Disruptive Innovation and the Future of Medicine: Are We Prepared?

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NBDA
National Biomarker Development Alliance

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ARIZONA STATE UNIVERSITY

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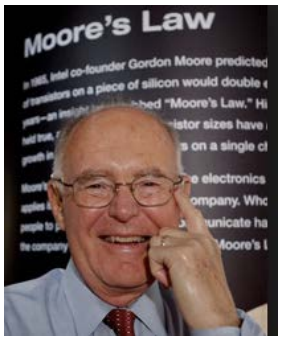
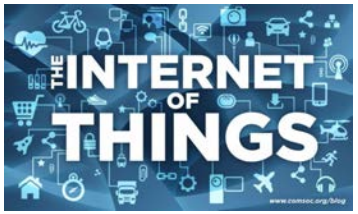
Technology Development
Unleashing the Potential for Progress



- **Technological change is exponential, not linear**
  - **Moore's Law (1965) -** Intel's Gordon Moore predicts that the power of computing technology* would double every two years
    - Number of transistors in a dense integrated circuit (computer microprocessor)
  - **Became and remains the mantra of technology development in general**
  - **Faster, better cheaper**
- **Exponential ↑ in data has resulted in exponential ↑ in human knowledge**
- **Today, all human knowledge is 1% of what it will be in 2050**
- **Knowledge now doubling very 12 months, soon to be every 12 hours with the build-out of the Internet of Things**



The Internet of Things, the Growth of Human Knowledge, and the Connection of Medicinal Universe

- Internet of Things (IoT) interconnects embedded sensors and computing devices within the internet structure
  - Smart objects, automation, machine-2-machine communications

- IoT uses:
  - Energy management
  - Environmental sensing systems
  - Urban planning
  - Transportation systems
  - Management of cities / urban systems
  - Law enforcement
  - Warfare

  - *Medicine and healthcare systems*

Disruptive Technological Advances: Changing the Science and Practice of Oncology

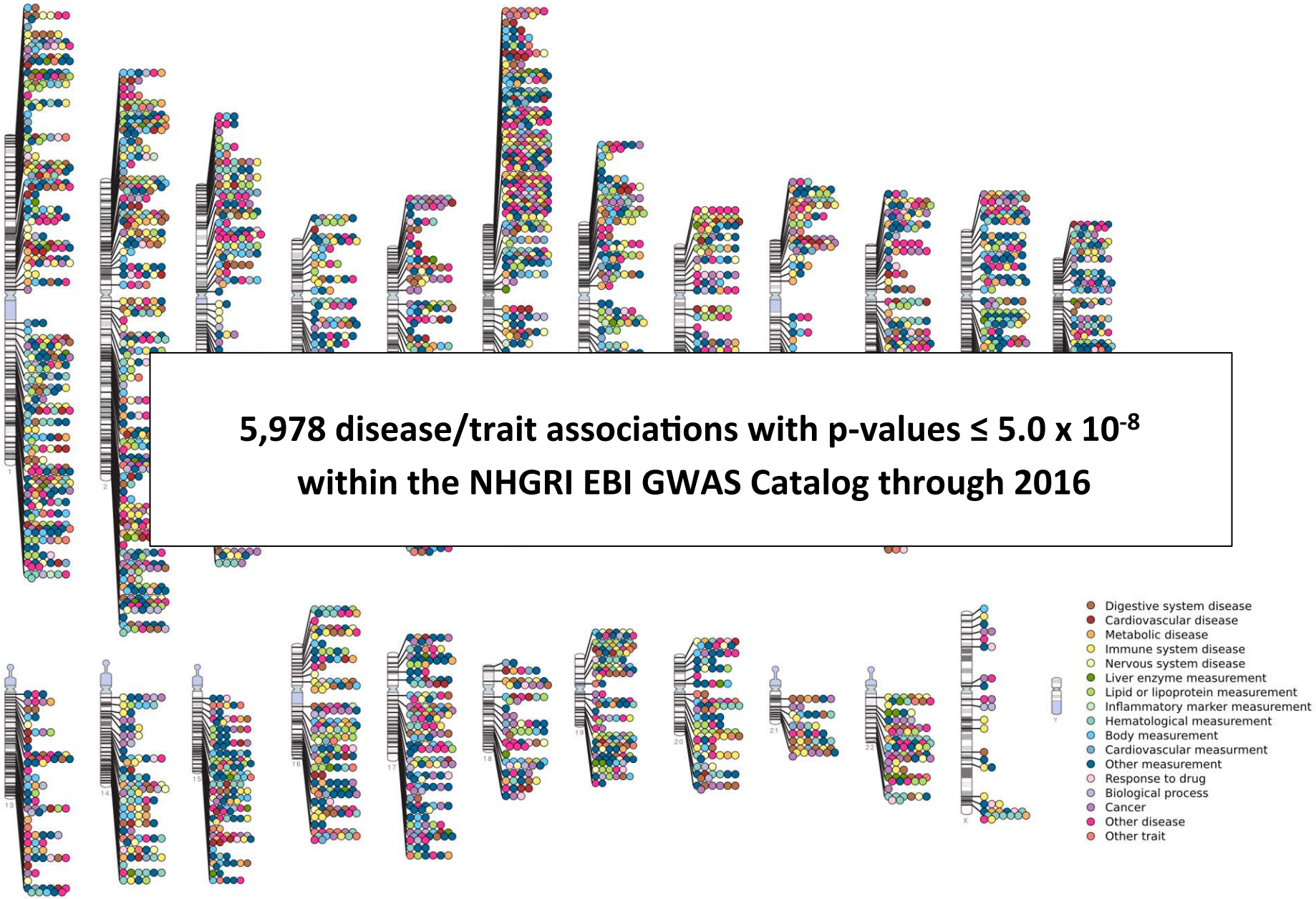
- **High-throughput, inexpensive molecular analysis: the $1000 genome**
- **Large-scale GWAS linking genetic variation to disease and treatment response**
- **Data science that analyzes, integrates and models huge amounts of data representing complex layers of biology**
- **Information technology removing the limitations of human cognitive capacity**

Disruptive Technological Advances:
Whole Genome Sequencing Becomes the New CBC

Yesteryear	A Decade Ago	Today	Tomorrow
1990	2000	2016	2016+
▪ 8 years	• 6-12 months	• <24 hours	• 8 hrs
▪ $3 billion	• $100 million	• $1000 +	• $100+

Whole Genome Sequencing: 3 billion-plus base pairs of DNA

Vetted Genome-Wide Associations through 2016



5,978 disease/trait associations with p-values ≤ 5.0×10^{-8} within the NHGRI EBI GWAS Catalog through 2016

Technology and Data Integration

Empowering researchers and clinicians to access and integrate increasing amounts and types of complex data

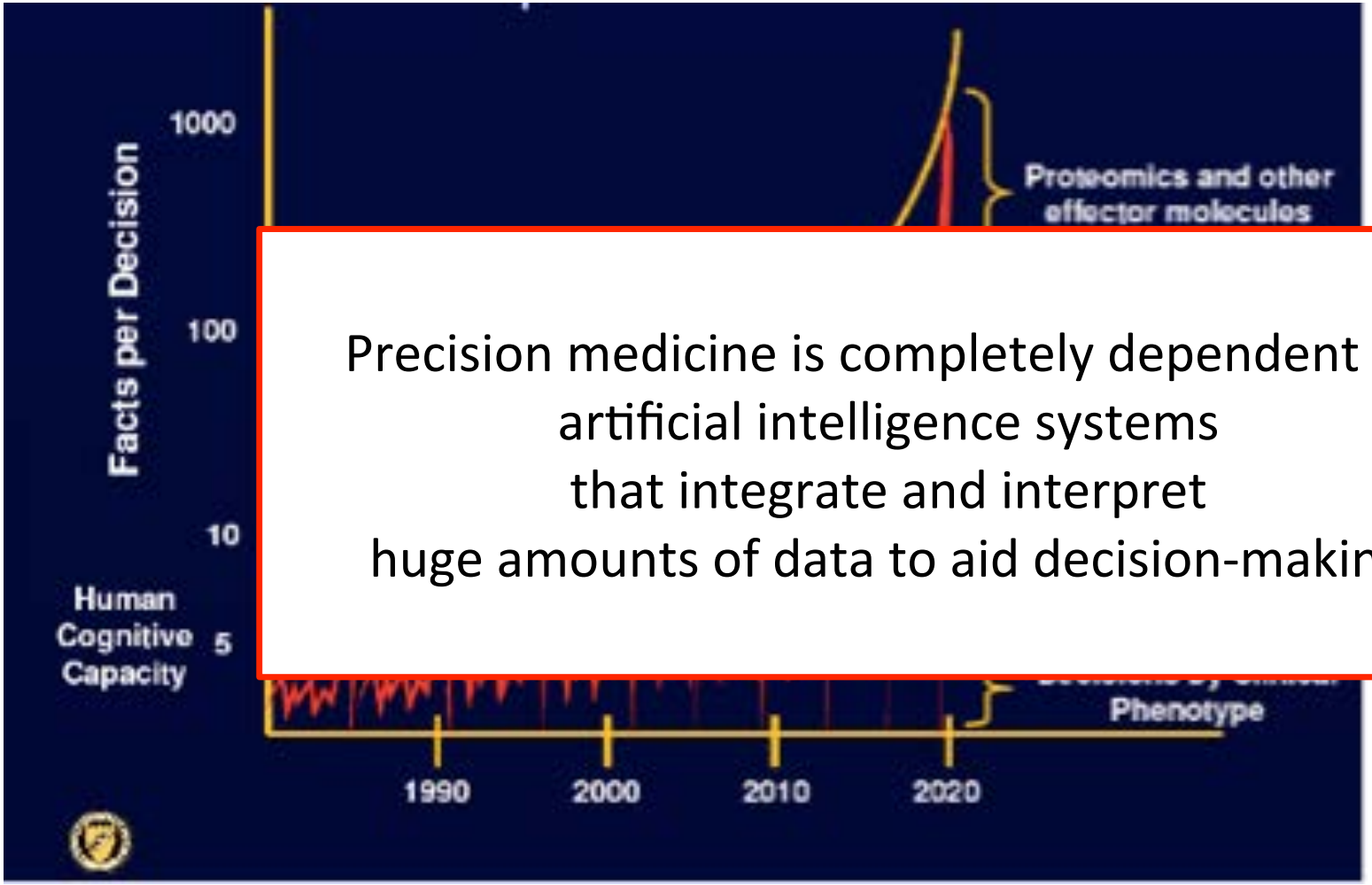
…… from genes to pathways to systems to clinical phenotypes

Enter the age of computational biomedicine

Genes ⟷ Genomes ⟷ Transcriptomes Proteomes ⟷ Pathways ⟷ Clinical Data

All from a computer… tablet…. smart phone…

Biomedical Data Have Far Outstripped the Cognitive Capacity of Human Beings



10^7 SNPs in HapMap

>2,000,000 proteins*

)0 genes

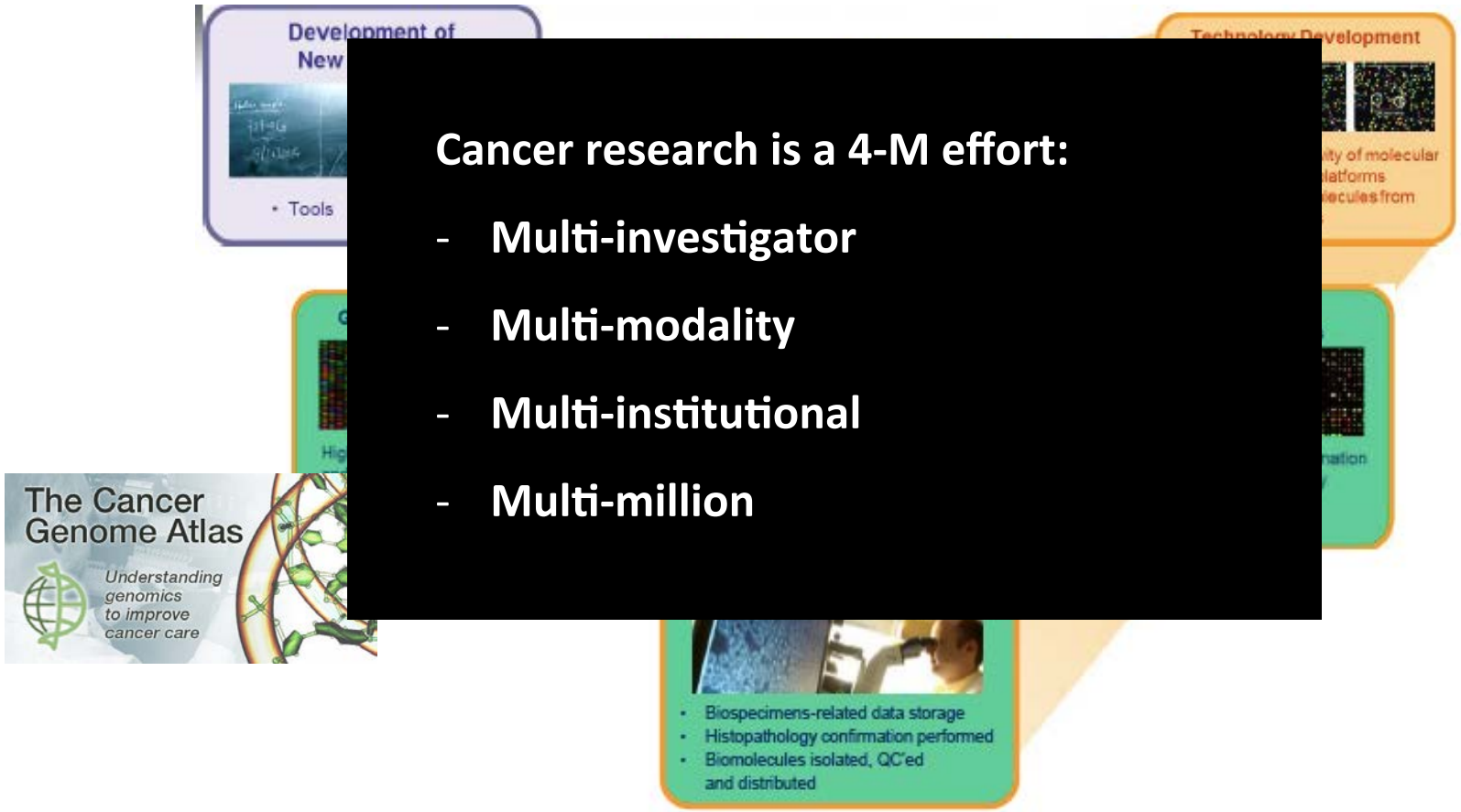
Precision medicine is completely dependent on artificial intelligence systems that integrate and interpret huge amounts of data to aid decision-making

*AMA Science 2014

Stead W. Beyond Expert Based Practice. Presented at: Institute Of Medicine; October 8, 2007.

Cancer, Team Science, Whole Genome Sequencing and Large-Scale Data Production

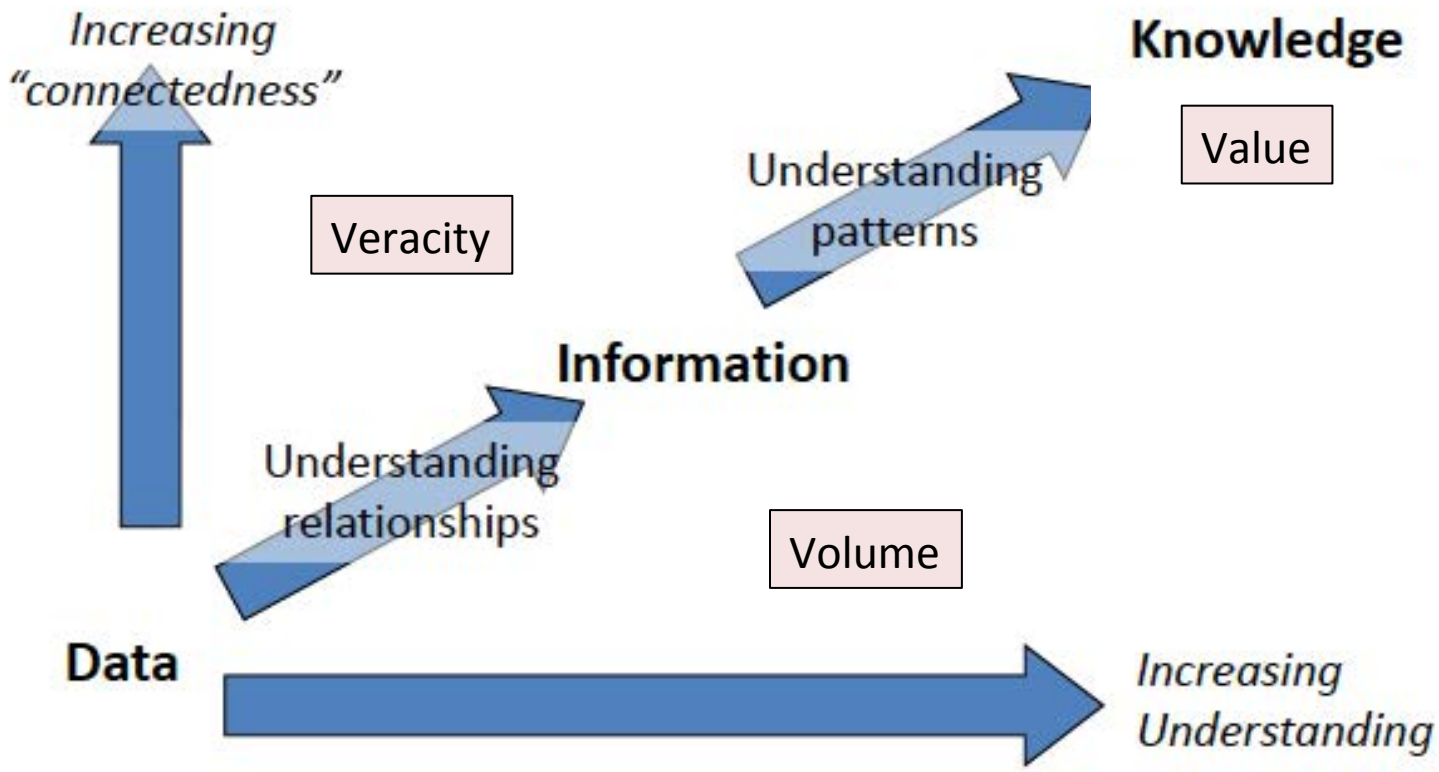
- **Cancer is the best example of enterprise-wide focus on whole genome sequencing to achieve precision medicine: e.g., TCGA**



Cancer research is a 4-M effort:

- **Multi-investigator**
- **Multi-modality**
- **Multi-institutional**
- **Multi-million**

Payoffs (ROI for Patients) Are Dependent on the Evolution of Data into Knowledge



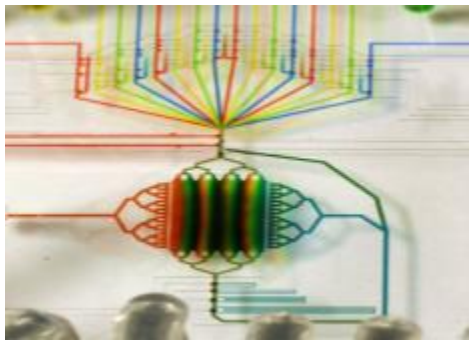
From Bellinger et al, http://www.systems-thinking.org

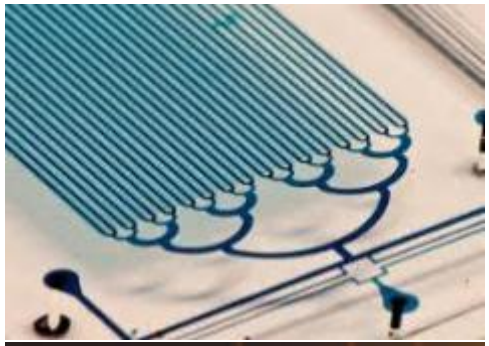
Technology Is Changing the Speed and Accuracy of Answering Questions from Unstructured Data (Knowledge Resources)

- IBM's Watson: natural language processing
- Instantly "reads" all the medical literature, makes associations to answer questions
- Utility for medical purposes is currently under study at major cancer centers

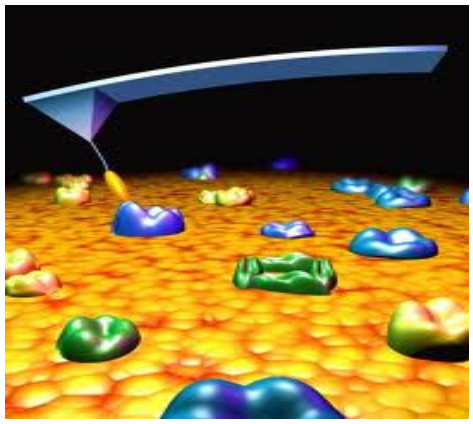
Technology Is Changing the World of Clinical Data Collection and Analysis

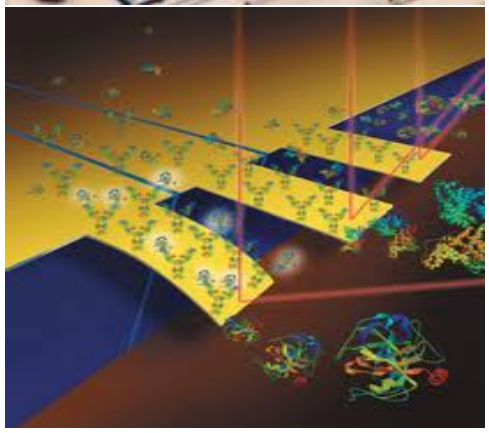
Technology Is Changing the World of Real Time, Point-of-Care Molecular Analysis



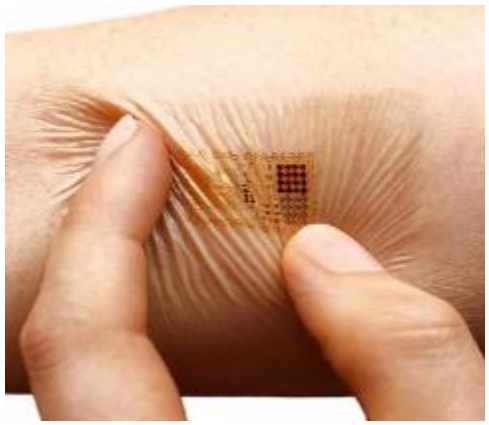


“Lab-on-a-Chip”



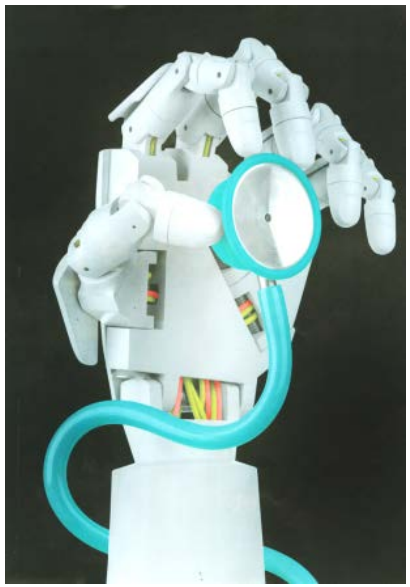


“Lab-on-a-Tip”



“Lab-Always On”
and
“Lab-On-Me”

Technology Is Changing the World of Home Healthcare: Robotics and Telemedicine

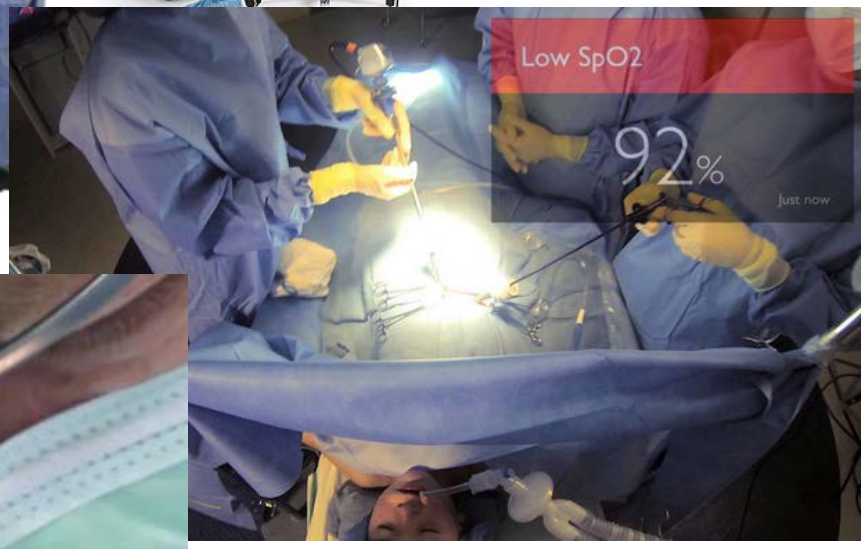


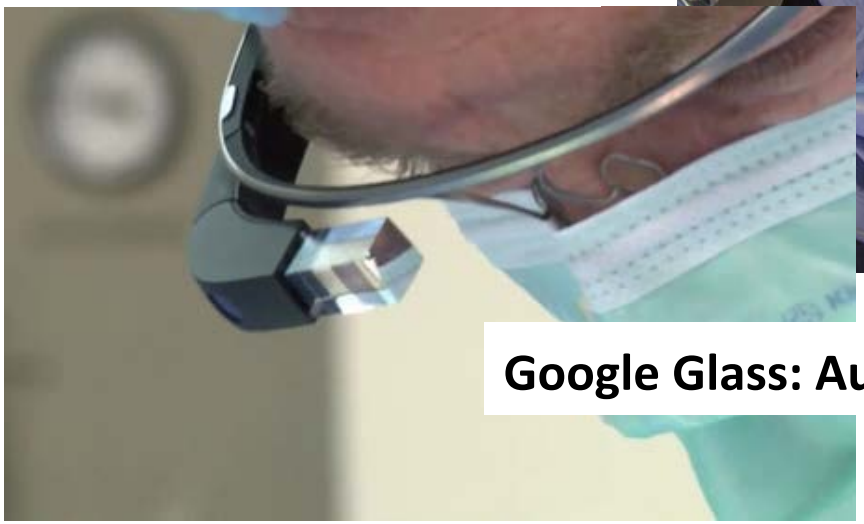
RP-VITA Remote Presence Robot:
(iRobot Corp) FDA 501(k) clearance 1/24/13

DocBot Physician Assistant

Technology Is Changing the World of Hospital Healthcare and Expanding the Abilities of Physicians

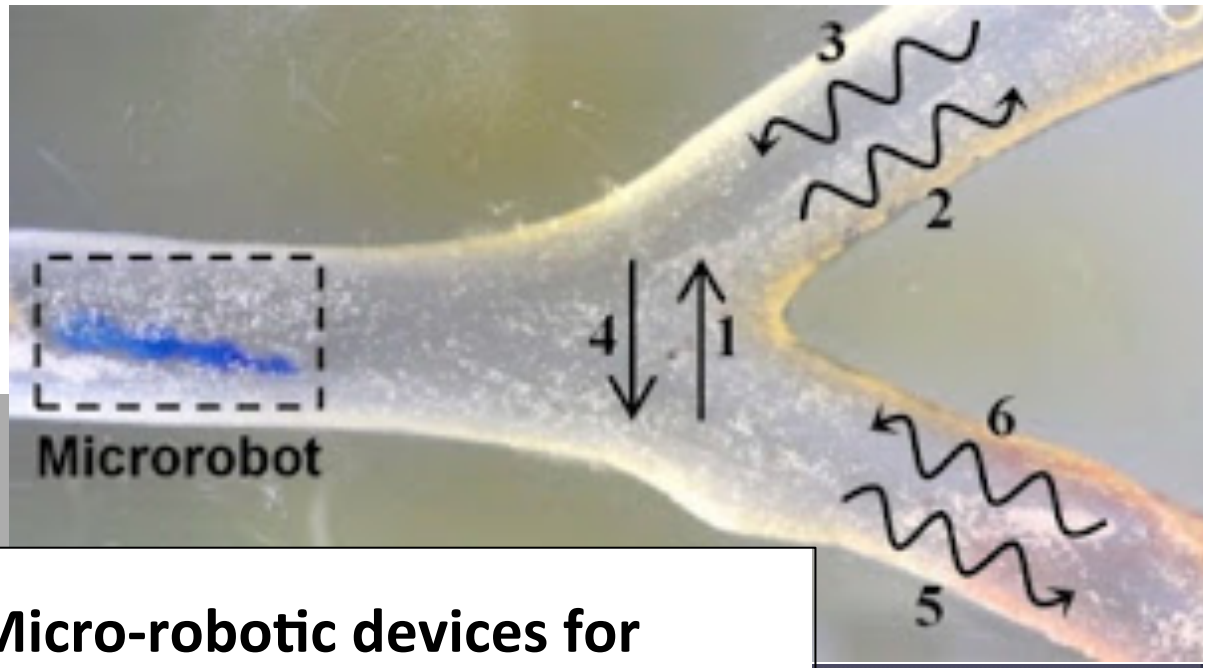
Robotic Surgery: Augmented Control, Visualization, Dexterity

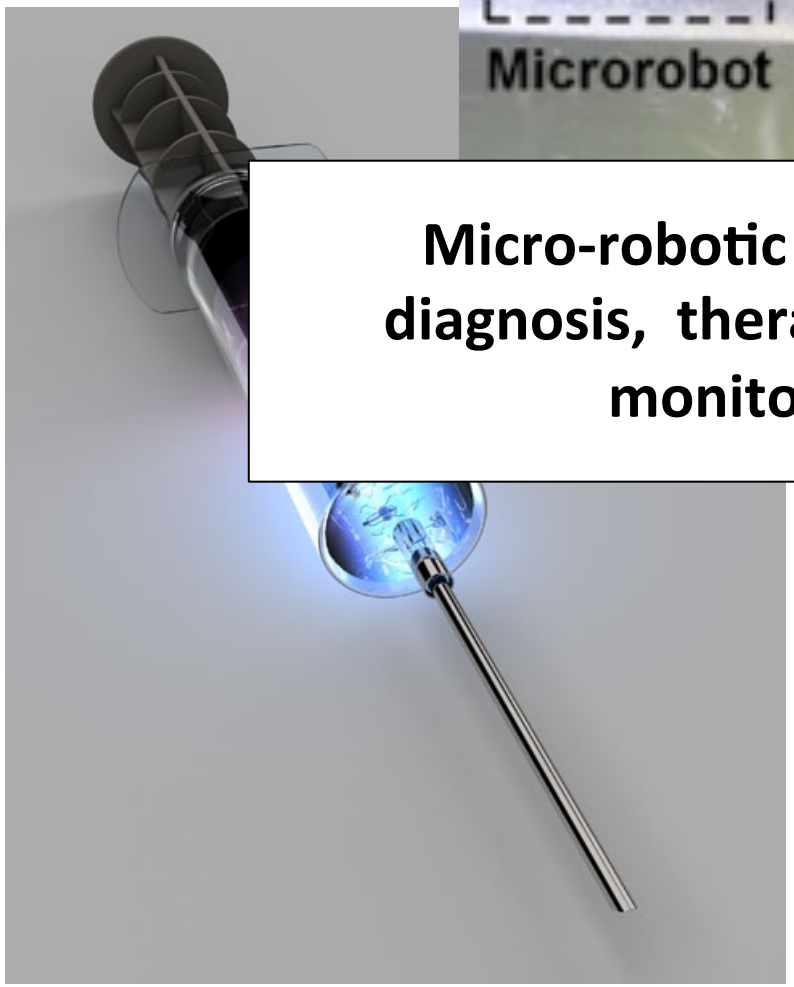




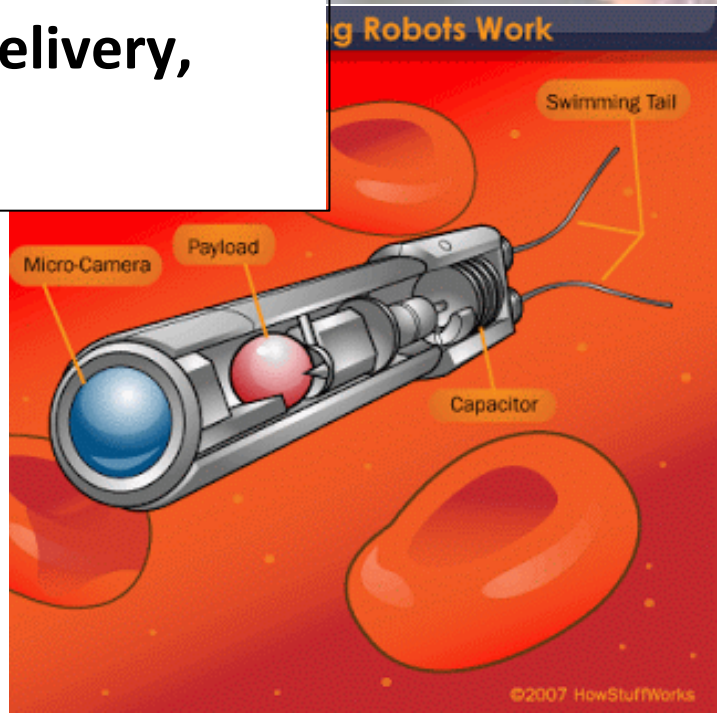
Google Glass: Augmented Reality

Robotic Tools of All Sizes Are Changing Medicine



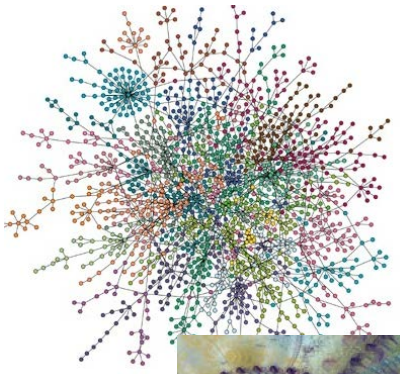


Micro-robotic devices for diagnosis, therapy delivery, monitoring

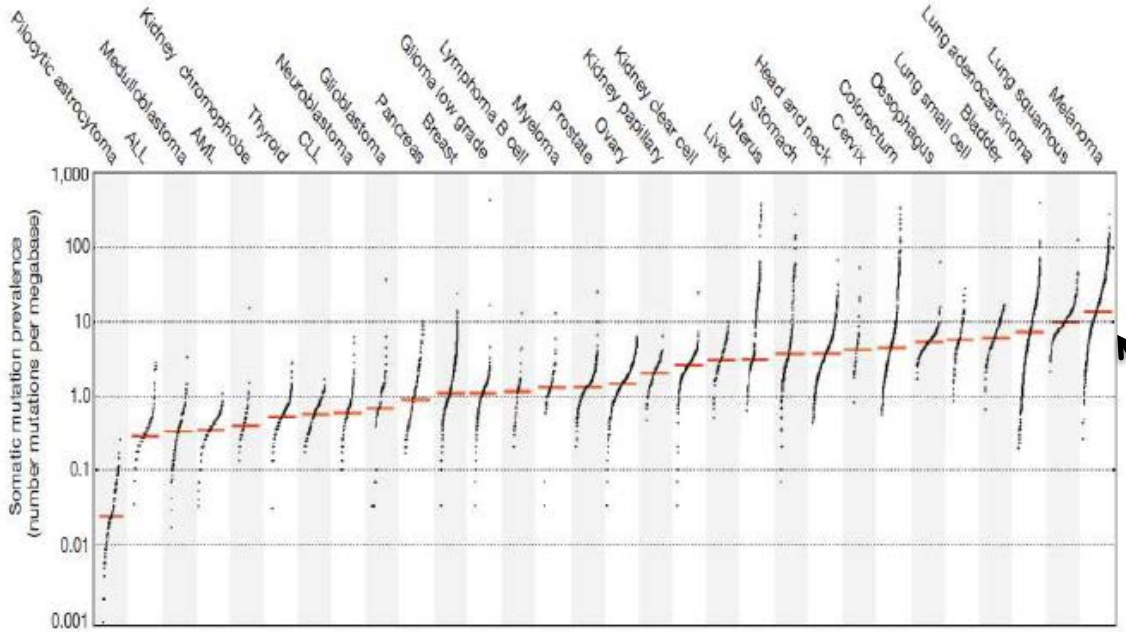


New Biological Insights Enabled by Technology: The Vision of Cancer as a Complex Adaptive System

- **Cancer genome complexity revealed: Formidably complex catalog of genomic changes and molecular network disruptions**
  - **Networks are highly interactive and redundant**
- **Cancer evolution exposed: Continued accumulation of genomic alterations generating numerous clones and sub-clones with different genomic alterations and phenotypes (heterogeneity)**
  - **In a patient**
    - **Within a lesion**
    - **Between lesions**
  - **Between patients**
  - **Treatment-driven evolution (selection and fitness)**



Panorama of Extravagant Genomic Alterations in Cancer

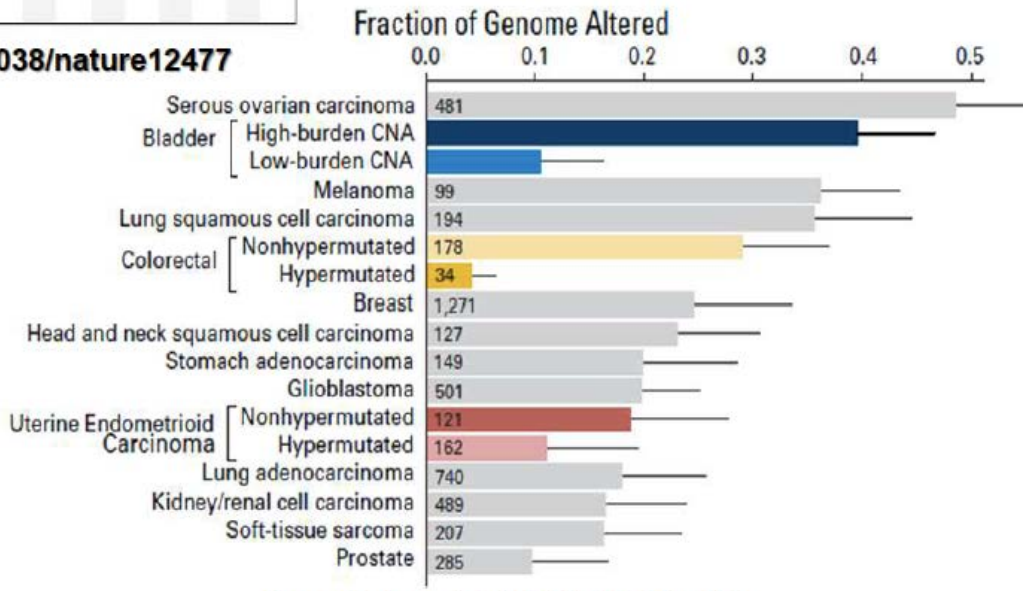


From: L. B. Alexandrove et al. (2013) Nature doi:10.1038/nature12477

Mutations per megabase tumor DNA (3K megabases in human genome)

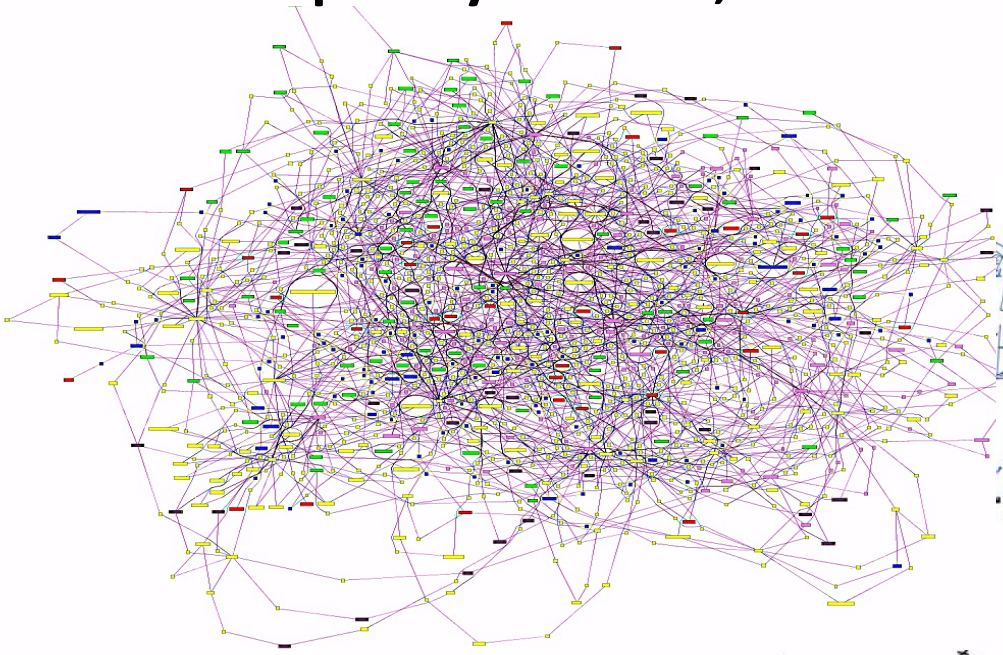
Average 10 per megabase for lung cancer and melanoma

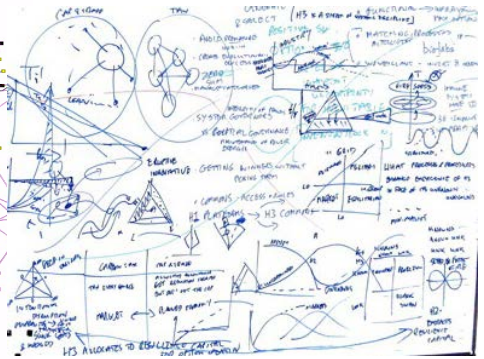
Copy number alterations in solid tumors

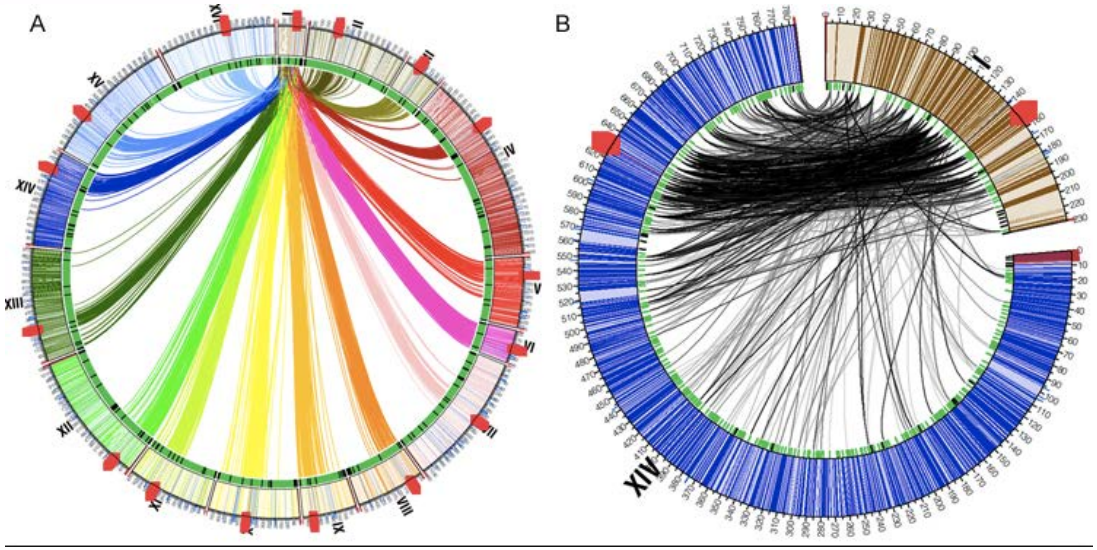


From: G. Iyer et al. (2013) JCO 31, 3133

The Complexity of Gene, Chromosome, and Network Interactions







Are We Prepared?

- I wasn't! Everything I have talked about there today was non-existent when I became a physician.
- It represents spectacular, thrilling, unimagined progress.
- Our challenge is to embrace the complexity and the opportunity to bring the power of technology, science and skill to the service of patients.