**Precision Health and Digital Health:
Evolving Inter-Dependencies in the Transformation
of Health Care Delivery**

Dr. George Poste
Chief Scientist, Complex Adaptive Systems Initiative
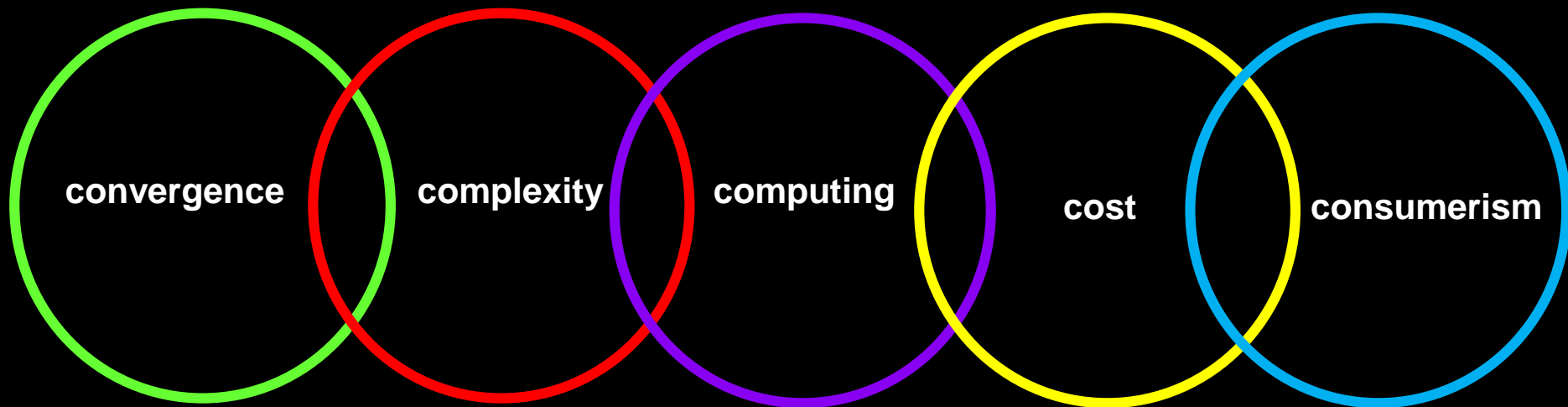and Regents Professor of Health Innovation
Arizona State University
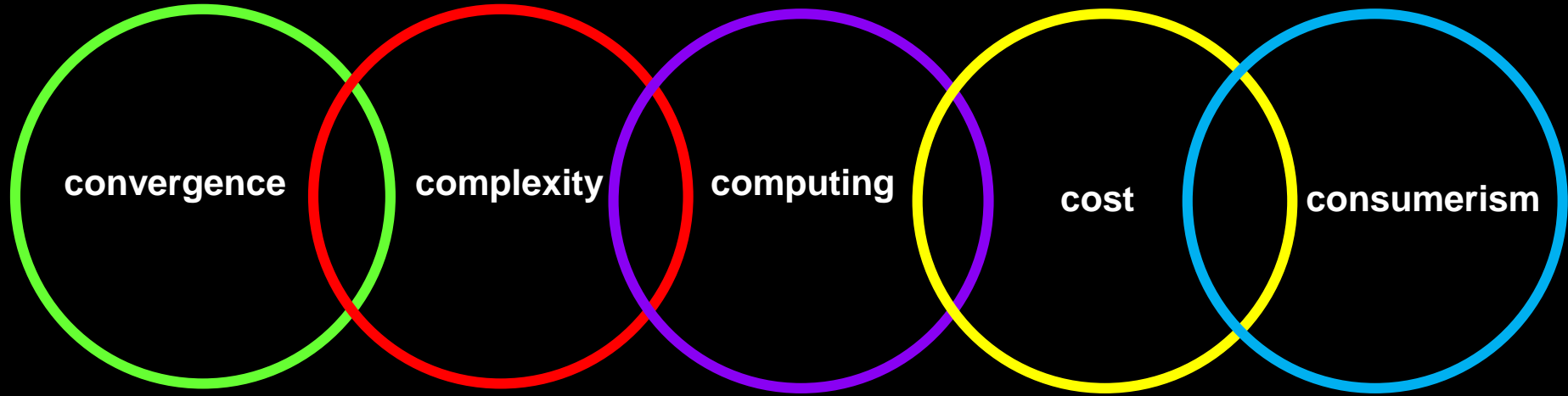george.poste@asu.edu
www.casi.asu.edu

Joint University Biomedical Innovation Task Force Meeting

Scottsdale (1 October 2018) and Tucson (15 October 2018)

# The Strategic Landscape for Healthcare

convergence   complexity   computing   cost   consumerism

The Strategic Landscape for Healthcare

convergence **complexity** **computing** **cost** **consumerism**

- the triple aim and the learning healthcare system

- accelerated adoption of digital platforms in healthcare

- impact on all aspects of the patient journey

- massive data streams: exabyte/zettabyte scale data

- the V7 challenge: volume, variety, velocity, validation, virtualization, visualization and value

The Strategic Landscape for Healthcare

convergence **complexity** **computing** **cost** **consumerism**
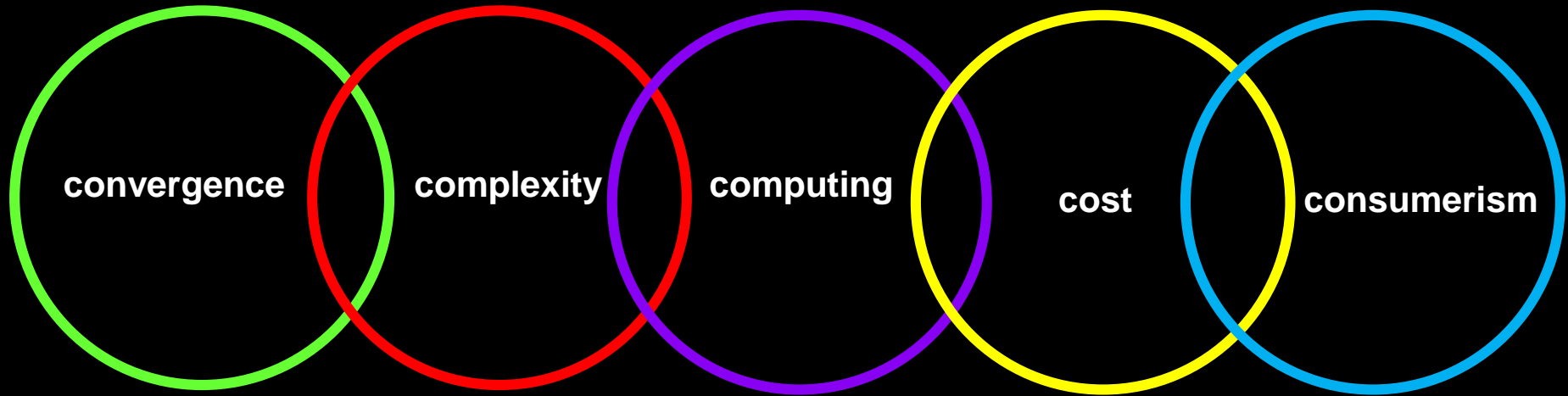
- **new analytical platforms for research, translation and care delivery**

- **data science, machine learning (ML) and artificial intelligence (AI)**

- **entry of new private sector participants**

- **implications for organization of care delivery, continuity of care and clinical decision support**

- **MD/HCP workforce education and training**

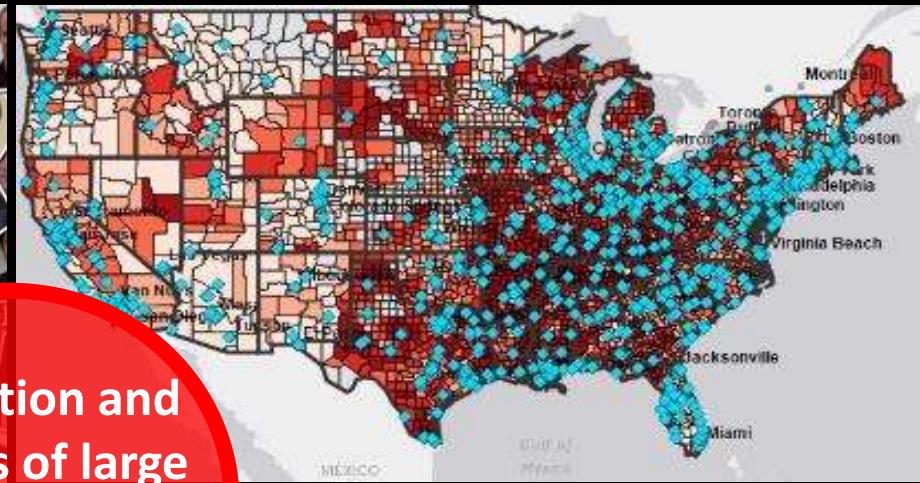# Convergence: Precision Health, Digital Health and Big Data
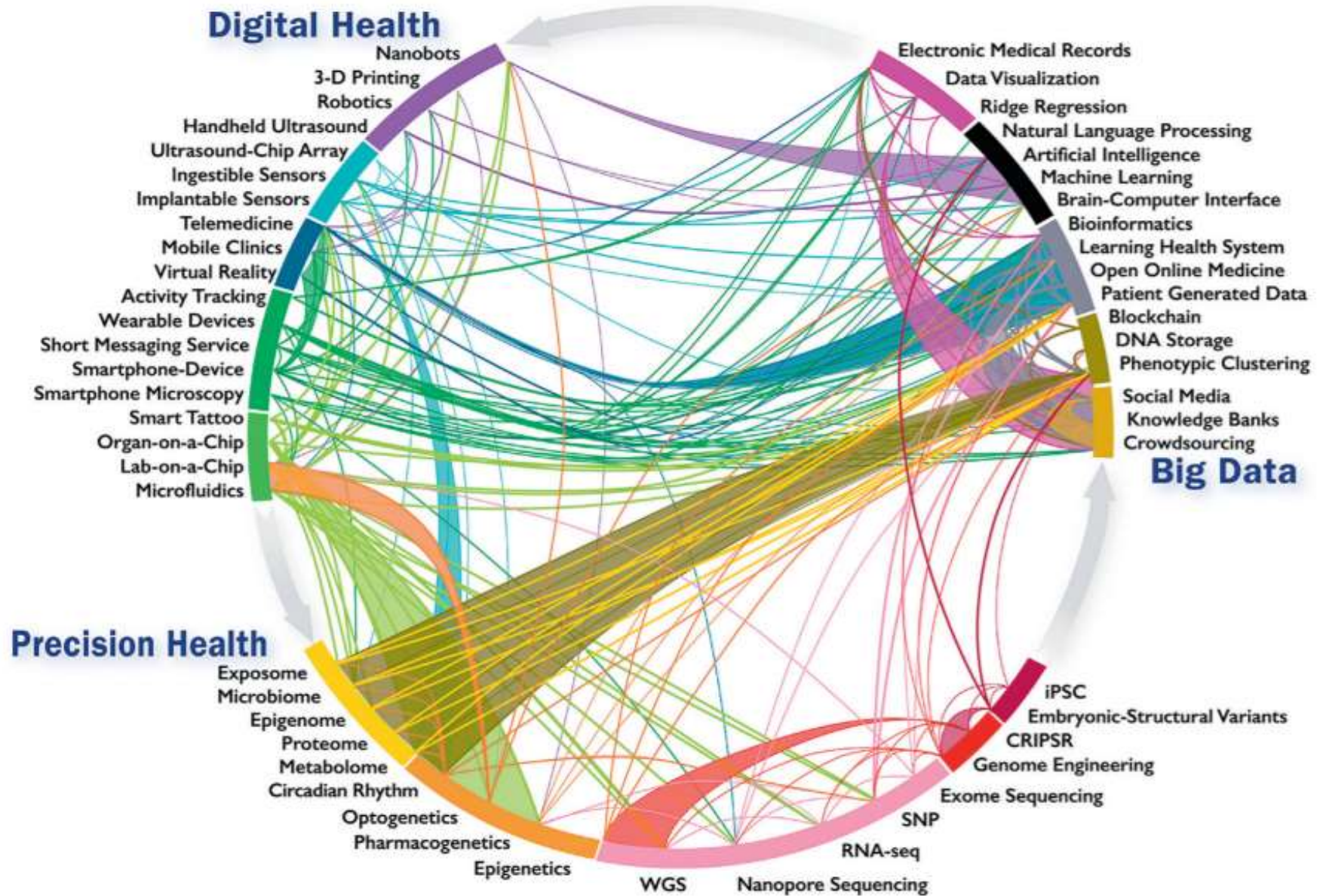
Precision Medicine and Digital Medicine: Evolving Inter-Dependencies

Individual Data

Population Databanks

integration and analysis of large scale, diverse data categories

Deep Phenotyping:

integration of (epi)genomic and multiOmic profiles, clinical, environmental and socio-behavioral data

"I don't think of Humana so much as an insurance company as an IT company who is helping us with the data that we need in order to deal with our population health tools."

Dr. Roy Beveridge, M.D.

CMO, Humana

Cited in Fierce Healthcare 9 May 2017

Population Health Research and Precision Medicine: Blurring the Boundaries Between Daily Life and Interactions with the Healthcare System
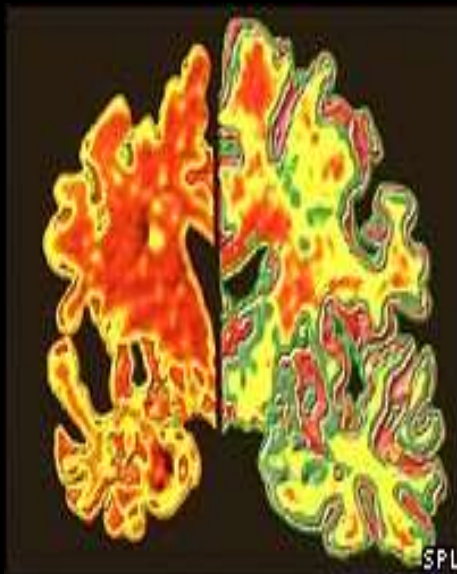
- **every monitored event (clinical and non-clinical) is a potential data point**

- **every individual is a data node**

- **every individual is a research asset**

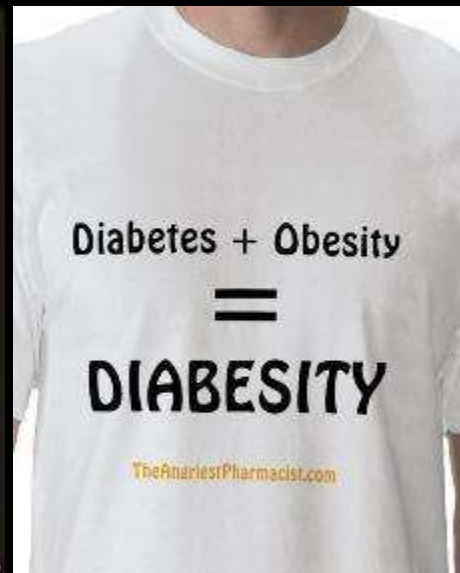- **every individual is their own control**

The Chronic Disease Burden:
Confronting the Largest Clinical and Economic Disruptions and Threats to Sustainable Healthcare

cancer

neurodegeneration

cardiovascular/ metabolic disease

mental illness

Innovation and Competitiveness in the Use of Digital Platforms in Healthcare

- remote health status monitoring

- AR/VR and novel brain-computer interface systems

- digital psychiatry

- reduced cost/cycle time of clinical trials

- robust capture of RWE and value-based payment systems

- machine learning/artificial intelligence and large scale data analytics

- facile integration of new data classes (multi-Omics, clinical, environmental, social) for improved clinical decisions and continuity in care

THE DIGITAL HOSPITAL: 82 COMPANIES REINVENTING THE PRACTICE OF MEDICINE

CARE PLANNING — dbazahealth, caremerge, caresync, Oncora Medical, wellframe, rimidi

SUPPLY MANAGEMENT — AETHON, Lab Sensor Solutions

EMR/ PRACTICE MANAGEMENT — MODERNIZING MEDICINE, pokitdok, CareCloud, eso, practicefusion, medCPU, FLATIRON, AUGMEDIX, yosko

COMMUNICATION — DrFirst, [m]pirik, cureatr, voalte, BeckonCall, patientsafe, Stitch, tigertext

RADIOLOGY — BUTTERFLY Network, Inc., HeartFlow, eagleyemed, ARTERYS, enlitic, lifeIMAGE, SonoCiné, imagia, Trice

DIAGNOSTICS — Genalyte, freenome, BLUEBEE, Lunit, lumiata

PATIENT MONITORING — SENTRIAN, MediBeacon, Glytec, OptiScan, Ornim medical, EarlySense, endotronix

SURGERY — gauss surgical, intellijoint, TOUCHSURGERY, CMR, Simulated, SURGICAL THEATER, ORTHOSENSOR

MEDICATION MANAGEMENT — PerceptiMed, TALYST, ZappRx, CAPSULE, RxRevu

REFERRALS — aidin, AristaMD, GRAND ROUNDS, KYRUUS, SOLERA, Healthify

HOSPITAL NAVIGATION — GOZIO Health, Connexient

READMISSIONS / EMERGENCY DEPARTMENT — analyticsMD, jvion, Position Health, check-ER

INFECTION CONTROL — AltitudeMedical, XENEX, Hyginex, Hand-in-Scan hand hygiene control

PATIENT EXPERIENCE — Bivarus, NarrativeDX, medstatix, appliedVR

CARE COORDINATION — HEALTH GORILLA, DASH, HealthLoop, SILVERVUE

CBINSIGHTS

CHRONIC CARE MANAGEMENT ECOSYSTEM

https://catalyst.com/research_item/chronic-care-market-map/

- **the majority of events that influence wellness/disease risk and treatment adherence occur largely 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**

Healthcare Beyond the Clinic
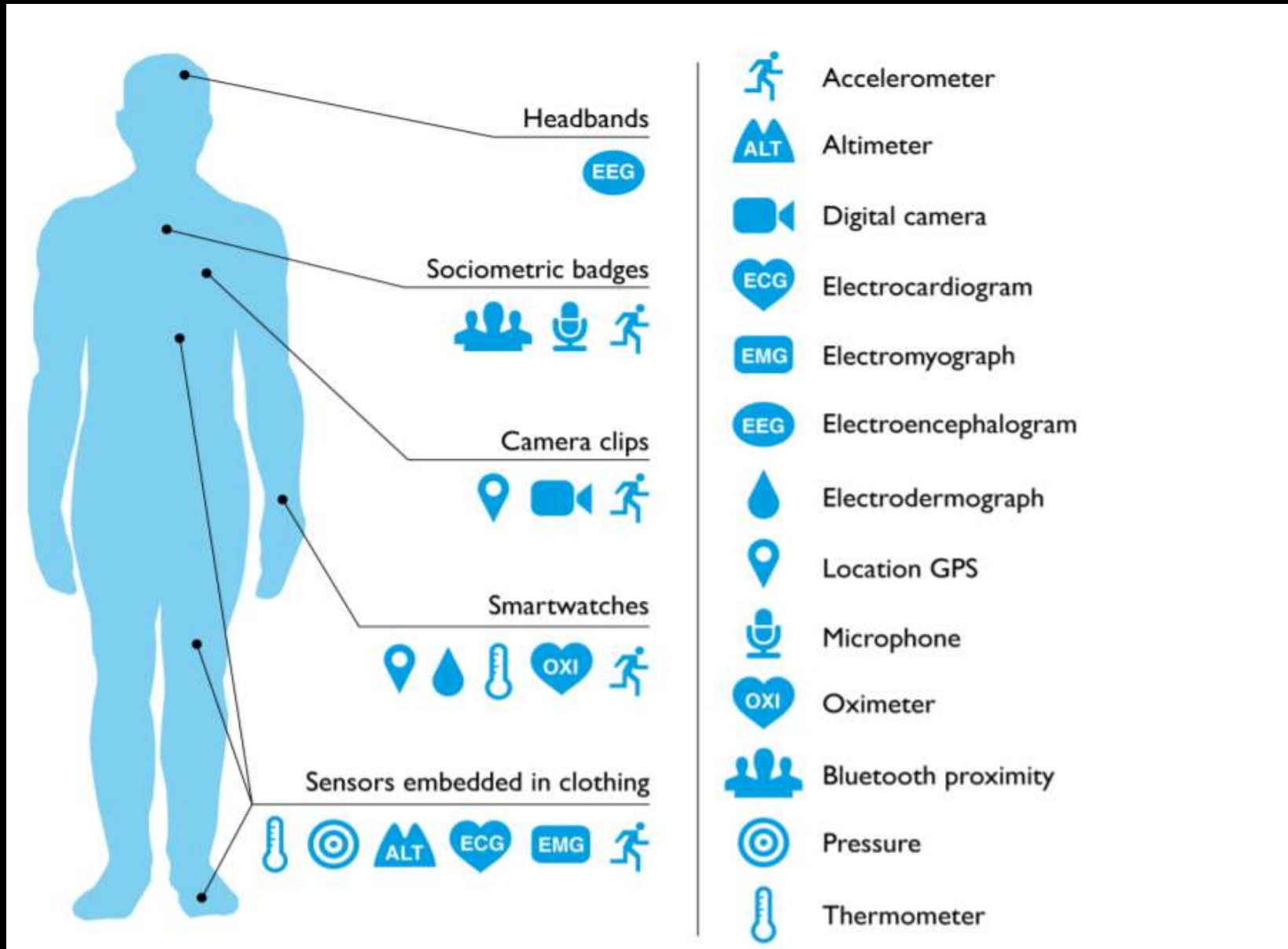# Changing The Touch Points in Healthcare Delivery

Remote Health Status Monitoring

Smartphones, Wearables, Devices and Telemedicine Services

AORTA: Always On, Real Time Access

M4: Making Medicine More Mobile

Wearables and Health Status Monitoring

Health Apps and Wearable Devices*

- **327,000 apps available**
  - **200 added each day**
  - **43 apps account for 52% of downloads**
  - **85% have less than 5,000 installs**
  - **55% of the most downloaded apps use sensor data**

- **370 consumer wearable devices available**

- **integration into over 1000 ongoing clinical trials**

Wellness Apps for Fitness, Diet and Exercise

Building Value in Wellness Apps and Wearables

- **clinical value still viewed as marginal by many physicians/payers**

- **lack of robust RCT data on improved outcomes**

- **need for third party evaluation and/or regulation**

  - **accuracy, security and privacy**

- **vulnerability of many current Apps, devices and text messaging to hacking**

- **lack of policy transparency for sharing of consumer-patient data with third parties by Apps developers and data aggregators**

Current Limitations of Consumer-Based Wearables for Health Status Monitoring

- restricted analyte menu

- novelty item, rapid abandonment and lack of user 'stickiness'

- limited data integration into EHR and alerts for anomaly events requiring prompt intervention

- inadequate incentives: users, payers and physicians

Performance Assessment of Top 50 Medical Apps

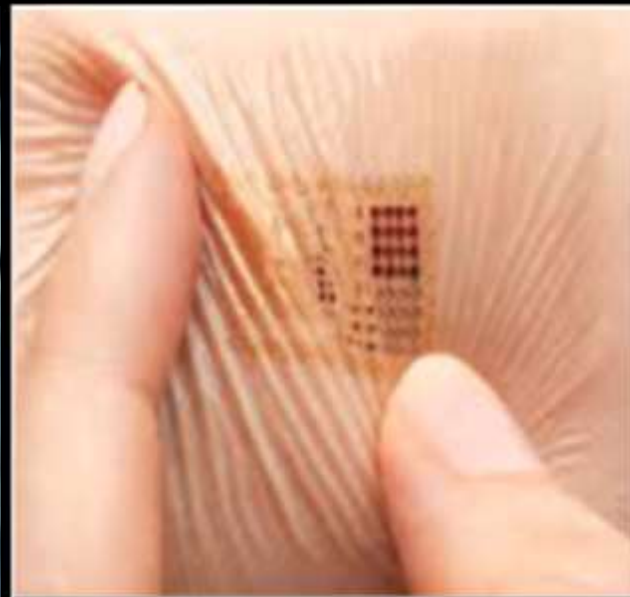Source: American Medical Association, Digital Health Study, Sep 2016; IQVIA Institute Analysis, Sep 2017
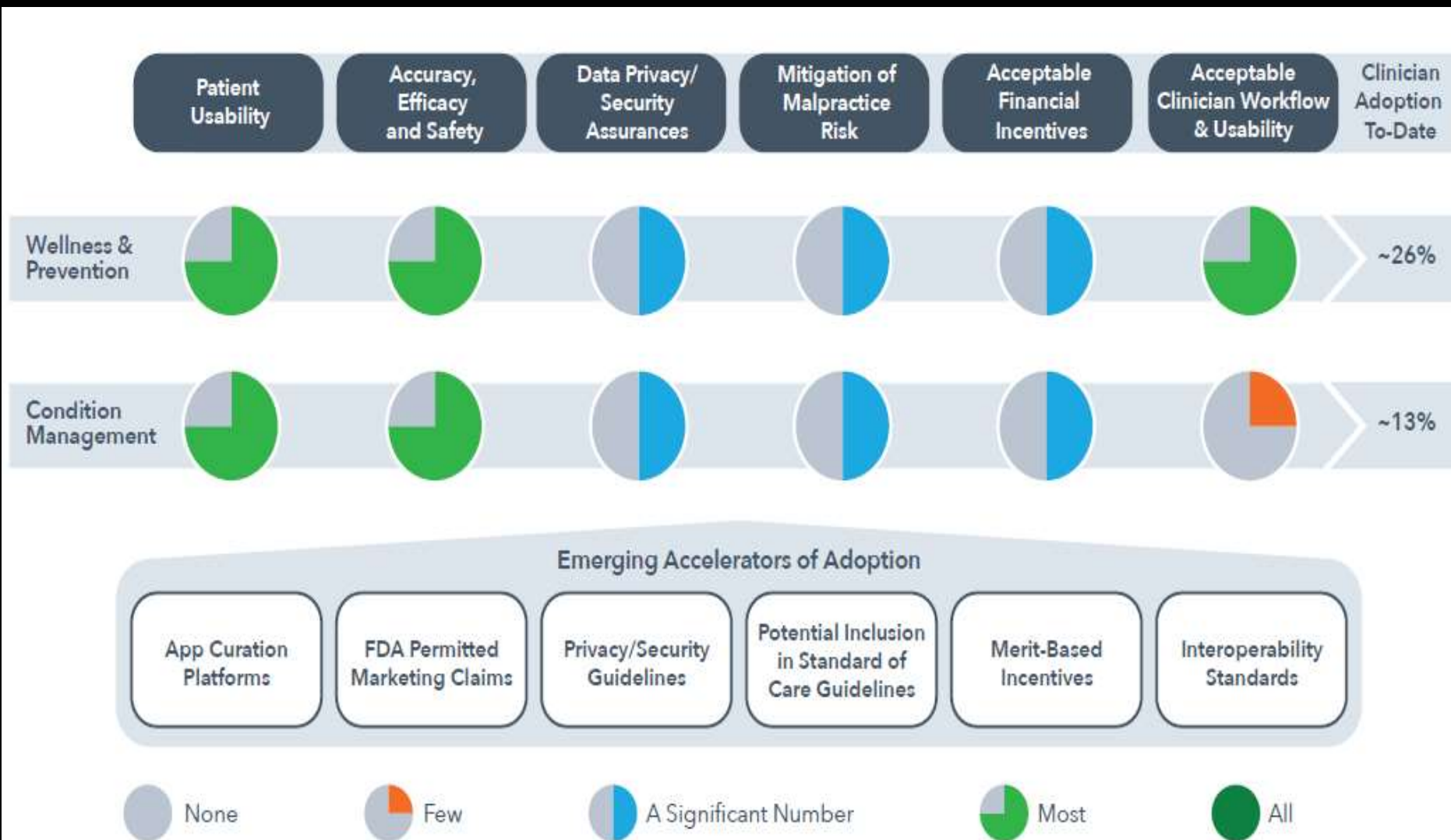
Maturity of Digital Health Efficacy Studies by Use Category (2017)

Average Study Results

ALL POSITIVE

ALL NEGATIVE

Candidates for Adoption

- Healthy Eating / Weight Management
- Asthma
- Infectious & Parasitic Disease
- COPD

- Hearing Loss & Tinnitus
- CHF
- Stroke
- Alzheimer's Disease
- Medication Management

- Alcohol & Substance Abuse
- Sleep / Insomnia
- Cancer
- Smoking Cessation
- Parkinson's Disease

- Hypertension
- Cardiac Rehab
- Stress Management
- Alcohol Moderation
- PTSD

- Genitourinary Conditions
- Diabetes Prevention
- Arthritis
- Kidney Disease
- Pulmonary Rehab

Candidates for Evaluation in an RCT

- AF Screening
- Medication Refills
- MI
- Hematology
- Dental

General Lack of Studies

- GI Conditions
- Self-Diagnosis & Symptom Checking
- Finding an HCP
- Managing Clinical and Financial Records
- Medication Discounts
- Pregnancy

- Well Newborn
- ADHD
- Hyperlipidemia
- Epilepsy
- Pneumonia
- Vision
- Oral Diseases
- General HC Info
- Social Media

Candidates for Inclusion in Clinical Guidelines

- Diabetes
- Depression
- Anxiety

Potential Disappointments — More Study Required

- Exercise
- Pain Management
- Dermatological Conditions

- Schizophrenia / Bipolar
- Multiple Sclerosis
- Autism

No Studies	One Observational Study	Multiple Observational Studies	One RCT Study	Multiple RCT Studies	One Meta-analysis	Multiple Meta-analysis Studies

LIMITED → Relative Quantity and Quality of Available Clinical Evidence → NOTABLE

● Cumulative # of Efficacy Studies

Remote Monitoring of Health Status

The Growth of Telehealth and Telemedicine: Expanding the Care Space

- **estimated use by 60% healthcare institutions and 50% hospitals***

- **virtual consults in Kaiser Permanente exceeded in-person visits in 2016**

- **healthcare consumerism and Ux**

- **21st Century Cures Act and efficacy evaluation projects for Medicare services**

*R.V. Tuckson et al. (2017) NEJM 377, 1585

ARIZONA TELEMEDICINE NETWORK
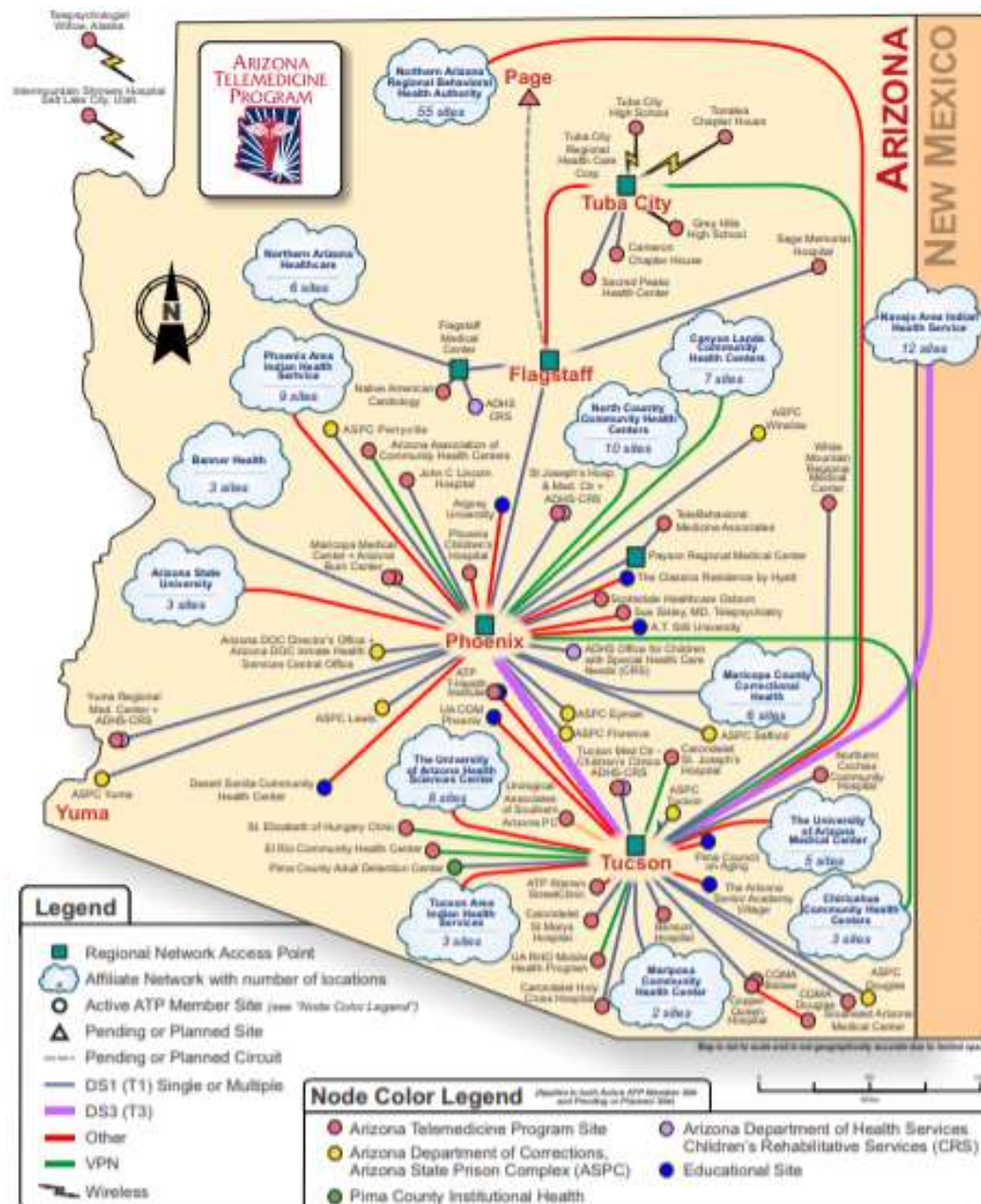
July 2018 Proposals for Year 3 of Physician Payment Program Under MACRA

- **expansion of telemedicine reimbursement beyond rural areas and outside of healthcare facilities**

- **payment of 'virtual check-ins' and review of patient photos/videos or 'store and forward' transmissions**

- **new billing codes for prolonged preventative services**

- **three new remote monitoring billing codes recommended by The APP Association**

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**

Grey Technologies and Ageing in Place: Independent But Monitored Living for Ageing Populations

Rx adherence

cognitive stimulation

in-home support and reduced readmissions

reduced office visits

Iora Primary Care—Designed Especially for Older Adults

03:36

vimeo

"The Medical Virtualist" and "Website Manners": The Next Clinical Specialty ?

- **M. Nochounite et al. JAMA (2017)e17094**

- **the rise of virtual consultants**
  - **tertiary to primary care**

- **investment by larger enterprises in centralized telehealth command centers**
  - **service provision across broad geographies including international**

- **lack of direct training of MD/HCPs in using virtual systems for patient consultations (website manner)**
  - **multi-specialty, multi-skill teams**

- **MD/HCP certification and cross-state licensure**

Chatbots and Support Robots in Healthcare

Project Catalyst:
Evaluation of How Seniors Use Mobile Health Apps and Devices

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

Aterica
Veta
EpiPen

Smart Materials:
Major Opportunities for Cross-Sector Adoption
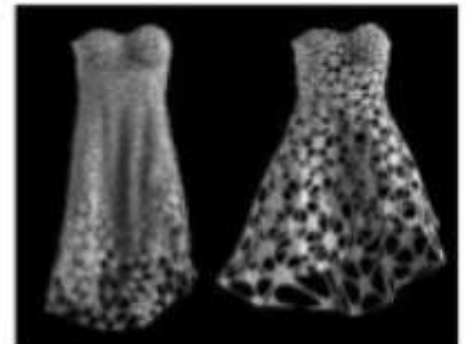
Implantable Devices and Wireless Monitoring (and Modulation)

next-generation miniaturized power sources

security and hacker protections
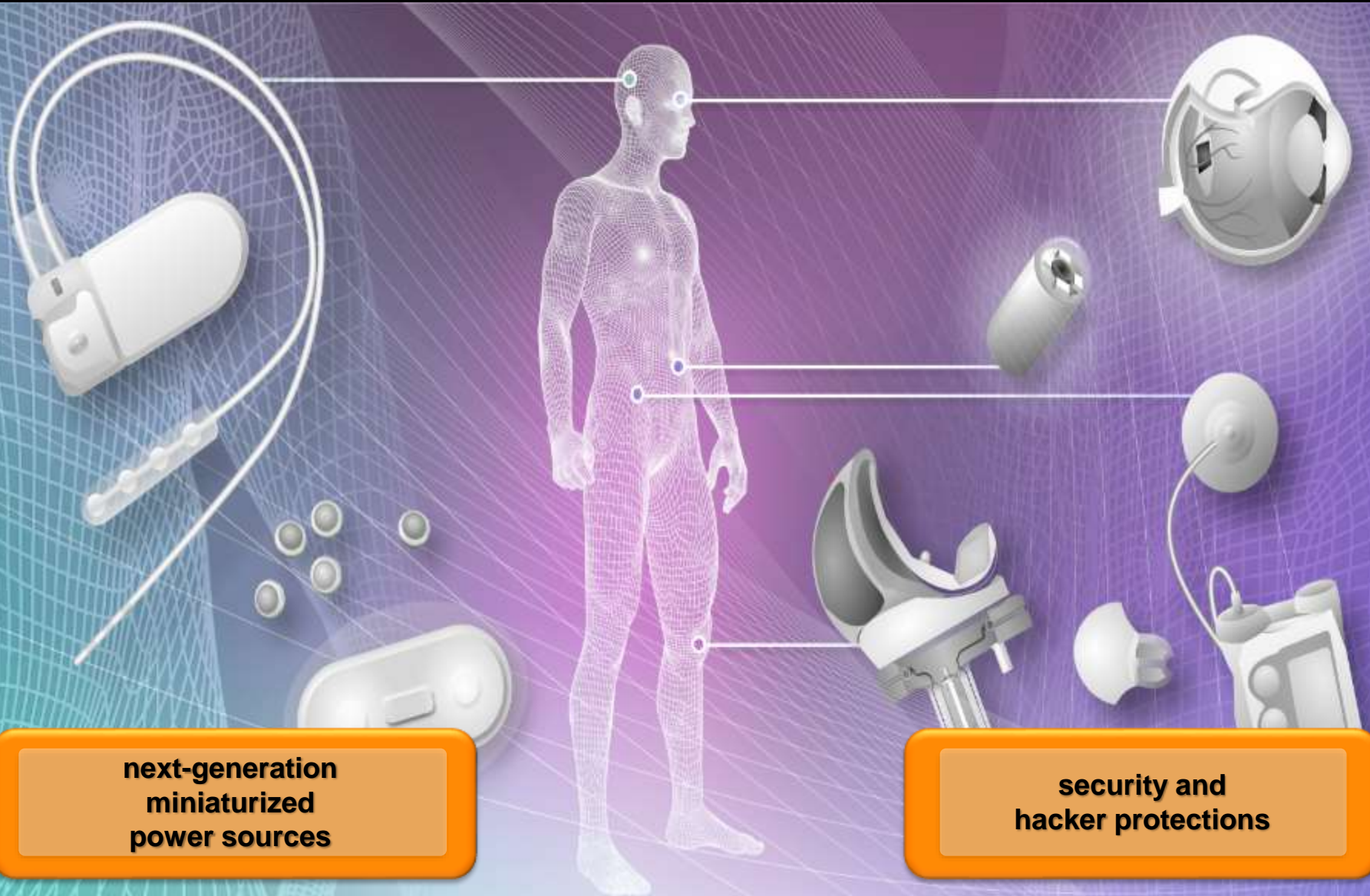
Mobile Neurotechnologies:
Recording Brain Activity and Task Performance
in Natural and Virtual Environments

Wearable EEG-BCI

Wearable Magnetoencephalography

- cognitive monitoring • device control • integration with Rx regimens
- 'brain leaks' and privacy

From: M. Ienca et al. (2018) Nature Biotechnology 36, 805

Regulatory Issues in Digital Health

- **Apps used as accessory to regulated medical device**

- **Apps which transform mobile platform into a regulated device**

- **application of existing FDA risk-based complexity thresholds (510K vs PMA)**

- **requirements for software review and constant V^n updates**

- **security and privacy**

- **SEC/State AG enforcement of false claims**

Software as Medical Device (SaMD)

DIGITAL HEALTH INNOVATION ACTION PLAN

FDA U.S. FOOD & DRUG ADMINISTRATION

April 2018

- **medical device regulatory frameworks enacted in 1976 designed for hardware-based platforms**

- **ill-suited for SaMD for mobile Apps and other digital platforms**

- **21st Century Cures Act requirement for FDA to codify SaMD standards and related cybersecurity vulnerabilities**

- **FDA Pre-Cert program to exempt companies with demonstrated predicate standards from multiple submissions due to constant software updates**

Defining Value

- **direct acute care savings**
  - reduced ER visits, rehospitalization
  - services with easily captured financial metrics

- **more complex clinical and econometric evaluation for chronic conditions**
  - weight control, HbA1c moderation
  - improved Rx adherence
  - symptom scale improvements in mental health
  - QOL
  - earlier return to workforce/school and duration of benefit
  - 'spillover' benefits on co-morbidities

Estimated Annual U.S. Cost Savings for Five Initial Uses with Potential to Reduce Acute Care Utilization ($Bn)

Key Assumptions

- **Use of 5 Curated Apps** used in 5 underlying studies suggesting acute care utilization benefits

- **Delivery** to each target patient for the given use case (but not necessarily used by patient)

- **No "Spill Over" Benefits** to other conditions (i.e., no reduced healthcare utilization for stroke based on improved blood sugar control in diabetics)

Chart values: Diabetes Prevention 4.5, Diabetes 1.6, Asthma 0.4, Pulmonary Rehab (COPD) 0.3, Cardiac Rehab (MI) 0.2, TOTAL $7.0Bn

Legend: Other Intervention Costs | Reduced Hospitalization Costs | Reduced ED Costs | Reduced Ambulatory Costs | Reduced Prescription Costs

The Increased Importance of Real World Data (RWD) and Evidence (RWE)

Deloitte Insights

A report by the Center for Health Solutions

Mission critical

Biopharma companies are accelerating real-world evidence adoption, investment, and application

- **expanded payer requirements to demonstrate efficacy/utility/value in intended-use population(s) with different characteristics to investigational trial population(s)**

  - **age, co-morbidities, polypharmacy**

  - **clinical setting (AMCs, community hospitals, primary care)**

- **analyze treatment outcomes in sub-populations**

- **quantify treatment outcomes for value-based contracting**

Use of RWE in Regulatory Decisions Regarding Rx Efficacy

- **FDA and payer receptivity to use of external (virtual) control arms generated from EHRs**

- **Rx approval from single arm trials and RWE-generated historical trials**

  - **Blincyto for ALL (blinatumomab: Amgen)**

  - **Bavencio for Merkel cell carcinoma (avelumab: Pfizer-Merck KGAA)**

  - **Tecentriq (atezolizumab) for 2L NSCLC (Roche-Genentech-Flatiron)***

  - **Alecensa (alectinib) for NLSC (Roche-Flatiron)***

  - **Opdivo (nivolumab) for esophageal cancer (BMS-Flatiron)***

*use for reimbursement pricing (US) and UK (NICE)

Digital Biomarkers in Drug Development
Information Exchange and Data Transformation (INFORMED)

- patient data capture from biosensors, wearables, smartphones, web-based platforms, social media

- expansion from investigational clinical trials to RWE capture

- exploration of blockchain protocols for data sharing at scale and enhanced security

Digital Platforms and Clinical Trials

- **faster recruitment by improved screening of potential subjects**

- **remote health status monitoring, real time data uploads and additional PRO data**

- **reduced cost and cycle times by fewer site visits**

- **improved patient compliance with study protocol**

- **enhanced patient retention by use of virtual visits to reduce time and cost of travel to trial centers**

Co-evolution of Human-Machine Interactions, Robotics and Augmented Cognition
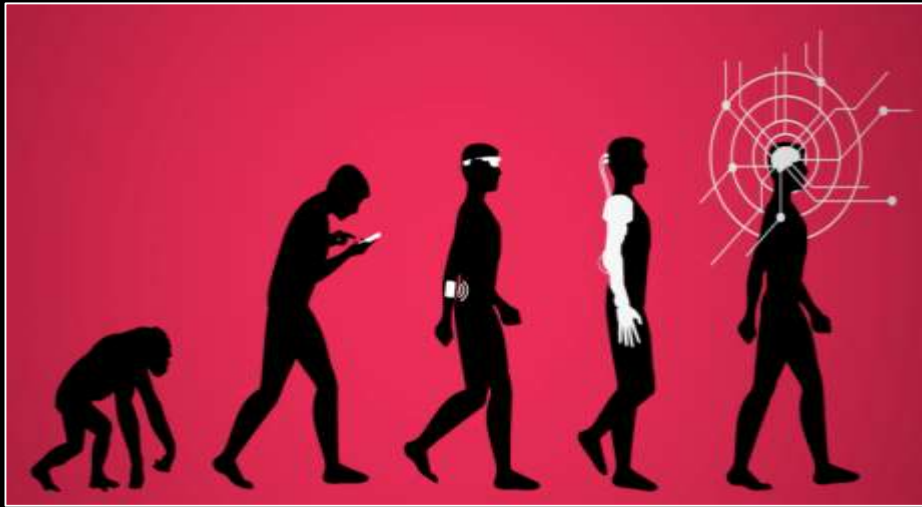
VR/AR and Preparation for Complex Procedures
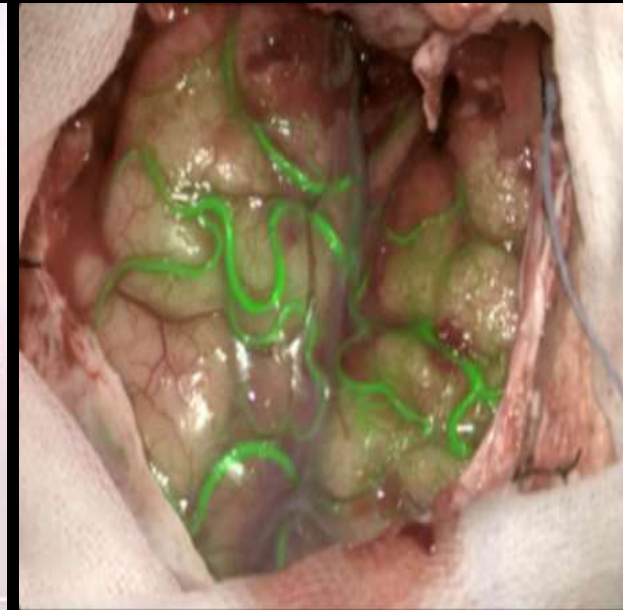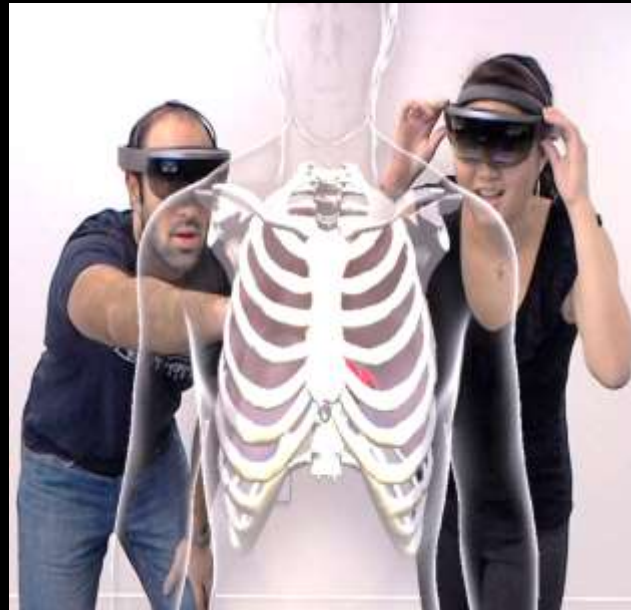
AR/VR Immersion Platforms

- **improved communication, comprehension and retention of complex information**

- **integration of multi-sensory and motor inputs**

- **spatial and temporal parameters**

- **simulation of complex surgical interventions**

- **multi-level education of HCPs**

- **improved patient education regarding interventions, Rx MOAs and importance of treatment adherence**

- **promotion of HCP empathy with patients' situation**

VR/AR Modulation of Cognition and Pain Management
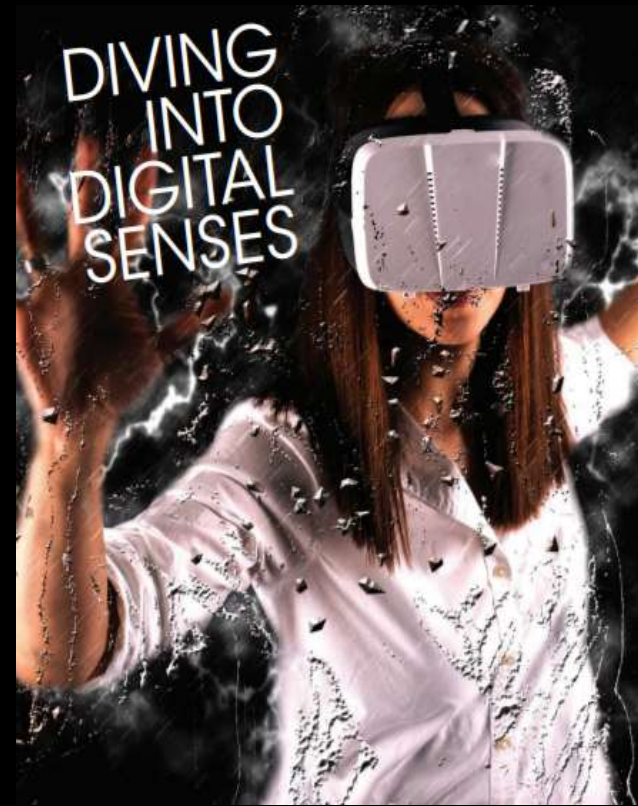
Robot–Human Directed Interactions

Robotic Assist Systems and Exoskeletons for Rehabilitation
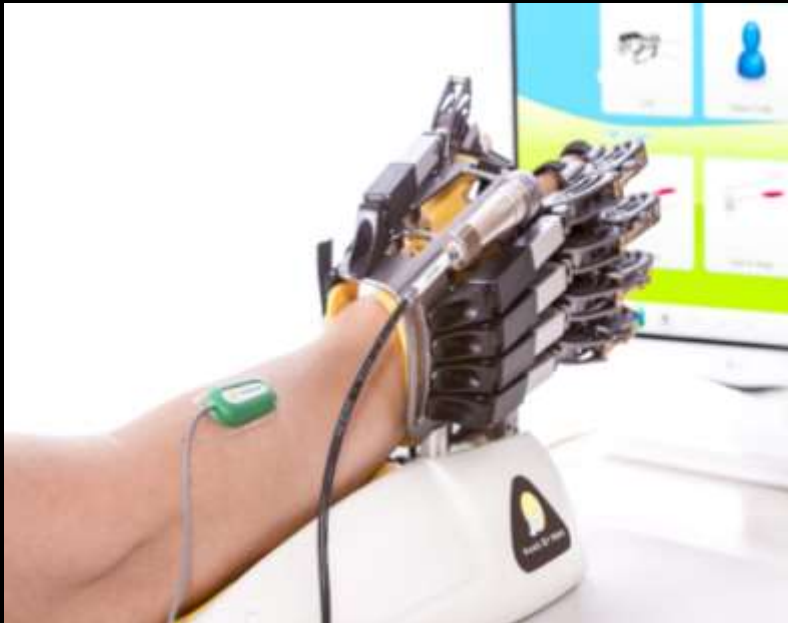
Digital Psychiatry:
Digital Psychometrics and Evaluation of Mental Illness
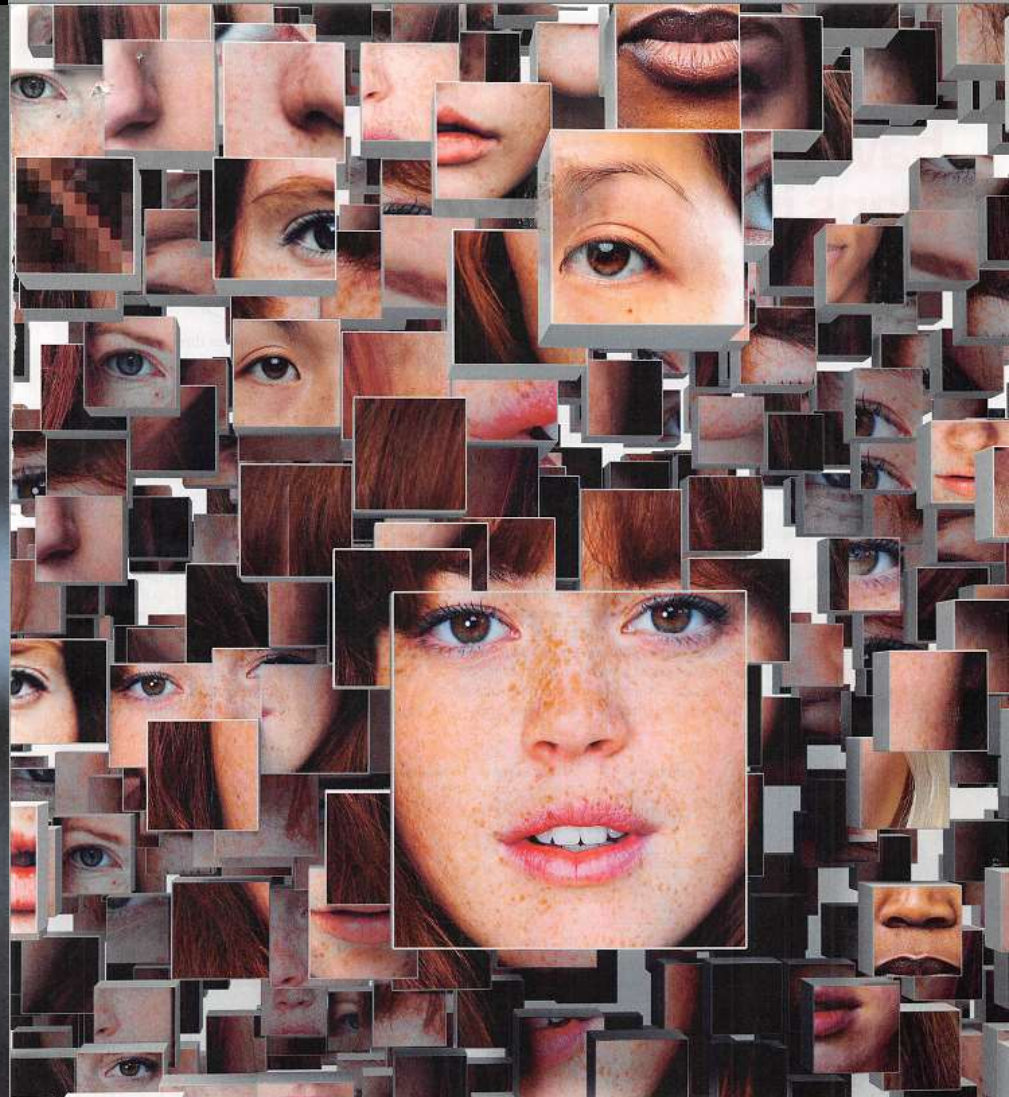
Digital Psychometrics and Mental Illness

- objective measurements of nuanced behavior
  and visit deltas
    - (micro) saccades, facial dynamics,
    - motor functions, gait
    - speech prosody (rhythm, tone, volume)
    - stimulus response reactions and interaction speed
    - mobile EEG and BCI devices
- interaction with digital assistants/chatbots
- machine learning and AI analytics of large video banks
  - bipolar disorder, schizophrenia, depression
  - suicidal ideation
  - PTSD
- signal alerts to care teams when immediate intervention
  indicated

Digiceuticals: Software as Therapy

"We envision empowering individuals with digital therapeutic solutions that address underlying motivational and technical deficits by deciphering neural pathways that support motivation, decision-making and reinforcement to prompt health."

Dr. Ben Wiegand
Global Head, Janssen R&D
World Without Disease Accelerator
PharmaVoice 2017

![PEAR THERAPEUTICS]

About Prescription Digital Therapeutics

Prescription Digital Therapeutics, or PDTs, are a new therapeutic class.

Similar to traditional biologics or drugs, PDTs:

- Directly treat serious diseases
- Are built under current Good Manufacturing Practices
- Demonstrate safety and efficacy in randomized clinical trials
- Receive labeled claims from the FDA
- Are used by physician prescription
- Are reimbursed as products, via Pharmacy and Medical benefits
- Have barriers to entry that span regulatory exclusivity and intellectual property

https://peartherapeutics.com/

Non-Invasive Brain Computer Interfaces
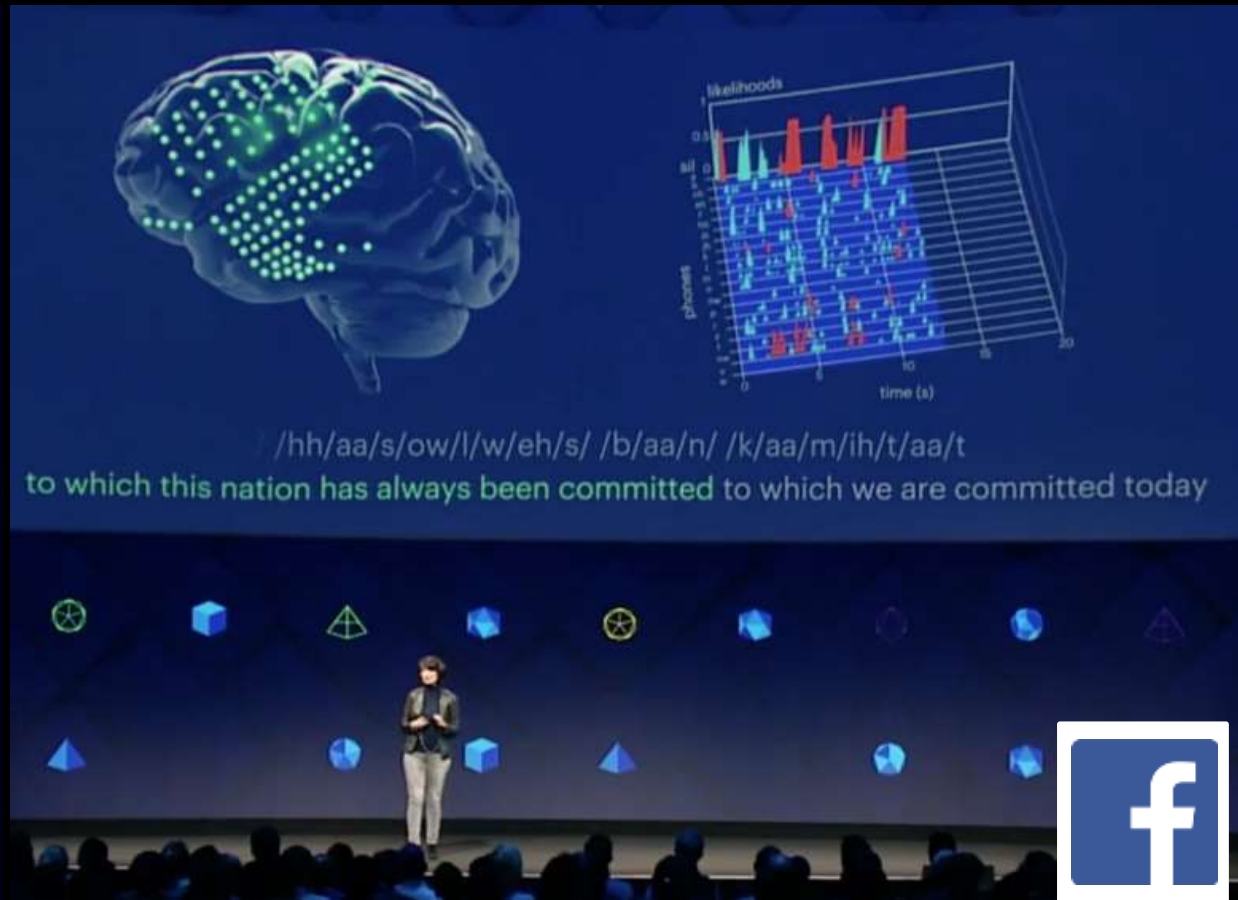
Will We Even Call It A Phone In 2020?

Bendable LED Screens

Wearable Mobile Computing

Holographic Imaging

Gesture Based UIs

Augmented Reality (AR)

Facial & Eye Recognition
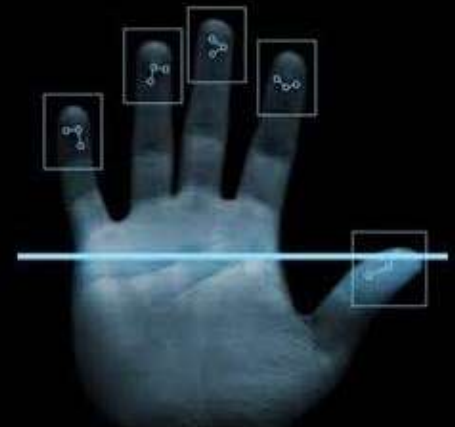
Mobile Biometrics

"Do you solemely swear to have no involvement in your own care?"

The New Yorker. Artist: Andrew Toos

Empowered Patients:
Social Networking Sites (SNS) 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

Major Investments in Digital Health by Major Corporations From Within and Outside of Traditional Healthcare Services

Entry of Large Scale Data Management and Analysis Companies into Healthcare

Alphabet

amazon

Apple

Microsoft

- data storage and analytics for population health and precision medicine

- Verily/Grail biomarkers for disease detection

- distribution logistics and expansion into multiple healthcare segments

- consumer products as patient health hubs

- cloud storage and analytics for population health and precision medicine

Amazon and Healthcare

Strategic Acquisitions and Alliances and Entry into Diverse Healthcare Services

- **leverage distribution logistics and supply chain scale**

- **AWS, cloud storage and large scale data analytics**

- **310M active customers, 100M Amazon Prime members**

- **Alexa-AI**
  - **in-home health concierge and support services?**
  - **real time HCP resource?**

- **disintermediation of PBMs and pharmacy wholesalers (PillPack)?**

- **claims administration and processing (AWS) and new insurance offerings (AMZ-JPM-BH)?**

- **Whole Foods and creation of new primary care sites?**

Making Alexa HIPPA Compliant

https://www.cbinsights.com/research/report/amazon-transforming-healthcare/

Amazon Echo and Home Care

THE **ALEXA DIABETES** CHALLENGE
Sponsored by Merck & Co., Inc., Kenilworth, New Jersey, U.S.A.

FINALISTS

DiaBetty

A virtual diabetes educator and at-home coach that is sensitive and responsive to the patient's mood, enhancing patient skills for self-management.

My GluCoach

A holistic management solution that blends the roles of voice-based diabetes teacher, lifestyle coach, and personal assistant to serve the individual and specific needs of the patient.

PIA: Personal intelligent agents for type 2 diabetes

A connected care intelligent agent that uses NASA-licensed AI technology integrated with IoT device data to encourage healthy habits, detect at-risk behaviors and abnormalities, and alert care teams.

Sugarpod

An interactive, multimodal diabetes care plan solution that provides tailored tasks based on patient preferences, delivered via voice, mobile, video, and web interactions; includes a smart foot scanner.

T2D2: Taming type 2 diabetes, together

A virtual nutrition assistant that uses machine learning to provide in-the-moment personalized education and recommendations as well as meal planning, and food and glucose logging.

https://www.cbinsights.com/research/report/amazon-transforming-healthcare/

Amazon Echo and Home Care

Development of Third-Party Alexa Apps

LIFE | HEALTH | FREEDOM
LIBERTANA®

Allows seniors to verbally report medical data, get exercise and adherence reminders, call a caregiver, and coordinate transport

MAYO CLINIC

Mayo Clinic First Aid

"Tell me about spider bites"   "Help for a burn"

Ask My Buddy

"Alexa, ask My Buddy to alert everyone."
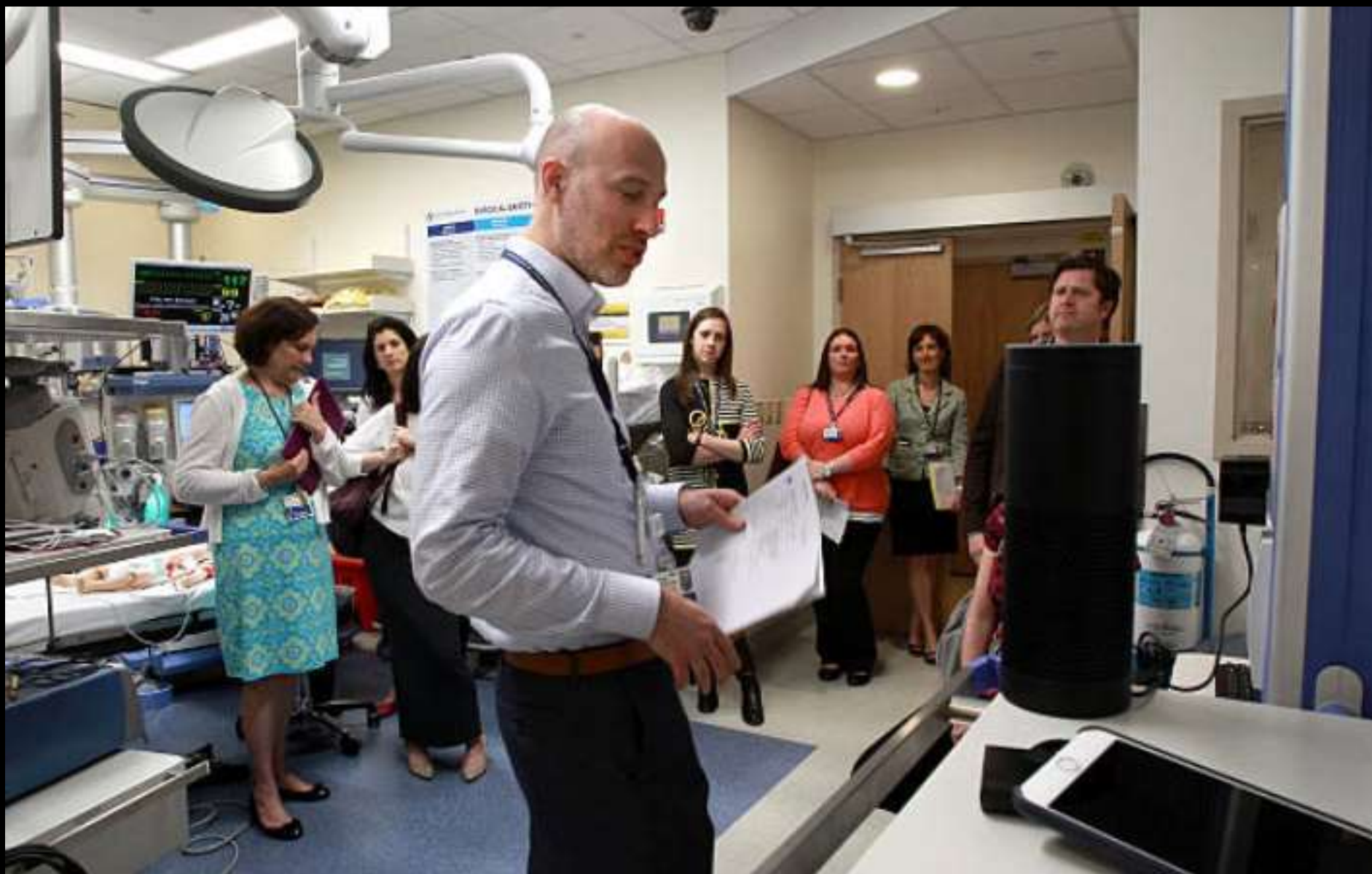
Rockpointe and AudioEducate Launch First Ever Accredited CME Program on Amazon's Alexa

By **Thomas Sullivan** — Last Updated **Jul 9, 2018**

Rockpointe & **AudioEducate**
Launch First Ever Accredited
CME Program on Amazon's
Alexa

Now Comes the Really Hard Part!

**Driving Precision Medicine and Data-Driven Healthcare
Into Routine Clinical Practice**

Big Biology and Biomedicine Meets Big Data

The Pending Zettabyte Era
1,000,000,000,000,000,000,000

Integration of Large Scale,
Multi-Disciplinary Datasets

Precision Medicine:

(Epi)Genomics

MultiOmics Profiling of Molecular Signaling Networks and Disruption in Disease
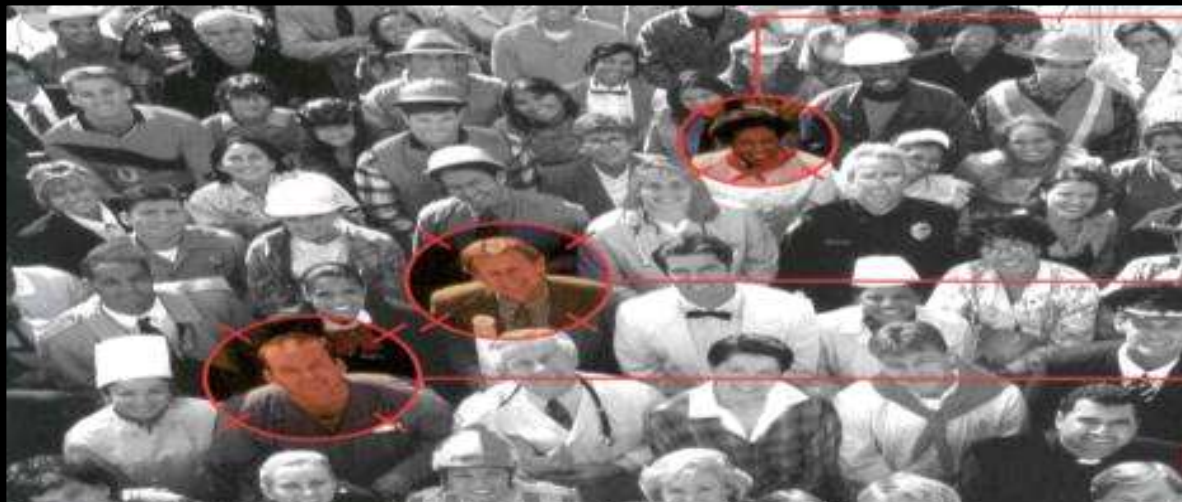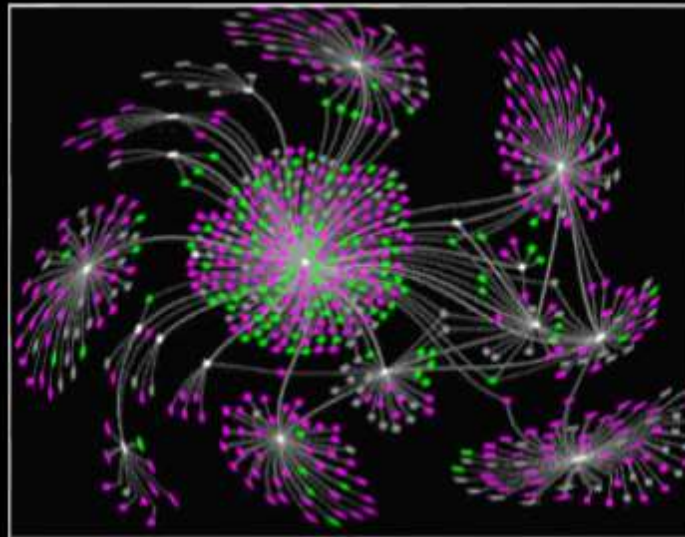
- **terabytes per individual**
- **zettabyte – yottabyte population databases**

Patient-Specific Signatures of Disease or Predisposition to Disease

Big (Messy) Data

Growth of Published MultiOmics Data
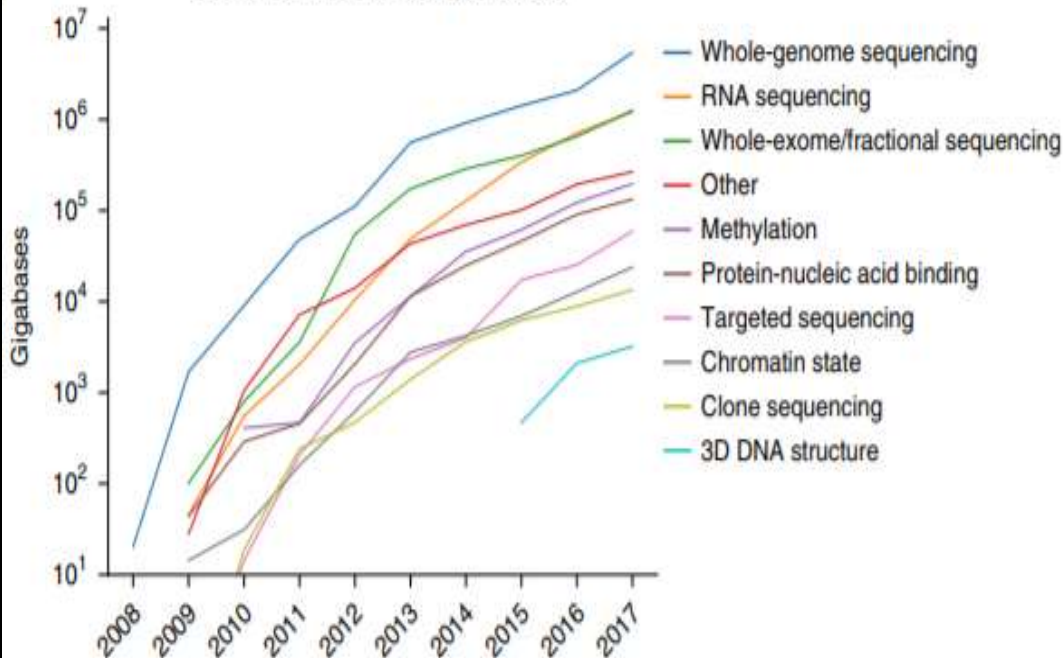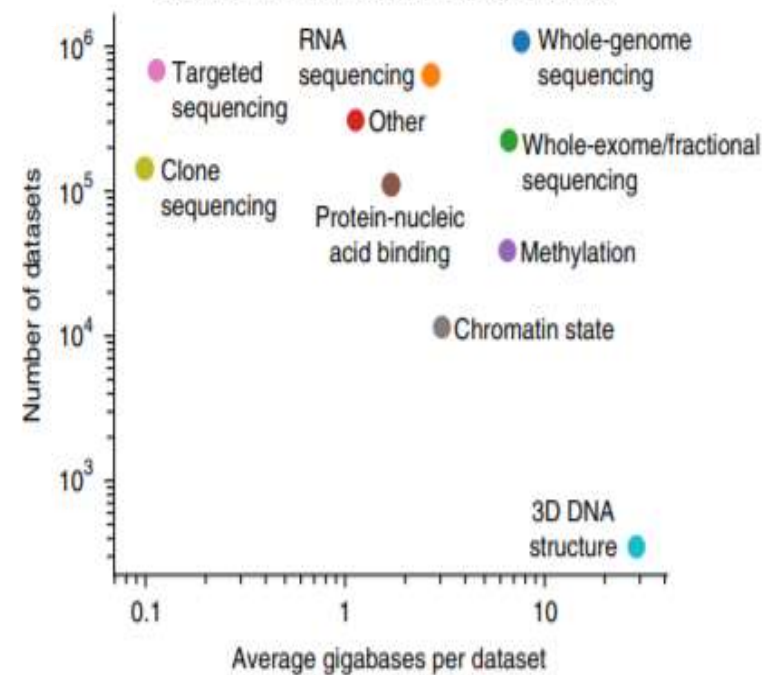
From: M. Wainberg et al. (2018) Nature Biotechnology 36, 829   https://www.nature.com/articles/nbt.4233.pdf

Deep Phenotyping

- **molecular profiling of large N cohorts of stringently clinically phenotyped patients**
  - **plus outcomes data and socio-behavioral parameters**

- **mapping genetic overlap between different diseases involving shared pathogenic elements and co-morbidity risks**
  - **cardiovascular-metabolic**
  - **autoimmunity**
  - **psychiatric disorders**

Genetic Overlap Between Stroke and Related Vascular Traits at 32 Genome Loci for Stroke Profiled in 520,000 Subjects
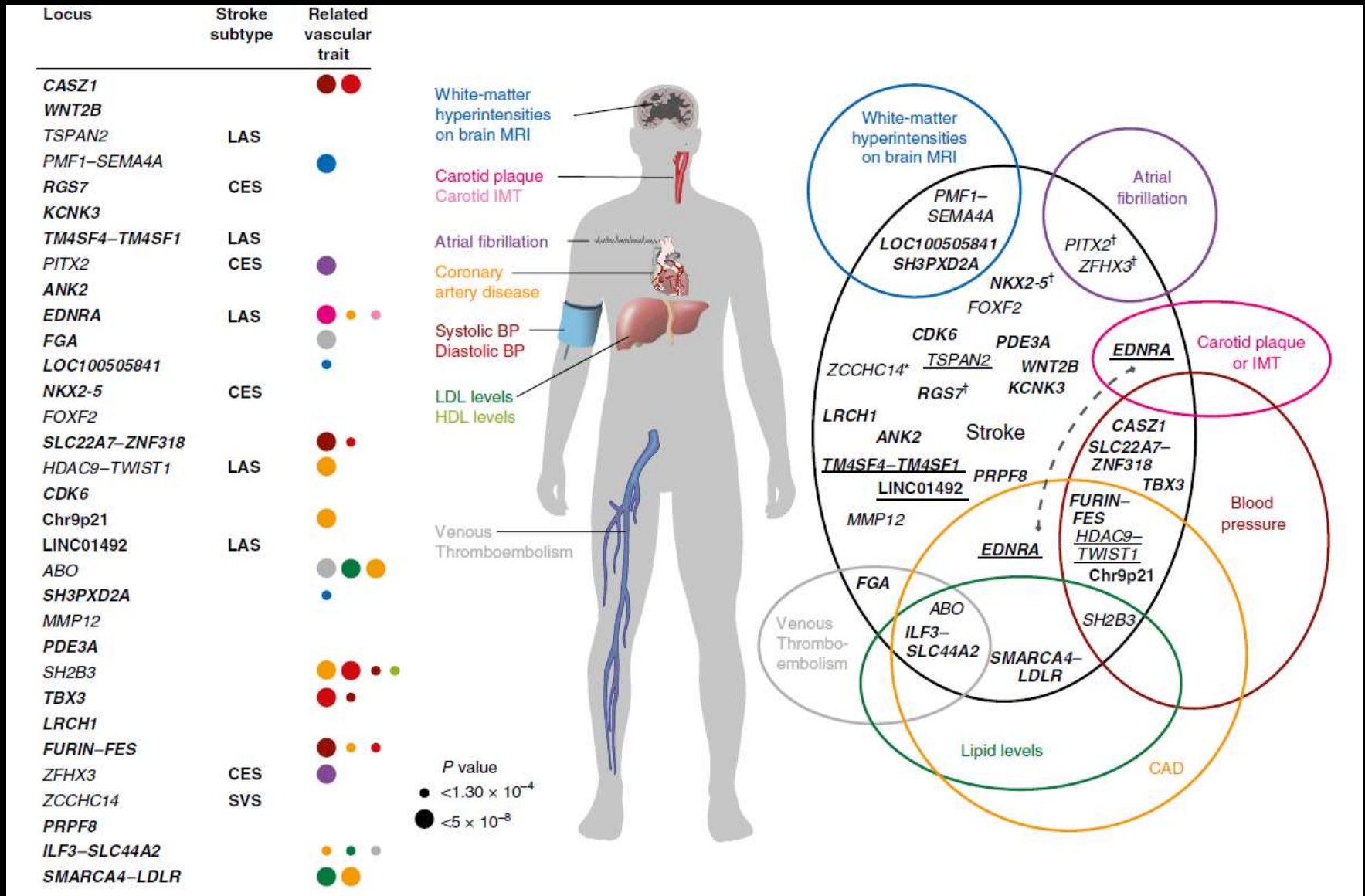
Integration of Molecular Profiling, Clinical and Social Data for Computable Disease Phenotypes

- **need for generalizable computational infrastructure for diverse deep phenotyping data classes**

  - **HL7 Fast Healthcare Interoperability Resources (FHIR)**

- **21st Century Cures Act requirements for EHR interoperability**

- **increased payer focus on RWE and value-based contracts**

  - **new RWE observational trial designs and patient registries**

Precision Medicine and Digital Health: Building a Learning Healthcare 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**

Reportable Healthcare Data Breaches (2010-2017)
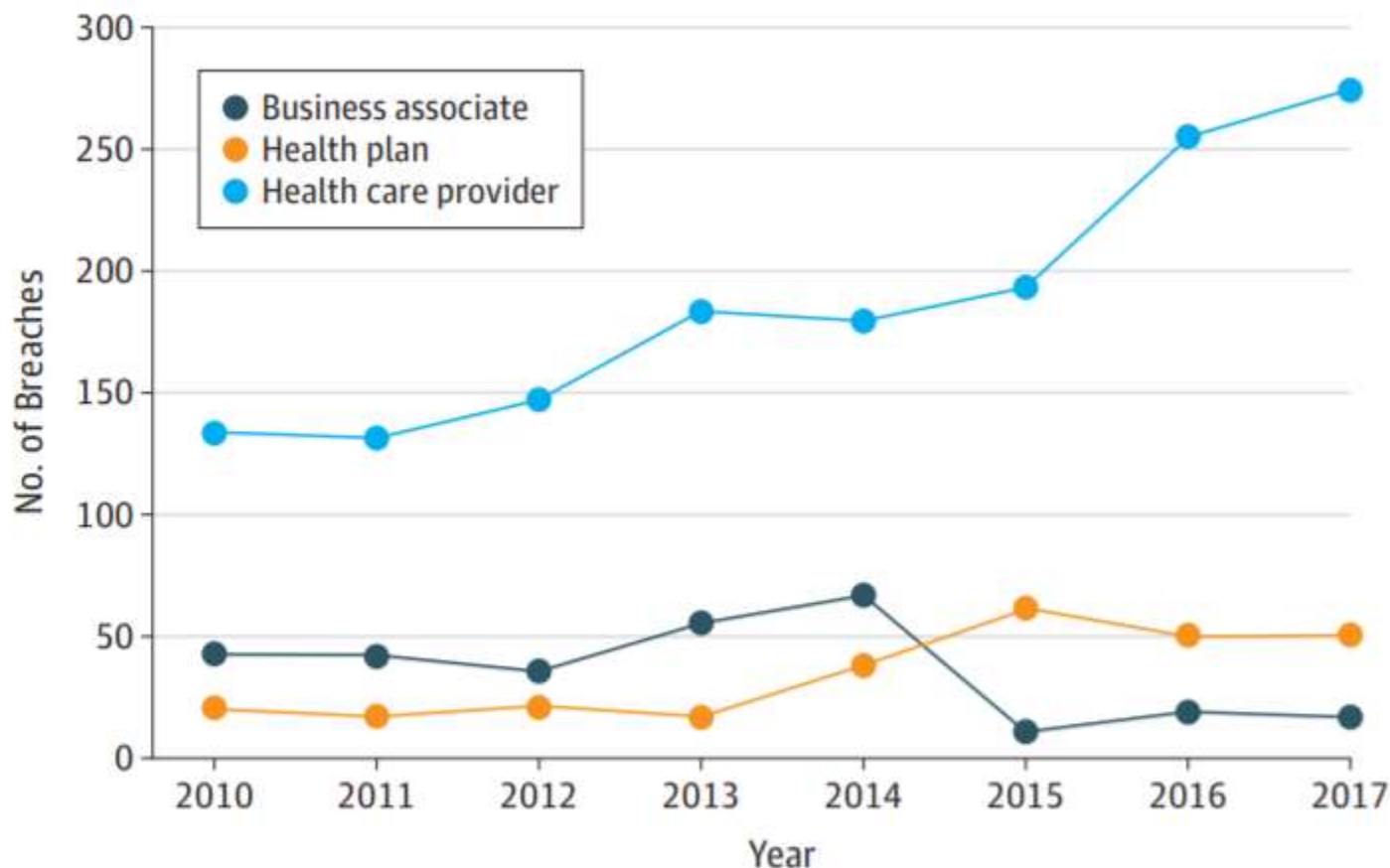
From: T. H. McCoy and R. H. Perlis (2018) JAMA, 320, 1283

Foreign Economic Espionage in Cyberspace

2018

"People Analytics" and Large Scale Databanks: Blurring the Boundaries Between Medical Research, Clinical Care and Daily Life

- every monitored event (clinical and non-clinical) is a potential data point

- every individual is a data node

- every individual is a research asset

- every individual is their own control

Social Spaces Become Quantifiable

- **who knows why people do what they do?**
  - **the fact is that they do!**

- **these actions can now be traced and measured with unprecedented precision**

- **with sufficient data, the numbers reveal increasingly predictable behavior and individual risk patterns**

- **the confessional of social media**

- **the blurring of private and public spaces**

- **complex ethical and legal issues**
  - **consent, privacy, security, surveillance**

The Future Issue

FORTUNE

MAY 01, 2017

FORTUNE.COM

The Doctor Will See You Now

> INSIDE THE DIGITAL HEALTH REVOLUTION & HOW IT WILL CHANGE YOUR LIFE
P. 36

The Future of

Television
Food
Finance
Security
Fashion

AND THE

41 Companies

THAT ARE CREATING TOMORROW TODAY

+ What Prediction Markets Can Tell Us About **Trump's Next Move**
P. 10

Newsweek.

06.02.2017

THE DOCTOR WILL SEE YOU NOW

HOW AI IS GOING TO CURE OUR SICK HEALTH CARE SYSTEM

DEEP LEARNING

AI

Artificial Intelligence, Pattern Analysis and Medical Practice

"I don't think any physician today should be practicing without artificial intelligence assisting in their practice.
It's just impossible otherwise to pick up on patterns, to pick up on trends to really monitor care."

Bernard J. Tyson
CEO, Kaiser Permanente
Cited in Forbes: The Future of Work
1 March 2017

Machine Learning and Big Data

Adapted from: A.L. Beam and I.S. Kohane (2018) JAMA 319,1317

90+ Startup AI Companies in Healthcare

The Quest for Robust Evidence When Drinking from the Fire Hose

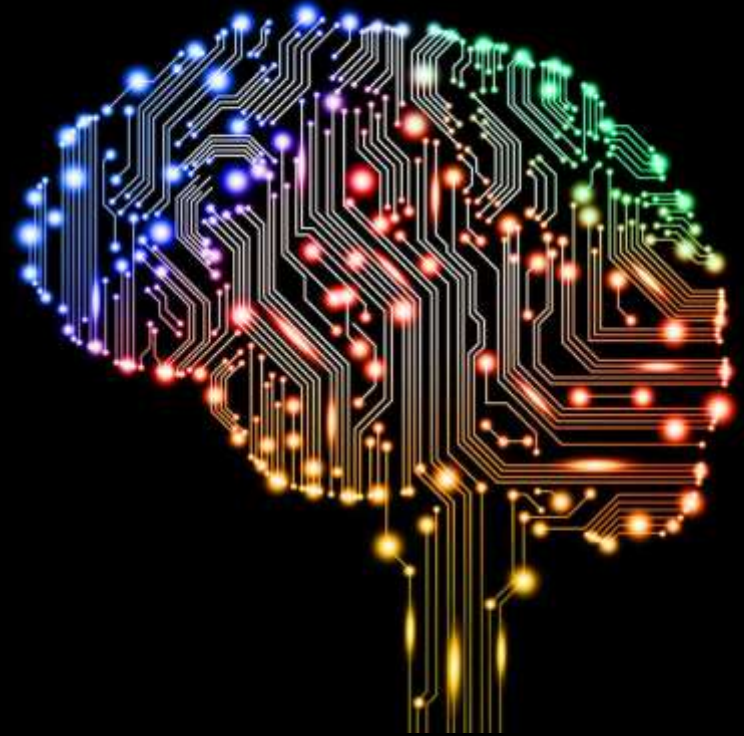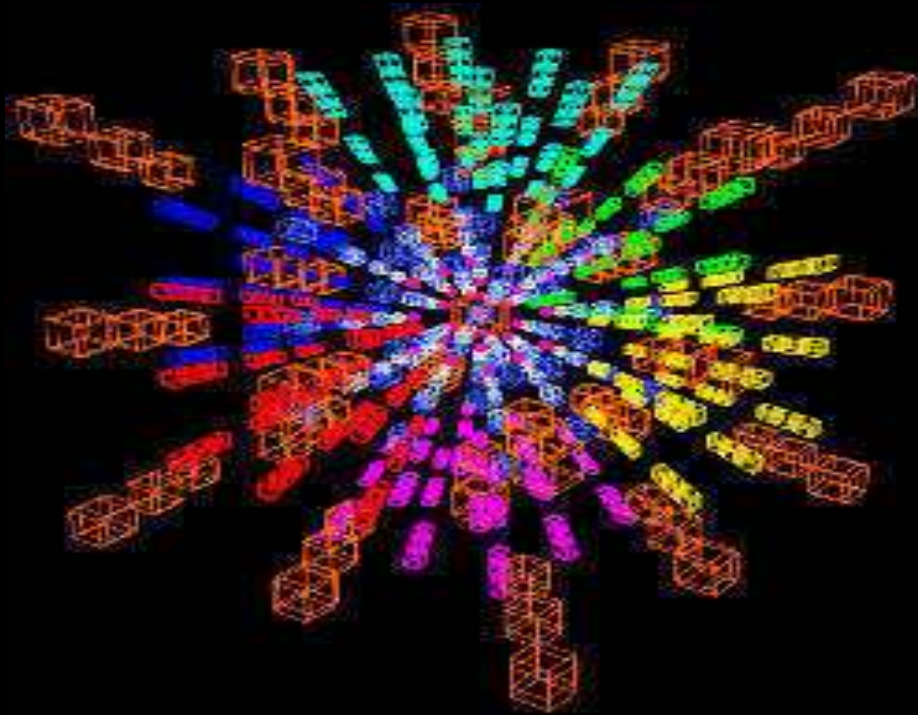The Future of 'Search' and 'Retrieval'

Deep Understanding of Content and Context

Collapse Time to Decision: Intelligence at Ingestion

Automated and Proactive Analytics:
Why Wait for the Slow Brain to Catch Up to the Fast Machine

Escalation of Data Complexity and Automation of Context
"Data Finding Data-Intelligence at Ingestion"

| **Feature Extraction and Classification** | → | **Context Analysis** ⇕ **Persistent Context** | → | • **Relevance Mapping**
 • **Learning Systems** | → | • **Situational Awareness**
 • **Rapid, Robust Decisions** |

Machine Learning and Image Analysis in Clinical Medicine
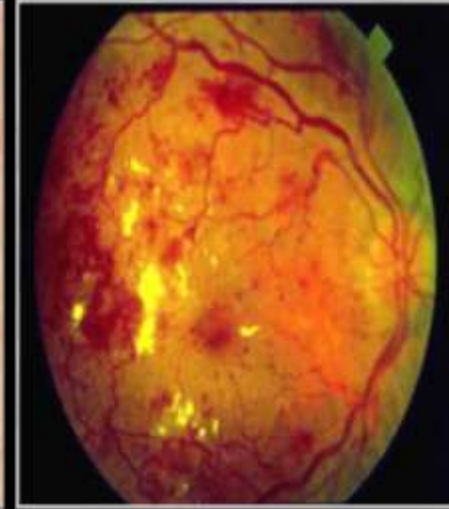
pathology	radiology	dermatology	ophthalmology

- **large scale training sets and classification parameters**

- **standardized, reproducible and scalable**

- **260 million images/day for $1000 GPU**

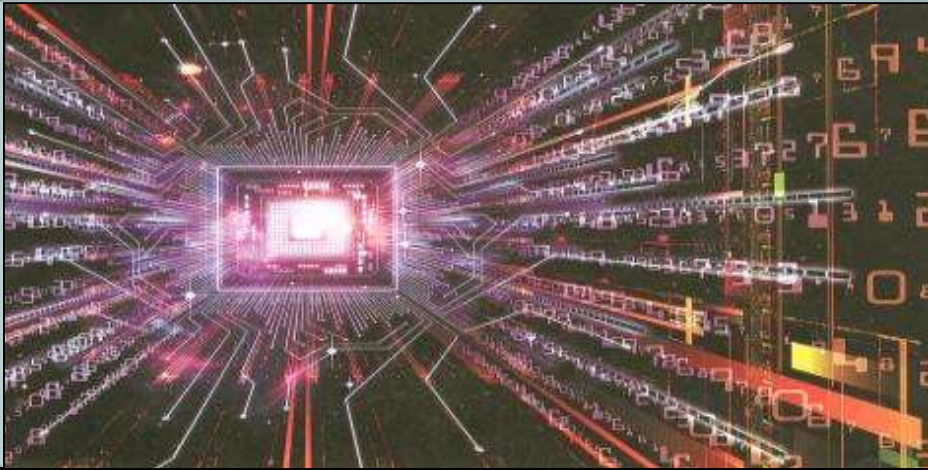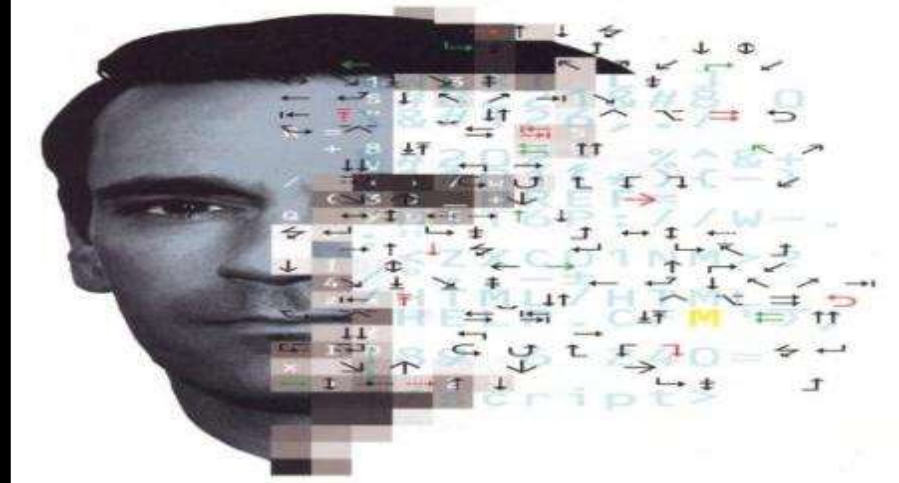# Technology Acceleration and Convergence: The Escalating Challenge for Professional Competency, Decision-Support and Future Medical Education

Data Deluge

Cognitive Bandwidth Limits

Automated Analytics and Decision Support

Facile Formats for Actionable Decisions

Just What the Data Ordered

Machine Intelligence and Algorithms for Clinical Diagnosis and Treatment Decisions

Black Box Medicine?

Machine Learning (ML), Artificial Intelligence (AI) and Healthcare

- how will ML-AI algorithms/decision analytics be validated/regulated?

- how will ML-AI tools be integrated into current work flow?

- will radical reorganization/re-training be required?

- how will ML-AI platforms alter payment schemes?

Machine Learning (ML), Artificial Intelligence (AI) and Healthcare

- **which clinical specialties/procedures/admin processes be at risk of replacement by ML-AI and when?**

- **how will professional competencies in using ML-AI decision-support tools be developed and sustained?**

  - **MD curriculum, CME**

  - **non-medical data science professionals**

- **what new malpractice liabilities will emerge by failure to use/interpret ML-AI platforms?**

Internal IBM Documents Reveal IBM Watson Recommended "Unsafe and Incorrect' Cancer Treatment

"IT HAS INGESTED ALL OF THE MEMORIAL SLOAN DATA, HISTORIC PATIENTS AND RESULTS."
JOHN KELLY, SENIOR VICE PRESIDENT OF COGNITIVE SOLUTIONS AND IBM RESEARCH, MAY 24, 2018

"MSK CASES ARE SYNTHETIC."
IBM INTERNAL DOCUMENT, JULY 27, 2017

C. Ross (2018) STAT 25 July

- **training used synthetic case histories versus RWE**

- **statistically underpowered training cohorts**

     - 635 lung, 106 ovarian

- **input from too few physicians (typically 1-2) on recommendations for each cancer type**

- **"raises serious questions about the process for building content and the underlying technology."**

https://www.statnews.com/2018/07/25/ibm-watson-recommended-unsafe-incorrect-treatments/

"Explainable AI"
Keeping Humans in the Decision Loop

- **need to better characterize the evolution of decision algorithms**

- **deconvolution of how and why machine learning algorithms reach flawed conclusions**

- **broad national security issues related to data integrity**

- **concern over AI-directed manipulation of social networks, advertising and personal data**

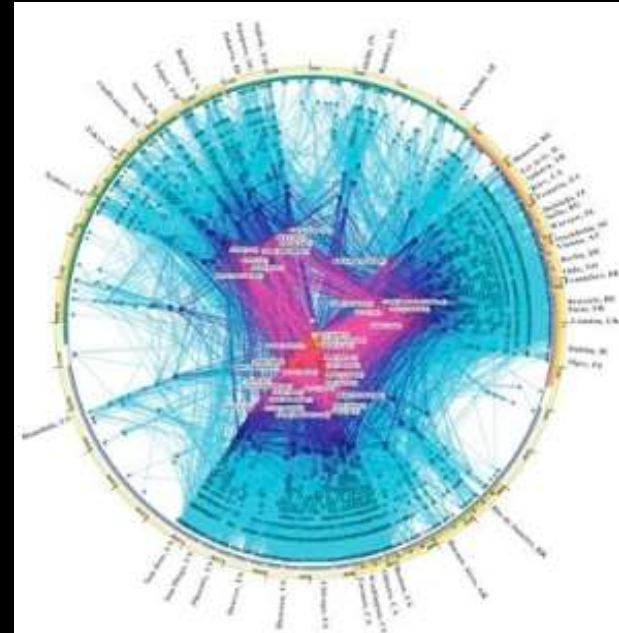- **corruption of critical military and civilian systems and decision tools**

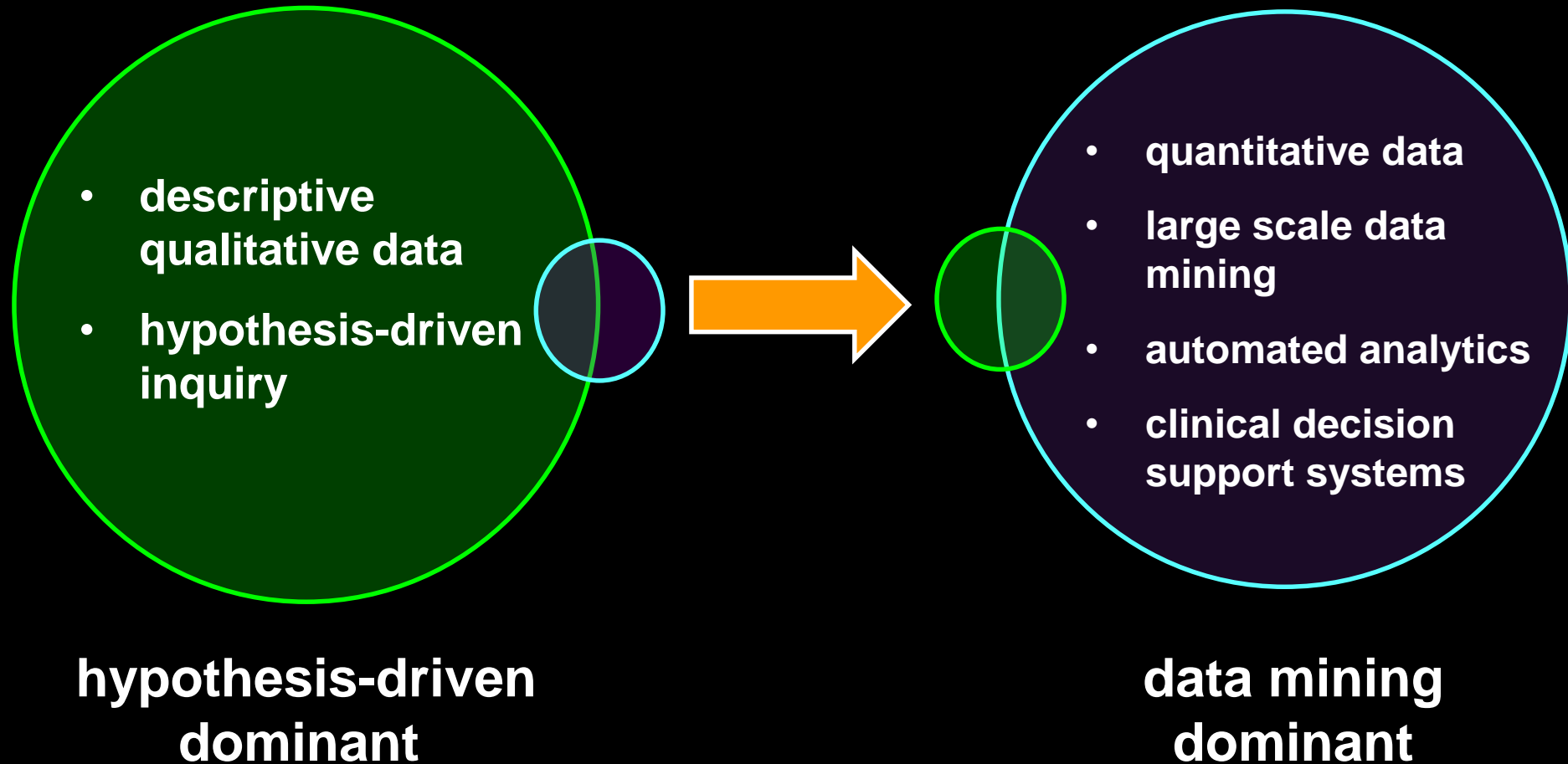# The Emergence of Big Data Changes the Questions That Can Be Asked

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

A Pending Transition in Biomedical Research and Clinical Care Decisions ?

- **descriptive qualitative data**
- **hypothesis-driven inquiry**

- **quantitative data**
- **large scale data mining**
- **automated analytics**
- **clinical decision support systems**

hypothesis-driven dominant

data mining dominant

"Digital Darwinism": A Looming Digital Divide?

- **understanding data structure and application to improve decisions and outcomes will become a critical institutional competency**

- **major skill gaps and predicted personnel shortages**

- **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**

Robotics, Autonomous Systems, Machine Learning and Artificial Intelligence

4-D Jobs – Dull, Dirty, Dangerous and Digital

Speed of Progressive Redundancy of Human Skills by ML-AI?
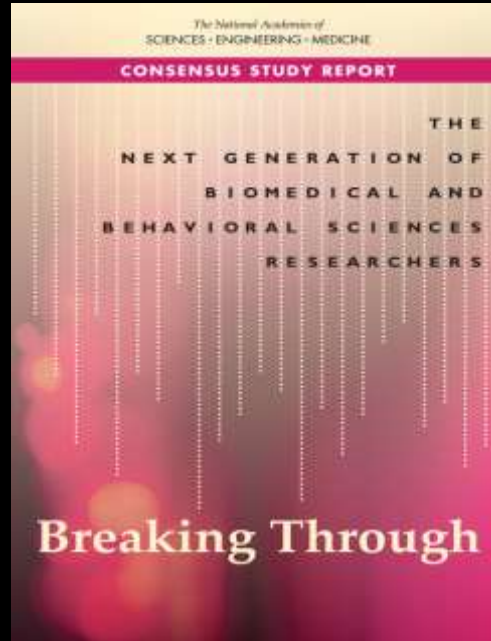
The Future of Work and The Future Workforce

COUNCIL on FOREIGN RELATIONS

Independent Task Force Report No. 76

The Work Ahead

Machines, Skills, and U.S. Leadership in the Twenty-First Century
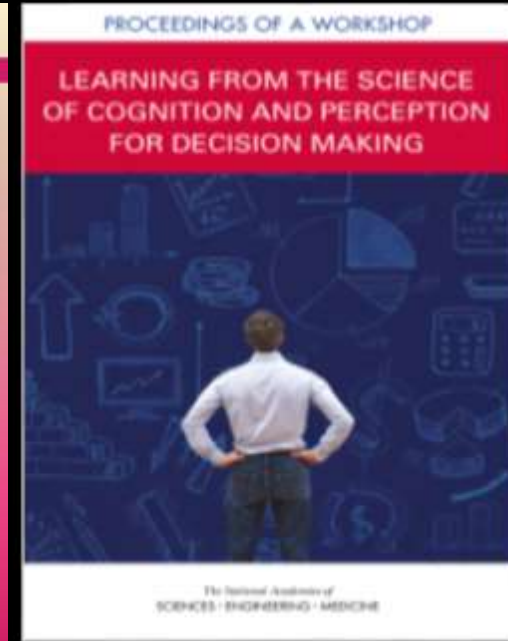
John Engler and Penny Pritzker, *Chairs*
Edward Alden, *Project Director*
Laura Taylor-Kale, *Deputy Project Director*

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

CONSENSUS STUDY REPORT

THE NEXT GENERATION OF BIOMEDICAL AND BEHAVIORAL SCIENCES RESEARCHERS

Breaking Through

PROCEEDINGS OF A WORKSHOP

LEARNING FROM THE SCIENCE OF COGNITION AND PERCEPTION FOR DECISION MAKING

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

World Health Organization

Global strategy on human resources for health: Workforce 2030

PROCEEDINGS OF A WORKSHOP

MOTIVATION NATIONAL ARTIFICIAL SKILLS
RECRUITMENT SECURITY INTELLIGENCE GROWTH
ANALYSIS TEAM SCIENCE KNOWLEDGE CAREER
COMMUNICATION ABILITIES NETWORK AUTOMATION
SELECTION EXPERIENCE INTELLIGENCE SENSEMAKING
GROWTH MANAGEMENT ANALYSIS TRAINING
DIVERSITY CAREER LEADERSHIP ABILITIES
WORKFORCE SKILLS TEAMWORK EDUCATION

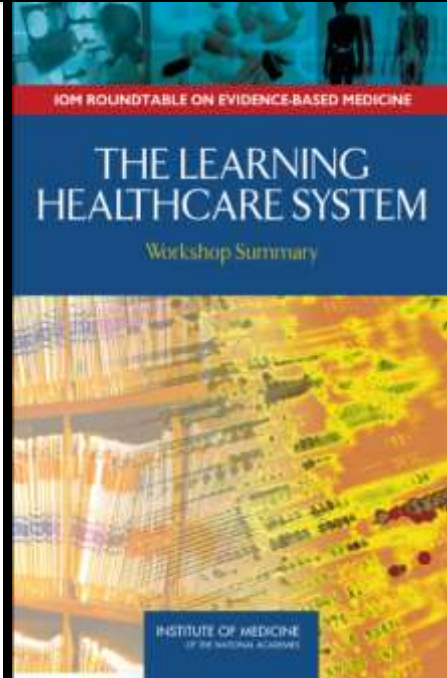## WORKFORCE DEVELOPMENT AND INTELLIGENCE ANALYSIS FOR NATIONAL SECURITY PURPOSES

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

New Patterns of Learning

Major Transitions in Medical Education and Healthcare

1910 - present   **2000 - present**   **2015 - ?**

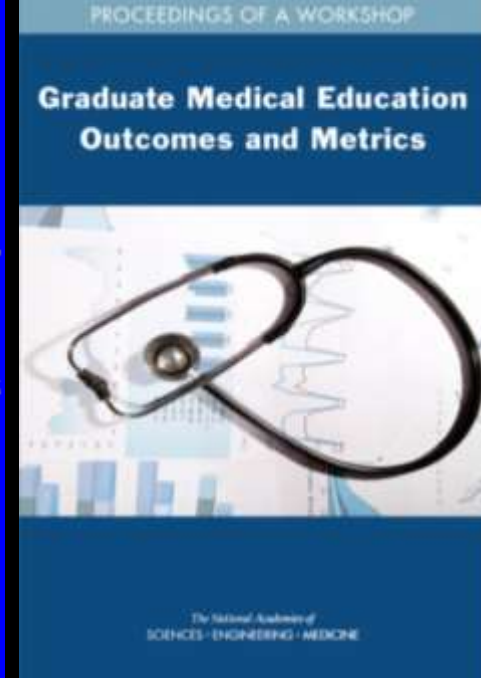**(science-centric)**   **healthcare as a learning system (data-centric)**   **mastery of escalating complexity and massive data (network-centric)**
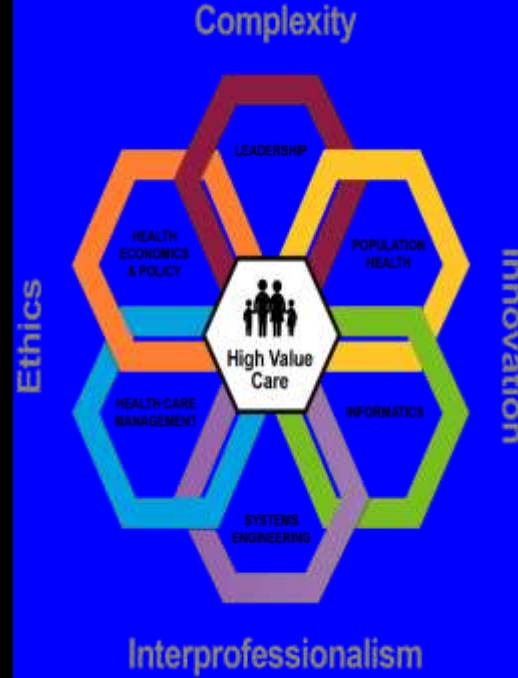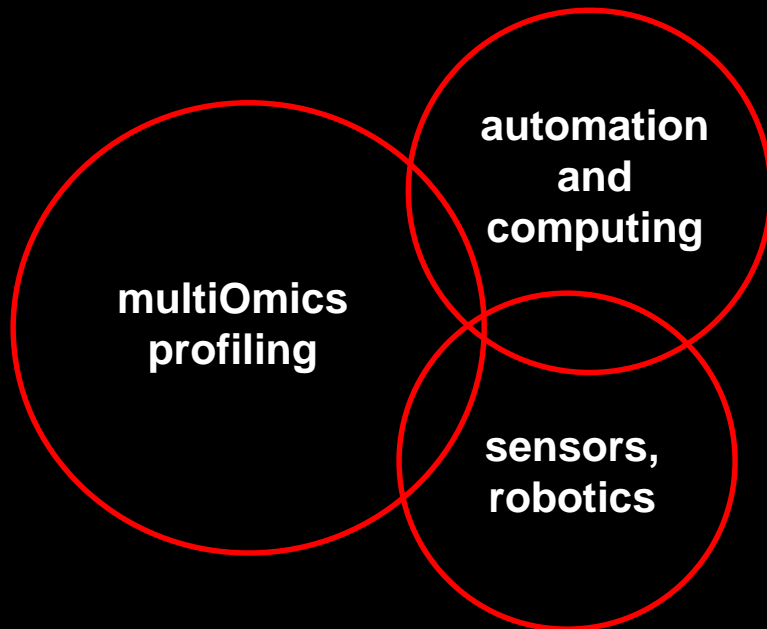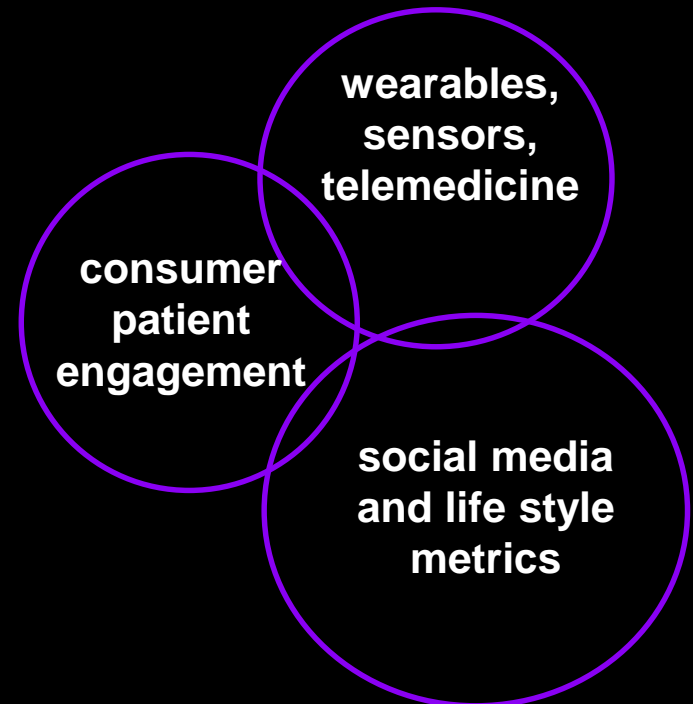
The Future of Healthcare: Precision Medicine and Digital Medicine

new technology platforms

the expanded care space

automation and computing

multiOmics profiling

sensors, robotics

wearables, sensors, telemedicine

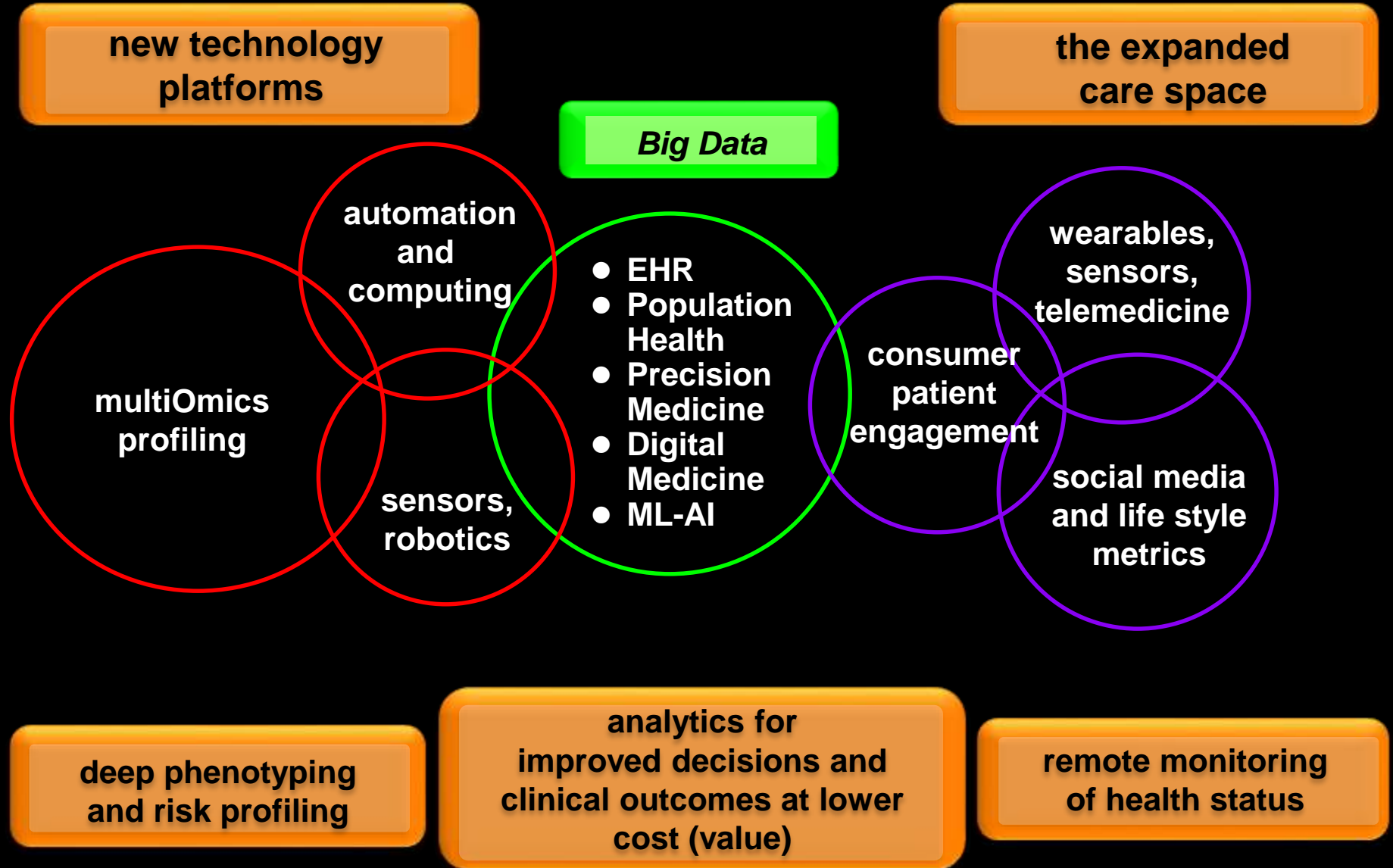consumer patient engagement

social media and life style metrics

deep phenotyping and risk profiling

remote monitoring of health status

The Future of Healthcare: Precision Medicine and Digital Medicine

new technology platforms

the expanded care space

Big Data

automation and computing

wearables, sensors, telemedicine

multiOmics profiling

consumer patient engagement

- EHR
- Population Health
- Precision Medicine
- Digital Medicine
- ML-AI

sensors, robotics

social media and life style metrics

deep phenotyping and risk profiling

analytics for improved decisions and clinical outcomes at lower cost (value)

**remote monitoring of health status**

"The Vision Beyond the Vision"

Michael D. Dake, M.D.
Senior VP for Health Services,
University of Arizona

Challenges and Opportunities

- **implementation and integration of digital health, big data and precision health into new models of patient care and research**

- **identify highest priority opportunities for validation pilots**

- **define evaluation processes and metrics for new innovations**

- **identify and build collaboration networks to accelerate innovation and adoption of new digital technologies**

The Evolution of Data-Intensive Precision Medicine

Technology Convergence and Acceleration
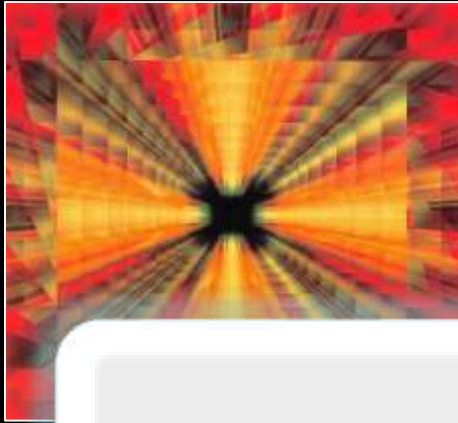
Mapping Geno-Phenotype Complexity
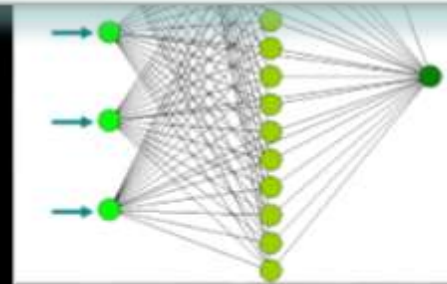
Topology of Biological Information Networks

V7 Big Data

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

Data Security and Privacy

Robotics and Human Machine Interactions

Artificial Intelligence and Decision Support

Ethics, Risk and Regulation