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MILKEN INSTITUTE

Transformative Computational Biology

A GIVING SMARTER GUIDE

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ABOUT US

About the Milken Institute

The Milken Institute is a nonprofit, nonpartisan think tank focused on accelerating measurable progress on the path to a meaningful life. With a focus on financial, physical, mental, and environmental health, we bring together the best ideas and innovative resourcing to develop blueprints for tackling some of our most critical global issues through the lens of what's pressing now and what's coming next.

About MI Philanthropy

MI Philanthropy advances the strategic deployment of philanthropic capital to create a better, more equitable world.

About the Science Philanthropy Accelerator for Research and Collaboration

The Milken Institute's Science Philanthropy Accelerator for Research and Collaboration (SPARC) works with philanthropists to develop comprehensive strategies and launch and lead high-impact science and health-oriented research initiatives.

FOREWORD

Computational biology is a unique field that combines the rapid pace of technological change with the potential for global impact by offering new avenues to tackle some of the most persistent challenges in disease understanding, diagnostics, and treatment.

This guide is dedicated to mapping out potential areas to accelerate the field, highlighting the transformative impact it can have on global health outcomes. Through philanthropic engagement, we have the opportunity to fast-track research breakthroughs, bringing immediate change and improving the lives of millions.

By investing in computational biology, philanthropists contribute to a foundational shift in the understanding and treatment of diseases like cancer and cardiovascular disease, which affect people in communities around the world. For the first time in history, we can now develop artificial intelligence systems to democratize access to diagnostics, identify new opportunities for disease prevention, and provide personalized care.

Private philanthropy plays a unique role in helping fill the funding gaps in computational biology, pushing the boundaries of what's possible in medical research and translational impact. Strategic investments made today can amplify the development of novel diagnostics, therapies, and preventive measures, which can turn into impact at scale within a few short decades.

We hope this guide inspires others to help accelerate the future of computational biology in global health.

Sanjit and Hope Biswas
Founders, The Biswas Family Foundation

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EXECUTIVE SUMMARY

In November 2022, the release of Open AI's chatbot, ChatGPT, catapulted and captivated the public's attention and understanding of artificial intelligence (AI). Before this point, people had gleaned a general concept of AI from news, media, and film. However, with the release of ChatGPT, free access to a powerful tool enabled people worldwide to experience the promise AI holds now and its potential for the future.

Leaders from across industries and sectors scrambled to understand this new AI tool and realized that the technology had progressed to a state that could transform business and societal functions. Conversations about practical and ethical uses of this emerging and rapidly advancing technology dominated the zeitgeist in 2023. As AI is increasingly woven into aspects of society and day-to-day life, biomedical research and the health-care ecosystem are fields with outsized potential for impact and benefit.

Principles of AI intersect with the larger discipline of computational biology, an interdisciplinary field encompassing concepts from computer science, mathematics, biology, statistics, informatics, and big data analysis. Computational biology focuses on developing, improving, and applying computational methods to biology-based questions, using mathematical modeling, simulations, analytics, statistical methods, and algorithm development. These tools and techniques can rapidly identify patterns in vast volumes of data to improve our understanding of biological systems and complex interactions, leading to discoveries and predictions applicable to human health. Computational biology concepts are being incorporated into many aspects of the biomedical ecosystem to address challenges across research disciplines and disease areas.

While the medical community recognizes the potential of the AI revolution to transform health around the globe, many challenges remain to be addressed before the technology reaches its full potential in this space. In 2023, the Milken Institute Science Philanthropy Accelerator for Research and Collaboration (SPARC) partnered with the Biswas Family Foundation to conduct a comprehensive landscape to facilitate greater understanding of the state of the computational biology field and identify areas where philanthropic support could enact a key role in realizing the potential of AI for health and medicine. This *Giving Smarter Guide* describes emerging trends, key stakeholders, funding patterns, critical barriers to progress, and areas of opportunity that philanthropic organizations are uniquely suited to address. We believe these opportunities will guide funders interested in making an impact at the intersection of AI and health care so that the technologies can be leveraged to improve the health and well-being of the global community.

Philanthropic Opportunities to Address Scientific and Systemic Needs

The opportunities outlined in this *Giving Smarter Guide* were informed by a thorough review of the scientific literature, an examination of public and private funding patterns, and conversations with more than 50 experts and stakeholders spanning multiple sectors, including academia, industry, research institutes, government entities, and nonprofit organizations. These individuals represented the research spectrum from basic science to clinical care. SPARC identified four opportunities where philanthropic investment could accelerate and optimize the integration of computational tools within biomedical research and clinical care to make a significant impact on human health.

Opportunity 1: Improve and Expand Large-Scale Open Data Initiatives and Infrastructure. For computational approaches to make a positive impact, large amounts of comprehensive research and clinical data will be needed. Philanthropic investment can help build the infrastructure support required to create, improve, and enhance large-scale open data initiatives that are standardized and complete.

Opportunity 2: Support the Development and Training of the Necessary Interdisciplinary Workforce. Building the computational biology workforce for the future is fundamental to all further progress. Philanthropic funding can support a variety of approaches, ensuring individuals are trained in this interdisciplinary field to facilitate the effective development and implementation of computational biology tools to improve human health.

Opportunity 3: Integrate Computational Tools into Research and Care through Pilot Studies and Expanded Infrastructure Access. Many universities and health systems lack the infrastructure and resources necessary to apply computational tools meaningfully within their biomedical research and clinical-care activities. Philanthropic capital is uniquely poised to fill these gaps by supporting the discovery of innovative tools and funding high-risk, pilot projects that may not appeal to other funders. Such projects can then be scaled up to have a more significant impact within the research and care ecosystem.

Opportunity 4: Expand the Implementation of Computational Tools for Clinical Application. Studies focused on the translational impact of computational tools in clinical settings currently lack adequate funding. These tools must undergo rigorous evaluation and validation so that new approaches are incorporated into clinical-care best practices and standards. Philanthropy can support the implementation of computational tools in health care by funding the assessment of models and facilitating tool deployment for patient care.

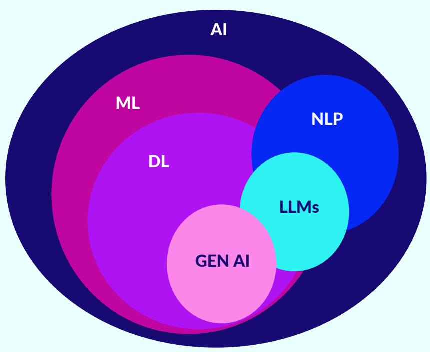
OVERVIEW OF COMPUTATIONAL BIOLOGY

Computational biology has recently undergone many advances with the rapid evolution of the technology that powers this interdisciplinary field. Computational biology sits at the nexus of biology, big data, and computer science, wherein computational tools are used to mine and analyze large amounts of biological and clinical information. The application of computational tools has the potential to revolutionize how we study, prevent, and treat human disease. However, the unique nature of the biomedical ecosystem brings specific challenges that must be overcome before the promise of these tools to help people live longer and healthier lives can be fully realized.

Artificial Intelligence Background

The biomedical ecosystem generates vast amounts of biological and clinical data, highlighting opportunities to integrate computational methods across the entire biomedical research continuum—from basic science and translational research to clinical applications and broader public health initiatives. Managing, analyzing, and using biomedical data require incorporating computational tools like artificial intelligence. **AI covers the broad discipline of creating systems and algorithms that can perform a wide range of tasks—including making predictions and solving problems—in an "intelligent manner."** AI encompasses different subfields, and various terms describe other aspects of AI, especially as the field evolves. Figure 1 provides an overview of some of these terms and how they are related.

Figure 1: Overview of Artificial Intelligence



Artificial Intelligence

Machine Learning (ML): Subset of AI that has systems that learn information and adapt this learning as more data are presented (with minimal intervention from humans). ML models are trained to use large amounts of information to make simple linear predictions and "learn" to iteratively improve.

Deep Learning (DL): A type of ML that requires very large datasets and uses layers of algorithms to generate artificial neural networks (interconnected nodes or neurons) to process data and identify patterns, similarly to how the human brain functions.

Generative AI: Any AI system that generates new content based on learnings obtained from data.

Natural Language Processing (NLP): Subset of AI that enables machines to understand human language by combining computer science, linguistics, and ML. Computer programs are trained to translate text across different languages, respond to commands, summarize large volumes of text, and complete speech-to-text dictation. Examples include virtual assistants (e.g., Siri, Alexa) and chatbots that utilize LLMs (e.g., ChatGPT).

Large Language Models (LLMs): Type of ML/DL model that can perform NLP tasks like generating text (and hence can also be a form of generative AI). LLMs are foundation models, which are trained on large amounts of textual data, can capture complex patterns in language, and generate responses to prompts or queries.

ML/DL tools are predictive statistical models that continue to evolve, learn, and improve as new data become available. These tools have applications across many industries, including self-driving cars, speech/voice recognition, and computer vision techniques such as image classification. DL models can predict more complex relationships than ML models so are useful in understanding complex biological systems.

Source: Milken Institute synthesis (2024), adapted from Rahmat (2023) and Halejak (2023)

Utilization of Computational Tools across the Research-to-Care Spectrum

Biomedical research has entered an era when vast amounts of data are continuously produced, and new technologies are becoming more easily accessible. Integrating, analyzing, and understanding these data from various sources is only possible with the use of computational tools. Incorporating such tools across the biomedical ecosystem has great promise to further the understanding of foundational biological mechanisms, advance translational research, and enhance clinical care for better patient outcomes.

COMPUTATIONAL TOOLS ACROSS THE BIOMEDICAL ECOSYSTEM

Foundational Biology Research: Using computational tools accelerates the understanding of biological processes, disease mechanisms, network interactions, and molecular structures.

Translational Research: Incorporating clinical data and computational approaches can lead to the creation of new AI tools and improve drug discovery.

Clinical Application: Implementation of computational tools in the clinic can assist with diagnosis, predict health outcomes, and personalize treatment strategies.

In this section, we first outline critical areas where biomedical research data and clinical data are being produced at a rapid pace, then highlight key examples where there is significant potential for computational biology to impact the integration and analysis of these data to improve research and care across the spectrum, as described in the callout.

FOUNDATIONAL BIOLOGY RESEARCH

Within foundational biology research, technological advancements over the last decade have enabled the generation of large amounts of biological data, specifically in **two main areas: (1) sequencing technologies and (2) protein structure predictions.** The concurrent advancement of computational tools has resulted in novel methods that reveal discoveries and a greater understanding of how biological processes and systems work within the human body. Computational biology-enabled discoveries have begun to disclose how the vast numbers of genes and proteins interact in highly complex ways for normal cellular function and how molecular mechanisms are altered to drive disease progression.

Advancements in Sequencing Technologies

The human genome was first sequenced in 2003 as part of the Human Genome Project, which took more than 13 years to complete. Since then, large-scale sequencing technologies have advanced considerably and are widespread, enabling researchers to sequence whole genomes in only a few hours. The breadth of biological data collected with these technologies is described below.

BIOLOGY REFRESHER

Genes, Transcripts, and Proteins
Deoxyribonucleic acid (DNA) contains genetic information that cells use to produce proteins, which are large molecules that perform biological functions. In order for a cell to produce a protein, the relevant DNA is transcribed into ribonucleic acid (RNA), and this transcript is then translated into the protein.

Omics
Almost every cell in the human body contains more than 20,000 genes. There are a variety of molecular processes within the cell, which include interactions between genes, proteins, transcripts, and other cellular mechanisms. Characterizing and understanding this cellular information on a massive scale is collectively referred to as "omics."

Multi-Omics: Datasets of different "omics" data are combined for analysis (e.g., genes, RNA, and proteins)

Singe-Cell Omics: Characterization of single cells within a larger mixed population of cells

Spatial Omics: Captures molecular measurements of a cell from intact tissue samples to avoid disturbing the cell's natural spatial location

Omics, Multi-Omics, Single-Cell Omics, and Spatial Omics: The term "omics" describes the study of molecular or cellular processes using high-throughput technologies and encompasses genomics, transcriptomics, proteomics, epigenomics, metabolomics, and related studies. The ability to gather multi-omics data easily and study biological mechanisms at single-cell resolution enables insights into disease etiology by revealing unique characteristics of individual cells that may not be found in analyses of cell populations. The positions, locations, and interactions of cells are important contributors to cellular function; therefore, using **spatial omics** techniques within healthy and diseased tissues can provide novel insights into disease mechanisms. Emerging trends include the development of spatial multi-omics technologies that measure and analyze various cell parameters—such as DNA, RNA, and protein levels—at the same time. The development of three-dimensional spatial omics technologies could be applied at the organ or organism level, along with spatial temporal-omics, which allows the collection of real-time data longitudinally. Examples of how DL models are used to analyze data from these types of sequencing technologies are highlighted in the HuBMAP case study.

EXAMPLES: APPLICATIONS OF DL MODELS WITH SEQUENCING DATA

A DL model analyzed **single-cell RNA sequencing data** from more than **13,000 cells** from postmortem **Alzheimer's disease** brain tissues to provide additional insight on disease mechanisms.

Computational tools were used to analyze **single-cell RNA sequencing data** from **600,000 cells** to identify differences in transcriptional activity between diseased and healthy hearts for a deeper understanding of the pathology of **cardiomyopathies**.

A DL model integrated **multi-omics data** from a group of more than **700 individuals** recently diagnosed with **type 2 diabetes** to better understand the mode of action for several diabetes drugs with the goal of developing more personalized treatments.

Geneformer is a DL foundation model that was trained on data from around **30 million single-cell transcriptomes** from a wide range of human tissues to gain fundamental biological knowledge. This model was then applied to other smaller datasets and was able to accurately predict known disease-causing gene variants. Geneformer was then used to further understand molecular mechanisms of cardiovascular disease by **predicting genes that might be associated with the development and function of cardiomyocytes** (heart muscle cells).

CASE STUDY

The Human BioMolecular Atlas Program (HuBMAP)

- The program is funded by the National Institutes of Health (NIH) Common Fund.
- The consortium's goal is to create an open-access platform that facilitates the development of spatial multi-omics maps of healthy human organs at single-cell resolution.
- This resource will serve as a reference and comparison of normal versus diseased tissue.

First Phase: concluded in 2023 with the establishment of the HuBMAP Data Portal for open-access data sharing

- Developed the infrastructure for protocols, processes, data storage, and computational methods

Next Phase: focused on producing the spatial multi-omics maps through collaborations with more than 60 institutions

- Includes developing ML/DL tools to mine and analyze the single-cell and spatial omics data being generated

Predicting Protein Structures and Designing Proteins

Accurate prediction of protein structures is another area where computational tools have driven significant advances in recent years. Knowing a protein's 3D folding structure is critical to understanding how molecules function in the body and has other applications, including designing drugs. Historically, sensitive but time-consuming techniques, such as X-ray crystallography, were the standard for determining protein structure.

> AlphaFold was released by Google DeepMind in 2018. The DL system is used to predict 3D protein structures, which are critical to understanding how proteins work and how therapies and other proteins might interact with them. This technology was revolutionary at the time of release and remains valuable to the research community.
>
> The accompanying free AlphaFold Protein Structure Database currently houses more than 200 million protein structures. The software's ability to predict protein folding structures rapidly in combination with the database has opened opportunities for biomedical research breakthroughs. Another software—RFdiffusion, released in March 2023—can identify protein sequences and structures that have the potential to bind to a protein of interest, which increased the accuracy of predicted designer proteins 100-fold.

These technological advances will help researchers understand how proteins interact and function, uncover new biological insights about gene mutations that impair protein function, and simulate molecular pathways that underlie various diseases. Additionally, AI tools can help in the early stages of drug discovery by creating targeted drug candidates, elucidating protein-drug interactions to enhance therapeutics, and using DL models to develop designer proteins custom-built for specific tasks. For example, programs like the Drugs for Neglected Diseases Initiative (DNDi) are using AlphaFold to aid in discovering drug candidates for ailments such as Chagas disease, a parasitic illness particularly devastating in Central and South America. The potential of computational tools can ultimately lead to the identification of novel therapeutic candidates for many diseases.

TRANSLATIONAL RESEARCH AND CLINICAL APPLICATIONS

Efforts to understand the fundamental building blocks of biology through foundational research lead to the development of translational research studies focused on integrating this knowledge into new or improved treatment options. Researchers and clinicians around the world are determining best practices for using AI in medicine to improve patient outcomes and overall health. Therefore, investments that aid the implementation of computational tools in clinical settings have the potential to advance treatment options and revolutionize health care. In addition to the vast datasets being generated with molecular and cellular information, clinical data are continually produced and collected, and computational biology approaches are needed to merge and analyze the data.

Clinical Data and Integration of Multimodal Datasets

Clinical data encompass a wide range of data from multiple sources, as shown in Figure 2. These include research data (as described above), clinical trial data, and other relevant information gathered from biological samples, electronic health records (EHRs), and medical images. Additionally, data not collected through research or in clinical settings contain significant health information about individuals (e.g., patient-reported outcomes, wearables data, and epidemiological factors affected by the environment).

With such a variety of data available, researchers and clinicians are focused on integrating this information to develop **multimodal datasets** that provide a more complete and holistic view of a person's health. However, it is challenging to develop multimodal datasets that systematically combine the information and create platforms that are easily accessible and interoperable. These factors are critical in ensuring researchers and clinicians can effectively use computational approaches to develop novel insights. Some initiatives focusing on collecting multimodal data from large groups of individuals are described below.

Figure 2: Sources of Clinical Data

Source: Milken Institute (2024)

UK BIOBANK

UK Biobank collects information from 500,000 participants, including data from whole-genome sequencing, medical imaging (e.g., brain, heart), EHRs, wearables, survey questionnaires, blood, and urine samples.

In November 2023, UK Biobank released the world's largest set of whole-genome sequencing data from all participants.

NIH'S ALL OF US RESEARCH PROGRAM

All of Us is building a database with 1 million participants who are diverse and representative of the US population.

In April 2023, *All of Us* released almost 250,000 whole-genome sequences as well as data from wearables, EHRs, and surveys.

ALZHEIMER'S DISEASE DATA INITIATIVE (ADDI)

ADDI is a coalition of multiple organizations that created an open-access platform to provide the infrastructure for the global research community to share data and analytical tools at no charge to spur Alzheimer's research.

A central part of ADDI is the disease-specific data platform: Alzheimer's Disease Workbench.

ADDI has focused on making existing data platforms for dementia-related diseases interoperable and allowed for increased sharing of data and computational tools to analyze these integrated datasets to lead to novel discoveries and new insights.

Application of Computational Tools in Translational Research and Clinical Care

Using computational tools to analyze clinical data and multimodal datasets can support precision medicine, drug discovery, disease diagnosis, clinical decision-making for individualized treatments, remote monitoring, and many other applications. This section highlights key examples and case studies.

Precision Medicine

The application of computational biology tools to multimodal datasets has enormous potential to advance precision medicine. Different computational and statistical methods can be used to determine how a person's genome can affect the response to various drugs and medications—a field of study called **pharmacogenomics**. AI can also uncover patterns leading to individualized treatment plans or risk assessments for specific diseases. Examples of how AI is used for precision medicine in oncology follow.

Drug Discovery and Predictive Modeling

Biotech and pharmaceutical companies are poised to lead the charge in using AI for **drug development**, a notoriously long and arduous process. Predictive AI models can reduce the time and costs of developing drugs. The tools can predict pharmacological activity or toxicity early in the development pipeline. They can also accurately predict and simulate drug-protein interactions to screen and identify better targets and small molecules.

EXAMPLES: AI IN PRECISION MEDICINE FOR ONCOLOGY

ML models can be used to predict tumor recurrence, response to chemotherapy/radiation, and deeply characterize the molecular subtype of a tumor.

These techniques are especially relevant for breast, prostate, and lung cancers since there are hundreds of thousands of mammography/CT-based scans publicly available for analysis.

BigMHC: DL model that predicts whether cancer patients will be responsive to **immunotherapy**, helping to develop more personalized cancer treatments. Determining whether specific mutations in cancer cells make them more responsive to immunotherapy can be challenging, time-consuming, and expensive. This model will be tested in several clinical trials and could potentially support clinicians to develop more tailored therapies.

Mayo Clinic and Google Health Collaboration: DL model was trained and validated to improve **head and neck cancer radiation** therapy planning.

Sybil: DL model developed in collaboration among MIT's Abdul Latif Jameel Clinic for Machine Learning in Health, the Mass General Cancer Center, and Chang Gung Memorial Hospital (Taiwan). This tool was built to analyze low-dose CT scans of the lung to predict the risk of developing **lung cancer** in the next six years, which could significantly aid lung cancer screening programs.

CASE STUDY

AI and Drug Development, Design, and Repurposing

Insilico Medicine

- Used AI to design a drug that inhibits a receptor involved in pulmonary fibrosis; currently in Phase II clinical trials
- Streamlined to nine weeks a process that typically takes several years
- First drug with a novel AI-discovered target and a novel AI-generated design, which has the potential to treat diseases like idiopathic pulmonary fibrosis

AI tools can be applied for drug repurposing to determine whether drugs that did not make it through Phase II or III clinical trials can be repurposed for other conditions.

Whiz.AI uses AI tools to analyze results from prior Phase II or III clinical trials and data from remote patient monitoring.

Insitro uses genomics data and ML tools to discover drugs for neurodegenerative diseases, including determining whether current drugs can be repurposed.

Disease Diagnosis, Monitoring, and Treatment

AI tools hold great promise for diagnosing diseases earlier and more accurately and can further the monitoring of disease progression. An area of active exploration is the use of computational tools, such as ML and NLP, to analyze changes in voice and speech that precede cognitive symptoms in people with Alzheimer's disease. Positive results could potentially help in earlier diagnosis or monitoring cognitive decline. Computational tools are also used to analyze and interpret medical images, especially in fields where large numbers of medical images are used. The opportunity to use such models for analysis, diagnosis, and treatment is compelling and could revolutionize care, as shown in the examples (see below).

EXAMPLES: AI AND MEDICAL IMAGING

Cardiovascular Disease

- AI models are being generated to assess a patient's risk for stroke, heart attack, or sudden cardiac death.
- Tools can analyze, detect, and diagnose cardiovascular disease based on patterns in MRIs the human eye cannot detect.
- Medical imaging data combined with other data from electrocardiograms and wearables allow for more effective analysis and diagnosis of conditions such as heart arrhythmia and atrial fibrillation.

Medical Robotics

- AI is being built into medical devices that use ML models, analysis of medical images, and computer vision for a variety of applications, such as diagnostic imaging and surgery.
- In cardiovascular disease, a patient's MRI images can be used to generate a virtual model of the heart. AI targets the diseased tissue on the model and outlines the area recommended for surgical ablation. This information guides therapeutic interventions for surgeons and clinicians.

Underserved Populations

- In areas where physicians are scarce, AI tools can be used to analyze medical images and triage patients to determine whether intervention is needed.
- The UK is investing more than $26 million within the National Health Service to support the utilization of AI tools to analyze medical imaging, specifically for faster diagnosis of cardiovascular diseases, stroke, and cancer.
- A WHO directive explains the use of AI to analyze medical images to diagnose tuberculosis, with potential widespread benefit, particularly in low- and middle-income countries.

With regard to broader **public health** strategies, the diagnosis and treatment of **infectious diseases** at the population scale require managing, analyzing, and interpreting large amounts of complex data, a process facilitated by the use of computational tools (see case study).

CASE STUDY

Clinical Metagenomics, Infectious Disease, and Public Health

Metagenomics is used to identify microbial communities found within patient samples by sequencing and analyzing both host and microbial genetic material.

Metagenomics analysis facilitates the differentiation between human and pathogen genomic material, leading to the identification of the source of infection.

Since thousands of bacterial and viral genomes have been sequenced, in the future, an infection could potentially be diagnosed by sequencing tissue from a patient.

Computational tools are key since these sequencing techniques produce massive amounts of data.

- AI models can also be used to analyze microbial genomic data to rapidly detect whether any pathogens have developed resistance to drugs such as antibiotics or antivirals, which would then inform more effective treatment plans for patients.
- The development of new diagnostic and detection tools will provide better visibility into pathogen genomes, biology, and spread, which can then be shared in real time locally, nationally, and globally.
- AI can be used to provide network analytics of disease clusters, track the beginning patterns of disease outbreaks, create diagnostic reports, and generate disease-spread predictions, many efforts that began during the COVID-19 pandemic.

Natural Language Processing and Generative AI in Health

As NLP and LLMs rapidly evolve, so does the exploration of how best to use AI tools in biomedical research and health care. NLP is used to analyze novel patterns in speech-to-text systems, and voice recognition data can now generate reports that rival physicians' notes. LLMs have the potential to support clinicians in various ways, such as by helping to explain clinical results; making earlier, more accurate predictions; communicating with patients; and gathering information to help determine an individual's health goals for more personalized care. Moreover, the shortage of primary-care physicians presents an opportunity for generative AI and chatbots to fill in some gaps, such as interacting with patients to answer routine questions.

> **Google DeepMind** recently released **Med-PaLM**, a chatbot trained to answer medically related questions. **Teladoc Health**, a telehealth platform, is partnering with **Microsoft** to address challenges around staff shortages and administrative burdens by using AI tools that automatically generate clinical notes and other necessary documentation from patient interactions.

This Generative AI Tracker is a continuously updated resource and includes examples of health systems that have shared how they use generative AI in patient care. As AI tools evolve and are increasingly deployed, they must be adapted effectively and ethically for clinical settings and tailored to individual patient circumstances to improve health outcomes. For example, models should consider patient characteristics, including educational level, cultural sensitivities, and language barriers, to enhance personalized medicine. Additionally, since biases are unintentionally built into AI systems based on the data used in the training process, issues of bias (arising, for example, from race) and equitable access need to be considered to avoid further alienating marginalized groups and aggravating health inequities.

THE GLOBAL COMMUNITY'S INVESTMENT IN AI FOR MEDICINE

As AI rapidly advances, global governments are engaged in discussions about its ethical implications and the development of best practices for its use. Each country has an essential stake in creating policies and funding initiatives that maintain AI safety and innovation. A country's health-care ecosystem directly correlates with its GDP. Researchers and political leaders worldwide, therefore, have financial—as well as ethical—imperatives to evaluate AI's potential impact on health care quality.

> Countries worldwide are making significant strides in AI research and technology development, as the global market size of AI in health care is expected to grow to $45.2 billion by 2026.

In 2023, members of the global community began convening representative stakeholders at the frontier of AI development—from technology companies, research, and policymaking—to understand and manage the possible risks of this rapidly advancing technology. The expansive utilization of AI across industries has pushed more than 15 countries to launch national strategies for AI, each with a unique approach to fit the country's structural, economic, and ethics policies. The following figure highlights recent initiatives from countries that facilitate integrating AI technology into biomedical research and clinical care.

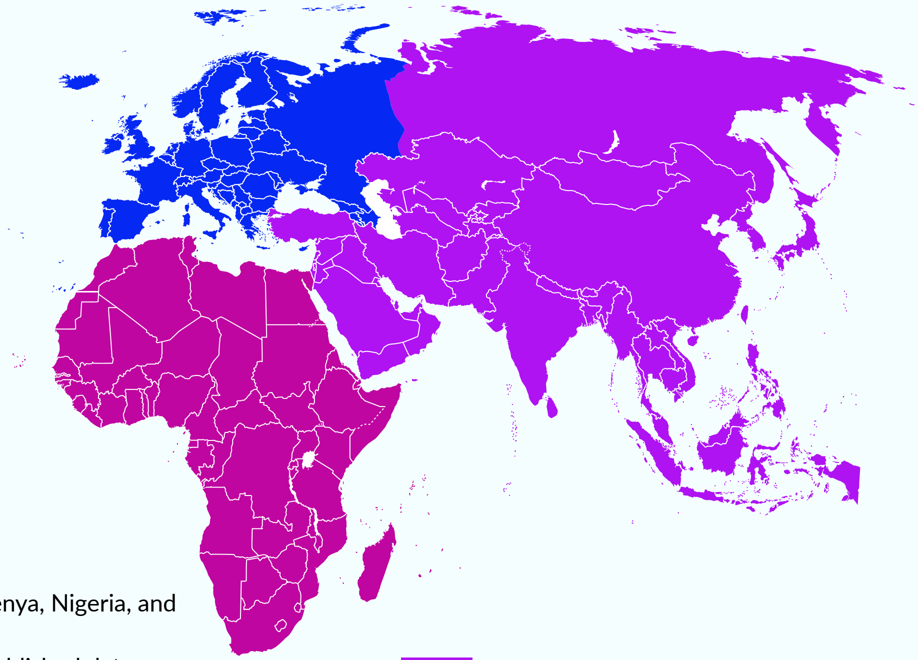
BUILDING INTERNATIONAL CONSENSUS ON AI SAFETY AND REGULATION

United States Agency for International Development (USAID) Center for Innovation and Impact
May 2022: AI in Global Health: Defining a Collective Path Forward focused on the unique health-care obstacles low and middle-income countries face due to the shortage of workers and medical equipment.

World Health Organization (WHO)
May 2023: WHO issued an alert for safe, rigorous, and ethical oversight in the growing experimental use of AI, specifically large language model usage for health-related purposes.

AI Safety Summit
November 2023: The United Kingdom hosted this first global summit with 28 countries across Africa, the Middle East, Asia, Europe, and North and South America participating to build international consensus on AI capabilities and legally binding standards for monitoring, compliance, and liability.

Figure 3: Highlighted Initiatives from Countries in Europe, Asia, and Africa



EUROPE

- **Leading Countries:** United Kingdom, France, Germany, and Denmark
- In 2023, the **UK** made a **$160 million** commitment to improve AI imaging and diagnostic tools.
- **France** allocated **$710 million** toward digital health advancement.

AFRICA

- **Leading Countries:** Egypt, Kenya, Nigeria, and South Africa
    - 35 countries have established data protection laws for responsible and regulated AI.
    - Mauritius, Egypt, and Rwanda have developed national AI strategies.
- Digital health companies secured $123 million in investment across the continent in 2021.
- Founded in 2022, the Heredity and Health in Africa Program fosters the continent's data science research community.
- African countries are joining collaborative efforts to establish comprehensive frameworks so that emerging AI initiatives have the potential to make transformative contributions to health care.

ASIA

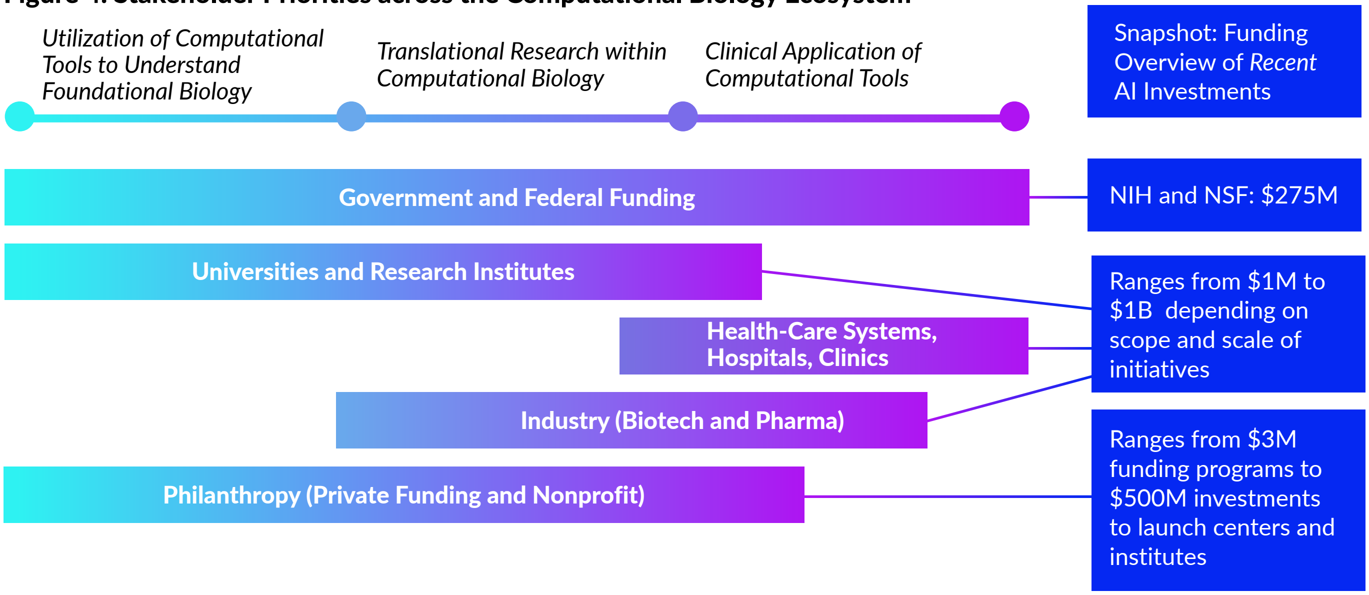
- **Leading Countries:** China, South Korea, Japan, and India
- In **China**, investments in the next frontier of AI R&D focus on faster drug discovery, clinical trial optimization, and clinical decision support (expected to generate $25 billion in economic value).
- **India** launched the National Digital Health Mission in 2020. The 2023–24 budget allocated $10.6 million toward innovative health-care initiatives to develop digital health infrastructure.

Source: Milken Institute (2024)

KEY STAKEHOLDERS AND FUNDING OVERVIEW IN THE US

The key stakeholders in the computational biology field represent multiple sectors, including governments, universities, health-care systems, industry, and philanthropy. While the global community is investing broadly in the AI and health space, as outlined in Figure 3, this section focuses on large stakeholder groups in the United States. As summarized in Figure 4, the priorities of these groups span the biomedical research and health ecosystem. When considering the funding landscape across stakeholder groups, we see large-scale as well as smaller, focused initiatives. This wide variety of investments is necessary to ensure the integration of computational approaches within biomedical research and care. Figure 4 also provides a snapshot of the funding range of *recent* investments across stakeholder groups, and more detail follows. This section surveys the unique role played by each stakeholder, describes the impact of each group on the scientific ecosystem, and outlines current funding mechanisms within the field.

Figure 4: Stakeholder Priorities across the Computational Biology Ecosystem



Source: Milken Institute (2024)

US Federal Funding for Computational Biology

Some US federal agencies have recently announced significant financial investments of more than several hundred million dollars into computational biology-related research projects and initiatives. The stated goals of this support are to facilitate the rapidly evolving computational biology field, decrease barriers to AI deployment, and provide new recommendations for health-care improvements. Figure 9 in the Appendix includes a timeline of recent US federal initiatives impacting AI usage in research and care. The sections below provide information about selected agencies working at the intersection of computational biology and human health, focusing on the Department of Health and Human Services (HHS) and the National Science Foundation (NSF). Other agencies, such as the Department of Defense, also have efforts in AI and health focused on topics relevant to their priorities.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Focused on enhancing the health and well-being of all Americans, HHS includes multiple agencies and offices. Several HHS entities are working at the intersection of AI and health.

- In March 2021, HHS established the **Office of the Chief Artificial Intelligence Officer**, with priorities to cultivate research collaborations and standards through a best-practice AI playbook, provide relevant guidance, and communicate new AI health innovations across industries.

- In March 2022, the **Advanced Research Projects Agency for Health** (ARPA-H) was created to accelerate biomedical and health solutions through pivotal investments in breakthrough technologies, with a $1 billion budget for FY2023. ARPA-H's 2024–2026 Strategic Plan articulates that AI will be critical in building a resilient health ecosystem and fostering data-driven innovation. The plan also emphasizes the importance of ensuring AI tools are accurate and safe as they are deployed in clinical care. As ARPA-H announces funded programs, we expect AI and computational tools to be incorporated across the research portfolio.

- The **Centers for Medicare & Medicaid Services** (CMS) is crucial when reimbursement policies for AI-driven medical tools are under consideration. HHS and CMS will continue to lead discussions on policies that must be developed and implemented within the health-care ecosystem to ensure that AI tools used for clinical care are reimbursable for providers.

Additionally, the NIH and the Food and Drug Administration (FDA), also part of HHS, have more central roles within this space.

National Institutes of Health

NIH is the primary federal agency that funds medical research through its 24 institutes and centers and has an essential role in advancing the field of computational biology. The Office of Data Science Strategy (ODSS) was formed in 2018 within the Office of the Director to plan NIH's strategy and coordinate all trans-NIH initiatives aimed at modernizing the data-resource ecosystem. Figure 5 showcases selected NIH initiatives within computational biology and AI.

> The FY2023 NIH budget included $135 million for AI/ML programs: $85 million for ODSS and $50 million for focused investments on projects that use AI/ML to better understand human diseases.

Figure 5: Selected Computational Biology and AI Initiatives at NIH

Office of Data Science Strategy	• Three funding initiatives **ranging from $80,000 to $200,000** supplemental grants will address gaps in the biomedical AI workforce, embed ethics in AI applications, and improve AI readiness for existing NIH datasets. • STRIDES (Science and Technology Research Infrastructure for Discovery, Experimentation, and Sustainability) Initiative partners with commercial cloud service providers so NIH-funded researchers can explore cloud environments at a reduced cost.	
Bridge2AI	Bridge to Artificial Intelligence Program aims to assemble cross-disciplinary teams for complex challenges, promote adoption of AI, and develop standards for best practices in ML data analysis. **The Common Fund plans to invest $130 million over four years.**	
AIM-AHEAD	AI/ML Consortium to Advance Health Equity and Researcher Diversity plans to leverage trusted partnerships to enhance participation of underrepresented communities in the development of AI/ML models. Some current partners are the University of North Texas Health Science Center, Vanderbilt University Medical Center, and Howard University.	
All of Us	All of Us aims to collect health data from 1 million US participants from different races, ethnicities, age groups, and regions of the country. **$1.5 billion budget supports data collection from 2016 to 2026.**	A **$30 million grant** for the new **Center for Linkage and Acquisition of Data** in October 2023 aims to expand the type of health data collected in the program and development of custom data analytics tools for linked data.
Multi-Omics for Health and Disease Consortium	The consortium aims to accelerate the generation and analysis of multi-omics and environmental data in ancestrally diverse populations. **Announced in September 2023** **Plans to award $50.3 million over five years**	• National Human Genome Research Institute • National Cancer Institute • National Institute of Environmental Health Sciences

Source: Milken Institute (2024)

Food and Drug Administration

The FDA is responsible for the regulatory protection of public health by assuring the safety of drugs, biological products, and medical devices. As the computational biology field rapidly evolves, it is imperative to have federal oversight of the safety and efficacy of new technology because the impact on patients can be significant. Digitalization within the health care industry has increased the incorporation of AI technologies into medical devices. FDA's Center for Devices and Radiological Health (CDRH) has cleared more than 500 medical devices utilizing AI/ML technology, the majority within radiology, others within cardiology, hematology, and neurology. In September 2020, CDRH launched the Digital Health Center of Excellence to foster partnerships to advance digital health, develop and share regulatory guidance documents, and increase awareness of digital health technology. The Artificial Intelligence/Machine Learning (AI/ML)-Based Software as a Medical Device (SaMD) Action Plan was released in 2021 to advance medical software oversight through FDA regulations. As the computational biology and AI technology ecosystem advances, the FDA is a key stakeholder in maintaining best practices in the deployment of these tools.

NATIONAL SCIENCE FOUNDATION

NSF has traditionally provided funding for developing computational tools and advancing their integration into non-medical fields—including mathematics, statistics, and engineering—by funding research focused on algorithm and software development at academic institutions. NSF is less focused on applying these tools to answer questions within the biomedical sciences. However, the organization's long-standing support of research within the fundamental computational field constitutes an essential building block for developing computational biology tools. In fiscal year 2023, NSF funded around 500 new AI projects and other AI-related initiatives, resulting in more than $800 million in funding. Key recent activities are highlighted below.

Recent Relevant National Science Foundation Initiatives	
2020	The **NSF FY2020** budget included a 70 percent increase for AI R&D research due to the National AI Initiative Act.
May 2023	$140 million investment to establish seven new National Artificial Intelligence Research Institutes to promote computational tool development. Three relevant institutes focus on: • Trustworthy AI in Law and Society • Neural and Cognitive Foundations of Artificial Intelligence • AI-Augmented Learning to Expand Education Opportunities
October 2023	NSF is tasked with launching the National Artificial Intelligence Research Resource pilot program. • Brings together federal and private-sector expertise to advance AI research and democratize access to resources

CHALLENGES RELATED TO FEDERAL GOVERNMENT FUNDING STRUCTURES

Although federal agencies have invested in the initiatives described above, they are not currently set up to *solely* power and drive the AI revolution in science and health. Data storage, computational equipment, and cloud computing are associated with significant costs; however, federal funding mechanisms cannot fully cover these expenses for tool and software development. Therefore, federal funds are insufficient to support the computing infrastructure necessary for researchers across *all* institutions to engage in computational biology research. Experts also emphasized that the NIH's current funding model does not always facilitate the interdisciplinary work needed to advance the computational biology field, and budget structures hinder effectively bringing the biology and computer science communities together. Finally, government funding cycles and the regulatory guidance development process struggle to match the rapid pace of AI innovation, which results in limited funding for the maintenance and evaluation of computational tools, thus stifling research and clinical implementation.

Universities and Health-Care Systems

Universities play an integral role in the multidisciplinary ecosystem of computational biology and are essential for conducting research that impacts the development and application of computational tools. The broad and diverse expertise within universities facilitates collaborative research that incorporates valuable approaches from computer science, biology, mathematics, and statistics. Universities are also critical stakeholders in the education and training of the computational biology workforce.

As AI technology spreads globally, universities are curating coursework and training programs that provide the most up-to-date scientific knowledge to trainees, including undergraduates, graduate students, postdoctoral fellows, and clinicians. This pivot is necessary to build the talent pool beyond computer science departments alone. For example, the College of Computing at MIT has developed courses to teach ML principles and applications with a supplemental research-based course for undergraduate and graduate students. Harvard University and Stanford University offer medical AI boot camps to train graduate students, medical students, and clinicians on the use of AI tools in medicine.

As computational tools evolve, universities around the US are building diverse programs and initiatives focused on the computational biology space. Initiatives include launching new centers and institutes focused on AI and health, developing programs to foster collaborations of researchers and data sharing between universities and institutions, and creating new interdisciplinary training programs. Funding for programs and initiatives ranges from $1 million to $1 billion, depending on the university, funding source, and scope and scale of the programs. Much of the funding to support these programs originates from individual philanthropic partnerships with specific institutions. Examples of AI-related initiatives and partnerships are listed in Table 2 of the Appendix.

Many research universities are integrated or affiliated with, or close to health-care systems, which aids the education and training of health-care professionals and facilitates accelerated knowledge-sharing to ensure that computational tools are deployed effectively and safely for clinical care. In the US, much of the top AI-related research is conducted in universities located in regionally focused hubs near medical centers. However, only some health systems currently have clinical leadership devoted to AI. High-level directors are critical to the deployment of AI tools within hospitals.

Hospitals affiliated with nearby universities and institutions have begun to establish advantageous partnerships with academic researchers for tool development, which are essential for keeping up with the AI revolution in health care.

> The Geisinger health system, based in Pennsylvania and serving more than 3 million patients, focuses on the use of AI and genetic sequencing to identify and address health gaps in the population. Geisinger was one of the earliest health systems with an AI medical director to facilitate the collaborative development of translational AI tools and a steering committee to review related ethical concerns.

Industry: Biotechnology and Pharmaceutical Companies

The biomedical industry sector, which represents biotechnology and pharmaceutical companies, is an important stakeholder group in computational biology. Companies use computational methods to accelerate R&D and address longstanding challenges in the drug-development process, such as selecting therapeutic targets and mitigating high failure rates of drugs in clinical trials. Some also use medical research, molecular engineering, and biological insights to develop products that accelerate computational analysis or support computing infrastructure. Biotech and pharma companies have implemented AI methods that are improving the sector's efficiency and have profoundly shifted business operations with shortened drug-development timelines, reduced R&D spending, and introduced new manufacturing automation, resulting in impactful improvements in treatment options.

Industry is also a significant stakeholder in the commercialization of equipment, hardware, and software, which is critical to implementing treatments that improve patient outcomes and care. In the biomedical ecosystem, industry partnerships between large and smaller pharmaceutical companies or other biotechnology companies allow each organization to leverage its technical expertise and resources for scientific innovation. Examples of projects and partnerships implementing AI-related approaches are shown in Table 3 of the Appendix.

Philanthropy

Philanthropic organizations are key stakeholders and drivers in advancing computational biology. These private funders fall into three general categories based on the type and scale of investment. Figure 6 provides snapshots of several key philanthropic stakeholders investing in computational biology. This list is not exhaustive but demonstrates the range of funding priorities for these types of philanthropic organizations.

Figure 6: Snapshot of Philanthropic Organizations and Priority Areas

	Organization Name	Foundational Biology	Translational Research	Clinical Applications
Philanthropic Organizations with Broadscale Initiatives: Early groundbreaking philanthropic investments within the computational biology field that include broadscale initiatives leading to significant shifts in the questions asked and how barriers are addressed	**Chan Zuckerberg Initiative ****	●	●	●
	Schmidt Futures **	●	●	
	Wellcome Trust **	●	●	●
Research Institutes: Philanthropist-funded institutes similar to academic universities but established and funded differently; aim to accelerate understanding of human disease using computational tools by fostering interdisciplinary collaborations and assembling researchers in a central location with focused objectives	**Allen Institute ****	●	●	
	Arc Institute	●		
	Brotman Baty Institute	●	●	
	Flatiron Institute	●		
	Salk Institute **	●		
Nonprofit Organizations and Foundations with Focused Initiatives: Organizations that have programs with focused, well-defined scopes in the computational biology field or at the intersection of computation and health	**Doris Duke Foundation**			●
	Gordon and Betty Moore Foundation	●		●

*** indicates the organization has programs focused on developing the computational biology workforce*
Source: Milken Institute (2024)

PHILANTHROPIC ORGANIZATIONS WITH BROADSCALE INITIATIVES

Organizations with broadscale initiatives support many programs across the computational biology ecosystem (see Figure 7). The investments made by the Chan Zuckerberg Initiative (CZI) and Schmidt Futures provide resources to scientists using computational tools to advance biomedical research. CZI began in 2015 with a $3 billion investment, followed by an additional $3.4 billion dedicated by the cofounders in 2021, which included a multitude of large, broadscale initiatives in computational biology. Schmidt Futures was founded to build and mobilize a network of talent to solve scientific and societal problems. To develop this network, 13 programs have been designed to gather exceptional talent globally, with a total $400 million investment. Wellcome Trust is an independent global charitable foundation that deploys philanthropic capital and is establishing efforts that bring computational tools directly into clinical settings. However, even within larger initiatives, there is limited funding from these philanthropic organizations for the translational and clinical parts of the medical ecosystem.

Figure 7: Selected Programs from Philanthropic Organizations with Broadscale Initiatives

Chan Zuckerberg Initiative	Schmidt Futures	Wellcome
	INFRASTRUCTURE SUPPORT	
Essential Open Source Software for Science Program provides up to $400,000 over two years to develop, maintain, and expand software essential to biomedical research. CZI initiated the development of the largest high-performance computing system comprising 1,000+ GPUs dedicated to nonprofit life science research using LLMs to model openly available human cell systems.	**Future House** is a newly funded moonshot initiative to accelerate the pace of discovery with nonhuman AI "scientists" that can reason scientifically without human intervention. The hope is that within 10 years, the AI scientists will enable human scientists to perform 100 times more experiments and democratize access and analysis.	**OpenSAFELY** is a secure software platform with more than 58 million EHRs, which was influential during the COVID-19 pandemic and was created from a grant initiative to develop open-source software tools.
	BROAD INITIATIVES	
In 2021, the **Kempner Institute** launched with a $500 million gift from CZI to Harvard University. The mission is to train future generations of researchers to advance the fundamental development of generative AI systems, including artificial neural networks.	**Eric and Wendy Schmidt Center** was established at the Broad Institute with a $300 million endowment gift to create a collaborative ecosystem for foundational biology and ML discoveries through academia and industry partnerships.	**Wellcome Leap** was initially funded in 2020 with $300 million to launch unconventional programs to achieve breakthrough scientific and technological solutions within 5 to 10 years. Another $335 million investment in 2022 will help support early-stage, high-risk ideas.
	WORKFORCE SUPPORT	
Investigator Program at CZ Biohub San Francisco awards a cohort of scientists $1 million in unrestricted funds over five years. **Physician-Scientist Fellowship** focuses on providing clinicians with research experience in computational biology.	$148 million developed the **Eric and Wendy Schmidt AI in Science Postdoctoral Fellowship**, which has an annual cohort of 20 fellows for up to six years and provides advanced AI training, research support, and professional development. **AI2050** program supports fellows with advanced research projects that are hard to fund through traditional funding sources.	**Wellcome Genome Campus** provides training and resources in genomics and bioinformatics for scientists and clinicians.

Source: Milken Institute (2024)

RESEARCH INSTITUTES

Within the five research institutes listed in Table 1, much of the focus is on the use and advancement of computational tools within foundational biology research. Current funding trends again underscore the need for additional efforts for translational research within the field to promote the integration of AI tools into clinical care.

Table 1: Selected Programs from Research Institutes

Research Institute	Programs and Initiatives
Allen Institute	• Prioritizes the importance of foundational biology in understanding disease mechanisms that lead to treatment development • Launched Allen Institute for AI in 2014 for fundamental AI research • Received $750,000 from the Bill & Melinda Gates Foundation in October 2023 to lead a program aimed at increasing the public understanding of AI • Launched Seattle Hub for Synthetic Biology, a new initiative linking the Allen Institute, CZI, and the University of Washington, which will focus on developing technologies that improve understanding of cellular and molecular changes over time
Arc Institute	• Launched in late 2021 with an initial investment of $650 million • Accelerates scientific progress, understands the root causes of disease, and narrows the gap between discoveries and their impact on patients by integrating key biotechnologies (multi-omics, genome engineering, cellular models, mammalian models, and computation)
Brotman Baty Institute	• Started with a $50 million gift; has worked in foundational biology to develop single-cell atlases • Facilitates translational projects in collaboration with the University of Washington, the Fred Hutchinson Cancer Research Center, and Seattle Children's Hospital
Flatiron Institute	• Established in 2016 as the internal scientific research division of the Simons Foundation • Focuses on computational astrophysics, computational biology, computational mathematics, computational neuroscience, and computational quantum physics • Within computational biology, develops innovative frameworks for examining data within the areas of biomolecular design, biophysical modeling, developmental dynamics, and genomics sciences
Salk Institute	• Expanded its major research areas to include a Computational Biology Division to develop mathematical and analytical frameworks that uncover new connections in biological systems • Launched the Collaboration Grant Program in 2019 to encourage efforts among Salk scientists after the success of the Innovative Grant Program, which offered preliminary funding for out-of-the-box ideas

Source: Milken Institute (2024)

NONPROFIT ORGANIZATIONS AND FOUNDATIONS WITH FOCUSED INITIATIVES

Philanthropic organizations with more focused initiatives in AI and health include the Doris Duke Foundation (DDF) and the Gordon and Betty Moore Foundation. Both foundations are in the early stages of developing funding programs around deploying AI tools in clinical settings. Additional philanthropic efforts focused on effectively integrating AI tools into patient care are needed.

- **June 2023:** DDF launched a $10 million grant to address racial biases in clinical algorithms. Five organizations—the American Academy of Pediatrics, the American Heart Association, the American Society of Hematology, the National Academies of Sciences, Engineering, and Medicine, and the Coalition to End Racism in Clinical Algorithms—will receive grant funding ranging from $1.2 million to $3.4 million to identify, update, and provide guidelines on medical algorithms that use race.

- **February 2022:** The Moore Foundation released the *Unlocking New Opportunities for AI-enabled Diagnosis* report, highlighting deficits in current AI tools and suggesting ways to develop tools for better diagnosis. Three resulting initiatives are (1) a grant program, AIM-HI, in partnership with Kaiser Permanente, to evaluate AI implementation in approving diagnostic decision-making for three to five US health-care systems; (2) Health AI Partnership to standardize best practices in AI software development and distribute guidance in open-source curriculums; and (3) a $1.25 million award to Vanderbilt University Medical Center and Duke University School of Medicine for the Measuring Artificial Intelligence (AI) Maturity in Healthcare Organization project, an initiative focused on improving the oversight of AI technology in health-care systems.

Cross-Sectoral Partnerships and Collaborations

Cross-sectoral partnerships and collaborations among key stakeholders are indispensable, as discussions around government regulations and standardized guidelines for AI deployment in health care will continue to require expertise and knowledge from all groups. Recognizing this need, some organizations are stepping forward to fill the void. For example, the American Association for the Advancement of Science (AAAS) launched an artificial intelligence fellowship program in 2023 to support Congress in drafting policies and legislation on these challenging topics. In addition, the National Academy of Medicine is developing a guiding framework with a consensus code of conduct for leaders using AI in health to ensure algorithms incorporate FAIR (findable, accessible, interoperable, reusable) principles.

Various nonprofit organizations are also focusing on bringing together experts and decision-makers. For example, The Alliance for Artificial Intelligence in Healthcare is a global advocacy organization with a wide range of stakeholders dedicated to realizing the potential for AI/ML, which advocates for appropriate regulatory principles for developing and deploying AI in health. The Coalition for Health AI is another organization bringing together universities, academic health systems, technology companies, and government entities to create guidelines for the responsible deployment of AI tools in patient care. These types of collaborative partnerships will continue to form and evolve as the technology advances. Convenings such as the National Academies AI for Scientific Discovery Workshop or the UK AI Safety Summit are essential in bringing together multistakeholder groups to foster consensus and standardization through coordinated global action.

> Our findings show that most philanthropic support currently focuses on investing in the use of computational tools—either within the foundational biology space to improve the understanding of biological systems or within targeted disease contexts. These funding initiatives are important and will accelerate discovery. However, there is a gap in funding from federal and philanthropic efforts focused on translational research and clinical applications for emerging computational tools. **Philanthropy has a significant opportunity, therefore, to provide unique support to drive the field forward—especially to facilitate the integration of tools at the point of care.**

CROSS-CUTTING OPPORTUNITIES FOR PHILANTHROPIC SUPPORT

The scientific community continues to make unprecedented advancements in computational biology, but traditional public funding mechanisms are not meeting all the needs of the field. The unparalleled growth of AI technology has broad-reaching implications that inevitably bring challenges cutting across foundational, translational, and clinical research. Key challenges fall into four major categories, as summarized in Figure 8.

The pursuit of transformative solutions can be facilitated by philanthropic support for initiatives that bring together interdisciplinary teams, foster collaborations across sectors, and accelerate the deployment of computational tools for clinical care. **The Milken Institute SPARC has identified four opportunities where philanthropic investment is uniquely poised to support work that accelerates the integration of computational tools into research and care to impact health.** As Figure 8 shows, most of the opportunities are focused on advancing translational research and facilitating the clinical application of computational tools—areas where funding gaps exist.

Figure 8: Cross-Cutting Opportunities for Philanthropic Funding to Address Critical Challenges

Utilization of Computational Tools to Understand Foundational Biology → *Translational Research within Computational Biology* → *Clinical Application of Computational Tools*

OPPORTUNITY 1: Improve and Expand Large-Scale Open Data Initiatives and Infrastructure

Challenge 1: Difficult to develop and access high-quality data that are complete and annotated for effective computational research and analysis

- Need high-quality data that are complete, annotated, and interoperable
- Scale of data needed for computational analysis
- Access to health systems and clinical data

OPPORTUNITY 2: Support the Development and Training of the Necessary Interdisciplinary Workforce

Challenge 2: Need more expansive initiatives to ensure the interdisciplinary workforce is supported within the computational biology field

- Lack of programs focused on the early stages of the educational pipeline
- Need long-term investments to train interdisciplinary teams
- Retain computational experts within academic research institutions and health-care systems
- Support health-care workforce to utilize computational tools

OPPORTUNITY 3: Integrate Computational Tools into Research and Care through Pilot Studies and Expanded Infrastructure Access

Challenge 3: Limited financial support exists for the computing infrastructure needed to maintain rapid innovation and development of computational tools

- More support for computing costs and expenses for tool and software development
- Costs related to sharing and deploying trained models for usage by others

OPPORTUNITY 4: Expand the Implementation of Computational Tools for Clinical Application

Challenge 4: Lack of systemic efforts focused on facilitating the safe implementation and deployment of computational tools to improve clinical care

- Reducing bias in AI tools and enhanced transparency of tool development
- Increased rigor for evaluation, validation, and deployment of models
- Regulation and governance of medical AI

Source: Milken Institute (2024)

PHILANTHROPIC OPPORTUNITY 1: IMPROVE AND EXPAND LARGE-SCALE OPEN DATA INITIATIVES AND INFRASTRUCTURE

Computational models must be trained and validated on well-annotated datasets that are complete and accessible. However, faced with more than 10,000 known diseases and thousands of independent health and research institutions, it is difficult to create interoperable datasets that combine, merge, and standardize diverse data from multiple sources. Philanthropy, a nimble and risk-tolerant asset, is well suited to invest in creating and enhancing large-scale open data initiatives and complementary infrastructure. Addressing barriers to data standardization, annotation, interoperability, and access would unlock the potential to use a wide range of well-trained computational tools. Philanthropy can catalyze long-term solutions to this challenge, which will require effort, collaboration, and coordination across many stakeholders, and includes the two approaches outlined below.

Drive collaboratives to develop and enhance multimodal data platforms: Researchers and clinicians need accurately integrated multimodal datasets for mining and analysis to capture a more complete and holistic view of an individual's health. Collaborative funding models that support institutions and health systems looking to enhance and scale up existing multimodal data platforms would be advantageous in developing needed datasets.

Funding mechanisms could also encourage merging multimodal data across institutions and facilitate the integration of newly generated data. This would contribute to acquiring the scale of data needed for the training and validation of computational models. Philanthropy can also provide seed funding to institutions and health systems poised to develop new open data platforms to ensure that computational tools are well trained on diverse research and clinical datasets.

Fund the development of disease registries and platforms: Many philanthropic efforts focus on a particular disease. These organizations can direct funding toward developing disease-specific registries and multimodal data platforms, similar to what the Alzheimer's Disease Data Initiative has done. Funding efforts that build free, open-access data platforms could make data collection more efficient by engaging all stakeholders—including patients—which would enhance the ability to use computational tools. Platforms could also include collaborative workspaces to share relevant AI models and—to reduce duplicative efforts—documentation of failed models.

Additionally, researchers studying rare diseases often struggle to reach the sample size needed for statistically powerful analysis. Philanthropic efforts are poised to facilitate the aggregation of data from related rare diseases. This would create a shared dataset that improved the required statistical scale for computational analysis, leading to the discovery of novel insights for some rare diseases.

PHILANTHROPIC OPPORTUNITY 2: SUPPORT THE DEVELOPMENT AND TRAINING OF THE NECESSARY INTERDISCIPLINARY WORKFORCE

The use of computational tools in research and patient care requires an intersectional perspective and expertise. Interdisciplinary teams that combine knowledge—such as from computer scientists, statisticians, bioinformaticians, clinicians, basic scientists, engineers, mathematicians, and bioethicists—are crucial to facilitating the implementation of computational tools in research and care.

To ensure the presence of a robust computational biology workforce in the future, computer science and biomedical research training must start earlier in the educational pipeline. A few such training programs currently exist, but the scale of growth in the sector and the potential for its application to accelerate research demands targeted efforts throughout the pipeline. Prioritizing the inclusion of varied perspectives while developing computational tools is also critical to deploying such technologies equitably for the benefit of all. Philanthropy has a significant role in building and retaining an interdisciplinary workforce that reflects the global population. We recommend the following three specific approaches.

Increase investments in individuals in the *early stages* of the education pipeline to build a diverse and inclusive workforce for the future: There is a clear gap in education and training of computational biology principles in the early stages of the education pipeline, especially for students from underrepresented groups and certain geographic areas. New funding can drive the creation of programs that train students in high school, community colleges, and undergraduate institutions, including a wide range of institutions such as historically Black colleges and universities and minority-serving institutions. These investments will create more paths for students nationwide—including more women and individuals from underrepresented groups—to enter this intersectional field.

Additionally, no postbaccalaureate programs focused on computational biology currently exist. Postbaccalaureate programs are a well-tested model in other areas of STEM workforce development to help recent college graduates be competitive for further professional training. Philanthropic organizations can begin to fill this gap by partnering with prominent research institutions to pilot postbaccalaureate programs that provide opportunities to conduct research in computational biology for one or two years. More efforts that expose individuals to this interdisciplinary field from an earlier stage will benefit the larger computational biology workforce, priming scientists and clinicians against future needs.

Create hubs of young talent in computational biology at research institutions and ensure that their expertise and knowledge are integrated across the biomedical research and clinical-care ecosystem: Setting up hubs and cohorts that connect early-career individuals in computer science, bioinformatics, and biomedical research (fields that are often spread out and dispersed) will bring together communities and provide mentorship to excel. Initiatives focusing on expanding graduate programs and postdoctoral fellowships at the intersection of computational tools and biomedical research would help build sustainable, nationwide cohorts of computational biology experts. Some universities have implemented a variety of training initiatives, such as the newly established Computational Precision Health PhD Program at the University of California (UC) Berkeley and UC San Francisco and the PhD track of the Harvard AI in Medicine Program.

However, more intentional, sustained training programs should be created to develop a common language that facilitates alignment across interdisciplinary teams. High-priority directions include expanding successful programs to more institutions so that talented students are supported across diverse geographies, as well as piloting new programs: for instance, an MD-PhD program explicitly focused on AI in health so that medical doctors also become experts in computational biology who can safely deploy these technologies in clinical care.

Retaining computational experts within academic research institutions and health-care systems is challenging, as professional-level data scientists, computer engineers, and computer scientists with skills applicable to multiple industries are in high demand. Philanthropic organizations can use innovative funding mechanisms to support academic computer scientists, bioinformaticians, and other computational experts looking to transition into research focused on the biomedical sciences. These initiatives could provide supplemental salaries that fill part of the pay gap between academia and other sectors and offer co-learning, mentorship, or training opportunities with biomedical scientists to foster the next generation of leaders in this rapidly advancing field. Since the demand for individuals with computational expertise will continue to rise as AI is interwoven into many industries, philanthropic investments must be made at research institutions nationwide to create hubs of young talent across the country. This wide-reaching investment will help expand the capacity and infrastructure of more institutions and increase the numbers and the diversity of the computational biology workforce, leading to the goal of more equitable innovations.

Build programs and partnerships that provide computational support for researchers and the health-care workforce to advance the implementation of computational tools for improving care: Universities and health systems are struggling to hire computer scientists and bioinformaticians because they cannot compete with technology companies' salaries for talent. Multiple experts emphasized that biomedical researchers could work with computational experts for specific projects rather than in permanent roles to advance research aims. Hospitals would also benefit from ad-hoc access to computational support for clinical data annotation and analysis. An emerging concept is to build programs that allow research institutions and hospitals access to computational experts for a limited amount of time, making these types of services accessible and affordable for a wide range of organizations.

Additionally, clinicians need more training and support to determine how AI tools should be deployed to improve care. Countries and regions with limited health-care personnel could benefit significantly from resources focused on how to use AI to triage patients, provide the first level of diagnosis, and help with disease surveillance and prevention. Philanthropy can develop and sustain educational initiatives that teach clinicians and others in the health-care workforce how to test and deploy AI tools at the point of care. Experts worldwide are actively considering ways to incorporate AI in their health-care ecosystems. Philanthropy can drive crucial collaborations for implementing and deploying AI tools both in the US and elsewhere.

PHILANTHROPIC OPPORTUNITY 3: INTEGRATE COMPUTATIONAL TOOLS INTO RESEARCH AND CARE THROUGH PILOT STUDIES AND EXPANDED INFRASTRUCTURE ACCESS

Philanthropy can catalyze the discovery of innovative computational tools to attract funding from other sources. Computational biology research is expensive, and there are limited public and private funding mechanisms to cover the costs related to computing infrastructure, technology, and personnel. Therefore, researchers often must prioritize the use of discretionary funding for operational expenses (computing time and infrastructure) rather than bringing on new talent or supporting the time a young scientist needs to work on a new idea. Philanthropy currently represents an important funding source for both computing costs and investing in high-risk pilot projects to ensure that computational models are continuously developed, maintained, and improved. We see two distinct opportunities for further philanthropic investment.

Create funding programs that provide computing costs and support long-term investment for software development and maintenance: Philanthropic organizations can take a variety of funding approaches to supplement the costs associated with computing, cloud storage, and software development and maintenance at academic research institutions. Programs, particularly those with connections to existing datasets, can facilitate the fair allocation of resources by providing subsidized cloud computing credits or a subscription policy for renting cloud hardware and servers. Experts across the field emphasized the need for additional funding avenues to support computing costs. Determining the best way to tackle these challenges, such as in partnerships with large data companies, will be crucial. Further, once a model is trained, sharing and deploying the model for use by other researchers is costly.

Failure to invest in infrastructure inhibits the use of many computational tools by researchers and clinicians, even though tool creation is prolific. AI tools require large online databases and software packages, which can be generated with short-term funding, but a 10+ year investment is needed to maintain centralized sites. Philanthropy is uniquely suited to test different funding approaches to see what is having the most significant impact on researchers and then collaborate on scaling solutions across institutions and health systems.

Support scientists globally and catalyze high-risk pilot studies focused on developing computational prototypes to drive translational impact: Traditional funding mechanisms are not currently set up to support high-risk initiatives that lack preliminary data, where significant computing funding is needed to drive innovation. A philanthropy-funded program available to the global scientific community can attract innovative ideas focused on the translational impact of computational tools. Such initiatives could focus on high-risk pilot studies to create prototypes of computational tools with more direct clinical impact, which can vary across countries and regions.

Philanthropy is also poised to sponsor computational-focused competitions that rely on a common task framework to drive translational impact. Competitions like these can help researchers in the field rally around a needed tool. On completion, the clearly defined tool must be available through open access. Competitions have been used in the AI space to reduce duplicative efforts. Philanthropic support can foster collaborative development of tools with translational impact.

PHILANTHROPIC OPPORTUNITY 4: EXPAND THE IMPLEMENTATION OF COMPUTATIONAL TOOLS FOR CLINICAL APPLICATION

Our analysis clearly revealed a gap in current public and private funding to facilitate the implementation of computational tools in clinical care. As AI assumes prominence in biomedical research and medicine, efforts that support evaluation, explain the potential benefits of AI in health care, expand diverse global datasets, and set standards for AI use could trigger a paradigm shift, allowing the community to build and deploy better models. Philanthropic organizations looking to engage in the AI and health ecosystem can make a sustained commitment to address these needs and work collaboratively with other stakeholders (health systems, policymakers, regulators, and others) to propel new computational technologies into clinical practice. We recommend investing in the three following areas.

Support validation and evaluation studies of AI models to safely expand the implementation of computational tools in clinical settings: Funding prospective trials to validate AI models is critical, since results from these studies affect how clinicians learn, train, and deploy the models. This area has had little philanthropic support and even less federal funding. A lack of evaluation studies, and insufficient transparency of the AI tool development process, training populations, and diagnostic capabilities, make clinicians apprehensive about using computational tools. Therefore, experts emphasized that more funding is needed, and philanthropy can catalyze this critical work by backing projects that evaluate whether and how AI technologies should be implemented in patient care.

Additionally, priority should be placed on studies that address bias concerns from the beginning of model creation, show reproducibility, and develop equitable algorithms that can be applied to different demographics, environments, populations, and communities. Dedicated funding programs could also encourage the combination of global datasets with samples from individuals representing multiple racial, ethnic, and regional backgrounds to increase opportunities for discovery.

Support operational research at hospitals to showcase the benefits of using AI tools in health care: Because many federally funded projects within the computational biology field are technical research studies, researchers often do not understand the process of deploying computational tools in clinical settings. For example, many hospitals allocate only about 5 percent of their total budget for IT support; thus, providing value for integrating computational tools is critical. Experts expressed a desire for philanthropic organizations to partner with hospitals and health-care systems to fund operational research studies on the effectiveness of AI tool deployment to help identify needed systemic improvements. In the future, as more health systems implement AI tools, funders could collaborate to scale up solutions and help enact widespread change in hospitals across the US.

Build initiatives that bridge health systems to set standards and guidelines for testing and deploying computational models for patient care: It is essential that models developed in one clinical environment with a particular dataset can be tested and evaluated with other datasets to assess reliability and reproducibility. For example, in November 2022, Wellcome partnered with the MIT Jameel Clinic to launch the AI Hospital Network in implementing AI tools at 35 hospitals across eight countries. Additional philanthropic capital can catalyze these types of collaborative programs that build partnerships among multiple academic institutions and hospital systems within a specific region or in different locations. This bridging of health systems will create more cross-institutional data-sharing and increase researchers' and clinicians' access to larger clinical datasets.

Philanthropy can also foster convenings to unite interdisciplinary communities in developing fieldwide standards and best practices as AI tools are incorporated into clinical care. Further, philanthropic organizations can assume a key role in advocating for federal policies that allow these tools to be regulated reasonably for safety and bias, setting guidelines to ensure models are ready for deployment, and promoting equitable access and affordability of AI tools for all populations.

CONCLUSION

AI and its potential in the health ecosystem have captured public attention. The computational biology field is advancing rapidly, and tools such as AI and ML can transform the understanding of biological mechanisms and improve patient care. Computational tools can be incorporated in most disease and research areas. As the technology evolves, key stakeholders—academic institutions, health systems, industry, government bodies—are making financial investments at various scales to enable even more widespread adoption of the tools by scientists and clinicians. Leaders within these organizations have integral roles in paving the way for the AI-in-health revolution.

Many cross-collaborations are being formed, signaling that decision-makers understand we are at an inflection point for the promise and potential use of computational tools like AI. While many federal funders and some philanthropic organizations are currently focused on using these tools to understand disease mechanisms—and industry is investing more in profit-driving technologies—**philanthropy can improve people's lives by fulfilling a crucial role in addressing key challenges to the deployment of computational tools in clinical settings**.

Philanthropic capital can be strategically and nimbly deployed to areas identified in this report, catalyzing innovation across the medical ecosystem and overcoming hindrances to progress. By acting on one or several opportunities identified, philanthropists can drive large-scale initiatives and collaborations, providing infrastructure support to enact changes throughout the biomedical and health ecosystem. The AI-in-health revolution requires key stakeholders to be engaged and thoughtful. Philanthropy is central to ensuring that equitable solutions reach the global population and improve health outcomes for all. Strong partnerships and collaborations will help grow the computational biology field, leading to transformative discoveries that will make it possible for people around the world to live healthier lives.

APPENDIX:

SNAPSHOT OF ADDITIONAL US GOVERNMENT INITIATIVES, UNIVERSITY PROGRAMS, AND PHARMACEUTICAL PARTNERSHIPS

The following sections provide additional information about stakeholders across the computational biology field, expanding on the information presented earlier in this Giving Smarter Guide.

US Government Policies for AI Usage in Health Care

As an early developer and international leader in AI, the US has a crucial role in creating a multipronged strategy to drive the advancement and adoption of AI. Over recent years, the US government has instituted a number of legislative initiatives and programs across federal agencies to strengthen AI development over sectors, including biomedical research and health care (see Figure 9).

Figure 9: Timeline of US Federal Directives and Legislations for AI

2018

White House Summit on Artificial Intelligence for American Industry
- The first effort to discuss the potential of AI across industries and related policies with more than 100 experts representing a broad swath of stakeholders

2019

Maintaining American Leadership in Artificial Intelligence (Executive Order)
- Goal: Increase investment in AI R&D, establish national AI research institutes, and provide regulatory guidance

2020

National AI Initiative Act
- Goal: Strengthen the US AI research infrastructure, train the workforce, and advance AI trustworthiness
- Directed the creation of the National Artificial Intelligence Initiative Office (NAIIO) and the National Artificial Intelligence Research Resource (NAIRR) Task Force

2021

Launch of NAIIO within the Office of Science and Technology Policy (OSTP)
- A central hub for federal activities and AI efforts (more than 20 federal agencies coordinate AI programs)

2022

Blueprint for an AI Bill of Rights
- OSTP released this to guide the development and deployment of AI for the US public's protection
- Developing effective automated systems that are safe with clear descriptions, data privacy, protection against algorithm discrimination, and quick human alternatives to remedy solutions

2023

January 2023—NAIRR Task Force Report
- Outlined the roadmap and implementation plan for building NAIRR to establish a secure and integrated platform that enables large-scale AI analysis from existing federal government data, including health-care data

February 2023—Further Advancing Racial Equity and Support for Underserved Communities Through the Federal Government (Executive Order)
- Guidelines for federal agencies to help eliminate bias in the design and use of AI technology

May 2023
- President's Council of Advisors on Science and Technology (PCAST) launched a working group on generative AI to evaluate risks and opportunities of the deployment of this rapidly advancing technology across sectors
- OSTP updated the National AI R&D Strategic Plan to define the guided R&D investment plan further

October 2023—Safe, Secure, and Trustworthy Artificial Intelligence (Executive Order)
- Established new standards for AI governance to protect Americans from the potential risk of AI usage across all industries, including the health-care space

Source: Milken Institute (2024)

Initiatives and Partnerships Established at Universities

The universities mentioned in the Appendix Table 2 are selected examples of recent initiatives and partnerships to connect the computational ecosystem with biomedical research and clinical care. These examples constitute a representative list of the types of efforts in development across universities focused on advancing computational biology and AI in health.

Table 2: AI-in-Health Initiatives at Universities

University	Computational Biology and AI Initiatives
Columbia University	• A $20 million grant from NSF was awarded to Columbia in the summer of 2023 to lead an interdisciplinary AI Institute for Artificial and Natural Intelligence Center, which will collaborate with nine academic institutions and seven industry partners to connect neuroscience and AI research.
Duke University	• Duke AI Health is a multidisciplinary, campus-spanning initiative to amplify theoretical and applied AI research that addresses challenges in medicine and population health. • Health Data Science Program unifies multiple initiatives to offer experiential education with projects focused on ML in health care, a learning experience seminar series, and workshops. • Algorithm-Based Clinical Decision Support Oversight is a framework that evaluates clinical algorithms with monitoring checkpoints throughout the development and deployment cycle.
Emory University	• The AI Humanity Initiative, launched in 2022, is Emory's five-year plan to hire AI-related research faculty, create AI-focused educational programs, foster cross-disciplinary collaborations, and develop standards for the ethical use of AI. • Empathetic AI Health Institute plans to harness supercomputers to develop/deploy AI-enabled predictive analytics that are accessible and equitable tools for all populations.
Harvard University	• The Harvard Data Science Initiative, launched in 2017, supports postdoctoral fellows, an open-access science platform, and research on data science methodology, personalized health, and evidence-based policies. • The AI in Medicine Program (AIM) brings investigators from affiliated hospitals to focus on AI development, research, and clinical trial translation.
Johns Hopkins University	• In 2023, a new Data Science and Translation Institute was announced to focus on the application, collection, and risk of ML while bringing together 80 new affiliated faculty and 30 new distinguished professors. • AI-X-Foundry is a university-based organization that combines all disciplines using AI applications for intentional collaborations among the related centers and institutes. • The Malone Center facilitates translational innovation for improved diagnosis and treatments that leverage novel data analytics with cross-disciplinary clinician-engineer teams. One research collaboration focuses on clinical imaging domains with the Radiology AI Lab, which aims to improve imaging processing and analysis.
Massachusetts Institute of Technology (MIT)	• The MIT-Takeda Program, started in 2020, aims to leverage expertise in the academic and industry sectors with annual funding for six to ten research projects at the intersection of ML and health, 11 annual fellowships, and AI educational programs for Takeda employees. • The MIT-Novo Nordisk Program aims to support 10 postdoctoral fellows for two-year terms on research projects focused on the intersection of AI and the life sciences. • In 2020, the Electrical Engineering and Computer Science Department was restructured to include Electrical Engineering, Computer Science, and Artificial Intelligence units. One goal of AI for health-care and life-science research is to develop AI technology that spans discoveries in biological mechanisms, disease diagnostics, and care personalization. • The Laboratory for Computer Science and the Artificial Intelligence Laboratory form CSAIL with the mission to develop fundamental technology and conduct research in the computing field.

University	Computational Biology and AI Initiatives
Mayo Clinic	• A partnership with Google Cloud gives medical clinicians and researchers access to the Generative AI App Builder to increase search experience capabilities by synthesizing information across many sources, as reported in Forbes. • Mayo Clinic has been testing Google's Med-PaLM-2 AI chatbot, which can answer health-related questions and perform labor-intensive tasks like summarizing reports or organizing data for the hospital, according to *Healthcare Dive*. • A $750,000 grant from NSF was awarded to establish the **Center for Computational Biotechnology** and Genomic Medicine with the University of Illinois at Urbana-Champaign to generate computational tools for genomic/genetic data analysis and ML models. • The **Division of Computational Biology** develops and maintains analytical/bioinformatic methods with collaborations through the Center for Individualized Medicine and the Comprehensive Cancer Center. • The **Department of Artificial Intelligence and Informatics** promotes the adoption of AI technology, the advancement of infrastructure in digital medicine, the unification of multidisciplinary faculty, and increased partnerships across the industry sector.
Stanford University	• In 2019, the **Institute for Human-Centered Artificial Intelligence** was launched as a university-wide institute that brings together research faculty focusing on AI from multiple departments to develop new technologies and guide societal and legislative impact.
UC Berkeley & UCSF	• In the fall of 2021, philanthropic support helped launch the **Computational Precision Health** PhD program. This included recruiting four newly endowed faculty and incorporating a novel bi-campus structure.
University of Florida (UF)	• In 2022, the **Artificial Intelligence Academic Initiative Center** was created to centralize university efforts to develop and coordinate AI academic programs and professional pathways. • A $3.6 million grant was awarded through the NIH Bridge2AI program for a four-year data generation project that supports the development of a comprehensive repository with data from critically ill patients in the UF Health intensive care unit, standards for AI ethical use in critical care, workforce training events, and guidelines for collaborative medical AI research. • A $70 million initiative between UF and NVIDIA aims to boost the capabilities of the university-owned supercomputers, establish the Equitable AI program, collaborate with the NVIDIA Deep Learning Institute to develop a new curriculum, and house the NVIDIA AI technology center.
University of Southern California	• A $1 billion investment into the **Frontiers of Computing Initiative** focuses on computing research in AI, ML, and data science. The multipronged goal encompasses creating a new School of Advanced Computing and hiring 30 computer science faculty who integrate computing and AI into the university. • A new $10 million **Center for Generative AI and Society**, announced in early 2023, aims to convene experts, prepare students for the workforce, and guide the ethical use of generative AI.
University of Texas Health Houston	• In April 2023, D. Bradley McWilliams made a $22 million commitment to the **School of Biomedical Informatics** to support faculty and students in developing diagnostic technology through data science, AI, and ML. • Biomedical informatics faculty were awarded 14 grants from the NIH and NSF for more than $31 million with projects aimed at innovation in health-care AI related to Alzheimer's disease, harmonization of EHR, neuroimage benchmarks, integration of genomic data, personalized immunotherapy, and training methods for clinical models.
University of Washington (UW)	• At the beginning of 2023, the School of Medicine, College of Engineering, and School of Public Health announced the **Institute for Medical Data Science**, supported by a $750,000 funding pool for five UW projects related to AI, ML, and health care. • A $12 million grant from the NSF has allowed UW to lead a partnership with the University of Wisconsin-Madison, the University of California Santa Cruz, and the University of Chicago teams to develop new approaches for incomplete/ambiguous datasets and the ethical implications of data-driven algorithms.
Washington University in St. Louis	• **AI for Health Institute** was launched in October 2023 to bring together AI and health researchers for interdisciplinary approaches that tackle complex health problems. The organizational infrastructure development aims to leverage FAIR principles, wearable data, imaging data, and NLP to improve health-care delivery and health-service research.

Source: Milken Institute (2024)

Pharmaceutical Projects and Partnerships That Use AI Approaches

The selected examples in Table 3 highlight projects and partnerships incorporating computational biology technology to improve business productivity and deployment of new drug treatments.

Table 3: Examples of Projects and Partnerships

Company	Projects	Partnerships
AstraZeneca	• **Oncology:** In drug development, the data science team uses AI tools to review multi-omics, clinical, and imaging data from more than 100,000 patients to generate novel hypotheses. ML algorithms guide the design of clinical trials and the selection of drug targets and aid the cycle of prediction validation.	• **Oncoshot**'s *InSite Feasibility* platform is an AI-enabled patient-to-clinical trial matching technology. Use of the platform helped to streamline the recruitment process and deidentify data from Singapore's cancer population into precise research analytics.
Genentech	• **Infectious Disease**: Scientists use AI/ML in developing new antibiotics by examining the chemical structure of billions of potential antibiotics to determine which can bypass the pathogen's membrane.	• **Recursion Pharmaceuticals**, in collaboration with Genentech and Roche, leverages the drug discovery platform with single-cell data to expedite the development of small-molecule medicines in neuroscience and oncology. • **NVIDIA** established a multiyear strategic research partnership to couple extensive datasets with accelerated computing capabilities to speed up drug development with generative AI models and next-generation AI platforms.
Janssen	• **Drug Discovery**: The Biosignature platform creates cell-imaging datasets from the profiles of small molecules. ML algorithms then refine the drug-design approach by integrating information from desired and undesired biological interactions to develop generative models based on the optimal compound design.	• **Institut Pasteur and Greater Paris University Hospitals**: This collaboration aims to use AI to understand chronic inflammatory disease by harnessing innovative genomics techniques to analyze patient samples and phenotypic data.
Novartis	• **Drug Design**: ML techniques scan billions of compounds in small molecule libraries to select desired target profiles and optimize compound suggestion in drug discovery. • **Pharmacovigilance**: The Adverse Event Brain system uses ML and NLP to optimize the supply chain and detect a potential mention of adverse events on social media posts, according to Deloitte.	• **Tencent**: This collaboration led to the development of the AI nurse app, a disease management tool that leverages speech-to-text, predicts disease progression, recommends treatments, and allows interaction with health-care providers. • **Microsoft**: Partnered to develop an AI-powered diagnostic tool that aids in detecting leprosy through the AI for Health Initiative. The AI Innovation Lab is another goal of the collaboration to optimize the re-engineering of cells and personalize dosing guidance and treatment plans.

Company	Projects	Partnerships
Pfizer	• Rare Disease Research: The development of a novel prediction model uses ML techniques to identify rare cardiomyopathy that results in heart failure, using medical claims and EHR data with 87 percent accuracy.	• CytoReason: Created biological models to enhance understanding of the human immune system. The $110 million funding over five years will be used for the continued license of the AI platform, which has provided insights into the immune drug development process for additional disease models. • IBM Watson: Partnered to use ML algorithms, supercomputers, and cloud-based tools to identify new immune-oncology drug targets. • Tempus: Collaborating to access the AI-enabled platform with multimodal data for developing oncology therapeutics and clinical trial matching programs. • XtalPi: This collaboration aids in using computer modeling techniques for crystal structure predictions by applying quantum physics to complex calculations; a four-month task now takes a couple of days.
Roche	• AI with Roche (AIR) Hub was created to foster the AI community by leading research at the forefront, facilitating partnerships, mobilizing AI into practice, and maintaining safety and privacy for all stakeholders. • Precision Oncology Screening Platform Enabling Clinical Trials (PrOSPECT) aims to improve access to clinical trials for Australians diagnosed with cancer with more efficient screening after comprehensive genomic profiling. • EndALS Challenge is an open data competition where data scientists use 150 datasets from ALS patients to generate models that provide solutions to research questions related to the overall biology of ALS. • Synthetic Data Bootcamp trains researchers on computational approaches and benchmark requirements for generative model development during a three-day experience. • Xcelerate Rare is an open science data challenge with Global Genes for researchers to use patient-provided data to address three tasks related to identifying underrecognized symptoms, predicting diagnoses based on symptoms, and expanding/refusing one or more therapeutic hypotheses within the rare pediatric neurodevelopment disease space.	• Roche Data Science Coalition is a group of public and private organizations working to solve the COVID-19 pandemic and tackle other challenges. • The COVID Long Hauler Project by the coalition also leverages NLP methodologies with unstructured X (formerly Twitter) data to get clinical insight on early signals of symptoms, as reported in *Multimodal AI in Healthcare. Studies in Computational Intelligence.*

Company	Projects	Partnerships
Sanofi	• **Platform Development**: In 2018, a companywide AI platform, called the "plai" app, aggregated reactive data interactions and all the company's internal data to support decision-making across the drug development process and clinical trial execution. • **Vaccine Research**: R&D teams use AI to accelerate and improve potential target identification across therapeutic areas and the selection of lipid nanoparticles for the most stable mRNA vaccine delivery. • **Supply and Manufacturing Processing**: An AI algorithm was developed to evaluate batch performance and asset quality processes for new manufacturing capabilities with more consistent yield and cost efficiency. The consumer health-care unit launched the Open Innovation Portal to facilitate open communication with the broader supply chain community on challenges and innovative solutions.	**Owkin**: This collaboration aims to use patient data on an AI-driven platform to build predictive models for treatment response. **Hillo**: This partnership, outlined in *Forbes*, aims to adapt digital twin AI solutions for insulin pens. **Exscientia**: This collaboration aims to explore 15 new small-molecule candidates for oncology and immunology treatments with the personalized medicine platform.

Source: Milken Institute synthesis (2024), adapted from Taylor et al. (2022)

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