Hasso Plattner Institut
Digital Engineering · Universität Potsdam

# Software Architectures for Digital Health

Borchert, Konak, Dr. Schapranow

Data Management for Digital Health

Winter 2020

# Agenda
# Pillars of the Lecture

Hasso Plattner Institut

## Medical Use Cases

Biology Recap

Oncology

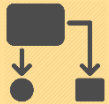
Infectious Diseases & Care

## Technology Foundation

Data Sources

Data Formats

Processing and Analysis



Software Architectures

## Machine Learning

Data

ML

Refine

Evaluate

Prediction + Probability

**Software Architectures for Digital Health**

Data Management for Digital Health, Winter 2020

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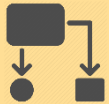
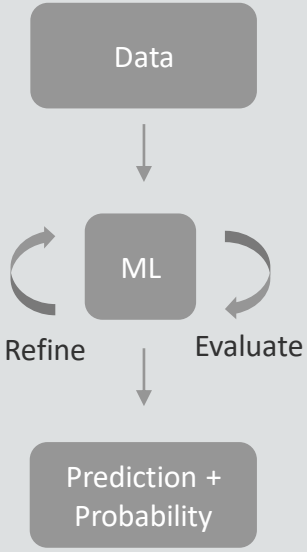


Software Architectures

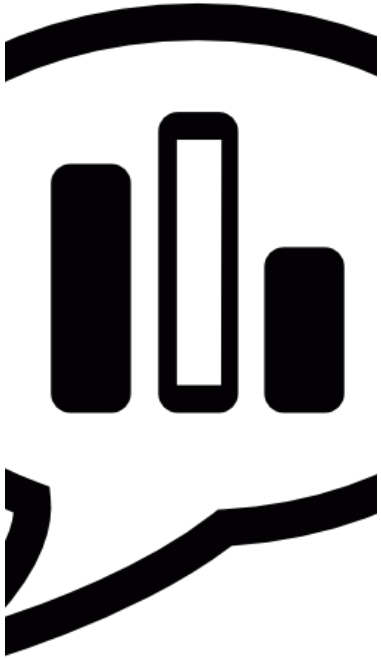
## Machine Learning



# Agenda

- Electronic Medical Records vs. Electronic Health Records
- Hospital Enterprise Functions
- Software Tools in a Hospital
- Standards and Data Formats

# What are you studying?
# << QUIZ >>



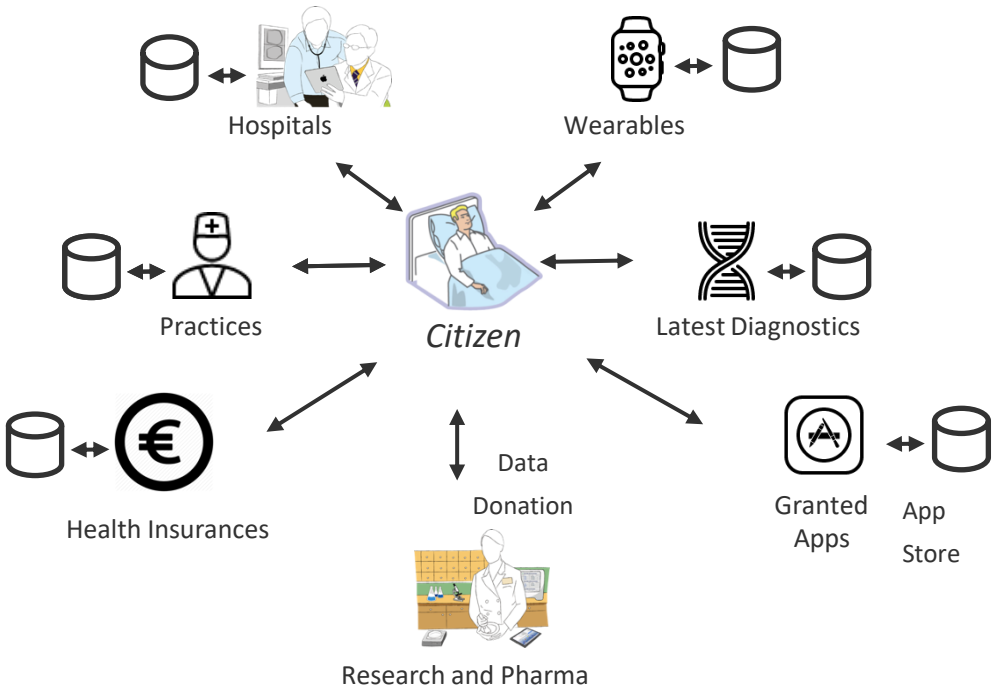
A. Digital Health

B. Data Engineering

C. IT-Systems Engineering

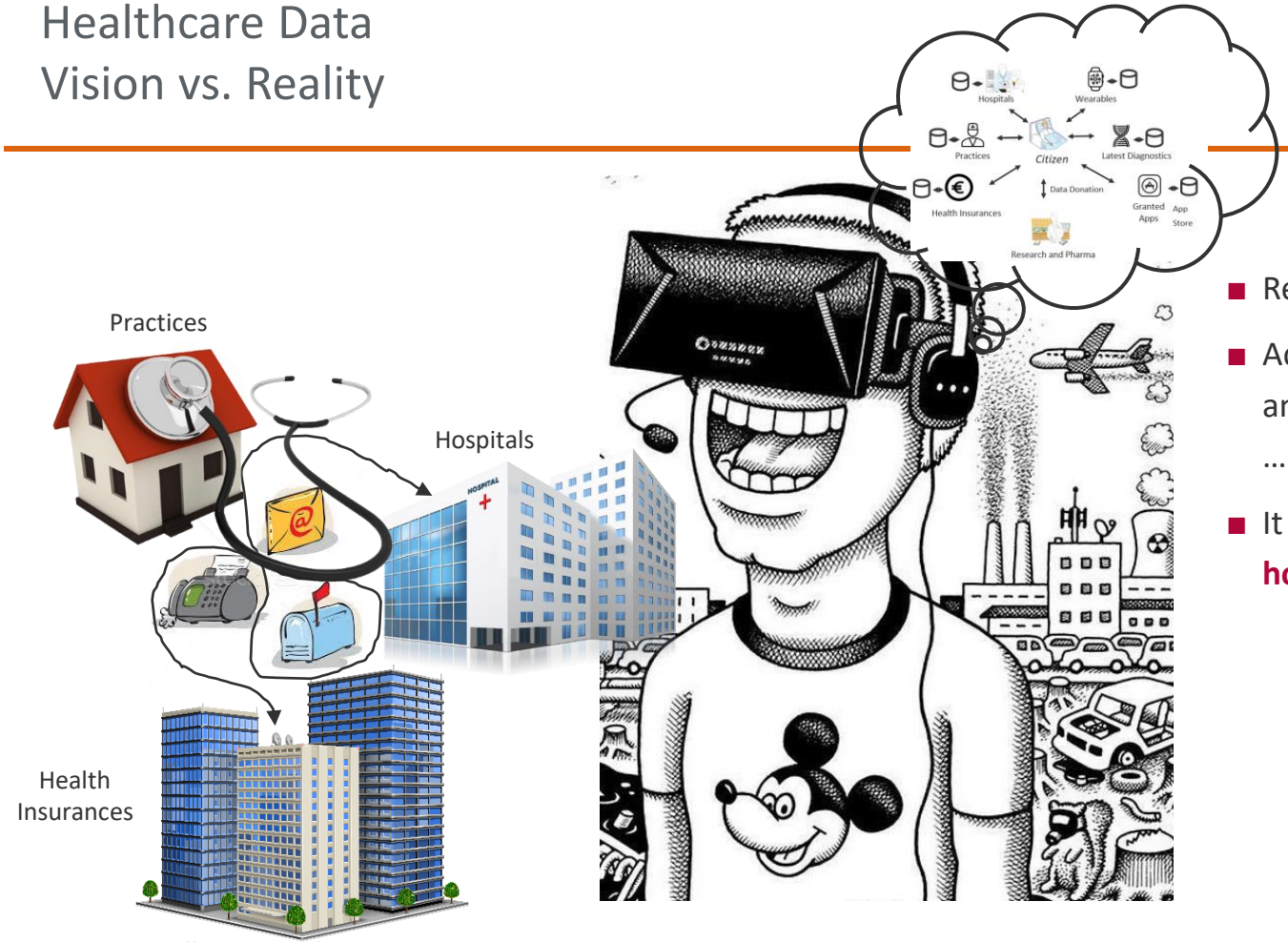
D. Other

# Healthcare Data Recap




- From citizens'/patients' perspective different actors involved
- All actors collect individual data
- Actors communicate with each other
- But: That is all still up in the air

# Healthcare Data
# Vision vs. Reality




https://www.hiclipart.com/free-transparent-background-png-clipart-lidfi

https://earthdesk.blogs.pace.edu/2015/02/22/virtual-reality-by-andy-singer/

- Reality looks different
- Actors mostly still communicate in an old-fashioned way via mail, fax, …
- It is a long way to go, but there is **hope**

# Agenda

- **Electronic Medical Records and Electronic Health Records**
  - Understand the basics of digital health transformation
- Hospital Enterprise Functions
- Software Tools in a Hospital
- Standardization

# A “Computerless“ Hospital?

# A “Paperless“ Hospital?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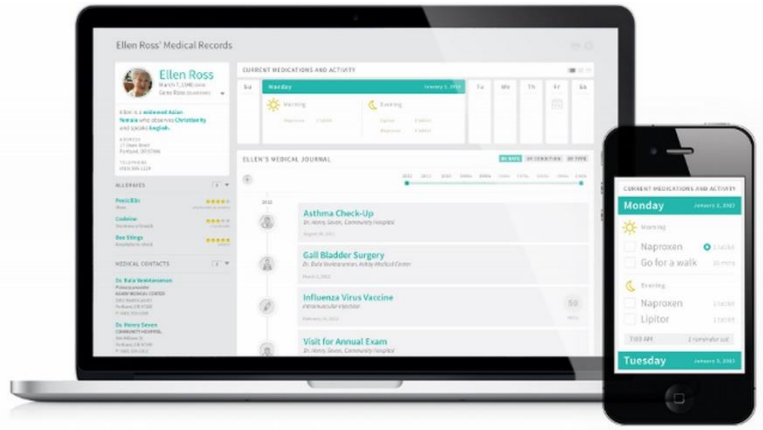
**10**

# Electronic Medical Record vs. Electronic Health Record?

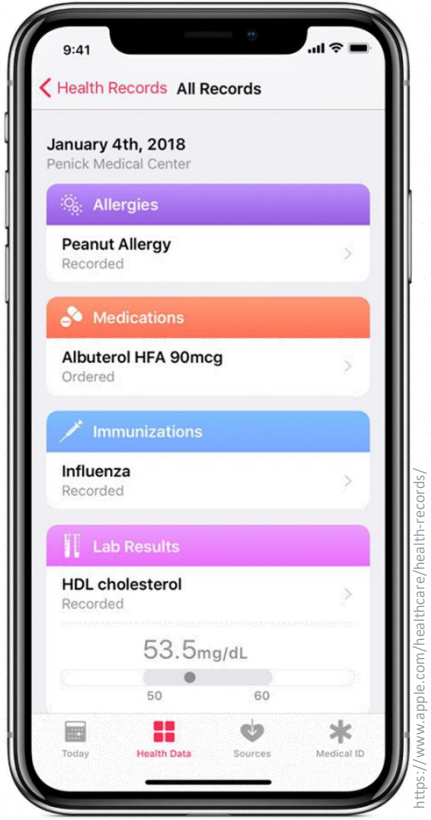
- **Electronic Medical Record (EMR)**
- Digital versions of traditional paperwork
- Includes amongst others medical history, diagnoses, medications, immunization dates, allergies
- Transferring data out of the practice from EMRs is not convenient
- Patient records have to be printed or mailed for consultations




https://www.theverge.com/2013/1/28/3925734/is-nightingale-the-future-of-user-friendly-medical-records

# Electronic Medical Record vs. Electronic Health Record?

- **Electronic Health Record (EHR)**
- Focuses on a patient's overall health
- Broader view of care including overall past medical history, EMR data, lab data, imaging reports
- Relevant information such as insurance information, demographics, wellness devices.
- Facilitates data sharing outside the practice with other health care providers such as laboratories and specialists




https://www.apple.com/healthcare/health-records/

# Elektronische Patientenakte (ePA)
# Gesundheitskarte

WIRTSCHAFT

**728 Mill**

Veröffentlicht

12. April 2018, 19:28 Uhr Elektronische Gesundheitskarte

## 14 Jahre, zwei Milliarden Euro - und technische Probleme


Ärzte sollen künftig Patientendaten untereinander austauschen können, um die Versorgung zu verbessern.
(Foto: Bernd Thissen/dpa)

# Elektronische Patientenakte (ePA)
# Gesundheitskarte

- Obligatory for public health insurance
- Support data exchange in German health care
- Expensive: 14 years and 2bi EUR
- Stores name, birth, address and insurance details
- (Future) applications: emergency infos and electronic medication plan


Source: Barmer

gematik
Gesellschaft für Telematikanwendungen der Gesundheitskarte mbH

https://www.bundesgesundheitsministerium.de/themen/krankenversicherung/egk.html

# Elektronische Patientenakte (ePA)
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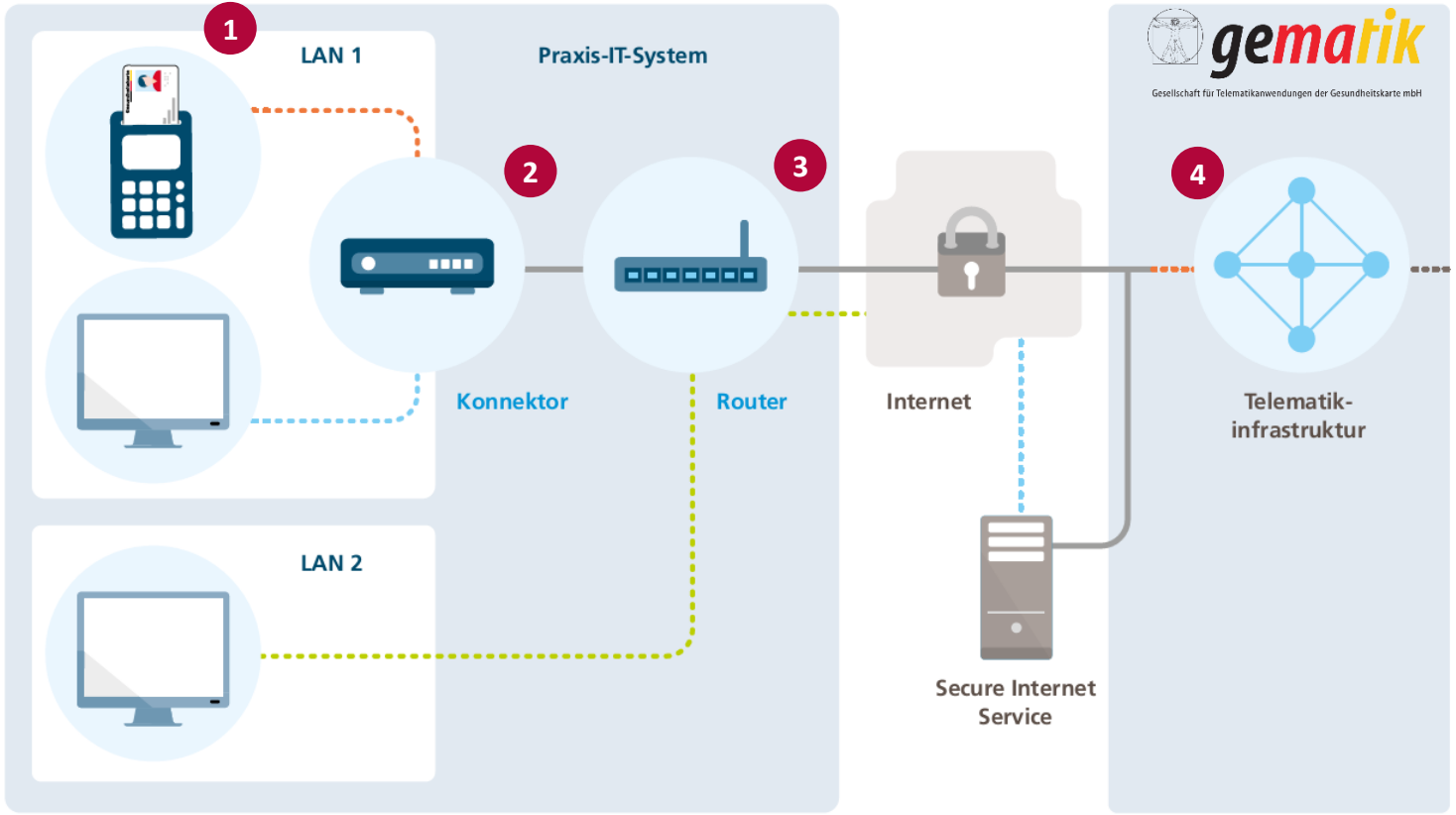
Source: Barmer

## Question: Have you heard of it?

https://www.bundesgesundheitsministerium.de/themen/krankenversicherung/egk.html

# Elektronische Patientenakte (ePA)
# Gesundheitskarte – Telematikinfrastruktur




Source: gematik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# Elektronische Gesundheitsakte (ELGA) Austria

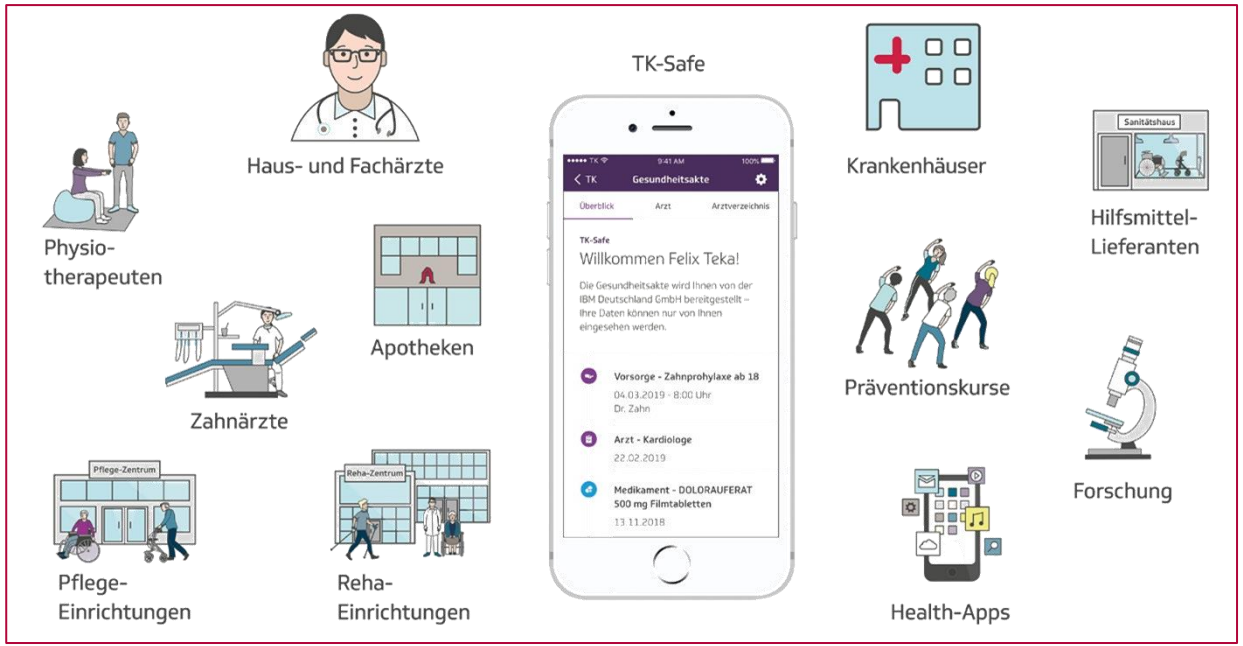
- ELGA is an interoperable document exchange platform for patients based on international standards, which is filled by physicians and other healthcare providers, but can be managed by patients
- Currently includes discharge letters, laboratory and radiology findings and medication data
- e-card serves as technical access key for patients
- All Austrian citizens are automatically part of the system
- Registered doctors and hospitals are obliged to participate in ELGA


https://www.elga.gv.at/elga-die-elektronische-gesundheitsakte/informationsunterlagen/

http://www.elga.gv.at/en/about-elga/

# Elektronische Gesundheitsakte (eGA)
# German Patient Apps

- German equivalent to EHR
- Example apps: TK-Safe, Vivy-App




Source: Techniker Krankenkasse

# EMR and EHR
# Summary

- One of the first and most foundational aspects of digital health, the EHR / EMR has been established in many settings for several years
- This important digital health field continues to evolve
- We will see continued improvements in interoperability to optimize the exchange of vital healthcare information across a variety of platforms and providers to ensure that patients get the best care possible
- It also helps to
  - Reduce costs
  - Integrate healthcare systems

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# Questions?

# Agenda

- Electronic Medical Records and Electronic Health Records
- **Hospital Enterprise Functions**
  - Let’s zoom into one major actor “The Hospital”
- Software Tools in a Hospital
- Standardization

# Main Hospital Enterprise Functions
# What does a Hospital do?


Foto: Berliner Zeitung/Volkmar Otto

# Question

- What do you think does a hospital do?
- Hint: There is more to it than you might think (not only patient care)
- Please write your thoughts in the “Shared Notes” section

# Main Hospital Enterprise Functions
# What does a Hospital do?


Foto: Berliner Zeitung/Volkmar Otto



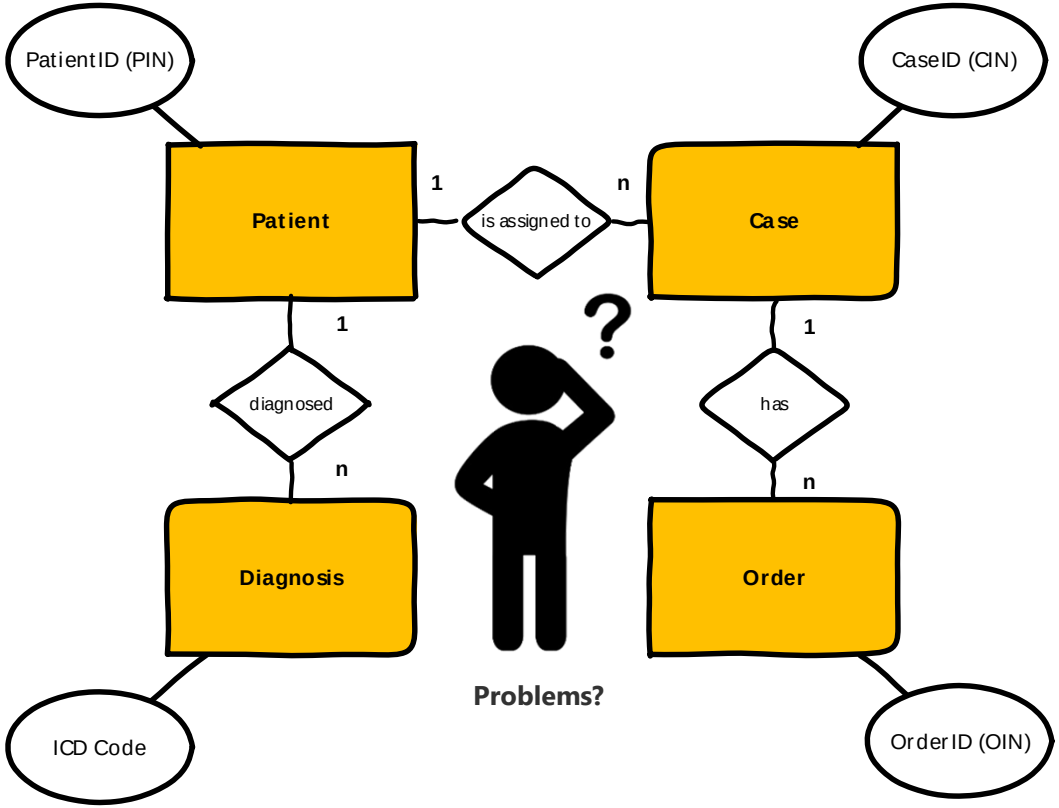
Winter, A. et al. (2010). Health information systems. In Health Information Systems (pp. 33-42). Springer, London.

# Main Hospital Enterprise Functions
# Data Processed in Hospitals: Patient Care

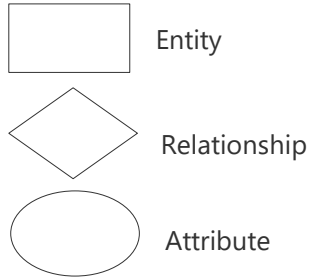
| Entity type | Description |
|---|---|
|  Patient | is a person being subject of care; information about a patient includes the patient identification number (PIN) |
|  Case | hospital stay from patient admission to patient discharge or several ambulatory treatments related to one disease; information about a case includes the case identification number (CIN) |
|  Order | is a request for a diagnostic, therapeutic or drug service, e.g. a laboratory order or a radiological order |
|  Diagnosis | is the identified cause or nature of a disease or medical condition |

Typical entity types representing certain object classes and data related to the patient and his or her histories:

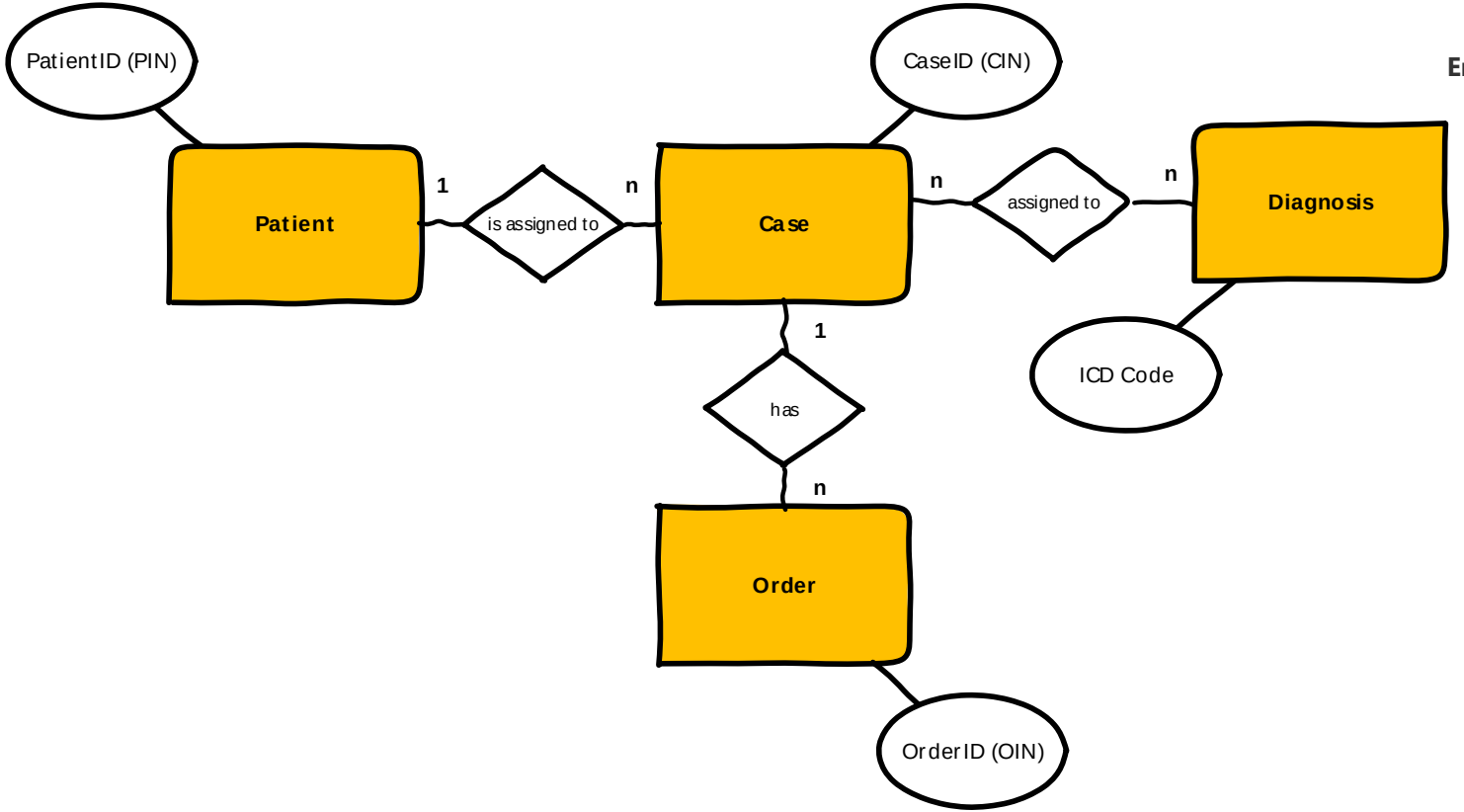
# Main Hospital Enterprise Functions
# Data Processed in Hospitals: Patient Care




**Entity-Relationship Diagram**



# Main Hospital Enterprise Functions
# Data Processed in Hospitals: Patient Care




**Entity-Relationship Diagram**

Entity

Relationship

Attribute

# Main Hospital Enterprise Functions
# Processed Data in Hospitals: Resources

| Entity type | Description |
|---|---|
|  Appointment | determines what persons have to be at a certain place at a given time. |
|  Bed | must be managed according to its occupation. |
|  Health care professional | treats patients according to his or her specialization (e. g. nephrology or pediatrics) with certain diagnoses. |
|  Drug | is a substance administered to a patient for treatment, diagnosis or prevention |

A hospital must guarantee that all resources needed for patient care are available continuously. The following resources are necessary:

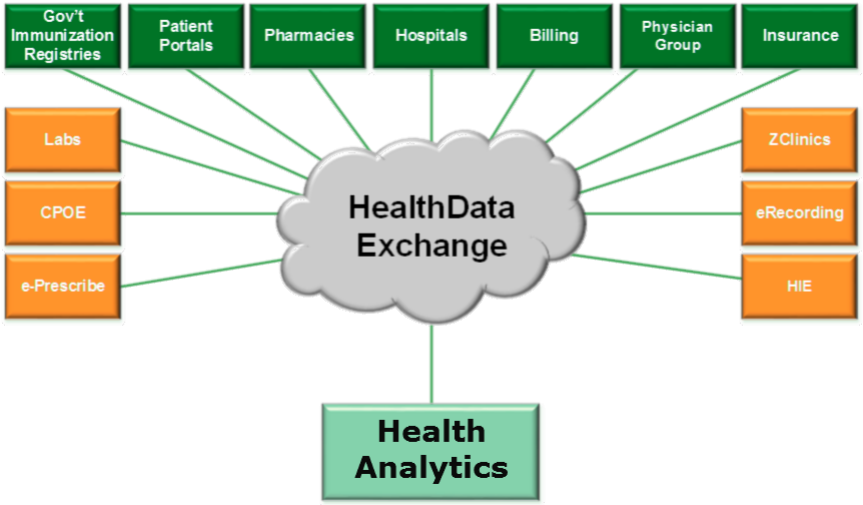
# Main Hospital Enterprise Functions
# Processed Data in Hospitals: Administration

| Entity type | | Description |
|---|---|---|
|  | Patient record archive | describes how and where the electronic or paper-based patient record can be found. |
|  | Classification | consists of a set of classes summarizing concepts not to be distinguished during analysis. |
|  | Classification of diagnoses | e. g. the International Classification of Diseases (ICD). |
|  | Cost unit | information about a person or an institution responsible for bearing the costs or a part of the costs for the services to be provided |

Besides information about resources, hospital administration needs the following entity type:

# Main Hospital Enterprise Functions Summary

- A hospital has many functions
- Each function generates and exchanges data with other systems
- Most medical information is still written and stored on paper- in filling cabinets at several medical office, or in folders and boxes in patient's home
- Electronic healthcare data exchange helps nurses, doctors, pharmacists and other healthcare providers and patients to access and share important medical information of patient
- This enhances the speed, safety, quality, and cost of patient care




https://healthitech.doodlekit.com/blog/entry/3989159/do-you-have-idea-about-healthcare-data-exchange-

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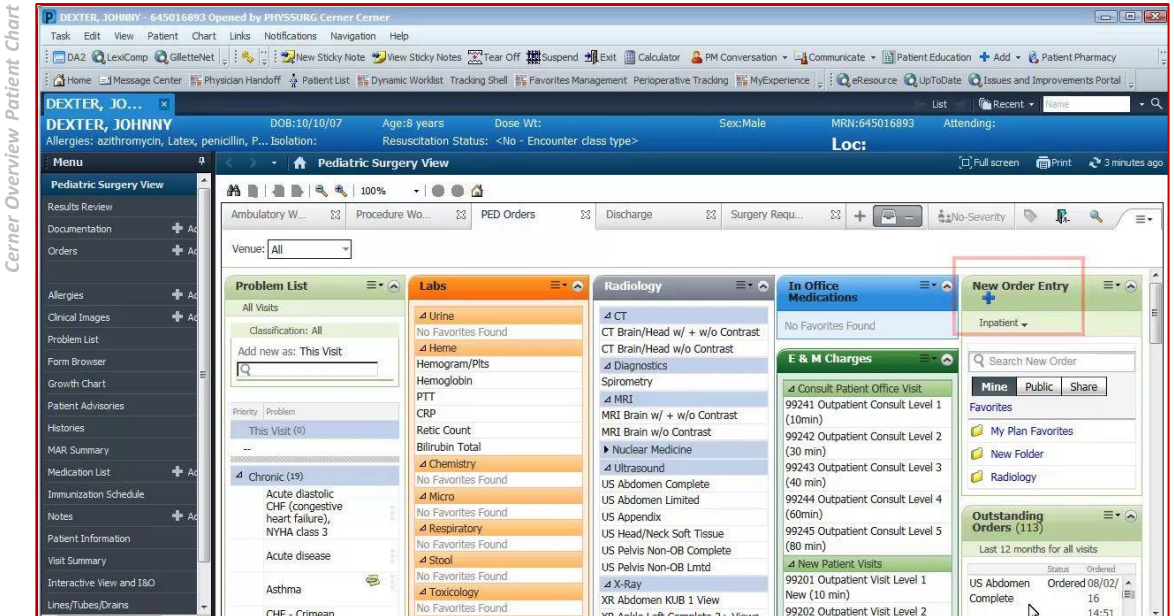
# Questions?

# Agenda

- Electronic Medical Records and Electronic Health Records
- Hospital Enterprise Functions
- **Software Tools in a Hospital**
  - What software is used in hospitals?
- Standardization

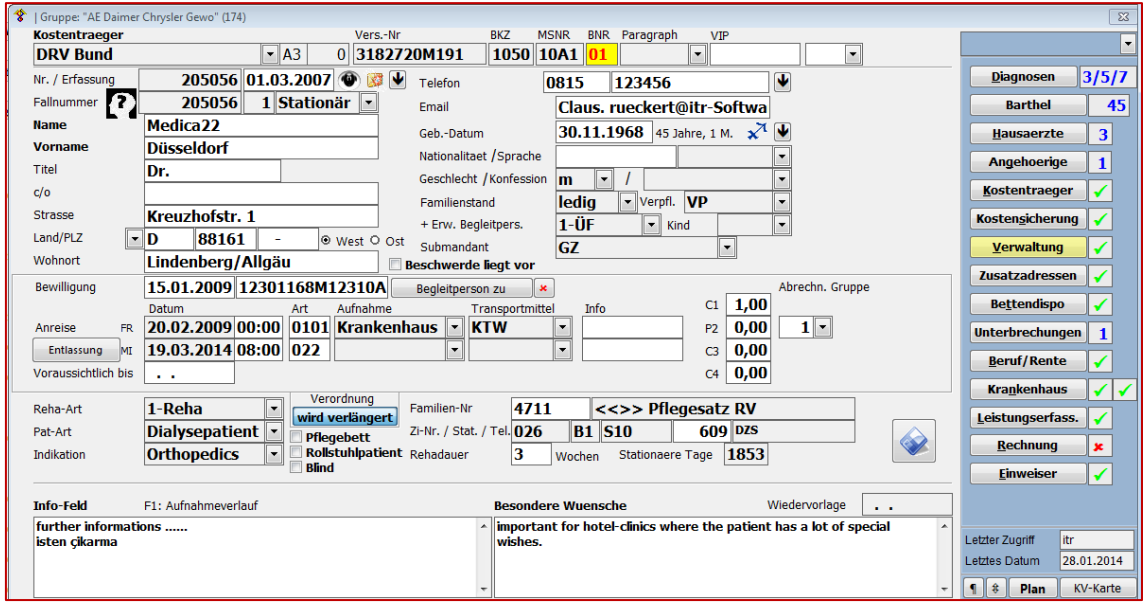
# Different Terms for Software Tools

- **Hospital Information Systems** := enables administrative functions around patient billing
- **Clinical Information Systems** := enables patient management (e.g. documentation, scheduling)
- **Clinical Decision Support Systems** := supports medical experts on therapy decisions



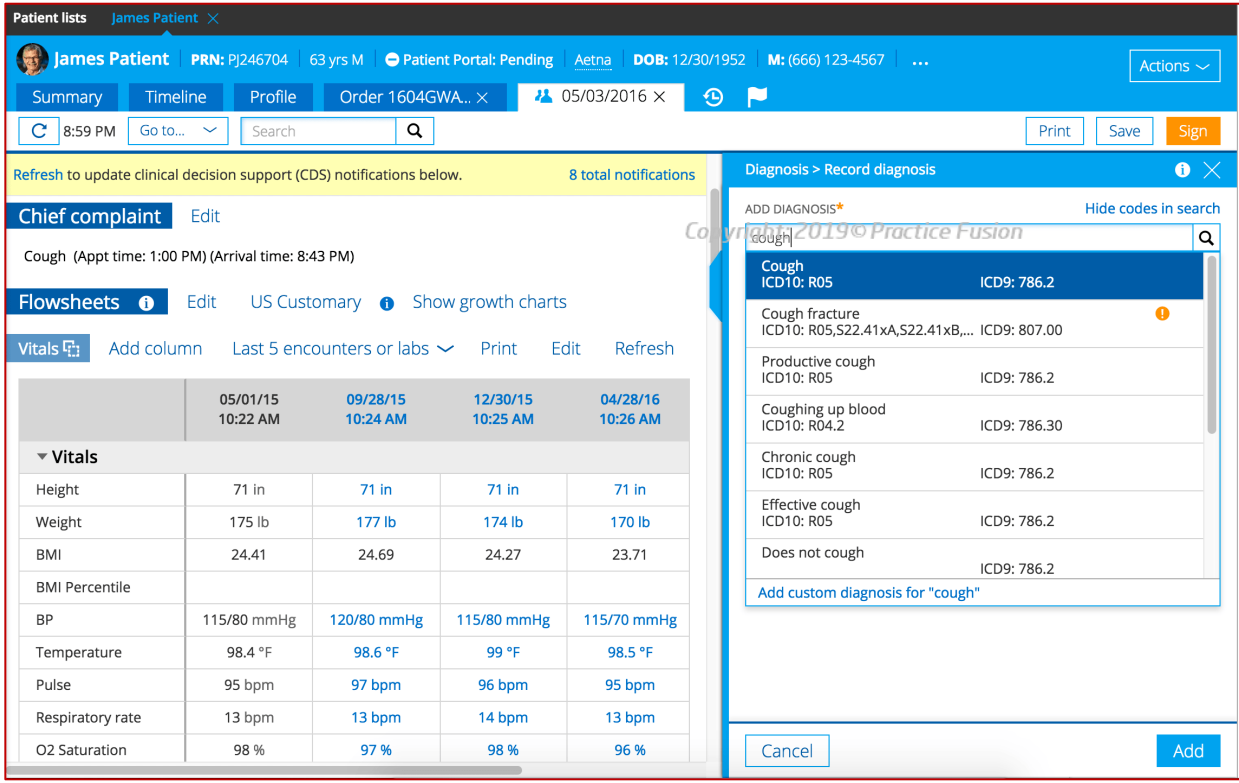
# Application Components: Patient Administration System

- Especially used for patient admission, discharge and billing
- It must provide correct, complete and up-to-date administrative patient data
- Application components must be able to transmit relevant administrative patient data



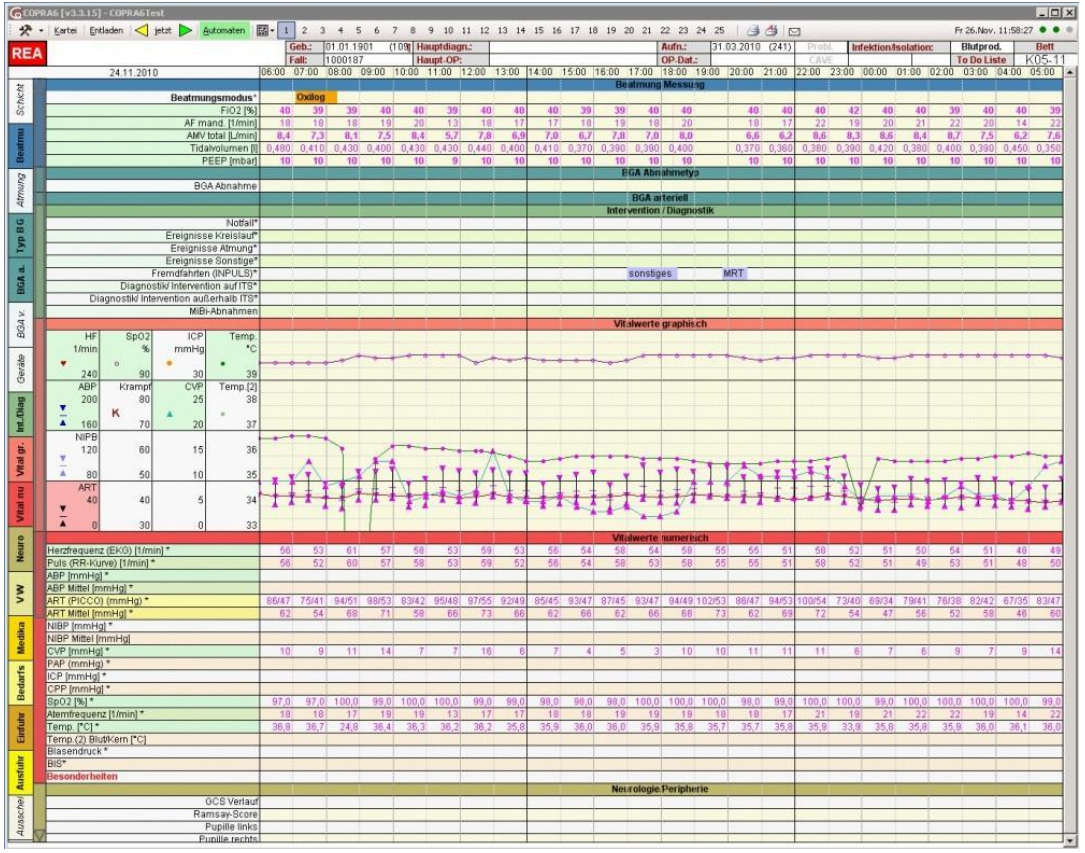
# Application Components: Medical Documentation System

- Supports specific documentation tasks with modules for different medical fields
- Provides functions like speech-to-text, reuse of already documented data
- Coding of diagnoses and procedures, must provide an easy search system
- Basis for decision making and planning



# Application Components
# Patient Data Management System (PDMS)

- Monitors, stores, and clearly presents a vast amount of patient-related clinical data in Intensive Care Units (ICU)
- May offer features for real-time decision-support and statistical analyses
- Provide means for patient discharge and transfer to other wards or institutions, e.g. a short summary of the therapy on the ICU

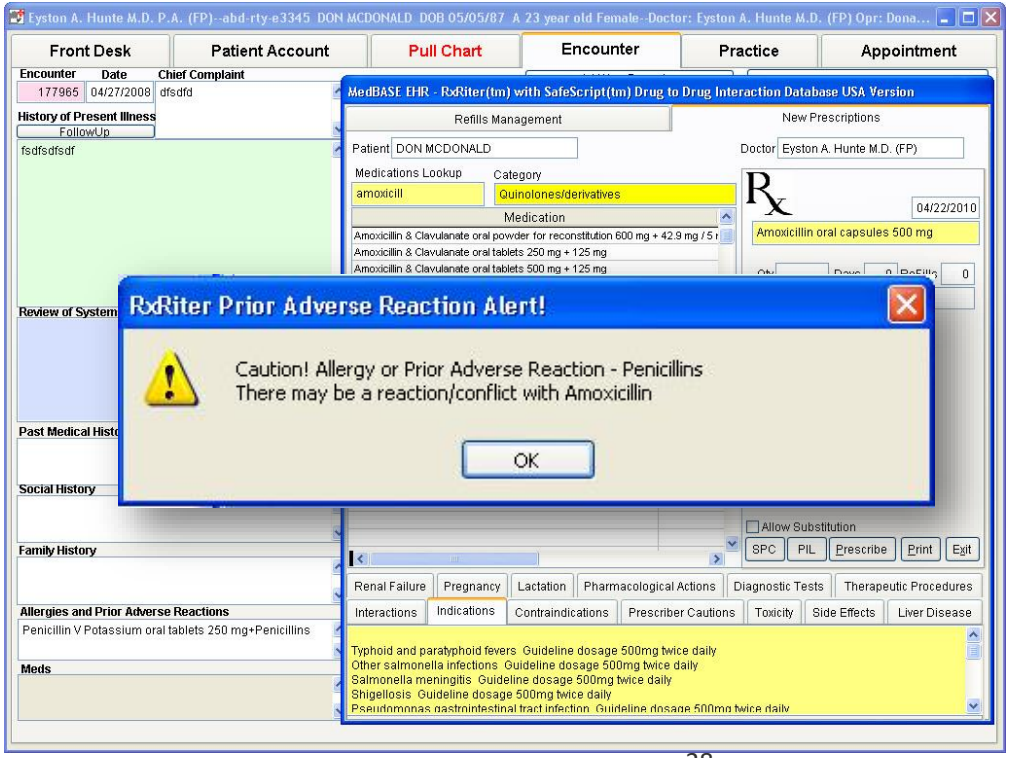



COPRA, https://docplayer.org/60370571-Christian-schade-lobeck.html

Screenshot of a patient data management system showing a patient's vital parameters and given drugs during a day

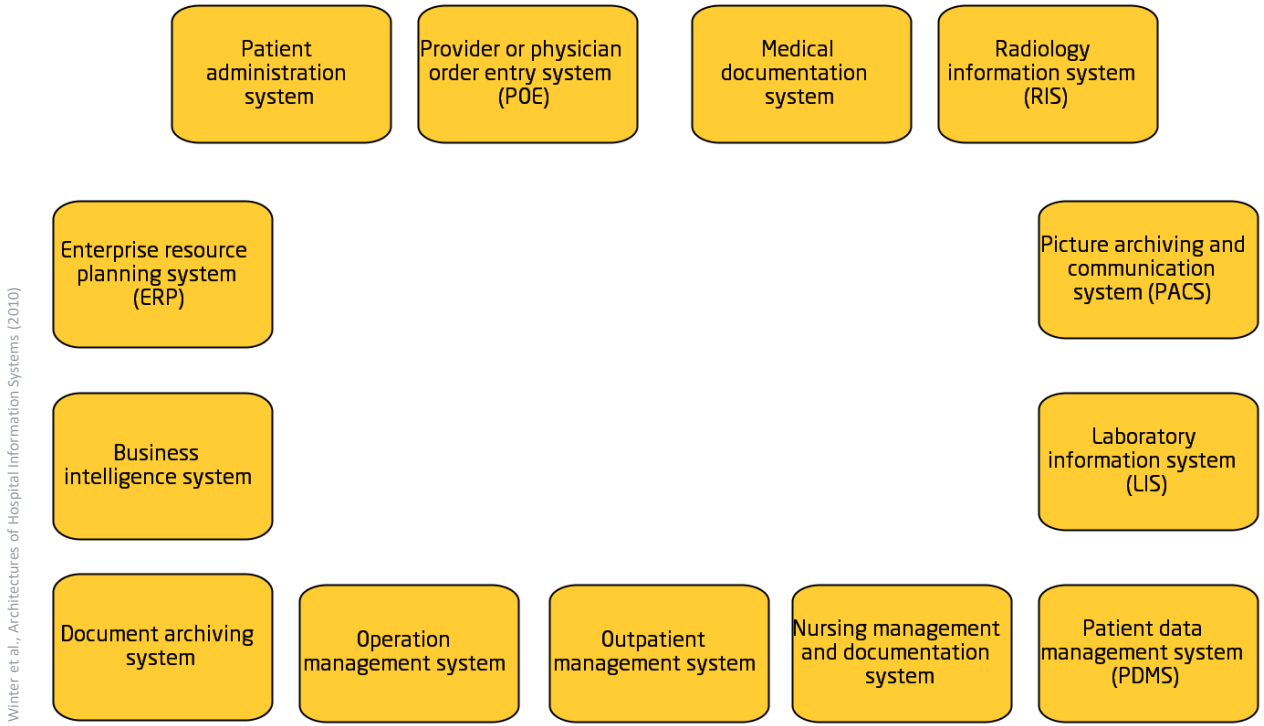
# Application Components:
# Clinical Decision Support Systems (CDSS)

- CDSS directly assist clinical professionals in data interpretation and decision-making
- CDSS can use the information stored to:
  - Monitor patients and issue alerts
  - Make diagnostics suggestions
  - Provide limited therapeutic advice
  - Provide information on medication costs




http://www.ehrscreenshots.com/files/2011/10/rxriter001.jpg

# Software Components
# Hospital Information Systems (Reference Architecture)

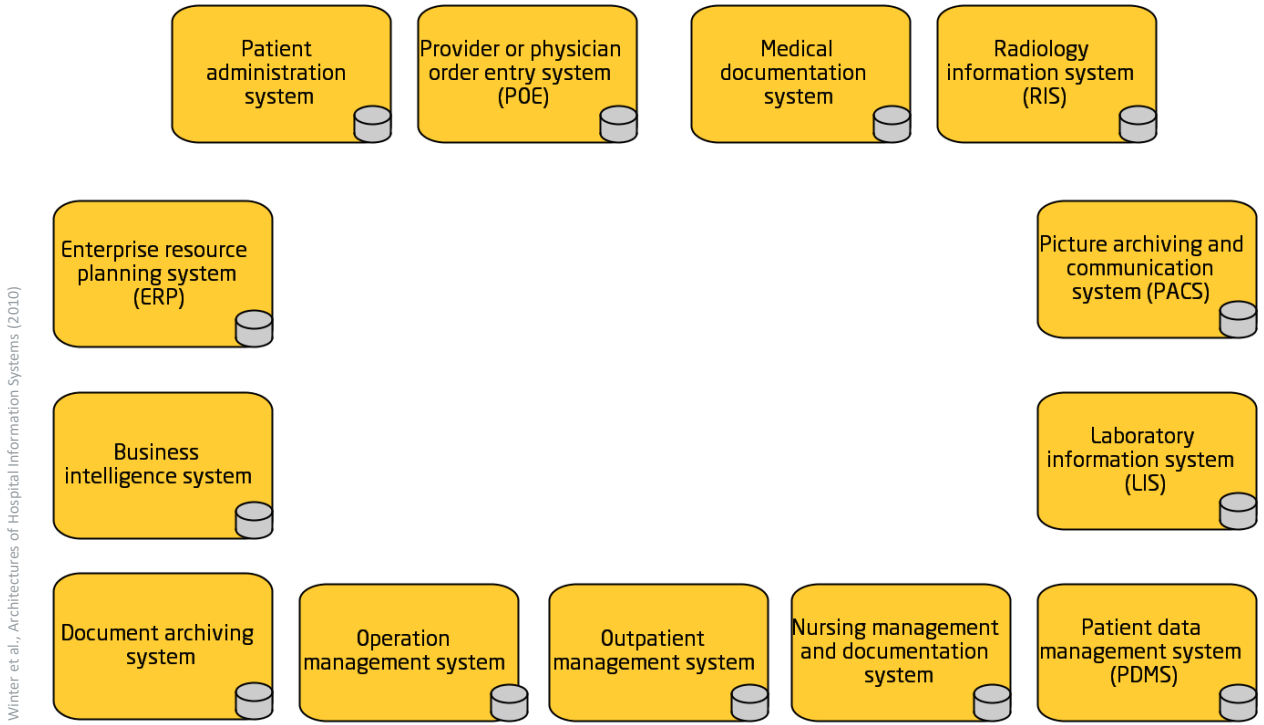



Multiple software components within one facility



A. Winter, R. Haux, E. Ammenwerth, B. Brigl, N. Hellrung, F. Jahn. Health Information Systems: Architectures and Strategies (2010)

# Software Components
# Hospital Information Systems (Reference Architecture)




Each software component carries appendant data → could cause data redundancy



A. Winter, R. Haux, E. Ammenwerth, B. Brigl, N. Hellrung, F. Jahn. Health Information Systems: Architectures and Strategies (2010)

# Software Components
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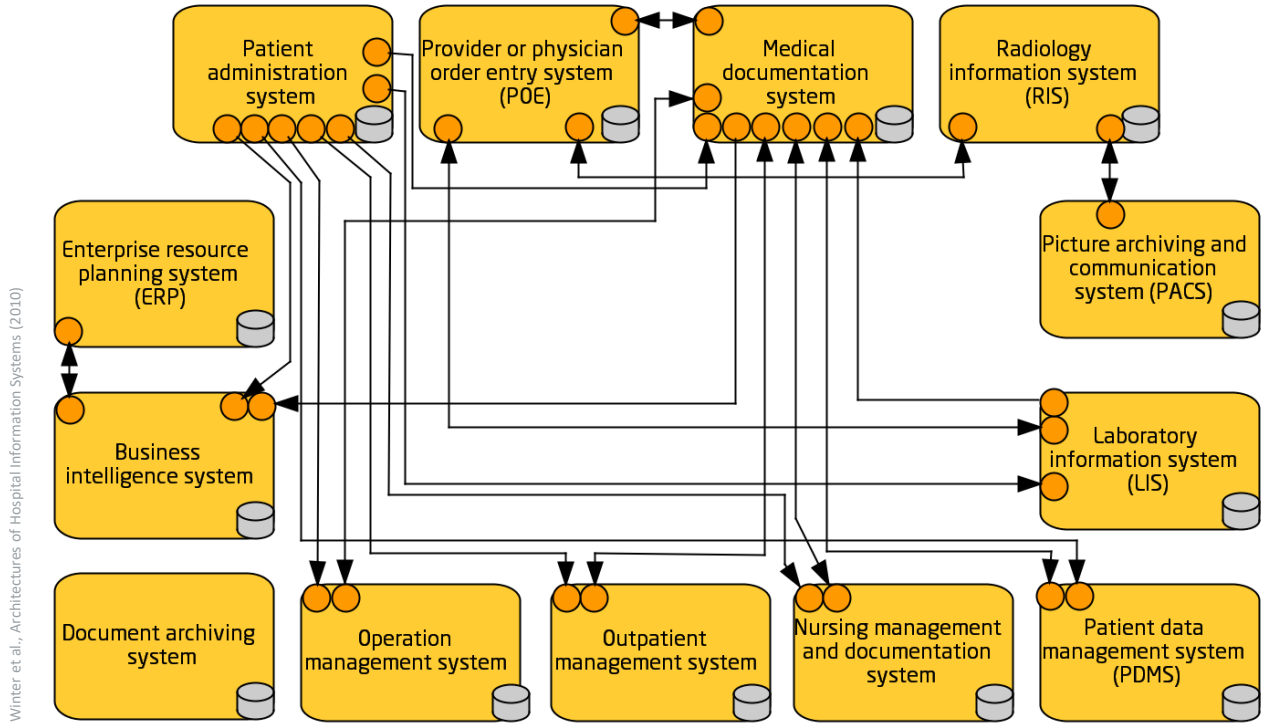
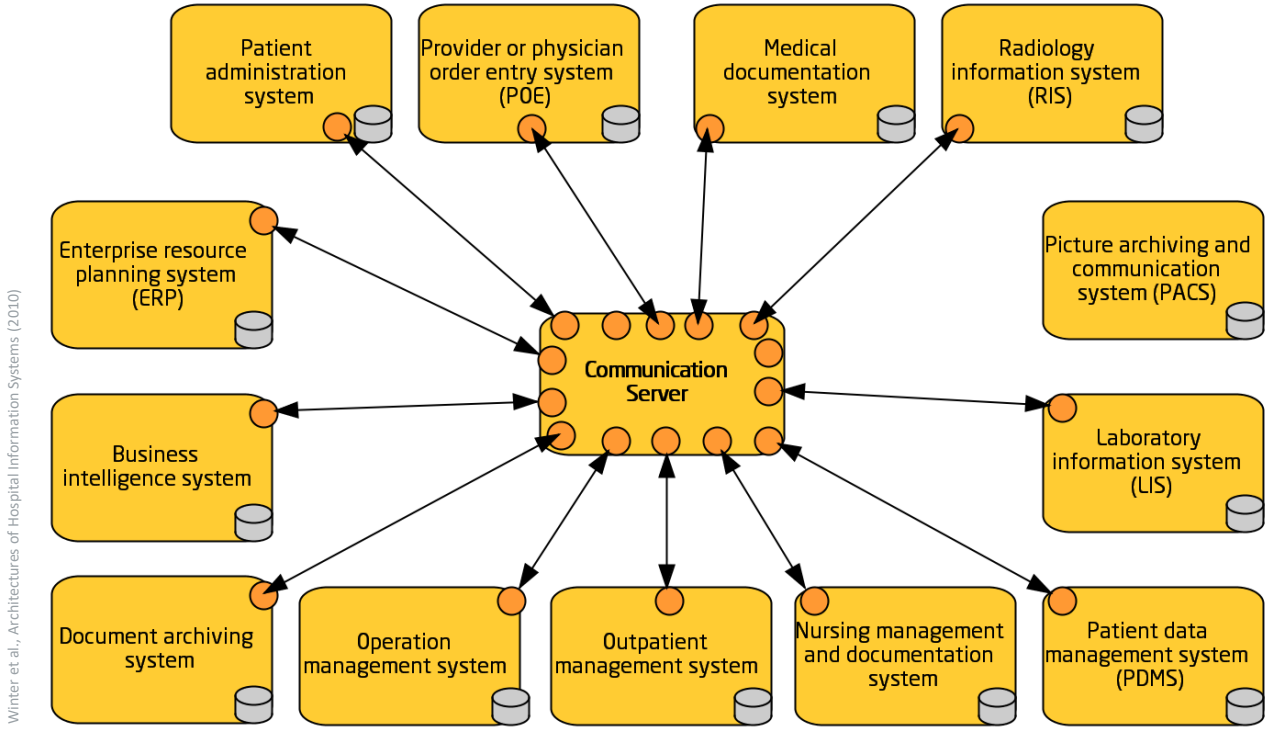



Spaghetti-styled communication pattern (direct connection) lead to an increasing number of bidirectional communication interfaces

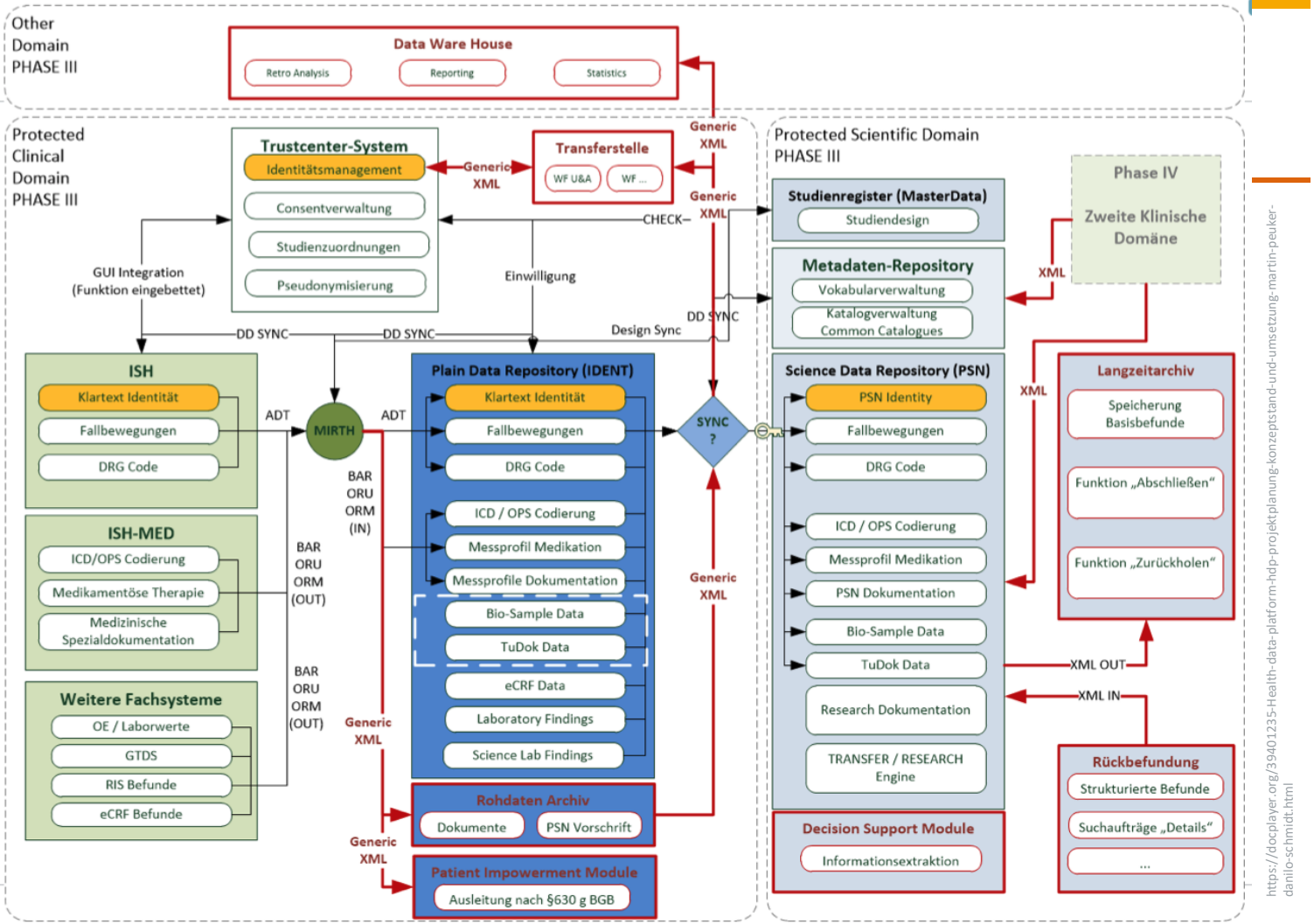
A. Winter, R. Haux, E. Ammenwerth, B. Brigl, N. Hellrung, F. Jahn. Health Information Systems: Architectures and Strategies (2010)

# Software Components
## Hospital Information Systems (Reference Architecture)




Star-styled communication pattern is smarter and reduces the large number of interfaces

A. Winter, R. Haux, E. Ammenwerth, B. Brigl, N. Hellrung, F. Jahn. Health Information Systems: Architectures and Strategies (2010)




https://docplayer.org/39401235-Health-data-platform-hdp-projektplanung-konzeptstand-und-umsetzung-martin-peuker-danilo-schmidt.html

… and that’s reality

# Software Components
# Summary

- Different software components can be found within one hospital; often with its own
  - Database
  - Application components
  - Software products and vendors
  - Patterns of communication

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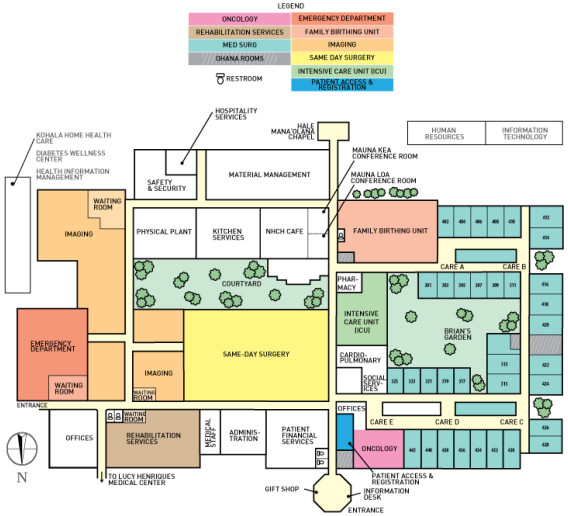
# Questions?

# Agenda

- Electronic Medical Records and Electronic Health Records
- Hospital Enterprise Functions
- Software Tools in a Hospital
- **Standardization**
  - How does communication work between the different software components?

# Standardization

- So far, we have seen that a hospital
  - is staffed by a wide variety of healthcare professionals,
  - contains one ore more departments/wards and has
  - various tasks, data, software
- There is some **crossover** between departments
- For example, physiotherapists often work in different departments and doctors often do the same, working on a general medical ward as well as an intensive or coronary care unit
- But how does communication and data exchange work?

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# Data Harmonization through Coding Systems Diagnoses and Procedures

- Imagine you would be in different breakout rooms and each group would have the task to discuss the condition of the same patient, but from different perspectives:
  - Different profession
  - Different ward, …
- How would you ensure data exchange and interoperability?
- Please write your thoughts in the “Shared Notes” section

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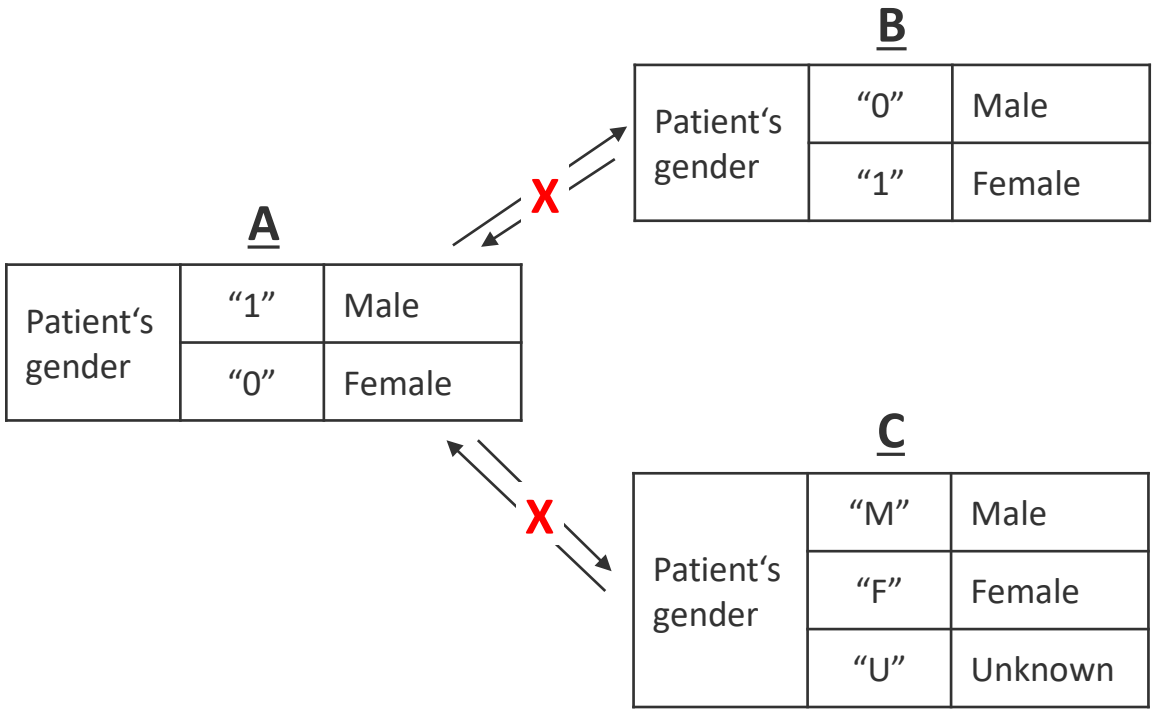
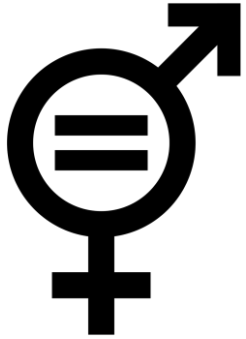
# Interoperability
## Data Format Standards vs. Data Exchange Standards




- A and B differ syntactically and cannot interoperate without translation
- A and C differ semantically
- A cannot represent the concept “Unknown”

# Interoperability
## Data Format Standards vs. Data Exchange Standards

- If this simple example can already lead to such complexity!? Just imagine concepts as diagnosis → That's why we need data standards



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= COMPLEXITY

DIAGNOSIS

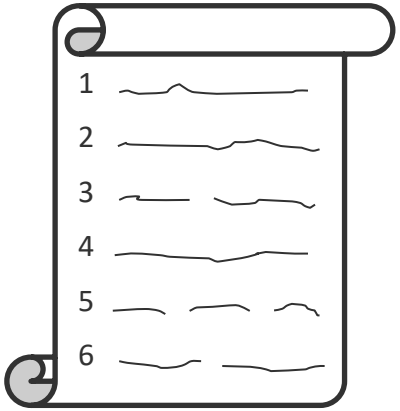
https://www.hiclipart.com/free-transparent-background-png-clipart-oqfen

= ???

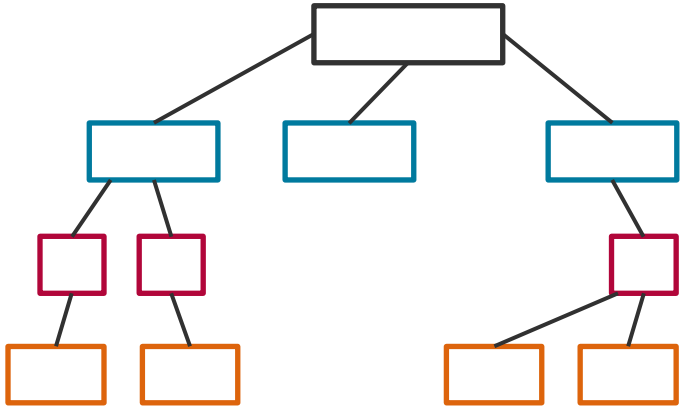
# Structural Standards

- Early data standards were lists, such as medical diagnosis, lab tests or medications
- **Classification :=** A systematic arrangement of similar objects, concepts, and other entities on the basis of certain differing characteristics
- **Ontology :=** A formal specification of how to represent relationships among objects, concepts, and other entities belonging to a particular area of human experience or knowledge

CLASSIFICATION

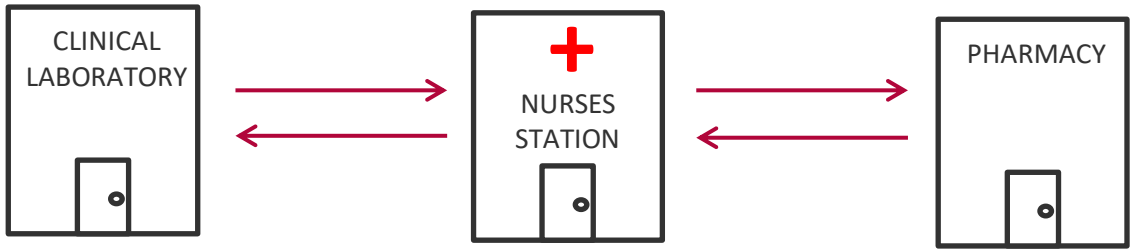



ONTOLOGY



# Standardization
# Physician Notes

- Precomputing, all early standards were for data
- Physicians would use International Code of Disease (ICD) → Classification



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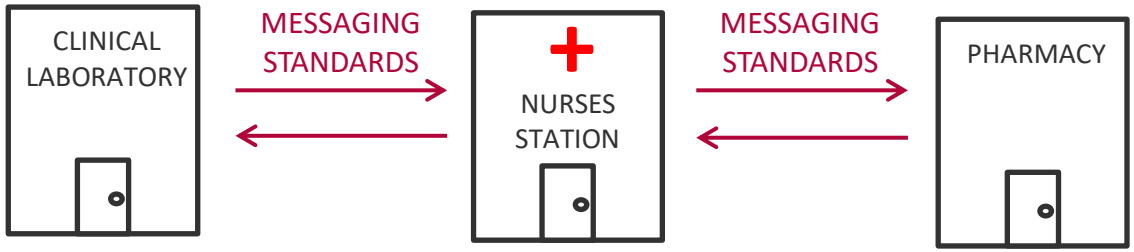
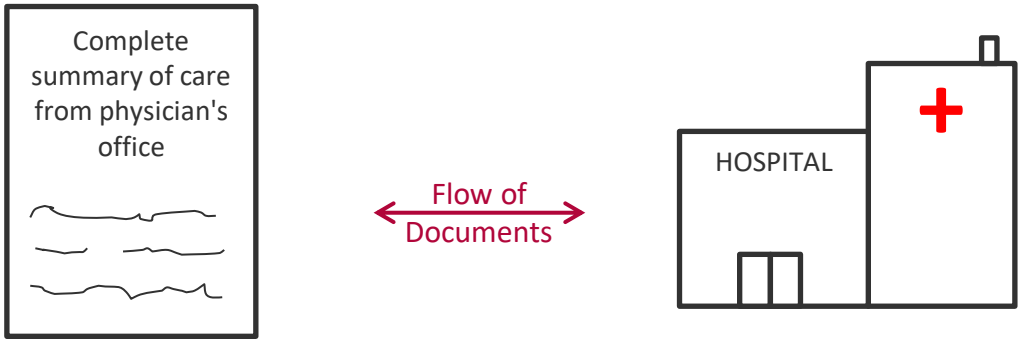


# Standardization
# Next Evolution

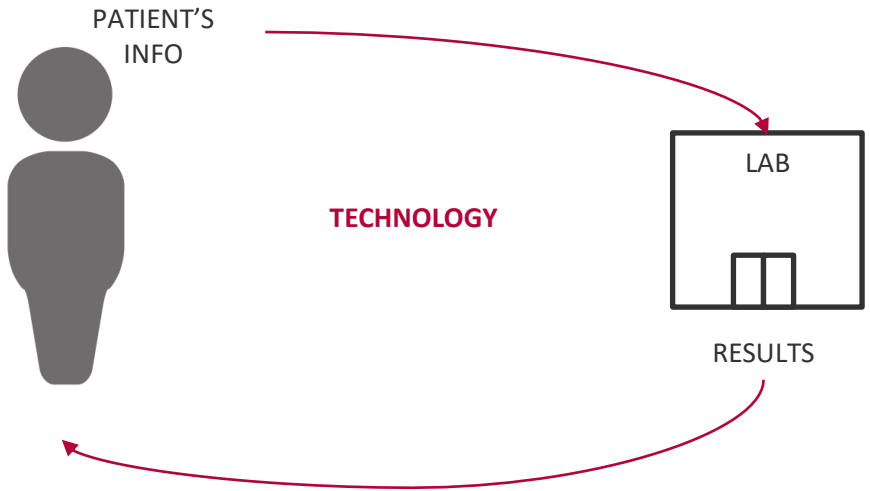
- Next evolution was standards for clinical documents → Document standards




- As computers have become more powerful, standards have been evolving to represent clinical workflows and processes

# Standardization Technology

- Data exchange standards: electronic messages are constructed out of fields using data standards
- Must be understood by the receiver's systems




## Example Data Standards

- International Classification of Diseases (**ICD**) – Diagnosis
- Logical Observation Identifiers Names and Codes (**LOINC**) – Lab tests & observations
- Systematized Nomenclature for Medicine (**SNOMED**) – Medicine

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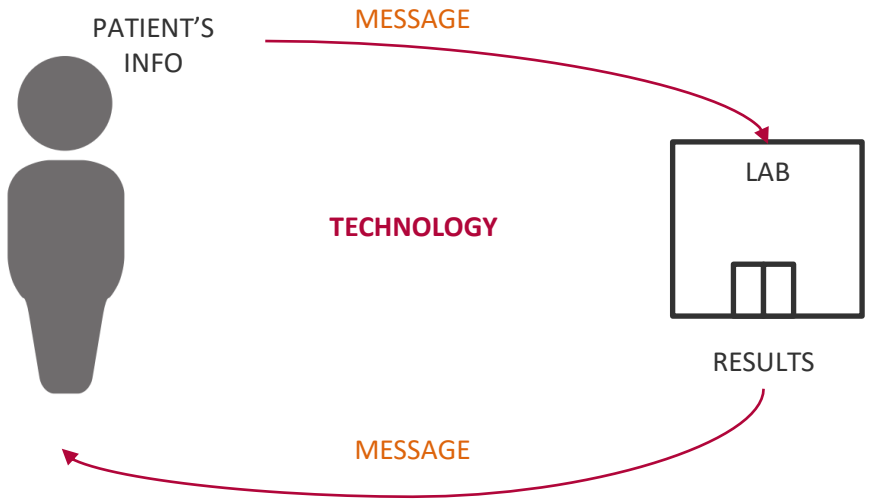


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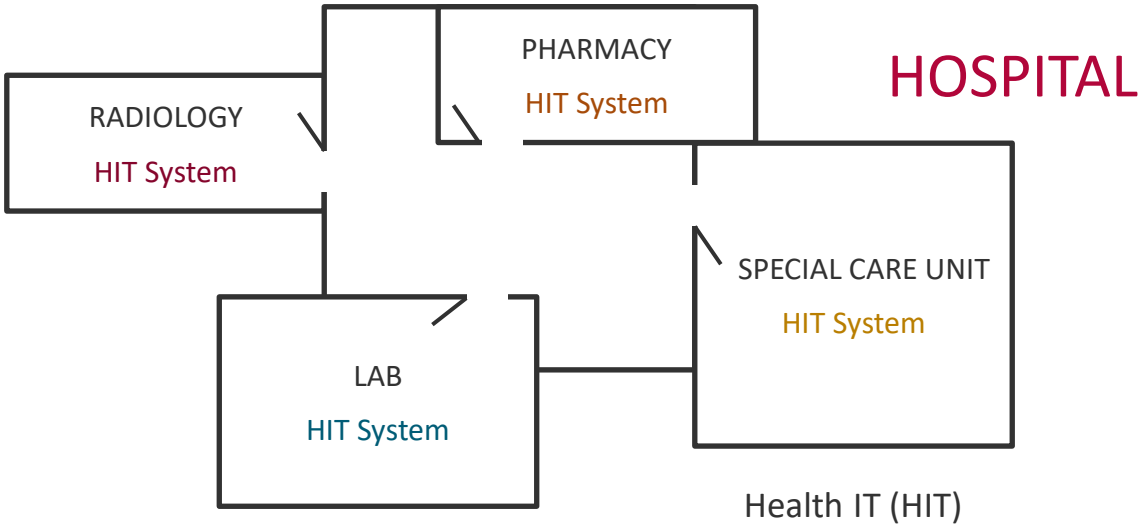
# Standardization Messages

- To be maximally useful in care coordination, the standardized data, typically along with other non-standardized data such as free-text notes, must be packaged into standard clinical documents and sent using standard message formats



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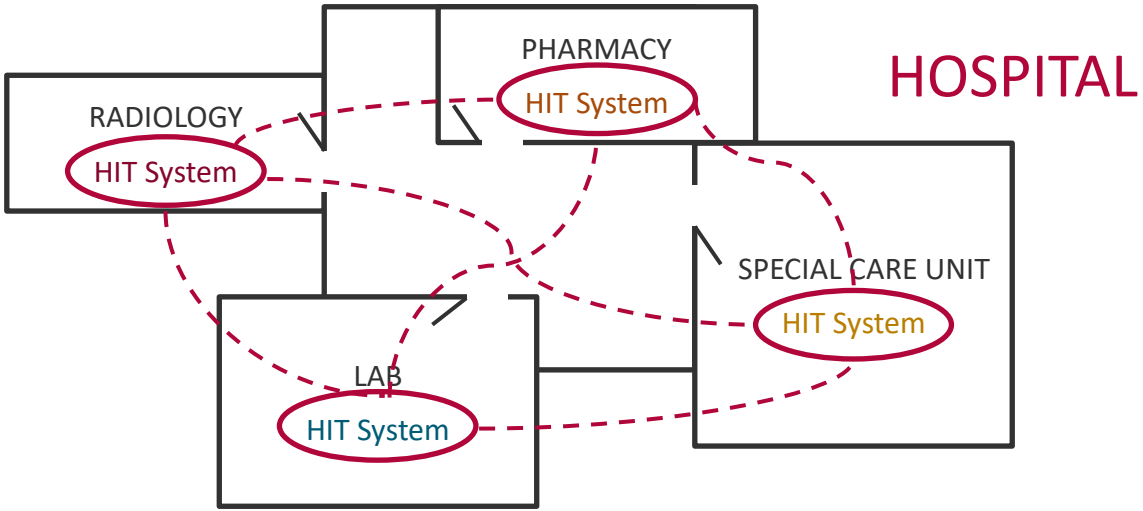


# Medical Data Formats
# Standards for Data Exchange

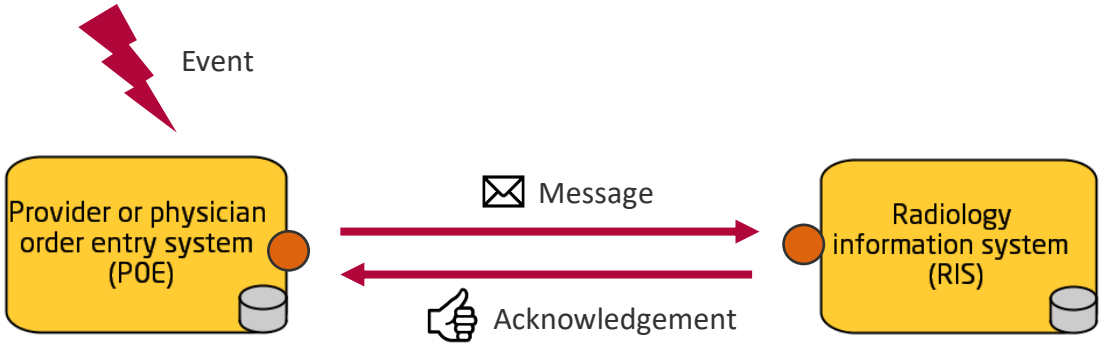
- Health Level 7 – **HL7**
- Fast Healthcare Interoperable Resources – **FIHR**
- Digital Imaging and Communications in Medicine – **DICOM**
- ISO/IEEE 11073
- Integrating the Healthcare Enterprise – **IHE**
- Clinical Document Architecture – **CDA**
- …






# Health Level 7 (HL7)

- Describes message and event types exchanged between application components
- Event-driven communication
- Example messages:
  - Admission Discharge Transfer (ADT)
  - Order entry message (ORM)



# Health Level 7 (HL7)

- 51 different types of ADT messages

```
MSH|^~\&|AcmeHIS|StJohn|ADT|StJohn|20050518073622||ADT^A01|MSGID
20050518073622|P|2.3
EVN|A01
```

| | |
|---|---|
| PID\|\|\|12001\|\|Jones^John^^^Mr.\|\|19670822\|M\|\|\|123 West St.^^Denver^CO^80020^USA\|\|(850)555-0809\|\|\|\|\|99345\|460-99-2928 | PID – Patient Info |
| PV1\|\|I\|Main^802^1\|\|\|\|^Quacker^John\|\|\|IP\|\|\|\|\|\|\|\|1\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|20050518073622 | PV1 – Visit Info |
| IN1\|1\|EPO\|80\|AETNA US HEALTHCARE\|PO BOX 981114^""^EL PASO^TX^79998^""\|\|\|1500004000001\|AETNA SERVICES INC\|19\|AETNA US HEALTHCARE\|""\|""\|\|2\|SOUTAR^RENEE^D\|3\|19700722\|13324 WHITE CEMETERY RD^""^HANNIBAL^NY^130740000^""\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|\|124705454\|\|\|\|\|\|1\|F\|225 GREENFIELD PARKWAY^^LIVERPOOL^NY^13088\|185428<br>IN2\|1\|\|124705454\|\|461-1200\|\|\|\|\| | IN1 & IN2 Insurance Info |

https://corepointhealth.com/resource-center/hl7-resources/hl7-adt

# Standardization
# Summary

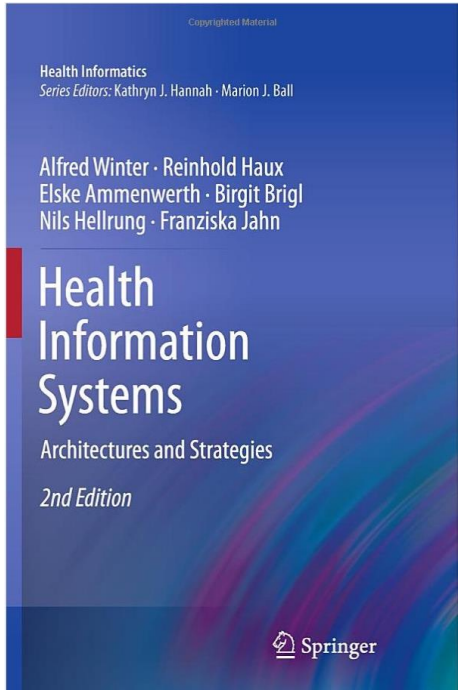
- By adopting data standards, the healthcare industry could:
  - Improve patient safety
  - Raise quality
  - Eliminate waste
  - Reduce costs
  - Increase accuracy
  - Reduce unnecessary testing and hospital stays

# To Know More

Winter, A., Haux, R., Ammenwerth, E., Brigl, B., Hellrung, N., & Jahn, F. (2010). Health information systems. In *Health Information Systems* (pp. 33-42). Springer, London.

Architecture of Hospital Information Systems

**Chapter 6**



# What to Take Home?

- Medical informatics is a broad field with many different standards, terminologies and applications
- There is an abundance of data and software tools in hospitals
- You know about the challenges faced by health data interoperability

Hasso Plattner Institut

# Questions?