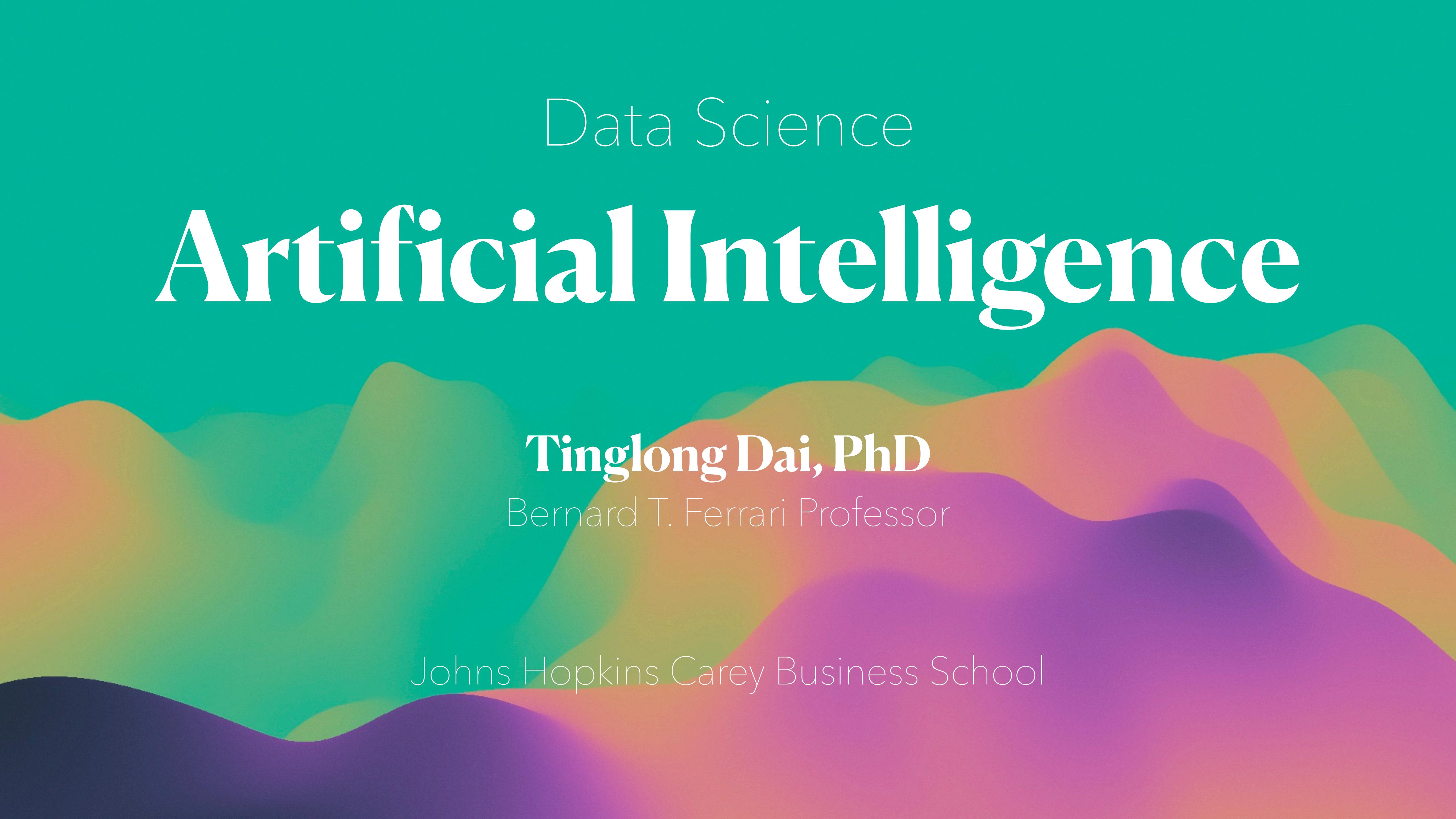


Data Science

Artificial Intelligence



Tinglong Dai, PhD

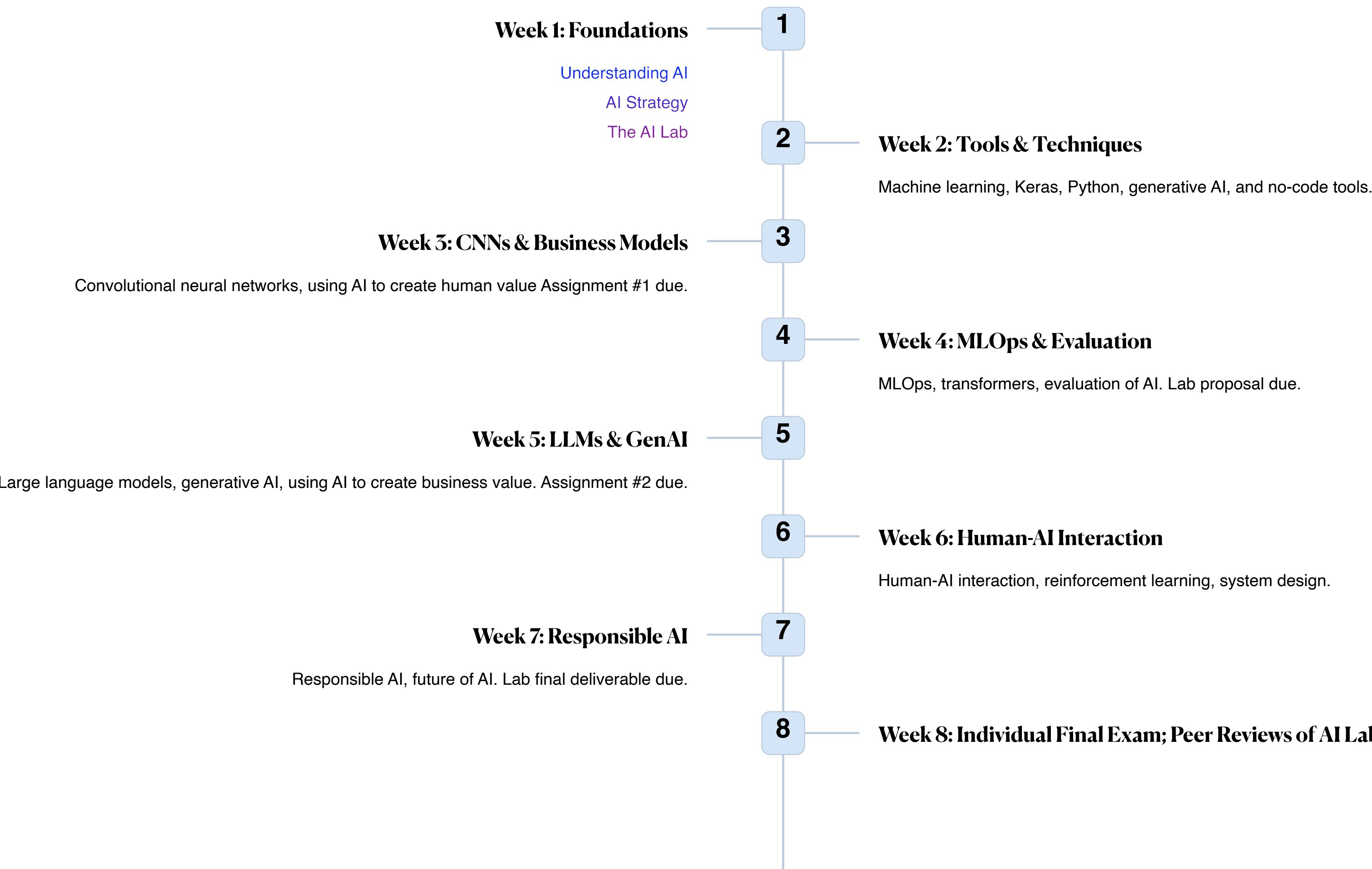
Bernard T. Ferrari Professor

Johns Hopkins Carey Business School

“AI is more important than
fire and electricity.”

Sundar Pichai, CEO of Alphabet

Agenda



Understanding AI

What is Artificial Intelligence?

Big Divide Here – *Humanlike* vs. *Rational* Agents

Thinking Like Humans

AI = “the automation of activities that we associate with human thinking” (Bellman 1978)

Thinking Rationally

AI = “the study of the computations that make it possible to perceive, reason, and act” (Winston 1992)

Acting Like Humans

AI = “the study of how to make computers do things at which, at the moment, people are better”
(Rich & Knight 1991)

Acting Rationally

AI = “the synthesis and analysis of computational agents that act intelligently” (Poole & Mackworth 2010)

Disciplines Shaping AI Over the Years

Philosophy

Where does knowledge come from?
How does knowledge lead to action?

Mathematics

What can & cannot be computed?
How to reason with uncertain info?

Economics

How to maximize payoffs?
How to think & reason strategically?

Neuroscience

How do brains process information?

Psychology

How do humans think and act?

Computer Engineering

How to build efficient computers?

Control Theory

How to automate operations?

Linguistics

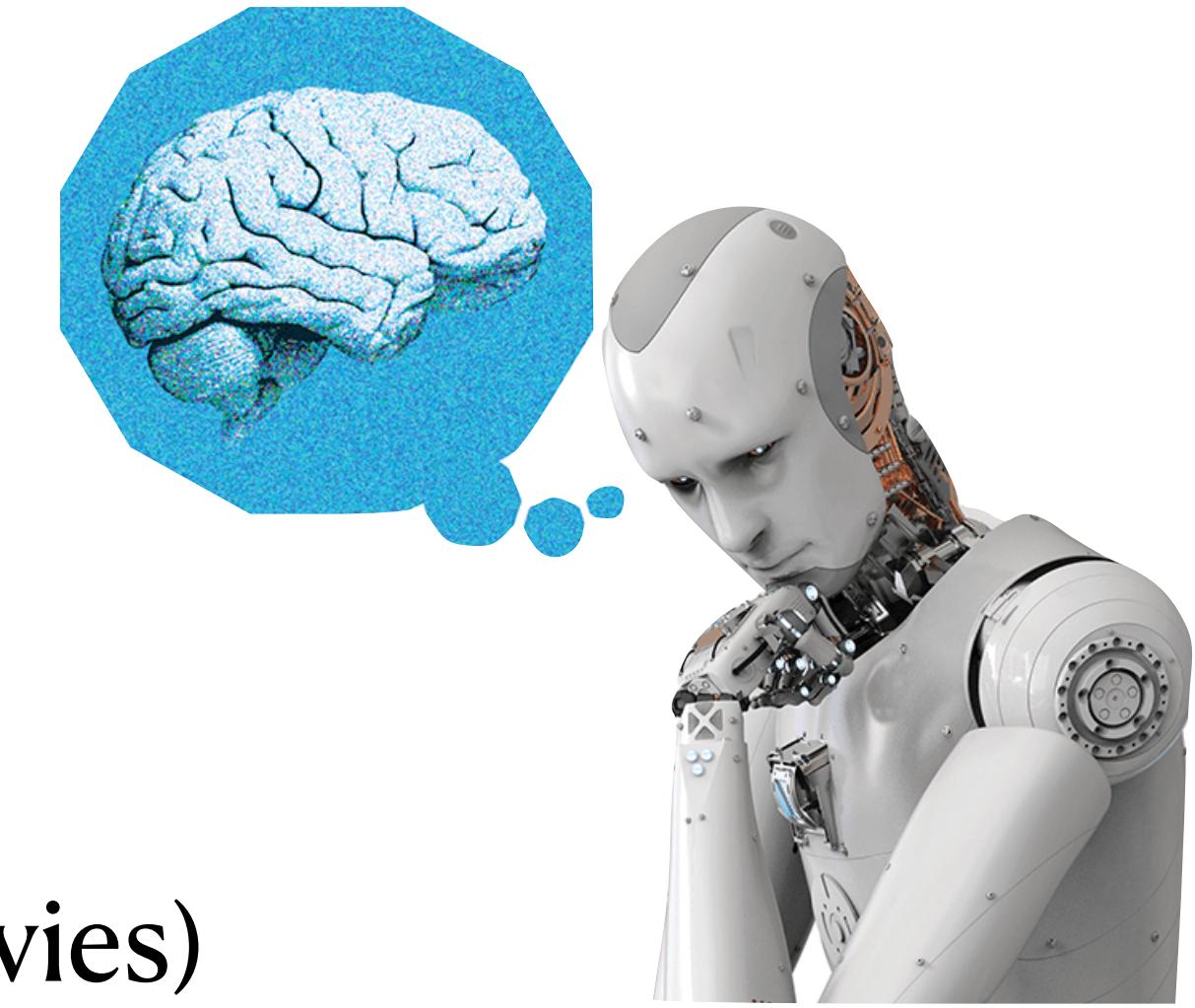
How to understand language?

Operations Management

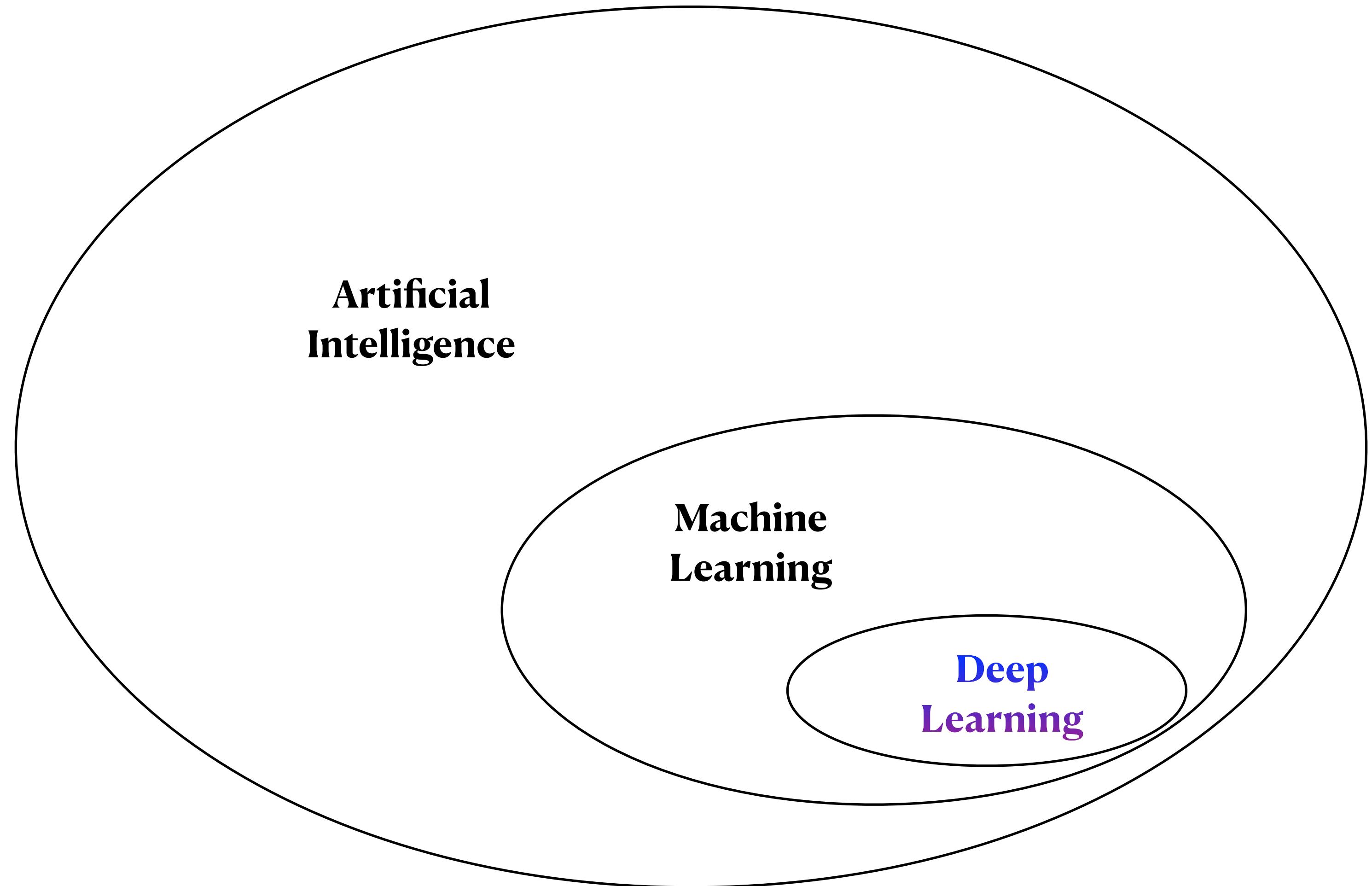
How to translate AI into value?

AI = Intelligent Machines

Mark Halpern, “No Ghost in the Machine”



- How “intelligent” depends on its speed
 - “Speed has the power to overawe and mislead us” (think about movies)
- “As soon as we solve a problem, instead of looking at the solution as AI, we come to view it as just another computer science” (Martha Pollack)
- AI cannot be truly autonomous; it’s about whether *user* or *designer* makes the decision
- Deep learning algorithms don’t see a cat; they merely assign weights to each layer of “neurons” in the program



We will focus on deep learning in this course

History of AI: Booms and Busts

1956–1974

The term of “artificial intelligence” was coined in 1956, marking the beginning of **The First AI Boom** 🔥

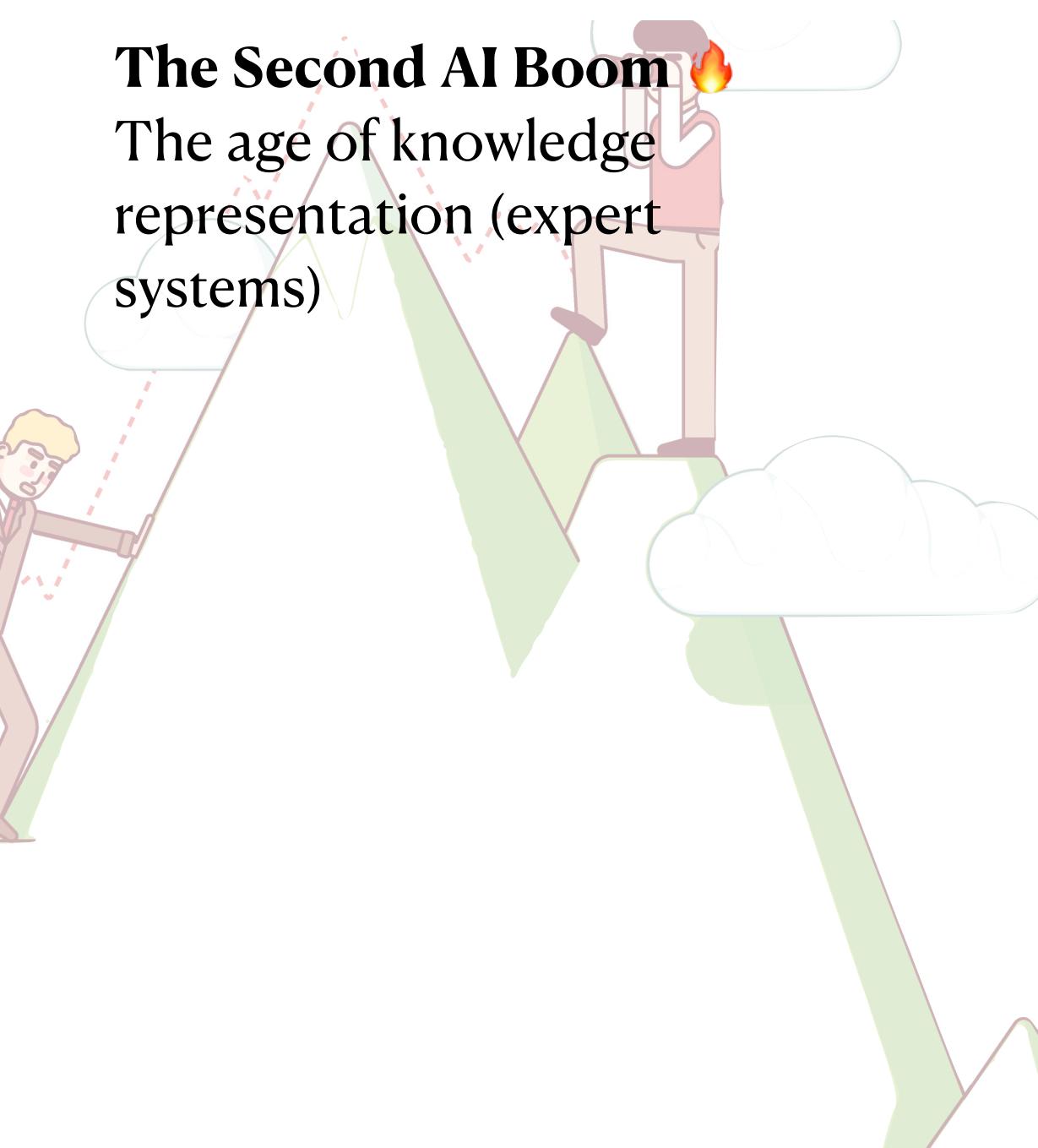


1974–1980

The First AI Winter ❄️

1980–1987

The Second AI Boom
The age of knowledge representation (expert systems)



1987–1993

The Second AI Winter ❄️

1993–2011

The AI Spring

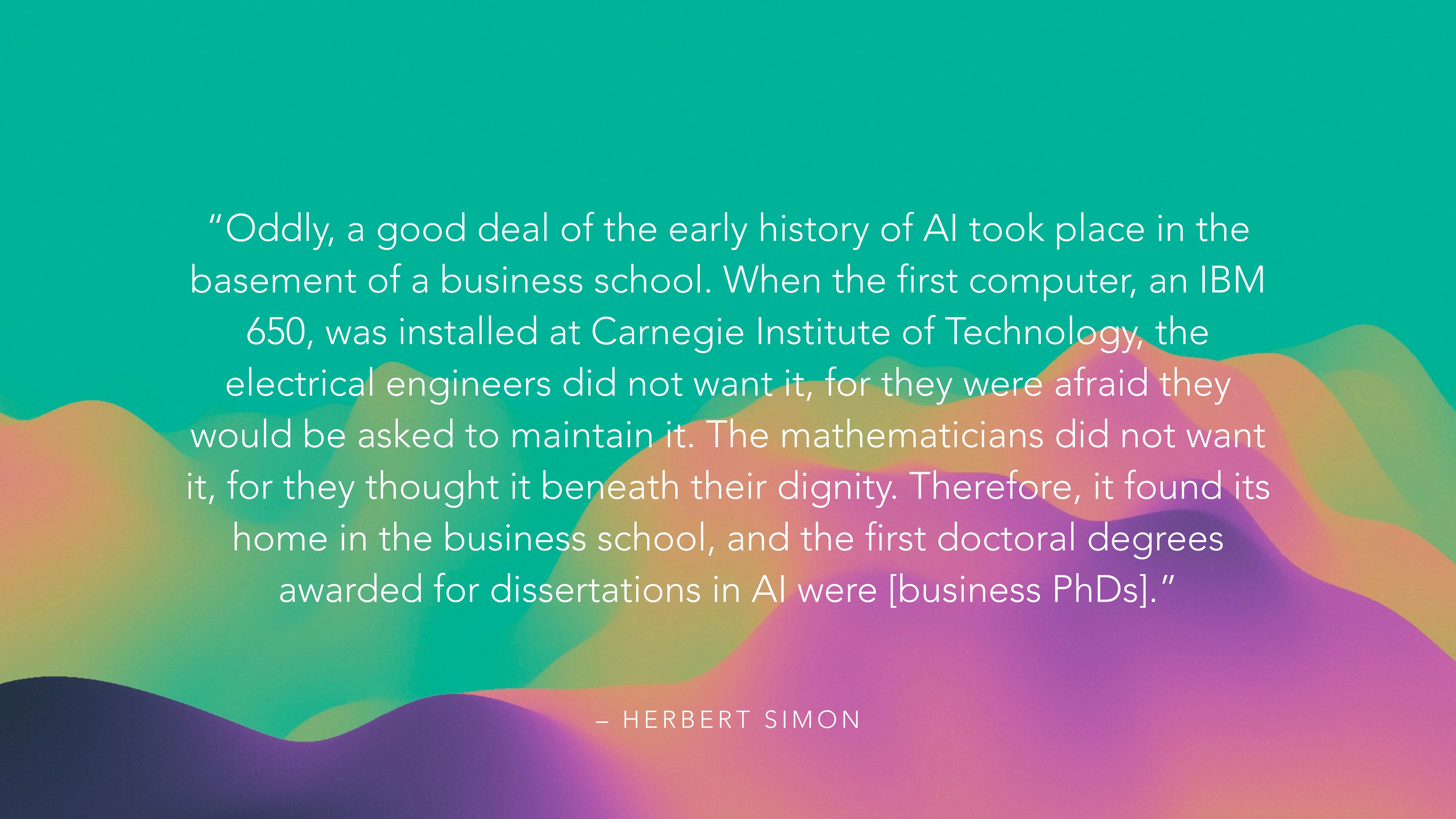


2011–present

The Third AI Boom 🔥

- **Deep Learning Revolution** (Convolutional Neural Networks)
- **AlphaGo Zero** (Reinforcement Learning)
- **The Generative AI Era**, marked by the launch of ChatGPT (GPT 3.5) on November 30, 2022
- **Incorporating AI into Workflows**

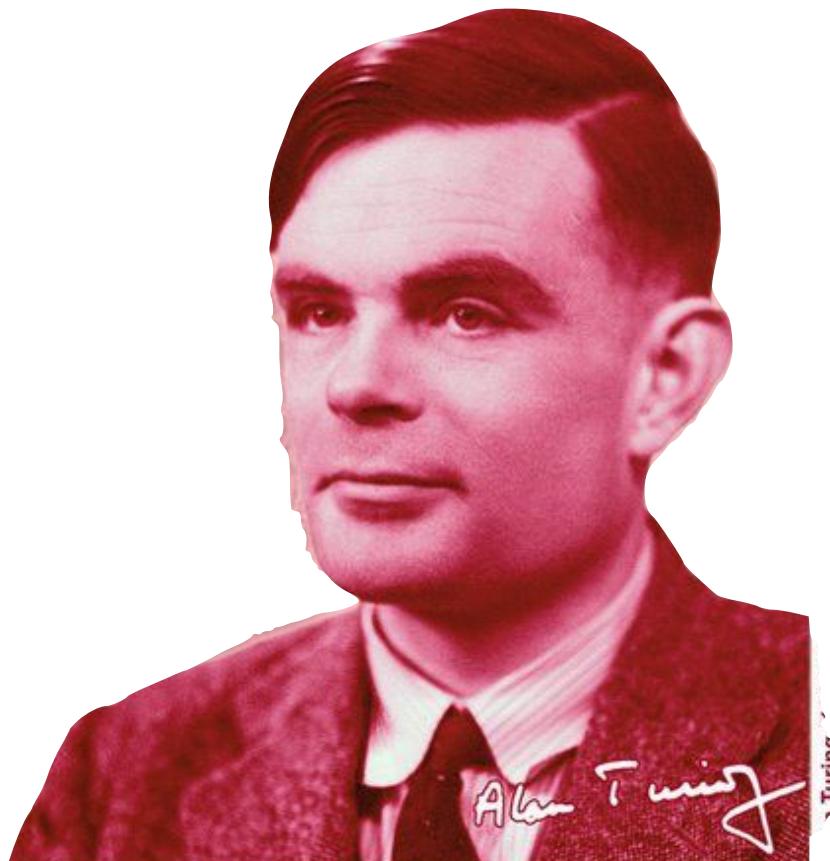




“Oddly, a good deal of the early history of AI took place in the basement of a business school. When the first computer, an IBM 650, was installed at Carnegie Institute of Technology, the electrical engineers did not want it, for they were afraid they would be asked to maintain it. The mathematicians did not want it, for they thought it beneath their dignity. Therefore, it found its home in the business school, and the first doctoral degrees awarded for dissertations in AI were [business PhDs].”

– HERBERT SIMON

Some AI Heros



Alan Turing (1912–1954)



Herbert Simon (1916–2001)



The Three Fathers of Deep Learning

Turing Awardee (1975)
Nobel Laureate in Economics (1978)

Turing Co-Awardees (2018)

Hinton: Nobel Laureate in Physics (2024)

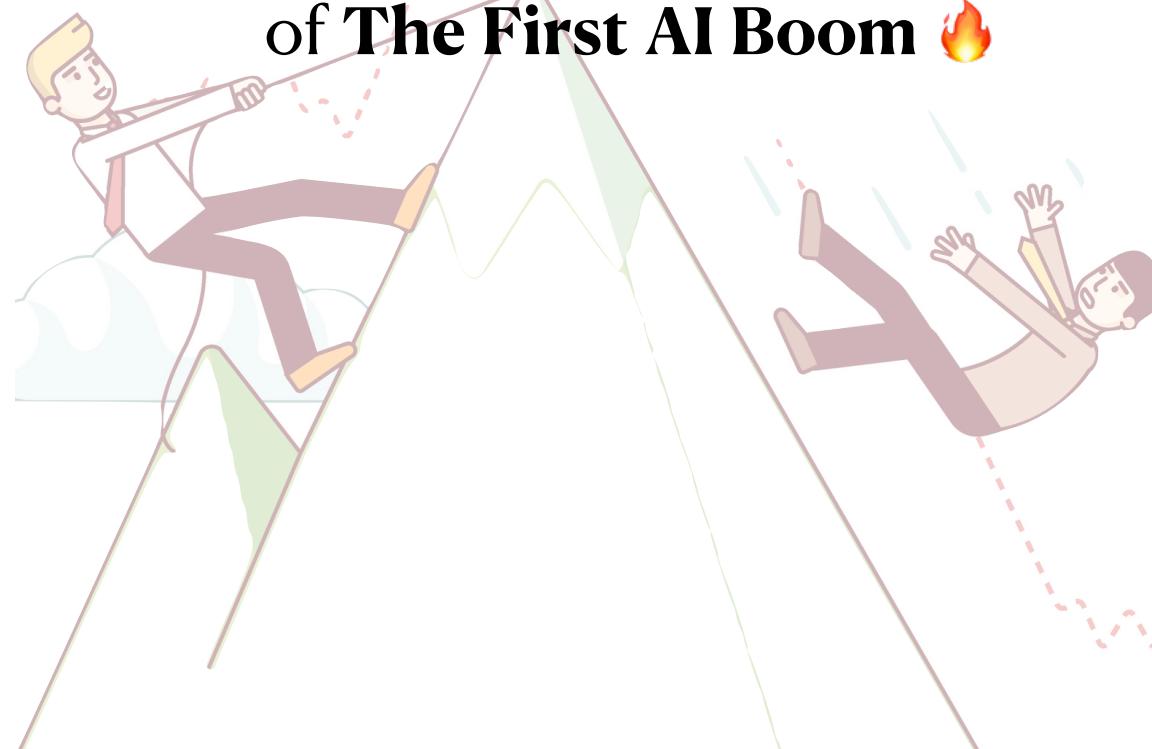
Rule-based (“symbolic”) AI

Learning-based (“connectionist”) AI

Medical AI: Two Milestones

1956–1974

The term of “artificial intelligence” was coined in 1956, marking the beginning of **The First AI Boom** 🔥

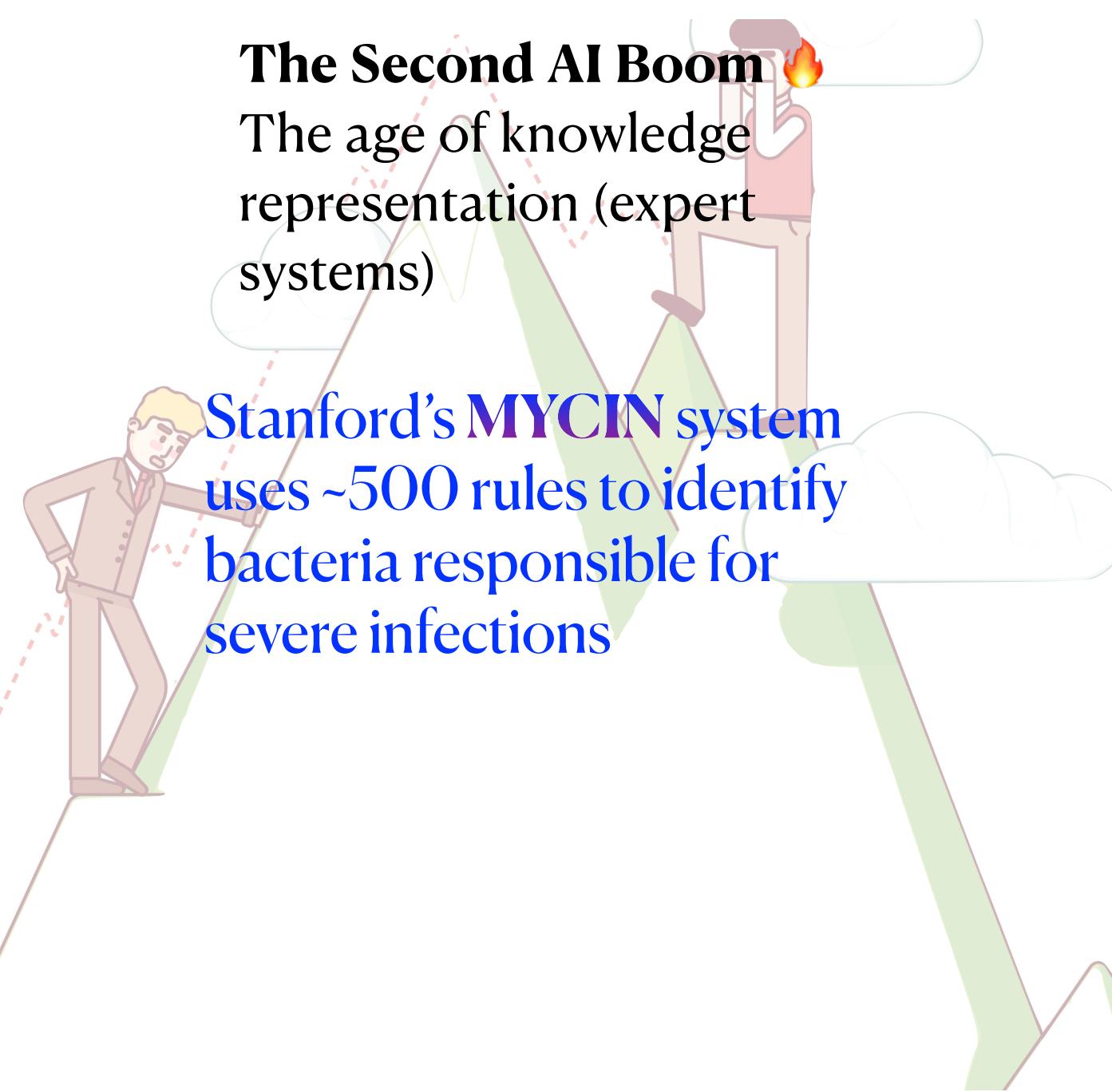


1974–1980

The First AI Winter ❄️

1980–1987

The Second AI Boom
The age of knowledge representation (expert systems)



Stanford's **MYCIN** system uses ~500 rules to identify bacteria responsible for severe infections

1987–1993

The Second AI Winter ❄️

1993–2011

The AI Spring



2011–present

The Third AI Boom 🔥

- **Deep Learning Revolution** (Convolutional Neural Networks)
- **AlphaGo Zero** (Reinforcement Learning)
- **The Generative AI Era**, marked by the launch of ChatGPT (GPT 3.5) on November 30, 2022
- **Incorporating AI into Workflows**

LumineticsCore AI became the first FDA-cleared autonomous AI (2018)



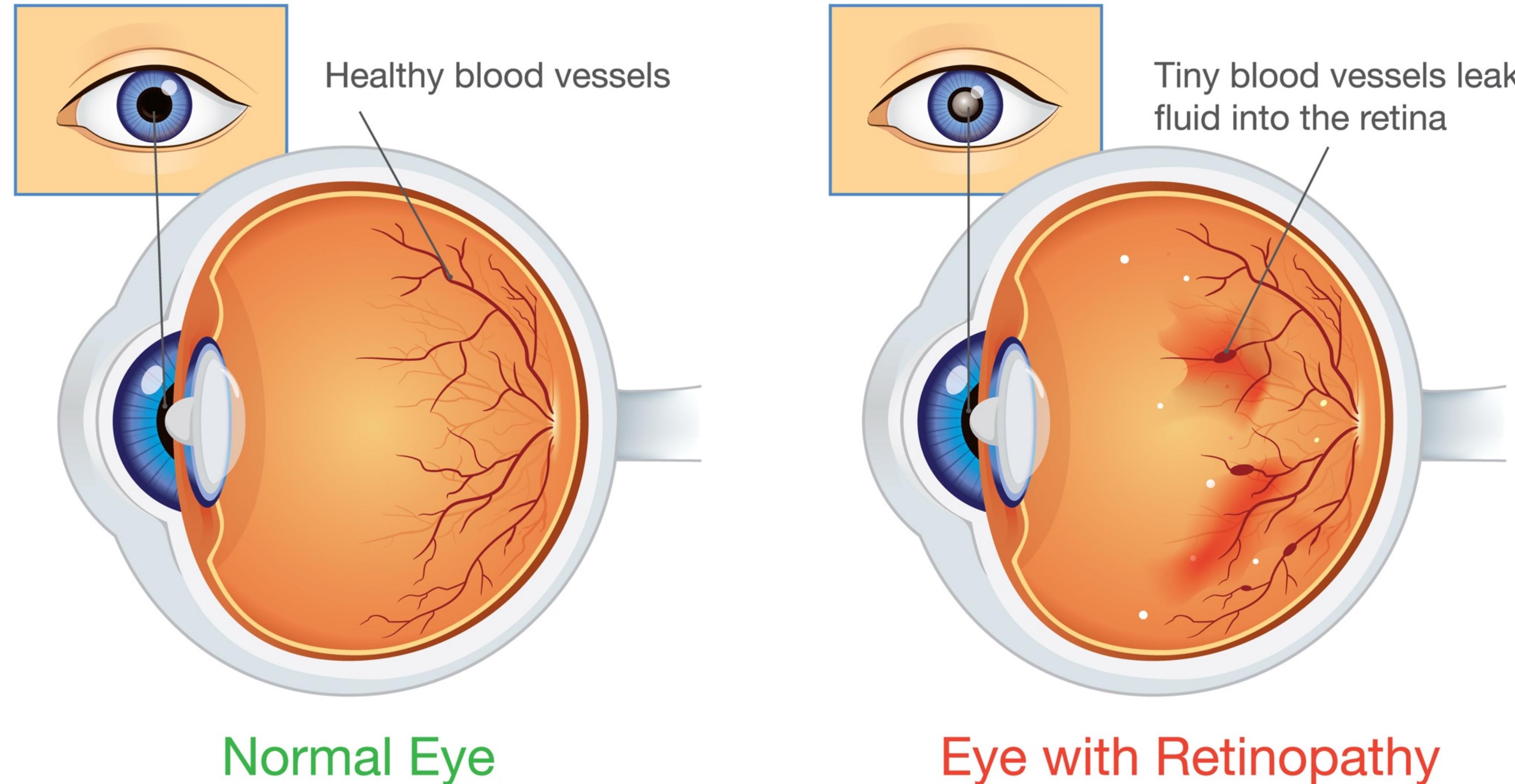
AI Has Become a Reality in Medicine



IDx-DR (for retinopathy screening), the first FDA-approved AI-enabled diagnostic device

Diabetic Retinopathy

Leading Cause of Blindness in Adults Aged 20 to 64



Why Screening Matters

- 1 in 3 diabetic patients (both types) will develop retinopathy
- 37 million people in the U.S. (11% of the population) have diabetes; Black adults are 60% more likely to be diagnosed with diabetes than white adults (HHS 2023)
- Early detection and treatment can reduce the risk of blindness by 95%
- Only **15%** of US diabetic patients receive recommended annual screening (Benoit et al. 2019)

82%

Among those not screened for retinopathy, the percentage of diabetes patients who visit a primary care physician annually

Gibson (2019) *JAMA Ophthalmology*

Current Standard vs. IDx-DR

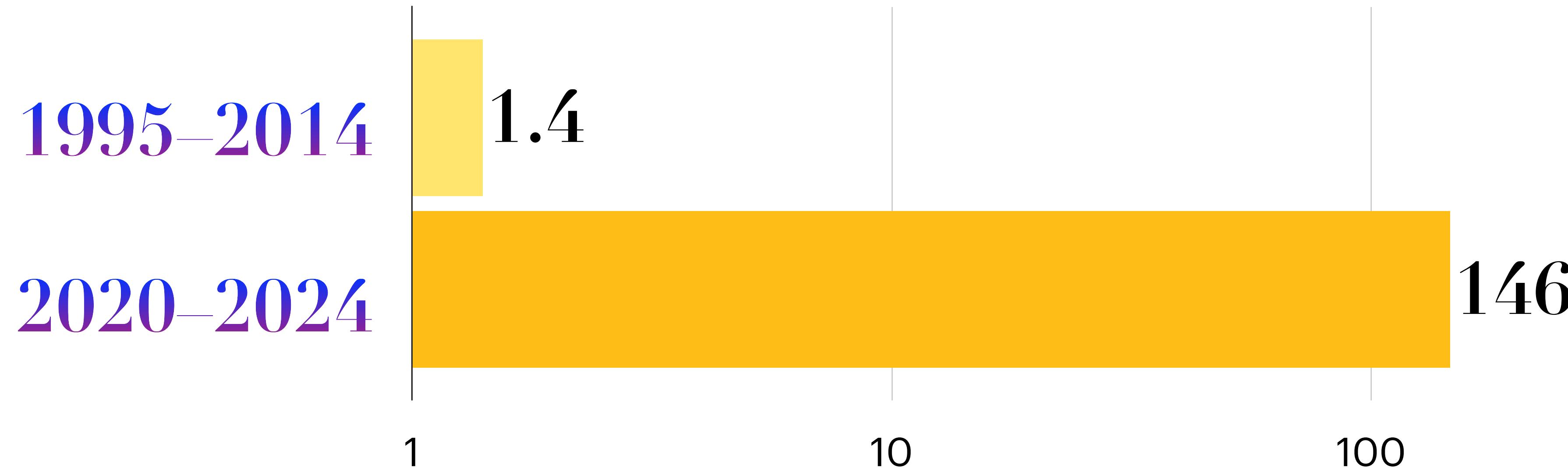
- Current standard for diabetic retinopathy detection: Dilated retinal exam by ophthalmologist/optometrist with handheld lens; **takes 2 hours**
- IDx-DR: Can be used in a primacy care physician's office; **takes <2 min**, no need for manual interpretation or data entry; identifies diabetic retinopathy with $\geq 90\%$ sensitivity and specificity



950

**Number of medical AI devices cleared
by FDA for clinical use (as of June 2024)**

Number of FDA-Cleared AI Devices Per Year

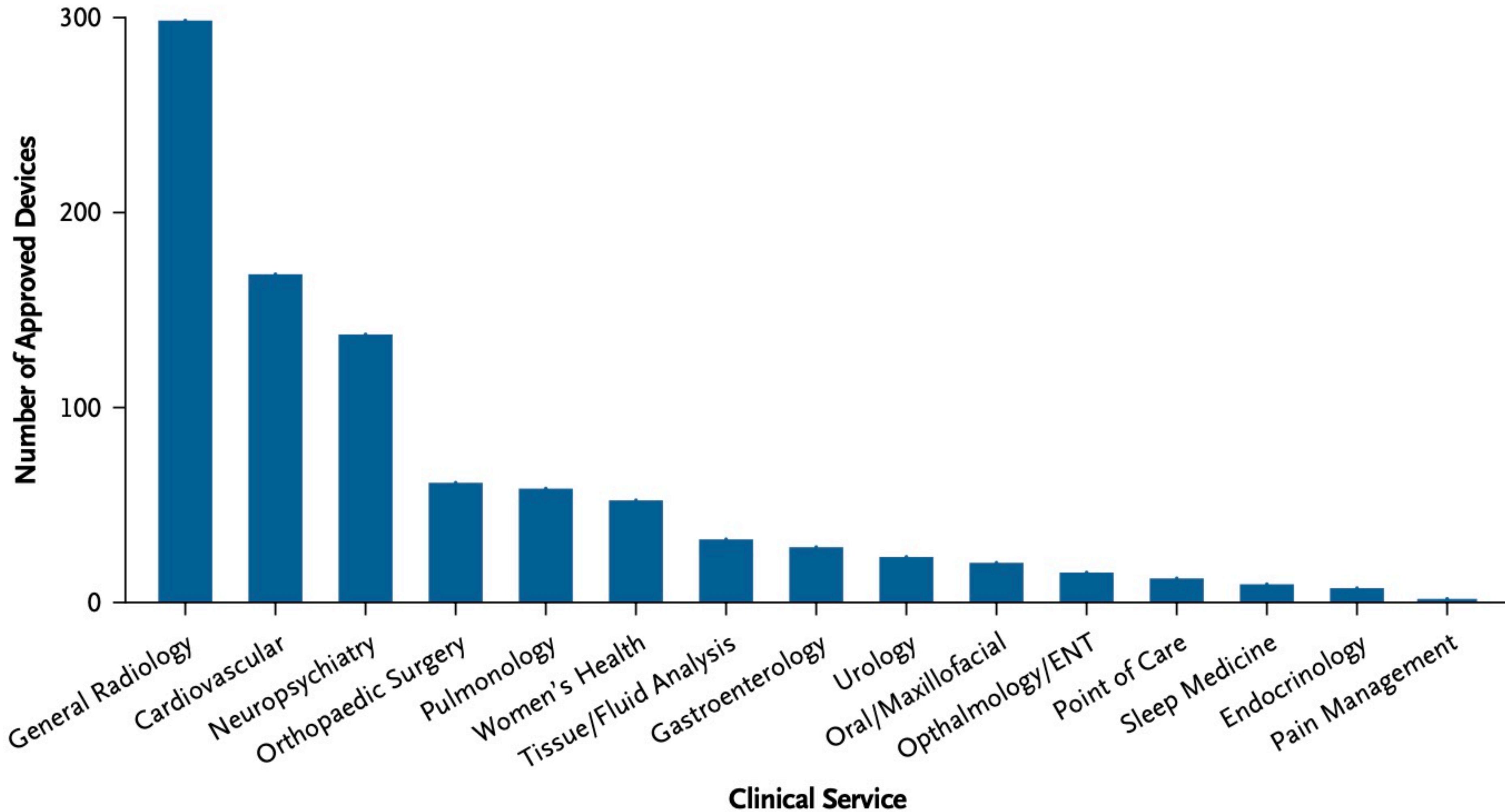


Development and Commercialization Pathways of AI Medical Devices in the United States: Implications for Safety and Regulatory Oversight

Authors: Branden Lee, B.S.  , Shivam Patel, B.S.  , Crystal Favorito, B.S.  , Sara Sandri, B.S.  , Maria Rain Jennings, Ph.D.  , and Tinglong Dai, Ph.D. 



Number of Devices by Clinical Service



AI Methods Used in FDA-Cleared AI Devices

AI Architecture, as Indicated in the FDA Approval Summary

All Devices (950)

- Explicit AI
- Nonexplicit AI

78.8%

21.2%

Explicit AI Devices (749)

- Explicit ML
- Unspecified AI
- Specified AI
- Multiple AI

77.7%

17.2%

1.5%

3.6%

Explicit ML Devices (582)

- Explicit DL
- Unspecified ML
- Specified ML
- ANN

69.4%

25.6%

1.2%

3.8%

Explicit DL Devices (404)

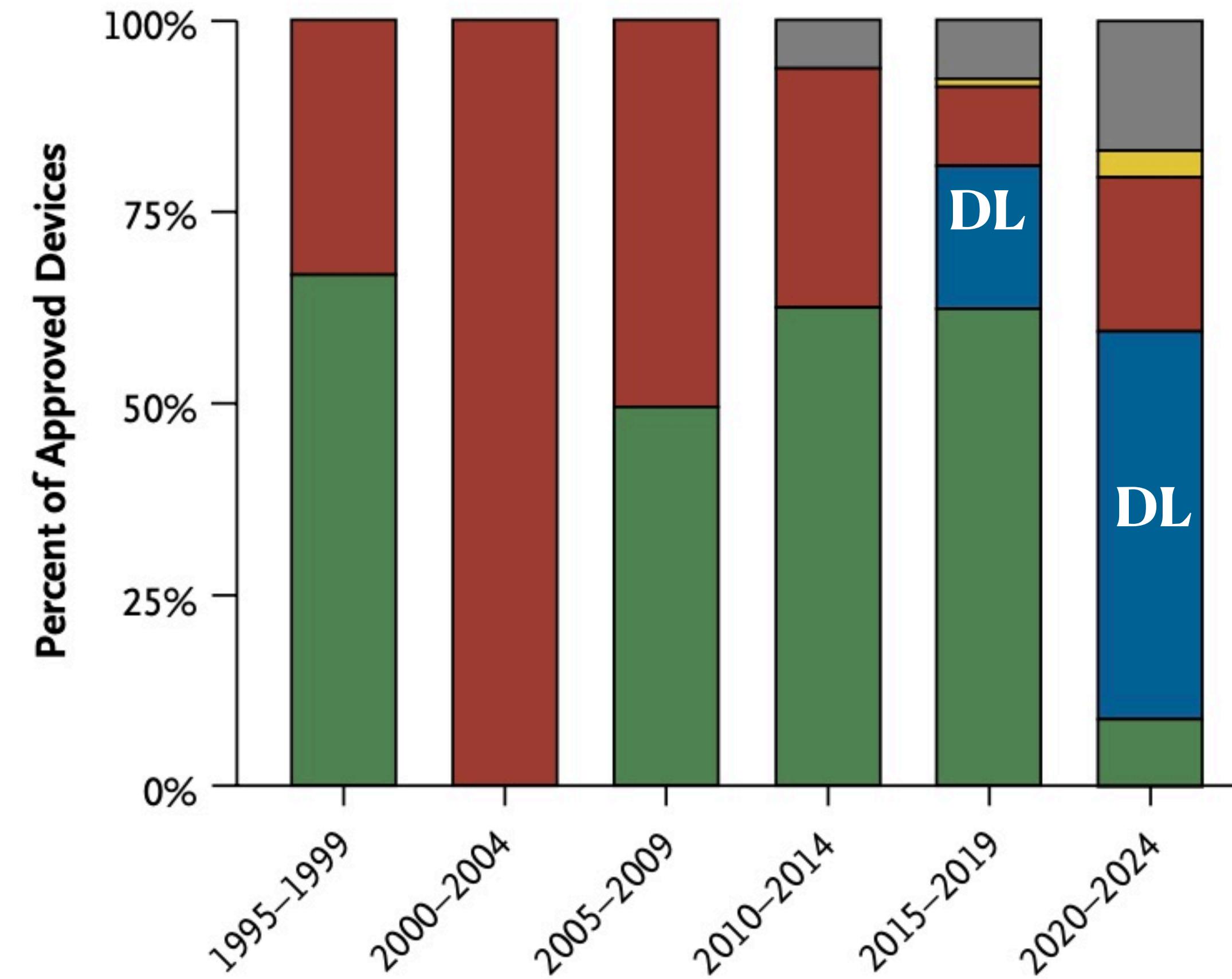
- Specified DL
- Unspecified DL

38.4%

61.6%

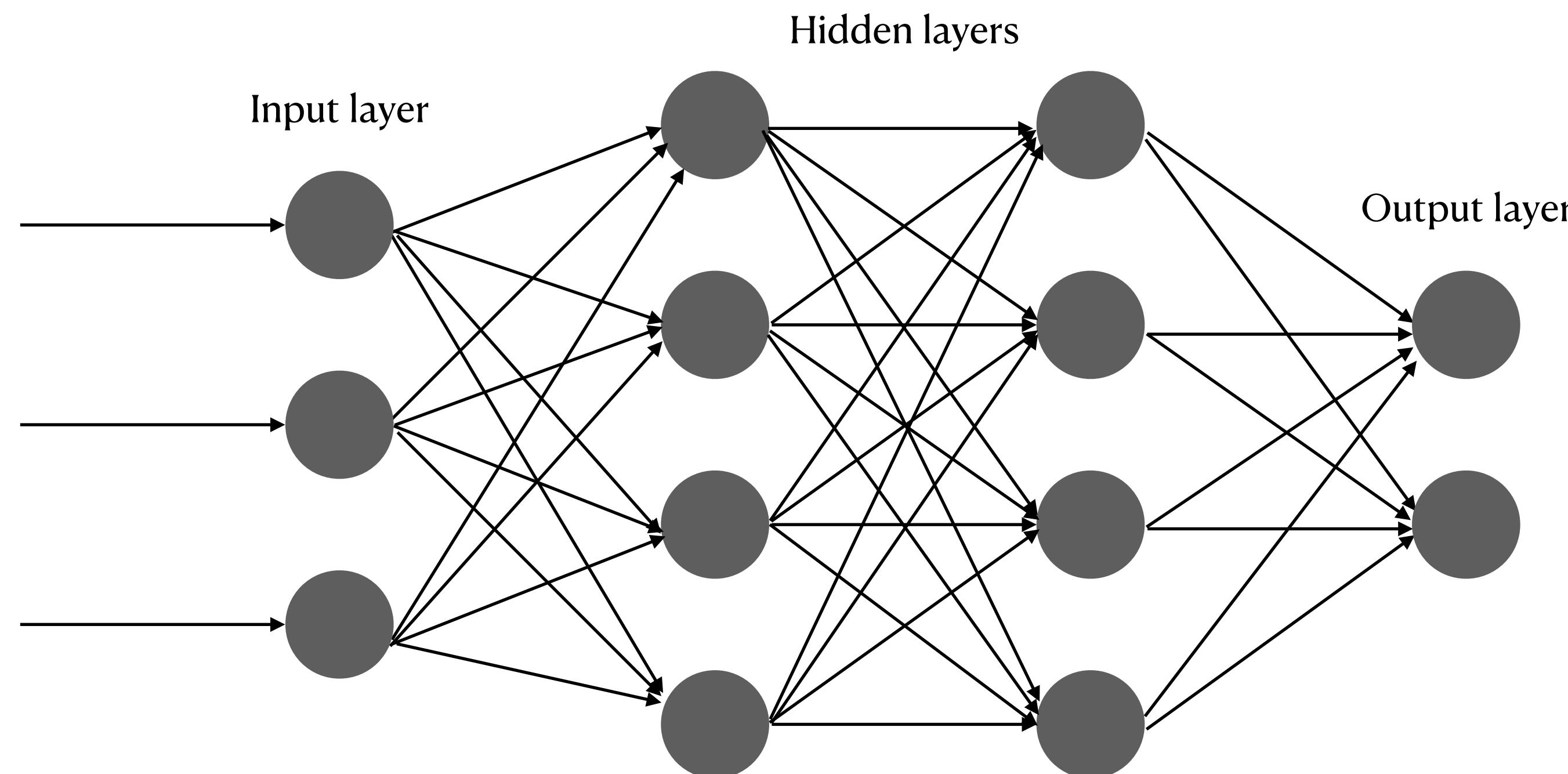
AI Methods by Commercial Model and Over Time

■ AI (Excluding ML and DL) ■ Multiple Approaches ■ ML (Excluding DL)
■ DL ■ No Explicit AI Use



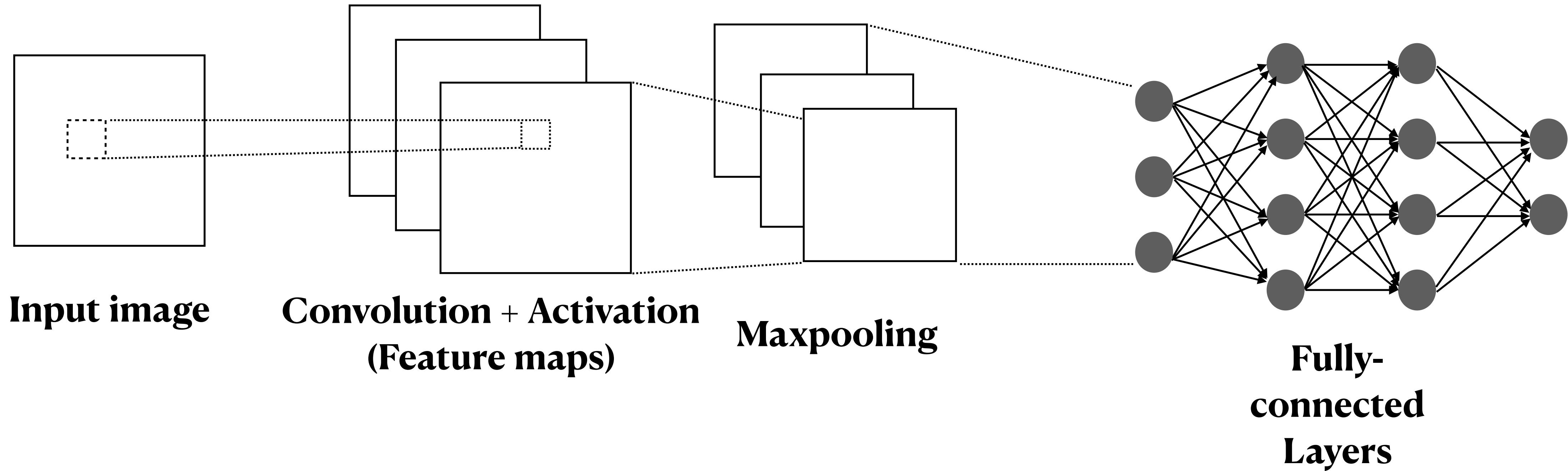
Deep Learning

Deep learning is an incremental, layer-by-layer learning approach in which increasingly complex representations are developed to map the input to output



Artificial Neural Network

Convolutional Neural Networks (CNNs)



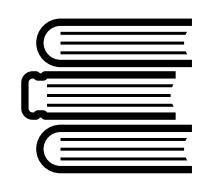
Convolutional Neural Network (CNN)

<https://bit.ly/cnnsimu>



AI Capabilities

Learning, Perception, and Cognition



Learning



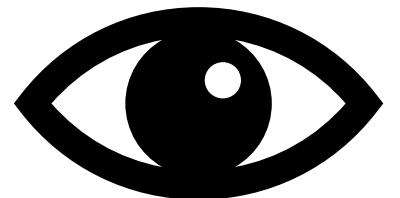
Supervised



Unsupervised



Reinforcement Learning



Perception



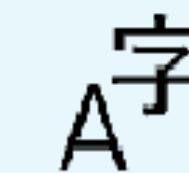
Vision



Audio



Speech



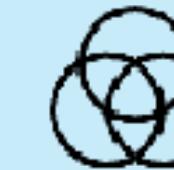
Natural Language



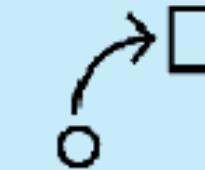
Cognition



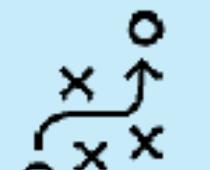
Regression



Classification



Recommendation



Planning



Optimization

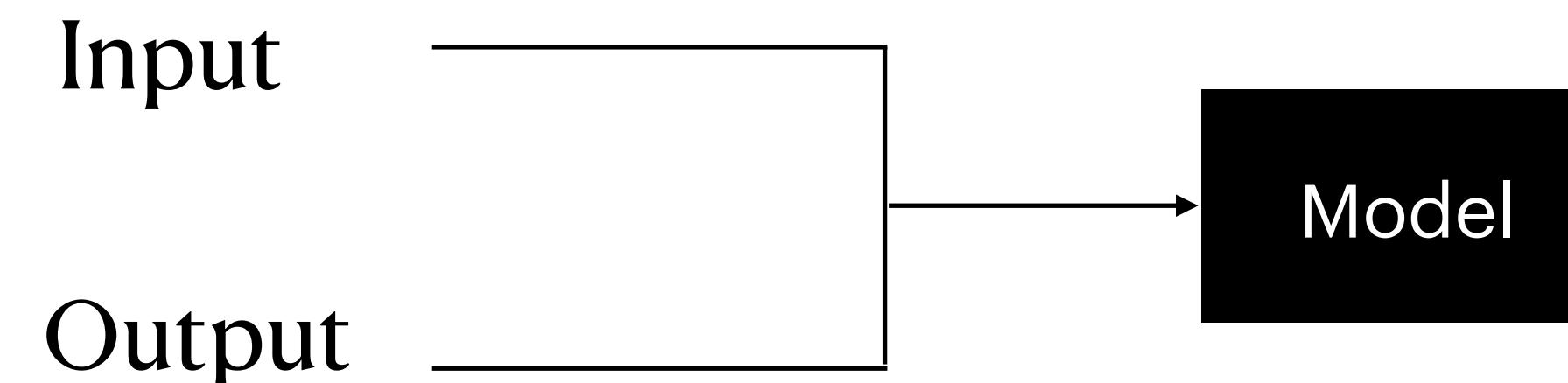
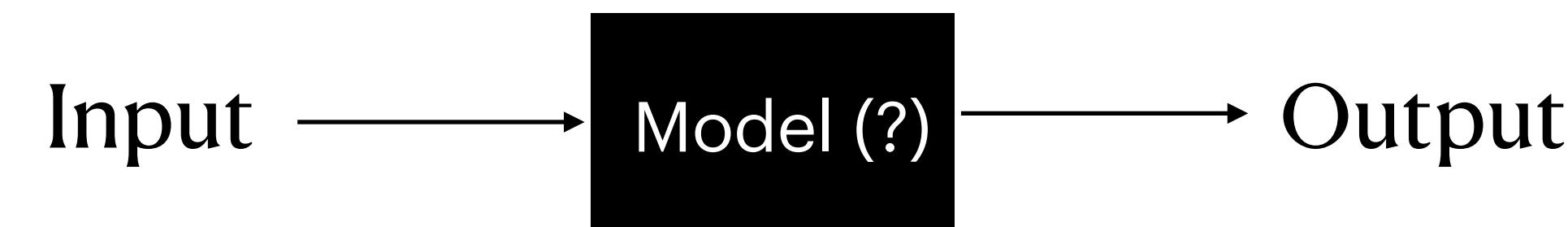


Pattern Recognition

AI Capabilities: Learning

Supervised Learning

- **Supervised learning**—the most popular technique that you will be using 90% of the time



Requirement: Training data with correct *labels*

Sean Cusack, a beekeeper, was curious if anything other than bees was entering his hives. So he made a tiny photo booth that snapped pictures whenever something moved around it. However, sorting through thousands of insect portraits proved time-consuming... So he used Lobe to create an AI solution.

“It was just really simple,” Mr. Cusack said, adding that the underlying data science was “over my head..” The Lobe platform allowed him to drag and drop sample photos and click a few buttons to make a system that could recognize his beloved bees and spot unwelcome visitors.

Smith, C. S. (2022) “‘No-code’ brings the power of A.I. to the masses,” *New York Times* (Mar. 15). <https://nyti.ms/3p78s2g>

<https://www.lobe.ai/>

Another example of supervised (deep) learning...

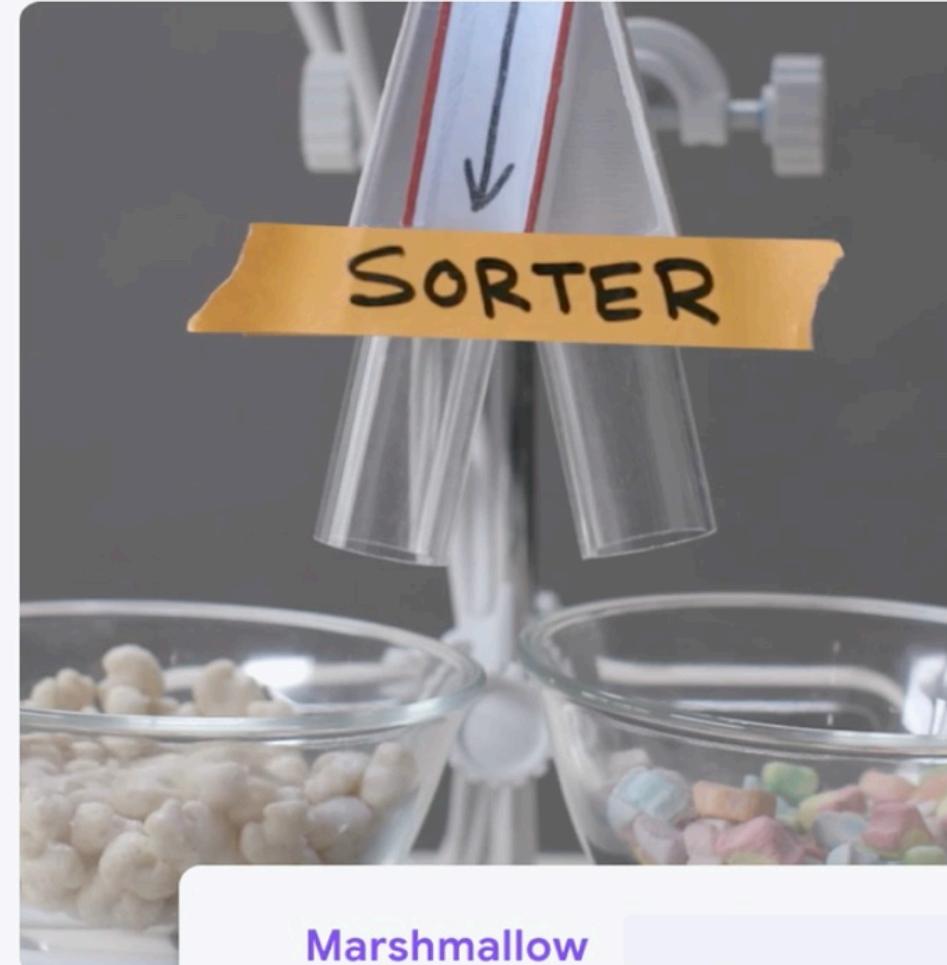
Teachable Machine

Train a computer to recognize your own images, sounds, & poses.

A fast, easy way to create machine learning models for your sites, apps, and more – no expertise or coding required.

[Get Started](#)



The image shows a robotic arm with a gripper sorting small white marshmallows from one bowl into another. A yellow banner across the arm reads "SORTER".

Marshmallow

Not Marshmallow

<https://teachablemachine.withgoogle.com>

Please Sign Up Your Teams via:

<https://bit.ly/jhuai25>

- Minimum team size = 3; maximize team size = 4
- Everyone must be from the same section

Now, we can use Python to do
deep learning, with the help of
HopGPT and **Google Colab**

<http://lab.ai.jh.edu>

<https://colab.research.google.com/>



We have been waiting for this moment.

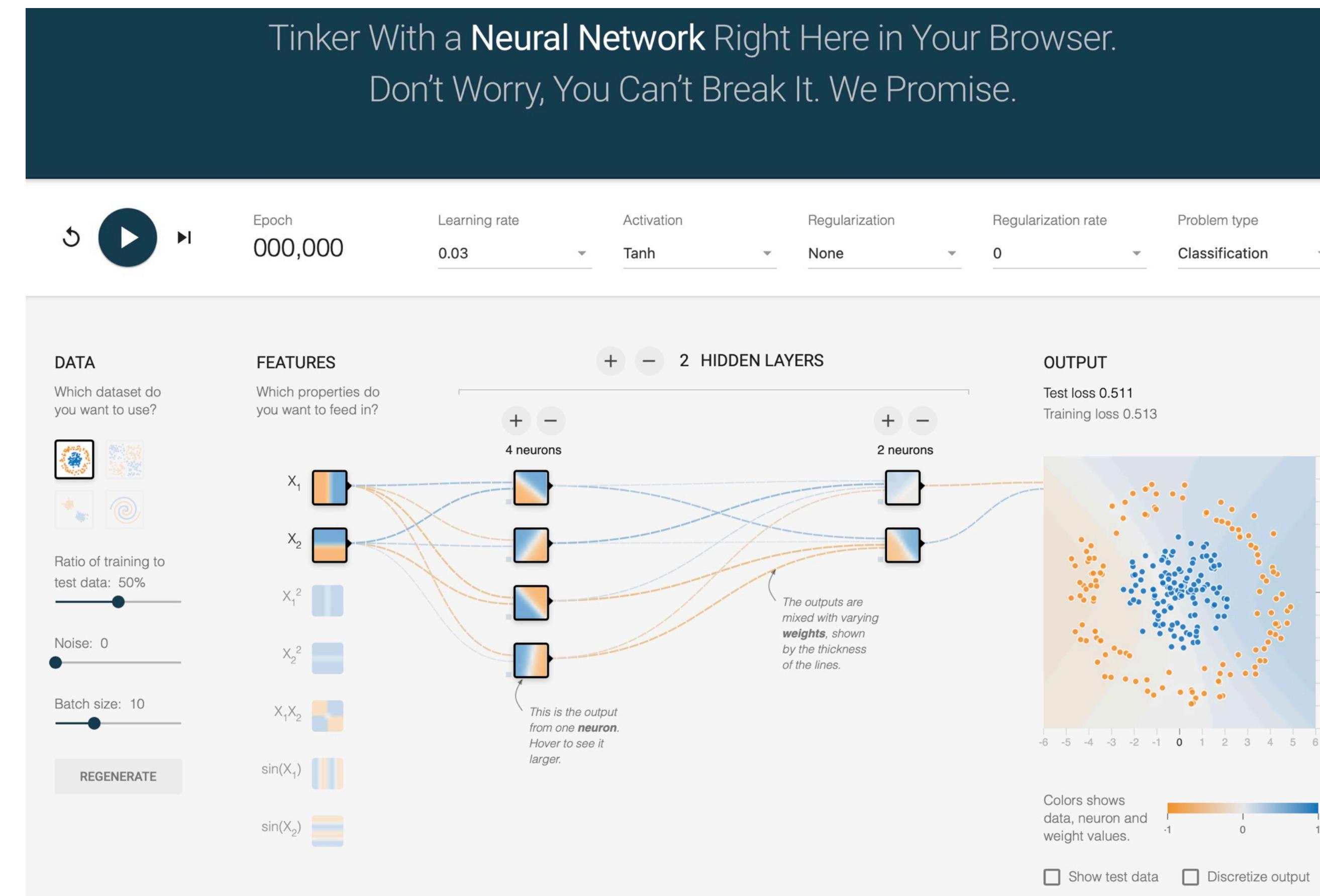
This is the moment we've been waiting for. This is the iPhone moment, if you will, of artificial intelligence. This is the time when all the big ideas about mobile computing and all of that came together in a product that everybody just kind of I see it. I see it. I can now use this as an API. And I connect it to a spreadsheet. I connect it to PowerPoint, I connect it to a drawing program, I connect it to a photo editing program, it makes everything better.

All of a sudden, anybody can program a computer. Literally anyone can program. We have democratized computing. It doesn't matter if you're a farmer, a doctor, a nurse, a front-line worker, an assistant, a travel agent, it doesn't matter. It doesn't matter if you're a small business owner or a restaurant owner. **Everyone is a programmer now.**

Isn't that right? You just have to ask this thing to write a program for you to do something for you to automate something for you.

Jensen Huang, President and CEO, Nvidia Corporation

Yet another example of supervised (deep) learning. This time, we're going a little “under the hood”



<https://playground.tensorflow.org>

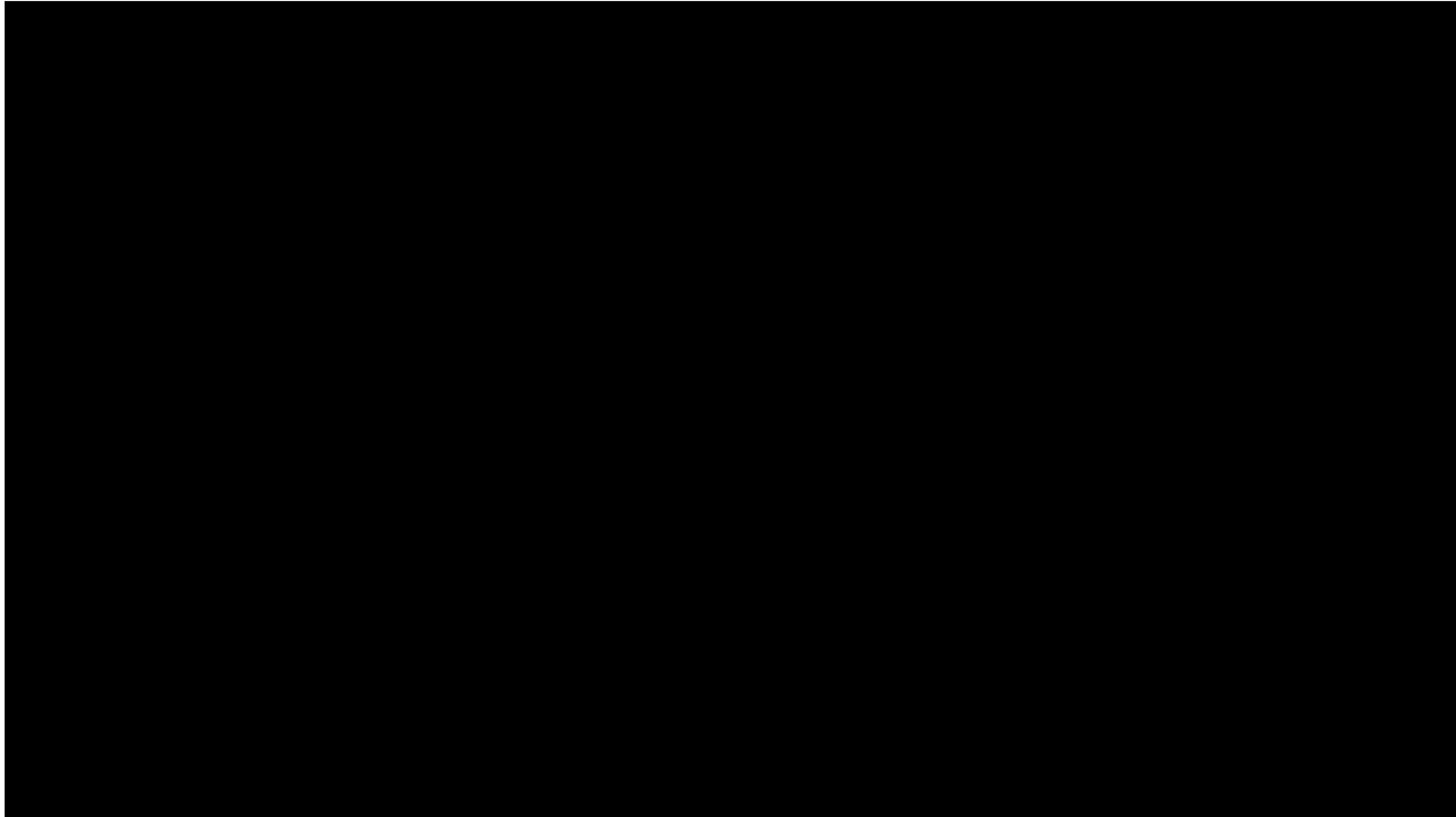
AI Capabilities: Learning

Unsupervised Learning

- **Unsupervised** learning is needed when we don't have labeled data. Instead, we take a set of unlabeled data and find structure in it
- Examples:
 - Identifying customer segments in your customer base or website visitors
 - “People who purchased this item also purchased...”
 - Online dating platform algorithms
 - Outlier detection

An example of
unsupervised learning...

<http://projector.tensorflow.org/>

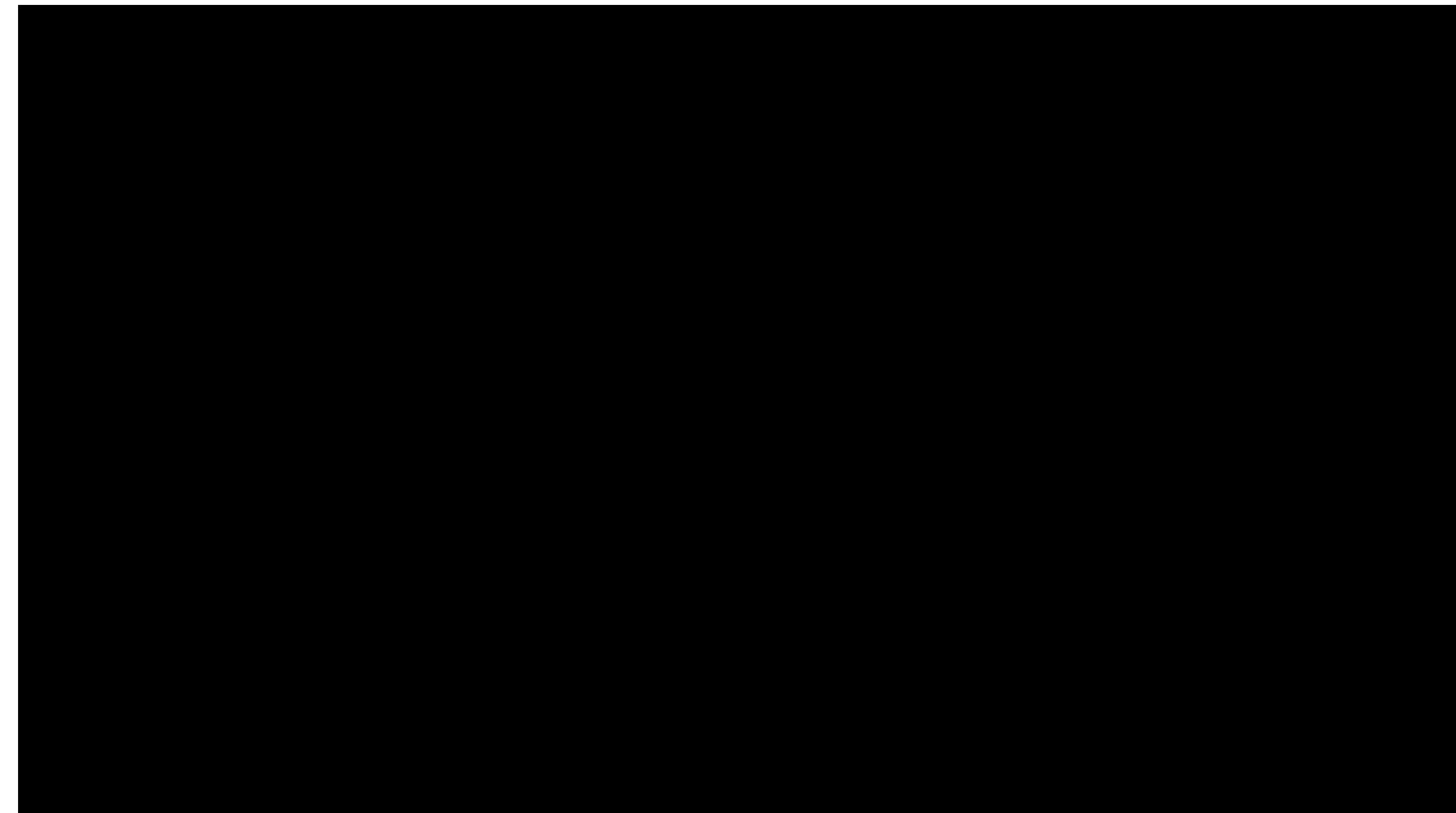


<http://projector.tensorflow.org/>

AI Capabilities: Learning

Reinforcement Learning

- **Reinforcement** learning is used when you don't use any training data at all



85%

Of the information we receive comes from our sense of sight.

11%: Hearing

Source: *Telling Ain't Training*, by Harold Stolovitch and Erica Keeps

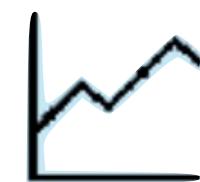
AI Capabilities: Perception

- Vision: Extract information from images and videos
- Audio: Perform audio processing tasks (e.g., identifying machinery failures based on sound)
- Speech: Interact with humans using speech
- Natural language processing (NLP): Understanding and generating text language

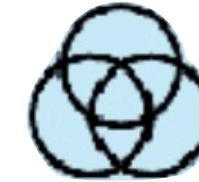
AI Capabilities: Cognition

The ability to acquire and process knowledge

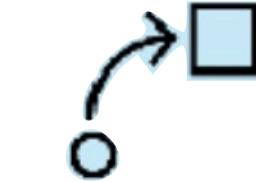
Can you name a company/organization famous for each of the following?



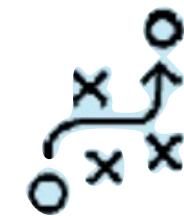
Regression



Classification



Recommendation



Planning



Optimization



Pattern Recognition

AI Capabilities

Learning, Perception, and Cognition



Learning



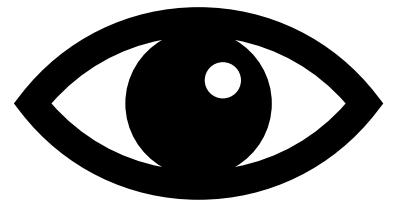
Supervised



Unsupervised



Reinforcement Learning



Perception



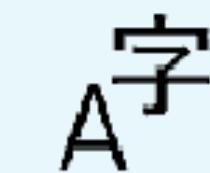
Vision



Audio



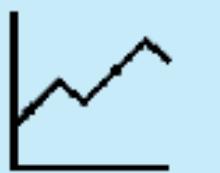
Speech



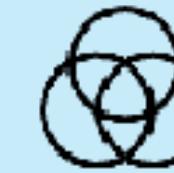
Natural Language



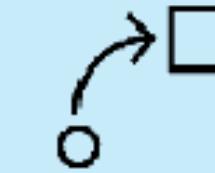
Cognition



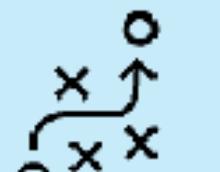
Regression



Classification



Recommendation



Planning

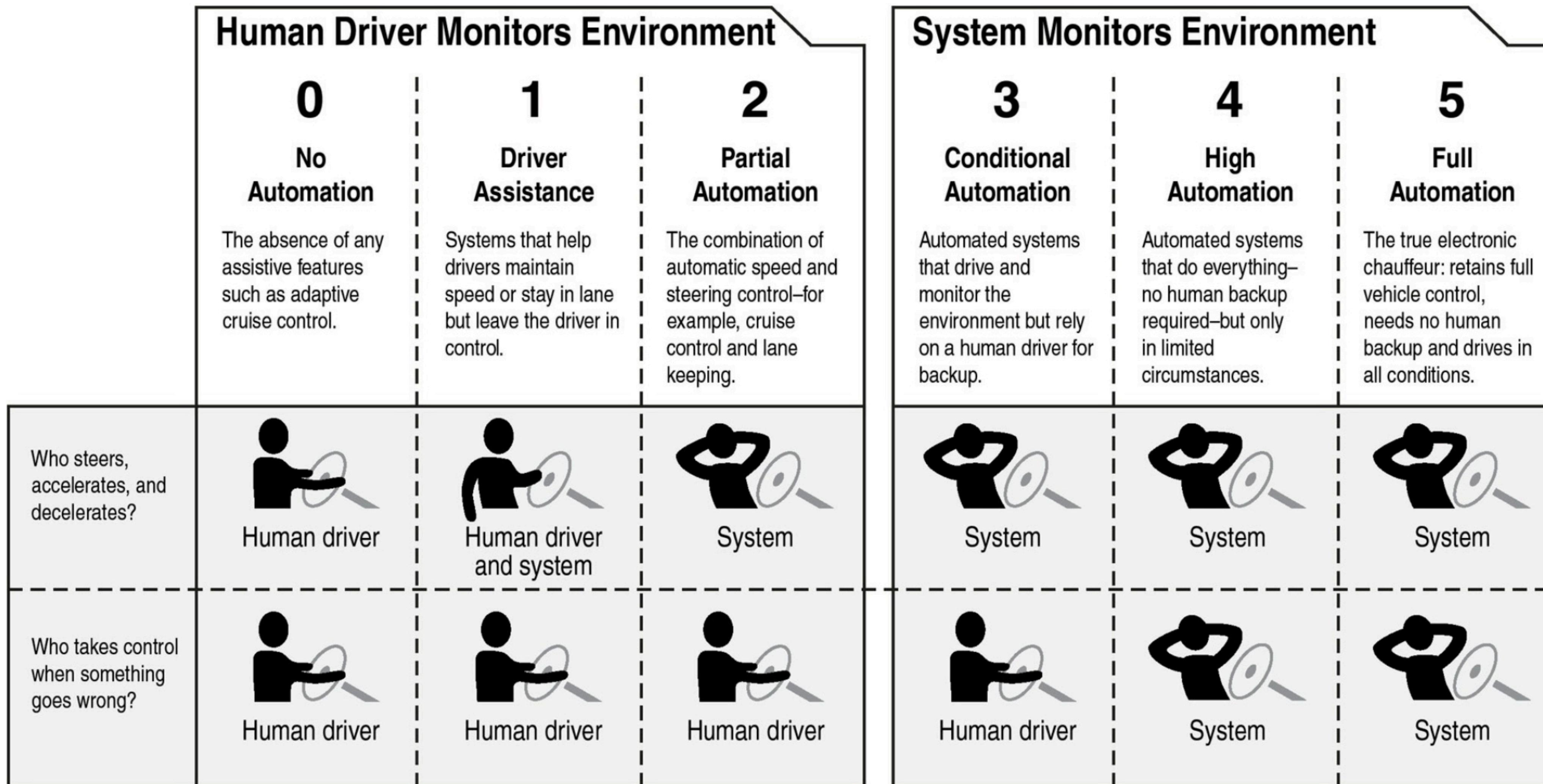


Optimization

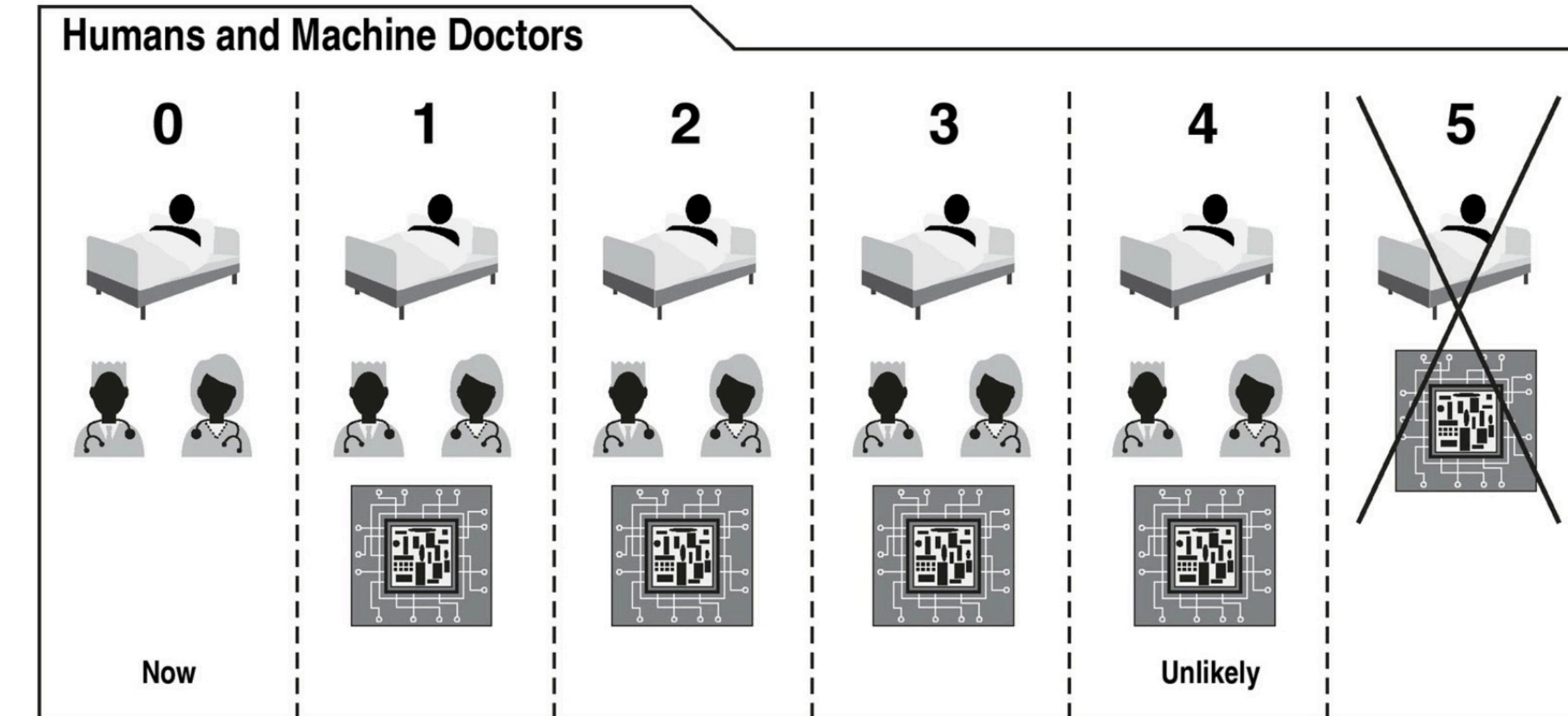
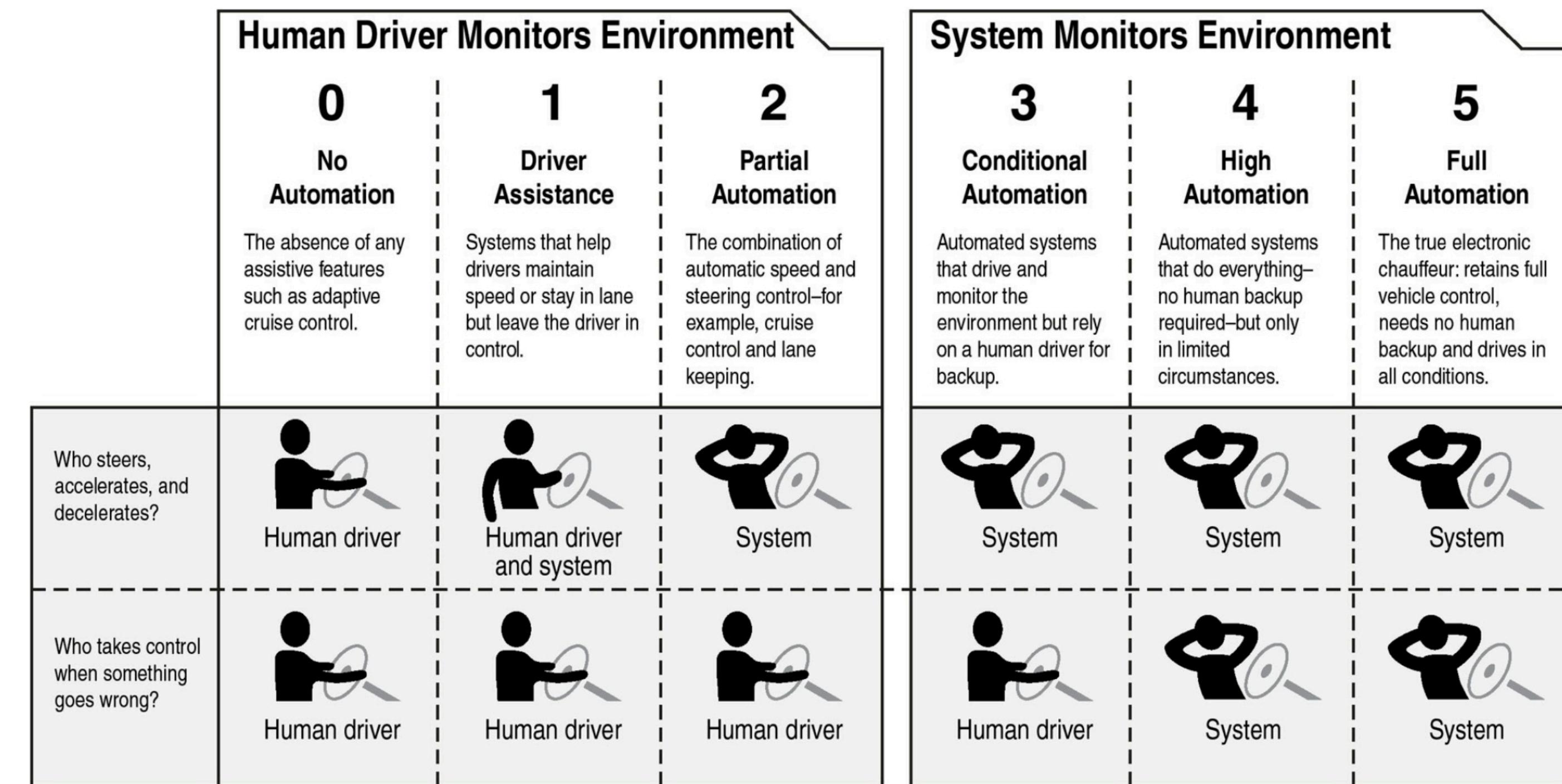


Pattern Recognition

Levels of Automation: Self-Driving Cars



Source: Eric Topol, *Deep Medicine*



Source: Eric Topol, *Deep Medicine*



AI Strategy

“Why AI Will Save the World” (Andreessen 2023)

- Moral Panics & Fear: Why do new technologies often trigger moral panics? Is this fear justified?
- Baptists vs. Bootleggers: What are the motives behind calls for AI regulation?
- AI Risks: What are the real vs. perceived AI risks? How can we differentiate them?
- **Discussion Prompt:** Do you agree with Andreessen's optimistic view of AI? Why or why not?

How Will AI Change Work (Knickrehm 2019)

Five Schools of Thought

- **Dystopians:** Man and machine will wage a Darwinian struggle that machine will win. Expect massive unemployment, falling wages, and wrenching economic dislocation
- **Utopians:** Intelligent machines will take on even more work, but the result will be unprecedented wealth, not economic decline. AI and computing power will advance to achieve the “singularity”
- **Technology optimists:** AI will result in a leap in productivity and create economic growth and improvements in living standards (Andreesen 2023, “Why AI Will Save the World”)
- **Productivity skeptics:** AI will result in little productivity increase and more income inequality
- **Optimistic realists:** AI will advance productivity in certain companies and sectors. It requires better human-AI interaction to realize the potential of AI

Which school do you belong to?

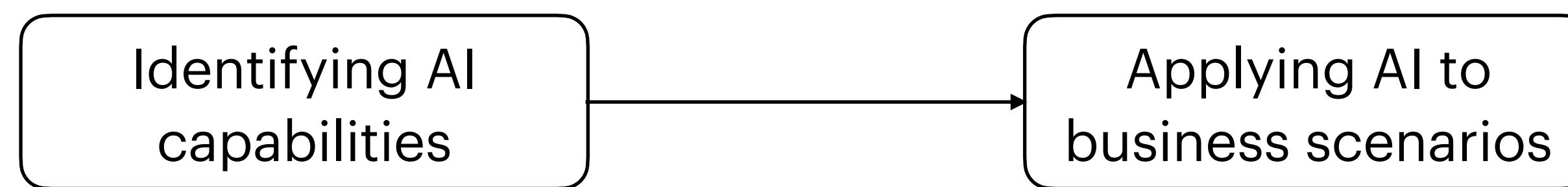
“It’s Easier to Invent the Future Than to Predict It”

- Ultimately, business leaders influence the future of work, so it is decisions rather than predictions that matter more
- Actions that can shape the future
 - Use technology to augment human skills and reinvent operating models
 - Refine jobs and rethink organizational design
 - Unleash human talents that machines cannot match: creativity, empathy, communications, adaptability, and problem solving

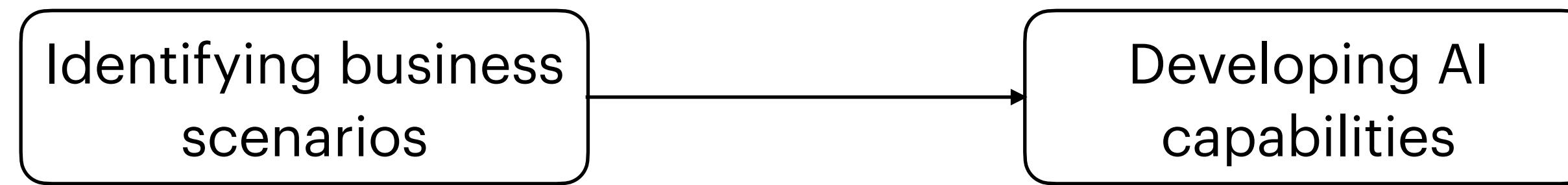
How to Bring AI into Business

Push vs. Pull

- Push: From technology to business



- Pull: From business to technology



What are pros and cons of each of these approaches?

Is AI *any* different from other technologies in terms of how we should apply them?

INSIDE FACEBOOK'S AI WORKSHOP

An interview with Joaquin Candela by Scott Berinato

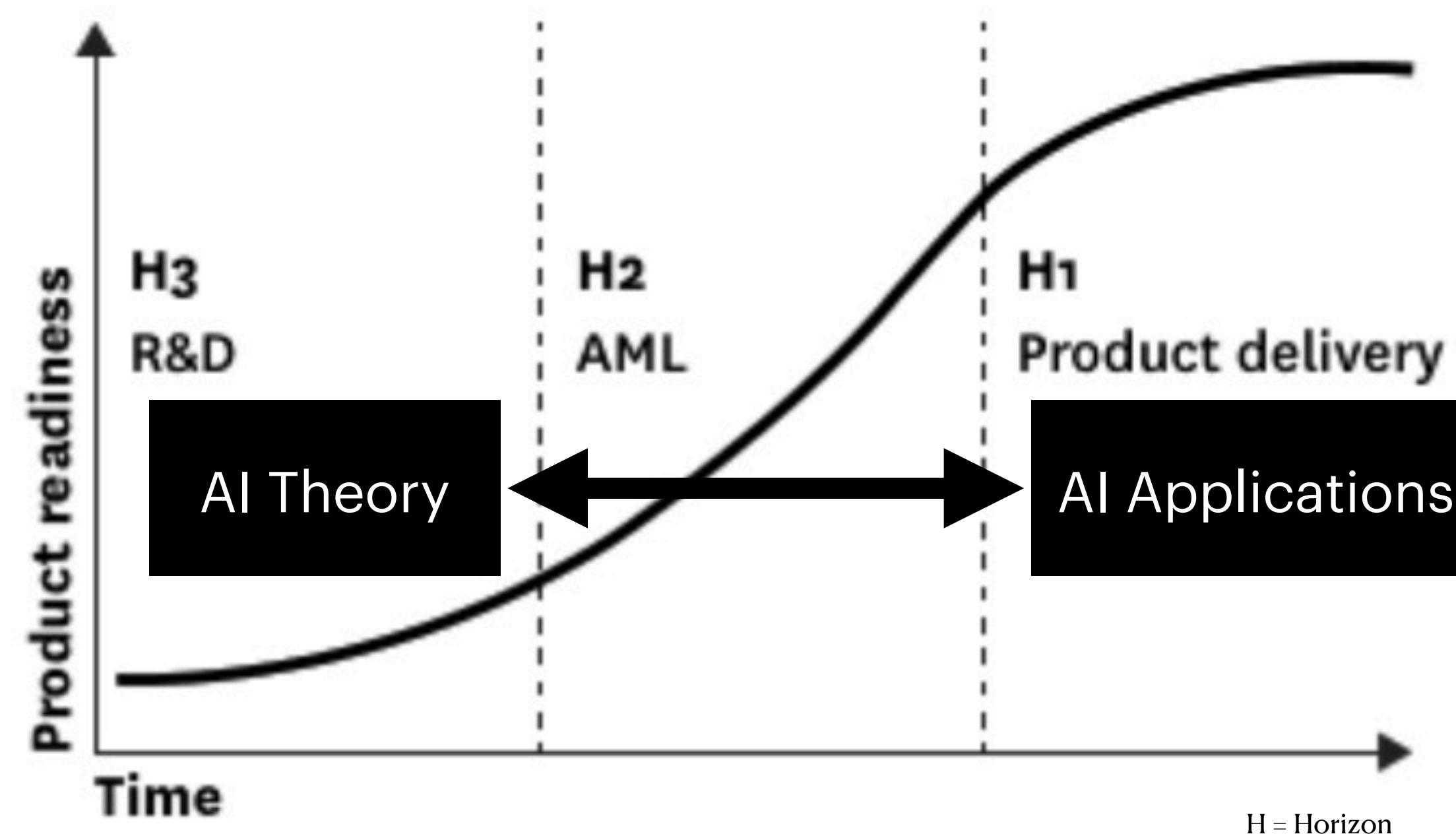


“Early on it was more push, more tenacity on our part.... Doing a little bit of the science and a little bit of the product in addition to its core function was meant to inspire the product team members to see what AML could do for them.”

“Now if I walk from one end of this building to the other and I bump into [someone], they’ll stop and say ‘Hey, we’re excited to try this. We think we can build a product on this.’ This didn’t happen before.”

FIGURE 2-1

Where AI fits in at Facebook



Source: Facebook

Rule of thumb: Something is going wrong if you only see push or pull, but not both.

The Nature of AI Applications

Horizontal AI applications (similar across industries)

Examples: Marketing, sales, finance, human resources, customer service, supply chains

Vertical AI applications
(unique to the industry vertical)

Manufacturing,
financial services,
retail,
public sector,
healthcare

Key Considerations Before Applying AI

- **Market differentiation:** Will AI create a strong and sustainable market differentiation?
- **Network effect:** Can this AI application help start a virtuous cycle of growth?
- **External disruptions:** Is there an external disruption the organization may miss out by not acting on this AI application?
- **Investment required:** Can the organization sustain the long-term investment required to develop and upgrade this AI application?
- **Cost:** What is the cost of implementation and operations?
- **Risk:** How likely is the implementation of the use case to be successful?

Performance Metrics

Business impact metrics

Revenue increase, cost savings, productivity increase, brand equity

Quality metrics

Accuracy of the system, user satisfaction, level of autonomy, verifiability, interpretability

Implementation metrics

Budget/schedule/scope performance, employee satisfaction

Introduction to AI Lab

AI Lab

- Identifying a problem in which AI can play a role in transforming unstructured data to tools with potential of generating business and human value
- Developing a prototype of an AI-based solution using Keras and/or GenAI tools or no-code AI tools (e.g., Google Teachable Machine and Roboflow)
- Proposal (5-page slide deck, see Canvas for instructions) due by Session 4
- Final report (15-page slide deck + appendix) due by Session 7

The Nature of AI Applications

Horizontal AI applications (similar across industries)

Examples: Marketing, sales, finance, human resources, customer service, supply chains

Vertical AI applications
(unique to the industry vertical)

Manufacturing,
financial services,
retail,
public sector,
healthcare

Most of AI's business uses will be in two areas

An examination of more than 400 AI use cases revealed the two areas where AI can have the greatest impact.

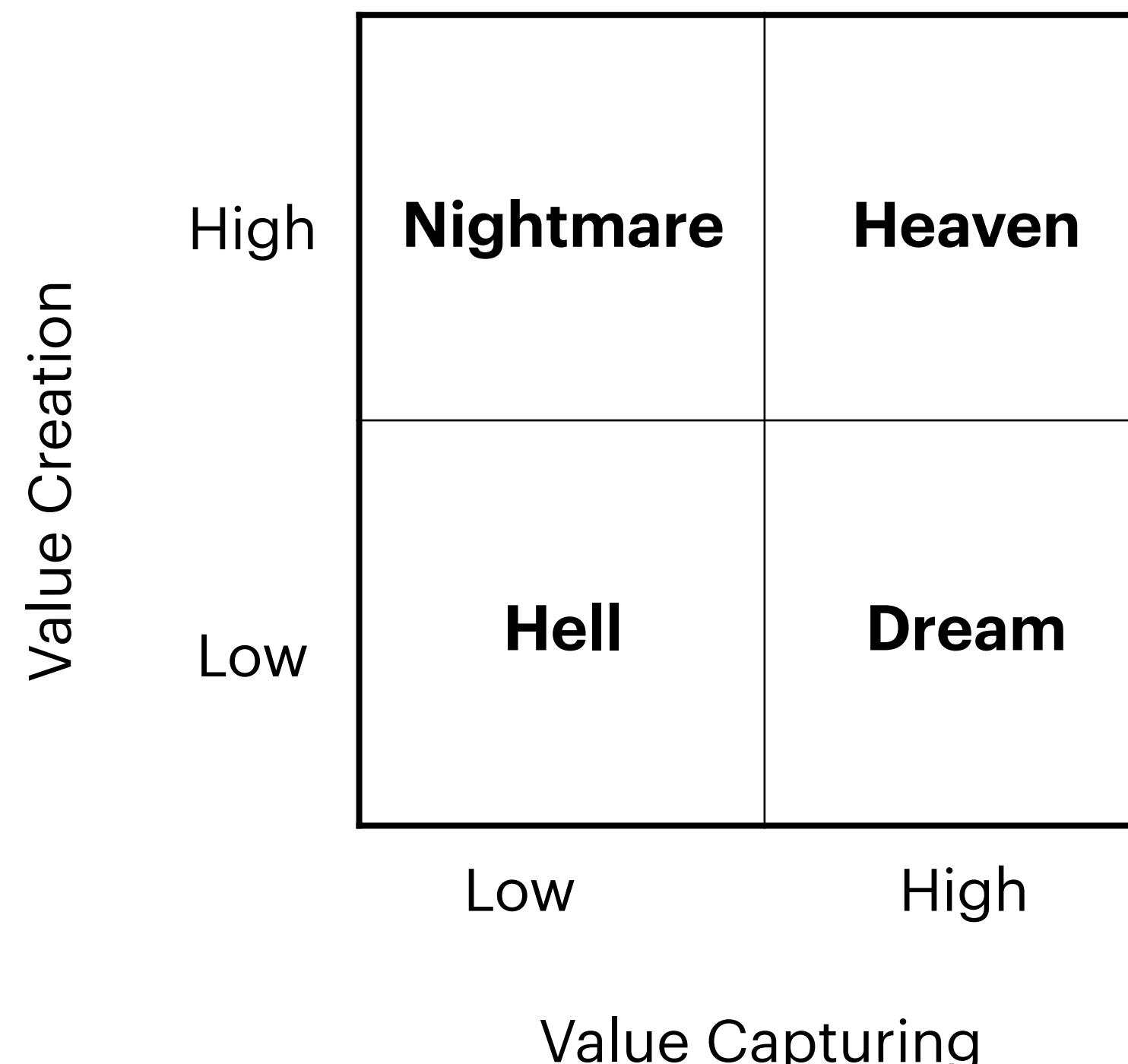
by Michael Chui, Nicolaus Henke, and Mehdi Miremadi



- “40% of all the potential value that can be created by analytics today comes from the AI techniques that fall under the umbrella **“deep learning,”** which could account for between \$3.5 trillion and \$5.8 trillion in annual value.”
- “While applications of AI cover a full range of functional areas, it is in fact in these two cross-cutting ones—supply-chain management/manufacturing and marketing and sales—where we believe AI can have the biggest impact.”

What Does Business Model Mean?

- Business model = the design of value creation and value capture mechanisms
 - Value creation = perceived (or received) benefits to the customer
 - Value capture = pricing and cost structures used to generate revenue and profits



Customer- vs. Employee-Facing AI Solutions

- For customer-facing AI solutions, value is usually related to **engagement**: Number of active users, time spent, money saved, better health etc.
 - Focus: Using AI to create more engaging applications
- For employee-facing AI solutions, value is usually related to **productivity**: Time saved, tasks performed, escalation rate, enhanced safety, etc.
 - Focus: Using AI to create more productive applications

What We are Looking from AI Lab

- Identifying a novel problem that existing AI solutions have not (sufficiently) addressed
- Proposed an AI prototype to tackle the problem
- Demonstrate human/business value
- Projects are measured by novelty, solution quality, and value-generating potential
- Your voices count — final reports (slide decks) will be posted for **peer voting**



We are Doomed...

Mitigating the risk of extinction from AI should be a global priority alongside other societal-scale risks such as pandemics and nuclear war.

Signatories:

AI Scientists Other Notable Figures

Geoffrey Hinton

Emeritus Professor of Computer Science, University of Toronto

Yoshua Bengio

Professor of Computer Science, U. Montreal / Mila

Demis Hassabis

CEO, Google DeepMind

Sam Altman

CEO, OpenAI

Dario Amodei

CEO, Anthropic



THE PROMISES OF AI



George Orwell, *Nineteen Eighty-Four*:

“The telescreen received and transmitted simultaneously. Any sound that Winston made, above the level of a very low whisper, would be picked up by it; moreover, so long as he remained within the field of vision which the metal plaque commanded, he could be seen as well as heard. There was of course no way of knowing whether you were being watched at any given moment... It was even conceivable that they watched everybody all the time. But at any rate they could plug in your wire whenever they wanted to. You had to live—did live, from habit that became instinct—in the assumption that every sound you made was overheard, and, except in darkness, every movement scrutinized.”

Until Next Class

- Readings for Session 1: See the syllabus for the list
- Readings for Session 2 (skim them through before class)
 - Deep Learning with Python, 3rd Edition, Chapters 2 and 5
 - Mims, C. (2022) “How to Build AI that Actually Works for Your Business,” Wall Street Journal (July 23).
 - Smith, C. S. (2022) “‘No-code’ Brings the Power of A.I. to the Masses,” New York Times (Mar. 15).



Thank You!



May AI Be With You