Communication protocols and norms in healthcare
HL7 FHIR

Course: Biomedical Informatics

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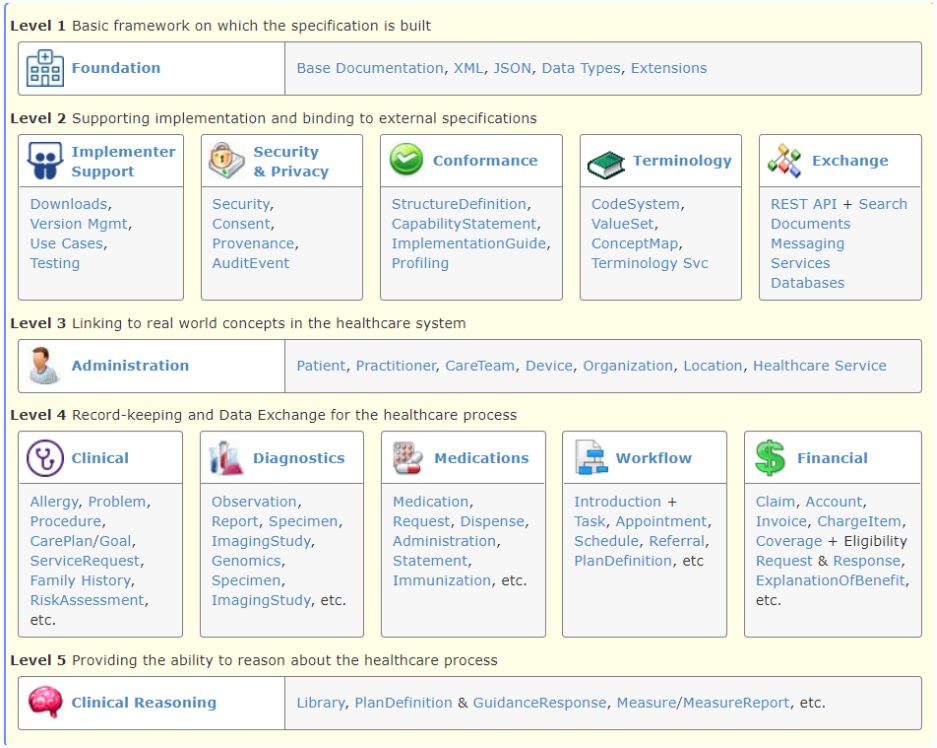
HL7 FHIR

- Recognizing all the challenges in HL7 norms, primarily optionality, localization (Z segments) and complexity in implementations, HL7 started a new development in the early 2010s
- FHIR – Fast Healthcare Interoperable Resources
- Questions like:
  - How to communicate data from my clinical server to the iOS App
  - How do I connect my applications using cloud servers
  - How to send queries to retrieve patient data



www.hl7.org/fhir

HL7 FHIR Manifesto

- Strong emphasis on implementations
- Multiple implementation libraries, large set of examples for rapid development
- Publicly available resources and specifications (Creative Commons)
- Interoperability – simple resources can be used *as is*, with the possibility of local adaptations
- Normal evolution path from HL7v2 and CDA
- Simple shared scenarios
- Support for RESTful architectures, and information exchange using messages, documents or service architectures
- Use of new web standards (XML, JSON, ATOM, HTTPS, Oauth)
- Human readability
- Ontology and data mapping for semantic consistency

HL7 FHIR

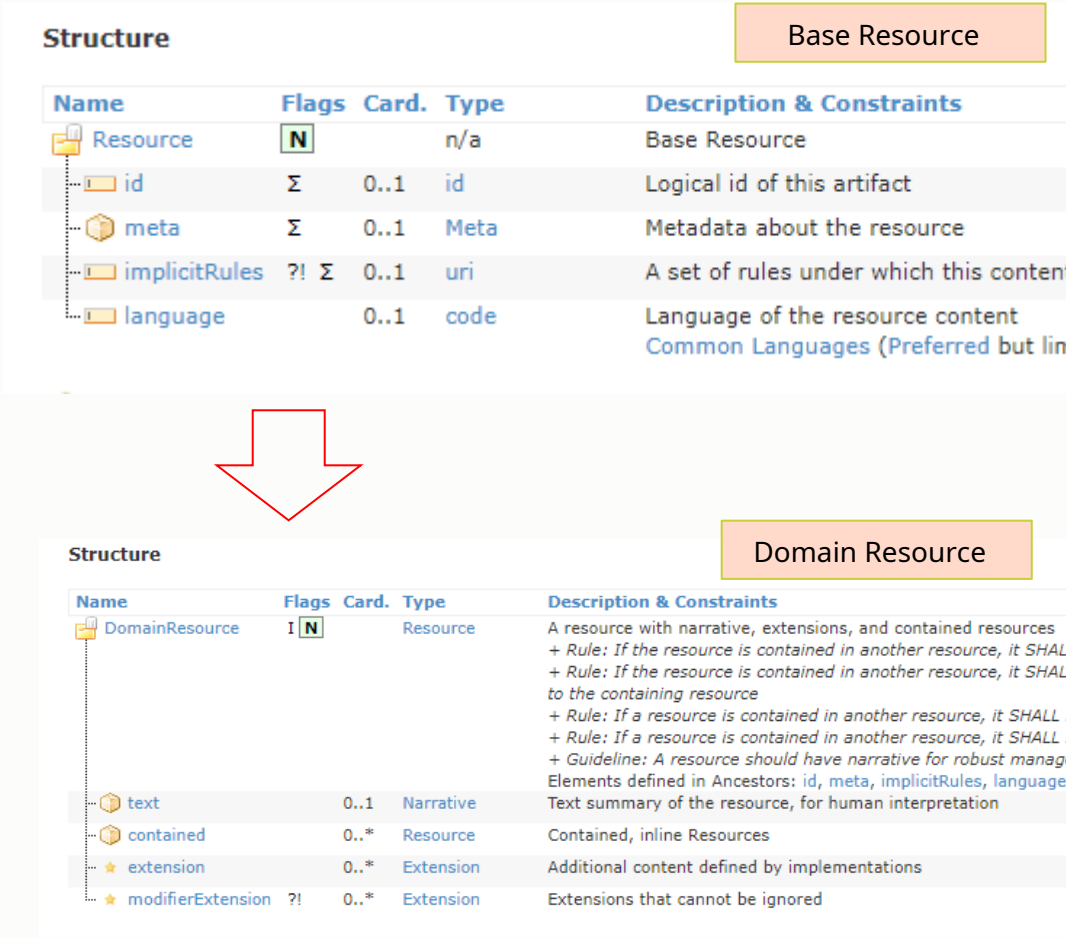
- The HL7 FHIR specification consists of two main parts
  - Definition of the information model of the clinical content itself (FHIR Resources)
  - Information Exchange Specification (FHIR API)
- It is also expanding into areas such as
  - Clinical knowledge management
  - Decision support
  - Quality control
  - Persistence
- Supported by the general public and various stakeholders of the system (SW development, suppliers of professional solutions, administration, health organizations, insurers, etc.)
- Supports all data exchange paradigms
  - Real time API's
  - Documents and messages
- Wide range of servers and testing tools

What are FHIR Resources?

- "Resources" are:
  - Logical units (*building blocks*) to change clinical, administrative and financial data
  - They define some behavior or meaning
  - The smallest possible units that are of interest in healthcare
- Consistent semantic model with controlled extensions
  - 80% of the content from all use cases is in the resource definition
  - 20% of the content is left for resource extensions
- Use of UML, XML or JSON technologies for resource representation
- The FHIR resource is conceptually similar to the HL7v2 segment

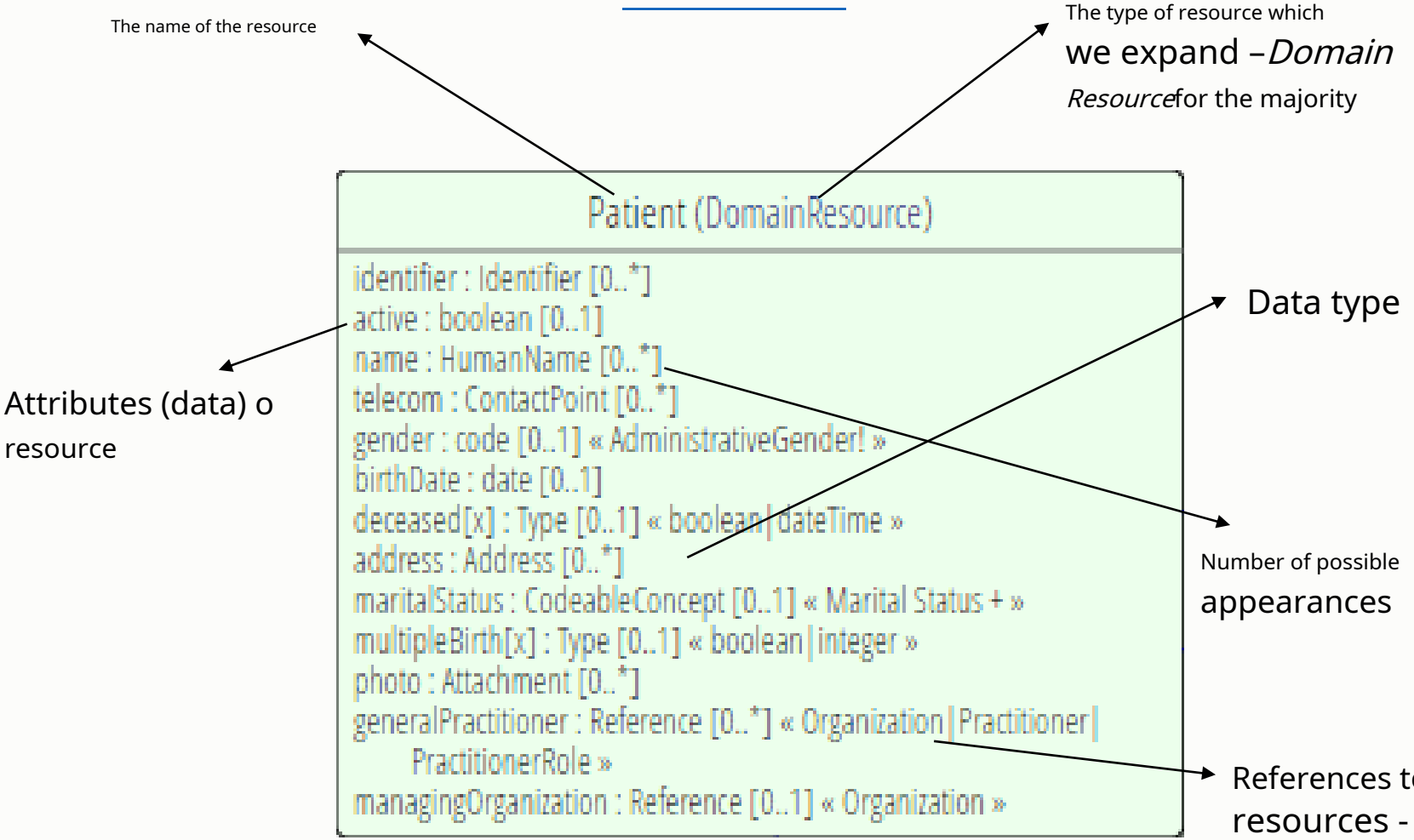
How do we define FHIR Resources?

- FHIR resource as an entity has:
  - Unique URL for identification
  - Defined resource type
  - A set of predefined structured elements
  - Version
- **FHIR Base Resource** is a base resource that defines attributes, which are inherited by all other resources
  - Logical Identity
  - Meta data (source, versionID, etc.)
  - Basic language
  - Implicit in the rules, which limit the use (eg Implementation Guide)
- **DomainResource** is the starting resource for all domain resources (except Bundle , Parameter and Binary) which additionally defines:
  - Human readable part of the text (XHTML)
  - Additional resources within the resource itself (Contained Resources)
  - Resource extensions



FHIR Resource Example

Patient



FHIR Resource - Example

```
<Patient xmlns="http://hl7.org/fhir">
  <id value="glossy"/>
  <meta>
    <lastUpdated value="2014-11-13T11:41:00+11:00"/>
  </meta>
  <text>
    <status value="generated"/>
    <div xmlns="http://www.w3.org/1999/xhtml">
      <p>Henry Levin the 7th</p>
      <p>MRN: 123456. Male, 24-Sept 1932</p>
    </div>
  </text>
  <extension url="http://example.org/StructureDefinition/trials">
    <valueCode value="renal"/>
  </extension>
  <identifier>
    <use value="usual"/>
    <type>
      <coding>
        <system value="http://hl7.org/fhir/v2/0203"/>
        <code value="MR"/>
      </coding>
    </type>
    <system value="http://www.goodhealth.org/identifiers/mrn"/>
    <value value="123456"/>
  </identifier>
  <active value="true"/>
  <name>
    <family value="Levin"/>
    <given value="Henry"/>
    <suffix value="The 7th"/>
  </name>
  <gender value="male"/>
  <birthDate value="1932-09-24"/>
  <careProvider>
    <reference value="Organization/2"/>
    <display value="Good Health Clinic"/>
  </careProvider>
</Patient>
```

Resource Identity & Metadata

Human Readable Summary

Extension with URL to definition

Standard Data:
- MRN
- Name
- Gender
- Birth Date
- Provider

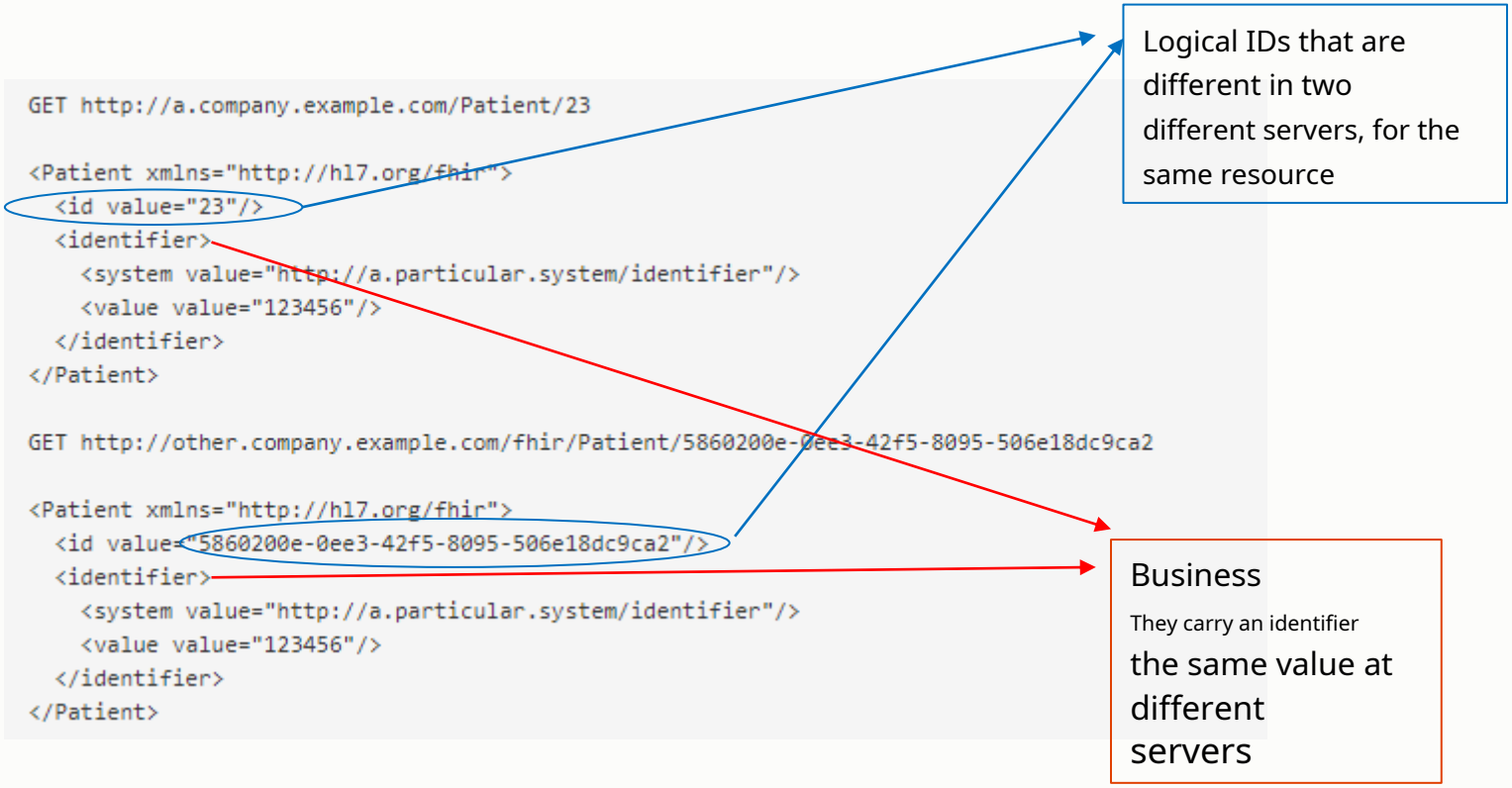
http://hl7.org/implement/standards/fhir/patient.html

Resource identification

- 2 basic ways of resource identification
  - Logical ID
  - Business Identifier and Canonical URL
- Logical IDis a location URI, which identifies where a particular resource can be accessed on the local server
  - Based on logical rather than physical ID.
  - It changes as a single resource changes location. However, on a single server, once a value is assigned, it does not change.
  - Example:http://test.fhir.org/rest/Patient/123
    - 123 is the Logical ID for the Patient resource on the serverhttp://test.fhir.org
- Business Identifier– an inherent part of the resource that remains fixed regardless of information transfer
  - A Business Identifier is part of a resource specification that defines a term in the real world. Although the Logical ID changes as the resource moves from one server to another, the actual meaning of the resource does not change.
  - All resources that have an identifier element, which is then of type Identifier
  - Preferred way to identify the same content on different servers (person identification like OIB or JMBG that doesn't change)
- Canonical URL
  - A special type of Business identifier
  - Preferred way to reference knowledge sources and conformance profiles
  - The format is actually URI, while URL is used for historical reasons

Resource identification - example

• Access and recognitionthe same patient on two different servers



Types of FHIR Resources

- Foundation Resources– a basic set of resources, often used in different infrastructure use cases
  - Conformance, Terminology, Security, Documents, Other
- Base Resources– the most frequently used resources, typically the last resources on the graph. They are very often referenced by other resources, but rarely reference other resources themselves. Therefore, they require strong consistency
  - Individuals, Entities, Workflow, Management
  - Examples - patient, Organization, Doctor, etc.
- Clinical Resources– frequently used information components in clinical practice. They can be used separately, but most often refer to resources from the base group
  - Examples - Summary, Diagnostics, Medications, Care Provision, Request & Response
- Financial Resources– they are built on the basis of basic and clinical resources, and are dedicated to the financial aspects of the healthcare process
  - Support, Billing, Payment, General
- Specialized Resources– resources related to less frequent use cases
  - Public Health & Research, Definitional Artifacts, Evidence-Based Medicine, Quality Reporting & Testing, Medication Definition

http://hl7.org/fhir/resourcelist.html

Examples of FHIR Resources

General

Patient

Practitioner

AllergyIntolerance

Condition (Problem)

Procedure

ClinicalImpression

FamilyMemberHistory

Care Provision

CarePlan

CareTeam

Goal

ReferralRequest

ProcedureRequest

NutritionOrder

VisionPrescription

Medication & Immunization

Medication

MedicationRequest

MedicationAdministration

MedicationDispense

MedicationStatement

Immunization

Diagnostics

Observation

DiagnosticReport

ProcedureRequest

Specimen

BodySite

ImagingStudy

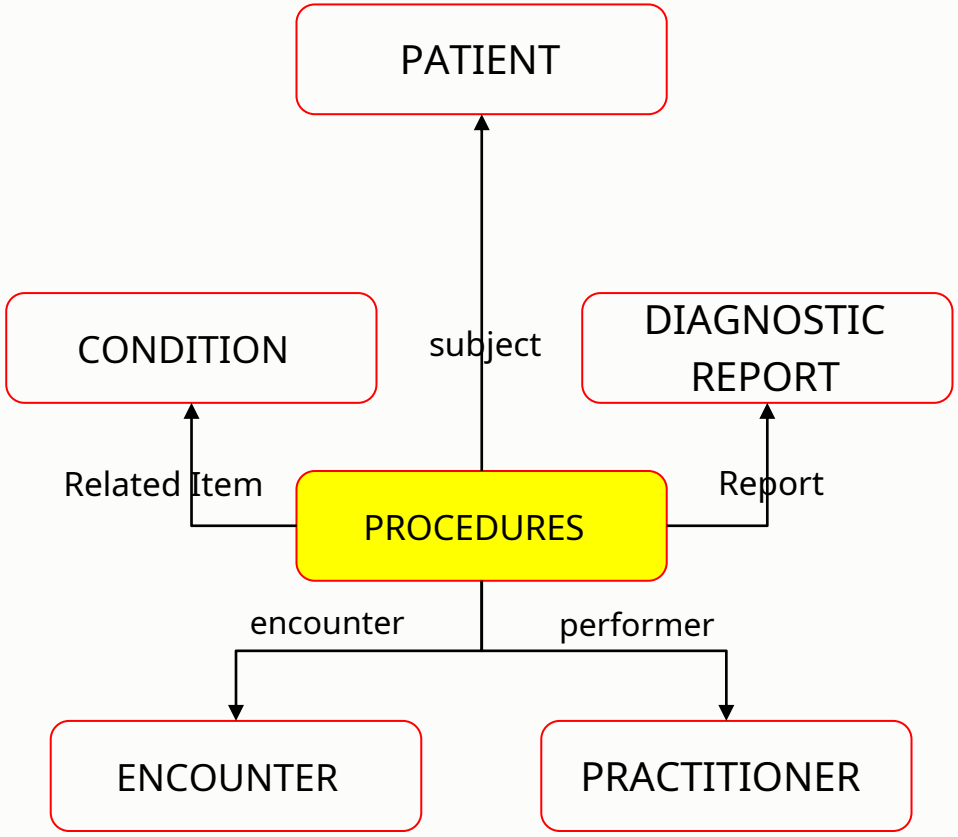
Sequence

What is not an FHIR Resource

- Sex
  - Too small
- Blood pressure
  - Too specific
- Pregnancy
  – Too broad and too abstract
- Electronic health record
  - Too big

Resource referencing

- We achieve the real power of HL7 FHIR through combining and referencing resources
- Using references, we build implementations of real scenarios in healthcare
- References are always shown in one direction
- Combining resources can be achieved through two basic ways
  - Standard/general references, through *References* type
  - Canonical references through the URL on the Identifier attribute of the resource, which are then unique for all contexts



Generic references

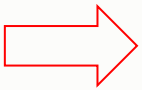
- To use resource references, at least one of the elements must be present
  - *references*
  - *identifier*
  - *display*
- The reference element refers to the explicit referencing of the content (literal reference).
  - *References* element contains a URL in one of the following formats
    - Absolute URL – secure and scalable access suitable for cloud/web server
    - Relative URL – relative URL to the underlying service base, or within *Bound* more resources
    - Internal resource fragment - contained resources (see slide behind)
- Logical references – through identifier element, when the Literal Reference is not known or available (such as a unique patient ID)
- Display – used as a plain text alternative for the referenced resource

Structure

Name	Flags	Card.	Type	Description & Constraints
Reference	Σ I N		Element	A reference from one resource to another *+ Rule: SHALL have a contained resource if a local reference is provided* Elements defined in Ancestors: id, extension
reference	Σ I	0..1	string	Literal reference, Relative, internal or absolute URL
type	Σ	0..1	uri	Type the reference refers to (e.g. "Patient") ResourceType (Extensible)
identifier	Σ	0..1	Identifier	Logical reference, when literal reference is not known
display	Σ	0..1	string	Text alternative for the resource

Contained Resources

- Addresses cases when a single referenced resource does not exist outside of the resource that contains it
  - It cannot be uniquely identified
  - It cannot be communicated/transmitted separately
- In practice, this happens when *middleware* layer/interface *engine* arranges some information on the basis of partially available information
- Example – Condition Resource that has partial information about the doctor
- A practice that should be avoided unless absolutely necessary, i.e. when all mandatory information about the resource is known



```
<Condition xmlns="http://hl7.org/fhir">
 <contained>
   <Practitioner>
     <id value="p1"/>
     <name>
       <family value="Person"/>
       <given value="Patricia"/>
     </name>
   </Practitioner>
 </contained>
 <!-- other attributes -->
 <asserter>
   <reference value="#p1" />
 </asserter>
 <!-- other attributes -->
</Condition>
```

An example of modeling

12-year-old-boy

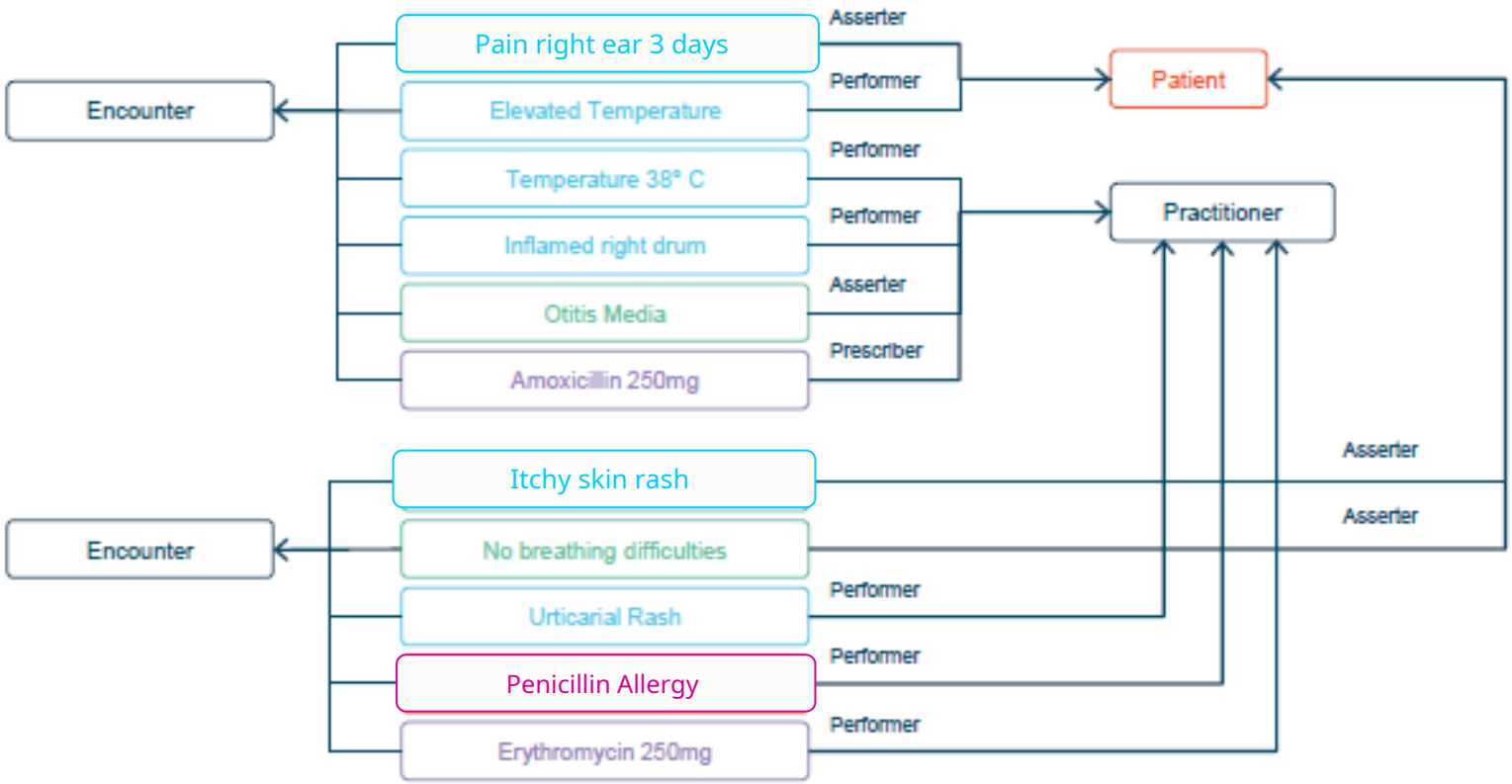
First consultation

Complaining of pain in the right ear for 3 days with an elevated temperature. On examination, temperature 38°C and an inflamed right eardrum with no perforation. Diagnosis Otitis Media, and prescribed Amoxicillin 250mg 3 times per day for 7 days.

Follow up consultation

2 days later returned with an itchy skin rash. No breathing difficulties. On examination, urticarial rash on both arms. No evidence meningitis. Diagnosis of penicillin allergy. Antibiotics changes to Erythromycin 250mg 4 times per day for 10 days.

Related Resources



Grouping of resources

- When changing data, as a rule, we communicate sets of resources that are related to a certain case and context
- For this purpose, a Bundle resource is defined, which is basically infrastructural *container* for a set of resources
- Used in a variety of applications
  - Access to a set of resources that suit someone *search* criterion
  - Retrieving several different versions of the same resource from a server
  - Sending a resource set as an HL7 message (*messaging*)
  - Grouping independent sets of resources into a document - for sending and persistence purposes (document exchange)
  - Create/update/delete a set of resources on the server as a single operation
  - Saving a set of resources in the database
- Bundle and Contained Resources (see slides before) imply an important difference – Bundle contains resources that are *independent*, while Contained Resources se*I cannot interpret it out of context* in which they are located

Grouping of resources

• In addition to the Bundle, there are 3 administrative/infrastructureresources which also enable content grouping

- Leaf– a list of individual resources such as*flat*a structure of references to other resources, with functions for managing them (e.g. list of diagnoses or medications received by the patient)
  - As a rule, the list is dynamic, in such a way that resources are added and subtracted over time
  - Unlike Bundle, List indicates some meaning/relationship of resources regardless of packaging
- Group– a group of specific people, animals, devices and the like, with additional common parameters shared by group participants
  - The idea is that there is a need and/or action to view the group of resources as a community (group therapy, group-related risk, etc.)
  - Often used in public health
- Composition- a set of health information that provides unique content, context and clinical evidence for a given situation (characteristics of the document)
  - Basic resource for FHIR document structure
  - Composition resource has no content in itself, but carries contextual information important to the document
  - The full content of the document is inside the Bundle
  - They often reference Lists as the focus of individual sections

• None of the resources above directly contain the resources themselves, but use the Resource link to connect the resources to a group

– Translated, it's about Containers for resources that share some context

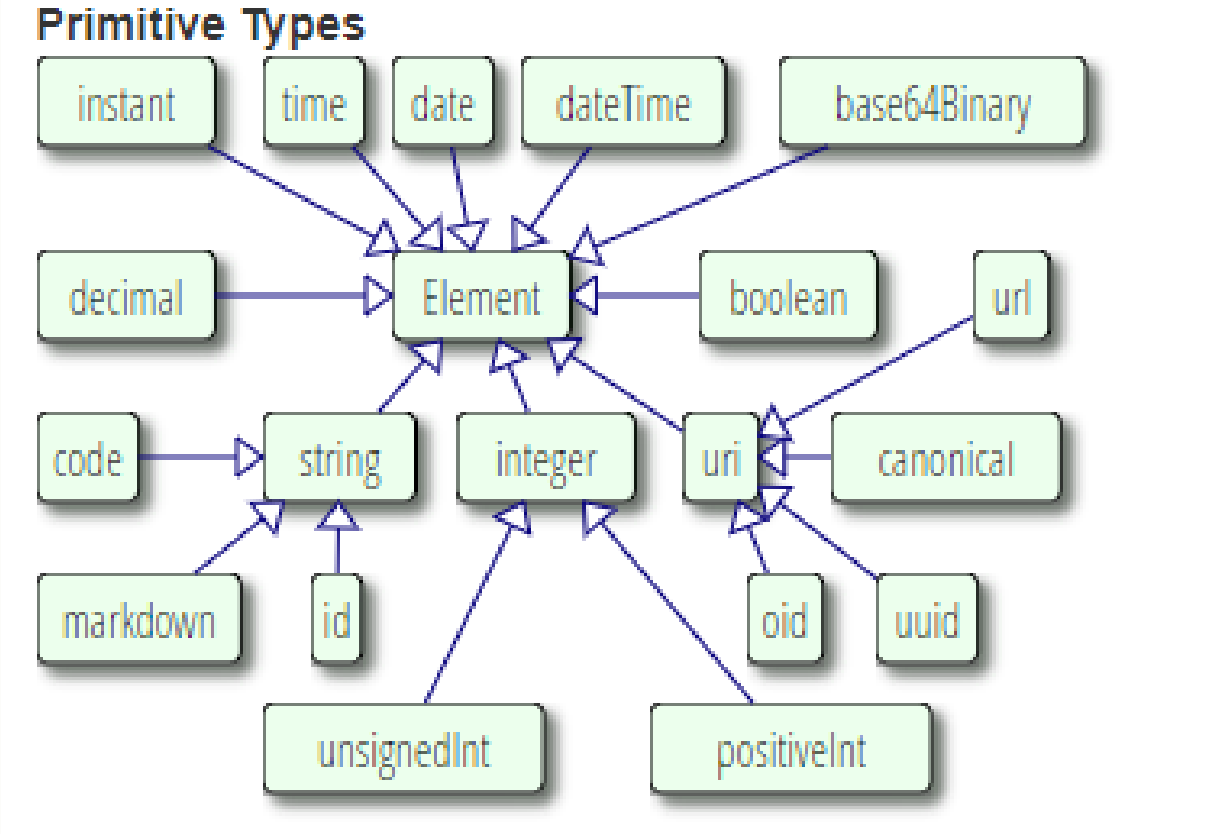
Types of data elements

within the resource

- Primitive (simple) data elements
- Complex elements for general use
- Meta data elements
- Data elements for special use

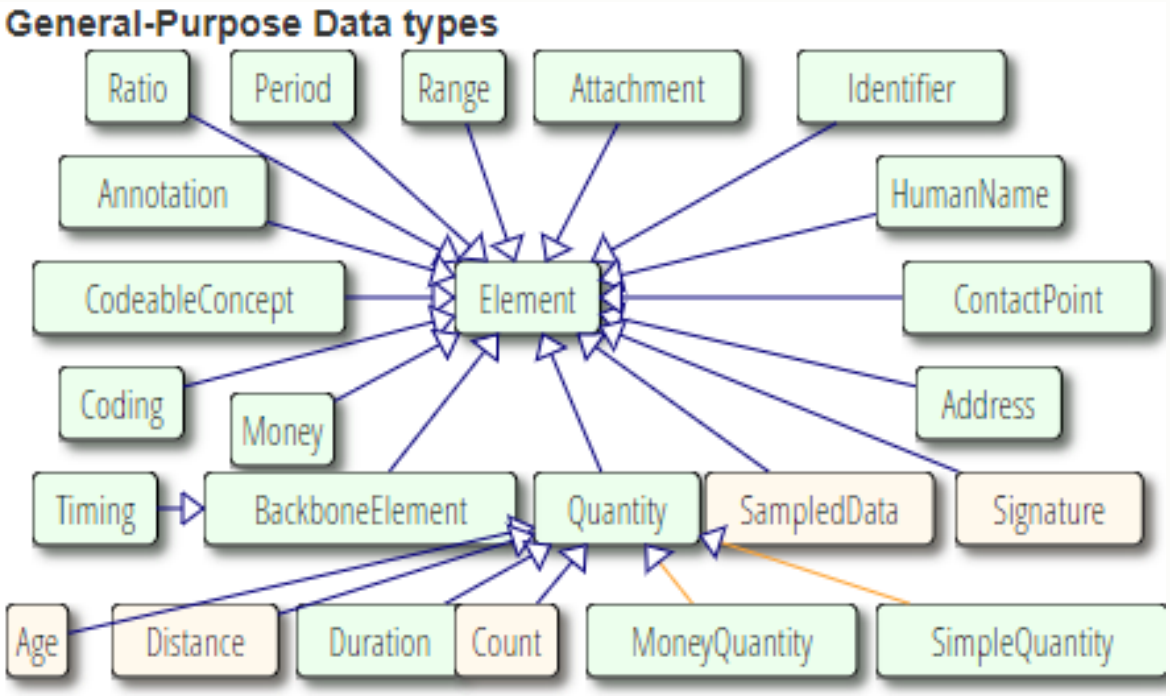
Primitive elements

- Based on W3C and ISO data elements



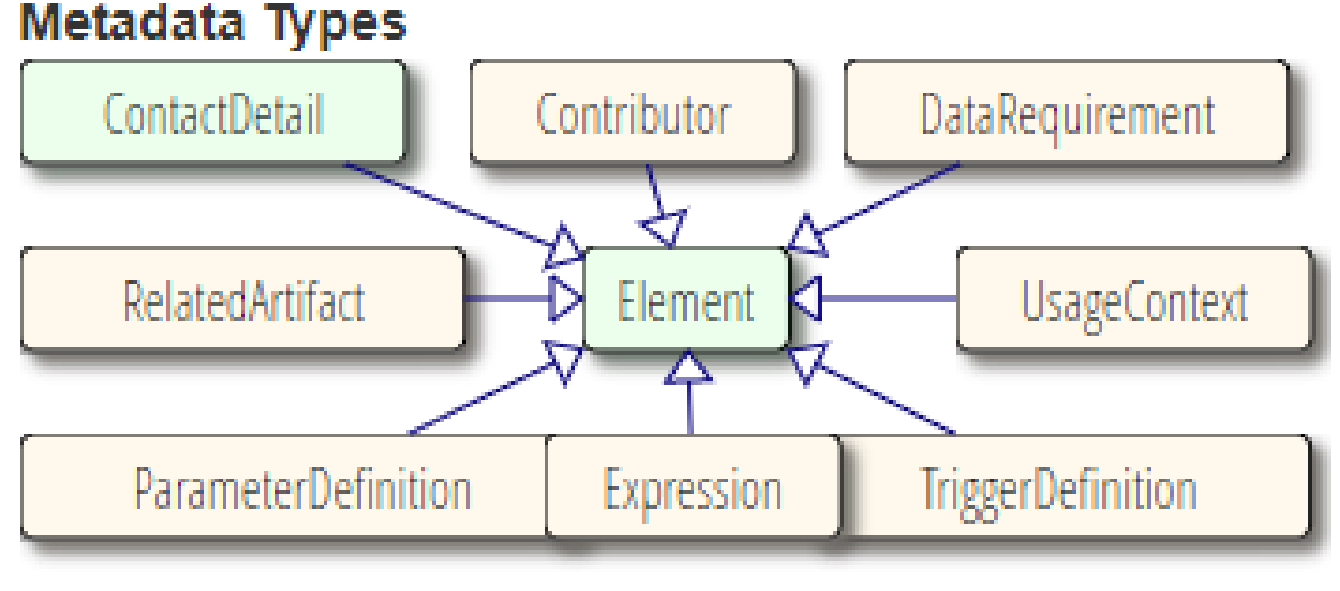
Complex elements for general use

- Using XML notation, these data types are represented as XML elements with *child* attributes
- Complex elements can be profiled



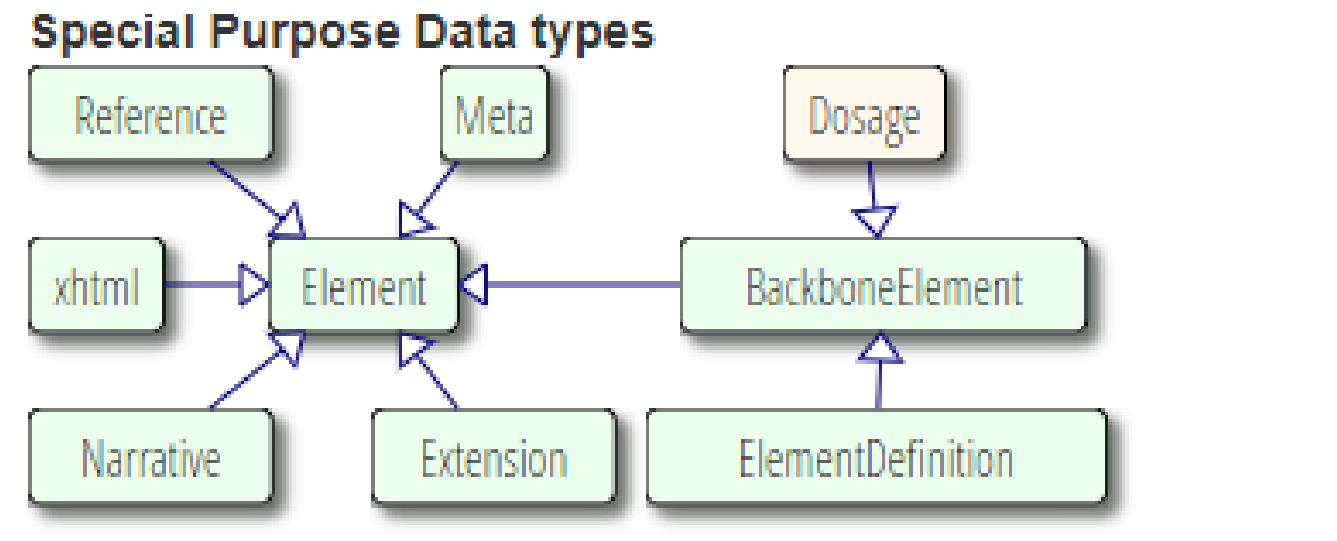
Metadata data types

- Set of data types used in resource metadata



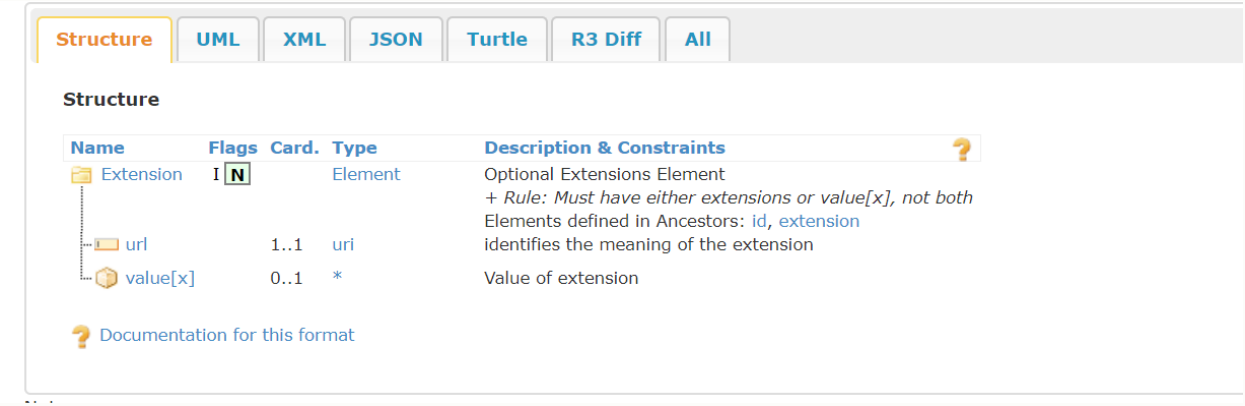
Data elements for special use

- Elements with a special purpose



Extensions

- The FHIR standard is built with the 80/20 concept at the heart of the definitions
  - 80% of all requests enter the normative/universal resource
  - 20% of other requests go to extensions
- Extensions are controlled, manageable and accessible
- Each element in the resource can have an extension, which then as *child* element describes additional information that is not part of the basic resource
  - As a rule, applications should not reject a resource just because it has an extension, but they can reject a resource because of the specific content of extensions
- Attributes
  - URL is a mandatory attribute that carries the URL address where the extension definition is located
  - Value is the value of the content of the extension, which is always in one of the formats recognized by HL7 FHIR.



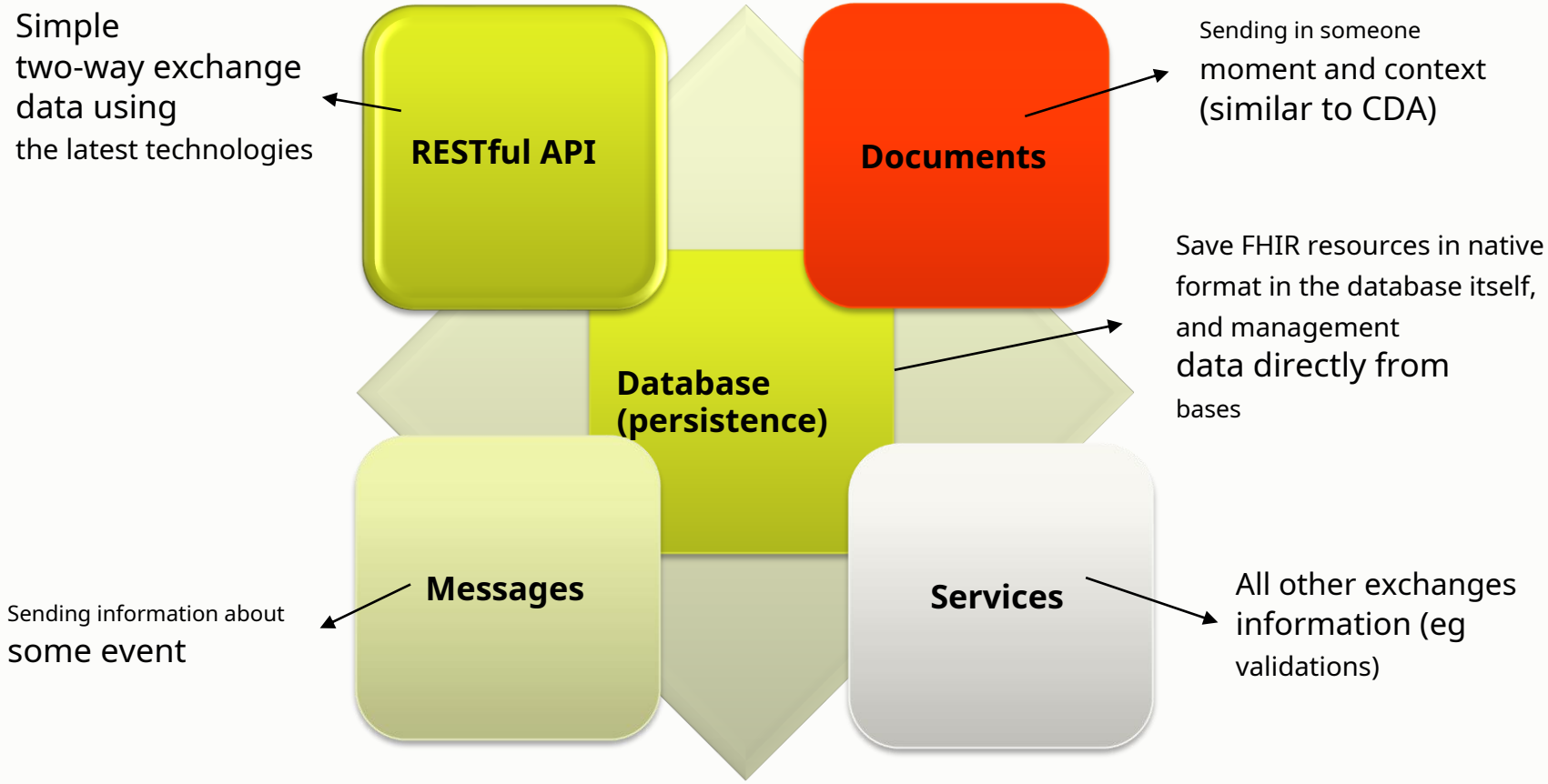
An example of an extension

Adding information about citizenship and period of the same to the patient resource

```
<Patient>
  <extension url="http://hl7.org/fhir/StructureDefinition/patient-citizenship " >
    <extension url="code" >
      <valueCodeableConcept>
        <coding>
          <system value="urn:iso:std:iso:3166" />
          <code value="DE" />
        </coding>
      </valueCodeableConcept>
    </extension>
    <extension url="period" >
      <valuePeriod>
        <start value="2009-03-14" /> </
        valuePeriod>
    </extension>
  </extension>
  <!-- other data for patient --> </
  Patient>
```

FHIR API

- FHIR Supports 5 implementation paradigms (R4)



FHIR REST API

- The most common choice of implementation teams, the technology used in all leading mobile/cloud environments today
- 4 standard operations - Create, Read, Update, Delete; and Search and Execution Support

- The API describes FHIR resources as a set of operations (interactions) on these resources, which are then used to manage these instances
- Syntax of the operation (see image below):
  - Base – address where all resources are located on a particular server
  - Type – name of the resource type (eg Patient)
  - Id – Logical ID of the resource
  - Mime time – coding (XML or JSON)
- [] – mandatory parts
- {} – optional parts
- A simple example – retrieving a patient whose logical ID is 23

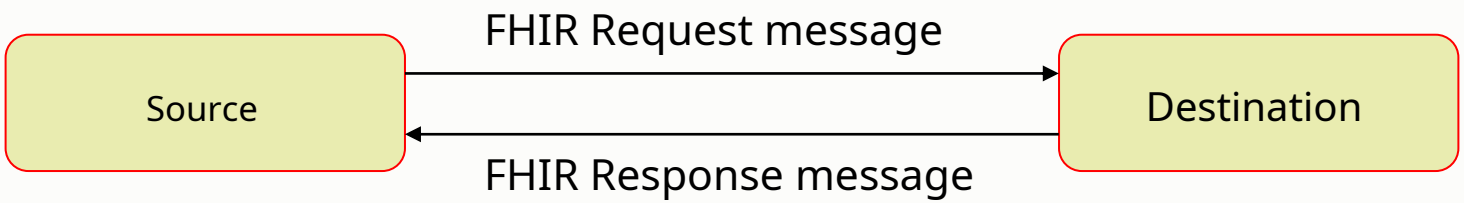
Instance Level Interactions	
read	Read the current state of the resource
vread	Read the state of a specific version of the resource
update	Update an existing resource by its id (or create it if it is new)
patch	Update an existing resource by posting a set of changes to it
delete	Delete a resource
history	Retrieve the change history for a particular resource
Type Level Interactions	
create	Create a new resource with a server assigned id
search	Search the resource type based on some filter criteria
history	Retrieve the change history for a particular resource type
Whole System Interactions	
capabilities	Get a capability statement for the system
batch/transaction	Update, create or delete a set of resources in a single interaction
history	Retrieve the change history for all resources
search	Search across all resource types based on some filter criteria

VERB [base]/[type]/[id] {?_format=[mime-type]}

GET http://a.company.example.com/Patient/23

FHIR Messaging

- Use of FHIR resources in traditional messaging architectures (HL7v2)
- A set of fixed information that is exchanged between applications when a specific event (TE) occurs.
- Two basic messages – Request and Response
- FHIR Request Message
  - FHIR Bundle identified with type = message
  - The first resource in the Bundle is the MessageHeader, which carries in the Message Event attribute information about the message, as well as additional meta data
- FHIR Response Message
  - One or more messages with the same logic as Request (Bundle, MessageHeader)
- An exampleRequest andResponse

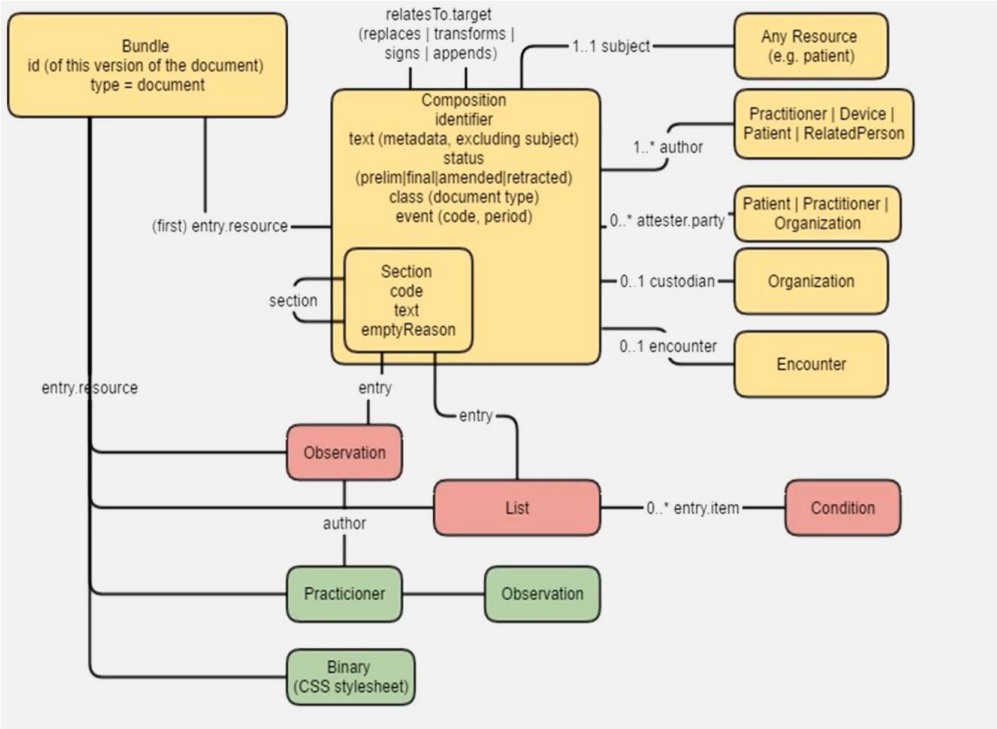


FHIR Documents

- FHIR resources can be used to build a document
  - A document in this context is any set of information that is undeniable and authorized by a person, device or organization
- In FHIR, we distinguish between two document types
  - One that is built from FHIR resources
  - References to existing documents using the DocumentReference resource (meta data about the document, and the document itself)
- All documents in FHIR have the same architecture
  - Bundle is a basic resource, which carries the document value in type
  - Composition is the first resource in Bundle, which then defines
    - Identity and purpose of the document
    - Context and meta data (author, subject, who authenticated the document)
    - Divides the document into sections, each with its own narrative part
  - In the continuation of the Bundle there are a number of other resources that we reference from the Composition resource

FHIR Documents

- The Bundle should include the following references from Composition
  - Composition. subject
  - Composition.encounter
  - Composition.author
  - Composition.attester.party
  - Composition. custodian
  - Composition.event.detail
  - Composition.section.author
  - Composition.section.focus
  - Composition.section.entry



Source: Rene Spronk, Ringholm.de
FHIR Dev Days 2019
http://www.ringholm.com/column/combining_ihe_xds_mhd_and_fhir.htm

HL7 FHIR Services

- Refers to the Service Oriented Architecture (SOA) paradigm of information exchange
- A set of functional operations implemented by a particular system
- Several approaches
  - FHIR + REST ("RESTful FHIR"), the dominant implementation approach
  - FHIR + WS* represents FHIR implementations that use web services for communication instead of REST. In that case, FHIR resources are transferred as payload parameters within the SOAP (Simple Object Access Protocol) call
  - FHIR + SOA Pattern illustrates the way interaction patterns, exception management and role management are applied, according to SOA practices, with different implementation technologies (SOAP, REST, etc)

Tools and Example Scenarios

- (David Hay's) clinFHIR tool
  - http://clinfhir.com/
  - Educational tool for non-technicians (especially medical and business professions)
- Visualization of FHIR SW
- Beta software!
  - Resource Builder
  - View Resources
  - Create Condition
  - Try to create your own scenario:
    - https://fhirblog.com/creating-a-simple-scenario/
    - http://clinfhir.com/builder.html

graphical representation

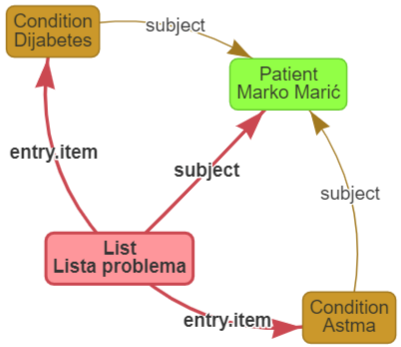
Scenario Builder | Hide Selector | Import resource | Show version | Validate All | Update Server | Refresh

Local Scenarios | New Scenario

Problem List
Lista problema za pacijenta

List | Description | Graph | FHIRPath | Add Resource | Mark

Zoom Graph | Show direct references to Condition only | Hide Patient



Astma
Condition cf-1578941028475

Structure & Reference | Current resource views | Changes 2 | Errors/Warnings

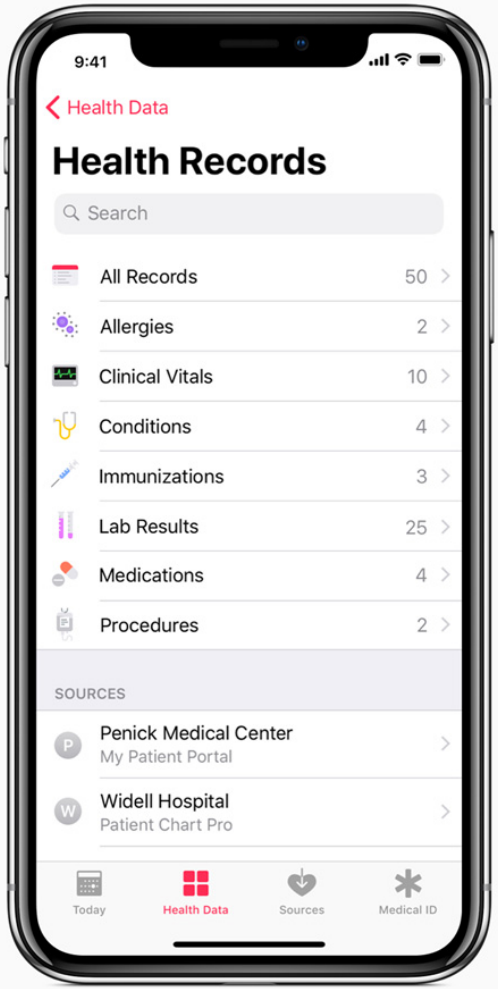
Toggle Input Mode

- Condition
  - identifier *
  - clinicalStatus
  - verificationStatus
  - category *
  - severity
  - code
  - bodySite *
  - subject[x]
  - context[x]
  - onset[x]
  - abatement[x]
  - assertedDate
  - asserter[x]
  - stage
  - evidence *
  - note *

Astma

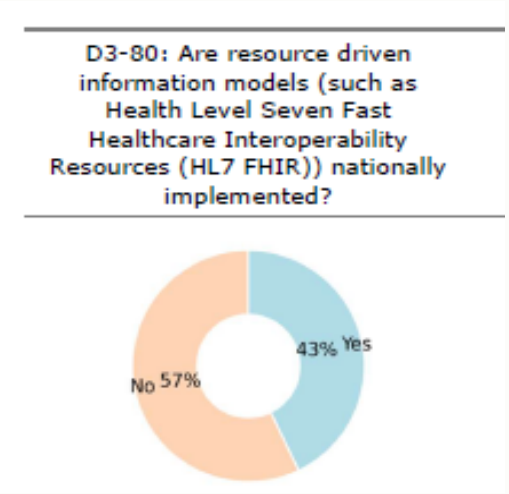
HL7 FHIR Implementations

- Argonaut Project:
  - Private sector initiative for the application of HL7 FHIR in industry, according to the HIT standards and policy committee
  - FHIR-based API and Core Data Services specifications (SMART of FHIR)
- Industry Pledge
  - "Amazon, Google, IBM Pledge Health Data Standards, Interoperability (Aug-2018 -link)
  - Apple iOS 11.3 native FHIR support – from the initial 12 to today 500+ health centers involved in the project (Jan 2018 –link)
- Da Vinci Project
  - EMR vendors in cooperation with insurers
  - Value-based care
  - Use cases - 30 day medication reconciliation and coverage discovery (link)

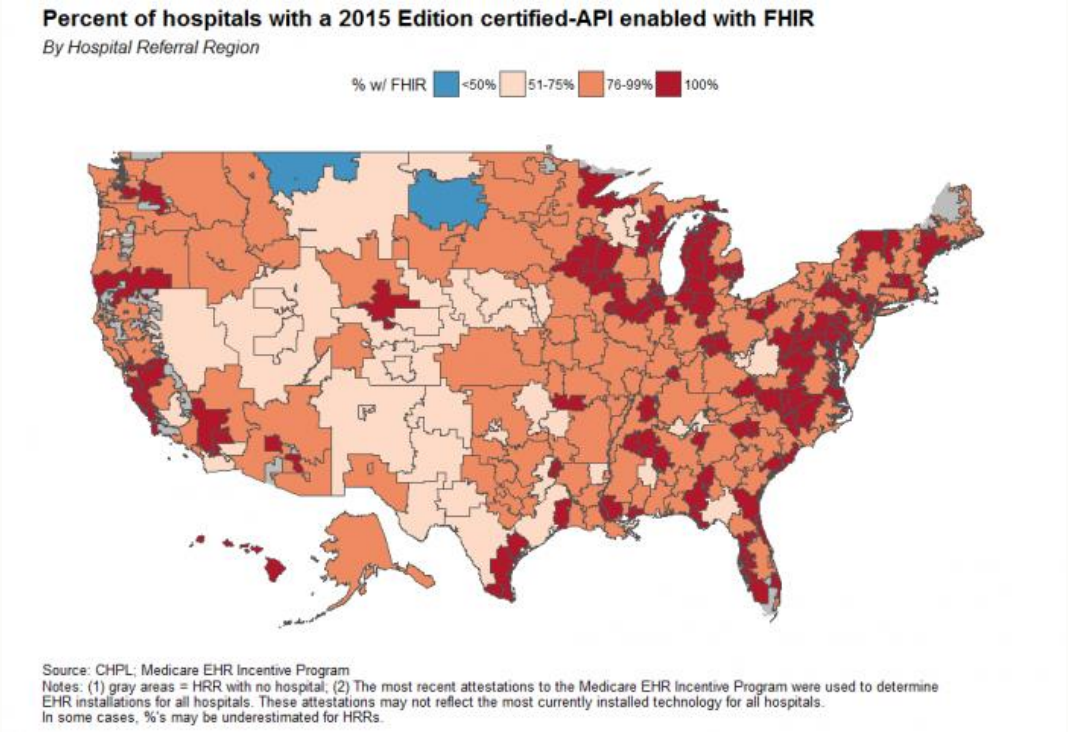


FHIR Application and Implementations

- The last official version - Release 4
- Release 5 is being prepared for 2022



Interoperability of Electronic Health Records in the EU (2020) European Commission



HL7 FHIR
Pros and Cons

- Avg
  - Strong momentum and support in the market
  - Simple and fast implementations
  - Use of modern technologies
  - Management of extensions and profiles
- Cons
  - The 80/20 rule can potentially result in an unmanageable number of extensions?
  - Persistence of maximum clinical models at the level of the Electronic Health Record (EHR) – the basic function of the resource is communication, not a complete record that is saved only once in the EHR, and changes only when the data changes.

Overview of HL7 Norms

	HL7 v2	HL7 v3	HL7 CDA	HL7 FHIR
Complexity implementation	Low	Very tall	Medium high	Low
Learning process	Short	Very long	Medium long	Short
Using new technology	Low	Low	Low	Strongly
Message paradigm vs documents	Messages (with possibility transmission documents)	Messages (with possibility transmission documents)	Documents	It supports everything paradigms
Two-way dynamic communication	The recipient does not initiates TE	The recipient does not initiates TE	Static documents	REST API
Representation in the market	Tall	Low	Medium	In a strong momentum
Accomplishing the mission interoperability	Low	Low	Medium	Medium to more significant?

Findings

- Summary - HL7 represents a leading standardization initiative in the field of medical informatics
  - HL7v2.x represents past and present
  - HL7v3 messaging is going towards its sunset… but RIM will definitely stay
  - HL7 CDA represents a quality solution for exchanging documents between organizations, but most often it is about Level1 and Level2 implementations
  - HL7 FHIR is the present and the future that has the potential to replace all existing (legacy?) implementations
- The HL7 standard represents a key component of the integration mechanisms of connecting applications

Literature

- HL7 FHIR Main Web site
  - www.hl7.org/fhir
- HL7 FHIR Foundation (community, implementation guides, extension registry)
  - http://www.fhir.org/
- HAPI FHIR Server open source
  - http://hapi.fhir.org/
- SMART on FHIR registry
  - https://apps.smarthealthit.org/apps/featured
- FHIR Executive Summary by Rene Spronk
  - https://www.youtube.com/watch?v=YKr-MpptnYU&t=1268s
  - Registry of FHIR implementations
  - http://www.fhir.org/
- HL7 Document vs. Messaging Paradigm
  - http://www.ringholm.de/docs/04200_en.htm
- HL7 message examples, v2 and FHIR
  - http://www.ringholm.com/docs/04350_mapping_HL7v2_FHIR.htm