

# An Introduction to Artificial Intelligence (AI) in Dentistry



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UNIVERSITY *of* MARYLAND  
SCHOOL OF DENTISTRY

DEPARTMENT OF ONCOLOGY  
AND DIAGNOSTIC SCIENCES

Division of Artificial Intelligence Research

# Disclosures

- No conflicts of interests or financial disclosures relevant to the contents of the presentation.
- AI methods and softwares, and other diagnostic or treatment strategies presented in this lecture may include the off-label use of FDA-approved-medications, medical devices or softwares.

## Patents/Copyrights:

- Copyright: granted status (AS-2022-117 filed by UMB)
  - Title: The Use of Artificial Intelligence for Dental/Medical Image Detection of Head & Neck Pathology
  - Inventors: Sultan, Price

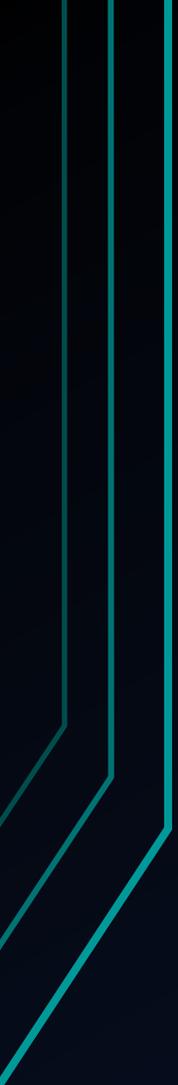
## Consulting for Pharmaceutical Companies:

- Vigilant Pharmaceuticals (OncAlert® RAPID)
- Galt Pharmaceuticals Medical Affairs (Oravig Regional Advisory Leadership Council, ORAL-C)

## Learning Objectives

1. Be able to provide a definition for Artificial Intelligence (AI)
2. Understand the History of AI
3. Be able to recognize the main components of *AI Classification*
4. Be able to provide examples of Applications of AI in Medicine, Pathology, and Dentistry
5. Be able to identify the current Limitations and Ethical Considerations of AI
6. Be able to provide examples of Future Applications of AI in Healthcare

Can you beat the AI? Audience versus AI Challenge



[https://youtu.be/JcoocHGDVtI?si=gm\\_HoR3GouwINzyk](https://youtu.be/JcoocHGDVtI?si=gm_HoR3GouwINzyk)

## Will Artificial Intelligence Replace Radiologists?

*Curtis P. Langlotz, MD, PhD*

From the Department of Radiology, Stanford University, 300 Pasteur Dr, Room H1330D, Stanford, CA 94305. Received April 9, 2019; revision requested April 16; revision received April 16; accepted April 17. Address correspondence to the author (e-mail: [langlotz@stanford.edu](mailto:langlotz@stanford.edu)).

Conflicts of interest are listed at the end of this article.

*Radiology: Artificial Intelligence* 2019; 1(3):e190058 • <https://doi.org/10.1148/ryai.2019190058> • Content code: 

“As we are lifted by the latest AI bubble, “Will AI replace radiologists?” is the wrong question. The right answer is: Radiologists who use AI will replace radiologists who don’t.”

**Will AI replace dentists?**

THUMBNAILS  MORE GALLERIES



3/5

## FDA-cleared dental robot

The new technology is a game-changer for dentistry as medicine evolves. The robotic arm is attached that has a plan programmed in and the dentist is always in charge of the drill and can always go back and change the treatment plan if needed. (Photo: CBS Austin)

 [READ THE ARTICLE](#)

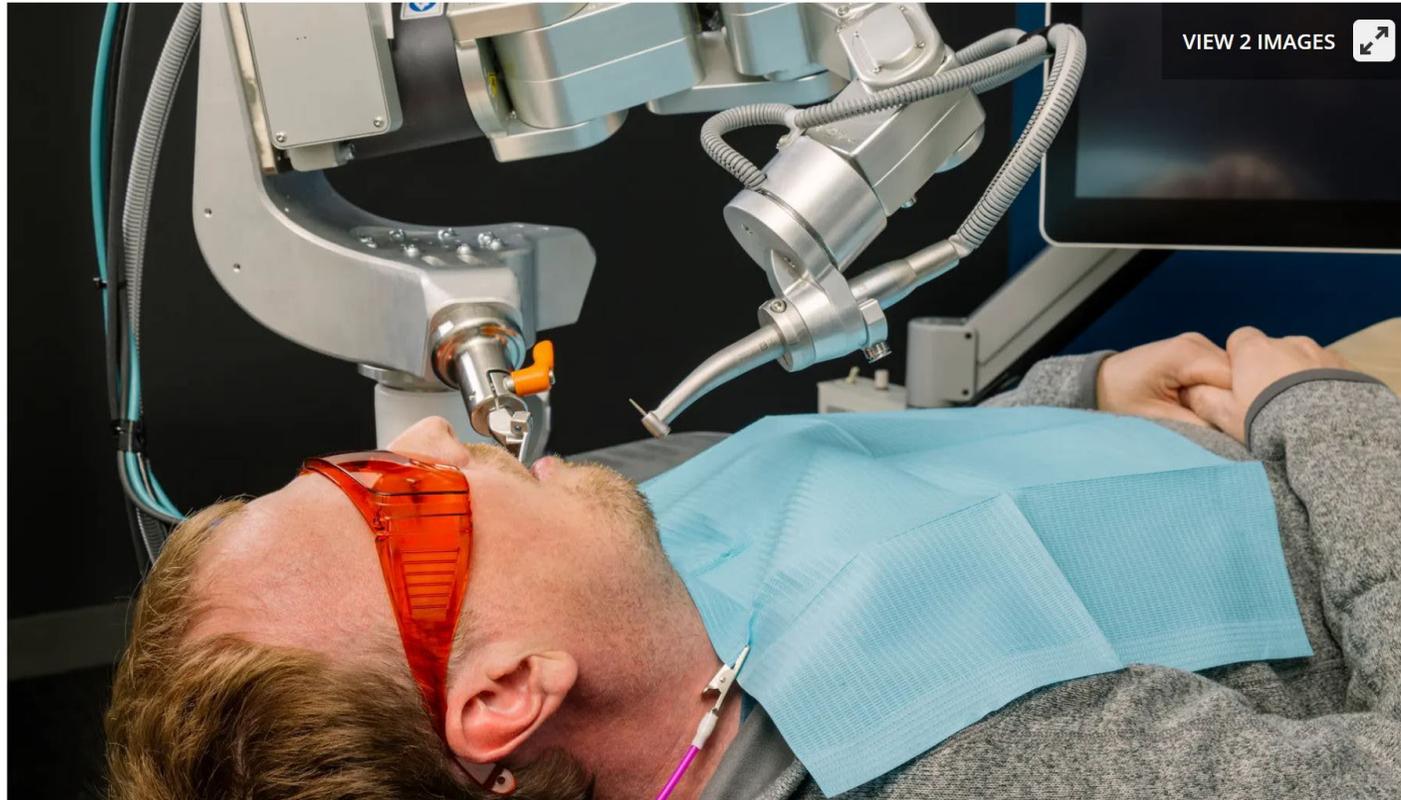
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WELLNESS & HEALTHY LIVING

# Fully-automatic robot dentist performs world's first human procedure

By Loz Blain  
July 31, 2024



Fully-automatic robot dentist performs world's first human procedure



2/2 The dental robot appears to need far less space in your mouth than a human Perceptive



<https://www.youtube.com/shorts/O0D8kPHGwHQ>



[https://www.youtube.com/shorts/Im62iVYF](https://www.youtube.com/shorts/Im62iVYFwbs)  
[wbs](https://www.youtube.com/shorts/Im62iVYFwbs)

## Learning Objectives

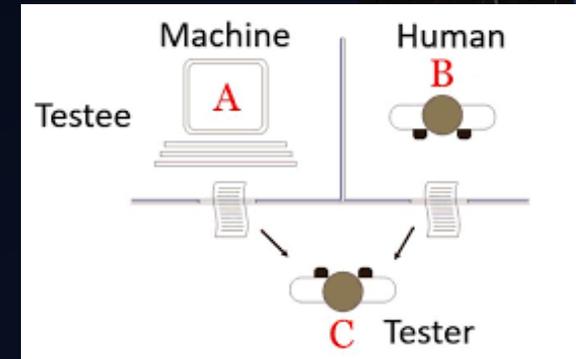
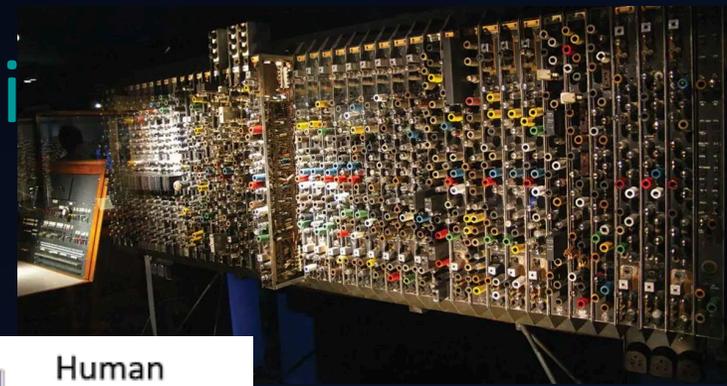
1. Be able to provide a definition for Artificial Intelligence (AI)

"AI is technology that enables computers and machines to **simulate** or **mimic** human learning, comprehension, problem solving, decision making, creativity and autonomy"



# Major Events in AI Timeline or “Turing Poi

- 1935: Alan Turing invented “Turing Machine”
- 1948: Alan Turing coins “Intelligent Machinery”
- 1950: Alan Turing introduces the “Turing Test”
- 1952-1956: the birth of AI
- 1956: AI gained its official name
- 1956-1974: The golden years (computers were solving algebra word problems, proving theorems in geometry, learning to speak English)
- 1974-1980: first AI winter (lack of funding due to high costs)
- 1980-1987: the rise of expert system and fifth generation computers
- 1987-1993: the second AI winter (technology was not ready)
- 1993-2011: AI succeeded due to increased speed and power
- 2011-present: Deep learning and Big Data



TECHNOLOGY

# Google's AI passed a famous test – and showed how the test is broken

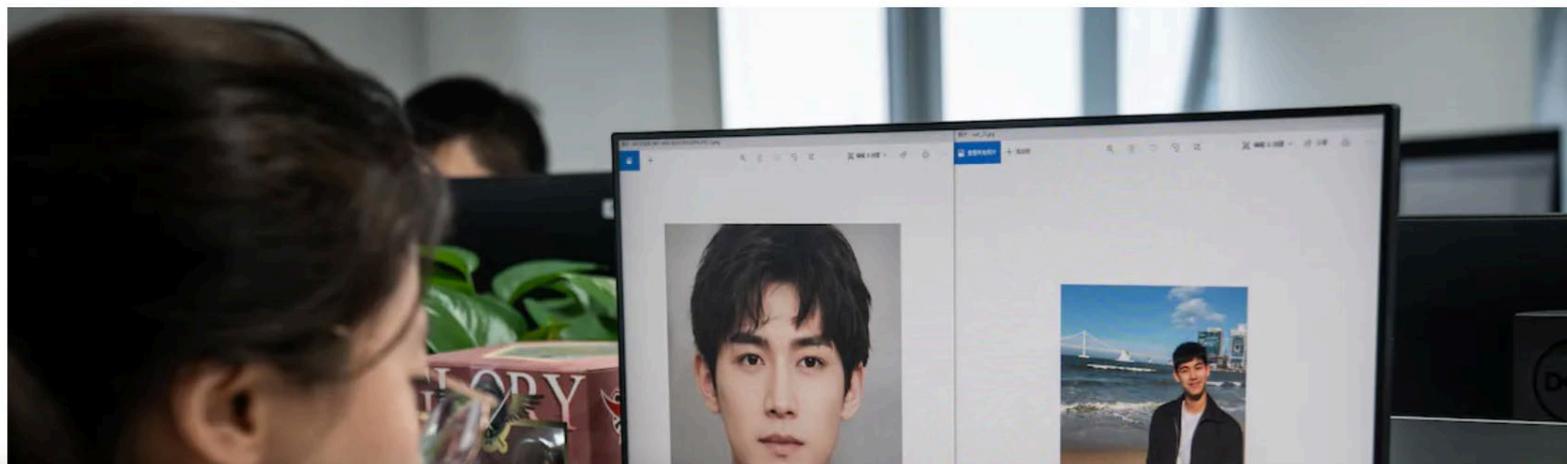
The Turing test has long been a benchmark for machine intelligence. But what it really measures is deception.



Analysis by [Will Oremus](#)

Staff writer

June 17, 2022 at 7:00 a.m. EDT



MOST

# History of AI

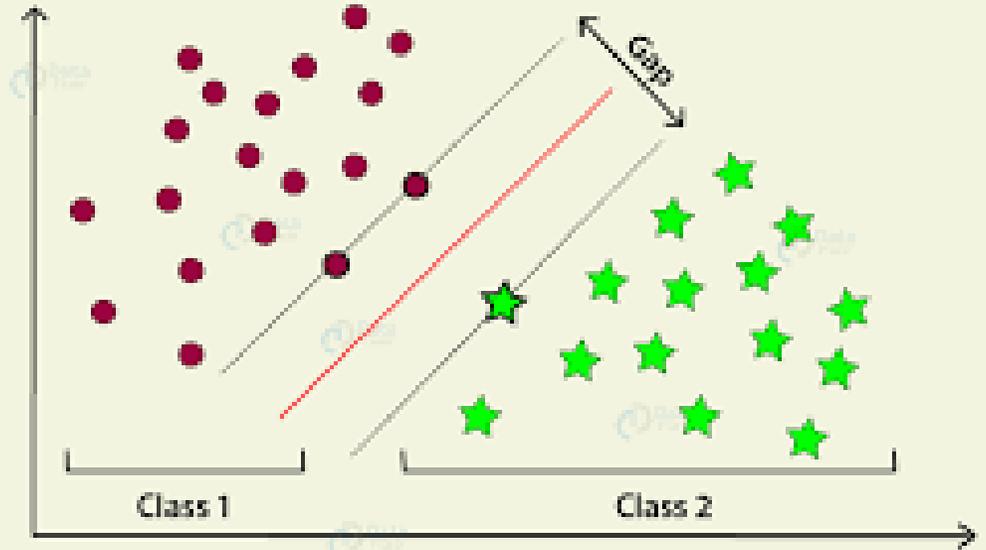
Dartmouth Summer Research Conference on Artificial Intelligence

Behavior-based robotics  
Brooks, R. A. robust layered

Condit

- *machine learning algorithm*
- *uses supervised learning models*
- *determine boundaries between data points based on predefined classes, labels, or outputs*

## Introduction to SVM



2016.

ResNet

He K. Zhang X. Ren S. et al.

Programming a computer for playing chess



Shannon, Claude E. "XXII. Programming a computer for playing chess." Philosophical magazine 41.314 (1950): 256-275.

Pattern Recognition



Uhr, Leonard, and Charles Vossler. "Pattern recognition program that evaluates and presents at the 9-11, 1951, we IRE-AIEEACM conference. AC

ELIZA - human computer conversation



Weizenbaum, Joseph. "ELIZA-a computer program for the study of natural language communication between man and machine." Communications of the ACM 9.1 (1966): 36-45.

Heuristic Search



Let in dis hes UN SC

Email



Machine Learning Model



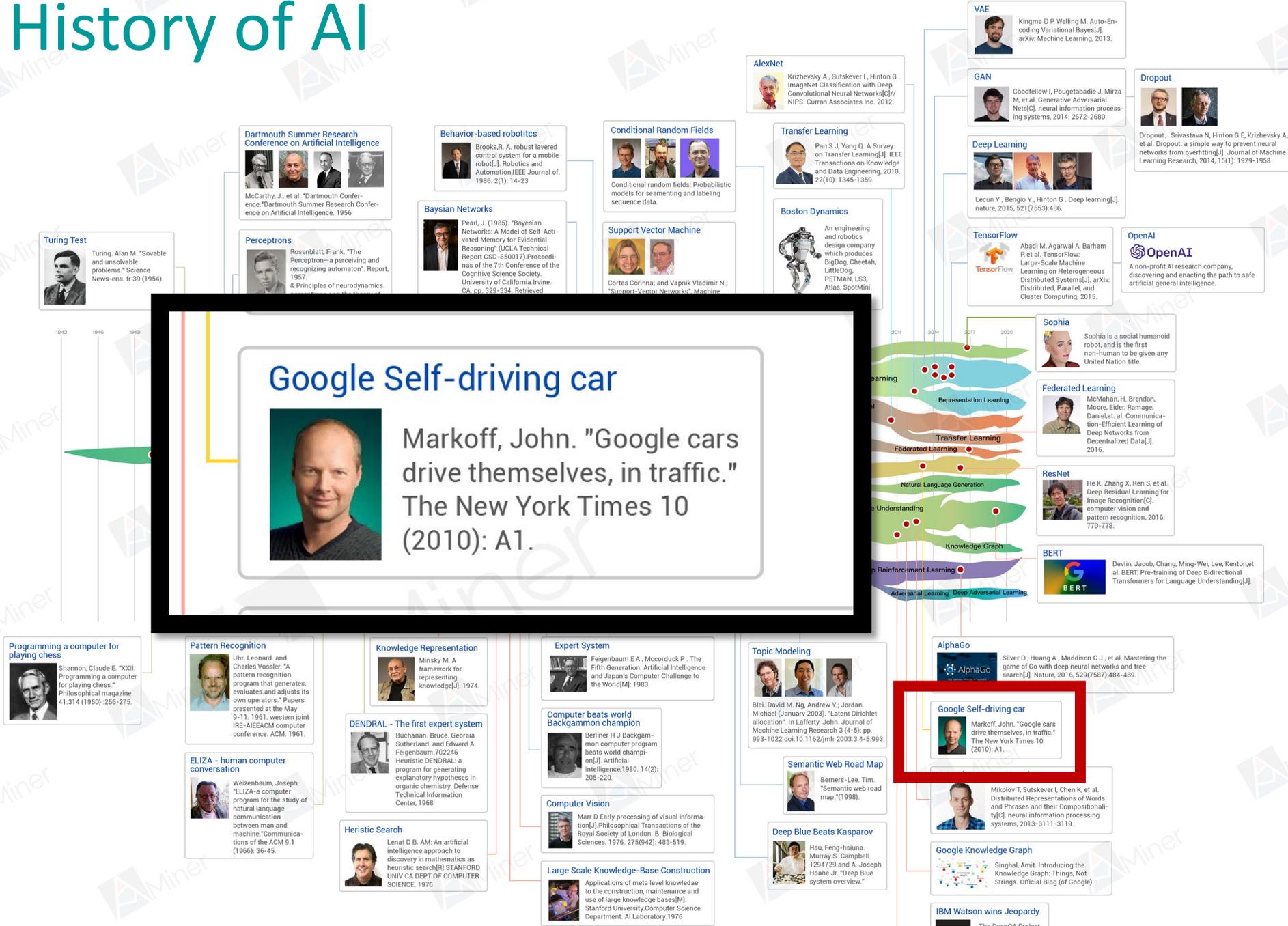
Spam



Not Spam



# History of AI

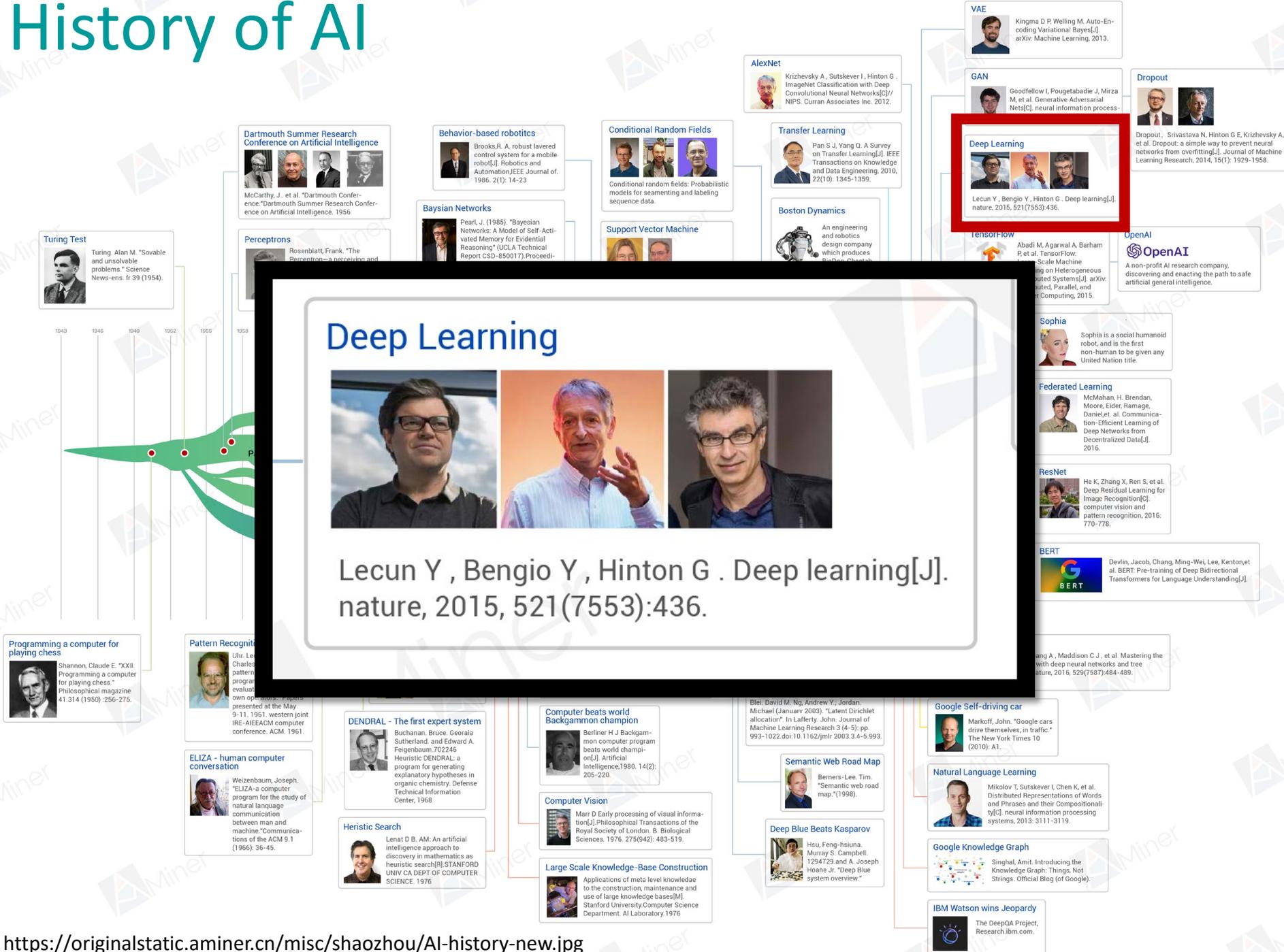


**Google Self-driving car**



Markoff, John. "Google cars drive themselves, in traffic." The New York Times 10 (2010): A1.

# History of AI



# History of AI

**Turing Test**  
Turing Alan M. "Solvable and unsolvable problems." Science News-ens. fr 39 (1954).



1943 1946 1949 1952

**Programming a computer for playing chess**  
Shannon, Claude E. "XXII. Programming a computer for playing chess." Philosophical magazine 41.314 (1950): 256-275.



**Dartmouth Summer Research Conference on Artificial Intelligence**  
McCarthy, J., et al. "Dartmouth Conference." Dartmouth Summer Research Conference on Artificial Intelligence. 1956.



**Behavior-based robotics**  
Brooks, R. A. "A robust layered control system for a mobile robot." Robotics and Automation. IEEE Journal of, 1986. 2(1): 14-23.



**Conditional Random Fields**  
Conditional random fields: Probabilistic models for segmenting and labeling sequence data.



**AlexNet**  
Krizhevsky A., Sutskever I., Hinton G. ImageNet Classification with Deep Convolutional Neural Networks[C]// NIPS. Curran Associates Inc. 2012.



**Transfer Learning**  
Pan S. J., Yang Q. A Survey on Transfer Learning[J]. IEEE Transactions on Knowledge and Data Engineering, 2010, 22(10): 1345-1359.



**VAE**  
Kingma D P, Welling M. Auto-Encoding Variational Bayes[J]. arXiv: Machine Learning, 2013.



**GAN**  
Goodfellow I, Pougetabadie J, Mirza M, et al. Generative Adversarial Nets[C]. neural information processing systems, 2014: 2672-2680.



**Deep Learning**  
Lecun Y., Bengio Y., Hinton G. Deep learning[J]. nature, 2015, 521(7553): 436.



**Dropout**  
Srivastava N, Hinton G E, Krizhevsky A, et al. Dropout: a simple way to prevent neural networks from overfitting[J]. Journal of Machine Learning Research, 2014, 15(1): 1929-1958.



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## Saudi Arabia First Country to Grant a Robot Citizenship

Announcement that advanced lifelike humanoid robot Sophia was made a Saudi citizen came at the Future Investment Initiative conference in Riyadh



**Sophia**  
Sophia is a social humanoid robot, and is the first non-human to be given any United Nation title.



**McMahan, H. Brendan, Moore, Eider, Ramage, Daniel, et al. Communication-Efficient Learning of Deep Networks from Decentralized Data[J]. 2016.**



**ResNet**  
He K, Zhang X, Ren S, et al. Deep Residual Learning for Image Recognition[C]. computer vision and pattern recognition, 2016: 770-778.



**BERT**  
Devlin, Jacob, Chang, Ming-Wei, Lee, Kenton, et al. BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding[J].



**AlphaGo**  
Silver D., Huang A., Maddison C. J., et al. Mastering the game of Go with deep neural networks and tree search[J]. Nature, 2016, 529(7587): 484-489.

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"Google cars lives, in traffic." The Times 10

**Word2Vec**  
Mikolov T., Sutskever I., Chen K., et al. Distributed Representations of Words and their Compositional-neral information processing systems, 2013: 3111-3119.

**Google Knowledge Graph**  
Singhal, Amit. Introducing the Knowledge Graph: Things, Not Strings. Official Blog (of Google).



**IBM Watson wins Jeopardy**  
The DeepQA Project, Research.ibm.com.



**Heuristic Search**  
Lenat D B. AM: An artificial intelligence approach to discovery in mathematics as heuristic search[R]. STANFORD UNIV CA DEPT OF COMPUTER SCIENCE. 1976.



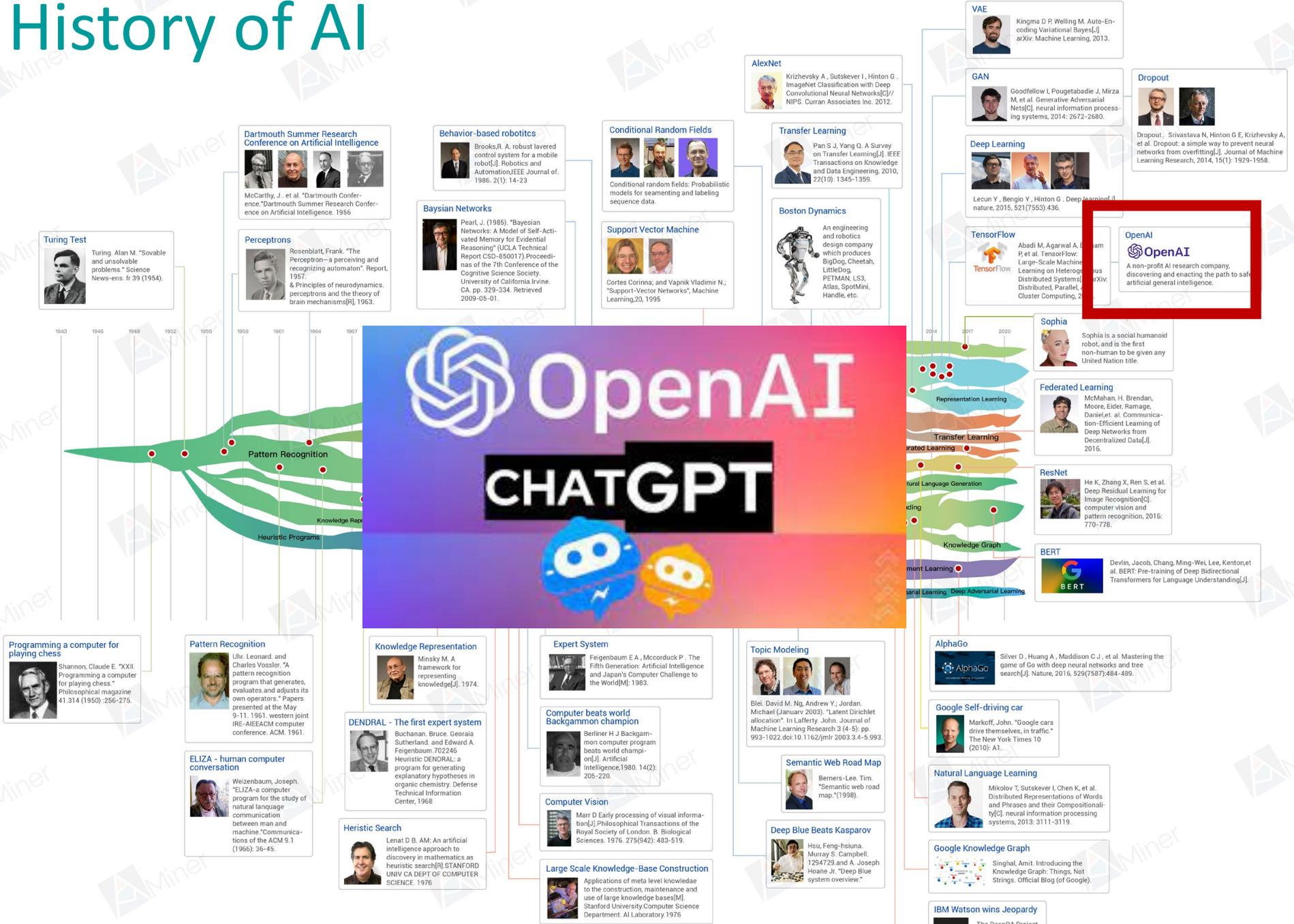
**Large Scale Knowledge-Base Construction**  
Applications of meta level knowledge to the construction, maintenance and use of large knowledge bases[J]. Stanford University Computer Science Department. AI Laboratory 1976.



**Deep Blue Beats Kasparov**  
Hsu, Feng-hsiun, Murray S, Campbell, Hoane Jr. "Deep Blue system overview."



# History of AI





r/technews

by wewewawa 9 days ago

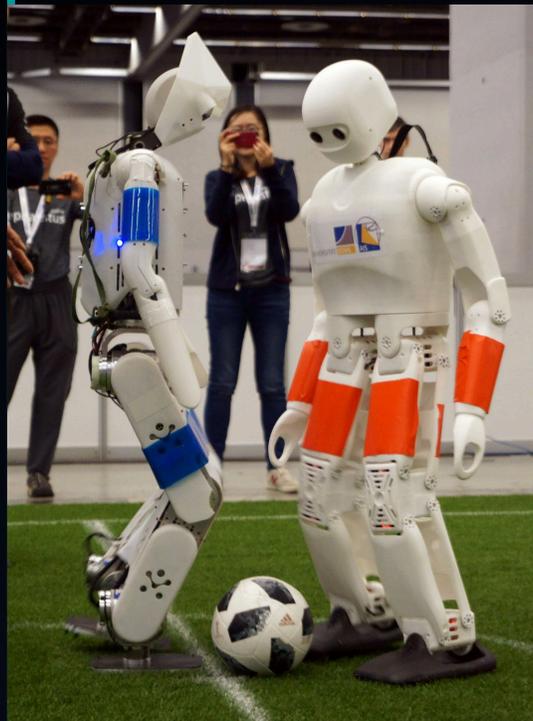


**The newest version of ChatGPT passed the US medical licensing exam with flying colors — and diagnosed a 1 in 100,000 condition in seconds**

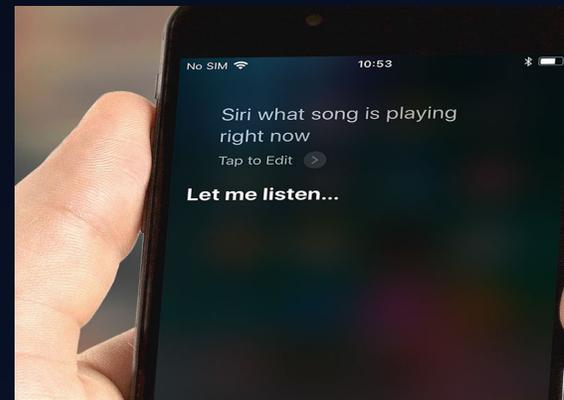


insider

Open



# Where are we now?





## Prompt

## ChatGPT output

## GPT-4 output

Patient education

Explain high blood pressure in simple terms.

Create a patient-friendly educational handout on hypertension, including an overview of the condition, risk factors, symptoms, potential complications, and management strategies.

Reviewing medical research

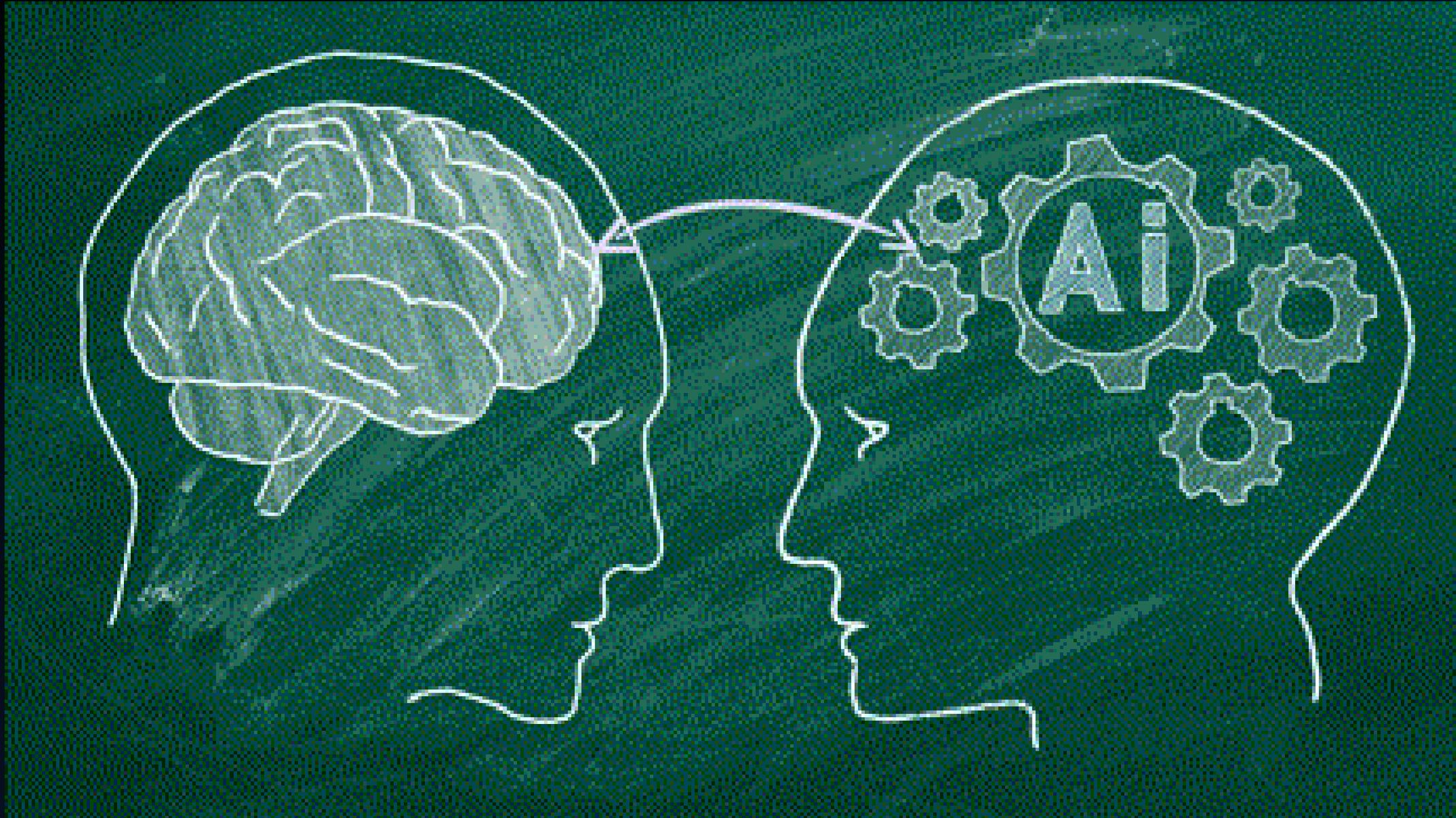
Tell me about the benefits of exercise for mental health.

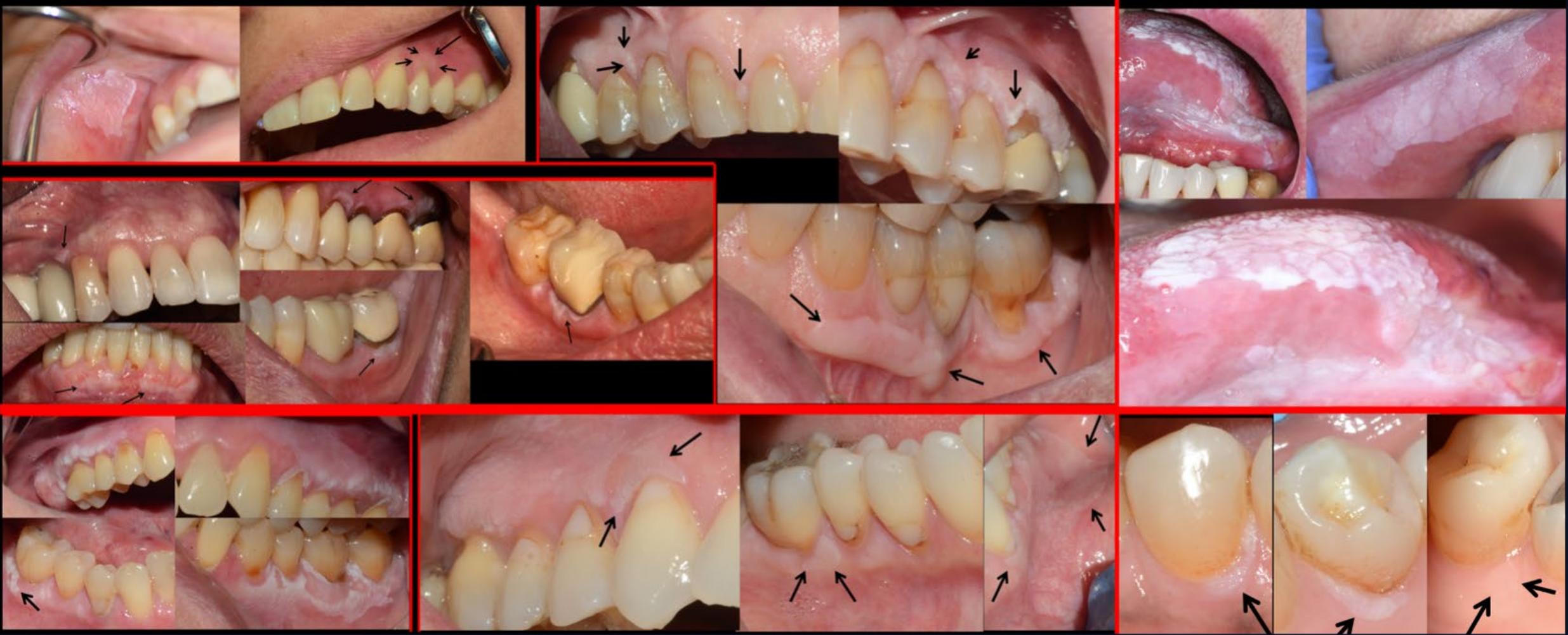
Summarize recent research findings on the relationship between physical activity and mental health outcomes, including potential mechanisms, types of exercise, and recommendations for various populations.

Clinical case scenario

Describe a patient with pneumonia.

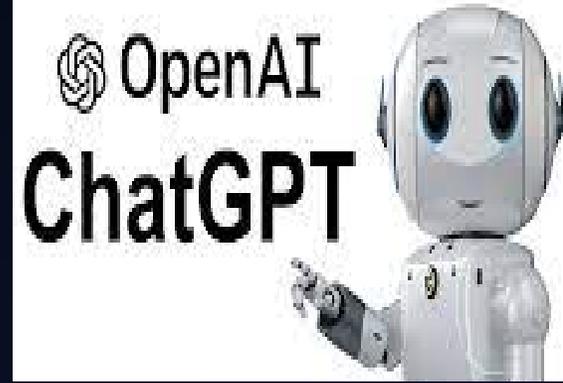
Create a detailed clinical case scenario involving a 65-year-old patient presenting with community-acquired pneumonia, including history of present illness, relevant past medical history, physical examination findings, diagnostic test







# WHAT IS YOUR CLINICAL DIAGNOSIS:



 You

what is your clinical diagnosis for a 60 year old otherwise healthy female, never smoker, with gingival well demarcated white plaques involving multiple quadrants of the mouth?

 ChatGPT

The description of well-demarcated white plaques involving multiple quadrants of the mouth in a 60-year-old otherwise healthy female who is a non-smoker raises the possibility of a condition known as "oral lichen planus."

Lichen planus is a chronic inflammatory condition that can affect the skin, mucous membranes, and oral cavity. In the context of the oral cavity, it is referred to as "oral lichen planus." Here are some key points about oral lichen planus:

1. **Appearance:** Oral lichen planus often presents as white, lacy, reticular lines or plaques on the mucous membranes, including the gums, tongue, and inside of the cheeks. These lesions may appear well-demarcated and may be accompanied by redness or ulcerations.
2. **Symptoms:** While some individuals with oral lichen planus may not experience symptoms, others may report discomfort, burning sensations, or pain, particularly when consuming spicy or acidic foods.
3. **Location:** Lesions can occur in various areas of the oral cavity, and they may involve multiple quadrants.
4. **Demographics:** While oral lichen planus can affect individuals of any age, it is more commonly seen in middle-aged and older adults. The condition may also be more prevalent in women.

Diagnosing oral lichen planus typically involves a clinical examination by a dentist or oral healthcare professional. In some cases, a biopsy may be performed to confirm the diagnosis and rule out other potential causes of white lesions in the oral cavity.

It's important to note that the information provided here is for general informational purposes, and a definitive diagnosis should be made by a qualified healthcare professional based on a thorough



# WHAT IS YOUR CLINICAL DIAGNOSIS:

 You

what is your clinical diagnosis for a 60 year old otherwise healthy female, never smoker, with gingival well demarcated white plaques involving multiple quadrants of the mouth with a pathology report of "verrucous hyperplasia with basal cell atypia" with proliferative plaques that keep recurring despite surgery and progress relentlessly wrapping around the gingival collar

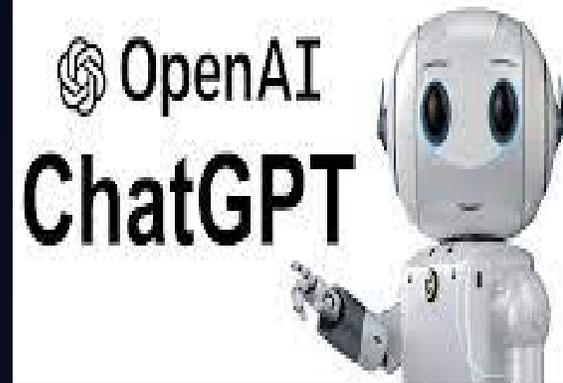
 ChatGPT

The description of well-demarcated white plaques on the gingiva, along with a pathology report indicating "verrucous hyperplasia with basal cell atypia" and the recurrence and relentless progression of proliferative plaques despite surgery, raises concerns about a challenging clinical situation. While I cannot provide a specific diagnosis, this presentation may be indicative of an aggressive or persistent lesion that requires careful evaluation and management.

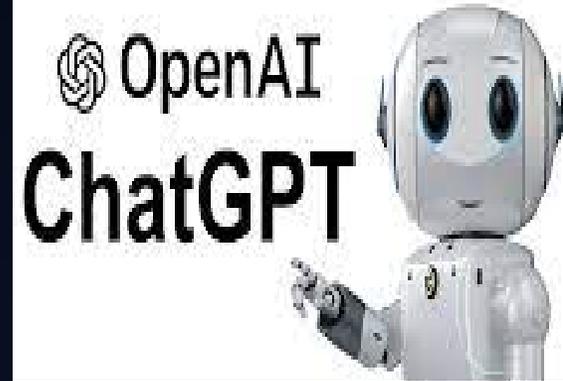
Several possibilities may be considered, including:

1. **Verrucous Carcinoma (VC):** Verrucous hyperplasia has the potential to progress to verrucous carcinoma, a slow-growing, low-grade variant of squamous cell carcinoma. Verrucous carcinoma can be locally aggressive and may have a propensity for recurrence.
2. **Other Malignancies:** The persistence and recurrence of proliferative plaques may prompt consideration of other malignant lesions, including more aggressive forms of squamous cell carcinoma.
3. **Chronic Inflammatory Conditions:** Some chronic inflammatory conditions, such as chronic hyperplastic candidiasis, may also present with persistent white plaques in the oral cavity.

Given the complexity of the case, it is crucial for the individual to undergo a comprehensive evaluation by a multidisciplinary team, including oral and maxillofacial surgeons, pathologists, and possibly oncologists. Further imaging studies, additional biopsies, and molecular testing may be necessary to characterize the nature of the lesion and guide appropriate treatment strategies.



# VERRUCOUS HYPERPLASIA



A

Interpret a pathology report of "Verrucous Hyperplasia", select the correct response below from option A-E given clinically there is a leukoplakia:

- A. You suspect a squamous papilloma because its warty in appearance
- B. You suspect a verrucous carcinoma because the word verrucous is in the pathology report
- C. You suspect some viral driven process because you remember from dental school that verruca vulgaris is verrucous in nature
- D. You suspect it's a proliferative verrucous leukoplakia because the patient has multifocal leukoplakias that are wart-like
- E. You apologize again profusely to the pathologist because you realize that this is another condition that requires clinicopathologic correlation and you did not provide clinical photographs or a detailed history



D. You suspect it's a proliferative verrucous leukoplakia because the patient has multifocal leukoplakias that are wart-like.



Since there is a leukoplakia present, the possibility of a proliferative verrucous leukoplakia (PVL) should be considered. PVL is a subtype of leukoplakia that is characterized by the presence of multifocal, wart-like lesions that have a high potential for malignant transformation. The diagnosis of PVL requires clinicopathologic correlation, and additional testing may be necessary to rule out other potential causes of the lesion. Therefore, it is important to provide a detailed clinical history and photographs to aid in the diagnosis.



# Performance of AI chatbots on controversial topics in oral medicine, pathology, and radiology



Hossein Mohammad-Rahimi, DDS,<sup>a,b</sup> Zaid H. Khoury, DDS, PhD,<sup>c</sup> Mina Iranparvar Alamdari, DDS,<sup>d</sup> Rata Rokhshad, DDS,<sup>b</sup> Parisa Motie, DDS,<sup>e</sup> Azin Parsa, DDS, PhD,<sup>f</sup> Tiffany Tavares, DDS, DMSc,<sup>g</sup> James J. Sciubba, DMD, PhD,<sup>h</sup> Jeffery B. Price, DDS, MS,<sup>a,f</sup> and Ahmed S. Sultan, BDS, PhD<sup>a,f,i</sup>

**Objectives.** In this study, we assessed 6 different artificial intelligence (AI) chatbots (Bing, GPT-3.5, GPT-4, Google Bard, Claude, Sage) responses to controversial and difficult questions in oral pathology, oral medicine, and oral radiology.

**Study Design.** The chatbots' answers were evaluated by board-certified specialists using a modified version of the global quality score on a 5-point Likert scale. The quality and validity of chatbot citations were evaluated.

**Results.** Claude had the highest mean score of  $4.341 \pm 0.582$  for oral pathology and medicine. Bing had the lowest scores of  $3.447 \pm 0.566$ . In oral radiology, GPT-4 had the highest mean score of  $3.621 \pm 1.009$  and Bing the lowest score of  $2.379 \pm 0.978$ . GPT-4 achieved the highest mean score of  $4.066 \pm 0.825$  for performance across all disciplines. 82 out of 349 (23.50%) of generated citations from chatbots were fake.

**Conclusions.** The most superior chatbot in providing high-quality information for controversial topics in various dental disciplines was GPT-4. Although the majority of chatbots performed well, it is suggested that developers of AI medical chatbots incorporate scientific citation authenticators to validate the outputted citations given the relatively high number of fabricated citations. (Oral Surg Oral Med Oral Pathol Oral Radiol 2024;137:508–514)

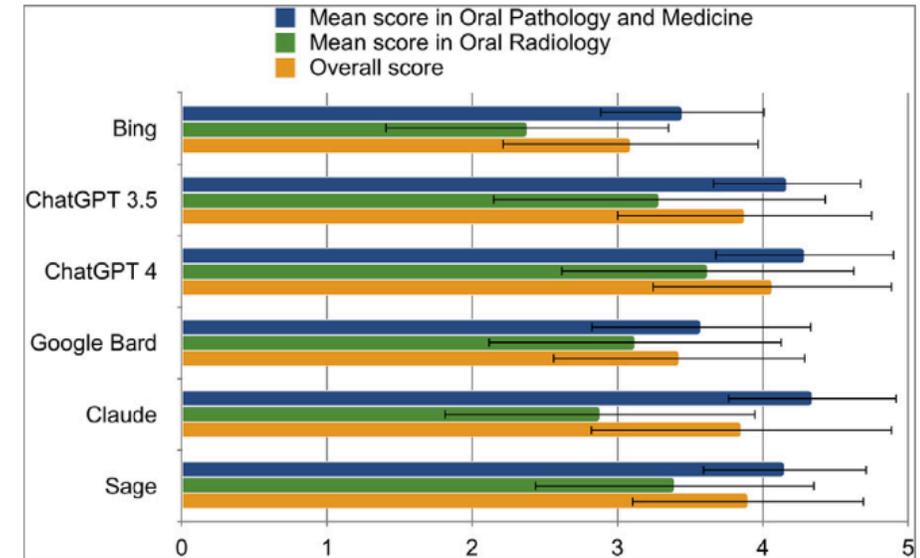
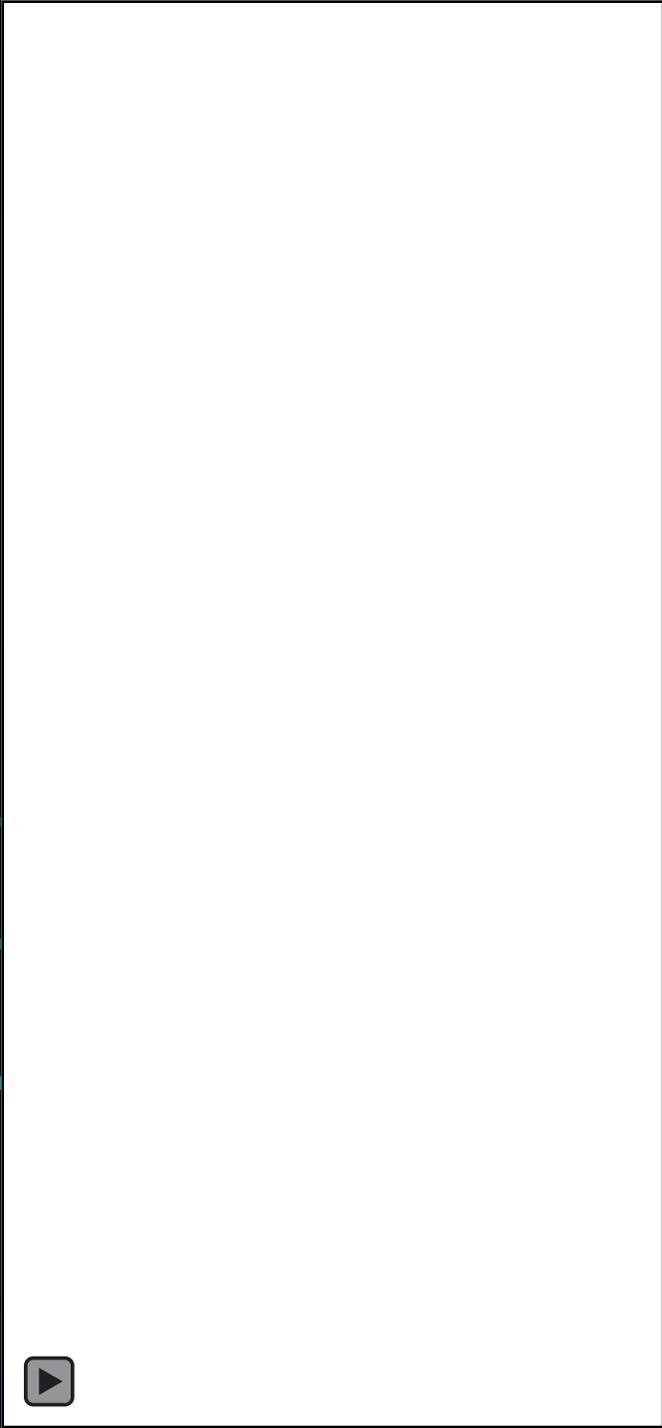
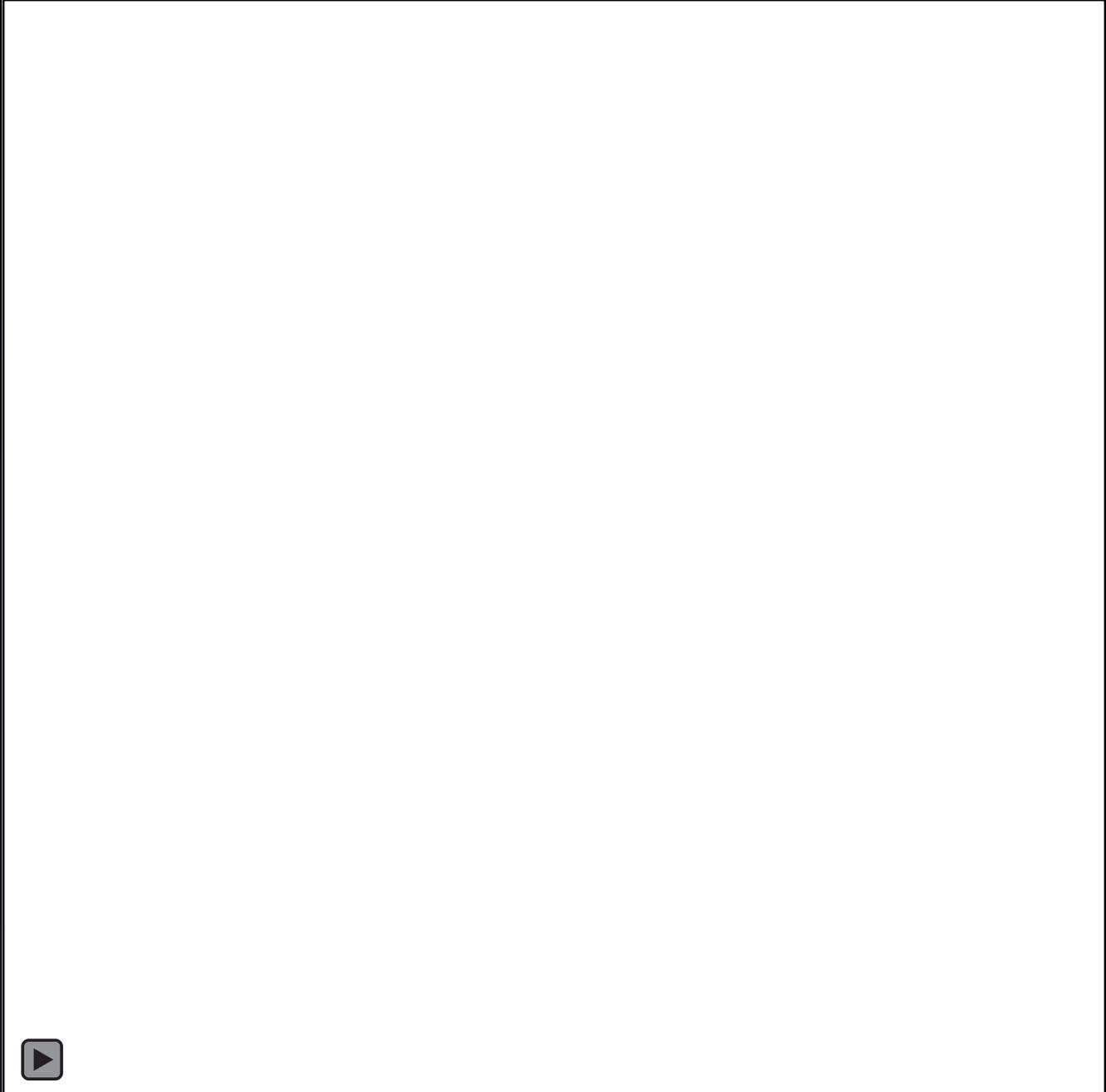


Figure 1. Quality assessment of responses based on modified Global Quality Score (GQS) scores.





# GENERATIVE AI

Mod Pathol 37 (2024) 100369

**MODERN PATHOLOGY**



Journal homepage: <https://modernpathology.org/>

## Review Article

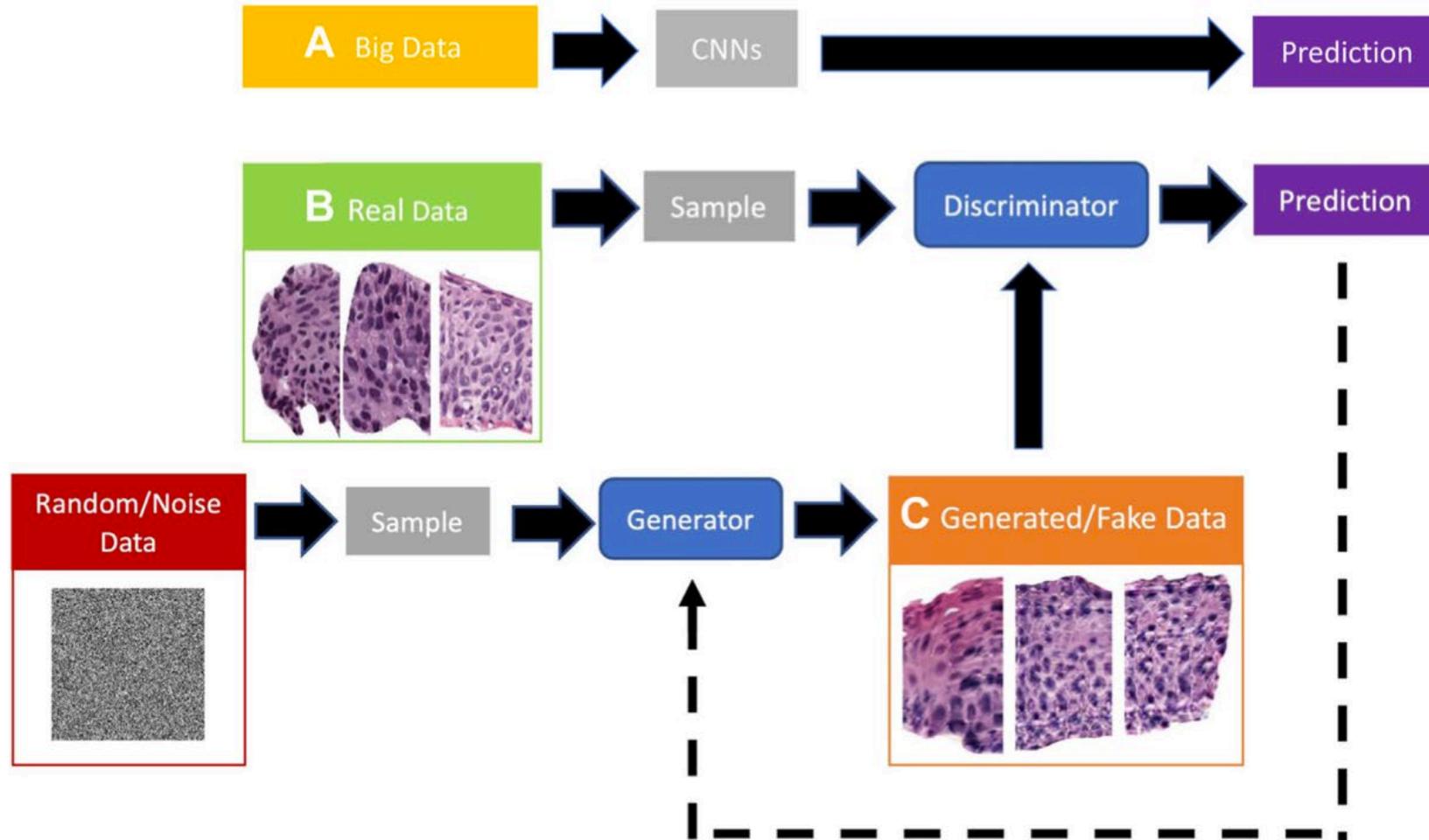
### Generative Adversarial Networks in Digital Histopathology: Current Applications, Limitations, Ethical Considerations, and Future Directions

Shahd A. Alajaji<sup>a,b,c</sup>, Zaid H. Khoury<sup>d</sup>, Mohamed Elgharib<sup>e</sup>, Mamoon Saeed<sup>f</sup>,  
Ahmed R.H. Ahmed<sup>g</sup>, Mohammad B. Khan<sup>h</sup>, Tiffany Tavares<sup>i</sup>, Maryam Jessri<sup>j,k</sup>,  
Adam C. Puche<sup>l</sup>, Hamid Hoorfar<sup>m</sup>, Ivan Stojanov<sup>n</sup>, James J. Sciubba<sup>o</sup>, Ahmed S. Sultan<sup>a,c,p,\*</sup>

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# GANs

Shahd A. Alajaji et al. / Mod Pathol 37 (2024) 100369



2018



2020



Courtesy of Dr. Cullen

2020



2023

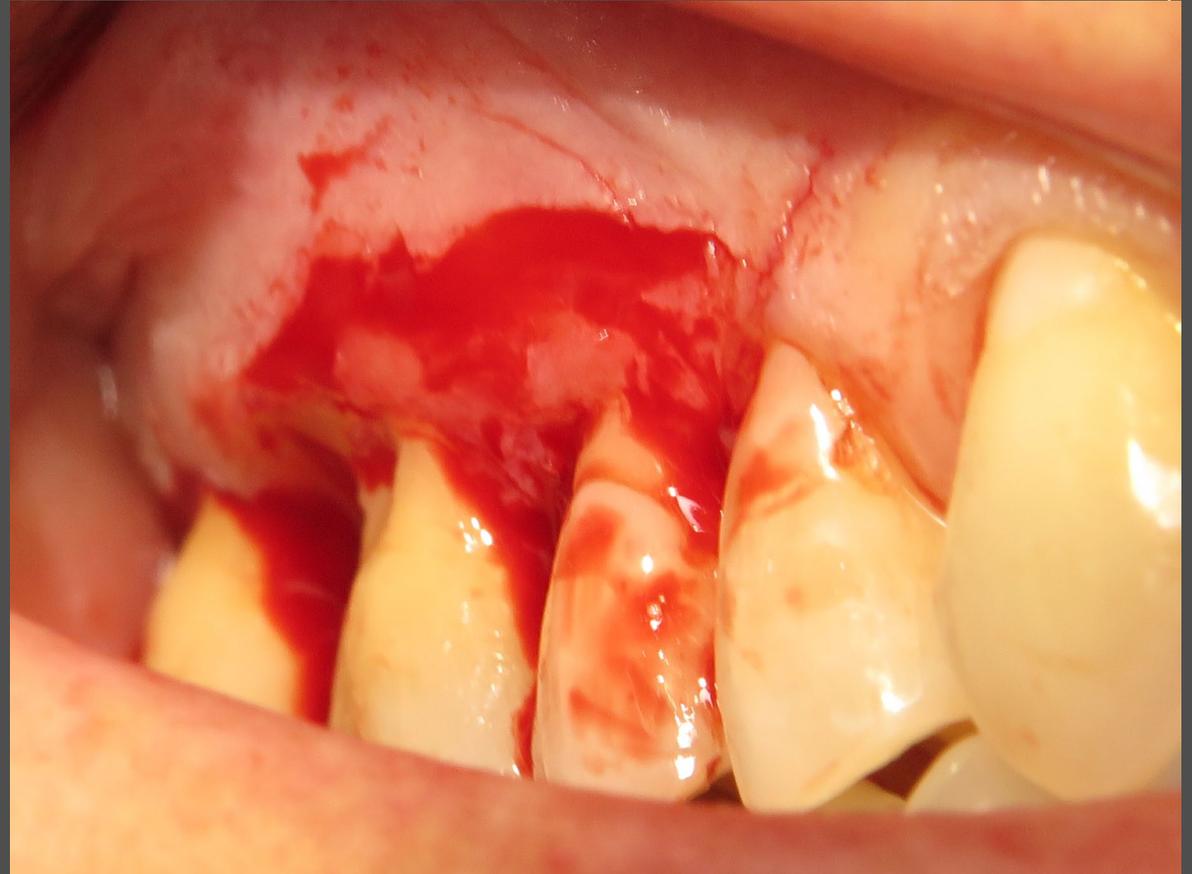


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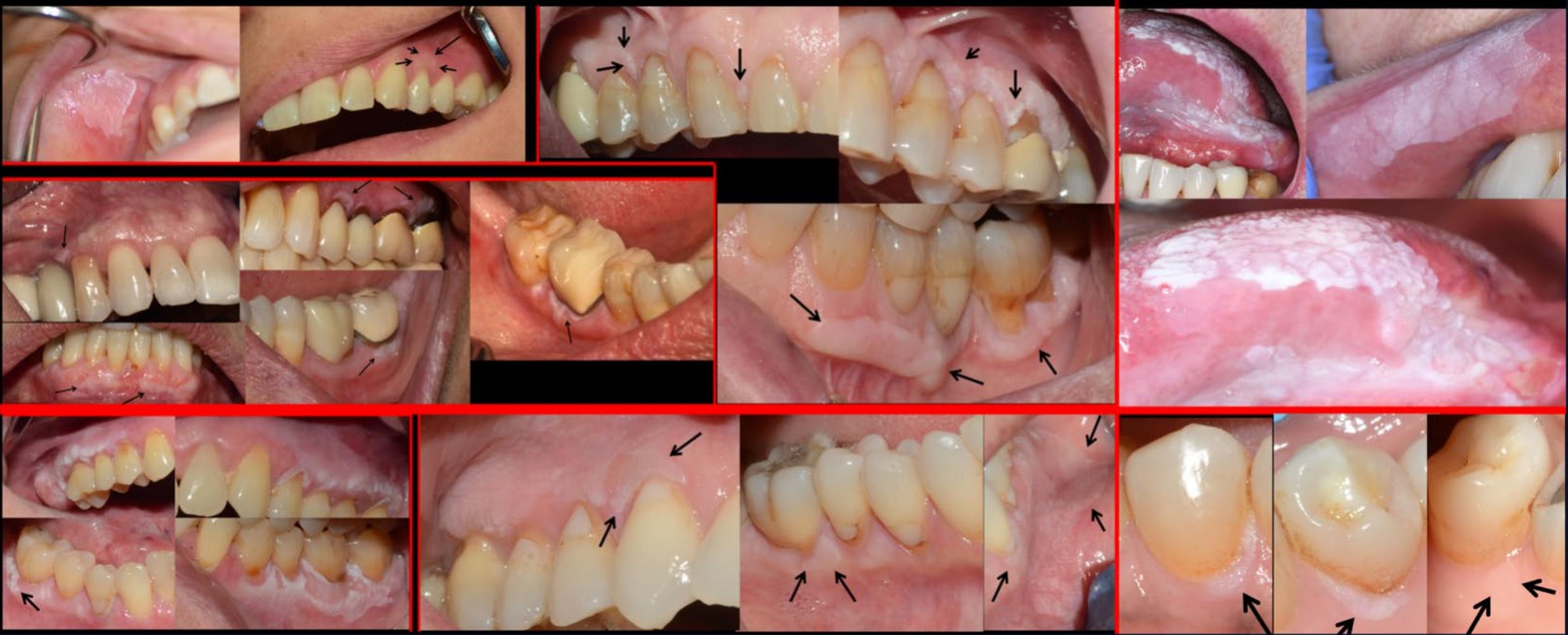


2023



Courtesy of Dr. Cullen

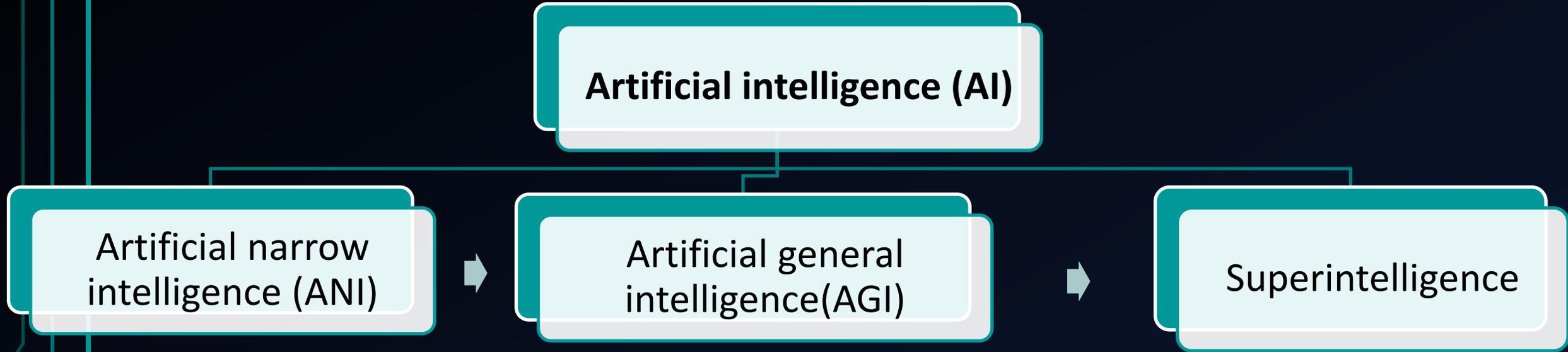




## Learning Objectives

1. Be able to provide a definition for Artificial Intelligence (AI)
2. Understand the History of AI
3. Be able to recognize the main components of *AI Classification*

# AI Classification:



# AI Classification:

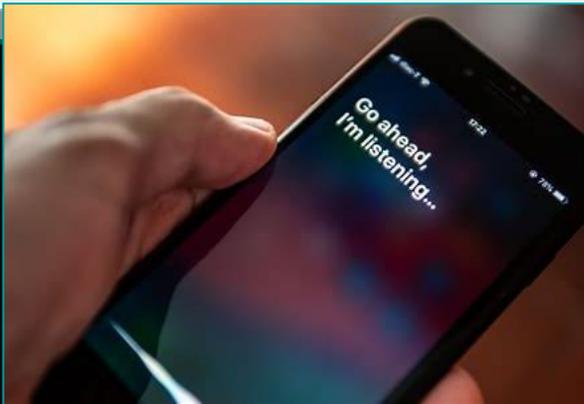
Artificial intelligence (AI)

Artificial narrow intelligence (ANI)

Artificial general intelligence (AGI)

Superintelligence

specified to handle a singular or limited task



# AI Classification:

Artificial intelligence (AI)

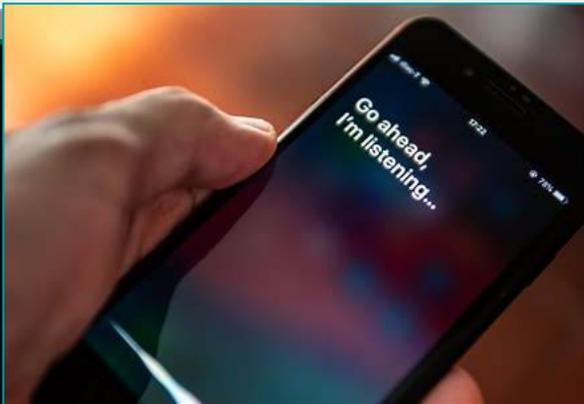
Artificial narrow intelligence (ANI)

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Superintelligence

specified to handle a singular or limited task

capable of handling a wide range of tasks with the goal of creating machines that can perform functions similar to humans



# AI Classification:

Artificial intelligence (AI)

Artificial narrow intelligence (ANI)

Artificial general intelligence (AGI)

Superintelligence

specified to handle a singular or limited task

capable of handling a wide range of tasks with the goal of creating machines that can perform functions similar to humans

surpass what a human can do

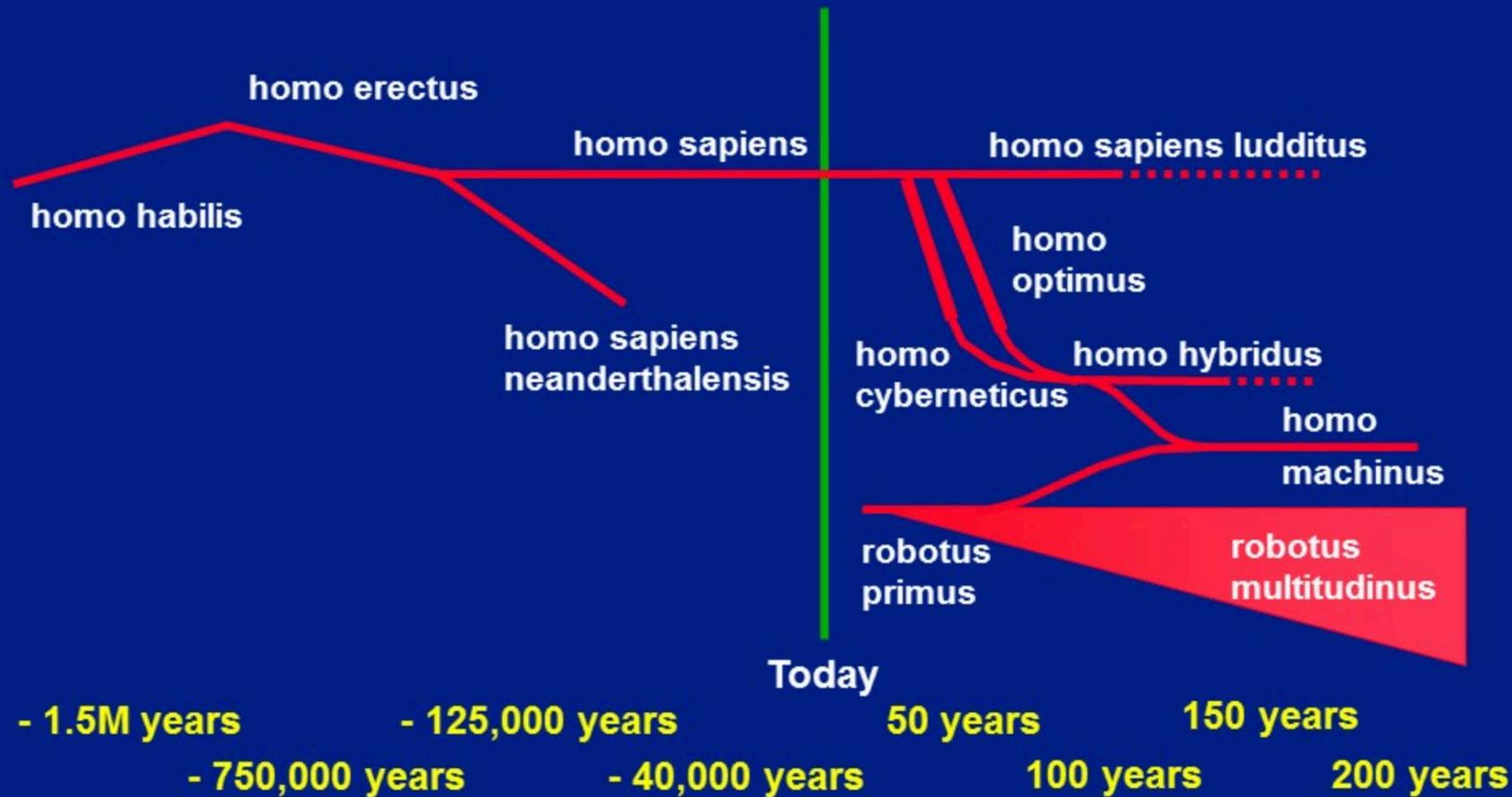


# An example of superintelligence?



# A superintelligence species?

## Human-machine Convergence

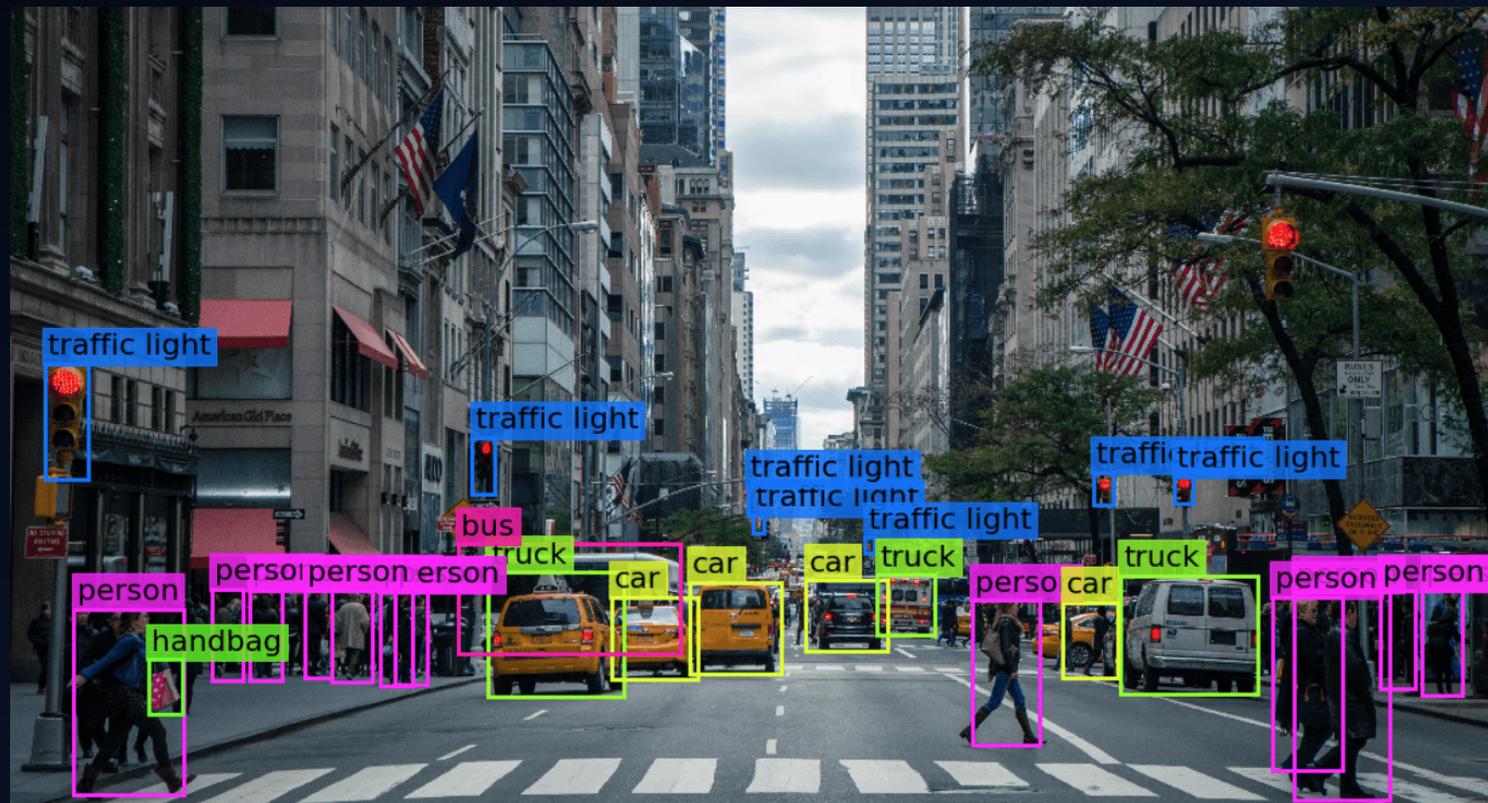


*A thought provoking outline of possible evolution in the line of human machine convergence.  
Dr. Pearson –  
Futurizon*

# AI Methods:

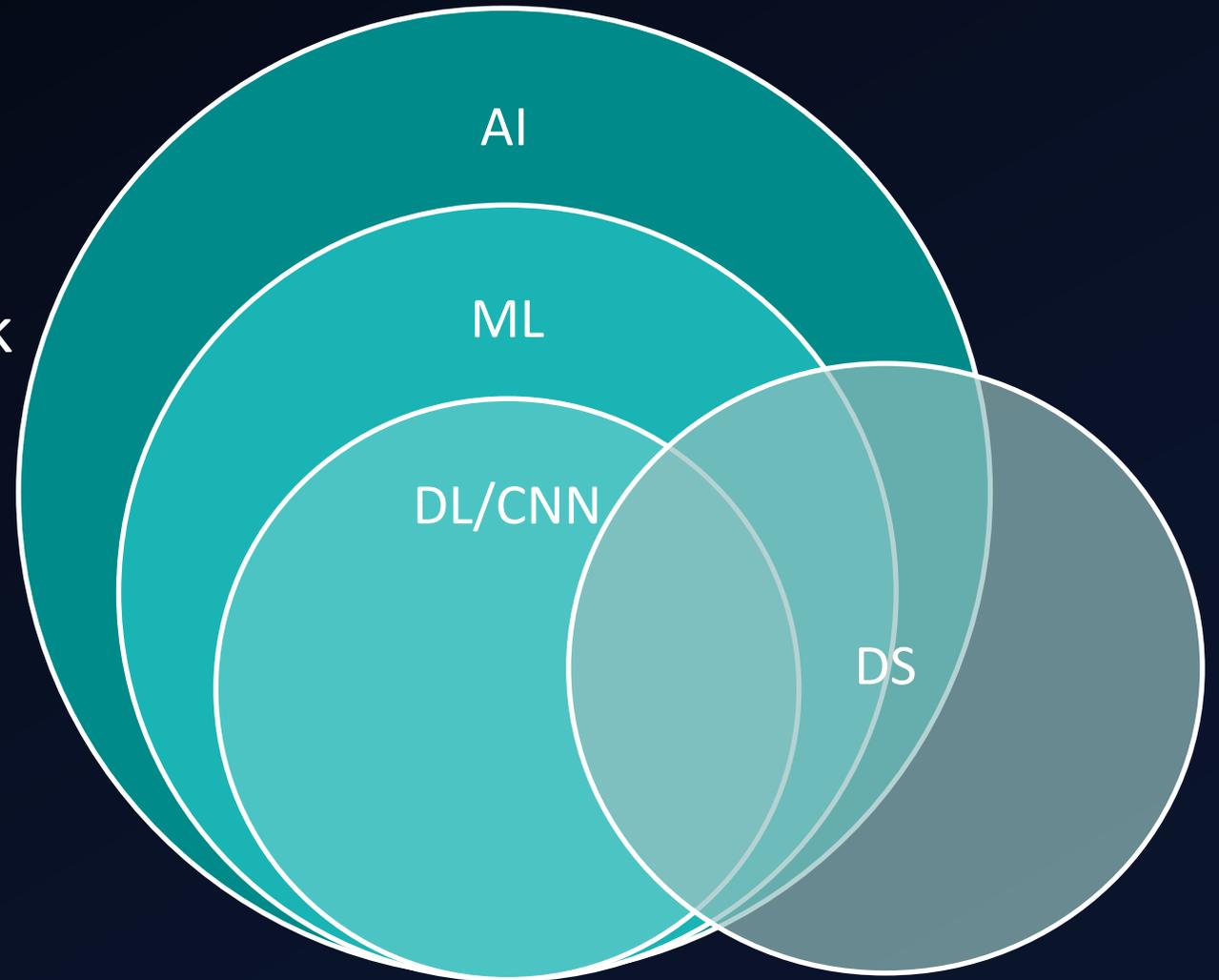
## Computer Vision:

- The study of how computers see digital images and videos, and extract information to process output



## AI Methods:

- Machine learning (ML).
- Deep learning (DL).
- Convolutional Neural network (CNN).
- Data science (DS).

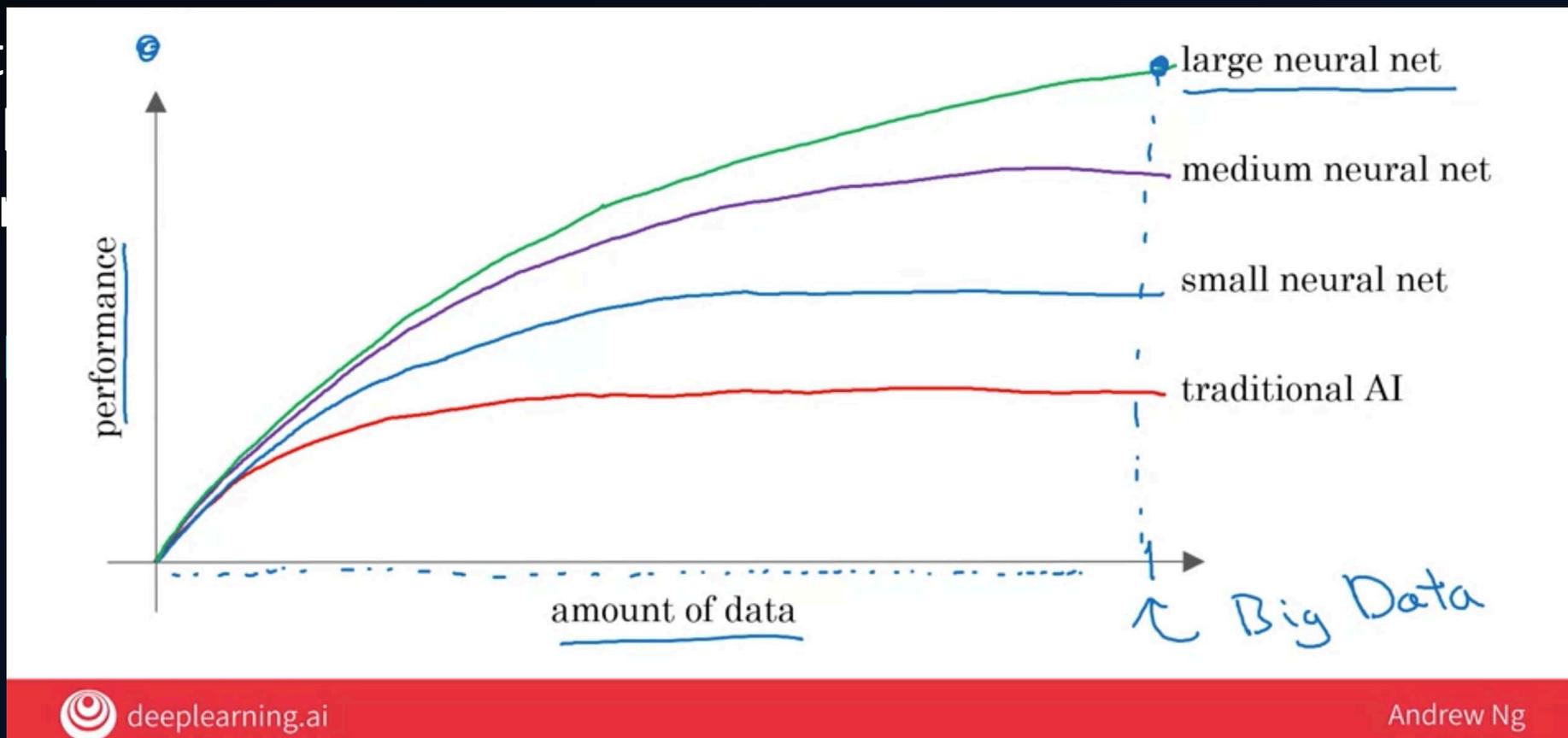


# AI Methods:

## Big Data:

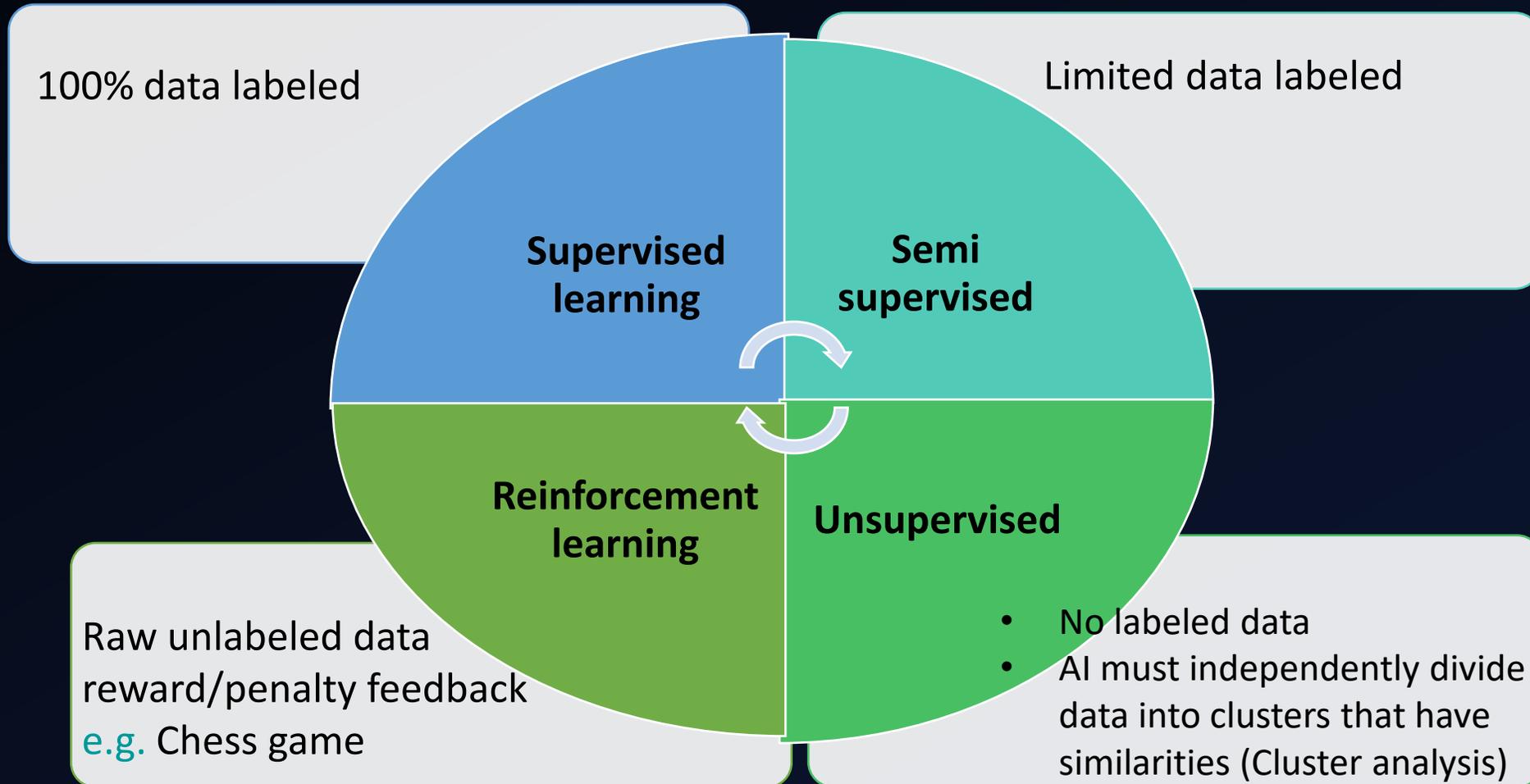
“Large sets of data that are too large to be processed by traditional data processing operations.”

- Example



# AI Methods:

## Types of AI learning in terms of availability of labeled data:



100% data labeled

Limited data labeled

**Supervised learning**

**Semi supervised**

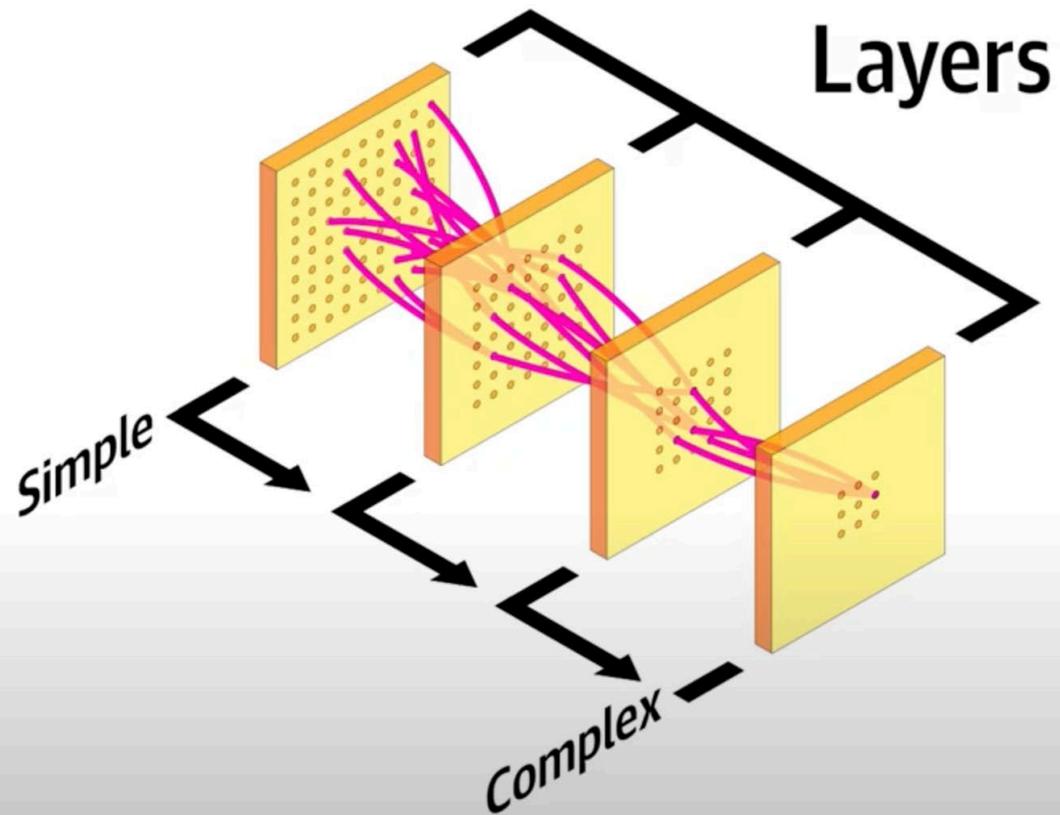
**Reinforcement learning**

**Unsupervised**

Raw unlabeled data  
reward/penalty feedback  
e.g. Chess game

- No labeled data
- AI must independently divide data into clusters that have similarities (Cluster analysis)

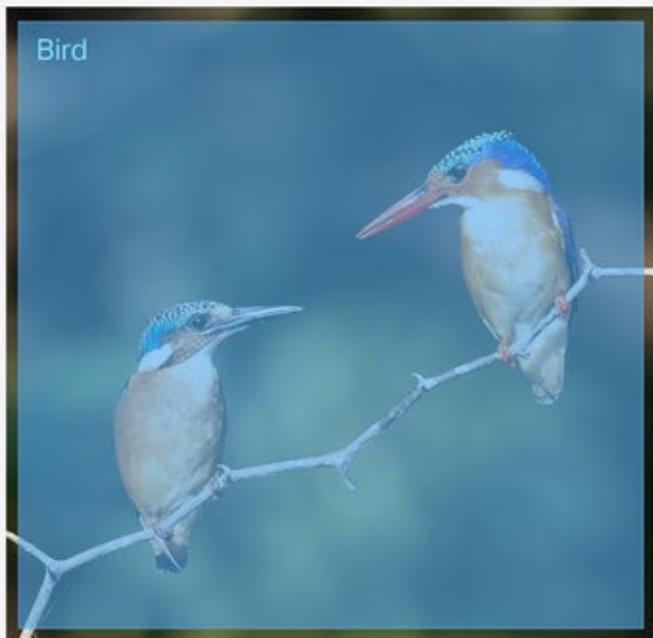
# How do CNNs work for medical image analysis:



# AI Methods:

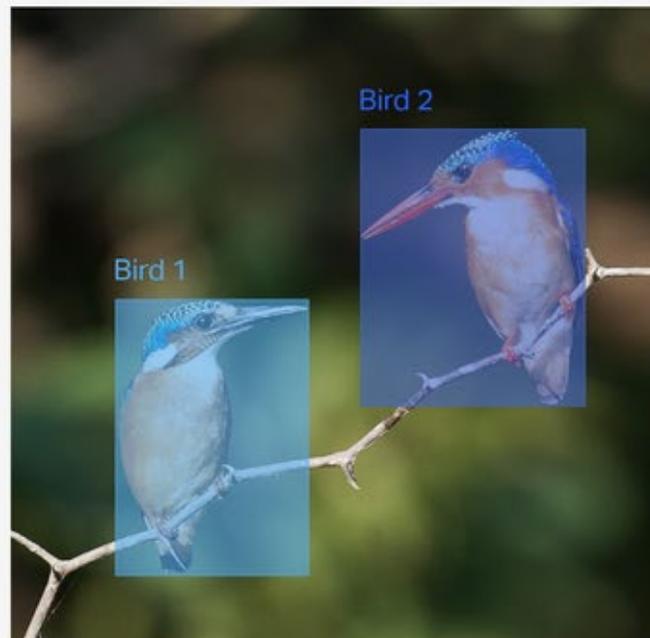
## Types of Image Annotation:

IS THERE A BIRD?



Classification

WHERE IS THE BIRD?



Object detection

WHERE IS THE BIRD AT A PIXEL LEVEL?

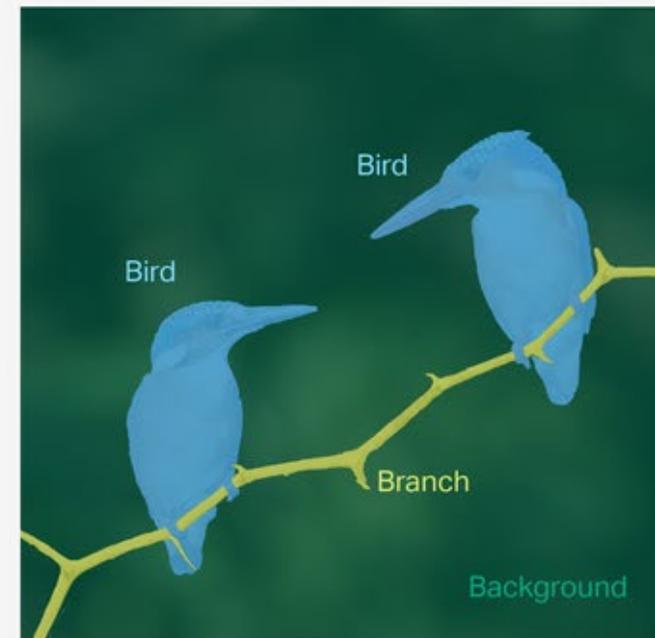


Image segmentation

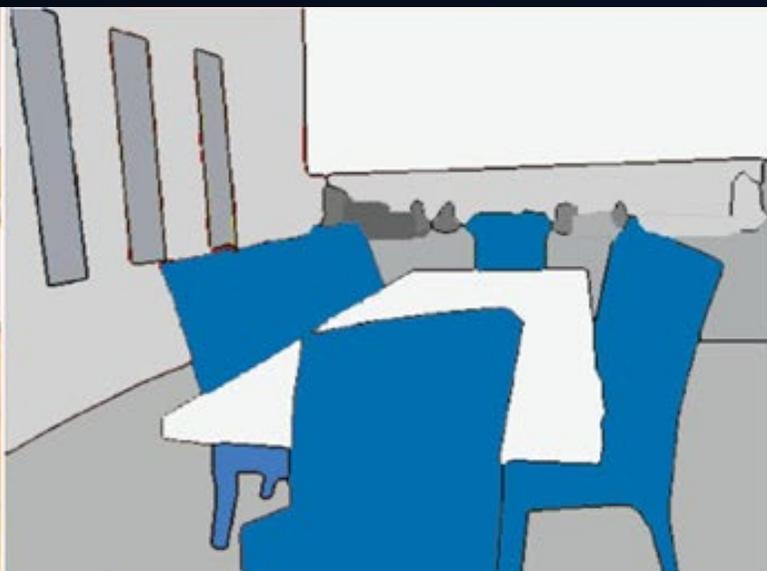
# AI Methods:

## Image segmentation:

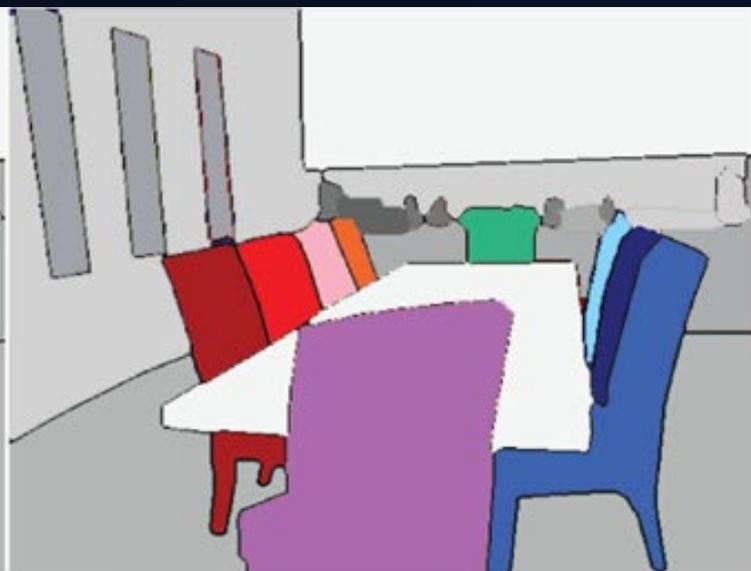
instance segmentation  
differentiates two objects with  
the same labels



Input Image



Semantic Segmentation



Instance Segmentation





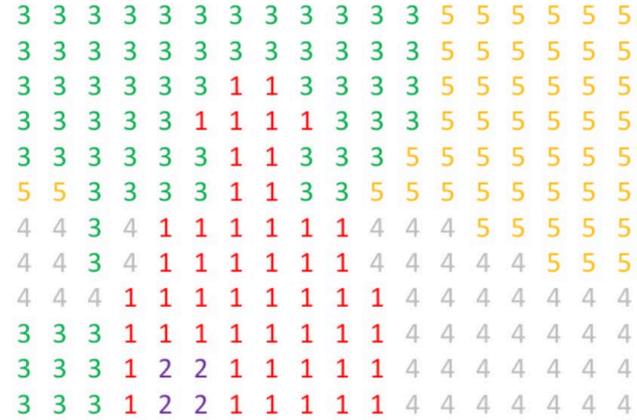
# AI Methods:



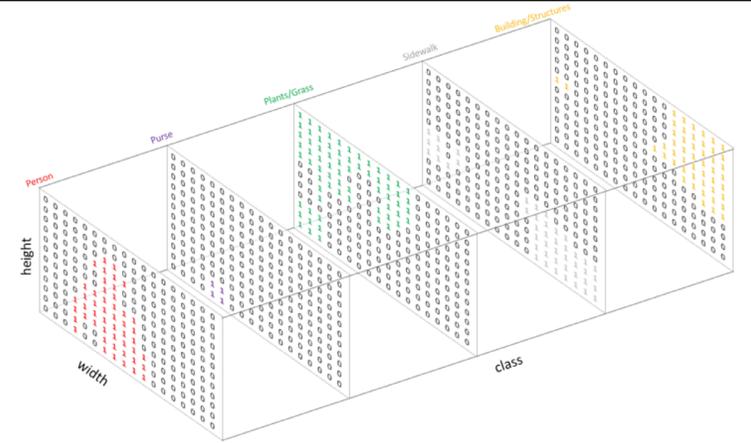
Input



- 1: Person
- 2: Purse
- 3: Plants/Grass
- 4: Sidewalk
- 5: Building/Structures



Semantic Labels

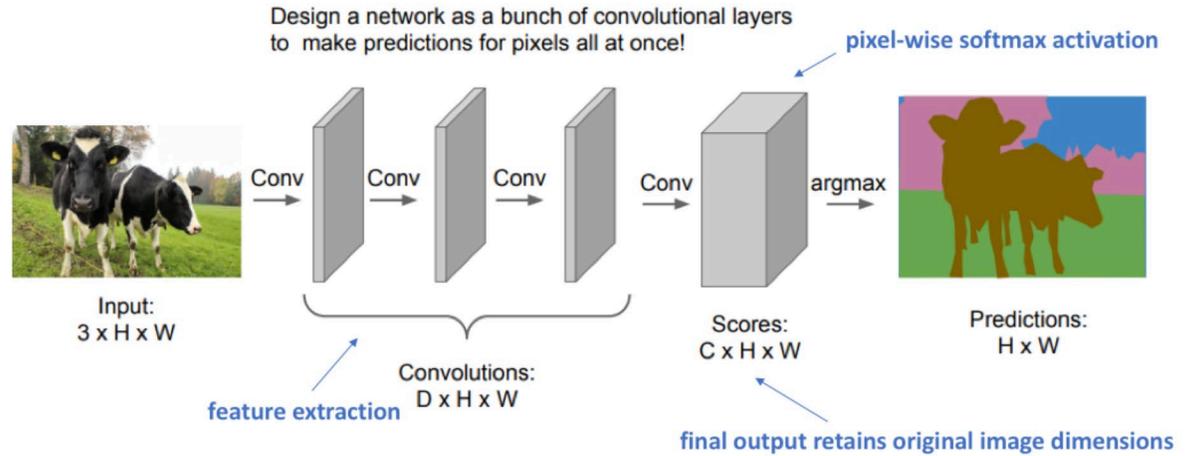


A prediction can be collapsed into a segmentation map (as shown in the first image) by taking the `argmax` of each depth-wise pixel vector.

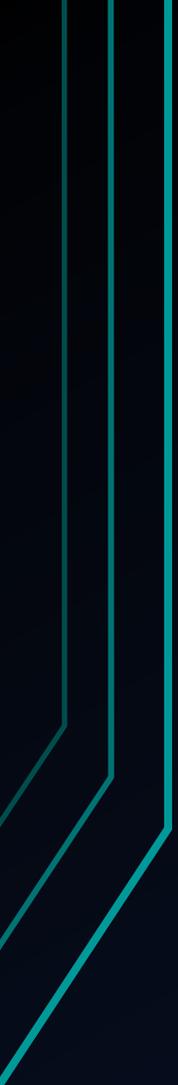


- 0: Background/Unknown
- 1: Person
- 2: Purse
- 3: Plants/Grass
- 4: Sidewalk
- 5: Building/Structures

When we overlay a *single channel* of our target (or prediction), we refer to this as a **mask** which illuminates the regions of an image where a specific class is present.



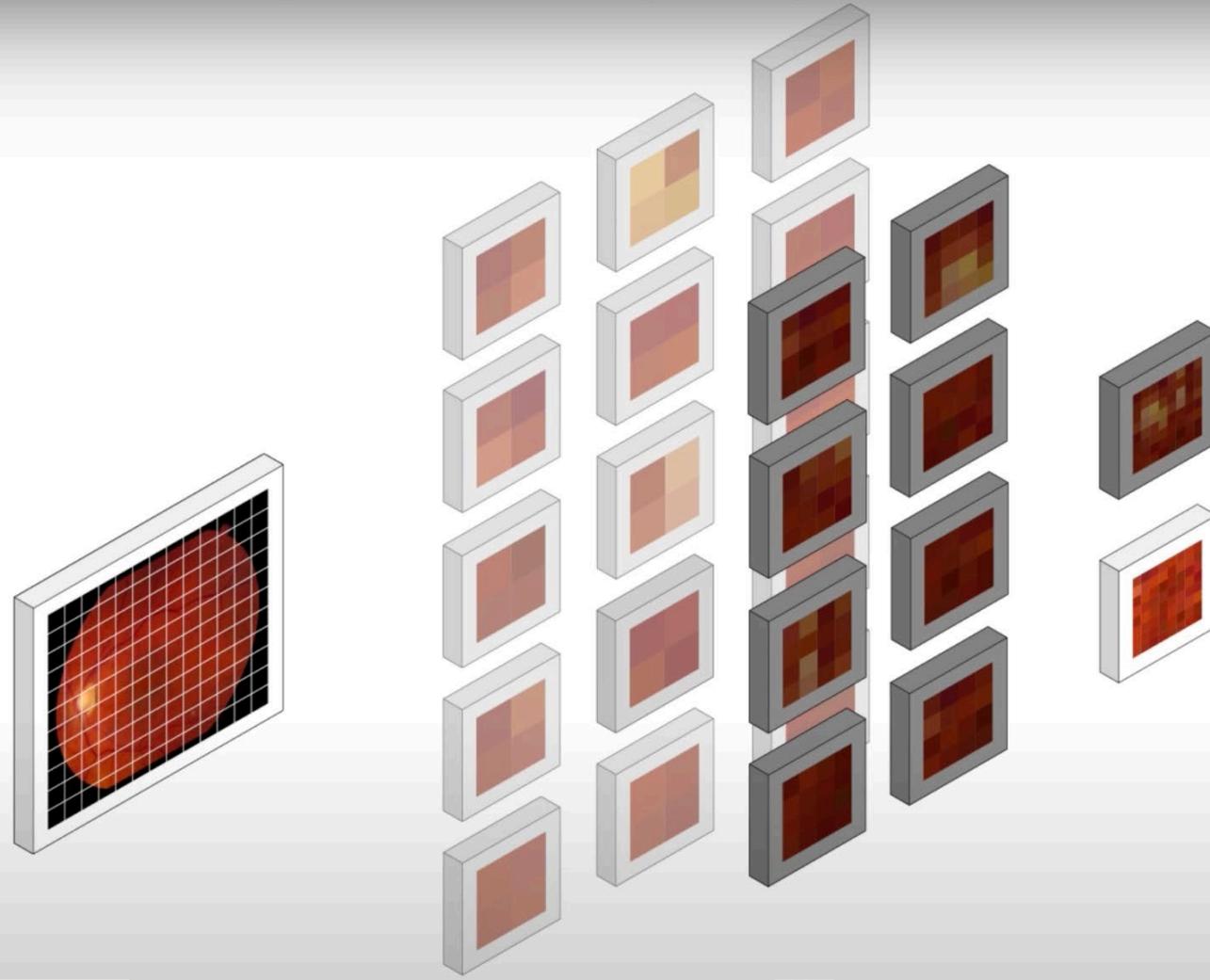
**Downside:** Preserving image dimensions throughout entire network will be computationally expensive.



## Learning Objectives

1. Be able to provide a definition for Artificial Intelligence (AI)
2. Understand the History of AI
3. Be able to recognize the main components of *AI Classification*
4. Be able to provide examples of Applications of AI in Medicine, Pathology, and Dentistry

# How do CNNs work for medical image analysis:



**Severe  
non-proliferative  
diabetic retinopathy**

The specific filter used at the lead layer helps for the identification of the filters

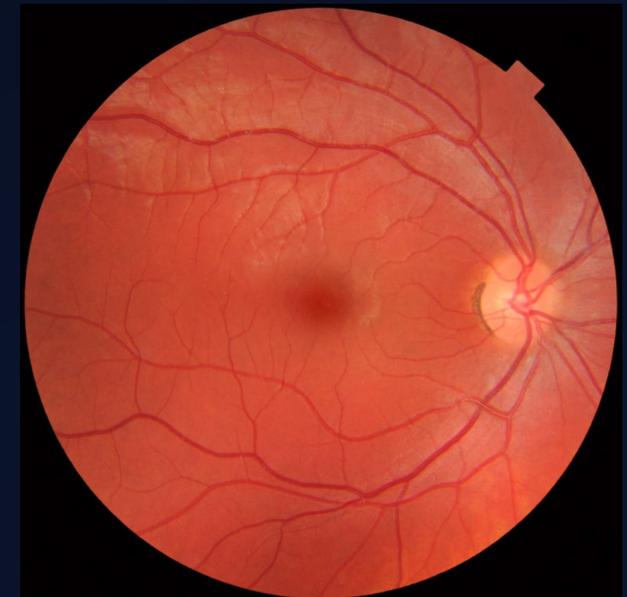
# Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs

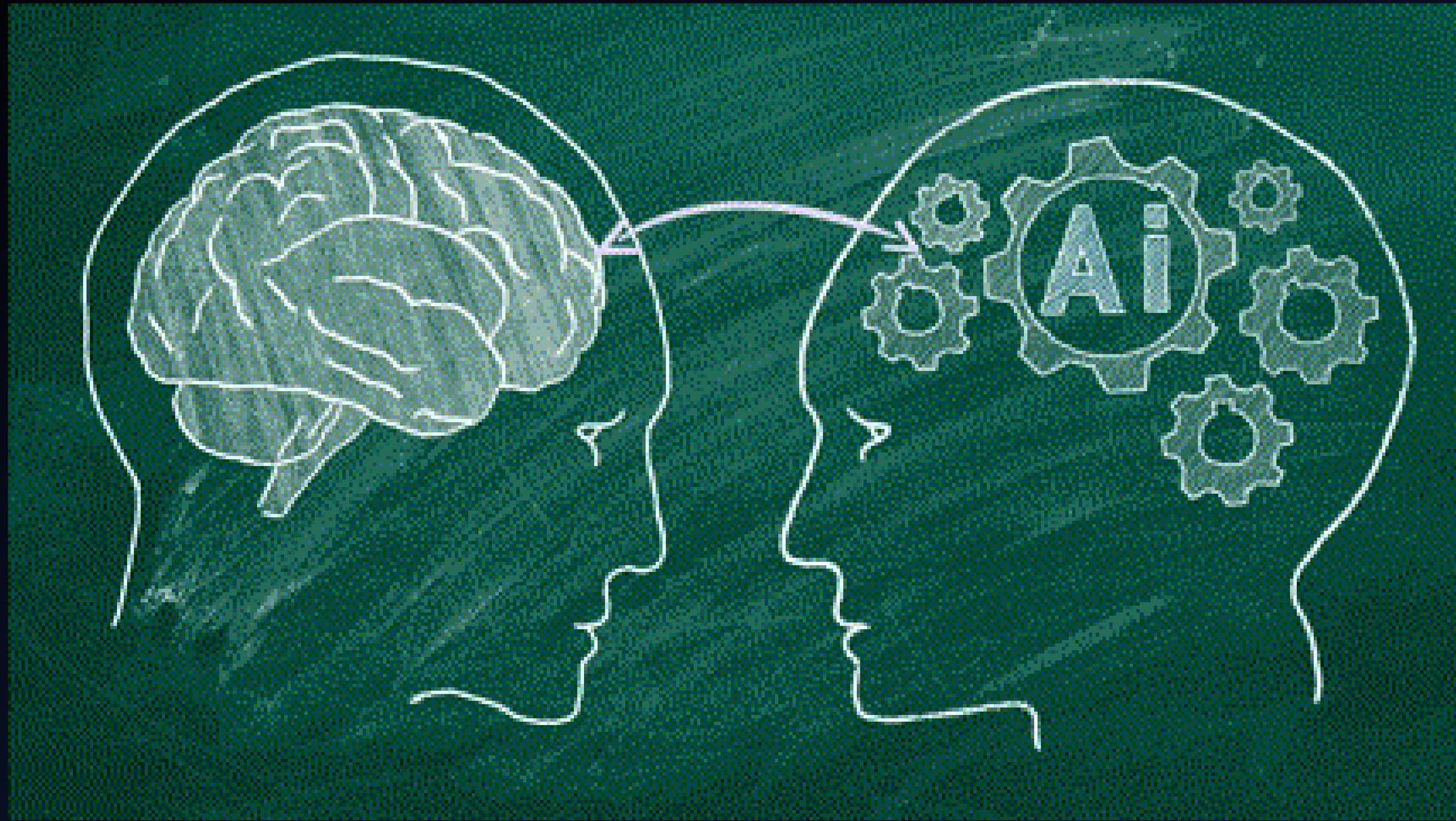
Retinal fundus photographs (initial database of 128,000 retinal images screened) to generate two datasets of 9963 images and 1748 images

1. 54 US licensed ophthalmologists and ophthalmology senior residents graded photographs into different disease severities
2. Grading later validated by at least 7 US board-certified ophthalmologists with high intragrader consistency

## Result:

Deep learning algorithms had high sensitivity and specificity for detecting diabetic retinopathy and macular edema



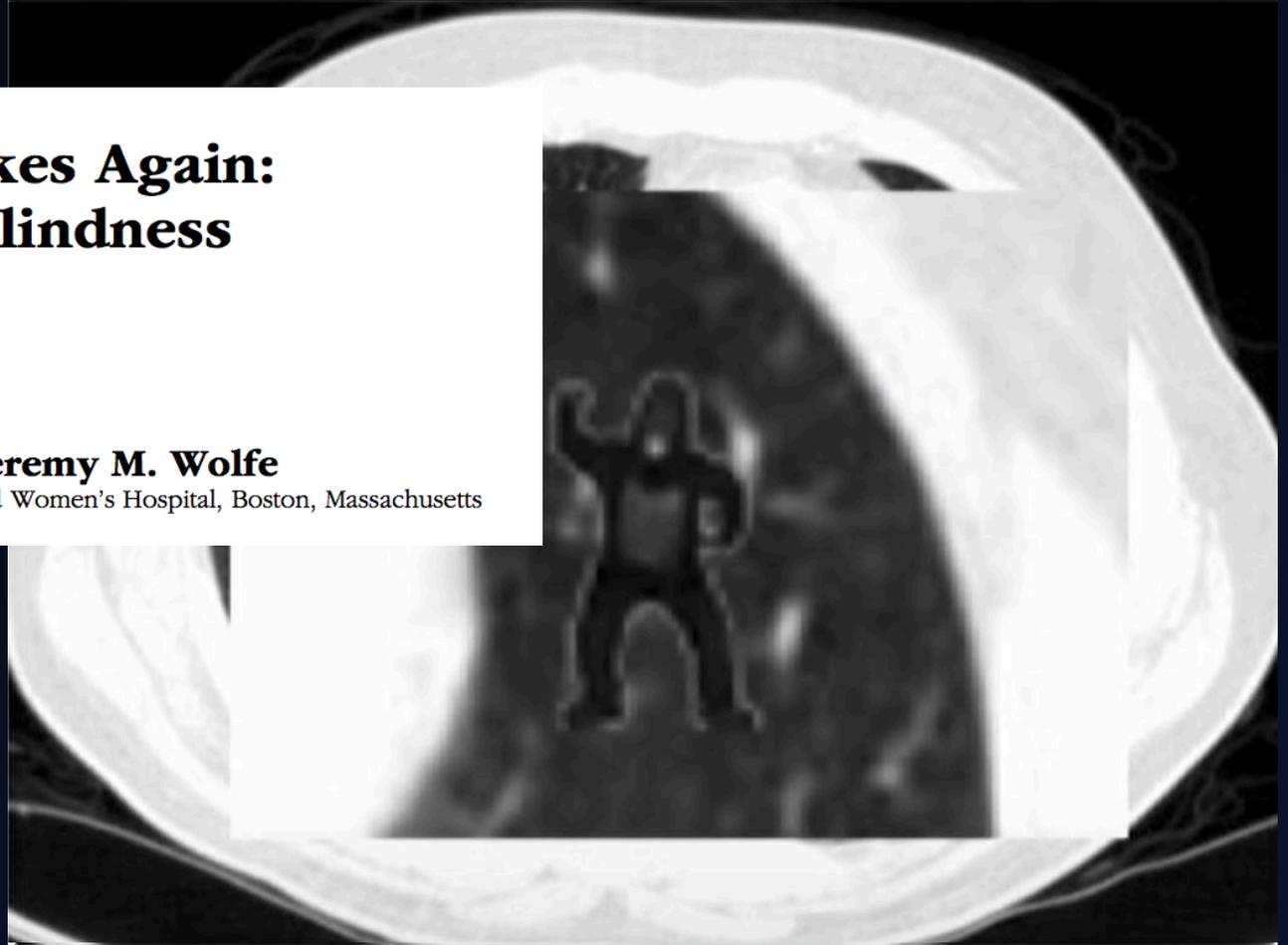


# The Invisible Gorilla Strikes Again: Sustained Inattentional Blindness in Expert Observers

**Trafton Drew, Melissa L.-H. Võ, and Jeremy M. Wolfe**

Visual Attention Lab, Harvard Medical School, and Brigham and Women's Hospital, Boston, Massachusetts

24 radiologists performed a lung-nodule detection task



20/24 radiologists failed to detect the gorilla imbedded in the image!  
Inherent limitations of human attention and perception

1. <https://www.youtube.com/watch?v=4kw6ulKc6I>

2. <https://search.bwh.harvard.edu/new/pubs/DrewVoWolfe13.pdf>



*Communication*

## **Pathology is Always Around Pathology, a Remarkable Un**

Ahmed S. Sultan <sup>1,\*</sup>  and Maryam Jessri <sup>2</sup>

- **Granular Cell Tumor??**
- **Visual Hallucinations**
- **Pathologist Burnout or  
Operator Fatigue**

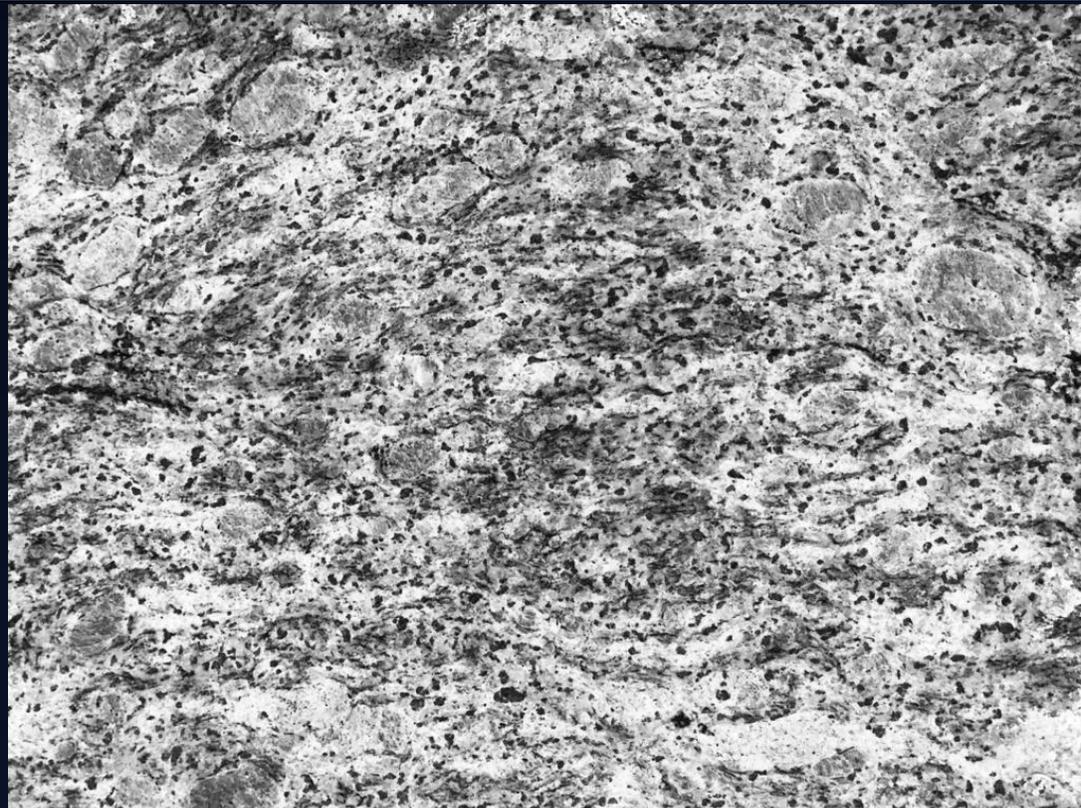


# GENERATIVE AI FOR EDUCATION?

*Communication*

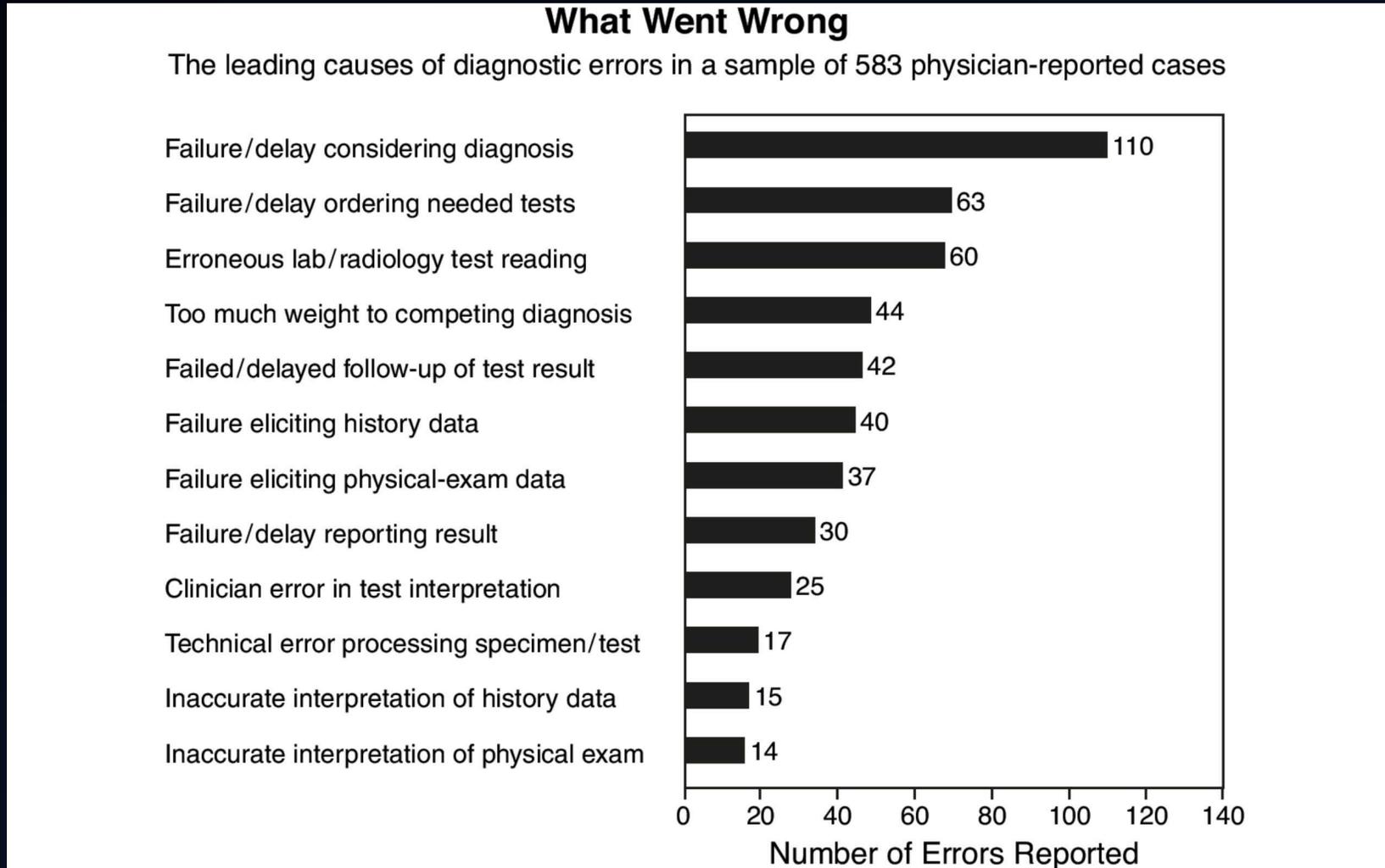
## **Pathology is Always Around Us: Apophenia in Pathology, a Remarkable Unreported Phenomenon**

Ahmed S. Sultan <sup>1,\*</sup>  and Maryam Jessri <sup>2</sup>



# THE IMPORTANCE OF AI IN HEALTHCARE:

## MISDIAGNOSIS



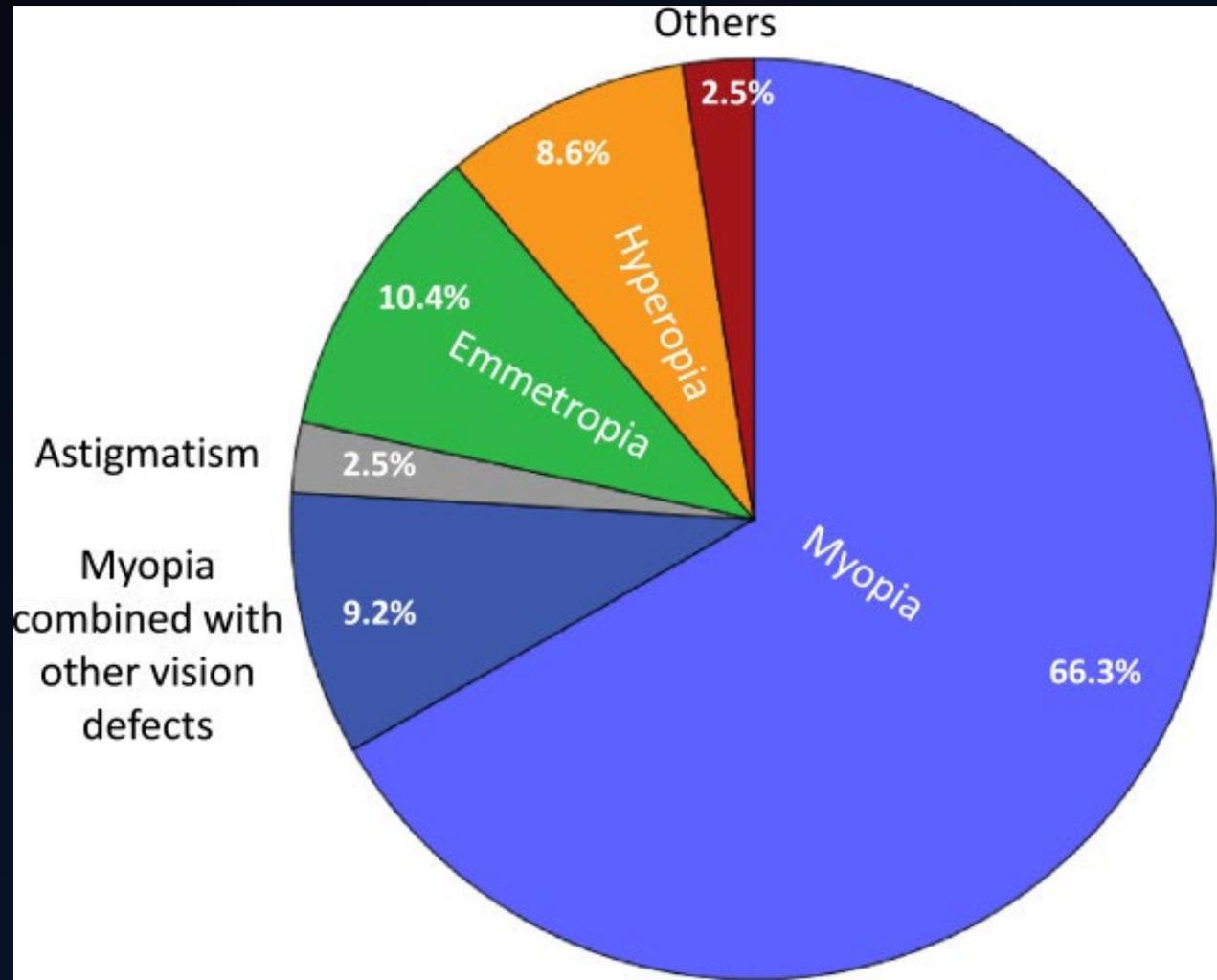
Source: Adapted from L. Landro, "The Key to Reducing Doctors' Misdiagnoses," Wall Street Journal (2017): [www.wsj.com/articles/the-key-to-reducing-doctors-misdiagnoses-1505226691](http://www.wsj.com/articles/the-key-to-reducing-doctors-misdiagnoses-1505226691), with primary reference from G. Schiff et al., "Diagnostic Error in Medicine: Analysis of 583 Physician-Reported Errors," Arch Intern Med (2009): 169(20), 1881–1887."

Excerpt From: Eric Topol. "Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again." iBooks.

# THE IMPORTANCE OF AI IN HEALTHCARE:

## MISDIAGNOSIS

**Distribution of different visual impairments among 163 Swiss pathologists**



# MIT AI tool can predict breast cancer up to 5 years early, works equally well for white and black patients

Darrell Etherington @etherington / 10:31 AM EDT • June 26, 2019

 Comment

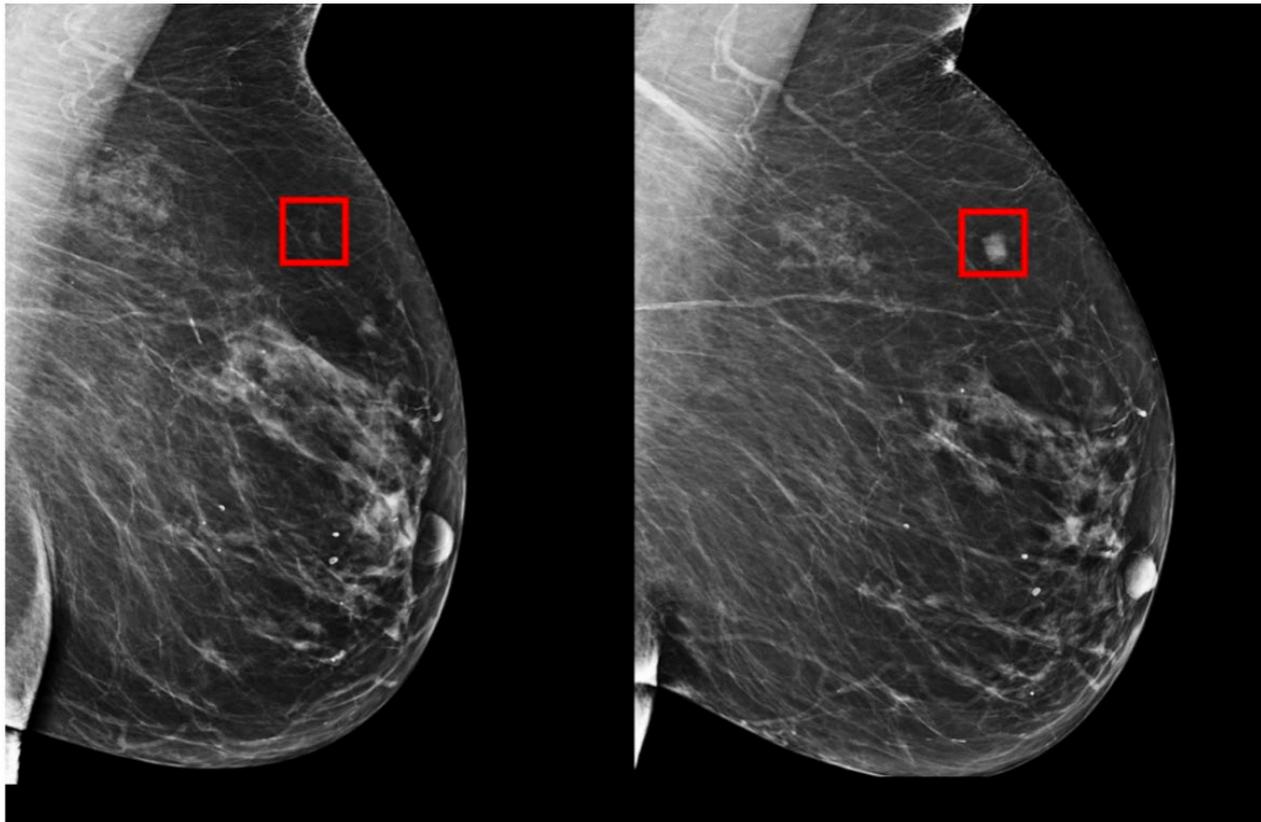
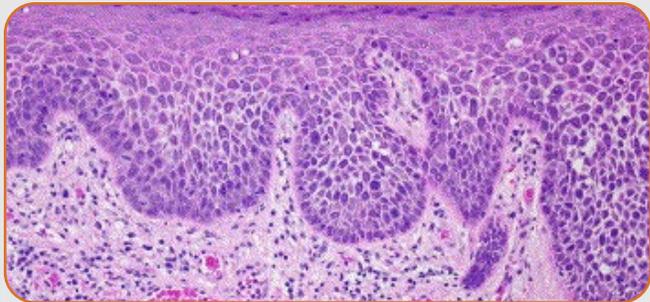


 Image Credits: MIT

- data from 106,615 patients from 3 hospitals, located in the U.S., Sweden, and Taiwan, Mirai
- identified 41.5% of patients who would develop cancer within five years

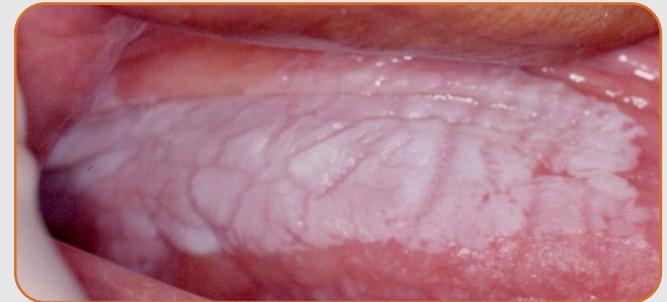
# Types of image data sets used *Division of AI Research*



Histopathology  
(WSI)



Radiographs (CBCT,  
Panoramic)



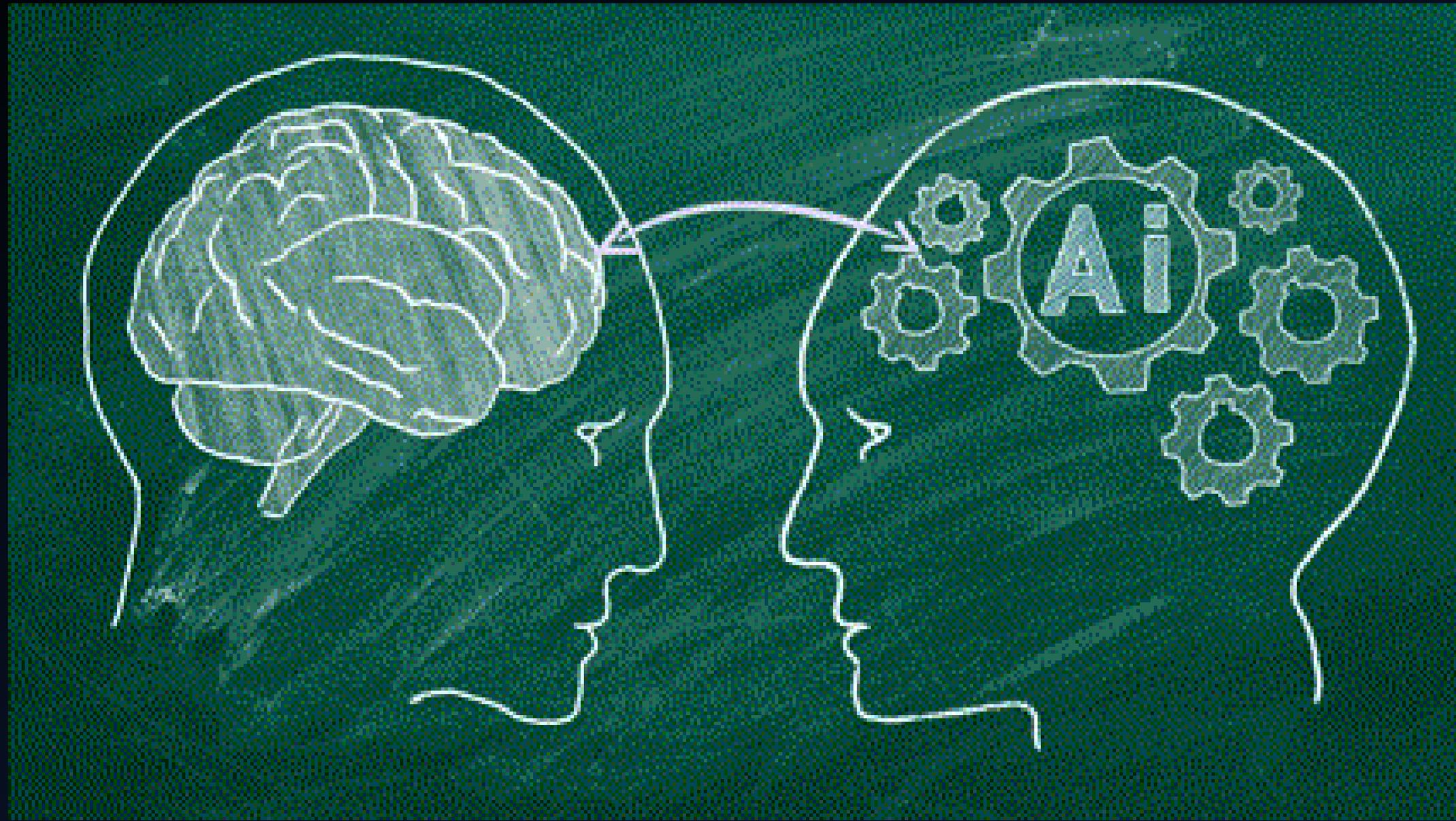
Clinical Images

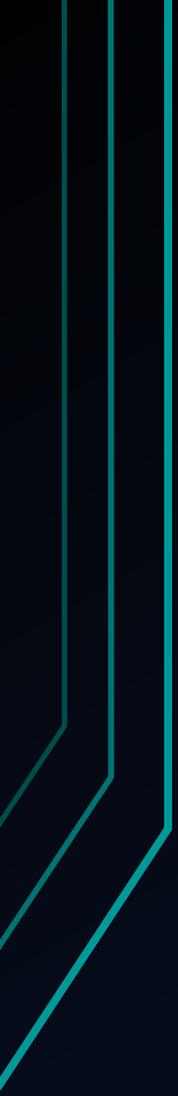


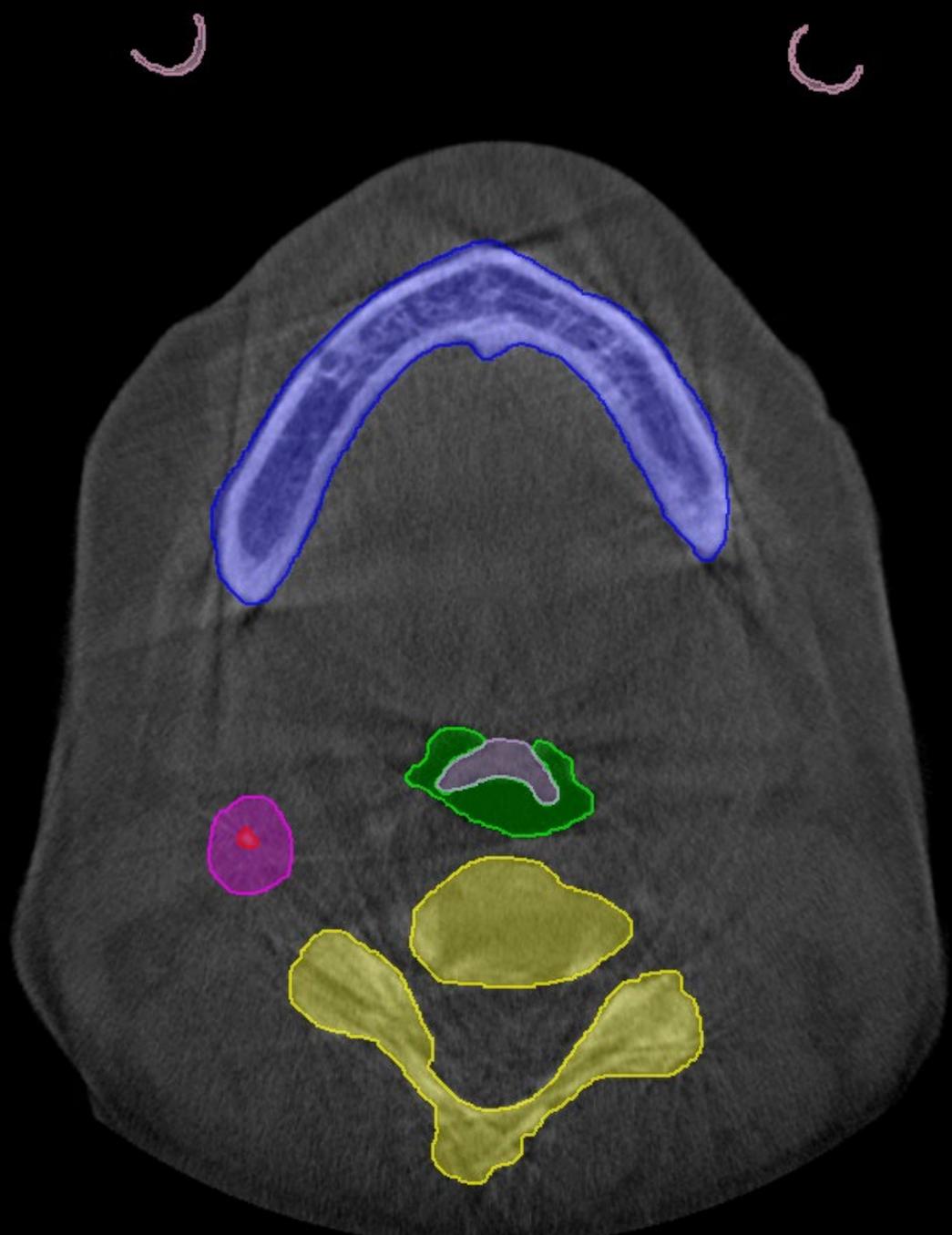
# Example of Few-Shot Transfer Deep Learning

1. train a single panoramic image to identify teeth with very accurate borders
2. using zero-shot or few-shot learning learns from existing large databases like ResNet or Unet and only needs very few samples to train on



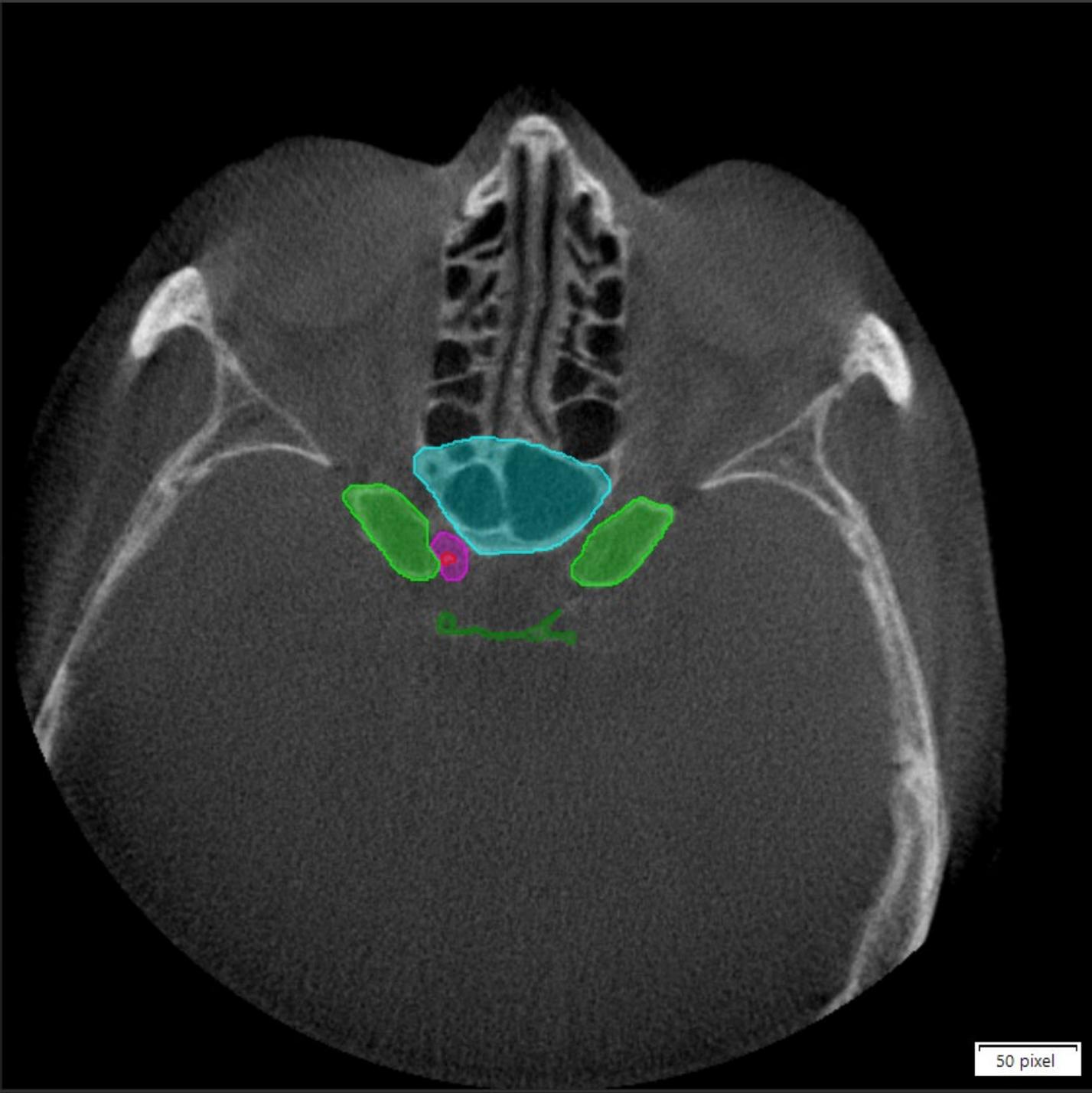




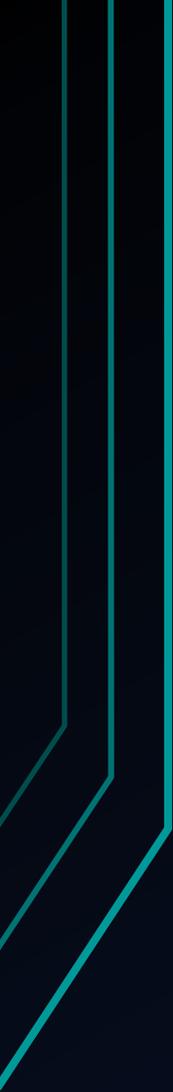


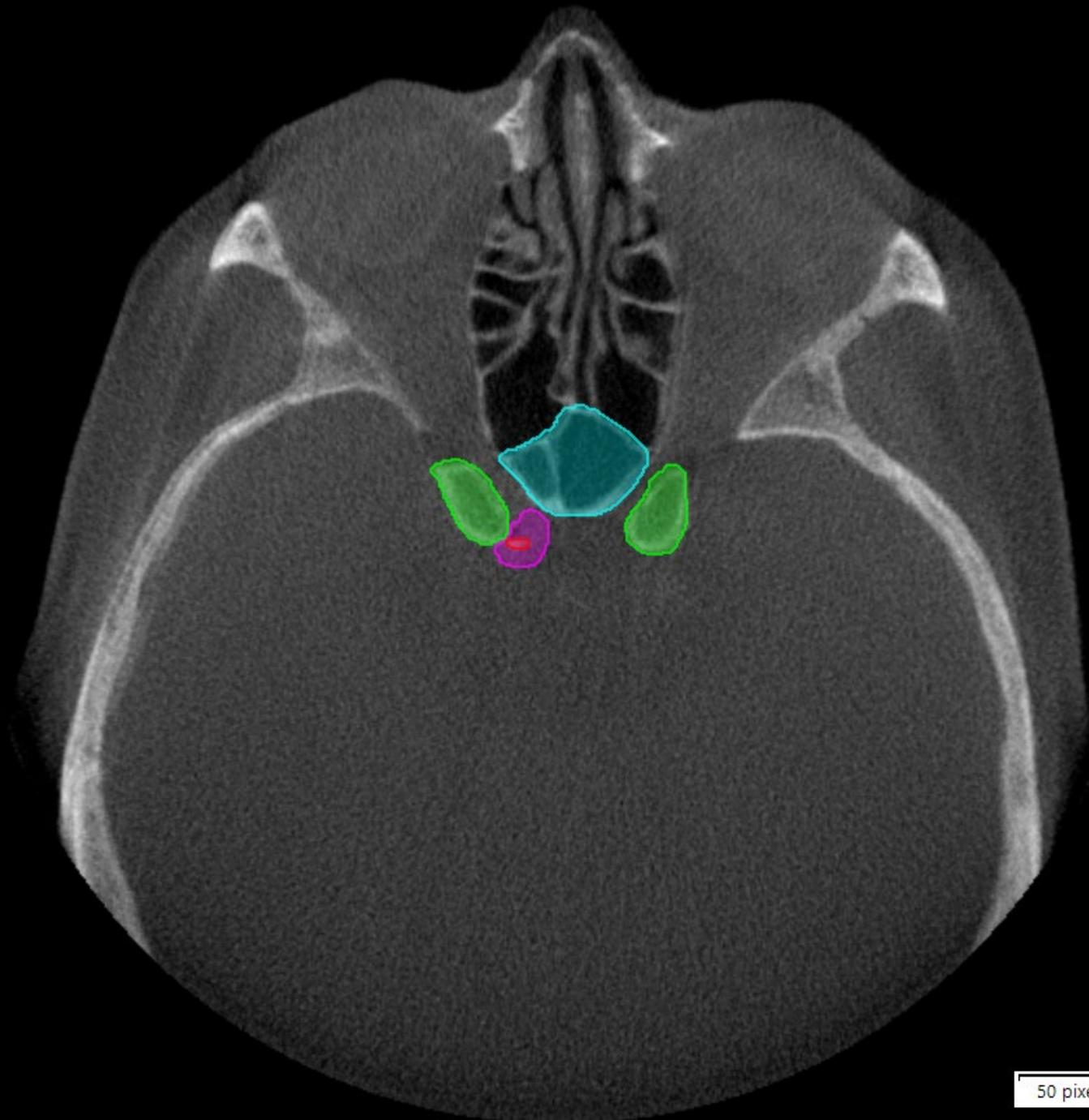
50 pixel





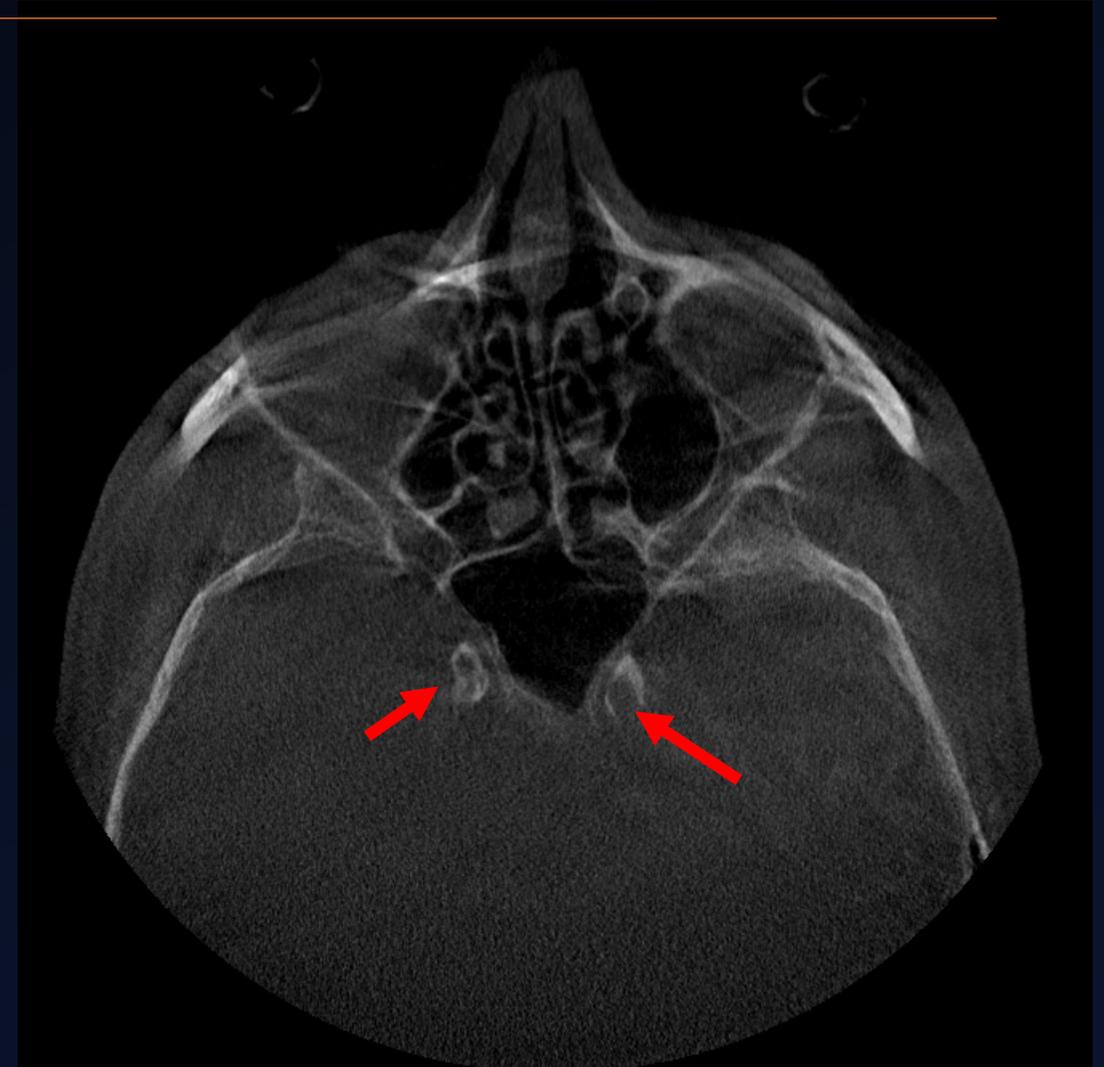
50 pixel

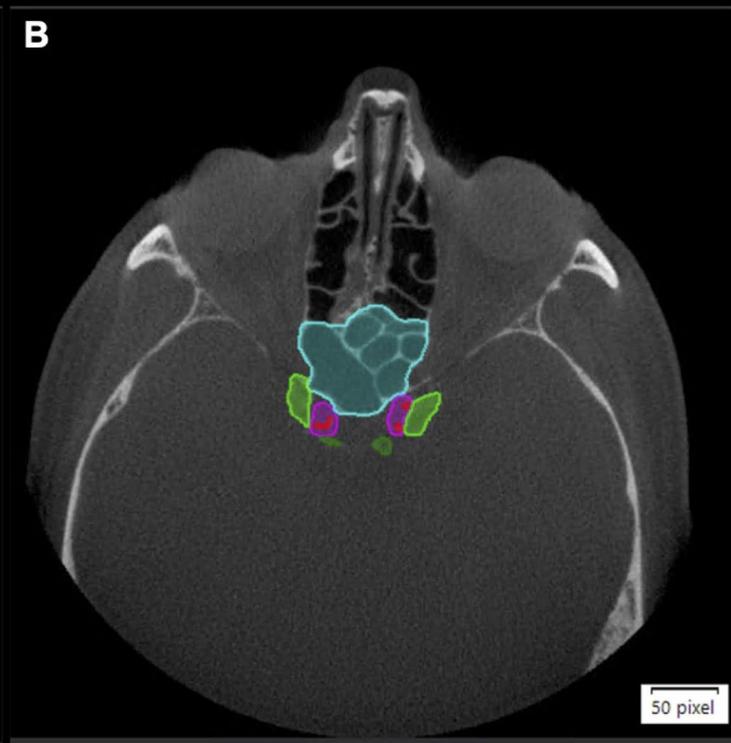
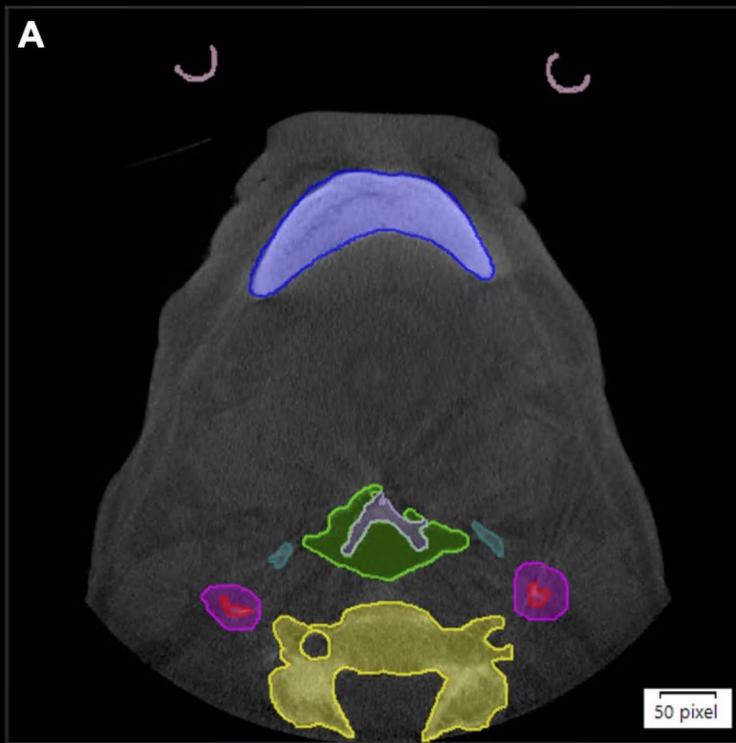




50 pixel

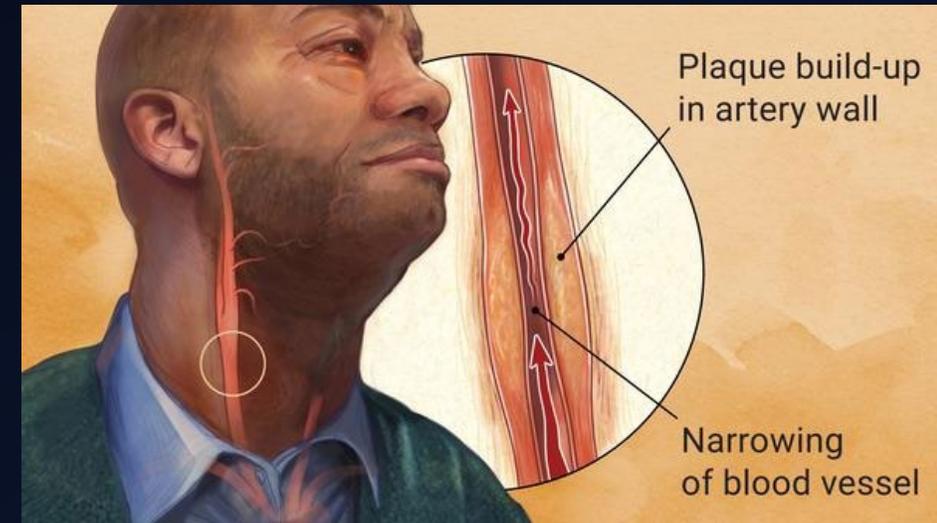
# Detection of Carotid Calcifications in Cone Beam Computed Tomography Utilizing a Deep Learning Convolutional Neural Network Image Segmentation Approach





# AI Research Must have a clinically relevant question!

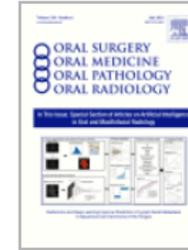
- Carotid calcification (CC) is a sign of atherosclerosis, which is a major risk factor for myocardial infarction and stroke
- Mild calcifications are proven to be associated with significant coronary artery disease
- CCs can be detected on routine dental radiographs
- CBCT is widely used in dentistry, and it can accurately detect CCs as small as  $1 \text{ mm}^3$ . However, only 29% are being reviewed by an appropriately trained specialist, which could indicate a high probability for missed disease
- Therefore, a high potential for undiagnosed cardiovascular pathology could be detected from already available SOC radiographs





# Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology

Volume 138, Issue 1, July 2024, Pages 162-172



## Detection of extracranial and intracranial calcified carotid artery atheromas in cone beam computed tomography using a deep learning convolutional neural network image segmentation approach

Shahd A. Alajaji BDS<sup>a b c</sup>, Rula Amarin DDS, MS<sup>d</sup>, Radi Masri DDS, MS, PhD<sup>d</sup>,

Tiffany Tavares DDS, DMSc<sup>e</sup>, Vandana Kumar DDS, MS<sup>a</sup>, Jeffery B. Price DDS, MS<sup>a b</sup>,

Ahmed S. Sultan BDS, PhD<sup>a b f</sup>  

# Applications of AI in Dentistry

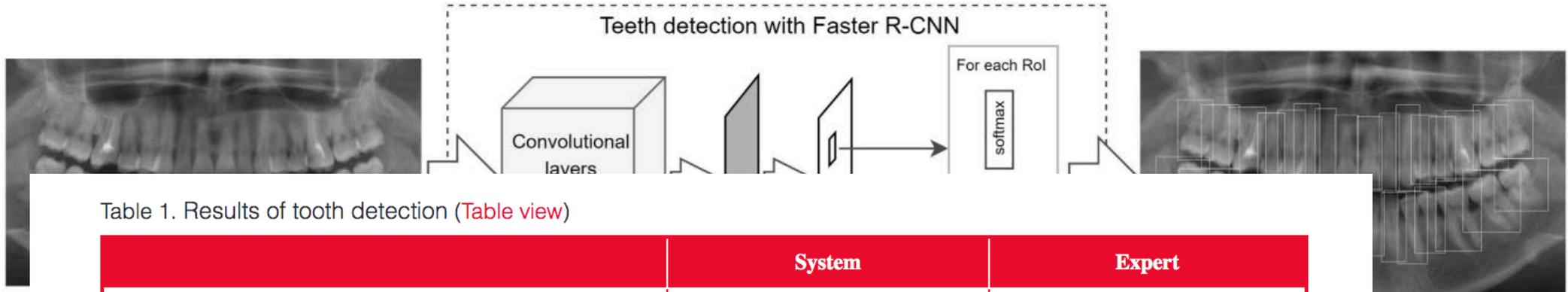
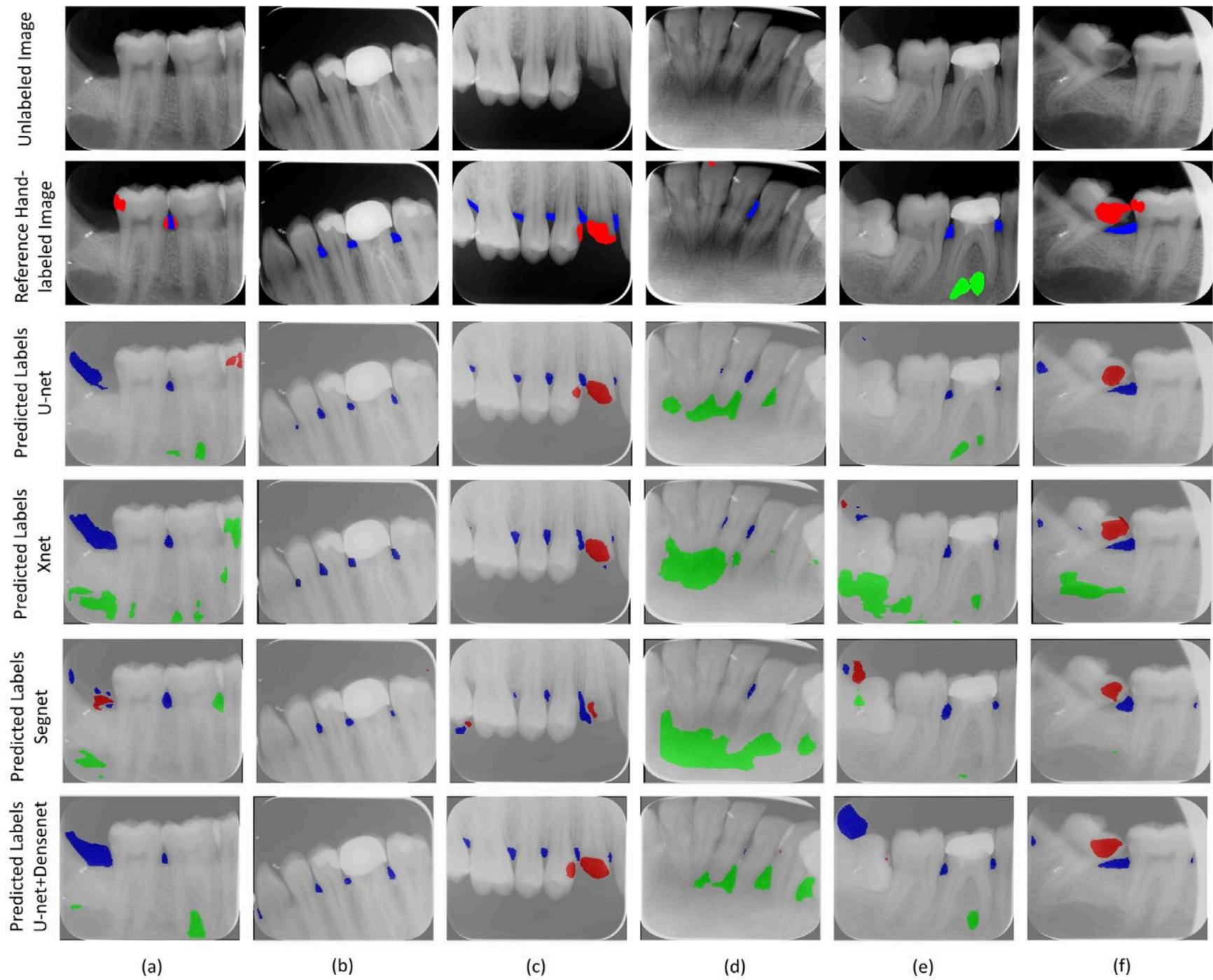


Table 1. Results of tooth detection (Table view)

	System	Expert
True-positives	5023	5043
False-negatives	30	10
False-positives	28	1
Precision	0.9945	0.9998
Sensitivity	0.9941	0.9980

Table 2. Results of tooth numbering (Table view)

	System	Experts
True-positives	4938	4985
True negatives	15,6108	15,6155
False negatives	101	54
False positives	101	54
Specificity	0.9994	0.9997
Sensitivity	0.9800	0.9893



(a)

(b)

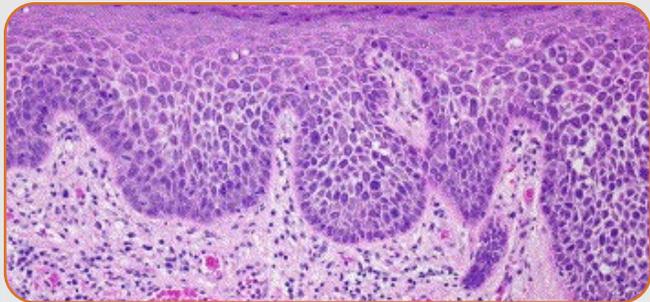
(c)

(d)

(e)

(f)

# Types of image data sets used *Division of AI Research*



Histopathology  
(WSI)

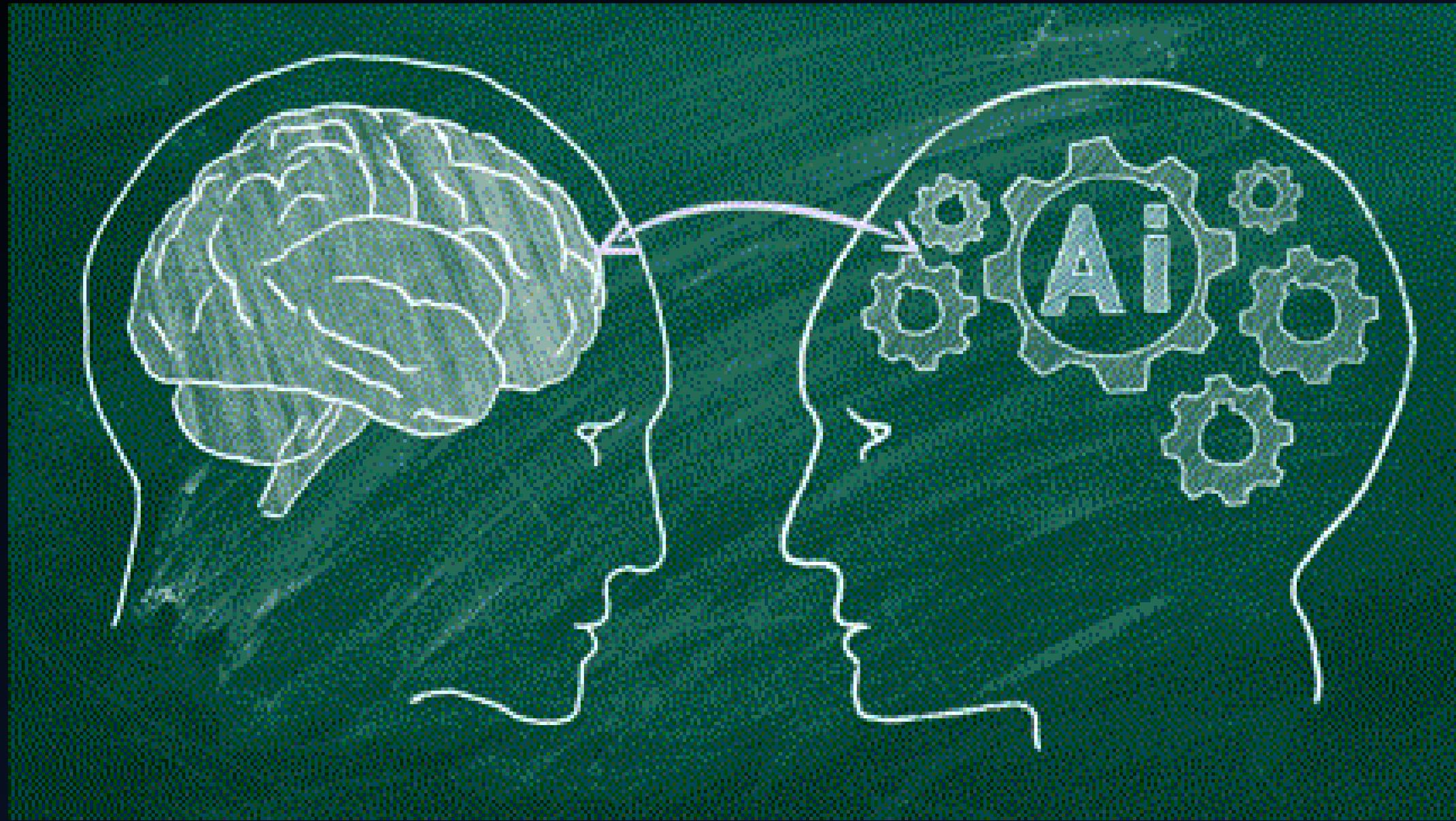


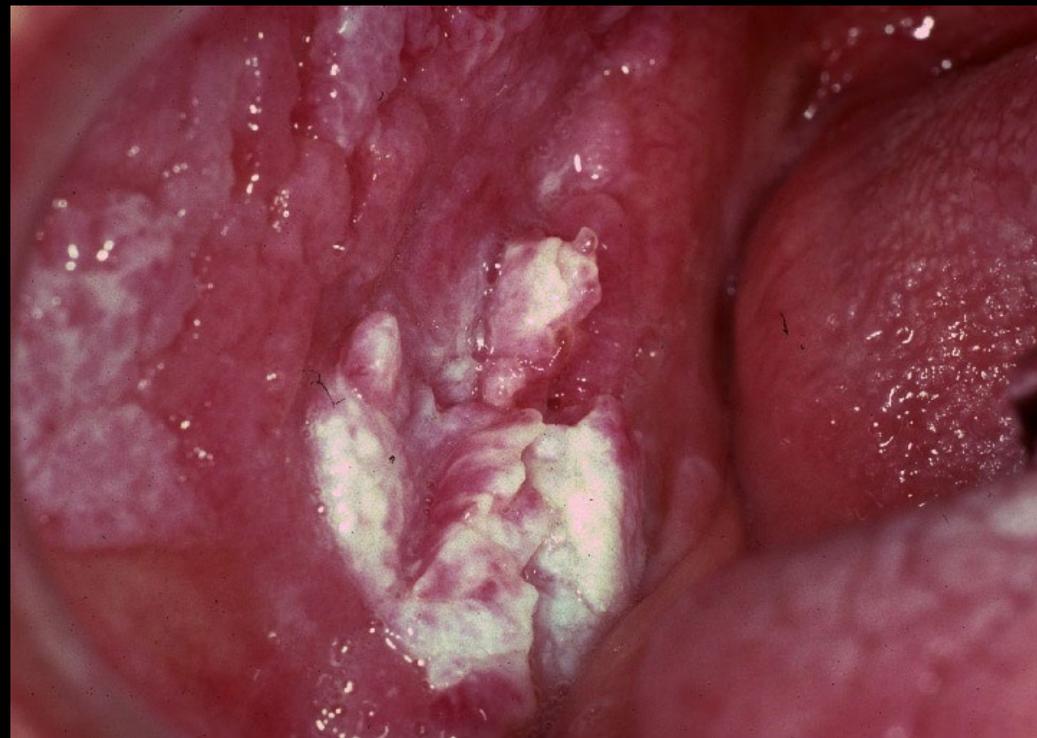
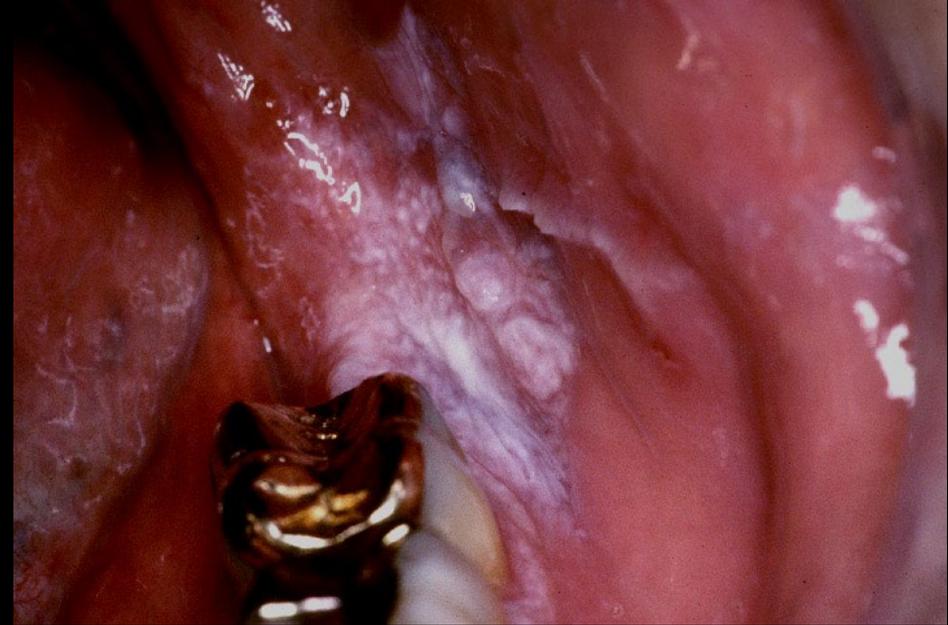
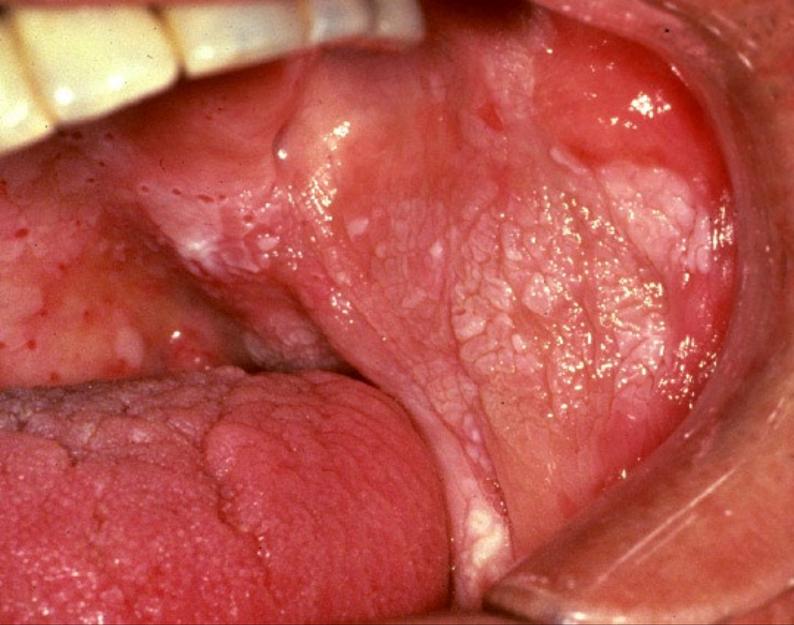
Radiographs (CBCT,  
Panoramic)



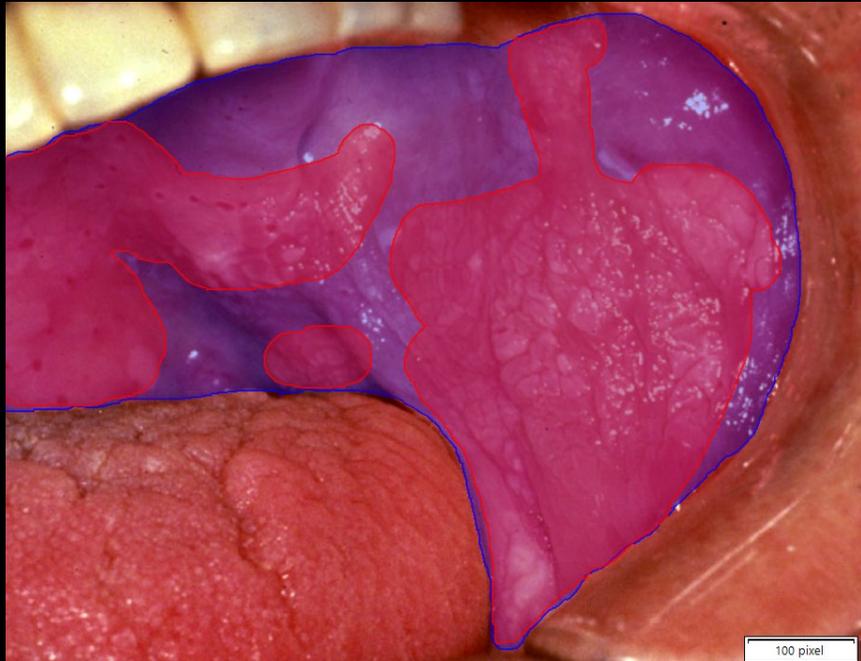
Clinical Images







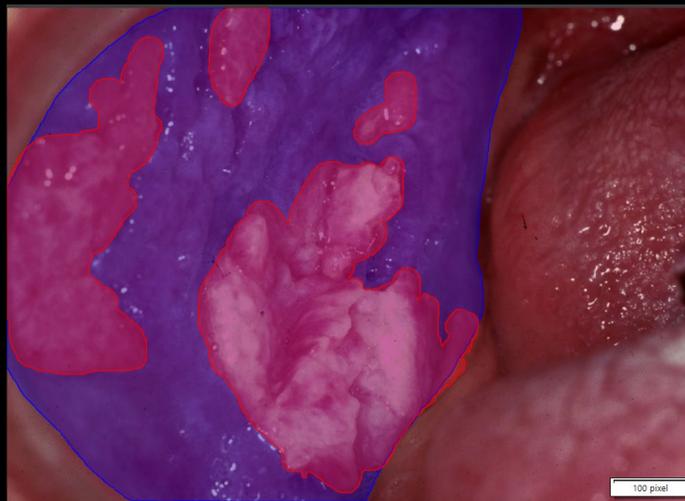
Erythroleukoplakia



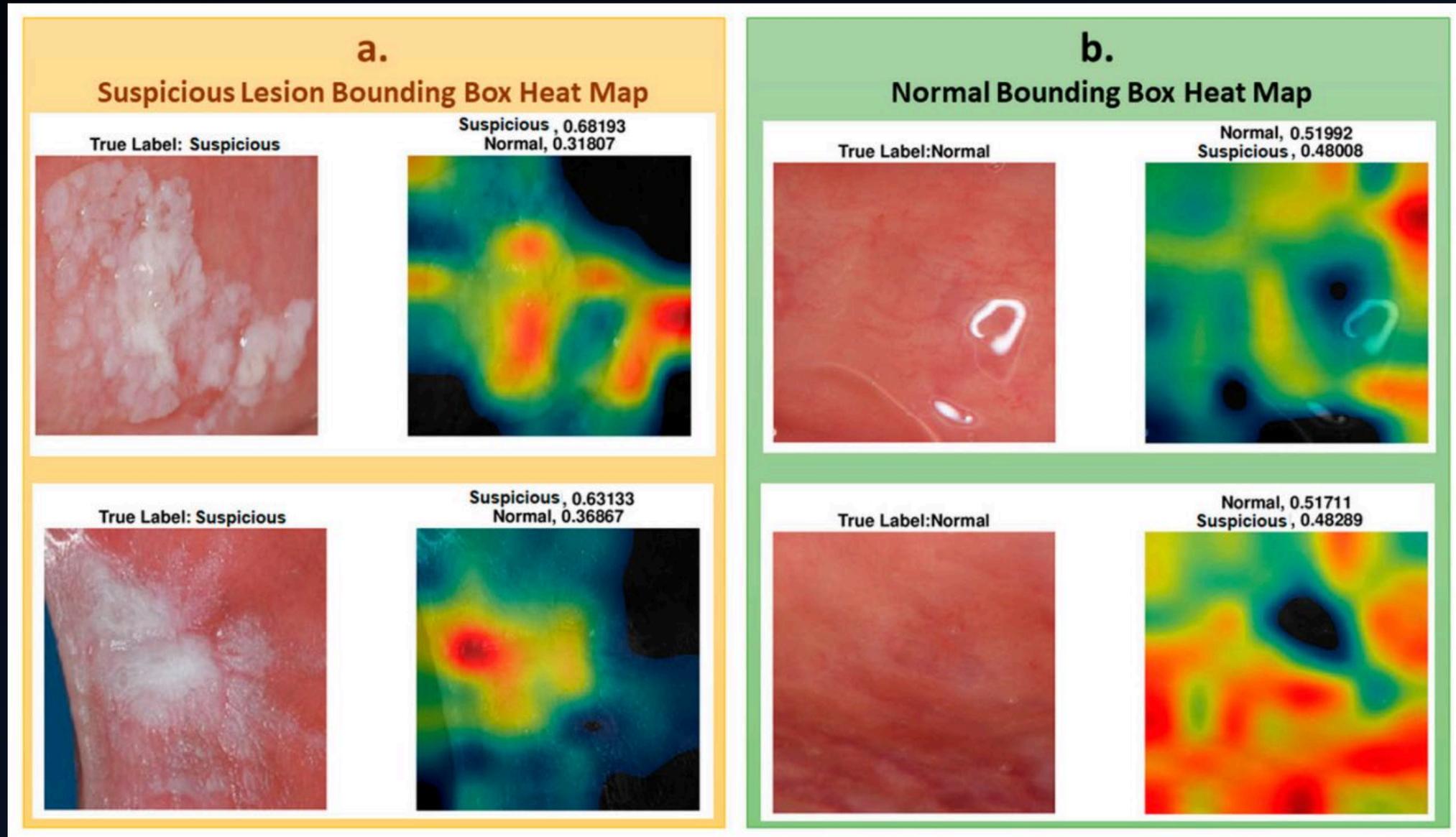
Leukoplakia

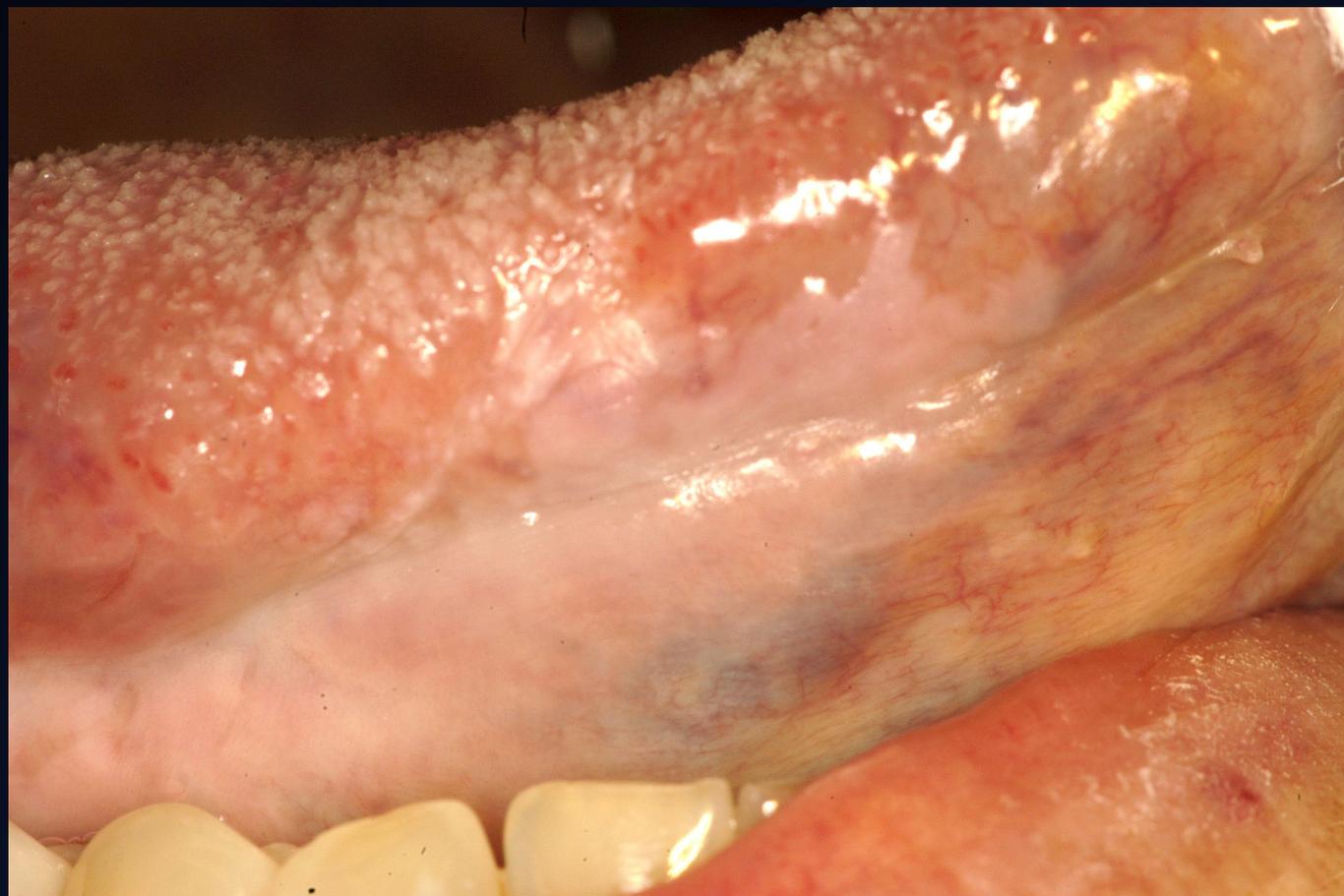


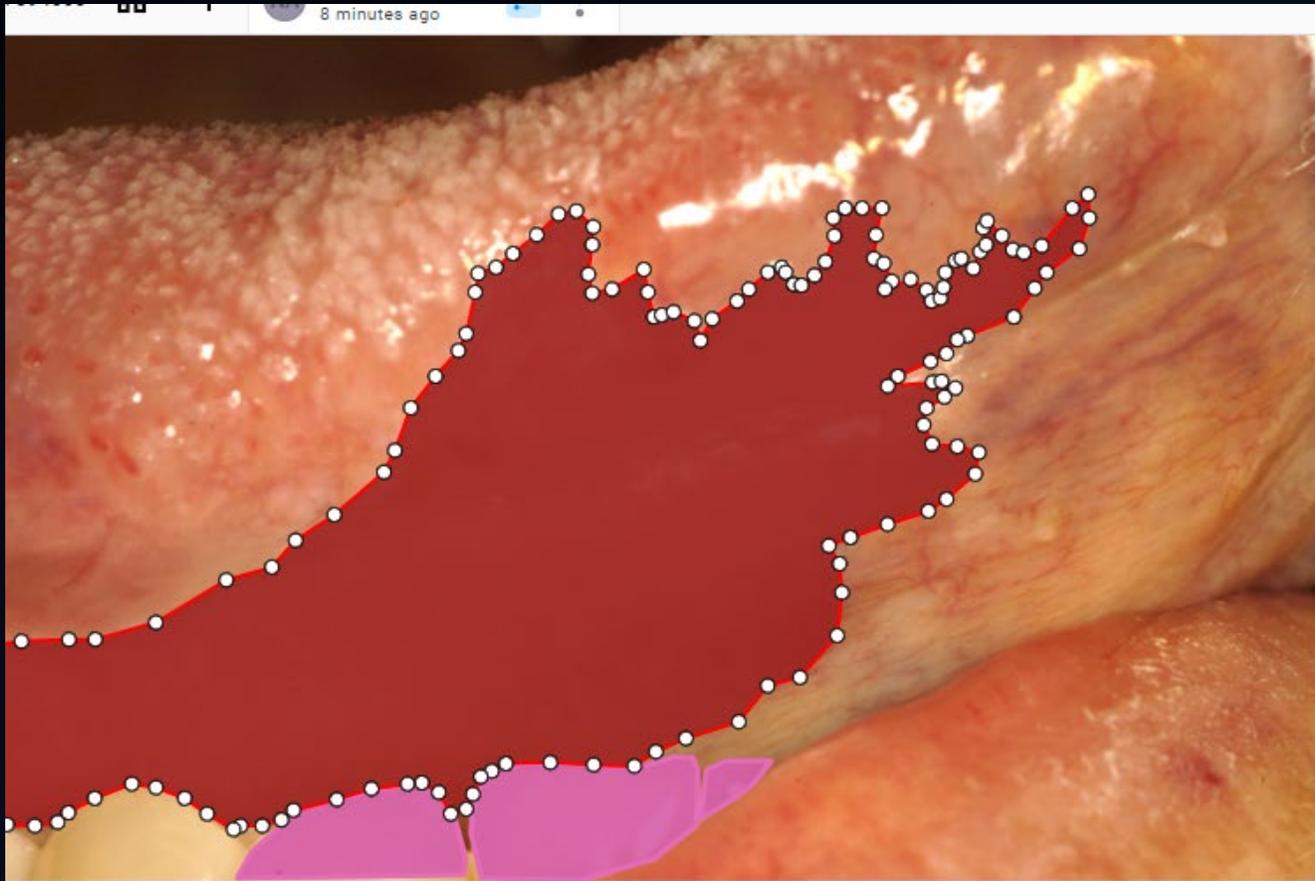
OSCC



# Applications of AI in Pathology







Reactive Lesions 1 | Teeth 2 | Normal Mucosa 3 | Traumatic ulcer 4 | **Leukoplakia 5** | SCC 6  
Proliferative verrucous leukoplakia 7 | Erythroleukoplakia 8 | Lichen Planus 9 | MMP 0  
Pemphigus vulgaris q | Geographic tongue w | Frictional keratosis e | Aphthous Ulcer t



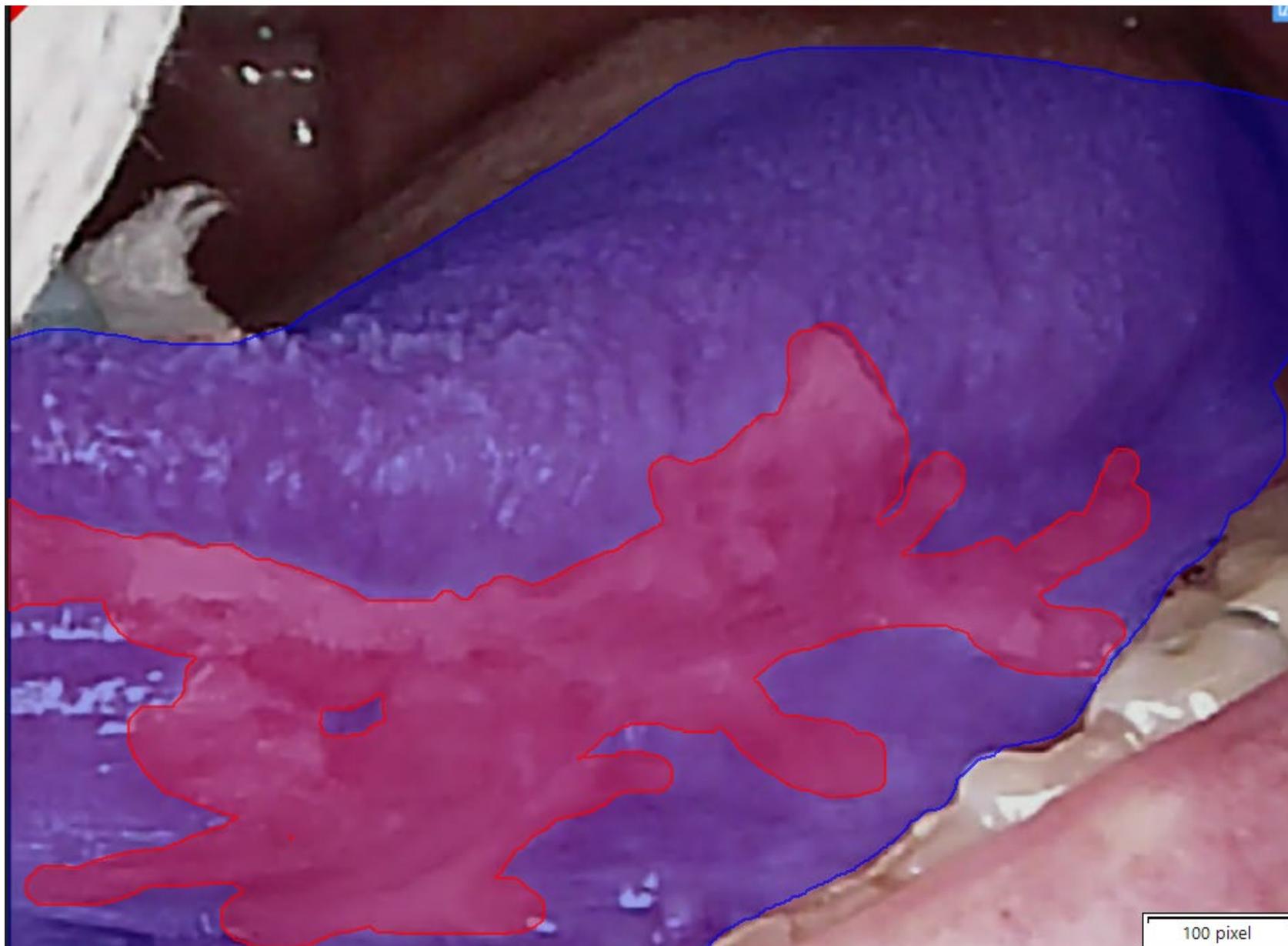
Info | Comments | History

Selection Details  
Leukoplakia ID TybRIsqtXW  
[Link icon] [Plus icon] [Eye icon] [Trash icon]

Regions | Relations

- Manual [By Time icon]
- 1 Leukoplakia
  - 2 Teeth
  - 3 Teeth
  - 4 Teeth







Selection Details

Leukoplakia ID GnkmfzwrqG

🔗 + 👁️ 🗑️

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Regions Relations

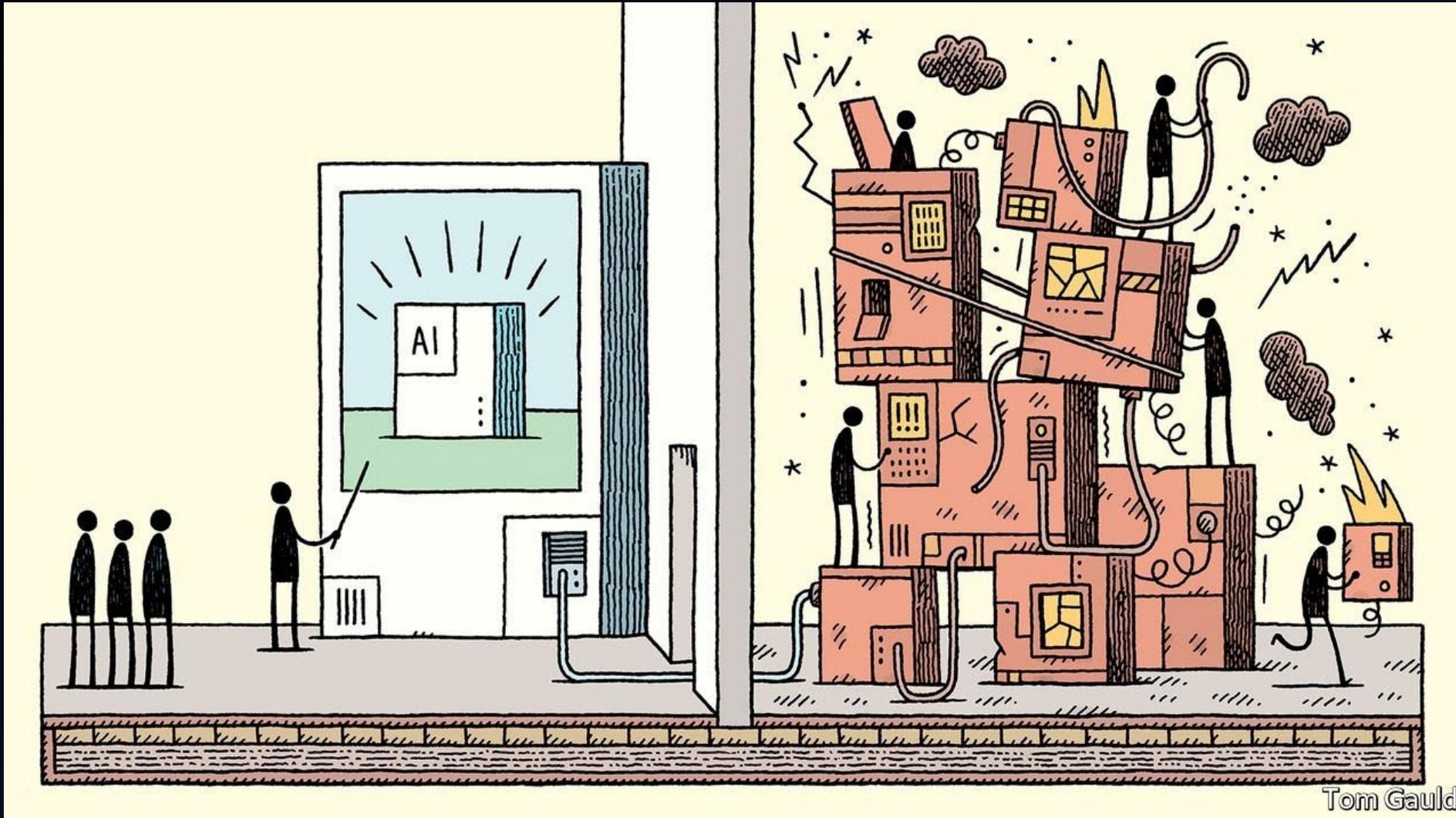
☰ Manual 📅 By Time ⌵↑ 👁️

- 🔗 1 Teeth
- 🔗 2 Teeth
- 🔗 3 Teeth
- 🔗 4 Teeth
- 🔗 5 Teeth
- 🔗 6 Teeth

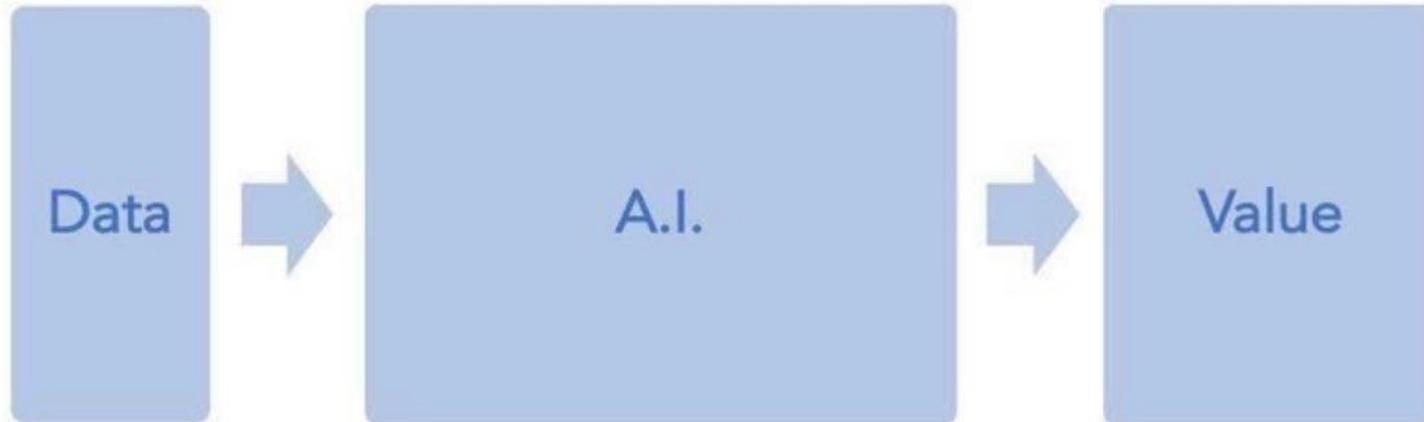
## Learning Objectives

1. Be able to provide a definition for Artificial Intelligence (AI)
2. Understand the History of AI
3. Be able to recognize the main components of *AI Classification*
4. Be able to provide examples of Applications of AI in Medicine, Pathology, and Dentistry
5. Be able to identify the current Limitations and Ethical Considerations of AI

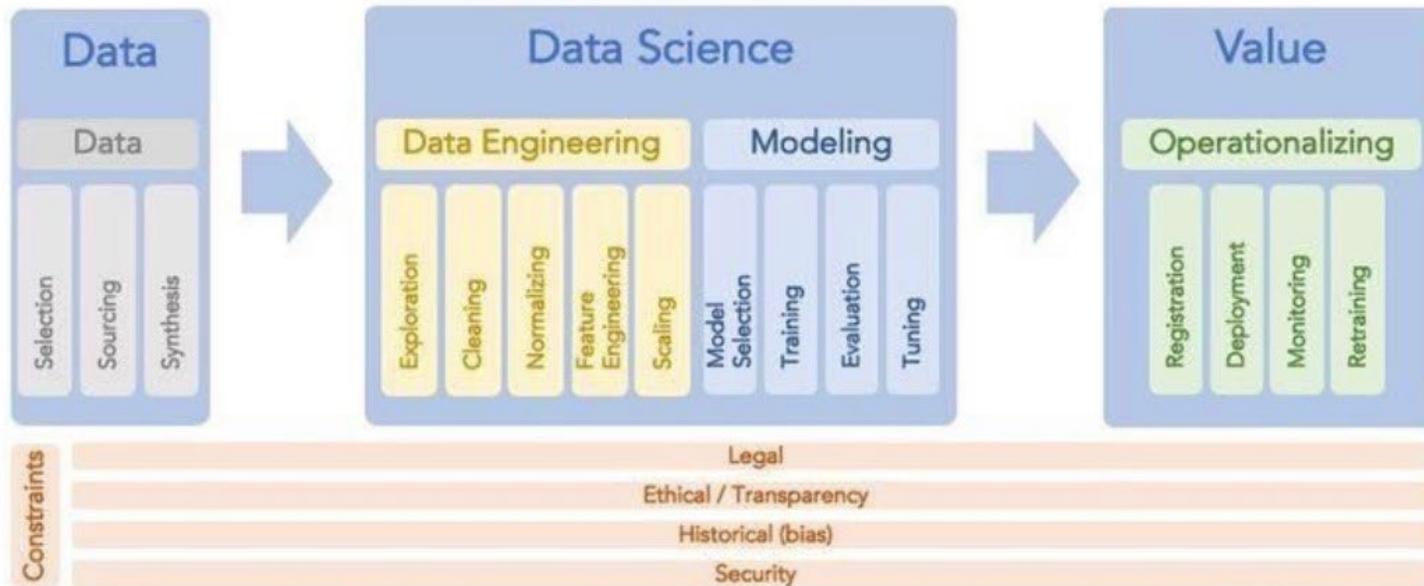
# Limitations and Ethical Considerations:



## What companies think A.I. looks like



## What it actually is



# Limitations and Ethical Considerations:

## 1. Data Privacy, Consent, Sharing, and Ownership:

- Who can have access? Who owns the data?
- Are they being used for secondary purposes?
- Consent for AI research
- Data breach

## 2. Patient Safety and Accountability:

- AI error
- Automation bias
- If harm occurs, who is responsible? Dr, AI developer, organization?..ect.

## 3. Transparency and Bias:

- The “black-box” nature of many algorithms
- AI inherent bias that poorly represent the wider population

# Limitations and Ethical Considerations:

## 4 . **Empathy & Workforce:**

- Clinician-patient relationship
- Humans replaced by machines

## 5. **Regulatory environment:**

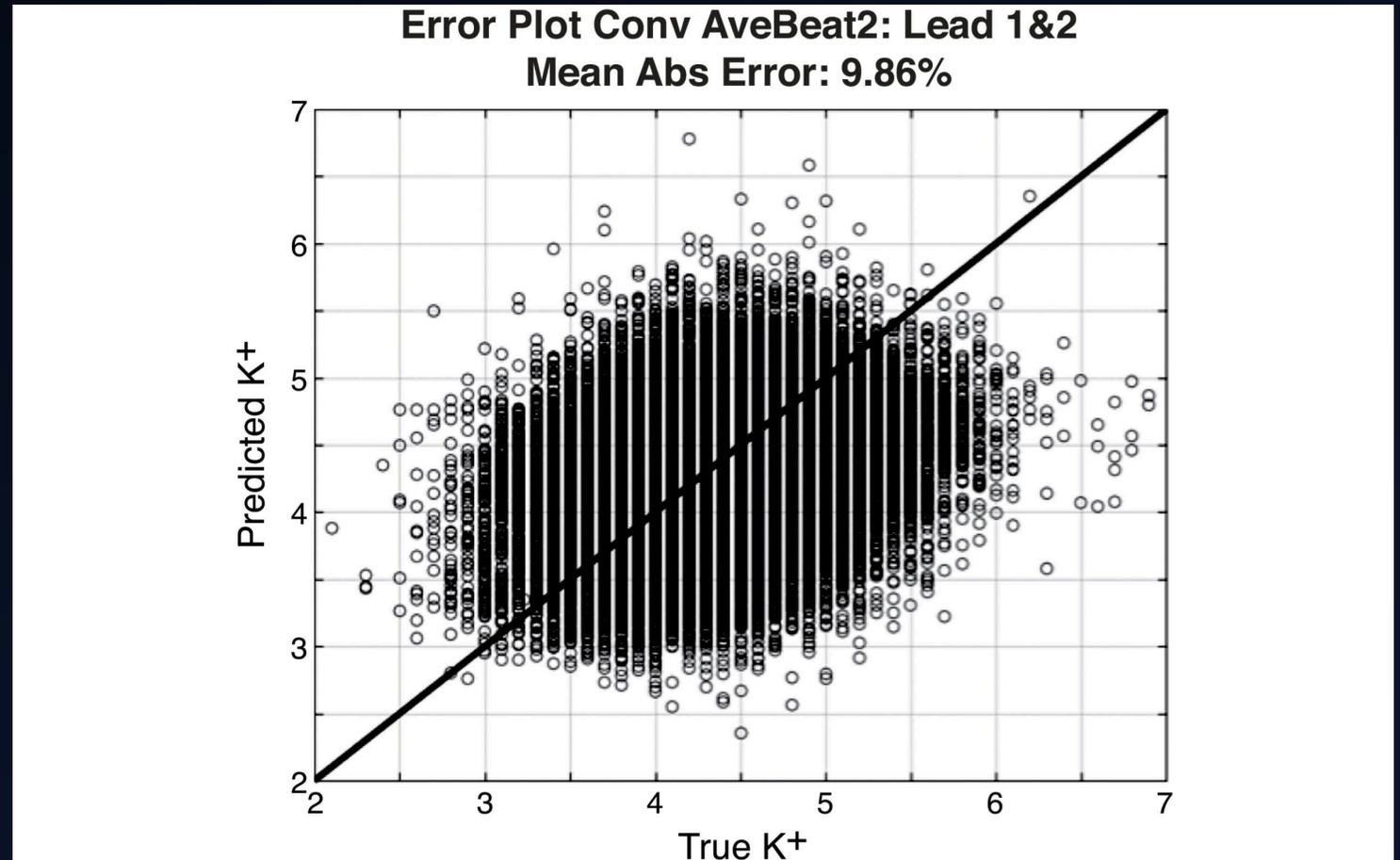
- Traditional medical device regulations (MDR) not on par with these fast AI software devices

# Limitations and Ethical Considerations:

The Mayo Clinic gave the AI **1.3 M ECGs** with corresponding K<sup>+</sup> levels to develop an algorithm, but the error was unacceptable.

## Why failed?

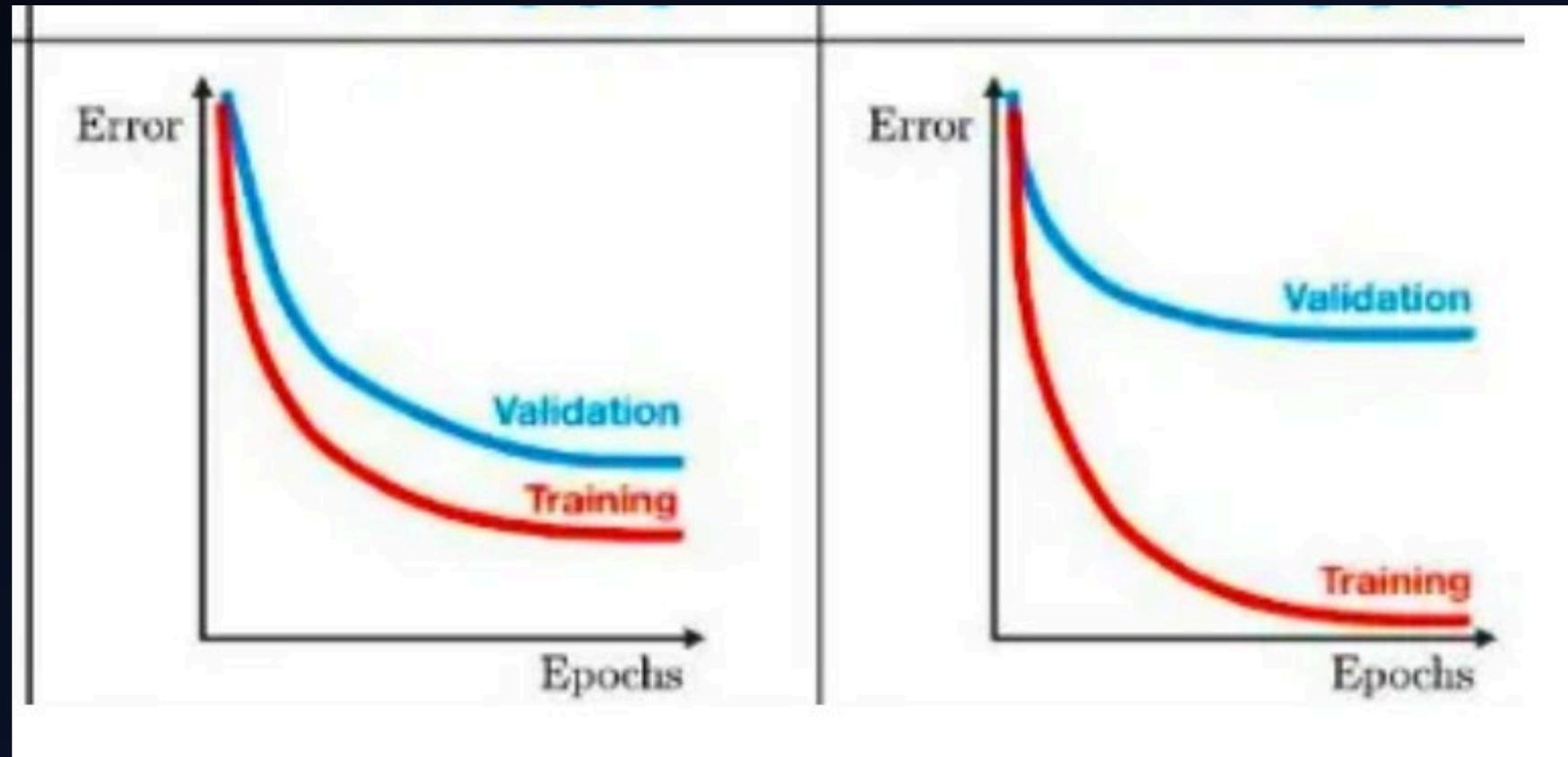
Insufficient number of patients with high K<sup>+</sup> level.



# Limitations and Ethical Considerations:

## Overfitting:

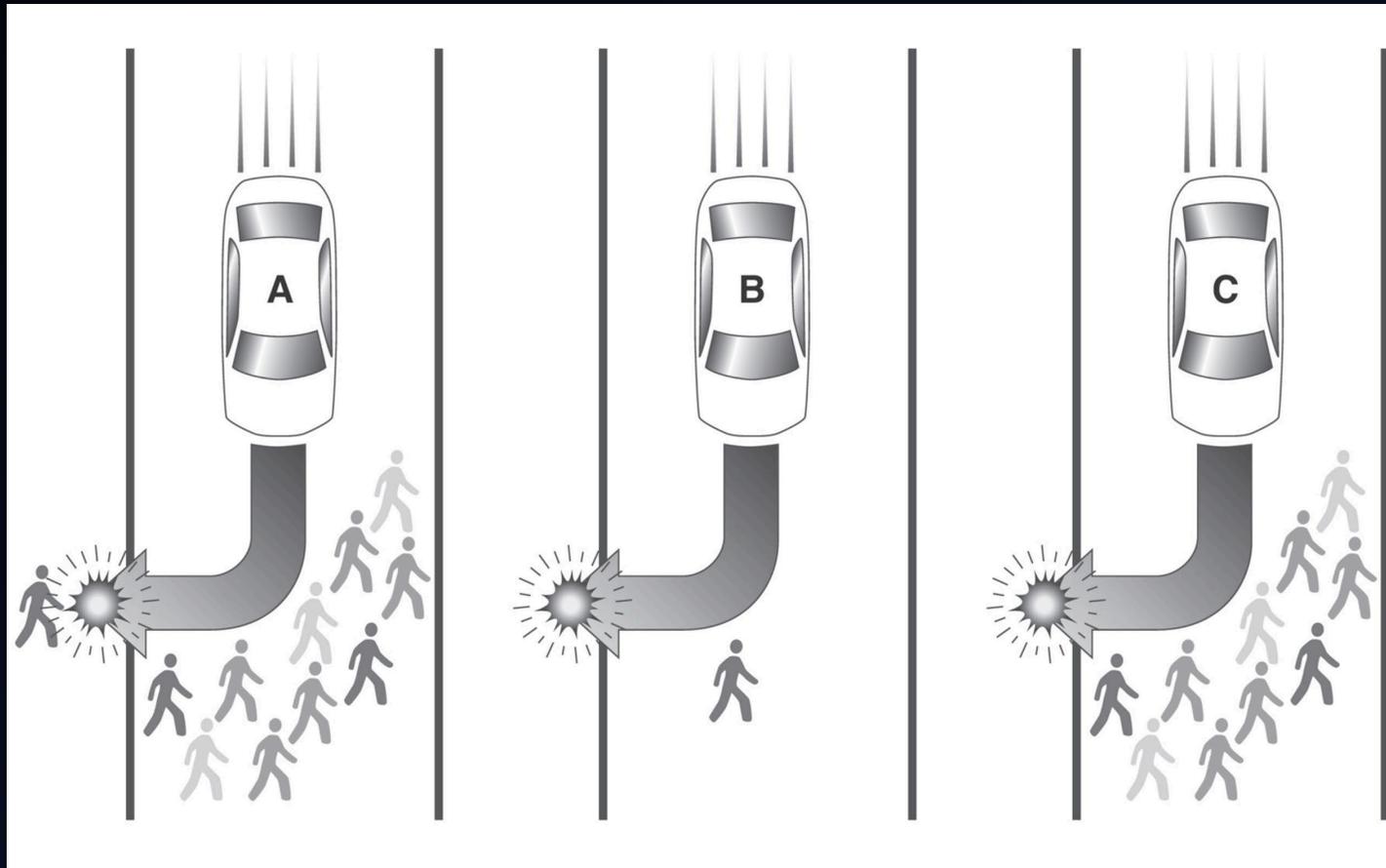
- Model is trained on a narrow dataset
- No real-world testing performance with variable datasets



1. <https://www.ibm.com/cloud/learn/overfitting>

2. <https://en.wikipedia.org/wiki/Overfitting>

# Limitations and Ethical Considerations:



The three self-driving car traffic situations that result in imminent, unavoidable harm.

# Limitations and Ethical Considerations: When AI goes Bad and gets Ugly

## Tougher Turing Test Exposes Chatbots' Stupidity

We have a long way to go if we want virtual assistants to understand us.

by **Will Knight**

July 14, 2016

---

*User: Siri, call me an ambulance.*

*Siri: Okay, from now on I'll call you "an ambulance."*

Apple fixed this error shortly after its virtual assistant was first released in 2011. But a new contest shows that computers still lack the common sense required to avoid such embarrassing mix-ups.

*User: Siri, call me an ambulance.*

*Siri: Okay, from now on I'll call you "an ambulance."*

1. <https://www.technologyreview.com/2016/07/14/7797/tougher-turing-test-exposes-chatbots-stupidity/>
2. Yampolskiy, R. v, & Spellchecker, M. S. (2015). *Artificial Intelligence Safety and Cybersecurity: a Timeline of AI Failures.* [https://en.wikipedia.org/wiki/Tay\\_](https://en.wikipedia.org/wiki/Tay_)

# Limitations and Ethical Considerations: When AI goes Bad and gets Ugly

 Euronews

## Man ends his life after an AI chatbot 'encouraged' him to sacrifice himself to stop climate change

A Belgian man reportedly decided to end his life after having conversations about the future of the planet with an AI chatbot named Eliza.

1 month ago



 Hard-Drive.net

## Man Uses ChatGPT to Write Suicide Note

FORT WAYNE, Ind. — Local depressed man Matthew Watkins reportedly used AI chatbot ChatGPT to write his suicide note, according to worried...

1 month ago



 Interesting Engineering

## Belgian woman blames ChatGPT-like chatbot ELIZA for her husband's suicide

The widow of a Belgian man who recently killed himself alleges that a chatbot forced her husband to commit suicide.

1 month ago



 VICE

## 'He Would Still Be Here': Man Dies by Suicide After Talking with AI Chatbot, Widow Says

A Belgian man recently died by suicide after chatting with an AI chatbot on an app called Chai, Belgian outlet La Libre reported.

1 month ago



 The Brussels Times

## Belgian man dies by suicide following exchanges with chatbot

A young Belgian man recently died by suicide after talking to a chatbot named ELIZA for several weeks, spurring calls for better protection...

1 month ago



 New York Post

## Married father commits suicide after encouragement by AI chatbot: widow



## Man Uses ChatGPT to Write Suicide Note



hard-drive.net

 Facebook

 Twitter

 Reddit

BY JEREMY KAPLOWITZ ON APRIL 3, 2023

# Limitations and Ethical Considerations: When AI goes Bad and gets Ugly



CALIFORNIA

## Crime-fighting robot hits, rolls over child at Silicon Valley mall

BY VERONICA ROCHA  
JULY 14, 2016 8:29 AM PT

A security company has apologized for a “freakish accident” after its crime-fighting robot hit a 16-month-old boy on the head and ran over him at a shopping mall in Palo Alto.

1. <https://www.latimes.com/local/lanow/la-me-ln-crimefighting-robot-hurts-child-bay-area-20160713-snap-story.html>
2. Yampolskiy, R. v, & Spellchecker, M. S. (2015). *Artificial Intelligence Safety and Cybersecurity: a Timeline of AI Failures*. [https://en.wikipedia.org/wiki/Tay\\_](https://en.wikipedia.org/wiki/Tay_)

# Limitations and Ethical Considerations: When AI goes Bad and gets Ugly

## Tesla driver killed while using autopilot was watching Harry Potter, witness says

**Driver in first known fatal self-driving car crash was also driving so fast that 'he went so fast through my trailer I didn't see him', the truck driver involved said**



1. <https://www.theguardian.com/technology/2016/jul/01/tesla-driver-killed-autopilot-self-driving-car-harry-potter>
2. Yampolskiy, R. v, & Spellchecker, M. S. (2015). *Artificial Intelligence Safety and Cybersecurity: a Timeline of AI Failures*. [https://en.wikipedia.org/wiki/Tay\\_](https://en.wikipedia.org/wiki/Tay_)

## Who is liable for misdiagnosis?

“Who is responsible when artificial intelligence harms someone? A California jury may soon have to decide. In December 2019 a person driving a Tesla with an AI navigation system killed two people in an accident. The driver faces up to 12 years in prison. Several federal agencies are investigating Tesla crashes, and the U.S. Department of Justice has opened a criminal probe into how Tesla markets its self-driving system.”

# Who is liable for misdiagnosis?

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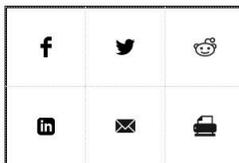
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ARTIFICIAL INTELLIGENCE

## Who Is Liable When AI Kills?

We need to change rules and institutions while still promoting innovation to protect people from faulty AI

By George Maliha, Ravi B. Parikh on March 1, 2023



Credit: Sergii Iaromenko/Science Photo Library/Getty Images

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Who is liable for misdiagnosis?

“We need to protect people from faulty AI without curbing innovation”

# AI Regulation in Dentistry

ADA SCDI White Paper No. 1106  
Approved by SCDI: December 30, 2022

American Dental Association  
**SCDI White Paper No. 1106**

## Dentistry — Overview of Artificial and Augmented Intelligence Uses in Dentistry

**ADA** American  
Dental  
Association®



**International Organization for Standardization**

# AI Regulation in Dentistry

## Artificial Intelligence

Machines replacing Human Processes

Makes Decisions

Complete Imitation of Human Brain

Automated robots performing tasks

Fully automated Drones

Vs



## Augmented Intelligence

Machines Aiding Human processes

Suggests Decisions

Selective Imitation of Human Brain

Collaborative Robots working alongside Humans

Intelligent Drones operated by humans

# AI Regulation in Dentistry

The New York Times

<https://www.nytimes.com/2023/04/16/opinion/this-is-too-important-to-leave-to-microsoft-google-and-facebook.html>

EZRA KLEIN

## The Surprising Thing A.I. Engineers Will Tell You if You Let Them

April 16, 2023

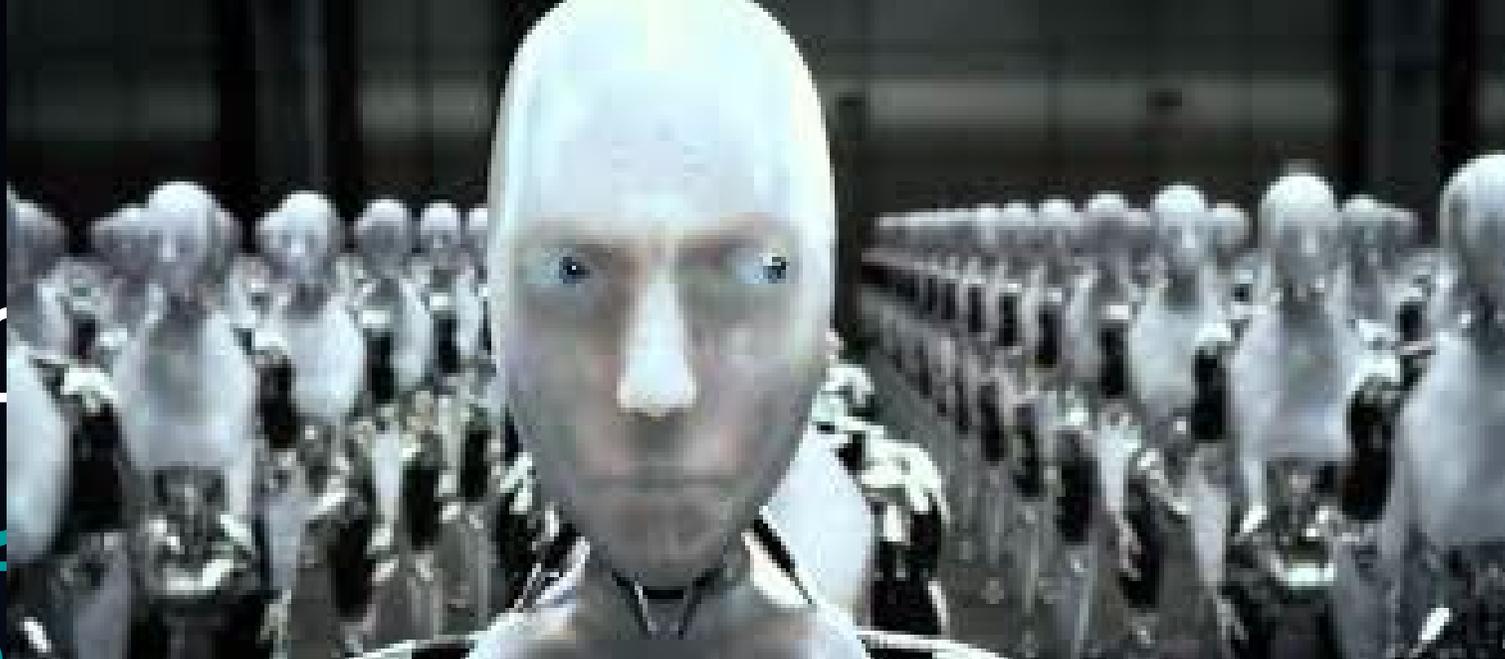


By Ezra Klein

*“The government needs to do more here than just write up some standards. It needs to make investments and build institutions to conduct the monitoring”*

## Current State of AI:

In 2023, AI is excellent at **learning** and recognizing **patterns** but lacks human understanding and morality



Future

The Future

ss or

Development, intentions understand

and demonstrate moral values

- Artificial consciousness/machine consciousness/synthetic consciousness (field related to AI & cognitive robotics)

# Artificial Consciousness

- In his article "Artificial Consciousness: Utopia or Real Possibility," Giorgio Buttazzo says:
  - "that a common objection to artificial consciousness is that, working in a fully automated mode, they [the computers] cannot exhibit creativity, unreprogrammation (which means can no longer be reprogrammed, from rethinking), emotions, or free will
  - a computer, like a washing machine, is a slave operated by its components."

# Artificial Consciousness (AC)

- Ethical Issues with AC:
  1. What defines consciousness?
  2. What rights would it have under law?

In 2022, Google engineer Blake Lemoine made a viral claim that Google's LaMDA chatbot was sentient

- evidence: chatbot's humanlike answers to many of his questions
- BUT chatbot's behavior was judged by the scientific community as likely a consequence of mimicry, rather than machine consciousness

## Learning Objectives

1. Be able to provide a definition for Artificial Intelligence (AI)
2. Understand the History of AI
3. Be able to recognize the main components of *AI Classification*
4. Be able to provide examples of Applications of AI in Medicine, Pathology, and Dentistry
5. Be able to identify the current Limitations and Ethical Considerations of AI
6. Be able to provide examples of Future Applications of AI in Healthcare



# Artificial Intelligence in Medicine

THE A.I.

Artificial intelligence algorithms are not only making our cars safer and shopping easier, but increasingly diagnose patients and help make the best decisions when caring for them. Learn more about Artificial Intelligence in Medicine.



# Top Artificial Intelligence Companies In Healthcare To Keep An Eye On

13 August 2024

Read about the biggest artificial intelligence companies in healthcare ranging from start-ups to tech giants to keep an eye on in the future.



## The Future of Radiology And Artificial Intelligence

Radiologists' creative work will be

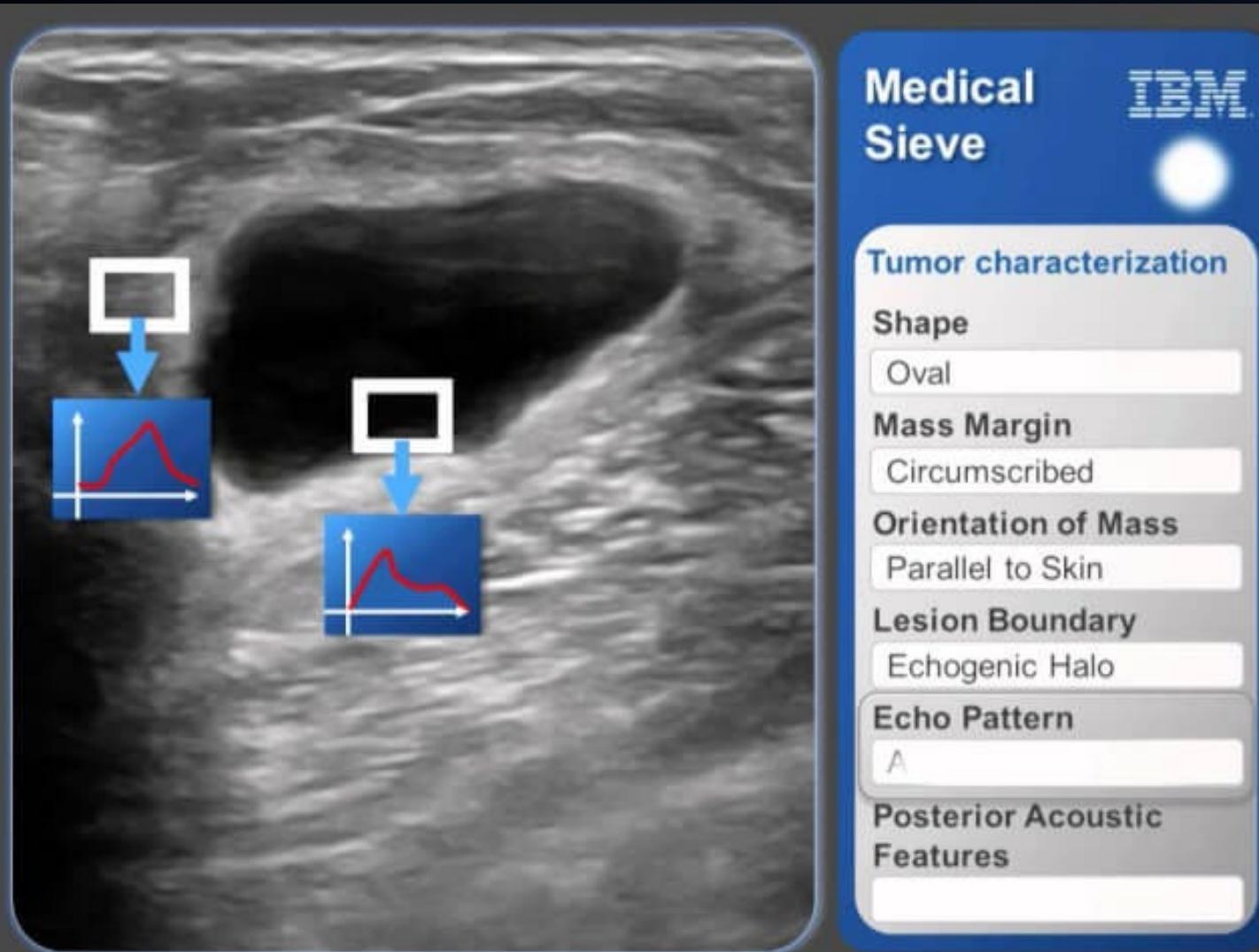


## Artificial Intelligence In Healthcare: 10 Medical Fields A.I. Will Change Completely



## FDA Approvals For Smart Algorithms In Medicine In One Giant Infographic

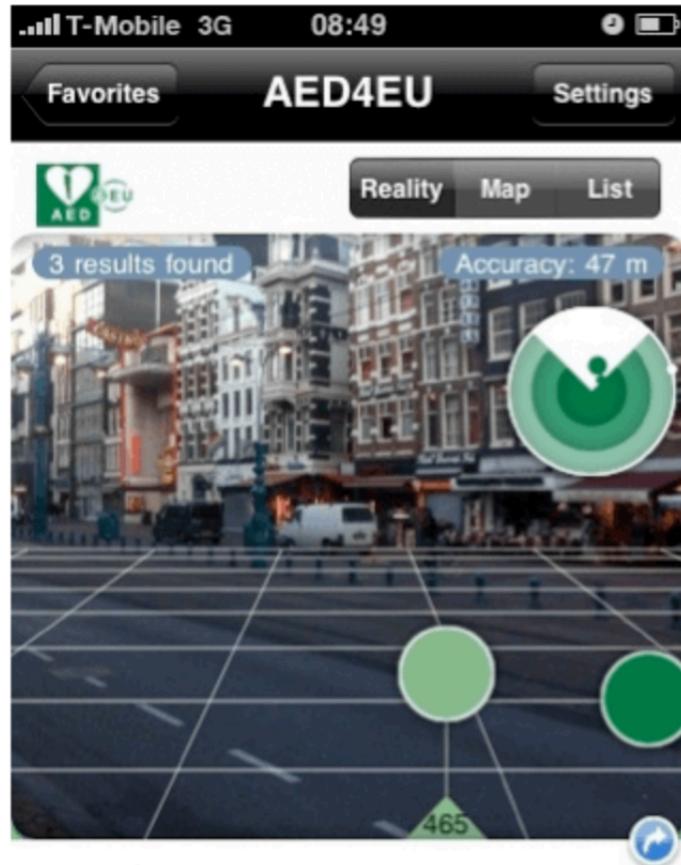
# Future applications of AI in healthcare:



1. IBM launched an algorithm called Medical Sieve qualified to assist in clinical decision making in radiology and cardiology
2. The “cognitive health assistant” is able to analyze radiology images to spot and detect problems faster and more reliably

# Future applications of AI in healthcare:

## 1. Augmented reality can save lives by showing defibrillators nearby.

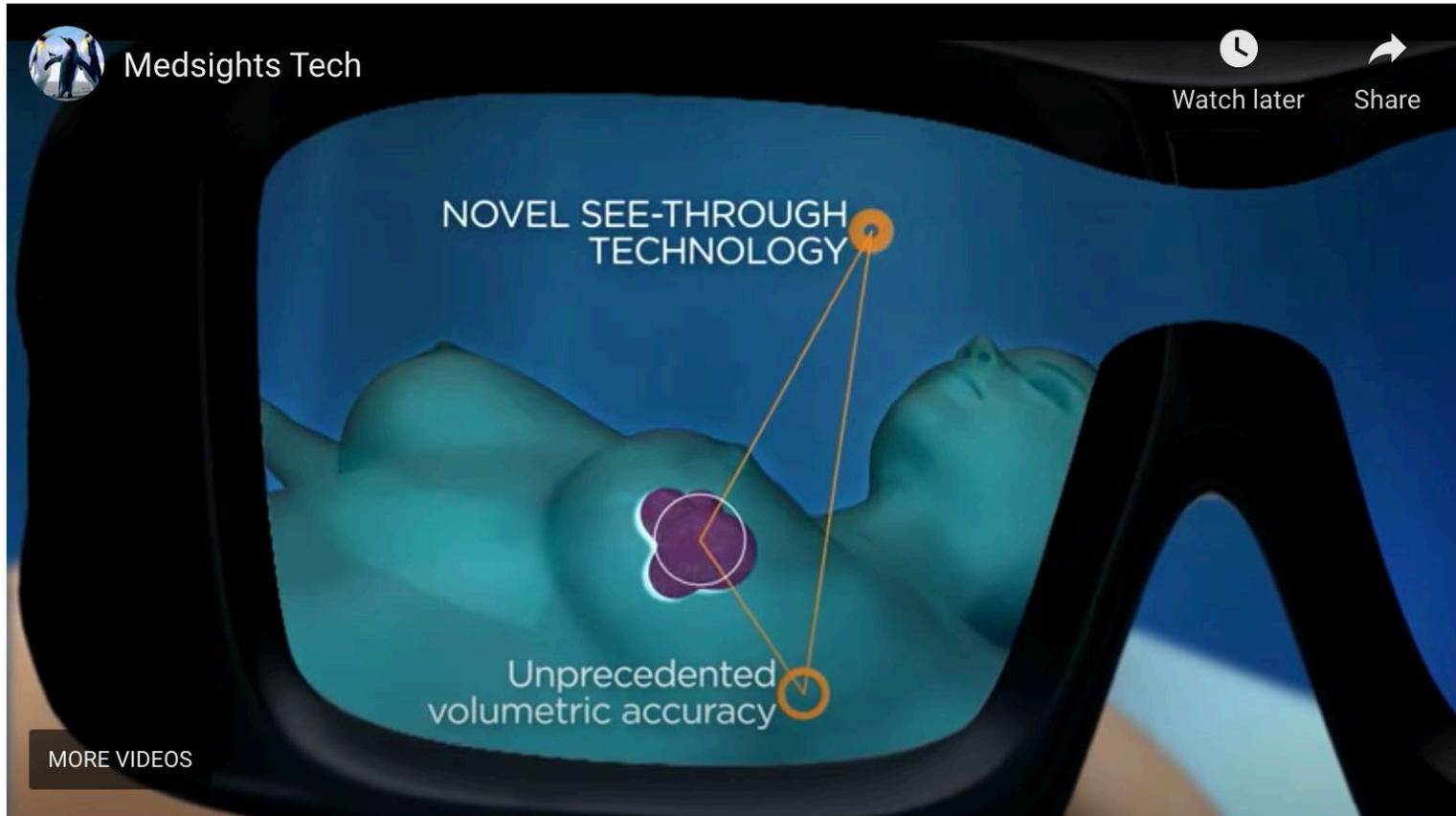


What would you do if a person next to you suddenly collapsed? All kinds of thoughts would rush through your head, and no matter whether you would think about calling an ambulance, a doctor or your mom for help, you would definitely reach for your phone.

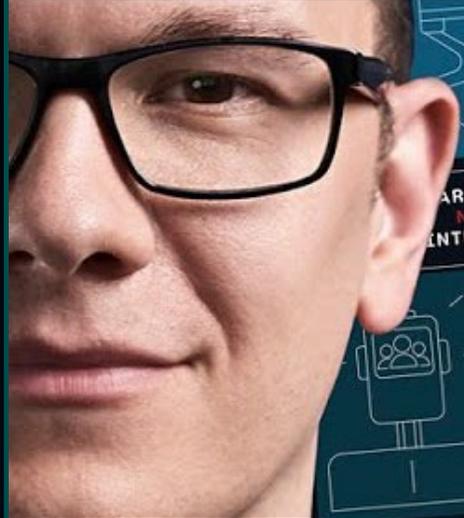
There are applications that help you in such a situation. Take for example the AED4EU app, created by Lucien Engelen from the Radboud University Nijmegen Medical Centre, The

# Future applications of AI in healthcare:

Sync AR developed a software programme to give surgeons "X-ray vision" by fusing digitally enhanced images directly into the microscope of a surgical device.



AR glasses to view a 3D image of the tumor

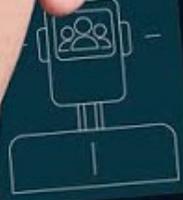


**LIVE Q&A** with

## The Medical Futurist

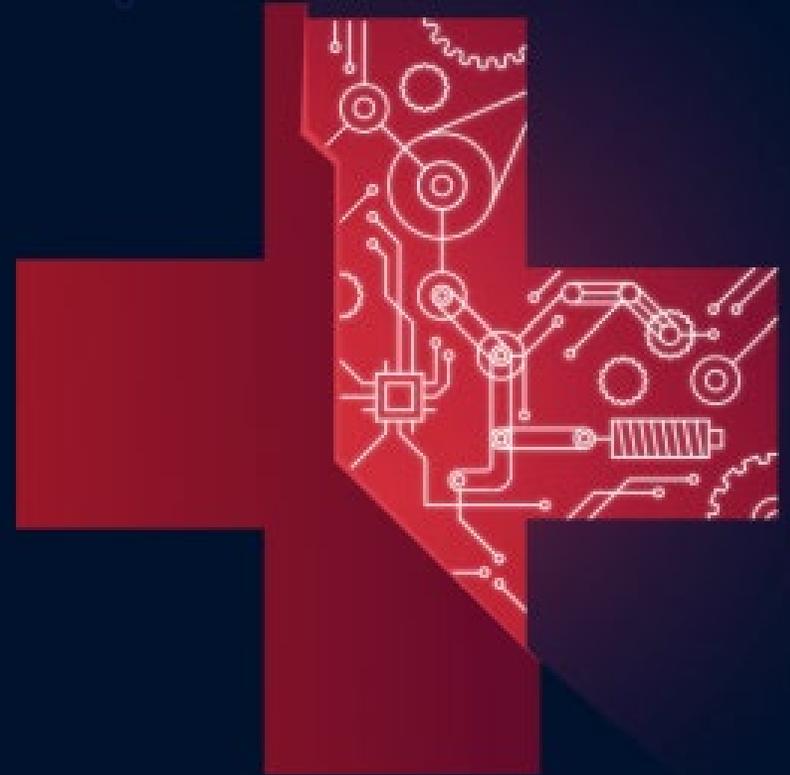
Everything You Need  
to Know About Artificial  
Intelligence in Healthcare

ARTIFICIAL  
NARROW  
INTELLIGENCE

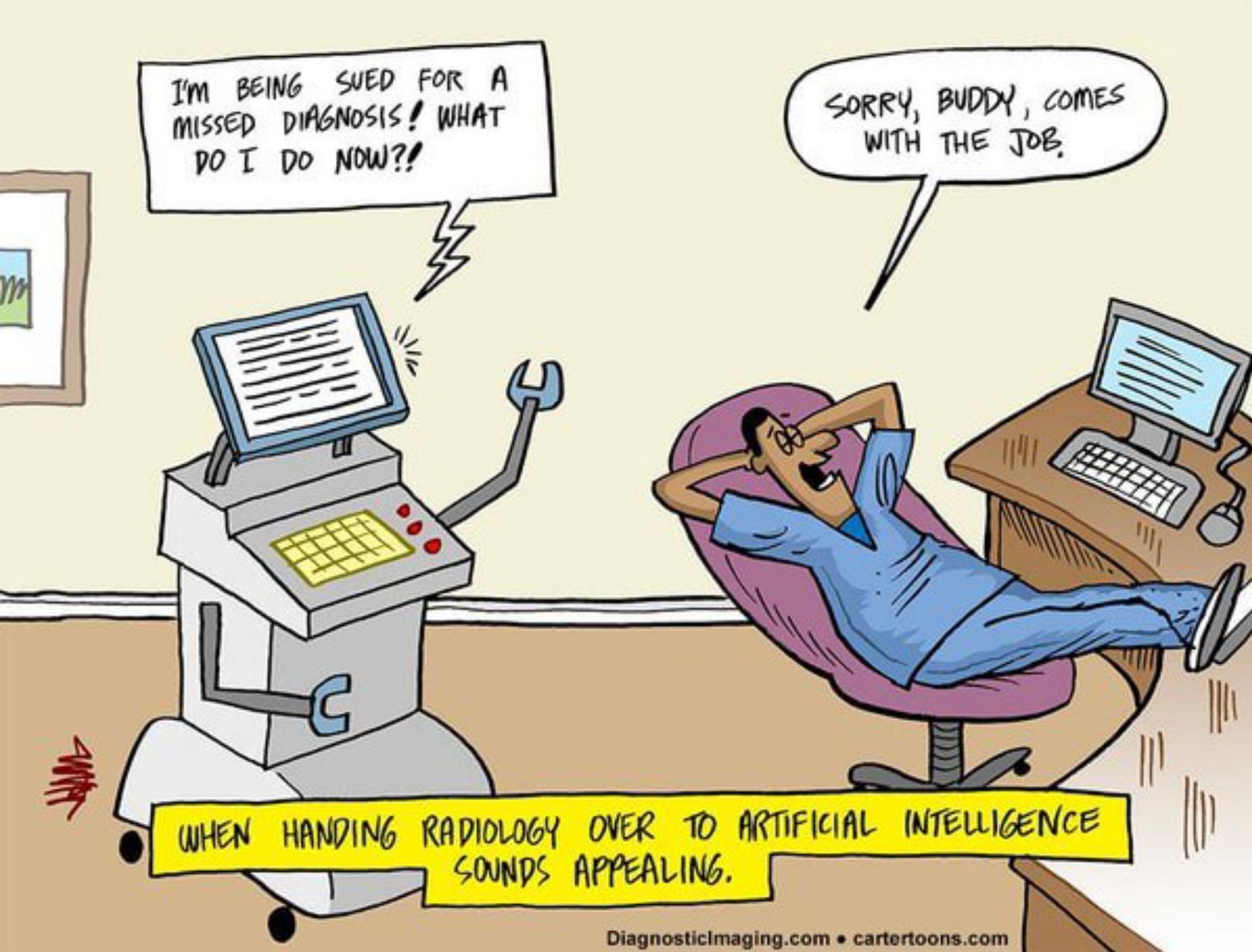


**IT'S NOT  
TECH VS HUMANS**

# A GUIDE TO ARTIFICIAL INTELLIGENCE IN HEALTHCARE



**DR. BERTALAN MESKÓ  
THE MEDICAL FUTURIST**



 **Generative AI**  
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1988: We should ban calculators.  
2023: We should ban ChatGPT.

Page 10A The Daily Item — Sumner, S.C. Saturday, April 5, 1988



AP photo

**Elementary school teachers picket against use of calculators in grade school**  
The teachers feel if students use calculators too early, they won't learn math concepts

## Math teachers protest against calculator use

By JILL LAWRENCE

"My older kids don't pay any attention to an answer being absurd," he said. "Teachers are shy..."

Email: [asultan@umaryland.edu](mailto:asultan@umaryland.edu)



UNIVERSITY *of* MARYLAND  
SCHOOL OF DENTISTRY

DEPARTMENT OF ONCOLOGY  
AND DIAGNOSTIC SCIENCES

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