Overview of FHIR RDF/OWL ValueSet approach

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In RDF/OWL, ValueSets are named Classes representing sets of CodingBase individuals (system and code).

A ValueSet may be indirectly defined by concept Classes (typically in a hierarchy). A concept can have one or more direct restriction of CodingBase individuals. A concept can only have restrictions on a single code system.

This document version shows two navigation options out of other possibilities:

1. ValueSets are named Classes with direct restrictions on CodingBase individuals (system + code)
2. ValueSets are named Classes representing sets of CodingBase restrictions via Concept restrictions.
3. Others – see later section on “Restriction equivalents to Compose Elements”

The approach is generally the same for HL7 FHIR internal code systems and external code systems such as SNOMED CT.

Since there is dependency between them, the document is arranged to cover definition of:

- CodingBase individual
- Approach to conformance
- Code System
- Concept
- ValueSet

1 RDF CodingBase Individual Example

Here is the raw RDF as exchanged:

```
###  http://record/AllergyIntolerance/1

<http://record/AllergyIntolerance/1> rdf:type profile:AllergyIntolerance , owl:NamedIndividual ;
   fhir:AllergyIntolerance.substance [ rdfs:label "beta-lactam (antibiotic)" ;
      fhir:ConceptBase.coding [
         fhir:CodingBase.system [ fhir:value <http://snomed.info/sct> ] ;
         fhir:CodingBase.code [ fhir:value "90614001" ] ;
         fhir:CodingBase.display [ fhir:value "beta-lactam (antibiotic)" ]
      ] ;
      fhir:ConceptBase.text [ fhir:value "beta-lactam (antibiotic)" ]
   ] ;

   fhir:Resource.id [ fhir:value "1" ] ;
   fhir:AllergyIntolerance.patient [ fhir:Reference.reference [ fhir:value "http://record/Patient/PeterPatient" ] ;
      fhir:Reference.display [ fhir:value "Peter Patient" ]
   ] ;

   fhir:AllergyIntolerance.status [ fhir:ConceptBase.coding
      [ fhir:CodingBase.code [ fhir:value "confirmed" ]
   ]
] .
```

Here is the RDF after the CodingBase individuals are classified to their terms and References have closure:

```
###  http://record/AllergyIntolerance/1


<http://record/AllergyIntolerance/1> a profile: AllergyIntolerance, owl:NamedIndividual ;
   fhir:Resource.id [ a fhir:id ; fhir:value "1" ] ;
   fhir:AllergyIntolerance.status [ a <http://hl7.org/fhir/allergyIntoleranceStatus#confirmed>;
      fhir:ConceptBase.coding [ fhir:CodingBase.code [ a fhir:codeBase ; fhir:value "confirmed" ]  ]
   ] ;
   fhir:AllergyIntolerance.patient [ a fhir:Reference ;
      fhir:Reference.reference [ a fhir:uri ; fhir:value "http://record/Patient/PeterPatient" ] ;
      fhir:Reference.display [ a fhir:string ; fhir:value "Peter Patient" ] ;
      fhir:Reference.link <http://record/Patient/PeterPatient> ;
   ] ;
   fhir:AllergyIntolerance.substance [ a fhir:ConceptBase , <http://snomed.info/id/90614001> ;
      fhir:ConceptBase.coding [ a fhir:CodingBase ;
         fhir:CodingBase.system [ a fhir:string ; fhir:value "http://snomed.info/sct" ] ;
         fhir:CodingBase.code [ a fhir:codeBase ; fhir:value "90614001" ] ;
         fhir:CodingBase.display [ a fhir:string ; fhir:value "beta-lactam (antibiotic)" ]
      ] ;
      fhir:ConceptBase.text [ a fhir:string ; fhir:value "beta-lactam (antibiotic)"
]
] .
```

2 Schema definition

2.1 FHIR Schema definition

2.1.1 Allergy Intolerance Status Structural Definition

```
    <element>
      <path value="AllergyIntolerance.status"/>
      <short value="active | unconfirmed | confirmed | inactive | resolved | refuted | entered-in-error"/>
      <definition value="Assertion about certainty associated with the propensity, or potential risk, of a reaction
       to the identified Substance."/>
      <comments value="Decision support would typically raise alerts for 'Unconfirmed', 'Confirmed', and 'Resolved'
       and ignore a 'Refuted' reaction. In particular, 'Refuted' may be useful for reconciliation of the Adverse Reaction
       List. Some implementations may choose to make this field mandatory."/>
      <alias value="State"/>
      <min value="0"/>
      <max value="1"/>
      <type>
        <code value="code"/>
      </type>
      <isModifier value="true"/>
      <isSummary value="true"/>
      <binding>
        <strength value="required"/>
        <description value="Assertion about certainty associated with a propensity, or potential risk, of a reaction
         to the identified Substance."/>
        <valueSetReference>
          <reference value="http://hl7.org/fhir/ValueSet/allergy-intolerance-status"/>
        </valueSetReference>
      </binding>
      <mapping>
        <identity value="v2"/>
        <map value="IAM-17"/>
      </mapping>
      <mapping>
        <identity value="w5"/>
        <map value="status"/>
      </mapping>
    </element>
```

2.1.2 AllergyIntolerance.substance Structural Definition

```
    <element>
      <path value="AllergyIntolerance.substance"/>
      <short value="Substance, (or class) considered to be responsible for risk"/>
      <definition value="Identification of a substance, or a class of substances, that is considered to be responsible
       for the adverse reaction risk."/>
      <comments value="It is strongly recommended that the substance be coded with a terminology, where possible.
       For example, some terminologies used include RxNorm, SNOMED CT, DM+D, NDFRT, ICD-9, IDC-10,
       UNI, ATC and CPT. Plain text should only be used if there is no appropriate terminology
       available. Additional details about a substance can be specified in the text."/>
      <alias value="Agent"/>
      <min value="1"/>
      <max value="1"/>
      <type>
        <code value="CodeableConcept"/>
      </type>
      <isSummary value="true"/>
      <binding>
        <strength value="example"/>
        <description value="Type of the substance and Negation codes for reporting no known allergies."/>
        <valueSetReference>
          <reference value="http://hl7.org/fhir/ValueSet/allergyintolerance-substance-code"/>
        </valueSetReference>
      </binding>
      <mapping>
        <identity value="v2"/>
        <map value="AL1-3 / IAM-3"/>
      </mapping>
      <mapping>
        <identity value="w5"/>
        <map value="what"/>
      </mapping>
    </element>
```

2.2 OWL Schema Definition

2.2.1 Allergy Intolerance Class

The OWL schema fragment for the class and object properties is shown here:

```
###  http://hl7.org/fhir/AllergyIntolerance

fhir:AllergyIntolerance rdf:type owl:Class ;

                        rdfs:subClassOf fhir:DomainResource ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.status ;
                                          owl:allValuesFrom fhirvs:allergy-intolerance-statusA
                                        ] ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.status ;
                                          owl:maxCardinality "1"^^xsd:nonNegativeInteger
                                        ] ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.patient ;
                                          owl:allValuesFrom fhir:Reference
                                        ] ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.patient ;
                                          owl:maxCardinality "1"^^xsd:nonNegativeInteger
                                        ] ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.substance ;
                                          owl:allValuesFrom fhirvs:allergyintolerance-substance-code
                                        ] ,
                                        [ rdf:type owl:Restriction ;
                                          owl:onProperty fhir:AllergyIntolerance.substance ;
                                          owl:maxCardinality "1"^^xsd:nonNegativeInteger
                                        ] ,
……..……..
.
```

It shows that:

- AllergyIntolerance.status is restricted to the set defined by fhirvs:allergy-intolerance-statusA.
- AllergyIntolerance.substance is restricted to the set defined by fhirvs:allergyintolerance-substance-code.

However due to OWA approaches by the reasoner (HermiT) an inconsistency is not detected.

2.2.2 AllergyIntolerance.status Object Property definition

```
###  http://hl7.org/fhir/AllergyIntolerance.status

fhir:AllergyIntolerance.status rdf:type owl:ObjectProperty ;
   fhir:binding.valueSetReference "http://hl7.org/fhir/ValueSet/allergy-intolerance-status"^^xsd:anyURI ;
   fhir:isModifier "true"^^xsd:boolean ;
   fhir:isSummary "true"^^xsd:boolean ;
   rdfs:comment "Decision support would typically raise alerts for 'Unconfirmed', 'Confirmed', and 'Resolved' and ignore
a 'Refuted' reaction. In particular, 'Refuted' may be useful for reconciliation  of the Adverse Reaction List. Some
implementations may choose to make this field mandatory." ;
   fhir:short "active | unconfirmed | confirmed | inactive | resolved | refuted | entered-in-error" ;
   fhir:binding.description "Assertion about certainty associated with a propensity, or potential risk, of a reaction to
the identified Substance." ;
   fhir:concept_definition "Assertion about certainty associated with the propensity, or potential risk, of a reaction to
the identified Substance." ;
   fhir:binding.strength "required" ;
   rdfs:domain fhir:AllergyIntolerance ;
   rdfs:range fhir:code ;
   rdfs:subPropertyOf fhir:objectProperty .
```

2.2.3 AllergyIntolerance.substance Object Property

```
###  http://hl7.org/fhir/AllergyIntolerance.substance

fhir:AllergyIntolerance.substance rdf:type owl:ObjectProperty ;
   fhir:isSummary "true"^^xsd:boolean ;
   fhir:binding.valueSetReference "http://hl7.org/fhir/ValueSet/allergyintolerance-substance-code" ;
   fhir:short "Substance, (or class) considered to be responsible for risk" ;
   fhir:concept_definition "Identification of a substance, or a class of substances, that is considered to be responsible
for the adverse reaction risk." ;
   fhir:binding.strength "example" ;
   rdfs:comment "It is strongly recommended that the substance be coded with a terminology, where possible.  For example,
some terminologies used include RxNorm, SNOMED CT, DM+D, NDFRT, ICD-9, IDC-10, UNI, ATC and CPT. Plain text should only
be used if there is no appropriate terminology available. Additional details about a substance can be specified in the
text." ;
   fhir:binding.description "Type of the substance and Negation codes for reporting no known allergies." ;
   rdfs:domain fhir:AllergyIntolerance ;
   rdfs:range fhir:CodeableConcept ;
   rdfs:subPropertyOf fhir:objectProperty .
```

3 Approach to Conformance

Binding strength to a ValueSet determines the conformance of the CodingBase.

Almost all of the elements that have a coded data type are bound to a value set. The bindings are associated with various degrees of flexibility as to how closely the value set should be followed:

required	To be conformant, instances of this element SHALL include a code from the specified value set
extensible	To be conformant, instances of this element must include a code from the specified value set if any of the codes within the value set can apply to the concept being communicated. If the valueset does not cover the concept (based on human review), alternate codings (from different code systems, including local ones) or (data type allowing) text) may be included instead.
preferred	Instances are encouraged, to draw from the specified codes for interoperability purposes but are not required to do so to be considered conformant

example	Instances are not expected or even encouraged to draw from the specified value set. The value set merely provides examples of the types of concepts intended to be included

The classes that the CodingBase individual belong to, are inferred and the individual must belong to the ValueSet class declared in the schema if its binding strength is “required”.

In the example above, the individual ConceptBase has a CodingBase which is a member of fhirvs:allergy-intolerance-statusA so the ConceptBase individual is conformant to the schema.

This implies that a reasoner will work from the values in the CodingBase.system and CodingBase.code to infer the classes. The ValueSet Class must be equivalent or a superclass of the restriction for this to work.

Being a member of the Target ValueSet meets the “required” binding strength. Being a member of another ValueSet meets the “extensible” binding strength.

Note that the binding strength for AllergyIntolerance.status is “example”. It is expected that a Profile would strengthen this to “required”.

In ORIM, the subclassing of restrictions approach (as a general Class axiom) is taken which avoids complications from propagation. This subclass approach for restrictions and the superclass approach for Concepts will be taken in FHIR/RDF.

The testing of the conformance is outside the scope of this paper but is expected to be performed with rules or query languages.

4 RDF Verbatim translation

The RDF direct verbatim translation of FHIR XML ValueSet is not useful since it cannot be assembled into graphs with other parts of the RDF. The elements of a CodeSystem in an XML ValueSet Resource will not be translated into RDF individuals but into one or more classes.

5 Code system

5.1 HL7 FHIR Internal Code System XML example

A definition of a code system, inlined into the value set (as a packaging convenience).

```
  <codeSystem>
    <extension url="http://hl7.org/fhir/StructureDefinition/valueset-oid">
      <valueUri value="urn:oid:2.16.840.1.113883.4.642.1.50"/>
    </extension>
    <system value="http://hl7.org/fhir/allergy-intolerance-status"/>
    <version value="1.0.0"/>
    <caseSensitive value="true"/>
    <concept>
      <code value="active"/>
      <display value="Active"/>
      <definition value="An active record of a reaction to the identified Substance."/>
      <concept>
        <code value="confirmed"/>
        <display value="Confirmed"/>
        <definition value="A high level of certainty about the propensity for a reaction to the identified
Substance,
          which may include clinical evidence by testing or rechallenge."/>
      </concept>
    </concept>
  </codeSystem>
```

5.2 RDF CodeSystemURI declaration

A code system will have one named individual representing the code system. This is a member of class: fhir:CodeSystemURI . CodeSystemURI is a subclass of fhir:uri and allows named individuals to represent the URI. The properties are added to it as annotation properties.

Thus the reference to a system in CodingBase.system can have a value e.g. <http://snomed.info/sct> and not have to declare a further anonymous individual.

5.2.1 HL7 Internal Code system URI example

```
###  http://hl7.org/fhir/cs/allergy-intolerance-status

fhircs:allergy-intolerance-status rdf:type fhir:CodeSystemURI , owl:NamedIndividual ;
   fhir:caseSensitive "true"^^xsd:boolean ;
   fhir:valueset-oid "urn:oid:2.16.840.1.113883.4.642.1.50" ;
   fhir:value "http://hl7.org/fhir/cs/allergy-intolerance-status" ;
   fhir:prefix "http://hl7.org/fhir/allergy-intolerance-status#" ;
   fhir:version "1.0.2" .
```

5.2.2 SNOMED Code System URI example

```
###  http://snomed.info/sct

<http://snomed.info/sct> rdf:type fhir:CodeSystemURI , owl:NamedIndividual ;
   fhir:value "http://snomed.info/sct"^^xsd:anyURI .
   fhir:caseSensitive "false"^^xsd:boolean ;
   fhir:prefix "http://snomed.info/id/"^^xsd:string ;
   fhir:valueset-oid "2.16.840.1.113883.6.96" ;
   fhir:version "US1000124_20140301" .
```

Code systems are published at http://hl7-fhir.github.io/terminologies-systems.html and the URI identifier is used for FHIR/RDF rather than the OID.

Version of code system as part of the name is TBD.

6 Concept

6.1 HL7 FHIR Concept XML

The following fragment from Allergy Intolerance Status found at
http://hl7-fhir.github.io/valueset-allergy-intolerance-status.html

In FHIR, Code System contains ValueSet.codeSystem.concept elements.

ValueSet.codeSystem.concept have code, abstract, display, definition, designation and nested Valueset.Concepts.

```
  <codeSystem>
    <extension url="http://hl7.org/fhir/StructureDefinition/valueset-oid">
      <valueUri value="urn:oid:2.16.840.1.113883.4.642.1.50"/>
    </extension>
    <system value="http://hl7.org/fhir/allergy-intolerance-status"/>
    <version value="1.0.0"/>
    <caseSensitive value="true"/>
    <concept>
      <code value="active"/>
      <display value="Active"/>
      <definition value="An active record of a reaction to the identified Substance."/>
      <concept>
        <code value="confirmed"/>
        <display value="Confirmed"/>
        <definition value="A high level of certainty about the propensity for a reaction to the identified
Substance,
          which may include clinical evidence by testing or rechallenge."/>
      </concept>
    </concept>
  </codeSystem>
</ValueSet>
```

The nesting of <concept> represents general to specific concepts although the structure does not indicate that semantic but rather a containment.

6.2 RDF Concept Definition

A Concept in RDF/OWL is a named Class which has a restriction for each CodingBase individual associated with that concept. A specific Concept is a specific subclass of the fhir:Concepts class or it is a subclass of another Concept. Where the restrictions are defined on the Concept they are the intersection of the restriction on ConceptBase.coding and CodingBase.code and CodingBase.system.

Concepts may have one or more CodingBase restrictions. The FHIR valueset resource structure definition only allows one but the RDF equivalent will relax that cardinality. A Concept which has multiple Codes associated with it, have a union of multiple CodingBase.code restrictions.

6.2.1 FHIR internal XML Concept mapping

The RDF Concept is a named Class which maps to the components of the ValueSet.codeSystem.concept element in FHIR Valueset Resource.

- System maps to the restriction on CodingBase.system
- Code maps to the restriction on CodingBase.code
- Display maps to rdfs:label
- Definition maps to fhir:concept_definition annotation
- Nesting maps to subclass assertions (as a default)

- An abstract Concept (ValueSetConcept.abstract = “true”) has no restriction on CodingBase.code just a position in the class hierarchy.
- Designation will probably transform into annotation language (e.g. @en) or type.

6.2.2 HL7 Internal Concept RDF Example

```
###  http://hl7.org/fhir/allergy-intolerance-status#Concept

allergy-intolerance-status:Concept rdf:type owl:Class ;
   rdfs:label "Allergy Intolerance Status Concept" ;
   rdfs:subClassOf fhir:Concepts ;
   fhir:concept_definition "Assertion about certainty associated with a propensity, or potential risk, of a reaction to
the identified Substance." .

###  http://hl7.org/fhir/allergy-intolerance-status#active

allergy-intolerance-status:active rdf:type owl:Class ;
   rdfs:label "Active" ;
   rdfs:subClassOf allergy-intolerance-status:Concept ;
   fhir:concept_definition "An active record of a reaction to the identified Substance" .

[ rdf:type owl:Restriction ;
  rdfs:subClassOf allergy-intolerance-status:active ; owl:onProperty fhir:ConceptBase.coding ;
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:intersectionOf ( [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.code ;
                                              owl:allValuesFrom [ rdf:type owl:Restriction ;
                                                                  owl:onProperty fhir:value ;
                                                                  owl:hasValue "active"
                                                                ]
                                            ]
                                            [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.system ;
                                              owl:hasValue fhircs:allergy-intolerance-status
                                            ]
                                          )
                     ]
] .

###  http://hl7.org/fhir/allergy-intolerance-status#confirmed

allergy-intolerance-status:confirmed rdf:type owl:Class ;
   rdfs:label "Confirmed"@en ;
   rdfs:subClassOf allergy-intolerance-status:active ;
   fhir:concept_definition "A high level of certainty about the propensity for a reaction to the identified Substance,
which may include clinical evidence by testing or rechallenge." .

[ rdf:type owl:Restriction ;
  rdfs:subClassOf allergy-intolerance-status:confirmed ; owl:onProperty fhir:ConceptBase.coding ;
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:intersectionOf ( [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.code ;
                                              owl:allValuesFrom [ rdf:type owl:Restriction ;
                                                                  owl:onProperty fhir:value ;
                                                                  owl:hasValue "confirmed"
                                                                ]
                                            ]
                                            [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.system ;
                                              owl:hasValue fhircs:allergy-intolerance-status
                                            ]
                                          )
                     ]
] .
```

6.2.3 External Concept RDF Example

An external terminology is treated differently in that it is assumed that the ontology provided by the external organization cannot be changed. A bridging ontology is therefore provided which allows the expressions to be added to bind to the FHIR CodingBase instances.

The bridging ontology is constructed to add the expressions to categorize FHIR CodingBase individuals. This binding occurs at both code/system and concepts. Direct use of the declared SNOMED concept identifier is shown here but it is also possible to make an equivalent class if needed.

6.2.3.1 External SNOMED Ontology

The following example from the SNOMED OWL extraction shows the two top Concepts referenced in the valueset substance-code:

```
###  http://snomed.info/id/105590001

<http://snomed.info/id/105590001> rdf:type owl:Class ;
                                  rdfs:label "Substance (substance)" ;
                                  rdfs:subClassOf <http://snomed.info/id/138875005> .

###  http://snomed.info/id/373873005

<http://snomed.info/id/373873005> rdf:type owl:Class ;
                                  rdfs:label "Pharmaceutical / biologic product (product)" ;
                                  rdfs:subClassOf <http://snomed.info/id/138875005> .
```

Notice there is no description and the display value is in rdfs:label. Concept 138875005 is the top level SNOMED CT concept.

The extensions of the value set beyond substance-code are defined in SNOMED:

```
###  http://snomed.info/id/160244002

<http://snomed.info/id/160244002> rdf:type owl:Class ;
   rdfs:label "No Known Allergies" ;
   rdfs:subClassOf <http://snomed.info/id/138875005> .

###  http://snomed.info/id/409137002

<http://snomed.info/id/409137002> rdf:type owl:Class ;
   rdfs:label "No Known Drug Allergies" ;
   rdfs:subClassOf <http://snomed.info/id/138875005> .

###  http://snomed.info/id/428607008

<http://snomed.info/id/428607008> rdf:type owl:Class ;
   rdfs:label "No Known Environmental Allergy" ;
   rdfs:subClassOf <http://snomed.info/id/138875005> .

###  http://snomed.info/id/429625007

<http://snomed.info/id/429625007> rdf:type owl:Class ;
   rdfs:label "No Known Food Allergies" ;
   rdfs:subClassOf <http://snomed.info/id/138875005> .
```

These are shown as subclasses of the top concept which is incorrect.

6.2.3.2 Bridging Ontology

The FHIR SCTBridge ontology imports both fhir and snomed ontologies so it can see both:

```
<http://hl7.org/fhirSCTBridge> rdf:type owl:Ontology ;
                               owl:imports <http://hl7.org/fhir> ,
                                           <http://snomed.info/id> .
```

The SNOMED ontology is named <http://snomed.info/id> which makes the concept URI construction natural.

The restrictions on the Concepts to CodingBase individuals are made through general class axioms in the same way as internal code systems:

```
[ rdf:type owl:Restriction ;
  rdfs:subClassOf <http://snomed.info/id/90614001> ;
  owl:onProperty fhir:ConceptBase.coding ;
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:intersectionOf ( [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.code ;
                                              owl:allValuesFrom [ rdf:type owl:Restriction ;
                                                                  owl:onProperty fhir:value ;
                                                                  owl:hasValue "90614001"
                                                                ]
                                            ]
                                            [ rdf:type owl:Restriction ;
                                              owl:onProperty fhir:CodingBase.system ;
                                              owl:hasValue <http://snomed.info/sct>
                                            ]
                                          )
                     ]
] .
```

This example shows that the Concept “Beta lactam antibiotic” is inferred when the ConceptBase.coding has a CodingBase where CodingBase.code has a code of 90614001 and CodingBase.system has value <http://snomed.info/sct>.

6.3 Relationship of Concept to Code SystemURI

The concept defines its CodeSystemURI through ConceptBase.system restriction.

The CodeSystemURI being an individual has no relationship to the Concepts in the Code system which are Classes.

7 ValueSet Definition

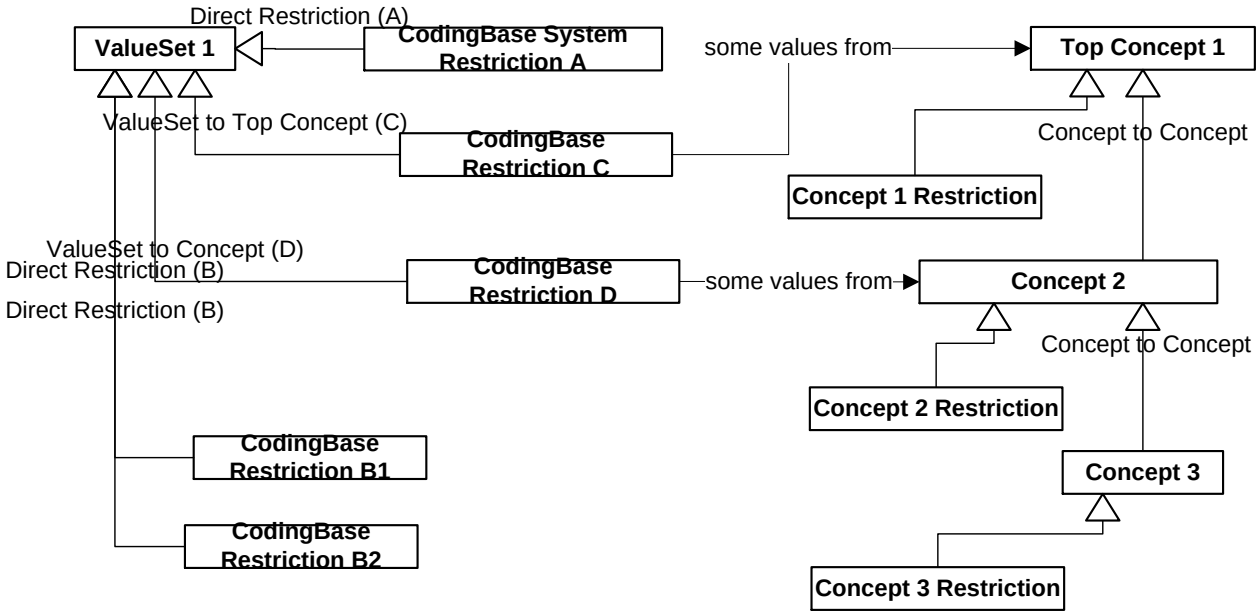
A ValueSet in RDF is a specific Class which defines the CodingBase individuals which are members of it.

There are two ways of declaring the ValueSet in RDF –

- ValueSets are named Classes with direct restrictions on CodingBase individuals (system + code)
- ValueSets are named Classes representing sets of CodingBase restrictions via Concept restrictions.

See the later section for more detailed consideration of the flexibility of ValueSet definitions. These definitions will be mapped into the two ways above.

The following diagram shows the subclass relationships between the classes:



A valueset defines a subset of CodingBase individuals which meet the constraints of that ValueSet.

Four cases are explored A & B are the direct restrictions and C & D are indirect via concepts:

A. Aligned ValueSet with Code system (all codes from).
B. Unaligned ValueSet direct restriction on CodingBase
C. Aligned ValueSet with Top Concept (all concepts from)
D. Unaligned ValueSet restriction on Concepts

7.1 HL7 Internal Concept RDF Example

7.1.1 CodeSystem and Concept XML

```
<ValueSet xmlns="http://hl7.org/fhir">
  <id value="allergy-intolerance-status"/>
  <meta>
    <lastUpdated value="2015-10-27T02:58:28.599+00:00"/>
    <profile value="http://hl7.org/fhir/StructureDefinition/valueset-shareable-definition"/>
  </meta>
  <text>

  </text>
  <extension url="http://hl7.org/fhir/StructureDefinition/valueset-oid">
    <valueUri value="urn:oid:2.16.840.1.113883.4.642.2.50"/>
  </extension>
  <url value="http://hl7.org/fhir/ValueSet/allergy-intolerance-status"/>
  <version value="1.0.2"/>
  <name value="AllergyIntoleranceStatus"/>
  <status value="draft"/>
  <experimental value="false"/>
  <publisher value="HL7 (FHIR Project)"/>
  <contact>
    <telecom>
      <system value="other"/>
      <value value="http://hl7.org/fhir"/>
    </telecom>
    <telecom>
      <system value="email"/>
      <value value="fhir@lists.hl7.org"/>
    </telecom>
  </contact>
  <date value="2015-10-27T02:58:28+00:00"/>
  <description value="Assertion about certainty associated with a propensity, or potential risk, of a reaction
   to the identified Substance."/>
  <codeSystem>
    <extension url="http://hl7.org/fhir/StructureDefinition/valueset-oid">
      <valueUri value="urn:oid:2.16.840.1.113883.4.642.1.50"/>
    </extension>
    <system value="http://hl7.org/fhir/allergy-intolerance-status"/>
    <version value="1.0.2"/>
    <caseSensitive value="true"/>
    <concept>
      <code value="active"/>
      <display value="Active"/>
      <definition value="An active record of a reaction to the identified Substance."/>
      <concept>
        <code value="unconfirmed"/>
        <display value="Unconfirmed"/>
        <definition value="A low level of certainty about the propensity for a reaction to the identified Substance."/>
      </concept>
      <concept>
        <code value="confirmed"/>
        <display value="Confirmed"/>
        <definition value="A high level of certainty about the propensity for a reaction to the identified Substance,
         which may include clinical evidence by testing or rechallenge."/>
      </concept>
    </concept>
    <concept>
      <code value="inactive"/>
      <display value="Inactive"/>
      <definition value="An inactive record of a reaction to the identified Substance."/>
      <concept>
        <code value="resolved"/>
        <display value="Resolved"/>
        <definition value="A reaction to the identified Substance has been clinically reassessed by testing or
rechallenge
         and considered to be resolved."/>
      </concept>
      <concept>
        <code value="refuted"/>
        <display value="Refuted"/>
        <definition value="A propensity for a reaction to the identified Substance has been disproven with a high
         level of clinical certainty, which may include testing or rechallenge, and is refuted."/>
      </concept>
      <concept>
        <code value="entered-in-error"/>
```

```
        <display value="Entered In Error"/>
        <definition value="The statement was entered in error and is not valid."/>
      </concept>
    </concept>
  </codeSystem>
</ValueSet>
```

7.1.2 RDF Direct Restriction Aligned with a Code System (A)

The first option for value set is where the valueset entry defines the direct restriction on code and system itself without referencing a named concept and when the ValueSet is aligned (all codes from) with the CodingSystem the declaration is simple.

Valueset allergy-intolerance-statusA is defined using general class axiom restriction on CodingBase.system

```
###  http://hl7.org/fhir/ValueSet/allergy-intolerance-statusA

fhirvs:allergy-intolerance-statusA rdf:type owl:Class ;
   rdfs:subClassOf fhir:Valuesets .

[ rdf:type owl:Restriction ;
  rdfs:subClassOf fhirvs:allergy-intolerance-statusA ;
  owl:onProperty fhir:CodingBase.system ;
  owl:hasValue fhircs:allergy-intolerance-status
] .
```

However, this mechanism does not validate that the coding is actually a member of the Code System which cannot be done without doing an indirect restriction (see C).

7.1.3 RDF Direct Restriction Unaligned with a Code System (B)

When the ValueSet is not aligned with the code system, then expressions which represent the allowed code values must be included as shown in allergy-intolerance-statusB. This is the most direct equivalent of the XML example above.

```
###  http://hl7.org/fhir/ValueSet/allergy-intolerance-statusB

fhirvs:allergy-intolerance-statusB rdf:type owl:Class ;
   rdfs:subClassOf fhir:CodingBase_in_Valuesets .

[ rdf:type owl:Class ;
  rdfs:subClassOf fhirvs:allergy-intolerance-statusB ;
  owl:intersectionOf ( [ rdf:type owl:Restriction ; owl:onProperty fhir:CodingBase.code ;
        owl:someValuesFrom [ rdf:type owl:Class ;
           owl:unionOf ( [ rdf:type owl:Restriction ; owl:onProperty fhir:value ;
                           owl:hasValue "confirmed"
                         ]
                         [ rdf:type owl:Restriction ; owl:onProperty fhir:value ;
                           owl:hasValue "unconfirmed"
                         ]
                       )
        ]
     ]
     [ rdf:type owl:Restriction ; owl:onProperty fhir:CodingBase.system ;
        owl:hasValue fhircs:allergy-intolerance-status
     ]
  )
] .
```

This expression shows the allergy-intolerance-statusB value set including the codes “confirmed” and “unconfirmed” within the Code System fhircs:allergy-intolerance-status . More sophisticated filtering

expressions in FHIR will have to be translated into this language but since there is no subclass relationships between the code tokens, all subclass trees must be spelled out as lists of tokens.

7.1.4 RDF Aligned ValueSet of CodingBase individuals within Top Concept (C)

Since we can use the set expressions of OWL on classes (Concepts) there is a simplification to the expression of Valuesets subclasses as shown in allergy-intolerance-statusC.

The concepts are named classes as shown earlier. The Valuesets subclass can now refer to these named classes avoiding repetitive declaration of anonymous classes.

When the valueset is aligned with the code system the ValueSet is a superclass of all the CodingBase individuals which have a type Concept of the top concept (inferred).

```
###  http://hl7.org/fhir/ValueSet/allergy-intolerance-statusC

fhirvs:allergy-intolerance-statusC rdf:type owl:Class ;
   rdfs:label "Allergy Int Status C" ;
   rdfs:subClassOf fhir:Valuesets .

[ rdf:type owl:Restriction ;
  rdfs:subClassOf fhirvs:allergy-intolerance-statusC ;
  owl:onProperty fhir:CodingBase.concept ;
  owl:someValuesFrom allergy-intolerance-status:Concept
] .
```

This is entered as a general class axiom as in the other examples.

Note the Object Property CodingBase.concept which is the inverse of ConceptBase.coding:

```
###  http://hl7.org/fhir/CodingBase.concept

fhir:CodingBase.concept rdf:type owl:ObjectProperty ;
   owl:inverseOf fhir:ConceptBase.coding ;
   rdfs:subPropertyOf fhir:objectProperty .
```

The object property is then used in the restriction to say that the CodingBase individual belongs to the Concept as defined in the Concept restriction (in section 4.2.3).

7.1.5 RDF CodingBase individuals of specific Concepts (D)

When the value set is all codes from the code system it can be defined as the union of concepts.

```
###  http://hl7.org/fhir/ValueSet/allergy-intolerance-statusD

fhirvs:allergy-intolerance-statusD rdf:type owl:Class ;
   rdfs:subClassOf fhir:CodingBase_in_Valuesets .

[ rdf:type owl:Restriction ;
  rdfs:subClassOf fhirvs:allergy-intolerance-statusD ;
  owl:onProperty fhir:CodingBase.concept ;
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:unionOf ( allergy-intolerance-status:confirmed
                                     allergy-intolerance-status:unconfirmed
                                   )
                     ]
] .
```

Notice that the prefixes for the code system are shown which makes it readable.

This valueset includes all the subclasses of “confirmed” and “unconfirmed” if they exist which is a default is-a operator in the filter.

This is equivalent to <compose><include/exclude><concept> and <codeSystem><concept> in the FHIR Valueset Resource Structural Definition. (see later discussion of the mapping to RDF).

7.2 External terminology ValueSets

No examples are given where the Valueset is all codes from an external code system since this is generally too broad. If this is required the same process as internal terminologies can be used.

7.2.1 ValueSet Resource example in XML

The valueset “allergyintolerance-substance-code” includes the valueset “substance-code” but adds some additional codes:

```
<ValueSet xmlns="http://hl7.org/fhir">
  <id value="substance-code"/>

  <description value="This value set contains concept codes for specific substances"/>
  <copyright value="This value set includes content from SNOMED CT, which is copyright © 2002+ International
   Health Terminology Standards Development Organisation (IHTSDO), and distributed by agreement
   between IHTSDO and HL7. Implementer use of SNOMED CT is not covered by this agreement"/>
  <compose>
    <include>
      <system value="http://snomed.info/sct"/>
      <filter>
        <property value="concept"/>
        <op value="is-a"/>
        <value value="105590001"/>
      </filter>
    </include>
    <include>
      <system value="http://snomed.info/sct"/>
      <filter>
        <property value="concept"/>
        <op value="is-a"/>
        <value value="373873005"/>
      </filter>
    </include>
  </compose>
</ValueSet>
```

```
<ValueSet xmlns="http://hl7.org/fhir">
  <id value="allergyintolerance-substance-code"/>

  <description value="This value set includes concept codes for specific substances and negation codes to
specify
   the absence of specific types of allergies."/>
  <copyright value="This value set includes content from SNOMED CT, which is copyright © 2002+ International
   Health Terminology Standards Development Organisation (IHTSDO), and distributed by agreement
   between IHTSDO and HL7. Implementer use of SNOMED CT is not covered by this agreement"/>
  <compose>
    <import value="http://hl7.org/fhir/ValueSet/substance-code"/>
    <include>
      <system value="http://snomed.info/sct"/>
      <concept>
        <code value="160244002"/>
        <display value="No Known Allergies"/>
      </concept>
      <concept>
        <code value="429625007"/>
        <display value="No Known Food Allergies"/>
      </concept>
      <concept>
        <code value="409137002"/>
        <display value="No Known Drug Allergies"/>
      </concept>
      <concept>
        <code value="428607008"/>
        <display value="No Known Environmental Allergy"/>
      </concept>
    </include>
  </compose>
</ValueSet>
```

Notice that allergyintolerance-substance-code extends substance-code with 4 concepts with their code restrictions and the system restriction at the beginning.

7.2.2 RDF Direct Restriction Unaligned with a Code System (B)

The Valueset substance-codeB is declared in the FHIR ontology with no restrictions:

```
###  http://hl7.org/fhir/ValueSet/substance-codeB

fhirvs:substance-codeB rdf:type owl:Class ;
   rdfs:label "Substance Code" ;
   rdfs:subClassOf fhir:Valuesets.
```

In the Bridging Ontology, substance-codeB is declared against CodingBase.system and CodingBase.code restrictions.

```
 [ rdf:type owl:Class ;
  rdfs:subClassOf <http://hl7.org/fhir/ValueSet/substance-codeB> ;
  owl:intersectionOf ( [ rdf:type owl:Restriction ; owl:onProperty fhir:CodingBase.code ;
        owl:allValuesFrom [ rdf:type owl:Class ;
           owl:unionOf (
              [ rdf:type owl:Restriction ; owl:onProperty fhir:value ; owl:hasValue "105590001" ]
              [ rdf:type owl:Restriction ; owl:onProperty fhir:value ; owl:hasValue "373873005" ]
           )
        ]
     ]
     [ rdf:type owl:Restriction ; owl:onProperty fhir:CodingBase.system ;
        owl:hasValue <http://snomed.info/sct>
     ]
  )
] .
```

This will only define the ValueSet as the top code and **does not** include all the subconcepts as codes. In order to do this an expansion must be made with a filter. See http://hl7-fhir.github.io/valueset-allergyintolerance-substance-code.html

The operation <filter><op> declares “is-a” to mean transitive subclassing. However this is not understood by RDF/OWL. What is understood is the subclassing of the SNOMED Concept ontology itself.

The only solution is to extract all the codes in the hierarchy and explicitly declare them in the Bridging Ontology. The treatment of allergyintolerance-substance-code is to add the concepts to the enumerated list.

7.2.3 RDF ValueSet binding to Concepts(D)

The valueset substance-codeD is declared in FHIR as before:

```
###  http://hl7.org/fhir/ValueSet/substance-codeD

fhirvs:substance-codeB rdf:type owl:Class ;
                       rdfs:label "Substance  Codes D" ;
                       rdfs:subClassOf fhir: Valuesets .
```

The allergyintolerance-substance-code valueset is also declared in FHIR

```
###  http://hl7.org/fhir/ValueSet/allergyintolerance-substance-code

<http://hl7.org/fhir//ValueSet/allergyintolerance-substance-code> rdf:type owl:Class ;
   rdfs:label " AllergyIntolerance Substance and Negation Codes" ;
   rdfs:subClassOf fhir:CodingBase_in_Valuesets .
```

The bridging ontology declares a general Class axiom which shows the mapping to the Concepts:

```
[ rdf:type owl:Restriction ;
  rdfs:subClassOf <http://hl7.org/fhir/ValueSet/substance-codeD> ;
  owl:onProperty fhir:CodingBase.concept ;
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:unionOf ( <http://snomed.info/id/105590001>
                                     <http://snomed.info/id/373873005>
                                   )
                     ]
] .
```

```
 [ rdf:type owl:Class ;
  rdfs:subClassOf <http://hl7.org/fhir/ValueSet/allergyintolerance-substance-code> ;
  owl:unionOf ( <http://hl7.org/fhir/ValueSet/substance-codeD>
                [ rdf:type owl:Restriction ;
                  owl:onProperty fhir:CodingBase.concept ;
                  owl:someValuesFrom [ rdf:type owl:Class ;
                                       owl:unionOf ( <http://snomed.info/id/160244002>
                                                     <http://snomed.info/id/409137002>
                                                     <http://snomed.info/id/428607008>
                                                     <http://snomed.info/id/429625007>
                                                   )
                                     ]
                ]
              )
] .
```

CodingBase.concept defines the restriction on concepts for the Codingbase.

The display values are redundant and since closure is achieved with these classes, their display as rdfs:label can be shown at any time in an OWL tool.

7.3 Restriction equivalents to Compose Elements

The Compose element has subelements – import, include, exclude.

7.3.1 Import

Import has a value of a ValueSet URI that is to be imported (see earlier Valueset example – 7.2.1)

```
  owl:unionOf ( <http://hl7.org/fhir/ValueSet/substance-codeD>
                [ rdf:type owl:Restriction ;
                Etc.]
              )
```

The import equivalent is the unionOf with the named Class representing the Valueset (here shown as <http://hl7.org/fhir/ValueSet/substance-codeD>.

7.3.2 CodeSystem – Concepts

The extensional definition of a Code system includes its concepts as subclasses of the top concept. This is translated into a CodeSystemURI individual with the annotation properties of the CodeSystem and the associated Concept Classes.

However, there is no direct ontology relationship between the CodeSystemURI and the top concept. Some thoughts about a pun relationship might be useful.

See - HL7 Internal Concept RDF Example.

7.3.3 Filter

The Filter element selects concepts by specify a matching criteria based on the properties (including relationships) defined by the system. If multiple filters are specified, they SHALL all be true.

The Filter Operator value set has an inline code system http://hl7.org/fhir/filter-operator, which defines the following codes:

Code	Display	Definition
=	Equals	The specified property of the **code** equals the provided value.
is-a	Is A (by subsumption)	Includes all **concept** ids that have a transitive is-a relationship with the concept Id provided as the value, including the provided concept itself.
is-not-a	Not (Is A) (by subsumption)	The specified property of the **code** does not have an is-a relationship with the provided value.
regex	Regular Expression	The specified property of the **code** matches the regex specified in the provided value.
in	In Set	The specified property of the **code** is in the set of codes or concepts specified in the provided value (comma separated list).
not-in	Not in Set	The specified property of the **code** is not in the set of codes or concepts specified in the provided value (comma separated list).

7.3.4 Is-a – by subsumption

7.3.4.1 XML example

```
    <include>
      <system value="http://snomed.info/sct"/>
      <filter>
        <property value="concept"/>
        <op value="is-a"/>
        <value value="105590001"/>
      </filter>
    </include>
    <include>
      <system value="http://snomed.info/sct"/>
      <filter>
        <property value="concept"/>
        <op value="is-a"/>
        <value value="373873005"/>
      </filter>
    </include>
```

The difficulty with this filter is that while it appears to apply to the concept class which can have is-a subsumption, the value is the CodingBase.code value which restricts it to the concept class without subsumption. CodingBase is a single class and the instances are not subsumable.

7.3.4.2 Compose Include is-a Concept

The approach is that the value must be translated into the Concept Class Name which would be <http://snomed.info/id/373873005> and would be used in the restriction.

```
<http://snomed.info/sct> fhir:prefix "http://snomed.info/id/"^^xsd:string .
```

An annotation property on the CodeSystem individual can be used to construct the concept name where a simple prefix is used with the codeBase value.

This may also be articulated by the ValueSet fragment class which has the system and filter annotation properties and could be translated into the final RDF form.

The include element in conjunction with filtering on is-a concept is transformed into a union of the named concept:

```
  owl:someValuesFrom [ rdf:type owl:Class ;
                       owl:unionOf ( <http://snomed.info/id/105590001>
                                     <http://snomed.info/id/373873005>
```

7.3.5 Exclude

7.3.5.1 XML Example

```
          <exclude>
            <system value="http://snomed.info/sct"/>
            <filter>
              <property value="concept"/>
              <op value="is-a"/>
              <value value="410942007"/>
            </filter>
          </exclude>
```

7.3.5.2 Compose Exclude is-a Concept

```
[ rdf:type owl:Class ;
  rdfs:subClassOf <http://hl7.org/fhir/ValueSet/allergyintolerance-substance-code> ;
  owl:unionOf ( <http://hl7.org/fhir/ValueSet/substance-codeD>
                [ rdf:type owl:Restriction ;
                  owl:onProperty fhir:CodingBase.concept ;
                  owl:someValuesFrom [ rdf:type owl:Class ;
                                       owl:intersectionOf ( [ rdf:type owl:Class ;
                                                              owl:unionOf ( <http://snomed.info/id/160244002>
                                                                            <http://snomed.info/id/409137002>
                                                                            <http://snomed.info/id/428607008>
                                                                            <http://snomed.info/id/429625007>
                                                                          )
                                                            ]
                                                            [ rdf:type owl:Class ;
                                                              owl:complementOf <http://snomed.info/id/410942007>
                                                            ]
                                                          )
                                     ]
                ]
              )
] .
```

In this case the concept <http://snomed.info/id/410942007> is in the intersection as a complementOf so as to be excluded.

7.3.6 Equals and In

7.3.6.1 XML Example

```
      <description value="All RxNorm codes that have TTY = IN,PIN,MIN,BN, but TTY != OCD."/>
      <compose>
        <include>
          <system value="http://www.nlm.nih.gov/research/umls/rxnorm"/>
          <filter>
            <property value="TTY"/>
            <op value="in"/>
            <value value="IN,PIN,MIN,BN"/>
          </filter>
        </include>
        <exclude>
          <system value="http://www.nlm.nih.gov/research/umls/rxnorm"/>
          <filter>
            <property value="TTY"/>
            <op value="="/>
            <value value="OCD"/>
          </filter>
        </exclude>
      </compose>
```

These properties are specific to the code systems illustrated and would be expressed in the bridging ontology for that system.

7.3.6.2 Filter RDF Expression

Each filter is defined as a class. In the RDF example these will be named to assist testing and visibility.

A filter class will declare the set meeting the filter properties which are annotation properties. The set are CodingBase individuals and the filter is therefore a fragment of a ValueSet.

```
###  http://hl7.org/fhir/SomeBridge/fragmentA

<http://hl7.org/fhir/SomeBridge/fragmentA> rdf:type owl:Class ;
                                          rdfs:subClassOf fhir:Valuesets ;
                                          fhir:filter.property "TTY" ;
                                          fhir:filter.op "in" ;
                                          fhir:filter.system "http://www.nlm.nih.gov/research/umls/rxnorm" ;
                                          fhir:filter.value "IN,PIN,MIN,BN" .

###  http://hl7.org/fhir/SomeBridge/fragmentB

<http://hl7.org/fhir/SomeBridge/fragmentB> rdf:type owl:Class ;
                                          rdfs:subClassOf fhir:Valuesets ;
                                          fhir:filter.property "TTY" ;
                                          fhir:filter.op "=" ;
                                          fhir:filter.system "http://www.nlm.nih.gov/research/umls/rxnorm" ;
                                          fhir:filter.value "OCD" .
```

The definition may not be interpreted by OWL but can be through other mechanisms.

Further exploration needs to be done on SPARQL and SWRL expressions to define the fragment membership of CodingBase individuals there thereby the membership of the ValueSet.

7.3.6.3 The RDF ValueSet

The fragments are combined together based on include and exclude elements:

```
###  http://hl7.org/fhir/ValueSet/substance-rxnorm

<http://hl7.org/fhir/ValueSet/substance-rxnorm> rdf:type owl:Class ;
   rdfs:label "DAF Substance RxNorm Codes" ;
   rdfs:subClassOf fhir:Valuesets ;
   fhir:telecom.other "http://hl7.org/fhir" ;
   fhir:lastUpdated "2015-10-15T03:44:57.526+00:00" ;
   fhir:publisher "FHIR Project team" ;
   fhir:status "draft" ;
   fhir:concept_definition "All RxNorm codes that have TTY = IN,PIN,MIN,BN, but TTY != OCD." ;
   fhir:valueset-oid "urn:oid:2.16.840.1.113762.1.4.1010.7" .

[ rdf:type owl:Class ;
  rdfs:subClassOf <http://hl7.org/fhir/ValueSet/substance-rxnorm> ;
  owl:intersectionOf ( <http://hl7.org/fhir/SomeBridge/fragmentA>
                       [ rdf:type owl:Class ;
                         owl:complementOf <http://hl7.org/fhir/SomeBridge/fragmentB>
                       ]
                     )
] .
```