

[Special AI Lecture for Hwarang Friends]

**Becoming the Leader of AI Era - From ChatGPT to
Your Future Superpower**

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About Speaker

- *Co-Founder & CTO @ Erudio Bio, Inc., San Jose & Novato, CA, USA* 2023 ~
- *Co-Founder & CEO @ Erudio Bio Korea, Inc., Korea* 2025 ~
- *Leader of Silicon Valley Privacy-Preserving AI Forum (K-PAI), CA, USA* 2024 ~
- *Director of AI Semiconductor @ K-BioX, CA, USA* 2025 ~
- *AI-Korean Medicine Integration Initiative Task Force Member @ The Association of Korean Medicine* 2025 ~
- *KFAS-Salzburg Global Leadership Fellow @ Salzburg Global Seminar* 2024 ~
- *Adjunct Professor, EE Department @ Sogang University, Seoul, Korea* 2020 ~
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- Global Advisory Board Member @ Innovative Future Brain-Inspired Intelligence System Semiconductor of Sogang University, Korea 2020 ~
- Technology Consultant @ Gerson Lehrman Group (GLG), NY, USA 2022 ~
- Chief Business Development Officer @ WeStory.ai, Cupertino, CA, USA 2025 ~
- Advisor @ CryptoLab, Inc., San Jose, CA, USA 2025 ~

- 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 2017 ~ 2020
- Principal Engineer @ Software R&D Center, Samsung Electronics 2016 ~ 2017
- Principal Engineer @ Strategic Marketing & Sales, Memory Business 2015 ~ 2016
- Principal Engineer @ DT Team, DRAM Development, Samsung 2012 ~ 2015
- Senior Engineer @ CAE Team, Memory Business, Samsung, Korea 2005 ~ 2012
- PhD - Electrical Engineering @ Stanford University, CA, USA 2001 ~ 2004
- Development Engineer @ Vyan, Santa Clara, CA, USA 2000 ~ 2001
- MS - Electrical Engineering @ Stanford University, CA, USA 1998 ~ 1999
- BS - Electrical & Computer Engineering @ Seoul National University 1994 ~ 1998

Highlight of Career Journey

- BS in Electrical Engineering (EE) @ Seoul National University
- MS & PhD in Electronics Engineering (EE) @ Stanford University
 - *Convex Optimization - Theory, Algorithms & Software*
 - advisor - *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 - drove \$200M* in sales via Amazon Mobile Shopping App
- *Co-Founder & CTO / Global R&D Head & Chief Applied Scientist* @ Gauss Labs, Inc.
- *Co-Founder & CTO* @ Erudio Bio, Inc.
- *Co-Founder & CEO* @ Erudio Bio Korea, Inc.

Unpacking AI

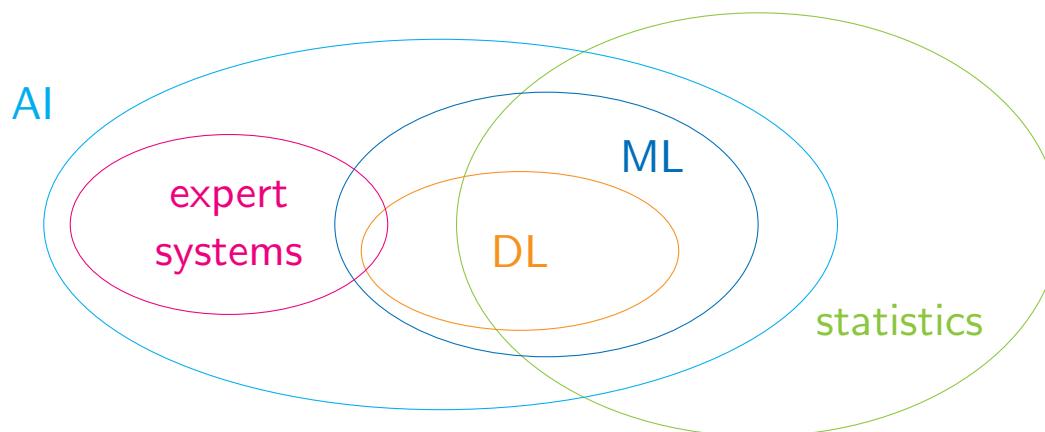
- Artificial Intelligence - 5
 - AI history & recent significant achievements
 - market indicators for unprecedented AI progress
- AI Agents - 30
 - Big Data → ML/DL → LLM & genAI → Agentic AI
 - implication of grand success of LLM in multimodal AI
- Building Your Superpower - Domain x AI - 38
 - AI power user vs AI expert
 - powerful combination - domain expert + AI expert
- Appendix - AI and Biotech - 53
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 - Why Human level AI? Can AI think, reason, believe, or even know something?
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Artificial Intelligence

Definition and History

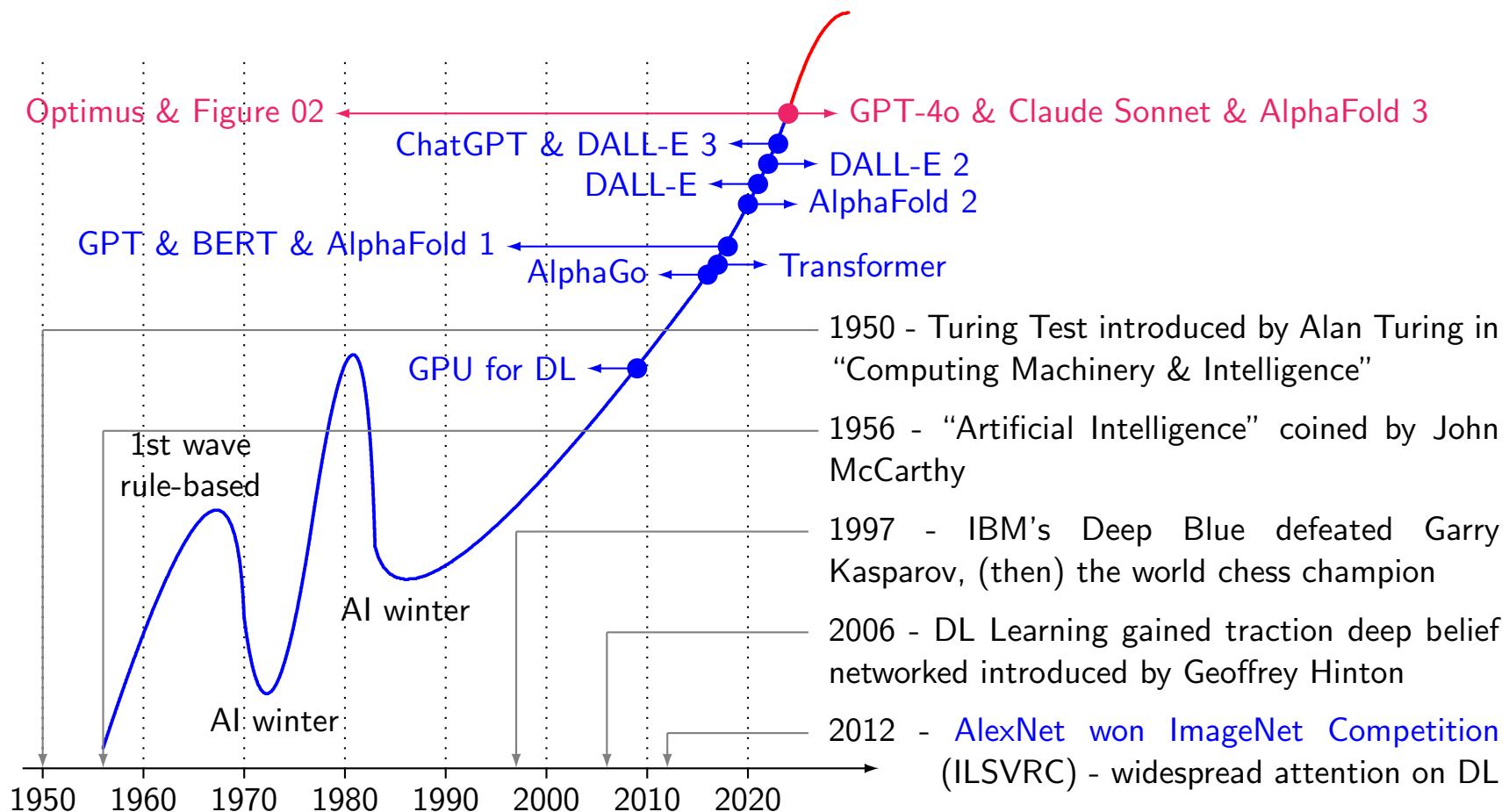
Definition & relation to other technologies

- 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 system¹ [HGH⁺22]



¹ML: machine learning & DL: deep learning

History



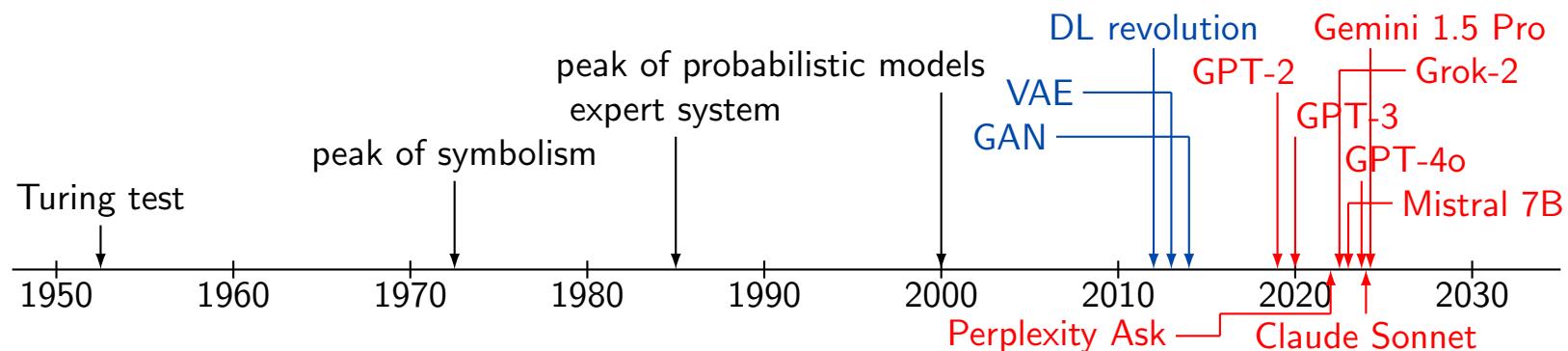
Birth of AI - early foundations & precursor technologies

- 1950s ~ 1970s
 - Alan Turing - concept of “*thinking machine*” & *Turing test* to evaluate machine intelligence (1950s)
 - *symbolists* (as opposed to connectionists) - early AI focused on symbolic reasoning, logic & problem-solving - Dartmouth Conference in 1956 by *John McCarthy, Marvin Minsky, Allen Newell & Herbert A. Simon*
 - precursor technologies - genetic algorithms (GAs), Markov chains & *hidden Markov models (HMMs)* - laying foundation for generative processes (1970s ~)



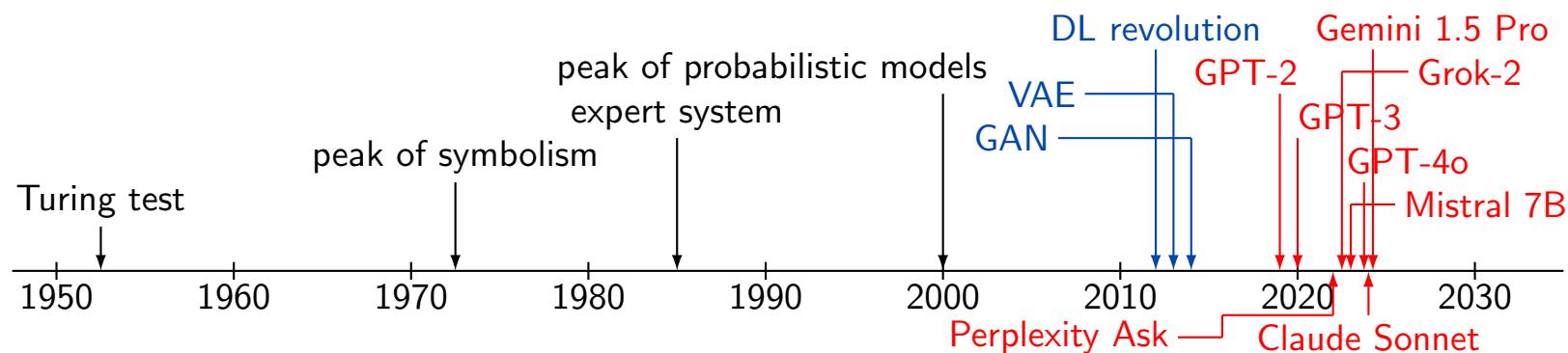
Rule-based systems & probabilistic models

- 1980s ~ early 2000s
 - *expert systems* (1980s) - AI systems designed to mimic human decision-making in specific domains
 - development of neural networks (NN) w/ backpropagation *training multi-layered networks* - setting stage for way more complex generative models
 - *probabilistic models* (including network models, *i.e.*, Bayesian networks) & Markov models - laying groundwork for data generation & pattern prediction



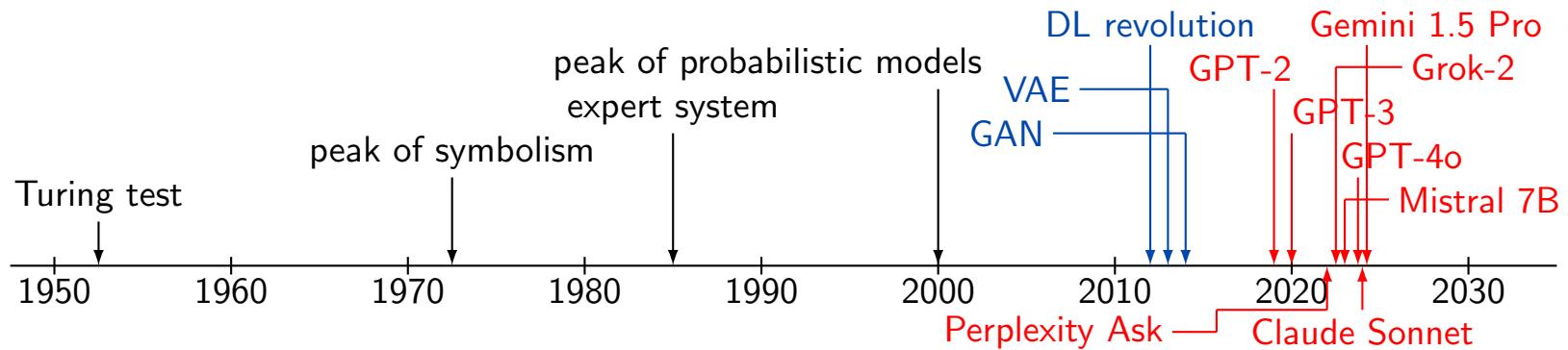
Rise of deep learning & generative models

- 2010s - breakthrough in genAI
 - *deep learning (DL) revolution* - advances in GPU computing and data availability led to the rapid development of deep neural networks.
 - *variational autoencoder (VAE)* (2013) - by Kingma and Welling - learns mappings between input and latent spaces
 - *generative adversarial network (GAN)* (2014) - by Ian Goodfellow - game-changer in generative modeling where two NNs compete each other to create realistic data
 - widely used in image generation & creative tasks



Transformer models & multimodal AI

- late 2010s ~ Present
 - Transformer architecture (2017) - by Vaswani et al.
 - *revolutionized NLP*, e.g., LLM & various genAI models
 - GPT series - generative pre-trained transformer
 - GPT-2 (2019) - generating human-like texts - *marking leap in language models*
 - GPT-3 (2020) - 175B params - set *new standards for LLM*
 - multimodal systems - DALL-E & CLIP (2021) - *linking text and visual data*
 - emergence of diffusion models (2020s) - new approach for generating high-quality images - progressively “denoising” random noise (DALL-E 2 & Stable Diffusion)



Significant AI Achievements - 2014 – 2025

Deep learning revolution

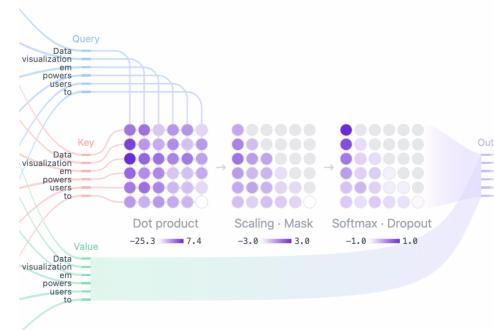
- 2012 – 2015 - DL revolution²
 - CNNs demonstrated exceptional performance in image recognition, e.g., *AlexNet's victory in ImageNet competition*
 - widespread adoption of DL learning in CV transforming industries
- 2016 - AlphaGo defeats human Go champion
 - DeepMind's AlphaGo defeated world champion in Go, extremely complex game *believed to be beyond AI's reach*
 - significant milestone in RL - AI's potential in solving complex & strategic problems



²CV: computer vision, NN: neural network, CNN: convolutional NN, RL: reinforcement learning

Transformer changes everything

- 2017 – 2018 - Transformers & NLP breakthroughs³
 - *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



³NLP: natural language processing, GPT: generative pre-trained transformer

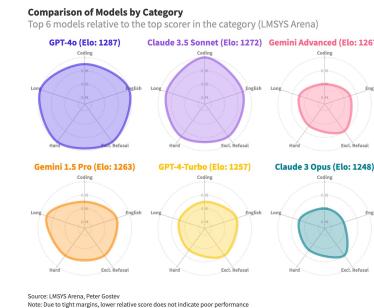
Lots of breakthroughs in AI technology and applications in 2024

- 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*



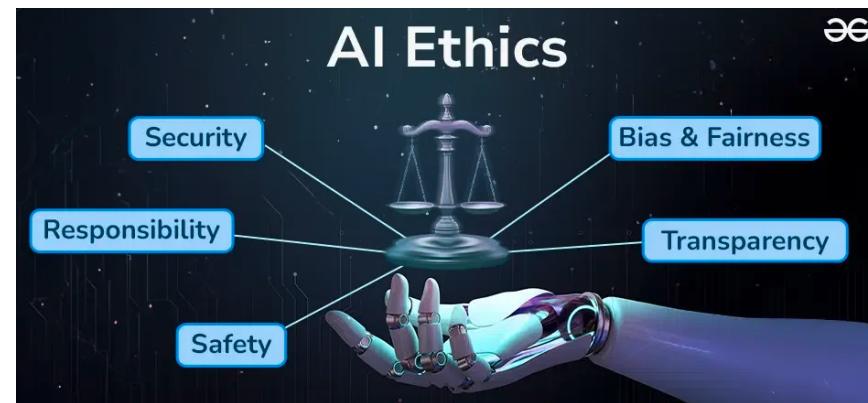
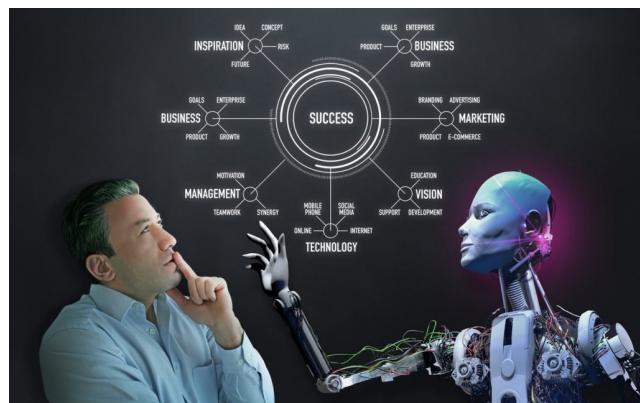
Major AI Breakthroughs in 2025

- 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

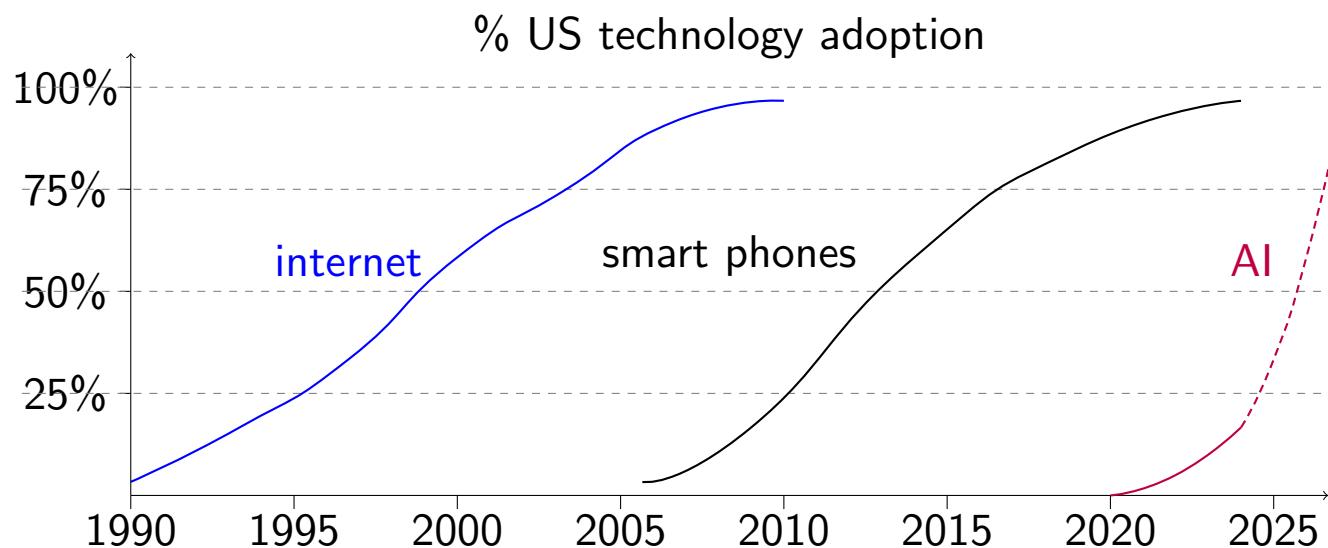
- accelerating human-AI collaboration
 - not only reshaping industries but *altering how humans interact with technology*
 - AI's role as collaborator and augmentor redefines productivity, creativity, the way we address global challenges, e.g., *sustainability & healthcare*
 - AI-driven automation *transforms 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

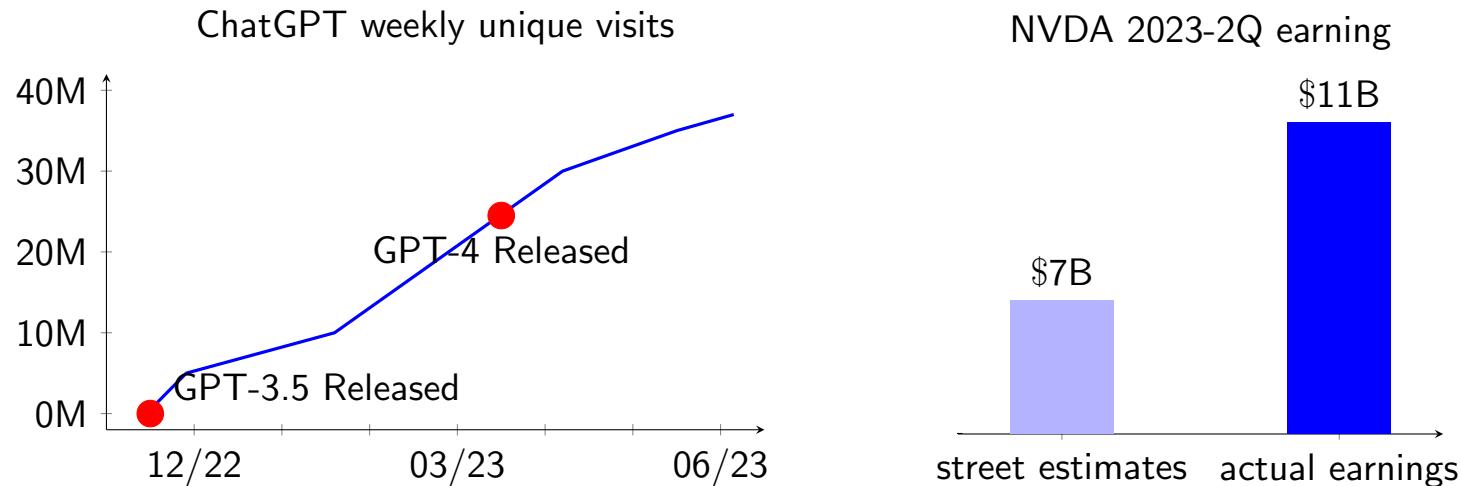
Where are we in AI today?

- 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

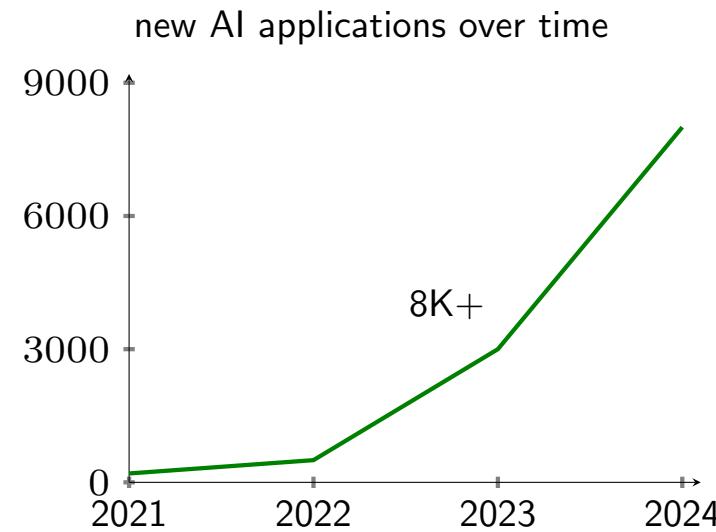
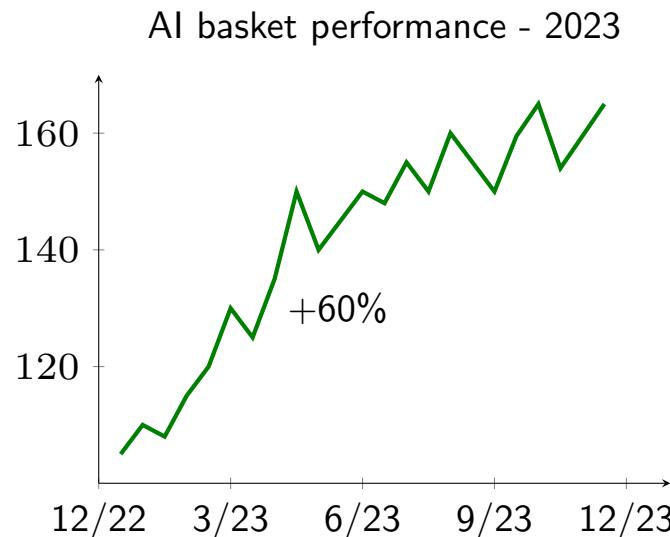
- took only *5 months for ChatGPT users to reach 35M*
- NVIDIA 2023 Q2 earning exceeds market expectation by big margin - \$7B vs \$13.5B
 - surprisingly, *101% year-to-year growth*
 - even more surprisingly *gross margin was 71.2%* - up from 43.5% in previous year⁴



⁴source - 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



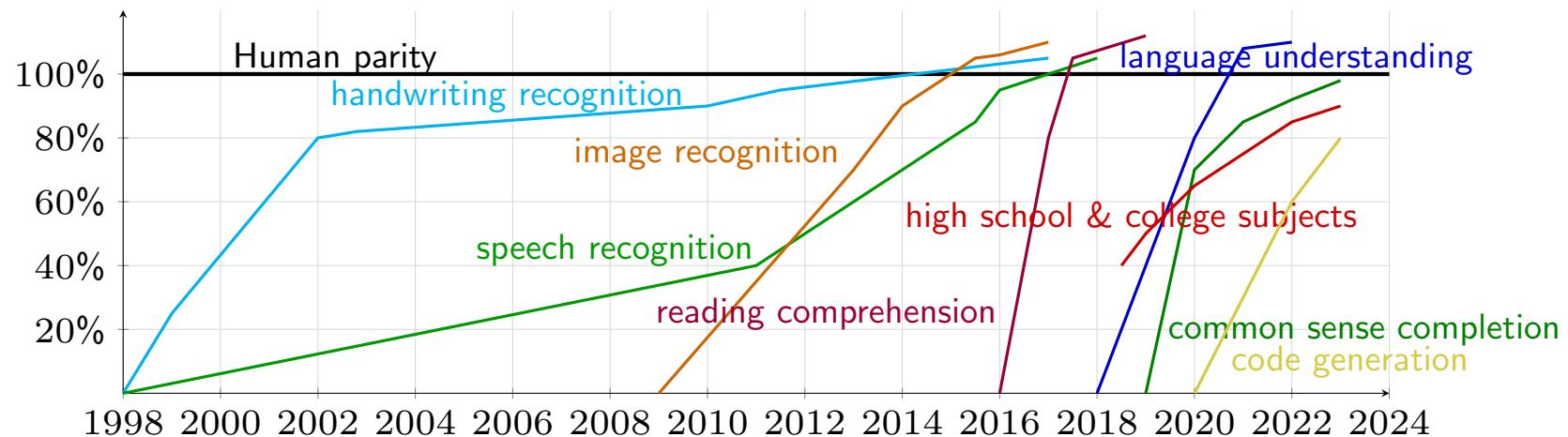
AI's transformative impact - adoption speed & economic potential

- 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



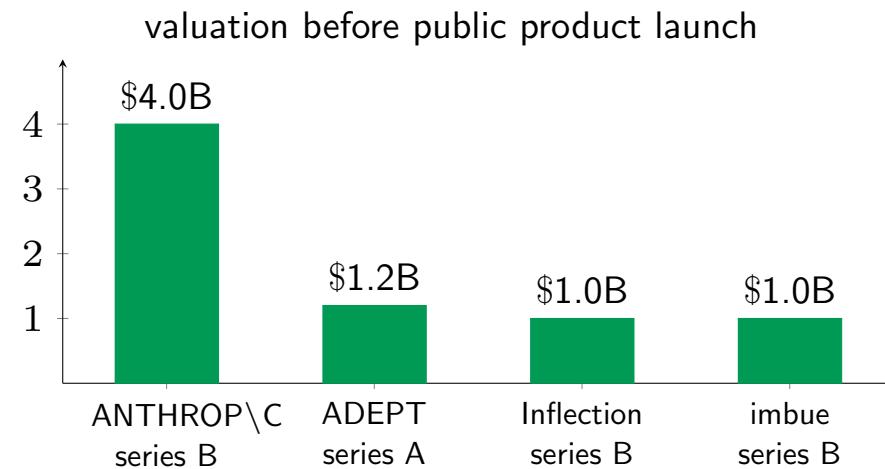
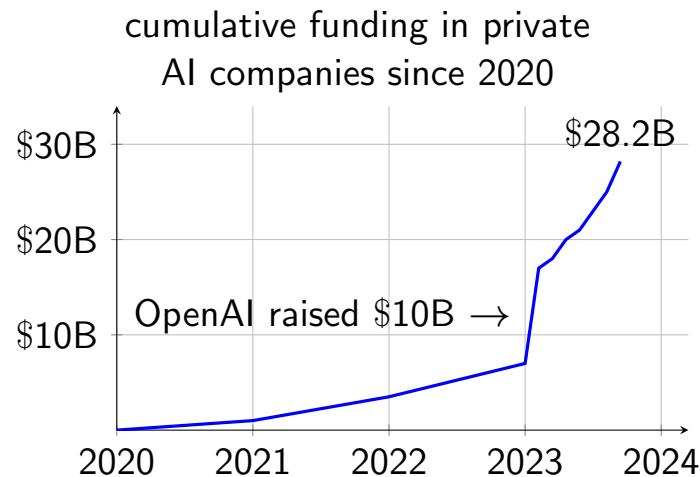
AI getting more & more faster

- 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



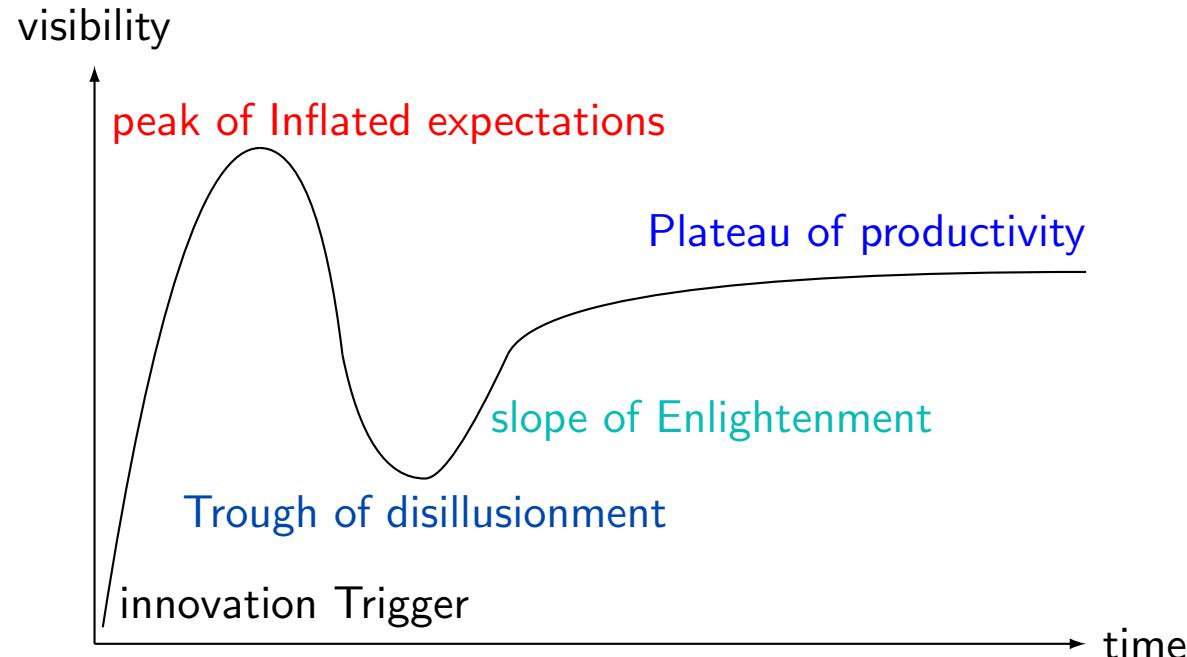
Massive investment in AI

- *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*



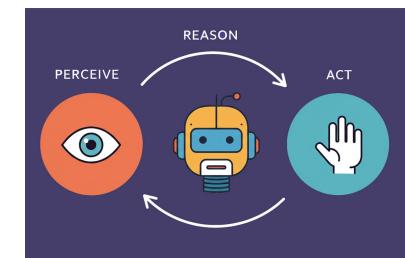
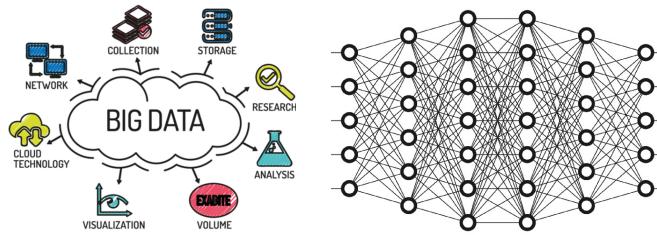
Yes & No

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

AI Agents

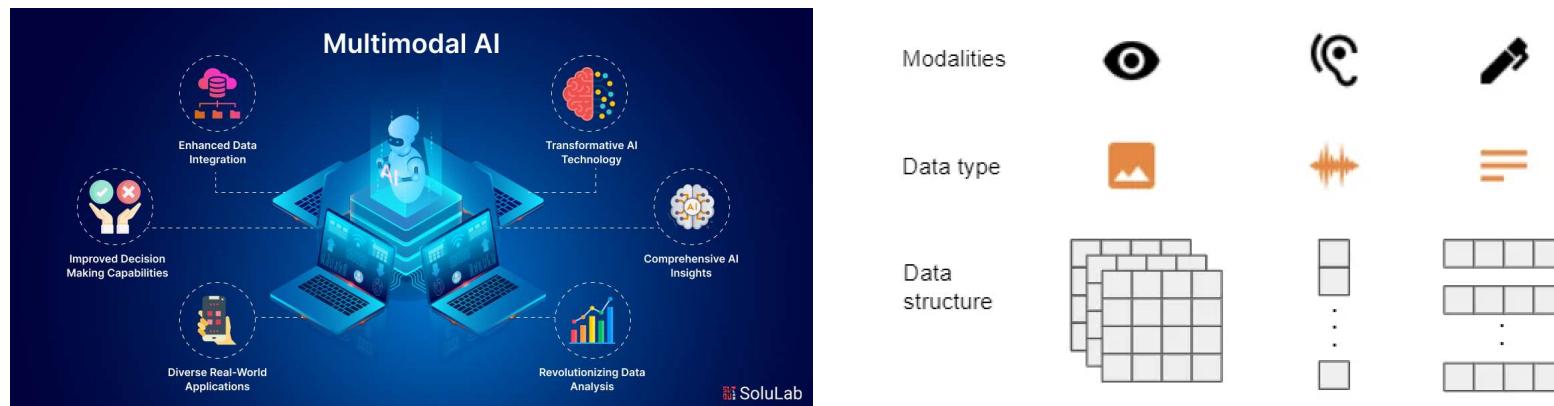
AI progress in 21st century in keywords

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



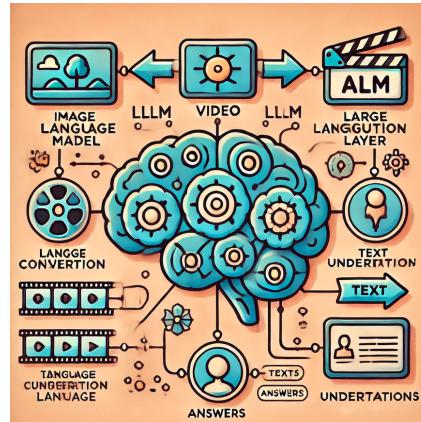
Multimodal learning

- 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)



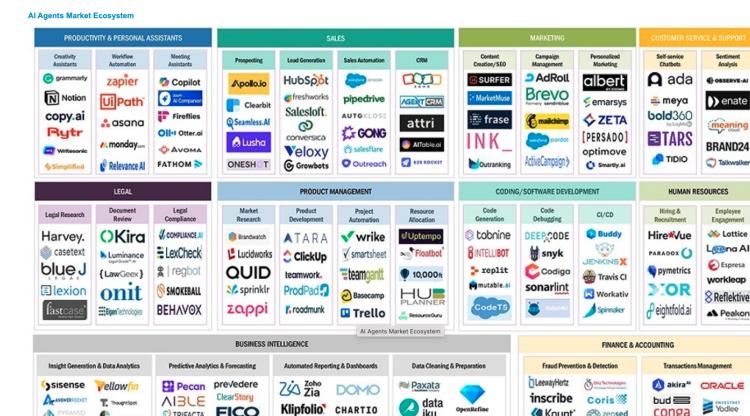
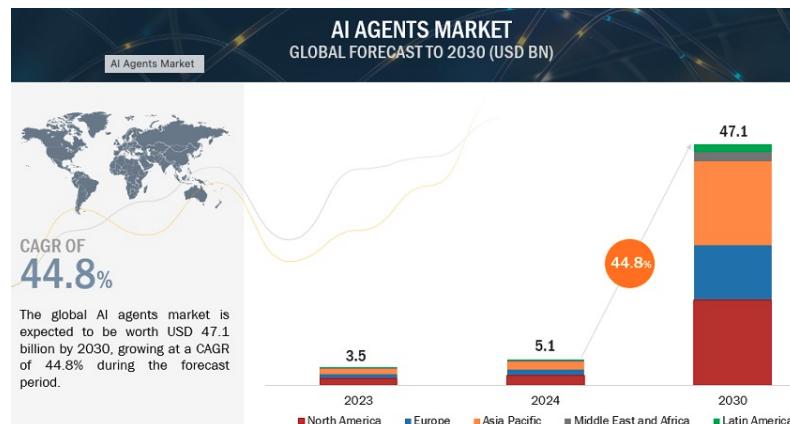
Implications of success of LLMs

- 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

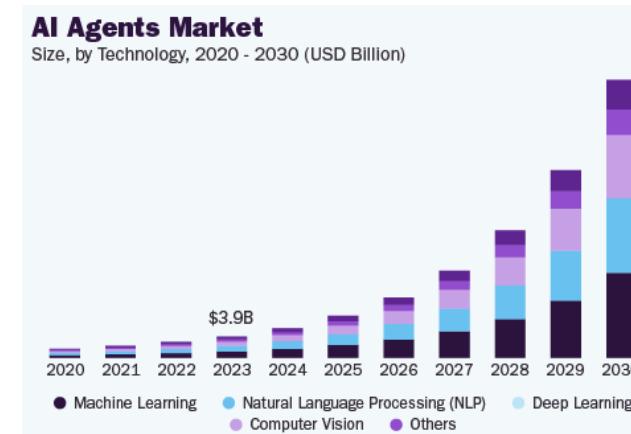
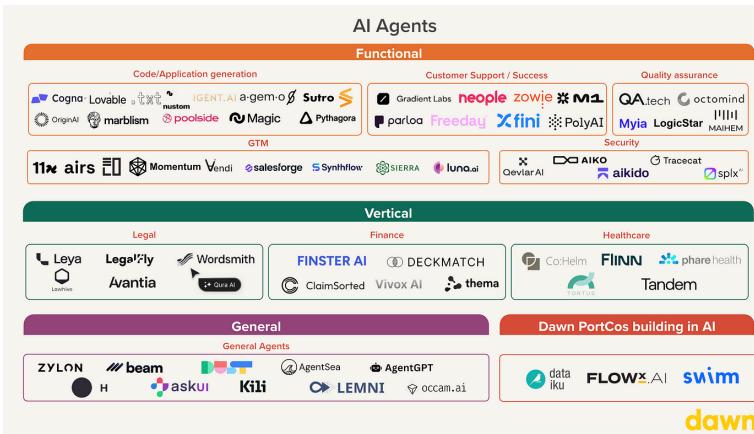


mmAI Technology

- 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

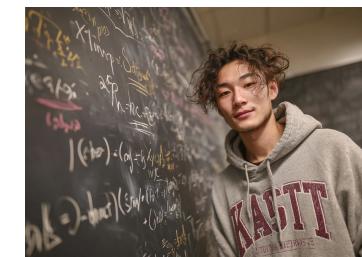
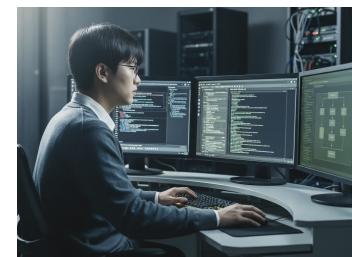
- emerging applications
 - scientific research - agents analyzing & running experiments & generating hypotheses
 - creative collaboration - AI partners in design & art combining multiple mediums
 - environmental monitoring - processing satellite sensor data for climate analysis
 - healthcare - enhanced 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



Building Your Superpower

Students already building with AI - two paths, one future

- AI power user - domain experts using AI (majority)
 - 17-year-old high school student - passionate about helping elderly grandparents
 - built medication reminder app using Claude - no programming background
 - “. . . didn’t learn to code. I learned to describe what grandparents need to AI.”
 - college business student - interested in K-beauty industry
 - used Claude to analyze social media sentiment to predict K-beauty trend
 - “I understood Korean beauty culture. AI understood data patterns.”
- AI expert - AI scientists & engineers & builders
 - computer science junior - 4 years studying math, algorithms, neural networks
 - fine-tuned open-source LLM for Korean medical terminology
 - collaborated with doctors (domain experts) on diagnostic tool



AI power user - domain expert AI-amplified

- who this is for?
 - you love literature, business, medicine, law, art, design, etc.
 - you find AI interesting as TOOL, not as end in itself
 - you get excited about domain problems, not algorithms
- what you'll do
 - deepen expertise in your chosen field (4+ years) - learn AI tools as power tools
 - use AI to amplify your domain work & compete on domain insight + AI leverage
- career examples
 - doctor using AI diagnostics, teacher using AI personalization
 - lawyer using AI research, artist using AI iteration
 - marketer using AI analytics, scientist using AI simulation



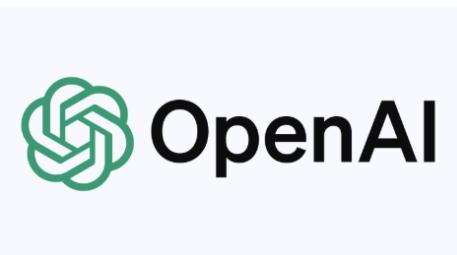
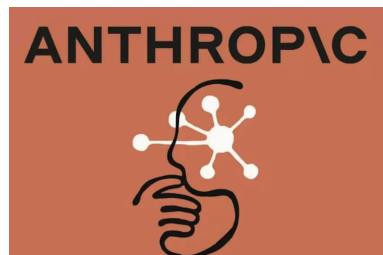
AI expert - researcher/scientist/engineer/developer

- who this is for?
 - you find algorithms, mathematics, systems *beautiful*, and read AI papers for fun
 - you want to work at AI labs being excited when new architectures are published
- what you'll do
 - deep study - mathematics, computer science, ML theory (*e.g.*, 4+ years)
 - understand neural networks, transformers to build and improve AI systems
 - *collaborate* w/ domain experts to apply your systems
- career examples
 - ML Engineer working for (tech) companies
 - AI Researcher in academia or industry labs
 - research scientist, robotics engineer, computer vision specialist



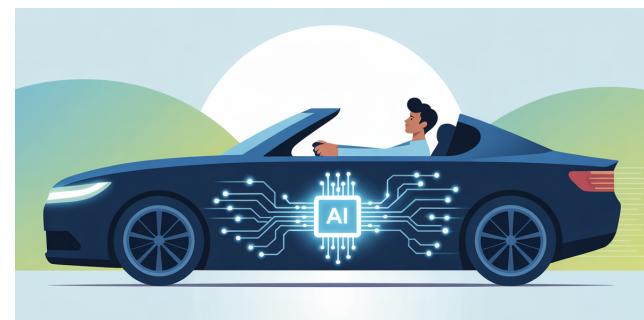
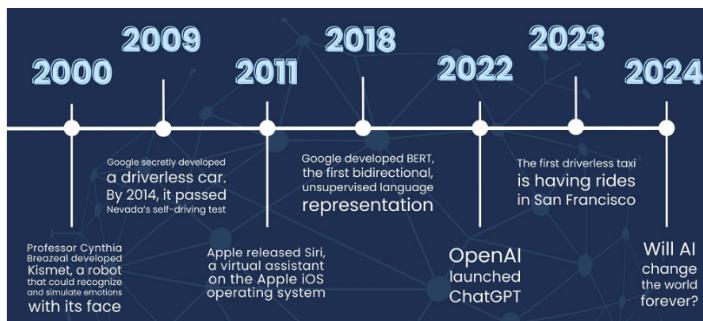
BIG shifts in AI landscape

- old assumption (2015 – 2020)
 - AI will be built by tech companies, everyone else will be disrupted
 - lots of tech companies will compete for best models/products
- new reality (2024 –)
 - AI is commoditized tool, domain expertise is where value accrues
 - only handful of companies can develop cutting-edge foundation models



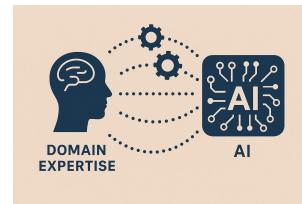
Domain expert revolution

- why domain experts are winning
 - problem identification requires domain knowledge
 - evaluation requires domain judgment
 - trust requires human domain expertise
 - context requires cultural/domain fluency
- pattern across industries
 - best medical AI applications → built by doctors collaborating with AI engineers
 - best legal AI tools → built by lawyers collaborating with AI engineers
 - best educational AI → built by teachers collaborating with AI engineers
 - domain expert leads & AI engineer supports (not the reverse)



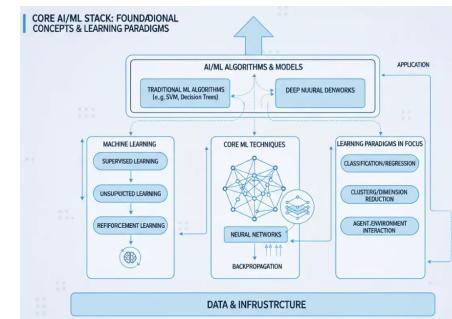
AI power user - what you actually need to learn

- tool awareness
 - what - know which AI tools exist and their capabilities
 - examples - ChatGPT for brainstorming, Claude for research, NotebookLM for synthesis
 - how - YouTube tutorials, free trials, experimentation
- right questions to throw - interactive way
 - what - communicate effectively with AI using domain knowledge
 - why it works - your domain knowledge makes prompts effective
 - how - practice + domain expertise
- tool integration
 - what - connect AI tools to your workflow, build custom GPTs, use APIs (no coding)
 - how - no-code tools + tutorials



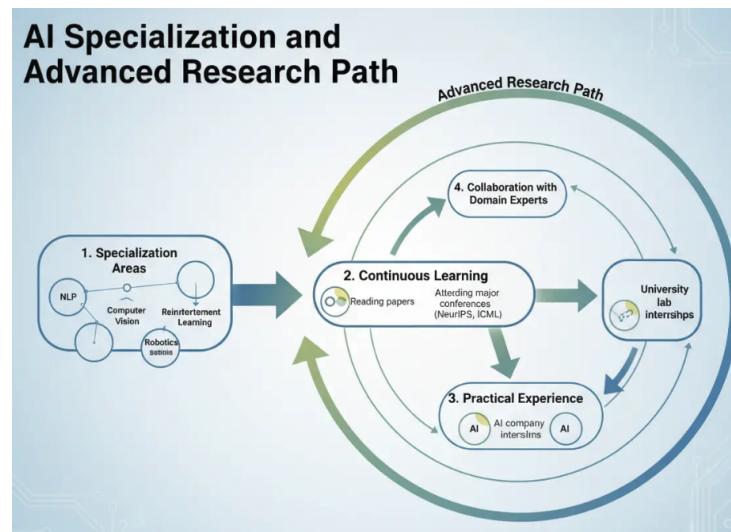
AI expert path - how to become AI scientist/researcher/engineer/practitioner

- foundation
 - mathematics - linear algebra, multivariable calculus, probability theory, optimization
 - programming - python w/ PyTorch, TensorFlow, . . .
 - computer science - data structures, algorithms, systems
- core AI/ML
 - machine learning (ML) - supervised/unsupervised learning, reinforcement learning, neural networks, backpropagation
 - deep learning (DL) - CNNs, RNNs, Transformers, attention mechanisms
 - practical projects - competitions, replicate papers, contribute to open source



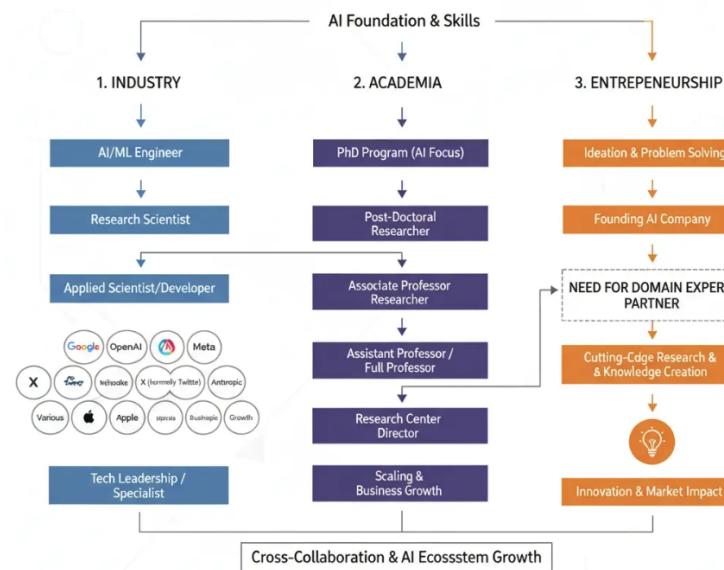
AI expert path - how to become AI scientist/researcher/engineer/practitioner

- specialization
 - choose area (or not!) - NLP, computer vision (CV), robotics, etc.
 - read papers - arxiv, attend conferences (e.g., NeurIPS, ICML, ICLR, CVPR, etc.)
 - research experience - lab work at university, internships at AI companies
 - collaboration - work with domain experts on real problems



AI expert path - how to become AI scientist/researcher/engineer/practitioner

- career paths
 - industry - Google, OpenAI, Meta, Apple, X, Anthropic, and numerous startups
 - academia - PhD → professor / research center
 - entrepreneurship - found AI company (but need domain expert partner!)



Powerful combination - domain expert + AI expert collaboration

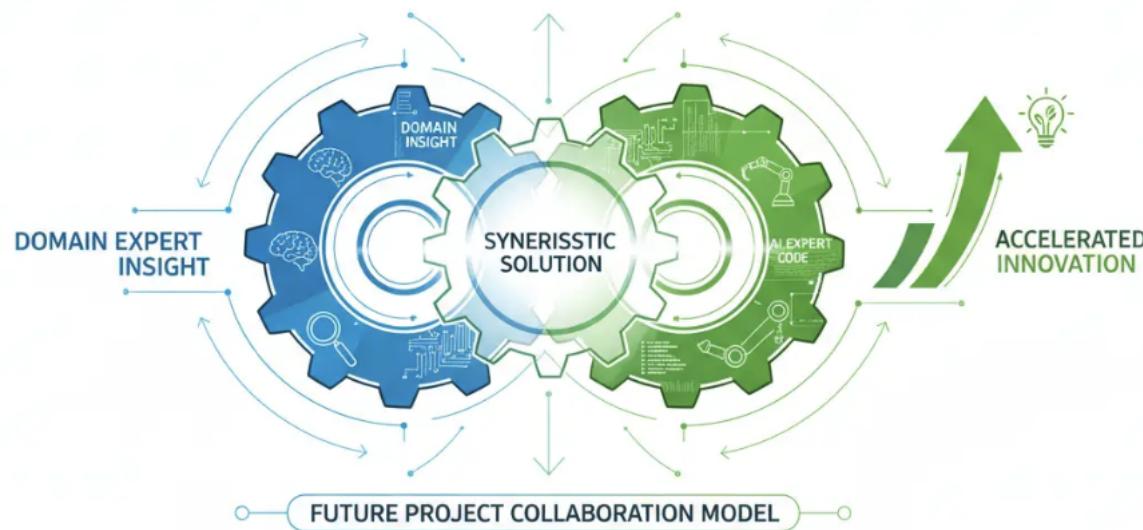
The magic happens at the intersection!

- case study 1 - AlphaFold (Protein Folding)
 - AI engineers - build transformer-based neural network, optimized training
 - structural biologists - identify protein folding as THE problem, validated outputs
 - result - 50-year problem solved - neither could do it alone
 - both Demis Hassabis (CEO @ Google DeepMind) & John Jumper (biochemistry background) got Nobel Prizes in chemistry in 2024!
- case study 2 - cancer diagnostic AI
 - AI engineer role - build model, handle large medical imaging datasets
 - oncologist role - label training data correctly, evaluate clinical relevance
 - result - 30% improvement in early detection
 - who makes final diagnosis - always the doctor!



Powerful combination - domain expert + AI expert collaboration

- case study 3 - your future project
 - domain expert & AI super user- identify problem in your field you understand deeply
 - AI expert - build custom solution beyond available tools
 - result - breakthrough that neither could achieve alone
 - who drives vision - TOGETHER!



Things AI can't do for you - choose who you'll become

- your technical superpower ($\text{Domain} \times \text{AI}$) is only as good as *your moral compass*
- why this matters more than ever
 - AI amplifies whatever you choose to do - good intentions OR bad ones
 - history shows us - brilliant minds + no moral foundation = catastrophe
 - your skills will make you powerful; your values determine what you do with that power
- virtues that actually matter in the long run
 - *integrity* - doing the right thing (even) when no one's watching
 - *empathy* - genuinely caring about people; your technology will affect them
 - *service* - building things that help others, not just things that benefit you
 - *morality* - having inner compass that guides you beyond what's legal or profitable

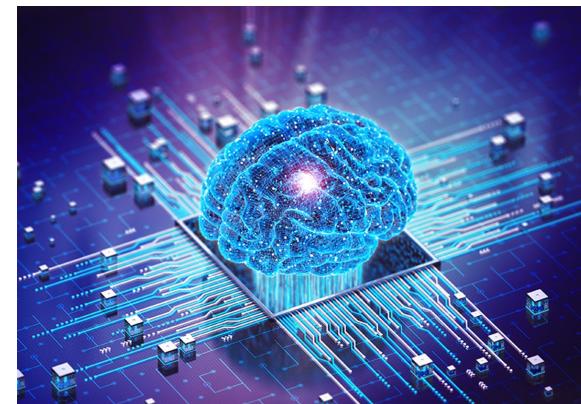


Appendices

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



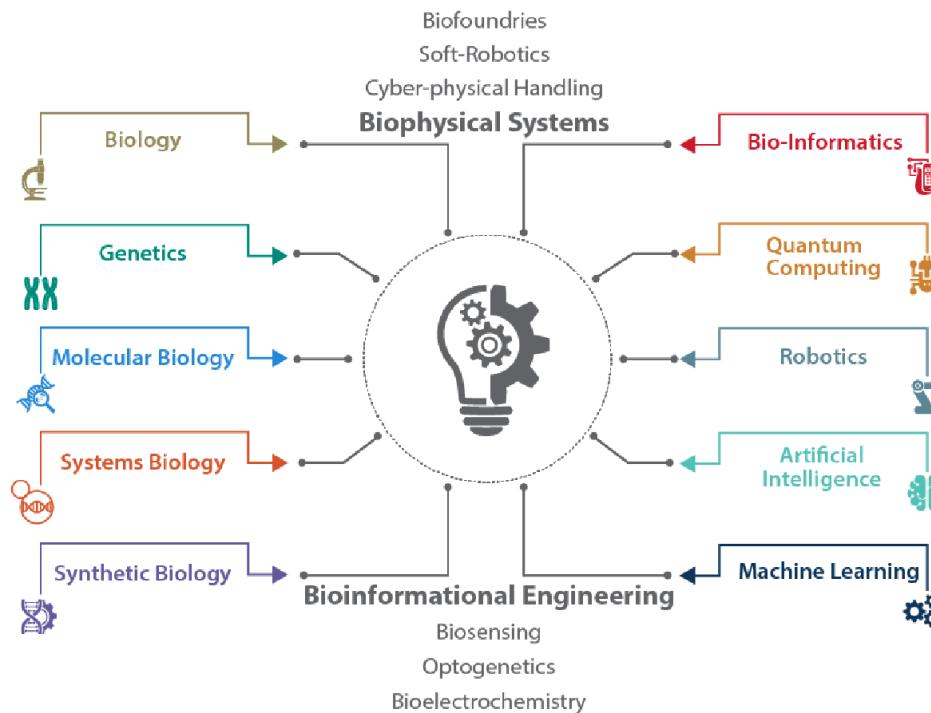
Biotech

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

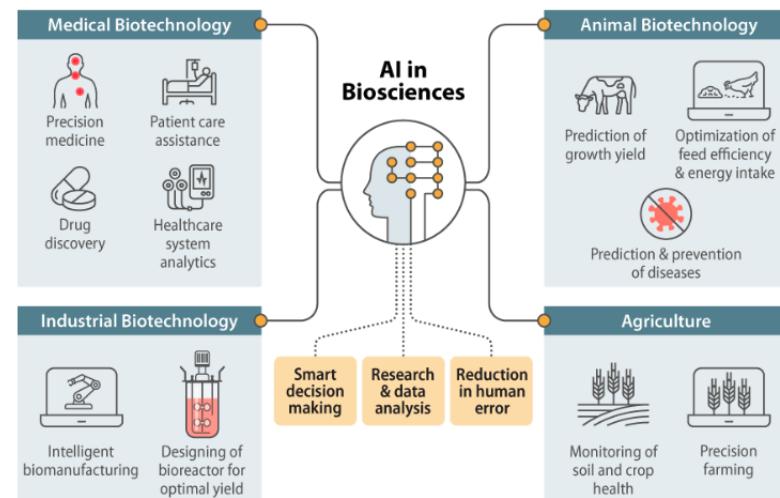
- sciences and technologies enabling biotechnology include (but not limited to)
 - (molecular) biology, genetics, systems biology, synthetic biology, bio-informatics, quantum computing, robotics [DFJ22]



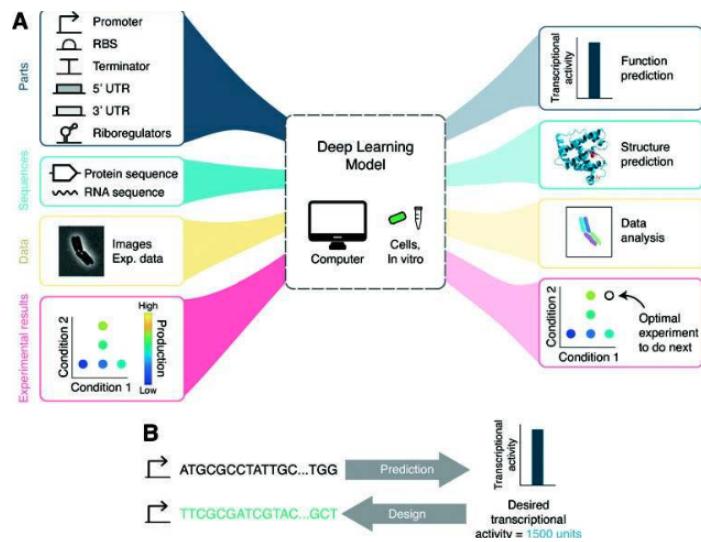
Convergence of AI and biological design

- 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



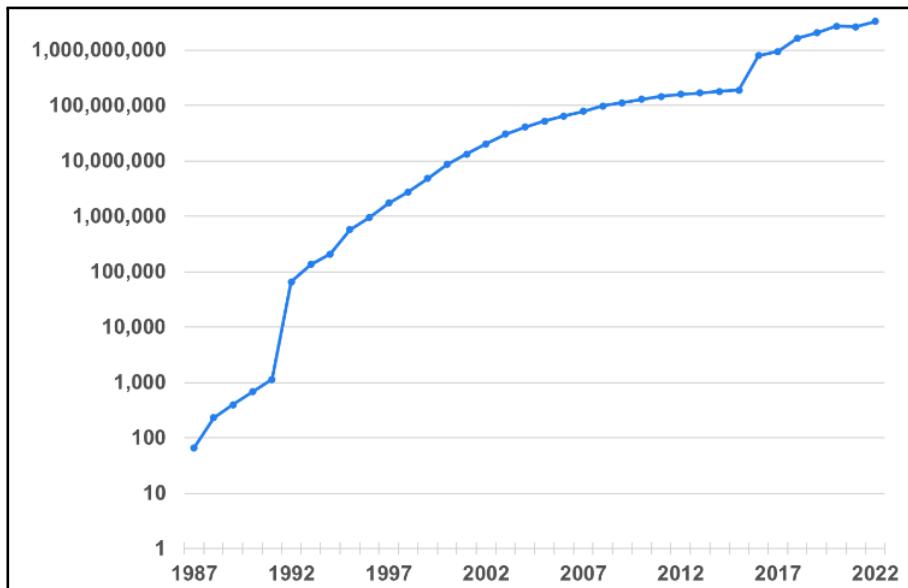
Rapid growth of biological data

- 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

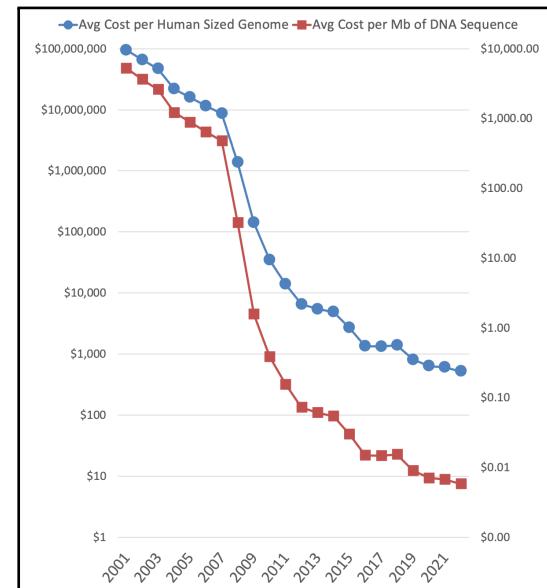
Volume and sequencing cost of DNA over time

- 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



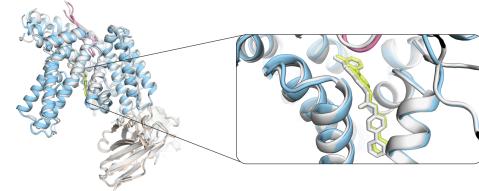
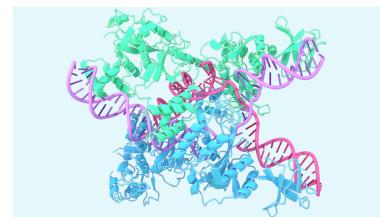
Bio data availability and bias

- 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

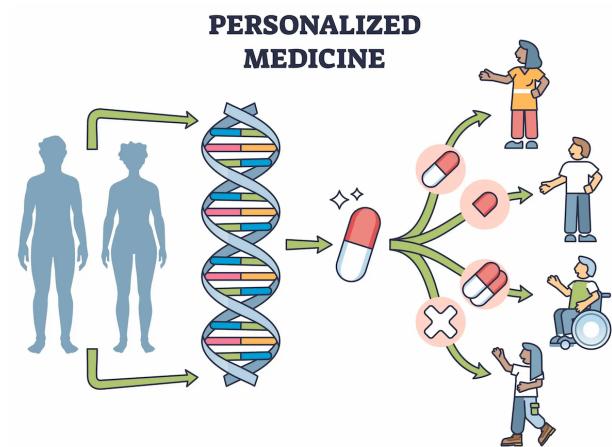


AlphaGo

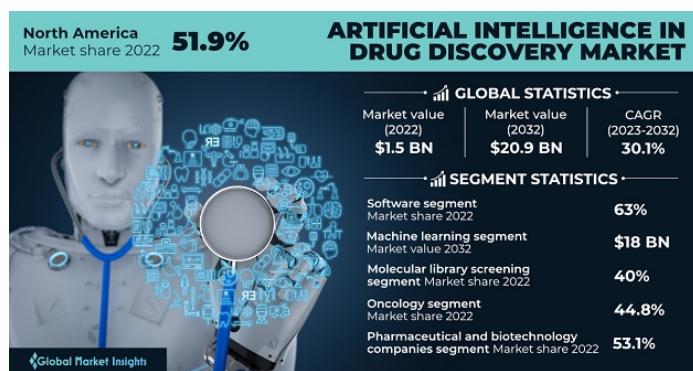
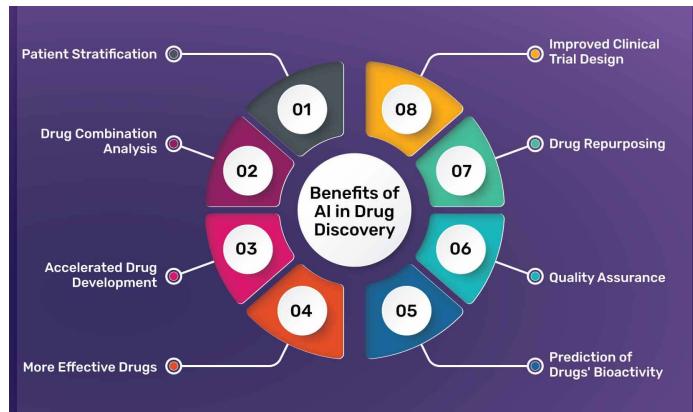


Personalized medicine

- *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.



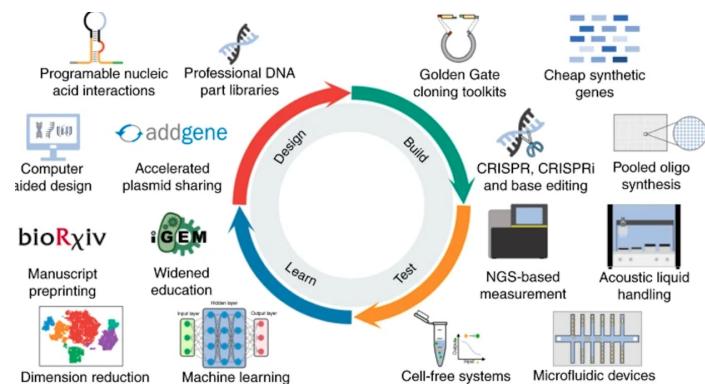
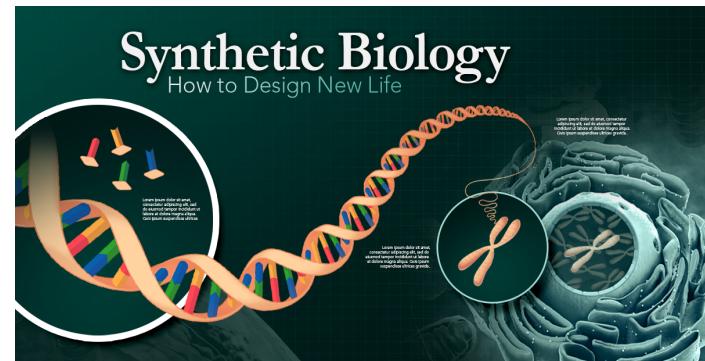
AI-driven drug discovery



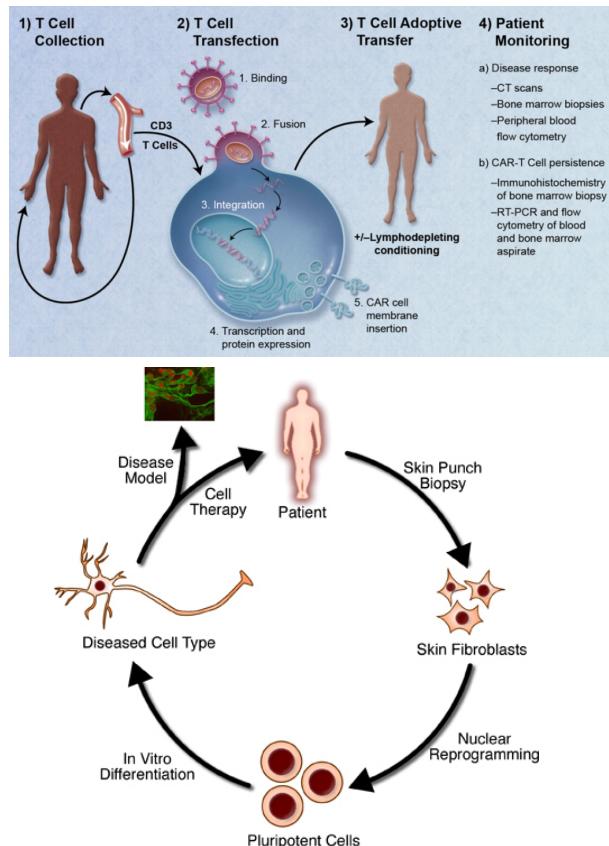
- traditional drug discovery process - time-consuming and costly often taking decades and billions of dollars
- AI streamlines this process by predicting the efficacy and safety of potential compounds with more speed and accuracy
- AI models analyze chemical databases to identify new drug candidates 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



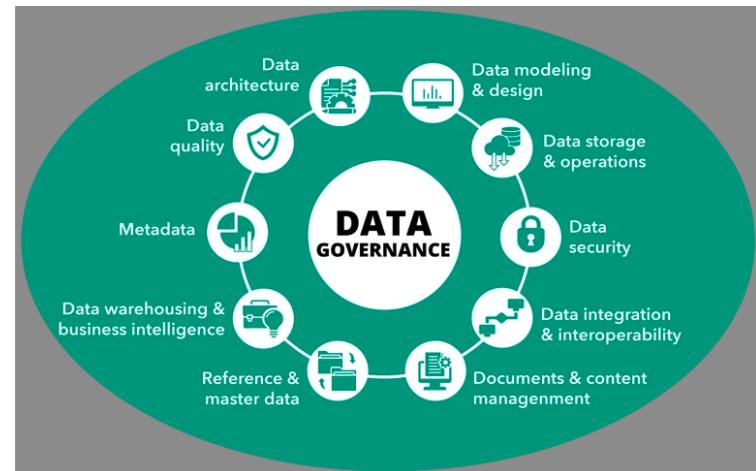
Regenerative medicine



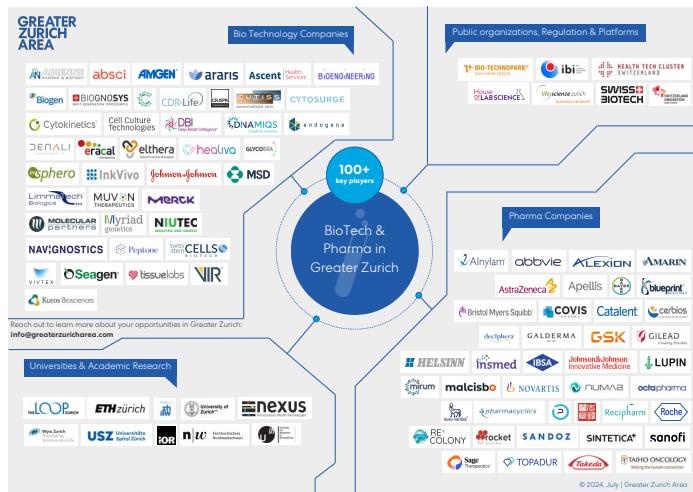
- AI advances development of stem cell therapies & tissue engineering
- AI algorithms assist in identifying optimal cell types, predicting cell behavior & personalized treatments
- particularly for conditions such as neurodegenerative diseases, heart failure and orthopedic injuries
- company - Organovo 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

Some Important Questions around AI

Some important questions around AI

- why human-level AI?
- what lies in very core of DL architecture? what makes it work amazingly well?
- biases that can hurt judgement, decision making, social good?
- AI ethics & legal issues
- consciousness
- utopia vs dystopia
- knowledge, belief, reasoning
- risk of anthropomorphization

Human-level AI?

Why human-level in the first place?

- lots of times, when we measure AI performance, we say
 - how can we achieve human-level performance, *e.g.*, CV models?
- why human-level?
 - are all human traits desirable? are humans flawless?
 - aren't humans still evolving?
- advantage of AI over humans
 - *e.g.*, self-driving cars can use extra eyes, GPS, computer network
 - *e.g.*, recommendation system runs for hundreds of millions of people overnight
 - AI is available 24 / 7 while humans cannot
 - . . . critical advantages for medical assistance, emergency handling
 - AI does not make more mistakes because task is repetitive and tedious
 - AI does not request salary raise or go on strike

What makes DL so successful?

Factors contributing to astonishing success of DL

- analysis based on speaker's mathematical, numerical algorithmic & statistical perspectives considering hardware innovations

30% universal approximation theorem? - (partially) yes! but that's not all

- function space of neural network is *dense* (math theory), *i.e.*, for every $f : \mathbf{R}^n \rightarrow \mathbf{R}^m$, exists $\langle f_n \rangle$ such that $\lim_{n \rightarrow \infty} f_n = f$

25% architectures/algorithms tailored for each class of applications, *e.g.*, CNN, RNN, Transformer, NeRF, diffusion, GAN, VAE, . . .

20% data labeling - expensive, data availability - unlimited web text corpus

15% computation power/parallelism - AI accelerators, *e.g.*, GPU, TPU & NPU

10% rest - Python, open source software, cloud computing, MLOps, . . .

Sudden leap in LLM performance

Probability inferred sequence is correct

- assume

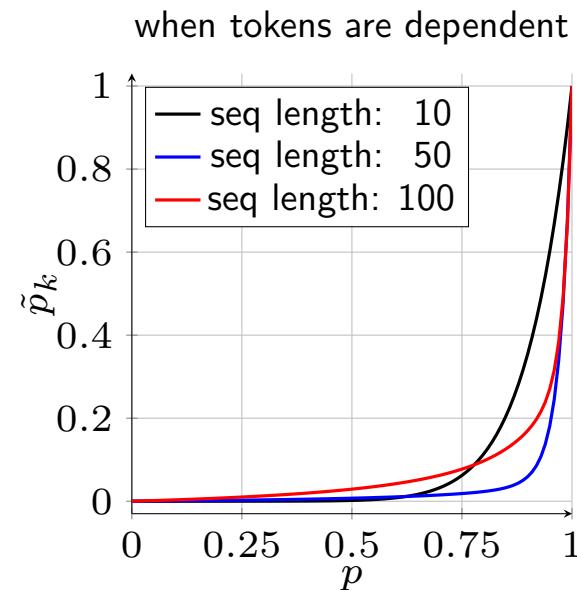
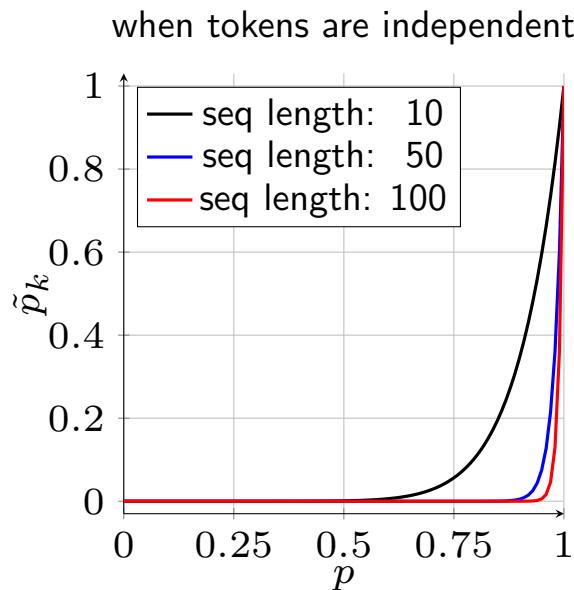
- t_i - i th token
 - p_i - probability that t_i is correct
 - ρ_i - correlation coefficient between t_{i-1} & t_i
 - \tilde{p}_k - probability that (t_1, \dots, t_k) are correct

- recursion

$$\rho_i = \frac{\tilde{p}_i - \tilde{p}_{i-1}p_i}{\sqrt{\tilde{p}_{i-1}(1 - \tilde{p}_{i-1})p_i(1 - p_i)}}$$
$$\Leftrightarrow \tilde{p}_i = \tilde{p}_{i-1}p_i + \rho_i \sqrt{\tilde{p}_{i-1}(1 - \tilde{p}_{i-1})p_i(1 - p_i)}$$

Dramatic improvement of LLM near saturation

- do simulations for both independent & dependent cases
 - assume p_i are same for all i
- (for both cases) sequence inference improves dramatically as p approaches 1
- this explains *why we have observed sudden dramatic performance improvement of certain seq2seq learning technologies*, e.g., LLM



Biases

Cognitive biases attributed to humans

- cognitive biases [Kah11]
 - confirmation bias, availability bias
 - hindsight bias, confidence bias, optimistic bias
 - anchoring bias, halo effect, framing effect, outcome bias
 - belief bias, negativity bias, false consensus



Biases of LLMs

- LLMs subject to
 - availability bias - biased by imbalancedly available information
 - LLM trained by imbalanced # articles for specific topics
 - belief bias - derive conclusion not by reasoning, but by what it saw
 - LLM easily inferring what it saw, *i.e.*, data it trained on
 - halo effect - overemphasize on what prestigious figures say
 - LLM trained by imbalanced # reports about prestigious figures
- similar facts true for other types of ML models,
 - *e.g.*, video caption, text summarization, sentiment analysis
- cognitive biases only humans represent
 - confirmation bias, hindsight bias, confidence bias, optimistic bias, anchoring bias, negativity bias, framing effect

AI Ethics

Ethical issues related to AI

- AI can be exploited by those who have bad intention to
 - manipulate / deceive people - using manipulated data corpus for training
 - *e.g.*, spread false facts
 - induce unfair social resource allocation
 - *e.g.*, medical insurance, taxation
 - exploit advantageous social and economic power
 - *e.g.*, unfair wealth allocation, mislead public opinion
- AI for Good - advocated by Andrew Ng
 - *e.g.*, public health, climate change, disaster management
- should scientists and engineers be morally & politically conscious?
 - *e.g.*, Manhattan project

AI related Legal Issues

Legal issues with ethical consideration

- scenario 1 - full self-driving algorithm causes traffic accident killing people
 - who is responsible? - car maker, algorithm developer, driver, algorithm itself?
- scenario 2 - self-driving cars kill less people than human drivers
 - *e.g.*, human drivers kill 1.5 people for 100,000 miles & self-driving cars kill 0.2 people for 100,000 miles
 - how should law makers make regulations?
 - utilitarian & humanitarian perspectives
- scenario 3 - someone is not happy with their data being used for training
 - “The Times sues OpenAI and Microsoft over AI use of copyrighted work” (Dec-2023)
 - “Newspaper publishers in California, Colorado, Illinois, Florida, Minnesota and New York said Microsoft and OpenAI used millions of articles without payment or permission to develop ChatGPT and other products” (Apr-2024)

Consciousness

Consciousness

- what is consciousness, anyway?
 - recognizes itself as independent, autonomous, valuable entity?
 - recognizes itself as living being, unchangeable entity?
- no agreed definition on consciousness exists yet
 - . . . and will be so forever
- does it have anything to do with the fact that humans are biologically living being?
- is SKYNET ever plausible?
 - can AI have *desire* to survive (or save earth)?



Utopia vs Dystopia

Utopia vs dystopia



- not important questions (at all) *I think . . .*
- what we should focus on is *not* the possibilities of doomsday or Judgment Day, but rather
 - our limits on controlling unintended impacts of AI
 - *misuse* by (greedy, immoral, and unethical) people possessing social, economic & political power
 - *social good and welfare impaired* by either exploiting AI or ignorance of (inner workings of) AI
- should concern
 - choice or balance among utilitarianism, humanitarianism & values
 - amend or improve laws/regulations
 - ethical issues caused by AI

Knowledge, Belief, and Reasoning

Does AI (LLM) have knowledge or belief? Can it reason?

**What categories of questions do they belong to?
engineering, scientific, philosophical, cognitive scientific, . . . ?**

LLMs . . .

- LLM is very different sort of animal . . . except that it is *not* an animal!
- *unreasonable* effectiveness of data [HNF09]
 - *performance scales with size of training data*
 - *qualitative leaps* in capability as models scale
 - tasks demanding human intelligence *reduced to next token prediction*
- focus on third surprise

conditional probability model looks like human with intelligence

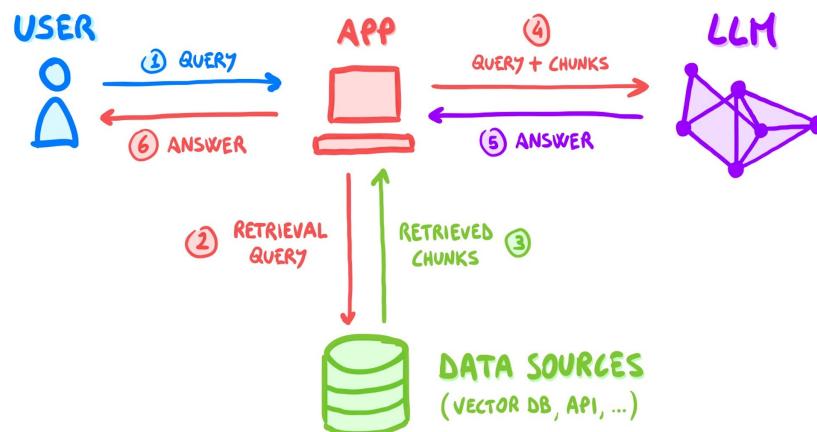
- making vulnerable to anthropomorphism
- examine it by throwing questions such as
 - “*does LLM have knowledge and belief?*”
 - “*can it reason?*”

What LLM really does!

- given prompt “the first person to walk on the Moon was”, LLM responds with “Neil Armstrong”. . . strictly speaking
 - it’s *not* being asked *who* was the first person to walk on the Moon
 - what are being *really* asked is “*given statistical distribution of words in vast public corpus of text, what words are most likely to follow ‘The first person to walk on the Moon was’?*”
- given prompt “after ring was destroyed, Frodo Baggins returned to”, LLM responds with “the Shire”
 - on one level, it seems fair to say, you might be testing LLM’s knowledge of fictional world of Tolkien’s novels
 - what are being *really* asked is “*given statistical distribution of words in vast public corpus of text, what words are most likely to follow ‘After the ring was destroyed, Frodo Baggins returned to’?*”

LLMs vs systems in which they are embedded

- crucial to distinguish between the two (for philosophical clarity)
 - LLM (bare-bones model) - highly specific & well-defined function, which is *conditional probability estimator*
 - systems in which LLMs are embedded, *e.g.*, for question-answering, news article summarization, screenplays generation, language translation



How ChatBot works?

- conversational AI agent does *in-context learning* or *few-shot prompting*
- for example,

- when the user enters

- who is the first person to walk on the Moon?

- ChatBot, LLM-embedded system, feeds the following to LLM

- User, a human, and BOT, a clever and knowledgeable AI agent.

- User: what is 2+2?

- BOT: the answer is 4.

- User: where was Albert Einstein born?

- BOT: he was born in Germany.

- User: who is the first person to walk on the Moon?

- BOT:

Knowledge, belief & reasoning around LLM

- *not* easy topic to discuss, or even impossible because
 - we *do not have agreed definition* of these terms especially in context of being asked questions like

does LLM have belief?
or
do humans have knowledge?
- let us discuss them in two different perspectives
 - laymen's perspectives
 - cognitive scientific & philosophical perspectives

Laymen's perspectives on knowledge, belief & reasoning

- does (good) LLM have knowledge?
 - Grandmother: looks like it cuz when instructed “*explaining big bang*”, it says
“*The Big Bang theory is prevailing cosmological model that explains the origin and evolution of the universe. . . . 13.8 billion years ago . . .*”
- does it have belief?
 - Grandmother: I don't think so, e.g., it does not believe in God!
- can it reason?
 - Grandmother: seems like it! e.g., when asked “*Sunghee is a superset of Alice and Beth is a superset of Sunghee. Is Beth a superset of Alice?*”, it says
“*Yes, based on information provided, if Sunghee is a superset of Alice and Beth is a superset of Sunghee, then Beth is indeed a superset of Alice . . .*”
- can it reason to prove theorem whose inferential structure is more complicated?
 - Grandmother: I'm not sure – actually, I don't know what you're talking about!

Knowledge

- could argue LLM “knows” which words follow which other words with high probability
- but, only *in context of capacity to distinguish truth from falsehood* can we legitimately speak of “knowledge” !
- LLM(-embedded BOT)
 - can be said to “*encode*”, “*store*”, or “*contain*” knowledge
 - lacks means to use words “true” & “false” in all ways & in all contexts because . . .
 - *does not inhabit the world* we human language-users share!



Belief

- nothing can count as *belief about the world* we share unless
 - is against backdrop of “*ability to update beliefs appropriately in light of evidence from that world*” - (again) essential capacity to distinguish truth from falsehood
- change taking place in humans when acquiring or updating belief is
 - reflection of their nature as language-using animals inhabiting shared world with community of language-users
- then, *what if LLM-embedded system updates LLM with outside world information?*
 - even so, when interacting with AI systems based on LLMs, these grounds are *absent!*



can you provide me up-to-date information about AI agent perplexity?

Sources

- Perplexity AI: A Guide for Beginners - Jeff Su
- Perplexity AI's value to our AI team as it raises new \$800K funding - siliconangle
- Perplexity At A Deep Dive - Reflections

Perplexity

Perplexity AI is an AI-powered search engine and answer engine that has gained significant traction in recent years. Founded in 2022, Perplexity uses large language models (LLMs) to generate answers to user queries, citing sources from the web within the text response. As of Q1 2024, Perplexity had reached 15 million monthly users.

Key features and developments of Perplexity AI include:

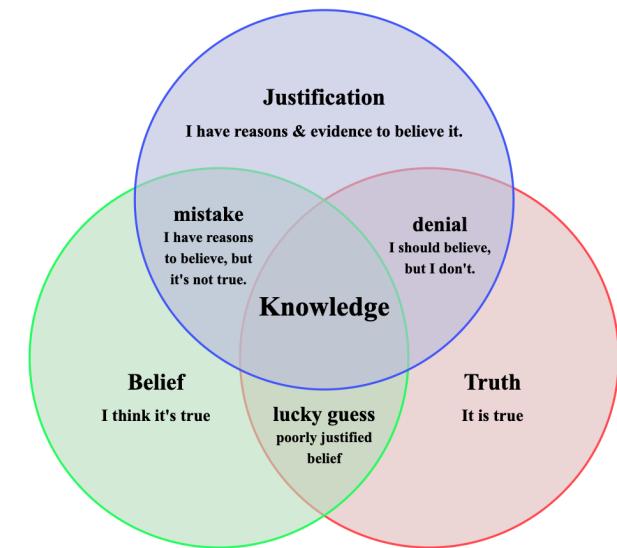
- Search functionality: Perplexity summarizes search results and produces text with inline citations, providing personalized results based on the context of user queries

Ask follow-up



Knowledge in philosophical and cognitive scientific sense

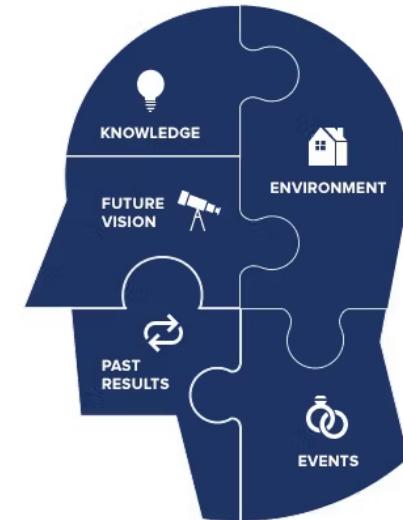
- does LLM have knowledge?
 - Sunghee: *I don't think so!*
- why?
 - we say we have “knowledge” when
“we do so against ground of various human capacities that we all take for granted when we engage in everyday conversation with each other.”
 - when asked *“who is Tom Cruise’s mother?”*, it says *“Tom Cruise’s mother is Mary Lee Pfeiffer.”*
 However, this is nothing but
“guessing” by conditional probability model the most likely words following “Tom Cruise’s mother is.”
 - so *we cannot say it really knows the fact!*



Belief in philosophical and cognitive scientific sense

- for the discussion
 - do *not* concern any specific belief
 - but concern *prerequisites for ascribing any beliefs to AI system*
- so does it have belief?
 - nothing can count as belief about the world we share unless
 - it is against ground of the ability to update beliefs appropriately in light of evidence from that world, essential aspect of the capacity to distinguish truth from falsehood*
 - LLM does not have this ground, essential consideration when deciding whether it *really* had beliefs.
- Sunghee: so *no, LLM cannot have belief!*

WHERE DO YOUR
BELIEFS COME FROM?



Reasoning in philosophical and cognitive scientific sense

- note reasoning is *content neutral*
 - e.g., following logic is perfect regardless of truth of premises
 - hence, no access to outside world does *not* disqualify
- when asked “*if humans are immortal, would Socrates have survived today?*”, LLM says “*... it's logical to conclude that Socrates would likely still be alive today. ...*”
- however, remember, once again, what we just asked it to do is *not* “deductive inference”
given the statistical distribution of words in public corpus, what words are likely to follow the sequence, “humans are immortal and Socrates is human therefore.”
- Sunghee: so *no, LLM cannot reason, either!*
- but, LLM
 - pretends to reason, and from which capabilities, we can benefit!
 - also, can *mimic even multi-step reasoning whose inferencing structure is complicated* using *chain-of-thoughts prompting*, i.e., *in-context learning* or *few-short prompting*

Simple example showing LLM not possessing knowledge



- User
"Who is Tom Cruise's mother?"
- LLM(-embedded question-answering system) (as of Jan 2022)
"Tom Cruise's mother is Mary Lee Pfeiffer. She was born Mary Lee South. . . . Information about his family, including his parents, has been publicly available, . . . "
- User
"Who is Mary Lee Pfeiffer's son?"
- LLM(-embedded question-answering system) (as of Jan 2022)
"As of my last knowledge update in January 2022, I don't have specific information about Mary Lee Pfeiffer or her family, including her son. . . . "

Risk of anthropomorphization

- unfortunately, contemporary LLMs are *too powerful, too versatile, and too useful for most people to accept (after understanding) previous arguments!*
- maybe, o.k. for laymen to (mistakenly) anthropomorphize LLM(-embedded systems)
- however, *imperative for (important, smart, and responsible) AI researchers, scientists, engineers & practitioners* to have rigorous understanding in these aspects especially when
 - advise and be consulted by law makers, policy makers, journalists, and various stakeholders responsible for *critical business decisions (in private sectors) and public policies (in public sectors)*
 - collaborate with or/and help professionals in liberal arts, such as *philosophy, ethics, law, religion, literature, history, music, cultural studies, psychology, sociology, anthropology, political science, economics, archaeology, linguistics, media studies, natural sciences, fine arts, . . .*
 - to address negative societal and economic impacts

Moral

- AI shows incredible utility and commercial potentials, hence should
 - make informed decisions about trustworthiness and safety
 - avoid ascribing capacities they lack
 - *take best utilization of remarkable capabilities of AI*
- today's AI so powerful, so (seemingly) convincingly intelligent
 - obfuscate mechanism
 - actively encourage *anthropomorphism* with philosophically loaded words like “*believe*” and “*think*”
 - easily mislead people about character and capabilities of AI
- matters not only to scientists, engineers, developers, and entrepreneurs, but also
 - *general public, law & policy makers, journalists, . . .*

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Selected references & sources

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Thank You