The Potential of AI in Health Care

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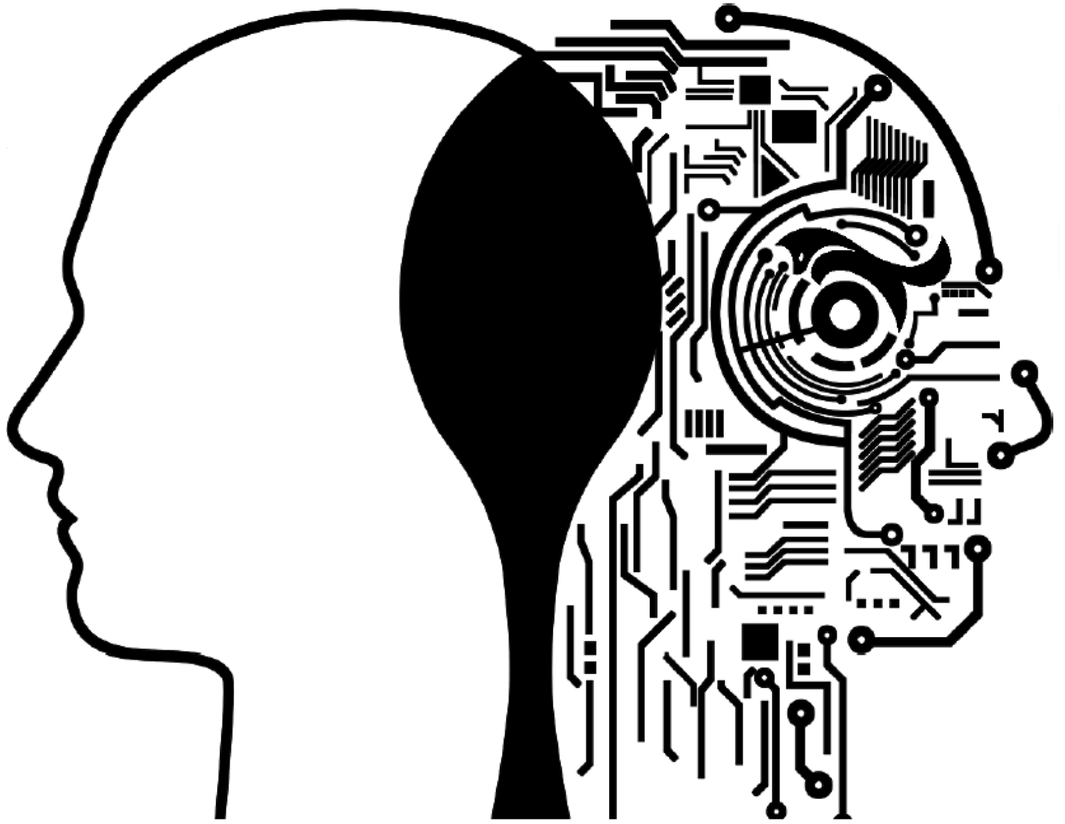
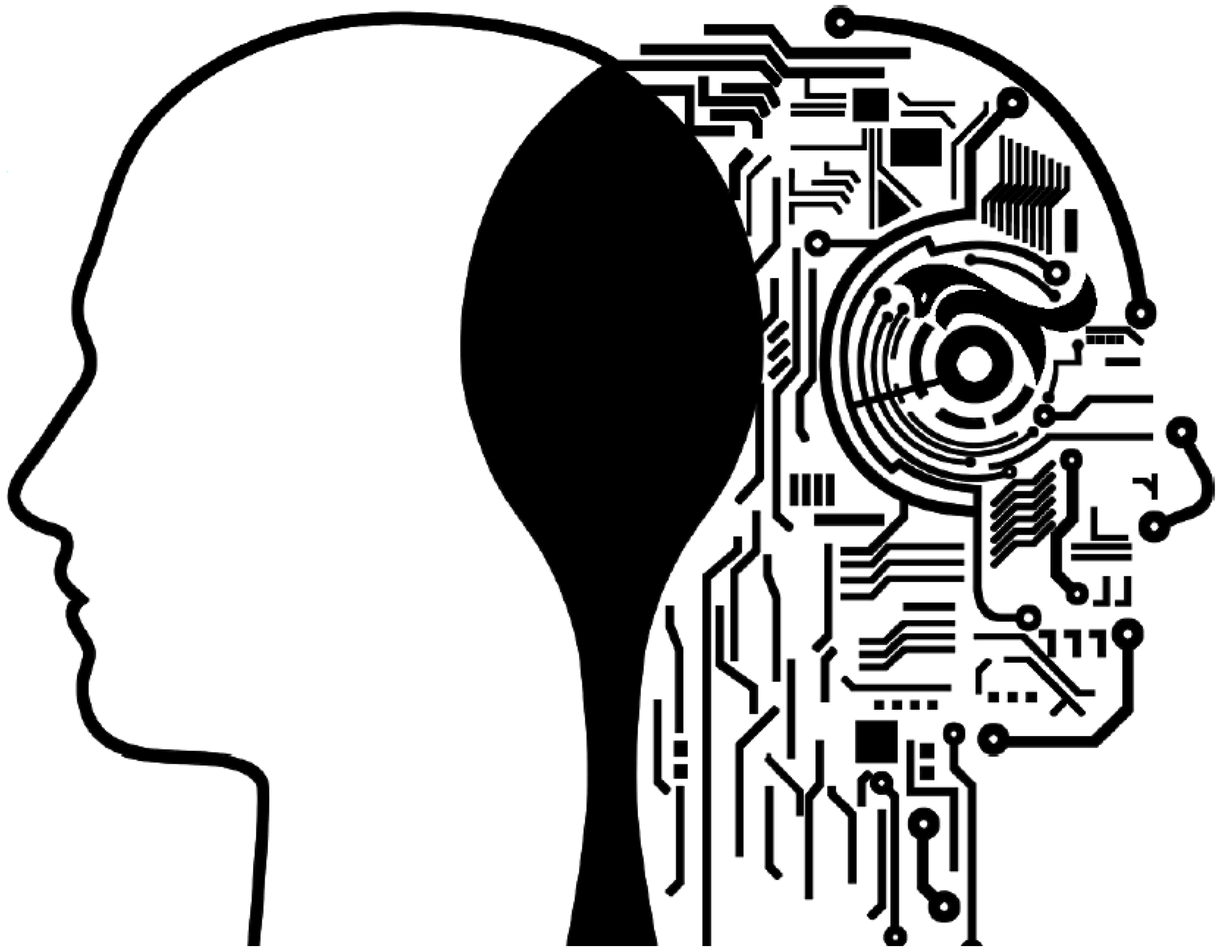
Vector Institute for AI



AI vs Humans

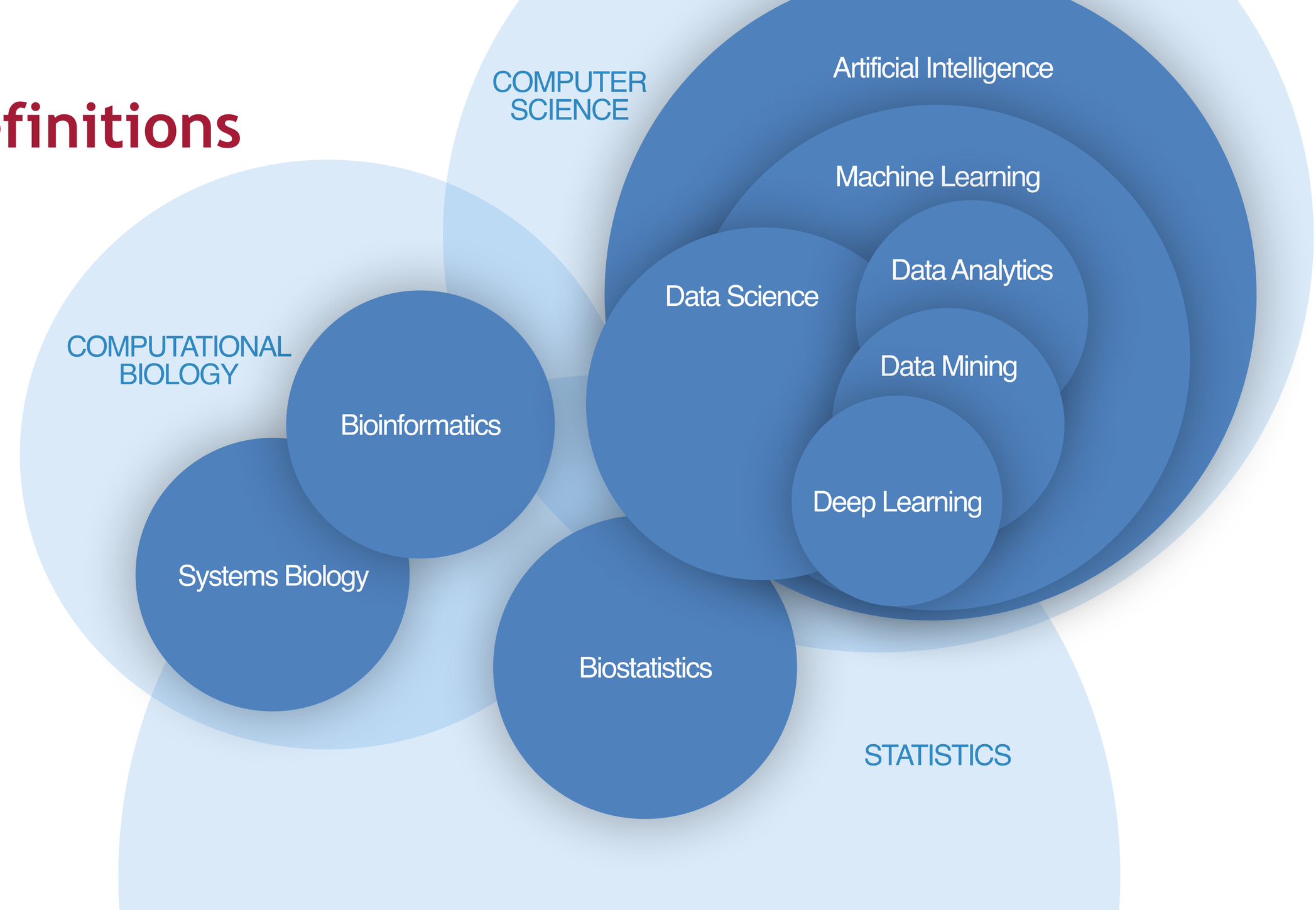
Implicit
Experiential
Skill-based
“Knowing How”

See One
Do One
Teach One



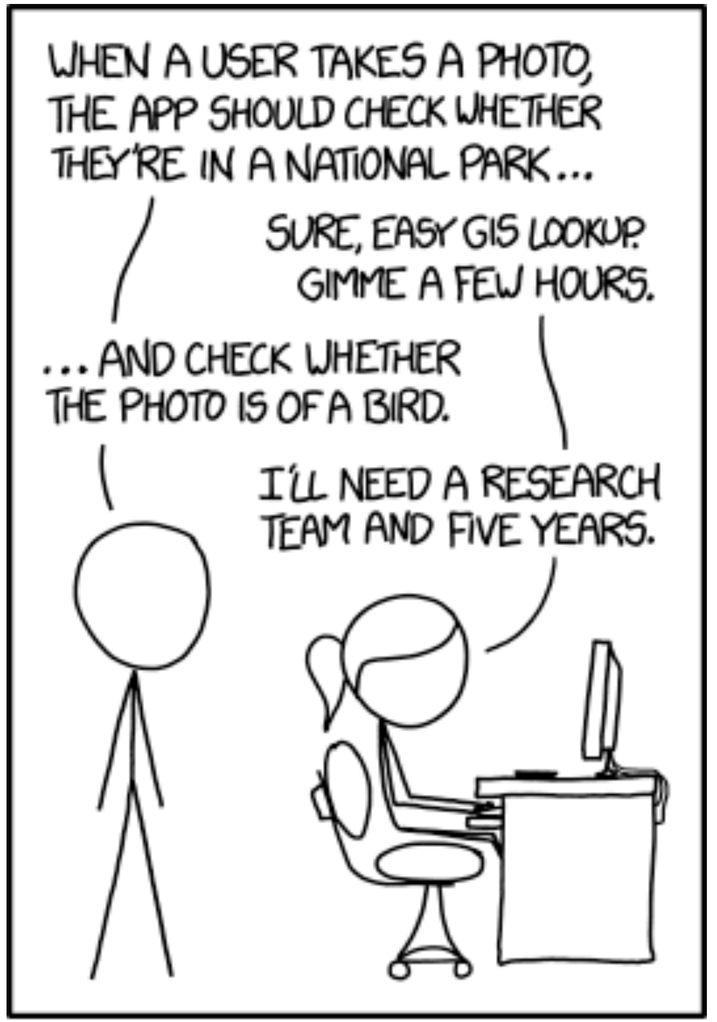
Factual
Propositional
“Knowing That”

Definitions



Beginnings of AI

In the 60s, Marvin Minsky assigned a couple of undergrads to spend the summer programming a computer to use a camera to identify objects in a scene. He figured they'd have the problem solved by the end of the summer. Half a century later, we're still working on it.



Deep Learning in Computer Vision

Deep learning rapidly set state of the art results in many computer vision problems

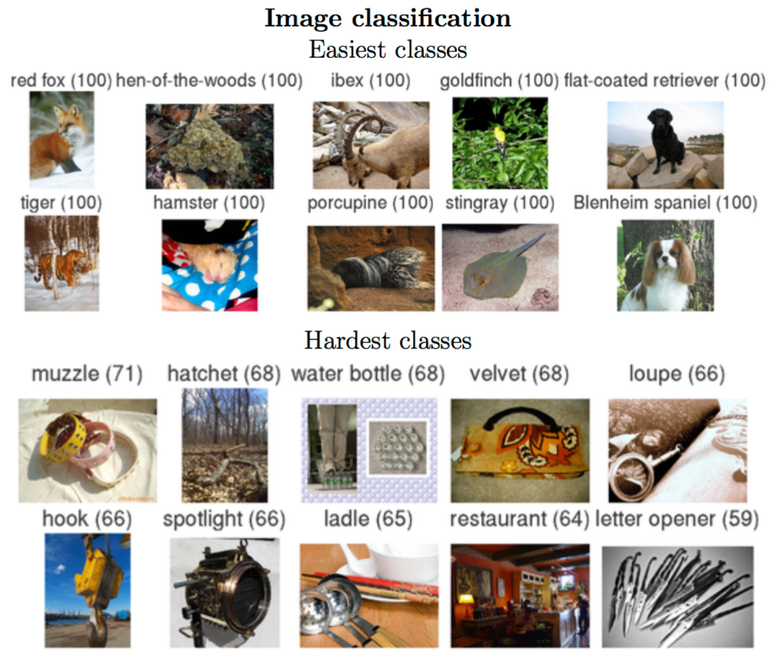
- Y. LeCun, Y. Bengio, G. Hinton (2015). Deep Learning. Nature 521, 436-444

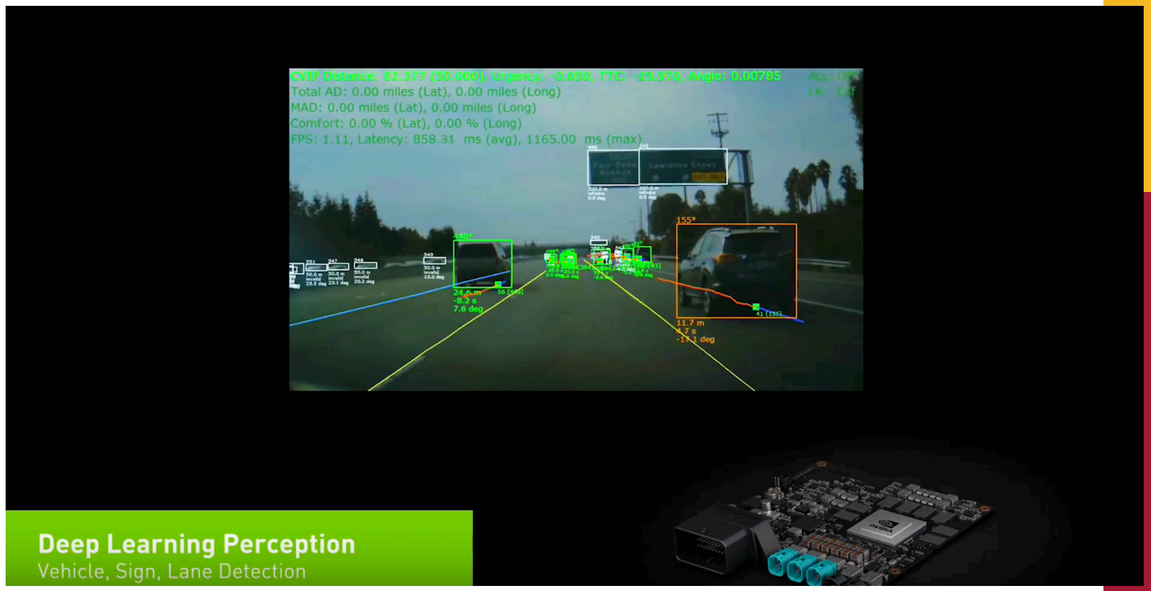
Why now?

- huge labelled data sets
- algorithmic advances
- increase in computing power (video games)
- open source software

Open Science Revolutionized Computer Vision

- Solved the object recognition problem
  - Visual Object Classes 2012 competition
  - Given an image, determine what is in the image (object recognition problem)
  - 10 million images with 1,000 labelled classes
  - Created ImageNet
  - Self-driving cars are now possible

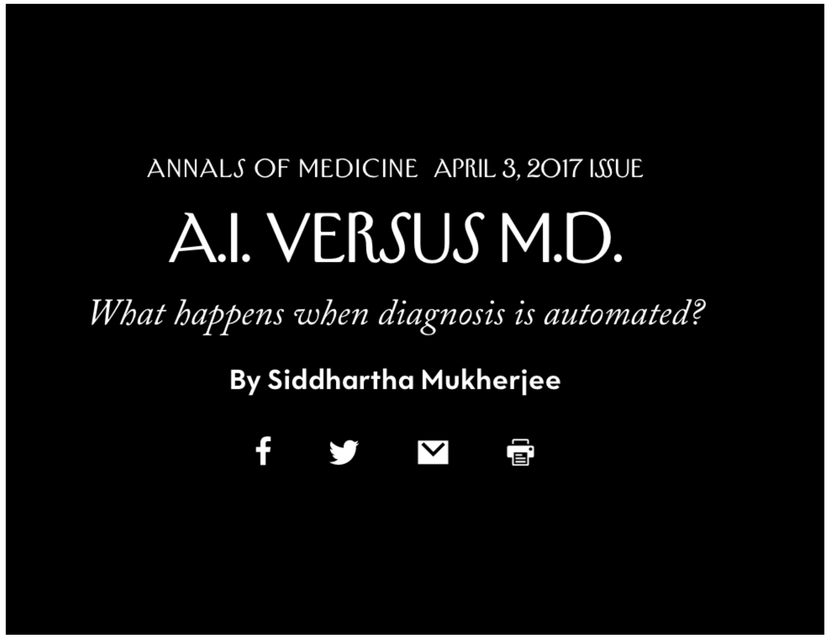




NVIDIA DRIVE

AI vs Humans

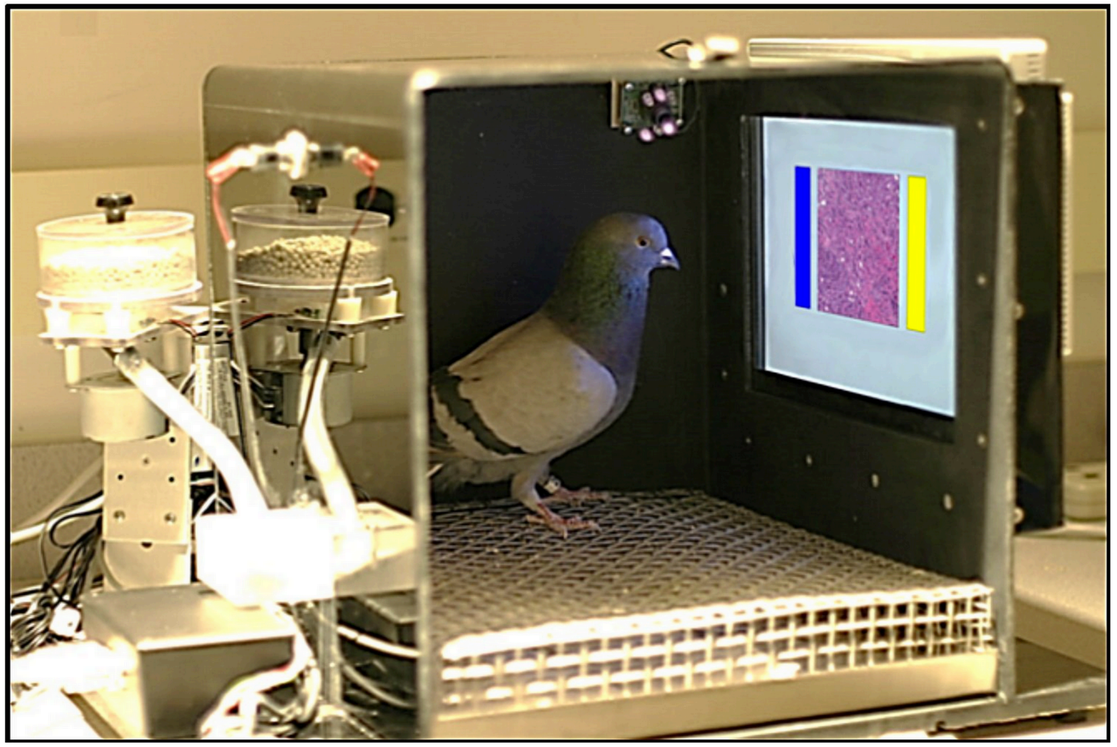
- Radiologists won't be replaced by AI but radiologists that don't use or understand AI will be replaced.
- "They should stop training radiologists now." -Geoffrey Hinton (father of deep learning, Turing Award winner)
- "The role of radiologists will evolve from doing perceptual things that could probably be done by a highly trained pigeon to doing far more cognitive things."



New Yorker, 2017

The New York Times

Paging Dr. Pigeon; You're Needed in Radiology



The pigeons' training environment at the University of Iowa included a food pellet dispenser, a touch-sensitive screen that projected medical images, and blue and yellow choice buttons on either side.
University of Iowa/Wassermann Lab

By Nicholas Bakalar

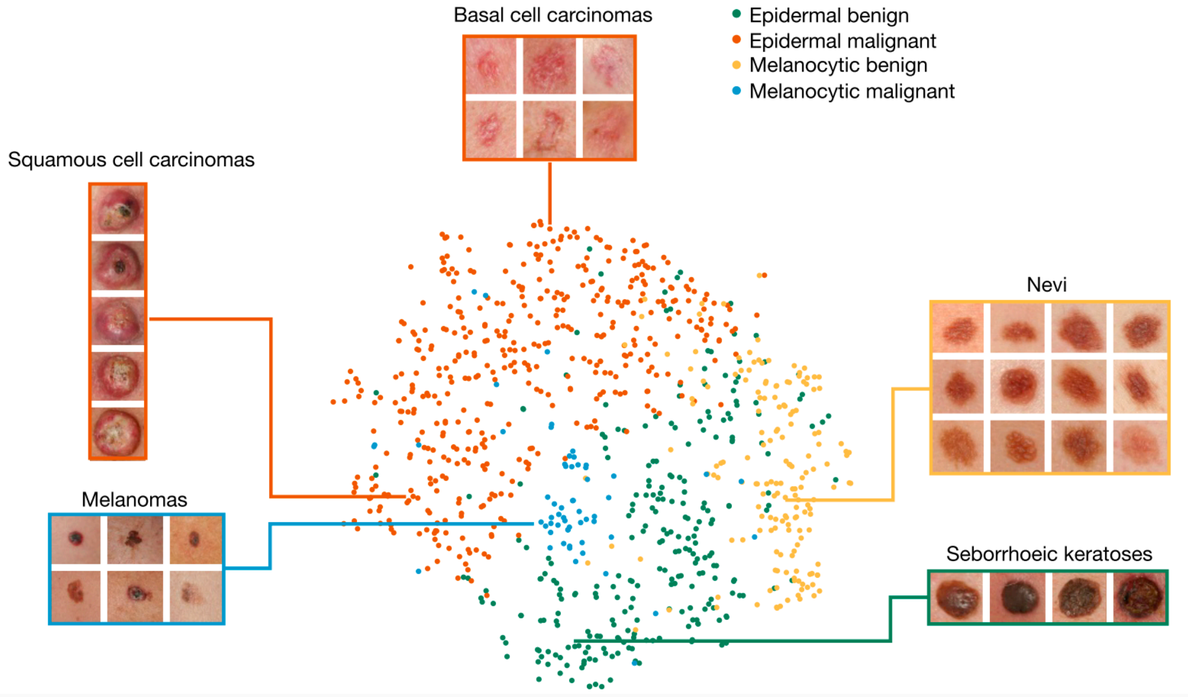
Nov. 24, 2015

Pigeons were trained to identify malignant vs benign in pathology and radiology images of the breast.

AI Performs Similar to Dermatologist

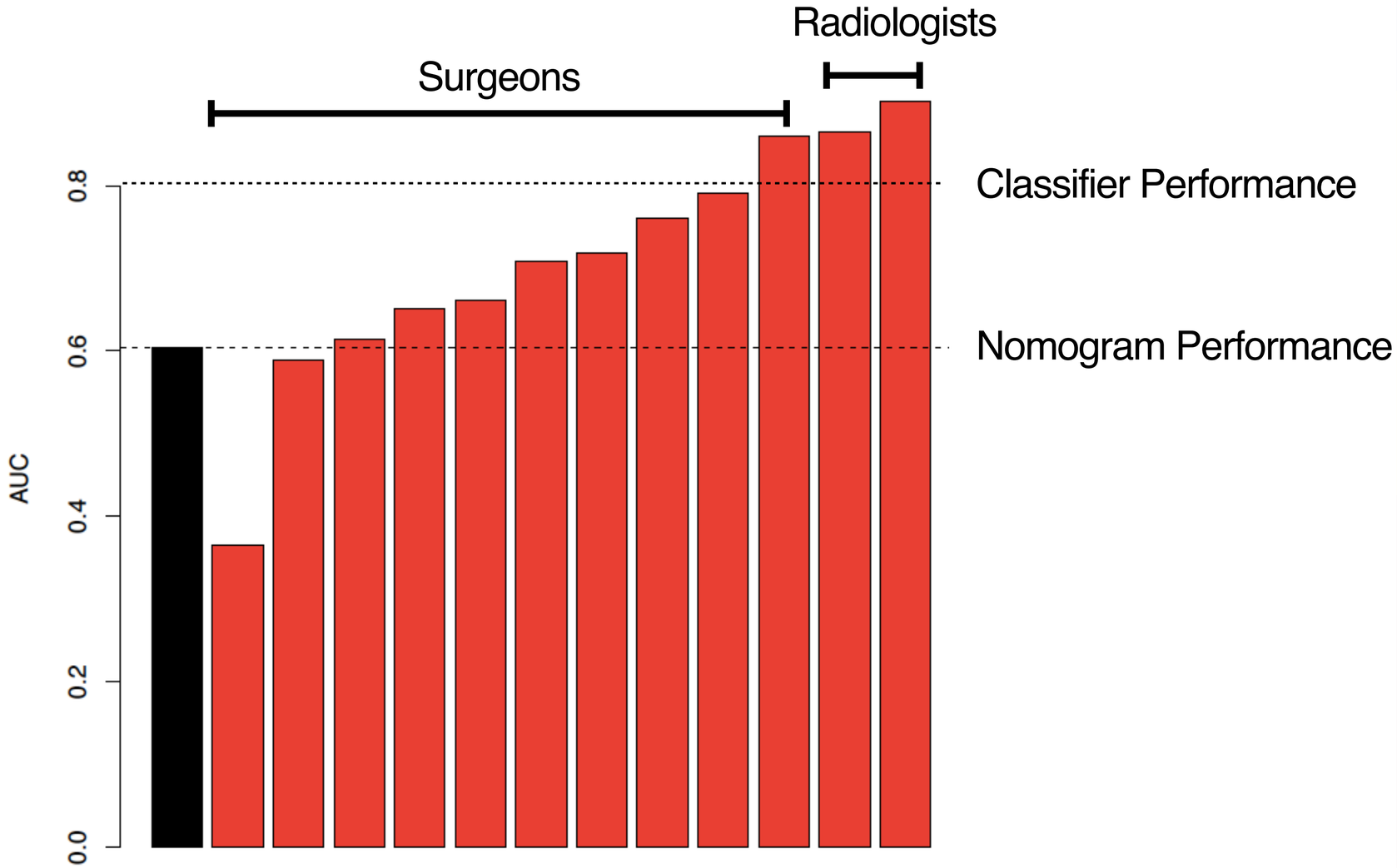
Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva[1]*, Brett Kuprel[1]*, Roberto A. Novoa[2,3], Justin Ko[2], Susan M. Swetter[2,4], Helen M. Blau[5] & Sebastian Thrun[6]



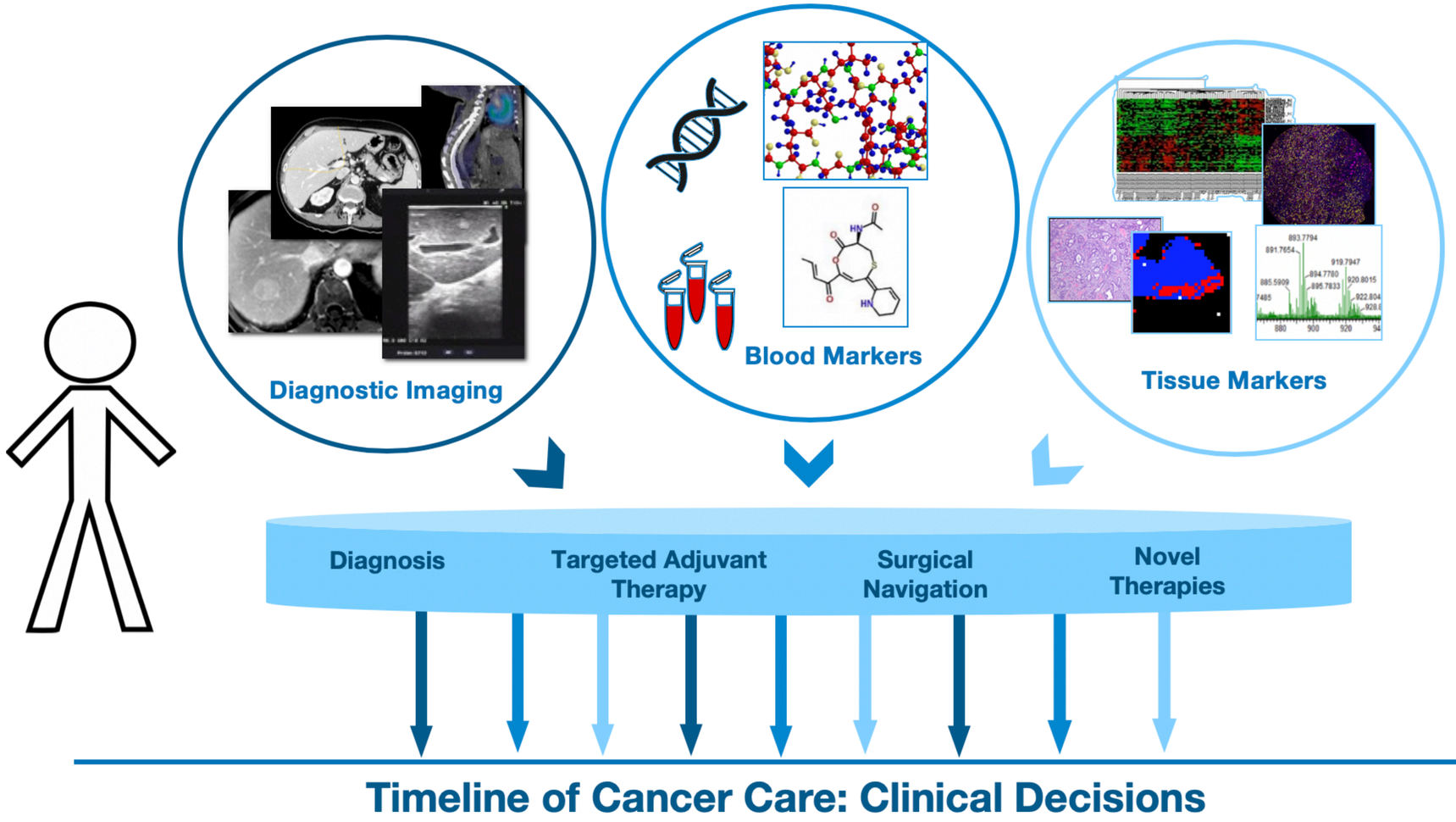
Physician Gestalt Outperforms AI

- Prediction of 2 year survival in pancreatic cancer

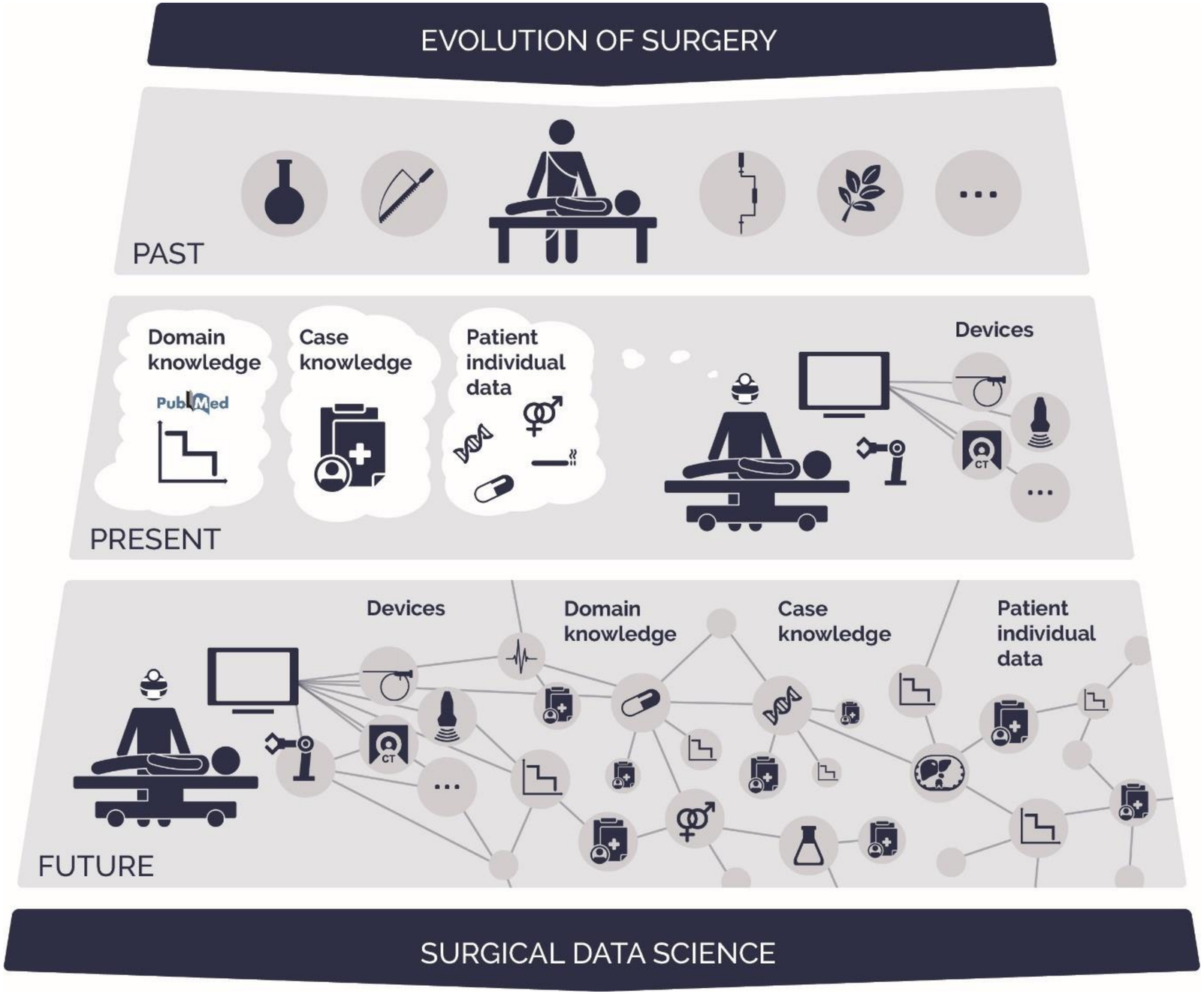


Pak LM et al. Can physician gestalt predict survival in patients with resectable pancreatic adenocarcinoma? Abdom Radiol. 2017.

The Holy Grail in Cancer Care



The right information to the right clinician at the right time.



Maier-Hein, 2019

AI is completely irrelevant to current clinical practice

The Reality

- Not one single company has ever received FDA (or Health Canada) approval for a clinical diagnostic device that is not overseen by a human.
- Only a handful of clinical trials have assessed an AI for clinical use.

IBM

Watson Health Perspectives Home Co

Blog Post

Watson Hea
the Record S

ALEX NABAUM

August 11, 2018 | Written by: Dr. John

Categorized: AI | Blog Post | Oncology

Share this post:

We at IBM have a lot to be proud of, including our pioneering work with Watson Health. Unfortunately, some media reports, including an August 11th story published by The Wall Street Journal, distort and ignore facts when suggesting IBM has not made "enough" progress on bringing the benefits of AI to healthcare. I feel it

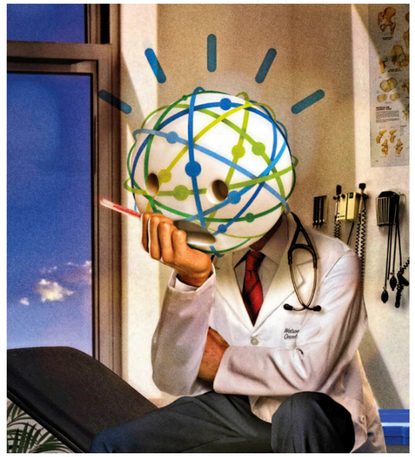
IEEE SPECTRUM Engineering Topics Special Reports Blogs Multimedia The Magazine

2 Apr 2019 | 15:00 GMT

How IBM Watson Overpromised and Underdelivered on AI Health Care

After its triumph on *Jeopardy!*, IBM's AI seemed poised to revolutionize medicine. Doctors are still waiting

By **Eliza Strickland**



In 2014, IBM opened swanky new headquarters for its artificial intelligence division, known as IBM Watson. Inside the glassy tower in lower Manhattan, IBMers can bring prospective clients and visiting journalists into the "immersion room," which resembles a miniature planetarium. There, in the darkened space, visitors sit on swiveling stools while fancy graphics flash around the curved screens covering the walls. It's the closest you can get, IBMers sometimes say, to being inside

The New York Times

Sloan Kettering's Cozy Deal With Start-Up Ignites a New Uproar

At Memorial Sloan Kettering Cancer Center in Manhattan, doctors and staff objected to a for-profit venture that could be lucrative for a few leading researchers and board members.

Gabriella Angotti-Jones/The New York Times

Paige.ai was attempting to monetize patient data and keep data in house

How can we use AI to solve fundamental biomedical problems?

RECIST

Response Evaluation in Criteria In Solid Tumors (RECIST)

- published rules assessing disease burden by imaging
- only for patients on clinical trials
- performed by radiologist, documented separate from the radiology report
- oncologist needs reliable, reproducible methods to assess treatment response

Eisenhauer, E. A. et al. New response evaluation criteria in solid tumours: Revised RECIST guideline (version 1.1). Eur. J. Cancer 45, 228–247 (2009).

RESIST 1.1

Reference Radiologist:

- Baseline
  - ID's measurable tumours (targets)
  - provides unidimensional measurements and records
- Follow ups:
  - use strict criteria to categorize: stable, progression, partial, or complete response

Limits to Our Understanding of Response Rates

RECIST Limits:

- Time consuming
- Only performed on patients enrolled in clinical trials
- Knowledge of response rates across the general cancer population is very limited

ChestX-ray8: Hospital-scale Chest X-ray Database and Benchmarks on Weakly-Supervised Classification and Localization of Common Thorax Diseases

Xiaosong Wang[1], Yifan Peng [2], Le Lu [1], Zhiyong Lu [2], Mohammadhadi Bagheri [1], Ronald M. Summers [1]
[1]Department of Radiology and Imaging Sciences, Clinical Center,
[2] National Center for Biotechnology Information, National Library of Medicine,
National Institutes of Health, Bethesda, MD 20892
{xiaosong.wang,yifan.peng,le.lu,luzh,mohammad.bagheri,rms}@nih.gov

Abstract

The chest X-ray is one of the most commonly accessible radiological examinations for screening and diagnosis of many lung diseases. A tremendous number of X-ray imaging studies accompanied by radiological reports are accumulated and stored in many modern hospitals' Picture Archiving and Communication Systems (PACS). On the other side, it is still an open question how this type of hospital-size knowledge database containing invaluable imaging informatics (i.e., loosely labeled) can be used to facilitate the data-hungry deep learning paradigms in building truly large-scale high precision computer-aided diagnosis (CAD) systems.

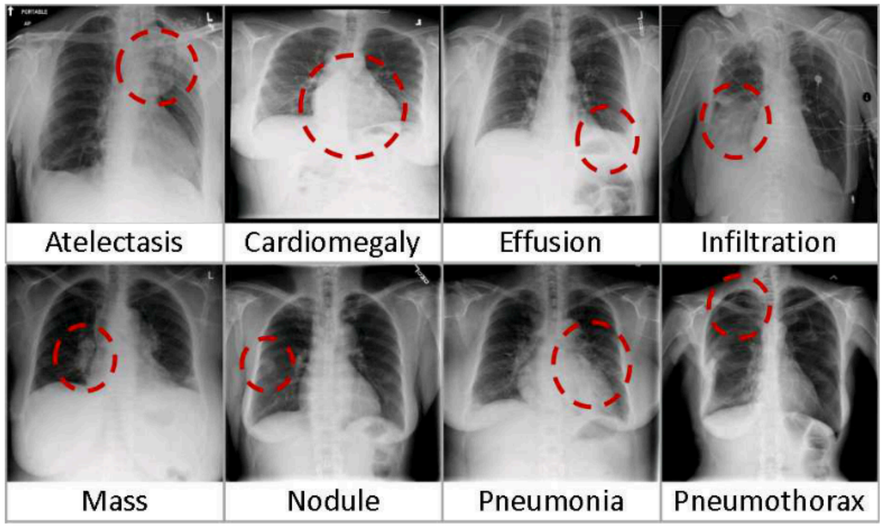


Figure 1. *Eight common thoracic diseases observed in chest X-rays that validate a challenging task of fully-automated diagnosis.*

Development of the “Cancer Twin”

Cancer Twin - a digital replica of a cancer patient.

Labeled database of disease burden for machine learning with CT images for disease recognition and localization.

Database of response (and progression) rates and mixed response rates for investigations into tumor heterogeneity.

MSK has Structured Reports Back to 2009

CT CAP reports were reporting template was followed:

- ~400,000 reports (50,000 patients undergoing cancer treatment)

FINDINGS:

LUNGS/AIRWAYS: Bilateral cavitary metastases have decreased. For example, a right lower lobe metastasis measures 2.9 x 2.5 cm, previously 3.3 x 2.9 cm. A left upper lobe metastasis measures 2.4 x 2.3 cm, previously 3.0 x 2.5 cm. Some of the other smaller solid nodules are unchanged. For example, a left lower lobe solid nodule measures 1.0 cm.

PLEURA/PERICARDIUM: No effusion.

MEDIASTINUM/THORACIC NODES: No adenopathy.

HEPATOBILIARY: Severe hepatic steatosis limits evaluation of the underlying hepatic parenchyma. Status post cholecystectomy. Minimal left-sided pneumobilia.

SPLEEN: Unremarkable.

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OTHER: Right chest wall port has its tip in the right atrium.

IMPRESSION:
1. Since February 2, 2018, some of the pulmonary metastases have decreased while others are unchanged.
2. No evidence for metastatic disease in the abdomen or pelvis.

Lung: METS.
Decreased
Pleura: No Dz
ThxNodes: No Dz
Liver: No Dz
Spleen: No Dz
Pancreas: No Dz.
Surgery.
Adrenals: No Dz.
Kidneys: No Dz.
AP nodes: No Dz.
Pelvis: No Dz.
Bowel: No Dz.
Bones: No Dz.
Other: Chest port.

Impression:
Decreased EOD

Impression Section of Report

IMPRESSION:
1. Since December 30, 2014 increasing pulmonary metastases.
2. Stable hepatic metastases and probable peritoneal carcinomatosis.
3. Increasing size of the ovaries with increasing cystic and low density component suspicious for disease.

IMPRESSION:
1. Since January 13, 2014 decreasing central hepatic mass. The satellite lesions and intrahepatic biliary dilatation are stable
2. Increasing left adnexal mass suspicious for metastatic disease.
3. Unchanged peritoneal carcinomatosis and abdominal adenopathy

"weak" labels going back to 2009

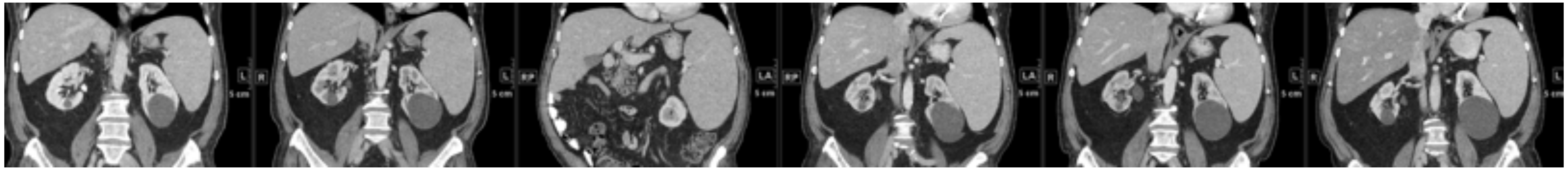
IMPRESSION:
1. Since August 19, 2016, unchanged liver metastases and probable lung metastases.
2. Decreased presacral fluid collection.

IMPRESSION:
1. Since July 3, 2017, new right lower lobe segmental pulmonary emboli. This finding was discussed between Dr. Do and Dr. Karlo Perica (beeper 3890) by phone at 2150 hours on September 14, 2017.
2. Increased left abdominal recurrence with new associated moderate left hydronephrosis.
3. Slightly increased extent of disease in the liver.

IMPRESSION:
1. Since December 3, 2015, unchanged extent of disease including pulmonary metastases, probable hepatic metastases, and retroperitoneal adenopathy.

IMPRESSION:
1. Since May 17, 2016, increased small left and decreased small right pleural effusions post right pleural catheter placement.
2. Decreased probable pleural carcinomatosis.
3. Since June 19, 2016, overall decreased extent of disease manifest by decrease peritoneal carcinomatosis and decreased peritoneal and soft tissue metastases.
4. Metastasis involving the distal 11th rib with new osseous destruction.

For each patient …



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+ treatment, demographics, and outcome

time →

F. Zulkernine
Co-PI

K. Batch
CS Student

The word “metastases" in different sections of the report

	Anus	Bones_Joints	Brain_Nervous_System	Breast	Cervix_Uteri	ColoRectal	Corpus	Esophagus	Head_Neck	Hodgkins_Lymphoma	Leukemia	Liver_Gallbladder_Bile_Duct	Lung_Bronchus	Melanoma	NHL	Other_Digestive_Organs	Other_Female_Genital_Organs	Other_Male_Genital_Organs	Other_Urinary	Ovary	Pancreas	Prostate	Soft_Tissue	Stomach	Thyroid_Other_Endocrine	UNKNOWN
AP nodes	12.2%	9.3%	3.9%	6.5%	14.7%	10.9%	13.8%	17.3%	9.6%	12.5%	26.8%	16.6%	10.3%	13.1%	23.0%	9.6%	15.7%	21.9%	14.8%	21.0%	15.7%	19.1%	7.3%	16.0%	14.2%	12.2%
Bones	4.2%	16.8%	6.9%	44.2%	8.0%	7.0%	7.1%	13.0%	26.2%	1.9%	2.4%	12.9%	34.4%	14.1%	1.8%	4.8%	6.3%	5.9%	22.0%	5.5%	9.9%	45.0%	14.3%	8.0%	29.1%	2.6%
Th nodes	6.6%	10.5%	5.6%	14.6%	9.2%	7.5%	7.4%	18.4%	21.9%	26.3%	25.1%	11.6%	27.7%	13.6%	18.4%	5.0%	8.1%	9.0%	14.1%	13.4%	7.0%	7.9%	7.3%	8.6%	16.0%	9.7%
Liver	10.4%	4.2%	5.3%	22.8%	5.6%	23.3%	5.7%	19.4%	16.8%	0.5%	0.4%	15.3%	16.5%	15.2%	0.3%	10.0%	3.6%	4.3%	10.3%	6.6%	30.8%	4.1%	11.9%	15.1%	33.0%	3.0%
Lungs	4.6%	25.4%	4.1%	8.4%	8.1%	13.4%	10.7%	6.9%	32.2%	0.1%	0.4%	9.1%	9.9%	15.1%	0.2%	4.3%	5.2%	10.8%	18.5%	2.5%	8.3%	2.8%	18.2%	3.3%	17.1%	1.2%
Peritoneu	1.9%	3.1%	1.3%	3.0%	5.5%	6.5%	12.3%	3.1%	3.1%	0.6%	0.9%	6.5%	3.4%	6.0%	0.7%	16.7%	6.5%	1.3%	5.4%	28.2%	8.1%	1.5%	8.8%	6.6%	5.4%	2.3%
Pleura	0.3%	4.9%	0.4%	2.6%	1.1%	0.5%	0.8%	1.0%	7.6%	0.0%	0.1%	0.5%	3.8%	1.2%	0.1%	0.6%	0.4%	0.6%	2.7%	1.1%	0.4%	0.3%	3.2%	0.3%	2.2%	0.2%
Adrenals	0.0%	0.3%	0.7%	0.9%	0.4%	1.0%	0.5%	2.5%	1.4%	0.0%	0.0%	1.7%	5.9%	3.4%	0.0%	0.1%	0.2%	0.3%	5.6%	0.3%	1.1%	0.6%	1.1%	1.2%	1.6%	0.1%
Kidneys	0.1%	1.2%	0.4%	0.4%	0.4%	0.2%	0.3%	0.4%	1.9%	0.0%	0.0%	0.2%	1.4%	1.6%	0.0%	0.1%	0.7%	0.3%	1.4%	0.2%	0.3%	0.1%	1.2%	0.4%	1.0%	0.0%
Spleen	0.1%	0.0%	0.4%	0.3%	0.2%	0.3%	0.4%	0.2%	1.8%	0.1%	0.0%	0.5%	1.1%	3.4%	0.0%	0.3%	0.2%	0.1%	0.4%	0.8%	0.4%	0.1%	0.5%	0.3%	0.5%	0.1%
Pancreas	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%	0.2%	0.6%	0.8%	0.0%	0.1%	0.3%	0.0%	2.6%	0.1%	0.3%	0.1%	1.1%	0.1%	0.3%	0.1%

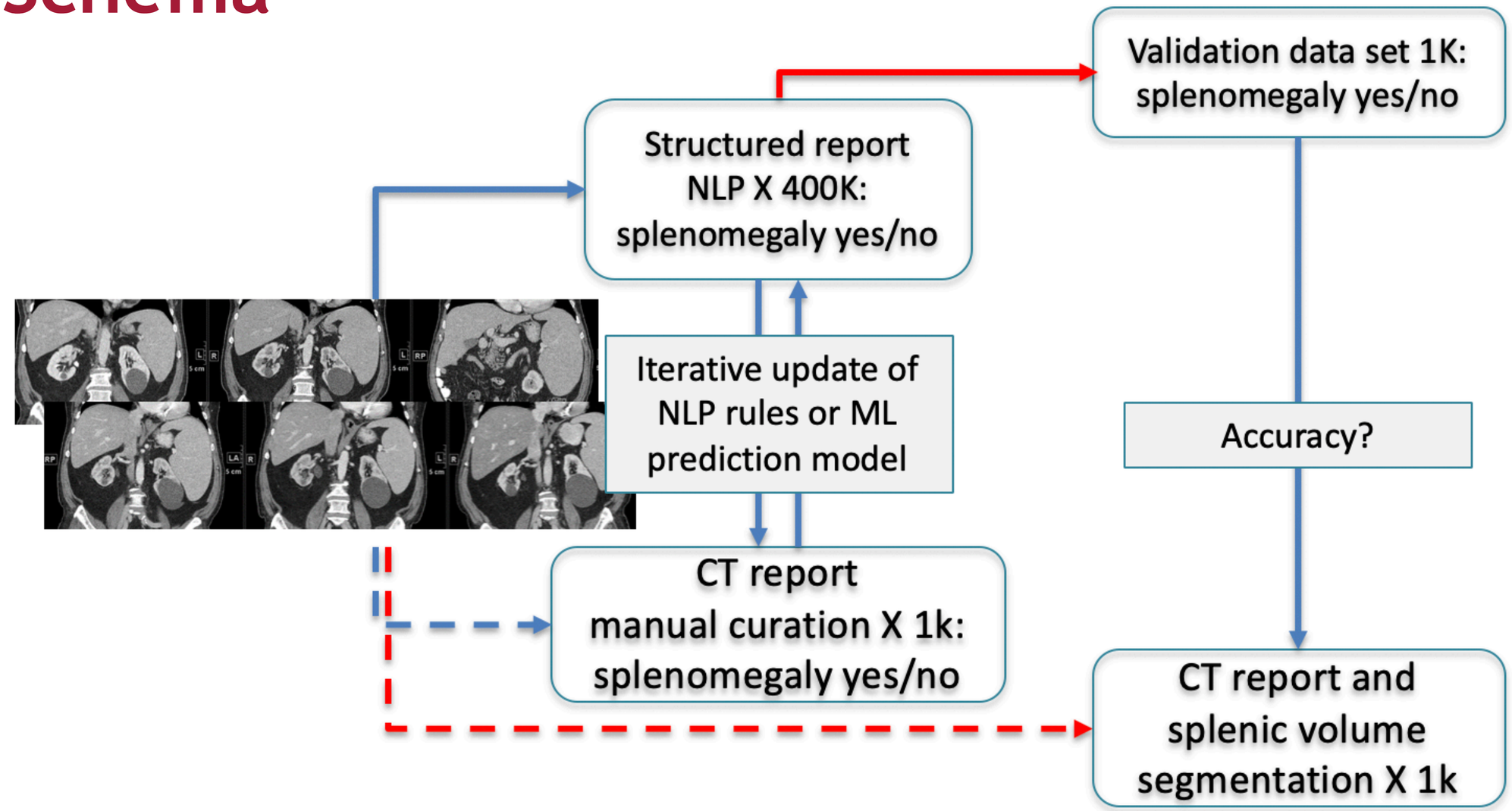
- Single word search does not identify metastases reliably – because someone may say: ‘no bone metastases.’
- Manual curation is first needed to train a machine learning/NLP model to label the entire data set.

Proof of Principle with Splenomegaly

Confirming splenomegaly in our reports based on reading the “Spleen” and “Impression” sections

1. Identify reports for manual curation – currently focused on leukemia, lymphoma, colorectal and liver primary cancer patients
2. Develop score sheet, create interface for scoring
3. Assign readers to score X number of report
4. Provide labels to ML/NLP experts to develop model
5. Measure accuracy and finalize model OR increase curated data set to improve accuracy
6. ‘Validate’ based on imaging directly (for splenomegaly, volumetric segmentation)
7. Measure inter-reader agreement for manual curation

Schema


Validation data set 1K:
splenomegaly yes/no
Structured report
NLP X 400K:
splenomegaly yes/no
Iterative update of
NLP rules or ML
prediction model
Accuracy?
CT report
manual curation X 1k:
splenomegaly yes/no
CT report and
splenic volume
segmentation X 1k

The possibilities are endless

Identity and the digital twin

- Even if can build a cancer digital twin - should we?
- If you were diagnosed with cancer, would you want an AI to tell you how long you have to live?
- How do we address the existential threats of AI and cancer?

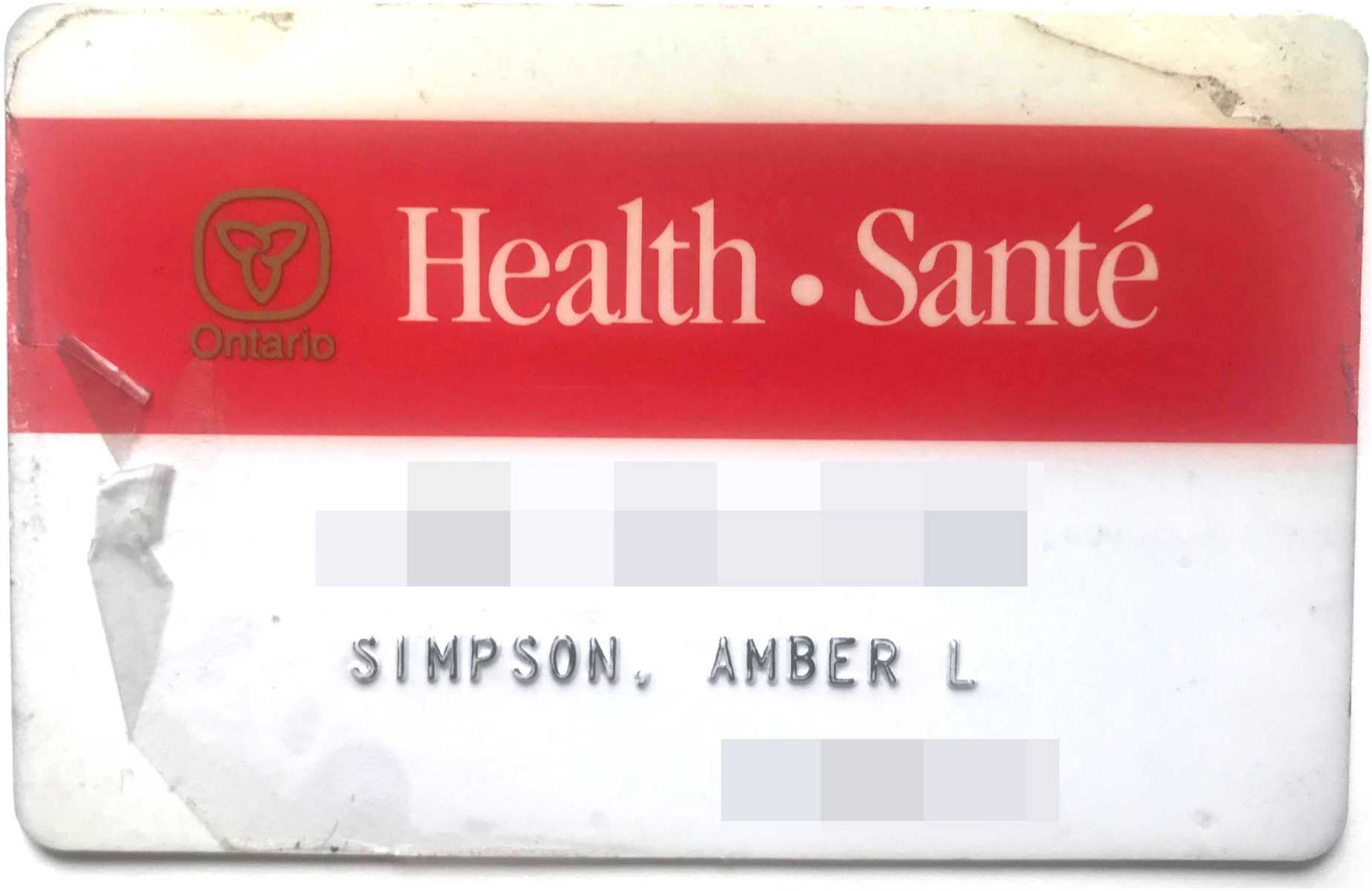
S. Mosurinjohn
PI - Humanist
Religious Studies

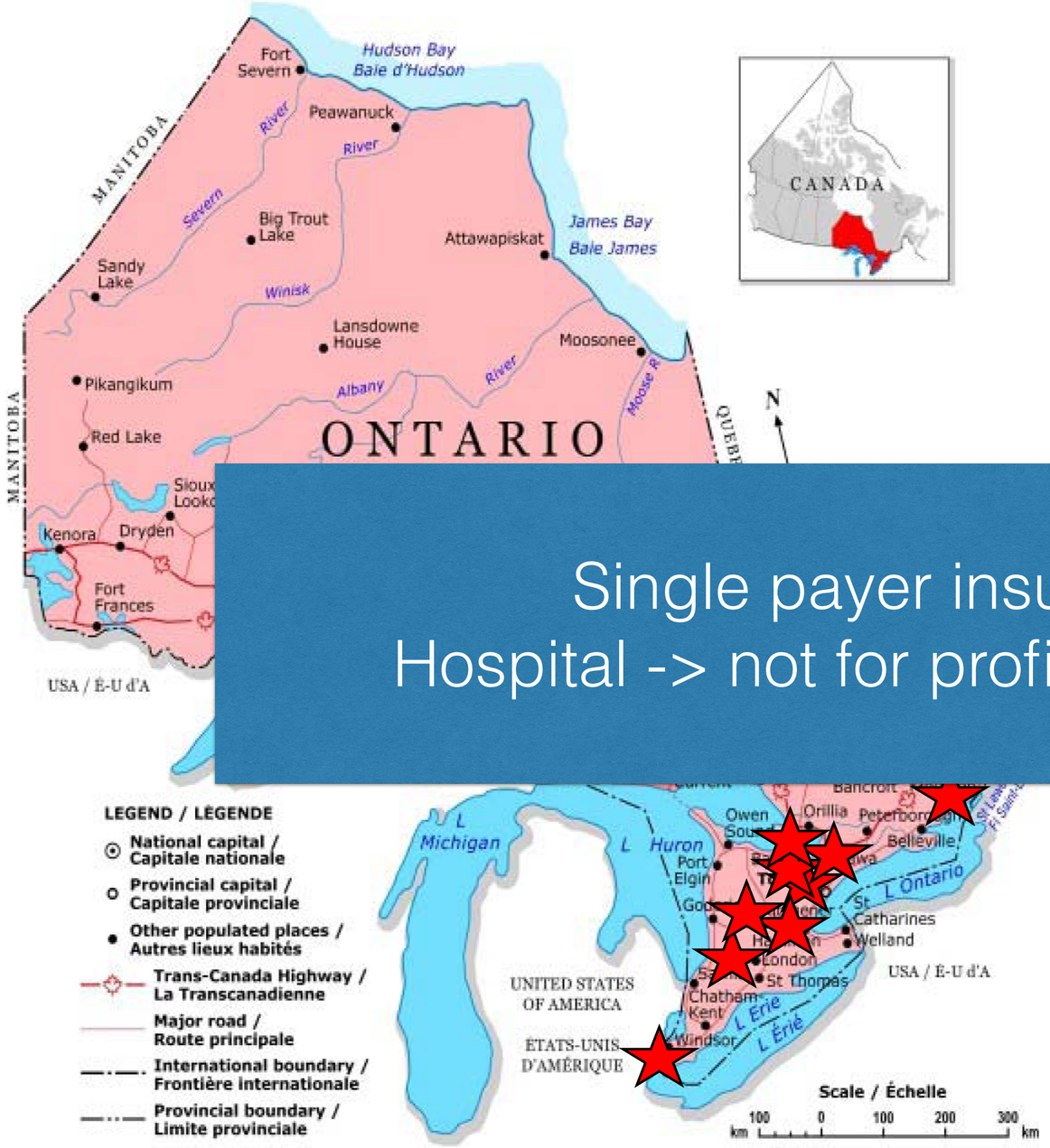
How will we use the current focus on AI to change patient care?

Health Data Landscape in the US

Health Data Challenges in the US

- clinicians have built their research careers on patient data, they likely paid to collect and annotate
- patient data is not accurately captured in hospitals (ICD-9/10 codes)
- “why should we give our data away for free and pay individuals to work with it?”
- no reward systems for hospitals to share data (e.g. Paige.ai)
- large-scale data sharing (e.g. Genie 2.0) pushed by an individual investigator


Ontario
Health • Santé
SIMPSON, AMBER L



Single payer insurance -> OHIP
Hospital -> not for profit private corporations

Slide courtesy of Dr. Alice Wei, UHN

Health Data Landscape Opportunities

Cancer Care Ontario

- Oversees all cancer care delivery in Ontario
- Surgical Oncology Program manages access to care, funding to institutions, and quality of care
- Regionalized complex cancer surgery

CCTG (Canadian Cancer Trials Group)

- Designs and administers cancer trials across Canada

ICES

- Access to episodic health data (demographic, outcome, etc)

Health Data Landscape at Queen's

CCTG

- Housed in Botterell (Lam Pho)

ICES

- Hosted in Centre for Advanced Computing (Don Aldridge)

CSSPN (Canadian Primary Care Sentinel Surveillance Network)

- Hosted in CAC

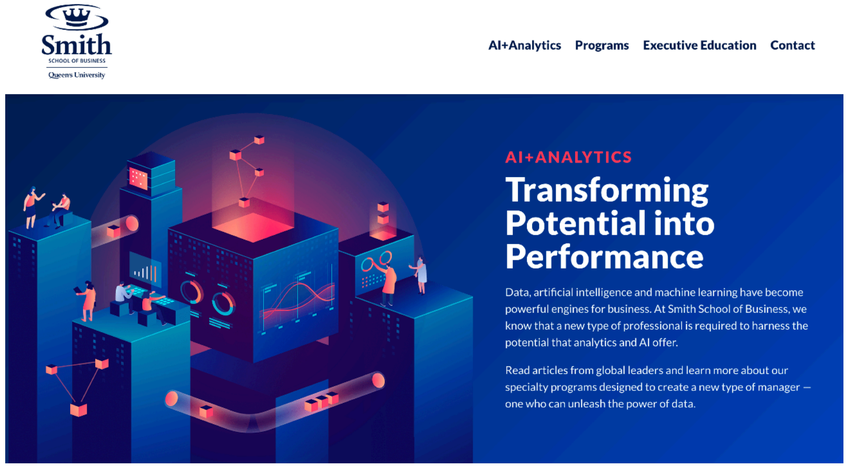
KHSC

- Low silos and a willingness to collaborate

Kingston Health Sciences Centre
Centre des sciences de la santé de Kingston

AI Training and Research at Queen’s

QMIND
Queen's
Artifical Intelligence
Hub



Department of Philosophy and School of Computing

Philosophical Implications of Artificial Intelligence Colloquium Series

Ingenuity Labs

Artificial Intelligence Landscape in Ontario

VECTOR INSTITUTE
FOR ARTIFICIAL INTELLIGENCE

How Canada has emerged as a leader in artificial intelligence

Academics, industry and government have joined togetl
for Canada to become a research and development pow

By MICHAEL SMITH | DEC 06 2017

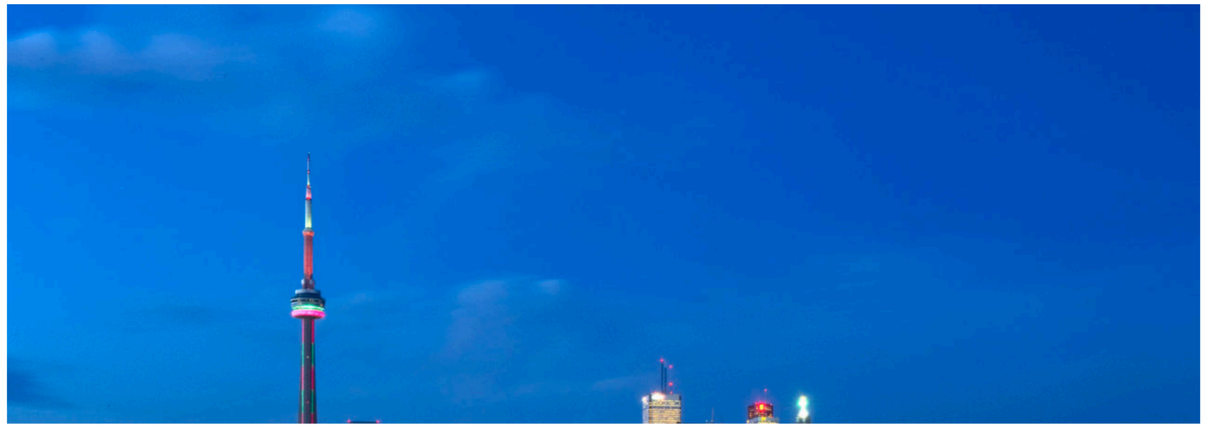
2 Comments | Share

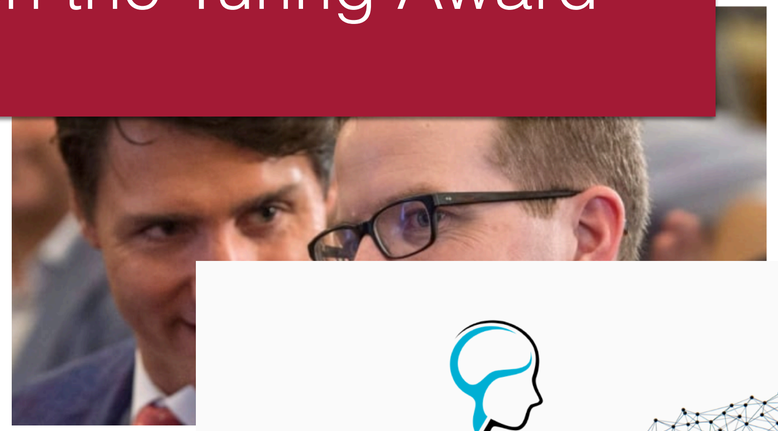
Facebook launches artificial intelligence research lab in Montreal

Hinton, LeCun, and Bengio won the Turing Award

NVIDIA C

June 13, 2018 by GAVRI





imagia

AI-DRIVEN PERSONALIZED CARE

We foster AI-first collaborative research
to accelerate accessible personalized healthcare

Predictions are meaningless without corresponding treatments

Clinical trials (CCTG, Health Sciences etc)

Biomarker development

Mechanism

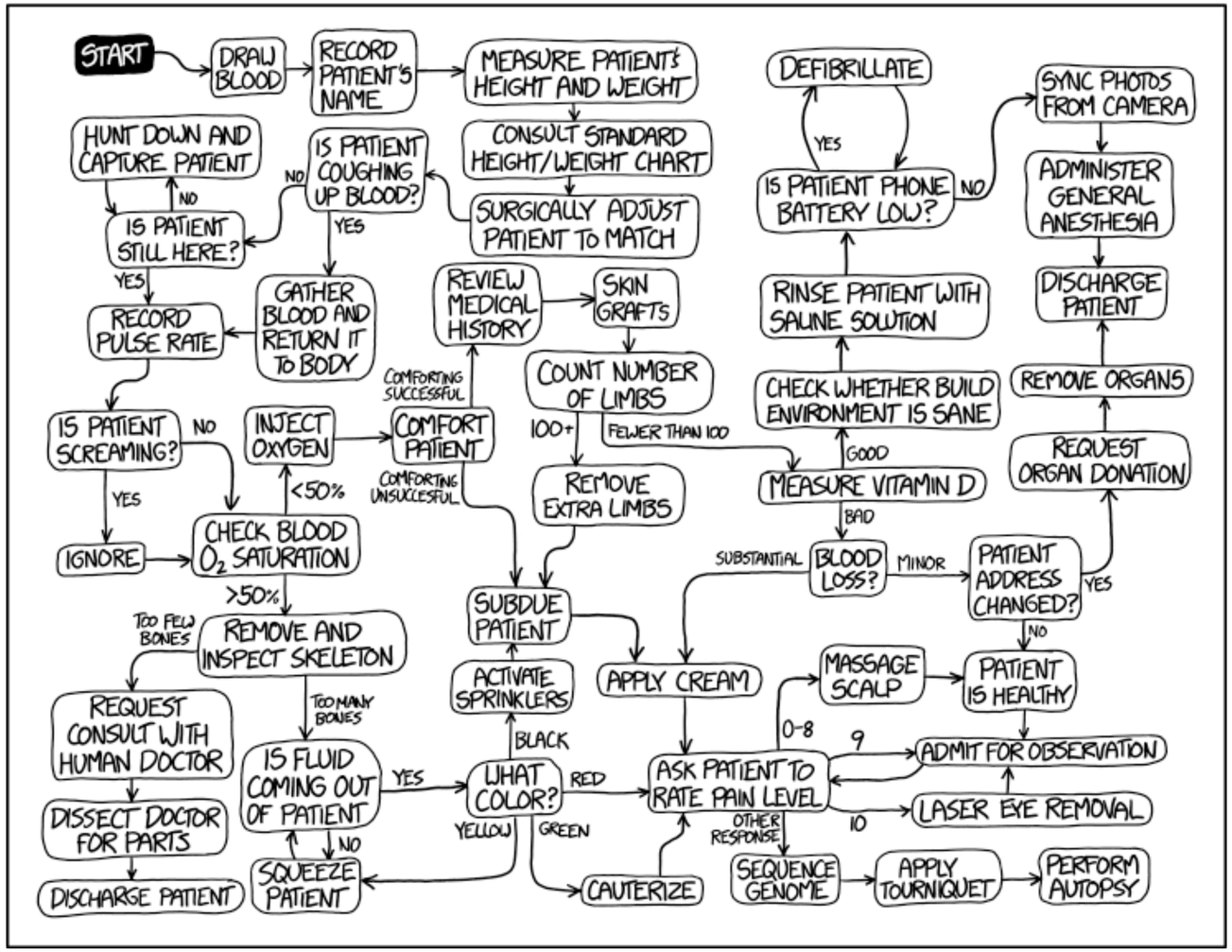
Canadian Cancer Trials Group / Groupe canadien des essais sur le cancer

Kingston Health Sciences Centre
Centre des sciences de la santé de Kingston
Hôpital Hotel Dieu Hospital · KGH Hôpital Général de Kingston General Hospital

Queen's University


Help!
Clinical Community
We have the answers!
Imaging Community
Inspired by Janet Eary, NCI

A GUIDE TO THE MEDICAL DIAGNOSTIC AND TREATMENT ALGORITHM USED BY IBM'S WATSON COMPUTER SYSTEM



source: xkcd