[San Jose State University Special AI Lecture Series III - AI + Biotech & Physical AI]
The Convergence Revolution - AlphaFold 3, AI-Driven Biotech, Humanoid Robots, and Future of Physical Intelligence

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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 ∼
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- *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 Gruop (GLG), NY, USA 2022 ∼
- Chief Business Development Officer @ WeStory.ai, Cupertino, CA, USA 2025 ∼
- 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 $\sim$ 2023
- Senior Applied Scientist @ Amazon.com, Inc., Vancouver, BC, Canada 2017 $\sim$ 2020
- Principal Engineer @ Software R&D Center, Samsung Electronics 2016 $\sim$ 2017
- Principal Engineer @ Strategic Marketing & Sales, Memory Business 2015 $\sim$ 2016
- Principal Engineer @ DT Team, DRAM Development, Samsung 2012 $\sim$ 2015
- Senior Engineer @ CAE Team, Memory Business, Samsung, Korea 2005 $\sim$ 2012
- PhD - Electrical Engineering @ Stanford University, CA, USA 2001 $\sim$ 2004
- Development Engineer @ Voyan, Santa Clara, CA, USA 2000 $\sim$ 2001
- MS - Electrical Engineering @ Stanford University, CA, USA 1998 $\sim$ 1999
- BS - Electrical & Computer Engineering @ Seoul National University 1994 $\sim$ 1998

Highlight of Career Journey

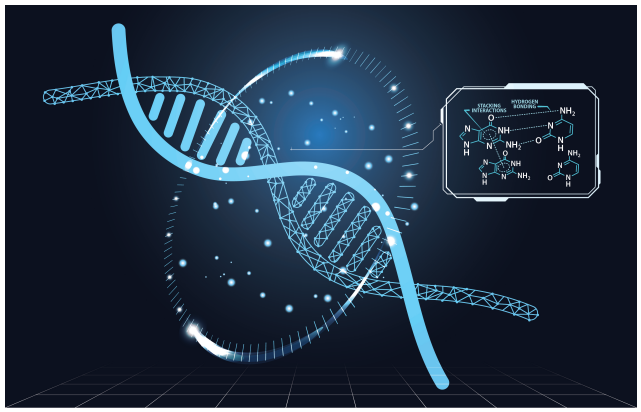
- BS in Electrical Engineering (EE) @ Seoul National University
- MS & PhD in Electronics Engineering (EE) @ Stanford University
  - *Convex Optimization - Theory, Algorithms & Software*
  - advisor - *Prof. Stephen P. Boyd*
- Principal Engineer @ Samsung Semiconductor, Inc.
  - *AI & Convex Optimization*
  - 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.

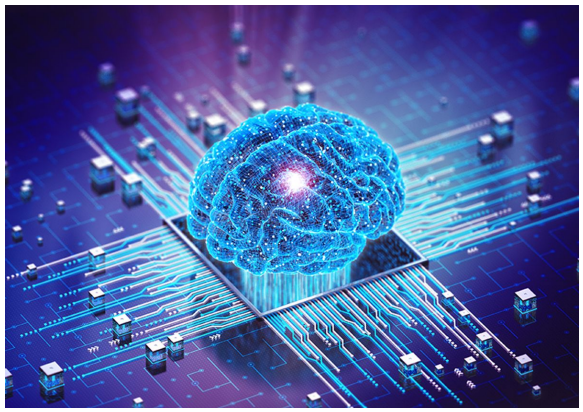
Unpacking AI

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





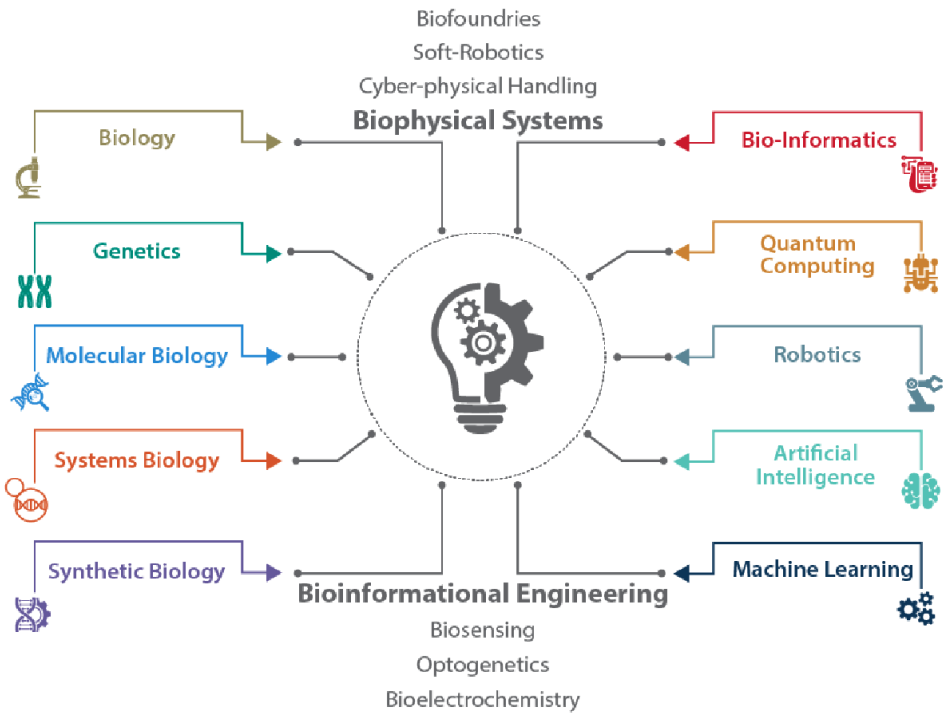
Biotech

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

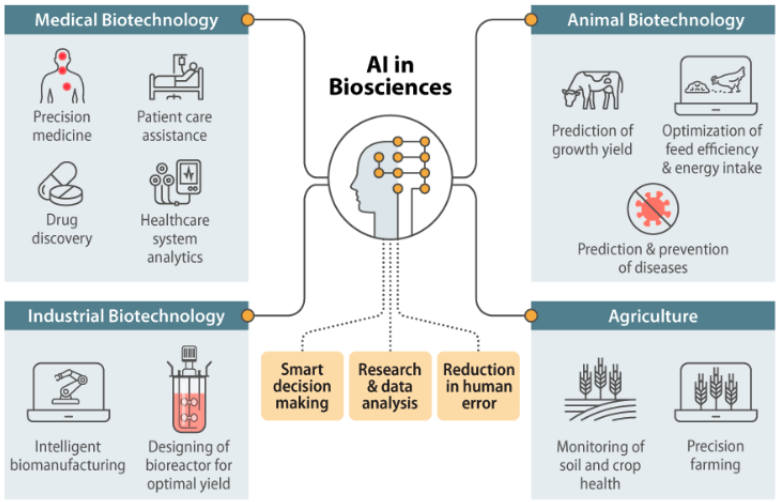
- sciences and technologies enabling biotechnology include (but not limited to)
  - (molecular) biology, genetics, systems biology, synthetic biology, bio-informatics, quantum computing, robotics [DFJ22]



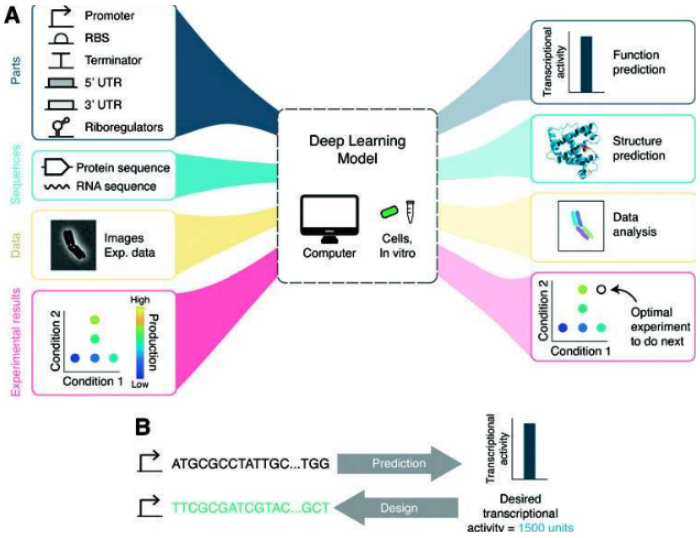
Convergence of AI and biological design

- 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

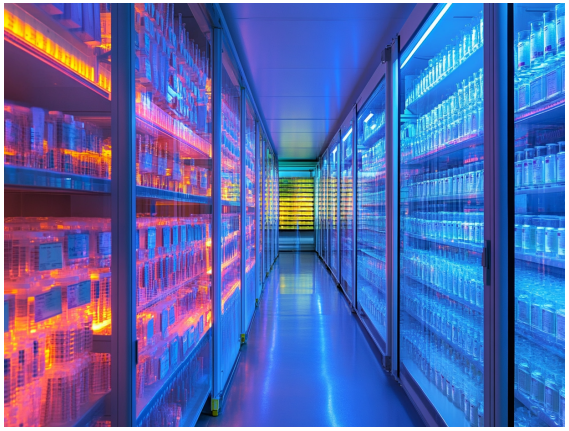
  "AI will be essential to fully understanding how genetic code interacts with biological processes" - US National Security Commission on Artificial Intelligence (NSCAI)

  – 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



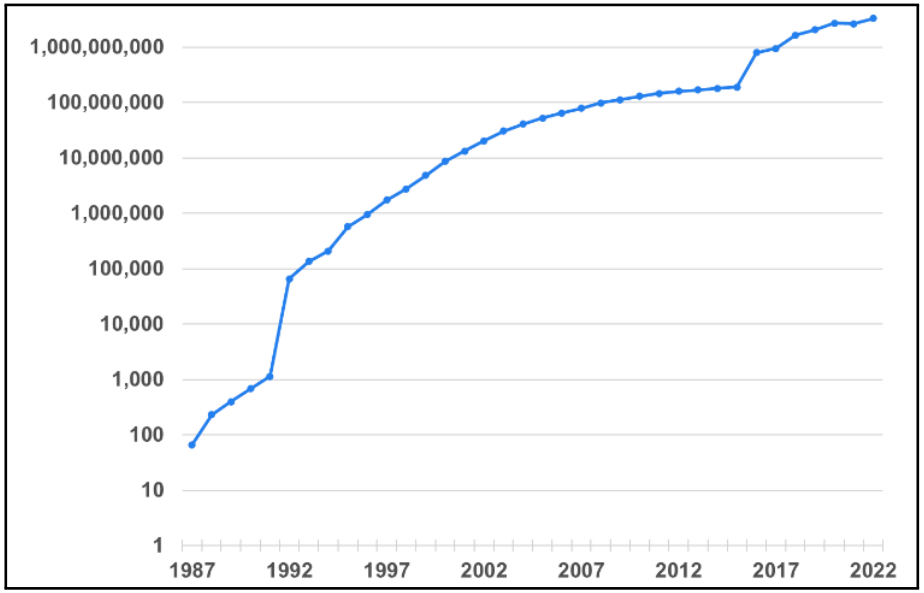
Rapid growth of biological data

- 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
    - 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

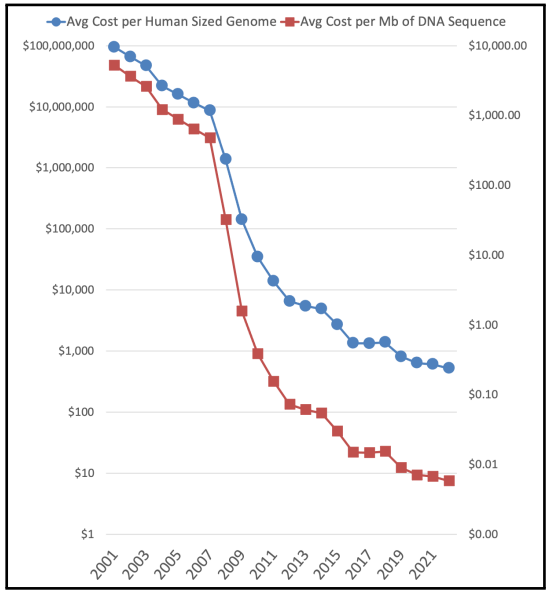
Volume and sequencing cost of DNA over time

- 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



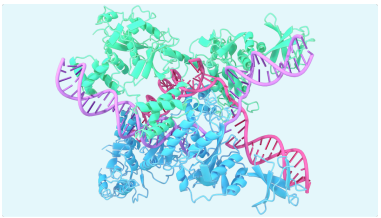
Bio data availability and bias

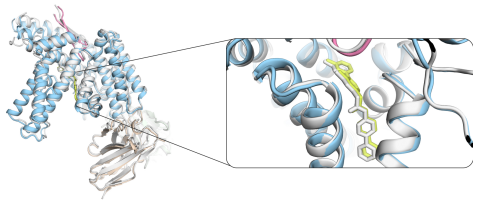
- US National Security Commission on Artificial Intelligence (NSCAI) recommends
  - US fund and prioritize development of a biobank containing *"wide range of high-quality biological and genetic data sets securely accessible by researchers"*
  - establishment of database of broad range of human, animal, 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

- Go board marked with 19×19 grid - $(19 \times 19)! = 361! \approx 1.44 \times 10^{768}$
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  0714137944348905859683839682333043216077138088370565578796691924861827097800358990211005794501073330
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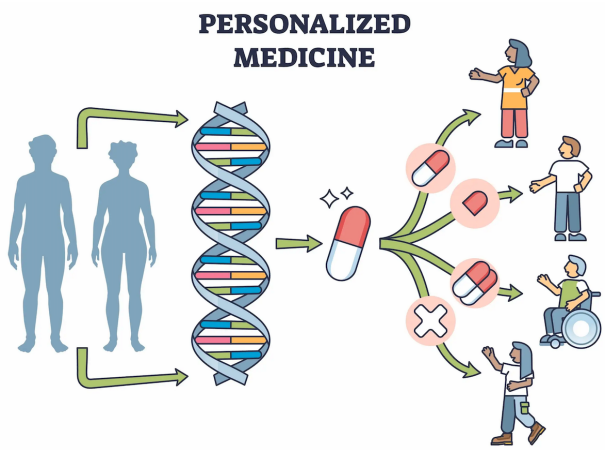
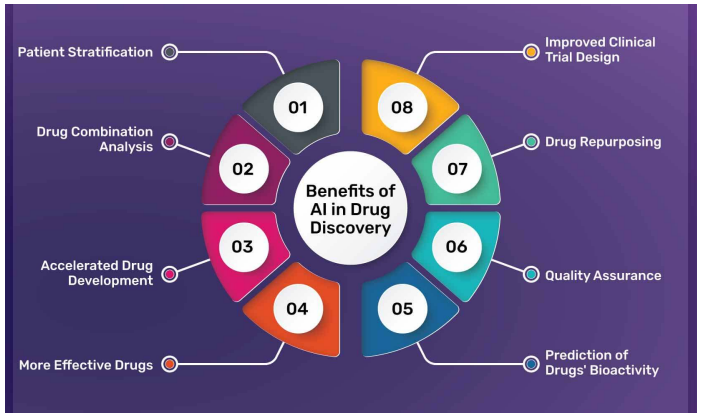
- deep reinforcement learning with Monte Carlo tree search
  - trained on thousands of years of Go game history
  - AlphaGo Zero learns by playing against itself
- development experience, insight, knowledge, know-how transferred to AlphaFold

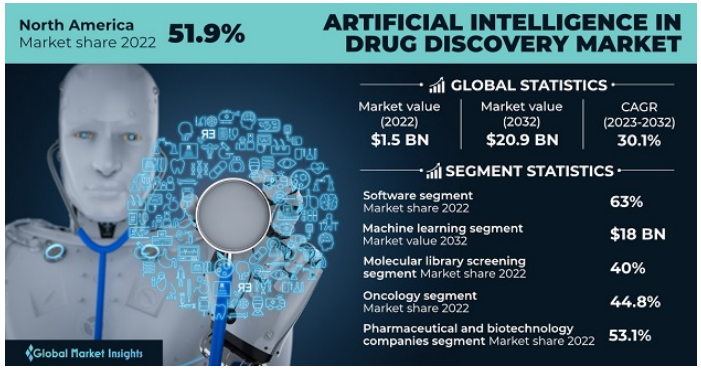
Personalized medicine

- *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

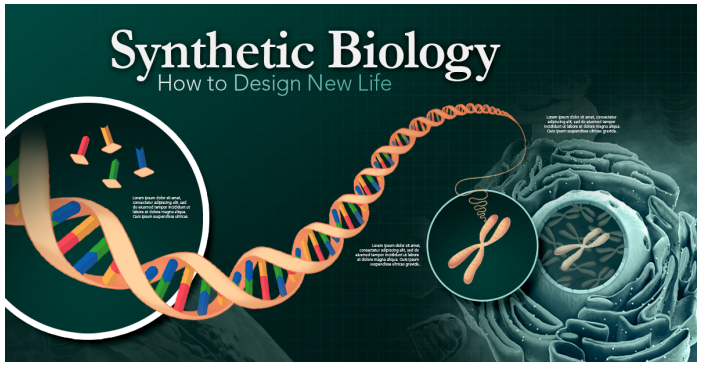


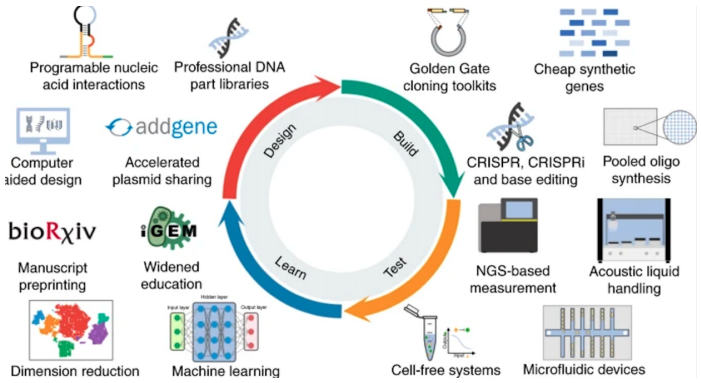


- traditional drug discovery process - time-consuming and costly often taking decades and billions of dollars
- AI streamlines this process by predicting the efficacy and safety of potential compounds with more speed and accuracy
- AI models analyze chemical databases to identify new drug candidates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

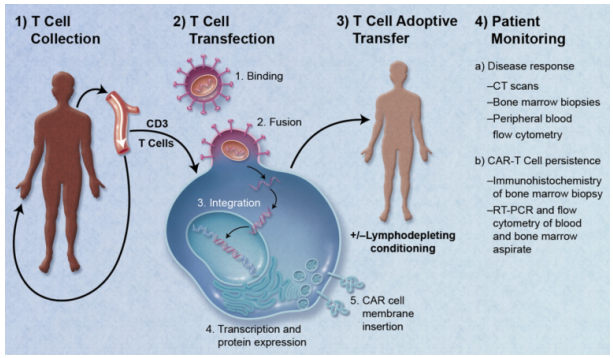
Synthetic biology

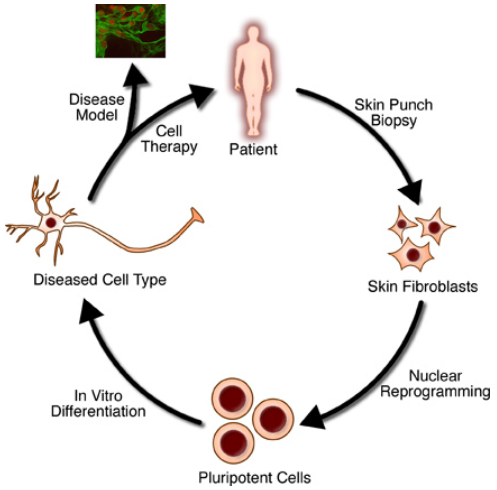
- use AI for gene editing, biomaterial production and synthetic pathways
- combine principles of biology and engineering to design and construct new biological entities
- AI optimizes synthetic biology processes from designing genetic circuits to scaling up production
- company - Ginkgo Bioworks uses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





Regenerative medicine

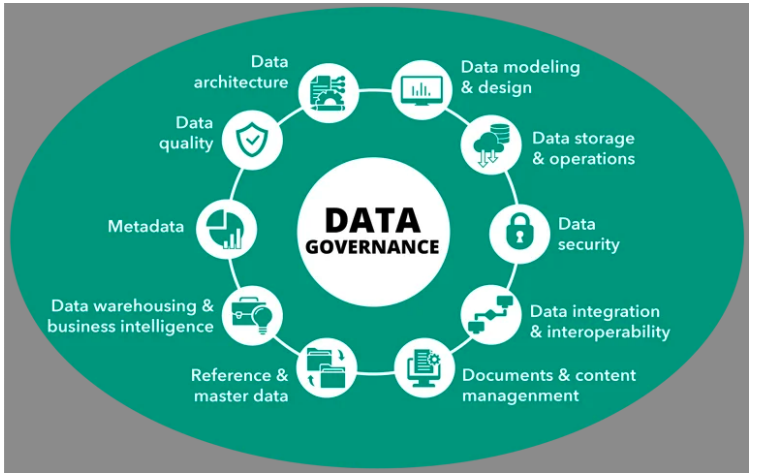




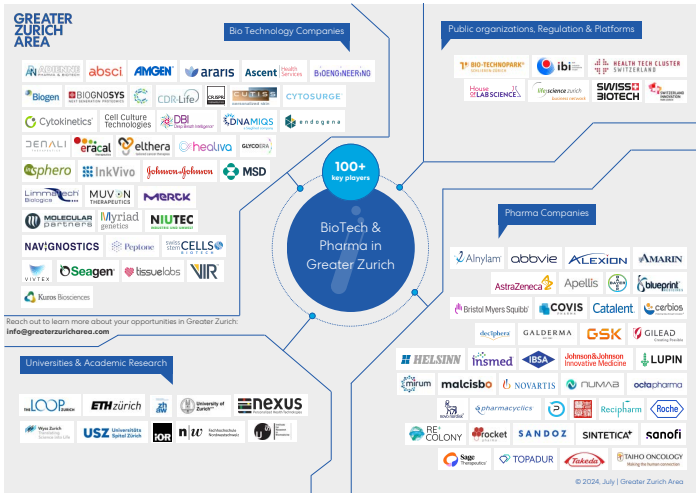
- AI advances development of stem cell therapies & tissue engineering
- AI algorithms assist in identifying optimal cell types, predicting cell behavior & personalized treatments
- particularly for conditions such as neurodegenerative diseases, heart failure and orthopedic injuries
- company - Organovo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



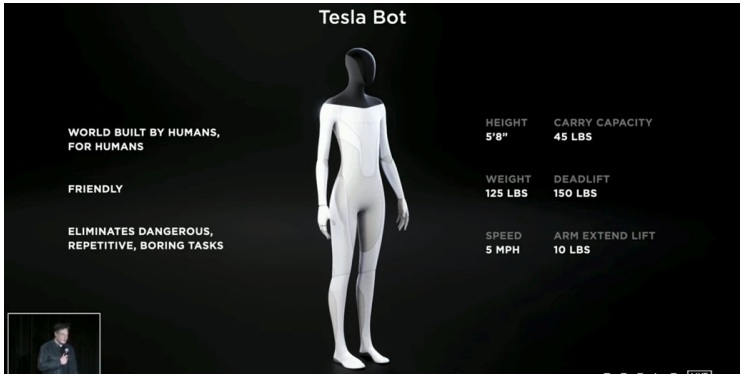
- Atomwise - small molecule drug discovery
- Cradle - protein design
- Exscientia - precision medicine
- Iktos - small molecule drug discovery and design
- Insilico Medicine - full-stack drug discovery system
- Schrödinger, Inc. - use physics-based models to find best possible molecule
- Absci Corporation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

AI-powered Humanoid Robots

Tesla Optimus

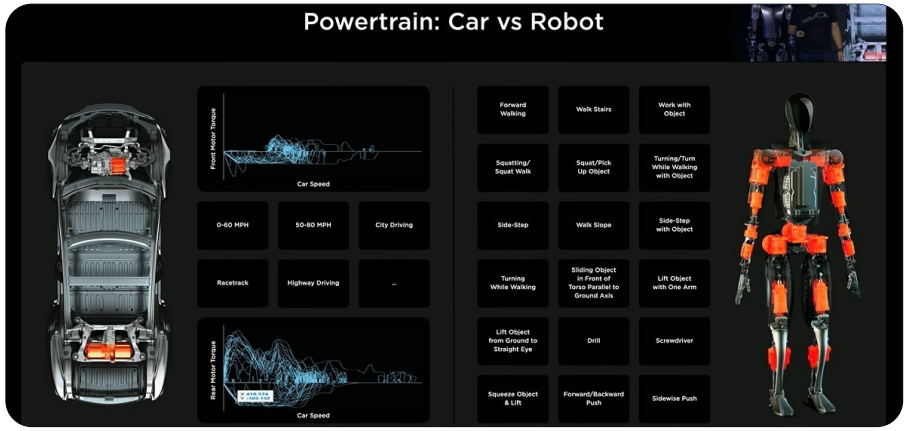
Tesla Optimus

- humanoid robot developed by Tesla intended to handle repetitive & dangerous tasks
- objective - *revolutionize automation* & assist in human labor across various industries
- features - YouTube - Optimus - Gen 2
  - dimensions - 5'8" tall & 125 lbs
  - capabilities - lifting weights, walking at 5 MPH & performing everyday tasks
  - AI-powered - runs on Tesla's AI leveraging same technology used in self-driving cars
  - power source - 2.3 KWH battery designed for efficient power management
  - launch year - announced by Elon Musk during Tesla AI Day in 2021
  - *price - $25,000∼$30,000* expected to decrease over time



History of Tesla Optimus

- inception - first conceptualized as extension of Tesla's AI & robotics capabilities
- AI day 2021 - *officially announced by Elon Musk* w/ vision to solve labor shortages & improve productivity
- Sep 2022 - prototype unveiled
- gen 2 introduced in 2023 - improved capabilities
- Jun 2024 w/ more advanced tasks - *towards mass production for commercial applications*



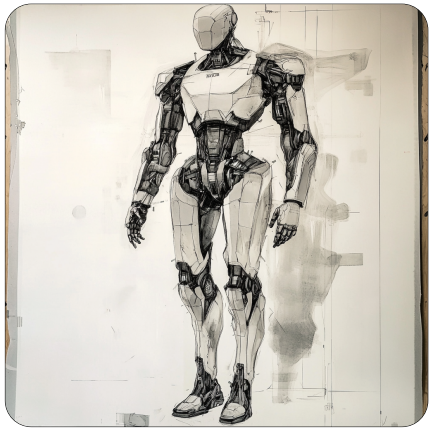
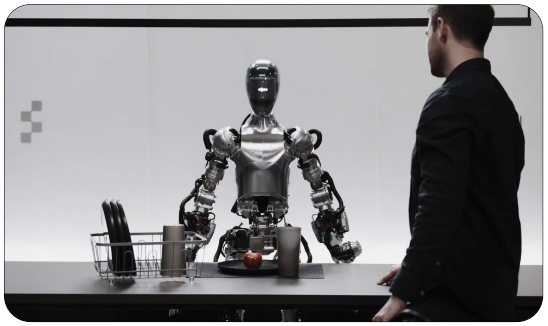
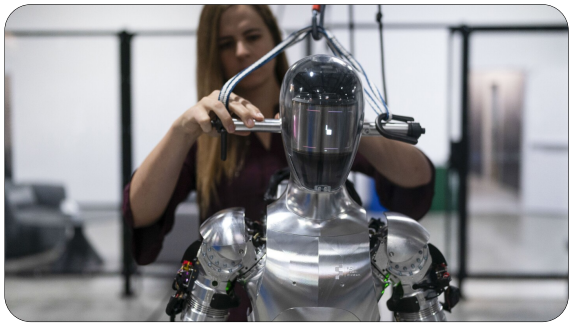


Figure AI

Figure AI robots

- Figure AI
  - founded in 2022 as Silicon Valley startup company by Brett Adcock - serial entrepreneur with successful Archer Aviation & Vettery
  - vision of enhancing productivity by integrating AI and robotics into both industrial & personal spaces
- Figure 02
  - 5'6" tall, 154 lbs, payload of 44 lbs, 5 hr runtime, 1.2 m/s speed
  - imitation learning
  - capabilities - advanced cognition, STS task, dexterous hands w/ 16 degrees of freedom





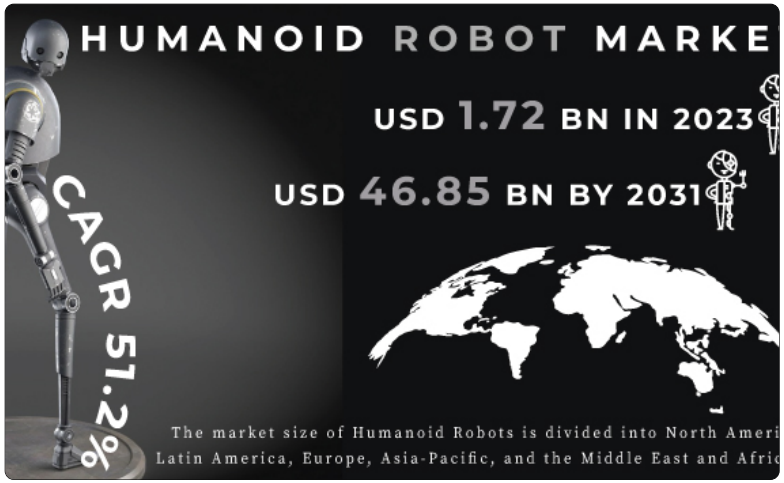
History of Figure AI

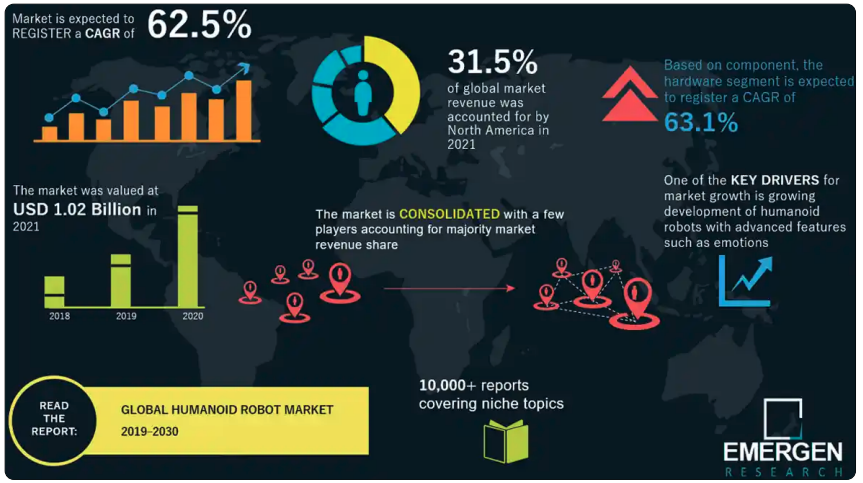
- 2022 - founded by Brett Adcock - previously co-founded Archer Aviation & Vettery
- 2022-2023 - early development - stealth mode focusing on developing their own technology
- May 2023 - public announcement - officially announces mission to develop general-purpose humanoid robots - already raised $70M @ announcement
- Aug 2023 - unveils Figure 01, first prototype w/ basic mobility & manipulation capabilities
- Oct 2023 - series B funding - raised $675M beyond initial goal of $500M - Jeff Bezos, Microsoft, OpenAI - valuation of $\sim$ $2.6B
- late 2023 $\sim$ early 2024 - partnership announcements - refines humanoid robot technology in locomotion, object manipulation & human-robot interaction
- 2024 - significant strides in robot control & decision-making

Impacts & Future

Impacts on industries & markets

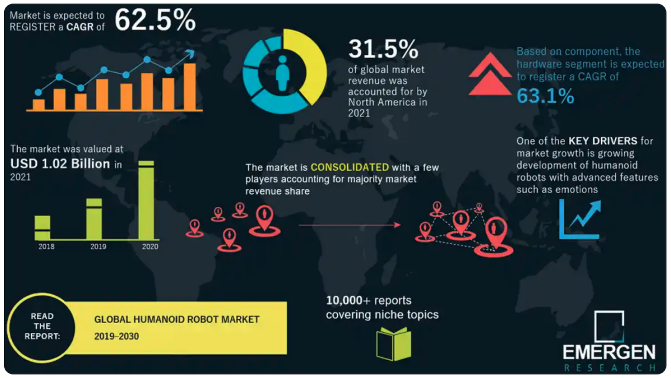
- impacts on robotics history
  - competitor benchmark - competes with robotics giants such as Boston dynamics
  - affordability & scale - predict to lead to *lower costs & higher adoption*
- impacts on labor market
  - task automation - replace human labor in *high-risk & repetitive roles*
  - *job displacement vs creation* - new roles in AI, robot maintenance & oversight
- impacts on consumer market - home automation





Future outlook & predictions

- widespread industrial adoption - expected to become common tool in factories by 2030
- market valued @ *$1.02B in 2021* - expected *CAGR of 62.5%, 63.1% in hardware segment by 2030* - *31.5% revenue increase in 2021* North America - *10,000 humanoid robots* will be shipped worldwide each year by 2027
- AI evolution - continuous learning and AI enhancements will lead to greater efficiency & adaptability
- consumer integration - long-term vision includes personal assistant
- societal impact - could redefine human roles in industries & homes *raising philosophical & ethical questions on human-robot collaboration*



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- CEOs, CTOs, CFOs, COOs, CMOs & CCOs @ startup companies in Silicon Valley
- VCs on Sand Hill Road - Palo Alto, Menlo Park, Woodside in California, USA

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Thank You