

CIMI and RDF

Harold Solbrig
Mayo Clinic

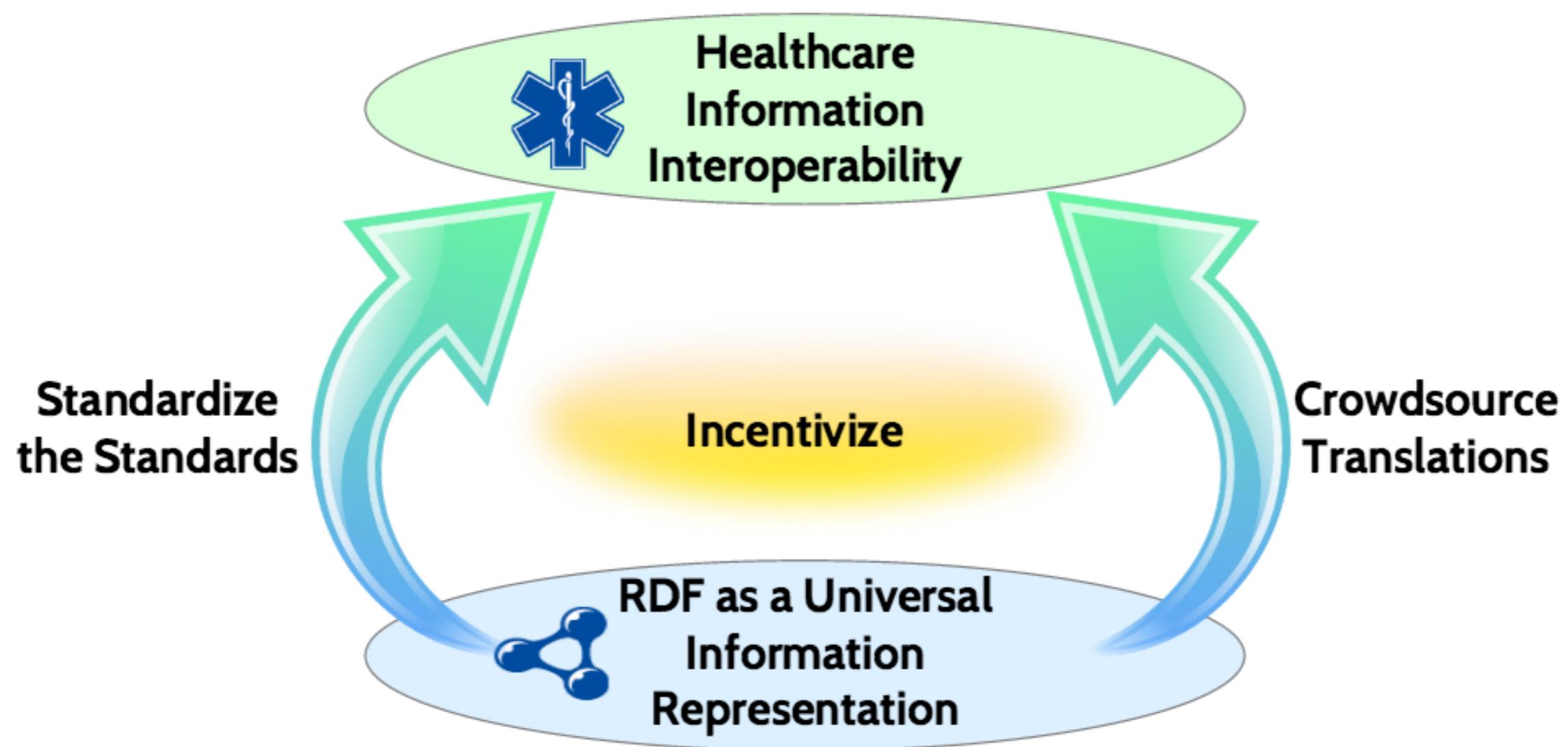


Clinical Information Modeling Initiative

CIMI and RDF — Harold Solbrig

Page 1

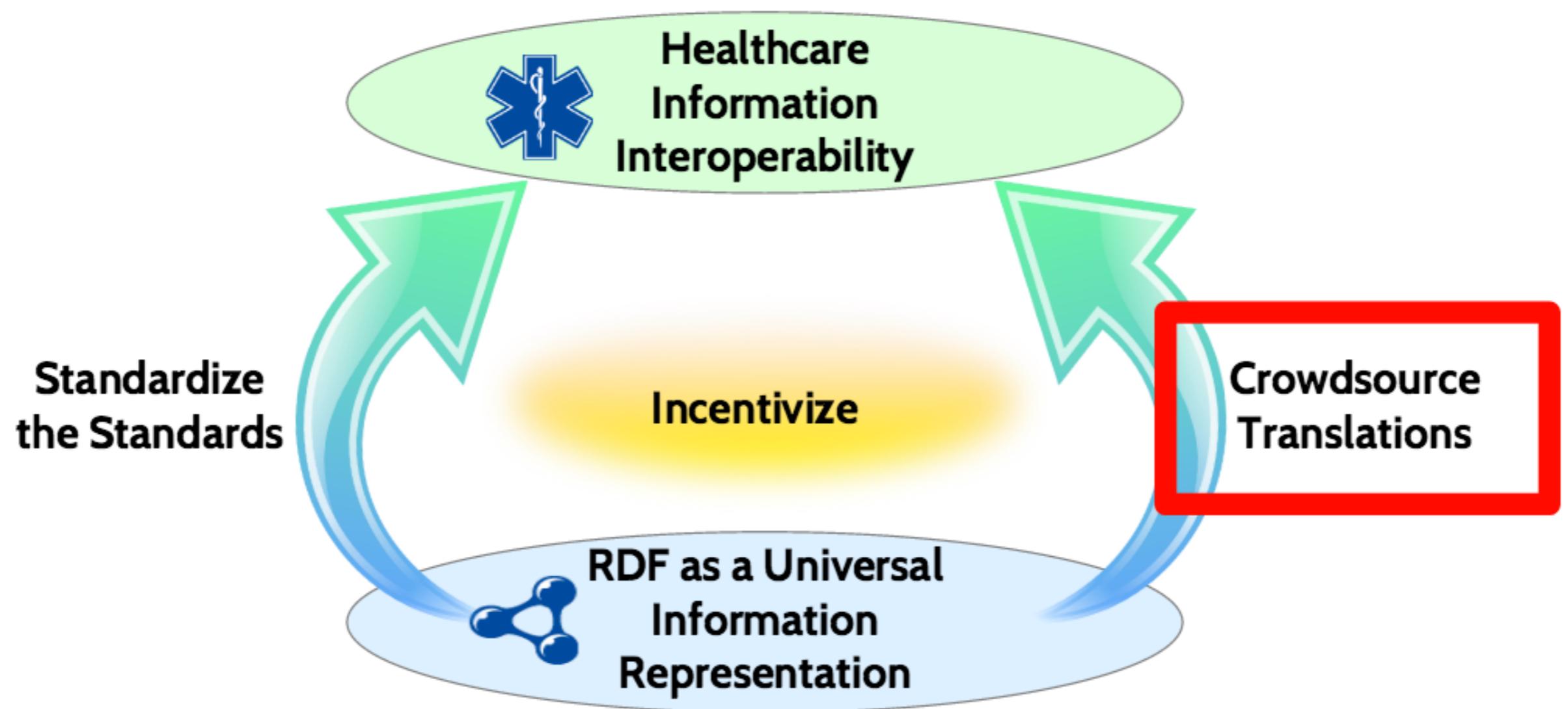
Interoperability Roadmap



<http://YosemiteProject.org/>

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Interoperability Roadmap



<http://YosemiteProject.org/>

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CIMI and RDF

Harold Solbrig
Mayo Clinic

Disclaimer: The opinions expressed in this document are those of the author and do not necessarily those of the CIMI Organization or the Mayo Clinic. Anyone who says otherwise is itching for a fight.

Outline

- Introduction to CIMI
- CIMI and Constraint Modeling
- Realizing CIMI as RDF + ShEx

Outline

- **Introduction to CIMI**
- CIMI and Constraint Modeling
- Realizing CIMI as RDF + ShEx

Clinical Information Modeling Initiative CIMI



Clinical Information Modeling Initiative

CIMI and RDF — Harold Solbrig

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The Ultimate Value Proposition of CIMI

Interoperable sharing of:

- Data
- Information
- Applications
- Decision logic
- Reports
- Knowledge



Patient



Core Assumptions

‘The complexity of modern medicine exceeds the inherent limitations of the unaided human mind.’

~ David M. Eddy, MD, Ph.D.

‘... man is not perfectible. There are limits to man’s capabilities as an information processor that assure the occurrence of random errors in his activities.’

~ Clement J. McDonald, MD



XTEST, BILI

Room: N901

DOB: 03/02/2007

Admit MD: BENNETT, STE

MRN: 10489

Logout

Admit Date: 03/02/2007

ENC #: 5761309

Age: 5D Sex: M

Admit Dx: INTERFACE TE

MMI: 548387685

Options

Select Patient
Clinic Schedule
Alert Review
Allergies
Clinical Notes
ECG
EDIS
Encounters
Demographics
Height/Weight
HELP/Tandem
HotText
Image Acquisition
Inbox
Inpatient Reports
Insurance
Lab
Lab Order Entry
Message Log
Meds Review
Micro
POE - Ordersets
Population View
Problems
Protocols
Radiology
Report Manager
Rx
Vital Signs
Web Forms
Web Kids
Nutrition Report

E-Resources
Need Help?
Password
CD Info

Comments

Webforms

Note Type: Progress Notes

Load Last Load Data Save Clear

Date: 3/7/2007 10:18



Note Status: Preliminary/Signable

Form: Bilirubin Management Tool

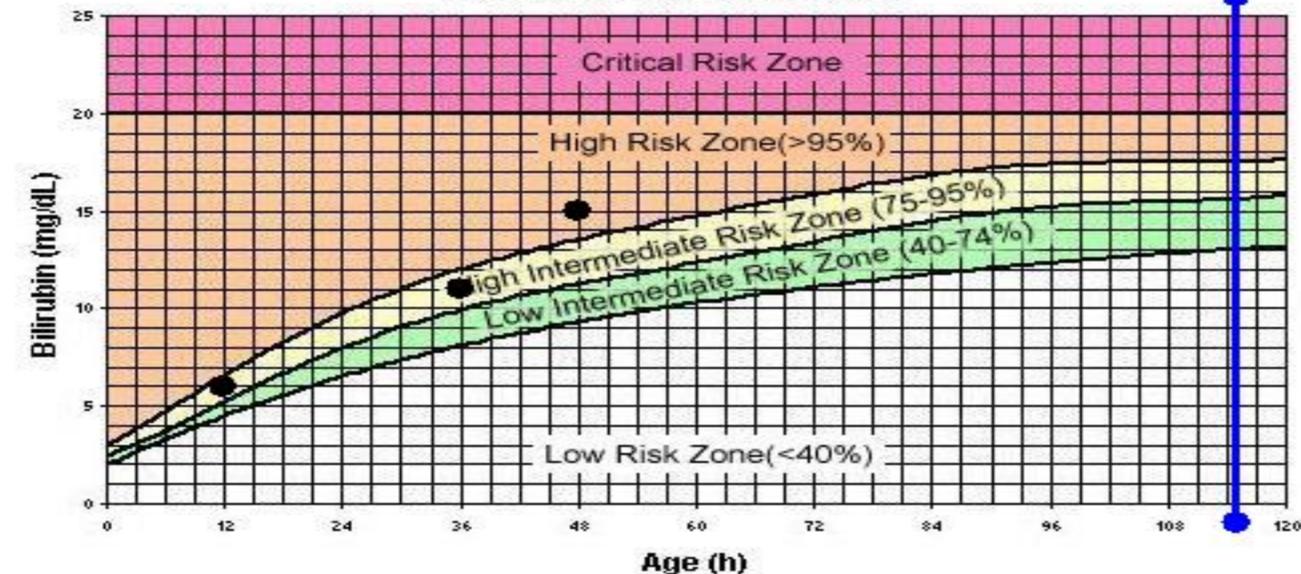
Prefs

Clinician: THOMPSON, BRYCE S

POC: Lake Park IHC

Current Encounter: Not Encounter Related

Hour Specific Bilirubin Risk Chart for Term & Near-Term Infants with NO Additional Risk Factors



Birth Date/Time

3/2/2007 15:12

Hours of Age

115.1

EDIT BIRTH DATE/TIME

Mom: O Negative

Baby: O Negative

Direct/Indirect Coombs

Antibody Screen.Cells I+II+III

03/06/2007 17:34

Positive

Transcutaneous Bilirubin Entry

ENTER DATE/TIME

Performed by: THOMPSON, BRYCE S

TcB Value:

ENTER

Contact Phone Numbers

1st:

2nd:

Date/Time	Result	Hours of Age	Value:Test	Risk Zone
03/03/2007 03:10	6.0	11.9	NSB : Neonatal Bilirubin, Serum or Plasma	High Intermediate Risk (75-95%)
03/04/2007 03:22	11.0	36.1	TcB : Transcutaneous Bilirubin Event Id	High Intermediate Risk (75-95%)
03/04/2007 15:00	15.0	47.8	NSB : Neonatal Bilirubin, Serum or Plasma	High Risk (>95%)

Order

Set:

High Risk

[Newborn Bilirubin \(High Risk Zone\)](#)

Jump to: All

Orders		Use this order if...
Laboratory <div style="display: flex; align-items: center;"> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bilirubin, Neonatal Total in 6-12 hours. Follow up on Date: <input type="text"/> at Time: <input type="text"/> at Location: <input type="text"/> </div>		
Others/Misc <div style="display: flex; align-items: center;"> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Phototherapy </div>		
Name of Provider: <input type="text"/> notified on Date: <input type="text"/> at Time: <input type="text"/> <input type="checkbox"/> Other instructions <input type="text"/>		
<input checked="" type="radio"/> English <input type="radio"/> Spanish		Generate Reports

Management of Hyperbilirubinemia in the Newborn Infant 35 or More Weeks of Gestation

Subcommittee on Hyperbilirubinemia

ABSTRACT

Jaundice occurs in most newborn infants. Most jaundice is benign, but because of the potential toxicity of bilirubin, newborn infants must be monitored to identify those who might develop severe hyperbilirubinemia and, in rare cases, acute bilirubin encephalopathy or kernicterus. The focus of this guideline is to reduce the incidence of severe hyperbilirubinemia and bilirubin encephalopathy while minimizing the risks of unintended harm such as maternal anxiety, decreased breastfeeding, and unnecessary costs or treatment. Although kernicterus should almost always be preventable, cases continue to occur.

These guidelines provide a framework for the prevention and management of hyperbilirubinemia in newborn infants of 35 or more weeks of gestation. In every infant, we recommend that clinicians 1) promote and support successful breastfeeding; 2) perform a systematic assessment before discharge for the risk of severe hyperbilirubinemia; 3) provide early and focused follow-up based on the risk assessment; and 4) when indicated, treat newborns with phototherapy or exchange transfusion to prevent the development of severe hyperbilirubinemia and, possibly, bilirubin encephalopathy (kernicterus).

Management of Hyperbilirubinemia in the Newborn Infant 35 or More Weeks of Gestation
Pediatrics, Vol. 114 no. 1 July 1, 2004

RECOMMENDATION 2.0: Clinicians should perform ongoing systematic assessments during the neonatal period for the risk of an infant developing severe hyperbilirubinemia.

Blood Typing

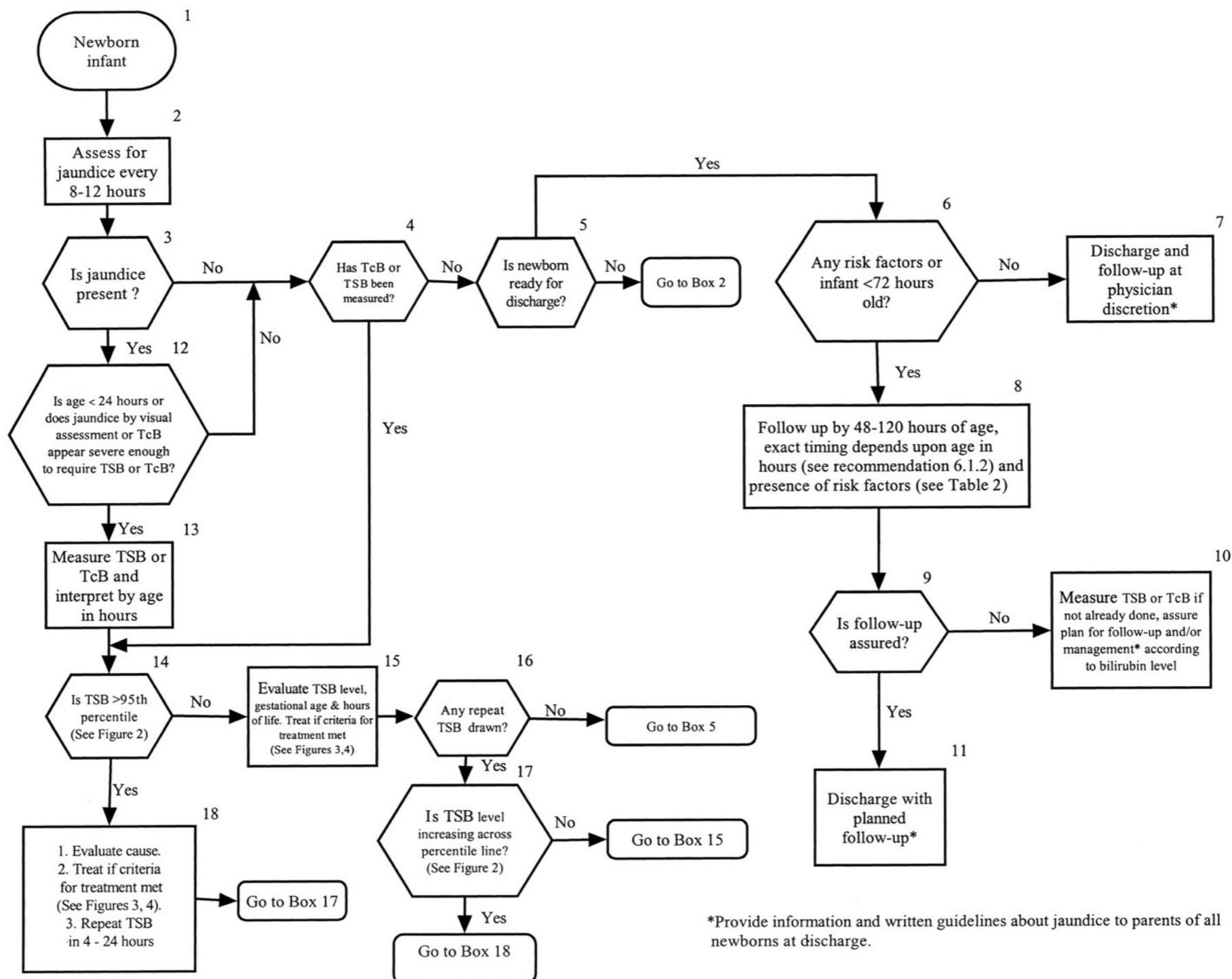
RECOMMENDATION 2.1: All pregnant women should be tested for ABO and Rh (D) blood types and have a serum screen for unusual isoimmune antibodies (evidence quality B: benefits exceed harms).

RECOMMENDATION 2.1.1: If a mother has not had prenatal blood grouping or is Rh-negative, a direct antibody test (or Coombs' test), blood type, and an Rh (D) type on the infant's (cord) blood are strongly recommended (evidence quality B: benefits exceed harms).

RECOMMENDATION 2.1.2: If the maternal blood is group O, Rh-positive, it is an option to test the cord blood for the infant's blood type and direct antibody test, but it is not required provided that there is appropriate surveillance, risk assessment before discharge, and follow-up²⁰ (evidence quality C: benefits exceed harms).

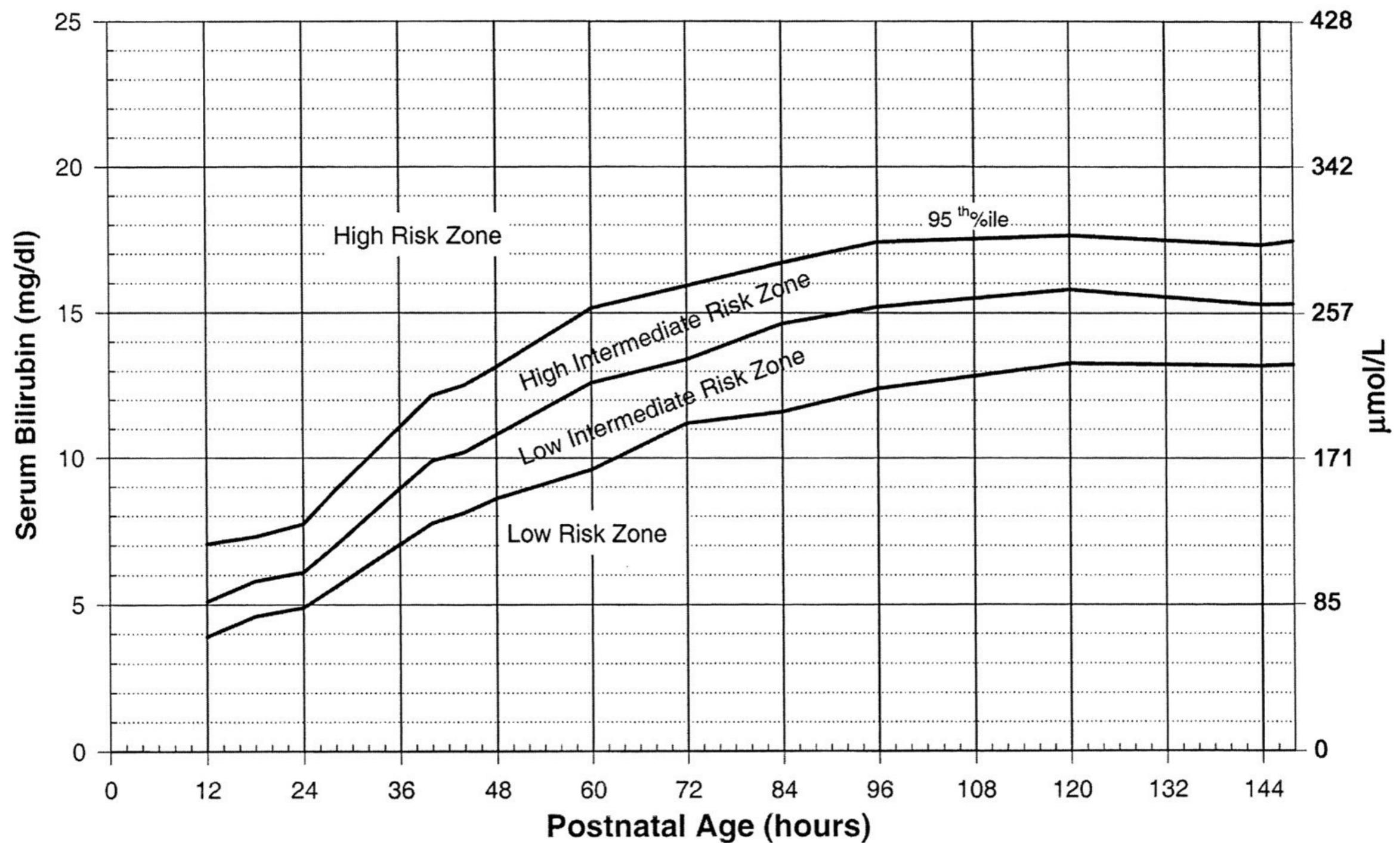
In newborn infants, jaundice can be detected by blanching the skin with digital pressure, revealing the underlying color of the skin and subcutaneous tissue. The assessment of jaundice must be performed in a well-lit room or, preferably, in daylight at a window. Jaundice is usually seen first in the face and progresses caudally to the trunk and extremities,²¹ but visual estimation of bilirubin levels from the degree of jaundice can lead to errors.²²⁻²⁴ In most infants with TSB levels of less than 15 mg/dL (257 µmol/L), noninvasive TcB-measurement devices can provide a valid estimate of the TSB level.^{2,25-29} See Appendix 1 for additional information on the clinical evaluation of jaundice and the use of TcB measurements.

Algorithm for the management of jaundice in the newborn nursery.



Subcommittee on Hyperbilirubinemia Pediatrics 2004;114:297-316

Nomogram for designation of risk in 2840 well newborns at 36 or more weeks' gestational age with birth weight of 2000 g or more or 35 or more weeks' gestational age and birth weight of 2500 g or more based on the hour-specific serum bilirubin values.



Subcommittee on Hyperbilirubinemia Pediatrics 2004;114:297-316

XTEST, BILI

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Image Acquisition
Inbox
Inpatient Reports
Insurance
Lab
Lab Order Entry
Message Log
Meds Review
Micro
POE - Ordersets
Population View
Problems
Protocols
Radiology
Report Manager
Rx
Vital Signs
Web Forms
Web Kids
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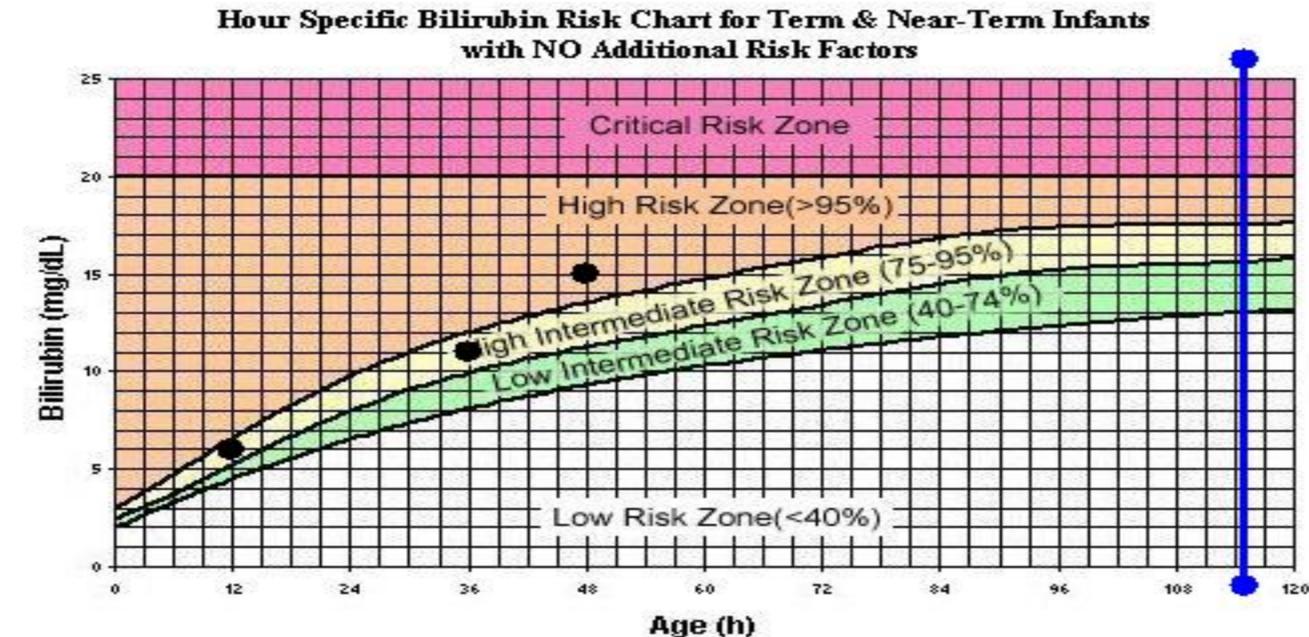
Note Status: Preliminary/Signable

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Prefs Clinician: THOMPSON, BRYCE S

POC: Lake Park IHC

Current Encounter: Not Encounter Related



Birth Date/Time	Hours of Age
3/2/2007 15:12	115.1
EDIT BIRTH DATE/TIME	
Blood Type	
Mom: O Negative	Baby: O Negative
Direct/Indirect Coombs	
Antibody Screen.Cells I+II+III	
03/06/2007 17:34	Positive
Transcutaneous Bilirubin Entry	
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ENTER	
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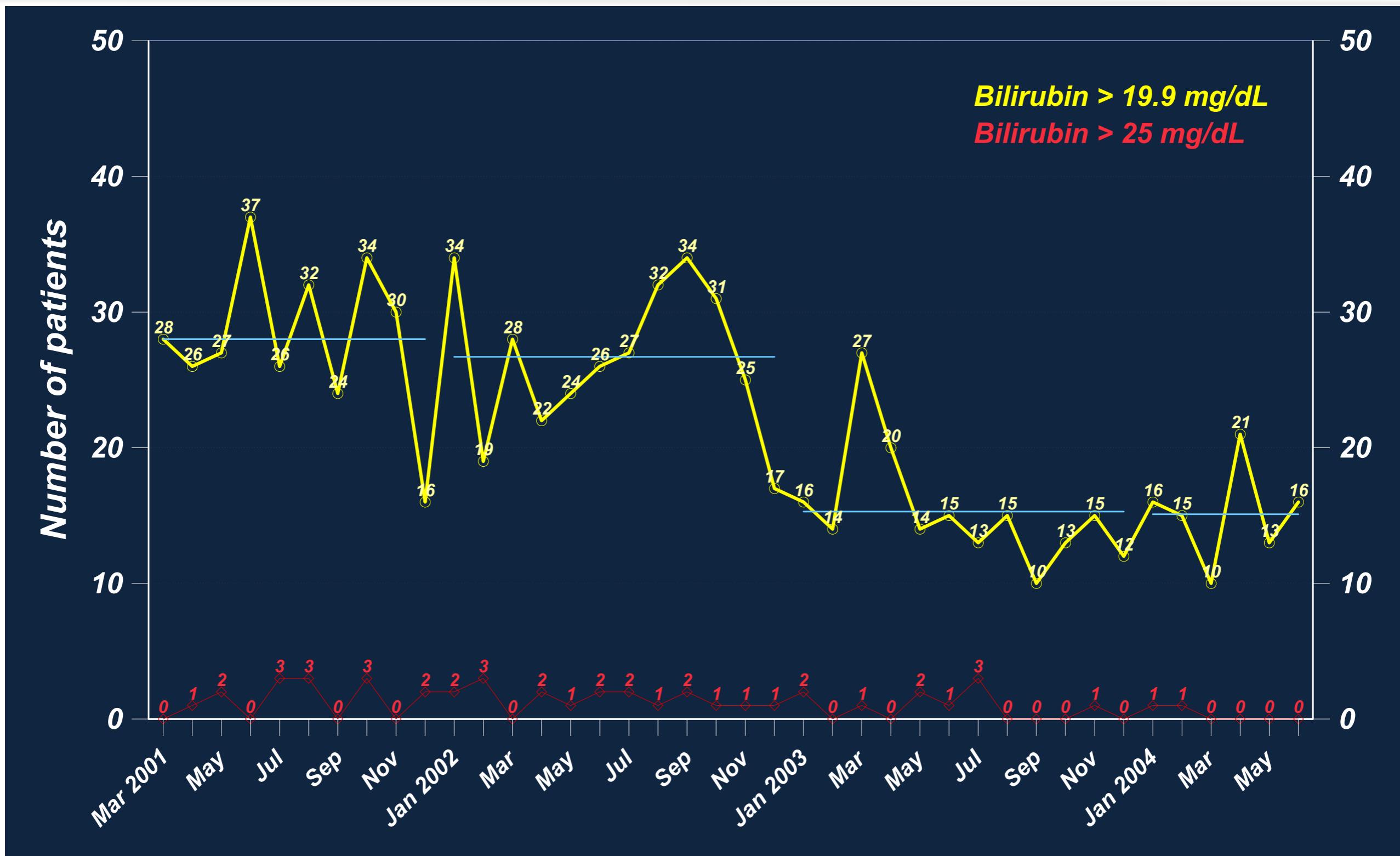
Order Set: High Risk

[Newborn Bilirubin \(High Risk Zone\)](#)

Jump to: All

Orders		Use this order if...
Laboratory <div style="display: flex; align-items: center;"> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Bilirubin, Neonatal Total in 6-12 hours. Follow up on Date: <input type="text"/> at Time: <input type="text"/> at <input type="text"/> </div> <div style="margin-top: 10px;"> <input checked="" type="checkbox"/> Location: <input type="text"/> </div>		
Others/Misc <div style="display: flex; align-items: center;"> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Phototherapy </div> <div style="margin-top: 10px;"> <input checked="" type="checkbox"/> Name of Provider: <input type="text"/> notified on Date: <input type="text"/> at Time: <input type="text"/> </div> <div style="margin-top: 10px;"> <input type="checkbox"/> Other instructions <input type="text"/> </div>		
<input checked="" type="radio"/> English <input type="radio"/> Spanish		<input type="button" value="Generate Reports"/>

Newborns with hyperbilirubinemia



Decision Support Modules

- Antibiotic Assistant
- Ventilator weaning
- ARDS protocols
- Nosocomial infection monitoring
- MRSA monitoring and control
- Prevention of Deep Venous Thrombosis
- Infectious disease reporting to public health
- Diabetic care
- Pre-op antibiotics
- ICU glucose protocols
- Ventilator disconnect
- Infusion pump errors
- Lab alerts
- Blood ordering
- Order sets
- Patient worksheets
- Post MI discharge meds

Clinical System Approach

Intermountain can only provide the highest quality, lowest cost health care with the use of advanced clinical decision support systems integrated into frontline clinical workflow

— Stan Huff

Guidelines and Decision Support

- Implementable guidelines are software
 - Unit tests are needed
 - Bug fixes need to be disseminated
 - Guidelines evolve over time
 - Data models evolve over time
- The cost and risk of guideline development needs to be shared across the clinical community

Strategic Goal

- Be able to share data, applications, reports, alerts, protocols, and decision support modules with anyone in the WORLD
- Goal is “plug-n-play” interoperability

CIMI Vision, Mission and Goals

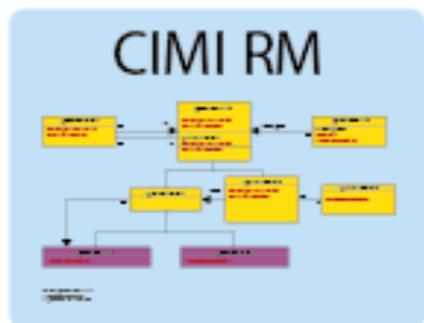
Clinical Information Modeling Initiative

Goals

- Create a shared repository of detailed clinical information models
- Using an approved formalism
 - Archetype Definition Language (ADL)
 - Archetype Modeling Language (AML)
- Based on a common set of base data types
- With formal bindings of the models to standard coded terminologies
- Repository is open to everyone and models are licensed free for use at no cost

CIMI Model Development Lifecycle

Standards Infusion



Standard Terminologies & Ontologies

CEMs

DCMs

CDA Templates

openEHR Archetypes

ISO EN 13606 Archetypes

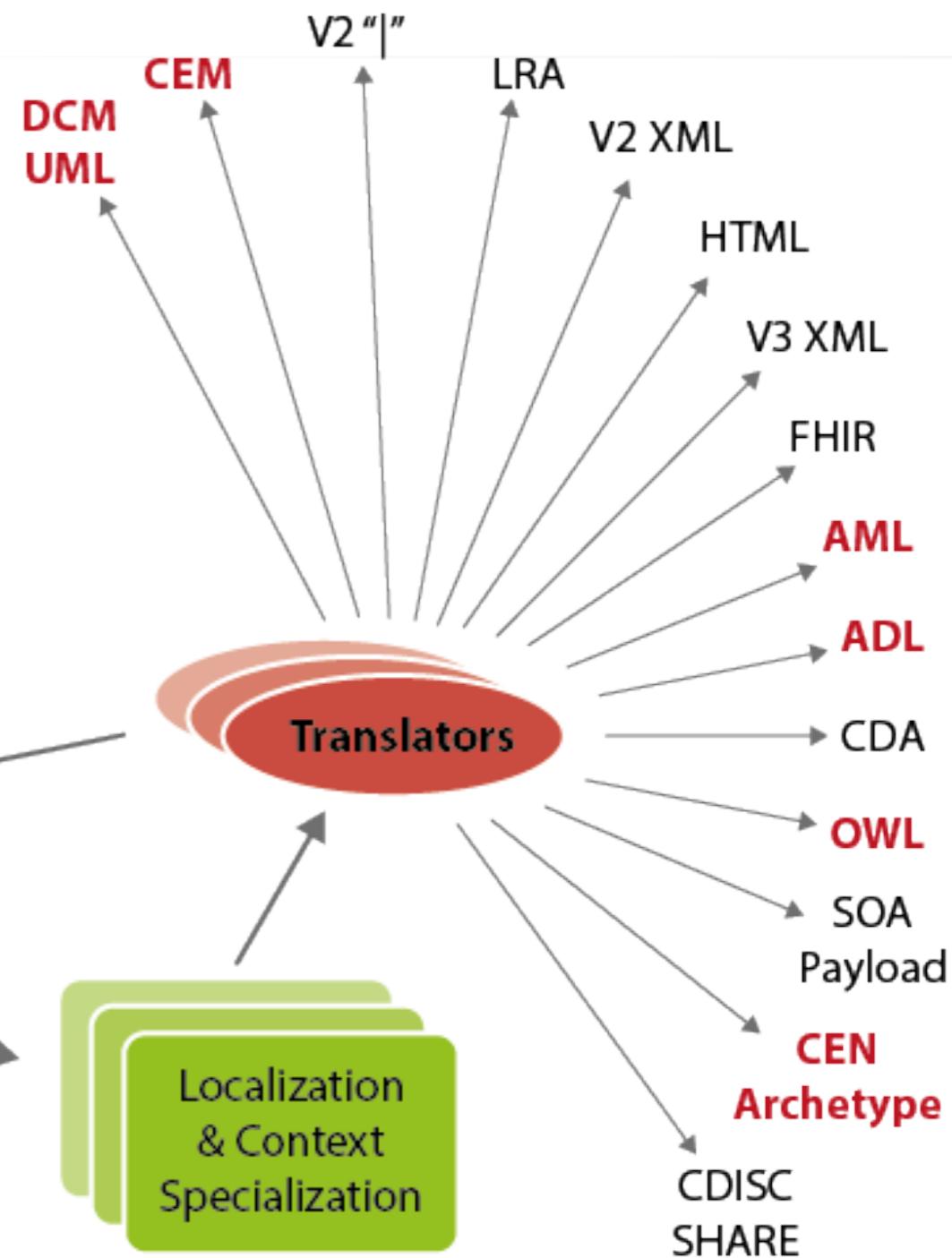
Model Review

Repository of Shared Models in an approved Formalism

LRA Models

FHIR Resources

Initial Loading of Repository



Model Dissemination

IsoSemantic Models – Example of Problem

(from Dr. Linda Bird)

e.g. “Suspected Lung Cancer”

The image displays three separate clinical input windows, each with a different background color and title, but all showing the same data entry fields for a medical problem.

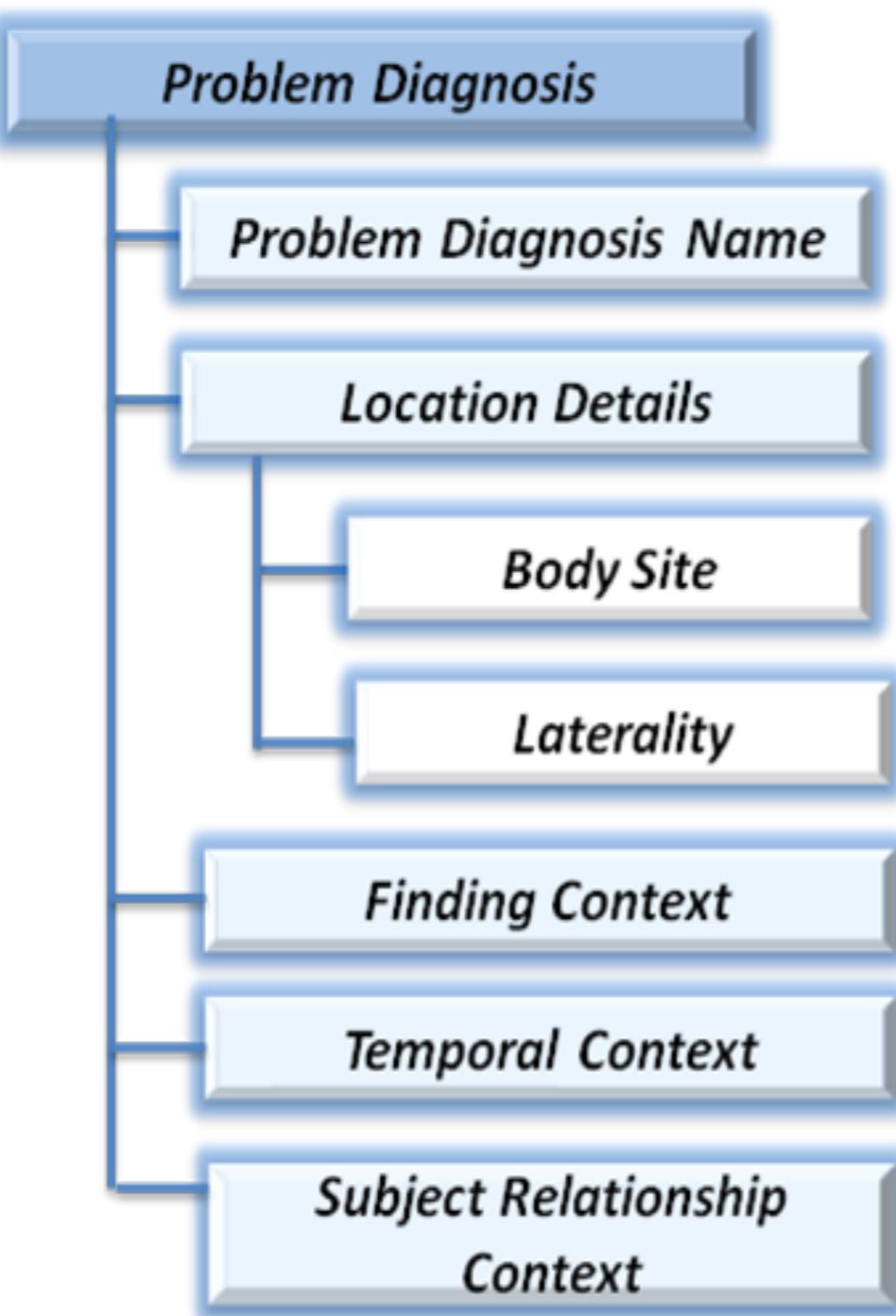
- General Practice** (Green Title Bar):
 - Problem/Dx**
 - Prob/Dx:** Cancer
 - Body Site:** Lung
 - Status:**
 - Suspected
 - Confirmed
 - Not found
 - OK** **Cancel**
- Polyclinic** (Orange Title Bar):
 - Problem/Diagnosis**
 - Prob/Dx Name:** Suspected cancer
 - Body Site:** Lung
 - OK** **Cancel**
- Restructured Hospital** (Red Title Bar):
 - Diagnosis**
 - Name:** Suspected lung cancer
 - OK** **Cancel**

IsoSemantic Models – Example Instances

(from Dr. Linda Bird)

e.g. “Suspected Lung Cancer”

Model Hierarchy



	General Practice	Polyclinic	Hospital
Cancer	Cancer	Suspected Cancer	Suspected Lung Cancer
Lung	Lung	Lung	
Suspected			

Isosemantic Models

CIMI supports isosemantic clinical models:

- We will keep isosemantic models in the CIMI repository that use a different split between pre-coordination versus post coordination (different split between terminology and information model)
- **One model in an isosemantic family will be selected as the CIMI preferred model for interoperability (as opposed to everyone supporting every model)**
- Collections of models for specific use cases will be created by authoritative bodies: professional societies, regulatory agencies, public health, quality measures, etc.

An ontology of clinical observation results

preferably, in daylight at a window. Jaundice is usually seen first in the face and progresses caudally to the trunk and extremities,²¹ but visual estimation of bilirubin levels from the degree of jaundice can lead to errors.²²⁻²⁴ In most infants with TSB levels of less than 15 mg/dL (257 µmol/L), noninvasive TcB-measurement devices can provide a valid estimate of the TSB level.^{2,25-29} See Appendix 1 for additional information on the clinical evaluation of jaundice

Clinical Condition

Observation

MRN: 10489
Date/Time: 3/03/2007 03:10
Total Serum Bilirubin Result: 6.0
Units: mg/dL
Hours of Age: 11.9
Risk zone: High Intermediate (75-95%)

Observation_Result

CIMI Clinical Views



Clinical Knowledge Manager

Username Password

Sign in Forgot your password? Sign up

Archetypes Templates Termsets Release Sets Projects Reports Help

Find Resources

A Liver ... tests

Liver function tests



+

-

Archetypes



EHR Archetypes

Entry

Observation

Liver function tests (v1)

Urinalysis (v1)

T Requestor order identifier

Requestor

T Receiver order Identifier

Receiving laboratory

T Laboratory test result identifier

Datetime result issued

Protocol

Liver function
tests

Description

T Test name

T Diagnostic service

T Test status

Specimen detail

Q Alkaline phosphatase (ALP)

Q Total bilirubin

Q Direct bilirubin

Total bilirubin

Quantity

Occurrences: 0..1 (Optional)

Concentration of bilirubin (conjugated and unconjugated) in the serum.

Property: Concentration

Units:

- >=0.0 µmol/l

Q Globulins

Q Total protein

Q Per-result annotation

T Overall interpretation

M Multimedia representation

Events

Any event

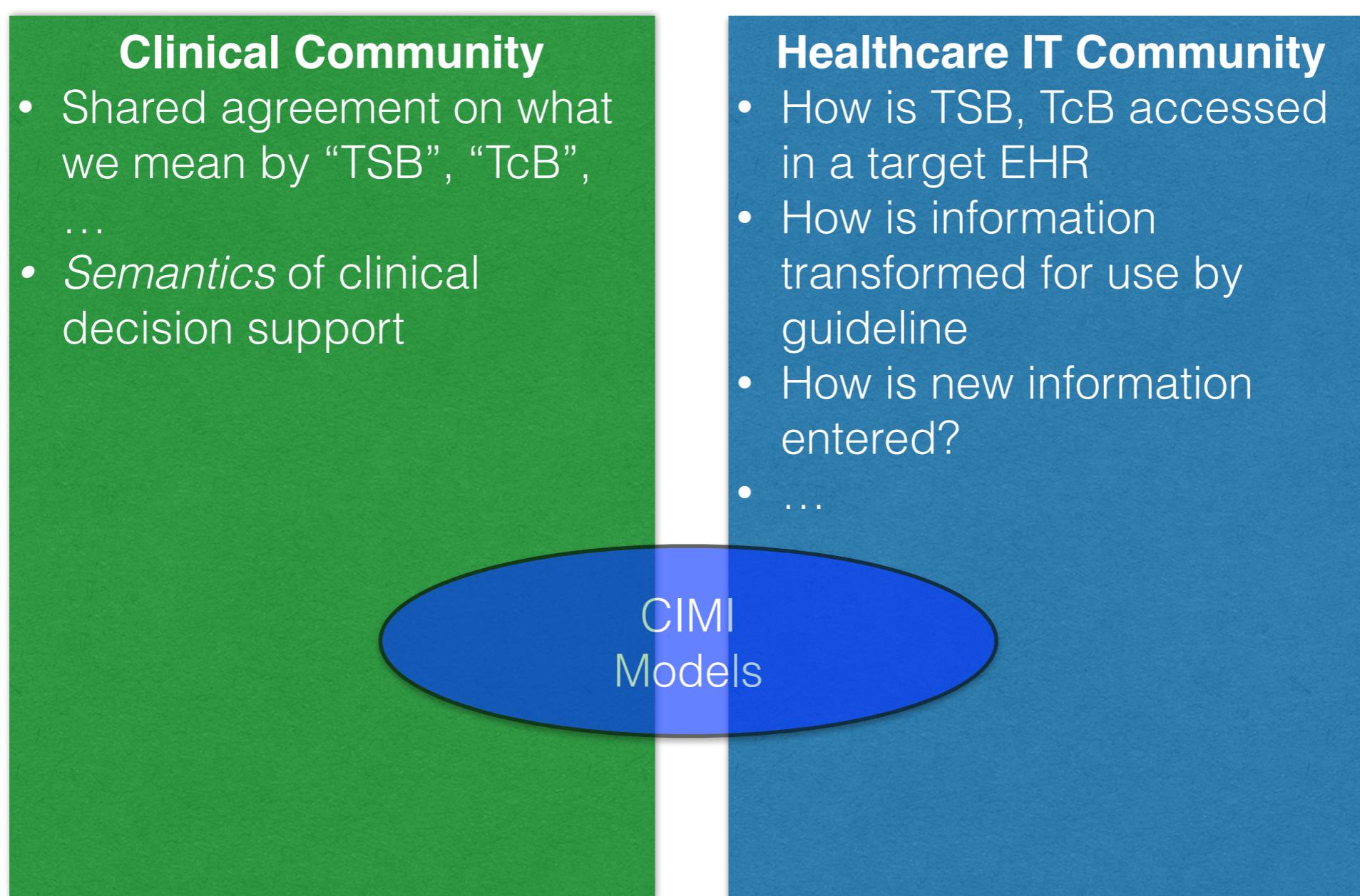
Attribution



Clinical Information Modeling Initiative

CIMI and RDF — Harold Solbrig

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CIMI Modeling

- Shared models of clinical information
- Varying granularity...
 - ... observation_result <→ abnormally high serum bilirubin
- In a language that is understandable and verifiable by the clinical community
- With sufficient detail and precision to be implemented by the technical IT community

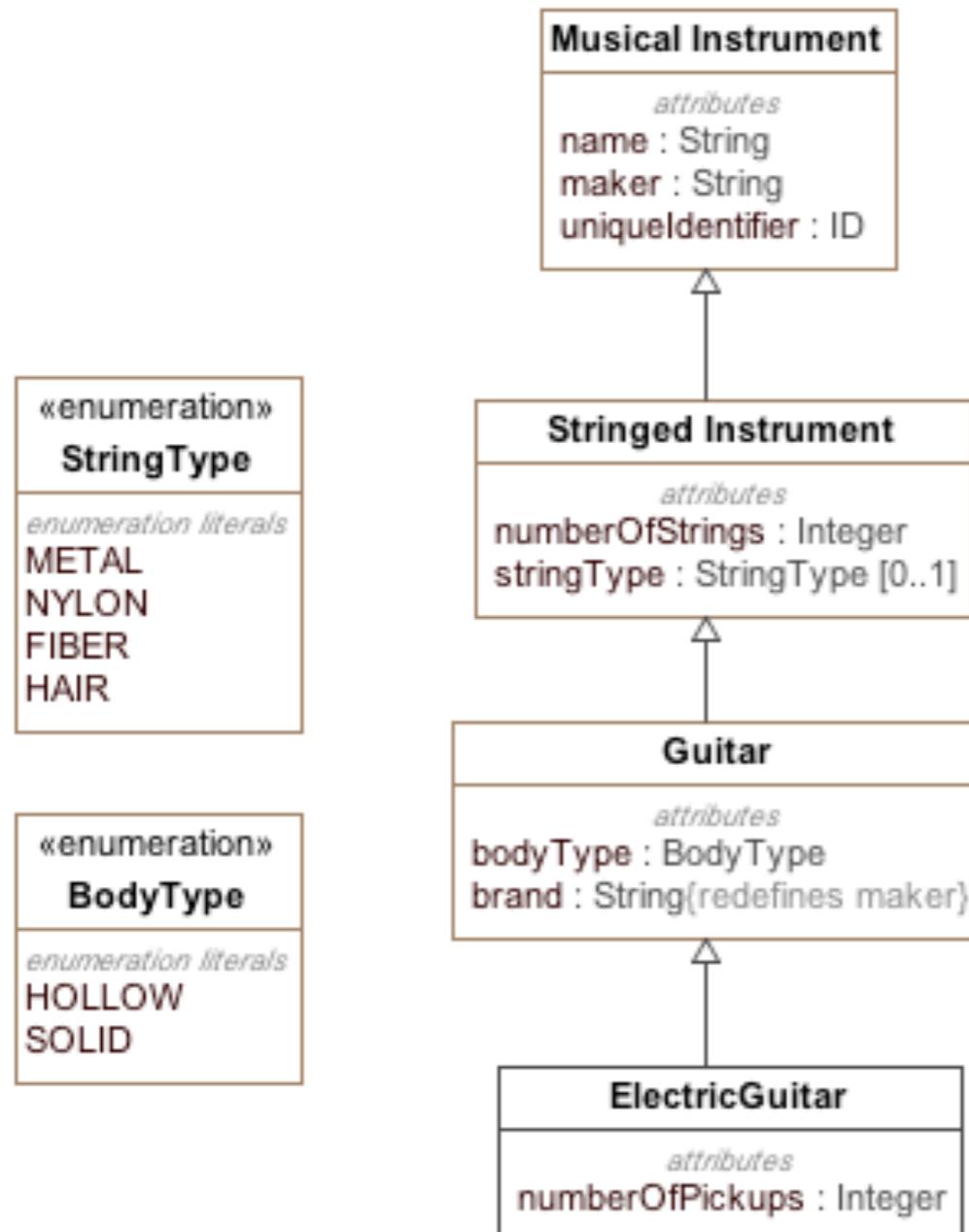
Outline

- Introduction to CIMI
- **CIMI and Constraint Modeling**
- Realizing CIMI as RDF + ShEx

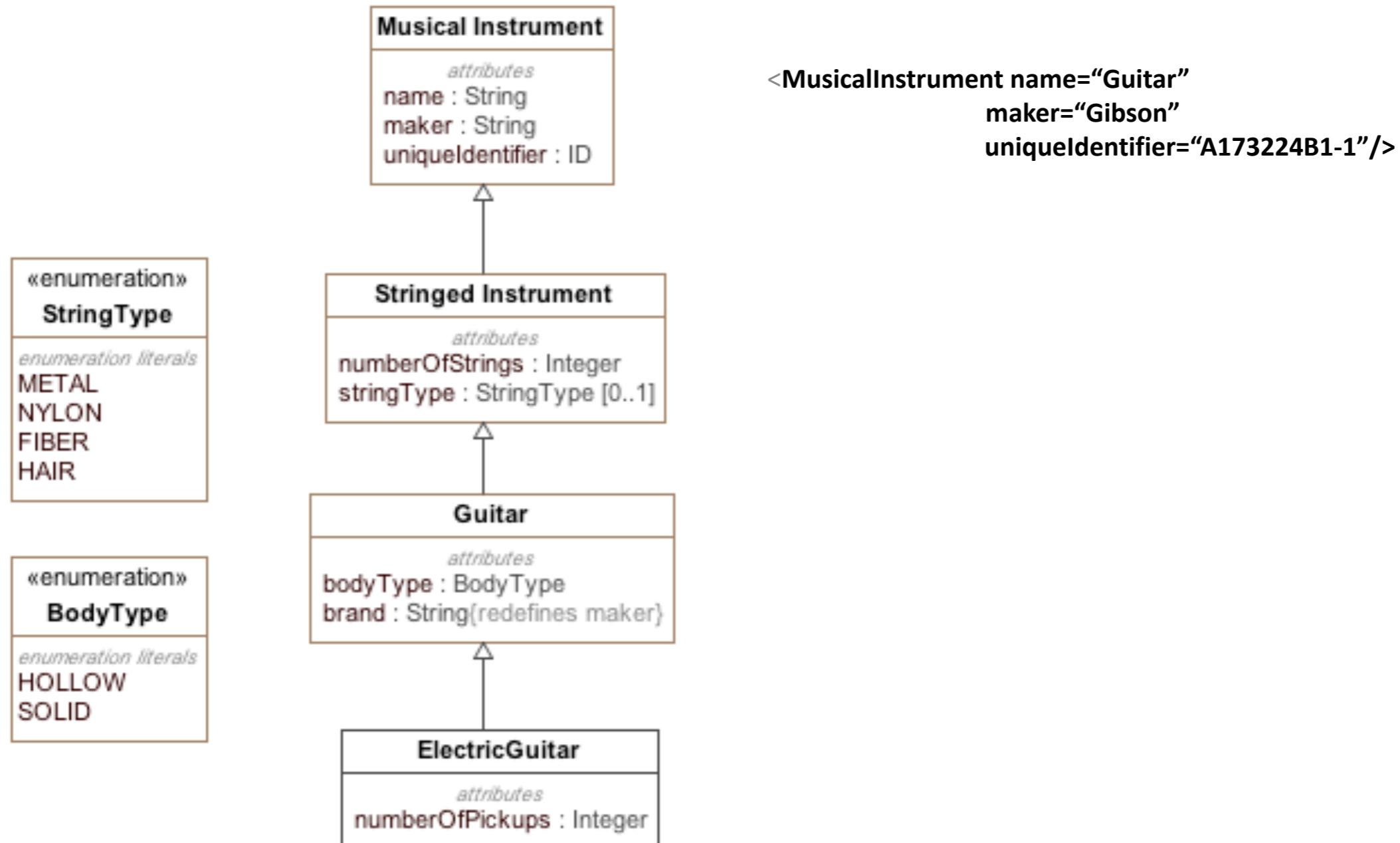
“Top Down” Modeling

- Additive
 - Start with most abstract
 - Specialize adding properties and relationships
- Instances only valid at selected level up

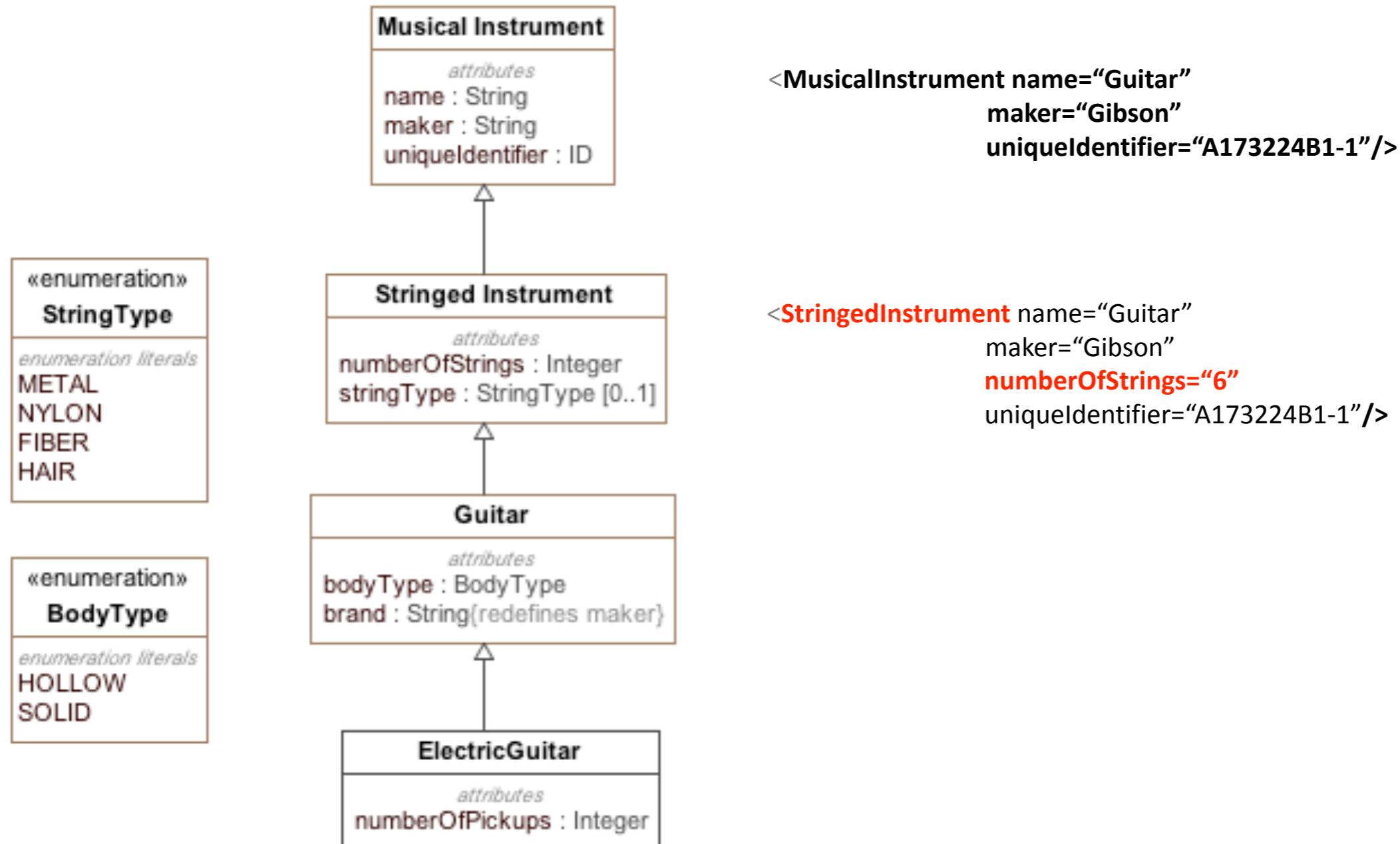
Top Down Modeling



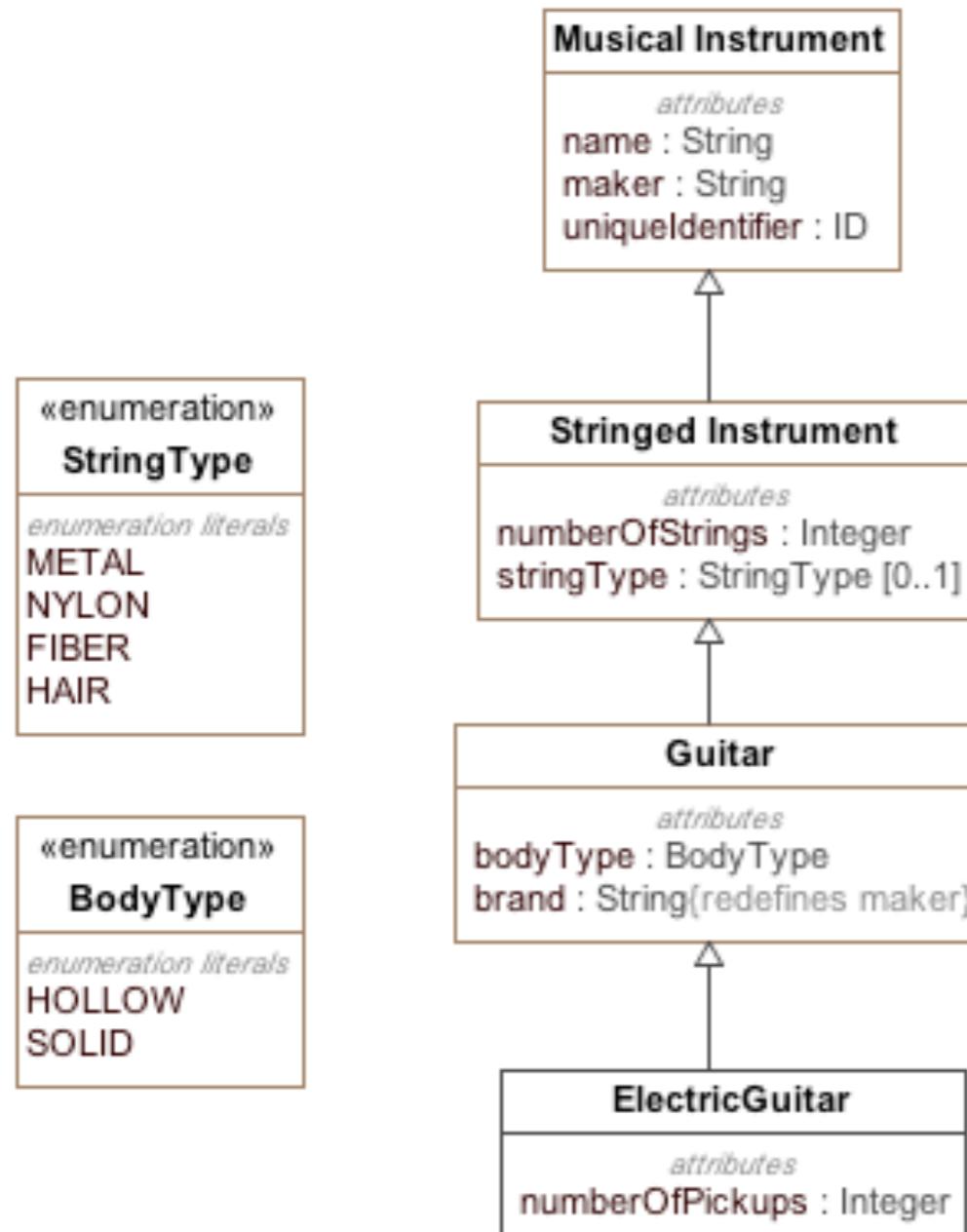
Top Down Modeling



Top Down Modeling



Top Down Modeling



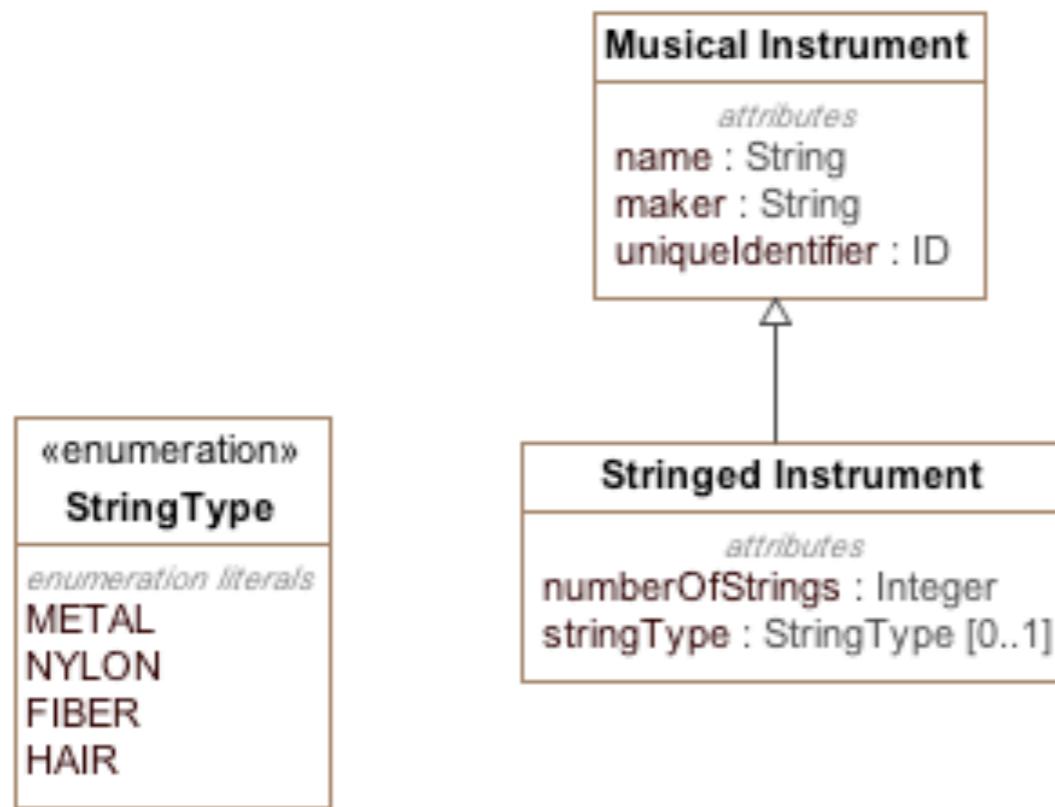
```
<MusicalInstrument name="Guitar"
                    maker="Gibson"
                    uniqueIdentifier="A173224B1-1"/>
```

```
<StringedInstrument name="Guitar"
                     maker="Gibson"
                     numberOfStrings="6"
                     uniqueIdentifier="A173224B1-1"/>
```

```
<Guitar name="Guitar"
        brand="Gibson"
        numberOfStrings="6"
        bodyType="SOLID",
        uniqueIdentifier="A173224B1-1"/>
```

```
<ElectricGuitar name="Guitar"
                  brand="Gibson"
                  numberOfStrings="6"
                  bodyType="SOLID",
                  numberOfPickups="3"
                  uniqueIdentifier="A173224B1-1"/>
```

Top Down Modeling



← If this is my model ...

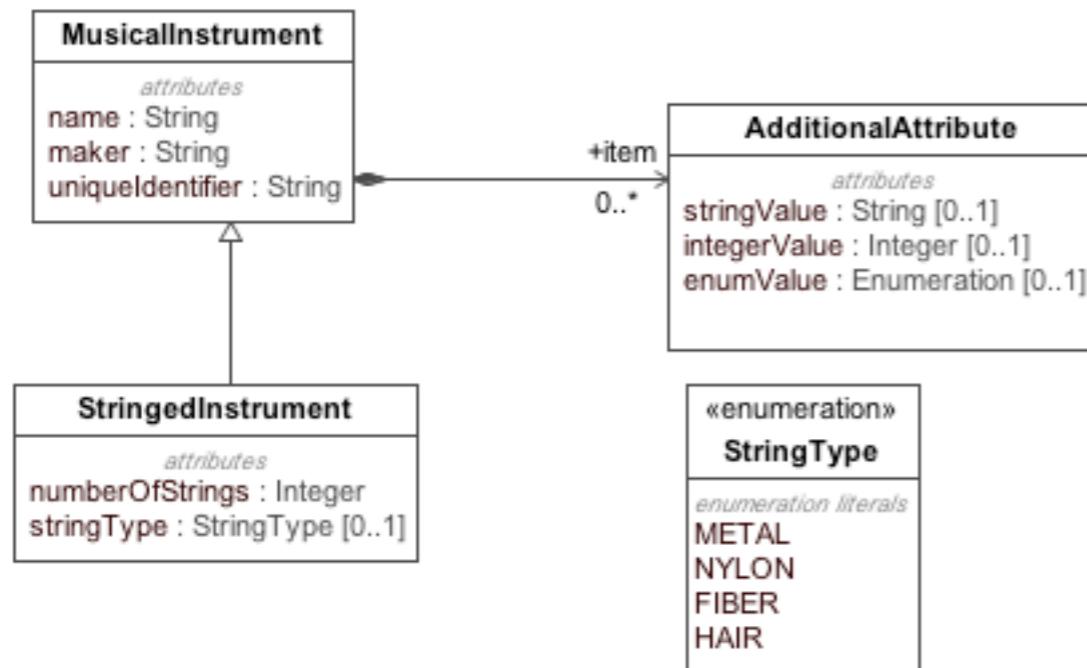
```
<ElectricGuitar name="Guitar"
    brand="Gibson
    numberOfStrings="6"
    bodyType="SOLID",
    numberOfPickups="3"
    uniqueIdentifier="A173224B1-1"/>
```

← ... this makes no sense!

Constraint Based Modeling

- Reference Model (typically UML) defines the maximal information set
- Constraints (Archetypes) define subsets of the Reference Model and/or other Archetypes

Constraint Based Modeling Reference Model



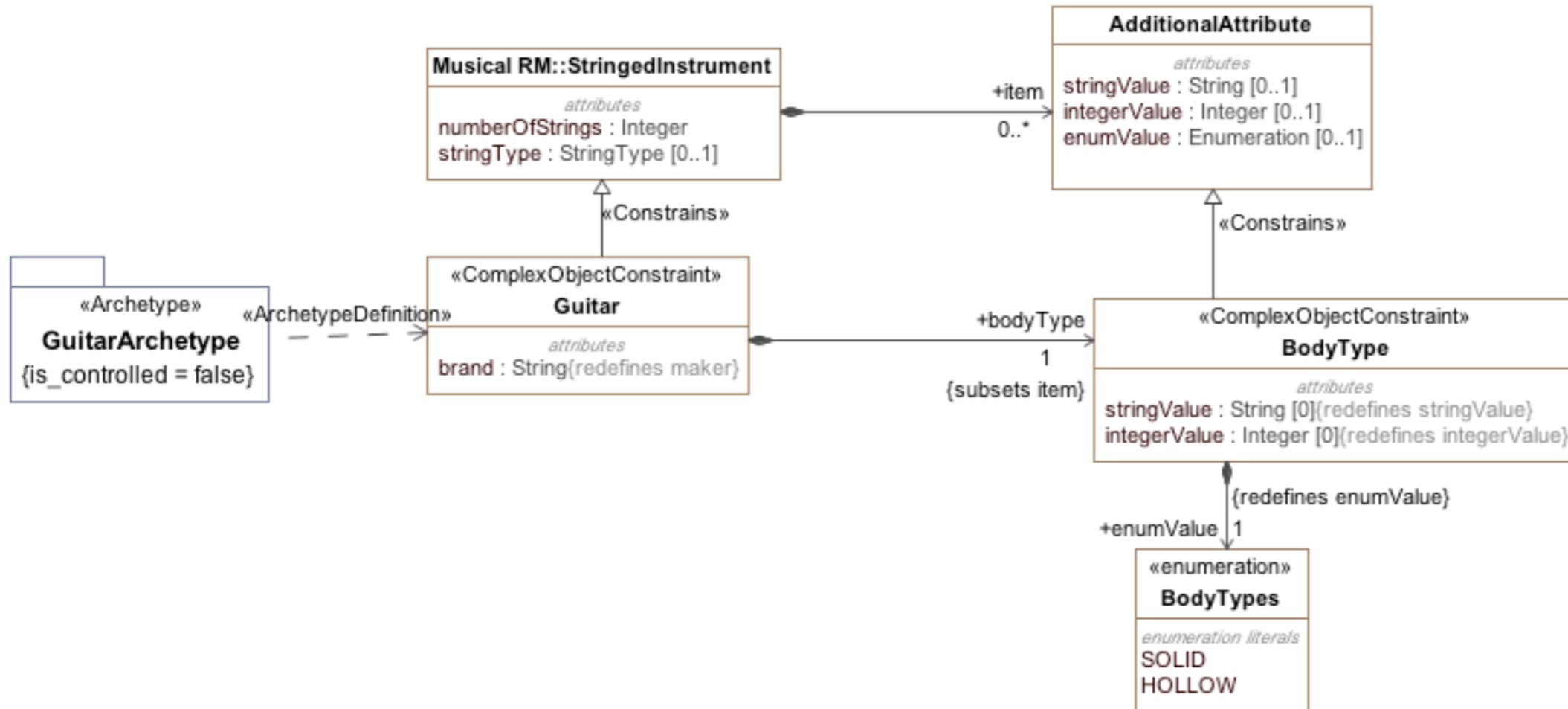
A Musical Instrument has a:

- name
- maker
- uniqueIdentifier
- any number of items

A Stringed Instrument has Musical Instrument with:

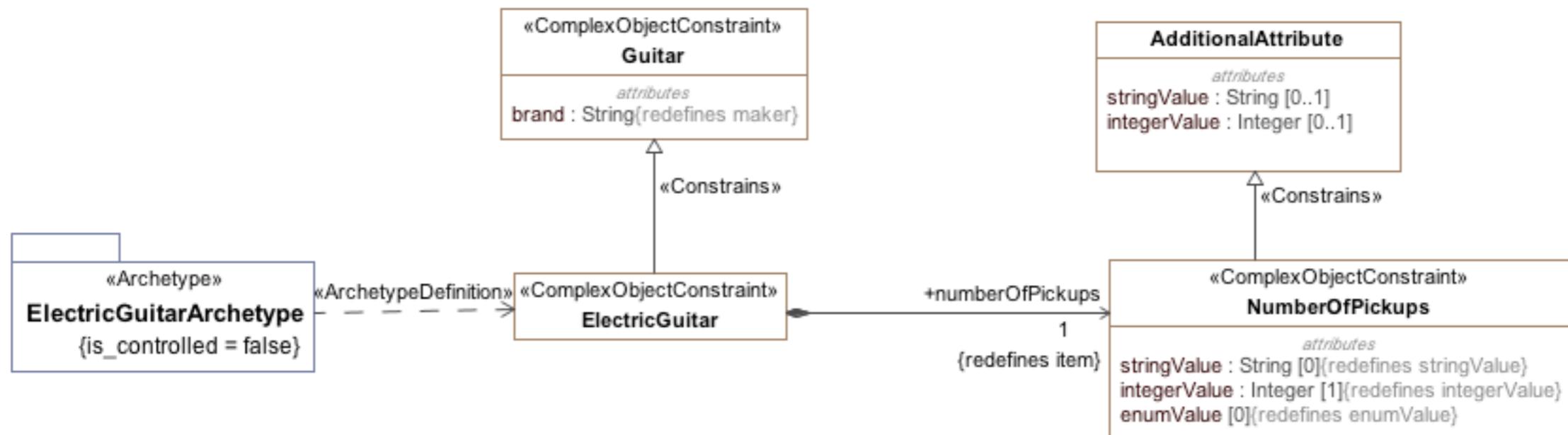
- `numberOfStrings`
- `stringType`

Constraint Based Modeling Archetype



A Guitar is a Stringed Instrument where exactly one of the items is an enumeration whose values derive from the BodyTypes enumeration

Constraint Based Modeling Archetype



An ElectricGuitar is a Guitar where exactly one of the items is an integer

Constraint Based Modeling

RDF Representation of StringedInstrument

```
# StringedInstrument
```

```
@prefix music_rm: <http://example.org/music/> .  
@prefix string_type_vs: <http://example.org/music/stringtype/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
@prefix : <http://example.org/music/stringed_instrument/> .
```

```
_:b a :stringed_instrument;  
  :name "Guitar";  
  :maker "Gibson";  
  :uniqueIdentifier "A173224B1-1";  
  :numberOfStrings "6"^^xsd:integer;  
  :stringType string_type_vs:METAL;  
  <http://example.org/music/guitar/brand> "Gibson";  
  :item (  
    [ a :additional-attribute;  
      :enumValue <http://example.org/music/guitar/bodytypes/SOLID>  
    ]  
    [ a :additional-attribute;  
      :integerValue "6"^^xsd:integer  
    ]  
  ).
```

Constraint Based Modeling RDF Representation of Electric Guitar

```
# ElectricGuitar
@prefix music_rm: <http://example.org/music/> .
@prefix string_type_vs: <http://example.org/music/stringtype/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix stringed_instrument: <http://example.org/music/stringed_instrument/> .
@prefix guitar: <http://example.org/music/guitar/> .
@prefix : <http://example.org/music/electric_guitar/> .
@prefix body_types_vs: <http://example.org/music/guitar/bodytypes/> .

_:b a :stringed_instrument;
_:b a :electric_guitar;
:name "Guitar";
:maker "Gibson";
:uniqueIdentifier "A173224B1-1";
:numberOfStrings "6"^^xsd:integer;
:stringType string_type_vs:METAL;
:guitar:brand "Gibson";
:item (
  [ a :additional_attribute;
    a guitar:body_type;
    :enumValue guitar_BodyTypes/SOLID>
  ]
  [ a :additional_attribute;
    a :number_of_pickups;
    :integerValue "6"^^xsd:integer
  ]
  [ ... ]
).
```

Predicates and objects
are always in terms of the
reference model

The key is that the type hierarchy
has to be known from the level
of abstraction up...

```
:electric_guitar rdfs:subClassOf guitar:guitar.
guitar:guitar rdfs:subClassOf music_rm:musical_instrument.
guitar:body_type refs:subClassOf music_rm:additional_attribute
...
```

Electric Guitar Modeling Initiative (EGMI)

Player Community

- Shared agreement on technical terms...
 - *Pickups*
 - *Single Coil*
 - *Tremolo Bridge*
 - *Humbucker*
 - *Super Slinky*
- Shared agreement on composite models
 - Stratocaster
 - Telecaster
 - Les Paul Goldtop

Technical community

- How are brands coded?
- How do I find all 60's era electric guitars with 3 single coil pickups and a tremolo bridge?
- How do I stay current with model changes, etc?

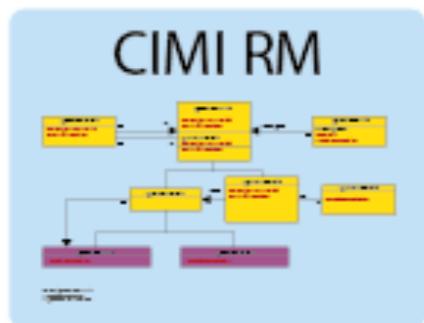
EGMI
Models

Outline

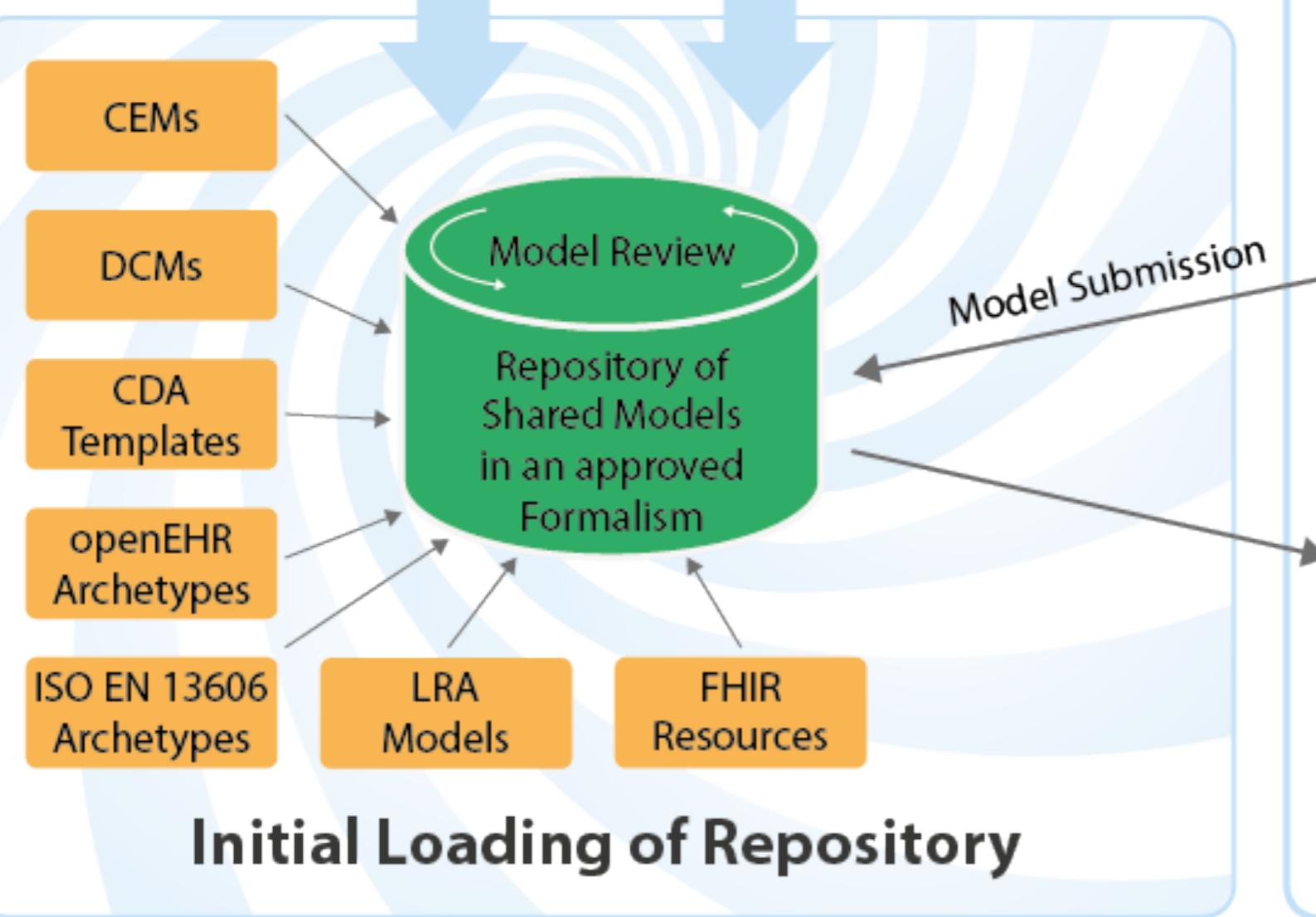
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CIMI Model Development Lifecycle

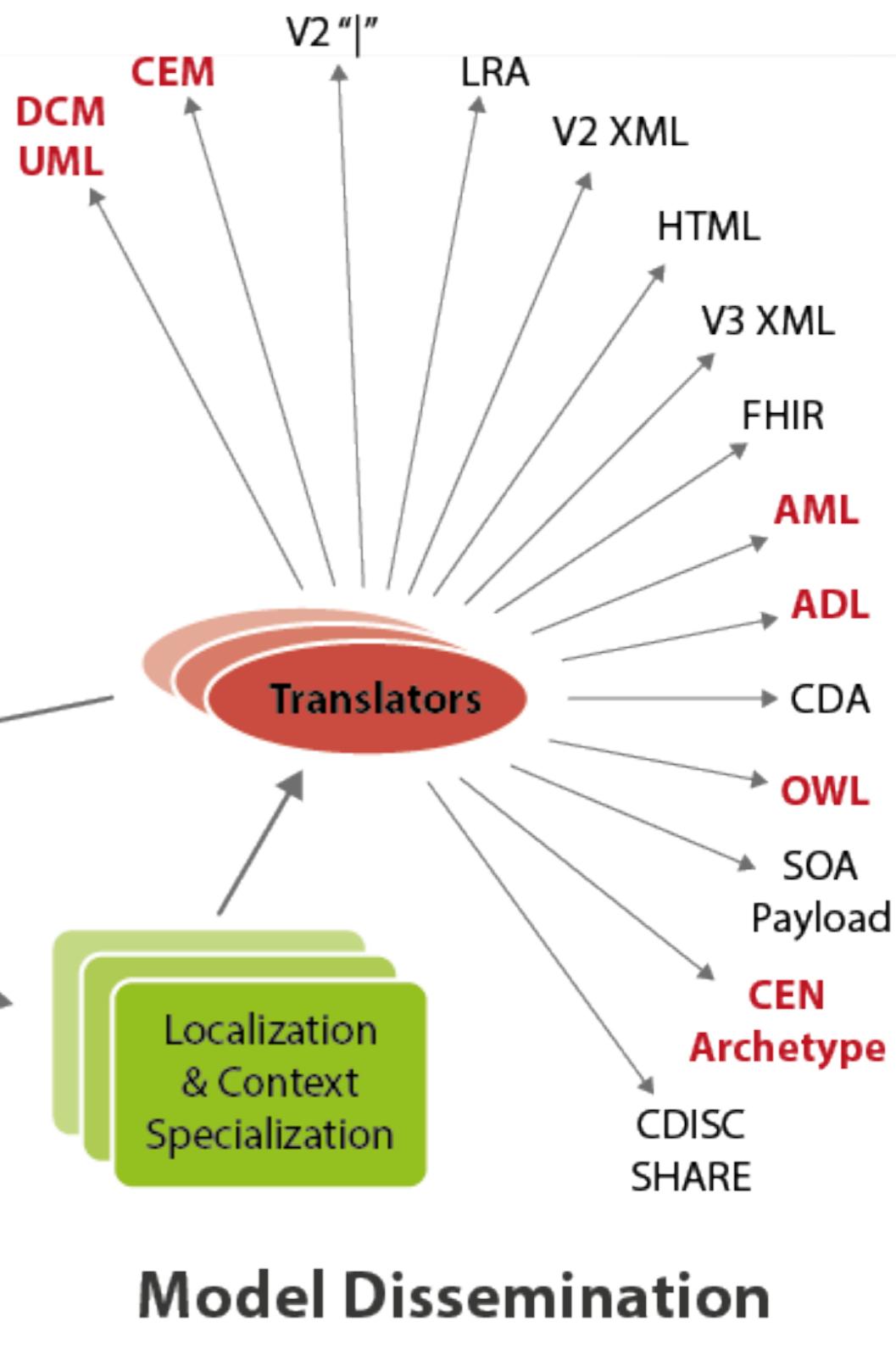
Standards Infusion



Standard Terminologies & Ontologies



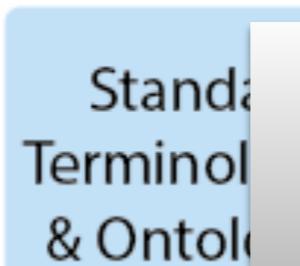
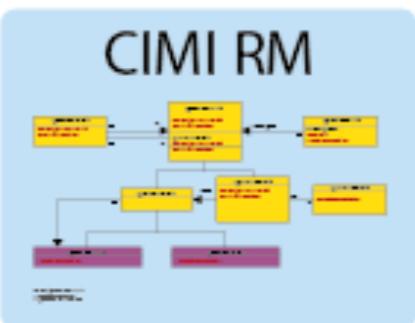
Initial Loading of Repository



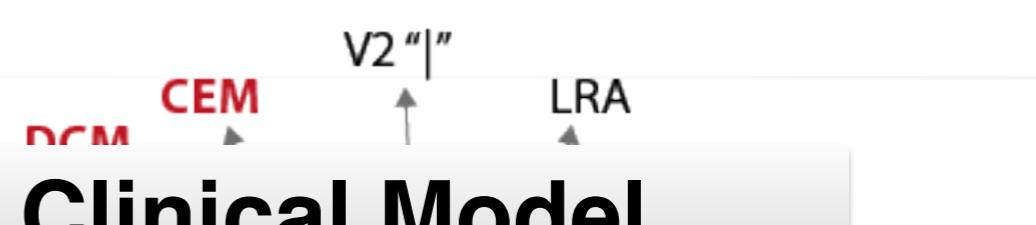
Model Dissemination

CIMI Model Development Lifecycle

Standards Infusion



We have **Clinical Model Definitions**

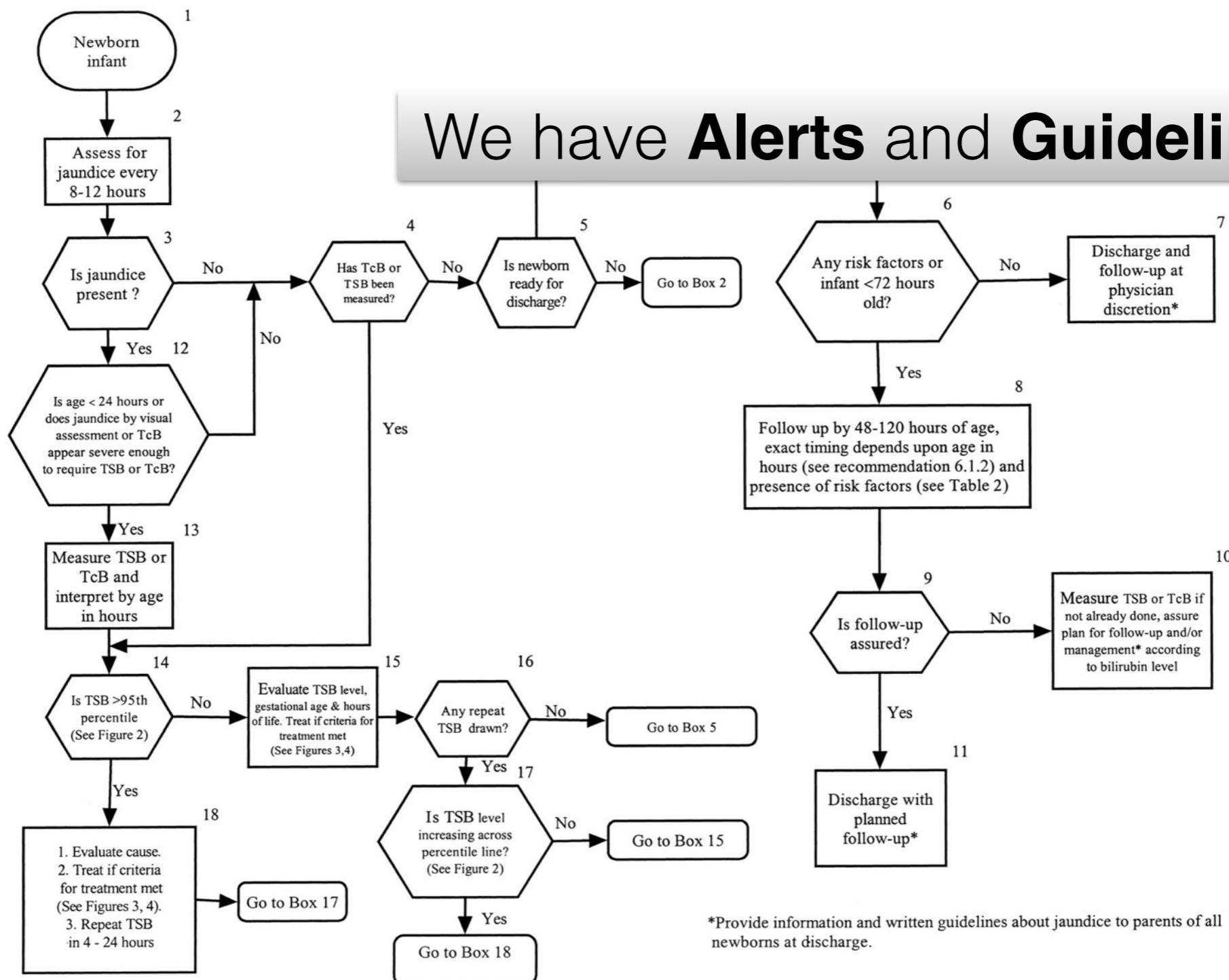


Model Submission

Initial Loading of Repository

Model Dissemination

Algorithm for the management of jaundice in the newborn nursery.



We have **Alerts** and **Guidelines**

Subcommittee on Hyperbilirubinemia Pediatrics 2004;114:297-316

The situation

- We have a library of clinical element models, the semantics of which is vetted on and agreed upon by a community of practice
- We have guidelines and rules with an emerging separation of concerns:
 - Clinical <→ Technical
 - Semantics <→ Syntax
- We don't have a clear plan of how all of this is going to be realized against existing EMR's, workflows and processing systems

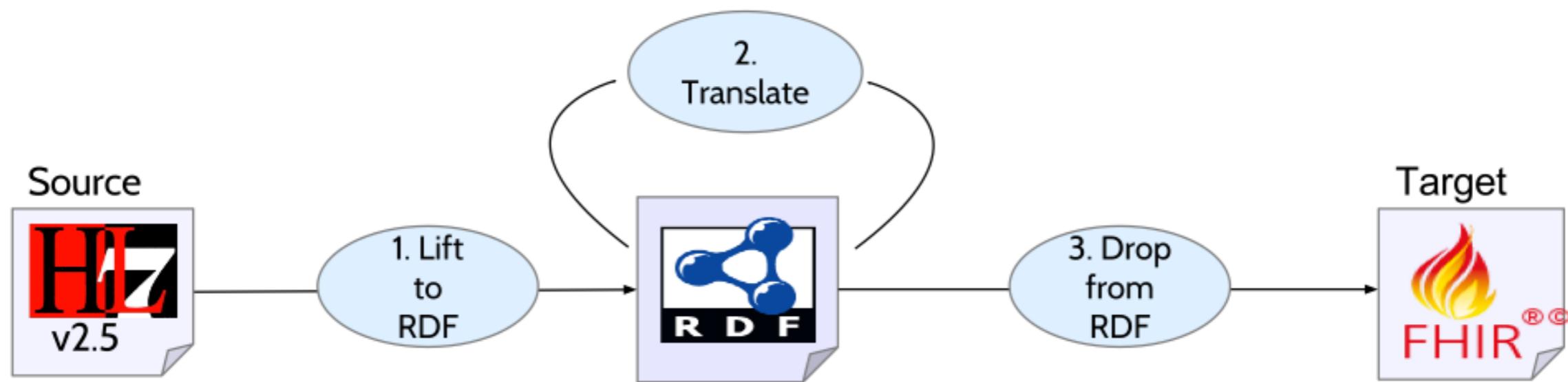
Excerpts from Yosemite Roadmap

How RDF helps translation

- RDF supports **inference**
 - Can be used for translation
- RDF acts as a **universal information representation**
- Enables data model and vocabulary translations to be **shared**

Yosemite Roadmap Basics

Translating patient data

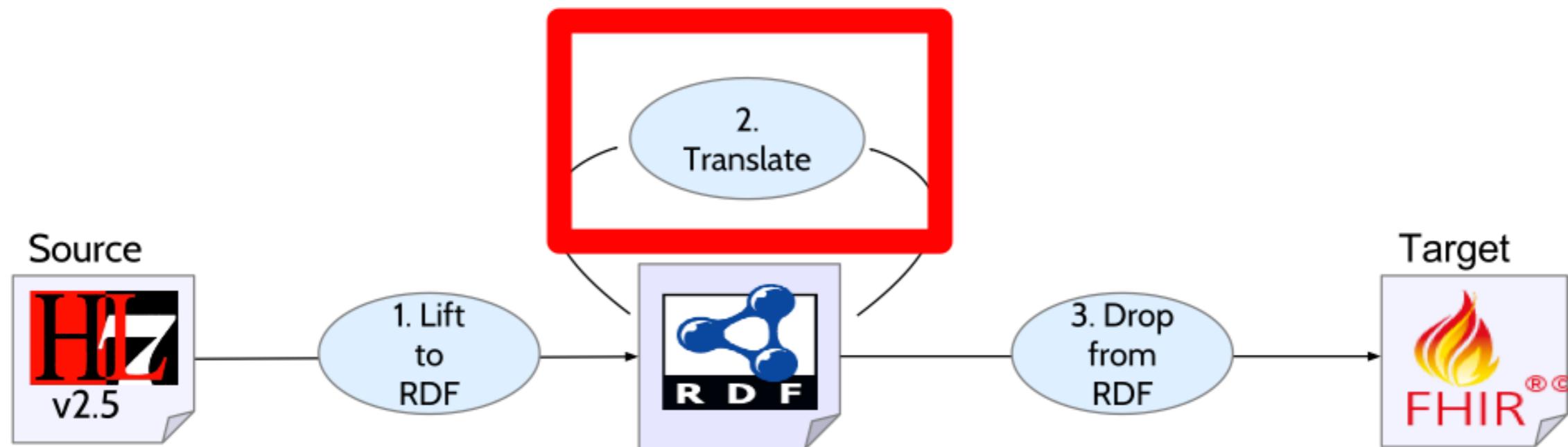


- Steps 1 & 3 map between source/target syntax and RDF
- Step 2 translates instance data between data models and vocabularies (RDF-to-RDF)
 - A/k/a semantic alignment, model alignment

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Yosemite Roadmap Translation

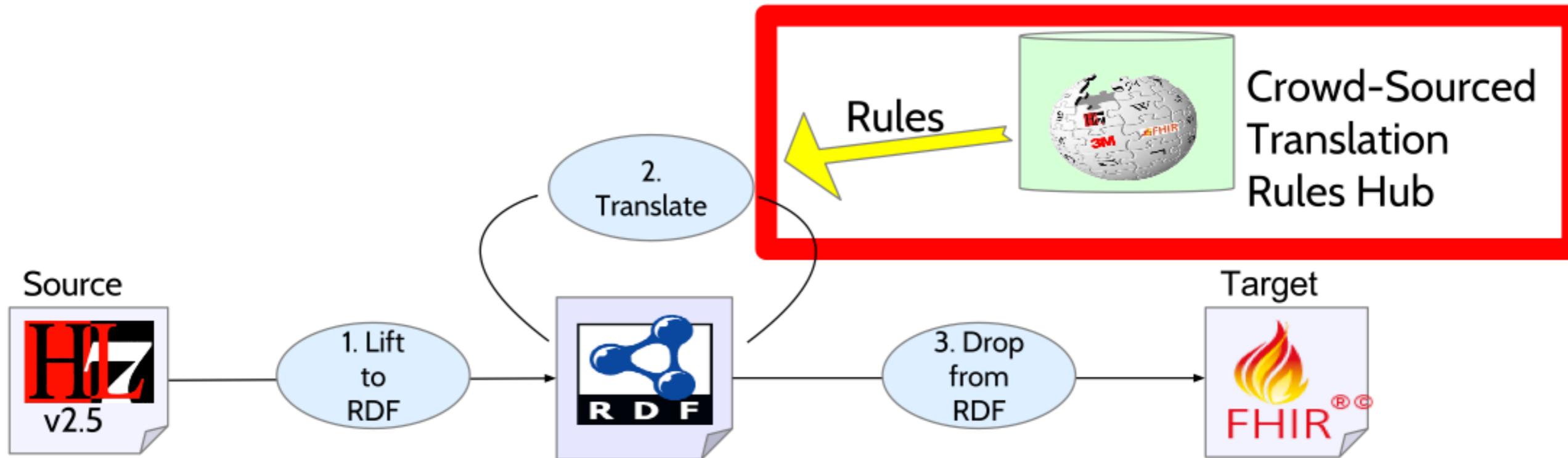
How should this translation be done?



- Translation is hard!
- Many different models and vocabularies
- Currently done in proprietary, black-box integration engines

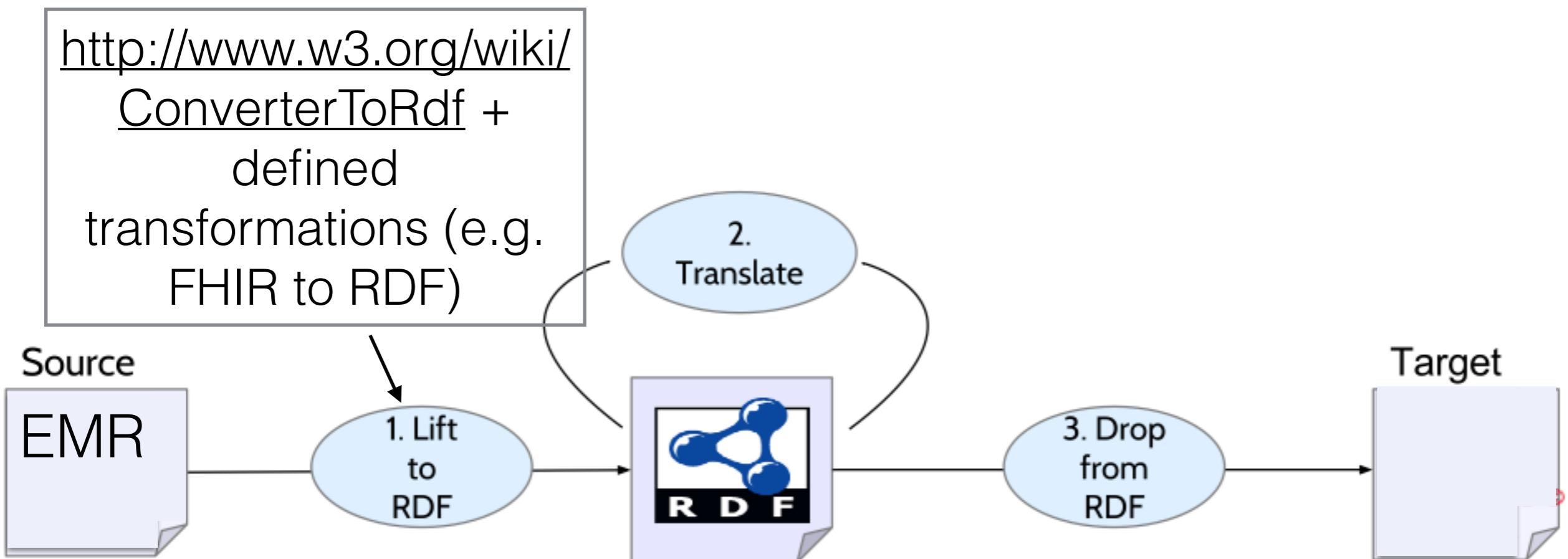
Yosemite Roadmap Crowdsourcing

Where are these translation rules?



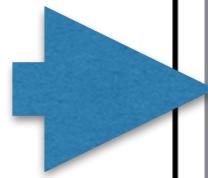
- By manipulating RDF data, rules can be mixed, matched and shared

Step 1: Any data → RDF



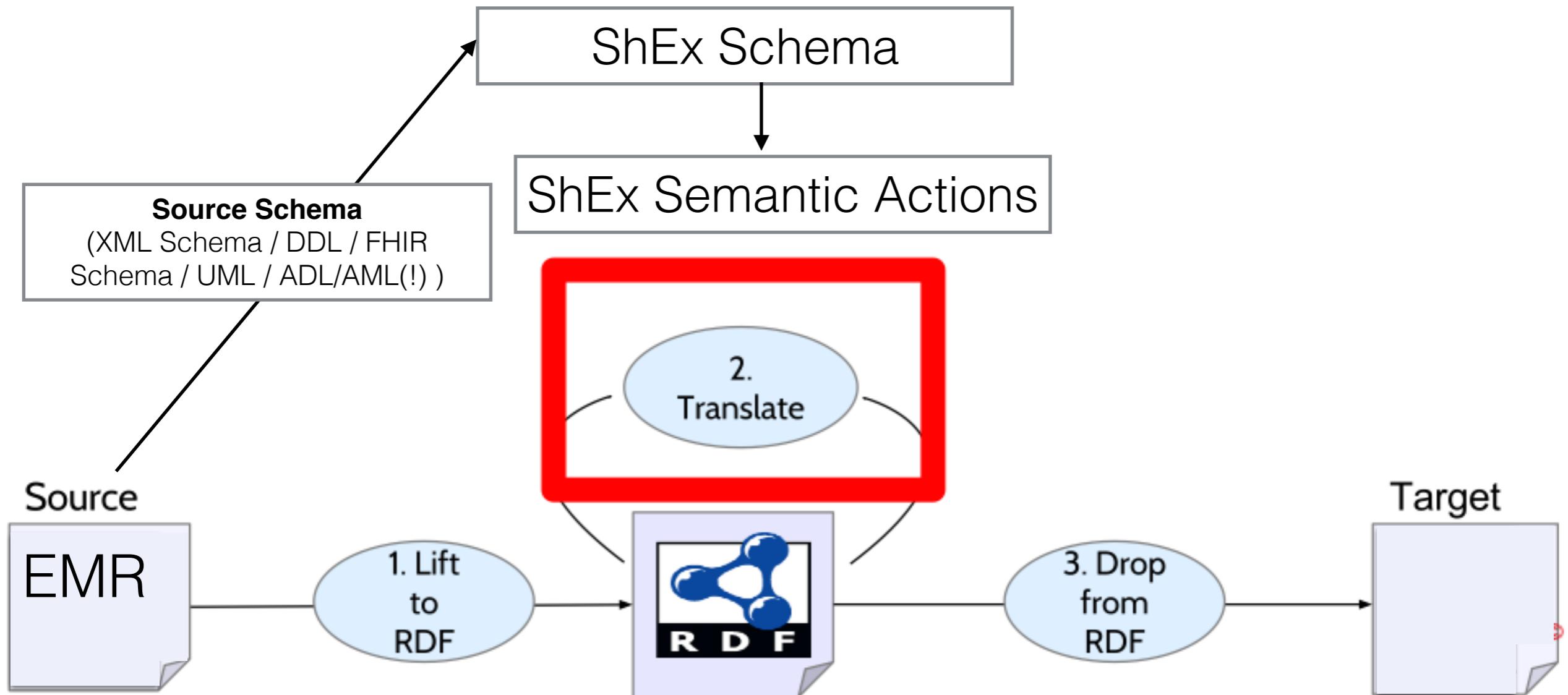
Step 1: Lift to RDF

```
"resourceType" : "Observation",
"id": "ID520409956-9f51efcd61f04eadb4715f83ee6557cf",
"code" :
{
  "coding" :
  [
    {
      "system" : "http://loinc.org",
      "code" : "58941-6",
      "display" : "Transcutaneous Bilirubin"
    }
  ],
  "valueQuantity" :
  {
    "value" : 13.0,
    "unit" : "mg/dL",
    "code" : "mg/dL"
  },
  "effectiveDateTime" : "2015-09-28T14:45:23",
  "status" : "final",
  "subject" :
  {
    "reference" : "Patient/ID9f51efcd61f04eadb4715f83ee6557cf"
  }
}
```



```
[] a :Observation;
Observation:name [a :CodeableConcept;
  CodeableConcept:coding [a :Coding;
    Coding:system [
      a fhir:uri;
      fhir:value "http://loinc.org";
    ];
    Coding:code [a fhir:code;
      fhir:value "58941-6";
    ];
    Coding:display [a fhir:string;
      fhir:value "Transcutaneous Bilirubin";
    ]; ]; ];
Observation:status [a fhir:code;
  fhir:value "final"; ];
Observation:identifier [a :Identifier;
  Identifier:system [a fhir:uri;
  fhir:value "urn:ietf:rfc:3986" ];
  Identifier:value [a fhir:string;
  fhir:value "520409956-9f51efcd61f04eadb4715f83ee6557cf"; ]; ];
Observation:component [
  Observation:component_name [a :CodeableConcept;
  CodeableConcept:coding [a :Coding;
    Coding:system [a fhir:uri;
      fhir:value "http://loinc.org"; ];
    Coding:code [a fhir:code;
      fhir:value "58941-6"; ];
    Coding:display [a fhir:string;
      fhir:value "Transcutaneous Bilirubin"; ]; ]; ];
  Observation:component_valueQuantity [a :Quantity;
    Quantity:value [a fhir:decimal;
      fhir:value "13.0"; ];
    Quantity:units [a fhir:string;
      fhir:value "mg/dL"; ]; ]; ].
```

Step 2: RDF → RDF Transformation (FHIR → CIMI)



Quick Aside: ShEx

- A “schema” for RDF Graphs
- A collection of predicates that identify graph subsets
 - Subjects with specific predicates
 - Subject/predicate with specific object types
 - Objects in URL or Literal Value Sets
 - Object of subject/predicate meets given ShEx predicate
 - ...

ShEx Example

```
BASE <http://base.example/#>
PREFIX ex: <http://ex.example/#>
PREFIX foaf: <http://foaf.example/#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

<IssueShape> {
    ex:state (ex:unassigned ex:assigned),
    ex:reportedBy @<UserShape>,
    ex:reportedOn xsd:dateTime,
    ( ex:reproducedBy @<EmployeeShape>,
      ex:reproducedOn xsd:dateTime )?,
    ex:related @<IssueShape>*}
<UserShape> {
    (foaf:name xsd:string
     | foaf:givenName xsd:string+,
       foaf:familyName xsd:string),
    foaf:mbox rdf:Resource}
```

The diagram illustrates the annotations for the ShEx code. Arrows point from specific ShEx terms to their corresponding definitions in boxes:

- An arrow points from "ex:state (ex:unassigned ex:assigned)" to a box containing "Has exactly one one ex:state of assigned or unassigned".
- An arrow points from "ex:reportedBy @<UserShape>" to a box containing "One reportedBy link to a subject that satisfied UserShape predicate".
- An arrow points from "ex:reportedOn xsd:dateTime" to a box containing "One reportedOn link to a valid dateTime".
- An arrow points from "(ex:reproducedBy @<EmployeeShape>, ex:reproducedOn xsd:dateTime)?," to a box containing "One or more reproducedBy/reproducedOn predicates".
- An arrow points from "ex:related @<IssueShape>*" to a box containing "Any number of related issues".

RDF-RDF Transformation (FHIR → CIMI)

```
[] a :Observation;
  Observation:name [a :CodeableConcept;
    CodeableConcept:coding [a :Coding;
      Coding:system [
        a fhir:uri;
        fhir:value "http://loinc.org";
      ];
      Coding:code [a fhir:code;
        fhir:value "58941-6";
      ];
      Coding:display [a fhir:string;
        fhir:value "Transcutaneous Bilirubin";
      ]; ]; ];
  ...
```

FHIR RDF

```
<Observation> {
  a (:Observation),
  Observation:name <Observation:name> %{CIMI cimi:code $$ %},
  Observation:identifier <Observation:identifier> %{CIMI cimi:identifier $$ %},
  Observation:component <Observation:component> %{CIMI cimi:result $$ %}
} %{CIMI :observation_result $$ $1 %}
```

```
<Observation:name> {
  a (:CodeableConcept),
  CodeableConcept:coding . %{CIMI data_value_types:code $$ %}
}
```

...

ShEx

```
@prefix primitive_types: <http://opencimi.org/rm/v3/primitive_types> .
@prefix party: <http://opencimi.org/rm/v3/party> .
@prefix core: <http://opencimi.org/rm/v3/core> .
@prefix data_value_types: <http://opencimi.org/rm/v3/data_value_types> .
@prefix ITEM_GROUP: <http://opencimi.org/model/CIMI-CORE-ITEM_GROUP/> .
@prefix identifier_types: <http://opencimi.org/idtypes/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

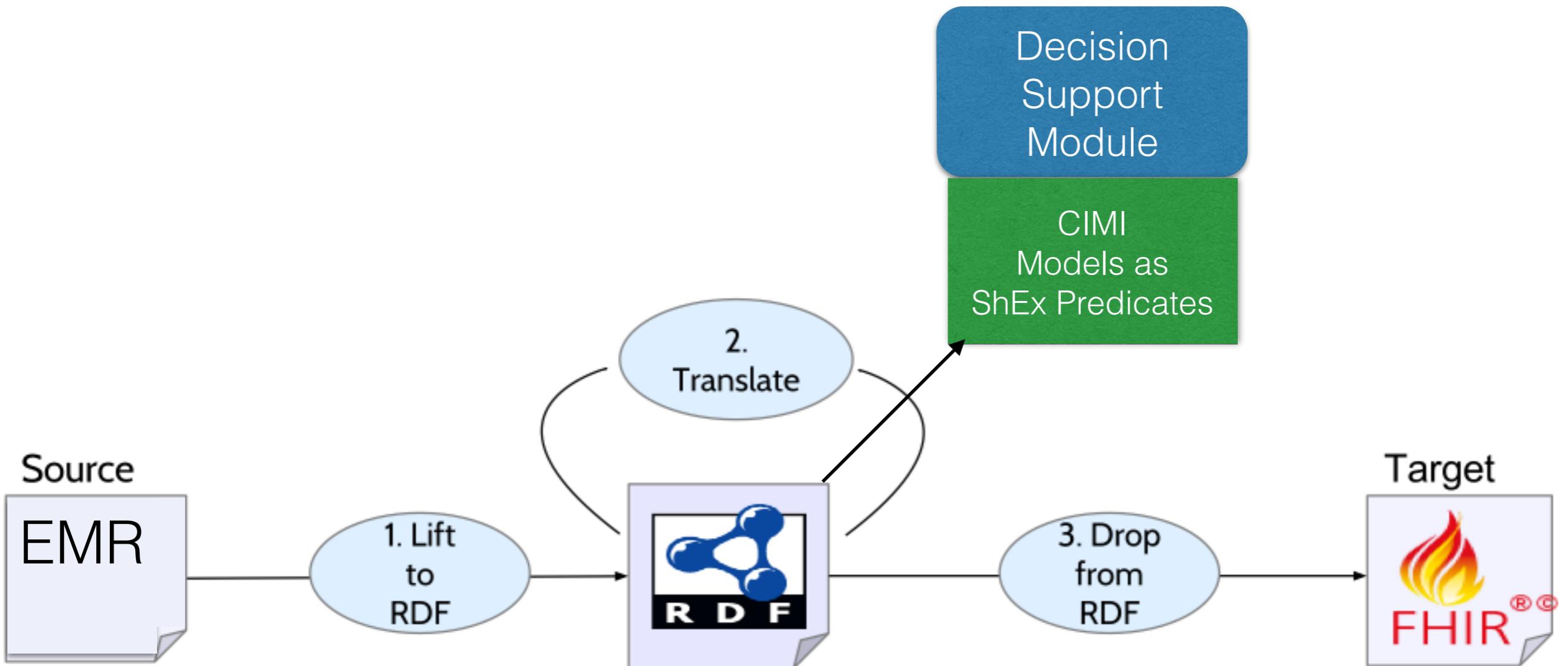
@prefix : <http://opencimi.org/model/CIMI-CORE-ITEM_GROUP/observation_result/v1> .

:_b a :observation_result;
  core:item [ a :identifier;
    data_value_types:value [
      data_value_types:id
      "ID520409956-9f51efcd61f04eadb4715f83ee6557cf";
      data_value_types:issuer "FHIR";
      data_value_types:type identifier_types:fhir_identifier_type
    ];
    core:item [ a :code;
      data_value_types:value [
        data_value_types:code "58941-6";
        data_value_types:terminology_id "http://loinc.org";
        data_value_types:string "Transcutaneous Bilirubin"
      ];
      core:item [ a :result;
        data_value_types:value [
          a data_value_types:QUANTITY;
          data_value_types:units [
            data_value_types:code "mg/dL";
            data_value_types:terminology_id "?";
            data_value_types:string "mg/dL"
          ];
          data_value_types:value "13.0"^^xsd:double
        ];
        core:item [ a :status;
          data_value_types:value [
            data_value_types:code "445665009";
            data_value_types:terminology_id "SNOMED_CT";
            data_value_types:terminology_version
            "http://snomed.info/sct/90000000000207008/version/20150131";
            data_value_types:uri "http://snomed.info/id/445665009";
            data_value_types:string "final"
          ];
        ].
```

CIMI RDF



Step 3: Apply Decision Logic to CIMI Standard Representation

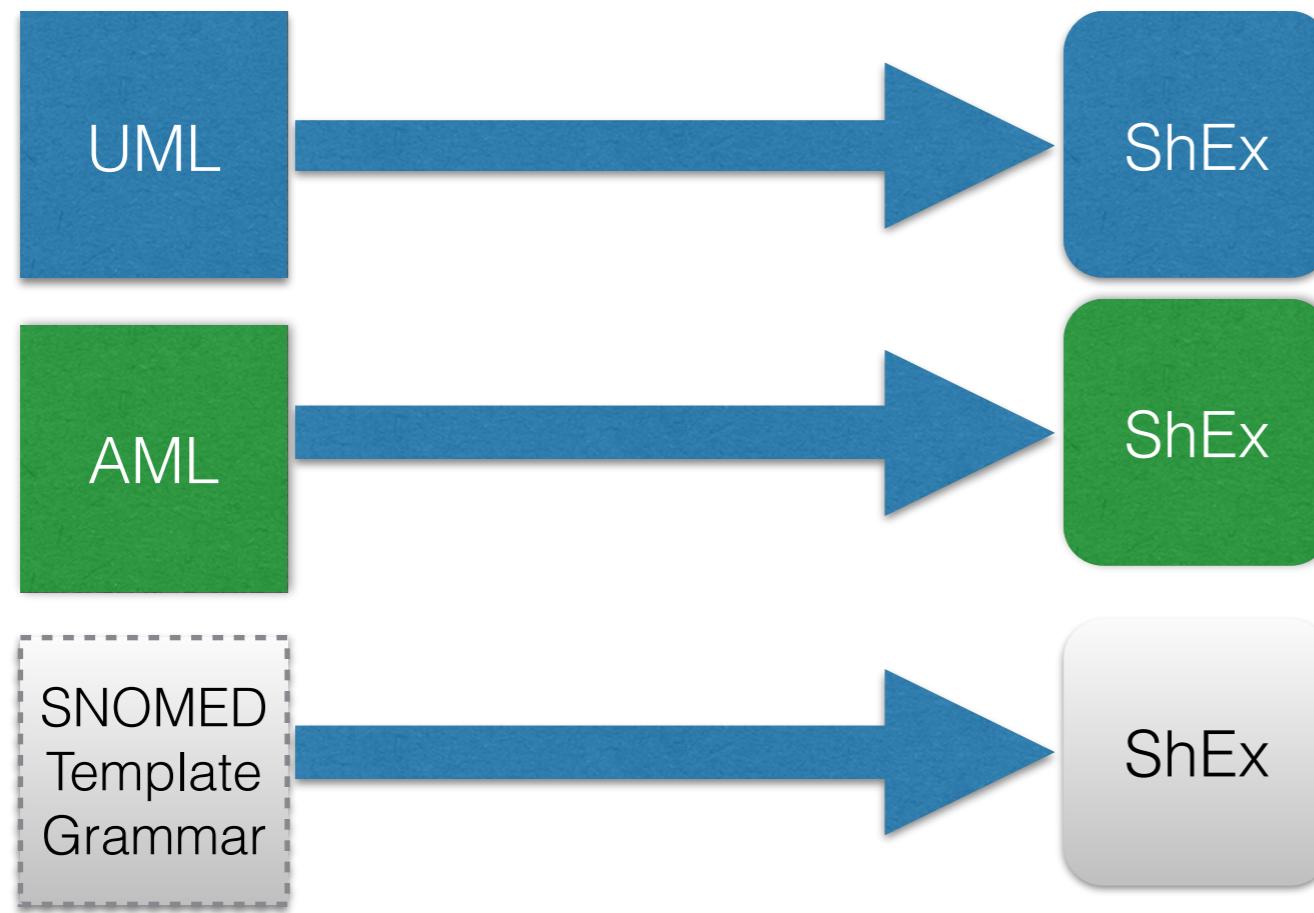


Step 3: Decision Support w/ ShEx Predicates

```
<TSB> &:observation_result {  
    a $:bilirubin_result_types?,  
  
    core:item {a $:observation_result/identifier_types?,           # identifier  
              {core:value @data_value_types:IDENTIFIER}},  
  
    core:item {a $:observation_result/code_types?,                 # Code  
              {core:value (loinc:58941-6)}},  
  
    core:item {a $:observation_result/status_types?,  
              {core:value $:observation_status_codes}},      # Status
```

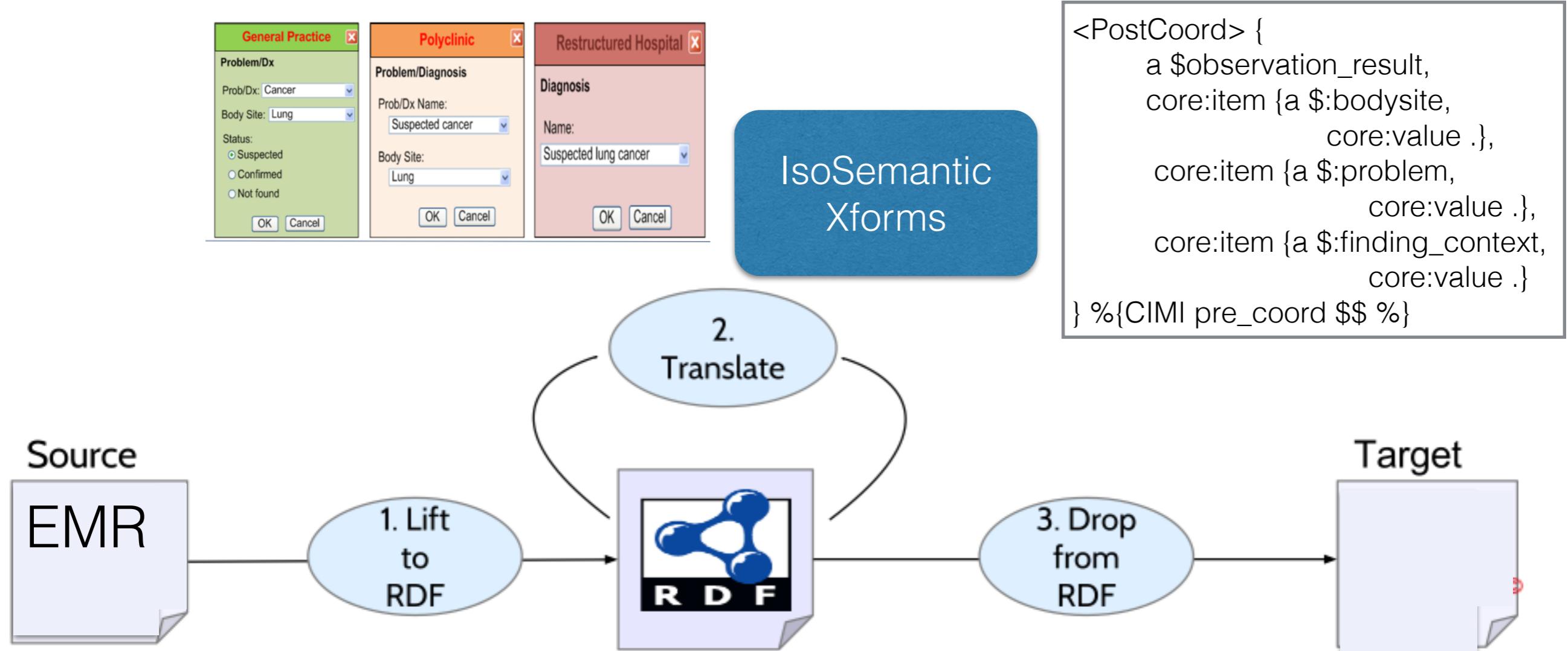
If TcB(graph) and value < 15.0:
 <action>
If TSB(graph) and value > 150.0:
 <action>
 ...

Proposed Tooling



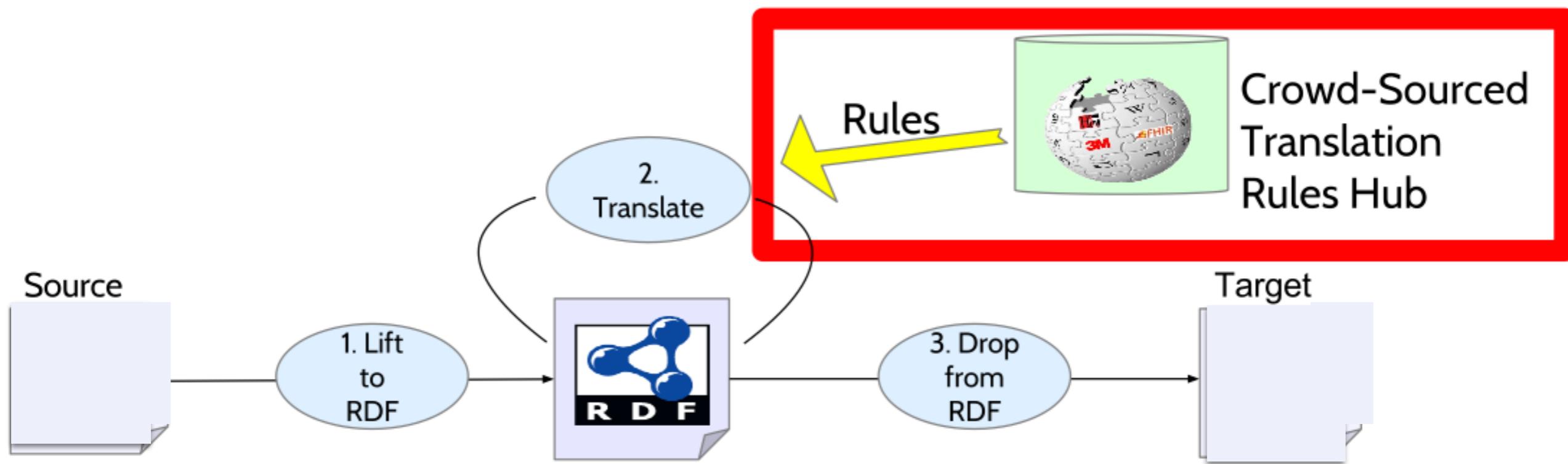
UML to ShEx and AML to ShEx in alpha stage
Waiting on Template Grammar completion for third form

IsoSemantic Transformations



Yosemite Crowdsourcing

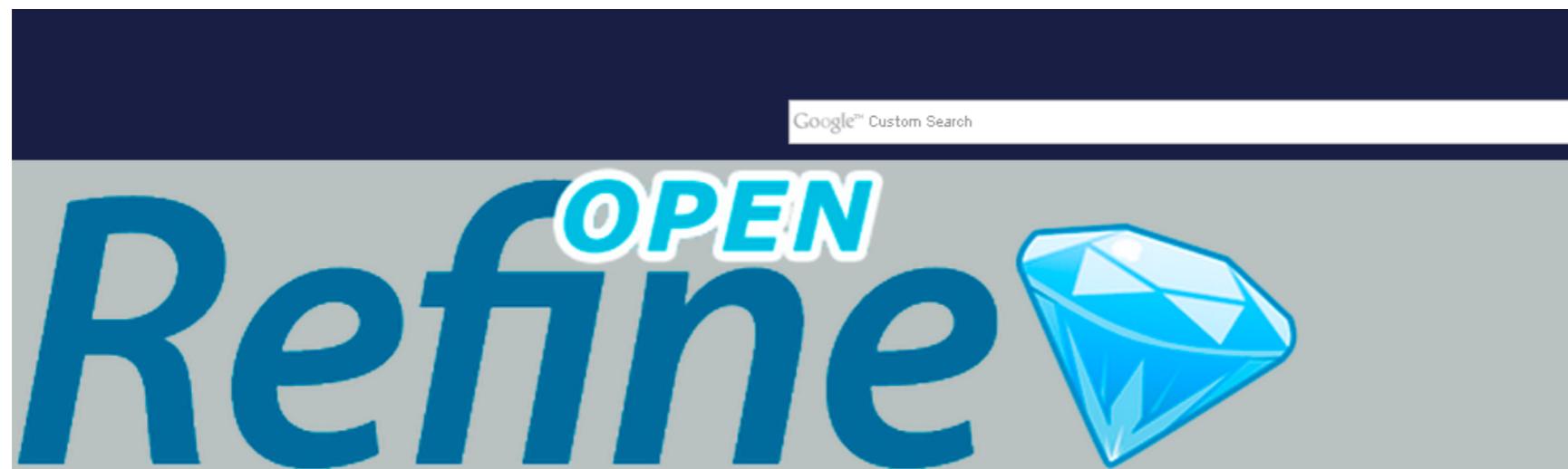
D2Refine + MDR



Open Refine

- What is Open Refine?

OpenRefine is a power tool that allows you to load data, understand it, clean it up, reconcile it to master database, and augment it with data coming from Freebase or other web sources. All with the comfort and privacy of your own computer.



<http://openrefine.org>

Open Refine

- Recognize:
 - patterns
 - common characteristics of row, columns
- Customize with:
 - Transform with Facets
 - Filters, Grouping/Clustering
 - Develop Extensions
 - Standardize, Link with local or external resources.

Open Refine

- Tool to work with messy data
- Fix Inconsistencies
- Transformation of Data
- Spreadsheet like interface in browser
- Parsing data from websites, web-services, Freebase.
- Extensions, Add Reconciliation Services

Open Refine RDF Extension

The screenshot shows the Open Refine interface with the RDF extension loaded. The top navigation bar includes 'Open...', 'Export...', and 'Help' buttons. Below the bar, the 'Extensions:' dropdown is set to 'Named-entity recognition' and includes options for 'Freebase' and 'RDF'. A context menu is open over a table row, with the 'RDF' option selected. The menu items are: 'Edit RDF Skeleton...', 'Reset RDF Skeleton...', and 'Add reconciliation service'. The main table view shows a single row with columns for 'Based on SPARQL endpoint...', 'Based on RDF file...', 'Based on a Sindice site search...', and 'Based on a Apache Stanbol EntityHub...'. The last two columns contain numerical values: '33' and '90'.

D2Refine

- Extension of Google OpenRefine
- Data element mapping based on the smart spreadsheet paradigm
- RDF Import for mapping
- CTS2 API for terminology mapping
- Interface to ShEx Schema + MDR

Open Refine - Reconciliation

The screenshot shows the Open Refine interface with a context menu open over a column header. The column header is labeled "variable - name". The menu has three main sections: "variable - name", "variable - type", and "variable - description". The "variable - type" section is currently active, showing the following options:

- Facet
- Text filter
- Edit cells
- Edit column** (highlighted)
- Transpose
- Sort...
- View
- Reconcile

The "Edit column" option is expanded, showing the following sub-options:

- Split into several columns...
- Add column based on this column...
- Add column by fetching URLs...
- Add columns from Freebase ...
- Rename this column
- Remove this column
- Move column to beginning
- Move column to end
- Move column left
- Move column right

Open Refine - Reconciliation

Add column based on column variable - name

New column name

On error set to blank store error copy value from original column

Expression Language Google Refine Expression Language (GREL)

'Patient.' + value No syntax error.

Preview History Starred Help

row	value	'Patient.' + value
1.	SUBJID	Patient.SUBJID
2.	Site of Primary (Event)	Patient.Site of Primary (Event)
3.	null	null
4.	age	Patient.age
5.	null	null
6.	sex	Patient.sex
-	--	--

OK Cancel

Open Refine - Reconciliation

	variable - value - code	variable - name	fhir-binding	variable - type	
	SUBJID	Patient.SUBJID		string	De
COLN	Site of Primary (Event)	Patient.Site of Primary (Event)		encoded value	In
RECT					
	9999	age	Patient.age	integer, encoded value	Ag
	1000				
F	sex	Patient.sex		encoded value	Ge
M					
NA					
UNK					
BRAIN	Site(s) of Disease	Patient.Site(s) of Disease		encoded value	The (e)
DIS NODE					
LIVER					
LUNG					
N/A					
NODES					
NODES, PRIM					

Open Refine - Reconciliation

The screenshot shows the Open Refine interface with a reconciliation menu open. The menu is triggered by a right-click on a column header labeled "Reconcile". The menu items are:

- Start reconciling... (highlighted)
- Facets
- QA facets
- Actions
- Copy reconciliation data...
- Discover related RDF datasets...

The main table view shows columns for "variable - name", "fhir-binding", "variable - type", and "variable - description". The "fhir-binding" column contains dropdown menus for "Facet", "Text filter", "Edit cells", "Edit column", "Transpose", "Sort...", "View", and "Reconcile". The "variable - type" column contains "string", "encoded value", "integer, encoded value", and "encoded value". The "variable - description" column contains "De-identifying", "Indicates", "Age at the event", and "Gender c".

Synopsis

- Constraint based modeling and CIMI allow one to represent information at different levels of abstraction (observation_value —> abnormally high total serum bilirubin result)...
- Tools exist today to map any data into RDF...
- ... ShEx provides the ability to traverse a schema and transform RDF —> RDF or RDF —> (target)
- CIMI provides canonical clinical models for decision support
- RDF + ShEx + DBRefine + (other tools) provide tools to define transformations from input data to canonical form (e.g. FHIR Observation —> CIMI Observation Value)
- ShEx provides the ability to realize UML + ADL/AML predicates against canonical form

Credits

- **David Booth, PhD** (Hokukahu LLC) — Yosemite vision
- **Eric Prud'hommeaux** (MIT) — ShEx tools + FHIR/RDF Work + general web sanitation engineering
- **Deepak Sharma** (Mayo Clinic) — D2Refine
- **Guoqian Jiang, M.D., PhD** (Mayo Clinic) — vision and funding
- **Stan Huff, M.D., CMIO** (IHC) — CIMI and all that
- **Visumpoint** — AML tooling and support

The project is supported in part by a NCI U01 Project (U01 CA180940) – caCDE-QA : A quality assurance platform for cancer study common data elements.

Links

The Yosemite Project

- <http://YosemiteProject.org/>

CIMI

- <http://opencimi.org/>

Tools

- <http://www.w3.org/wiki/ConverterToRdf>
- <https://github.com/caCDE-QA>
- <https://json-ld.org>
- <http://www.w3.org/2013/ShEx/FancyShExDemo>
- <http://www.w3.org/wiki/ConverterToRdf>
- <https://github.com/w3c/hcls-fhir-rdf>

D2Refine

- <https://github.com/caCDE-QA>

ShEx

- <http://shexspec.github.io/primer/>
- <http://www.w3.org/TR/shacl/>