Arrowpoint Labs

ESTABLISHING INDIANA AS A NATIONAL HUB FOR COMPUTATIONAL MEDICINE

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BioCrossroads®

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Message from Vince Wong, President and CEO, BioCrossroads

With advances in sensors, sequencing, single cell analysis, and spatial genomics, we have an increasing array of tools to generate incredible amounts of phenotypic and genomic data. When combined with powerful and rapidly advancing data analytics platforms, including quantum computing and AI, researchers' ability to analyze these large data pools to unlock deep insights into disease biology are greater than ever. These advances will only accelerate, placing us forefront of a transformative era in healthcare and life sciences.

The intersection of computer science, data analytics, and biology is shaping how we understand and treat diseases and serve as a catalyst for improved health and economic growth.

Indiana's unique combination of academic research excellence, industry leadership, and collaborative spirit has positioned the state to lead in this rapidly evolving field. Having a skilled talent pool, such as doctoral graduates in computational medicine, will be a critical factor for continued leadership. The economic and societal impact of computational medicine is already evident. Indeed, over a quarter of open life sciences positions now require expertise in this area.

Looking ahead, the potential is vast and tremendously exciting. By leveraging Indiana's robust network of academic, industry, and public partners, we can accelerate innovations that will not only benefit our state but also set national and global benchmarks for healthcare advancements. The investments made today will pay dividends for decades, driving economic growth while improving the health and well-being of our communities.

Together, we have the opportunity to shape the future of medicine—one where data-driven insights and technological advancements lead to faster diagnoses, more effective treatments, and ultimately, better global health.

Vince Wong
President and CEO

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ESTABLISHING INDIANA AS A NATIONAL HUB FOR COMPUTATIONAL MEDICINE

EXECUTIVE SUMMARY

- Computational medicine is a rapidly growing segment of the life sciences industry, accounting for nearly 28% of all active job postings on BioSpace. Further, computational medicine offers jobs that span education requirements from high school to graduate degree.
- Indiana's existing assets and investments position the state for continued leadership in computational medicine and bioinformatics. Indiana's industry, academic, and non-profit stakeholders have unlocked tens of millions of dollars in investment in workforce and infrastructure to ensure that the state plays a key role in the future of computational medicine.
- Among these investments is a proposed PhD Program at the Indiana University School of Medicine, which will position graduates to enter a robust and growing job market that has economic impact multipliers well above the average for other sectors. Graduates from the Program could generate over $24m in national and $6m in in-State annual economic impact via direct and indirect job creation alone by 2036.

Table 1: NAICS codes relevant to computational medicine

<table>
<tr><th colspan="2" rowspan="2">Sector</th><th rowspan="2">NAICS code</th><th rowspan="2">Example products / services</th><th colspan="2">U.S. economic impact (2022)</th><th rowspan="2">Relevance of computational medicine (examples)</th></tr>
<tr><th>By commercial revenues</th><th>By private capital investment</th></tr>
<tr><td colspan="2">Biopharmaceutical manufacturing</td><td>325412</td><td>Manufacturing of medicines and vaccines</td><td>$153.9 billion</td><td>$21.1 billion</td><td>Modeling of new manufacturing methods, particularly in biologics</td></tr>
<tr><td rowspan="2">Biopharm-aceutical research and develop-ment</td><td>Agricultural biology and other non-biotechnology life sciences R&D</td><td>541715</td><td>Agricultural production research
Plant genomics</td><td>$94.1 billion</td><td rowspan="2">$11.7 billion[1]</td><td>De novo generation of plant genomes</td></tr>
<tr><td>Research and development in clinical biotechnology</td><td>541714</td><td>Research into new medicines

Genomics research</td><td>$25.6 billion</td><td>Computer-aided drug discovery and development
Functional genomics</td></tr>
<tr><td colspan="2">Medical laboratories</td><td>621511</td><td>Laboratory diagnostic testing</td><td>$35.3 billion</td><td>$2.9 billion</td><td>Computational pathology and imaging</td></tr>
</table>

[1] Reporting for these NAICS codes combined by U.S. Census Capital Expenditure Survey

I. Defining and contextualizing computational medicine: Computational medicine is a rapidly maturing field at the intersection of computer science, informatics, and biology. It pertains to several industry and occupational codes and plays a critical role in emergent biotechnology trends.

Computational medicine ("CompMed") refers to the field at the intersection of computer science, biology, and informatics. CompMed enables innovators to leverage powerful tools in data science and computation to address previously difficult or intractable problems in the life sciences, ranging from target identification for drug discovery to genomic analysis revealing drivers of rare and common diseases. In the past two decades, CompMed has rocketed past its "emergent" stage to become a mature field of science, with active communities of practice in industry, academia, and government.

Private- and public-sector leaders recognize the transformative potential of CompMed, both as a field unto its own and as a key component of large existing economic sectors like Information Technology and Biomedicine. The economic impact of CompMed can be demonstrated via its alignment to existing occupational and industry codes that form the bedrock of most economic impact reporting by the Bureau of Labor Statistics, the Bureau of Economic Analysis, and other experts.

Due to its emergent and interdisciplinary nature, computational medicine as a field does not have a one-to-one alignment to existing standard occupational (Standard Occupational Classification, or "SOC") [1] and industry (North American Industry Classification System, or "NAICS") [2] codes. However, computational medicine is a critical and growing portion of several NAICS and SOC codes that constitute large portions of the Indiana and United States economies, demonstrated in **Table 1**. Relevant SOC codes to computational medicine include 19-1029 (Biological Scientists, All Other), 15-2041 (Statisticians), 15-2051 (Data Scientists), 17-2031 (Bioengineers and Biomedical Engineers), and 15-1211 (Health Informatics Specialists). These NAICS and SOC codes will appear throughout this report to demonstrate the economic and workforce relevance of CompMed.

Ia. CompMed's workforce demands: CompMed plays a role in over a quarter of existing job openings in the life sciences sector, demanding a trained workforce in the interdisciplinary field.

Interdisciplinary training in computational medicine is an increasingly common requirement for jobs in biotechnology. In particular, as the roles of data science and bioinformatics grow within healthcare and biotechnology, employers seek candidates with advanced degrees in computational medicine and related fields.

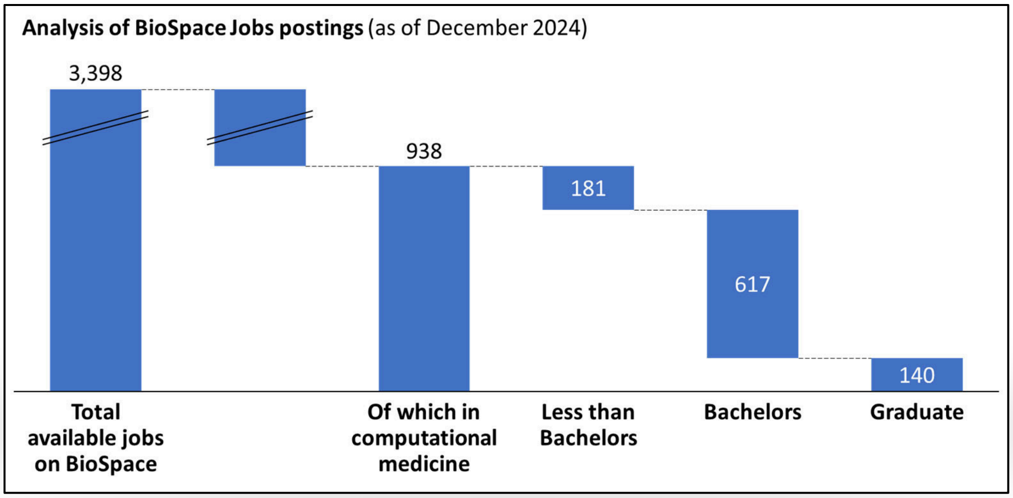
This trend can be quantitatively assessed through a longitudinal analysis of job postings on websites that focus specifically on biotechnology hiring. **Figure 1** demonstrates a five-year lookback analysis for one such site, BioSpace, on which many mid-size and large biotechnology industry organizations post available positions. As of December 2024, over 28% of postings on BioSpace also contained "computational" or "bioinformatics" tags [3], demonstrating the proliferation of roles requiring deep and interdisciplinary training across bioscience and computational disciplines. Further, these roles span levels of educational attainment. While the majority require a Bachelors degree nearly 20% require solely a high school or Associates degree, demonstrating the potential in computational medicine for **laddered career opportunities** that serve a wide array of potential workers.

In addition to jobs in the biopharmaceutical industry, computational medicine has substantial relevance toward jobs in the healthcare sector requiring backgrounds in data science and analytics. While difficult to identify the number of jobs and growth rate for positions at the intersection of data science and healthcare, the size of the healthcare data analytics market can be used as an indicator for labor growth figures. The healthcare data analytics market is estimated to have a size of $50.7b in 2024. The field has an 11% compound annual growth rate (CAGR) projected through 2033, projecting a total market size of $145.4b. This CAGR for market size is validated by Bureau of Labor Statistics estimated growth rates for data scientists (36% per year) [4] and healthcare information technologists (16% per year) [5].

In addition to seeing substantial demand from industry anchors, careers in bioinformatics that require graduate training also see growth and wages well above national averages. According to the Occupational Information Network ("O*NET"), a database of standardized and occupation-specific descriptors sponsored by the U.S. Department of Labor, "Bioinformatics Scientists" are described by the enhanced SOC code **19-1029.01** [6]**.** According to O*NET, the median wage for a Bioinformatics Scientist is $91,100 annually, 4.7% higher than that across all Life Sciences SOC codes ($86,950 annually) and 50.4% higher than the median wage in Indiana ($60,548) as reported by the Bureau of Labor Statistics. Further, O*NET characterizes the "Bioinformatics Scientists" SOC codes as seeing a "higher than average" job growth, estimated at 6% to 8% annually.

Figure 1: **Total jobs on BioSpace Jobs Board, broken down by education requirements and relevant tags**

(28% of all BioSpace jobs are relevant to computational medicine, with positions spanning all levels of education)



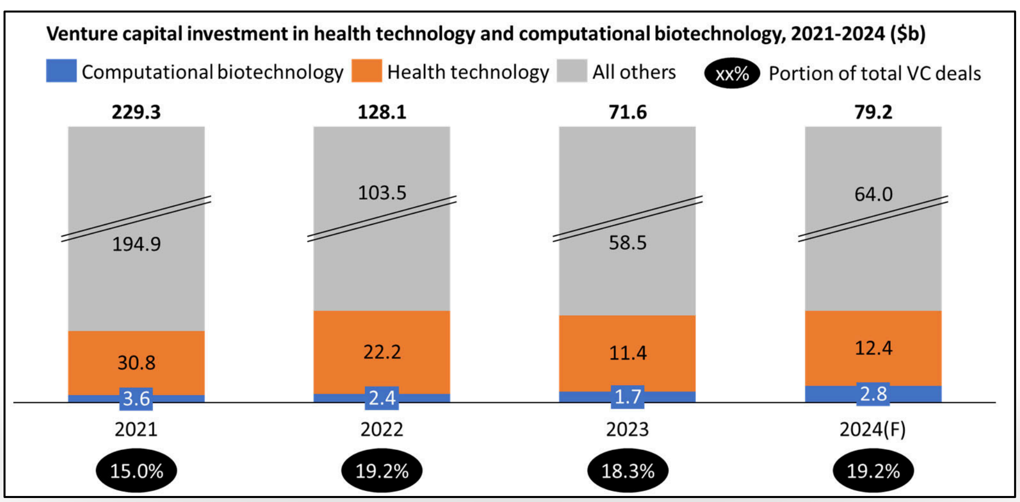
Ib. Innovation and investment: Computational medicine has driven substantial private-sector investment into innovative platforms and technologies.

CompMed additionally drives economic impact by drawing investment toward companies built upon intellectual property developed by participating faculty, staff, and students. New technologies in CompMed could include new artificial intelligence (AI), software platforms for disease diagnosis and treatment, clinical decision support tools, and health informatics tools that could increase the efficiency and quality of care. As most of these technologies are likely to be grown via startup companies taking on private funding, the analysis of economic impact through innovation in CompMed focuses on venture capital. Even amid a slower capital investment landscape in 2024 compared to that in 2021-2022, companies in computational medicine, particularly those leveraging AI, have continued to draw outsized and increasing investment. Companies leveraging computational medicine remain attractive to venture capital firms for several reasons. First, they are less capital-intensive than other life sciences or "deep tech" investments. Second, their platforms often provide a faster timeline to revenue generation; a computational model can quickly form the basis of a fee-for-service model for other life sciences companies developing new medicines. Finally, technology in computational medicine is rapidly advancing and evolving, creating a network effect wherein investors and industry partners ensure exposure to the newest emerging models via direct investment or partnership.

For example, CompMed technologies can facilitate faster and less expensive discovery of targets and biomarkers; can generate and optimize therapeutic candidates; can simulate safety and efficacy of prospective medicines; and can address elements of the clinical trials landscape that are currently time- and labor-intensive, including patient matching, recruitment, trial design, data capture, and data analysis. CompMed technologies therefore often underlie investments in therapeutic assets, or are made part of portfolio to support multiple other investments.

An analysis of venture capital funding reveals that the health technology and computational biotechnology sectors constitute 19.2% of venture capital in 2024 to date, up from 15% in 2021. Technologies related to computational medicine are a rapidly growing portion of venture capital investment. As shown in **Figure 2,** 2024 saw over $15b in venture investment toward computational biotechnology [11-13]. The largest VC of the year to date in 2024 was a $1b founding investment in Xaira Therapeutics, an AI drug discovery and development startup.

Figure 2: **Venture capital investment in health and computational biotechnologies.**
(While investment has fallen in line with overall venture capital funding, computational medicine technologies constitute nearly one in five VC dollars invested)



II. Indiana's computational medicine leadership: Indiana public, private, and non-profit stakeholders are already making investments that position the state for leadership in computational medicine.

Indiana is already demonstrating national leadership in multi-sector collaboration to advance CompMed platforms and use cases. These partnerships have already unlocked tens of millions of dollars in investment in health data infrastructure necessary for CompMed and are additionally building the foundation for future.

IIa. Case studies of Indiana's active investments in computational medicine

AnalytiXIN: Building on Indiana's distinctive health data assets through multi-sector collaboration

In 2021 several Indiana stakeholders, led by the Central Indiana Corporate Partnership and BioCrossroads, embarked upon an ambitious journey to build Indiana's data economy, in large part by leveraging the State's distinctive health data assets. Indiana has long been a leader in health data infrastructure. The Indiana Health Information Exchange (IHIE) served as one of the first statewide cross-stakeholder databases in the nation, integrating data stored across provider, payer, and public-sector sources at the patient level to enable data portability across settings for patients. In doing so, IHIE and the Regenstrief Institute, a leading health informatics non-profit, established Indiana as a first-mover in large scale health data infrastructure that could serve other purposes with high economic development impact potential, from facilitation of clinical trials to creation of commercial healthcare and biotechnology solutions requiring large data. Among its programs, AnalytiXIN is leading the creation of an open-access clinical-genomic database that brings together patient-level health outcomes data and genomic information to enable healthcare innovation spanning the pipeline from early research to clinical trials to post-market adoption. This database, a joint project of CICP, IHIE, IU Health, the IU School of Medicine, the Indiana Clinical and Translational Sciences Institute, and Eli Lilly, has already sequenced 35,000 genomes since 2021 and is targeting 100,000 by 2027. In doing so, it will become one of the largest comprehensive and geography-targeted integrated clinical-genomic databases in the world. AnalytiXIN partners are already building collaborations to leverage this data to support research and clinical trials in cardiometabolic disease.

Industry hiring and investment: Meeting the needs of Indiana's substantial private-sector bioscience anchors

In addition to AnalytiXIN, which drew upon substantial investments from the non-profit, academic, and industry sectors, Indiana's private sector life sciences anchors are also themselves planning for the central impact of computational medicine to their own business models. Computational medicine will impact the end-to-end life sciences value chain, becoming increasingly necessary for the efficient and successful operation of functions from research & development to commercial. Critical use cases, from target and biomarker identification for drug discovery, to participant matching for clinical trials, to targeted delivery for commercial operations, to pharmacovigilance, are not just emerging but rather in rapid adoption by industry actors large and small. A clear indicator as to the importance of computational medicine for Indiana's anchor industry organizations can be seen in their upcoming budgeting and hiring plans. In interviews with senior leaders at Elanco and Eli Lilly, both indicated that as many as 20% of all upcoming research & development hires in the next five years will require cross-functional training in computational medicine.

Further, computational medicine will play a large role in external research & development partnerships. As much as 10% of externalized or partnered research & development spend will come in collaborations in CompMed. This speaks not only to the importance of CompMed for large industry anchors, but also to the necessity of small- and medium-size enterprises bringing new technologies and platforms to market for adoption by larger partners.

Indiana's research institutions: Building unique research assets leveraging CompMed

Biomedical research institutions in Indiana are already leveraging CompMed methods and technologies to build unique and distinctive research assets. At Indiana University, researchers at the Melvin and Bren Simon Comprehensive Cancer Center developed the most complete mapping of healthy breast cells to better understand the origin and drivers of breast cancer.

By incorporating detailed genomic and gene expression data, this comprehensive atlas provides a tool that will enable researchers throughout the world to use CompMed methods to better understand the disease pathology of breast cancer, leading to new therapeutic targets, therapeutic candidates, and potential approved treatments. Similarly, the IU Stark Neurosciences Research Institute and Indiana Institute of Biomedical Imaging Sciences jointly operate the Advanced Imaging Research group. This group aims to integrate the use of advanced MRI and PET imaging into basic and clinical research. Advanced imaging assets are data-rich and enable researchers to obtain longitudinal and spatial insights as to the progression and treatment of disease. However, these datasets are highly complex and require strong bases in both computational and biological scientists to derive value. The Advanced Imaging Research group at IU focuses particularly on neurological and psychiatric disorders ranging from neurodegenerative disease to substance use disorders. Similar groups at Purdue University are also advancing research assets and expertise in CompMed.

The Weldon School of Biomedical Engineering identifies computational biomedicine as a key research area, leveraging mathematics, systems analysis, and engineering to derive biomedical insights to better understand disease and treatment. Researchers within the Weldon School have developed computational models for predictive safety and toxicology; have built optimization models for clinical decision-making and healthcare delivery; and have built mathematical and computational models for nerve modulation therapies. Additionally, the Bindley Bioscience Center has established core capabilities in CompMed, including multi-omic data processing and analysis, structural biology, and development of computational tools for biomedical research. Finally, the cross-institution Indiana Clinical and Translational Sciences Institute (CTSI) brings together the expertise from Indiana's research universities and the Regenstrief Institute, a leading biomedical health data research institution. In addition to its Translational Informatics Program and Biostatistics, Epidemiology, and Research Design program which focus specifically on clinical and biological data analysis, programs like the Indiana Biobank serve as enabling infrastructure for efforts like the previously outlined AnalytiXIN program.

IIb. Corresponding national investments: Economic and workforce developers across the United States are beginning to make corresponding investments in computational medicine and bioinformatics.

Success in computational medicine is essential for Indiana's continued competitiveness as a life sciences hub. Other ecosystems in the United States are making corresponding investments in workforce development, training, and research related to computational medicine. First, other universities around the U.S. are investing in corresponding interdisciplinary programs in computational medicine and informatics. For example, Johns Hopkins University's Institute for Computational Medicine provides access to several PhD tracks across the university's degree-granting departments [14]. New York University and the University of Michigan similarly offer programs in computational biology and medicine. Beyond higher education, economic development organizations are continuing to prioritize the computational medicine cluster as a vector for economic growth. This was made evident via the Economic Development Administration's (EDA) Regional Tech Hubs program ("Tech Hubs"), a substantial investment by the federal government to advance regional industrial strategy in the United States. A signature portion of the CHIPS and Science Act of 2022, the Tech Hubs program directed the Department of Commerce, via the EDA, to designate and direct over $10b toward historically underinvested post-industrial rural and urban communities. Of nearly 200 applicants, 31 regions were designated "Phase 1" awardees and received $500k toward regional economic development planning activities. Subsequently, 12 regions, including Central Indiana, were designated finalists and received a cumulative $504m to advance regional innovation strategies, including programs to advance workforce development, industry engagement, and commercialization of new technologies to support the respective Hubs. As such, the Tech Hubs program provides an opportunity to discern the primary economic cluster strategies for various regions across the United States. Successful Phase 1 awardees in Birmingham, AL; Baltimore, MD; Philadelphia, PA; and Madison, WI (representing over 10% of all Phase 1 awardees) selected clusters pertaining to the intersection between medicine and AI / computation. Indianapolis's successfully funded Tech Hub focuses on biomanufacturing, a topic still adjacent to this Program's computational medicine focus.

III. Building a first-of-its-kind interdisciplinary PhD Program: The Indiana University School of Medicine plans to launch a PhD program in Computational medicine that will provide training and research opportunities at the intersection of computer science, biotechnology, and informatics.

The Center for Computational Biology and Bioinformatics (CCBB), a research center within the Indiana University (IU) School of Medicine, and the Department of Biomedical Engineering and Informatics (BEMI) at Luddy School of Informatics, Computing and Engineering (SICE) plans to launch in 2025 a PhD Program in Computational Medicine that will provide interdisciplinary training and research opportunities for students seeking careers at the intersection of computer science, biotechnology, and informatics. This program positions Indiana to attract and train a workforce that will support industry needs in computational medicine and generate new bioinformatics innovations. The potential economic impact of the program from a workforce development standpoint can be holistically estimated by the wage multiplier effects of graduating students who remain in the State of Indiana. This total economic impact can be estimated by examining following four figures: (a) the total number of students graduating from the program on an annual basis; (b) the average wage per graduate; (c) the employment multiplier for jobs in computational medicine; and (d) the average wage for employment induced. For this analysis, it is assumed that the program will graduate 6 students by 2032, an assumed seven years from the launch of the Program, and each year thereafter.

Owing to the advanced nature of the training of this program, the median O*NET salary figure for the relevant enhanced SOC code is used. A real wage growth of 3% annually for each year of experience is additionally factored [7]. Finally, the Economic Policy Institute estimates a total employment multiplier of 8.4 jobs per one job in scientific research and development, among the highest of job classifications analyzed [8]. This comprises 5.2 jobs from "upstream" supplier impacts and 3.2 jobs from "downstream" induced impacts. Conservatively, earnings for all induced jobs are assumed to be the State median, despite the fact that many upstream jobs induced will also come from the scientific research and development sector, which provides above-median wages. Accumulating nominal wage growth and adjusting for inflation (assumed to be 2.1% [9]), the estimated U.S. and in-State economic impact from wages of Program graduates as shown in **Table 2**. To arrive at in-State economic figures, a 2012 report from the Indiana Business Research Center at the IU Kelley School of Business is used, finding that 26.0% of Biology/Life Sciences doctoral graduates remain in the State of Indiana [10]. The program is anticipated to generate nearly $6.4m in economic impact in the State from graduates' wages alone. This analysis does not consider the economic impact of investment via investment in innovations that emanate from the Program's faculty, staff, and students.

Table 2: Annual economic impact of the Program from graduate wages, nominal dollars ($k)

	2032	2033	2034	2035	2036
Cumulative Economic Impact					
U.S.	$ 4,256	$ 8,822	$ 13,718	$ 18,961	$ 24,572
Indiana	$ 1,106	$ 2,294	$ 3,567	$ 4,930	$ 6,389

If Indiana can capture the same share of investment in its computational medicine innovation as its share of overall national venture capital investment, 0.13%, its share of national investment could total nearly $200m annually [11]. However, to compete for this investment, Indiana's academic and industry institutions must generate according technology and startups and other Indiana economic development and entrepreneurial support organizations must build relevant infrastructure to enable success of related startups. Finally, the Program could provide an avenue through which faculty, staff, and students can generate such technology through federal, State, and industry-sponsored funding.

Similarly, Indiana's focus on CompMed innovation will assume mounting importance in the State's ability to capture venture capital investments in biotechnology and healthcare; CompMed technologies are not only increasingly common investments by themselves, but often also form the backbone for investments in more traditional assets such as biomanufacturing platforms and therapeutics.

Indiana's existing research and industry anchors have already positioned the State as a leader in CompMed through prior investments and efforts. The rapidly evolving landscape of CompMed will necessitate similarly bold and proactive investments in talent, innovation, and industry engagement to facilitate continued success.

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