

The Art of Scientific Surprise: Using Humor, Magic, and Art to Enhance Communication and Thinking

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The scientific method follows a particular pattern: the background is established, a hypothesis is postulated, then tested by experiment, to reveal the hidden truth. Humor and magic follow similar patterns: expectations are established, and then broken, to enact the joke or trick. Humor and magic can often reveal truths or illuminate portions of the truth in interesting ways. In science, humor, magic, and art are sometimes used as ways of communicating scientific ideas and concepts. Research has shown that use of these approaches can improve understanding of complex scientific concepts and retention of knowledge. Interestingly, beyond just communication, aspects of these can be thought of as useful scientific tools – allowing us to approach problems in ways that may not be evident otherwise. Finally, the advent of sophisticated large language models presents the question of how these new tools may provide a basis for communication of scientific findings and thought but also of the limitations and dangers of relegating these important skills to machines. This workshop is aimed at discussing and understanding these ideas and exploring how humor, magic, and art can be used in your own science communication – and maybe even research.

Keywords: science communication, humor, magic, art, science, AI.

1. Introduction

Humor, magic, and the scientific method each work by establishing an expectation, formulating an implicit or explicit hypothesis about what will happen next, and then breaking (in the case of humor and magic) or testing (in the case of science) that expectation to yield surprise, delight, and insight ('haha!', 'ooooh!', and 'eureka!', respectively). These reactions are united by – perhaps – a single emotion: wonder. Wonder at the turn of logic or sense that comes with the punchline of a really good joke or pun. Wonder at the mysteries of reality and illusion when one is presented with a seemingly impossible magic trick. And wonder at the revealing of secrets of the natural world around us through a particularly surprising scientific finding. This wonder is an inherently human reaction and lies at the heart of science communication, and in some senses at the center of scientific thought.

Studies have shown that humor and art – beyond being useful devices for communication – can improve understanding of scientific concepts and retention of that knowledge (Yeo, et al., 2020; Yeo, et al., 2021), and we and others have written on the use of such devices in scientific communication (McDermott, et al., 2018). Interestingly, metaphor – a foundational concept that humor and magic often build on – can also be considered a scientific tool. One that, according to the science cartoonist Matteo Farinella, 'can enable scientists to visualize the invisible, bringing into focus useful details while blurring others' (Farinella, 2018).

Being able to communicate the wonder of your scientific problem, the importance of solving it, and its wider societal impact is foundational to a successful career in science—nearly as important as the science itself. Conveying complex information and concepts in a way that's clear, engaging, and easy to understand is a constant learning process. Even the best science communicators look for new approaches to improve these important pieces.

The advent of AI that can shape language and re-frame complex concepts brings another set of facets to this topic (Boies, 2026; Feldman, et al., 2026; Kobayashi, et al., 2026; Noy and Zhang, 2023). If communication of science is an inherently human activity can conveying the wonder and magic of science discovery be accomplished using machines? How does this impact the process of scientific thought and reasoning for the individual researcher and how does AI affect the state of science as a whole? Though these new tools are powerful and seemingly omnipresent, science communication must wrestle with similar questions that are presented to many different areas: will use of such tools improve communication, and will their use necessarily promote atrophy of human skills in these areas?

Underlying each of these points, education and scientific literacy for students, junior researchers, and the broader public is critically important to prevent further misinformation and distrust in science and the findings it brings to society. When used judiciously in science communication, humor, magic, and art can greatly increase engagement, interest, and even knowledge retention for the audience – no matter if it's fellow researchers or if it's your uncle Sid (a taxpayer, he tells you) at the Thanksgiving dinner table.

The ability to communicate our science to other scientists, and to taxpayers who fund our research, is an important and, in many ways, underappreciated skill. The inherent interdisciplinary nature of bioinformatics and PSB itself highlights the need for effective communication across disciplines between scientists.

2. Workshop Format

The workshop will be led by talks from Drs. McDermott and Chen on the role of humor, magic, AI, and art in science and science communication followed by discussion of these topics. Finally, the last half of the workshop will be a hands-on session where participants will be guided through drawing their own comic about their science, learning a magic trick with a science basis, and will be able to discuss their own ideas about science communication in a receptive, fun, and informal environment.

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Digital Health and Precision Medicine in Reproductive Health in the AI Era: Data, Methods, and Translation

From Real-World Data to Equitable Clinical Impact

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This workshop aims to examine how artificial intelligence, digital health, and precision medicine can be adapted to the distinctive data, biological, and clinical challenges of reproductive health. The program will connect computational methodology with clinically grounded applications across the reproductive lifespan, drawing on electronic health records, genomics and other molecular data, wearables, and patient-generated data. Emphasis will be placed on longitudinal modeling, multimodal integration, risk prediction, clinical decision support, responsible AI, and the practical requirements for translation into care. By convening computational scientists, reproductive health researchers, clinicians, and industry and implementation experts, the workshop will identify shared methodological challenges and opportunities for rigorous, equitable, and clinically meaningful innovation.

Keywords: reproductive health; artificial intelligence; precision medicine; digital health; multimodal data; clinical decision support

1. Motivation and Rationale

Reproductive health is central to population health and clinical decision-making, yet it remains underrepresented in precision medicine and biocomputing research relative to its complexity and impact^{1,2}. At the same time, there has been a rapid rise in enthusiasm around predictive modeling,

artificial intelligence, and clinical decision support (CDS) tools in healthcare^{3,4}. Reproductive health presents both a high-impact opportunity and a rigorous testing ground for these approaches⁵.

Advances in digital health have enabled large-scale, longitudinal data streams relevant to reproductive health, including electronic health records, genomics and other molecular data, wearable sensor data, and patient-generated data from mobile health applications^{6,7}. These multimodal data sources are increasingly being used to develop AI-driven risk prediction models, patient stratification approaches, and CDS tools to support clinical management across fertility, pregnancy, and menopause⁸. While these developments create new opportunities for precision medicine, they also introduce substantial methodological and translational challenges⁵.

Reproductive health data are characterized by strong temporal dynamics, heterogeneous phenotypes, and clinically meaningful subpopulations that are often poorly captured by traditional modeling approaches^{8,9}. Issues of missingness, bias, and limited generalizability are particularly acute, especially for pregnancy-related outcomes and conditions that disproportionately affect historically underrepresented populations. In addition, despite the inherently longitudinal nature of reproductive health, it remains difficult to effectively link data across life stages, limiting our ability to examine how acute reproductive events shape long-term health trajectories and chronic disease risk^{10–12}.

This workshop aims to bring together researchers, practitioners, and stakeholders working at the intersection of biocomputing, digital health, reproductive medicine, and health AI to examine how computational methods and new tools can be adapted, extended, and translated to address these challenges. Topics of interest include AI approaches for modeling longitudinal reproductive health trajectories, chronic disease prediction models, and design and evaluation of precision medicine frameworks and CDS tools that advance care in pregnancy and menopause. By focusing on reproductive health as a use case, the workshop will surface methodological and translational insights that generalize broadly across precision medicine while addressing a critical and timely application area with implications for understanding sex differences in health across the lifespan.

2. Objectives

This workshop will bring together computational scientists, biomedical researchers, technologists, and clinicians working at the intersection of AI and reproductive health. Through invited talks, the workshop will highlight recent methodological advances, explore open problems, and encourage discussion of future directions. Key objectives include:

- Showcase recent advances in computational and statistical methods applied to reproductive health and digital health data, including multimodal data integration and longitudinal modeling^{8,9}.
- Highlight emerging applications of AI-driven prediction and risk stratification, spanning fertility, pregnancy, postpartum health, menopause, and reproductive-related chronic disease risk³.
- Examine the development and evaluation of clinical decision support (CDS) tools that translate predictive models into actionable insights across clinical and digital health settings¹³.
- Facilitate cross-sector dialogue between academic researchers, clinicians, and industry practitioners working on precision medicine and AI-enabled care delivery¹⁴.

- Identify shared challenges and open research questions related to data quality, bias, interpretability, generalizability across populations, and clinical integration¹⁵.
- Discuss methodological and implementation barriers to integrating AI and CDS tools into reproductive healthcare workflows, including usability, regulatory considerations, and provider trust^{16,17}.
- Encourage responsible and equitable translation of precision medicine approaches into reproductive health settings, with attention to fairness, representation, and patient-centered outcomes¹⁵.

3. Workshop Format

The workshop will be organized as a half-day session that balances invited presentations with interactive discussion. Opening remarks will frame reproductive health within broader precision medicine and health AI efforts, emphasizing both the opportunity created by emerging data sources and the challenges of developing models that are clinically useful, trustworthy, and generalizable.

The scientific program will consist of a sequence of focused presentations spanning methods and applications. Rather than organizing the program around a fixed speaker roster, the session is designed around complementary perspectives: computational method development, disease- and life-stage-specific applications, population and genetic epidemiology, clinical informatics, digital health, and responsible AI. This structure allows the program to remain responsive to new work while preserving coherent scientific coverage.

The workshop will conclude with a moderated discussion and audience Q&A focused on the transition from research prototypes to real-world care. Discussion will address evidence standards, external validation, data fragmentation, regulation, workflow integration, bias and equity, patient and clinician trust, and the conditions under which predictive tools can meaningfully improve reproductive healthcare.

4. Scientific and Translational Scope

The program will cover reproductive health across multiple conditions and life stages rather than centering on a single clinical problem. Pregnancy and maternal-fetal health provide a natural setting for longitudinal modeling because care is structured around repeated measurements over a defined interval, while menopause creates a complementary challenge involving heterogeneous symptoms, changing risk profiles, and long-term health consequences. Chronic and often underdiagnosed conditions such as uterine fibroids and endometriosis further highlight the need for improved phenotyping, population-scale data resources, and individualized risk assessment. Fertility, menstrual health, and postpartum trajectories provide additional settings in which patient-generated data and digital health tools can complement clinical records.

Across these applications, the workshop will emphasize several methodological themes: integration of EHR, genomic, multi-omic, imaging, wearable, and mobile-health data; temporal and trajectory modeling; disease and outcome phenotyping; risk prediction and patient stratification; systems-level and mechanistic modeling; foundation and generative models where appropriate; and methods for evaluating uncertainty, robustness, interpretability, and fairness.

A central translational theme will be the distinction between model performance and clinical impact. Predictive accuracy alone is insufficient when data are fragmented, interventions are limited, or clinical workflows cannot act on model outputs. The workshop will therefore consider how decision-support tools should be evaluated, what evidence is needed for deployment, how models should be monitored after implementation, and how regulatory, usability, and trust considerations shape adoption^{12,17}.

5. Participant Perspectives and Cross-Sector Discussion

The workshop will intentionally draw on different kinds of expertise. Computational and statistical investigators will contribute approaches for high-dimensional and longitudinal modeling. Reproductive health researchers and clinicians will ground these methods in biological mechanisms, disease-specific phenotypes, clinical decision points, and unmet needs. Population health and genetic epidemiology perspectives will address heterogeneity, environmental context, and generalizability across populations. Clinical informatics and responsible AI perspectives will focus on workflow integration, validation, bias, transparency, and governance. Digital health and industry participants will add practical experience with patient-generated data, product development, diagnostics, implementation, and real-world evidence.

Bringing these perspectives together is particularly important because many barriers to reproductive-health AI are not purely technical. Data ownership, interoperability, missingness, representation, regulatory pathways, reimbursement, clinician burden, patient engagement, and the availability of effective interventions all influence whether a model can create value. The discussion will therefore emphasize the full translational pathway from data and methods to validation, implementation, and measurable patient benefit.

6. Organizers Contributions

The organizing team spans computational genetics, biobank analytics, biomedical informatics, systems biology, multi-omics, genetic epidemiology, maternal and reproductive health, clinical informatics, digital health, and responsible machine learning. Organizers will contribute scientific framing, selected presentations, moderation, and synthesis across the workshop. This breadth is intended to ensure that methodological innovation remains connected to disease biology, clinical needs, population-level evidence, implementation realities, and equity.

7. Overall Impact

The workshop is intended for researchers, practitioners and industry partners in biocomputing, computational biology, biomedical informatics, digital health, and related fields, with particular relevance for those working on predictive modeling and AI for health using real-world data. By bringing together stakeholders across academic and industry environments, we will provide participants with exposure to differing perspectives and experiences. This will facilitate opportunities for scientific and resource exchange as well as encourage the formation of new collaborations.

There is no shortage of hype around AI and prediction in healthcare. This workshop will take a more grounded view. Reproductive health offers a setting where the promises and limits of predictive modeling are immediately visible: outcomes are time-dependent, data are noisy and biased, and clinical decisions carry real consequences. Pregnancy, in particular, represents an exceptional model system for developing and evaluating precision medicine approaches. It is a defined period with clear start and endpoints, during which patients engage regularly with the healthcare system through routine prenatal care, generating rich longitudinal data. Pregnant individuals are highly motivated to optimize health outcomes but frequently experience complications for which there are limited to no effective interventions. Moreover, pregnancy represents a period during which traditional pharmaceutical trials are rarely conducted, making pregnant individuals systematically excluded from evidence-based therapeutic development. This creates both an urgent need and a unique opportunity for precision medicine approaches that can stratify risk, optimize the timing of surveillance and intervention, and identify modifiable factors. Importantly, events during pregnancy have lifelong consequences for both maternal and offspring health.

By centering reproductive health, the workshop creates space to move past abstract claims and examine how precision medicine methods actually perform in practice. In doing so, it highlights methodological challenges that extend well beyond this domain and helps shape a research agenda focused on clinically meaningful, trustworthy, and equitable models.

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From Infrastructure to Impact: Developing Actionable Solutions and Community Challenges in Biomedical Cyberinfrastructure*

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Biomedical research increasingly depends on distributed data resources, cloud services, high-performance computing, and artificial intelligence (AI). Translating these capabilities into scientific impact requires cyberinfrastructure that is open and interoperable. The 2026 Pacific Symposium on Biocomputing (PSB) workshop examined the evolving cyberinfrastructure at the National Institutes of Health and established a foundation for discussing reusable infrastructure needs and building blocks and barriers to their adoption. The proposed PSB 2027 workshop, “From Infrastructure to Impact,” builds on that foundation by moving from awareness to structured prioritization, solution development, and community pilot framing. The workshop will address three interconnected themes: AI-enabled biomedical infrastructure, secure and interoperable computing environments, and government-academic partnerships and ecosystem alignment. Short invited talks, collaborative breakout activities, and plenary synthesis will guide participants in developing three to four well-scoped community pilots with concrete solution pathways and measurable milestones over a two- to five-year horizon. Expected outputs include prioritized problem statements and a structured community summary or white paper. By linking infrastructure needs to actionable collaborative efforts, the workshop aims to inform sustained cross-sector engagement beyond PSB.

Keywords: Biomedical cyberinfrastructure; artificial intelligence; interoperability; secure computing; community pilots; government-academic partnerships.

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1. Introduction

Biomedical discovery increasingly depends on integrating complex biomedical data (e.g., genomic, clinical, imaging, digital, and real-world) across institutional and computational boundaries. Artificial intelligence (AI) and large-scale data analytics expand research opportunities but also increase demands on supporting infrastructure. Open, standards based approaches to scalable biomedical research computing remain central challenges.¹ Addressing them requires coordinated effort rather than isolated tools.

The PSB 2026 workshop, “The Evolving Cyberinfrastructure at the National Institutes of Health to Support Data and AI in Biomedical Research,” introduced reusable infrastructure needs and building blocks for cloud access, researcher authentication and authorization, and secure analytics workspaces.¹ Its accompanying program included perspectives on data platforms and harmonized resources for neurodegenerative disease research.² The PSB 2027 workshop, From Infrastructure to Impact, extends this foundation by moving from infrastructure needs awareness to recommended solutions and proposed community pilots. This article describes the workshop's scope, planned activities, and anticipated outputs.

2. From Infrastructure Awareness to Coordinated Action and Impact

Existing programs provide starting points for coordinated action. NIH’s Science and Technology Research Infrastructure for Discovery, Experimentation, and Sustainability (STRIDES) initiative is the NIH’s enterprise solution to the cloud and reduces barriers to commercial cloud services³ The Researcher Auth Service (RAS) supports authentication, authorization, and audit logging.⁴ Finally, secure workspaces bring analysis capabilities closer to data¹. These platforms use Global Alliance for Genomics and Health (GA4GH) standards⁵ and the Findable, Accessible, Interoperable, and Reusable (FAIR) principles⁶ as a “North Star” for responsible sharing and reuse.

The workshop will convene experts from the meeting to synthesize lessons across data platforms, cloud services, AI, and high-performance computing (HPC). The workshop will be largely interactive with interdisciplinary breakout teams developing tractable solutions to shared infrastructure needs. The proposed solutions and associated proposed community pilots will be summarized in a structured community report or white paper.

3. Workshop Scope and Themes

The workshop focuses on cross-cutting cyberinfrastructure technology challenges rather than domain-specific scientific problems. It is organized around three themes, each framed by a core question that anchors the invited talks and breakout discussions. Within each theme, breakout groups will define a specific problem or opportunity, map a solution pathway, and develop a community pilot or engagement framework that could build on existing initiatives.

3.1. AI-enabled biomedical infrastructure

This theme addresses AI as durable infrastructure within national and institutional digital ecosystems with a focus on embedding AI using standards. Topics include operationalizing AI at scale; open and responsible model sharing; benchmarking and evaluation; and workflow acceleration and automation. The central question is how to embed AI using standards. Proposed approaches may address reusable interfaces and workflow integration. The National Institute of Standards and Technology (NIST) AI Risk Management Framework provides a voluntary reference for discussing trustworthiness and responsible implementation.⁷

3.2. Secure and interoperable computing environments

This theme examines technical mechanisms for secure, advanced computation across sensitive and heterogeneous environments. Topics include federated learning and distributed AI; portable and containerized workflows; encryption and privacy-enhancing technologies; researcher identity, authentication, and authorization; and secure cross-platform interoperability. The central question is how to enable advanced computation across distributed data environments while maintaining strong identity, access control, and security. Existing standards provide building blocks: RAS supports authentication and authorization⁴; GA4GH's Data Repository Service (DRS) standardizes data retrieval⁸; Health Level Seven (HL7) Fast Healthcare Interoperability Resources (FHIR) supports data exchange⁹; and Common Workflow Language (CWL) describes portable tools and workflows.¹⁰ Solutions should remain open, standards-based, and community driven.

3.3. Government-academic-industry partnerships and ecosystem alignment

This theme addresses the partnership, policy, and incentive structures needed to build and sustain shared infrastructure across institutions and sectors. Topics include coordination models for shared infrastructure, alignment with federal standards, governance of controlled-access and clinical real-world data, partnership models for co-developing tools and platforms, and incentives to build, sustain, and share infrastructure. The central question is how government, academic, and industry partners can jointly build, govern, and sustain shared cyberinfrastructure that serves the broader biomedical research community. The NIST Cybersecurity Framework 2.0 supports assessment, prioritization, and communication of security outcomes.¹¹ Breakout groups will consider technical plans alongside implementation and adoption, including key requirements and dependencies.

4. Workshop Organization and Community Pilots

The half-day workshop combines short invited talks, structured breakout activities and report-outs, and plenary synthesis. Speakers and participants will represent academia, federal, and institutional infrastructure programs, with attention to diversity across institutions and career stages.

4.1. *Invited talks and shared problem framing*

Invited talks of 10-15 minutes will present infrastructure limitations, opportunities, and successes; identify technical, operational, or partnership gaps; and articulate community pilots aligned with the three themes. These speakers will share perspectives to form a basis for problem prioritization:

- Travis Wheeler, PhD; University of Arizona
- Kenneth D. Mandl, MD, MPH; Boston Children's Hospital
- David Haussler, PhD; University of California Santa Cruz
- Roxana Daneshjou, MD, PhD, FAAD; Stanford University

4.2. *Structured problem prioritization*

Within themes, participants will converge on a limited set of high-impact, tractable problems. Proposed considerations include relevance across research settings and opportunities for coordinated action. These considerations support discussion rather than prescribing a solution.

4.3. *Breakout groups: solution development and pilot design*

Each breakout will develop a solution pathway and a community pilot, specifying feasibility and measurable milestones over a two- to five-year horizon. Groups will then share back their solutions and pilots with the full group. Table 1 proposes reporting fields to support comparison and synthesis.

Table 1. Proposed breakout reporting fields for solution and pilot development.

Field	Content to be developed by participants
Problem and scope	Shared problem, intended beneficiaries, and boundaries.
Solution pathway	Technical mechanisms, governance, and existing capabilities.
Feasibility and milestones	Barriers, dependencies, resources, and measurable two- to five-year milestones.
Stakeholders and partnerships	Collaborators, alignment opportunities, and sustained support.
Community pilot and success criteria	Bounded pilot or framework, links to existing initiatives, anticipated impact, and success criteria.
Advancement and next steps	Research, infrastructure, policy, or partnership pathways beyond PSB.

4.4. *Plenary share-back and synthesis*

Groups will present their feedback. A moderated summary from the leaders will seek convergence on three to four priority challenges. Related proposals may be aligned around shared capabilities or stakeholders, with next steps outlined for engagement beyond PSB.

5. Expected Outcomes and Community Impact

Expected outputs are three to four prioritized problems with solution pathways, community pilots, and success criteria tied to measurable two- to five-year milestones. A structured community summary or white paper will document next steps for researchers and infrastructure providers. These are planned outputs, not completed deployments or validated solutions; implementation will depend on resources, governance, and partner commitments. By connecting computational innovation with shared infrastructure needs, the workshop aims to spark new cross-sector partnerships and a community that keeps working together after PSB.

6. Conclusion

Building on PSB 2026, this “From Infrastructure to Impact” workshop will move from awareness to coordinated action across AI-enabled infrastructure, secure and interoperable computing, and government, academic, and industry partnerships. Its intended contribution is a focused set of actionable community pilots connecting computational advances to the infrastructure, governance, and collaborations needed for sustained biomedical impact.

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Workshop Introduction

Multi-modal Spatial-Omics: From AI Models to Translational Applications

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The workshop “Multi-modal Spatial-Omics: From AI Models to Translational Applications” at the Pacific Symposium on Biocomputing 2027 brings together researchers developing and applying computational methods for spatial molecular data. Two keynote presentations and eleven selected talks connect advances in multimodal integration, tissue reconstruction, and mechanistic modeling with applications in cancer, brain aging, and kidney biology. The program spans histology-guided analysis, cross-assay representation learning, spatial genomics, and patient-level prediction. Through presentations and discussion, the workshop will examine how AI and statistical methods can support interpretable biological discovery and rigorously evaluated translational applications.

Keywords: Spatial omics; multimodal integration; artificial intelligence; histopathology; translational bioinformatics.

1. Background

Spatial omics technologies measure molecular variation within its tissue context, connecting cellular states to local organization and interactions. Integrating spatial transcriptomics, proteomics, metabolomics, and epigenomics with histological imaging provides complementary views of tissue biology. These data create opportunities to investigate how molecular programs are organized across cells and tissue regions, how this organization changes in disease, and which spatial features may inform clinical research.

Realizing these opportunities requires addressing substantial computational challenges. Modalities differ in resolution, coverage, noise, and sampling, and measurements may come from different tissue sections or patients. Integrative methods must align these observations while

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preserving biologically meaningful variation. Analyses also need to distinguish technical effects from tissue structure and connect two-dimensional measurements to three-dimensional organization. For predictive applications, evaluation across independent patients and cohorts is essential to assess whether a model generalizes beyond its training data.

AI and machine learning offer approaches to these problems through graph-based representations, deep learning, generative modeling, and transfer across modalities. Statistical modeling provides complementary tools for uncertainty assessment and interpretable inference. The central challenge is to connect computational advances to biological questions and establish when their predictions are reliable enough to support further experimental or translational investigation.

2. Workshop goals

This workshop brings together computational scientists, statisticians, experimental biologists, and translational researchers to examine the progression from multimodal data integration to biological interpretation and patient-level prediction. Building on the PSB 2026 workshop “Advances of AI Methods in Single Cell Spatial Omics,” the 2027 program places particular emphasis on relationships among molecular assays, histopathology, and tissue architecture.

The workshop will address methods for cross-modal and cross-sample integration; representations that preserve spatial context; reconstruction of molecular and tissue organization; and models that connect spatial measurements to disease mechanisms or clinical outcomes. Across these themes, discussion will consider interpretability, uncertainty, reproducibility, and evaluation. A shared aim is to identify the evidence needed to move from descriptive spatial patterns toward testable biological hypotheses and robust predictive models.

3. Workshop program

The program combines two keynote presentations with eleven selected talks. Together, the contributions connect general computational methods with specific biological questions, from subcellular genome organization to tissue microenvironments and patient outcomes.

3.1. Keynote presentations

Mingyao Li, Professor of Biostatistics at the University of Pennsylvania, develops statistical and computational methods for single-cell, spatial, and multimodal genomics. Her research on cellular heterogeneity and integrative analysis provides a perspective on connecting spatial molecular measurements to disease biology.

Smita Krishnaswamy, Professor of Genetics and of Computer Science at Yale University, develops AI and machine learning methods for biological data. Her work in manifold learning, deep learning, and generative modeling provides a complementary perspective on representing cellular states, tissue organization, and biological dynamics.

3.2. *Selected presentations*

Multimodal integration and representation learning. Ben Raphael's contribution addresses spatial alignment and morphology mapping. Chao Chen presents LUDEN, which incorporates uncertainty into morphology-aware denoising of spatial transcriptomics. Yue Li and Dylan Mann-Krzisnik present SpatialJEPA, using graph-context distillation to transfer tissue and metabolic context across molecular assays. These contributions motivate discussion of how spatial and morphological information can guide integration without obscuring assay-specific biological signals.

Mechanistic interpretation and three-dimensional organization. Paveethran Swaminathan and colleagues present MetaKnogic, a framework for biochemically grounded AI reasoning about metabolic variation using multimodal spatial omics. Weixiu Dong and colleagues address reconstruction of extrachromosomal DNA (ecDNA) organization and its relationship to function in cancer. Caleb Hallinan and colleagues examine kidney nephron pseudostructure reconstruction for pseudo-three-dimensional comparison of gene expression gradients. Together, these talks connect computational representations to biochemical mechanisms and spatial structure.

Disease biology and translational prediction. Rachel Fox and colleagues investigate shared cortical axes of genomic variation and spatial transcriptomics in human brain aging. Spencer Watson, Raphael Gottardo, and the Mosaic Consortium present a multimodal glioblastoma atlas focused on extracellular matrix differences in perivascular border zones associated with immune infiltration. Lana Garmire and colleagues present HisToSpatialCNV, an interpretable deep learning approach for predicting spatial copy number variation from histopathology. Lihe Liu and colleagues present NICER, integrating spatial transcriptomics and histopathology for niche detection and patient-level prediction. Lulu Shang and colleagues address prototype-driven fusion of pathology and spatial transcriptomics for interpretable survival prediction. These studies raise questions about biological validation, patient-level evaluation, and the interpretation of spatial predictors.

Discussion across the program will focus on evaluating integration across assays and cohorts, distinguishing predictive associations from mechanistic explanations, and identifying useful benchmarks for translational research. If additional program time is approved, a panel will provide a dedicated forum for these questions.

4. **Conclusions**

Multimodal spatial omics creates opportunities to connect molecular measurements, tissue organization, and disease phenotypes. By bringing methodological contributions into dialogue with biological and translational applications, this workshop aims to clarify current capabilities, identify limitations that require further validation, and encourage collaboration on interpretable and generalizable computational approaches. The program provides a focused forum within PSB for defining the next questions at the interface of AI, spatial biology, and medicine.

NEXT-GENERATION BIOCOMPUTING DOCTORAL TRAINING IN THE ERA OF AI

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This PSB 2027 workshop examines how doctoral education in health AI, biomedical informatics, computational biomedicine, computational biology and related fields should evolve in the era of artificial intelligence and large language models. Invited perspectives address international AI and digital-health training, computational biology within computer science, biomedical informatics curriculum innovation, health-system-embedded Health AI education, and AI-augmented research practices including vibe coding. The workshop will compare training models, examine tensions involving technical depth, domain expertise, mentoring, assessment, and research ownership, and identify practical experiments that students, faculty, and program leaders can implement in their own settings.

Keywords: doctoral education; health AI; biomedical informatics; computational biology; large language models; AI-assisted research; curriculum design; assessment; vibe coding

1. Introduction

Artificial intelligence is reshaping the scientific and professional environment in which the next generation of biocomputing researchers will be trained. Advances in machine learning, large language models, automated coding, and AI-assisted research are changing how computational methods are developed, how analyses are conducted, and how scientific knowledge is communicated. In health AI, biomedical informatics, computational biomedicine, and computational biology and related fields, these changes intersect with distinctive challenges. Researchers must work with heterogeneous, incomplete, and longitudinal clinical and biological data; connect computational models to disease mechanisms, patient trajectories, and care processes; collaborate across computational, biological, and clinical disciplines; and account for the consequences of error in settings where model outputs may influence scientific conclusions, clinical decisions, or health-system operations.

These conditions create substantial opportunities for doctoral education, while also challenging existing assumptions about what students need to learn and how they should be trained. Biocomputing programs must integrate contemporary AI and machine-learning methods without displacing the methodological, clinical, biological, and socio-technical foundations of their disciplines. They must prepare students to work in environments where AI systems can generate code, summarize literature, propose analyses, and assist with scientific writing, while ensuring that students can evaluate, explain, reproduce, and take responsibility for AI-assisted work. The goal is

therefore not simply to add more AI content to already dense curricula, but to develop researchers with the capacity to learn continuously, formulate meaningful problems, collaborate across disciplines, and exercise sound judgment in complex biomedical settings.

The workshop, *Next-Generation Biocomputing Doctoral Training in the Era of AI*, brings together educators, program leaders, researchers, faculty mentors, and trainees to examine how doctoral education should evolve in response to these changes. It focuses on health AI, biomedical informatics, computational biomedicine, and computational biology, with particular attention to how different institutional and disciplinary contexts shape doctoral training. The workshop asks how programs can balance technical depth with domain expertise, formal coursework with self-directed learning, methodological rigor with rapid experimentation, and traditional expectations of independence with new forms of AI-assisted research.

The workshop is intended for PhD students and postdocs, faculty mentors, instructors, program directors, and health-system or industry leaders who contribute to doctoral training. By connecting program-level questions with the everyday practices of mentoring, evaluating AI-assisted work, and conducting research with clinical and biological data, the workshop aims to help the biocomputing community prepare researchers not only to use AI systems, but also to understand, evaluate, govern, and responsibly extend them.

2. Workshop Talks

The program combines short talks on distinct doctoral training models with a guided panel and a practicum-style closing discussion. The talks provide examples of international, computational biology, biomedical informatics, and health-system-embedded approaches to doctoral education. The panel will examine design tensions involving curriculum, mentoring, assessment, research ownership, and the distinctive identity of a Health AI or biomedical informatics PhD. The closing practicum will focus on practical experiments that participants can implement in a course, laboratory, mentoring relationship, or doctoral program, including approaches to AI-use policies, code validation, assessment, and self-curated learning.

The workshop features invited perspectives on distinct approaches to doctoral training in the era of AI. Karin Verspoor from RMIT University will discuss international approaches to education in artificial intelligence, natural language processing, and digital health. Her perspective will highlight how national training initiatives, institutional structures, funding environments, and interdisciplinary programs shape doctoral education and the development of computational health researchers.

Ben Raphael from Princeton University will describe computational biology training within a computer science PhD environment. His perspective will examine a mentoring-centered, method-intensive model in which students develop expertise through research in computational and cancer genomics, including genomic alterations, tumor evolution, single-cell and spatial methods, and AI-driven modeling. This model provides an opportunity to consider how specialization, supervision, and research experience can substitute for or complement formally defined health AI curricula.

John H. Holmes from the University of Pennsylvania will contribute a biomedical informatics perspective grounded in doctoral education and curriculum innovation. His discussion will address how established informatics programs can incorporate modern AI and machine-learning methods while preserving foundational training in clinical informatics, population health, data governance, and responsible research practice. This perspective is particularly important for understanding how mature programs can evolve without losing the disciplinary depth that supports trustworthy biomedical research.

Graciela Gonzalez-Hernandez from Cedars-Sinai Medical Center will discuss a health-system-embedded model of doctoral training in Health AI. The PhD pedagogy adopted at Cedars-Sinai emphasizes students' capacity to learn, rather than dependence on a fixed body of technical content that may quickly become outdated. Students develop as researchers through an apprenticeship model in which they work closely with faculty and clinicians, learn to formulate meaningful problems, and iteratively connect computational methods to clinical needs. Active learning, clinical immersion, project-based work with real hospital data, and integration with AI governance and evaluation are central to this model. The health-system setting allows students to learn not only how to build models, but also how clinical workflows, institutional priorities, data provenance, safety, and implementation constraints shape responsible Health AI research.

Steven E. Brenner from the University of California, Berkeley, will focus on AI-augmented research and the emergence of vibe coding in computational biology and the life sciences. Natural-language-to-code systems may allow researchers to prototype analyses, explore datasets, and construct computational pipelines more rapidly, including for students without extensive formal programming backgrounds. However, vibe coding also introduces new risks and responsibilities. Doctoral students must be able to validate AI-generated code, recognize hidden assumptions and errors, reproduce analyses, explain computational decisions, and modify generated pipelines when research questions change. These developments challenge traditional assumptions about programming competence, supervision, authorship, and independent work. The talk will consider how doctoral programs should teach students to validate, explain, debug, modify, and take responsibility for AI-generated code.

Together, these talks present complementary perspectives on doctoral training across institutional, disciplinary, and national contexts. They address established and emerging program models, the role of mentoring and clinical immersion, the integration of AI and machine learning into curricula, and the changing expectations surrounding computational competence and independent research.

3. Discussion

The workshop's central discussion will examine the design tensions that arise when doctoral programs adapt to pervasive AI. One tension concerns depth versus breadth. Students increasingly need familiarity with machine learning, large language models, software engineering, clinical data, responsible AI, and domain-specific science. However, doctoral training cannot simply expand indefinitely. Programs must determine which competencies are essential, which can be developed through self-directed learning, and which should remain the responsibility of formal coursework and supervision.

A second tension concerns methods versus domain knowledge. Health AI researchers must understand both advanced computational methods and the clinical, biological, and organizational contexts in which those methods are applied. Programs that emphasize generic AI skills may produce technically capable graduates who lack sufficient understanding of healthcare and biomedical research. Conversely, programs that focus primarily on domain knowledge may leave students unprepared for rapidly changing computational practices.

A third tension concerns assessment and research ownership. When AI systems can generate code, analyses, literature summaries, and written text, conventional assignments and milestones may no longer reliably measure individual understanding. Doctoral programs may need to place greater emphasis on oral examinations, live problem-solving, code walkthroughs, reproducibility exercises, and the ability to explain and defend an analytical pipeline. These approaches can distinguish productive use of AI as a research tool from reliance on AI outputs that a student cannot evaluate or justify.

These questions will be explored through an open, moderated panel rather than a sequence of independent program descriptions. The panel will ask whether programs have deliberately removed or de-emphasized topics to make room for AI, what makes a Health AI or biomedical informatics PhD distinct from a generic AI or data-science degree, how programs can demonstrate that students own and understand AI-assisted work, and how doctoral education can remain attractive and meaningful when students can enter industry without pursuing a PhD.

The discussion will also consider how programs should establish expectations for responsible AI use. Important questions include how students should document AI assistance, how AI-generated code should be validated, how errors should be attributed, and how mentors can supervise work in which substantial portions of the implementation were generated through natural-language interaction. These issues affect not only coursework and examinations but also dissertation research, authorship, research integrity, and professional preparation.

Finally, the workshop will address opportunities for collaboration and self-curated learning. Participants may benefit from shared curricula, open syllabi, peer-led reading or coding groups, cross-institutional project opportunities, common assessment frameworks, repositories of validated teaching materials, and communities of practice for mentoring in AI-intensive research environments. Because many faculty members and students do not control an entire doctoral program, the practicum-style closing discussion will ask each participant to identify one concrete experiment for the coming year, such as changing an assessment, piloting an AI-use policy, creating a code-validation exercise, or developing a structured learning plan.

4. Conclusion

The workshop highlights that next-generation biocomputing doctoral education cannot be defined solely by adding AI courses to existing curricula. It requires reconsidering how programs combine

methodological depth, domain expertise, clinical and biological context, mentorship, assessment, and research practice.

The invited perspectives provide a basis for comparing different models: international and interdisciplinary training initiatives, computer-science-based computational biology programs, established biomedical informatics curricula, health-system-embedded Health AI programs, and AI-augmented approaches to computational research. Their convergence suggests that future doctoral training will need to support both technical adaptability and deep scientific understanding.

The workshop's intended outcome is a set of practical experiments that participants can pursue over the following year. These may include revised assessment practices, explicit guidance for AI-assisted research, new approaches to teaching and validating AI-generated code, self-curated learning opportunities, and stronger cross-institutional collaboration. The discussion will also support longer-term community efforts, such as a shared resource repository or a perspective on doctoral training in Health AI and biomedical informatics in the era of pervasive AI and vibe coding. More broadly, the workshop aims to help the biocomputing community develop doctoral programs that prepare researchers not only to use AI systems, but also to understand, evaluate, govern, and responsibly extend them.