

**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 @ <http://casi.asu.edu/presentations>

Disclosures



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No GAI Platforms Were Used in Content Selection, Design, Assembly and Formatting This Presentation



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IMPROVING POPULATION HEALTH

Preventing and managing prevalent, costly, and chronic diseases^{2,4}



REDUCING COST OF CARE

Reducing resource utilization and readmissions while assuming greater risk²

QUADRUPLE AIM³



ENHANCING THE PATIENT EXPERIENCE

Motivating and engaging patients to play an active role in their care to improve outcomes and safety⁴



IMPROVING PROVIDER SATISFACTION

Providing access to tools and resources to address provider burden and burnout³

The US Health Ecosystem

Fragmentation, Fragilities and Looming Disruptions

- **isolated silos of expertise and care services**
 - **poor continuity in care and myriad embedded inefficiencies**
- **economically unsustainable cost escalation without improved outcomes**
- **disproportionate investment of \$4.4 trillion annual expenditure on reactive management of active disease (90%) versus proactive focus on health optimization (10%)**
 - **disease-centric (sick-care) versus health optimization (wellness)**
- **decoupling of population health initiatives from care delivery to individuals**
- **myriad fragilities and fault lines revealed and amplified by COVID-19 pandemic**
- **neglect of social determinants of health and adverse impact on minority/marginalized communities**
- **systemic vulnerabilities create major opportunities for disruptive innovation**

The Health Ecosystem

- **facing a confluence of complex events that will radically alter all aspects of biomedical research and health care delivery**
 - **national and global**
- **cross-domain technology convergence**
 - **biomedicine, engineering and computing**
- **cross-sector industry convergence**
 - **diagnostics, therapeutics, big data analytics, AI and social media**
- **economics of scale with drive increased vertical and horizontal consolidation**
- **public and political expectations**
 - **access, availability, affordability and outcomes**
 - **reduce disparities and inequities**

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

- **increasingly rational public health and clinical interventions to optimized health based on features unique to specific individuals/population cohorts**
- **improved detection of disease risk predisposition**
- **earlier detection of overt disease and prognosis/prediction of disease progression patterns**
- **shift societal disease burden from current predominant focus on treating advanced chronic disease to management of earlier stage disease and disease prevention**
- **strengthen surveillance and preparedness for rapid, resilient responses to disruptive external biosecurity threats**
 - **emerging infectious diseases, climate, cyber-risks**

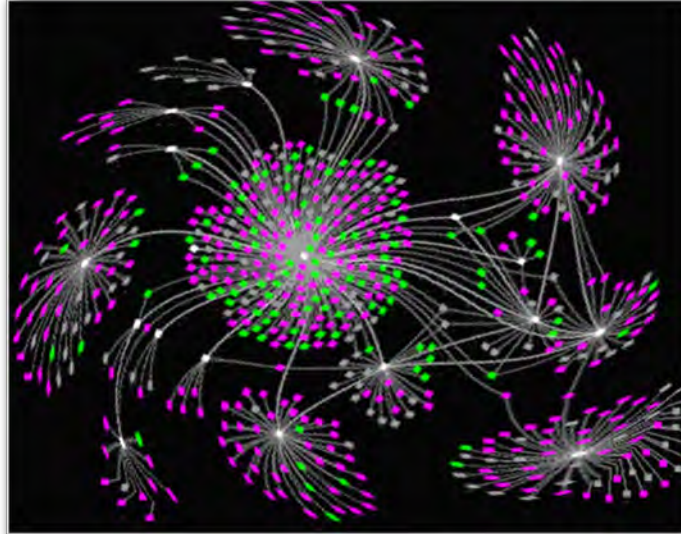
Precision Health

- **optimize the health of populations and individuals by improved precision in the identification and mitigation of health risks**
- **the organization, capabilities, incentives and accountabilities of multiple elements of the current health ecosystem are misaligned with this strategic aspiration**

Precision Health

**(Epi)Genomics and
MultiOmics Profiling**

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

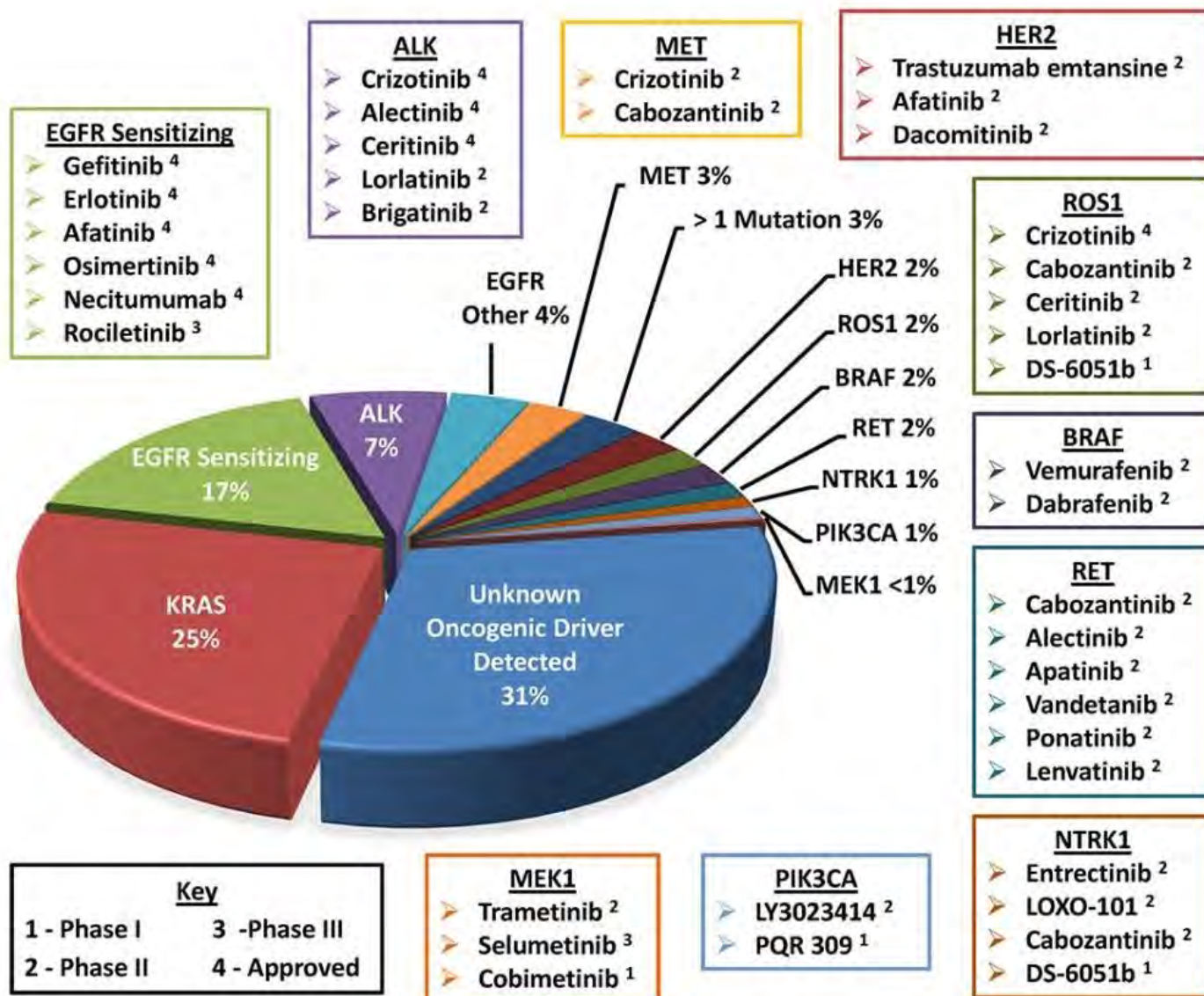


- **terabytes per individual**
- **zettabyte – yottabyte population databases**

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

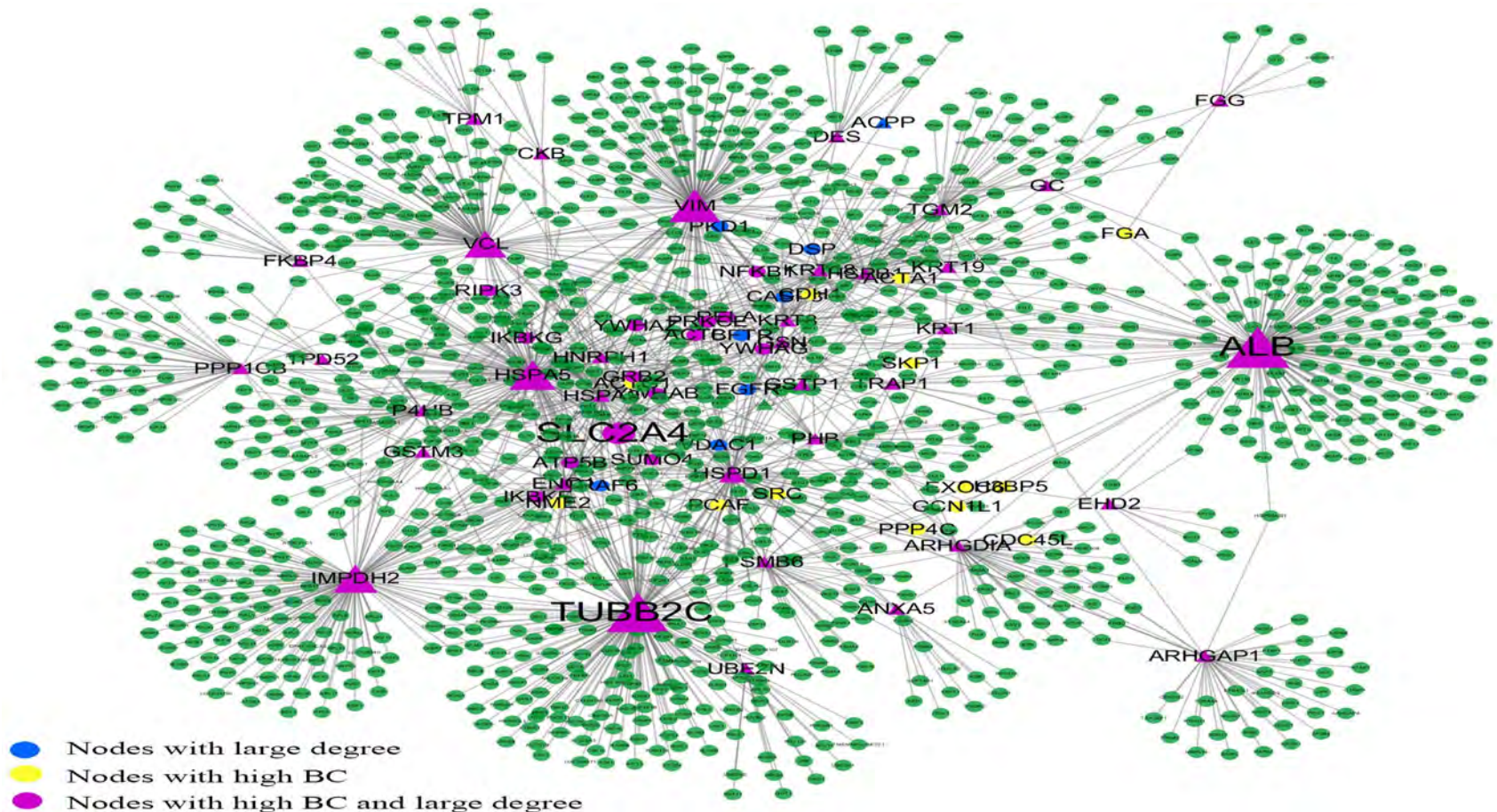
**The Challenge of
Big (Messy) Data**

Molecular Classification of Non-Small Cell Lung Cancer

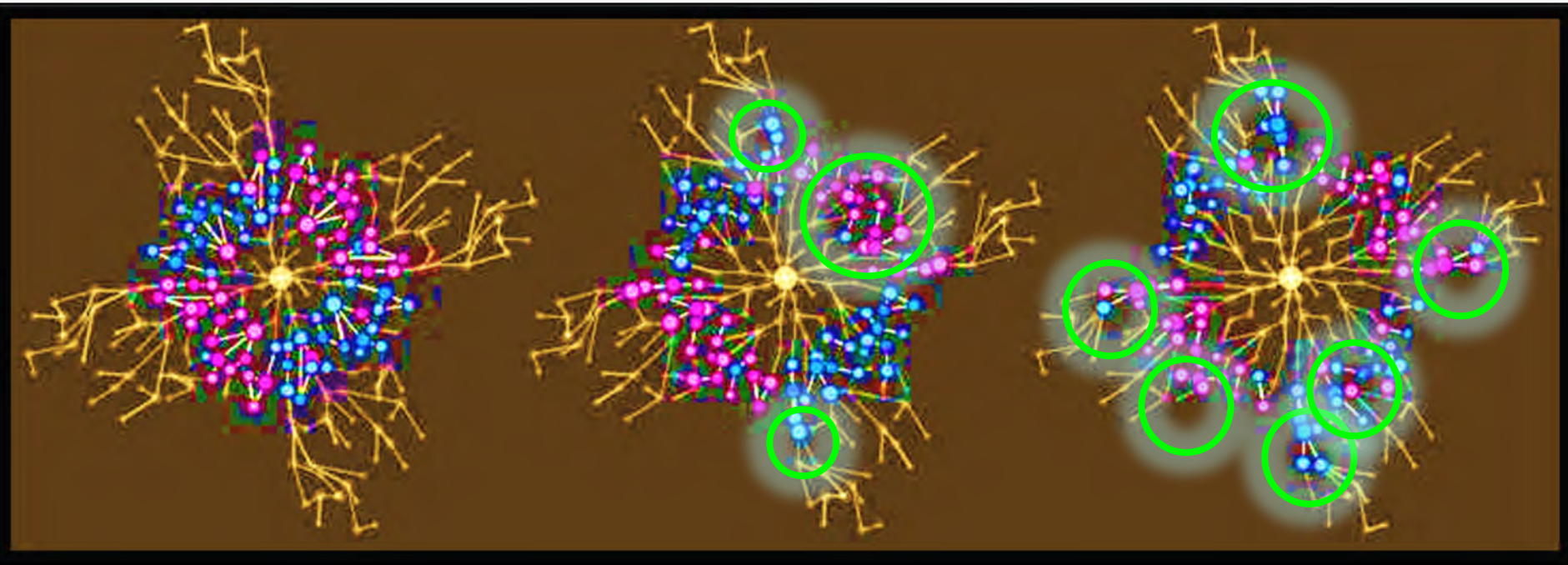


Understanding the Organization and Dynamics of Molecular Information Networks in Health (Physiology) and Disease (Pathology)

- mapping information flow (communication) within and between networks
- the progression from health to disease reflects the graded degradation in the fidelity of signal transmission



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 staging, prognosis and predicted progression**
 - **optimum treatment selection based on specific disease features in individuals and cohorts with similar phenotypes**
 - **prediction of Rx response, resistance and adverse events**
 - **faster alert of clinical deterioration and treatment non-adherence**
 - **tracking social determinants of health and exposure to environmental hazard exposures**
 - **proactive monitoring to detect pathogens with epi-/pandemic potential**

Deep Phenotyping: “Much More Than Omics”

**From Womb to Tomb:
Systematic Longitudinal Integration of Multi-modal Health Data**



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



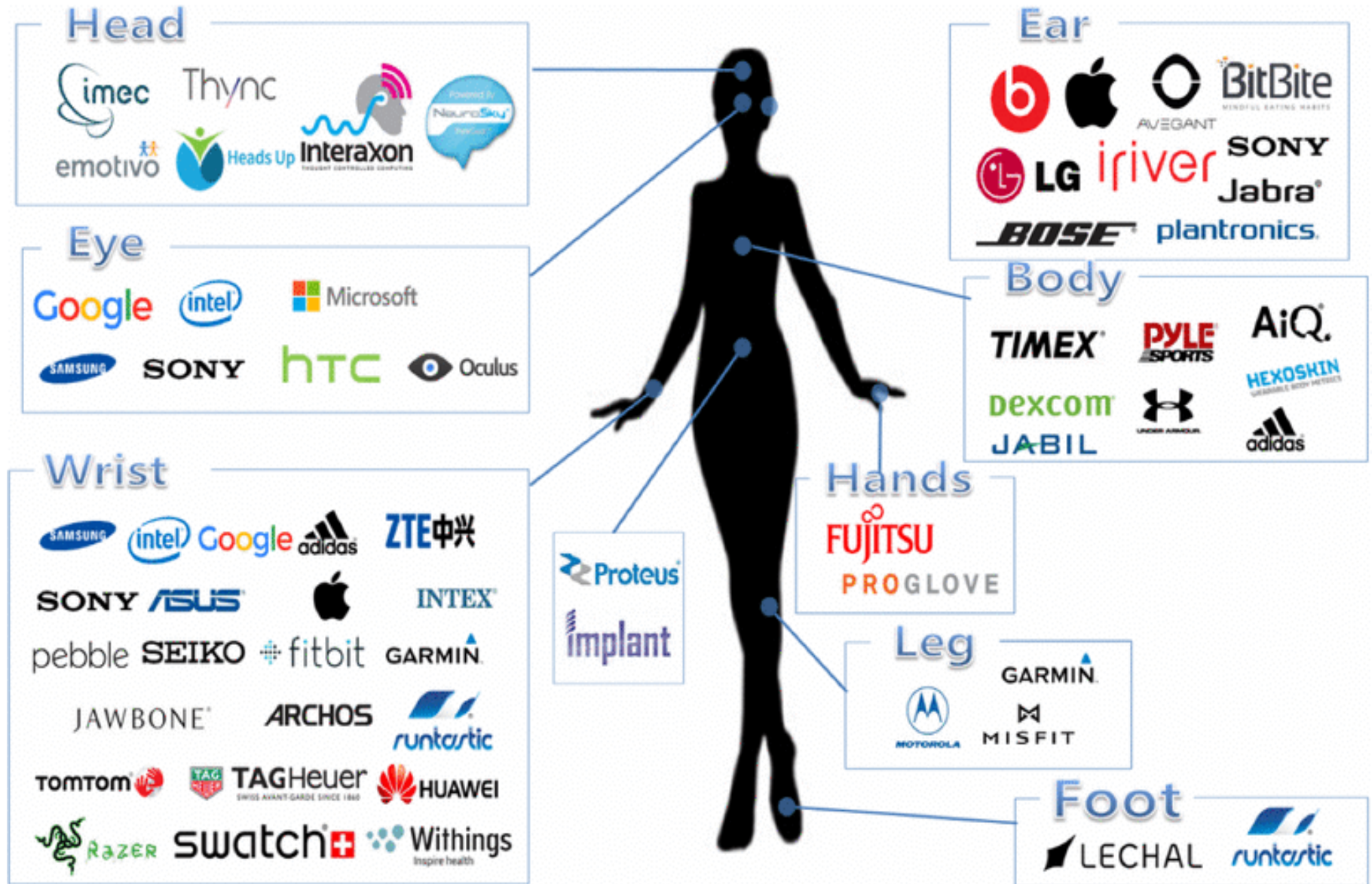
Expanding the 'Care Space' in Healthcare

- **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**
 - **longitudinal tracking**
 - **every population cohort/individual becomes their own control (tracking the Delta)**
 - **Internet-of-Medical Things (IOMT)**

Rapid Growth in Wearables, Sensors and Devices for Remote Health Status Monitoring



Wearables and Remote Health Status Monitoring



Smart Devices for Automated Drug Delivery and Improved Therapeutic Adherence



Propeller Health



Gecko (now Teva)



CapMedic



Biocorp Inspair



Help patients get **onboard**
with **onbody** injections

Onbody Trainers

Device Replication
Activation Simulation
Cartridge Simulation
Replaceable Device Adhesives
Injection Speed Simulation



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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

1%

- projected increase in number of caregivers aged 45 to 64 from 2010 to 2030

348,000

- projected number of home health aides needed in next decade

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 rise 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 physician-patient relationships**
- **Ux and formation of senior executive level Chief Patient Experience Officer posts in large provider organizations**

Economies of Scale and Consumer Convenience



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



Robot-Human Directed Interactions



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



Cyber-Physical-Biological Systems

Immersive Human-Machine Interfaces and Surgery

- **robotics, automation and AR/VR/XR**
- **integration of robot controls with advanced 3D imaging**
- **multiplex sensor arrays and endoscopes/catheters**
- **precision actuators, sensing and automated controls**
- **instant presentation of comparable cases into headdress of surgical team members**
- **address shortages in surgical specialities**
 - **331 million US population**
 - **4000 cardiothoracic surgeons**
 - **3500 neurosurgeons**

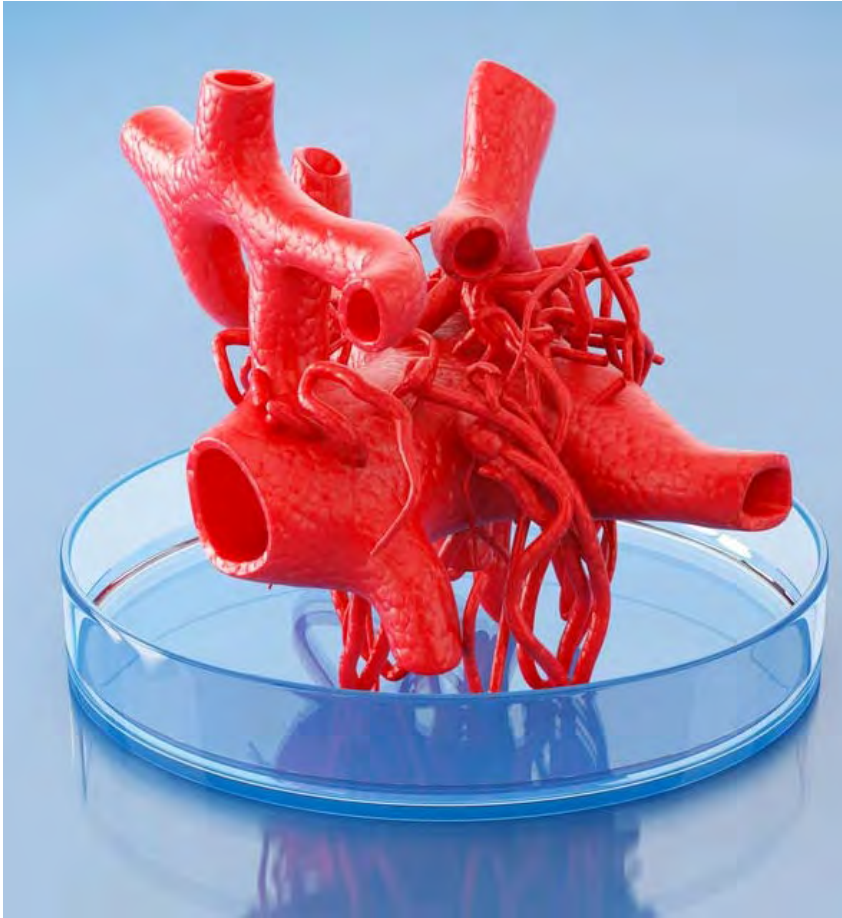
AR/VR/XR Neuromodulation in Clinical Care



- injury rehabilitation
- reduce apprehension/distraction in painful procedures
- anxiety, depression, PTSD, phobias

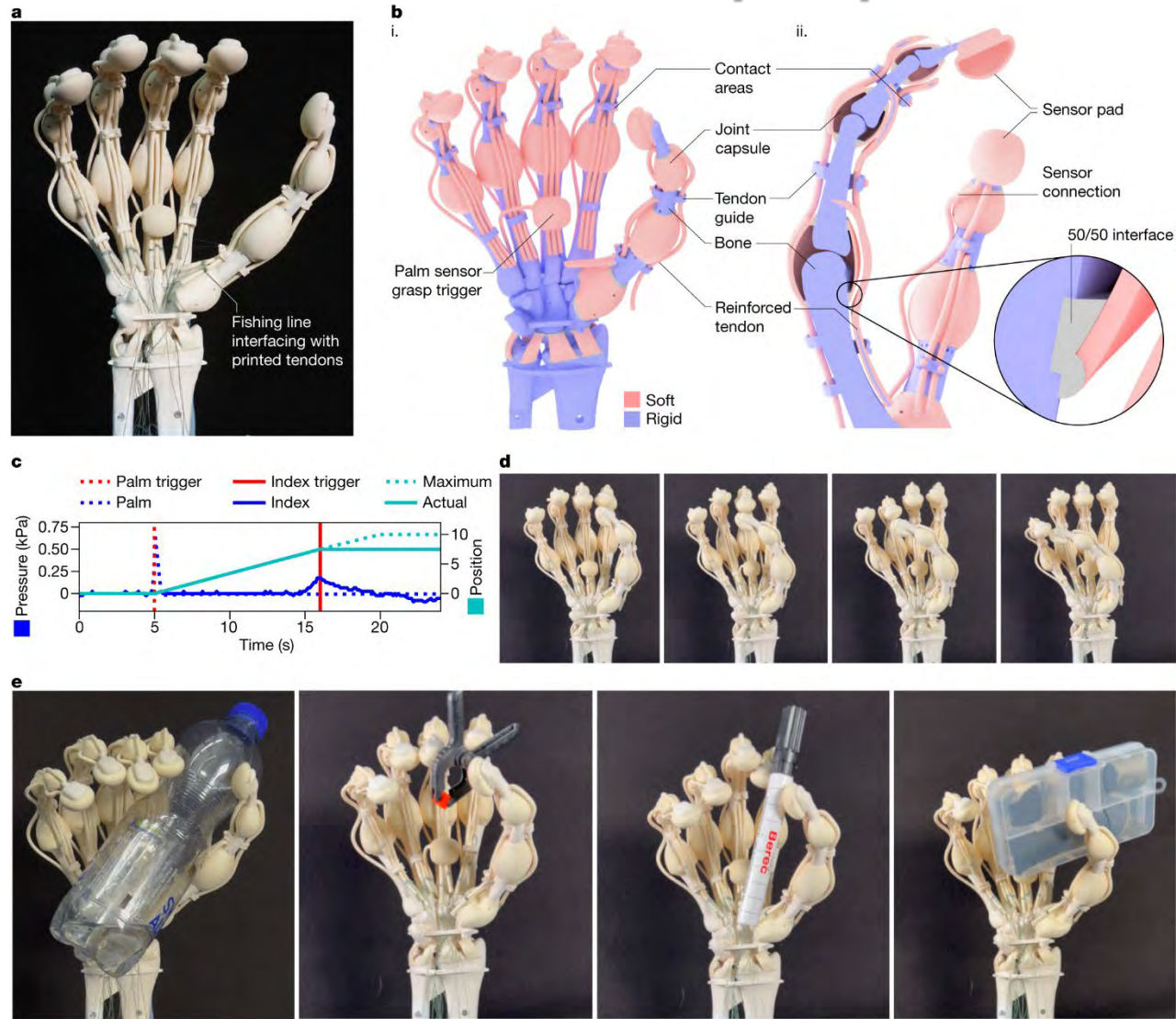
The Future of Making: Industry 4.0 Technologies

Advances in Materials Science and Bioprinting of New Biological Implants

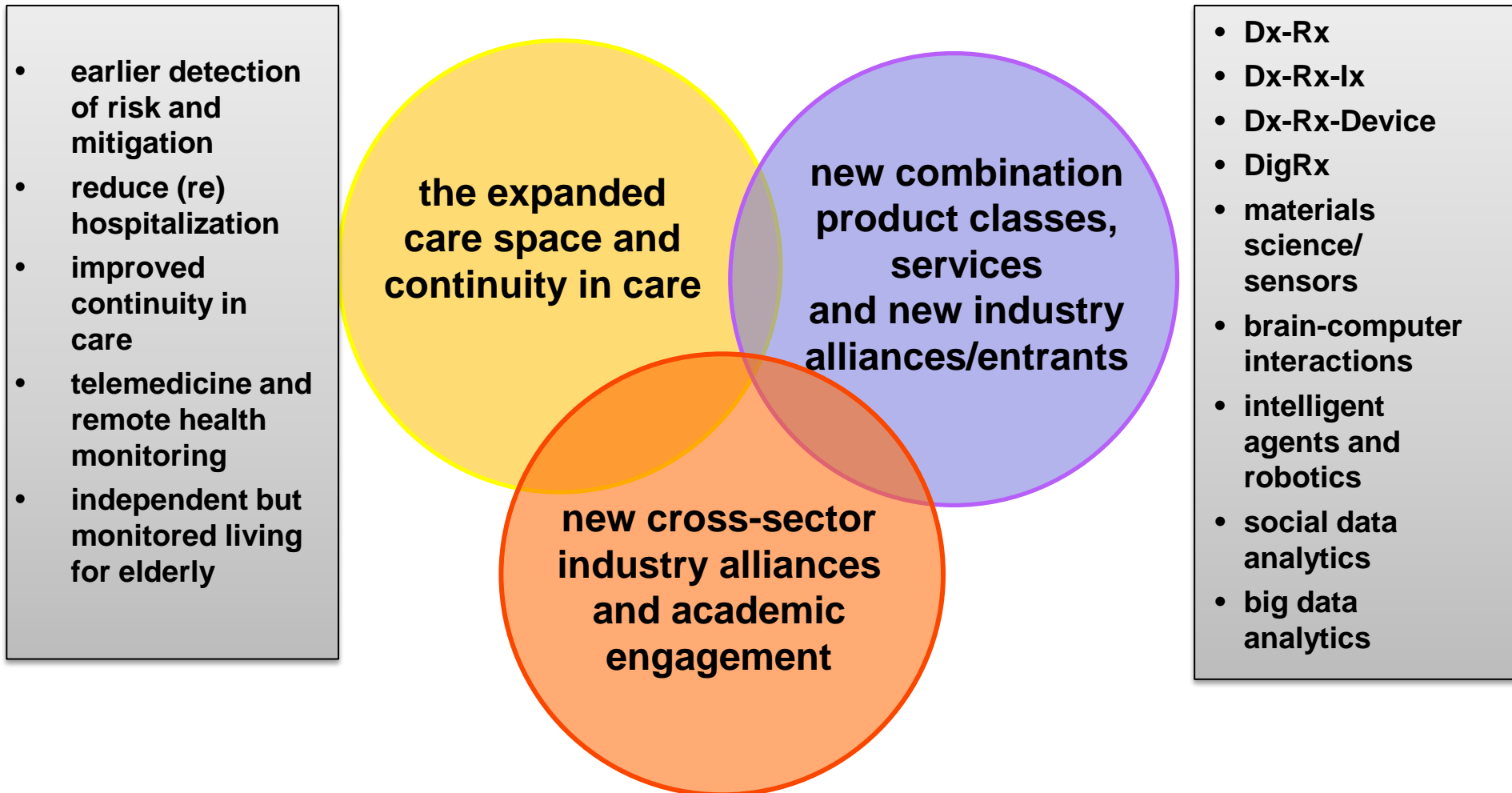


- **automated generative design and assembly**
- **additive manufacturing**
 - **multi-materials, multi-control elements**
 - **biotic: abiotic combinations**
- **real-time remote data transmission on performance**
- **automated self-repair and agile reconfiguration in response to altered environments**

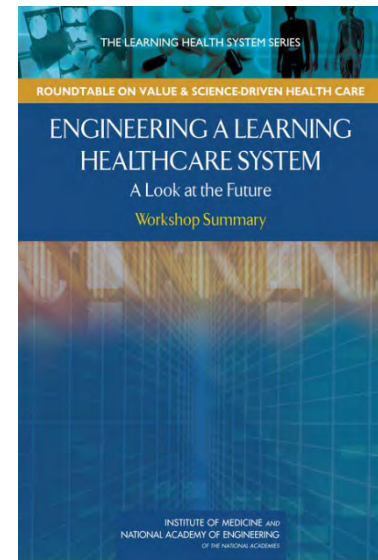
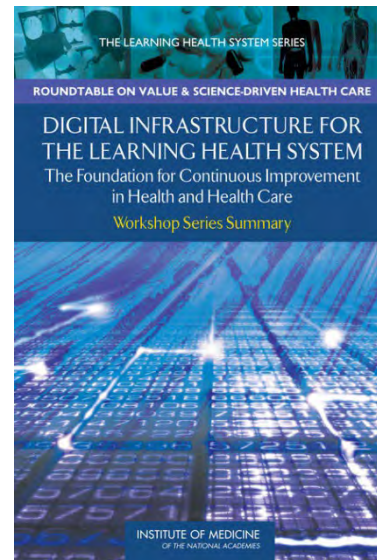
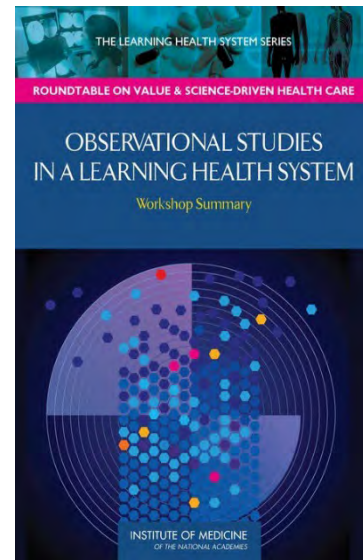
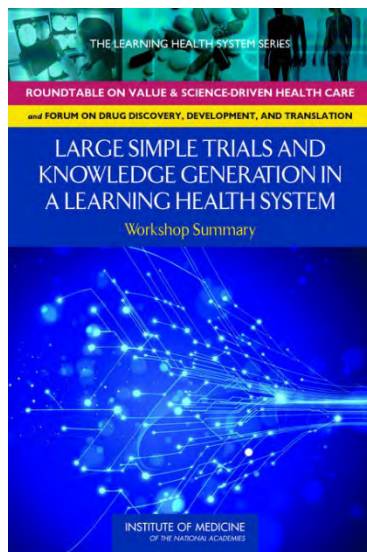
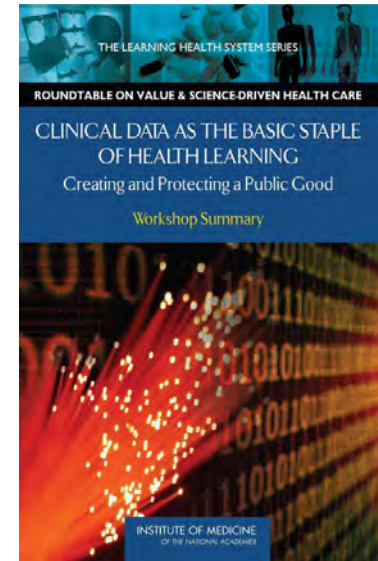
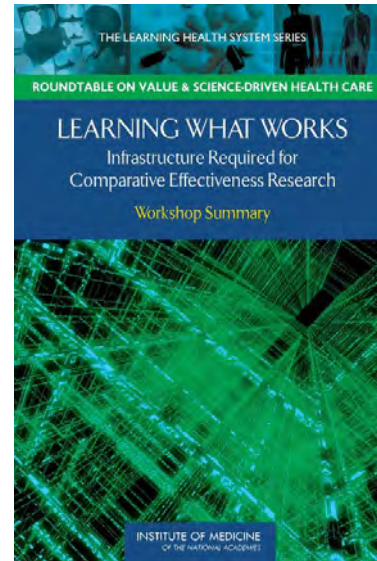
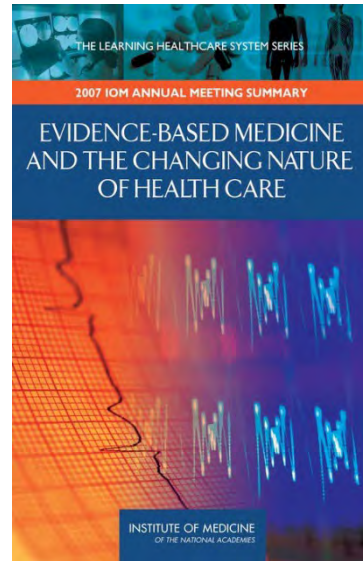
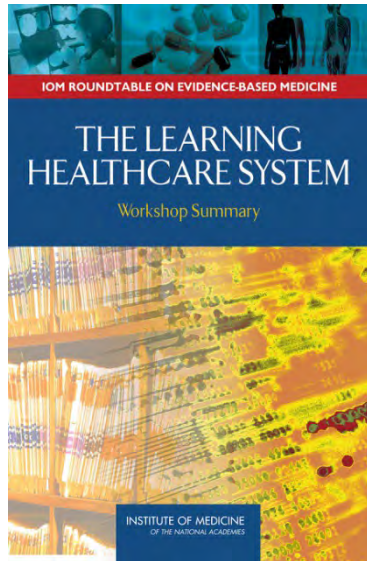
3D One Process Manufacture of Sensorized Robotic Hand with Tendon-Driven Grip Capabilities




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



The Learning Healthcare System





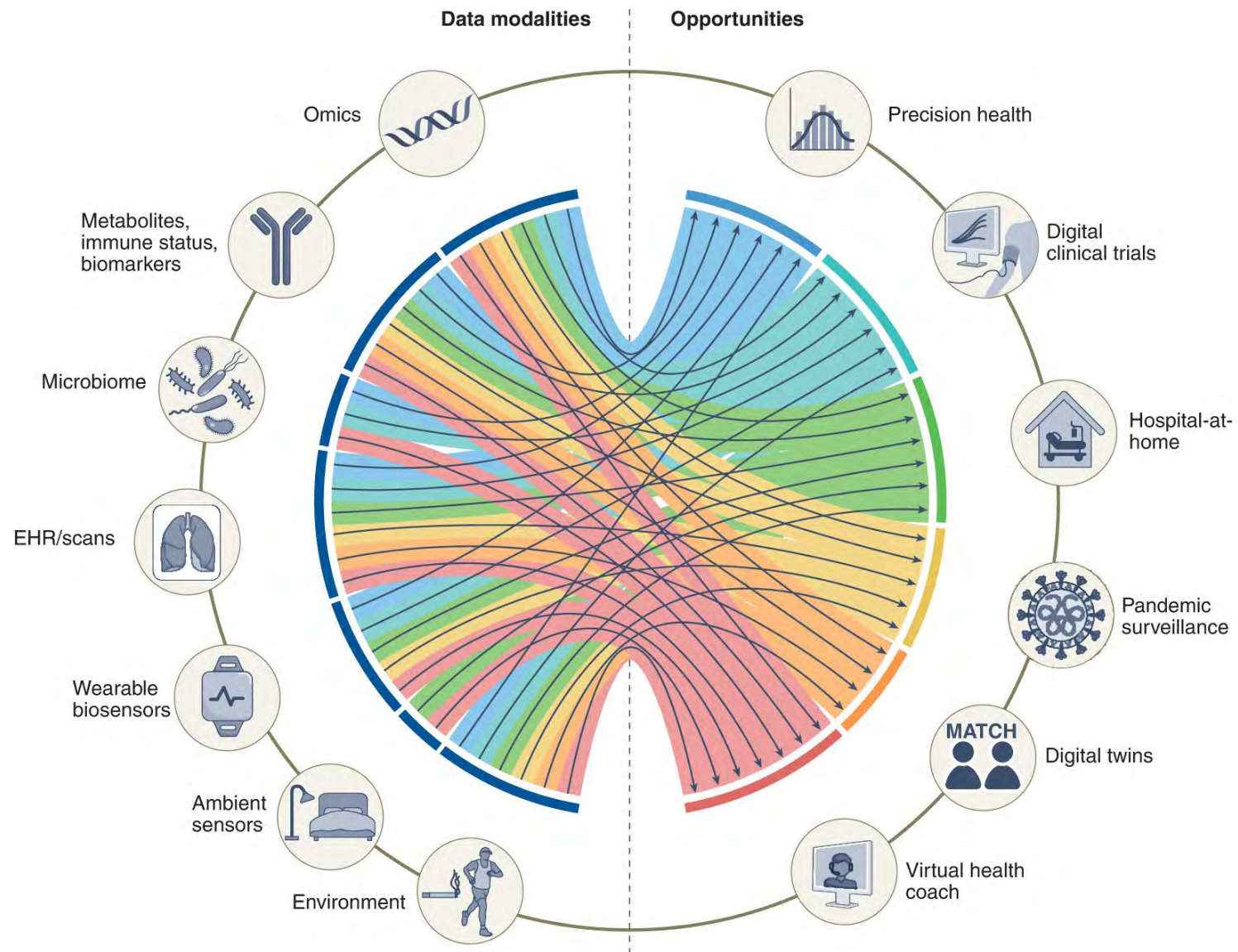
HELL IS THE PLACE WHERE NOTHING CONNECTS — T.S. ELIOT



**Welcome to
The World of
Biomedical Research
and
Healthcare Information Systems**

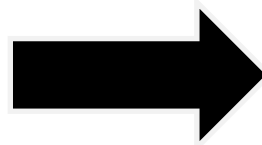


Precision Health and Deep Phenotyping: Multimodal Data Integration for Longitudinal Management of Health Risks



Precision Health and Digital Health: Building a Learning Health System

qualitative,
descriptive
information of
variable quality and
provenance



quantitative data
of known
provenance and
validated quality

complex ecosystem
of largely
unconnected
data sources



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

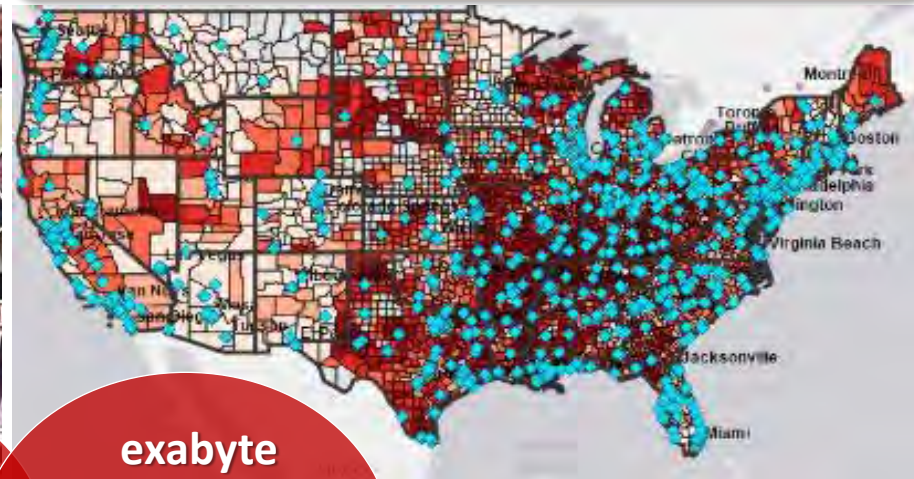
Precision Health and Digital Health: Evolving Inter-Dependencies

Individual Data



integration
and analysis
of large-scale
diverse data

Population Data



exabyte
and
zettabyte
data deluge

Deep Phenotyping:

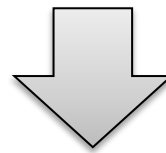
- multiOmics
- clinical history- EHR/PHR
- remote health monitoring
- socio-behavioral data
- environmental exposures

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**

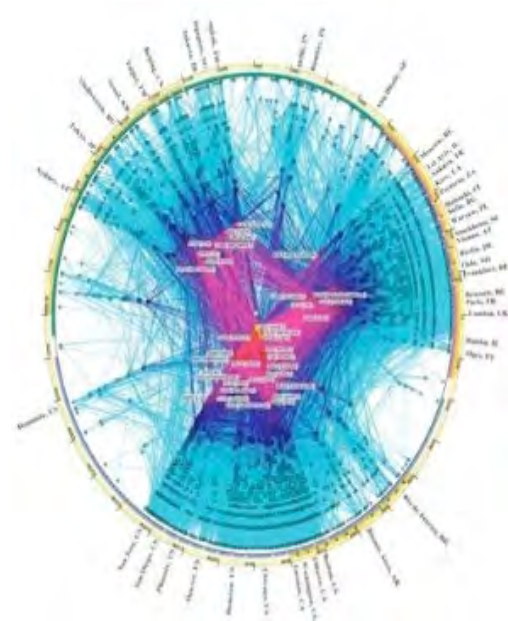
Big Data Changes the Questions That Can Be Asked



Isolated
Data



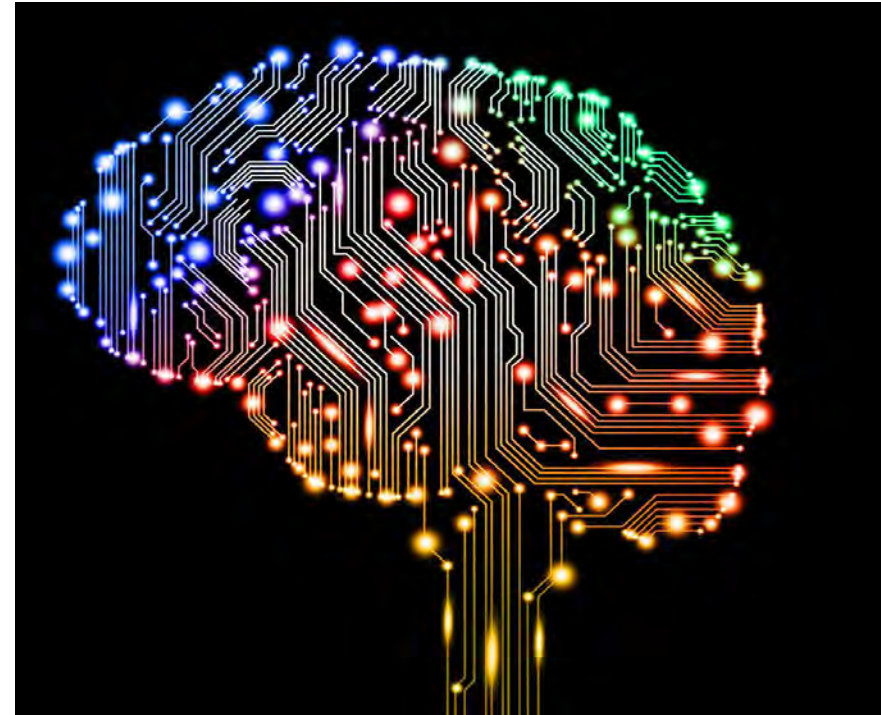
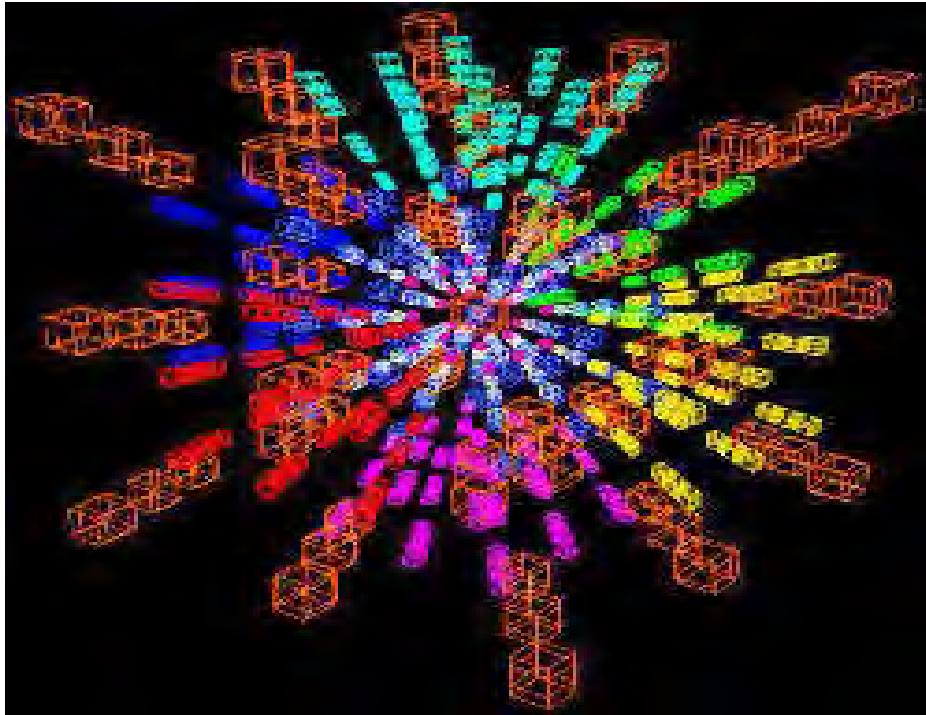
Complex
Networked Data



Complex
Computational Data

Automated Context: Data Finding Data

“Intelligence at Ingestion” and Collapse Time to Decision



**Feature
Extraction
and
Classification**



**Context
Analysis**

**Persistent
Context**



- **Knowledge
Topologies**
- **Learning
Systems**



- **Data
Fidelity**
- **Rapid,
Robust
Decisions**

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

Data Deluge



Cognitive Bandwidth Limits



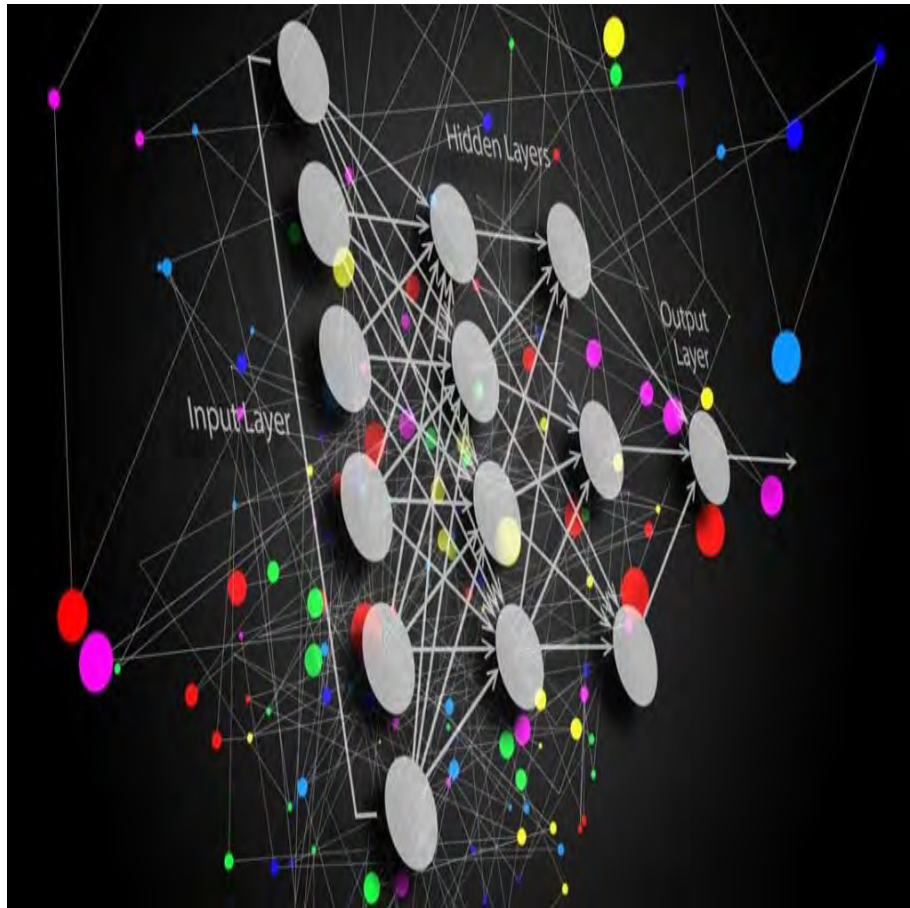
Automated Analytics and Decision Support



Facile Formats for Actionable Decisions

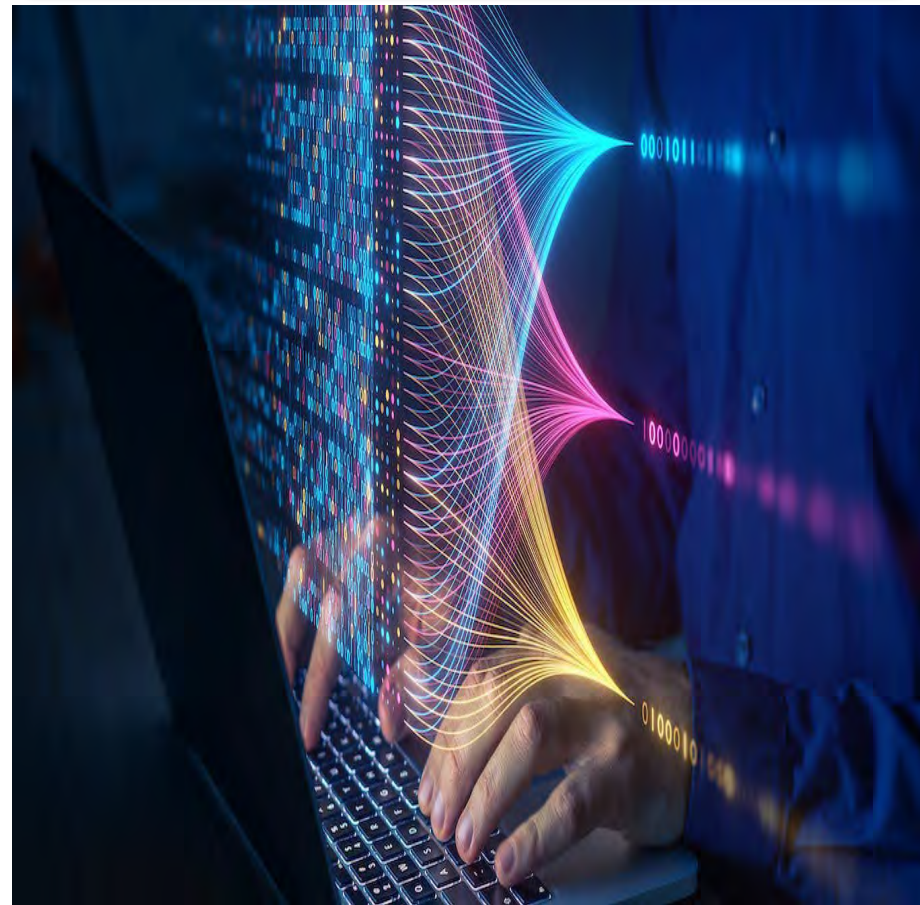
AI Large Language Models (LLMs): Transformation of the Research Process and Clinical Decision-Making

GAI Platforms



<https://insidebigdata.com/2023/10/01/video-highlights-vicuna-gorilla-chatbot-arena-and-socially-beneficial-llms-with-prof-joe-gonzalez/>

Deep Learning and Pattern Analysis in Multi-model Data Integration



<https://techxplore.com/news/2023-07-chatgpt-people-surprised-where-technologies-difference.html>

The GAI Investment Frenzy 2023

 Meta

PyTorch, LLaMA (24 Feb.)





Palm (10 March)

BARD

ANTHROPIC

 OpenAI

GPT4 (14 March)

 Microsoft



(7 March)



ERNIE (15 March)

 Microsoft

 GitHub

Copilot X (22 March)



expand
partnerships



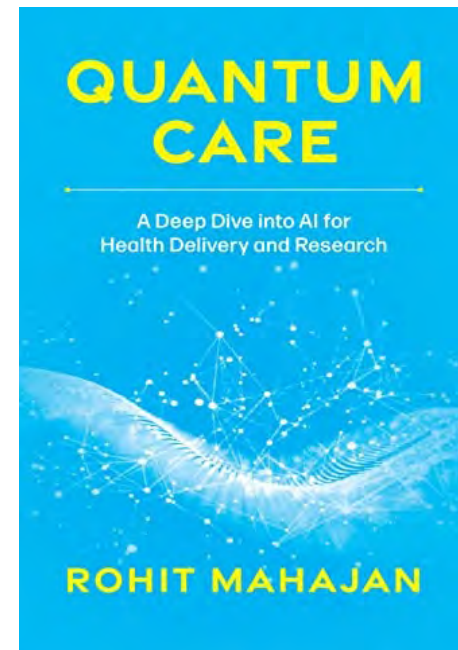
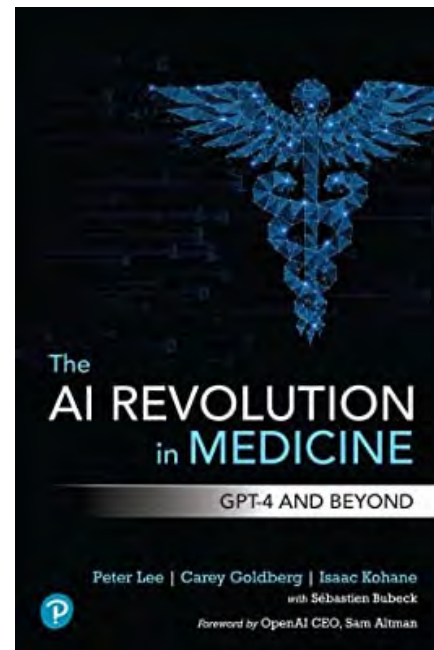
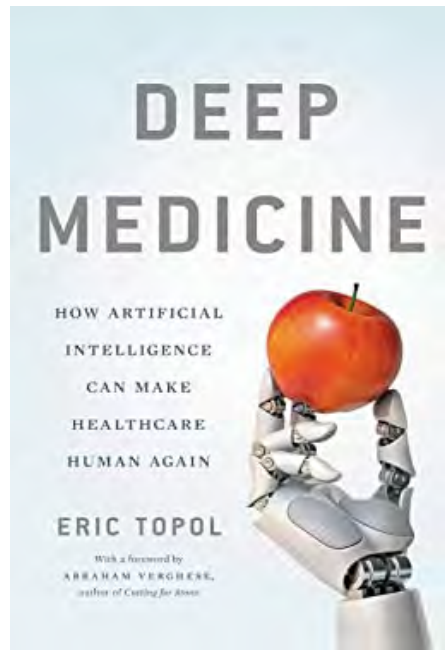
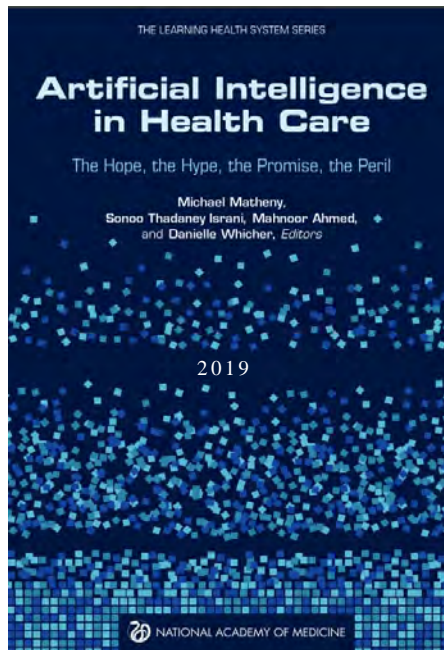
Hugging Face

ANTHROPIC



ChatGPT app added its Slack and Einstein
platforms

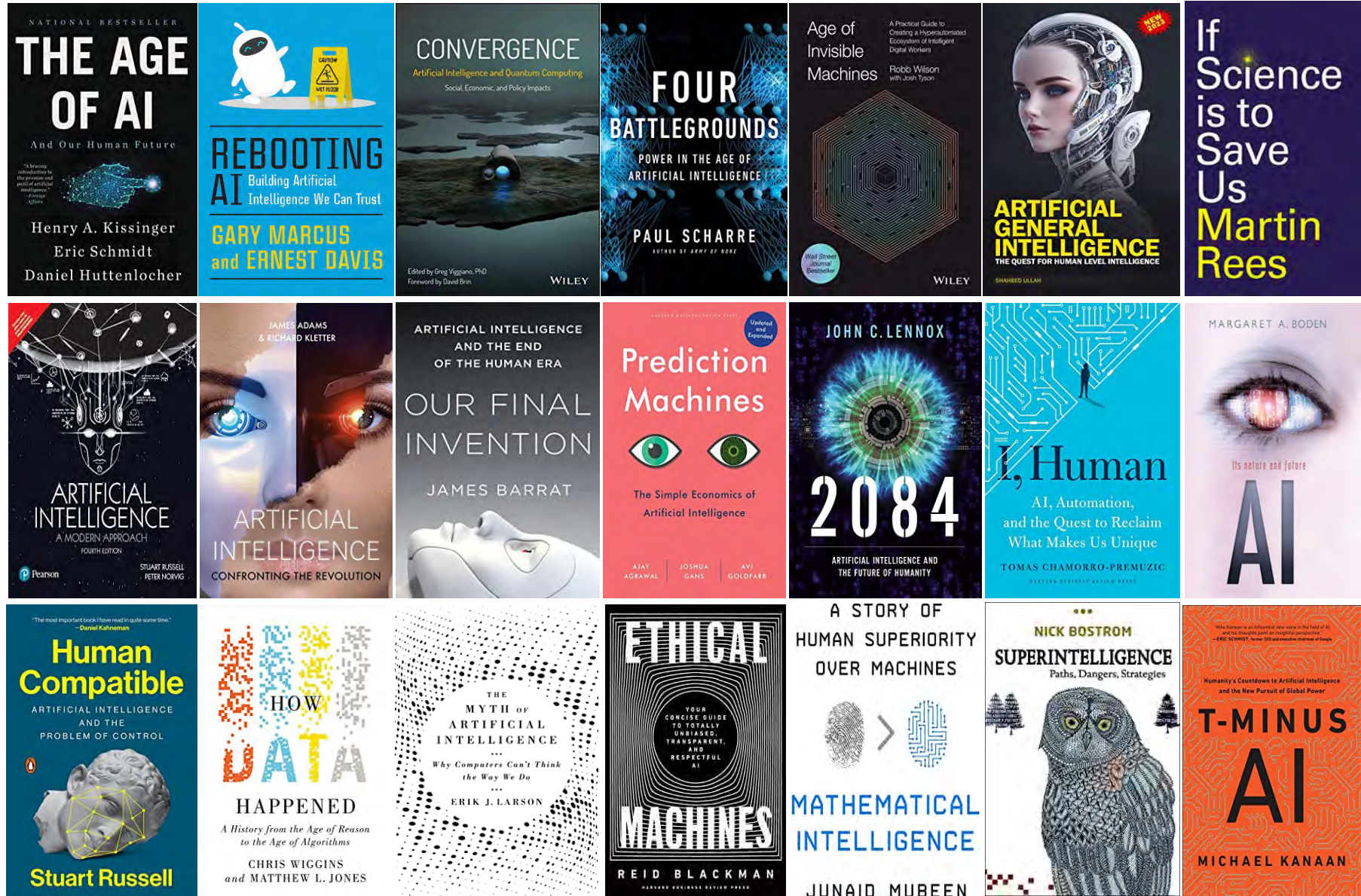
Generalized Artificial Intelligence and Healthcare



AI and Healthcare

- **impressive examples of generation of rapid and accurate responses to questions from HCPs and patients**
- **but frequency of inaccurate and/or nonsensical responses (“hallucinations”) remains problematic**
- **intrinsic learning property of LLMs with access to more data, new hallucination detection filters and refined ‘prompt semantics’ is anticipated to rapidly overcome this vulnerability**

No Shortage of Commentaries on the Potential of AI for Limitless Benefits or the Road to Dystopian Futures and Machine Control





OCTOBER 30, 2023

FACT SHEET: President Biden Issues Executive Order on Safe, Secure, and Trustworthy Artificial Intelligence



KMB/DA/AS

Committee on the Internal Market and Consumer Protection
Committee on Civil Liberties, Justice and Home Affairs

9/5/2023

Version: 1.0

DRAFT Compromise Amendments on the Draft Report

Proposal for a regulation of the European Parliament and of the Council
on harmonised rules on Artificial Intelligence (Artificial Intelligence Act)
and amending certain Union Legislative Acts

(COM(2021)0206 – C9 0146/2021 – 2021/0106(COD))



December 18, 2023

Preparedness Framework (Beta)

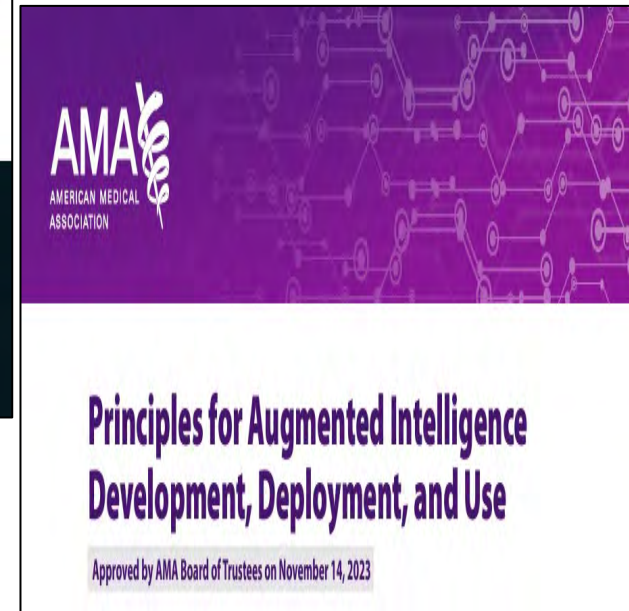
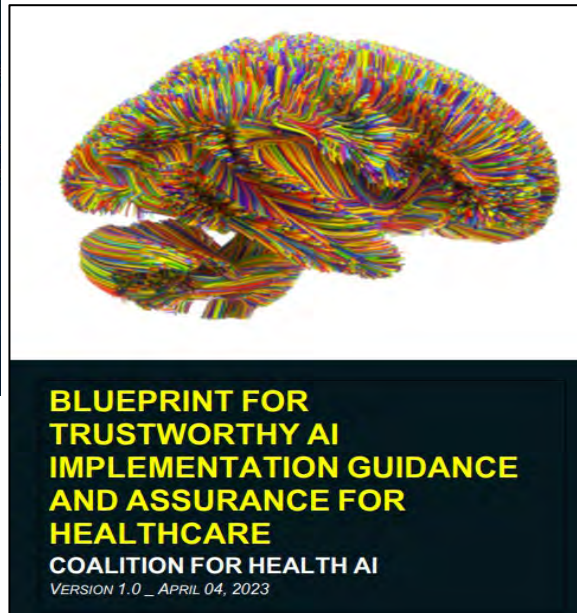
We believe the scientific study of catastrophic risks from AI has fallen far short of where we need to be.

To help address this gap, we are introducing our Preparedness Framework, a living document describing OpenAI's processes to track, evaluate, forecast, and protect against catastrophic risks posed by increasingly powerful models.

U.S. DEPARTMENT OF DEFENSE RESPONSIBLE ARTIFICIAL INTELLIGENCE STRATEGY AND IMPLEMENTATION PATHWAY

Prepared by the DoD Responsible AI Working Council in accordance with the memorandum issued by Deputy Secretary of Defense Kathleen Hicks on May 26, 2021, Implementing Responsible Artificial Intelligence in the Department of Defense.
June 2022

Oversight and Regulation of AI in Healthcare



The Rush to Regulate AI: We've Been There Before

Wall Street Journal, 2 January 2024

- **each new technology with broad multi-domain applications evokes calls for one-size-fits-all governance policies and regulation**
- **1980s: biotechnology**
- **1990s: www and internet**
- **2023: generative artificial intelligence**

**Cyberspace and the Law of the Horse:
1996 Opinion by Judge Frank Easterbrook 7th US Grand Court of Appeals**

- **calls for a single regulator/regulation for governance of the web and the emerging internet would be as futile as an effort to create a single pathway to regulate the multiple uses of horses in the 19th century economy**



US Regulation of AI Platforms in Healthcare

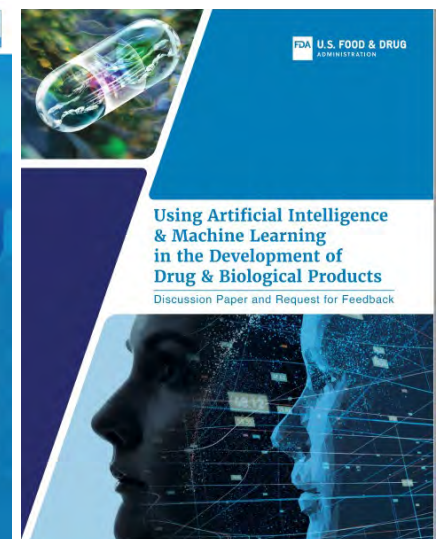


“FDA needs to be nimble in the use and regulation of large language models to avoid being swept up quickly by something we hardly understand.”

Dr. R. Califf

FDA Commissioner, 9 May 2023

2023 Science for Patient Engagement Symposium



Regulatory Oversight and Validation of Large Language Model (LLM) AI Platforms in Clinical Decisions

- **transparency and patient informed consent when AI tools used in their care**
- **malpractice liabilities**
 - **harm from use (platform developers, HCPs, or the health systems which approved adoption)**
 - **harm from failure to use or ignored recommendations when AI-decision support systems are integrated into SOC, professional guidelines or regulatory labeling**

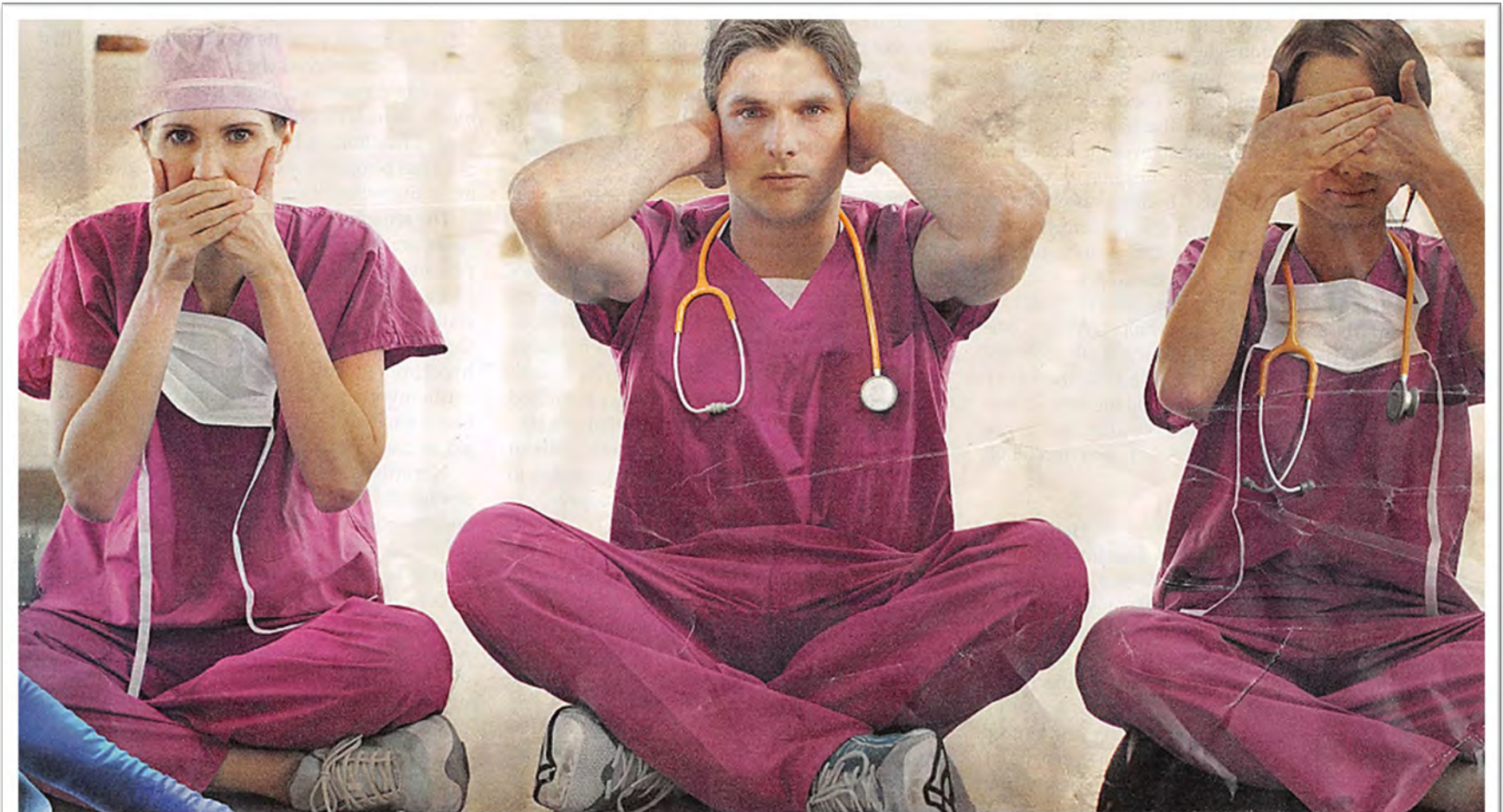
Navigating Disruptive Change



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

- Peter Drucker

DNR: Cultural Barriers to Adoption of Innovation



Denial

Negativity

Resistance

New Thinking and New Capabilities



MITRE



Agency for Healthcare
Research and Quality



MAYO CLINIC



OPTUM

The Office of the National Coordinator for
Health Information Technology



Microsoft



Stanford
University

Drake
UNIVERSITY

UCSF

University of California
San Francisco

Berkeley
UNIVERSITY OF CALIFORNIA



VANDERBILT
UNIVERSITY



JOHNS HOPKINS
UNIVERSITY



PARTNERSHIP ON AI

GORDON AND BETTY
MOORE
FOUNDATION



Stanford
MEDICINE



Stanford University
Human-Centered
Artificial Intelligence

RAISE-Health

Responsible AI for Safe and Equitable Health



Lloyd Minor, MD

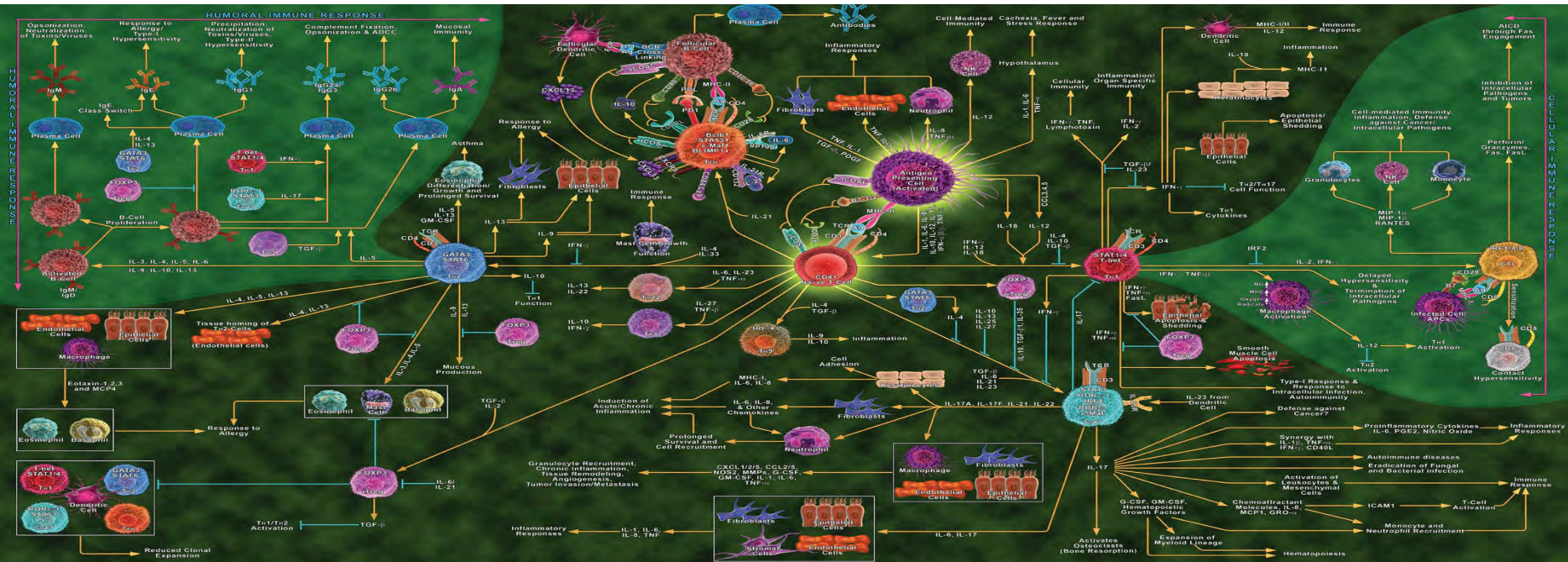
Carl and Elizabeth Naumann Dean,
Stanford University School of Medicine



Fei-Fei Li, PhD

Co-Director, Stanford Institute
for Human-Centered Artificial
Intelligence (HAI)

Navigation of Escalating Scientific and Clinical Complexities



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Major Transitions in Medical Education and Healthcare

1910 - present

MEDICAL EDUCATION IN THE UNITED STATES AND CANADA

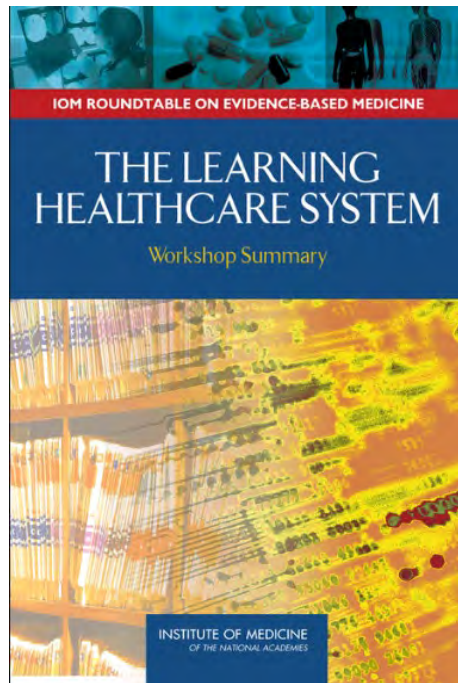
A REPORT TO
THE CARNEGIE FOUNDATION
FOR THE ADVANCEMENT OF TEACHING
BY
ABRAHAM FLEXNER

WITH AN INTRODUCTION BY
HENRY S. PRITCHETT
PRESIDENT OF THE FOUNDATION

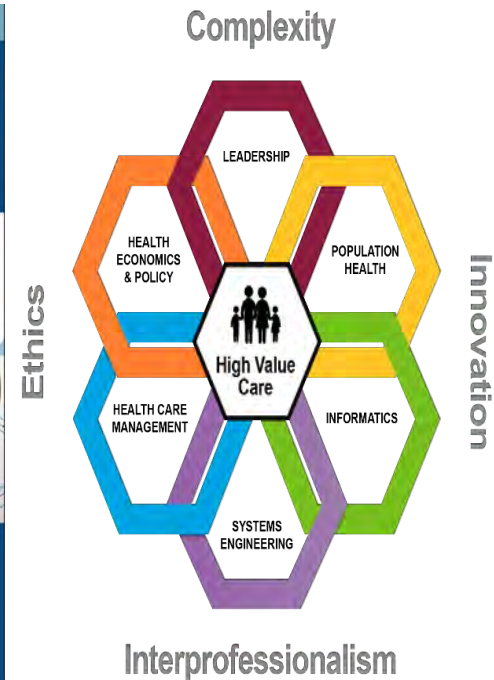
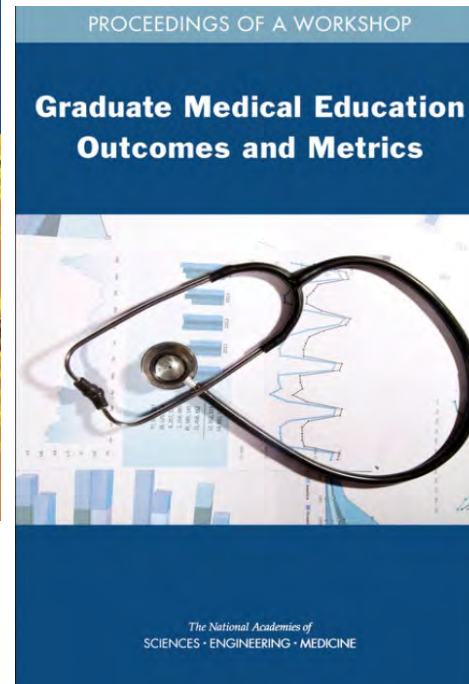
BULLETIN NUMBER FOUR (1910)
(Reproduced in 1960)
(Reproduced in 1978)

437 MADISON AVENUE
NEW YORK CITY 10022

2000 - present



2015 - ?



NATIONAL
ACADEMIES

Sciences
Engineering
Medicine

Artificial Intelligence in Health Professions Education



Proceedings of a Workshop

Harvard Business Review

Reskilling in the Age of AI

New approaches
for managers and
employees

PAGE 56

HBR.ORG



September-
October
2023



Issue Brief

AI Faculty Shortages

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

Authors

Remco Zwetsloot

Jack Corrigan

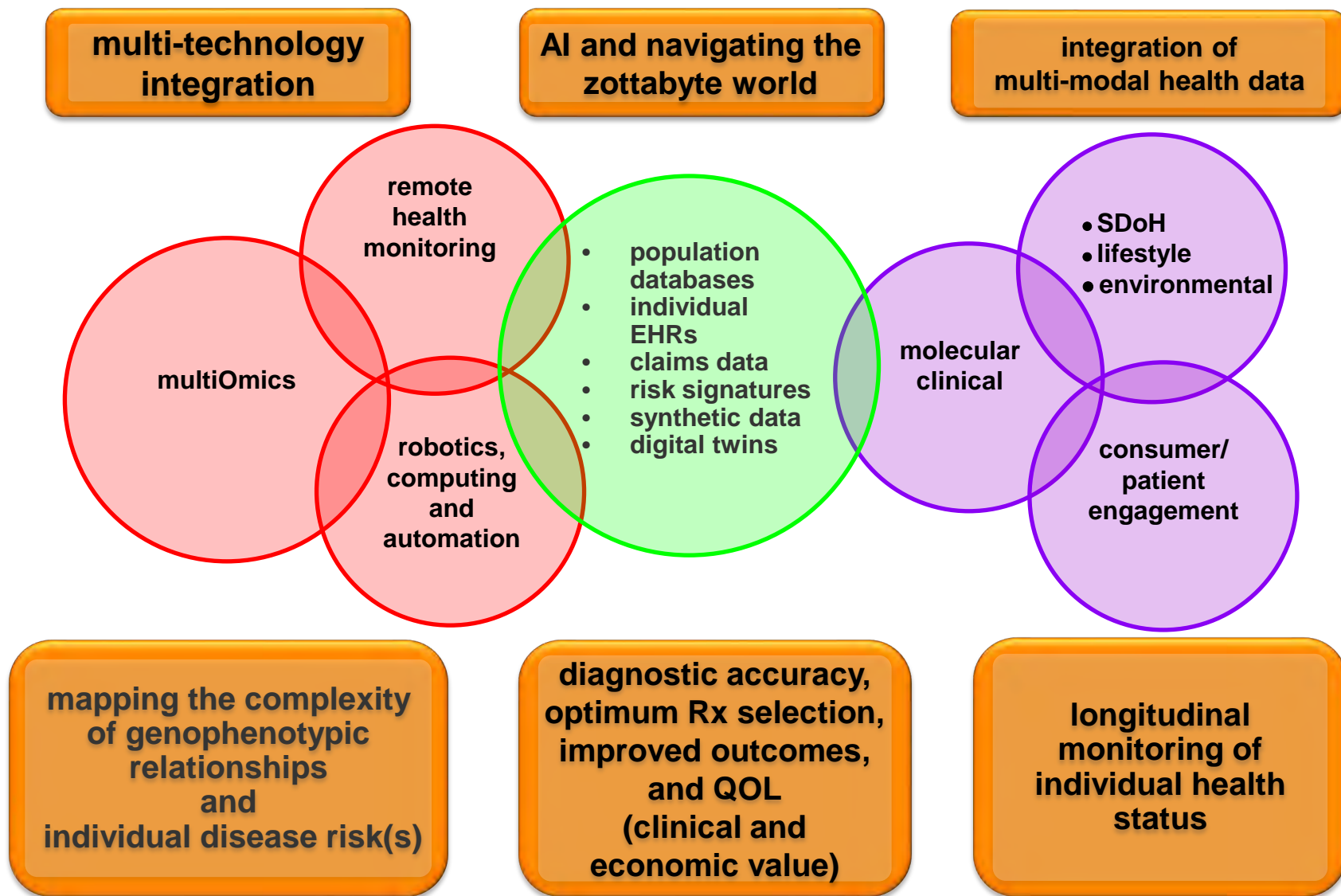
 **CSET** CENTER for SECURITY and
EMERGING TECHNOLOGY

July 2022

“Digital Darwinism”: A Looming Digital Divide

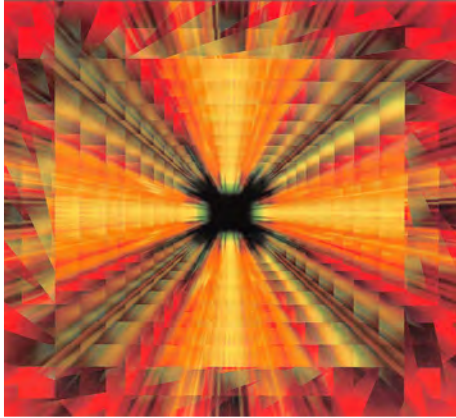
- **understanding data structure and its productive application/customization for acceleration of research and clinical care will become a critical institutional competency**
- **major skill gaps and personnel shortages in biomedicine**
- **training of a new cadre of data scientists (medical and non-medical)**
- **institutions lacking adequate computational infrastructure and critical mass in data analytics will suffer ‘cognitive starvation’ and relegation to competitive irrelevance**

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



The Evolution of Data-Intensive Precision Health

**Technology
Convergence
and Acceleration**



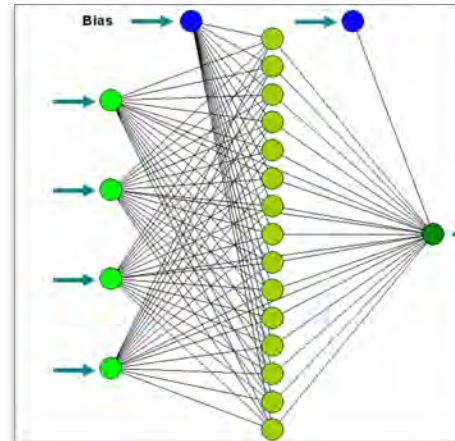
**Mapping
Geno-Phenotype
Complexity**



**Topology of
Biological
Information
Networks**



**Multi-modal Data
Integration**



**Data Security
and Privacy**

**Robotics and Human
Machine Interactions**

**Artificial Intelligence
and Decision Support**

**Public Policy:
Ethics, Risk and
Regulation**

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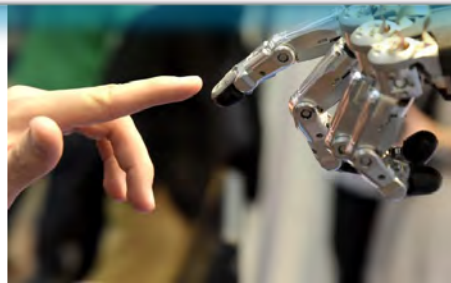
**Multi-modal Data
Integration**



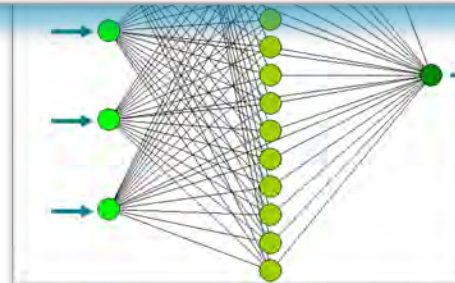
Slides Available @ <http://casi.asu.edu/presentations>



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