ASU Complex Adaptive Systems Initiative
Arizona State University

ASU Sandra Day O'Connor College of Law
Arizona State University

Wearables, Apps and Big Data in the Age of Precision Medicine

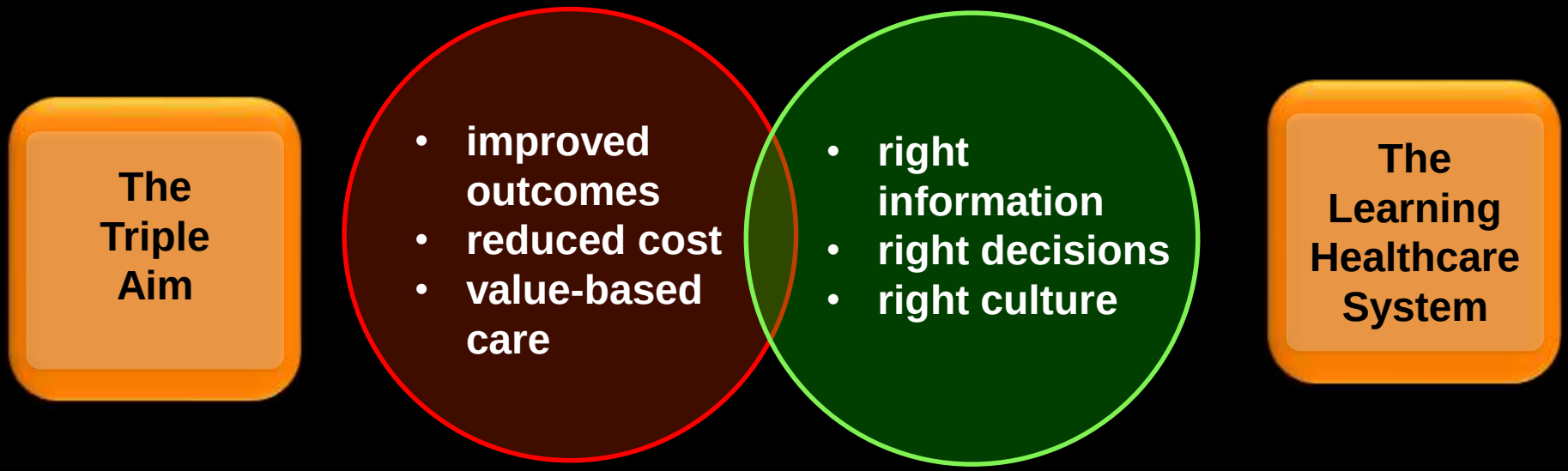
Dr. George Poste
Chief Scientist, Complex Adaptive Systems Initiative
and Regents Professor of Health Innovation
Arizona State University
george.poste@asu.edu
www.casi.asu.edu

Center for Law, Science and Technology
Spring 2018/Study Group on Biological Revolutions
11 January 2018

The US Healthcare Ecosystem

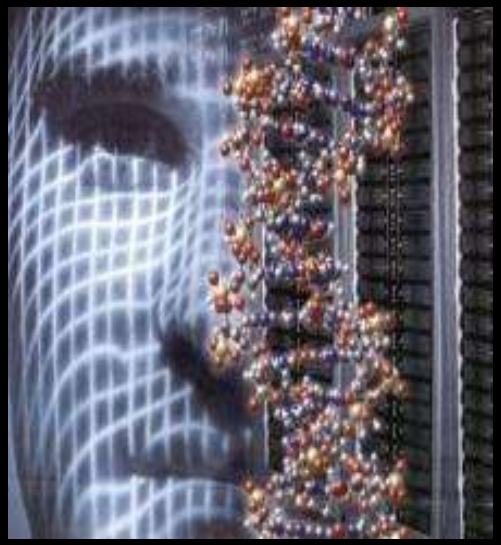
- economically unsustainable
  - $3.5 trillion, 18% GDP and projected 3-5% CGR
- looming clinical and economic impact of aging population
- dominance of reactive episodic interventions to overt disease versus proactive risk monitoring and mitigation
- lags other sectors in access and proficient use of information to optimize care allocation of high cost resources
- waste, inefficiency, error and wide variation in standards of care

Aspirations for the U.S. Healthcare System: National Academy of Medicine

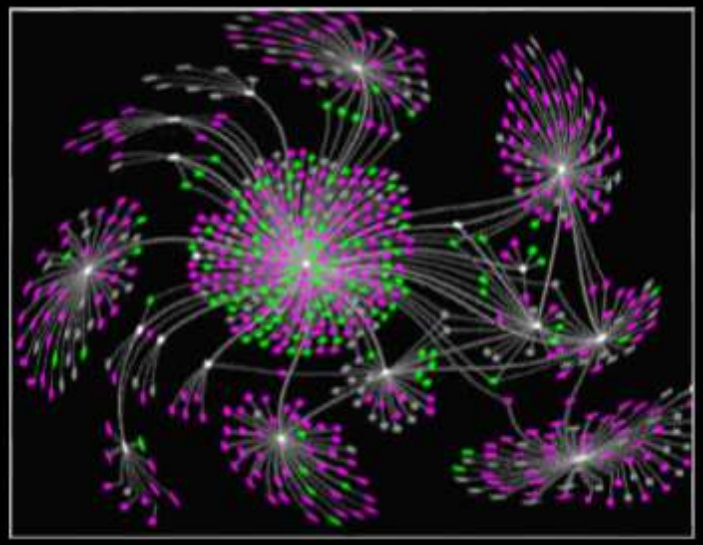


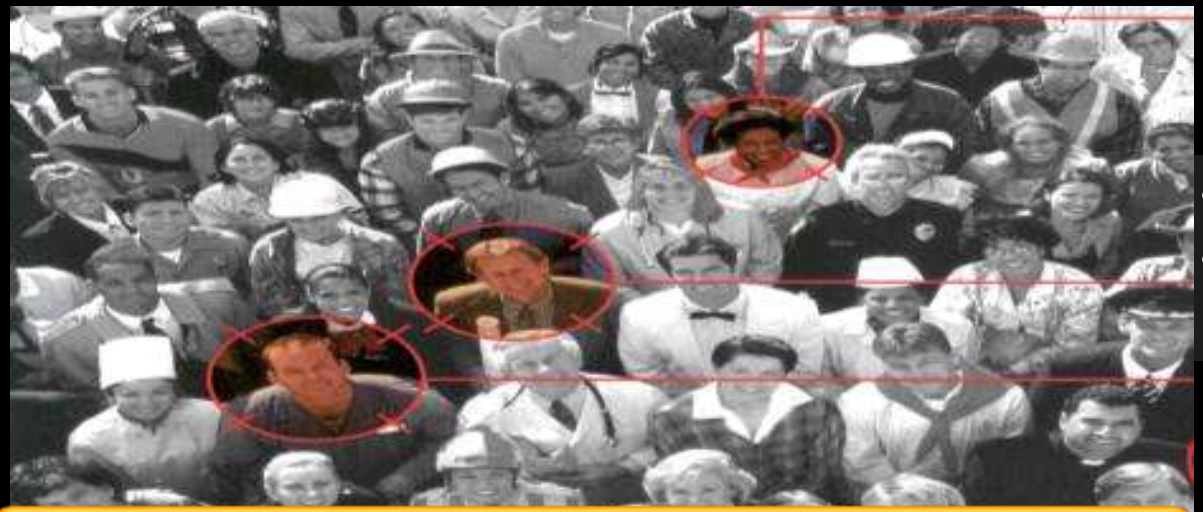
Precision Medicine:

(Epi)Genomics

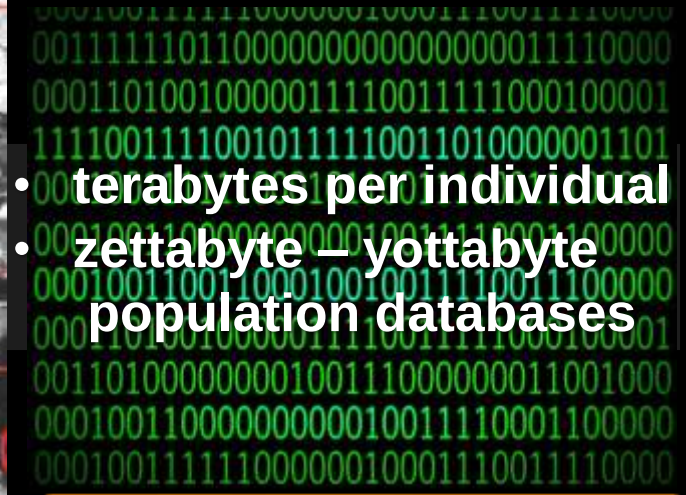


Causal Relationships Between Molecular Signaling Network Disruptions and Disease





Patient-Specific Signatures of Disease or Predisposition to Disease



- terabytes per individual
- zettabyte – yottabyte population databases

Big (Messy) Data

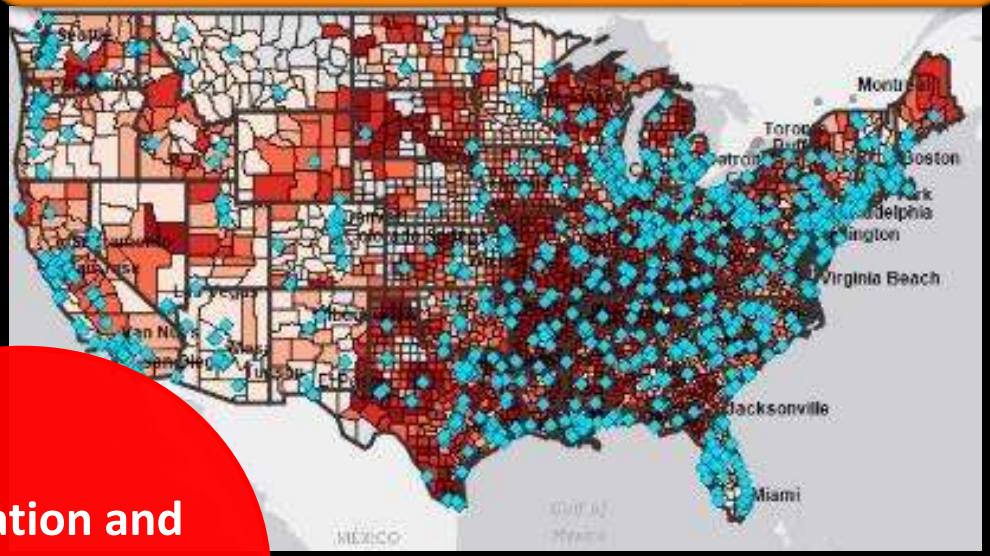
Consortium for Exome Sequencing of 500,000 UK Biobank Samples by 2020

- announced January 2018: each company committed to $10MM investment
- integration with medical records, lab test data and psychological assessments

Precision Medicine and Data-Intensive Medicine: Obligate Inter-Dependencies

Individual Data

Population Databanks



integration and analysis of large scale, diverse data

"matching" individual profiles to 'best match' cohorts with data or outcomes

The Slow Adoption of Precision Medicine Into Routine Healthcare

precision medicine early adoption

routine healthcare delivery

individual-centric protocols

- one-size-fits-all protocols
- reimbursement policies
- fragmented data

estimated $ 20 - 50 billion

$ 3.2 trillion

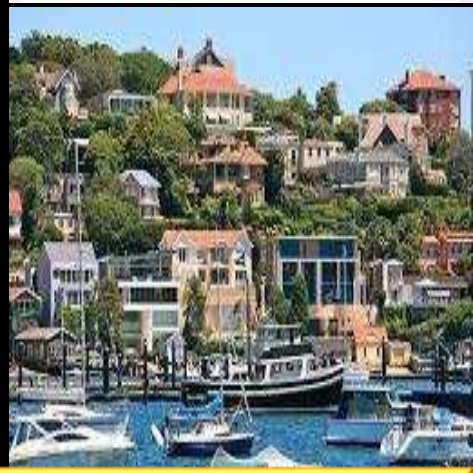
Most Events That Affect Our Health Occur Outside of the Healthcare System And Are Not Monitored

Need for Continuity of Care Record: From Womb to Tomb







Behavior

Environment

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

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

- every recorded action (clinical and non-clinical) is a data point
- every individual is a data node
- every individual is a research asset
- every individual is their own control
- every contact builds a personal risk profile (social contagion)

Humana

“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.

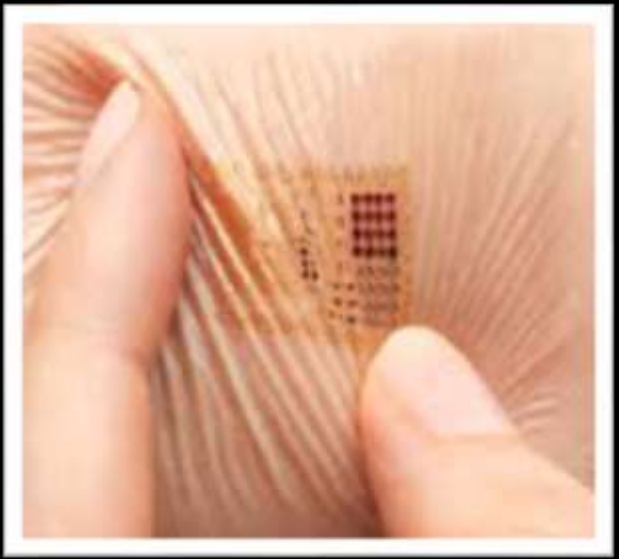
CMO, Humana

Cited in Fierce Healthcare 9 May 2017

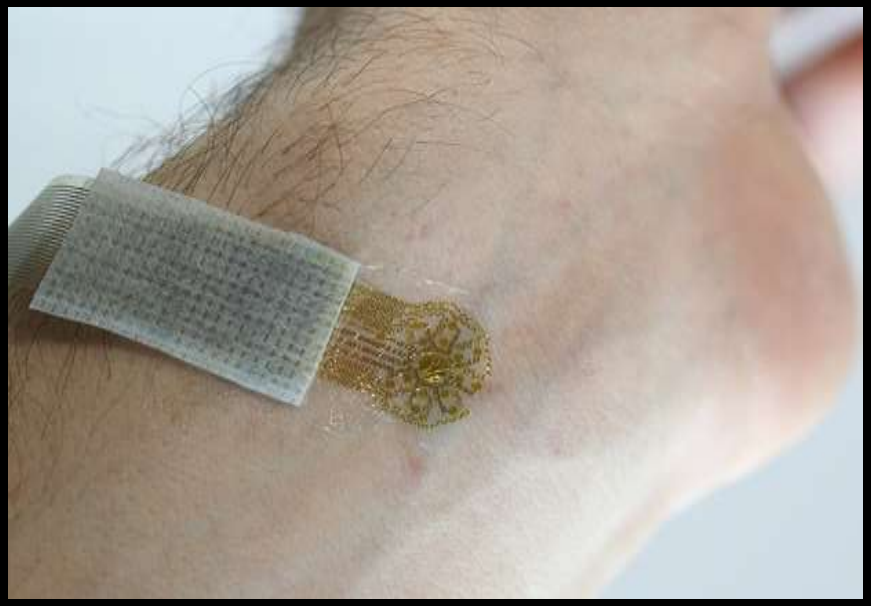
A Data-Intensive World

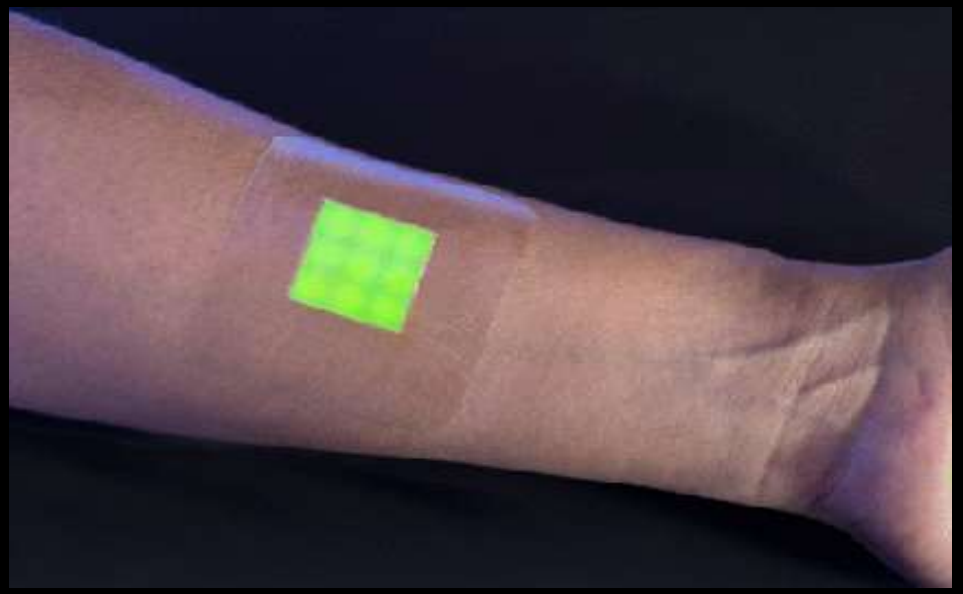
- Ubiquitous Sensing
- Internet – of – Things (IoT)
- Biometrics and Surveillance
- AORTA: Always On, Real Time Awareness
- Faster Data, Smarter Analytics, Better Decisions
- Robotics, Machine Learning and Artificial Intelligence

Remote Monitoring of Health Status



Smart Materials for Improved Therapeutic Adherence





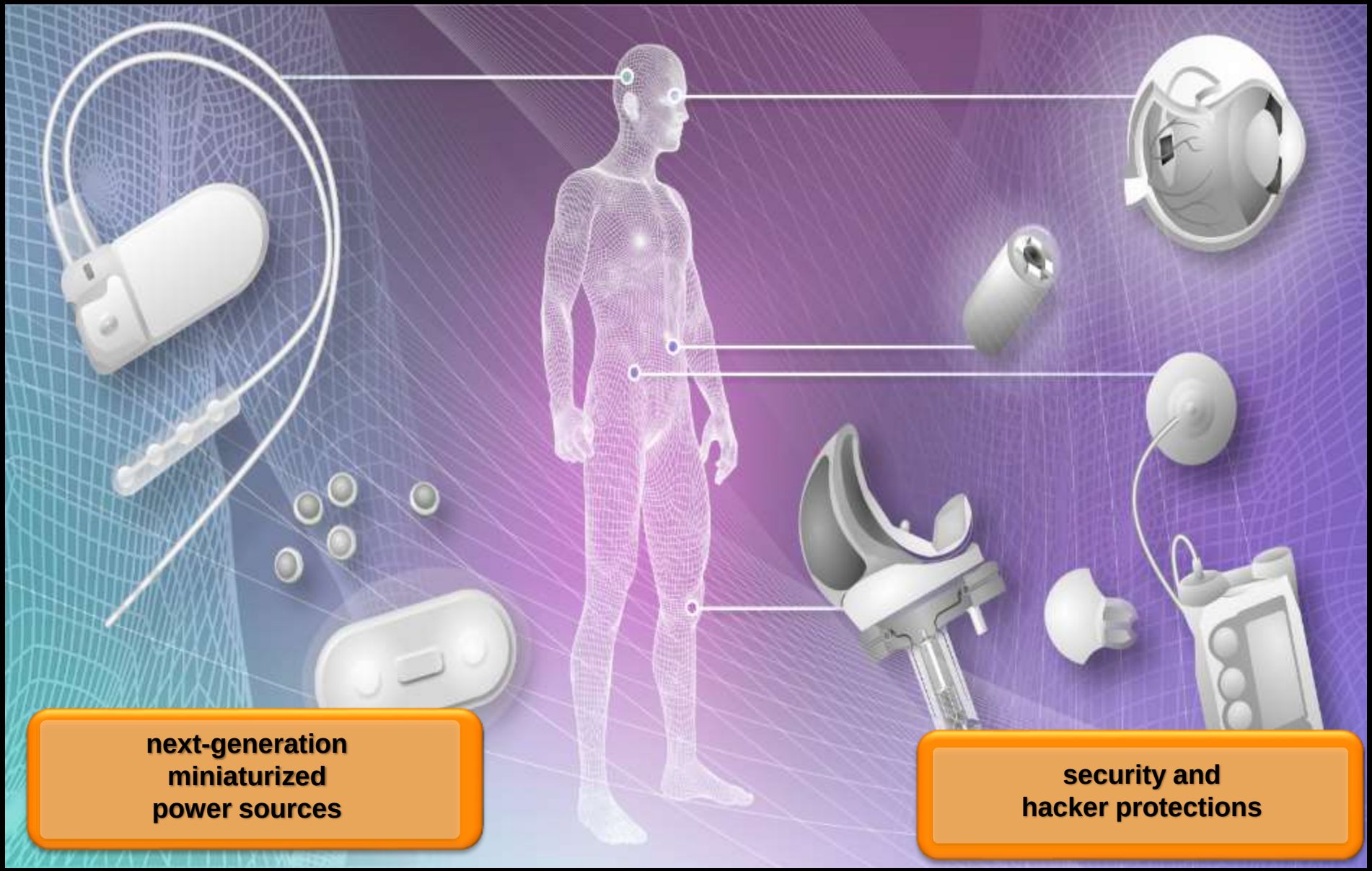
Swallowing a Spy — The Potential Uses of Digital Adherence Monitoring

Lisa Rosenbaum, M.D.

NEJM (2018) 378, 107

- **improve clinical outcomes**
- **financial penalties/coercion for non-adherence ?**
- **privacy protections ?**
- **stealth reporting of non-R_x issues?**

Implantable Devices and Wireless Monitoring (and Modulation)



NavCog: Carnegie Mellon University
Sensory Substitution Devices: Hearing Sights

From: Comm. ACM 2018 61, 15

“Medical Selfies”: The Proliferation of Mobile Devices in Healthcare

The Growth of Telehealth and Telemedicine: Expanding the Care Space

- estimated use by 60% HCI's and 50% hospitals (NEJM 2017, 377, 1585)
- virtual consults in Kaiser Permanente exceeded in-person visits in 2016
- reduced cost, travel time for patients
- healthcare consumerism and Ux expectancy
- 21st Century Cures Act and efficacy evaluation for Medicare services

The Eldercare Gap

10,000

- boomers turn 65 every day

79 %

- increase in boomers 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 aide jobs needed in next decade

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

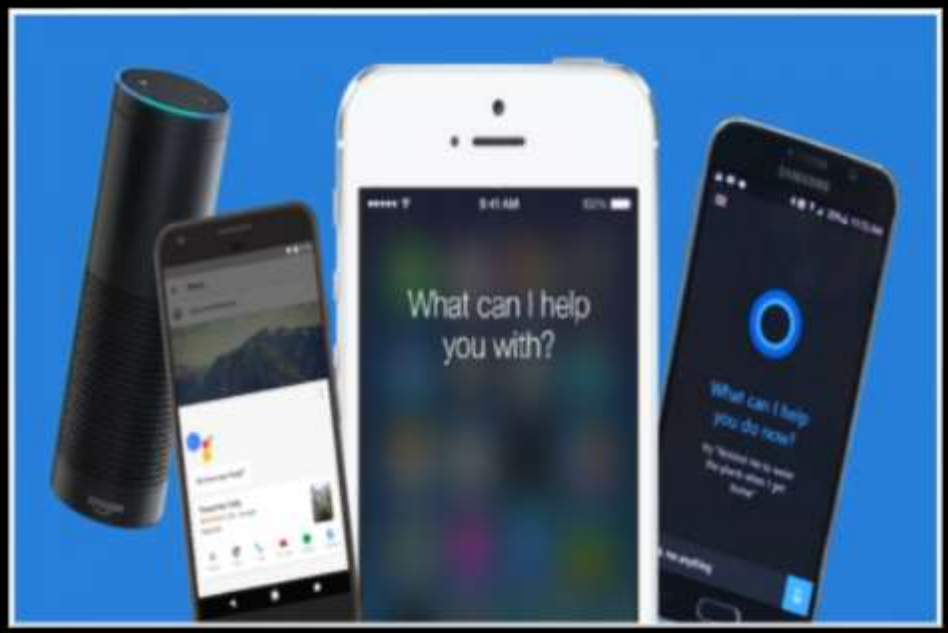
Rx adherence

cognitive stimulation

in home support and reduced readmissions

reduced office visits

Digital Assistants and Support Robots in Healthcare



The Omnipresent Digital Assistants

alexa

BMW

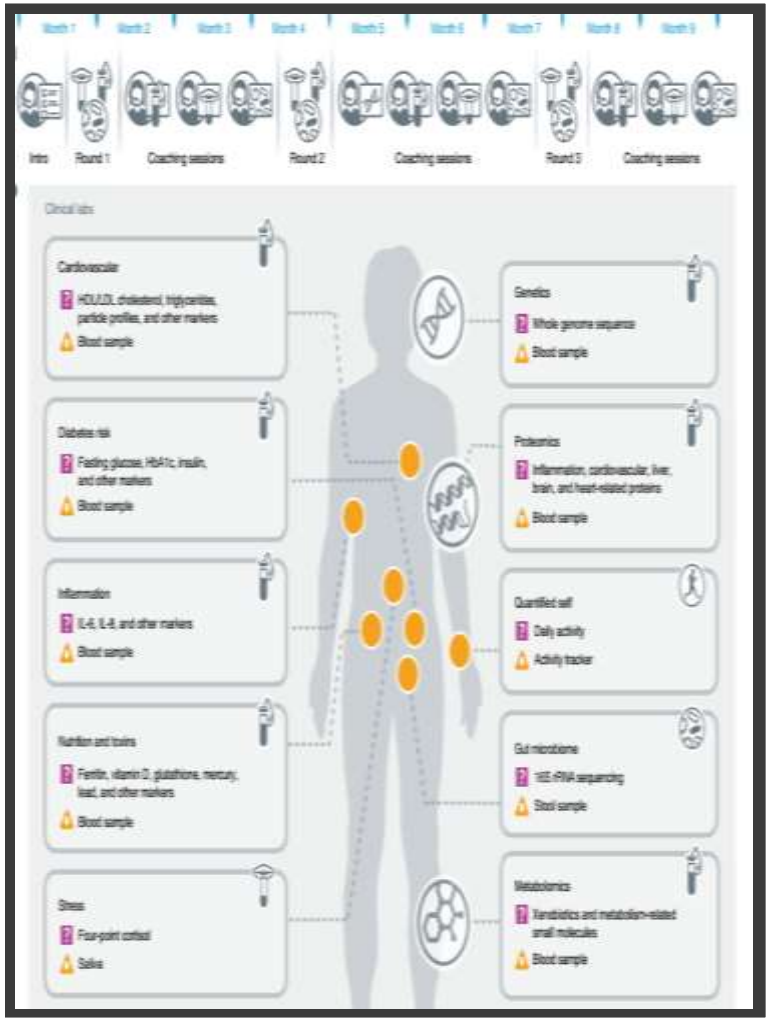
SONOS

GARMIN

Source: Micormass 2016

Personal, Dense, Dynamic Data Clouds: Comprehensive Profiling of Health Status of 108 Individuals Over 9 Months

N. D. Price et al. (2017) Nature Biotechnology 35, 747

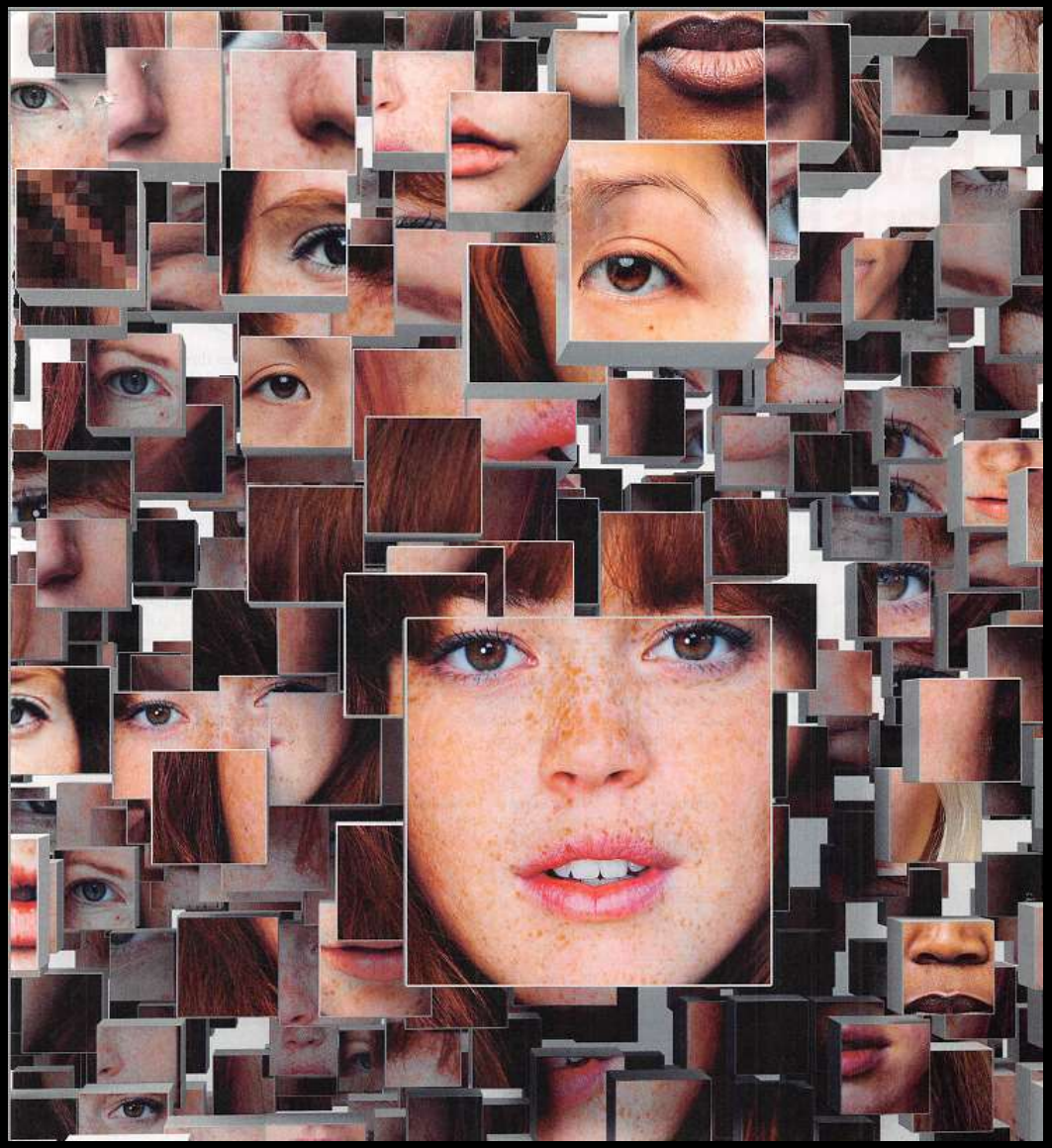


- WGS
- daily physical and sleep activities
- 3 month blood, saliva, urine and stool analysis
- 643 metabolites
- 262 proteins

- cost
- scalability
- data interpretation
- clinical utility

Use of Incentives and Rewards for Adoption of Wearables in Treatment Adherence and Wellness Initiatives

Digital Psychiatry:
Digital Psychometrics and Evaluation of Mental Illness



From: Scientific America Oct 2016

Computational Analysis of Facial Expressions, Voice and Social Interaction Patterns in Diagnostic Profiling of Psychiatric Disorders

- high variation in assessment of same patients by different psychiatrists
- major need for objective measurements of nuanced behavior
  - gaze, microsaccades, facial muscles, skin galvanics
  - speech prosody (rhythm, tone, volume)
  - stimulus response reactions and interaction speed
- AI and learning from large video banks
  - bipolar disorder, schizophrenia, depression
  - suicidal ideation
  - PTSD
- signal alerts to care teams when interventions indicated

Avatar Personalities in Gaming Reveal Behavioral Clues to Match With Other Aspects of User Activities

- risk profiling
- predispositions to anti-social actions/susceptibilities
- mapping correlation with real world actions, including law breaking

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

Mobile Apps, Wearables, Sensors and Continuous Health Status Monitoring

- who sets the standards?
- who integrates and interprets the data?
- who pays?
- who consents?
- who owns the data?

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 engagement of consumers/patients/families
- more transparent information on treatment options, cost and provider performance
- new clinical practice tools to optimize HCP: patient relationships
- improved recruitment of patients into investigational and pragmatic clinical trials
- Ux

Virtual Visits/Consultations: In-Person Healthcare as Option B

"What if ill-person visits were the second, third or even the last option for meeting routine patient needs rather than the first?"

S. Duffy and T.H. Lee
NEJM (2018) 378, 104

“The Medical Virtualist” and “Website Manners”: The Next Clinical Specialty ?

- 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
- need for new training courses

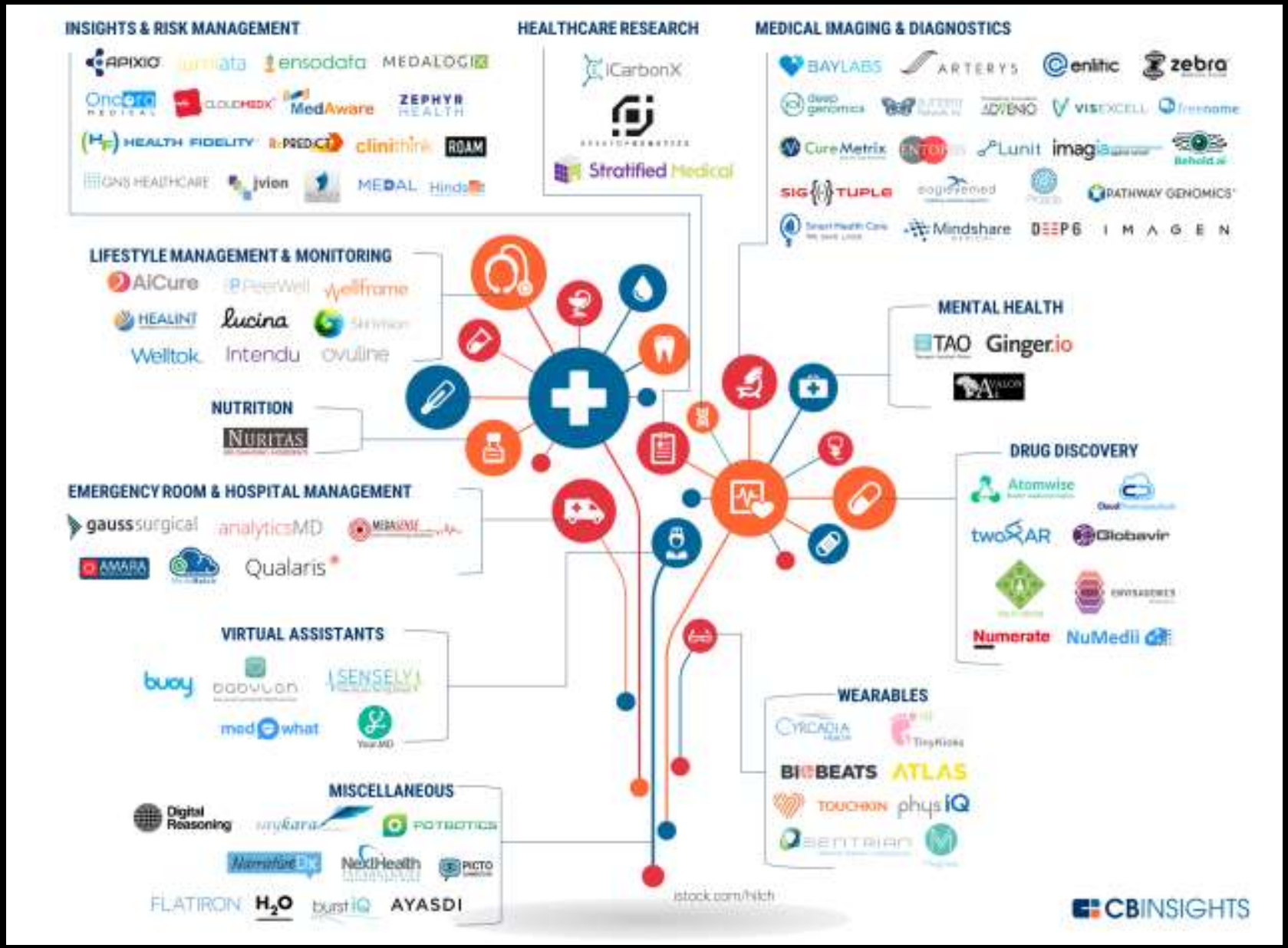
Artificial Intelligence, Pattern Analysis and Medical Practice

"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

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

90+ Startup AI Companies in Healthcare

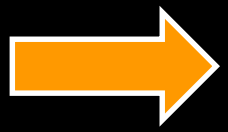


The Worst Supply Chain in Society: The Health Information Supply Chain

- no area of the economy generates as much information as the health sector yet uses it so poorly
- fragmented, disconnected data
- incomplete and inaccurate data
- incompatible data formats as barrier to data integration
- slow transition from paper to electronic systems
- inadequate information on behavioral and environmental influences on health
- legislative barriers to data transfer based on well intentioned privacy protections

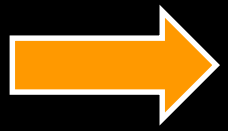
Precision Medicine, Digital Health and A Learning Healthcare System

qualitative, descriptive information of uncertain quality and provenance



quantitative data of known provenance and validated quality

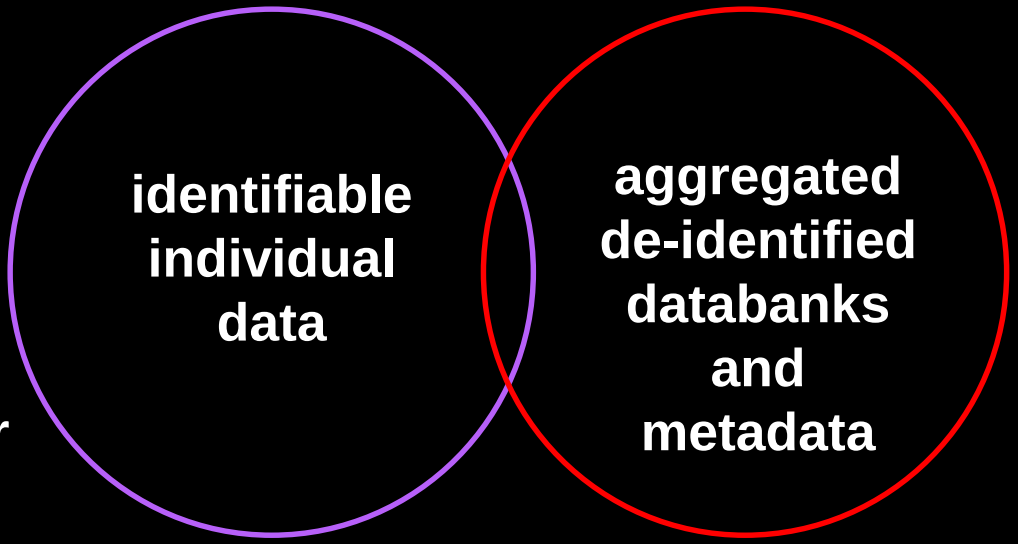
complex ecosystem of largely unconnected data sources



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

Protection and Privacy Provisions for Personal Healthcare Data

- informed consent
- legal provisions/ penalties for breach



- variable levels of consent
- probabilistic, multi-parameter individual ‘match’

Protection and Privacy Provisions for Personal Healthcare Data

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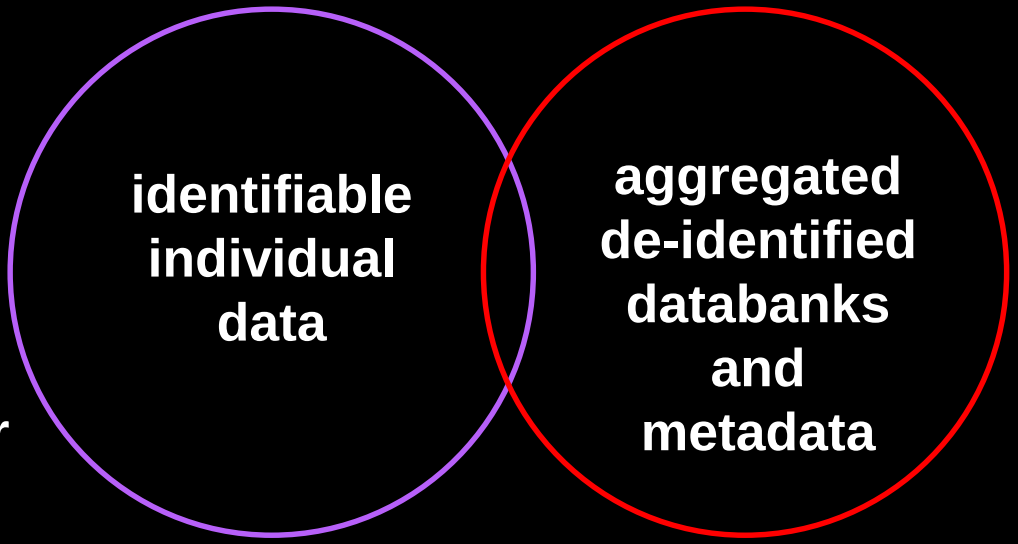
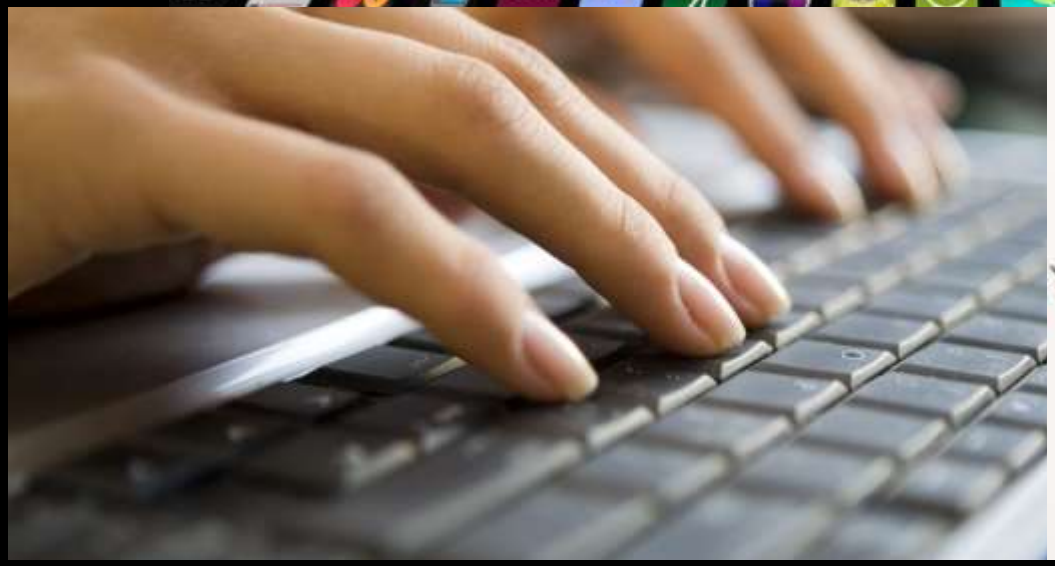


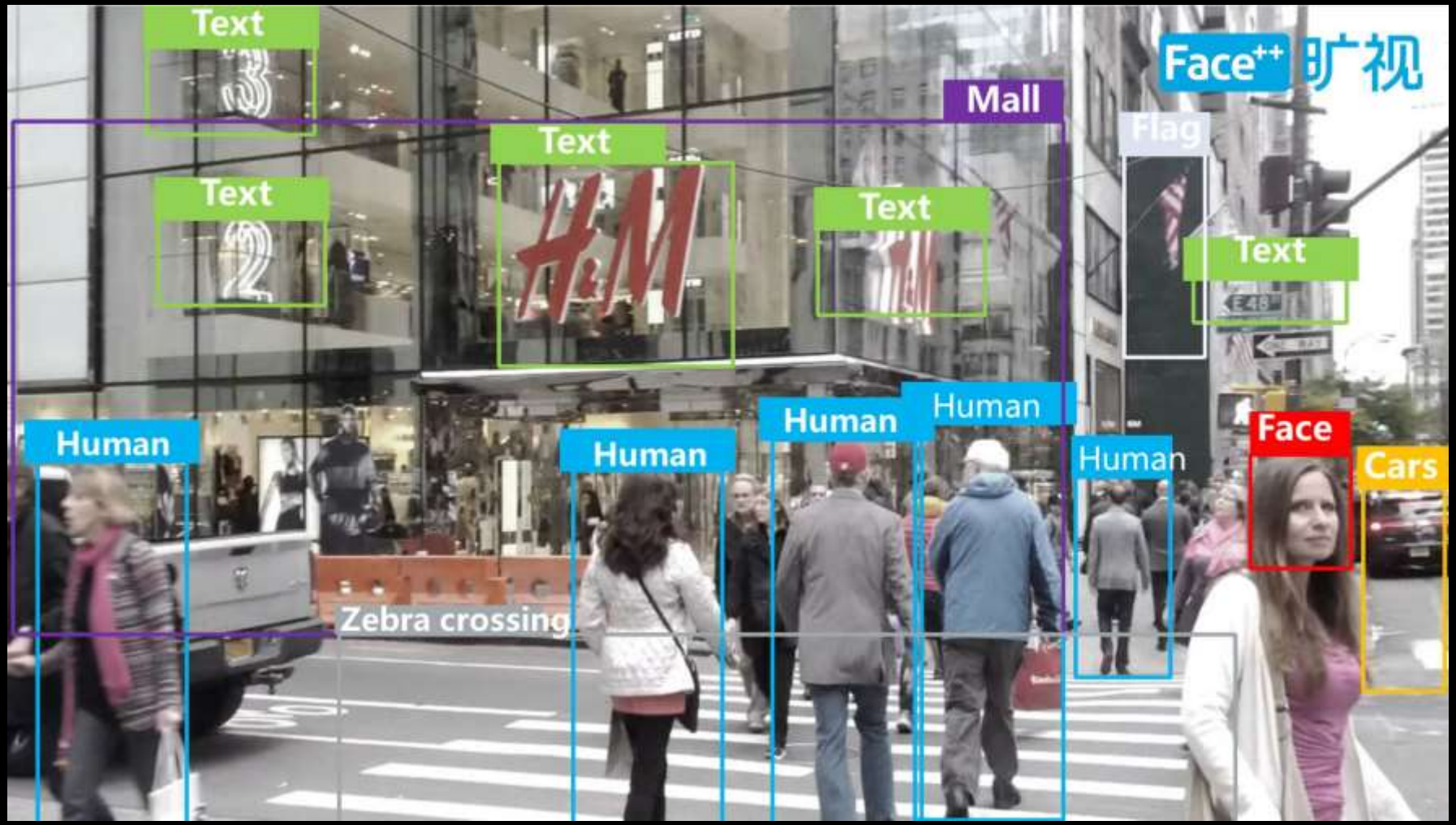
- variable levels of consent
- probabilistic, multi-parameter individual ‘match’

Are Anonymity and Privacy Illusory in Today’s e. Universe?

Individual-Specific Patterns of App Use and Keyboard Dynamics



Computer-Based Computer Facial Recognition and Idiosyncratic Patterns of Body Language, Gait, and Routes

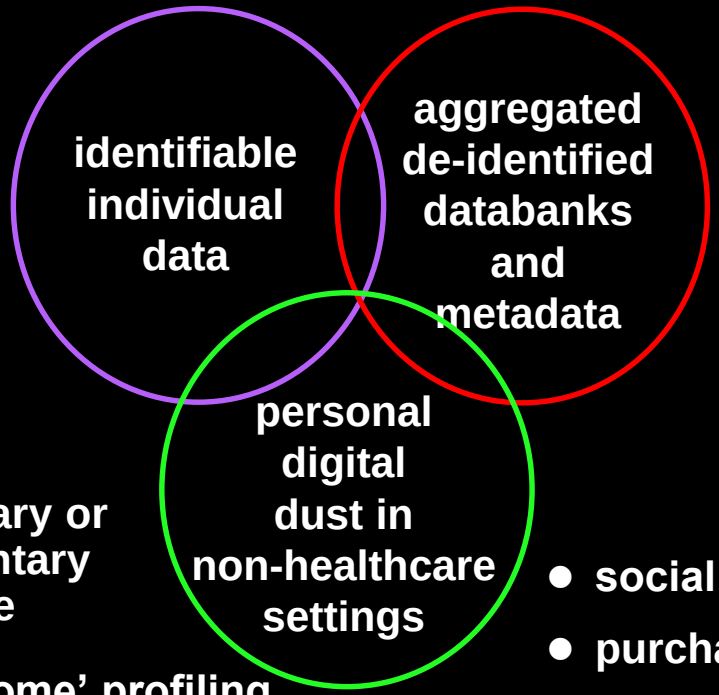


Making Faces

Your Car Knows A Lot About You

Protection and Privacy Provisions for Personal Healthcare Data

- informed consent
- legal provisions/ penalties for breach



- variable levels of consent
- probabilistic, multi-parameter individual 'match'

- voluntary or involuntary capture
- 'exposome' profiling and escalating prospect of individual identification

- social media 'firehose'
- purchasing preferences
  - diet, food, alcohol, travel
- political versus
- social graphs: network contagion
  - ratings of 'friends' impact personal rating

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Special Publication 800-122

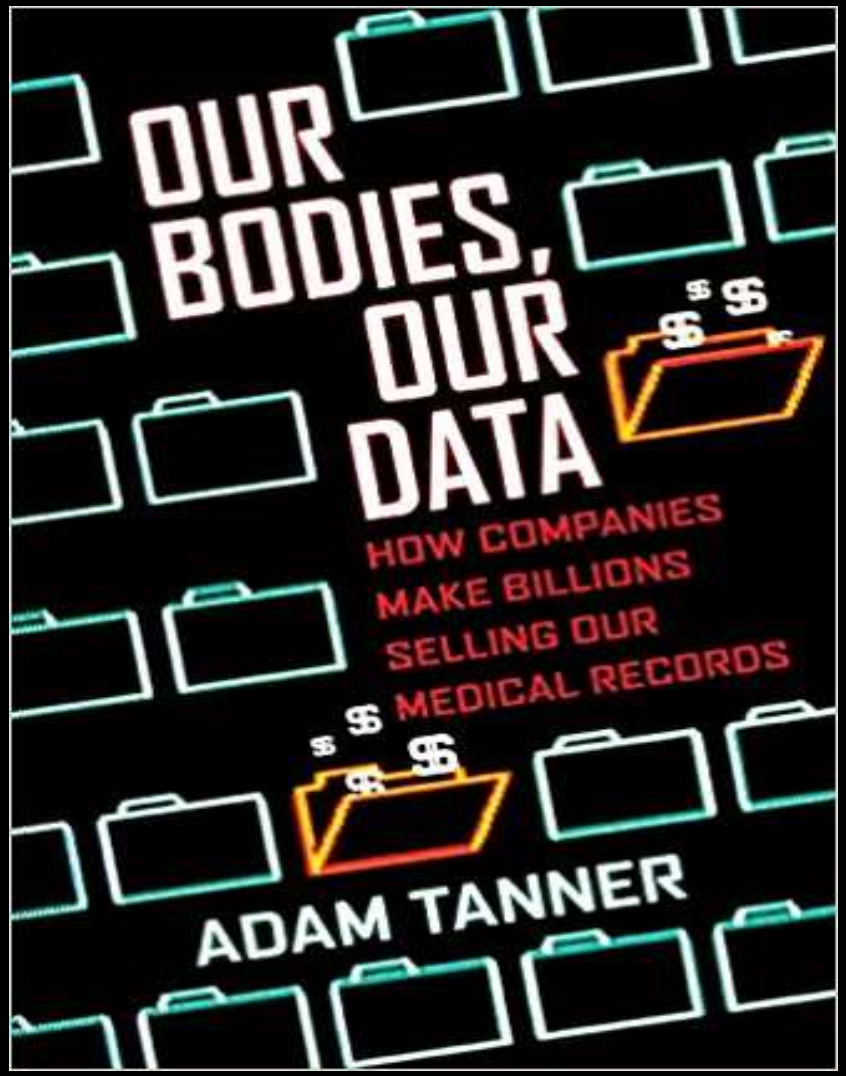
6 April 2010

Guide to Protecting the Confidentiality of Personally Identifiable Information (PII)

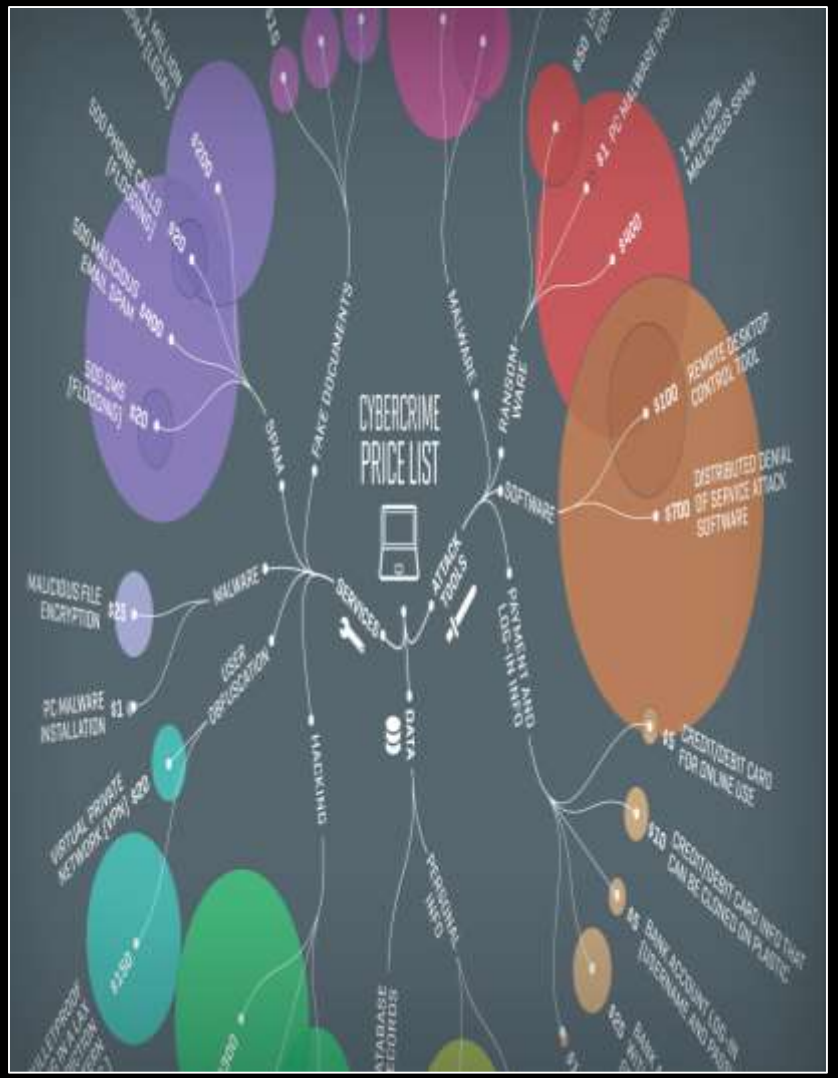
Recommendations of the National Institute of Standards and Technology

Erika McCallister
Tim Grance
Karen Scarfone

Data Brokers ('Selling-On')



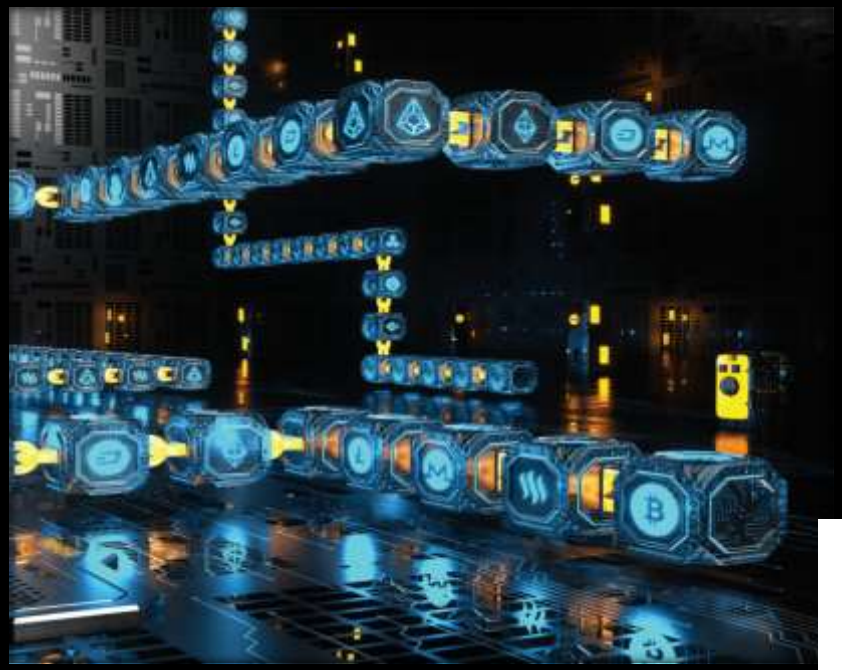
Data Theft



Consumer Genomics

- over 7 million samples sequenced in 2017

Early Entrants Into The Use of Blockchain for Secure Contract Transactions in Healthcare



IBM
Microsoft
Google
GE
guardtime
pokitdok
Gem
patientory
iSolve
Curisium

Big Data and Individual Rights

- agency, autonomy and consent
- right to port/share
- right to know
- right to amend/correct
- right to be forgotten
- protection(s) from harms
- legacy and inheritance rights
- complexities of entangled co-ownership

European Union General Data Protection (25 May 2018) A Death Blow to Precision Medicine ?

- precision medicine requires large scale population data
- requires consent from every individual whose genetic sequence is in a database every time a clinician/researcher needs to access
- undermines individual rights to chose how and where they share their data and engage/promote medical research

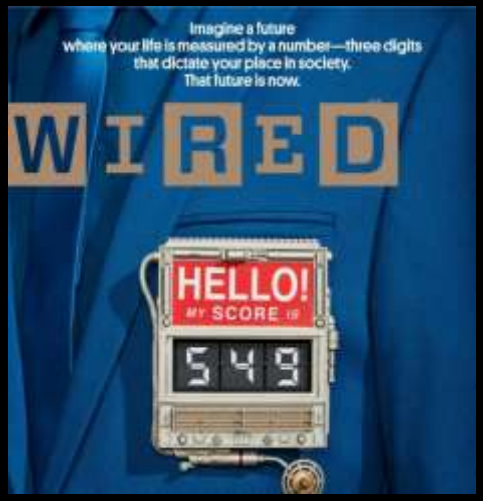
Big Data

- the merciless memory of ubiquitous (meta) data
- apps become increasingly anticipatory and automatic
- dataveillance and privacy: sacrificing privacy for utility
- risk profiling: individuals and their connected social graphs (“social fitness”)
- social and economic discrimination/coercion
- opt-in versus opt-out

Principle for the Post-Privacy Age: Connections

- identity in both personal and extended social domains
- the way we behave today will determine the choices we will face, or are allowed to make, in future decades
- an individual's place in the social graph (network contagion)
- much of the data about you is entangled with data about others

From Credit Score to Social Credit Score (Lifescore)



- 14 June 2014
- “Planning Outline for the Construction of a Social Credit System”
- implemented for 1.3 billion citizens on ‘voluntary’ basis but mandatory by 2020

信而富 China Rapid Finance

Tencent 腾讯

Sesame Credit in China

蚂蚁金服 ANT FINANCIAL

Alibaba.com

Human-Computer Interactions/Integration

Virtual Reality and Training for Complex, Dynamic Tasks

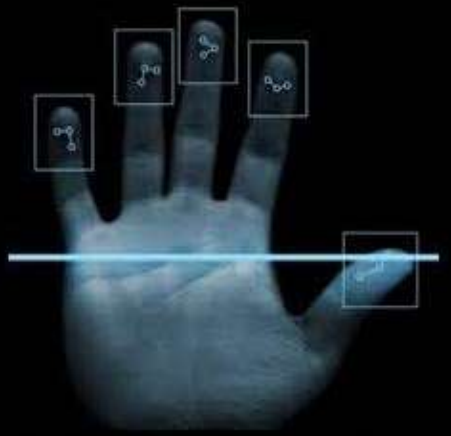
Will We Even Call It A Phone In 2020?

Bendable LED Screens

Holographic Imaging

Wearable Mobile Computing

Gesture Based UIs

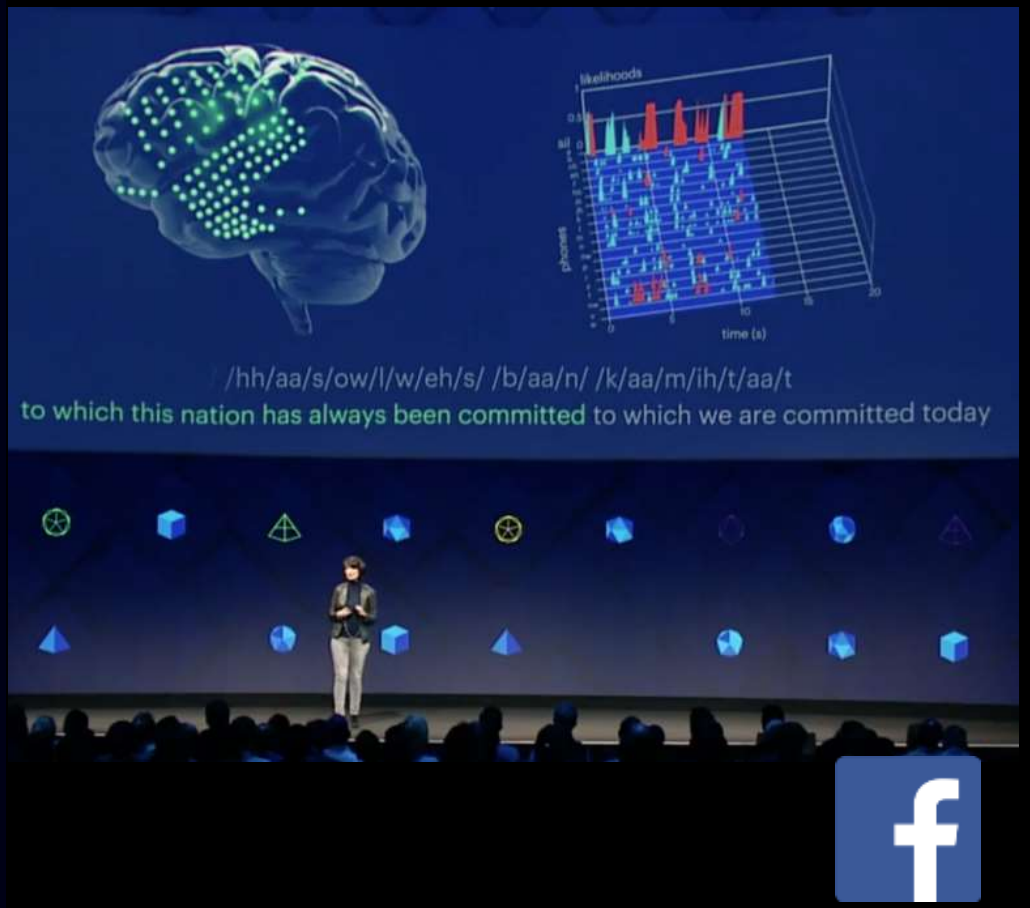


Augmented Reality (AR)

Facial & Eye Recognition

Mobile Biometrics


The Economist
The message of protests in Iran
Blue-state Republicans: no right left
Education lessons from Pakistan
The world's worst airports
JANUARY 6TH–12TH 2018
The next frontier
When thoughts control machines


likelihoods
phones
time (s)
/hh/aa/s/ow/l/w/eh/s/ /b/aa/n/ /k/aa/m/ih/t/aa/t
to which this nation has always been committed to which we are committed today

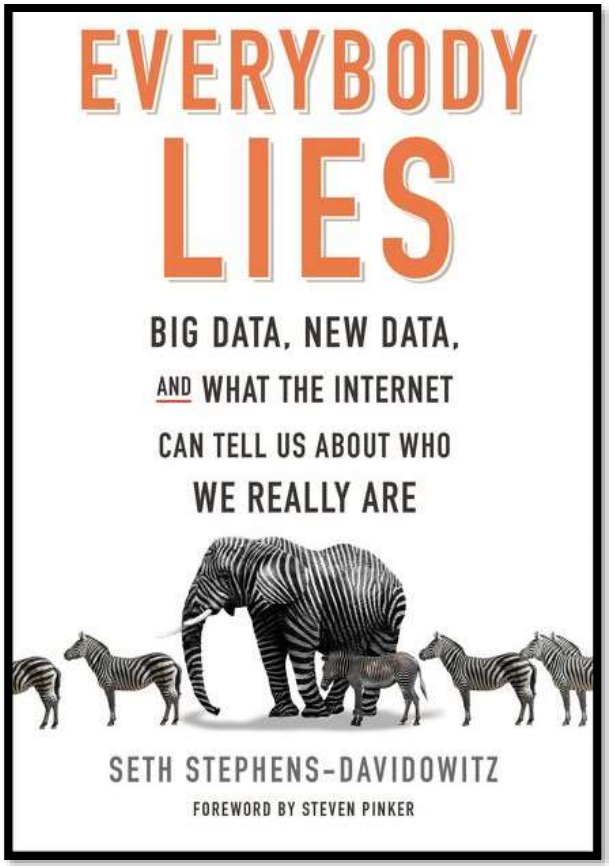
Non-Invasive Brain Computer Interface

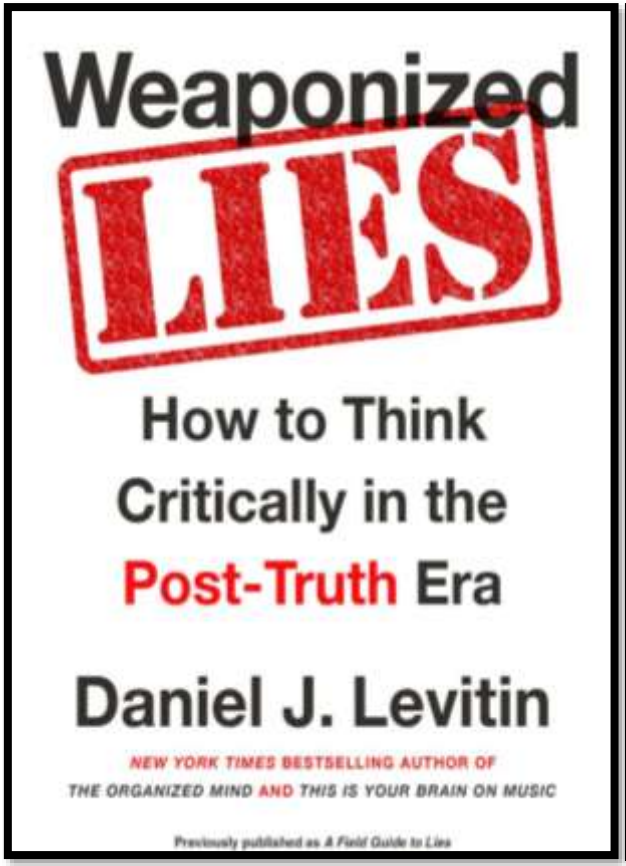
Inside the Black Box of Algorithms

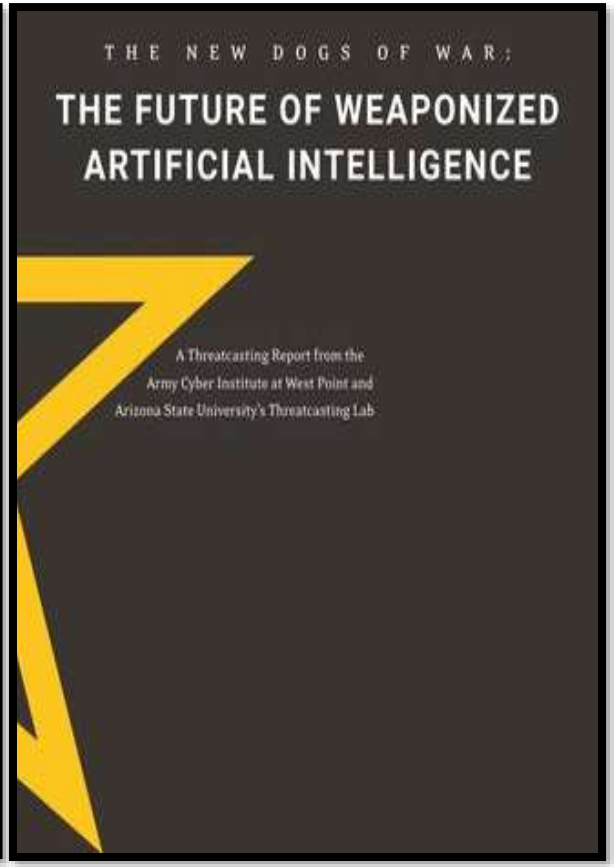
- Data is Inherently Dumb
- Algorithms Define Action and Value
- Algorithms with Agendas
- Risk, Regulation and Responsibility

Algorithms with Agendas: Channeled Lives

- social media and ‘filter bubbles’
  - online “echo chambers” of ‘facts-to-fit’
  - bias ideologies/perceptions
- facts and authentication tools swept away in a flood of falsehoods and trivia
- influence of purposely biased data mining to support/manipulate individual/group opinions


EVERYBODY
LIES
BIG DATA, NEW DATA,
AND WHAT THE INTERNET
CAN TELL US ABOUT WHO
WE REALLY ARE
SETH STEPHENS-DAVIDOWITZ
FOREWORD BY STEVEN PINKER


Weaponized
LIES
How to Think
Critically in the
Post-Truth Era
Daniel J. Levitin
NEW YORK TIMES BESTSELLING AUTHOR OF
THE ORGANIZED MIND AND THIS IS YOUR BRAIN ON MUSIC
Previously published as A Field Guide to Lies


THE NEW DOGS OF WAR:
THE FUTURE OF WEAPONIZED
ARTIFICIAL INTELLIGENCE
A Threatcasting Report from the
Army Cyber Institute at West Point and
Arizona State University's Threatcasting Lab

Deep Learning and The Rise of the Algorithmic Black Box(es)

- deep learning systems do not have explanatory power
- algorithms increase accuracy but how and why are becoming increasingly unpredictable/ unanswerable
- the more powerful the system becomes the greater opacity and complexity of deconvolution
- generative adversarial networks

"Explainable AI"

- need to better characterize the evolution of decision algorithms
  - keeping humans in the loop
- 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 control tools

Deep Learning, AI and New Automated Decision Support Tools for Data-Intensive Environment

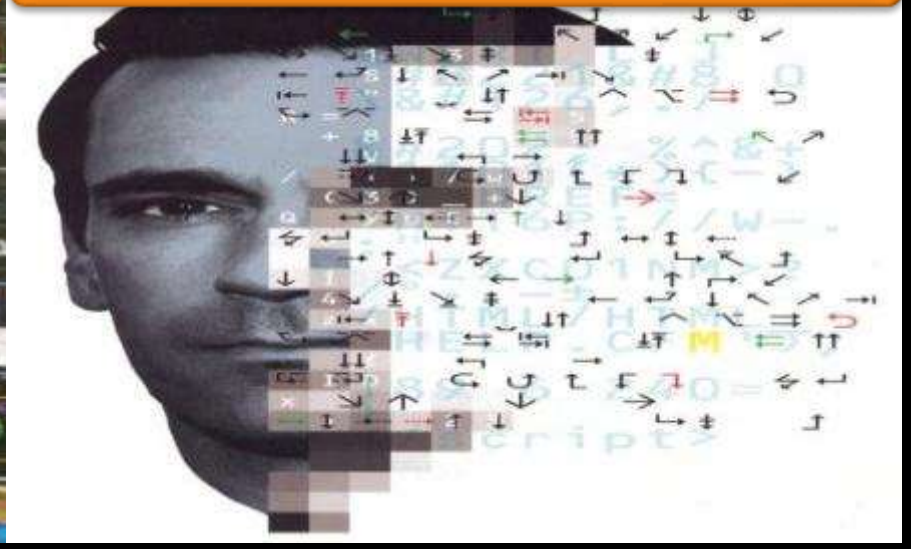
What the Data Ordered:
The Future of Healthcare?

Why Wait for the Slow Brain to Catchup With the Fast Machine?

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

Data Deluge

Cognitive Bandwidth Limits



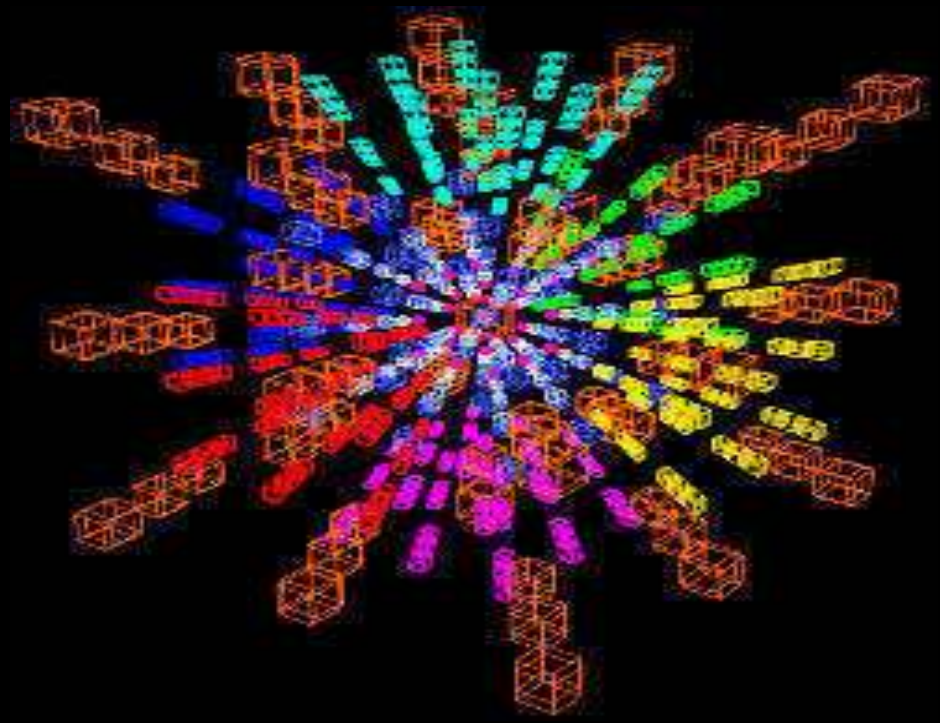
Automated Analytics and Decision Support

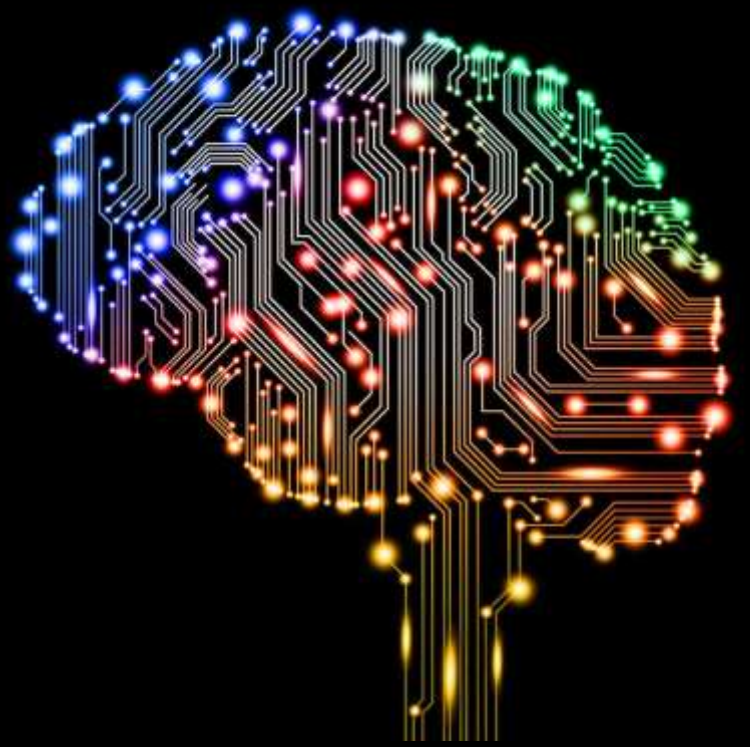
Facile Formats for Actionable Decisions

The Pending Era of Cognitive Computing and Decision-Support Systems: Overcoming the "Bandwidth" Limits of Human Individuals

- limits to individual expertise
- limits to our multi-dimensionality
- limits to our sensory systems
- limits to our experiences and perceptions
- limits to our objective decision-making

Automated Context: Data Finding Data
"Intelligence at Ingestion"





Feature Extraction and Classification

Context Analysis

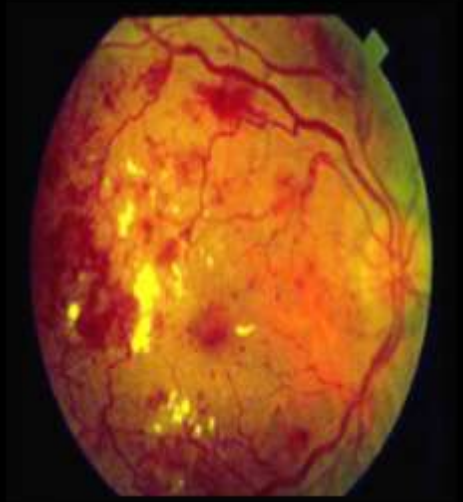
Persistent Context

- **Relevance Detection**
- **Learning Systems**

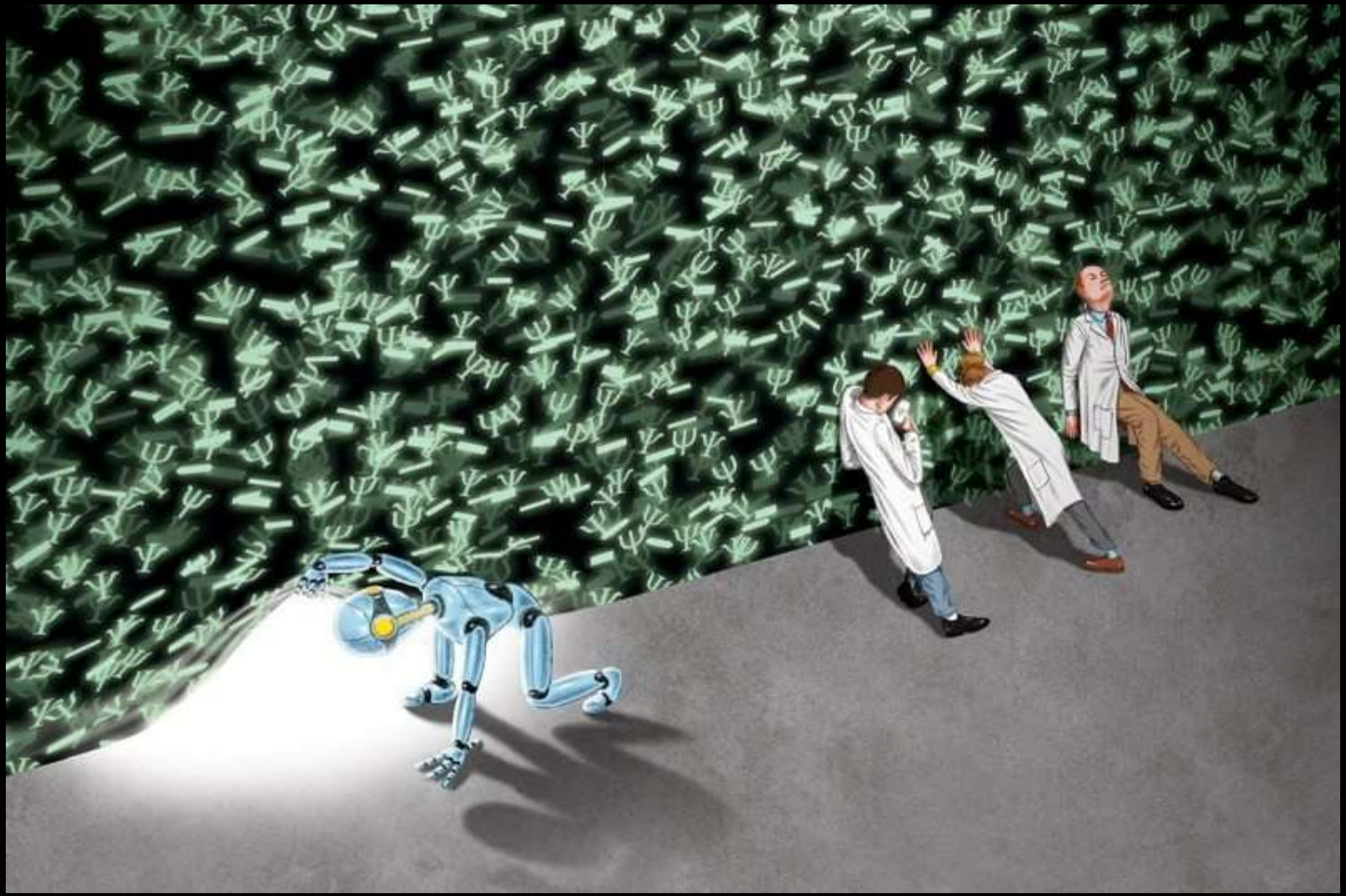
- **Situational Awareness**
- **Rapid, Robust Decisions**

Robotics, Artificial Intelligence and Workforce Automation and Replacement

Machine Learning and Image Analysis in Clinical Medicine

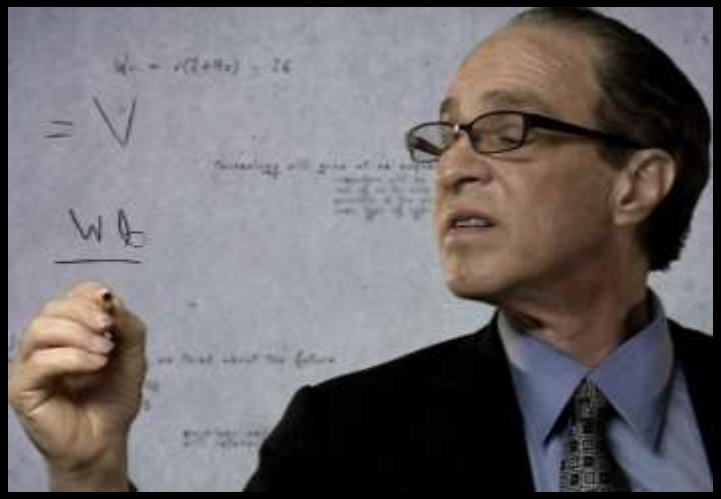
pathology	radiology	dermatology	ophthalmology
			

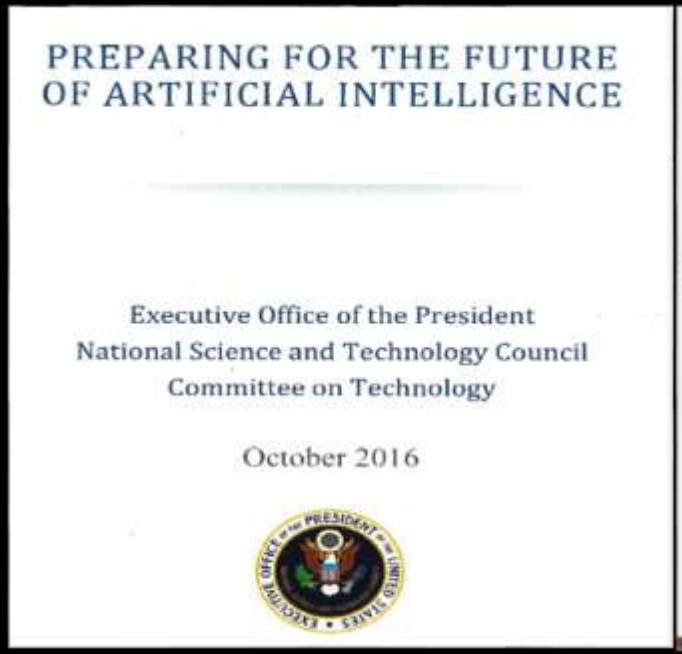
- large scale training sets and classification parameters
- standardized, reproducible and scalable
- 260 million images/day for $1000 GPU

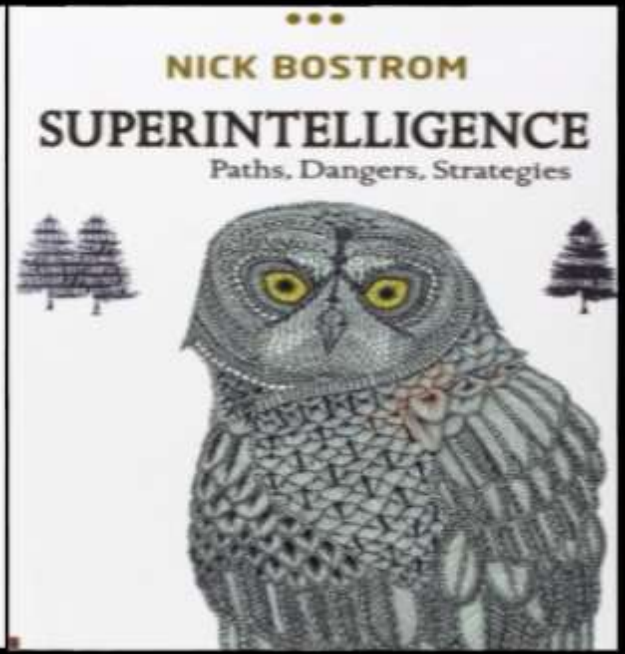


New Scientist 28 Oct 2017

Smart Machines, Deep Learning, Artificial Intelligence and Existential Threats







Artificial Intelligence (AI) and Healthcare

- will physicians, payers and patients trust AI?
- how will AI tools be integrated into current work flow or will radical reorganization/re-training be required?
- how will AI platforms alter payment schemes?
- how will AI algorithms/decision analytics be regulated?
- which clinical specialities/processes be at risk of replacement by AI and when?
- how will professional competencies in using AI decision-support tools be defined?
  - MD curriculum, CME
- what new malpractice liabilities will emerge by failure to use/interpret AI platforms

Deep Learning, Machine Learning and Artificial Intelligence in Data Analytics and Decision Support

“I Can’t Let You Do That Dave”

Automated Decision Support Tools and “Gated Autonomy” in the Management of Complex Systems

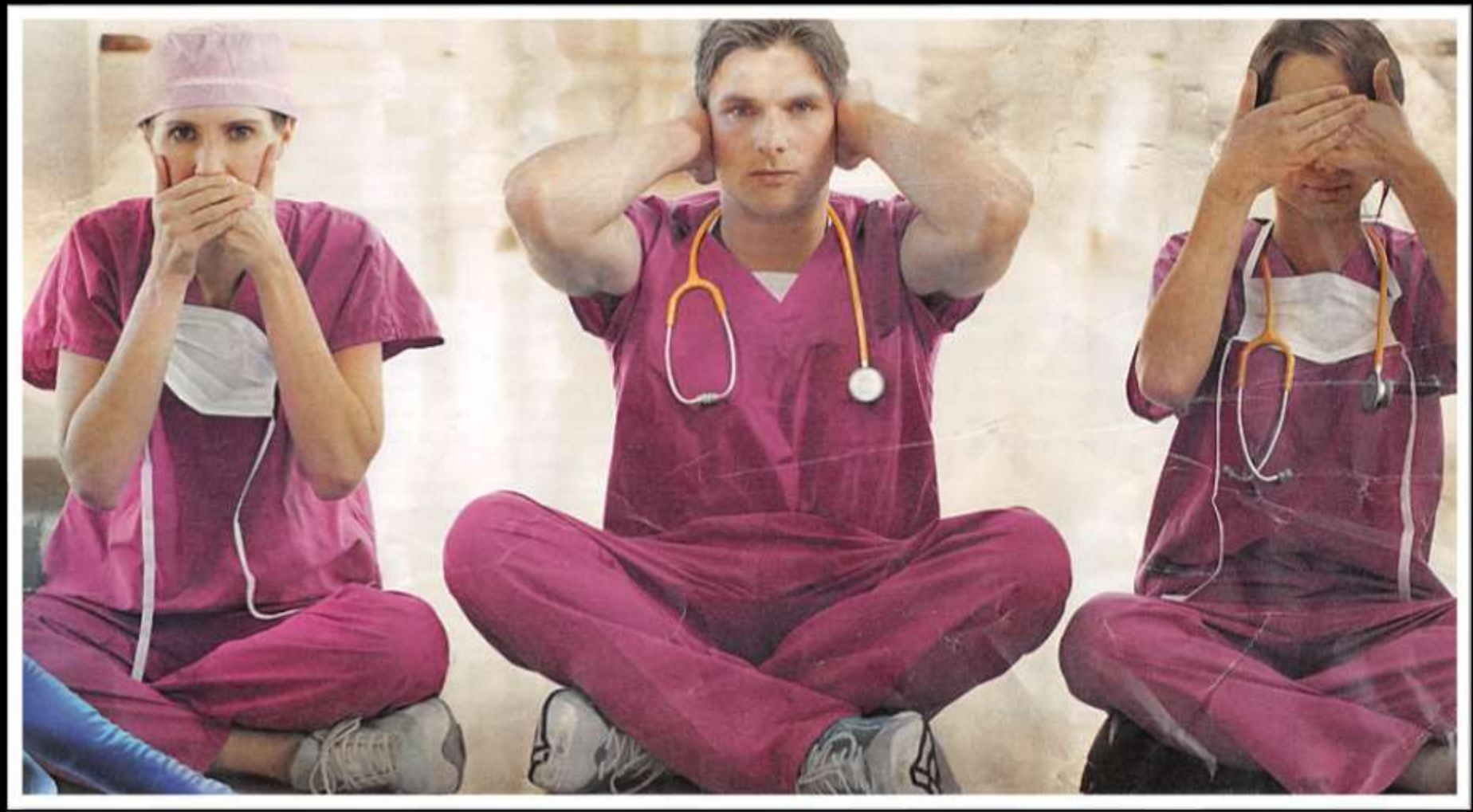
Living in a World Where the Data Analytics and Interpretation Algorithms Are Obscure to the End User

- ceding decision authority to computerized support systems
- culturally alien to professionals in their claimed expertise domain but they accept in all other aspects of their lives
- who will have the responsibility for validation and oversight of critical assumptions used in decision tree analytics for big data?
  - regulatory agencies and professional societies?
  - humans?
  - machines?

Digital Darwinism

- information asymmetries in access to data and mastery of large scale data analytics
- enterprise competitiveness, relevance and viability
- individual status
  - from credit score to social credit score
  - employability
- impact of peer network behavior on personal classification
- danger of digital monopolies
  - corporations and state surveillance
- AI, national security and military advantage

The Rise of Data-Intensive Medicine: The Pending Disruption and Reorganization of Care Delivery



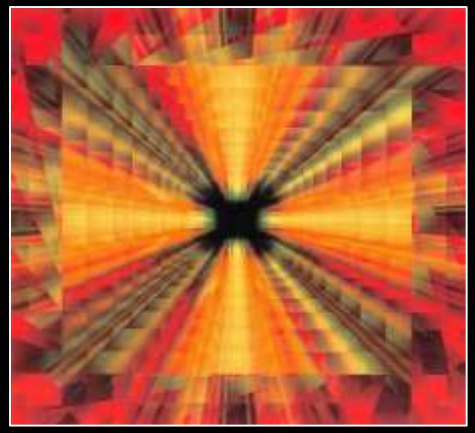
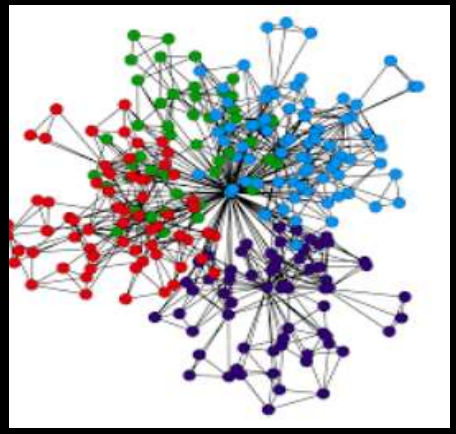
DNR

Denial	Negativity	Resistance

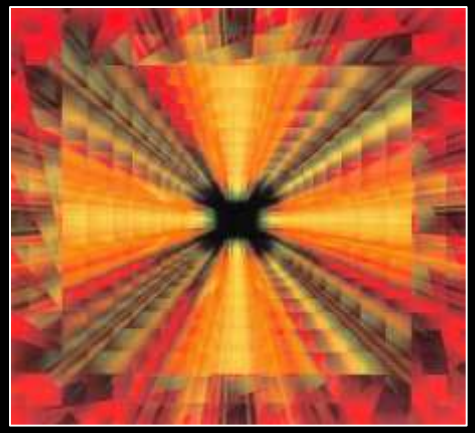
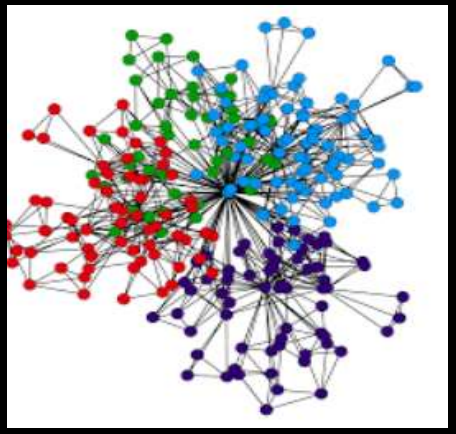
"So, as you can see, health care is so complicated you may never get well."

The New Yorker 3.13.17

The Evolution of Data-Intensive Computational Medicine

Technology Convergence and Acceleration	Precision Medicine and Digital Healthcare	Big Data	Networked Data
			
			
Data Security Privacy	**Robotics and Human Machine Interactions**	**Artificial Intelligence and Decision Support**	**Identity, Ethics, Risk and Regulation**

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

Technology Convergence and Acceleration	Precision Medicine and Digital Healthcare	Big Data	Networked Data
			
			
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