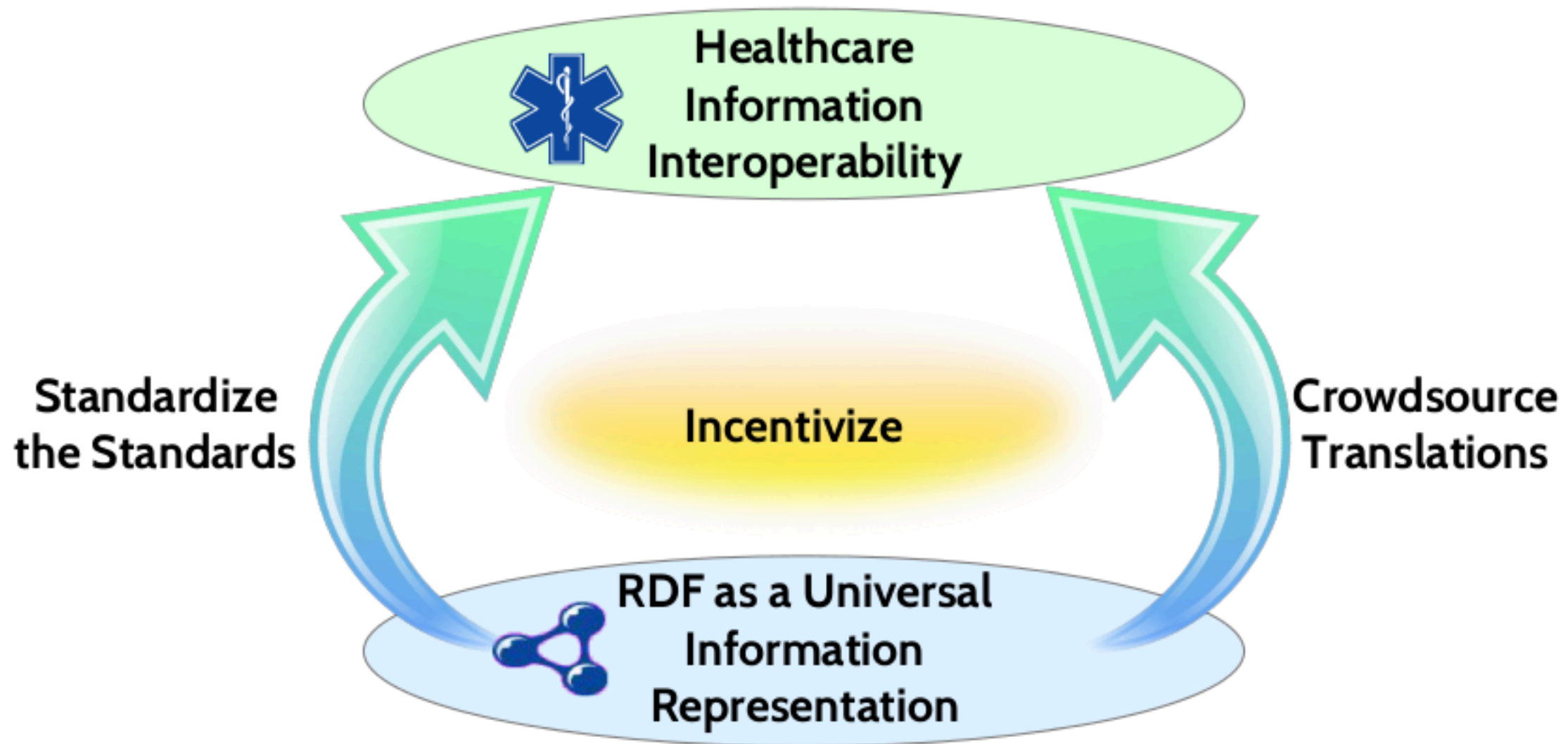


# **FHIR RDF as a Bridge to the Semantic Web in Healthcare**

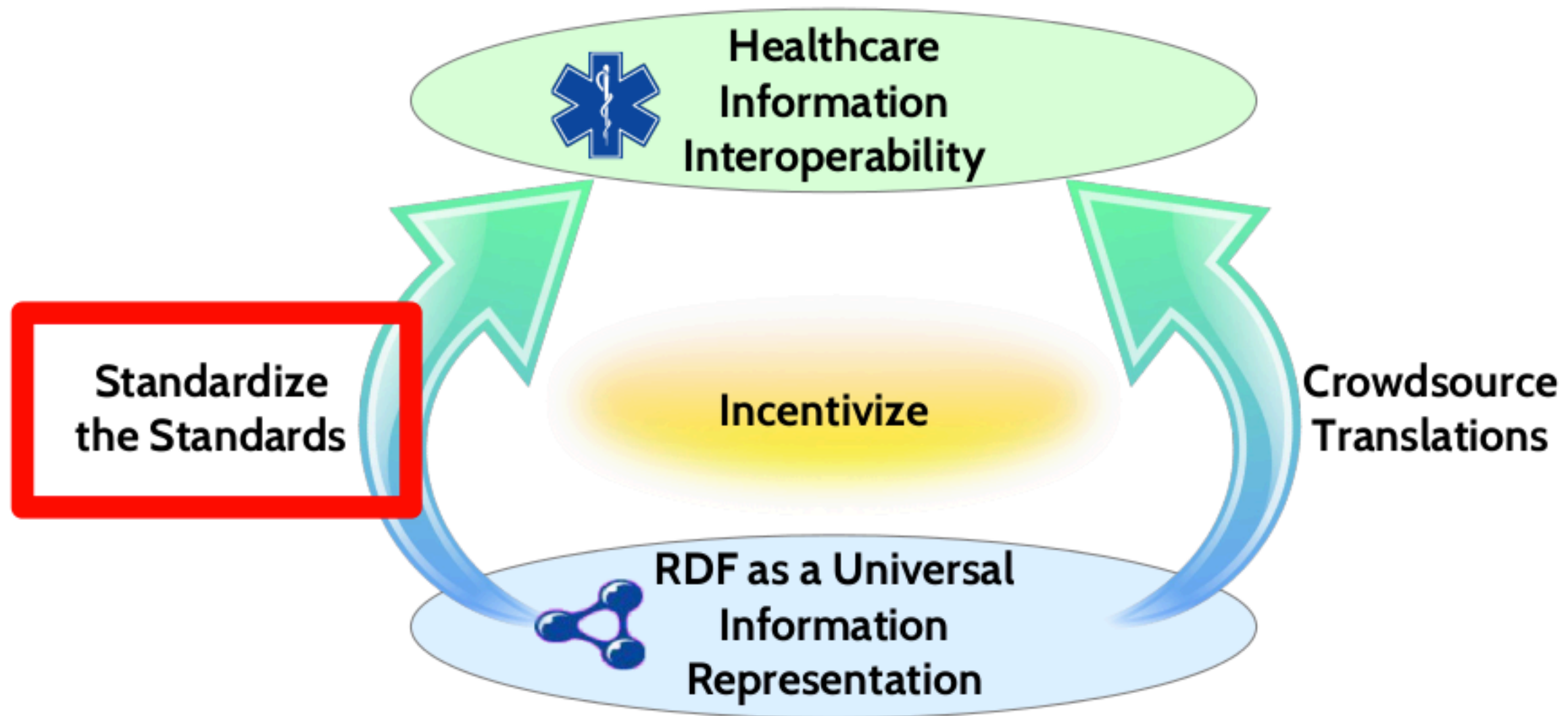
Harold Solbrig  
Mayo Clinic

# 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

# FHIR®©

## Fast Healthcare Interoperability Resources

The screenshot shows the FHIR website homepage. The browser address bar displays [www.hl7.org/FHIR/](http://www.hl7.org/FHIR/). The page header includes the FHIR logo and the text "FHIR Release 3 (STU)". A navigation menu lists: Home, Getting Started, Documentation, Resources, Profiles, Extensions, Operations, and Terminologies. Below the menu, a yellow banner states: "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 heading is "Welcome to FHIR®". A box for "First time here?" provides links to the executive summary, developer's introduction, clinical introduction, architect's introduction, overview/roadmap & timelines, open license, and table of contents. Under "Technical Corrections:", a bullet point mentions "Apr-19 2017: Corrections to invariants & generated conformance resources, and add note about isSummary". The "Level 1 Basic framework on which the specification is built" section includes a box for "Foundation" (Base Documentation, XML, JSON, REST API + Search, Data Types, Extensions). The "Level 2 Supporting Implementation, and binding to external specifications" section contains five boxes: "Implementer Support" (Downloads, Common Use Cases, Testing), "Security & Privacy" (Security, Consent, Provenance, AuditEvent), "Conformance" (StructureDefinition, CapabilityStatement, ImplementationGuide, Profiling), "Terminology" (CodeSystem, ValueSet, ConceptMap, Terminology Svc), and "Linked Data" (RDF). The "Level 3 Linking to real world concepts in the healthcare system" section includes a box for "Administration" (Patient, Practitioner, Device, Organization, Location, Healthcare Service). The "Level 4 Record-keeping and Data Exchange for the healthcare process" section contains four boxes: "Clinical" (Allergy, Problem, CarePlan, DetectedIssue), "Diagnostics" (Observation, Report, Specimen), "Medications" (Order, Dispense, Administration), and "Workflow" (Task, Appointment, Schedule, Definition). The "Observation, Report, Specimen" box is circled in red. A small number "5" is visible between the "Medications" and "Workflow" boxes.

www.hl7.org/FHIR/

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](#).

### 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**

<b>Foundation</b>	Base Documentation, XML, JSON, REST API + Search, Data Types, Extensions
-------------------	--

**Level 2 Supporting Implementation, and binding to external specifications**

<b>Implementer Support</b> Downloads, Common Use Cases, Testing	<b>Security &amp; Privacy</b> Security, Consent, Provenance, AuditEvent	<b>Conformance</b> StructureDefinition, CapabilityStatement, ImplementationGuide, Profiling	<b>Terminology</b> CodeSystem, ValueSet, ConceptMap, Terminology Svc	<b>Linked Data</b> RDF
--	--	--	---	---------------------------

**Level 3 Linking to real world concepts in the healthcare system**

<b>Administration</b> Patient, Practitioner, Device, Organization, Location, Healthcare Service
--

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

<b>Clinical</b> Allergy, Problem, CarePlan, DetectedIssue	<b>Diagnostics</b> Observation, Report, Specimen	<b>Medications</b> Order, Dispense, Administration	<b>Workflow</b> Task, Appointment, Schedule, Definition
--	---	---	--

# FHIR Resource Definition

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

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, images, interpretation, as well as formatted reports Elements defined in Annotations: id, meta, implicitRules, language, text, contained, extension, modifierExtension
identifier	X	0..*	Identifier	Business identifier for report
basedOn		0..*	Reference(CarePlan   ImmunizationRecommendation   MedicationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	What was requested
status	YI X	1..1	code	requested   partial   preliminary   final + DiagnosticReportStatus (Required)
category	I	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	Z	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)	Health care event when test ordered
effective[x]	I	0..1		Clinically relevant time/time period for report
effectiveDateTime			dateTime	
effectivePeriod			Period	
issued	Z	0..1	Instant	DateTime this version was released
performer	X	0..*	BackboneElement	Participants in producing the report
role	Z	0..1	CodeableConcept	Type of performer Procedure Performer Role Codes (Example)
actor	Z	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)	Reference to full details of imaging associated with the diagnostic report
image	Z	0..*	BackboneElement	Key images associated with this report
comment		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
codedDiagnoses		0..*	CodeableConcept	Codes for the conclusion SNOMED CT Clinical Findings (Example)
presentedForm		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 and formatted reports
identifier		0..*	Identifier	Elements defined in Annexes: id, meta, implicitRules, language, test, Reason for referral for report
basedOn		0..*	Reference(CarePlan   Immunization   Recommendation   MedicationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	What was requested
status		1..1	code	registered   partial   preliminary   final + DiagnosticReportStatus (Required)
category		0..1	CodeableConcept	Service category
code		1..1	CodeableConcept	Diagnostic Service Section Codes (Example)
subject		0..1	Reference(Patient   Group   Location)	Name/Code for this diagnostic report
context		0..1	Reference(Encounter   EpisodeOfCare)	LOINC Diagnostic Report Codes (Preferred)
effective[x]		0..1	dateTime	The subject of the report - usually, but not always, the patient
effectiveTime		0..1	Period	Clinically relevant time/time period for report
issued		0..1	dateTime	Health care event when test ordered
performer		0..*	BackboneElement	Clinically relevant time/time period for report
role		0..1	CodeableConcept	Date/Time this version was released
actor		1..1	Reference(Practitioner   Organization)	Participants in producing the report
specimen		0..*	Reference(Specimen)	Type of performer
result		0..*	Reference(Observation)	Procedure Performer Role Codes (Example)
imagingStudy		0..*	Reference(ImagingStudy   ImagingManifest)	Practitioner or Organization participant
image		0..*	BackboneElement	Specimens this report is based on
comment		0..1	string	Observations - simple, or complex nested groups
link		1..1	Reference(Media)	Reference to full details of imaging associated with the diagnostic report
conclusion		0..1	string	Key Images associated with this report
codedDiagnosis		0..*	CodeableConcept	Comment about the image (e.g. explanation)
presentedForm		0..*	Attachment	Reference to the image source

Documentation for this format

Alternate definitions: Nestor Definition (XML, JSON), XML Schema/Schematron (for) - 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>General</b></p></div>
  <status value="final"/>
  <category>
    <!-- The request was honored by the Department of Radiology -->
    <coding>
      <system value="http://snomed.info/ct"/>
      <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/ct"/>
      <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="Acel"/>
  </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 images not available - following reference used to demonstrate t -->
  <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/ct"/>
      <code value="188340000"/>
      <display value="Malignant tumor of craniopharyngeal duct"/>
    </coding>
  </codedDiagnosis>
</DiagnosticReport>
```

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

# FHIR Resource Instance (JSON)

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, images, interpreted formatted reports Elements defined by extensions: id, meta, implicitRules, language, text, contained, extension, ResourceReference for report
identifier		0..*	Identifier	
basedOn		0..*	Reference(CarePlan   Immunization   ImmunizationRecommendation   MedicationRequest   NutritionOrder   ProcedureRequest   ReferralRequest)	What was requested
status		1..1	code	registered   partial   preliminary   final + DiagnosticReportStatus (Required)
category		0..1	CodeableConcept	Service category
code		0..1	CodeableConcept	Diagnostic Service Section Codes (Example)
subject		0..1	Reference(Patient   Group   Device   Location)	The subject of the report - usually, but not always, the patient
context		0..1	Reference(EpisodeOfCare   EpisodeOfCare)	Health care event within test history
effective[x]		0..1	dateTime	Clinically relevant time/time period for report
effectiveDateTime			dateTime	
effectivePeriod			Period	
issued		0..1	Instant	DateTime this version was released
performer		0..*	BackboneElement	Participants in producing the report
role		0..1	CodeableConcept	Type of performer
actor		0..1	Reference(Practitioner   Practitioner   Organization)	Procedure Performer Role Codes (Example)
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)	Reference to full details of imaging associated with the diagnostic report
image		0..*	BackboneElement	Key Images associated with this report
comment		0..1	string	Comment about the image (e.g. explanation)
link		0..1	Reference(Media)	Reference to the image source
conclusion		0..1	string	Clinical Interpretation of test results
codedDiagnosis		0..*	CodeableConcept	Codes for the conclusion SNOMED CT Clinical Findings (Example)
presentedForm		0..*	Attachment	Online report as issued

Documentation for this format

Alternate definitions: Nestor Definition (XML, JSON), XML Schema/Schematron (for ) - JSON Schema, ShEx (for Turtle)

```
{
  "resourceType": "DiagnosticReport",
  "id": "f201",
  "text": {
    "status": "generated",
    "div": "div xmlns=\"http://www.w3.org/1999/xhtml\"><p><b>Generated</b></p><p><b>status</b>: final</p><p><b>category</b>: Radiology <span>given as 'Radiology'; (http://hl7.org/fhir/v2/0074 code 'RAD')</span></p><p><b>Details</b>: {SNOMED CT code '429858000' = 'Computed tomography (head and neck)'}</span></p><p><b>subject</b>: <a>Roel</a></p><p><b>effectiveDateTime</b>: 2012-12-01T12:00:00+01:00</p><p><b>performer</b>:</p><table><tr><td></td><td></td></tr></table><p><b>imagingStudy</b>: HEAD and NECK CT DICOM imaging sphenoid/clinivus.</p><p><b>codedDiagnosis</b>: Malignant tumor of craniopharyngeal duct, given as 'Malignant tumor of craniopharyngeal duct'</p></div></text>
  },
  "status": "final",
  "category": {
    "coding": [
      {
        "system": "http://snomed.info/sct",
        "code": "394914008",
        "display": "Radiology"
      }
    ]
  },
  "code": {
    "coding": [
      {
        "system": "http://snomed.info/sct",
        "code": "429858000",
        "display": "Computed tomography (CT) of head and neck"
      }
    ],
    "text": "CT of head-neck"
  },
  "subject": {
    "reference": "Patient/f201",
    "display": "Roel"
  },
  "effectiveDateTime": "2012-12-01T12:00:00+01:00",
  "issued": "2012-12-01T12:00:00+01:00",
  "performer": [
    {
      "actor": {
        "reference": "Organization/f203",
        "display": "Blifdorp MC"
      }
    }
  ],
  "imagingStudy": {
    "display": "HEAD and NECK CT DICOM imaging study"
  },
  "conclusion": "CT brains: large tumor sphenoid/clinivus.",
  "codedDiagnosis": [
    {
      "coding": [
        {
          "system": "http://snomed.info/sct",
          "code": "188340000",
          "display": "Malignant tumor of craniopharyngeal duct"
        }
      ]
    }
  ]
}
```

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



# (RDF)

**http://www.hl7.org/fhir/diagnosticreport-example-f201-brainct.ttl**

# 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#> .
```

**Prefixes**

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

**subject predicate object ;  
predicate object ;**

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

**subject predicate object ,  
object ,**

```
# - 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" ]  
  ] ;
```

# Syntax “maturity”

## 2.6.1 XML Representation of Resources

<a href="#">Implementable Technology Specifications</a> <a href="#">Work Group</a>	Maturity Level: 5	Ballot Status: Trial Use
--	-------------------	--------------------------

<http://www.hl7.org/fhir/xml.html>

<a href="#">Implementable Technology Specifications</a> <a href="#">Work Group</a>	Maturity Level: 5	Ballot Status: Trial Use
--	-------------------	--------------------------

<http://www.hl7.org/fhir/json.html>

<a href="#">FHIR Infrastructure</a> <a href="#">Work Group</a>	Maturity Level: 2	Ballot Status: Trial Use
--	-------------------	--------------------------

<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 FMG
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": "394314008",
      "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:394314008;
      fhir:Coding.system [ fhir:value "http://snomed.info/sct" ];
      fhir:Coding.code [ fhir:value "394314008" ];
      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
```

**Identify root documents**

**Preserve order in lists**

**RDF**  
14

# 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**

```
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" ]  
  ]  
];
```

**Concept URI**

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

**Reference URI**

**Reference Type**

```
<http://hl7.org/fhir/Patient/f201> a fhir:Patient .
```

**Ontology and  
import declaration**

```
# - 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> .
```

**RDF**

**<<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))
- WHO has a standard
  - <http://>

# Using FHIR RDF With a DL Reasoner

```

class MyPrivateClass {
private:
    int myPrivateVar = 12345;
    void myPrivateMethod() {
        // Private method implementation
    }
public:
    // Public methods and variables
    int myPublicVar = 67890;
    void myPublicMethod() {
        // Public method implementation
    }
};

// Usage of MyPrivateClass
int main() {
    MyPrivateClass obj;
    obj.myPublicMethod();
    // Accessing private member through public interface
    obj.myPublicMethod();
    return 0;
}

```

# FHIR DiagnosticReport Instance

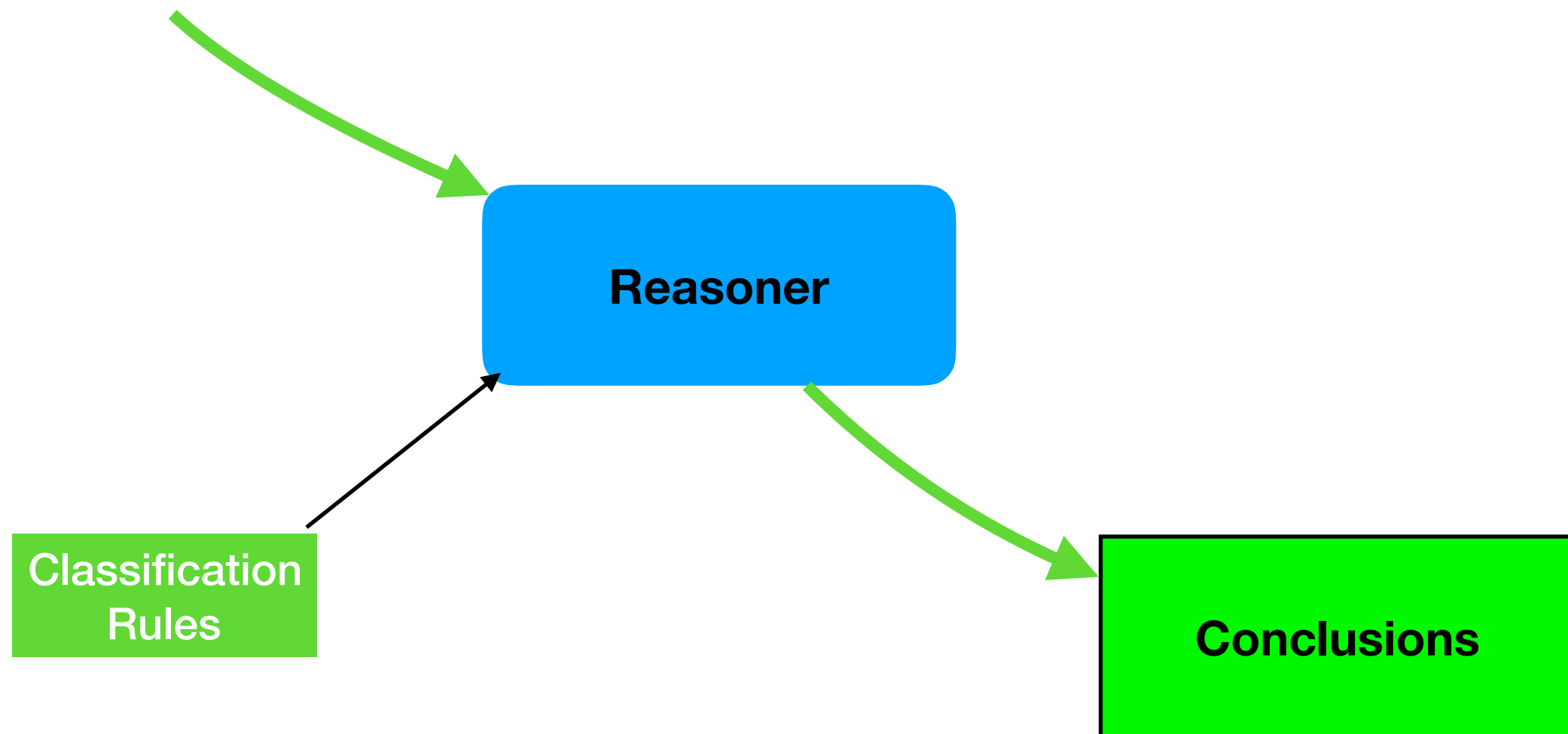
# Reasoner

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

**Instance is (or is not)  
an instance of Class  
'CancerDiagnosis'**

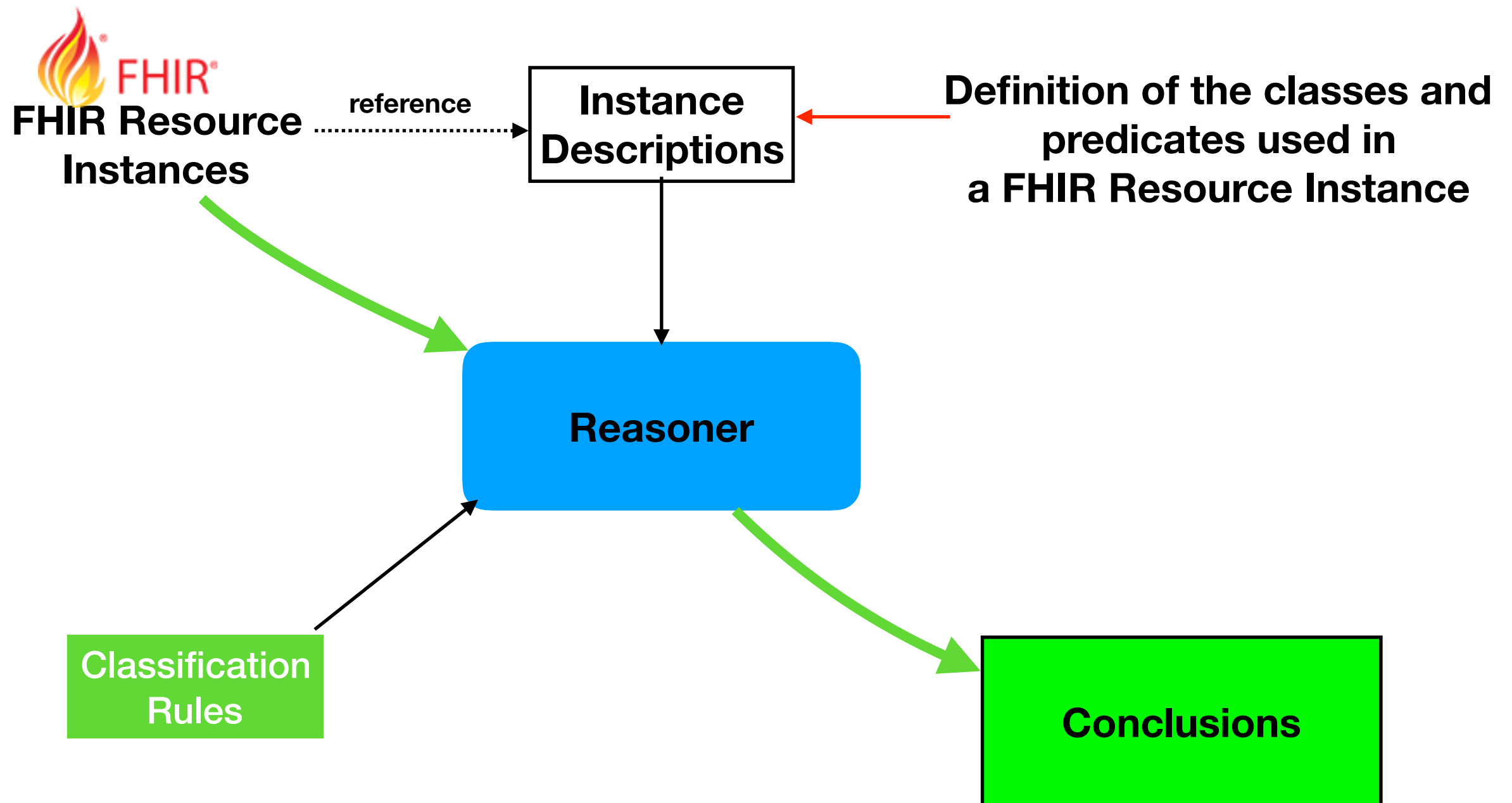
# Using FHIR RDF With a DL Reasoner

 **FHIR**  
FHIR Resource  
Instances





# 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 cran
    ]
  ]
```

```
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 inte
rpretations, and formatted representation of diagnostic reports." ;
  rdfs:label "DiagnosticReport" ;
  rdfs:subClassOf fhir:DomainResource, w5:clinical.diagnostics ;
```

<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" .
```

# FMV Definition of DiagnosticReport

cancerreport (http://example.org/swat4/cancerreport)

Active Ontology x Entities x Individuals by class x DL Query x

Class hierarchy: DiagnosticReport

Class hierarchy (inferred)

Class hierarchy: DiagnosticReport

owl:Thing

- administrative
- clinical
  - careprovision
  - diagnostics
    - BodyStructure
    - DiagnosticReport**
    - 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 (special concept)'
    - 'Substance (substance)'
  - treeRoot
  - workflow

Superclass hierarchy (inferred)

Superclass hierarchy (inferred): DiagnosticReport

DiagnosticReport — http://hl7.org/fhir/DiagnosticReport

Description: DiagnosticReport

Equivalent to

SubClass Of

- (DiagnosticReport.effectiveDateTime **only** dateTime) or (DiagnosticReport.effectivePeriod **only** Period)
- DiagnosticReport.basedOn **only** Reference
- DiagnosticReport.category **only** CodeableConcept
- DiagnosticReport.code **some** CodeableConcept
- DiagnosticReport.codedDiagnosis **only** CodeableConcept
- DiagnosticReport.conclusion **only** string
- DiagnosticReport.context **only** Reference
- DiagnosticReport.identifier **only** Identifier
- DiagnosticReport.image **only** DiagnosticReportImageComponent
- DiagnosticReport.imagingStudy **only** Reference
- DiagnosticReport.issued **only** instant
- DiagnosticReport.performer **only** Reference
- DiagnosticReport.presentedForm **only** Attachment
- DiagnosticReport.result **only** Reference
- DiagnosticReport.resultsInterpreter **only** Reference
- DiagnosticReport.specimen **only** Reference
- DiagnosticReport.status **some** code
- DiagnosticReport.subject **only** Reference
- diagnostics
- DomainResource

General class axioms

SubClass Of (Anonymous Ancestor)

- DomainResource.modifierExtension **only** Extension
- DomainResource.contained **only** Resource
- DomainResource.extension **only** Extension
- DomainResource.text **only** Narrative
- Resource.meta **only** Meta
- Resource.language **only** code
- Resource.implicitRules **only** uri
- nodeRole **only** treeRoot
- Resource.id **only** id

# The Ontology Header

```
# - 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**

The screenshot shows an OWL editor interface. At the top, a tab labeled 'Annotations: f201' is highlighted with a red box. Below it, a red arrow points from the ontology header in the text block to the 'Annotations: f201' tab. The main area of the editor displays a hierarchical tree structure of the ontology. The root node is 'DiagnosticReportCategory', which has a child 'CodeableConcept.coding'. This node has a 'Coding.code' property with a value of '394914008' and a 'Coding.display' property with a value of 'Radiology'. The 'Coding.system' property has a value of 'http://snomed.info/sct'. The 'index' property has a value of '0'. Below this, there is another 'CodeableConcept.coding' node with a 'Coding.code' property with a value of 'RAD' and a 'Coding.system' property with a value of 'http://hl7.org/fhir/20074'. The 'index' property has a value of '1'.

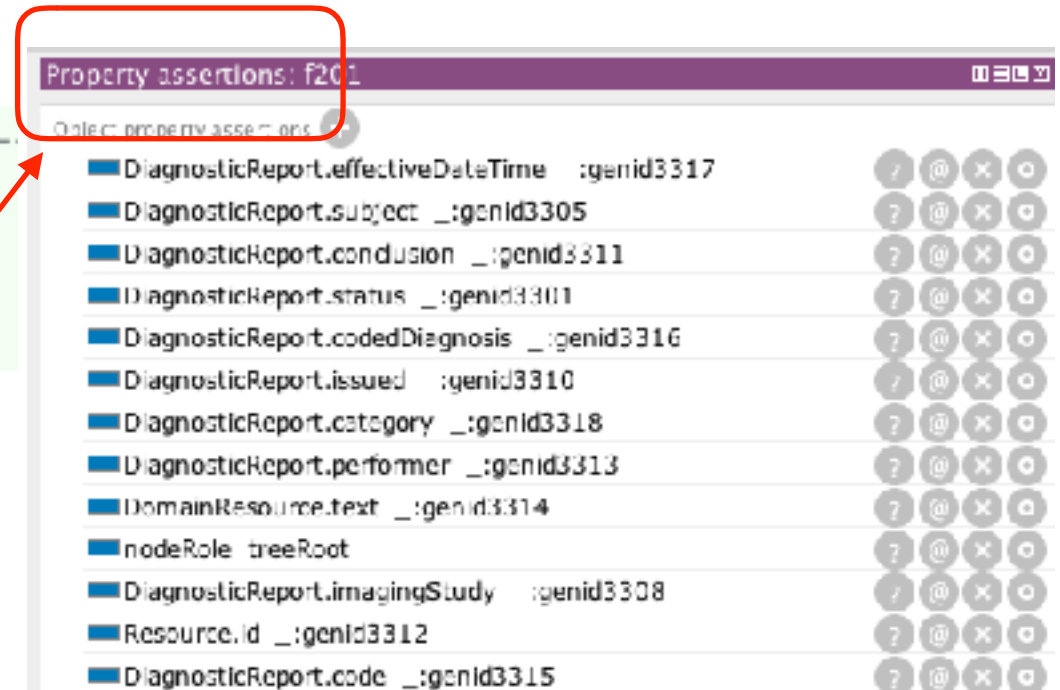


# Why the Ontology Header

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

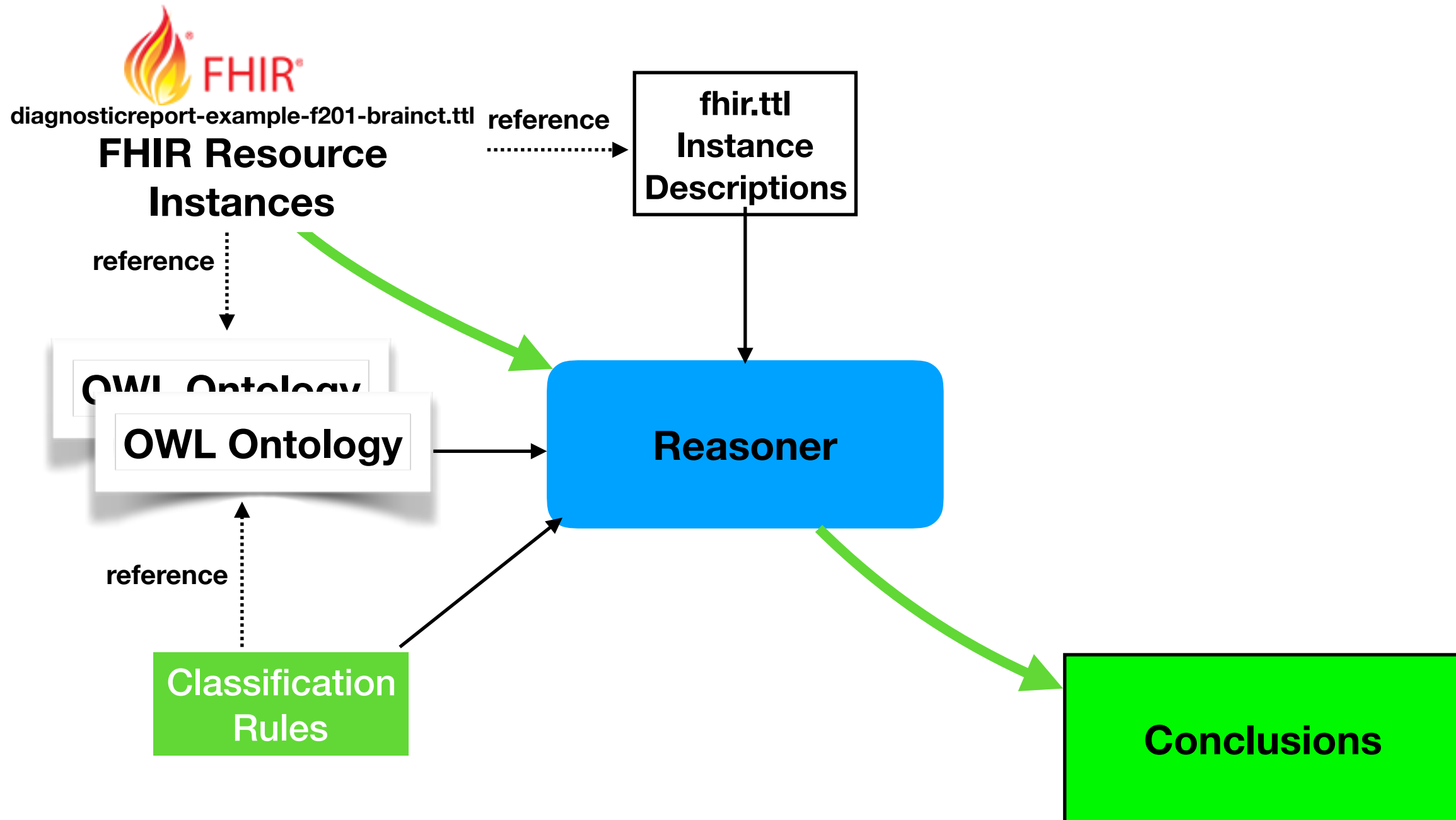
```
# - ontology header -----  
<http://hl7.org/fhir/DiagnosticReport/f201.ttl> a owl:Ontology;  
  owl:imports fhir:fhir.ttl.
```

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



Property assertions: f201	
Object	Property assertions
DiagnosticReport.effectiveDateTime	:genid3317
DiagnosticReport.subject	_:genid3305
DiagnosticReport.conclusion	_:genid3311
DiagnosticReport.status	_:genid3301
DiagnosticReport.codedDiagnosis	_:genid3316
DiagnosticReport.issued	_:genid3310
DiagnosticReport.category	_:genid3318
DiagnosticReport.performer	_:genid3313
DomainResource.text	_:genid3314
nodeRole	treeRoot
DiagnosticReport.imagingStudy	_:genid3308
Resource.id	_:genid3312
DiagnosticReport.code	_:genid3315

# Using FHIR RDF With a DL Reasoner



# FHIR Resource Instance

## Concept References

Class hierarchy (Inferred): "Malignant tumor of craniopharyngeal duct (disorder)"

Class hierarchy (Inferred): "Malignant tumor of craniopharyngeal duct (disorder)"

Equivalent To:

- Neoplasm of craniopharyngeal 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 craniopharyngeal duct (disorder)

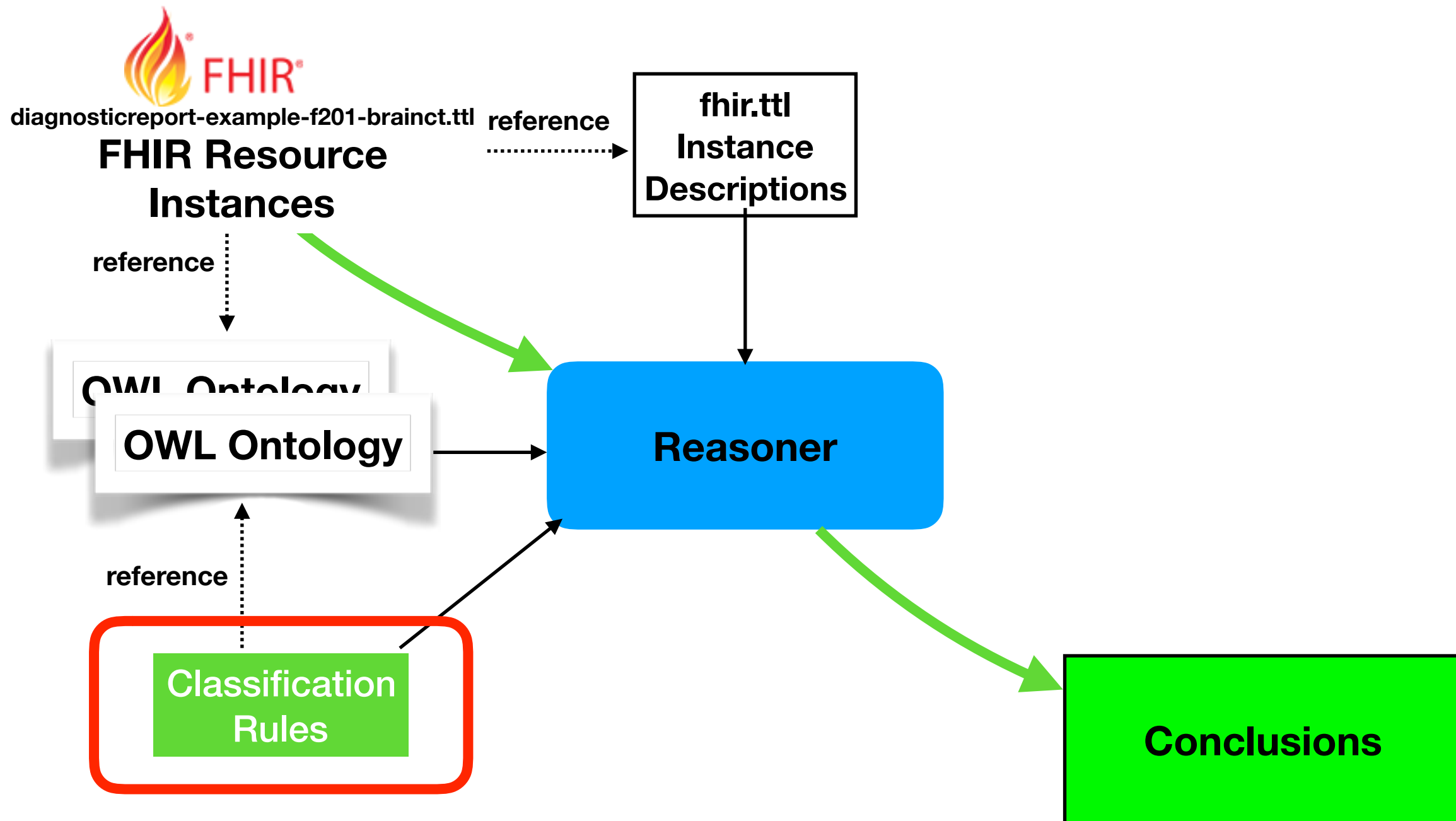
Generalization:

- 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 structure (body structure)))

http://snomed.info/id/188340000

```
<http://hl7.org/fhir/CodeableConcept>
  fhir:Diagnosis
    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" ]
    ]
  ]
```

# Using FHIR RDF With a DL Reasoner



# Sample Classification Rule

```
Ontology(<http://example.org/swat4ls/cancerreport>  
Import(<http://snomed.info/sct/9000000000000207008>)  
Import(<http://hl7.org/fhir/fhir.ttl>  
Import(<http://hl7.org/fhir/DiagnosticReport/f201.ttl>)
```

SNOMED CT
FHIR.TTL
Sample Data

```
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))  
)
```



**OWL Functional Syntax**



# Classification Rules

## Concept Reference

Declaration(Class(:ReportWithCancerDiagnosis))

EquivalentClasses(:ReportWithCancerDiagnosis

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

)

900000000000207008x (http://snomed.info/sct/900000000000207008x)

Active Ontology x Entities x Individuals by class x DL Query x

Class hierarchy Class hierarchy (inferred)

Class hierarchy: 'Malignant neoplastic disease (disorder)'

Class hierarchy (inferred):

- 'Disease (disorder)'
- 'Acute disease (disorder)'
- 'Chronic disease (disorder)'
- 'Complication (disorder)'
- 'Degenerative disorder (disorder)'
- 'Disorder by body site (disorder)'
- 'Disorder of fetus or newborn (disorder)'
- 'Foreign body (disorder)'
- 'Inflammatory disorder (disorder)'
- 'Neoplasm and/or hamartoma (disorder)'
- 'Neoplastic disease (disorder)'
- 'Malignant neoplastic disease (disorder)'
- 'Malignant neoplasm of endocrine gland (disorder)'
- 'Malignant neoplasm of nervous system (disorder)'
- 'Malignant tumor of head and/or neck (disorder)'
- 'Primary malignant neoplasm (disorder)'
- 'Secondary malignant neoplastic disease (disorder)'
- 'Neoplasm by body site (disorder)'
- 'Tumor of unknown origin or ill-defined site (disorder)'
- 'Sequela (disorder)'
- 'Traumatic AND/OR non-traumatic injury (disorder)'

Superclass hierarchy (inferred) Superclass hierarchy

Superclass hierarchy: 'Malignant neoplastic disease (disorder)'

Superclass hierarchy (inferred):

- 'Malignant neoplastic disease (disorder)'
- 'Neoplastic disease (disorder)'
- 'Neoplasm and/or hamartoma (disorder)'
- 'Disease (disorder)'

Asserted

http://snomed.info/id/363346000

'Neoplastic disease (disorder)' and ('Role group (attribute)' some ('Associated morphology (attribute)' some 'Malignant neoplasm of primary, secondary, or uncertain origin (morphologic abnormality)'))

SubClass Of +

General class axioms +

SubClass Of (Anonymous Ancestor)

- '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 +

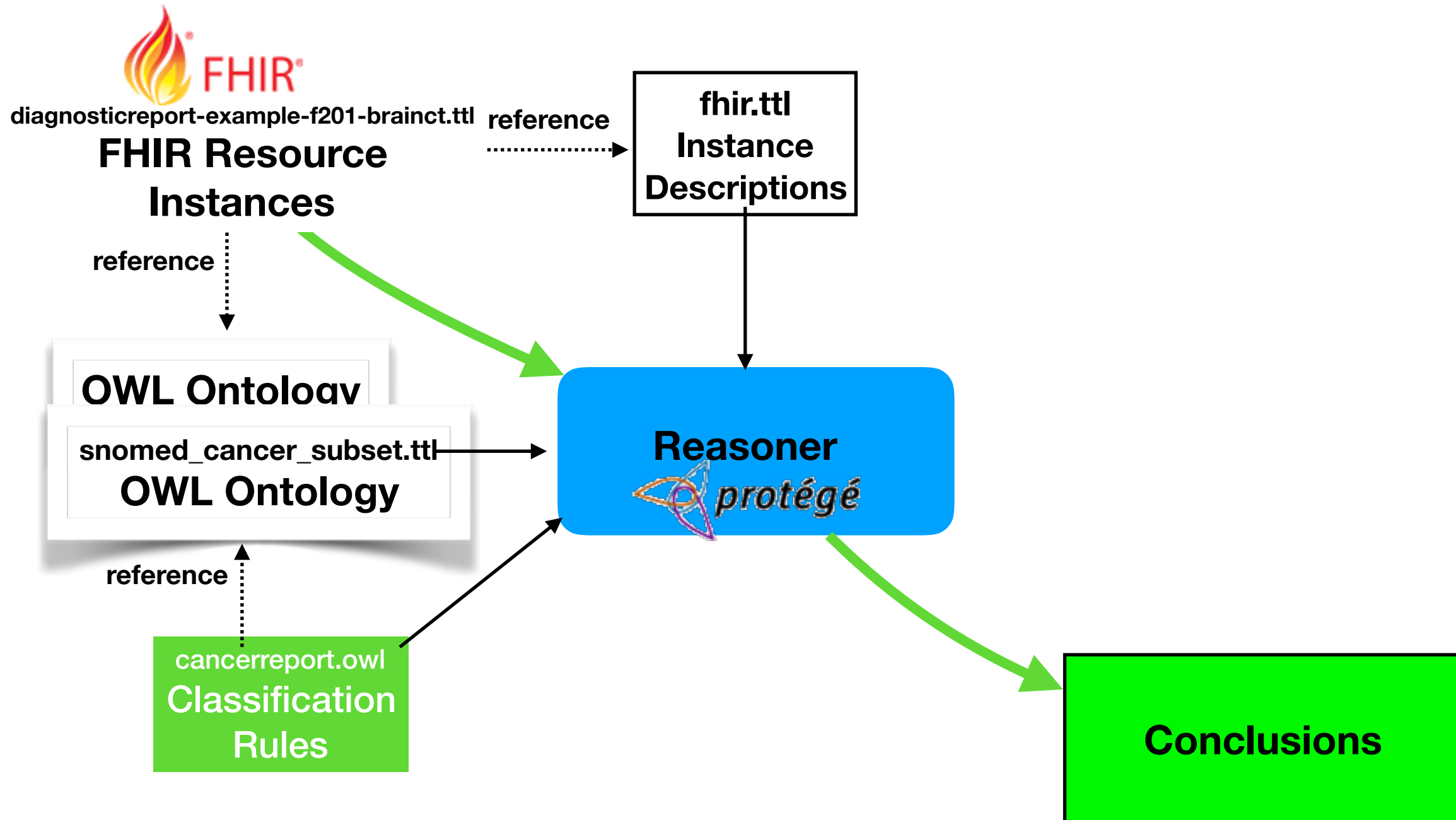
Usage: Malignant neoplastic disease (disorder)

Show: ☒ this ☒ disjoint ☒ named sub/superclasses

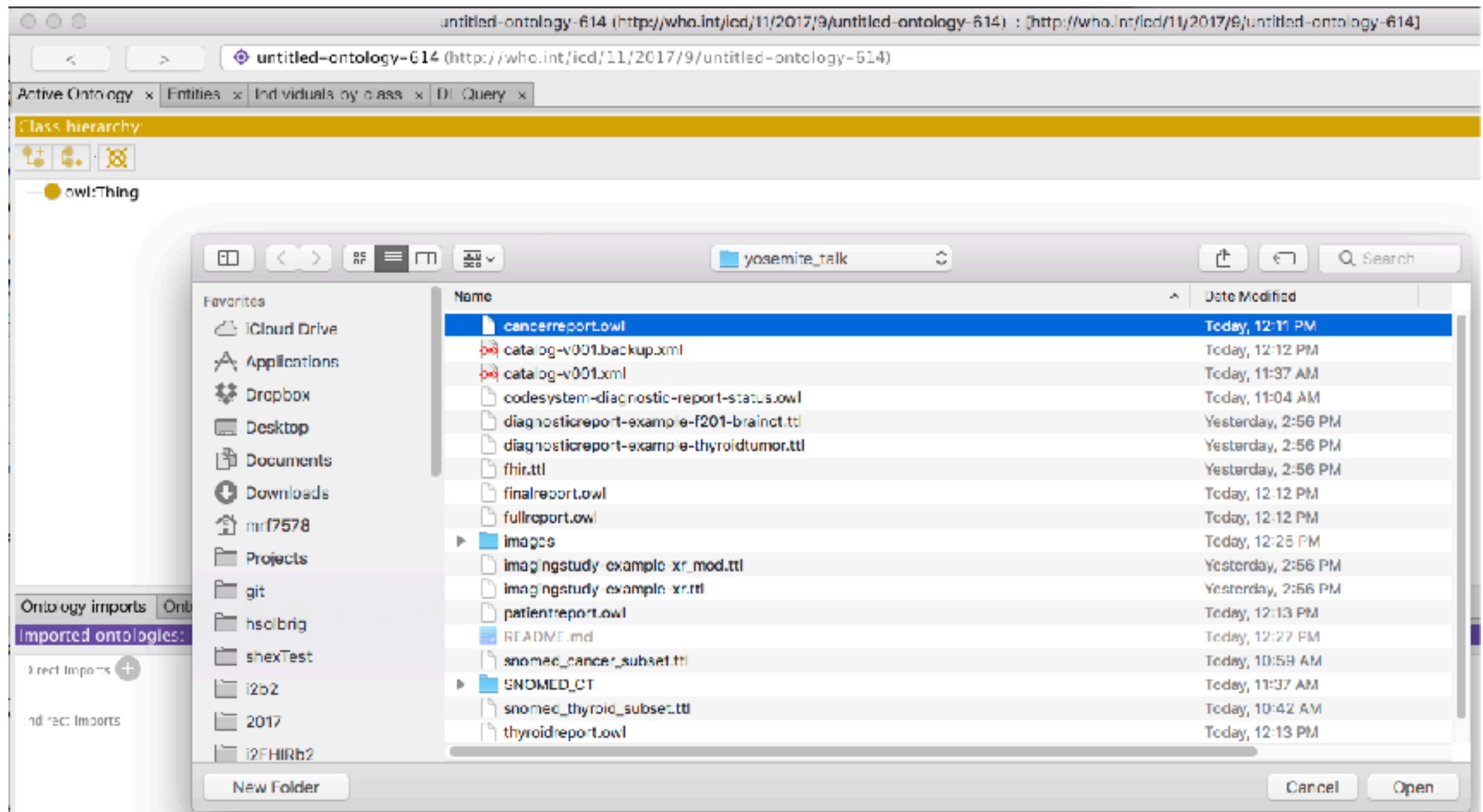
Found 15 uses of 'Malignant neoplastic disease (disorder)'

- 'Malignant neoplasm of endocrine gland (disorder)'
- 'Malignant neoplasm of endocrine gland (disorder)' EquivalentTo 'Malignant neoplastic disease (disorder)' (( 'Associated morphology (attribute)' some 'Malignant neoplasm of primary, secondary, or uncertain origin (morphologic abnormality)'))
- 'Malignant neoplasm of nervous system (disorder)'

# Using FHIR RDF With a DL Reasoner




# Load the Classification Rules

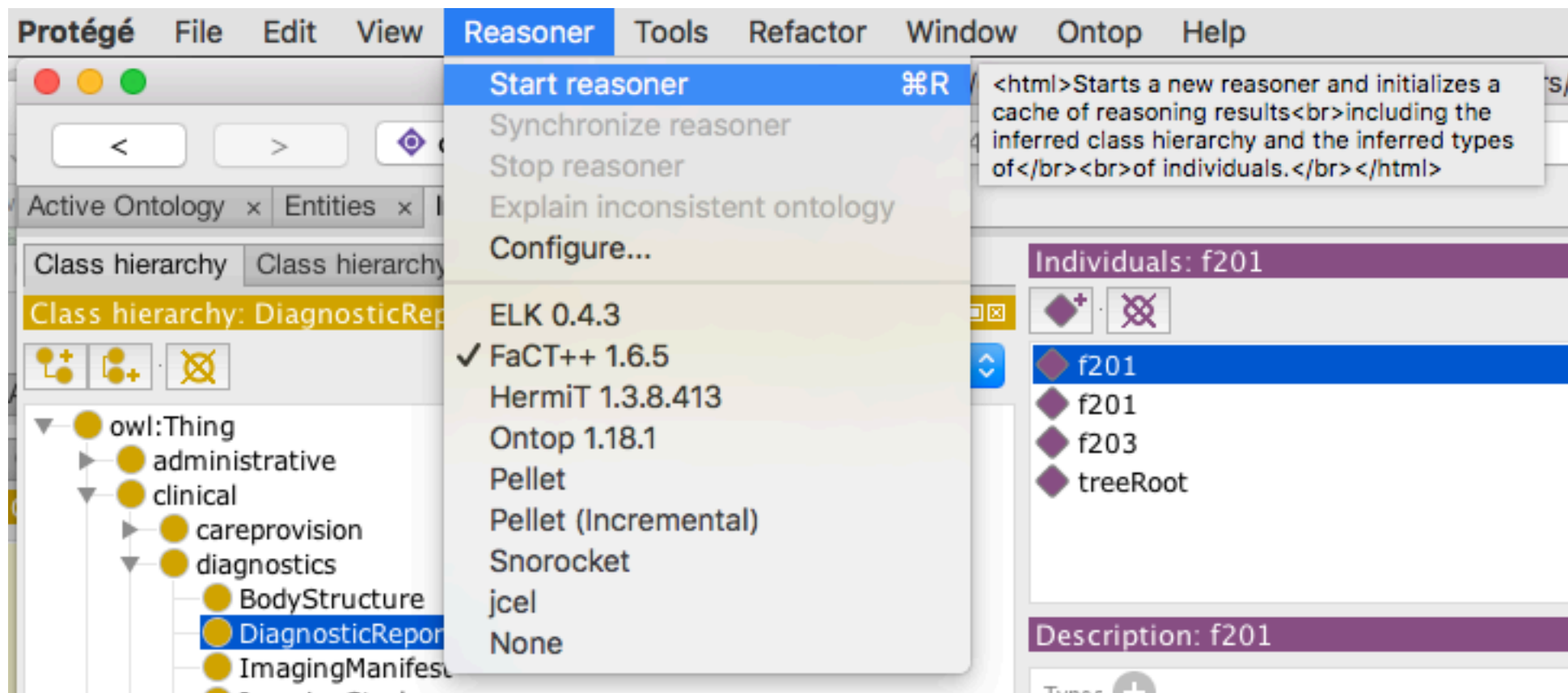


[https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite\\_talk/cancerreport.owl](https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/cancerreport.owl)

# Verify the Imports

Ontology imports	Ontology Prefixes	General class axioms
Imported ontologies:		
Direct Imports 		
<hr/>		
<p>&lt;<a href="http://hl7.org/fhir/DiagnosticReport/f201.ttl">http://hl7.org/fhir/DiagnosticReport/f201.ttl</a>&gt; f201.ttl Ontology IRI: &lt;<a href="http://hl7.org/fhir/DiagnosticReport/f201.ttl">http://hl7.org/fhir/DiagnosticReport/f201.ttl</a>&gt; Location: <a href="#">/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/diagnosticreport-example-f201-brainct.ttl</a></p>		
<hr/>		
<p>&lt;<a href="http://snomed.info/sct/900000000000207008cancer_subset">http://snomed.info/sct/900000000000207008cancer_subset</a>&gt; 900000000000207008cancer_subset Ontology IRI: &lt;<a href="http://snomed.info/sct/900000000000207008cancer_subset">http://snomed.info/sct/900000000000207008cancer_subset</a>&gt; Location: <a href="#">/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/snomed_cancer_subset.ttl</a></p>		
<hr/>		
<p>&lt;<a href="http://hl7.org/fhir/fhir.ttl">http://hl7.org/fhir/fhir.ttl</a>&gt; fhir.ttl Ontology IRI: &lt;<a href="http://hl7.org/fhir/fhir.ttl">http://hl7.org/fhir/fhir.ttl</a>&gt; Location: <a href="#">/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/fhir.ttl</a></p>		
<hr/>		
Indirect Imports		
<p>&lt;<a href="http://hl7.org/fhir/fhir.ttl">http://hl7.org/fhir/fhir.ttl</a>&gt; fhir.ttl Ontology IRI: &lt;<a href="http://hl7.org/fhir/fhir.ttl">http://hl7.org/fhir/fhir.ttl</a>&gt; Location: <a href="#">/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/fhir.ttl</a></p>		
<hr/>		
<p>&lt;<a href="http://hl7.org/fhir/w5#">http://hl7.org/fhir/w5#</a>&gt; w5 Ontology IRI: &lt;<a href="http://hl7.org/fhir/w5#">http://hl7.org/fhir/w5#</a>&gt; Location: <a href="#">/Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/w5.ttl</a></p>		
<hr/>		

# Run the Reasoner





# Result

The screenshot displays a web-based ontology viewer interface. The browser address bar shows the URL: `http://example.org/swat4ls/cancerreport/`. The interface is divided into several panels:

- Class hierarchy:** A tree view on the left showing the hierarchy of classes. The 'diagnostics' class is expanded, and 'DiagnosticReport' is selected. Below it, 'ReportWithCancerDiagnosis' is highlighted with a red circle.
- Individuals:** A panel on the right showing the individuals of the selected class. The individuals listed are 'f201', 'f202', 'f203', and 'treeRoot'.
- Property assertions:** A panel on the right showing the property assertions for the selected individual. The assertions are listed as follows:
  - DiagnosticReport.status \_:genid13306
  - DiagnosticReport.conclusion \_:genid13332
  - 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 \_:genid13326
  - nodeRole treeRoot

# Restrict to Patients

				LOINC Diagnostic Report Codes (Preferred)
subject	Σ	0..1	Reference(Patient   Group   Device   Location)	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  
  
Declaration(Class(:PatientReport))  
EquivalentClasses(:PatientReport  
  ObjectSomeValuesFrom(fhir:DiagnosticReport.subject.link fhir:Patient))  
)
```

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

# Finalized Reports Only

status	?! Σ 1..1	code	registered   partial   preliminary   final + DiagnosticReportStatus (Required)
--------	-----------	------	---

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 not 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"))))
```

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

# 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

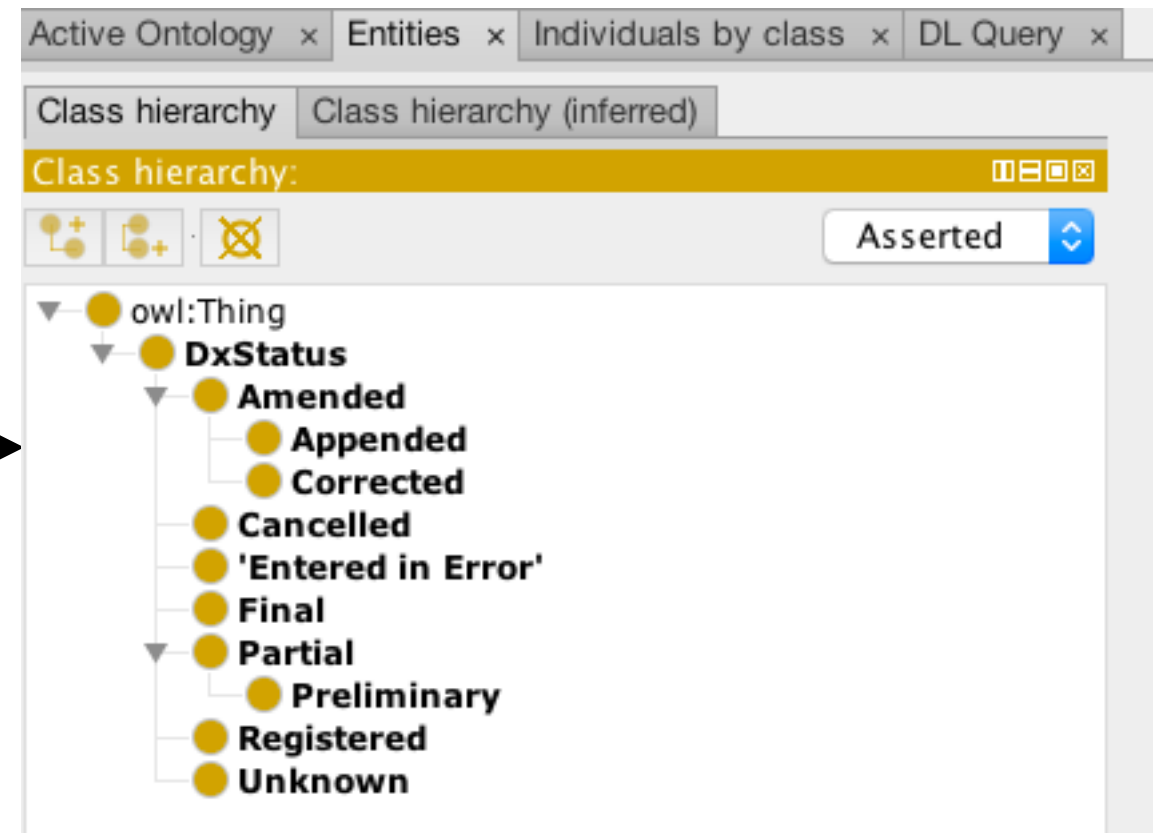
# Finalized Reports Proposed Solution

```
@prefix fhir: <http://hl7.org/fhir/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix diagnostic-report-status: <http://hl7.org/fhir/diagnostic-report-
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix 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 ...



# 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

```
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 displays a web browser window with the URL `http://example.org/swat4ls/finalpatientcancerreport`. The browser's address bar shows the page title `finalpatientcancerreport`. Below the address bar, there are tabs for `Active Ontology`, `Entities`, `Individuals by class`, and `DL Query`. The `Active Ontology` tab is selected, and the `Class hierarchy` sub-tab is active. The class hierarchy is displayed on the left side of the browser window, showing a tree structure of classes. The class `FinalPatientReportWithCancerDiagnosis` is highlighted in blue. The right side of the browser window shows the definition of the selected class. The title bar of the definition panel reads `FinalPatientReportWithCancerDiagnosis — http://example.org/swat4ls/finalpatientcancerreport`. Below the title bar, the description of the class is shown: `Description: FinalPatientReportWithCancerDiagnosis`. The definition panel includes several sections: 

- Equivalent To**: A list of classes that are equivalent to the selected class, including `ReportWithCancerDiagnosis`, `FinalReport`, and `PatientReport`.
- SubClass Of**: A list of classes that the selected class is a subclass of, including `DiagnosticReport`, `subject.link`, `some Patient`, `DiagnosticReport.codedDiagnosis.coding`, `some 'Malignant neoplastic disease (disorder)'`, and `DiagnosticReport.status`, `some FinalStatus`.
- General class axioms**: A list of axioms that define the class, including `DiagnosticReport.subject.link some Patient`, `DiagnosticReport.codedDiagnosis.coding some 'Malignant neoplastic disease (disorder)'`, and `DiagnosticReport.status some FinalStatus`.
- Instances**: A list of instances of the class, currently empty.

# Result

The screenshot shows a web browser window with the address bar displaying 'finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport)'. The browser has tabs for 'Active Ontology', 'Entities', 'Individuals by class', and 'DL Query'. The 'Active Ontology' tab is selected, showing a class hierarchy on the left and details for 'FinalPatientReportWithCancerDiagnosis' on the right.

**Class hierarchy (inferred):** FinalPatientReportWithCancerDiagnosis

- owl:Thing
  - administrative
  - clinical
  - conformance
  - DxStatus
  - Element
  - FinalStatus
  - financial
  - infrastructure
  - Narrative.div
  - PatientReport
    - FinalPatientReportWithCancerDiagnosis**
  - Primitive
  - ReportWithCancerDiagnosis
    - FinalPatientReportWithCancerDiagnosis**
  - Resource
  - 'SNOMED CT Concept (SNOMED RT+CTV3)'
  - treeRoot
  - workflow
  - xhtml

**FinalPatientReportWithCancerDiagnosis** — http://example.org/swat4ls/finalpatientcancerreport

**Description:** FinalPatientReportWithCancerDiagnosis

**Equivalent To** +

- ReportWithCancerDiagnosis and FinalReport and PatientReport**

**SubClass Of** +

- FinalReport
- PatientReport
- ReportWithCancerDiagnosis

**General class axioms** +

**SubClass Of (Anonymous Ancestor)**

- DiagnosticReport.subject.link **some** Patient
- DiagnosticReport.codedDiagnosis.coding **some** 'Malignant neoplastic disease (disorder)'
- DiagnosticReport.status **some** FinalStatus

**Instances** +

- f201**

# Post-Coordinated Expressions

```
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



One possible format for compositional expression



[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

The screenshot displays a software interface for managing diagnostic reports. The left sidebar is divided into two sections: 'Individuals: dxreport117' and 'Description: dxreport117'.

**Individuals: dxreport117**

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

**Description: dxreport117**

Types

- DiagnosticReport
- ReportOfThyroidDisease** (highlighted with a red box)

Same Individual As +

Different Individuals +

**Property assertions: dxreport117**

Object property assertions +

Property	Value	Actions
DiagnosticReport.conclusion	_:genid23666	? @ X O
DiagnosticReport.performer	_:genid23668	? @ X O
DiagnosticReport.status	_:genid23646	? @ X O
DiagnosticReport.code	_:genid23669	? @ X O
DiagnosticReport.effectiveDateTime	_:genid23671	? @ X O
Resource.id	_:genid23667	? @ X O
nodeRole	treeRoot	? @ X O
DiagnosticReport.codedDiagnosis	_:genid23662	? @ X O
DiagnosticReport.category	_:genid23653	? @ X O
DiagnosticReport.imagingStudy	_:genid23663	? @ X O
DiagnosticReport.issued	_:genid23665	? @ X O
DiagnosticReport.subject	_:genid23670	? @ X O
DomainResource.text	_:genid23655	? @ X O
nodeRole	treeRoot	? @

# 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/dicm" ];
    fhir:Coding.code [ fhir:value "DX" ];
  ];
  fhir:ImagingStudy.series.numberOfInstances [ fhir:value "2"^^xsd:nonNegativeInteger ];
  fhir:ImagingStudy.series.availability [ fhir:value "ONLINE" ];
  fhir:ImagingStudy.series.endpoint [
    fhir:index 0;
    fhir:link <http://hl7.org/fhir/Endpoint/example-wadors>;
    fhir:Reference.reference [ fhir:value "Endpoint/example-wadors" ];
  ];
  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?**

# 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" ]
];
```

# 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**

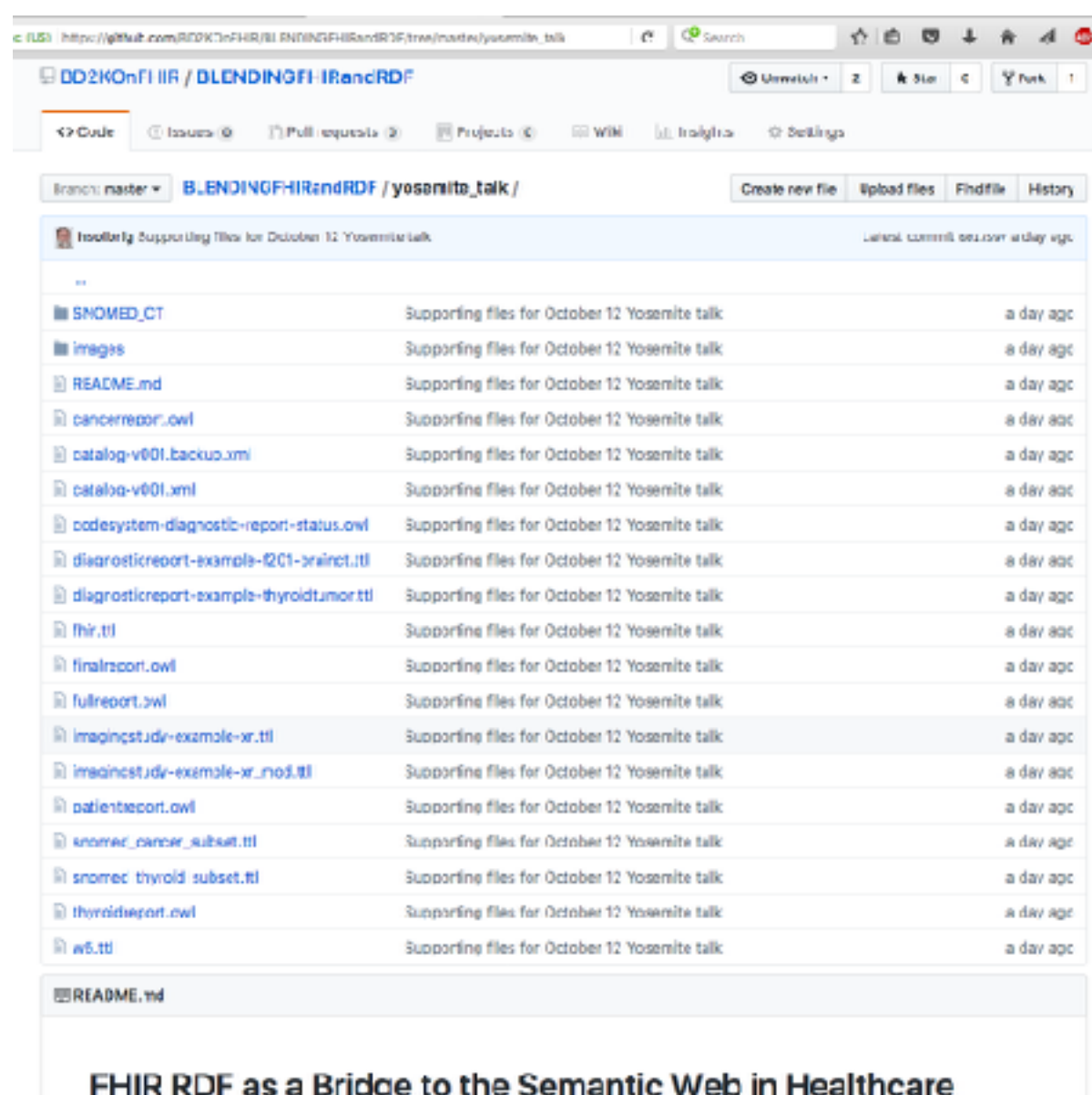
**Dr. Guoqian Jiang**

**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)



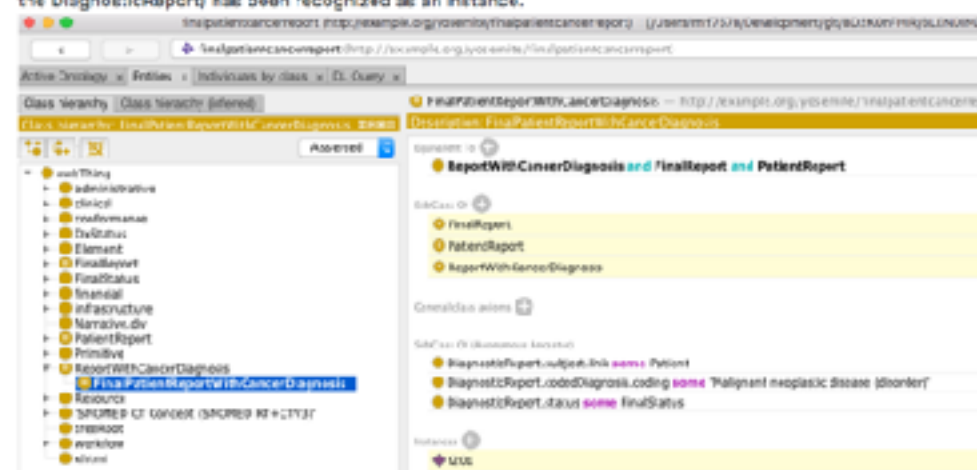
The screenshot shows the GitHub repository page for `BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk`. The repository is under the `master` branch. The file list includes:

File Name	Description	Time
SNOMED_CT	Supporting files for October 12 Yosemite talk	a day ago
images	Supporting files for October 12 Yosemite talk	a day ago
README.md	Supporting files for October 12 Yosemite talk	a day ago
cancerreport.owl	Supporting files for October 12 Yosemite talk	a day ago
catalog-v001.backup.xml	Supporting files for October 12 Yosemite talk	a day ago
catalog-v001.xml	Supporting files for October 12 Yosemite talk	a day ago
codesystem-diagnostic-report-status.owl	Supporting files for October 12 Yosemite talk	a day ago
diagnosticreport-example-1201-brainct.ttl	Supporting files for October 12 Yosemite talk	a day ago
diagnosticreport-example-thyroid.tumor.ttl	Supporting files for October 12 Yosemite talk	a day ago
fhir.ttl	Supporting files for October 12 Yosemite talk	a day ago
finalreport.owl	Supporting files for October 12 Yosemite talk	a day ago
fullreport.owl	Supporting files for October 12 Yosemite talk	a day ago
imagingstudy-example-xr.ttl	Supporting files for October 12 Yosemite talk	a day ago
imagingstudy-example-xr_nod.ttl	Supporting files for October 12 Yosemite talk	a day ago
patientreport.owl	Supporting files for October 12 Yosemite talk	a day ago
snomed_cancer_subset.ttl	Supporting files for October 12 Yosemite talk	a day ago
snomed_thyroid_subset.ttl	Supporting files for October 12 Yosemite talk	a day ago
thyroidreport.owl	Supporting files for October 12 Yosemite talk	a day ago
ws.ttl	Supporting files for October 12 Yosemite talk	a day ago

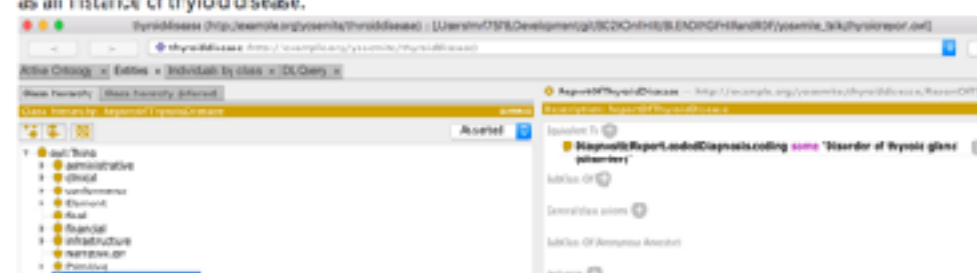
The `README.md` file is also visible at the bottom of the list.

## Use

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 *#221* (the id of the *DiagnosticReport*) has been recognized as an instance.



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 *diagnosticreport117* has been classified as an instance of *thyroid disease*.



# Questions