



## Diagnostics and AI: The Core Technology Drivers of Precision Health

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ASU National Diagnostics Summit 15 October 2025 ASU Health Futures Center, Phoenix, AZ Slides available @ https://casi.asu.edu/presentations/

### The Diagnostics Journey

- from historical predominance of unianalyte Dx tests to increasingly complex multianalyte (multiplex) assays
- from dominance of centralized laboratory testing to include new decentralized diagnostic capabilities for real-time remote health monitoring
- from isolated diagnostic "snapshots" in episodes of overt disease to lifelong longitudinal profiling of health risk across the health-to-disease continuum
- ever earlier detection and proactive mitigation of health risk
- extending the disease-free "health span" as the core value proposition in precision health

## Multimodal Diagnostic Technologies as the Foundational Drivers of Precision Health

biomarkers and biosignatures

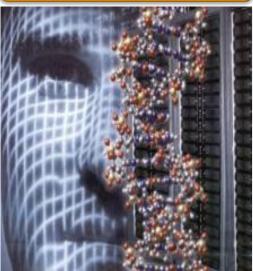
digital health technologies

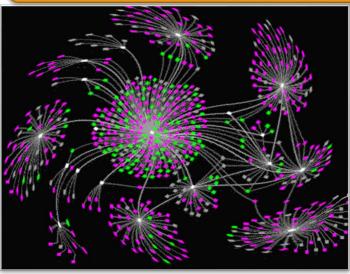
a new taxonomy of disease and causal molecular mechanisms of disease longitudinal monitoring of changes in health status

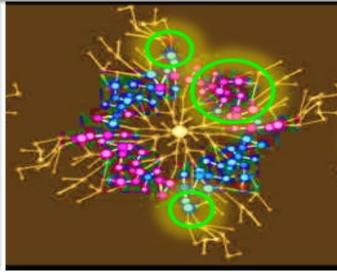
### **MultiOmics and Precision Health**

(Epi)Genomics and MultiOmics Profiling

Mapping Altered Molecular Signaling Networks in Disease:
Disease Subtyping and New MDx/Rx Targets









MDx Biomarkers of Disease Predisposition and Subtyping of Overt Disease for Optimum Rx Selection

The Challenge of Big (Messy) Data

### Remote Health Status Monitoring and Precision Health



networked connectivity: telemedicine, wearables, sensors, smart devices and ChatBots (IoMT)

### Remote Health Monitoring and Precision Health

- decentralized Dx testing in settings outside the clinic
  - in-home convenience (and expansion of hospital-at-home)
- improved therapeutic adherence
  - polypharmacy and chronic disease comorbidities
- faster detection of altered clinical risk and reduced hospitalization
- facile EHR data integration and automated 'risk alerts' to implement changes in case management

## Major Knowledge Gaps: SDoH, Lifestyle, Environmental Exposure (Exposome)

#### From Womb to Tomb:







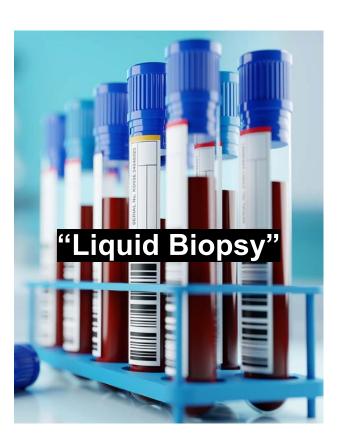
SDoH, Lifestyle, Health Disparities, Environmental Hazards (Exposome)







### Blood-Based Multiplex Molecular Diagnostics for Longitudinal Health Monitoring

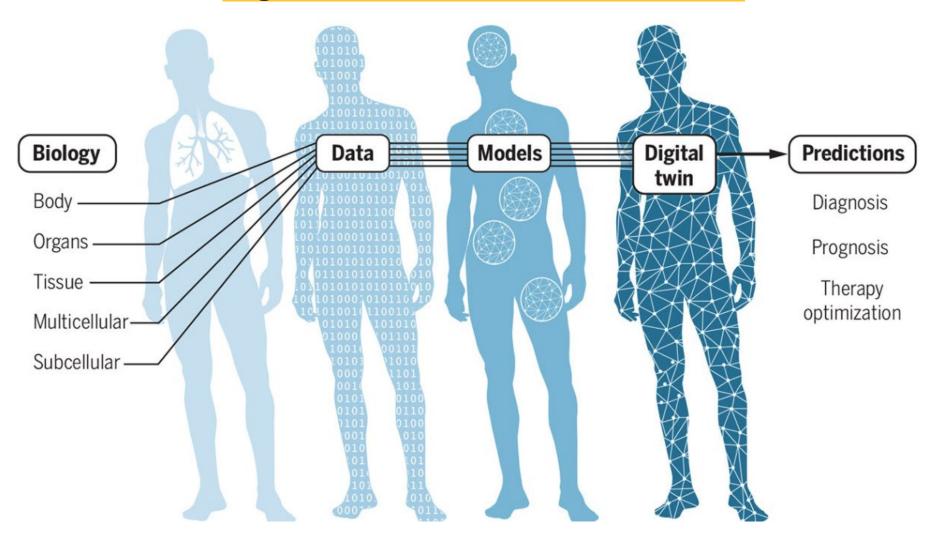


- minimally invasive platform for repeat assays for longitudinal profiling
  - everyone becomes their own control
- high biomarker information content in both plasma and buffy coat
- validation of 'signature' fidelity and concordance between blood and affected tissue(s)
  - limit of detection
  - population heterogeneity
  - accuracy in disease staging
- design of pan-analyte, pan-disease multiplex tests

#### Blood-Based Multi-Cancer Early Detection (MCED) Liquid Biopsy

- aspiration to detect early-stage cancers (class I/II) and preneoplastic lesions in 50 cancer lineages
- high specificity but low sensitivity (15-40%) reported in data published to date
  - unacceptable rates of false-positive and falsenegative cases
  - follow up cost and psychosocial burden for FP and misplaced assurance for FN
- variation between different tumor lineages in kinetics of biomarker 'shedding' and different types of tumor-derived analytes

#### **Digital Twins and Precision Health**



"best match" of individual deep phenotyping signatures with larger cohorts with known treatment and clinical outcomes

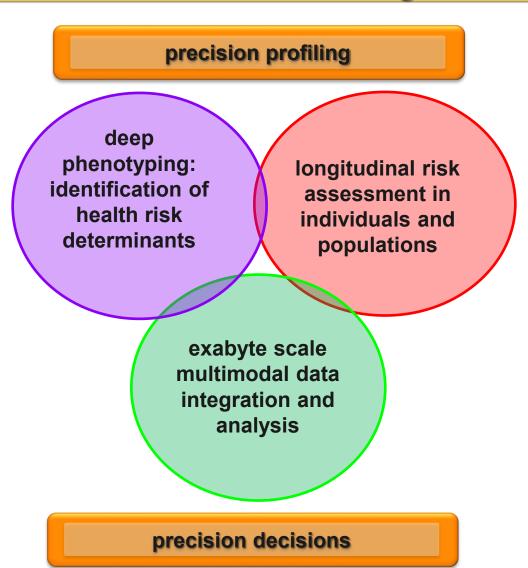
#### **Computational Modeling to Predict Future Disease Risk**

## Learning the natural history of human disease with generative transformers

A. Shmatko et al. (2025) Nature <a href="https://doi.org/10.1038/s41586-025-09529-3">https://doi.org/10.1038/s41586-025-09529-3</a>

- Delphi 2M
  - training set: 0.4M UK Biobank participants
  - external validation set: 1.9M Danish health system
- Al pattern analysis of multimodal health data
  - inherited risk, diagnoses, clinical treatments, lifestyle and socioeconomic status
- accuracy in 20-year forward modeling of chronic disease and clustered co-morbidities
- assembly of ever larger population data sets, inclusion of new data categories and new Al platforms will increase accuracy
  - revealing currently 'cryptic' risk patterns

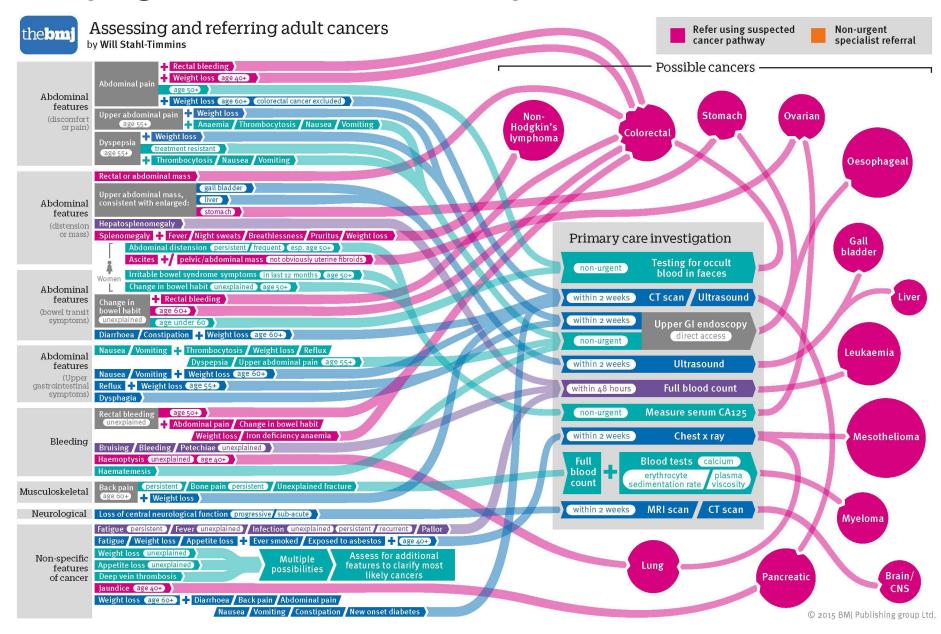
# Big Biology: Big Data The Defining Paradigm in Precision Health and the Evolution of a Data-Centric Learning Health Ecosystem



### The Reality Gap in Precision Health

- many aspects of structure, capabilities and incentives of current health ecosystem misaligned with delivery of precision health
- major HCP knowledge gaps outside AMCs
  - anachronistic education/training curricula
- slow adoption
  - oncology in vanguard but estimated only 30% cancer patients receive CMP and MRD monitoring
- expertise and CapEx investment to conduct high cost, high complexity tests
- regulatory ambiguities and reimbursement barriers

### Keeping Current in an Era of Rapid Innovation

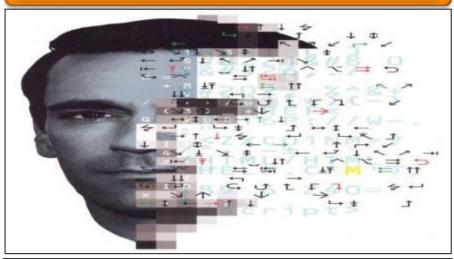


# Technology Acceleration and Convergence: The Escalating Challenge for Professional Competency, Decision-Support Systems and Future Medical Education

#### **Data Deluge**







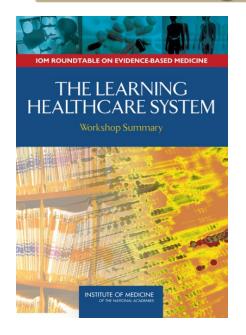


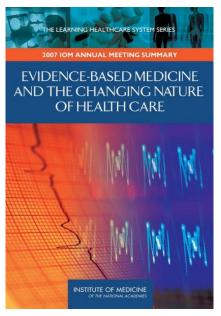


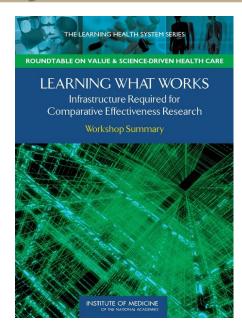
**Automated Analytics and Decision Support** 

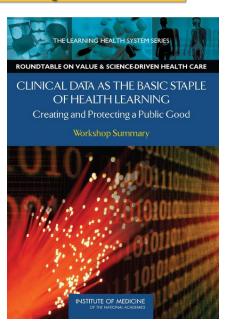
**Facile Formats for Actionable Decisions** 

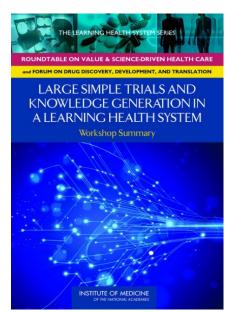
#### The Learning Healthcare Ecosystem: Elusive Aspirations

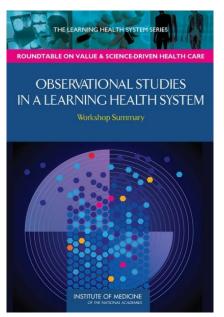


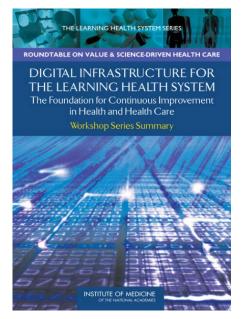


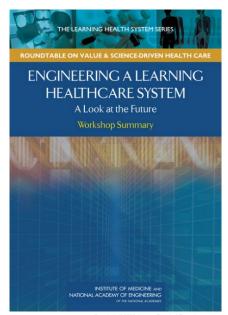


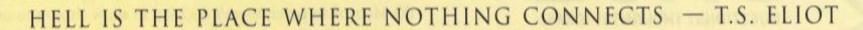










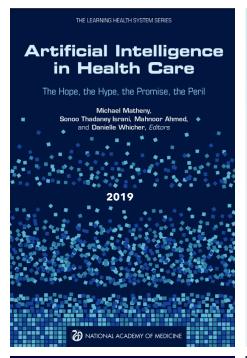


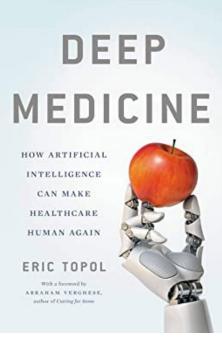


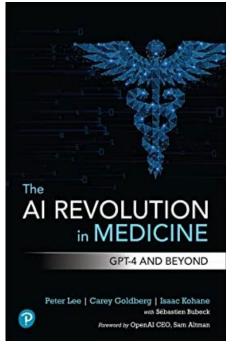
## Health Ecosystem Among Largest Producer of Data but Poorest in Use to Improve Health Outcomes

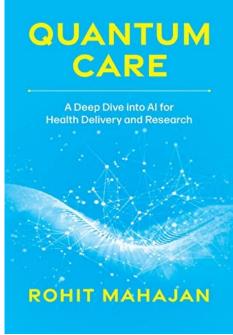
- legacy data systems and data tombs
- fragmented and poorly standardized data
- unstructured data
- database incompatibilities (intra- and inter-institutional)
- validation of data provenance including consents
- poor metadata

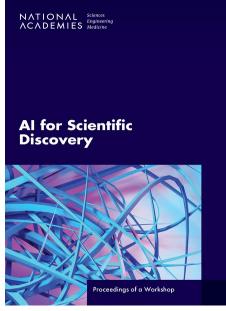
### Generalized Artificial Intelligence (GAI) and Healthcare

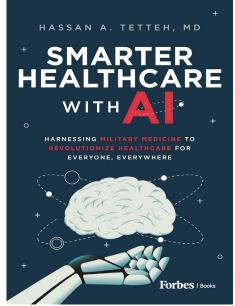


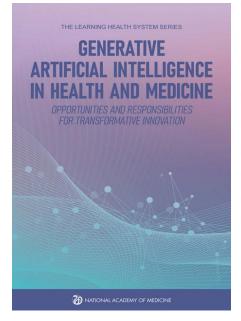


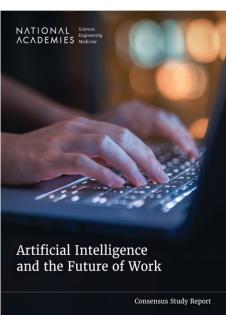












### The Changing Dimension of Big Data Analysis



ML/Al, LLMs and the Evolution of a Data-Centric Health Ecosystem

### Large-Language Models and Generative Artificial Intelligence: A Major Paradigm Shift in Biomedical Innovation



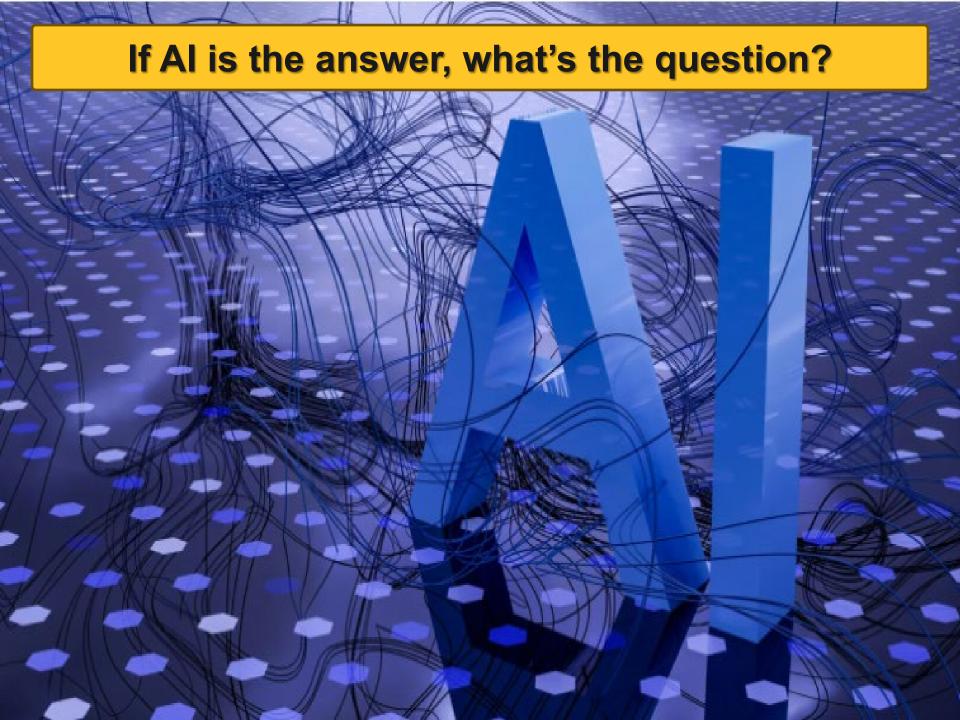
Isolated Data

Complex Networked Data

Complex Computational Data

## LLMs: An Inflection Point in the Evolution of a Data-Centric Learning Health Ecosystem

- multimodal data integration at scale
- NLP analysis of unstructured legacy data trapped in data tombs
- pattern analysis of hyperdimensional datasets
  - hypothesis-free mining to identify new diagnostic signatures from currently cryptic information on drivers of health risk
- accelerated adoption of automated agentic and autonomous systems
  - streamlining workflows
  - decisions



### If AI is the Answer, What's the Question?

- how was the specific Al platform validated for the claimed utility?
  - "fit-for-purpose"
- what are the productivity gains from the envisaged use and who benefits?
- which current processes will be improved or replaced (immediately or progressively?)
- workforce competencies and what upskilling will be required for proficient and safe adoption?

### ML/Al Platforms for Large-Scale Data Analysis, Workflow Redesign and Decision Support in Biomedicine

- explainable (transparent algorithmic design)
- actionable (fit-for-purpose)
- verifiable (pre-and post-deployment)
- scalable  $(V_1, V_2...V_n)$
- generalizable (multiple applications)
- controllable (anomaly detection audit, prevention of untoward/unintended outcomes, "kill switches")
- trusted (end user adoption)

### Validation of Large Language Model Al Platforms in Clinical Care Decisions

- transparency and patient informed consent when Al is used in care decisions
- new malpractice liabilities?
  - harm and liability from premature use of poorly validated algorithms (platform developers, HCPs, or the health systems which approved adoption?)
  - harm from failure to use platforms validated as SOC (professional guidelines or regulatory labeling)

### The Rush to Regulate Al







- one size-fits-all oversight/legislation is ill-suited to technologies with broad applications (GPTs)
  - biotechnology (1980's), internet and social media (2000's) synthetic biology (2010's) and GAI (today)
- balancing perceived harms versus risk of stifling innovation
- private sector as predominant innovation driver and scrutiny of closed proprietary algorithms

### **DNR: Cultural Barriers to Adoption of Innovation in Healthcare**



**Denial** 

**Negativity** 

Resistance

## The Changing Nature of Human-Computer Interactions in an Era of LLMs and Al



- user education, training and experience
- Human Al-Teaming and Human-Al Joint Cognitive Systems
- varied retention of humans-in-the-loop in process automation and decision systems
- level of task complexity will determine the level of responsibilities and authorities assigned to humans or agentic/autonomous systems

## Al-Driven Decisions and Keeping 'Humans-in-the-Loop'

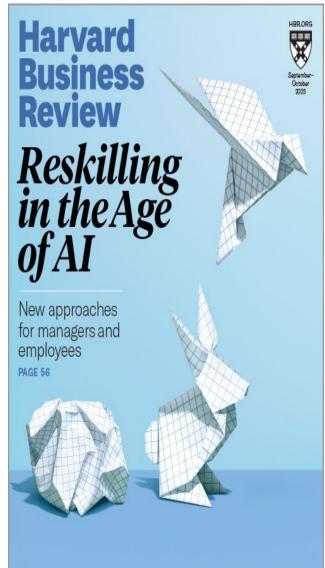
 widely different views on scale and timing of AI impact on future workforce competencies

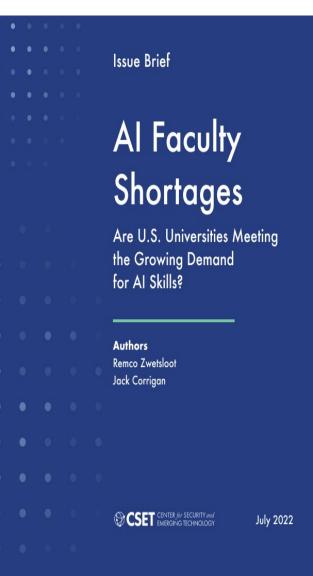




### Al and The Academic Biomedical Enterprise







## Competitive Success in an Era of Big Biology and Big Data

#### Standards

- analyte and test validation (fit-for-purpose)
- the disturbing reproducibility problem in academic publications

#### Scale

 managing the V7 data tsunami: volume, variety, velocity, validation, visualization, virtualization and VALUE

#### Speed

assimilation of new concepts, technologies and methods

#### Silos Subvert Solutions

 systematic integration of expertise, infrastructure and investment for agile design of new work process and decision trees

# Competitive Success in an Era of Big Biology and Big Data

#### Solutions

- new value propositions for the principal 'pain points' in healthcare
  - earlier risk identification and proactive mitigation
  - improve outcomes and health span
  - constrain the unsustainable growth in cost of care
  - resilience to global risks: pandemics, climate and commercial/military implications of losing the Al race

# Multimodal Diagnostic Technologies and Al and as the Foundational Drivers in Precision Health and a Data-Centric Learning Health Ecosystem

### health status of individuals and populations (precision profiling)

molecular profiling of health status

- biomarkers
- biosignatures

big biology big data big compute big bucks digital
health
and
remote
health
monitoring

Al analysis of exabyte-scale multimodal health data (precision decisions)

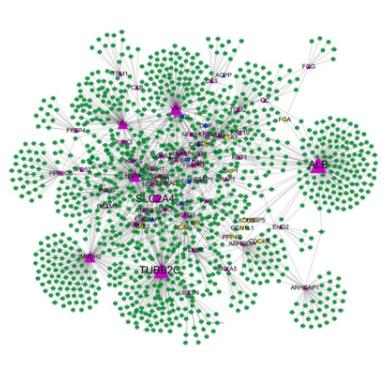
## Navigating Disruptive Change Demands New Thinking and New Capabilities



"The greatest danger in times of turbulence, is not the turbulence, it is to act with yesterday's logic."

- Peter Drucker (1980)

#### Multimodal Diagnostics and AI as Foundational Drivers of Precision Health:



- new thinking and new capabilities in an era of big biology and big data
- mapping 'signatures' of biological networks and dysregulation in disease
- new diagnostic technologies for life-long 'signature' monitoring to assess health status and risk
- improve risk prediction and ever earlier detection of evolving health risk and proactive intervention
- Al analysis of massive 'lottabyte' multimodal health data and data-centric 'decision-trees' to optimize health
- the disease-free health-span as the ultimate metric for health system performance

