MEDEXTER Healthcare

Artificial intelligence and clinical decision support

Educational material, part 1

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Better care, patient safety, and quality assurance by Medexter, Vienna, Austria

MEDEXTER Healthcare

Digitalization in medicine

Digitization, digitalization, and digital transformation in medicine

macro

healthcare systems	national and transnational eHealth
patient data	EHRs, interoperability
medical data	EMRs, data models, ontologies
patient care	CDS, expert systems, AI, NLP
images, signals	imaging and visualization
systems biology	modelling and simulation
molecular medicine	bioinformatics

micro

Digitalization in clinical medicine

- Stage I: Digitalizing medical patient data
  - EHRs, EMRs, Health Apps, images, bio-signals, national, …
- Stage II: Digitalizing clinical workflows
  - In-patient care, wards, departments, out-patient, home, chronic care, …
- Stage III: Digitalizing medical knowledge
  - Anatomy, physiology, pathophysiology, nosology, pharmacology, pharmacogenomics, …

Clinical decision support—Applying knowledge to data

clinical demand

Better care

Patient safety

Quality assurance

Cost reduction

Artificial intelligence in clinical medicine

History

- Clay tablets with cuneiform writing from New Babylonian (about 650 B.C.)
  - instructions to medical examination, diagnosis, and prognosis

- “Reasoning Foundations of Medical Diagnosis” by Ledley and Lusted in Science (1959)
  - computer-assisted medical diagnosis and therapy

- medical expert system MYCIN by Shortliffe et al. (Stanford University, 1975)
  - diagnostic and therapeutic proposals for patients suffering from infectious diseases (evaluation JAMA, 1979)

Antimicrobial Selection by a Computer

A Blinded Evaluation by Infectious Diseases Experts

Victor L. Yu, MD; Lawrence M. Fagan; Sharon M. Wraith; William J. Clancey; A. Carlisle Scott, MS; John Hannigan, MS; Robert L. Blum, MD; Bruce G. Buchanan, PhD; Stanley N. Cohen, MD

• An evaluation of a computer-based consultation system called MYCIN was made. Eight independent evaluators with special expertise in the management of meningitis compared MYCIN's choice of antimicrobials with the choices of nine human prescribers for ten test cases of meningitis. MYCIN received an acceptability rating of 65% by the evaluators; the corresponding ratings for acceptability of the regimen prescribed by the five faculty specialists ranged from 42.5% to 62.5%. The system never failed to cover a treatable pathogen while demonstrating efficiency in minimizing the number of antimicrobials prescribed. The study design may be useful in assessing the performance of other computer-based clinical decision-making systems.

(*JAMA* 242:1279-1282, 1979)

DURING the last two decades, many computer programs have been developed to assist physicians in the diagnosis or treatment of a variety of medical disorders.[1] However, to our knowledge, the medical accuracy of these programs has not undergone clinical evaluation by independent experts. We present a comparison of meningitis before the causative agent had been identified.

The computer program, MYCIN, provides advice for the diagnosis of diseases and the treatment of patients with infectious diseases.[2,3] During the last five years, MYCIN's extensive knowledge base and its therapy-selection process have been

therapy, MYCIN takes into account the specific clinical situations (eg, trauma, neurosurgery), host factors (eg, age, immunosuppression), and the possible presence of unusual pathogens (eg, *Francisella tularensis*, *Candida* non-*albicans*). In selecting antimicrobial therapy, the system considers antimicrobial factors (eg, organism susceptibility, synergistic combinations) and relative contraindications (eg, patient allergies, poor response to prior therapy).

When knowlege about a new area of infectious disease is incorporated into MYCIN's knowledge base, the system's performance is evaluated to determine whether its therapeutic regimens are as reliable as the regimens that an infectious diseases specialist would recommend. An evaluation of the system's ability to diagnose and treat patients with bactere-

MYCIN-I

- diagnostic and therapeutic proposals for patients suffering from infectious diseases

IF

1) the stain of the organism is grampos, and
2) the morphology of the organism is coccus, and
3) the growth conformation of the organism is clumps,

THEN

there is suggestive evidence (0.7), that the identity of the organism is staphylococcus.

Example of a heuristic MYCIN rule

A multiplicity of intelligences

Maya Angelou

1. LINGUISTIC

A mastery and love of language and words with a desire to explore them.

Poets, writers, linguists: T. S. Eliot, Noam Chomsky, W. H. Auden

patient–physician dialogue

Paul Erdös

2. LOGICAL-MATHEMATICAL

Confronting and assessing objects and abstractions and discerning their relations and underlying principles.

Mathematicians, scientists, philosophers: Stanislaw Ulam, Alfred North Whitehead, Henri Poincaré, Albert Einstein, Marie Curie

diagnostician [Dr. House]

…

Alvin Ailey

5. BODILY-KINESTHETIC

Controlling and orchestrating body motions and handling objects skillfully.

Dancers, athletes, actors: Marcel Marceau, Martha Graham, Michael Jordan

surgeon, internist, …

Margaret Mead

6. and 7. PERSONAL INTELLIGENCES

Accurately determining moods, feelings and other mental states in oneself (intrapersonal intelligence) and in others (interpersonal) and using the information as a guide for behavior.

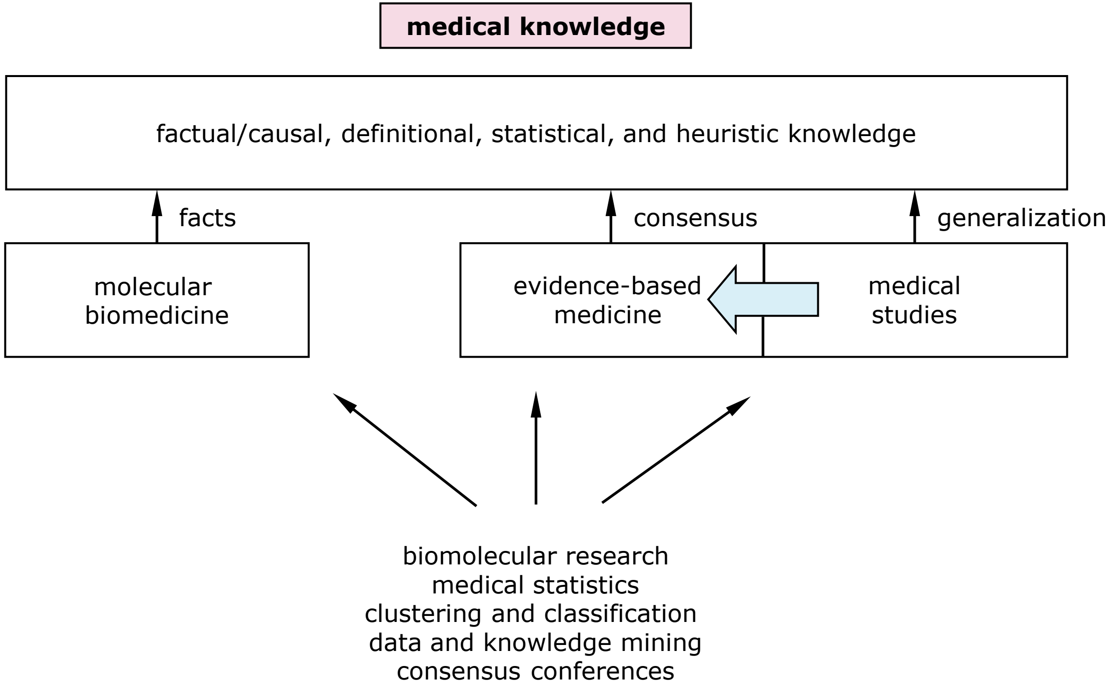
Psychiatrists, politicians, religious leaders, anthropologists: Sigmund Freud, Mahatma Gandhi, Eleanor Roosevelt

emotional and social intelligence

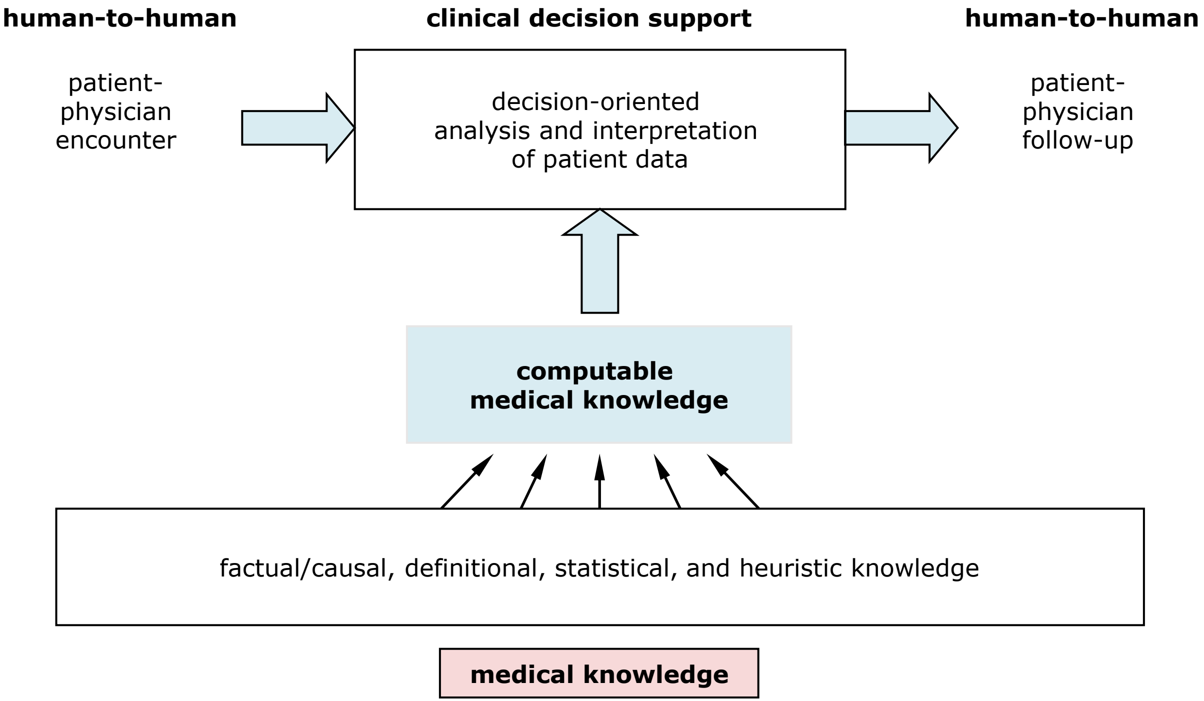
…

from: Gardner, H. (1998) A Multiplicity of Intelligences. *Scientific American Presents* 9(4), 19–23.

Medical research



Patient care



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Artificial Intelligence (AI)—applicable to clinical medicine

- *Definition*: AI is the science of artificial simulation of human thought processes with computers.

  from: Feigenbaum, E.A. & Feldman, J. (eds.) (1995) *Computers & Thought*. AAAI Press, Menlo Park, back cover.

- It is the decomposition of an entire clinical thought process and its separate artificial simulation—also of simple instances of "clinical thought"—that make the task of AI in clinical medicine manageable.

- A functionally-driven science of AI that extends clinicians through computer systems step by step can immediately be established.

$$\Downarrow$$

artificial-intelligence-augmented clinical medicine

Clinical decision support

Towards clinical decision support

Steps of natural progression

- patient administration
  - admission, transfer, discharge, and billing
- documentation of patients’ medical data
  - electronic health record: all media, distributed, life-long (partially fulfilled)
- patient and hospital analytics
  - data warehouses, quality measures, reporting and research databases, data and text mining, patient study recruitment
    … population-specific
- **clinical decision support**
  - safety net, quality assurance, evidence-based
    … patient-specific

Perspectives on Informatics JAMIA

AMIA Board White Paper ■

Core Content for the Subspecialty of Clinical Informatics

REED M. GARDNER, PHD, J. MARC OVERHAGE, MD, PHD, ELAINE B. STEEN, MA,, BENSON S. MUNGER, PHD, JOHN H. HOLMES, PHD, JEFFREY J. WILLIAMSON, DON E. DETMER, MD, MA, FOR THE AMIA BOARD OF DIRECTORS

Abstract The Core Content for Clinical Informatics defines the boundaries of the discipline and informs the Program Requirements for Fellowship Education in Clinical Informatics. The Core Content includes four major categories: fundamentals, clinical decision making and care process improvement, health information systems, and leadership and management of change. The AMIA Board of Directors approved the Core Content for Clinical Informatics in November 2008.

■ **J Am Med Inform Assoc.** 2009;16:153–157. DOI 10.1197/jamia.M3045.

Background

The Core Content for a medical subspecialty defines the boundaries of the discipline and informs the Program Requirements for Fellowship Education. Program Requirements identify the knowledge and skills that must be mastered through the course of fellowship training and specify accreditation requirements for training programs.[1] The American Board of Medical Specialties considers these two documents along with other requirements and factors when deciding whether to establish a new medical subspecialty. The Core Content for Clinical Informatics is the result of a two-year national development process initiated by the American Medical Informatics Association and supported by the Robert Wood Johnson Foundation.[2] In November 2008, the AMIA Board of Directors approved both the Core Content and Program Requirements for clinical informatics.

Affiliations of the authors: Department of Medical Informatics, University of Utah (RMG), Salt Lake City, UT; Regenstrief Institute and Indiana Health Information Exchange (JMO), Indianapolis, IN; American Medical Informatics Association (EBS, JJW, DED), Bethesda, MD; Arizona Emergency Medicine Research Center, University of Arizona (BSM), Tucson, AZ; Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine (JHH), Philadelphia, PA; University of Virgina School of Medicine (DED), Charlottesville, VA.

The American Medical Informatics Association (AMIA) Board of Directors thanks the members of the Clinical Informatics Core Content team for their thoughtful and energetic discussions that resulted in this document. Team members included: Joan S. Ash, PhD, MBA; James J. Cimino, MD; H. Dominic Covvey, MSc; Reed M. Gardner (Chair), PhD; John H. Holmes, PhD; Nancy C. Nelson, MS; J. Marc Overhage, MD, PhD (Vice Chair); Charles Safran, MS, MD; Richard N. Shiffman, MD, MCIS; and Heiko Spallek, DMD, PhD. AMIA acknowledges the contributions of over fifty reviewers whose input strengthened the core content. AMIA thanks the Robert Wood Johnson Foundation for generously supporting this

Definition and Description of the Subspecialty

Clinical informaticians transform health care by analyzing, designing, implementing, and evaluating information and communication systems that enhance individual and population health outcomes, improve patient care, and strengthen the clinician-patient relationship.

Clinical informaticians use their knowledge of patient care combined with their understanding of informatics concepts, methods, and tools to:

- assess information and knowledge needs of health care professionals and patients,
- characterize, evaluate, and refine clinical processes,
- develop, implement, and refine clinical decision support systems, and
- lead or participate in the procurement, customization, development, implementation, management, evaluation, and continuous improvement of clinical information systems.

Physicians who are board-certified in clinical informatics collaborate with other health care and information technology professionals to promote patient care that is safe, efficient, effective, timely, patient-centered, and equitable.

As illustrated in Figure 1, clinical informatics encompasses three spheres of activity:

- clinical care (i.e., the provision of clinical services to an individual patient),

A "holy grail" of clinical informatics is scalable, interoperable ***clinical decision support****.*

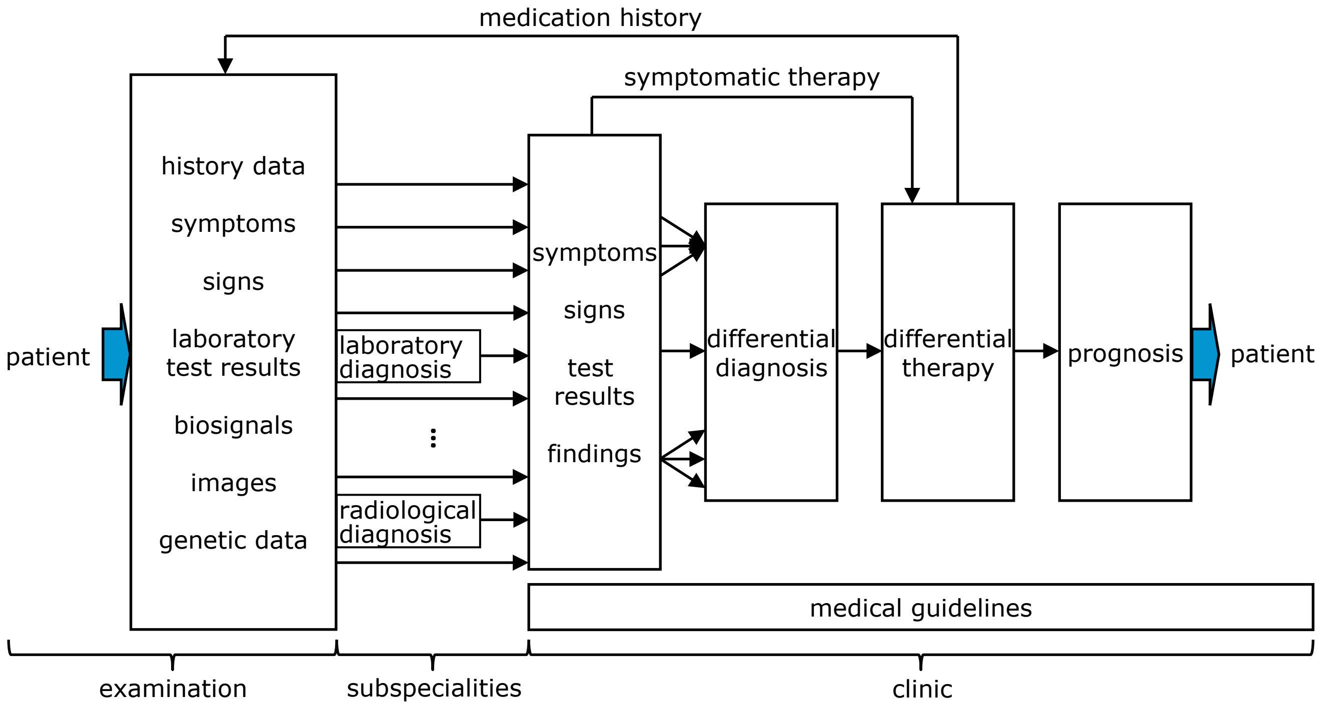
according to

Kensaku Kawamoto

HL7 Work Group Meeting,

San Diego, CA, September 2011

Clinical medicine



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Clinical medicine: high complexity

- **sources of medical knowledge**
  - factual/causal
  - definitional
  - statistical/study-based
  - heuristic

  evidence-based medicine

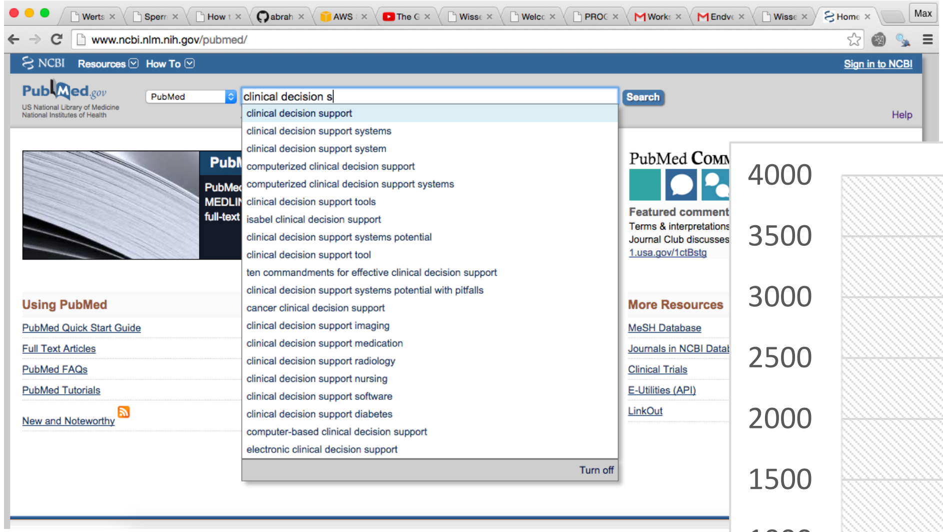
- **layers of medical knowledge**
  - observational and measurement level
  - interpretation, abstraction, aggregation, summarization
  - pathophysiological states
  - diseases/diagnoses, therapies, prognoses, management decisions

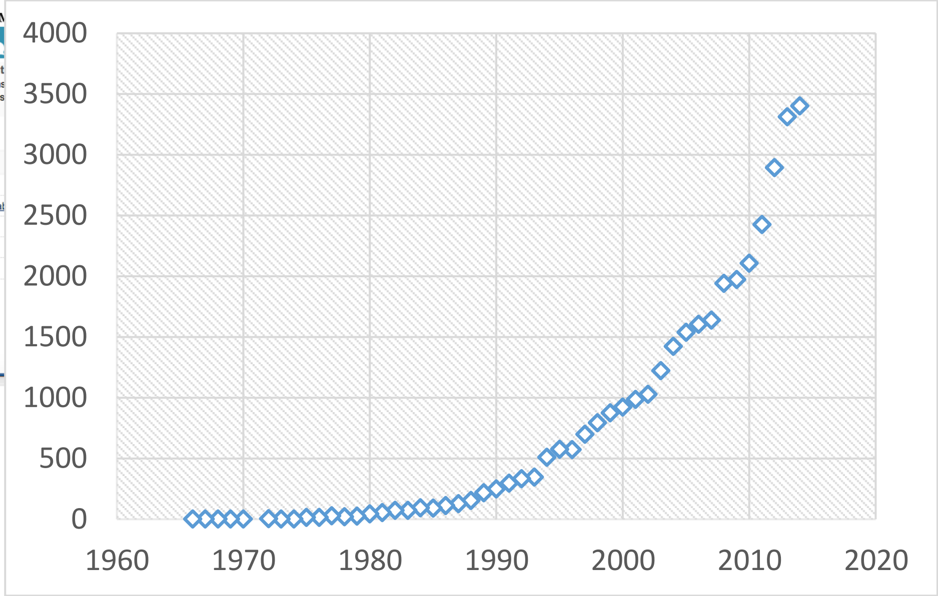
- **imprecision, uncertainty, and incompleteness**
  - imprecision (=fuzziness) of medical concepts
    - due to the unsharpness of boundaries of linguistic concepts
  - uncertainty of medical conclusions
    - due to the uncertainty of the occurrence and co-occurrence of precise and imprecise medical concepts
  - incompleteness of medical data and medical theory
    - due to only partially known medical data and partially known explanations for medical phenomena

- **"gigantic" amount of medical data and medical knowledge**
  - patient history, physical examination, laboratory test results, clinical findings
  - symptom-disease relationships, disease-therapy relationships, gene-drug relationships, …
  - terminologies, ontologies: SNOMED CT, LOINC, UMLS, …

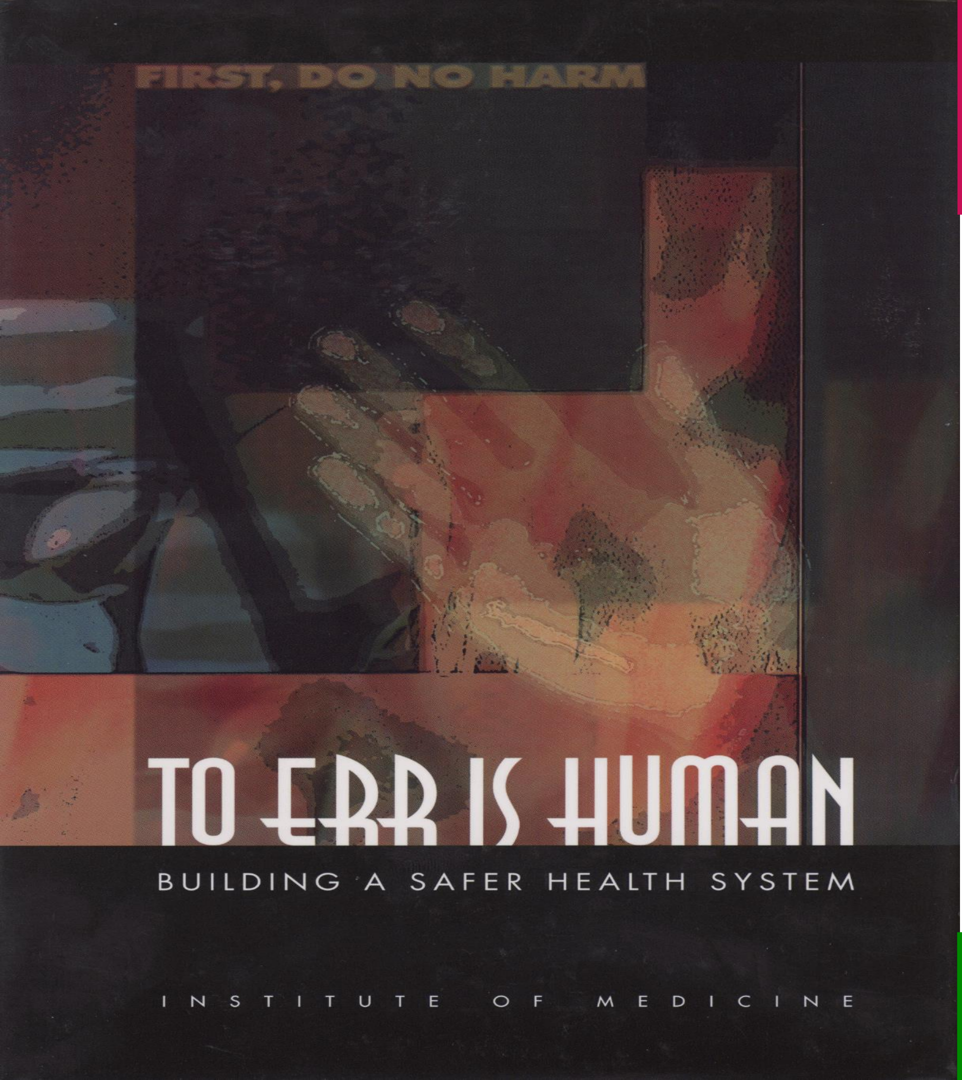
specialization, teamwork, quality management, **computer support → CDS**

Literature on "Clinical Decision Support": 36,211 publications





Max Plischke, 2015

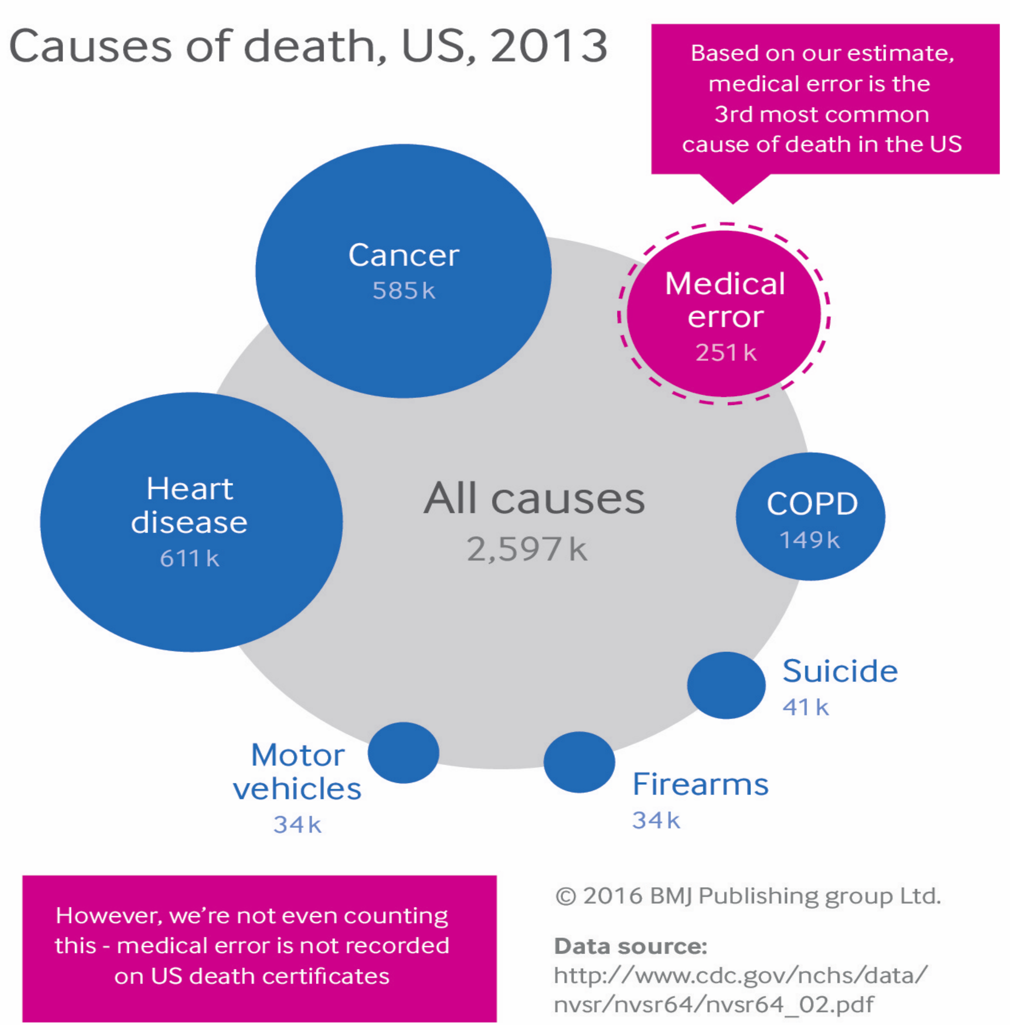


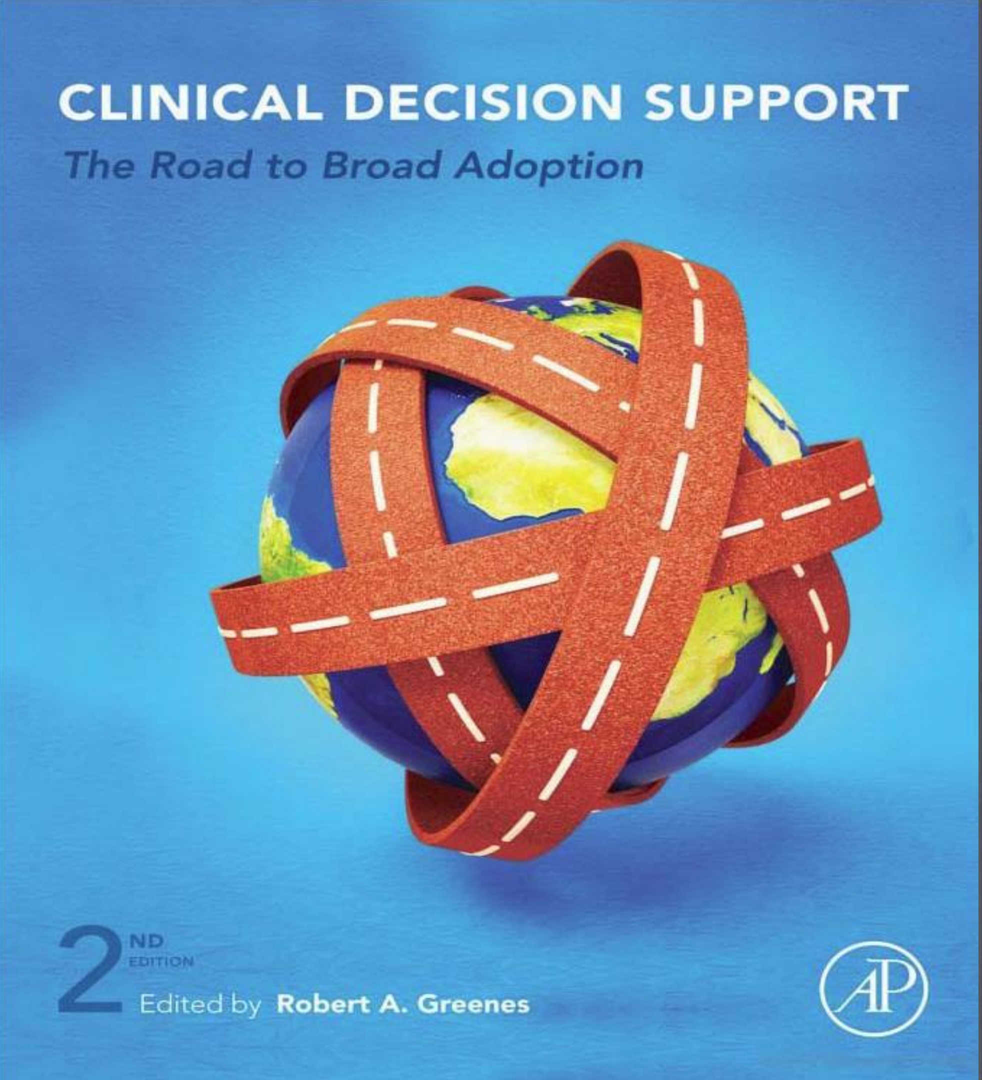
- studies in Colorado and Utah and in New York (1997)
  - errors in the delivery of health care leading to the death of as many as 98,000 US citizens annually
- causes of errors
  - error or delay in diagnosis
  - fail… by indicated tests
  - use of outmoded tests or therapy
  - failure to act on results of testing or monitoring
  - error in the performance of a test, procedure, or operation
  - error in administering the treatment
  - error in the dose or method of using a drug
  - avoidable delay in treatment or in responding to an abnormal test
  - i… indicated) care
  - fa…ication
  - equipment failure

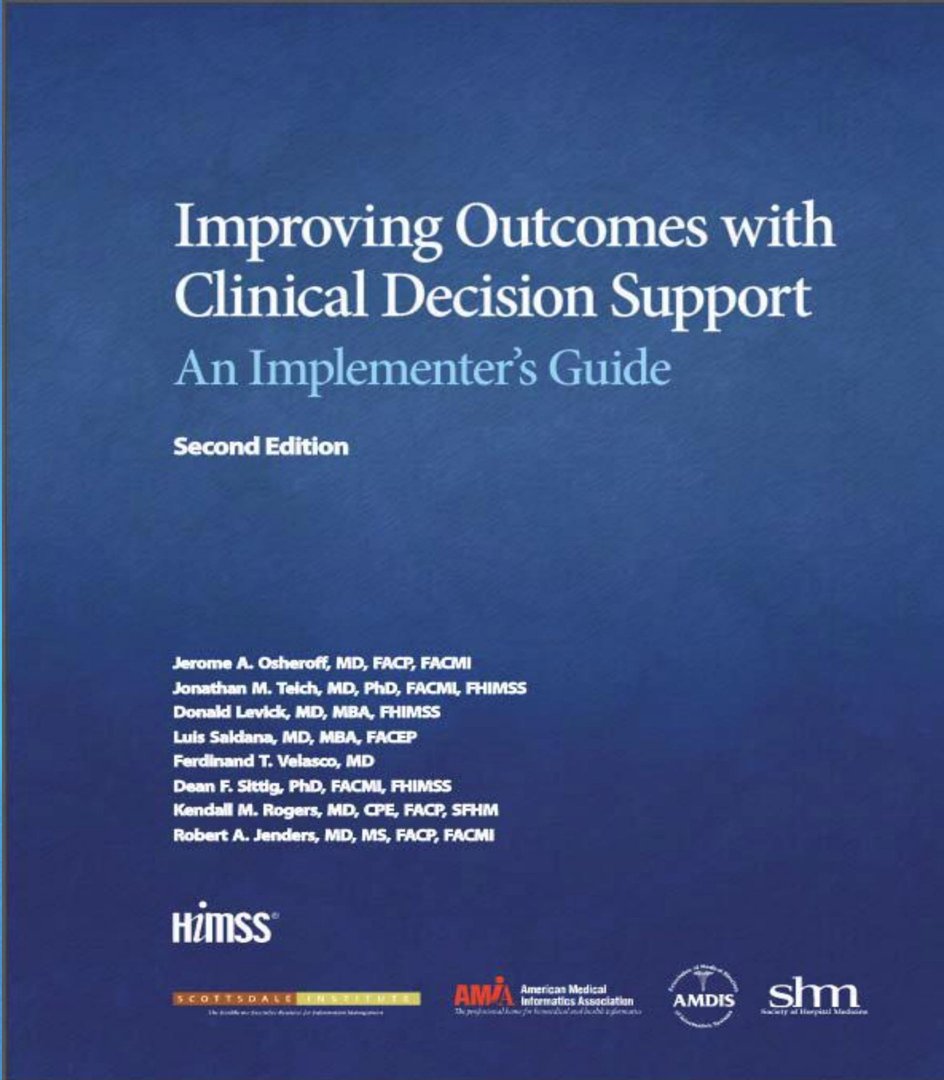
errors

prevention

- prevention of errors
  - we must systematically **design safety** into processes of care


Causes of death, US, 2013
Based on our estimate, medical error is the 3rd most common cause of death in the US
Cancer 585k
Medical error 251k
Heart disease 611k
All causes 2,597k
COPD 149k
Suicide 41k
Motor vehicles 34k
Firearms 34k
However, we're not even counting this - medical error is not recorded on US death certificates
© 2016 BMJ Publishing group Ltd.
Data source: http://www.cdc.gov/nchs/data/nvsr/nvsr64/nvsr64_02.pdf


CLINICAL DECISION SUPPORT
The Road to Broad Adoption
2ND EDITION
Edited by Robert A. Greenes
AP


Improving Outcomes with Clinical Decision Support
An Implementer's Guide
Second Edition
Jerome A. Osheroff, MD, FACP, FACMI
Jonathan M. Teich, MD, PhD, FACMI, FHIMSS
Donald Levick, MD, MBA, FHIMSS
Luis Saldana, MD, MBA, FACEP
Ferdinand T. Velasco, MD
Dean F. Sittig, PhD, FACMI, FHIMSS
Kendall M. Rogers, MD, CPE, FACP, SFHM
Robert A. Jenders, MD, MS, FACP, FACMI
HIMSS
SCOTTSDALE INSTITUTE
AMIA American Medical Informatics Association
AMDIS
shm

Clinical decision support: Definitions

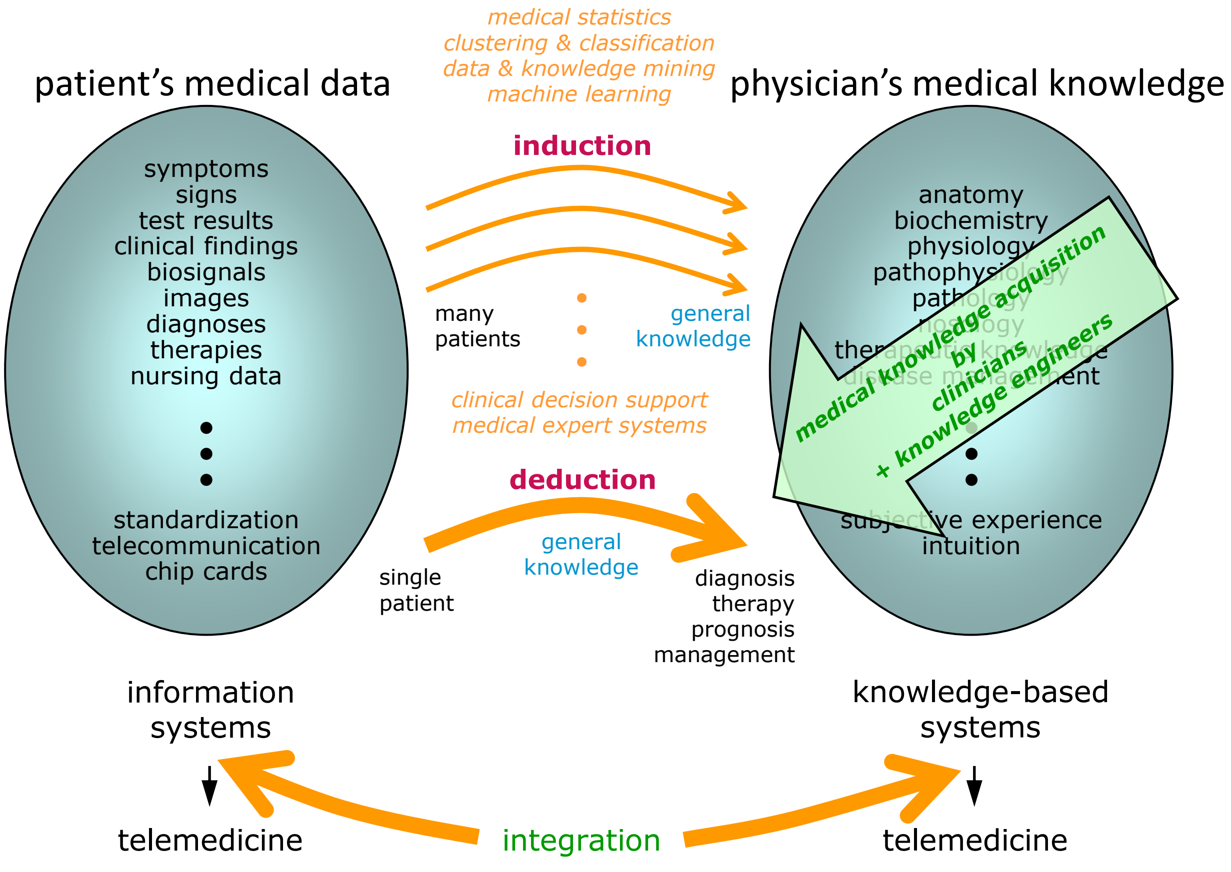
- Foundational: Key origin of field of biomedical informatics
  - AIM = artificial intelligence in medicine
  - computer-based diagnosis in the heyday of AI

- Now: Intelligent assistant
  - support/assist human decision makers, not supplant them

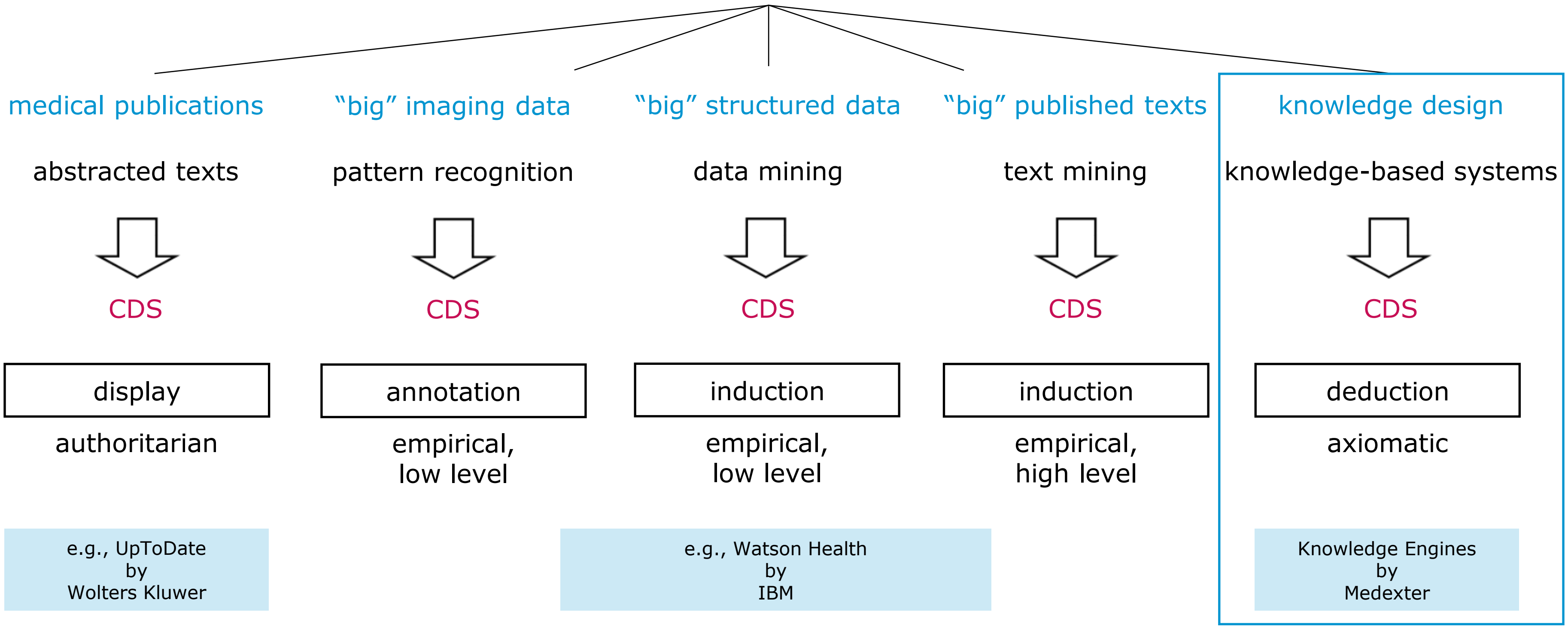
⇒ Core: Applying knowledge to data

Miller RA. Medical diagnostic decision support systems—past, present and future: a threaded bibliography and brief commentary. Journal of the American Medical Informatics Association 1994;1:8-27.

EMRs with CDS through knowledge-based systems



Approaches to CDS



Knowledge-based clinical decision support

Knowledge design

based upon

individual "proprietary" knowledge

consensual "institutional" knowledge

written documents

designed knowledge for the digital age

multi-stakeholder Kaizen events

computable biomedical knowledge

e.g.,
EHR alerts, MES, AppStore apps, SaaS apps, CDS Hooks, medical knowledge engines

Kai – change; Zen – (continuous) improvement

UpToDate by Wolters Kluwer: Abstracted published texts

Hepatitis B and pregnancy...

https://www.uptodate.com/contents/hepatitis-b-and-pregnancy?source=see_link

uptodate

UpToDate®

Language | Hilfe

Willkommen, Wiener Krankenanstaltenverbund KAV | Anmelden

Hepatitis at Pregnancy

Inhalt | Patientenschulung | Neuigkeiten | Praxisrelevante News | Rechner | Arzneimittelwechselwirkungen

Hepatitis B and pregnancy

hepatitis at pregnancy Find Print Email

Hepatitis B and pregnancy

Authors: Hannah Lee, MD, Anna SF Lok, MD

Section Editors: Rafael Esteban, MD, Louise Wilkins-Haug, MD, PhD

Deputy Editor: Jennifer Mitty, MD, MPH

Contributor Disclosures

All topics are updated as new evidence becomes available and our peer review process is complete.

Literature review current through: Feb 2017. | **This topic last updated:** Feb 04, 2017.

INTRODUCTION — Hepatitis B virus (HBV) infection during pregnancy presents with unique management issues for both the mother and the fetus. These include the effects of HBV on maternal and fetal health, the effects of pregnancy on the course of HBV infection, treatment of HBV during pregnancy, and prevention of mother-to-child transmission.

Prevention of mother-to-child transmission is an important component of global efforts to reduce the burden of chronic HBV since vertical transmission is responsible for approximately one-half of chronic infections worldwide. The risk of developing chronic HBV infection is inversely proportional to the age at time of exposure. The risk is as high as 90 percent in those exposed at birth without vaccination, while the risk is much lower (about 20 to 30 percent) in those exposed during childhood. Maternal screening programs and universal vaccination of infants have significantly reduced transmission rates.

This topic will review special considerations for the management of patients with acute and chronic HBV infection during pregnancy and the post-partum period, as well as prevention of mother-to-child transmission. Additional topic reviews that address prevention and management of HBV infection in children, and liver disease in pregnancy, are found elsewhere:

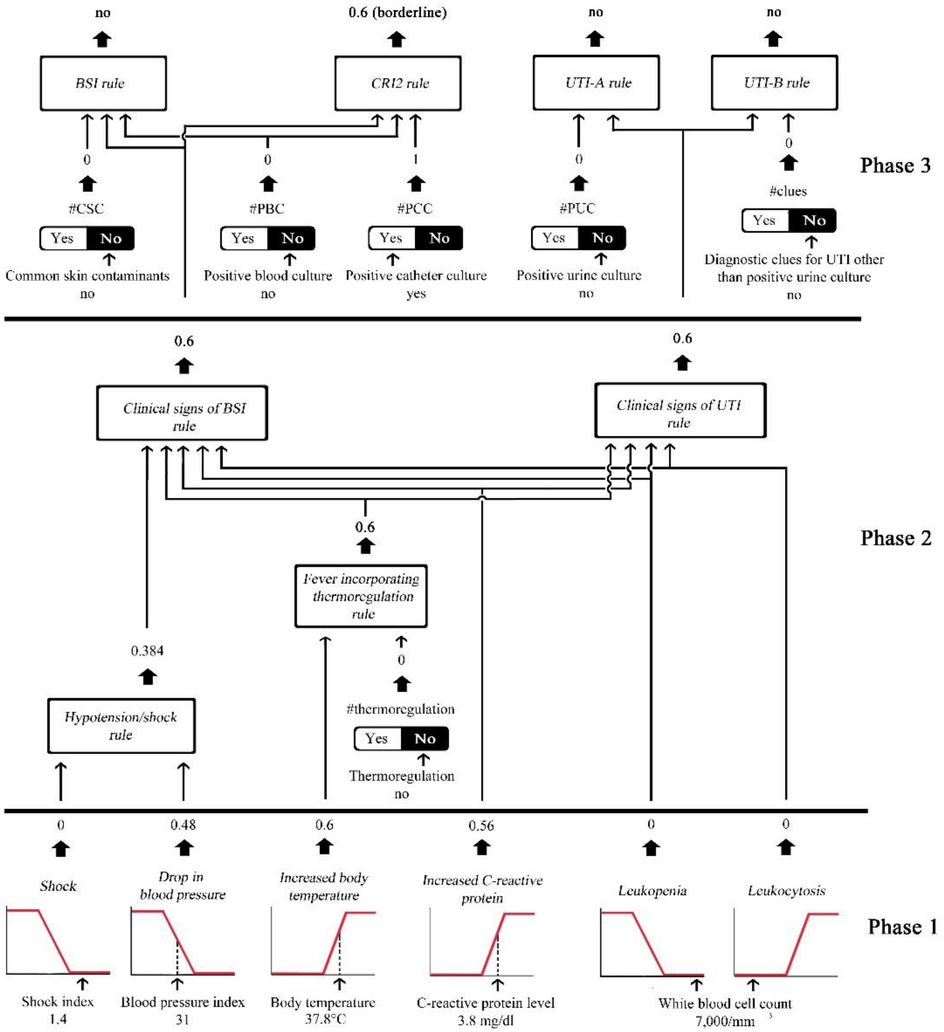
- (See "Hepatitis B virus immunization in infants, children, and adolescents".)
- (See "Hepatitis viruses and the newborn: Clinical manifestations and treatment".)
- (See "Overview of hepatitis B virus infection in children and adolescents".)
- (See "Acute fatty liver of pregnancy".)
- (See "HELLP syndrome".)
- (See "Intrahepatic cholestasis of pregnancy".)
- (See "Approach to liver disease occurring during pregnancy".)
- (See "Pregnancy in women with pre-existing chronic liver disease".)

ACUTE HEPATITIS B VIRUS INFECTION — Acute viral hepatitis is the most common cause of jaundice in pregnancy [1]. Other causes include liver diseases associated with pregnancy, such as acute fatty liver of pregnancy, HELLP syndrome, and intrahepatic cholestasis of pregnancy. (See "Approach to liver disease occurring during pregnancy" and "Acute fatty liver of pregnancy" and "HELLP syndrome" and "Intrahepatic cholestasis of pregnancy".)

Acute hepatitis B virus (HBV) infection during pregnancy is usually mild and not associated with increased mortality or teratogenicity [1,2]. Thus, infection during gestation should not prompt consideration of termination of the pregnancy. However, there have been reports of an increased incidence of low birth weight and prematurity in infants born to mothers with acute HBV infection [2,3].

Acute HBV occurring early in the pregnancy has been associated with a 10 percent perinatal transmission rate [3]. Transmission rates significantly increase if acute infection occurs at or near the time of delivery, with rates as high as 60 percent reported [1]. Thus, serial monitoring should be performed throughout pregnancy, and if the mother remains hepatitis B surface antigen (HBsAg)-

Feedback zum Thema

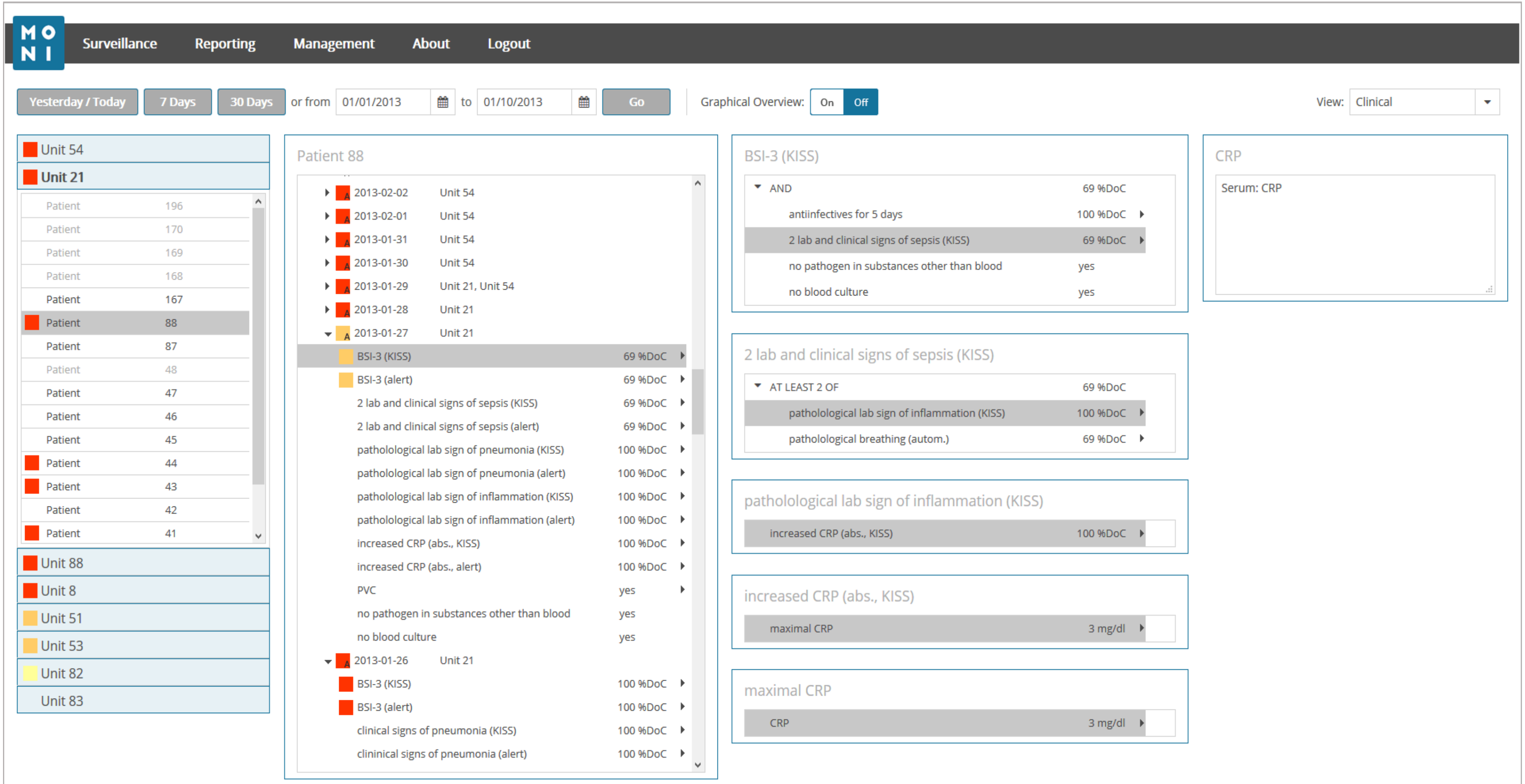


Moni:

Healthcare-associated infection surveillance at ICUs

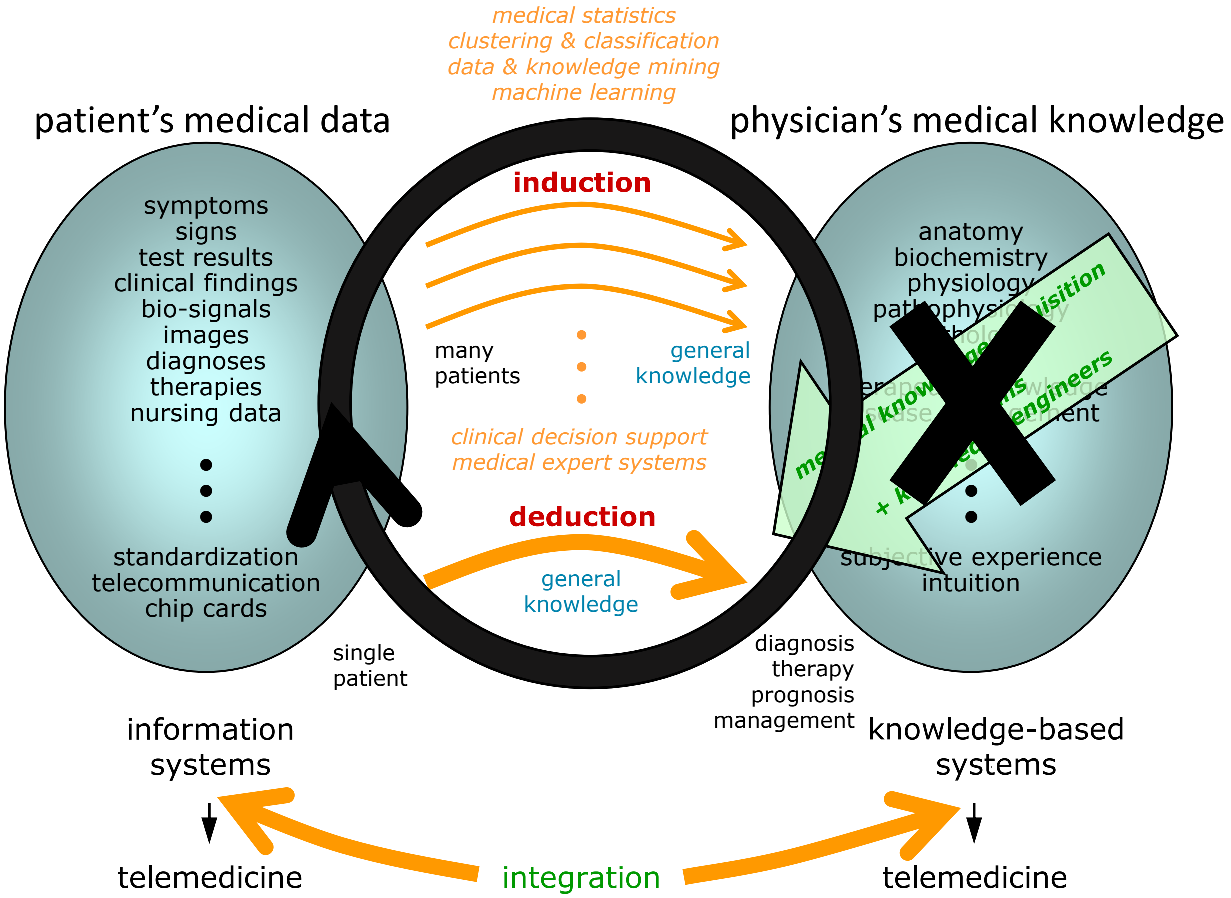
- Septicemias
  - primary, secondary, device-associated, unknown origin
- ICU-acquired pneumonias
  - bronchitis, pneumonia, various degrees of mibi confirmation
- Urinary tract infections
  - mibi-confirmed, not mibi-confirmed
- Central-venous-catheter-related infections
  - local, global, no positive blood culture, mibi-confirmed

Moni by Medexter for HAI surveillance: Knowledge design

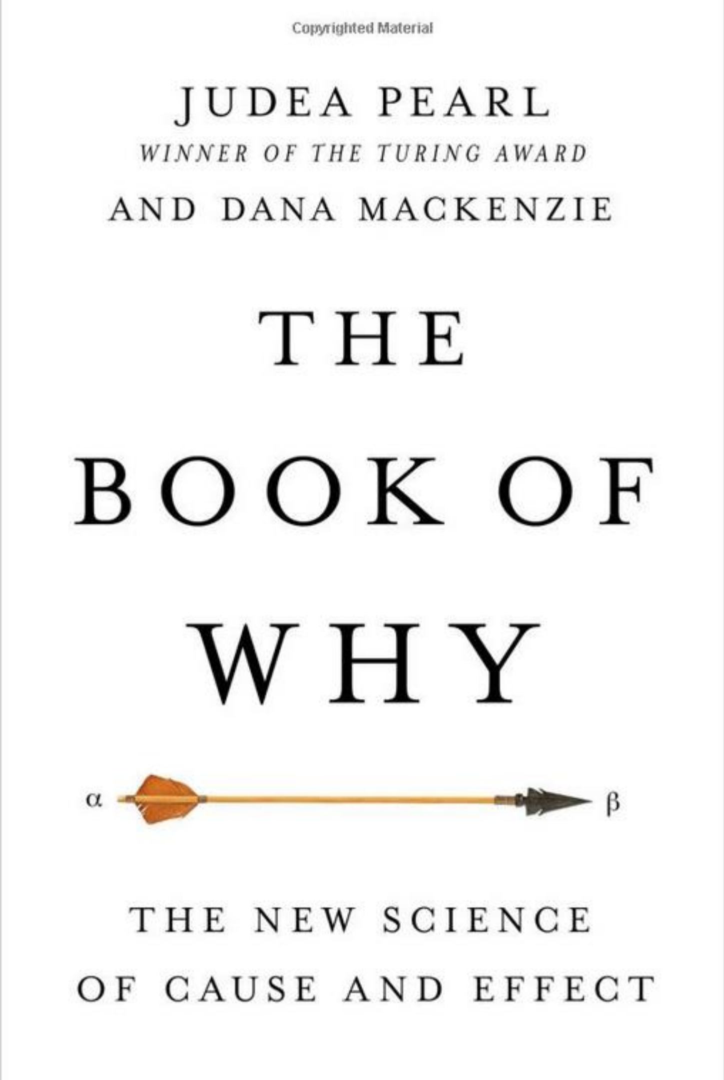


Machine-learning artificial intelligence

Machine-learning AI as shortcut



RSNA
aws
RSNA AI THEATER
ARTERYS
KHEIRON
MEDICAL TECHNOLOGIES
KHEIRON
MEDICAL TECHNOLOGIES
Helping radiologists detect breast cancer
Mia
Directly supports radiologists
with the most critical decision:
to recall or not to recall
CADx
Vitu
Healthcare
KOREA
GE Healthcare
intel
DeepRadio
CR Chest Service



Correlation is not causation.

Today's machine learning relies on correlation, not causation.

⇒ study of causality by causal inference networks

Lucky is he/she who has been able to understand the causes of things.

Virgil, 29 BC

Big data—false positives/false negatives

Amazon

user
book ordering

⇩ AI algorithm

recommendations
hits/misses

user
It’s not essential.

≠

clinical medicine
(more than medical imaging)

patient
symptoms, signs, laboratory test results, clinical findings

⇩ AI-supported clinician

diagnosis
confirmed/hypothesis/screening/missing
therapy
selection/optional/patient preference

patient (and clinician)
It’s essential!

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Explainable machine-learning artificial intelligence

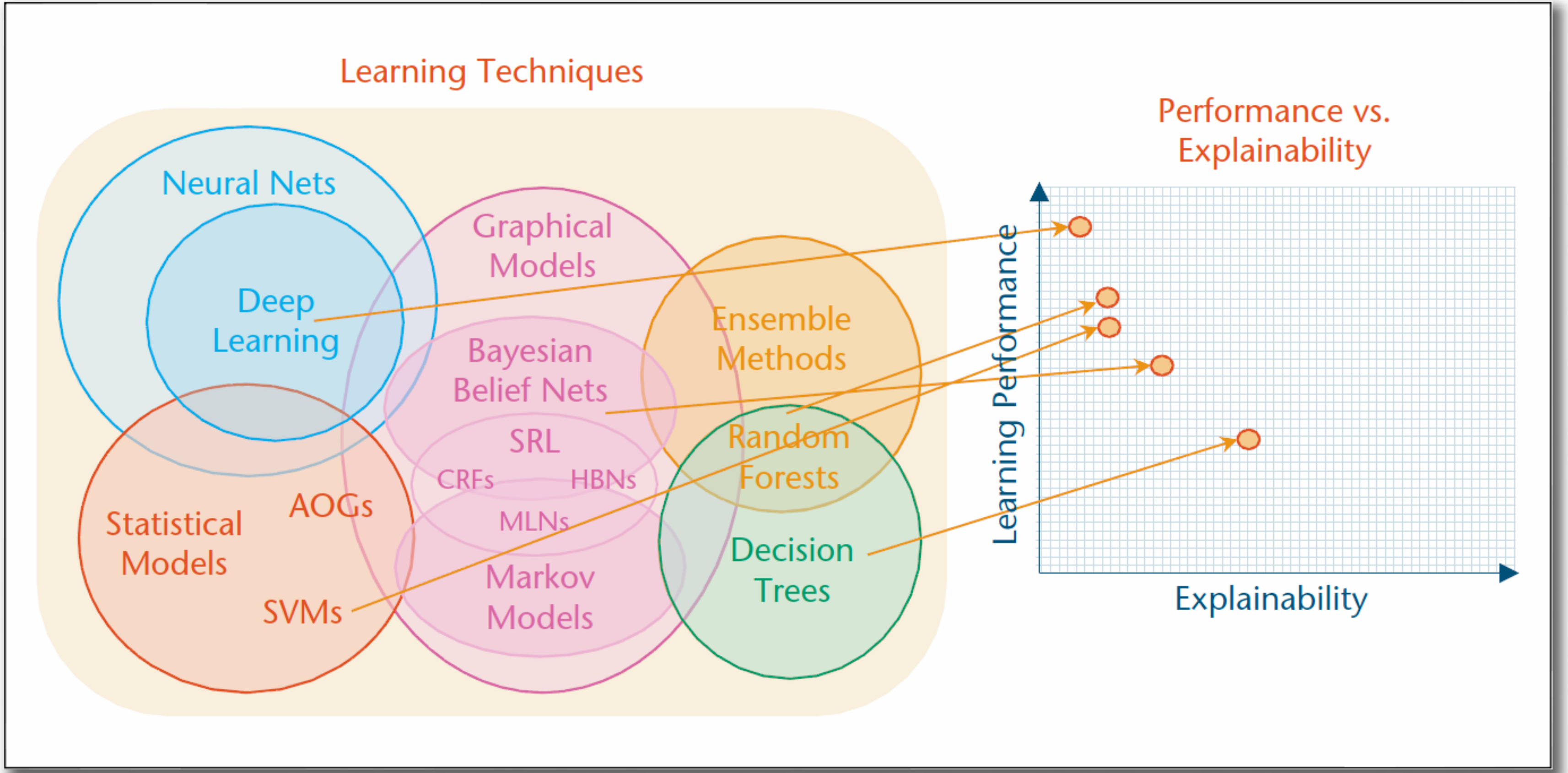

Figure 1. Learning Performance Versus Explainability Trade-Off for Several Categories of Learning Techniques.

from: Gunning, D., Aha D.W. (2019) DARPA's Explainable Artificial Intelligence Program. *AI Magazine* 40(2), 44–58.

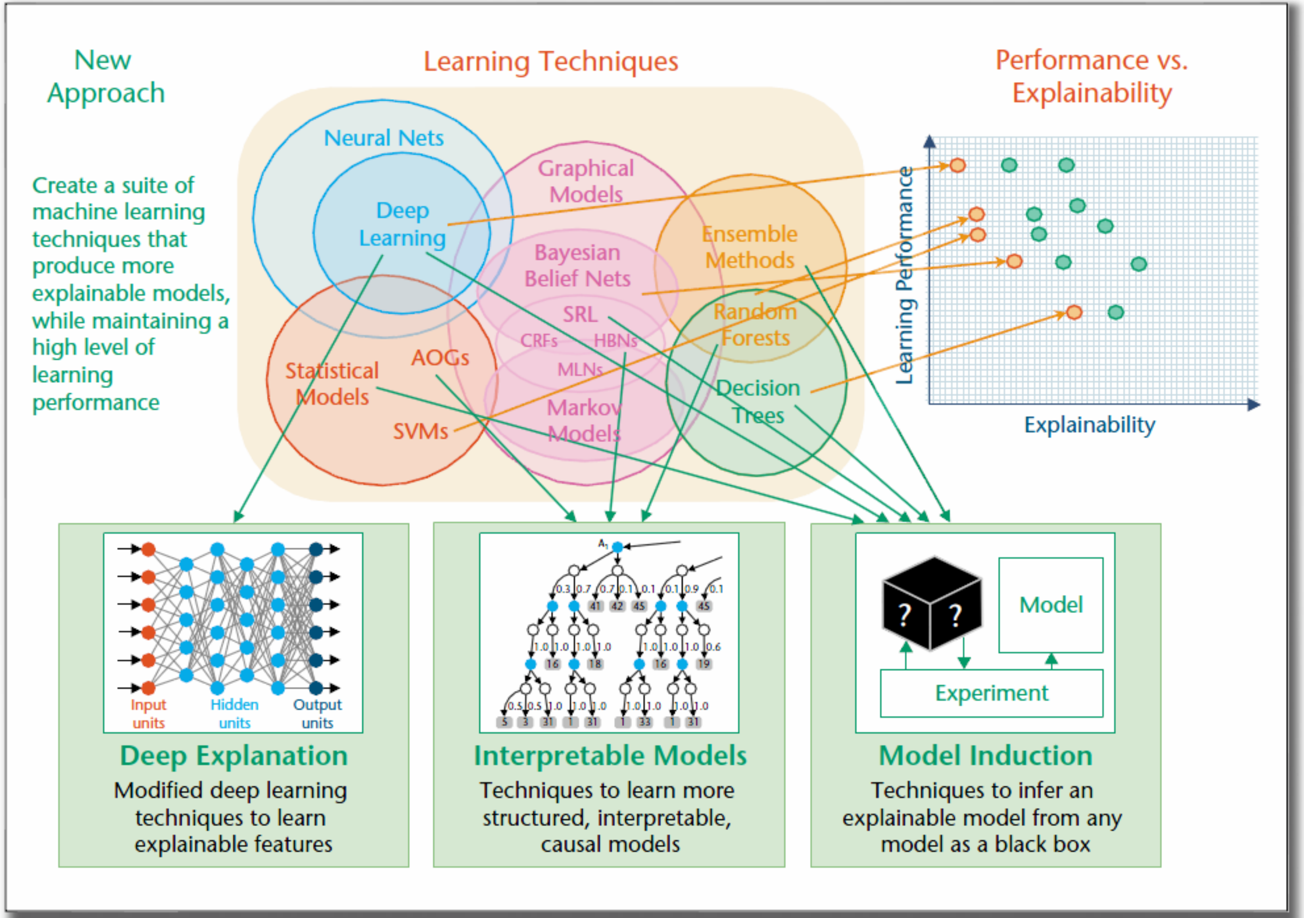

Figure 2. Strategies for Developing Explainable Models.

from: Gunning, D., Aha D.W. (2019) DARPA's Explainable Artificial Intelligence Program. *AI Magazine* 40(2), 44–58.

Outlook

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Clinical decision support with knowledge engines

Knowledge Engines

DIAGNOSIS

- alerts, reminders, to-do lists
- clinical test interpretations and temporal abstraction
- (tele)monitoring of chronic conditions
- differential diagnostics
  - rare diseases, rare syndromes
  - further diagnostic procedures
  - multi-morbidity
- genetics, proteomics
  - molecular variations

THERAPY

- drug alerts, reminders, calculations
  - indication, contraindications, redundant medications, cost-effective substitutions
  - dosage calculations, drug-drug and gene-drug interactions
  - adverse drug events
- management of antimicrobial therapies
  - susceptibility and resistance rates
- pharmacogenomics

PROGNOSIS

- illness severity scores, prediction rules
- trend detection and visualization

HOSPITAL MANAGEMENT

- computerized evidence-based workflows, clinical guidelines, protocols, SOPs
- surveillance criteria and quality benchmarking

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Clinical decision support: Infinite extent

Medical data

+ national health systems
+ EHR, EMR
+ GP SW
+ mobile health apps

⋮

Medical knowledge with processing engines

+ alerts, reminders, recommendations, calculations, …
+ hepatitis serology, toxoplasmosis serology, …
+ rheumatology for GPs, …
+ rheumatology for clinics, …
+ HAI alerts, surveillance, reports, …
+ guidelines for diabetes, …
+ hepatitis at pregnancy, …

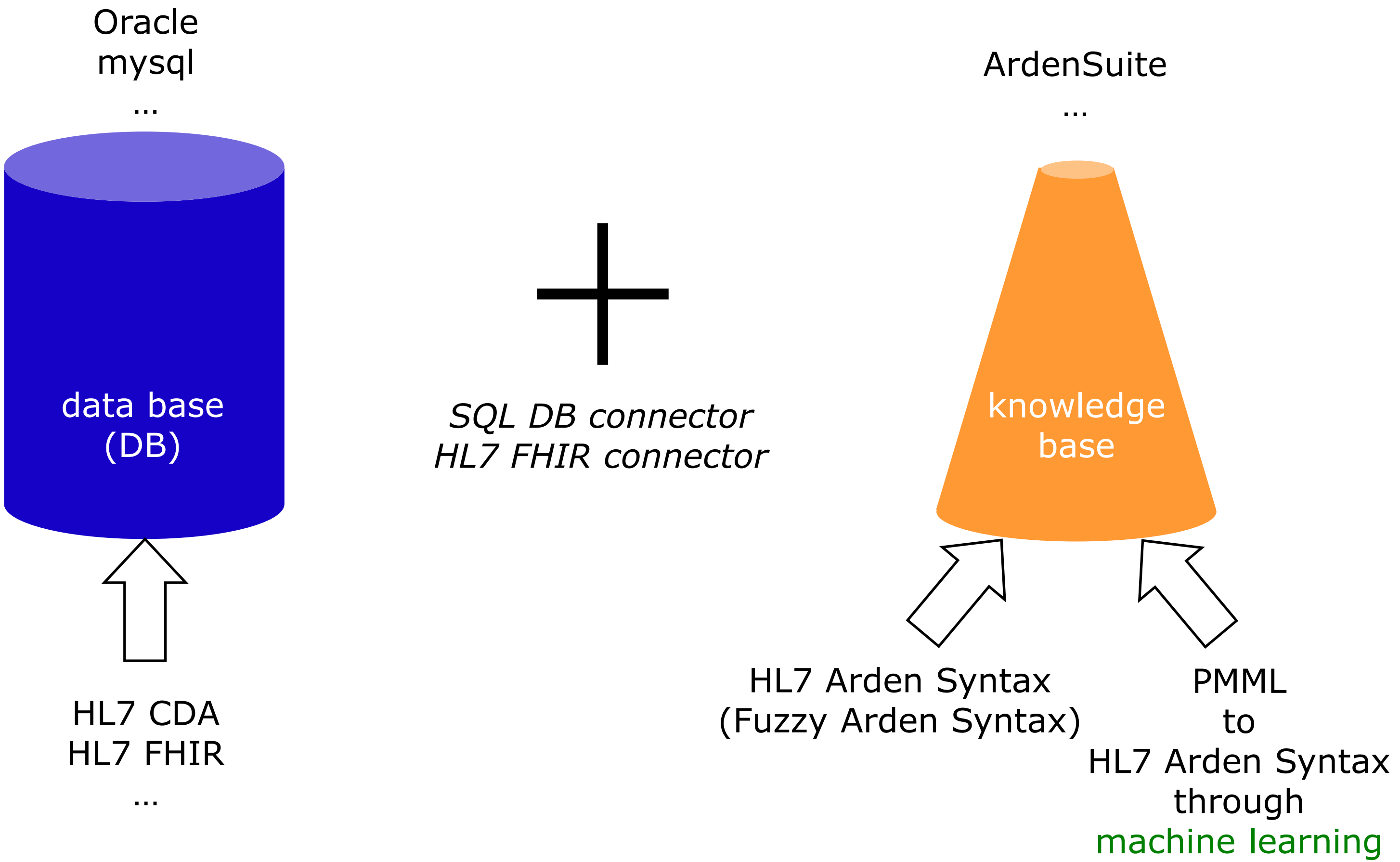
infinite
content complexity

infinite
clinical subjects

INFINITE
APPLICATIONS

data systems + knowledge systems

Standards-based hospital IT for CDS



Medical Knowledge Engines

Use it
as part of your EMR
or
as stand-alone application

KNOWLEDGE ENGINE

Medical Knowledge
medical logic modules

+

CDS Engine

The prediction:

In the future, any clinical activity will be either supported or substituted by Medical Knowledge Engines.

The medical knowledge

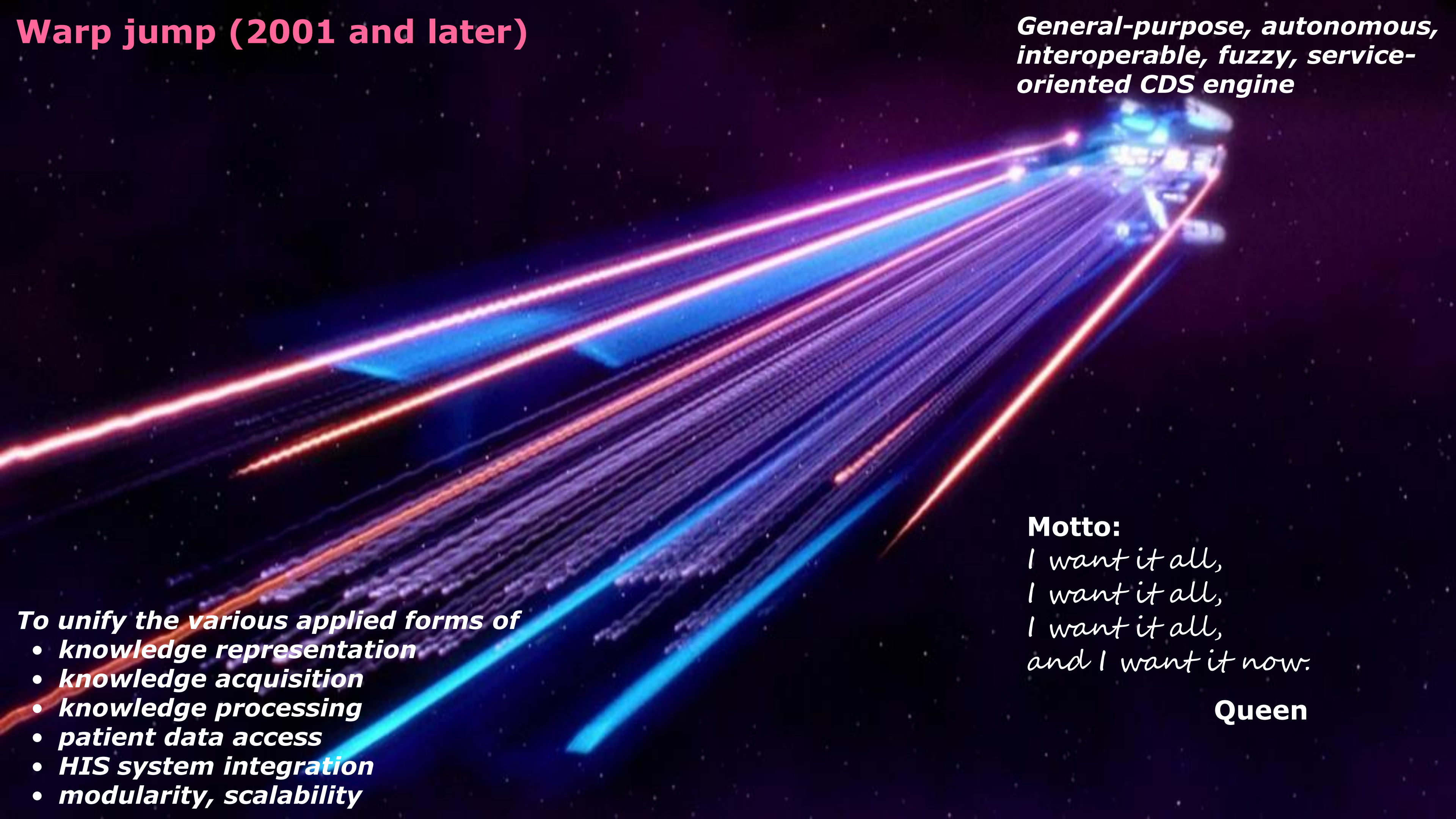
- clinically proven knowledge: rules, tables, decision trees, guidelines, scores, algorithms, …
- evidence-based, application-ready knowledge packages
- knowledge design or knowledge through machine learning

+

The CDS engine

- HL7's Arden Syntax medical knowledge representation and processing, with fuzzy methodologies
- scalable from cloud-based services to mobile apps

Arden Syntax



Warp jump (2001 and later)

General-purpose, autonomous, interoperable, fuzzy, service-oriented CDS engine

To unify the various applied forms of

- ***knowledge representation***
- ***knowledge acquisition***
- ***knowledge processing***
- ***patient data access***
- ***HIS system integration***
- ***modularity, scalability***

Motto:

I want it all,
I want it all,
I want it all,
and I want it now.

Queen

Arden Syntax: HL7- and ANSI-approved

- An HL7 standard language for writing situation-action rules, procedures, or knowledge bases that trigger results based on clinical events detected in patient data
- Each module, referred to as a medical logic module (MLM), contains sufficient knowledge to make at least a single medical decision
  - extended by medical knowledge packages (MKPs) consisting of interconnected MLMs for complex clinical decision support
- Continuous development
  - The Health Level Seven Arden Syntax for Medical Logic Systems, version 2.9—including fuzzy methodologies—was approved by Health Level Seven (HL7) International and the American National Standards Institute (ANSI) in 2013.
  - The latest version, Version 2.10—including ArdenML, an XML-based representation of Arden Syntax MLMs—was approved in 2014.

⇒ healthcare industry and academic users

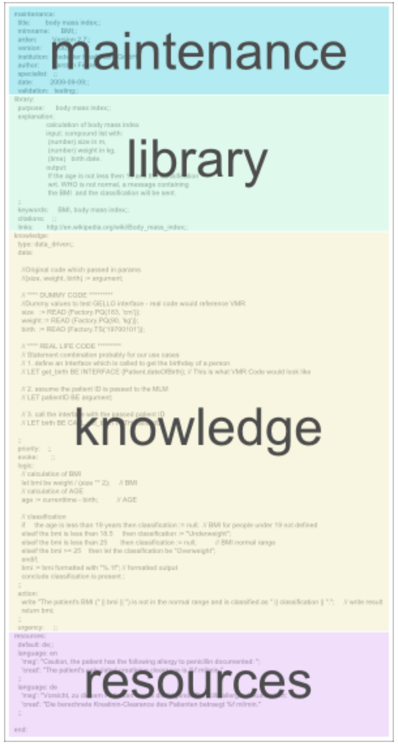
MEDEXTER Healthcare

What is Arden Syntax?

- … a knowledge representation standard primarily meant for medical knowledge.
- … used for sharing computerized health knowledge bases across personnel, information systems, and institutions.
- … organized in modules. Each module is referred to as a medical logic module (MLM) and contains sufficient knowledge to make at least a single medical decision.
- … a computer-interpretable format that is used by clinical decision support systems.

Arden Syntax – Structure

- In Arden Syntax, medical knowledge is hierarchically arranged within medical logic modules (MLMs)
- Each MLM represents sufficient knowledge to make at least one single medical decision
- An MLM is stored in a file that has the file extension ".mlm"
- Each MLM is well organized and structured into **categories** and **slots.**
- Categories must appear in a predefined order.
- Each category contains a category-specific set of **slots,** also in a predefined order.




```
maintenance:
    title:          ;;
    mlmname:        [required];;
    arden:          [required];;
    version:        [required];;
    institution:    [required];;
    author:         ;;
    specialist:     ;;
    date:           [required];;
    validation:     [required];;
library:
    purpose:        ;;
    explanation:    ;;
    keywords:       ;;
    citations:      ;;
    links:          ;;
knowledge:
    type:           data_driven;;
    data:           ;;
    priority:       ;;
    evoke:          ;;
    logic:          ;;
    action:         ;;
    urgency:        ;;
resources:          [optional]
    default:        ;;
    language:       ;;
end:
```

Arden Syntax MLM – Knowledge Category – Example

SIRS Notification

ALERT if ≥ 2 Criteria

Temperature > 38°C (100.4°F) or < 36°C (96.8°F)
and/or

Heart rate > 90 beats per minute
and/or

Respiratory rate > 20 breaths per minute or arterial carbon dioxide tension (PaCO2) < 32 mm Hg
and/or

White blood cell count (>12,000/µL or < 4,000/µL or >10% immature [band] forms)

SIRS: systemic inflammatory response syndrome, unsharpness of boundaries not considered

```
knowledge:
    type: data_driven;;
    data:
          (Temperature,HeartRate,RespRate,
           PaCO2,WBcellCount,ImmatureBand):= ARGUMENT;
        ;;
    priority: ;;
    evoke: ;;
    logic:

        //Start - Checking SIRS criteria
        counter := 0;

        IF Temperature IS GREATER THAN 38 OR Temperature IS LESS THAN 36 THEN
            counter:= counter + 1;
        ENDIF;

        IF HeartRate IS GREATER THAN 90 THEN
            counter:= counter + 1;
        ENDIF;

        IF RespRate IS GREATER THAN 20 OR PaCO2 IS LESS THAN 32 THEN
            counter:= counter + 1;
        ENDIF;

        IF WBcellCount  IS GREATER THAN 12000 OR WBcellCount IS LESS THAN 4000
        OR ImmatureBand IS GREATER THAN 10 THEN
            counter:= counter + 1;
        ENDIF;

        IF counter IS GREATER THAN OR EQUAL 2 THEN
            notification:= LOCALIZED 'SIRS';
            CONCLUDE TRUE;
        ENDIF;
        //End - Checking SIRS criteria

        ;;
    action:
        RETURN notification;
        ;;
    urgency: ;;
```

Closing

AI & CDS in clinical medicine (now and in the future)

Mission

AI & CDS to empower clinicians

- for better care, patient safety, quality assurance, and cost reduction
  by
- teaming intelligence between health IT and clinicians[1)]

Evolution of methods

- Knowledge-based systems (classic symbolic AI)
- Machine learning and big data
  - pattern recognition, data mining, text mining
- and many, many more

➢ *Something to consider:*
  - But big data is usually dumb data.[2)]
  - Correlation is not causation.[3)]

Clinical benefit

"AI & CDS health IT must support us in our patient care."

The clinicians

1) Johnson M., Vera A.H. (2019) No AI Is an Island: The Case for Teaming Intelligence. *AI Magazine*, 40(1), 16–28.
2) Thiel P., Masters B. (2014) *Zero to One – Notes on startups, or how to build the future*. Crown Business, New York.
3) Pearl J., Mackenzie D. (2018) *The Book of Why: The New Science of Cause and Effect*. Basic Books, New York.