National Institutes of Health
NIH...Turning Discovery Into Health

Clinical Decision Support: An Overview

Blackford Middleton, MD, MPH, MSc
Partners Healthcare System – Harvard Medical School

National Library of Medicine – National Institute of Biomedical Imaging and Bioengineering
Joint Workshop April 23-24, 2012
NLP and CDS

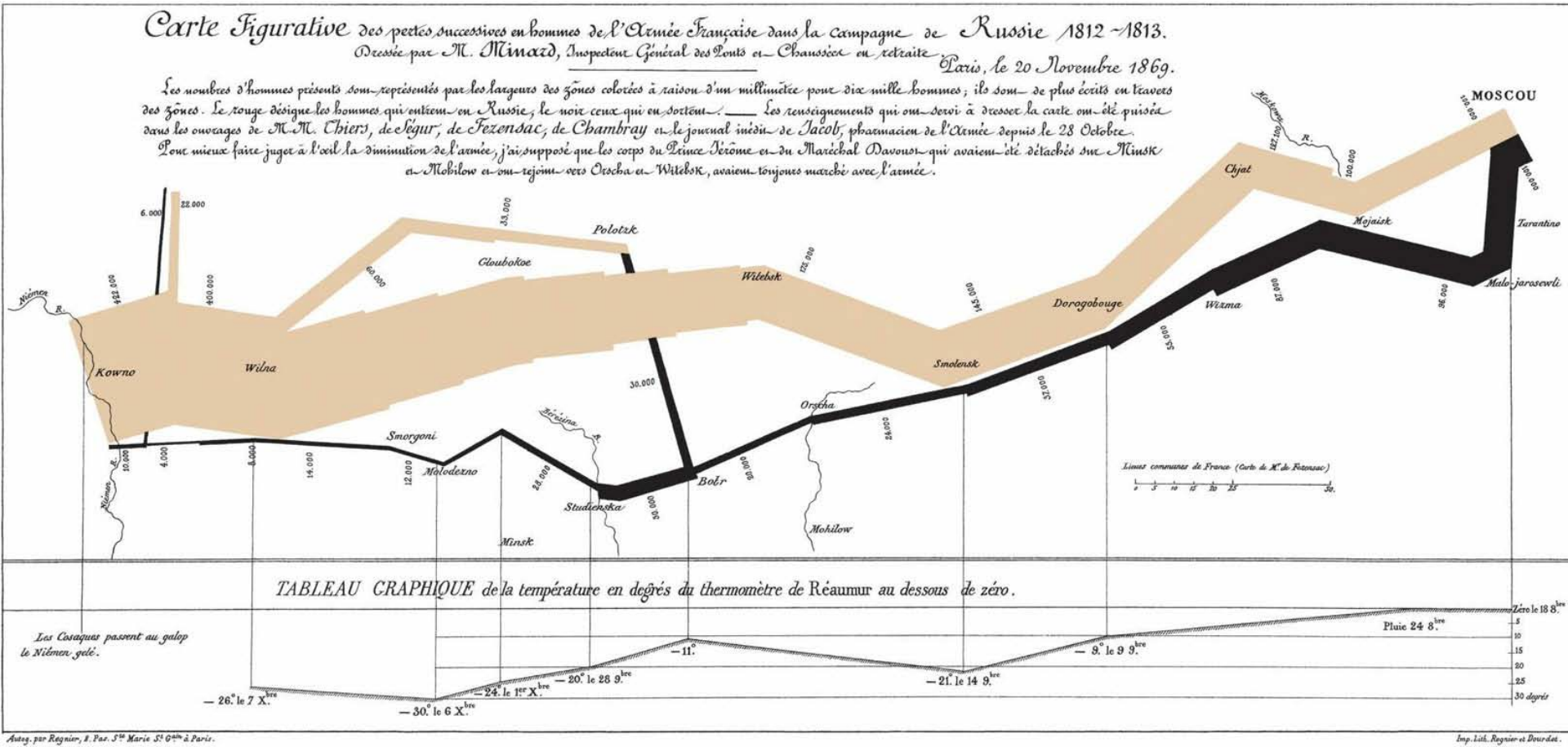
FOUNDED BY BRIGHAM AND WOMEN'S HOSPITAL
AND MASSACHUSETTS GENERAL HOSPITAL


Overview

- Motivation for Clinical Decision Support (CDS)
- What is CDS today?
- Evidence for and against CDS
- What will CDS be tomorrow?
- Research Questions and Challenges

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813 (1869)

Charles Joseph Minard's diagram of Napoleon's ill-fated march on Moscow
From Tufte, E. The Visual Display of Quantitative Information, p. 41



US Motivation for CDS

- Providers have incomplete knowledge of their patients
  - Patient data unavailable in 81% of cases in one clinic,
    - average of 4 missing items per case.
  - 18% of medical errors are due to inadequate availability of patient information.
  - Medicare beneficiaries see 1.3 – 13.8 unique providers annually, on average 6.4 different providers/yr
- Delayed translation of new knowledge to clinical practice
  - From bench to bedside, on average it takes > 17 years for new medical knowledge to be routinely applied in clinical practice
- Clinical Information Needs of Practitioners are unmet
  - Physicians in US urban and rural practices have on average more than 1 unanswered question per patient on optimal therapy diagnosis, or procedure

Clinical Information Exceeding Human Cognitive Capacity

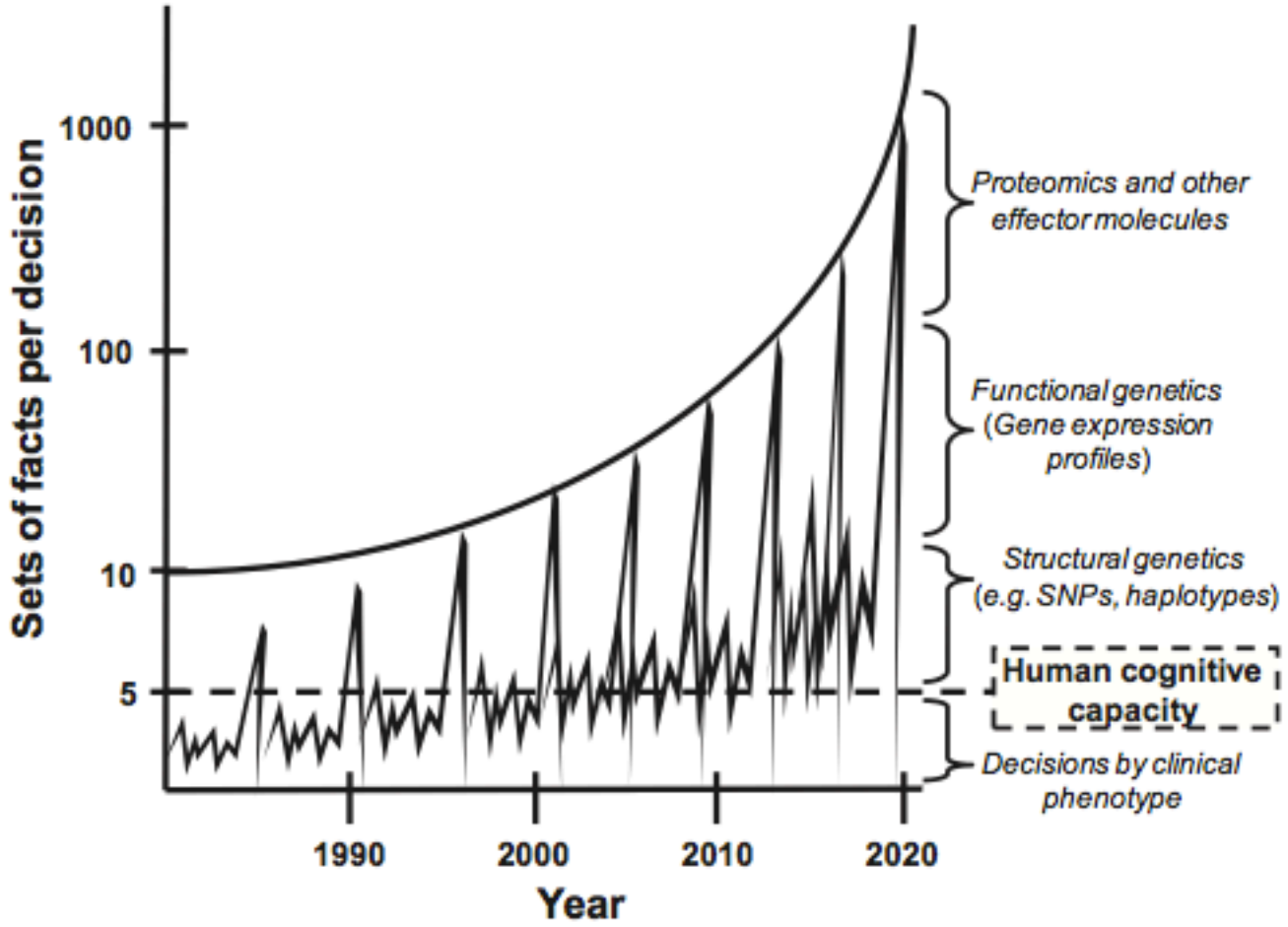


Figure 1 Schematic contrasting human cognitive capacity (e.g., the number of sets of facts the brain can correlate in a decision) with the explosion of new biomedical data types. SNP indicates single nucleotide polymorphism. The authors adapted this figure with permission from Stead.[5]

SPECIAL ARTICLE

The Quality of Health Care Delivered to Adults in the United States

Elizabeth A. McGlynn, Ph.D., Steven M. Asch, M.D., M.P.H., John Adams, Ph.D., Joan Keesey, B.A., Jennifer Hicks, M.P.H., Ph.D., Alison DeCristofaro, M.P.H., and Eve A. Kerr, M.D., M.P.H.

ADA Guideline	Compliance
least annually and during pregnancy.	23.62%
Dilated and comprehensive **eye exam** at diagnosis of Type 2 and annually.	14.21%

On average, Patients receive 54.9% of recommended care

McGlynn EA, NEJM 2003; 348:2635.

Flexner Report

"...The curse of medical education is the excessive number of schools. The situation can improve only as weaker and superfluous schools are extinguished."

"Society reaps at this moment but a small fraction of the advantage which current knowledge has the power to confer."

Abraham Flexner,

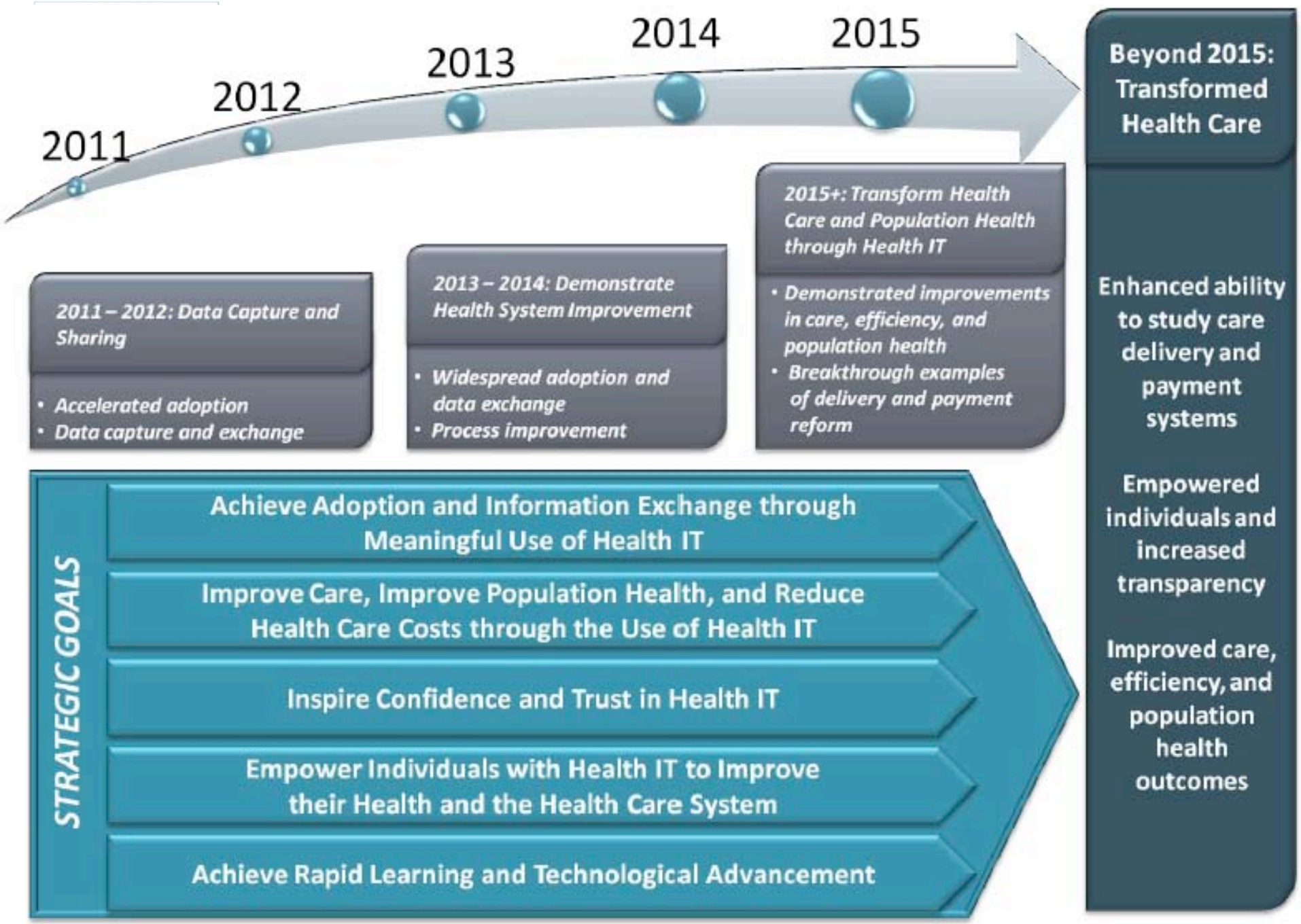
Medical Education in the United States and Canada.

Boston: Merrymount Press, 1910

CITL HIT Value Assessments

- **Net US could save $150B with HIT adoption, or approximately 7.5% or US Healthcare Expenditure**
  - The Value of Ambulatory Computerized Order Entry (ACPOE)
    - $44B US nationally; $29K per provider, per year
  - The Value of HealthCare Information Exchange and Interoperability (HIEI)
    - $78B/yr
  - The Value of IT-enabled Chronic Diabetes Management (ITDM)
    - $8.3B Disease Registries; Advanced EHR $17B
  - The Value of Physician-Physician Tele-healthcare
    - >$20B*
  - The Value of Personal Health Records
      - Approx. $20B


The Economist
Iran's agony
The mystery of Mrs Merkel
Asia's consumers to the rescue?
The Greeks and those marbles
Evolution and depression
JUNE 27TH–JULY 3RD 2009
Economist.com
Reforming health care
This is going to hurt


2011
2012
2013
2014
2015
Beyond 2015: Transformed Health Care
2011 – 2012: Data Capture and Sharing
• Accelerated adoption
• Data capture and exchange
2013 – 2014: Demonstrate Health System Improvement
• Widespread adoption and data exchange
• Process improvement
2015+: Transform Health Care and Population Health through Health IT
• Demonstrated improvements in care, efficiency, and population health
• Breakthrough examples of delivery and payment reform
STRATEGIC GOALS
Achieve Adoption and Information Exchange through Meaningful Use of Health IT
Improve Care, Improve Population Health, and Reduce Health Care Costs through the Use of Health IT
Inspire Confidence and Trust in Health IT
Empower Individuals with Health IT to Improve their Health and the Health Care System
Achieve Rapid Learning and Technological Advancement
Enhanced ability to study care delivery and payment systems
Empowered individuals and increased transparency
Improved care, efficiency, and population health outcomes

A perfect storm for CDS?

- Lots of clinical data going online
  - Increasing std, interop
- Lots of genetic data coming
- Lots of personal/social data coming
- Lots of geospacial data coming
- Inexorable rise of Healthcare costs…
- Healthcare Reform

How do clinicians reason?

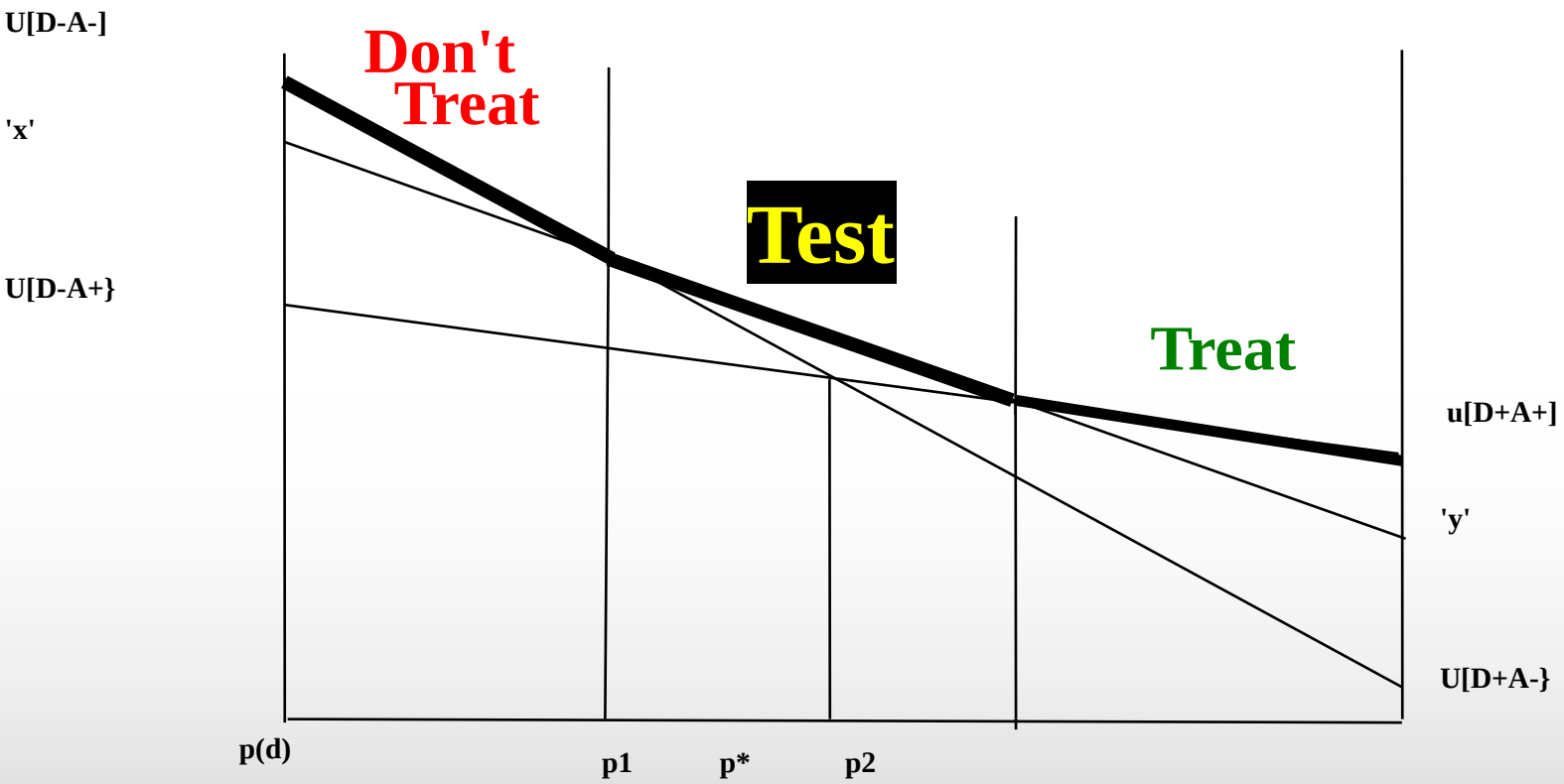
- Formulating the Problem List:
  (Differential Diagnosis)
  - Listen and Generate Hypotheses
  - Cross-examine to gather data for hypothesis testing
  - Evaluate Hypotheses
  - Take action

(H C Sox, *et al.* Medical Decision Making. Butterworths, Boston, 1988)

Principles of DDx – Empirical Studies Reveal:

- Hypotheses are generated early
- Just a few active hypotheses under consideration at one time
- Bias and Cognitive Errors in differential diagnosis
  - Representativeness heuristic
    - Prior probability
    - Using clinical cues that do not accurately predict disease
    - Overcounting dependent predictors
    - Undercounting independent predictors
    - Mistaken use of regression toward the mean as evidence
    - Limited experience (few prior cases, or atypical)
  - Availability heuristic
  - Anchoring and Adjustment heuristics

Probabilistic Reasoning Test:Treatment Thresholds



Where 'x' = p(T+|D-) x U[D-A+] + (1 - p(T+|D-) x U[D-A-] - U[T]

'y' = p(T+|D+) x U[D+A+] + (1 - p(T+|D+) x U[D+A-] - U[T]

p1 = no treatment - test threshold { U[A-] = U[T] }

p2 = test - treatment threshold { U[T] = U[A+]

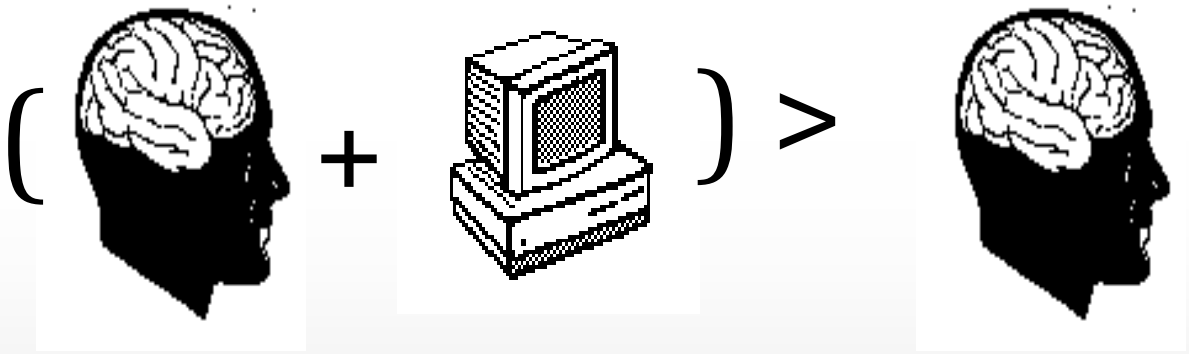
Therefore,

$$p1 = \frac{FPR \times C - U[T]}{FPR \times C + TPR \times B} = \frac{p^* \times (1 - FPR) +}{p^* \times (1 - FPR) + (1 - p^*) \times (1 - TPR)}$$

$$p2 = \frac{(1-FPR) \times C + U[T]}{(1-FPR) \times C + (1 - TPR) \times B} = \frac{p^* \times (1-FPR)}{p^* \times (1-FPR) + (1-p^*) \times (1 - TPR)}$$

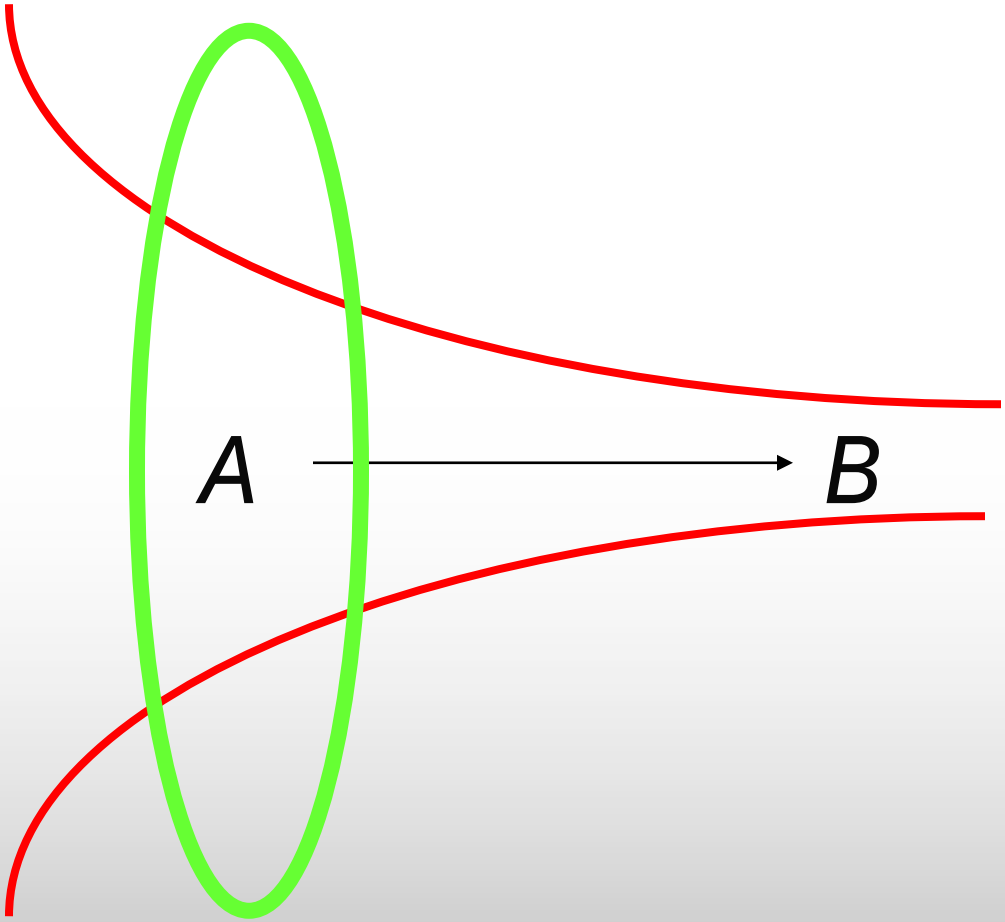
if U[T} is small.

The BMI Fundamental Theorem



Friedman, C. P. (2009). A "fundamental theorem" of biomedical informatics JAMIA, 16(2), 169–170.

Recall Blois' Cognitive Funnel… Behavior at the Entrance is the Key



Blois MS. Clinical Judgment and Computers
N Engl J Med 1980; 303:192-197

Humility

"I typed in your description of the symptoms. The computer says you have Dutch elm disease."

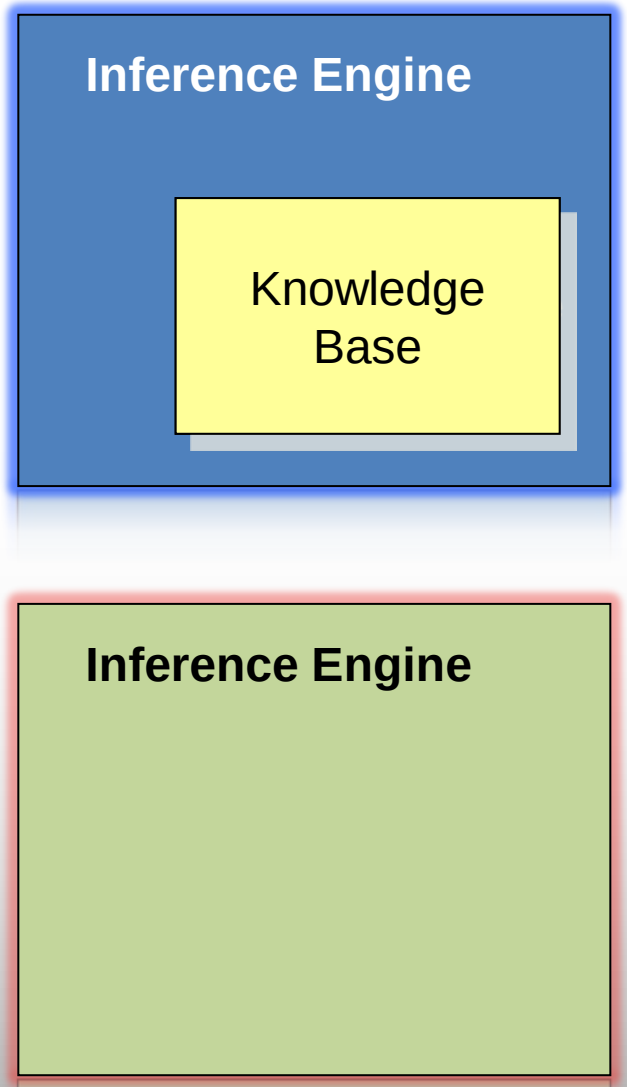
Knowledge - based systems

- "A knowledge-based system is an AI program whose performance depends more on the explicit presence of a large body of knowledge than on the presence of ingenious computational procedures…"

Duda RO, Shortliffe EH. Expert systems research. Science. 1983 Apr 15;220(4594):261-8.

Inference Methods Used in Expert Systems

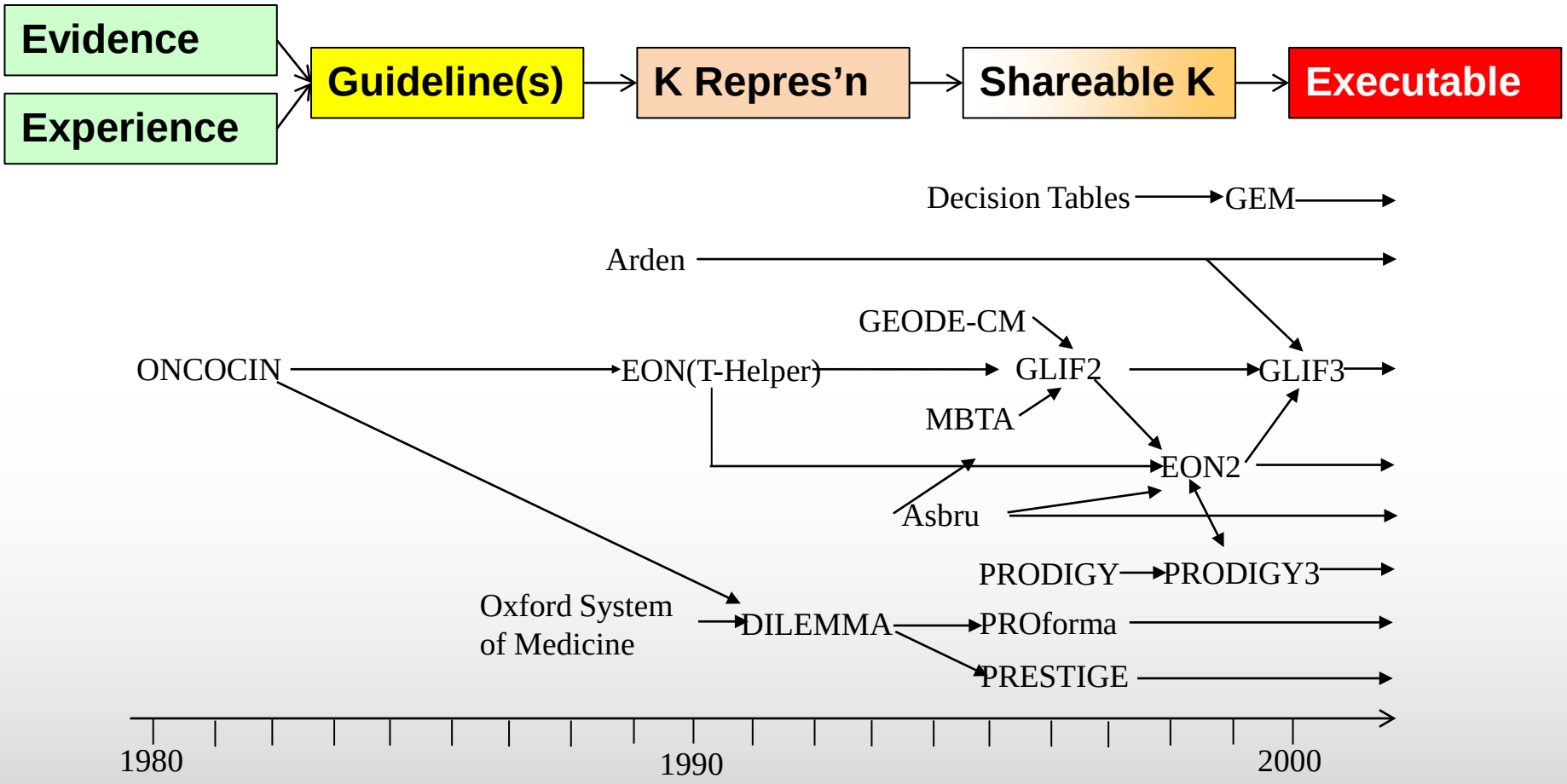
- Algorithmic
- Statistical
- Pattern Matching
- Rule-based (Heuristic)
- Fuzzy sets
- Neural nets
- Bayesian
- TBD…



The Evidence Cup Less than Half Full

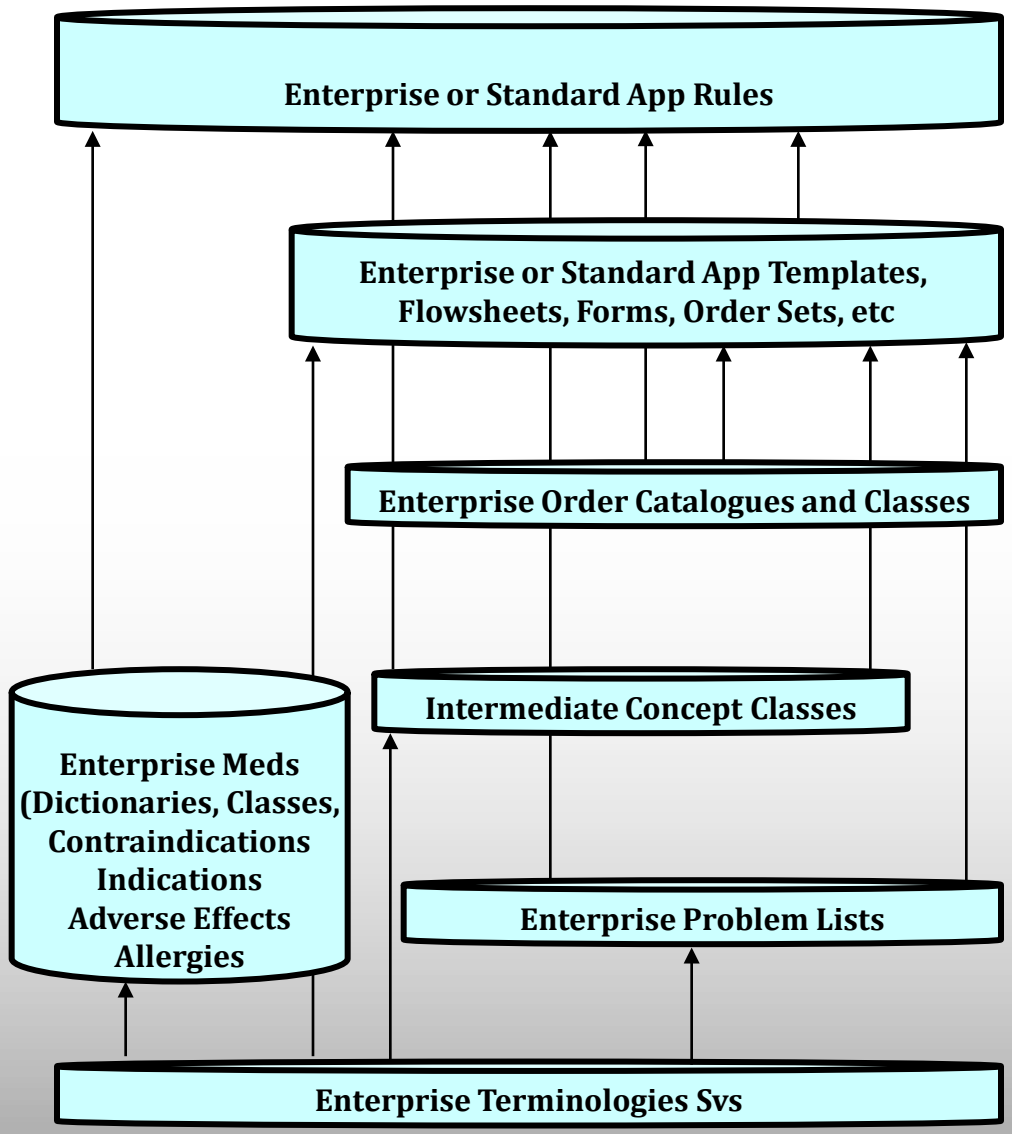
- Brent James estimate of evidence-base to support current clinical practice
  - = 25%
- 75% of what we do not supported by evidence…
- Need for ‘real-time clinical epidemiology’: what have others done with patinets like mine?

Knowledge Translation and Specification



P. L. Elkin, M. Peleg, R. Lacson, E. Bernstam, S. Tu, A. Boxwala, R. Greenes, & E. H. Shortliffe. Toward Standardization of Electronic Guidelines. *MD Computing* 17(6):39-44, 2000

Knowledge is like a Cake-stack



If Braden Score < 11
→ Low Air Loss Bed,etc
If Abn Vasc Exam → Vascular Consult

Collections of Concepts –
Braden Assessment→ Full Nursing Assessment
Collections of Orders – Order Sets

Med Orders, Special Beds, Topicals
Consults -Neurology or Vascular

Dorsalis Pedis Pulse→ Present or Absent
Posterior Tibial Pulse → Present or Absent
Color→ Pink, Pale, or Rubor on Dependency
Ankle Brachial Index → range 0.7→1.0

Taxonomies of Problems such as
CAD, Diabetes, Peripheral Vascular DZ

Taxonomies of Terms such as
Skin Exam, Decub Ulcer, Pulse, Skin Turgor

What is CDS Today?

- Formatting
  - Results review, "pocket rounds" reports
- Interpreting
  - EKG, PFTs, Pap, ABG
- Consulting
  - QMR, DxPlain, Iliad, Meditel, Abd Pain, MI risk
- Monitoring
  - Alerts: Critical labs, ABx/Surgery, ADEs
- Critiquing
  - Vent mgmt, anesthesia mgmt, HTN Rx, Radiology test selection, Blood products ordering
- ***Add***: Consumer 'smart apps'
  - Diet, exercise, medication management, diabetes care, etc.

Kuperman GJ et al. J Hlth Info Mgmt (13)2, pg 81-96

Evidence Review for CDS

- Systematic Review of 97 studies
- Practitioner performance improved
  - Overall in 64% of studies
  - 40% of 10 diagnostic systems
  - 76% of 21 reminder systems
  - 66% of 29 drug dosing or prescribing systems
- Patient outcomes
  - Only 7 of 52 studies reported improvements
- Factors associated with success
  - Automated prompts vs. requiring users to activate the system
  - When authors were developers of the system.

Garg, A. X., N. K. Adhikari, et al. (2005). "Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review." JAMA 293(10): 1223-1238

The Evidence for CDS

- CDS yields increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors
  - *(Chaudhry et al., 2006)*
- CDS, at the time of order entry in a computerized provider order entry system can help eliminate overuse, underuse, and misuse.
  - *(Bates et al., 2003; Austin et al., 1994; Linder, Bates and Lee, 2005; Tierney et al., 2003)*
- For expensive radiologic tests and procedures this guidance at the point of ordering can guide physicians toward ordering the most appropriate and cost effective, radiologic tests.
  - *(Bates et al., 2003; Khorasani et al., 2003)*
- Showing the cumulative charge display for all tests ordered, reminding about redundant tests ordered, providing counter-detailing during order entry, and reminding about consequent or corollary orders may also impact resource utilization
  - *(Bates and Gawande, 2003; Bates, 2004; McDonald et al., 2004).*

Problems with HIT

- Koppel R et al. JAMA 293:10, Mar 2005
  - Studied how CPOE can facilitate prescription error risk
  - Survey research assessed users perceptions of risk
  - Perception of users was that CPOE increased 22 types of medication error risks

22 Categories of Perceived Increased Medication Risk

- Information Errors
  - Assumed dose
  - Med d/c failure
  - Procedure-linked med error
  - Give now, and prn d/c error
  - Antibiotic renewal
  - Diluent option error
  - Allergy display
  - Conflict or duplicate med
- HCI/Workflow Errors
  - Patient selection
  - Med selection
  - Unclear log on/off
  - Meds after surgery
  - Post surgery suspended meds
  - Time/data loss when CPOE down
  - Med delivery error
  - Timing errors
  - Delayed nursing documentation
  - Rigid system design

Koppel R et al. JAMA 293:10, Mar 2005

Types of Unintended consequences

	Frequency(%)
work for clinicians	19.8
unfavorable workflow issues	17.6
never ending system demands	14.8
problems related to paper persistence	10.8
untoward changes in communication patterns and practices	10.1
negative emotions	7.7
generation of new kinds of errors	7.1
unexpected changes in the power structure	6.8
overdependence on the technology	5.2

Campbell EM, Sittig DS et al., JAMIA 2006

Duke EPC Report on CDS: 7 Key factors for successful CDSS

- Three from Kawamoto 2005 review are confirmed as key:
  - Automatic provision of decision support as part of clinician workflow
  - Provision of decision support at time and location of decisionmaking
  - Provision of a recommendation, not just an assessment

- Meta-analysis identified four additional
  - Integration with charting or order entry system to support workflow integration
  - Promotion of action rather than inaction
  - No need for additional clinician data entry
  - Local user involvement in the development process

- Note: 15 (11.5%) of studies reviewed included all 7 factors

The future is here… it is just not evenly distributed*…

Chaudry B., et al. Ann Intern Med. 2006;144:742-752.

Regenstrief Institute

Brigham & Women's Hospital / Partners HealthCare

VA Healthcare System

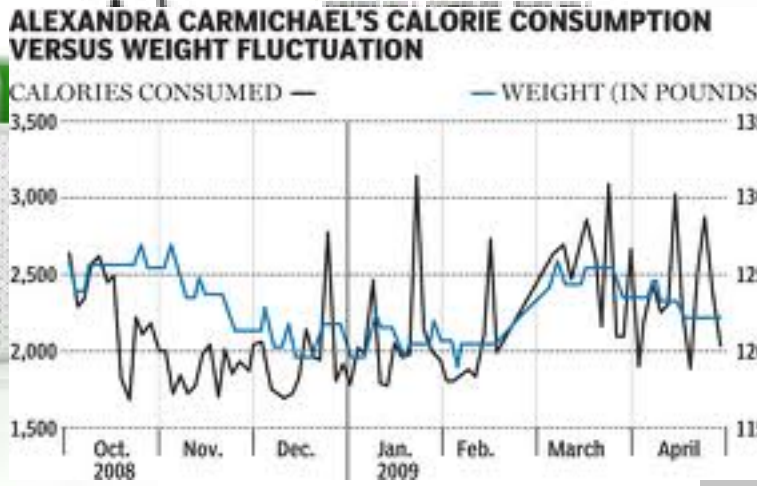
Intermountain Healthcare

…a 2006 systematic review in *Annals of Internal Medicine* found that 25% of all studies on CDS took place at the above four institutions.

**William F. Gibson The Economist, Dec. 4, 2003*

It's Coming… CDS and Big Data

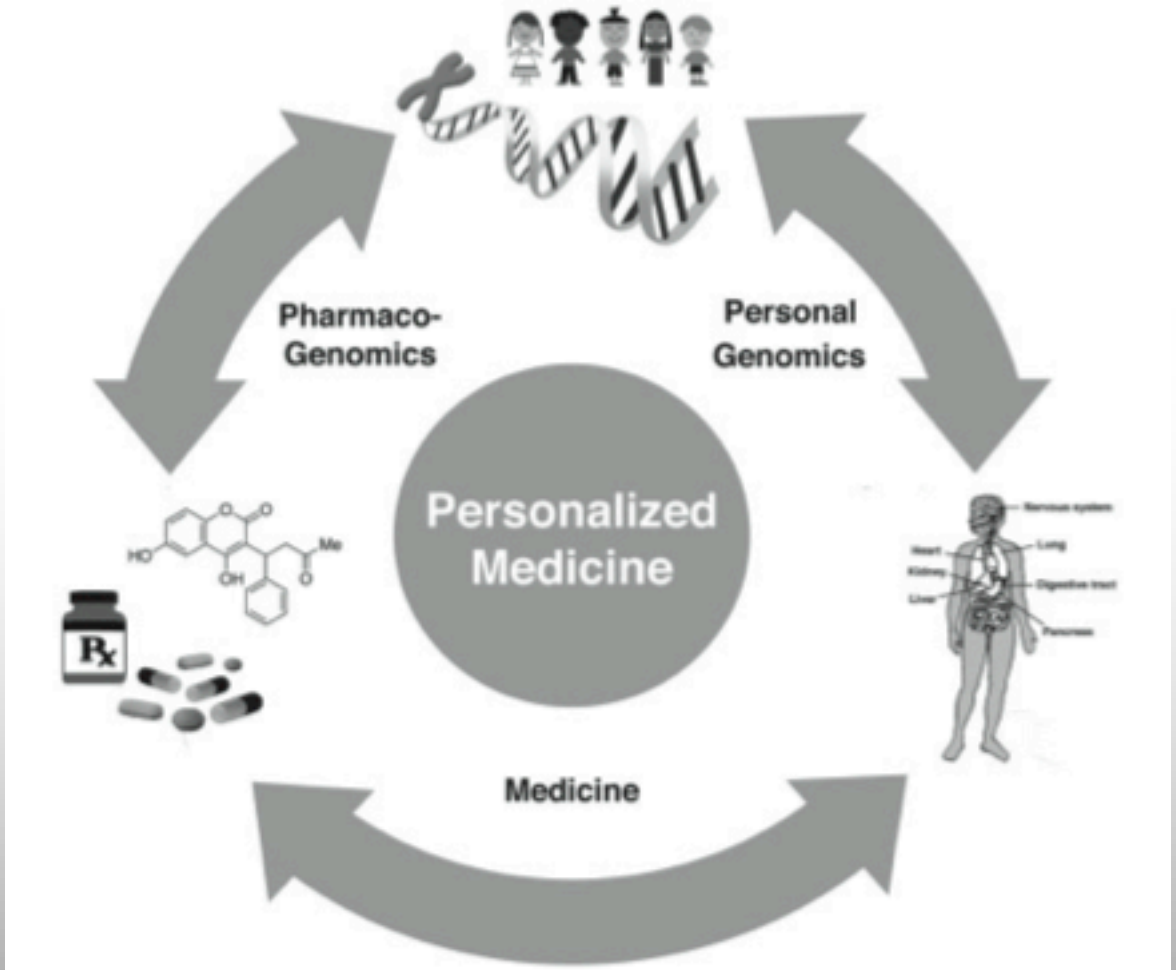
The Quantified Self



http://bit.ly/xMDwm2

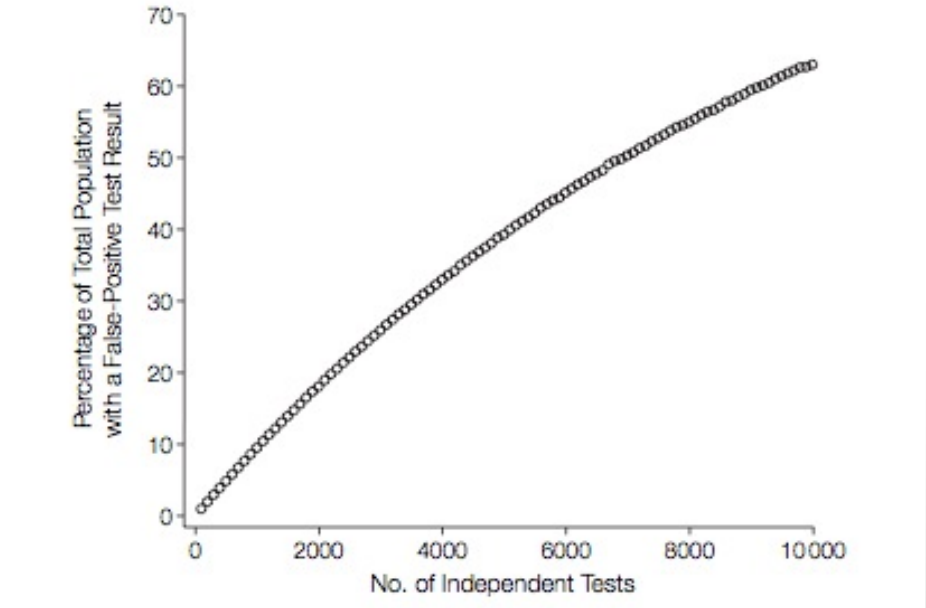
Personalized Medicine

Fernald GH, Capriotti E, Daneshjou R, Karczewski KJ, Altman RB. Bioinformatics challenges for personalized medicine. Bioinformatics. 2011;27(13):1741–1748.



Genetics, Incidentalomes, and Patient Preferences

Figure. Percentage of Total Population With a False-Positive Test Result



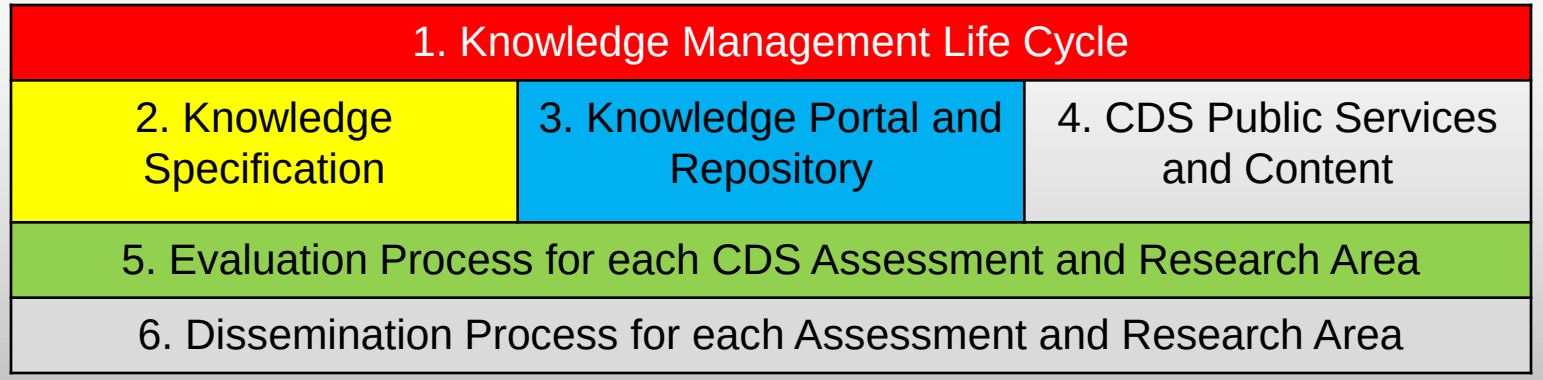
- Sensitivity 100%, FPR 0.01%
- 10,000 tests > 60% with a FP test result
- What should we tell patients?
- What will patients want to know?

*Kohane, I.S., Masys, D.R. & Altman, R.B. The incidentalome: a threat to genomic medicine. JAMA **296**, 212–215 (2006).*
*Kohane, I.S. & Taylor, P.L. Multidimensional results reporting to participants in genomic studies: getting it right. Sci Transl Med **2**, 37cm19 (2010).*

CDS Consortium: Goal and Significance

- **Goal:** To assess, define, demonstrate, and evaluate best practices for knowledge management and clinical decision support in healthcare information technology at scale – across multiple ambulatory care settings and EHR technology platforms.

- **Significance:** The CDS Consortium will carry out a variety of activities to improve knowledge about decision support, with the ultimate goal of supporting and enabling widespread sharing and adoption of clinical decision support.



FOUNDED BY BRIGHAM AND WOMEN'S HOSPITAL
AND MASSACHUSETTS GENERAL HOSPITAL

HARVARD
MEDICAL SCHOOL

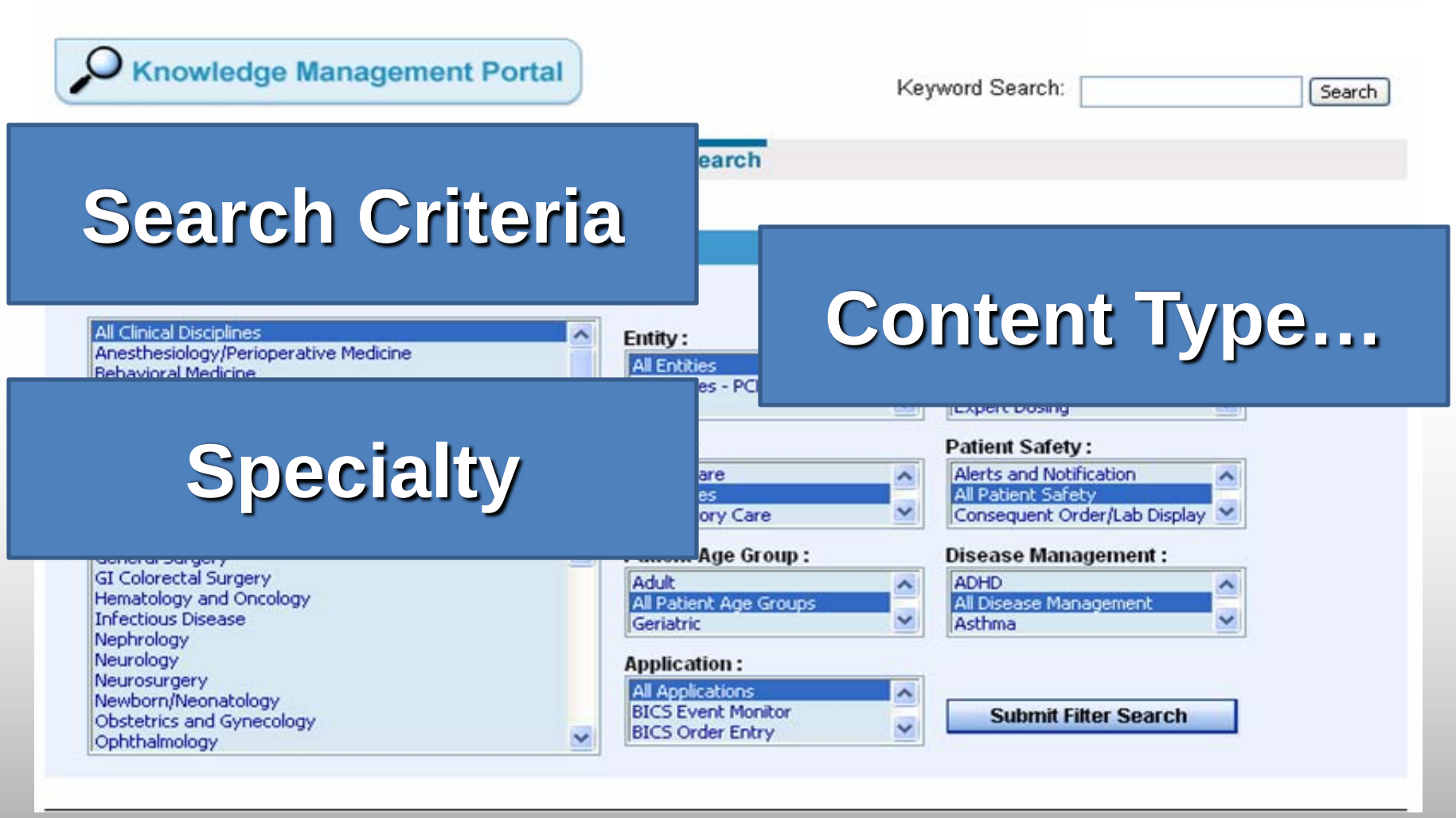
SIEMENS

NextGen
Healthcare Information Systems, Inc.

PHILIPS
sense and simplicity

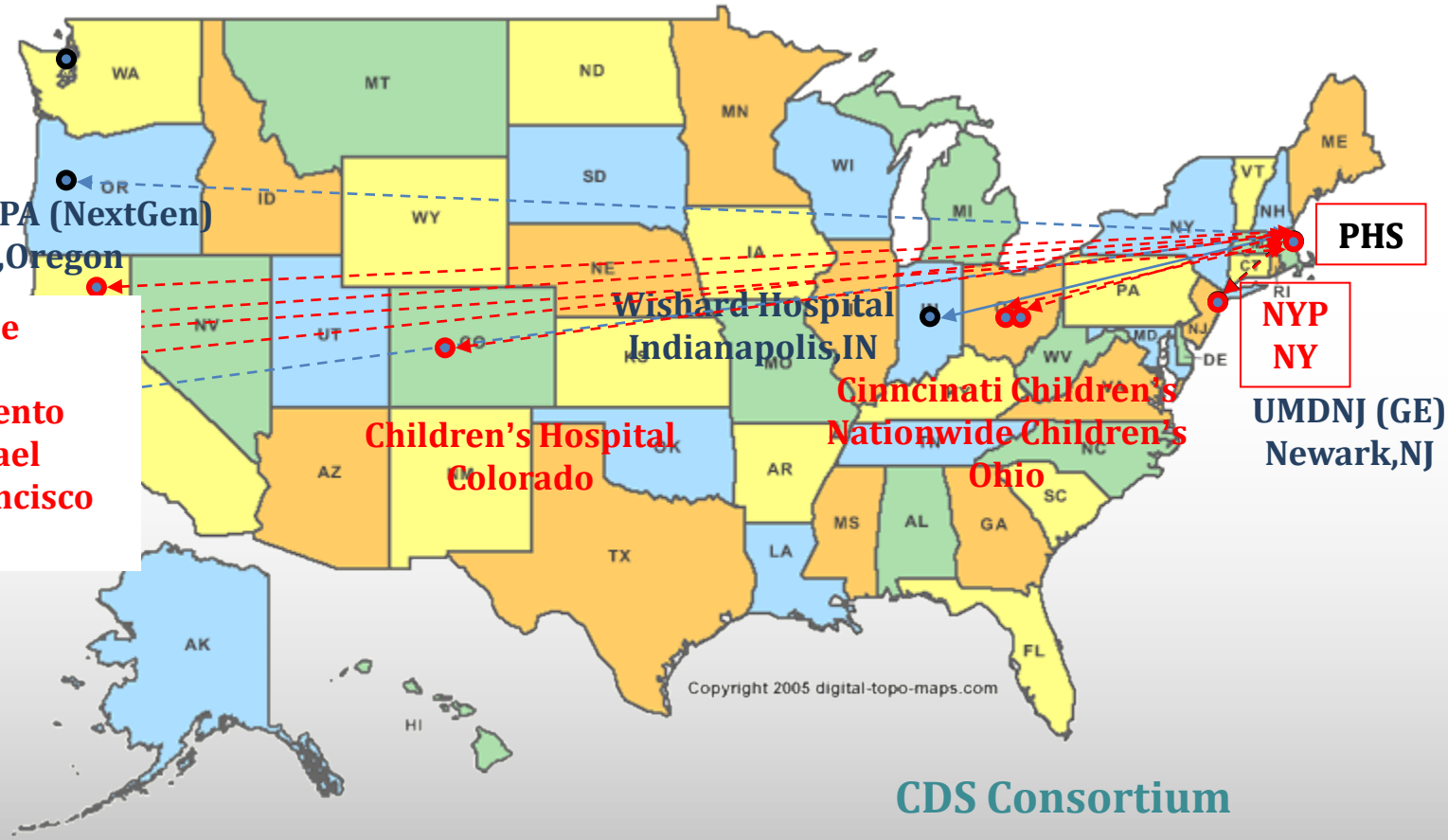
Mid IPA Valley
INDEPENDENT PHYSICIANS ASSOCIATION

An external repository of clinical content with web-based viewer



CDS Consortium Demonstrations

Toward a National Knowledge Sharing Service



CDS Consortium

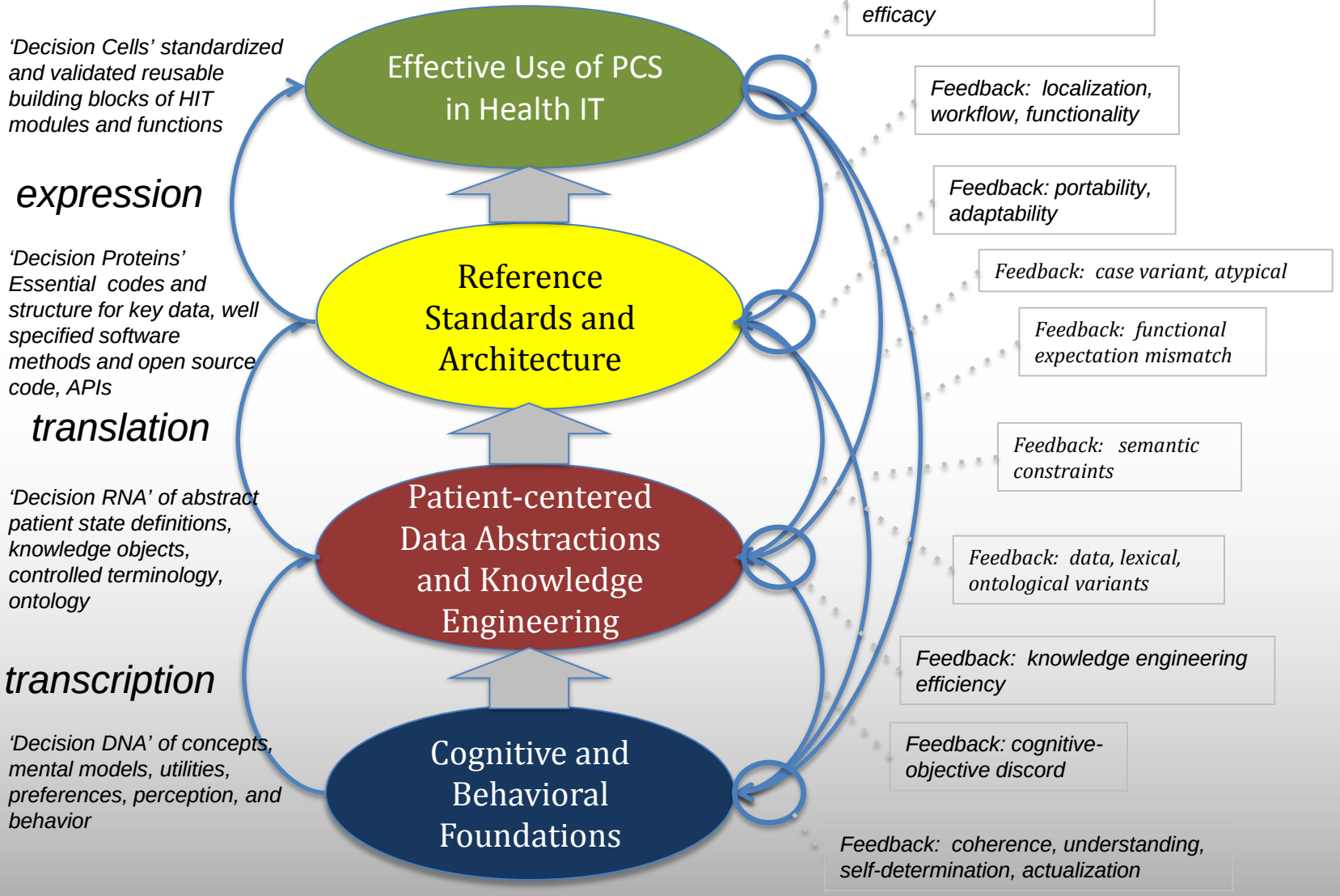
PECARN TBI CDS

CDS Grand Challenges

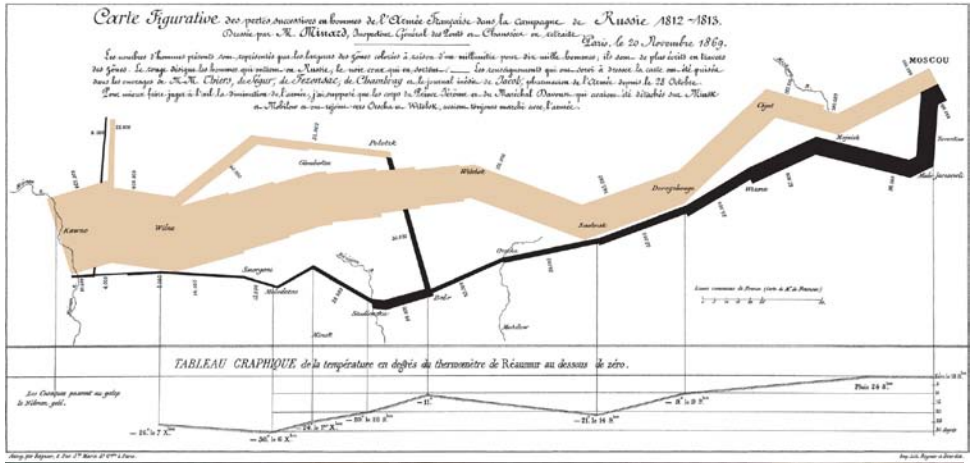
- Summarize patient-level information
- Prioritize recommendations to users
- Combine recommendations for patients with co-morbidities
- Improve the human-computer interface
- Use free text information in clinical decision support
- Manage large clinical knowledge databases
- Create a internet-accessible, clinical decision support repository
- Prioritize CDS content development and implementation
- Disseminate best practices
- Create an architecture for sharing executable CDS modules
- Mine large clinical databases to create new CDS

Sittig et al., J Bio Inf 2008

Integrated CDS Research Portfolio

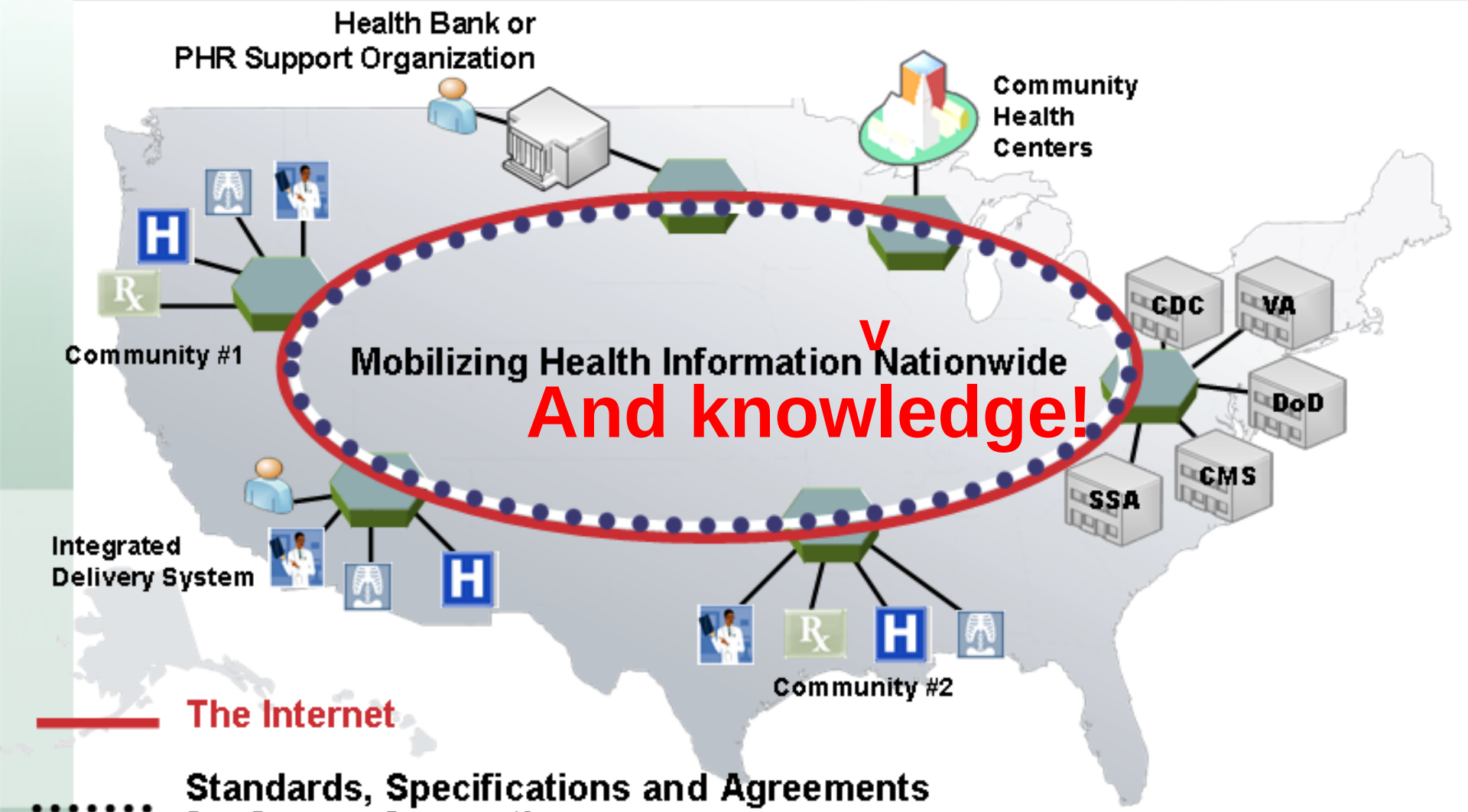


CDS: The Emperor's New Clothes



- Clinicians, and Patients, are ill-equipped with the unaided mind to reason over the complexity and uncertainty of modern medicine
- …. Thus, CDS is an essential component of care
- Knowledge sharing is the only way to scale CDS.

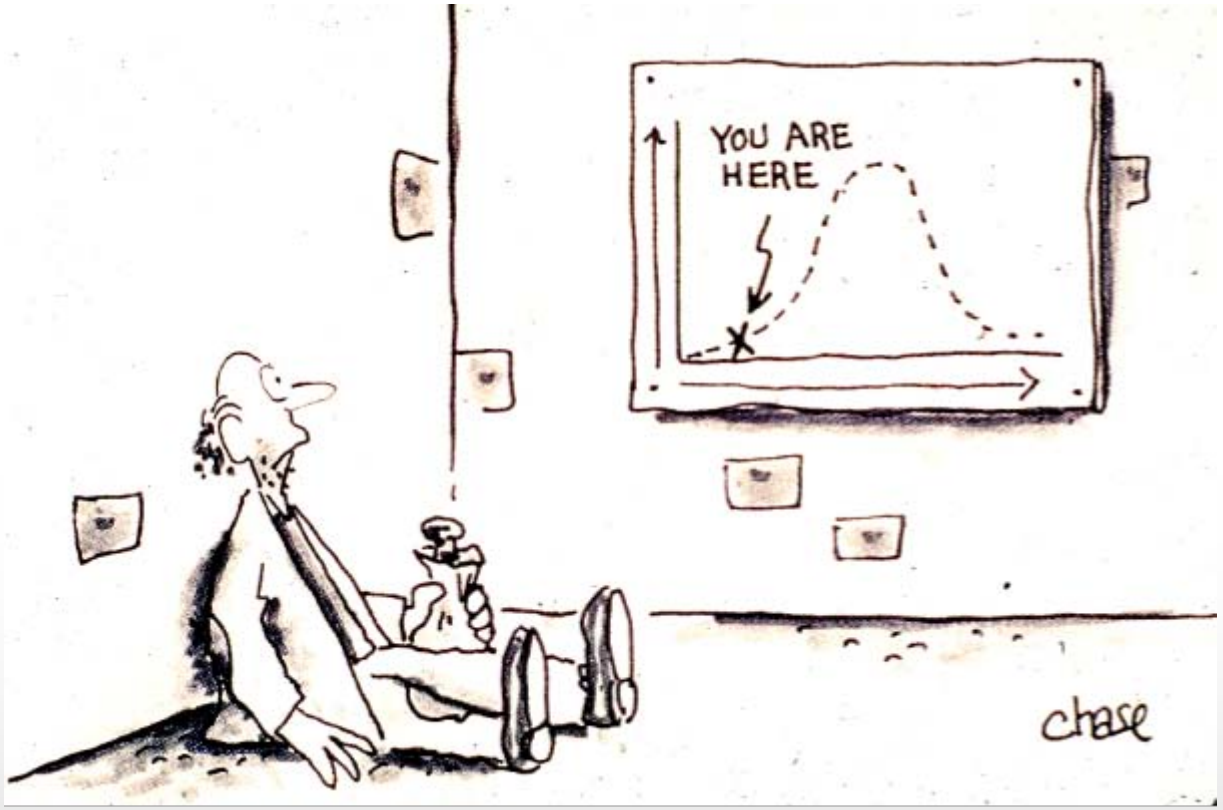
The Nationwide Health Information Network



Where are we?

"I conclude that though the individual physician is not perfectible, the system of care is, and that the computer will play a major part in the perfection of future care systems."

Clem McDonald, MD NEJM 1976



Thank you!

Blackford Middleton, MD
bmiddleton1@partners.org
www.partners.org/cird