

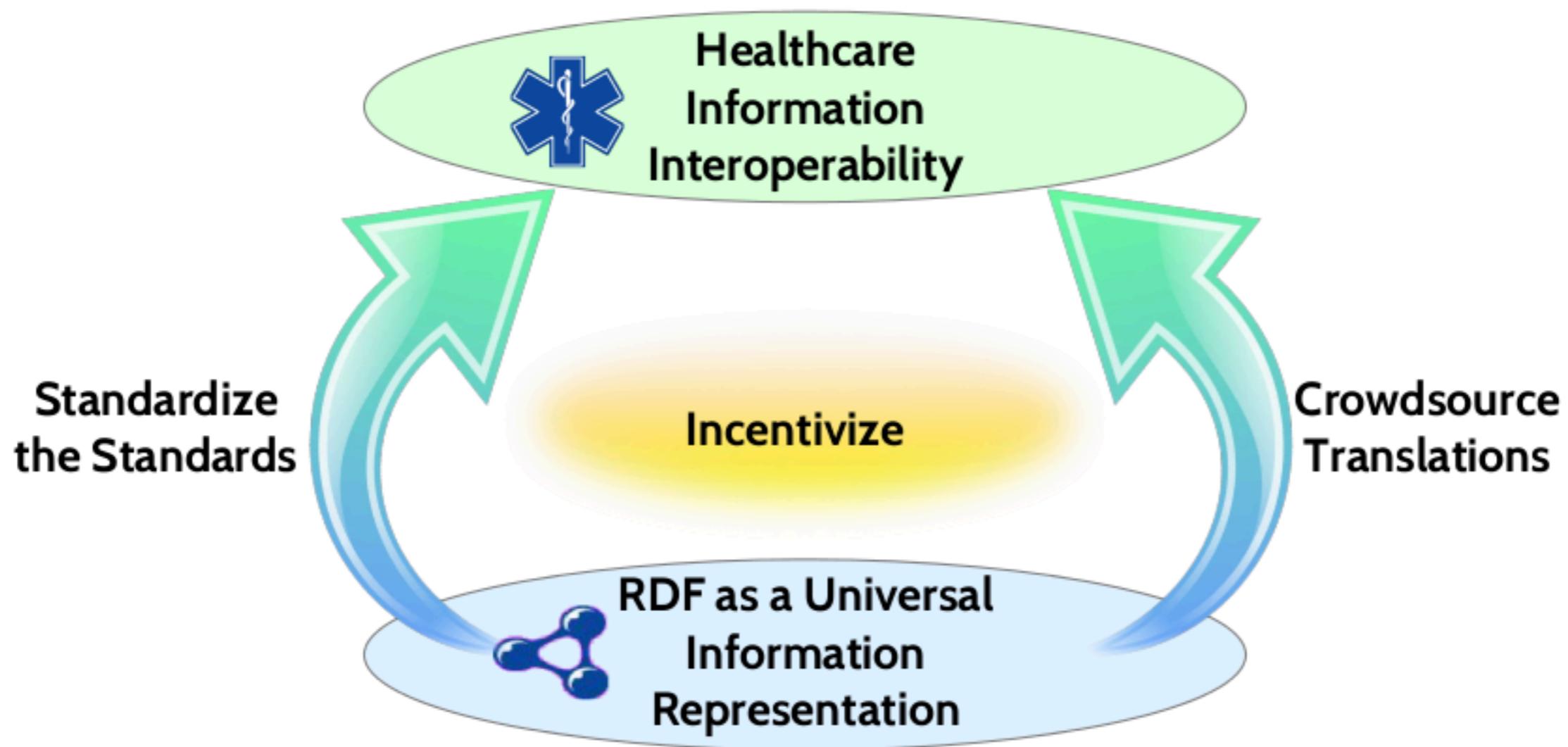
# FHIR RDF as a Bridge to the Semantic Web in Healthcare

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Politecnico di Milano

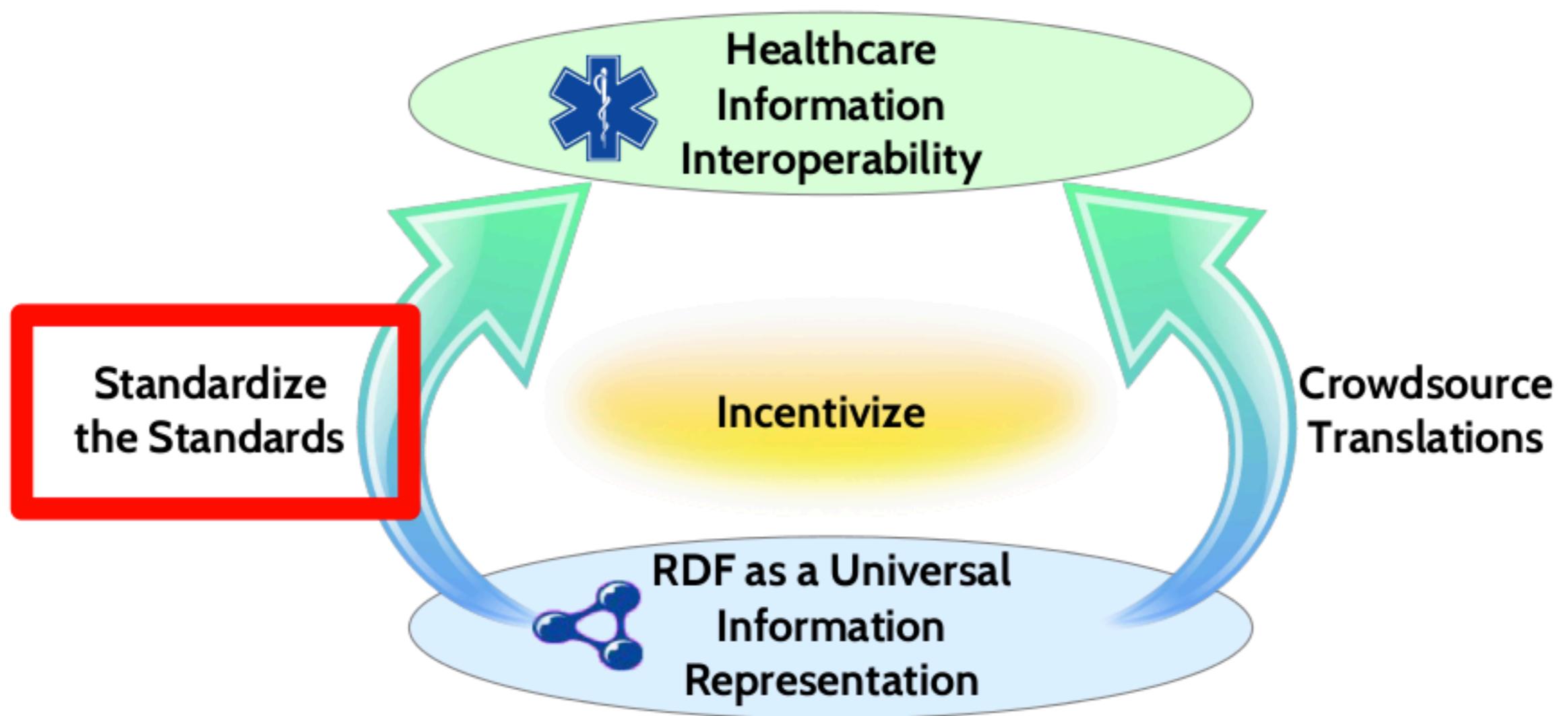
forked repo at [https://github.com/emanueledellavalle/BlendingFHIRandRDF/upload/master/yosemite\\_talk](https://github.com/emanueledellavalle/BlendingFHIRandRDF/upload/master/yosemite_talk)

# Interoperability Roadmap



<http://YosemiteProject.org/>

# Interoperability Roadmap



<http://YosemiteProject.org/>

# Outline

- FHIR and RDF
- Using FHIR RDF with a DL Reasoner
- Caveats, Issues, Next Steps

SEE PREVIOUS LECTURES

FHIR®

# Fast Healthcare Interoperability Resources

The screenshot shows the FHIR Release 3 (STU) website. At the top, there's a navigation bar with links for Home, Getting Started, Documentation, Resources, Profiles, Extensions, Operations, and Terminologies. Below the navigation is a main content area with a yellow banner stating: "This is the Current officially released version of FHIR, which is Release 3 (STU) with 1 technical errata. For a full list of available versions, see the [Directory of published versions](#)." The main section is titled "0 Welcome to FHIR®". It includes a "First time here?" box with links to the executive summary, developer's introduction, clinical introduction, architect's introduction, overview, roadmap & timelines, open license, table of contents, and search. Below this is a "Technical Corrections" section with a note about April 19, 2017 corrections. The page is organized into four levels: Level 1 (Foundation), Level 2 (Supporting Implementation), Level 3 (Linking to real world concepts), and Level 4 (Record-keeping and Data Exchange). Each level has a grid of icons and descriptions. In the Level 4 grid, the "Observation, Report, Confirmation" row is circled in red.

www.fhir.org/FHIR/

FHIR Release 3 (STU)

Home Getting Started Documentation Resources Profiles Extensions Operations Terminologies

Home

This is the Current officially released version of FHIR, which is Release 3 (STU) with 1 technical errata. For a full list of available versions, see the [Directory of published versions](#).

## 0 Welcome to FHIR®

First time here?

See the [executive summary](#), the [developer's introduction](#), [clinical introduction](#), or [architect's introduction](#), and then the FHIR [overview / roadmap & Timelines](#). See also the [open license](#) (and don't miss the full [Table of Contents](#) or you can [search this specification](#)).

Technical Corrections:

- Apr-19 2017: Corrections to invariants & generated conformance resources, and add note about `isSummary`

Level 1 Basic framework on which the specification is built

Foundation	Base Documentation, XML, JSON, REST API + Search, Data Types, Extensions
------------	--

Level 2 Supporting Implementation, and binding to external specifications

Implementer Support	Security & Privacy	Conformance	Terminology	Linked Data
Downloads, Common Use Cases, Testing	Security, Consent, Provenance, AuditEvent	StructureDefinition, CapabilityStatement, ImplementationGuide, Profiling	CodeSystem, ValueSet, ConceptMap, Terminology Svc	RDF

Level 3 Linking to real world concepts in the healthcare system

Administration	Patient, Practitioner, Device, Organization, Location, Healthcare Service
----------------	---

Level 4 Record-keeping and Data Exchange for the healthcare process

Clinical	Diagnostics	Medications	Workflow
Allergy, Problem, CarePlan, DetectedIssue	Observation, Report, Confirmation	Order, Dispense, Administration	Task, Appointment, Schedule, Outcome

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# FHIR Resource Definition

<http://hl7.org/fhir/diagnosticreport.html>

10.2.4 Resource Content

Structure    UML    XML    JSON    Turtle    R2 Diff    All

### Structure

Name	Flags	Card.	Type	Description & Constraints
<a href="#">DiagnosticReport</a>		*	DomainResource	A Diagnostic report - a combination of request information, atomic results, images, interpretation, as well as formatted reports. Elements defined in Annexelor: id, meta, implicitRules, language, text, contained, extension, modifierExtension
<a href="#">identifier</a>	x	0..*	Identifier	Business identifier for report
<a href="#">basedOn</a>	x	0..*	Reference(CarePlan   ImmunizationRecommendation   MedicationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	What was requested
<a href="#">status</a>	x	0..1	code	registered   partial   preliminary   final + DiagnosticReportStatus (Required)
<a href="#">category</a>	x	0..1	CodeableConcept	Service category Diagnostic Service Section Codes (Example)
<a href="#">code</a>	x	1..1	CodeableConcept	NamingCode for this diagnostic report LOINC Diagnostic Report Codes (Preferred)
<a href="#">subject</a>	x	0..1	Reference(Patient   Group   Device   Location)	The subject of the report - usually, but not always, the patient
<a href="#">context</a>	x	0..1	Reference(Encounter   EpisodeOfCare)	Health care event when test ordered
<a href="#">effective(x)</a>	x	0..1		Clinically relevant time/time period for report
<a href="#">effectiveDateTime</a>			dateTime	
<a href="#">effectivePeriod</a>			Period	
<a href="#">issued</a>	x	0..1	Instant	Date/Time this version was released
<a href="#">performer</a>	x	0..*	BackboneElement	Participants in producing the report
<a href="#">role</a>	x	0..1	CodeableConcept	Type of performer Procedure Performer Role Codes (Example)
<a href="#">actor</a>	x	1..1	Reference(Practitioner   Organization)	Practitioner or Organization participant
<a href="#">specimen</a>	x	0..*	Reference(Specimen)	Specimen this report is based on
<a href="#">result</a>	x	0..*	Reference(Observation)	Observations - simple, or complex nested groups
<a href="#">imagingStudy</a>	x	0..*	Reference(ImagingStudy   ImagingManifest)	Reference to full details of imaging associated with the diagnostic report
<a href="#">image</a>	x	0..*	BackboneElement	Key Images associated with this report
<a href="#">comment</a>	x	0..1	string	Comment about the image (e.g. explanation)
<a href="#">link</a>	x	1..1	Reference(Media)	Reference to the image source
<a href="#">conclusion</a>	x	0..1	string	Clinical Interpretation of test results
<a href="#">codedDiagnoses</a>	x	0..*	CodeableConcept	Codes for the conclusion SNOMED CT Clinical Findings (Example)
<a href="#">presentedForm</a>	x	0..*	Attachment	Entire report as issued

Documentation for this format

# FHIR Resource Instance (XML)

www.hl7.org/FHIR/diagnosticreport.html

## 10.2.4 Resource Content

Structure UML XML JSON Turtle R2 DIFF All

Structure

Name	Flags	Card.	Type	Description & Constraints
DiagnosticReport			DomainResource	A Diagnostic report - a combination of request information, atomic results and formatted reports.
identifier	X	0..*	Identifier	Elements defined in Annexelor: id, meta, implicitRules, language, text, status, identifier for report
basedOn		0..*	Reference(CarePlan   ImmunizationRecommendation   MutationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	What was requested
status	X	0..1	code	required   partial   preliminary   final + DiagnosticReportStatus (Required)
category	X	0..1	CodeableConcept	Service category Diagnostic Service Section Codes (Example)
code	X	1..1	CodeableConcept	Name/Code for this diagnostic report LOINC Diagnostic Report Codes (Preferred)
subject	X	0..1	Reference(Patient   Group   Device   Location)	The subject of the report - usually, but not always, the patient
context	X	0..1	Reference(Encounter   EpisodeOfCare)	Non-acute event when test ordered
effective[x]	X	0..1		Clinically relevant time/time period for report
effectiveDateTime			dateTime	
effectivePeriod			Period	
issued	X	0..1	Instant	Date/Time this version was released
performer	X	0..*	BackboneElement	Participates in producing the report
role	X	0..1	CodeableConcept	Type of performer Procedure Performer Role Codes (Example)
actor	X	1..1	Reference(Practitioner   Organization)	Practitioner or Organization participant
specimen		0..*	Reference(Specimen)	Specimens this report is based on
result		0..*	Reference(Observation)	Observations - simple, or complex nested groups
imagingStudy		0..*	Reference(ImagingStudy   ImagingManifest)	References to full details of imaging associated with the diagnostic report
image	X	0..*	Attachment	Key Images associated with this report
comment	X	0..1	string	Comment about the image (e.g. explanation)
link	X	1..1	Reference(Media)	Reference to the image source
conclusion		0..1	string	Clinical Interpretation of test results
codedDiagnosis		0..*	CodeableConcept	Codes for the diagnosis SNOMED CT Clinical Findings (Example)
presentedForm		0..*	Attachment	Entire report as issued

Documentation for this format

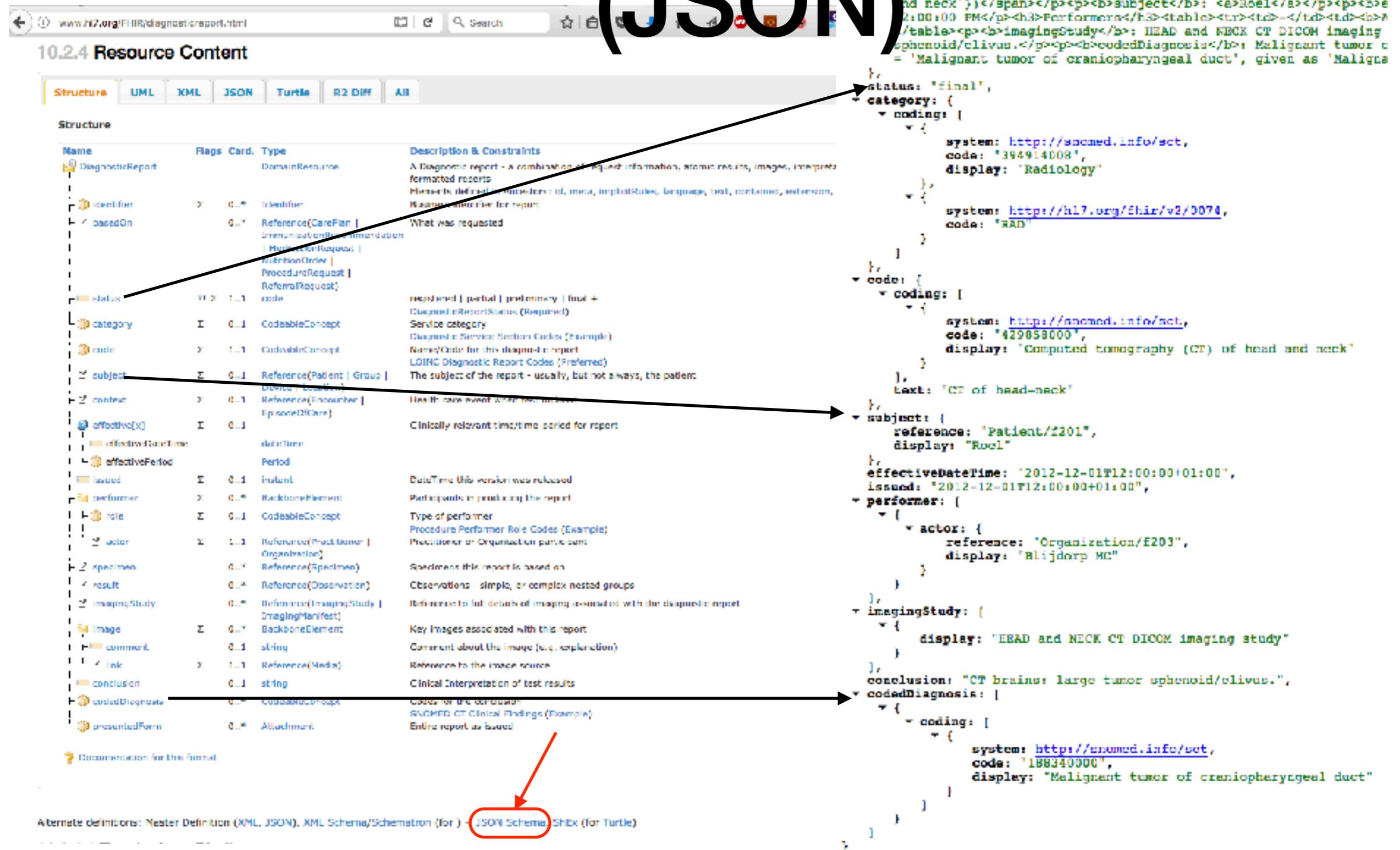
Alternate definitions: Master Definition (XML, JSON), XML Schema/Schematron (or) + JSON Schema, ShEx (for Turtle)

```
<?xml version="1.0" encoding="UTF-8"?><DiagnosticReport xmlns="http://hl7.org/fhir">
  <id value="f201"/>
  <text><status value="generated"/><div xmlns="http://www.w3.org/1999/xhtml"><p><b>Generated</b></p></div></text>
  <status value="final"/>
  <category>
    <!-- The request was honored by the Department of Radiology -->
    <coding>
      <system value="http://snomed.info/sct"/>
      <code value="394914008"/>
      <display value='Radiology'/>
    </coding>
    <coding>
      <system value="http://hl7.org/fhir/v2/0074"/>
      <code value="RAD"/>
    </coding>
  </category>
  <code>
    <coding>
      <system value="http://snomed.info/sct"/>
      <code value="429858000"/>
      <display value='Computed tomography (CT) of head and neck'/>
    </coding>
    <text value="CT of head-neck"/>
  </code>
  <subject>
    <reference value="Patient/f201"/>
    <display value="Roel"/>
  </subject>
  <effectiveDateTime value="2012-12-01T12:00:00+01:00"/>
  <issued value="2012-12-01T12:00:00+01:00"/>
  <performer>
    <actor>
      <reference value="Organization/f203"/>
      <display value="Blijdorp MC"/>
    </actor>
  </performer>
  <!-- The actual CT imangenet available - following reference used to demonstrate the concept -->
  <imagingStudy>
    <display value="HEAD and NECK CT DICOM imaging study"/>
  </imagingStudy>
  <conclusion value="CT brains: large tumor sphenoid/clivus."/>
  <codedDiagnosis>
    <coding>
      <system value="http://snomed.info/sct"/>
      <code value="188340000"/>
      <display value='Malignant tumor of craniopharyngeal duct'/>
    </coding>
  </codedDiagnosis>
</DiagnosticReport>
```

<http://www.hl7.org/fhir/diagnosticreport-example-f201-brainct.xml>

# NOT COVERED

# FHIR Resource Instance (JSON)



<http://www.hl7.org/fhir/diagnosticreport-example-f201-brainct.json>

# FHIR Resource Instance (RDF)

[www.hl7.org/FHIR/diagnosticreport.html](http://www.hl7.org/FHIR/diagnosticreport.html)

## 10.2.4 Resource Content

Structure UML XML JSON Turtle R2 DIFF All

Name	Flags	Card.	Type	Description & Constraints
<a href="#">DiagnosticReport</a>			DomainResource	A Diagnostic report - a combination of request information, atomic results, images, interpreted reports
<a href="#">identifier</a>	X	0..*	Identifier	Elements defined in AnnEx1: id, meta, implicitRules, language, test, contained, extension
<a href="#">basedOn</a>		0..*	Reference(CarePlan   ImmunizationRecommendation   MedicationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	Reasons identifier for report
<a href="#">status</a>	X	1..1	code	required   partial   preliminary   final + DiagnosticReportStatus (Required)
<a href="#">category</a>	X	0..1	CodeableConcept	Service category
<a href="#">code</a>	X	1..1	CodeableConcept	Name/Code for this diagnostic report
<a href="#">subject</a>	X	0..1	Reference(Patient   Group   Device   Location)	The subject of the report - usually, but not always, the patient
<a href="#">context</a>	X	0..1	Reference(Encounter   EpisodeOfCare)	Health care event when test ordered
<a href="#">effective[x]</a>	X	0..1	dateTime   Period	Clinically relevant dateTime, coded for report
<a href="#">issued</a>	X	0..1	Instant	dateTime This version was released
<a href="#">performer</a>	X	0..*	BackboneElement	Participates in producing the report
<a href="#">role</a>	X	0..1	CodeableConcept	Type of performer
<a href="#">actor</a>	X	1..1	Reference(Practitioner   Organization)	Practitioner or Organization participant
<a href="#">specimen</a>		0..*	Reference(Specimen)	Specimen this report is based on
<a href="#">result</a>		0..*	Reference(Observation)	Observations - simple, or complex nested groups
<a href="#">imagingStudy</a>		0..*	Reference(ImagingStudy   ImagingManifest)	Refers to full details of imaging associated with the diagnostic report
<a href="#">image</a>	X	0..*	Attachment	Key Images associated with this report
<a href="#">comment</a>		0..1	string	Comment about the image (e.g., explanation)
<a href="#">link</a>	X	1..1	Reference(Media)	Reference to the image source
<a href="#">conclusion</a>		0..1	string	Clinical Interpretation of test results
<a href="#">codedDiagnosis</a>		0..1	CodeableConcept	Date for the conclusion
<a href="#">presentedForm</a>		0..*	Attachment	SNOMED CT Clinical Findings (Example)
<a href="#">Documentation for this format</a>				Entire report as issued

Alternate definitions: Master Definition (XML, JSON), XML Schema/Schematron (for ) + JSON Schema [SHTX \(for Turtle\)](#)

```

@prefix fhir: <http://hl7.org/fhir/> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sct: <http://snomed.info/id/> .
@prefix xdm: <http://www.w3.org/2001/XMLSchema#> .

# - resource -
<http://hl7.org/fhir/DiagnosticReport/E201> a fhir:DiagnosticReport;
  fhir:nodeRole fhir:treeRoot;
  fhir:Resource.id [ fhir:value "E201"];
  fhir:Resource.text [
    fhir:Narrative.status [ fhir:value "generated" ];
    fhir:Narrative.div <div xmlns="http://www.w3.org/1999/xhtml"><p>Generated Narrative with computed status<br/><code>fhir:DiagnosticReport</code> fhir:DiagnosticReport:status : (SNOMED CT code '39491400' 'Radiology'); (http://hl7.org/fhir/v2/3024 code 'RAT' = 'Radiology')</p><p><b>CT of head-neck</b> = 'Computed tomography (CT) of head and neck', given as 'Computed tomography (CT) of head-neck'</p><p><b>Actor</b></p><p><b>Imaging Study</b></p><p><b>Conclusion</b>: CT brains: large tumor sphenoid/clivus.</p><p><b>codedDiagnosis</b>: Malignant (SNOMED CT code '188340000' = 'Malignant tumor of cranio-pharyngeal duct', given as 'Malignant tumor of cranio-pharyngeal duct'</p>];
  fhir:DiagnosticReport.status [ fhir:value "final"];
  fhir:DiagnosticReport.category [
    fhir:CodeableConcept.coding [
      fhir:index 0;
      a set:39491400;
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
      fhir:Coding.code [ fhir:value '39491400' ];
      fhir:Coding.display [ fhir:value "Radiology" ]
    ];
    fhir:CodeableConcept.coding [
      fhir:index 1;
      fhir:Coding.system [ fhir:value "https://hl7.org/fhir/v2/3024" ];
      fhir:Coding.code [ fhir:value "RAN" ];
      fhir:Coding.display [ fhir:value "Radiology" ]
    ];
    fhir:DiagnosticReport.code [
      fhir:CodeableConcept.coding [
        fhir:index 0;
        a set:429858000;
        fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
        fhir:Coding.code [ fhir:value '429858000' ];
        fhir:Coding.display [ fhir:value "Computed tomography (CT) of head and neck" ]
      ];
      fhir:CodeableConcept.text [ fhir:value "CT of head-neck" ]
    ];
    fhir:DiagnosticReport.subject [
      fhir:Link <http://hl7.org/fhir/Patient/E201>;
      fhir:Reference.reference [ fhir:value "Patient/E201" ];
      fhir:Reference.display [ fhir:value "Koal" ]
    ];
    fhir:DiagnosticReport.effectiveDateTime [ fhir:value "2012-12-01T12:00:00+01:00"^^xsd:dateTime ];
    fhir:DiagnosticReport.issued [ fhir:value "2012-12-01T12:00:01+01:00"^^xsd:dateTime ];
    fhir:DiagnosticReport.performer [
      fhir:index 0;
      fhir:DiagnosticReport.performer.actor [
        fhir:Link <http://hl7.org/fhir/Organization/E203>;
        fhir:Reference.reference [ fhir:value "Organization/E203" ];
        fhir:Reference.display [ fhir:value "Alijdwp NC" ]
      ];
      fhir:DiagnosticReport.imagingStudy [
        fhir:index 0;
        fhir:Reference.display [ fhir:value "HEAD and NECK CT DICOM imaging study" ]
      ];
      fhir:DiagnosticReport.conclusion [ fhir:value "CT brains: large tumor sphenoid/clivus." ];
      fhir:DiagnosticReport.codedDiagnosis [
        fhir:index 0;
        fhir:CodeableConcept.coding [
          fhir:index 0;
          a set:188340000;
          fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
          fhir:Coding.code [ fhir:value '18834000' ];
          fhir:Coding.display [ fhir:value "Malignant tumor of cranio-pharyngeal duct" ]
        ];
        fhir:CodeableConcept.text [ fhir:value "Malignant tumor of cranio-pharyngeal duct" ]
      ];
    ];
  ];

```

# RDF Turtle Syntax

```
@prefix fhir: <http://hl7.org/fhir/> .  
@prefix owl: <http://www.w3.org/2002/07/owl#> .  
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
@prefix sct: <http://snomed.info/id/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
```

```
# - resource -----  
<http://hl7.org/fhir/DiagnosticReport/f201> a fhir:DiagnosticReport;  
  fhir:nodeRole fhir:treeRoot;  
  fhir:Resource.id [ fhir:value "f201" ];  
  fhir:DomainResource.text [  
    fhir:Narrative.status [ fhir:value "generated" ];  
    fhir:DiagnosticReport.status [ fhir:value "final" ];  
    fhir:DiagnosticReport.category [  
      fhir:CodeableConcept.coding [  
        fhir:index 0;  
        a sct:394914008;  
        fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
        fhir:Coding.code [ fhir:value "394914008" ];  
        fhir:Coding.display [ fhir:value "Radiology" ]  
      ],  
      fhir:index 1;  
      fhir:Coding.system [ fhir:value "http://hl7.org/fhir/v2/0074" ];  
      fhir:Coding.code [ fhir:value "RAD" ]  
    ]  
  ];  
  fhir:DiagnosticReport.code [  
    fhir:CodeableConcept.coding [  
      fhir:index 0;  
      a sct:429858000;  
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
      fhir:Coding.code [ fhir:value "429858000" ];  
      fhir:Coding.display [ fhir:value "Computed tomography (CT) of head and neck" ]  
    ],  
    fhir:CodeableConcept.text [ fhir:value "CT of head-neck" ]  
  ];
```

**Prefixes**

**'a' == rdf:type**

**subject predicate object ;  
predicate object ;**

**'[...]' == Blank Node**

**See last part of the practice  
on RDF serialization in turtle**

**subject predicate object ,  
object ,**

# Syntax “maturity”

## 2.6.1 XML Representation of Resources

Implementable Technology Specifications ↗ Work Group	Maturity Level: 5	Ballot Status: Trial Use
--	-------------------	--------------------------

**http://www.hl7.org/fhir/xml.html**

Implementable Technology Specifications ↗ Work Group	Maturity Level: 5	Ballot Status: Trial Use
--	-------------------	--------------------------

**http://www.hl7.org/fhir/json.html**

FHIR Infrastructure ↗ Work Group	Maturity Level: 2	Ballot Status: Trial Use
----------------------------------	-------------------	--------------------------

3 as of 2024-12-1

**http://www.hl7.org/fhir/rdf.html**

0. the resource or profile (artifact) has been published on the current build. This level is synonymous with *Draft*.
1. PLUS the artifact produces no warnings during the build process and the responsible WG has indicated that they consider the artifact substantially complete and ready for implementation
2. PLUS the artifact has been tested and successfully exchanged between at least three independently developed systems leveraging at least 80% of the core data elements using semi-realistic data and scenarios based on at least one of the declared scopes of the resource (e.g. at a connectathon). These interoperability results must have been reported to and accepted by the FHIR Infrastructure WG
3. PLUS the artifact has been verified by the work group as meeting the *Trial Use Quality Guidelines* ↗ and has been subject to a round of formal balloting; has at least 10 implementer comments recorded in the tracker drawn from at least 3 organizations resulting in at least one substantive change
4. PLUS the artifact has been tested across its scope (see below), published in a formal publication (e.g. a FHIR Release), and implemented in multiple prototype projects. As well, the responsible work group agrees the resource is sufficiently stable to require implementer consultation for subsequent non-backward compatible changes.
5. PLUS the artifact has been published in two formal publication release cycles at FMM1+ (i.e. *Trial Use* level) and has been implemented in at least 5 independent production systems in more than one country
6. "Normative": the artifact is now considered stable

# FHIR RDF Rendering

Requirement: RDF Rendering must be fully “round-trippable”:



Which is why:

```
fhir:Person.active [ fhir:value "true"^^xsd:boolean].
```

instead of:

```
fhir:Person.active "true"^^xsd:boolean.
```

# FHIR RDF Rendering Preserving Extensions

Boolean, like all FHIR elements, is extensible. Processing for:

```
fhir:Person.active [ fhir:value "true"^^xsd:boolean].
```

and:

```
fhir:Person.active [  
  fhir:Element.extension [  
    fhir:index 0;  
    fhir:Extension.url [ fhir:value "http://example.org/fhir/boolean/Certainty" ];  
    fhir:Extension.valueDecimal [ fhir:value "0.75"^^xsd:decimal ]  
  ];  
  fhir:value "true"^^xsd:boolean] .
```

should be the same.

# “Round Tripability”

```
{  
  "resourceType": "DiagnosticReport",  
  "id": "f201",  
  "text": {  
    "status": "generated"  
  }  
}
```

```
"category": [  
  "coding": [  
    {  
      "system": "http://snomed.info/sct",  
      "code": "394914008",  
      "display": "Radiology"  
    },  
    {  
      "system": "http://hl7.org/fhir/v2/0074",  
      "code": "RAD"  
    }  
  ]  
],
```

**JSON**

```
<http://hl7.org/fhir/DiagnosticReport/f201> a fhir:DiagnosticReport;  
  fhir:nodeRole fhir:treeRoot; ←  
  fhir:Resource.id [ fhir:value "f201"];  
  fhir:DomainResource.text [  
    fhir:Narrative.status [ fhir:value "generated" ];  
    fhir:Narrative.div "<div xmlns=\"http://www.w3.org/1999/xhtml\">(deleted)</div>"  
  ];  
  fhir:DiagnosticReport.status [ fhir:value "final"];  
  fhir:DiagnosticReport.category [  
    fhir:CodeableConcept.coding [  
      fhir:index 0; ←  
      a sct:394914008;  
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
      fhir:Coding.code [ fhir:value "394914008" ];  
      fhir:Coding.display [ fhir:value "Radiology" ]  
    ], [  
      fhir:index 1; ←  
      fhir:Coding.system [ fhir:value "http://hl7.org/fhir/v2/0074" ];  
      fhir:Coding.code [ fhir:value "RAD" ]  
    ]  
  ];  
  fhir:DiagnosticReport.code [  
    fhir:CodeableConcept.coding [  
      fhir:index 0;  
      a sct:429858000;  
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
      fhir:Coding.code [ fhir:value "429858000" ];  
      fhir:Coding.display [ fhir:value "Computed tomography (CT) of head and neck" ]  
    ],  
    fhir:CodeableConcept.text [ fhir:value "CT of head-neck" ]  
  ];  
  fhir:DiagnosticReport.subject [  
    fhir:link <http://hl7.org/fhir/Patient/f201>;  
    fhir:Reference.reference [ fhir:value "Patient/f201" ];  
    fhir:Reference.display [ fhir:value "Roel" ]  
  ];  
  fhir:DiagnosticReport.effectiveDateTime [ fhir:value "2012-12-01T12:00:00+01:00"^^xsd:dateTime
```

**Identify root documents**

**Preserve order in lists**

# RDF Rendering Extensions

```
"category": {  
    "coding": [  
        {  
            "system": "http://snomed.info/sct",  
            "code": "394914008",  
            "display": "Radiology"  
        },  
        {  
            "system": "http://hl7.org/fhir/v2/0074",  
            "code": "RAD"  
        }  
    ]  
},
```

JSON

```
    "subject": {  
        "reference": "Patient/f201",  
        "display": "Roel"  
    },
```

JSON

```
    thir:DiagnosticReport.category [  
        fhir:CodeableConcept.coding [  
            fhir:index 0;  
            a sct:394914008; ← Concept URI  
            fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
            fhir:Coding.code [ fhir:value "394914008" ];  
            fhir:Coding.display [ fhir:value "Radiology" ]  
        ], [  
            fhir:index 1;  
            fhir:Coding.system [ fhir:value "http://hl7.org/fhir/v2/0074" ];  
            fhir:Coding.code [ fhir:value "RAD" ]  
        ]  
    ];
```

```
    fhir:DiagnosticReport.subject [  
        fhir:link <http://hl7.org/fhir/Patient/f201>; ← Reference URI  
        fhir:Reference.reference [ fhir:value "Patient/f201" ];  
        fhir:Reference.display [ fhir:value "Roel" ]  
    ];  
  
<http://hl7.org/fhir/Patient/f201> a fhir:Patient . ← Reference Type
```

```
# - ontology header -----  
  
<http://hl7.org/fhir/DiagnosticReport/f201.ttl> a owl:Ontology;  
owl:imports fhir:fhir.ttl;  
owl:versionIRI <http://build.fhir.org/DiagnosticReport/f201.ttl> . ← Ontology and import declaration
```

RDF

[<http://snomed.info/id/394914008>](http://snomed.info/id/394914008)

# Concept URI's

For this (or any linked data to work) both the data and the ontology have to use the same URI's

Progress is being made:

- SNOMED International has a standard:
  - [http://snomed.info/id/\(concept code\)](http://snomed.info/id/(concept code))
  - Spec: <https://confluence.ihtsdotools.org/display/DOCURI/URI+Standard>
- WHO has a standard
  - [http://id.who.int/icd/release/10/\(code\)](http://id.who.int/icd/release/10/(code))
  - Spec: <https://icdaccessmanagement.who.int/docs/APIdoc-md.html>

# Using FHIR RDF With a DL Reasoner

```
http://hl7.org/fhir/rdf/resource/DiagnosticReport/1?_format=jsonld
{
  "id": "DiagnosticReport-1",
  "resourceType": "DiagnosticReport",
  "status": "final",
  "category": [
    "abnormal"
  ],
  "subject": {
    "reference": "Patient-1"
  },
  "date": "2018-01-01T00:00:00Z",
  "display": "Initial evaluation of the patient's condition",
  "issue": [
    {
      "type": "diagnosis",
      "diagnosis": {
        "text": "Cancer of the liver"
      }
    }
  ],
  "note": [
    {
      "text": "This report was generated by a computer system and does not contain handwritten annotations."}
  ]
}
```

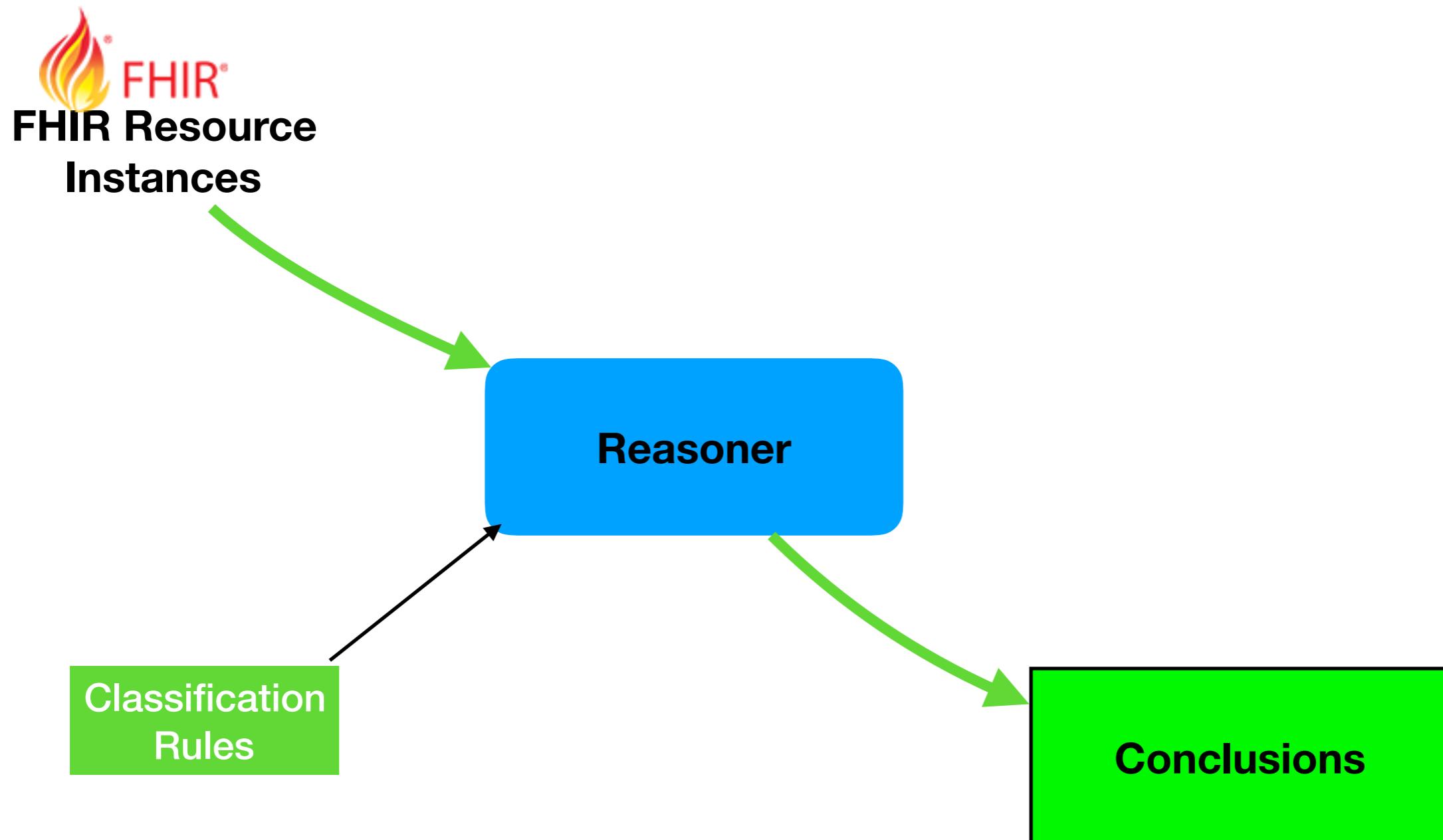
FHIR DiagnosticReport  
Instance

Reasoner

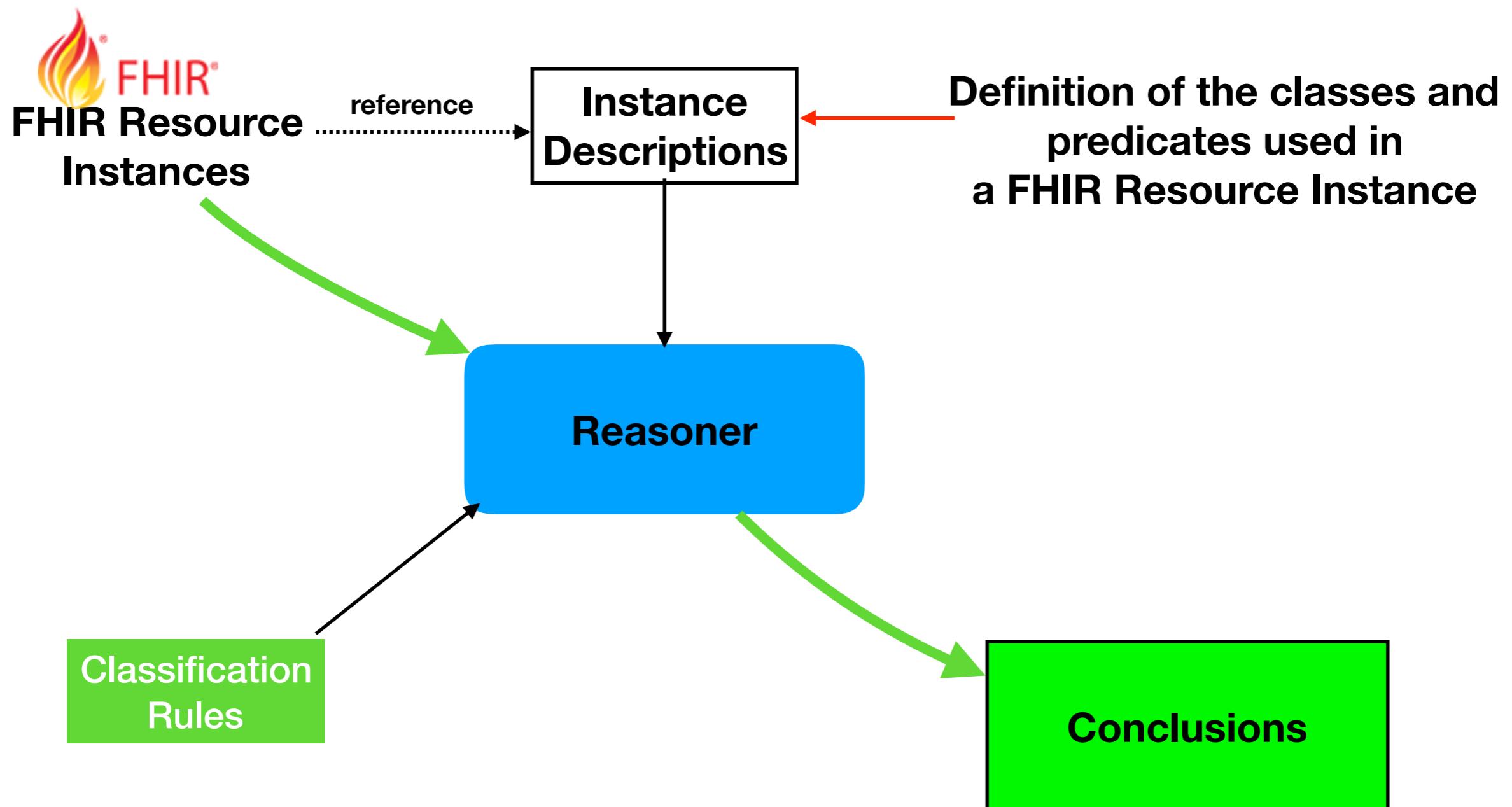
Class `CancerDiagnosis` == any DiagnosticReport  
w/ a dx of a type of malignant neoplasm  
  
with a diagnosis

Instance is (or is not)  
an instance of Class  
`CancerDiagnosis`

# Using FHIR RDF With a DL Reasoner



# Using FHIR RDF With a DL Reasoner



# Instance Descriptions

# The FHIR Metadata Vocabulary

## Example FHIR resource (data record)

```
<http://hl7.org/fhir/DiagnosticReport/f201> a fhir:DiagnosticReport;
  fhir:DiagnosticReport.subject [
    fhir:link <http://hl7.org/fhir/Patient/f201>;
    fhir:Reference.reference [ fhir:value "Patient/f201" ];
    fhir:Reference.display [ fhir:value "Roel" ]
  ];
  fhir:DiagnosticReport.code [
    fhir:CodeableConcept.coding [
      fhir:index 0;
      a sct:429858000;
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
      fhir:Coding.code [ fhir:value "429858000" ];
      fhir:Coding.display [ fhir:value "Computed tomography (CT) of head and neck" ]
    ];
    fhir:CodeableConcept.text [ fhir:value "CT of head-neck" ]
  ];
  fhir:DiagnosticReport.codedDiagnosis [
    fhir:index 0;
    fhir:CodeableConcept.coding [
      fhir:index 0;
      a sct:188340000;
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
      fhir:Coding.code [ fhir:value "188340000" ];
      fhir:Coding.display [ fhir:value "Malignant tumor of craniopharyngeal duct" ]
    ]
  ]
```

# Instance Descriptions

## The FHIR Metadata Vocabulary

```
<http://hl7.org/fhir/DiagnosticReport/f201> a
  fhir:DiagnosticReport.subject [
    fhir:link <http://hl7.org/fhir/Patient/f
    fhir:Reference.reference [ fhir:value "P
    fhir:Reference.display [ fhir:value "Roe
  ];
  fhir:DiagnosticReport.code [
    fhir:CodeableConcept.coding [
      fhir:index 0;
      a sct:429858000;
      fhir:Coding.system [ fhir:value "http:/
      fhir:Coding.code [ fhir:value "42985800
      fhir:Coding.display [ fhir:value "Compu
    ];
    fhir:CodeableConcept.text [ fhir:value "C
  ];
  fhir:DiagnosticReport.codedDiagnosis [
    fhir:index 0;
    fhir:CodeableConcept.coding [
      fhir:index 0;
      a sct:188340000;
      fhir:Coding.system [ fhir:value "http://snomed.info/sct"
      fhir:Coding.code [ fhir:value "188340000" ];
      fhir:Coding.display [ fhir:value "Malignant tumor of crani
  ]
```

fhir:DiagnosticReport  
a owl:Class ;  
rdfs:comment "The findings and interpretation of diagnostic tests performed on patients, groups of patients, devices, and locations, and/or specimens derived from these. The report includes clinical context such as requesting and provider information, and some mix of atomic results, images, textual and coded interpretations, and formatted representation of diagnostic reports." ;  
rdfs:label "DiagnosticReport" ;  
rdfs:subClassOf fhir:DomainResource , w5:clinical.diagnostic ;

<http://hl7.org/fhir/fhir.ttl>

fhir:DiagnosticReport.code  
a owl:ObjectProperty ;  
rdfs:comment "A code or name that describes this diagnostic report." ;  
rdfs:domain fhir:DiagnosticReport ;  
rdfs:label "DiagnosticReport.code" ;  
rdfs:range fhir:CodeableConcept ;  
rdfs:subPropertyOf w5:what ;  
dc:title "Name/Code for this diagnostic report" .

fhir:DiagnosticReport.codedDiagnosis  
a owl:ObjectProperty ;  
rdfs:comment "Codes for the conclusion." ;  
rdfs:domain fhir:DiagnosticReport ;  
rdfs:label "DiagnosticReport.codedDiagnosis" ;  
rdfs:range fhir:CodeableConcept ;  
dc:title "Codes for the conclusion" .

fhir:value a owl:DatatypeProperty ;  
rdfs:label "fhir:value" ;  
dc:title "Terminal data value" .

FHIR  
Metadata  
Vocabulary

# FMV Definition of DiagnosticReport

The screenshot shows the Protégé ontology editor interface with the following details:

- Title Bar:** cancerreport (http://example.org/swat4ls/cancerreport) : [/Users/mr7576/Development/git3D2KOnFHIR/BLENDINCPH/RandRDF/swat4ls]
- Toolbar:** Active Ontology, Entities, Individuals by class, DL Query.
- Left Panel:** Class hierarchy for DiagnosticReport. The tree includes owl:Thing, administrative, clinical, careprovision, diagnostics, BodyStructure, DiagnosticReport (which is selected), ImagingManifest, ImagingStudy, Observation, ResearchStudy, ResearchSubject, Sequence, Specimen, SpecimenDefinition, general, medication, conformance, Element, final, financial, infrastructure, Narrative.div, Primitive, ReportWithCancerDiagnosis, Resource, 'SNOMED CT Concept (SNOMED RT+CTV3)', 'Body structure (body structure)', 'Clinical finding (finding)', 'Observable entity (observable entity)', 'Pharmaceutical / biologic product (product)', 'Physical force (physical force)', 'Physical object (physical object)', 'Procedure (procedure)', 'Qualifier value (qualifier value)', 'Situation with explicit context (situation)', 'SNOMED CT Model Component (metadata)', 'Social context (social concept)', 'Special concept (spedal concept)', 'Substance (substance)', treeRoot, and workflow.
- Right Panel:**
  - DiagnosticReport — http://hl7.org/fhir/DiagnosticReport**: Description, DiagnosticReport.
  - Equivalent To**: SubClass Of (DiagnosticReport.effectiveDateTime **only** dateTime | DiagnosticReport.effectivePeriod **only** Period).
  - General class axioms**: SubClass Of (Anonymous Ancestor). This section lists various constraints involving modifierExtension, contained, extension, text, meta, language, implicitRules, nodeRole, and resourceId.
- Status Bar:** Superclass hierarchy (inferred), Superclass hierarchy, 22.

# The Ontology Header

The diagram illustrates the relationship between a FHIR resource file and its ontology header. On the left, a code editor shows a FHIR resource file with two sections: '# - resource' and '# - ontology header'. The '# - ontology header' section contains two lines of code: '#<http://hl7.org/fhir/DiagnosticReport/f201.ttl> a owl:Ontology;' and '# owl:imports fhir:fhir.ttl.'. A red circle highlights the first line of this section, and a red arrow points from it to the 'Annotations' tab of an ontology editor on the right. The ontology editor shows the 'Annotations' tab selected, with a list of annotations for the 'DiagnosticReportCategory' class. One annotation is highlighted with a red box: 'DiagnosticReportCategory' → 'CodeableConcept.coding' → 'Coding.code' → 'value' → '394914008'. Another annotation is also visible: 'DiagnosticReportCategory' → 'Coding.display' → 'value' → 'Radiology'. A third annotation is partially visible: 'DiagnosticReportCategory' → 'Coding.system' → 'value' → 'http://snomed.info/sct'. The 'Annotations' tab also lists an 'index' entry with type 'xsd:integer'.

# - resource -----

```
<http://hl7.org/fhir/DiagnosticReport/f201> a fhir:DiagnosticReport;
  fhir:nodeRole fhir:treeRoot;
  fhir:Resource.id [ fhir:value "f201"];
  fhir:DomainResource.text [
```

# - ontology header -----

```
#<http://hl7.org/fhir/DiagnosticReport/f201.ttl> a owl:Ontology;
# owl:imports fhir:fhir.ttl.
```

If the resource itself doesn't include the FHIR Metadata Vocabulary...  
... the OWL tooling assumes that everything is an annotation

A detail you can avoid understanding because it is a problem of the RDF standard that misses the notion of import.

# Why the Ontology Header

The diagram illustrates the connection between FHIR JSON, an ontology header, and an RDF triple store.

**FHIR JSON:** On the left, there is a code block representing FHIR JSON. It includes a resource definition for a DiagnosticReport with an ID of "f201" and a treeRoot nodeRole.

**Ontology Header:** Below the FHIR JSON is another code block representing an ontology header. It defines an ontology at <http://hl7.org/fhir/DiagnosticReport/f201.ttl> and imports the FHIR ontology (<http://hl7.org/fhir/fhir.ttl>).

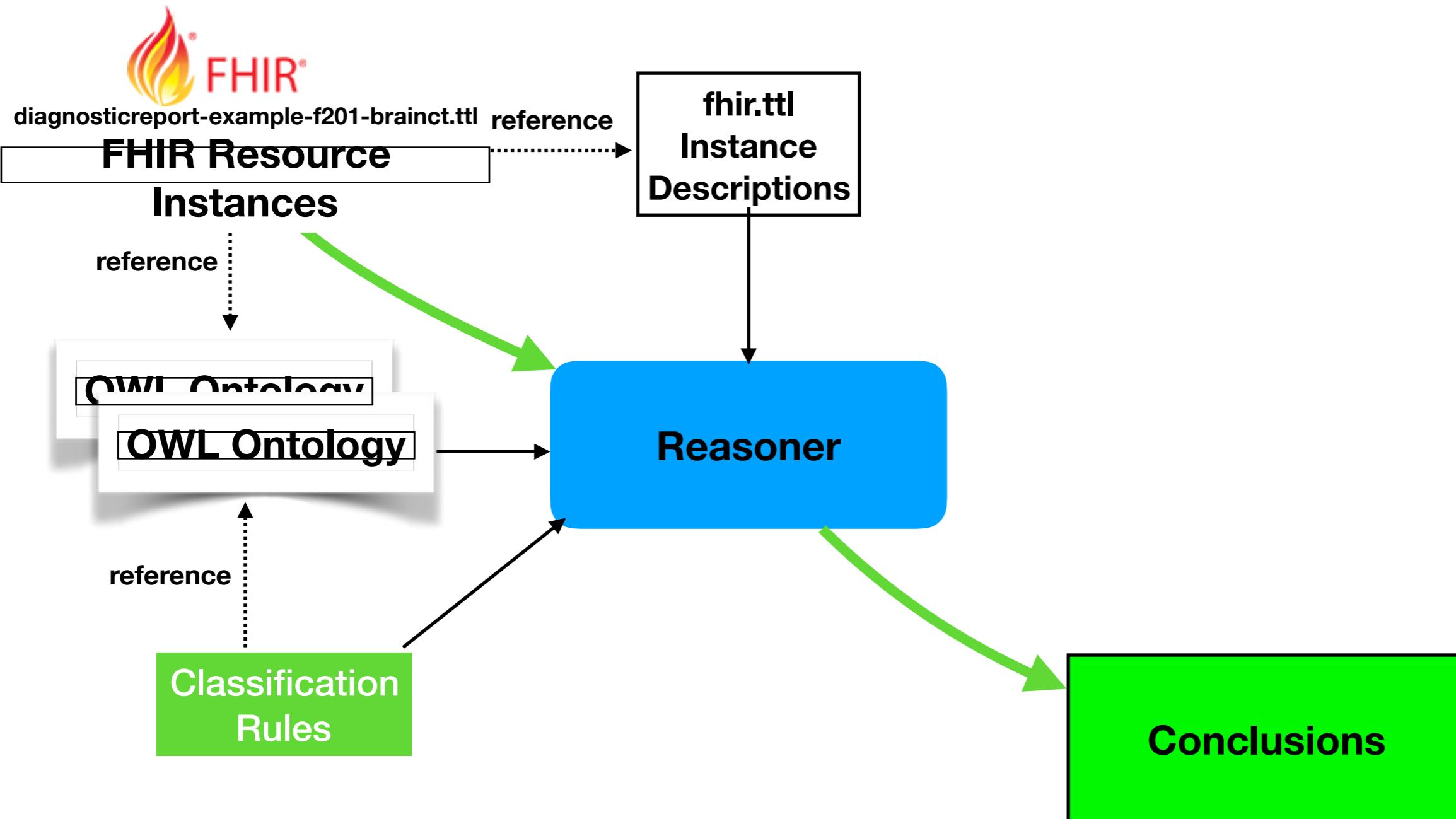
**RDF Triple Store:** On the right, a screenshot of a triple store interface titled "Property assertions: f201" is shown. It lists various triples related to the DiagnosticReport resource. A red box highlights the first triple, and a red arrow points from the ontology header code to this highlighted triple.

Subject	Predicate	Object
<http://hl7.org/fhir/DiagnosticReport/f201>	fhir:DiagnosticReport	
<http://hl7.org/fhir/DiagnosticReport/f201>	fhir:nodeRole	fhir:treeRoot
<http://hl7.org/fhir/DiagnosticReport/f201>	fhir:Resource.id	"f201"
<http://hl7.org/fhir/DiagnosticReport/f201>	fhir:DomainResource.text	
<http://hl7.org/fhir/DiagnosticReport/f201.ttl>	a	owl:Ontology
<http://hl7.org/fhir/DiagnosticReport/f201.ttl>	owl:imports	fhir:fhir.ttl

**With the import statement, the data is interpreted correctly**

A detail you can avoid understanding because it is a problem of the RDF standard that misses the notion of import.

# Using FHIR RDF With a DL Reasoner



# FHIR Resource Instance Concept References

`<http://hl7.org/fhir/StructureDefinition/MalignantTumorOfCraniopharyngealDuct>`

`fhir:Diagnos`

`fhir:li`

`fhir:Re`

`fhir:Re`

`];`

`fhir:Diagnos`

`fhir:Cod`

`fhir:i`

`a sct:`

`fhir:0`

`fhir:0`

`fhir:Coding.display [ fhir:value "Computed tomography (CT) of head and neck`

`];`

`fhir:CodeableConcept.text [ fhir:value "CT of head neck" ]`

`];`

`fhir:Diagn`

`fhir:index 0;`

`fhir:CodeableConcept.coding [`

`fhir:index 0;`

`a sct:188340000;`

`fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];`

`fhir:Coding.code [ fhir:value "188340000" ];`

`fhir:Coding.display [ fhir:value "Malignant tumor of craniopharyngeal duct" ]`

`]`

<http://snomed.info/id/188340000>

Malignant tumor of craniopharyngeal duct (disorder) — http://snomed.info/id/188340000

Description: Malignant tumor of craniopharyngeal duct (disorder)

Equivalent To +

- Neoplasm of cranipharyngeal duct (disorder)  
and Malignant tumor of pituitary gland (disorder)  
and ('Role group (attribute)' some  
('Associated morphology (attribute)' some 'Malignant neoplasm of primary, secondary, or uncertain origin (morphologic abnormality)'  
and ('Finding site (attribute)' some 'Structure of craniopharyngeal duct (body structure)'))

SubClass Of +

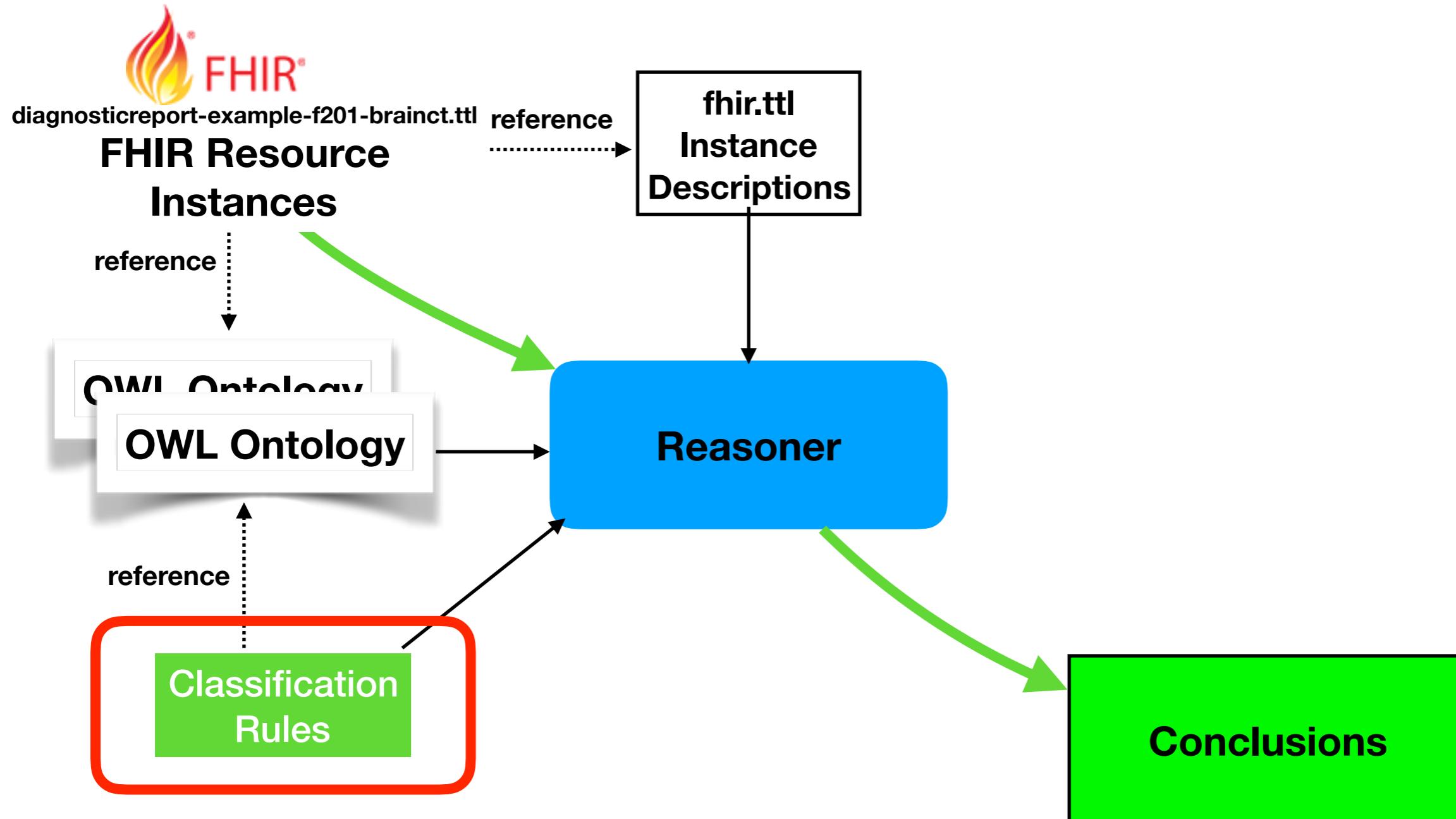
- Malignant tumor of pituitary gland (disorder)
- Neoplasm of cranipharyngeal duct (disorder)

Generalization +

SubClass Of (Anonymous Ancestor)

- Clinical finding (finding)  
and ('Role group (attribute)' some ('Finding site (attribute)' some 'Anatomical or acquired body structure (body structure)'))
- Finding by site (finding)  
and ('Role group (attribute)' some ('Finding site (attribute)' some 'Body system structure (body structure)'))

# Using FHIR RDF With a DL Reasoner



# Sample Classification Rule

```
Ontology(<http://example.org/swat4ls/cancerreport>
Import(<http://snomed.info/sct/900000000000207008>)
Import(<http://hl7.org/fhir/fhir.ttl>)
Import(<http://hl7.org/fhir/DiagnosticReport/f201.ttl>)
```

<b>SNOMED CT</b>
<b>FHIR.TTL</b>
<b>Sample Data</b>

```
Declaration(ObjectProperty(fhir:DiagnosticReport.codedDiagnosis.coding))
SubObjectPropertyOf(
  ObjectPropertyChain(fhir:DiagnosticReport.codedDiagnosis
fhir:CodeableConcept.coding) fhir:DiagnosticReport.codedDiagnosis.coding)
```



```
Declaration(Class(:ReportWithCancerDiagnosis))
EquivalentClasses(:ReportWithCancerDiagnosis
ObjectSomeValuesFrom(fhir:DiagnosticReport.codedDiagnosis.coding sct:363346000))
```

Similarly to my glowFHIR, this code creates an object property that shortcuts the semantic tagging of the diagnostic report with the SNOMED CT term

this code creates the set of the reports with cancer diagnosis using the object property declared above

**OWL Functional Syntax**

I know, we didn't see it in the course ...

# Classification Rules

## Concept Reference

Declaration(Class(:ReportWithCancerDiagnosis))

EquivalentClasses(:ReportWithCancerDiagnosis)

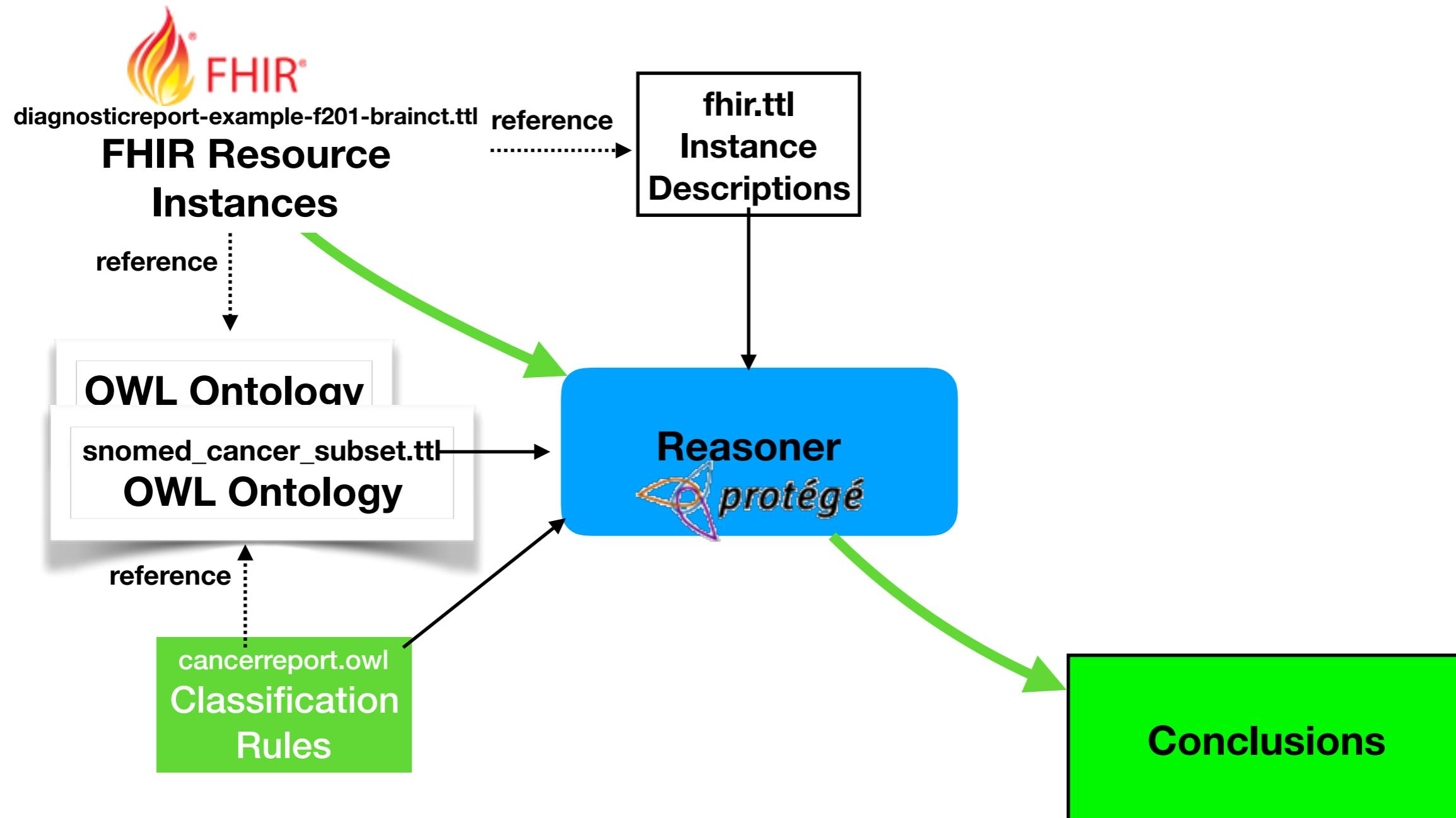
ObjectSomeValuesFrom(fhir:DiagnosticReport.codedDiagnosis.coding sct:363346000))

)

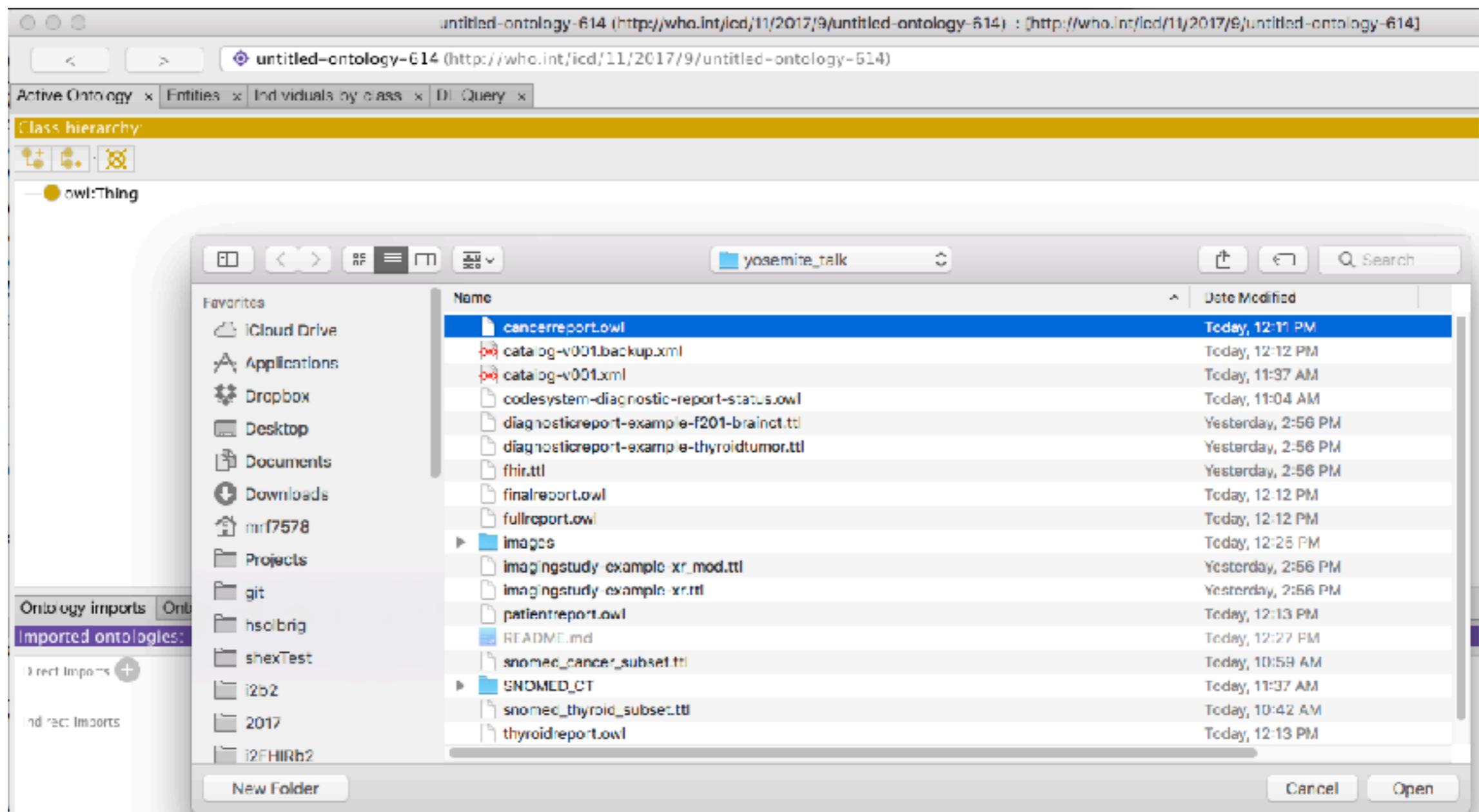
The screenshot shows the SNOMED CT web interface with the following details:

- Address Bar:** http://snomed.info/sct/S000C000C000207008x
- Left Panel (Class hierarchy):** Shows the class hierarchy for 'Malignant neoplastic disease (disorder)'. A red box highlights the node 'Malignant neoplastic disease (disorder)'.
- Right Panel (Individual View):**
  - URI:** http://snomed.info/id/363346000
  - Asserted:** Shows logical asserted rules:
    - 'Neoplastic disease (disorder)' and ('Role group (attribute)' some ('Associated morphology (attribute)' some 'Malignant neoplasm of primary, secondary, or uncertain origin (morphologic abnormality)'))
  - Subclass Of:** Shows general class axioms and subclass of anonymous ancestors:
    - 'Disease (disorder)' and ('Role group (attribute)' some ('Associated morphology (attribute)' some 'Neoplasm and/or hamartoma (morphologic abnormality)'))
    - 'Neoplasm and/or hamartoma (disorder)' and ('Role group (attribute)' some ('Associated morphology (attribute)' some 'Neoplasm (morphologic abnormality)'))
  - Instances:** Shows 15 uses of 'Malignant neoplastic disease (disorder)'.
- Bottom Panel (Superclass hierarchy):** Shows the superclass hierarchy for 'Malignant neoplastic disease (disorder)'.

# Using FHIR RDF With a DL Reasoner



# Load the Classification Rules



[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/cancerreport.owl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/cancerreport.owl)

# Verify the Imports

Ontology imports    Ontology Prefixes    General class axioms

Imported ontologies:

Direct Imports +

<<http://hl7.org/fhir/DiagnosticReport/f201.ttl>>  
f201.ttl  
Ontology IRI: <<http://hl7.org/fhir/DiagnosticReport/f201.ttl>>  
Location: [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/diagnosticreport-example-f201-brainct.ttl](#)

---

<[http://snomed.info/sct/900000000000207008cancer\\_subset](http://snomed.info/sct/900000000000207008cancer_subset)>  
900000000000207008cancer\_subset  
Ontology IRI: <[http://snomed.info/sct/900000000000207008cancer\\_subset](http://snomed.info/sct/900000000000207008cancer_subset)>  
Location: [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/snomed\\_cancer\\_subset.ttl](#)

---

<<http://hl7.org/fhir/fhir.ttl>>  
fhir.ttl  
Ontology IRI: <<http://hl7.org/fhir/fhir.ttl>>  
Location: [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/fhir.ttl](#)

---

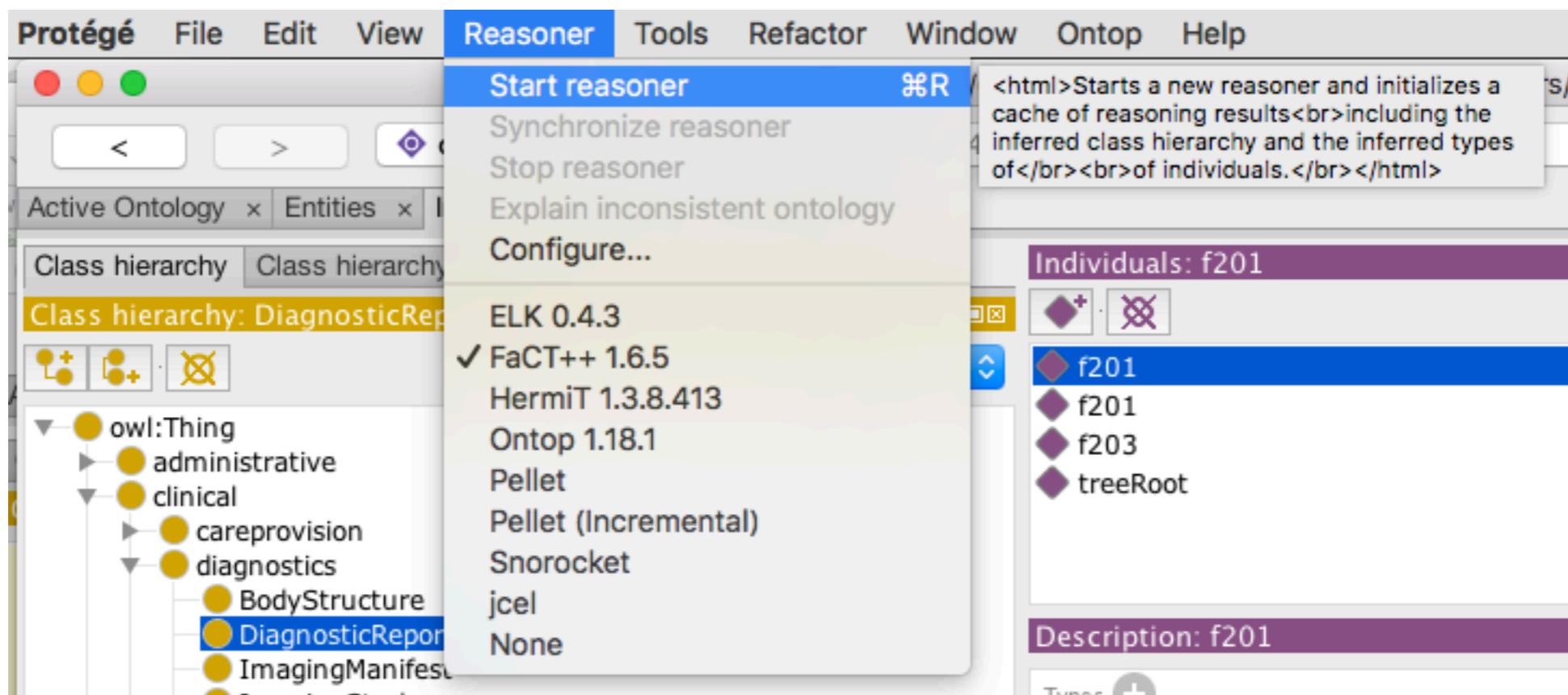
Indirect Imports

<<http://hl7.org/fhir/fhir.ttl>>  
fhir.ttl  
Ontology IRI: <<http://hl7.org/fhir/fhir.ttl>>  
Location: [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/fhir.ttl](#)

---

<<http://hl7.org/fhir/w5#>>  
w5  
Ontology IRI: <<http://hl7.org/fhir/w5#>>  
Location: [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/w5.ttl](#)

# Run the Reasoner



# Result

The screenshot shows the Protégé ontology editor interface with the following details:

- Top Bar:** cancerreport (<http://example.org/swat4ls/cancerreport>) : [/Users/mrf7576/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/swat4ls/hcls/cancerreport.owl]
- Navigation:** < > cancerreport (<http://example.org/swat4ls/cancerreport>)
- Tabs:** Active Ontology, Entities, Individuals by class, DL Query
- Class hierarchy:** DiagnosticReport is the selected class.
- Individuals:** f201 is selected. Other individuals listed are f201, f203, and treeRoot.
- Description:** f201 is described as a DiagnosticReport and ReportWithCancerDiagnosis. The ReportWithCancerDiagnosis type is highlighted with a red oval.
- Property assertions:** A list of asserted properties for f201, including:
  - DiagnosticReport.status \_:genid13306
  - DiagnosticReport.conclusion \_:genid13312
  - DiagnosticReport.performer \_:genid13325
  - DiagnosticReport.subject \_:genid13328
  - DiagnosticReport.codedDiagnosis \_:genid13316
  - DiagnosticReport.issued \_:genid13331
  - DiagnosticReport.category \_:genid13336
  - Resource.id \_:genid13333
  - DomainResource.text \_:genid13334
  - DiagnosticReport.effectiveDateTime \_:genid13335
  - DiagnosticReport.code \_:genid13323
  - nodeRole treeRoot
  - DiagnosticReport.ImagingStudy \_:genid13325
  - nodeRole treeRoot

# Restrict to Patients

subject	0..1	Reference(Patient   Group   Device   Location)	LOINC Diagnostic Report Codes (Preferred) The subject of the report - usually, but not always, the patient
---------	------	--	---

```
Declaration(ObjectProperty(fhir:DiagnosticReport.subject.link))
SubObjectPropertyOf(
    ObjectPropertyChain(fhir:DiagnosticReport.subject fhir:link)
    fhir:DiagnosticReport.subject.link)
```

Similarly to my glowFHIR, shortcuts the relationship from a report to a patient

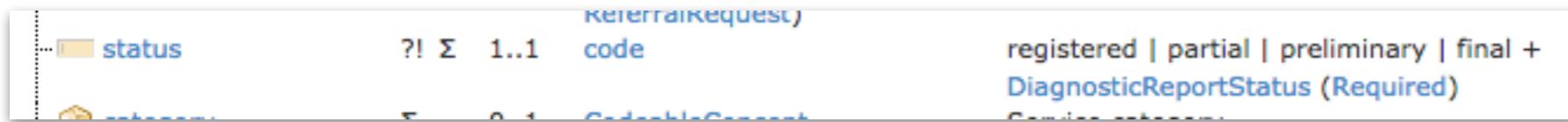
```
Declaration(Class(:PatientReport))
EquivalentClasses(:PatientReport
    ObjectSomeValuesFrom(fhir:DiagnosticReport.subject.link fhir:Patient))
)
```

Defines the set of the Reports linked with a Patient

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/patientreport.owl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/patientreport.owl)

**NOT COVERED IN DETAILS**

# Finalized Reports Only



Code	Display	Definition
registered	Registered	The existence of the report is registered, but there is nothing yet available.
partial	Partial	This is a partial (e.g. initial, interim or preliminary) report: data in the report may be incomplete or unverified.
preliminary	Preliminary	Verified early results are available, but not all results are final.
final	Final	The report is complete and verified by an authorized person.
amended	Amended	Subsequent to being final, the report has been modified. This includes any change in the results, diagnosis, narrative text, report that has been issued.
corrected	Corrected	Subsequent to being final, the report has been modified to correct an error in the report or referenced results.
appended	Appended	Subsequent to being final, the report has been modified by adding new content. The existing content is unchanged.
cancelled	Cancelled	The report is unavailable because the measurement was not started or not completed (also sometimes called "aborted").
entered-in-error	Entered in Error	The report has been withdrawn following a previous final release. This electronic record should never have existed, though world decisions were based on it. (If real-world activity has occurred, the status should be "cancelled" rather than "entered-in-error".)
unknown	Unknown	The authoring system does not know which of the status values currently applies for this request. Note: This concept is no longer used in FHIR. If one of the listed statuses is presumed to apply, it's just not known which one.

**Declaration(Class(:FinalizedReport))**  
**EquivalentClasses(:FinalizedReport ObjectSomeValuesFrom**  
**(fhir:DiagnosticReport.status DataSomeValuesFrom**  
**(fhir:value DataOneOf("amended" "appended" "corrected" "final"))))**

**NOT COVERED IN DETAILS**

# Finalized Reports Only

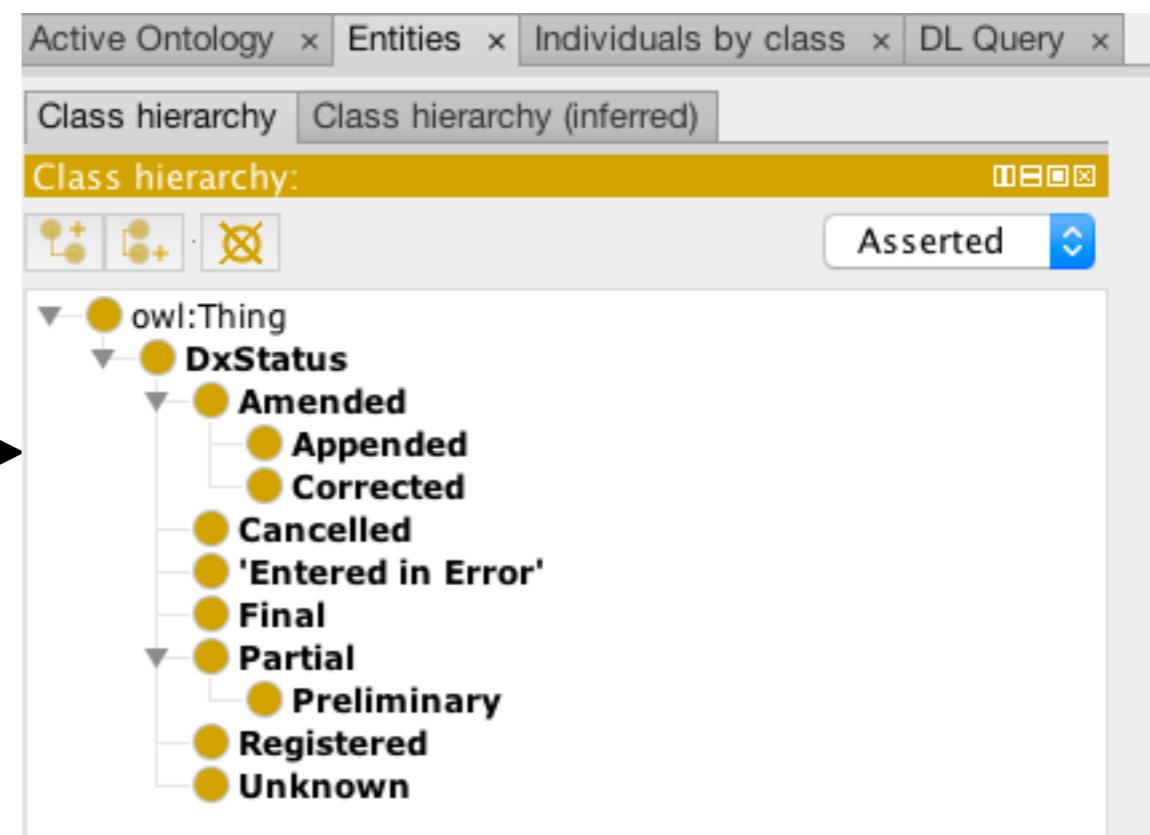
Approach is “brittle”:

- Code system hierarchy is replicated as flattened strings
- No link to fact that system is being used
- DataProperty constraints potentially make reasoner more complex

NOT COVERED IN DETAILS

# Finalized Reports Proposed Solution

```
Prefixes: fhir: <http://hl7.org/fhir/> .  
Prefixes: rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
Prefixes: owl: <http://www.w3.org/2002/07/owl#> .  
Prefixes: diagnostic-report-status: <http://hl7.org/fhir/diagnostic-report-status#> .  
Prefixes: xsd: <http://www.w3.org/2001/XMLSchema#> .  
Prefixes: skos: <http://www.w3.org/2004/02/skos/core#> .  
Prefixes: rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
Prefixes: w5: <http://hl7.org/fhir/w5#> .  
  
diagnostic-report-status:root  
  a owl:Class ;  
    rdfs:label "DxStatus" ;  
    skos:definition "Diagnostic Report Status Values" ;  
    skos:prefLabel "DxStatus" .  
  
diagnostic-report-status:partial  
  a owl:Class ;  
  rdfs:subClassOf diagnostic-report-status:root ;  
  rdfs:label "Partial" ;  
  skos:definition "This is a partial (e.g. initial, interim or pre-  
  may be incomplete or unverified)." ;  
  skos:prefLabel "Partial" .  
  
diagnostic-report-status:cancelled  
  a owl:Class ;  
  rdfs:subClassOf diagnostic-report-status:root ;  
  rdfs:label "Cancelled" ;  
  skos:definition "The report is unavailable because the measure  
  (also sometimes called 'aborted')." ;  
  skos:prefLabel "Cancelled" .
```



1) OWL representation (and URIs!) for *all* code systems ...

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/codesystem-diagnostic-report-status.owl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/codesystem-diagnostic-report-status.owl)

NOT COVERED IN DETAILS

# Finalized Reports Proposed Solution (cont)

```
];
fhir:DiagnosticReport.status [
    a diagnostic-report-status:final;
    fhir:value "final"];
fhir:DiagnosticReport.category [
```



- 2) Revise FHIR RDF specification to allow rdf:type on *all* codes

```
Import(<http://hl7.org/fhir/diagnostic-report-status/>)
```

```
...
```

```
Declaration(Class(:FinalStatus))
```

```
SubClassOf(diagnostic-report-status:final :FinalStatus)
```

```
SubClassOf(diagnostic-report-status:amended :FinalStatus)
```

```
Declaration(Class(:FinalReport))
```

```
EquivalentClasses(:FinalReport)
```

```
ObjectSomeValuesFrom(fhir:DiagnosticReport.status :FinalStatus))
```

# Finalized Patient Reports having a Cancer Dx

 Diagnosis

```
Import(<http://example.org/swat4ls/patientreport>)
Import(<http://example.org/swat4ls/cancerreport>)
Import(<http://example.org/swat4ls/finalreport>)
```

```
# Class declaration
Declaration(Class(:FinalPatientReportWithCancerDiagnosis))
AnnotationAssertion(dc:title :FinalPatientReportWithCancerDiagnosis
    "The set of diagnoses that are instances of malignant neoplastic disease
(sct:363346000)")
EquivalentClasses(:FinalPatientReportWithCancerDiagnosis
    ObjectIntersectionOf
        (<http://example.org/swat4ls/patientreport/PatientReport>
        <http://example.org/swat4ls/cancerreport/ReportWithCancerDiagnosis>
        <http://example.org/swat4ls/finalreport/FinalReport>))
)
```

# Definition

The screenshot shows the Protégé ontology editor interface. The top bar displays the title "finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport) : [/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGC]" and the navigation buttons < and >. Below the title, there are tabs for "Active Ontology", "Entities", "Individuals by class", and "DL Query". The "Individuals by class" tab is selected.

In the center, the class hierarchy is shown with "FinalPatientReportWithCancerDiagnosis" at the top. A yellow box highlights the "Description: FinalPatientReportWithCancerDiagnosis" section, which contains the text "FinalPatientReportWithCancerDiagnosis — http://example.org/swat4ls/finalpatientcancerreport".

On the left, a tree view shows the class hierarchy under "owl:Thing", including categories like administrative, clinical, conformance, DxStatus, Element, FinalReport, FinalStatus, financial, infrastructure, Narrative.div, PatientReport, Primitive, ReportWithCancerDiagnosis, and Resource. "FinalPatientReportWithCancerDiagnosis" is highlighted in blue.

On the right, the "Asserted" tab is selected. It shows the following details for the class:

- Equivalent To:** ReportWithCancerDiagnosis and FinalReport and PatientReport
- SubClass Of:** (no entries)
- General class axioms:** (no entries)
- SubClass Of (Anonymous Ancestor):**
  - DiagnosticReport.subject.link **some** Patient
  - DiagnosticReport.codedDiagnosis.coding **some** 'Malignant neoplastic disease (disorder)'
  - DiagnosticReport.status **some** FinalStatus
- Instances:** (no entries)

# Result

The screenshot shows the Protégé ontology editor interface. The title bar reads "finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport) : [/Users/mrf7578/Development/git/BD2KOnFHIR/BLEN...]".

The tabs at the top are "Active Ontology", "Entities", "Individuals by class", and "DL Query".

The left sidebar shows the "Class hierarchy" tree. The node "FinalPatientReportWithCancerDiagnosis" is selected and highlighted in blue. Other nodes visible include owl:Thing, administrative, clinical, conformance, DxStatus, Element, FinalStatus, financial, infrastructure, Narrative.div, PatientReport, ReportWithCancerDiagnosis, Primitive, and various resources like 'SNOMED CT Concept (SNOMED RT+CTV3)', treeRoot, workflow, and xhtml.

The main panel displays the details for "FinalPatientReportWithCancerDiagnosis".

- Description:** FinalPatientReportWithCancerDiagnosis
- Equivalent To**: ReportWithCancerDiagnosis and FinalReport and PatientReport
- SubClass Of**: FinalReport, PatientReport, ReportWithCancerDiagnosis
- General class axioms**: DiagnosticReport.subject.link some Patient, DiagnosticReport.codedDiagnosis.coding some 'Malignant neoplastic disease (disorder)', DiagnosticReport.status some FinalStatus
- Instances**: f201

**NOTE: NICE! However, this is “only” subsumption. We could do this by creating a table with “all” the codes of the malignat neoplastic diseases and looking up the specific code in such a table.**

# Post-Coordinated Expressions

i.e., beyond simple SNOMED CT's code lookup

```
fhir:DiagnosticReport.conclusion [ fhir:value "CT brains: tumor of the left lobe of the thyroid gland."];
fhir:DiagnosticReport.codedDiagnosis [
  fhir:index 0;
  fhir:CodeableConcept.coding [
    fhir:index 0;
    a sct:363346000;
    a [ a owl:Restriction ;
        owl:onProperty sct:609096000 ;
        owl:someValuesFrom [ a owl:Restriction ;
          owl:onProperty sct:363698007 ;
          owl:someValuesFrom sct:170784008 ] ] ;
    fhir:Coding.system [ fhir:value "http://snomed.info/sct" ],
    fhir:Coding.code [ fhir:value "363346000:{363698007=170784008}" ];
    fhir:Coding.display [ fhir:value "Malignant tumor of left lobe of thyroid gland" ]
  ]
].
```

**Transformation rules for OWL equivalent**

**finding site**

**the “left lobe” of the thyroid gland**

**is a malignant tumor**

**One possible format for compositional expression**

For more info on SNOMED CT's compositional grammar, see: <http://snomed.org/scg>

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/diagnosticreport-example-thyroidtumor.ttl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/diagnosticreport-example-thyroidtumor.ttl)

# Thyroid Disease Classifier

...

**Declaration(Class(:ReportOfThyroidDisease))**

**AnnotationAssertion(dc:title :ReportOfThyroidDisease**

**"Thyroid Disease Dx - disorder of the thyroid gland (sct:14304000)"**

**EquivalentClasses(:ReportOfThyroidDisease**

**ObjectSomeValuesFrom(fhir:DiagnosticReport.codedDiagnosis.coding sct:14304000)**

)

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/thyroidreport.owl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/thyroidreport.owl)

# Result

If you have a disease to a part of an organ  
(e.g., the left lobe of the thyroid gland),  
you have a disease to the organ (i.e., the thyroid gland)

The screenshot shows a semantic web interface with two main panels: 'Individuals' and 'Property assertions'.

**Individuals: dxreport117**

- dxreport117 (selected)
- f201
- f201
- f203
- treeRoot

**Description: dxreport117**

Types:

- DiagnosticReport
- ReportOfThyroidDisease (highlighted with a red box)

Object property assertions:

- DiagnosticReport.conclusion \_:genid23666
- DiagnosticReport.performer \_:genid23668
- DiagnosticReport.status \_:genid23646
- DiagnosticReport.code \_:genid23669
- DiagnosticReport.effectiveDateTime \_:genid23671
- Resource.id \_:genid23667
- nodeRole treeRoot
- DiagnosticReport.codedDiagnosis \_:genid23662
- DiagnosticReport.category \_:genid23653
- DiagnosticReport.imagingStudy \_:genid23663
- DiagnosticReport.issued \_:genid23665
- DiagnosticReport.subject \_:genid23670
- DomainResource.text \_:genid23655
- nodeRole treeRoot

NOT COVERED IN DETAILS

# What doesn't work

```
fhir:ImagingStudy.description [ fhir:value "XR Wrist 3+ Views"];
fhir:ImagingStudy.series [
  fhir:index 0;
  fhir:ImagingStudy.series.uid [ fhir:value "urn:oid:2.16.124.113543.6003.1154777499.30246.19789";
  fhir:ImagingStudy.series.number [ fhir:value "3"^^xsd:nonNegativeInteger ];
  fhir:ImagingStudy.series.modality [
    fhir:Coding.system [ fhir:value "http://nema.org/dicom/dicom" ];
    fhir:Coding.code [ fhir:value "DX" ]
  ];
  fhir:ImagingStudy.series.bodySite [
    a sct:7467003;
    fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
    fhir:Coding.code [ fhir:value "7467003" ];
    fhir:Coding.display [ fhir:value "Wrist joint structure" ]
  ];
  fhir:ImagingStudy.series.laterality [
    a sct:7771000;
    fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
    fhir:Coding.code [ fhir:value "7771000" ];
    fhir:Coding.display [ fhir:value "Left" ]
  ];
  fhir:ImagingStudy.series.started [ fhir:value "2011-01-01T11:01:20+03:00"^^xsd:dateTime ];
```

**Does laterality modify bodySite? Is it an independent attribute?**

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/imagingstudy-exmple.xr.ttl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/imagingstudy-exmple.xr.ttl)

# What we need

```
fhir:ImagingStudy.series.bodySite [  
  a sct:7467003;  
  a [owl:Restriction;  
    owl:onProperty sct:272741003;  
    owl:someValuesFrom sct:7771000];  
  fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
  fhir:Coding.code [ fhir:value "7467003" ];  
  fhir:Coding.display [ fhir:value "Wrist joint structure" ]  
];  
fhir:ImagingStudy.series.laterality [  
  a sct:7771000;  
  fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];  
  fhir:Coding.code [ fhir:value "7771000" ];  
  fhir:Coding.display [ fhir:value "Left" ]  
];
```

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/imagingstudy-exmple.xr.ttl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/imagingstudy-exmple.xr.ttl)

# Why the imaging study doesn't work

There is a tacit ontological model included in the data (this is always the case....)

The modelers know that the laterality attribute modifies the body site – it isn't an image of a 'left', it is an image of the left wrist.

Transformation is necessary

- Watch the work that Grahame Grieve and Linda Bird are doing on SNOMED model alignment
- Keep an eye on what is happening in the Shape Expressions (ShEx) mapping group

# Issues and Discussion

- FHIR Metadata Vocabulary
  - Uses types not recognized in OWL spec (xsd:date, xsd:time, etc)
  - Value Set references not yet included
  - Include path expressions?
- FHIR and RDF
  - URI's for all concept codes
  - OWL rendering of all code systems
  - RDF Profile? URI's, links and link types aren't RDF specific
- Reasoner
  - ELK and Snorocket don't work — have to use FaCT++
    - FaCT++ is too slow for complete SNOMED CT, so we're generating subsets
    - Snorocket community willing to address issues
  - Production environment would need pre-classified SNOMED w/ queries (ala. CTS2 approach)
- Some issues wrt. CONNEG (content negotiation)

# Summary

- FHIR RDF allows seamless integration with DL reasoners
- DL reasoners can be applied to many, but not all(!) classification tasks
- Still some “rough edges”, but approach appears to be solid and useable in a production level environment

# Credits

**This study is supported in part by NIH grants U01 HG009450 and U01 CA18094.**

**This work was conducted using the Protégé resource, which is supported by grant GM10331601 from the National Institute of General Medical Sciences of the United States National Institutes of Health.**

**Eric Prud'hommeaux  
David Booth  
Dr. Guoqian Jiang**

**The HCLS team**

# Presentation Materials

Materials for this talk, along with this slide deck can be found at:

[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk)

Screenshot of a GitHub repository page for 'BLENDINGFHIRandRDF / yosemite\_talk'. The repository contains several files and folders related to FHIR RDF development, including SNOMED\_CT, images, README.md, cancerreport.owl, catalog-v001.backup.xml, catalog-v001.xml, codesystem-diagnostic-report-status.owl, diagnosticreport-example-(201-).n3net.ttl, diagnosticreport-example-thyroidtumor.ttl, fhir.ttl, finalreport.owl, fullreport.owl, imagingstudy-example-xr.ttl, imagingstudy-example-xr.nod.ttl, patienticort.owl, knowner\_cancer\_subset.ttl, snomed\_thyroid\_subset.ttl, thyroidreport.owl, w5.ttl, and README.md. The files were last committed on October 12, 2018.

FHIR RDF as a Bridge to the Semantic Web in Healthcare

Two screenshots of the Protégé ontology editor illustrating the use of FHIR RDF in a semantic web context.

The first screenshot shows the 'Use' tab with a numbered list of steps:

1. Install a current version of [Protégé](#) (we use 5.1.0)
2. Clone a copy of the [BLENDINGFHIRandRDF](#) repository
3. Change to the `yosemite_talk` directory
4. Start Protégé and open `fullreport.owl`
5. Select the FaCT++ reasoner under the Reasoner menu
6. Select Start reasoner under the Reasoner menu
7. Navigate to `FinalPatientReportWithCancerDiagnosis` in the Class Hierarchy tab and observe that `tzx1` (the id of the `DiagnosticReport`) has been recognized as an instance.

The second screenshot shows the Protégé interface with the 'Knowner\_Cancer\_Subset' ontology loaded. It displays the class hierarchy, instances, and asserted facts for `ReportWithCancerDiagnosis`.

8. Open `thyroidreport.owl`, answering 'no' to the current window prompt.
9. Select start reasoner under the reasoner menu.
10. Navigate to `ReportOfThyroidDisease` in the Class Hierarchy tab and observe that `okreport117` has been classified as an instance of `thyroid disease`.

# Questions

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