*Séminaires Recherche et Pratique en Santé Publique*

Institut de Santé Publique d'Epidémiologie et de Développement

Université de Bordeaux, France

October 11, 2019

# Interoperability for clinical analytics

*Observational Health Data Sciences and Informatics (OHDSI)*


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U.S. National Library of Medicine

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# Outline

- Observational Health Data Sciences and Informatics (OHDSI)
  - OHDSI in action
    - Analyzing drug treatment pathways for 3 chronic diseases from clinical data warehouse in multiple countries
  - How do they do that?
- The context of clinical data science
  - Datasets
  - Data models
  - Terminologies
- Current trends and future directions

# Observational Health Data Sciences and Informatics (OHDSI)

# OHDSI Outline

- OHDSI in action
  - Analyzing drug treatment pathways for 3 chronic diseases from clinical data warehouse in multiple countries
- How do they do that?
  - From OMOP to OHDSI
  - Foundational principles
  - OHDSI software, test data and methods

# Characterizing treatment pathways at scale using the OHDSI network

CrossMark click for updates

COLLOQUIUM PAPER

## Characterizing treatment pathways at scale using the OHDSI network

George Hripcsak[a,b,c,1], Patrick B. Ryan[c,d], Jon D. Duke[c,e], Nigam H. Shah[c,f], Rae Woong Park[c,g], Vojtech Huser[c,h], Marc A. Suchard[c,i,j,k], Martijn J. Schuemie[c,d], Frank J. DeFalco[c,d], Adler Perotte[a,c], Juan M. Banda[c,f], Christian G. Reich[c,l], Lisa M. Schilling[c,m], Michael E. Matheny[c,n,o], Daniella Meeker[c,p,q], Nicole Pratt[c,r], and David Madigan[c,s]

www.pnas.org/cgi/doi/10.1073/pnas.1510502113 PNAS | July 5, 2016 | vol. 113 | no. 27 | 7329–7336

# Characterizing treatment pathways at scale using the OHDSI network

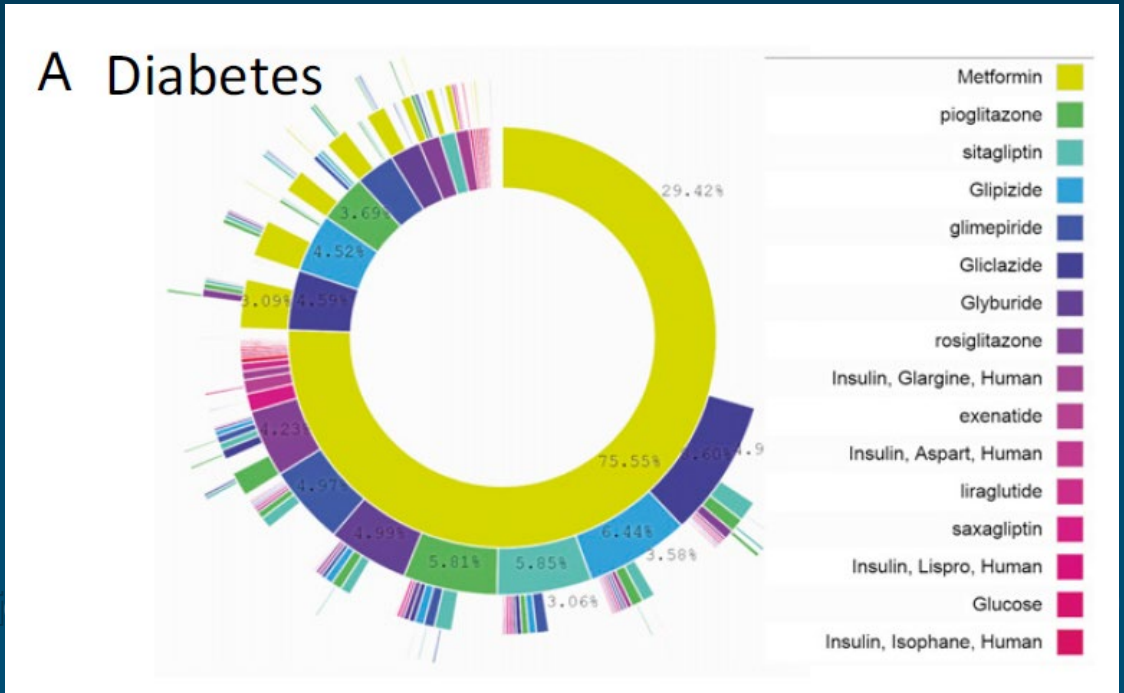
- Objectives: analyze the variability of pharmacological treatment interventions over three years across three diseases (type-2 diabetes mellitus, hypertension, or depression)
- Inclusion criteria: exposure to an antidiabetic, antihypertensive, or antidepressant medication for 3 years, as well as presence of at least one diagnostic code for the corresponding disease
- Exclusion criteria: based on diagnostic data (e.g., exclusion of schizophrenia patients from the depression cohort)

# Characterizing treatment pathways at scale using the OHDSI network

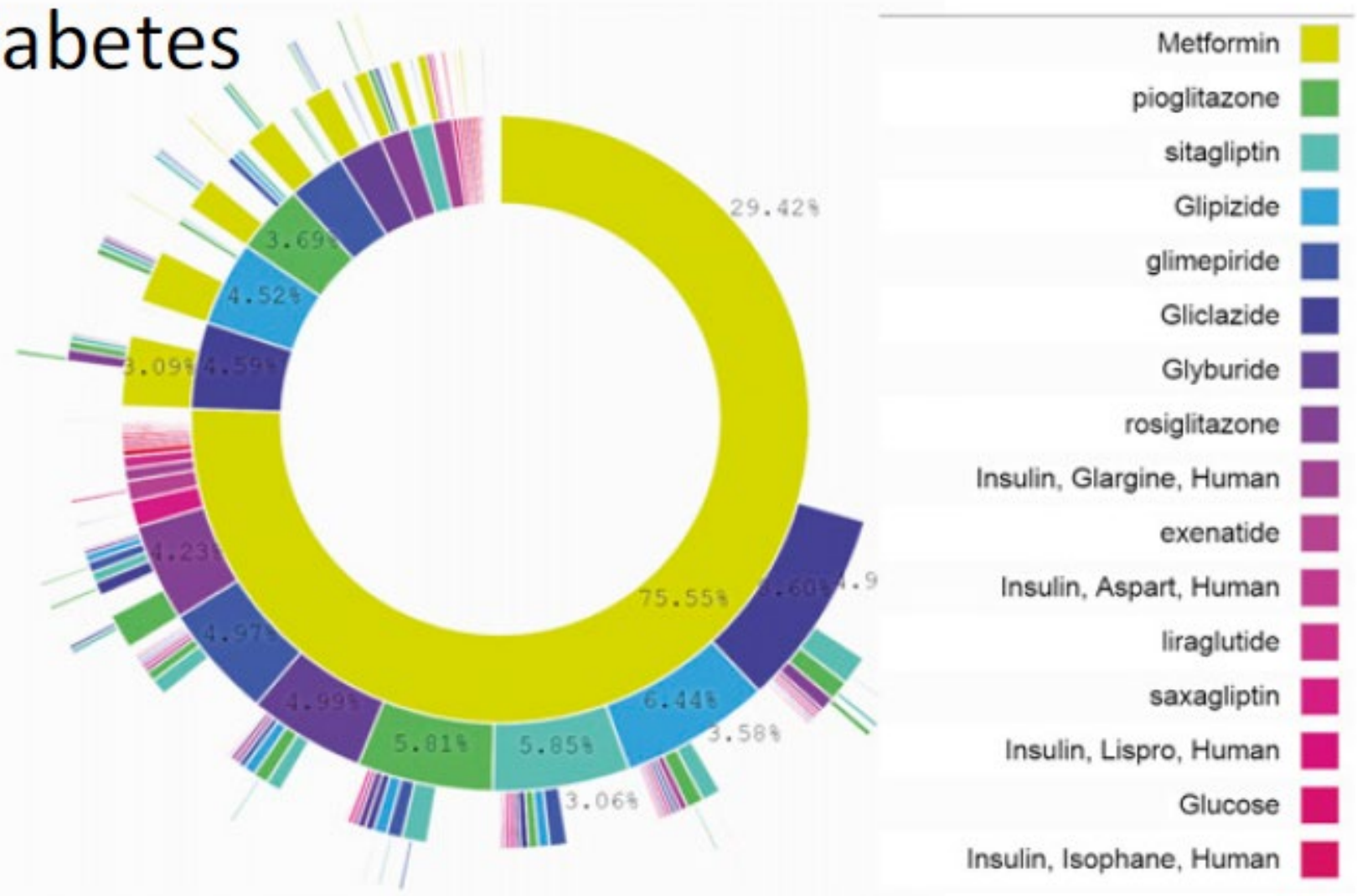
- Materials: 11 datasets representing a total of 255 million patients
  - EHR data (South Korea, U.K., U.S.) 67M
  - Claims data (U.S., Japan) 188M
- Methods: Analyze the sequences of medications that patients were placed on during those 3 years, to reveal patterns and variation in treatment among data sources and diseases

# Characterizing treatment pathways at scale using the OHDSI network

- Results
  - Patients with 3 years of uninterrupted therapy
    - 327,110 diabetes patients
    - 1,182,792 hypertension patients
    - 264,841 depression patients
  - Treatment pathways

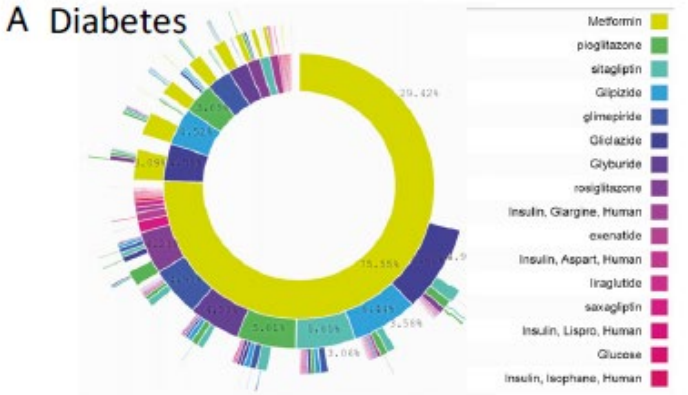


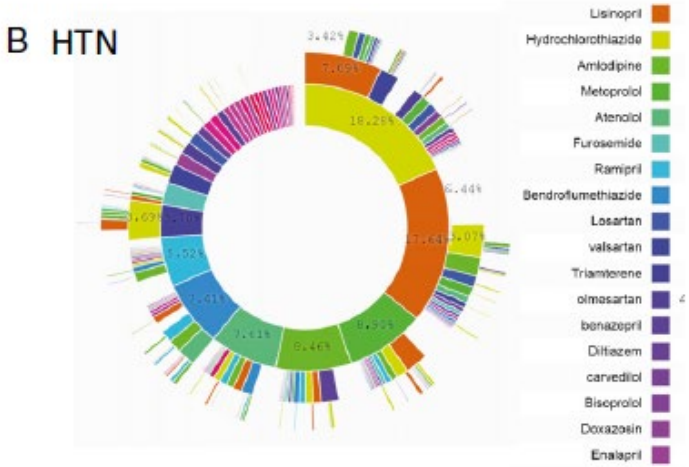
# A Diabetes

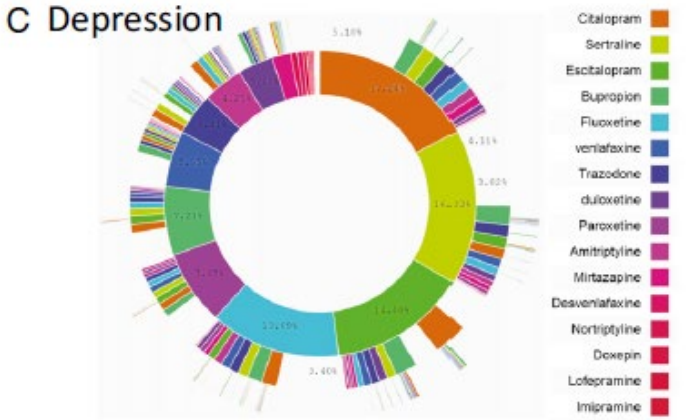

29.42%
75.55%
6.44%
5.85%
5.01%
4.99%
4.97%
4.23%
3.09%
4.52%
3.69%
3.58%
3.06%
Metformin
pioglitazone
sitagliptin
Glipizide
glimepiride
Gliclazide
Glyburide
rosiglitazone
Insulin, Glargine, Human
exenatide
Insulin, Aspart, Human
liraglutide
saxagliptin
Insulin, Lispro, Human
Glucose
Insulin, Isophane, Human

# Differences across diseases

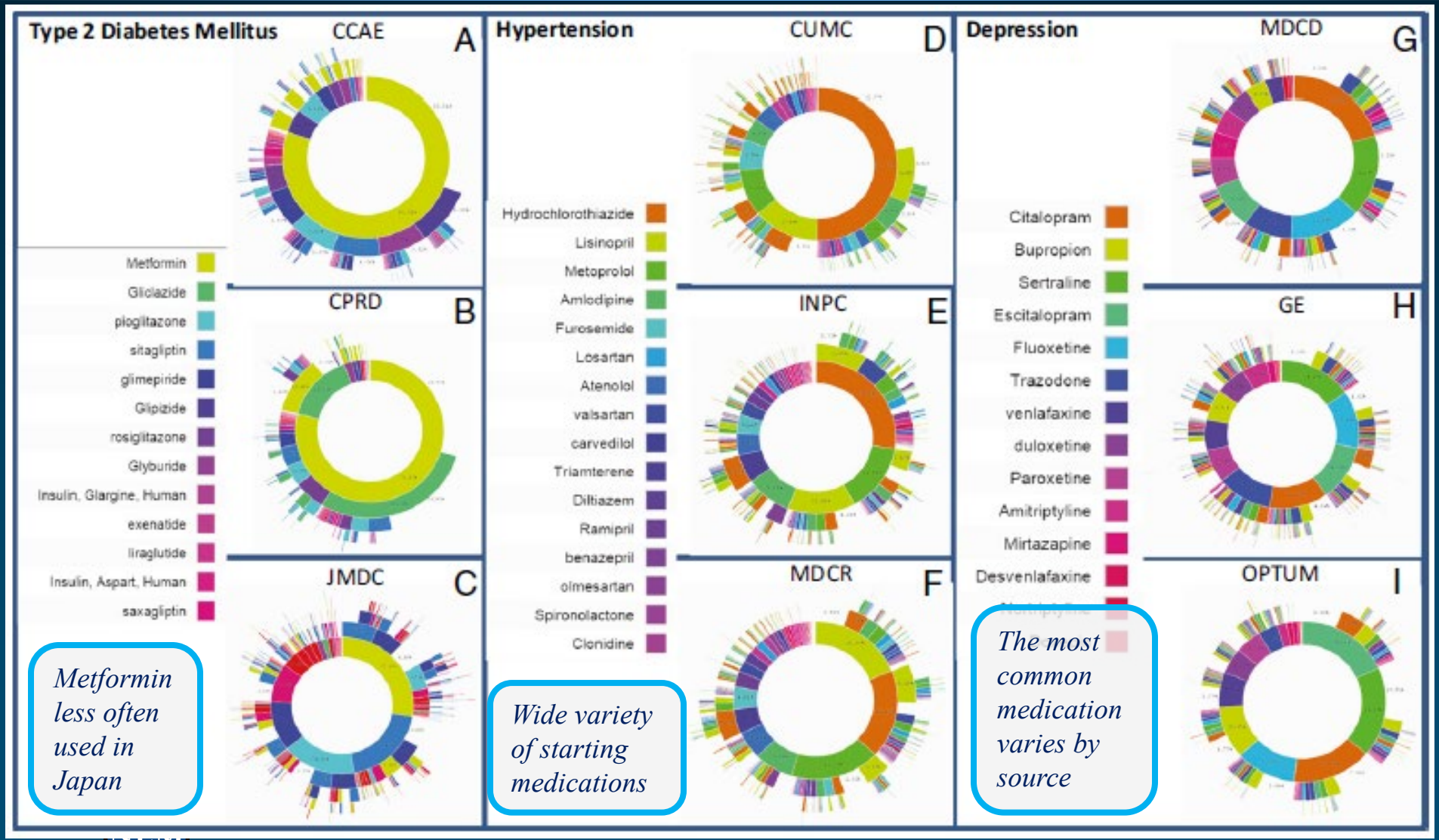
- Diabetes
  - Metformin is the first line of treatment and often the only treatment
- Hypertension
  - Slight predominance of HCTZ, frequently paired with other medications
- Depression
  - Even spread of medications
- Unique treatment pathways (within a cohort)
  - 10% TDM
  - 25% HTN



# Differences across countries



# From OMOP to OHDSI

- OMOP – Observational Medical Outcomes Partnership
  - Public-private partnership established to inform the appropriate use of observational healthcare databases for studying the effects of medical products (2008-2013)
  - Community of researchers from industry, government, and academia
  - Achievements
    - Conduct methodological research to empirically evaluate the performance of various analytical methods on their ability to identify true associations and avoid false findings
    - Develop tools and capabilities for transforming, characterizing, and analyzing disparate data sources across the health care delivery spectrum
    - Establish a shared resource so that the broader research community can collaboratively advance the science

# From OMOP to OHDSI

- OHDSI – Observational Health Data Sciences and Informatics
  - Multi-stakeholder, interdisciplinary collaborative to bring out the value of health data through large-scale analytics
  - International network of researchers and observational health databases with a central coordinating center housed at Columbia University
  - Continues to actively use the OMOP Common Data Model and Standardized Vocabularies
  - Develops open-source solutions [with Greek names]
  - Annual symposium

# Foundational principles

- Data standardization through
  - Common data model (OMOP CDM)
  - Standard vocabularies
- Conversion (ETL) of the local clinical data warehouse to the OMOP CDM and standard vocabularies
  - Supported by the *RabbitInAHat* tool
- Applicable to various types of observational data (EHR, claims)
- Data remain local to a clinical institution
- The same query/protocol can be executed at each site and the results aggregated across sites
- Research projects are based on rigorous protocols
- Open science (Open-source software, open protocols, open results)

# OHDSI (open-source) software

- Tools for mapping data to OHDSI
  - WhiteRabbit – profile your source data
  - RabbitInAHat – map your source structure to CDM tables and fields
  - ATHENA – standardized vocabularies for all CDM domains
  - Usagi – map your source codes to CDM vocabulary
  - ACHILLES – database characterization and data quality assessment

# OHDSI (open-source) software

- CALYPSO – analytical component for clinical study feasibility assessment
- CIRCE – cohort creation
- HERACLES – cohort-level analysis and visualization
- LAERTES – system for investigating the association of drugs and health (adverse events)
- DRUG EXPOSURE EXPLORER – visualize drug exposures (an experimental deployment using the SynPUF 1% simulated patient data set)
- […]

# OHDSI methods

- Types of methods
  - Population-Level Estimation
    - Safety surveillance
    - Comparative effectiveness
  - Patient-Level Prediction
- Effect estimation & calibration
  - Confidence interval calibration
- Implemented with open-source tools for large-scale analytics
  - R packages

# Examples of network research studies

- Characterizing treatment pathways at scale using the OHDSI network
- Levetiracetam and risk of angioedema in patients with seizure disorder
- Comparison of combination treatment in hypertension (against RCTs)
- Drug utilization in children
- Comparative effectiveness of alendronate and raloxifene in reducing the risk of hip fracture

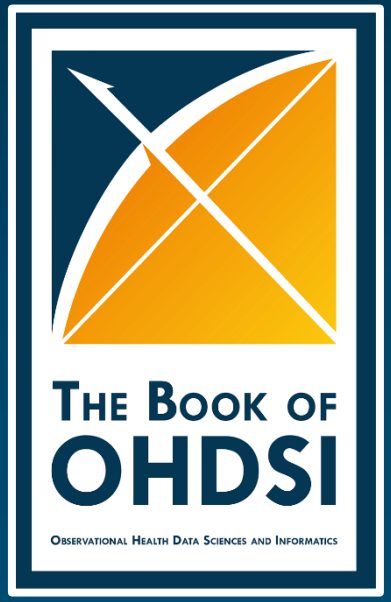
# More about OHDSI

- OHDSI Europe

  https://www.ohdsi-europe.org/

- The Book of OHDSI (Aug. 2019)

  https://ohdsi.github.io/TheBookOfOhdsi/



# The context of clinical data science

# The context of clinical data science Outline

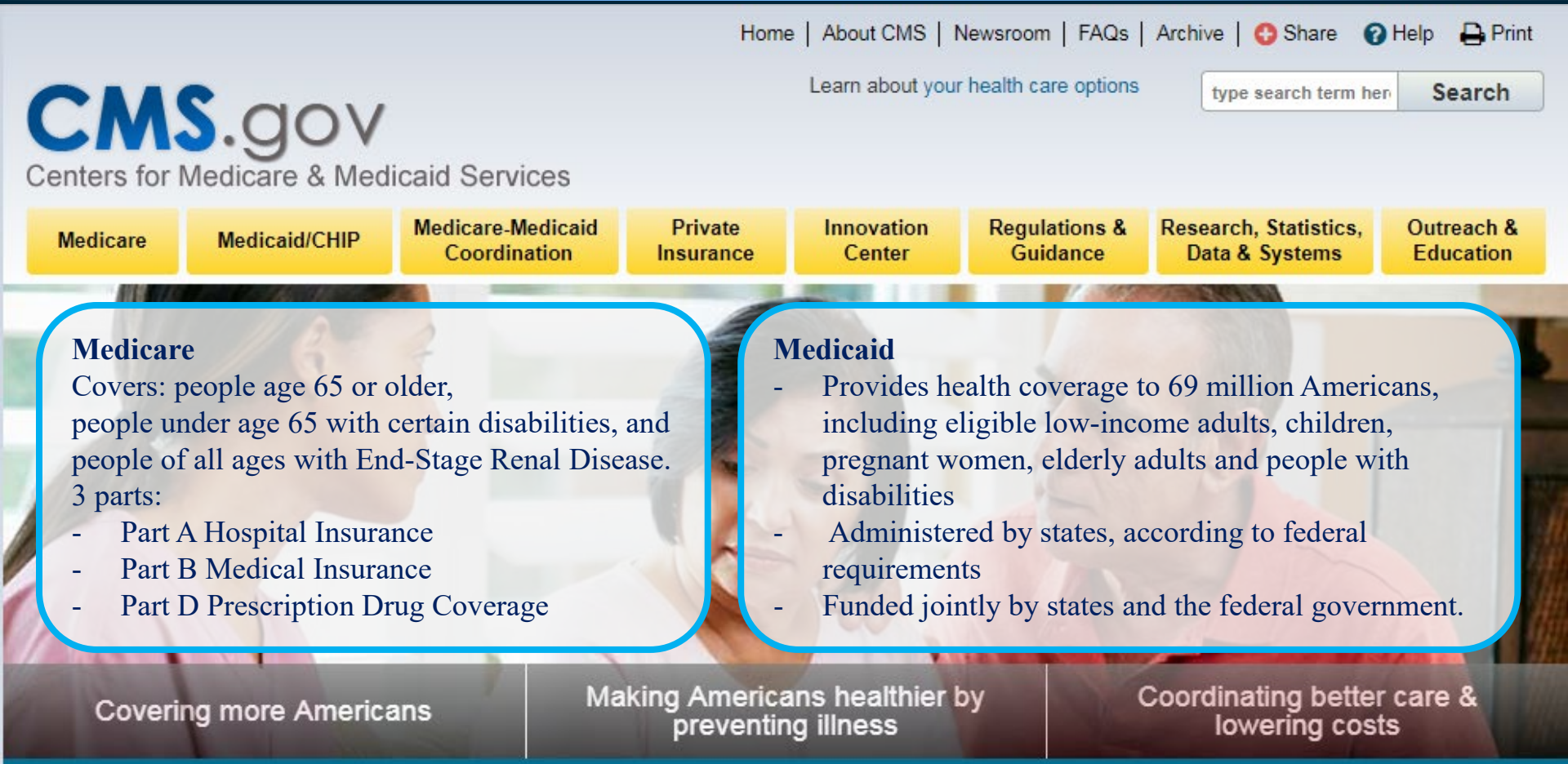
- Datasets
- Data models
- Terminologies

# Datasets

- Center for Medicare and Medicaid (CMS) data
- MIMIC III
- Clinical data warehouses (academic medical centers, Veterans Administration)
- EHR vendors (GE Centricity; EPIC Clarity; Cerner Health Facts)
- Commercial datasets (OPTUM, Truven)

https://www.cms.gov/

# Center for Medicare and Medicaid (CMS)



CMS covers 100 million people...

# Center for Medicare and Medicaid (CMS) data

- Available through the CMS Virtual Research Data Center (VRDC)
  - At a cost
  - Cloud-based environment – data cannot be downloaded
- Longitudinal data available
  - From 1999 for demographics, hospitalization and ambulatory data
  - From 2006 from drug coverage

# Example of use of CMS data

Am J Surg. 2017 Jun 24. pii: S0002-9610(17)30289-1. doi: 10.1016/j.amjsurg.2017.06.007. [Epub ahead of print]

## Outpatient beta-blockers and survival from sepsis: Results from a national cohort of Medicare beneficiaries.

Singer KE[1], Collins CE[1], Flahive JM[2], Wyman AS[1], Ayturk MD[1], Santry HP[3].

Author information

**Abstract**

**BACKGROUND:** Elderly Americans suffer increased mortality from sepsis. Given that beta-blockers have been shown to be cardioprotective in critical care, we investigated outpatient beta-blocker prescriptions and mortality among Medicare beneficiaries admitted for sepsis.

**METHODS:** We queried a 5% random sample of Medicare beneficiaries for patients admitted with sepsis. We used in-hospital and outpatient prescription drug claims to compare in-hospital and 30-day mortality based on pre-admission beta-blocker prescription and class of beta-blocker prescribed using univariate tests of comparison and multivariable logistic regression models and another class of medications for control.

**RESULTS:** Outpatient beta-blocker prescription was associated with a statistically significant decrease in in-hospital and 30-day mortality. In multivariable modeling, beta-blocker prescription was associated with 31% decrease in in-hospital mortality and 41% decrease in 30-day mortality. Both cardioselective and non-selective beta-blockers conferred mortality benefit.

**CONCLUSIONS:** Our data suggests that there may be a role for preadmission beta-blockers in reducing sepsis-related mortality.

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PMID: 28666578 DOI: 10.1016/j.amjsurg.2017.06.007

# MIMIC III

- Medical Information Mart for Intensive Care
- Freely available to researchers worldwide
- Encompasses a diverse and very large population of ICU patients (~40k)
- Includes demographics, vital signs, laboratory tests, medications, and bedside monitor trends and waveforms
- Contains high temporal resolution data

# Example of use of MIMIC data

## Lower short- and long-term mortality associated with overweight and obesity in a large cohort study of adult intensive care unit patients

Swapna Abhyankar ✉, Kira Leishear, Fiona M Callaghan, Dina Demner-Fushman and Clement J McDonald

*Critical Care* 2012 **16**:R235 | **DOI:** 10.1186/cc11903 © Abhyankar et al.; licensee BioMed Central Ltd. 2012

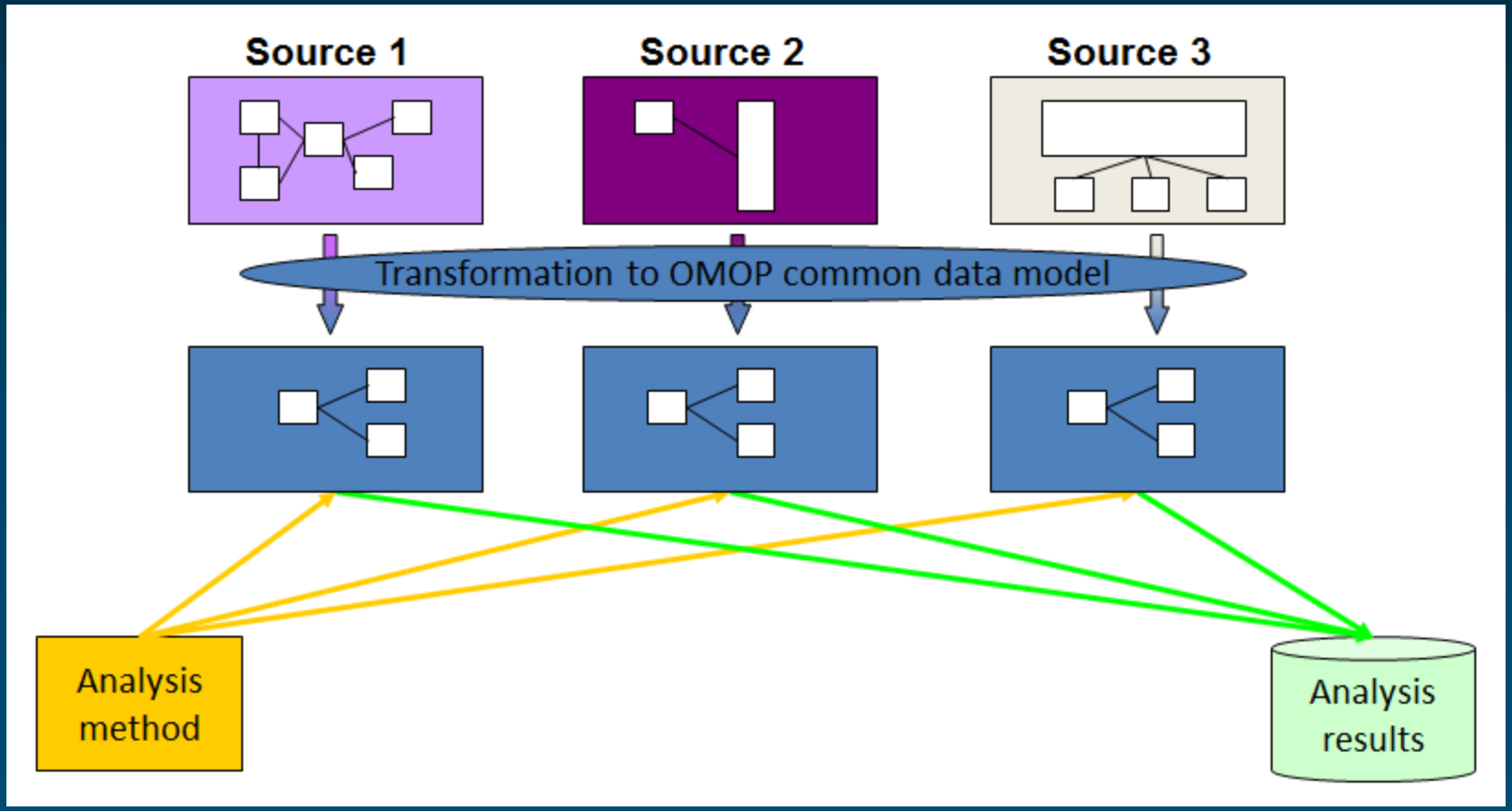
**Received:** 2 August 2012 | **Accepted:** 13 December 2012 | **Published:** 18 December 2012

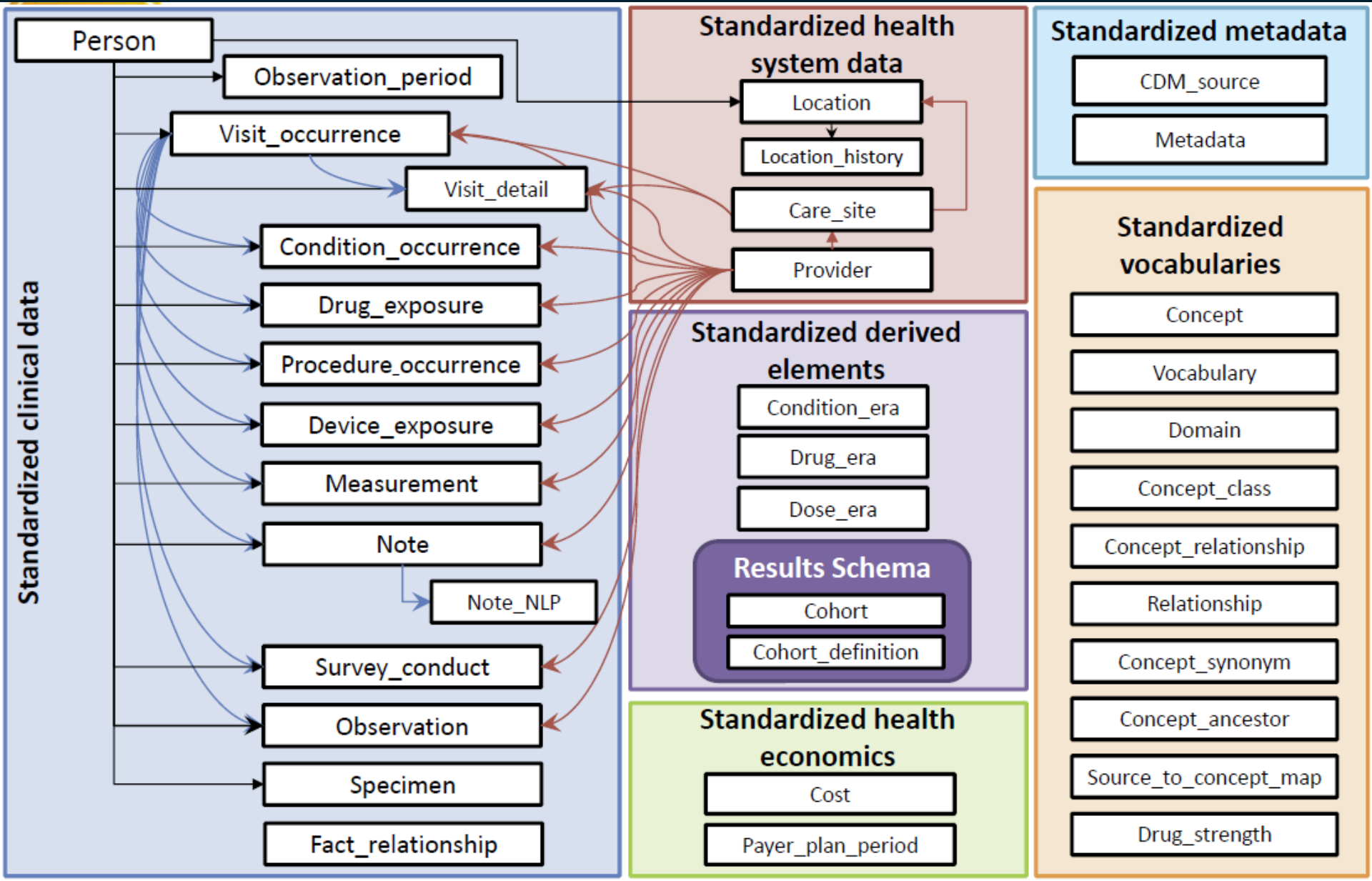
# Data models

- OMOP
- i2b2
- PCORnet
- Sentinel
- CDISC

# OMOP

- OMOP – Observational Medical Outcomes Partnership

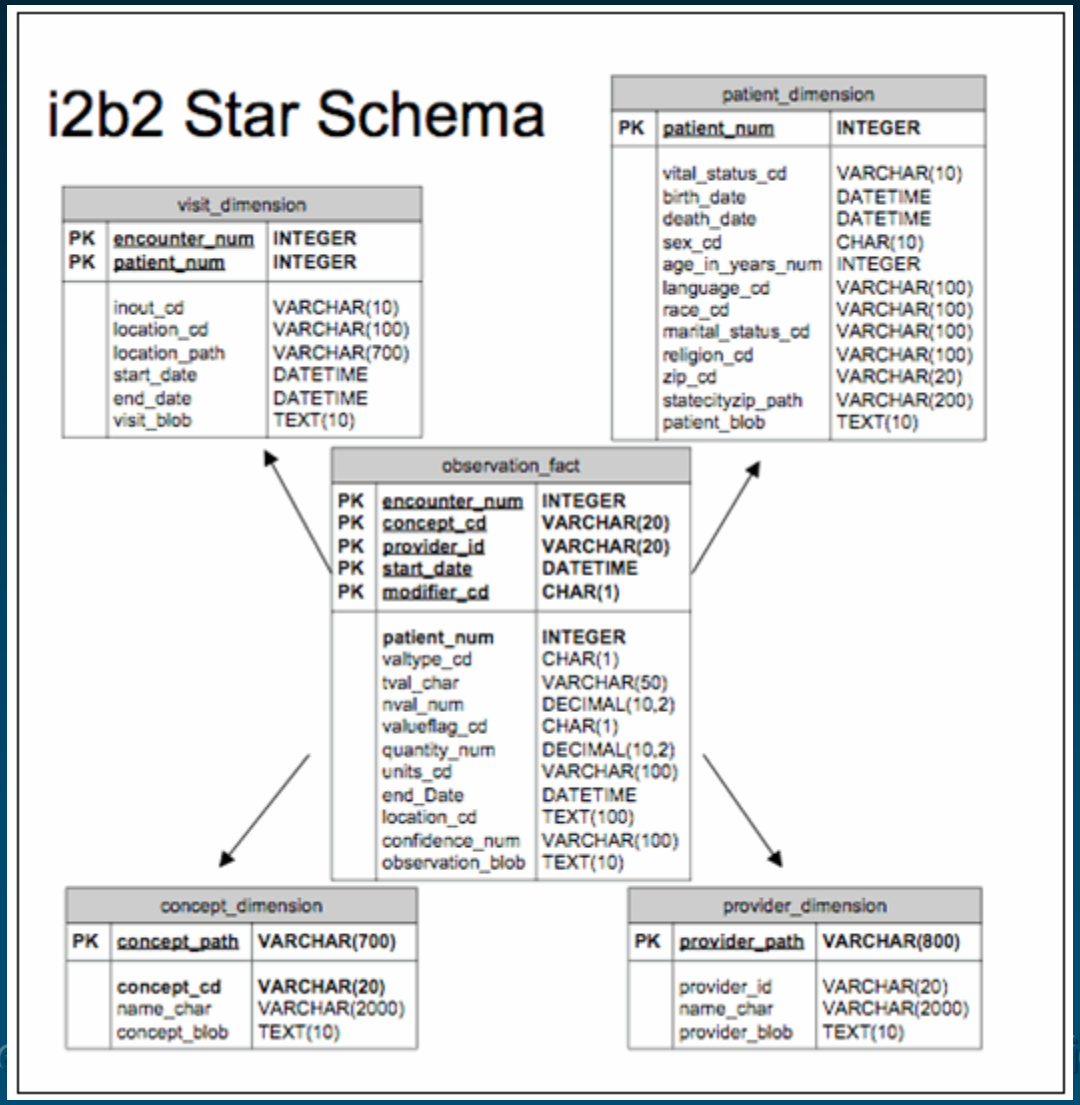



Standardized clinical data
Person
Observation_period
Visit_occurrence
Visit_detail
Condition_occurrence
Drug_exposure
Procedure_occurrence
Device_exposure
Measurement
Note
Note_NLP
Survey_conduct
Observation
Specimen
Fact_relationship
Standardized health system data
Location
Location_history
Care_site
Provider
Standardized derived elements
Condition_era
Drug_era
Dose_era
Results Schema
Cohort
Cohort_definition
Standardized health economics
Cost
Payer_plan_period
Standardized metadata
CDM_source
Metadata
Standardized vocabularies
Concept
Vocabulary
Domain
Concept_class
Concept_relationship
Relationship
Concept_synonym
Concept_ancestor
Source_to_concept_map
Drug_strength

# i2b2

- i2b2 – Informatics for Integrating Biology & the Bedside
- Originally developed by the i2b2 National Center for Biomedical Computing (2004-2013)
  - Now i2b2 tranSMART Foundation
- Platform to support translational research
- Widely adopted worldwide

# i2b2 data model – original "star schema"



# i2b2-OMOP convergence

- i2b2 on OMOP
  - Supports query formulation against an OMOP-compliant data source through i2b2 tools

# PCORnet

- PCORnet – National Patient-Centered Clinical Research Network
- Initiative of the Patient-Centered Outcomes Research Institute (PCORI)
  - Funded through the Patient Protection and Affordable Care Act of 2010
- "designed to make it faster, easier, and less costly to conduct clinical research"
- Made up of
  - 13 Clinical Data Research Networks (CDRNs)
  - 20 Patient-Powered Research Networks (PPRNs)

Current version is 4.1

http://www.pcornet.org/pcornet-common-data-model/

# PCORnet Common Data Model v3.0

New to v3.0

**DEMOGRAPHIC**
**PATID**
BIRTH_DATE
BIRTH_TIME
SEX
HISPANIC
RACE
BIOBANK_FLAG

Fundamental basis

**ENROLLMENT**
**PATID**
**ENR_START_DATE**
ENR_END_DATE
CHART
**ENR_BASIS**

**DISPENSING**
**DISPENSINGID**
**PATID**
PRESCRIBINGID (optional)
**DISPENSE_DATE**
**NDC**
DISPENSE_SUP
DISPENSE_AMT

**DEATH**
**PATID**
**DEATH_DATE**
DEATH_DATE_IMPUTE
**DEATH_SOURCE**
DEATH_MATCH_CONFIDENCE

**DEATH_CONDITION**
**PATID**
**DEATH_CAUSE**
**DEATH_CAUSE_CODE**
**DEATH_CAUSE_TYPE**
**DEATH_CAUSE_SOURCE**
DEATH_CAUSE_CONFIDENCE

Data captured from processes associated with healthcare delivery

**VITAL**
**VITALID**
**PATID**
ENCOUNTERID (optional)
**MEASURE_DATE**
MEASURE_TIME
**VITAL_SOURCE**
HT
WT
DIASTOLIC
SYSTOLIC
ORIGINAL_BMI
BP_POSITION
SMOKING
TOBACCO
TOBACCO_TYPE

**CONDITION**
**CONDITIONID**
**PATID**
ENCOUNTERID (optional)
REPORT_DATE
RESOLVE_DATE
ONSET_DATE
CONDITION_STATUS
**CONDITION**
**CONDITION_TYPE**
**CONDITION_SOURCE**

**PRO_CM**
**PRO_CM_ID**
**PATID**
ENCOUNTERID (optional)
**PRO_ITEM**
PRO_LOINC
**PRO_DATE**
PRO_TIME
**PRO_RESPONSE**
PRO_METHOD
PRO_MODE
PRO_CAT

Data captured within multiple contexts: healthcare delivery, registry activity, or directly from patients

**ENCOUNTER**
**ENCOUNTERID**
**PATID**
**ADMIT_DATE**
ADMIT_TIME
DISCHARGE_DATE
DISCHARGE_TIME
PROVIDERID
FACILITY_LOCATION
**ENC_TYPE**
FACILITYID
DISCHARGE_DISPOSITION
DISCHARGE_STATUS
DRG
DRG_TYPE
ADMITTING_SOURCE

**DIAGNOSIS**
**DIAGNOSISID**
**PATID**
**ENCOUNTERID**
*ENC_TYPE (replicated)*
*ADMIT_DATE (replicated)*
*PROVIDERID (replicated)*
**DX**
**DX_TYPE**
**DX_SOURCE**
PDX

**PROCEDURES**
**PROCEDURESID**
**PATID**
**ENCOUNTERID**
*ENC_TYPE (replicated)*
*ADMIT_DATE (replicated)*
*PROVIDERID (replicated)*
PX_DATE
**PX**
**PX_TYPE**
PX_SOURCE

**LAB_RESULT_CM**
**LAB_RESULT_CM_ID**
**PATID**
ENCOUNTERID (optional)
LAB_NAME
SPECIMEN_SOURCE
LAB_LOINC
PRIORITY
RESULT_LOC
LAB_PX
LAB_PX_TYPE
LAB_ORDER_DATE
SPECIMEN_DATE
SPECIMEN_TIME
**RESULT_DATE**
RESULT_TIME
RESULT_QUAL
RESULT_NUM
RESULT_MODIFIER
RESULT_UNIT
NORM_RANGE_LOW
NORM_MODIFIER_LOW
NORM_RANGE_HIGH
NORM_MODIFIER_HIGH
ABN_IND

**PRESCRIBING**
**PRESCRIBINGID**
**PATID**
ENCOUNTERID (optional)
RX_PROVIDERID
RX_ORDER_DATE
RX_ORDER_TIME
RX_START_DATE
RX_END_DATE
RX_QUANTITY
RX_REFILLS
RX_DAYS_SUPPLY
RX_FREQUENCY
RX_BASIS
RXNORM_CUI

Data captured from healthcare delivery, direct encounter basis

**PCORNET_TRIAL**
**PATID**
**TRIALID**
**PARTICIPANTID**
TRIAL_SITEID
TRIAL_ENROLL_DATE
TRIAL_END_DATE
TRIAL_WITHDRAW_DATE
TRIAL_INVITE_CODE

Associations with PCORnet clinical trials

**HARVEST**
**NETWORKID**
NETWORK_NAME
**DATAMARTID**
DATAMART_NAME
DATAMART_PLATFORM
CDM_VERSION
DATAMART_CLAIMS
DATAMART_EHR
BIRTH_DATE_MGMT
ENR_START_DATE_MGMT
ENR_END_DATE_MGMT
ADMIT_DATE_MGMT
DISCHARGE_DATE_MGMT
PX_DATE_MGMT
RX_ORDER_DATE_MGMT
RX_START_DATE_MGMT
RX_END_DATE_MGMT
DISPENSE_DATE_MGMT
LAB_ORDER_DATE_MGMT
SPECIMEN_DATE_MGMT
RESULT_DATE_MGMT
MEASURE_DATE_MGMT
ONSET_DATE_MGMT
REPORT_DATE_MGMT
RESOLVE_DATE_MGMT
PRO_DATE_MGMT
REFRESH_DEMOGRAPHIC_DATE
REFRESH_ENROLLMENT_DATE
REFRESH_ENCOUNTER_DATE
REFRESH_DIAGNOSIS_DATE
REFRESH_PROCEDURES_DATE
REFRESH_VITAL_DATE
REFRESH_DISPENSING_DATE
REFRESH_LAB_RESULT_CM_DATE
REFRESH_CONDITION_DATE
REFRESH_PRO_CM_DATE
REFRESH_PRESCRIBING_DATE
REFRESH_PCORNET_TRIAL_DATE
REFRESH_DEATH_DATE
REFRESH_DEATH_CAUSE_DATE

Process-related data

**Bold font** indicates fields that cannot be null due to primary key definitions or record-level constraints.

# Sentinel

- Initiative of the Food and Drug Administration (FDA)
- Effort to create a national electronic system for monitoring the performance of FDA-regulated medical products (drugs, vaccines, and other biologics)
- Develop a system to obtain information from existing electronic health care data from multiple sources to assess the safety of approved medical products
- Distributed dataset with 300 million person-years of high quality, unduplicated, curated data

https://www.sentinelinitiative.org/sentinel/data/distributed-database-common-data-model

# Sentinel Common Data Model

## Administrative Data

| Enrollment | Demographic | Dispensing | Encounter | Diagnosis | Procedure |
|---|---|---|---|---|---|
| Patient ID | Patient ID | Patient ID | Patient ID | Patient ID | Patient ID |
| Enrollment Start & End Dates | Birth Date | Dispensing Date | Service Date(s) | Service Date(s) | Service Date(s) |
| Drug Coverage | Sex | National Drug Code (NDC) | Encounter ID | Encounter ID | Encounter ID |
| Medical Coverage | Zip Code | Days Supply | Encounter Type and Provider | Encounter Type and Provider | Encounter Type and Provider |
| Medical Record Availability | Etc. | Amount Dispensed | Facility | Diagnosis Code & Type | Procedure Code & Type |
| | | | Etc. | Principal Discharge Diagnosis | Etc. |

## Clinical Data

| Lab Result | Vital Signs |
|---|---|
| Patient ID | Patient ID |
| Result & Specimen Collection Dates | Measurement Date & Time |
| Test Type, Immediacy & Location | Height & Weight |
| Logical Observation Identifiers Names and Codes (LOINC®) | Diastolic & Systolic BP |
| Etc. | Tobacco Use & Type |
| | Etc. |

## Registry Data

| Death | Cause of Death | State Vaccine |
|---|---|---|
| Patient ID | Patient ID | Patient ID |
| Death Date | Cause of Death | Vaccination Date |
| Source | Source | Admission Date |
| Confidence | Confidence | Vaccine Code & Type |
| Etc. | Etc. | Provider |
| | | Etc. |

## Inpatient Data

| Inpatient Pharmacy | Inpatient Transfusion |
|---|---|
| Patient ID | Patient ID |
| Administration Date & Time | Administration Start & End Date & Time |
| Encounter ID | Encounter ID |
| National Drug Code (NDC) | Transfusion Administration ID |
| Route | Transfusion Product Code |
| Dose | Blood Type |
| Etc. | Etc. |

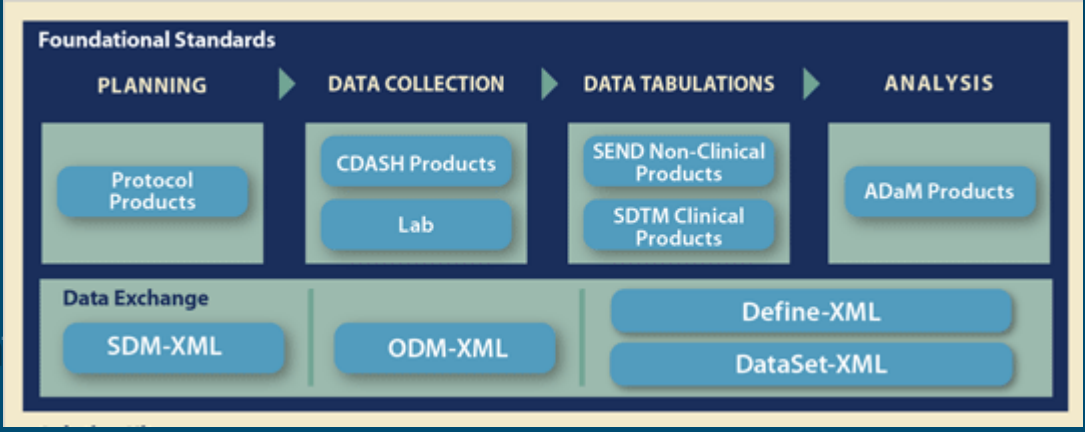
## Mother-Infant Linkage Data

| Mother-Infant Linkage |
|---|
| Mother ID |
| Mother Birth Date |
| Encounter ID & Type |
| Admission & Discharge Date |
| Child ID |
| Child Birth Date |
| Mother-Infant Match Method |
| Etc. |

https://www.cdisc.org/

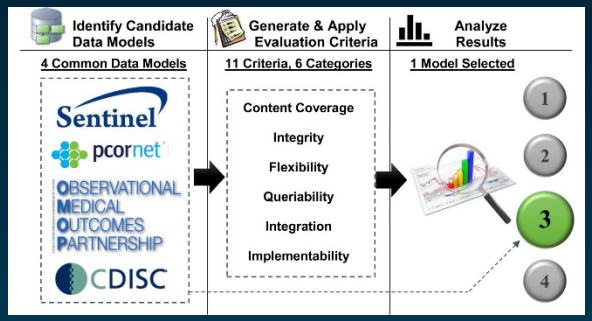
# CDISC

- CDISC – Clinical Data Interchange Standards Consortium
- "develop and support global, platform-independent data standards that enable information system interoperability to improve medical research and related areas of healthcare"
- Set of standards required by FDA for regulatory submissions (clinical research)




Lister Hill National Cen

# Differences among data models



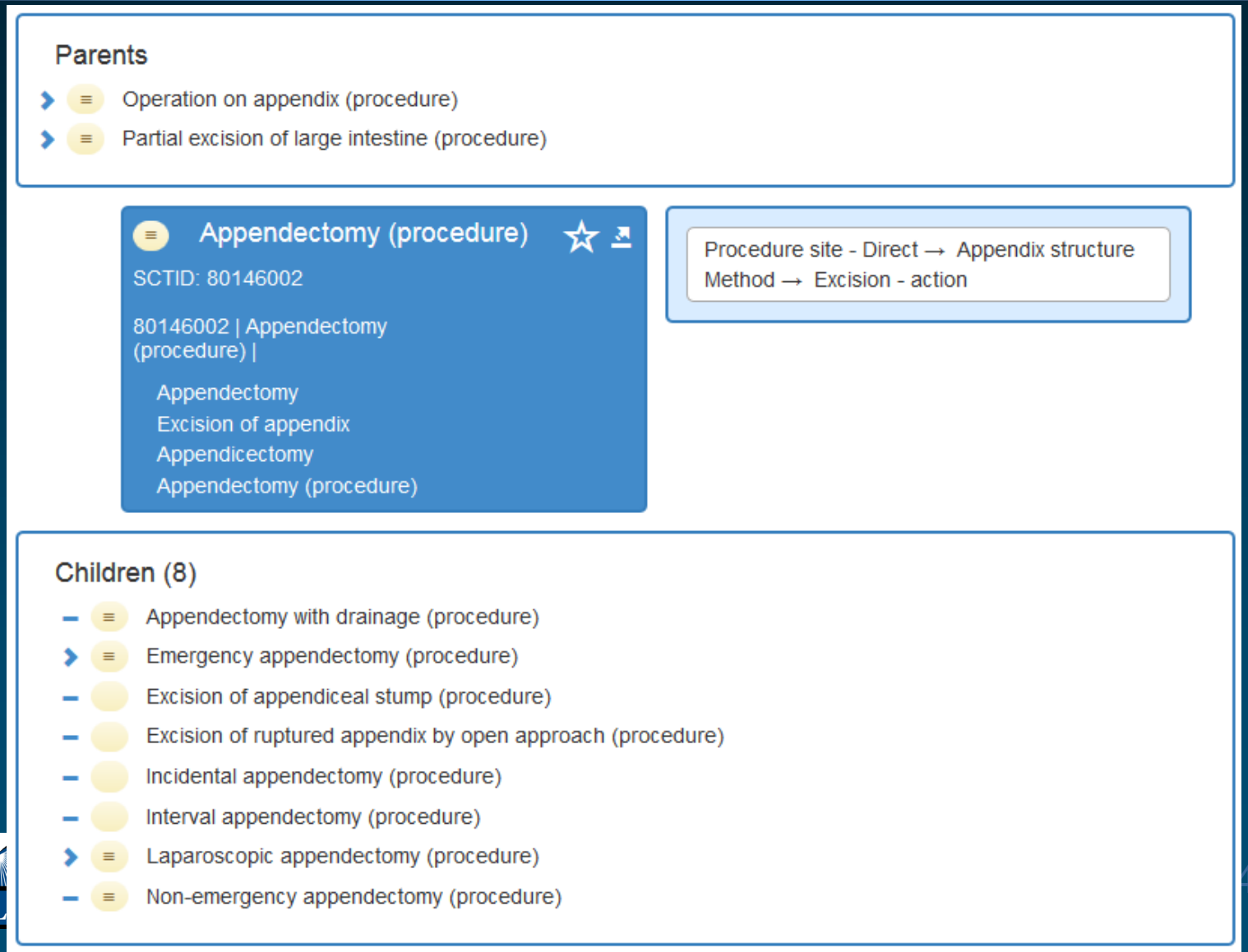

- Comparison of 4 CDMs found OMOP the best for use with a longitudinal community registry
- Examples of differences
  - Derivative data and assumptions
    - Drug eras in OHDSI
  - Terminology binding
    - Commitment to standard terminologies (e.g., OHDSI)
- Ongoing harmonization (?)

https://aspe.hhs.gov/harmonization-various-common-data-models-and-open-standards-evidence-generation

# Terminologies

- Main clinical terminologies for the Meaningful Use incentive program (clinical documentation; clinical quality measures)
  - SNOMED CT
  - LOINC
  - RxNorm
- Legacy terminologies (billing)
  - [ICD9-CM]; ICD10-CM
  - CPT
- Other terminologies (CDISC)
  - NCI Thesaurus

# SNOMED CT Example



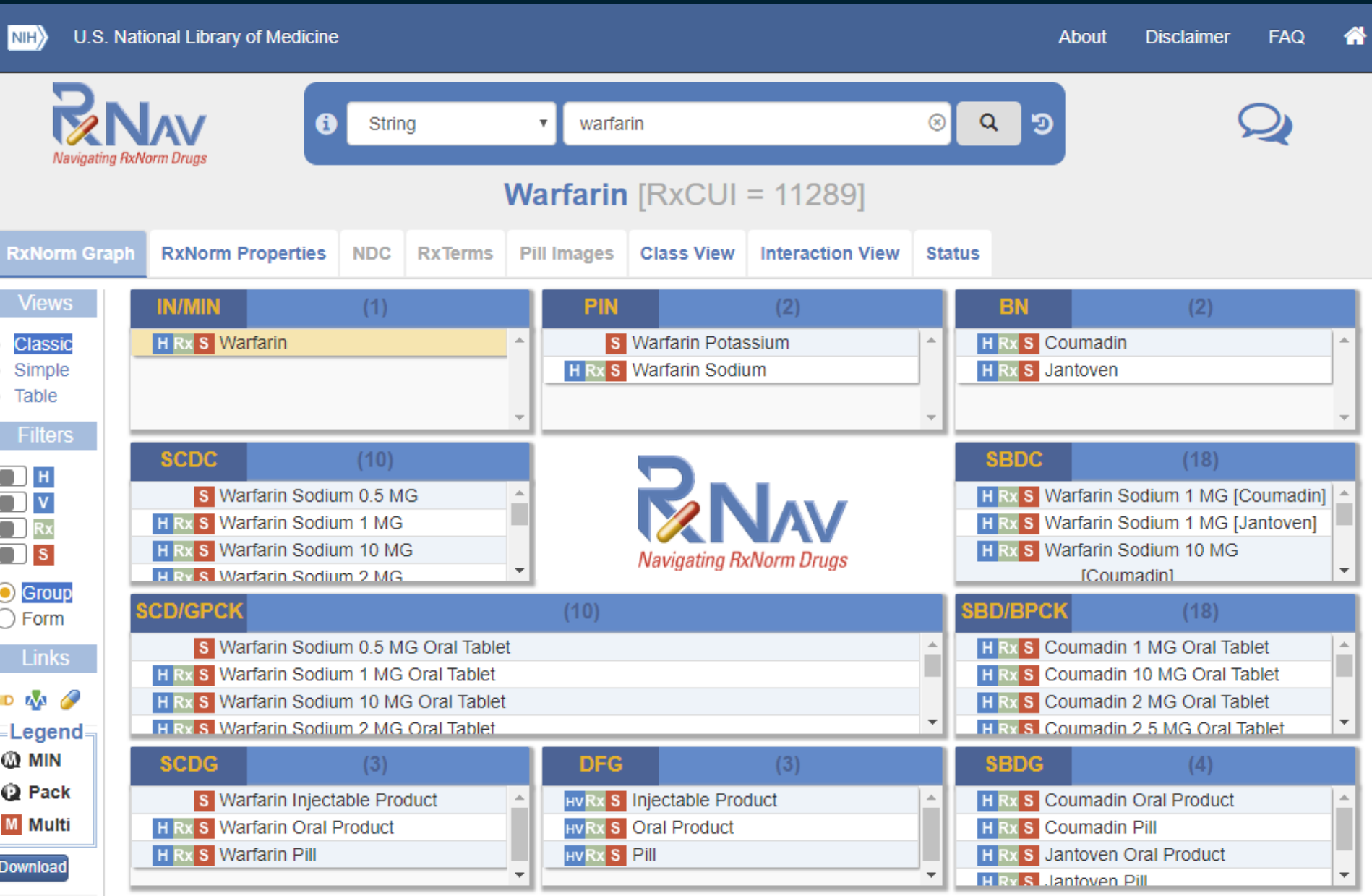
# LOINC Example

- *Sodium [Moles/volume] in Serum or Plasma*
  [the molar concentration of sodium is measured in the plasma (or serum), with quantitative result]

| Axis | Value |
|---|---|
| Component | Sodium |
| Property | SCnc – Substance Concentration (per volume) |
| Timing | Pt – Point in time (Random) |
| System | Ser/Plas – Serum or Plasma |
| Scale | Qn – Quantitative |
| Method | -- |

# RxNorm Example

https://mor.nlm.nih.gov/RxNav/



# ICD-10 vs. ICD-10-CM

**E72** **Other disorders of amino-acid metabolism**

***Excl.:*** abnormal findings without manifest disease (R7
disorders of:
- aromatic amino-acid metabolism (E70.-)
- branched-chain amino-acid metabolism (
- fatty-acid metabolism (E71.3)
- purine and pyrimidine metabolism (E79.-

gout (M10.-)

**E72.0** **Disorders of amino-acid transport**

Cystine storage disease† (N29.8*)
Cystinosis
Cystinuria
Fanconi(-de Toni)(-Debré) syndrome
Hartnup disease
Lowe syndrome

***Excl.:*** disorders of tryptophan metabolism (E70.8)

x6

**E72** **Other disorders of amino-acid metabolism**

**Excludes1:** disorders of:
aromatic amino-acid metabolism (E70.-)
branched-chain amino-acid metabolism (E71.0-E71.2)
fatty-acid metabolism (E71.3)
purine and pyrimidine metabolism (E79.-)
gout (M1A.-, M10.-)

**E72.0** **Disorders of amino-acid transport**

**Excludes1:** disorders of tryptophan metabolism (E70.5)

**E72.00** **Disorders of amino-acid transport, unspecified**

**E72.01** **Cystinuria**

**E72.02** **Hartnup's disease**

**E72.03** **Lowe's syndrome**

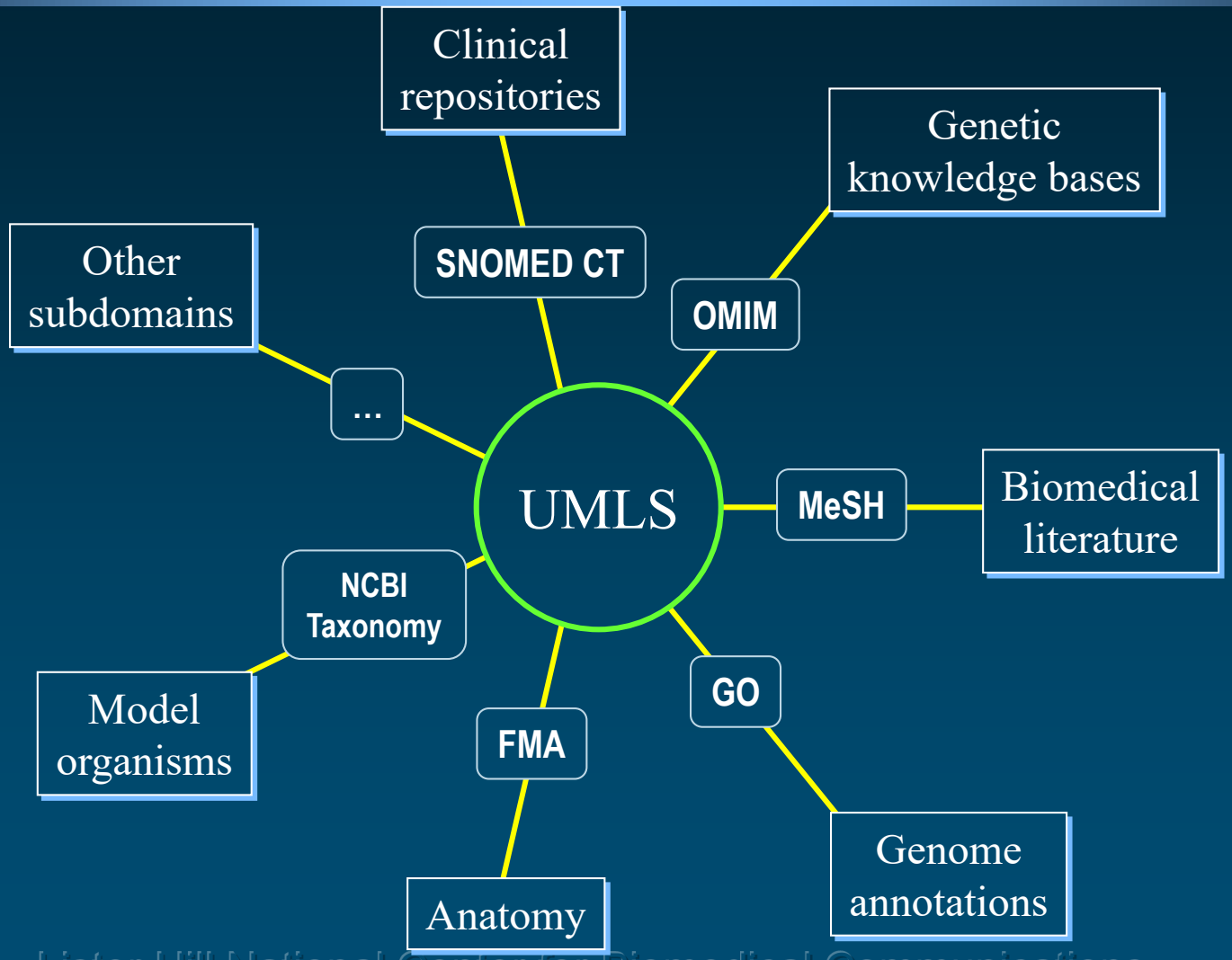
**Use additional** code for associated glaucoma (H42)

**E72.04** **Cystinosis**
Fanconi (-de Toni) (-Debré) syndrome with cystinosis

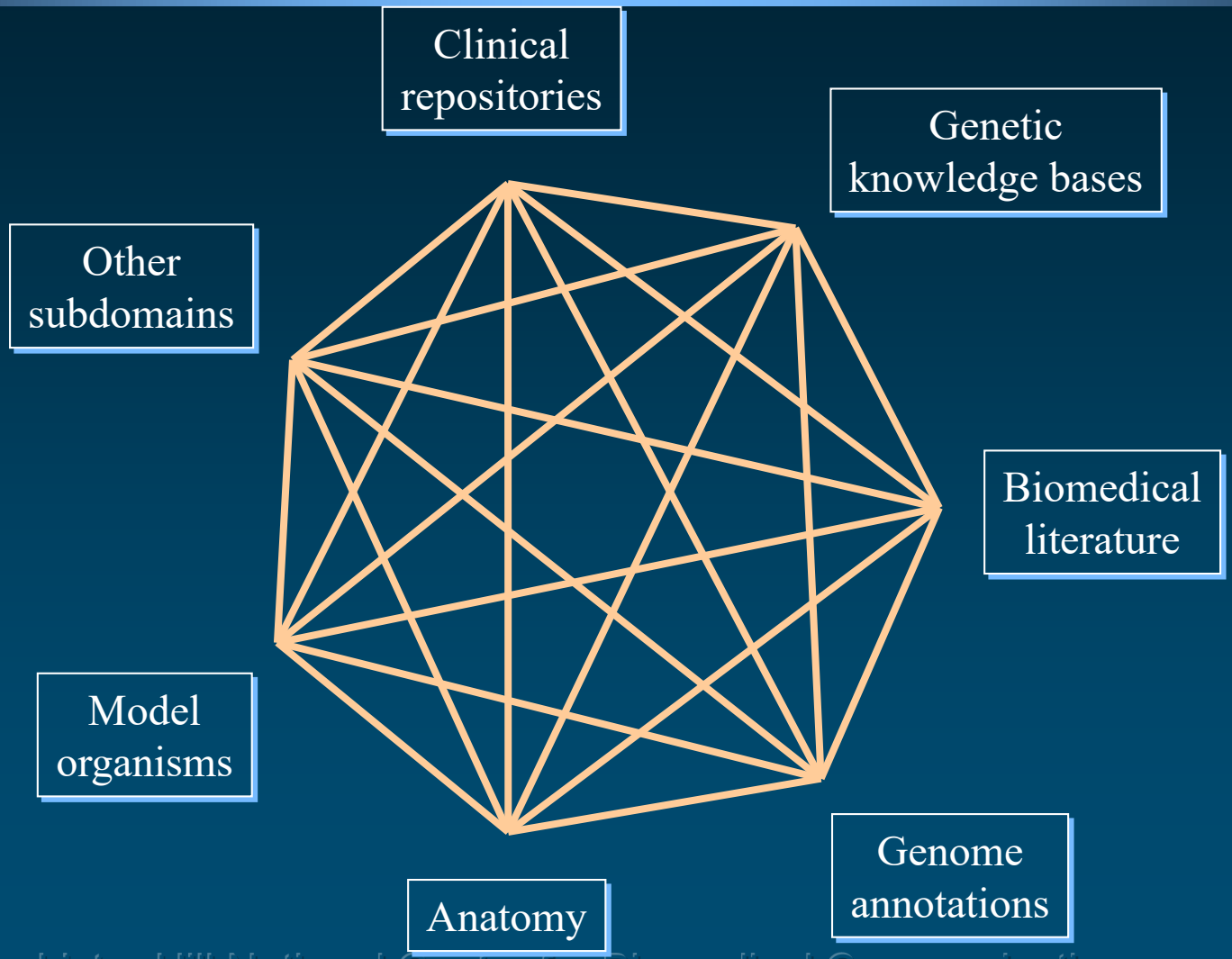
**Excludes1:** Fanconi (-de Toni) (-Debré) syndrome wit

**E72.09** **Other disorders of amino-acid transport**
Fanconi (-de Toni) (-Debré) syndrome, unspecified

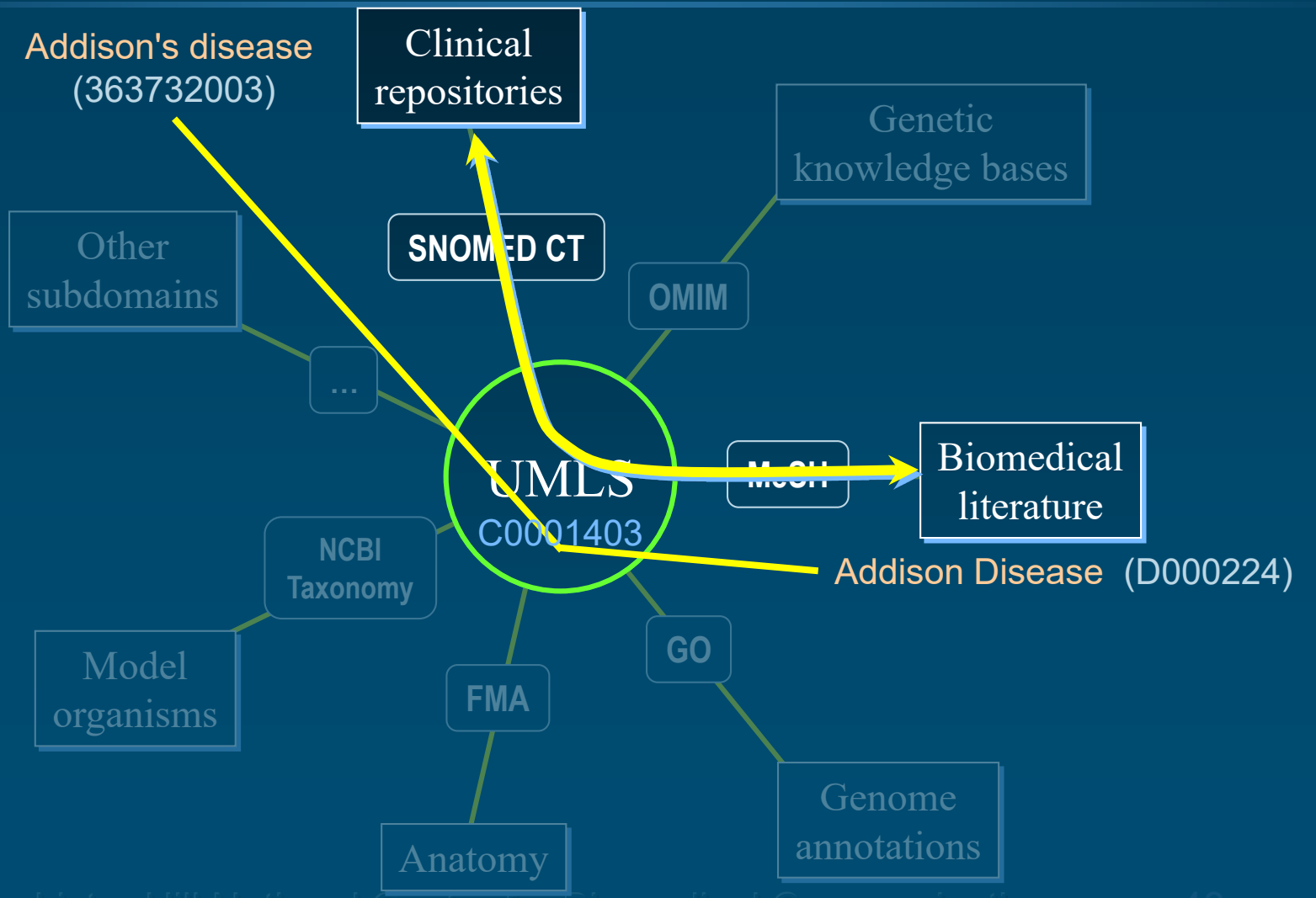
# Unified Medical Language System



# Integrating terminologies



# Integrating terminologies



# Current trends and future directions

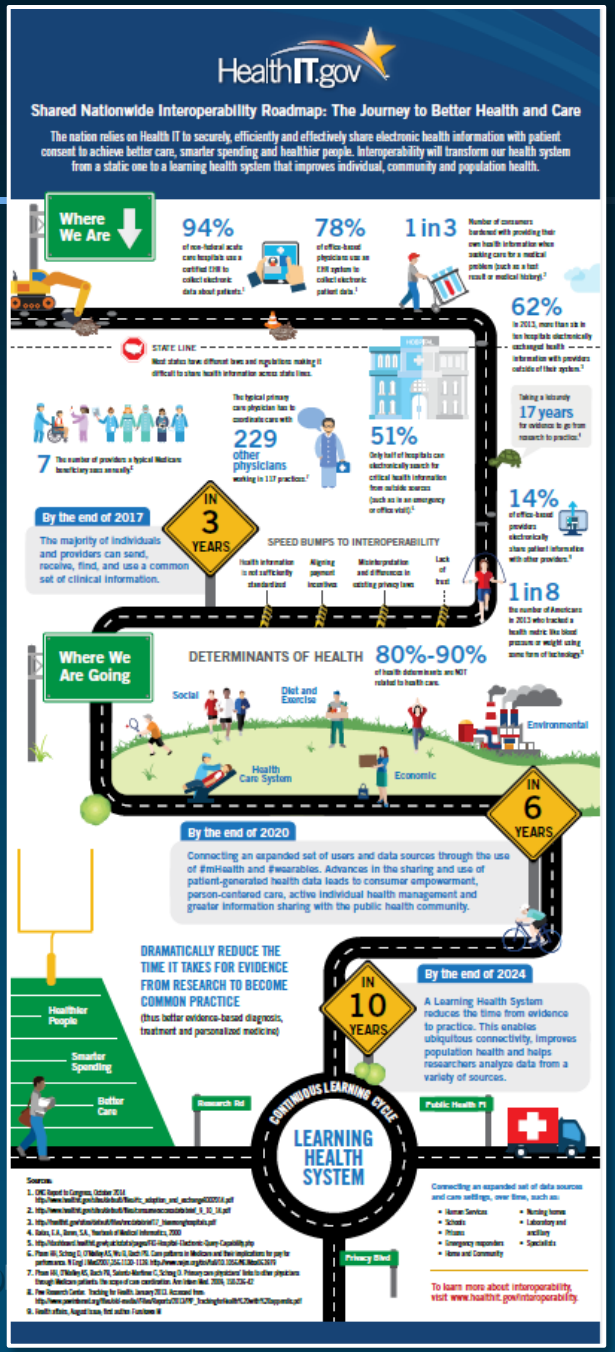
https://www.healthit.gov/sites/default/files/hie-interoperability/nationwide-interoperability-roadmap-final-version-1.0.pdf

# ONC interoperability roadmap

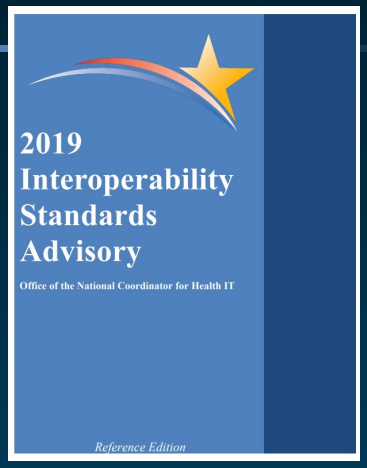
October 2015

**The goals are:**

- **2015-2017:** Send, receive, find and use priority data domains to improve health care quality and outcomes.
- **2018-2020:** Expand data sources and users in the interoperable health IT ecosystem to improve health and lower costs.
- **2021-2024:** Achieve nationwide interoperability to enable a learning health system, with the person at the center of a system that can continuously improve care, public health, and science through real-time data access.

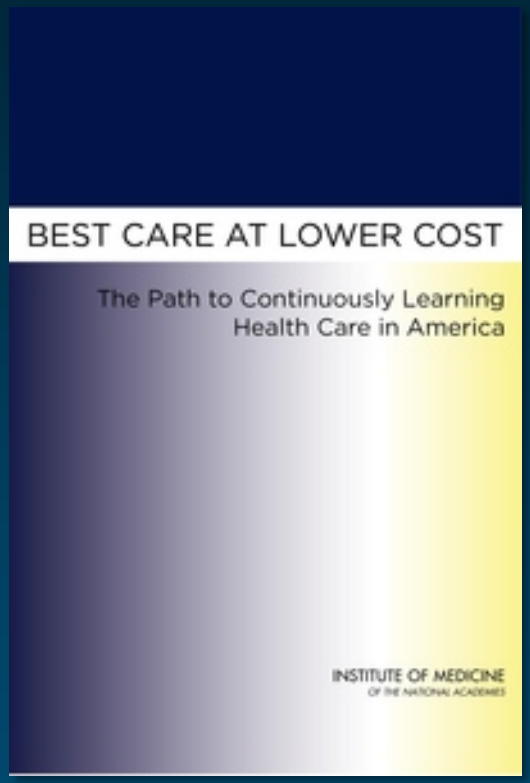


# ONC Interoperability Standards Advisory

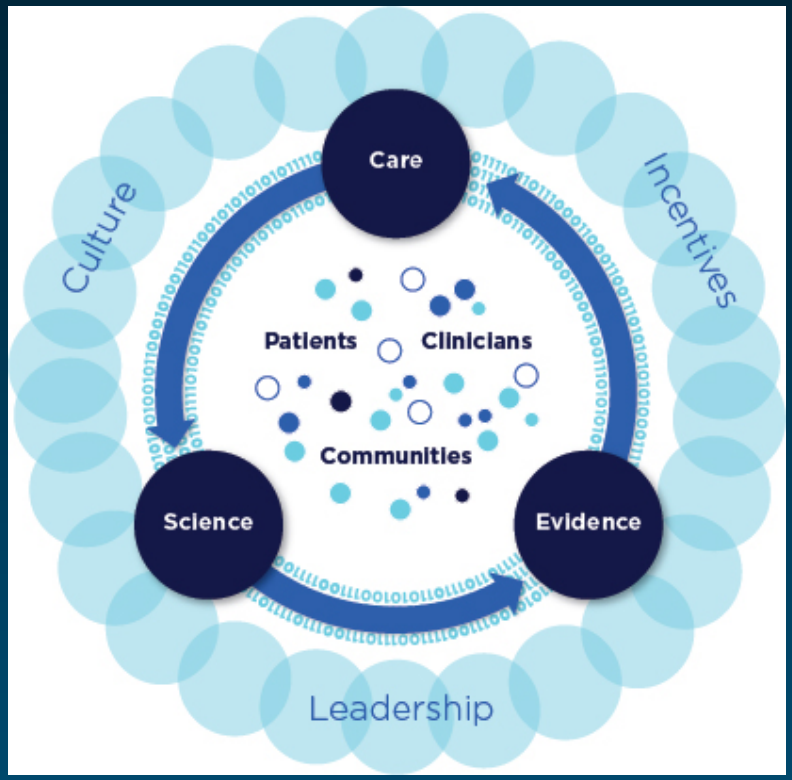



- Introduction to the ISA
  - Scope; Purpose; ISA Structure
- Sections
  - I: Vocabulary/Code Set/Terminology Standards and Implementation Specifications
  - II: Content/Structure Standards and Implementation Specifications
  - III: Standards and Implementation Specifications for Services
  - IV: Administrative Standards and Implementation Specifications
- Appendices
  - I – Sources of Security Standards and Security Patterns
  - II - Models and Profiles
  - III - Educational and Informational Resources
  - IV - State and Local Public Health Readiness for Interoperability

# Learning health system




**IOM, May 2013**

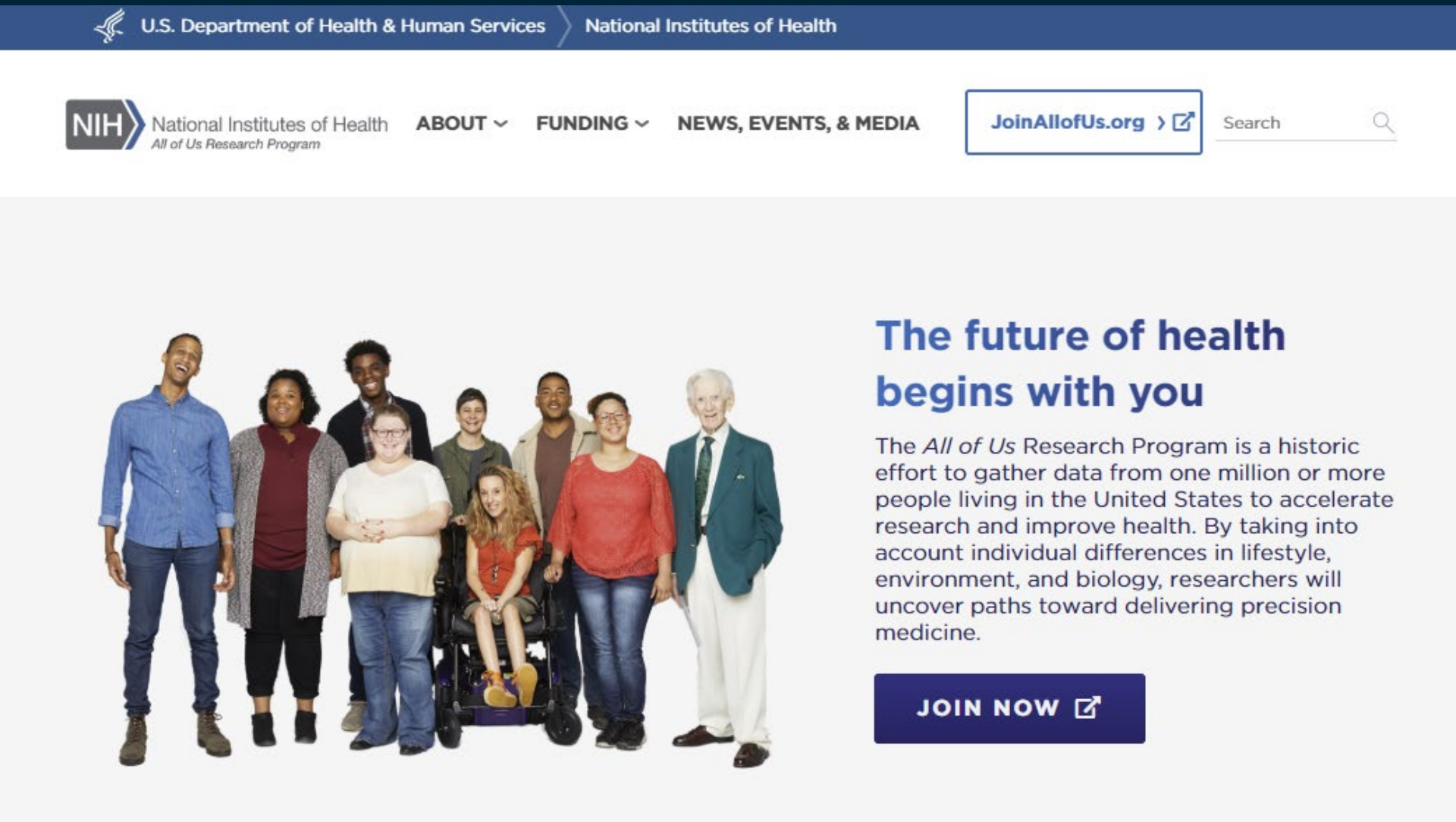


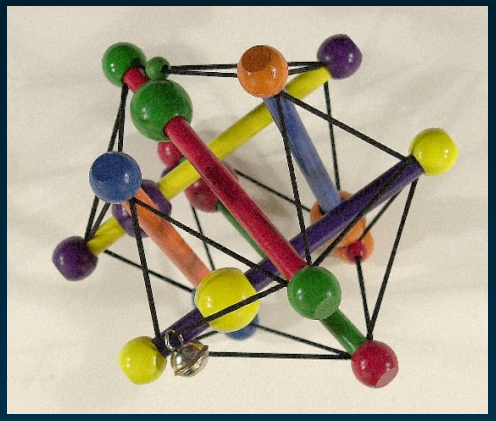
# Fast Healthcare Interoperability Resources

- New standard for exchanging healthcare information electronically
- Developed by HL7 FHIR foundation
- Based on resources
  - Basic building blocks of information (patient, condition, procedure, practitioner)
  - Can be extended as needed
- Supports 4 different paradigms for exchange: the RESTful API, Messaging, Documents, and Services

https://allofus.nih.gov/

# *All of Us* – Precision Medicine Initiative (NIH)





# Medical Ontology Research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