FHIR, RDF and the Semantic Web

Semantic Representation of Clinical Care and Research in HL7 FHIR

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November 14, 2019
(Slides derived from 2018 SWAT4LS Tutorial)

FHIR is defined using FHIR

FHIR® FHIR Release 3 (STU)

Home | Getting Started | Documentation | Resources | Profiles | Extensions | Operations | Terminologies

Conformance > **StructureDefinition**

Content | Examples | Detailed Descriptions | Mappings | Profiles & Extensions | Operations | R2 Conversions

5.3 Resource StructureDefinition - Content

FHIR Infrastructure Work Group	Maturity Level: 5	Trial Use	Compartments: Not linked to any defined compartments

A definition of a FHIR structure. This resource is used to describe the underlying resources, data types defined in FHIR, and also for describing extensions and constraints on resources and data types.

5.3.1 Scope and Usage

The StructureDefinition resource describes a structure - a set of data element definitions, and their associated rules of usage. These structure definitions are used to describe both the content defined in the FHIR specification itself - Resources, data types, the underlying infrastructural types, and also are used to describe how these structures are used in implementations. This allows the definitions of the structures to be shared and published through repositories of structure definitions, compared with each other, and used as the basis for code, report and UI generation.

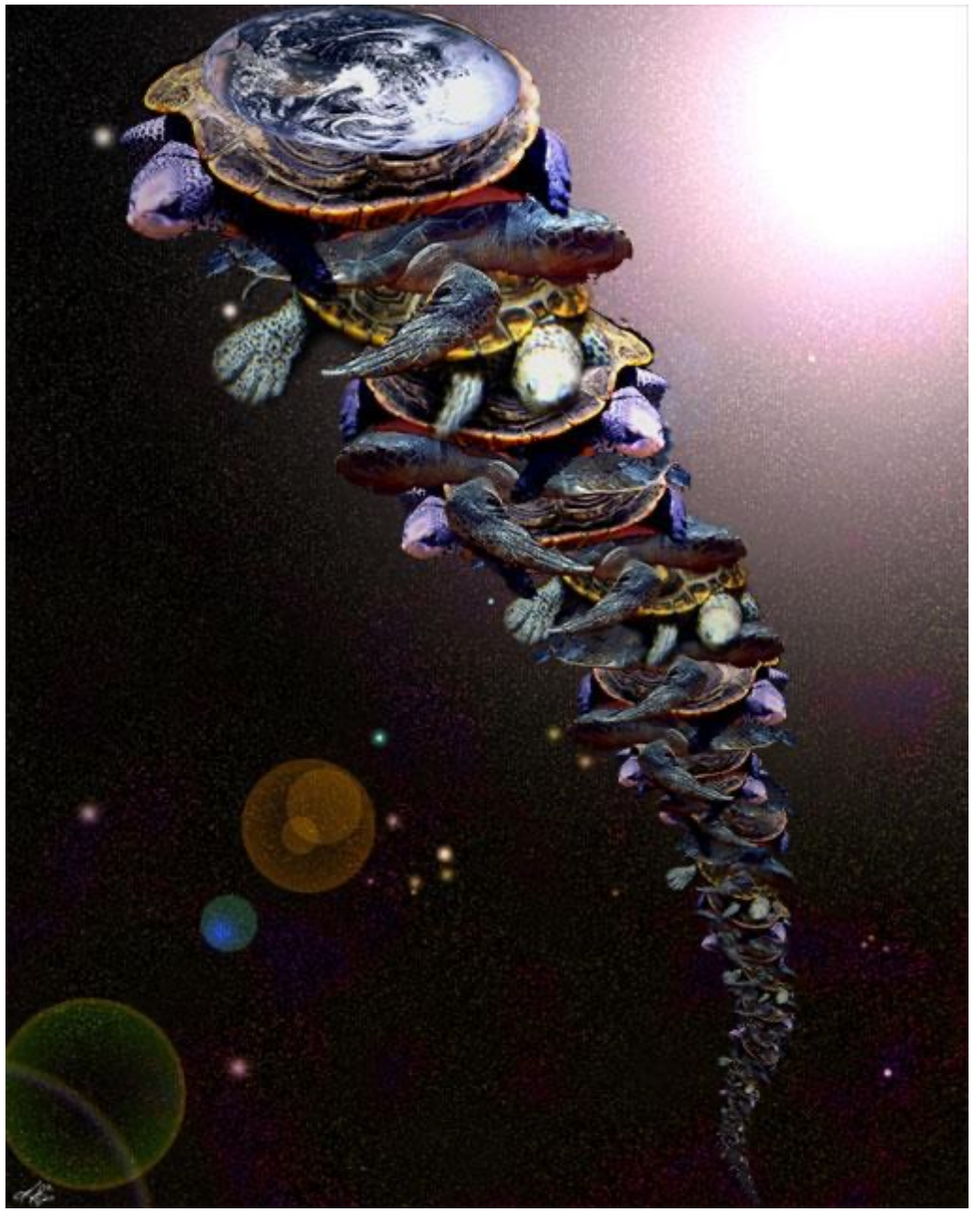
Note that as part of the specification itself, a full set of structure definitions for all resources and data types is published.

5.3.2 Boundaries and Relationships

- StructureDefinitions are used by CapabilityStatement instances for specifying how resources are used
- StructureDefinitions use Value Sets to specify the content of coded elements

http://www.hl7.org/FHIR/structuredefinition.html
www.hl7.org/FHIR/StructureDefinition/patient/
http://hl7.org/fhir/StructureDefinition/structuredefinition/

Turtles all the way down….



http://prosperouswaydown.com/wp-content/uploads/2013/11/Fig2.jpg

… but not all turtles are created equal

http://www.pxleyes.com/images/users/a/anatole/298/fullsize/4a51dc3b8760b.jpg

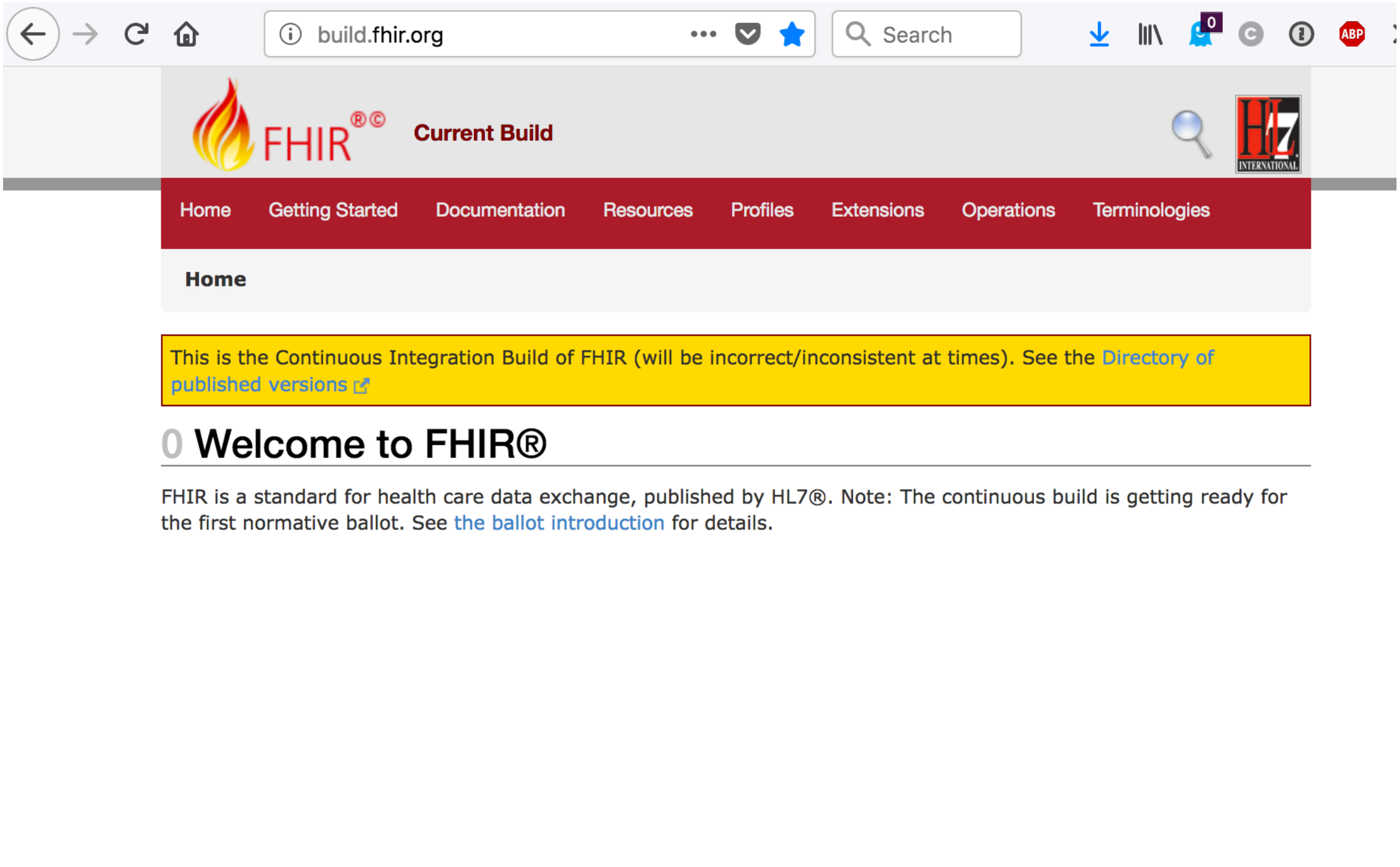
FHIR “turtles” - ~~five~~ **six** different languages

- StructureDefinition & friends — core model
- Extension — tag/value
- Constraint — FhirPath
- “Slicing” —
- Value Sets
- Terminology Property Language

Some things that FHIR **isn't**

- A solution to healthcare interoperability
- A standard (yet)
- Resource Oriented Architecture (ROA)
- A tool for representing / standardizing clinical *semantics* (CIMI in particular)

FHIR is not a standard (yet)



FHIR Normative Ballot

Categorized | Alphabetical | R2 Layout | By Maturity | By Ballot Status | By Committee

Foundation

Conformance	Terminology	Security	Documents	Other
• CapabilityStatement 3 N	• CodeSystem 5 N	• Provenance 3	• Composition 2	• Basic 1
• StructureDefinition 5 N	• ValueSet 5 N	• AuditEvent 3	• DocumentManifest 2	• Binary 5 N
• ImplementationGuide 1	• ConceptMap 3 N	• Consent 1	• DocumentReference 3	• Bundle 5 N
• SearchParameter 3	• ExpansionProfile 2		• EntryDefinition 0	• Linkage 0
• MessageDefinition 1	• NamingSystem 1			• MessageHeader 4
• OperationDefinition 4 N	• TerminologyCapabilities 0			• OperationOutcome 5 N
• CompartmentDefinition 1				• Parameters 5 N
• StructureMap 2				• Subscription 3
• GraphDefinition 0				• UserSession 0
• ExampleScenario 0				

Base

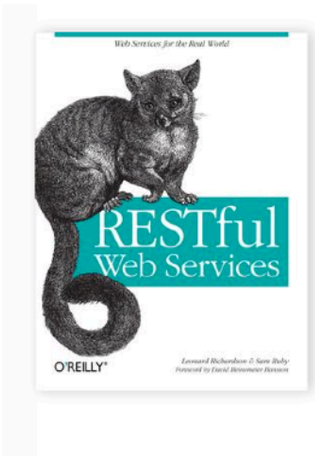
Individuals	Entities	Workflow	Management
• Patient 5 N	• Organization 3	• Task 2	• Encounter 2
• Practitioner 3	• OrganizationRole 0	• Appointment 3	• EpisodeOfCare 2
• PractitionerRole 2	• HealthcareService 2	• AppointmentResponse 3	• Flag 1
• RelatedPerson 2	• Endpoint 2	• Schedule 3	• List 1
• Person 2	• Location 3	• Slot 3	• Library 2
• Group 1	• Substance 2	• ProcessRequest 2	
	• BiologicallyDerivedProduct 0	• ProcessResponse 2	
	• Device 2		
	• DeviceComponent 1		
	• DeviceMetric 1		

Summary	Diagnostics	Medications	Care Provision	Request & Response
• AllergyIntolerance 3	• Observation 5 N	• MedicationRequest 3	• CarePlan 2	• Communication 2

FHIR is not Resource-Oriented Architecture

That's the Resource-Oriented Architecture. It's just four concepts:

1. Resources
1. Their names (URIs)
1. Their representations
1. The links between them



RESTful Web Services

26 reviews

by Sam Ruby, Leonard Richardson

Publisher: O'Reilly Media, Inc.

Release Date: May 2007

ISBN: 9780596529260

Topics: Java

View table of contents

and four properties:

1. Addressability
2. Statelessness
3. Connectedness
4. A uniform interface

"A web service is connected to the extent that you can put the service in different states just by following links and filling out forms"

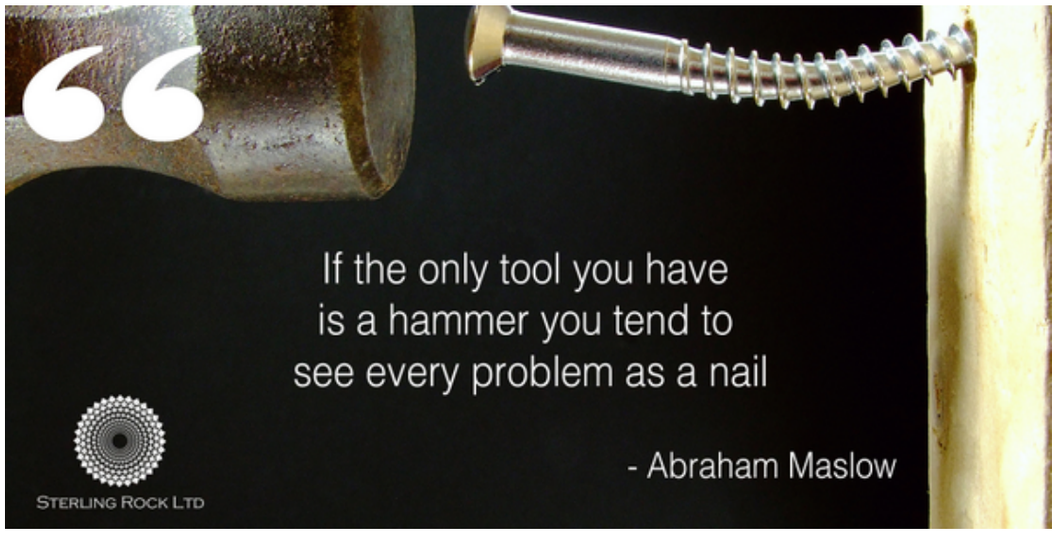
http://my.safaribooksonline.com/9780596529260/restclients

FHIR is *not* the solution to clinical <u>semantics</u>

2.15.1 Why FHIR is better

FHIR offers many improvements over existing standards:

- A strong focus on implementation – fast and easy to implement (multiple developers have had simple interfaces working in a single day)
- Multiple implementation libraries, many examples available to kick-start development
- Specification is free for use with no restrictions
- Interoperability out-of-the-box– base resources can be used as is, but can also be adapted for local requirements
- Evolutionary development path from HL7 Version 2 and CDA – standards can co-exist and leverage each other
- Strong foundation in Web standards– XML, JSON, HTTP, OAuth, etc.
- Support for RESTful architectures, seamless exchange of information using messages or documents, and service based architectures
- Concise and easily understood specifications
- A human-readable serialization format for ease of use by developers
- Solid ontology-based analysis with a rigorous formal mapping for correctness



FHIR is focused in *implementors.*

- **Communities can use FHIR to develop specifications for *how* clinical information is represented.**
- **FHIR does not provide tooling for representing the *meaning* of said information**
- **FHIR's target audience is NOT clinicians (!)**

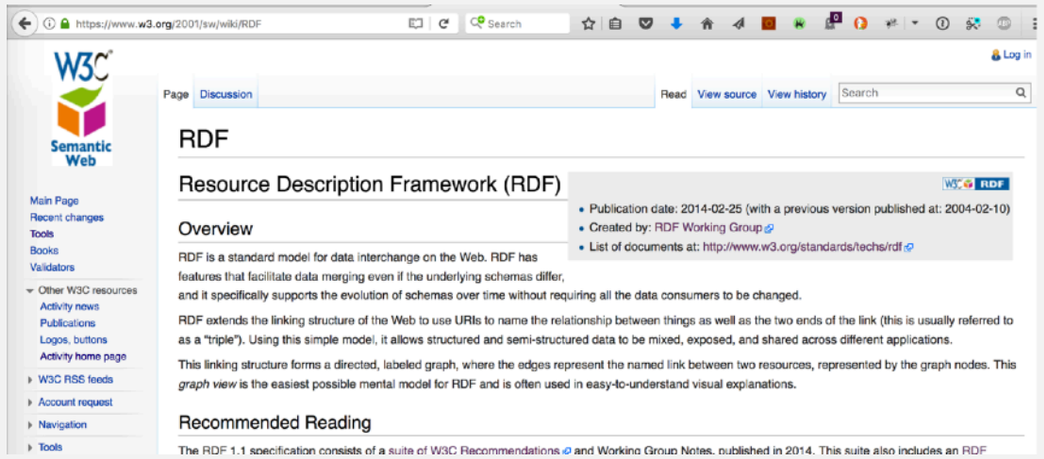
Part 2

The Resource Description Framework (RDF)

- **Triples, URI's and BNodes**
- RDF Catalogs

Resource Description Framework (RDF)

- “Standard model for data interchange on the Web.”
- “Facilitates data merging even if the underlying schemas differ.”
- URI based linking structure in the form of a directed, labeled graph.



https://www.w3.org/2001/sw/wiki/RDF

RDF – Informal Graph Model

```
<Bob> <is a> <person>.
<Bob> <is a friend of> <Alice>.
<Bob> <is born on> <the 4th of July 1990>.
<Bob> <is interested in> <the Mona Lisa>.
```

```
<Leonardo da Vinci> <is the creator of> <the Mona Lisa>.
<The video 'La Joconde à Washington'> <is about> <the Mona Lisa>
```

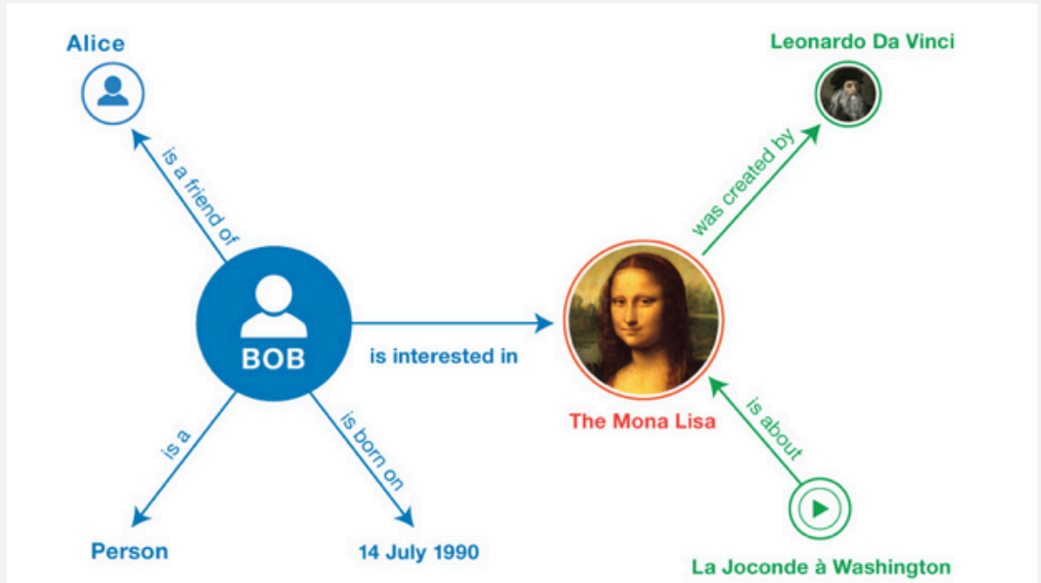


Fig. 1 Informal graph of the sample triples

https://www.w3.org/TR/rdf11-primer/

RDF Components

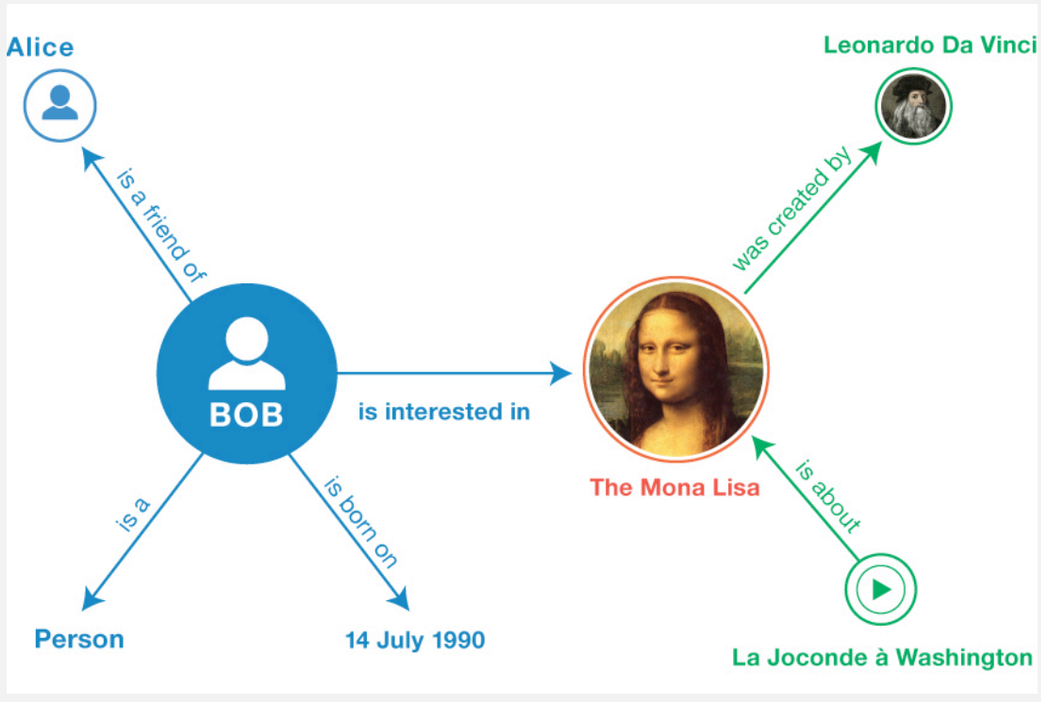
URI (IRI)

- <Bob>: http://corporation.org/employee#BobGleeson
- <is a>: http://www.w3.org/1999/02/22-rdf-syntax-ns#type
- <is born on>: http://schema.org/birthDate
- <Person>: http://xmlns.com/foaf/1.0/Person

Literal

- String - “Bob”
- String + Language - “avalanche”@en
- Typed String - “1990-07-14”^^xsd:date

  “42”^^xsd:integer



RDF Triples

Subject Predicate Object

- **Subject**: URI or Blank Node
- **Predicate**: URI
- **Object**: URI or Literal or Blank Node

Subject (URI):

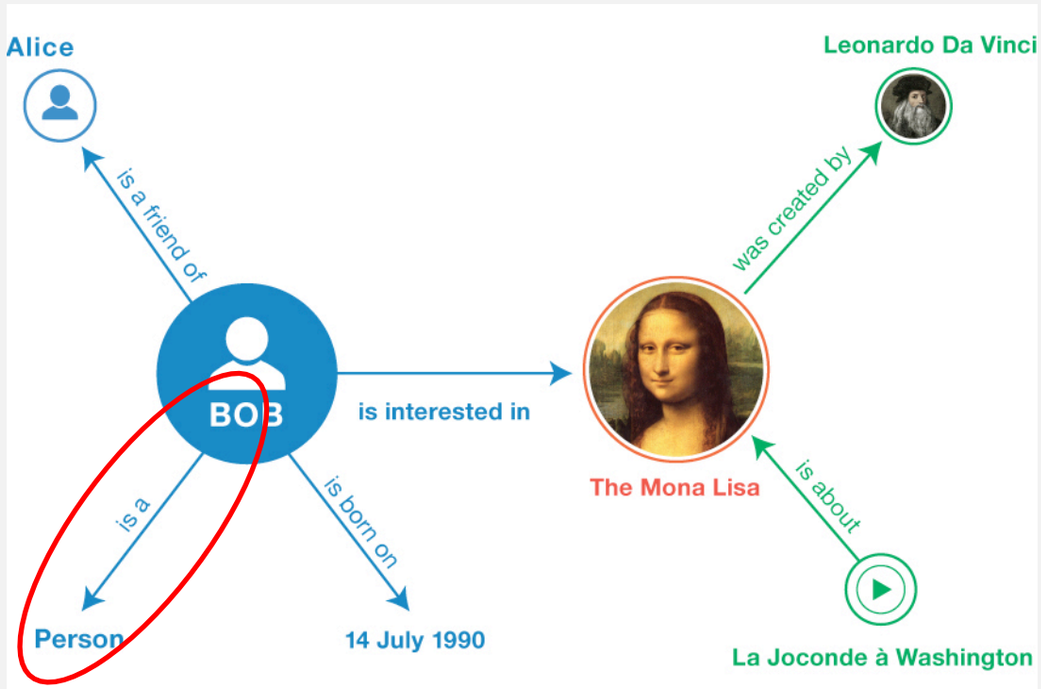
http://corporation.org/employee#BobGleeson

Predicate (URI):

http://www.w3.org/1999/02/22-rdf-syntax-ns#type

Object (URI):

http://xmlns.com/foaf/1.0/Person



RDF Triples

Subject Predicate Object

Subject (URI):

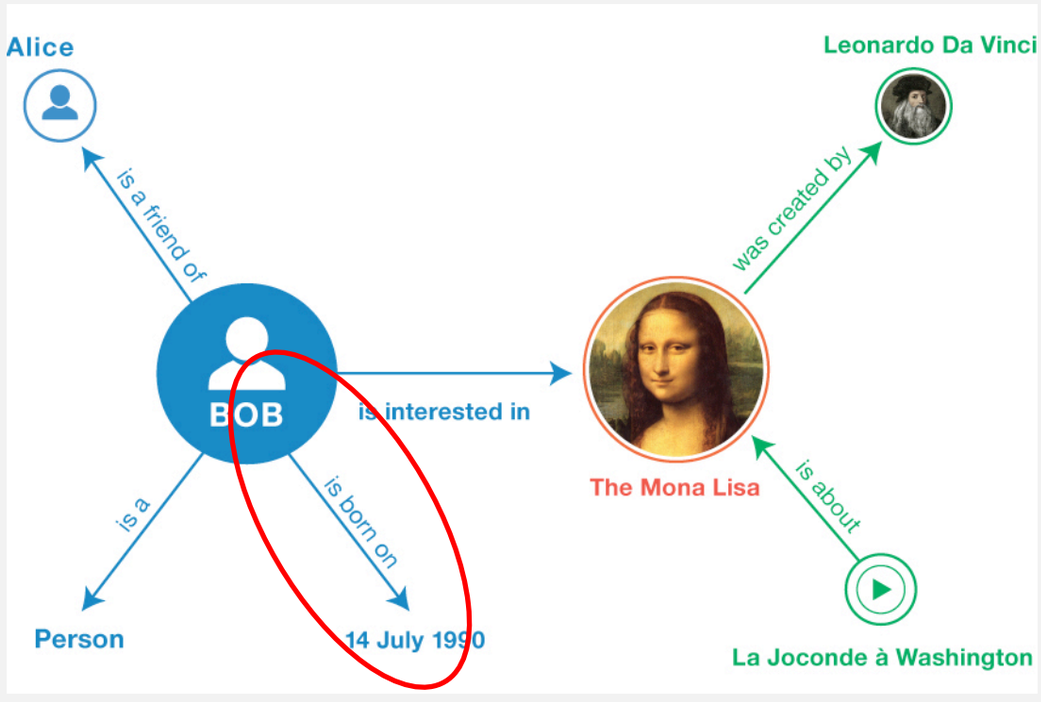
http://corporation.org/employee#BobGleeson

Predicate (URI):

http://schema.org/birthDate

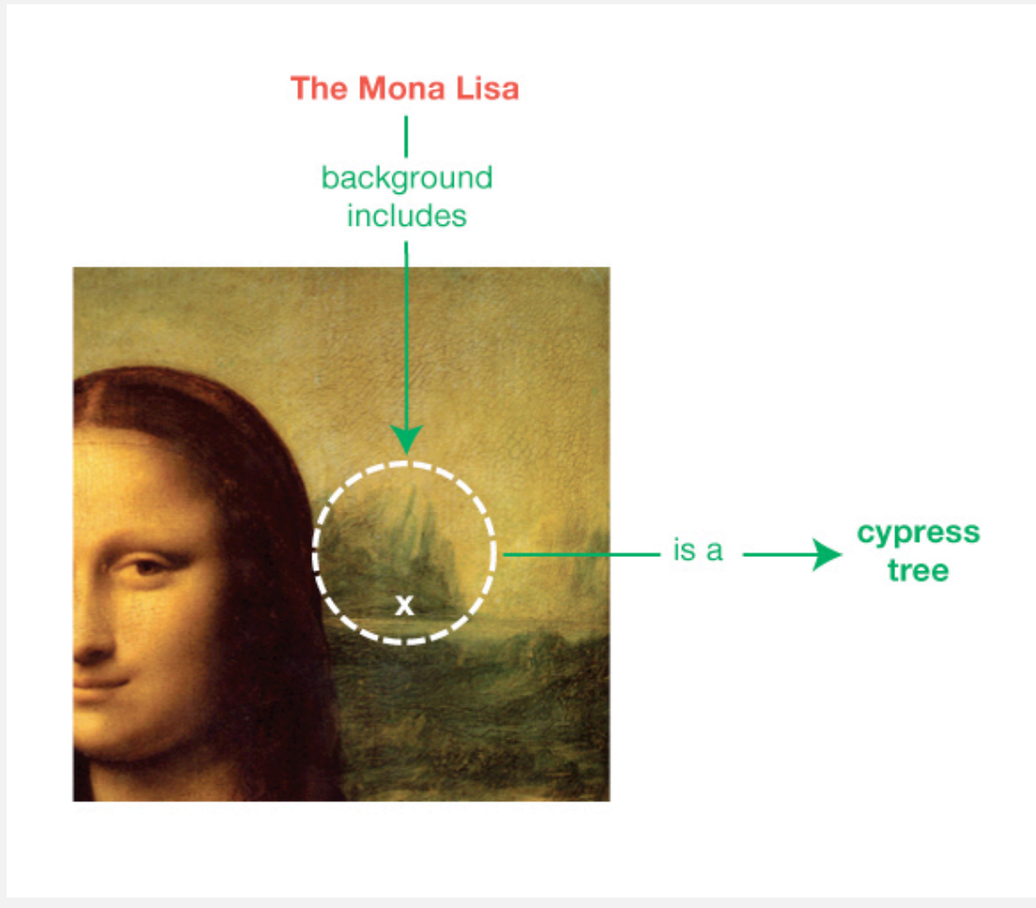
Object (Literal):

“1990-07-04”^^<http://www.w3.org/2001/XMLSchema#date>



RDF Triples – Blank Nodes (BNodes)

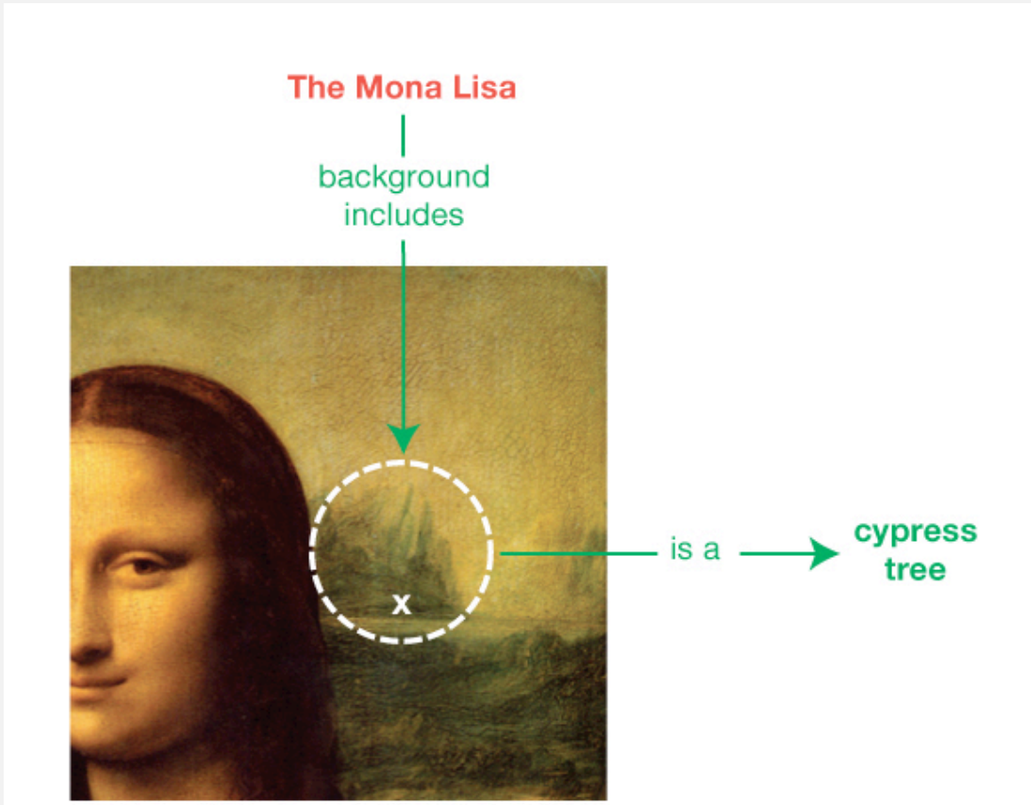
- Blank – unnamed
- NOT a URI
- “The last house on the hill”
- “The person who hit me”
- “An item in the background of the painting, ‘The Mona Lisa’”



RDF Triples – Blank Nodes (BNodes)

Subject (URI):
http://dbpedia.org/resource/Mona_Lisa
Predicate (URI):
http://purl.org/net/lio#shows
Object (BNode):
_:abc17

Subject (BNode):
_:abc17
Predicate (URI):
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
Object (URI):
http://dbpedia.org/resource/Cypress



RDF Turtle Notation

- **T**erse RDF **T**riple **L**anguage”
- One of *several* possible formats for representing RDF
- Others include:
  - RDF XML
  - RDF Ntriples
  - JSON-LD
  - …

NTriples

```
<http://corporation.org/employee>
    <http://schema.org/birthDate>
     "1990-07-04"^^<http://www.w3.org/2001/XMLSchema#date> .
```

RDF XML

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF
   xmlns:ns1="http://schema.org/"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
>
  <rdf:Description rdf:about="http://corporation.org/employee">
    <ns1:birthDate rdf:datatype="http://www.w3.org/2001/XMLSchema#date">1990-07-04
</ns1:birthDate>
  </rdf:Description>
</rdf:RDF>
```

JSON-LD

```
[
  {
    "@id": "http://corporation.org/employee",
    "http://schema.org/birthDate": [
      {
        "@type": "http://www.w3.org/2001/XMLSchema#date",
        "@value": "1990-07-04"
      }
    ]
  }
]
```

RDF Turtle Notation

Notation	Equivalent
subject predicate object .	subject predicate object .
subject predicate1 object1 ; predicate1 object2 ; … predicateN objectN .	subject predicate1 object1 . subject predicate2 object2 . … subject predicateN objectN .
subject predicate object1 , object2 , … objectN .	subject predicate object1 . subject predicate object2 . … subject predicate objectN .

RDF Turtle Notation - Prefixes

@prefix ex: <http://example.org/some/really/long/path#> .

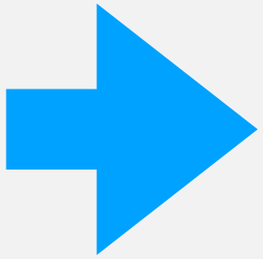
@prefix fhir: <http://hl7.org/fhir/> .

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix : <http://example.org/some/really/long/path#> .

ex:Jim rdf:type fhir:Patient .

:Jim a fhir:Patient .



<http://example.org/some/really/long/path#Jim>
<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<http://hl7.org/fhir/Patient> .

RDF Turtle Notation – Blank Nodes

```
subject predicate1 [
    predicate2 object2 ;
    predicate3 object 3
] .
subject predicate4 [
    predicate5 “abc” ] .
```

```
subject predicate1 _:a1 .
_:a1 predicate2 object2 ;
predicate3 object3 .

Subject prediate4 _:b1 .
_:b1 predicate5 “abc” .
```

RDF – The Good News

Minimal Structure

- No rules
- Anyone can say anything anywhere (AAA)

2 ½ Data Types

- IRI
- Literal
  - More like a “data type” – second language embedded within
  - “text”^^<URI for type>.
  - “text”@<language> .
- Blank Node
  - NO Identity (!)

RDF – The Bad News

Minimal Structure

- No rules
- Anyone can say Anything Anywhere

URI's

- Anyone can create them
- **RDF is strictly a *syntax* until agreement can be reached on the use and meaning of IRI's**

Outline (continued)

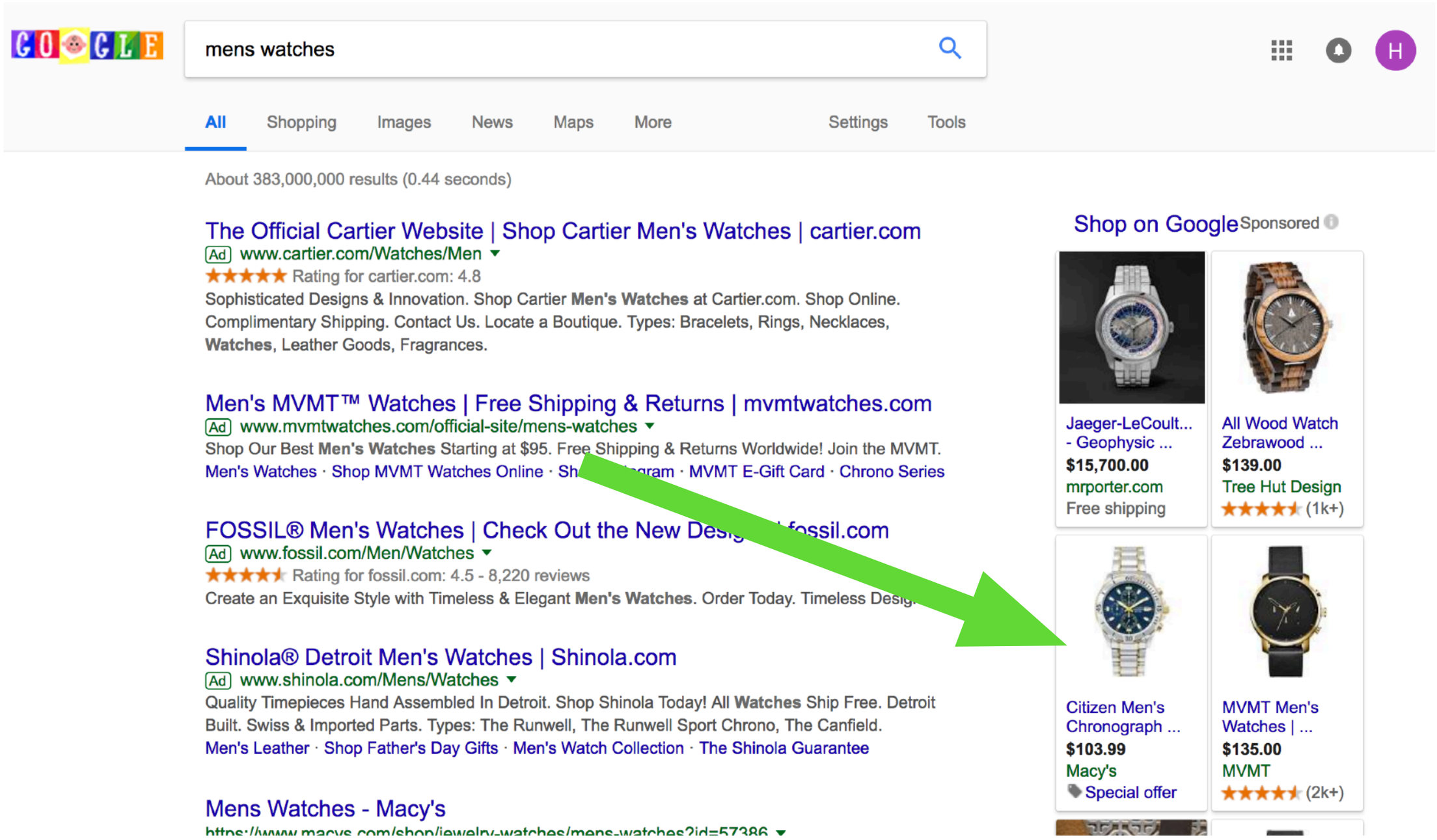
The Resource Description Framework (RDF)

- Triples, URI's and BNodes
- **RDF Catalogs**

(some) RDF Catalogs

- Resource Description Format – rdf:type, rdf:Resource
- RDF Schema – rdfs:domain, rdfs:range, rdfs:subClassOf
- Web Object Language (OWL) –
- owl:Restriction, owl:someValueFrom
- Dublin Core (dc, dcterms)
- Simple Knowledge Organization System (skos)
- Friend of a Friend (foaf)
- dbPedia
- …
- **schema.org**

How do it know?



What you see...

https://www.mrporter.com/en-us/mens/jaeger_lecou

Search

FREE STANDARD DELIVERY AVAILABLE ON ALL ORDERS

SHOP FOR HER

SHIPPING TO
UNITED STATES

MR PORTER

Search

SALE WHAT'S NEW DESIGNERS CLOTHING SHOES ACCESSORIES WATCHES SPORT GROOMING EDITORIAL

JAEGER-LECOULTRE

Geophysic Universal Time 41mm Stainless Steel Watch

$15,700

EDITORS' NOTES −

Swiss-engineered with a True Second® system and Gyrolab® balance wheel developed in Jaeger-LeCoultre's Le Sentier workshop, this 'Geophysic® Universal Time' watch is calibrated for accuracy and reliability across all 24 timezones. Housed in sleek polished stainless steel, the lacquered sunray dial depicts an intricate map of the world encircled with the names of major cities. It'll prove a thoughtful gift for globetrotters and business travellers alike.

We offer a five-year warranty for all working parts and manufacturing faults for luxury watches. Call our Customer Care team for more information.

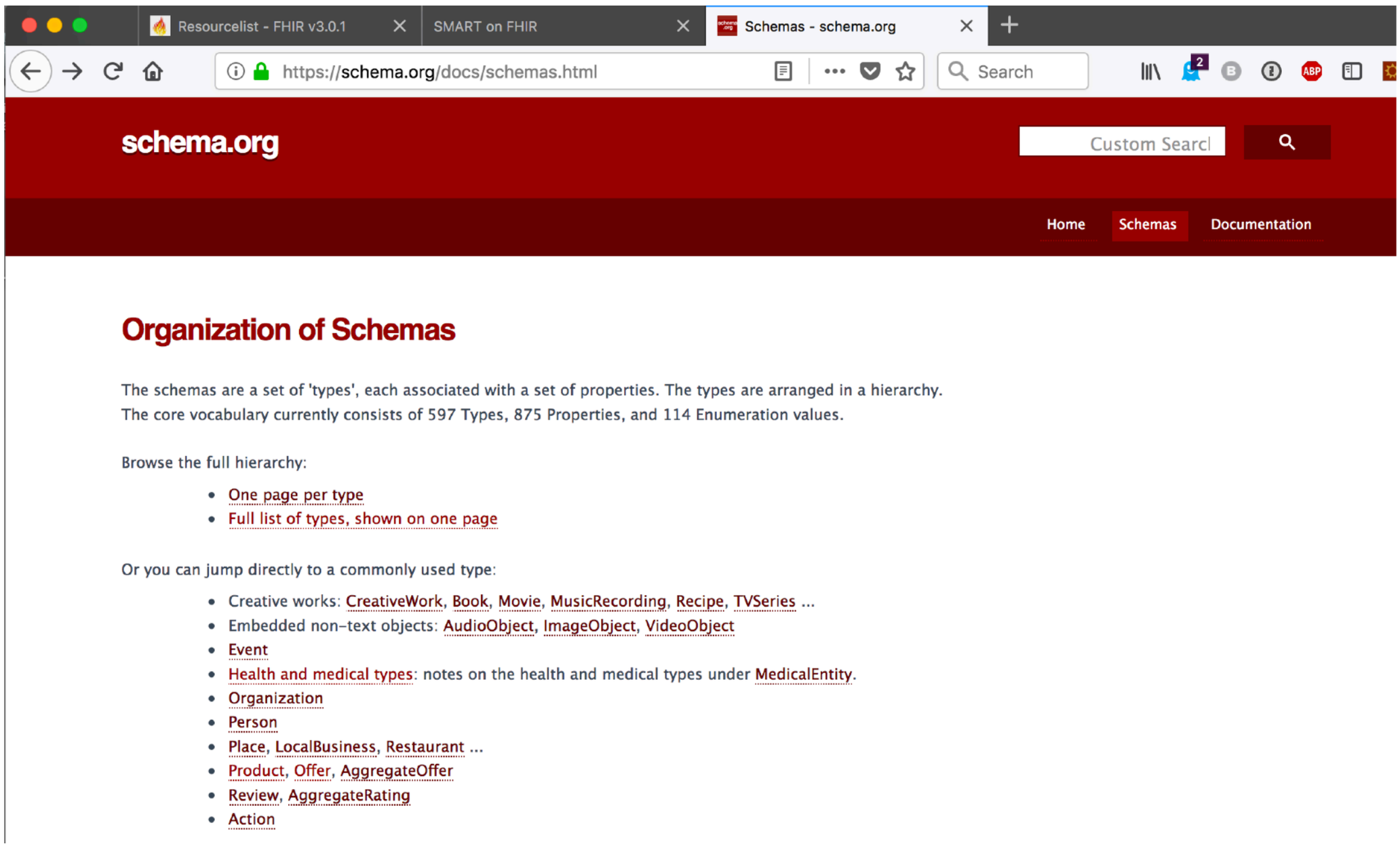
Need more advice? Read the Luxury Watch Guide.

SIZE & FIT +

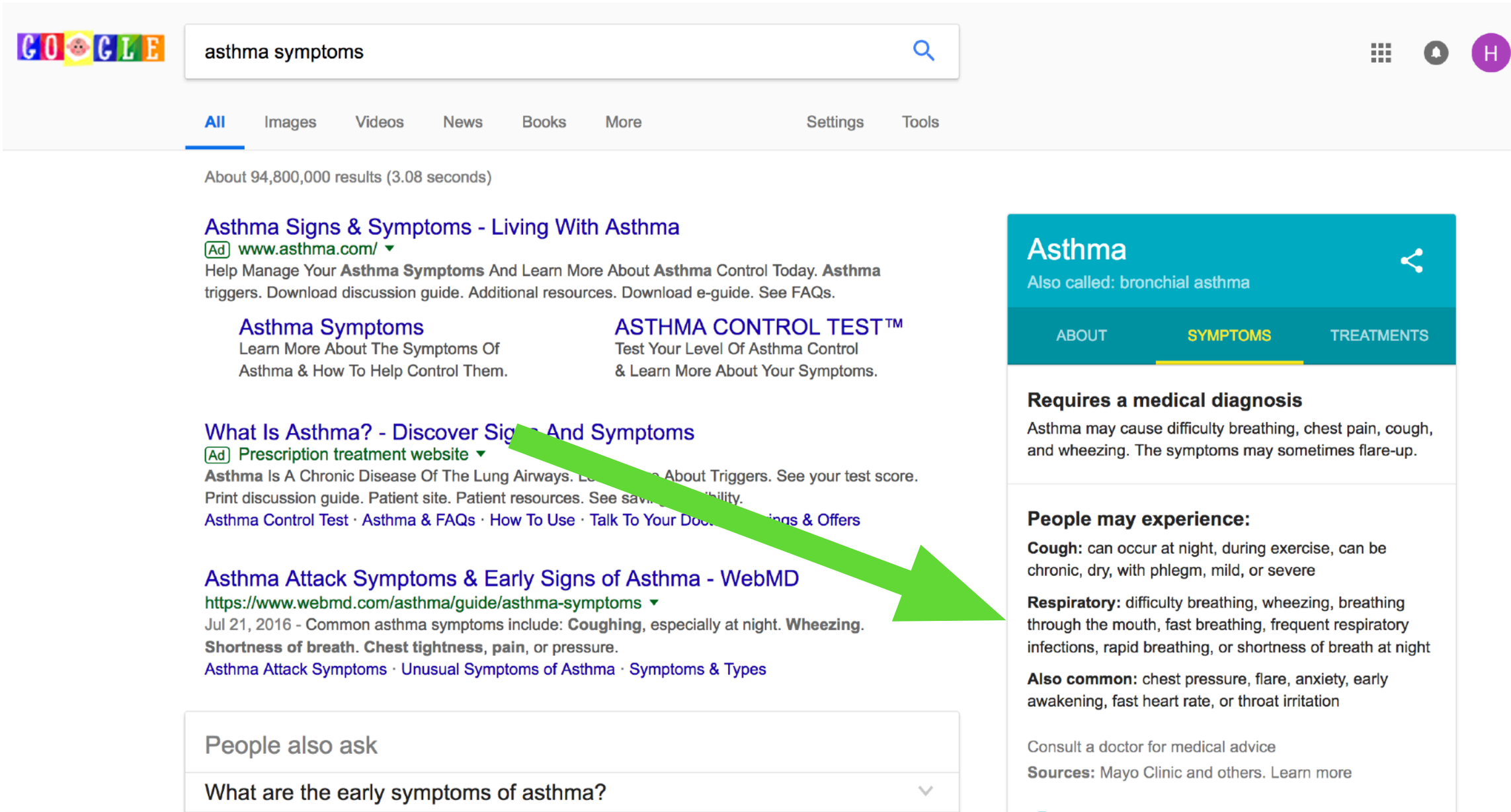
What the search engine sees

```
</nav>

<div id="wrap-content">
    <main id="main">
        <div id="content" class="clearfix"><div id="product-page"><div><section
        class="product-page"><noscript></noscript><section class="product-details js-product-details"
        itemtype="//schema.org/Product"><span class="product-details__badge"></span><h1><a href="/en-us/mens/
        designers/Jaeger_LeCoultre" class="product-details__designer--link" title="View all Jaeger-LeCoultre"><span
        class="product-details__designer" itemprop="brand"><span>Jaeger-LeCoultre</span></span></a><span
        class="product-details__name" itemprop="name"><span>Geophysic Universal Time 41mm Stainless Steel
        Watch</span></span></h1><span class="product-details-price undefined" itemprop="offers"
        itemtype="//schema.org/Offer"><noscript></noscript><span class="product-details__price price-sale"
        itemprop="priceSpecification" itemscope itemtype="http://schema.org/PriceSpecification"><span
        class="price-sale" itemprop="priceCurrency" content="USD"></span><span class="product-details__price--value
        price-sale" itemprop="price"
        content="15700">$15,700</span><noscript></noscript><noscript></noscript></span></span></section><section
        class="product-gallery"><div class="product-fullscreen"><div class="product-fullscreen__carousel"><div
```

schema.org
RDF Catalog



How do it know?



What you see

https://www.mayoclinic.org/diseases-conditions/asthma/symptoms

Search

MAYO CLINIC

MENU

Search Mayo Clinic

Request an Appointment
Find a Doctor
Find a Job
Give Now

Log in to Patient Account

English

Patient Care & Health Information › Diseases & Conditions

Asthma

Request an Appointment

Symptoms & causes | Diagnosis & treatment | Doctors & departments | Care at Mayo Clinic

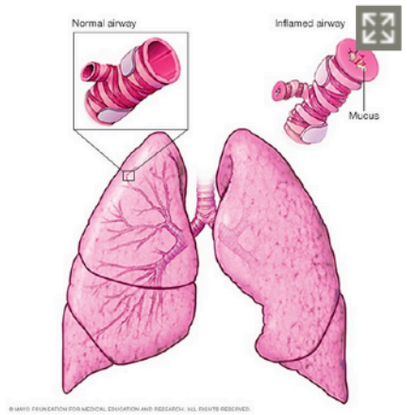
Overview

Print

Asthma is a condition in which your airways narrow and swell and produce extra mucus. This can make breathing difficult and trigger coughing, wheezing and shortness of breath.

For some people, asthma is a minor nuisance. For others, it can be a major problem that interferes with daily activities and may lead to a life-threatening asthma attack.

Asthma can't be cured, but its symptoms can be controlled. Because asthma often changes over time,

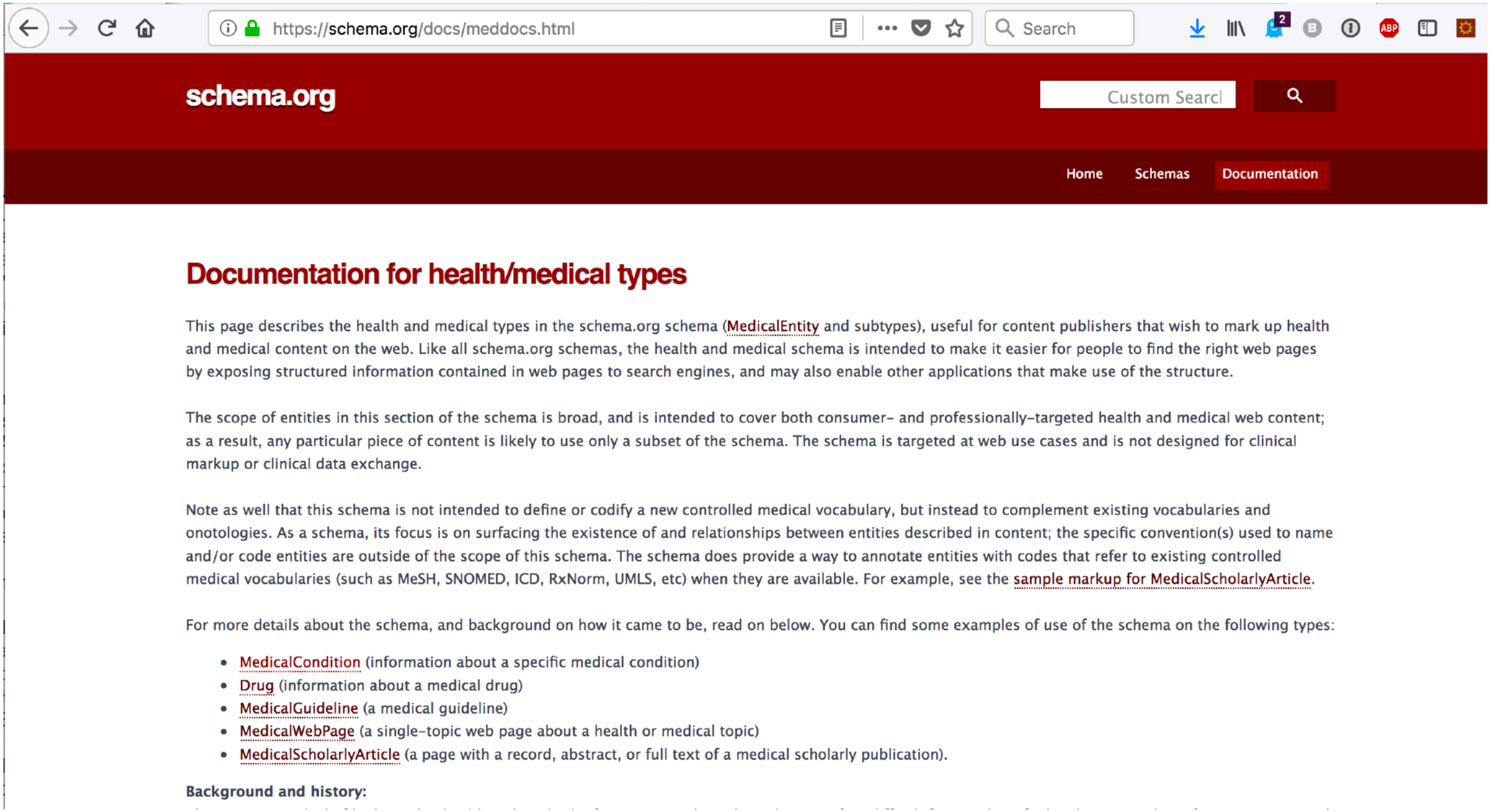


Asthma attack

What the search engine sees

```
<meta property="og:image" content="http://www.mayoclinic.org/-/media/web/GBS/Shared/Images/SocialMedia-Metadata/
MC_OpenGraph_600x315.jpg" />

    <link rel="alternate" href="https://www.mayoclinic.org/diseases-conditions/asthma/symptoms-causes/syc-20369653" hreflang="en"/>
<link rel="alternate" href="https://www.mayoclinic.org/es-es/diseases-conditions/asthma/symptoms-causes/syc-20369653" hreflang="es"/>
<link rel="alternate" href="https://www.mayoclinic.org/ar/diseases-conditions/asthma/symptoms-causes/syc-20369653" hreflang="ar"/>
<link rel="canonical" href="https://www.mayoclinic.org/diseases-conditions/asthma/symptoms-causes/syc-20369653"/>
<meta name="PublishDate" content="2018-03-09" />
<script type="application/ld+json">{"@context": "http://schema.org", "@type": "WebPage","name": "Asthma - Symptoms and causes - Mayo
Clinic" ,"datePublished": "2018-03-09", "url": "https://www.mayoclinic.org/diseases-conditions/asthma/symptoms-causes/syc-20369653"}</
script>

    <!--[if lt IE 9]>
        <script src="//html5shim.googlecode.com/svn/trunk/html5.js"></script>
    <![endif]-->

    <link rel="stylesheet" type="text/css" href="/styles/css/gbs/mayocombinded_7CFF73F48D4FC2542Q8B8QD07C70FF404.css" />
```

Healthcare and schema.org



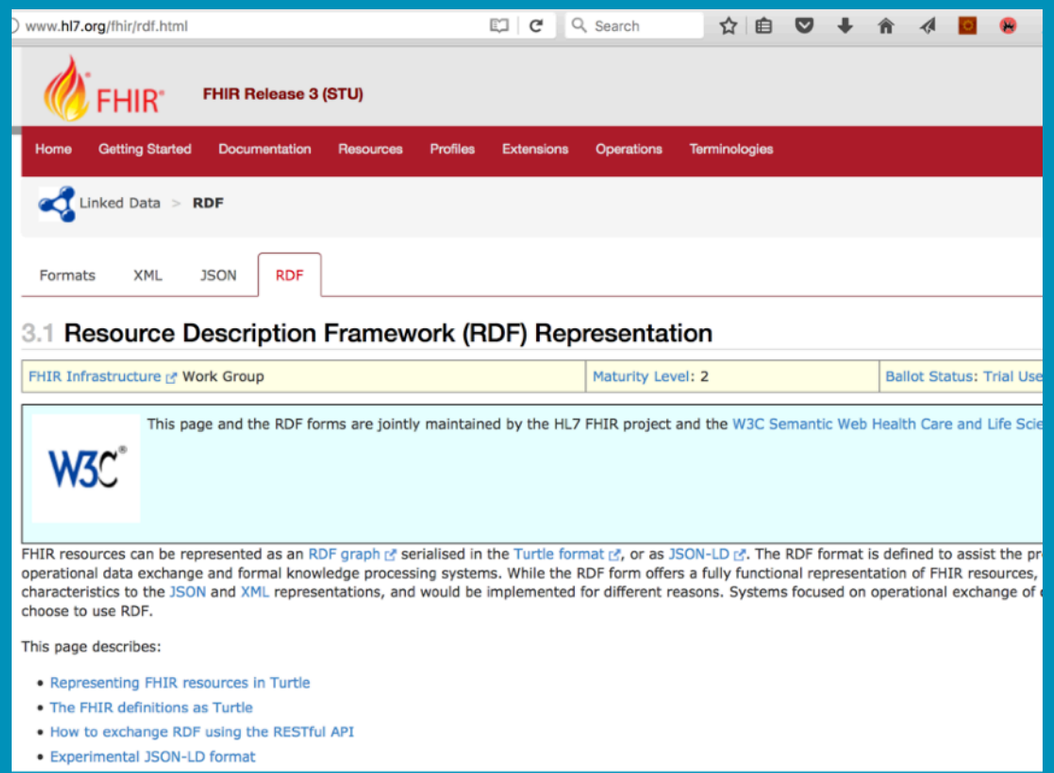
Part 3

FHIR, RDF and the Semantic Web

- **The FHIR RDF Specification**
- Why RDF and FHIR

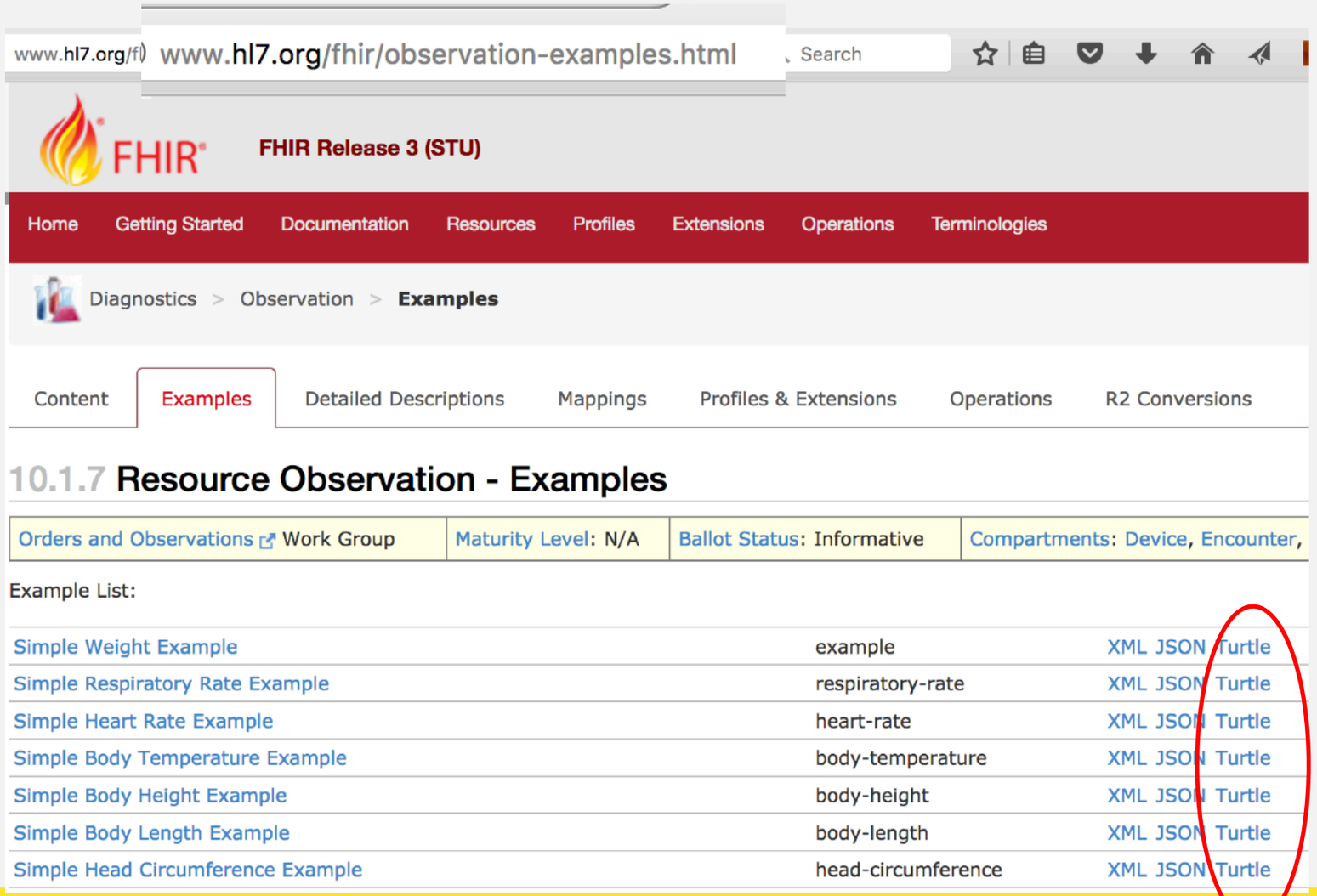
FHIR and RDF

- First released in STU3
- Maturity Level: 2
- Ballot status: Trial Use
- Components
  - FHIR → RDF RDF→FHIR
  - StructureDefinition → Shape Expressions (ShEx)
  - StructureDefinition → FHIR Resource Catalog



RDF in FHIR

R4 Examples Available in RDF Turtle



Comparison JSON and RDF

JSON

```
{
  "resourceType": "Observation",
  "id": "example",
  "text": {
    "status": "generated",
    "div": "<div xmlns=\"http://www.w3.org/1999/xhtml\"><p><b>Generated Narrative with Details</
b></p><p><b>id</b>: example</p><p><b>status</b>: final</p><p><b>category</b>: Vital Signs <span>
(Details : {http://hl7.org/fhir/observation-category code 'vital-signs' = 'Vital Signs', given a
s 'Vital Signs'})</span></p><p><b>code</b>: Body Weight <span>(Details : {LOINC code '29463-7' =
'Body weight', given as 'Body Weight'}; {LOINC code '3141-9' = 'Body weight Measured', given as
'Body weight Measured'}; {SNOMED CT code '27113001' = 'Body weight', given as 'Body weight'}; {h
ttp://acme.org/devices/clinical-codes code 'body-weight' = 'body-weight', given as 'Body Weight'
})</span></p><p><b>subject</b>: <a>Patient/example</a></p><p><b>context</b>: <a>Encounter/exampl
e</a></p><p><b>effective</b>: 28/03/2016</p><p><b>value</b>: 185 lbs<span> (Details: UCUM code [
lb_av] = 'lb_av')</span></p></div>"
  },
  "status": "final",
  "category": [
    {
      "coding": [
        {
          "system": "http://hl7.org/fhir/observation-category",
          "code": "vital-signs",
          "display": "Vital Signs"
        }
      ]
    }
  ],
  "code": {
    "coding": [
      {
        "system": "http://loinc.org",
        "code": "29463-7",
        "display": "Body Weight"
      },
      {
        "system": "http://loinc.org"
```

RDF

Simple Weight Example

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

# - resource -------------------------------------------------------------------

<http://hl7.org/fhir/Observation/example> a fhir:Observation;
  fhir:nodeRole fhir:treeRoot;
  fhir:Resource.id [ fhir:value "example"];
  fhir:DomainResource.text [
     fhir:Narrative.status [ fhir:value "generated" ];
     fhir:Narrative.div "<div xmlns=\"http://www.w3.org/1999/xhtml\"><p><b>Generated Narrative w
ith Details</b></p><p><b>id</b>: example</p><p><b>status</b>: final</p><p><b>category</b>: Vital
Signs <span>(Details : {http://hl7.org/fhir/observation-category code 'vital-signs' = 'Vital Sig
ns', given as 'Vital Signs'})</span></p><p><b>code</b>: Body Weight <span>(Details : {LOINC code
'29463-7' = 'Body weight', given as 'Body Weight'}; {LOINC code '3141-9' = 'Body weight Measured
', given as 'Body weight Measured'}; {SNOMED CT code '27113001' = 'Body weight', given as 'Body
weight'}; {http://acme.org/devices/clinical-codes code 'body-weight' = 'body-weight', given as '
Body Weight'})</span></p><p><b>subject</b>: <a>Patient/example</a></p><p><b>context</b>: <a>Enco
unter/example</a></p><p><b>effective</b>: 28/03/2016</p><p><b>value</b>: 185 lbs<span> (Details:
UCUM code [lb_av] = 'lb_av')</span></p></div>"
  ];
  fhir:Observation.status [ fhir:value "final"];
  fhir:Observation.category [
     fhir:index 0;
     fhir:CodeableConcept.coding [
       fhir:index 0;
       fhir:Coding.system [ fhir:value "http://hl7.org/fhir/observation-category" ];
       fhir:Coding.code [ fhir:value "vital-signs" ];
       fhir:Coding.display [ fhir:value "Vital Signs" ]
     ]
  ];
  fhir:Observation.code [
     fhir:CodeableConcept.coding [
       fhir:index 0;
       a loinc:29463-7;
       fhir:Coding.system [ fhir:value "http://loinc.org" ];
       fhir:Coding.code [ fhir:value "29463-7" ];
```

FHIR Data Types

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

FHIR SD —> FHIR RDF —> FHIR SD

Which is why:

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

instead of:

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

Preserving Extensibility

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.

RDF “Round Trippability”

JSON

```
{
  "resourceType": "DiagnosticReport",
  "id": "f201",
  "text": {
```

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

Identify Document Root

Preserve List Order

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

RDF Rendering Extensions – Concept URIs

```
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" ]
   ]
];
```

RDF

<http://snomed.info/id/394914008>

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

JSON

RDF Rendering Extensions – Resource Types

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

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

Resource Type

Construct the actual URI

Ontology Header

```
# - 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> .
```

Requirement: import FHIR URI Catalog

- No ‘import in RDF’ – have to use OWL
- owl:imports requires owl:Ontology
- ‘f201.ttl’ vs. ‘f201’ – reasoners don’t cope well with something that is *both* a fhir:DiagnosticReport *and* an owl:Ontology (ontology *describes* report, not IS the report)

Stay tuned:

- Looking at http://hl7.org/fhir/DiagnosticReport/owl/f201 as an alternative

Accessing FHIR RDF

- Mime Types
  - ‘text/turtle’
  - (Discussing others)
- Format
  - _format=
    - ttl
    - turtle
    - text/
    - text/turtle

Accessing FHIR RDF

Supporting servers

- STU3 (http://hl7.org/fhir/)
  - Doesn't recognize format or mime types – have to access physical file
  - http://hl7.org/fhir/Patient/f201 ← NO
  - http://hl7.org/fhir/patient-example-f201-roel.ttl
- Latest Build (http://build.fhir.org/)
  - Same as STU3
- FHIR Test Server (http://test.fhir.org/Patient)
  - http://test.fhir.org/r3/Patient/f201?_format=text/turtle
  - Accept: text/turtle;q=0.9, …

> curl http://test.fhir.org/r3/Patient/204?_format=text/turtle

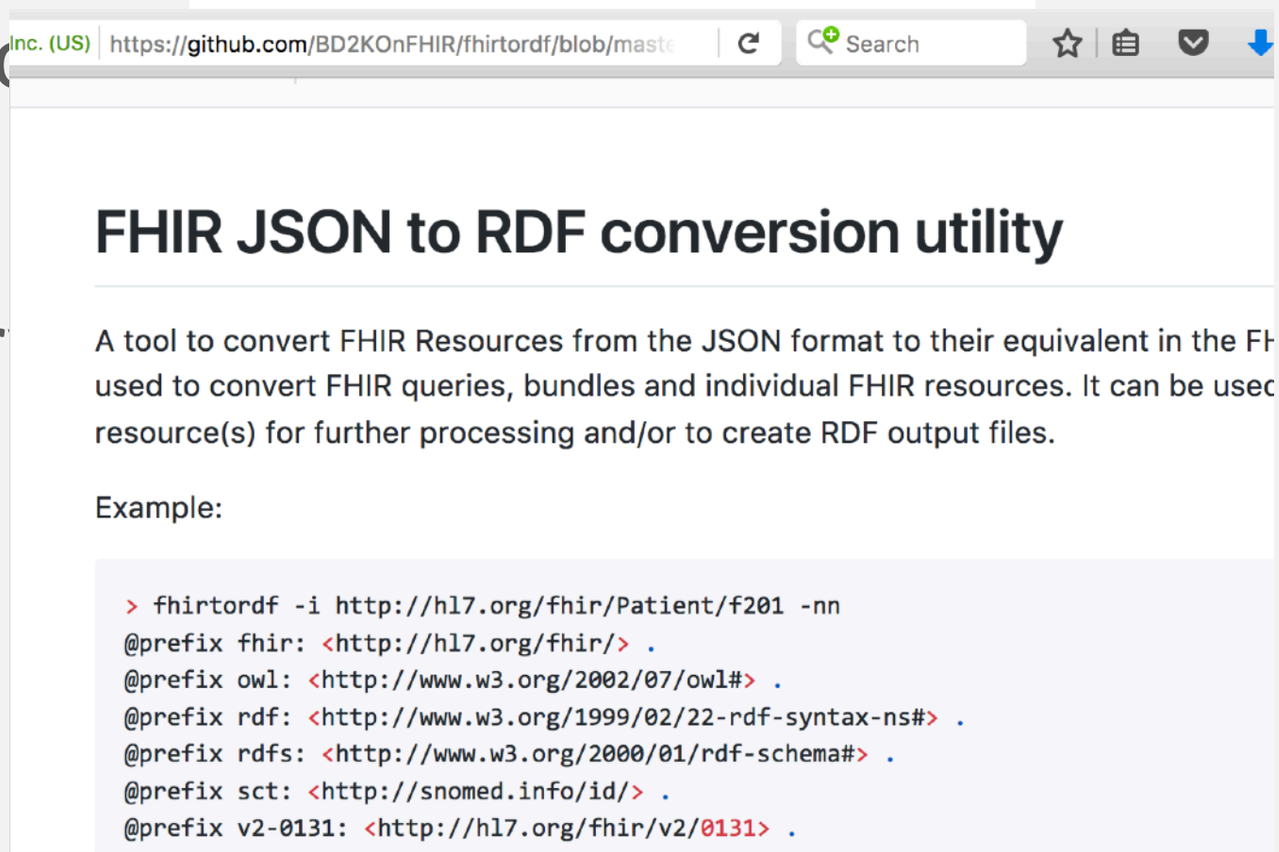
```
@prefix fhir: <http://hl7.org/fhir/> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<http://test.fhir.org/r3/Patient/204>  a fhir:Patient  ;
  fhir:nodeRole fhir:treeRoot  ;
  fhir:Resource.id  [  fhir:value "204"^^xsd:string ]  ;
  fhir:Resource.meta  [
    fhir:Meta.versionId  [  fhir:value "1"^^xsd:string ]  ;
    fhir:Meta.lastUpdated  [  fhir:value
"2017-09-26T21:59:49Z"^^xsd:dateTime ]
  ]  ;
  fhir:DomainResource.text  [
```

Accessing FHIR RDF – JSON to RDF

FHIR JSON to RDF Converte

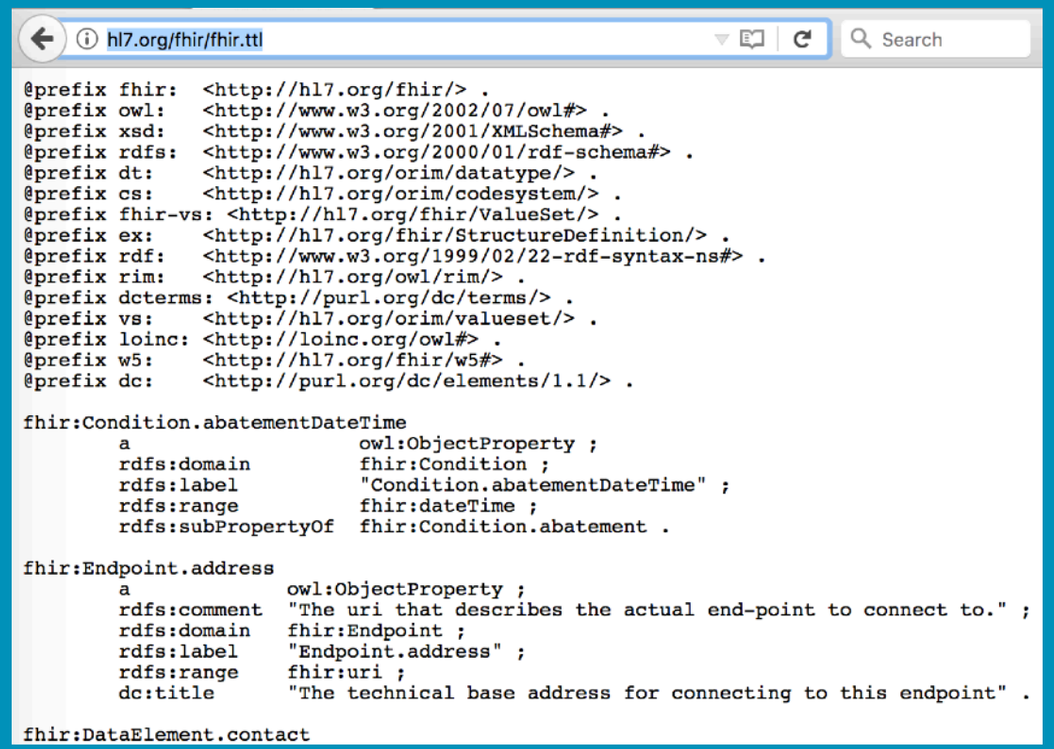
- Python3
- Command line and librar
- Used in i2FHIRb2

https://github.com/BD2KOnFHIR/fhirtordf



FHIR Structure Vocabulary

- Sometimes referred to as the "FHIR Ontology"…
- http://hl7.org/fhir/fhir.ttl
- Direct representation of FHIR StructureDefinition information
  - (Very) proper subset
- Purpose is (or includes):
  - Define the classes and predicates used in the FHIR RDF representation



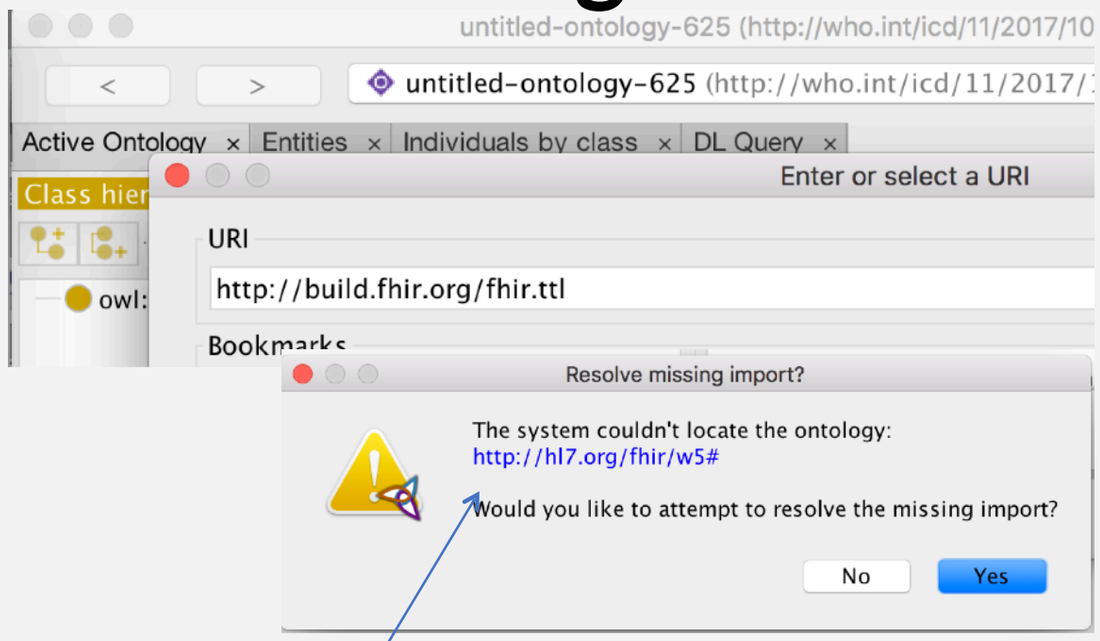
FHIR Structure Vocabulary

```
fhir:Observation  a       owl:Class ;
        rdfs:comment      "Measurements and simple assertions made about a patien
        rdfs:label        "Observation" ;
        rdfs:subClassOf   fhir:DomainResource , w5:clinical.diagnostics ;
        rdfs:subClassOf   [ a                    owl:Restriction ;
                            owl:allValuesFrom    fhir:ObservationRelatedComponent ;
                            owl:onProperty       fhir:Observation.related
                          ] ;
```

```
rdfs:subClassOf   [ a                    owl:Restriction ;
                    owl:cardinality      1 ;
                    owl:onProperty       fhir:Observation.status ;
                    owl:someValuesFrom   fhir:code
                  ] ;
```

```
fhir:Observation.status
        a                   owl:ObjectProperty ;
        rdfs:comment        "The status of the result value." ;
        rdfs:domain         fhir:Observation ;
        rdfs:label          "Observation.status" ;
        rdfs:range          fhir:code ;
        rdfs:subPropertyOf  w5:status ;
        dc:title            "registered | preliminary | final | amended +" .
```

Protégé

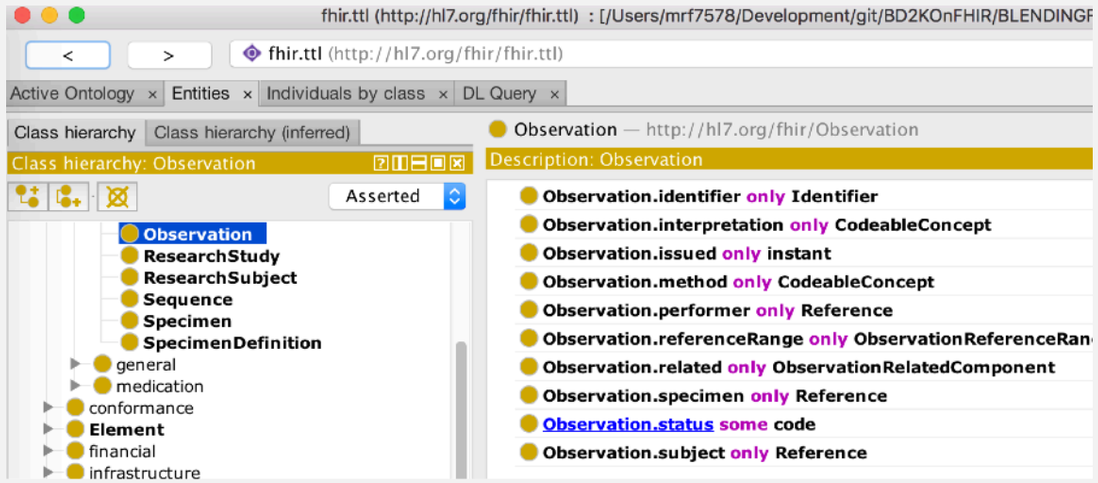


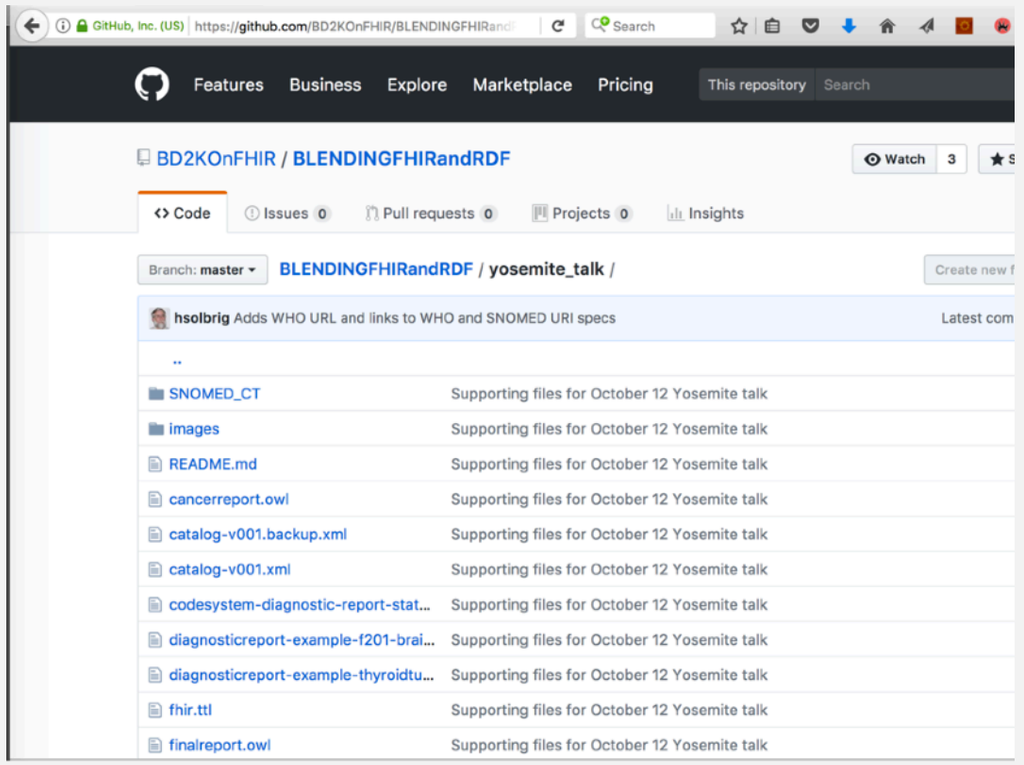
ISSUE

Short term solution:

Keep a local copy of http://hl7.org/fhir/w5.ttl

FHIR Structure Vocabulary in Protégé

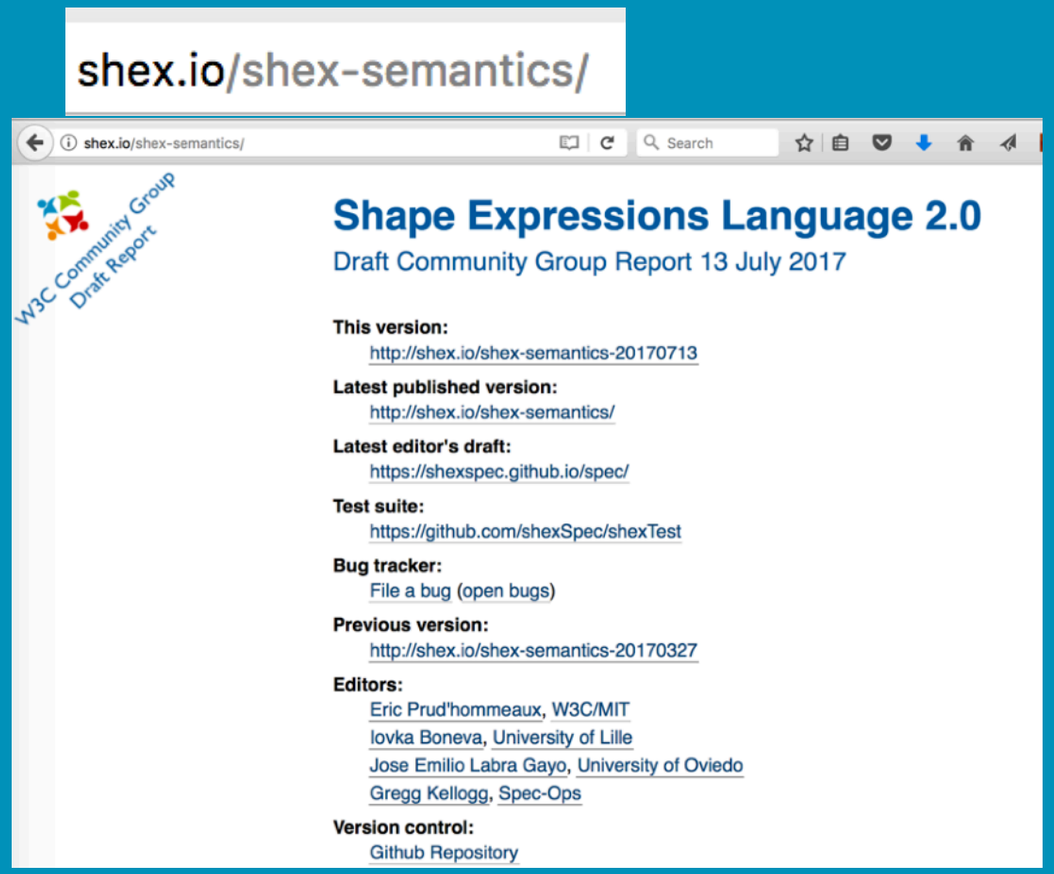




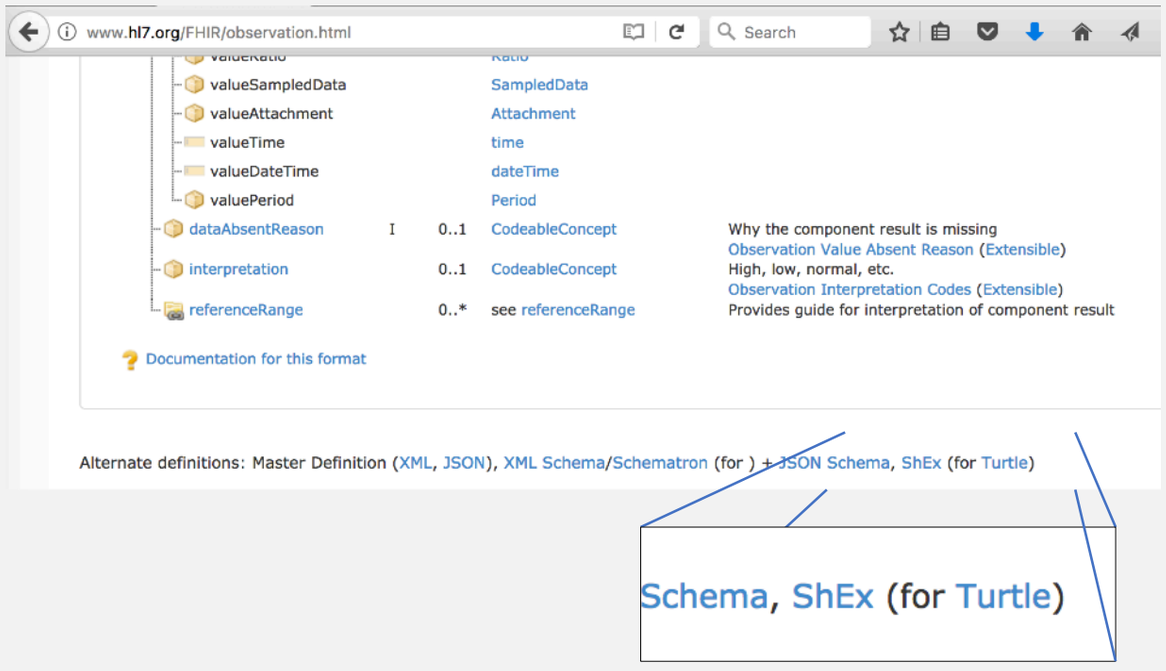
https://github.com/BD2KOnFHIR/BLENDINGFHIRandRDF/tree/master/yosemite_talk

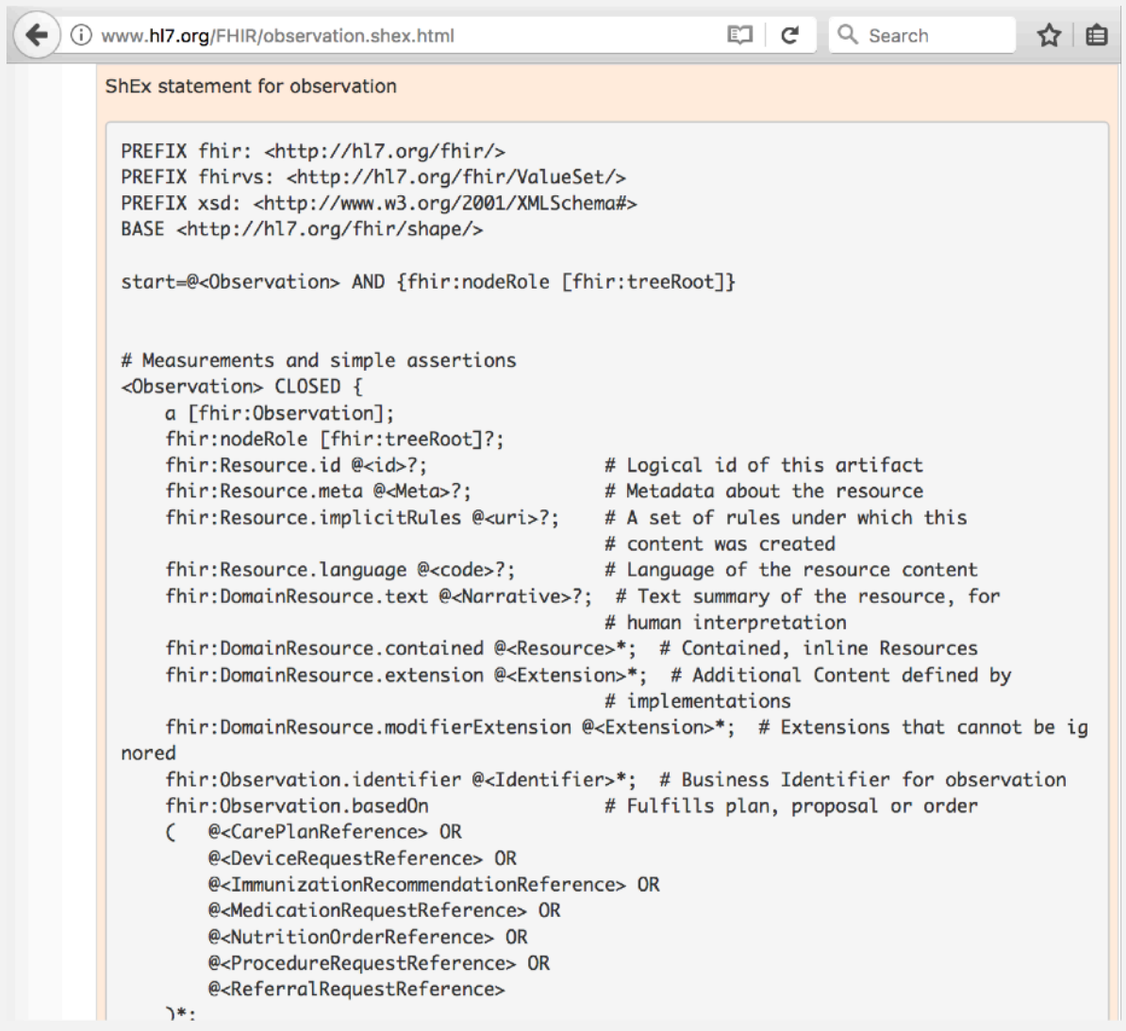
Shape Expressions (ShEx) - RDF “Schema”

- “Schema” because “RDF Schema” is also used for something else
- Called Shape Expressions (ShEx)
  - Good for almost as many puns as “FHIR” …
  - … but you have to be very careful

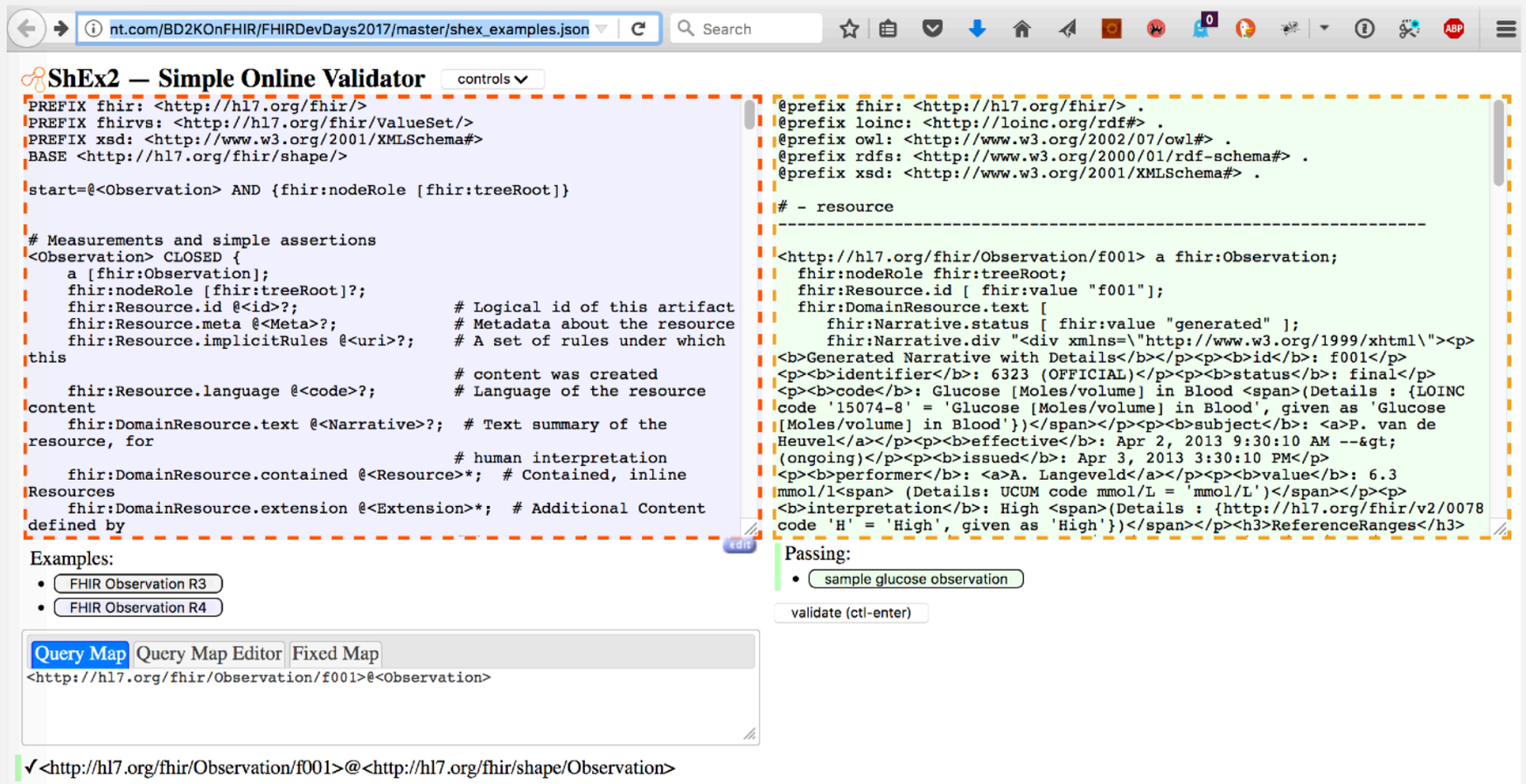


ShEx Schemas available for all R4 resources





ShEx Conformance checking



http://shaclex.herokuapp.com/validate?examples=https://raw.githubusercontent.com/BD2KOnFHIR/FHIRDevDays2017/master/shex_examples.json

http://rawgit.com/shexSpec/shex.js/master/doc/shex-simple.html?examples=https://raw.githubusercontent.com/BD2KOnFHIR/FHIRDevDays2017/master/shex_examples.json

FHIR and RDF -- Summary

- FHIR R4 specification includes RDF representational format
  - RDF is available on some FHIR servers
  - Python JSON to RDF conversion tool is available
- FHIR RDF specification includes FHIR Structure Vocabulary
  - A public, standard catalog of URI's for FHIR resources
  - Potentially the "Dublin Core" for healthcare?
- Shape Expression (ShEx) schemas are available for FHIR Resources
  - Today: basic RDF validation
  - Near future: will include slicing, constraints and other enhancements

Part 3

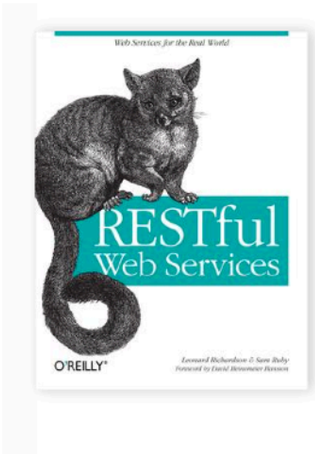
FHIR, RDF and the Semantic Web

- The FHIR RDF Specification
- **Why RDF and FHIR**

FHIR RDF *is* ~~not~~ Resource-Oriented Architecture

That's the Resource-Oriented Architecture. It's just four concepts:

1. Resources
1. Their names (URIs)
1. Their representations
1. The links between them



RESTful Web Services

26 reviews

by Sam Ruby, Leonard Richardson

Publisher: O'Reilly Media, Inc.

Release Date: May 2007

ISBN: 9780596529260

Topics: Java

View table of contents

and four properties:

1. Addressability
2. Statelessness
3. Connectedness
4. A uniform interface

“A web service is connected to the extent that you can put the service in different states just by following links and filling out forms”

http://my.safaribooksonline.com/9780596529260/restclients

FHIR “turtles” - ~~five~~ **six** different languages

- StructureDefinition & friends — core model
- Extension — tag/value
- Constraint — FhirPath
- “Slicing” —
- Value Sets
- Terminology Properties

RDF + ShEx (can) reduce these to a *single* idiom

FHIR Structure Vocabulary (fhir.ttl)

fhir.schema.org

Search

About Schemas Documentation

Welcome to fhir.schema.org

Introduction

The FHIR® – Fast Healthcare Interoperability Resources are built from a set of modular components called "Reso
resources could potentially be viewed as a loose set of "semantics" that could be used as markup for HTML, XML

While we aren't certain whether the FHIR resource constructs make sense in the context of the schema.org ecosy
this question might be to propose a way of representing FHIR in the schema.org environment and use it to demo

To accomplish this, we have created two schema.org extensions:

1. The FHIR W5 "ontology" – this provides a upper level classification of FHIR resources, as well as providing
   predicates
2. The FHIR resource definitions themselves – this is the set of resources and their attributes as defined in t

It would also be possible (and even sensible) to extend this core ontology with appropriate FHIR Profiles

Relationship to other schema.org schemas

At the moment, there is almost no overlap between the FHIR schema elements and the components of the core s
ontology (w5) is currently a direct subclass of THING. All other classes in the W5 and FHIR schemas subclass W5
structure is also preserved.

Assuming that the FHIR schema.org resource can be proven to be potentially useful, an obvious next step would

- The proposed Health and medical types
- The Bioschemas proposal
- Schema.org root classes themselves

Thing > Resource > DomainResource > Observation
clinical.diagnostics > Observation

Base StructureDefinition for Observation Resource

Usage: Fewer than 10 domains

[more.

Property	Expected Type	Description
Properties from Observation		
Observation.bodySite	body-site	Indicates the site on the subject's body where the observation was made (i.e. the target site).
Observation.category	observation-category	A code that classifies the general type of observation being made. This is used for searching, sorting and display purposes.
Observation.code	observation-codes or ldlcholesterol-codes	LDL Cholesterol –measured or calculated per code.
Observation.comments	Text	May include statements about significant, unexpected or unreliable. values, or information about the source of the value where this may be relevant to the interpretation of the result.
Observation.component	BackboneElement	Some observations have multiple component observations. These component observations are expressed as separate code value pairs that share the same attributes. Examples include systolic and diastolic component observations for blood pressure measurement and multiple component observations for genetics observations.
Observation.component.code	observation-codes	Describes what was observed. Sometimes this is called the observation "code".
Observation.component.dataAbsentReason	observation-valueabsentreason	Provides a reason why the expected value in the element Observation.value[x] is missing.
Observation.component.valueAttachment	Attachment	The information determined as a result of making the observation, if the information has a simple value.
ableConcept	CodeableConcept	The information determined as a result of making the observation, if the information has a simple value.
od	Period	The information determined as a result of making the observation, if the information has a simple value.
ity	Quantity	The information determined as a result of making the observation, if the information has a simple value.

Observation

Defined in the fhir.schema.org extension.

Canonical URL: http://schema.org/Observation

FHIR Structure Vocabulary (fhir.ttl)

PotentialUse Cases

- Provenance for FHIR Narrative Text
- HTML FHIR Interchange Format
- Markup for personal device measurements
- Mapping for HL& Continuity of Care (CCD) and other data formats
- Markup for blogs and other Personal Health Records (PHR)
- Linking Medical Knowledge / Data / Products

WHY FHIR RDF

Where are we on that curve, people want to know? Well, my answer is that as far as I can tell, the rate of

HL7 is an IT standardisation Organization. We have severely limited ability to standardise the practice of healthcare or medicine. We just have to accept them as they are. So we can't provide prescriptive information models. We can't force vendors or institutions to do things the same way. We can't force them to share particular kinds of information at particular times. All we can do is describe a common way to do it, if people want to do it.

So what things do I see that I think are hype? Well there are many symptoms, but one fundamental cause: there's an apparently widely held view that "FHIR will solve interoperability".

It's not going to.

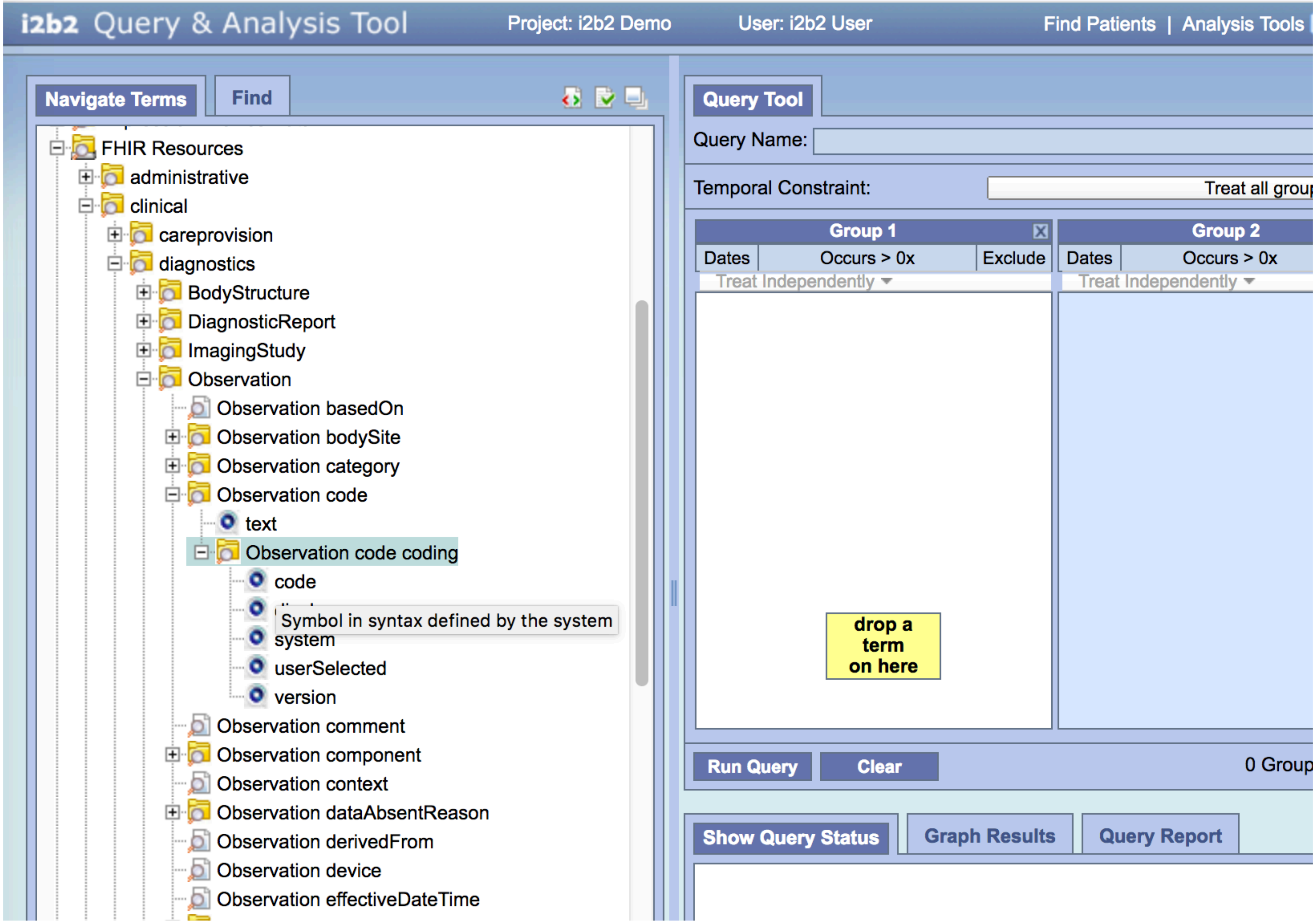
FHIR is 2 things: a technology, and a culture. I'm proud of both of those things. I think both of those will make a huge contribution towards solving the problems of interoperability in healthcare. But people who think that problem will be solved anytime soon don't understand the constraints we work under.

HL7 is an IT standardisation Organization. We have severely limited ability to standardise the practice of

!!!

http://www.healthintersections.com.au/?p=2514

FHIR Structure Vocabulary (FSV) in i2b2



I2b2 Client Query with Literal Model

Query Tool

Query Name: lt140Triglicerides1

Temporal Constraint: Items Instance will be the same

Group 1			Group 2			Group 3		
Dates	Occurs > 0x	Exclude	Dates	Occurs > 0x	Exclude	Dates	Occurs > 0x	Exclude
Items Instance will be the same			Items Instance will be the same			*Occurs in Same Encounter*		
Observation code coding [code [Exact: 2571-8]]			Observation code coding [system [Exact: http://loinc.org]]			Observation valueQuantity [value < 140]		
one or more of these			one or more of these			one or more of these		

AND AND

Run Query | Clear | 3 Groups | New Group

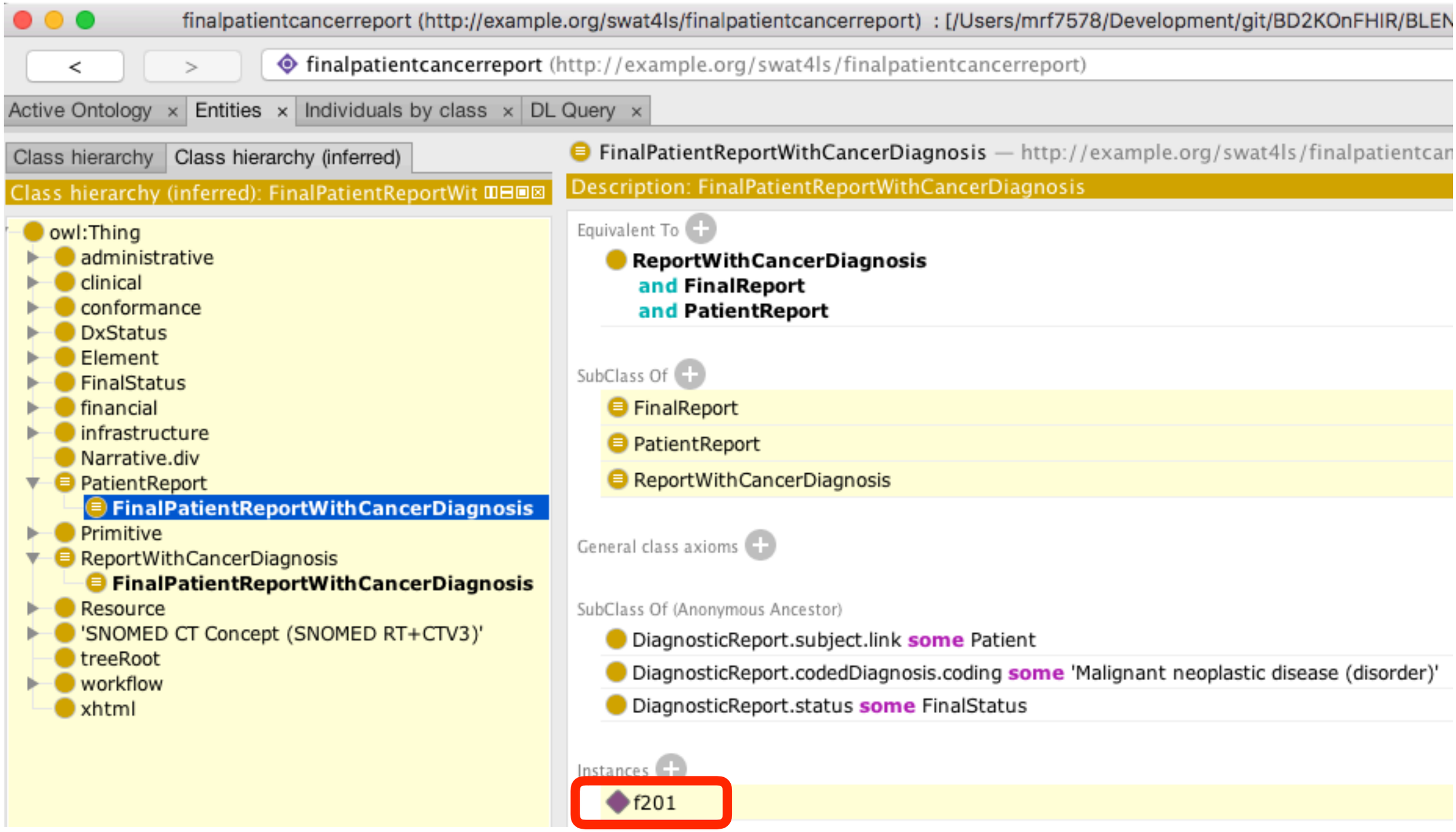
Show Query Status | Graph Results | Query Report

Number of patients

82

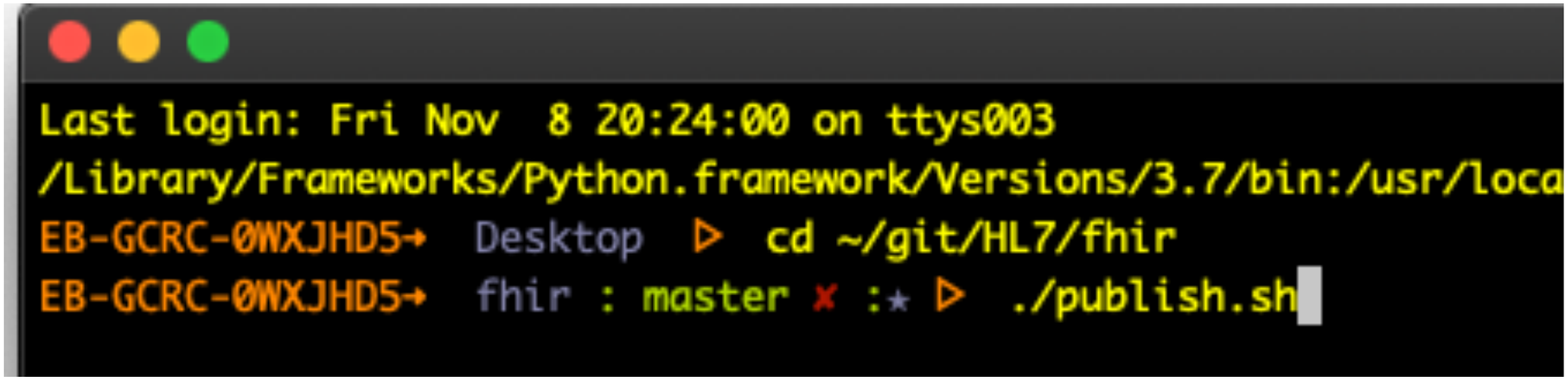
For Query "lt140Triglicerides1"

Result


finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport) : [/Users/mrf7578/Development/git/BD2KOnFHIR/BLEN
finalpatientcancerreport (http://example.org/swat4ls/finalpatientcancerreport)
Active Ontology
Entities
Individuals by class
DL Query
Class hierarchy
Class hierarchy (inferred)
Class hierarchy (inferred): FinalPatientReportWit
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/finalpatientcan
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

HOW FHIR RDF is generated today

- Clone https://github.com/HL7/fhir
- cd fhir



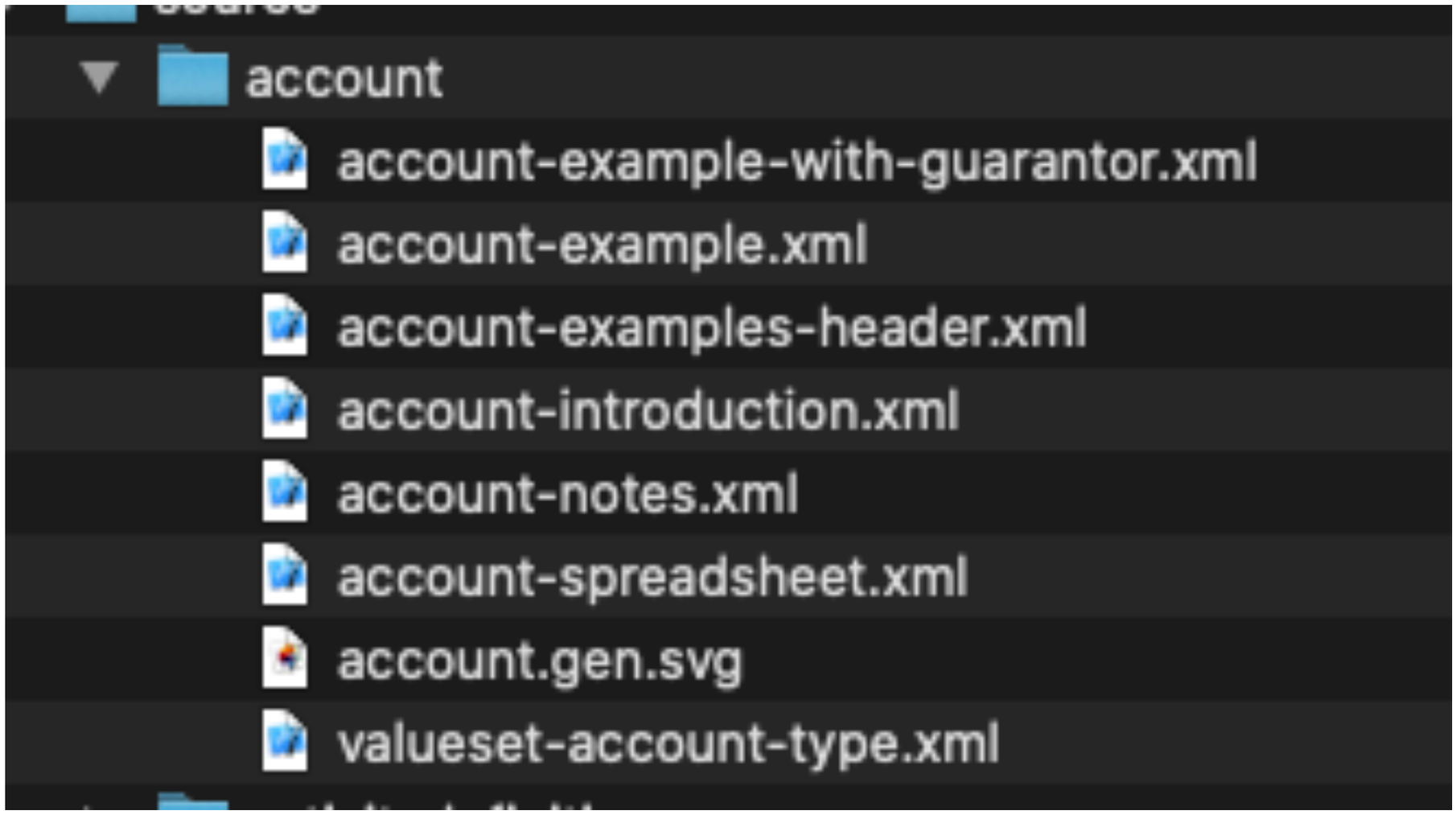
… time elapses …

How HL7 FHIR is Generated

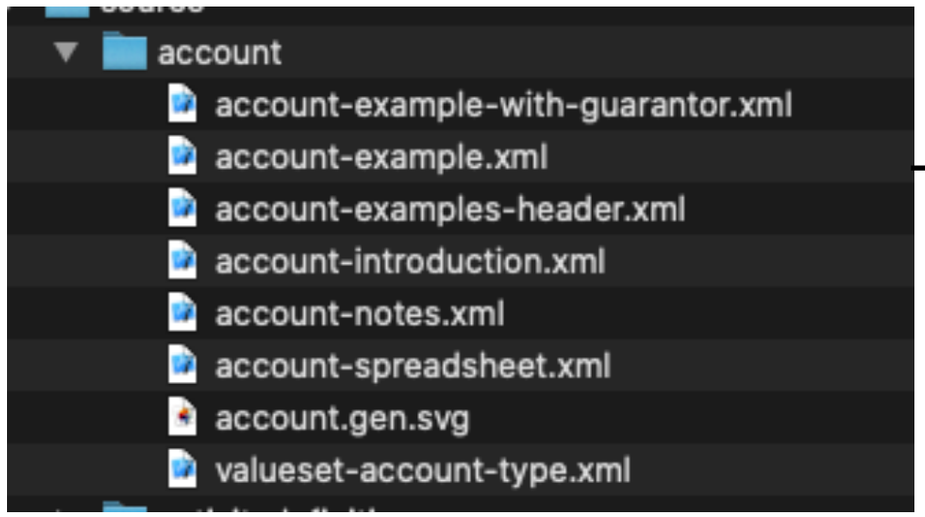
```
[java]  ...resource Resource                                    3.554 266sec 1307MB
[java]  ...resource Account                                     0.893 267sec 1845MB
[java]  ...resource ActivityDefinition                          1.785 268sec 3349MB
[java]  ...resource AdministrableProductDefinition              6.672 275sec 1778MB
[java]  ...resource AdverseEvent                                 3.68 279sec 3696MB
[java]  ...resource AllergyIntolerance                          2.893 282sec 1368MB
[java]  ...resource Appointment                                  2.29 284sec 3356MB
[java]  ...resource AppointmentResponse                         3.622 288sec 1339MB
```

What is happening

fhir/source/account:



What is happening



Core Parser

StructureDefinition Instance

StructureDefinition Serializations

- Account.profile.xml
- Account.profile.json
- Account.profile.ttl

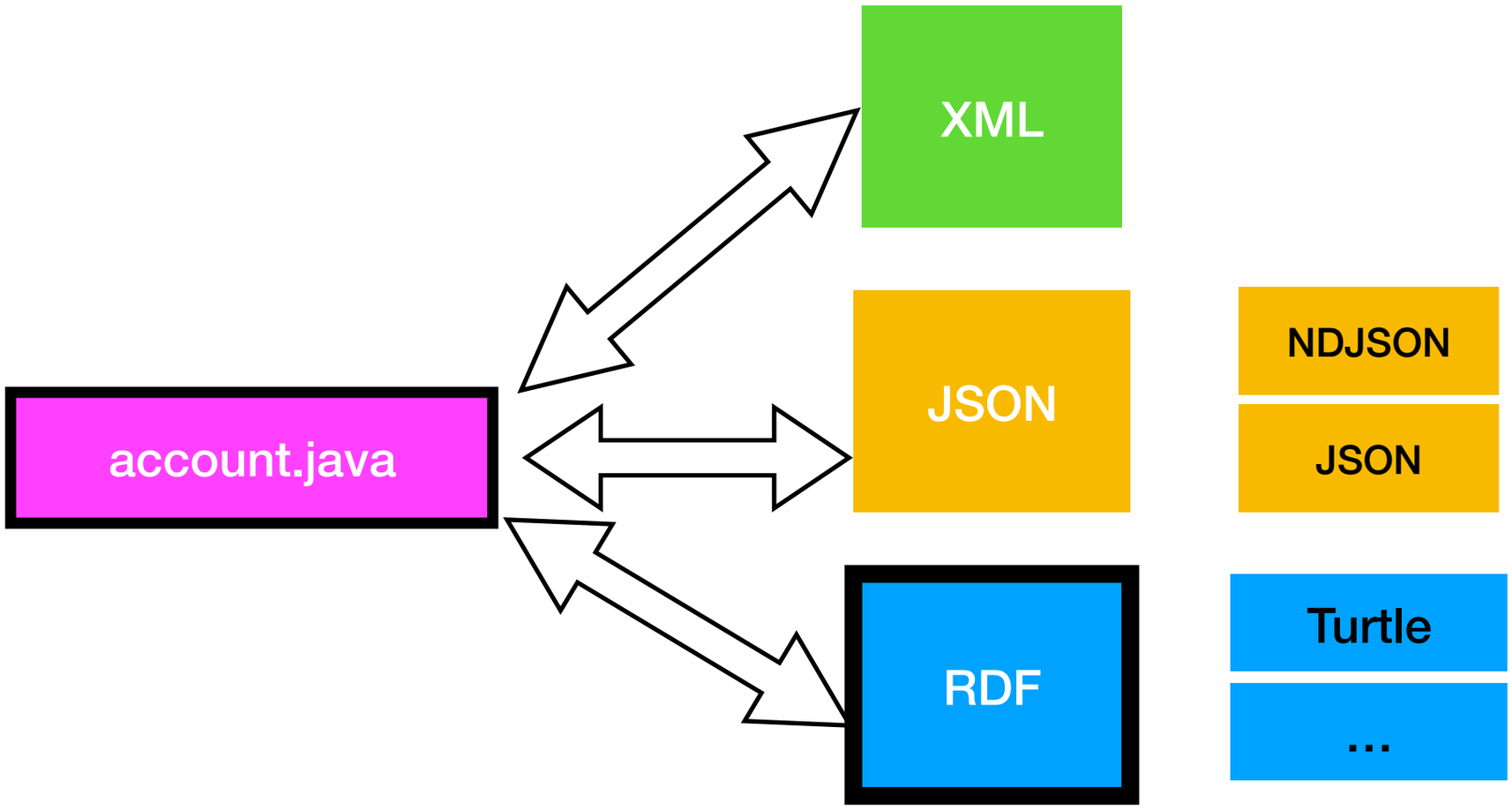
Representations

- HTML Rendering
- XML Example
- JSON Example

Model Representations

- account.java
- Account.xsd
- Account.sch
- Account.shex

FHIR Representation Formats



Credits

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