

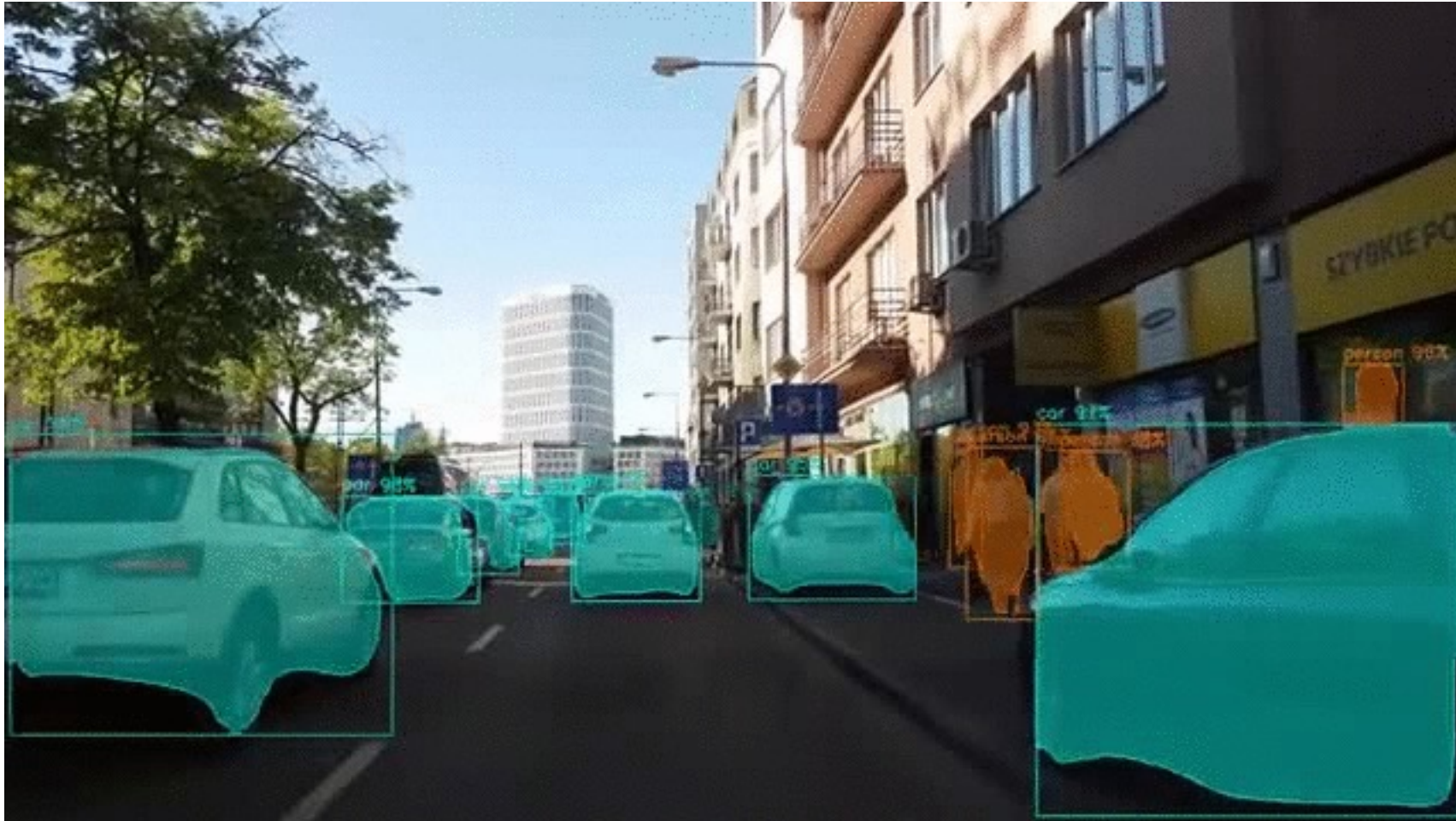
# Introduction to AI in Health

Matt Engelhard, Department of Biostatistics & Bioinformatics

# 10,000-foot view of machine learning in 2024

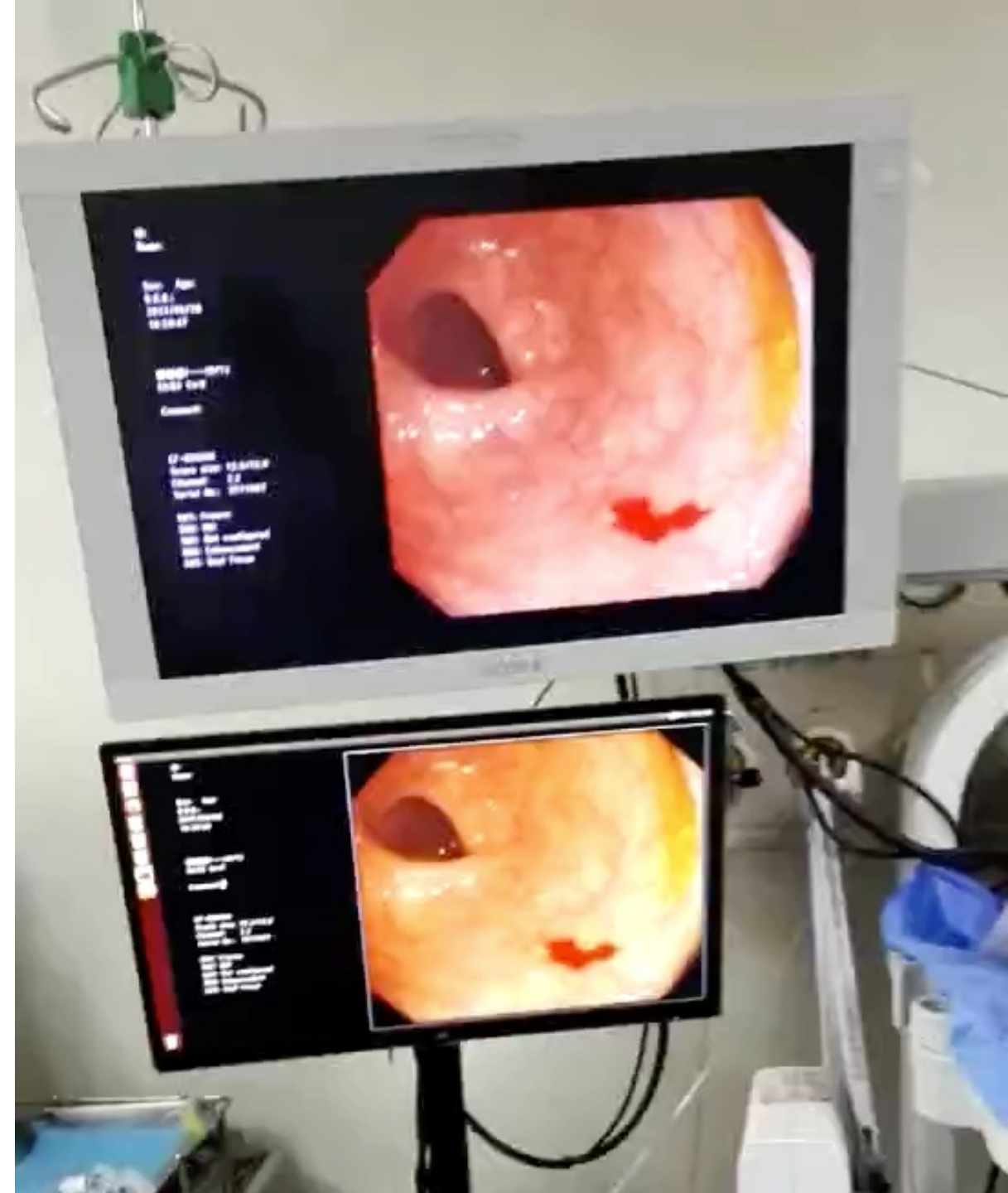
- Computer vision (self-driving)
- Natural language processing (NLP) (ChatGPT)
- Reinforcement learning (AlphaGo)
- Each of these has high clinical relevance
- ML for large, high-dimensional biomedical data
  - electronic health record
  - -omics
  - digital health

# Computer Vision: Real-Time Object Detection & Segmentation



Real-time polyp  
detection:

a second set of eyes  
during colonoscopy



# Segment Anything (even unfamiliar objects)

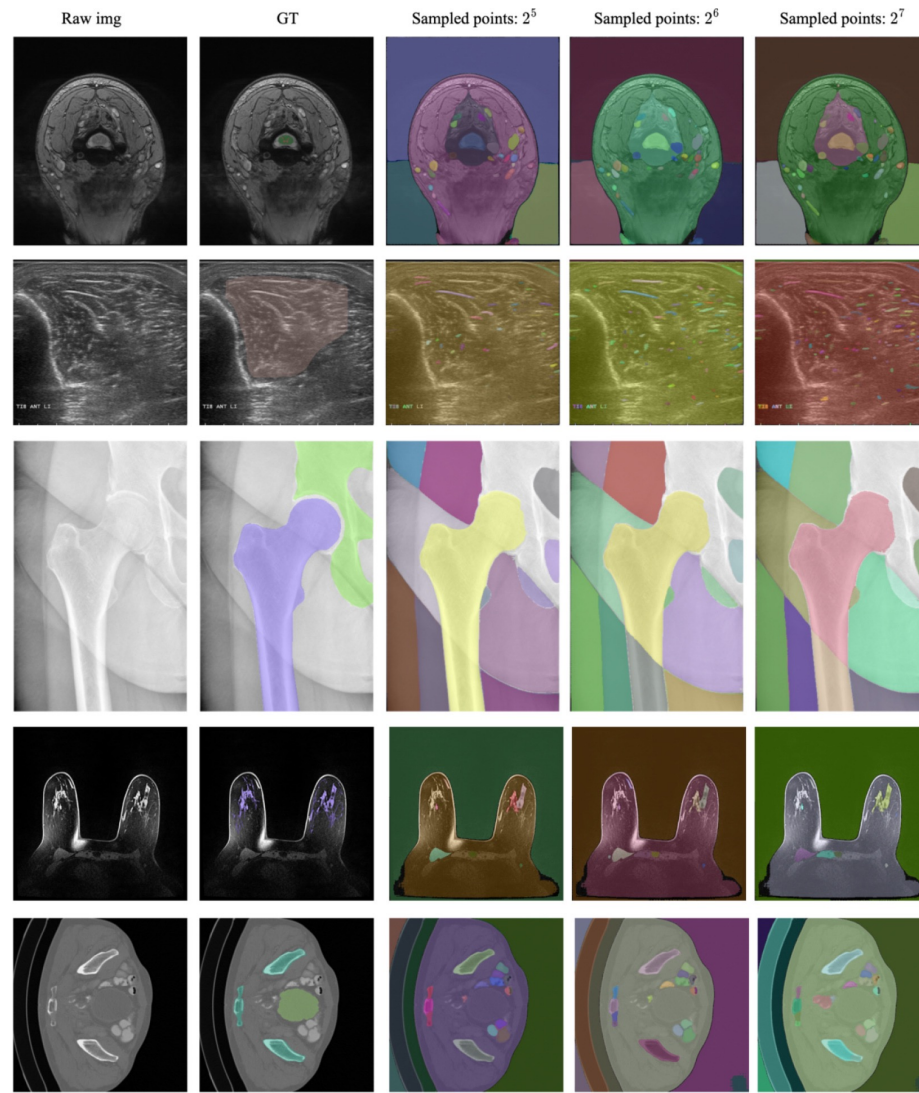


Kirillov, Alexander, et al. "Segment anything." *arXiv preprint arXiv:2304.02643* (2023).

<https://segment-anything.com>



# Segment Everything in Medical Images



**Mazurowski, Maciej A., et al.**  
"Segment anything model for  
medical image analysis: an  
experimental study." *Medical Image  
Analysis* 89 (2023): 102918.

# NLP: Text Generation

ME

I'm giving a lecture to our first-year medical students introducing them to AI and its applications to clinical medicine. What should I tell them about natural language processing, and about you (ChatGPT) specifically?




Natural Language Processing (NLP) is a subfield of artificial intelligence that focuses on enabling machines to understand and process human language. It has numerous applications in clinical medicine, including but not limited to clinical documentation, medical coding, clinical decision support, and patient communication.



As for ChatGPT, you can introduce me as a state-of-the-art NLP model trained by OpenAI. I can answer a wide range of questions and engage in natural language conversations with humans, which has numerous potential applications in the medical field. For example, I can be used to provide virtual assistants for patients to answer their medical questions, to help physicians with documentation and coding, and to analyze large amounts of medical records to identify patterns and insights that might not be immediately apparent to human analysts.

However, it's important to note that while AI and NLP models like ChatGPT have great potential, they are not a substitute for human expertise in the medical field. It's important to use these technologies in conjunction with human clinicians to improve patient care and outcomes.

 Regenerate response



# Text Generation via GPT-3 (ChatGPT precursor)

## SYSTEM PROMPT (HUMAN-WRITTEN)

*A train carriage containing controlled nuclear materials was stolen in Cincinnati today. Its whereabouts are unknown.*

**“Better Language Models and Their Implications”**

2/14/19

OPENAI

## MODEL COMPLETION (MACHINE-WRITTEN, FIRST TRY)

The incident occurred on the downtown train line, which runs from Covington and Ashland stations.

In an email to Ohio news outlets, the U.S. Department of Energy said it is working with the Federal Railroad Administration to find the thief.

“The theft of this nuclear material will have significant negative consequences on public and environmental health, our workforce and the economy of our nation,” said Tom Hicks, the U.S. Energy Secretary, in a statement. “Our top priority is to secure the theft and ensure it doesn’t happen again.”

The stolen material was taken from the University of Cincinnati’s Research Triangle Park nuclear research site, according to a news release from Department officials. The Nuclear Regulatory Commission did not immediately release any information.

According to the release, the U.S. Department of Energy’s Office of Nuclear Material Safety and Security is leading that team’s investigation.

“The safety of people, the environment and the nation’s nuclear stockpile is our highest priority,” Hicks said. “We will get to the bottom of this and make no excuses.



# Natural Language Processing: Find Predictive Text in Notes

## Passage (from note) | Change in predicted autism dx log-odds

subjective intake chief complaint problems with sleep, inattention, and behavioral concerns both in the home and school setting. DATE, recently more anger and recent tic like behavior +6.95

psychologist presenting problem NAME is a 3 year, 4 month old female who was referred for a neurodevelopmental assessment due to concerns regarding her overall development, behavior, and social emotional functioning and to assess for autism spectrum disorder +6.82

problem list diagnosis • disruptive behavior disorder • impaired speech articulation • daytime enuresis • other subjective visual disturbances • hypermetropia of both eyes • adhd attention deficit +6.81

problem list diagnosis • anemia of prematurity • history of colitis • meconium tox for thc • extreme immaturity of newborn, 27 completed weeks • nasal congestion of newborn • presumed +6.78

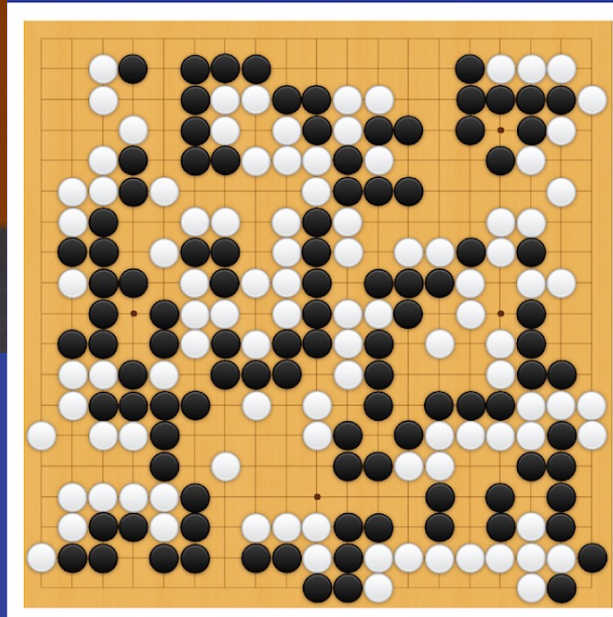
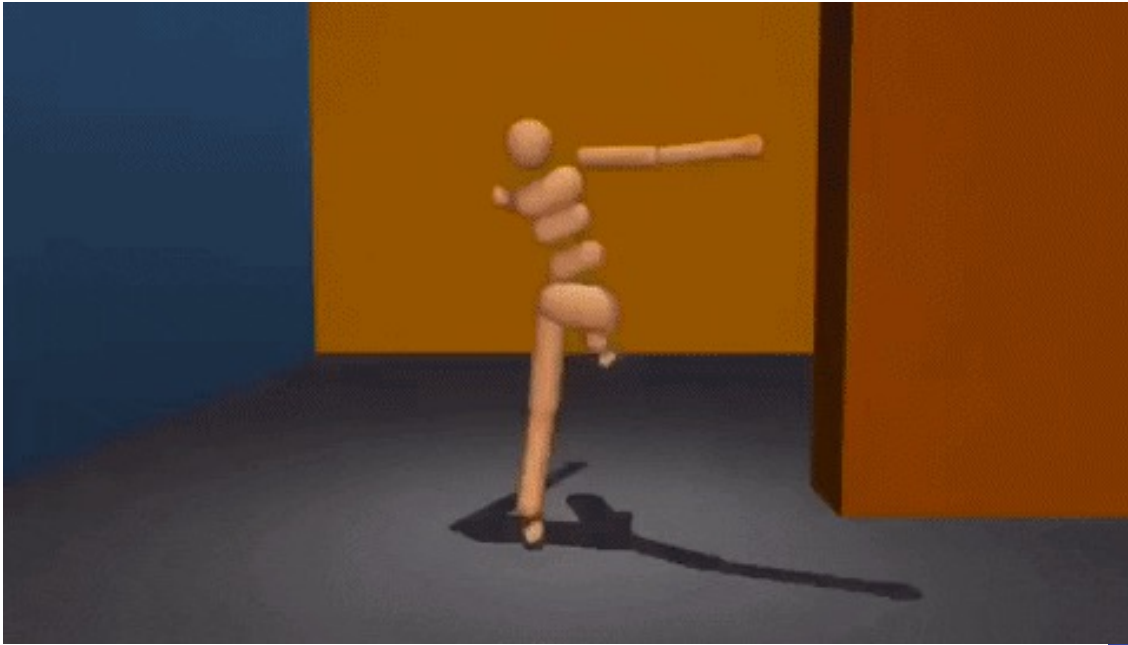
motor delay DATE • hypotonia DATE • clasped thumb DATE • polydactyly DATE • developmental +6.74

therapy NAME was seen for developmental support during rop eye exam today. the +6.65

← Developmental and behavioral concerns are highly predictive

← Premature birth and perinatal complications are also highly predictive

# Reinforcement Learning: goal-directed sequential decision-making



**THE ULTIMATE GO CHALLENGE**

GAME 3 OF 3

27 MAY 2017



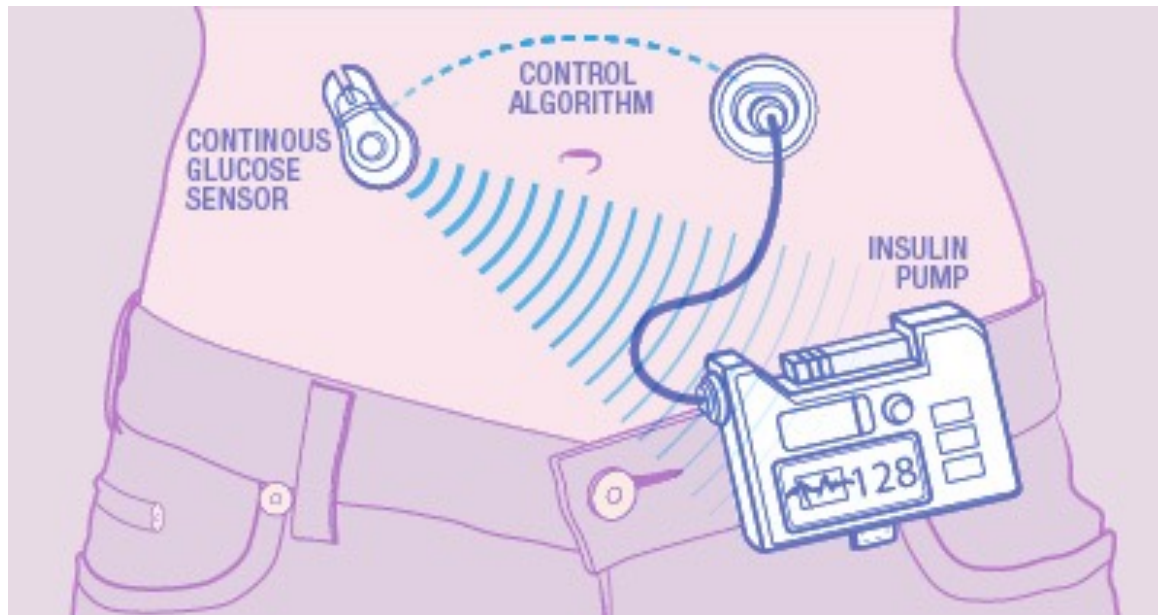
**AlphaGo**  
*Winner of Match 3*

**Ke Jie**

**RESULT B + Res**

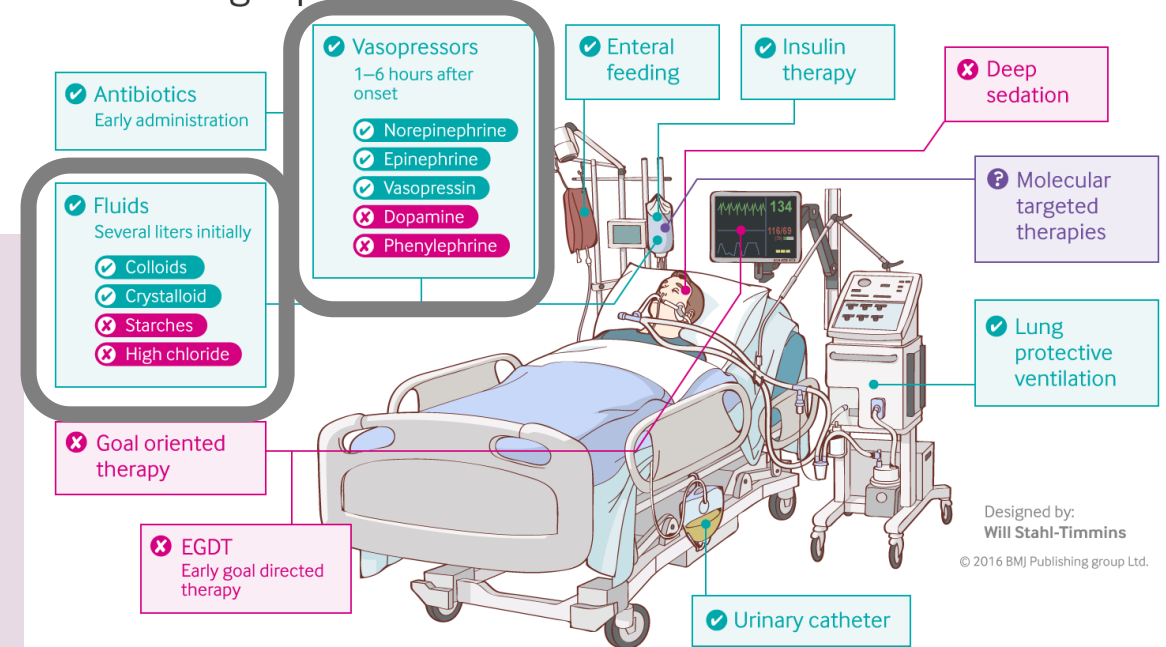
# Reinforcement Learning in Medicine

## Closed-loop blood glucose control ("artificial pancreas")



<https://www.mayo.edu/research/labs/artificial-pancreas/overview>

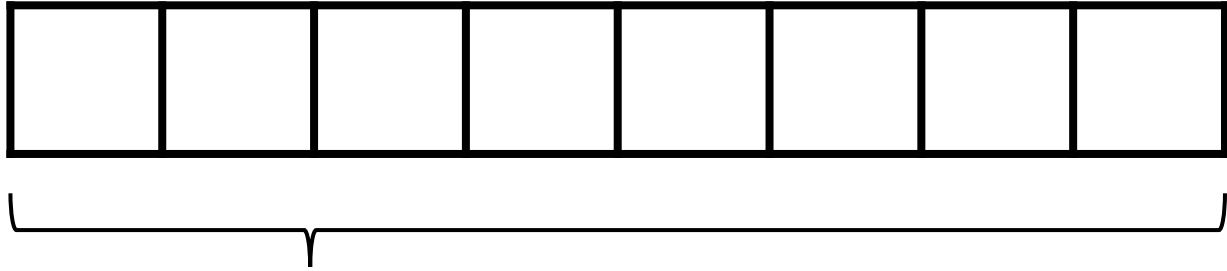
## Treating sepsis: the latest evidence



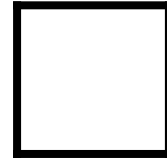
## Fluid and vasopressor administration for sepsis treatment

Gotts JE, Matthay MA. Sepsis: pathophysiology and clinical management. *bmj*. 2016 May 23;353(i1585).

All of these have, at their core, a predictive model



$x$ , data/features for  
a subject or patient



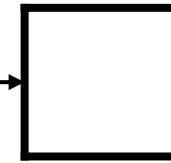
$y$ , associated  
value or label

End goal: predict  $y$  from  $x$

# Computer Vision: prediction via convolutional neural network



$x$ , retinal image



$y$ , referable diabetic  
retinopathy

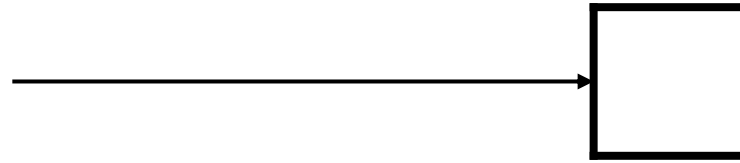
End goal: predict  $y$  from  $x$



# Natural Language Processing: prediction via stacked attention networks

psychologist presenting problem NAME is a 3 year, 4 month old female who was referred for a neurodevelopmental assessment due to concerns regarding her overall development, behavior, and social emotional functioning and to

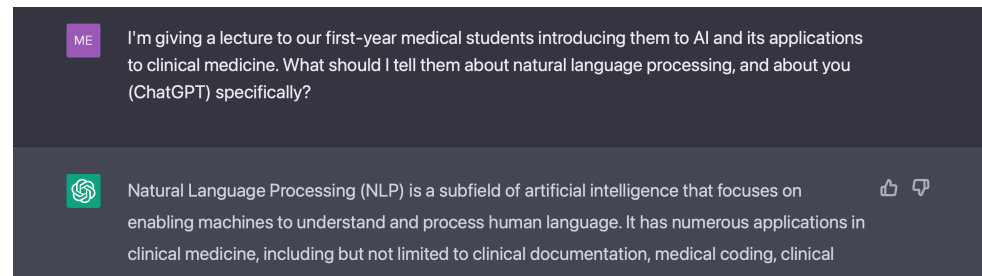
$x$ , clinical note



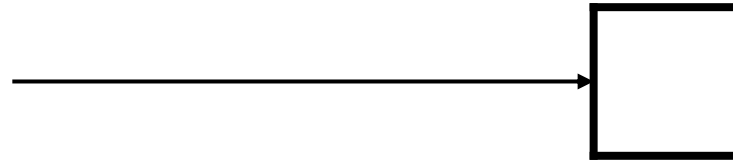
$y$ , autism risk

End goal: predict  $y$  from  $x$

# Natural Language Processing: prediction via stacked attention networks



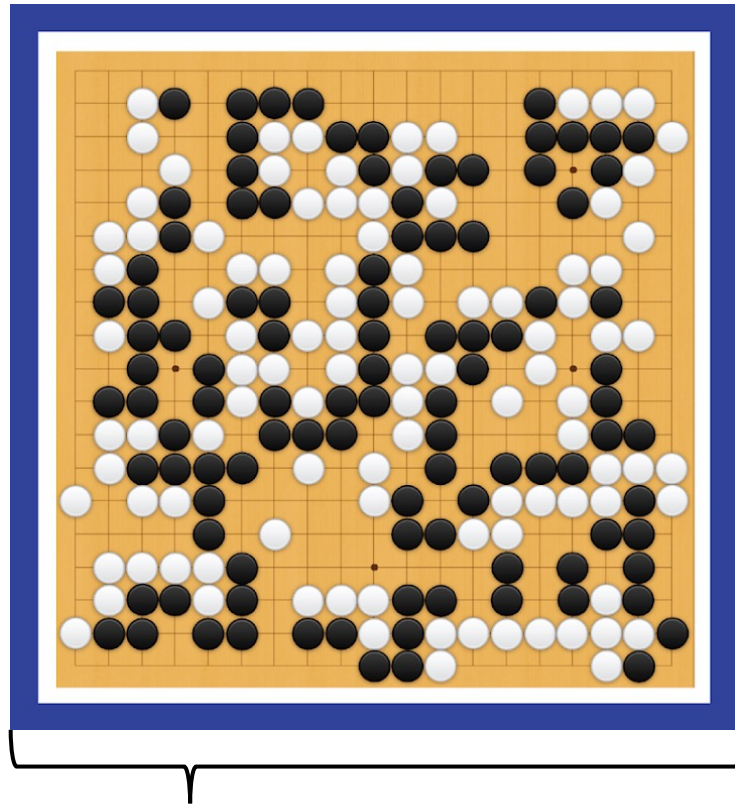
$x$ , conversation history



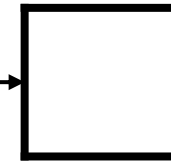
$y$ , next word

End goal: predict  $y$  from  $x$

# Reinforcement Learning: state to action predictions via dense neural network



$x$ , Go board state



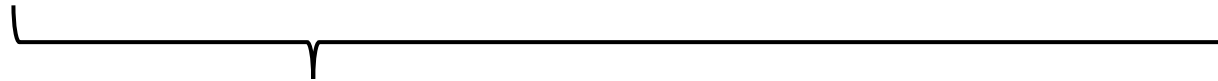
$y$ , next move

End goal: predict  $y$  from  $x$

# APACHE III: A model for predicting ICU mortality



Age  
Pulse Rate  
Mean BP  
Temperature  
Respiratory Rate  
Hematocrit  
WBC Count  
Creatinine



$x$ , data/features for  
a subject or patient

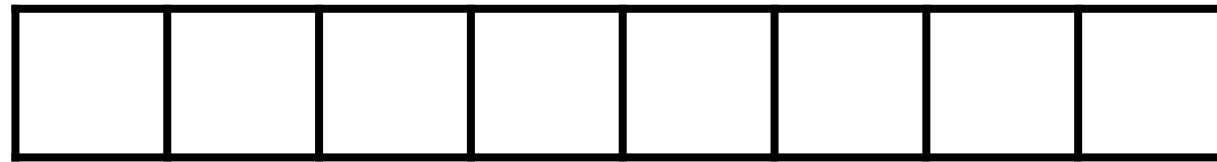


Survival

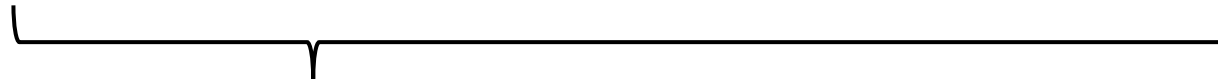
$y$ , associated  
value or label

End goal: predict odds  
of hospital mortality

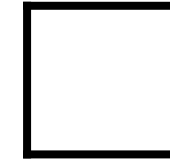
Traditional models (e.g. logistic regression)  
tend to work well for data like this.



Age  
Pulse Rate  
Mean BP  
Temperature  
Respiratory Rate  
Hematocrit  
WBC Count  
Creatinine



$x$ , data/features for  
a subject or patient



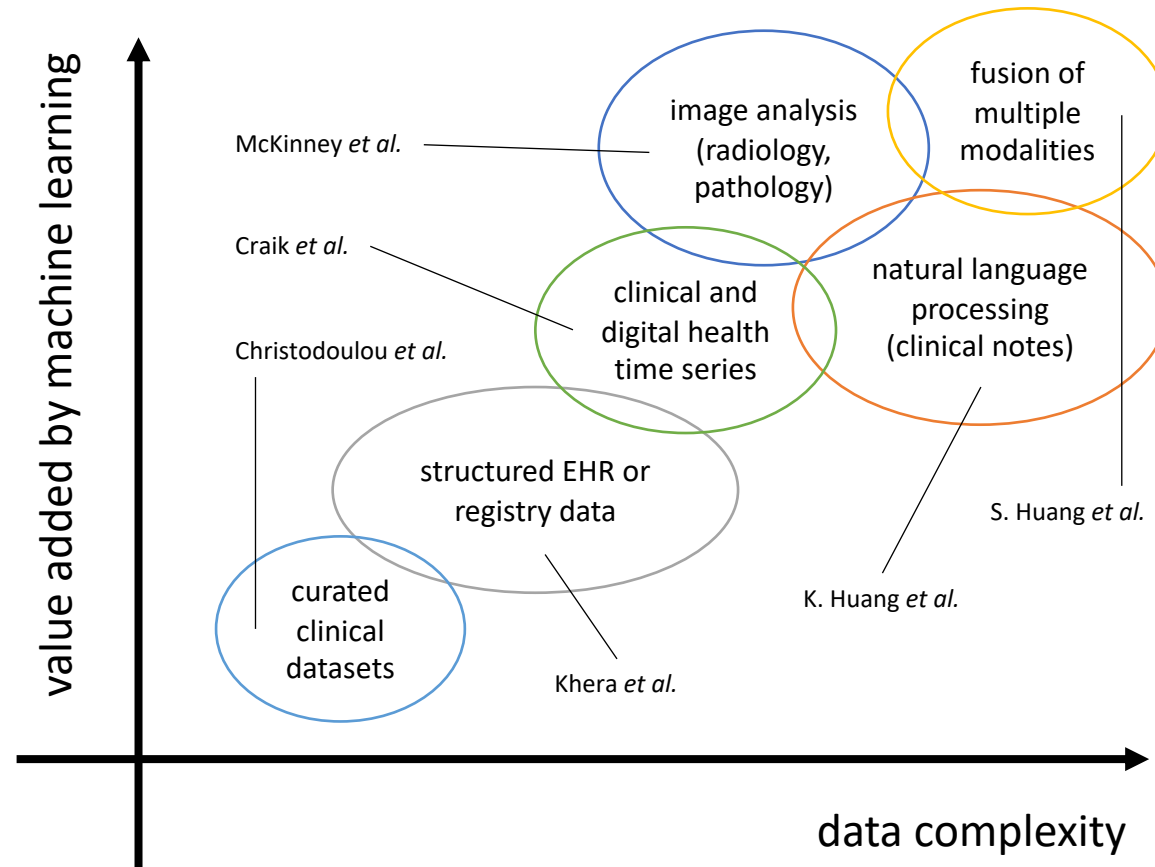
Survival

$y$ , associated  
value or label

End goal: predict odds  
of hospital mortality



As the complexity of the underlying data increases, so too does the probable value added by machine learning



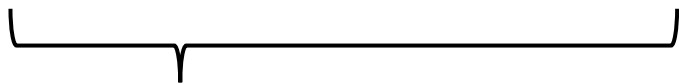
**Simple models** based on clinical variables remain highly relevant

\*Use the simplest model that gets the job done\*

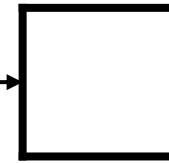
# What do we mean by complex data?

And why are machine learning methods so helpful when modeling complex data?

Predictions from complex data:  
What does a single feature (e.g. pixel) tell us?



$x$ , data/features for  
a subject or patient



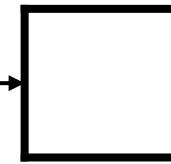
$y$ , associated  
value or label

End goal: predict  $y$  from  $x$

# Classification of Medical Images: What does a single pixel tell us?



$x$ , data/features for  
a subject or patient



$y$ , associated  
value or label

End goal: predict  $y$  from  $x$

# What do we mean by complex data?

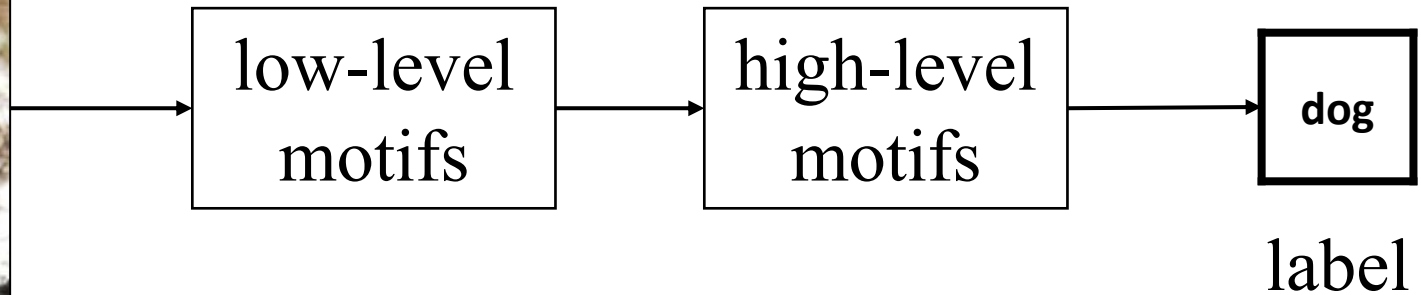
- Less about *big* data (i.e. large N)
- More about *high-dimensional* data (i.e. large M)
- Data with underlying temporal, sequential, or spatial structure  
(i.e. *dependent* data that are indexed by a second set)
- Applications where feature engineering was previously required



Predictions from complex data:  
Deep learning builds a *hierarchy* of features.



pixels



End goal: predict *dog* from *pixels*

Predictions from complex data:  
Deep learning builds a *hierarchy* of features.



pixels

low-level  
motifs

- edges
- shapes
- textures

high-level motifs are  
*specific arrangements*  
of low-level motifs

high-level  
motifs

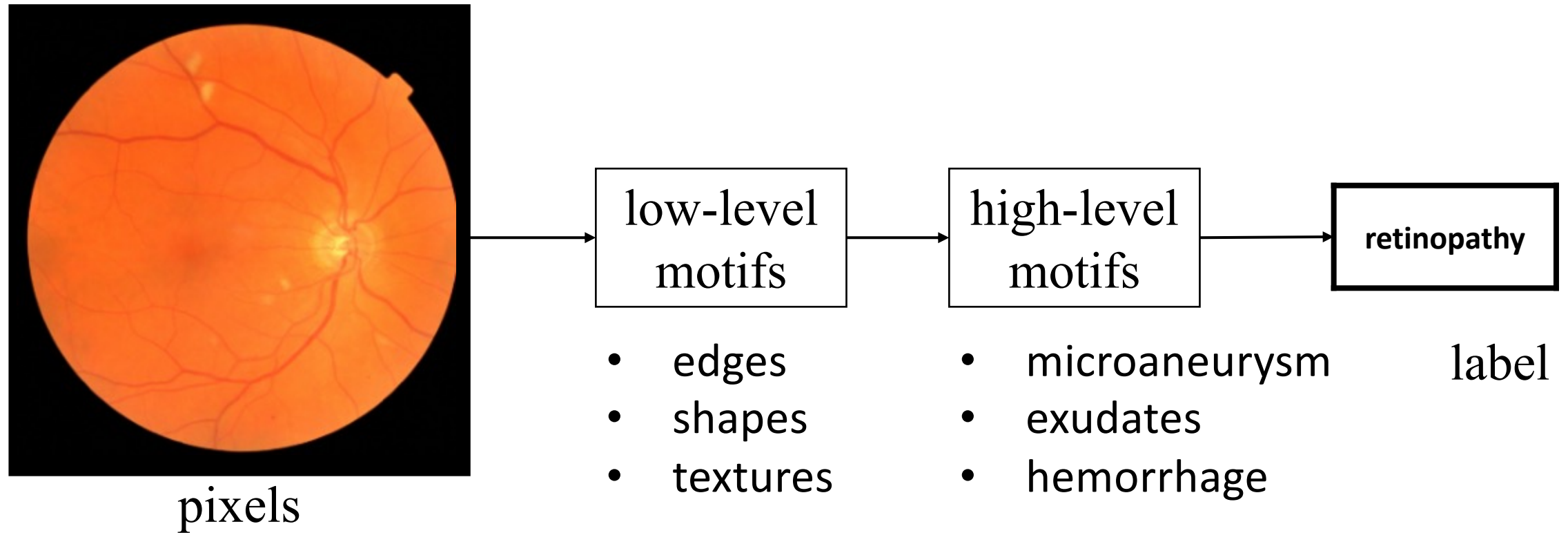
- eyes
- ears
- paws

dog

label

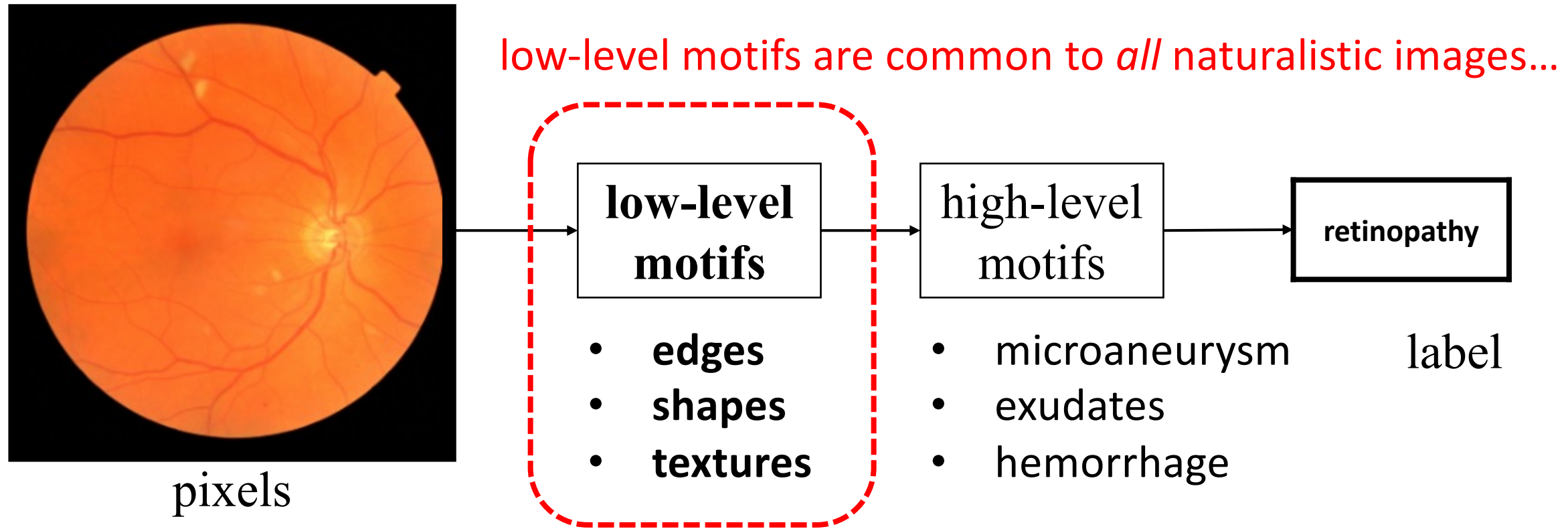
End goal: predict *dog* from *pixels*

Predictions from complex biomedical data:  
Deep learning builds a *hierarchy* of features.



End goal: predict *retinopathy* from *pixels*

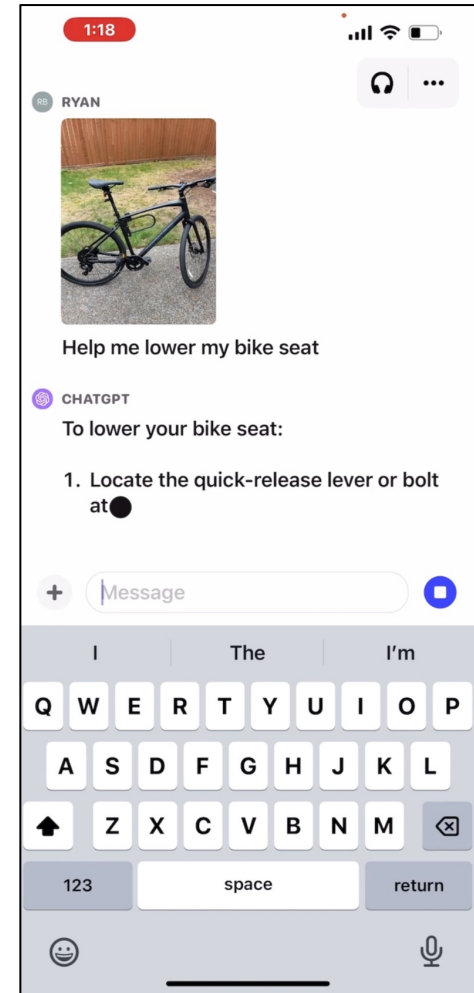
Predictions from complex biomedical data:  
Deep learning builds a *hierarchy* of features.



End goal: predict *retinopathy* from *pixels*

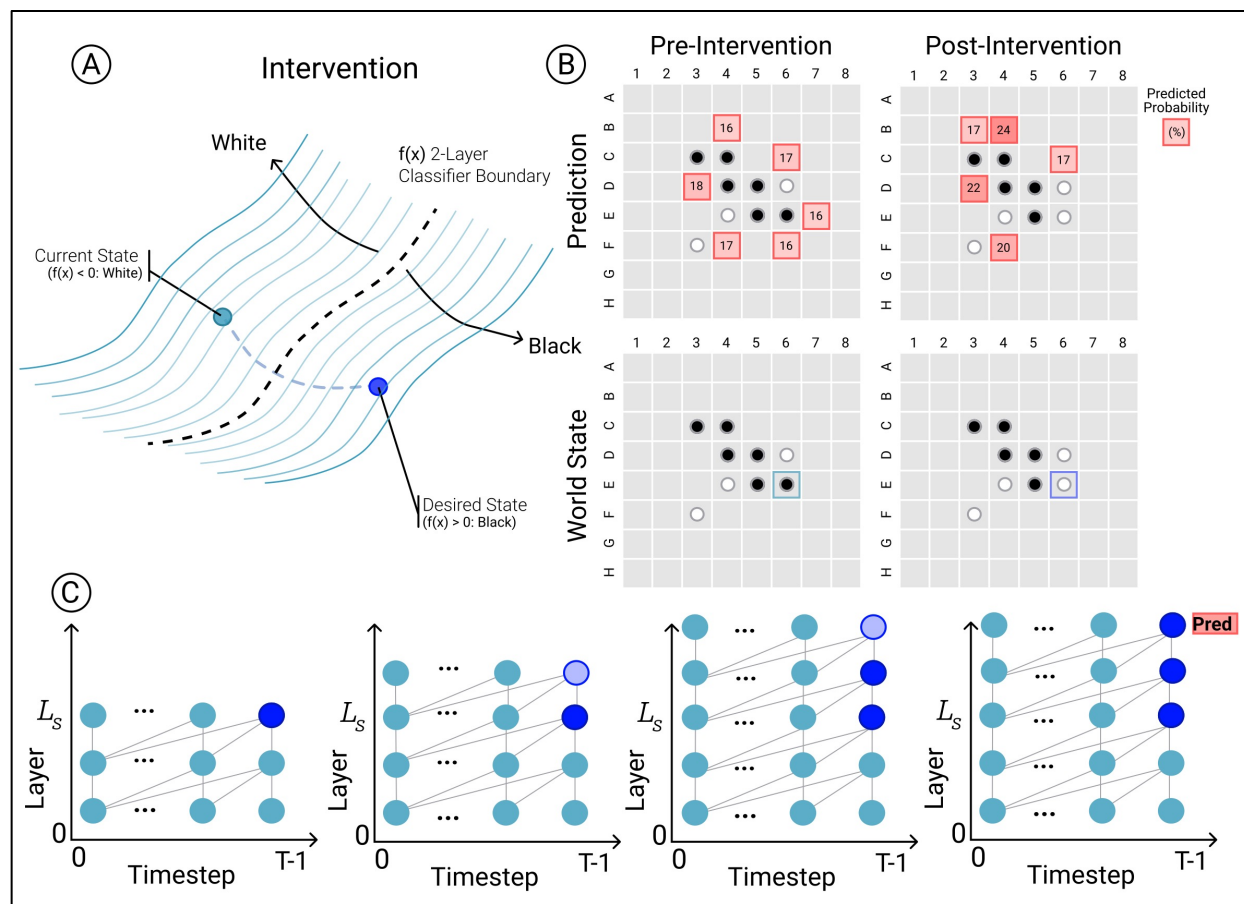
# How far can we push our prediction machines.... And what properties will emerge?

- High-dimensional, multi-modal data
- Broader range of possible predictions
- Bigger: more parameters, more data, more computation (e.g. GPT4)
- Leaner: efficient use of parameters and computation (e.g. LLAMA)





# Property 1: Internal representations of the world



Li, Kenneth, et al. "Emergent world representations: Exploring a sequence model trained on a synthetic task." *arXiv preprint arXiv:2210.13382* (2022).

# Property 2: Abstract reasoning and common sense

## GPT-4 vs ChatGPT

**Prompt:** Here we have a book, 9 eggs, a laptop, a bottle and a nail. Please tell me how to stack them onto each other in a stable manner.

### GPT-4:

One possible way to stack the objects onto each other in a stable manner is:

- Place the book flat on a level surface, such as a table or a floor. The book will serve as the base of the stack and provide a large and sturdy support.
- Arrange the 9 eggs in a 3 by 3 square on top of the book, leaving some space between them. The eggs will form a second layer and distribute the weight evenly. Make sure the eggs are not cracked or broken, and handle them gently to avoid dropping them.
- Place the laptop on top of the eggs, with the screen facing down and the keyboard facing up. The laptop will fit snugly within the boundaries of the book and the eggs, and its flat and rigid surface will provide a stable platform for the next layer. Make sure the laptop is closed and turned off, and do not press any keys or buttons.
- Place the bottle on top of the laptop, with the cap facing up and the bottom facing down. The bottle will add some height and balance to the stack, and its cylindrical shape will reduce the contact area with the laptop. Make sure the bottle is empty and closed, and do not shake or tilt it.
- Place the nail on top of the bottle cap, with the pointy end facing up and the flat end facing down. The nail will be the final and smallest object in the stack, and its sharp tip will prevent it from rolling or sliding off the bottle. Make sure the nail is clean and straight, and do not touch or move it.

Bubeck, Sébastien, et al.  
"Sparks of artificial general intelligence: Early experiments with gpt-4." *arXiv preprint arXiv:2303.12712* (2023).

Getting started is easier than ever...

 PyTorch

+



+

 TensorFlow



...but real-world impact is more challenging