

[Special AI Lecture for Legal Professionals]
The AI Paradigm Shift for Legal Minds - Silicon Valley
Insights, Cognitive Science Foundations, and the
Intersection of Logic and Pattern Recognition

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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 ~
- *Advisor to Korean American Semiconductor Professional Alliance (KASPA)* 2026 ~
- *CGO / Global Managing Partner @ LULUMEDIC, Seoul, Korea* 2025 ~
- *KFAS-Salzburg Global Leadership Fellow @ Salzburg Global Seminar, Austria* 2024 ~
- *Adjunct Professor, EE Department @ Sogang University, Seoul, Korea* 2020 ~
- *Advisory Professor, EECS Department @ DGIST, Korea* 2020 ~
- *AI-Korean Medicine Integration Initiative Task Force Member @ The Association of Korean Medicine, Seoul, Korea* 2025 ~
- *Director of AI Semiconductor @ K-BioX, CA, USA* 2025 ~
- *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 ~
- *Advisor @ CryptoLab, Inc., Seoul, Korea* 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 @ Voyan, 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 for Legal Professionals

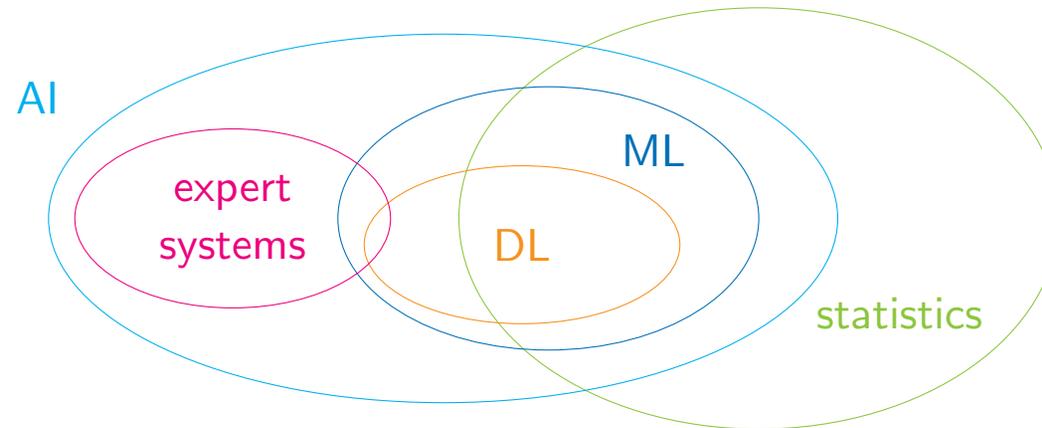
- Artificial Intelligence - 5
 - AI history & recent significant achievements, market indicators
- AI Agents - 30
 - LLM as highly effective knowledge-transfer representation learner
- AI Paradigm Shift for Legal Professionals - 38
 - AI as prevention, NOT replacement
 - preparing legal professionals for AI era
- Some Important Questions around AI - 55
 - consciousness, AI ethics, legal issues, knowledge, belief, and reasoning
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Artificial Intelligence

Definition and History

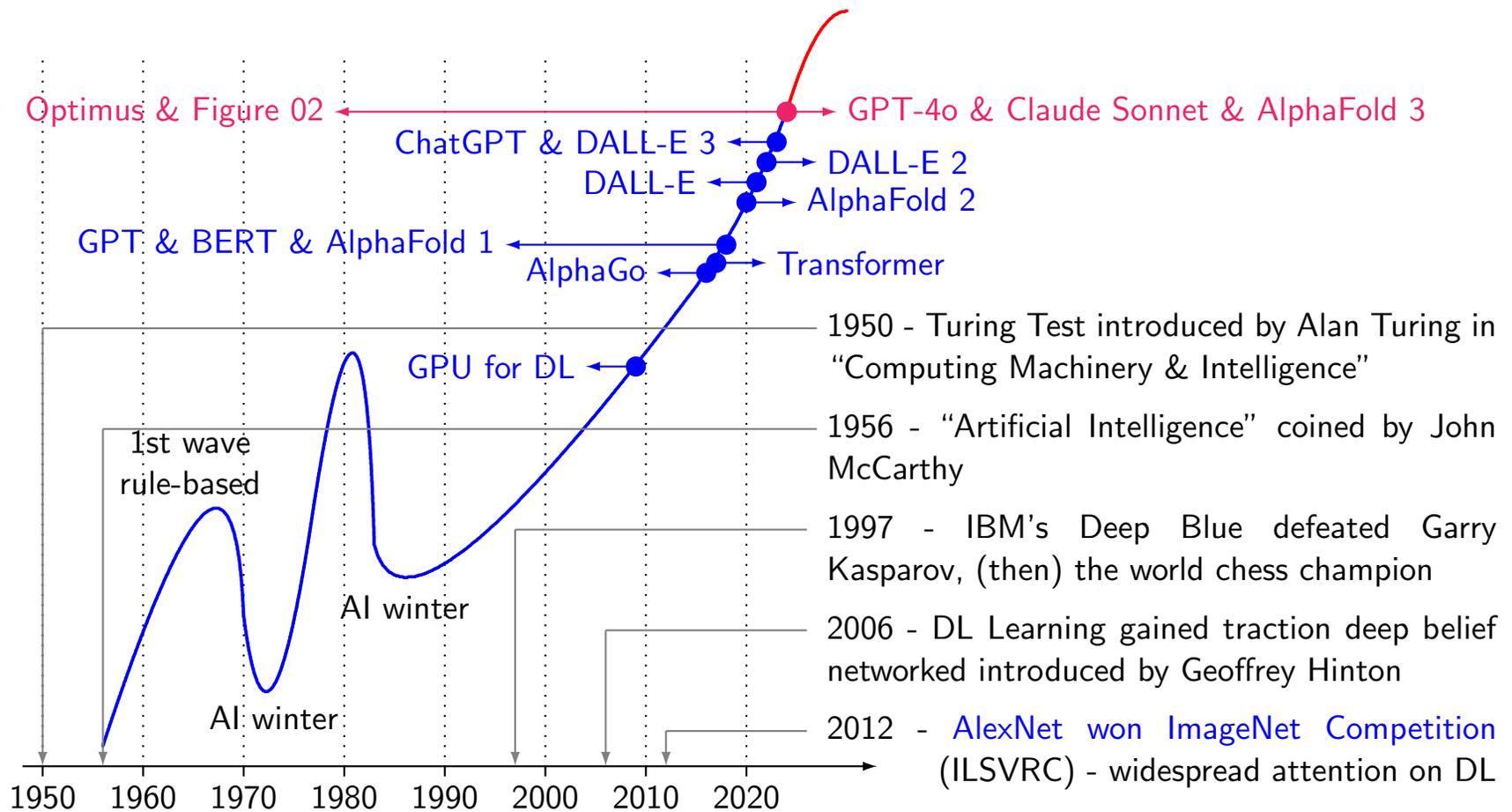
Definition & relation to other technologies

- 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]



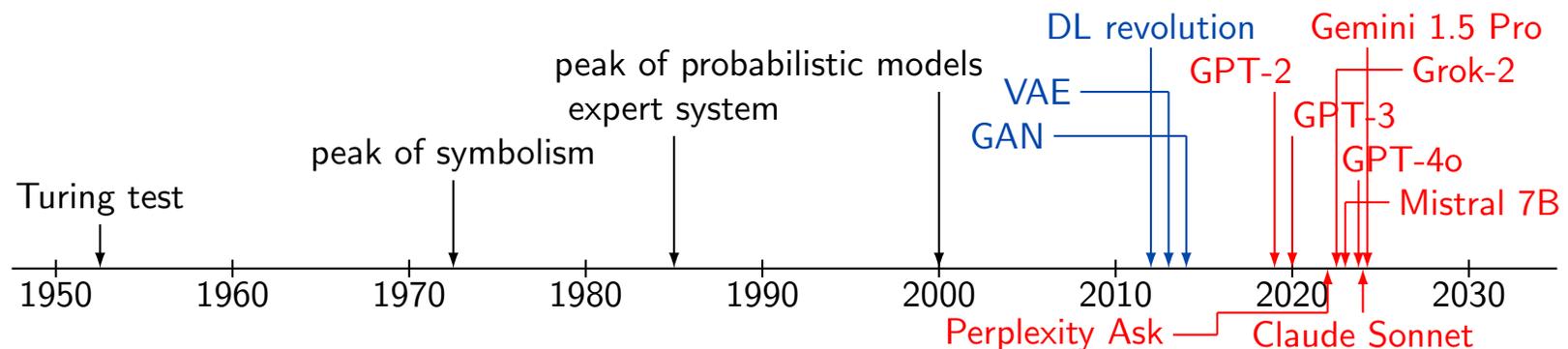
¹ML: machine learning & DL: deep learning

History



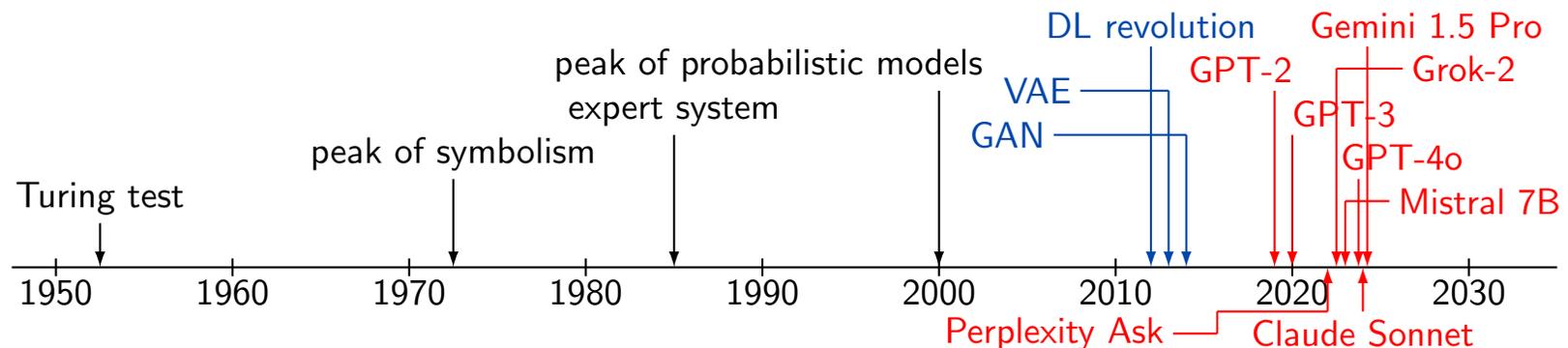
Birth of AI - early foundations & precursor technologies

- 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 ~)



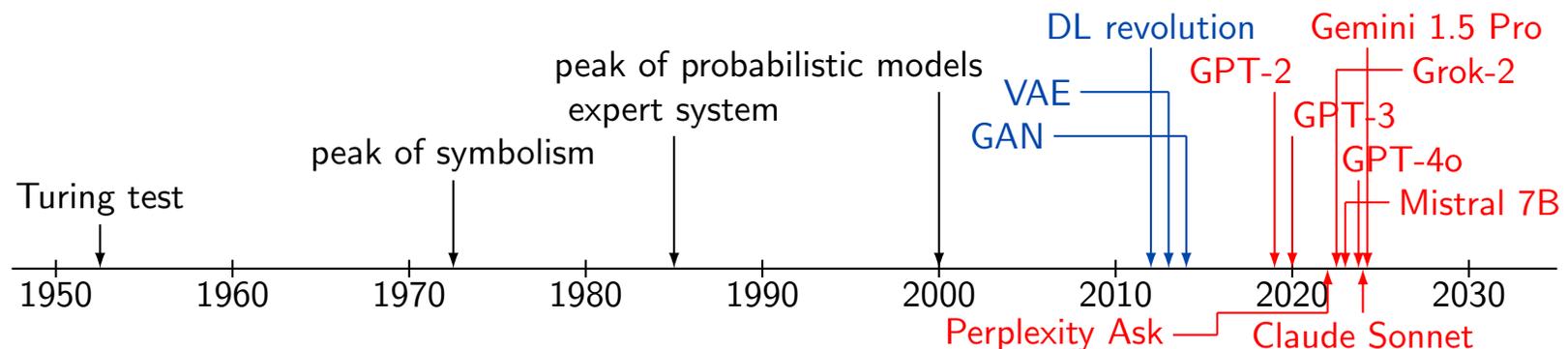
Rule-based systems & probabilistic models

- 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



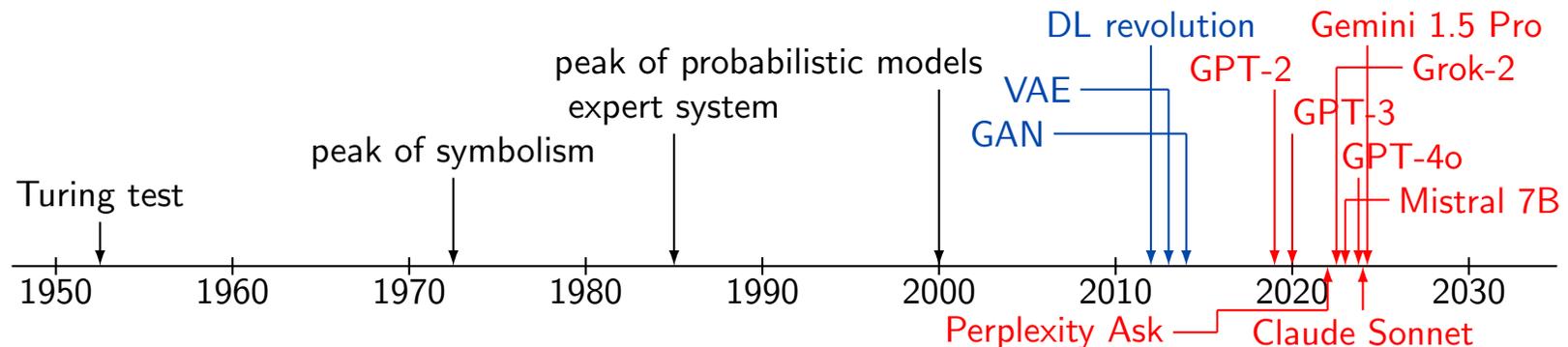
Rise of deep learning & generative models

- 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

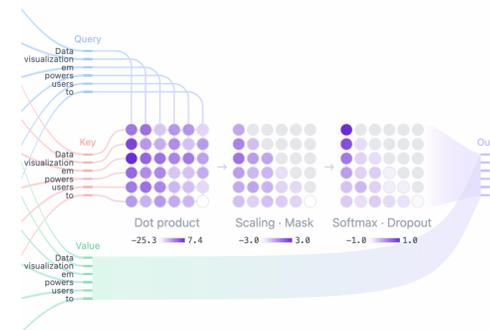
- 2012 – 2015 - DL revolution²
 - CNNs demonstrated exceptional performance in image recognition, *e.g.*, [AlexNet's victory in ImageNet competition](#)
 - widespread adoption of DL learning in CV transforming industries
- 2016 - AlphaGo defeats human Go champion
 - DeepMind's AlphaGo defeated world 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

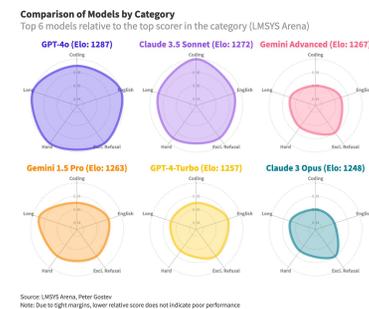
Lots of breakthroughs in AI technology and applications in 2024

- 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*



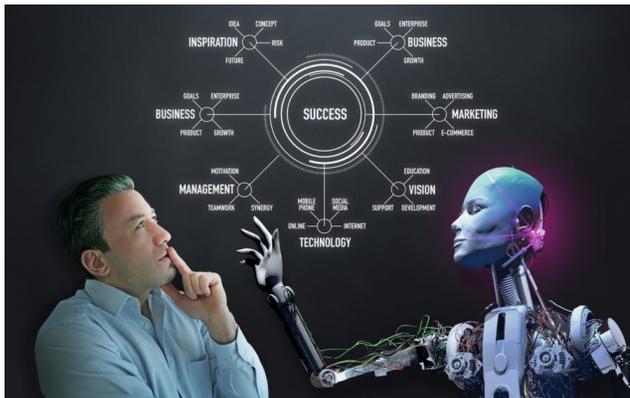
Major AI Breakthroughs in 2025

- 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

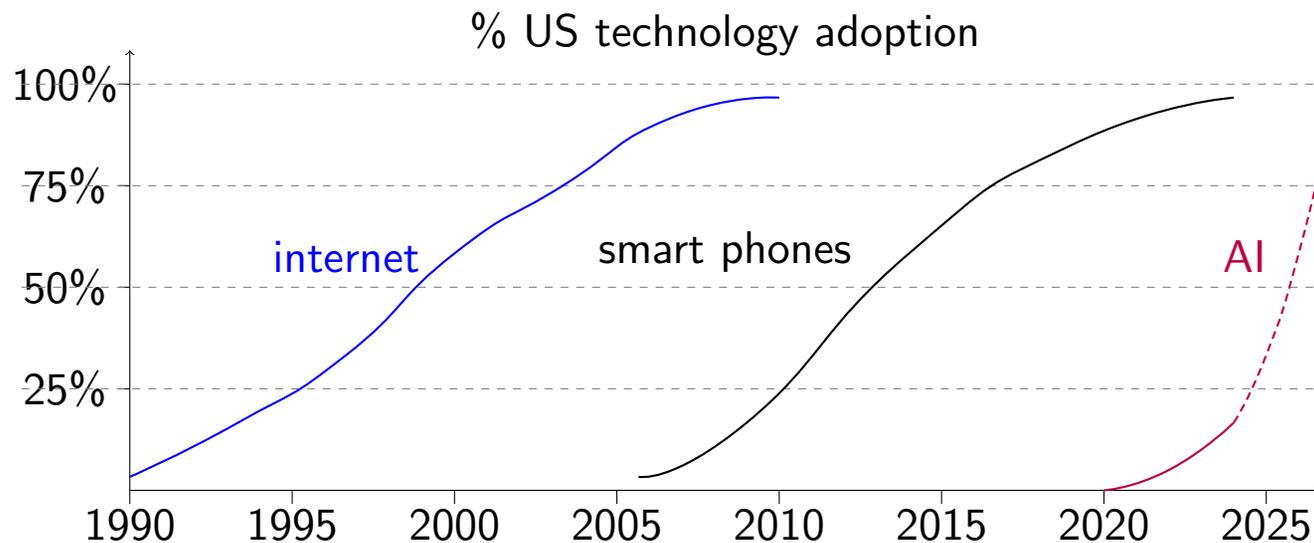
- accelerating human-AI collaboration
 - not only reshaping industries but *altering how humans interact with technology*
 - AI's role as collaborator and augmentor redefines productivity, creativity, the way we address global challenges, *e.g., sustainability & healthcare*
- AI-driven automation *transforms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

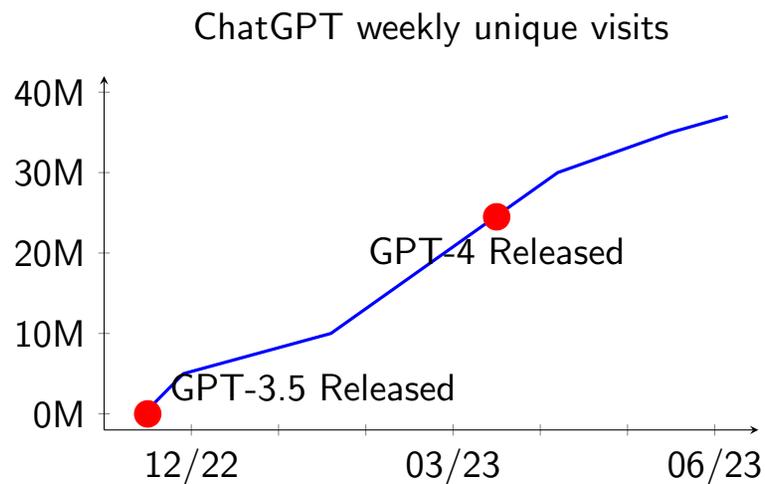
Where are we in AI today?

- 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

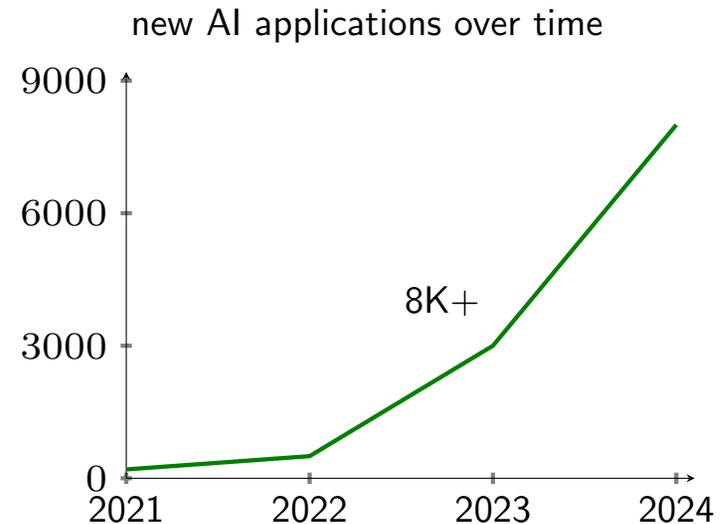
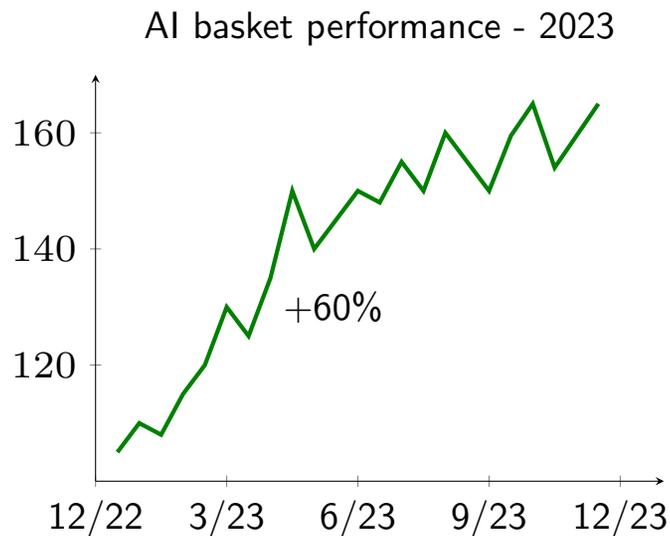
- took only *5 months for ChatGPT users to reach 35M*
- NVIDIA 2023 Q2 earning exceeds market expectation by big margin - \$7B vs \$13.5B
 - surprisingly, *101% year-to-year growth*
 - even more surprisingly *gross margin was 71.2%* - up from 43.5% in previous year⁴



⁴source - Bloomberg

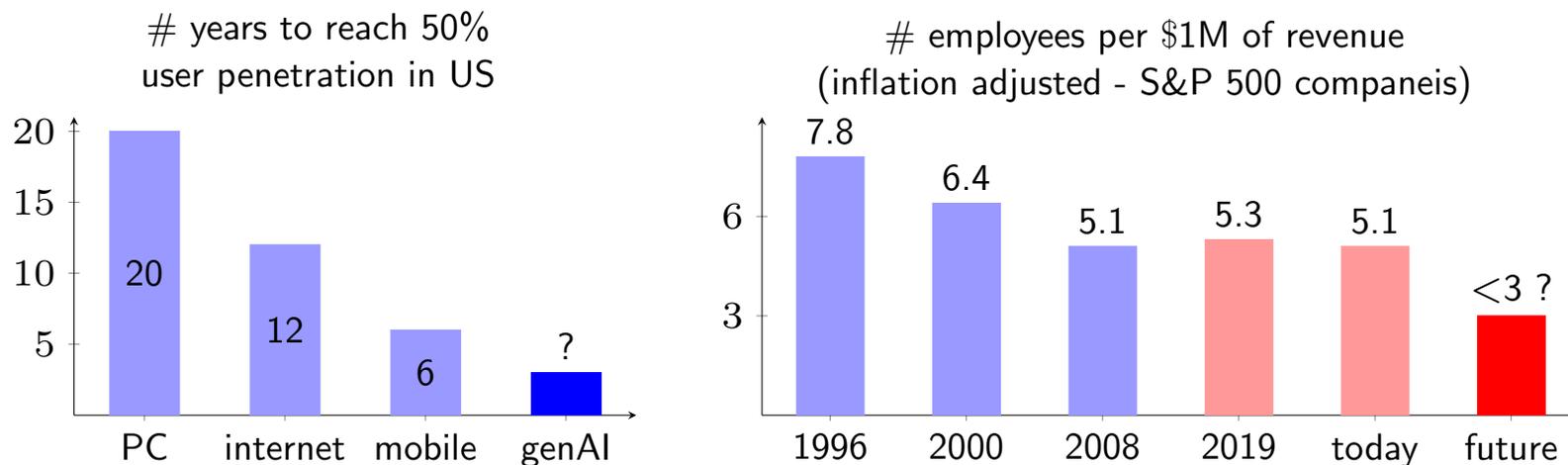
Explosion of AI ecosystems - AI stock market

- *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



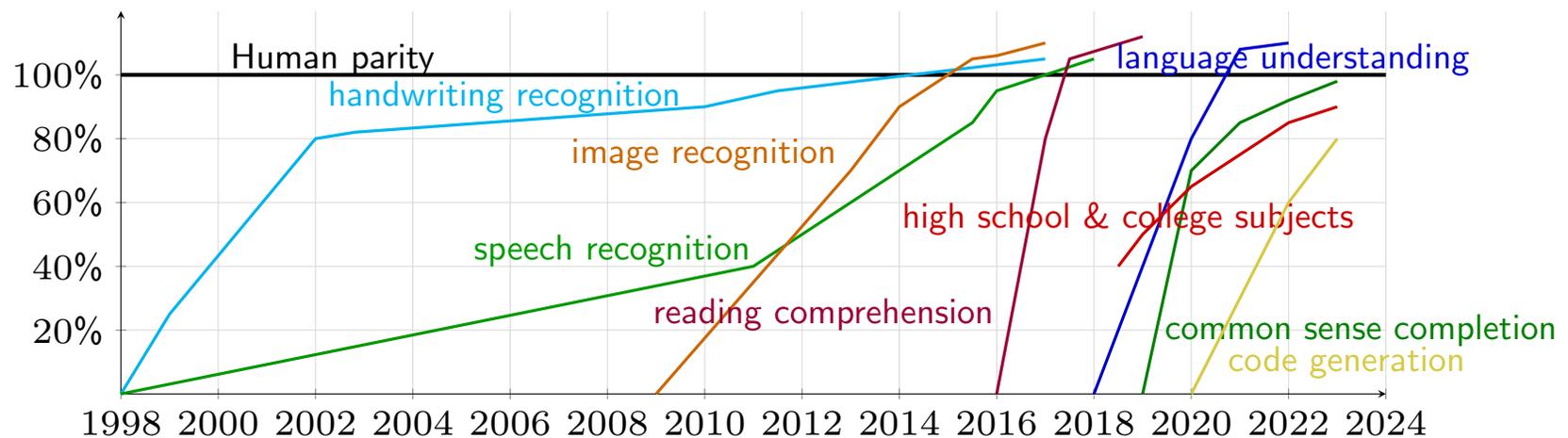
AI's transformative impact - adoption speed & economic potential

- 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



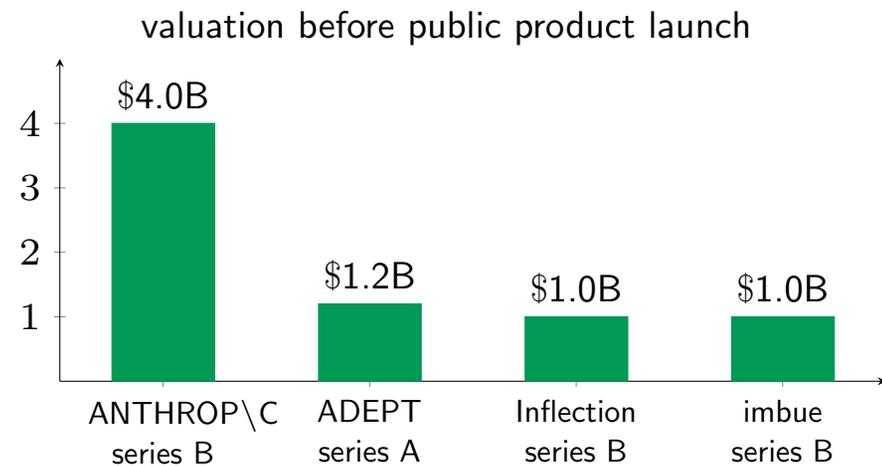
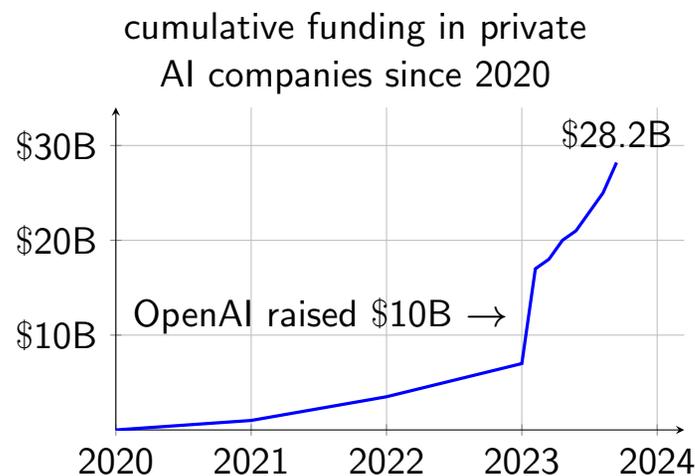
AI getting more & more faster

- 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



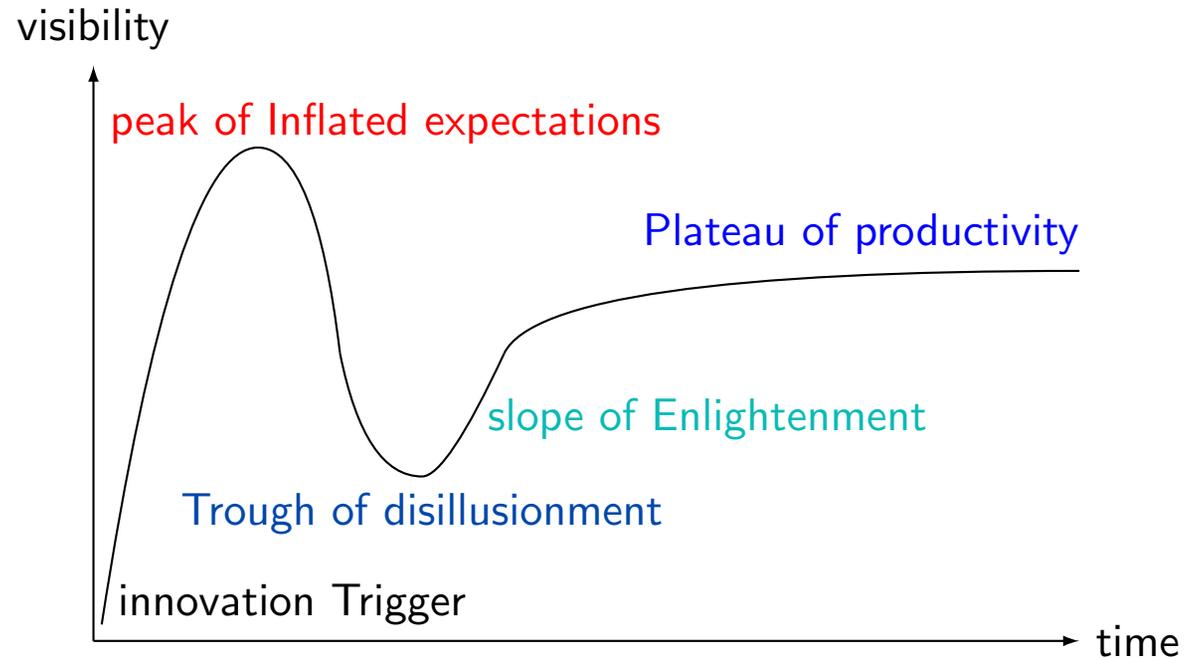
Massive investment in AI

- *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



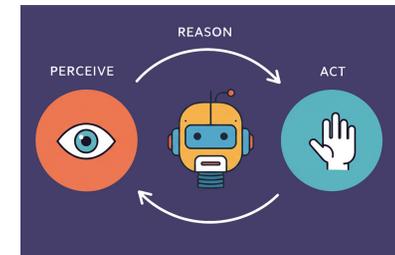
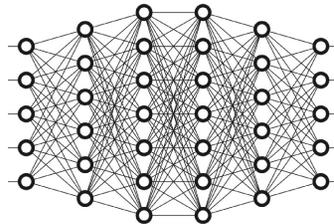
Yes & No

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

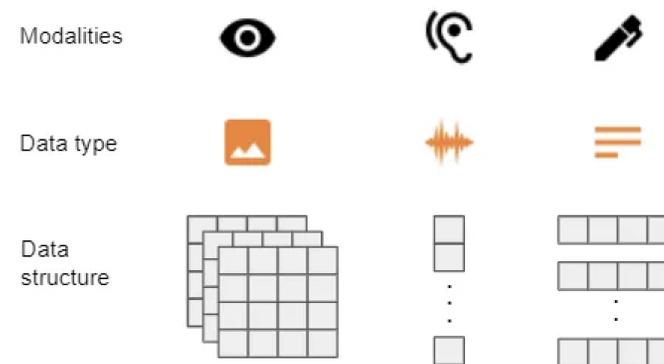
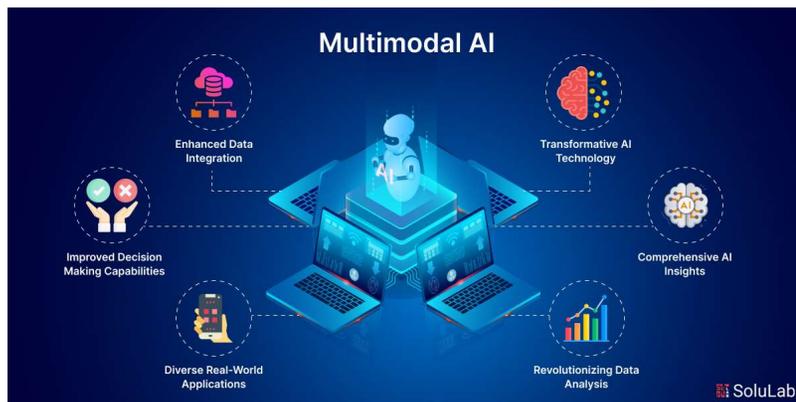
AI progress in 21st century in keywords

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



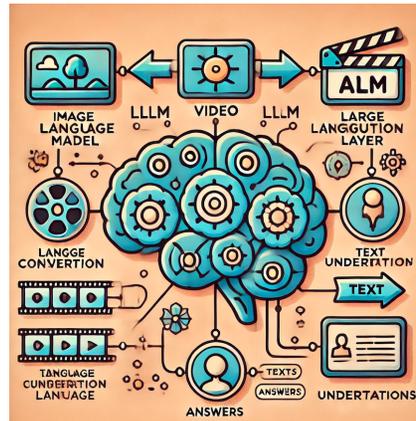
Multimodal learning

- 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)



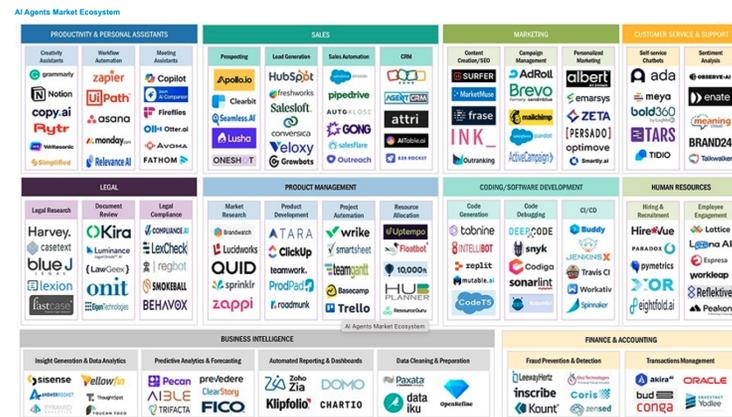
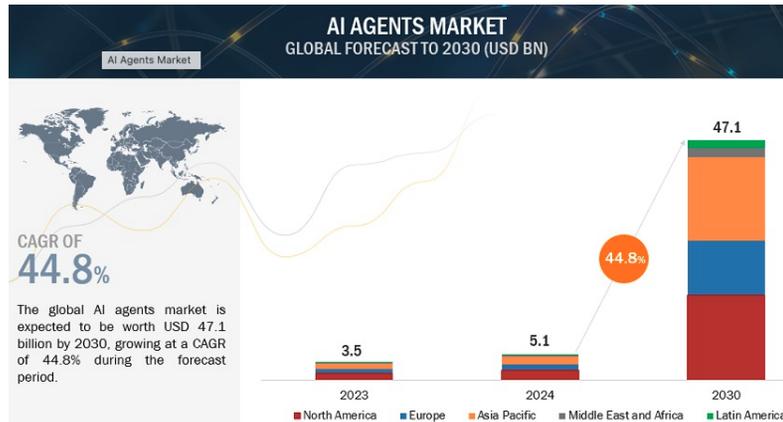
Implications of success of LLMs

- 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

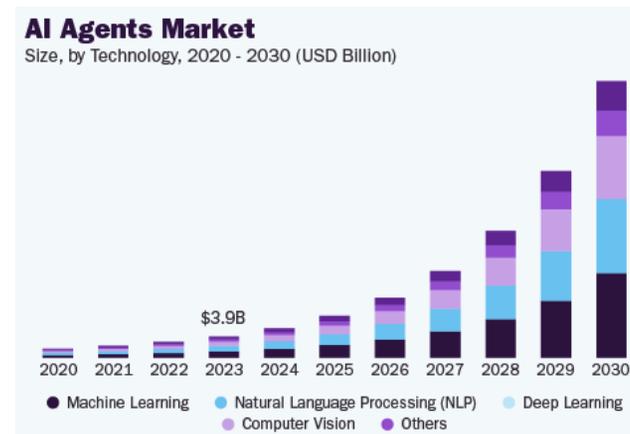
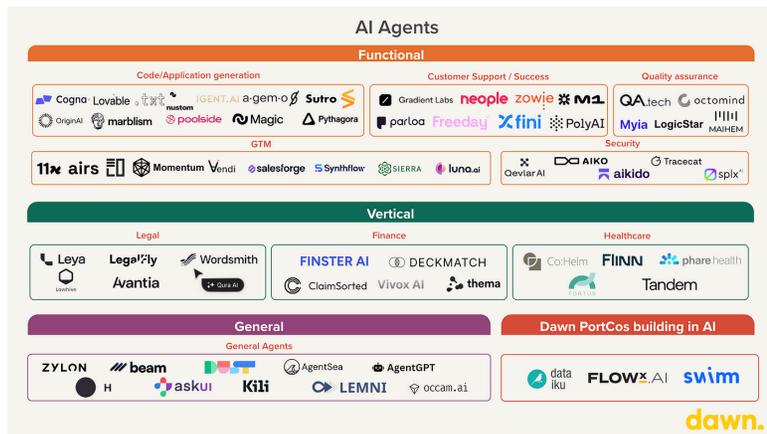


mmAI Technology

- 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



AI Paradigm Shift for Legal Professionals

Why AI Replacement is Impossible?

Myth of perfect legal AI

- seductive myth - “with enough data, AI can make perfect legal decisions”
 - Silicon Valley marketing vs mathematical reality
 - confusion between correlation and causation
 - “complete information” fallacy! **Nor is Complete Information Sufficient!**
- deeper problem - even complete information \neq proper judgment
 - legal decisions encode societal values that evolve
 - same facts, different eras = different “correct” decisions
- case example - same-sex marriage laws (1990s vs 2020s)
 - identical constitutional text (14th Amendment), evolved interpretation
 - shows why “algorithmic justice” is philosophically incoherent

Legal judgment actually requires . . .

- beyond pattern matching - legal reasoning requires moral frameworks
 - distinguishing letter of law from spirit of law
 - balancing competing values (individual vs collective rights)
 - understanding cultural and historical context
- generational value evolution - what's "reasonable" changes with society
 - brown v. Board (1954) overturned Plessy v. Ferguson (1896) - same Constitution
 - privacy expectations - 1970s phone booths vs. 2020s smartphones - "reasonable expectation of privacy" (4th Amendment)
- human element - compassion, wisdom, cultural understanding
 - reading between lines of human behavior
 - understanding unspoken social contracts
 - mercy vs justice - requires human discernment

Where AI could replace humans

- traffic violations & routine infractions
 - clear rules, objective facts, minimal discretion
 - parking tickets, speed cameras, routine compliance
- simple contract disputes
 - standardized terms, clear breaches, mathematical calculations
 - late payment fees, delivery date violations
- administrative law with clear criteria
 - building permit applications, tax calculations
 - immigration status checks, licensing renewals
- high-volume document review
 - discovery process, contract analysis, due diligence
 - pattern recognition at scale where human judgment minimal

Where AI can or rather should NEVER replace humans

- constitutional interpretation
 - requires understanding of evolving social values
 - balancing competing constitutional principles
 - protecting minority rights against majority algorithms
- criminal sentencing & family law
 - justice vs mercy requires human wisdom
 - cultural context, emotional intelligence crucial
 - each family situation unique, defies algorithmic solutions
- corporate ethics & civil rights
 - distinguishing legal compliance from moral responsibility
 - understanding systemic bias and historical injustice
 - creating precedent for unprecedented situations

AI as Prevention, NOT Replacement

Beyond the replacement debate - self-driving analogy

- wrong question to ask - “can AI replace judges (or lawyers)?”
 - focuses on competition rather than collaboration
 - misses the real opportunity for systemic improvement
- right question - “how can AI prevent cases from needing judges?”
 - focus on upstream prevention rather than downstream replacement
 - maximize human judicial capacity for truly complex matters
- self-driving car framework
 - level 3 already transforms driving without full replacement
 - drivers focus on navigation, AI handles routine steering
 - same principle applies to legal system

Legal AI's "level 3" applications

- contract prevention - AI flags problematic clauses before signing
 - real-time analysis during negotiations
 - historical pattern recognition for risk assessment
 - prevents disputes rather than resolving them later
- compliance automation - continuous monitoring prevents violations
 - regulatory change notifications
 - automatic policy updates
 - risk scoring for business decisions
- dispute resolution - AI-mediated negotiations *could* resolve 80% pre-court
 - automated settlement calculations
 - communication facilitation between parties
 - early intervention when tensions escalate

Multiplier effect on justice quality

- courts focus on - constitutional questions, complex moral issues
 - precedent-setting cases that shape society
 - novel legal questions requiring human wisdom
 - cases where societal values must be interpreted
- AI handles - routine disputes, administrative processing
 - high-volume, low-complexity matters
 - pattern-based decisions with clear criteria
 - document processing and information synthesis
- result - higher quality justice for truly complex matters
 - judges have more time for careful deliberation
 - resources allocated to cases that need human insight
 - overall system efficiency improves

Preparing Legal Professionals for the AI Era

Fundamental paradigm shift

- old question - “how do I compete with AI?”
 - assumes zero-sum competition
 - focuses on defending existing practices
 - creates fear and resistance to change
- new question - *e.g.*, “how do I collaborate with AI to serve justice better?”
 - recognizes complementary strengths
 - focuses on value creation and system improvement
 - embraces technology as tool for better outcomes
- even deeper question - “what does it mean to be irreplaceably human?”
 - moving beyond task-based thinking to purpose-based thinking
 - understanding unique human contributions to justice
 - redefining professional identity around wisdom, not information

Skills that become MORE valuable in AI era

- ethical reasoning & moral navigation
 - navigating complex value trade-offs AI cannot handle
 - understanding cultural and generational differences
 - balancing competing ethical frameworks
- creative problem-solving & systems thinking
 - finding novel solutions to unprecedented legal issues
 - understanding how legal decisions ripple through society
 - connecting patterns across different domains of law
- emotional intelligence & human connection
 - reading clients, juries, opposing counsel beyond words
 - building trust in high-stakes situations
 - translating complex legal concepts to human terms

Skills that transform (not disappear)

- legal research - from finding to synthesizing insights
 - AI finds information, humans create meaning
 - focus shifts to asking better questions
 - cross-domain pattern recognition becomes crucial
- client relations - from explaining to translating & strategizing
 - interpreting AI insights for human contexts
 - helping clients understand AI-assisted legal options
 - building long-term relationships based on wisdom
- writing & advocacy - from documenting to persuading
 - storytelling becomes more important than information transfer
 - crafting arguments that resonate with human values
 - creating compelling narratives from data patterns

Your action plan for the AI Era

- immediate steps
 - develop technical literacy - understand AI capabilities/limitations
 - experiment with AI tools in low-risk scenarios
 - build ethical frameworks for AI use in your practice
- medium-term preparation
 - cultivate collaboration skills with AI systems
 - develop expertise in AI-human interface design
 - build reputation as thoughtful AI adopter
- long-term positioning
 - become “AI translator” - interpreting machine insights for human contexts
 - specialize in areas requiring human wisdom + AI amplification
 - lead profession in ethical AI adoption
- mindset shift - from fear to opportunity
 - AI democratizes basic legal services = more people can access justice
 - your expertise becomes more valuable, not less
 - focus on serving human flourishing, not just legal compliance

Philosophical & Cognitive-Scientific Discourses

My blog articles

- AI (with current ML/DL architecture) does not believe nor reason nor know nor think!
- Partial information is not (necessarily) better than ignorance - Wisdom of Strategic Ignorance
- Nor is Complete Information Sufficient!
- Dimensional Paradox of Music
- The Multi-Agent AI Revolution - Building Collective Intelligence for the Next Generation of Business
- Technology, Growth, and Inequality – The Case of AI
- Bridging Technology and Humanity - Reflections from Lyon, Salzburg, and München

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

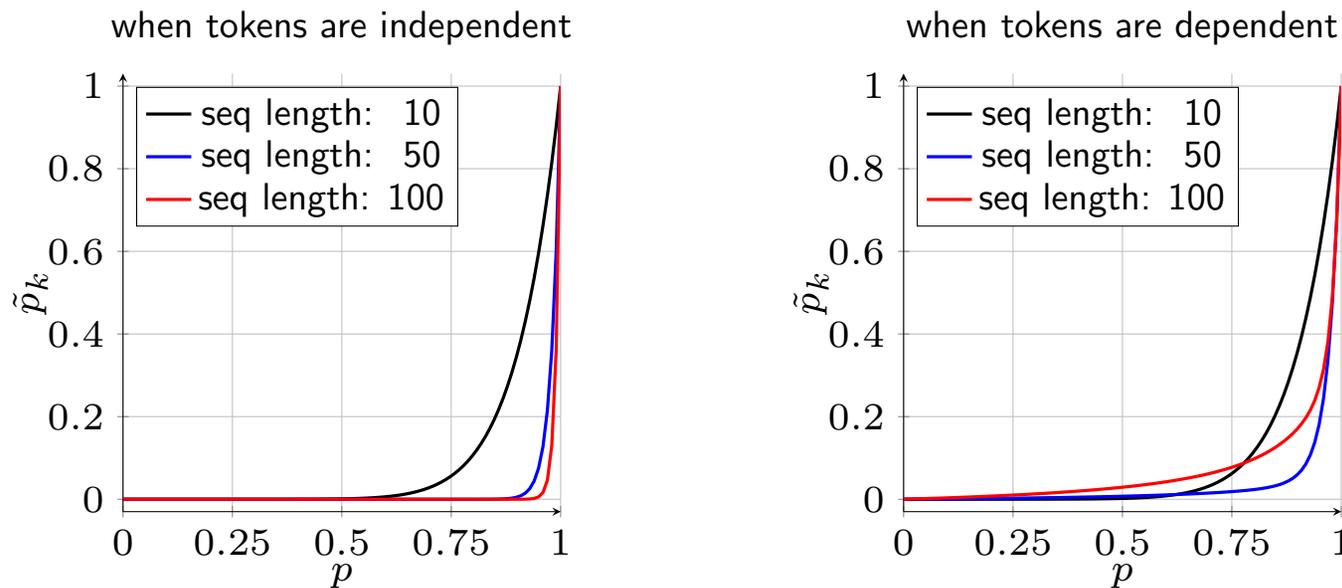
- assume
 - t_i - i th token
 - p_i - probability that t_i is correct
 - ρ_i - correlation coefficient between t_{i-1} & t_i
 - \tilde{p}_k - probability that (t_1, \dots, t_k) are correct
- recursion

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

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

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

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 inferencing 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 human 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 doomday 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’?”*

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 soar to \$8B as it features new \$800M funding...
Perplexity AI: A Deep Dive - Redhouse

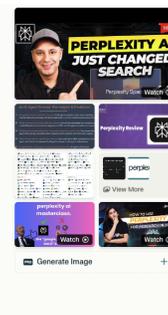
Perplexity

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:

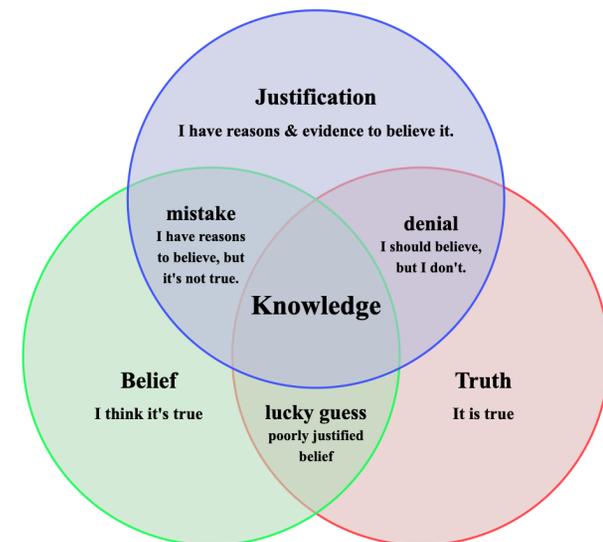
1. Search functionality: Perplexity summarizes search results and produces text with inline citations, providing personalized results based on the context of user queries.

Ask follow-up



Knowledge in philosophical and cognitive scientific sense

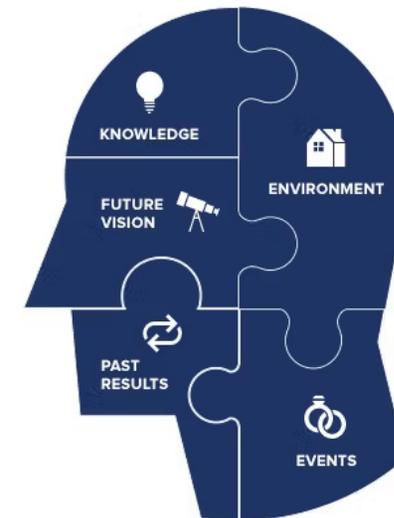
- does LLM have knowledge?
 - Sunghee: *I don't think so!*
- why?
 - we say we have “knowledge” when
“we do so against ground of various human capacities that we all take for granted when we engage in everyday conversation with each other.”
 - when asked *“who is Tom Cruise's mother?”*, it says *“Tom 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-shot 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, . . .*

Appendices

**K-PAI - Silicon Valley
Privacy-Preserving AI Forum**

Silicon Valley Privacy-Preserving AI Forum (K-PAI)

- pioneering community of professionals dedicated to building privacy-preserving AI solutions, products, and systems
- comprehensive expertise across AI domains
 - biotechnology, healthcare, and medical research
 - industrial applications and data centers
 - cloud infrastructure, storage solutions, mobile technologies
 - customer service platforms, multi-agent systems
 - RAG implementations, vector databases, agentic AI frameworks
- vision
 - *shaping future where AI innovation and privacy protection go hand in hand*
- active community with [homepage](#) & KakaoTalk collaboration platform for members



Our journey - forum history

- Nov-Dec 2024 - “The AI Strikes Back” & “Free Your Data”
 - Prof. Jung Hee Cheon (homomorphic encryption revolution)
- Jan 2025 - “The AI Knight Rises”
 - [Sunghee Yun](#) @ Erudio Bio on deep learning to flourishing societies
- Feb 2025 - “Silicon Citadel”
 - Chanik Park @ MangoBoost on AI data infrastructure
- Mar 2025 - “Blockchain Awakens”
 - Daejun Park @ a16z crypto on decentralized AI
- Apr 2025 - “Advancing Humanity”
 - Stanford Medicine team on bio/medical AI
 - co-hosting with K-BioX
- May 2025 - “The Autonomous Alliance”
 - Microsoft, GitHub, Uclone, SK Hynix on AI agents

Our journey - forum history

- Jun 2025 - “Silicon Companions”
 - Altos Ventures on robotics & smart devices
- Aug 2025 - “The Human-Centric AI Revolution”
 - address legal and ethical issues related to AI
- Nov 2025 - “The AI Silicon Race”
 - Korea-US Innovation Leadership at K-ASIC



Strategic partnerships & ecosystem

- *Perpetual Partnership with KOTRA Silicon Valley as Strategic Alliance*
- 2026 co-hosting partners
 - K-ASIC (Korea AI & IC Innovation Center)
 - K-BioX (biotech innovation)
 - KOTRA Silicon Valley (trade & investment)
 - Korean Consulate General, San Francisco (diplomatic support)
 - KABANC (Korean American Bar Association of Northern California - legal expertise)
- building bridges between Silicon Valley innovation and Korean institutional networks
- creating comprehensive support ecosystem: technical, legal, business, diplomatic



Community & engagement

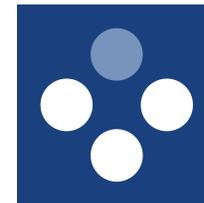
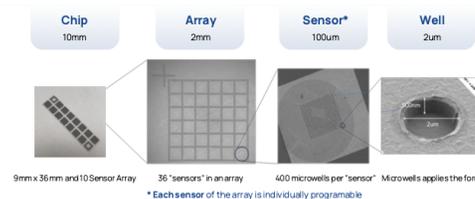
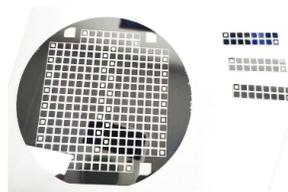
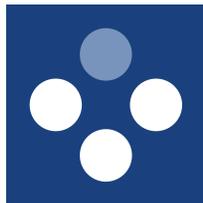
- membership requirements
 - attend 2+ K-PAI Forums to qualify
- member benefits
 - networking with AI professionals across all domains
 - knowledge sharing and collaboration opportunities
 - direct access to world-class speakers and experts
- forum format - 5pm-8pm, typically Wednesdays at premier Silicon Valley venues
- venues - Stanford, KOTRA, SK Hynix, Altos Ventures, K-ASIC, and more
- active community engagement and professional development



Erudio Bio

Powering AI-driven medicine with ground-truth binding data

- problems we solve
 - 90% of drugs fail in clinical trials due to poor early-stage prediction
 - multiplexed diagnostics suffer from false positives and cross-reactivity
- *Erudio Bio's Innovation*
 - VSA platform uses patented “dynamic force spectroscopy” to generate 1000x more high-quality binding data from single sample ($\sim 10\mu\text{L}$)
 - measuring not just presence, but *strength* and *kinetics* of molecular interactions
- *dual business model*
 - diagnostics - multi-cancer biomarker detection with clinical institutions & hospitals (Seoul National University Hospital Bundang, Keimyung University Dongsan Hospital)
 - drug discovery - bioTCADTM platform providing ground-truth labels to train & validate pharma AI models, reducing preclinical cycles



Validated technology, proven team, clear path to market

- validated impact
 - *\$1M Gates Foundation Grant* (2025) to democratize drug development for global health
 - partnerships with top research institutions (KRIBB, KAIST)
- unique team - *Stanford-trained founders* combining
 - semiconductor TCAD expertise & force spectroscopy innovation (20+ years)
 - AI & optimization leadership (Samsung, Amazon, SK hynix, Gauss Labs)
- market entry
 - *Korea → Asia hub & US* strategy with 2026 regulatory milestones and expanding pharma partnerships

Gates Foundation



Biological assays struggle with scale & accuracy

Data is expensive

- so we make decisions with *incomplete* picture
- status quo
 - limited, small-scale testing confirms diagnosis
 - outcome only as good as doctor's ability to determine which tests, limiting the picture
 - cross reactivity prevents larger scale testing
- Erudio creates
 - *comprehensive, large-scale* testing will drive diagnosis without assumptions
 - increased scale enables enhanced scientific discovery leading to
 - *better patient care*
 - *reduced time to diagnosis*
 - *cost reduction*



Erudio Bio starting Revolution

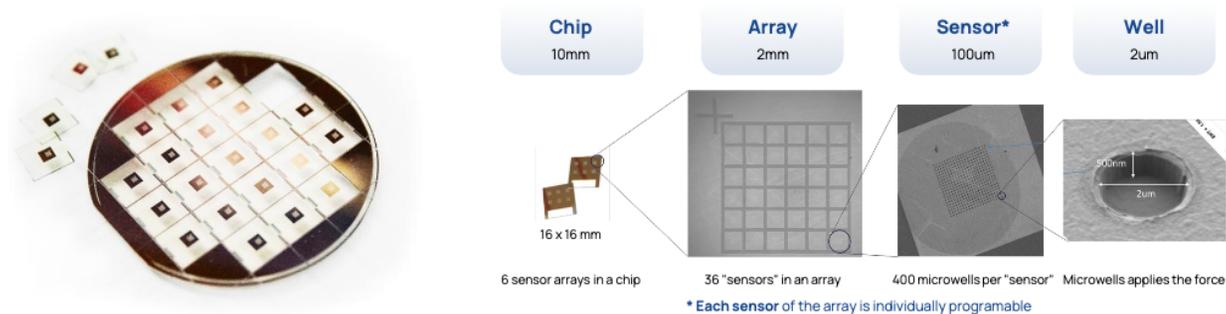
Erudio Bio starts revolution with Gates Foundation's support

- more data
 - comprehensive data from single biological sample
 - multiplexed analysis of nucleic acid, protein, cells, and more!
 - *multi-omic platform*
- actionable data
 - combined quality score from all data sources for comprehensive & conclusive assessment
- earlier data
 - complete data early to drive accurate decision making



Versatile Smart Assay (VSA) Platform

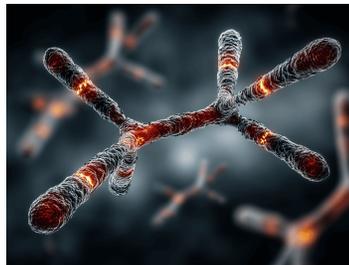
VSA technology



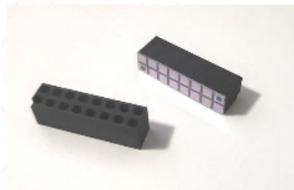
- generates *1000x more data* than the prevailing technology
 - scalable multi-omic microarray sensor
- *21 patents* in US, Canada, China, and Europe
- indicates how good the data is in real time
 - patented “dynamic force spectroscopy” and “powerful Bayesian inference” method provides our data *quality score* to know their accuracy for actionable data
- AI software extracts a detailed, interpretable picture for quick diagnosis
 - leads to *AI knowledge discovery* resulting in *data-driven diagnosis*

Enabling comprehensive data acquisition

- antibodies - versatile tools in biology
 - can engineer to target virtually *anything* we want
 - problem
 - indiscriminate interactions severely limits use of antibodies in multiplex formats
 - error-prone results due to non-specific binding
- solution - comprehensive data with *dynamic force spectroscopy*
 - comprehensive binding strength to distinguish specific from non-specific binding
 - *quality score* discerns noise from useful data to enable multiplexing



Erudio Bio's business models



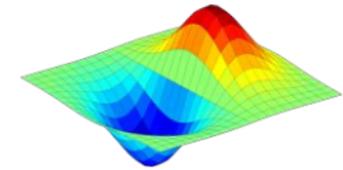
Consumable chip
& flowcell



Instrument



Consumable
reagent kit



Software
AI/ML & SaaS

- VSA platform
 - instrument - recurring revenue with high margin
 - modular licensable software - AI based data interpretation and feature extraction
- SaaS
 - subscription based pre-validation of reagent database
 - AI feature extraction and knowledge discovery

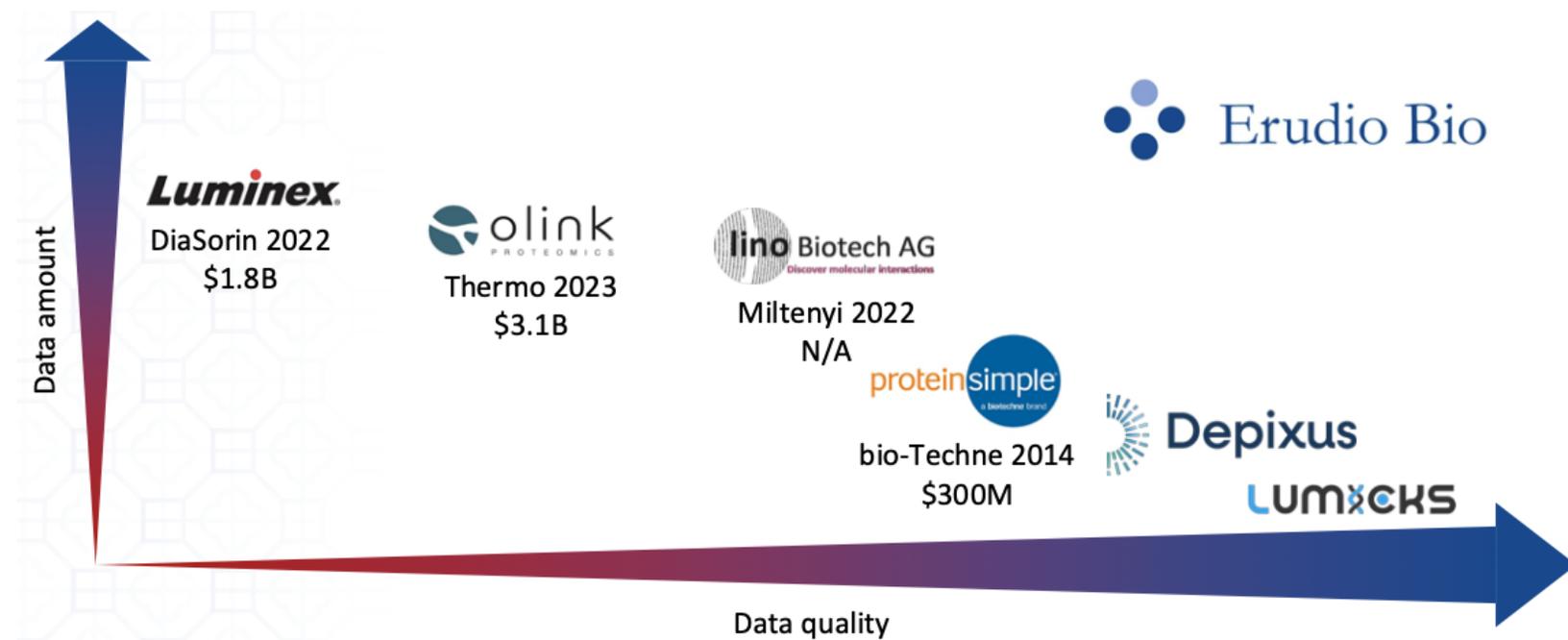
Milestones

Erudio Bio key milestones

- IP developed at Stanford School of Medicine under mentorship by father of microarrays
 - Dr. Ronald Davis
- data vetted by Analog Devices (\$115B market cap semiconductor company), Harvard Medical School & Massachusetts General Hospital
- commercial partnership with Analog Devices to manufacture at scale
- JDA with Shanghai General Hospital's National Clinical Research Center for Eye Diseases
- JDA with Seoul National University General Hospital (SNUBH) for multiplexed cancer biomarker detections
- partnerships with
 - Keimyung University Dongsan Hospital, KRIBB, KAIST NanoFab, Lulumedic



Competitive landscape



- Erudio Bio
 - *only company* providing both high quality data and large data output
- efficient workflow integration facilitates customer adoption

Erudio Bio engaging with Customers

Validating out technology in clinical settings



- joint development agreement signed with *Shanghai General Hospital's National Clinical Research Center for Eye Diseases*
 - co-develop multiplexed diagnostic test for uveitis
 - addresses low sample volume and diagnostic inaccuracies
- globally unique partner, customer so large that it is a market by itself
 - 45 large hospitals with 83M patient visits per year
 - standard of care for smaller hospitals in Shanghai to access additional 280M patients

Clinical validation to market leadership in Korean preventive care



- market opportunity - *preventive care* is foundation of Korean healthcare
 - ~ 15M health screenings performed in S. Korea testing
 - ideal market segment for Erudio Bio's multi-omic multiplexed VSA platform
 - multi-billion dollar addressable market for multi-cancer early detection
- joint development agreed with *Seoul National University Hospital Bundang (SNUBH)*
 - premier hospital of national importance
 - enabling expansive proactive health assessment for efficient health care system
 - collaboration with target of *multiplexed cancer biomarker medical equipment business*

Teams

Team & advisory board

- team
 - Sunghee Yun, Ph.D. (CTO) - AI, optimization, business development, software
 - Kee-Hyun Paik, Ph.D. (CEO) - chip, microfluidics, instrumentation
 - Susanne Baumhueter, Ph.D. - biology, immunology, project management
 - Leon Chen, MBA, CFA (COO) - business development, product, operations
 - Jin Young Huh (CLO) - chief legal officer, business development in Korea
- advisory board
 - Michael Cola - CEO of AEVI Genomic Medicine (\$62B sales to Takeda)
 - Tim Germann - CCO of Carterra Bio
 - Karyn Eliot - retired CIA Sr. Executive
 - Ronald W. Davis - Director of Stanford Genome Tech Center (\$15B+ exits)
 - William J. Greenleaf - Prof. Genetics and Applied Physics, Stanford University



Gates Foundation Grant

Erudio Bio wins \$1M Gates Foundation Grant - scaling bioTCAD

Gates Foundation

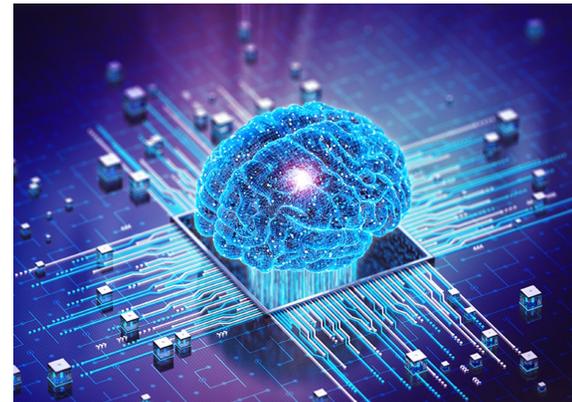
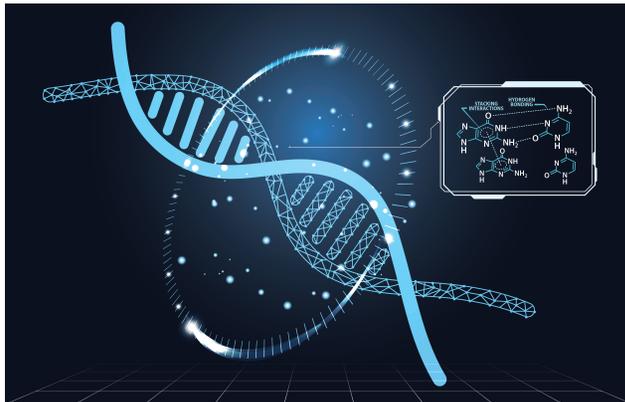


- \$1M Grant Award (August 2025)
 - Gates Foundation recognizes Erudio Bio’s potential to transform drug development for global health
- mission alignment - democratizing medicine by making preclinical drug design faster, yet reliable & accessible
 - lowering development costs for diseases affecting low- and middle-income countries (LMICs)
 - addressing the 90% clinical trial failure rate that drives up drug costs
- funded project - scale bioTCADTM platform to generate ground-truth binding datasets
 - expand force spectroscopy measurements across high-burden disease targets
 - train AI models with kinetics-resolved binding data (on/off rates, unbinding forces)
 - enable pharma/biotech to prioritize candidates earlier with higher confidence

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 others 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



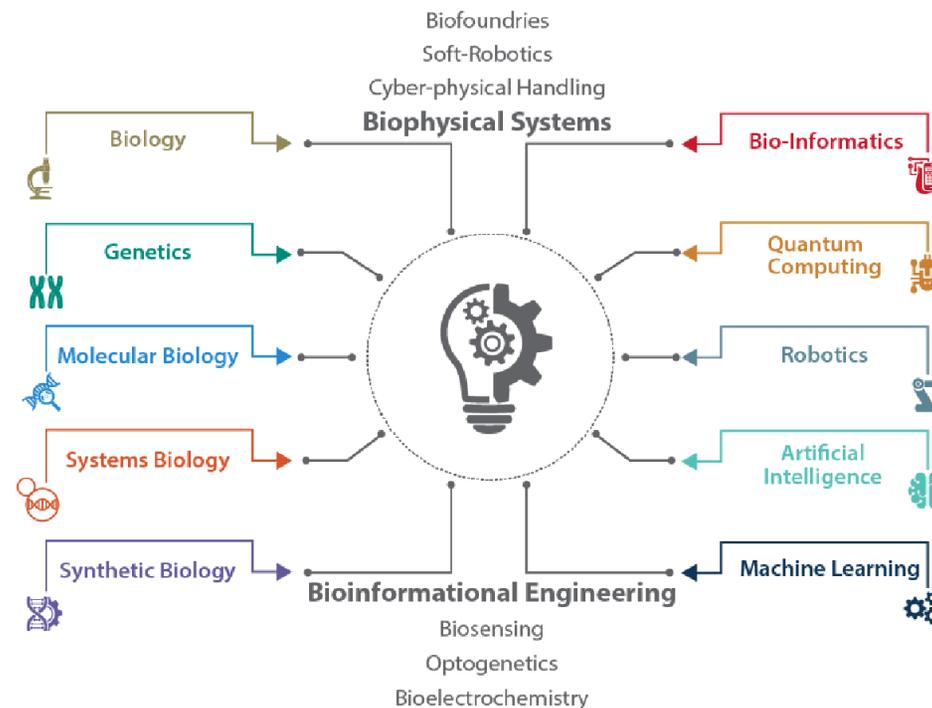
Biotech

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

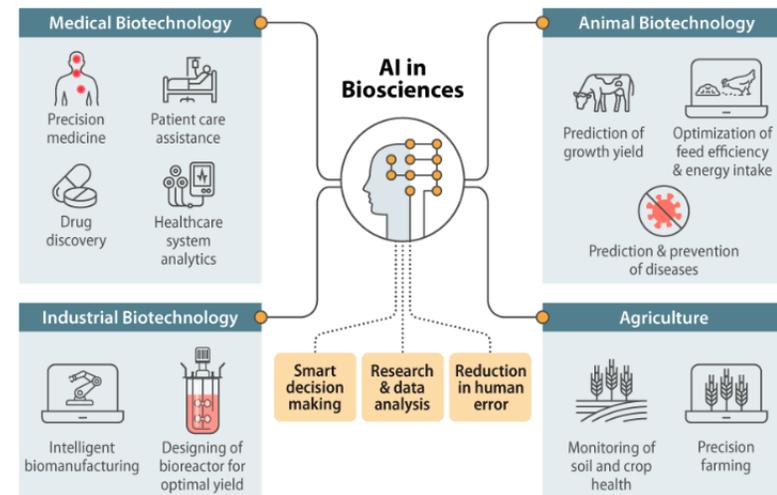
- sciences and technologies enabling biotechnology include (but not limited to)
 - (molecular) biology, genetics, systems biology, synthetic biology, bio-informatics, quantum computing, robotics [DFJ22]



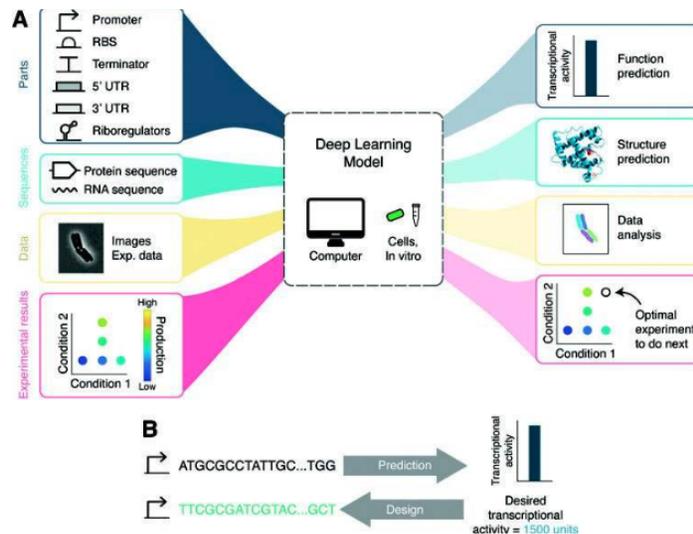
Convergence of AI and biological design

- 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



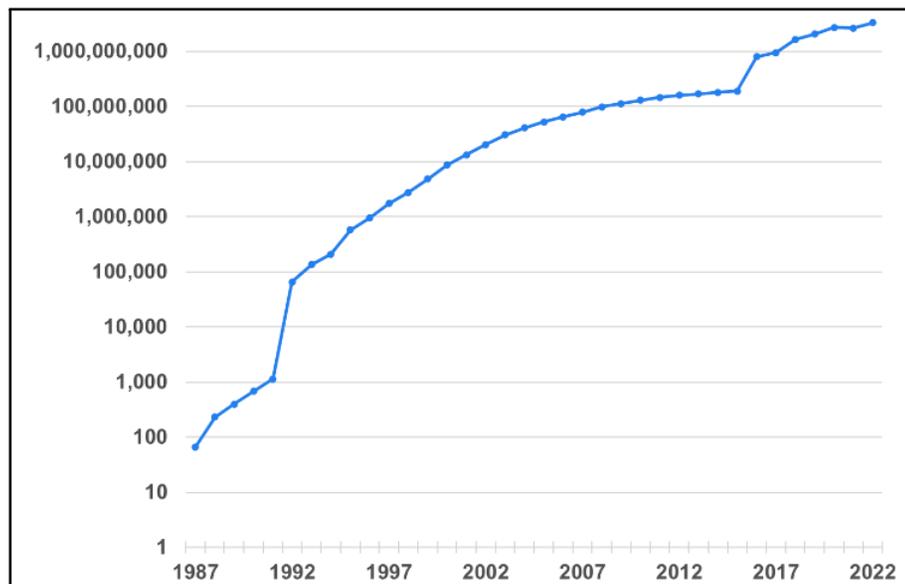
Rapid growth of biological data

- 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
 - Ginkgo 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

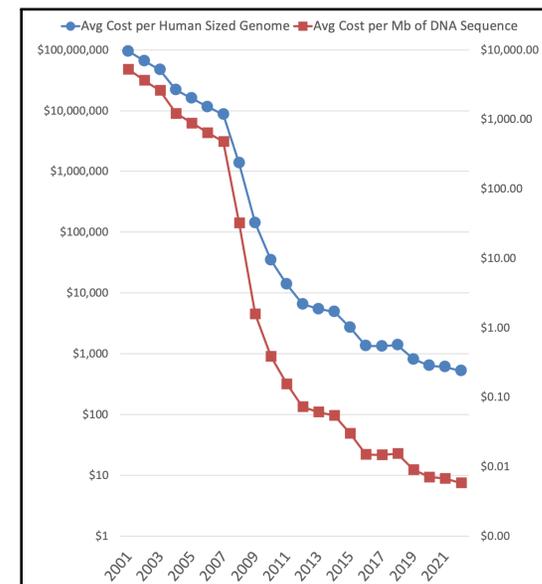
Volume and sequencing cost of DNA over time

- 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



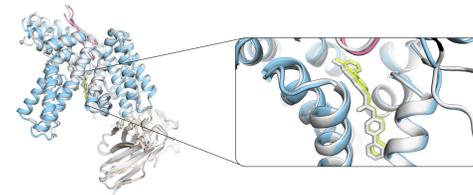
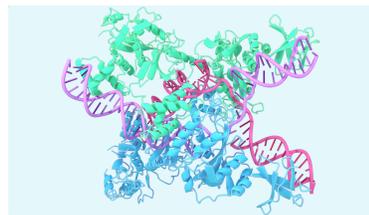
Bio data availability and bias

- 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

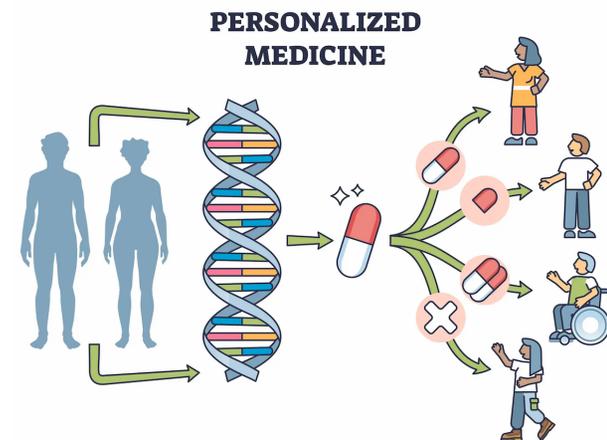
AlphaFold

- 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

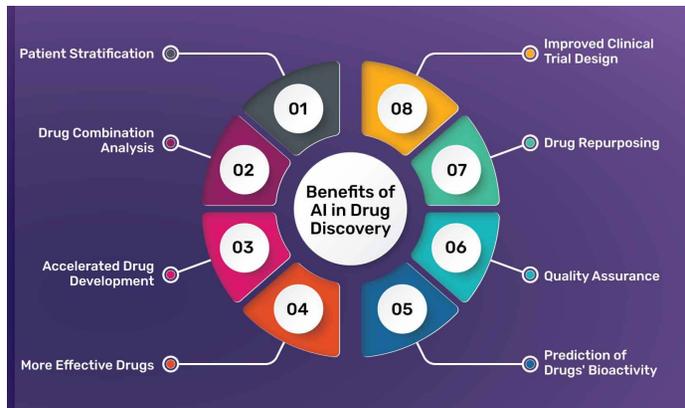


Personalized medicine

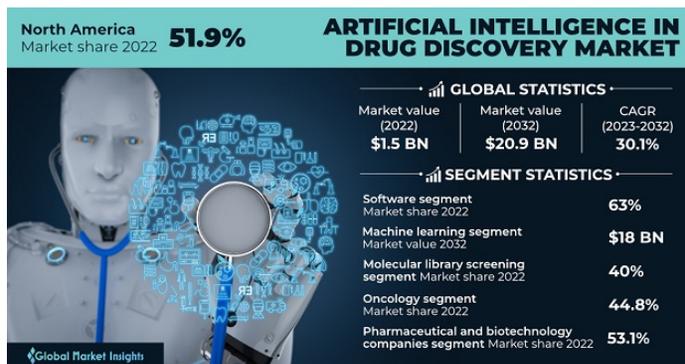
- *shift from one-size-fits-all approach to tailored treatments*
- based on individual genetic profiles, lifestyles & environments
- AI enables analysis of vast data to predict patient responses to treatments, thus enhancing efficacy and reducing adverse effects
- *e.g.*
 - custom cancer therapies
 -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



AI-driven drug discovery

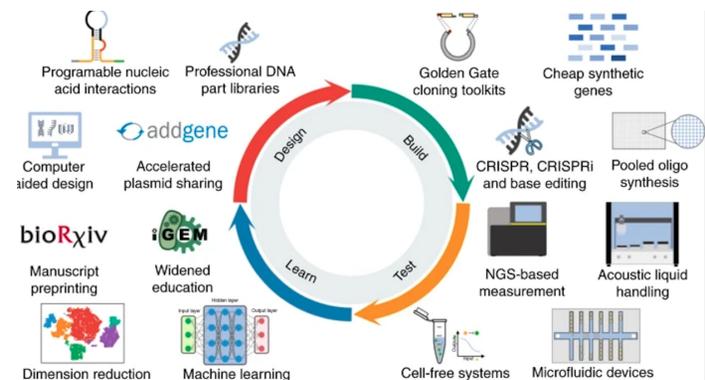
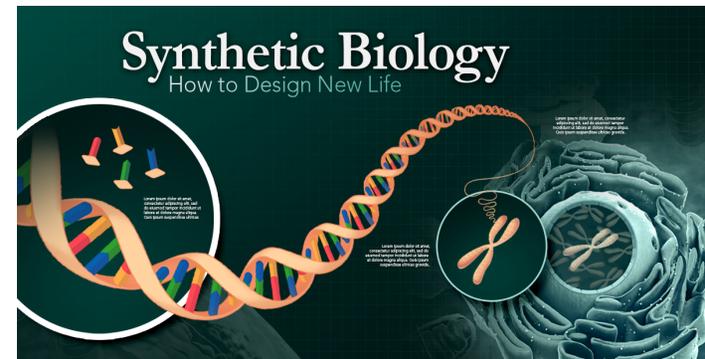


- traditional drug discovery process - time-consuming and costly often taking decades and billions of dollars
- AI streamlines this process by predicting the efficacy and safety of potential compounds with more speed and accuracy
- AI models analyze chemical databases to identify new drug candidates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

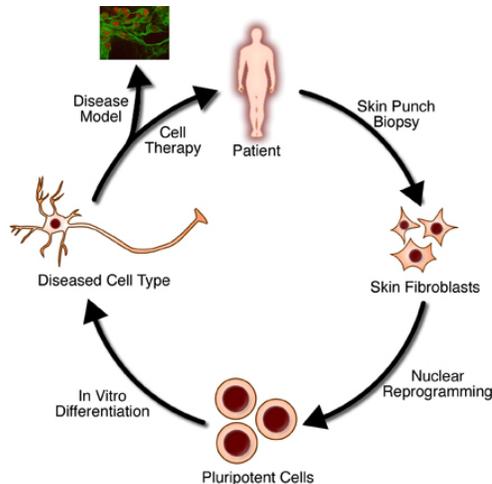
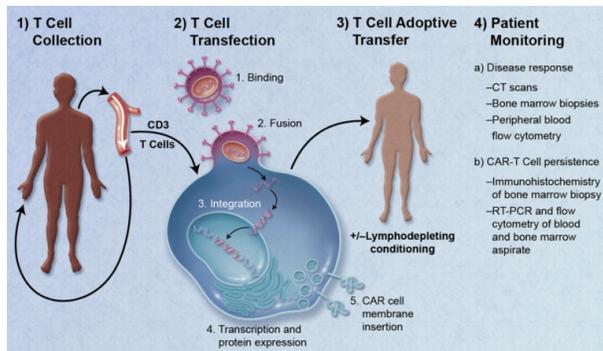


Synthetic biology

- 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



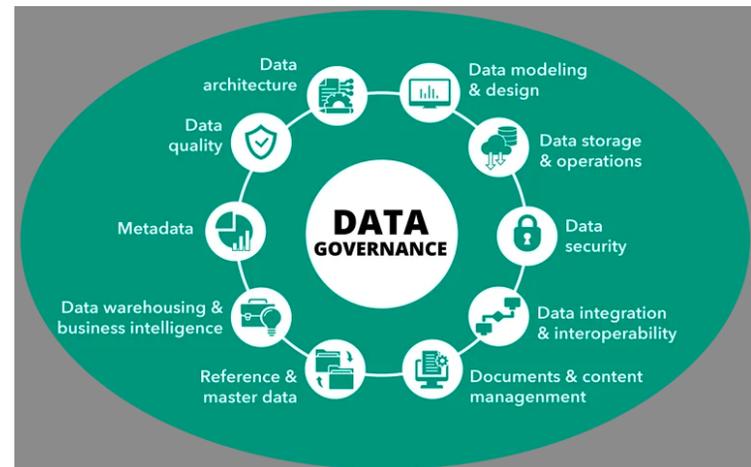
Regenerative medicine



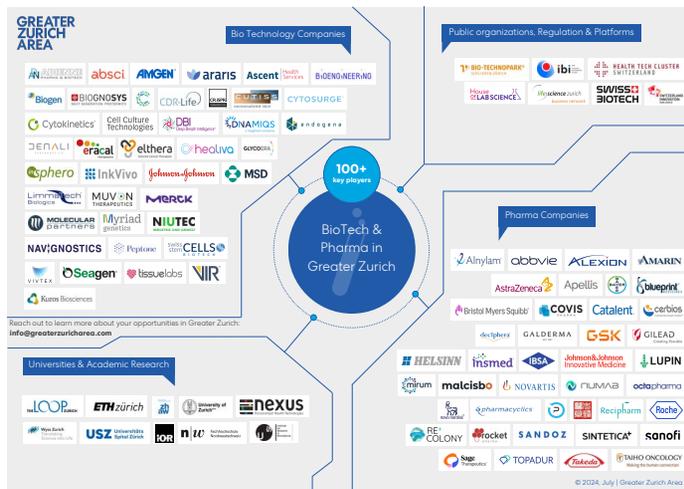
- AI advances development of stem cell therapies & tissue engineering
- AI algorithms assist in identifying optimal cell types, predicting cell behavior & personalized treatments
- particularly for conditions such as neurodegenerative diseases, heart failure and orthopedic injuries
- company - Organovo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

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Thank You