Introduction to Clinical Informatics

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About Me

- **About the instructor:**
  - Jake Luo, PhD, Associate Professor
    Department of Health Informatics and Administration
  - Director of Center for Heath System Solutions
    LinkedIn: https://www.linkedin.com/in/jakeluo/
  - Lab research deals with massive amount of data: patient records, clinical trials, social media, FDA drugs data, consumer comments; leveraging the data to find new knowledge to advance medicine and health care

- **Book**: Biomedical Informatics: Computer Applications in Health Care and Biomedicine (Health Informatics)

- **Overall goal of this class?**
  - Introduce clinical informatics
  - Cover major biomedical data types and common standards
  - Discuss common functions of electronic health record (EHR) systems
  - Describe clinical decision support systems

Health/Clinical Informatics

- Health Informatics is a cross-disciplinary field that lies in the intersection of information science, computer science, and health care
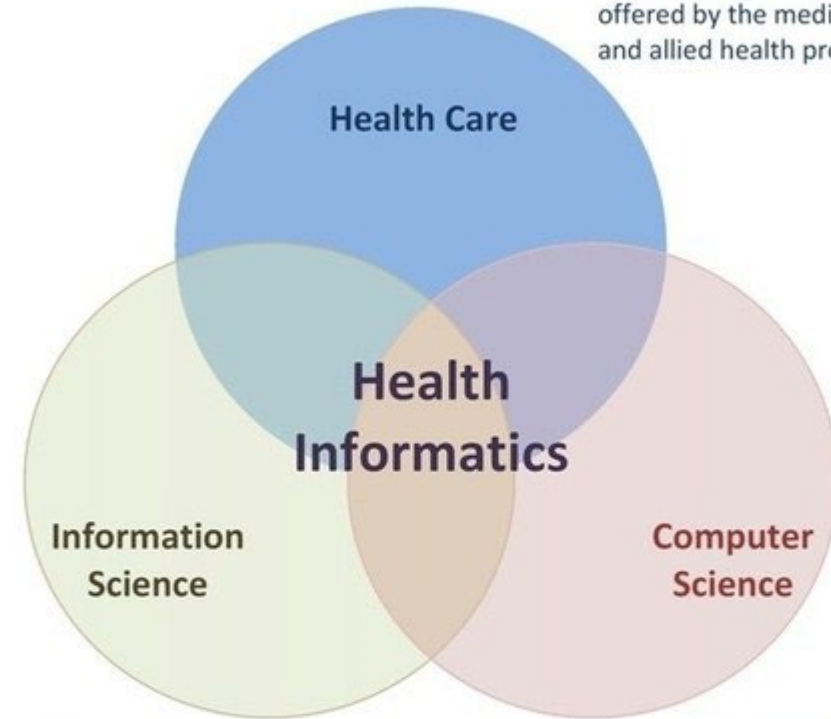
The prevention, treatment and management of illness and the promotion of health and well-being through the services offered by the medical, nursing and allied health professions

Health Care

Health Informatics

Information Science

Computer Science

The collection, classification, manipulation, storage, retrieval and dissemination of information;
The application and use of knowledge;
The interaction between people, organisations and information systems.

The theoretical foundations of information and computation together with their implementation and application in computer systems

Why We Need Informatics?

- Healthcare is very <u>complex</u>: complex business, multidisciplinary, diverse service population, happening on many levels on a person and in our society

- Informatics provides systematic information <u>strategies and solutions</u> to support the healthcare system

- Better information leads to better <u>decisions</u>

- Better information system leads to better <u>management and collaboration</u>

- Health services, health business <u>management, governing and policy making</u> all needs good information system

Significant Growth of Healthcare Cost

- Growing population size

- Aging

- Shortage of labor

- Healthcare Informatics is a key strategy to reduce health care cost and improve health outcome
  -Improve efficiency
  -Share information and knowledge
  -Encourage patient participation
  -Increase coordination between departments
  -Improve health outcome
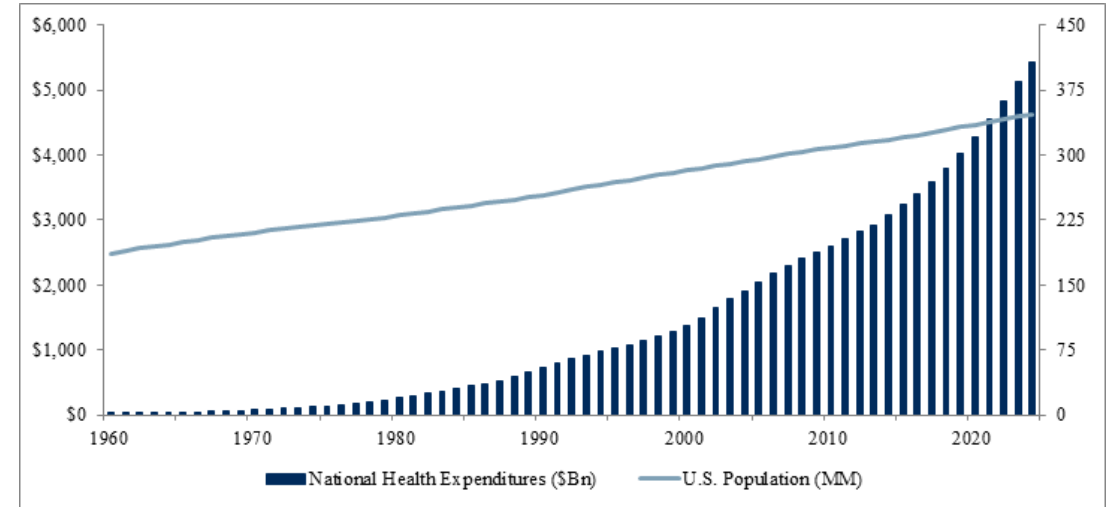
per capita health expenditure

5
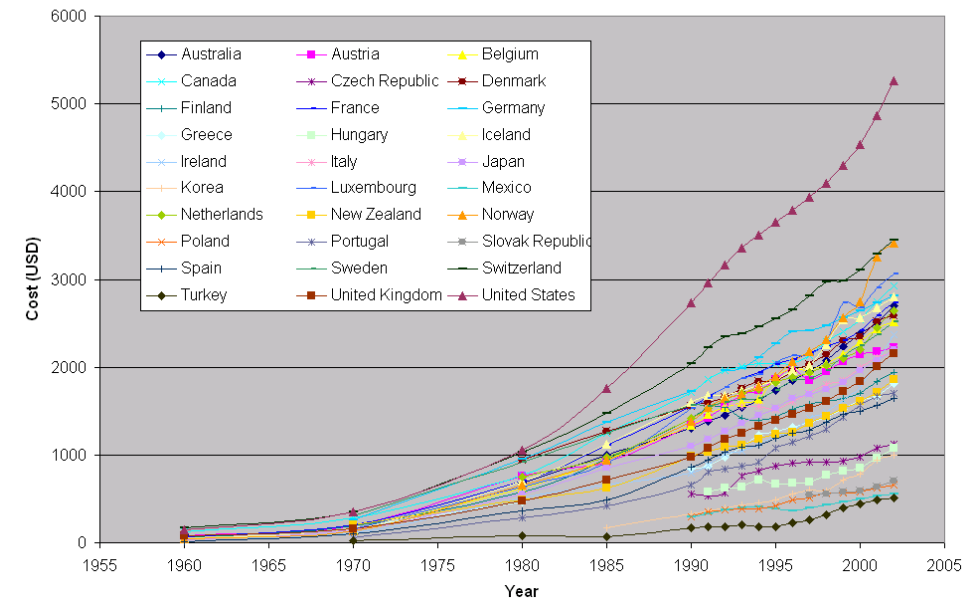
Who Involves in Health Informatics (stakeholders)

- Health professionals
  - Doctors (Primary / secondary care)
  - Nurses
  - Allied professions

- Healthcare Administrators

- Government and policy makers

- Biomedical Researchers

- Pharmaceutical Companies

- IT professionals

- Patients

Clinical Data

Clinical Data

- Clinical data are central to health care, because they focus on <u>patients</u>. They are critical to the process of clinical decision making

- All modern health care <u>encounter activities</u> involve gathering, analyzing, or using data.
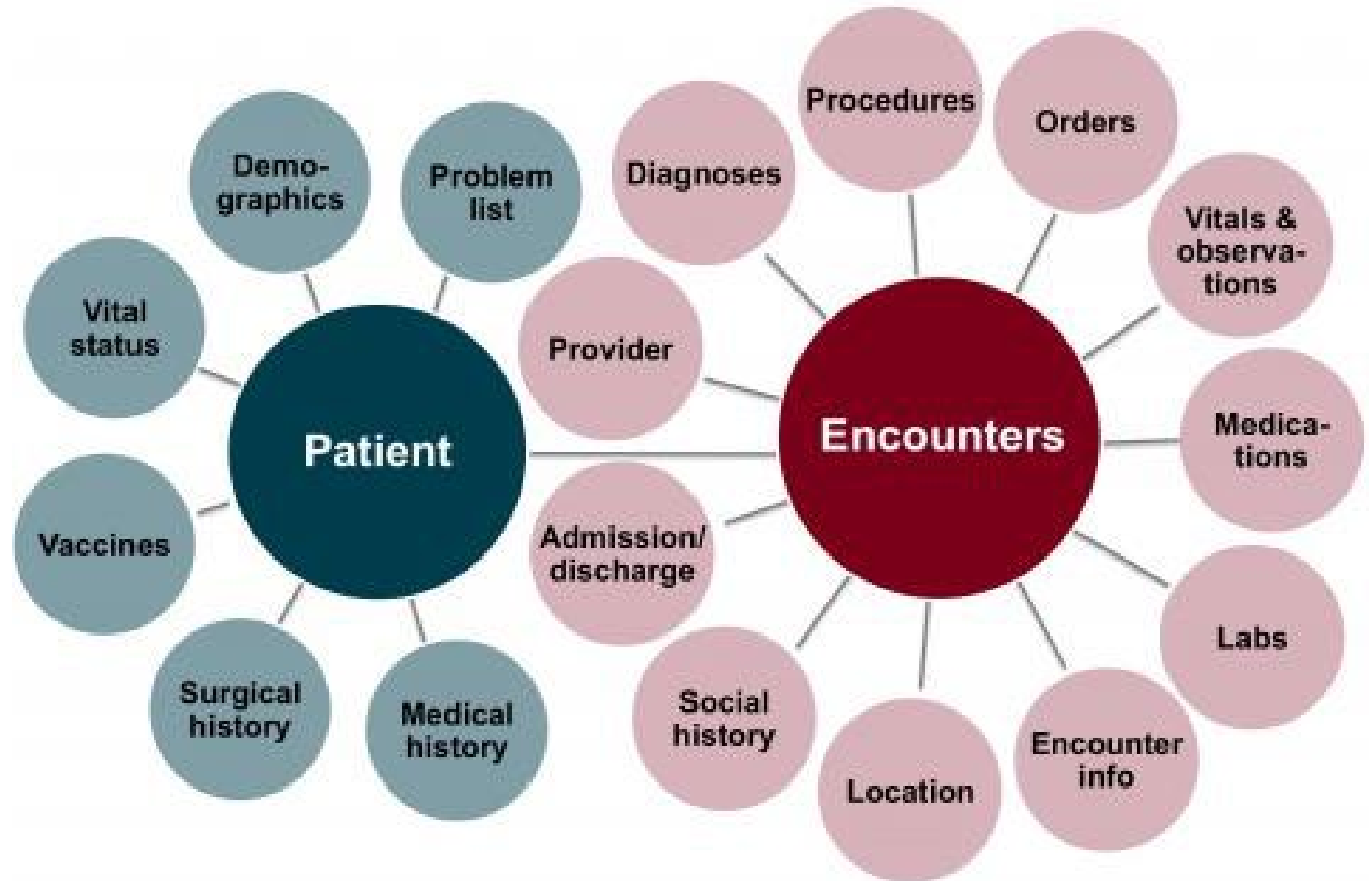
Who collects data

- Data collection team:
  physician, nurse, administrator, staff, lab technician, radiologist, pharmacists, patients

- Nowadays, a lot of the data are also generated by technologies,
  such as vital sign sensors, wearable devices, voice-to-text summary machines

Health data usage scenarios

- Aggregation use: public health, clinical research (P45)
- Used as history of patient records (P46)
- Support communication (Fig 2.5, 2.6)
- Anticipate future problem (P48)
- Prevention measure (P48)
- Identify outliers (P49, Fig 2.7)
- Clinical research (P50)
  – Randomized Clinical Trials
  - Retrospective Studies

Structure of clinical data

- Standardized controlled vocabulary (coding systems)
  - A lack of formal definition of medical terms
  - A lack of vocabulary standards
- Clinical Ontology
  - Clinical entities, such as disease names, lab test items, procedure names, drug names etc
  - Relationships of clinical entities, such as drug -> treat - diseases
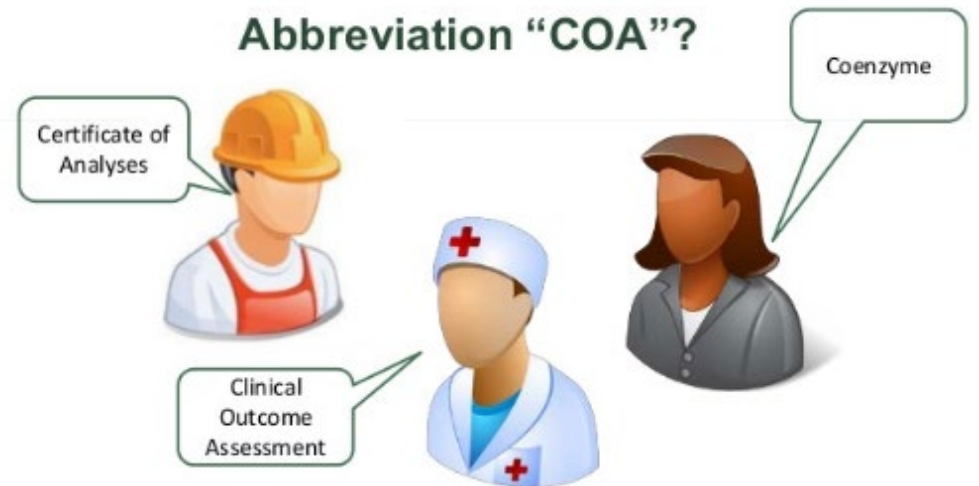
Diagnosis Coding System

- ICD: international classification of diseases

- SNOMED-CT: Systematized Nomenclature of Medicine – Clinical Terms

TENTH REVISION

ICD-10

INTERNATIONAL CLASSIFICATION OF DISEASES

ICD-10 is a new code set for reporting medical diagnoses & inpatient procedures.

Delivering

SNOMED CT

The global language of healthcare

ICD code example

- Commonly used in billing, insurance reimbursement, classifying patients, patient population research

174.5:	Malignant neoplasm of female breast, lower-outer quadrant	Three possible codes based on laterality: • C50.511- Malignant neoplasm of lower-outer quadrant of right female breast • C50.512- Malignant neoplasm of lower-outer quadrant of left female breast • C50.519- Malignant neoplasm of lower-outer quadrant of unspecified female breast
174.6:	Malignant neoplasm of female breast, axillary tail	Three possible codes based on laterality: • C50.611- Malignant neoplasm of axillary tail of right female breast • C50.612- Malignant neoplasm of axillary tail of left female breast • C50.619- Malignant neoplasm of axillary tail of unspecified female breast
174.8:	Malignant neoplasm of female breast, other specified sites of female breast	Three possible codes based on laterality: • C50.811- Malignant neoplasm of overlapping sites of right female breast • C50.812- Malignant neoplasm of overlapping sites of left female breast • C50.819- Malignant neoplasm of overlapping sites of unspecified female breast
174.9:	Malignant neoplasm of female breast, unspecified	• Three possible codes based on laterality: • C50.911- Malignant neoplasm of unspecified site of right female breast • C50.912- Malignant neoplasm of unspecified site of left female breast • C50.919- Malignant neoplasm of unspecified of unspecified female breast

CPT (Current Procedural Terms)

- First published by American Medial Association in 1966

- Commonly used in billing and reimbursement

- CPT-4 is the most widely accepted in use for reporting physician procedures for insurance reimbursement

- Link: https://www.ama-assn.org/practice-management/cpt-current-procedural-terminology

LOINC (logical observation identifiers names and codes)

- For encoding lab test, lab test results, clinical observations

- Link:
  https://loinc.org/international/

Blood glucose	GLUCOSE:MCNC:PT:BLD:QN:
Plasma glucose	GLUCOSE:MCNC:PT:PLAS:QN:
Serum glucose	GLUCOSE:MCNC:PT:SER:QN:
Urine glucose concentration	GLUCOSE:MCNC:PT:UR:QN:
Urine glucose by dip stick	GLUCOSE:MCNC:PT:UR:SQ:TEST STRIP
Glucose tolerance test at 2 hours	GLUCOSE 2H POST 100 G GLUCOSE PO: MCNC:PT:PLAS:QN:
Ionized whole blood calcium	CALCIUM.FREE:SCNC:PT:BLD:QN:
Serum or plasma ionized calcium	CALCIUM.FREE:SCNC:PT:SER/PLAS:QN:
24-hour calcium excretion	CALCIUM.TOTAL:MRAT:24H:UR:QN:
Whole blood total calcium	CALCIUM.TOTAL:SCNC:PT:BLD:QN:
Serum or plasma total calcium	CALCIUM.TOTAL:SCNC:PT:SER/PLAS:QN:
Automated hematocrit	HEMATOCRIT:NFR:PT:BLD:QN: AUTOMATED COUNT
Manual spun hematocrit	HEMATOCRIT:NFR:PT:BLD:QN:SPUN
Urine erythrocyte casts	ERYTHROCYTE CASTS:ACNC:PT:URNS:SQ: MICROSCOPY.LIGHT
Erythrocyte MCHC	ERYTHROCYTE MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION:MCNC:PT:RBC:QN:AUTOMATED COUNT
Erythrocyte MCH	ERYTHROCYTE MEAN CORPUSCULAR HEMOGLOBIN:MCNC:PT:RBC:QN: AUTOMATED COUNT
Erythrocyte MCV	ERYTHROCYTE MEAN CORPUSCULAR VOLUME:ENTVOL:PT:RBC:QN:AUTOMATED COUNT
Automated Blood RBC	ERYTHROCYTES:NCNC:PT:BLD:QN: AUTOMATED COUNT
Manual blood RBC	ERYTHROCYTES:NCNC:PT:BLD:QN: MANUAL COUNT
ESR by Westergren method	ERYTHROCYTE SEDIMENTATION RATE:VEL:PT:BLD:QN:WESTERGREN
ESR by Wintrobe method	ERYTHROCYTE SEDIMENTATION RATE:VEL:PT:BLD:QN:WINTROBE

RxNORM

- Collaboration result of NLM, FDA, and VA
- Specialized in drug terms
- Link: https://www.nlm.nih.gov/research/umls/rxnorm/
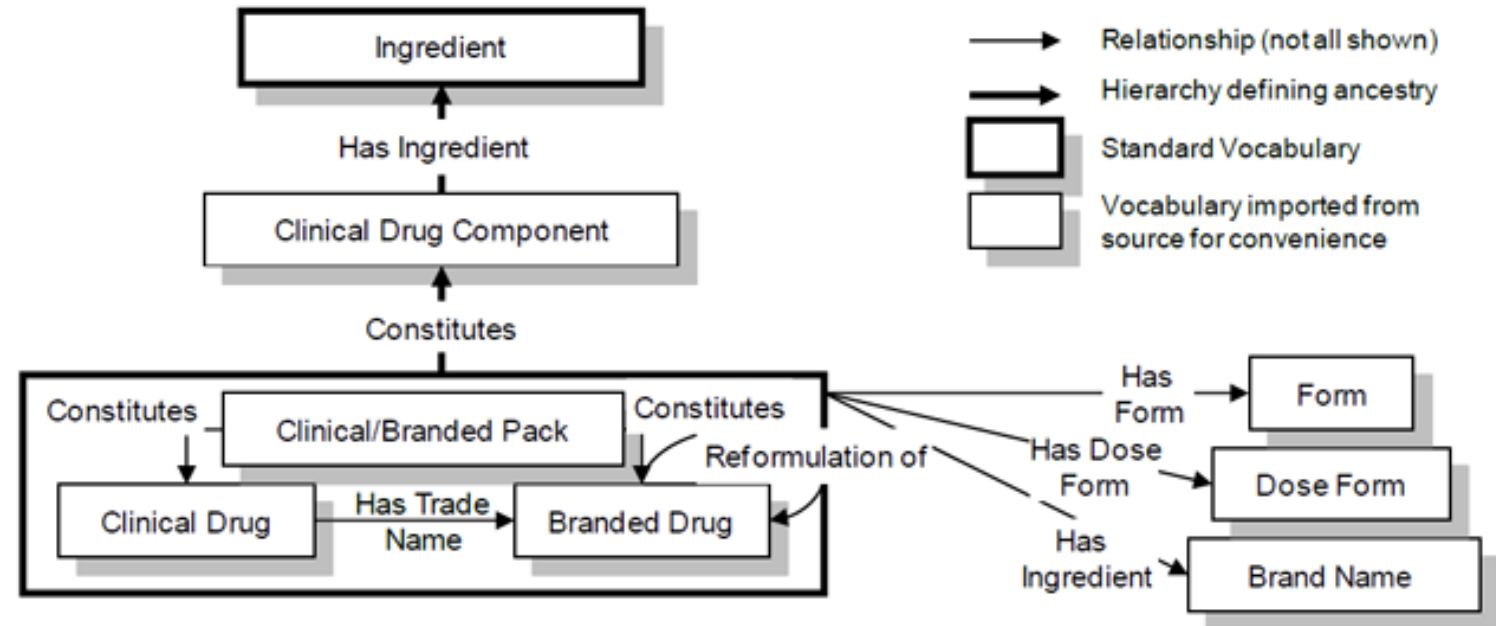
MeSH

- Medical Subject Heading (MeSH) is developed and maintained by NLM
- Primarily used to index and organize the topics of research publications
- https://meshb.nlm.nih.gov/treeView
- Demo: https://www.ncbi.nlm.nih.gov/pubmed/29109303

Anatomy [A] ⊖
- Body Regions [A01] ⊕
- Musculoskeletal System [A02] ⊕
- Digestive System [A03] ⊕
- Respiratory System [A04] ⊕
- Urogenital System [A05] ⊕
- Endocrine System [A06] ⊕
- Cardiovascular System [A07] ⊕
- Nervous System [A08] ⊕
- Sense Organs [A09] ⊕
- Tissues [A10] ⊕
- Cells [A11] ⊕
- Fluids and Secretions [A12] ⊕
- Animal Structures [A13] ⊕
- Stomatognathic System [A14] ⊕
- Hemic and Immune Systems [A15] ⊕
- Embryonic Structures [A16] ⊕
- Integumentary System [A17] ⊕
- Plant Structures [A18] ⊕
- Fungal Structures [A19] ⊕
- Bacterial Structures [A20] ⊕
- Viral Structures [A21] ⊕

Organisms [B] ⊕

Diseases [C] ⊕

Chemicals and Drugs [D] ⊕

Analytical, Diagnostic and Therapeutic Techniques, and Equipment [E] ⊕

Psychiatry and Psychology [F] ⊕

Phenomena and Processes [G] ⊕

Disciplines and Occupations [H] ⊕

Anthropology, Education, Sociology, and Social Phenomena [I] ⊕

Technology, Industry, and Agriculture [J] ⊕

Humanities [K] ⊕

Information Science [L] ⊕

Named Groups [M] ⊕

Health Care [N] ⊕

Publication Characteristics [V] ⊕

Geographicals [Z] ⊕

RadLex

- Produced by Society of North America (RSNA)

- Used in the radiology domain for indexing and information retrieval

- Includes names of anatomic parts, radiology devices, exams, procedures etc.

- Link: http://www.radlex.org/
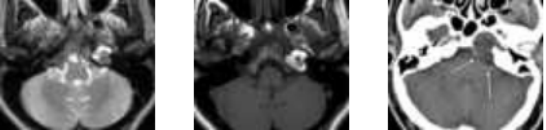
UMLS

- Unified medical language system (UMLS)

- Maintained by NLM and first published in 1989

- Probably the largest controlled medical terminology

- Metathesaurus 8.9 million terms from over 160 sources

- Link: https://www.nlm.nih.gov/research/umls/

Data Interchange Standards: HL7

- Version 1.0 was published in 1987.
- HL7 is a messaging data interchange protocol
- Link: http://www.hl7.org/

Fig. 7.15 An example of an HL7 ADT transaction message. This message includes the Message Heading segment, the EVN trigger definition segment, the PID patient-identification segment, the PV1 patient-visit segment, the OBR general-order segment, and several OBX results segments

```
MSH|^~&\|DHIS|OR|TMR|SICU|199212071425|password|ADT|16603529|P|2.1<cr>

EVN|A02|199212071425||<cr>

PID|||Z99999^5^M11||GUNCH^MODINE^SUE|RILEY|19430704 |F||C|RT. 1, BOX
97^ZIRCONIA^NC^27401 |HEND|(704)982-1234|(704)983-1822||S|C||245-33-
9999<cr>

PV1|1|I|N22^2204|||OR^03|0940^DOCTOR^HOSPITAL^A||| SUR|||||A3<cr>

OBR|7|||93000^EKG REPORT|R|199401111000|199401111330|||RMT||||19940111
11330|?|P030||||||199401120930|||||||88-126666|A111|VIRANYI^ANDREW<cr>

OBX|1|ST|93000.1^VENTRICULAR RATE(EKG)||91|/MIN|60-100<cr>

OBX|2|ST|93000.2^ATRIAL RATE(EKG)||150|/MIN|60-100<cr>

. . .

OBX|8|ST|93000&IMP^EKG DIAGNOSIS|1|^ATRIAL FIBRILATION<cr>
```

New Data Challenges

- Omic data

- Biomedical Data, translational data

- Aggregated clinical research

- Public health data

- The "big data" problem

DATA CHALLENGES
Volume, Velocity, Variety, Veracity, Data discovery

PROCESSING CHALLENGES
Data collection
Resolving similarities
Modification of data
Data analysis
Output representation

BIG DATA

MANAGEMENT CHALLENGES
Data privacy
Data security
Governence and ethical issues
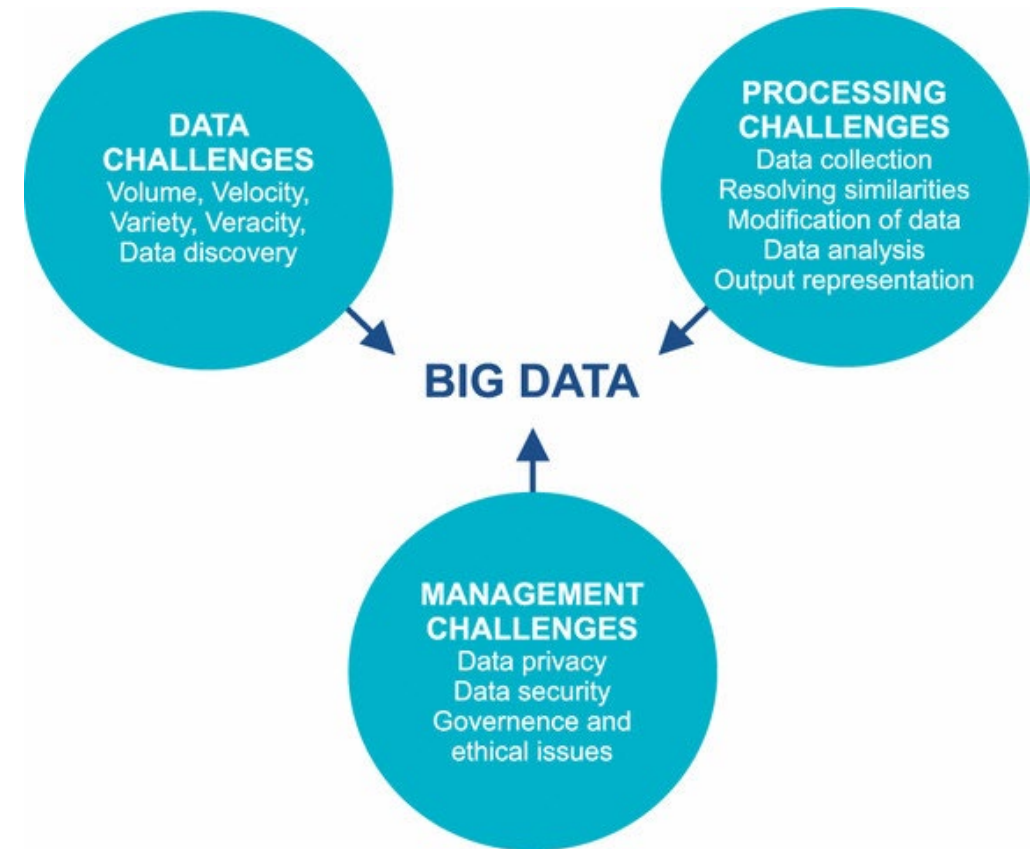
The rise of "big" clinical data

- More and more clinical and biomedical data are collected in the past 20 years, such EHRs, genomic, large-scale survey, clinical trials
- Very valuable for knowledge discover and advancing medical science
- Can be used to create new application
- How to process and leverage the data for research and application development becomes a hot topic
- "Health Data Science"
- Five "V"

Just having Big Data is of no use unless we can turn it into value

The size of the data

1 Volume

2 Velocity

The speed at which the data is generated

5 Value

4 Veracity

The trustworthiness of the data in terms of accuracy

3 Variety

The different types of data

Big Data

- NEJM Article:

Healthcare Big Data and the Promise of Value-Based Care
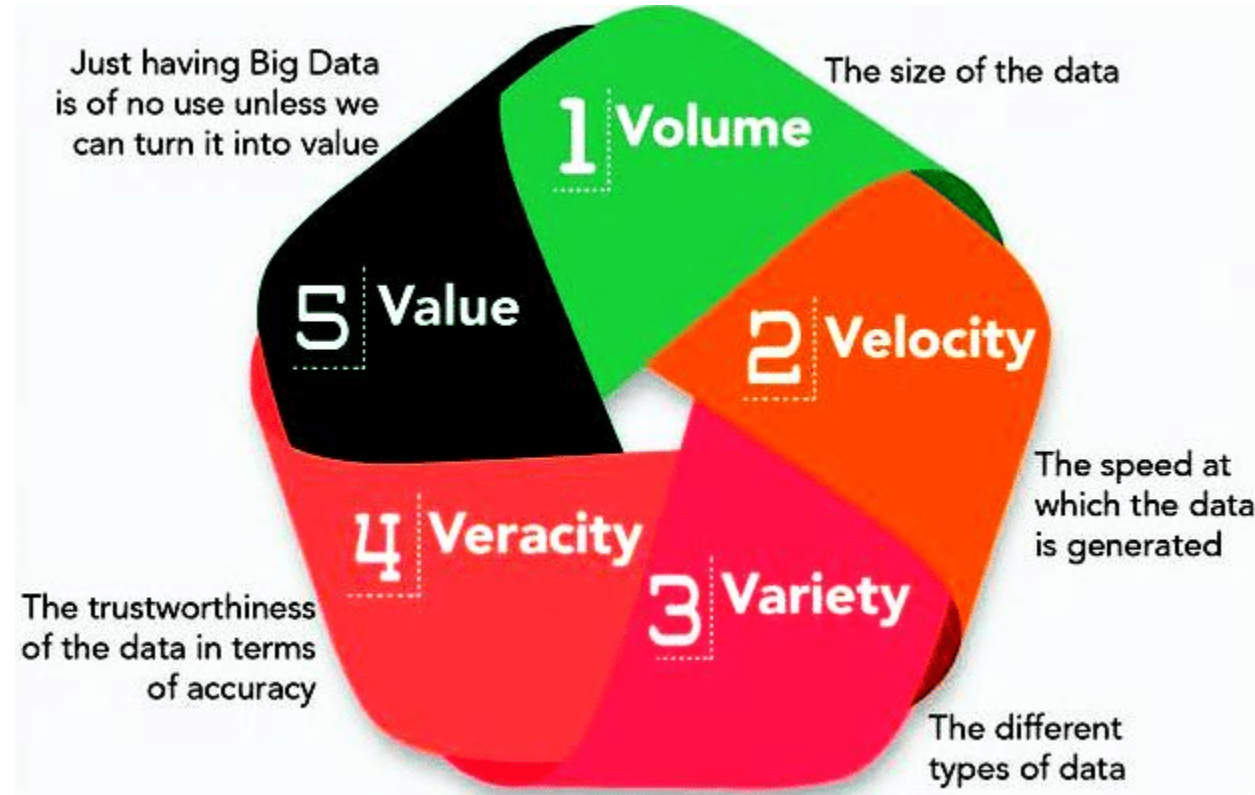
Sources of Big Data in Health Care

NEJM Catalyst (catalyst.nejm.org) © Massachusetts Medical Society
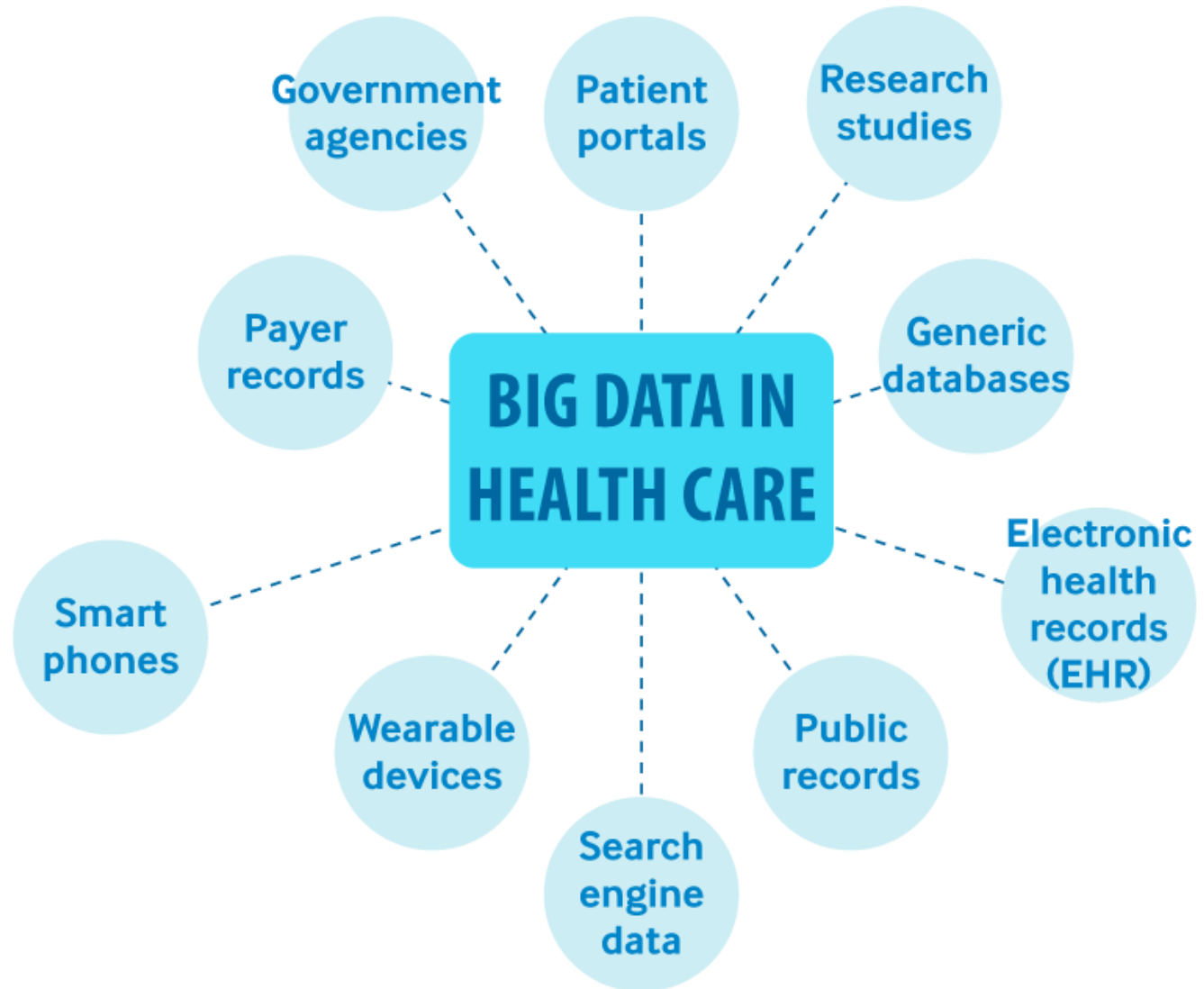
Applications for Big Data in Healthcare

Diagnostics
Data mining and analysis to identify causes of illness

Preventative medicine
Predictive analytics and data analysis of genetic, lifestyle, and social circumstances to prevent disease

Precision medicine
Leveraging aggregate data to drive hyper-personalized care

Medical research
Data-driven medical and pharmacological research to cure disease and discover new treatments and medicines

Reduction of adverse medication events
Harnessing of big data to spot medication errors and flag potential adverse reactions

Cost reduction
Identificaton of value that drives better patient outcomes for longterm savings

Population health
Monitor big data to identify disease trends and health strategies based on demographics, geography, and socio-economics

Reading Materials

- Clinical Informatics, clinical data, and common clinical data standards
    a. Recent advances of HCI in decision-making tasks for optimized clinical workflows and precision medicine.
    b. Healthcare Big Data and the Promise of Value-Based Care.

Electronic Health Record System (EHRs)

EHR: Electronic Patient Records

- An **electronic health record** (**EHR**) is a repository of electronically maintained information about an individual's health status and health care, stored such that it can serve the multiple legitimate uses and users of the record.

- The term **electronic health record** <u>system</u> (also referred to as a computer-based patient record system) includes the active tools that are used to manage the information, but in common use, the term EHR can refer to the entire system.

EHR: Data Perspective (P396)

- Fig 12.1
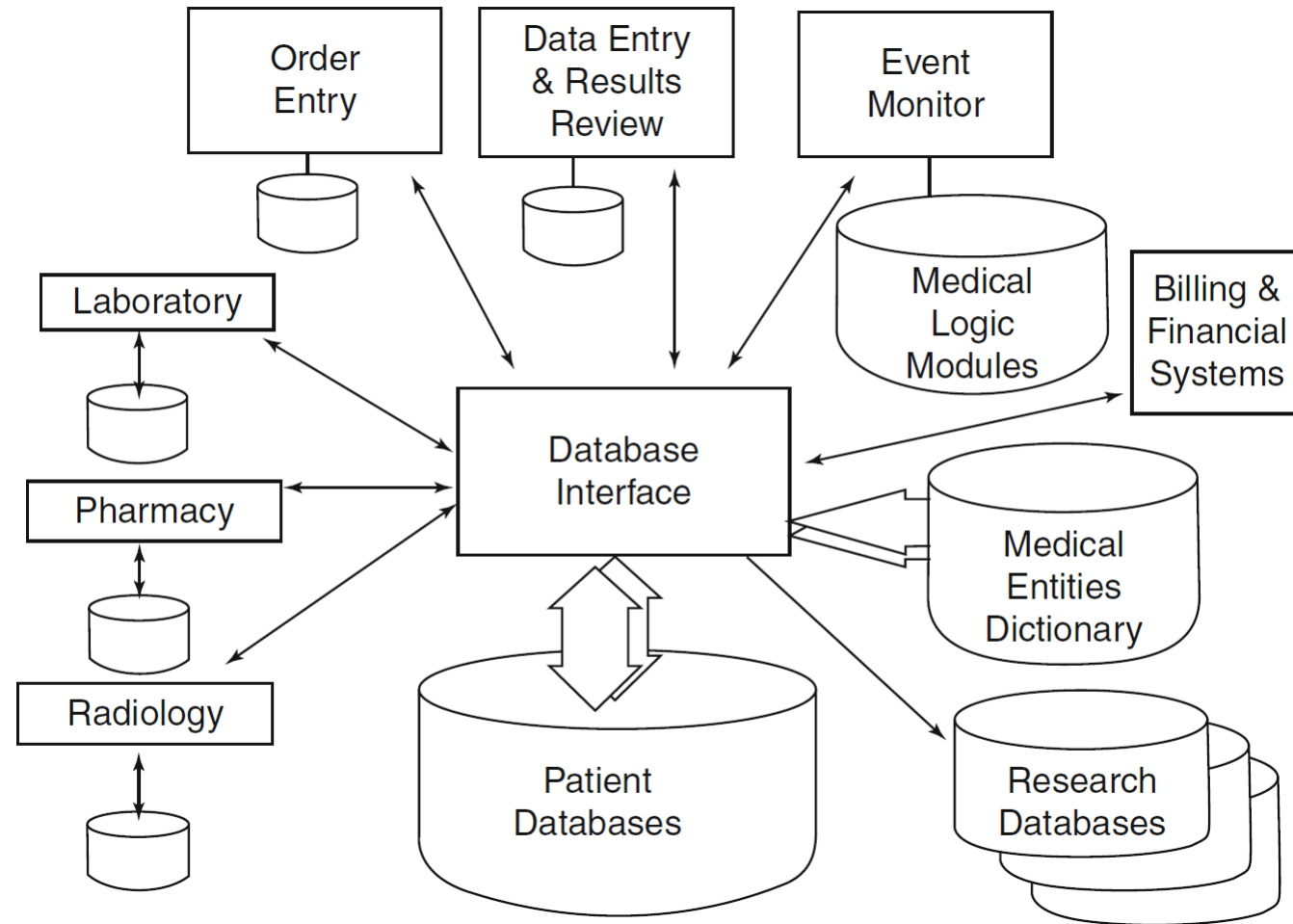
EHR Components – Integrated View

- Fig 12.1

Order Entry

- Order entry: clinicians make decisions and take actions
- E.g. check vital sign three times a day, take one finasteride once a day, order blood test
- Computer assist and document this process

Order Entry Example using an informatics tool

- Fig 12.3
- Vanderbilt Total Parenteral Nutrition (TPN)
- Computerized Physician Order Entry (CPOE)

Oder Entry example 2

- Drug intervention entry

Oder Entry example 3

- Lab test entry

Data Capture

Two common methods for data capture:

- 1. Using electronic interface to transfer from other systems, e.g. lab test results, drug orders

- 2. Manual input data, e.g. discharge summaries (narrative text input), ICD diagnosis (code input)

EHR lab report

- Lab report data

EHR discharge summary

EHR ICD Code input

- Diagnosis coding
- Billing

Displaying Physician Entered Data

- Charts: Problem list, medication, diagnosis
- Images: x-ray, MRI
- Forms: lab test results
- Textual narratives: e.g., discharge summary

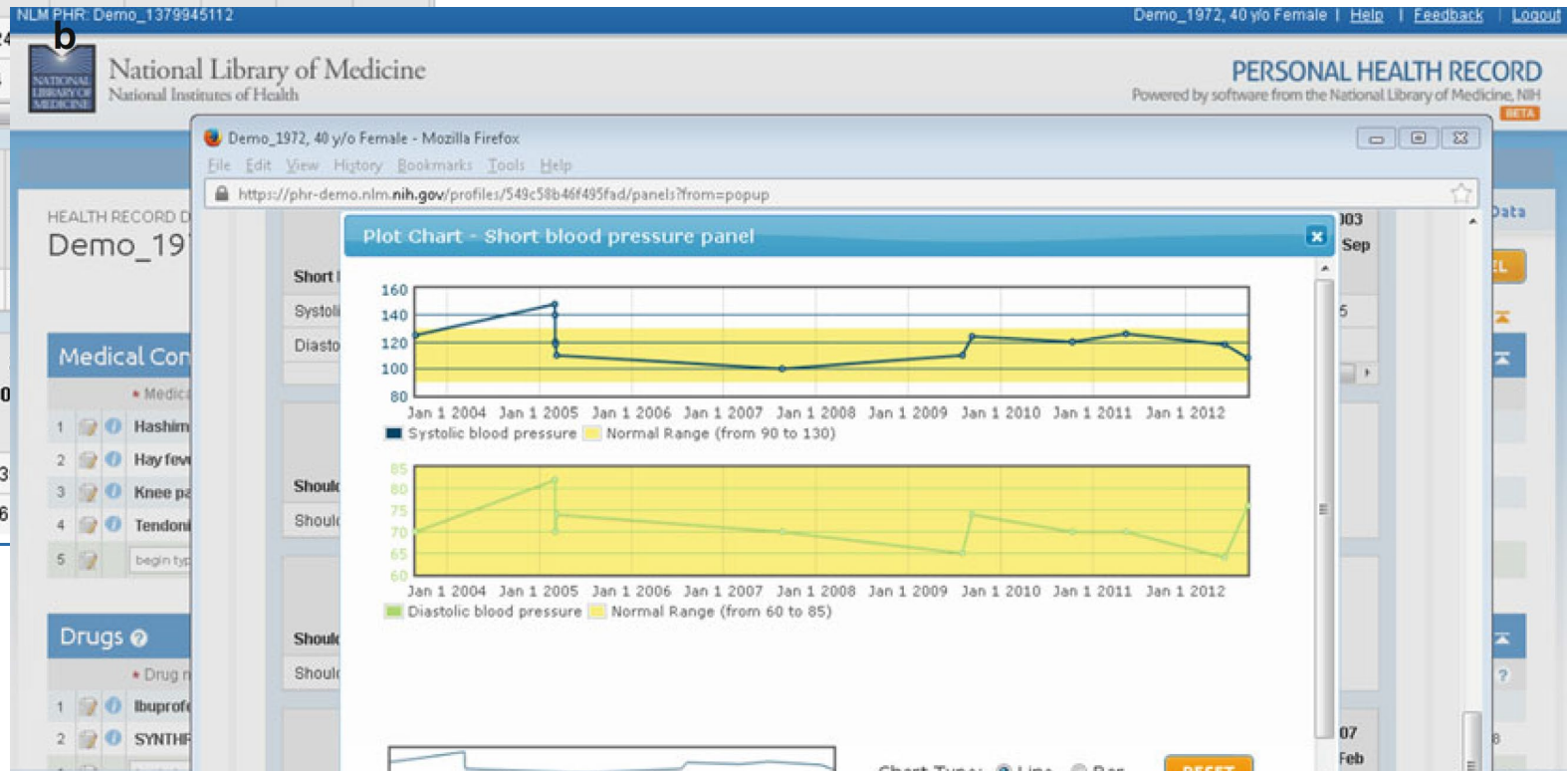# Data Display – Timeline (P412, Fig 12.12)

Data Display – Summaries and Snapshots (P412)

- Fig 12.15 (P417)

Tablet and Smart Phone Example

- Fig 12.11
- A) a list of patient
- B, C) summaries
- D) lab test results
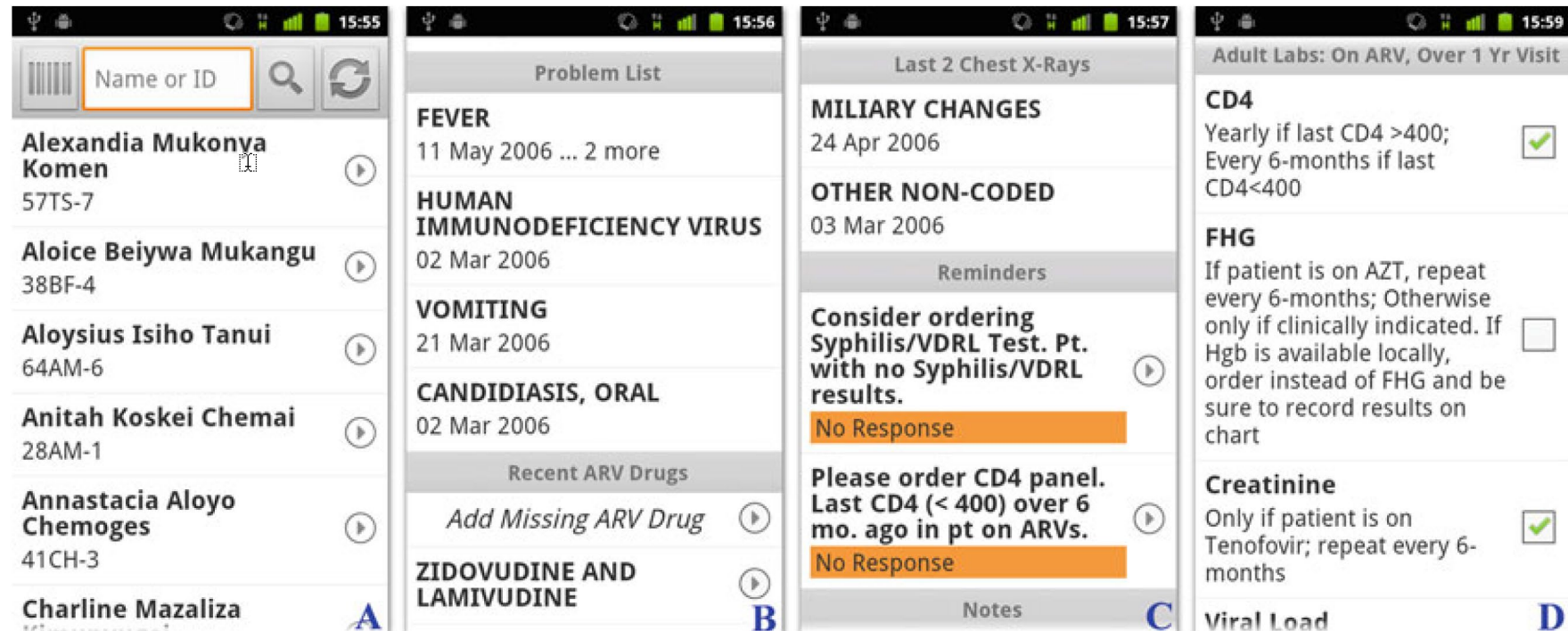
Example of imaging information (P413-414)

Query and Surveillance

- Find data and use the searched data for analysis, such as outcome or patient patterns.

- Use the results to support decision making, such as alert and notification based on query results

Health Service Support

- Identify patients based on certain condition
- For example:
  - Due for periodic screening
  - Generating patient calling list
  - Identify patients that need to be notified about new development, such as recall of drug
  - Find candidate patients for review

Clinical Research

- Identify patient who meet eligibility criteria for clinical trials
- Identify a population of patients and analyze their patterns

Quality Reporting

- Use patient data for quality measures
- For example:
  - Treatment outcome
  - Symptom reports
  - Cost analysis
  - Physician efficiency

Support Administration

- Billing
- Claim
- Insurance
- Time management
- Resource allocation

Reading Materials

- Roles of Electronic Health Records (EHRs) and Clinical Data
  a. Integrated precision medicine: the role of electronic health records in delivering personalized treatment.
  b. Digital Twins from Personalized Medicine to Precision Public Health

Clinical Decision Support System

EHR: Clinical Decision Support Perspective

- Clinical Decision Support (CDS): the process that provides clinicians, staff, patients, or other individual with <u>knowledge</u> and <u>person-specific information</u>, filtered or present at <u>appropriate times</u>, to enhance health and health care.

- Clinical Decision Support <u>Systems</u> (CDSS)
  - Informatics system offering situation-specific information and recommendation
  - Provide knowledge or analysis to support decision makers

Motivation of CDSS

- Challenges of knowledge management and clinical practice
  - Significant growth of data and knowledge
  - Limited time for providers
  - Error due to inadequate patient information
- Meaningful use of electronic health records
  - American Recovery and Reinvestment Act (ARRA) created widespread adoption of health information technologies (HIT)
  - Achieving meaningful use of HIT: safety, quality, efficacy
- Delivering **personalized health services**
  - **Personalized medicine**: the need to tailor care to individual factors – personal factors (clinical and biological), family history, social and environmental factors
  - **Optimize well-being**: not just treating diseases, but changing lifestyle and other behavior to achieve overall healthier condition
  - **Prospective health**: risk assessment based on genomic, family history, social history, environmental history

"Five-rights" model of CDSS

Intervention contains complex triggers, reasoning logics, data processing, and actions, therefore it is essential to provide decision support correctly:

- Provide right information
- To right person
- In the right format
- Through the right channel
- At right time

Can be viewed as general guidelines for designing CDSS

Right Information	Right Person	Right Format

Right Channel	Right Time
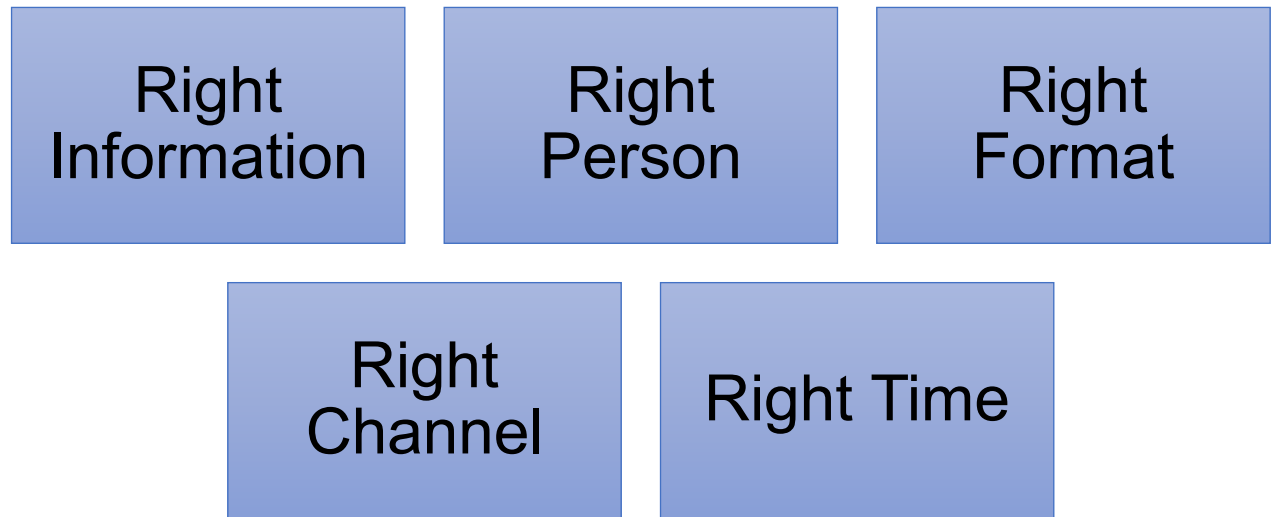
CDS Example

- Fig 12.4
- Antibiotic

a

ADULT ANTIBIOTIC ASSISTANT

000000000 Doe, J.Q.   67Y   M   ROOM   LDS Hospital
Admited: 06/27/05 16:50   **Diagnosis: SEPSIS**
WBC is down: Max 24hr WBC: 23.6 - Prev.: 27.5   **Temp is down:** Max 24hr Temp: 37.8 - Prev.: 38.2
Renal Function is Impaired: CrCl = 46   Cr is up: Max 24 Hour Cr: 1.7- Prev. 1.4   **IBWeight:** 77kg
Antibiotic Allergies: --None reported--
Current Antibiotics:
  1. 06/27/05.18:24   1day   LINEZOLID (ZYVOX), IV SOLN. 600.   Q12hrs
  2. 06/27/05.18:24   1day   FLUCONAZOLE IN NS [DIFLUCAN], INJ 200.   Q24hrs
  3. 06/28/05.09:12   1day   ERTAPENEM (INVANZ), VIAL 1000.   Q24hrs

Identified Pathogens	Specimen, Site	Collected
Clostridium subterminale	Peritoneal Fluid,	06/21/05 23:29
Escherichia coli	Peritoneal Fluid,	06/21/05 23:29
Klebsiella pneumoniae	Peritoneal Fluid,	06/21/05 23:29
Enterococcus faecium BL neg VRE	Peritoneal Fluid,	06/21/05 23:29

** Suggest ID consult **

Therapeutic Suggestion	Dosage	Route	Interval	Comment
Imipenem	500mg	IV	*q12h	Infuse over 1hr
Suggested Antibiotics Not Adequate, Call ID				

* Adjusted based on patient's renal function.
--The antibiotic suggestions should not replace clinical judgement--

| OrganismSuscept | Drug Info | Explain | Empiric Abx | Abx Hx | ID Rnds | Outpatient Models | Help |

b

- Patient should receive IV antibiotics.
- Renal function dictates that dosage should be adjusted.
- Cultures show fungi or yeast that were not considered pathogens.
- The suggested antibiotic(s) will treat the identified anaerobes.
- Patient's vitals (Temp, WBC, Bands) do not support chest Xray: Wed Jun 22 06:14:00 MDT 2005)
- Suggest vancomycin & an aminoglycoside to empirically treat the Dx of sepsis.
- Suggest ticar/clav or imipenem due to the site of Clostridium infection.
- Prophylactic antibiotics are not suggested for this patient at this time.
- Suggest ID consult based on the complexity of this patient's condition.

CDS Common Implementation

- Commonly provided as reminder or alerts

- Preferable implemented in a way a physician can reject or accept with a click

- Annotate the suggestion with rationales

Alert example

- Significant abnormality of lab test

Messages   Patients   **Alerts** 1   Calls

Low   8/23/18, 11:30 P

Nurse Call

Clara Young, 1IS Room 32

Snooze   Call   Escalate

Critical Lab Result   3:32 PM

Lab Type   Lactate

Lab Value   3.5 mmol/L (Critical)

Ref Range   0.5 mmol/L - 1.0 mmol/L

iew Results

Admit   11:17 AM

Chief Complaint   Pneumonia and tachycardia

Admission Time   8/23/2018 T3:28:55Z

Admission Type   Inpatient

Location   Floor

Add Care Team Members

Alert example

- Adverse drug-drug interaction

Alert example

- Alert with reference knowledge

Clinical Alert: Asthma

Clinical Alert:
1. Review asthma care plan with patient and/or family.
2. Discuss and recommend the annual flu shot.

Clinical References:
- Asthma
- Albuterol
- Flu shot

Citation:
Bibliographic Citation: This is the Citation for Asthma
Developer: Developer
Funding Source: Funding Source
Release Date: 12/29/13
Revision Date(s): 12/29/15

Continue

Headed to regional soccer championships 10/11.

CDSS: Access to Knowledge

- Provide knowledge resource references to physician when they are writing notes or orders for patients.

- Common knowledge source:
  - National Library of Medicine (NLM): research results, evidence
  - Center for Disease Control and Prevention (CDC): travel, vaccines, out breaks
  - Agency for Healthcare Research and Quality (AHRQ): health care quality comparison, service comparison

Knowledge Ref Example (P401)

- Fig 12.6
- Drug allergic and drug interaction

Knowledge Ref - Inforbutton

- Fig 12.8 (P402)

CDSS: Integrated Communication and Reporting

- Support health care across departments or different organizations

- Fig 12.9 (P404): patient handoff report: when the responsibility of care is transferred

Reading Materials

- Clinical decision support systems (CDSS) implementation and its application in precision medicine
  a. Clinical informatics accelerates health system adaptation to the COVID-19 pandemic examples from Colorado.
  b. Clinical decision support systems for improving diagnostic accuracy and achieving precision medicine.

- Thank you!

- Jake Luo, PhD

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