Kaiser Permanente Convergent Medical Terminology (CMT)

Using Oxford RDFox and SNOMED for Quality Measures

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About Kaiser Permanente

- Largest health maintenance organization in the US.
- Operates in 7 different regions (states + D.C)
    - Ncal/Scal
    - Hawaii
    - Georgia
    - Colorado
    - Mid Atlantic
    - Pacific North-West
- Organize as an “entity structure composed of;
    - Kaiser HealthPlan
    - Kaiser Hospitals
    - Permanente Medical Group

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About Kaiser Permanente

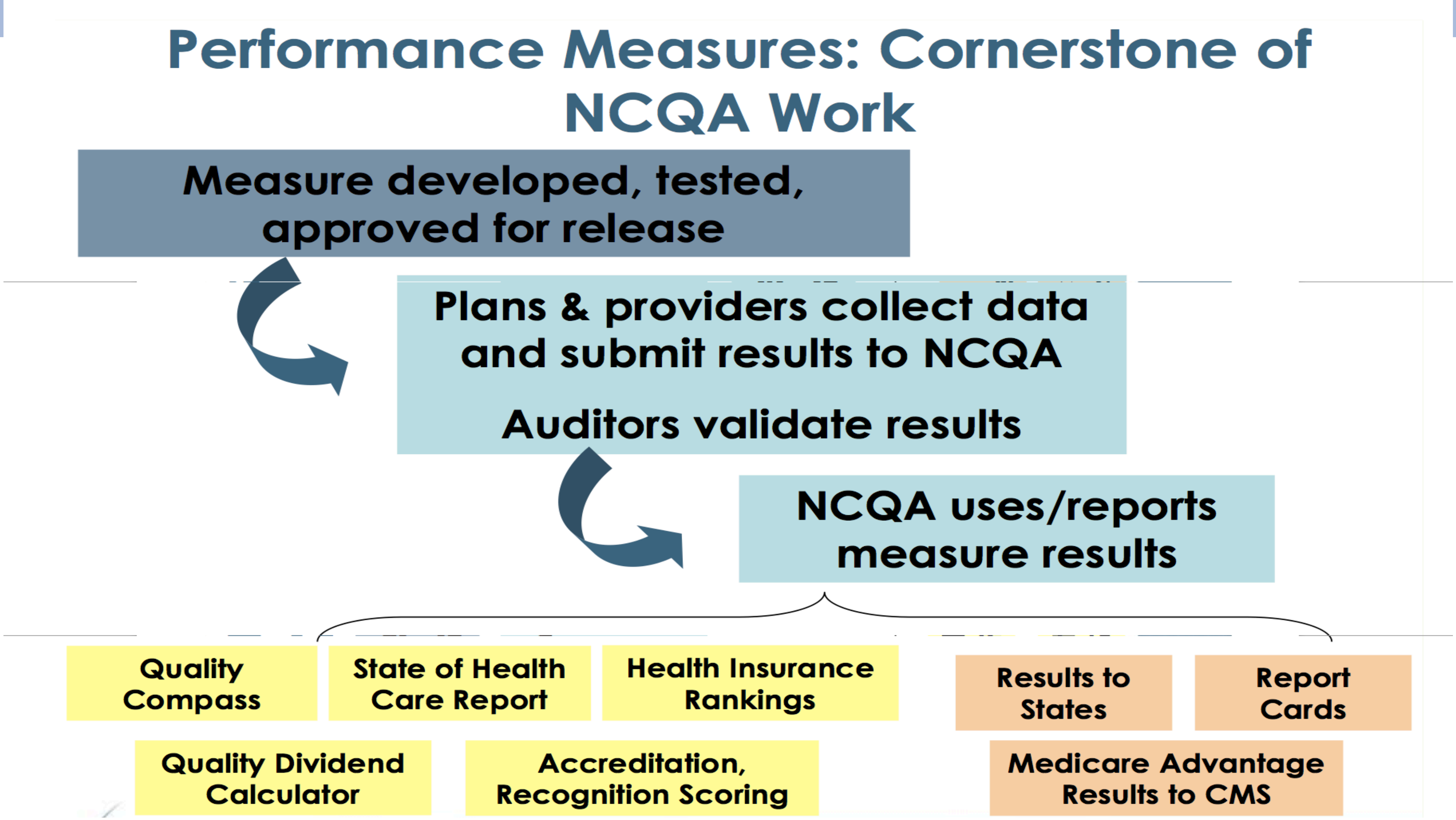
- Over 10 M member
- 38 medical centers
- 620 medical offices
  - Over 17k physicians
  - Over 50k nurses
  - Over 177 k employees
- KP HealthConnect; largest civilian electronic health record system in the US

Kaiser Permanente's Mission

To provide affordable, high-quality health care services and to improve the health of our members and the communities we serve.

SNOMED and OWL

NCQA, the National Committee for Quality Assurance, is a private, not-for-profit organization dedicated to improving health care quality.
NCQA develops quality standards and performance measures for a broad range of health care entities.



Performance Measures: Cornerstone of NCQA Work

Measure developed, tested, approved for release

Plans & providers collect data and submit results to NCQA

Auditors validate results

NCQA uses/reports measure results

Quality Compass

State of Health Care Report

Health Insurance Rankings

Results to States

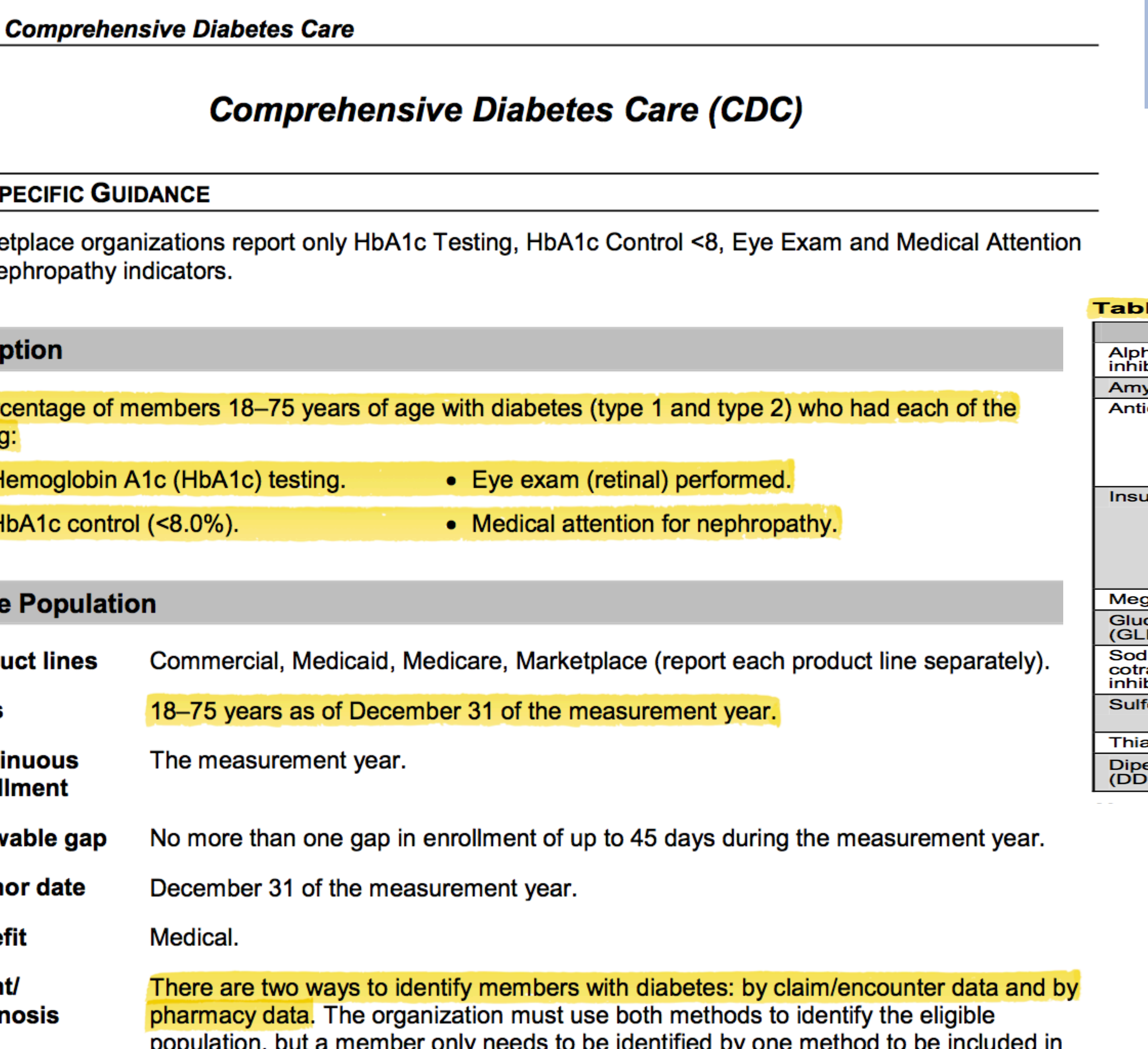
Report Cards

Quality Dividend Calculator

Accreditation, Recognition Scoring

Medicare Advantage Results to CMS

SNOMED and OWL



Comprehensive Diabetes Care

Comprehensive Diabetes Care (CDC)

PECIFIC GUIDANCE

etplace organizations report only HbA1c Testing, HbA1c Control <8, Eye Exam and Medical Attention ephropathy indicators.

ption

centage of members 18–75 years of age with diabetes (type 1 and type 2) who had each of the g:

lemoglobin A1c (HbA1c) testing.	• Eye exam (retinal) performed.
lbA1c control (<8.0%).	• Medical attention for nephropathy.

e Population

uct lines	Commercial, Medicaid, Medicare, Marketplace (report each product line separately).
s	18–75 years as of December 31 of the measurement year.
inuous llment	The measurement year.
vable gap	No more than one gap in enrollment of up to 45 days during the measurement year.
nor date	December 31 of the measurement year.
efit	Medical.
nt/ nosis	There are two ways to identify members with diabetes: by claim/encounter data and by pharmacy data. The organization must use both methods to identify the eligible population, but a member only needs to be identified by one method to be included in

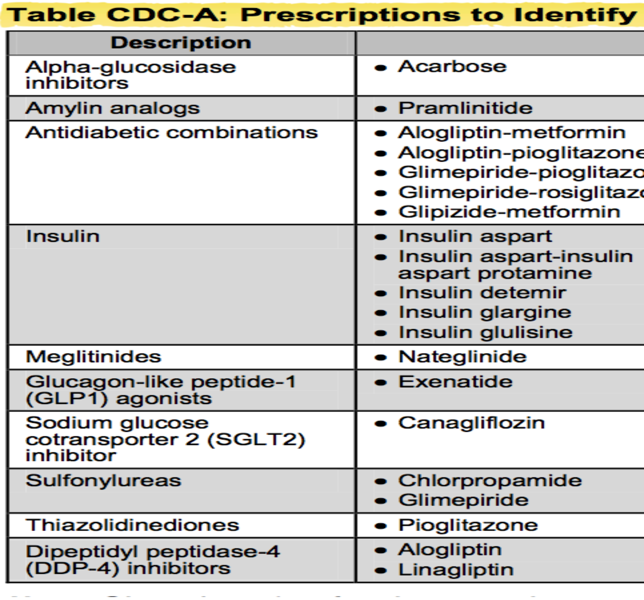
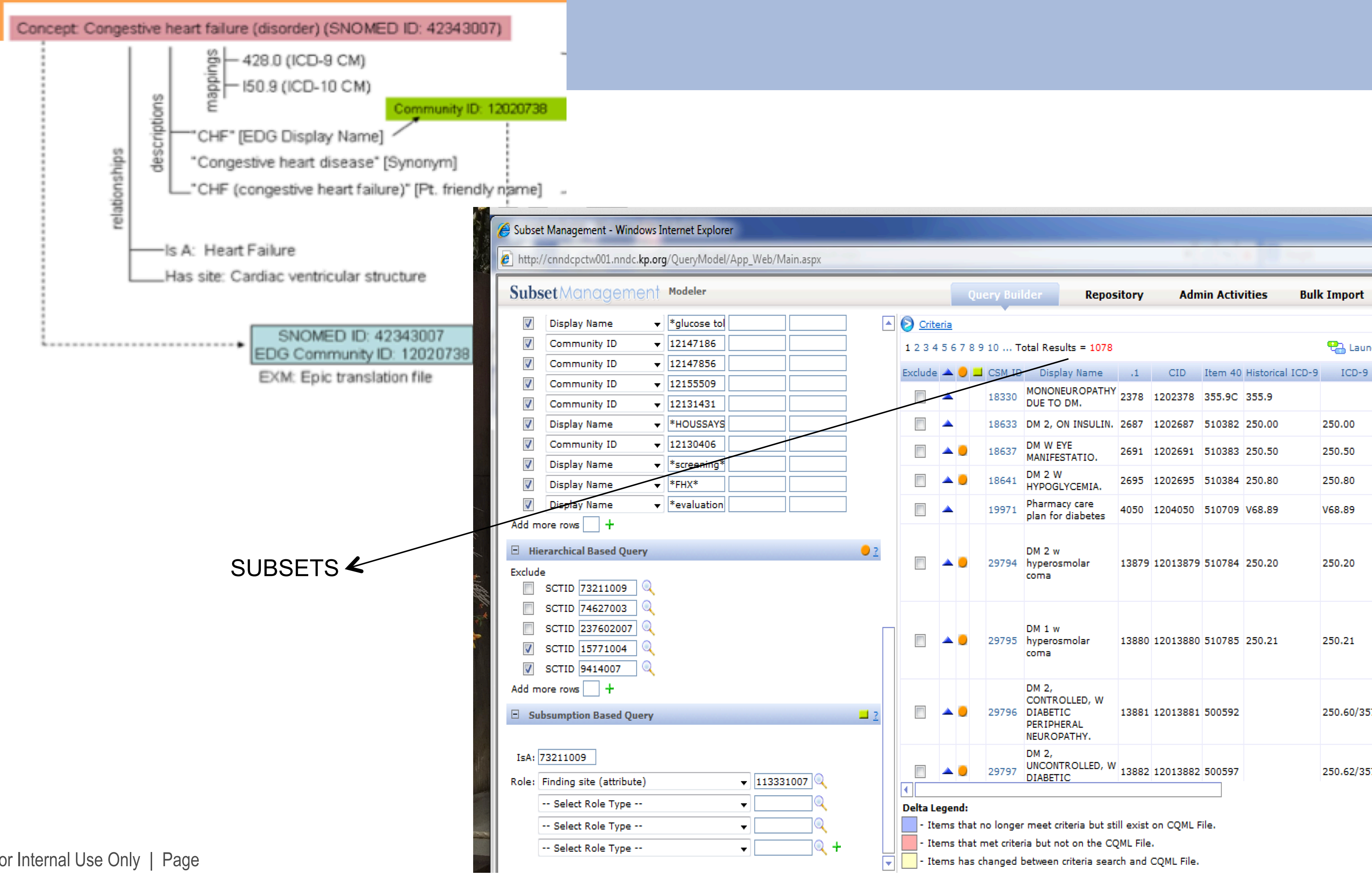


Table CDC-A: Prescriptions to Identify

Description	
Alpha-glucosidase inhibitors	• Acarbose
Amylin analogs	• Pramlinitide
Antidiabetic combinations	• Alogliptin-metformin • Alogliptin-pioglitazone • Glimepiride-pioglitazo • Glimepiride-rosiglitazo • Glipizide-metformin
Insulin	• Insulin aspart • Insulin aspart-insulin aspart protamine • Insulin detemir • Insulin glargine • Insulin glulisine
Meglitinides	• Nateglinide
Glucagon-like peptide-1 (GLP1) agonists	• Exenatide
Sodium glucose cotransporter 2 (SGLT2) inhibitor	• Canagliflozin
Sulfonylureas	• Chlorpropamide • Glimepiride
Thiazolidinediones	• Pioglitazone
Dipeptidyl peptidase-4 (DDP-4) inhibitors	• Alogliptin • Linagliptin

SNOMED and OWL- Current State



Concept: Congestive heart failure (disorder) (SNOMED ID: 42343007)

428.0 (ICD-9 CM)

I50.9 (ICD-10 CM)

Community ID: 12020738

"CHF" [EDG Display Name]

"Congestive heart disease" [Synonym]

"CHF (congestive heart failure)" [Pt. friendly name]

Is A: Heart Failure

Has site: Cardiac ventricular structure

SNOMED ID: 42343007
EDG Community ID: 12020738
EXM: Epic translation file

SUBSETS

Subset Management - Windows Internet Explorer

http://cnndcpctw001.nndc.kp.org/QueryModel/App_Web/Main.aspx

☑	Display Name	*glucose tol
☑	Community ID	12147186
☑	Community ID	12147856
☑	Community ID	12155509
☑	Community ID	12131431
☑	Display Name	*HOUSSAYS
☑	Community ID	12130406
☑	Display Name	*screening*
☑	Display Name	*FHX*
☑	Display Name	*evaluation

Add more rows +

Hierarchical Based Query ● ?

Exclude

☐	SCTID	73211009
☐	SCTID	74627003
☐	SCTID	237602007
☑	SCTID	15771004
☑	SCTID	9414007

Add more rows +

Subsumption Based Query ■ ?

IsA: 73211009

Role: Finding site (attribute) 113331007

-- Select Role Type --

-- Select Role Type --

-- Select Role Type -- +

Criteria

1 2 3 4 5 6 7 8 9 10 ... Total Results = 1078

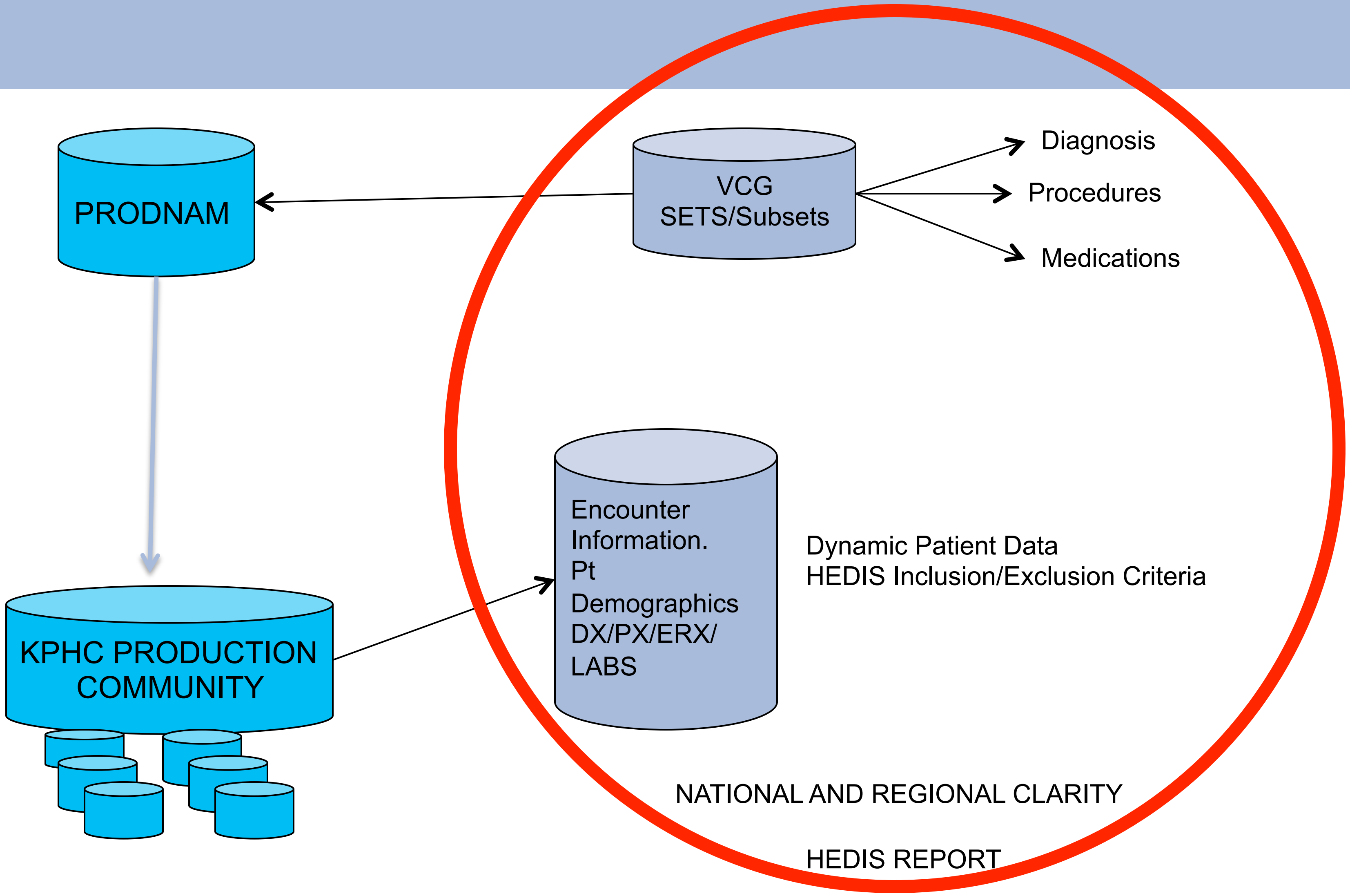
Laun

Exclude	▲	●	■	CSM ID	Display Name	.1	CID	Item 40	Historical ICD-9	ICD-9
☐	▲			18330	MONONEUROPATHY DUE TO DM.	2378	1202378	355.9C	355.9	
☐	▲			18633	DM 2, ON INSULIN.	2687	1202687	510382	250.00	250.00
☐	▲	●		18637	DM W EYE MANIFESTATIO.	2691	1202691	510383	250.50	250.50
☐	▲	●		18641	DM 2 W HYPOGLYCEMIA.	2695	1202695	510384	250.80	250.80
☐	▲			19971	Pharmacy care plan for diabetes	4050	1204050	510709	V68.89	V68.89
☐	▲	●		29794	DM 2 w hyperosmolar coma	13879	12013879	510784	250.20	250.20
☐	▲	●		29795	DM 1 w hyperosmolar coma	13880	12013880	510785	250.21	250.21
☐	▲	●		29796	DM 2, CONTROLLED, W DIABETIC PERIPHERAL NEUROPATHY.	13881	12013881	500592		250.60/35
☐	▲	●		29797	DM 2, UNCONTROLLED, W DIABETIC	13882	12013882	500597		250.62/35

Delta Legend:

- 🟦 - Items that no longer meet criteria but still exist on CQML File.
- 🟥 - Items that met criteria but not on the CQML File.
- 🟨 - Items has changed between criteria search and CQML File.

SNOMED and OWL- Current State


PRODNAM
VCG
SETS/Subsets
Diagnosis
Procedures
Medications
KPHC PRODUCTION COMMUNITY
Encounter Information. Pt Demographics DX/PX/ERX/ LABS
Dynamic Patient Data
HEDIS Inclusion/Exclusion Criteria
NATIONAL AND REGIONAL CLARITY
HEDIS REPORT

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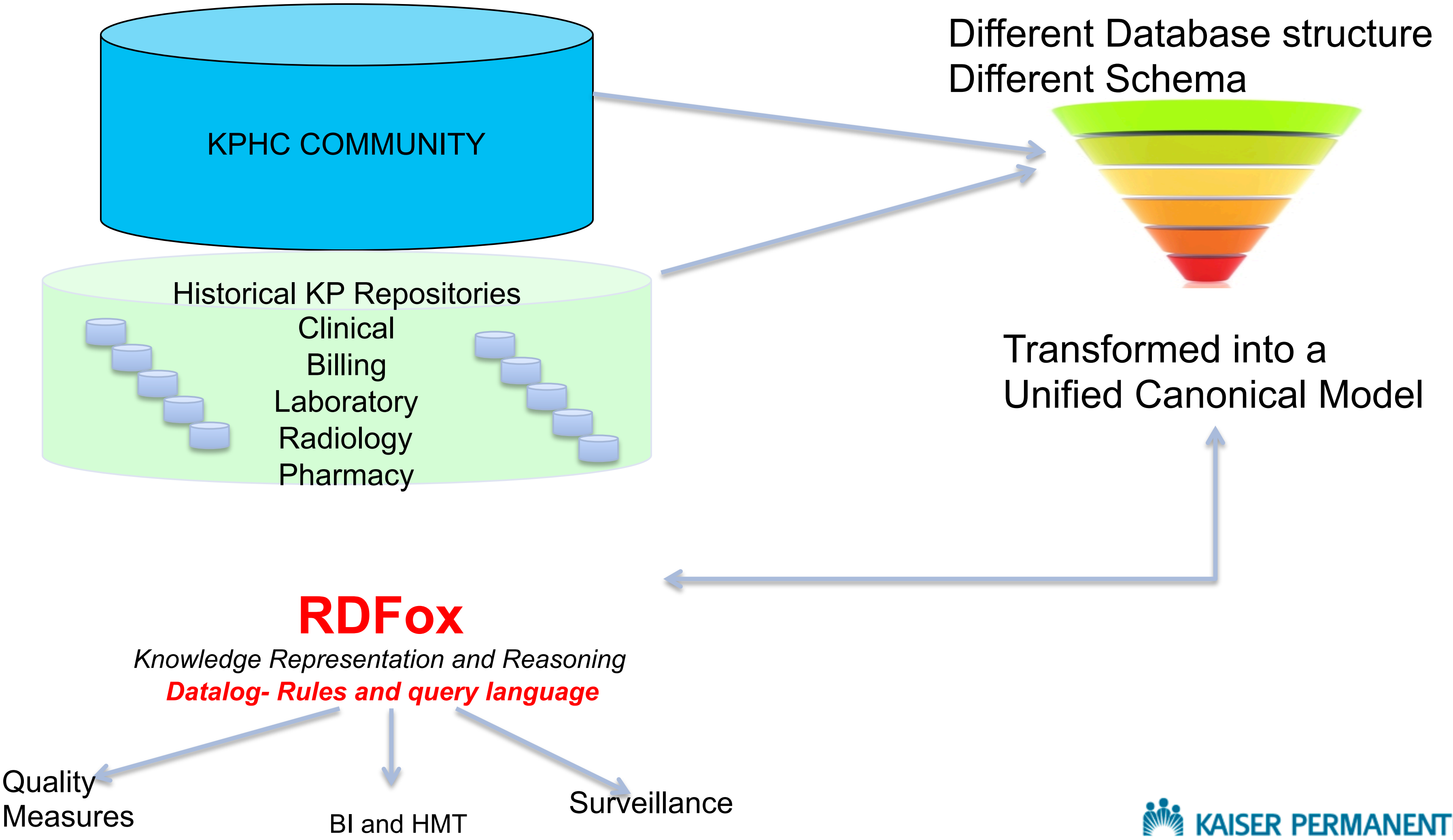
SNOMED and OWL- Future State



KPHC COMMUNITY

Historical KP Repositories
Clinical
Billing
Laboratory
Radiology
Pharmacy

Different Database structure
Different Schema

Transformed into a
Unified Canonical Model

RDFox

Knowledge Representation and Reasoning

Datalog- Rules and query language

Quality Measures

BI and HMT

Surveillance

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SNOMED and OWL

- The logical model of SNOMED is based on one flavor of Web Ontology Language (OWL)
- The flavor of OWL-2 which SNOMED follows is called EL +
- Another flavor of OWL-2 is called RL
- Oxford University Department of Computer Science (Ian Horrock's group) has developed a powerful scalable OWL-2 RL reasoning platform called RDFox (RDF Oxford)

SNOMED and RDFox

- SNOMED and it's OWL EL+ does a good job of representing procedures, diagnoses, findings, organisms, anatomic structures etc.
- SNOMED does not represent patient data. It does not represent MRN, Name, Age for example.
- It does not represent "who did what?" and "when and where did that happen?"
- Clinical data requires both a terminology of the "what" such as SNOMED, and also the "who, where, why, and when" that SNOMED does not cover

SNOMED and RDFox

- Oxfords RDFox can cover massive amounts of clinical data (who, what, when, where, why) and store it in RDF (Resource Definition Framework) format.
- SNOMED can be used (with subsumption searches) to create "value sets". For example, what are all the SNOMED codes that indicate Diabetes?

SNOMED and RDFox

- Given a Value Set (vs) created with SNOMED subsumption, and given RDFox, any clinical data can be analyzed for complex queries on a massive scale.
- For our example we are demonstrating how this can be done for a Diabetes quality measure
- A brief explanation follows:

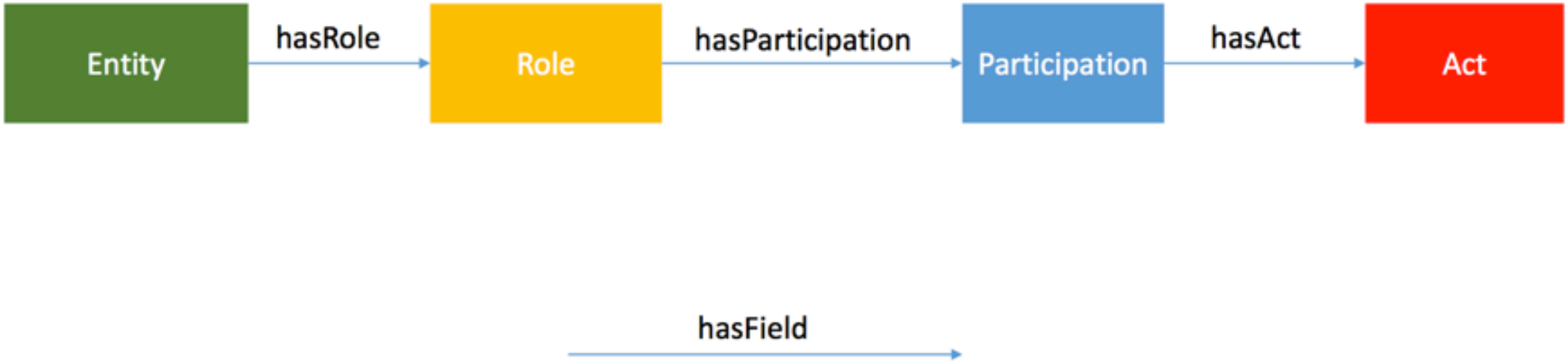
What is RDFox

- RDFox is developed by Oxford Department of Computer Science
- It is a massively scalable, parallel threaded logic engine that can make logical inferences
- It is based on OWL-RL and the Datalog language

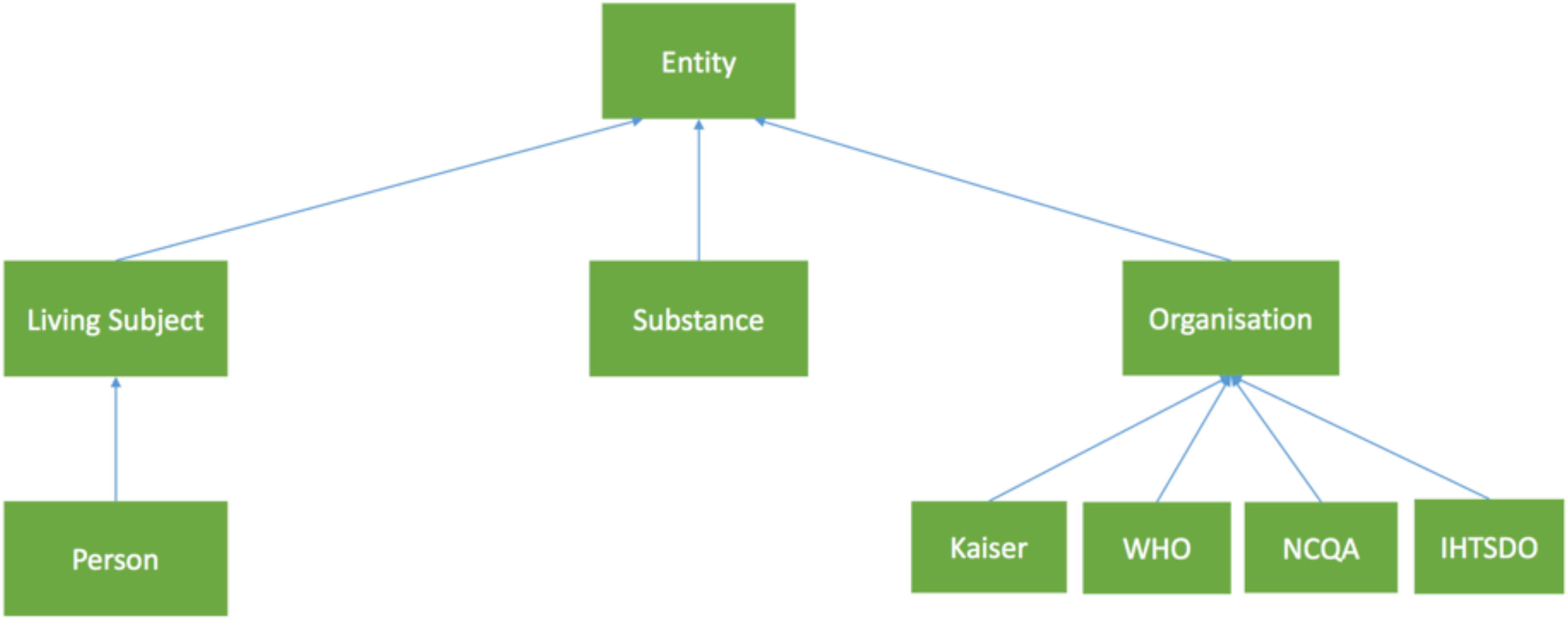
Translate E.H.R. to RDF Triples

- First clinical data from the E.H.R. is translated into an Ontology. A model based on relationships.
- All clinical information, can be expressed by an Ontology that is based on Entities In Roles that Participate in Acts, and Acts related to other Acts.

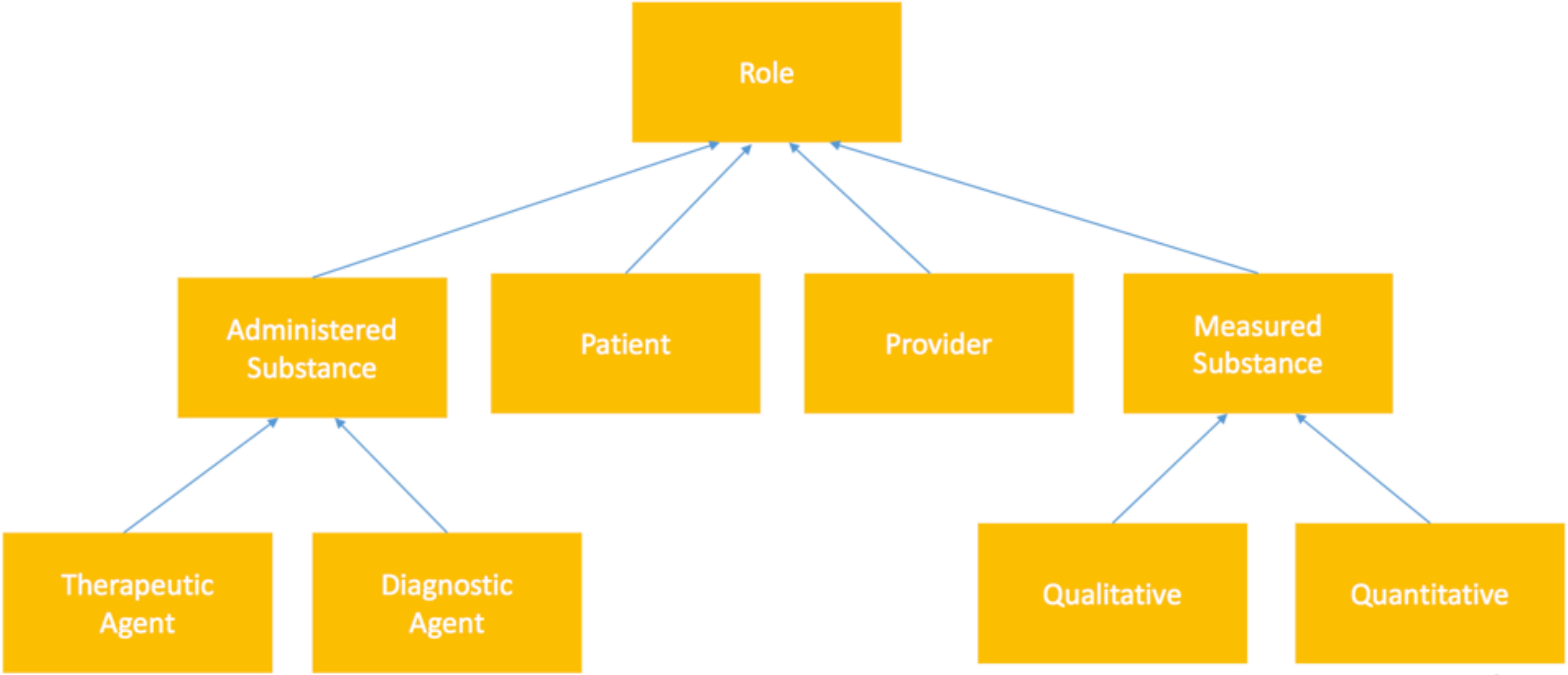
Top-Level Classes and Roles



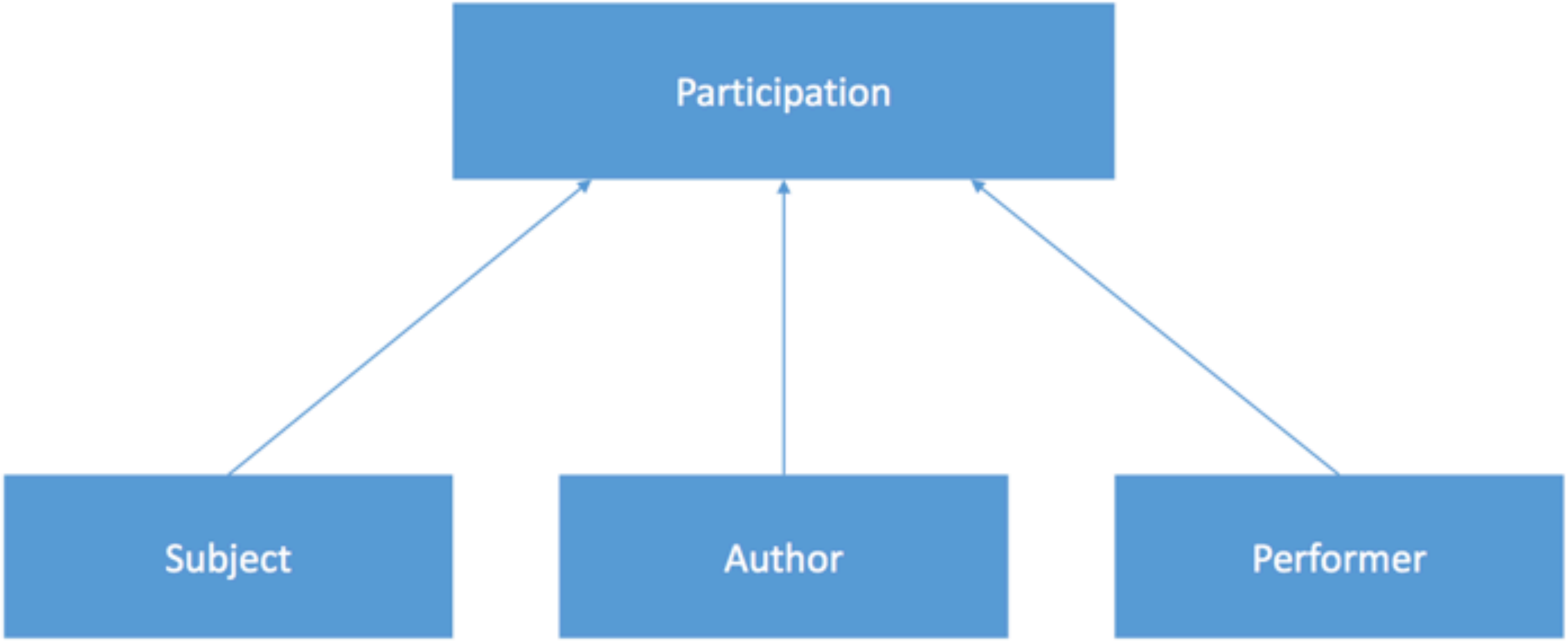
Entity Objects (UML Diagram)



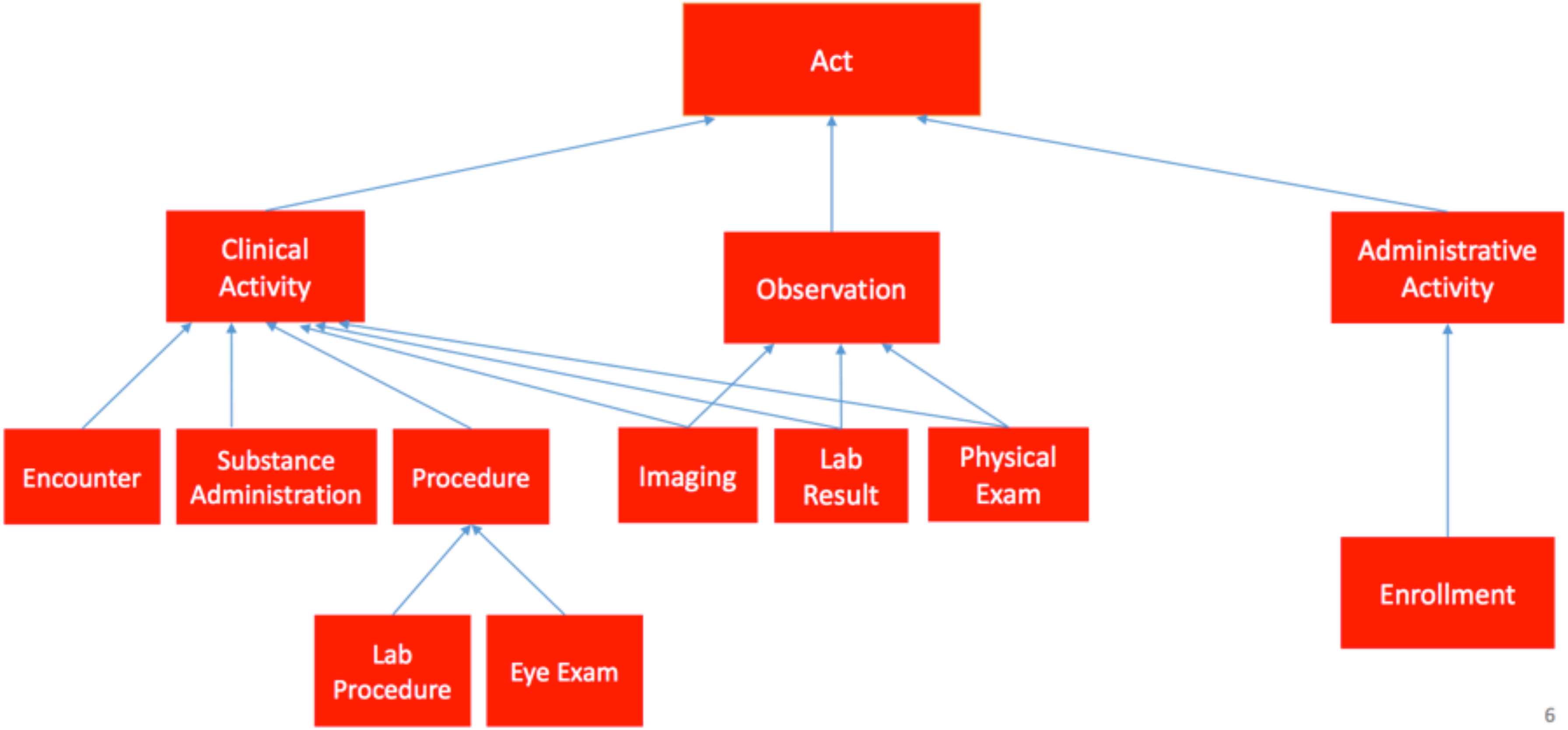
Role Objects (UML Diagram)



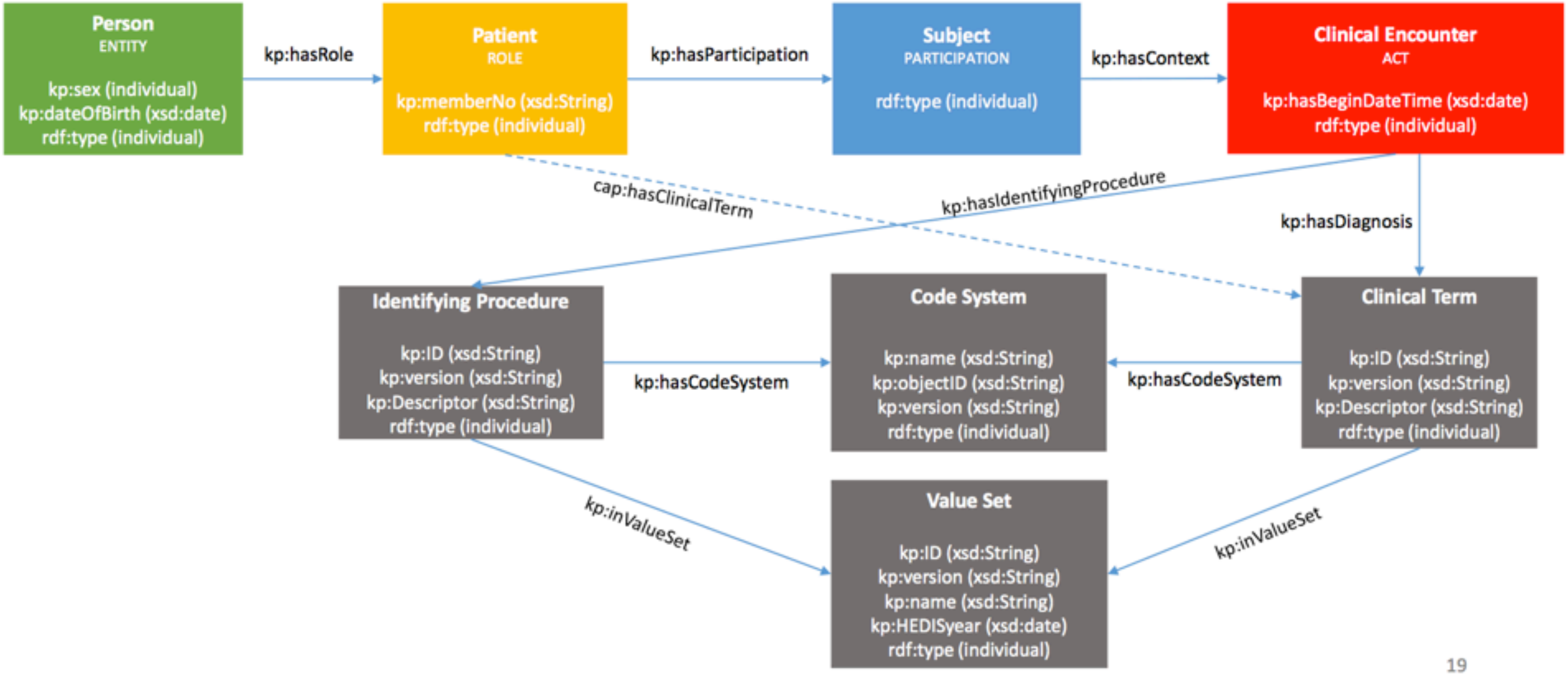
Participation Objects (UML Diagram)



Act Objects (UML Diagram)



Clinical Encounter



Person
ENTITY
kp:sex (individual)
kp:dateOfBirth (xsd:date)
rdf:type (individual)

kp:hasRole

Patient
ROLE
kp:memberNo (xsd:String)
rdf:type (individual)

kp:hasParticipation

Subject
PARTICIPATION
rdf:type (individual)

kp:hasContext

Clinical Encounter
ACT
kp:hasBeginDateTime (xsd:date)
rdf:type (individual)

cap:hasClinicalTerm

kp:hasIdentifyingProcedure

kp:hasDiagnosis

Identifying Procedure
kp:ID (xsd:String)
kp:version (xsd:String)
kp:Descriptor (xsd:String)
rdf:type (individual)

kp:hasCodeSystem

Code System
kp:name (xsd:String)
kp:objectID (xsd:String)
kp:version (xsd:String)
rdf:type (individual)

kp:hasCodeSystem

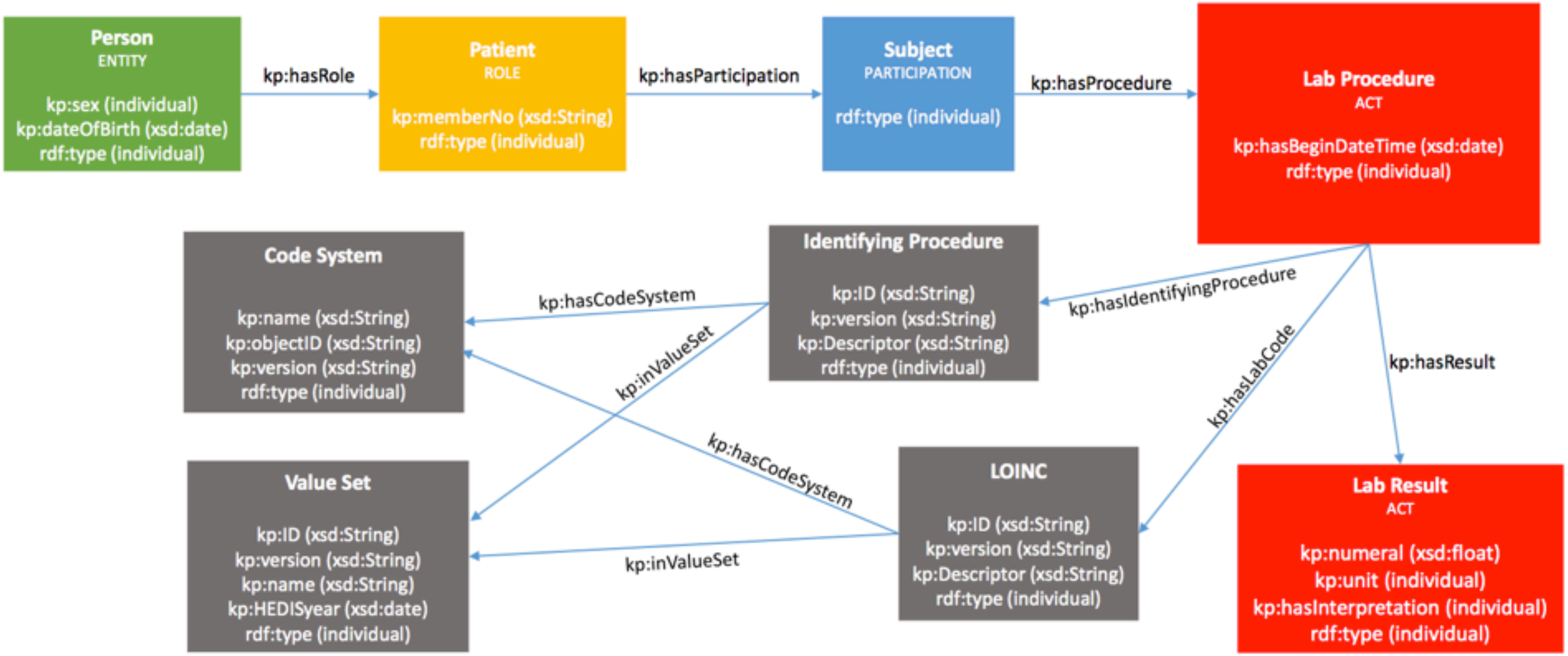
Clinical Term
kp:ID (xsd:String)
kp:version (xsd:String)
kp:Descriptor (xsd:String)
rdf:type (individual)

kp:inValueSet

Value Set
kp:ID (xsd:String)
kp:version (xsd:String)
kp:name (xsd:String)
kp:HEDISyear (xsd:date)
rdf:type (individual)

kp:inValueSet

Lab Results and Procedures



Person
ENTITY

kp:sex (individual)
kp:dateOfBirth (xsd:date)
rdf:type (individual)

Patient
ROLE

kp:memberNo (xsd:String)
rdf:type (individual)

Subject
PARTICIPATION

rdf:type (individual)

Lab Procedure
ACT

kp:hasBeginDateTime (xsd:date)
rdf:type (individual)

Code System

kp:name (xsd:String)
kp:objectID (xsd:String)
kp:version (xsd:String)
rdf:type (individual)

Identifying Procedure

kp:ID (xsd:String)
kp:version (xsd:String)
kp:Descriptor (xsd:String)
rdf:type (individual)

Value Set

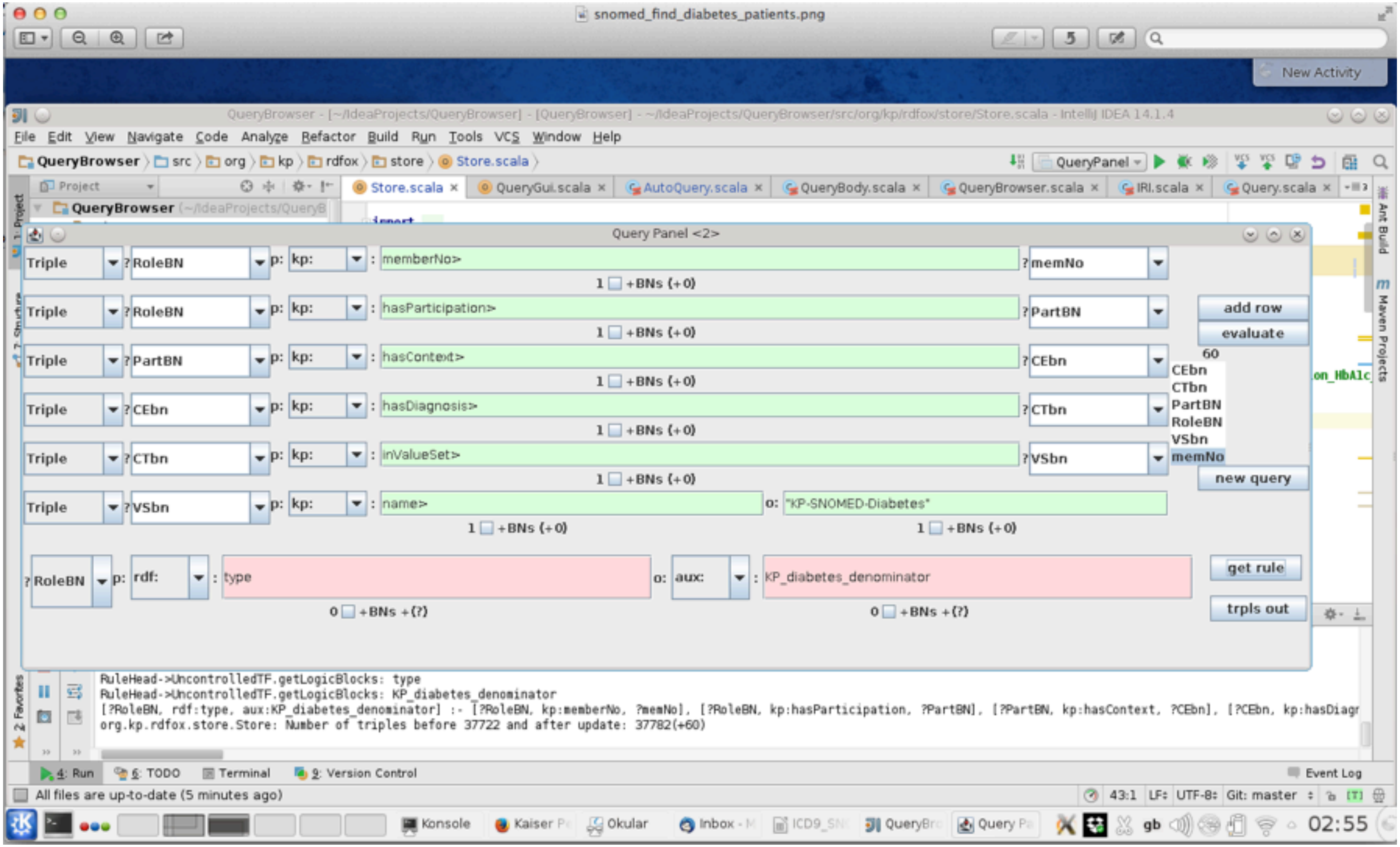
kp:ID (xsd:String)
kp:version (xsd:String)
kp:name (xsd:String)
kp:HEDISyear (xsd:date)
rdf:type (individual)

LOINC

kp:ID (xsd:String)
kp:version (xsd:String)
kp:Descriptor (xsd:String)
rdf:type (individual)

Lab Result
ACT

kp:numeral (xsd:float)
kp:unit (individual)
kp:hasInterpretation (individual)
rdf:type (individual)



snomed_find_diabetes_patients.png

QueryBrowser - [~/IdeaProjects/QueryBrowser] - [QueryBrowser] - ~/IdeaProjects/QueryBrowser/src/org/kp/rdfox/store/Store.scala - IntelliJ IDEA 14.1.4

Query Panel <2>

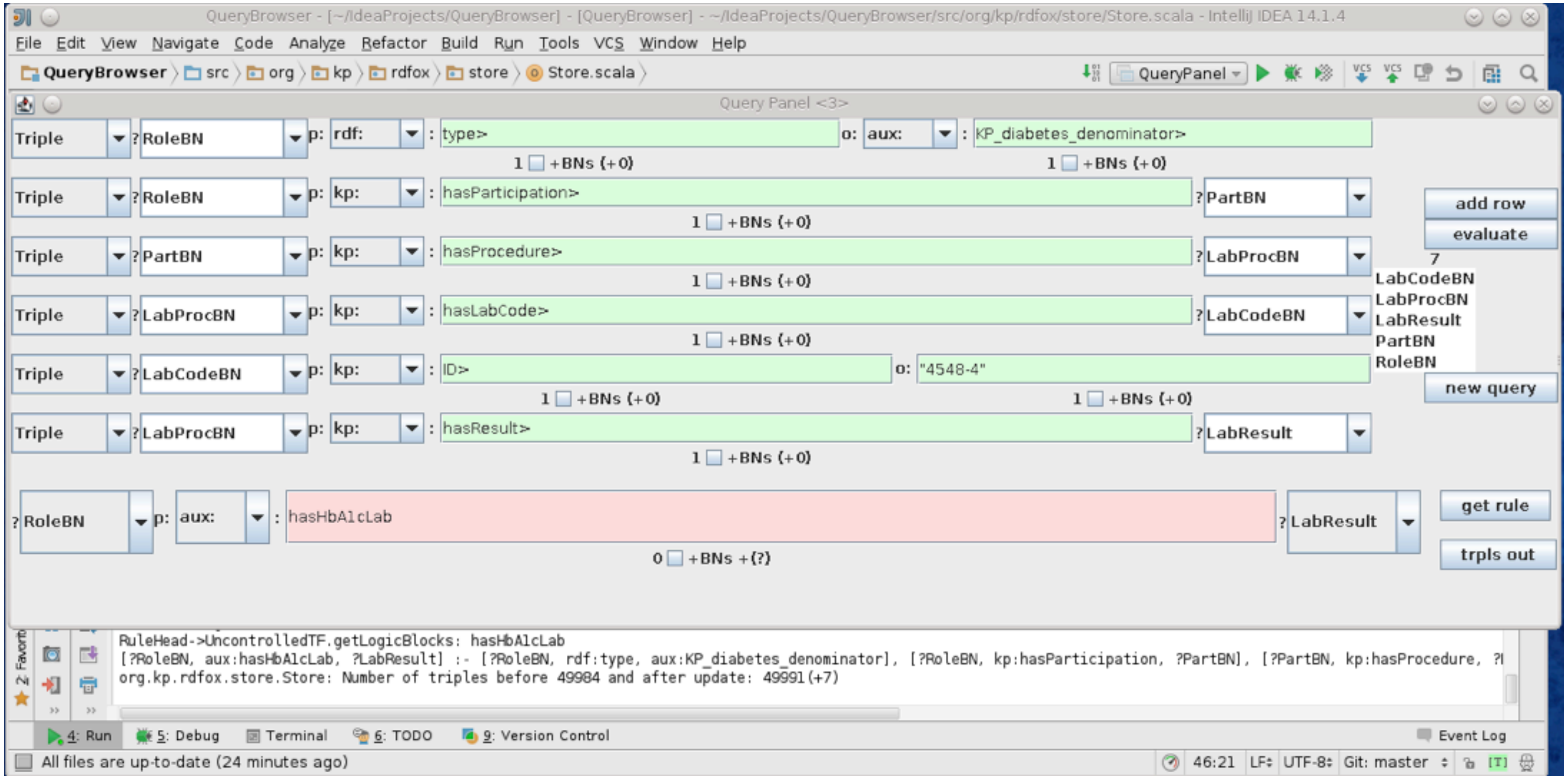
```
Triple  ?RoleBN  p: kp: : memberNo>          ?memNo
                 1 □ +BNs (+0)
Triple  ?RoleBN  p: kp: : hasParticipation>  ?PartBN
                 1 □ +BNs (+0)
Triple  ?PartBN  p: kp: : hasContext>        ?CEbn
                 1 □ +BNs (+0)
Triple  ?CEbn    p: kp: : hasDiagnosis>      ?CTbn
                 1 □ +BNs (+0)
Triple  ?CTbn    p: kp: : inValueSet>        ?VSbn
                 1 □ +BNs (+0)
Triple  ?VSbn    p: kp: : name>   o: "KP-SNOMED-Diabetes"
                 1 □ +BNs (+0)       1 □ +BNs (+0)

?RoleBN  p: rdf: : type   o: aux: : KP_diabetes_denominator
                 0 □ +BNs +(?)       0 □ +BNs +(?)
```

add row
evaluate
60
CEbn
CTbn
PartBN
RoleBN
VSbn
memNo
new query
get rule
trpls out

```
RuleHead->UncontrolledTF.getLogicBlocks: type
RuleHead->UncontrolledTF.getLogicBlocks: KP_diabetes_denominator
[?RoleBN, rdf:type, aux:KP_diabetes_denominator] :- [?RoleBN, kp:memberNo, ?memNo], [?RoleBN, kp:hasParticipation, ?PartBN], [?PartBN, kp:hasContext, ?CEbn], [?CEbn, kp:hasDiagr
org.kp.rdfox.store.Store: Number of triples before 37722 and after update: 37782(+60)
```

All files are up-to-date (5 minutes ago)



QueryBrowser - [~/IdeaProjects/QueryBrowser] - [QueryBrowser] - ~/IdeaProjects/QueryBrowser/src/org/kp/rdfox/store/Store.scala - IntelliJ IDEA 14.1.4

Query Panel <3>

Triple ?RoleBN p: rdf: : type> o: aux: : KP_diabetes_denominator>
1 □ +BNs (+0) 1 □ +BNs (+0)

Triple ?RoleBN p: kp: : hasParticipation> ?PartBN
1 □ +BNs (+0)

Triple ?PartBN p: kp: : hasProcedure> ?LabProcBN
1 □ +BNs (+0)

Triple ?LabProcBN p: kp: : hasLabCode> ?LabCodeBN
1 □ +BNs (+0)

Triple ?LabCodeBN p: kp: : ID> o: "4548-4"
1 □ +BNs (+0) 1 □ +BNs (+0)

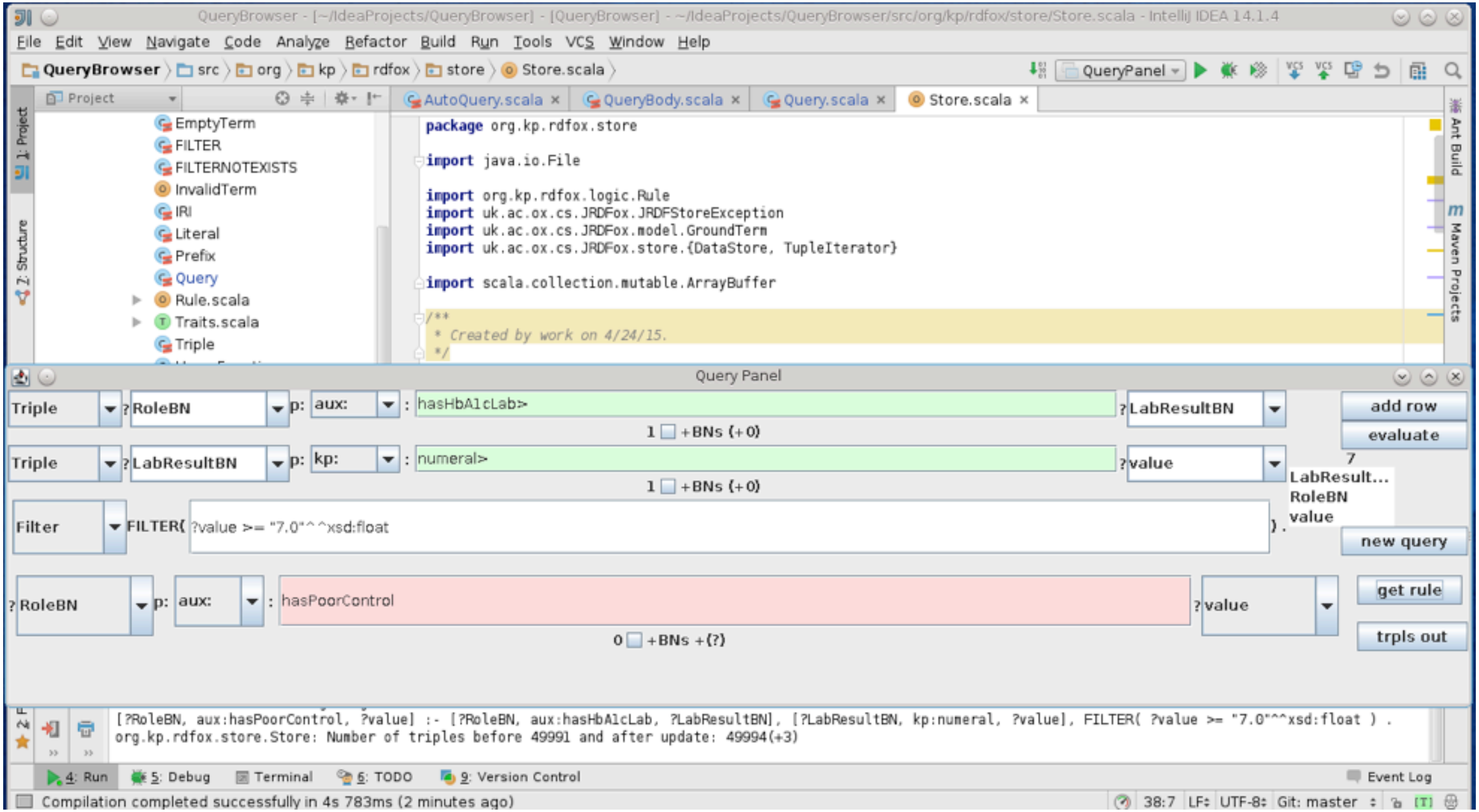
Triple ?LabProcBN p: kp: : hasResult> ?LabResult
1 □ +BNs (+0)

?RoleBN p: aux: : hasHbA1cLab ?LabResult
0 □ +BNs +(?)

7
LabCodeBN
LabProcBN
LabResult
PartBN
RoleBN

```
RuleHead->UncontrolledTF.getLogicBlocks: hasHbA1cLab
[?RoleBN, aux:hasHbA1cLab, ?LabResult] :- [?RoleBN, rdf:type, aux:KP_diabetes_denominator], [?RoleBN, kp:hasParticipation, ?PartBN], [?PartBN, kp:hasProcedure, ?l
org.kp.rdfox.store.Store: Number of triples before 49984 and after update: 49991(+7)
```

All files are up-to-date (24 minutes ago)



QueryBrowser - [~/IdeaProjects/QueryBrowser] - [QueryBrowser] - ~/IdeaProjects/QueryBrowser/src/org/kp/rdfox/store/Store.scala - IntelliJ IDEA 14.1.4
File Edit View Navigate Code Analyze Refactor Build Run Tools VCS Window Help
QueryBrowser src org kp rdfox store Store.scala
QueryPanel
Project
1: Project
7: Structure
EmptyTerm
FILTER
FILTERNOTEXISTS
InvalidTerm
IRI
Literal
Prefix
Query
Rule.scala
Traits.scala
Triple
AutoQuery.scala
QueryBody.scala
Query.scala
Store.scala
Ant Build
Maven Projects

```
package org.kp.rdfox.store

import java.io.File

import org.kp.rdfox.logic.Rule
import uk.ac.ox.cs.JRDFox.JRDFStoreException
import uk.ac.ox.cs.JRDFox.model.GroundTerm
import uk.ac.ox.cs.JRDFox.store.{DataStore, TupleIterator}

import scala.collection.mutable.ArrayBuffer

/**
 * Created by work on 4/24/15.
 */
```

Triple ?RoleBN p: aux: : hasHbA1cLab> ?LabResultBN
1 □ +BNs (+0)

Triple ?LabResultBN p: kp: : numeral> ?value
1 □ +BNs (+0)

Filter FILTER(?value >= "7.0"^^xsd:float) .

?RoleBN p: aux: : hasPoorControl ?value
0 □ +BNs +(?)

7
LabResult...
RoleBN
value

```
[?RoleBN, aux:hasPoorControl, ?value] :- [?RoleBN, aux:hasHbA1cLab, ?LabResultBN], [?LabResultBN, kp:numeral, ?value], FILTER( ?value >= "7.0"^^xsd:float ) .
org.kp.rdfox.store.Store: Number of triples before 49991 and after update: 49994(+3)
```

Compilation completed successfully in 4s 783ms (2 minutes ago)

Results Diabetes Test Run. Data From One Region

- Members in total

SELECT DISTINCT ?memno WHERE { ?role kp:memberNo ?memno }

=> 465774

The number of members which are according to your definition (KP Diabetes Denominator) SELECT DISTINCT ?role WHERE { ?role rdf:type aux:KP_diabetes_denominator }

=> 51359

Results Diabetes Test Run. Data From One Region

The number of diabetic members which had a Lab Result associated with a Lab Procedure code "4548-4"

SELECT DISTINCT ?role WHERE { ?role aux:hasHbA1cLab ?labResult }

=> 38497 (75% of diabetic members)

(For 38497 were 163828 Lab Procedures registered; on average every diabetic member was 4.26x tested)

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Diabetes Patients with a Specific Lab Result

- The number of diabetic members with poor HbA1c control (>= 7%)

SELECT DISTINCT ?role WHERE { ?role aux:hasPoorControl ?value }

=> 18181 (47% of those tested diabetic members)

This is at any time including at time of Dx

SNOMED and RDFox

- Further RDFox queries showed that of all the patients who ever had a level of HgbA1c over 7, 100% of them were below 7 “at the last measurement”, and so were successfully managed.
- The definition of Diabetes in this test run, was a value set for terms subsumed by SNOMED Diabetes.

SNOMED and RDFox Conclusion

- The combination of the SNOMED subsumption logic and the RDFox logic allowed us to determine a quality measure for an entire region, including programming and running, in a few hours.

SNOMED and RDFox Conclusion

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