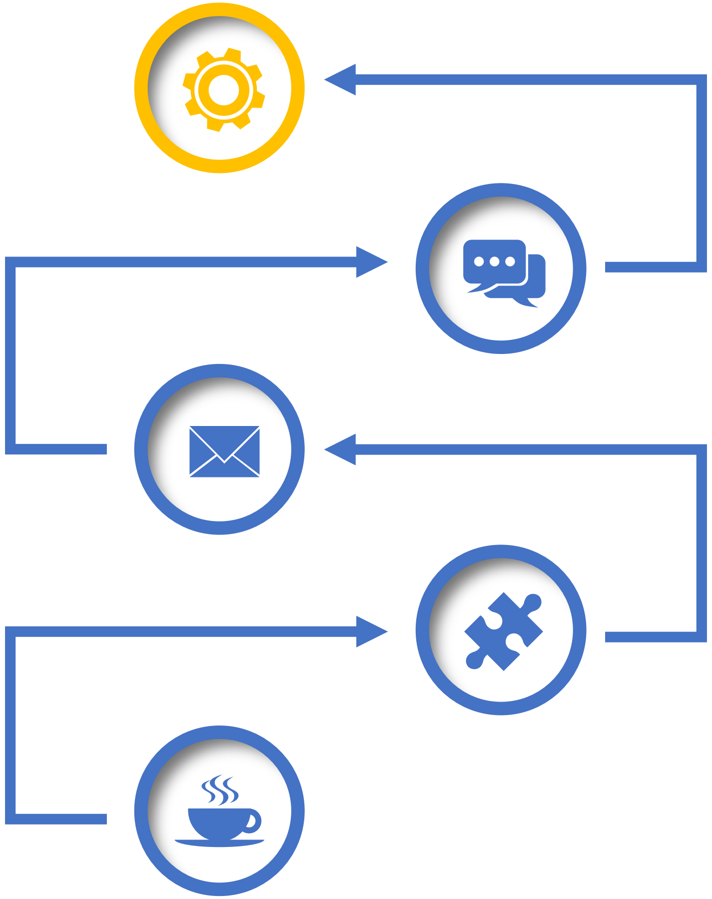


Match the right patients to the right cure
Uses AI to Enroll more patients in appropriate trials, or uses AI to Analyze medical records to find patients for clinical trials

Simulate clinical trials and silico
Uses AI to Run experiments in a central lab from anywhere in the world, or use ai to Optimize, reproduce, automate, and scale experiment workflows.

Publish data;
Uses AI to Write a draft scientific manuscript based on provided data.

- **The point of view of the clinical trials:**
- **AI act as an opportunity**



Data is value (STRENGHT)

Everything is based on data evidence. We must preserve it, and be compliant with regulatory requirements (i.e. Privacy)

Patient is the king (WEAKNESS/OPPORTUNITY)

Patient must be at the center of the trials..

Bureaucracy (THREAT)

Especially in Italy, bureaucracy stops investment and generate inefficiency

Integration with new technologies(OPPORTUNITY)

E-pro, AI, wearables could improve the clinical research.

• Why does CT Fails?

Well, failures in clinical research usually occur in two dimensions:

1. Project failure, e.g. the budget has been overspent, project targets haven't been achieved and deadlines haven't been met.
2. Research failure, e.g. not being able to reach statistical significance in a research area and so failed to prove the efficacy of a drug or obtain controversial results.

Obviously both dimensions cover two very large areas of clinical research. For sake of ease, let's assume that we have met the following research conditions:

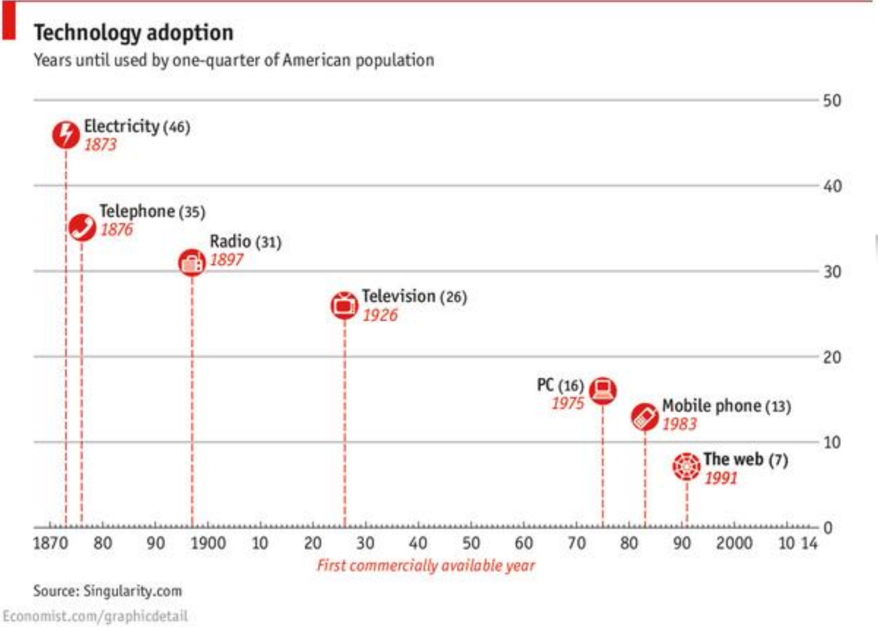
1. The candidate drug is safe and efficacious;
2. The study design is adequate;
3. The study is conducted according to Good Clinical Practice;

Interestingly enough, when we focus on the project management side of clinical studies, we found that the surveyed experts identify the project manager's skill set as the most common source of issues.

50% of unsuccess rate derive by uncorrect Project management

Source https://cyntegrity.com/7-reasons-clinical-trials-fail/

Technological Adoption



Why AI is so important for us

Past:
Changes were inter generational and society, people, productive systems could adapt

Past:
Positive workforces could balance in the long term

Today
Changes are Intra generational and society, people, productive systems have no time to adapt

Today
Negative workforces in the short term, no proof to be balanced in the long term

• What AI can do for us applied on a CT

01 **Reduce Costs of a CT**

Less time means less money. We could use AI such as a really quick tool to analyze large amount of data and simulate trials

02 **Improve the research process with more efficiency and efficacy**

Using AI we could save time and be more efficacy/efficiency. Creating a new machine learning models to anticipate issues and enhance research programs

03 **Expand our knowledge**

We can use Ai to discover relationship and reproduce a cognitive process to evaluate new drugs or use old drugs to a new therapeutical indications

04 **Faster access to therapy for patients**

Patience can enjoy o new AI tools to be a part of the research program and be used in active way

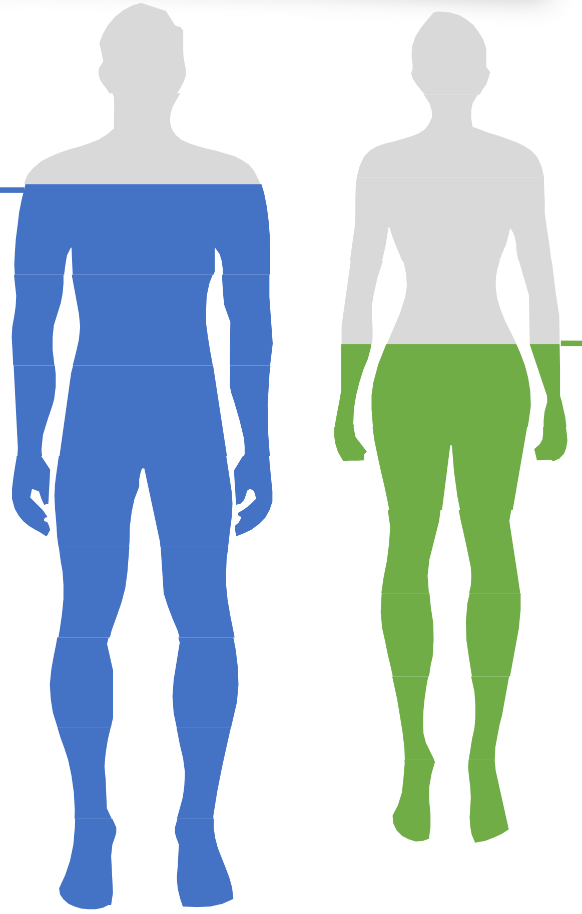
• Value for Clinical Trials: data

What we don't know ← Exogenous data

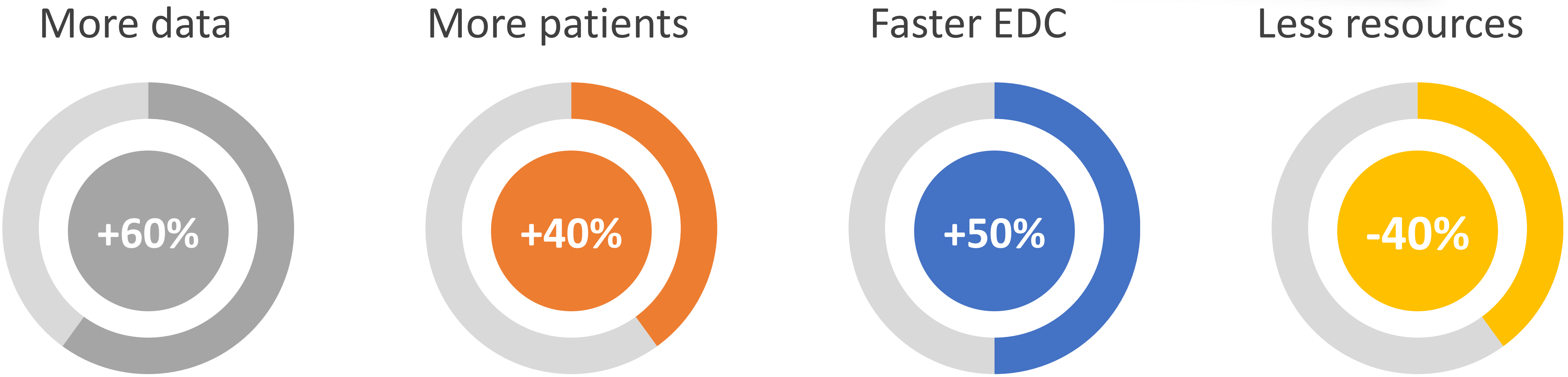
Factors that contribute to health outcomes, % — **Average amount of data generated over a person's lifetime**

	%	
Social determinants of health	~40	1,100 terabytes (volume, variety, velocity, veracity)
Health behaviors	~20	
Clinical care	~15	0.4 terabytes (clinical data)
Nonmodifiable factors (e.g., genetics)	~25	6 terabytes

Source: Bureau of Labor Statistics; Robert Wood Johnson Foundation; IBM Watson (Latts L. *The age of big data and the power of Watson.* European Medicines Agency presentation. Updated April 1, 2017); McKinsey analysis



• Clinical trials vs smart-trials



Change of paradigm

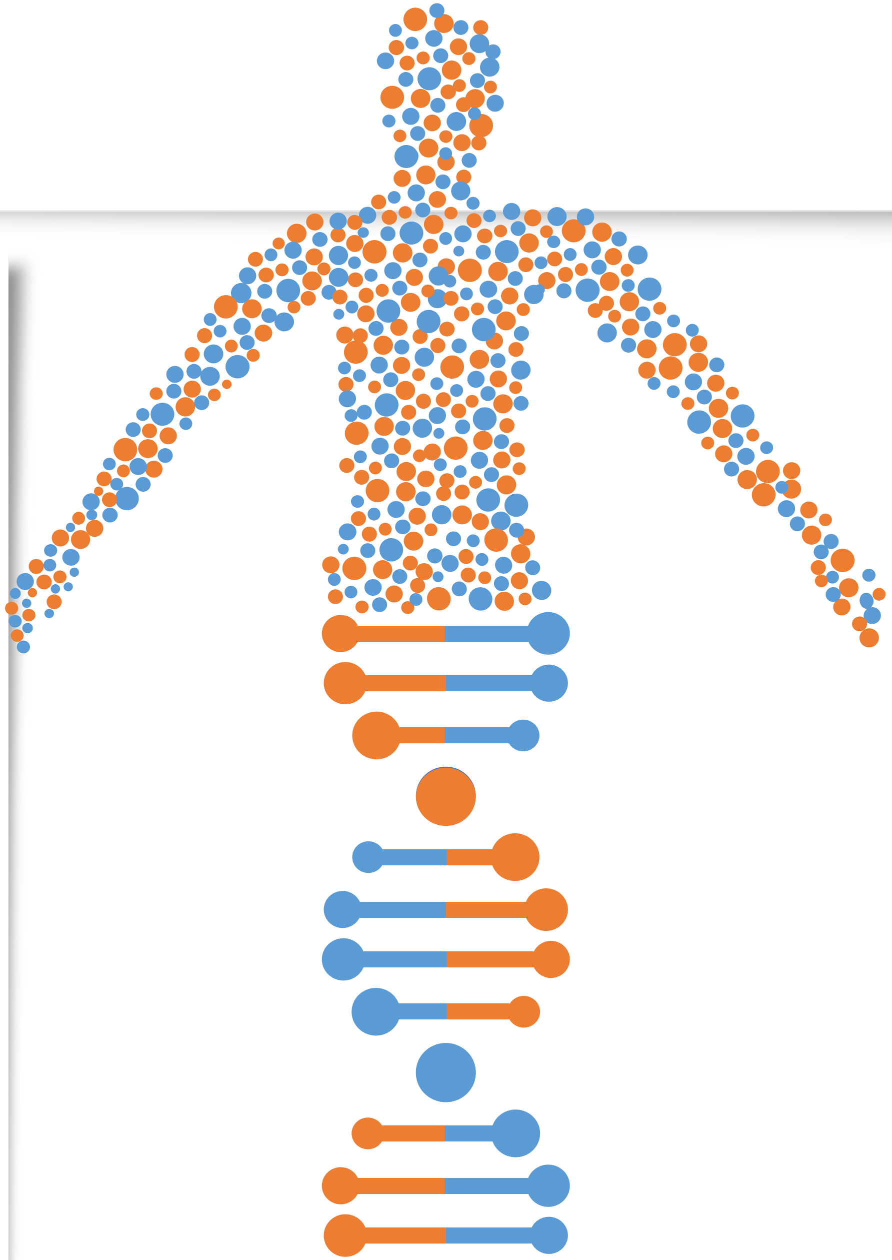
More data, faster and with reduced resources spending

60%

Saving

With wearable technologies we provide not only an incomparable improvement of data collection, but a change in paradigm which can boost clinical development plans of small to medium to large pharmaceutical/biomedical firms.

All data are estimated between interna advice pharma benchmark



Data is the new fuel

Analyzing the value chain odf a clinical trial we know that data is the key of success

80%

Patients could have access a new services for their lifestyle control. Could. 80% are the data loss

Patients could accelerate the technology adoption, asking for new therapies now. Nowadays they are skilled and prepared

New value added services

Manage data according GDPR law, storing genomic and IT patient relate a single patience. We could also make a personalize medicine

Patient centricity

All is designed to give to the patient a services and a therapy. In the future an AI could process the enormous amount of data and give a “precision medicine”

Efficiency/Efficacy

We can define a better quality of life standard. Less costs and more precision on predictive models.

SMART TRIAL:

When we use automatic system to catch data directly from patient without any human support. When we use data scientist and AI to analyze big data.

- New way to opmize the Clinical trials:
- The Smart-trials era

Pharma/bimedical companies don’t reach the patient

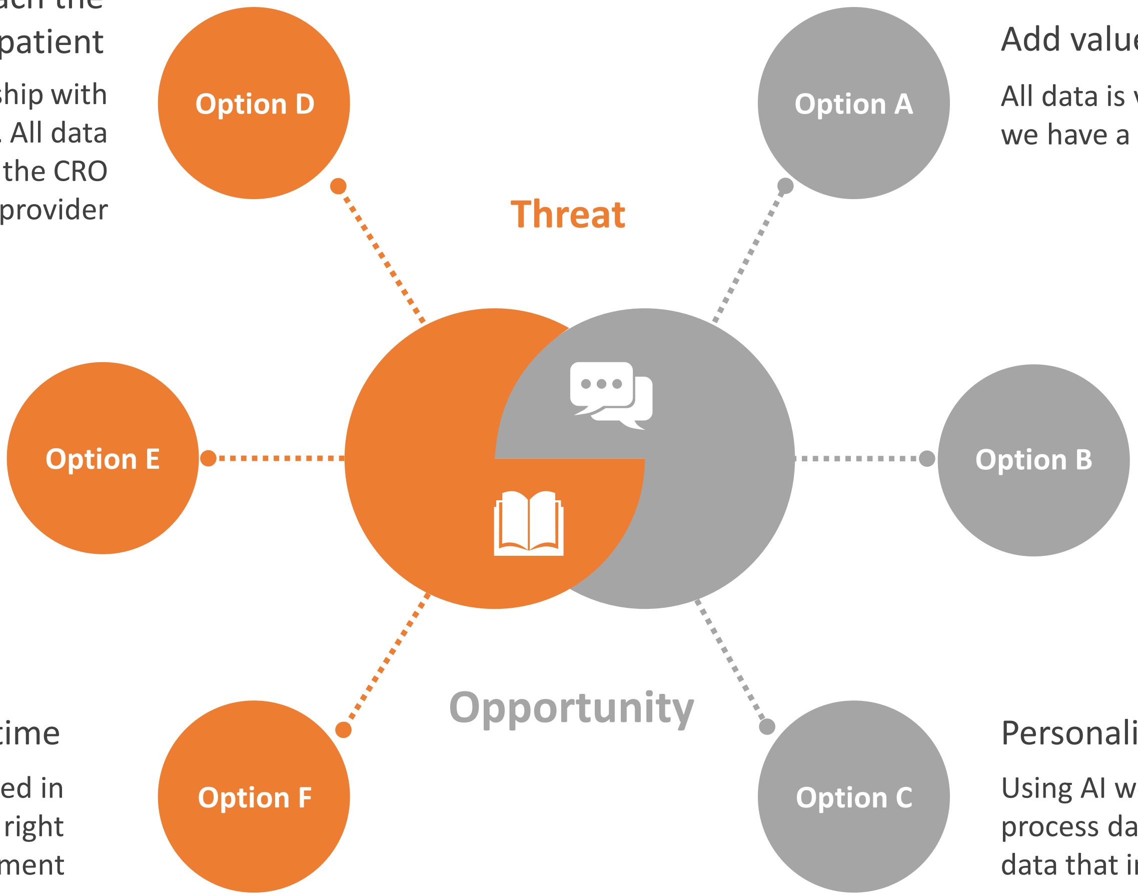
New change in relationship with the patient. All data responsibilities is tied to the CRO or the provider

Differentiation and big data

From the previous model we could collect tons of data. We need automatic system to analyze

Real time

All the data can be collected in real time, but we need a right environment



Add value

All data is validated and ready to use. And we have a huge amount of data

Cost optimizer

We have less monitoring visits and

Personalize the therapy

Using AI we could collect and process data, underline only the data that interesting us

AI in Clinical Trials: two real case

Virtual assistant

Uses AI to: create a virtual assistant that support the clinical project management
Allows researchers to: Improve the performance to manage a clinical trials

Digital Tatoo

Uses AI to: Analyze pattern and big data to store the correct information **Allows researchers to**: Predict a patient's disease progression and treatment response, for clinical trial stratification and diagnostics.


FPG
www.madhouse.cz
Warning !!!
Nuclear War
no
YES
WASHINGTON D.C. PENTAGON 1:47 a.m.

Thank You

Massimo Beccaria
Alfa Technologies International
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Machine Learning for the Healthcare Industry

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Carnegie Mellon University
EPD Lab
EVENT AND PATTERN DETECTION LABORATORY

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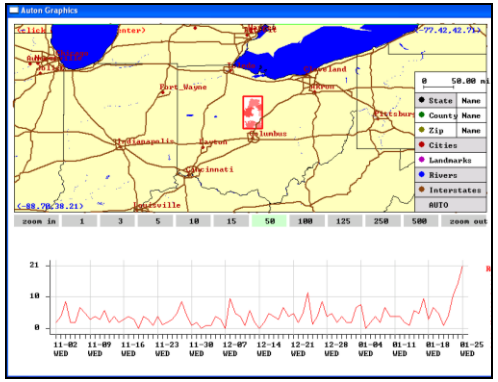
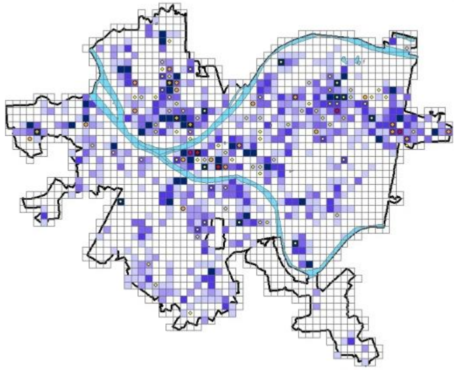
Director, Event and Pattern Detection Laboratory
Courtesy Associate Professor of Machine Learning and Robotics

My research is focused at the intersection of two fields, **machine learning** and **public policy,** with two main goals**:**

1) Develop new machine learning methods for better (more scalable and accurate) **detection** and **prediction** of events and other patterns in massive datasets.

2) Apply these methods to improve the quality of public health, safety, and security.





<u>Disease Surveillance</u>: Very early and accurate detection of emerging outbreaks.

<u>Law Enforcement</u>: Detection, prediction, and prevention of “hot-spots” of violent crime.

<u>Patient Care</u> (today’s talk)

Improve accuracy of diagnosis, prognosis, and risk prediction.

Optimize hospital processes such as resource allocation and patient flow.

Identify patient subgroups for personalized and precision medicine.

Reduce medication errors and adverse events.

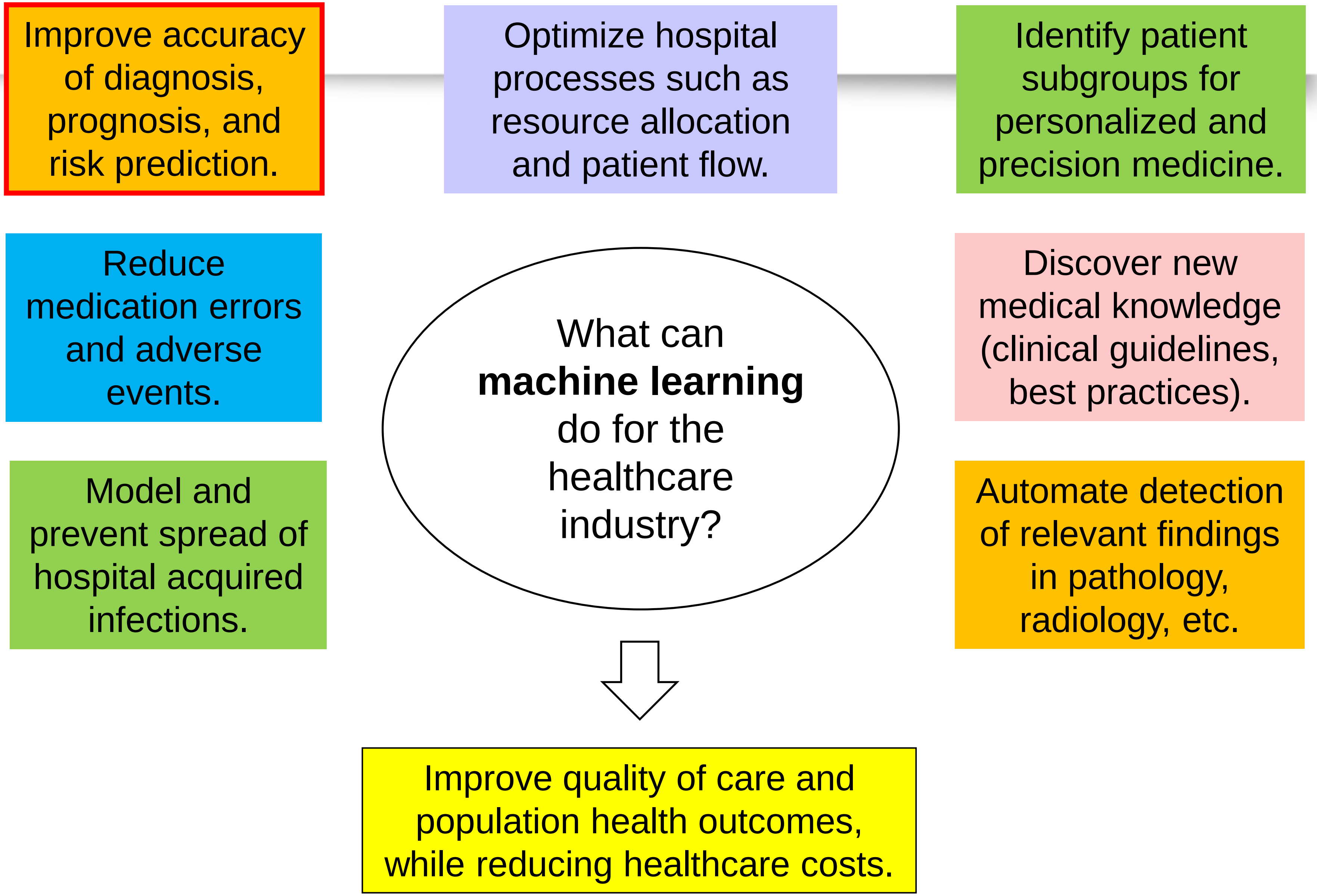
What can **machine learning** do for the healthcare industry?

Discover new medical knowledge (clinical guidelines, best practices).

Model and prevent spread of hospital acquired infections.

Automate detection of relevant findings in pathology, radiology, etc.

Improve quality of care and population health outcomes, while reducing healthcare costs.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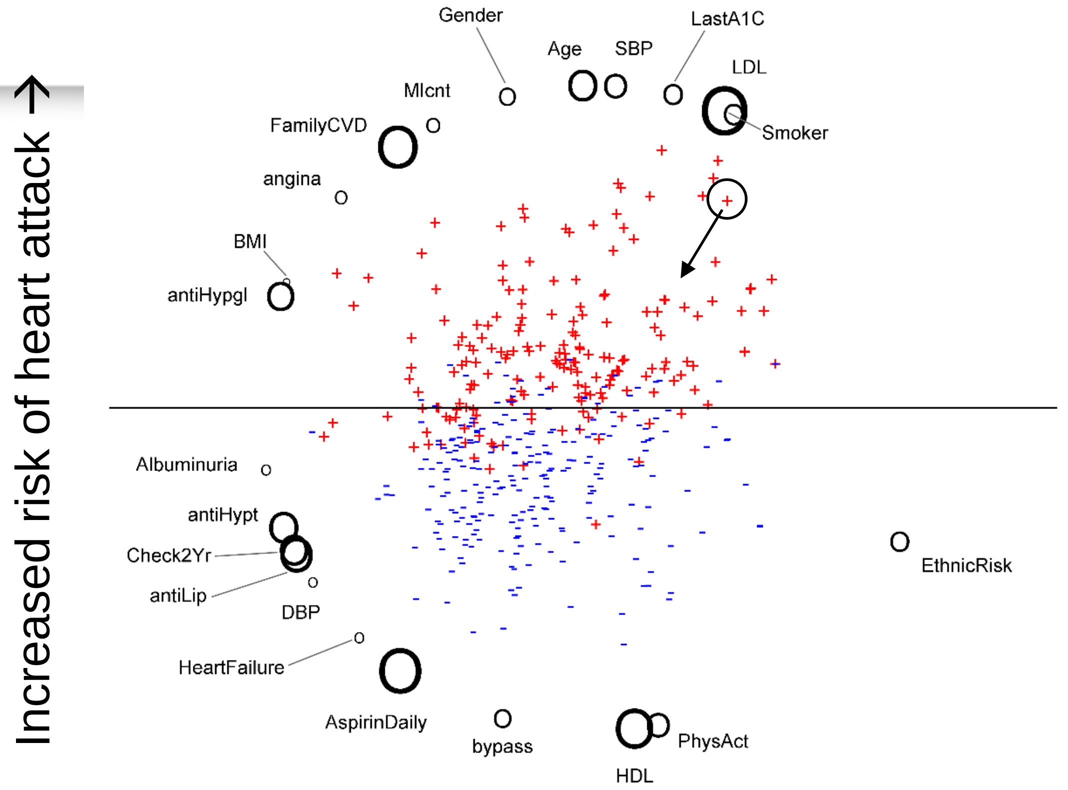

We have developed new methods for chronic disease **risk prediction** and **visualization** that give clinicians a comprehensive view of their patient population, risk levels, and risk factors, along with the estimated effects of potential interventions.

Link to paper

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By early and accurate prediction of each patient's **Diagnosis Related Group** (DRG), we can better predict demand and allocate scarce hospital resources such as beds and operating rooms.

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Better **prediction** of patients' future diagnoses, risks, and care needs can enable more effective and efficient treatment and preventive care.

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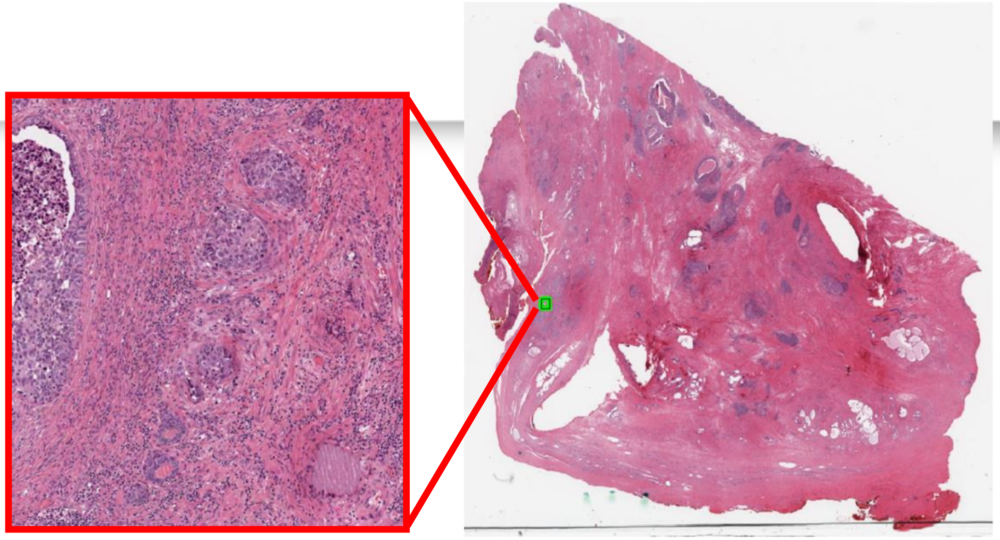

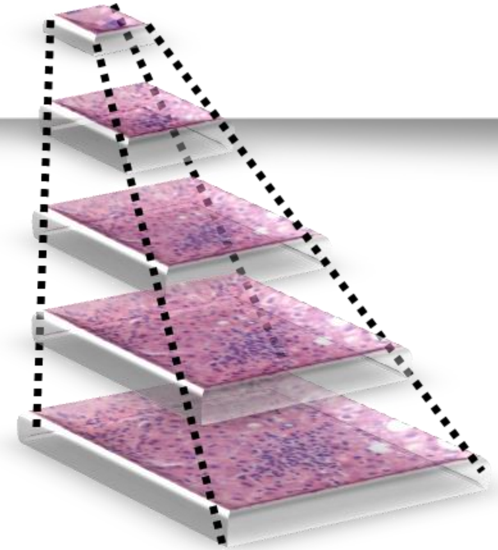

Key advance 1: Very efficient, accurate search over subareas of an image.

Key advance 2: Use hierarchy to search at multiple resolutions (coarse to fine).

Automate detection of relevant findings in pathology, radiology, etc.

Our pattern detection approaches have been successfully applied to detect regions of interest in digital pathology slides, and work surprisingly well to detect prostate cancer.

Link to paper

Automatic **detection** of anomalies and patterns is especially valuable when the key to diagnosis is a tiny piece of the patient's health data.

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Detection is also valuable when key patterns of interest are discovered by **integrating** information across many patients, and might not be visible from a single patient's data.

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Claims data: ~125K patients with diseases of the circulatory system

↓ APC-Scan

Most significant detected pattern:
Glucocorticoids are associated with dramatically increased hospitalizations and length of stay in the **subpopulation** of ~2K overweight, hypertensive males with endocrine secondary diagnoses.

Regression on separate, held-out patient dataset:
51% increase in hospitalizations for this subpopulation; vs. 11% for entire patient population.

	Glucocorticoids Yes	Glucocorticoids No
Number of Patients	264	1713
Mean Number of Hospitalizations	0.606 (0.069)	0.280 (0.016)

Discover new medical knowledge (clinical guidelines, best practices).

We are currently working to analyze massive quantities of patient care data (EHR and health insurance claims) to discover anomalous patterns of care (APC) which significantly impact outcomes.

Link to paper

Questions?

More details on EPD Lab website:
http://epdlab.heinz.cmu.edu

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neill@cs.cmu.edu