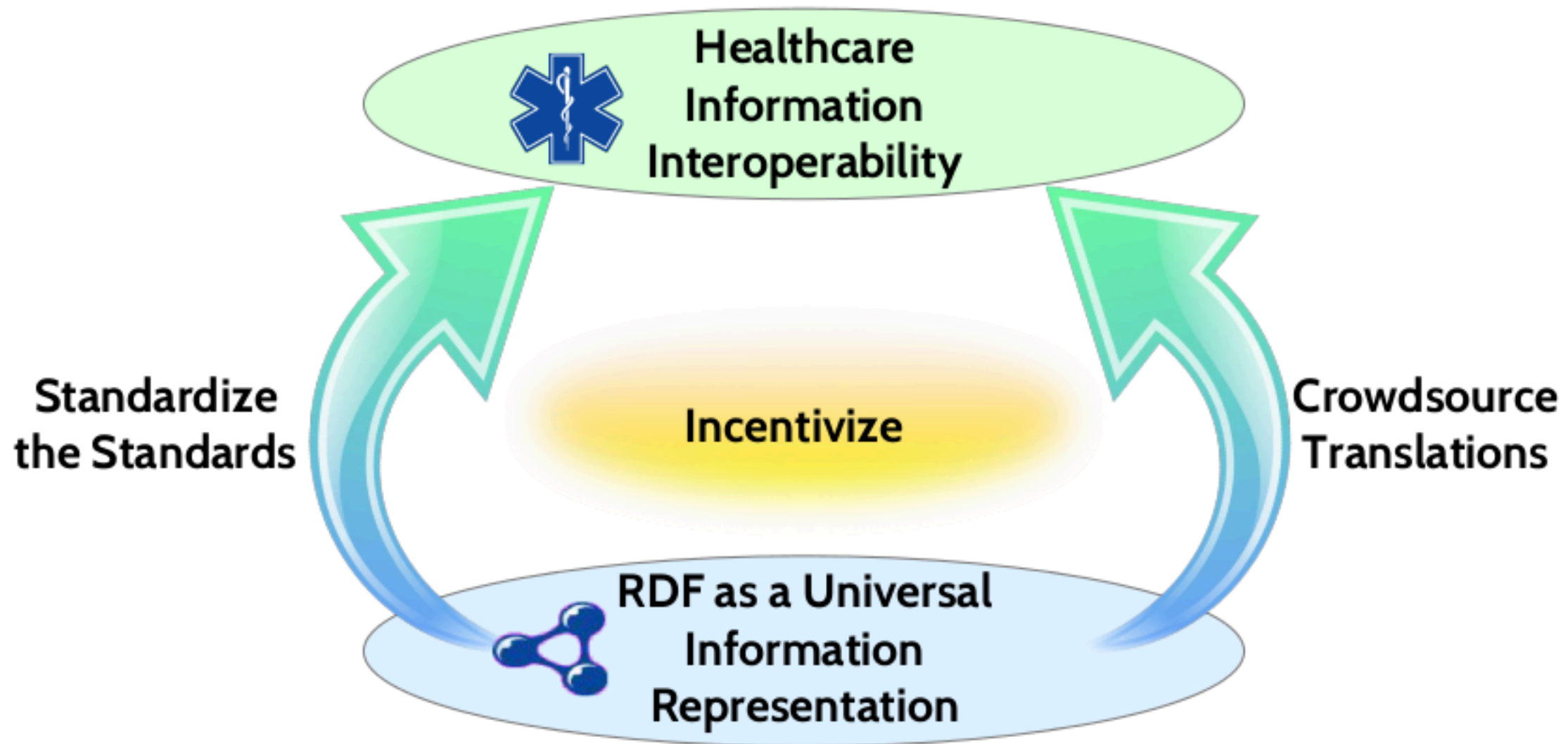


FHIR RDF as a Bridge to the Semantic Web in Healthcare

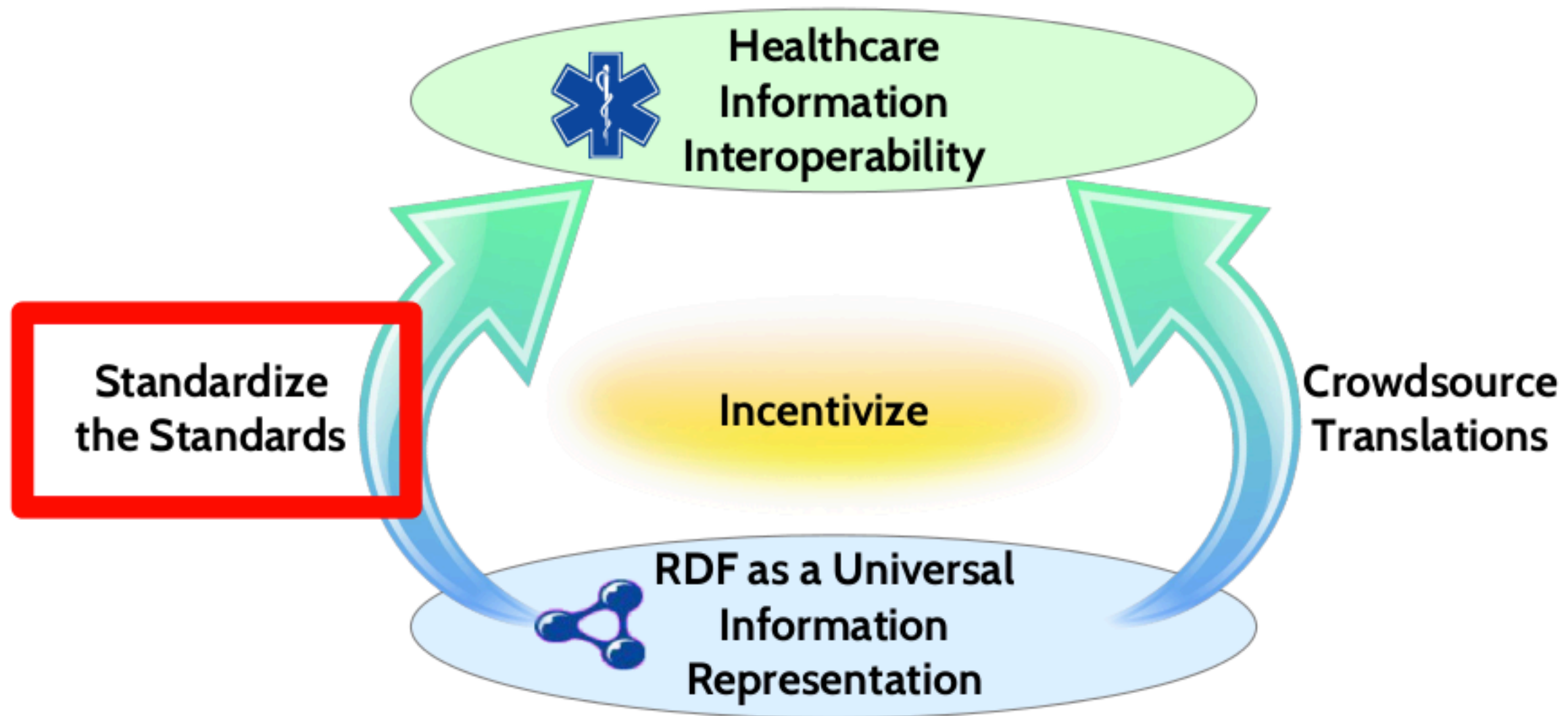
Harold Solbrig
Mayo Clinic

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/. 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 main content area is divided into four levels of the specification:

- 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:** Downloads, Common Use Cases, Testing
 - Security & Privacy:** Security, Consent, Provenance, AuditEvent
 - Conformance:** StructureDefinition, CapabilityStatement, ImplementationGuide, Profiling
 - Terminology:** CodeSystem, ValueSet, ConceptMap, Terminology Svc
 - Linked Data:** 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:** Allergy, Problem, CarePlan, DetectedIssue
 - Diagnostics:** Observation, Report, Specimen
 - Medications:** Order, Dispense, Administration
 - Workflow:** Task, Appointment, Schedule, Referral

The "Observation, Report, Specimen" link under the Diagnostics category is circled in red. A small number "5" is visible next to the Medications category.

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
codedDiagnosis		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 reference 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 Device 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
		0..1	string	Clinical Interpretation of test results
		0..*	CodeableConcept	Codes for the conclusion
		0..*	Attachment	ENCODING CT Clinical Findings (Example)
		0..*	Attachment	Entire report as issued

Documentation for this format

Alternate definitions: Nestor 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>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="Acet"/>
  </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
effectiveTime		0..1	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 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)'}</p><p><b>subject</b>: <a>Roel</a></p><p><b>effectiveTime</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

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
--	-------------------	--------------------------

<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
4

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 AS2Server {
private:
    static AS2Server * instance;
    static AS2Server * getInstance() {
        if (instance == 0) {
            instance = new AS2Server();
        }
        return instance;
    }
    AS2Server() {
        // Initialize the server
    }
    ~AS2Server() {
        // Clean up the server
    }
    void start() {
        // Start the server
    }
    void stop() {
        // Stop the server
    }
    void send(const AS2Message & message) {
        // Send the message
    }
    void receive(const AS2Message & message) {
        // Receive the message
    }
    void connect(const AS2Address & address) {
        // Connect to the address
    }
    void disconnect() {
        // Disconnect
    }
    void listen() {
        // Listen for connections
    }
    void accept() {
        // Accept a connection
    }
    void read() {
        // Read data from the connection
    }
    void write() {
        // Write data to the connection
    }
    void close() {
        // Close the connection
    }
    void setOption(const AS2Option & option) {
        // Set the option
    }
    void getOption(const AS2Option & option) const {
        // Get the option
    }
    void setCertificate(const AS2Certificate & certificate) {
        // Set the certificate
    }
    void getCertificate() const {
        // Get the certificate
    }
    void setPrivateKey(const AS2PrivateKey & privateKey) {
        // Set the private key
    }
    void getPrivateKey() const {
        // Get the private key
    }
    void setPublicKey(const AS2PublicKey & publicKey) {
        // Set the public key
    }
    void getPublicKey() const {
        // Get the public key
    }
    void setSignature(const AS2Signature & signature) {
        // Set the signature
    }
    void getSignature() const {
        // Get the signature
    }
    void setTimestamp(const AS2Timestamp & timestamp) {
        // Set the timestamp
    }
    void getTimestamp() const {
        // Get the timestamp
    }
    void setVersion(const AS2Version & version) {
        // Set the version
    }
    void getVersion() const {
        // Get the version
    }
    void setContentType(const AS2ContentType & contentType) {
        // Set the content type
    }
    void getContentType() const {
        // Get the content type
    }
    void setContent(const AS2Content & content) {
        // Set the content
    }
    void getContent() const {
        // Get the content
    }
    void setHeader(const AS2Header & header) {
        // Set the header
    }
    void getHeader() const {
        // Get the header
    }
    void setFooter(const AS2Footer & footer) {
        // Set the footer
    }
    void getFooter() const {
        // Get the footer
    }
    void setBody(const AS2Body & body) {
        // Set the body
    }
    void getBody() const {
        // Get the body
    }
    void setEnvelope(const AS2Envelope & envelope) {
        // Set the envelope
    }
    void getEnvelope() const {
        // Get the envelope
    }
    void setDocument(const AS2Document & document) {
        // Set the document
    }
    void getDocument() const {
        // Get the document
    }
    void setAttachment(const AS2Attachment & attachment) {
        // Set the attachment
    }
    void getAttachment() const {
        // Get the attachment
    }
    void setRecipient(const AS2Recipient & recipient) {
        // Set the recipient
    }
    void getRecipient() const {
        // Get the recipient
    }
    void setSender(const AS2Sender & sender) {
        // Set the sender
    }
    void getSender() const {
        // Get the sender
    }
    void setTo(const AS2To & to) {
        // Set the to
    }
    void getTo() const {
        // Get the to
    }
    void setFrom(const AS2From & from) {
        // Set the from
    }
    void getFrom() const {
        // Get the from
    }
    void setCc(const AS2Cc & cc) {
        // Set the cc
    }
    void getCc() const {
        // Get the cc
    }
    void setBcc(const AS2Bcc & bcc) {
        // Set the bcc
    }
    void getBcc() const {
        // Get the bcc
    }
    void setSubject(const AS2Subject & subject) {
        // Set the subject
    }
    void getSubject() const {
        // Get the subject
    }
    void setBodyID(const AS2BodyID & bodyID) {
        // Set the body ID
    }
    void getBodyID() const {
        // Get the body ID
    }
    void setDocumentID(const AS2DocumentID & documentID) {
        // Set the document ID
    }
    void getDocumentID() const {
        // Get the document ID
    }
    void setAttachmentID(const AS2AttachmentID & attachmentID) {
        // Set the attachment ID
    }
    void getAttachmentID() const {
        // Get the attachment ID
    }
    void setRecipientID(const AS2RecipientID & recipientID) {
        // Set the recipient ID
    }
    void getRecipientID() const {
        // Get the recipient ID
    }
    void setSenderID(const AS2SenderID & senderID) {
        // Set the sender ID
    }
    void getSenderID() const {
        // Get the sender ID
    }
    void setToID(const AS2ToID & toID) {
        // Set the to ID
    }
    void getToID() const {
        // Get the to ID
    }
    void setFromID(const AS2FromID & fromID) {
        // Set the from ID
    }
    void getFromID() const {
        // Get the from ID
    }
    void setCcID(const AS2CcID & ccID) {
        // Set the cc ID
    }
    void getCcID() const {
        // Get the cc ID
    }
    void setBccID(const AS2BccID & bccID) {
        // Set the bcc ID
    }
    void getBccID() const {
        // Get the bcc ID
    }
    void setSubjectID(const AS2SubjectID & subjectID) {
        // Set the subject ID
    }
    void getSubjectID() const {
        // Get the subject ID
    }
    void setBodyIDID(const AS2BodyIDID & bodyIDID) {
        // Set the body ID ID
    }
    void getBodyIDID() const {
        // Get the body ID ID
    }
    void setDocumentIDID(const AS2DocumentIDID & documentIDID) {
        // Set the document ID ID
    }
    void getDocumentIDID() const {
        // Get the document ID ID
    }
    void setAttachmentIDID(const AS2AttachmentIDID & attachmentIDID) {
        // Set the attachment ID ID
    }
    void getAttachmentIDID() const {
        // Get the attachment ID ID
    }
    void setRecipientIDID(const AS2RecipientIDID & recipientIDID) {
        // Set the recipient ID ID
    }
    void getRecipientIDID() const {
        // Get the recipient ID ID
    }
    void setSenderIDID(const AS2SenderIDID & senderIDID) {
        // Set the sender ID ID
    }
    void getSenderIDID() const {
        // Get the sender ID ID
    }
    void setToIDID(const AS2ToIDID & toIDID) {
        // Set the to ID ID
    }
    void getToIDID() const {
        // Get the to ID ID
    }
    void setFromIDID(const AS2FromIDID & fromIDID) {
        // Set the from ID ID
    }
    void getFromIDID() const {
        // Get the from ID ID
    }
    void setCcIDID(const AS2CcIDID & ccIDID) {
        // Set the cc ID ID
    }
    void getCcIDID() const {
        // Get the cc ID ID
    }
    void setBccIDID(const AS2BccIDID & bccIDID) {
        // Set the bcc ID ID
    }
    void getBccIDID() const {
        // Get the bcc ID ID
    }
    void setSubjectIDID(const AS2SubjectIDID & subjectIDID) {
        // Set the subject ID ID
    }
    void getSubjectIDID() const {
        // Get the subject ID ID
    }
    void setBodyIDIDID(const AS2BodyIDIDID & bodyIDIDID) {
        // Set the body ID ID ID
    }
    void getBodyIDIDID() const {
        // Get the body ID ID ID
    }
    void setDocumentIDIDID(const AS2DocumentIDIDID & documentIDIDID) {
        // Set the document ID ID ID
    }
    void getDocumentIDIDID() const {
        // Get the document ID ID ID
    }
    void setAttachmentIDIDID(const AS2AttachmentIDIDID & attachmentIDIDID) {
        // Set the attachment ID ID ID
    }
    void getAttachmentIDIDID() const {
        // Get the attachment ID ID ID
    }
    void setRecipientIDIDID(const AS2RecipientIDIDID & recipientIDIDID) {
        // Set the recipient ID ID ID
    }
    void getRecipientIDIDID() const {
        // Get the recipient ID ID ID
    }
    void setSenderIDIDID(const AS2SenderIDIDID & senderIDIDID) {
        // Set the sender ID ID ID
    }
    void getSenderIDIDID() const {
        // Get the sender ID ID ID
    }
    void setToIDIDID(const AS2ToIDIDID & toIDIDID) {
        // Set the to ID ID ID
    }
    void getToIDIDID() const {
        // Get the to ID ID ID
    }
    void setFromIDIDID(const AS2FromIDIDID & fromIDIDID) {
        // Set the from ID ID ID
    }
    void getFromIDIDID() const {
        // Get the from ID ID ID
    }
    void setCcIDIDID(const AS2CcIDIDID & ccIDIDID) {
        // Set the cc ID ID ID
    }
    void getCcIDIDID() const {
        // Get the cc ID ID ID
    }
    void setBccIDIDID(const AS2BccIDIDID & bccIDIDID) {
        // Set the bcc ID ID ID
    }
    void getBccIDIDID() const {
        // Get the bcc ID ID ID
    }
    void setSubjectIDIDID(const AS2SubjectIDIDID & subjectIDIDID) {
        // Set the subject ID ID ID
    }
    void getSubjectIDIDID() const {
        // Get the subject ID ID ID
    }
    void setBodyIDIDIDID(const AS2BodyIDIDIDID & bodyIDIDIDID) {
        // Set the body ID ID ID ID
    }
    void getBodyIDIDIDID() const {
        // Get the body ID ID ID ID
    }
    void setDocumentIDIDIDID(const AS2DocumentIDIDIDID & documentIDIDIDID) {
        // Set the document ID ID ID ID
    }
    void getDocumentIDIDIDID() const {
        // Get the document ID ID ID ID
    }
    void setAttachmentIDIDIDID(const AS2AttachmentIDIDIDID & attachmentIDIDIDID) {
        // Set the attachment ID ID ID ID
    }
    void getAttachmentIDIDIDID() const {
        // Get the attachment ID ID ID ID
    }
    void setRecipientIDIDIDID(const AS2RecipientIDIDIDID & recipientIDIDIDID) {
        // Set the recipient ID ID ID ID
    }
    void getRecipientIDIDIDID() const {
        // Get the recipient ID ID ID ID
    }
    void setSenderIDIDIDID(const AS2SenderIDIDIDID & senderIDIDIDID) {
        // Set the sender ID ID ID ID
    }
    void getSenderIDIDIDID() const {
        // Get the sender ID ID ID ID
    }
    void setToIDIDIDID(const AS2ToIDIDIDID & toIDIDIDID) {
        // Set the to ID ID ID ID
    }
    void getToIDIDIDID() const {
        // Get the to ID ID ID ID
    }
    void setFromIDIDIDID(const AS2FromIDIDIDID & fromIDIDIDID) {
        // Set the from ID ID ID ID
    }
    void getFromIDIDIDID() const {
        // Get the from ID ID ID ID
    }
    void setCcIDIDIDID(const AS2CcIDIDIDID & ccIDIDIDID) {
        // Set the cc ID ID ID ID
    }
    void getCcIDIDIDID() const {
        // Get the cc ID ID ID ID
    }
    void setBccIDIDIDID(const AS2BccIDIDIDID & bccIDIDIDID) {
        // Set the bcc ID ID ID ID
    }
    void getBccIDIDIDID() const {
        // Get the bcc ID ID ID ID
    }
    void setSubjectIDIDIDID(const AS2SubjectIDIDIDID & subjectIDIDIDID) {
        // Set the subject ID ID ID ID
    }
    void getSubjectIDIDIDID() const {
        // Get the subject ID ID ID ID
    }
    void setBodyIDIDIDIDID(const AS2BodyIDIDIDIDID & bodyIDIDIDIDID) {
        // Set the body ID ID ID ID ID
    }
    void getBodyIDIDIDIDID() const {
        // Get the body ID ID ID ID ID
    }
    void setDocumentIDIDIDIDID(const AS2DocumentIDIDIDIDID & documentIDIDIDIDID) {
        // Set the document ID ID ID ID ID
    }
    void getDocumentIDIDIDIDID() const {
        // Get the document ID ID ID ID ID
    }
    void setAttachmentIDIDIDIDID(const AS2AttachmentIDIDIDIDID & attachmentIDIDIDIDID) {
        // Set the attachment ID ID ID ID ID
    }
    void getAttachmentIDIDIDIDID() const {
        // Get the attachment ID ID ID ID ID
    }
    void setRecipientIDIDIDIDID(const AS2RecipientIDIDIDIDID & recipientIDIDIDIDID) {
        // Set the recipient ID ID ID ID ID
    }
    void getRecipientIDIDIDIDID() const {
        // Get the recipient ID ID ID ID ID
    }
    void setSenderIDIDIDIDID(const AS2SenderIDIDIDIDID & senderIDIDIDIDID) {
        // Set the sender ID ID ID ID ID
    }
    void getSenderIDIDIDIDID() const {
        // Get the sender ID ID ID ID ID
    }
    void setToIDIDIDIDID(const AS2ToIDIDIDIDID & toIDIDIDIDID) {
        // Set the to ID ID ID ID ID
    }
    void getToIDIDIDIDID() const {
        // Get the to ID ID ID ID ID
    }
    void setFromIDIDIDIDID(const AS2FromIDIDIDIDID & fromIDIDIDIDID) {
        // Set the from ID ID ID ID ID
    }
    void getFromIDIDIDIDID() const {
        // Get the from ID ID ID ID ID
    }
    void setCcIDIDIDIDID(const AS2CcIDIDIDIDID & ccIDIDIDIDID) {
        // Set the cc ID ID ID ID ID
    }
    void getCcIDIDIDIDID() const {
        // Get the cc ID ID ID ID ID
    }
    void setBccIDIDIDIDID(const AS2BccIDIDIDIDID & bccIDIDIDIDID) {
        // Set the bcc ID ID ID ID ID
    }
    void getBccIDIDIDIDID() const {
        // Get the bcc ID ID ID ID ID
    }
    void setSubjectIDIDIDIDID(const AS2SubjectIDIDIDIDID & subjectIDIDIDIDID) {
        // Set the subject ID ID ID ID ID
    }
    void getSubjectIDIDIDIDID() const {
        // Get the subject ID ID ID ID ID
    }
    void setBodyIDIDIDIDIDID(const AS2BodyIDIDIDIDIDID & bodyIDIDIDIDIDID) {
        // Set the body ID ID ID ID ID ID
    }
    void getBodyIDIDIDIDIDID() const {
       
```

FHIR DiagnosticReport Instance

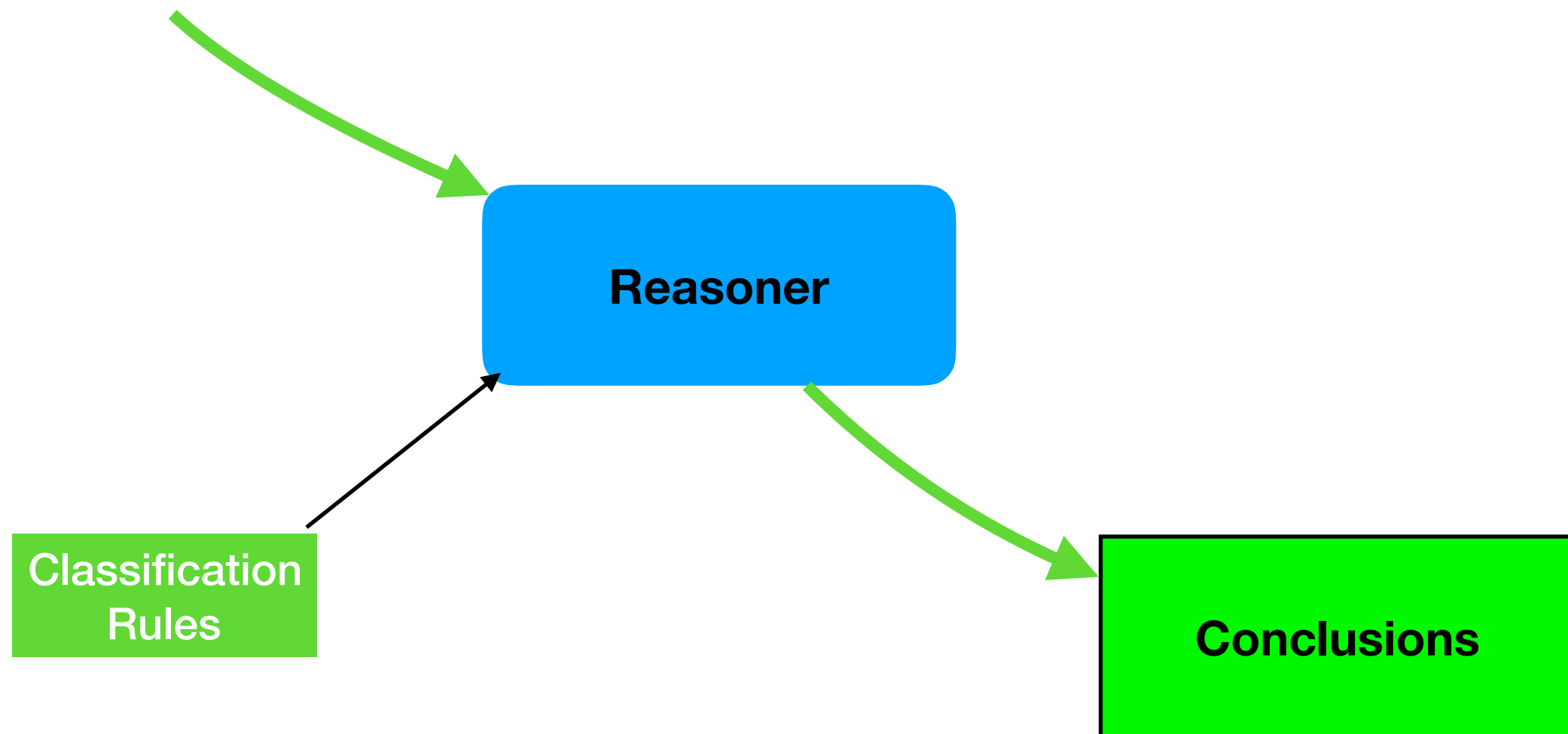
Reasoner

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

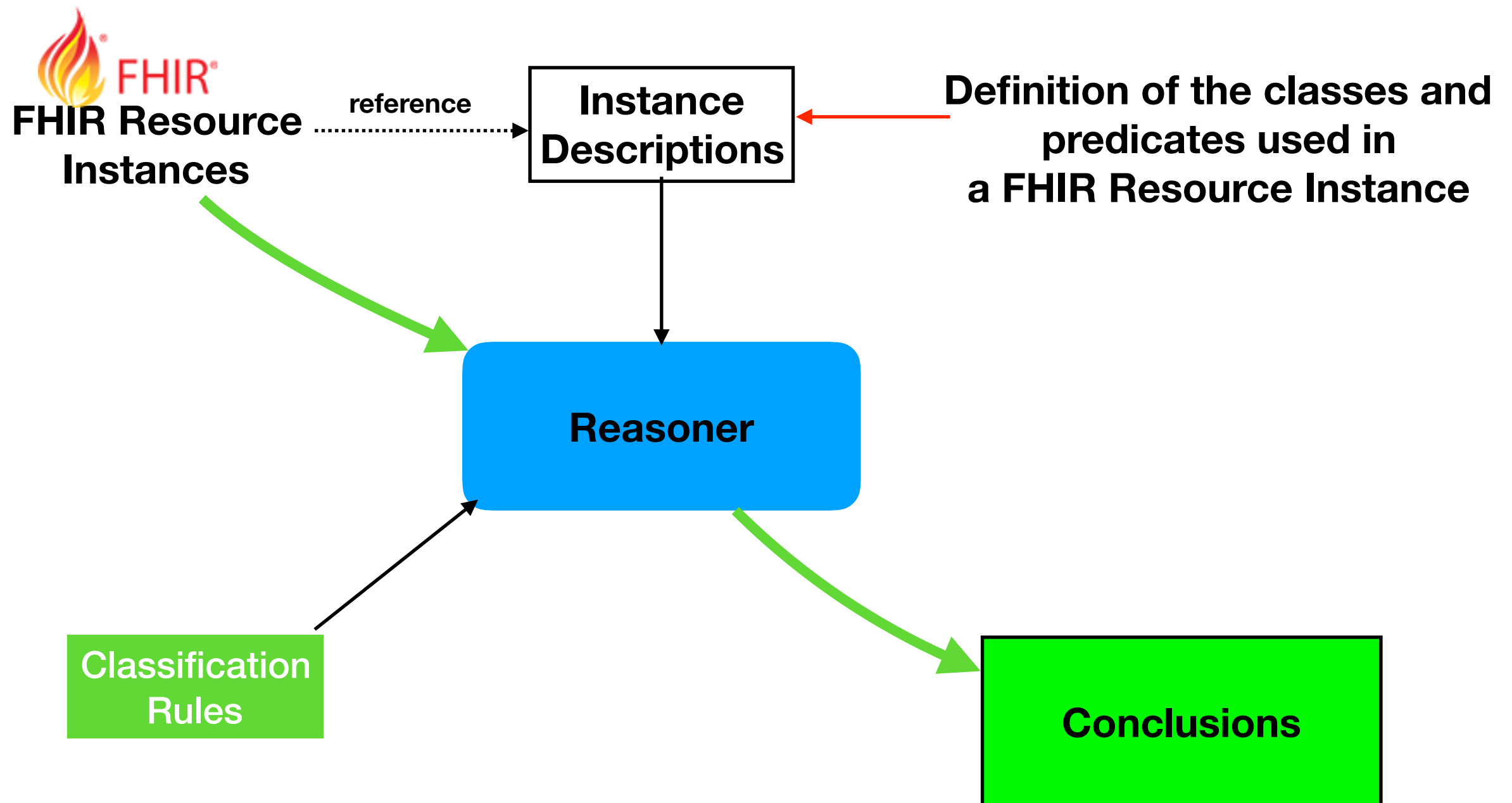
Instance is (or is not) an instance of Class 'CancerDiagnosis'

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 / biological 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 **same** 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**

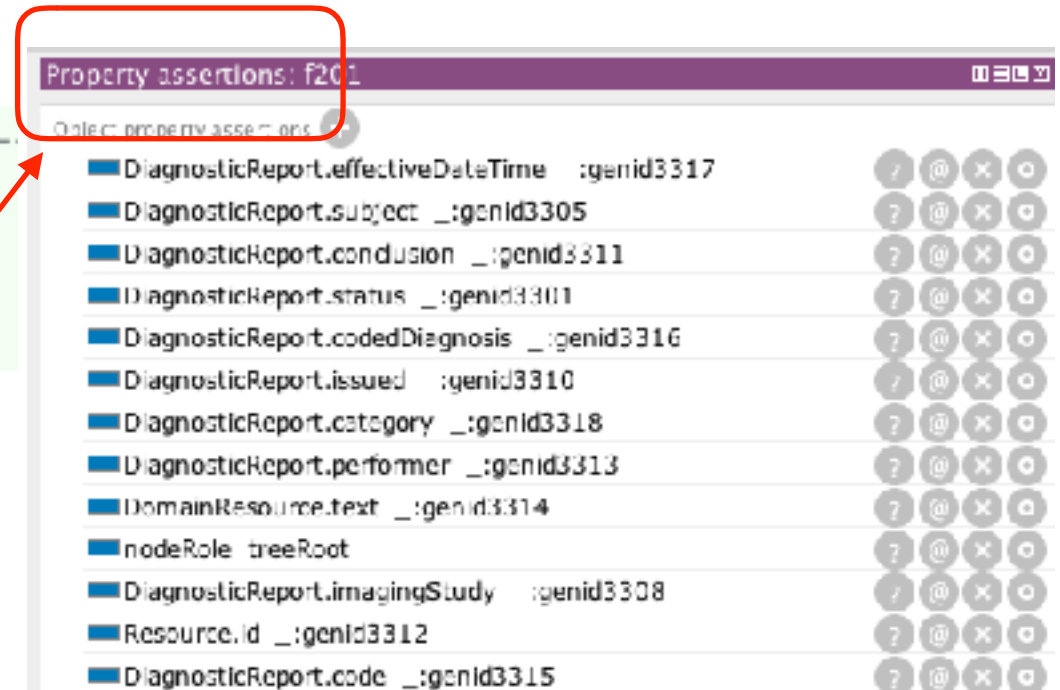
The screenshot shows an OWL editor interface. At the top, a purple header bar displays 'Annotations: f201'. Below it, a list of annotations is shown. The first annotation is 'DiagnosticReportCategory', which is expanded to show its properties: 'CodeableConcept.coding' (with a value of '394914008' and a coding system of 'http://snomed.info/sct') and 'Coding.display' (with a value of 'Radiology'). The second annotation is 'CodeableConcept.coding', which is also expanded to show its properties: 'Coding.code' (with a value of 'RAD') and 'Coding.system' (with a value of 'http://hl7.org/fhir/20074').

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 [
```

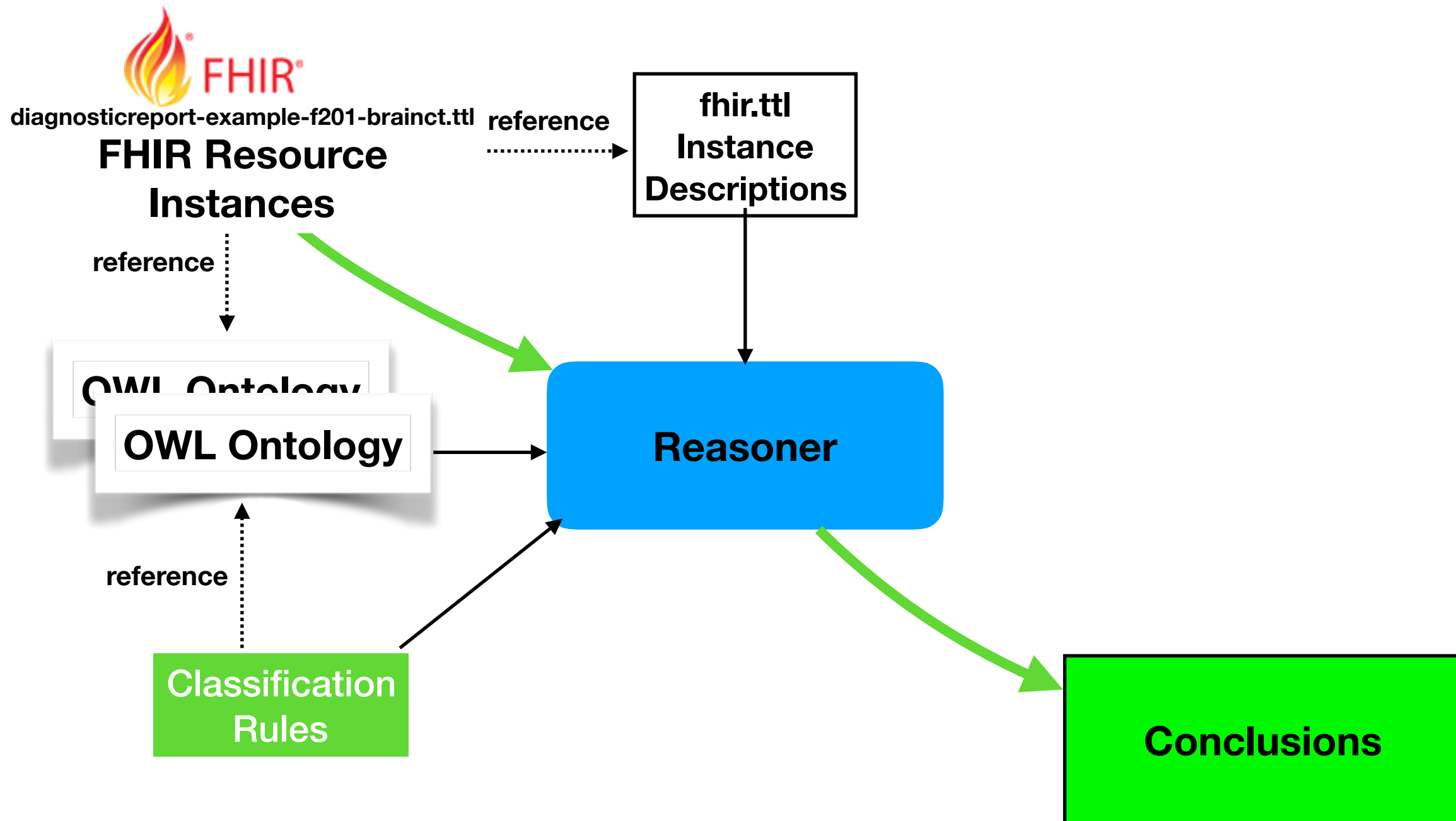
```
# - ontology header -----  
<http://hl7.org/fhir/DiagnosticReport/f201.ttl> a owl:Ontology;  
  owl:imports fhir:fhir.ttl.
```

**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)

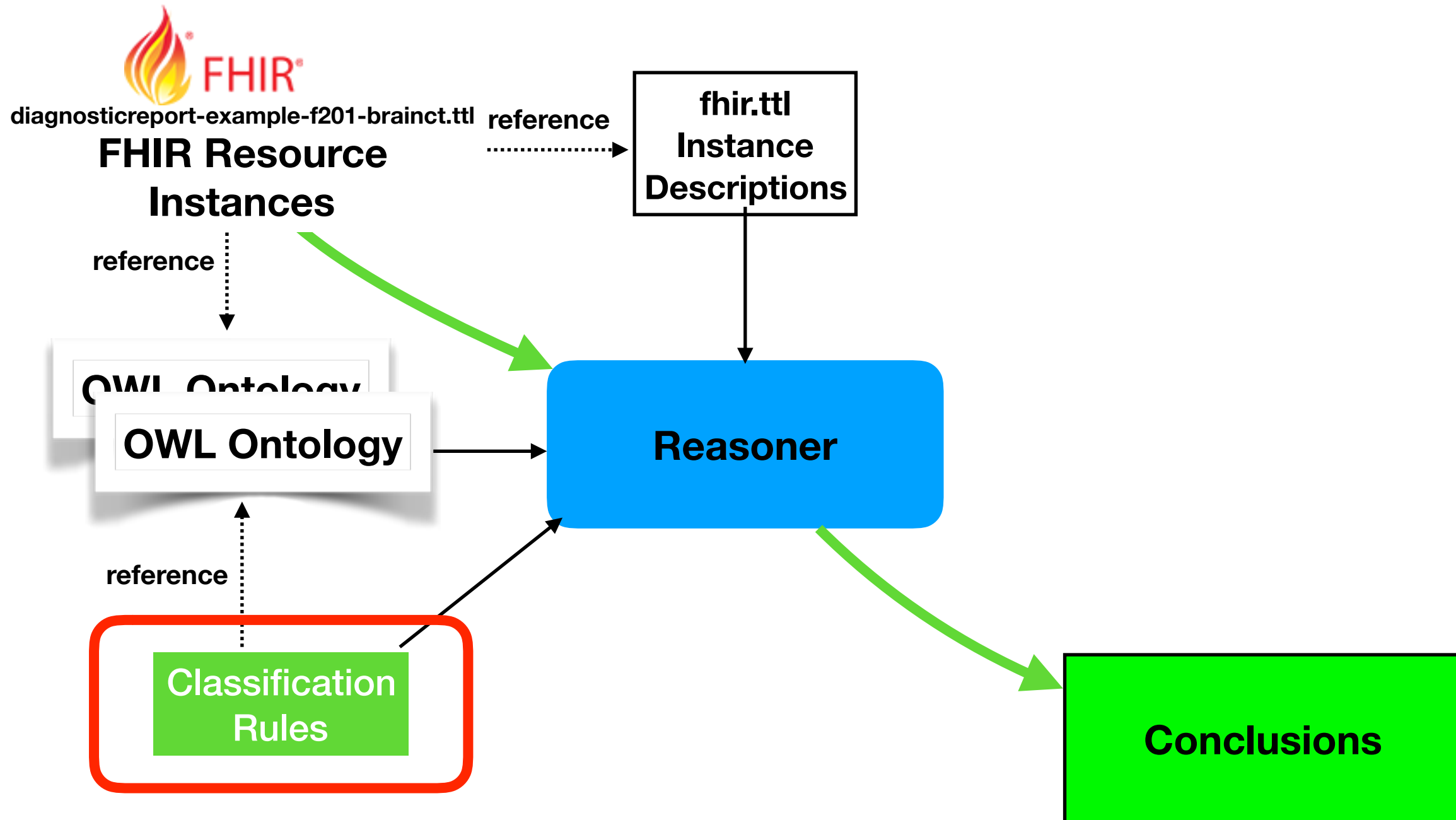
Generalization:

- 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))

)

The screenshot displays the SNOMED CT web interface for the concept 'Malignant neoplastic disease (disorder)' (ID: 363346000). The URL <http://snomed.info/id/363346000> is highlighted in a box. The interface shows a class hierarchy on the left, a central panel with the selected class and its sub-classes, and a right panel with usage information and a list of found uses.

Class hierarchy: 'Malignant neoplastic disease (disorder)'

- '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)'

SubClass Of:

- 'Disease (disorder)' and ('Role group (attribute)' some ('Associated morphology (attribute)' some 'Neoplasm and/or hamartoma (morphologic abnormality)'))

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:

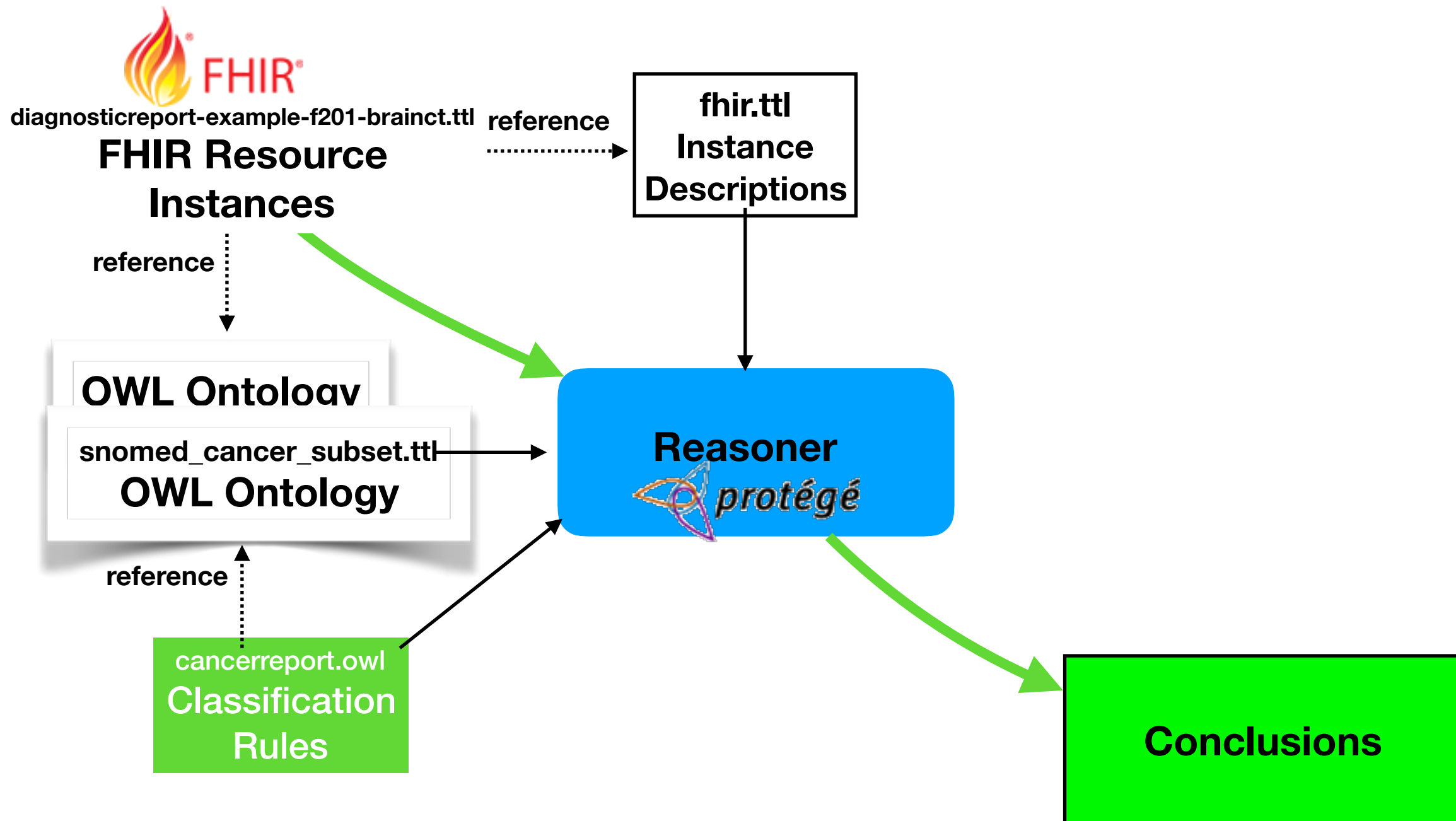
Usage: Malignant neoplastic disease (disorder)

Show: ☒ this ☒ disjoint ☒ named sub/superclasses

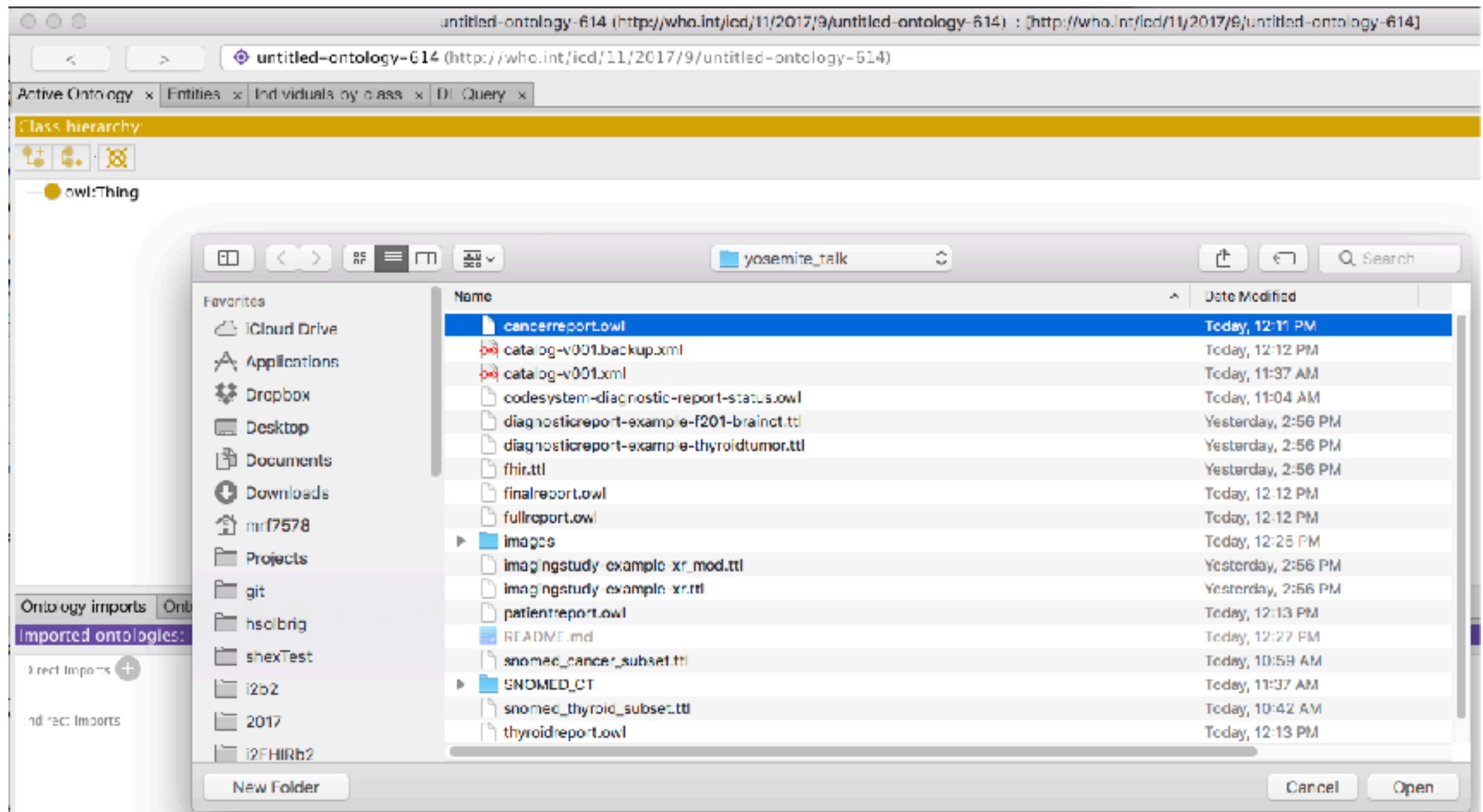
Found 15 uses of 'Malignant neoplastic disease (disorder)'

- '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

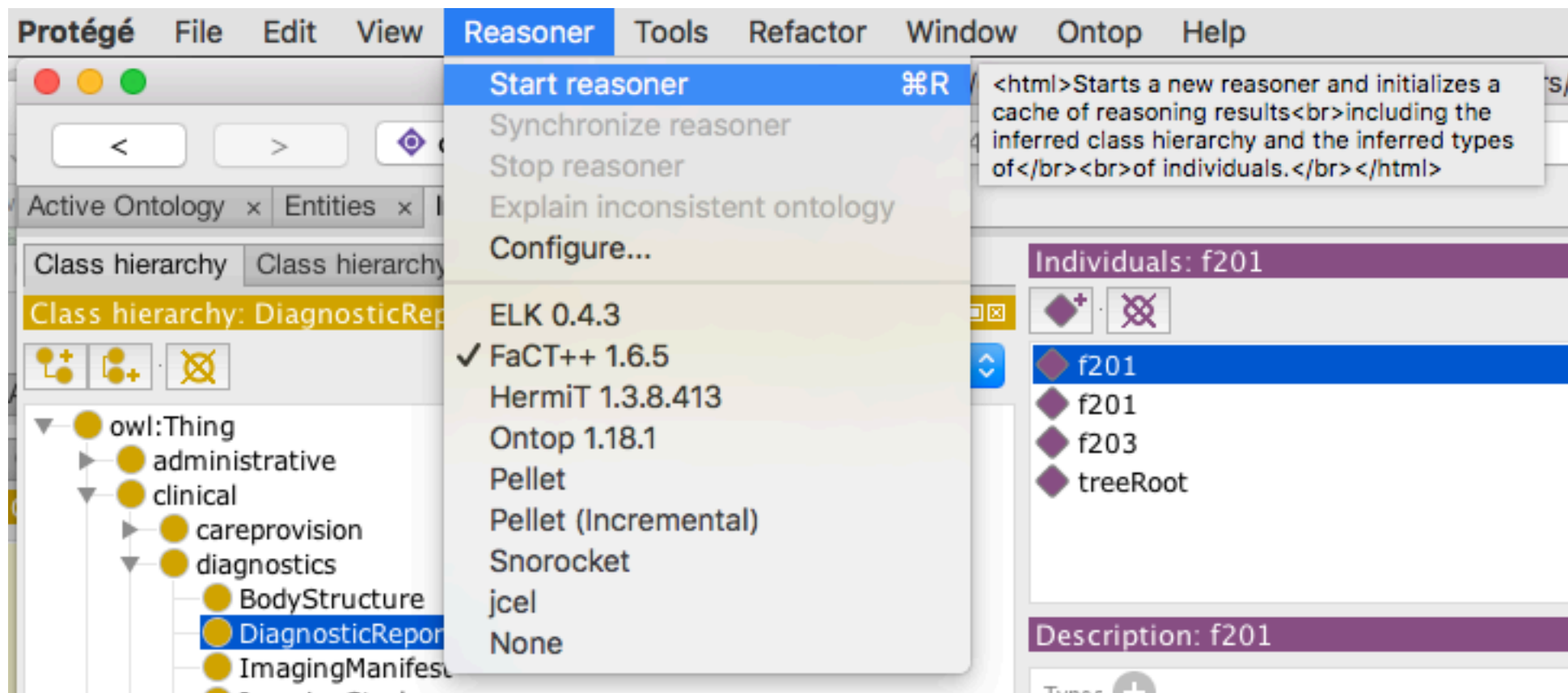


https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/cancerreport.owl

Verify the Imports

Ontology imports	Ontology Prefixes	General class axioms
Imported ontologies:		
Direct Imports 		
<hr/>		
<p><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</p>		
<hr/>		
<p><http://snomed.info/sct/900000000000207008cancer_subset> 900000000000207008cancer_subset Ontology IRI: <http://snomed.info/sct/900000000000207008cancer_subset> Location: /Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/snomed_cancer_subset.ttl</p>		
<hr/>		
<p><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</p>		
<hr/>		
Indirect Imports		
<p><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</p>		
<hr/>		
<p><http://hl7.org/fhir/w5#> w5 Ontology IRI: <http://hl7.org/fhir/w5#> Location: /Users/mrf7578/Development/git/BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk/w5.ttl</p>		
<hr/>		

Run the Reasoner



Result

The screenshot displays a web-based ontology viewer interface for the 'cancerreport' ontology. 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 highlighted. Below it, 'ReportWithCancerDiagnosis' is also highlighted and circled in red.
- Individuals:** A panel on the right showing the individuals of the selected class. The individuals listed are 'f201', 'f201', 'f203', and 'treeRoot'.
- Description:** A panel below the individuals showing the description of the selected class. The description is 'ReportWithCancerDiagnosis'.
- Property assertions:** A panel on the far right showing the property assertions for the selected class. 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

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

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

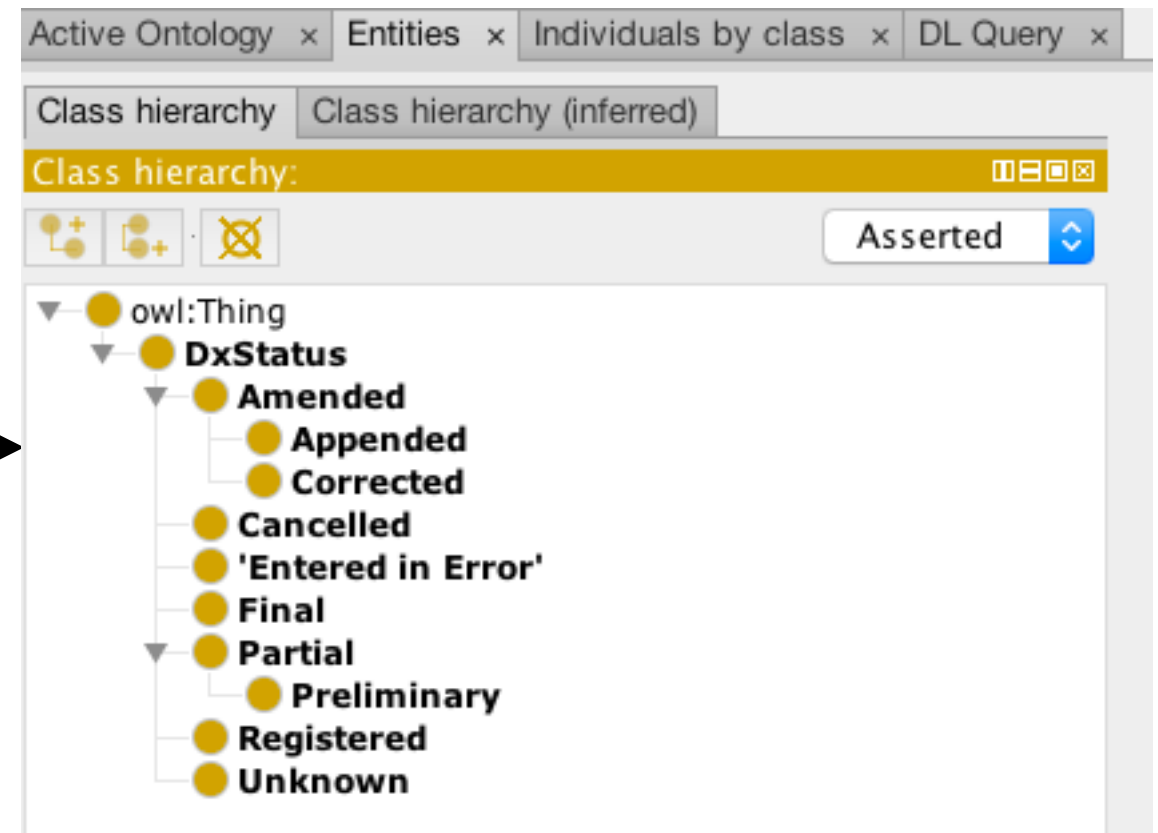
Finalized Reports Proposed Solution

```
@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 shows a web browser window with the URL `http://example.org/swat4ls/finalpatientcancerreport`. The browser's address bar and tabs show the active ontology. The main content area displays the definition of the class `FinalPatientReportWithCancerDiagnosis`.

Class hierarchy: `FinalPatientReportWithCancerDiagnosis` is shown as a subclass of `ReportWithCancerDiagnosis`, which is a subclass of `PatientReport`. The hierarchy is displayed in a tree view on the left side of the interface.

Description: `FinalPatientReportWithCancerDiagnosis` is defined as:

- Equivalent To: `ReportWithCancerDiagnosis and FinalReport and PatientReport`
- SubClass Of: `ReportWithCancerDiagnosis`
- General class axioms: `DiagnosticReport.subject.link some Patient`, `DiagnosticReport.codedDiagnosis.coding some 'Malignant neoplastic disease (disorder)'`, and `DiagnosticReport.status some FinalStatus`
- SubClass Of (Anonymous Ancestor): `DiagnosticReport.subject.link some Patient`, `DiagnosticReport.codedDiagnosis.coding some 'Malignant neoplastic disease (disorder)'`, and `DiagnosticReport.status some FinalStatus`
- Instances: (None listed)

Result

The screenshot shows a web browser window with the address bar displaying 'finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport)'. The browser tabs include 'Active Ontology', 'Entities', 'Individuals by class', and 'DL Query'. The main content area is divided into two panels. The left panel, titled 'Class hierarchy (inferred): FinalPatientReportWithCancerDiagnosis', shows a tree structure of classes. The right panel, titled 'Description: FinalPatientReportWithCancerDiagnosis', provides details about the selected class.

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

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

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

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	?	@	x	o
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

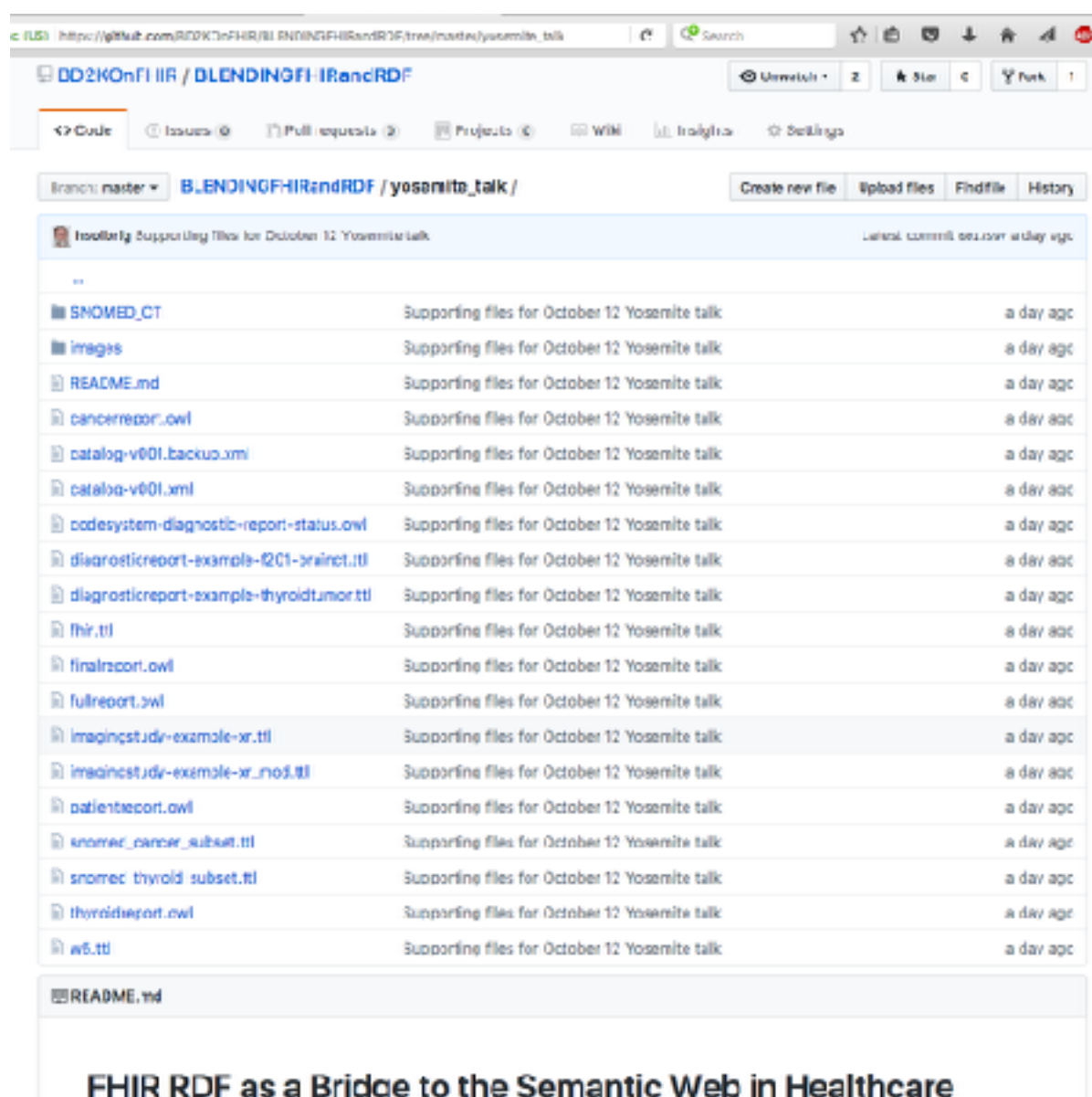
Dr. Guoqian Jiang

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



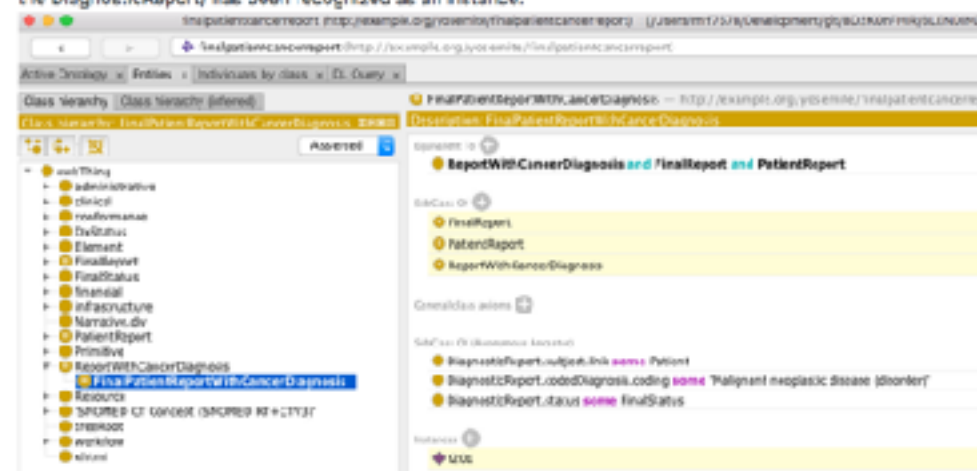
The screenshot shows the GitHub repository page for `BD2KOnFHIR/BLENDINGFHIRandRDF/yosemite_talk`. The repository is under the `master` branch. The file list includes:

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

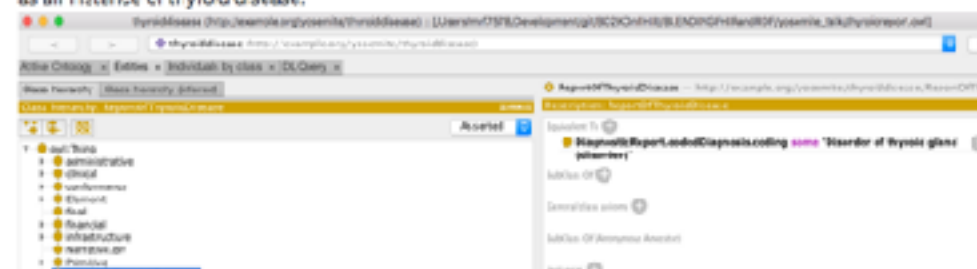
The README.md file is also visible at the bottom of the page.

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 *#261* (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 *diagnostic117* has been classified as an instance of *thyroid disease*.



Questions

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