

# AI applications in medicine/healthcare

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Aug 2021



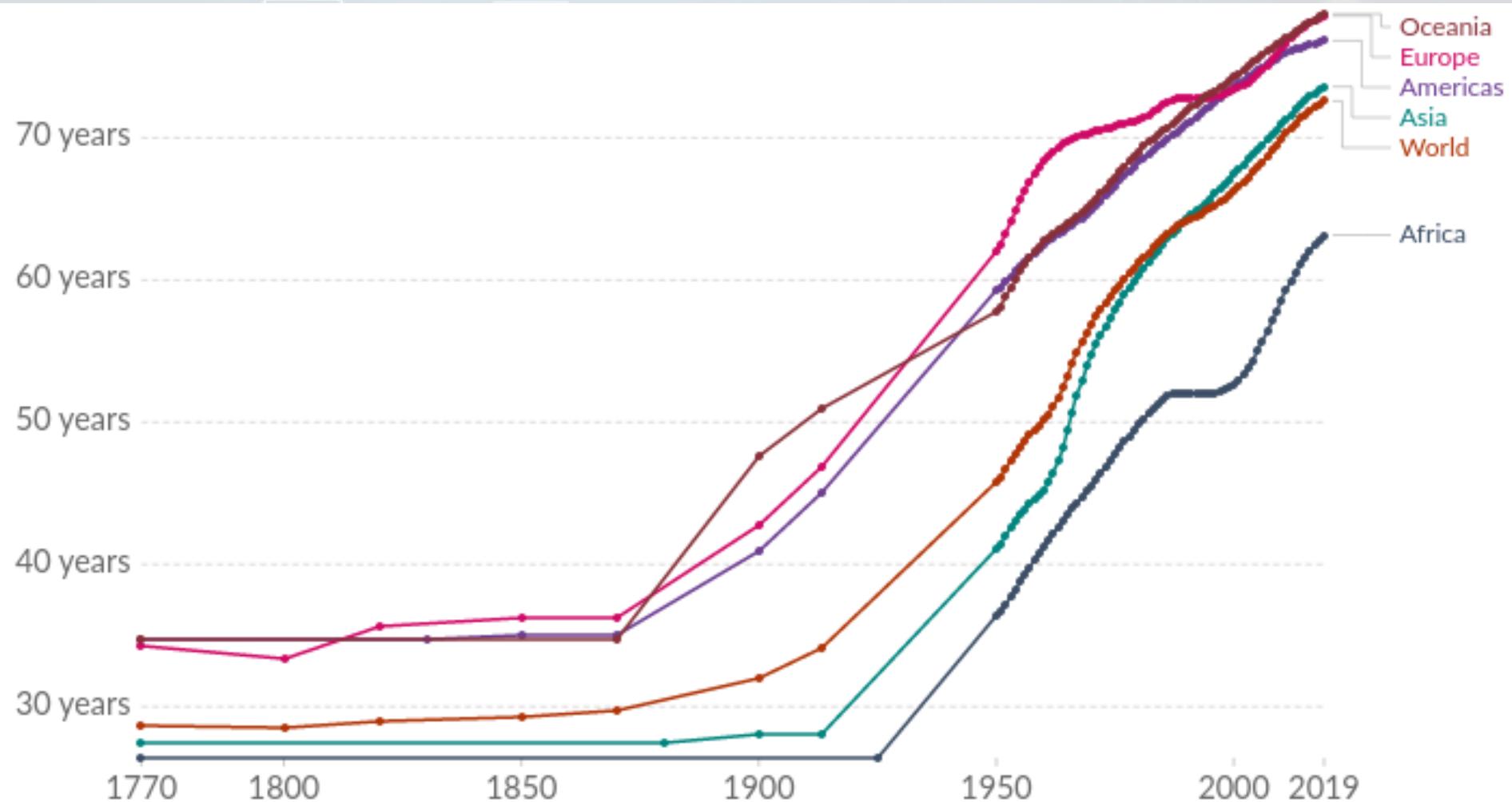
UNIVERSITÉ  
DE GENÈVE



“The groundwork of all  
happiness is good health”  
Leigh Hunt

# پرده‌ی اول







# How it is related to medicine and healthcare system?

## The top 10 medical advances in history

- Vaccines (1796)
- Anaesthesia (1846)
- Germ theory (1861)
- Medical imaging (1895)
- Penicillin (1928)
- Organ transplants (1954)
- Antiviral drugs (1960s)
- Stem cell therapy (1970s)
- Immunotherapy (1970s)
- **Artificial intelligence (21st century)**

# Some examples



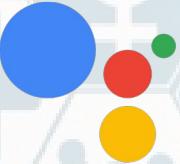
# Examples:



- 10 Likes for the computer to outperform a work colleague
- 70 to do better than a friend
- 150 to outscore a family member
- 227 to almost predict you as good as your spouse (if you are married!)

Computer-based personality judgments are more accurate than those made by humans

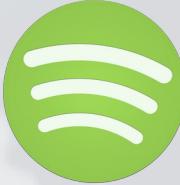
# Some cool examples



Google Assistant



TAPSI



waze

OUTSMARTING TRAFFIC, TOGETHER

Spotify, Google translate, Siri, Cortana,  
Google digital assistants, Pinterest,  
Instagram, Facebook and LinkedIn, Uber,  
Tapsi, Gmail, Waze

Google for “Google's DeepMind AI Just Taught Itself To Walk”

Google for “Looking to Listen: Audio-Visual Speech Separation”

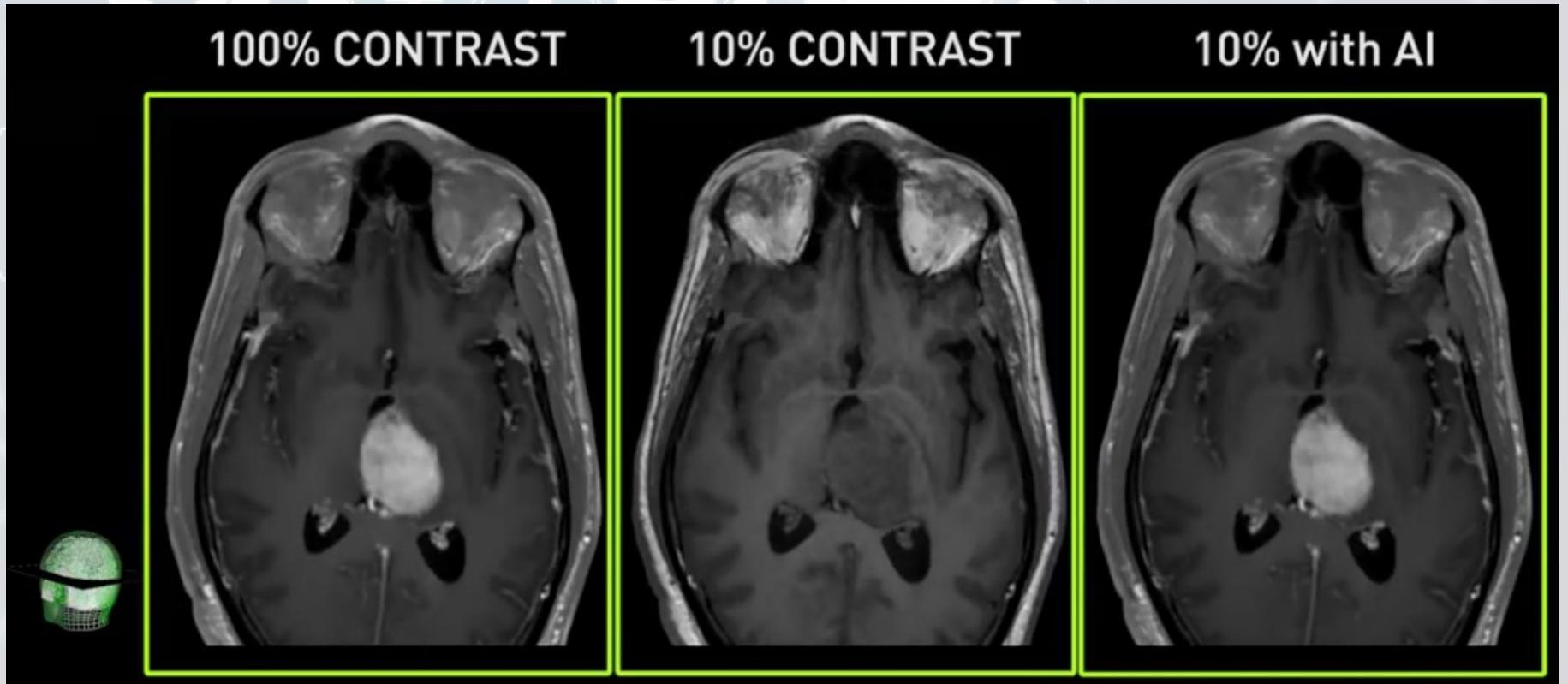
Google for “AI brings Mona Lisa to life”

# Examples:

In the US dataset, the software performed significantly better than human experts, producing 5.7 percent fewer false positive diagnoses. Even more impressively, the system recorded 9.4 percent fewer false negatives, suggesting it picked up several breast cancers that human experts missed.



# Examples:



# Examples:



پردهی دوم

why data science?

# سیر تکاملی علوم طبیعی





## Empirical evidence

$$\Psi(x) = R_p - \frac{1}{2} R g_p = \frac{\omega_p \epsilon}{c^3} T_{p*}$$

$$S_B = \frac{k_B 4\pi G}{\hbar c} M^2$$

$$\psi(x) = \frac{i}{\sqrt{R}} (A_+ e^{ix} + A_- e^{-ix}) \quad x < 0$$

$$k = \sqrt{2mE/\hbar^2}$$

$$R_p - \frac{1}{2} R g_p + \Delta g_p = \frac{8\pi G}{c^2} T_{p*}$$

$$H = \frac{P_p P_e}{2m} + V(r)$$

$$P = -i\hbar\nabla$$

$$Re[\Psi(x)]$$

$$S = \frac{1}{2k} \int R \sqrt{-g} d^3x$$

$$S = \frac{e k A}{4 \hbar G}$$

$$H|\Psi(t)\rangle = i\hbar \frac{\partial}{\partial t} |\Psi(t)\rangle$$

$$\delta(k_1 + k_2)$$

$$L = \Gamma_r \left[ \frac{1}{g} F_{13} F^{13} - i \lambda \Gamma_1^\dagger \Gamma_1 \lambda \right]$$

$$E = mc^2$$

$$E^2 = (pc)^2 + (mc^2)^2$$

$$r = \frac{\theta}{2\pi} + \frac{4\pi}{g^2}$$

$$I = \int e^{-\alpha x^2/2} dx = \sqrt{\frac{2\pi}{\alpha}}$$

$$E^1 = p^2 c^2 + m^2 c^4$$

$$p = \hbar k = \frac{\hbar v}{\lambda}$$

$$A_{ij} = \frac{8\pi \hbar v}{c^3} B_{ij}$$

$$S_{fi} = \langle f | S | i \rangle$$

$$S = \frac{1}{2} \int d^3x \left( R + \frac{R^2}{6M^2} \right)$$

$$V = -e^{-\int_a^b V(X_{trn}) dx_{trn}} \int_a^b \frac{\partial u}{\partial x} dw$$

## Scientific theory



## Computational science

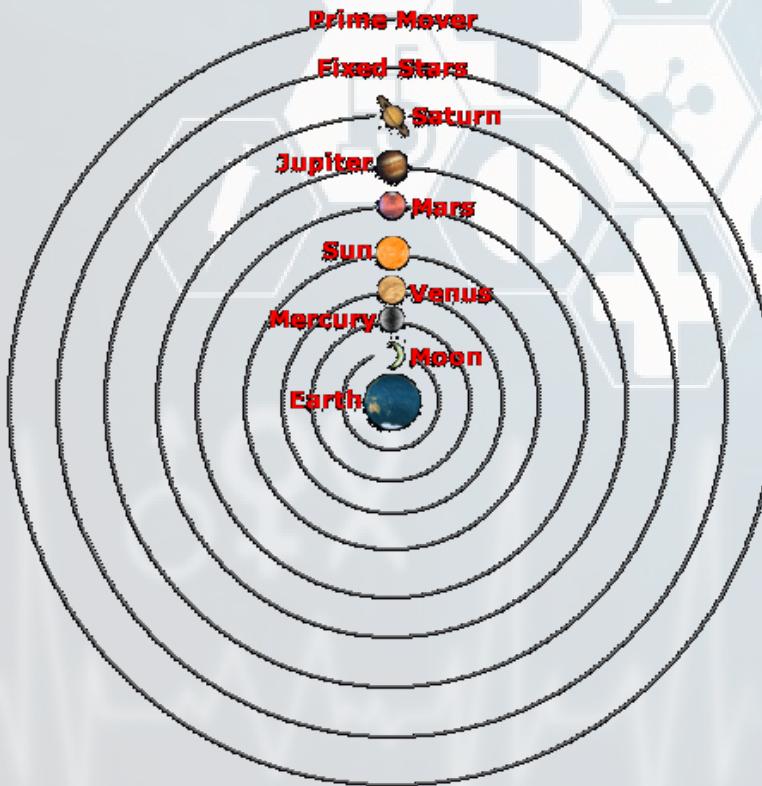
**BIG  
DATA**

## Data science

# شواهد تجربی



# شواهد تجربی



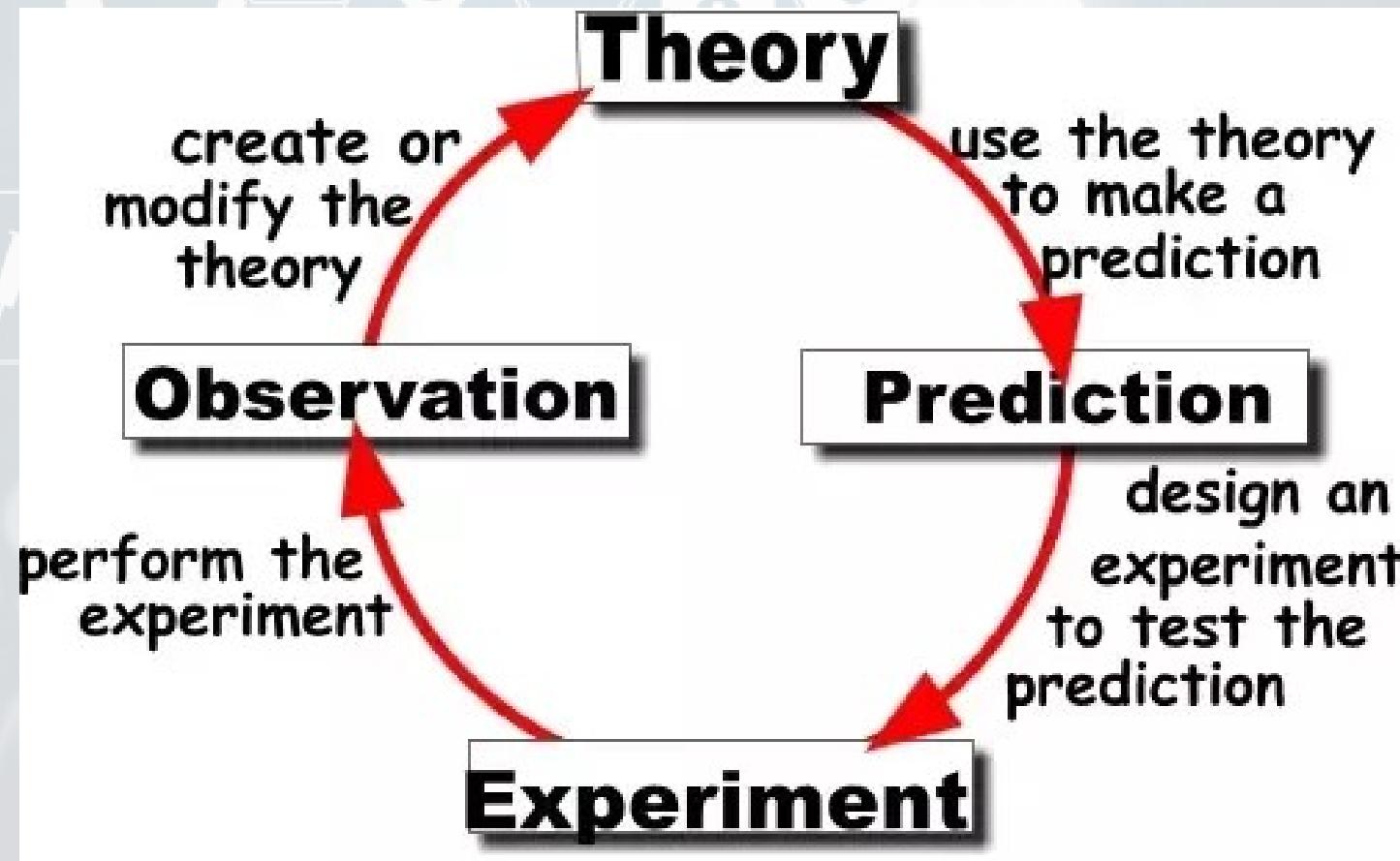
# شواهد تجربی



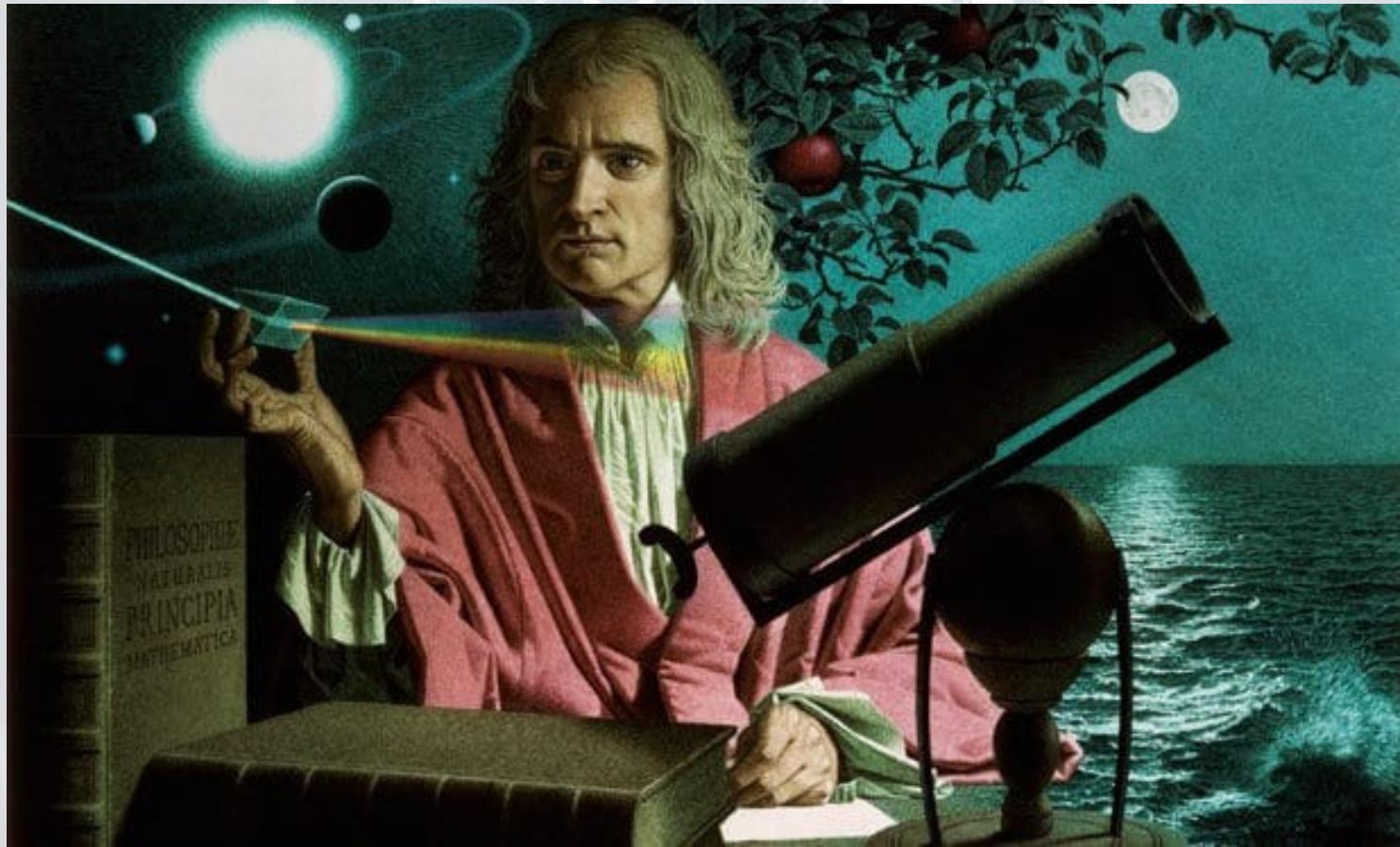
# نظريه علمي



# نظریه علمی



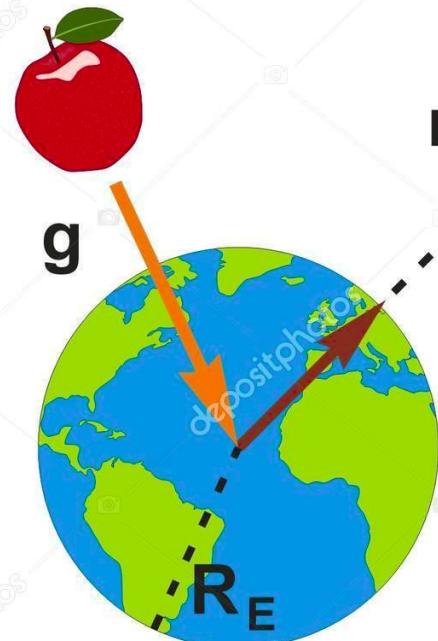
# نظریه علمی



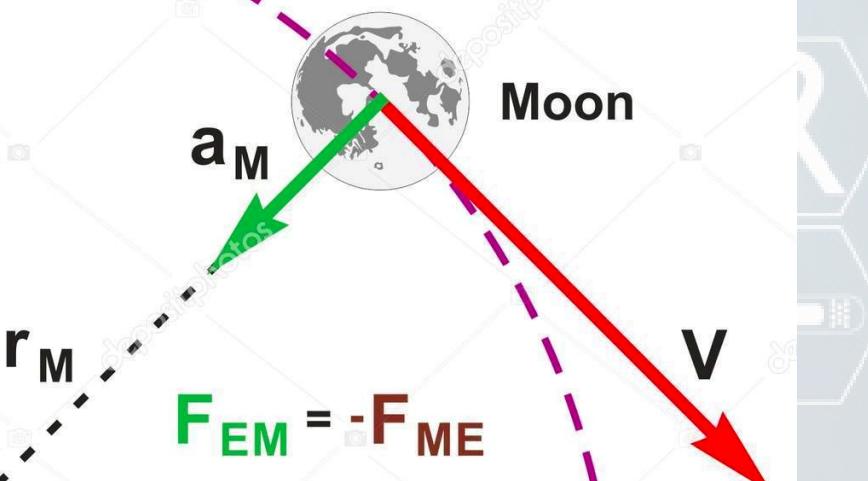
# نظریه علمی

## Newton's Universal Law of Gravitation

$$F_G = \frac{Gm_E m_M}{r_{EM}^2}$$



The Moon's Gravitational Field is causing the Earth to Accelerate Toward the Moon



$$F_{EM} = -F_{ME}$$

Newton's Third Law

# عصر کامپیوٽر



# عصر کامپیوٹر

کامپیوٹر  
۱۹۵۰-۱۶۱۳

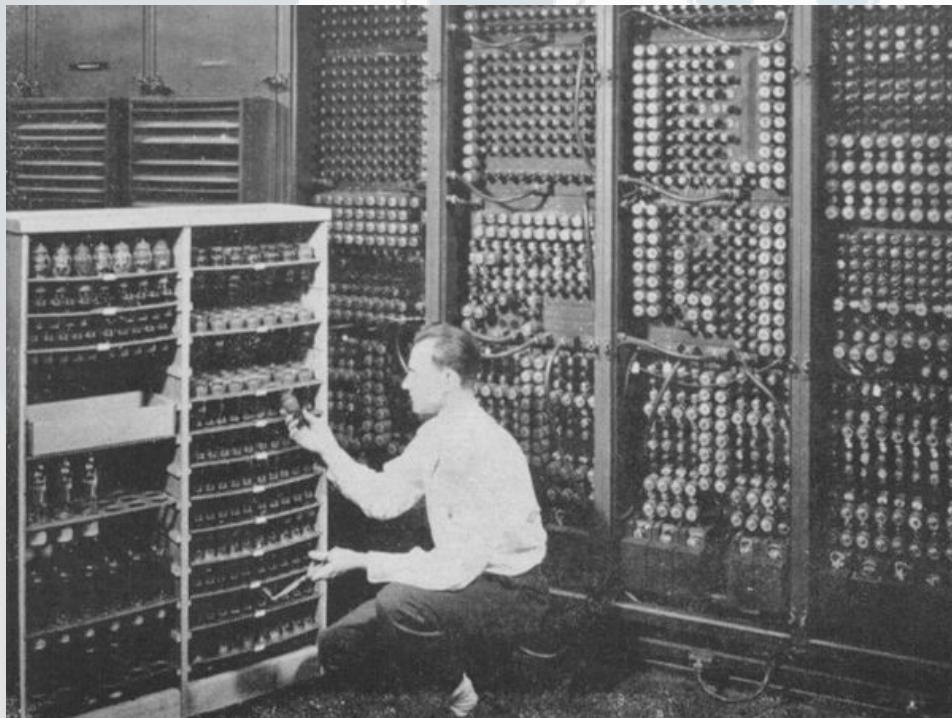


عصر کامپیوٹر

- عمليات رياضي
- عمليات منطقى



# عصر کامپیوٹر



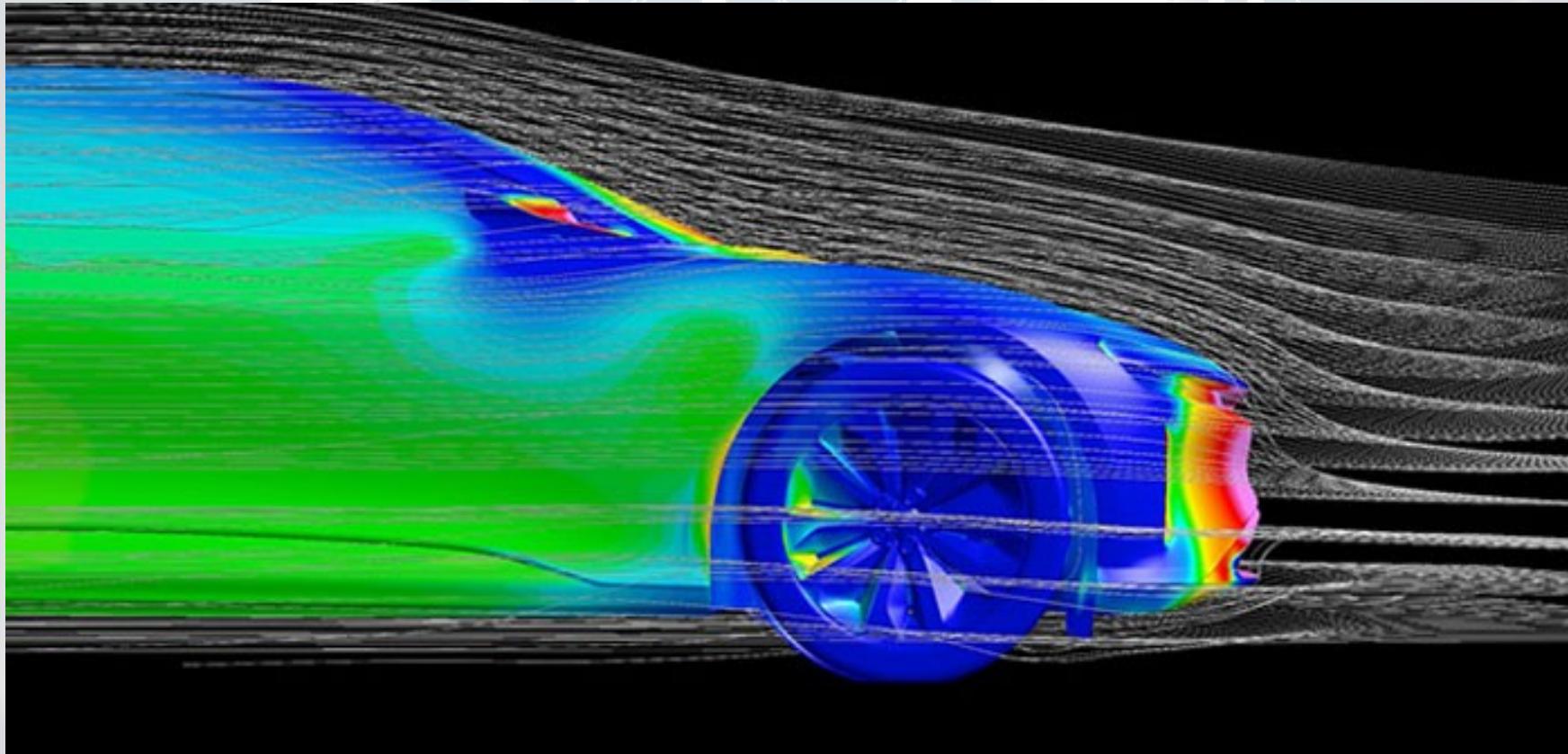
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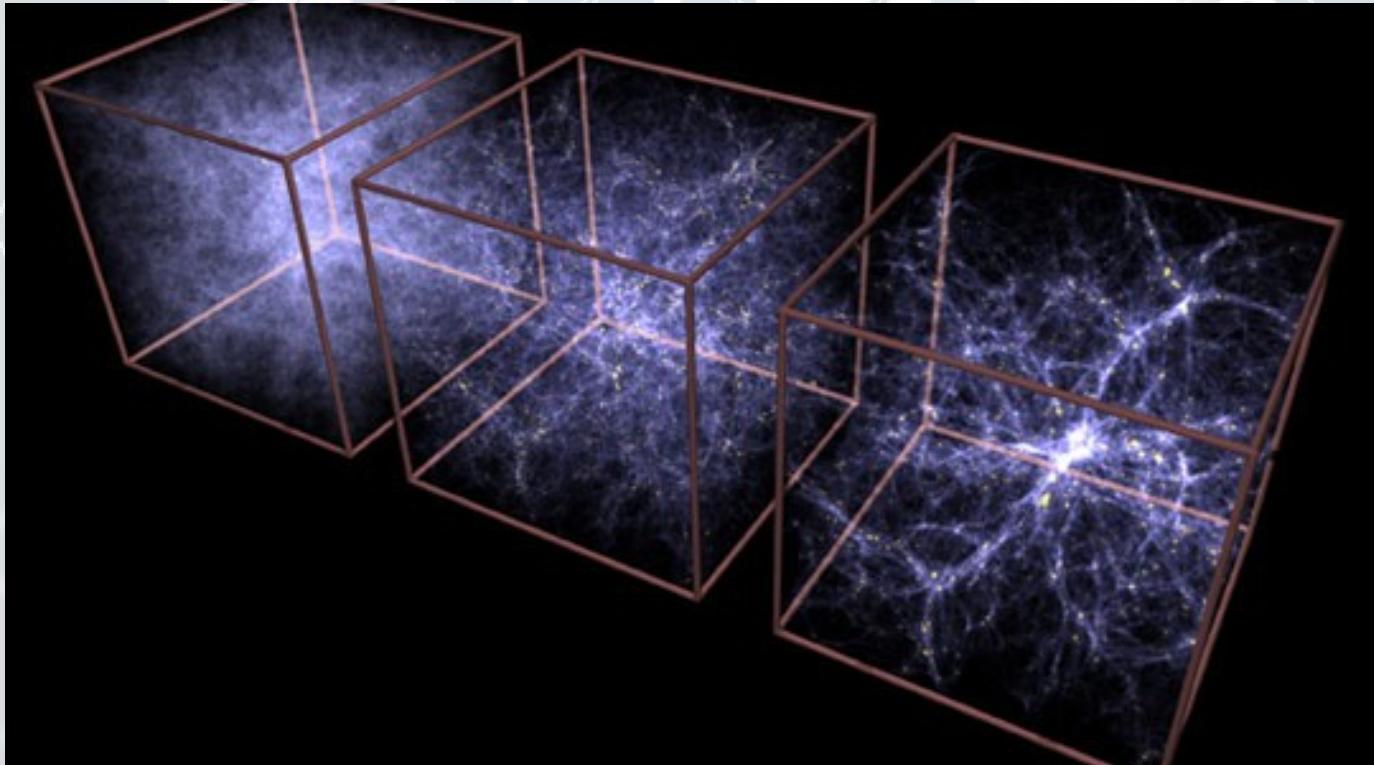
# عصر کامپیوٹر



# عصر کامپیووتر



# عصر کامپیوٹر



# عصر داده‌های بزرگ



# عصر داده‌های بزرگ



# عصر داده‌های بزرگ



Agriculture



Climate



Consumer



Ecosystems



Education



Energy



Finance



Health



Local  
Government



Manufacturing



Maritime



Ocean



Public Safety



Science &  
Research

# عصر داده‌های بزرگ

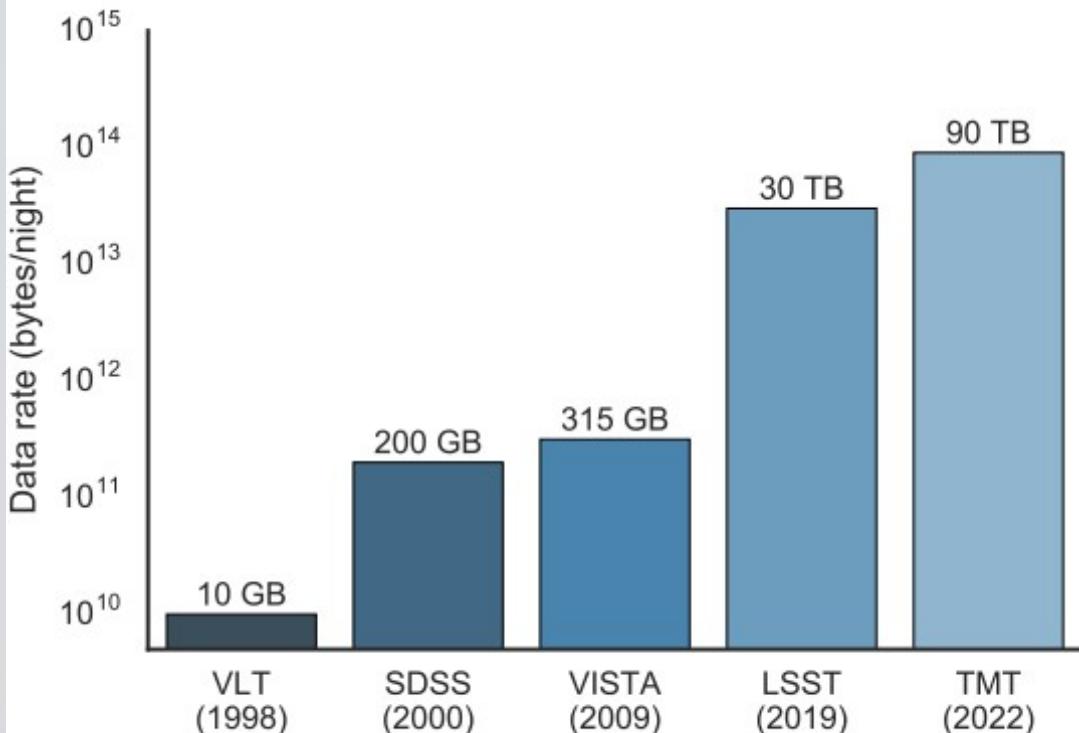


# عصر داده‌های بزرگ

## کیهان‌شناسی و داده‌های غول آسا:

Big Universe, Big Data: Machine Learning  
and Image Analysis for Astronomy

Jan Kremer, Kristoffer Stensbo-Smidt, Fabian Gieseke, Kim  
Steenstrup Pedersen, and Christian Igel



# عصر داده‌های بزرگ



# عصر داده‌های بزرگ

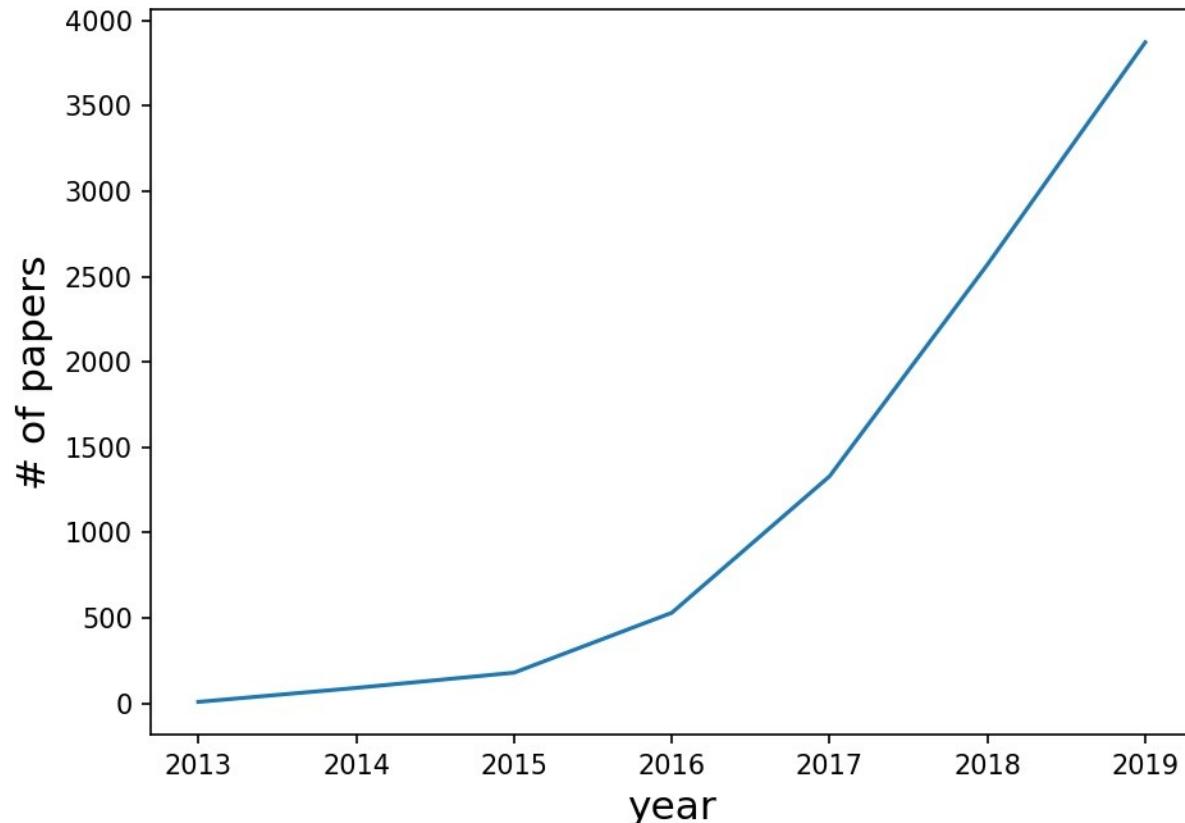
- Hypothesis-Driven:  
What kind of data do we need to help solve a problem?
- Data-Driven:  
What interesting problems can be solved with this data!?

# عصر داده‌های بزرگ

Table 1 Major discoveries made by the Hubble Space Telescope (*HST*). Of the *HST*'s “top ten” discoveries (as ranked by National Geographic magazine), only one was a key project used in the *HST* funding proposal (Lallo 2012). A further four projects were planned in advance by individual scientists but not listed as key projects in the *HST* proposal. Half the “top ten” *HST* discoveries were unplanned, including two of the three most cited discoveries, and including the only *HST* discovery (Dark Energy) to win a Nobel prize. This Table was previously published by Norris et al. (2015).

Project	Key Project?	Planned?	Nat Geo top ten?	Highly cited?	Nobel Prize?
Use cepheids to improve value of $H_0$	✓	✓	✓	✓	
UV spectroscopy of ig medium	✓	✓			
Medium-deep survey	✓	✓			
Image quasar host galaxies		✓	✓		
Measure SMBH masses		✓	✓		
Exoplanet atmospheres		✓	✓		
Planetary Nebulae		✓	✓		
Discover Dark Energy			✓	✓	✓
Comet Shoemaker-Levy			✓		
Deep fields (HDF, HDFS, GOODS, FF, etc)			✓	✓	
Proplyds in Orion			✓		
GRB Hosts			✓		

Number of papers that include “Machine learning” in the manuscript (biorxiv.org)



## Fast Facts

### Famous Data Scientist



Larry Page  
CEO of Google

### Job Opportunities

**15,000%**

increase in job postings for data scientists between 2011 & 2012.

### Majors



physics



applied maths



social sciences



statistics



analytics



computer science



marketing

**\$80K**

average starting salary

**\$120K**

average data science salary

**\$250K**

data science team manager

**\$400K**

highest paid data scientist

پرده‌ی سوم

What is ML?

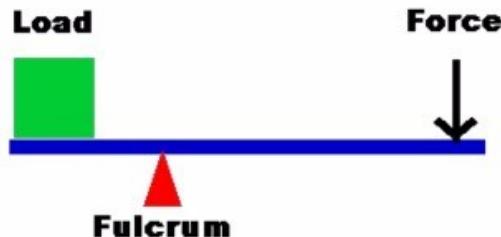
# ماشین چیست؟



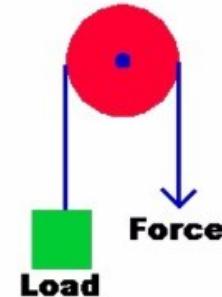
ماشین چیست؟

نیرو وارد کند و حرکت را  
کنترل کند...

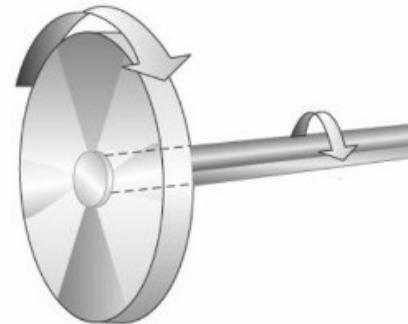
# ماشین چیست؟



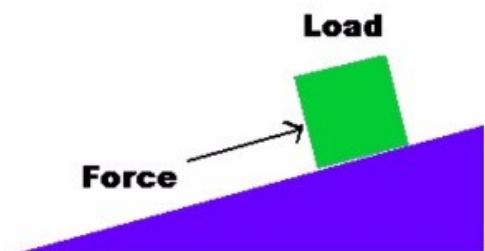
Lever



Pulley



Wheel & Axle



Inclined Plane

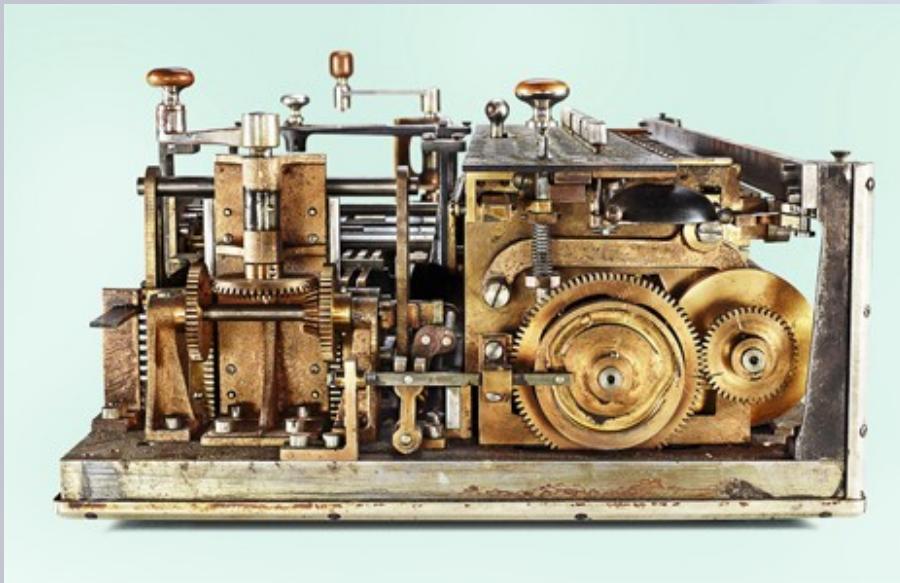


Wedge



Screw

# ماشین چیست؟



# ماشین چیست؟

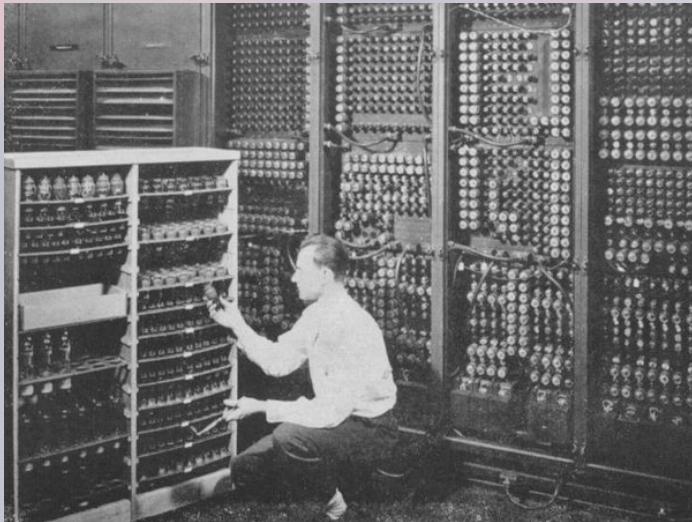


# ماشین چیست؟



- عمليات رياضي
- عمليات منطقى

# ماشین چیست؟



# یادگیری چیست؟



# یادگیری چیست؟

- اصلاح و تقویت
- رفتار
- دانش
- توانمندی
- انتخاب

# یادگیری چیست؟



# یادگیری چیست؟



# یادگیری چیست؟



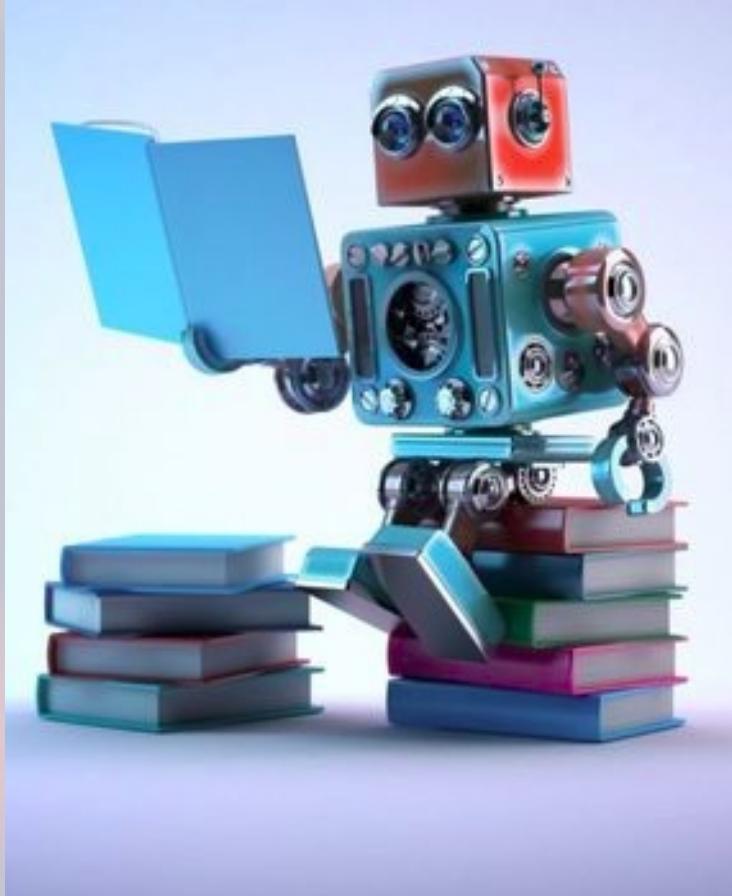
# یادگیری چیست؟

- آنی نیست
- خودآگاهی نیاز ندارد

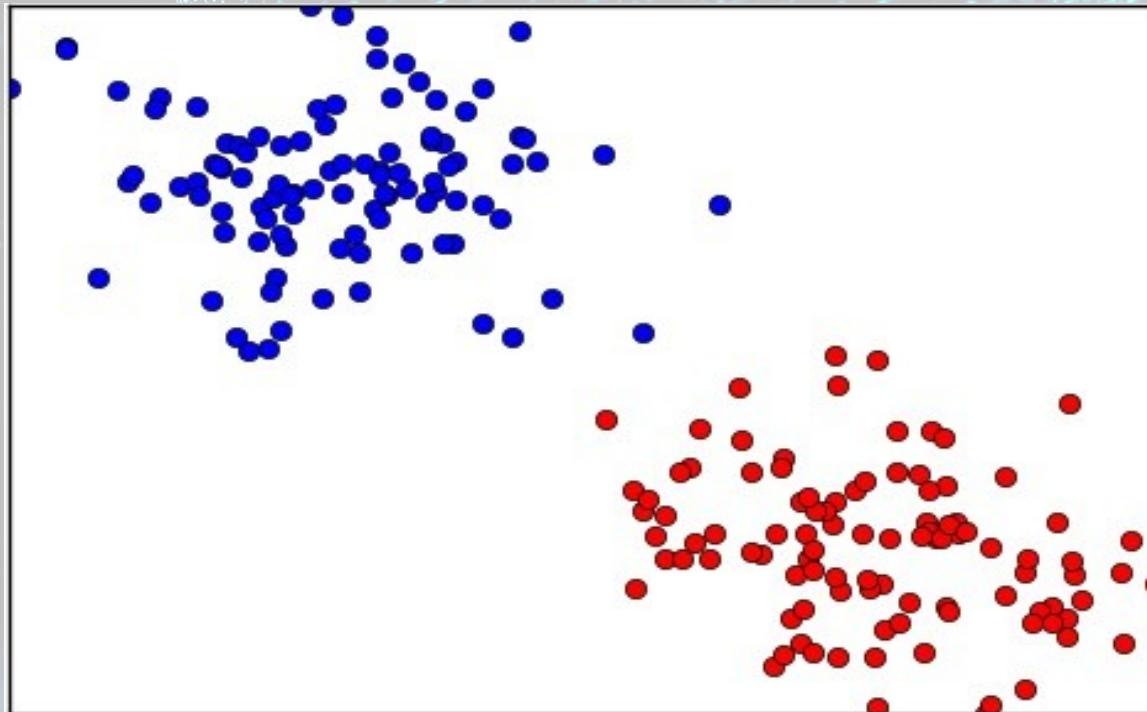
- کارکردگرایی
- شناختی
- تداعیگرایی
- نوروفیزیولوژیک
- تکاملی

نظریه های  
 مختلف

# یادگیری ماشینی چیست؟

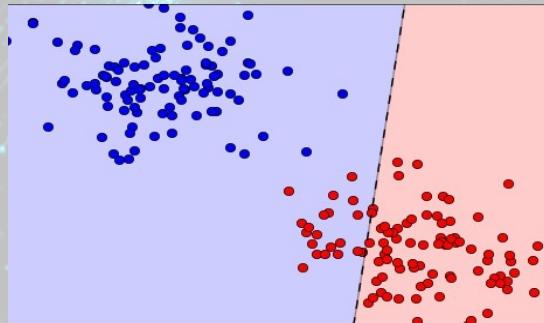
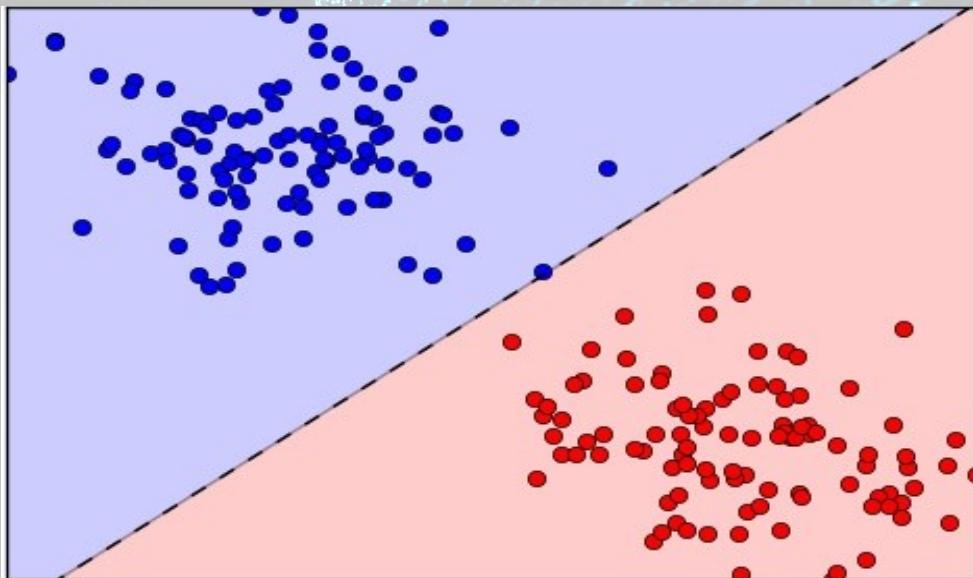


# یادگیری ماشینی چیست؟



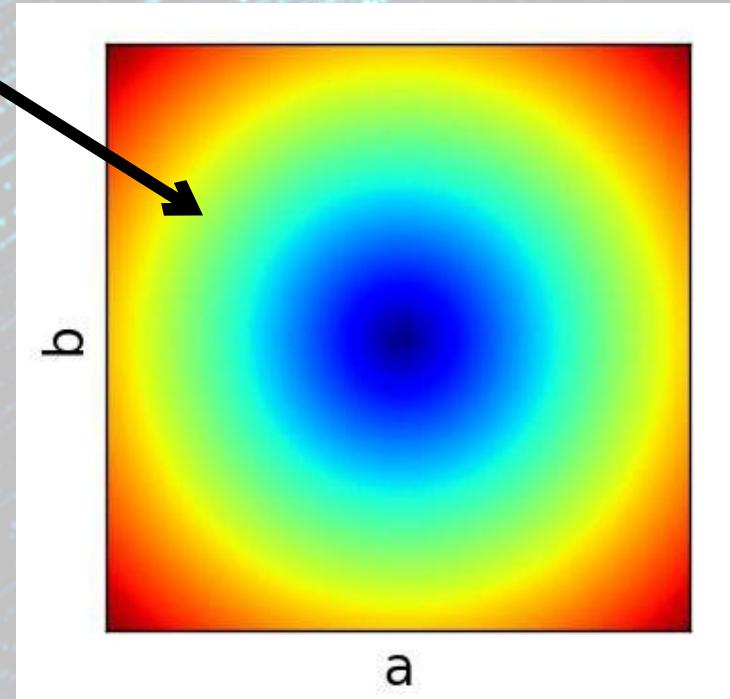
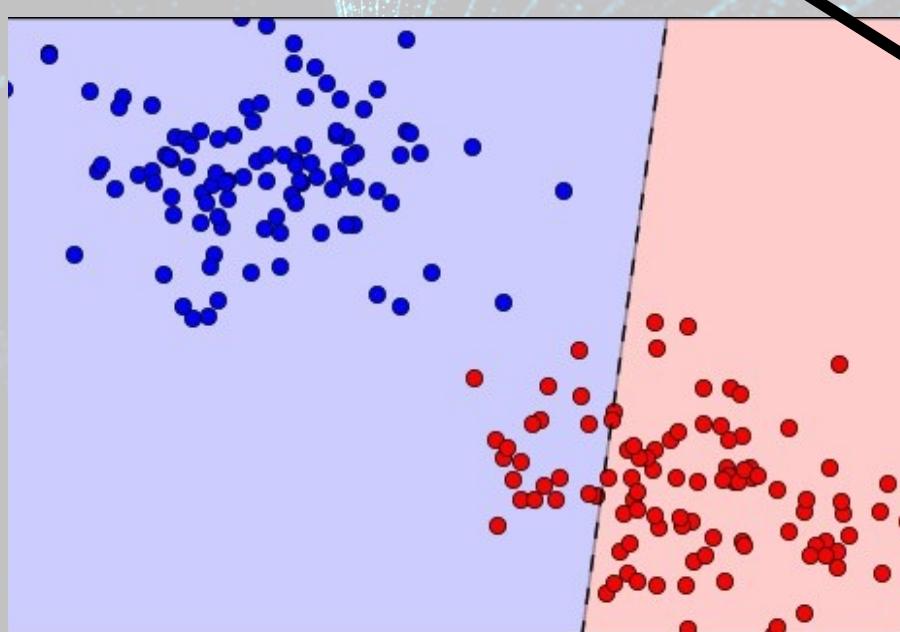
# یادگیری ماشینی چیست؟

$$y = ax + b$$



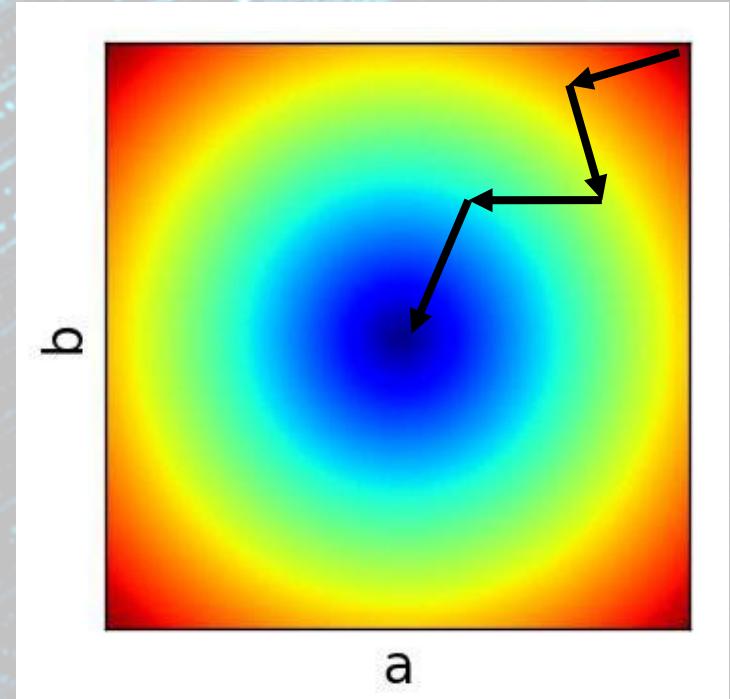
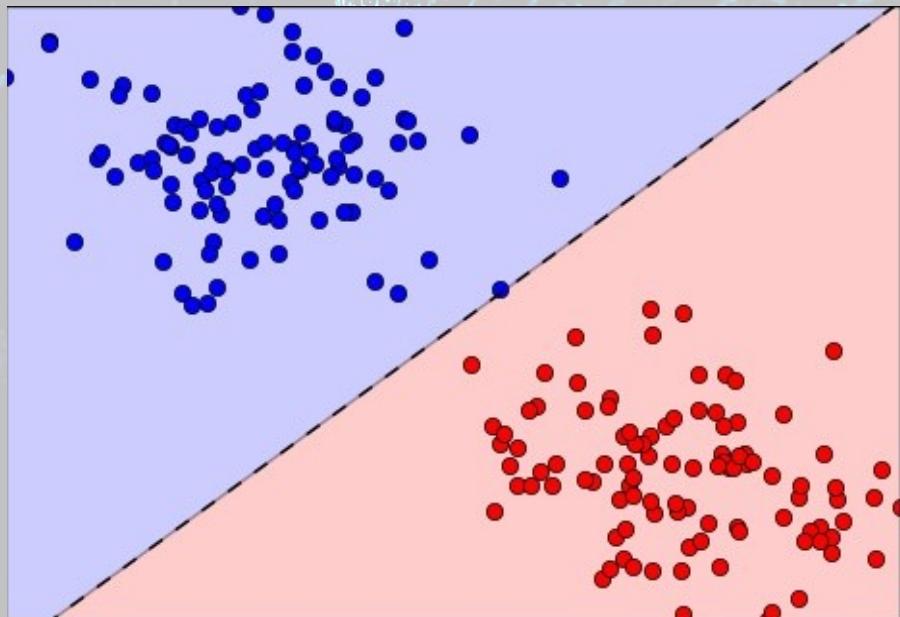
# یادگیری ماشینی چیست؟

$$y = ax + b$$

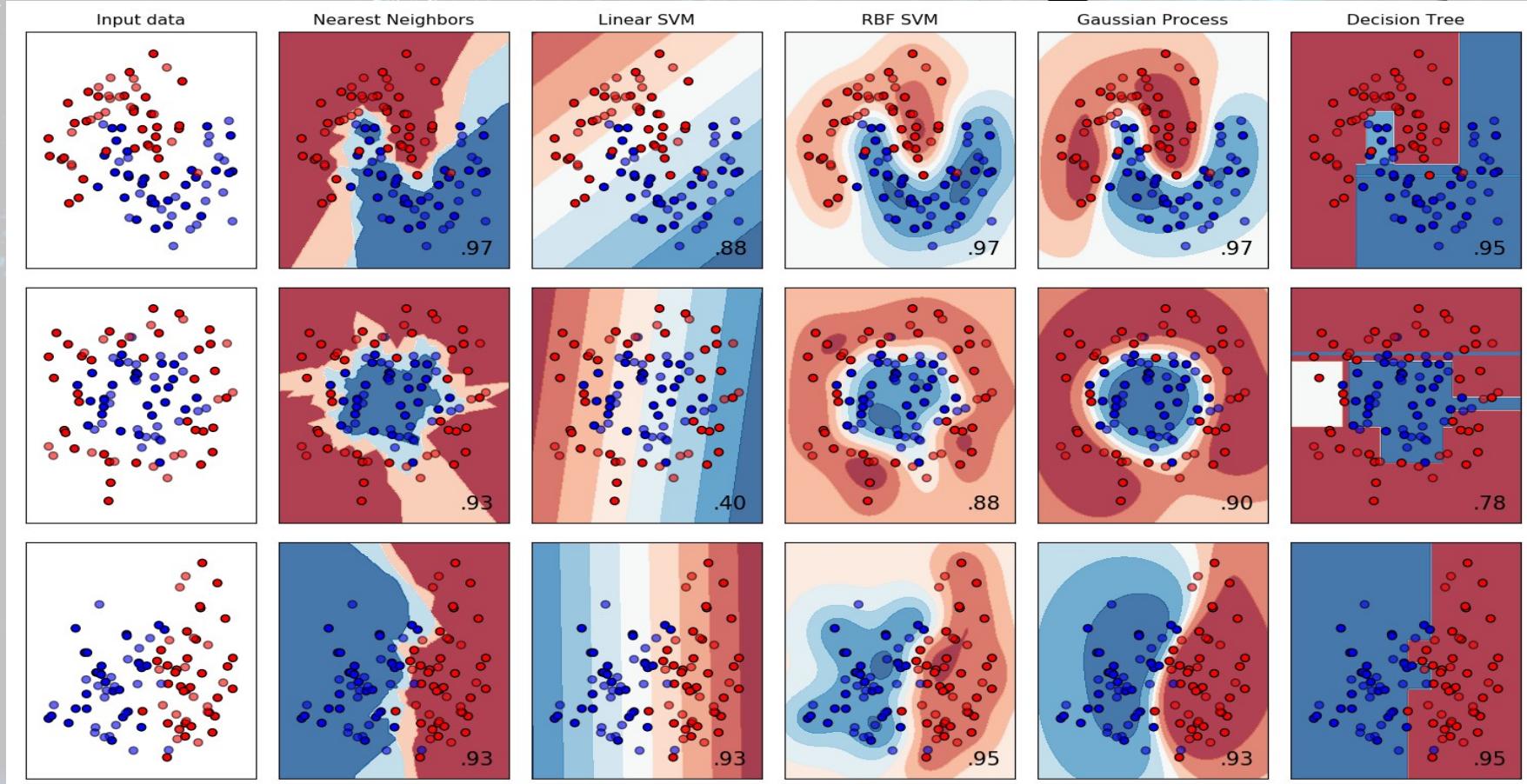


# یادگیری ماشینی چیست؟

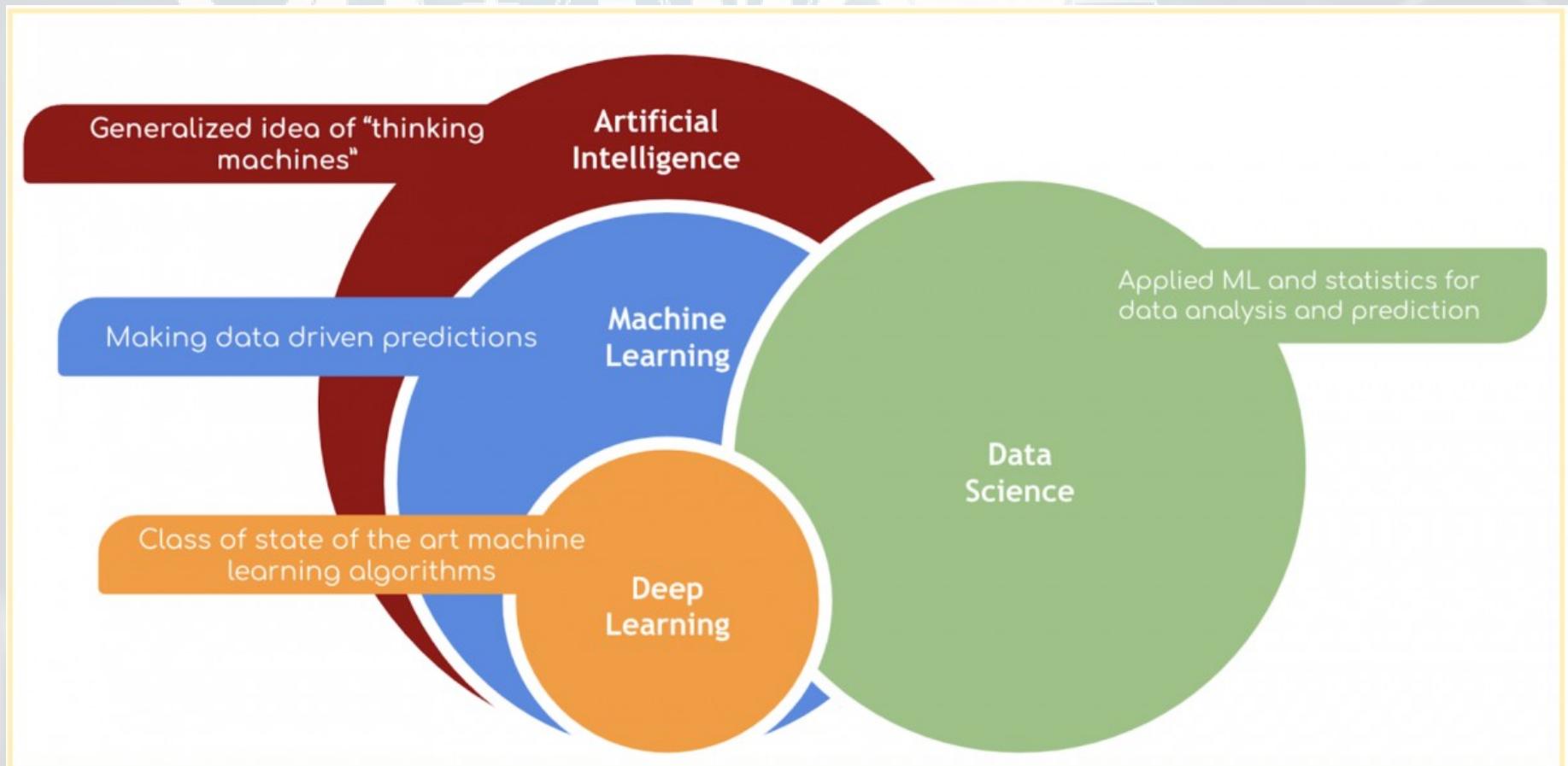
$$y = ax + b$$



# یادگیری ماشینی چیست؟



# DS vs ML



# Classification



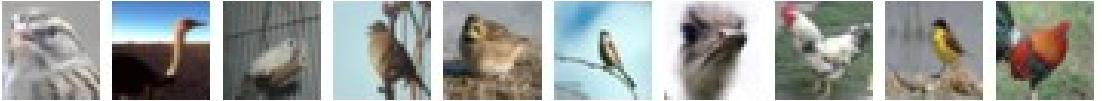
**airplane**



**automobile**



**bird**



**cat**



**deer**



**dog**



**frog**



**horse**



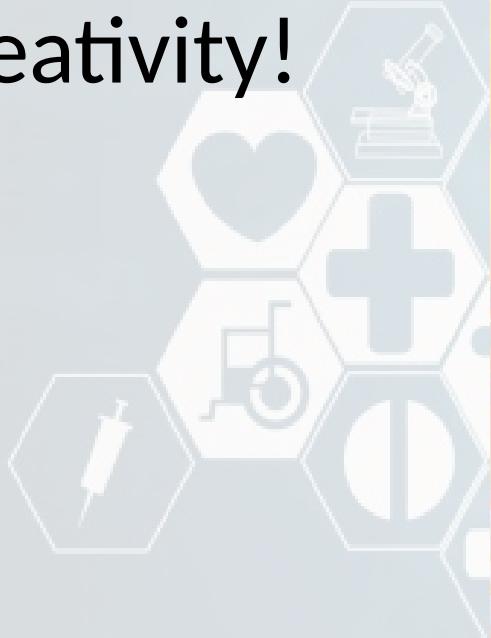
**ship**



**truck**

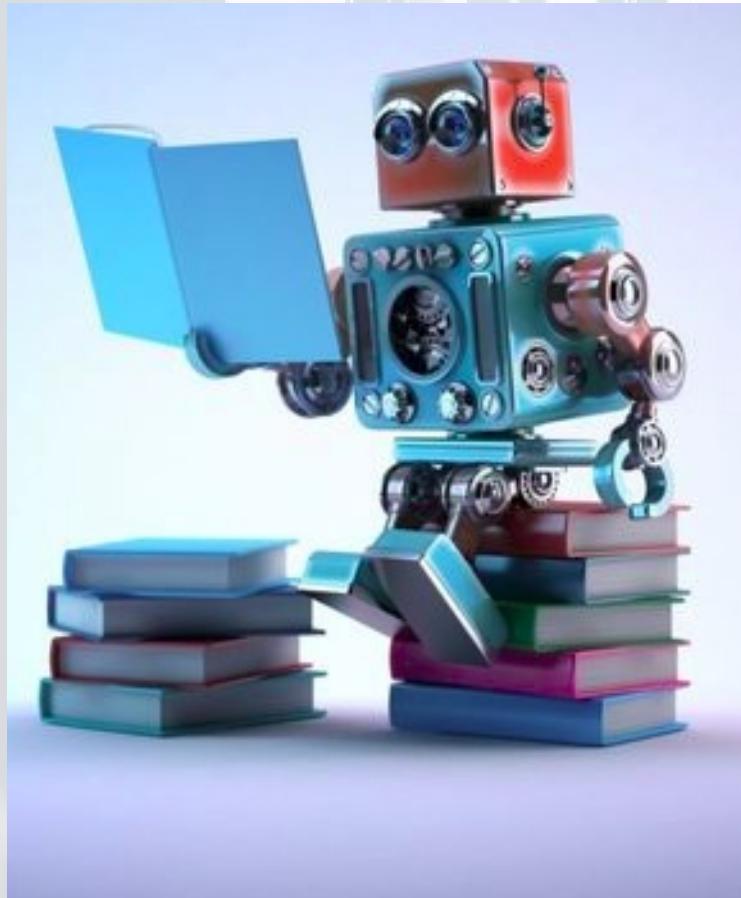


# Creativity!



Creative adversarial networks: generating art!

# یادگیری ماشینی چیست؟



# Creativity!



Google for “These People Do Not Exist!”

This Person Does Not Exist  
This Cat Does Not Exist  
This Rental Does Not Exist  
This Waifu Does Not Exist  
This URL Does Not Exist  
This Startup Does Not Exist  
This Question Does Not Exist  
This Resume Does Not Exist  
This Emotion Does Not Exist  
This Vessel Does Not Exist  
These Lyrics Do Not Exist  
This Snack Does Not Exist  
This Meme Does Not Exist  
This Chair Does Not Exist

This Foot Does Not Exist  
This Artwork Does Not Exist  
This Chemical Does Not Exist  
This Horse Does Not Exist  
This Word Does Not Exist  
This Satire Does Not Exist  
This Automobile Does Not Exist  
This Butterfly Does Not Exist  
This Beetle Does Not Exist  
This City Does Not Exist  
This Food Blog Does Not Exist  
This Night Sky Does Not Exist  
This Music Video Does Not Exist



## Yona

Article | August 17, 2015

### Genome organization and DNA replication in the single cell continuum

An algorithm-based approach is used to map the spatial distribution of DNA strands in the genome; within-cell movement of long-distance replication occurs in a canyon-like pattern, whereas propagating strands move freely within the genome.

This is Fake



Article | June 14, 2009

### Distinctive chromatin in human sperm packages genes for embryo development

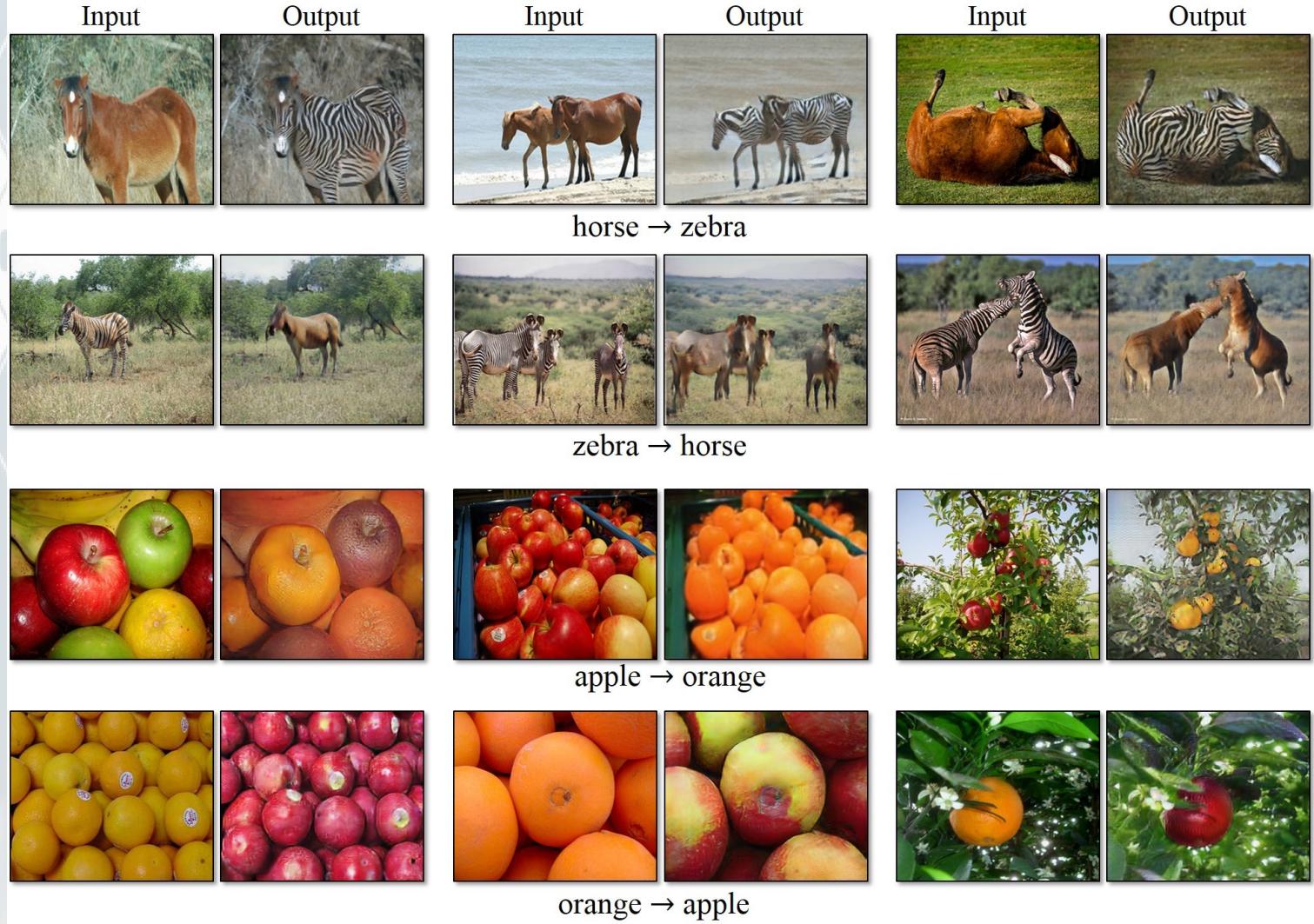
During spermiogenesis, canonical histones are largely exchanged for protamines, and whether the rarely retained nucleosomes have any function has been unclear. Here, high-resolution genomic approaches are used to localize the nucleosomes retained in mature human sperm; they are found to be significantly enriched at developmentally important genes and to have distinctive patterns of histone modifications.

This is Fake



Enigm  
a

# CycleGAN



# StyleGAN



Coarse styles copied

source



destination



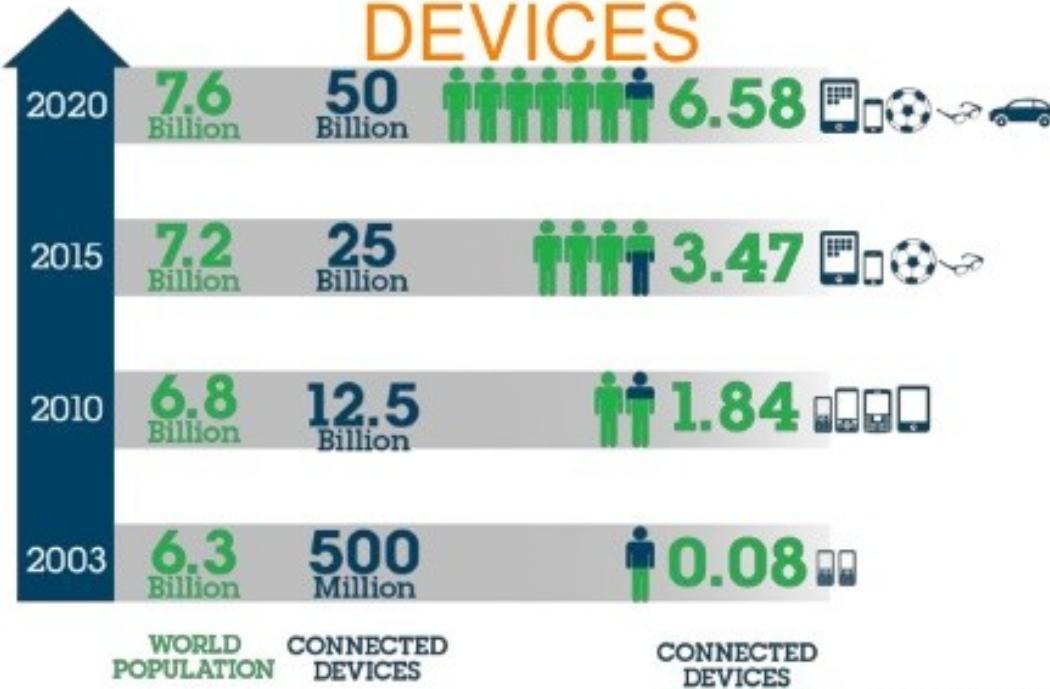
# پرده‌ی چهارم

Do we have Big Data?

# How BIG?

- According to the National Hospital Discharge Survey (2010): there were 35.1 million discharges with an average length of 4.8 days a stay”
- According to the National Hospital Ambulatory Medical Care Survey (2011): there were 125.7 million outpatient visits and 136.3 million emergency department visits.”
- A human body generates around 2000 GB of data every single day.

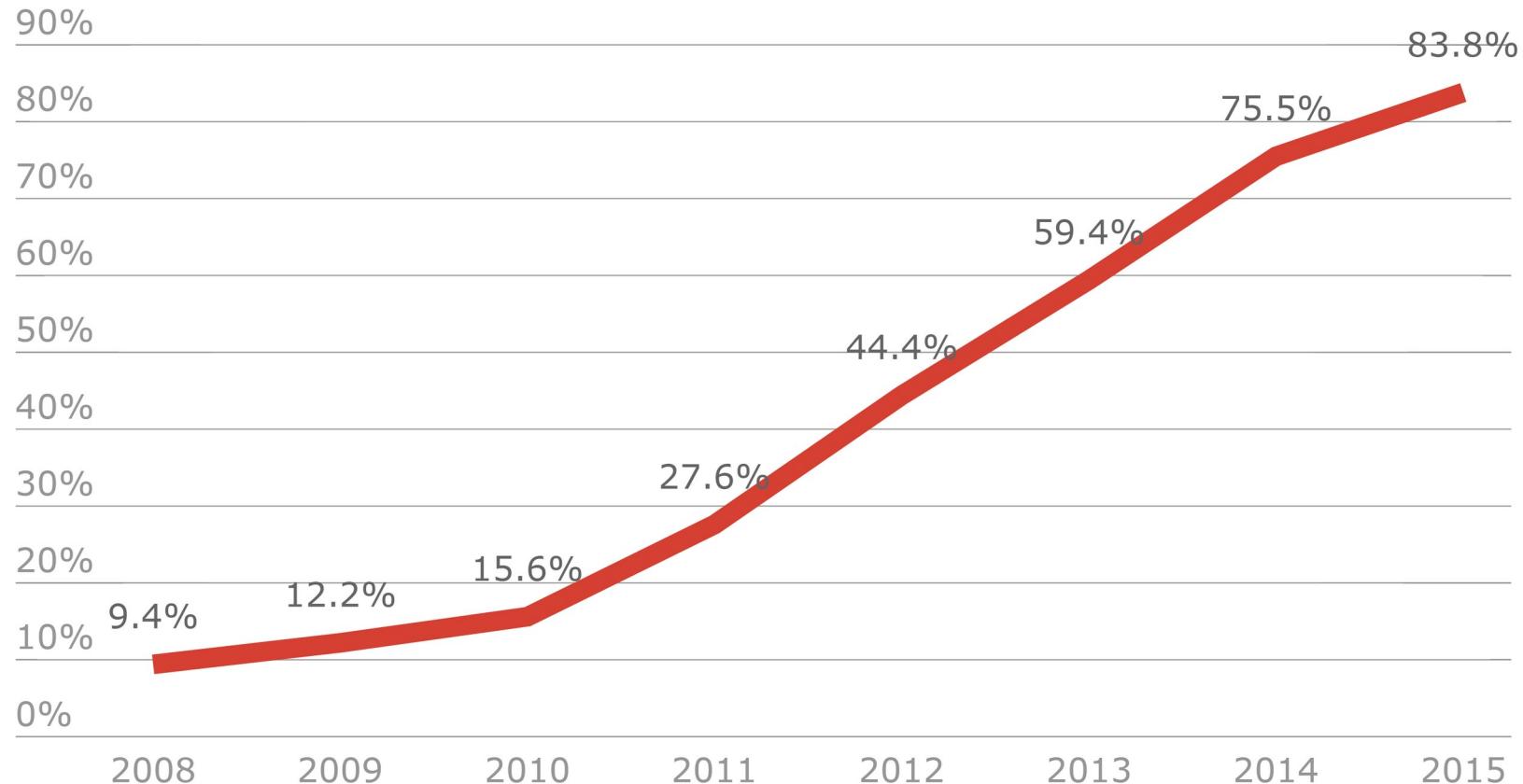
# INCREASE IN CONNECTED DEVICES



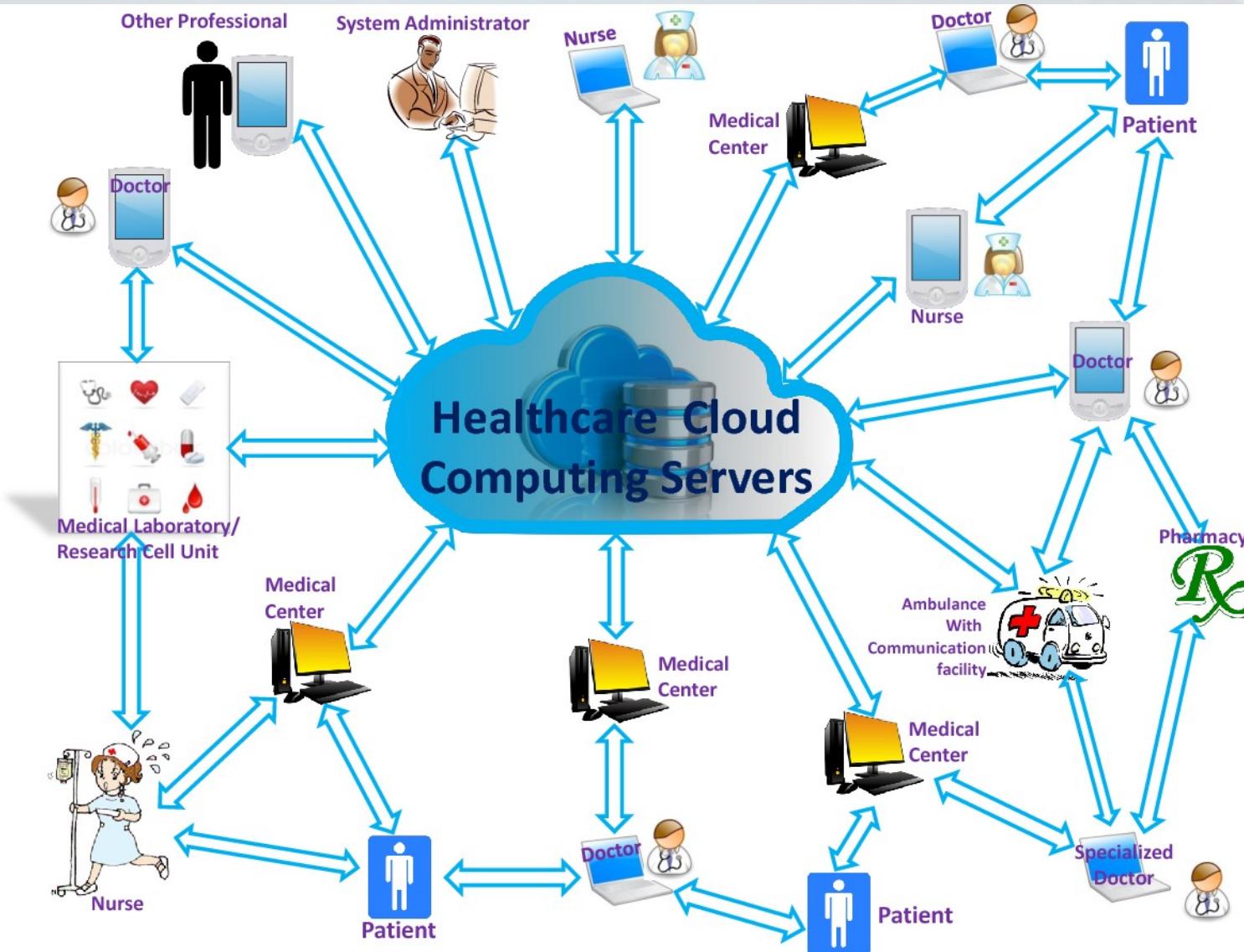
Source: Cisco IBSG, April 2011

# Rapid adoption of EHRs

% of acute-care hospitals with a basic electronic records system



Source: ONC/American Hospital Association



## Growth in healthcare data

1 exabyte = 1 billion gigabytes

2013  
**153**  
EXABYTES



2020  
**2,314**  
EXABYTES

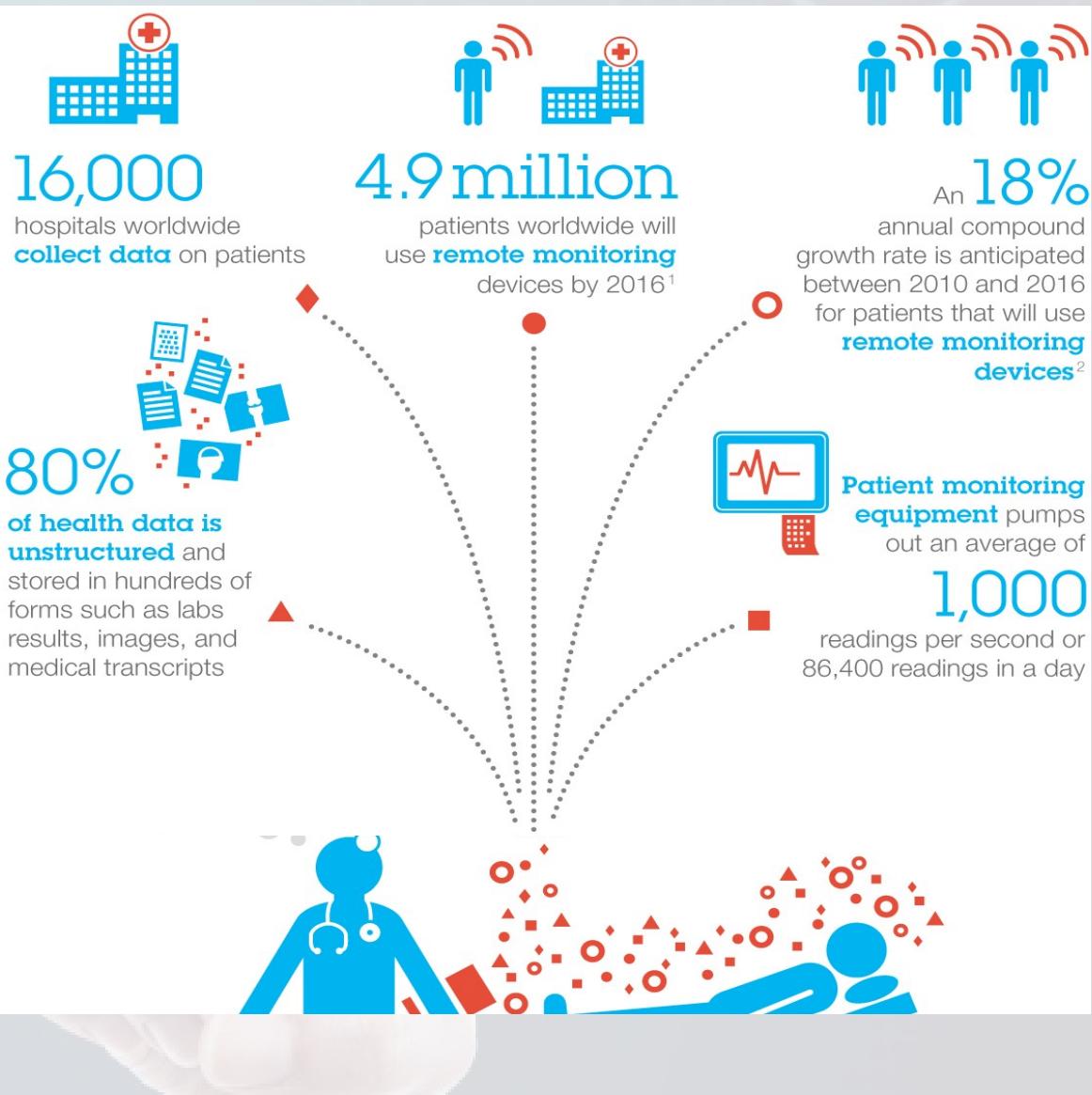
Source: Stanford Medicine 2013, IDC 2014

## TO PUT THAT INTO PERSPECTIVE, DATA CENTERS GLOBALLY

will only have enough room for an estimated

# 985 exabytes by 2020

meaning that almost two and a half times this capacity would be required to house all the healthcare data.



## Growth in healthcare data

1 exabyte = 1 billion gigabytes

Source: Stanford Medicine 2017, IDC 2014

2013  
153  
EXABYTES



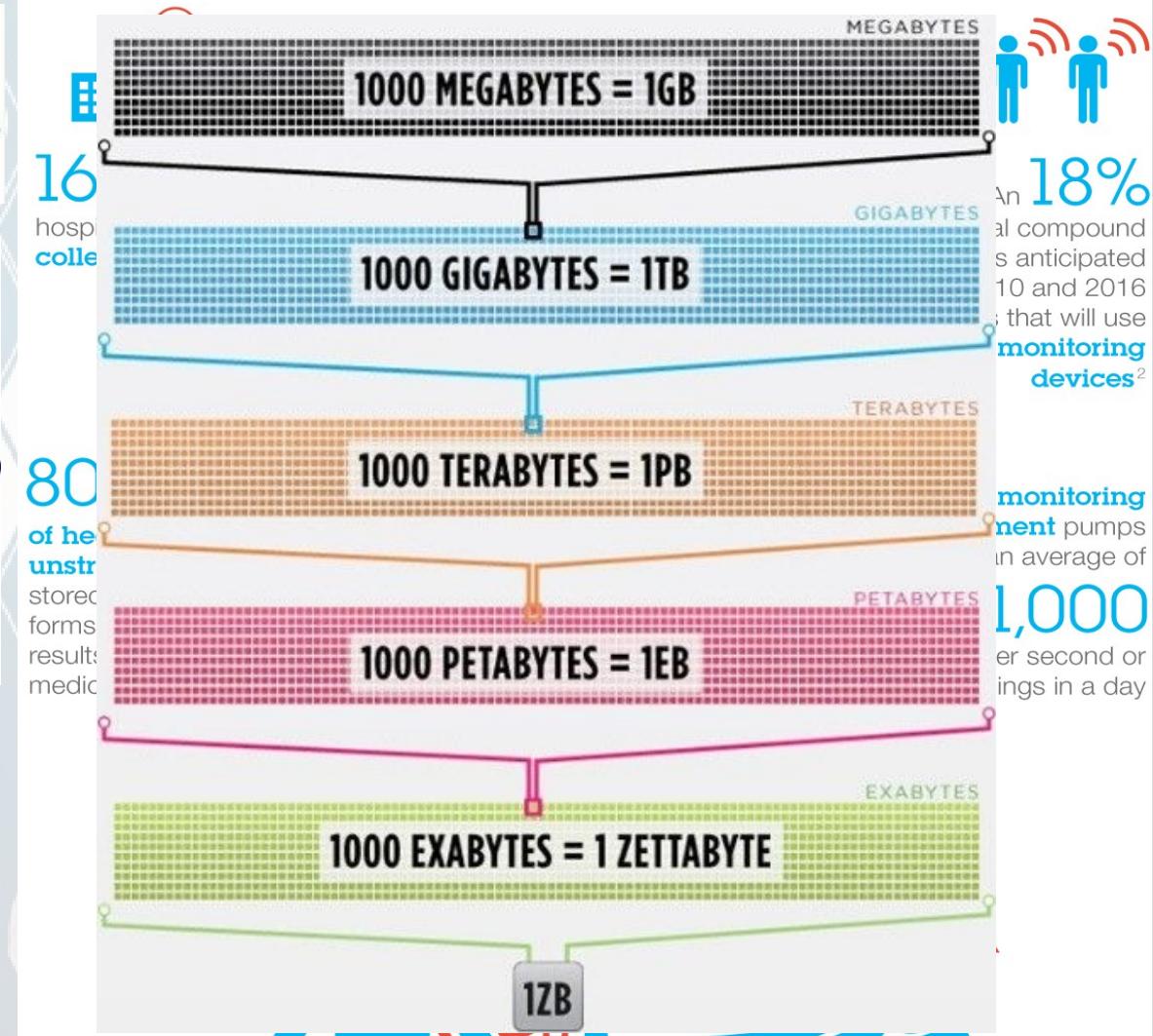
2020  
2,314  
EXABYTES

## TO PUT THAT INTO PERSPECTIVE, DATA CENTERS GLOBALLY

will only have enough room for an estimated

# 985 exabytes by 2020

meaning that almost two and a half times this capacity would be required to house all the healthcare data.



## **Big Data in Health Care**

## Generates Exabytes of Data

2,314

Exabytes in 2020

153

## Exabytes in 2013



Source: "Harnessing the Power of Data in Health."



## Search Engine Data



Pharmaceutical  
Research



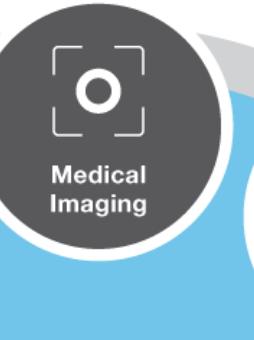
## Smartphones



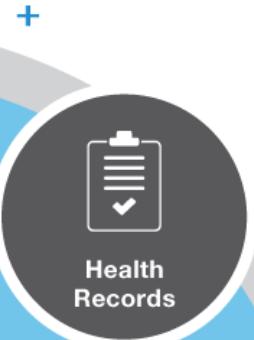
## Wearables



## Payor Records



## Medical Imaging



+

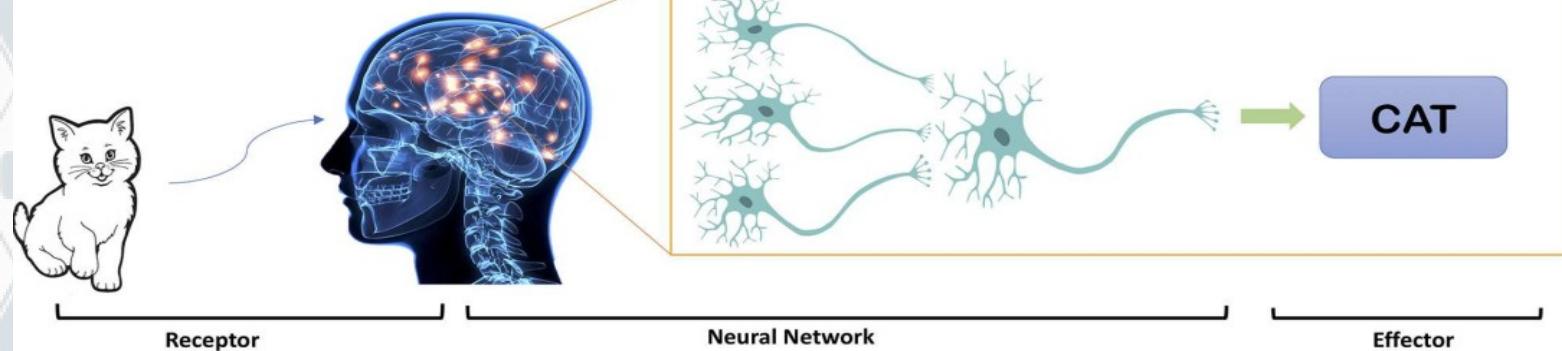
پردهی پنجم

AI  
in  
**Medicine/Healthcare**

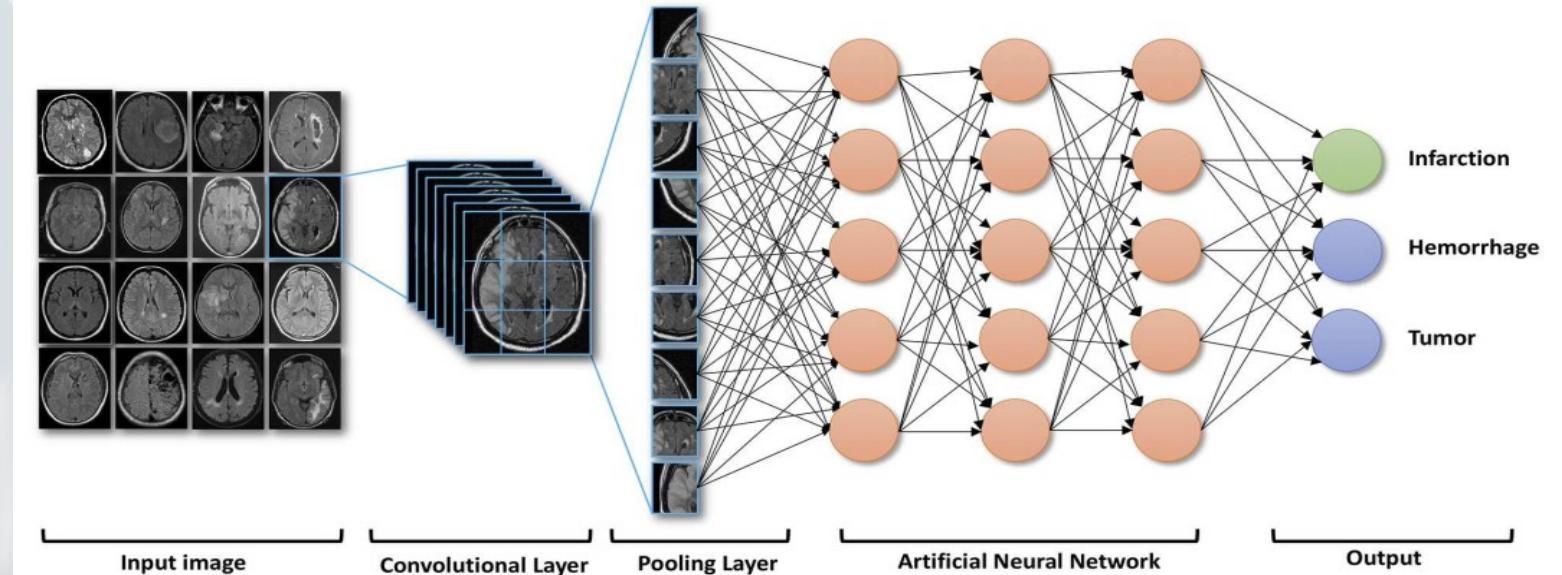


# Classification

## A Biological Neural Network



## B Computer Neural Network (Convolutional Neural Network)



# Classification -> interpretation



# Image2image transfer - style transfer

Input



Output



Input



Output



Input



Output



horse → zebra



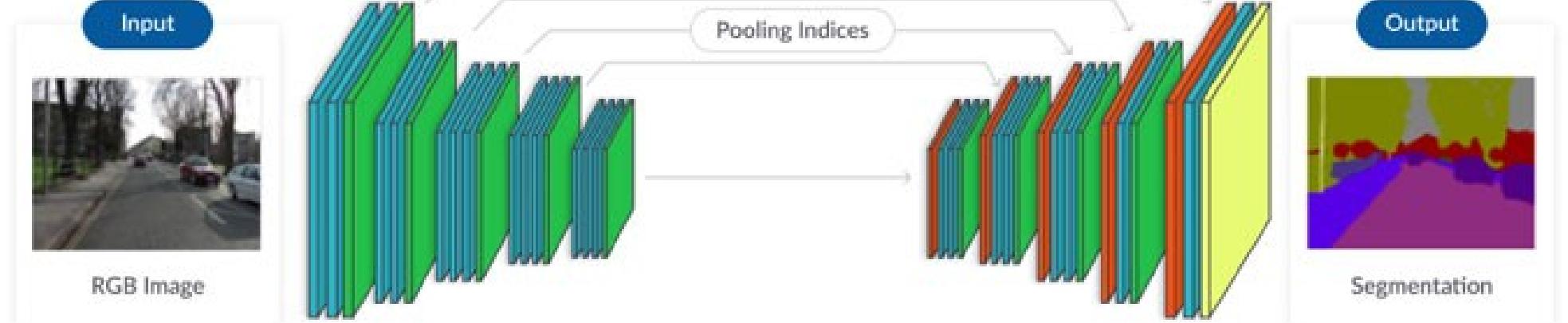
zebra → horse

# Image transfer - style transfer

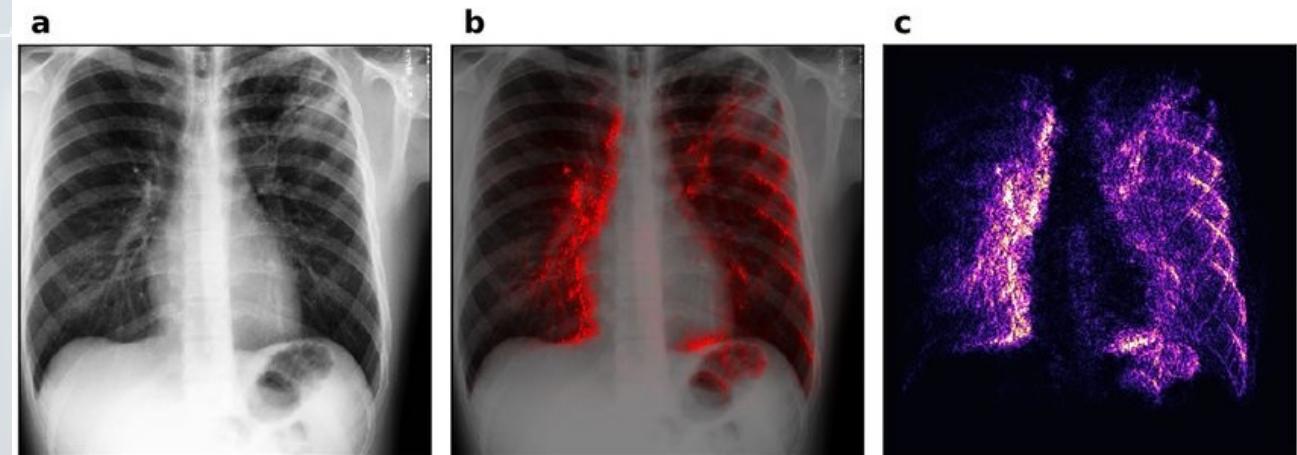
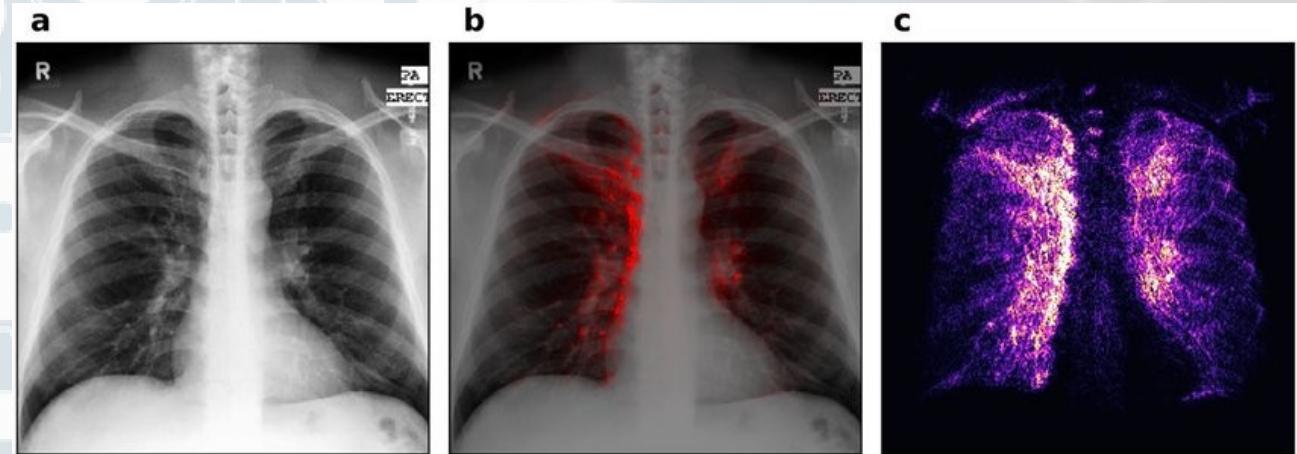
## ARTIFACTS REDUCTION

- Low Signal-To-Noise Ratio
- Motion Artifact
- Metal Artifact

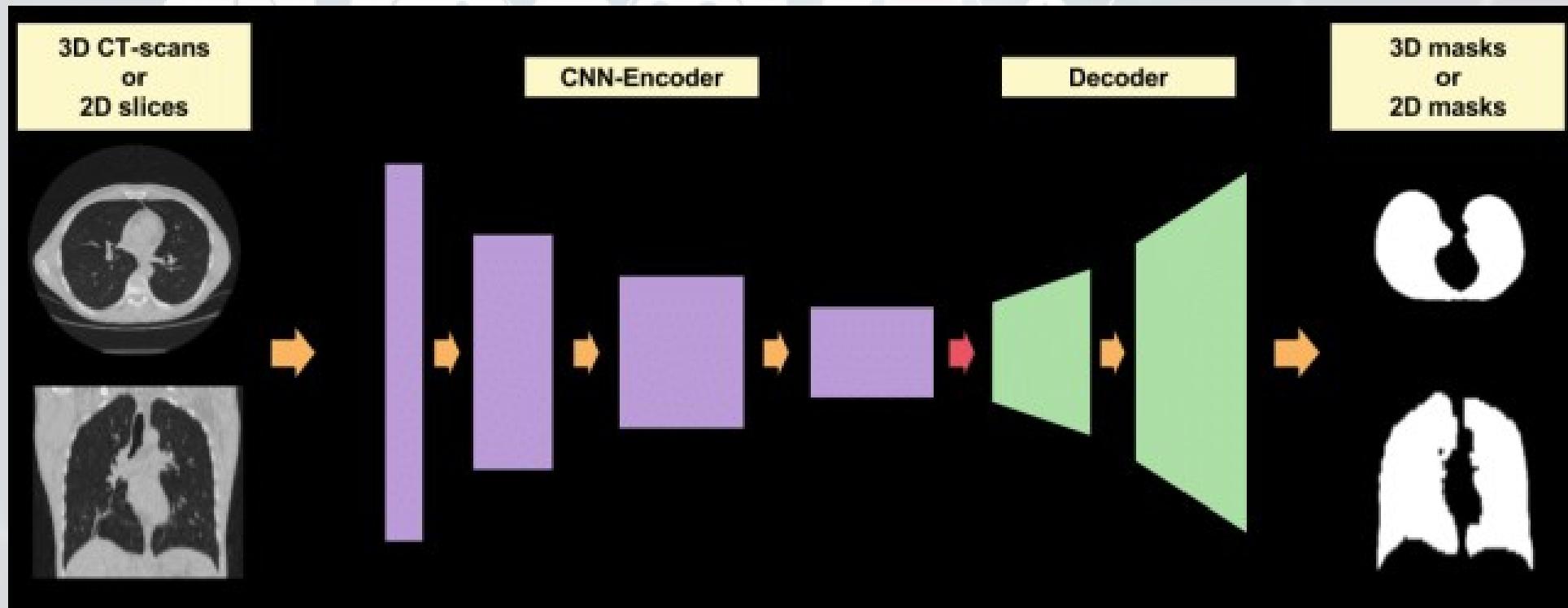
Convolutional Encoder-Decoder



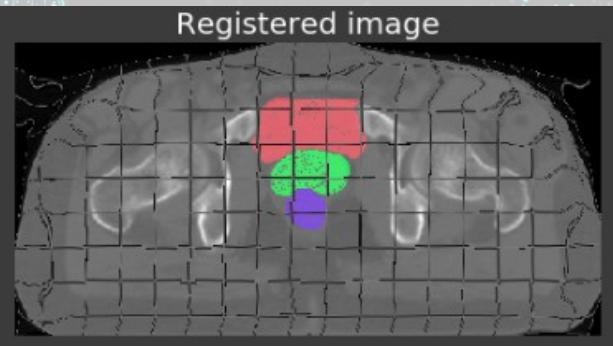
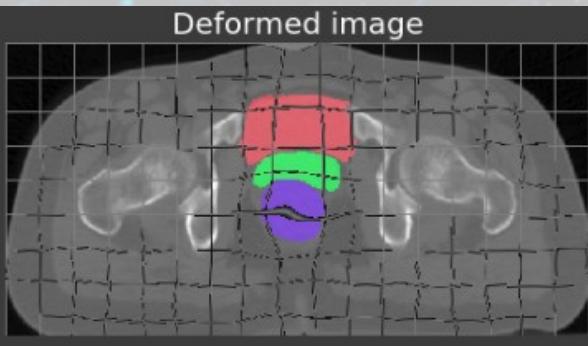
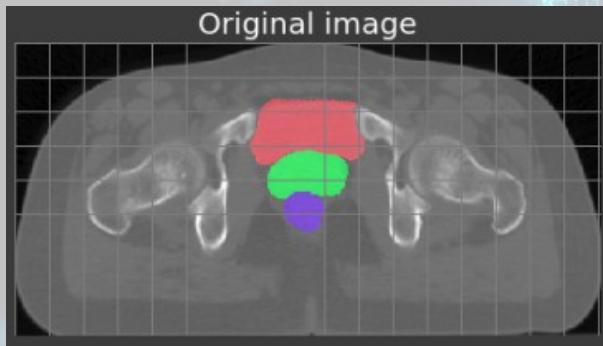
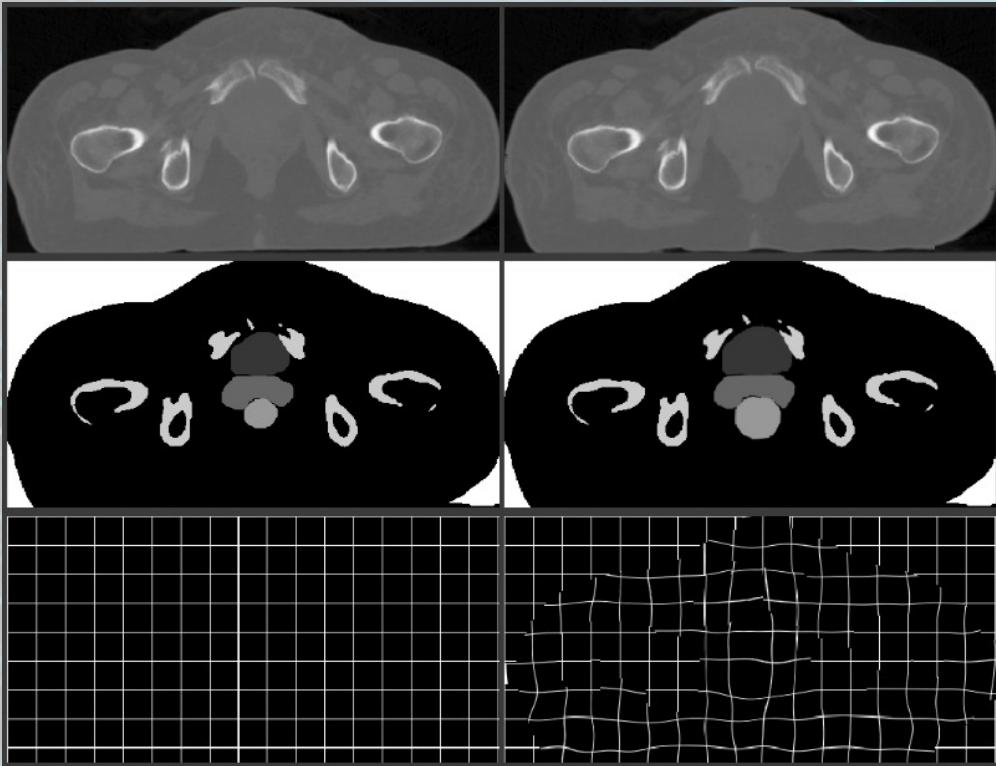
# Classification and interpretation

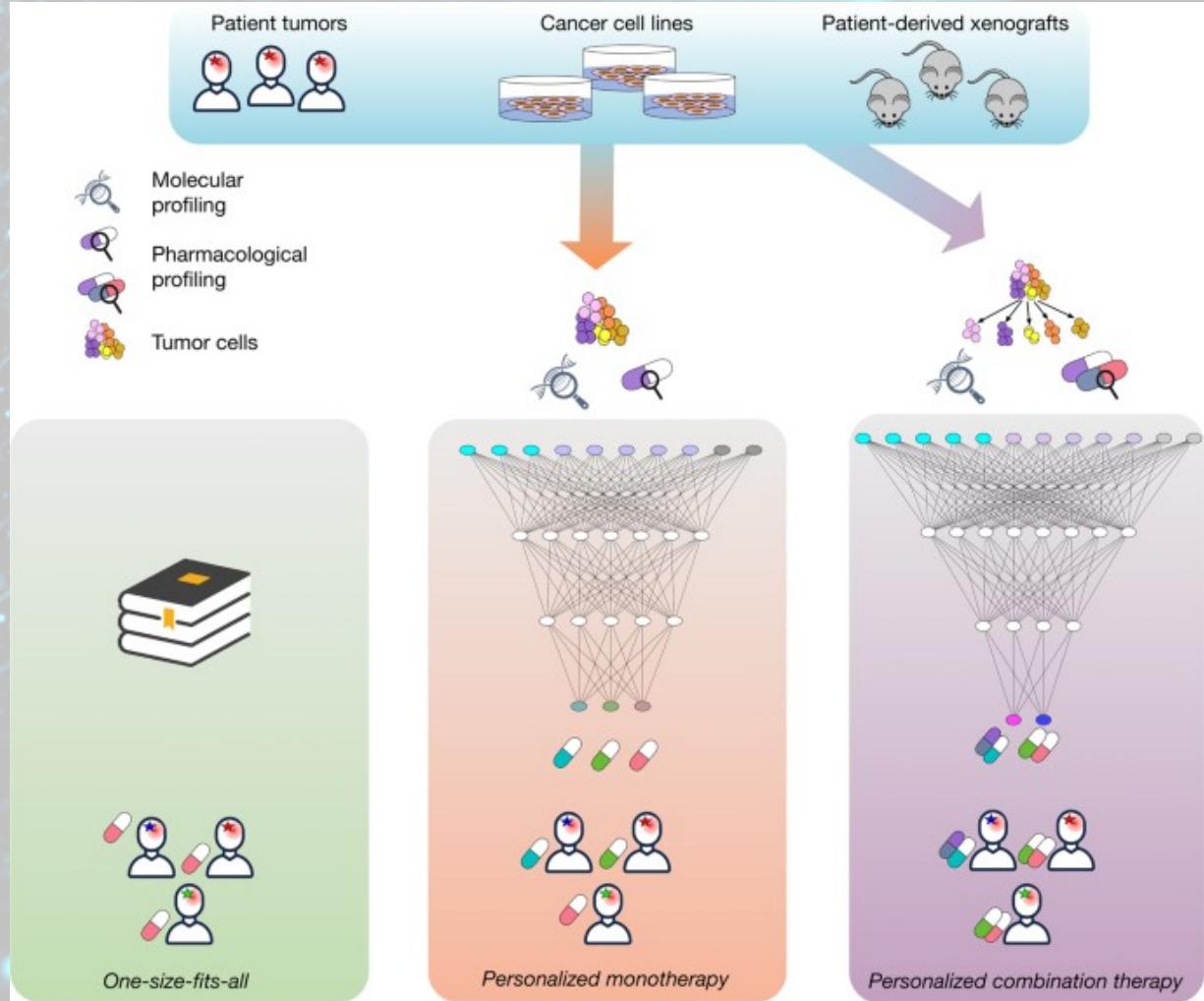
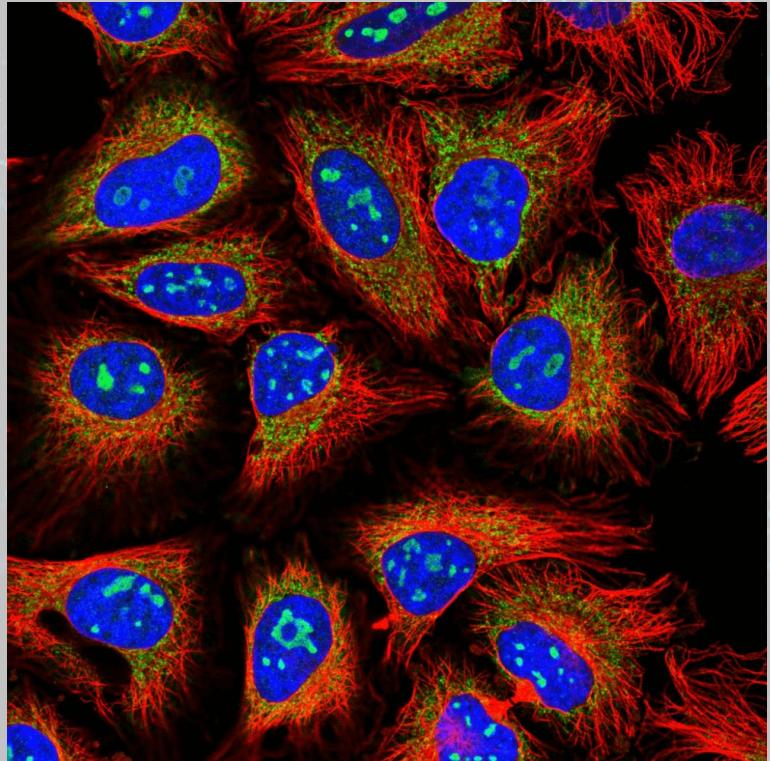


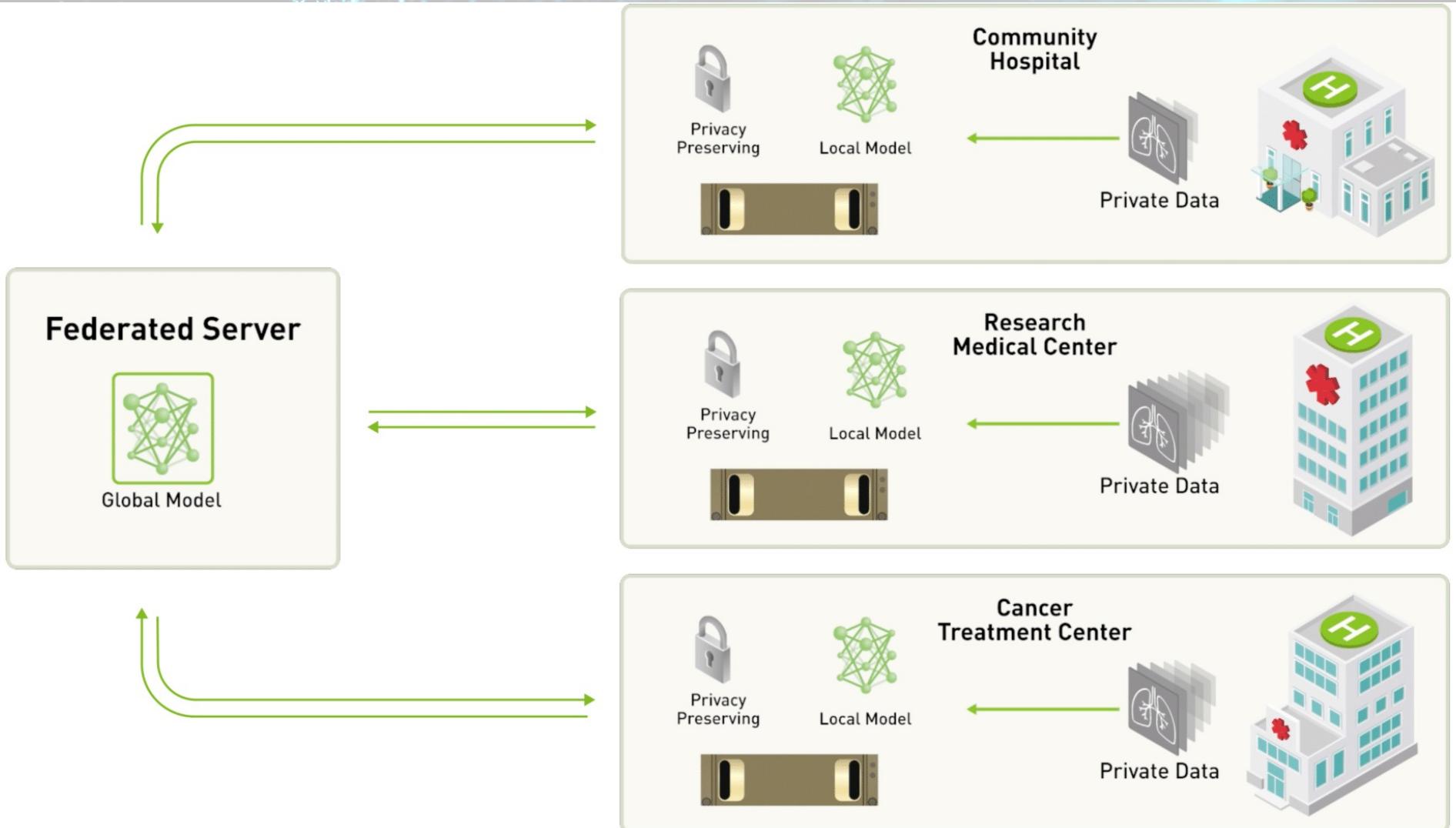
# Image segmentation



# IMAGE REGISTRATION







# Datasets

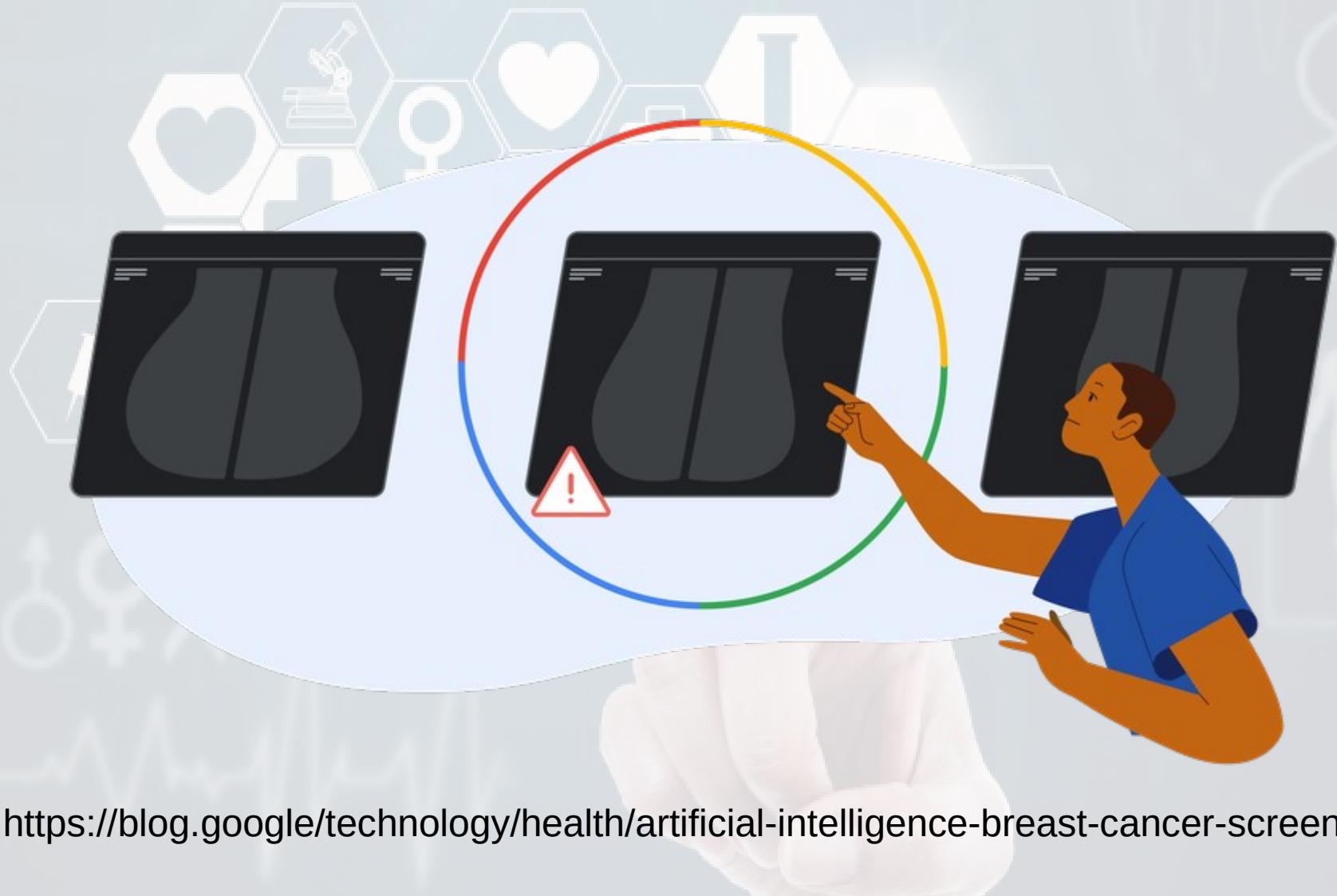


A short list of medical imaging data sets and repositories.

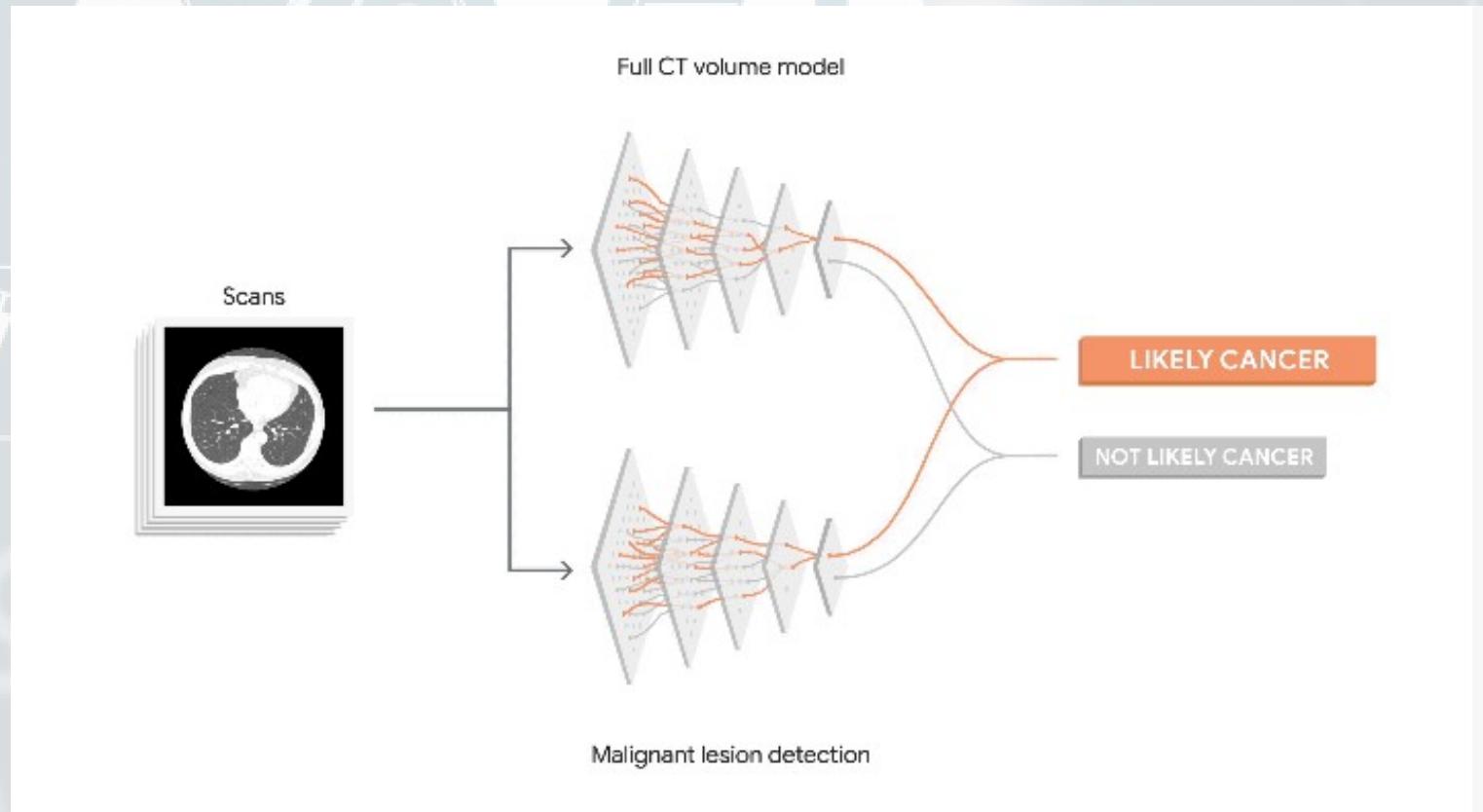
Name	Summary	Link
OpenNeuro	An open platform for sharing neuroimaging data under the public domain license. Contains brain images from 168 studies (4,718 participants) with various imaging modalities and acquisition protocols.	<a href="https://openneuro.org">https://openneuro.org</a> <sup>a</sup>
UK Biobank	Health data from half a million participants. Contains MRI images from 15,000 participants, aiming to reach 100,000.	<a href="http://www.ukbiobank.ac.uk/">http://www.ukbiobank.ac.uk/</a>
TCIA	The cancer imaging archive hosts a large archive of medical images of cancer accessible for public download. Currently contains images from 14,355 patients across 77 collections.	<a href="http://www.cancerimagingarchive.net">http://www.cancerimagingarchive.net</a>
ABIDE	The autism brain imaging data exchange. Contains 1114 datasets from 521 individuals with Autism Spectrum Disorder and 593 controls.	<a href="http://fcon_1000.projects.nitrc.org/indi/abide">http://fcon_1000.projects.nitrc.org/indi/abide</a>
ADNI	The Alzheimer's disease neuroimaging initiative. Contains image data from almost 2000 participants (controls, early MCI, MCI, late MCI, AD)	<a href="http://adni.loni.usc.edu/">http://adni.loni.usc.edu/</a>

<sup>a</sup> Data can be downloaded from the AWS S3 Bucket <https://registry.opendata.aws/openneuro>.

Name	Summary	Link
Grand-Challenges	Grand challenges in biomedical image analysis. Hosts and lists a large number of competitions	<a href="https://grand-challenge.org/">https://grand-challenge.org/</a>
RSNA Pneumonia Detection Challenge	Automatically locate lung opacities on chest radiographs	<a href="https://www.kaggle.com/c/rsna-pneumonia-detection-challenge">https://www.kaggle.com/c/rsna-pneumonia-detection-challenge</a>
HVSMR 2016	Segment the blood pool and myocardium from a 3D cardio-vascular magnetic resonance image	<a href="http://segchd.csail.mit.edu/">http://segchd.csail.mit.edu/</a>
ISLES 2018	Ischemic Stroke Lesion Segmentation 2018. The goal is to segment stroke lesions based on acute CT perfusion data.	<a href="http://www.isles-challenge.org/">http://www.isles-challenge.org/</a>
BraTS 2018	Multimodal Brain Tumor Segmentation. The goal is to segment brain tumors in multimodal MRI scans.	<a href="http://www.med.upenn.edu/sbia/brats2018.html">http://www.med.upenn.edu/sbia/brats2018.html</a>
CAMELYON17	The goal is to develop algorithms for automated detection and classification of breast cancer metastases in whole-slide images of histological lymph node sections.	<a href="https://camelyon17.grand-challenge.org/Home">https://camelyon17.grand-challenge.org/Home</a>
ISIC 2018	Skin Lesion Analysis Towards Melanoma Detection	<a href="https://challenge2018.isic-archive.com/">https://challenge2018.isic-archive.com/</a>
Kaggle's 2018 Data Science Bowl	Spot Nuclei. Speed Cures.	<a href="https://www.kaggle.com/c/data-science-bowl-2018">https://www.kaggle.com/c/data-science-bowl-2018</a>
Kaggle's 2017 Data Science Bowl	Turning Machine Intelligence Against Lung Cancer	<a href="https://www.kaggle.com/c/data-science-bowl-2017">https://www.kaggle.com/c/data-science-bowl-2017</a>
Kaggle's 2016 Data Science Bowl	Transforming How We Diagnose Heart Disease	<a href="https://www.kaggle.com/c/second-annual-data-science-bowl">https://www.kaggle.com/c/second-annual-data-science-bowl</a>
MURA	Determine whether a bone X-ray is normal or abnormal	<a href="https://stanfordmlgroup.github.io/competitions/mura/">https://stanfordmlgroup.github.io/competitions/mura/</a>



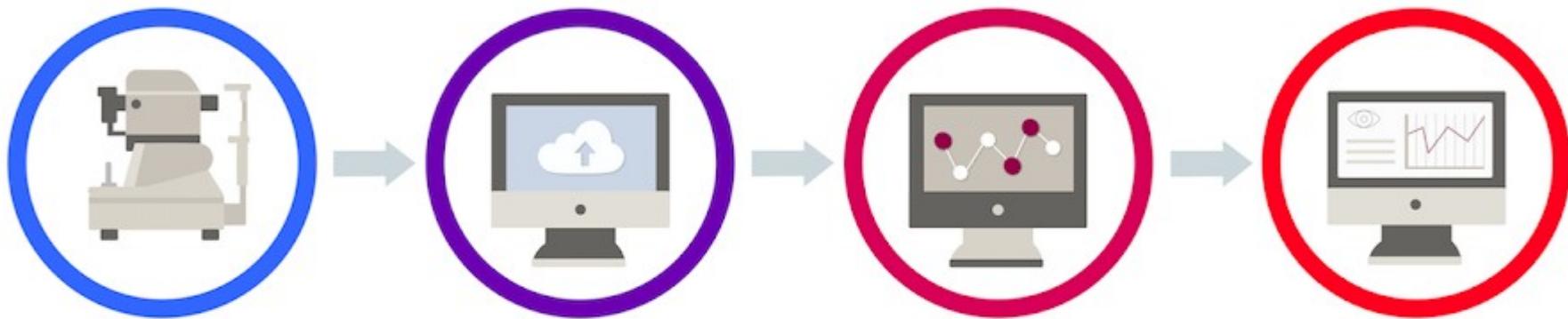
<https://blog.google/technology/health/artificial-intelligence-breast-cancer-screening/>



<https://www.blog.google/technology/health/lung-cancer-prediction/>



## Machine Learning Solution

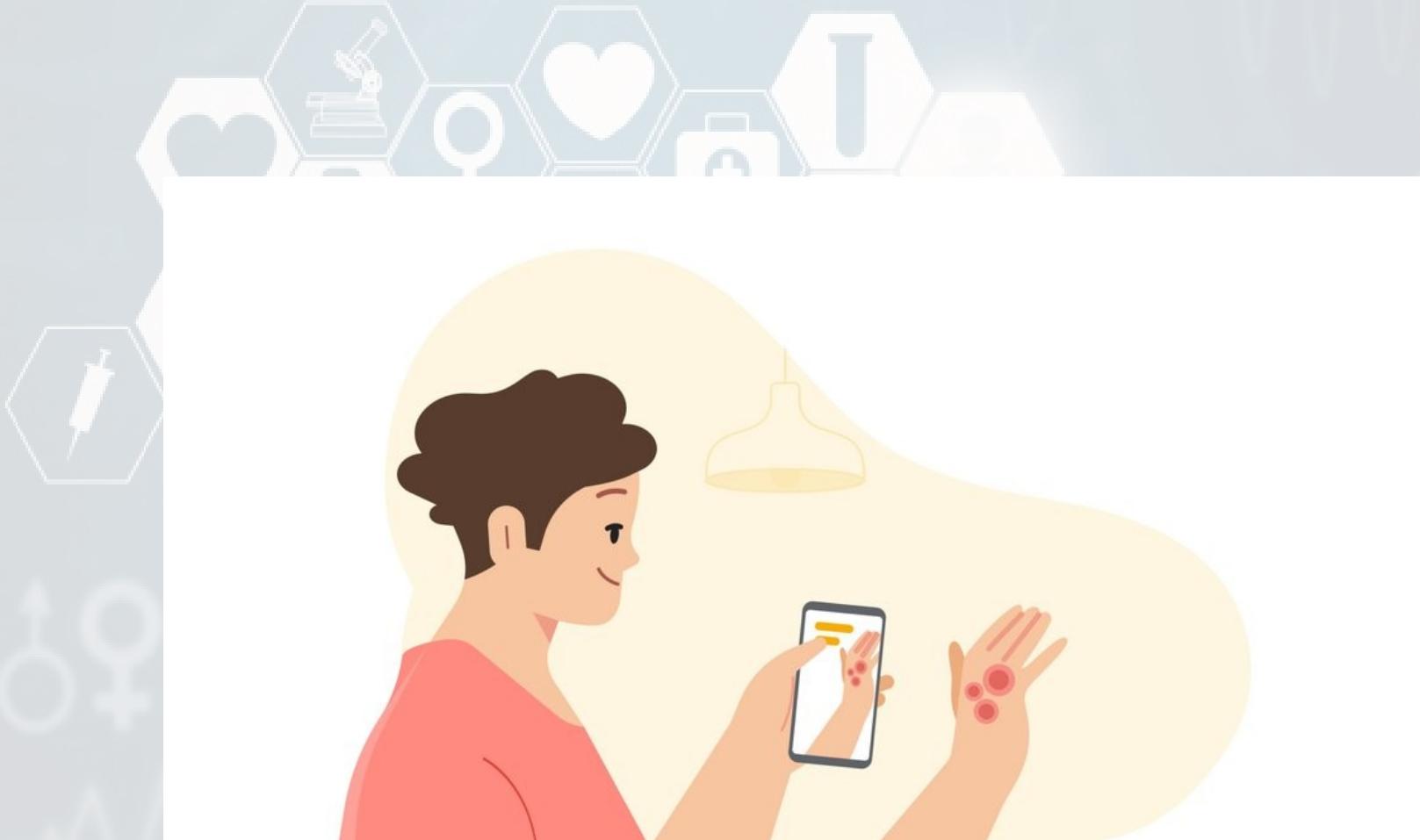


Patient imaged by  
trained staff using a  
fundus camera

Image uploaded to  
screening algorithm via  
management software

Automated machine  
learning screens for  
DR and DME

Screening  
results delivered

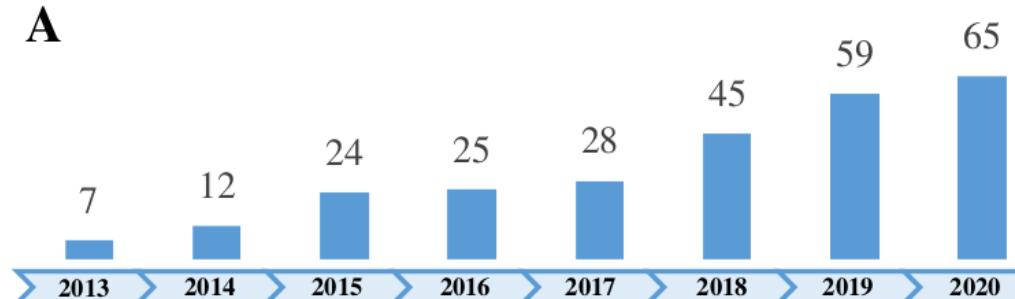
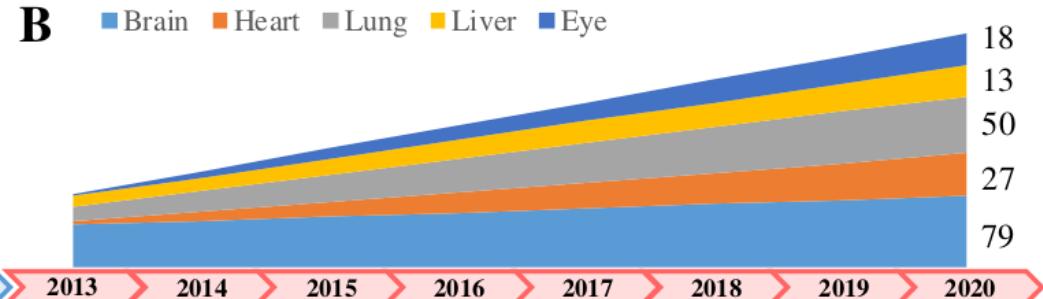
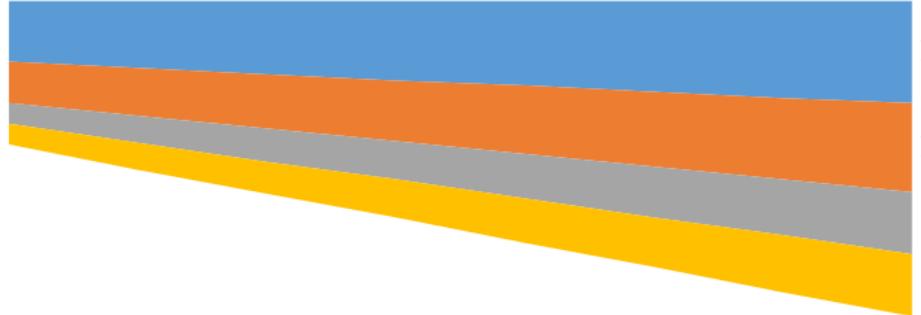


<https://blog.google/technology/health/ai-dermatology-preview-io-2021/>



Over the past 5 years  
AI base health companies received  
**a total of more than \$1.8 billion investments**  
in 446 separate transactions.

- Hot Market Trend 1: AI and ML
- Hot Market Trend 2: Blockchain
- Other Segments Still Gaining Momentum

**A****B****C****D**

■ Segmentation

■ Classification

■ Detection

■ Other

■ MRI ■ CT/CR/PET ■ Path. image ■ Other

**PathAI: More Accurate Cancer Diagnosis With AI - Cambridge, Massachusetts**

**Buoy Health: An Intelligent Symptom Checker - Boston, Massachusetts**

**Enlitic: AI Deep Learning For Actionable Insights - San Francisco, California**

**Freenome: Earlier Cancer Detection With AI - San Francisco, California**

**Beth Israel Deaconess Medical Center: Diagnosing Deadly Blood Diseases Faster - Boston, Massachusetts**

**Zebra Medical Vision: AI-Powered Radiology Assistant - Shefayim, Israel**

**BioXcel Therapeutic: AI In Biopharmaceutical Development - New Haven, Connecticut**

**BERG Health: Treating Rare Disease With AI - Framingham, Massachusetts**

**XtalPi: AI, Cloud-based Digital Drug Discovery - Cambridge, Massachusetts**

**Atomwise: Neural Network For Clinical Trials - San Francisco, California**

**Deep Genomics: Finding Better Candidates For Developmental Drugs - Toronto, Canada**

**BenevolentAI: Deep Learning For Targeted Treatment - London, England**

**Olive: Automating Healthcare's Most Repetitive Processes - Columbus, Ohio**

**Qventus: Real-time Patient Flow Optimization - Mountain View, California**

**Babylon Health: Increasing Access To Healthcare - New York, New York**

CloudMedX: Using Machine Learning For a Better Patient Journey - San Francisco, California

Cleveland Clinic: Personalized Healthcare Plans With AI - Cleveland, Ohio

Johns Hopkins Hospital: Faster Hospital Visits, Courtesy of AI - Baltimore, Maryland

Tempus: a Massive Data Library For Personalized Health - Chicago, Illinois

KenSci: AI For Hospital Risk Prediction - Seattle, Washington

Proscia: Looking At The Data Behind The Medical Image - Philadelphia, Pennsylvania

H2O.ai: AI For Data Throughout The Health System - Mountain View, California

IBM: Watson's Side Gig Helping Hospitals - Armonk, N.Y.

Google DeepMind Health: Alerting Doctors When Patient's are in Trouble - London, England

IcarbonX: Data and the 'Digital Life' - Shenzhen, China

Vicarious Surgical: Virtual Reality-enabled Robotics For Surgery - Charlestown, Massachusetts

Auris Health: AI Robots Revolutionizing Endoscopy -Accuray

Accuray: Precision Robotic Treatment For Treating Cancer - Sunnyvale, California

Intuitive: Pioneering Robotic Surgery - San Francisco, California

**Medical Decathlon, Liver Seg: 10 GB**

**Medical Ebooks: 20 GB**

**Human Protein Atlas - Single Cell Classification: 160 GB : award \$37000 and \$25000**

**Ultrasound Nerve Segmentation: 2.5 GB : \$100000**

**COVID-19 Open Research Dataset Challenge (CORD-19) : 7 GB**

**Ocular Disease Recognition: 2 GB**

**Retinal OCT Images (optical coherence tomography): 11 GB**

**Medical Masks: 6 GB**

**Medical Speech, Transcription, and Intent: 5 GB**

**Metastatic Tissue Classification – PatchCamelyon: 7 GB**

**Skin Lesion Images for Melanoma Classification: 9 GB**

**MeDAL Dataset: 7GB**

**BraTS2020 Dataset: 4 GB**

**Medical Decathlon, Hepatic Vessel Segmentation: 36 GB**

**Lung Vessel Segmentation: 3 GB**



پرده‌ی آخر

Let's begin!







“Without big data analytics, companies are blind and deaf, wandering out onto the web like deer on a freeway.” – Geoffrey Moore

“Hiding within those mounds of data is knowledge that could change the life of a patient, or change the world.” – Atul Butte



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