ASU Complex Adaptive Systems Initiative
Arizona State University

# The Evolution of Personalized Medicine: Opportunities and Challenges

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Master of Healthcare Innovation Course
ASU College of Nursing and Health Innovation
14 January 2011

**Slides available @**
**www.casi.asu.edu**

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**Sustaining Healthcare Innovation in an Era of Constraint**

**The Convergence of Molecular Medicine, Engineering and Information Technologies and Implications for Healthcare Delivery**

**Building Sustainable Health Systems and Services: A Complex Multi-Dimensional Challenge**

# Major Challenges in Healthcare

| Cost and Access | Demographics | Politics | Variation in Clinical Practice |
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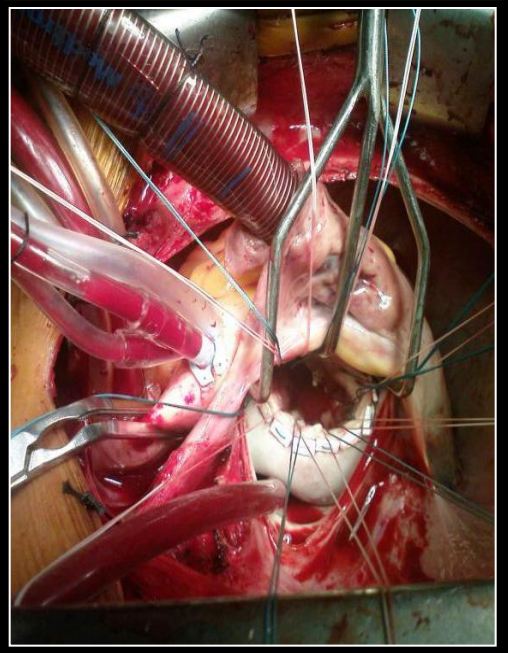
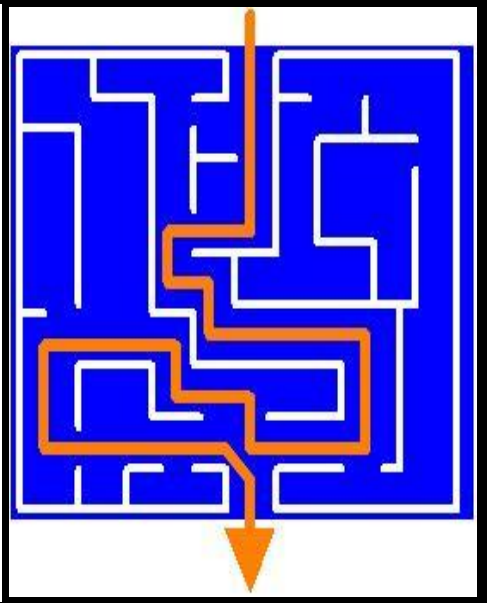
|  |  |  |  |

# Major Challenges in Healthcare

**Inefficient Use of Information**

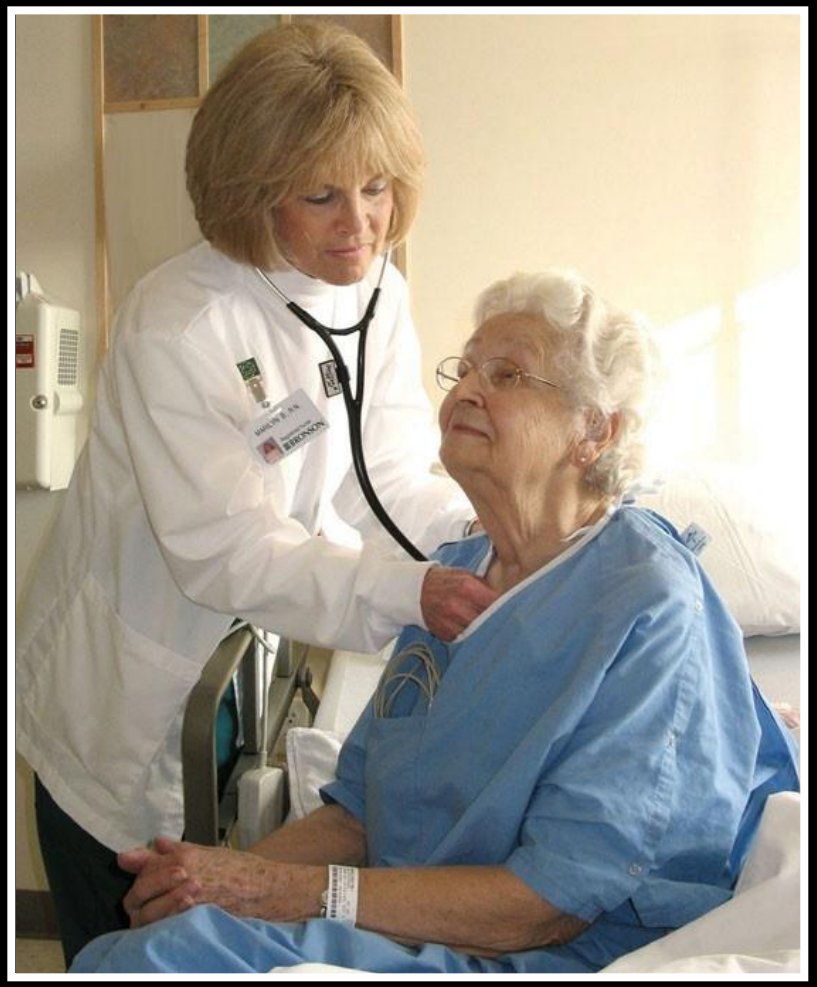
**Fragmented Care Versus Integrated Care**

**Duplication, Error and Pervasive Inefficiencies**



**Protracted Adoption of Innovation**

# Demographic Trends and the Clinical and Economic Burden of Complex, Chronic Conditions/Co-Morbidities



- 23% Medicare beneficiaries have 5 or more conditions
- polypharmacy and AEs
- poor patient compliance
- multiple physician/venue encounters
- poor communication/ coordination between siloed healthcare services
- procedure-based reimbursement versus a continuum of integrated care

# Fragmentation Versus Integration in Healthcare Delivery

## Physicians

- specialization and fee-for-service drives volume and siloed care provision
- lack of curriculum reform and propagation of anachronistic behaviors/expectations

## Payors

- impenetrable thickets of eligibility/reimbursement criteria
- bloated administrative infrastructure to accommodate multiple payment channels

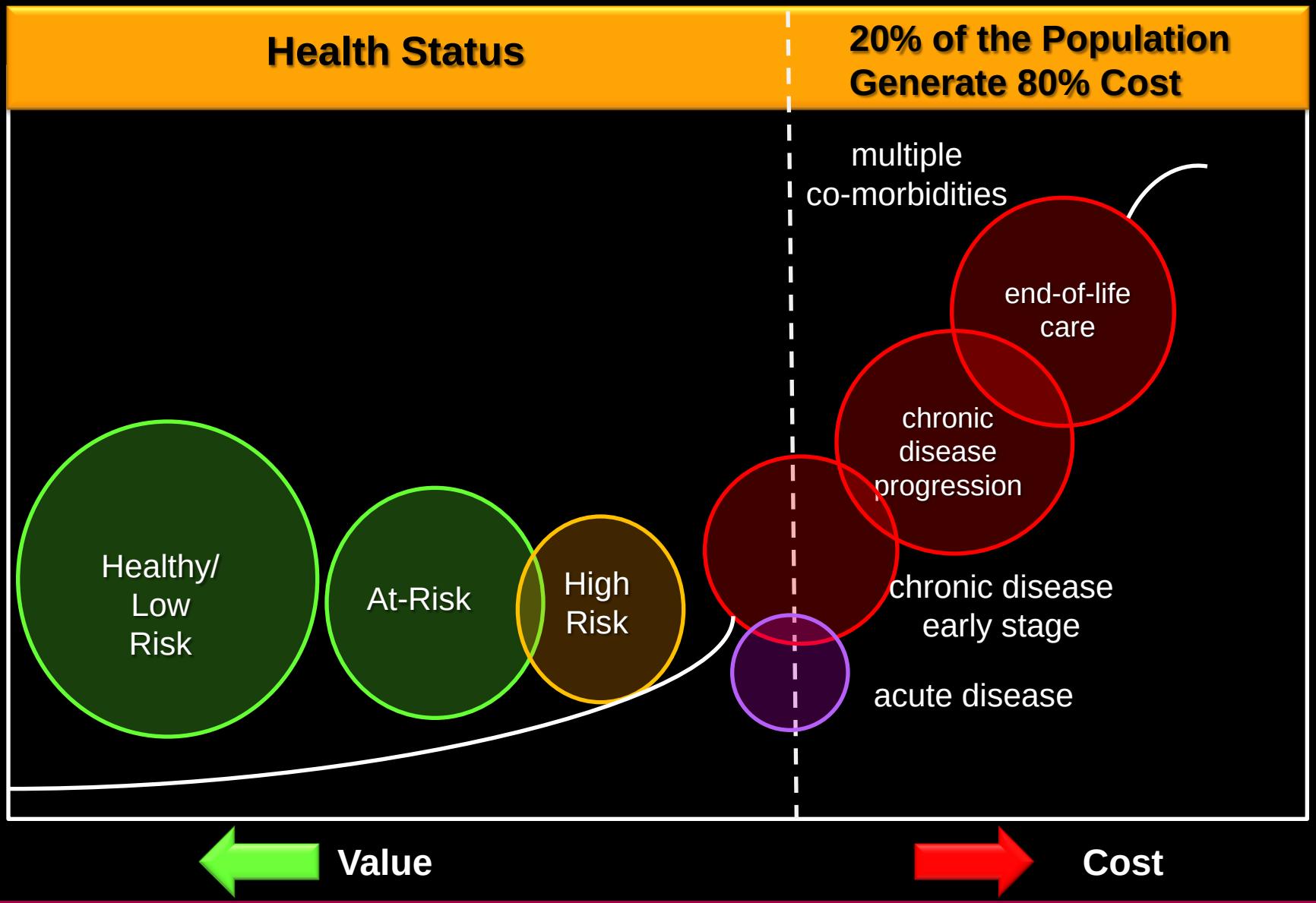
## Politicians

- boldness or timidity in healthcare reform?

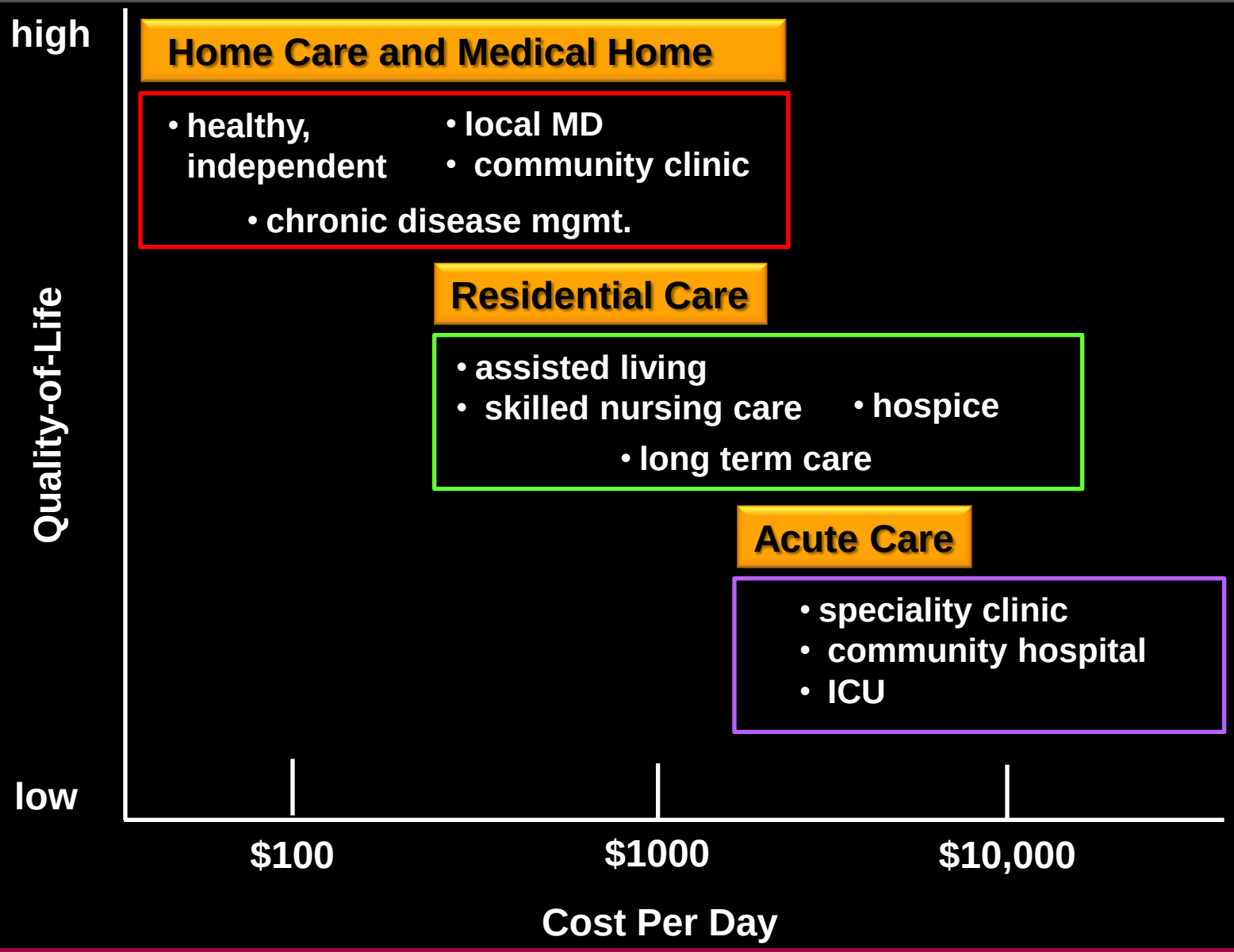
## Patients

- confused and increasingly afraid

# The Economic, Social and Clinical Benefits of Proactive Mitigation of Disease Risk and Chronic Disease Co-Morbidities



# The Challenge of Cost Reduction and Improved Quality-of-Life



# Excessive Use of Services

**“If you lie down long enough, someone will scan you.”**

**Mike McCallister**
**CEO, Humana**
**www.forbes/com/2009/03/19**

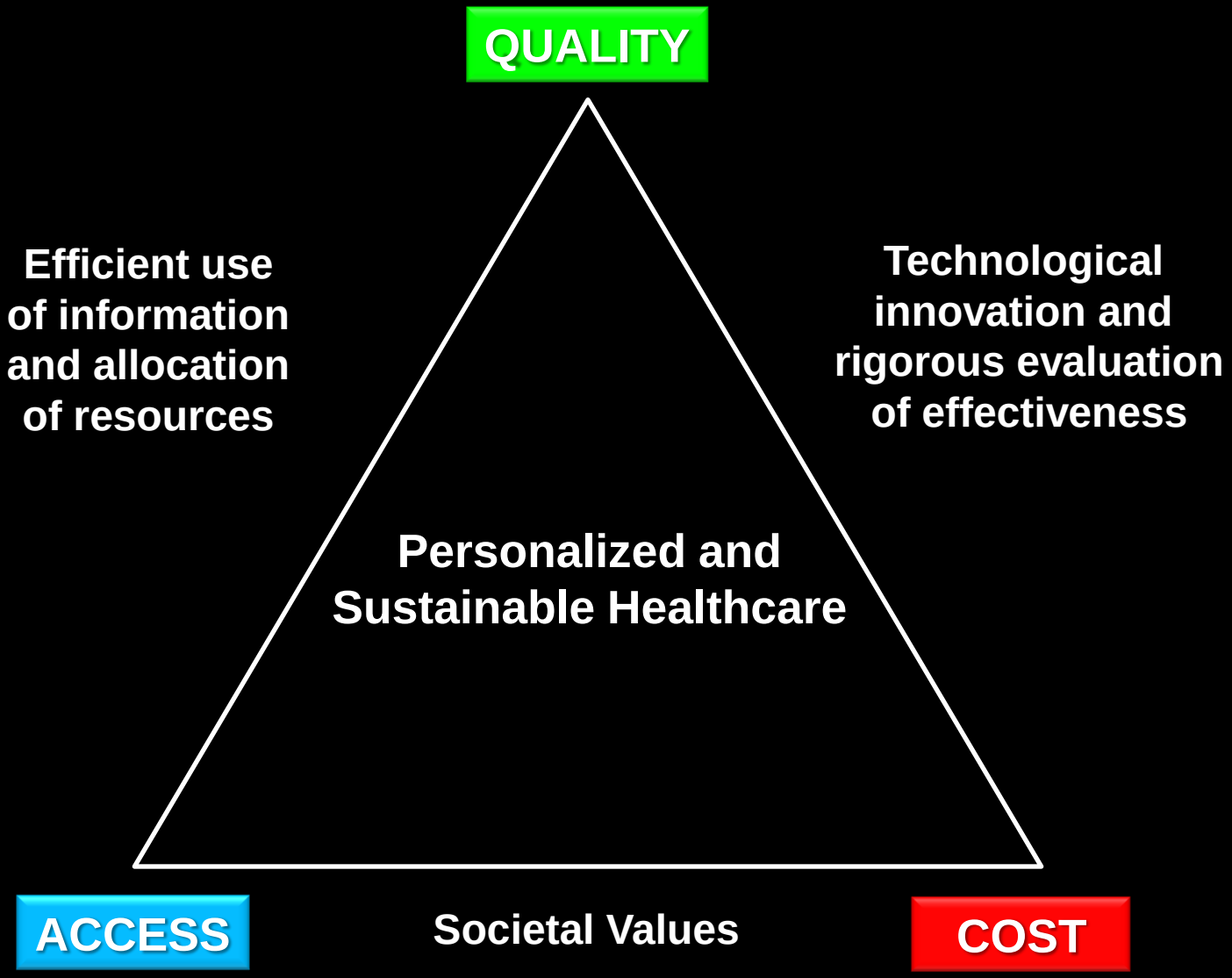
# New Priorities in Biomedical Innovation

- historical “progress at any price” in an environment that largely ignored cost
- shift to increasing value-conscious environment
  - improved outcomes at same or lower cost
  - reducing cost with same quality (common in sectors other than healthcare)

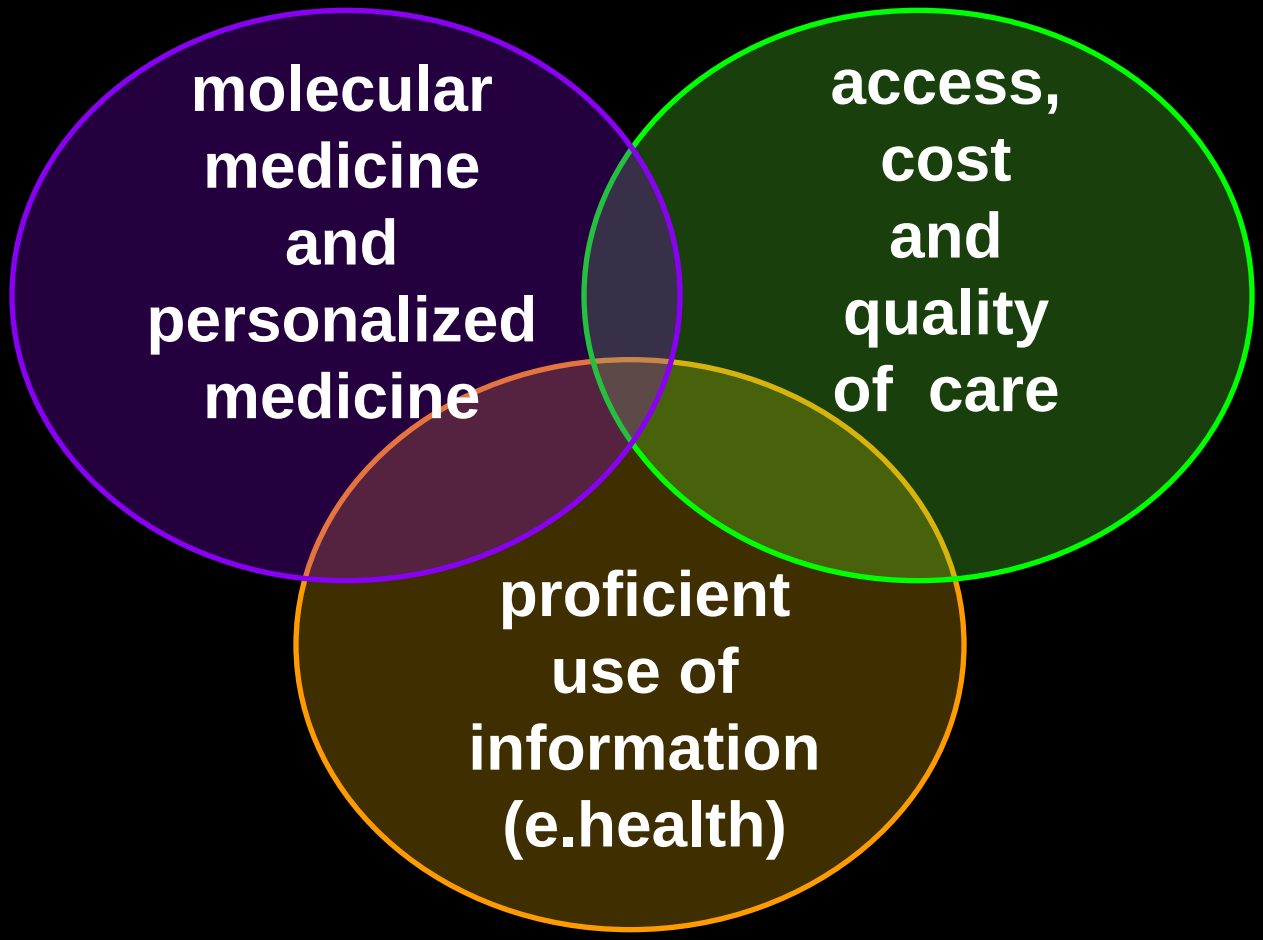
# New Value Propositions in Healthcare

- social and economic value of reducing disease burden will rise
  - earlier disease detection and mitigation
  - rational Rx and guaranteed outcomes
  - integrated care management of complex chronic diseases
  - extension of working life
- progressive shift from ‘reactive’ medicine to ‘proactive’ care and ‘integrated’ delivery
  - prospering in an era of increasing constraints
  - managing the limit(s) of society’s willingness and ability to pay for innovation

# Sustainable Health

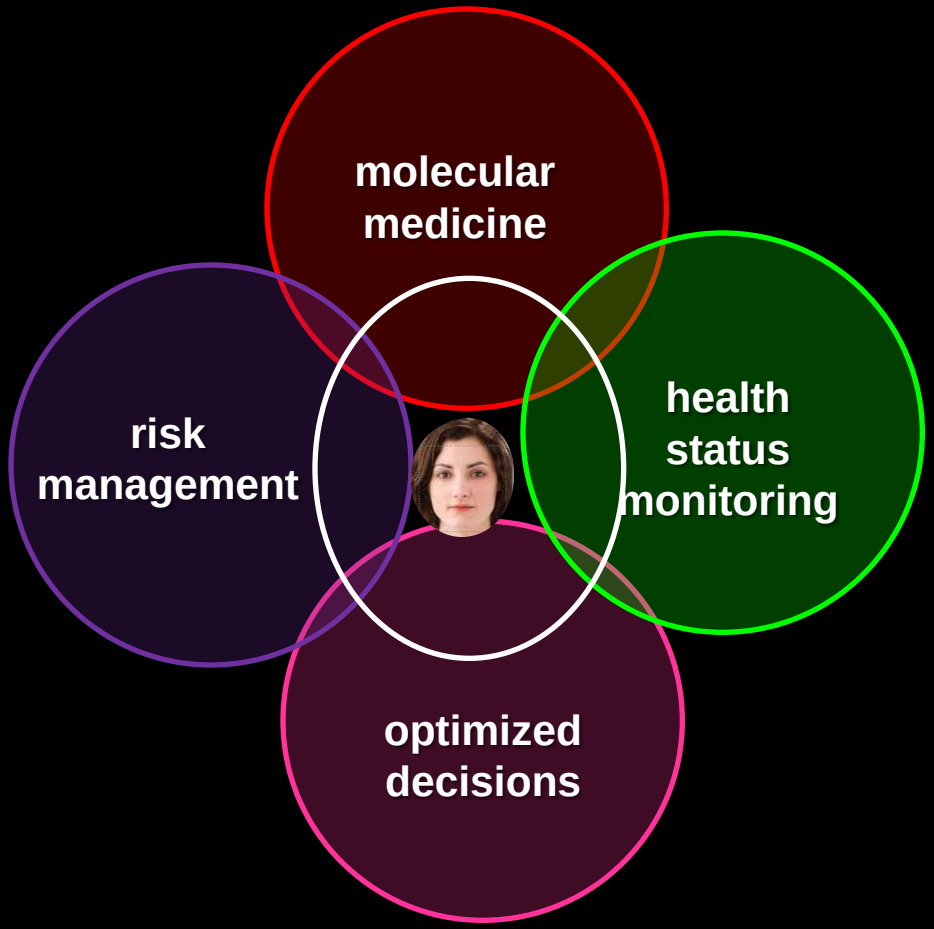


# The Three Convergent Forces Shaping the Evolution of Healthcare

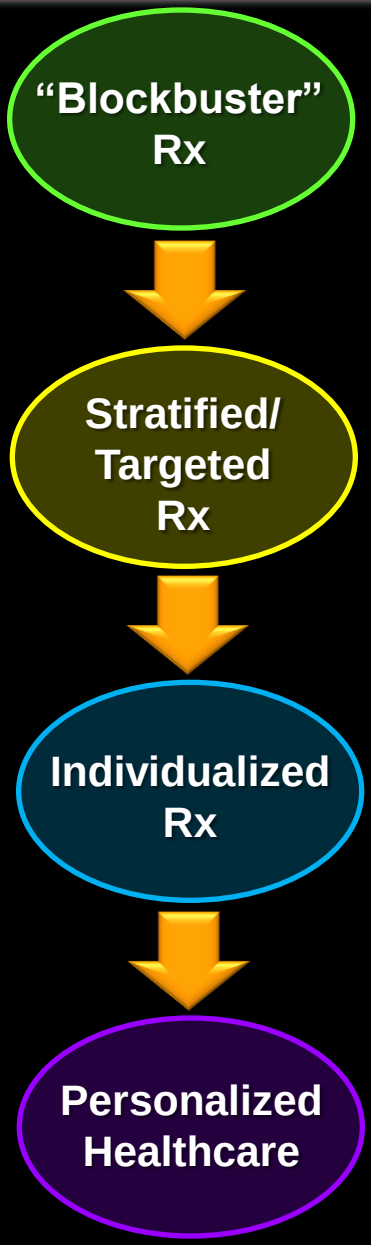



**VALUE**

# The Key Strategic Elements in the Evolution of Healthcare: Consumer: Patient Centric Care



# The Progressive Evolution of Personalized Healthcare




- empirical "one-size-fits-all"
- population-based Rx

- Rx targeted to patient subgroups with same molecular pathology
- Dx-Rx combinations and Rx labeling

- individualized Rx
  - relevant disease subtype and AE risk profiling
  - identification and mitigation of disease predisposition risk(s)

- integrated framework of coordinated care and longitudinal care

# Molecular Diagnostics:
# The Key Value Driver in
# Improving Healthcare and Maximizing Wellness

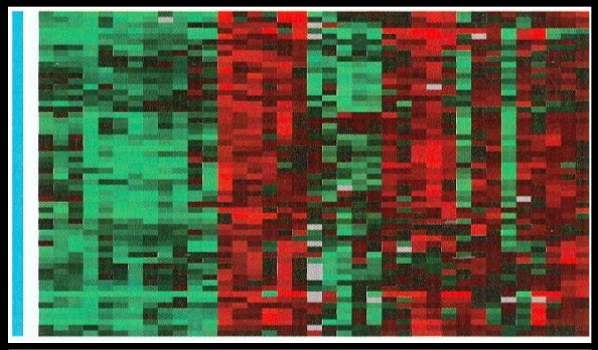
# US Healthcare Costs

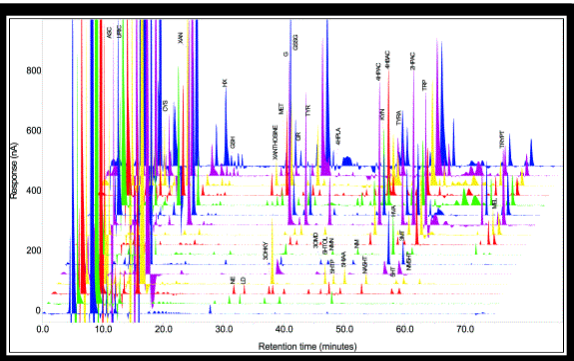
- administration 35%
- personnel costs 35%
- procedures 18%
- drugs 12%
- in vitro diagnostics 0.1%
- diagnostic tests (Dx) influence 85% of clinical actions

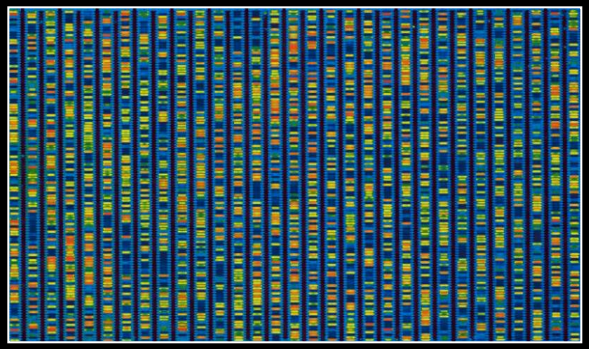
# Molecular Diagnostics and Miniaturized Devices: A Key Future Driver in the Healthcare Value Chain

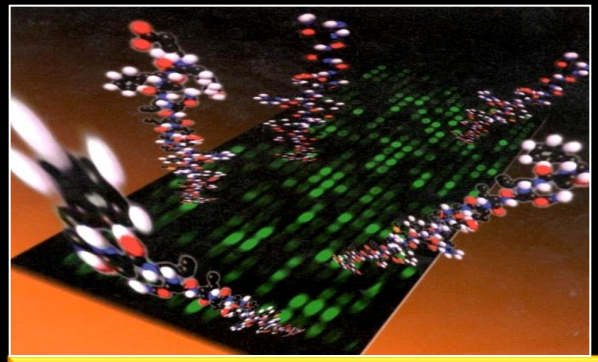
## Complex Biosignature Profiling

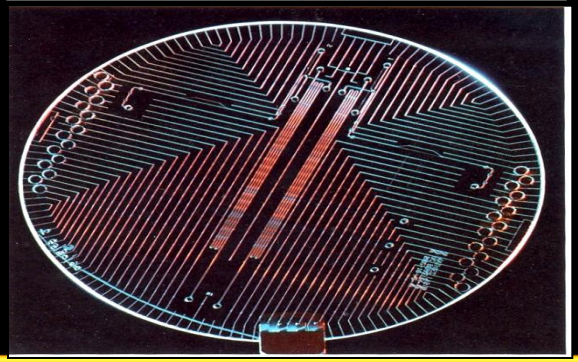
| genomics | proteomics | immunosignatures |
|---|---|---|

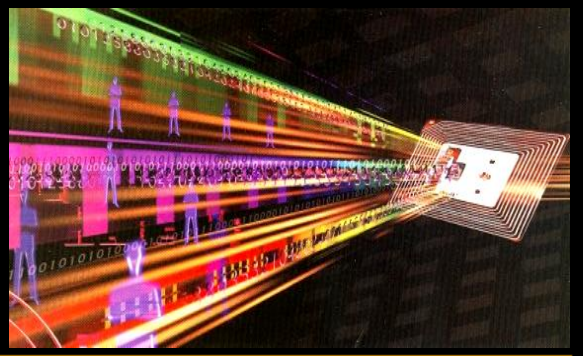










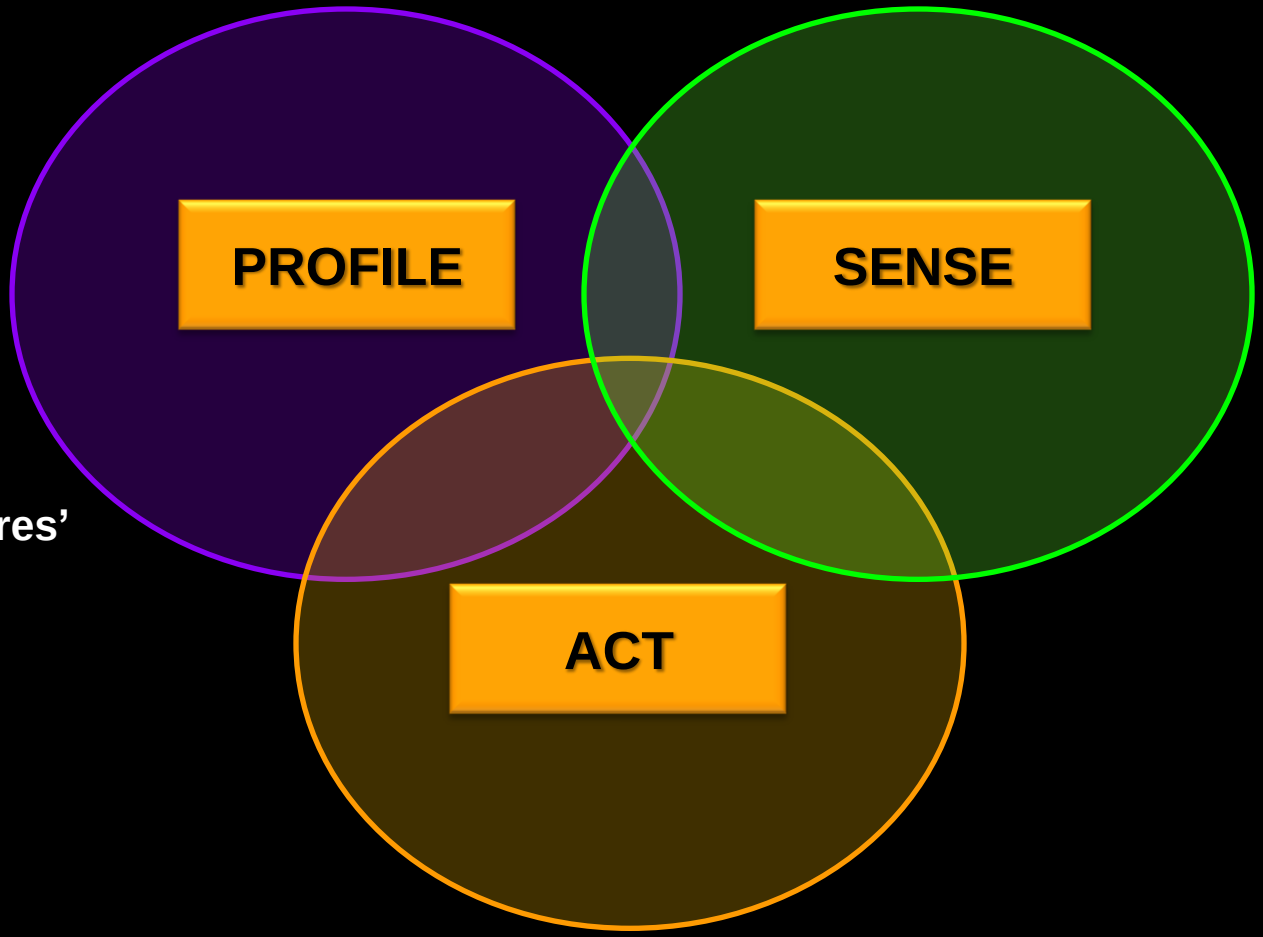
## Signature Detection, Deconvolution and Multivariate Analysis

| automated, high throughput multiplex assays | novel test formats and devices (POC) | new algorithms for complex signal deconvolution |
|---|---|---|

# Mapping the Molecular Signatures of Disease: Building Integrated End-to-End Systems as the Foundation of Personalized Medicine

ID patterns of molecular pathways dyregulation in disease

– "biosignatures'




automated platforms for rapid detection of multiplex analytes

rapid analytics and customized data formats/visualization to guide optimum treatment and reimbursement decisions

# Trends in Mapping Diagnostic Signatures of Health and Disease

- unianalyte → multiplex
- simple analytical endpoint(s) → complex analytical algorithms
- technician dependent → high throughput automated; lab-on-a-chip; remote fault-diagnostics/ repair
- centralized laboratory → migration to POC/m.Health; wireless remote monitoring
- population-based reference index → individualized profile and longitudinal personal record as reference index

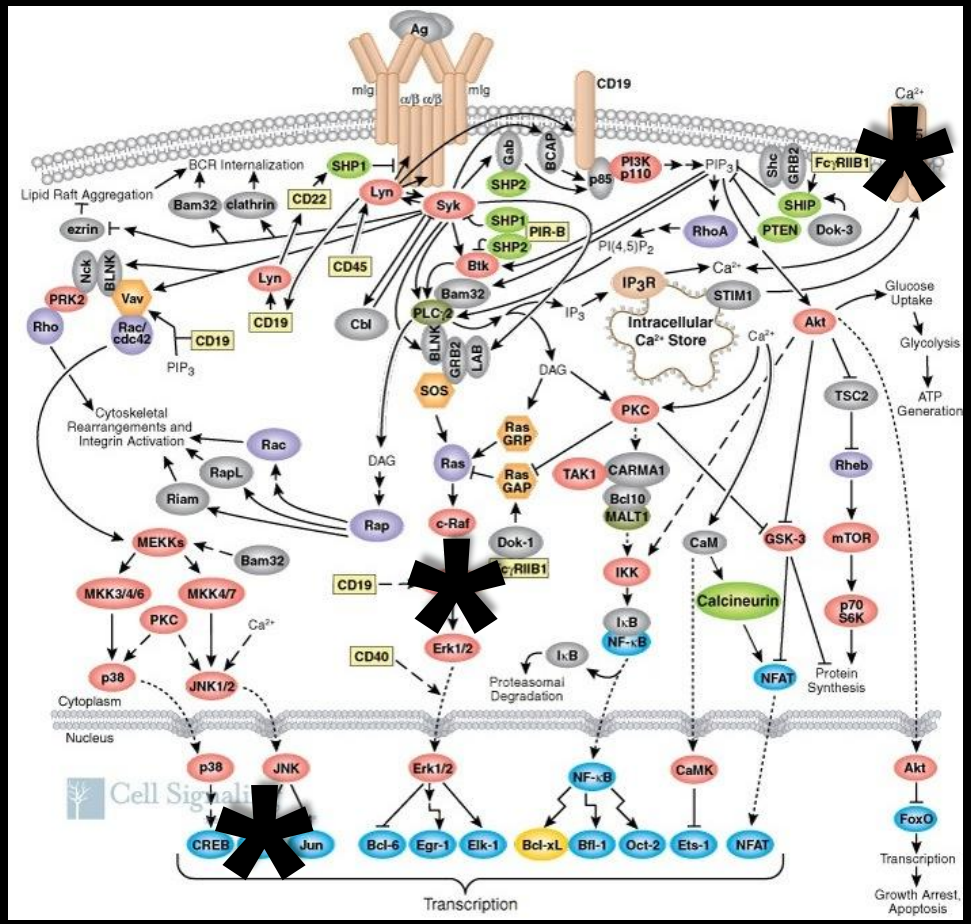
# The Waste and Risk of Empirical Rx: Ignoring The Obvious in Clinical Practice

- diseases are not uniform
- patients are not uniform
- a “one-size fits all” Rx approach cannot continue

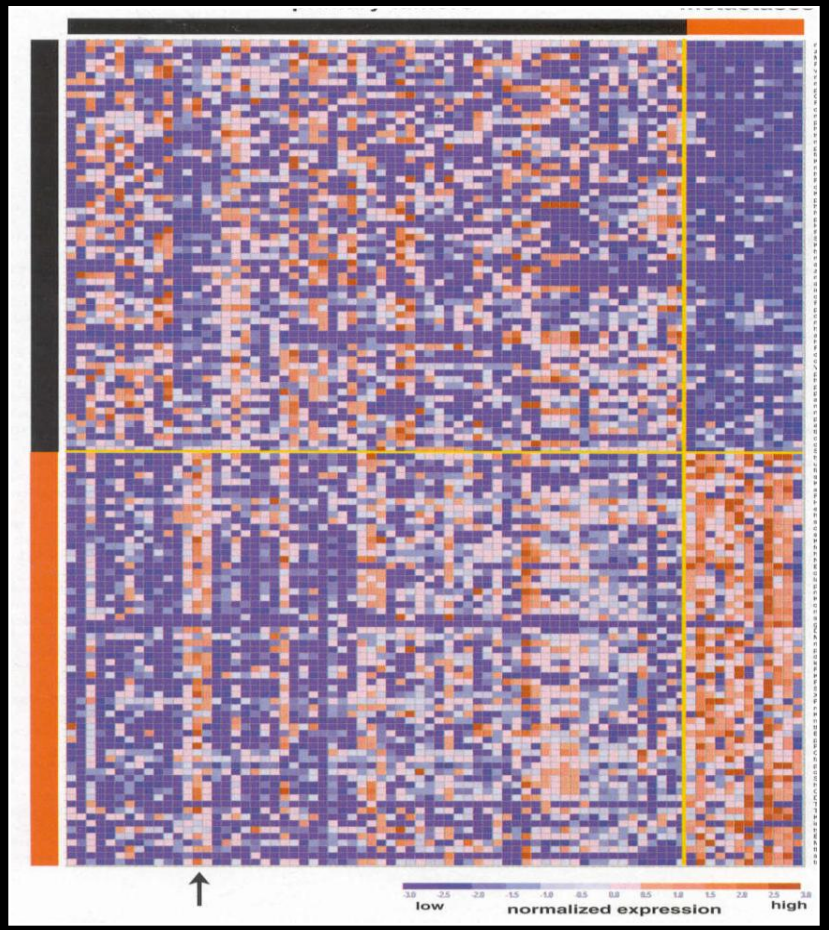
- inefficiency and waste of empirical Rx
- cost of futile therapy
- medical error and adverse events (AEs)

# From Pharmaceuticals to Pharmasuitables: Right Rx for the Right Disease (Subtype)

## ID Molecular Targets for Rx Action




## Disease Profiling to Identify Subtypes (+ or - Rx Target)



# K-RAS Profiling and Anti-EGFR Monoclonal Antibody Therapy

Vectibix® (panitumumab)

ERBITUX® CETUXIMAB

NCCN

ASCO®

clinical guidelines

- higher response in patients with K-RAS versus mutant-K-RAS
- estimated $604 million/year savings (ASCO)

EUROPEAN MEDICINES AGENCY
SCIENCE MEDICINES HEALTH

FDA

- regulatory endorsement in product labeling

# The Emergence of Drug: Diagnostic Combinations





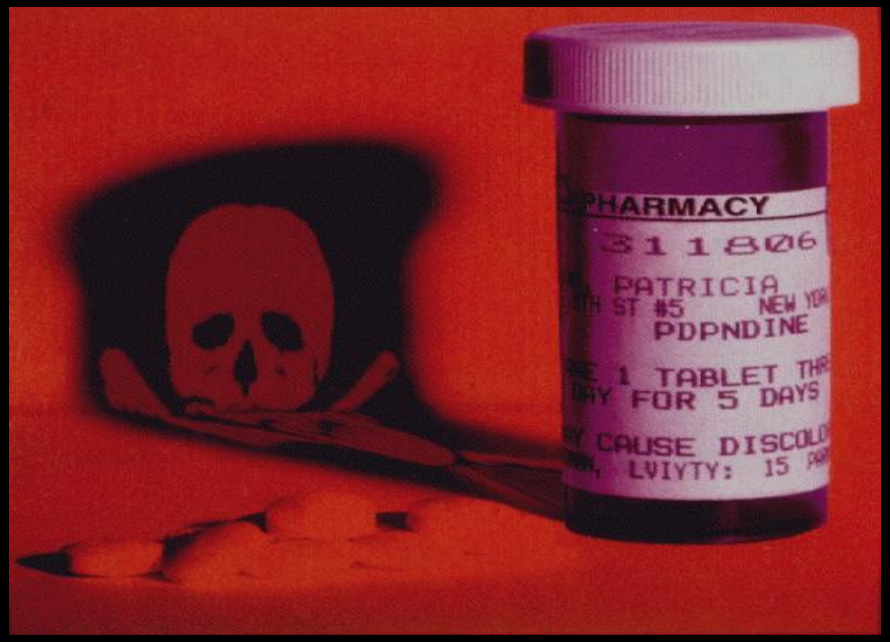





# Outcomes-Based Risk-Sharing Agreements (ORBAs) Come to the USA

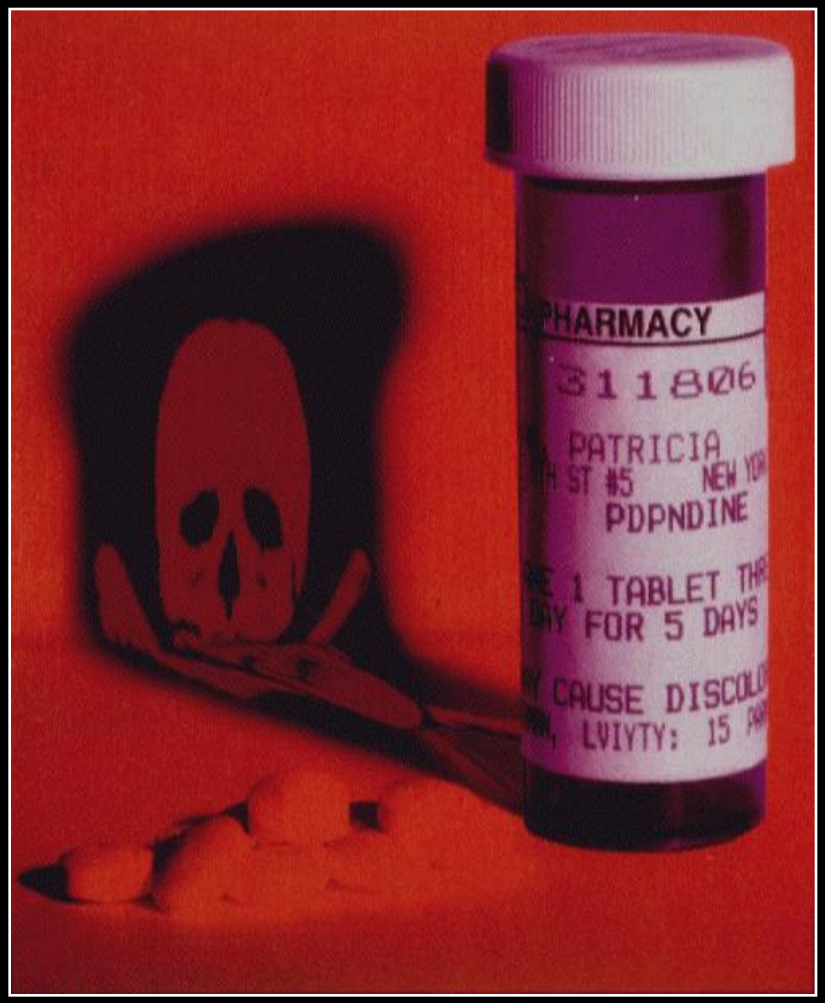

- reimburse average treatment cost (not just Rx) for fractures incurred after 6 months therapy
- improved Hb1Ac levels in diabetics over one year increases Rx discount to Cigna

# Pharmacogenetic Predisposition to Adverse Drug Reactions




- 1.5 to 3 million annual hospitalizations (US)
- 80 to 140 thousand annual deaths (US)
- est. cost of $30-50 billion

# From Pharmaceuticals to Pharmasuitables: The Right Rx for the Right Patient




- Rx adverse events (AE) as major source of injury and death
- AEs due to genetic variation in drug transport and metabolism systems
  - fast and slow metabolizers
- AE due to drug interactions
  - action of one Rx in inhibiting metabolic capacity to handle second drug
- AE due to Rx and OTC drugs/supplements
  - latter not tracked

# Genetic Associations in Drug-Induced Liver Injury: Polymorphisms in Drug Metabolism Enzymes

| Drugs | High-risk genotypes |
|---|---|
| Perhexiline | CYP2D6*3, *4, *5, and *6 |
| Carbamazepine | GSTM1 null |
| Tacrine | GSTM1 and T1 null |
| Troglitazone | GSTSM1 and T1 null |
| Diverse | GSTM1 and T1 null |
| Methotrexate | GSTM1 non-null, RFC1 G80A |
| Anti-TB drugs | NAT2*5, *6, *7, CYP2E1 c1/c1, MnSOD T/C or C/C, GSTM1 null |
| Diclofenac | UGT2B7*2, CYP2C8 haplotype, ABCC2 C24T |
| Tolcapone | UGT1A haplotype |
| Indinavir | UGT1A1*28, UGT1A3 T66C-UGT1A7 T57G<br>UGT1A1*6 |
| Atazanavir | UGT1A1*28, UGT1A3 T66C-UGT1A7 T57G |
| Azathioprine | TPMT*3A and *3C |

from: Y-S Huang (2010) Pers. Med. 7, 5

# Genetic Associations in Drug-Induced Liver Injury: Polymorphisms in Immune-Related Pathways

| Drugs | High-risk genotypes |
|---|---|
| Flucloxacillin | HLA-B*5701 |
| Amoxicillin | HLA-DRB1*1501-DRB5*0101-DQB1*0602 |
| Clavulanate | HLA-DQA1*0102-DQB1*0602 |
| Ticlopidine | HLA-A*3303, HLA-DQB1*06 |
| Ximelagastran | HLA-DRB1*07, HLA-DQA1*02 |
| Anti-TB drugs | HLA-DQB1*0201 |
| Diverse | HLA-DRB1*15, DQB1*06 |
| Diclofenac | IL-10-627A and IL-4-590T |
| Tacrine | IL-6-597A-572G-174G haplotype |

from: Y-S Huang (2010) Pers. Med. 7, 5

# Lancet (2010) 376, 1320

## Effect of *CYP2C19* and *ABCB1* single nucleotide polymorphisms on outcomes of treatment with ticagrelor versus clopidogrel for acute coronary syndromes: a genetic substudy of the PLATO trial

*Lars Wallentin, Stefan James, Robert F Storey, Martin Armstrong, Bryan J Barratt, Jay Horrow, Steen Husted, Hugo Katus, P Gabriel Steg, Svati H Shah, Richard C Becker, for the PLATO investigators*

*Lancet* 2010; 376: 1320–28

Published Online
August 29, 2010
DOI:10.1016/S0140-6736(10)61274-3

See Comment page 1278

### Summary

**Background** In the PLATO trial of ticagrelor versus clopidogrel for treatment of acute coronary syndromes, ticagrelor reduced the composite outcome of cardiovascular death, myocardial infarction, and stroke, but increased events of major bleeding related to non-coronary artery bypass graft (CABG). *CYP2C19* and *ABCB1* genotypes are known to influence the effects of clopidogrel. In this substudy, we investigated the effects of these genotypes on outcomes between and within treatment groups.

# Ethnic Genetic Variation and Drug Metabolism

*Clinical Pharmacology & Therapeutics* **87**, 445-451 (April 2010) |

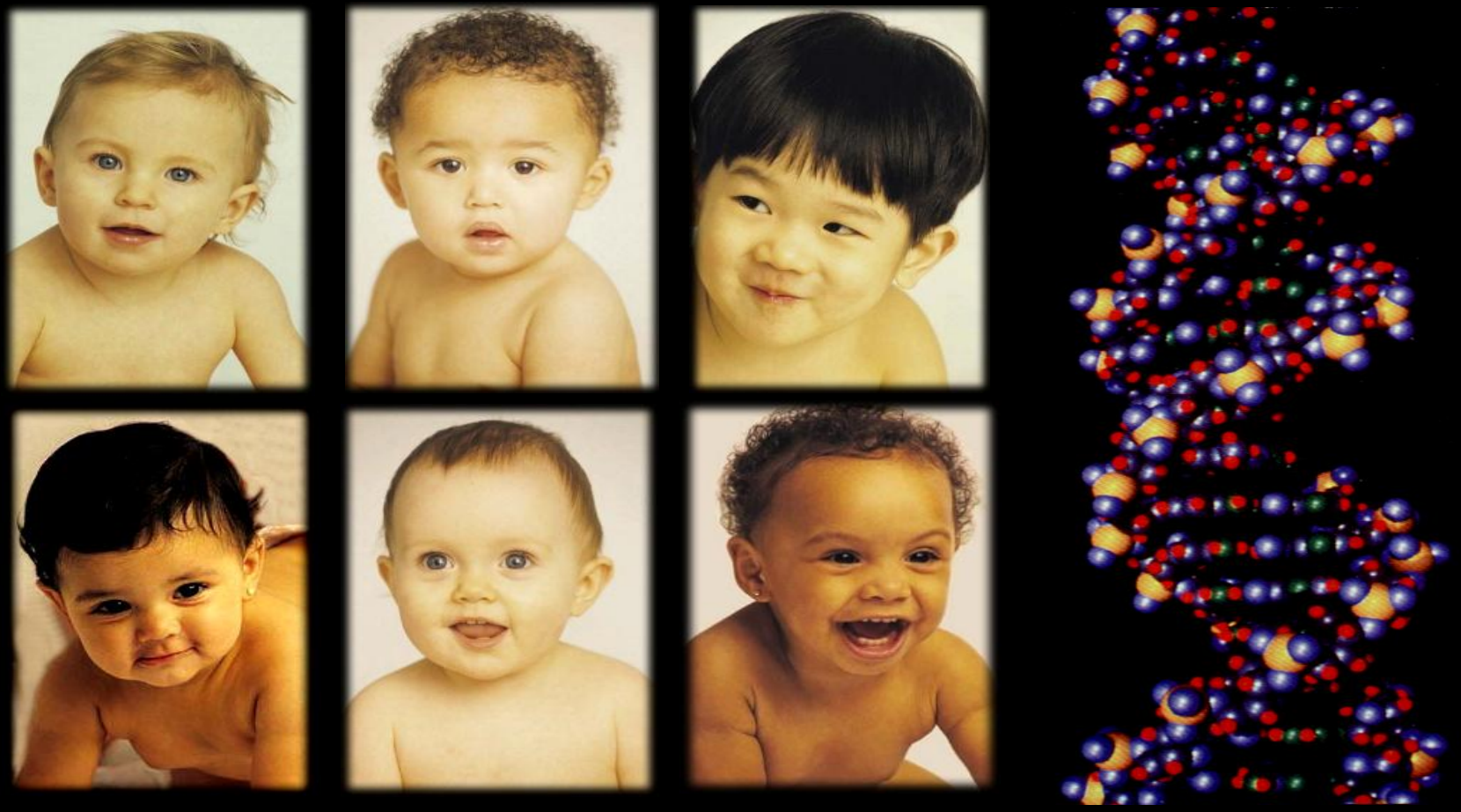
## A Polymorphism in the VKORC1 Regulator Calumenin Predicts Higher Warfarin Dose Requirements in African Americans

D Voora, D C Koboldt, C R King, P A Lenzini, C S Eby, R Porche-Sorbet, E Deych, M Crankshaw, P E Milligan, H L McLeod, S R Patel, L H Cavallari, P M Ridker, G R Grice, R D Miller and B F Gage

# Mapping Human Genetic Diversity

- transcending PC and “biological egalitarianism”
- non-trivial genetically-based biological variation exists in individuals and groups
- ignoring such variations is illogical, poor science, poor clinical medicine and potentially dangerous
- mapping group genetic diversity is fundamental knowledge
  - human evolution and trait acquisition
  - interplay of genomes and environment in determining outcomes
  - variations in disease susceptibility, xenogeneic metabolism and clinical decisions for optimum treatment

# The Hunt for Gene Loci Associated with Complex Human Diseases



# Disease Predisposition Risk Profiling for Common, Multigenic Late-Onset Disorders

- slower evolution than many predict
- Genome-Wide Association Studies (GWAS)
  - high cost and to date low yield in terms of clinically exploitable markers
  - disease origins from multiple low penetrance alleles versus small, dominant set of high penetrance alleles
- substantial ambiguities regarding probabilistic risk of overt disease
  - epistasis
  - epigenetics
  - environmental confounders, including Rx


DNAdirect
Your Genes In Context


Consumer Genetics
Bringing Science Home


CyGene
LABORATORIES


GeneLink


GENECARE
Medical Genetics Center


GENETIC
TECHNOLOGIES, INC.
DNA / FORENSIC / PATERNITY TESTING


genelex


g-Nostics


INTERLEUKIN
GENETICS
Empowering


MediChecks.com


ScientificMatch.com
"The Science of Love"


NEUROMARK


SURACELL
Personal Genetic Health™


23andMe


Navigenics


Knome

# Disease Predisposition Risk Profiling for Common, Multigenic Late-Onset Disorders

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  - epistasis
  - epigenetics
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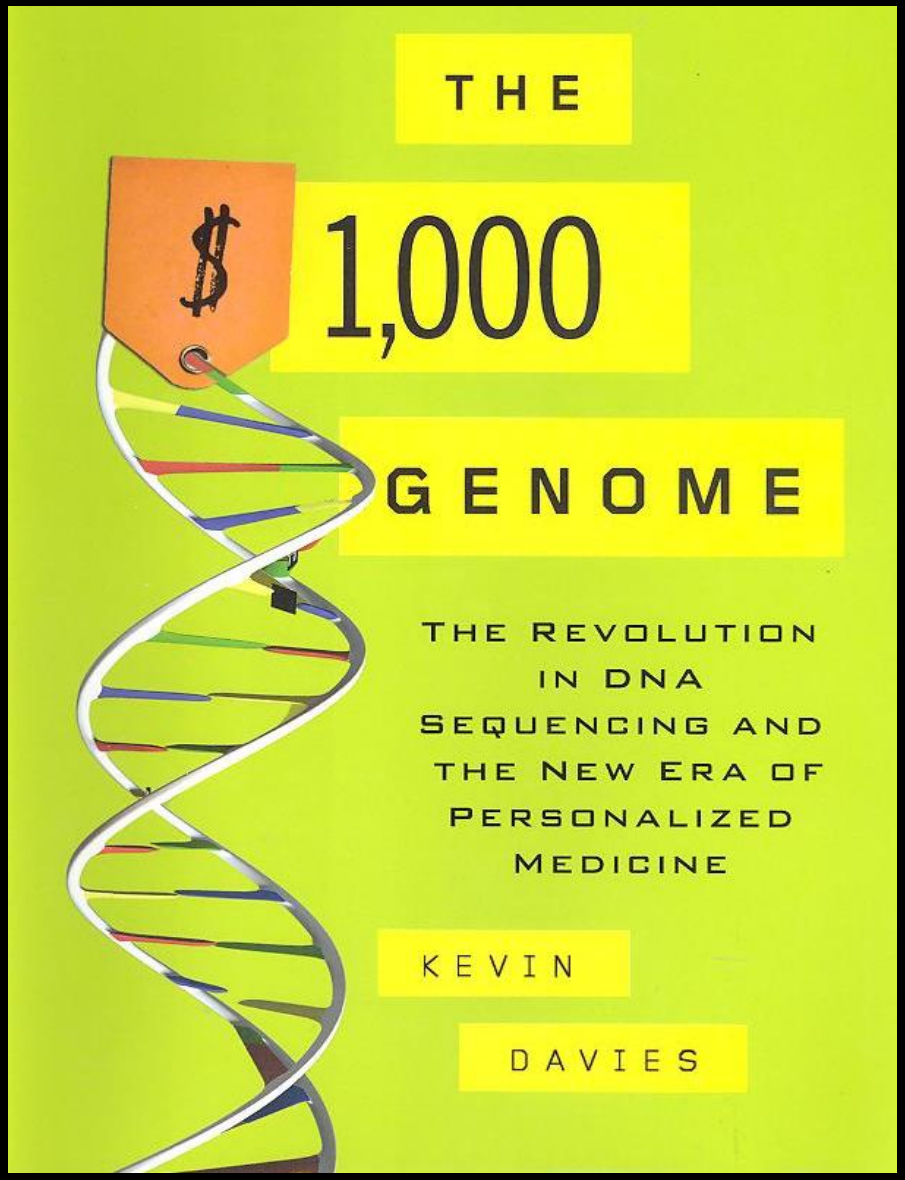
**The premature quest to provide consumer genomic testing (CGx) for future risk of major diseases**

# Will Low Cost Whole Genome Sequencing Change Everything?



**BIO-IT World, November 2010**



# Sequence, Drugs and Rock n' Roll: How Ozzy Osbourne Took a Bite Out Of His Genome

## Genes reveal alcohol tolerance, caffeine intolerance, equal parts worrier and warrior.

BY KEVIN DAVIES

Last year, shortly after completing work on rock music legend Ozzy Osbourne's memoir, *I Am Ozzy*, *The Sunday Times* (London) reporter Chris Ayres was sitting next to Knome CEO Jorge Conde at the TedMed conference in San Diego. "When Ozzy and I began to do the weekly 'Dr Ozzy' column for *The Sunday Times*—now also in *Rolling Stone*—I got the idea to ask [Knome] about possibly sequencing Ozzy's genome as a one-off article. It snowballed from there," says Ayres.

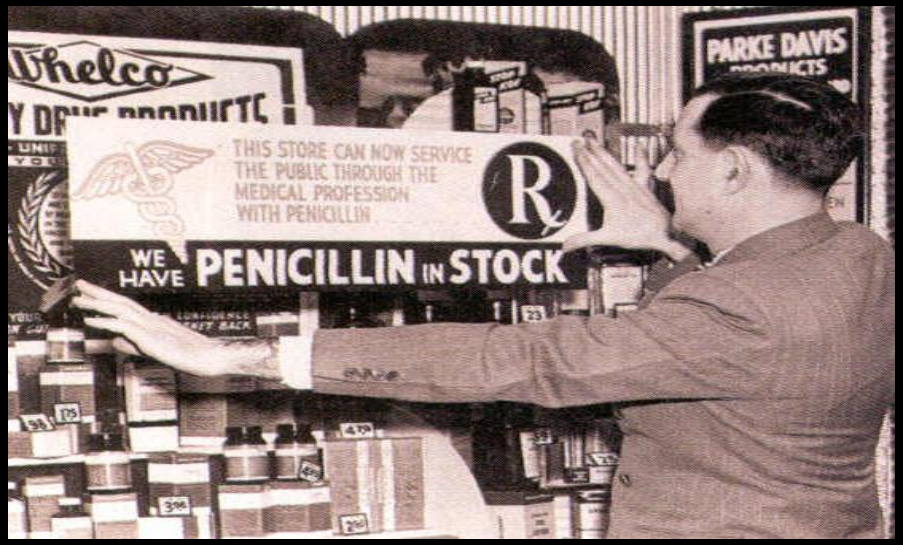
John Michael "Ozzy" Osbourne, the former lead singer of Black Sabbath, has become the latest member of the celebrity genome club, joining Glenn Close, Archbishop Desmond Tutu, Jim Watson, Craig Venter, Henry 'Skip' Gates and others. On October 24, Osbourne penned an absorb-

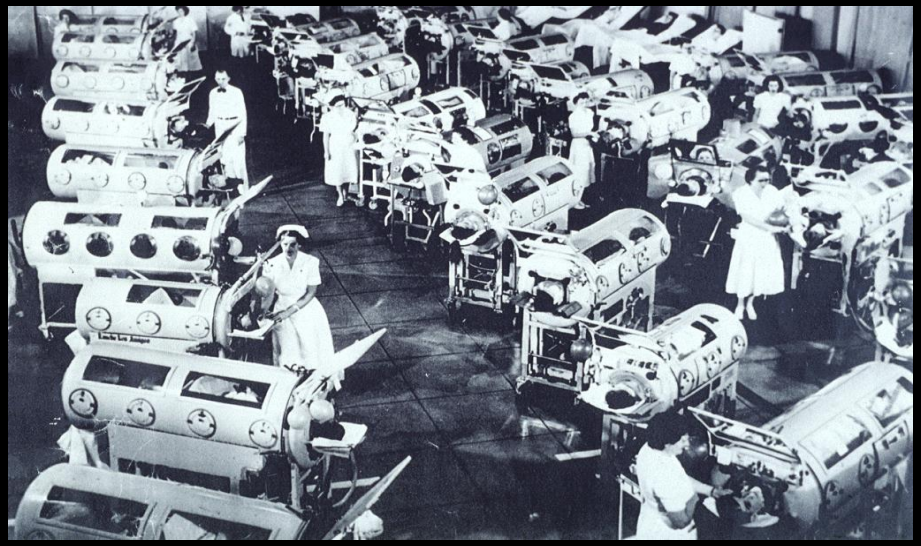
ALLSTAR PICTURE LIBRARY/ALAMY

"Given the swimming pools of booze I've guzzled over the years - not to mention all the [drugs]... there's really no plausible medical reason why I should still be alive. Maybe my DNA could say why."

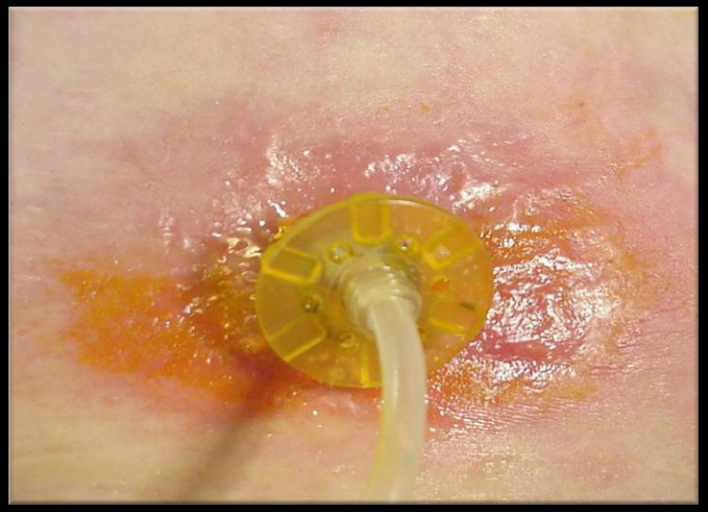
**Ozzy Osbourne**, writing in *The Sunday Times Magazine*

# Comfort and Complacency: The Enemies of Vigilance and Preparedness



# The Growing Challenge Posed by Antimicrobial Drug Resistance (AMR)



**NO ESKAPE**

***E**nterococcus faecium*

***S**taphylococcus aureus*

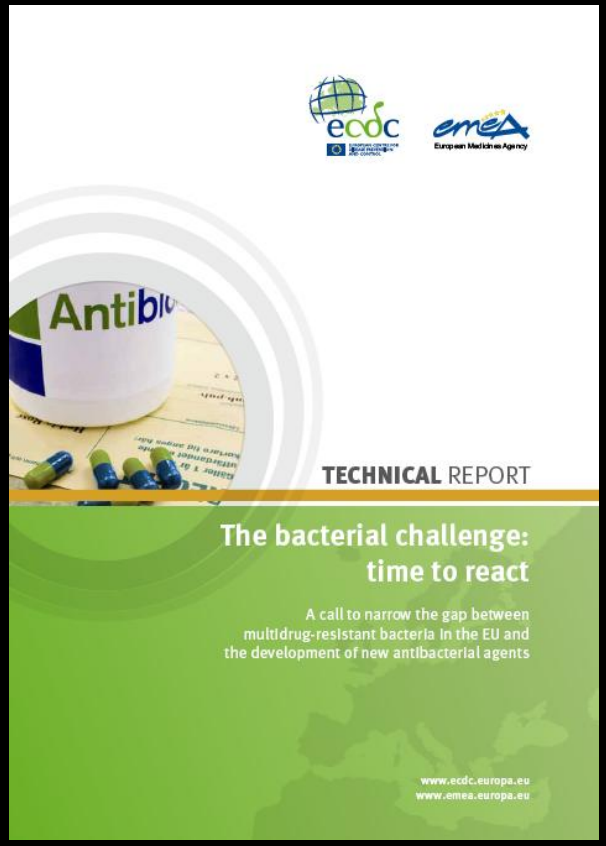
***K**lebsiella Pneumoniae*

***A**cinetobacter baumannii*

***P**seudomonas aeruginosa*

***E**nterobacter species*

# The Valley of Dearth: The Consequence of Declining R&D Investment in Antibiotic Discovery*



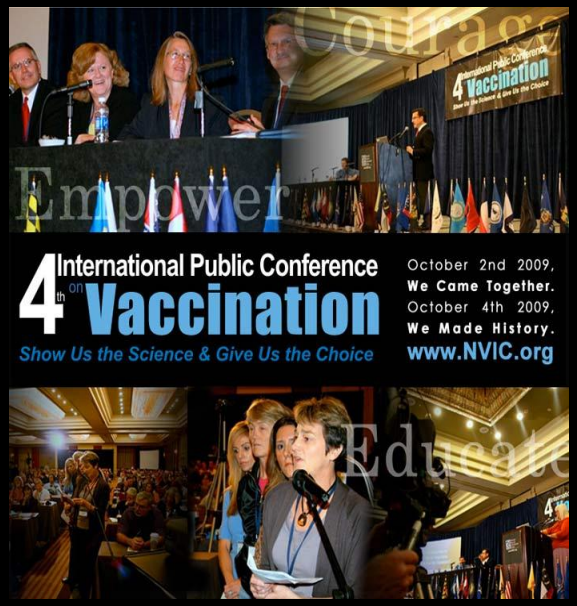

- 75% decrease in antibacterials approved from 1983 to 2009
- only 16 agents currently in Phase II / III clinical trials
  - only 3 as new ‘classes’ with novel mechanisms of action
  - absence of agents for therapy of AMR in Gram-negative bacilli
  - lack of systemic agents in advanced development for organisms resistant to all current antibacterials

* source: H.W. Boucher et. al. (2009) Clin. Inf. Dis. 48, 1

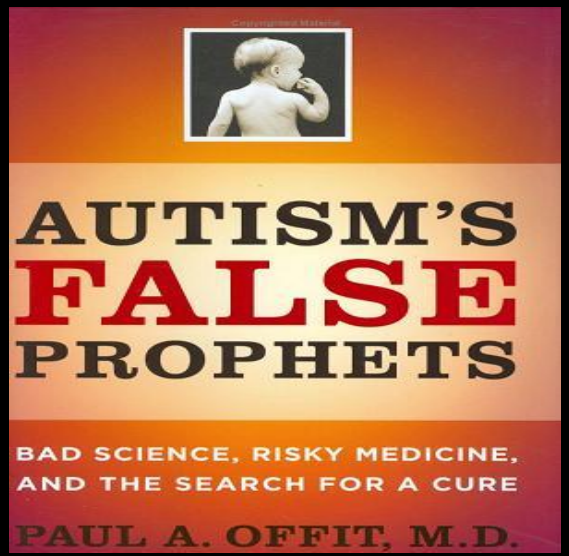
# Vaccine Safety:
# Informing the Misinformed

# Vaccine Safety:
# Media Sensationalism and Celebrity Quackery









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BMJ 2011;342:c5347 doi:10.1136/bmj.c5347 (Published 5 January 2011)
**Cite this as:** BMJ 2011;342:c5347

Feature

**Secrets of the MMR scare**

# How the case against the MMR vaccine was fixed

**Brian Deer**, journalist

+ Author Affiliations

briandeer.com

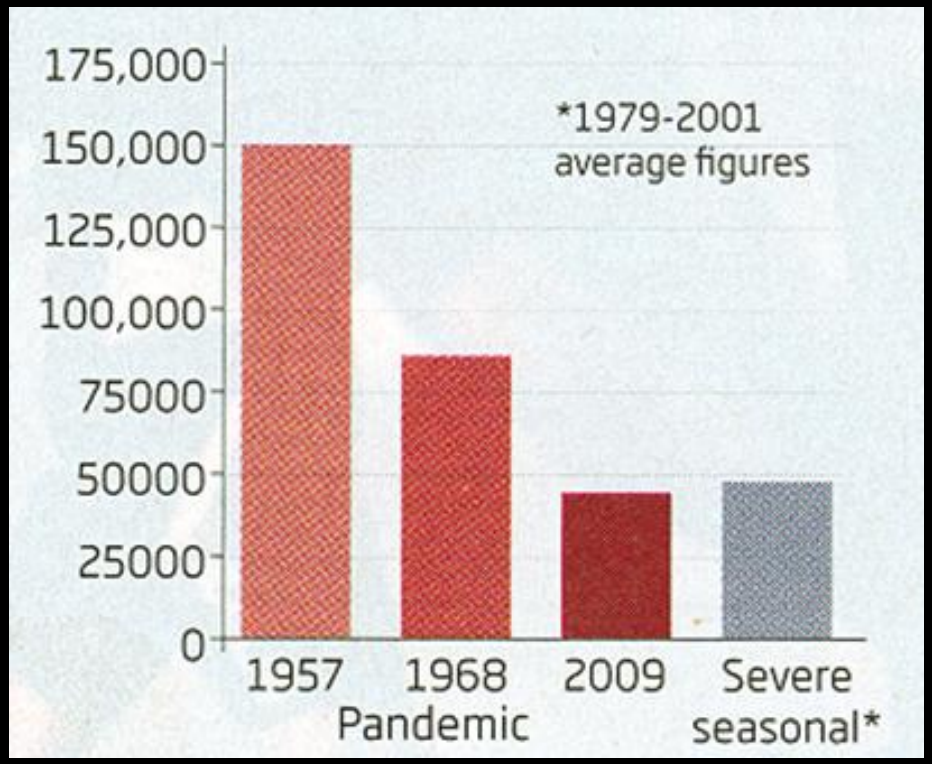
*In the first part of a special BMJ series, **Brian Deer** exposes the bogus data behind claims that launched a worldwide scare over the measles, mumps, and rubella vaccine, and reveals how the appearance of a link with autism was manufactured at a London medical school*

When I broke the news to the father of child 11, at first he did not believe me. "Wakefield told us my son was the 13th child they saw," he said, gazing for the first time at the now infamous research paper which linked a purported new syndrome with the measles, mumps, and rubella (MMR) vaccine.[1] "There's only 12 in this."

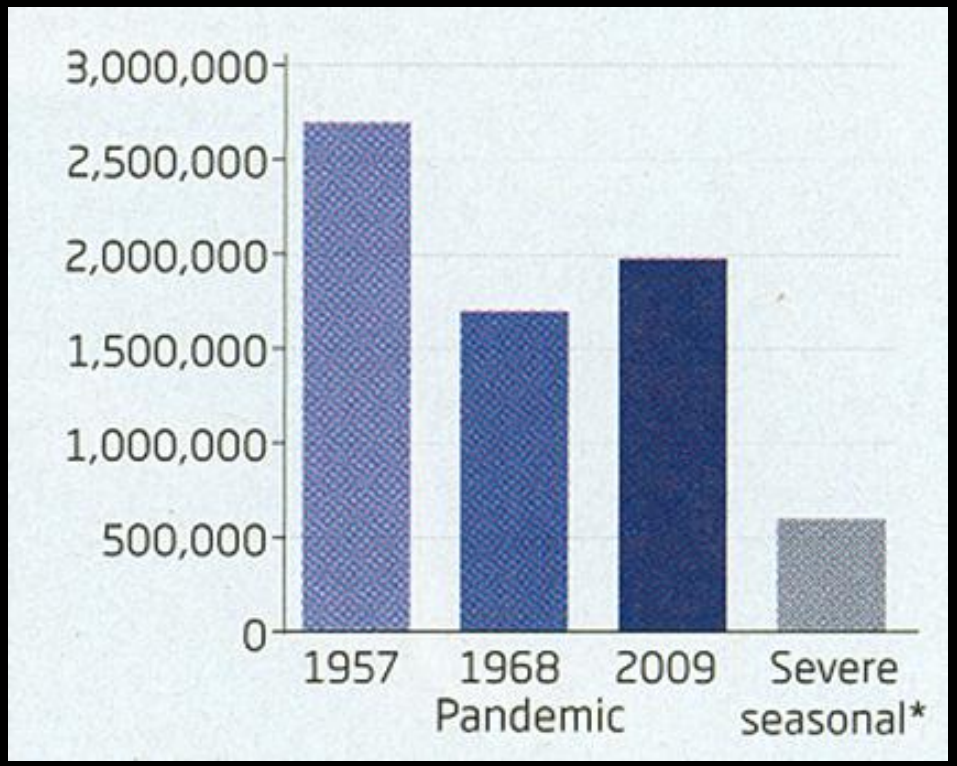
That paper was published in the *Lancet* on 28 February 1998. It was retracted on 2 February 2010.[2] Authored by Andrew Wakefield, John Walker-Smith, and 11 others from the Royal Free medical school, London, it reported on 12 developmentally challenged children,[3] and triggered a decade long public health scare.

# H1N1 Influenza (2009): Years Life Lost Analysis

**NUMBER OF US DEATHS FROM FLU**
**(adjusted to 2000 population)**




**YEARS OF LIFE LOST DUE TO FLU IN US**
**(adjusted to 2000 population)**




**From: PLoS Currents: Influenza (bit.ly/dis6p7).**

http://www.newscientist.com/article/mg20627545.000-swine-flu-no-big-deal-look-at-years-of-life-lost.html

# Translation of the Major Potential of Molecular Medicine into Routine Clinical Practice

## A Complex Multi-Dimensional Challenge

# The Real World

- innovation in science and technology alone is necessary but not sufficient
- adoption requires overcoming multiple barriers
  - existing competition/standard of care
  - cultural conservatism
  - reimbursement and other financial obstacles
  - regulatory hurdles
- wide variation in routine adoption speed of new technologies by different sectors
  - healthcare (10-30 years)
  - computing (1-2 years)
  - engineering (1-10 years)

# If You Build It Will They Pay?
# Adoption of Disruptive Innovation

- new technology/service that simplifies a complex/costly problem
- business model that allows market adoption of the simplified solution at low(er) cost
- incentivized supply and demand to networks to reinforce the disruption

# Reasonable Expectations for Rational Healthcare

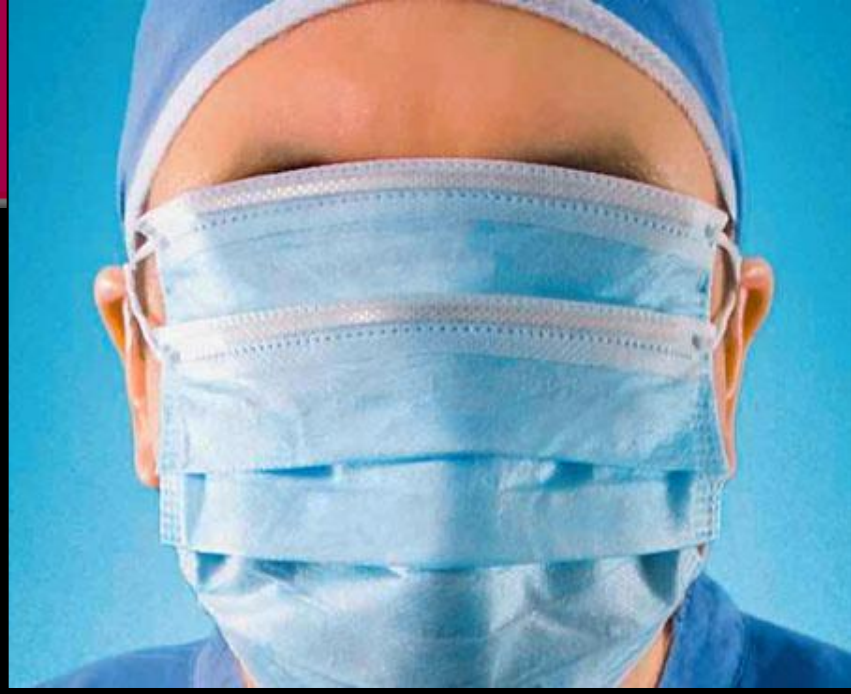
- what works?
- why it works?
- who it works for?
- what works best?
- when should it be used optimally?

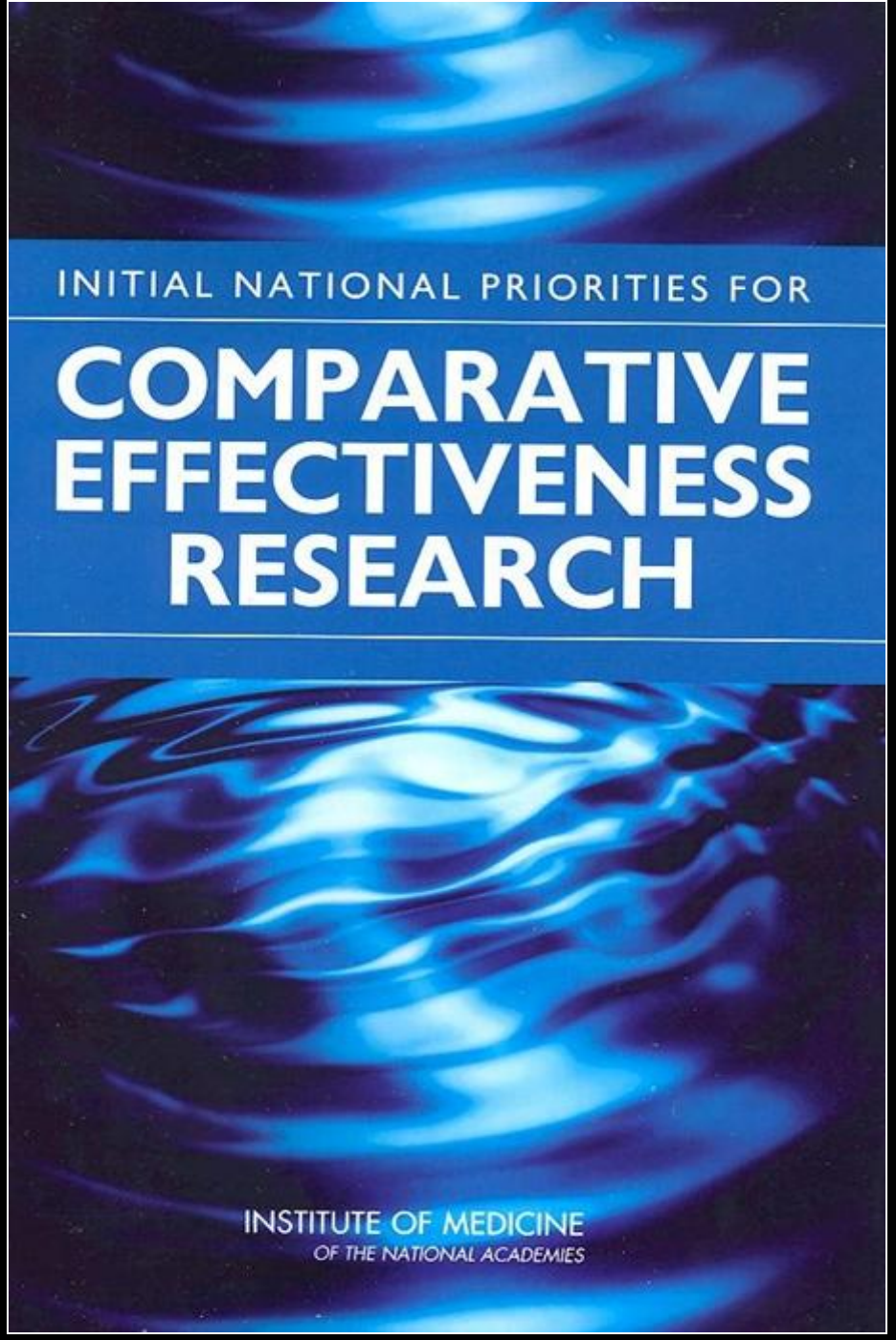
- validated evidence
- mechanism of action
- personalized medicine
- comparative effectiveness
- best practice guidelines, standard-of-care and malpractice

**VALUE**

# Knowing What Works (or Doesn't)

- Pervasive Inefficiencies and Errors in Healthcare Created by Empirical Care and Lack of Robust Outcomes and Performance Data



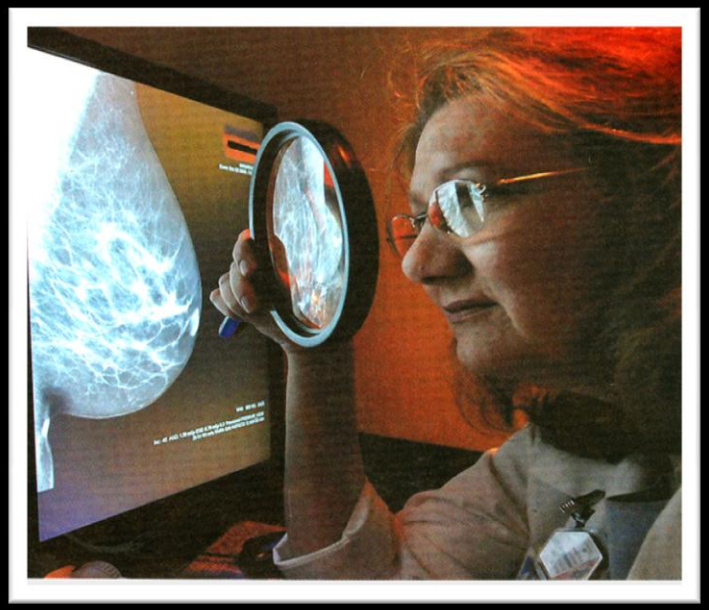


INITIAL NATIONAL PRIORITIES FOR
COMPARATIVE EFFECTIVENESS RESEARCH
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES

# Comparative Effectiveness Research (CER)

- superficial appeal of rational policy belies the complexity of rigorous CER
  - endpoints/outcomes
  - methodological and reporting standardization
  - stringency of patient selection/treatment regimen/compliance
  - prospective versus retrospective data
- payor engagement and impact on reimbursement policies
  - predisposition to chose lower cost intervention(s)?
  - risk of abuse and rationing of care

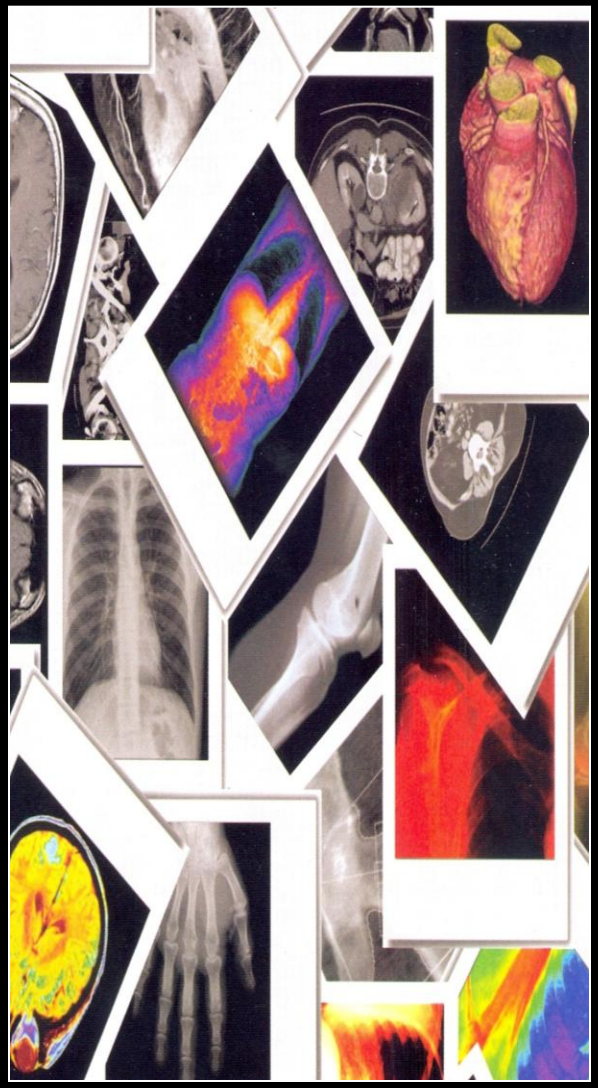
**WHO SETS PRIORITIES AND EVALUATION CRITERIA?**

# Who Defines Best Practices?



- controversy over US Preventive Task Force (USPTF) recommendations on mammograms for women age 40-49
- endorsed by ACP
- opposed by ASCO and NCCN
- USPTF did not address cost but it dominated public debate
- “should policy makers set a price on saving a life?”

# How Much New Technology Can We Afford?



# UK National Institute for Health and Clinical Excellence (NICE)

# NICE Gets Nasty (or Rational?)

# What Are We Willing to Pay for Added Months of Survival in Cancer?

| Lifetime cost above standard care | If cancer is on par with other diseases ($150,000 per life year gained), months of added overall survival benefit needed | Treating cancer as worthy of much higher reimbursement ($250,000 per life year gained), months of added overall survival benefit needed |
|---|---|---|
| $50,000 | 4 months | 2.4 months |
| $100,000 | 8 months | 4.8 months |
| $150,000 | 12 months | 7.2 months |
| $200,000 | 16 months | 9.6 months |
| $250,000 | 20 months | 12 months |
| $300,000 | 24 months | 14.4 months |
| $350,000 | 28 months | 16.8 months |
| $400,000 | 32 months | 19.2 months |
| $450,000 | 36 months | 21.6 months |
| $500,000 | 40 months | 24 months |

Source: Pink Sheet 13 Sept. 2010. Adapted from S. Ramsey FHCRC, ASCO 2010

Dr. Donald Berwick

**“I have a very romantic view of the NHS”**

**Interview in Health Affairs**
**April 2010**

NEJM (2010) 363, 2124

SPECIAL ARTICLE

# Temporal Trends in Rates of Patient Harm Resulting from Medical Care

Christopher P. Landrigan, M.D., M.P.H., Gareth J. Parry, Ph.D., Catherine B. Bones, M.S.W., Andrew D. Hackbarth, M.Phil., Donald A. Goldmann, M.D., and Paul J. Sharek, M.D., M.P.H.

ABSTRACT

BACKGROUND

In the 10 years since publication of the Institute of Medicine's report *To Err Is Human*, extensive efforts have been undertaken to improve patient safety. The success of these efforts remains unclear.

METHODS

We conducted a retrospective study of a stratified random sample of 10 hospitals in North Carolina. A total of 100 admissions per quarter from January 2002 through December 2007 were reviewed in random order by teams of nurse reviewers both within the hospitals (internal reviewers) and outside the hospitals (external reviewers) with the use of the Institute for Healthcare Improvement's Global Trigger Tool for Measuring Adverse Events. Suspected harms that were identified on initial review were evaluated by two independent physician reviewers. We evaluated changes in the rates of harm, using a random-effects Poisson regression model with adjustment for hospital-level clustering, demographic characteristics of patients, hospital service, and high-risk conditions.

RESULTS

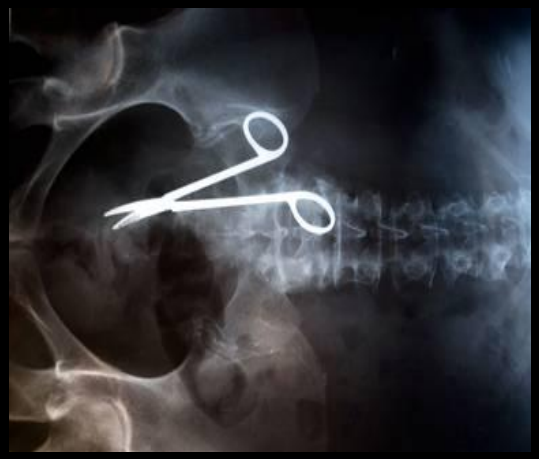
**Among 2341 admissions, internal reviewers identified 588 harms (25.1 harms per 100 admissions; 95% confidence interval [CI], 23.1 to 27.2). Multivariate analyses of harms identified by internal reviewers showed no significant** changes in the overall rate of harms per 1000 patient-days (reduction factor, 0.99 per year; 95% CI, 0.94 to 1.04; P=0.61) or the rate of preventable harms. There was a reduction in preventable harms identified by external reviewers that did not reach statistical significance (reduction factor, 0.92; 95% CI, 0.85 to 1.00; P=0.06), with no significant change in the overall rate of harms (reduction factor, 0.98; 95% CI, 0.93 to 1.04; P=0.47).

CONCLUSIONS

In a study of 10 North Carolina hospitals, we found that harms remain common, with little evidence of widespread improvement. **Further efforts are needed to translate effective safety interventions into routine practice and to monitor health care safety over time.** (Funded by the Rx Foundation.)

# Patient Safety:
# The Dimension of the Problem

**Overt Error** | **Non-Compliance** | **Adverse Rx Event**





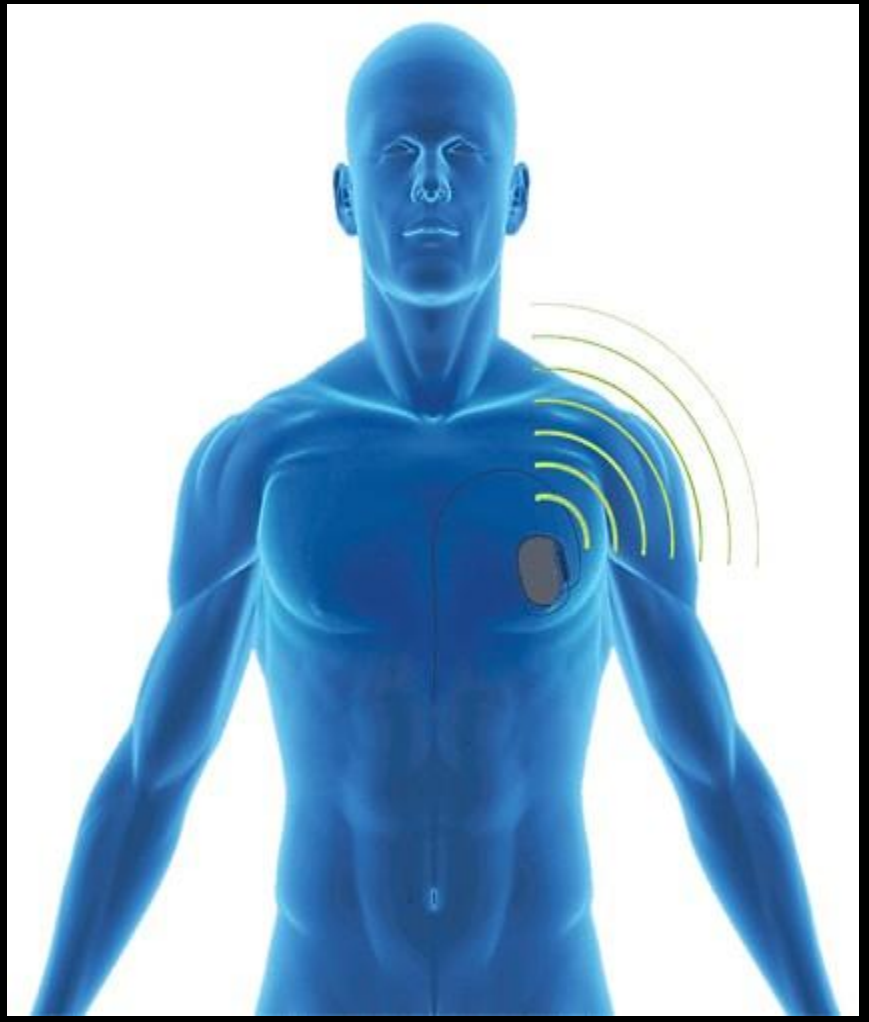
**Hospital-Acquired Infections** | **Cost of Hospital Re-admissions** | **Inaccurate, Inaccessible or Ignored Information**

# Applications of RFID Technology in Healthcare

- patient ID, tracking and status monitoring
- location of equipment and assets
- supply chain management
- surgical QC inventory of instruments/materials
- directed endoscopy and placement of microdevices
- patient support device alarms
- product authentication
- capture of device-generated data and uploading to EHR

# Safety

Interference in High Density Medical Device Areas



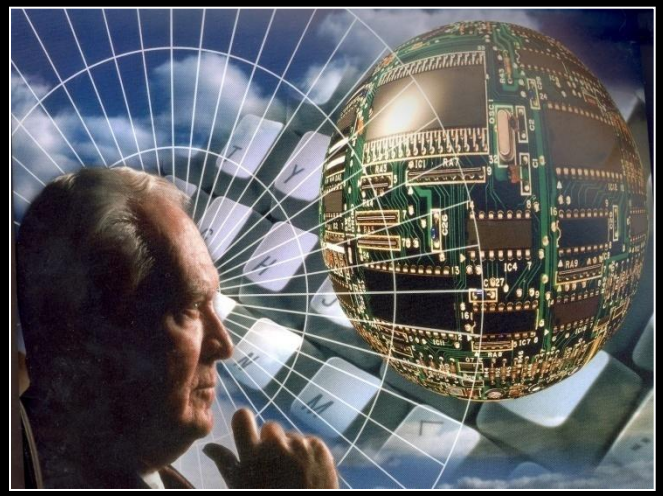
The Security of Medical Devices is Not a Luxury

# Bad Habits

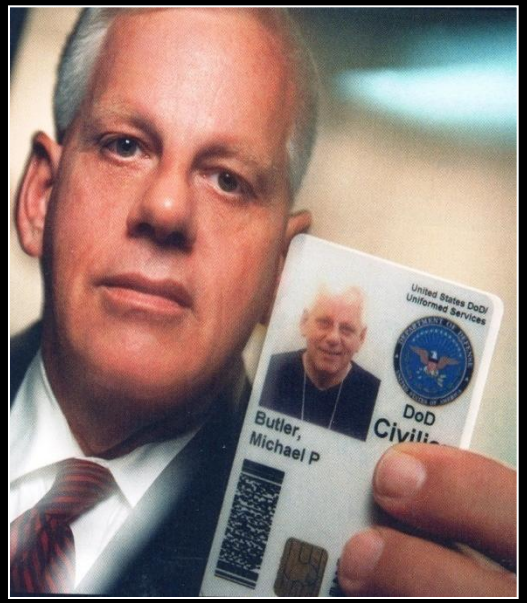
non-sterilizable m.devices


non-consented ID

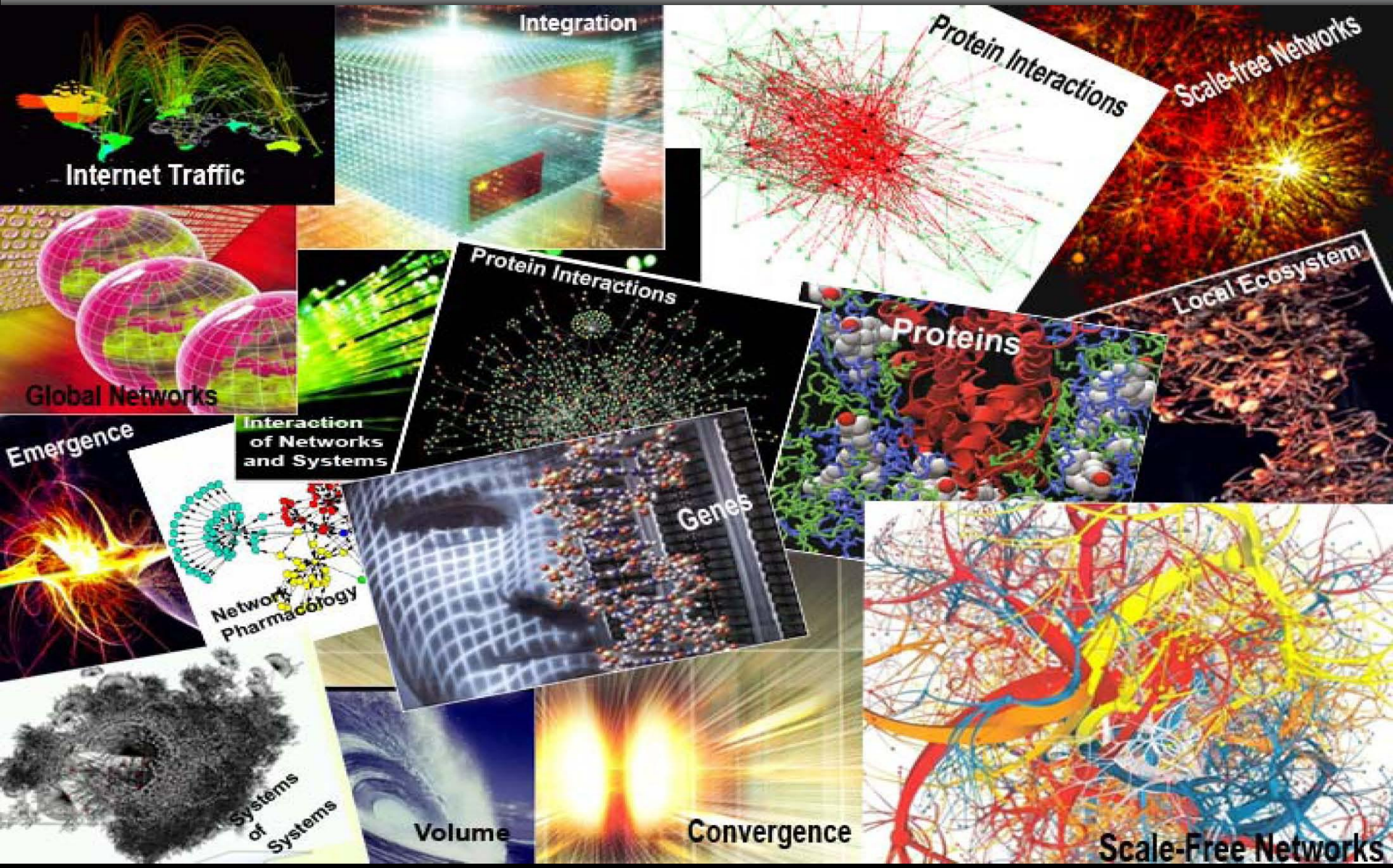
# The Infocosm: Emerging Networks of Global Connectivity



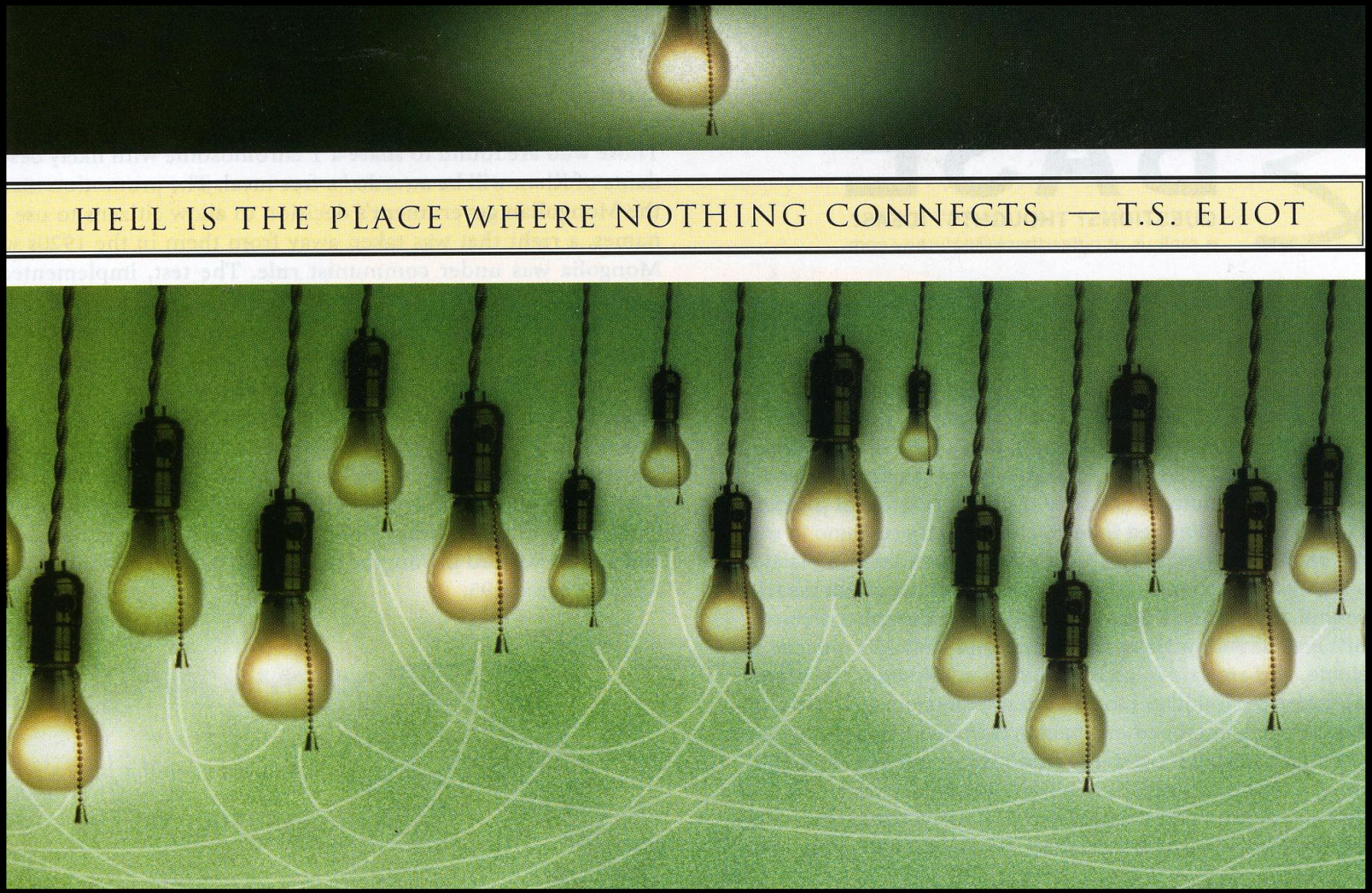




# Data: The Fastest Growing Resource on Earth



# Information-Based Medicine

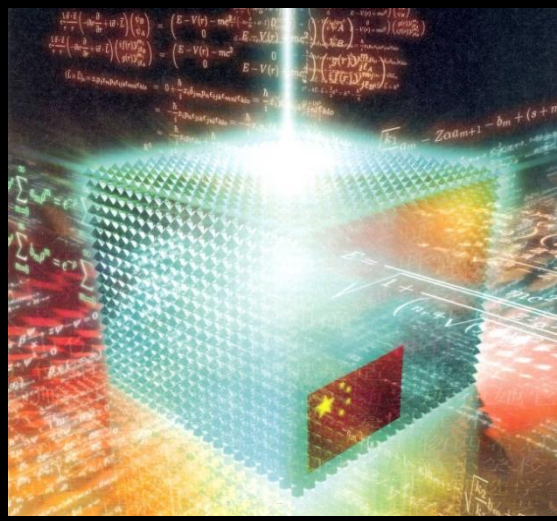


# “Managing Mega-Data”

volume

infrastructure

global networks



multiscale heterogeneity

integration

# Data Exchange Standards

- integrate data from multiple sources
- inter-operability challenge from discovery to clinical practice
- leveraging existing HL7 standards
  - Draft Standards for Trial Use (DSTU)
- engage major data generators and regulators
  - CDISC, ICH
- Digital Imaging and Communications in Medicine (DICOM)
- seamless federation with healthcare system and reimbursement databases
  - CPT, ICD (USA)
- certification of compliance with HITECH EHR Standards (HIMSS, AHIMA)

# Telecommunications and Media Industry Convergence: Implications for Healthcare

# Sensor Networks for Remote Health Status Monitoring
# Wireless Integrated Data Systems

- geolocation data (where)
- temporal information (when)
- contextual information (what)

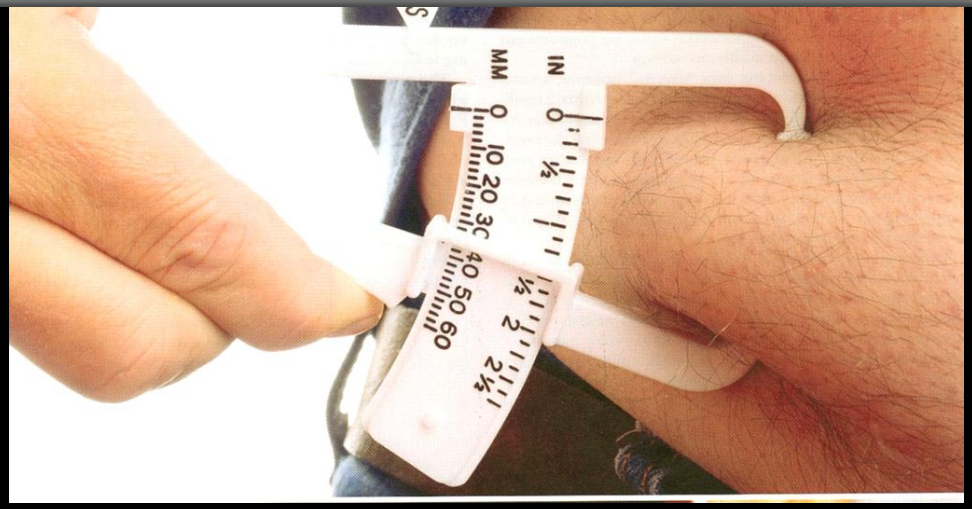
# Wellness:

**The Most Broad and Most Valuable Definition of Successful Healthcare**

**Consumers at the Center**

# After a Short Stay in America, Michelangelo's David Returned to Europe

# Consumer Behavior and Healthcare Costs



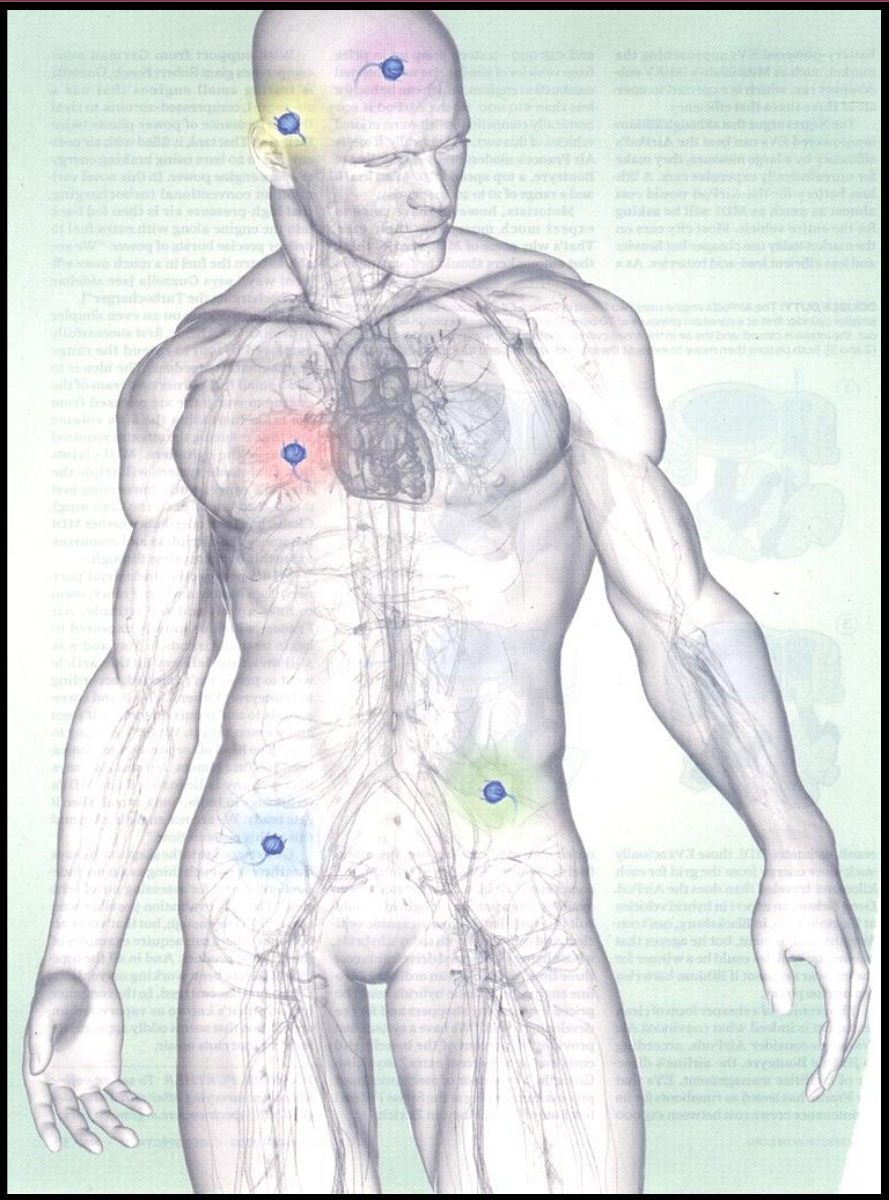

**“diabesity” $200 billion**

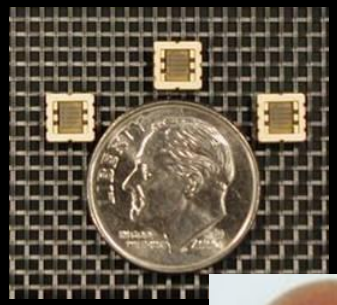
**smoking $190 billion**
**alcohol $20 billion**

# Engaging Consumers and Patients for Wellness and Greater Responsibility for Mitigation of Health Risk(s)

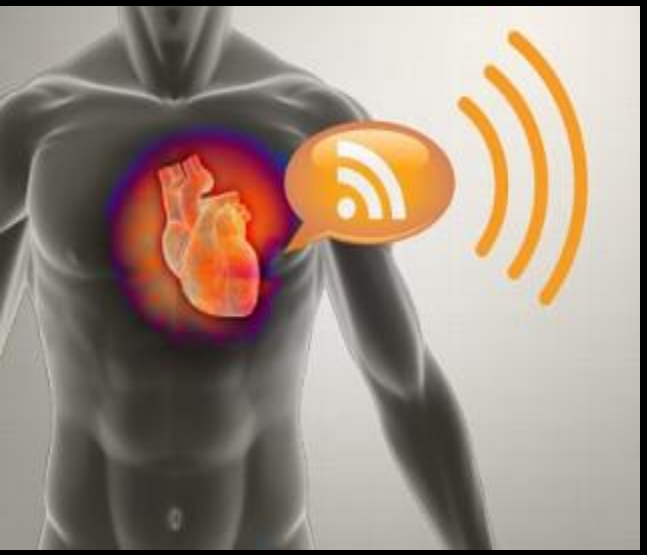
- entitlement mentality
- lack of accountability
- lack of transparency in pricing and evidence-based performance to guide choice
- cost-shifting
  - a negative but blunt economic driver
- economic incentives
  - positive drivers for wellness
  - employers, payors, taxation policies
- providing tools and information to support informed choices and improved outcomes tracking

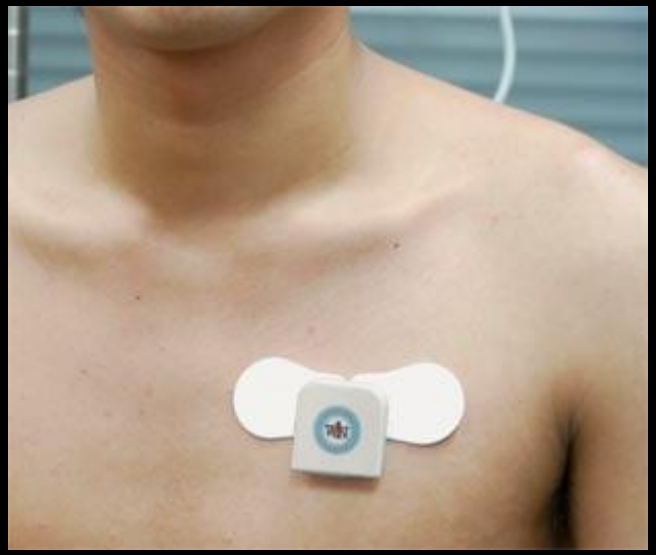
# On Body: In Body Sensors/Devices: Real Time and Remote Monitoring of Individual Health Status



# Wireless Devices and Health Status Monitoring



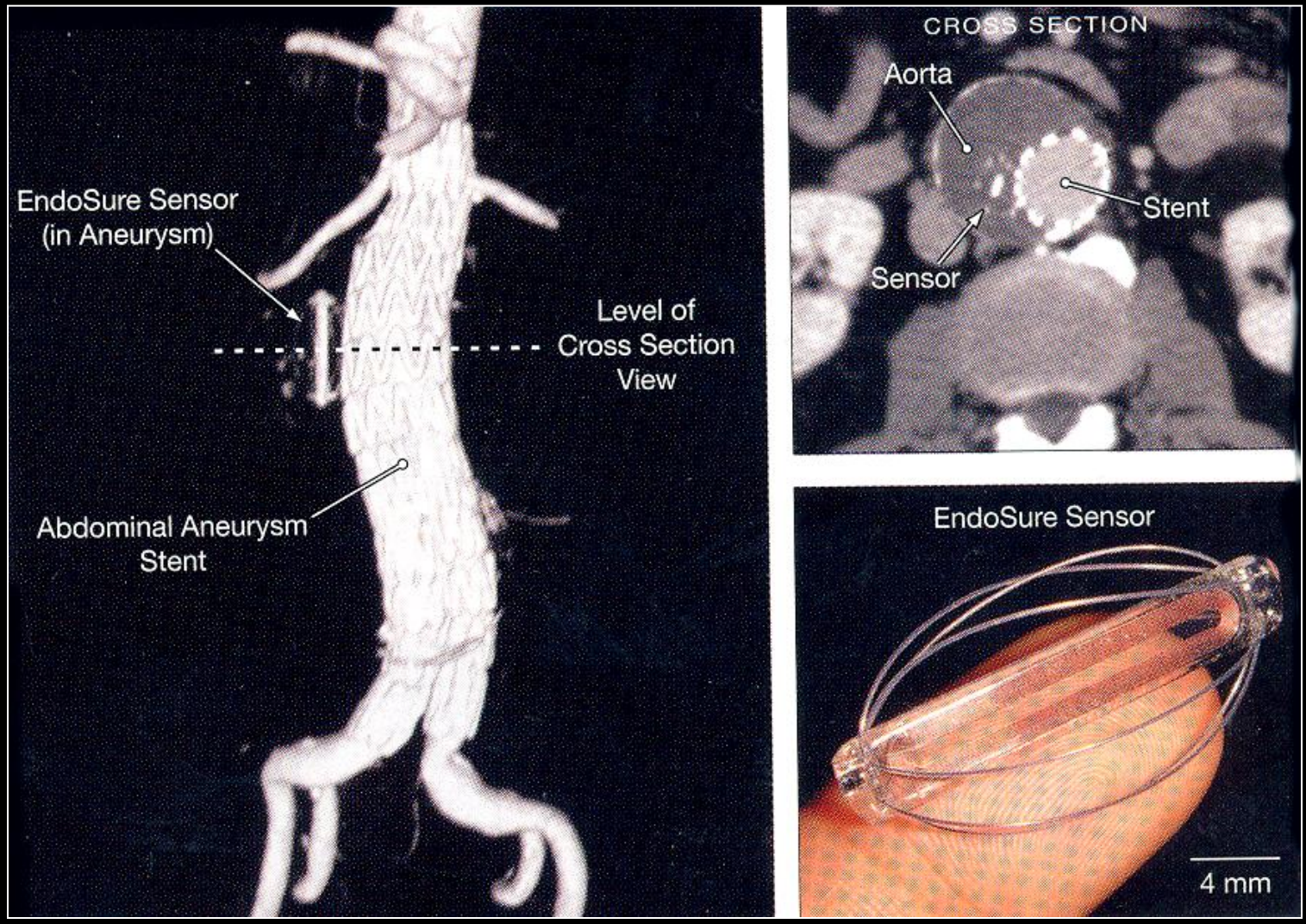


# PressureAlert™ Orthotic System



A pressure sensing Orthotic to alert patients and/or their caregivers when blood flow may have been compromised to the point where serious injury may occur

# Wireless Biosensor to Monitor Stent Stability in Surgically-Repaired Abdominal Aortic Aneurysm




T. Ohki (2006) JAMA 296, 2667 and CardioMEMS, Atlanta

# The Economist 10 April 2010


Wireless health care

## When your carpet calls your doctor

# Biomarkers and Personalized Medicine: A Broader Perspective

- real-time monitoring of patient (consumer) behavior
- sensors and remote health status monitoring
  - physiological parameters and deterioration
  - Rx compliance
  - emergency medical response
- telecare: mHealth
- support services for EMI (elderly-mentally infirm)

# Personal Health


**“This isn’t a device it’s a service.”**

**Jeff Bezos**
**CEO, Amazon**

# m.Health




**Remote Health Monitoring and Chronic Disease Management**

**Lifestyle and Fitness**

**Information for Proactive Health Awareness (Wellness)**

# Personal Health Systems: On-Body: In-Body Sensors (OBIBs)

- wearable
- portable/mobile
- point-of-care
- implantable
- multi-parametric
- interoperability with electronic records

**Mobile Health (mHealth)**

# Major Target Markets for Wireless Medicine

| Disease | *Patients | Parameter |
|---|---|---|
| Alzheimer's | 5 million | vital signs, location, activity, balance |
| Asthma | 20 million | respiratory rate, FEV, air quality, oximetry, pollen count |
| Breast CA | 3 million | ultrasound self-exam |
| COPD | 10 million | respiratory rate, FEV, air quality, oximetry |
| Depression | 19 million | medication compliance, communication |
| Diabetes | 21 million | glucose, hemoglobin ATC |
| Heart Failure | 5 million | cardiac pressures, weight, blood pressure fluid status |
| Hypertension | 74 million | continuous blood pressure monitoring, medication compliance |
| Obesity | 80 million | smart scales, caloric in/out, activity |
| Sleep Disorders | 15 million | sleep phases, quality, apnea, vital signs |

From: West Wireless Health Institute, Medtech Insight, August 2009

# On Body: In Body Sensors and Devices

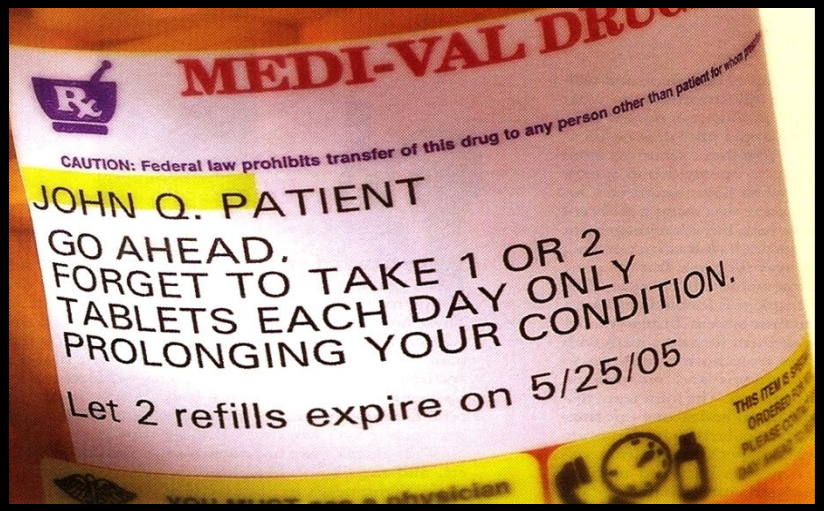
## Objective

- remote monitoring of health status

## Applications

- multi-feature monitoring and broad-band wireless networks
  - ubiquitous sensing
- enhanced autonomy for in-home aged
- proactive alerting and intervention to mitigate health incidents
- monitoring of patient compliance
- coupled linkage to remote Rx dispensing for efficient disease management

# The Costs of Non-Compliance with Rx Regimens





- **$177 billion projected cost**
- **20 million workdays/year lost (IHPM)**
- **40% of nursing home admissions**
- **projected 45-75% non-compliance (WHO)**
- **50-60% depressed patients (IHPM)**
- **50% chronic care Rx (WHO)**

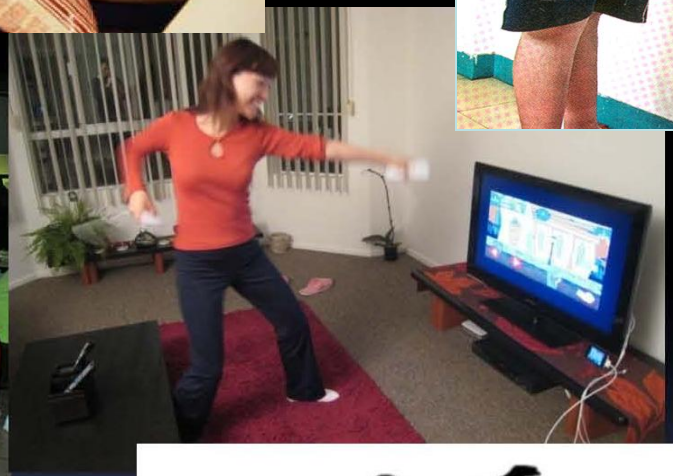
# Intelligent Medicine Dispensers for Enhanced Rx Compliance

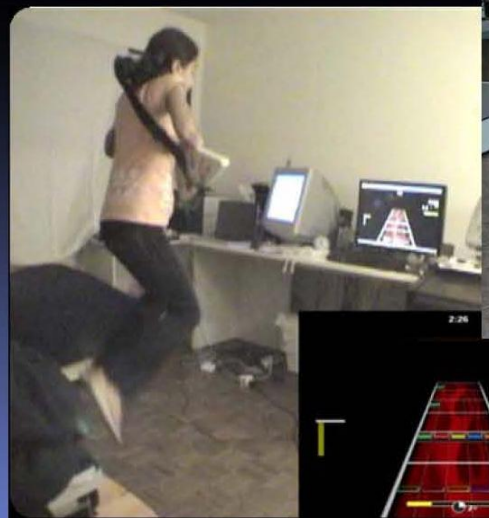

http://hypedesire.blogtv.com.pt/img/image/HypeDesire/2009/abril/glowcap3.jpg

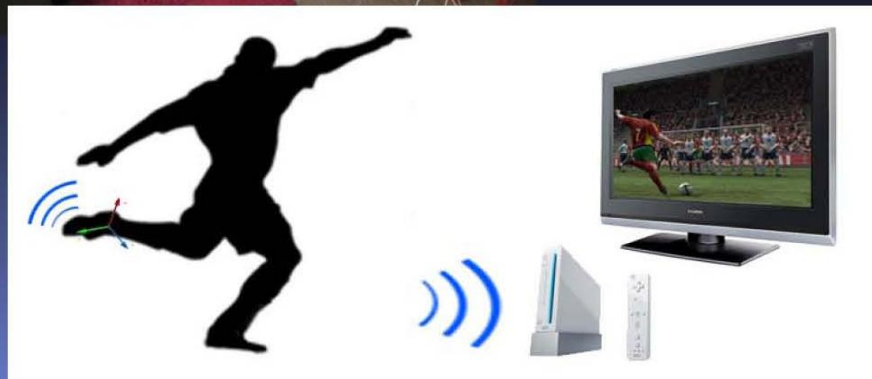
# Gaming for Health:











Wii Fit Plus

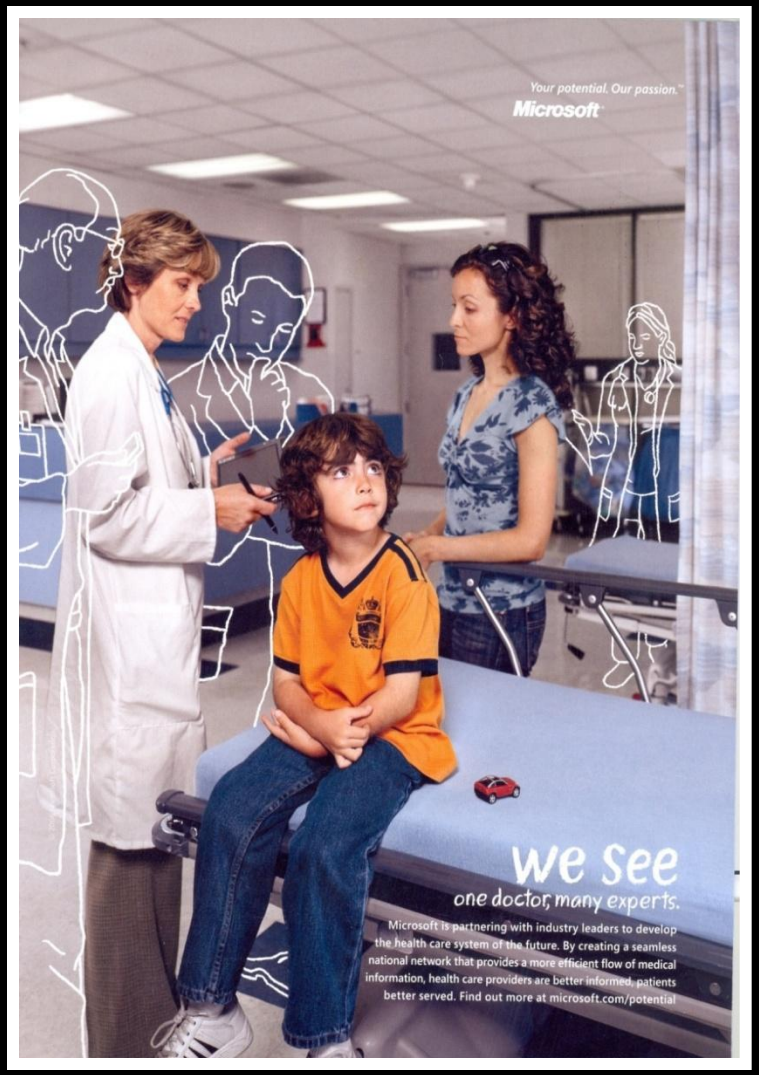
# You, Me and Health in a Networked World

- mobile
- multimedia
- monitored
- measured
- me, and those like me
- multiple markets of one, but primarily ME!

# m.Health as a Disruptive Change

- multidimensional impact on broad range of healthcare technologies/delivery processes
  - individual wellness to global public health
- information is power
  - redress medical paternalism and information asymmetry in healthcare decisions
  - consumer : patient empowerment
  - increased consumer:patient accountability for mitigation compliance risk
- key element in evolution of decentralized healthcare services
  - point-of-care diagnostics
  - treatment compliance
  - remote health status monitoring
  - emergency response

# Virtual Medicine Networks: Increasingly Integrated Care and Continuity of Care




## Clinical Networks

- rapid, real time access to expertise
- broader range of clinical specialties
- integrated health records
- availability of lab and Rx lab data
- drug interactions risk
- electronic Rx prescribing

## Consumer Health

- optimum use of ‘wellness’ products and
- databases on OTC product performance to accelerate Rx to OTC conversion for products that regulators would otherwise be reluctant to grant full OTC approval

# The Dominant Future Element in Primary Healthcare Delivery???

Walgreens
As far as you want to go.™

CVS CAREMARK

WAL★MART®
Save money. Live better.™



# The Expanding Universe of Health Information Resources

- diversified information sources
- dramatic expansion of social-media networks
- new brokers for validation of information authenticity
- shift in trust from traditional medical establishment to other institutions

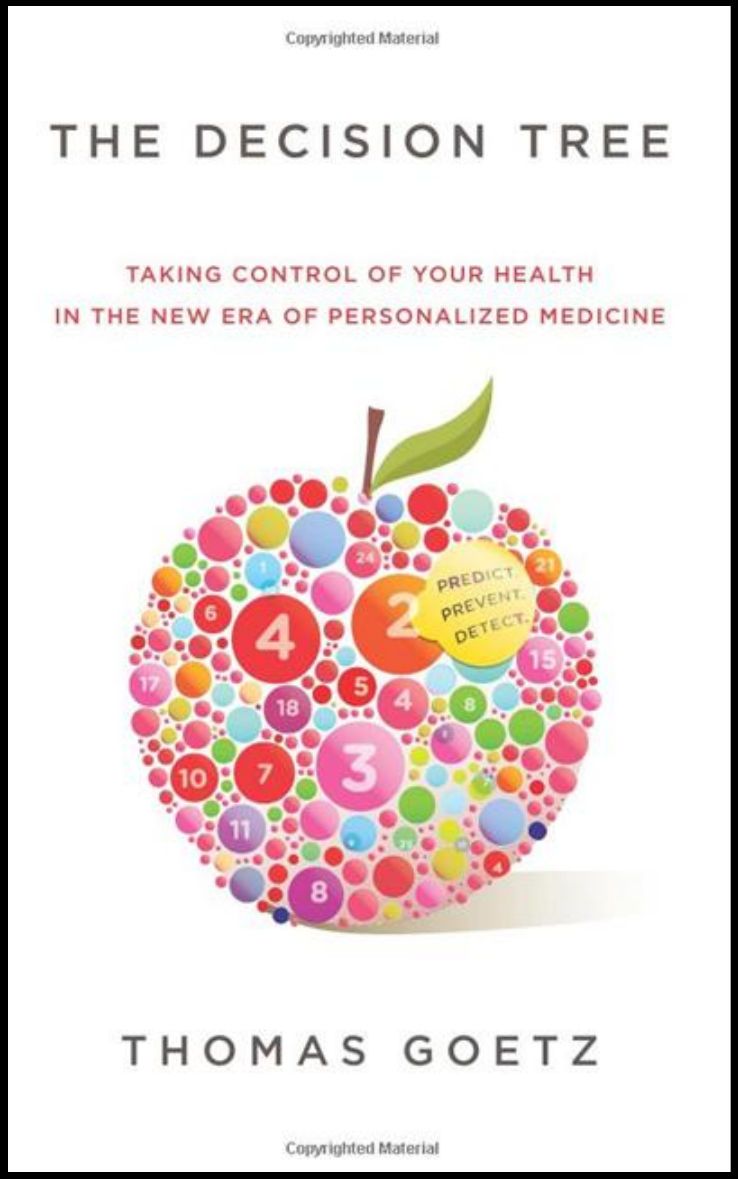
# Consumer: Patient Empowerment and a New Relationship with Healthcare Professionals

"What can you learn from your doctor that is not available on the internet?"

P. Hartzband and J. Groopman
Untangling the Web-Patients, Doctors and the Internet
NEJM (2010) 362, 1063

"In medicine, paternalism isn't a dirty word; it's the default mode."

Thomas Goetz
The Decision Tree (2010)
Rodale, New York, p. 245




**"Real personalized medicine should begin long before we're faced with pharmacology"**

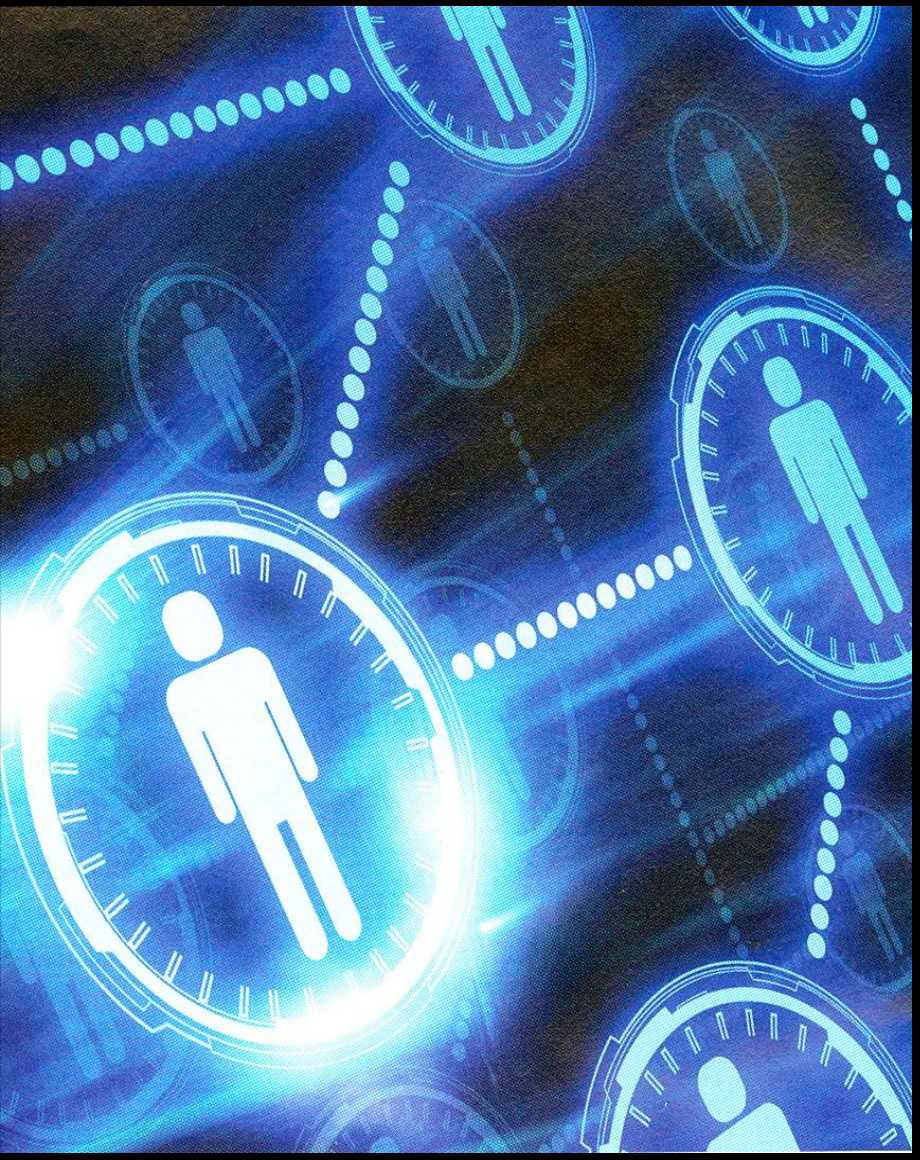
**"Our health information is too important to leave to an archaic, insular system.**

**If there's no longer a need to rely solely on a doctors advice for treatment and care, why should we be expected to artificially limit our options."**

**Thomas Goetz**
**Deputy Editor of Wired**

**The Decision Tree: Taking Control of Your Health in the New Era of Personalized Medicine (Hardcover)**
**Thomas Goetz** (Author) . Image Source: Amazon.com

# Social Networks and Consumer: Patient Empowerment




Source: R&D Directions May 2010

# From
# Healthcare Delivery
# To
# Health Systems and Services

## A Learning Health System

# Integration of Services
# and
# Simplification of Services

# ‘The Medical Home’: Integrated Care Services for Independent Living

Deloitte.

## Connected Care

*Technology-enabled Care at Home*

Produced by the
Deloitte Center
for Health Solutions

Audit . Tax . Consulting . Financial Advisory.

## State of Technology in Aging Services According to Field Experts and Thought Leaders


**By:**
Majd Alwan, Ph.D.,
Center for Aging Services Technologies (CAST)
American Association of Homes and Services for the Aging (AAHSA)

and

Jeremy Nobel, M.D., M.P.H.,
Harvard School of Public Health

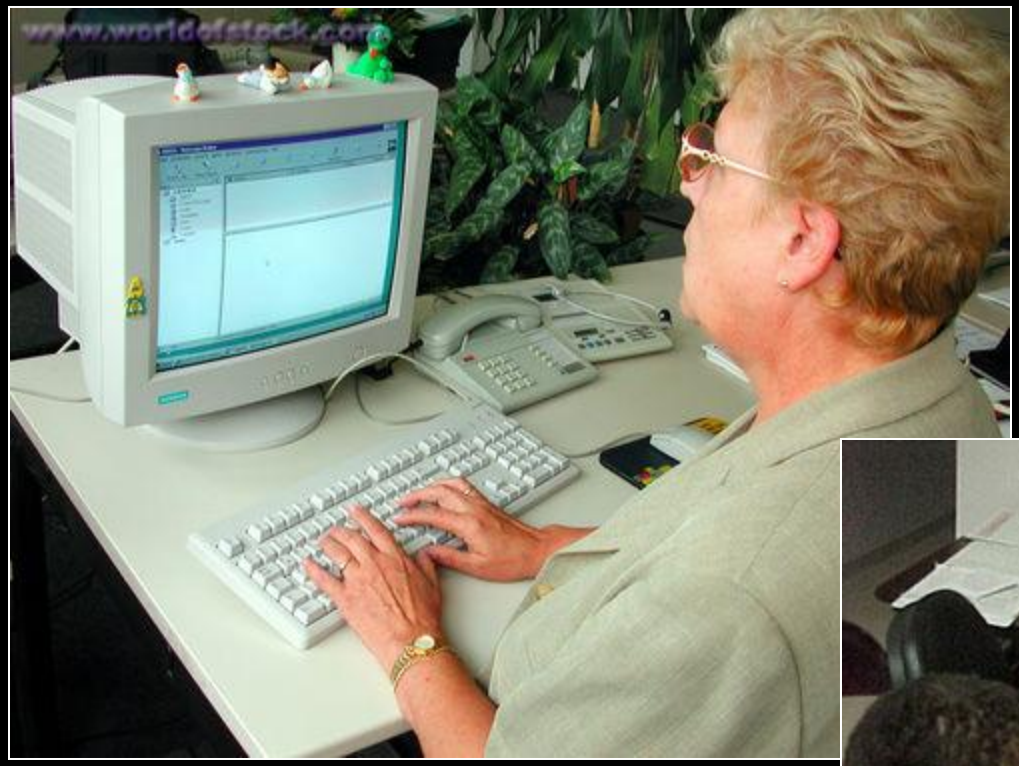


Report Submitted to: Blue Shield of California Foundation

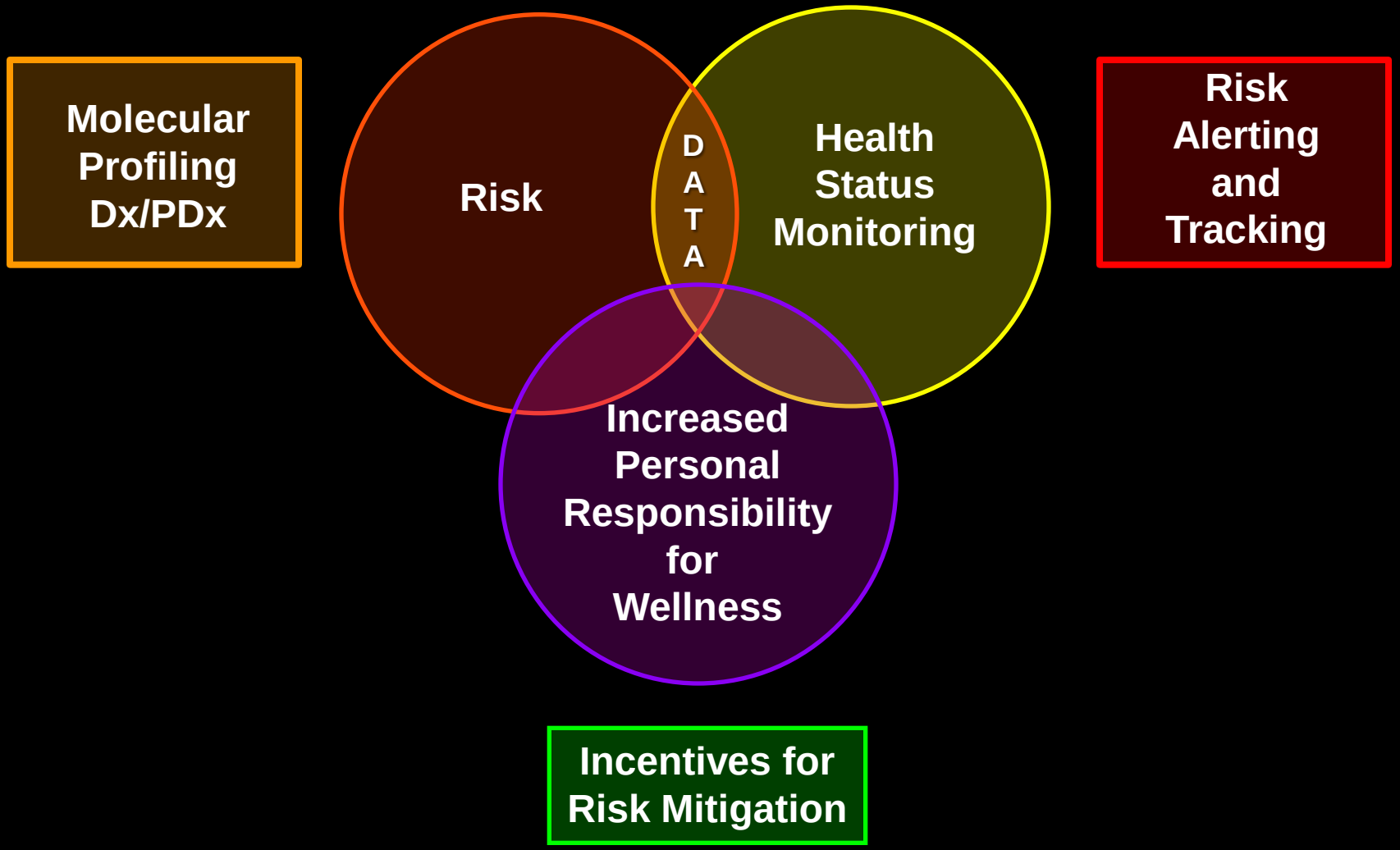
**February 2008**


cast™
Center for Aging Services Technologies

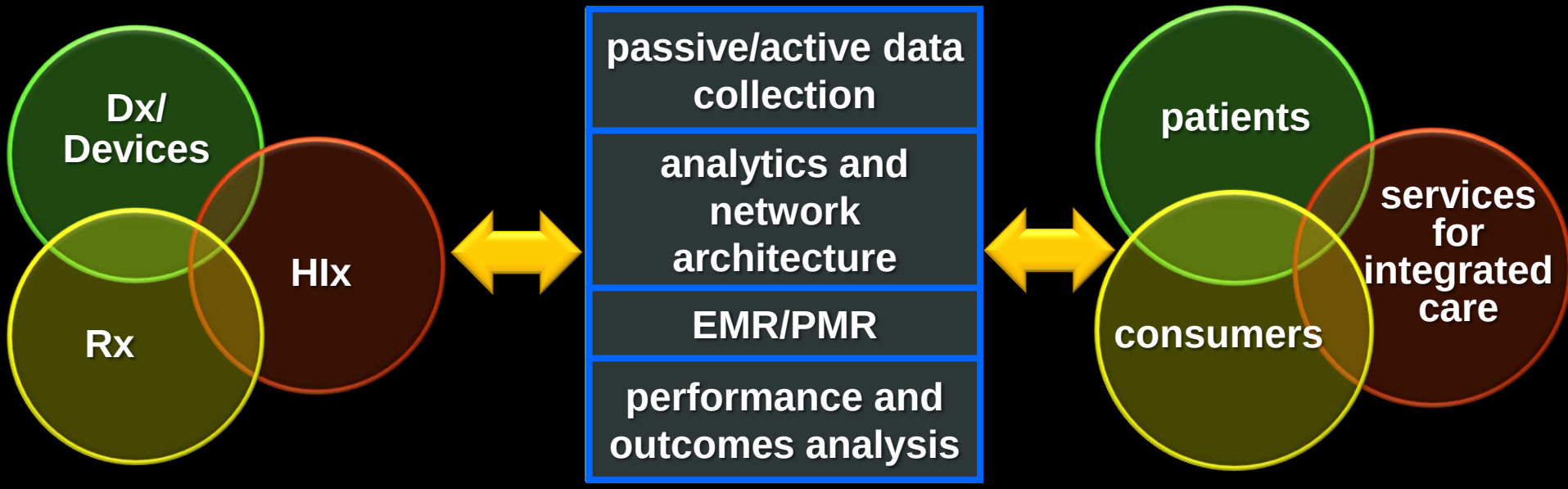
# In-Home Health Connection: Engaging the Elderly



# Molecular Diagnostics and Health Information Systems as a Key Element in the Evolution of Integrated Healthcare Delivery



# A New Healthcare Ecosystem Arising From Technology and Market Convergence




Integrated Technology Platforms

Data Mining and Integration Services

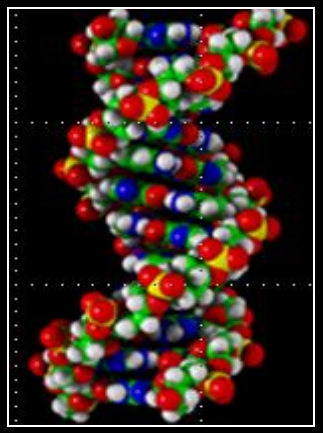
Increasingly Targeted Care and Efficient Use of Finite Resources

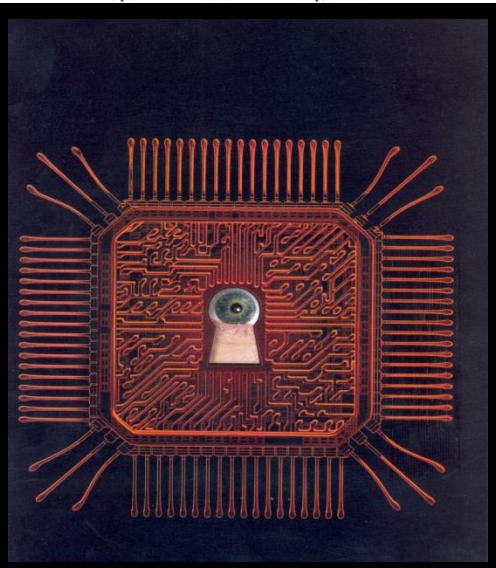
# Privacy and Health Information

- 2010: 15 Petabits ($10^{16}$) / $250,000
- Human Genome: 10 Gigabits ($10^{11}$)

*For a few million dollars, one could store the complete genome of every American and European*

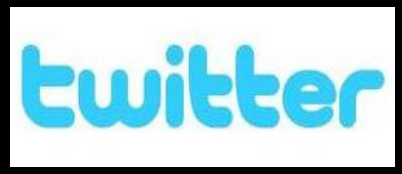
*…for several more, could add credit card records, telephone logs, travel history,…*





“We’ll have an entire generation of people
who never truly have a private moment”

Patrick Tucker
Director of Communications
World Future Society
www.laptopmag.com/2008/sept.



# From Ambiguity to Certainty: Competitive Superiority via Analysis of a Burgeoning Infocosm

- new intermediaries for analysis/packaging of healthcare data
- global sourcing of data and expertise
- decision-support systems, metrics and CER
- lower transactional costs
- higher efficiency in use of expensive, finite resources
- increasingly predictable cost structure and predictable performance of products and procedures
- improved clinical and economic outcomes

**CHANGING MINDS AND CHANGING BEHAVIORS**

# Sociology

# Patients

- want information regarding treatment options
- increasingly informed about options via web sources but want professional input to assist in interpretation
- generation-dependent preference/expectancy for shared role in decision-making
- improved outcomes and increased compliance when patients are engaged and informed

- major cultural gap in professional-patient interactions
- time and cost to healthcare professionals

# Certain Death in Uncertain Time: Balancing Hope and Hash Reality in Terminal Illness

"I respect the seriousness of death
I've had many occasions to meditate on its intrusions.
….the way the message was delivered.
Frankly, it made me furious."

Sen. Edward Kennedy
True Compass. A Memoir. 2009

# The Too Often Overlooked Communication Interaction Gap in Healthcare and Patient Safety

- "do you understand"
  - MD paternalism and patient timidity
  - a dangerous combination
- challenge for healthcare professionals
  - time and money but large component originates in culture/training
- often hold different perception to patients and priorities versus increasing problem in managing chronic disease and multiple co-morbidities
  - increased incidence of Rx/treatment errors, non-compliance and hospital readmissions
  - positive impact of discharge counseling by RNs and other non-MD health personnel
- the sociology of medical training and practice
  - hierarchical, authoritarian, paternalistic
  - inadequate focus on team-based needs

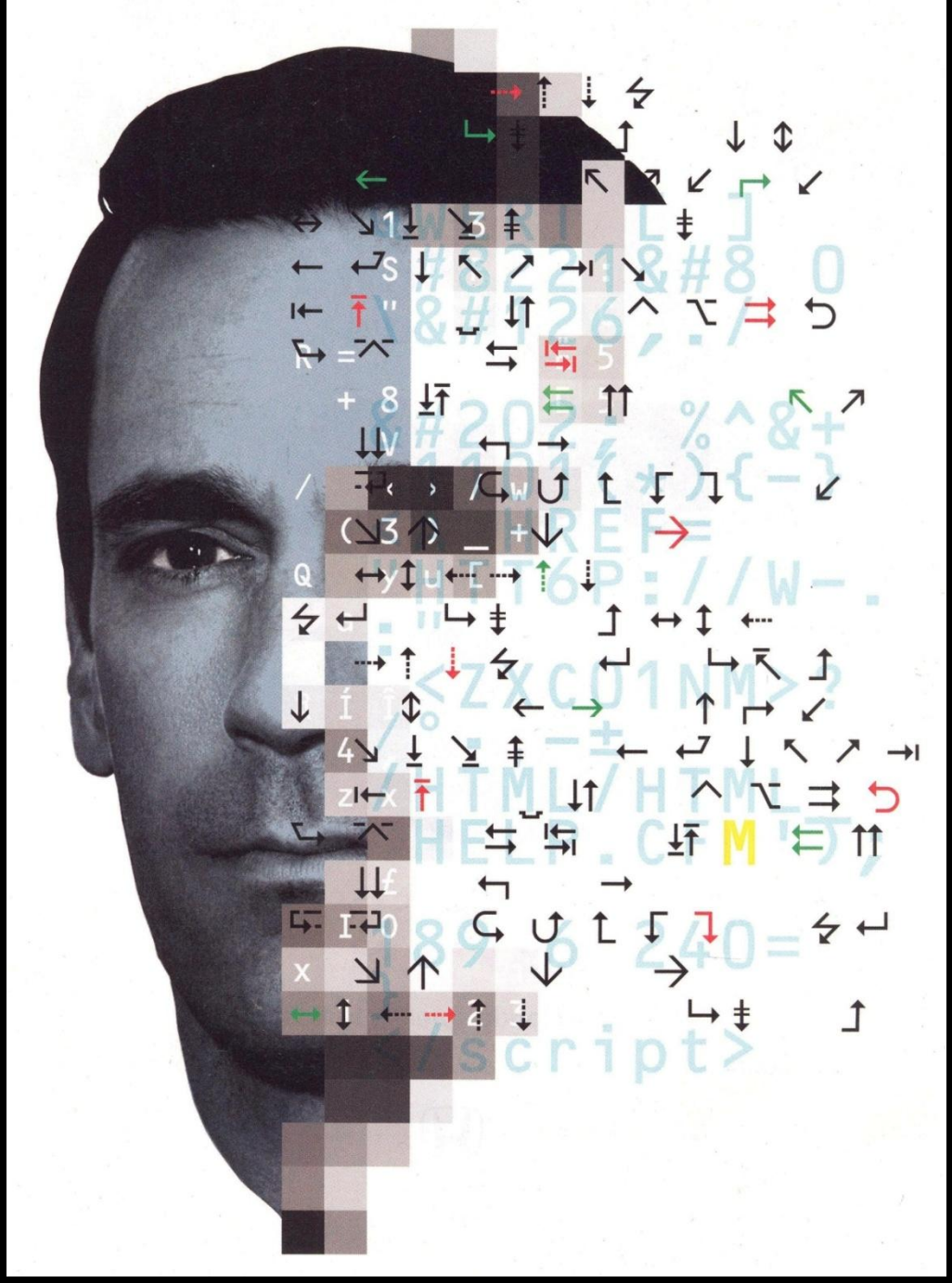
# The Fundamental Drivers of Healthcare Delivery: Implications for Training Physicians and Healthcare Professionals

- molecular medicine
- engineering-based medicine
- information-based medicine
- consumer-centric medicine
- recalibration of the roles/expectations and status of healthcare professionals

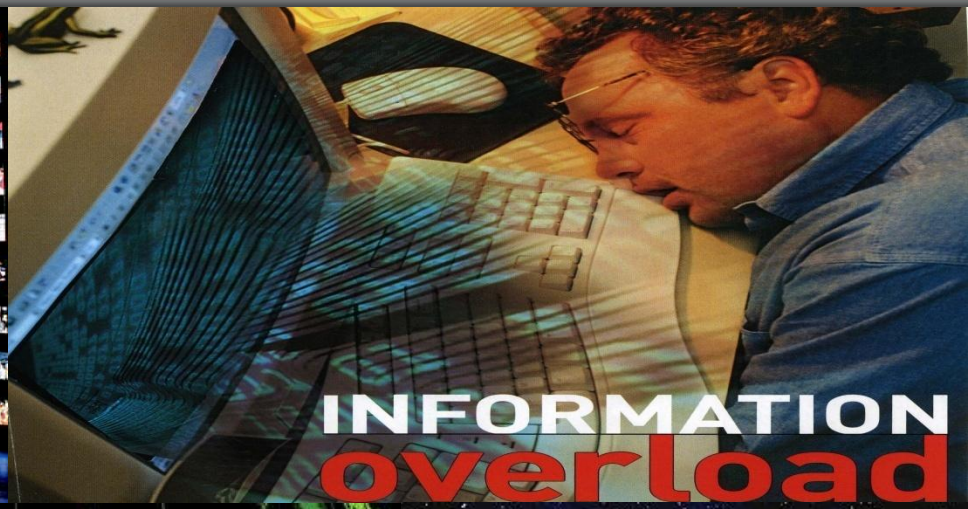
# Analytics for m.Health and HIT

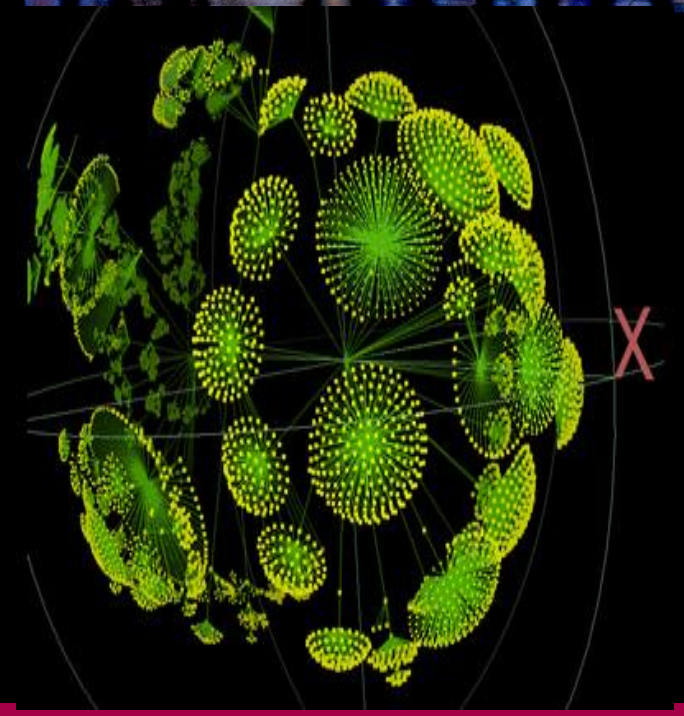
## New Roles and Competencies

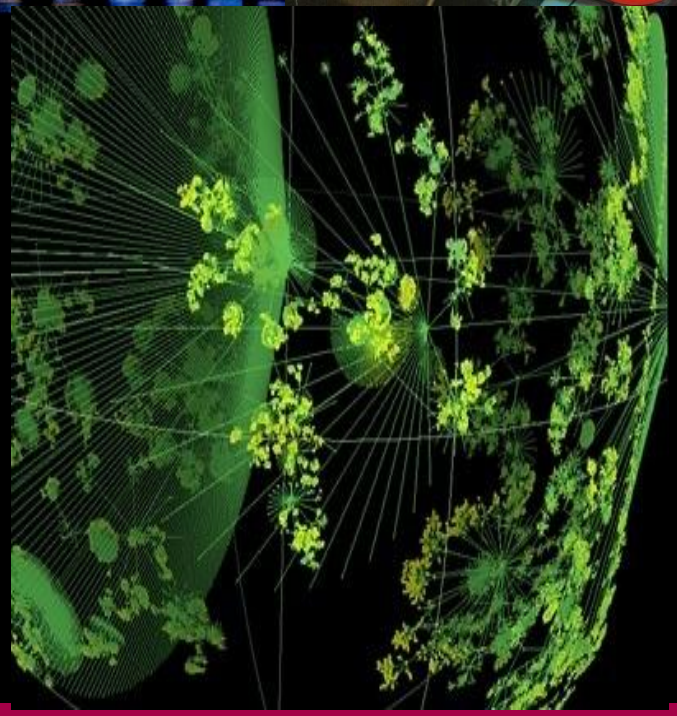
- recalibration of roles/expectations of healthcare professionals
  - integrated teams, medical homes
  - embrace of decision-support tools
- education and training
  - information-based medicine meets patient:consumer-centric care
  - accelerated skills training in developing countries

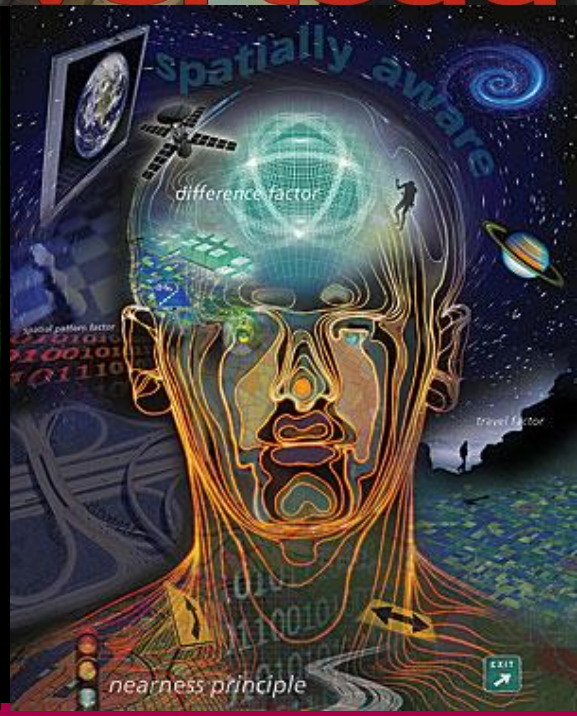


# Enhancing Human Capabilities to Use the Increased Volume, Diversity and Complexity of Information Flows

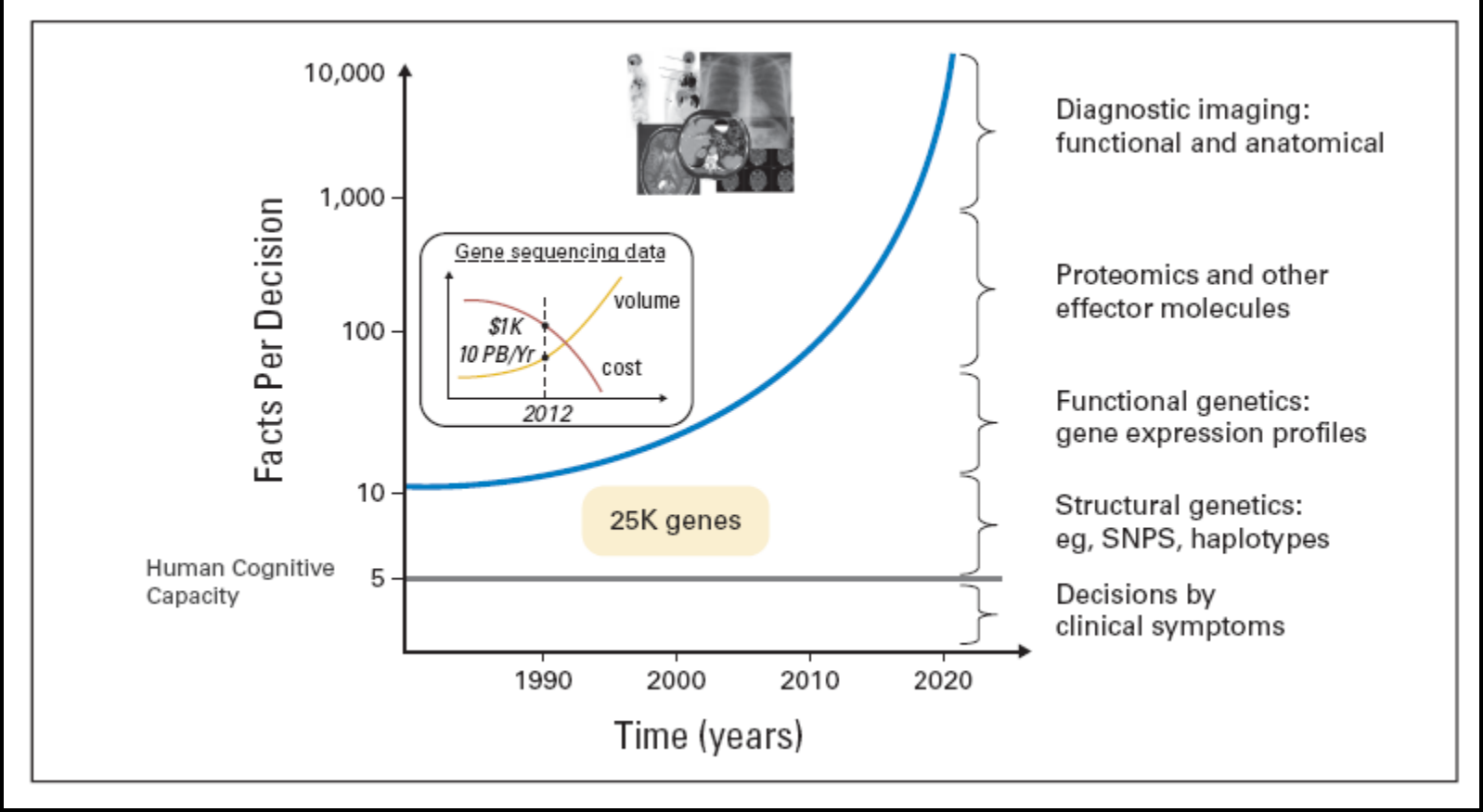






# Increase in Data Parameters for Clinical Decision Points Relative to Human Cognitive Capacity

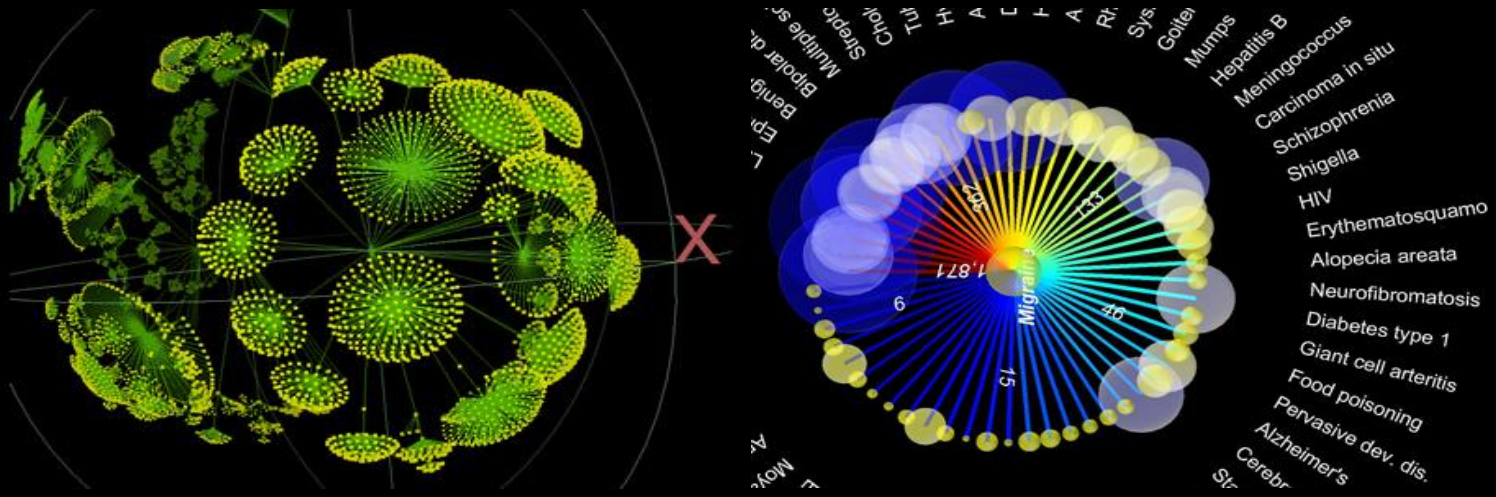


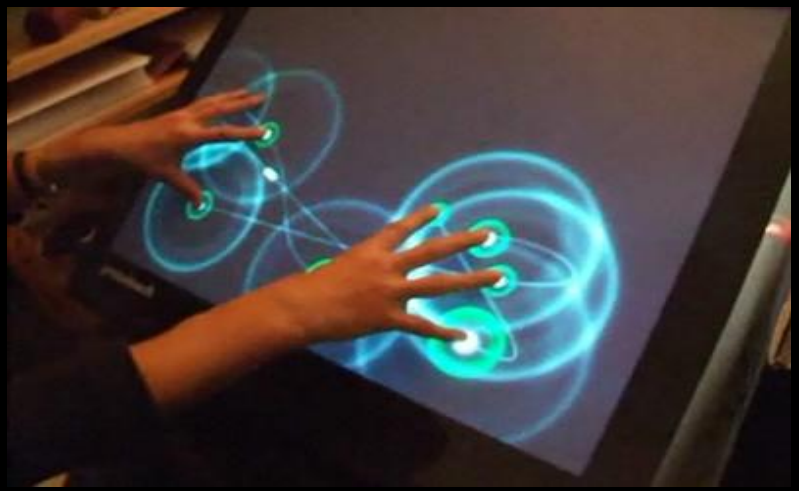

From: A. Abernathy et al. (2010) J. Clin. Oncol. 28, 4268

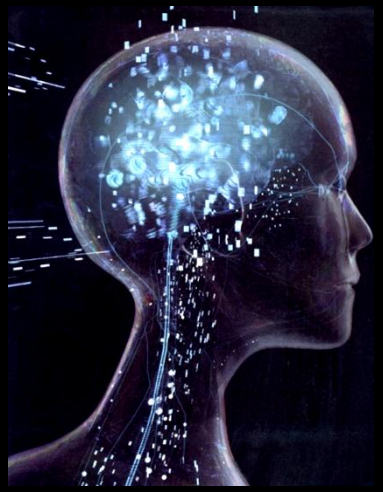
# Integration of Advances in Customized Data Formating and Visualization Tools for Different User Constituencies

- escalating quantities and diversity of information
- real time decision support systems under conditions of uncertainty
- new multi-modal, multi-sensory high performance human: information interfaces
- representation and comprehensibility of information flows
  - optimize representation (perception and recognition)
  - integrated multi-user interfaces (customized and actionable)
- adoption of advances in cognitive neurobiology in customizing data formats (kinds of minds)

# Design of Context-Dependent Data Mining and Visualization Tools and Integration with Advances in Cognitive Biology





# Health Systems and Services: Changing Minds and Changing Behaviors

- technology is only the enabler
- emergence of new organizational structures, alliances and business models
- engage and educate multiple constituencies with long entrenched behaviors
- ‘care’ space will be increasingly decentralized
  - from hospital/clinic to ‘personal health space’
- from episodic encounters to continuous interactions
- new business opportunities in customized health services and health broker/concierge services

# Sustainable Health

- complex problems can’t be solved uni-dimensional ‘quick fixes’ and political populism
- complex problems reflect the intrinsic complexity embedded in all multi-component systems
- comprehension and control of complex systems requires systems-level analytics
- examination of complex systems at the subsystem level(s) will not enable design of robust, sustainable performance

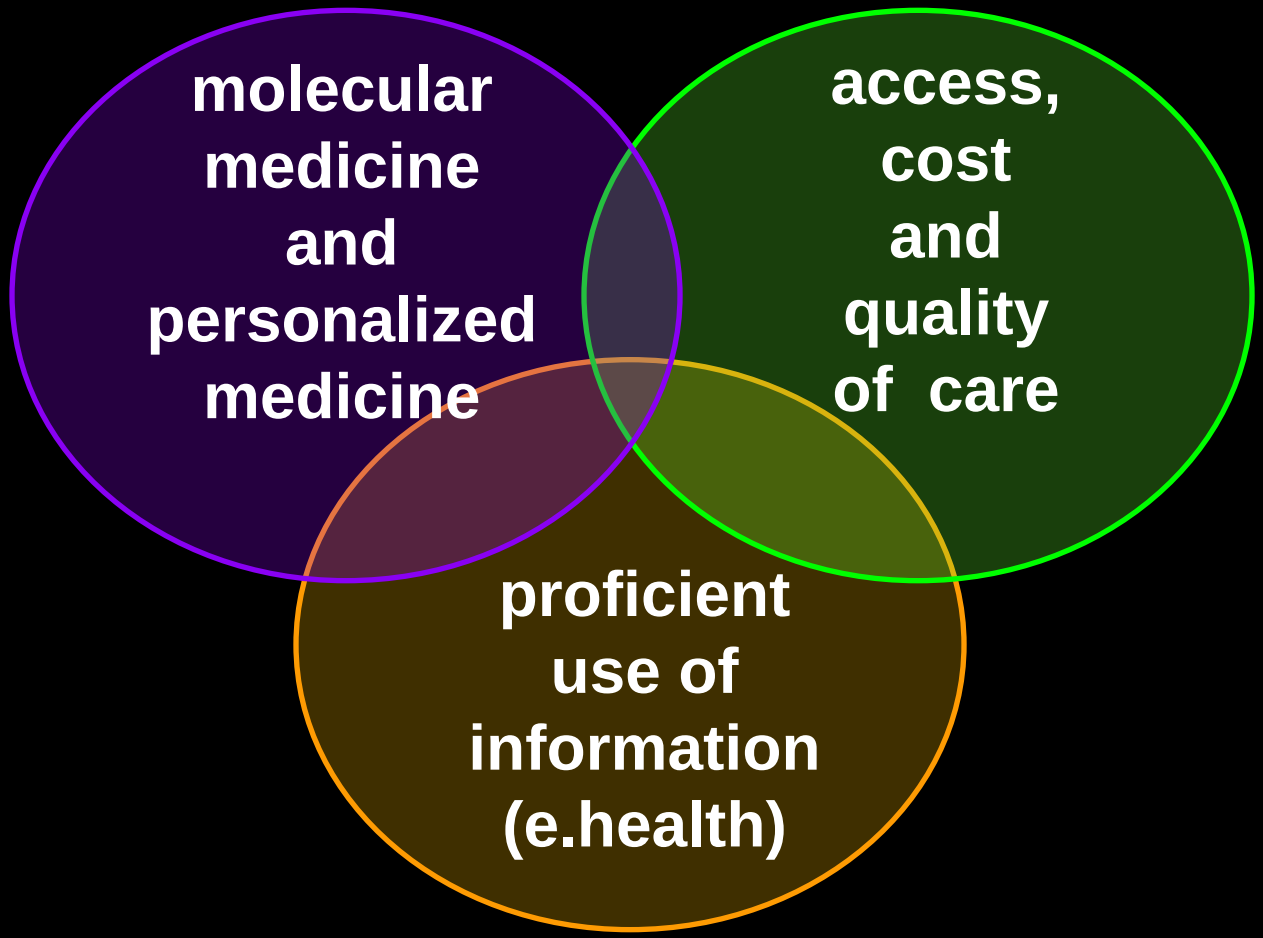
## Healthcare Delivery

- MD/payor-centric
- controlled information
- medical paternalism
- patient:consumer dependency
- reactive, episodic interaction/intervention
- fragmented care and information silos
- system-constraints on PC-centric services
- system-shielded from economic competitiveness and outcomes metrics

## Health Systems and Services

- patient:consumer (PC)-centric
- transparency
- active PC participation in care decisions
- health literacy and accountability
- proactive, integrated care continuum
- PHR + ERH + mobility and ambient intelligence
- options + choice
- performance metrics/ emergence of a real market

# The Three Convergent Forces Shaping the Evolution of Healthcare




**VALUE**

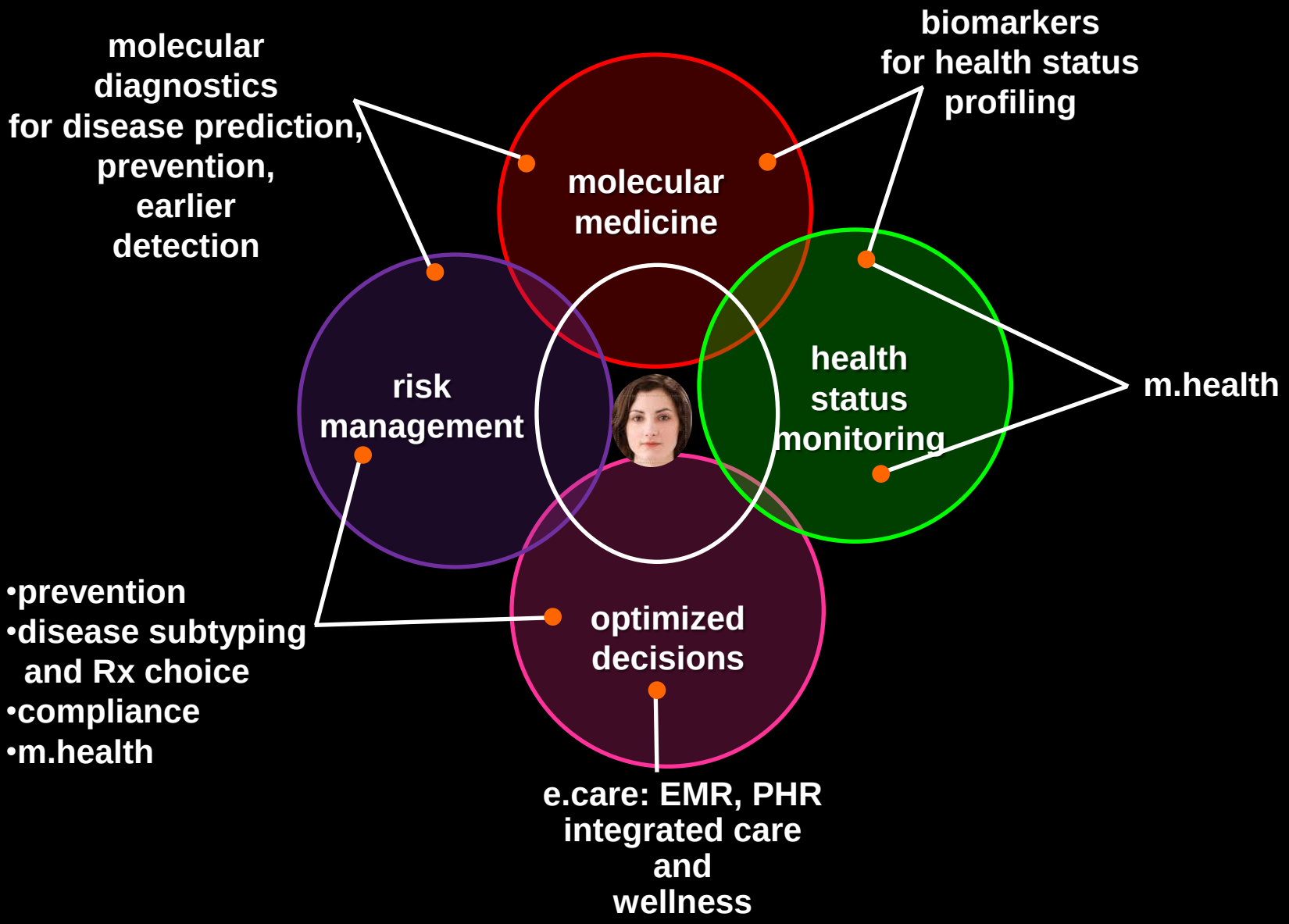
# The Coming Convergence in Healthcare Delivery and Consumer Health

## New Delivery Pathways

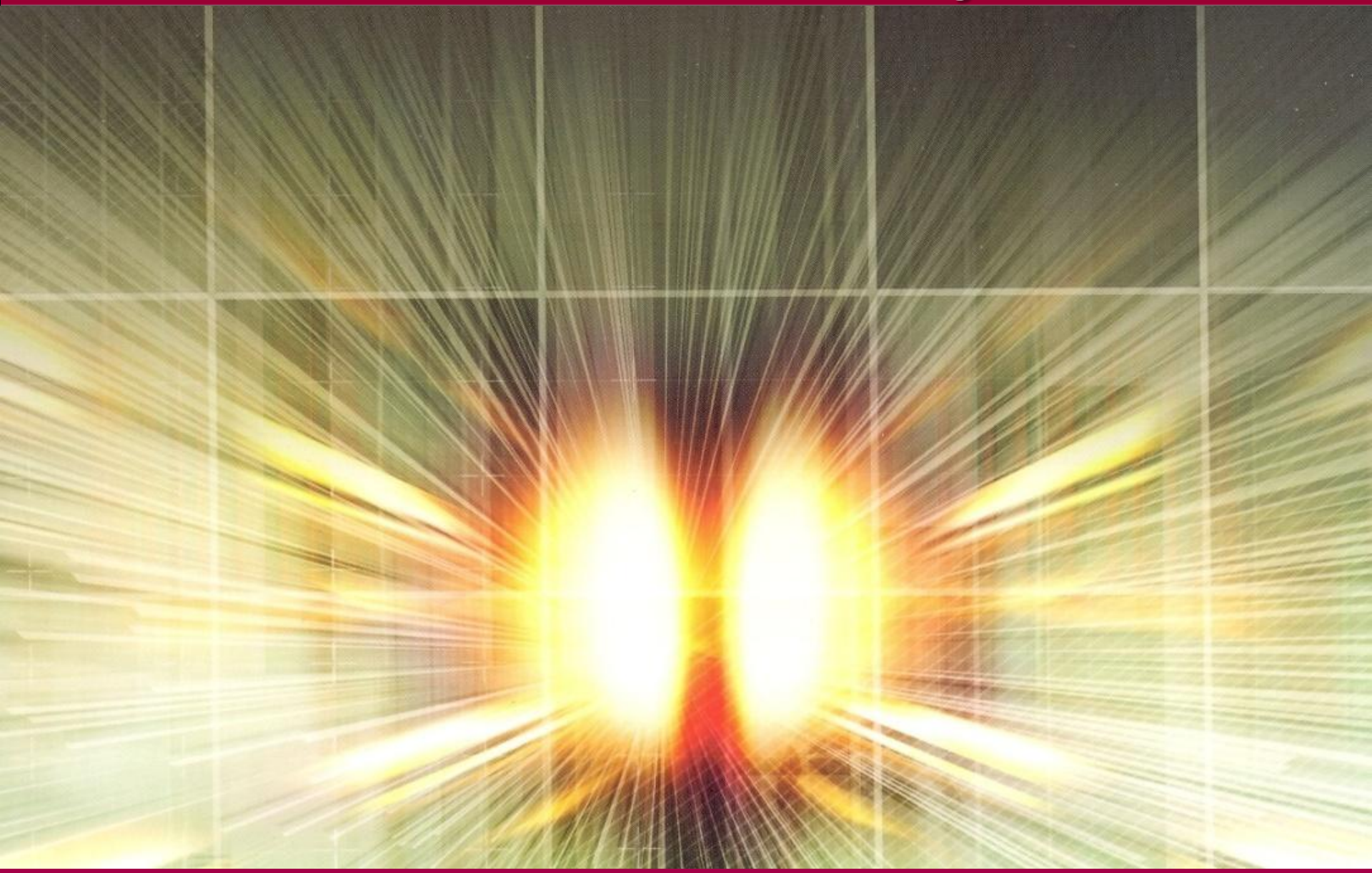
- new organizational/business models
- rapid expansion of e.health/m.health
- social media and promotion/adoption of OTC/wellness/lifestyle products/services
- integration of consumer health product categories with remote health monitoring services
- new ‘infomediaries’ will change balance of power between healthcare professionals and consumer
  - transparency, positive outcomes and performance
  - consumer choice

**VALUE**

# The Key Strategic Elements in the Evolution of Healthcare



# Technology Acceleration and Convergence in Healthcare Delivery



# The Coming Convergence in Healthcare Delivery

## Technologies

- biotechnology, medicine, engineering, computing, telecommunications and social media

## Clinical Practice

- molecular medicine and increasingly customized care
- diagnostic, drug and device combinations
- POC testing and remote monitoring
- reduced error and improved compliance
- improved outcomes

## Realigned Incentives

- integrated care for complex chronic diseases
- earlier disease detection and risk reduction
- wellness versus illness
- remote health status monitoring

# The Coming Convergence in Healthcare Delivery

## Consumers

- increased personal responsibility for health
- new incentives for wellness/compliance
- remote health status monitoring

## Connectivity

- integrated care networks for chronic disease
- social media networks and informed consumers
- new supplier networks of specialized turnkey expertise
- value added ‘content’ services for clinical data mining
- clinical decision-support systems

## Control

- cost of care
- quality-of-care
- personal health, quality-of-life, and wellness