Exploiting Electronic Health Record Standard openEHR to Manage Experimental Data in Computational Physiology

Koray Atalag[1], Geoff Williams[2], Gary R. Mirams[2], David Nickerson[1], Jonathan Cooper[2]

[1]Auckland Bioengineering Institute, University of Auckland
[2]Department of Computer Science, University of Oxford

openEHR

AUCKLAND BIOENGINEERING INSTITUTE
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Te Whare Wānanga o Tāmaki Makaurau

Outline

- Physiome/VPH & Data Linkages
- Experimental Data
- openEHR fundamentals
- Beyond Experimental >Health Data

Experimental Data

- For Simulation Experiments mature standards (MIASE/MIBBI and COMBINE) for both data and meta-data
- For Wetlab Experiments there is limited agreement on standard data and meta-data formats;
- Some examples (for meta-data)
  - The Cardiac Electrophysiology Ontology (EP);
  - The Ontology for Biomedical Investigations (OBI)
  - Just Enough Results Model (JERM) Ontology;
  - Bioassay Ontology (BAO);
  - ISA-Tab experimental metadata from FAIRDOM
- Motivation of this study: handle experimental data and meta-data using openEHR Information Modelling
  - Very flexible, model driven
  - Supports ontology based semantic linkages

Study Source (Wetlab) Data

- Time-series type experimental data
- 1Hz steady state pacing membrane potential data from dog myocytes

Johnstone RH, Chang ETY, Bardenet R, de Boer TP, Gavaghan DJ, Pathmanathan P, et al. Uncertainty and variability in models of the cardiac action potential: Can we build trustworthy models? Journal of Molecular and Cellular Cardiology

- 572 traces as .csv files each containing 3248 rows of two data points:
  - measurement time (in seconds)
  - membrane potential (in volts)
- No structured set of meta-data

Information Modelling (IM)

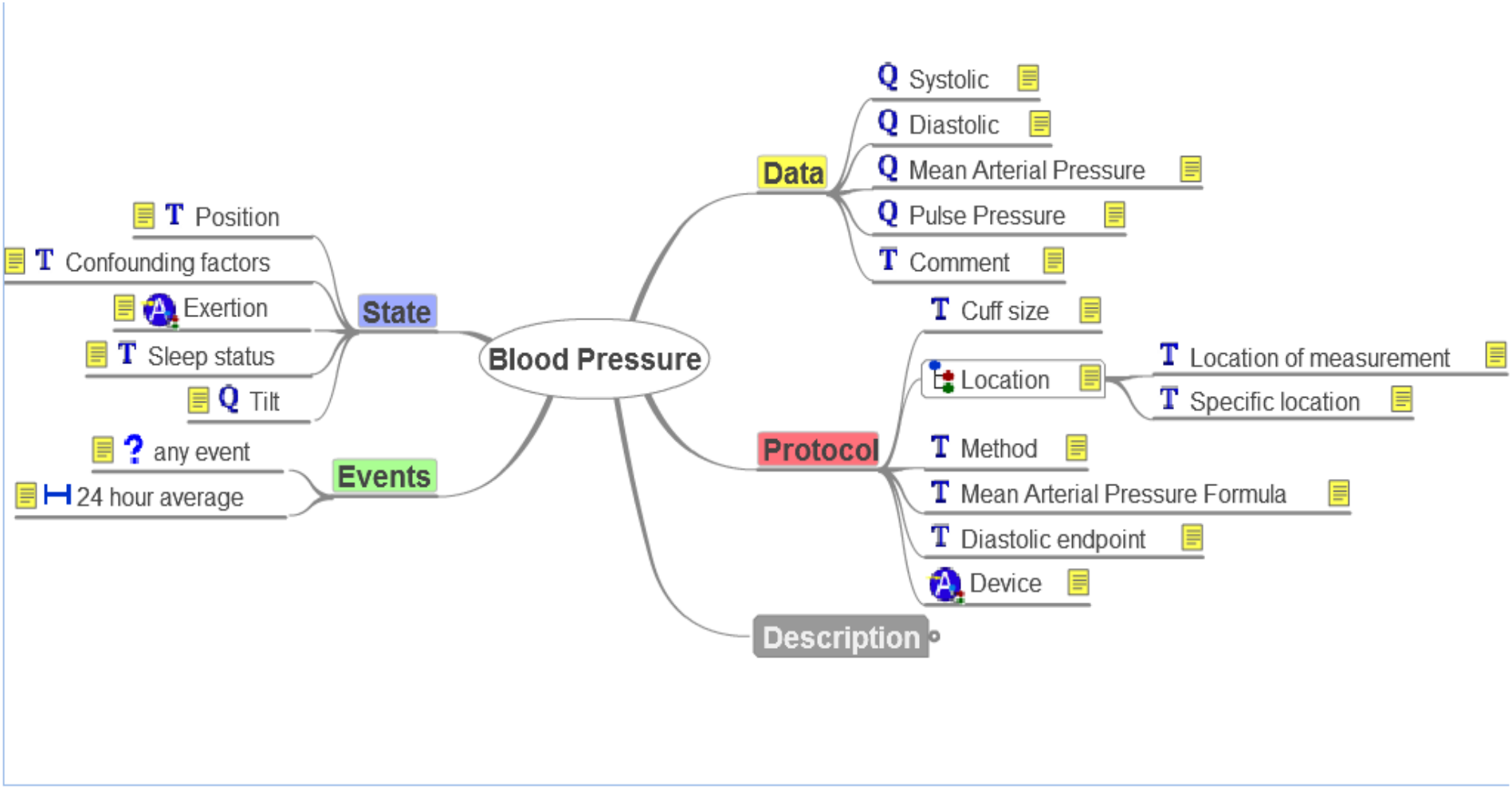
Archetypes, Detailed Clinical Models, Clinical Models etc.

- Computable representations of **data+context = information**

- Define both the **information structure** and **formal semantics** of documented concepts

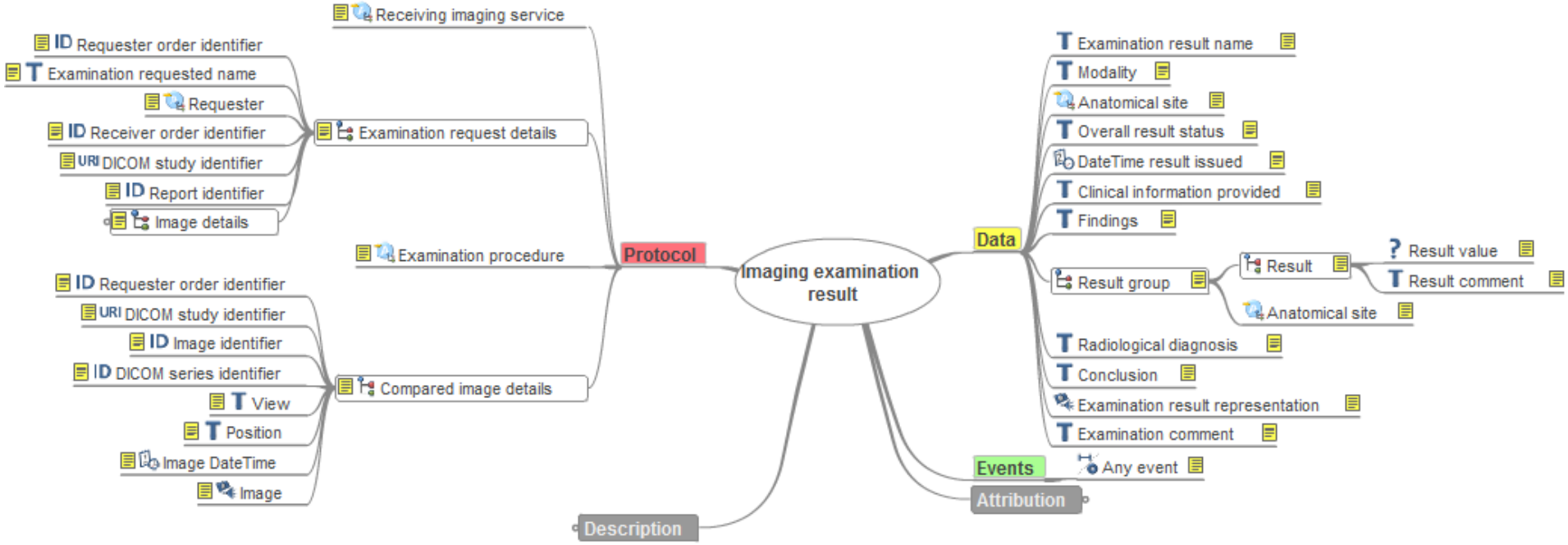
- They facilitate:
  - Domain ←→ technical communication
  - Managing size, complexity and changeability (of biomedicine)
  - Organizing, storing, querying & displaying data
  - Data exchange & distributed computing
  - Data linkage, analytics & decision support

Clinical IM Examples: Blood Pressure Measurement



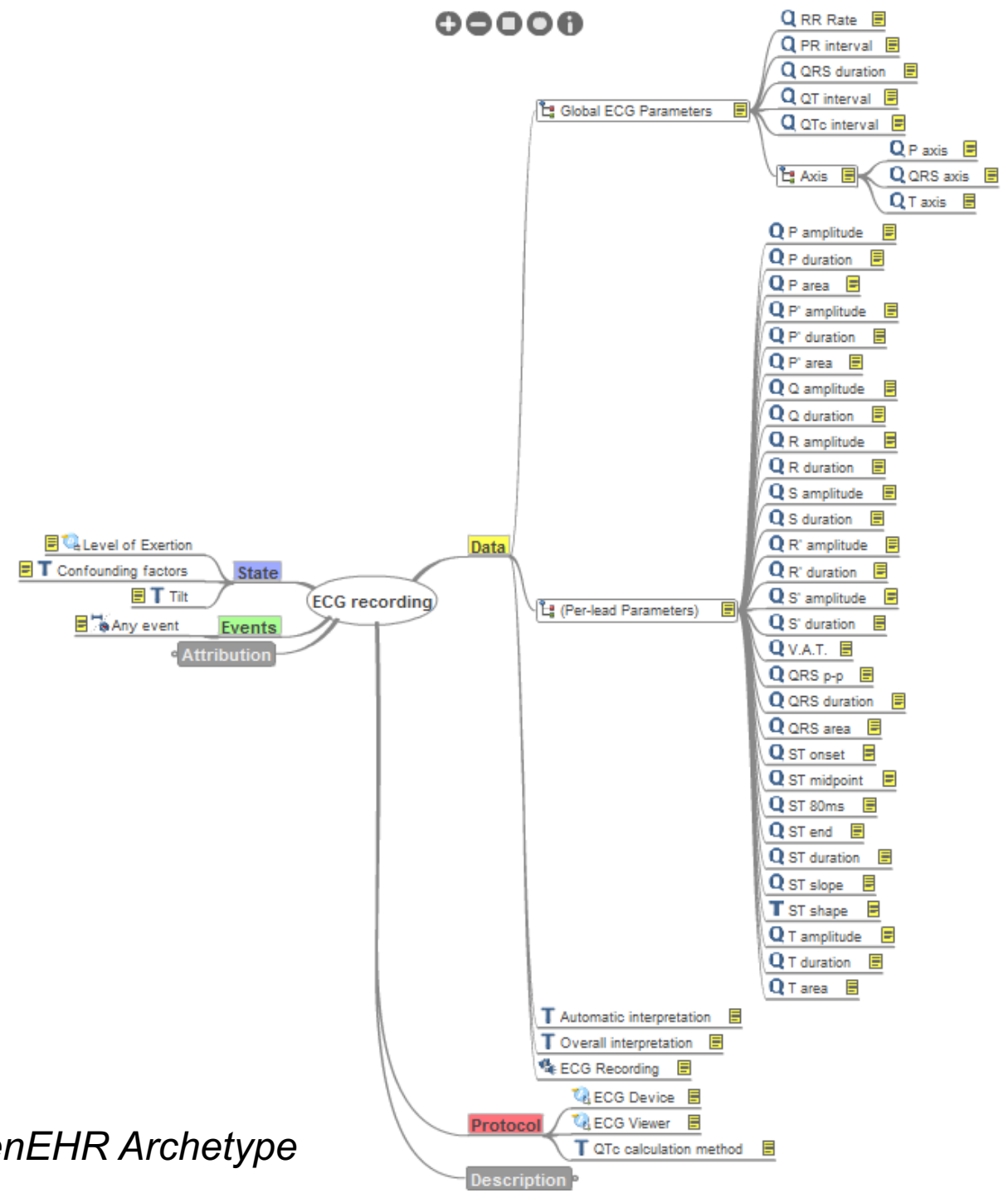
mindmap representation of openEHR Archetype

Imaging exam result



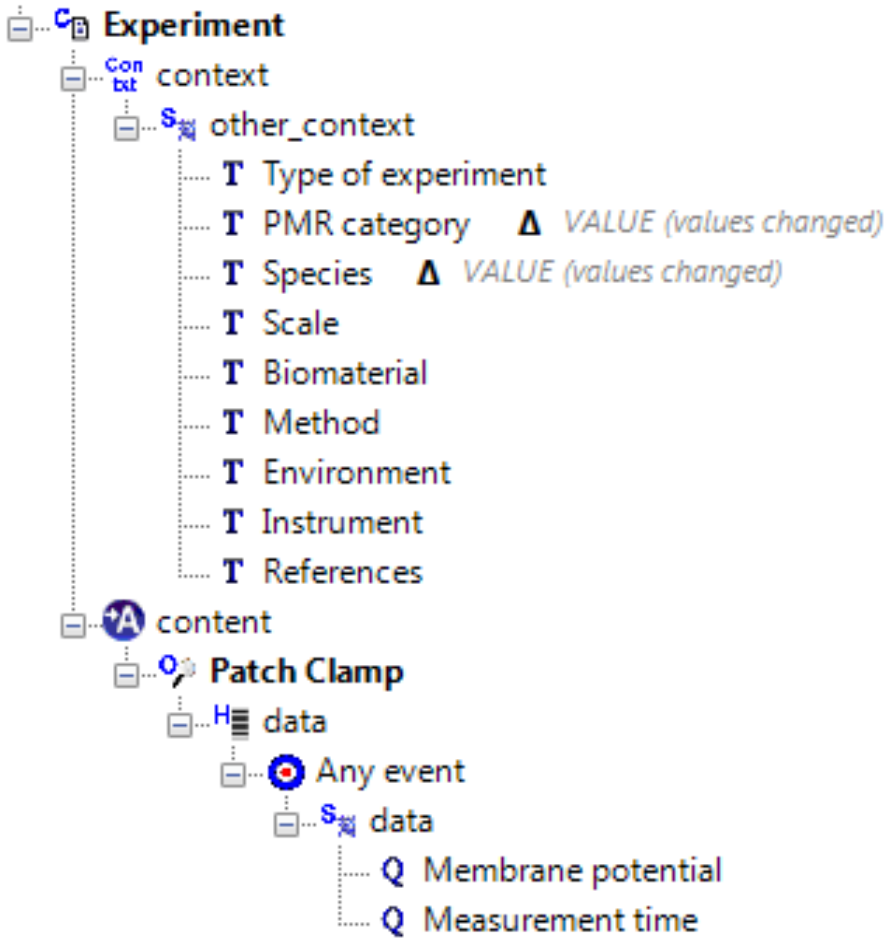
mindmap representation of openEHR Archetype

ECG recording



mindmap representation of openEHR Archetype

Study Information Model (with meta-data)



openEHR

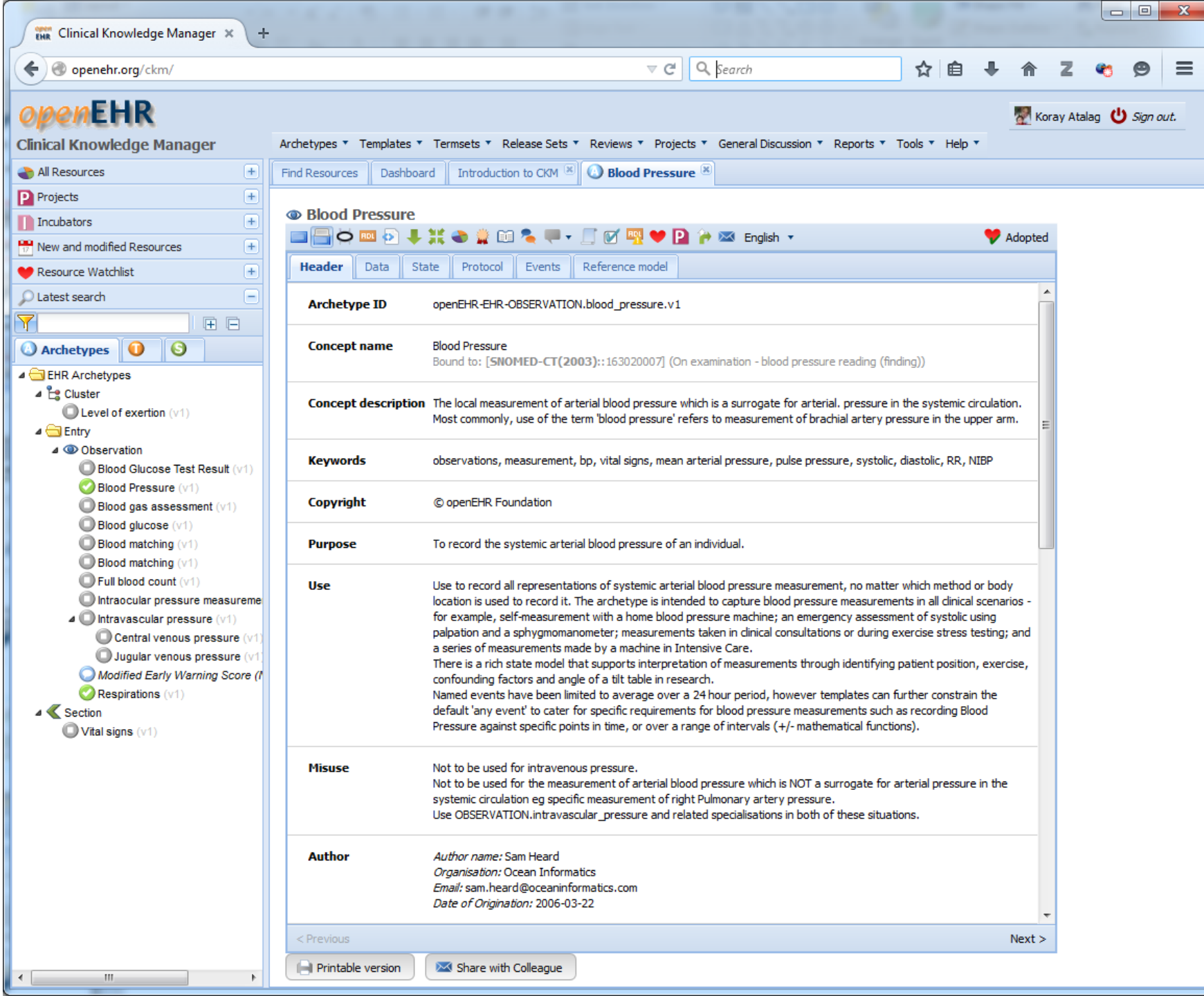
- Open source specs & tooling for representing health information and building EHRs
  - Based on 20 years of international research
  - Also an ISO/CEN standard
- Not-for-profit organisation - established in 2001 www.openEHR.org
- Extensively used in research
- Separation of clinical and technical worlds

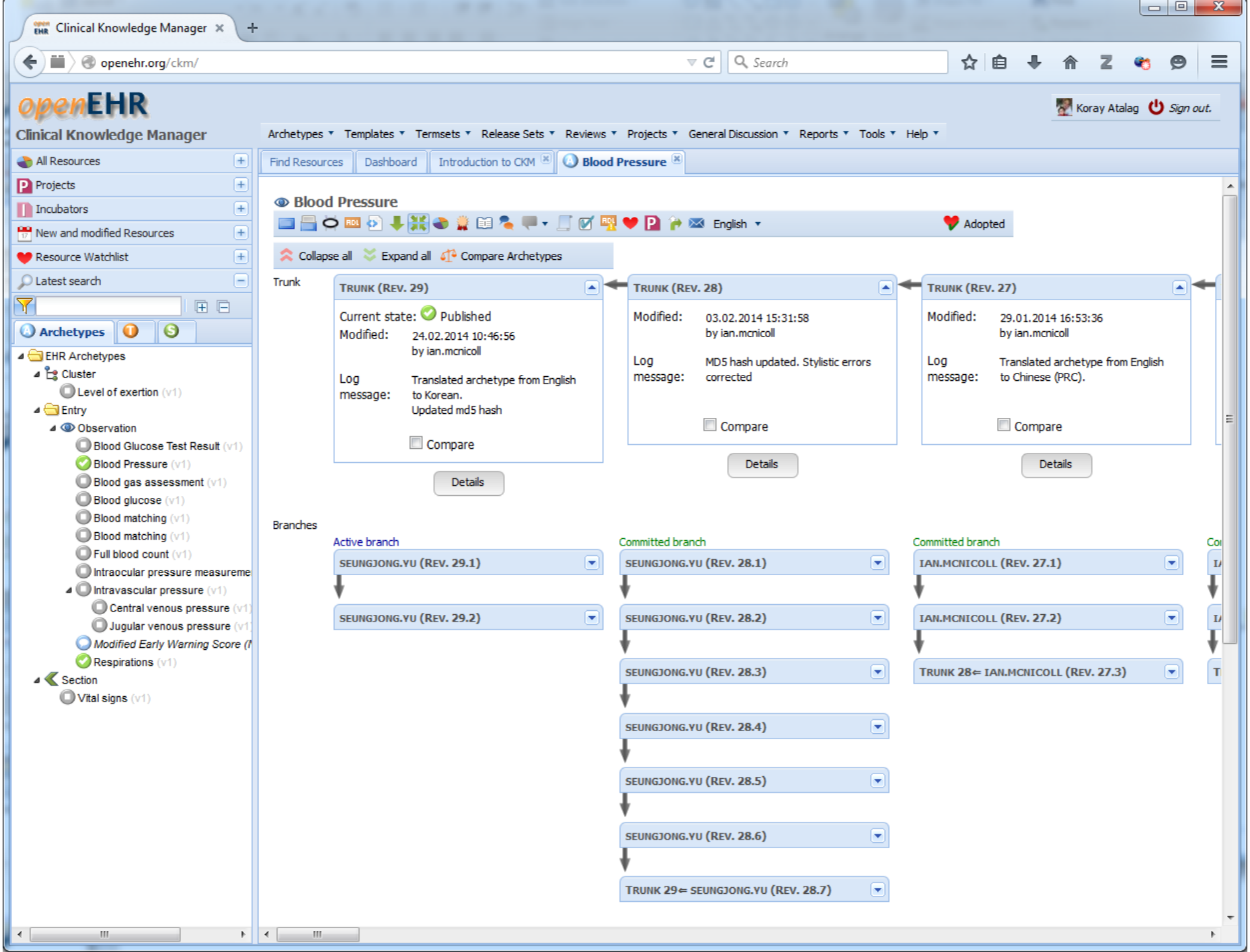
- Big international community
- Open Access online models repository http://openehr.org/ckm

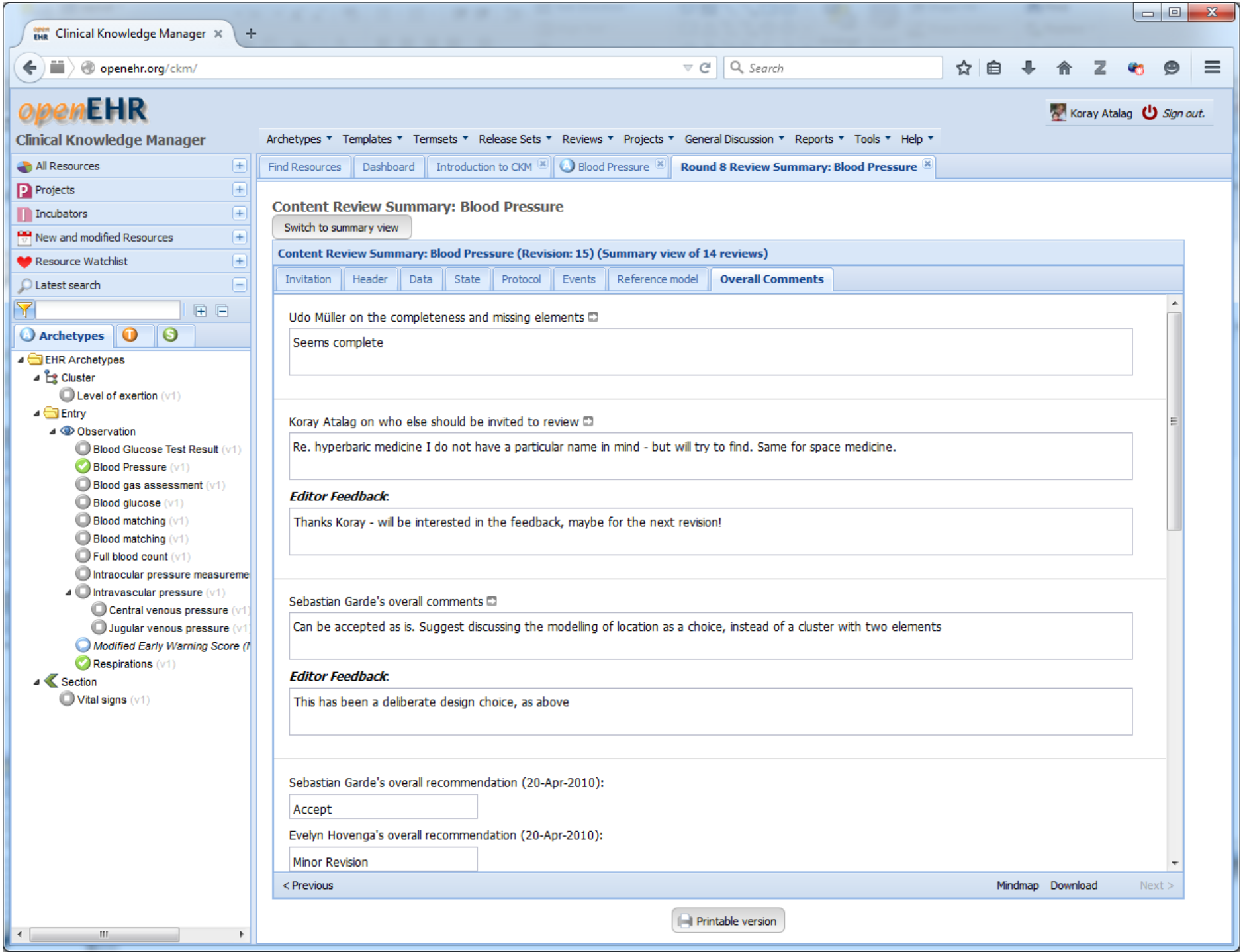
openEHR IM: Archetypes

- **Constraints (OCL)** on Data
  - Structural constraints: List, table, tree
  - What labels can be used?
  - What data types can be used?
  - What values are allowed for these data types?
  - How many times a data item can exist?
  - Whether a particular data item is mandatory
  - Whether a selection is involved from a number of items/values
- Formal semantics via **terminology bindings**
- Flexible Meta-data definition

Online Model Repository




Clinical Knowledge Manager
openehr.org/ckm/
Search
openEHR
Clinical Knowledge Manager
Koray Atalag
Sign out.
Archetypes
Templates
Termsets
Release Sets
Reviews
Projects
General Discussion
Reports
Tools
Help
All Resources
Projects
Incubators
New and modified Resources
Resource Watchlist
Latest search
Archetypes
EHR Archetypes
Cluster
Level of exertion (v1)
Entry
Observation
Blood Glucose Test Result (v1)
Blood Pressure (v1)
Blood gas assessment (v1)
Blood glucose (v1)
Blood matching (v1)
Blood matching (v1)
Full blood count (v1)
Intraocular pressure measureme
Intravascular pressure (v1)
Central venous pressure (v1)
Jugular venous pressure (v1)
Modified Early Warning Score (
Respirations (v1)
Section
Vital signs (v1)
Find Resources
Dashboard
Introduction to CKM
Blood Pressure
Blood Pressure
English
Adopted
Collapse all
Expand all
Compare Archetypes
Trunk
TRUNK (REV. 29)
Current state: Published
Modified: 24.02.2014 10:46:56 by ian.mcnicoll
Log message: Translated archetype from English to Korean. Updated md5 hash
Compare
Details
TRUNK (REV. 28)
Modified: 03.02.2014 15:31:58 by ian.mcnicoll
Log message: MD5 hash updated. Stylistic errors corrected
Compare
Details
TRUNK (REV. 27)
Modified: 29.01.2014 16:53:36 by ian.mcnicoll
Log message: Translated archetype from English to Chinese (PRC).
Compare
Details
Branches
Active branch
SEUNGJONG.YU (REV. 29.1)
SEUNGJONG.YU (REV. 29.2)
Committed branch
SEUNGJONG.YU (REV. 28.1)
SEUNGJONG.YU (REV. 28.2)
SEUNGJONG.YU (REV. 28.3)
SEUNGJONG.YU (REV. 28.4)
SEUNGJONG.YU (REV. 28.5)
SEUNGJONG.YU (REV. 28.6)
TRUNK 29⇐ SEUNGJONG.YU (REV. 28.7)
Committed branch
IAN.MCNICOLL (REV. 27.1)
IAN.MCNICOLL (REV. 27.2)
TRUNK 28⇐ IAN.MCNICOLL (REV. 27.3)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Vital signs (v1)
Find Resources
Dashboard
Introduction to CKM
Blood Pressure
Round 8 Review Summary: Blood Pressure
Content Review Summary: Blood Pressure
Switch to summary view
Content Review Summary: Blood Pressure (Revision: 15) (Summary view of 14 reviews)
Invitation
Header
Data
State
Protocol
Events
Reference model
Overall Comments
Udo Müller on the completeness and missing elements
Seems complete
Koray Atalag on who else should be invited to review
Re. hyperbaric medicine I do not have a particular name in mind - but will try to find. Same for space medicine.
Editor Feedback:
Thanks Koray - will be interested in the feedback, maybe for the next revision!
Sebastian Garde's overall comments
Can be accepted as is. Suggest discussing the modelling of location as a choice, instead of a cluster with two elements
Editor Feedback:
This has been a deliberate design choice, as above
Sebastian Garde's overall recommendation (20-Apr-2010):
Accept
Evelyn Hovenga's overall recommendation (20-Apr-2010):
Minor Revision
< Previous
Mindmap
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Next >
Printable version

Semantics in openEHR

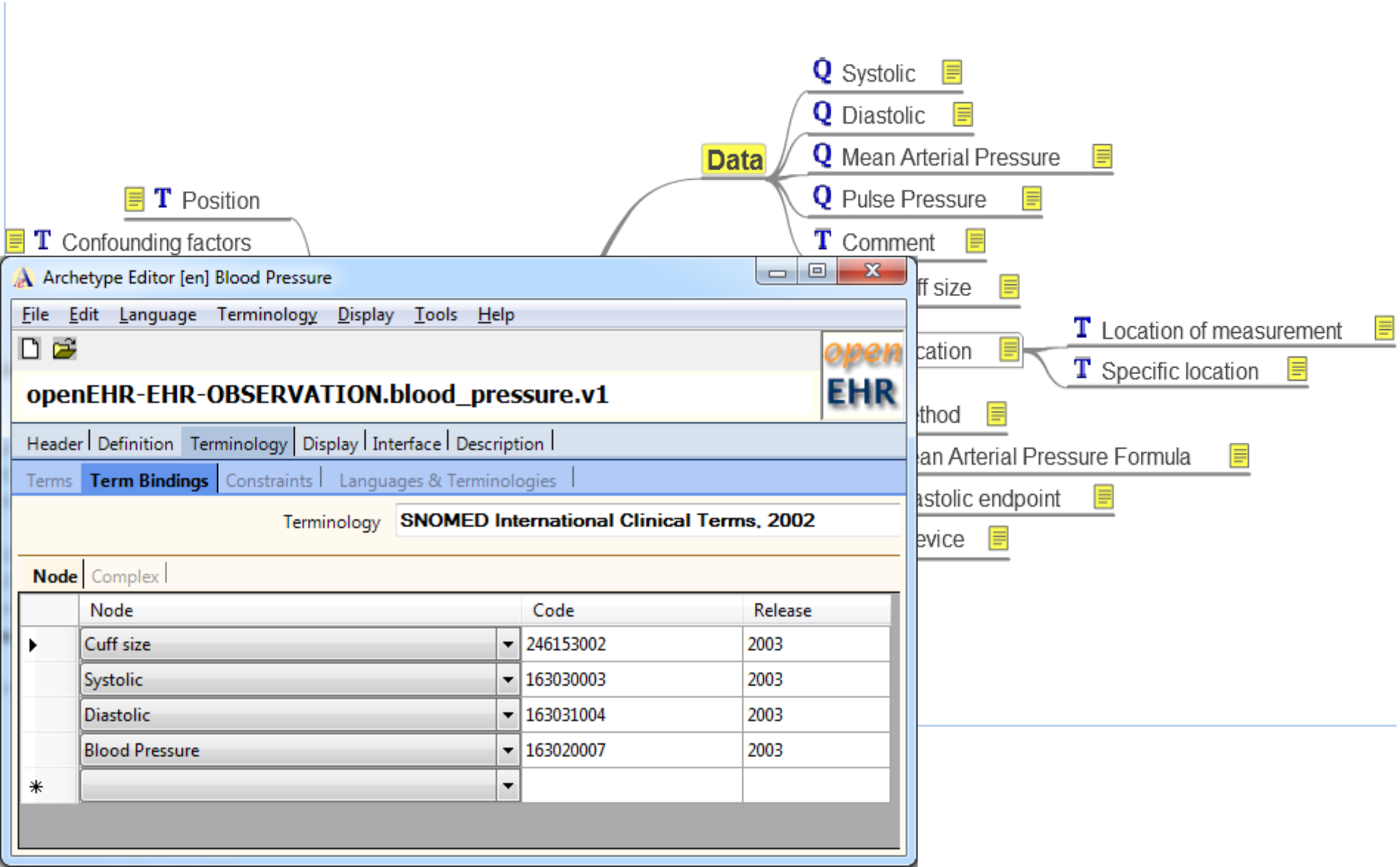
- Whole-of-model meta-data:
  - Description, concept references (terminology/ontology), purpose, use, misuse, provenance, translations
- Item level semantics **(Schema level)**
  - Trees/Clusters (Structure)
  - Leaf nodes (Data Elements)

Formally: different types of terminology bindings:

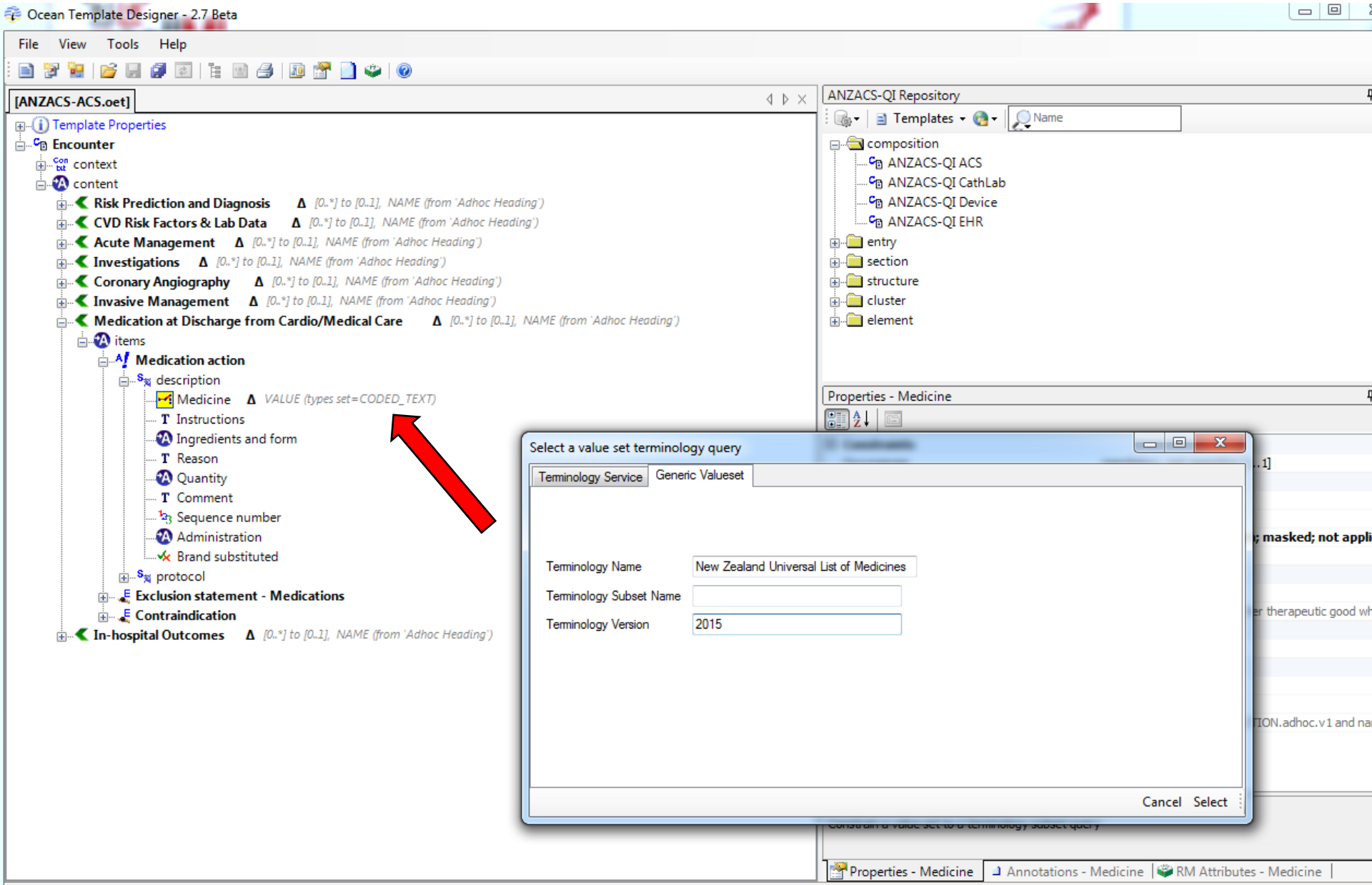
1) linking an item to external terminology/ontology for the purpose of defining its real-world clinical/biological **meaning**
2) Linking data element **values** to external terminology (e.g. a RefSet or terminology query)

Also➔Instance level semantic annotations – applies to actual data collected

1) Linking data items to Ontology to define real-world meaning (~semantic annotation)



2) Linking data element values to an ontology (or subset)



Result: Experimental & Simulation Data Integration

-Extended WebLab
(doi: 10.1016/j.bpj.2015.12.012)

Conclusion

- Experimental data and meta-data can be modelled using mature EHR standard
  - No need for a concrete persistence model
  - Supports model based querying
  - Auto-generated GUI for data and meta-data entry
- Good open source tooling and data platforms
- Models can be created and maintained collaboratively
  - Including semantic annotations
  - Supports provenance and version control
- Same tools and methods can be used for managing real-world healthcare data

Beyond Experimental Data: Healthcare Data

- Healthcare data/longitudinal EHRs are sinks of valuable knowledge/causality
  - Embody effects of environment/psychosocial factors
- Therefore linking with EHRs will enable:
  - Better understanding (genotype>enviro>phenotype)
  - Large scale validation of computational models
  - Personalised computational models

  ➔Predictive tools & decision support systems

Another emerging IM standard: HL7 FHIR (Fast Healthcare Interoperability Resources)

- Purpose: Information Exchange (not persistence)
  - Scope smaller than openEHR
  - Support simpler use-cases (for exchange)
- Rapid adoption
- Developer oriented / pragmatic
- RESTful API
- Inspired by modern Web technologies – leveraging W3C standards (XML family, ATOM, RDF etc.)
- Information models defined as **Resources**;
  - Semantic linkages supported

Big Picture: Linking Computational Models to Data

Computational Systems / Modelling and Simulation

Modelling Formalism
CellML, FieldML, SBML, SED-ML, BioSignalML

Tooling & Software
openCOR
OpenCMISS
SemGen/SemSim
RICORDO/ApiNATOMY

Physiome Model Repository
CellML, FieldML
-biological/biophysical concepts
-maths
-experiment protocols
-annotations
-versioning / exposures
-web view / API

Imaging Data
>CT, MRI, X-Ray etc.
>Biosignals (ECG, EEG)

Measurement Data
>Reference phenotypes/ study specific biomarkers
>Experimental data
>Simulation results

Semantic Web / Knowledge Engineering

Ontologies
Genomic/ Molecular
Clinical terminology
Environment
Bio-ontologies
Physical/ Chemical

Identifiers
URI, GUID, OID

W3C Standards
XML, RDF, OWL, SPARQL, LOD

Tooling & Software
XML tools
Ontology editors
Inference engines
Lexical tools
Open Data frameworks
Discovery/visualisation

Shared Semantic Annotations

Shared Semantic Annotations

Information Systems / Clinical Data

Modelling Formalism
openEHR, HL7 FHIR

Tooling & Software
Archetype Editors
Template Designers
Software frameworks
Data transformation
Terminology service

Clinical Model Repository
Archetypes, Terminology
-clinical/administrative objects
-provenance / peer review
-annotations and term bindings
-versioning
-web view / API
openEHR

Biobanks/ Research Data

EMR / EHR

Clinical Systems

National/Regional Clinical Data Repositories

Personal Health Records

Some concluding thoughts

Linking the two universes – shared semantics!

- Semantic annotation mechanisms & tooling already exist in both universes
  - CellML annotations➔ openCOR, SemGen
  - openEHR Archetypes, SNOMED, CTSII etc.

➔ **Key considerations should be:**

- Shared ontologies / identifiers
  - SNOMED>UMLS> FMA/GO etc.
  - But SNOMED and FMA anatomy not same but similar!
    Bodenreider O, Zhang S. Comparing the Representation of Anatomy in the FMA and SNOMED CT. AMIA Annu Symp Proc. 2006;2006:46–50.
- Shared annotation approach
  - RICORDO, PMR2, SemGen etc.
  - More research on joint semantic annotations.
- Shared modelling patterns & governance?