

[KASBP AI-biotech Seminar]  
**Beyond AlphaFold – Building AI-Powered Biomarker  
Platforms for the Next Generation of Drug Discovery**

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## About Speaker

- *Co-Founder & CTO @ Erudio Bio, San Jose & Novato, CA, USA*
- *Advisor & Evangelist @ CryptoLab, Inc., San Jose, CA, USA*
- Chief Business Development Officer @ WeStory.ai, Cupertino, CA, USA
- Advisory Professor, Electrical Engineering and Computer Science @ DGIST, Korea
- Adjunct Professor, Electronic Engineering Department @ Sogang University, Korea
- Global Advisory Board Member @ Innovative Future Brain-Inspired Intelligence System Semiconductor of Sogang University, Korea
- *KFAS-Salzburg Global Leadership Initiative Fellow @ Salzburg Global Seminar*, Salzburg, Austria
- Technology Consultant @ Gerson Lehrman Group (GLG), NY, USA
- *Co-Founder & CTO / Head of Global R&D & Chief Applied Scientist / Senior Fellow @ Gauss Labs, Inc., Palo Alto, CA, USA* 2020 – 2023

- Senior Applied Scientist @ Amazon.com, Inc., Vancouver, BC, Canada – 2020
- Principal Engineer @ Software R&D Center, DS Division, Samsung, Korea – 2017
- Principal Engineer @ Strategic Marketing & Sales Team, Samsung, Korea – 2016
- Principal Engineer @ DT Team, DRAM Development Lab, Samsung, Korea – 2015
- Senior Engineer @ CAE Team, Samsung, Korea – 2012
- PhD - Electrical Engineering @ Stanford University, CA, USA – 2004
- Development Engineer @ Vyan, Santa Clara, CA, USA – 2001
- MS - Electrical Engineering @ Stanford University, CA, USA – 1999
- BS - Electrical & Computer Engineering @ Seoul National University 1994 – 1998

## Highlight of Career Journey

- BS in EE @ SNU, MS & PhD in EE @ Stanford University
  - *Convex Optimization - Theory, Algorithms & Software*
  - advised by *Prof. Stephen P. Boyd*
- Principal Engineer @ Samsung Semiconductor, Inc.
  - AI & Convex Optimization
  - collaboration with *DRAM/NAND Design/Manufacturing/Test Teams*
- Senior Applied Scientist @ Amazon.com, Inc.
  - e-Commerce AIs - anomaly detection, deep RL, and recommender system
  - Jeff Bezos's project - boosted up sales by *\$200M* via Amazon Mobile Shopping App
- *Co-Founder & CTO* / Global R&D Head & Chief Applied Scientist @ Gauss Labs, Inc.
- *Co-Founder & CTO* - AI Technology & Business Development @ Erudio Bio, Inc.

# Today

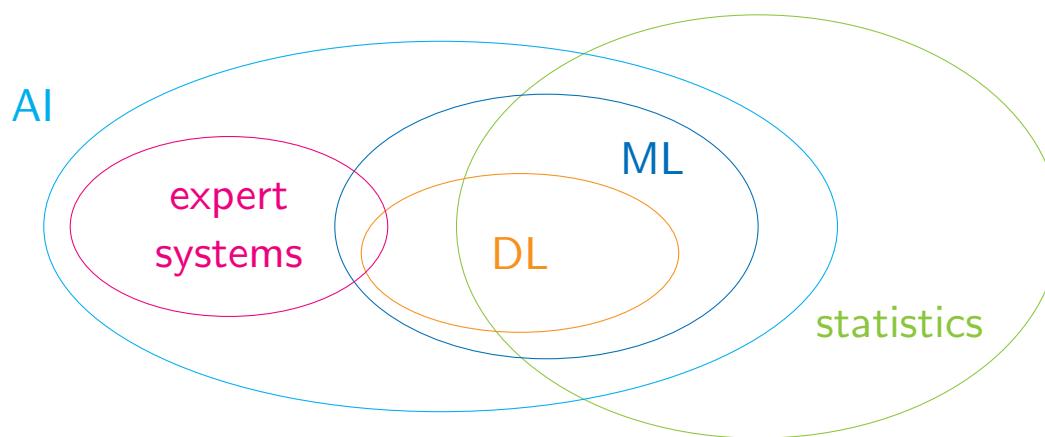
- Artificial Intelligence - 5
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# **Artificial Intelligence**

## **Definition and History**

## Definition & relation to other technologies

- AI
  - is technology doing tasks requiring human intelligence, such as learning, problem-solving, decision-making & language understanding
  - encompasses *range of technologies, methodologies, applications & products*
- AI, ML, DL, statistics & expert system<sup>1</sup> [HGH<sup>+</sup>22]



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<sup>1</sup>ML: machine learning & DL: deep learning

## History



# **Significant AI Achievements - 2014 – 2025**

## Deep learning revolution

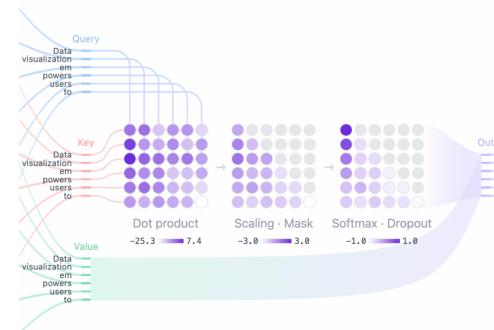
- 2012 – 2015 - DL revolution<sup>2</sup>
  - CNNs demonstrated exceptional performance in image recognition, e.g., *AlexNet's victory in ImageNet competition*
  - widespread adoption of DL learning in CV transforming industries
- 2016 - AlphaGo defeats human Go champion
  - DeepMind's AlphaGo defeated world champion in Go, extremely complex game *believed to be beyond AI's reach*
  - significant milestone in RL - AI's potential in solving complex & strategic problems



<sup>2</sup>CV: computer vision, NN: neural network, CNN: convolutional NN, RL: reinforcement learning

## Transformer changes everything

- 2017 – 2018 - Transformers & NLP breakthroughs<sup>3</sup>
  - *Transformer (e.g., BERT & GPT) revolutionized NLP*
  - major advancements in, *e.g.*, machine translation & chatbots
- 2020 - AI in healthcare – AlphaFold & beyond
  - DeepMind's *AlphaFold solves 50-year-old protein folding problem* predicting 3D protein structures with remarkable accuracy
  - accelerates drug discovery and personalized medicine - offering new insights into diseases and potential treatments



<sup>3</sup>NLP: natural language processing, GPT: generative pre-trained transformer

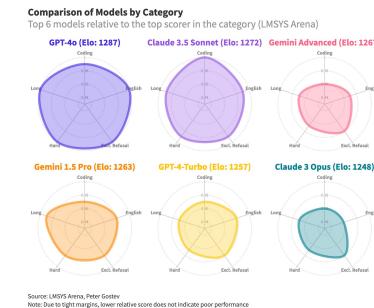
## Lots of breakthroughs in AI technology and applications in 2024

- proliferation of advanced AI models
  - GPT-4o, Claude Sonnet, Claude 3 series, Llama 3, Sora, Gemini
  - *transforming industries* such as content creation, customer service, education, etc.
- breakthroughs in specialized AI applications
  - Figure 02, Optimus, AlphaFold 3
  - driving unprecedented advancements in automation, drug discovery, scientific understanding - *profoundly affecting healthcare, manufacturing, scientific research*



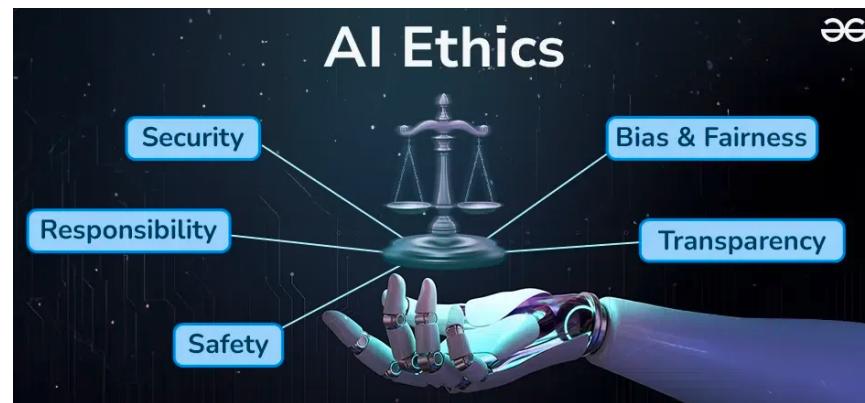
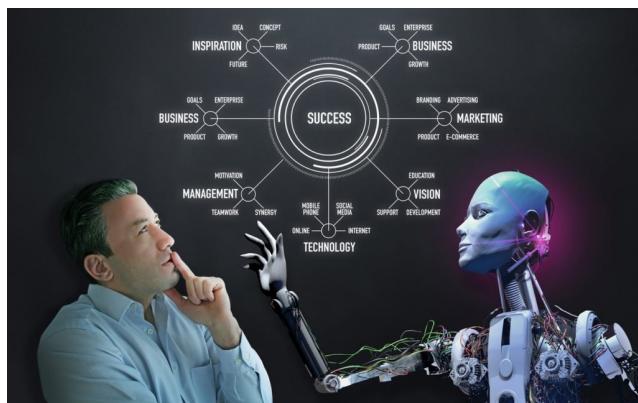
## Major AI Breakthroughs in 2025

- next-generation foundation models
  - GPT-5 and Claude 4 demonstrate emergent reasoning abilities
  - open-source models achieving parity with leading commercial systems from 2024
- hardware innovations
  - NVIDIA's Blackwell successor architecture delivering 3-4x performance improvement
  - AMD's MI350 accelerators challenging NVIDIA's market dominance
- AI-human collaboration systems
  - seamless multimodal interfaces enabling natural human-AI collaboration
  - AI systems effectively explaining reasoning and recommendations
  - augmented reality interfaces providing real-time AI assistance in professional contexts



# Transformative impact of AI - reshaping industries, work & society

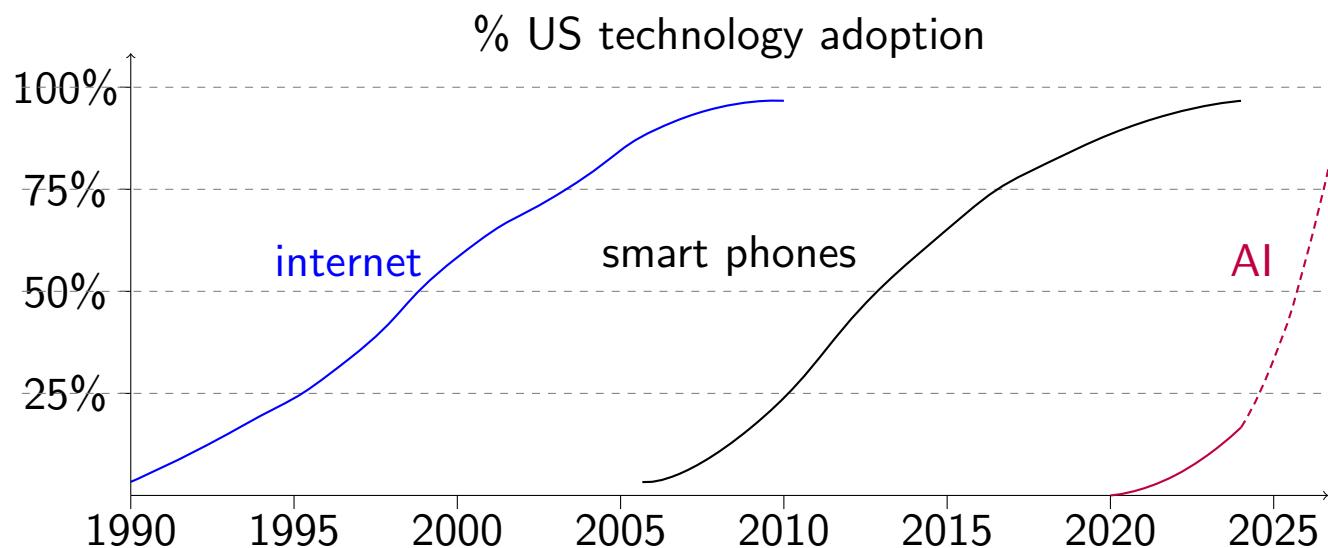
- accelerating human-AI collaboration
  - not only reshaping industries but *altering how humans interact with technology*
  - AI's role as collaborator and augmentor redefines productivity, creativity, the way we address global challenges, e.g., *sustainability & healthcare*
- AI-driven automation *transforms workforce dynamics* - creating new opportunities while challenging traditional job roles
- *ethical AI considerations* becoming central not only to business strategy, but to society as a whole - *influencing regulations, corporate responsibility & public trust*



# **Measuring AI's Ascent**

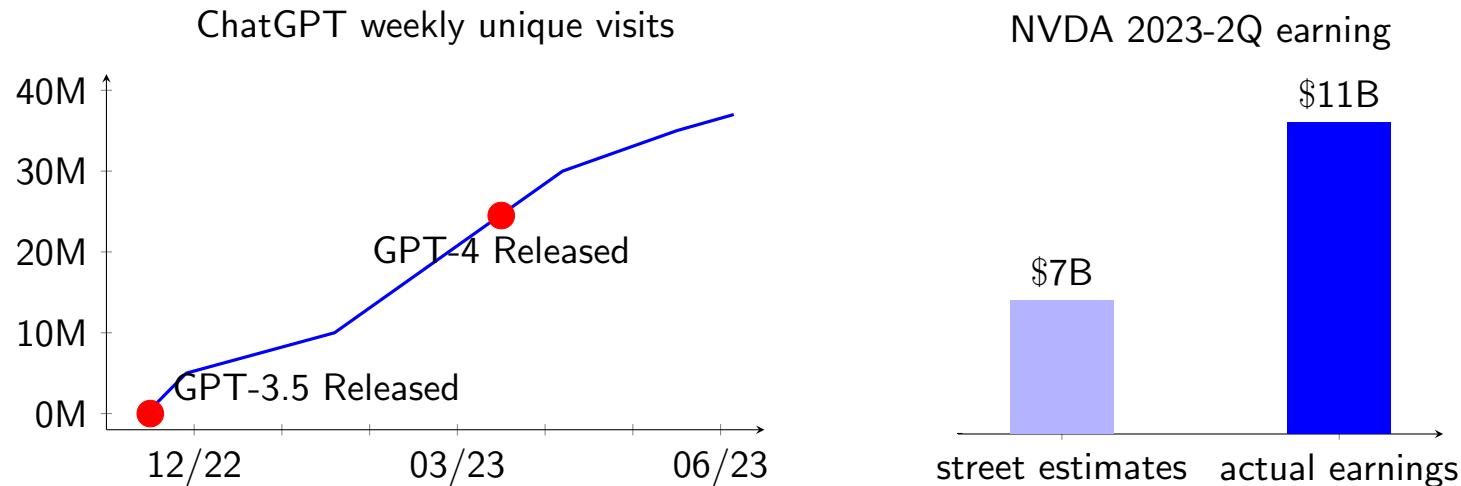
## Where are we in AI today?

- sunrise phase - currently experiencing dawn of AI era with significant advancements and increasing adoption across various industries
- early adoption - in early stages of AI lifecycle with widespread adoption and innovation across sectors marking significant shift in technology's role in society



## Explosion of AI ecosystems - ChatGPT & NVIDIA

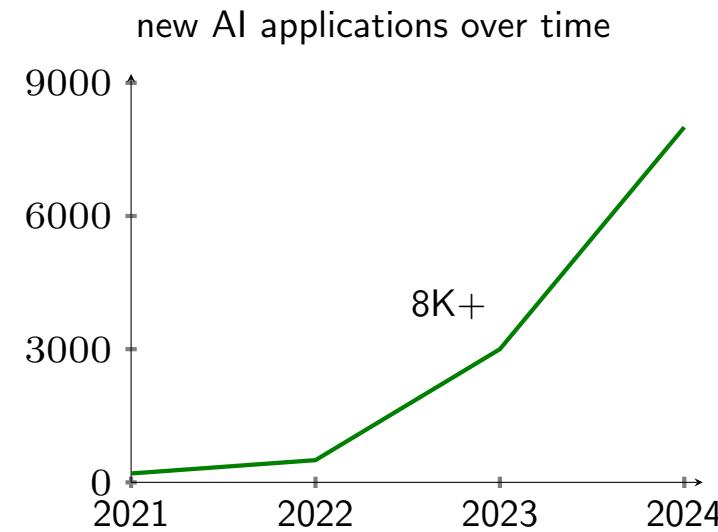
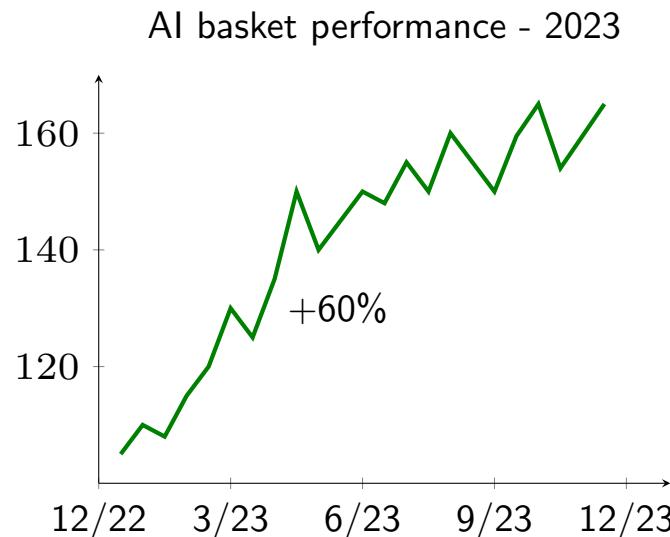
- took only *5 months for ChatGPT users to reach 35M*
- NVIDIA 2023 Q2 earning exceeds market expectation by big margin - \$7B vs \$13.5B
  - surprisingly, *101% year-to-year growth*
  - even more surprisingly *gross margin was 71.2%* - up from 43.5% in previous year<sup>4</sup>



<sup>4</sup>source - Bloomberg

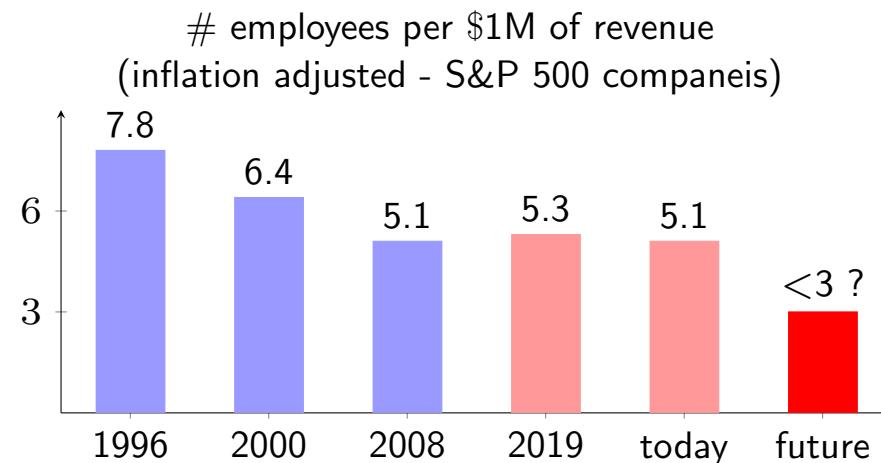
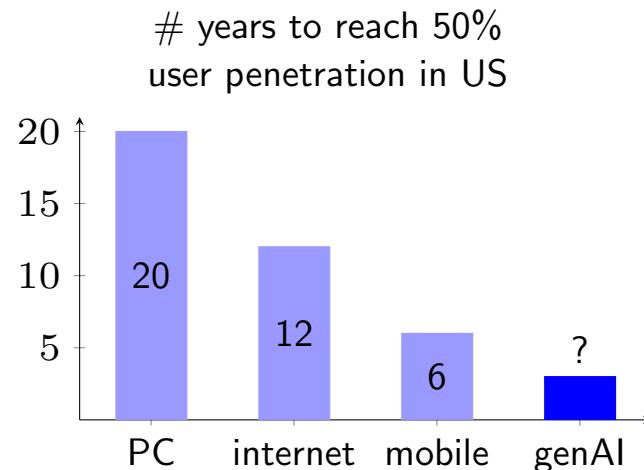
## Explosion of AI ecosystems - AI stock market

- *AI investment surge in 2023 - portfolio performance soars by 60%*
  - AI-focused stocks significantly outpaced traditional market indices
- *over 8,000 new AI applications* developed in last 3 years
  - applications span from healthcare and finance to manufacturing and entertainment



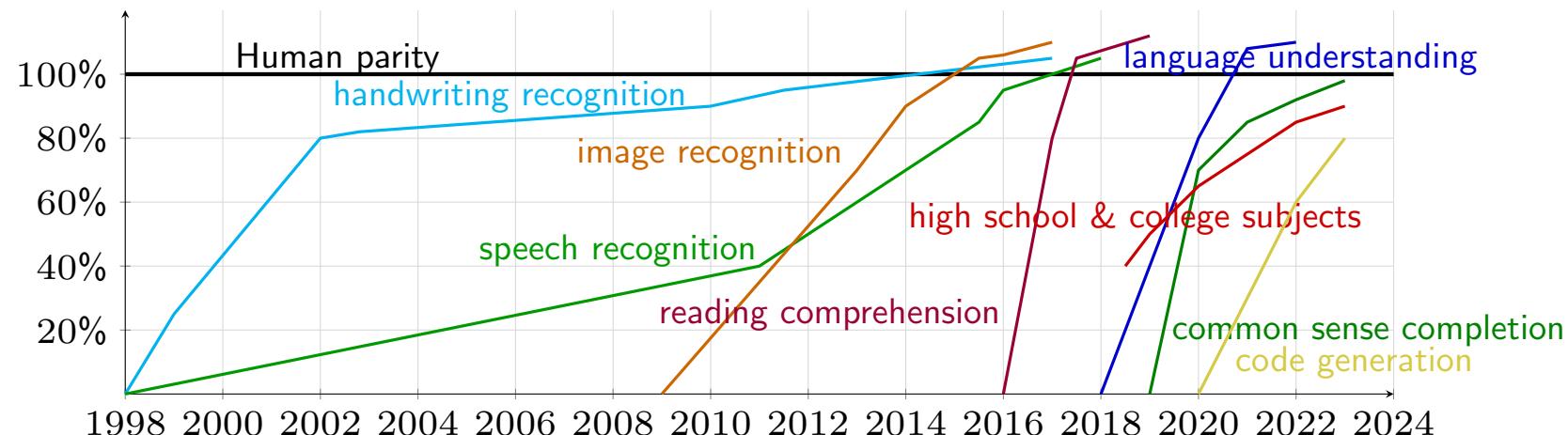
## AI's transformative impact - adoption speed & economic potential

- adoption - has been twice as fast with platform shifts suggesting
  - increasing demand and readiness for new technology improved user experience & accessibility
- AI's potential to drive economy for years to come
  - 35% improvement in productivity driven by introduction of PCs and internet
  - greater gains expected with AI proliferation



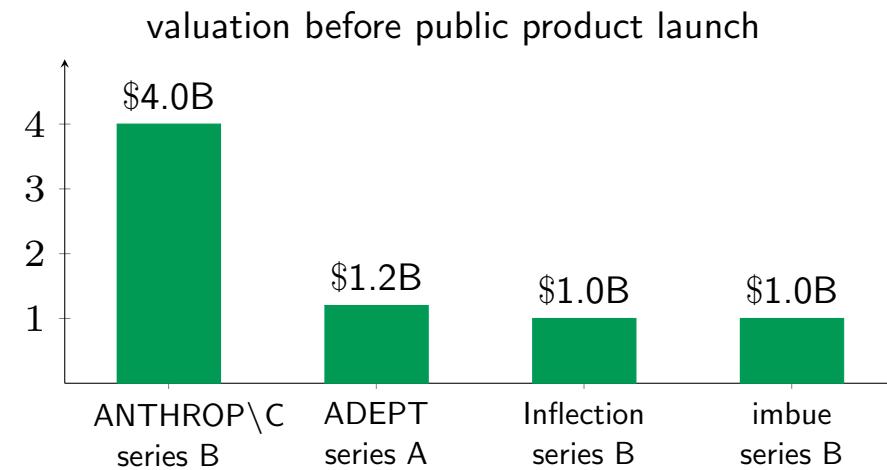
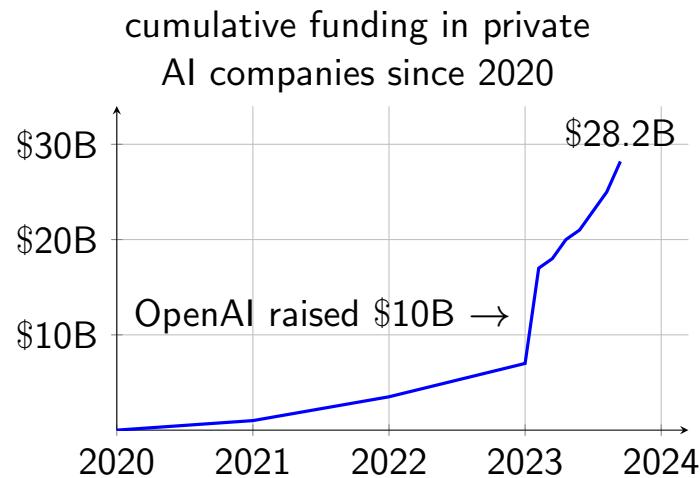
## AI getting more & more faster

- steep upward slopes of AI capabilities highlight accelerating pace of AI development
  - period of exponential growth with AI potentially mastering new skills and surpassing human capabilities at ever-increasing rate
- closing gap to human parity - some capabilities approaching or arguably reached human parity, while others having still way to go
  - achieving truly human-like capabilities in broad range remains a challenge



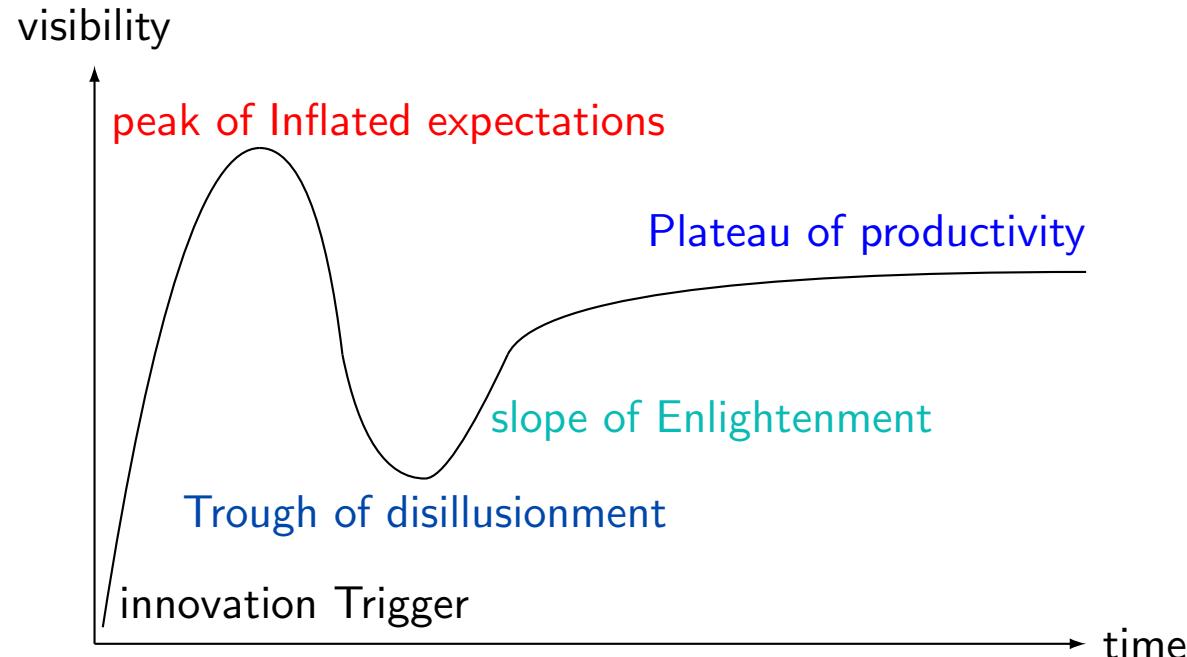
## Massive investment in AI

- *explosive growth* - cumulative funding skyrocketed reaching staggering \$28.2B
- OpenAI - significant fundraising (= \$10B) fueled rapid growth
- *valuation surge* - substantial valuations even before public products for stellar companies
- *fierce competition for capital* among AI startups driving innovation & accelerating development
- massive investment indicates *strong belief in & optimistic outlook for potential of AI* to revolutionize industries & drive economic growth



**Is AI hype?**

## Technology hype cycle



- innovation trigger - technology breakthrough kicks things off
- peak of inflated expectations - early publicity induces many successes followed by even more
- trough of disillusionment - expectations wane as technology producers shake out or fail
- slope of enlightenment - benefit enterprise, technology better understood, more enterprises fund pilots

## Fiber vs cloud infrastructure

- fiber infrastructure - 1990s
  - Telco Co's raised \$1.6T of equity & \$600B of debt
  - bandwidth costs decreased 90% within 4 years
  - companies - Covage, NothStart, Telligent, Electric Lightwave, 360 networks, Nextlink, Broadwind, UUNET, NFS Communications, Global Crossing, Level 3 Communications
  - became *public good*
- cloud infrastructure - 2010s
  - entirely new computing paradigm
  - mostly public companies with data centers
  - *big 4 hyperscalers generate \$150B + annual revenue*



## Yes & No

characteristics of hype cycles	speaker's views
value accrual misaligned with investment	<ul style="list-style-type: none"><li>• OpenAI still operating at a loss; business model <i>still</i> not clear</li><li>• gradual value creation across broad range of industries and technologies (<i>e.g.</i>, CV, LLMs, RL) unlike fiber optic bubble in 1990s</li></ul>
overestimating timeline & capabilities of technology	<ul style="list-style-type: none"><li>• self-driving cars delayed for over 15 years, with limited hope for achieving level 5 autonomy</li><li>• AI, however, has proven useful within a shorter 5-year span, with enterprises eagerly adopting</li></ul>
lack of widespread utility due to technology maturity	<ul style="list-style-type: none"><li>• AI already providing significant utility across various domains</li><li>• vs quantum computing remains promising in theory but lacks widespread practical utility</li></ul>

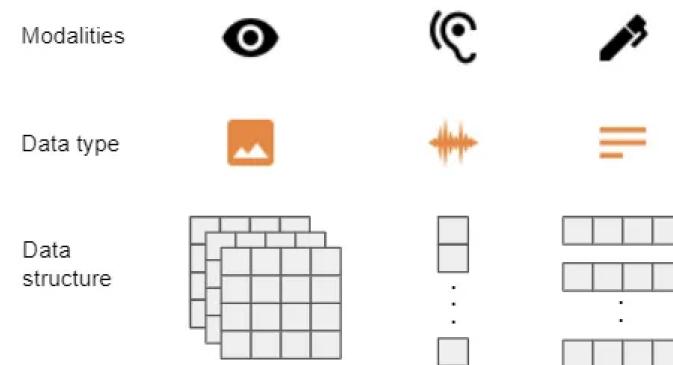
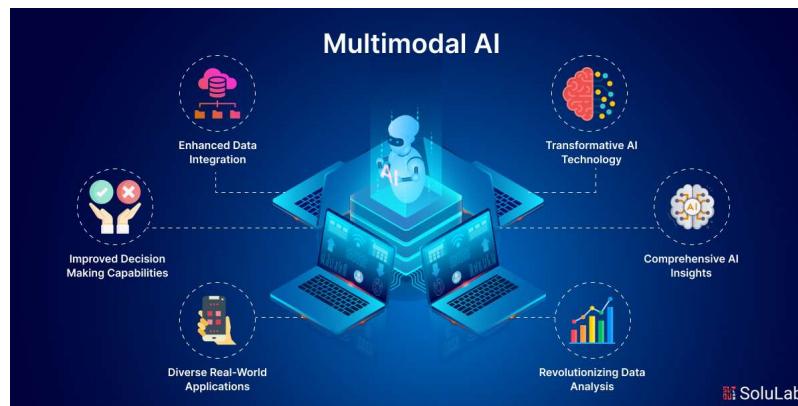
# AI Agents

## Recent AI progress in keywords

- ~ 2010 - Big Data
- ~ 2012 - Deep Learning
- ~ 2017 - Transformer - Attention is All you need!
- ~ 2022 - LLM & genAI
- ~ 2024 - AI Agent (Agentic AI)

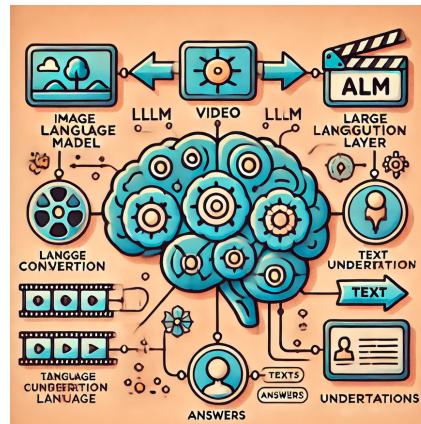
# Multimodal learning

- understand information from multiple modalities, *e.g.*, text, images, audio, video
- representation learning methods
  - combine multiple representations or learn multimodal representations simultaneously
- applications
  - images from text prompt, videos with narration, musics with lyrics
- collaboration among different modalities
  - understand image world (open system) using language (closed system)



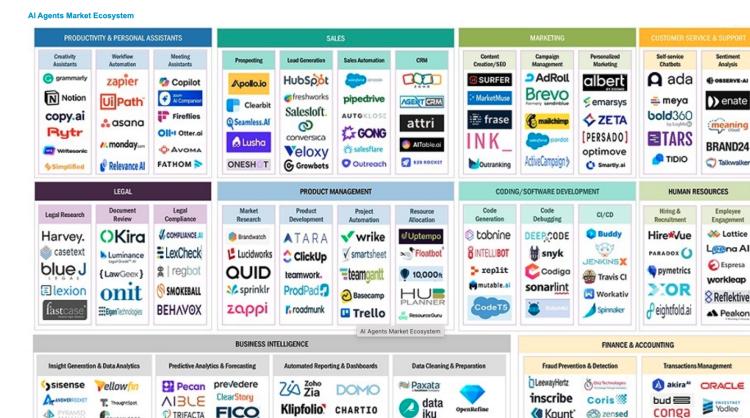
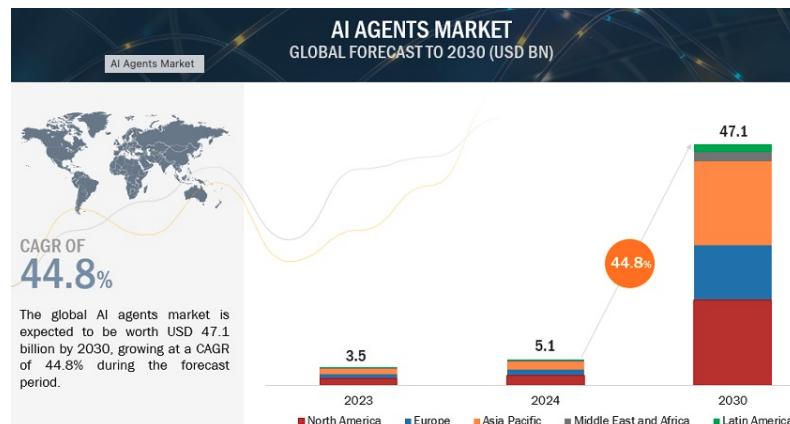
## Implications of success of LLMs

- many researchers change gears towards LLM
  - from computer vision (CV), speech, music, video, even reinforcement learning
- *LLM is not only about NLP . . . humans have . . .*
  - evolved to optimize natural language structures for eons
  - handed down knowledge using *this natural languages* for thousands of years
  - internal structure (or equivalently, representation) of natural languages optimized via *thousands of generation by evolution*
- *LLM connects non-linguistic world (open system) via natural languages (closed system)*



# Multimodal AI (mmAI)

- mmAI - systems processing & integrating data from multiple sources & modalities, to generate unified response / decision
  - 1990s – 2000s - early systems - initial research combining basic text & image data
  - 2010s - CNNs & RNNs enabling more sophisticated handling of multimodality
  - 2020s - modern multimodal models - Transformer-based architectures handling complex multi-source data at highly advanced level
  - mmAI *mimics human cognitive ability* to interpret and integrate information from various sources, leading to holistic decision-making

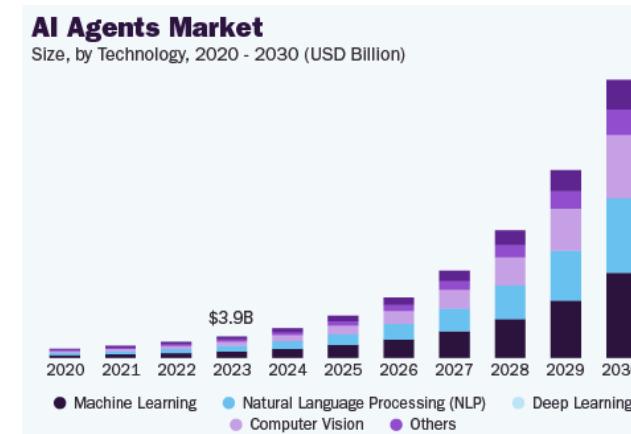
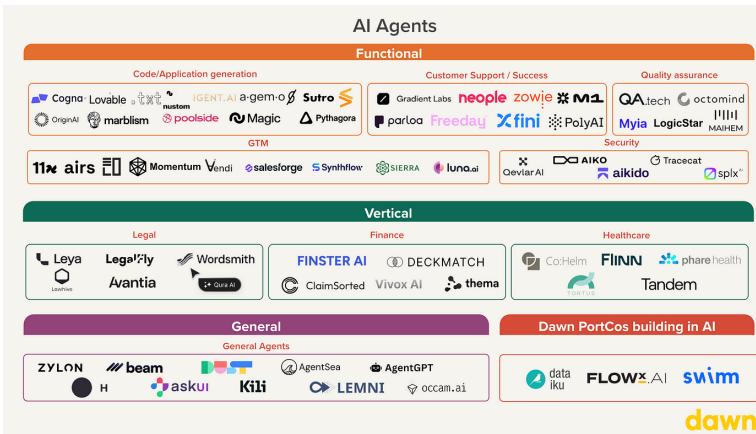


## mmAI Technology

- core components
  - data preprocessing - images, text, audio & video
  - architectures - unified Transformer-based (*e.g.*, ViT) & cross-attention mechanisms / hybrid architectures (*e.g.*, CNNs + LLMs)
  - integration layers - fusion methods for combining data representations from different modalities
- technical challenges
  - data alignment - accurate alignment of multimodal data
  - computational demand - high-resource requirements for training and inferencing
  - diverse data quality - manage variations in data quality across modalities
- advancements
  - multimodal embeddings - shared feature spaces interaction between modalities
  - self-supervised learning - leverage unlabeled data to learn representations across modalities

# AI agents powered by multimodal LLMs

- foundation
  - integrate multimodal AI capabilities for enhanced interaction & decision-making
- components
  - perceive environment through multiple modalities (visual, audio, text), process using LLM technology, generate contextual responses & take actions
- capabilities
  - understand complex environments, reason across modalities, engage in natural interactions, adapt behavior based on context & feedback



## AI agents - Present & Future

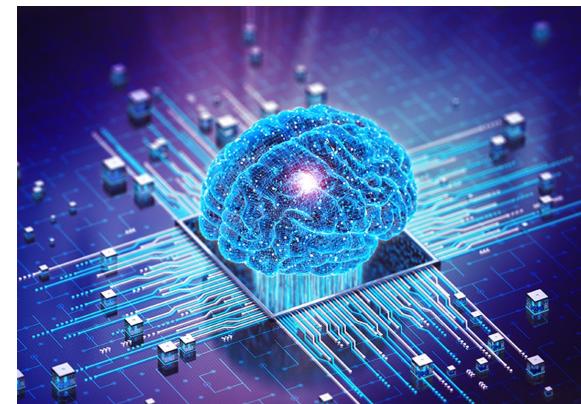
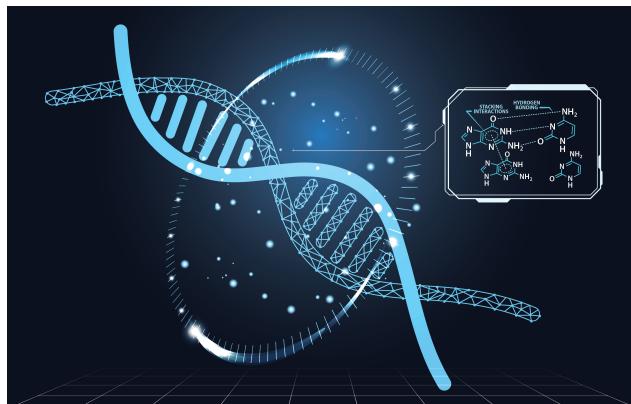
- emerging applications
  - scientific research - agents analyzing & running experiments & generating hypotheses
  - creative collaboration - AI partners in design & art combining multiple mediums
  - environmental monitoring - processing satellite sensor data for climate analysis
  - healthcare - enhanced diagnostic combining imaging, *e.g.*, MRI, with patient history
  - customer experience - virtual assistants understanding spoken language & visual cues
  - autonomous vehicles - integration of visual, radar & audio data
- future
  - ubiquitous AI agents - seamless integration into everyday devices
  - highly tailored personalized experience - in education, entertainment & healthcare



**AI & Biotech**

## AI in biology

- AI has been used in biological sciences, and science in general
- AI's ability to process large amounts of raw, unstructured data (*e.g.*, DNA sequence data)
  - reduces time and cost to conduct experiments in biology
  - enables other types of experiments that previously were unattainable
  - contributes to broader field of engineering biology or biotechnology
- AI increases human ability to make direct changes at cellular level and create novel genetic material (*e.g.*, DNA and RNA) to obtain specific functions



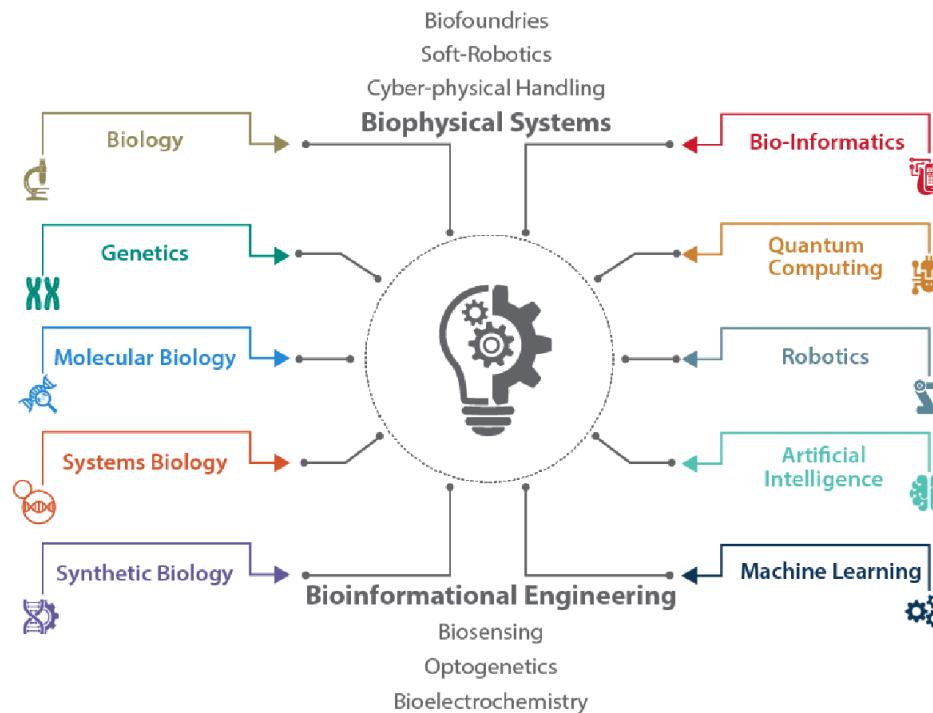
**Biotech**

## Biotech

- biotechnology
  - is multidisciplinary field leveraging broad set of sciences and technologies
  - relies on and builds upon advances in other fields such as nanotechnology & robotics, and, increasingly, AI
  - enables researchers to read and write DNA
    - sequencing technologies “read” DNA while gene synthesis technologies take sequence data and “write” DNA turning data into physical material
- 2018 National Defense Strategy & Senior US Defense and Intelligence Officials identified emerging technologies that could have disruptive impact on US national security [[Say21](#)]
  - *AI*, lethal autonomous weapons, hypersonic weapons, directed energy weapons, *biotechnology*, quantum technology
- other names for biotechnology are engineering biology, synthetic biology, biological science (when discussed in context of AI)

## Biotech - multidisciplinary field

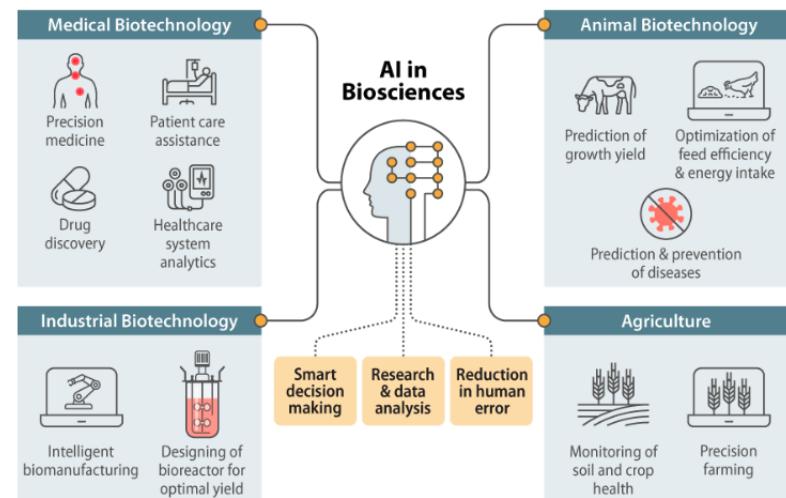
- sciences and technologies enabling biotechnology include (but not limited to)
  - (molecular) biology, genetics, systems biology, synthetic biology, bio-informatics, quantum computing, robotics [DFJ22]



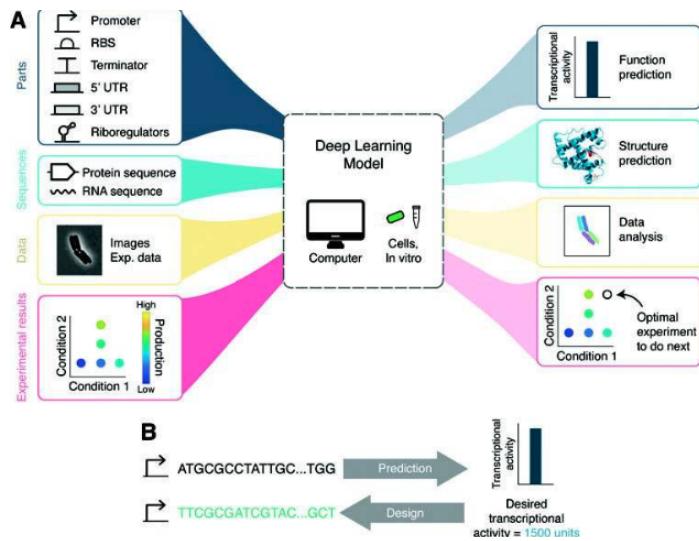
# Convergence of AI and biological design

- AI & biological sciences converging [BKP22]
  - each building upon the other's capabilities for new research and development across multiple areas
- Demis Hassabis, CEO & cofounder of DeepMind, said of biology [Toe23]
 

“. . . biology can be thought of as information processing system, albeit extraordinarily complex and dynamic one . . . just as mathematics turned out to be the right description language for physics, biology may turn out to be *the perfect type of regime for the application of AI!*”
- both AI & biotech rely on and build upon advances in other scientific disciplines and technology fields, such as nanotechnology, robotics, and increasingly big data (e.g., genetic sequence data)
  - each of these fields itself convergence of multiple sciences and technologies
- so *their impacts can combine to create new capabilities*



## Multi-source genetic sequence data



- AI, essential to analyzing exponential growth of genetic sequence data
 

“AI will be essential to fully understanding how genetic code interacts with biological processes” - US National Security Commission on Artificial Intelligence (NSCAI)

  - process huge amounts of biological data, e.g., genetic sequence data, coming from different biological sources for understanding complex biological systems
    - sequence data, molecular structure data, image data, time-series, omics data
  - e.g., analyze genomic data sets to determine the genetic basis of particular trait and potentially uncover genetic markers linked with that trait

## Quality & quantity of biological data

- limiting factor, however, is *quality and quantity* of biological data, *e.g.*, DNA sequences, that AI is trained on
  - *e.g.*, accurate identification of particular species based on DNA requires reference sequences of *sufficient quality* to exist and be available
- databases have varying standards - access, type, and quality of information
- design, management, quality standards, and data protocols for reference databases can affect utility of particular DNA sequence



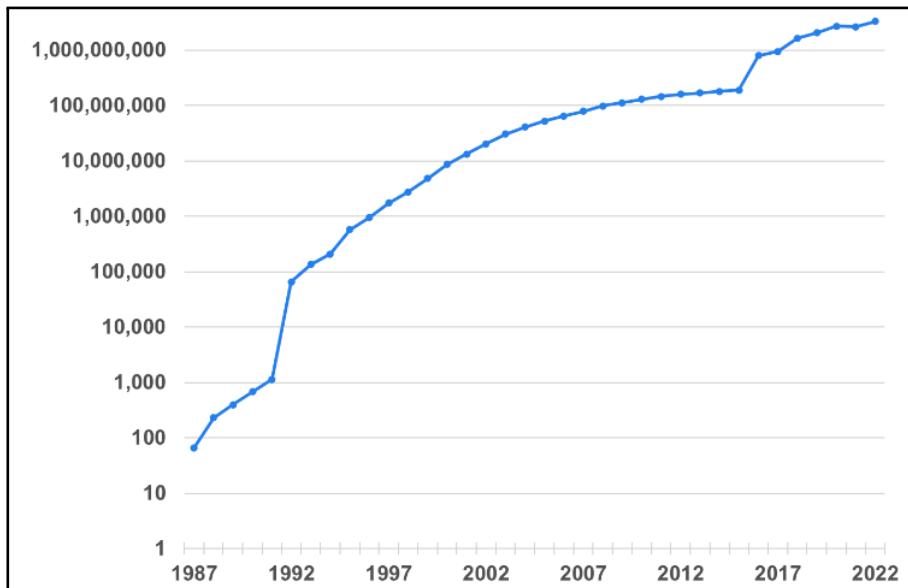
## Rapid growth of biological data

- volume of genetic sequence data grown exponentially as sequencing technology evolved
- more than 1,700 databases incorporating data on genomics, protein sequences, protein structures, plants, metabolic pathways, *etc.*, *e.g.*
  - open-source public database
    - Protein Data Bank, US-funded data center - more than *terabyte of three-dimensional structure data* for biological molecules, *e.g.*, proteins, DNA, RNA
  - proprietary database
    - Gingko Bioworks - more than *2B protein sequences*
  - public research groups
    - Broad Institute - produces roughly *500 terabases of genomic data per month*
- great potential value in aggregate volume of genetic datasets that can be collectively mined to discover and characterize relationships among genes

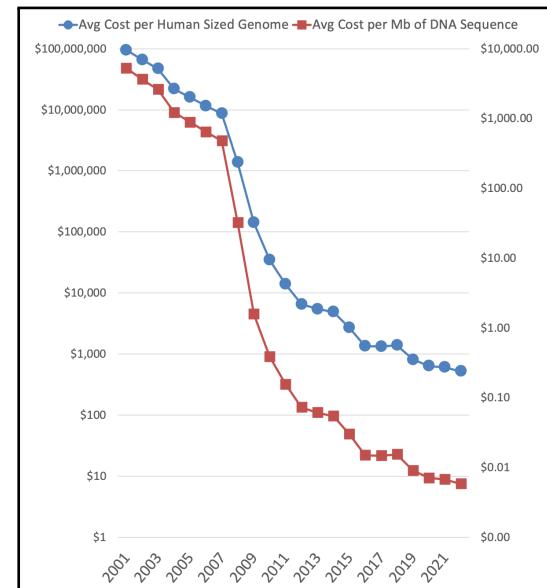
## Volume and sequencing cost of DNA over time

- volume of DNA sequences & DNA sequencing cost
  - data source: National Human Genome Research Institute (NHGRI) [[Wet23](#)] & International Nucleotide Sequence Database Collaboration (INSDC)
- more dramatic than Moore's law!*

# sequences in INSDC



DNA sequencing cost



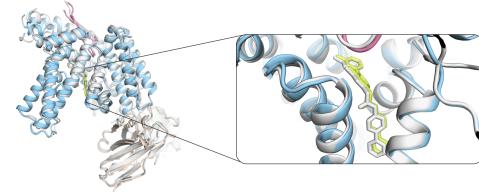
## Bio data availability and bias

- US National Security Commission on Artificial Intelligence (NSCAI) recommends
  - US fund and prioritize development of a biobank containing "*wide range of high-quality biological and genetic data sets securely accessible by researchers*"
  - establishment of database of broad range of human, animal, and plant genomes would
    - *enhance and democratize biotechnology innovations*
    - *facilitate new levels of AI-enabled analysis of genetic data*
- bias - availability of genetic data & decisions about selection of genetic data can introduce bias, e.g.
  - training AI model on datasets emphasizing or omitting certain genetic traits can affect how information is used and types of applications developed - *potentially privileging or disadvantaging certain populations*
  - access to data and to AI models themselves may impact communities of differing socioeconomic status or other factors unequally

# **Emerging Trends in Biotech**

## AlphaFold

- solving 50-year-old protein folding problem, “*one of biology's grand challenges*”
  - definition - given amino acid sequence, predict how it folds into a 3D structure
  - proteins fold in microseconds, but predicting computationally nearly impossible
- AlphaFold 1 (2018) - DL + physics-based energy functions → AlphaFold 2 (2020)
  - attention-based NN solving protein folding “in principle” → AlphaFold 3 (2024) - diffusion-based DL, drug-protein interactions, protein complexes
- AlphaFold protein structure database
  - >200MM protein structures - nearly every known protein, used by >2MM researchers
- Applications & implications
  - drug discovery - target identification, lead optimization, side effect prediction
  - enzyme engineering, agriculture, environmental, vaccine development

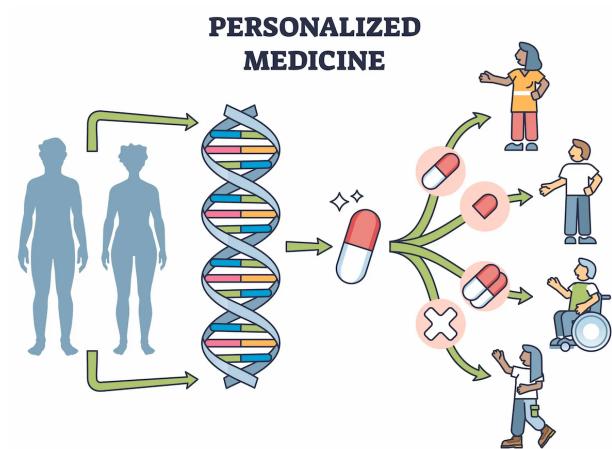


# AlphaGo

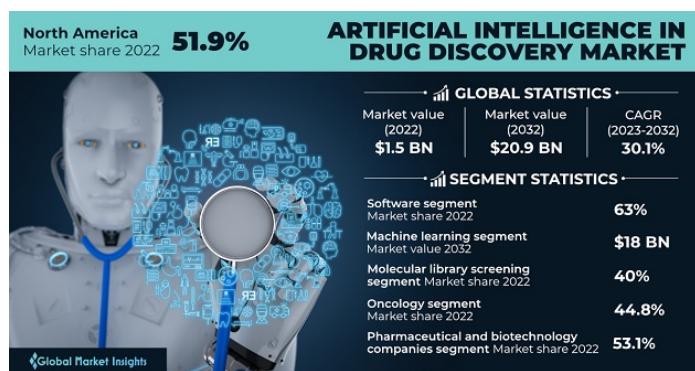


## Personalized medicine

- *shift from one-size-fits-all approach to tailored treatments*
- based on individual genetic profiles, lifestyles & environments
- AI enables analysis of vast data to predict patient responses to treatments, thus enhancing efficacy and reducing adverse effects
- e.g.
  - custom cancer therapies
  - personalized treatment plans for rare diseases
  - precision pharmacogenomics
- companies - Tempus, Foundation Medicine, etc.



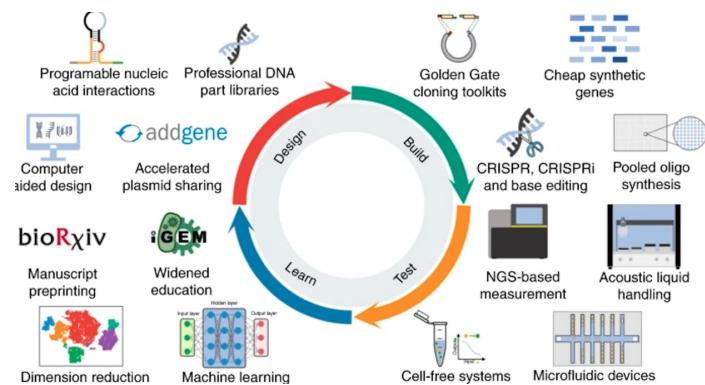
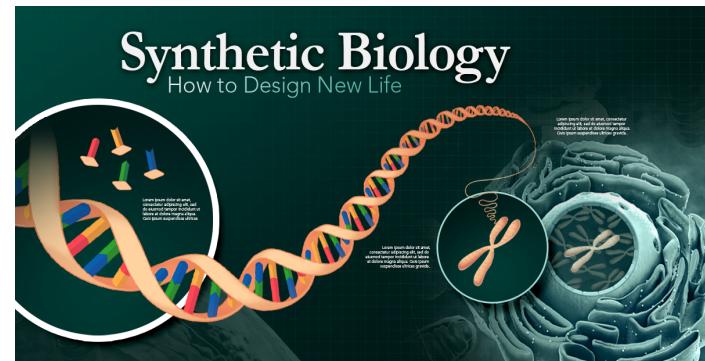
# AI-driven drug discovery



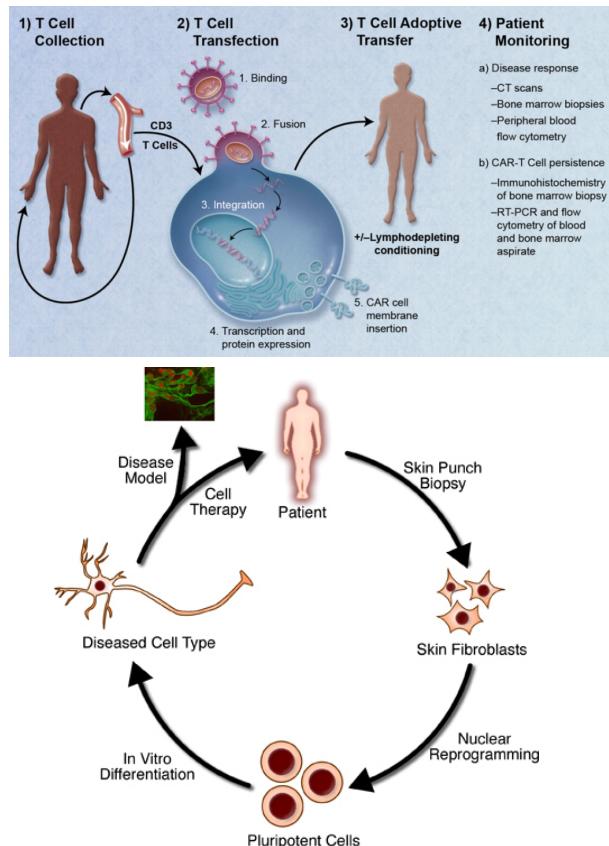
- traditional drug discovery process - time-consuming and costly often taking decades and billions of dollars
- AI streamlines this process by predicting the efficacy and safety of potential compounds with more speed and accuracy
- AI models analyze chemical databases to identify new drug candidates or repurpose existing drugs for new therapeutic uses
- companies - Insilico Medicine, Atomwise.

## Synthetic biology

- use AI for gene editing, biomaterial production and synthetic pathways
- combine principles of biology and engineering to design and construct new biological entities
- AI optimizes synthetic biology processes from designing genetic circuits to scaling up production
- company - Ginkgo Bioworks uses AI to design custom microorganisms for applications ranging from pharmaceuticals to industrial chemicals



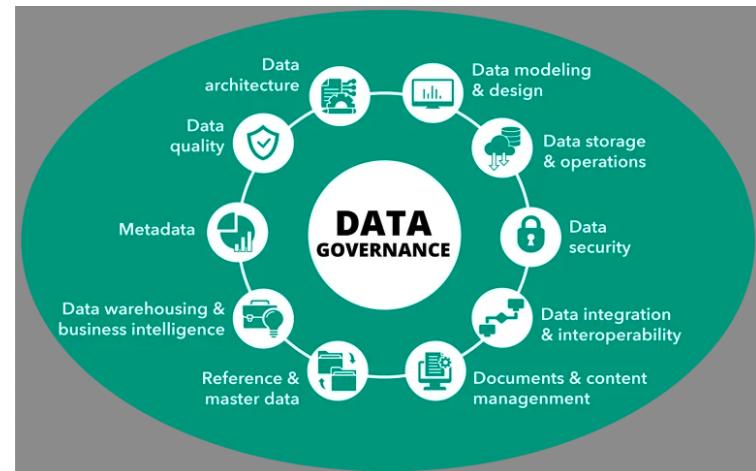
# Regenerative medicine



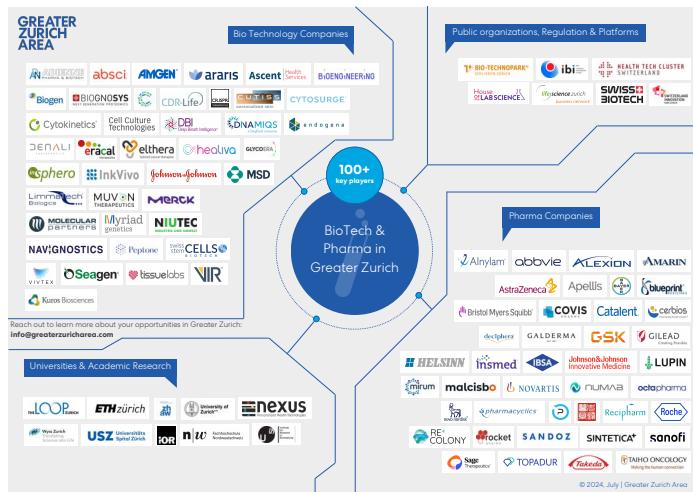
- AI advances development of stem cell therapies & tissue engineering
- AI algorithms assist in identifying optimal cell types, predicting cell behavior & personalized treatments
- particularly for conditions such as neurodegenerative diseases, heart failure and orthopedic injuries
- company - Organovo leverages AI to potentially improve the efficacy and scalability of regenerative therapies, developing next-generation treatments

## Bio data integration

- integration of disparate data sources, including genomic, proteomic & clinical data - one of biggest challenges in biotech & healthcare
- AI delivers meaningful insights *only when* seamless data integration and interoperability realized
- developing platforms facilitating comprehensive, longitudinal patient data analysis - vital enablers of AI in biotech
- company - Flatiron Health working on integrating diverse datasets to provide holistic view of patient health



# Biotech companies



- Atomwise - small molecule drug discovery
- Cradle - protein design
- Exscientia - precision medicine
- Iktos - small molecule drug discovery and design
- Insilico Medicine - full-stack drug discovery system
- Schrödinger, Inc. - use physics-based models to find best possible molecule
- Absci Corporation - antibody design, creating new from scratch antibodies, *i.e.*, “*de novo* antibodies”, and testing them in laboratories

# **Serendipities around Als**

## Serendipity or inevitability?

- What if Geoffrey Hinton had not been a persistent researcher?
- What if symbolists won AI race over connectionists?
- What if attention mechanism did not perform well?
- What if Transformer architecture did not perform super well?
- What if OpenAI had not been successful with ChatGPT in 2022?
- What if Jensen Huang had not been crazy about making hardware for professional gamers?
- Is it like Alexander Fleming's Penicillin?
- Or more like Inevitability?

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**Thank You**