Lecture Notes

Big Data in Medical Informatics

Week 5:
Electronic Health Records

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EHR

Electronic Health Records (EHR)

Definition

“The set of components that form the mechanism by which patient records are created, used, stored, and retrieved. A patient record system is usually located within a health care provider setting. It includes people, data, rules and procedures, processing and storage devices (e.g., paper and pen, hardware and software), and communication and support facilities.”

The Institute of Medicine’s 1991 report, Computerized Patient Record

EHR

"(1) longitudinal collection of electronic health information for and about persons, where health information is defined as information pertaining to the health of an individual or health care provided to an individual;
(2) Immediate electronic access to person- and population-level information by authorized, and only authorized, users;
(3) provision of knowledge and decision-support that enhance the quality, safety, and efficiency of patient care; and
(4) Support of efficient processes for health care delivery."

The 2003 IOM Letter Report, Key Capabilities of an Electronic Health Record System

EHR

- An Electronic Health Record (EHR) is
  - a digital version of a patient's medical history.
  - longitudinal record of patient health information
  - generated by one or several encounters in any
  - healthcare providing setting.
- Alternative terms
  - EMR (Electronic Medical Record)
  - CPR (Computer-based Patient Record).

History of EHR

- Medical record – 5th century B.C. Hippocrates
  - gave importance to observation and documentation
  - made careful, regular note of many symptoms including complexion, pulse, fever, pains, movement, and excretions
  - extended clinical observations into family history and environment.
- prescribed two goals for medical records:
  - A medical record should accurately reflect the course of disease.
  - A medical record should indicate the probable cause of disease.

History of EHR

- 1960s - Early EHRs
  - 1967 Logical Programming (HELP) software. HELP is notable for its pioneering logical decision support features.
  - 1969, Harvard Medical School developed its own software Computer Stored Ambulatory Record (COASTER)
- 1970- Computer Provided Order Entry (CPOE) system
  - the Technicon Medical Information Management System/ Technicon Data System (TDS) implemented in El Camion Hospital in California
- 1985 - automated data processing systems
  - The Department of Veterans Affairs - Decentralized Hospital Computer Program (DHCP), which includes extensive clinical and administrative capabilities within its medical facilities
- 1983 - patient scheduling
  - Epic Systems , Cadence.
- 1992 the first Windows-based EHR software (Epic- Care)
- 2000 and beyond,
  - EHR software has been increasingly trying to incorporate other functionalities to become an interactive companion for physicians and professionals.

Hospital 1915

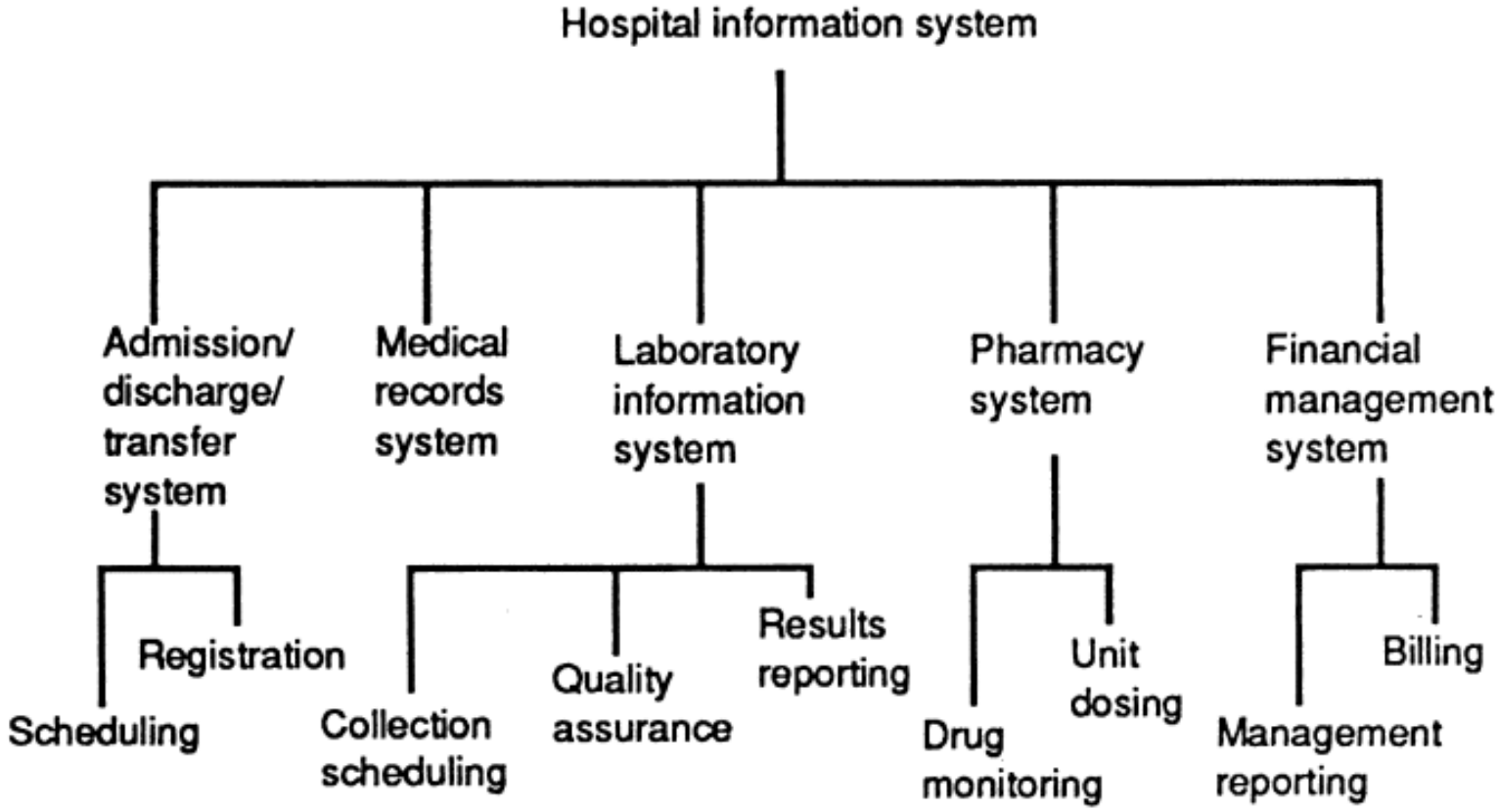
Hospital 2015

Ref: VeraTech: EHR models, standards and semantic interoperability

Hospital Information Systems (HIS)

- An Illustrative HIS Case
- A major teaching hospital purchased and installed a large computer system that assists physicians with ordering drugs and laboratory tests,
  the clinical laboratories with reporting laboratory test results,
  head nurses with creating nursing schedules, and
  the admissions staff with monitoring hospital occupancy.
  Personnel access the system using workstations located in each nursing unit.
  There also are printers associated with each unit so that the computer can generate reports for the patient charts (which continue to be paper-based) and worksheets used by the hospital staff.
  This information system depends on a large, dedicated computer,
  which is housed in the hospital complex and is supported by several full-time personnel.
  It has modules to assist hospital staff with both administrative and clinical duties.

Hospital Information Systems



Architecture of HIS

Federated database system

- A federated database system is an integrated system of autonomous (component) database systems which are part of respective application components
- The point of integration is to logically bring the database schemata of the component database systems to a single database schema, the federated database schema, in order to attain data integration even when there are redundant data in HIS with a DBn architecture
- This virtual federated database schema should be able to be accessed by application components as though it was a real database schema

Architecture of HIS

Transaction Management: 2-phase-commit protocol and master application components

Transaction management in databases but also in sets of distributed databases ensures that every update of data, which are consistent, will lead to another state in which data are consistent again

Transaction management guarantees **c**onsistency of data by **a**tomicity, **i**solation and **d**urability of any transaction (ACID conditions)

Architecture of HIS

The “2-phase commit protocol” was developed for transaction management in DB^n architectures

- In the initial phase, this protocol checks if the transaction can be carried out by all affected database systems.
- Only if the changes are possible everywhere, they are actually carried out in in a second phase in all database systems

For carrying out the protocol, the database systems must be tightly coupled by synchronous communication, and the database schemata of all involved database systems must be known

Architecture of HIS

Middleware

Generally the term middleware describes the software components of a computer-based information system that serve for the communication between application components.

Middleware can be considered as the „glue" in between application components, i.e. in the „middle" of a set of components

- Communication server
- Remote function calls
- Service-oriented architecture (SOA) and portals

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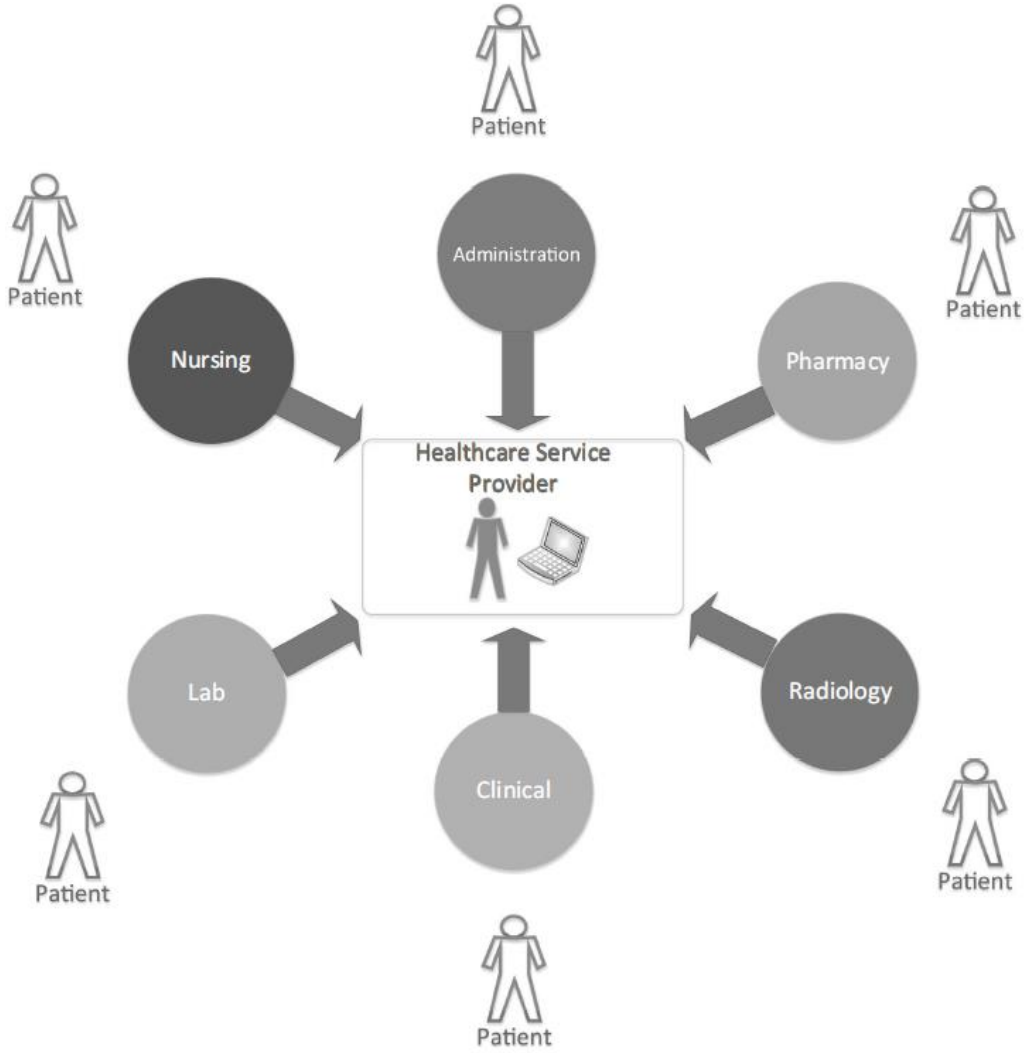
Components of EHR

- The main purpose of EHR is to support clinical care and billing
- It improves
  - the quality and convenience of patient care,
  - the accuracy of diagnoses and health outcomes,
  - care coordination and patient participation,
  - cost savings,
  - The general health of the population

- Electronic records may be generated from any department.
  - Hospitals and clinics may have a number of different ancillary system providers
  - systems are not necessarily integrated to the main EHR system: stand-alone systems , different standards of vocabularies

Components of EHR

- EHR systems are designed to integrate data from different components such as
  - administrative,
  - nursing,
  - pharmacy,
  - laboratory,
  - radiology,
  - physician' entries, etc.



Ref: Healthcare Data Analytics, **Chapman & Hall**

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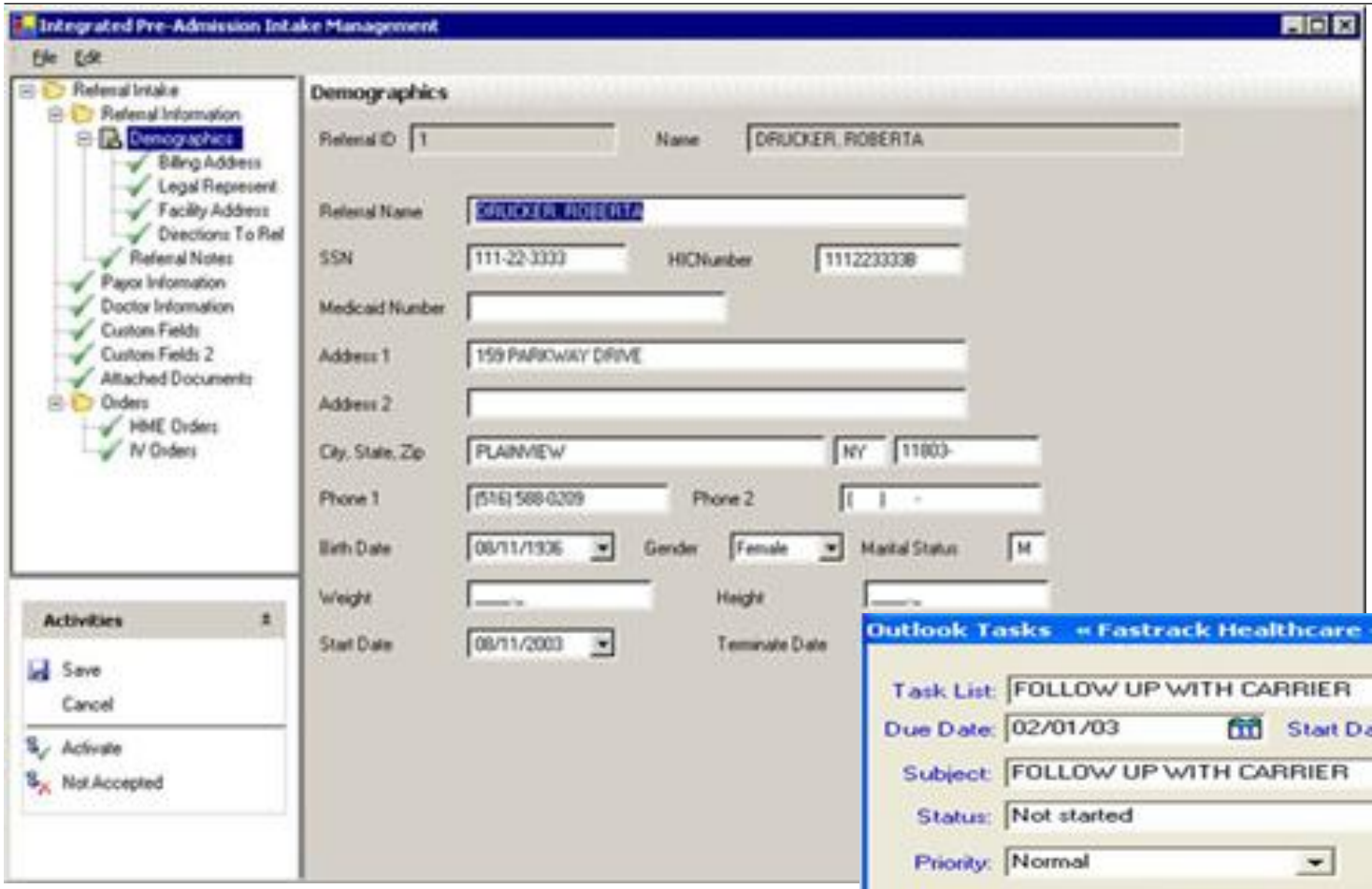
Components of EHR: Administrative System Components

- Administrative data created during
  - patient registration,
  - admission,
  - discharge,
  - transfer
- Includes
  - name, demographics, employer history, chief compliant, patient disposition, etc.
  - Social history data e.g. marital status,
  - home environment, daily routine, dietary patterns, sleep patterns, exercise patterns, tobacco use, alcohol use, drug use
    - family history data e.g. personal health history, hereditary diseases, father, mother and sibling(s)
    - health status, age, and cause of death can also be a part of it.
  - patient billing information
  - <name-value> pairs: “comments” or “description”

Components of EHR: Administrative System Components



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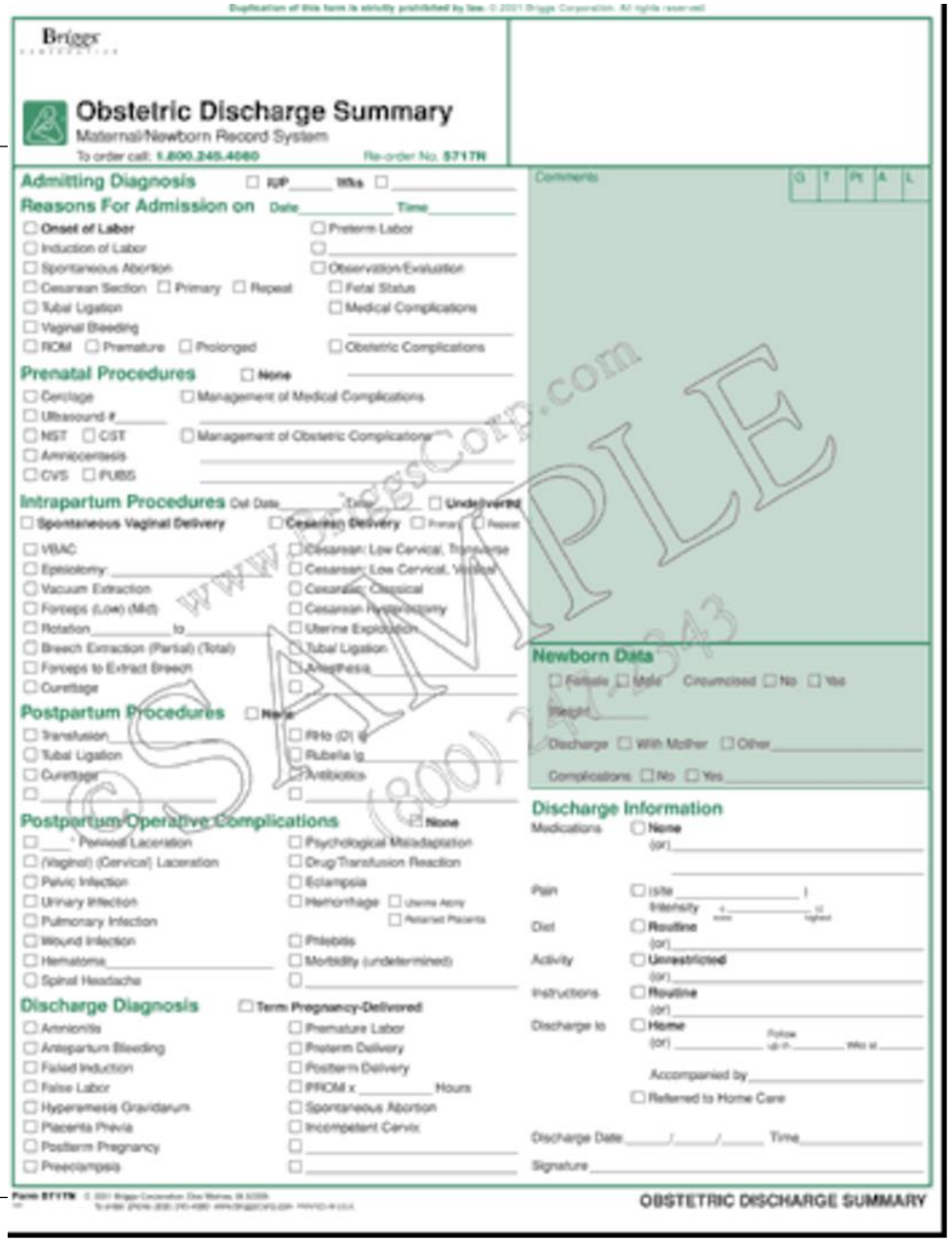
discharge summary

- The discharge summary includes basic information:
  - the period of time that the patient stayed in the hospital,
  - the patient's condition when they arrived at the hospital
  - the patient's condition during the hospital stay,
  - the diagnosis given, the treatment given,
  - the medicines given,
  - the patient's condition upon discharge.



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Components of EHR: Administrative System Components

- Why is it important ?
  - Administrative information is used to identify and assess a patient
  - During the registration process, a patient is generally assigned a unique identification key comprising of a numeric or alphanumeric sequence.
  - This key helps to link all the components across different platforms.
  - Administrative data allows the aggregation of a person's health information for clinical analysis and research.

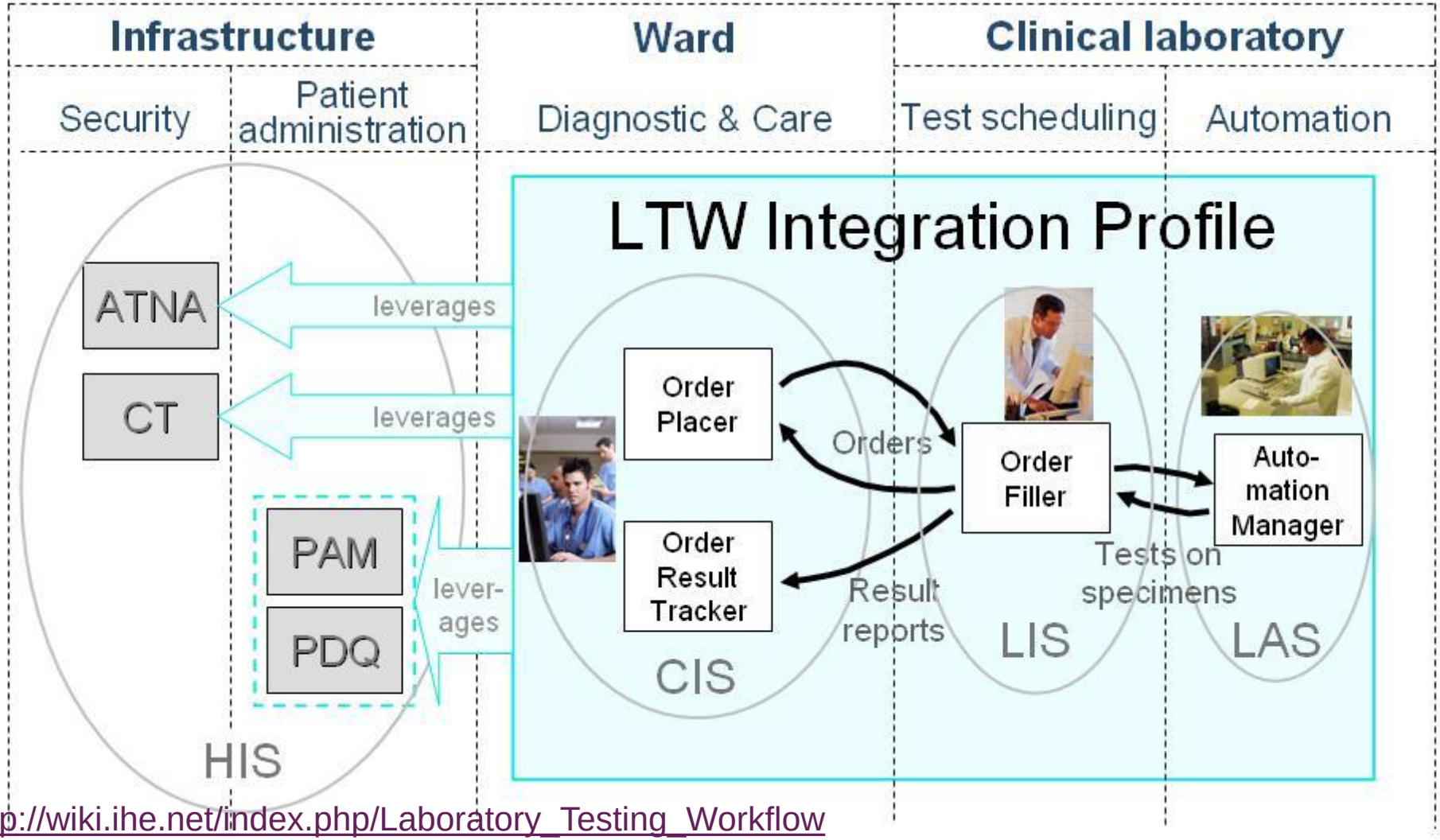
- Example:
  - lab test data can create an electronic record; and another record is created from radiology results. Both records will have the same identifier key to represent a single patient. Records of a previous encounter are also pulled up using this key.
  - It is often referred to as the medical record number or master patient index (MPI).

Components of EHR: Laboratory System Components & Vital Signs

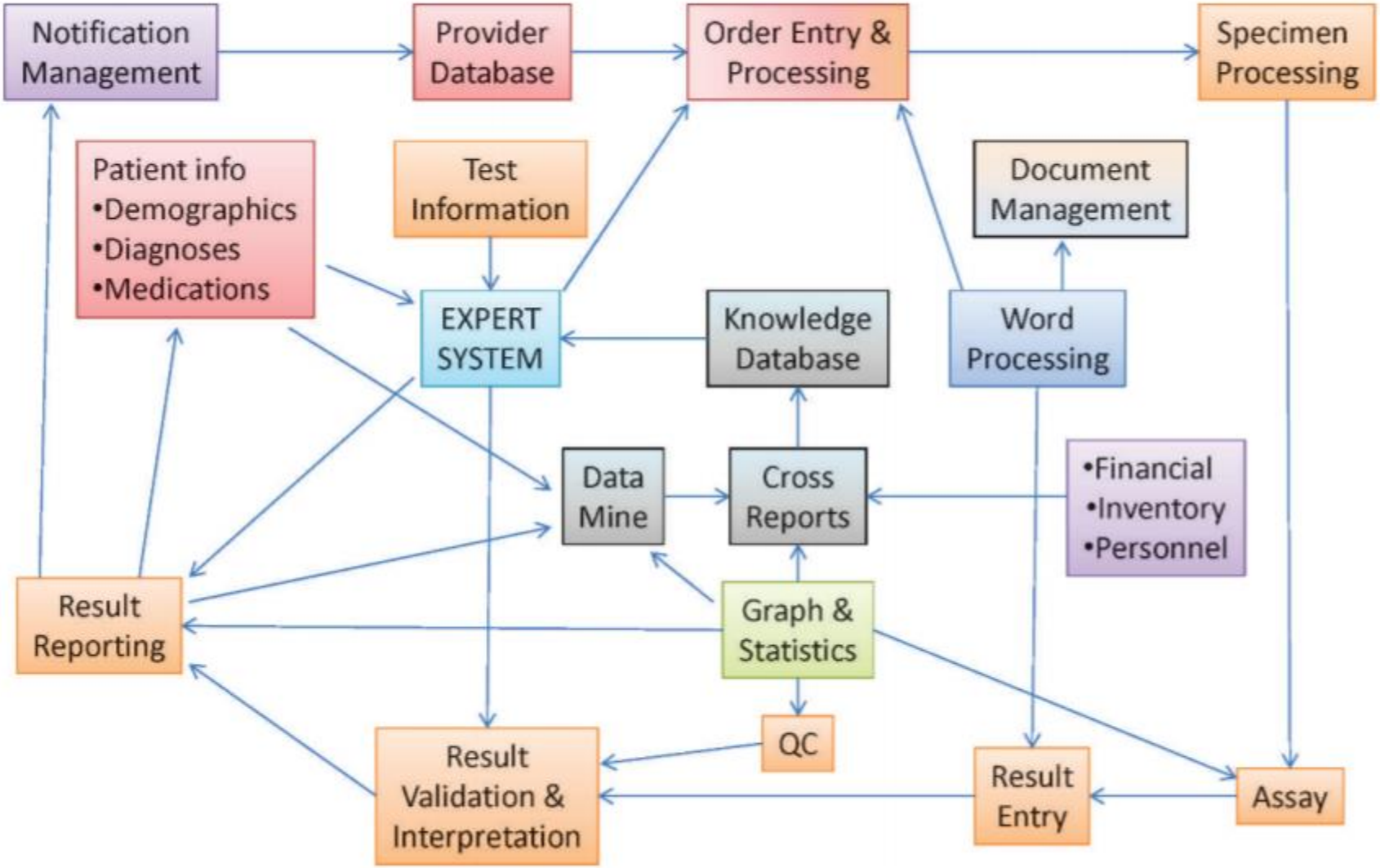
- Laboratory Systems:
  - Mostly stand-alone systems
  - interfaced to the central EHR system.
  - important for clinical care process: prevention, diagnosis, treatment, and health management.
  - About 60% to 70% of medical decisions are based on laboratory test results
- Data models:
  - structured data expressed in a standard terminology
  - most common coding system : LOINC
  - most hospitals use their local dictionaries
  - stored in the form of a name-value pair.
- Functions:
  - reduction of error due to manual data entry
  - compare the results from previous tests
  - Automated analyze of data results with respect to normal ranges

Components of EHR: Laboratory System Components & Vital Signs

- IHE Laboratory Testing Workflow
  - integrates the ordering, scheduling, processing, and result reporting activities associated with in vitro diagnostic tests performed by clinical laboratories in healthcare institutions.



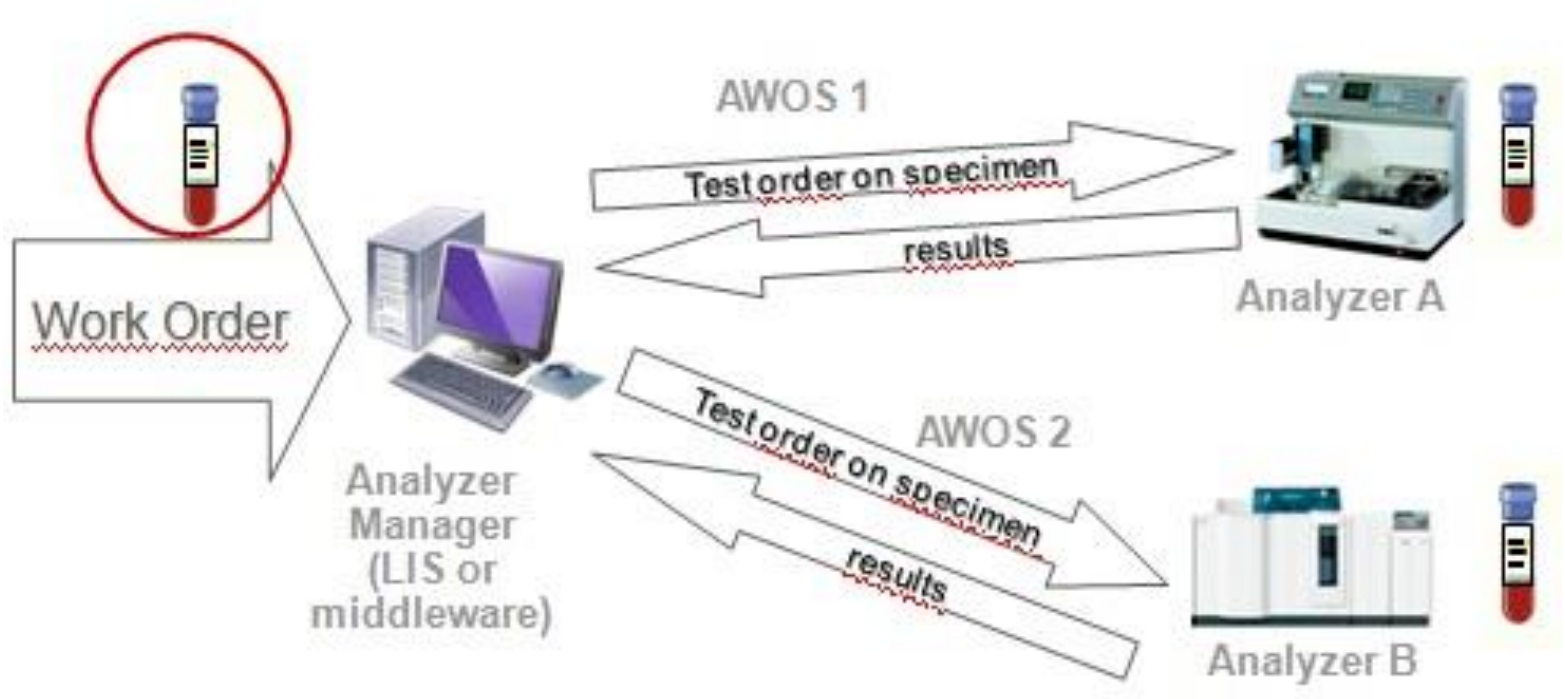
http://wiki.ihe.net/index.php/Laboratory_Testing_Workflow



Modules contributing to the ideal laboratory information system.

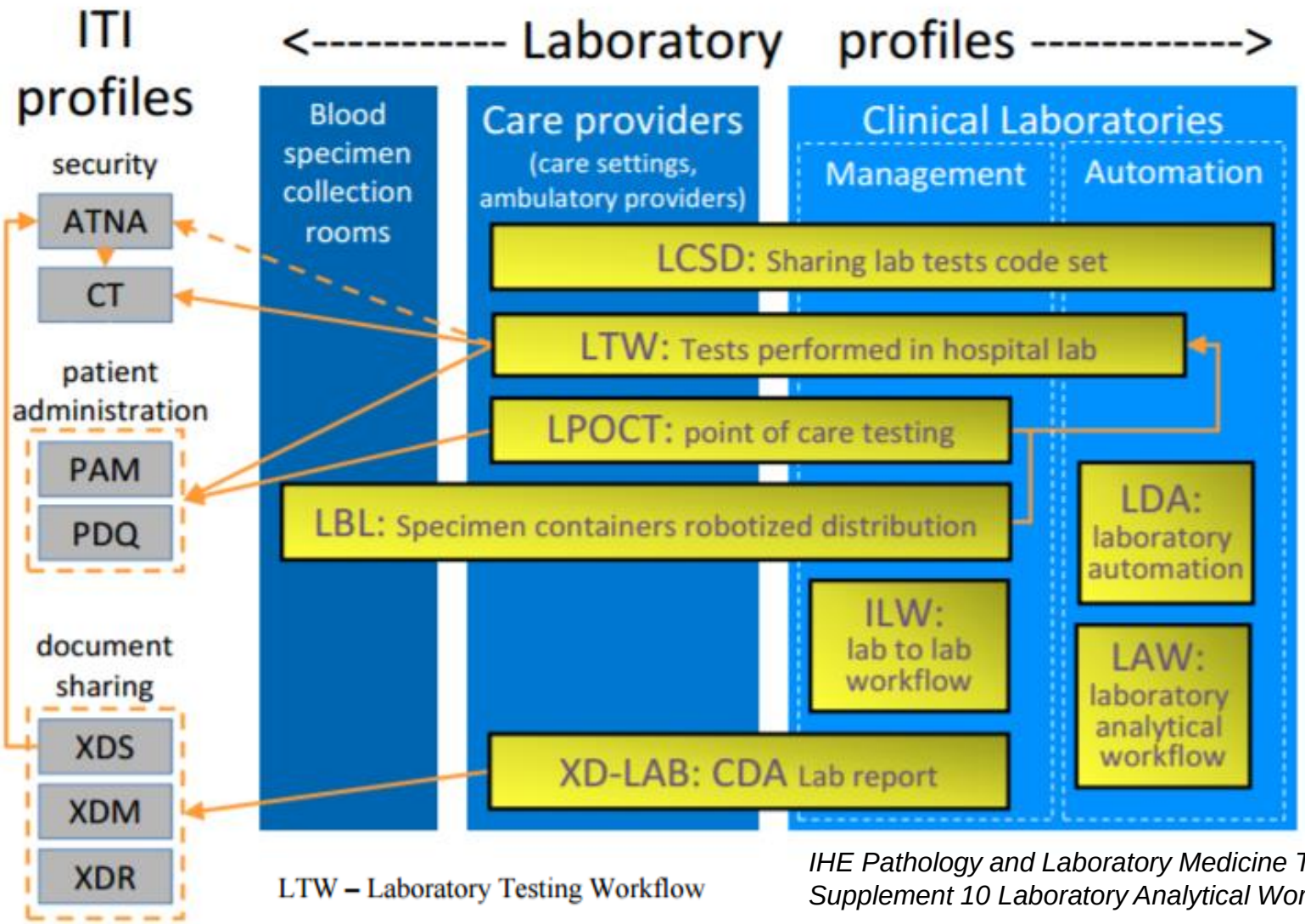
Sepulveda, Jorge L., and Donald S. Young. "The ideal laboratory information system." Archives of Pathology and Laboratory Medicine 137.8 (2013): 1129-1140.

Components of EHR: Laboratory System Components & Vital Signs



http://wiki.ihe.net/index.php/Laboratory_Analytical_Workflow_Profile

- IHE Laboratory Analytical Workflow Profile
  - the exchange of information related to patient and QC test orders & results between testing systems and health informatics systems



IHE Pathology and Laboratory Medicine Technical Framework Supplement 10 Laboratory Analytical Workflow , 2016

LTW – Laboratory Testing Workflow

LDA – Laboratory Device Automation

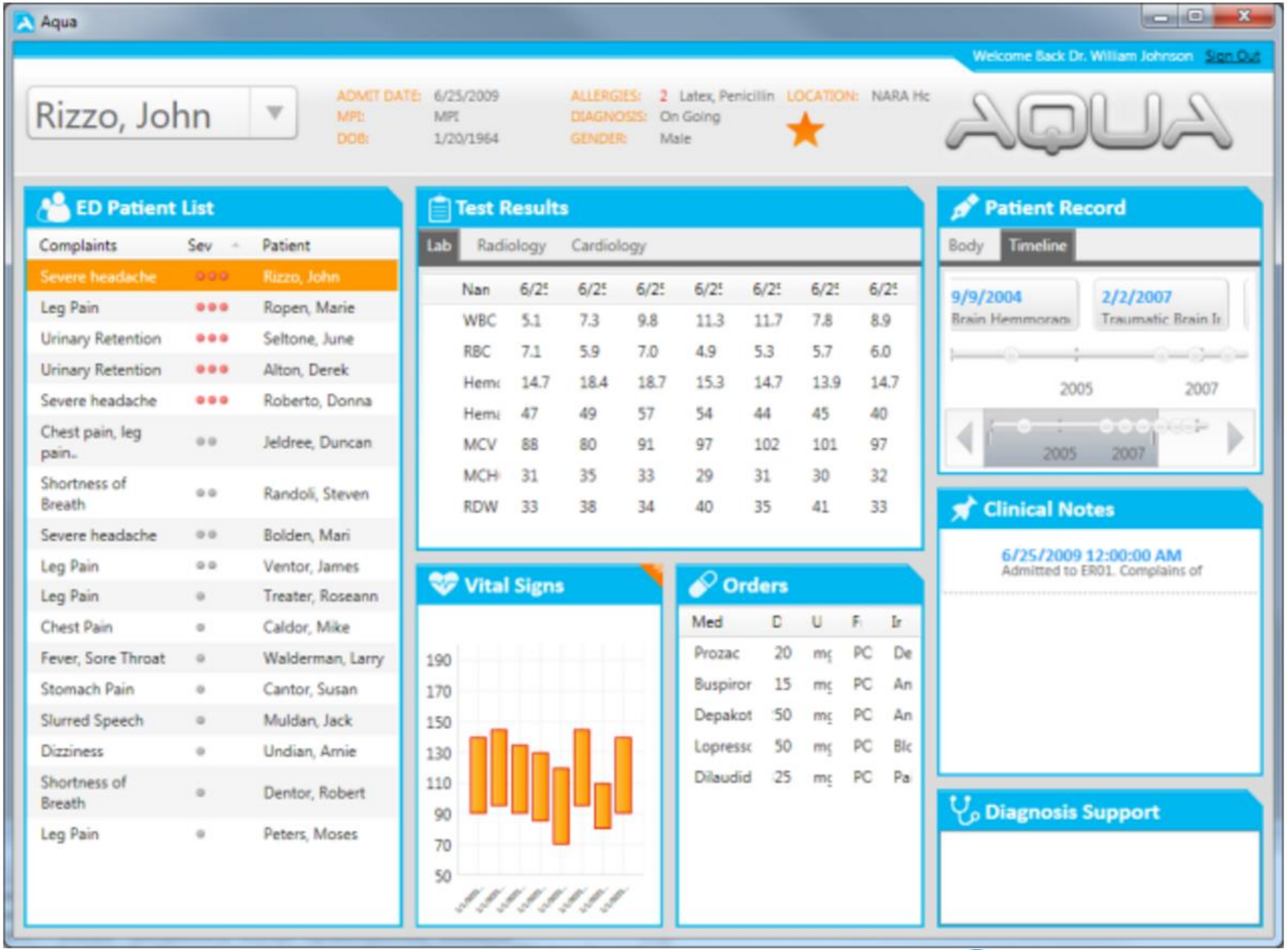
LBL – Laboratory Barcode Labeling

LPOCT – Laboratory Point Of Care Testing

LCSD – Laboratory Code Set Distribution

XD-LAB – Sharing Laboratory Reports

LAW - Laboratory Analytical Workflow


Aqua
Welcome Back Dr. William Johnson Sign Out
Rizzo, John
ADMIT DATE: 6/25/2009
MPI: MPI
DOB: 1/20/1964
ALLERGIES: 2 Latex, Penicillin
DIAGNOSIS: On Going
GENDER: Male
LOCATION: NARA Hc
AQUA
ED Patient List
Complaints Sev Patient
Severe headache Rizzo, John
Leg Pain Ropen, Marie
Urinary Retention Seltone, June
Urinary Retention Alton, Derek
Severe headache Roberto, Donna
Chest pain, leg pain.. Jeldree, Duncan
Shortness of Breath Randoli, Steven
Severe headache Bolden, Mari
Leg Pain Ventor, James
Leg Pain Treater, Roseann
Chest Pain Caldor, Mike
Fever, Sore Throat Walderman, Larry
Stomach Pain Cantor, Susan
Slurred Speech Muldan, Jack
Dizziness Undian, Amie
Shortness of Breath Dentor, Robert
Leg Pain Peters, Moses
Test Results
Lab Radiology Cardiology
Nan 6/2: 6/2: 6/2: 6/2: 6/2: 6/2: 6/2:
WBC 5.1 7.3 9.8 11.3 11.7 7.8 8.9
RBC 7.1 5.9 7.0 4.9 5.3 5.7 6.0
Hem 14.7 18.4 18.7 15.3 14.7 13.9 14.7
Hem 47 49 57 54 44 45 40
MCV 88 80 91 97 102 101 97
MCH 31 35 33 29 31 30 32
RDW 33 38 34 40 35 41 33
Vital Signs
190
170
150
130
110
90
70
50
Orders
Med D U F Ir
Prozac 20 mg PC De
Buspiror 15 mg PC An
Depakot 50 mg PC An
Lopressc 50 mg PC Blc
Dilaudid 25 mg PC Pa
Patient Record
Body Timeline
9/9/2004
Brain Hemmorag
2/2/2007
Traumatic Brain I
2005 2007
2005 2007
Clinical Notes
6/25/2009 12:00:00 AM
Admitted to ER01. Complains of
Diagnosis Support

Components of EHR: Laboratory System Components & Vital Signs

- Vital signs
  - the indicators of a patient's general physical condition.
  - E.g. pulse, respiratory rate, blood pressure, body temperature, body mass index (BMI), etc.

- A typical EHR system must provide the option to accommodate these kinds of variables.

Aqua

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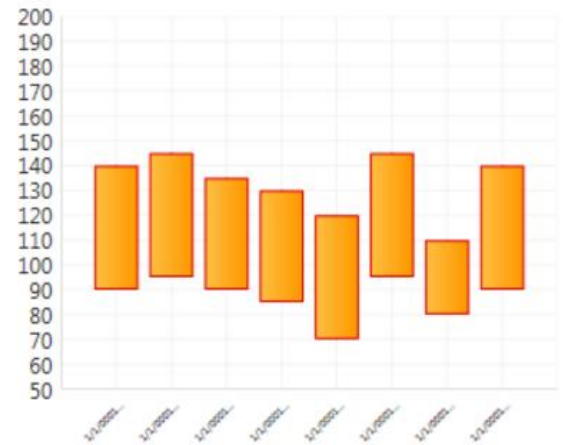
GENDER: Male

LOCATION: NARA Hospital (

AQUA

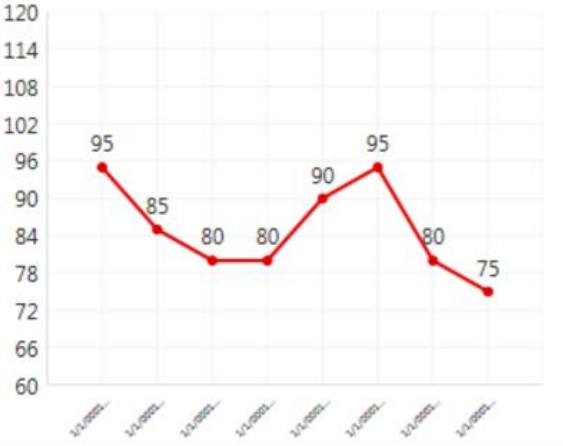
Vital Signs

Blood Presure



Temperature

Pulse



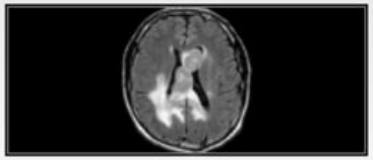
Pain

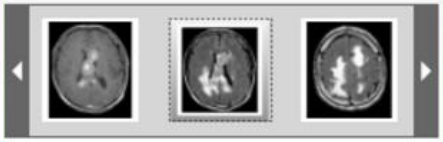
ED Patient List

Test Results

Lab | Radiology | Cardiology

MRI 6/25/2009





Orders

Patient Record

Clinical Notes

Diagnosis Support

Components of EHR: Radiology Information Systems

- Radiology information systems (RIS)
  - Computer-based information system that supports radiology department operations
  - Manage medical imagery and associated data

- Tasks:
  - patient tracking, scheduling, result reporting, and image tracking

- Data Standards:
  - to identify procedures and resources: Current Procedural Terminology (CPT) or ICD coding systems
  - DICOM

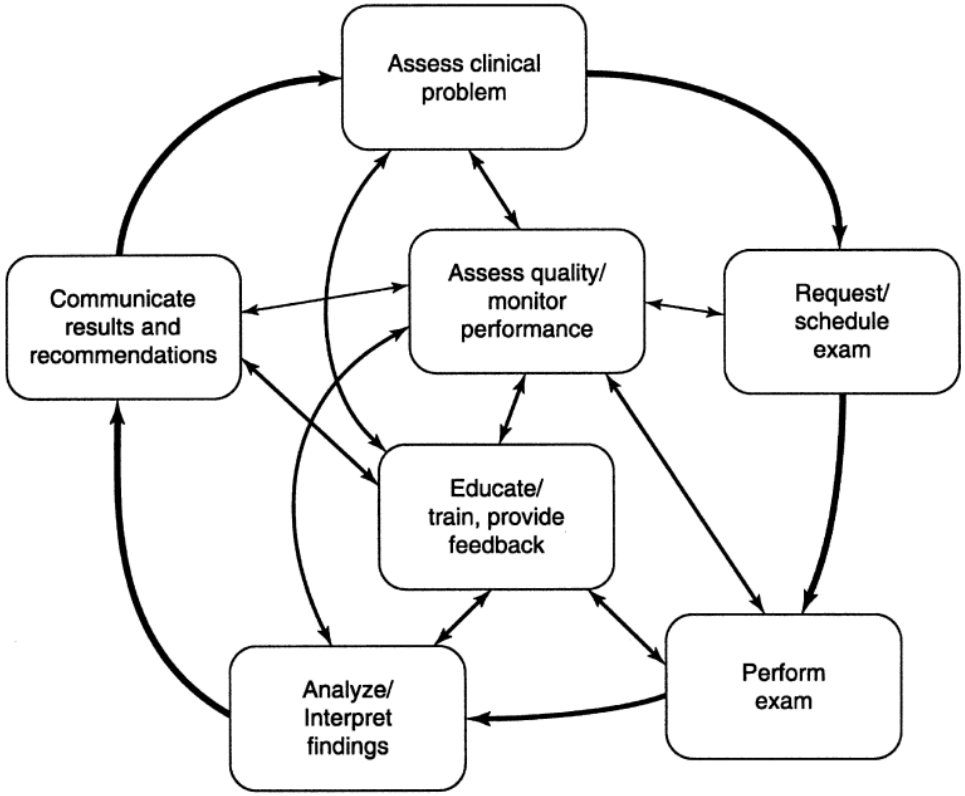
- RIS is usually used along with a picture archiving communications system (PACS)

- Although many hospitals are using RIS, it may or may not be integrated with the central EHR system.

Components of EHR: Radiology Information Systems

The radiologic process:

- an evaluation of a clinical problem and determination of the need by clinician
- The procedure is requested and scheduled
- The imaging procedure is carried out, and images are acquired.
- The radiologist reviews the images (a) perception of the relevant findings (b) interpretation of those findings in terms of clinical meaning and significance.
- The radiologist creates a report communicate the results to the referring clinician



- Quality control and monitoring are carried out: quality of images, radiation dose, yields of procedures, incidence of complications are measured and adjusted.
- Continuing education and training are carried out through a variety of methods

Components of EHR: Radiology Information Systems

- Picture-archiving and communication system (PACS)
  - a medical technology for providing economical storage and convenient access to the digital images
  - (PACS) image-management functions must be integrated with RISs and HISs.
    - RIS (or, in some cases, an HIS) keeps track of examinations and associates them with patients,
    - PACS keeps track of images and associates them with examinations
  - Interoperability task: to provide coordination between the examination data on the two systems.
  - Alternative approaches:
    - the RIS (or HIS) can be augmented such that examination records indicate the presence of associated images. The path to the images can be stored directly with the examination record on the RIS (or HIS),
    - the examination data can be duplicated on the PACS, where pointers to the images for each examination are maintained.
    - PACS can be augmented with patient-lookup and examination-lookup capabilities and the databases from an RIS or HIS duplicated on it.

Components of EHR: Radiology Information Systems

- Storage Requirements
  - On-line digital archiving of image data for a busy radiology department requires vast amounts of storage.
  - Image modalities differ substantially in their storage requirements, depending on the contrast and spatial resolution needed, the number of images or the size of the data sets, whether raw or processed data are stored, and whether data-compression techniques are used.

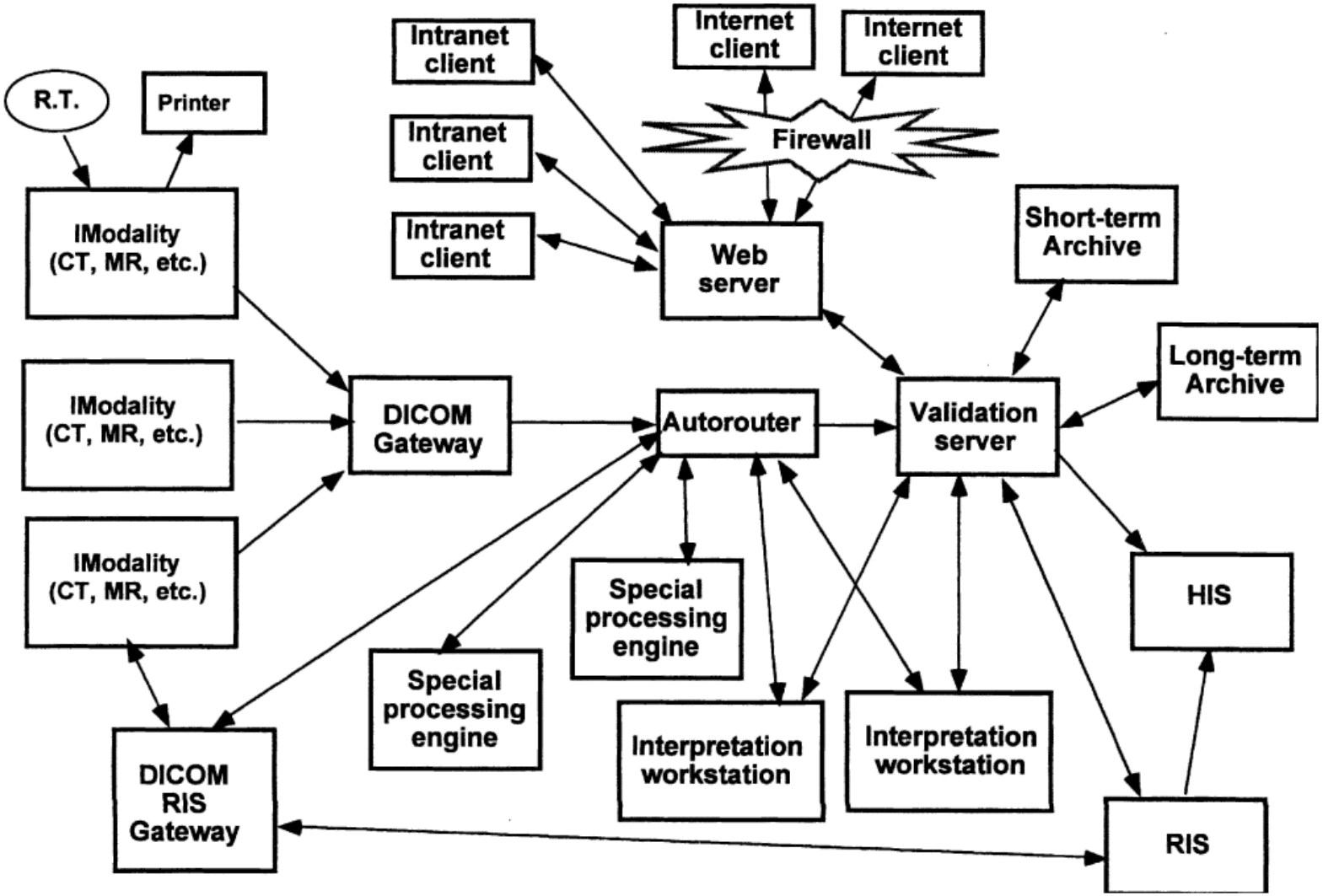
	CR	MRI	CT	US	NM
Pixels per image	2048×2560	256×256	512×512	512×512	128×128
Bits per pixel	12	10	12	8	8
Typical no. of mages per study	2	100	60	30 (plus dynamic series)	30
Bytes per study*	20M	12M	30M	7.5M (for static images only)	0.5M
Contrast resolution	low	high	high	low	low
Spatial resolution	high	Low	mod	mod	low
Temporal resolution	low	low	mod	high	high
Radiation	mod	none	mod	none	mod
Portability	some	no	no	no	yes
Physiologic function	no	yes	no	no	yes
Cost	mod	high	high	low	mod

CR = computed radiography, MRI = magnetic resonance imaging, CT = computed tomography, US = ultrasound, NM = nuclear medicine.

*Assume 2 bytes needed per pixel for images with pixel depth of 10 or 12 bits.

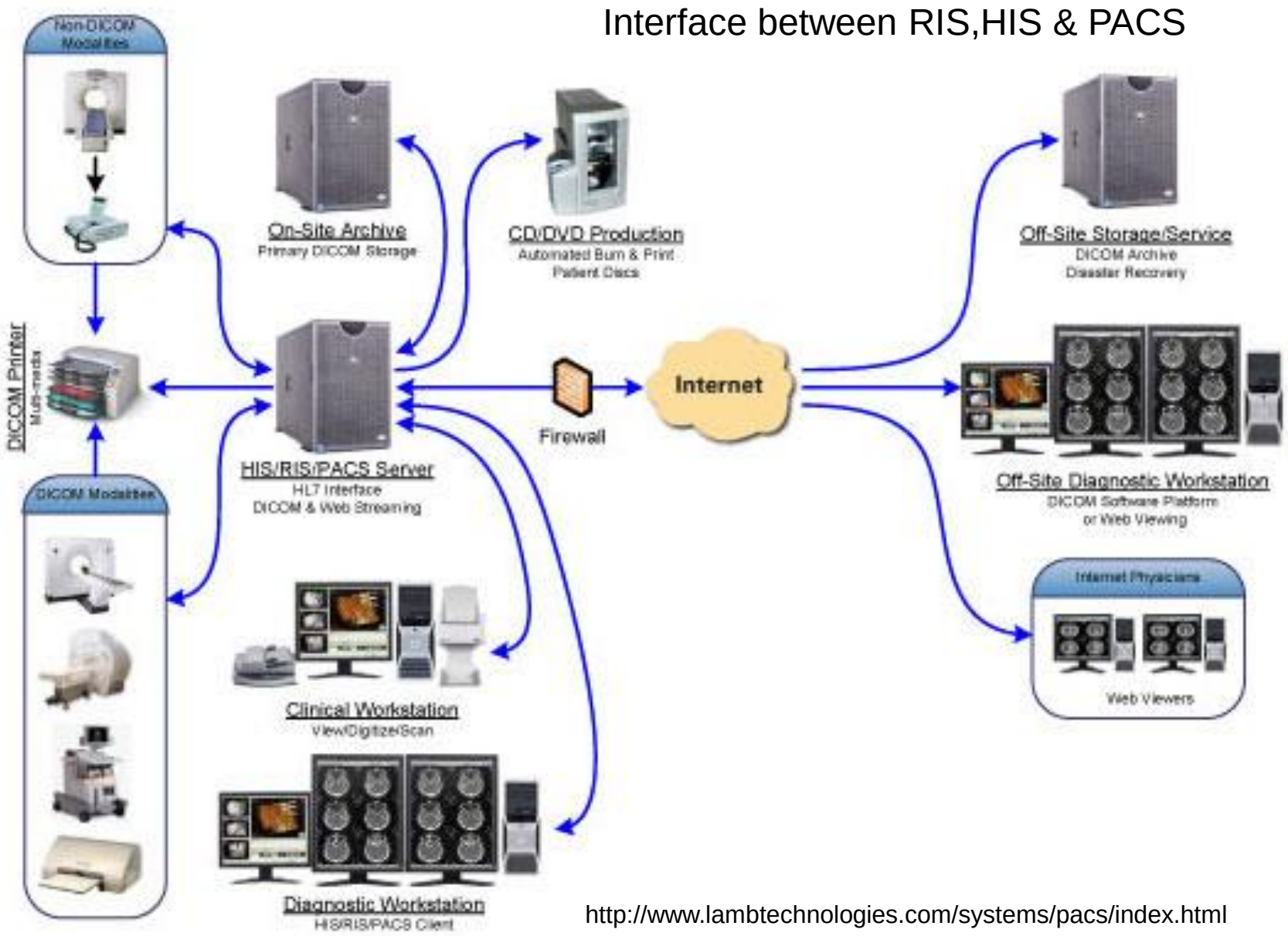
Components of EHR: Radiology Information Systems

- Architecture of a typical picture-archiving and communication system (PACS)



Components of EHR: Radiology Information Systems

Interface between RIS,HIS & PACS



http://www.lambtechnologies.com/systems/pacs/index.html

Digital Imaging and Communications in Medicine (DICOM)

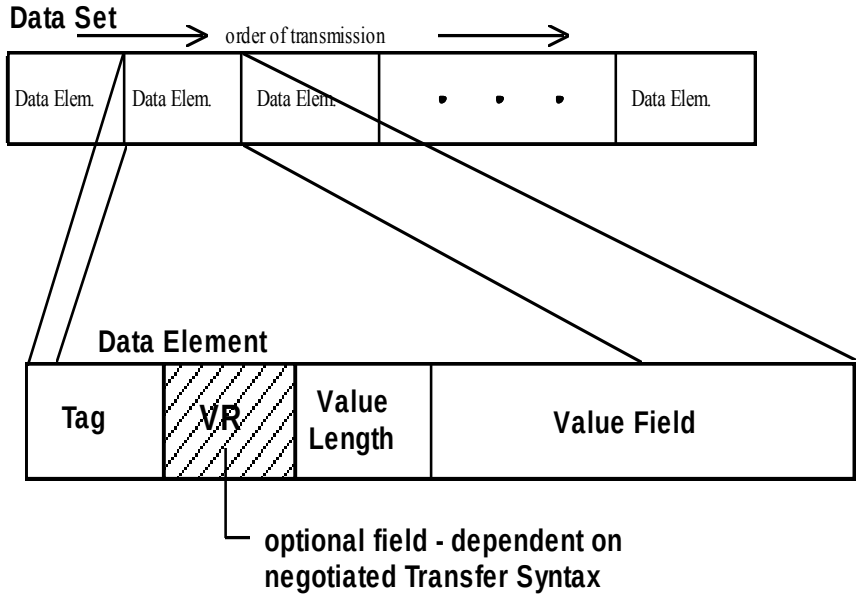
- The need for a standard:
  - Since medical images are acquired in many different locations and by many different modalities (e.g., CT,MRI, ultrasound, ...) and are communicated tomany other devices (e.g., printers, radiology workstations, image analysis systems, mobile devices, ...), a common communication standard is required.

- The Digital Imaging and Communications in Medicine (DICOM)
  - a widely accepted medical imaging standards.
  - promotes interoperability between radiology systems.
  - developed by the American College of Radiology (ACR) and National Electric Manufacturers Association (NEMA). The first version in 1985.
  - determines the data exchange protocol, digital image format, and file structure for biomedical images and related information
  - DICOM allows the integration of scanners, servers, workstations, printers, and network hardware into a PACS.
  - extensively used by the hospitals and other organizations.

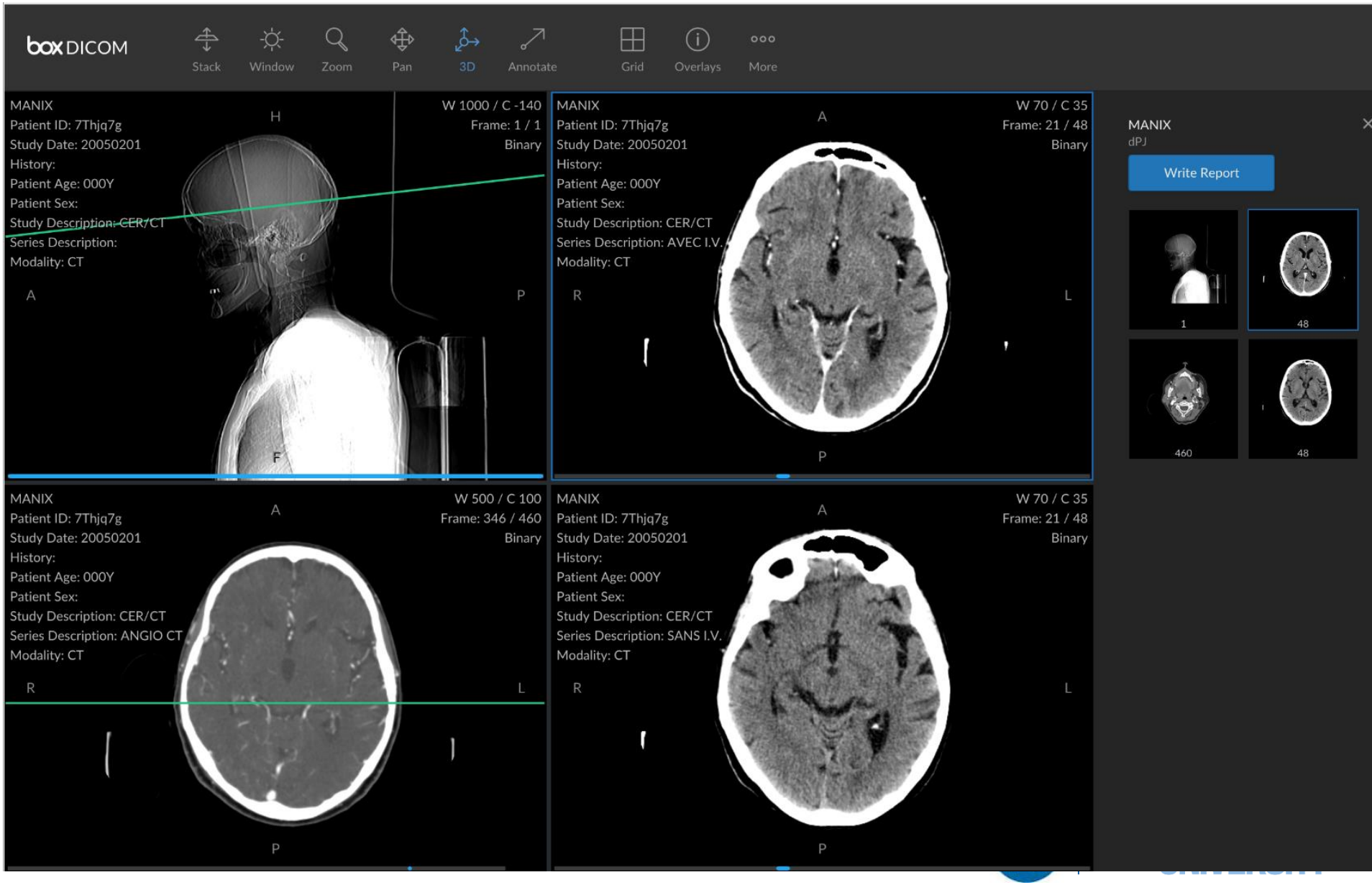
Digital Imaging and Communications in Medicine (DICOM)

DICOM consists of two parts

1. DICOM Object Classes:
   - DICOM generically describes image properties, patient data, and metadata using a tag value concept.
   - Each piece of information is addressed by its tag and, hence, can be placed on any position in the resulting data stream.
   - This concept allows storing multiple images within one DICOM file (e.g., a series of multiple CT slices or images from different modalities).
   - DICOM also supports compression of image data.



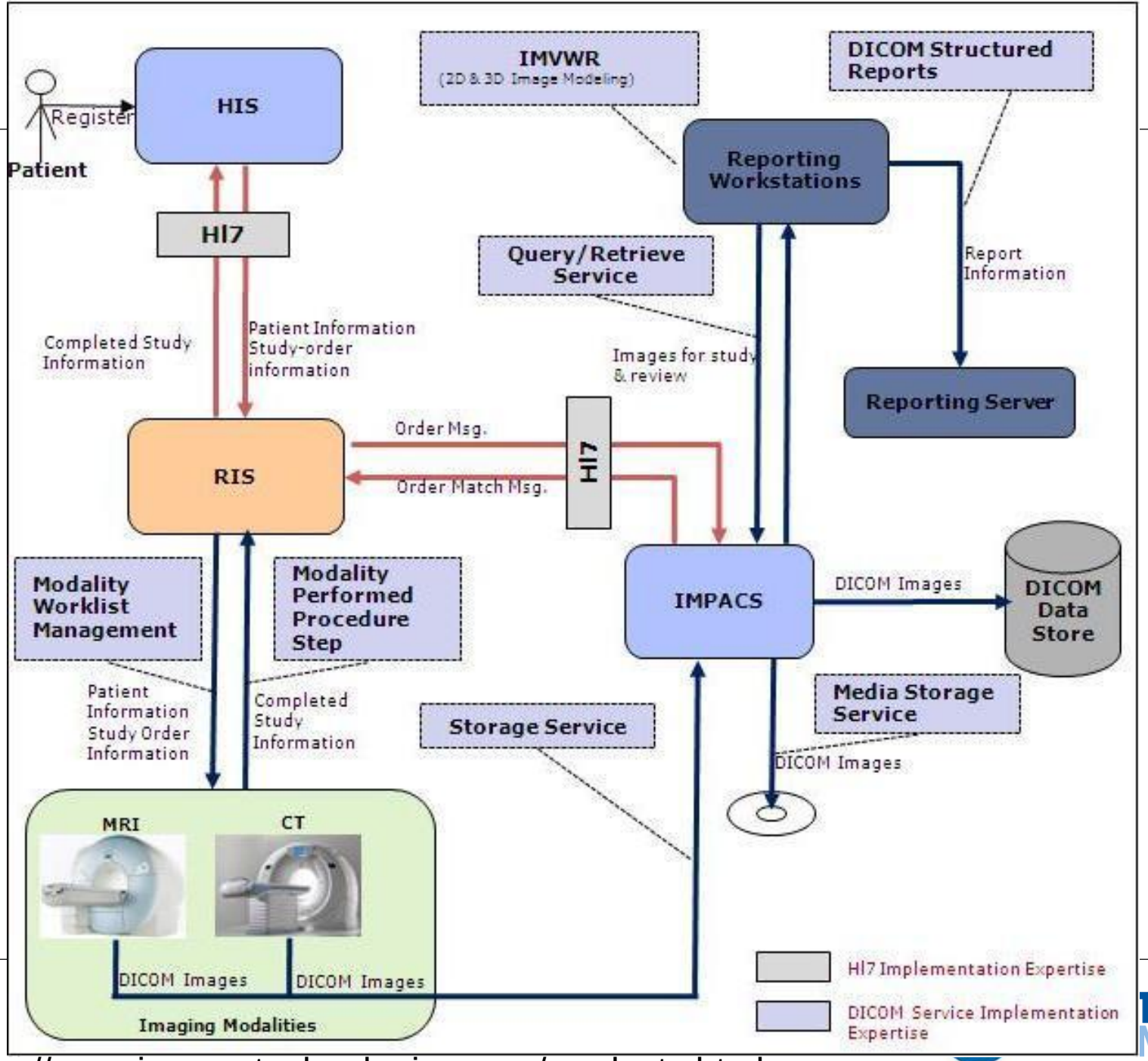
Digital Imaging and Communications in Medicine (DICOM)



Digital Imaging and Communications in Medicine (DICOM)

DICOM consists of two parts

2. DICOM Service Classes:
   - A service describes the action that is intended with the data.
   - They support storage and retrieval of image data as well as the organization of examinations.
- The basic DICOM services are:
   - Verify (check conformance of external network node)
   - Storage (actually two commands, “Store” for storage and “Move” to transfer)
   - Storage Commitment (confirm storage before deletion)
   - Query/Retrieve (search objects and initiate transfer with storage)
   - ModalityWorklist Management (metadata to modality)
   - Modality Performed Procedure Step (confirm acquisition, may differ from requests)



http://www.imposetechnologies.com/products.html

Components of EHR: Pharmacy Systems

- The pharmacy department's responsibilities:
  - to maintain the inventory,
  - prescription management,
  - billing, and
  - dispensing medications.

- The pharmacy component in EHR hold the complete medication history of a patient such as
  - drug name,
  - dosage,
  - route,
  - quantity,
  - frequency,
  - start and stop date,
  - prescribed by,
  - allergic reaction to medications,
  - source of medication, etc.

Components of EHR: Pharmacy Systems

- Pharmacists serve an important public health role:
  - administering immunizations
  - share this information with other healthcare providers and public health organizations.

- They assure safe and effective medication and supporting patient-centered care.

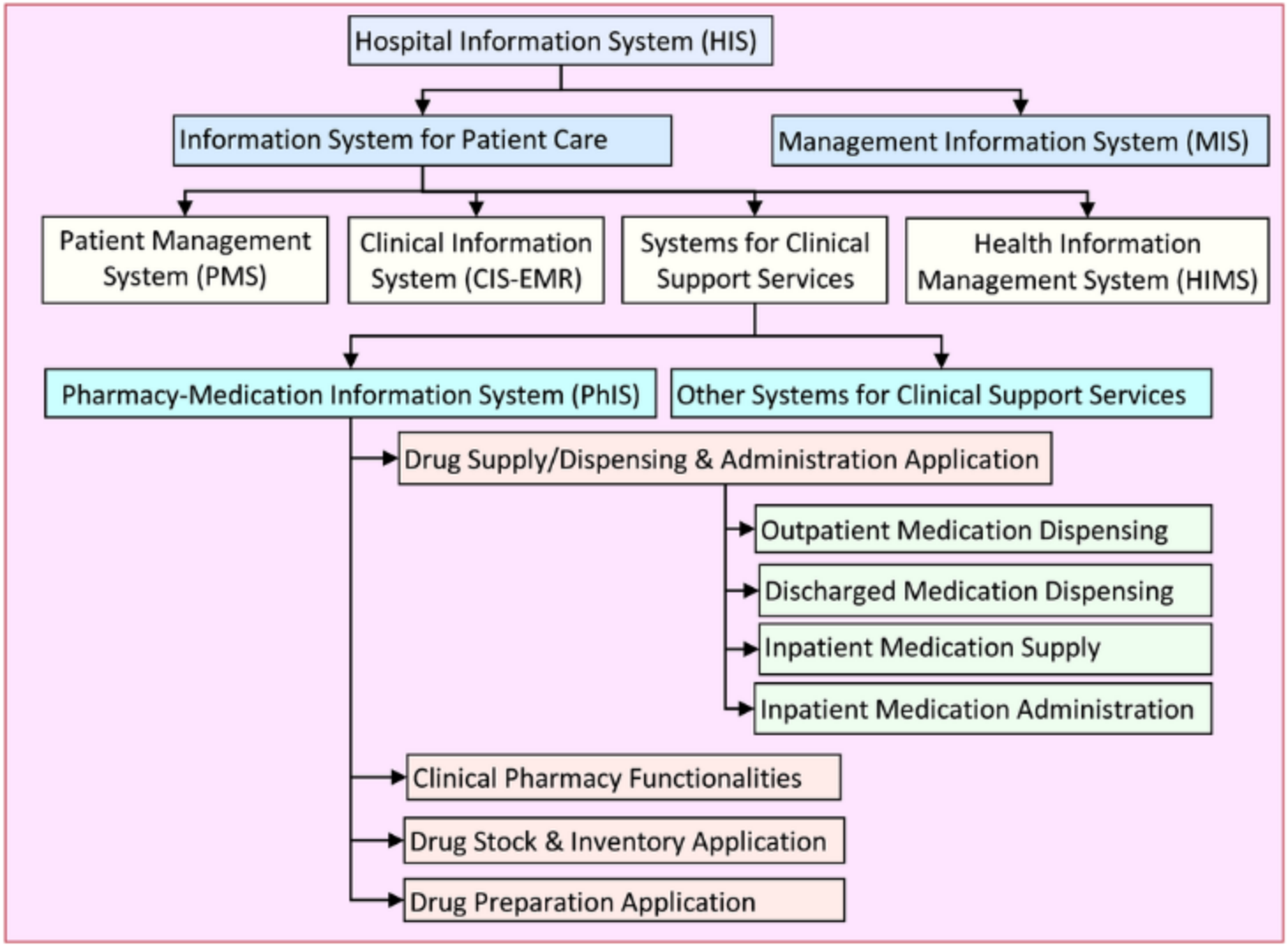
- Pharmacies are highly automated in large hospitals -may be independent of central EHRs.

Components of EHR: Pharmacy Systems

- The Pharmacy Information System integrates the distinct functions of the Pharmacy service with the medication functions carried out by nurses and doctors within EHR.

	Services and Functions		Applications / Functionalities
01	**Medication function**	01	**Part of CIS-EMR re: Medication**
a	Plan drug treatment	a	Treatment Plan
b	Select and Prescribe (order) medication	b	Order entry
c	Administer & record medication given	c	Medication Administration Record
02	**Pharmacy Function**	02	**Functionality**
a	Procure and stock medications	a	Drug Stock and Inventory System
b	Receive, vet verify and fill the prescription	b	Supply and Dispensing Functionality
c	Supply / dispense medication		
d	Provide guides, advice and decision support	c	Clinical Pharmacy Functionalities

Components of EHR: Pharmacy Systems



Components of EHR: Computerized Physician Order Entry (CPOE)

Computerized Physician Order Entry (CPOE)

- refers to any system in which clinicians directly place orders electronically, with the orders transmitted directly to the recipient.

Advantages:

- decreases delay in order completion,
- reduces errors related to handwriting or transcription,
- allows order entry at the point of care or off-site,
- provides error-checking for duplicate or incorrect doses or tests,
- Improve safety by add intelligent rules for checking allergies, contradictions, and other alerts
- simplifies inventory and posting of charges.

- CPOE is a form of patient management software.

Components of EHR: Computerized Physician Order Entry (CPOE)

Computerized Physician Order Entry (CPOE)

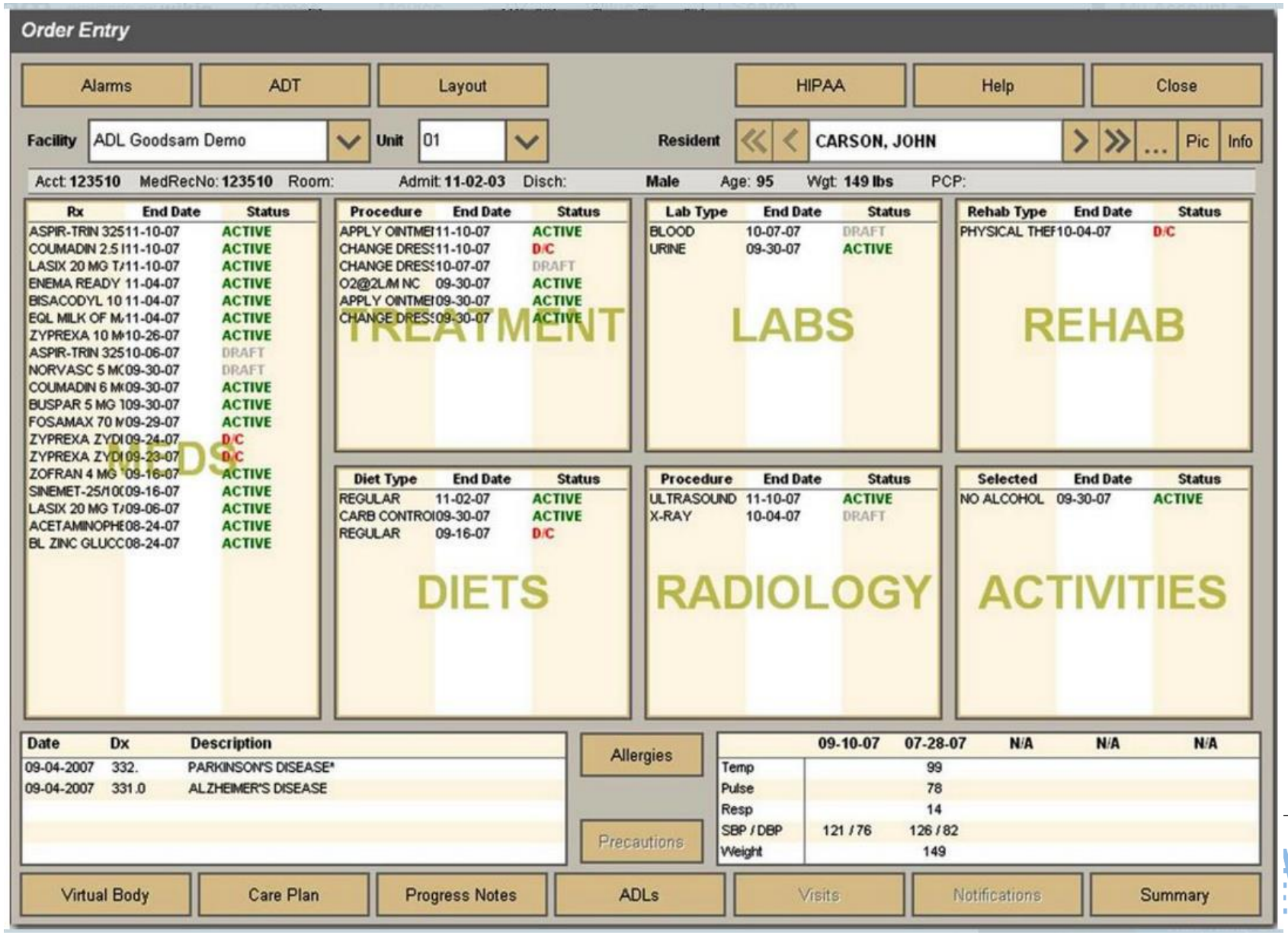
- refers to any system in which clinicians directly place orders electronically, with the orders transmitted directly to the recipient.

Advantages:

- decreases delay in order completion,
- reduces errors related to handwriting or transcription,
- allows order entry at the point of care or off-site,
- provides error-checking for duplicate or incorrect doses or tests,
- Improve safety by add intelligent rules for checking allergies, contradictions, and other alerts
- simplifies inventory and posting of charges.

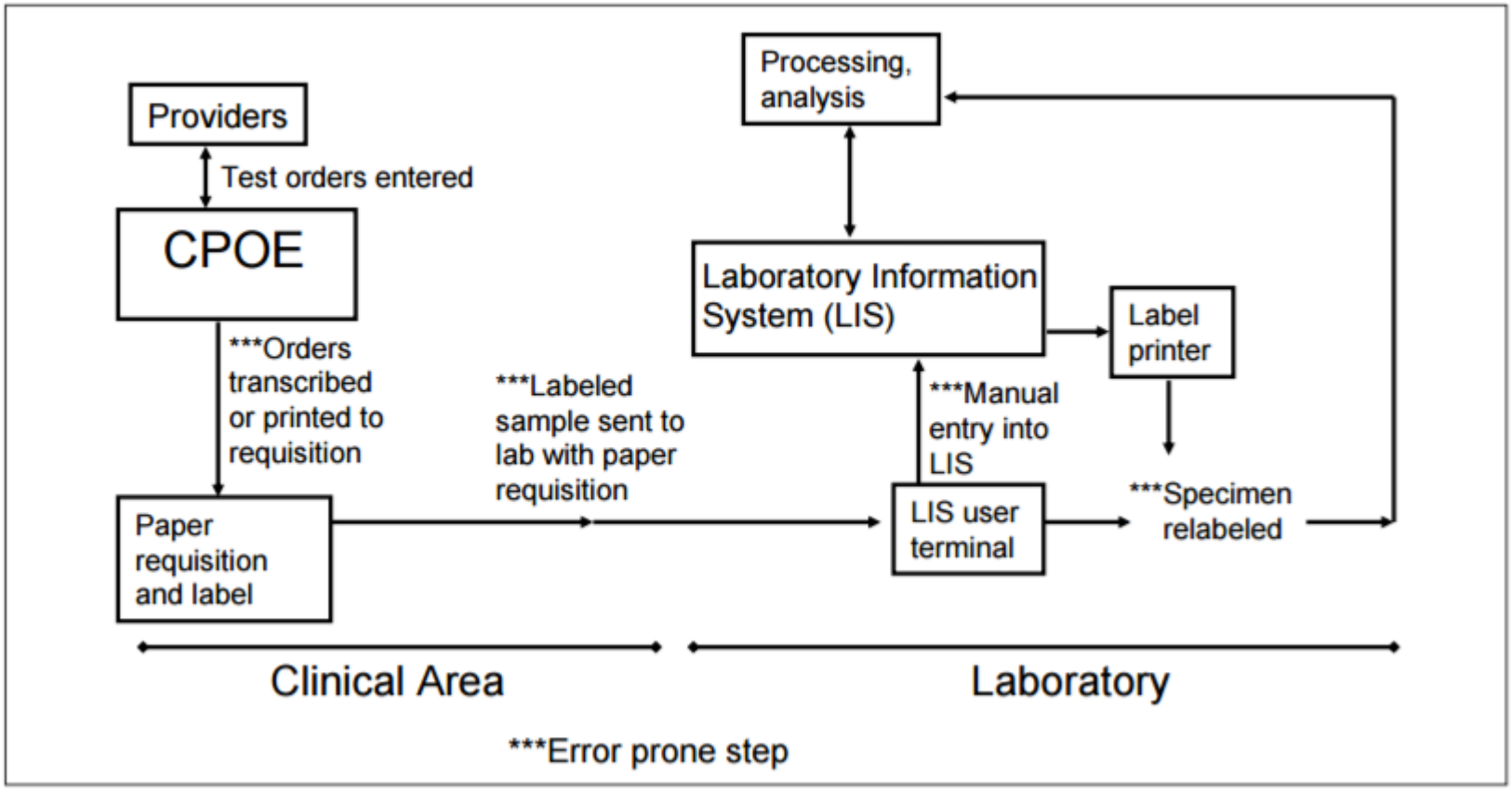
- CPOE is a form of patient management software.

Components of EHR: Computerized Physician Order Entry (CPOE)



Components of EHR: Computerized Physician Order Entry (CPOE)

CPOE system lacking order communication functionality. Involves several manual / paper based steps (noted by ***)

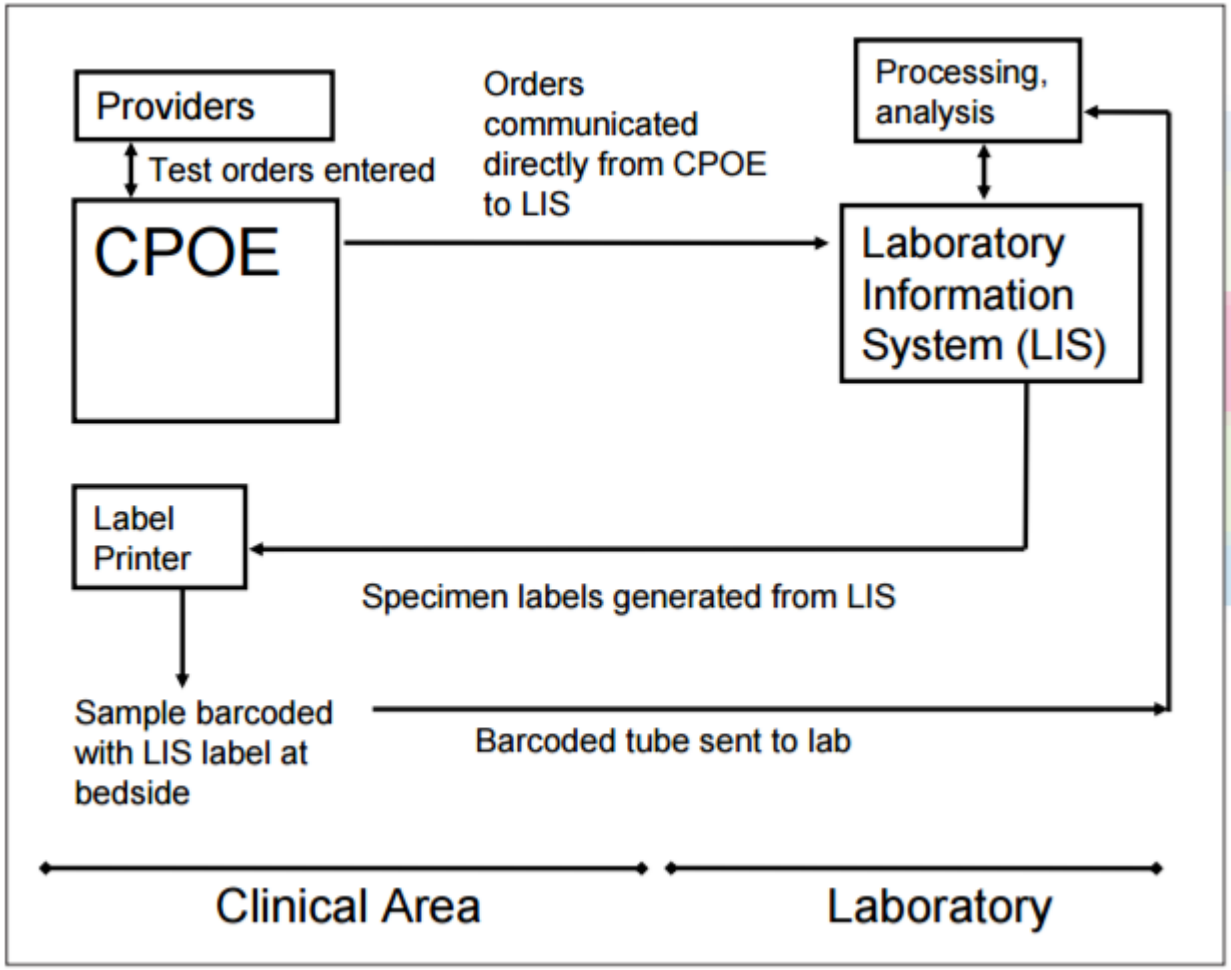


Baron, Jason M., and Anand S. Dighe. "Computerized provider order entry in the clinical laboratory." Journal of pathology informatics 2.1 (2011): 35.

Components of EHR: Computerized Physician Order Entry (CPOE)

CPOE system with order communication functionality. It avoids several potentially inefficient and error prone steps.

Directly communicates with LIS system.



Baron, Jason M., and Anand S. Dighe. "Computerized provider order entry in the clinical laboratory." Journal of pathology informatics 2.1 (2011): 35.

SOAP Narratives

- A SOAP note is a documentation method employed by health care providers to create a patient's chart.

- **Subjective:**
- Describes the patient's current condition in narrative form. This section usually includes the patient's chief complaint, or reason why they came to the physician.
- Includes:
  - Onset (when and mechanism of injury – if applicable)
  - Chronology (better or worse since onset, episodic, variable, constant, etc.)
  - Quality (sharp, dull, etc.)
  - Severity (usually a pain rating)
  - Modifying factors (what aggravates/reduces the complaint – activities, postures, drugs, etc.)
  - Additional symptoms (un/related or significant symptoms to the chief complaint)
  - Treatment (has the patient seen another provider for this symptom?)

SOAP Structure

Objective:

- Documents objective, repeatable, and traceable facts about the patient's status.
- Includes:
  - Vital signs
  - Findings from physical examinations, such as posture, bruising, and abnormalities
  - Results from laboratory
  - Measurements, such as age and weight of the patient

Assessment

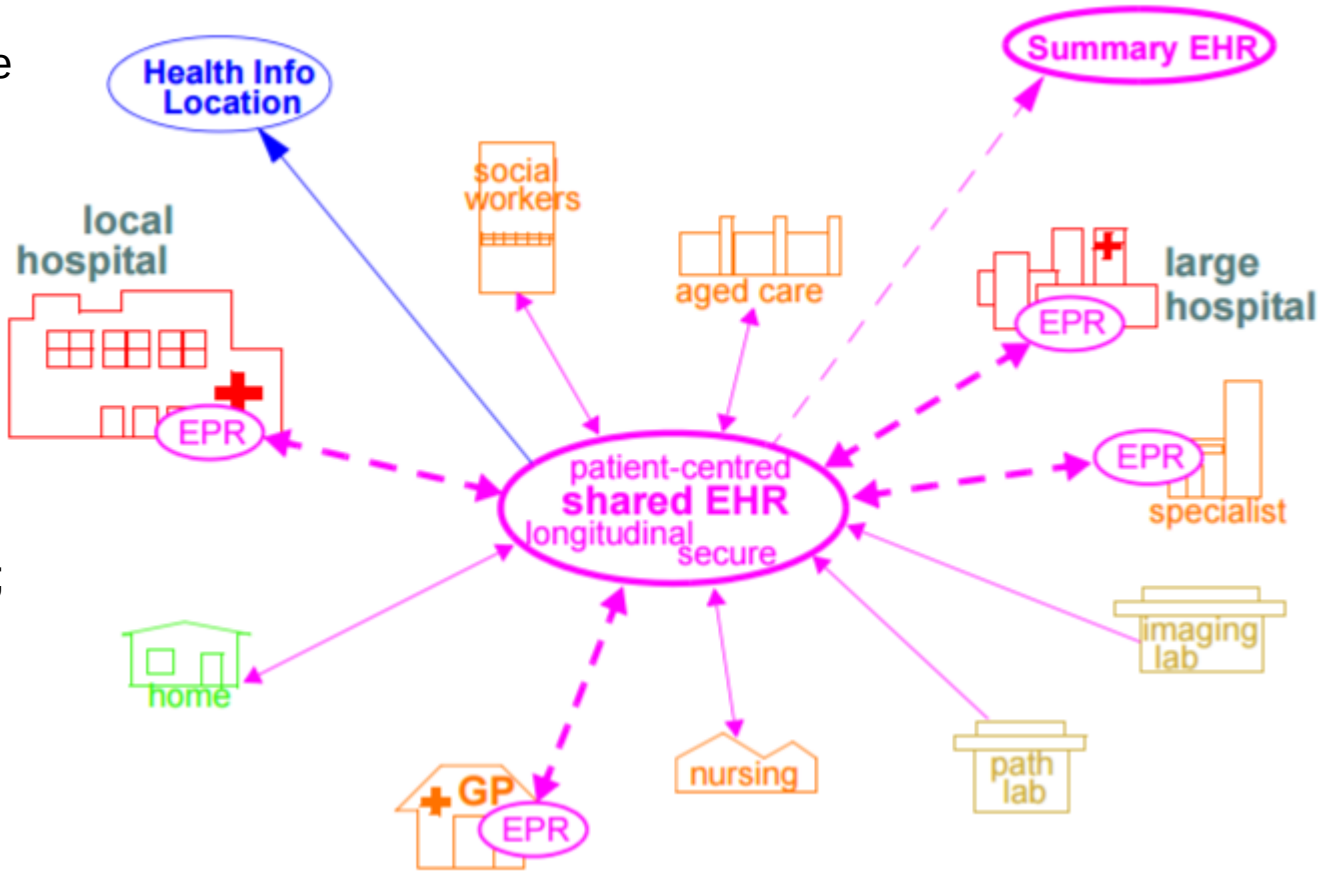
- The Physician's medical diagnoses for the medical visit on the given date of a note written.

Plan

- This describes what the health care provider will do to treat the patient – ordering labs, referrals, procedures performed, medications prescribed, etc.

Deployment Environments

- shared-care community or regional health service EHRs;
- summary EHRs at a national, state, province or similar level;
- small desktop GP systems;
- hospital EMRs;
- consolidated and summary EHRs in federation environments;
- legacy data purification and validation gateways;
- web-based secure EHR systems for mobile patients.



Continuity of Care Record (CCR)

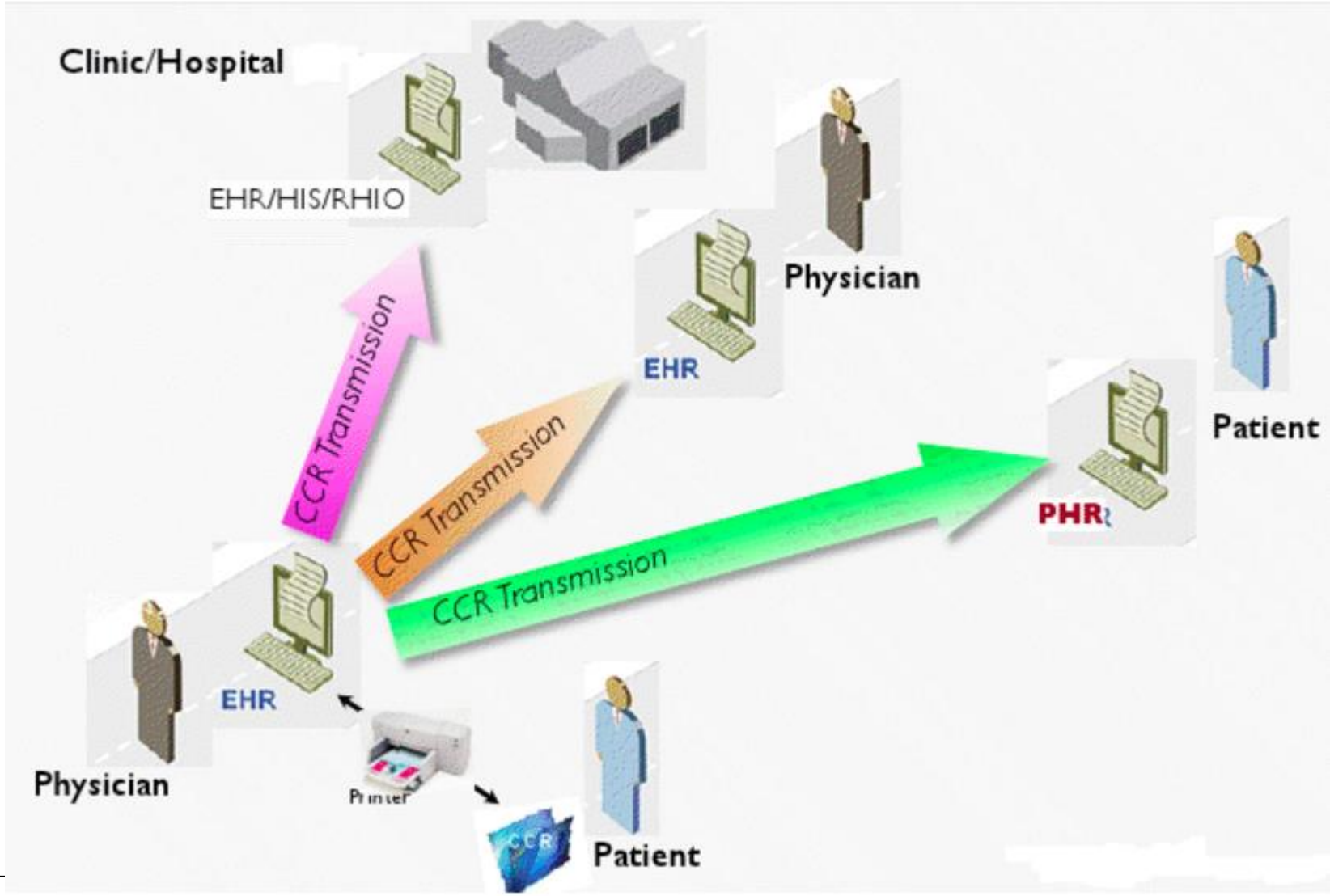
- Continuity of Care Record is a standard specification
- developed jointly by ASTM International, the Massachusetts Medical Society (MMS), the Health Information Management and Systems Society (HIMSS), and the American Academy of Family Physicians (AAFP)

- It is intended to assure at least a minimum standard of health information transportability when a patient is referred or transferred to, or is otherwise seen by, another provider

- provide a snapshot in time containing the relevant clinical, demographic, and administrative data for a specific patient

- The CCR data set includes a summary of the patient's health status (for example, problems, medications, allergies) and basic information about insurance, advance directives, care documentation, and the patient's care plan.

Continuity of Care Record (CCR)



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Continuity of Care Record (CCR)

- To ensure interchangeability of electronic CCRs this specification specifies XML coding
-
- The specified XML coding provides flexibility that will allow users to prepare, transmit, and view the CCR in multiple ways:
  - in a browser,
  - as an element in a Health Level 7 (HL7) message
  - CDA compliant document,
  - in a secure email,
  - as a PDF file,
  - as an HTML file, o
  - as a word processing document.

Continuity of Care Record (CCR)

- Structure has 6 elements:
- 1. Header
- 2. Information Identifying the Patient
- 3. Information od Financial and Insurance Issues of Patient
- 4. Health Status
- 5. Documentation for Care
- 6. Recommendation for a Care Plan

```
<FamilyHistory>
    <FamilyHistoryEntry>
        <Relations>Father</Relations>
        <Condition Code="22298006" Type="SNOMED CT" OnSet="age 57"/>
            <!-- myocardial infarction -->
        <HealthStatus>Deceased</HealthStatus>
        <CauseOfDeath>Yes</CauseOfDeath>
    </FamilyHistoryEntry>
</FamilyHistory>
```

Ferranti, Jeffrey M., et al. "The clinical document architecture and the continuity of care record." *Journal of the American Medical Informatics Association* 13.3 (2006): 245-252.

Personal Health Records (PHR)

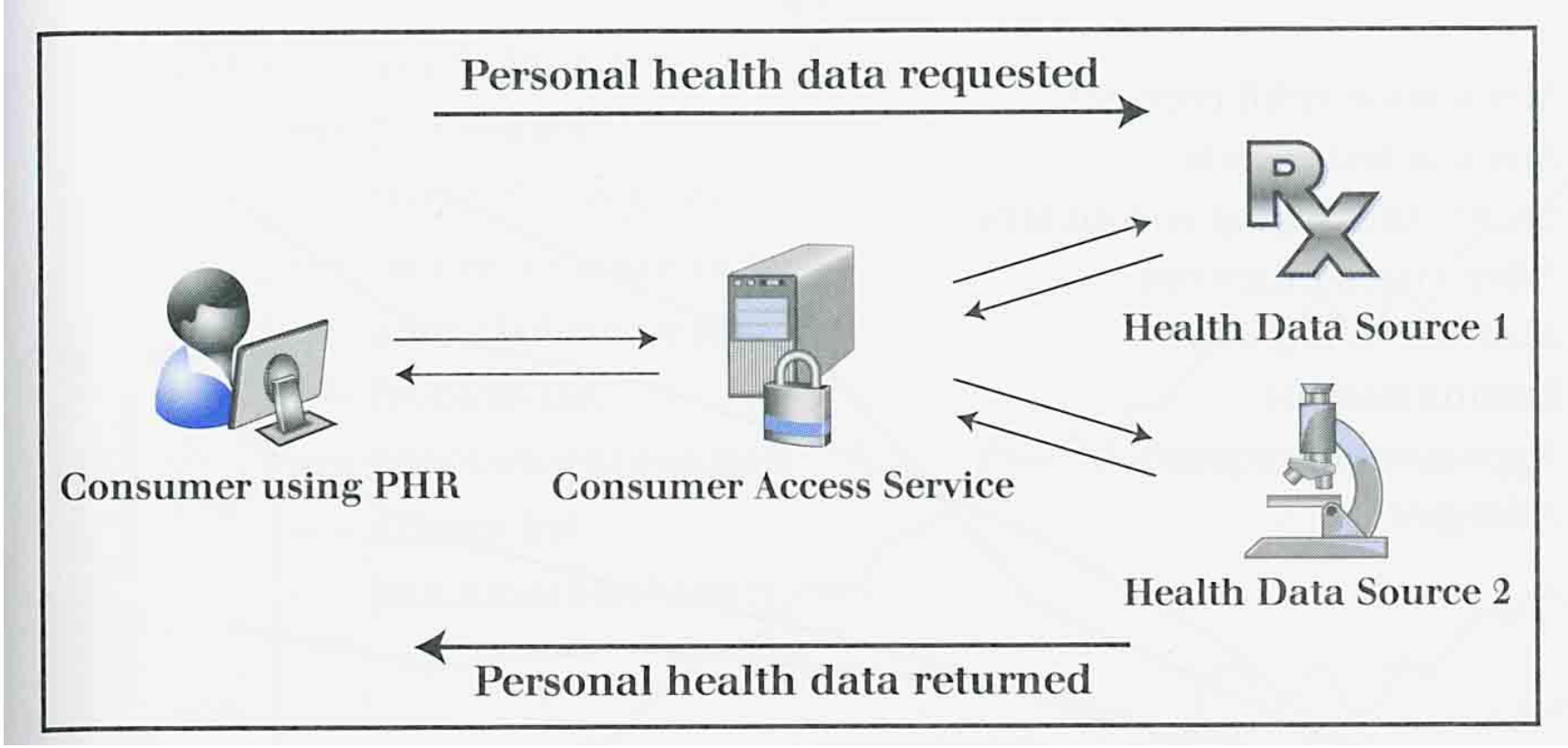
"An electronic application through which individuals can access, manage and share their health information, and that of others for whom they are authorized, in a private, secure, and confidential environment."

- PHR is a tool to use in sharing health information, increasing health understanding, and helping transform patients into better-educated consumers of health care.

- A PHR includes health information managed by the *individual*.

- several possible approaches :
  - Standalone systems: not tied to any healthcare system: Google Health PHR, Microsoft's Health Vault
  - Tethered systems: tied into a healthcare system. E.g. My HealtheVet PHR from the VA
  - Networked systems : access data from multiple locations

Personal Health Records (PHR)



Personal Health Records (PHR)

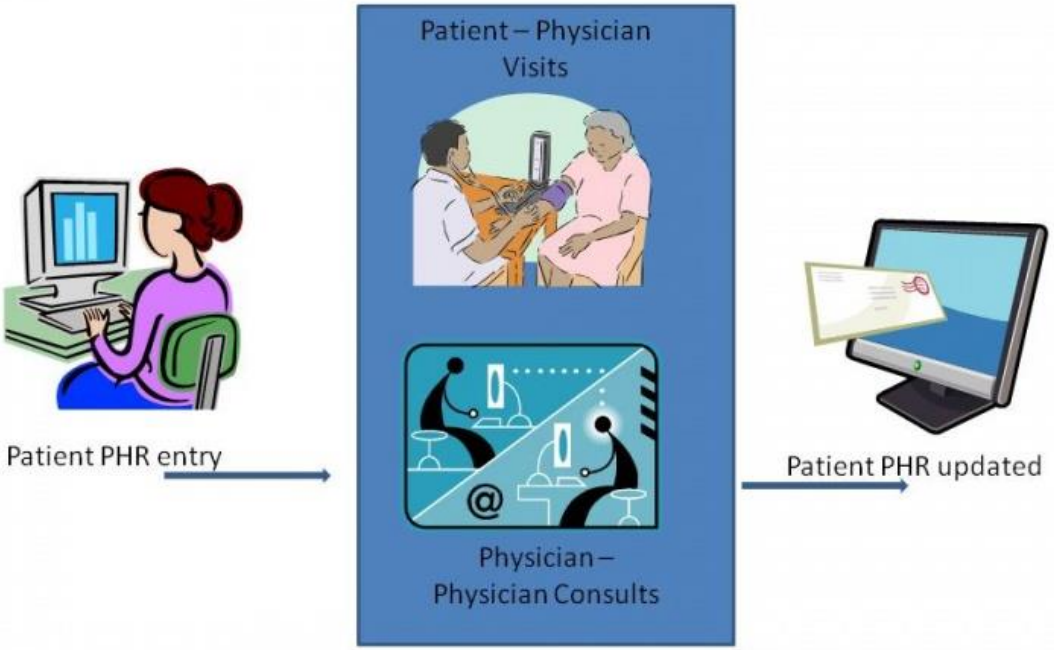
Sample PHR Data Types and Potential Sources

Data Type	Source
Problem list	Patient, EHR
Procedures	Patient, EHR, or claims
Major illnesses	Patient, EHR, or claims
Provider list, potentially linked to problems	Patient, EHR
Allergy data	Patient, EHR
Home-monitored data (eg., BP, glucose, peak flow)	Patient, automated interface with equipment
Family history	Patient, EHR
Social history and lifestyle	Patient, EHR
Immunizations	Patient, EHR, immunization registries
Medications	Patient, EHR, claims history (partial data)
Laboratory tests	Patient, EHR, commercial

Tang, Paul C., et al. "Personal health records: definitions, benefits, and strategies for overcoming barriers to adoption." *Journal of the American Medical Informatics Association* 13.2 (2006): 121-126.

Personal Health Records (PHR)

- IHE- The Exchange of Personal Health Record Content (XPHR) profile provides a standards-based specification for managing the interchange of documents between a Personal Health Record used by a patient and systems used by other healthcare providers to enable better interoperability between these systems.



http://wiki.ihe.net/index.php/Exchange_of_Personal_Health_Record_Content_Profile

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Functional Components of EHR Systems

- Integrated view of patient data
- Clinical decision support
- Clinician order entry
- Access to knowledge resources
- Integrated communication and reporting support

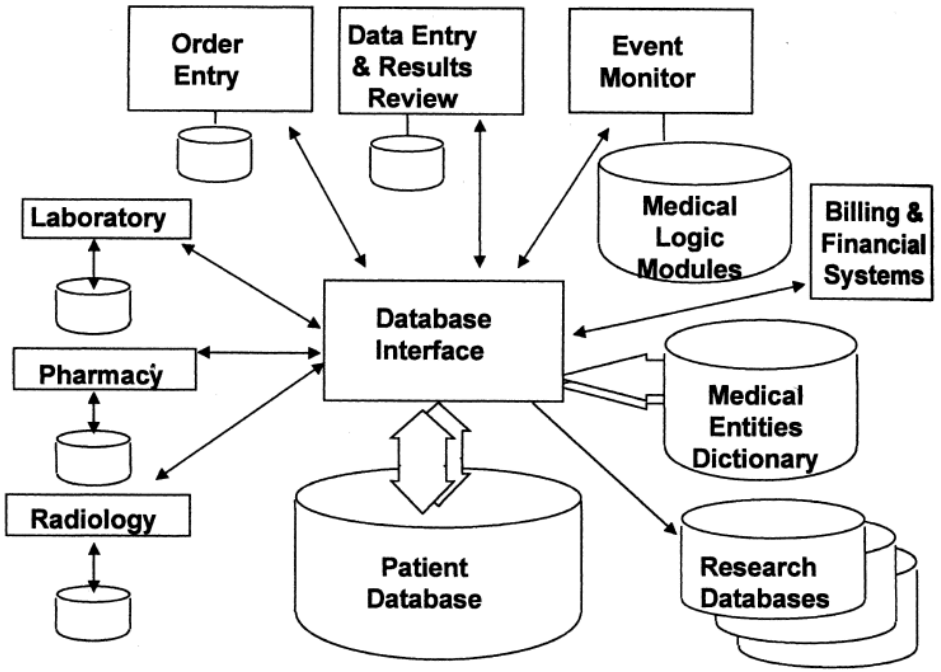
Functional Components of EHR Systems

Integrated view of Patient Data

- integrated access to all patient data is the primary purpose of an EHR
- challenges : the complexity and diversity of the data
- different patient data source systems use different identifiers, data content terminologies, and data formats creates substantial work.

integrate data from multiple source systems.

- message-handling capability
- Automatic translation of codes from the source system to the preferred codes of the receiving EHR
- human labor is needed to define the mappings that drive this automatic translation.



Functional Components of EHR Systems

Clinical Decision Support Systems (CDSS)

- powerful feature of electronic medical records is their use of protocols or algorithms to review the patient's electronic data and provide alerts and reminders

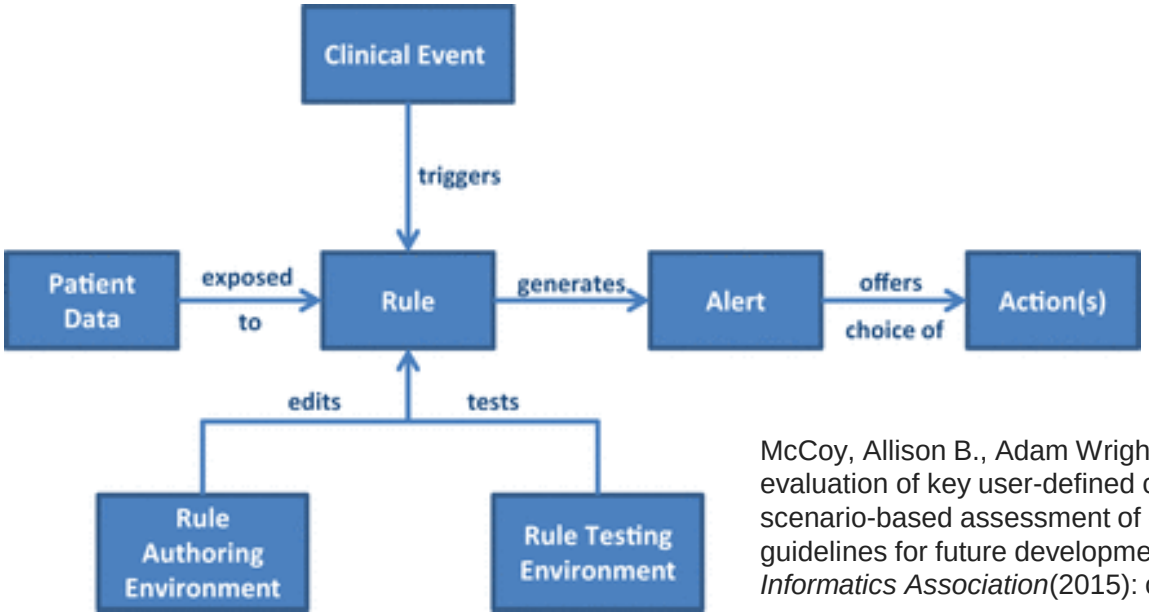
- CDSS provides clinicians, staff, patients or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care

- Benefits
  - Increased quality of care and enhanced health outcomes
  - Avoidance of errors and adverse events
  - Improved efficiency, cost-benefit, and provider and patient satisfaction

Functional Components of EHR Systems

- Knowledge-based CDSS
  - consist of three parts: the knowledge base, an inference engine, and a mechanism to communicate.

- Non-knowledge-based CDSS
  - use a form of artificial intelligence called machine learning,[9] which allow computers to learn from past experiences and/or find patterns in clinical data



McCoy, Allison B., Adam Wright, and Dean F. Sittig. "Cross-vendor evaluation of key user-defined clinical decision support capabilities: a scenario-based assessment of certified electronic health records with guidelines for future development." *Journal of the American Medical Informatics Association*(2015): ocv073.

Functional Components of EHR Systems

Clinical Decision Support Guidelines for Electronic Health Record Certification

Expose patient data elements to rules	Input data elements are used by rules to make inferences and are a critical component of CDS systems. The development of effective CDS requires the ability to include all available patient data elements in rules.[2]
	Basic patient data elements include: patient demographics (e.g., age, sex, race), patient location, patient type (e.g., outpatient, inpatient, observation), medications, diagnoses/problems, vital signs, diagnostic test results, allergies, and other relevant condition statuses (e.g., pregnancy, smoking, advanced directive).
	Each data element should have appropriate metadata, including timestamps (e.g., order date/time, collection date/time, result date/time, and review date/time for diagnostic tests) and entering clinician.
Use standard, controlled vocabularies	The routine use of standard, controlled vocabularies enables robust CDS that is shareable across implementations.[1,2,24]
	Appropriate vocabularies may include RxNorm for medications, NDF-RT (National Drug File-Reference Terminology) for medication classes, SNOMED-CT (Systematized Nomenclature of Medicine-Clinical Terms) for allergy reactions and severity, SNOMED-CT for clinical problems and diagnoses, and LOINC (Logical Observation Identifiers Names and Codes) or SNOMED-CT for diagnostic test results.

Functional Components of EHR Systems

Clinical Decision Support Guidelines for Electronic Health Record Certification

Allow clinical events to trigger rules	Triggering clinical events provide event-driven, action-oriented, real-time, point-of-care clinical decision support. Selecting the appropriate clinical event to trigger CDS rules to avoid unnecessary workflow interruptions is critical for delivering effective CDS.[1,25–27]
	Important clinical events include: patient chart opening or closing, medication order entry or modification, diagnostic test or procedure order entry, problem list entry or modification, allergy entry or modification, diagnostic test result receipt, passage of time after a clinical event, and trending clinical data elements.
Support mathematical, temporal, and logical operators in rules	The ability to use mathematical, temporal, and logical operators in rules is necessary for creating highly specific CDS rules that are likely to have an impact on clinical care.[1]
	Mathematical operators include: greater than, less than, equal to, addition, subtraction, multiplication, division, exponents, order of operation controls, minimum, and maximum.
	Temporal operators include: first, last, before, during, and after.[28]
	Logical operators include: and, or, not, xor, and exists.
	Operators should be able to be combined arbitrarily.

Functional Components of EHR Systems

Clinical Decision Support Guidelines for Electronic Health Record Certification

Generate actionable alerts	Actionable alerts allow clinicians to complete a recommended task directly from the alert interface and then return to their previous workflow without being excessively interrupted. Removal of unnecessary interruptions is key to delivering effective CDS. [6,21,26,27]
	Actions include: cancel entered order, modify the order, choose an alternate order, modify or cancel an existing order or other data element, add a task to the ordering clinician or another user's work list, order a diagnostic test, suppress the alert for the patient for a specified time interval, defer the alert for the next order entry session, override and proceed, document a reason for overriding, and report an error about the alert or rule.
Provide comprehensive rule authoring environment	Tools to manage CDS rules allow organizations to add and modify key rules for improving care based on national recommendations or local needs.[6,27,29]
	Within the rule authoring environment, informaticians should be able to create, modify, and delete rules; designate clinical events as rule triggers; designate alert types that are generated by rules; and designate choices that are offered within alerts.

McCoy, Allison B., Adam Wright, and Dean F. Sittig. "Cross-vendor evaluation of key user-defined clinical decision support capabilities: a scenario-based assessment of certified electronic health records with guidelines for future development." *Journal of the American Medical Informatics Association*(2015): ocv073.

Functional Components of EHR Systems

Clinical Decision Support Guidelines for Electronic Health Record Certification

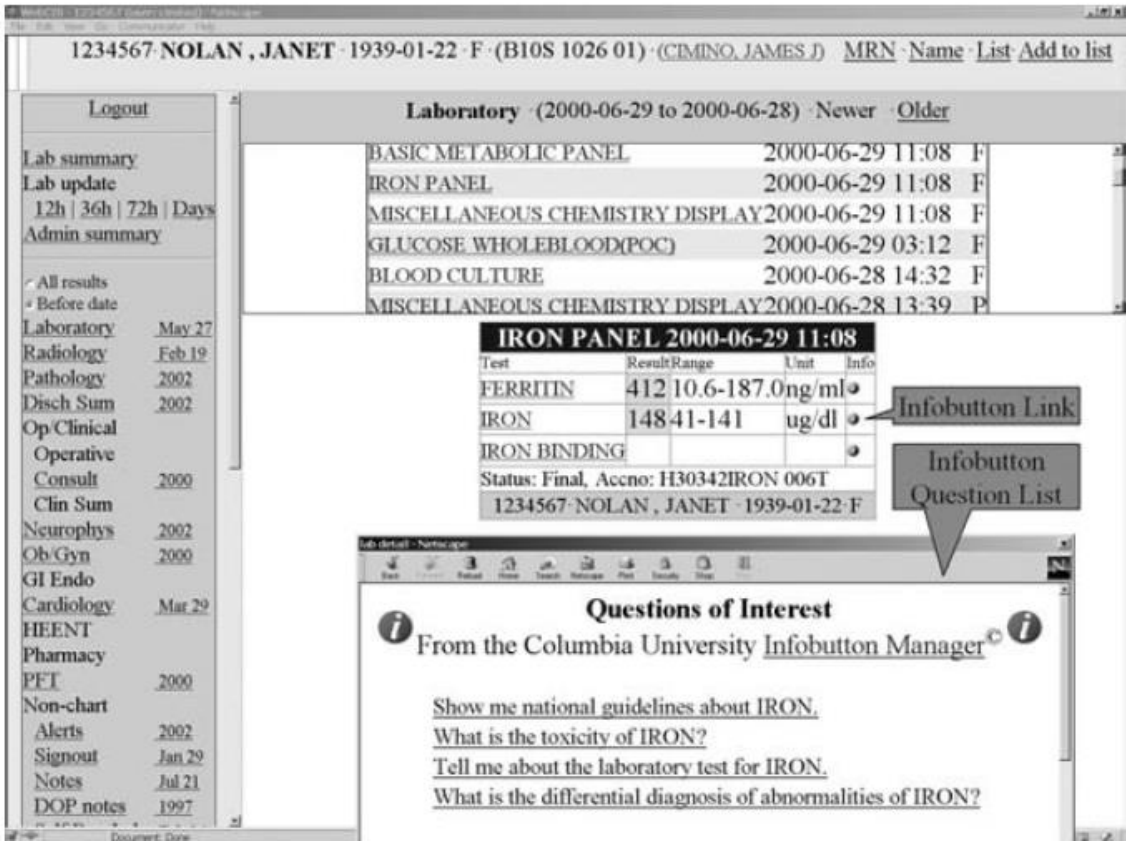
Support randomization of alerts	In the early phases of CDS implementation, it is necessary to allow organizations to test the effectiveness of rules within the production environment.[21,30,31]
	Randomization should be supported at the patient, clinician, and practice levels.
Support evaluation of rules	To ensure the safety and effectiveness of clinical decision support (CDS), all rules should be reviewed and approved by designated clinicians prior to implementation and following implementation on a regular basis. It is also important for the organization to continuously monitor and report on all displayed alerts and user actions to ensure that the CDS is working as intended.[6,8,13,14,27,32–36]
	Logs of the rules, the patient data values, and user actions with timestamps should be recorded, and the EHR should include a mechanism for viewing in real time, exporting, and analyzing these logs within the rule testing environment. The environment should also allow rules to be exported in a human-readable format for clinician review.

McCoy, Allison B., Adam Wright, and Dean F. Sittig. "Cross-vendor evaluation of key user-defined clinical decision support capabilities: a scenario-based assessment of certified electronic health records with guidelines for future development." *Journal of the American Medical Informatics Association*(2015): ocv073.

Functional Components of EHR Systems

- Access to knowledge resources
- Sources:
  - National Library of Medicine's literature search,
  - PubMed
  - full-text resources such as OVID
  - Onli

- active presentation of literature relevant to a particular clinical situation, such as an "Infobutton"



Functional Components of EHR Systems

Integrated communication and reporting support

- care function becomes increasingly distributed among multidisciplinary health care professionals

- Integrate communication tools with the EHR system ,
  messages (including system messages or laboratory test results) are electronically attached to a patient's record

- Geographic separation of team members:
  – the providers' offices, the hospital, the emergency room, and the home.

- Communication tools that support timely and efficient communication between patients and the health care team can enhance coordination of care and more effective disease management.

Clinical Documentation

A clinical document contains the information related to the care and services provided to the patient. A clinical document may include :

- Physician, nurse, and other clinician notes
- Relevant dates and times associated with the document
- The performers of the care described
- Flow sheets (vital signs, input and output, and problems lists)
- Perioperative notes
- Discharge summaries
- Transcription document management
- Medical records abstracts
- Advance directives or living wills
- Durable powers or attorney for healthcare decisions
- Consents (procedural)
- Medical record/chart tracking
- Release of information (including authorizations)
- Staff credentialing/staff qualification and appointments documentations
- Chart deficiency tracking
- Utilization management
- The intended recipient of the information and the time the document was written
- The sources of information contained within the document

Barriers to Adopting EHR

- Financial barriers:
  - the average initial cost of setting up an EHR is $44,000
- Physician's resistance:
  - can technology return financial profits, save time, and be good for their patients' well-being?
- Loss of productivity:
  - Adoption of an EHR system is a time-consuming process
- Usability issues
- Lack of standards
- Privacy and security concerns
- Legal aspects
  - EHRs may increase the physicians' legal responsibility and accountability

Challenges: Incompleteness

- Data incompleteness or missingness is a widespread problem while using EHR data for secondary purpose
- can occur due to a lack of collection or lack of documentation
- Patients' irregularity of communicating with the health system can also produce incompleteness

- Case: A pancreatic malignancies study using ICD-9-CM code at the Columbia University Medical Center found that 48% of the patients had corresponding diagnoses or disease documentation missing in their pathology reports

Variables	Endocrine
Necrosis	20%
Number of Mitoses	21%
Lymph Node Metastasis	28%
Perineural/Lymphovascula Invasion	15%
Differentiation	38%
Size	6%
Chronic Pancreatitis	14%
Smoking—Alcohol	27%–29%
History of Other Cancer	35%
Family History of Cancer	39%
Tumor Markers	46%

Challenges: Data Quality

- Erroneous Data
  - Data is collected from different service areas, conditions, and geographic locations, or by busy practitioners and staff.
  - the data can be erroneous due to
    - human errors ; Faulty equipment..

- Uninterpretable
  - Data: closely related with data incompleteness.
  - It may occur when some part of the data is captured but the rest is missing.

- Inconsistency:
  - Data collection technologies, coding rules, and standardsmay change over time and across institutions
  - different healthcare centers use different vendors for providing apparatus, softwares, and other technologies

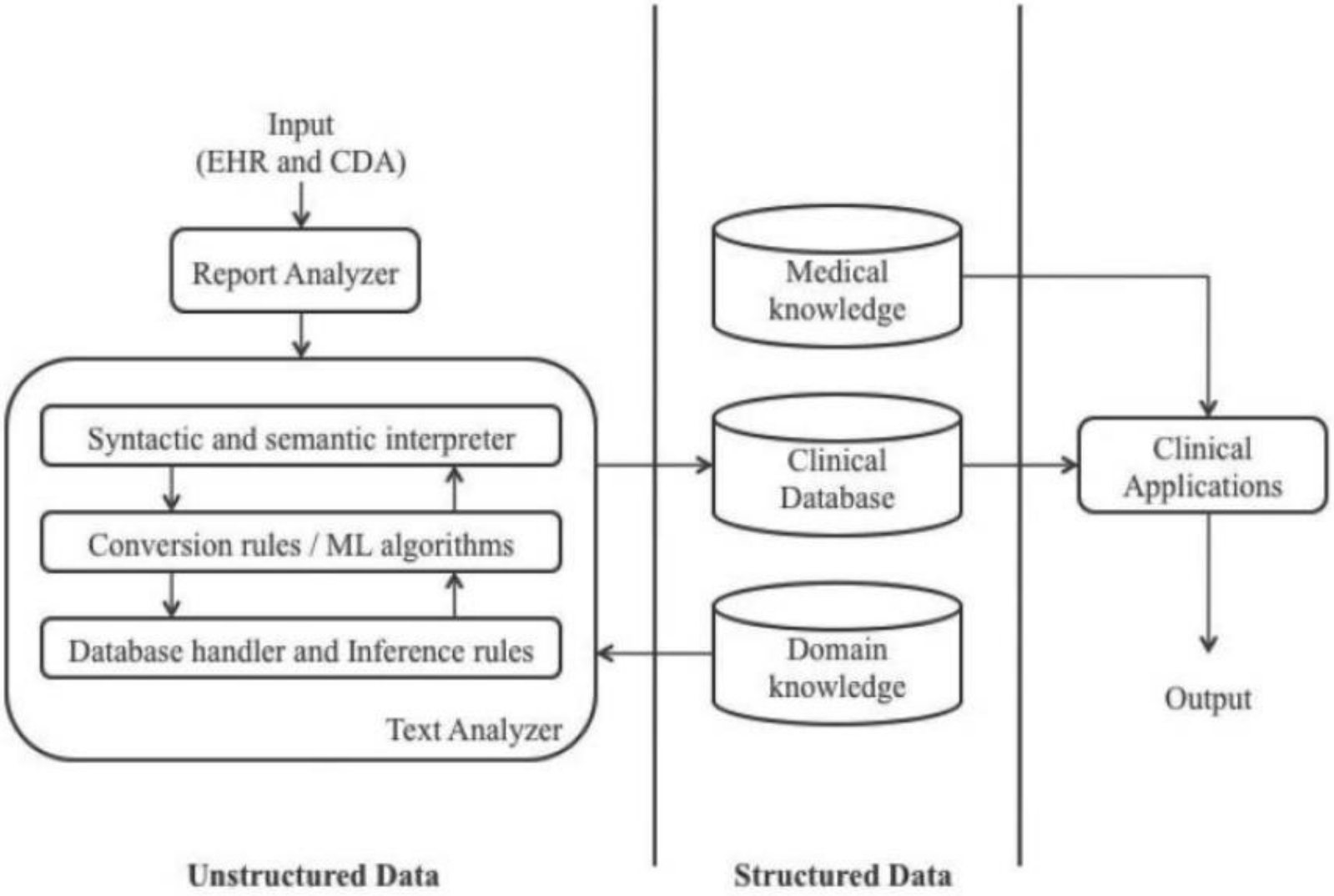
Challenges: Unstructured Text

- a large portion of the EHR data contain unstructured text

- It is easy to understand them for humans, but not machine readable
- data extraction techniques like Natural Language Processing (NLP) are being used to identify information from text notes

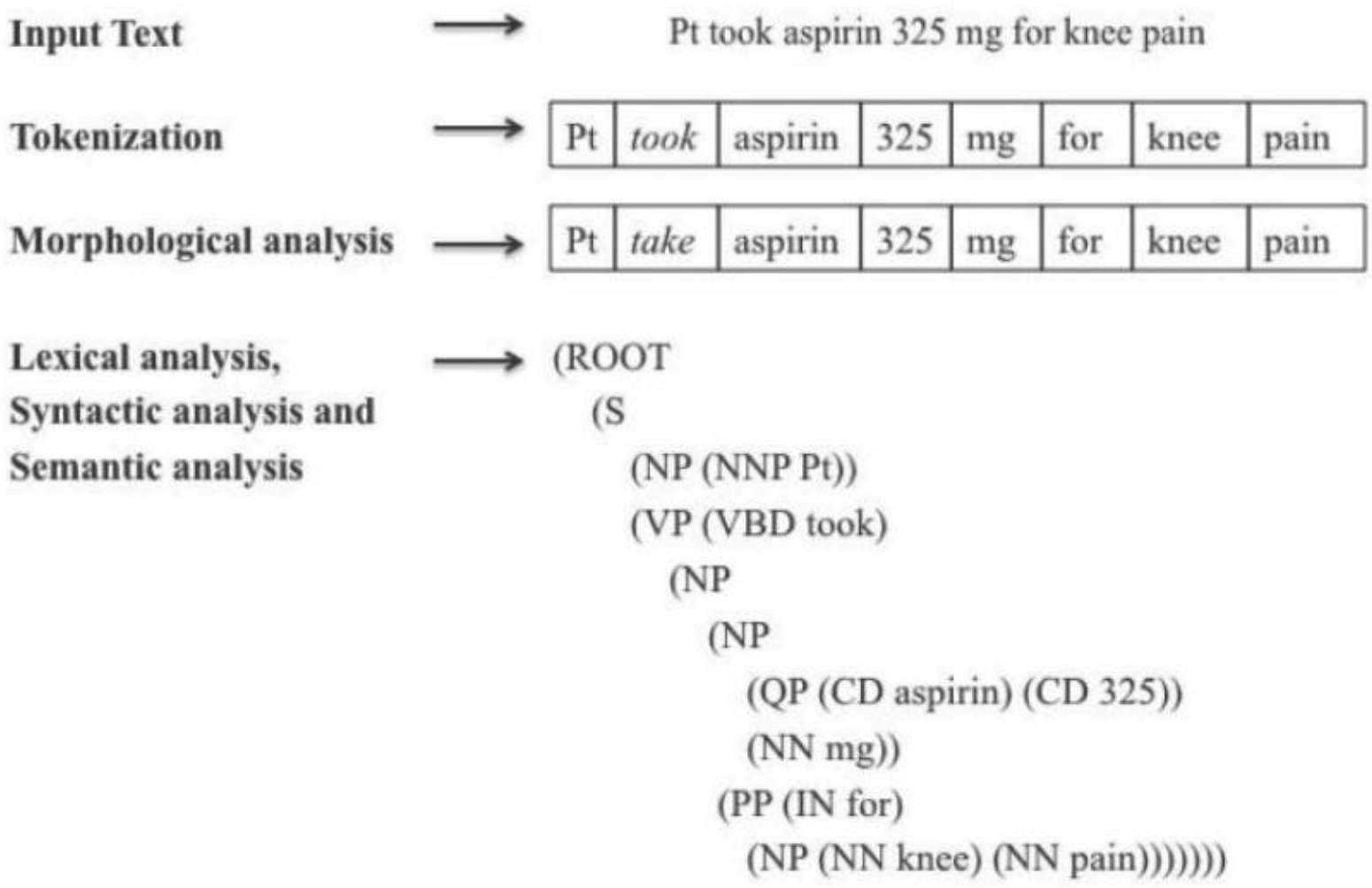
Challenges: Unstructured Text

- General workflow of a NLP system



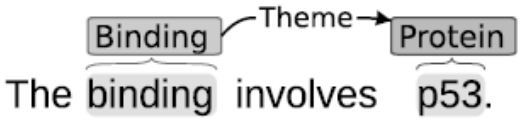
Challenges: Unstructured Text

- Core NLP components

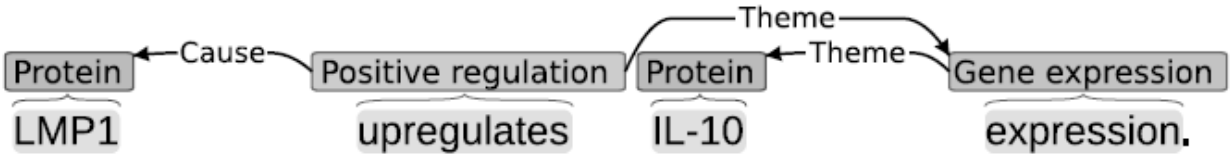


Challenges: Unstructured Text

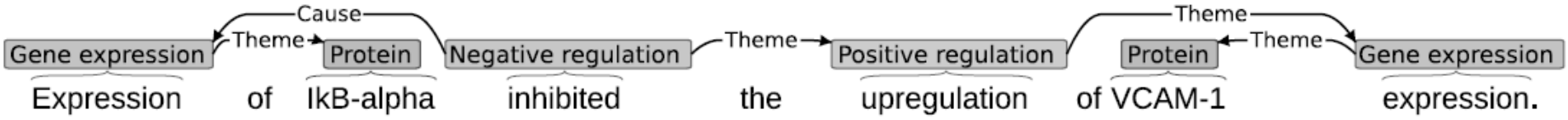
- Simple bio-event example



- Sentence containing two events



- More complex sentence containing multiple events



Challenges: Unstructured Text

Phenotyping algorithms

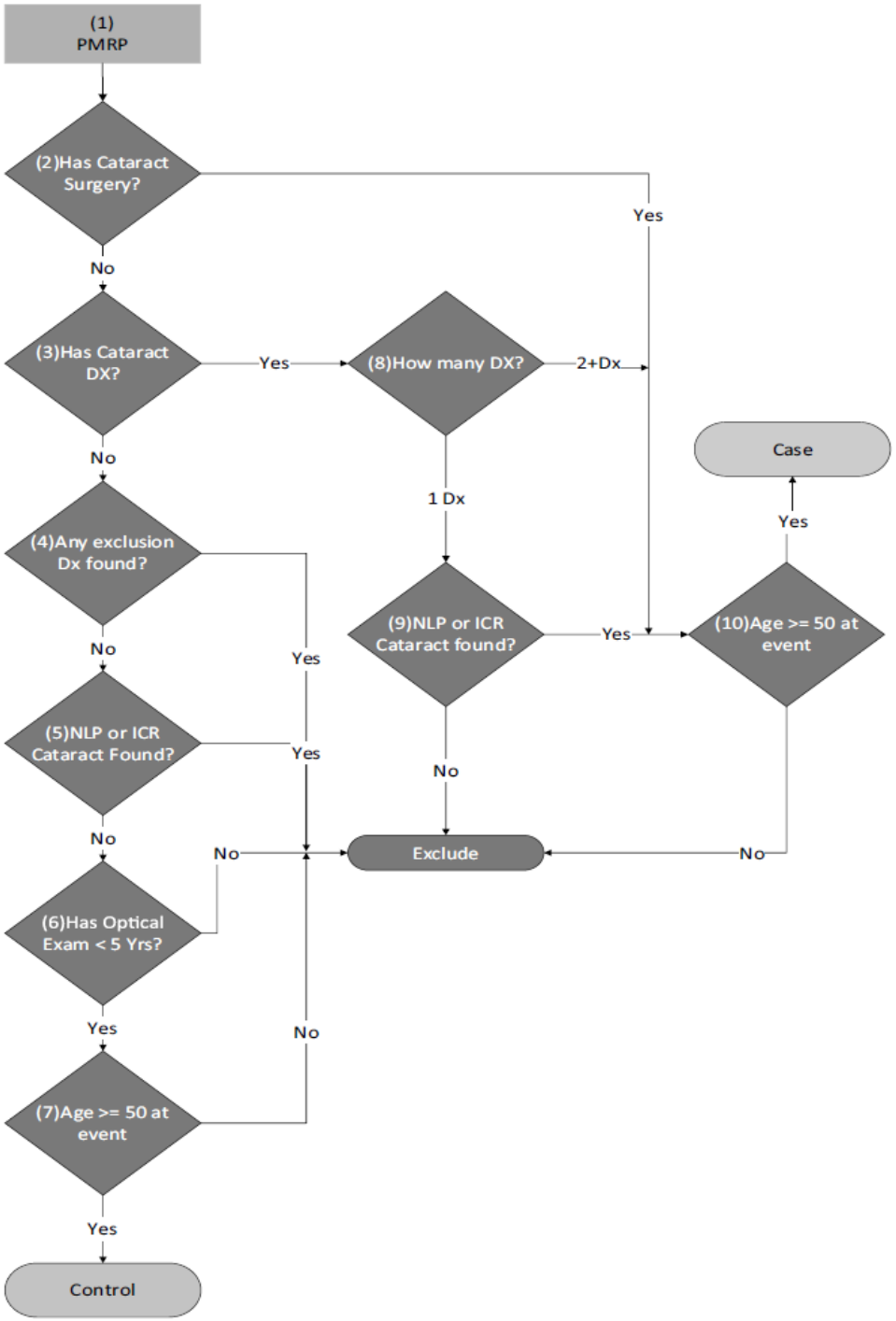
- combinations of multiple types of data and their logical relations to accurately identify cases (disease samples) and controls (non-disease samples) from EHR

- Algorithm combines multiple types of data and their logical relations to accurately identify cases and controls from EHR

- Building a phenotype algorithm:
  - select the phenotype of interest,
  - Identify key clinical elements that define the phenotype
  - Data sources: may contain billing codes, laboratory and test results, radiology reports, medication history,
  - NLP-extracted information.

Challenges: Unstructure

- Flowchart for cataracts phenotyping algorithm



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Challenges: Interoperability

- Lack of EHR interoperability is a major barrier towards improved healthcare, innovation, and lowering costs

- We need a robust healthcare information sharing and aggregation and interoperability

- building blocks:
  - Core technical standards and functions
  - Certification to support adoption and optimization of health IT products and services
  - Privacy and security protections for health information
  - Supportive business, clinical, cultural, and regulatory environments
  - Rules of engagement and governance

References

- Healthcare Data Analytics (Chapman & Hall/CRC Data Mining and Knowledge Discovery Series) by Chandan K. Reddy (Editor), Charu C. Aggarwal (Editor)

- Biomedical Informatics: Computer Applications in Health Care and Biomedicine (Health Informatics) by Edward H. Shortliffe (Editor), James J. Cimino (Editor)