Machine Learning Fundamentals

David McClintock, MD
Pathology Informatics Summit 2018 Boot Camp
May 21, 2018

DISCLOSURES

I have no relevant financial relationships with commercial interests to disclose in relation to the content of this presentation.

Who Am I??

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President, Association for Pathology Informatics (API)

DISCLAIMERS

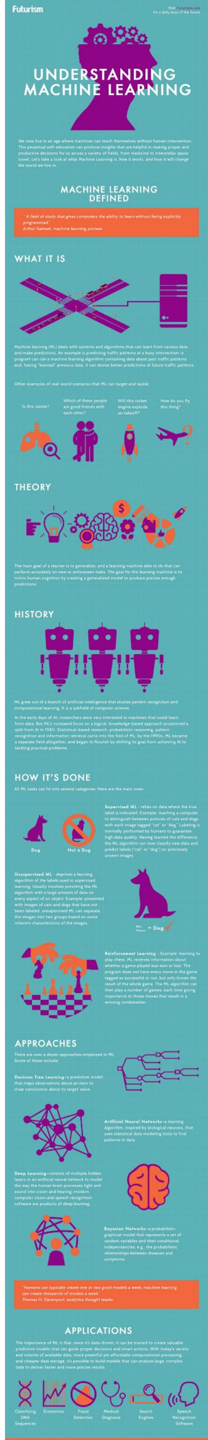
Machine Learning is HUGE…

- Practically impossible to learn everything on such a vast and rapidly evolving topic

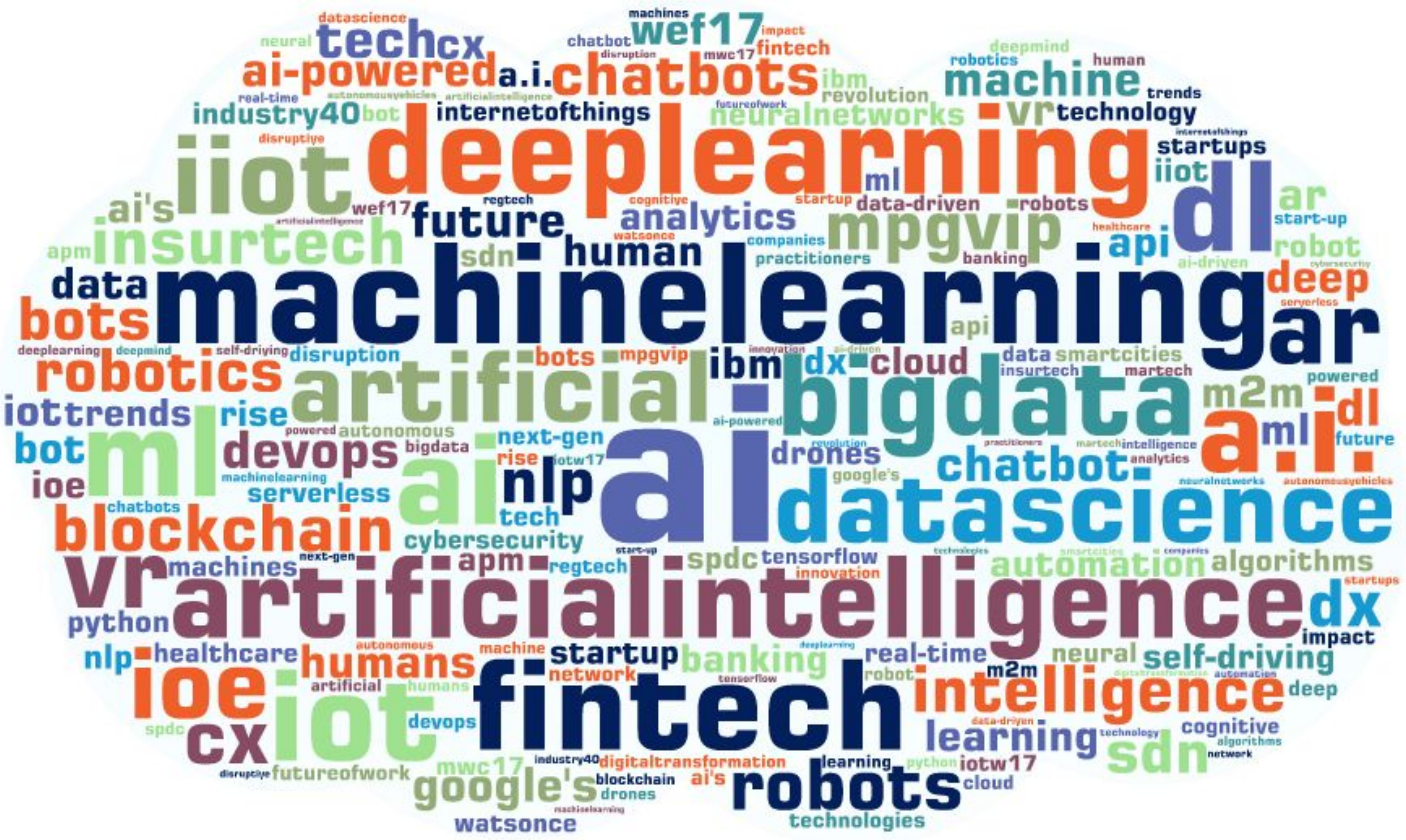
I am not an über expert in Machine Learning

- Goal is to make this topic UNDERSTANDABLE

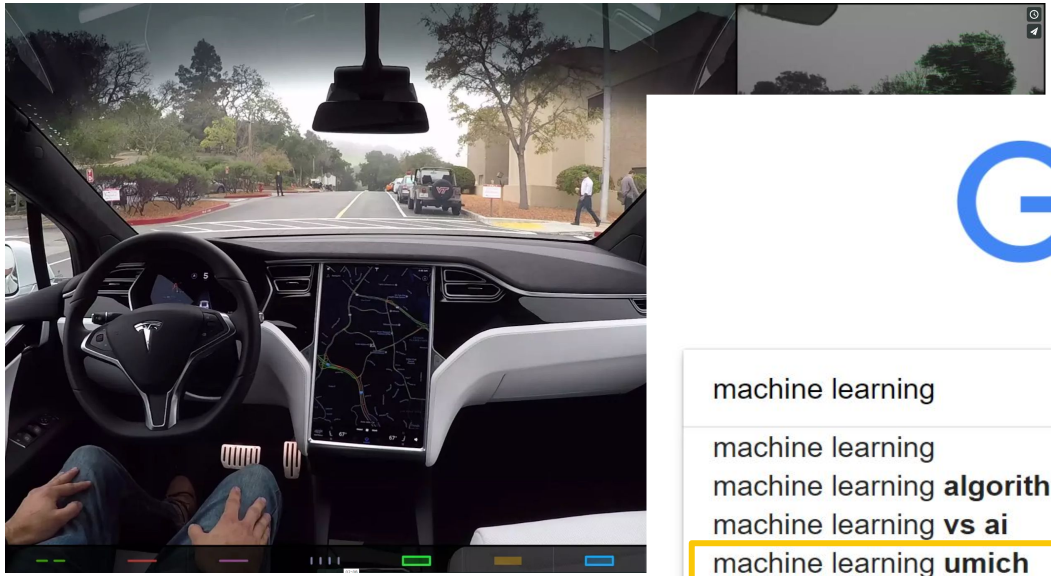
For today → make you familiar with basic machine learning terminology and concepts

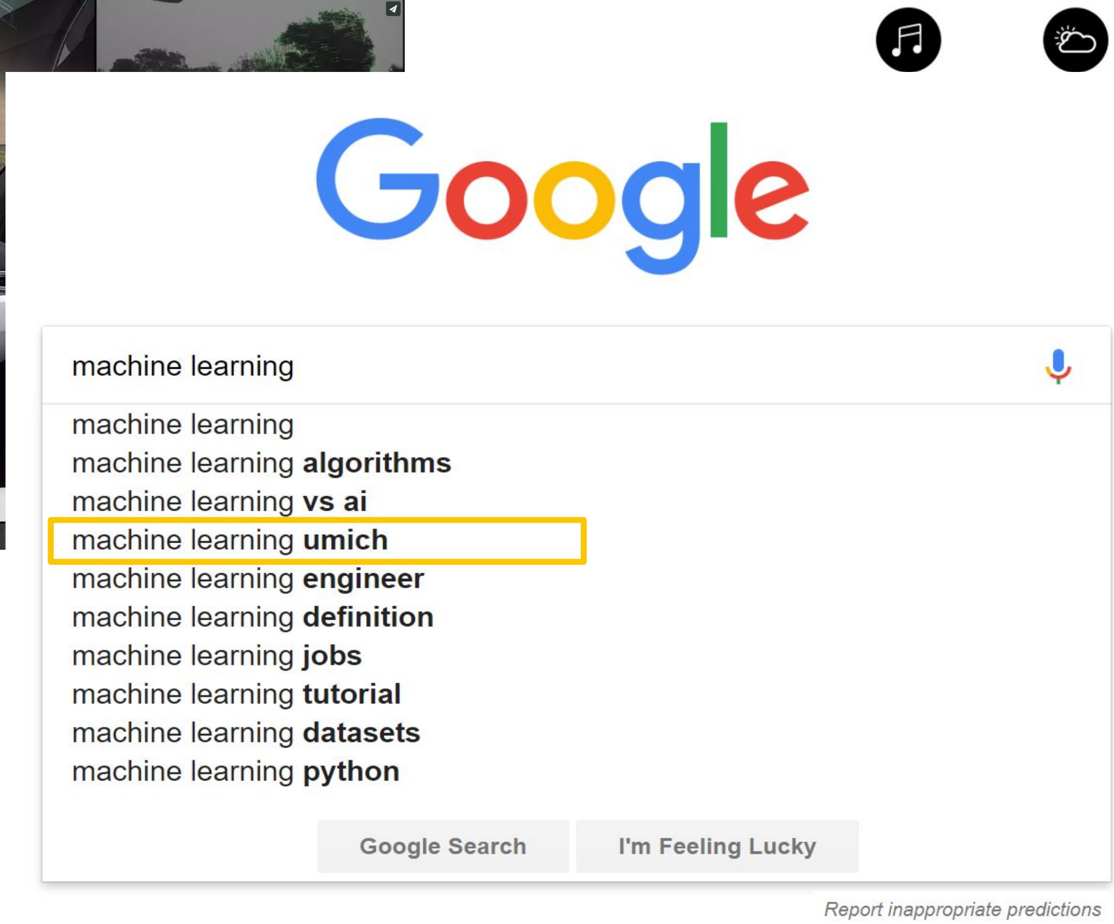


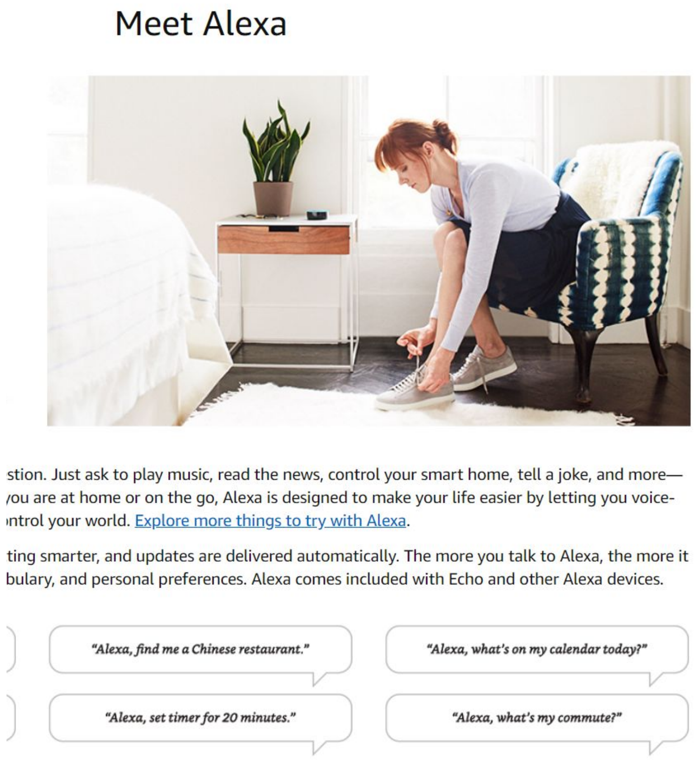
So...Machine Learning?



Machine Learning Is Everywhere





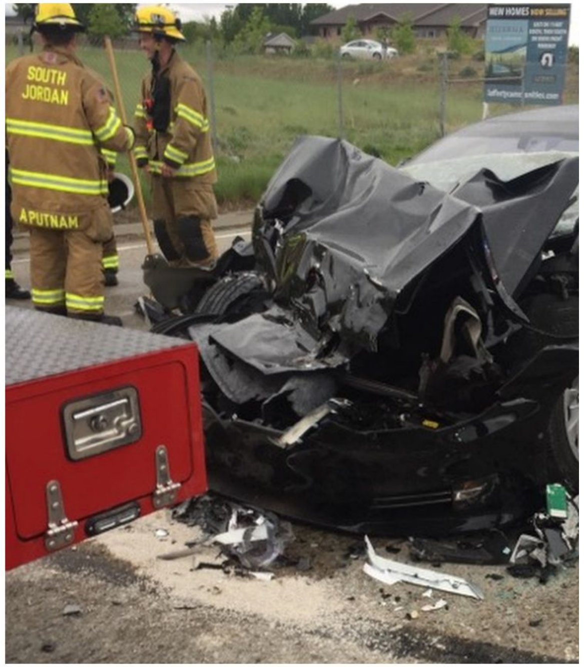


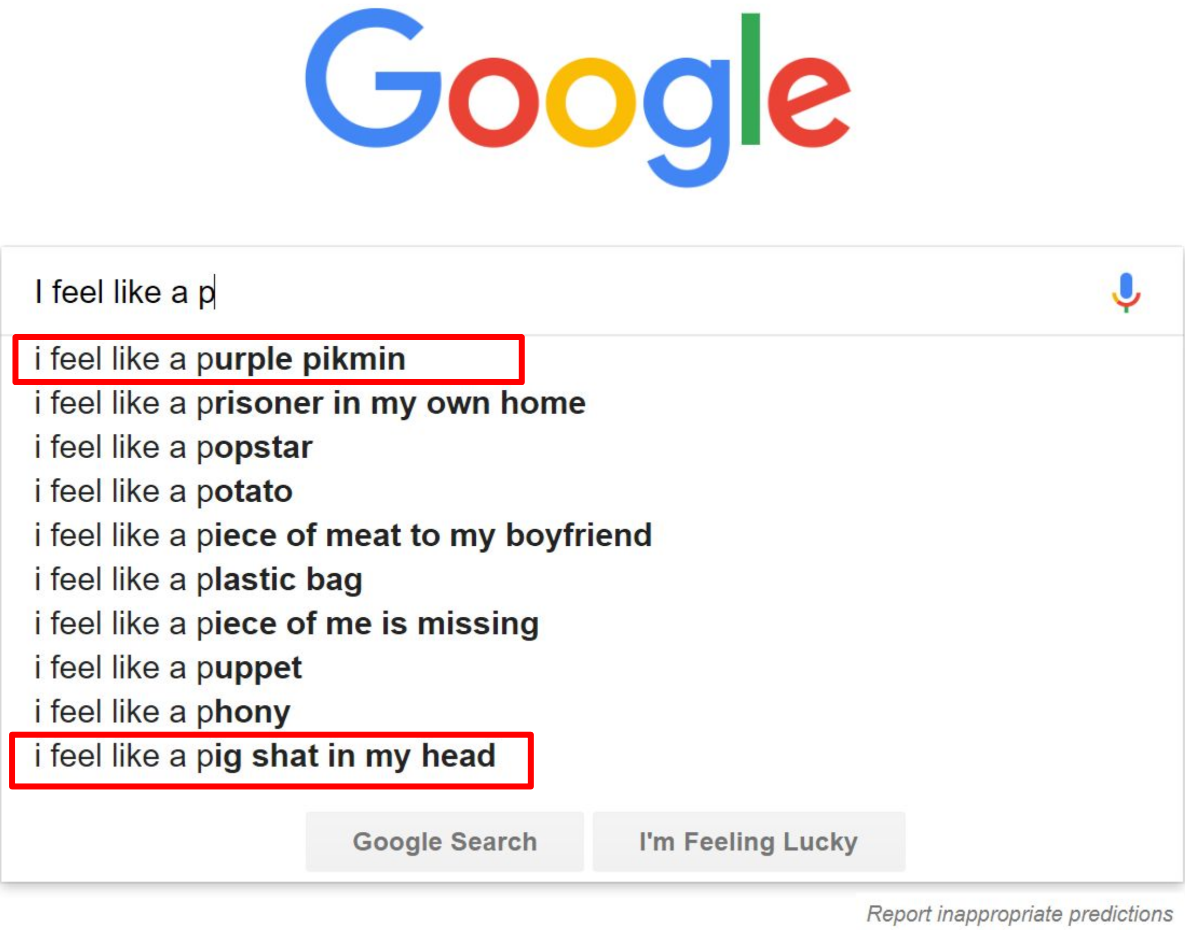
But is NOT Infallible

Federal Agency Investigate
Driver Says Car Was On Au

May 16, 2018 · 8:30 PM ET

VANESSA ROMO



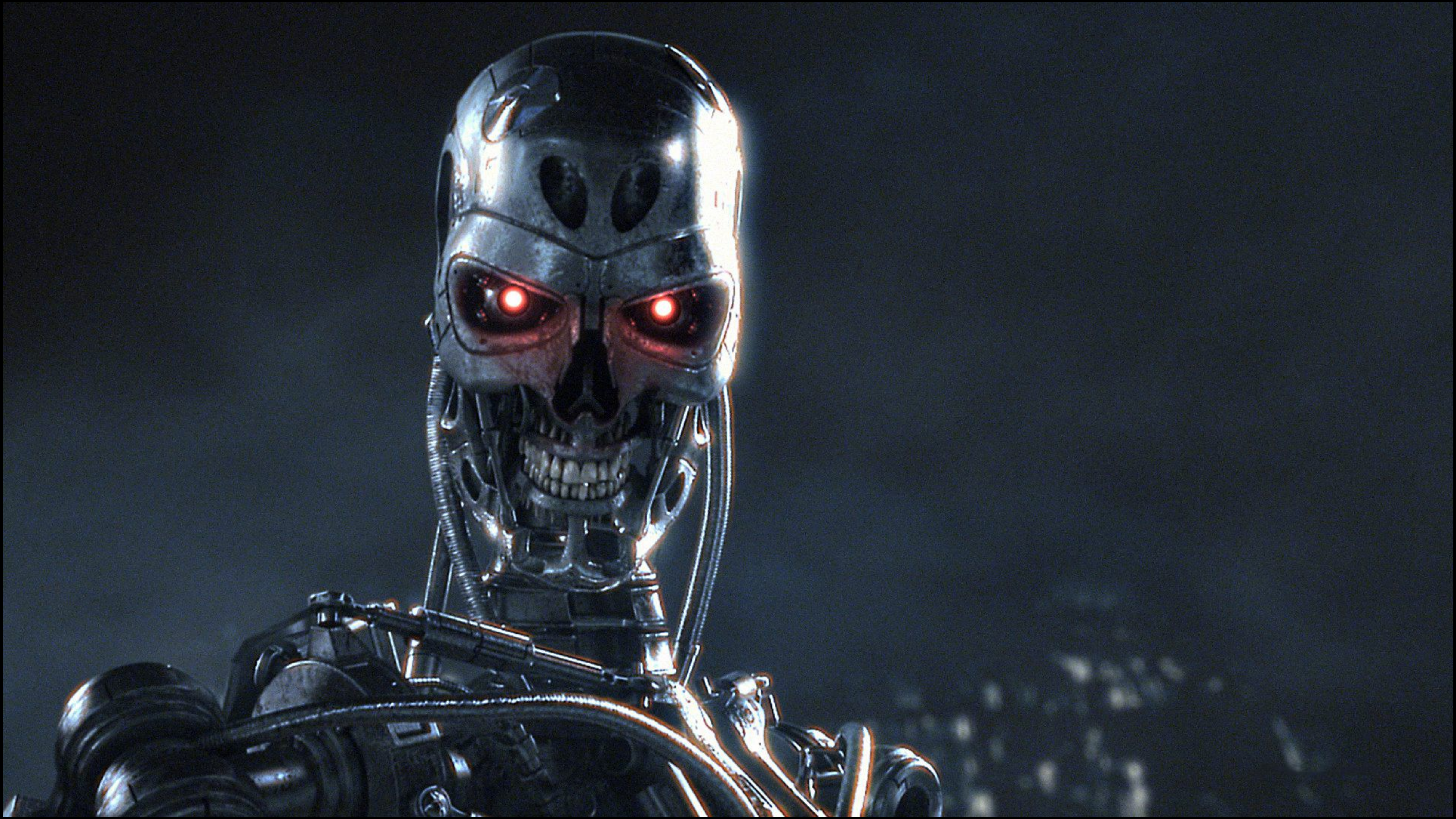


g or laughing? Amazon's Alexa is
out with unprovoked chuckle

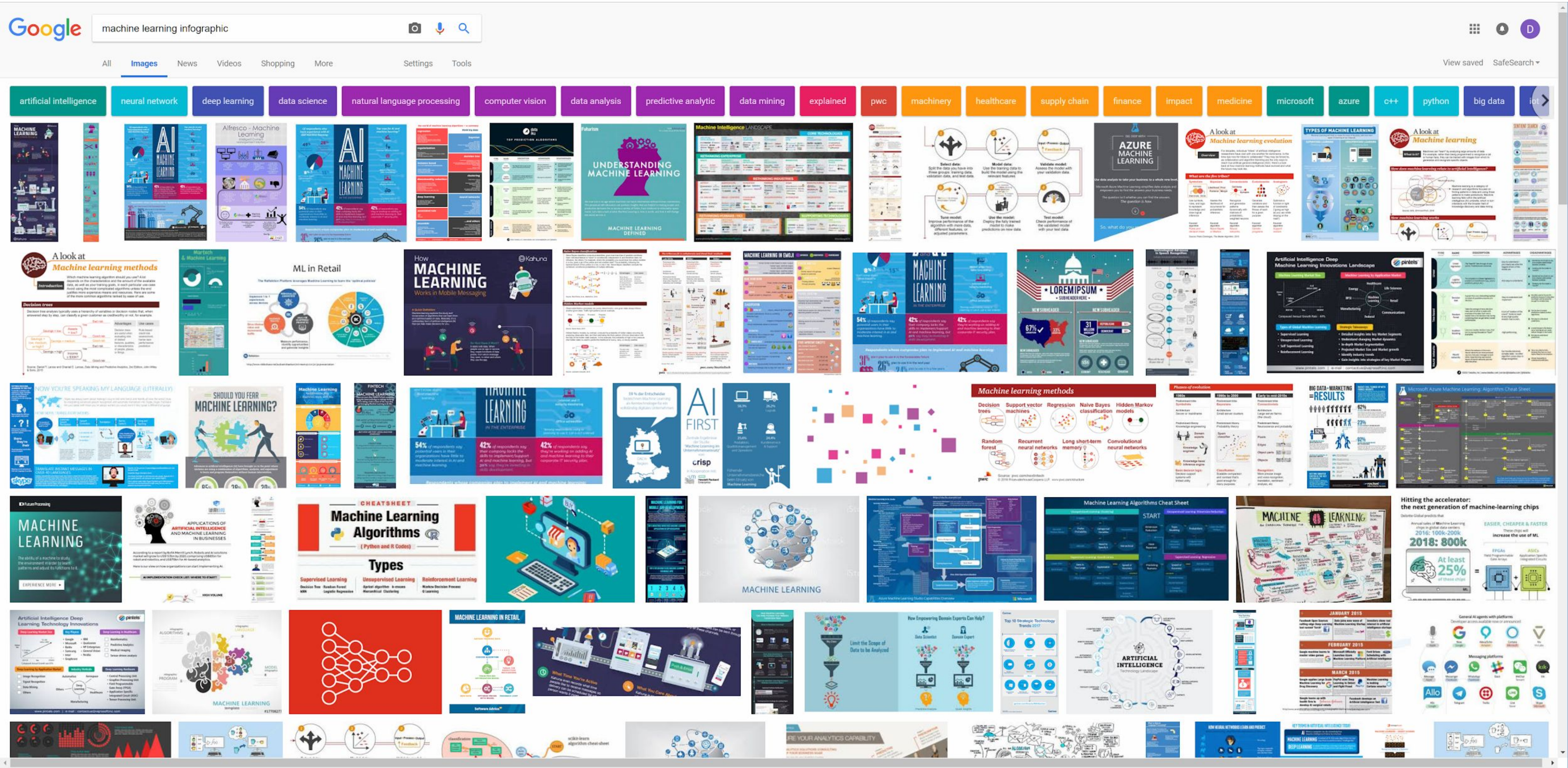
2018 at 12:35 pm

Wire Photo / Kurt Schlosser)

And it’s only a
matter of time...



Where Do We Start?



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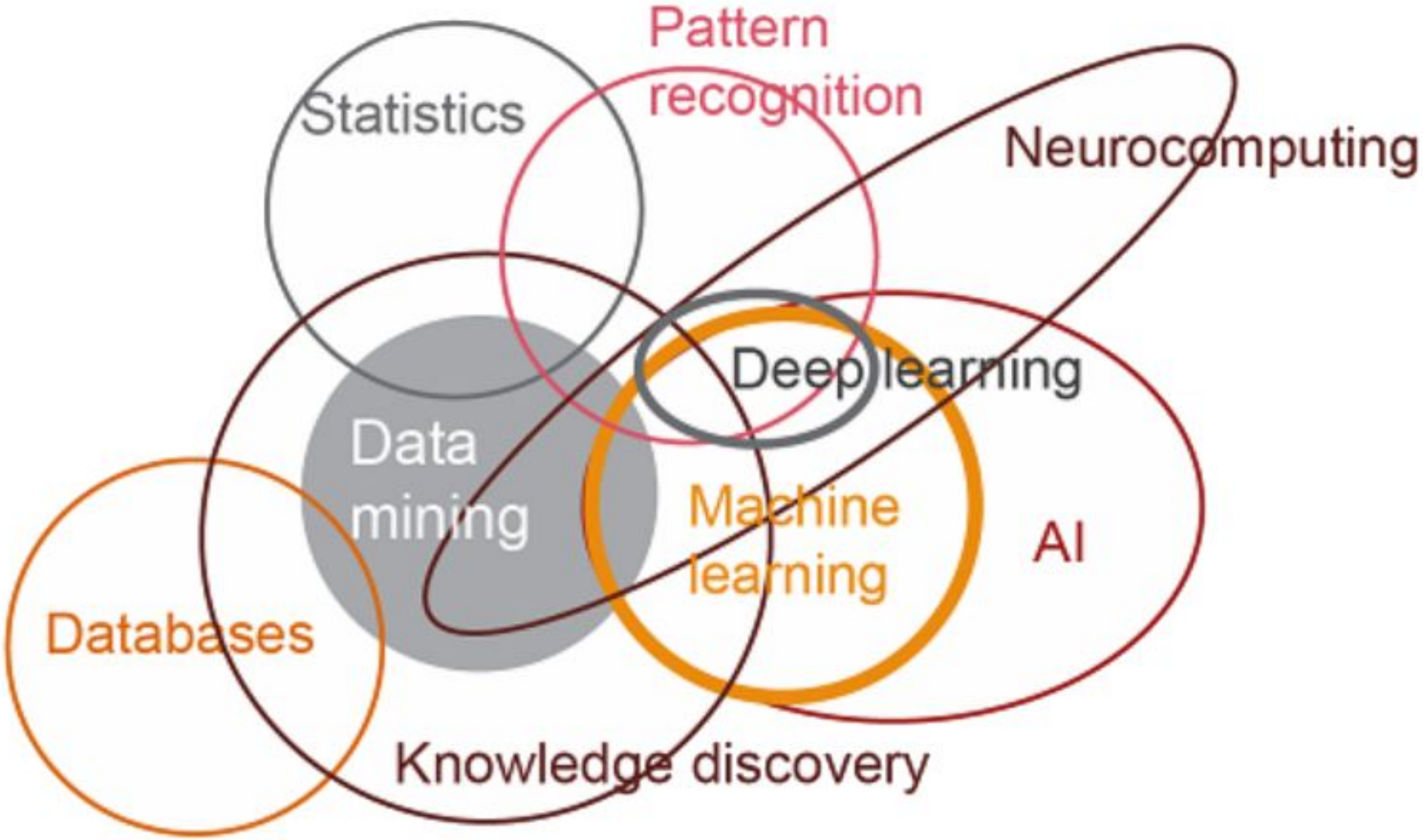


Source: SAS, 2014 and PwC, 2016

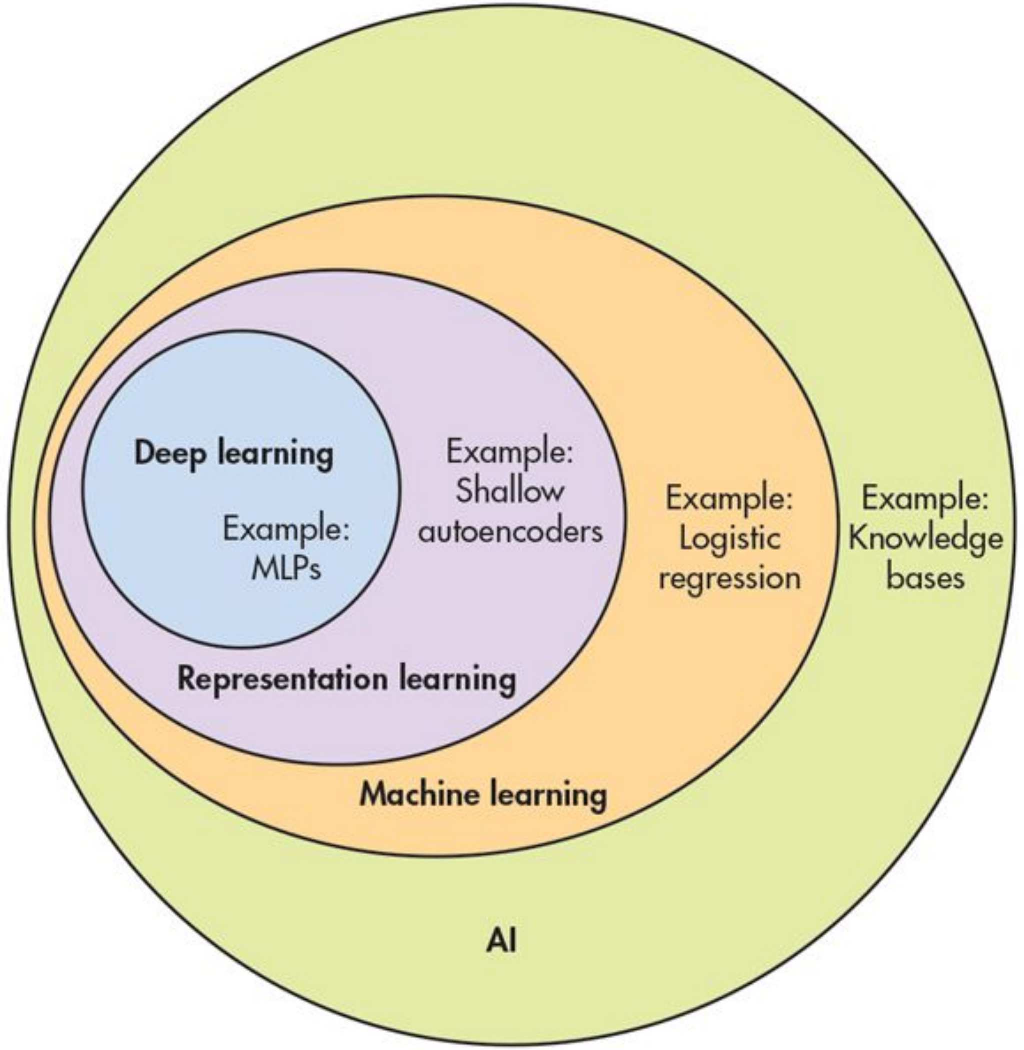
Where Do We Start?

Artificial Intelligence

Machine Learning

Representation Learning

Deep Learning



Artificial Intelligence - Definition

- Machines that think the way humans think

- How to make machines that can:
  - Understand the world
  - Make predictions
  - Choose appropriate actions
  - Perform judgemental processes we associate with human intelligence
  - And, do it all better than humans can

Definition (bottom) from Dr. Ian Goodfellow (https://www.youtube.com/watch?v=vi7lACKOUao&t=684s)

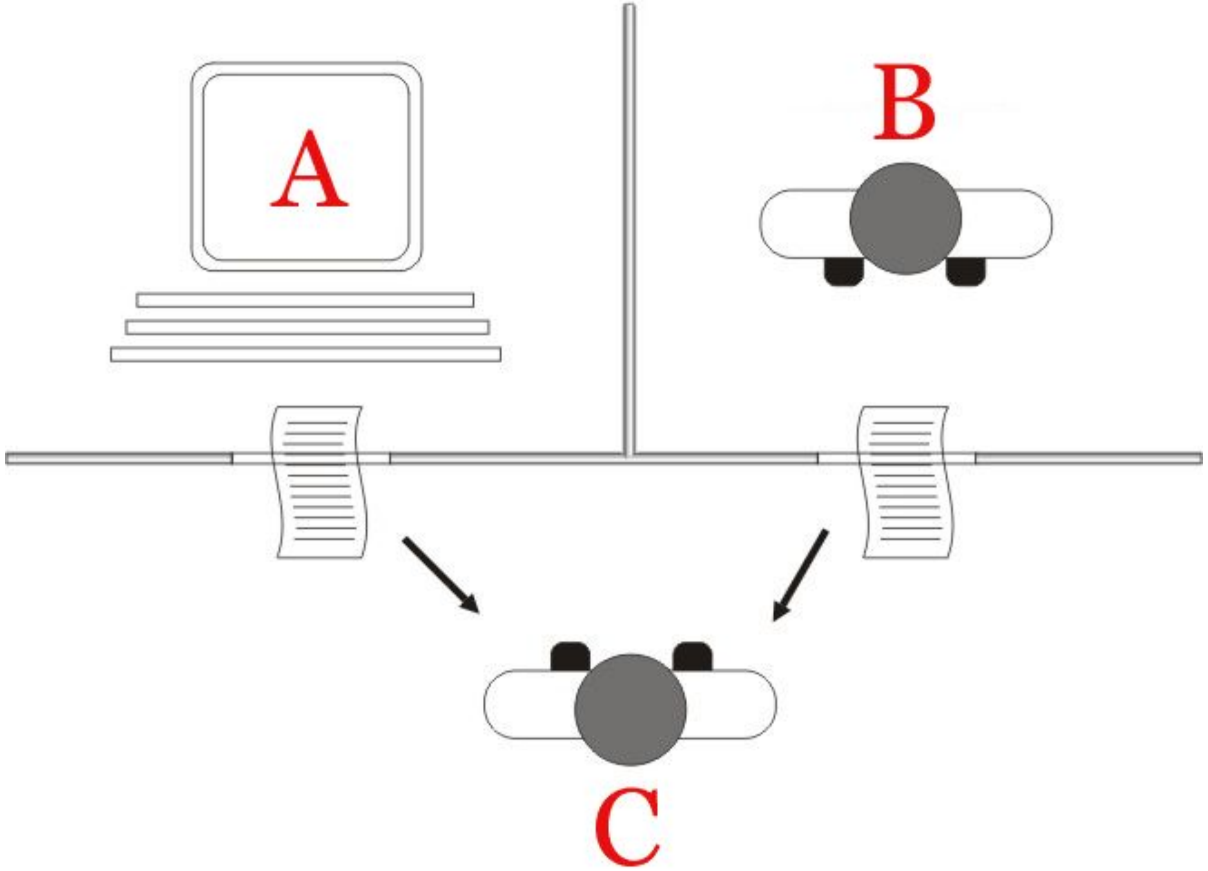
AI Has Deep Roots

- Ancient Greeks
  - Myths of automatons created by the gods that think
- 1600s - Leibniz, Thomas Hobbes and Descartes
    - All rational thought could be expressed as algebra or geometry
- 1800s - 1900s
  - Many instances of early "AI" in literature
- 1950 - Alan Turing
  - Groundbreaking paper "Computing Machinery and Intelligence"
  - Can machines "think"? → Turing Test

AI - The Turing Test

- Test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human

- A computer can be said to be intelligent, or “think”, if a human judge cannot tell if he/she is interacting with a human or a machine



AI - 1956 Dartmouth University Workshop

- AI founded as a discipline
- Experts there coined the term Artificial Intelligence
- Recommended further study of:
  - "...the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."
  - "An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves."

From: https://www.datamation.com/data-center/artificial-intelligence-vs.-machine-learning-whats-the-difference.html

Artificial Intelligence in Popular Culture

STANLEY KUBRICK'S
2001:
a space odyssey

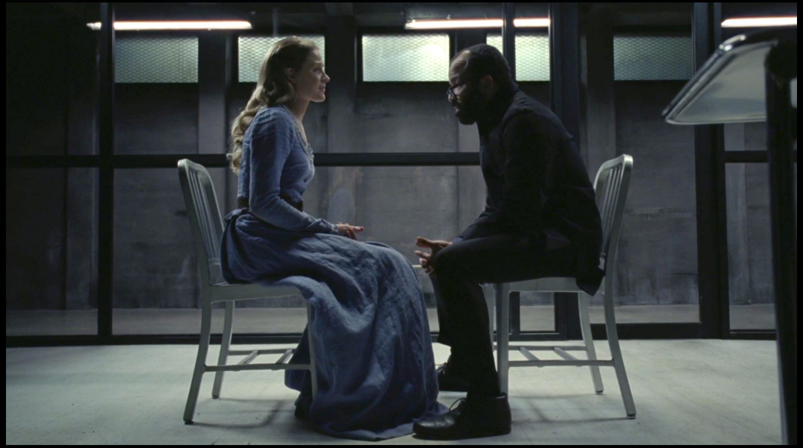
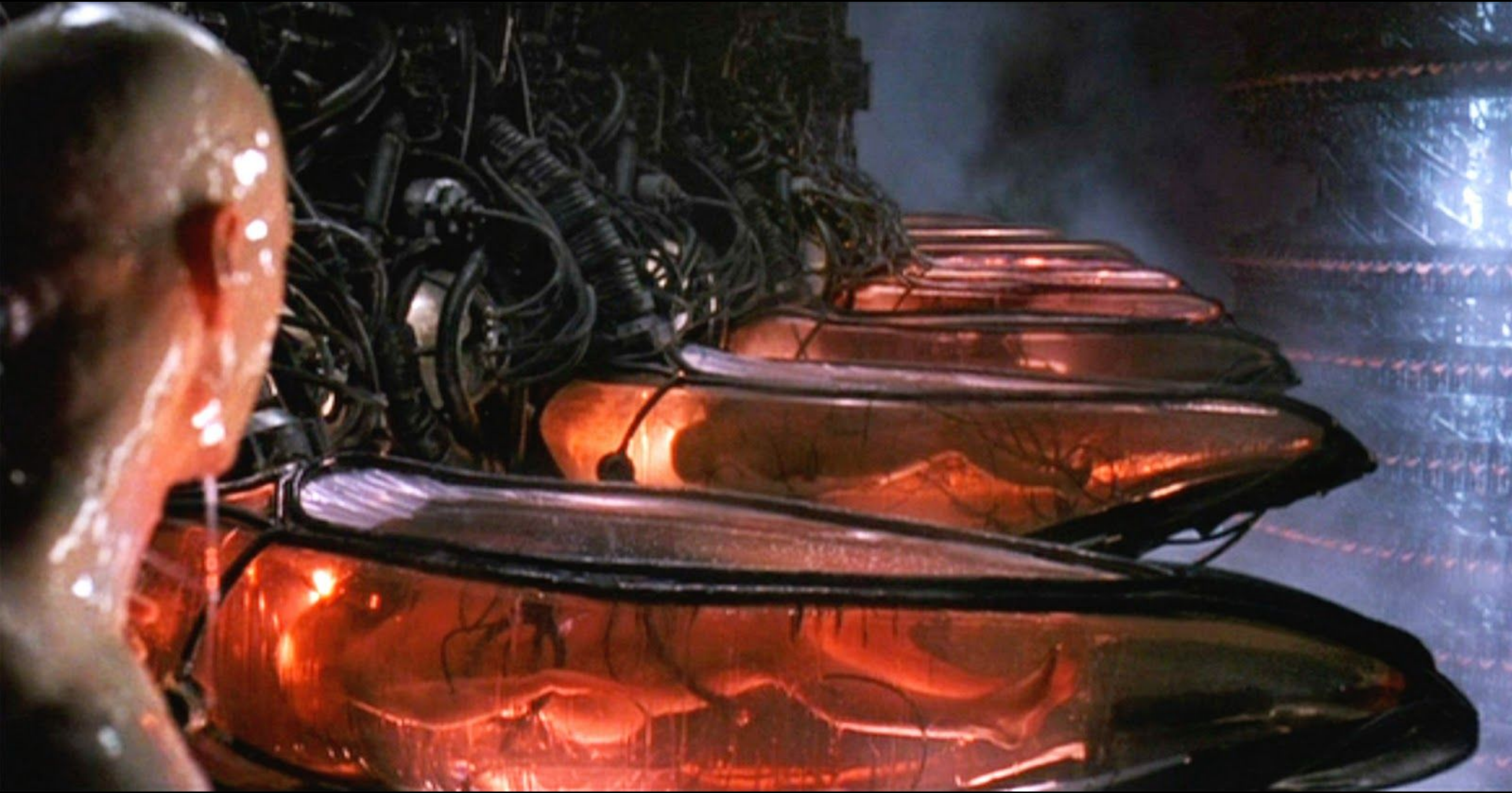


Image from : http://files.abovetopsecret.com/files/img/rl582d143b.jpg



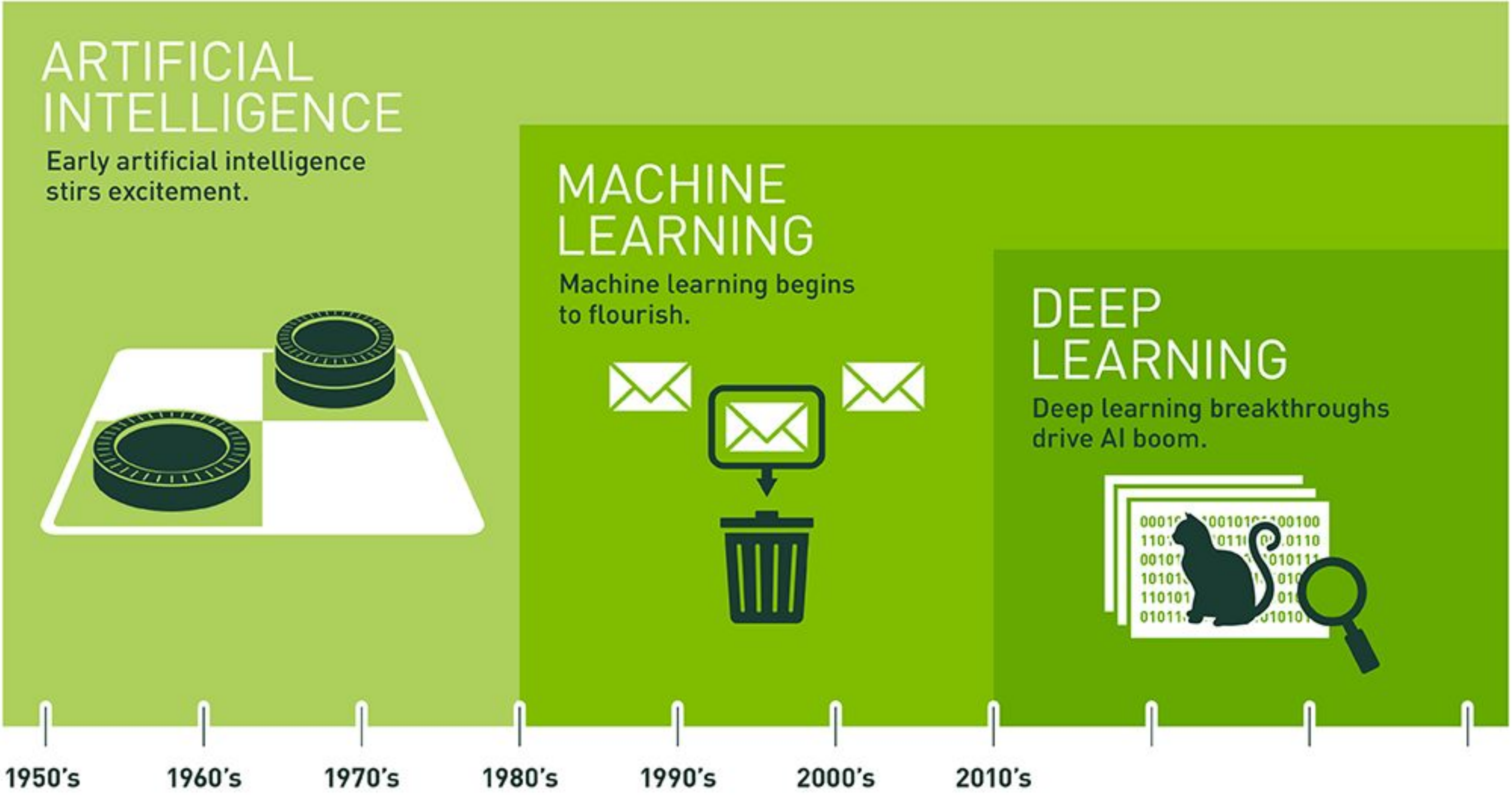
Primary AI Goals

- Deduction, Reasoning, & Problem Solving
- Knowledge representation (expert systems)
- Automated planning and scheduling
- **Machine learning**
- Natural language processing
- Perception (a computer's "five senses")
- Creativity
- Social intelligence (affective computing)
- General intelligence

AI - General Intelligence

- Ability for machines to solve problems as well as humans do
- Example: Machine Translation
  - Must read and write in both languages (NLP)
  - Follow the author's argument (reason)
  - Recognize what is being talked about (knowledge)
  - Faithfully reproduce the author's original intent (social intelligence)
- Considered "AI-complete"
  - All of these problems need to be solved simultaneously in order to reach human-level machine performance

From: https://en.wikipedia.org/wiki/Artificial_intelligence#Problems



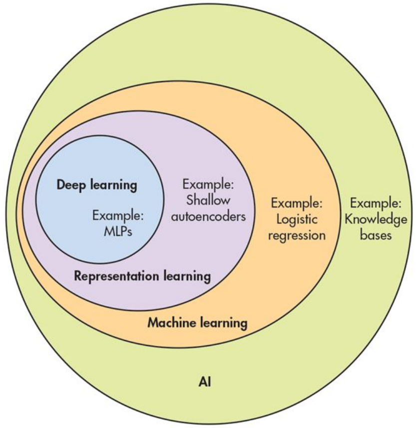
From: https://blogs.nvidia.com/wp-content/uploads/2016/07/Deep_Learning_Icons_R5_PNG.jpg.png

Machine Learning - Definition

- The field of study giving computers the ability to learn without being explicitly programmed
  - Term first used in 1959 by Arthur Samuel at IBM

- Process of using intelligent statistical techniques to construct algorithms that progressively improve performance on a specific task by making data-driven predictions or decisions, typically through building a model from sample inputs

AI vs Machine Learning

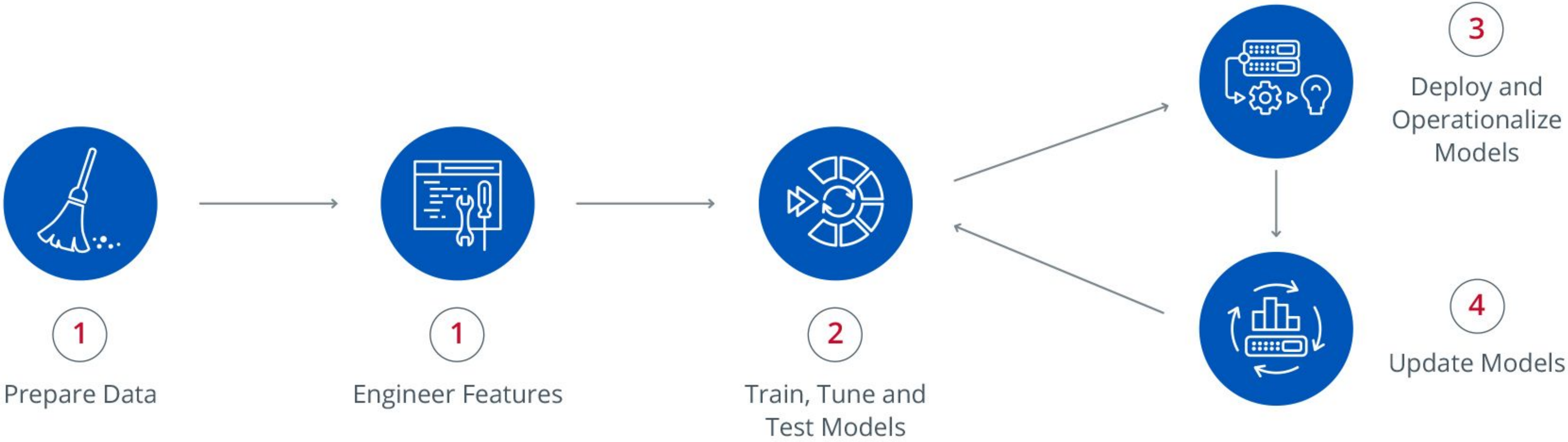


- ML can be thought of as a *subset* of AI
- Artificial Intelligence USES machine learning to minimize the manual input necessary to program an AI construct
  - Requires very large databases that contain many different examples of different scenarios
  - ML algorithms can study these databases and "learn" their own description of elements of interest (feature learning)
  - All done without additional human input

Features

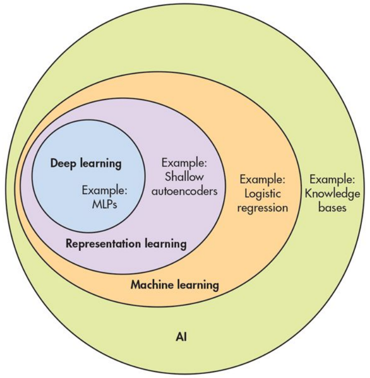
- Attribute or property shared by all of the independent units on which analysis or prediction is to be done
    - Any attribute can be a feature, as long as it is useful to the model
- Feature engineering
    - Process of using domain knowledge of the data to create features that make ML algorithms work
- Features are easier to understand in the context of a problem!!
    - Characteristic(s) that might help when solving the problem

ML Basics - Creating Models



1) Understand patterns in large sets of input data
2) Generate models based on this data
3) Predict outputs based on the models it generates

Representation Learning - Definition



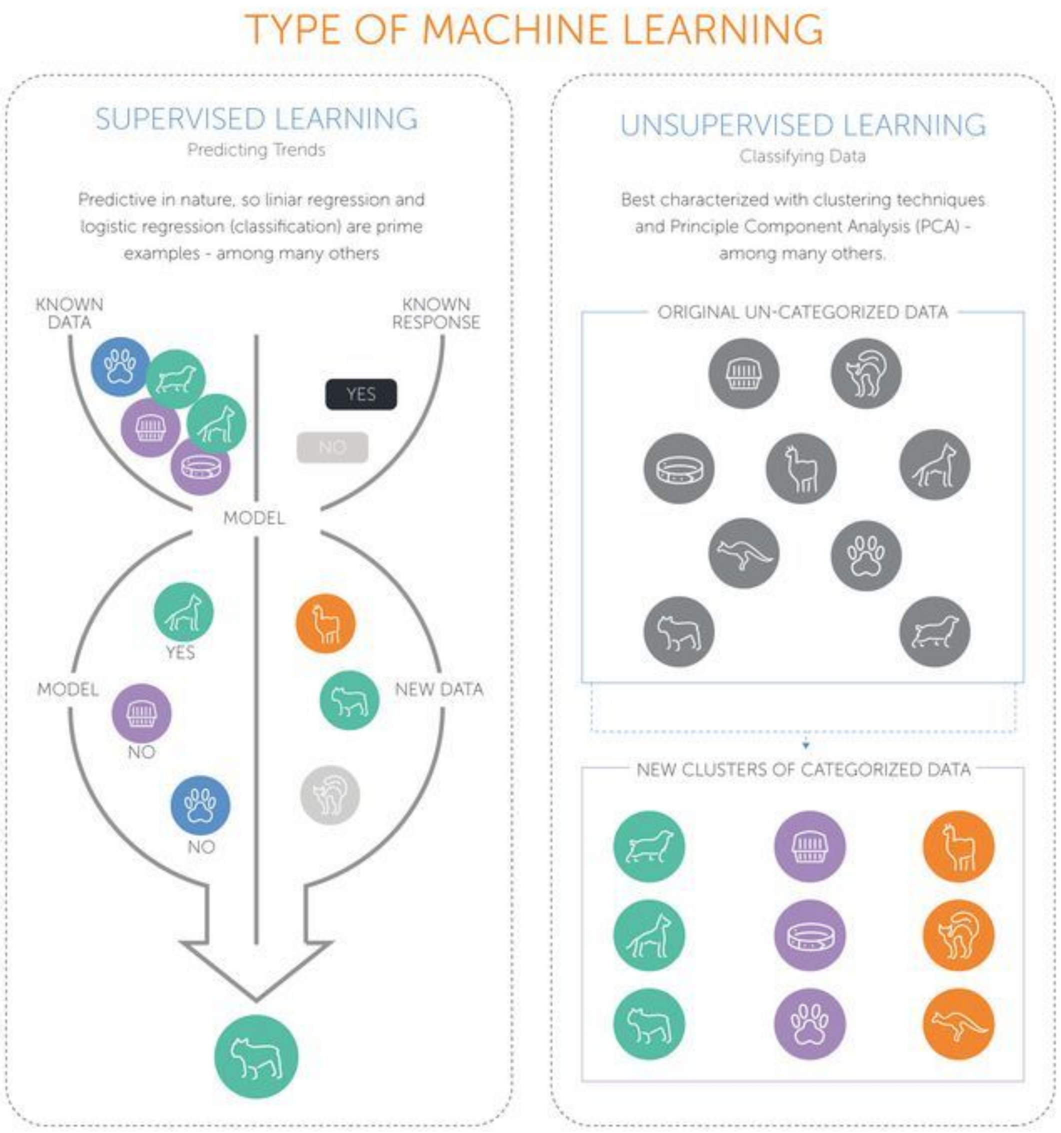
- A.k.a. Feature Learning

- Strategy for machine learning where the representation learning algorithms figure out how to process the data
  - System uses RAW DATA to automatically discover the representations needed for feature detection/classification
  - Replaces manual feature engineering
  - Allows a machine to both learn the features and use them to perform a specific task

Representation Learning

Discovering features or representations through examination, without relying on explicit algorithms

Two main types: Supervised and Unsupervised



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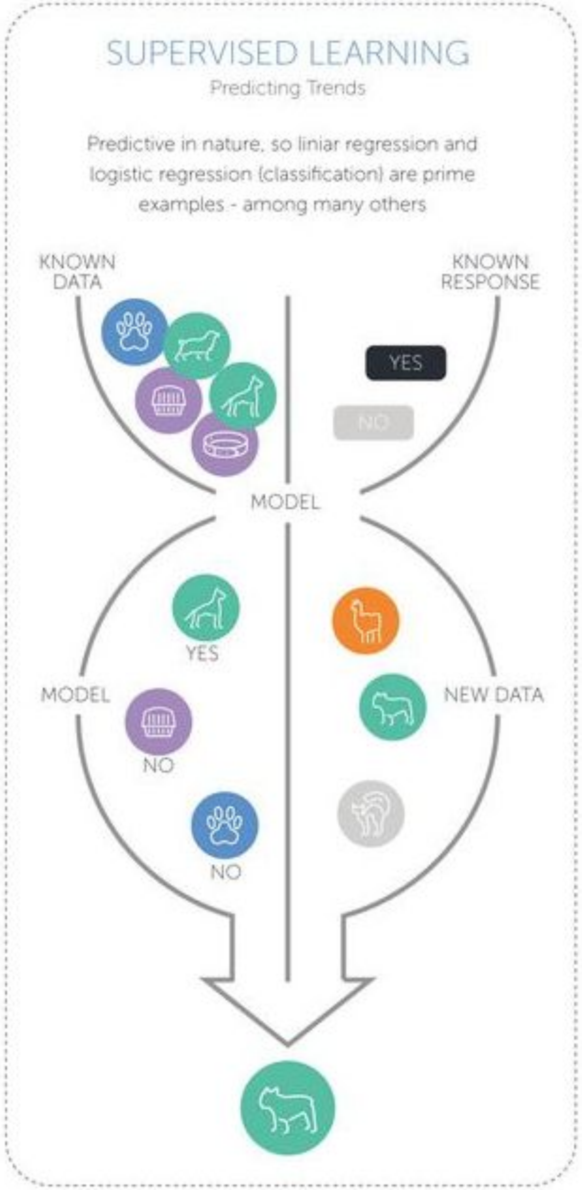
Supervised Feature Learning

- Learning features from labeled data
  - System has knowledge of the output
    - Training data set exists where the feature is known
  - Goal is to discover patterns in the data relating to targeted data attributes
    - Patterns utilized to predict values in new, untested data
  - Examples
    - Bayesian classifiers
    - Neural networks
    - Decision trees
    - Support vector machines
    - Linear regression
    - Random Decision Forests

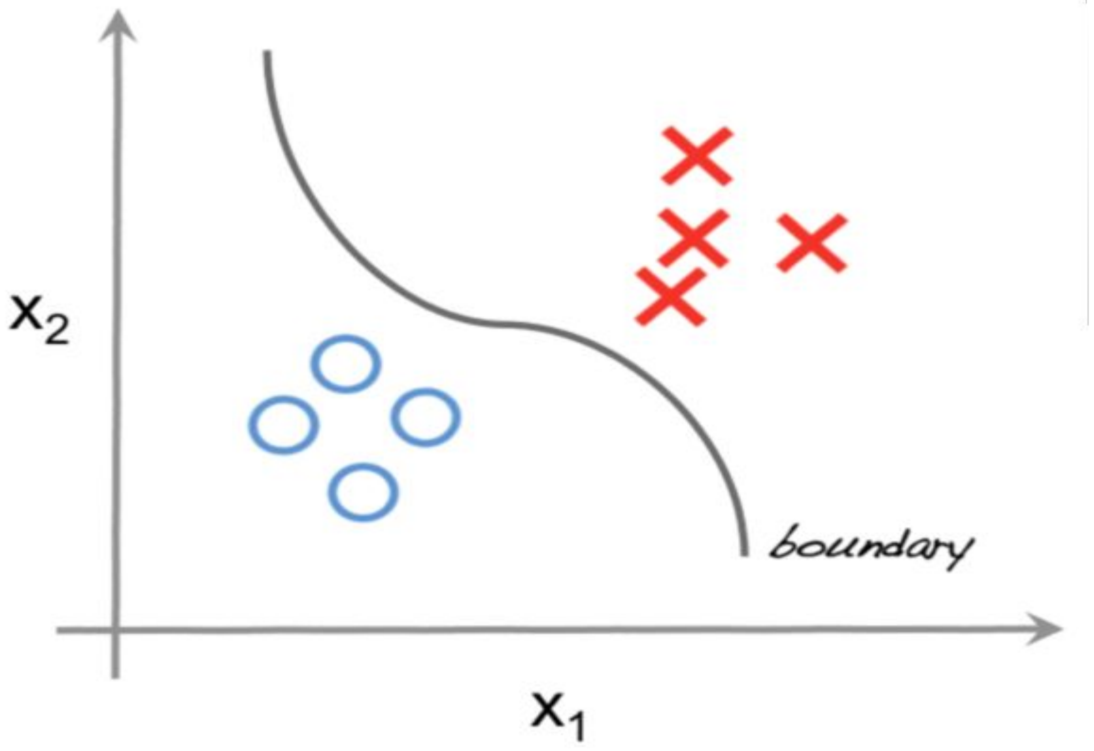


Unsupervised Feature Learning

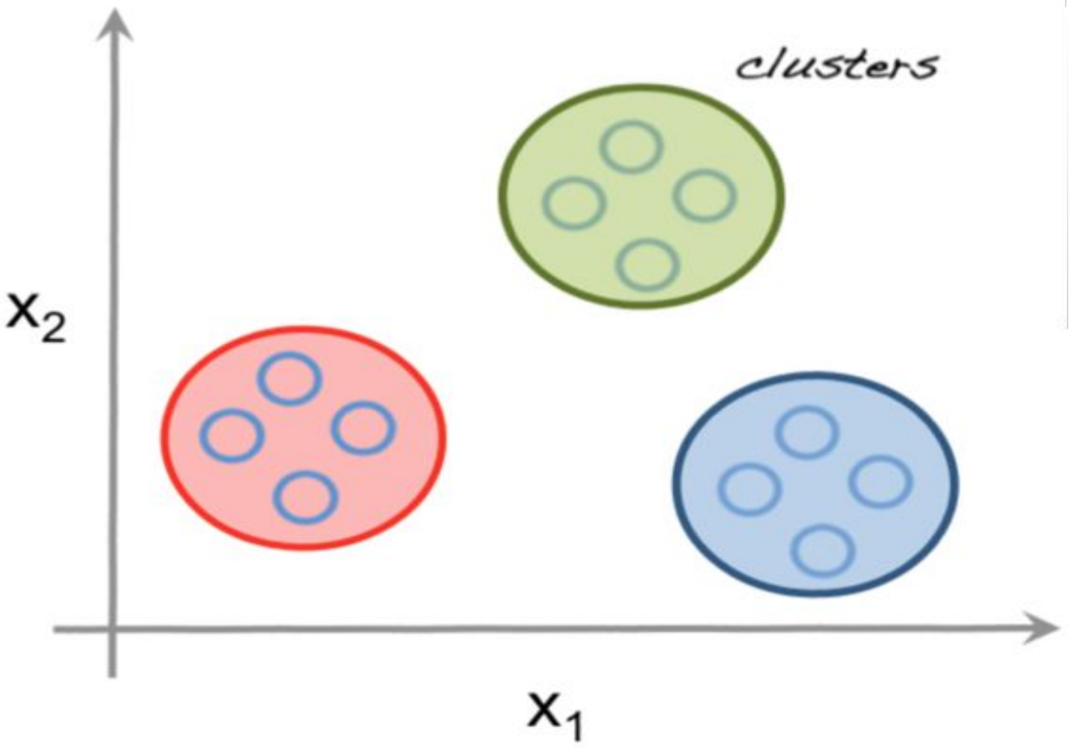
- Learning features from unlabeled data
  - System has NO knowledge of the output
    - The data have no target attributes
  - Goal is to determine data patterns/groupings
    - Discover low-dimensional features capturing some structure underlying the high-dimensional input data
  - Examples
    - Hierarchical clustering
    - k-means clustering
    - Gaussian mixture models
    - Self-organizing maps
    - Hidden markov models

Supervised vs Unsupervised Learning

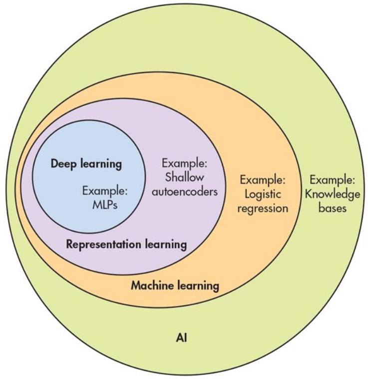
Supervised



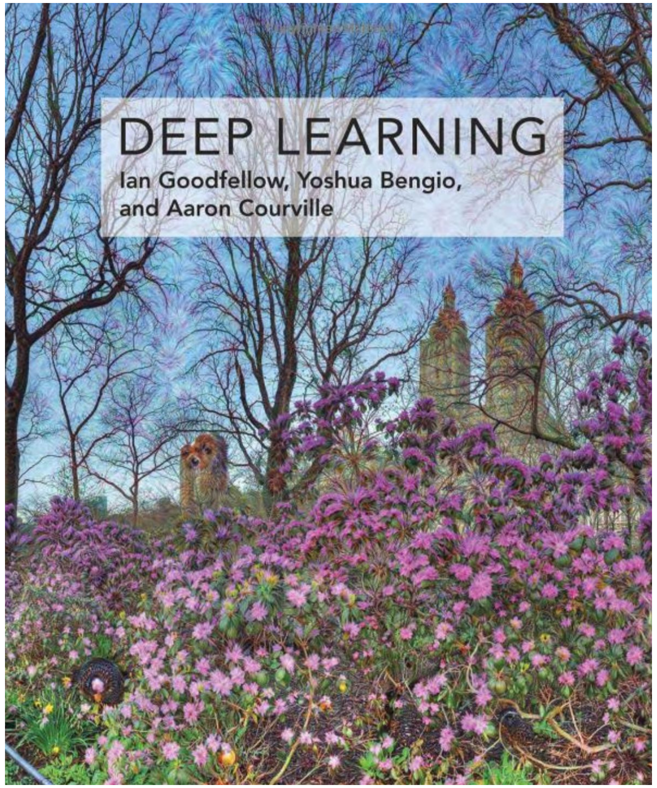
Unsupervised



Deep Learning - Definition



- Subset of representation learning
  - Feature learning algorithms that apply several different sequential transformations of the data
  - Eventually arrives at very sophisticated transformations of the data
  - Can solve very difficult and complex engineering tasks
- "Deep" refers to the number of layers through which the data is transformed



Example - Deep Learning Model

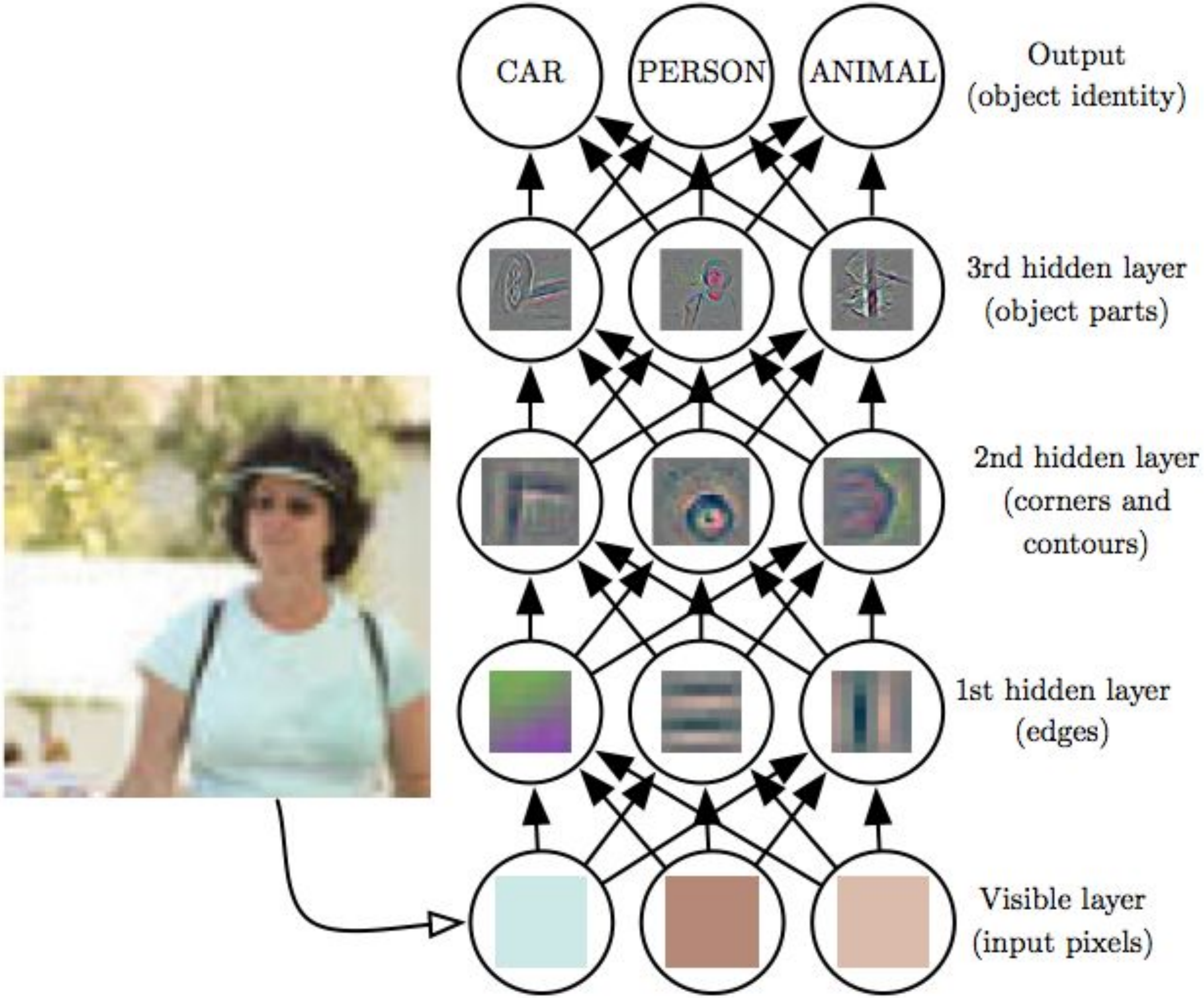
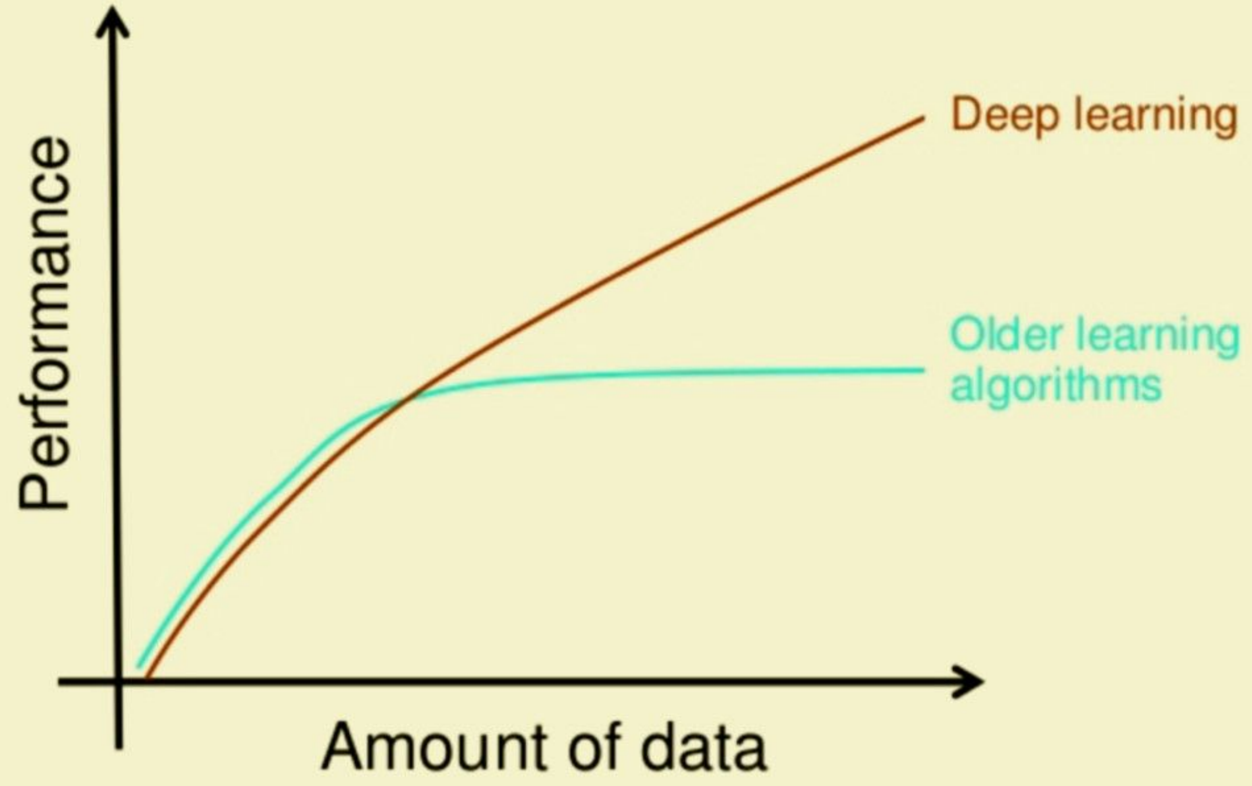


Figure from: Goodfellow et. al. Deep Learning. 2016. MIT Press, Boston, MA. Page 6.

When Should Deep Learning Be Used?

1) For large data sets
   a) Traditional ML algorithms preferred for smaller data sets
      - Less likely to “overtrain” the data
2) If you have a high end infrastructure → DL is much faster!!
3) Lack of domain knowledge for feature engineering
   a) Automated feature learning obviates the need for manual feature engineering
4) For dealing with complex problems, e.g.
   a) Image classification
   b) Natural language processing
   c) Speech recognition

Big Data and Deep Learning



How do data science techniques scale with amount of data?

Traditional ML vs DL

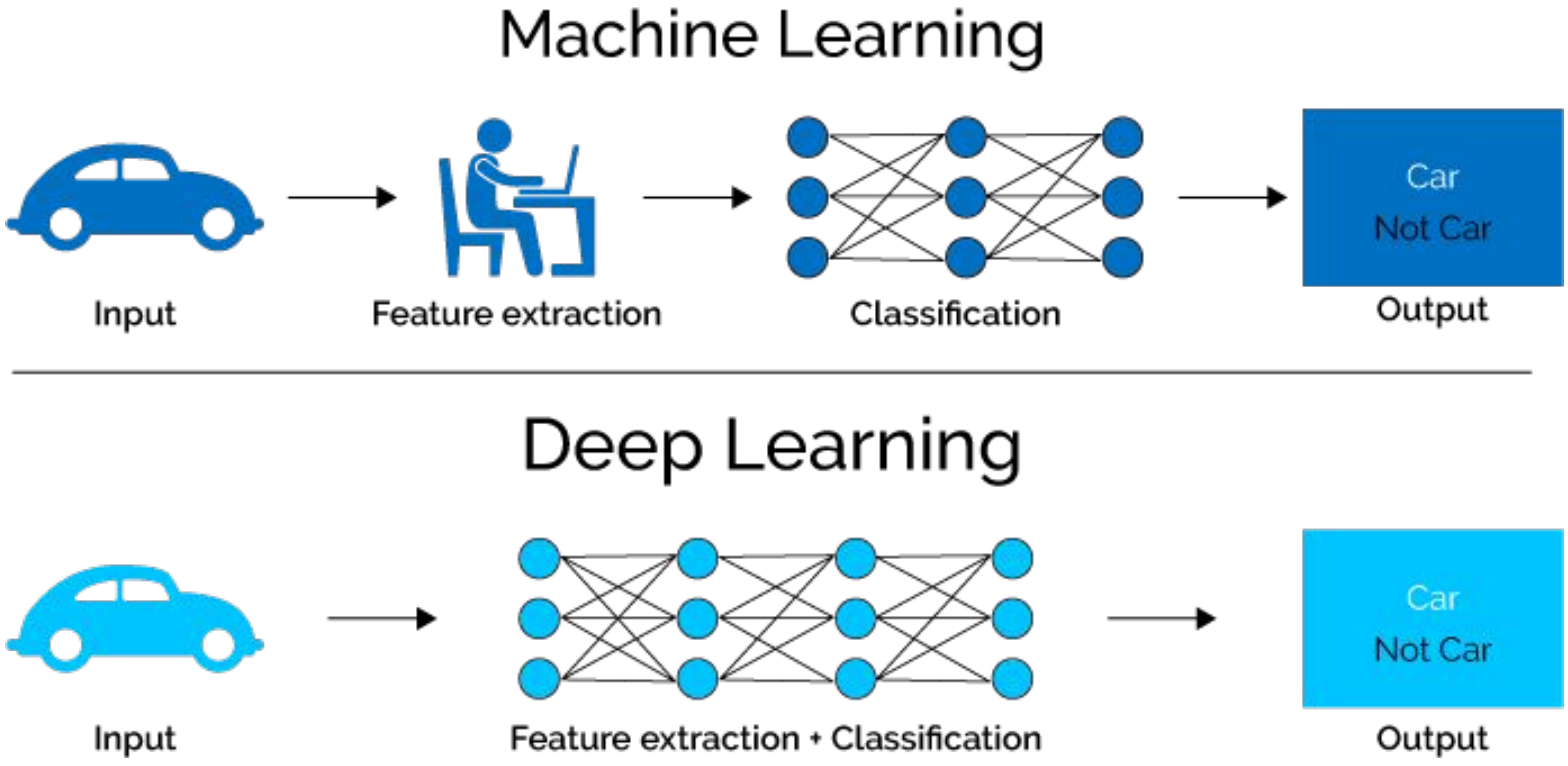
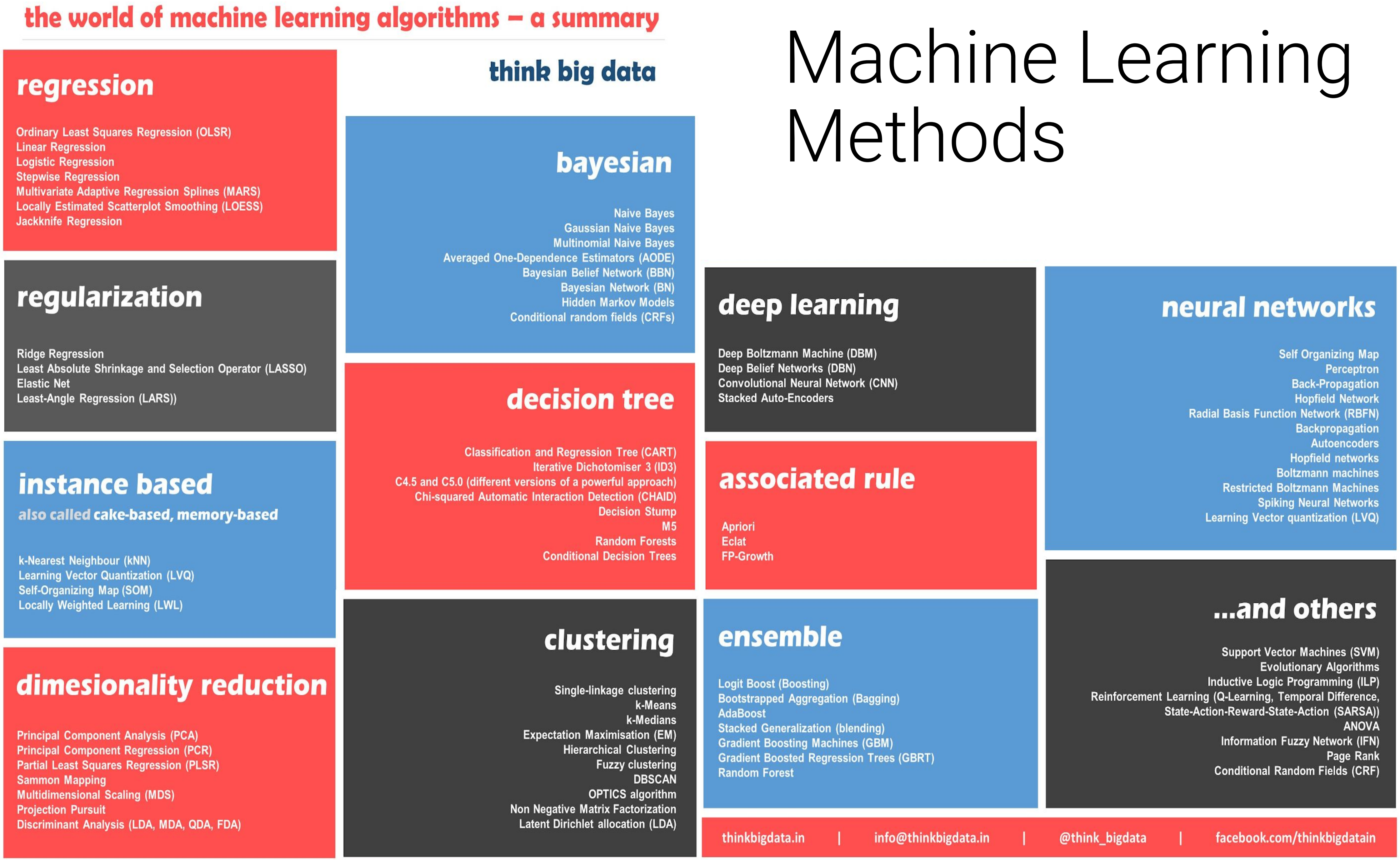
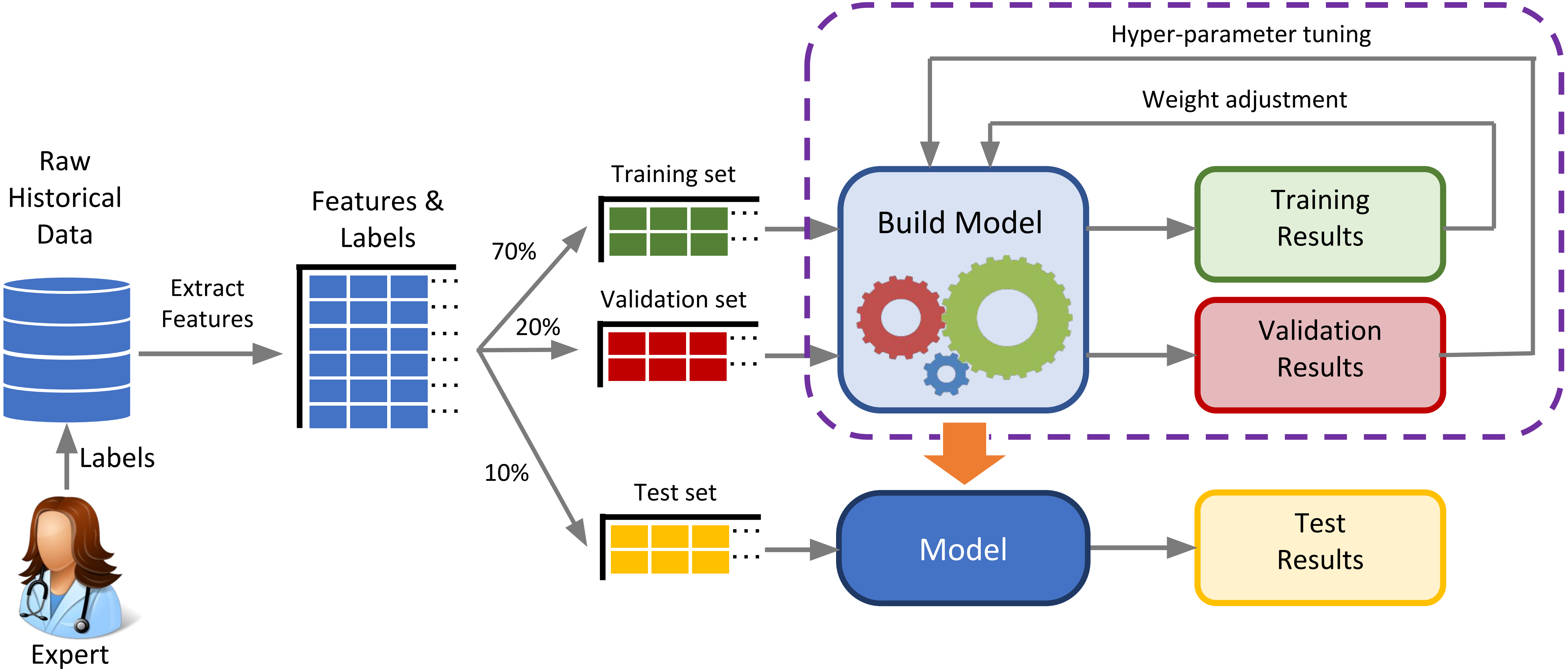


Image (left): https://towardsdatascience.com/why-deep-learning-is-needed-over-traditional-machine-learning-1b6a99177063

Machine Learning Methods

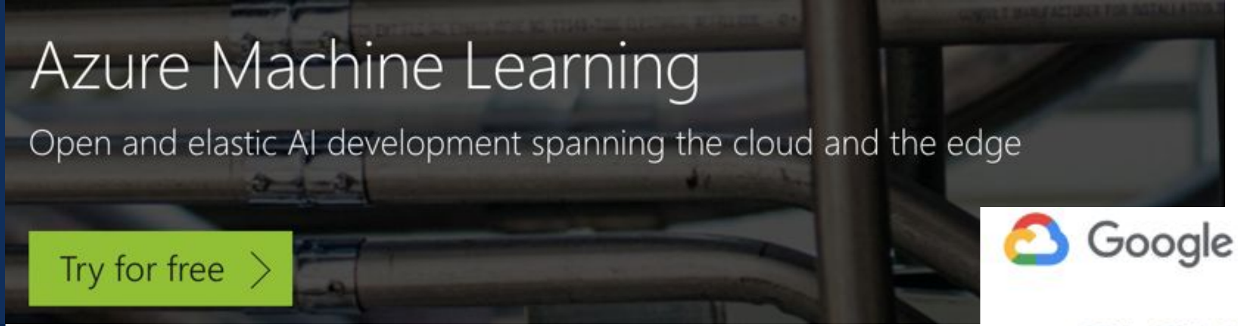


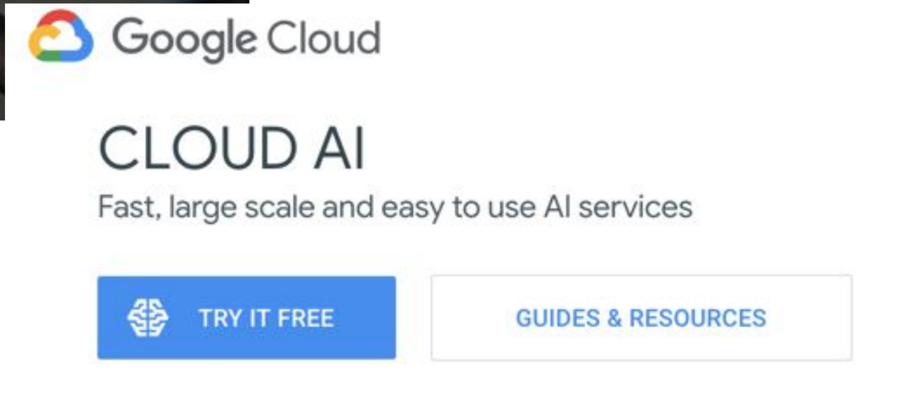
Machine Learning Workflow

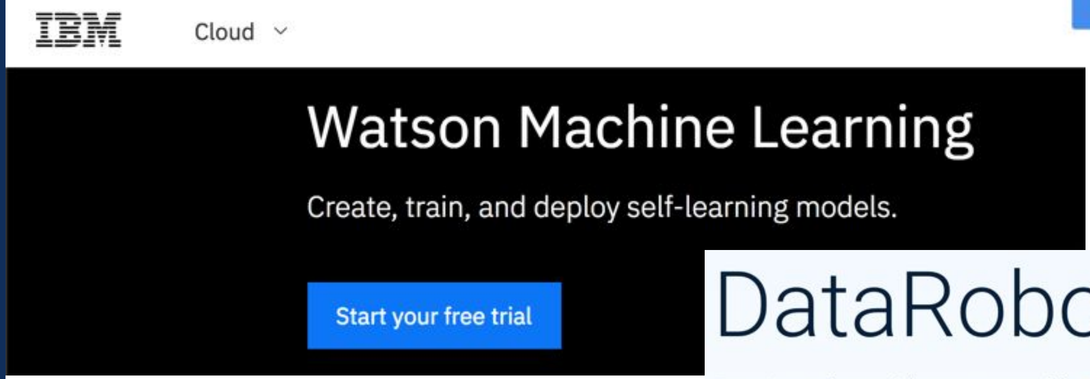


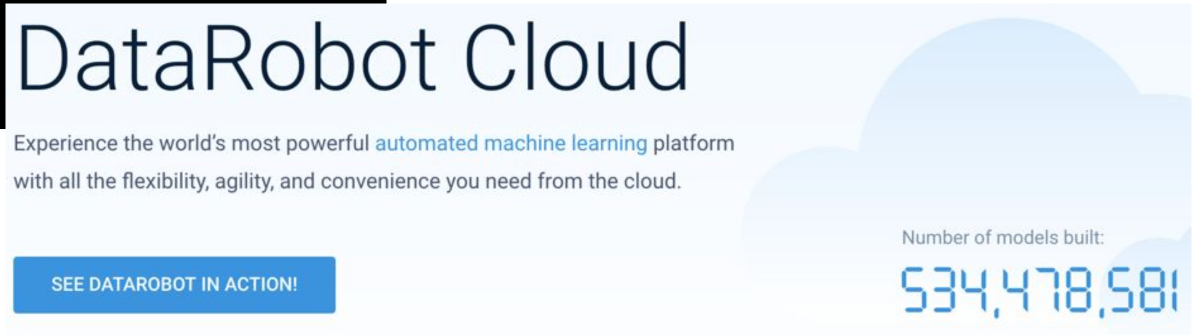
Automating Machine Learning

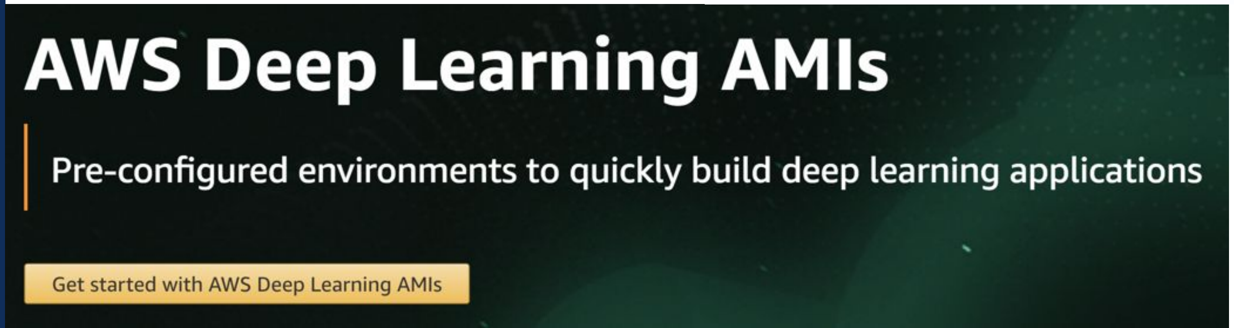
Many cloud and enterprise based ML platforms available







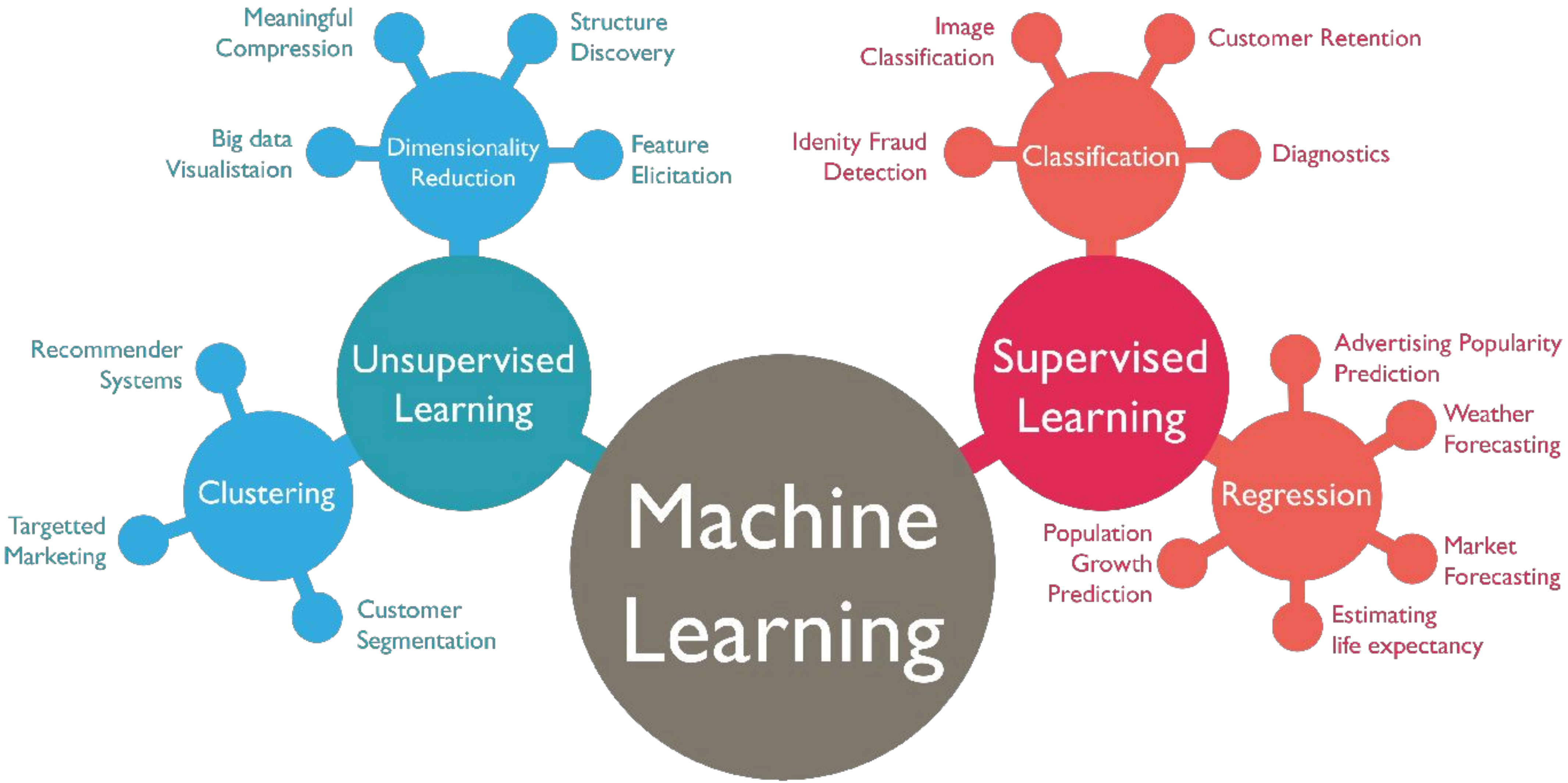




For other popular vendors, see: http://www.butleranalytics.com/20-machine-learning-service-platforms/

Slide (modified) courtesy of Toby Cornish, MD
All images from vendor's websites, current as of 5/20/18

Machine Learning in Everyday Life



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Machine Learning in Everyday Life

Machine Learning Use Cases

	Supervised Learning	Unsupervised Learning	Reinforcement Learning
Banking	**Predict credit worthiness of credit card holders**: Build a machine learning model to look for delinquency attributes by providing it with data on delinquent and non-delinquent customers	**Segment customers by behavioral characteristics**: Survey prospects and customers to develop multiple segments using clustering	**Create a 'next best offer' model for the call center group**: Build a predictive model that learns over time as users accept or reject offers made by the sales staff
Healthcare	**Predict patient readmission rates**: Build a regression model by providing data on the patients' treatment regime and readmissions to show variables that best correlate with readmissions	**Categorize MRI data by normal or abnormal images**: Use deep learning techniques to build a model that learns different features of images to recognize different patterns	**Allocate scarce medical resources to handle different types of ER cases**: Build a Markov Decision Process that learns treatment strategies for each type of ER case
Retail	**Analyze products customers buy together**: Build a supervised learning model to identify frequent item sets and association rules from transactional data	**Recommend products to customers based on past purchases**: Build a collaborative filtering model based on past purchases by "customers like them"	**Reduce excess stock with dynamic pricing**: Build a dynamic pricing model that adjusts the price based on customer response to offers

Figure from: https://pbs.twimg.com/media/Crwm_p1WEAALRG_.png

Machine Learning in Healthcare

CBINSIGHTS Platform Services Customers About Login

RESEARCH

From Virtual Nurses To Drug Discovery: 106 Artificial Intelligence Startups In Healthcare

February 3, 2017

Artificial Intelligence

The number of startups entering the healthcare AI space has increased in recent years, with over 50 companies raising their first equity rounds since January 2015. Deals to healthcare-focused AI startups went up from less than 20 in 2012 to nearly 70 in 2016. Last year also saw two new unicorns emerge in the space: China-based iCarbonX and oncology-focused Flatiron Health.

"By 2025, AI systems could be involved in everything from population health management, to digital avatars capable of answering specific patient queries." — Harpreet Singh Buttar, analyst at Frost & Sullivan.

We identified over 100 companies that are applying machine learning algorithms and predictive analytics to reduce drug discovery times, provide virtual assistance to patients, and diagnose ailments by processing medical images, among other things.

Machine Learning in Healthcare

- Many opportunities for ML in healthcare
  - Reduce readmission rates
  - Reduce hospital Length-of-Stay (LOS)
  - Prevent hospital acquired infections (HAIs)
  - Predicting chronic disease
  - Diagnosis in medical imaging
  - Enhanced robotic surgery
  - Personalized medicine
  - Computational Pathology
  - ...and many more!

Use Cases - ML in Healthcare

- Clinical decision support and predictive analytics
  - Computationally based assay for 6-MP (mercaptopurine), predicts toxicity and compliance (ThioMon, University of Michigan)
- Imaging analytics
  - Discrimination of physiological versus pathological patterns of cardiac hypertrophic remodeling in 2D echocardiography (Mount Sinai, New York)
- Natural Language Processing
  - Automated speech analysis to measure subtle, clinically relevant mental state changes to predict psychosis onset in youths (Columbia University)

Limits of Human Cognition

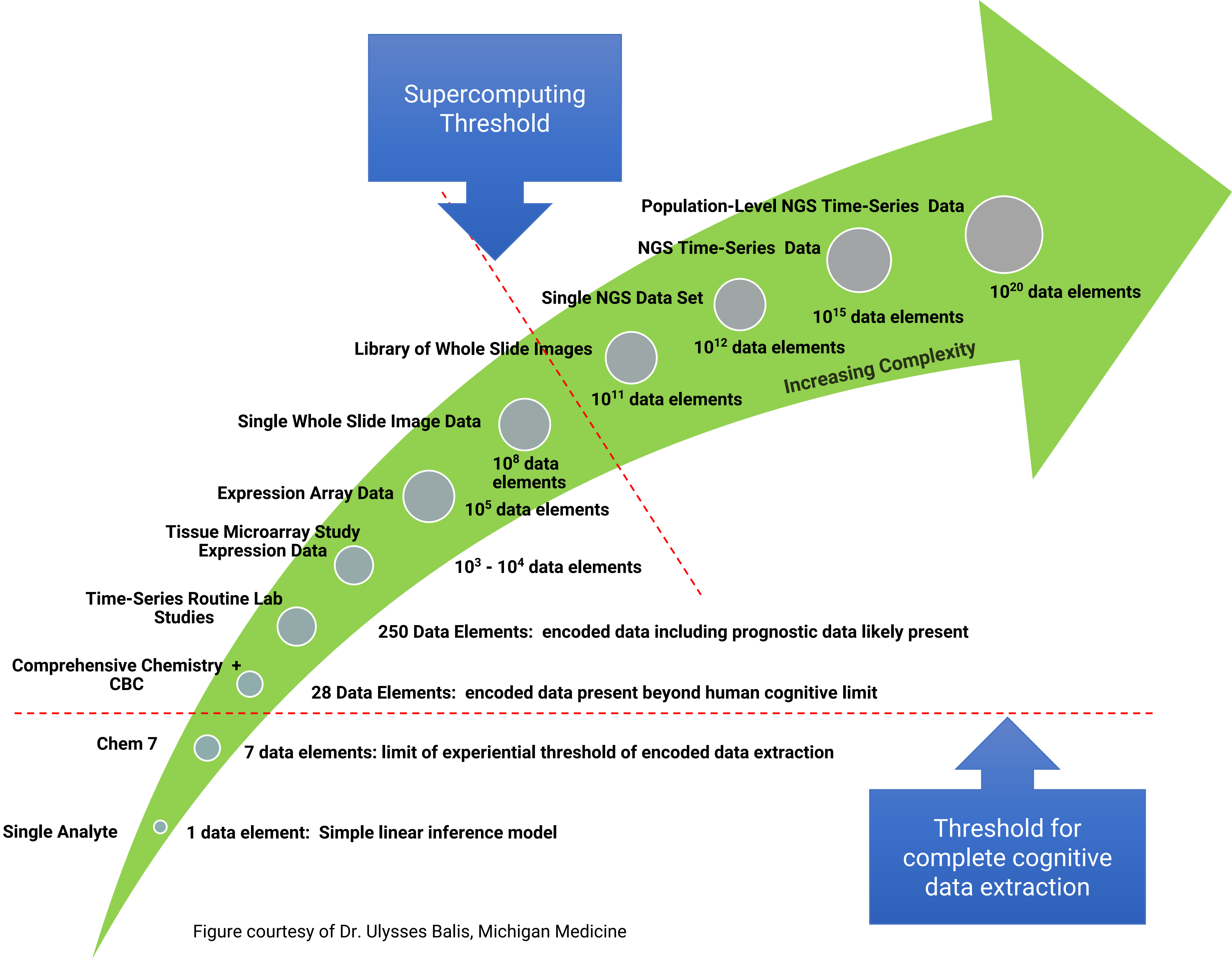
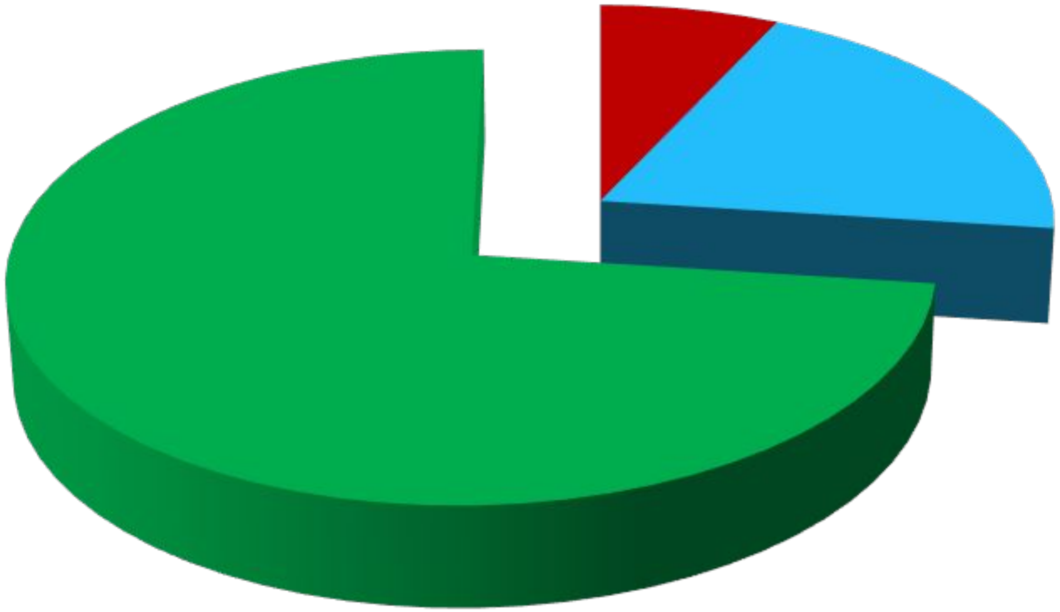


Figure courtesy of Dr. Ulysses Balis, Michigan Medicine

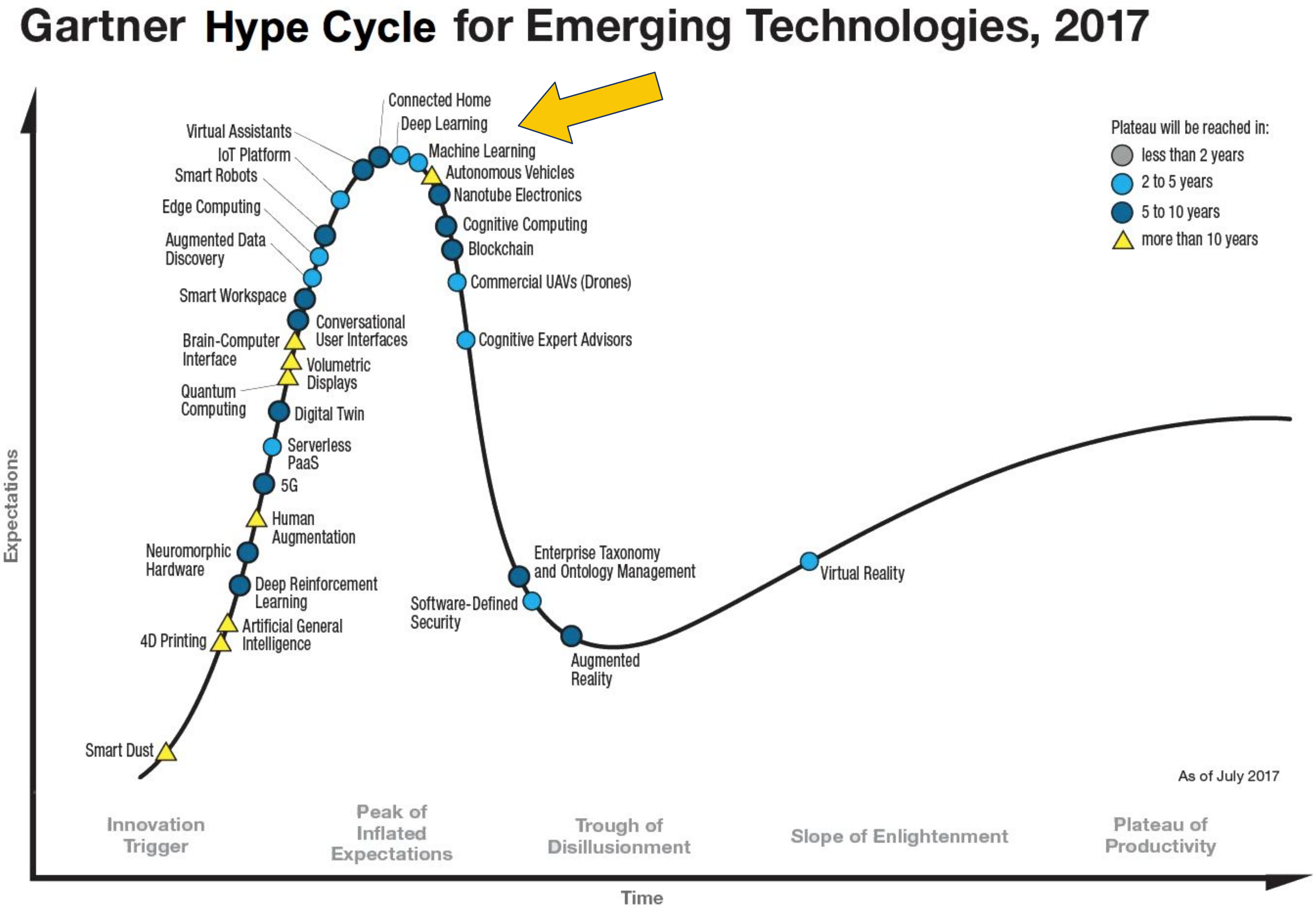
Limits of Human Cognition



Machine learning techniques and tools are intended to take advantage of **the *full* extent** of data available to interrogation and clinical use...and not just for the red and blue segments!

Figure courtesy of Dr. Ulysses Balis, Michigan Medicine

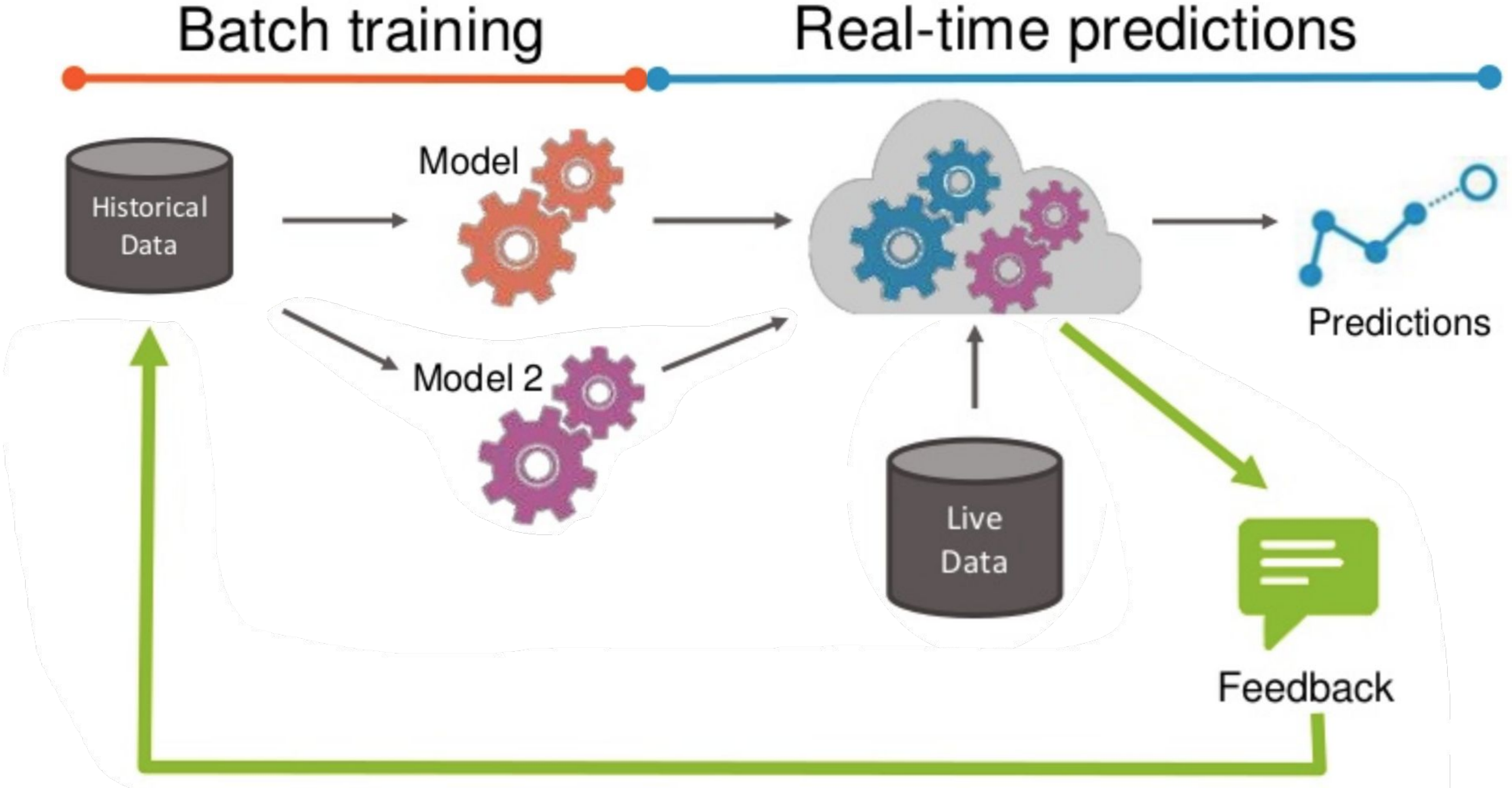
Machine Learning: Expectations for the Future?



Source: Gartner (July 2017)

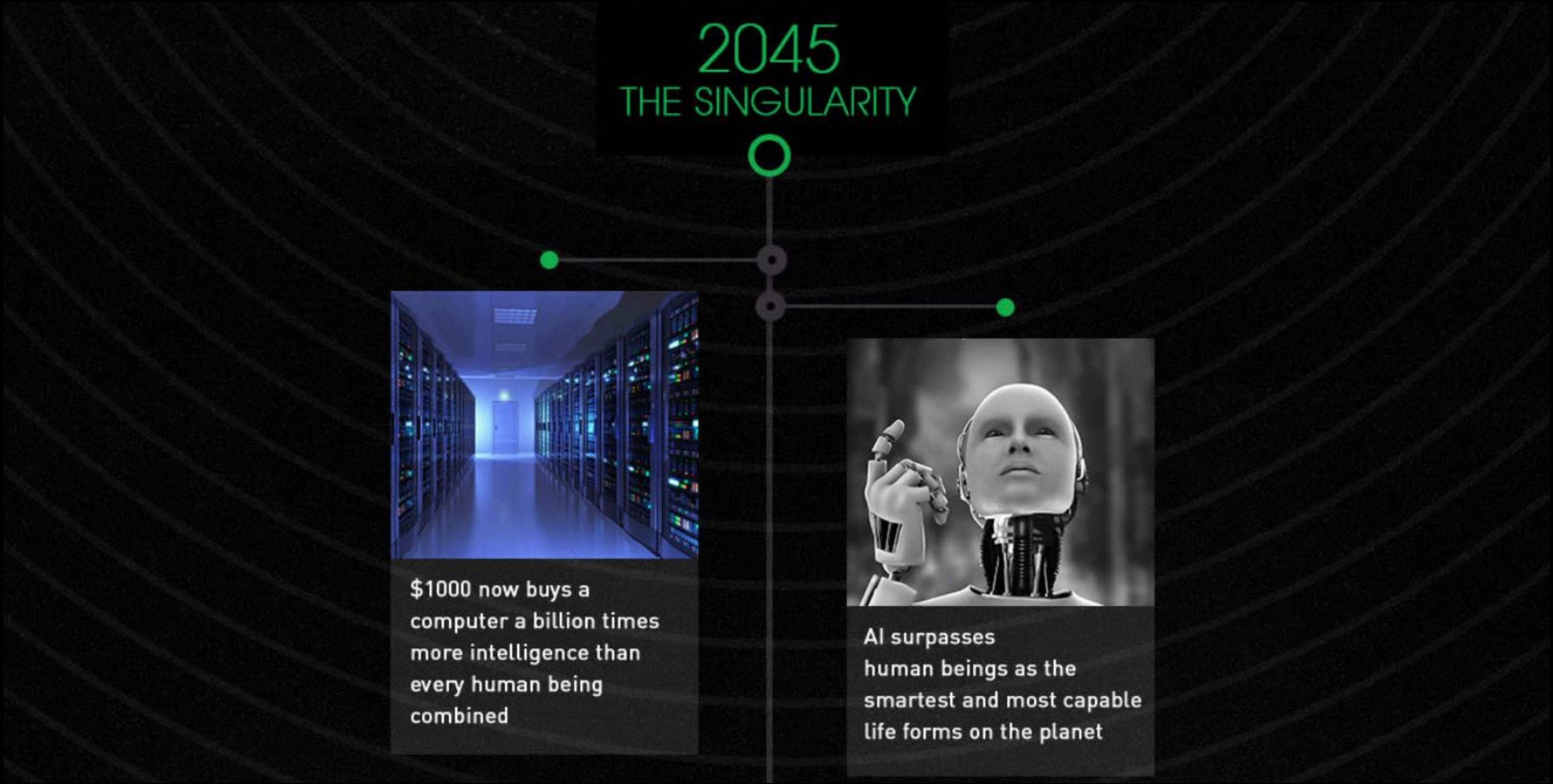
https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

Machine Learning Deployment



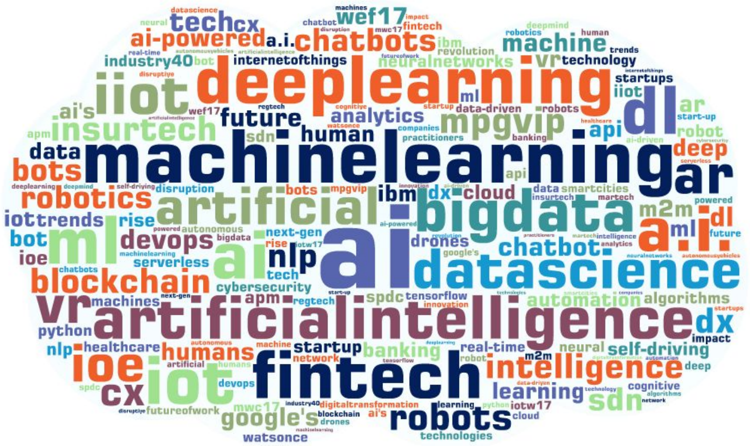
From: R Arya and A Zheng. Production and Beyond: Deploying and Managing Machine Learning Models. Available at https://www.slideshare.net/turi-inc/model-management/21

In closing...The Singularity is fast approaching



https://futurism.com/images/the-dawn-of-the-singularity/

QUESTIONS?



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Association for Pathology Informatics

https://pathologyinformatics.org

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