eHealth

Overview

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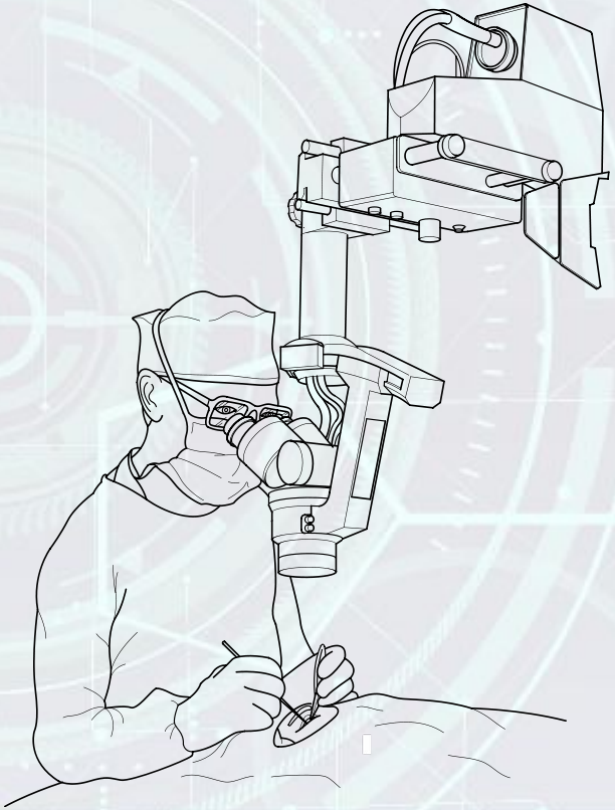
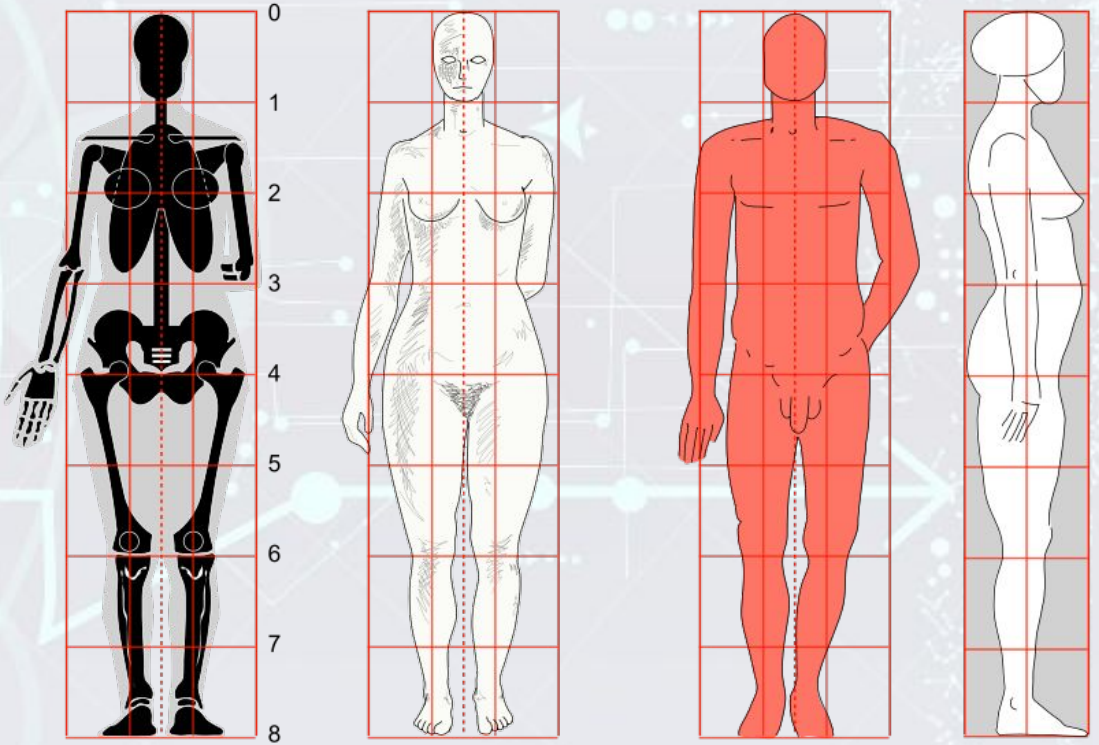
February 2018

Surgery

Surgery

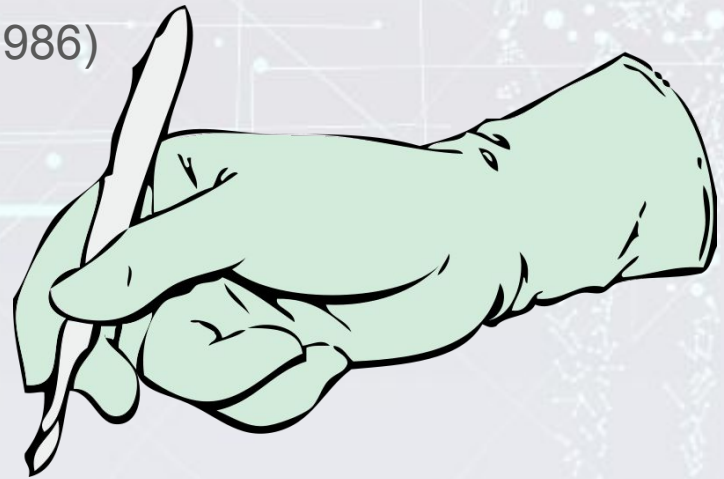




Surgery

- Started with a Knife
- Knife science?

Computer Science like Knife Science (Dijkstra, 1986)



The Patient

The Digital Patient

Digital Patient

- "a technological framework that, once fully developed, will make it possible to create a **computer representation of the health status of each citizen** that is descriptive and interpretive, integrative and predictive." Discipulus Consortium (2013)

Digital Patient Vision

Discipulus Consortium (2013)

Descriptive and Interpretive

- information about the patient's health determinants including life-style
- **interpretive** - it helps to gain new understanding.

Integrative

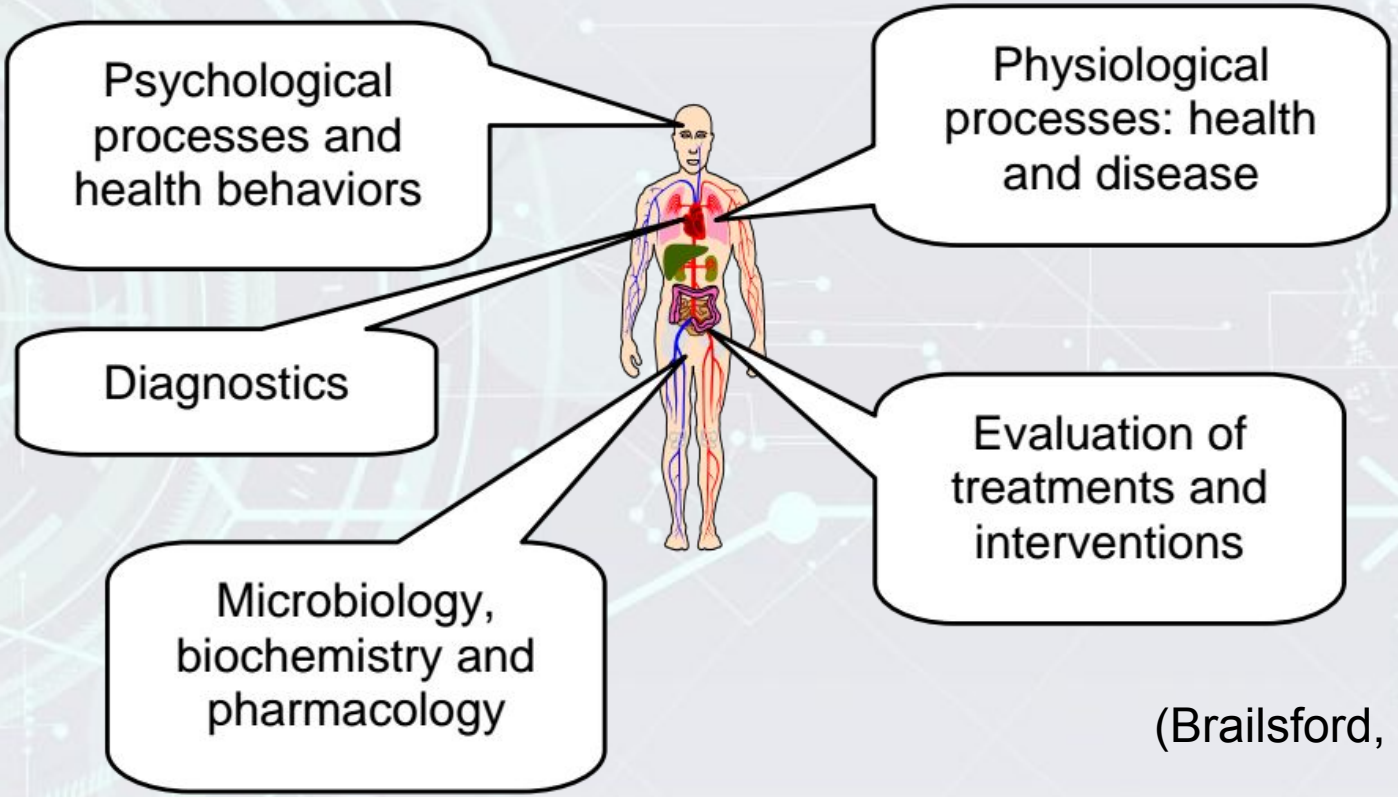
- automatically combines all the available information
- provide better decision-support based on a large volume of information

Predictive

- inform individualised simulations
- predict how specific aspects of subject's health will develop over time

The Virtual Patient

Models of the Human Body



(Brailsford, 2007)

Models of the Human Body

- "studying the clinical effectiveness or cost-effectiveness of some intervention"
  - E.g., "simulating the **progression of breast cancer** in the female population it is possible to **compare the effects of different screening policies** for early detection."

(Brailsford, 2007)

Virtual Physiological Human

"The Virtual Physiological Human (VPH), also identified with the word '**in silico medicine**' is the field that encompasses the use of individualised physiology based computer simulations in all aspects of the prevention, diagnosis, prognostic assessment, and treatment of a disease and development of a biomedical product." (http://www.vph-institute.org/what-is-vph-institute.html)

http://www.vph-institute.org

The Fourth Paradigm
(Gray, 2007)

- "Thousand years ago: science was **empirical**;
  describing natural phenomena
- Last few hundred years: **theoretical** branch;
  using models, generalizations
- Last few decades: a **computational** branch;
  simulating complex phenomena
- Today: **data exploration** (eScience)
  unify theory, experiment, and simulation
  - Data captured by instruments or generated by simulator
  - Processed by software
  - Information/knowledge stored in computer
  - Scientist analyzes database/ files using data management and statistics"

The Digital and Virtual Patient

Forms of Virtual Patient Applications

- Research
  - VP is reduced to a complex series of algorithms that model her/his behavior
  - e.g., the pharmacological behaviour of new drugs
- Electronic Patient Records (EPRs)
  - reflection of the real patient in their electronic records
- Education
  - a patient case or presentation is used for educational purposes
  - designed to address particular topics or educational objectives
  - key component of the problem-based learning (PBL)

(Ellaway, 2004)

Virtual + Digital Patient

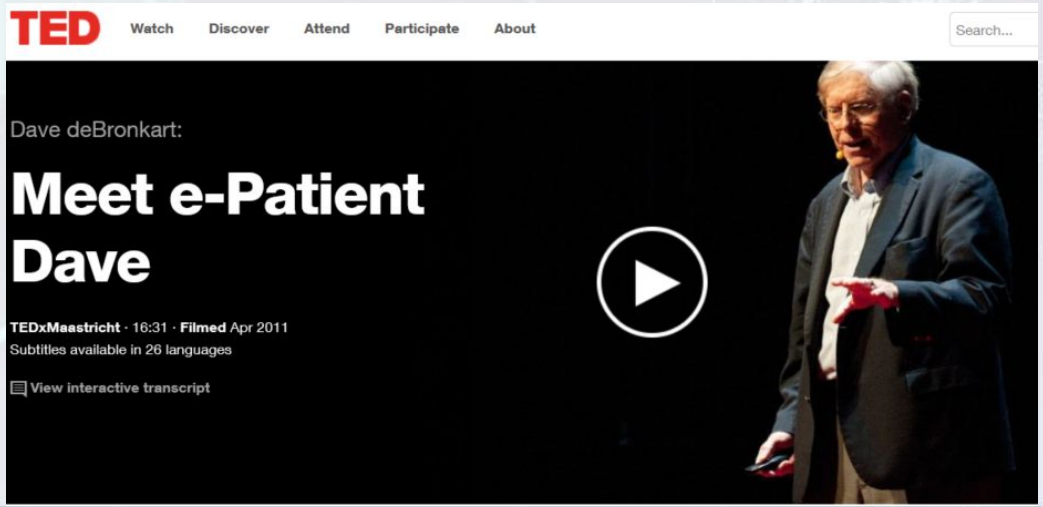
- "a set of data that describes an individual as a patient"
- "This may be data about a real patient, a hypothecated patient or some combination of the two."

(Ellaway, 2004)

The e-Patient

The e-Patient

- When Dave deBronkart learned he had a rare and terminal cancer, he turned to a group of fellow patients online — and found the medical treatment that saved his life.
- https://www.ted.com/talks/dave_debronkart_meet_e_patient_dave



Meet e-Patient Dave

- “I want to note especially the importance of the resource that is most often underutilized in our information systems – our patients” Charles Safran MD and Warner Slack MD
- "Kidney cancer is an uncommon disease. Get yourself to a specialist center. There is no cure, but there's something that sometimes works -- it usually doesn't -- called high-dosage interleukin. Most hospitals don't offer it, so they won't even tell you it exists. Don't let them give you anything else first. And by the way, here are four doctors in your part of the United States who offer it, and their phone numbers."

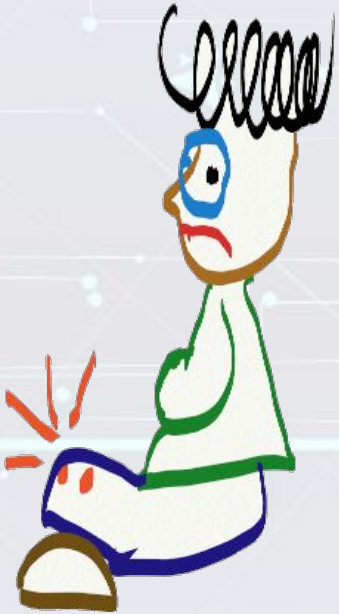
The Network Effect
acor.org

"ACOR is a unique collection of online cancer communities designed to provide timely and accurate information in a supportive environment. It is a free lifeline for everyone affected by cancer & related disorders."

The Health Team

The Doctor

How does a Doctor "see" a Patient?

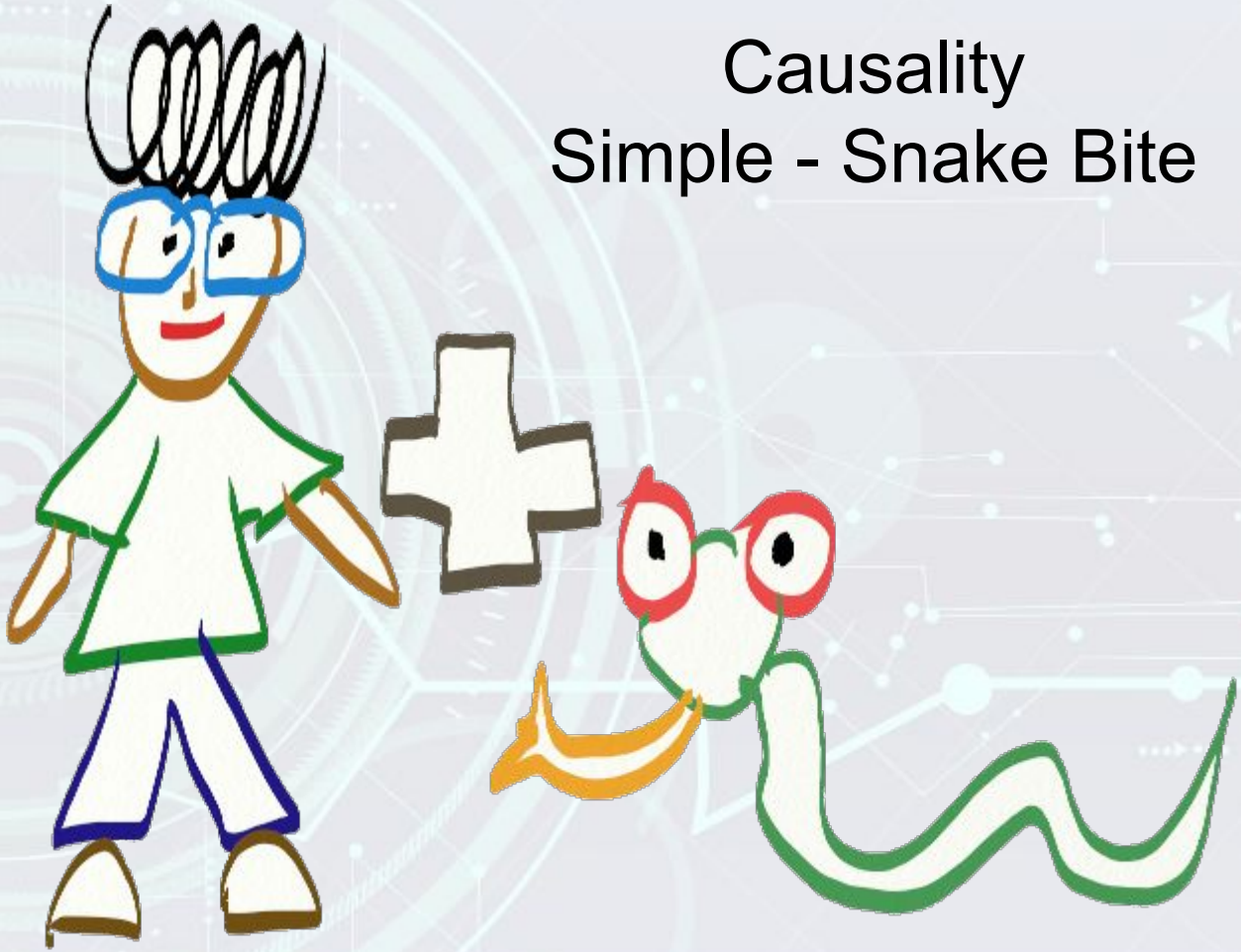


Causal Reasoning

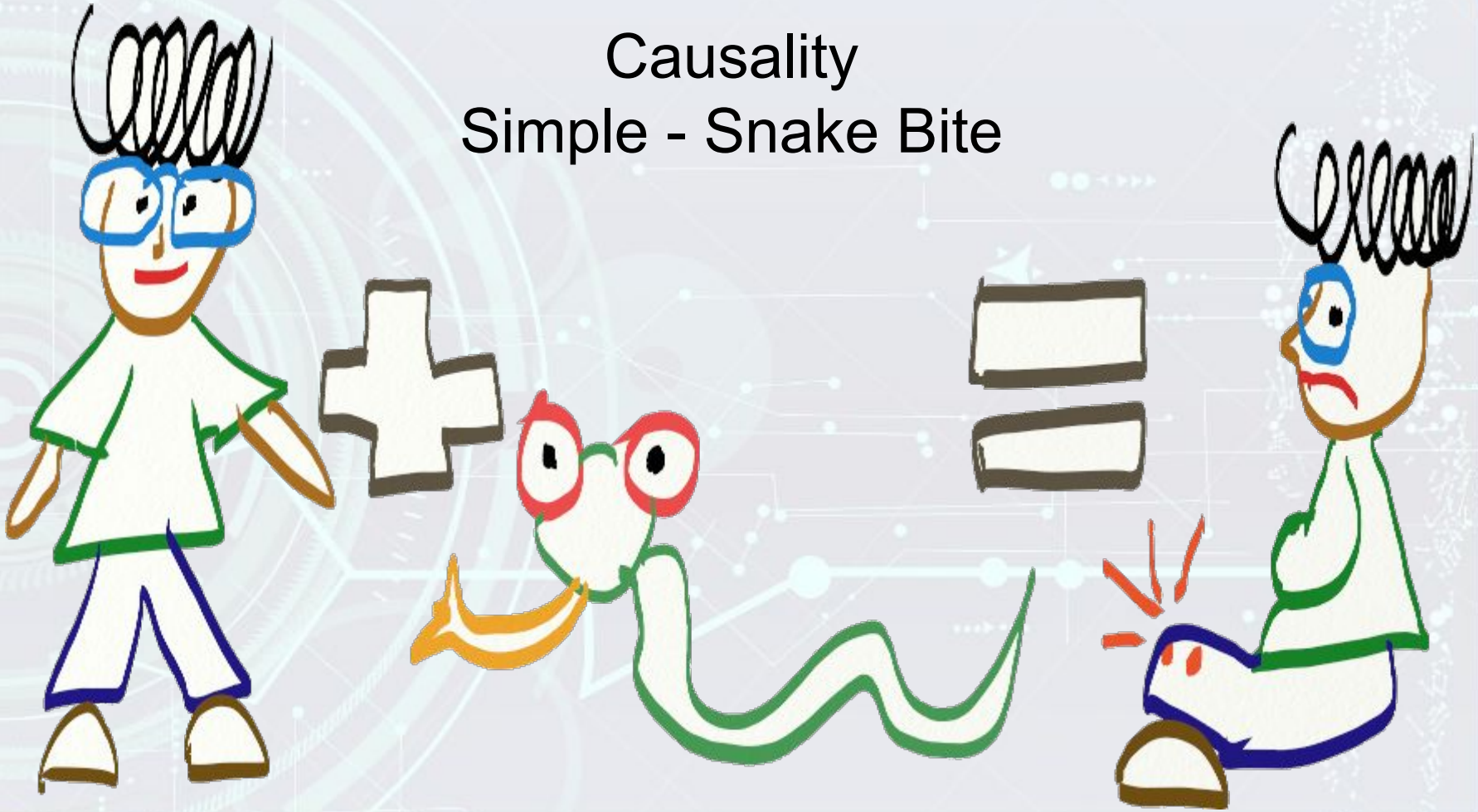
"Causal reasoning in science relies on the premise that for each **observed phenomenon**, there exists an **underlying mechanism** that **links cause and effect**." (Sobolev, 2012)

Causality
Simple - Snake Bite

Causality
Simple - Snake Bite



Causality
Simple - Snake Bite



Causality
Complex - Arrhythmia

Causality
Complex - Arrhythmia

Differential Diagnosis

"a type of analytical task wherein the decision maker is confronted with a fixed set of **diagnostic alternatives**. His job is to determine whether sufficient data are available to make a decision among elements of this set and if not, to obtain whatever additional data may be required to make a decision." (Pople, 1982)

Doctors Thinking Process

"[...] thinking processes are based on the complex interconnection of **signs and symptoms** presented by the patient that are aggregated in the physician's mind through a **complex hierarchical chain of interconnections**."

"Traditionally, doctors used to learn to value these signs and symptoms without a scientific approach based on their real epidemiology, but relying on a repository of **collective memories**."

Marco Antonio de Carvalho Filho in (Mota et al., 2018)

Evidence-based Medicine (EBM)

"[...] movement aiming at increasing the use of conscientious and rational clinical decision making, emphasizing the use of evidence from **previous, reliable and well-conducted research**. (Shaughnessy et al., 2016) (Rosenberg & Donald, 1995)"

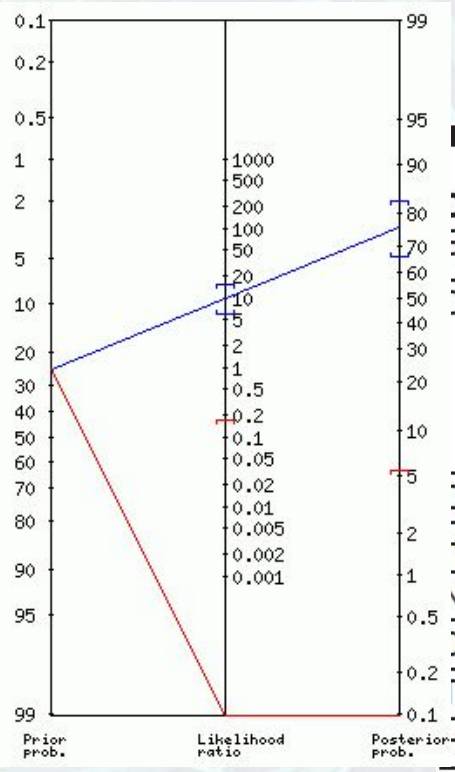
"Nowadays, EBM is the best approach to developing a therapeutic plan to a patient, since it **comprises the best evidence, patient values, and personal characteristics together with clinical experience**."

Marco Antonio de Carvalho Filho in (Mota et al., 2018)

EBM Sources

"Several articles describing systematic reviews, meta-analyses, and randomized controlled trials are available in the literature in multiple repositories."

Marco Antonio de Carvalho Filho in (Mota et al., 2018)



Evidence-based Medicine

Clinical Feature	Likelihood Ratio (95% Confidence Interval)
Pain in chest or left arm	2.7*
Chest pain radiation	
Right shoulder	2.9 (1.4-6.0)
Left arm	2.3 (1.7-3.1)
Both left and right arm	7.1 (3.6-14.2)
Chest pain most important symptom	2.0*
History of myocardial infarction	1.5-3.0†
Nausea or vomiting	1.9 (1.7-2.3)
Diaphoresis	2.0 (1.9-2.2)
Third heart sound on auscultation	3.2 (1.6-6.5)
Hypotension (systolic blood pressure ≤80 mm Hg)	3.1 (1.8-5.2)
Pulmonary crackles on auscultation	2.1 (1.4-3.1)

(Panju et al., 1998)

Causal/Probabilistic Reasoning Models

Rules
Mycin

Mycin

1) Patient's name: (first-last)
** **FRED BRAUN**
2) Sex:
** **M**
3) Age:
** **55**
4) Are there any cultures for Fred Braun which may be related to the present illness, and from which organisms have been grown successfully in the microbiology laboratory?
** **Y**

(Questions 1-3 request background patient data.)

(Buchanan & Shortliffe, 1984)

Mycin

--------CULTURE-1--------
5) From what site was the specimen for CULTURE-1 taken?
** **BLOD**
=**BLOOD**
6) Please give the date and time when CULTURE-1 was obtained.
(mo/da/yr time)
** **JUN 20, 1977**
The first organism isolated from the blood culture of 20-JUN-77
(CULTURE-1) will be referred to as:

--------ORGANISM-1--------
7) Enter the laboratory-reported identity of ORGANISM-1:
**UNKNOWN
8) The stain (gram or Ziehl-Neelsen acid-fast) of ORGANISM-1:
** **NEG**
9) Is ORGANISM-1 rod or coccus (etc.):
** **ROD**
10) What is the form of the individual organisms (e.g. lancet-
shaped for cocci, fusiform for rods, etc.)?
** **FUSIFORM**

(System corrects typing error.)

(Typically identity is not yet known.)

(Preliminary lab results give some clues.)

(. . . more questions follow in order to gather sufficient information to infer the identity and significance of the infecting organisms . . .)

(Buchanan & Shortliffe, 1984)

Mycin

23) What is the suspected portal of entry of the gramneg rod from the blood culture of 20-JUN-77 (ORGANISM-1) into this sterile site?
** **GI (6)** *(User indicates the uncertainty of his response.)*
24) Is Fred Braun a burn patient?
** **N**
25) Is Fred Braun a compromised host (e.g. alcoholic, sickle-cell-disease, immunosuppressed)?
** **N**
26) Is Fred Braun febrile?
** **Y**

(. . . after about 50–60 questions, MYCIN prints the diagnostic hypotheses on which therapy will be based . . .)

My therapy recommendations will be designed to treat for organisms that are either very likely or, although less likely, would have a significant effect on therapy selection if they were present. It is important to cover for the following probable infection(s) and associated organism(s):

INFECTION-1 is BACTEREMIA

<ITEM-1> E.COLI [ORGANISM-1]
<ITEM-2> KLEBSIELLA [ORGANISM-1]
<ITEM-3> ENTEROBACTER [ORGANISM-1]
<ITEM-4> KLEBSIELLA-PNEUMONIAE [ORGANISM-1]

(Buchanan & Shortliffe, 1984)

Mycin Rule

RULE N

IF

1) Site of the culture is **BLOOD**
2) Gram stain is **NEGATIVE**
3) Morphology is **ROD**
4) Portal of entry is **URINE**
5) Genito-urinary manipulative procedure **NO**
6) Cystitis treatment **NO**

THEN

suggestive evidence (60%)

E. COLI

(van Melle, 1979)

Mycin

(. . . questions follow to evaluate possible therapy choices, and finally MYCIN prints its therapy recommendations . . .)

[REC-1] My preferred therapy recommendation is as follows:
In order to cover for items <1 2 3 4>:
Give: GENTAMICIN *(One drug covers 4 possible identities.)*
Dose: 119 mg (6.0 ml) q8h IV for 10 days [calculated on basis of 1.7 mg/kg]
Comments: Modify dose in renal failure.

(Buchanan & Shortliffe, 1984)

Mycin Architecture

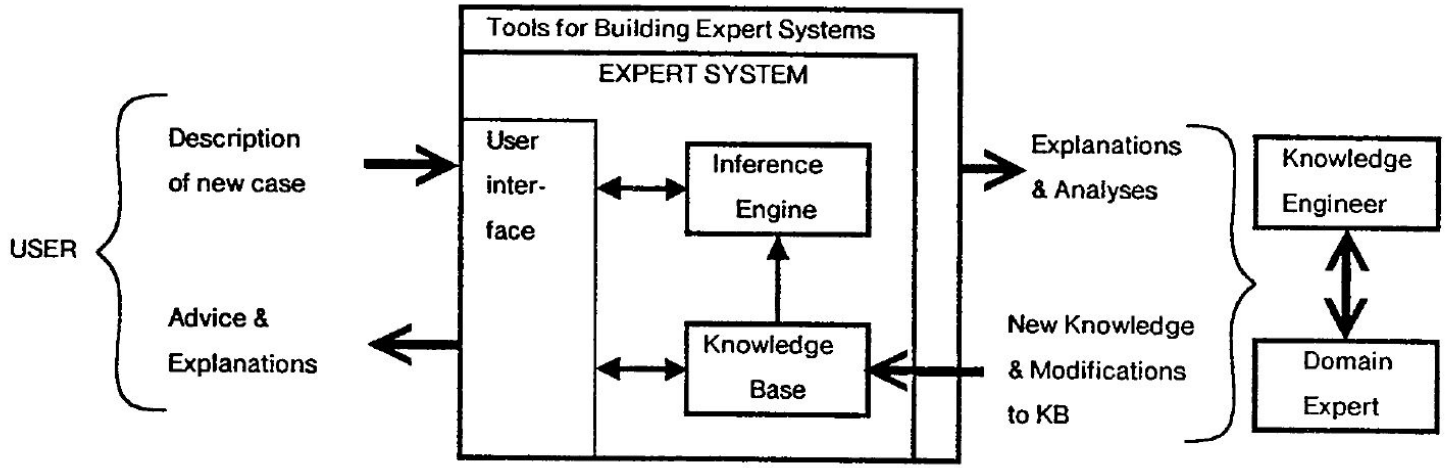


FIGURE 1-2 Interaction of a knowledge engineer and domain expert with software tools that aid in building an expert system. Arrows indicate information flow.

(Buchanan & Shortliffe, 1984)

Mycin Explaining

34) Was penicillinase added to this blood culture (CULTURE-1)?
**** WHY**

[i.e. WHY is it important to determine whether penicillinase was added to CULTURE-1?]

[3.0] This will aid in determining whether ORGANISM-1 is a contaminant.
It has already been established that
[3.1] the site of CULTURE-1 is blood, and
[3.2] the gram stain of ORGANISM-1 is grampos
Therefore, if
[3.3] penicillinase was added to this blood culture
then
there is weakly suggestive evidence (.4) that ORGANISM-1 is a contaminant [RULE039]

**** WHY**

[i.e. WHY is it important to determine whether ORGANISM-1 is a contaminant?]

[4.0] . . . In order to determine whether there is significant disease associated with this occurrence of ORGANISM-1.
It has already been established that
[4.1] this blood culture was taken from a sterile source
Therefore, if
[4.2] ORGANISM-1 is not a contaminant
then
there is strongly suggestive evidence (.9) that there is significant disease associated with this occurrence of ORGANISM-1 [RULE032]

**** WHY**

[i.e. WHY is it important to determine whether there is significant disease associated with this occurrence of ORGANISM-1]

[5.0] . . . In order to determine the organisms which require therapy.
It has already been established that
[5.1] the infection is known, and
[5.2] the identity of ORGANISM-1 is known
Therefore, if
[5.3] there is significant disease associated with this occurrence of ORGANISM-1
then
it is definite (1.0) that ORGANISM-1 is one of the organisms which require therapy
[RULE090]

**** HOW 5.2**

[i.e. HOW was it established that the identity of ORGANISM-1 is known?]

Question 9 was asked, but you weren't sure; so the following was used:

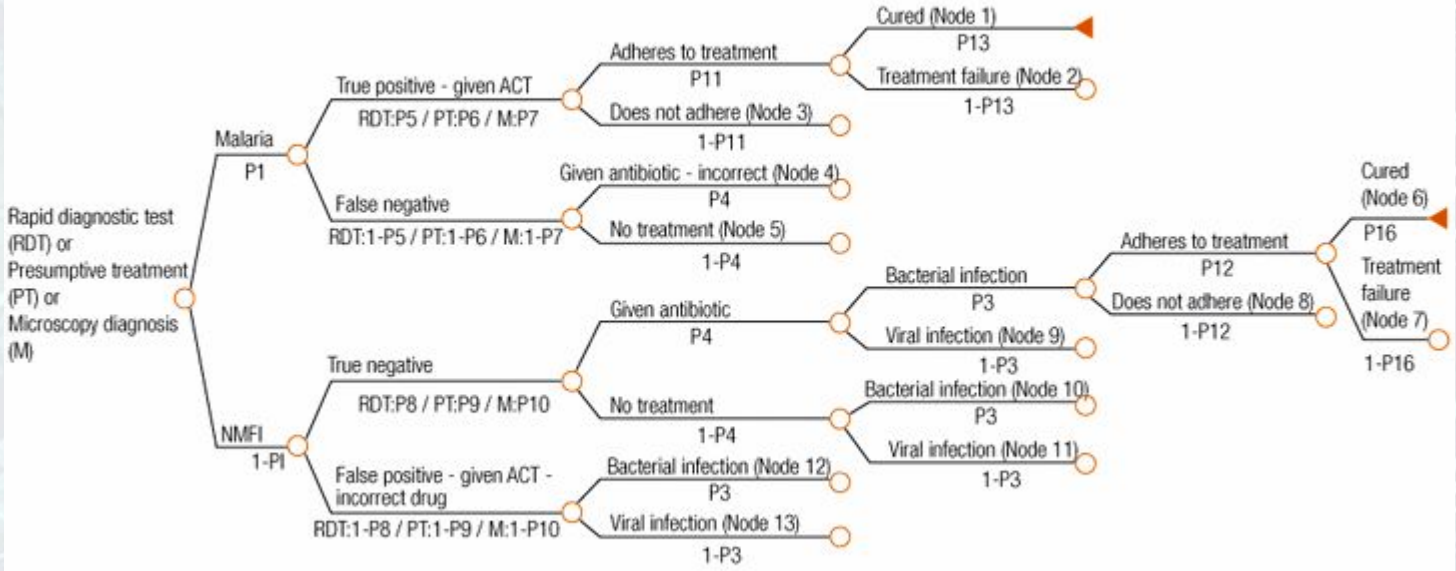
[5.5] RULE084 was used to conclude that the identity of ORGANISM-1 is streptococcus-group-a (.29).

(Buchanan & Shortliffe, 1984)

Decision Tree

Diagnostic Tree

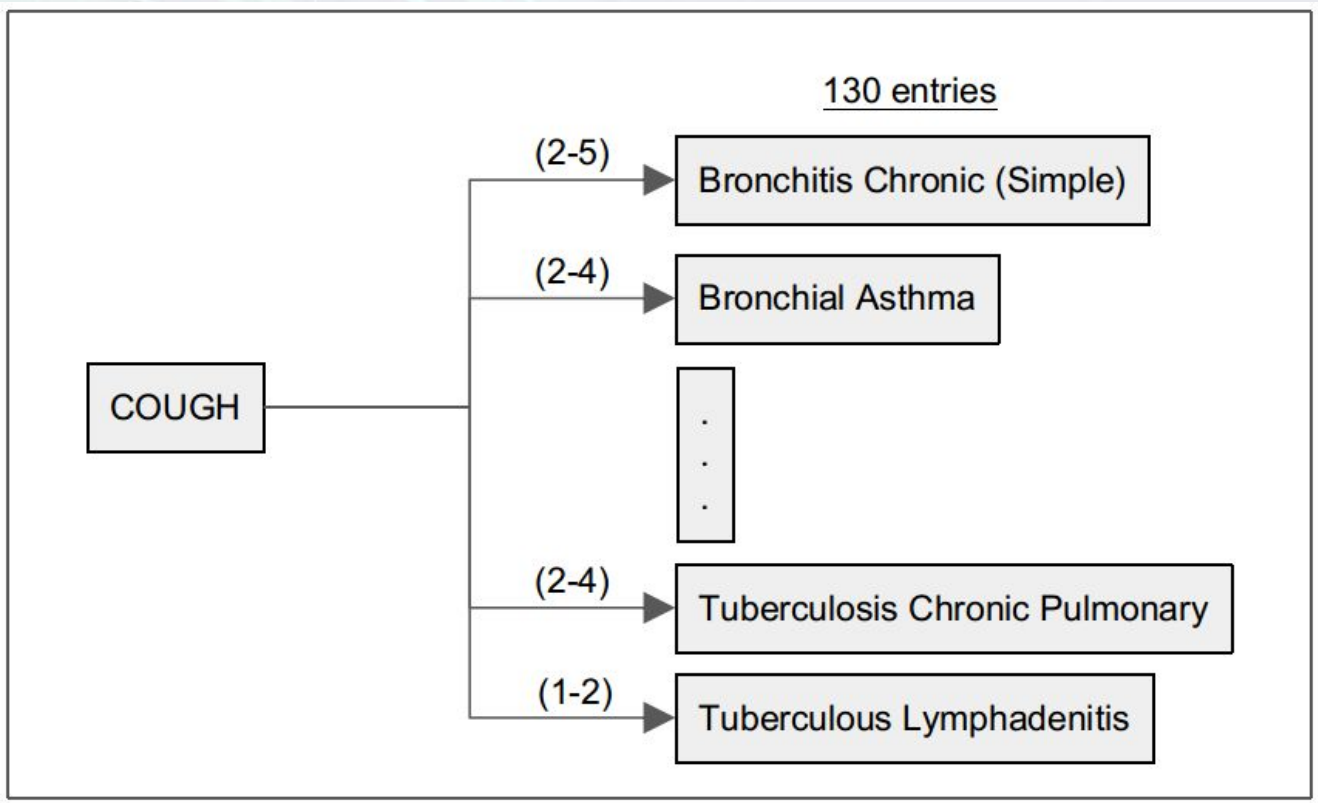
Fig. 1. **Root decision tree applying to all diagnostic strategies, mapping diagnosis and subsequent events according to malaria and non-malarial febrile illness (NMFI)**



ACT, artemisinin-based combination therapy.

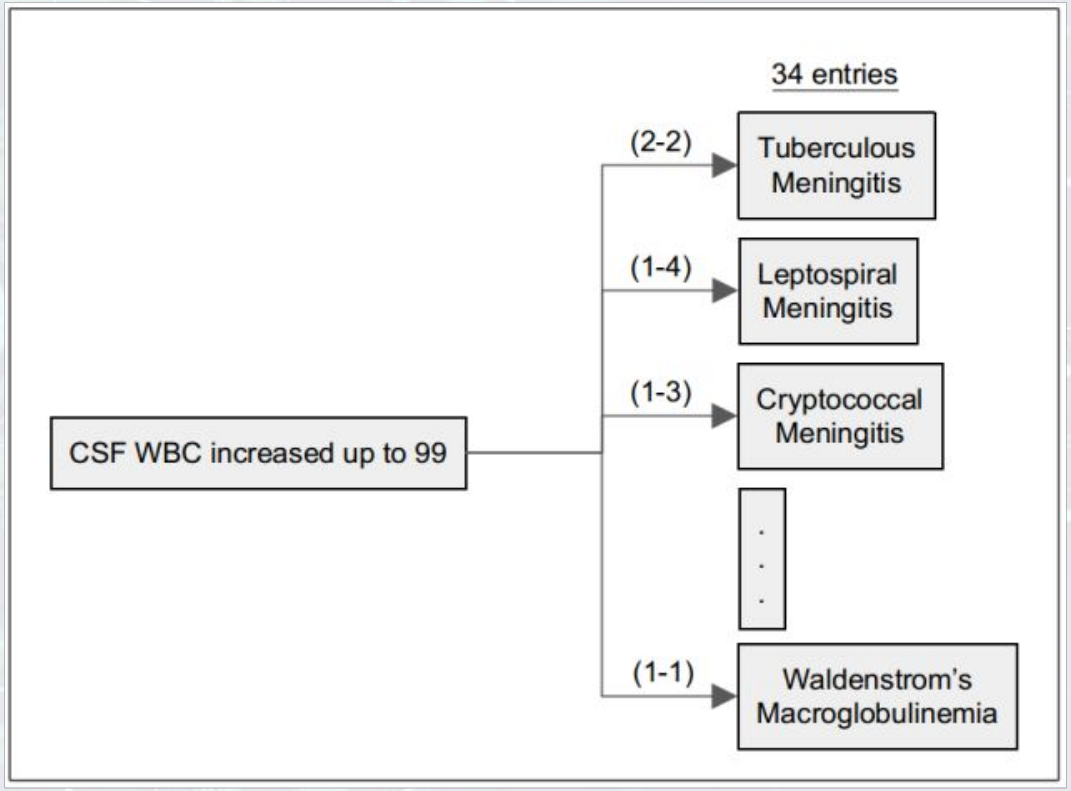
Probabilistic Models

Internist I



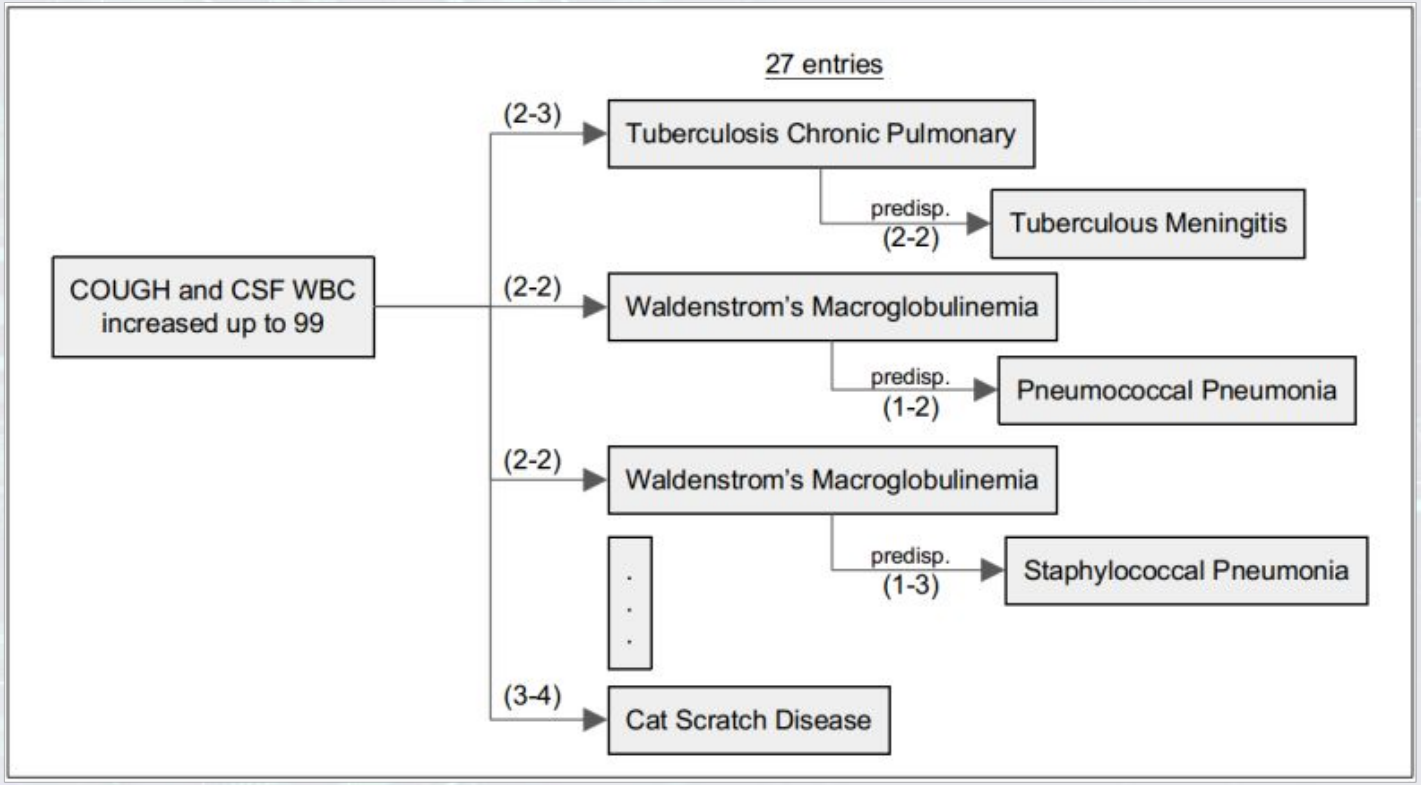
(First, 1985)

Internist I



(First, 1985)

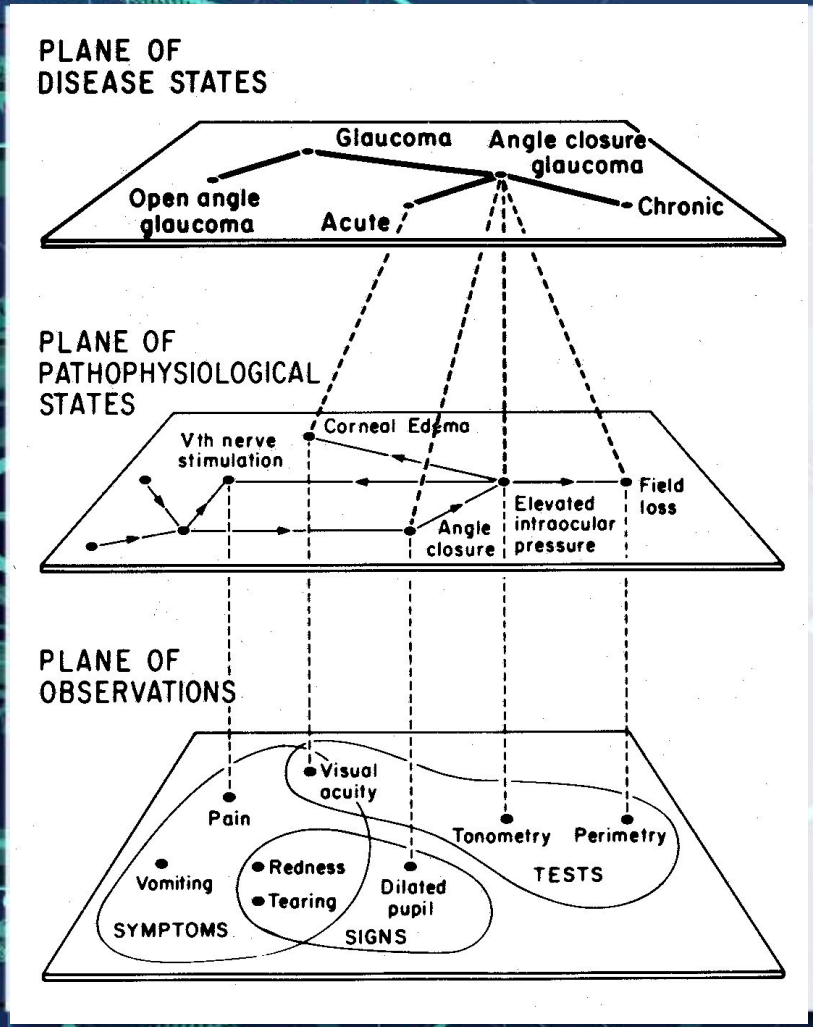
Internist I



(First, 1985)

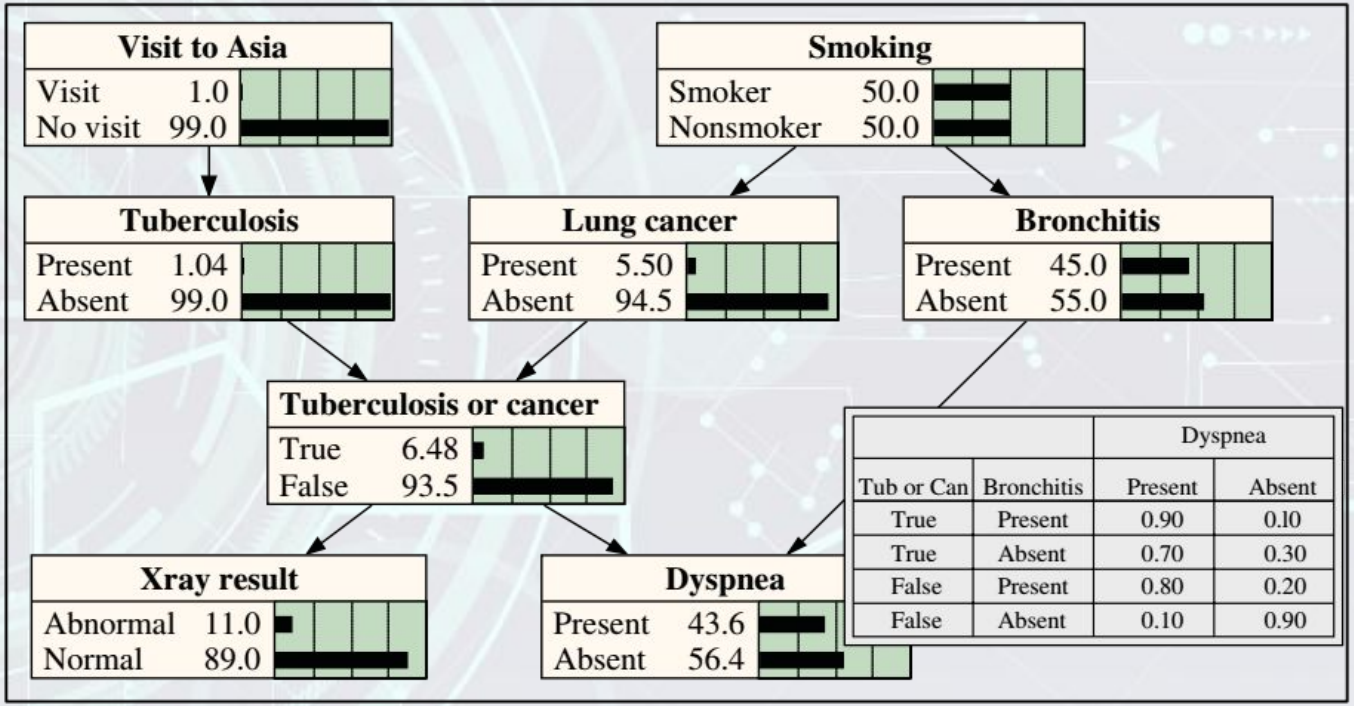
Causal Networks

Casnet



(Kulikowski & Weiss, 1982)

Bayesian Networks



		Dyspnea	
Tub or Can	Bronchitis	Present	Absent
True	Present	0.90	0.10
True	Absent	0.70	0.30
False	Present	0.80	0.20
False	Absent	0.10	0.90

(Combs et al., 2016)

The Nurse

The Nurse

"Nurses often develop close relationships with patients. These relationships may allow the nurse to make observations that are missed by other staff. This ability is just one of the ways in which nurses play a key role in data collection and recording (Photograph courtesy of Janice Anne Rohn)"

(Shortliffe & Cimino, 2014)

The Process

Information

"The practice of medicine is inextricably entwined with the management of information." (Shortliffe & Cimino, 2014)

Electronic Health Records

- "[...] no applied clinical computing topic is gaining more attention currently than is the issue of electronic health records (EHRs)."
- "In the past, **administrative and financial data** were the major elements required for such planning, but comprehensive clinical data are now also important for institutional selfanalysis and strategic planning."
- "[...] the EHR is best viewed not as an object, or a product, but rather as a set of processes that an organization must put into place, supported by technology."

(Shortliffe & Cimino, 2014)

Environment for Clinical Trial

- "We are also seeing the development of **novel authoring environments for clinical trial** protocols that can help to ensure that the data elements needed for the trial are compatible with the local EHR’s conventions for representing patient descriptors." (Shortliffe & Cimino, 2014)

Mining Data for Better Medicine

(Savage, 2011)

- Large hospital systems - employ full-time database research teams
- "[...] more than **100 research projects** using electronic records from the VA's **six million patients**, who are seen at **152 hospitals** and **804 outpatient clinics** across the country." Laurence Meyer
- "If you're looking at a single hospital's cases of, say, hypertrophic cardiomyopathy, you might have 20 or 30 over 10 years, whereas all of a sudden we're looking at thousands of cases" Laurence Meyer

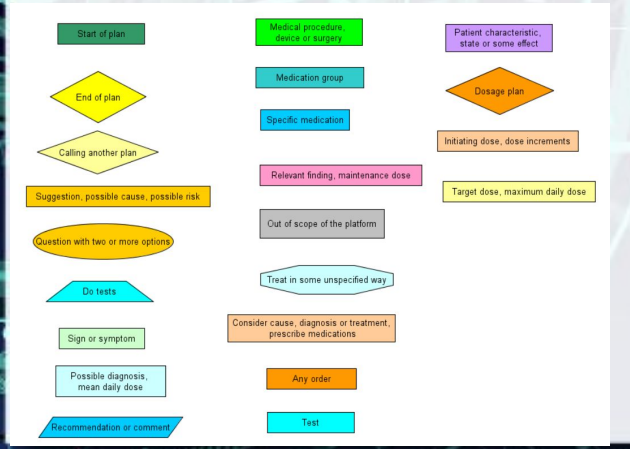
Guidelines and Pathways

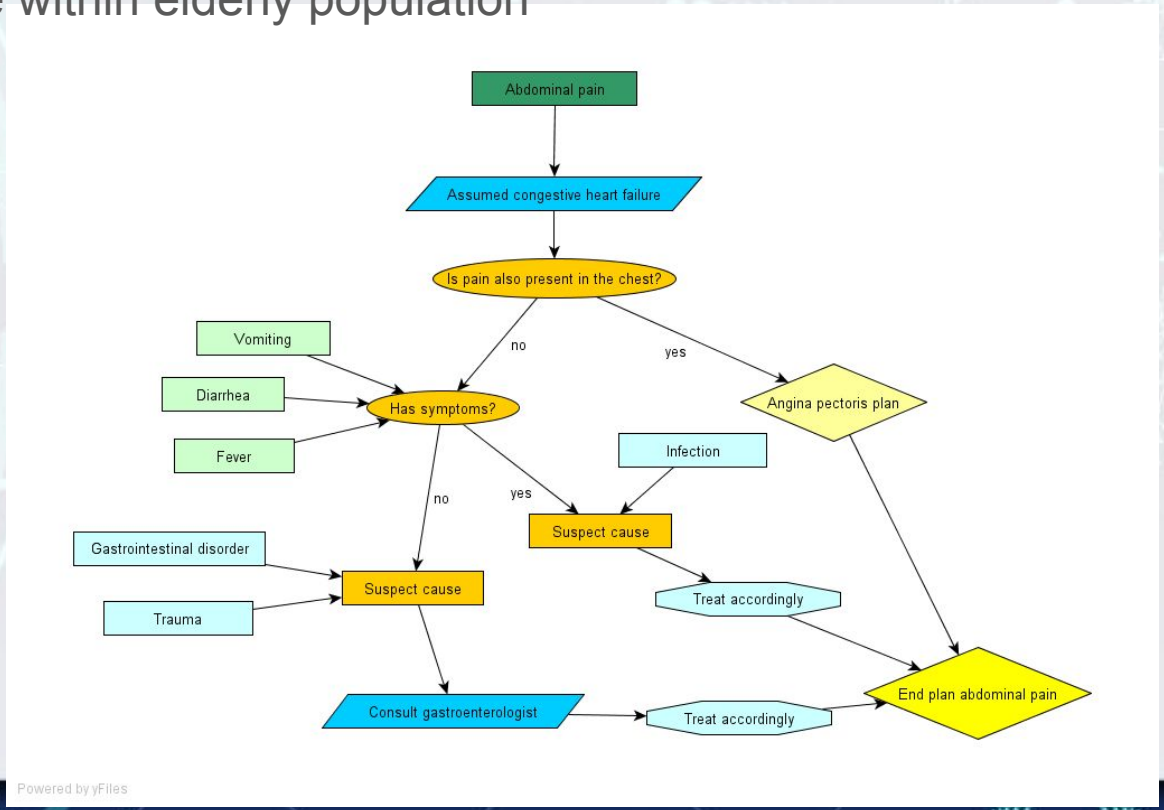
- "Another theme in the changing world of health care is the increasing investment in the creation of standard order sets, clinical guidelines, and clinical pathways [...], generally in an effort to reduce practice variability and to develop consensus approaches to recurring management problems." (Shortliffe & Cimino, 2014)
- **EBM:** "Several government and professional organizations, as well as individual provider groups, have invested heavily in guideline development, often putting an emphasis on using clear evidence from the literature, rather than expert opinion alone, as the basis for the advice." (Shortliffe & Cimino, 2014)

Medical Plan

Heartfaid "A knowledge based platform of services for supporting medical-clinical management of heart failure within elderly population"

Abdomnal Pain Plan
http://lis.irb.hr/heartfaid/



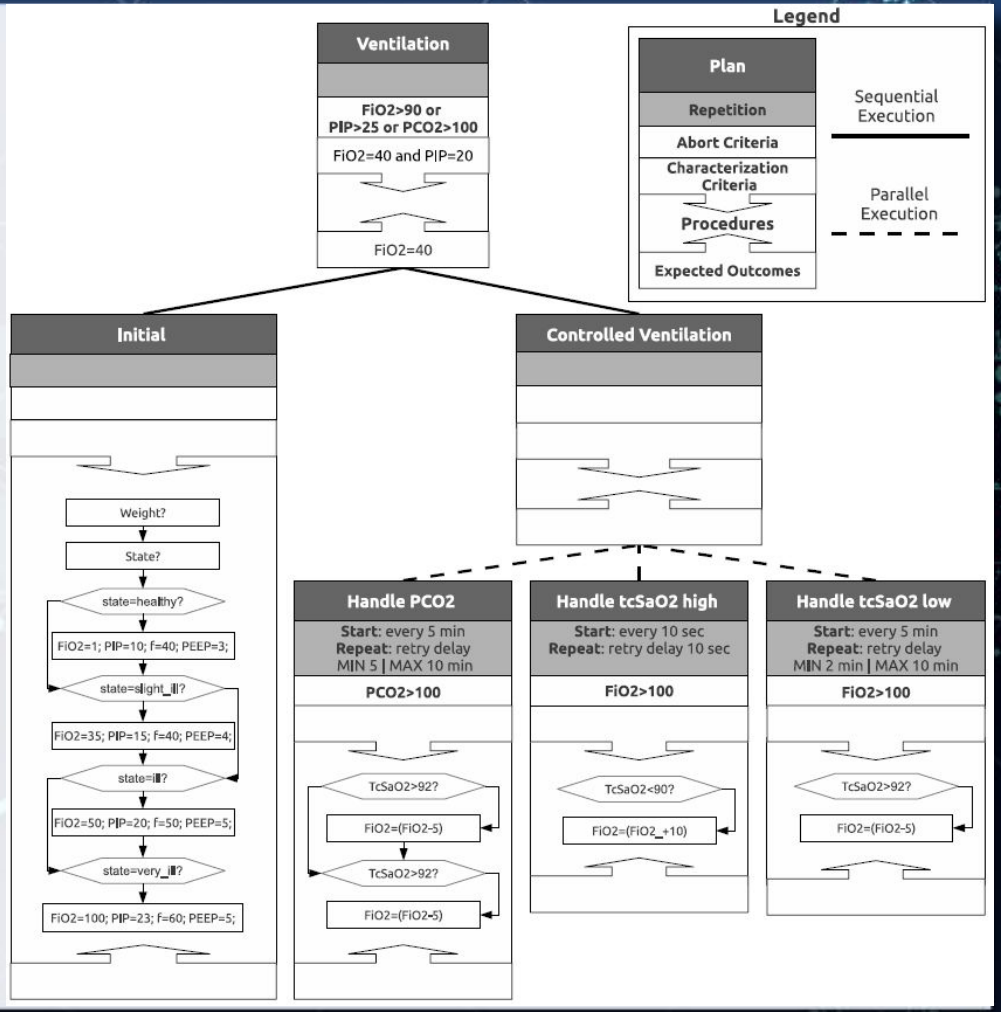


Computer-Interpretable Guidelines (CIGs)

- "**Clinical Practical Guidelines (CPGs)** are written guidelines that describe the evidence-based procedures to be followed during diagnosis, treatment, and clinical decision making for a specific disease."
- **Computer-Interpretable Guidelines:** "CIGs adopt models to represent the content to support decisions. Examples:
  - Task-Network Models (TNMs)
  - Medical Logic Modules (MLMs)
  - Augmented Decision Tables (ADTs)

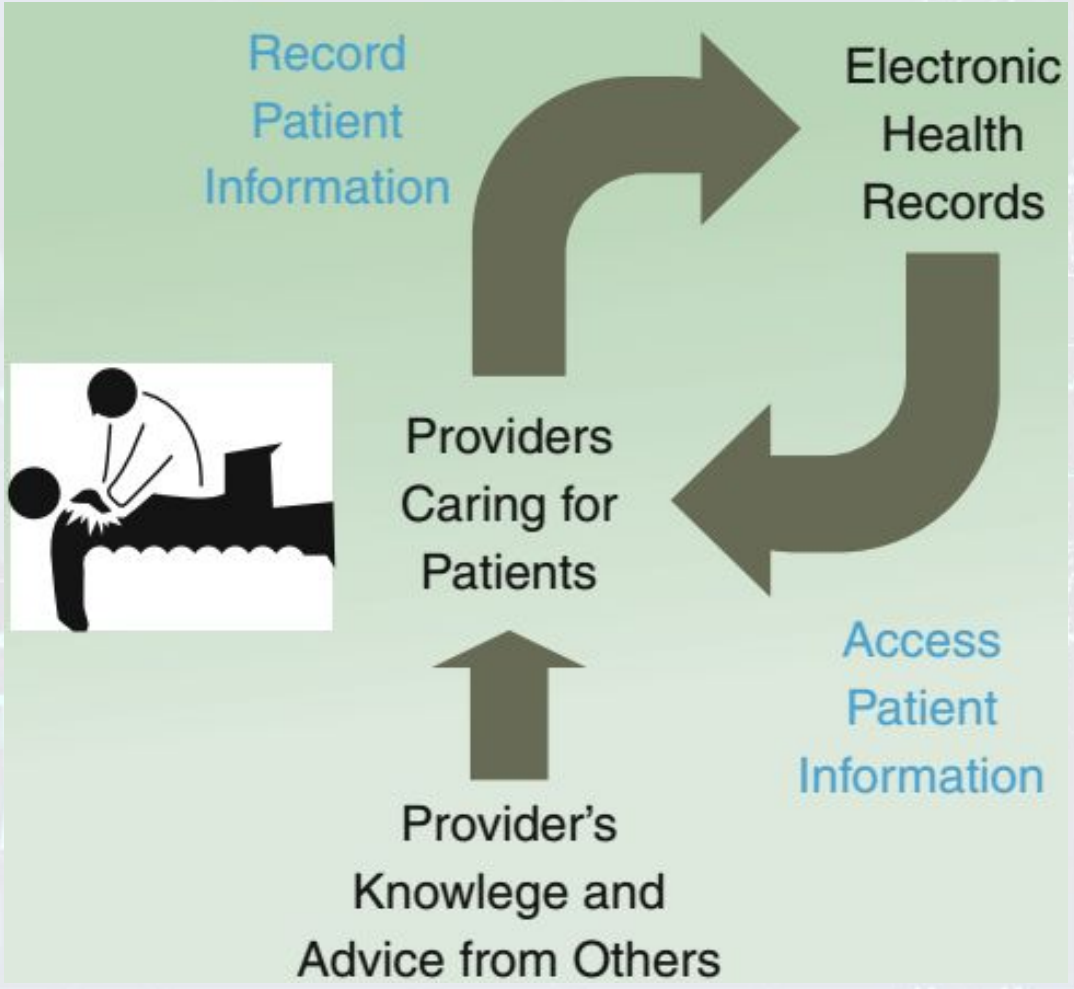
(Vilar, 2009)

Controlled Ventilation plan CIG / TNM



(Vilar, 2009)

Limited View of EHRs



(Shortliffe & Cimino, 2014)

Learning Health Care System

Providers Caring for Patients

Electronic Health Records

Regional and National Public Health and Disease Registries

Biomedical and Clinical Resarch

Standards for Prevention and Treatment

A "Learning Healthcare System"

Creation of Protocols. Guidelines, and Educational Materials

Information, Decision-Support, and Order-Entry Systems

(Shortliffe & Cimino, 2014)

Learning Health Care System

"This notion of a system that allows us to learn from what we do, unlocking the experience that has traditionally been stored in unusable form in paper charts, is gaining wide attention now that we can envision an interconnected community of clinicians and institutions, building digital data resources using EHRs. The concept has been dubbed a **learning health care system** [...]" (Shortliffe & Cimino, 2014)

Healthcare, Research and Education

Safe Patient Care
NANDA / NIC / NOC

NANDA – North American Nursing Diagnosis Association

NIC – Nursing interventions classification

NOC – Nursing outcomes classification

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