Complex Adaptive Systems Initiative
Arizona State University

pwc

# Reconfiguring the Healthcare Ecosystem: The Future of Care

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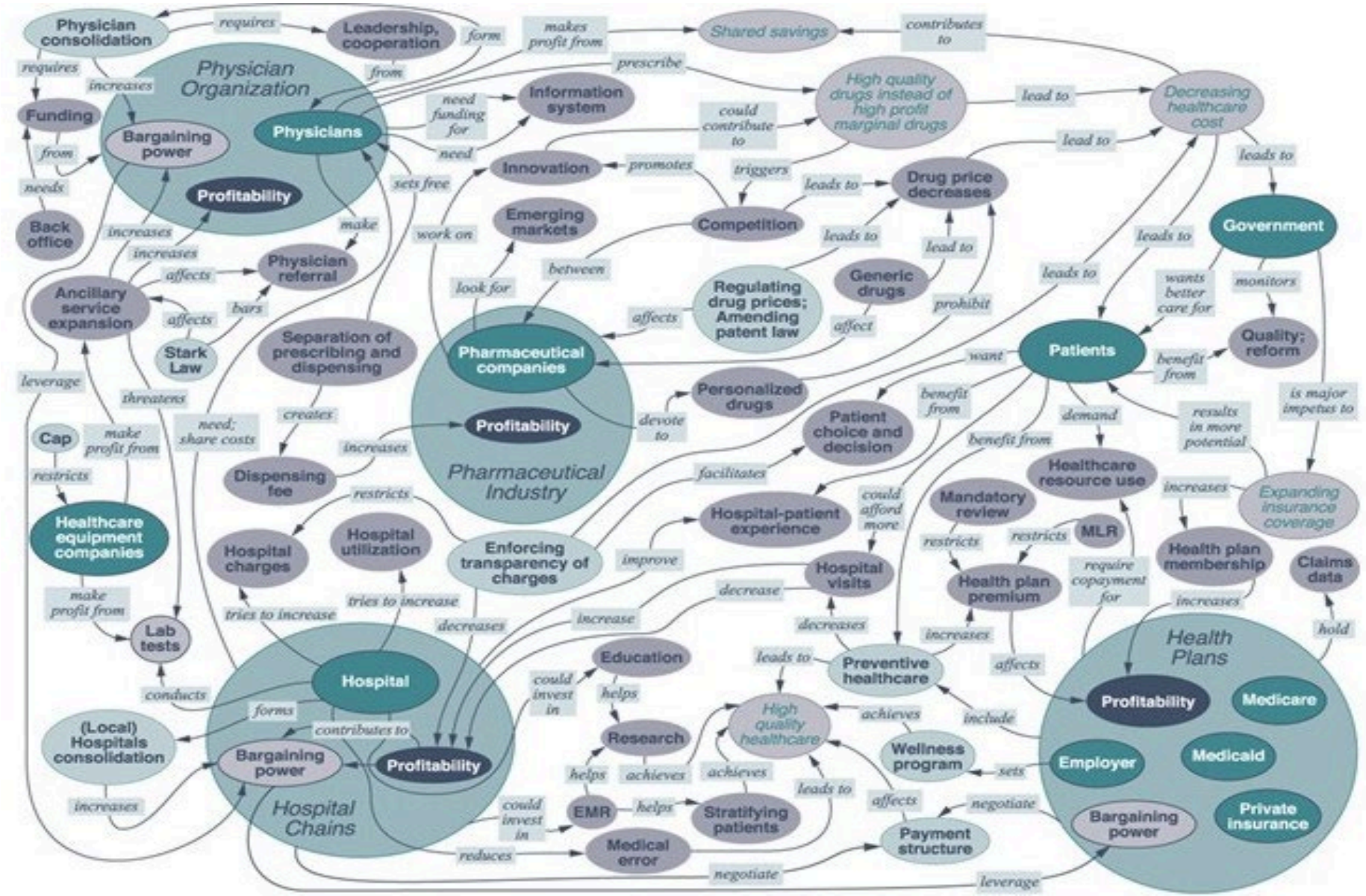
**PwC Global Health Summit 2025**
**13 May 2025, New York City**
**Slides available @ https://casi.asu.edu/presentations**

# The US Health Ecosystem




https://hmpi.org/2022/01/22/the-u-s-healthcare-ecosystem-payers-providers-producers/

# The US Health Ecosystem
# Fragmentation, Fragilities and Looming Disruptions

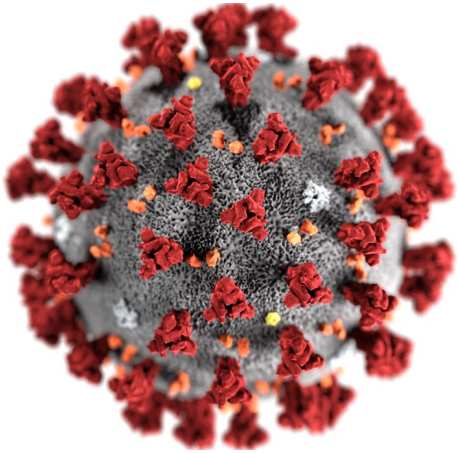
- disproportionate investment of $4.9 trillion annual expenditure on reactive management of active disease (90%) versus proactive focus on health optimization (10%)
- isolated silos of expertise and care services
- poor continuity in patient care
- unacceptable levels of error
- cost escalation without improved outcomes
- continued dominance of fee-for-service versus value-based-care
- wide zip code cost variation for same procedure and site-dependent pricing

# The US Health Ecosystem
# Fragmentation, Fragilities and Looming Disruptions

- aging society and chronic multi-morbidity disease burden
- widening health disparities
- workforce: labor shortages, burnout and technological obsolescence
- administrative burden and bloat
- largest producer of data but poorest in productive use
- growing cybersecurity breaches
- manufacturer offshoring and supply chain vulnerabilities

# Health Implications of Global Risks

## New Pandemic Threats



## Inadequate Pandemic Preparedness

## US Retreat from Global Health Initiatives

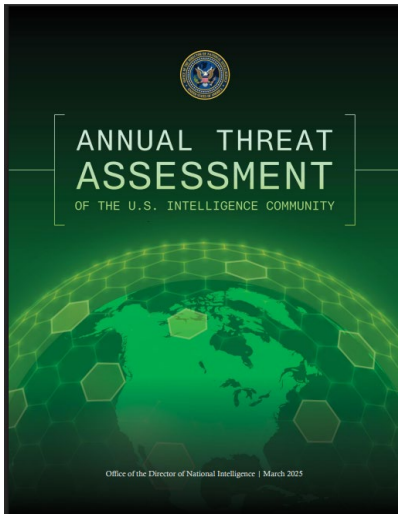
## Antimicrobial Resistance

## Agricultural Productivity Food Security

## Conflict and Humanitarian Disaster

# Climate and Health


# The Intensifying Competition for Commercial and Military Domination of the Bioeconomy and AI Innovation




## commercial bioeconomy

- synthetic biology
  - protein engineering
  - gene editing
- novel bioprocesses
- bioremediation
- ‘soft diplomacy’ to counter PRC-BRI expansion

## military applications

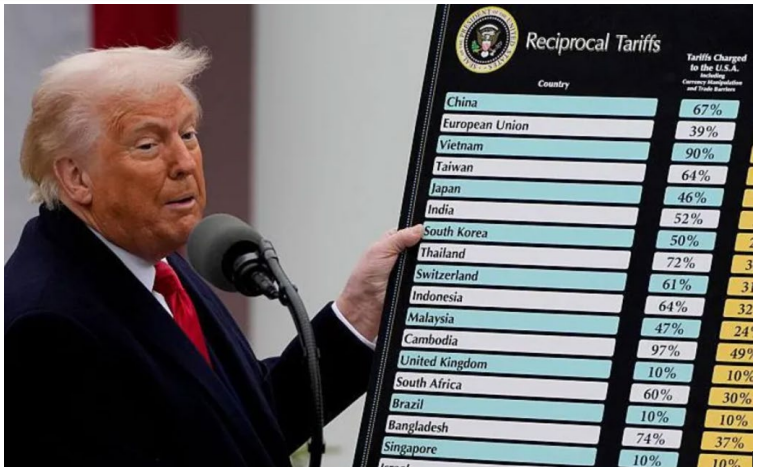
- proliferation of dual-use technologies
  - CBW
- industrial espionage/IP theft
- cyberwarfare and disinformation campaigns
- the race for quantum computing
  - Q-Day

# 100 Tumultuous Days in Healthcare
# Overdue Rational Reforms or Ill-informed Destruction?


- HHS workforce reduction and policy shifts
  - CMS, CDC, FDA, NIH
- reduced public sector funding for academic biomedical research

# Uncertainties for the Biopharmaceutical Industry

## Import Tariffs?




## International Reference Pricing ?


## Complete Ban on DTC Advertising or Elimination of Tax Credits ?

DUPIXENT® (dupilumab)

RINVOQ® upadacitinib

Skyrizi® risankizumab-rzaa

Tremfya® (guselkumab)

OZEMPIC® semaglutide injection

REXULTI® brexpiprazole tablets

Jardiance® (empagliflozin) tablets

KEYTRUDA® (pembrolizumab)

# Convergence

## Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

# The Physical: Digital Fusion

- new products and services which combine advances in biotechnology, engineering and computing
- new regulatory and reimbursement paradigms
- expanded cross-sector alliances/M&A in product innovation
- new cross-disciplinary workforce competencies
- escalating competitive risk from technological obsolescence

# Precision Health

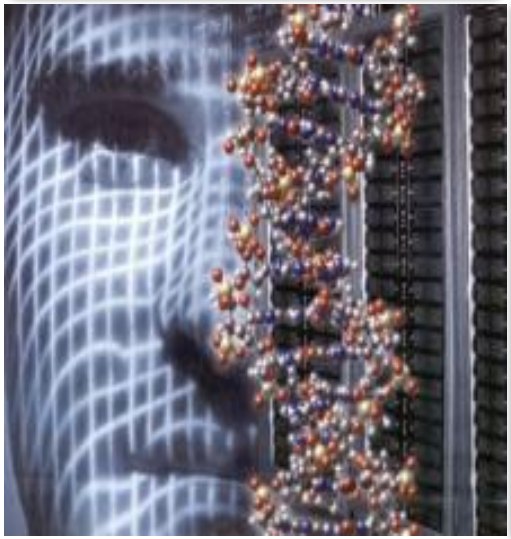
- optimize the health of populations and individuals by improved accuracy in the proactive identification and mitigation of health risks across the life span

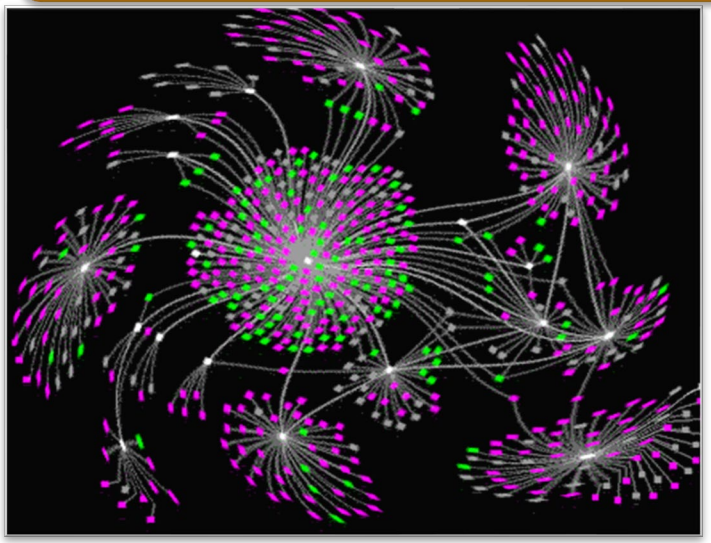
- multiple elements of the organization, capabilities, incentives and deliverables of the current health ecosystem are increasingly misaligned with this strategic aspiration

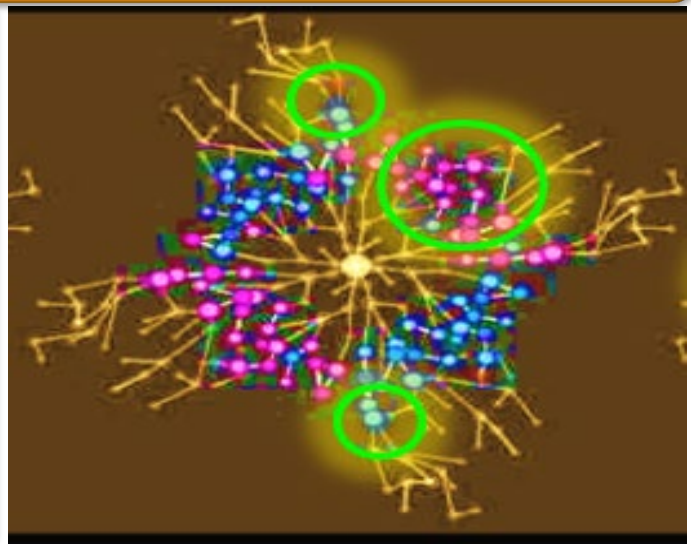
# Precision Health

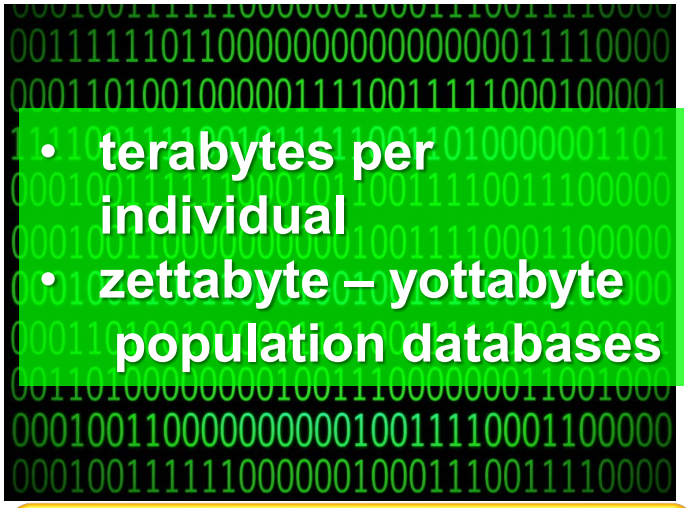
**(Epi)Genomics and MultiOmics Profiling**

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









- terabytes per individual
- zettabyte – yottabyte population databases

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

**The Challenge of Big (Messy) Data**

# From Reactive, Episodic Static "Snapshots" to Real Time, Continuous Monitoring of Multiple Signatures of Health Status

# Blood-Based (Liquid Biopsy) Profiling of Health Status in Individuals and Populations

- liquid biopsy
  - value of MultiOmics molecular biomarkers in diagnosis and treatment selection pioneered in oncology
  - now expanding to other diseases
- minimally invasive platform for longitudinal routine tracking of health status

# Expanding the ‘Care Space’ in Healthcare

- the majority of events that influence wellness/disease risk and treatment adherence occur outside of formal interactions with the healthcare system

- daily decisions by individuals have greater effects on their health than decisions controlled by the healthcare system

- rapid evolution of new technologies for real time remote monitoring of health status
  - Internet-of-Medical Things (IOMT)

# Remote Health Status Monitoring


networked connectivity: telemedicine, wearables, sensors and devices

# Smart Devices

automated drug delivery and improved therapeutic adherence

## Improved Use of Specialized Resources and Access to Expert Consultations


## Networked Telehealth Between Provider Organizations: Centralized 24/7 Connectivity

# The Demographics of an Aging Society: Clinical and Economic Challenges

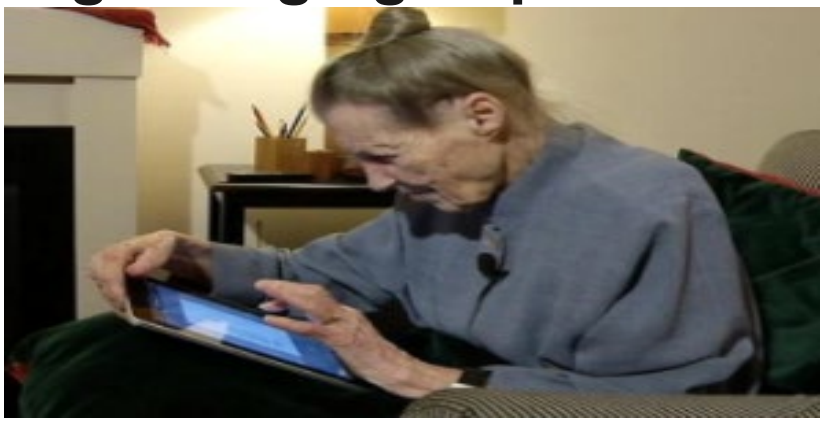
**longevity with extended wellness (health span)**

**OR**

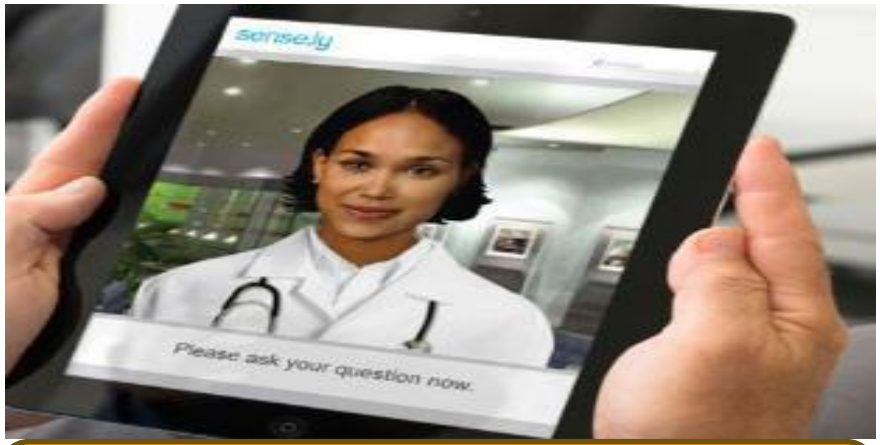
**multiple co-morbidities and low QOL**

# Digital Technologies and Aging in Place: Independent But Monitored Living for Aging Populations

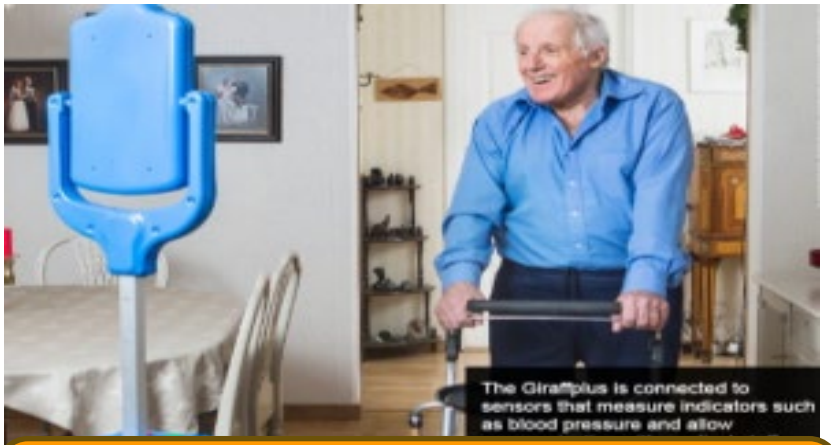
Rx adherence



cognitive stimulation




in-home support and reduced hospital readmissions




Chatbots and faster identification of clinical deterioration

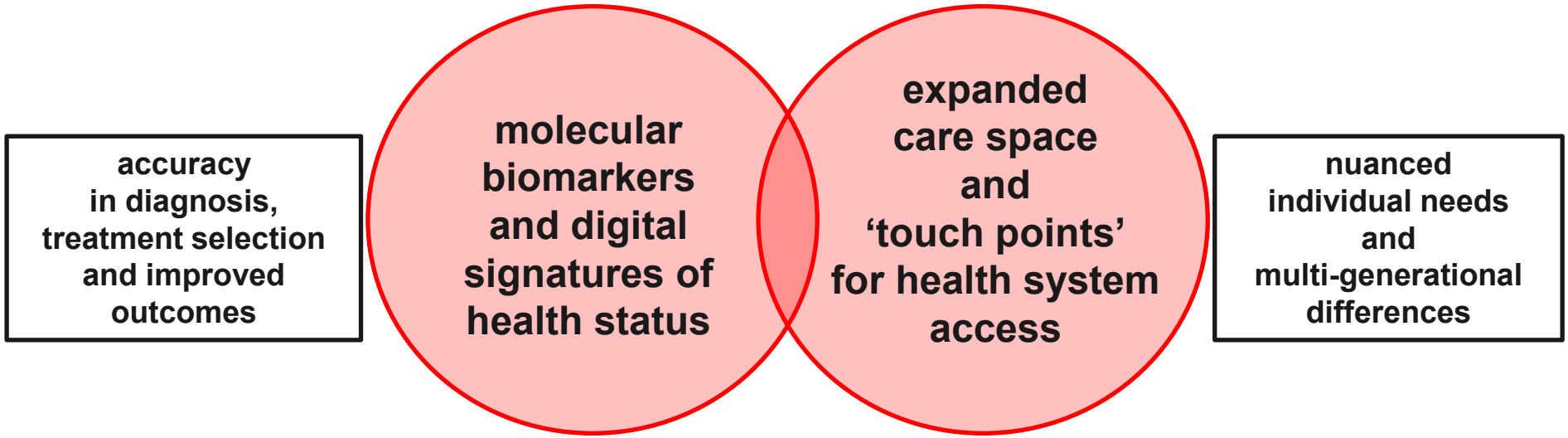
# Digital Health:
# Expanding the 'Care Space' in Healthcare

- **shift resources from speciality and acute care services into lower cost decentralized services and capitated care**
  - **primary care, preventative care, behavioral health**
  - **in home services for chronic disease care, including hospital at home**
  - **address SDoH and health disparities**

# Digital Health and Empowered Patients

- increasingly proactive and engaged consumers/ patients/families
- greater access to information on treatment options, cost and provider performance
- new clinical practice tools to optimize HCP-patient communication
- creation of senior executive level Chief Patient Experience Officer posts in large health provider organizations

# The Strategic Landscape for Health Risk Management

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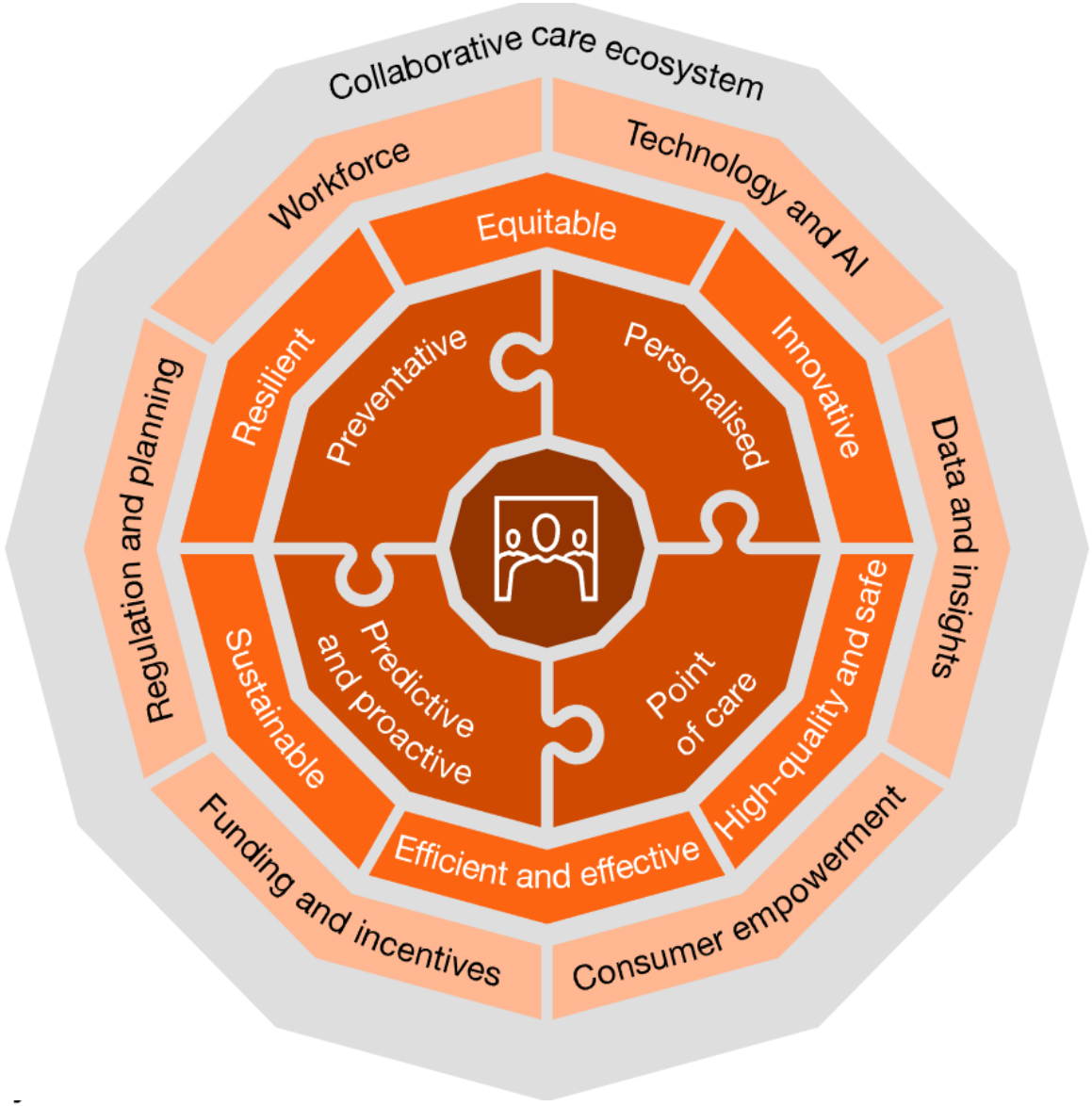
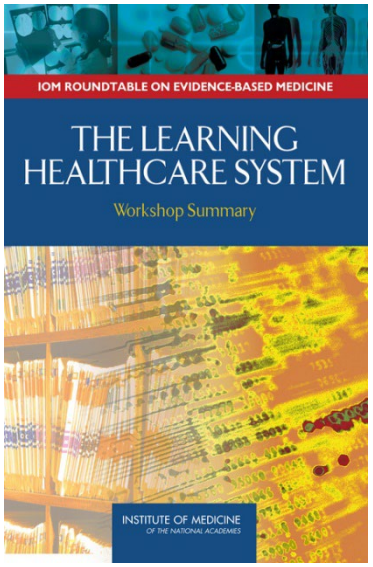
- proactive
- predictive
- preventative
- point-of-care
- personalized

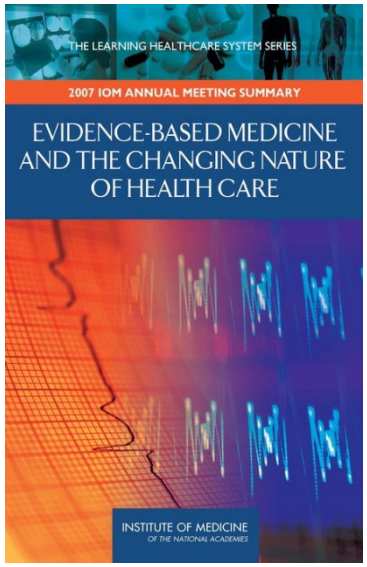
# The Strategic Landscape for Health Risk Management to Optimize Care

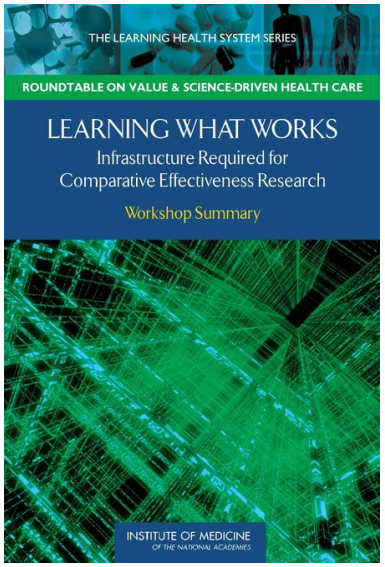


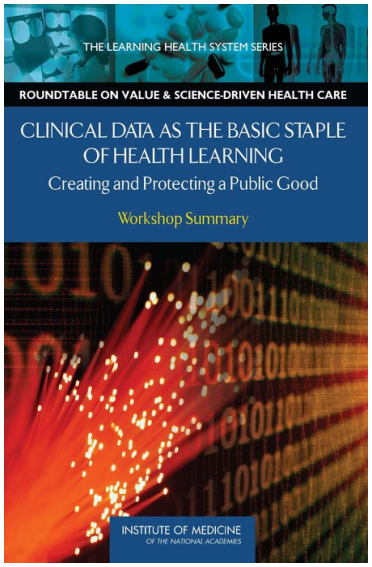

https://www.pwc.com/gx/en/issues/business-model-reinvention/how-we-care-for-ourselves/future-of-care-healthcare-ecosystem.html

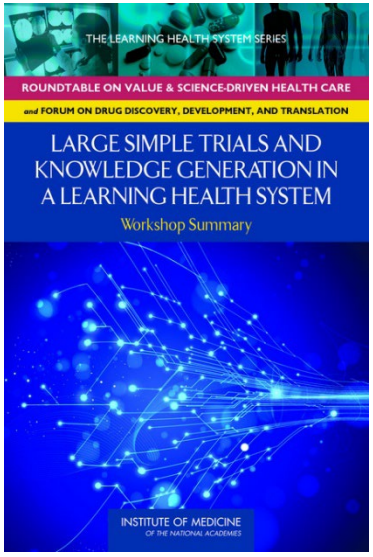
# The Learning Healthcare System

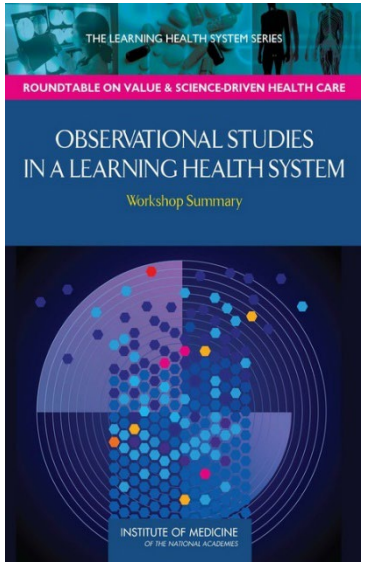


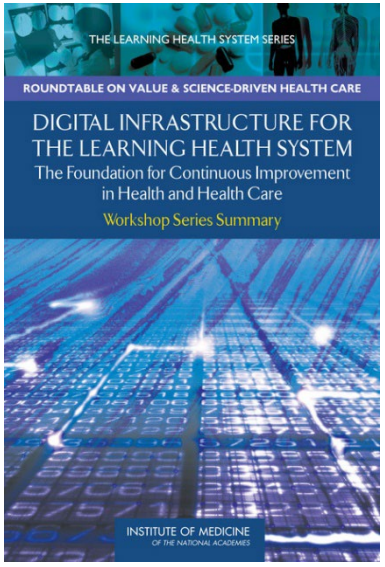



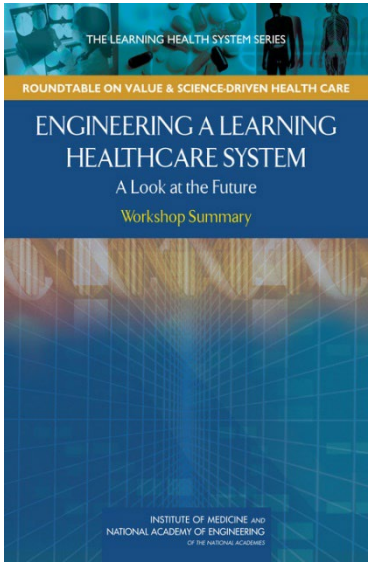



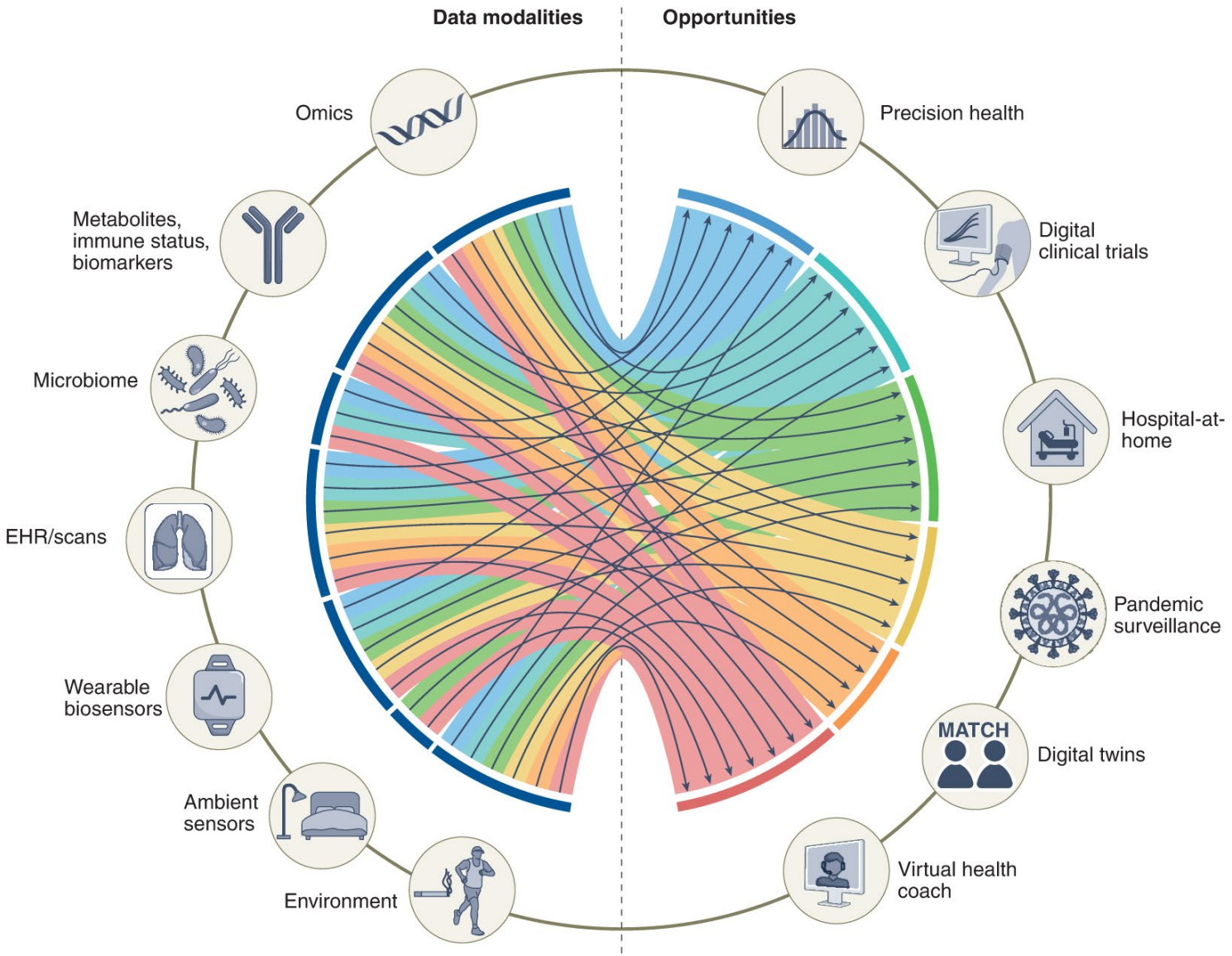




HELL IS THE PLACE WHERE NOTHING CONNECTS — T.S. ELIOT
Welcome to the Health Ecosystem

# Precision Health and Digital Health: Multimodal Data Integration for Management of Health Risk




J.N. Acosta (2022) Nature Med 28, 1784

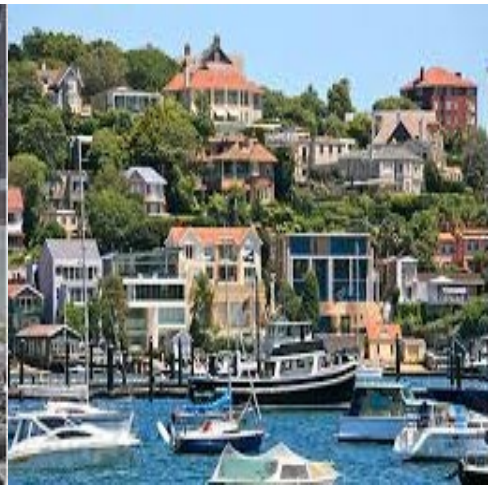
# Deep Phenotyping:
# Systematic Integration of Multimodal Data to Identify Health Risk

## From Womb to Tomb:




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

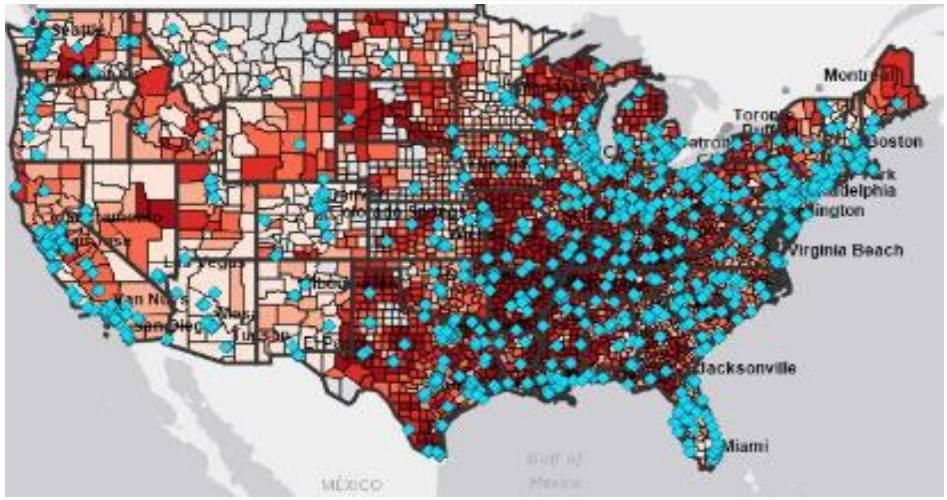


# Building Personalized ‘Digital Twins’: Matching Individual Deep Phenotypes to ‘Best Match’ Cohorts

**Individual Data**

**Population Databanks**




- ‘digital twins and siblings’: imputed ‘risk’ phenotypes
- risk predisposition and disease prevention
- selection of optimum treatment regimen for overt disease
- improved outcomes and QOL

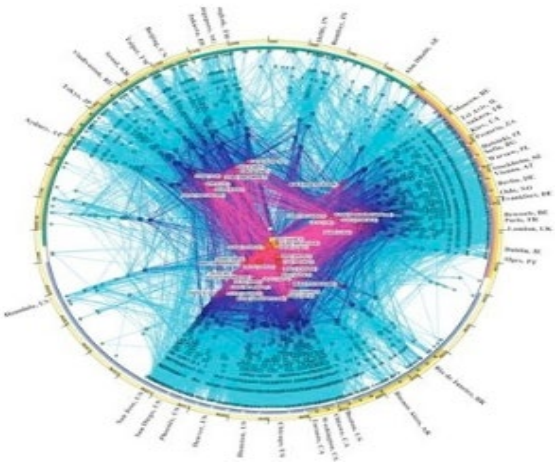
# Managing Big Data in Biomedicine Will Not Be a Simple Extrapolation from Current Practices

## Evolution of New Professional Competencies for Proficient Use of Advanced Computing, AI and Automated Clinical Decision Systems

# The Changing Dimensions of Big Data Analysis


**ML/AI and LLMs and Evolution of a Data-Centric Health Ecosystem**

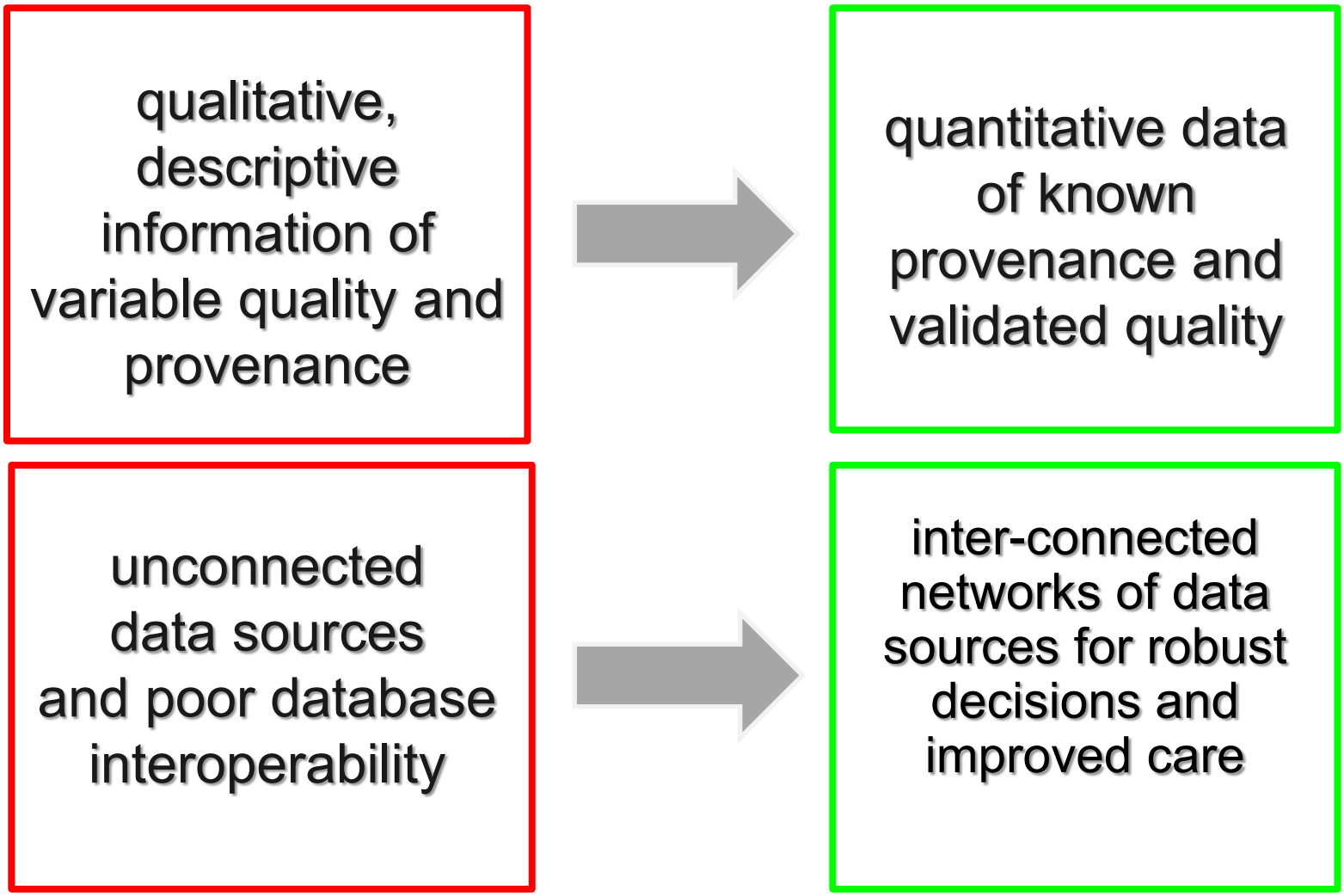
# Large-Language Models and Generative Artificial Intelligence: A Looming Paradigm Shift in Biomedical Innovation



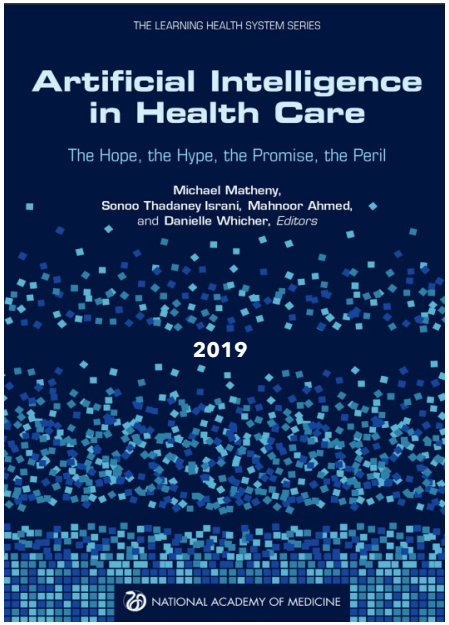
| Isolated Data | Complex Networked Data | Complex Computational Data |
|---|---|---|

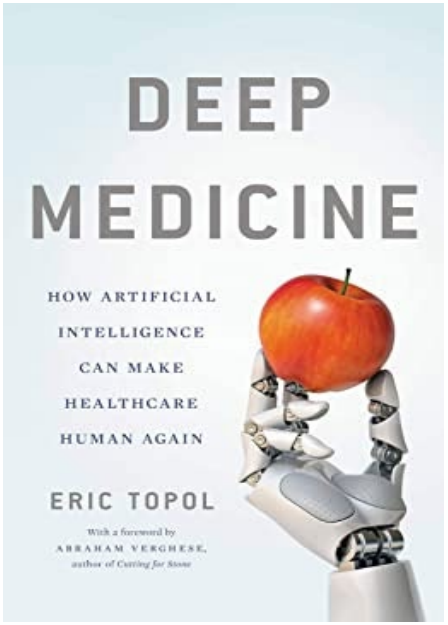
- availability of ever larger multimodal datasets for training GAI-based LLM analytics
  - exabyte data scale (and beyond)
  - NLP rescue of clinical notes trapped in data tombs
- automated combinatorial hyperdimensional analysis
  - large N parameters X large N entities (biospecimens, individuals, populations)

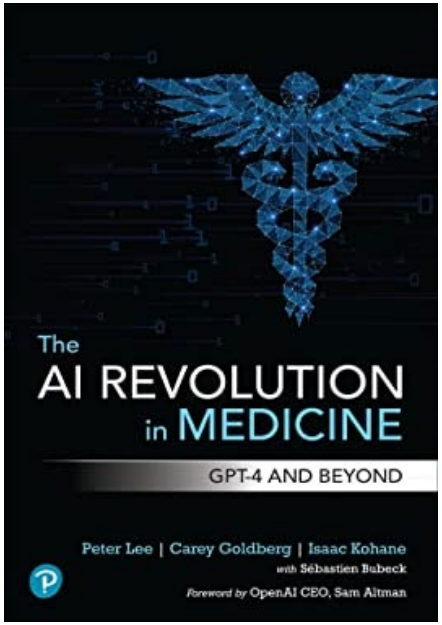
# Building a Learning Health Ecosystem
# Data Standards and Database Interoperability

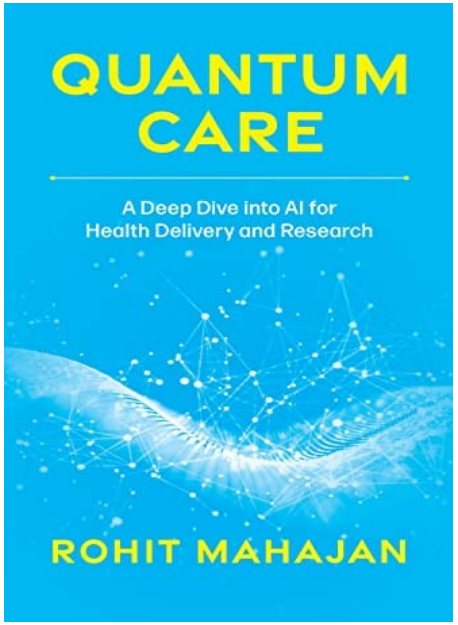


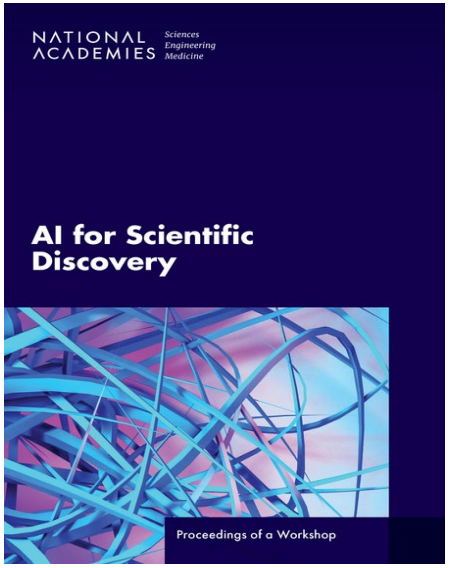
# Generalized Artificial Intelligence (GAI) and Healthcare

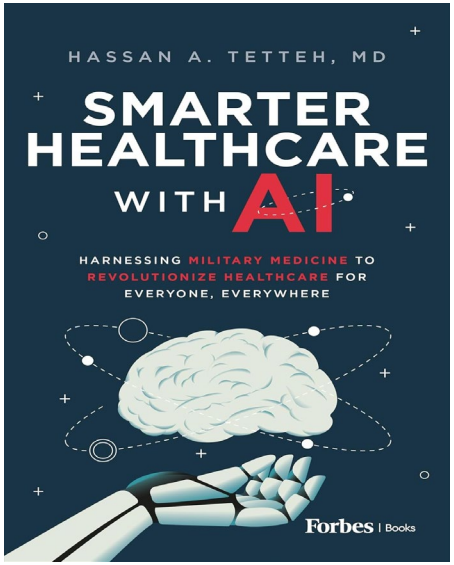


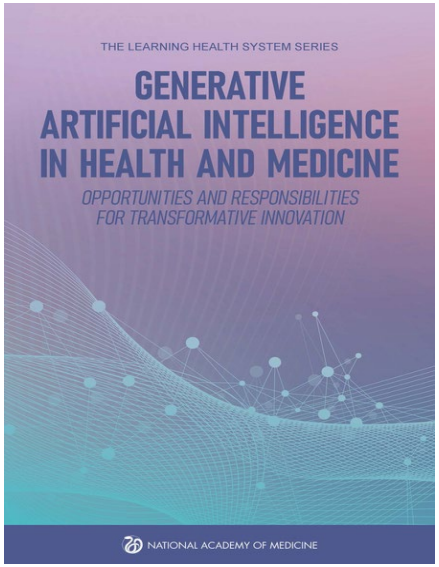



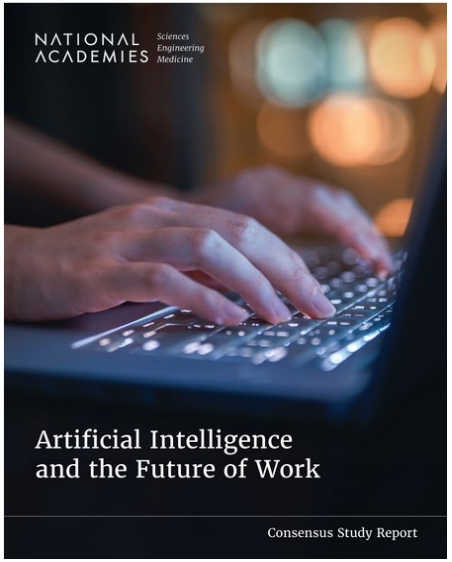



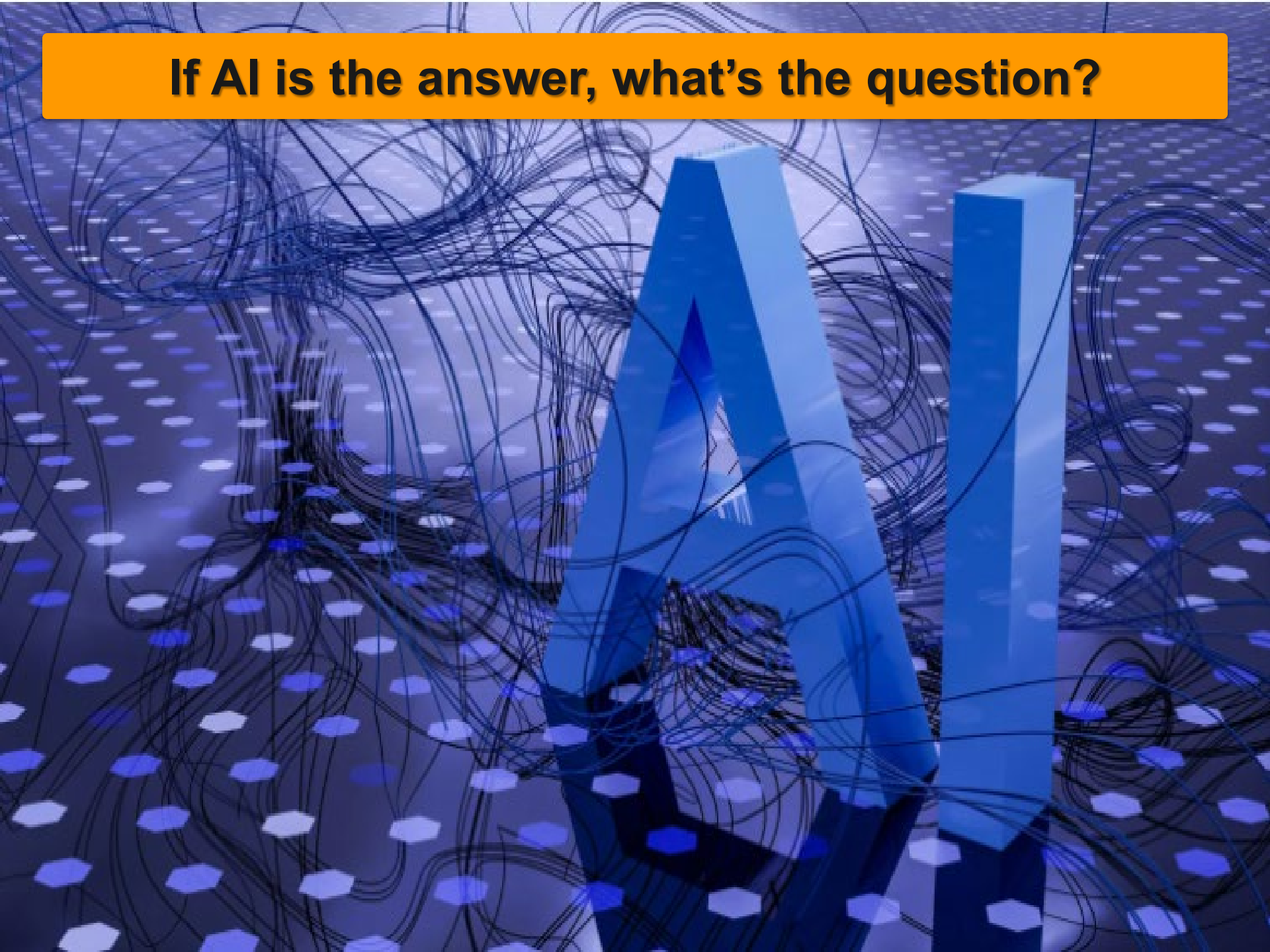



# The Future AI Landscape

- Assistive AI
- Augmented AI
- Addictive AI
- Agentic AI
- Autonomous AI
- Artificial General Intelligence

# If AI is the answer, what's the question?



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

- how was the specific AI platform validated for the claimed utility?
  - transparent and explainable AI
  - "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?)
  - cost savings, workforce impact, supply chain efficiencies/resiliency

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

- how generalizable is the platform for other uses?
- what upskilling and investment are needed for proficient and safe adoption?
- what are the advantages and risks of leading versus a fast-follower strategy?

Just What the Data Ordered

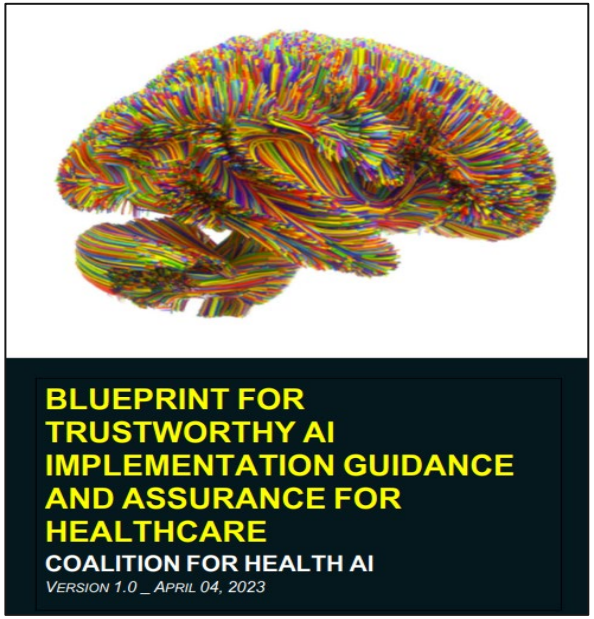
Machine Intelligence and AI Algorithms for Clinical Diagnosis and Treatment Decisions

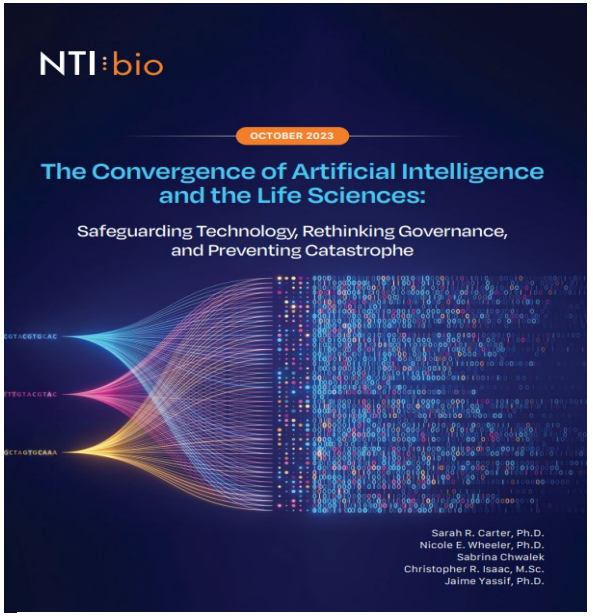
Black Box Medicine?

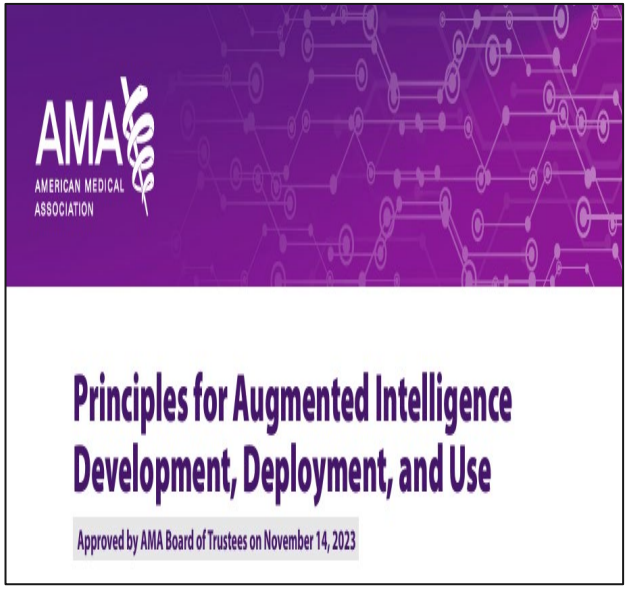
# The Rush to Regulate AI


- one size-fits-all oversight/legislation is ill-suited to technologies with broad applications
  - 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
- low probability of international harmonization

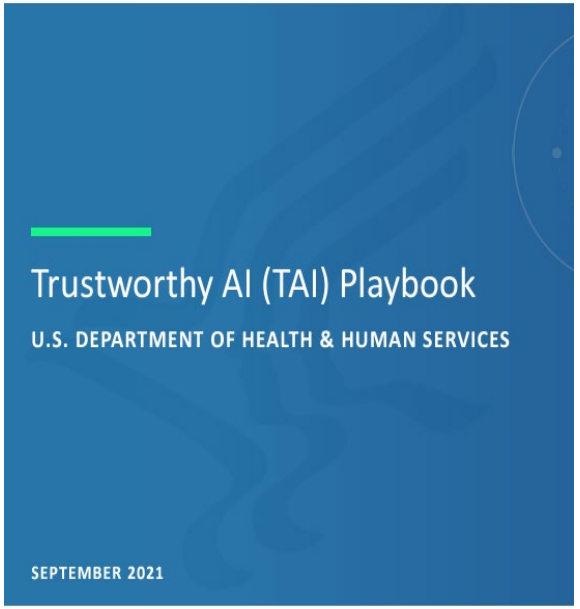
# Oversight and Regulation of AI in Healthcare





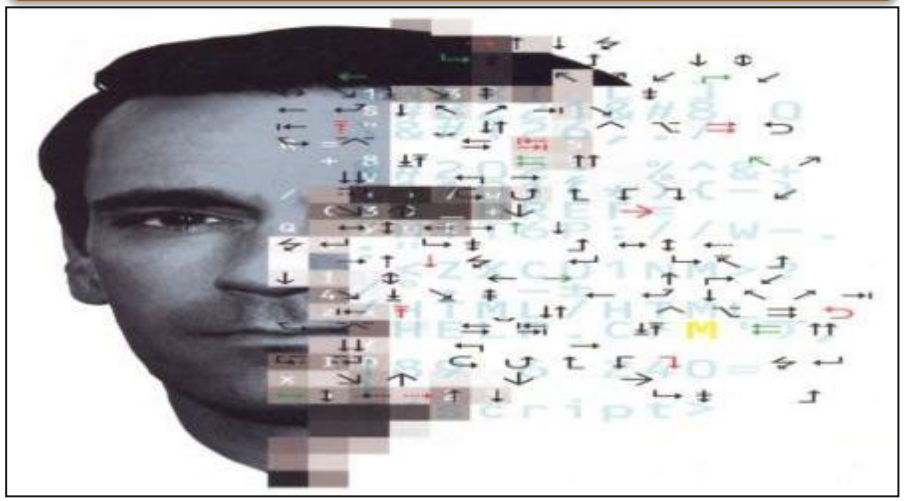
# Regulatory Oversight and Validation of Large Language Models AI Platforms in Clinical Decisions

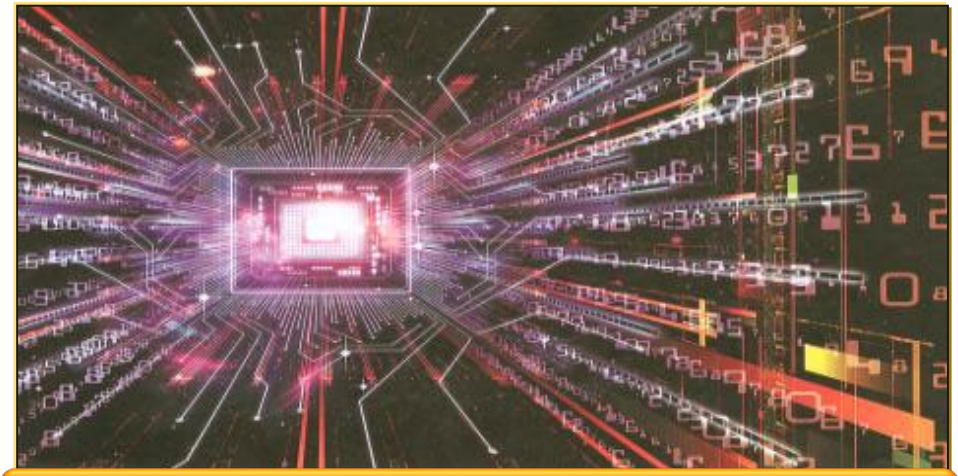
- transparency and patient informed consent when AI is used in care decisions
- new malpractice liabilities?
  - harm from premature use of poorly validated algorithms (platform developers, HCPs, or the health systems which approved adoption?)
  - harm from failure to use platforms validated as SOC (professional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

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

## Data Deluge

## Cognitive Bandwidth Limits

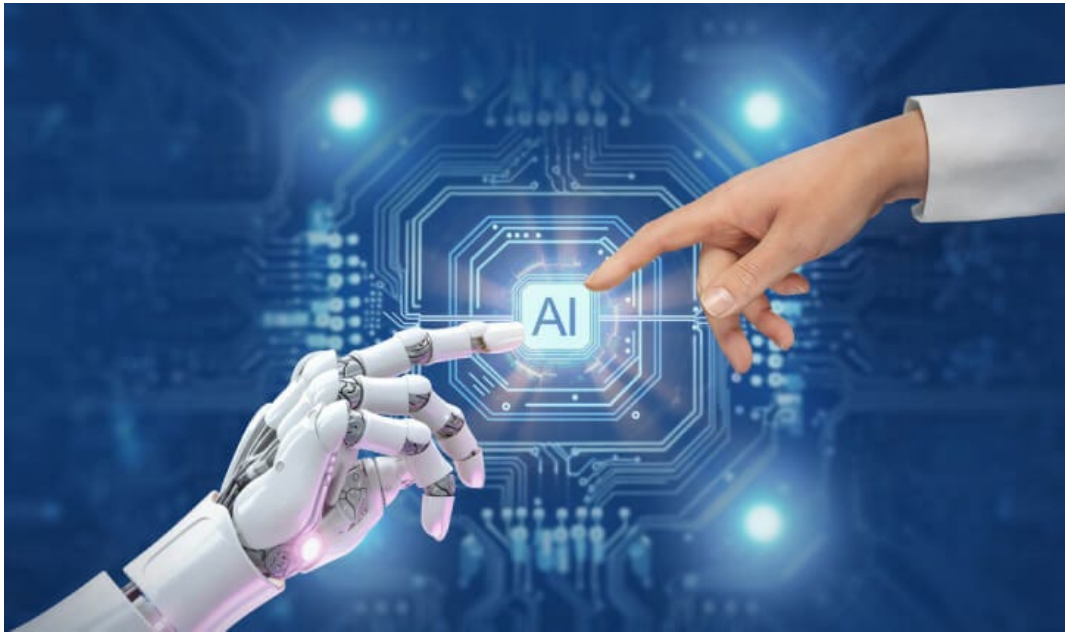




## Automated Analytics and Decision Support

## Facile Formats for Actionable Decisions

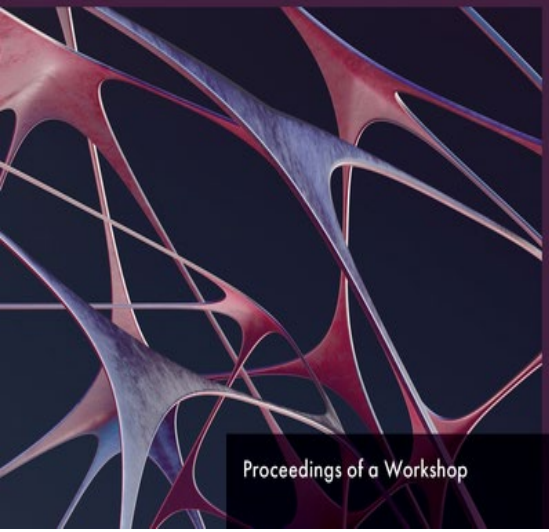
# The Changing Nature of Human-Computer Interactions in an Era of LLMs and AI




- Human-Computer Interactions and User Education, Training and Experience
- Human AI-Teaming and the Human AI Joint Cognitive Systems
- varied retention of human-in-the-loop in process design and decisions
- level of task complexity will determine the level of responsibilities and authorities assigned to humans or agentic/autonomous systems

NATIONAL ACADEMIES Sciences Engineering Medicine

# Artificial Intelligence in Health Professions Education



Proceedings of a Workshop

Harvard Business Review

HBR.ORG

September–October 2023

# Reskilling in the Age of AI

New approaches for managers and employees

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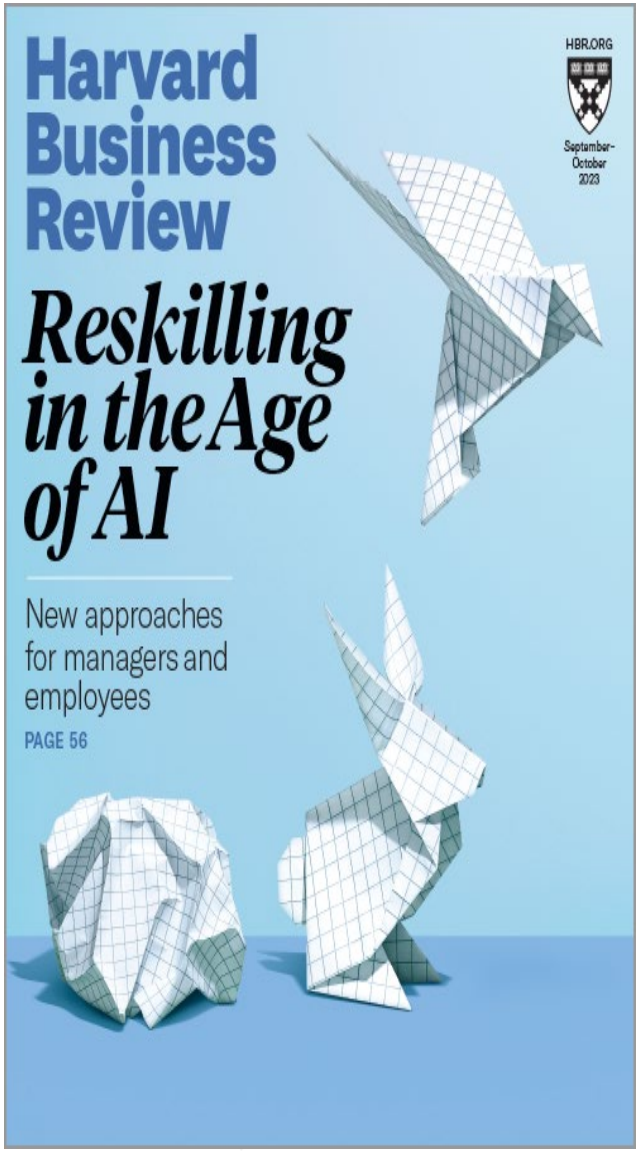

Issue Brief

# AI Faculty Shortages

## Are U.S. Universities Meeting the Growing Demand for AI Skills?

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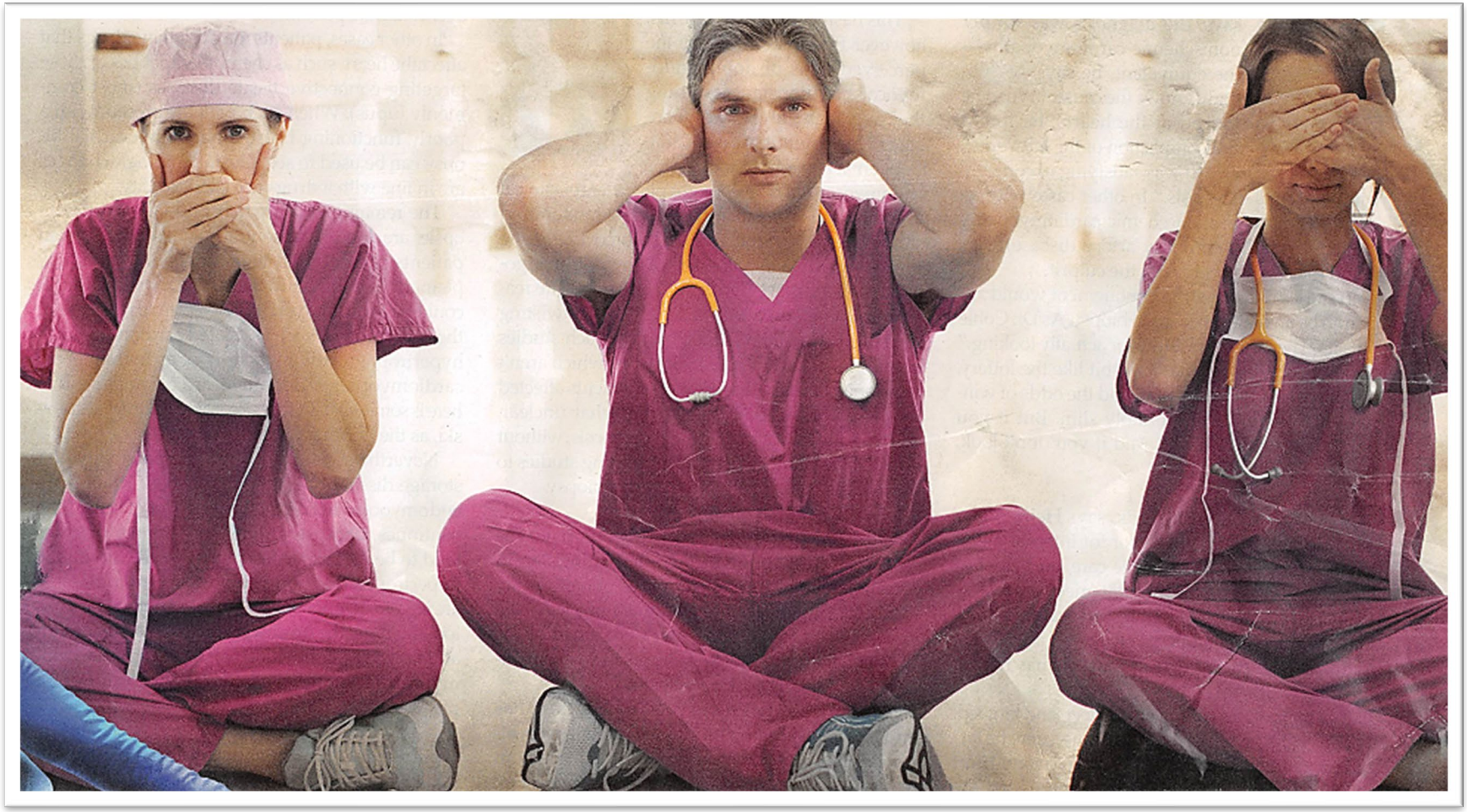
CSET CENTER for SECURITY and EMERGING TECHNOLOGY

July 2022

# DNR: Cultural Barriers to Adoption of Innovation

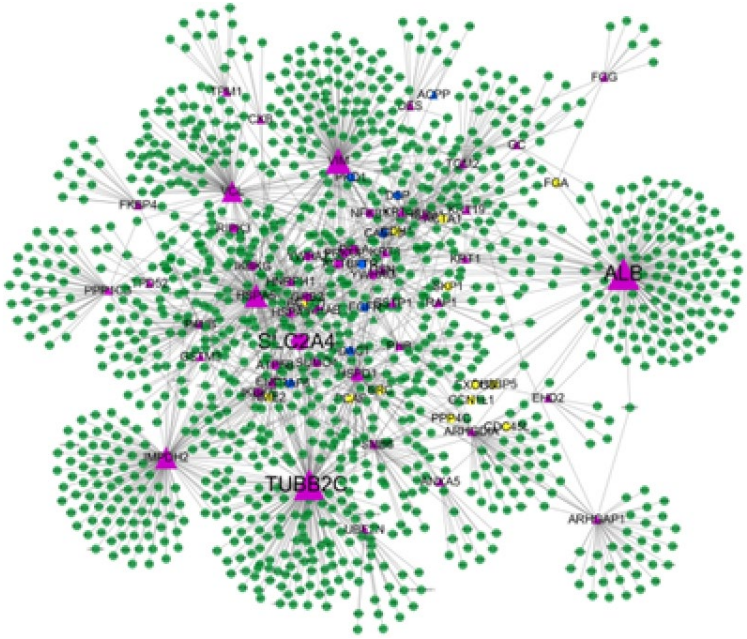


**Denial**

**Negativity**

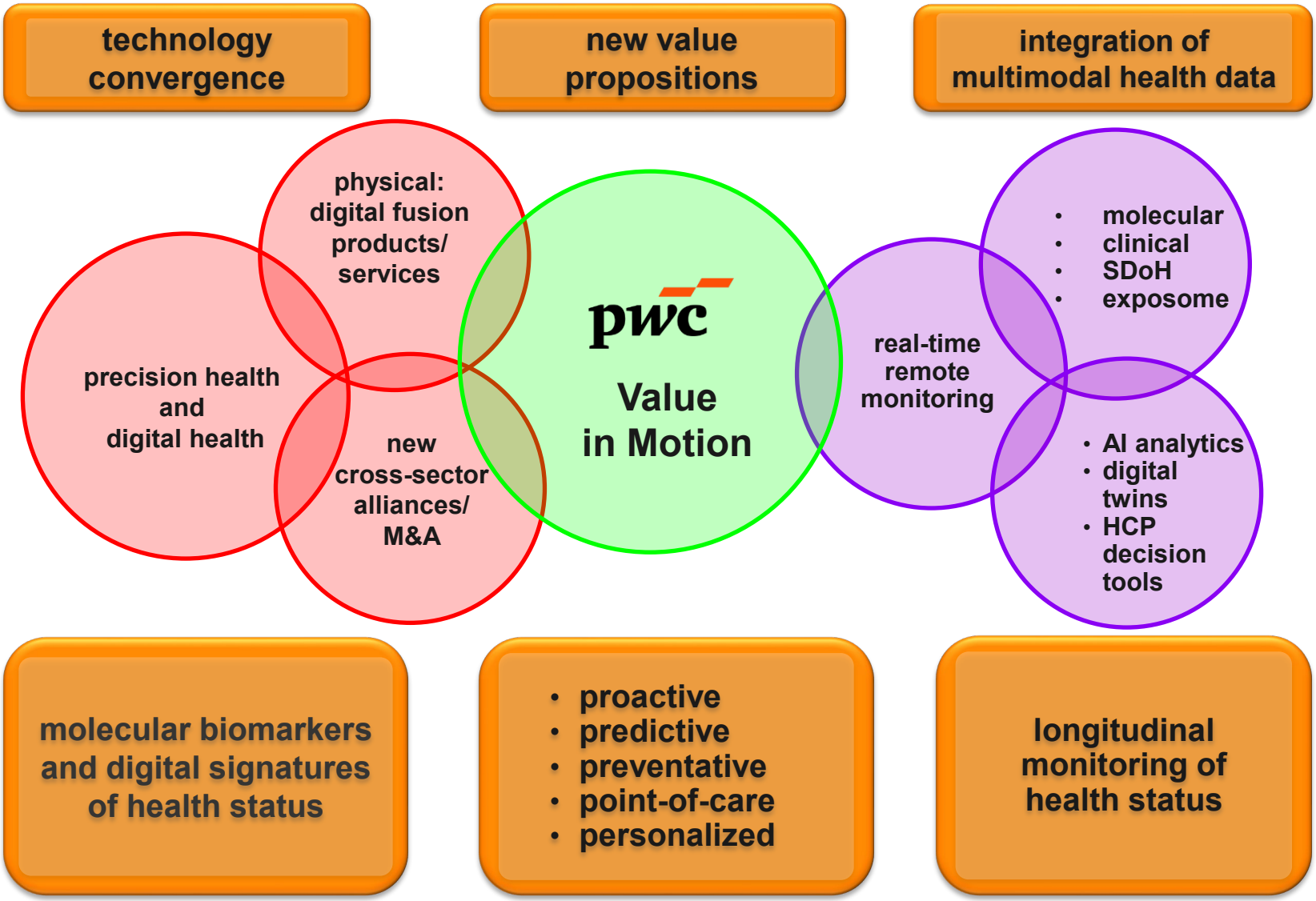
**Resistance**

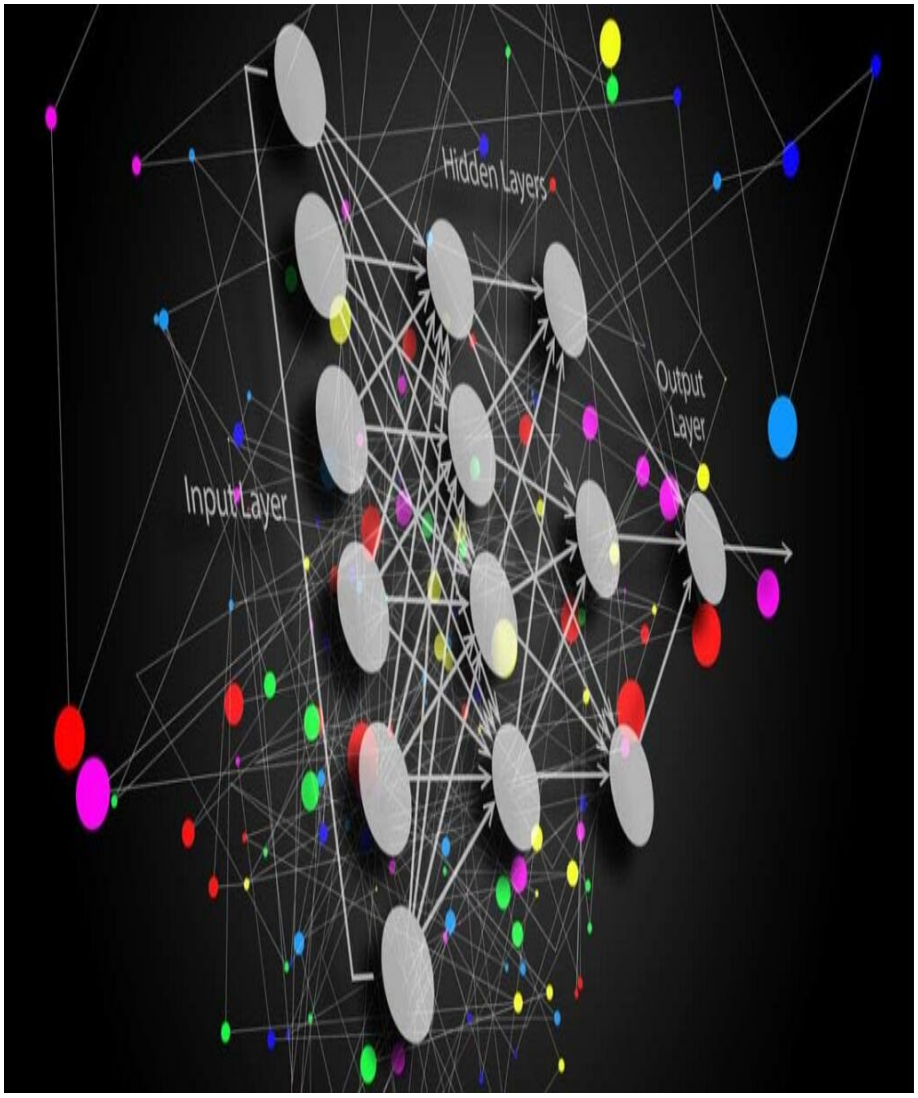
# Navigating Disruptive Change in the Health Ecosystem: New Thinking and New Capabilities

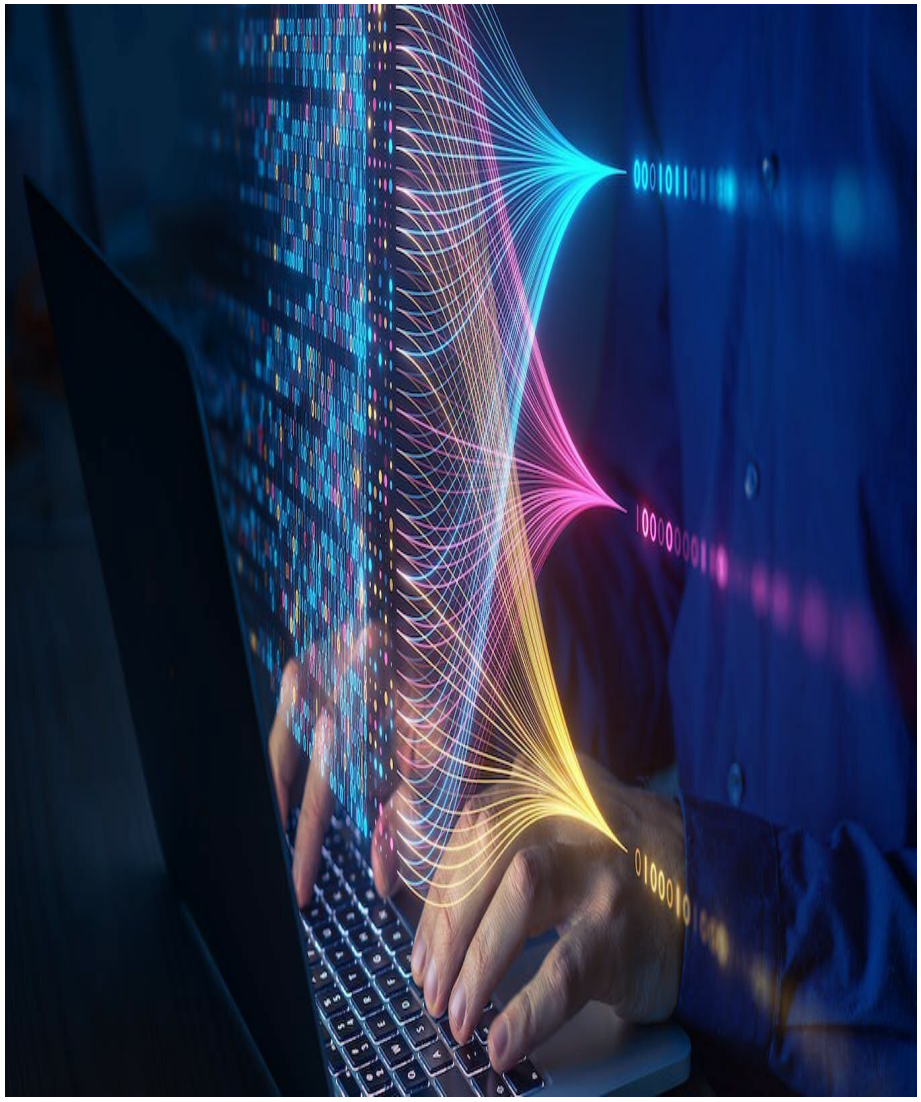



- unprecedented acceleration and convergence of disruptive technical, economic and political forces
- escalating complexity, amplified ambiguities and ubiquitous uncertainties
- rigorous analysis of disruptive change drivers
- competitive premium for proactive institutional adaptive agility (resiliency) to capture new value propositions from disruptive change

# Redesign and Reconfiguration of a Data-Centric Health Ecosystem





**Slides available @ http://casi.asu.edu/presentations**