



Big Picture: AI/ML in HEP and in the wild

2019-07-01, DESY

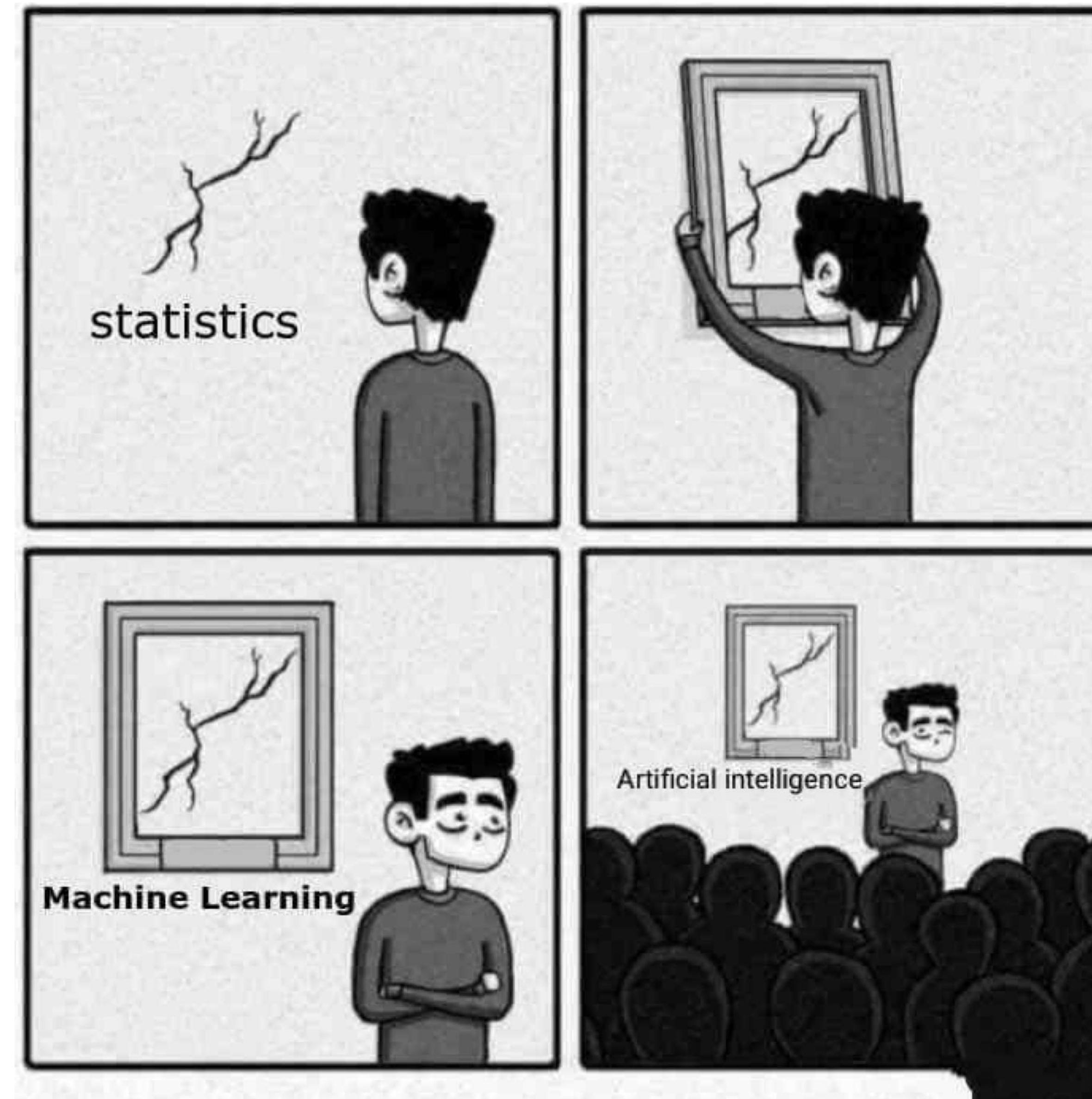
Andrey Ustyuzhanin

NRU HSE

YSDA

ICL

What is Artificial Intelligence? Machine Learning?





Tesler's theorem:
“AI is whatever hasn’t
been done yet”

Larry Tesler

**AI/ML as a life driver.
Time is now**



Life complexity

Stone Age



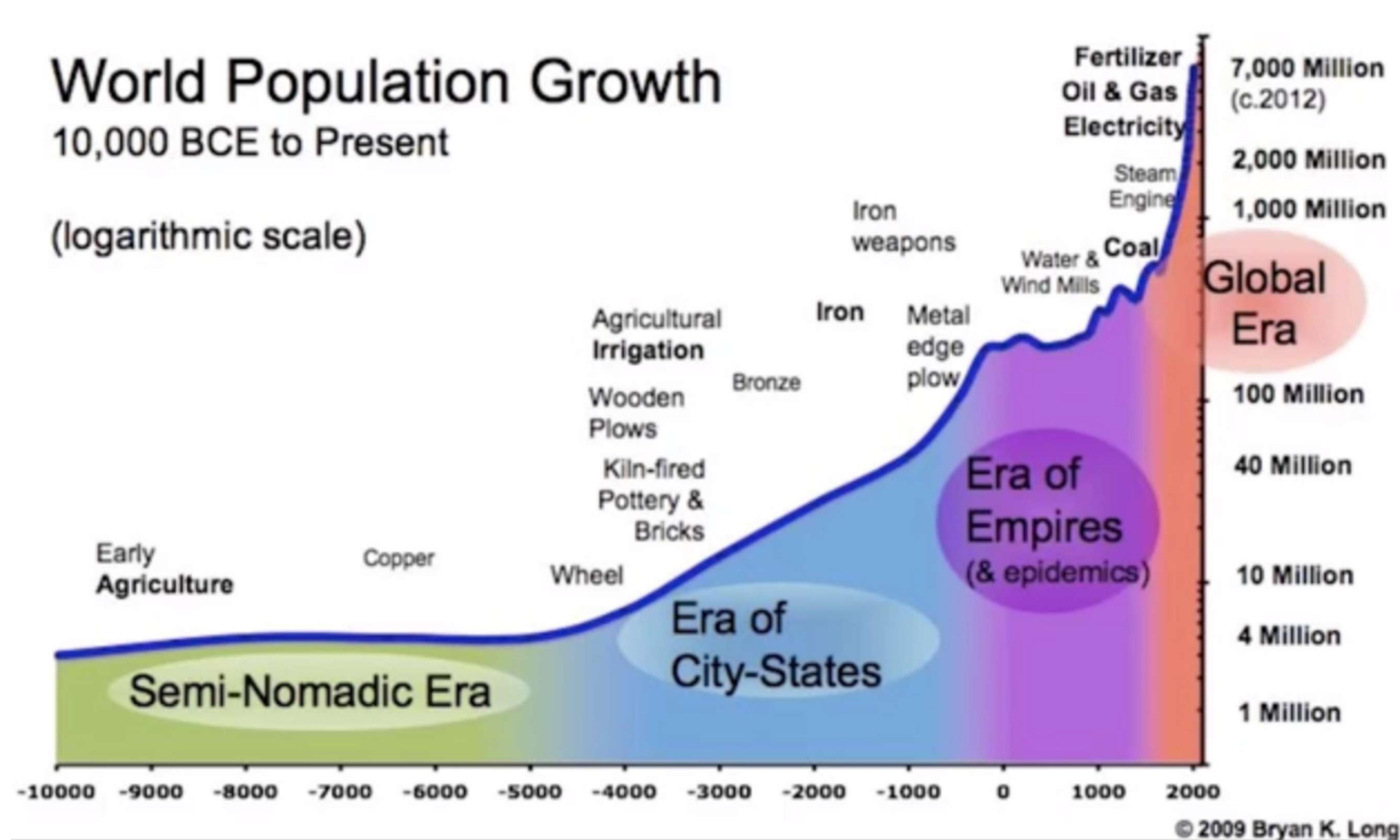
Population $\sim 10^5$
Items ~ 10

Nowadays



Population $\sim 10^{10}$
Items $\sim 10^{10}$

Humanity by numbers



Economic cycles

There were 3 distinct economic cycles so far

1. Steam
2. Electricity
3. Computing/Automation

Every cycle is characterized by

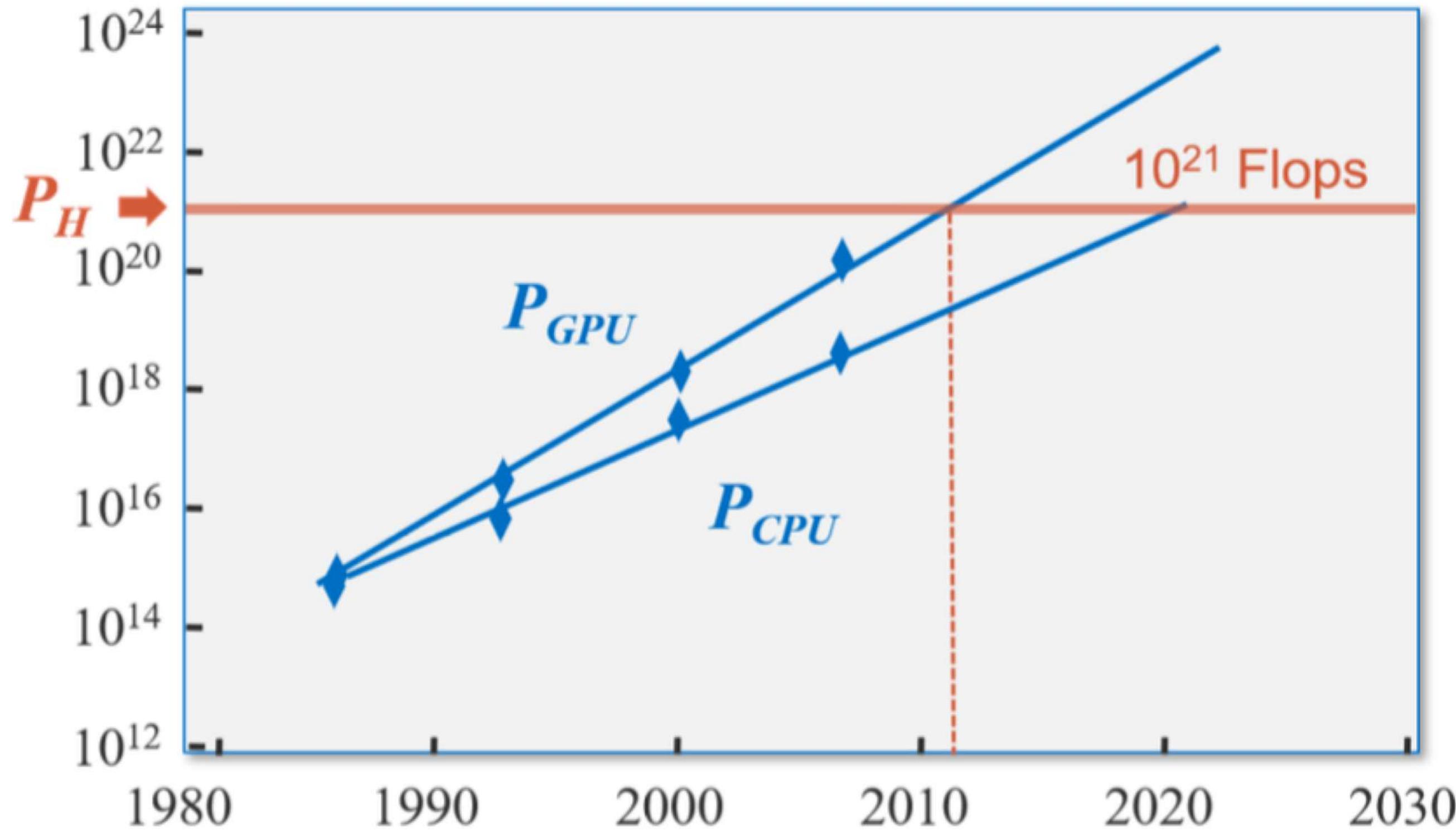
Cheap Resource
Technological “package”
Market structure



Those cycles are changed through techno revolutions.

We are at the beginning of the 4th cycle.

4th cycle resource



Humanity Computing Power:
 10^{10} humans * 10^{10} bytes * 10 Hz ~
~ 10^{21} Flops

Those resources are programmed just by 10^7 people

Technological packages. Industry disruptions

Finance
Bio-Medicine
Transportation
Aero-Space
Management
Agriculture
Energy
Entertainment
...



Industry disruptions

Finance
Bio-Medicine
Transportation
Aero-Space
Management
Agriculture
Energy
Entertainment
...



Whippets with blocked myostatin production
<https://www.nature.com/articles/srep25029>

Industry disruptions

Finance
Bio-Medicine
Transportation
Aero-Space
Management
Agriculture
Energy
Entertainment
...

The screenshot shows the homepage of the journal **nature**, described as an "International weekly journal of science". The navigation bar includes links for Home, News & Comment, Research, Careers & Jobs, Current Issue, Archive, Audio & Video, and For Authors. Below the navigation is a breadcrumb trail: Archive > Volume 530 > Issue 7588 > News > Article. The main headline reads: "NATURE | NEWS UK scientists gain licence to edit genes in human embryos". A sub-headline states: "Team at Francis Crick Institute permitted to use CRISPR–Cas9 technology in embryos for early-development research." The author's name, "Ewen Callaway", is visible at the bottom of the article summary.

Industry disruptions

Finance
Bio-Medicine
Transportation
Aero-Space
Management
Agriculture
Energy
Entertainment
...



Market Structure

3rd cycle:

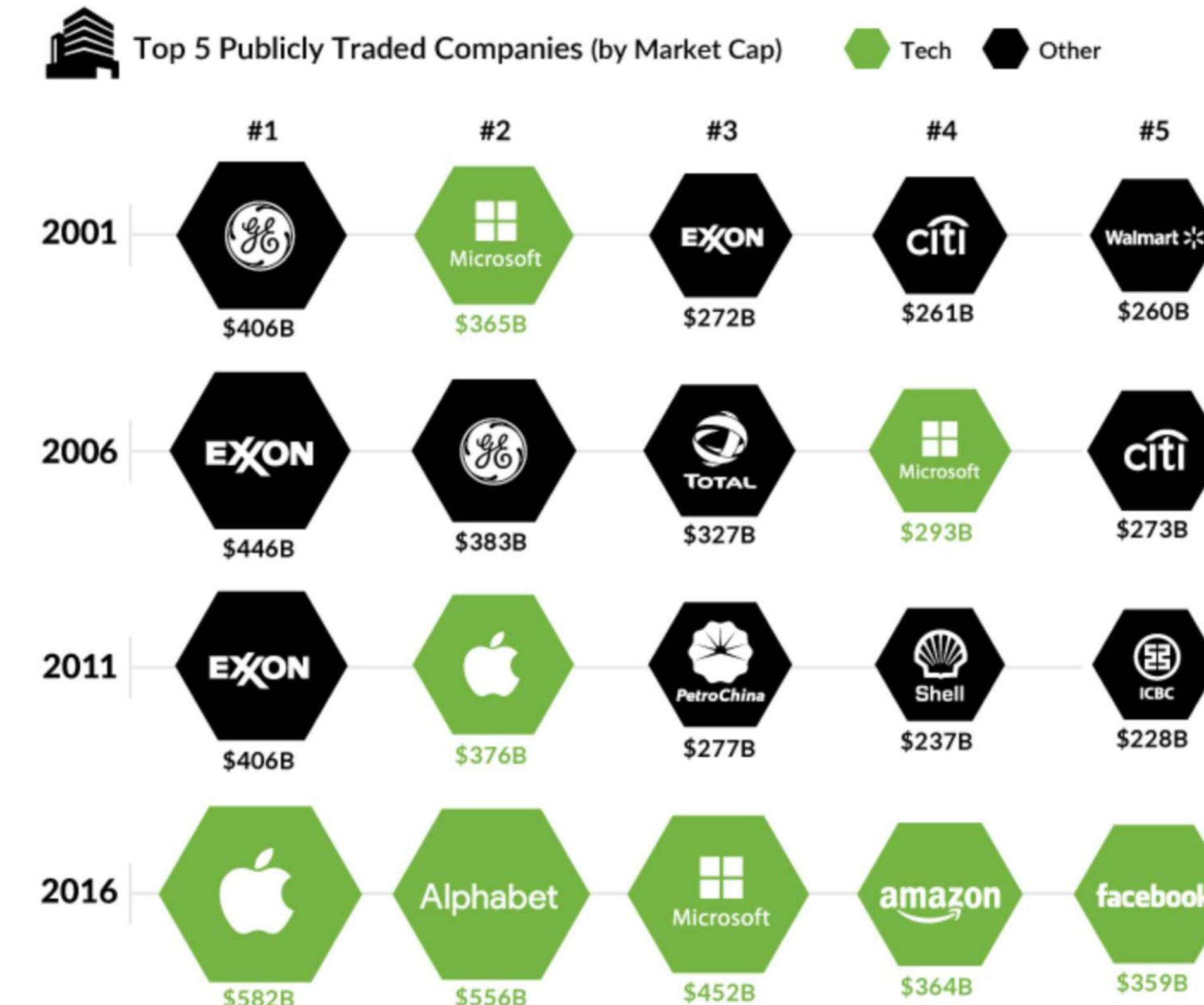
Mass production
Consumerism stimulation

4th cycle:

Individual targeting
Shared (gig) economics
Experience as a product
Online platform as a selling media

THE LARGEST COMPANIES BY MARKET CAP

The oil barons have been replaced by the whiz kids of Silicon Valley



Wrap up (4th Cycle)

Cheap resource: computing

Technology package:

- › robotics,
- › nanotechnology,
- › quantum computing,
- › biotechnology,
- › ...
- › fifth-generation wireless technologies (5G),
- › 3D printing,
- › fully autonomous vehicles
- › Artificial Intelligence is essential component of the package

Market structure: online platforms, personalised experience

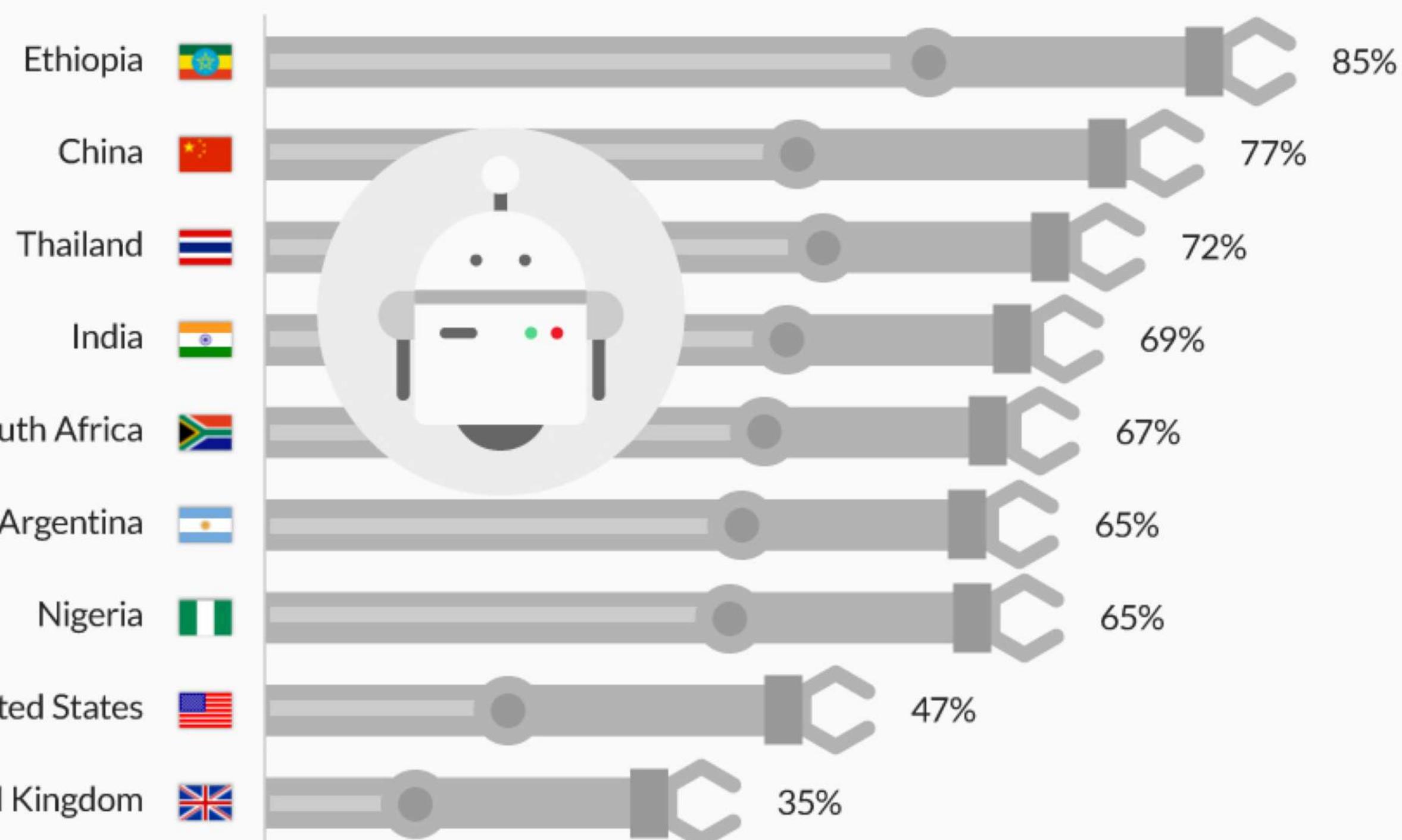
"[AI] is inspired by people, it's created by people, and—most importantly—it impacts people. It is a powerful tool we are only just beginning to understand, and that is a profound responsibility."

Fei-Fei Li

Jobs at risk

Where are jobs most likely to be replaced by robots?

Risk of jobs being replaced by automation in selected countries in 2016



Source: World Bank Development Report, Citigroup

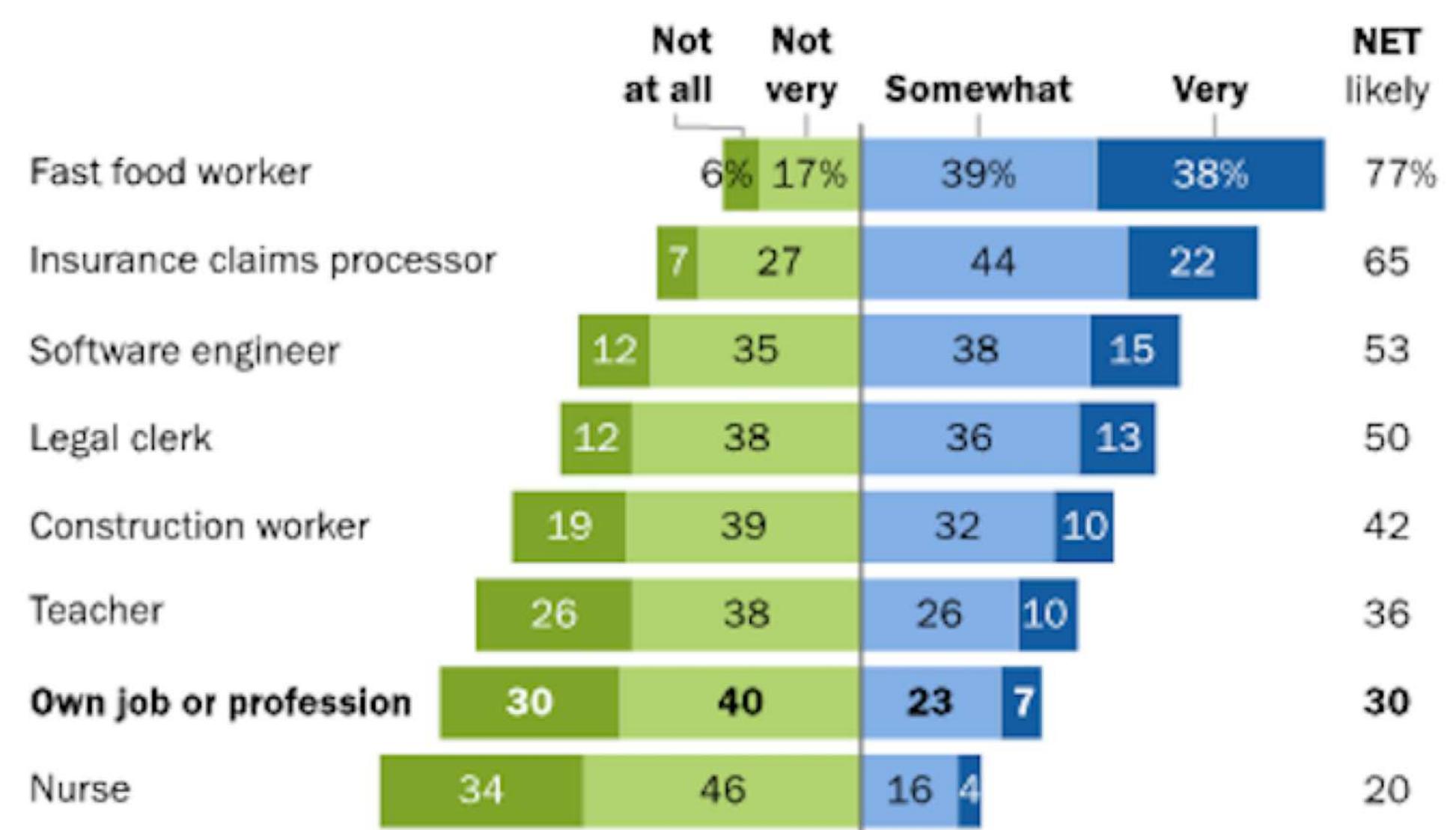
indy100

from
The INDEPENDENT

statista

Americans view certain professions as being at greater risk of automation than others

% of U.S. adults who say it is ___ likely that the following jobs will be replaced by robots or computers in their lifetimes



Note: Data for "own job or profession" is based on those who are currently employed. Respondents who did not give an answer are not shown.

Source: Survey conducted May 1-15, 2017.

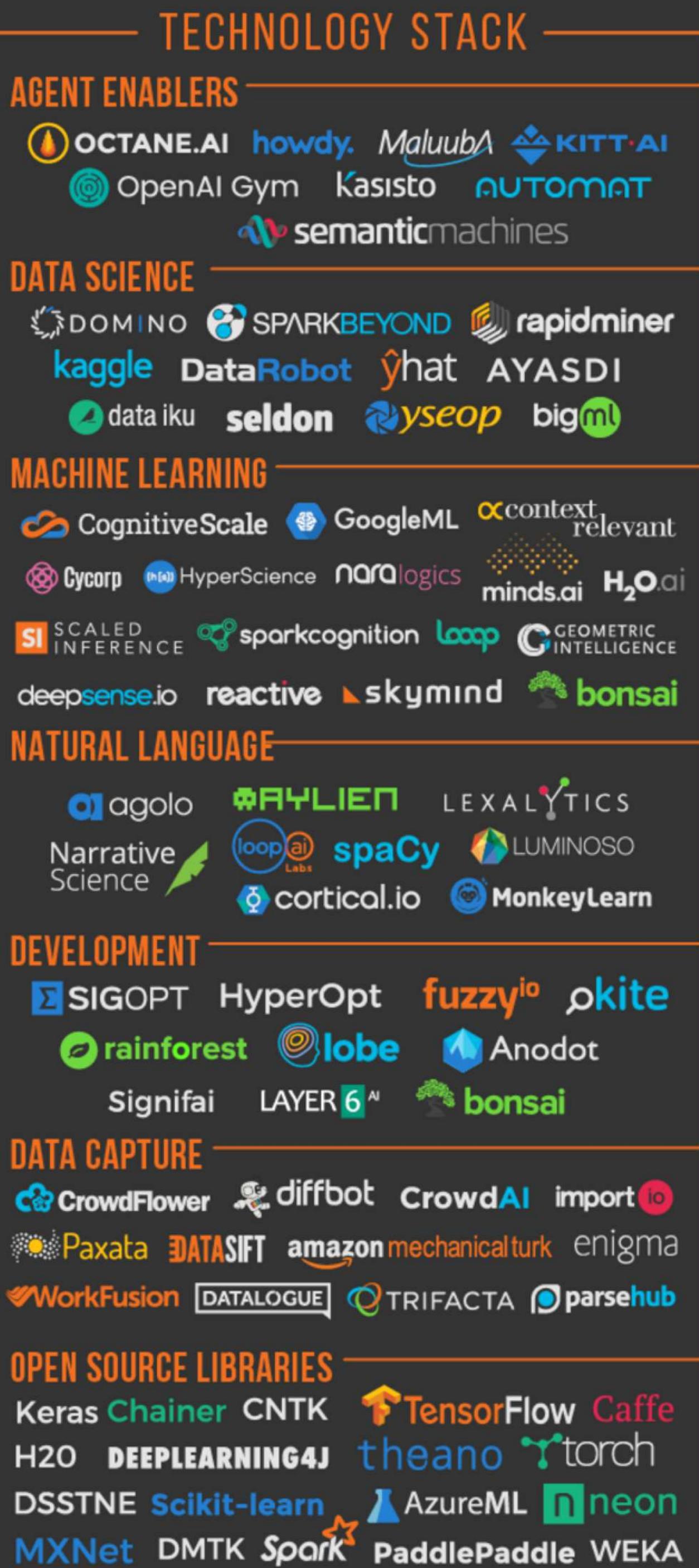
"Automation in Everyday Life"

PEW RESEARCH CENTER

AI as a tool = Machine
Learning



MACHINE INTELLIGENCE 3.0



ENTERPRISE FUNCTIONS

CUSTOMER SUPPORT

DigitalGenius Kasisto
ELOQUENT Wiseio
ACTIONIQ zendesk
Preact CLARABRIDGE

SALES

collective[i] 6sense
fusemachines AVISO
salesforce INSIDE SALES .COM clari
Zensight

MARKETING

MINTIGO Lattice RADIUS
Liftigniter [PERSADO]
brightfunnel retention SCIENCE
COGNICOR AIRPR msgai

SECURITY

CYLANCE DARKTRACE
ZIMPERIUM deepinstinct
Sentinel DEMISTO
graphistry drawbridge
SignalSense AppZen

RECRUITING

textio entelo
Wade & Wendy hiQ
unitive SpringRole
GIGSTER HireVue

AUTONOMOUS SYSTEMS

GROUND NAVIGATION

drive.ai AdasWorks
zoox MOBILEYE
UBER Google TESLA
nutonomy Auro Robotics

AERIAL

SKYDIO SHIELD AI
Airware dji LILY
DroneDeploy SKYCATCH

INDUSTRIAL

JAYBRIDGE OSARO
CLEARPATH fetch
KINDRED rethink robotics
HARVEST AUTOMATION

AGENTS

PERSONAL

amazon alexa
Cortana Allo
facebook Siri
Replika

PROFESSIONAL

butter.ai pogo SKIPFLAG
clara x.ai slack
talla Zoom.ai sudo

AGRICULTURE

BLUEBIRD mavrx
tule TRACE GENOMICS Pivot Bio
Terravion AGRI-DATA
Descartes Labs udio abundant ROBOTICS

EDUCATION

KNEWTON volley
gradescope
VCTI coursera
UDACITY alt school

INDUSTRIES

INVESTMENT

Bloomberg sentient
iSENTIUM KENSHO
alphasense Dataminr
CEREBELLUM CAPITAL Quandl

LEGAL

blueJ BEAGLE
Everlaw RAVEL
seal ROSS
LEGAL ROBOT

LOGISTICS

NAUTO Acerta
PRETECKT clearmetal
Routific MARBLE PITSTOP

INDUSTRIES CONT'D

MATERIALS

zymergen Citrine
Eigen Innovations
SIGHT MACHINE
GINKGO BIOWORKS nantronics
CALCULARIO

RETAIL FINANCE

TALA zest finance
Lendo earnest
Affirm MIRADOR
wealthfront Betterment

PATIENT

PULSE CareScore
ZEPHYR HEALTH IBM Watson Health
Oncora SENTRIAN
Atomwise Numerate

HEALTHCARE

IMAGE

BUTTERFLY 3SCAN
ARTERYs enlitic
BAYLABS imagia
Google DeepMind

BIOLOGICAL

iCarbonX color GRAIL
deep genomics RECURSION
LUMINIST Numerate
Atomwise verify WHOLE BIOME

MACHINE LEARNING

CognitiveScale GoogleML context relevant
Cycorp HyperScience nara logics minds.ai H2O.ai
SCALED INFERENCE sparkcognition loop GEOMETRIC INTELLIGENCE
deepsense.io reactive skymind bonsai

NATURAL LANGUAGE

agolo RYLIEN LEXALYTICS
Narrative Science loop lab spaCy LUMINOSO
cortical.io MonkeyLearn

DEVELOPMENT

SIGOPT HyperOpt fuzzy io okite
rainforest globe Anodot
Signifai LAYER 6 bonsai

DATA CAPTURE

CrowdFlower diffbot CrowdAI import io
Paxata DATASIFT amazon mechanical turk enigma

WorkFusion DATALOGUE TRIFACTA parsehub

OPEN SOURCE LIBRARIES

Keras Chainer CNTK TensorFlow Caffe
H2O DEEPLearning4J theano torch
DSSTNE Scikit-learn AzureML neon
MXNet DMTK Spark PaddlePaddle WEKA

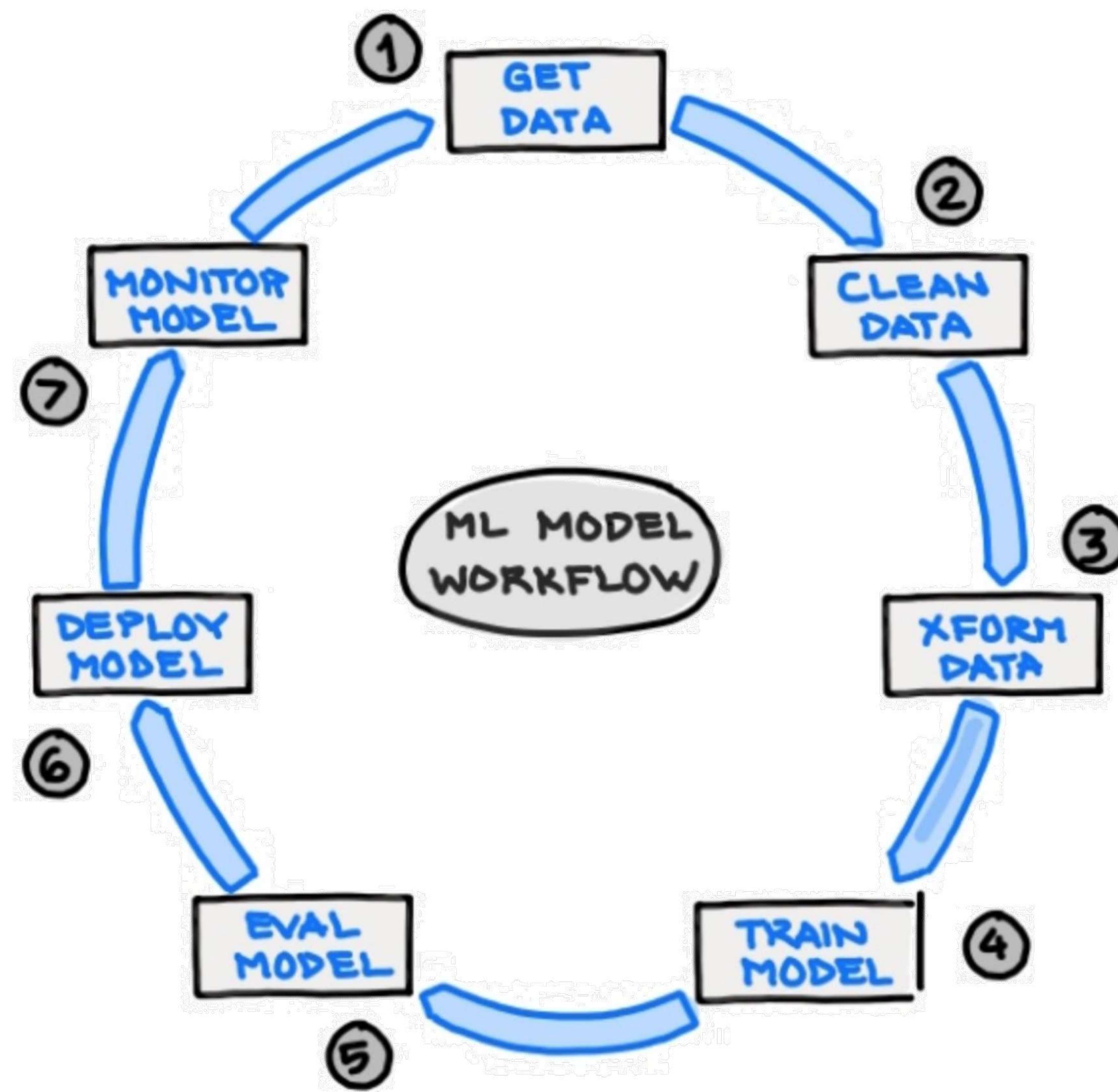
HARDWARE

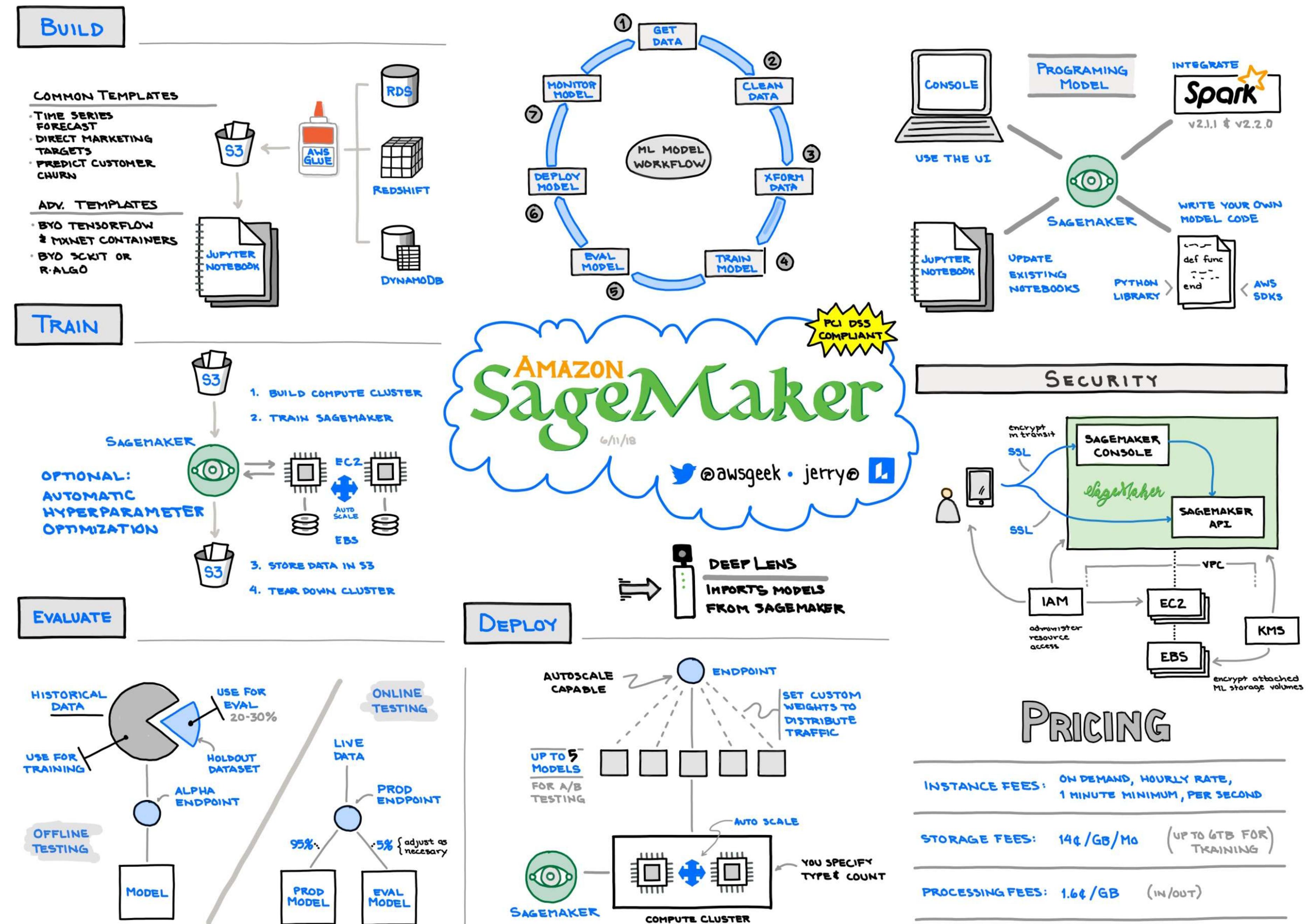
KNUPATH TENSTORRENT Cirrascale
NVIDIA nervana Movidius
tensilica GoogleTPU 10²⁶ Labs Qualcomm
Cerebras Isosemi

RESEARCH

OpenAI nnaisense ELEMENT vicarious
KNOGIN Numenta Kimera Systems Cogital

Stages of Machine-Learning study in industry

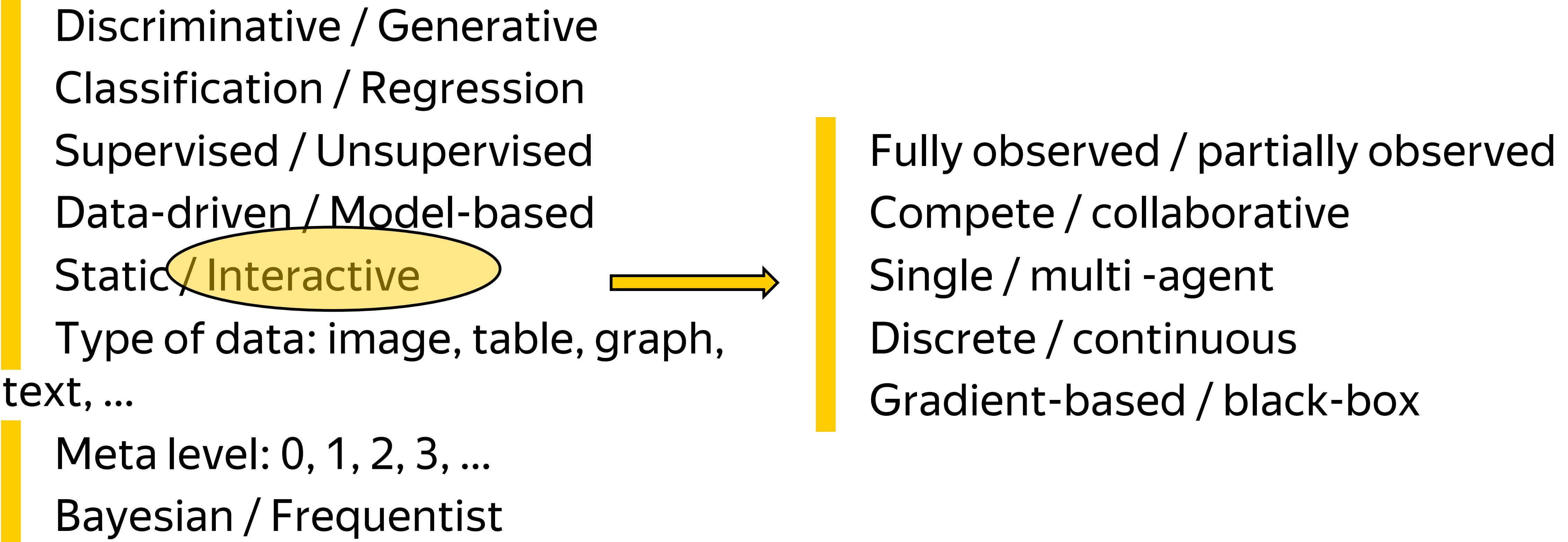








High-level dimensions for ML methods



AI as a science



Abridged history of Science

1000+ years - empirical (Aristotle, Democritus,)

100+ years – theoretical (Newton, Kepler,)

50+ years – computational (John von Neumann,)

10+ years – data driven (the “Fourth paradigm”, Jim Gray,)

- › Unify theory, experiment and simulation
- › Data is captured or simulated
- › Processed by software
- › Information/knowledge is stored in computer
- › Scientists analyzes database/files using data management and statistics

Demand for more

From 'shallow' AI to Artificial Generic Intelligence

From optimization heuristic to theory of how mind works

Biological-inspired computing architectures

https://blogs.scientificamerican.com/observations/ais-big-challenge1/?fbclid=IwAR2KMaT3D_Jpl43T4EtOuyL5qmp1qoMpMfDbeXkwBJ-MhXmmAnpEd7o_1Gc

“Man is something that shall be overcome. Man is a rope tied between beast and overman - a rope over an abyss. What is great in man is that he is a bridge and not an end.”

Friedrich Nietzsche

AI challenges

- Going Beyond iid assumption (extrapolation)
- Predictive model bias estimation
- Human in the loop training
- Partially observable environment / behaviour
- Privacy-enabled AI
- Simulated environment (fast, realistic, comprehensive)
- Richer knowledge / experience representation
- AI-enabled science



Thanks to machine-learning algorithms,
the robot apocalypse was short-lived.

Physics as AI driver



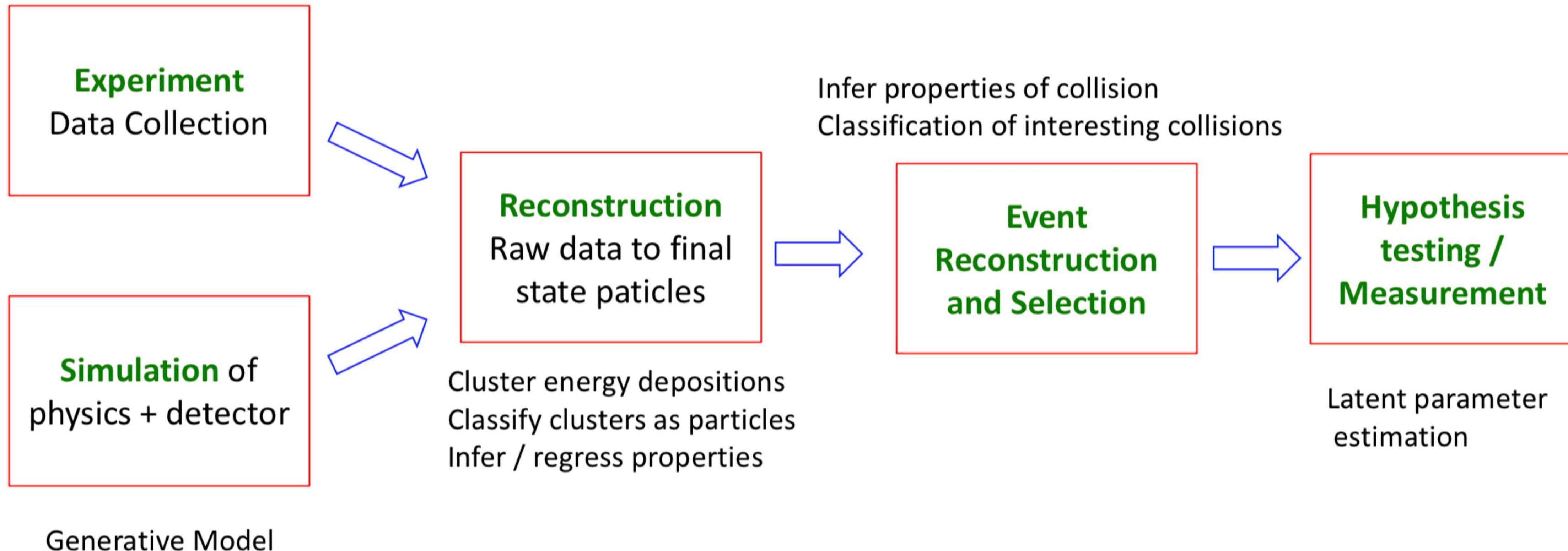
Physics-inspired ML approaches



- Simulated Annealing
- MCMC techniques
- Gibbs sampling
- Gaussian process
- Gradient descent
- Boltzmann Machine
- Energy-based GANs

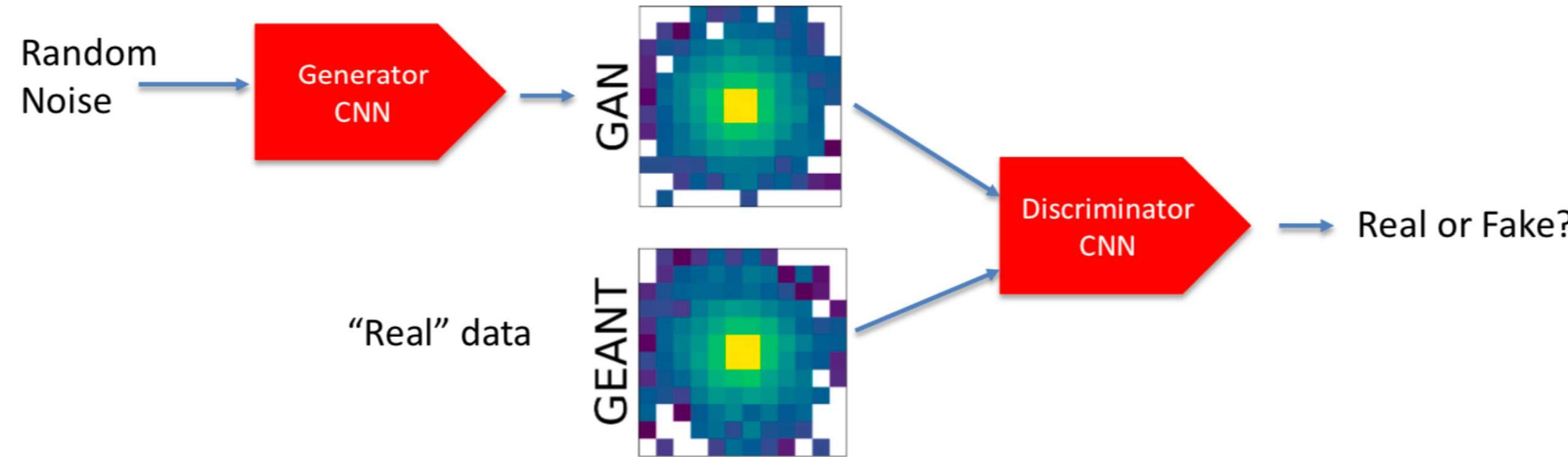
Arxiv:1903.10563

Main application areas

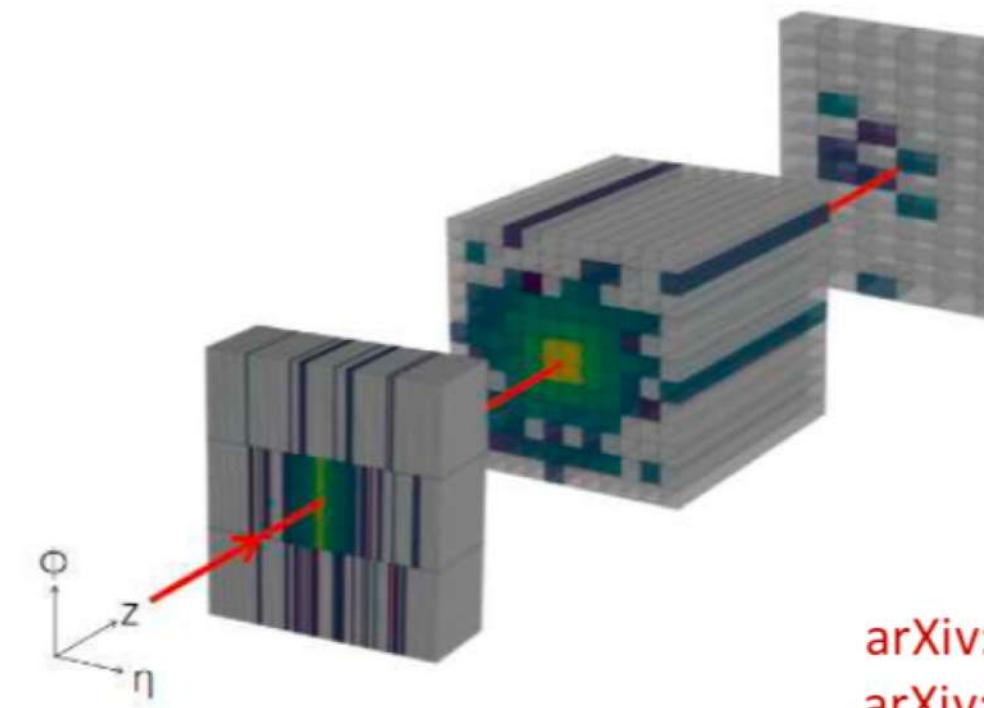


<http://bit.ly/2FHWTZ4>

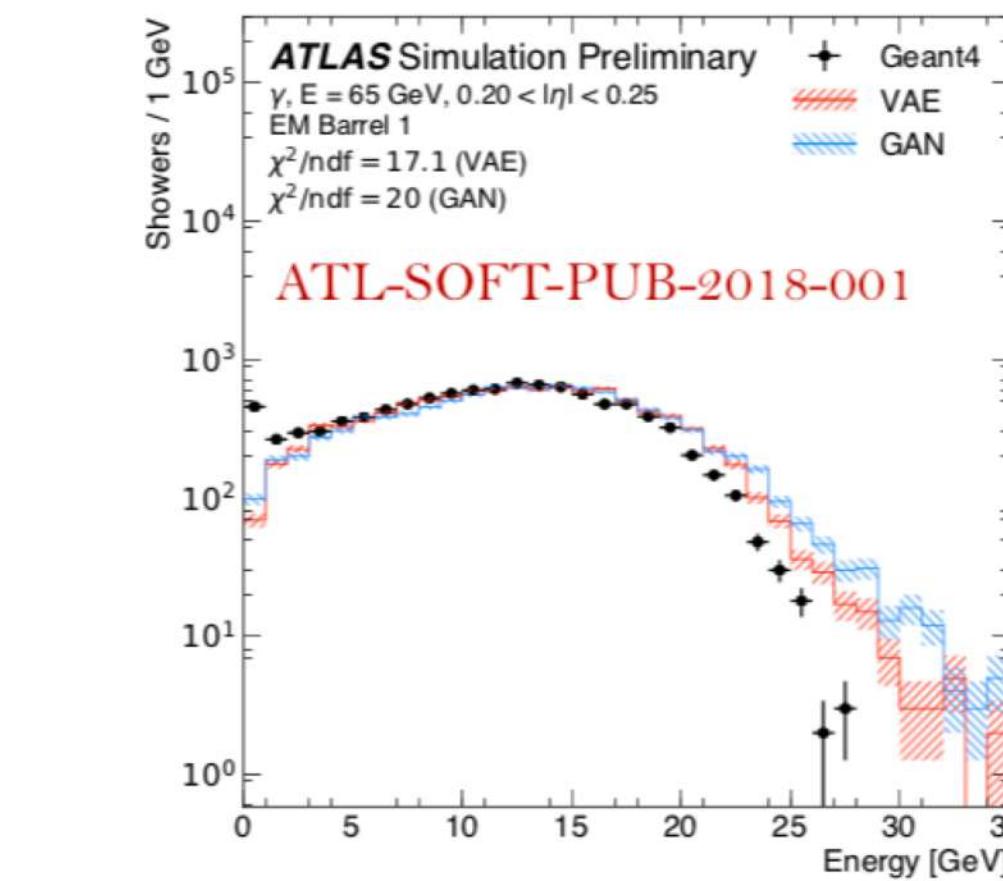
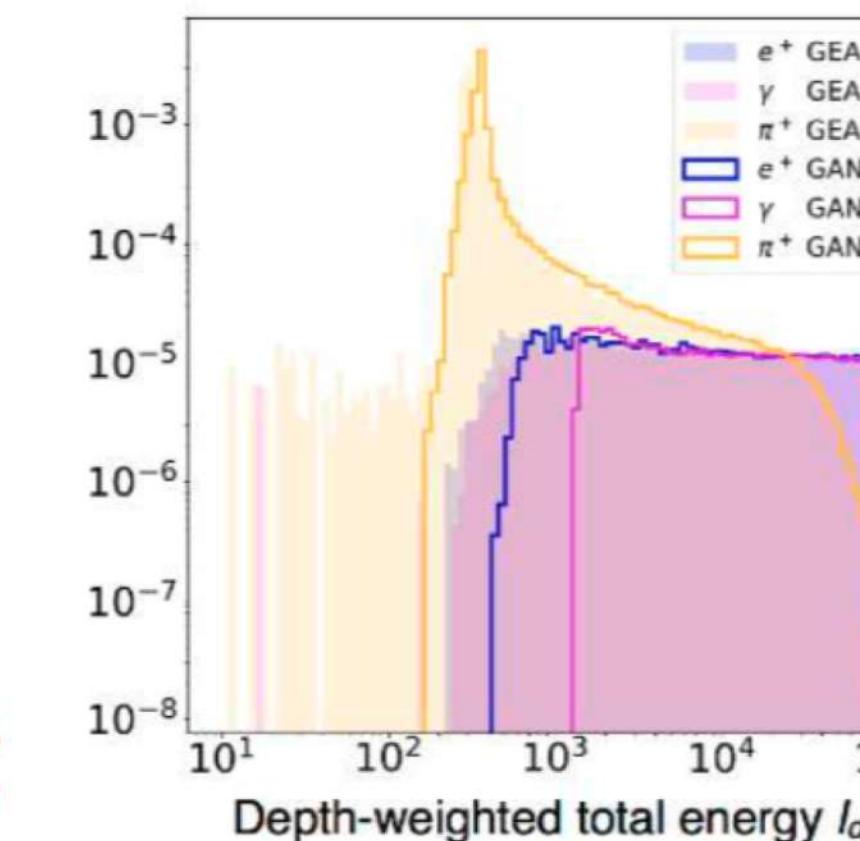
Generative model example



- GANs and VAEs being studied for generating Jet-images, and 3D calorimeter energy depositions in toy simulation and at the LHC experiments!



arXiv:1705.02355
arXiv:1701.05927



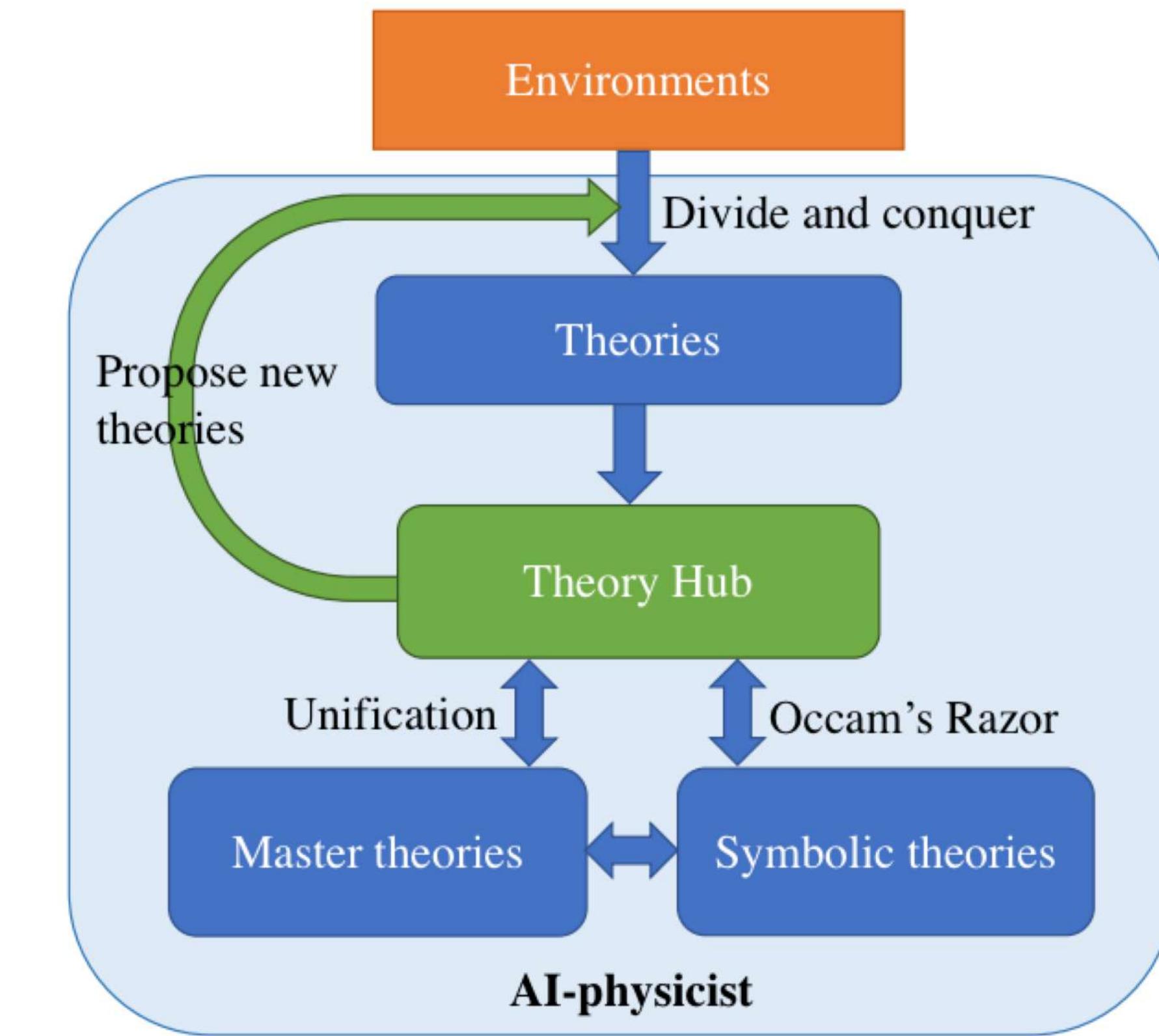
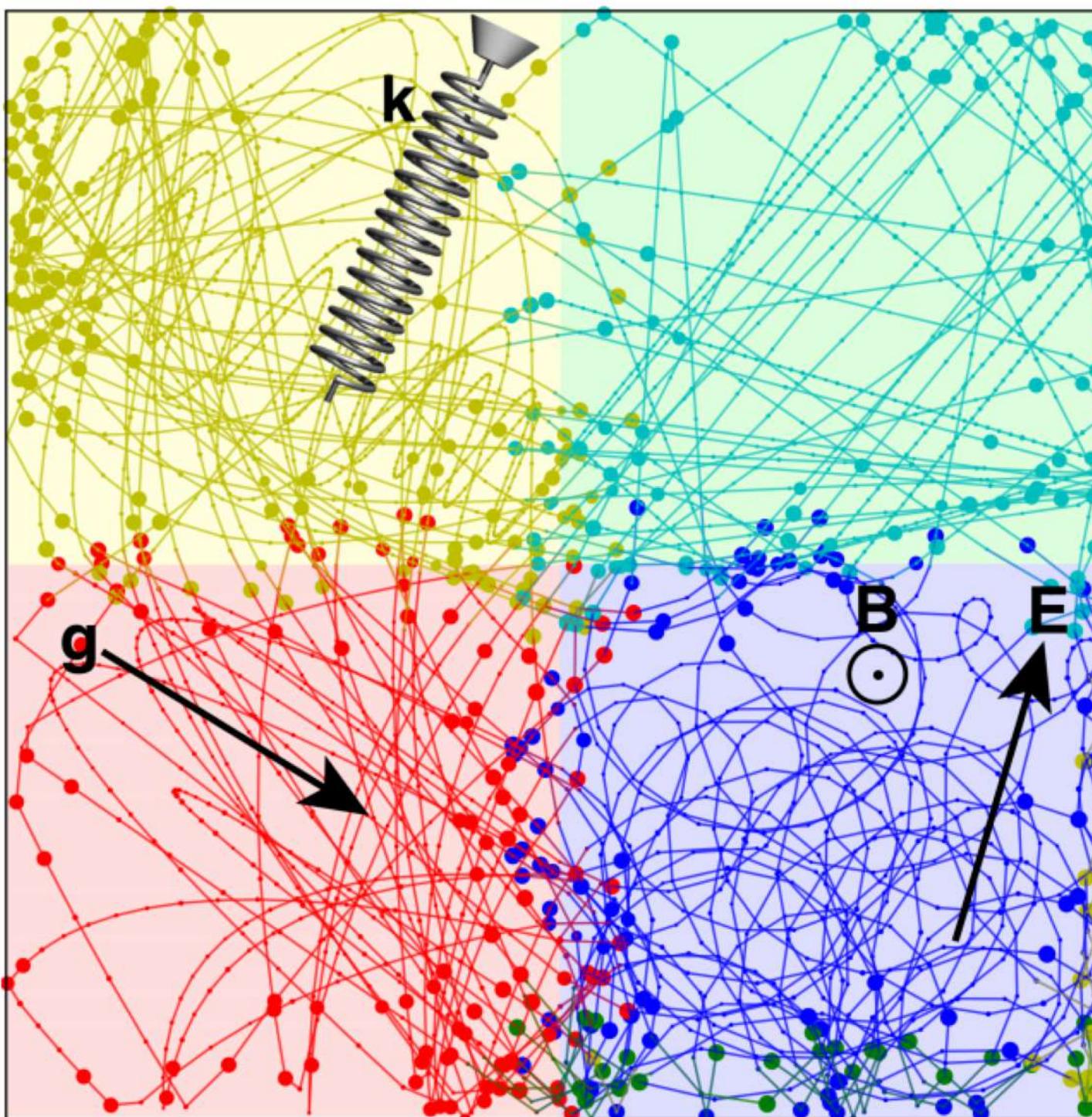
Modern AI Challenges in Physics

- Better understanding how to use computer vision and natural language processing techniques
- Thinking about new data structures, like trees and graphs, that can be analyzed with Deep Learning
- Can ML help with our most computationally costly problems, like simulation or the combinatorial challenge of tracking?
- Can fast $O(ns-\mu s)$ NN inference be done with FPGAs to put ML early in the trigger / data acquisition process?
- Can we design better architectures and training algorithms to tackle our HEP challenges?
- How can we make best use of our simulation for inference without the PDF, i.e. Likelihood Free Inference?

nature.com/articles/s41586-018-0361-2

AI Physicist

Unsupervised explorer algorithm



Conclusion

Humanity demand for augmentation

- › AI as a driver/enabler for ongoing industrial revolution
- › AI as a set of tools / methods
- › AI as playground for theory of intelligence

Huge room for development

- › Post-disciplinary science
- Physics is playing leading role in adoption of ML methods / even production of new ideas for those

Backup



References

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<https://www.amazon.com/Sapiens-Humankind-Yuval-Noah-Harari/dp/0062316095>

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Schwab, Klaus. The Fourth Industrial Revolution. New York: Crown Publishing Group, 2017.

UN Sustainable Development Goals



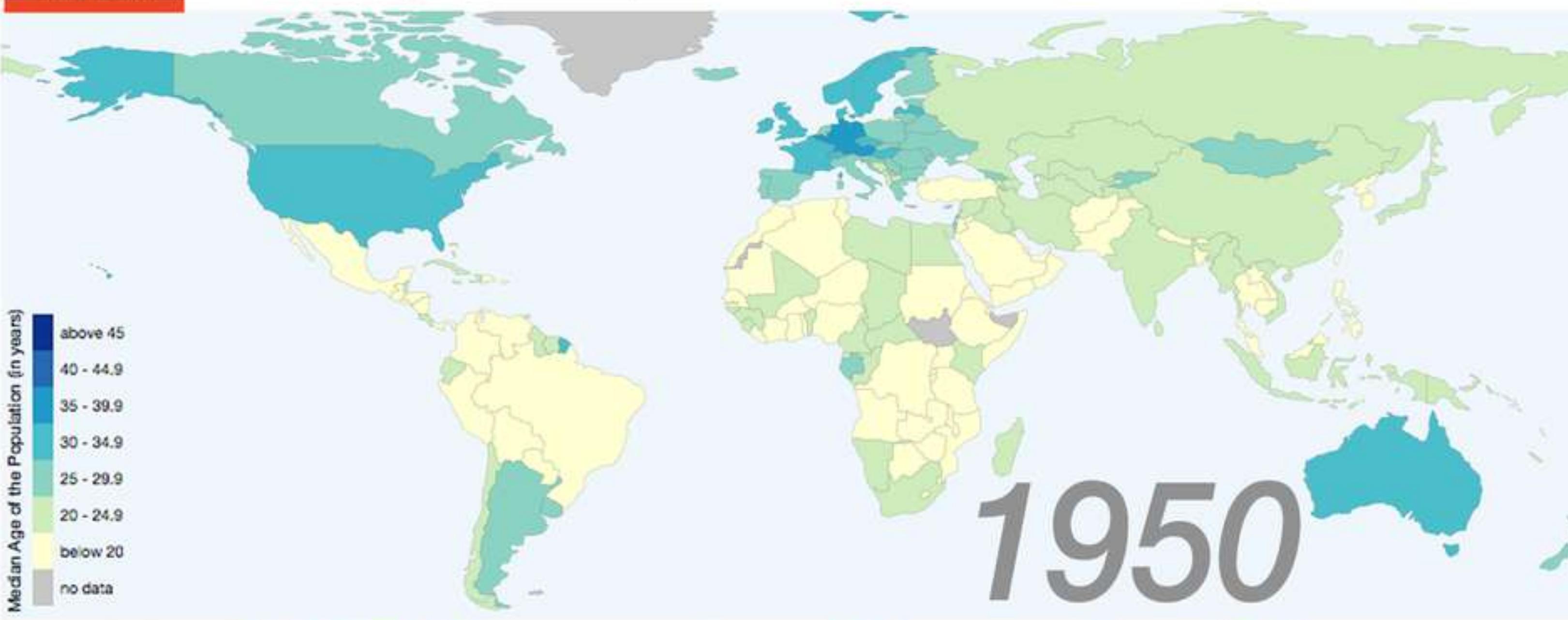
Source: RobecoSAM

<https://xkcd.com/1838/>

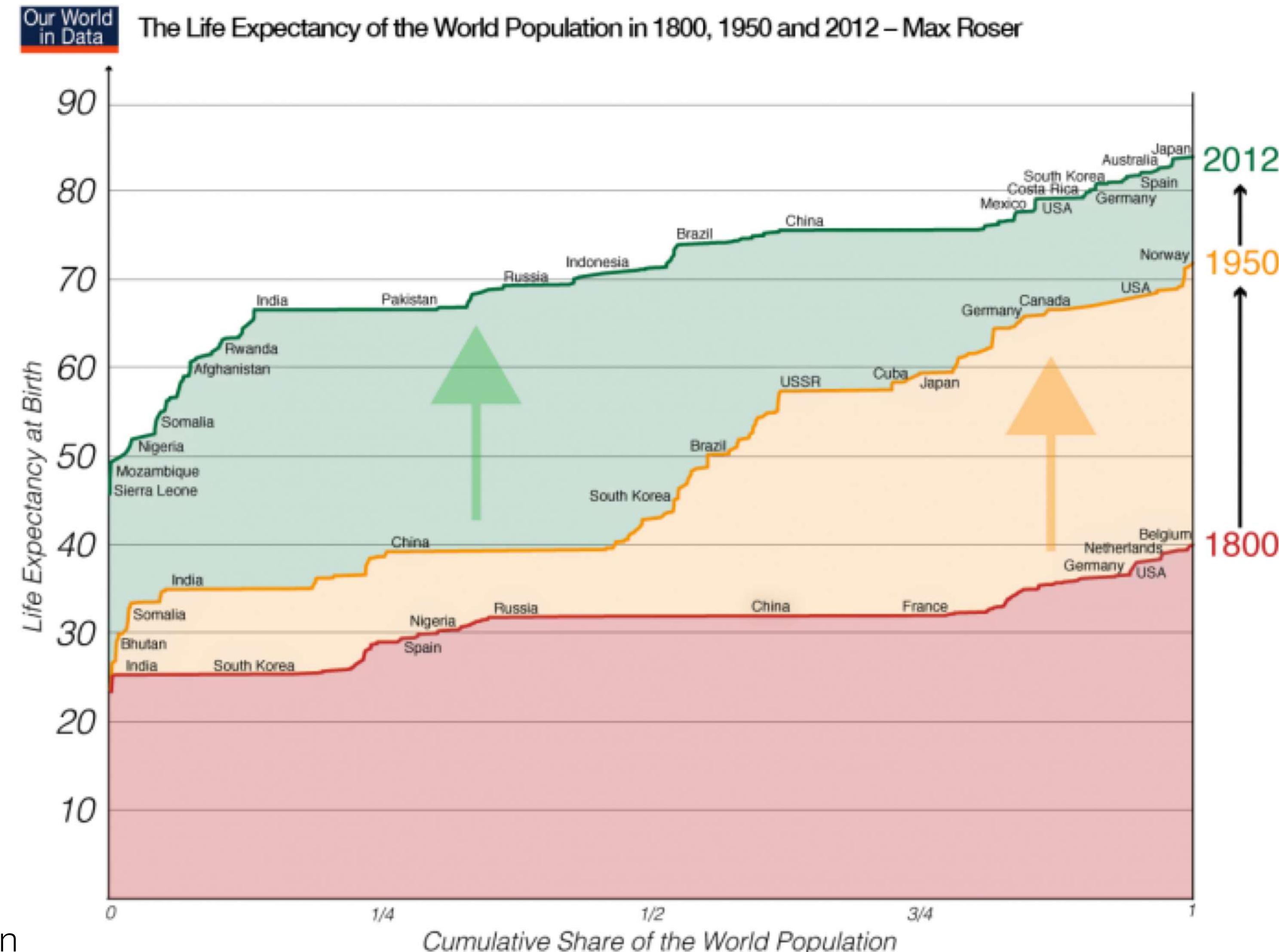
© British Telecommunications plc 2019



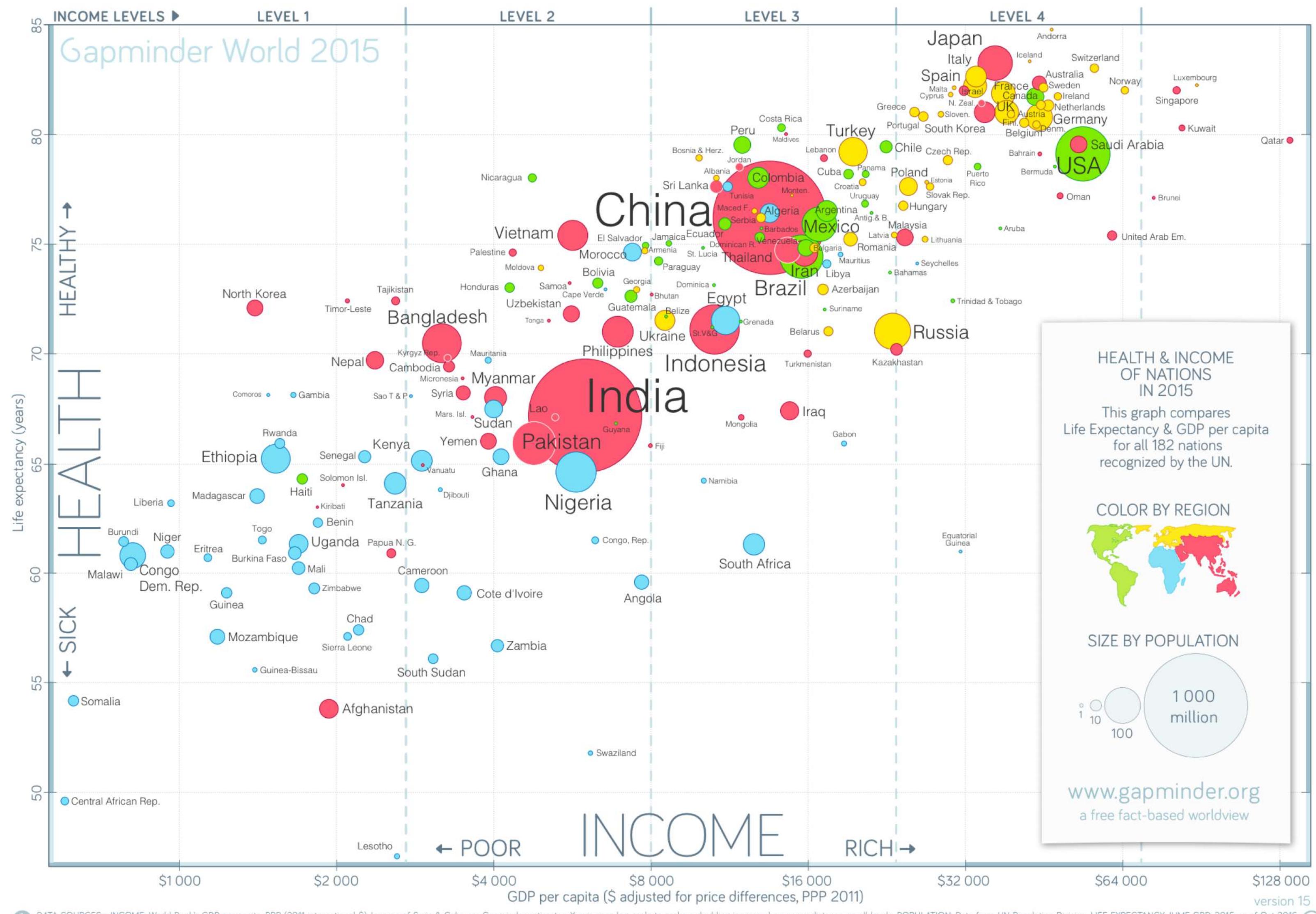
Median Age of the Population in 1950 and 2010



Industrial Revolution vs Life Expectancy



Humanity in numbers



Utopian/dystopian movie

Star Trek

Valerian and the City of a
Thousand Planets

Fifth Element

Her

Matrix

Star Wars

Black Mirror

Blade Runner

Altered Carbon

Westworld