The Strategic Landscape for the Evolution of Precision Health:
Disruptive Changes in Biomedical Research, Public Health and Care Delivery

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Slides available @ https://casi.asu.edu/presentations/

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
- cost escalation without improved outcomes
- continued dominance of fee-for-service and volume- based acute care/hospital-centric business models
- aging society and increased chronic (multi-morbidity) disease burden
- neglect of social determinants of health and health disparities

Precision Health

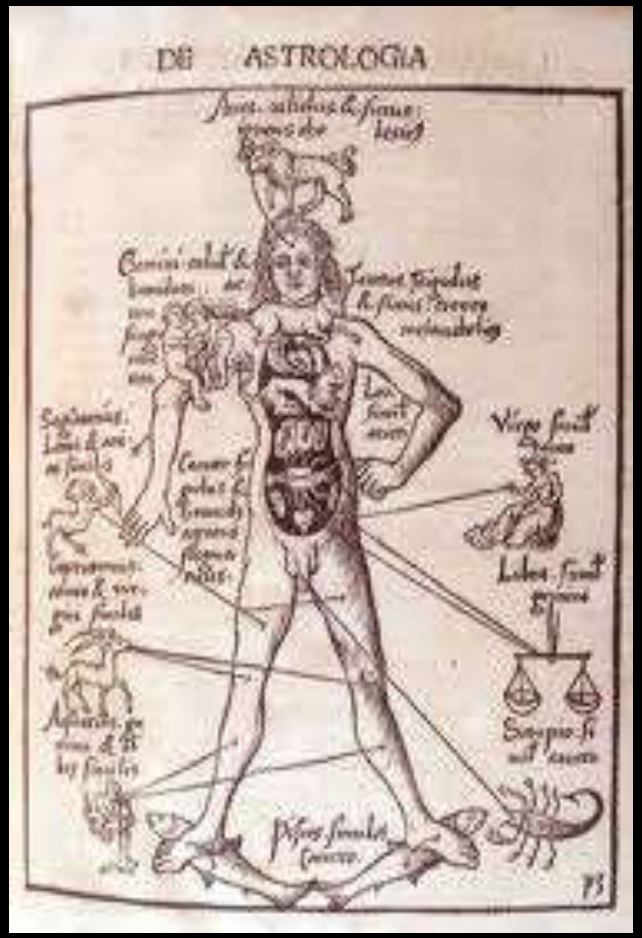
- optimize the health of individuals and populations by improved precision in the identification and mitigation of health risks across the life span

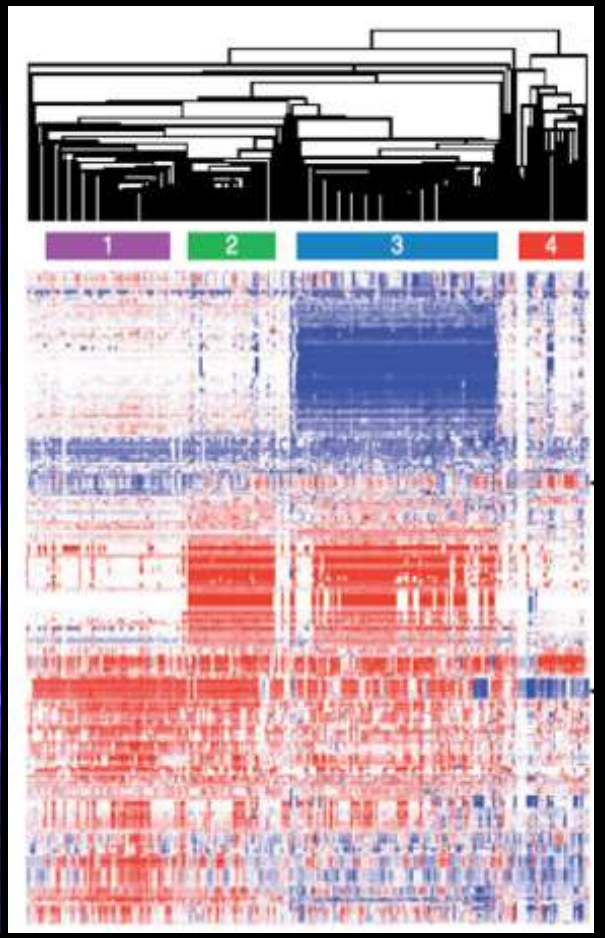
multiple elements of the organization, capabilities, incentives and performance of the current health ecosystem are misaligned with strategic aspiration

The Evolution of Precision Health: Improved Identification and Mitigation of Health Risk

- increasingly rational public health and clinical care interventions to optimize health based on features unique to specific individuals/population cohorts
- shift societal burden from current predominant demands of treating advanced chronic disease to management of earlier stage disease and disease prevention
- strengthen proactive surveillance, preparedness and resilience to disruptive external threats to health
  - emerging infectious diseases, climate, cyber-risks

The Path to Precision Health: From Superstitions to Symptoms to Molecular Signatures of Health Risk





humors; astrology, shamanism, sin and divine fate

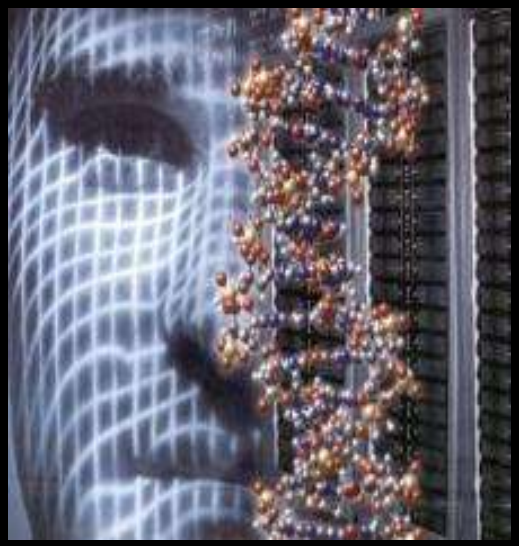
biochemistry and organ-based pathophysiology

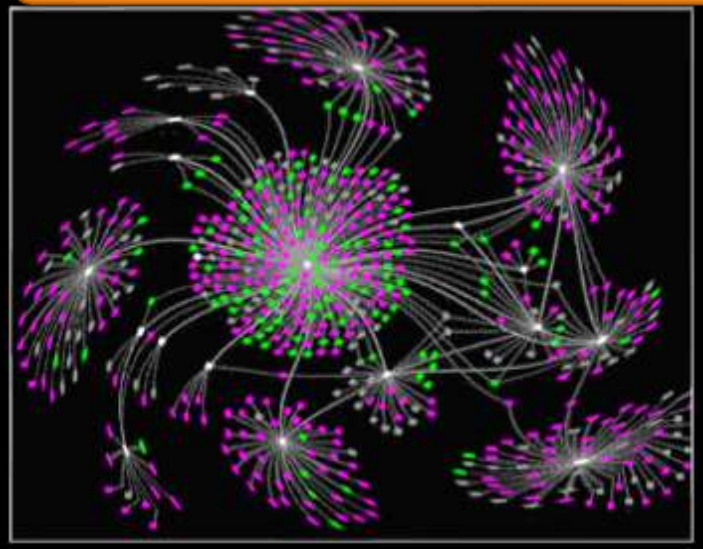
molecular biology and multi-omics profiling

Precision Health

(Epi)Genomics and MultiOmics Profiling

Detection of Altered Molecular Signaling Networks in Disease: A New Taxonomy of Disease and Subtype Classification



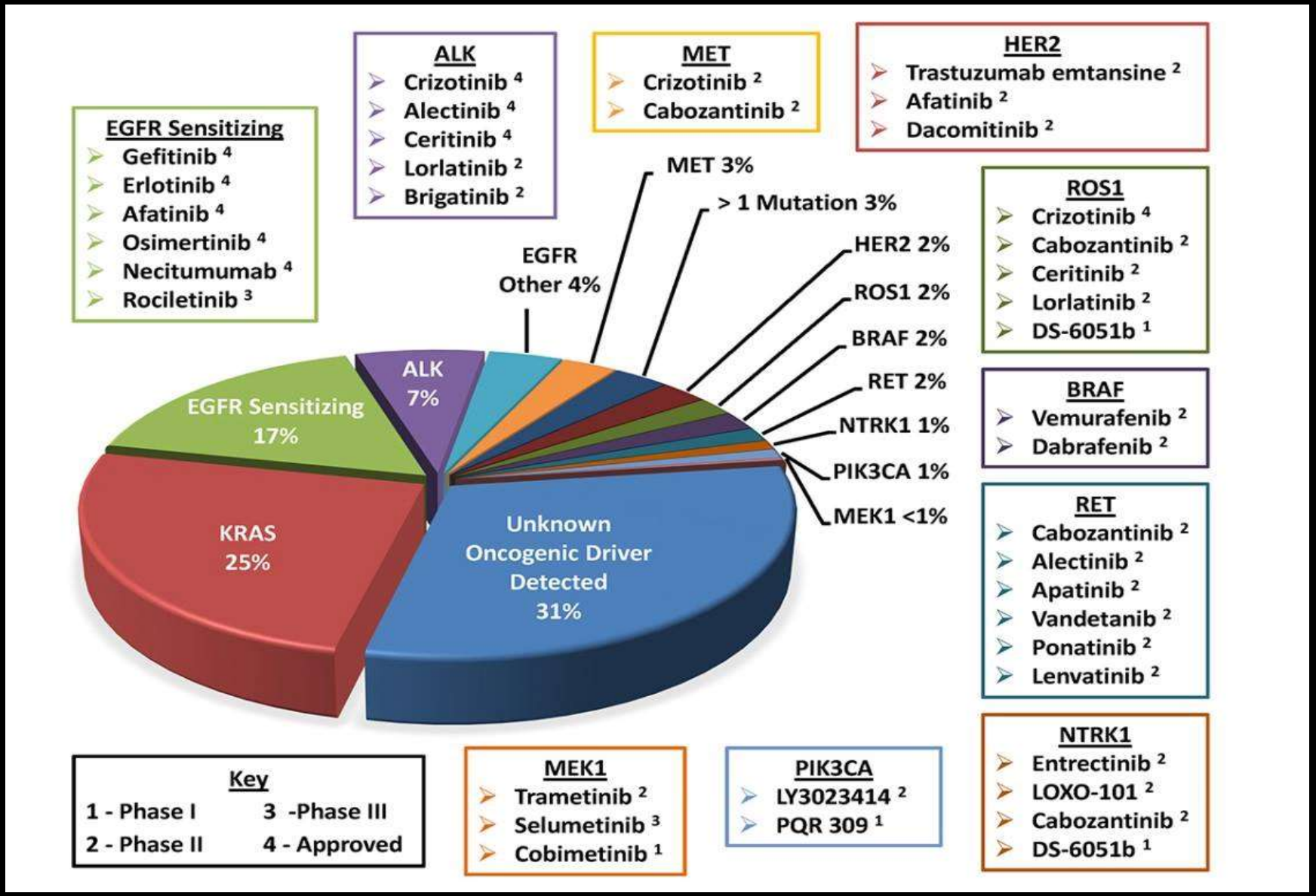


- terabytes per individual
- zettabyte – yottabyte population databases

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

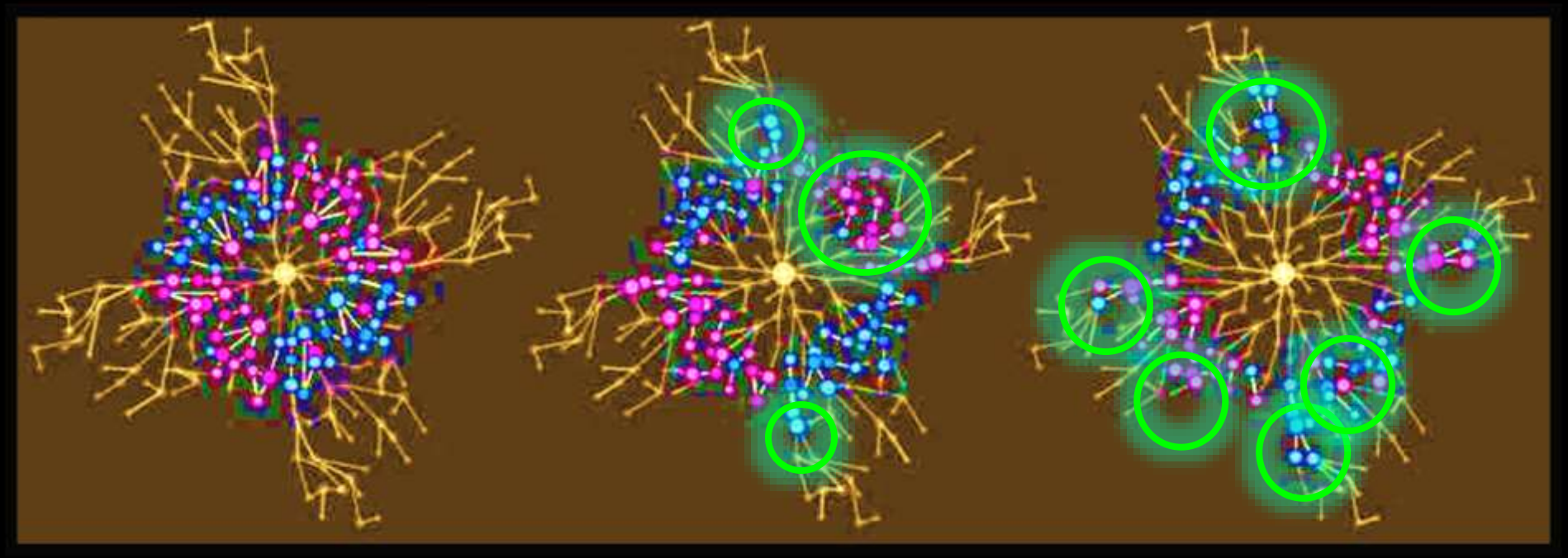
The Challenge of Big (Messy) Data

Molecular Classification of Non-Small Cell Lung Cancer



https://www.iaslc.org/

Understanding System State Shifts (Phenomes) and Emergent Perturbations in Molecular Signaling Networks in the Health to Disease Continuum



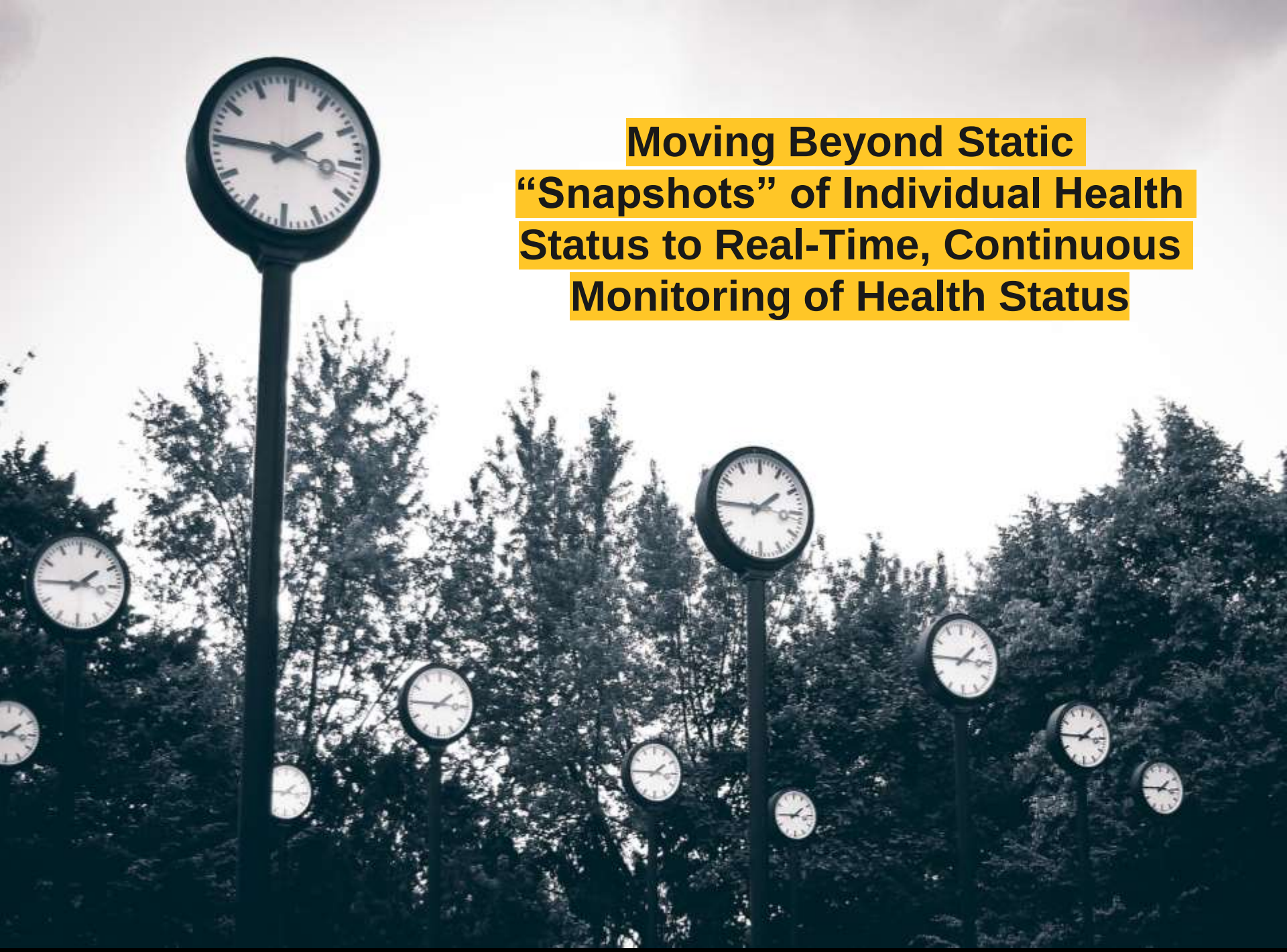
$T_{1(n)}$ health

$T_{2(n)}$ subclinical disease

$T_{3(n)}$ overt disease

Precision Health: New Concepts and Methods for More Proficient Identification and Mitigation of Health Risks

- "signatures" of health risk (individuals and populations)
  - disease predisposition, early disease detection
  - disease subtyping, staging and prognosis
  - treatment selection based on specific disease features in individuals
  - prediction of Rx response, resistance and adverse events
  - faster alert of clinical deterioration due to treatment non-adherence and reduce high-cost re-hospitalization
  - tracking social determinants of health and exposure to environmental hazards


Moving Beyond Static
“Snapshots” of Individual Health
Status to Real-Time, Continuous
Monitoring of Health Status

Deep Phenotyping:

From Womb to Tomb:
Systematic Longitudinal Integration of Multi-modal Data to identify Health Risk(s)




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



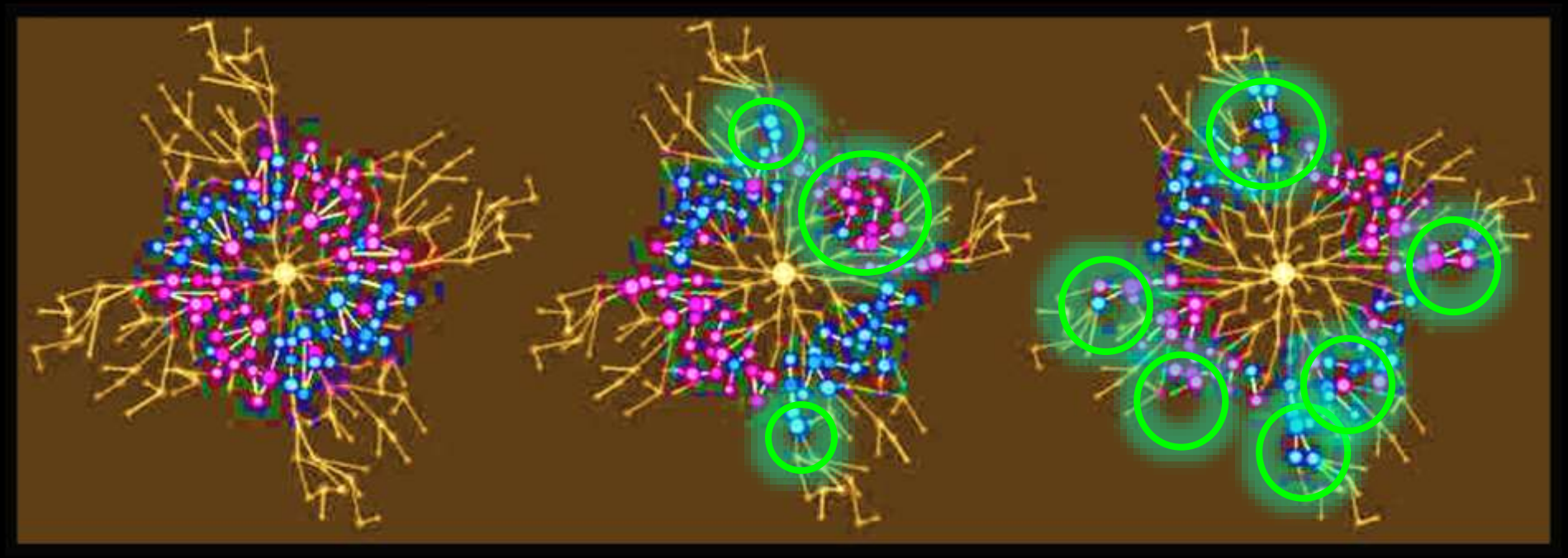

Expanding the ‘Care Space’ in Healthcare

- 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

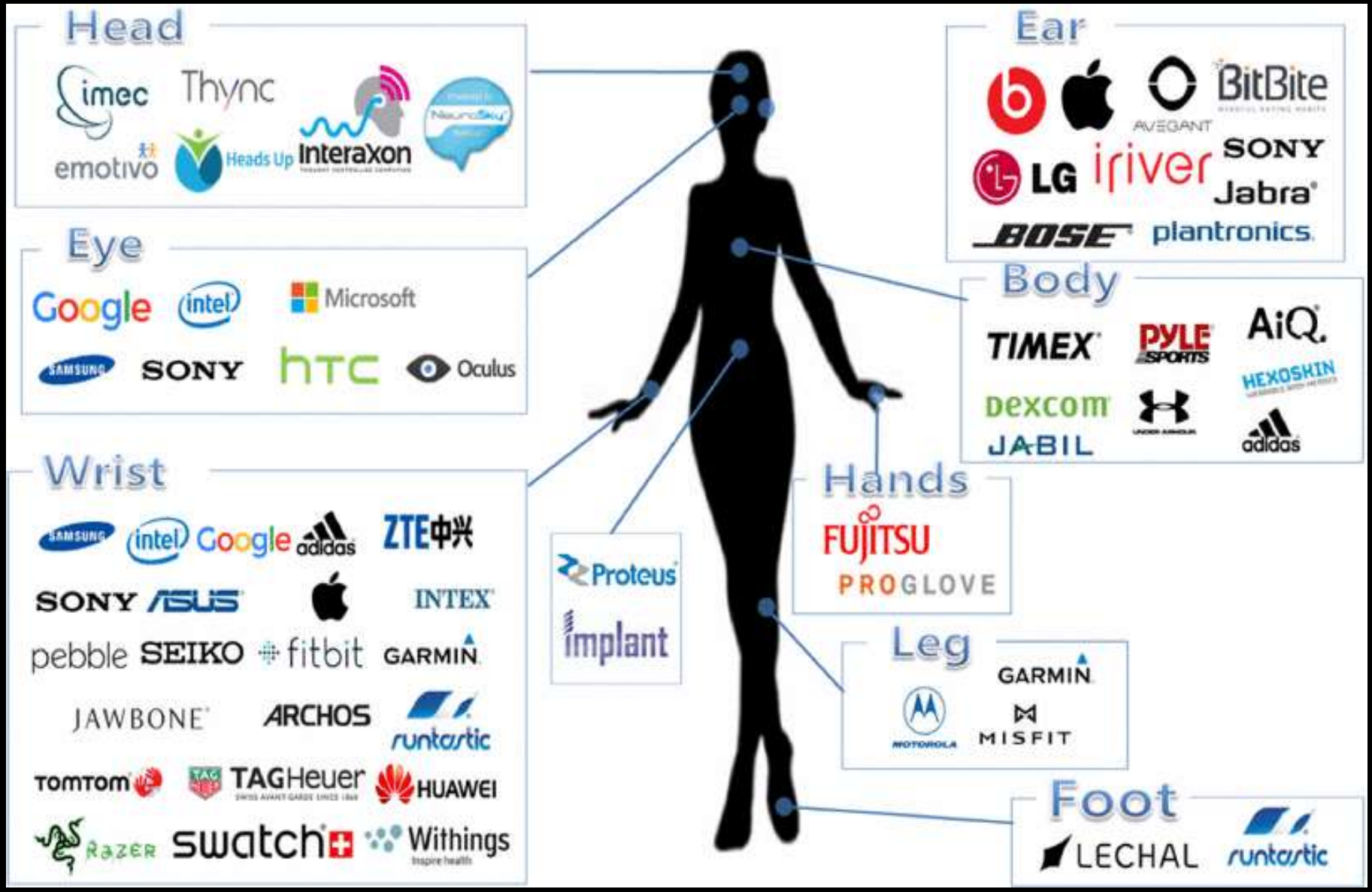
- rapid evolution of new technologies for real time remote monitoring of health status in non-clinical settings
  - Internet-of-Medical Things (IoMT)
  - longitudinal continuous tracking vs. episodic ‘static snapshots’ of health status
  - every population cohort/individual becomes their own control (tracking the Delta)

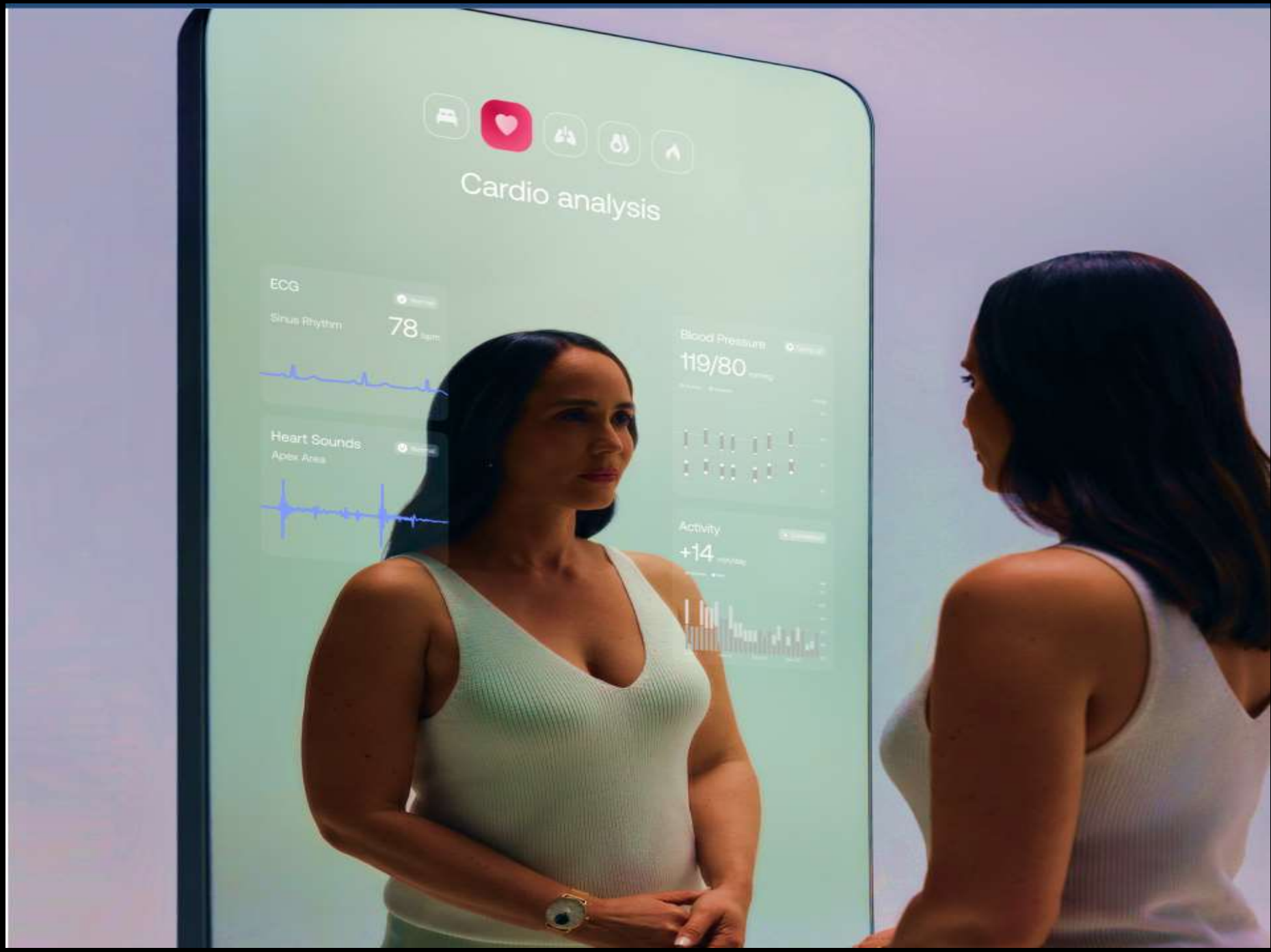
The Health Observatory: Mapping Individual and Community Interaction Networks and Population Health Patterns



$T_{1(n)}$	$T_{2(n)}$	$T_{3(n)}$
baseline health demographics	identification of risk foci: SDoH, disparities, EIDs	new patterns of disease prevalence and distribution

Wearables and Remote Health Status Monitoring





https://www.pcmag.com/news/mirror-mirror-withings-omnia-wants-to-display-all-your-health-data

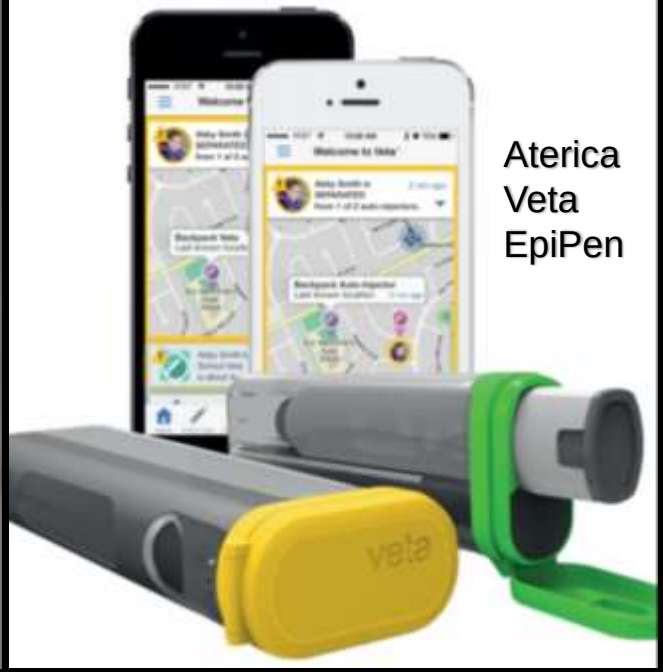
Smart Devices for Automated Drug Delivery and Improved Therapeutic Adherence

Propeller Health

Gecko (now Teva)

CapMedic

Biocorp Inspair



Aterica
Veta
EpiPen

The Eldercare Gap

10,000

- boomers turn 65 every day

79%

- increase in boomers age 80 or older from 2010 to 2030

348,000

- projected number of home health aides needed in next decade

5

- average number of prescription drugs taken by individuals 65 or older due to disease co-morbidities

The Demographics of an Aging Society: Clinical and Economic Challenges

wellness with longevity and high QOL

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 readmissions

reduced office visits

Empowered Patients:
Social Networking Sites and Their Role in Clinical Care

- logical extension to healthcare of rapid growth of web/apps in mainstream culture
- 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
- Ux and formation of senior executive level Chief Patient Experience Officer posts in large provider organizations

New Sites for Primary Care Delivery: Economies of Scale and Consumer Convenience

‘one stop’ shopping and telemedicine
- disease prevention/ screening
- primary care
- pharmacy
- discounted pricing

projected expansion of NP/PA in primary care
personalized/customized services for improved treatment adherence

Networked Telehealth Between Provider Organizations: Centralized 24/7 Monitoring of Critical Care

Improved Use of Specialized Resources and Access to Expert Consultations

Instrumented Modular Health Monitoring “Pods”

- hospital acute care/ICUs
- infection control
  - higher risk patients
  - surge mobilization in epidemic/disaster settings
- modification for ‘hospital-at-home’

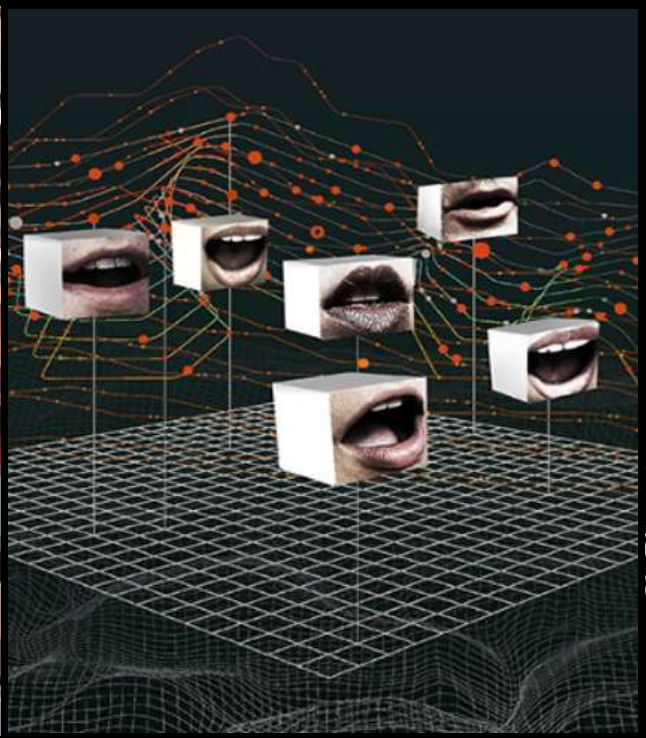
https://www.biopharminternational.com/view/considering-the-promises-of-point-of-care-manufacturing

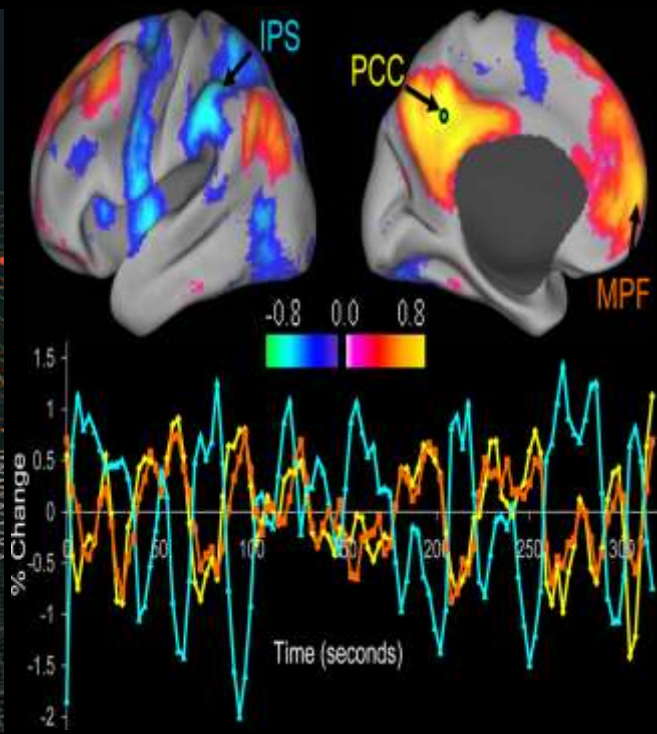
Cyber-Physical-Biological Systems
Immersive Human-Machine Interfaces and Surgery

AR/VR/XR Neuromodulation in Clinical Care

- injury rehabilitation
- reduce apprehension/distraction in painful procedures
- anxiety, depression, PTSD, phobias (digital therapeutics: DTx)

Computer Vision, Facial Recognition and New Digital Psychometrics for Improved Diagnostic Accuracy in Psychiatry





- eye movements
- facial dynamics
- stimulus response reaction and interaction speeds

- speech patterns (rhythm, tone, volume)
- semantic construction

- 256 lead EEG
- brain imaging functional MRI in sensory, motor and cognitive tasks

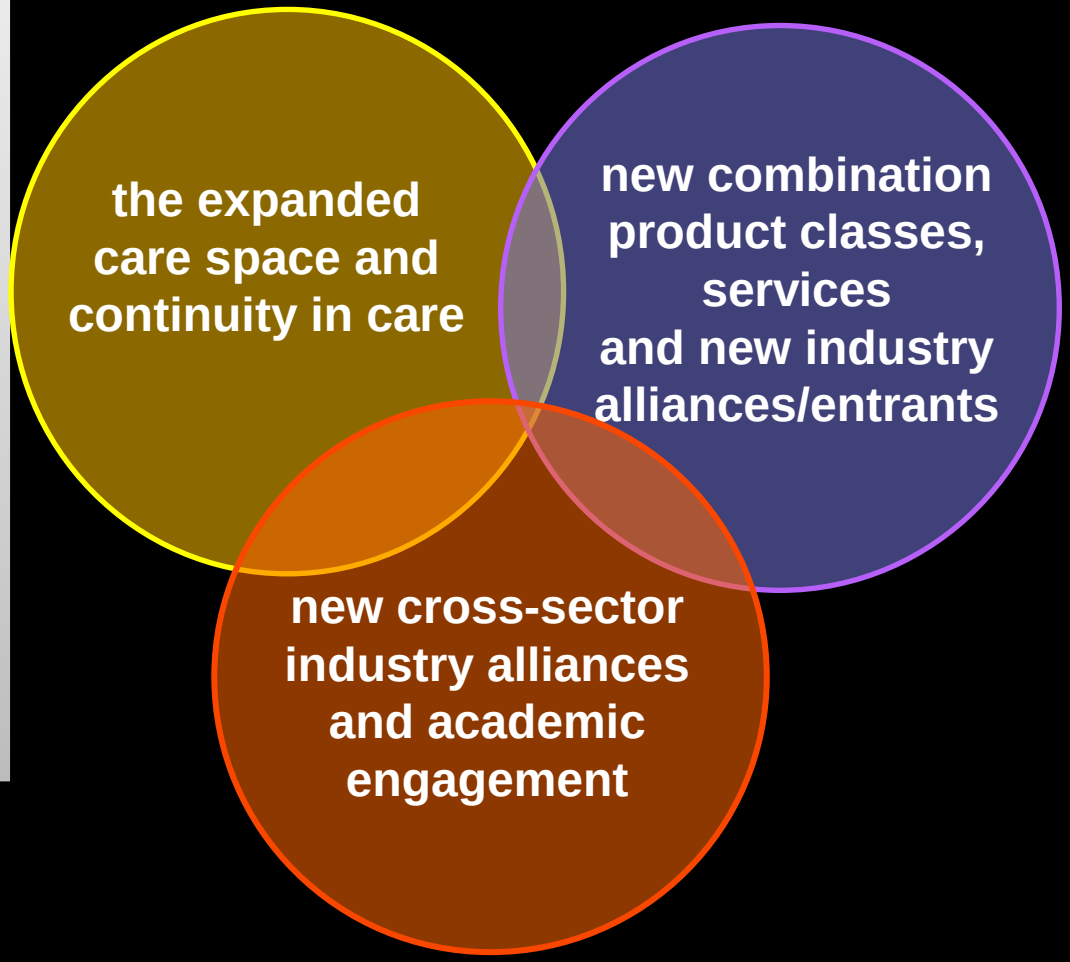
ML/AI analysis of individual multiparameter responses matched to large-scale analysis of video data banks of patients with clinically validated mental disorders

Human Computer Interactions for Non-Pharmacological Neuromodulation in Mental Health
Digital Therapeutics Alliance

https://www.dtxalliance.org/about-dta/

The Convergence of Precision Health and Digital Health: The Expanded Care Space and New Classes of Products and Services

- earlier detection of risk and mitigation
- reduce (re) hospitalization
- improved continuity in care
- telemedicine and remote health monitoring
- independent but monitored living for elderly



- Dx-Rx
- Dx-Rx-Ix
- Dx-Rx-Device
- DigRx
- materials science/ sensors
- brain-computer interactions
- intelligent agents and robotics
- social data analytics
- big data analytics

January 2, 2025

JAMA. Published online January 2, 2025. doi:10.1001/jama.2024.25875

Enter the Physicianeers—How They Will Transform Health Care

Roderic Ivan Pettigrew, PhD, MD[1,2]

January 16, 2025

JAMA. Published online January 16, 2025. doi:10.1001/jama.2024.27365

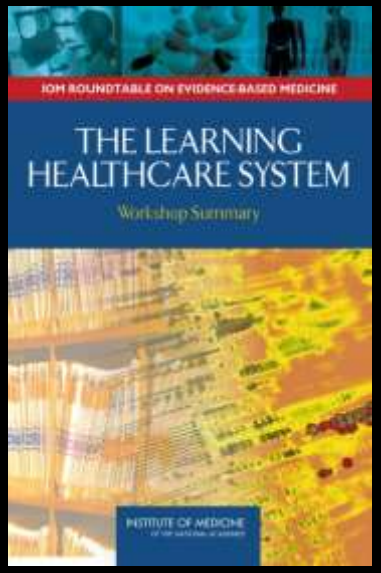
Advocating for a Master of Digital Health Degree

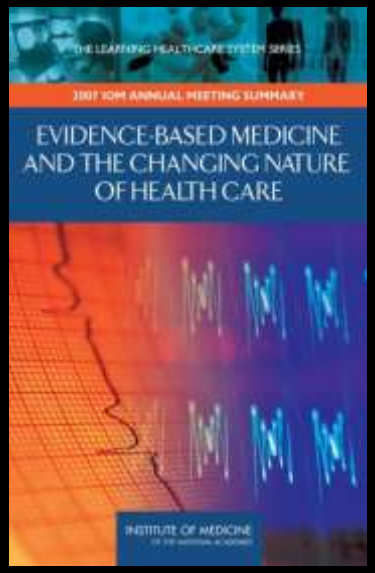
Josip Car, PhD[1]; Eric J. Topol, MD[2]

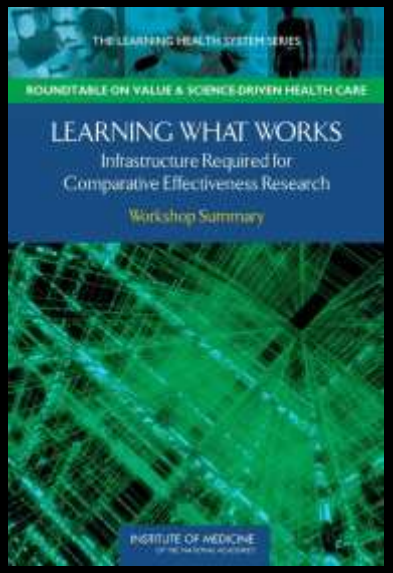
ASU Arizona State University

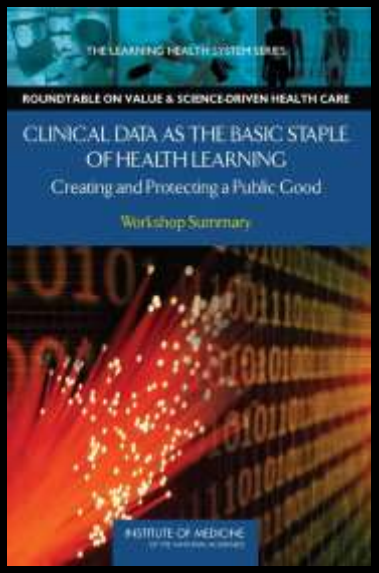
- **School of Medicine and Advanced Medical Engineering**
- **School of Technology for Public Health**
- **The Health Observatory at ASU**

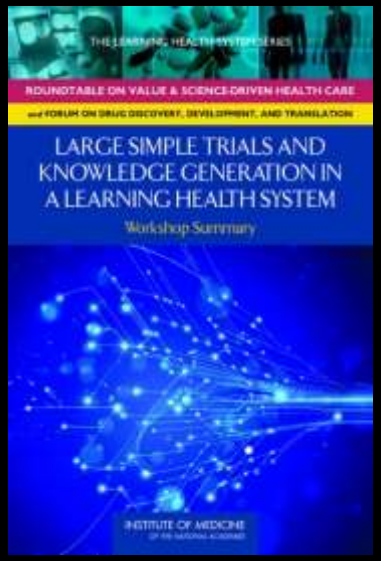
The Learning Healthcare System

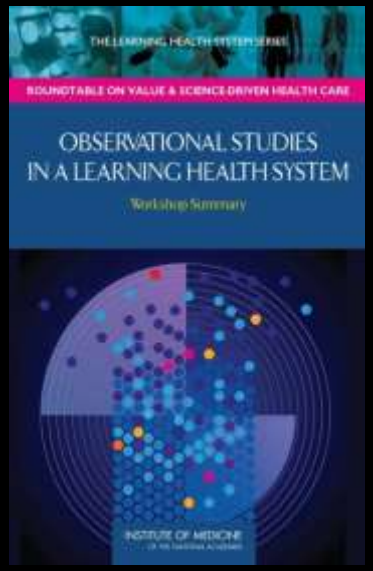


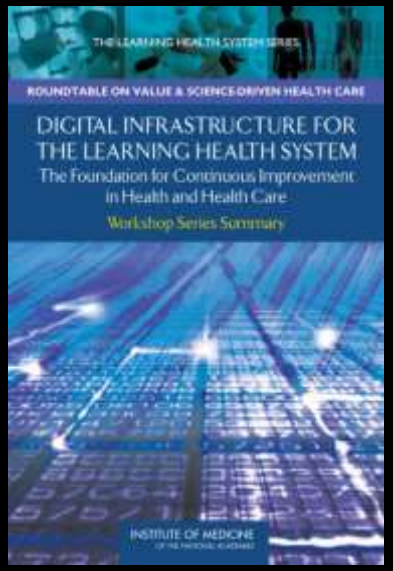


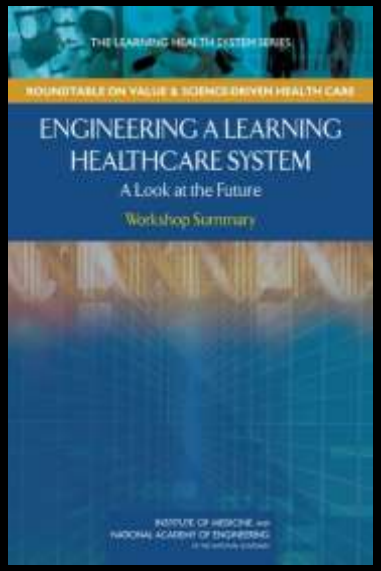


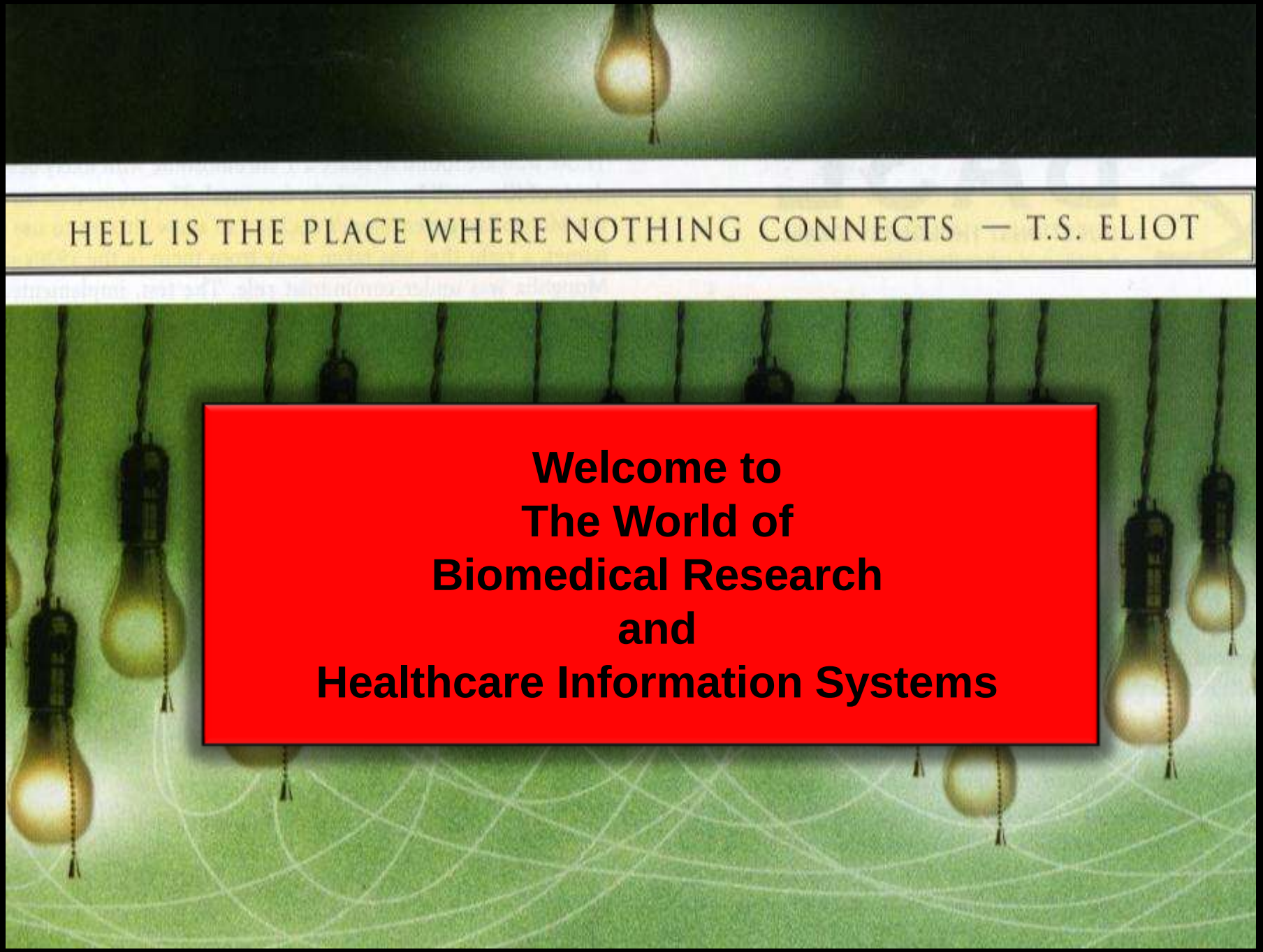












Welcome to The World of Biomedical Research and Healthcare Information Systems

The Health Ecosystem
Data Rich: Application Poor

- biomedical research and healthcare are among the largest producers of data but among the least proficient in translation to optimize health outcomes

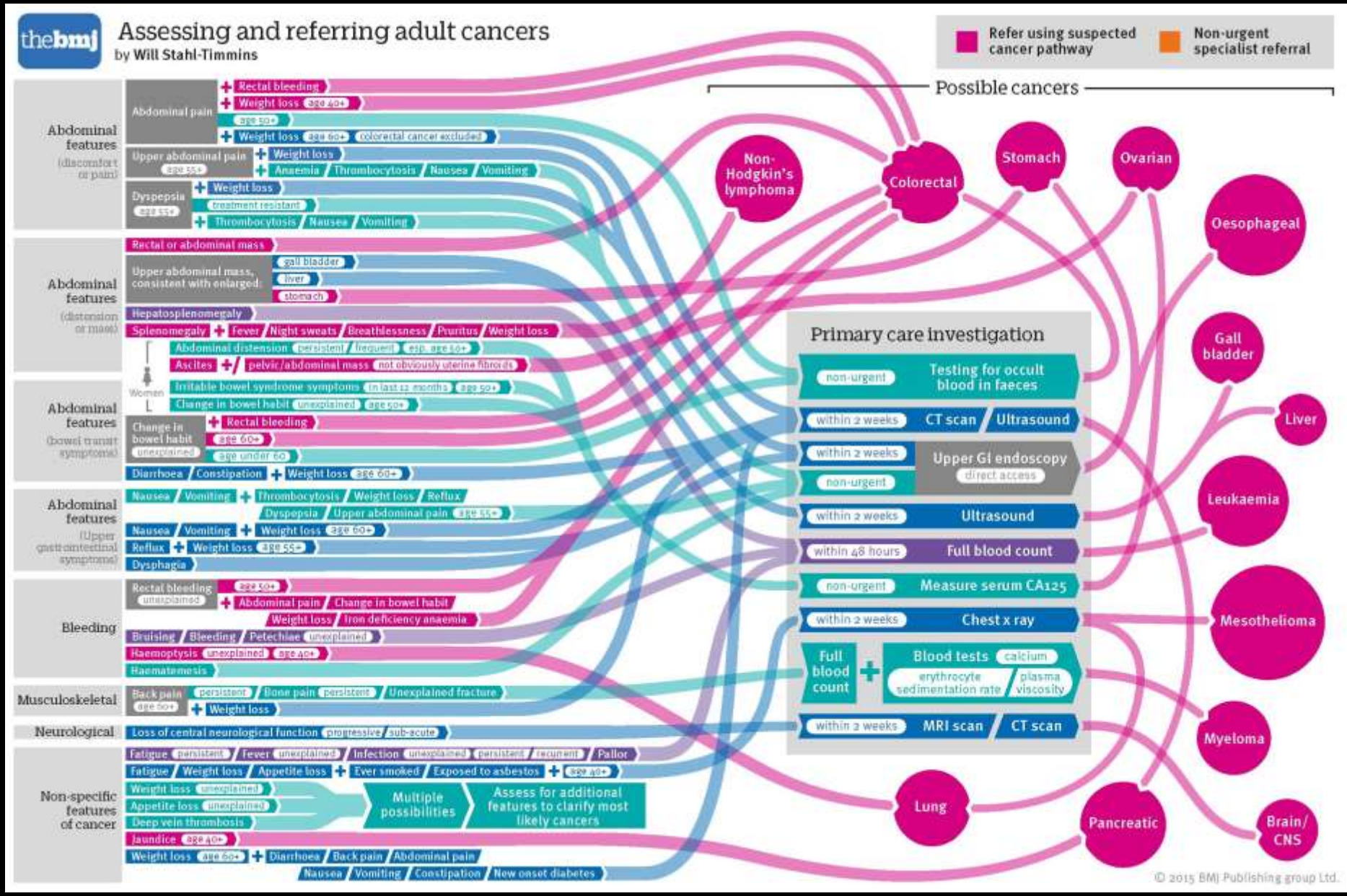
- projected zettabyte data deluge by 2030 (10^{21} or one sextillion bytes)

- making precision health a reality will require adoption of holistic, systems-based integration of diverse (multimodal) data categories on an unprecedented scale

Biomedical Data: Vast, Growing Rapidly But Poorly Used

- inadequate standardization
- fragmented, incomplete, inaccurate data and uncertain provenance
- incompatible data formats as barrier to data integration and sharing (data tombs)
- obstacles to EHR integration of new data classes (multi-Omics; wearables; IoMT)
- legislative barriers to data transfer based on well intentioned privacy protections (HIPAA)
- organizational, economic and cultural barriers to open data sharing
- static, episodic snap shots of complex dynamics in disease progression
- major impediments to research productivity, optimum clinical decisions and continuity-of-care for patients

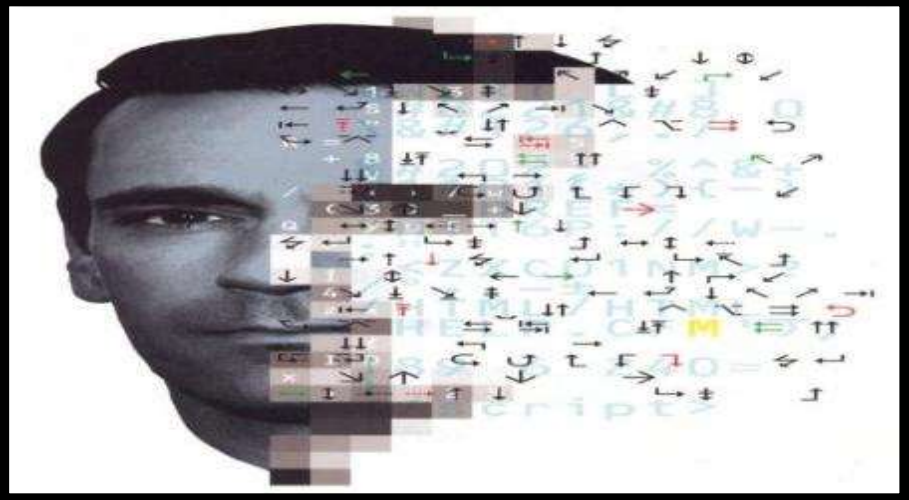
Keeping Current in an Era of Rapid Innovation

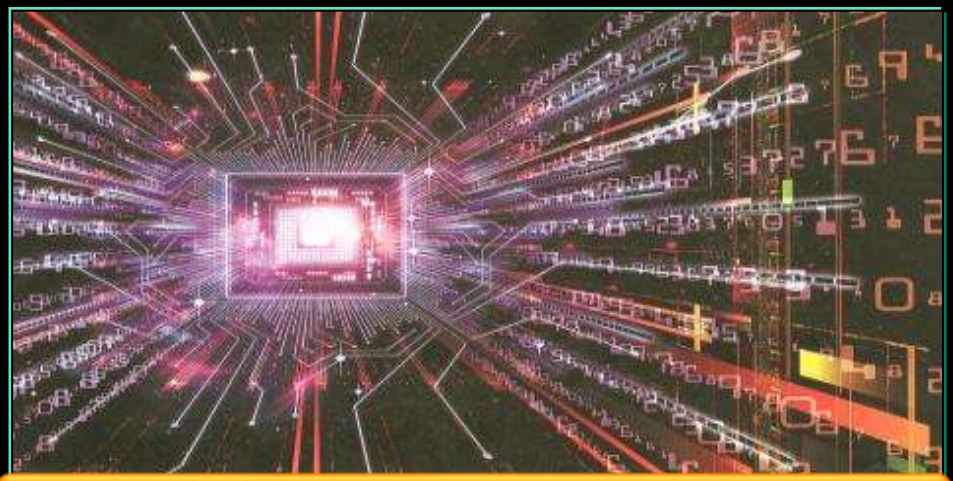


Technology Acceleration and Convergence: The Escalating Challenge for Professional Competency, Decision-Support and Future Medical Education

Data Deluge

Cognitive Bandwidth Limits





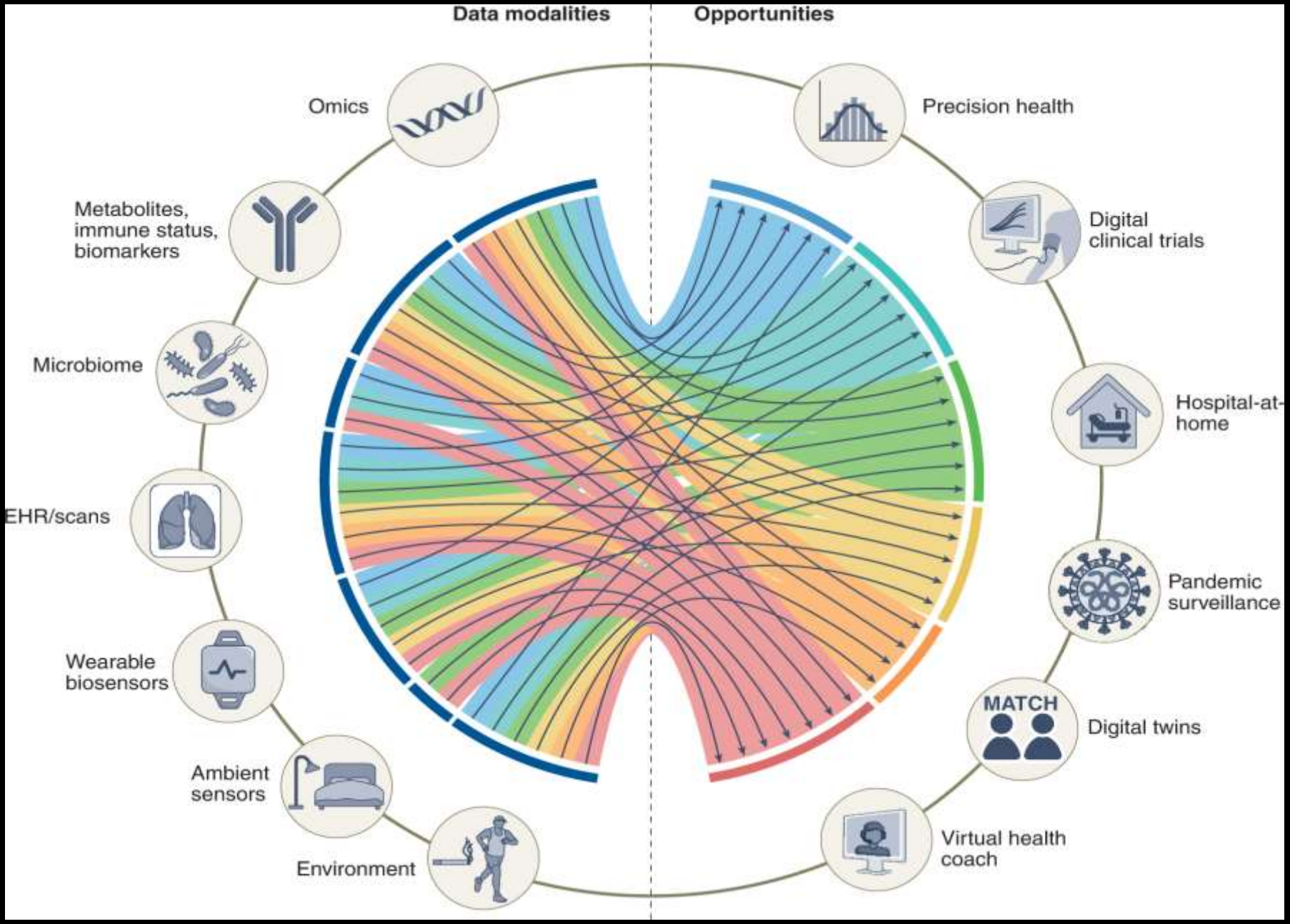
Automated Analytics and Decision Support

Facile Formats for Actionable Decisions

The Changing Dimensions of Big Data

Role of ML/AI and LLMs in Evolution of Data-Centric Health Ecosystem

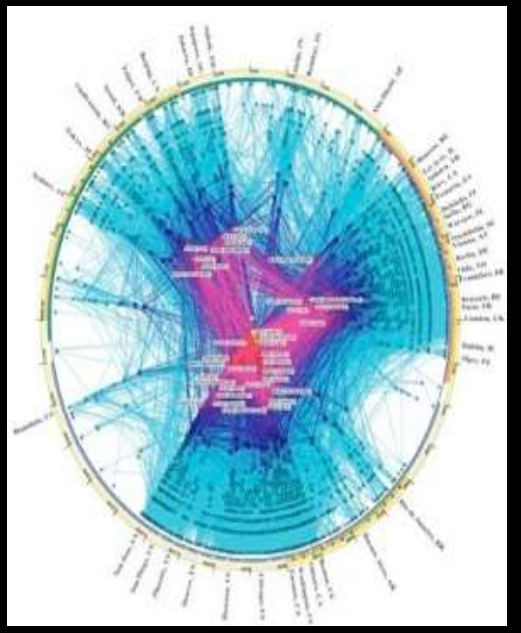
Multimodal Data Integration for Management of Health Risk



Big Data Changes the Questions That Can Be Asked

Isolated Data

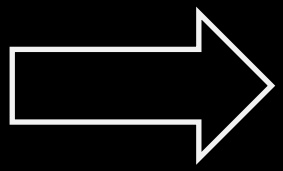
Complex Networked Data



Complex Computational Data

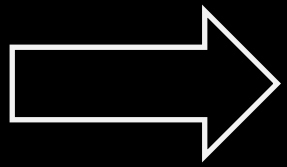
Building a Learning Health Ecosystem
The Co-evolution of Precision Health and Digital Health:

qualitative, descriptive information of variable quality and provenance



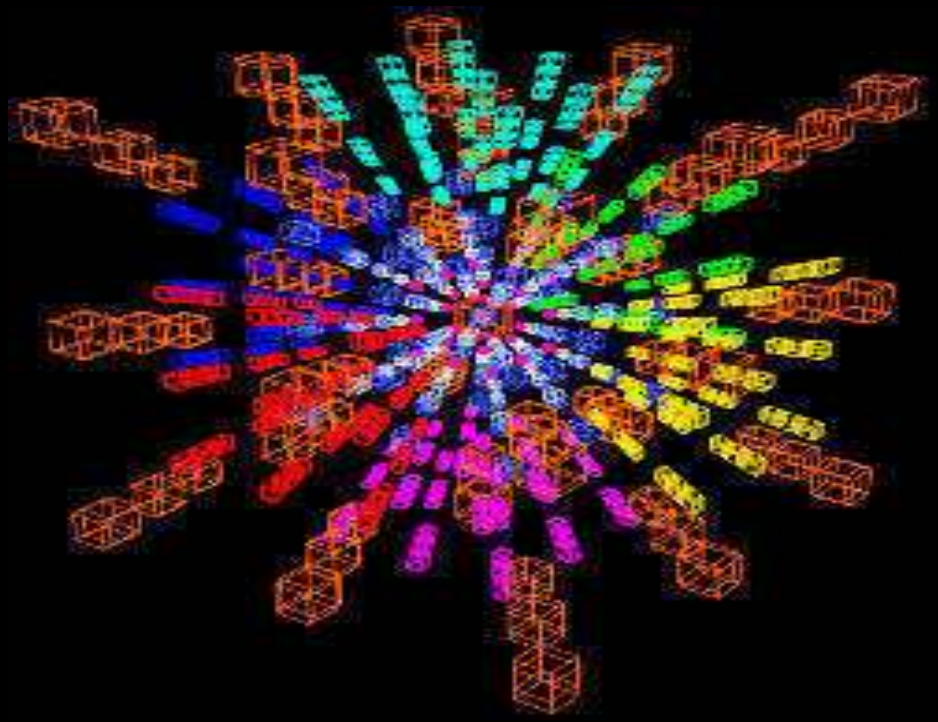
quantitative data of known provenance and validated quality

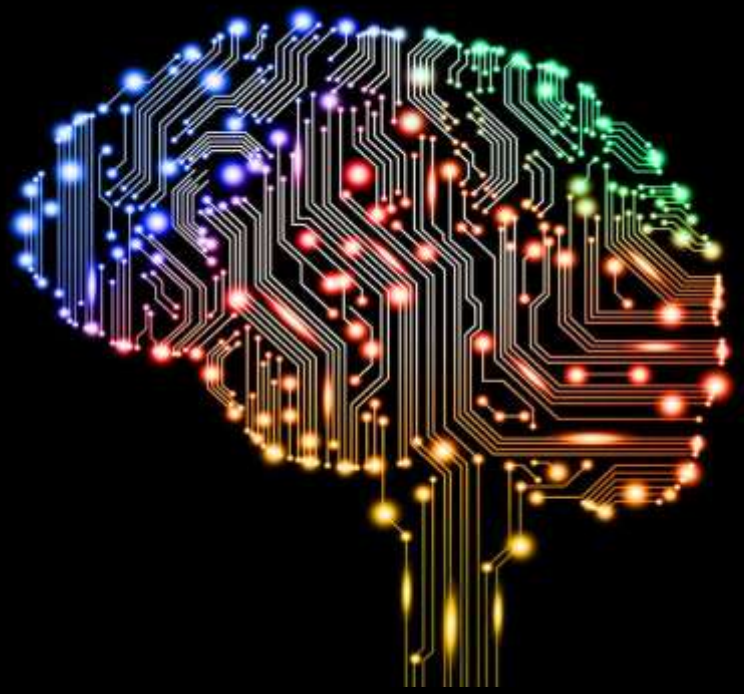
unconnected data sources and poor database inter-operabilities



inter-connected networks of data sources for robust decisions and improved care

Automated Context: Data Finding Data
"Intelligence at Ingestion" and Collapse Time to Decision





- Data Fidelity
- Feature Extraction

→

Context Analysis

↕

Persistent Context

→

- Knowledge Topologies
- Learning Systems

→

- Rapid, Robust Decisions

Building Personalized 'Digital Twins': Matching Individual Deep Phenotypes to 'Best Fit' Cohorts

Individual Data

Population Databanks

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

U.S. Department of Health and Human Services: Strategic Plan for the Use of Artificial Intelligence in Health, Human Services, and Public Health

Overview Version

January 2025

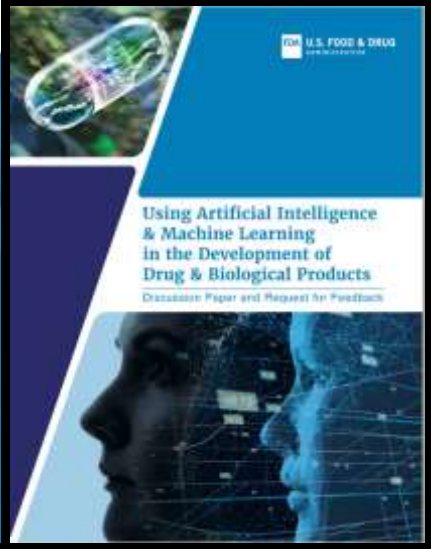
United States Department of Health and Human Services

https://www.healthit.gov/topic/hhs-ai-strategic-plan

US Regulation of AI Platforms in Healthcare

“FDA needs to be nimble in
the use and regulation of large language models
to avoid being swept up quickly
by something we hardly understand.”

Dr. R. Califf
FDA Commissioner, 9 May 2023
2023 Science for Patient Engagement Symposium



Oversight, Regulation and Governance of AI and Advanced Computing

- the ubiquity challenge: safety, security and trust across multi-domain applications
- narrow or broad scope of intended controls
- short-term vs long-term risk: benefit assessment
- algorithmic bias and discrimination
- liability in autonomous systems and decision-support tools
- expanded surveillance technologies, civil liberties and privacy
- dual-use foundational models
- private sector voluntary guard rails versus governmental regulation/legislation
- international policy harmonization

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

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

Different Design Strategies*

- how will LLMs/AI reshape biomedicine (and society)?

or

- how should the intended biomedical applications shape the training of LLMs/AI?

*N.H. Shah et al. (2023) JAMA 330, 866

LLMs and AI in Healthcare*

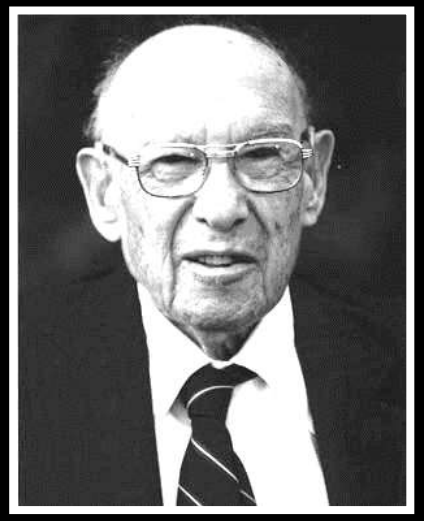
- medical profession did not play an active role in the design of most current IT platforms in healthcare
  - user frustration at burdensome formats of EHRs, poor database designs and inter-operabilities

- importance of avoiding the same mistakes in the rapid deployment of LLMs/AI without input on user requirements

*N.H. Shah et al. (2023) JAMA 330, 866

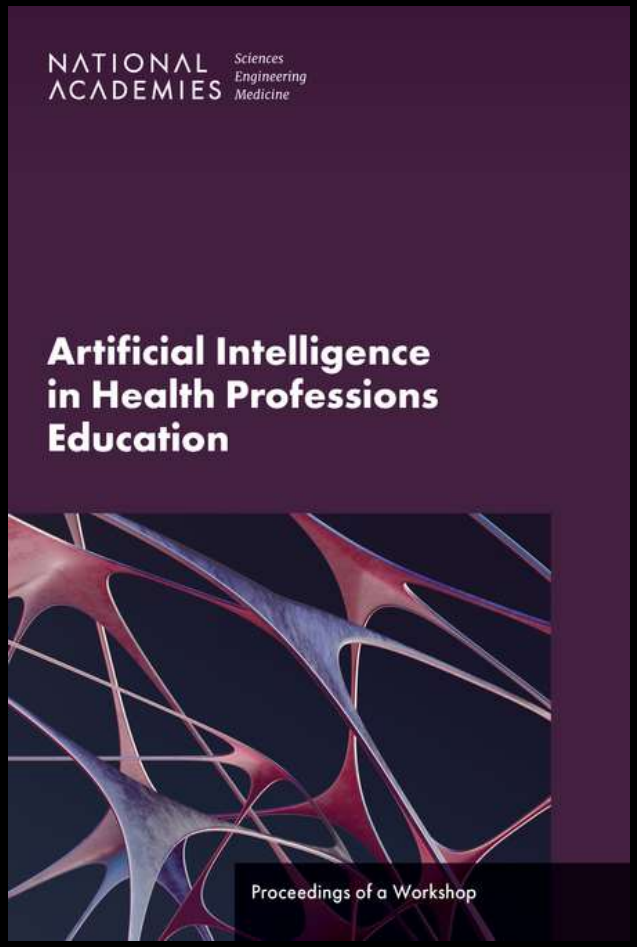
New Thinking and New Capabilities

Navigating Disruptive Change:
New Thinking and New Capabilities



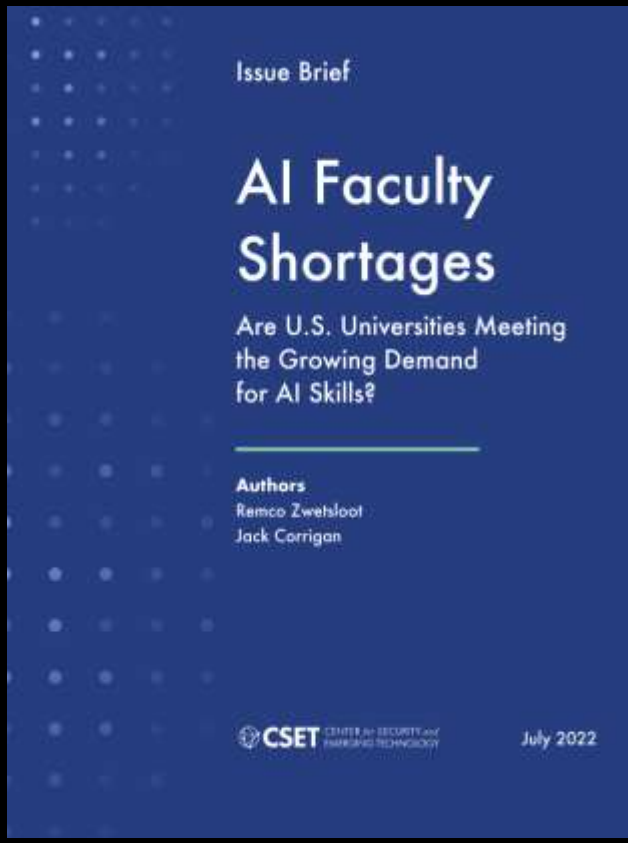
“The greatest danger in times of turbulence,
is not the turbulence,
it is to act with yesterday’s logic.”

- Peter Drucker

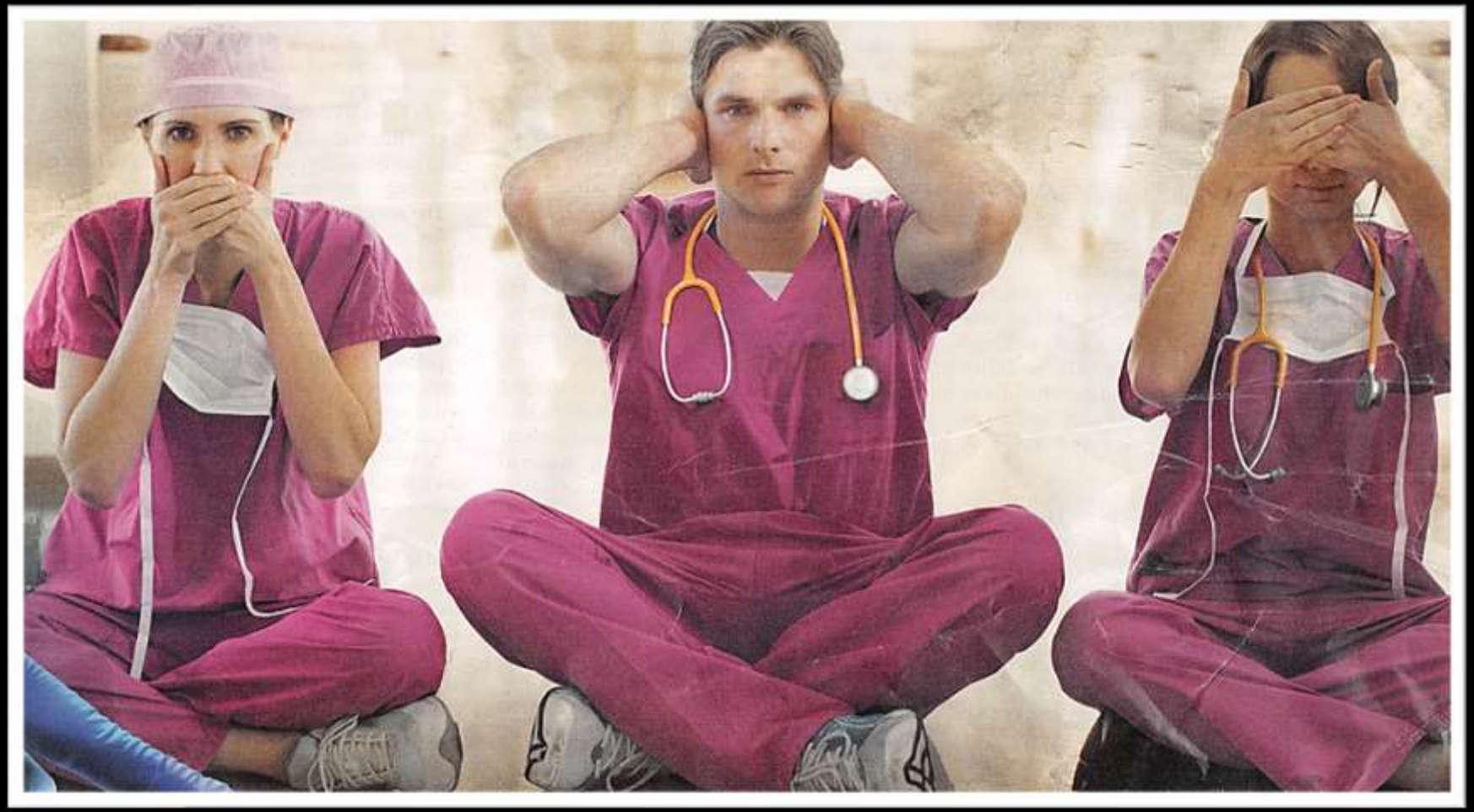

NATIONAL ACADEMIES
Sciences
Engineering
Medicine
Artificial Intelligence in Health Professions Education
Proceedings of a Workshop


Harvard Business Review
HBR.ORG
Reskilling in the Age of AI
New approaches for managers and employees
PAGE 56

(2023)


Issue Brief
AI Faculty Shortages
Are U.S. Universities Meeting the Growing Demand for AI Skills?
Authors
Remco Zwetsloot
Jack Corrigan
CSET
July 2022

DNR: Cultural Barriers to Adoption of Innovation



Denial

Negativity

Resistance

Stanford MEDICINE | HAI Stanford University Human-Centered Artificial Intelligence

RAISE-Health

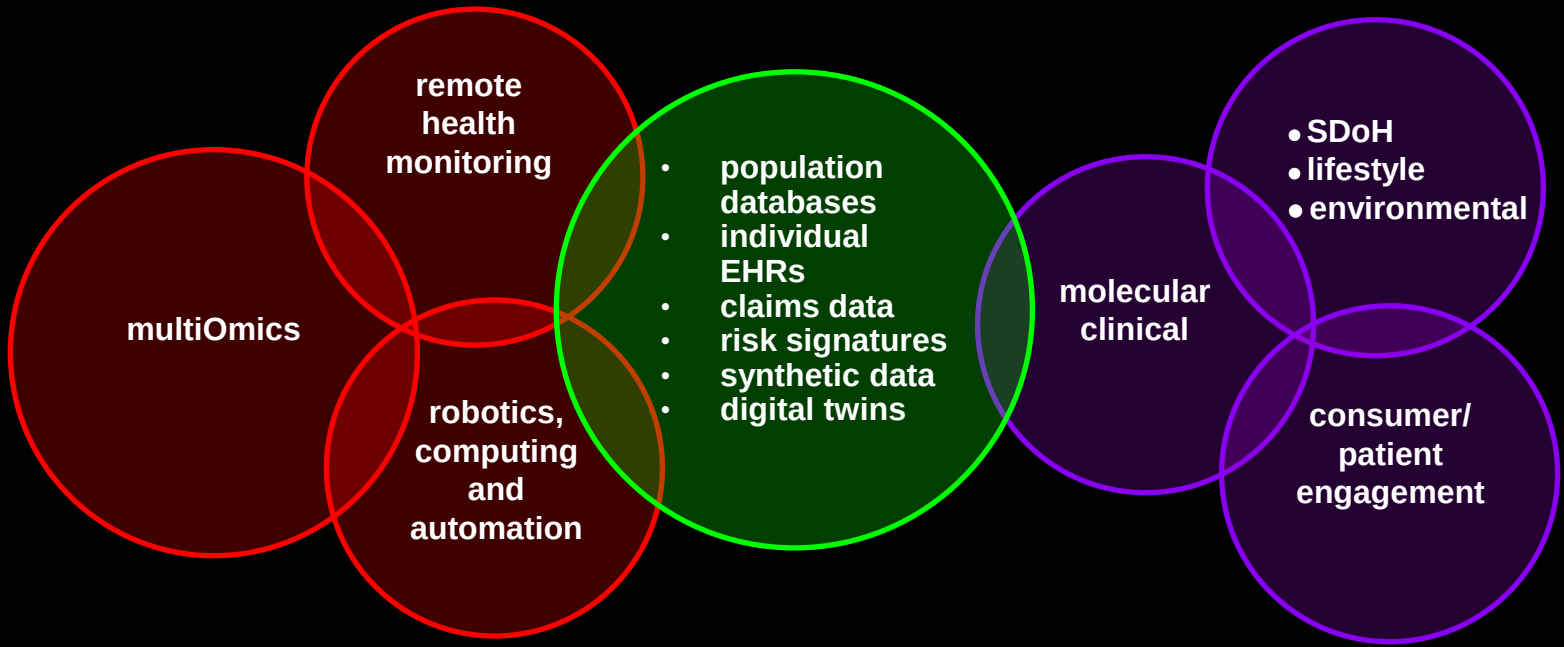
Responsible AI for Safe and Equitable Health

The Co-Evolution of Precision Health, Digital Health and AI

multi-technology integration

AI and navigating the zettabyte world

integration of multi-modal health data



mapping the complexity of geno-phenotypic relationships and individual disease risk(s)

diagnostic accuracy, optimum Rx selection, improved outcomes, and QOL (clinical and economic value)

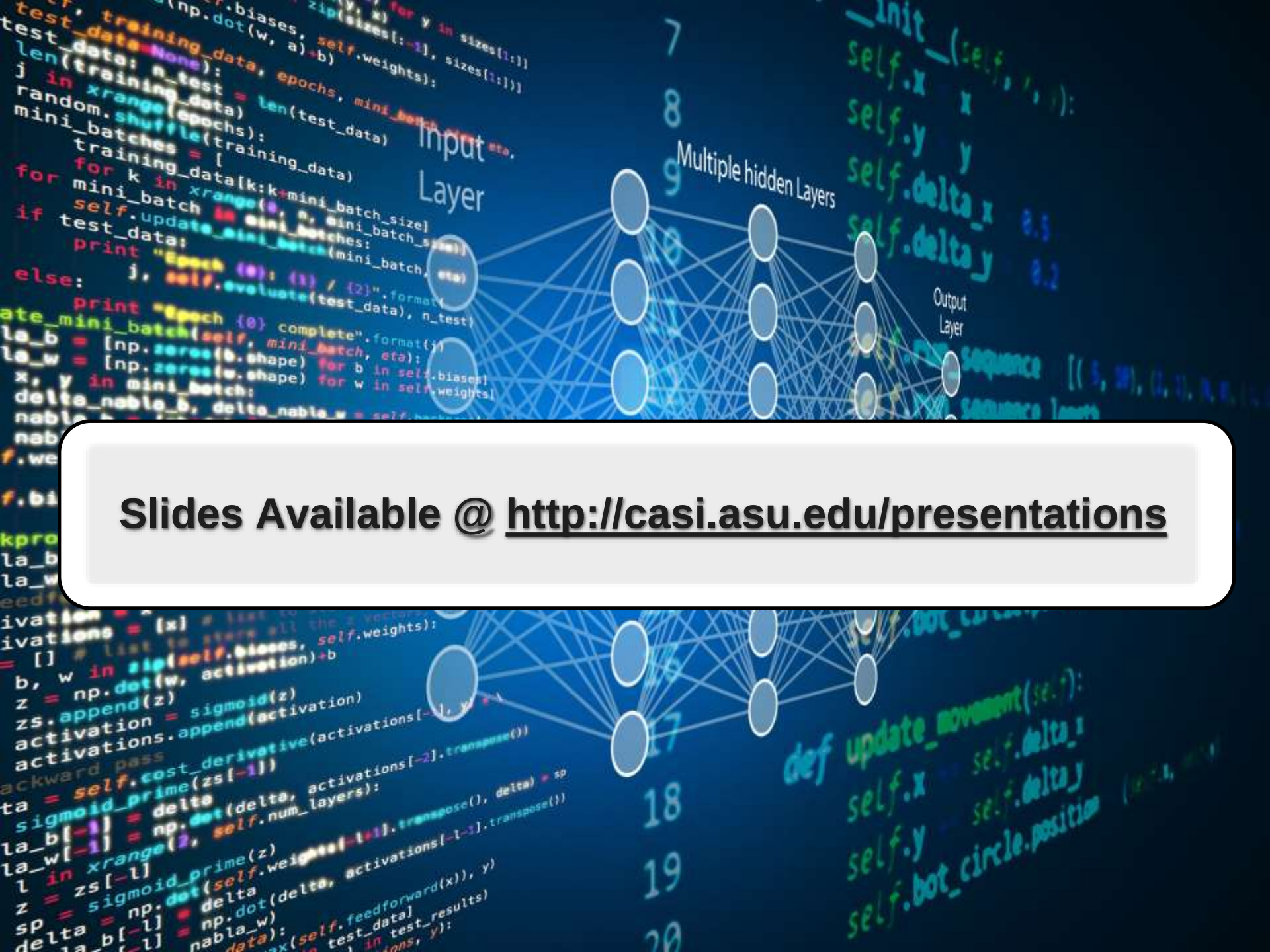
longitudinal monitoring of individual health status

The Evolution of a Data-Centric Learning Health Ecosystem

Earlier Detection of Health Risk and Mitigation

Improve Health Outcomes and QOL

Control the Unsustainable Growth in Health Cost



Slides Available @ http://casi.asu.edu/presentations