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Enlightenment

The View From Here

# Deep Reinforcement Learning

## Deep Learning — Unit 8

Dr. Jon Krohn

jon@untapt.com

December 7th, 2019

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# Categories of A.I.

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- 1 ANI: *Narrow*
- 2 AGI: *General*
- 3 ASI: *Super*



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- 1 supervised learning
- 2 unsupervised learning
- 3 reinforcement learning

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# Supervised Learning

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The View From Here

- **have  $x$  and  $y$**
- goal is to approximate function that predicts  $y$  with  $x$
- e.g.: classification (MNIST digits, IMDB sentiment), regression (sales of a product, future value of an asset)

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- **have  $x$  without  $y$  labels**
- goal is to learn data's underlying hidden structure
- e.g.: word vectors, GANs

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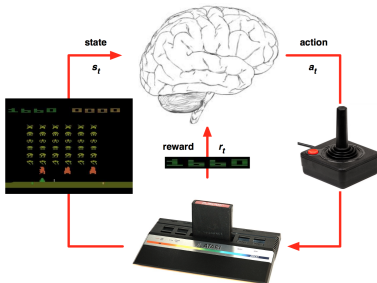
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The View From Here



- an *agent* takes action in an *environment*
- environment returns *state*, i.e., *reward* at  $t$ , state at  $t + 1$
- repeat

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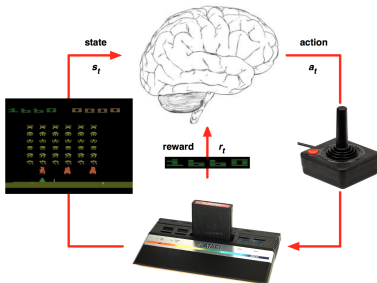
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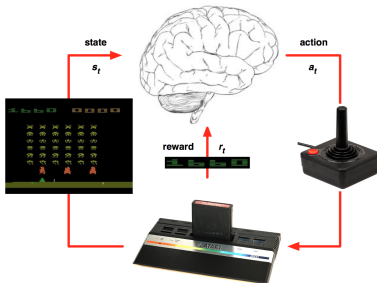
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# Deep Q-Learning

Mnih et al. (2013)

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- “Playing Atari with Deep RL”
  - NIPS and arXiv paper
  - played seven Atari 2600 games
  - beat previous ML approaches on six
  - beat human expert on three

# Deep Q-Learning

Mnih et al. (2013)

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Mnih et al. (2013)

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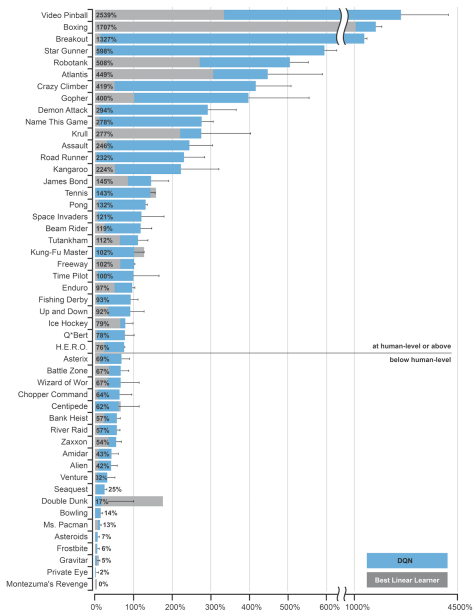
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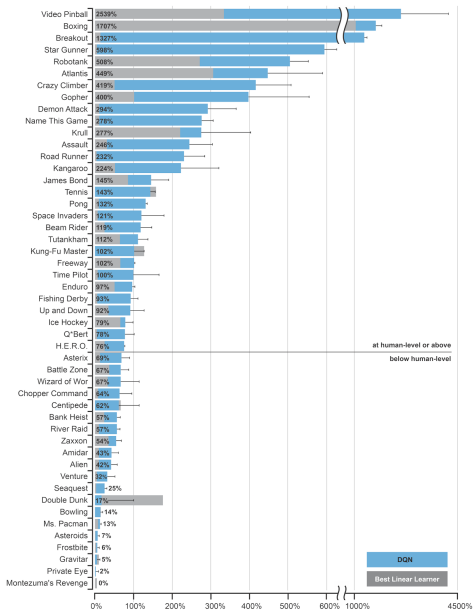
Mnih et al. (2015)



[Atari Games]

# Deep Q-Learning

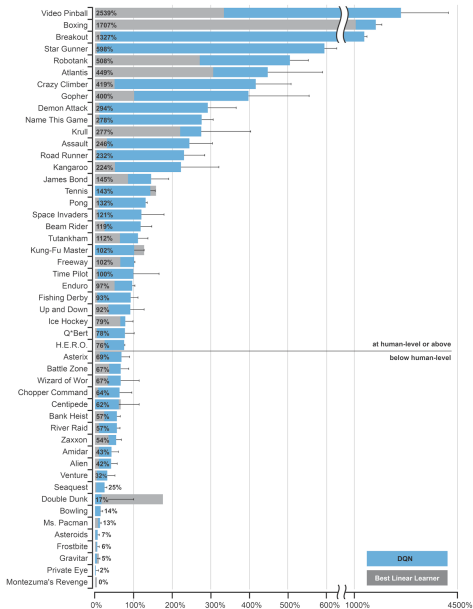
Mnih et al. (2015)



[Atari Games]

# Deep Q-Learning

Mnih et al. (2015)



[Atari Games]

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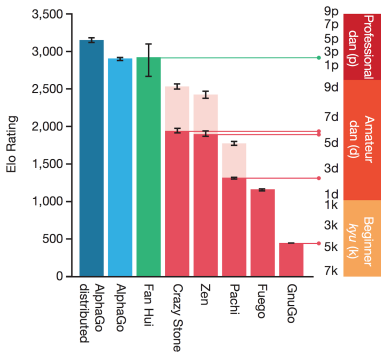
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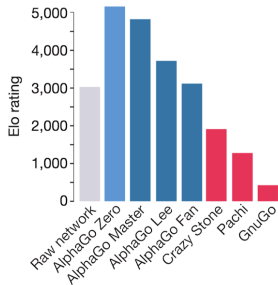
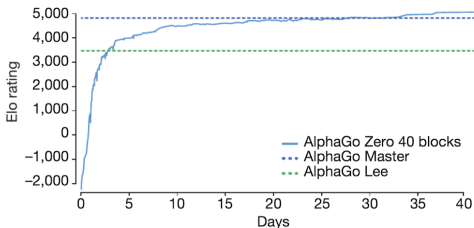
# AlphaGo

Silver et al. (2016)



# AlphaGo Zero

Silver et al. (2017a)





# AlphaZero

Silver et al. (2017b)

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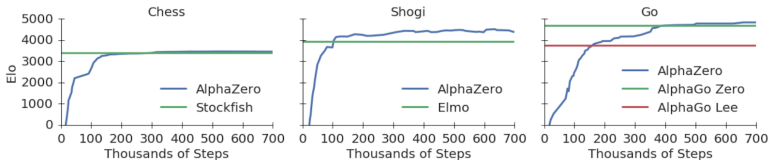
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# AlphaFold

Evans et al. (2018)

[ animation of protein-structure prediction ]

# Real-World End-to-End

Levine et al. (2016)

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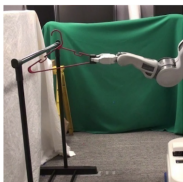
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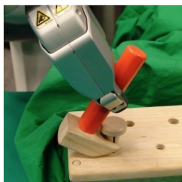
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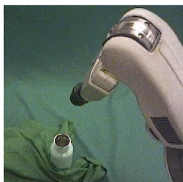
(a) hanger



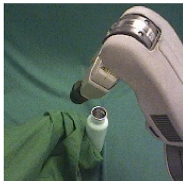
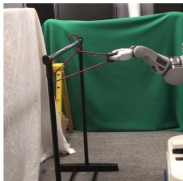
(b) cube



(c) hammer



(d) bottle



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- 1 OpenAI Gym
- 2 DeepMind Lab
- 3 Unity

...or create your own with, e.g., the PyGame Learning Environment

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# Essential Deep Q-Learning Theory

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[ whiteboarding ]



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# The Cartpole Game

OpenAI

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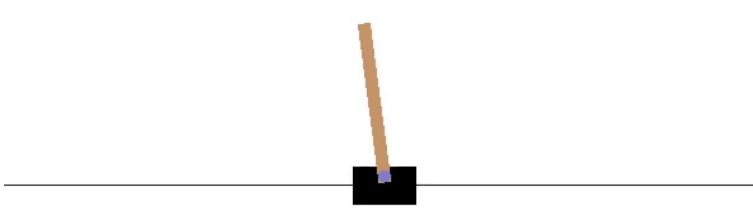
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- 1 cart position
- 2 cart velocity
- 3 pole angle
- 4 pole angular velocity

# The Cartpole Game

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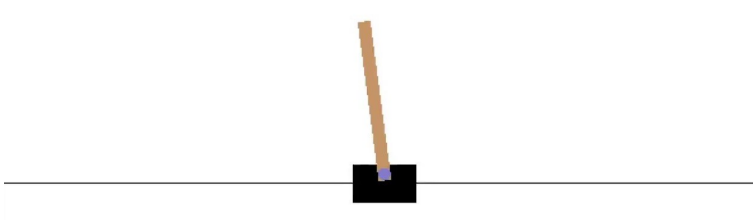
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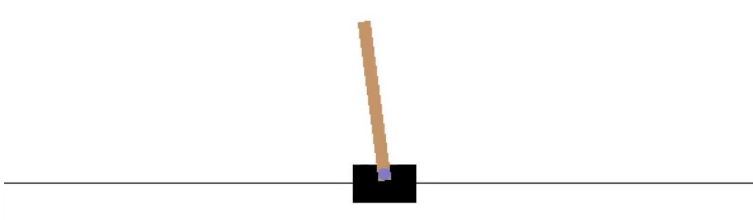
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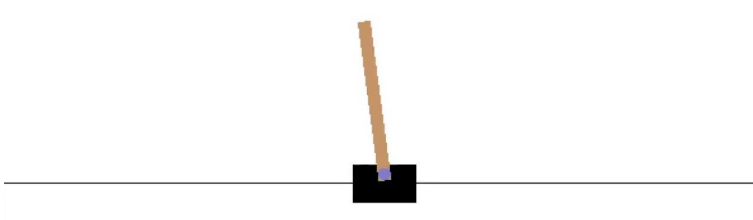
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[ *cartpole* notebook ]

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# Genetic Algorithms

[ Mar/I/O ]

# Ready-Made Agents

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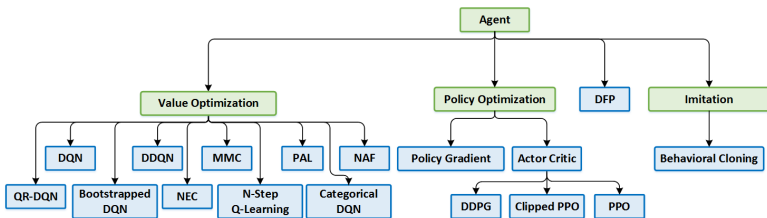
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[ Coach ]

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[ OpenAI Lab ]



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# Human Imitation Learning

Warneken & Tomasello (2006)

[ videos ]

# Machine Imitation Learning

Finn, Levine & Abbeel

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[ videos ]

# Software 2.0 Pros

Karpathy (2017)

- 1 Computational Homogeneity
- 2 Constant Running Time
- 3 Constant Memory Use
- 4 Portable Across Devices
- 5 Easy
- 6 Superior

[ Medium ]

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# Jeanne Calment

(1875-1997 — i.e., 122 years)

21



1896

121



1996

# Life in the Year 2140

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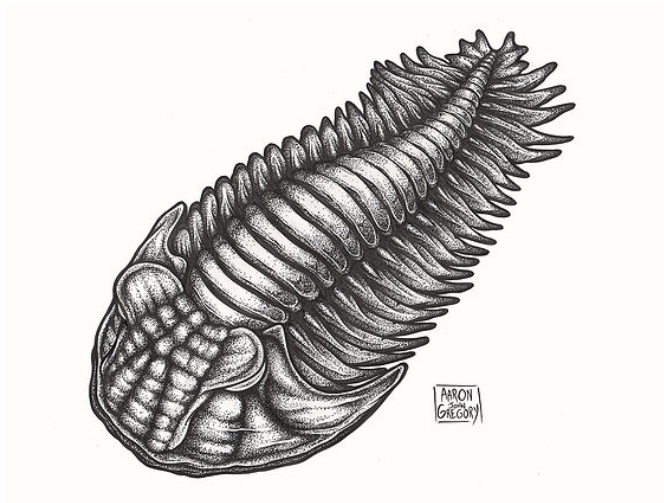
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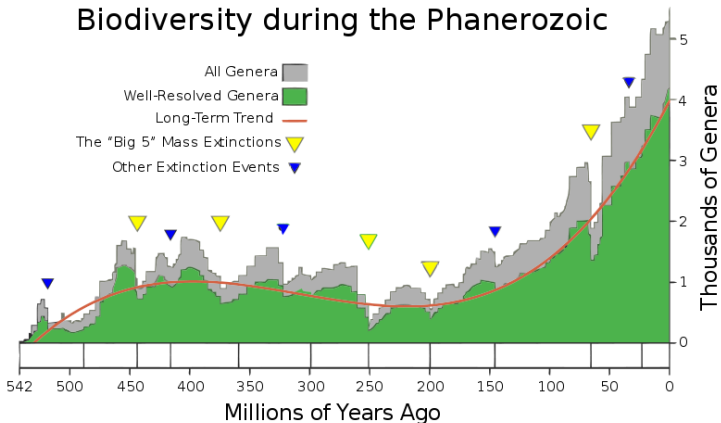
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## Biodiversity during the Phanerozoic





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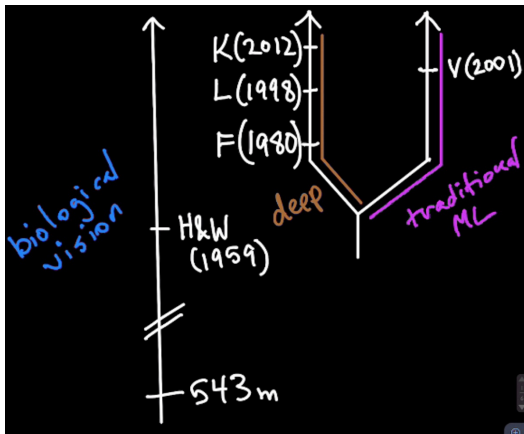
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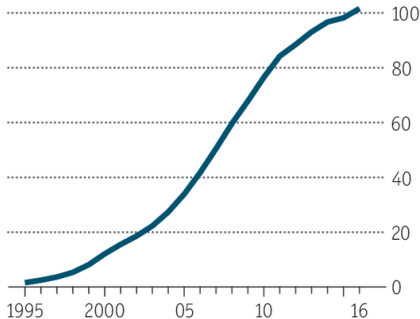
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## Everybody's choice

Mobile-phone penetration

Per 100 people, worldwide



Source: ITU

Economist.com

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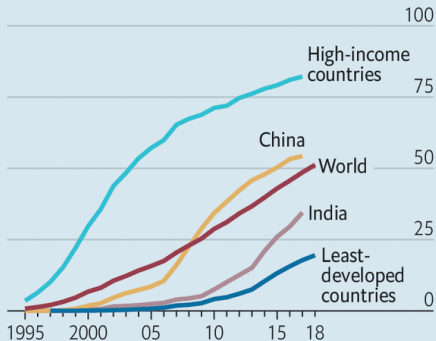
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## More to come

1

Population using the internet, %



Source: ITU

The Economist

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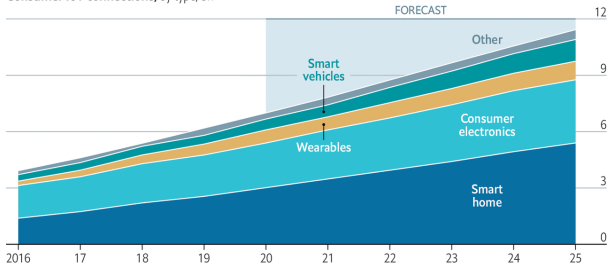
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## Get connected

Consumer IoT connections, by type, bn



Worldwide smart-speaker shipments, m



Sources: GSMA Intelligence; Canalis  
The Economist

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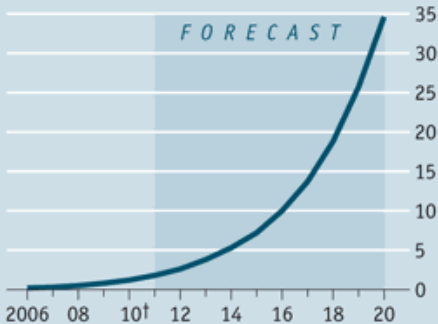
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Worldwide digital data created and replicated  
Zettabytes\*



Source: IDC \*1 zettabyte = 1 trillion gigabytes †Estimate

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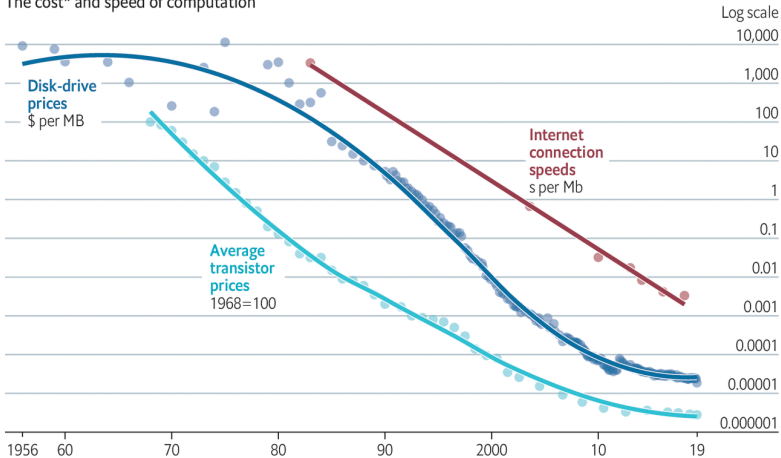
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## Decline and fall

The cost\* and speed of computation



Sources: John C. McCallum; Gordon Moore; The Linley Group; Nielsen Norman Group; *The Economist*

\*Nominal prices

The Economist

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- 1 Data, incl. Sensors Everywhere
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- 3 Algorithms
- 4 Infrastructure

[ Wait But Why ]



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# Categories of A.I.

- 1 ANI: *Narrow*
- 2 AGI: *General*
- 3 ASI: *Super*

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# AGI

## Deep Learning Barriers

- 1 Requires Many, Many Samples
- 2 Black Box
- 3 Doesn't Leverage Knowledge of the World
- 4 Correlation = Causation
- 5 Unintuitive / Embarrassing / Adversarial Failures

- 1 Requires Many, Many Samples
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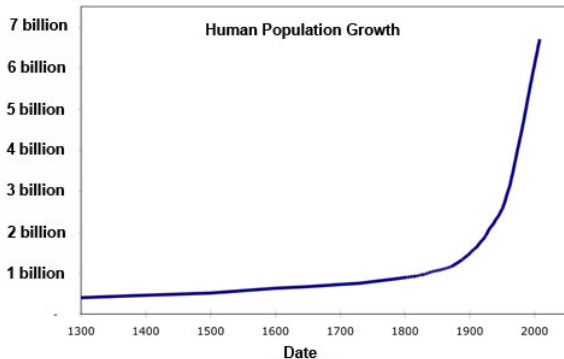
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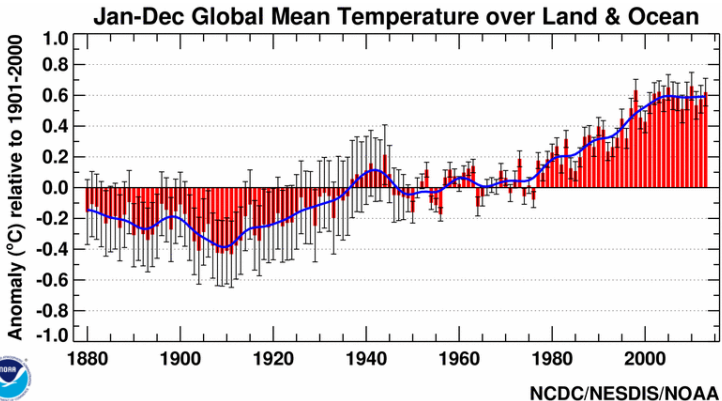
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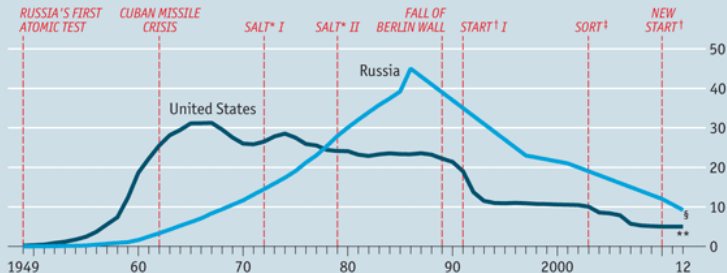
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## Still lots to go around

Nuclear-warhead stockpile, '000



\*Strategic Arms Limitation Treaty †Strategic Arms Reduction Treaty

‡Strategic Offensive Reductions Treaty §Includes 5,500 retired warheads awaiting dismantling

\*\*Excludes retired warheads

Source: Bulletin of the Atomic Scientists

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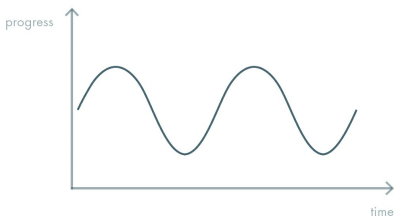
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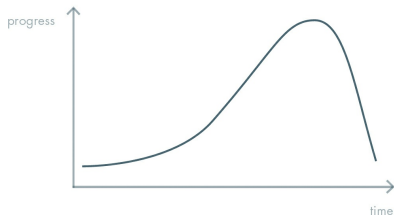
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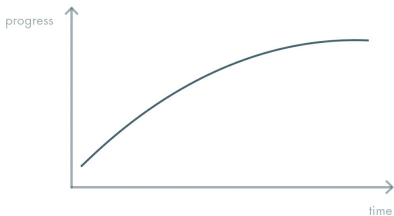
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## EXTINCTION



## PLATEAU



## TAKEOFF





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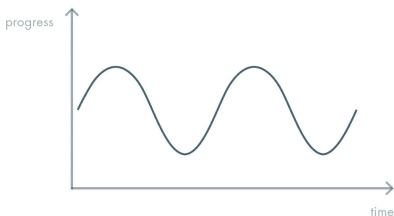
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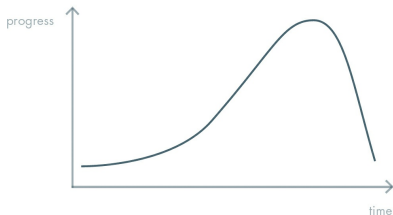
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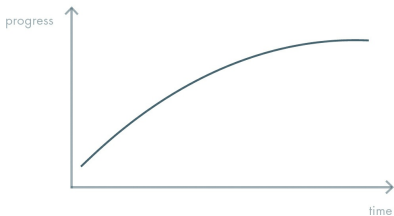
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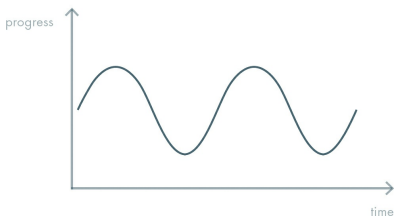
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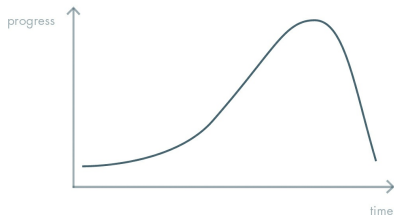
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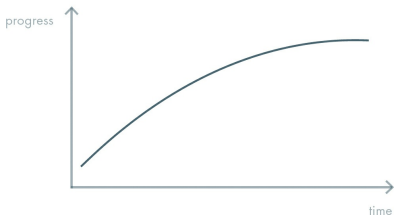
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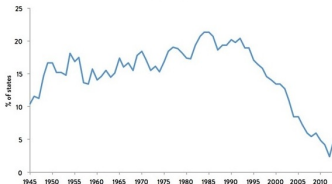
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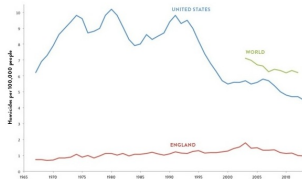
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**PREVALENCE OF MASS KILLINGS  
1945-2013**



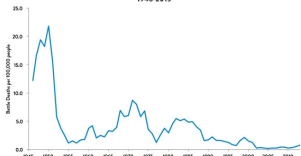
Source: Early Warning Project, <https://earlywarning.worpress.com/>; Ulfelder, Jay and Valentino, Benjamin, "Assessing Risks of State-Sponsored Mass Killing" (Feb. 1, 2006). Available at SSRN: <https://ssrn.com/abstract=1033426> or <http://dx.doi.org/10.2339/arm-031426>

**HOMICIDE RATES IN THE US AND ENGLAND  
1967-2013, AND THE WORLD, 2003-2012**



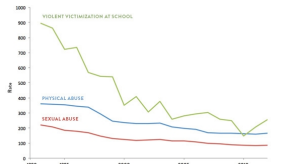
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Source: Utopia Conflict Data Program Battle-Related Deaths v5-2014, 1999-2013, "Best Estimates" Missing estimator for 2013 for the Syria civil war calculated from a revised ICDP "Low Estimate" and a "High Estimate" from the Peace Research Institute Oslo (both obtained in consultation with Erik Meisler of ICDP, The "High Estimate" is for May 2013-April 2014, rather than calendar year 2013, and comes from Page 9 of H. Price, A. Gendau, & P. East, "Underestimated: Statistical Analysis of Documentation of Killings in the Syria Arab Republic," Human Rights Data Analysis Group, [http://www.hrdag.org/Documents/Countries/SY/HRDAG\\_SyriaReportAug2014.pdf](http://www.hrdag.org/Documents/Countries/SY/HRDAG_SyriaReportAug2014.pdf). World population figures from U.S. Census Bureau, [http://www.census.gov/population/international/data/worldpop/stable\\_population.php](http://www.census.gov/population/international/data/worldpop/stable_population.php)

**VICTIMIZATION OF CHILDREN IN THE US  
1990-2012**



Rates for physical and sexual abuse are per 100,000 children younger than 18. Rates for violent victimization at school are per 10,000 children age 5-12.

Sources: Physical and sexual abuse, National Child Abuse and Neglect Data System, analyzed by David Brothman, 2014, in "Trends in Child Welfare," Presentation at the Carney Institute Policy Series, March 30, 2014. Victimization at school, Bureau of Economic Analysis (top.gov), using the National Crime Victimization Survey Victimization Analysis Tool.



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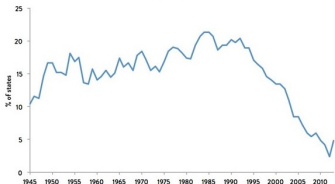
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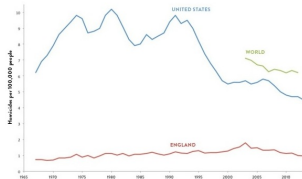
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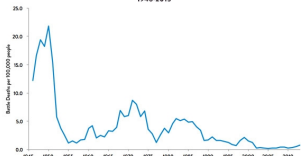
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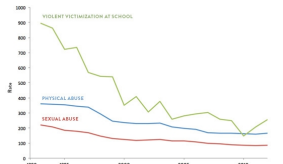
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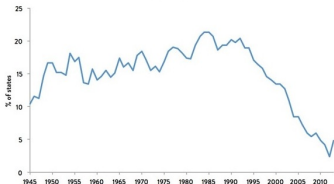
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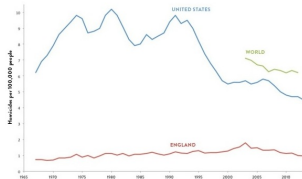
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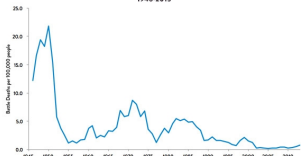
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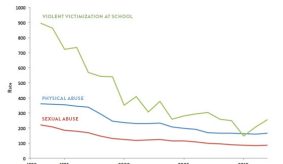
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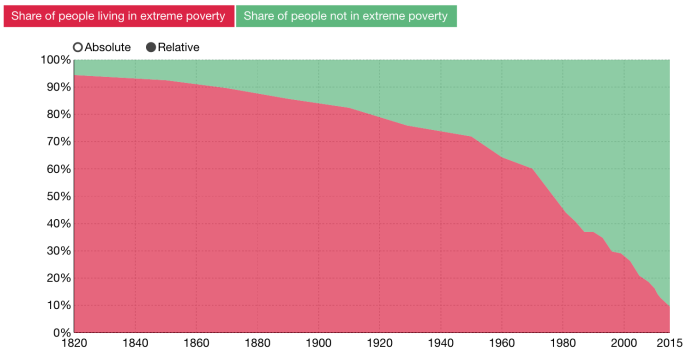


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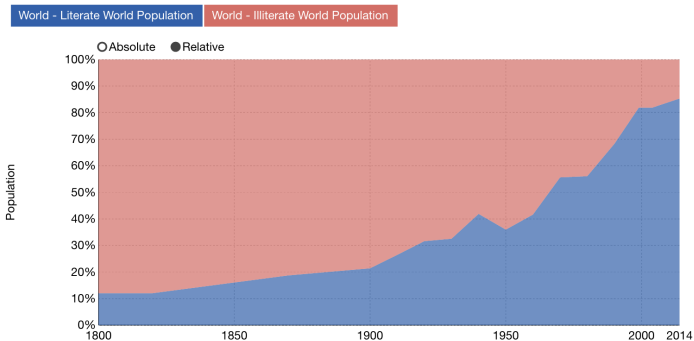
## World population living in extreme poverty, 1820 to 2015



Data source: World Poverty in absolute numbers (Max Roser based on World Bank and Bourguignon and Morrisson (2002))

## Literate and illiterate world population, 1800 to 2014

Our World  
in Data



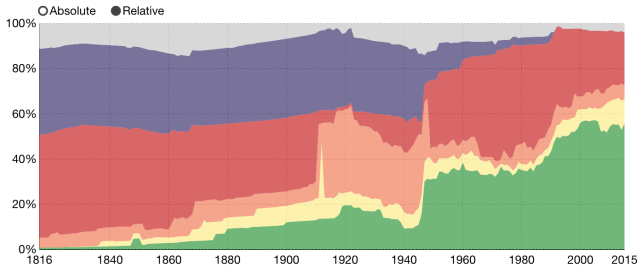
Data source: Literate World Population (Our World In Data based on OECD and UNESCO)



## Number of world citizens living under different political regimes



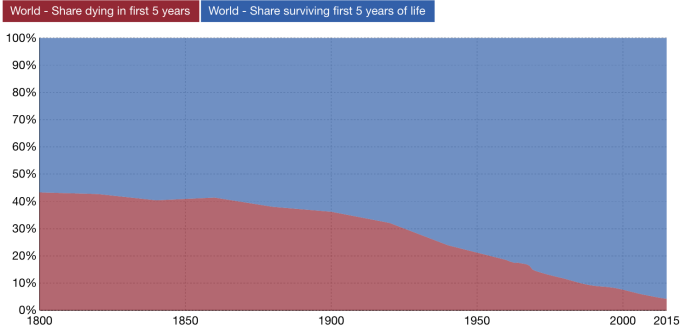
The Polity IV score captures the type of political regime for each country on a range from -10 (full autocracy) to +10 (full democracy). Regimes that fall into the middle of this spectrum are called anocracies.



Data source: World Population by Political Regime they live in (by Our World In Data)

## Global child mortality, 1800 to 2015

Share of the world population dying and surviving the first 5 years of life.



Data source: Global child mortality (since 1800) based on Gapminder and World Bank

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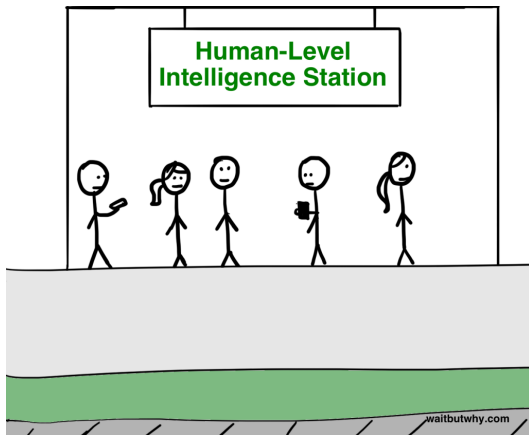
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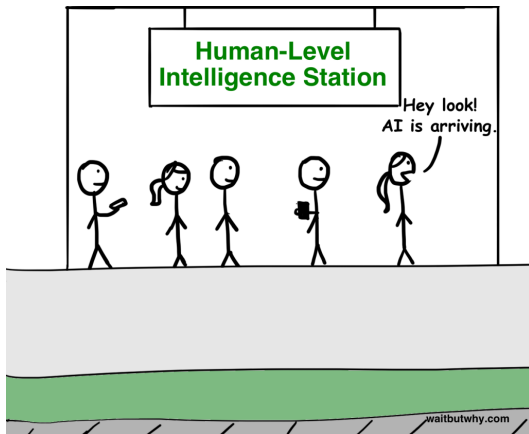
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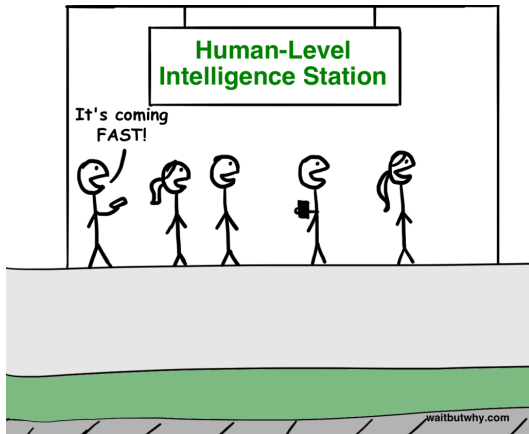
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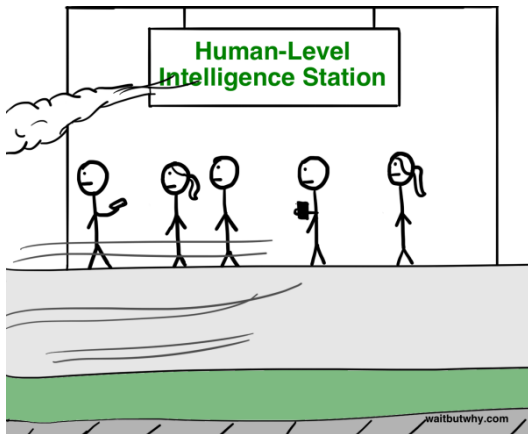
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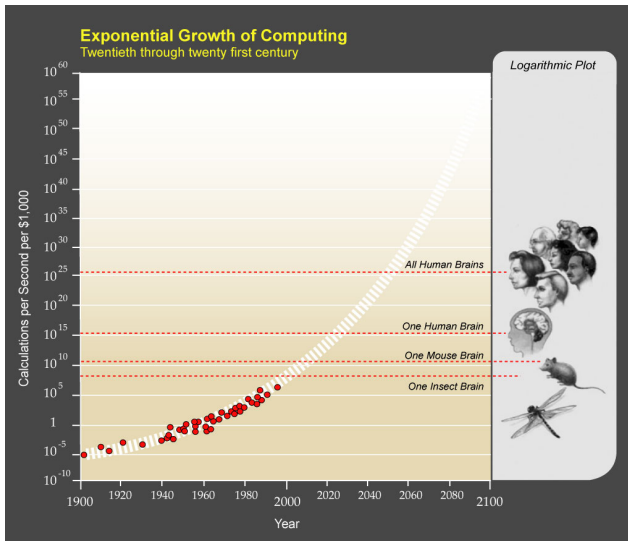
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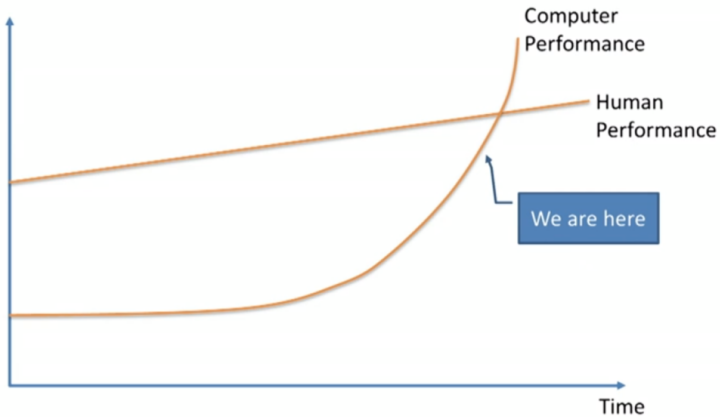
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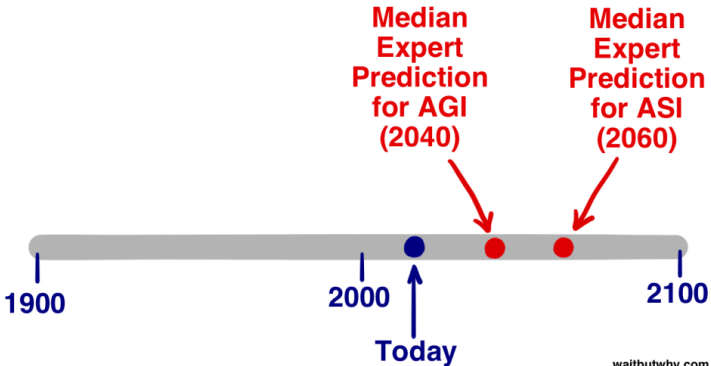
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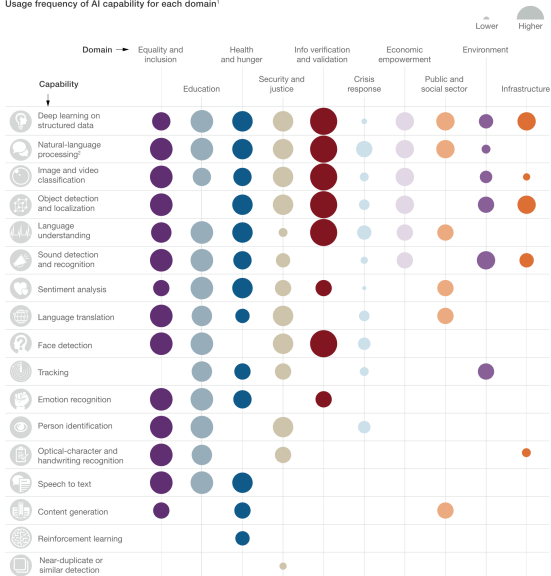
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Usage frequency of AI capability for each domain<sup>1</sup>



Usage frequency of analytics capability for each domain



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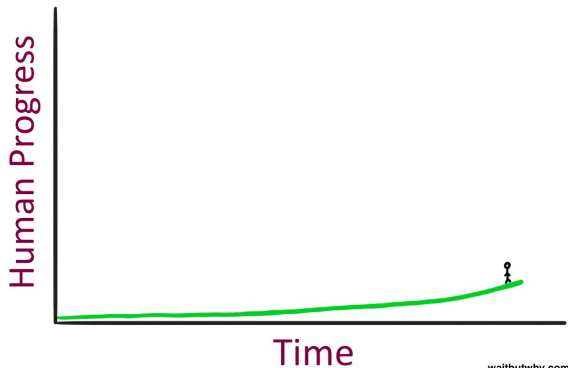
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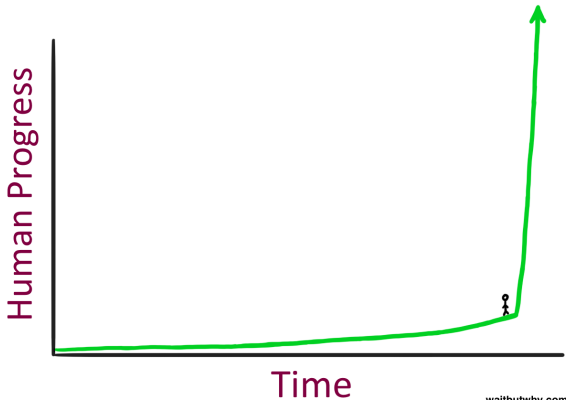
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