ASU® Complex Adaptive Systems Initiative
Arizona State University

Intelligent Healthcare: Biotechnology, AI and Precision Health

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

The US Health Ecosystem

- **unsustainable cost of continued growth in health expenditures**

- **$4.9 trillion in 2024 (18% GDP) and projected $7 to 9 trillion by 2035**

- **higher per capita spend (2 to 5 times) than other G20 industrialized nations but inferior health outcomes and shorter average lifetime**

- **top one third of US income earners enjoy 15 to 20-year greater longevity than the lowest third**

- **aging society and chronic disease burden will intensify cost pressures on public healthcare funding (Medicaid; Medicare) and OOP spend by individuals**

The US Health Ecosystem

- **disproportionate expenditure on reactive management of active disease (90%) versus proactive emphasis on disease prevention and health optimization (10%)**

- **administrative 'bloat': 25% total cost**

- **continued dominance of fee-for-service versus value-based-care**

- **byzantine and opaque pricing and billing practices**

The US Health Ecosystem

- **largest producer of data but poorest in its use to improve care and operational efficiency**

- **HCP 'burnout'**
  - **job dissatisfaction**
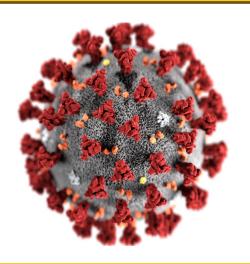 - **physician and nursing shortages**

Global Health Risks:
What Happens Over There, Doesn't Stay Over There

Inadequate Pandemic Preparedness

US Retreat from Global Health Initiatives

Climate and Health

2024 US Healthcare Climate Survey

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Antimicrobial Resistance

Agricultural Productivity Food Security

Conflict and Humanitarian Disaster

Turbulence and Trust

The Erosion of Trust

- **political responses to COVID accelerated erosion of trust in institutions and expert opinion**

- **proliferation of conspiracy theories**

- **skepticism amplified by destructive partisan political polarization**

The Erosion of Trust:
Broader Societal Concerns About Technological Innovation

- **public concern over risk, safety and adverse consequences of new technologies**
  - **the "distraction" ecosystem of electronically tethered lifestyles**
  - **decline in attention spans and cognitive literacy**
  - **AI automation and job losses**
- **cynicism over incentives and profitability of bigPharma, BigTech, mega-health insurers**

Disruptive Technology-Driven Redesign of the Health Ecosystem

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Industry is our edge

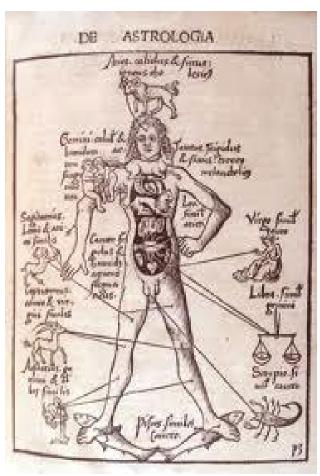**From breaking point to breakthrough: the $1 trillion opportunity to reinvent healthcare**

- **unprecedented acceleration of new technologies**

- **radical redesign of all aspects of the health ecosystem**

- **the evolution of precision health as the core strategic value proposition**
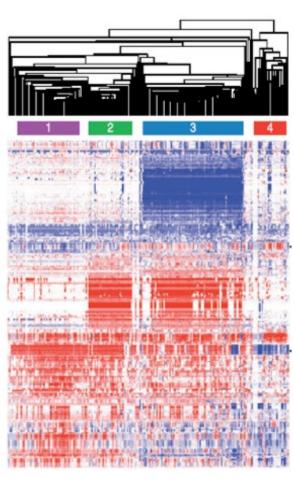
The Journey to Precision Health

- from one-size-fits-all treatment approaches to "precision" interventions that better reflect the specific disease risk(s) for individuals and populations
- new technologies for ever earlier detection and mitigation of health risk
- extend healthspan versus lifespan
  - number of years a person remains free of disease or debilitating illness

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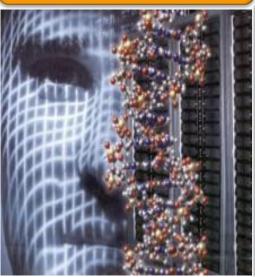

humors, astrology, shamanism, sin and divine fate

biochemistry and organ-based pathophysiology
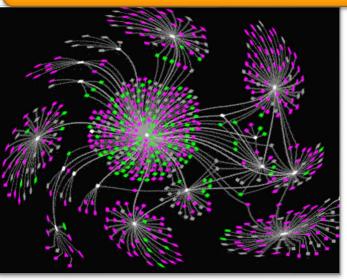
molecular biology and multiOmics profiling
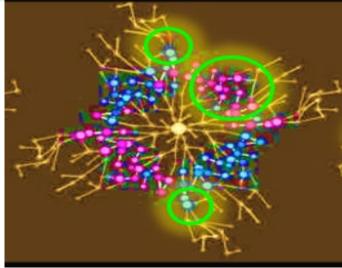
MultiOmics Profiling and Precision Health

(Epi)Genomics and MultiOmics Profiling

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

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

Signatures of Individual Health Risk

The Challenge of Big (Messy) Data

From Isolated "Snapshots" During Disease Episodes to Real Time, Continuous Monitoring of Health Status

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

- **comprehensive multiOmics profiling of molecular biomarkers in diagnosis and treatment selection**
  - **pioneered in oncology now expanding to other diseases**
- **minimally invasive platform for routine longitudinal tracking of health status**

Expanding the 'Care Space' in Healthcare

- **most events that influence wellness and health risk 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 Monitoring (RHM) and Precision Health

Bot and Doc

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

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 Remote Health Monitoring: In-home Support Services and Reduced Hospital Readmissions

polypharmacy and Rx adherence

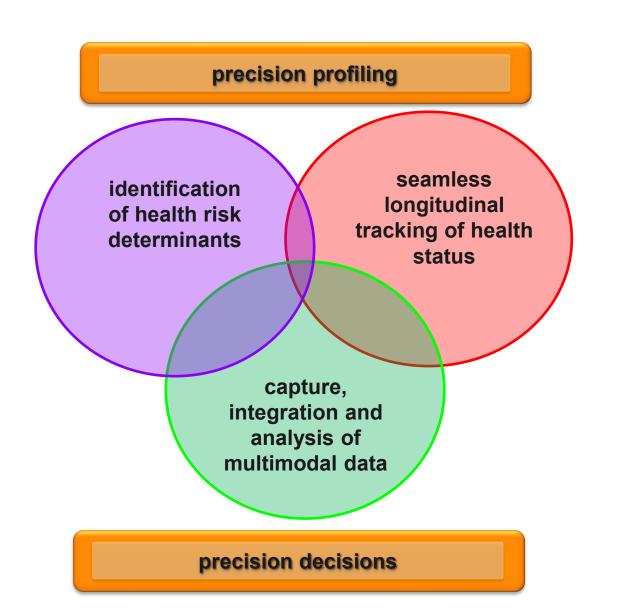**assessment of cognitive status**

chatbots, RHM and faster identification of change in health status

'Hospital at Home'

Big Biology: Big Data
The Central Paradigm in Precision Health

precision profiling

identification of health risk determinants

seamless longitudinal tracking of health status

capture, integration and analysis of multimodal data

precision decisions

Keeping Current in an Era of Rapid Innovation

thebmj — Assessing and referring adult cancers
by Will Stahl-Timmins

Legend:
- ■ Refer using suspected cancer pathway
- ■ Non-urgent specialist referral

Possible cancers

Abdominal features (discomfort or pain)
- Abdominal pain
  - + Rectal bleeding
  - + Weight loss (age 40+)
  - (age 50+)
  - + Weight loss (age 60+) (colorectal cancer excluded)
- Upper abdominal pain (age 55+)
  - + Weight loss
  - + Anaemia / Thrombocytosis / Nausea / Vomiting
- Dyspepsia (age 55+)
  - + Weight loss
  - treatment resistant
  - + Thrombocytosis / Nausea / Vomiting

Abdominal features (distension or mass)
- Rectal or abdominal mass
- Upper abdominal mass, consistent with enlarged:
  - gall bladder
  - liver
  - stomach
- Hepatosplenomegaly
- Splenomegaly + Fever / Night sweats / Breathlessness / Pruritus / Weight loss

Women
- Abdominal distension (persistent / frequent) (esp. age 50+)
- Ascites +/ pelvic/abdominal mass (not obviously uterine fibroids)
- Irritable bowel syndrome symptoms (in last 12 months) (age 50+)
- Change in bowel habit (unexplained) (age 50+)

Abdominal features (bowel transit symptoms)
- Change in bowel habit (unexplained)
  - + Rectal bleeding (age 60+)
  - (age under 60)
- Diarrhoea / Constipation + Weight loss (age 60+)

Abdominal features (Upper gastrointestinal symptoms)
- Nausea / Vomiting + Thrombocytosis / Weight loss / Reflux
- Dyspepsia / Upper abdominal pain (age 55+)
- Nausea / Vomiting + Weight loss (age 60+)
- Reflux + Weight loss (age 55+)
- Dysphagia

Bleeding
- Rectal bleeding (age 50+) (unexplained)
  - + Abdominal pain / Change in bowel habit
  - Weight loss / Iron deficiency anaemia
- Bruising / Bleeding / Petechiae (unexplained)
- Haemoptysis (unexplained) (age 40+)
- Haematemesis

Musculoskeletal
- Back pain (age 60+) / persistent / Bone pain (persistent) / Unexplained fracture
  - + Weight loss

Neurological
- Loss of central neurological function (progressive / sub-acute)

Non-specific features of cancer
- Fatigue (persistent) / Fever (unexplained) / Infection (unexplained) (persistent) (recurrent) / Pallor
- Fatigue / Weight loss / Appetite loss + Ever smoked / Exposed to asbestos + (age 40+)
- Weight loss (unexplained)
- Appetite loss (unexplained)
- Deep vein thrombosis
- Jaundice (age 40+)
- Weight loss (age 60+) + Diarrhoea / Back pain / Abdominal pain
- Nausea / Vomiting / Constipation / New onset diabetes
- Multiple possibilities → Assess for additional features to clarify most likely cancers

Primary care investigation
- non-urgent — Testing for occult blood in faeces
- within 2 weeks — CT scan / Ultrasound
- within 2 weeks — Upper GI endoscopy
- non-urgent — direct access
- within 2 weeks — Ultrasound
- within 48 hours — Full blood count
- non-urgent — Measure serum CA125
- within 2 weeks — Chest x ray
- Full blood count + Blood tests (calcium) / erythrocyte sedimentation rate / plasma viscosity
- within 2 weeks — MRI scan / CT scan

Possible cancers (nodes):
- Non-Hodgkin's lymphoma
- Colorectal
- Stomach
- Ovarian
- Oesophageal
- Gall bladder
- Liver
- Leukaemia
- Mesothelioma
- Myeloma
- Lung
- Pancreatic
- Brain/CNS

Big Data:
The Escalating Challenge for Professional Competency and Future Medical Education

Data Deluge
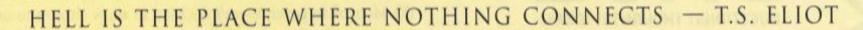
Cognitive Bandwidth Limits

Automated Analytics and Decision Support

Facile Formats for Actionable Decisions

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

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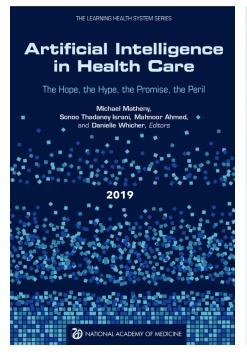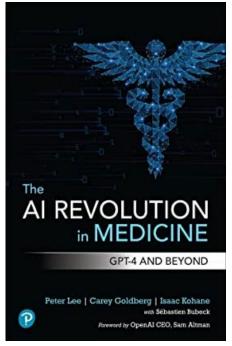# Biomedical Research
and
Healthcare Information Systems

The US Health Ecosystem
Largest Producer of Data But Poorest in Productive Use

- **10,000 exabytes in 2024 (30% of world's data volume)**

- **projected 36% annual growth rate**

- **legacy data tombs: inaccessible, forgotten or under-utilized**

- **EHR navigation obstacles**

- **inefficient access and coordination to optimize continuity in patient care**

The Changing Dimension of Big Data Analysis
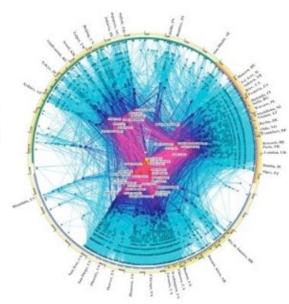
ML/AI, LLMs and the Evolution of a Data-Centric Health Ecosystem

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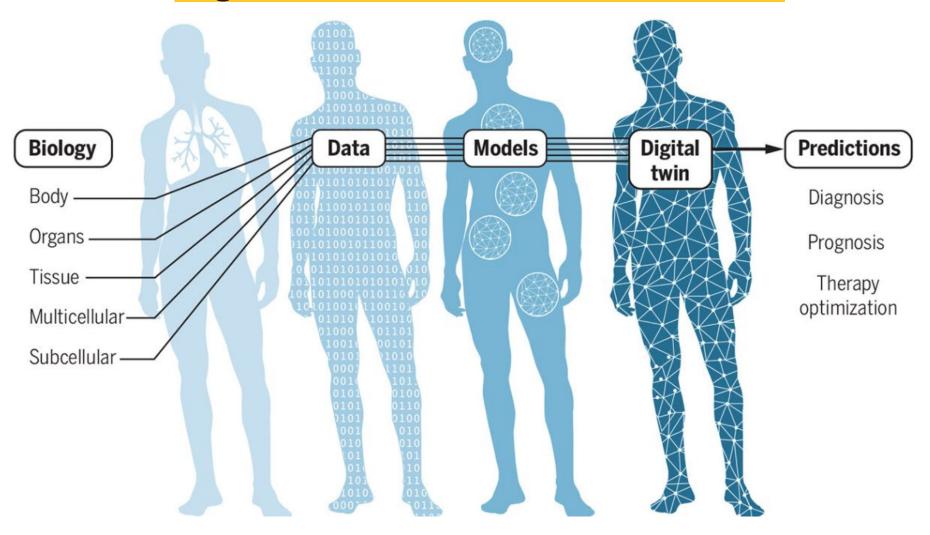

Isolated Data
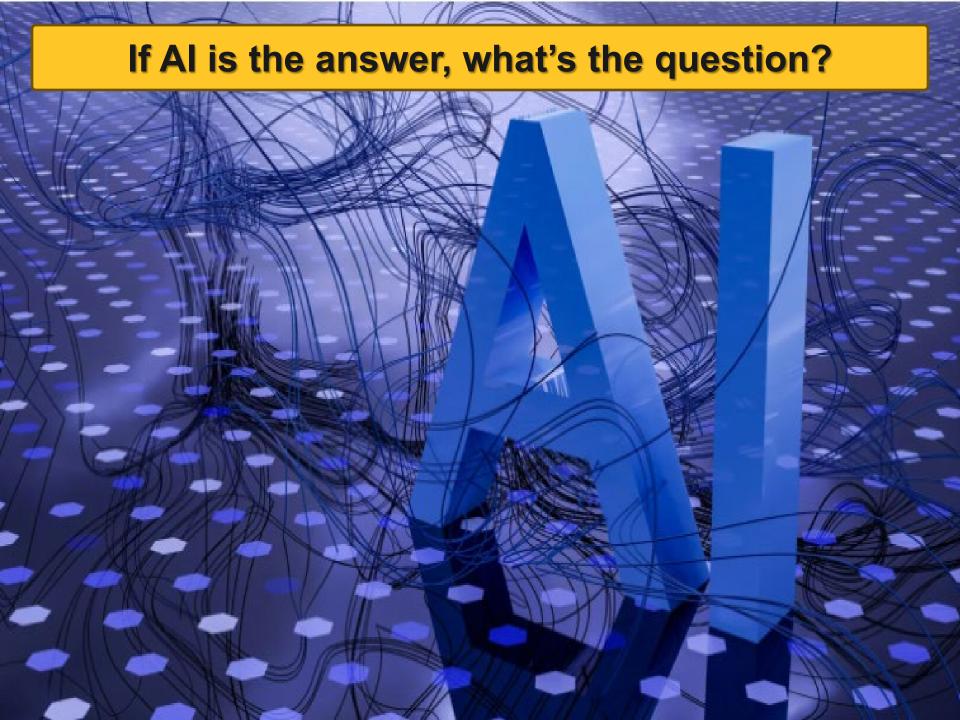
Complex Networked Data

Complex Computational Data

AI Modeling of Large-Scale Health Data to Predict Future Disease Risk

- **Delphi 2M** **(A. Shmatko et al. (2025) Nature https://doi.org/10.1038/s41586-025-09529-3)**

    - **revealing currently hidden signals of health risk**

- **AI pattern analysis of multimodal data from 2.3M patient records**

    - **inherited risk, clinical diagnoses, treatments, lifestyle and socioeconomic status**

- **accurate 20-year forward predictive modeling of risk of over 1000 chronic diseases plus co-morbidities**

- **access to ever larger population data, new data categories and new AI tools will increase predictive accuracy**

Digital Twins and Precision Health

Biology

- Body
- Organs
- Tissue
- Multicellular
- Subcellular

Data — **Models** — **Digital twin** → **Predictions**

- Diagnosis
- Prognosis
- Therapy optimization

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

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?**

    - "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?)**

- **what workforce competencies and upskilling will be required for timely and safe adoption?**

Just What the ~~Doctor~~ Data Ordered

Machine Intelligence and AI Algorithms for Clinical Diagnosis and Treatment Decisions

Validation and Regulation

Regulatory Oversight

"I do not believe there's a single
    health system in the United States,
    that's capable of validating an
    AI algorithm that's put into place in a
    clinical care system."

Dr. Robert Califf
FDA Commissioner
KFF Health News 15 January 2025

Use of Large Language Model AI Platforms in Clinical Care Decisions

- **transparency and patient informed consent when AI is used in care decisions**

- **new malpractice liabilities?**

  - **harm(s) from premature use of inadequately validated algorithms (platform developers, HCPs or the health systems which approved adoption?)**

  - **harm(s) from failure to use AI platforms validated for SOC (professional guidelines or regulatory labeling)**
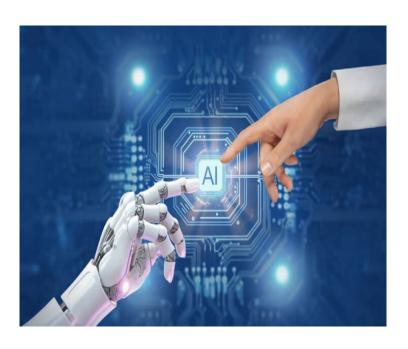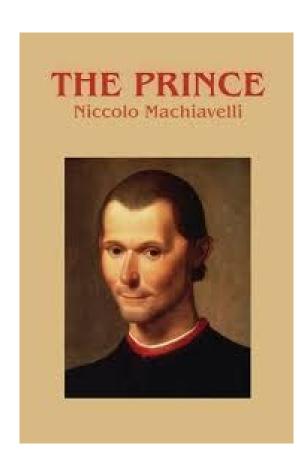
The Rush to Regulate AI

- **one size-fits-all oversight/legislation is ill-suited to generate purpose 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 now predominant innovation driver and oversight of closed data and proprietary algorithms**

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

- **Human-AI Teaming**

- **user education, training and experience**

- **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 autonomous agentic systems**

THE PRINCE
Niccolo Machiavelli

"There is nothing more difficult
    than to take the lead
    in a new order of things.
    This is the consequence of people's fear of
        the future, but also their reluctance to
        believe in new things until they have had
        a long experience with them."

Machiavelli
The Prince, Chapter V1

Denial   **Negativity**   **Resistance**

AI and Employment

- **widely different views on scale and timing of AI impact on job losses and future workforce competencies**

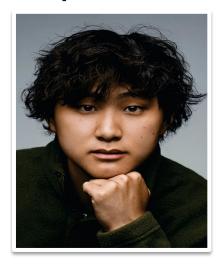- **CEO Predictions of up to 50% white collar job losses by 2030**

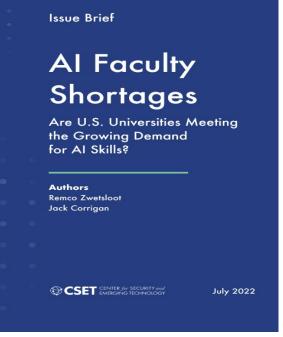- **outcomes still far from certain but complex strategic terrain for C-Suite navigation**

The Talent Recruitment Wars and Workforce Reskilling

Mega Bucks for Top AI Talent

Alexander Wang, Chief AI Officer

∞ Meta

Harvard Business Review

September–October 2023
HBR.ORG

Reskilling in the Age of AI

New approaches for managers and employees
PAGE 56

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

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."
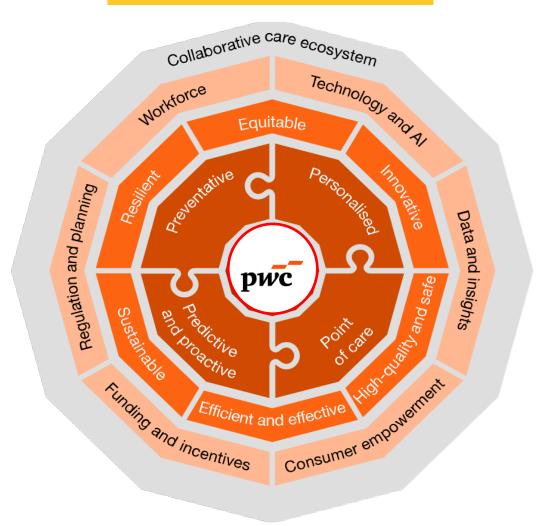
- Peter Drucker (1980)

Precision Health and Competitive Success in an Era of Big Biology and Big Data

- new value propositions for solutions to the principal 'pain points' and 'cost drivers' in healthcare

- shift from current reactive management of overt disease to proactive earlier detection, intervention and mitigation of health risk

- improved health outcomes and increased health span

- control the unsustainable cost of healthcare

Precision Health and Competitive Success in an Era of Big Biology and Big Data

- **technology-driven shifts in the principal value chains in healthcare**

  - **away from current high cost drugs, procedures and infrastructure to treat advanced (chronic) disease**

  - **reward for innovation in new diagnostic and AI analytical platforms to enable earlier detection and mitigation of health risk and reduce cost of care**

Who Knows Wins!

Precision Health and a Data-Centric Learning Health Ecosystem
- **proactive**
- **predictive**
- **preventative**
- **point-of-care**
- **personalized**

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