

National Institute of Allergy and Infectious Diseases

Health Innovations Conference

# Harnessing the 4<sup>th</sup> Industrial Revolution for Health

19 March 2019

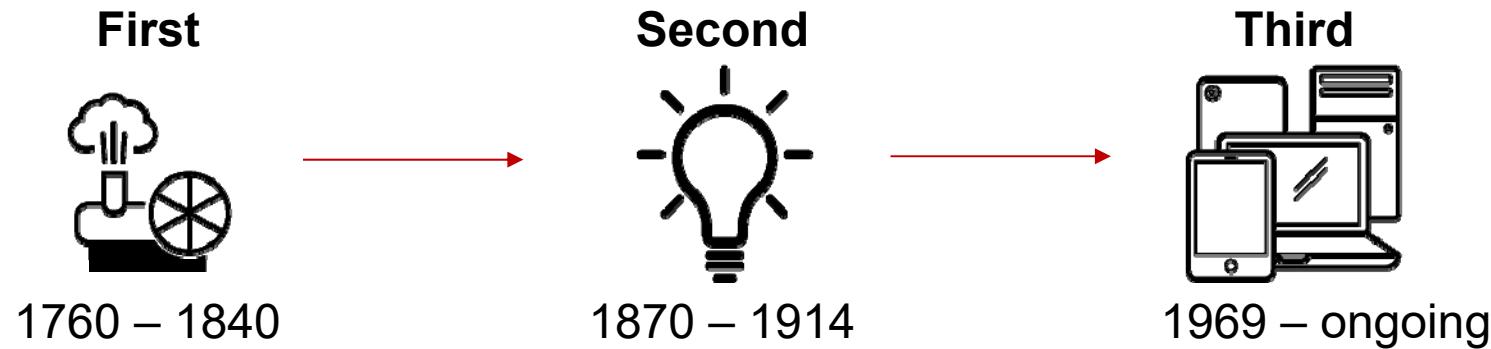
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**Michael Tartakovsky**  
Presenter's Title  
Presenter's Organization

# Previous Industrial Revolutions



# The Fourth Industrial Revolution

“The Fourth Industrial Revolution describes the exponential changes to the way we live, work, and relate to one another due to the adoption of cyber-physical systems, the Internet of Things, and the Internet of Systems.”

Bernard Marr, Forbes

# The Fourth Industrial Revolution

"The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential peril. My concern, however, is that decision-makers are too often caught in traditional, linear (and non-disruptive) thinking or too absorbed by immediate concerns to think strategically about the forces of disruption and innovation shaping our future."

Klaus Schwab, World Economic Forum



# Navigating the Next Industrial Revolution

- Keynote presented by Thomas Philbeck at National Academies of Sciences, Engineering, and Medicine's Government-University-Industry Roundtable
- Principled Framework for the Fourth Industrial Revolution
  - Think systems, not technologies
  - Empowering, not determining
  - Future by design, not by default
  - Values as a feature, not a bug



# What is Driving this Change?

- AI
- Blockchain
- Computational technologies
- VR
- Biotechnologies
- Robotics
- 3D printing
- Internet of Things
- Energy capture, storage, and transmission

Source: <https://www.salesforce.com/blog/2018/12/what-is-the-fourth-industrial-revolution-4IR.html>



Franklin D. Roosevelt  
Dedication of the NIH Campus in Bethesda  
Oct. 31, 1940

***"The NIH speaks the universal language of humanitarianism. It has been devoted throughout its long and distinguished history to furthering the health of all mankind, in which service it has recognized no limitations imposed by international boundaries; has recognized no distinctions of race, of creed, or of color."***

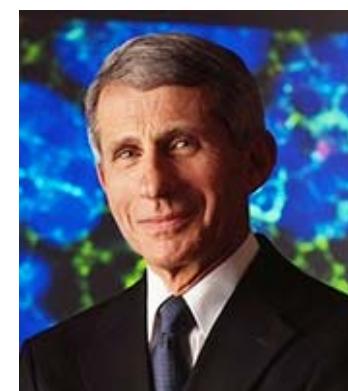
Courtesy of Anthony S. Fauci/NIAID

# Global Health Research is a Priority

“The United States has a vital interest in the health of people around the globe, rooted in an enduring tradition of **humanitarian concern** as well as in enlightened self-interest... It is imperative that the nation sustain momentum and work with its global partners to deliver the fruits of **global research** to the people who need them most, both at home and abroad. Without such a commitment, we may miss opportunities to curtail or even eliminate important diseases such as AIDS and also risk the resurgence of major global health threats such as drug-resistant bacteria, tuberculosis, and malaria, for which **new interventions are badly needed.**”

- Diagnostics
- Novel drugs
- Clinical trials network
- Structure-assisted vaccine design

Science 2010; **327**(5961), 36-37.  
Science 2015; **348**(6231), 159.  
JAMA 2015; **313**(2), 131–132.



# “No non-computational disciplines left”



Mike  
Tarkovsky

## Recent Nobel Prizes

- 2017: Cryo-EM
- 2016: mol. machines (crystallography)
- 2015: therapies for tropical diseases
- 2014: super-resolved microscopy
- 2013: molecular dynamics →
- 2012: GPCRs (crystallography)
- 2009: ribosome (crystallography)
- 2009: CCDs
- 2008: virus discoveries

“Martin Karplus, Michael Levitt, and Arieh Warshel laid the foundation for the powerful programs that are used to understand and predict chemical processes. Computer models mirroring real life have become crucial for most advances made in chemistry today...”

Today the computer is just as important a tool for chemists as the test tube. Simulations are so realistic that they predict the outcome of traditional experiments.”

# OCICB Strategic Areas

- Creation of Novel Databases & Tools
- Training/Education
- Scientific Research/Collaborations
- Scientific & High Performance Computing Infrastructure
- Clinical & Medical Informatics
- Emerging Technologies

Technology as  
an Enabler

# **Powerful new technologies that are changing Public Health, Biology, & Medicine**

## **Biotech**

- CRISPR
- Stem cell technology
- Better drugs
- Gene therapy

## **Tech that depends heavily on computers**

- Imaging (medical & microscopy)
- Genomic sequencing
- Simulations
- Medical implants: nerve, diabetes, etc.
- Robotic health checks, telemedicine
- Patient engagement, chatbots
- Centralized monitoring
- 3D printing

## **Direct computer technologies**

- Internet of (medical) things (IoT)
- High-perf. computing (HPC)
- Data science/analytics
- Virtual Research Orgs. (VROs)
- Blockchain
- 5G
- Artificial Intelligence (AI)
- Virtual Reality (VR)

# Blockchain

“encrypted, immutable distributed ledger”

## What it does

- Solves the problem of trust in a complex environment
- Does not require the participation of a centralized organization
- Maintains a single version of the truth

## Benefits

- Proves, enforces, and tracks ownership of digital assets
- Completely transparent
- Secure

## Biomedical Applications

- Track supply chain to eliminate counterfeit drugs
- Patient-centered medicine
  - Patient owns and supplies health data
    - EHR
    - IoT
  - Consent
- Telemedicine



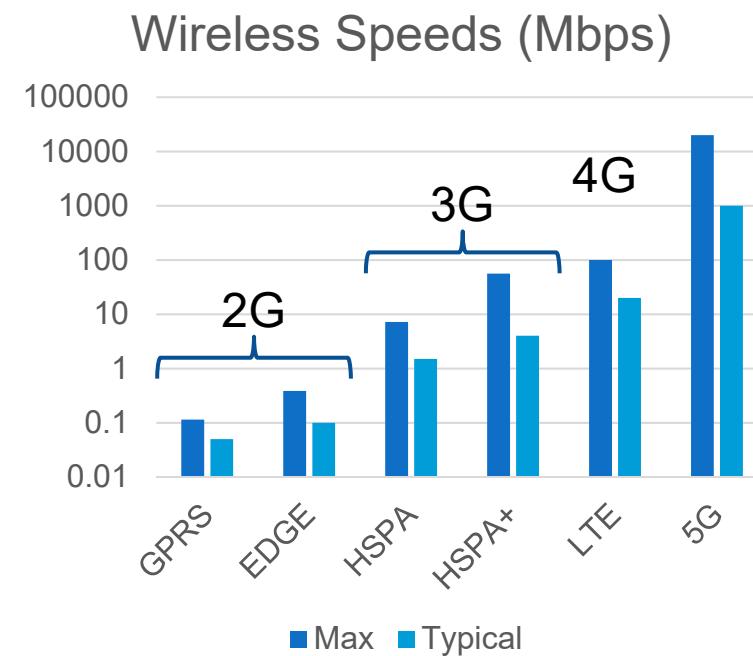
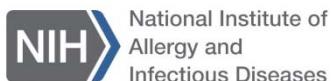
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<https://medium.com/crypto-oracle/why-crypto-needs-a-doctor-and-medicine-needs-blockchain-technology-its-not-what-you-think-9a193c2b9d02>

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# 5G

- High data rate
  - Typically 50x than typical 4G
  - Faster than typical ethernet
- Massive device connectivity ( $1M/km^2$ ) – IoT!
- Reduced latency
- Energy saving
- Cost reduction
- Higher system capacity



Full-size diagnostic-quality CT in less than 1 s

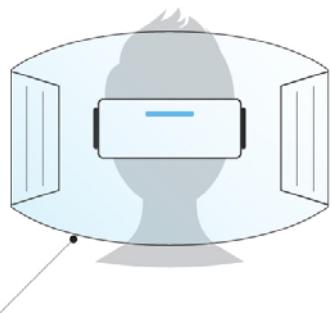
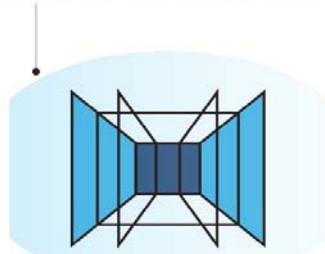
# Artificial Intelligence

- Machine Learning
  - Neural networks – non-linear statistical data modeling
  - Support Vector Machines
  - Clustering
  - Bayesian networks
  - Genetic/evolutionary algorithms
  - Decision Trees
- Natural Language Processing
- Deep Learning
  - Neural network with multiple hidden layers
  - Computer Vision
- Robotic Process Automation
  - “Learning” software robot
  - Automates business processes that are otherwise not programmable

# Virtual Reality

## VIRTUAL REALITY (VR)

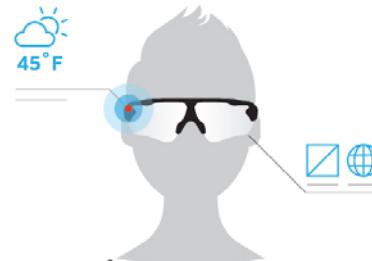
Completely digital environment



Fully enclosed, synthetic experience with no sense of the real world.

## AUGMENTED REALITY (AR)

Real world with digital information overlay

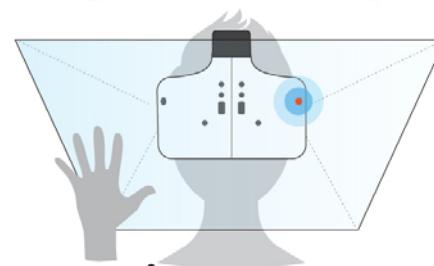
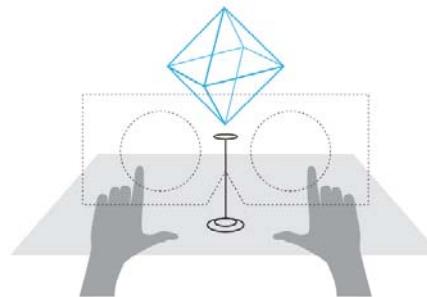


Real world remains central to the experience, enhanced by virtual details.

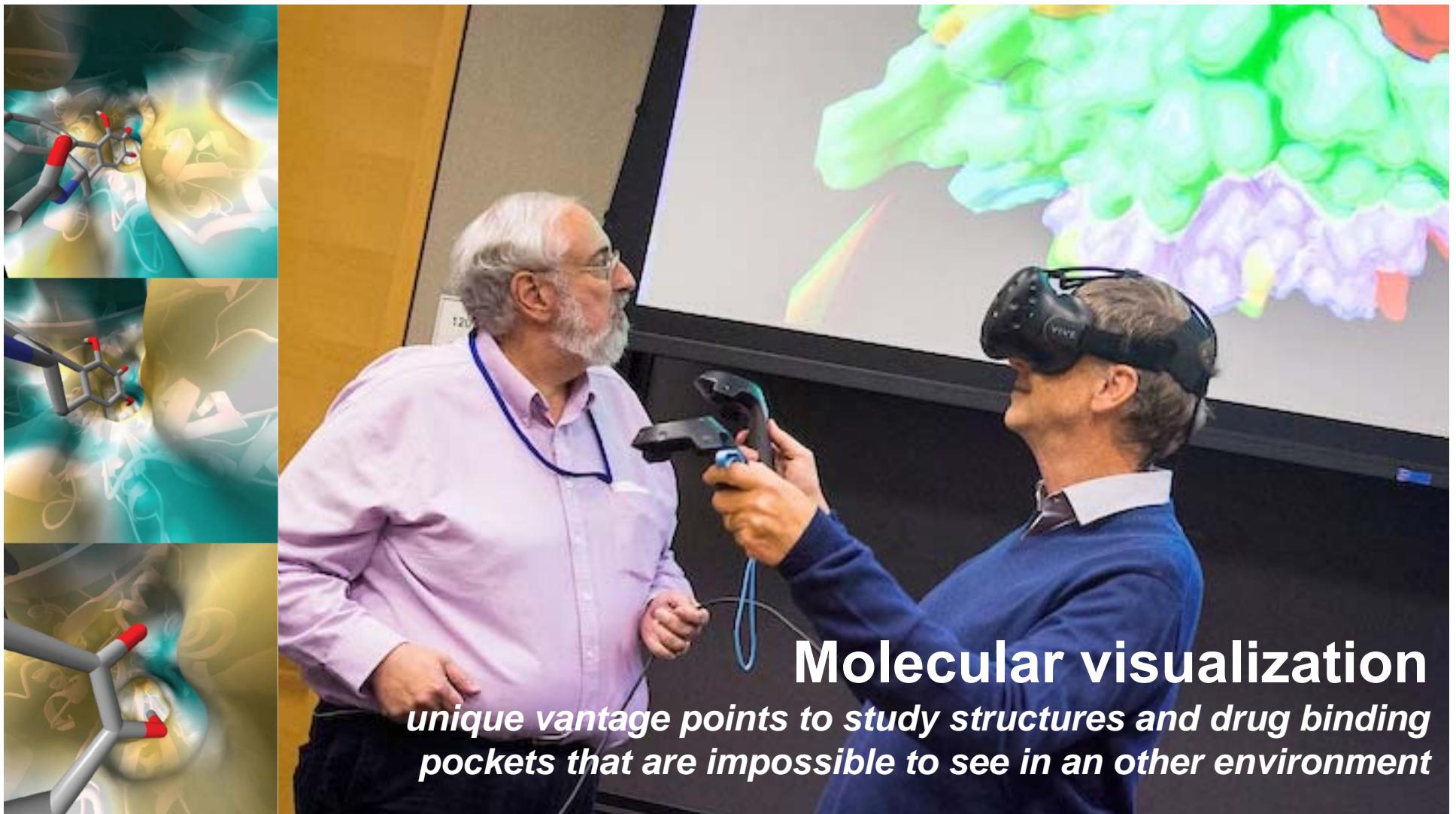
<https://www.extremetech.com/extreme/249328-mixed-reality-can-take-augmented-reality-mainstream>

## MERGED REALITY (MR)

Real and the virtual are intertwined

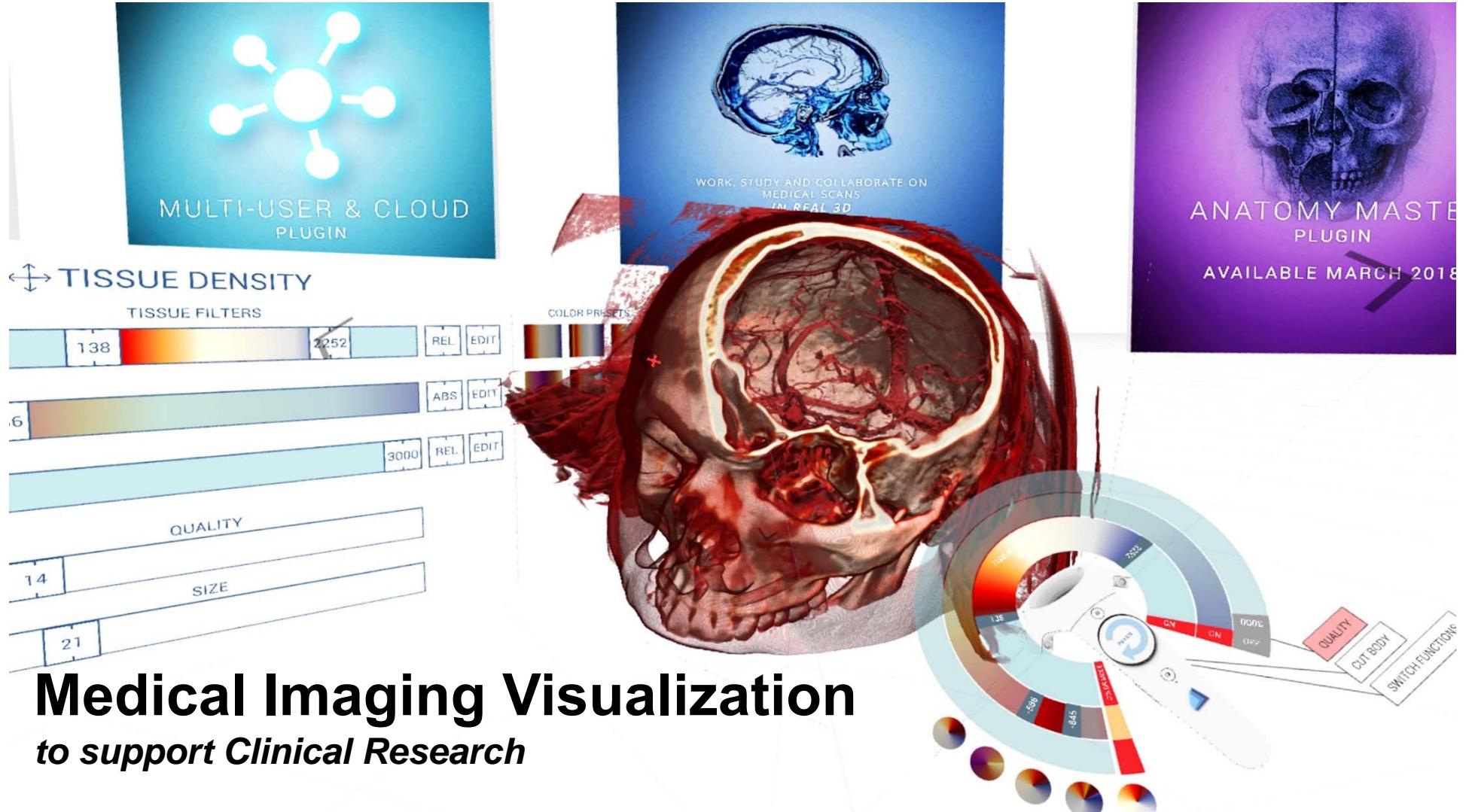


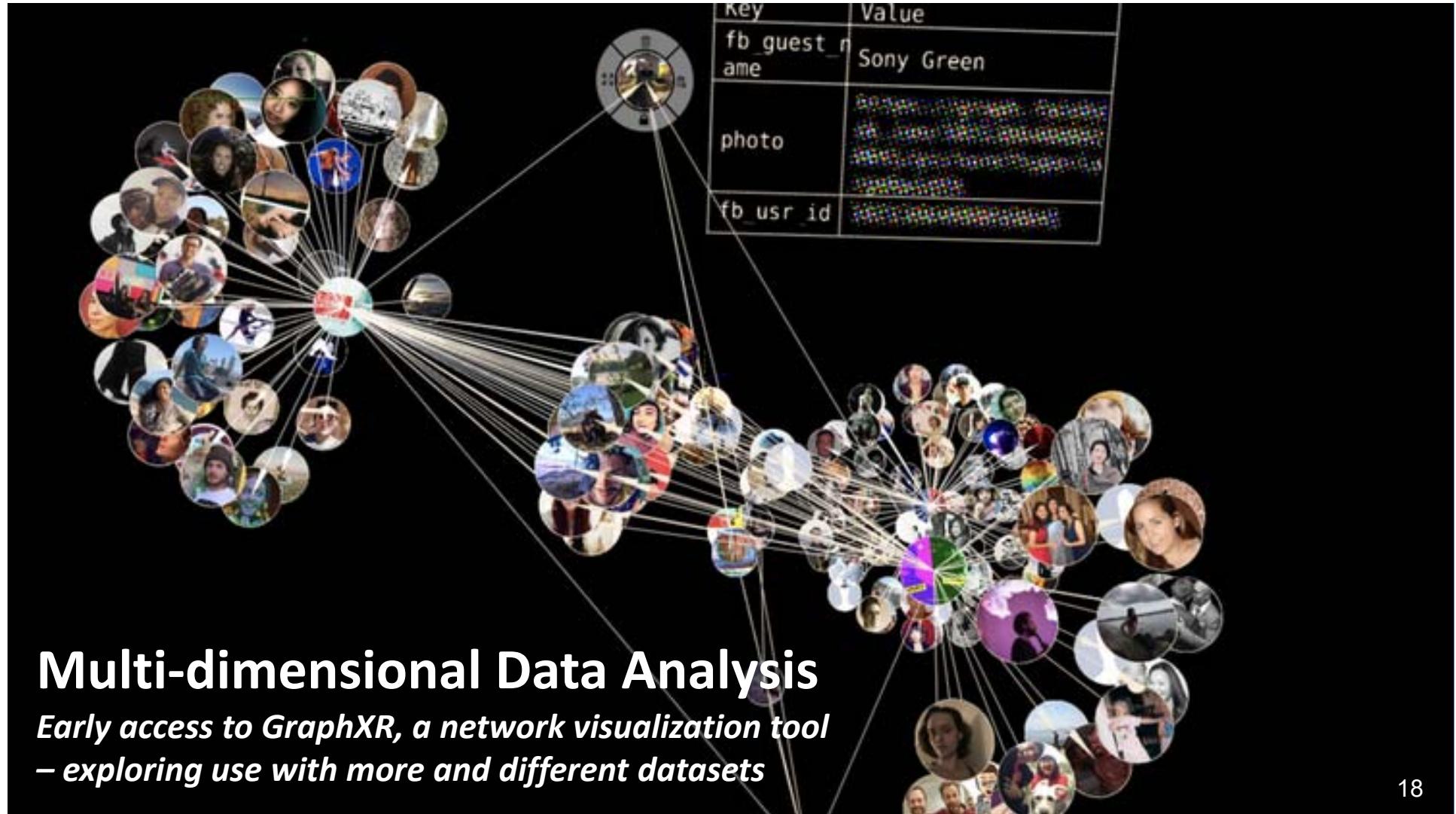
Interaction with and manipulation of both the physical and virtual environment.



## Molecular visualization

*unique vantage points to study structures and drug binding pockets that are impossible to see in an other environment*





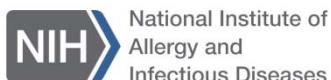
## Multi-dimensional Data Analysis

*Early access to GraphXR, a network visualization tool  
– exploring use with more and different datasets*

# Use Cases

## Data Visualization

- Molecular visualization for structure exploration and drug discovery
- Medical imaging scans
- Large-scale networks and databases
- Full microbial genome sequence visualization and alignment
- Flow cytometry data



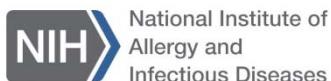
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## Training & Education

- Scientific and non-scientific training
- Clinical procedures and anatomy
- Basic and BSL-4 laboratory orientation
- Clinical center patient education
- Emergency response and medical aid worker training (e.g., mass casualty events or disease outbreak areas)

# Imagine this:

A **5G**-connected **IoT**  
transmitting patient-consented health data via **blockchain**  
to a **VRO**  
for **data analytics**  
using **AI**  
on an **HPC**  
and visualization with **VR/AR/MR**



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# Internet of (medical) Things

- \$158.1 billion by 2022
  - Smart wearable devices
  - Home-use medical devices
  - Point-of-care kits
  - Mobile healthcare applications



# High-Performance Computing

- Supercomputer vs. cluster computing
- Interconnected nodes
- Batch processing
- Massively parallel
- Dedicated system maintenance



# Data Science & Data Analytics

## Data Science

- Unknown Unknowns
- Ask the right questions
  - Locate potential avenues of study, with less concern for specific answers.
- Important for scientific research



## Data Analytics

- Known Unknowns
- Find immediately actionable data
  - Process and perform statistical analysis on existing data sets.
  - Produce results that can lead to immediate improvements.
- Important for health care

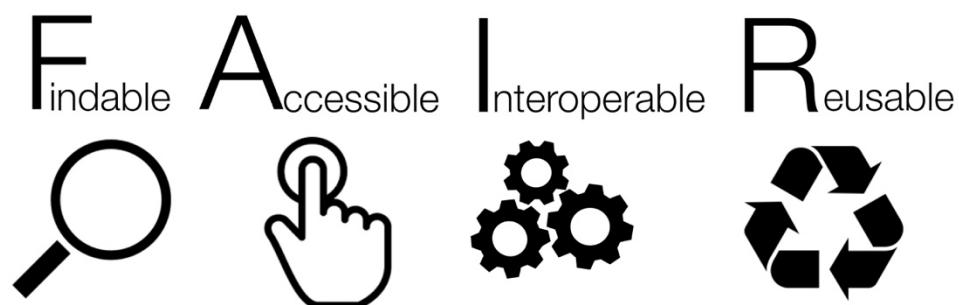
# Culture of Data Sharing

## More Openly Shared

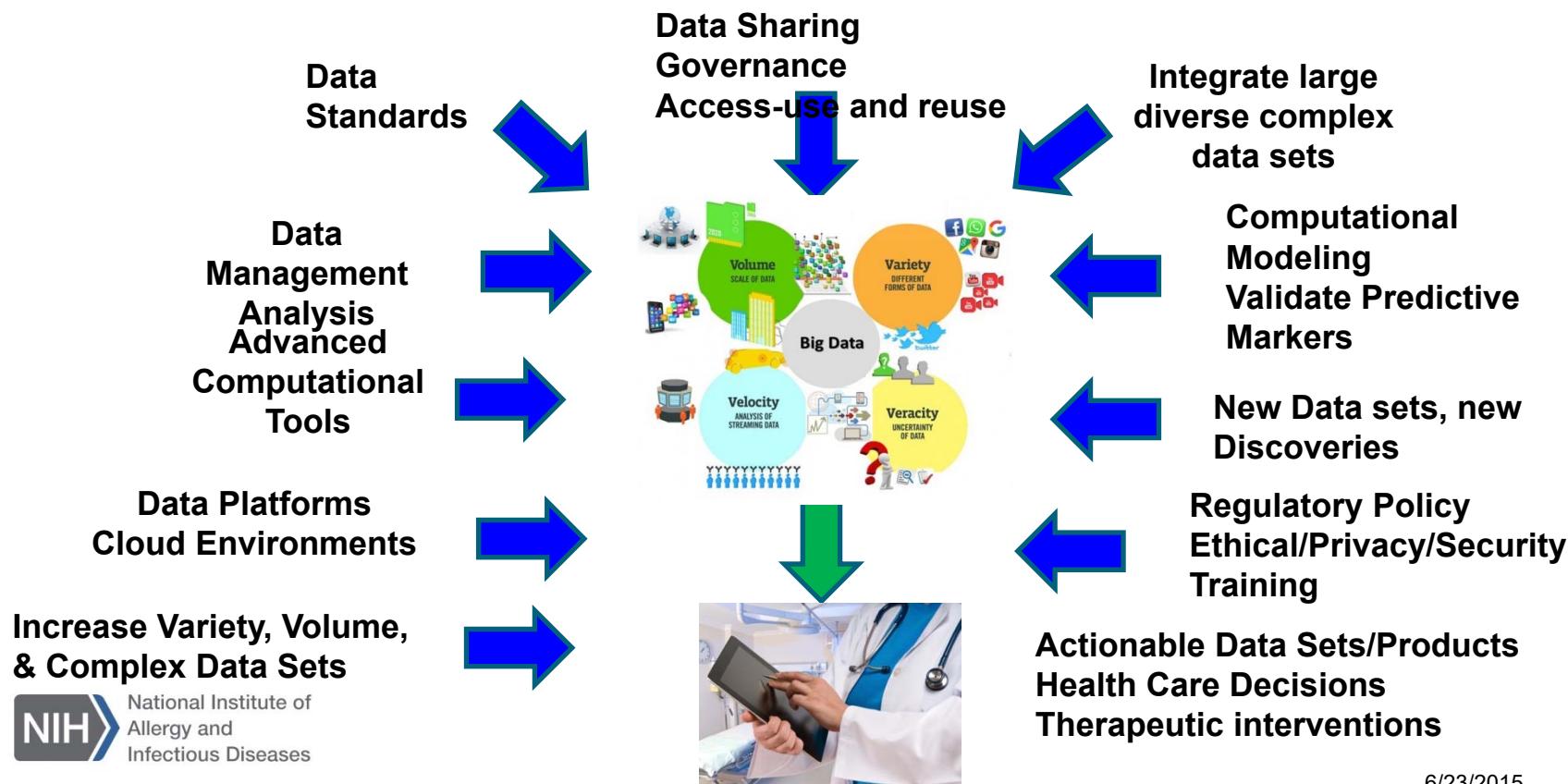
- Epidemiological data
- Sequencing data
  - ‘omics
  - microbiome
- Expression data
- Structure data
  - Crystallography
  - Cryo-EM
- FACS analysis data

## Less Openly Shared

- Clinical data
- Imaging data
- Microscopy data



# Transforming Data to Knowledge: Opportunities and Challenges



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# Collaboration is the New Normal

- Infectious disease research requires **global** collaboration



Scientific Collaboration Networks

"Collaborations: The rise of research networks" *Nature* **490**, 335–336 (18 October 2012) doi:10.1038/490335a  
<http://olihb.com/2014/08/11/map-of-scientific-collaboration-redux/>

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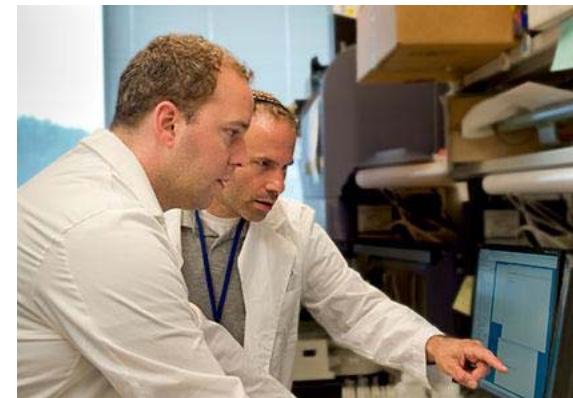
# Genomics

- Preventative and personalized medicine
- Genome editing
- NIAID Centralized Sequencing initiative

# Genomics

NIAID Centralized Sequencing Initiative

Objective: To understand the genetics of immune disorders caused by DNA variants



# Genomics

## Genomic Analysis Tool for TB Portals' Data

The Genomic Analysis Portal (G-AP) facilitates the in-depth analysis of genomic data from the TB Portals project as well as data from other TB sequencing projects.

### PLINK

GWAS to identify significant variants



### RESISTANCE PREDICTION

Predict resistance to TB drugs



### GENOME BROWSER

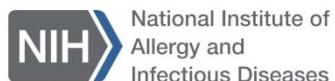
Browse the TB genome



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# Telemedicine



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