DATE

IMPROVING ONTOLOGIES TO FOSTER AI IN BIOMEDICINE

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UAMS Health

Ontologies and AI

Just as a reminder: What is AI?

Thinking Humanly "The exciting new effort to make computers think …*machines with minds,* in the full literal sense." (Haugland, 1985)	**Thinking Rationally** "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly "The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)	**Acting Rationally** Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998)

S. Russell, P. Norvig: Artificial Intelligence. A Modern Approach. 3rd Edition, 2016.

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What we are concerned with today

Acting Humanly

- Natural language processing
- Knowledge representation
- Automated reasoning
- Machine learning

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What we are concerned with today

Acting Humanly

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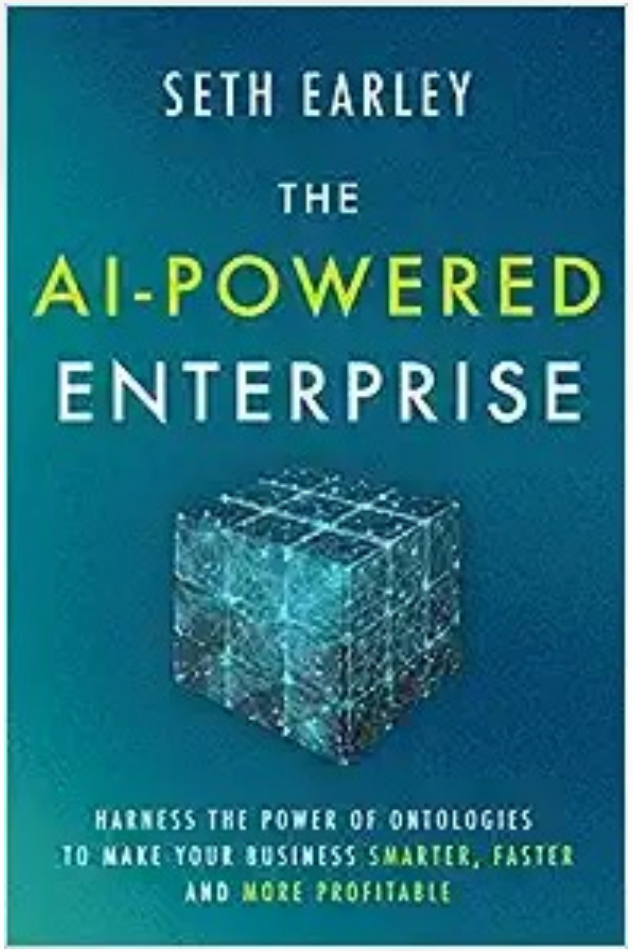
S. Russell, P. Norvig: Artificial Intelligence. A Modern Approach. 3rd Edition, 2016.

"The ontology is the tool that teaches intelligent machines how your business runs."



S. Early: The AI-Powered Enterprise. 2020.

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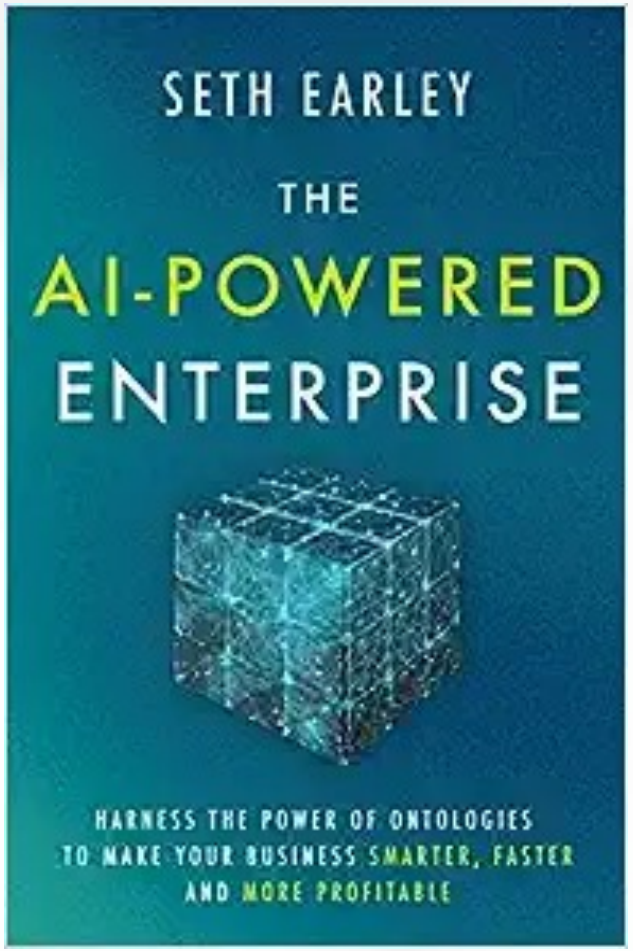
"Machine learning algorithms may not need an ontology to function, but applying the results to the business does require the consistency and efficiency provided by an ontology and the resulting knowledge architecture."



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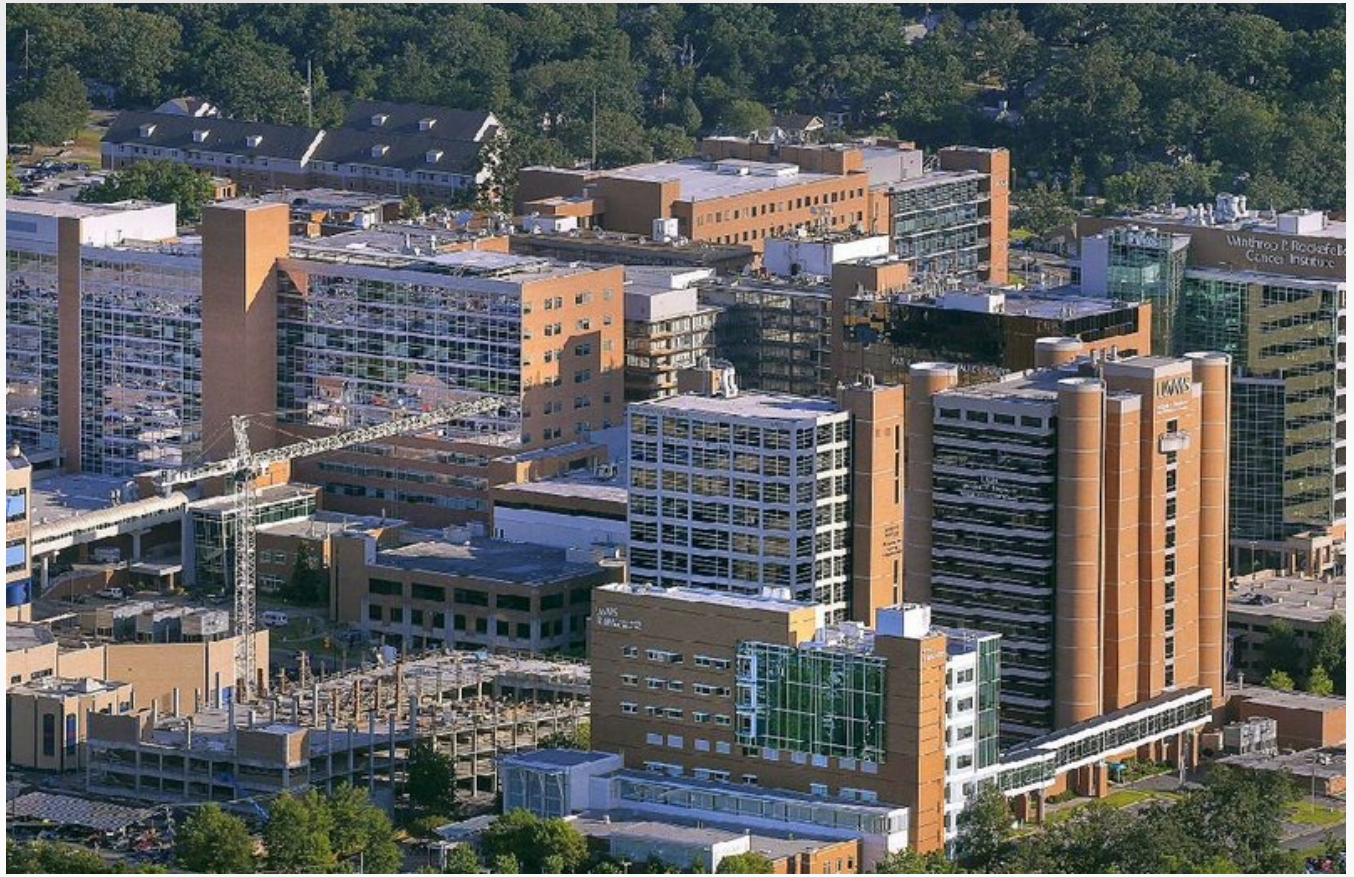
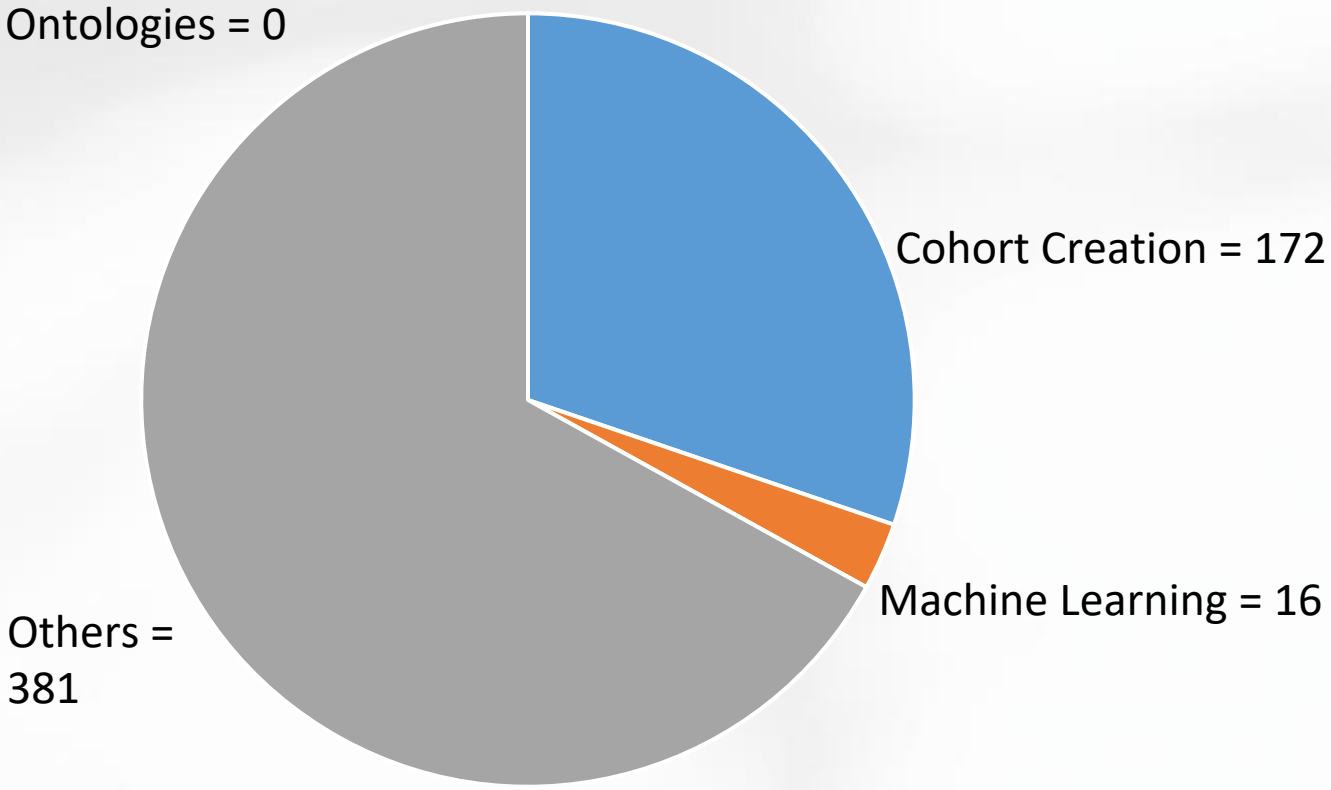
An Academic Health Center is a business!



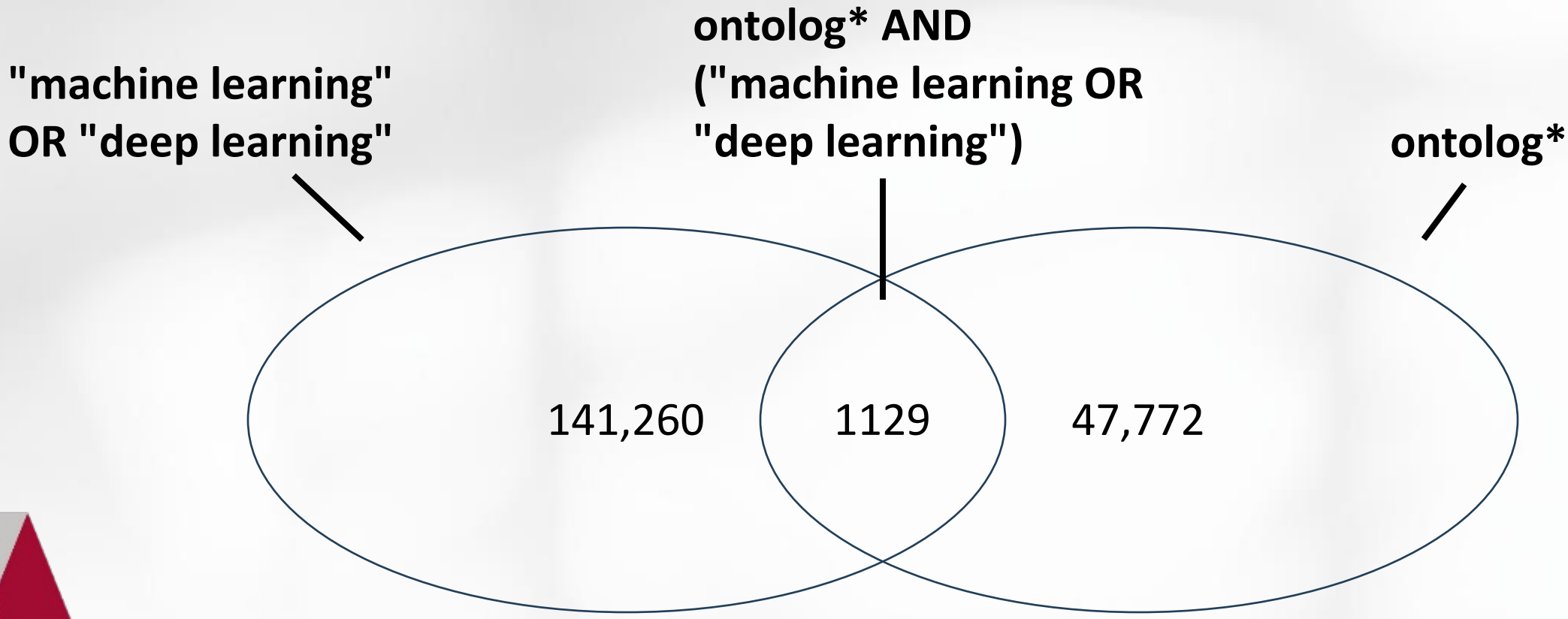
Informatics Service Requests

UAMS Translational Research Institute's Informatics Service line receives request for biomedical informatics support from translational researchers.



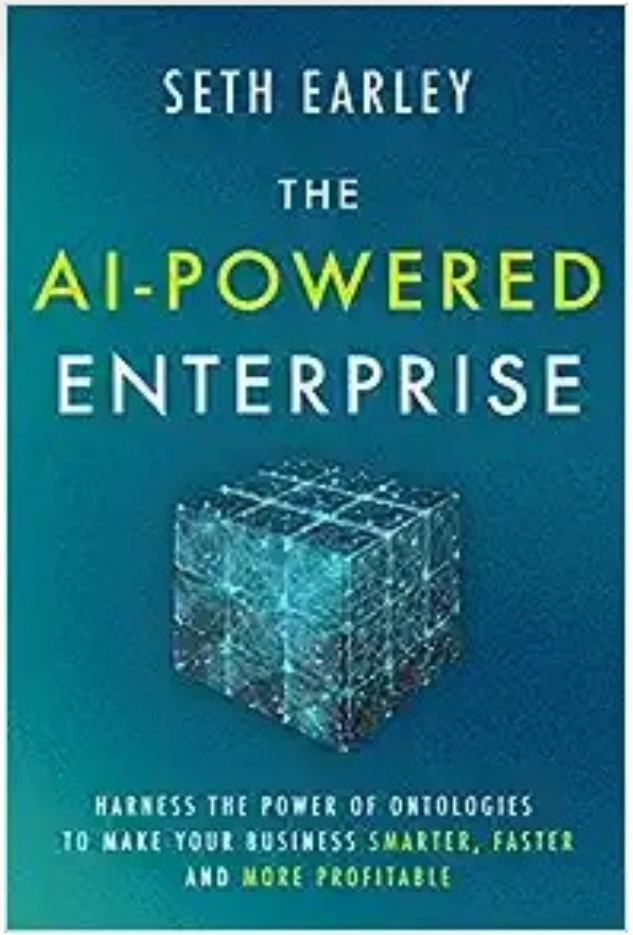
Service Line requests 2019-2023

PubMed searches



Ontologies…

- …organize and translate information.
- …provide the enterprise-wide vocabulary.
- …represent knowledge regarding the information structure.
- …link the results from other AI methods (e.g., ML) to the business problems.
- …foster analysis and interpretation for results generated by AI.



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What do ontologies need?

- Classes and axioms that foster organization and integration/translation of data
- Well built, user-friendly vocabularies
- Representation of the information structure and the business processes

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Axioms that foster organization and integration/translation of data

The Children's Hospital
it's all better™

BP – 2016 Only

Measure Name	unique patients	number entered
BLOOD PRESSURE	164311	2,337,303
R AN NIBP	20167	834,840
ABP INVASIVE PRESSURE	1084	529,118
R AN IBP ART	1273	284,701
PAP	384	41,613
BP #2	746	8,705
BP #3	668	6,513
EDU STAND BP	1451	5,079
EDU LYING BP	1446	4,623
CARD BP 3	2626	3,796
BP #4	535	3,365
BP - STANDING	1184	1,719
BP - LYING	1189	1,709
R AN IBP AO	20	1,654
BP - SITTING	1177	1,648
CARD BP 2	1197	1,503
R AN IBP P1	14	1,138
R AN IBP FAP	7	1,128
EDU SIT BP	890	1,035
CARD BP 4	750	1,007
R AN IBP LAP	4	275
R AN IBP UAP	7	137
RV PRESSURE	4	8
R AN IBP P	4	5
R AN IBP P4	1	1

CHCO Slides from Maggie Massary. Used with permission

EHR Workflows meet Consistency

- Core vital signs: Blood Pressure, Height & Weight
- Blood Pressure: 113 unique BP Names:
  - 15 have been deleted
  - 45 are hidden
  - 52 are in available:
    - 37 are in use (have values)
    - **29 have been used more than a thousand times**
    - 14 has been used on less than 71 patients
    - 23 have been used on more than 371 patients

CHCO Slides from Maggie Massary. Used with permission

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R AN IBP P	4	5
R AN IBP P4	1	1

(…)

is about

blood pressure
http://purl.obolibrary.org/obo/VSO_0000004

CHCO Slides from Maggie Massary. Used with permission

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Well built, user-friendly vocabularies

Lapses in vocabularies

The Inexistent

INCORRECT PATIENT ID : "" *Radiology Lexicon (RadLex)*

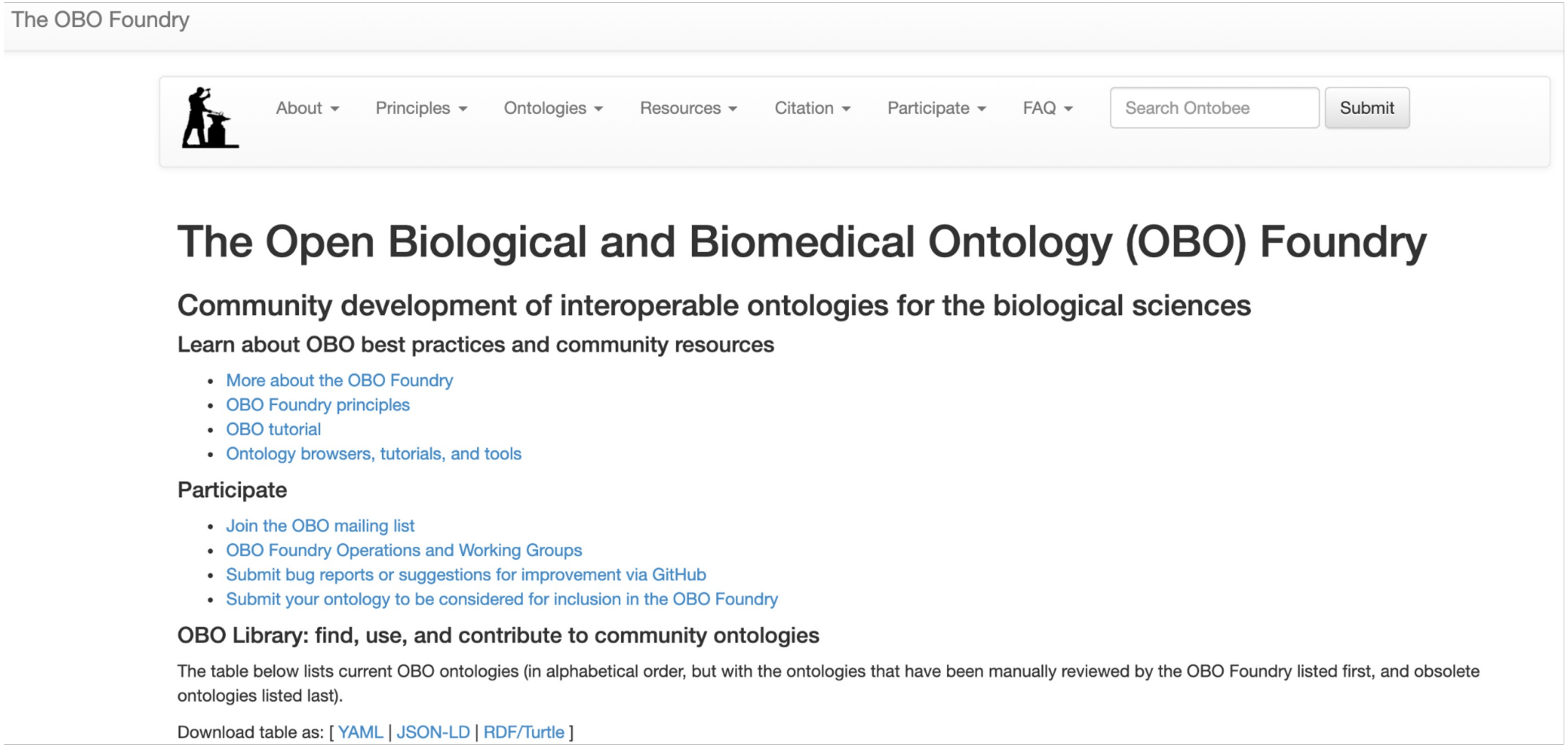
The Circular

DRUG NAME : "common name of a drug" *Bioscientific Data Analysis Ontology (EDAM)*

The Puzzling

PREGNANT: “Observed to be or have been pregnant" *National Cancer Institute Thesaurus (NCIT)*

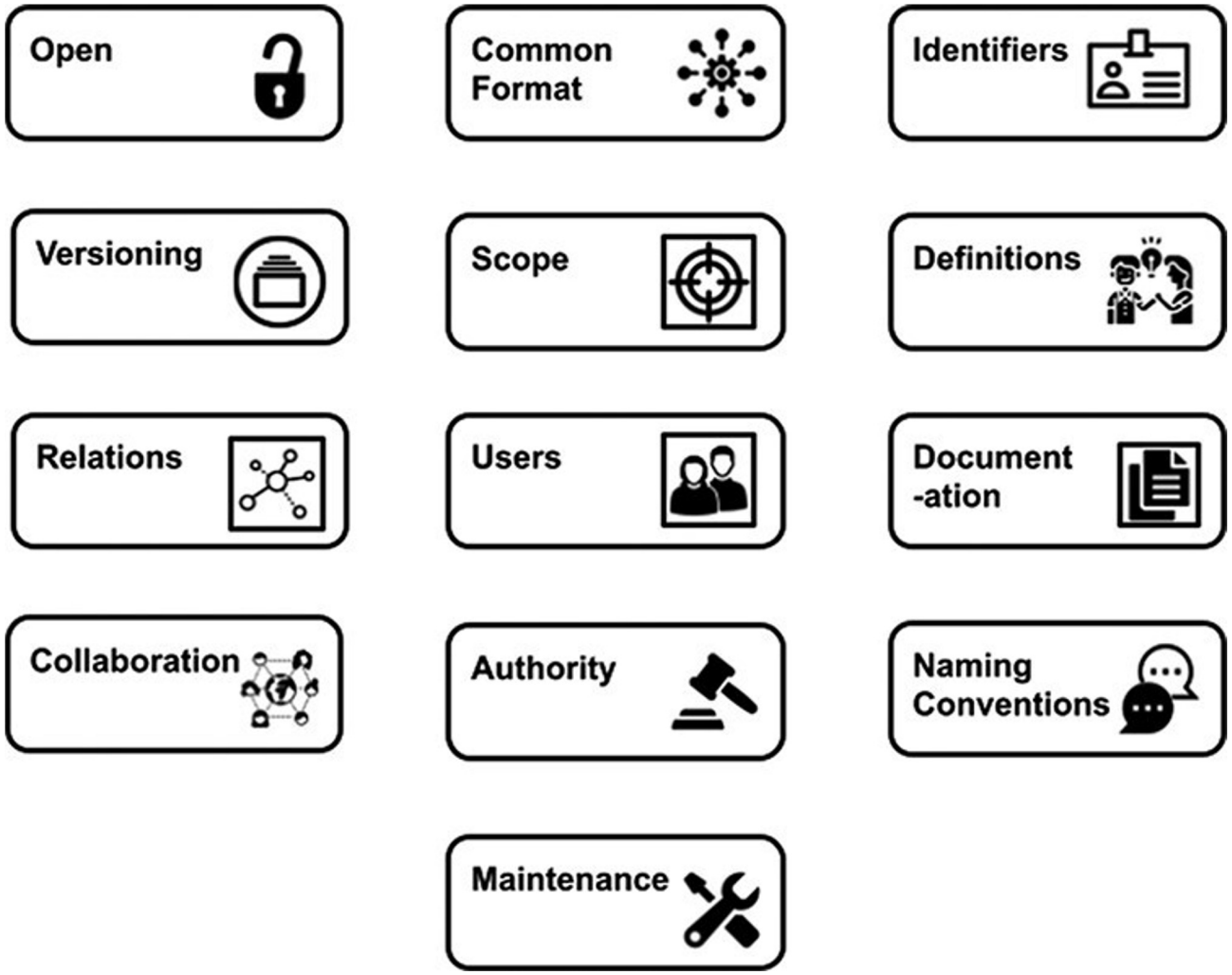
What is the OBO Foundry?



A community of ontologists committed to a shared set of principles to build open biomedical ontologies.

http://obofoundry.org/

OBO Foundry Principles



Jackson et al, Database, 2021

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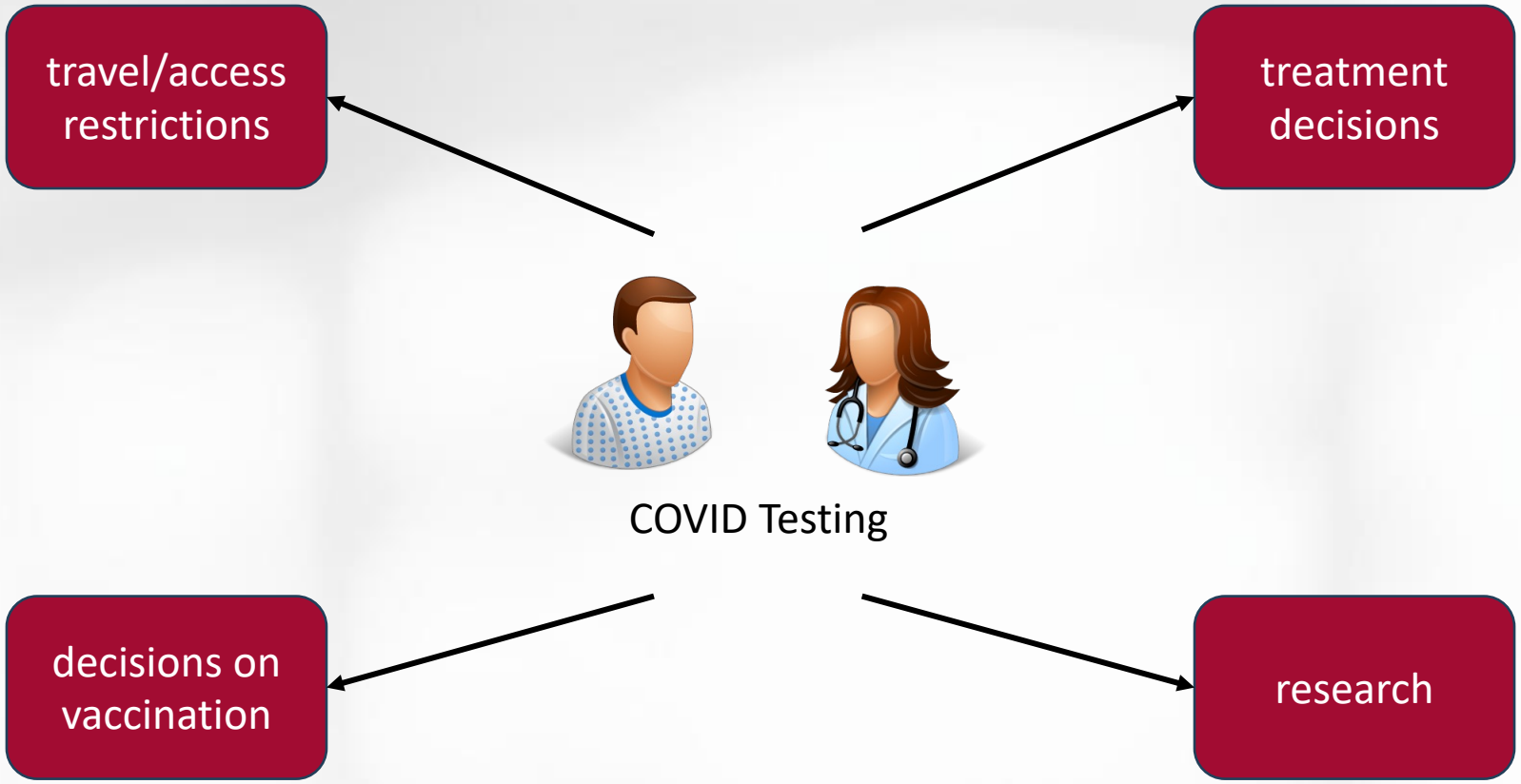
Representation of the information structure and the business processes

Business process

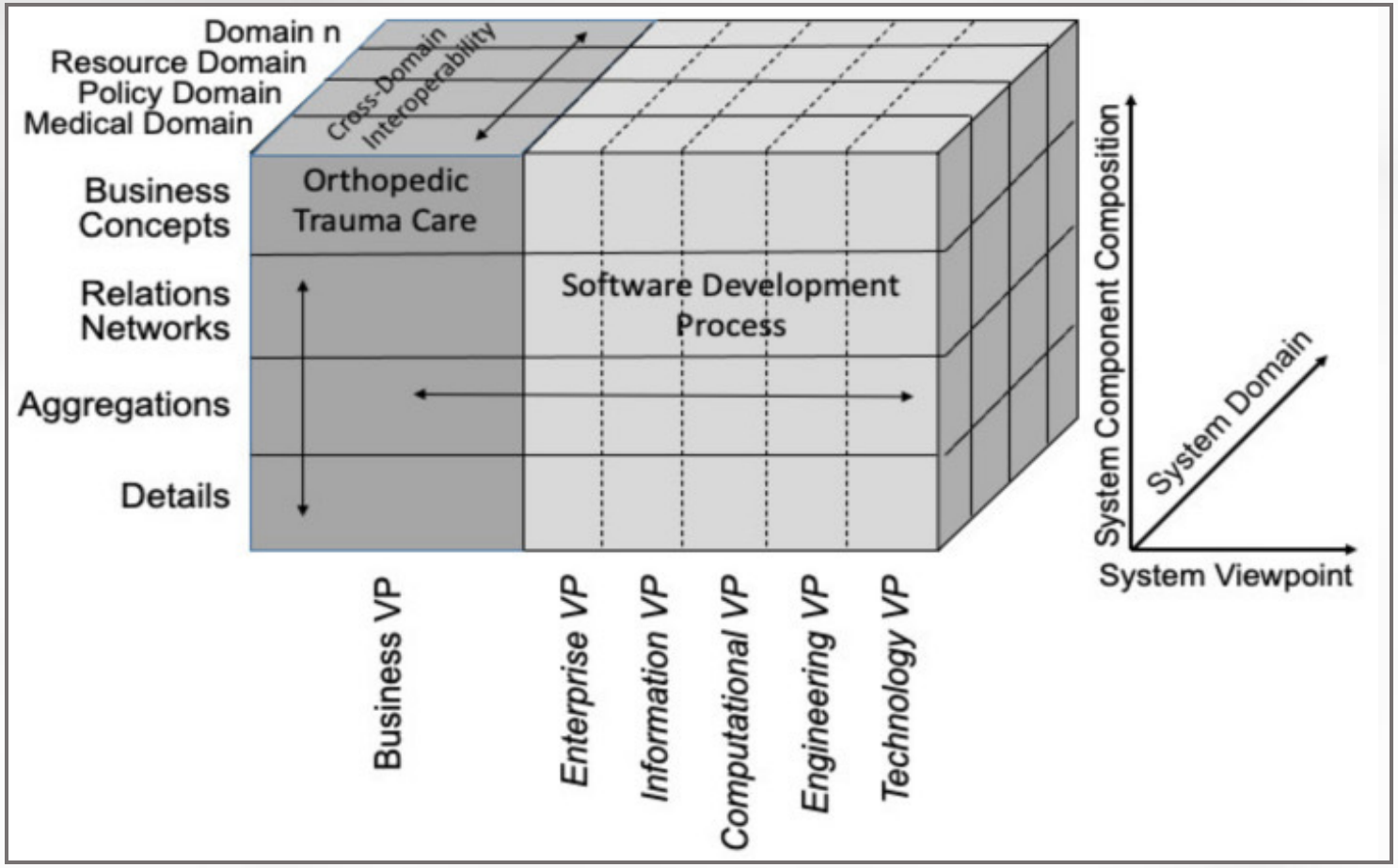


Representation of Information Structure

I am more skeptical about this aspect.

- You may think about how is the data collected and stored. The collection aspect might be related to the business process.
- Is the data structured or unstructured?
- Use of common data elements in same information will guide the looks of that data.

What we need:



M. Brochhausen et al. *Assessing the Need for Semantic Data Integration for Surgical Biobanks- A Knowledge Representation Perspective*. J Pers Med. 2022 May 7;12(5):757

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TIPTOE-ing to Artificial Intelligence

Trauma Institutional Priorities and Teams for Outcome Efficacy

The mission of TIPTOE is to address two knowledge gaps:

a) Which organization parameters affect patient outcomes in trauma care?

b) Which organizational features are indicative of institutional commitment to trauma care?

We aim to provide actionable information to answer those questions to stakeholders and decision makers. Thus, improving outcomes of trauma patients.

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Trauma care, trauma centers, level, etc.

In trauma care (in the US and in some other countries) we have 4 levels of trauma centers (TC):

- Level 1 & 2 are similar in medical care.
  - Level 1 TCs are academic medical centers, which Level 2 TCs are not.
    - Level 1 TCs have a education and research component.

TIPTOE: What got us started

- Even between Level 1 and Level 2 TCs we find significant differences in patient outcomes.
- Even among TCs of the same level, this is the case
- These results might partially be explained by external factors (e.g., catchment area), but it still might be organizational patterns at a lower granularity level.
- Impact of organizational parameters on patient outcomes remains underresearched.

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From CAFÉ to TIPTOE

- **CAFE** laid the groundwork for addressing these problems by enabling comparison of different roles (e.g. trauma medical director), the different components (e.g. multidisciplinary stakeholder group) and their requirements, rights, and obligations, which we have found to be different from organization to organization.
- **TIPTOE** will link organizational parameters to patient outcomes and provide tools for decision makers to improve patient outcomes using those insights.

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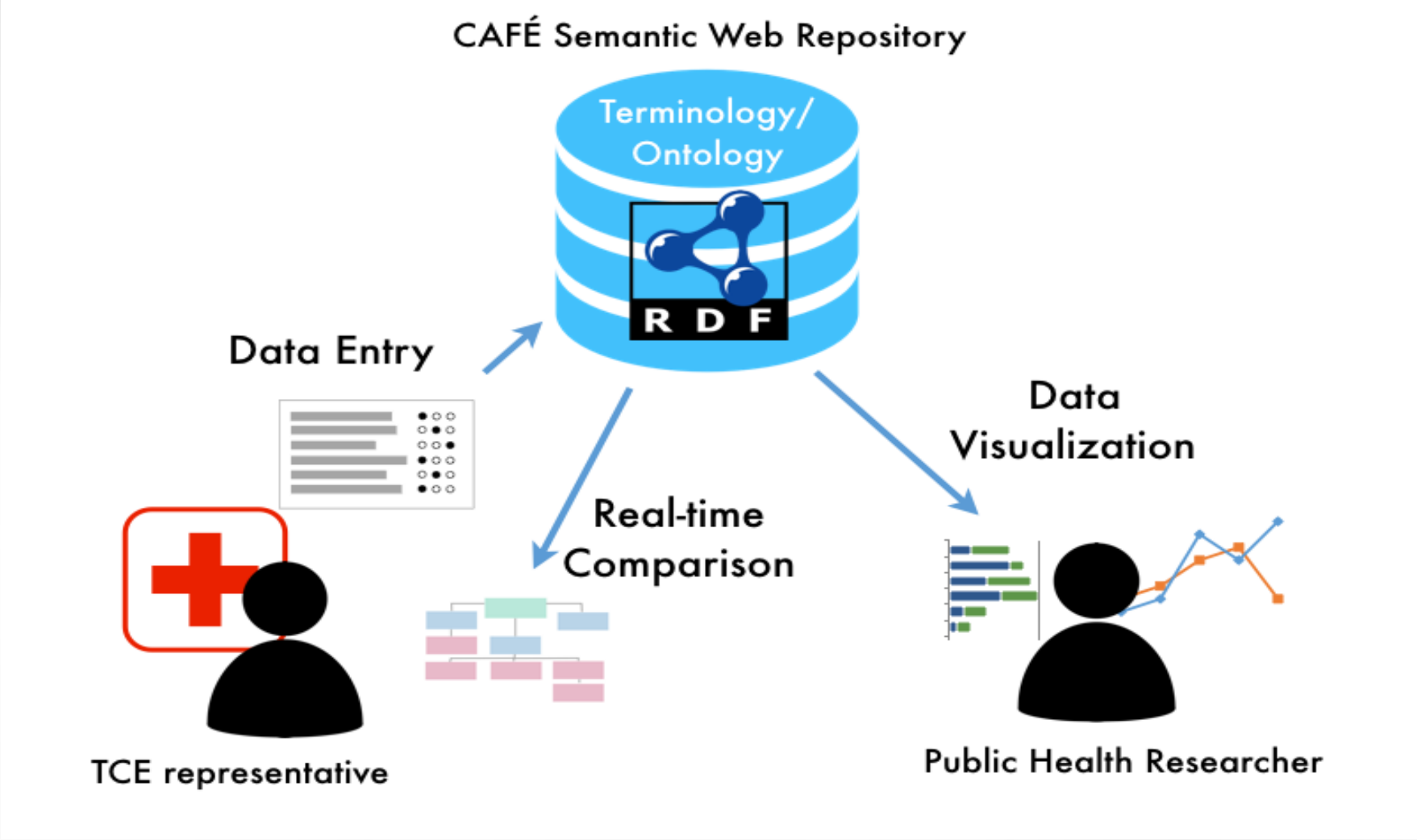
TIPTOE Project Architecture



CAFÉ Achievements

- Created a shared vocabulary/ontology (OOSTT)
- Created a questionnaire that utilizes the shared vocabulary
- Questionnaire produces a representation of a trauma center or system that is compared to other organizations of the same type.
- Provide visualizations of the data collected for public health research.

New in TIPTOE

- We changed from single PI to multiple PI. Dr. Sexton, a trauma surgeon and biomedical informaticist joined as one of two MPIs.
- We are using existing outcomes data from multiple Level 1 and Level 2 trauma centers for outcome measures. Our recruitment goal is 230 trauma centers.
- Organizational parameters have been restricted from over 100 to 40 to lessen workload of participating centers.

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Specific Aims

1. To determine the impact of organizational features of Level 1 and Level 2 trauma centers on patient outcomes
2. To assess which organizational features of trauma centers are indicative of institutional commitment
3. To test the feasibility and perceived impact of a novel knowledge exploration tool, the TIPTOE Knowledge Path

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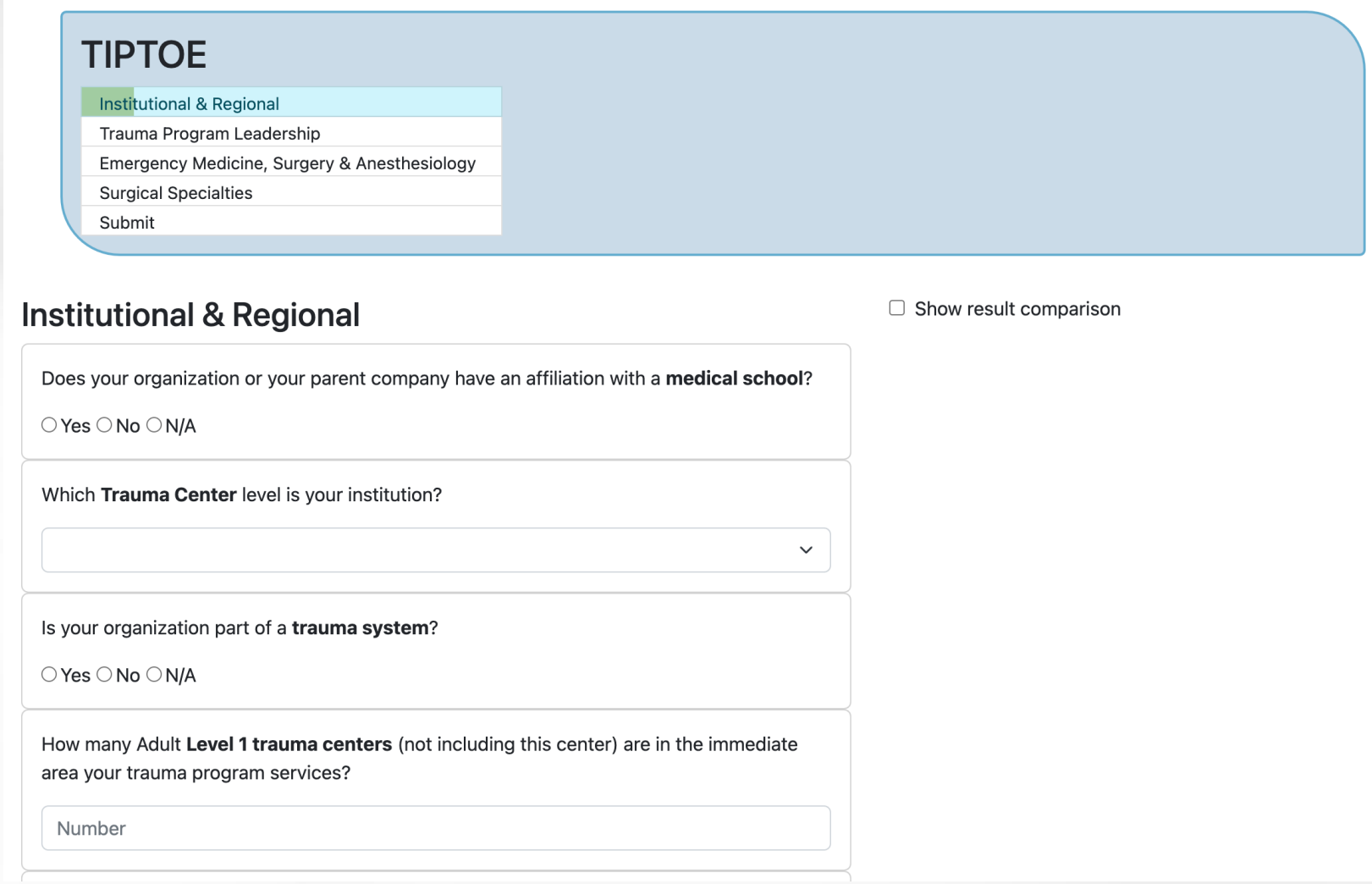
The TIPTOE Study (Aim 1)

- Currently recruiting!
- Eligible are (Adult) Level 1 and Level 2 trauma centers.
- Data submission and participation is iterative every 3 months
- Participants upload deidentified TQIP data quarterly and answer a questionnaire with 40 questions every 6 months.
- Total effort is 2-4 hours per year.

TIPTOE Questionnaire



TIPTOE Data Collection

What is collected?

Data about 40 parameters via an online questionnaire and de-identified TQIP data.

- Focus on 3 outcomes: **mortality, length of stay, and major complications**

How will the data be analyzed?

Data will be analyzed using **descriptive statistics** and **multivariable regression models** to determine the impact of organizational features on patient outcomes.

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Where do I get more information about TIPTOE?

https://innovation.uams.edu/tiptoe/

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OOSTT and its extensions

OOSTT

- Ontology of Organizational Structures of Trauma centers and Trauma system
- Freely and publicly available
- http://purl.obolibrary.org/obo/oostt.owl
- funded as part of TIPTOE/CAFE (R01GM111324)

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Job descriptions in Medicine

from:
https://www.prospects.ac.uk/job-profiles/hospital-doctor

Responsibilities

Specific tasks depend on the specialty - a surgeon's daily tasks are significantly different from those of a doctor working in accident and emergency (A&E) or a general physician.

However, the following responsibilities are likely to be carried out on a daily or weekly basis, regardless of the doctor's specialty:

- monitoring and providing general care to patients on hospital wards and in outpatient clinics;
- admitting patients requiring special care, followed by investigations and treatment;
- examining and talking to patients to diagnose their medical conditions;
- carrying out specific procedures, e.g. performing operations and specialist investigations;
- making notes and preparing paperwork, both as a legal record of treatment and for the benefit of other healthcare professionals;
- working with other doctors as part of a team, either in the same department or within other specialties;
- liaising with other medical and non-medical staff in the hospital to ensure quality treatment;
- promoting health education;
- undertaking managerial responsibilities such as planning the workload and staffing of the department, especially at more senior levels;
- teaching and supervising junior doctors and medical students;
- carrying out auditing and research.

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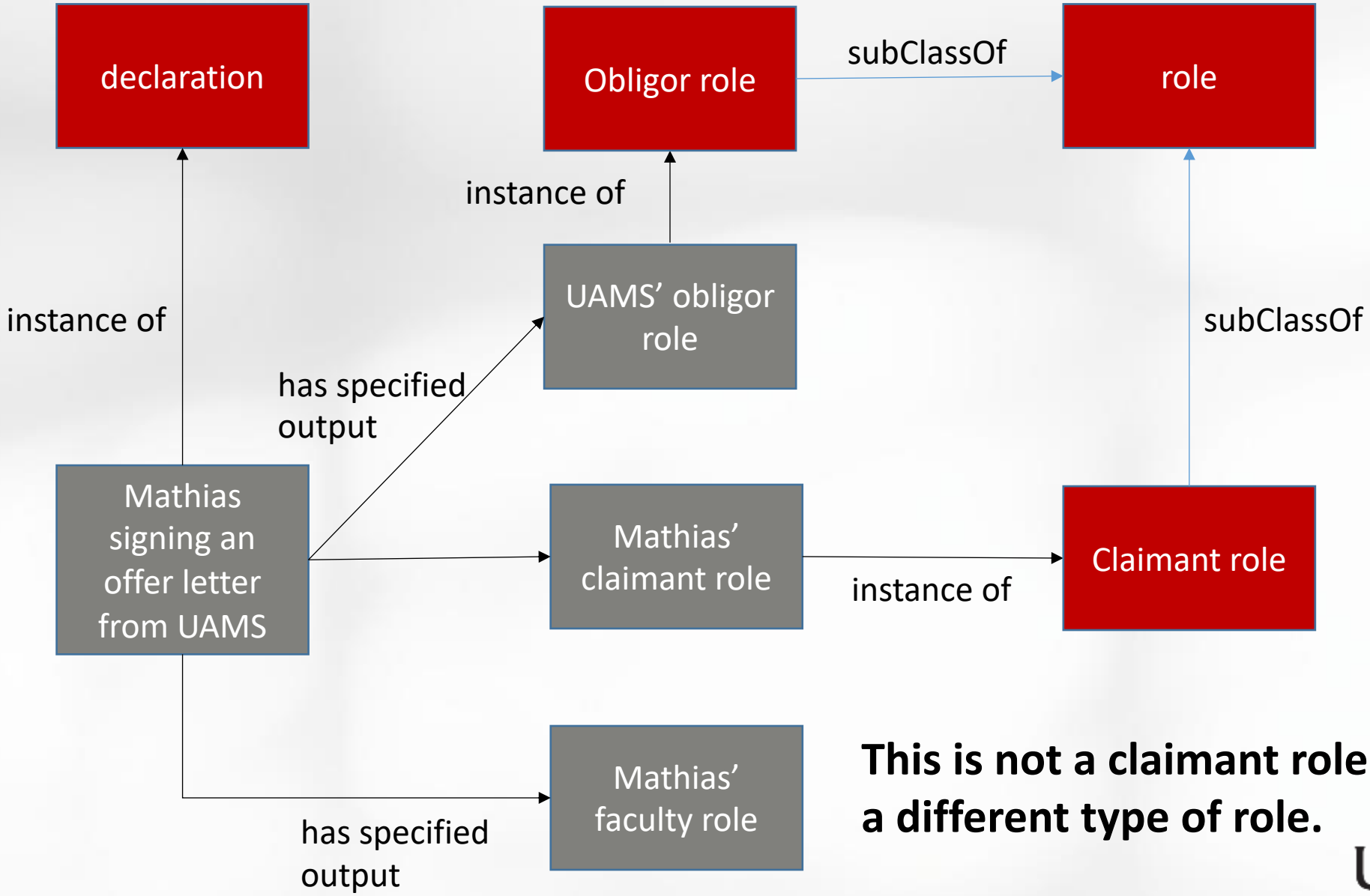
Competency questions for the CAFÉ ontology (OOSTT)

- What are the obligations of a trauma medical director?
- What are the privileges of a trauma program manager?
- Does the trauma medical director have the authority to staff the trauma panel?



This is not a claimant role! It is a different type of role.

Institutional role

The role within an organization for which one was primarily hired.

Examples: physician role, nurse role, surgeon role, trauma medical director role, etc.

Deontic role

Definition: "A role that inheres in an agent and which is externally grounded in the normative expectations that other agents within a social context have concerning how that agent should behave."

Document Act Ontology (d-acts)

- The development of the Document Act Ontology (d-acts) was started in 2012.
- d-acts is an OWL implementation of the theory of document acts
- d-acts is based on BFO and follows OBO Foundry principles.
- It reuses classes and relations from OBI and IAO.
- OOSTT imports the d-acts ontology in its entirety!

d-acts OWL Implementation

- d-acts (document act ontology):
  - http://purl.obolibrary.org/iao/d-acts.owl
  - Extension of BFO and IAO
  - Using the IAO namespace
- Project homepage (including issue tracker):
  - https://github.com/d-acts/d-acts

What do we mean when we talk about rights?

Opposites

If *A* has a claim… …then *A* lacks a no-claim.

If *A* has a privilege… …then *A* lacks a duty.

If *A* has a power… …then *A* lacks a disability.

If *A* has an immunity……then *A* lacks a liability.

Hohfeld, WN. (1919) *Fundamental Legal Conceptions as Applied in Judicial Reasoning*. New Haven, CT: Yale University Press.

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What do we mean when we talk about rights?

Correlatives

If *A* has a claim… …then *B* has a duty.

If *A* has a privilege… …then *B* has a no-claim.

If *A* has a power… …then *B* has a liability.

If *A* has an immunity……then *B* has a disability.

Hohfeld, WN. (1919) *Fundamental Legal Conceptions as Applied in Judicial Reasoning*. New Haven, CT: Yale University Press.

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Extending d-acts/OOSTT

- Many of those were implemented in early 2021.
- These will help keeping the types rights exemplified below separate
  - My claim to remuneration for my trip to ICBO against UAMS.
  - Dr. Doe's OR privileges.
  - Dr. Boe's power to revoke Dr. Doe's OR privileges.

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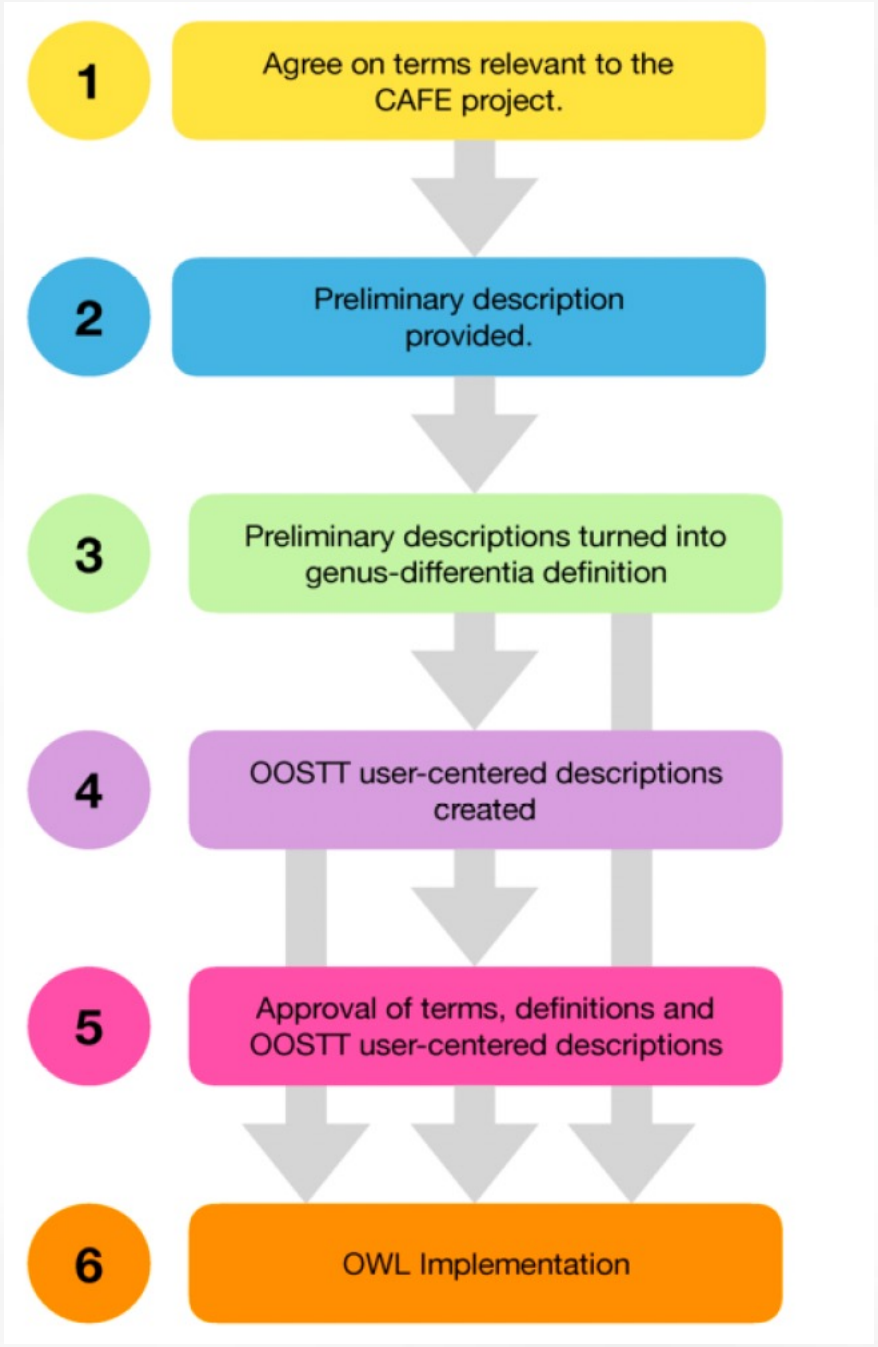
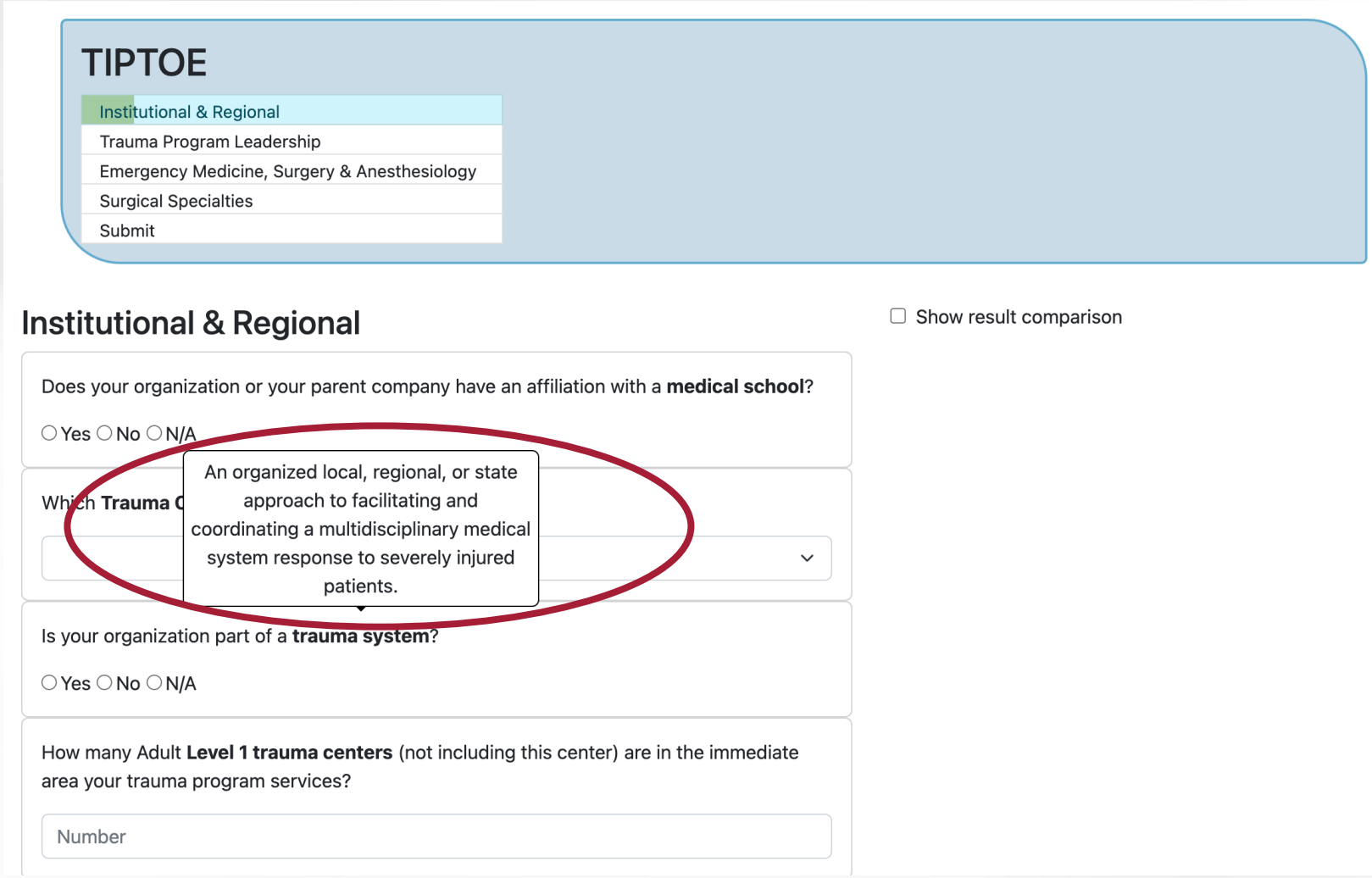
The TIPTOE Vocabulary

Test term approval



TIPTOE Questionnaire



Term approval survey

*

Trauma Center:

A hospital that provides emergency trauma care through specially trained personnel at all times.

- ◯ Agree
- ◯ Agree, with revision
- ◯ Disagree
- ◯ Don't know

*

Trauma Performance improvement/patient safety process:

A program (a plan specification) specifying the monitoring, evaluating and improving of the quality of care for trauma patients and of a trauma service as whole.

- ◯ Agree
- ◯ Agree, with revision
- ◯ Disagree
- ◯ Don't know

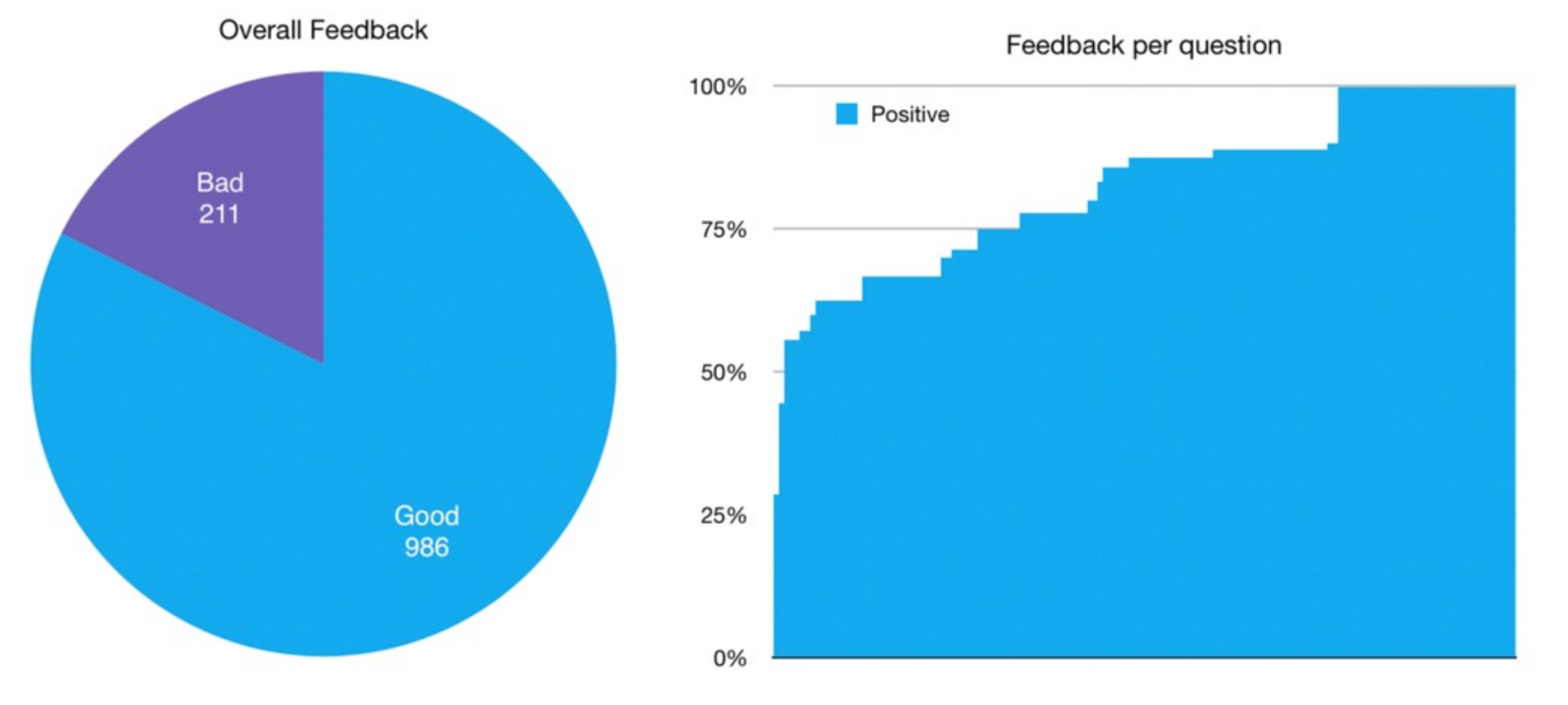
*

Trauma Performance improvement/patient safety process:

A program (a plan specification) specifying the monitoring, evaluating and improving of the quality of care for trauma patients and of a trauma service as whole.

- ◯ Agree
- ◯ Agree, with revision
- ◯ Disagree
- ◯ Don't know

Controlled Vocabulary 2



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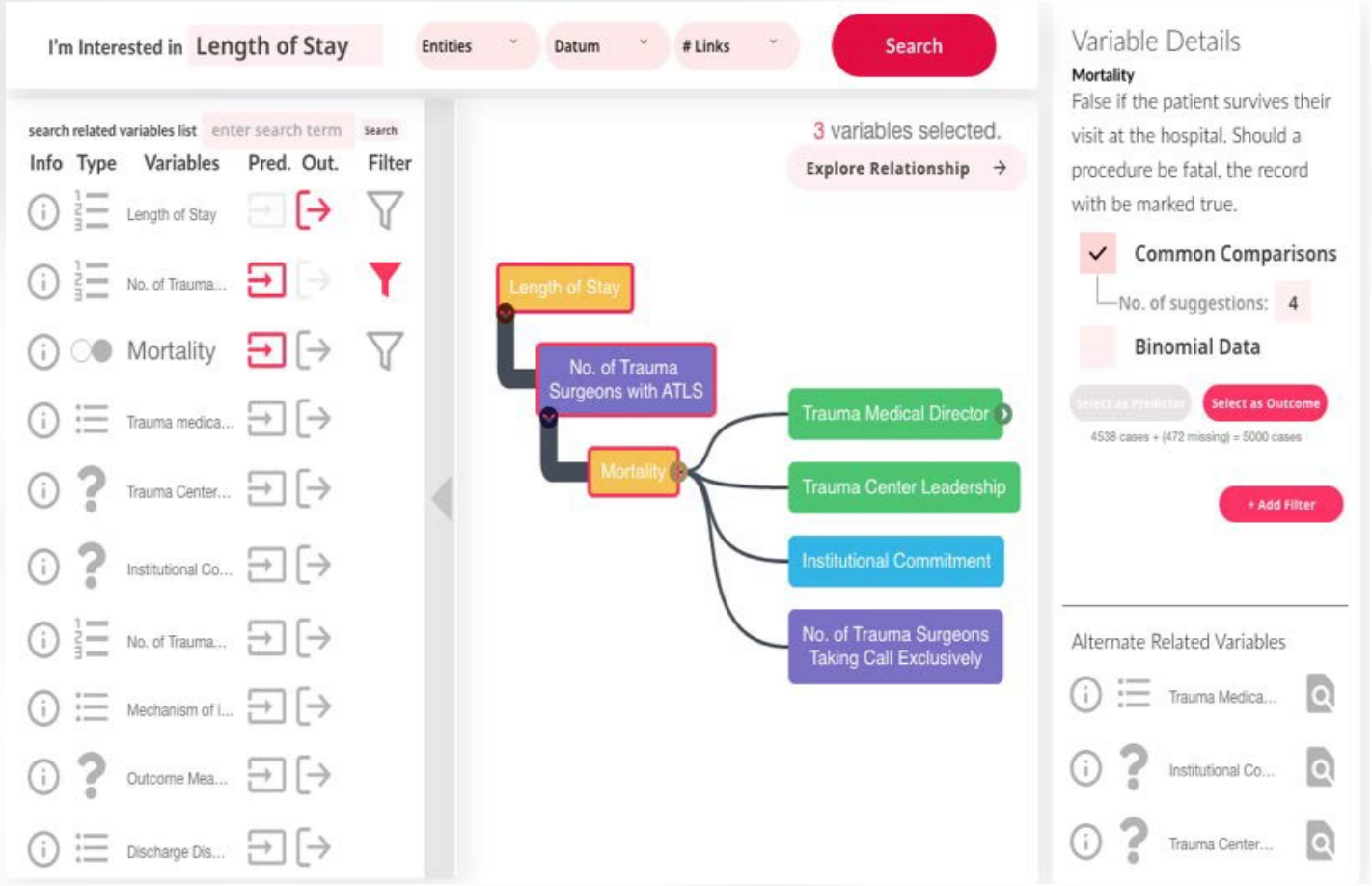
The TIPTOE Knowledge Graph

The TIPTOE Knowledge Path

Participants will gain early access to **deidentified** study results, receive semi-annual interval reports, have access to the TIPTOE Knowledge Path, and be able to provide feedback for study improvement.



mock-up created by E. Ragan for TIPTOE grant proposal

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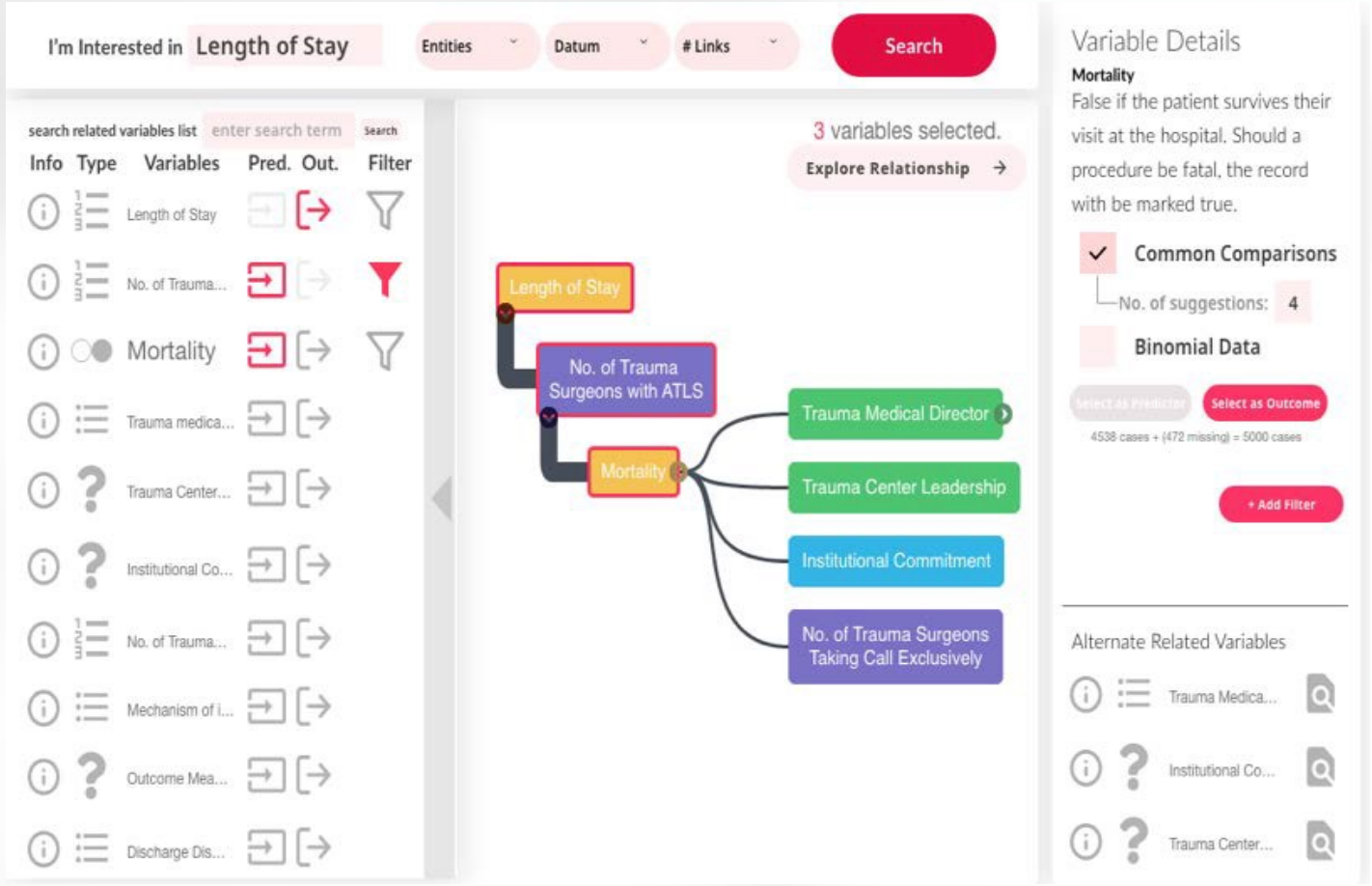
The TIPTOE Knowledge Path

This knowledge graph integrates:

- TQIP outcomes data
- Organizational parameters collected through the TIPTOE Questionnaire
- Knowledge from OOSTT

All data will be shown for 1 institution only!



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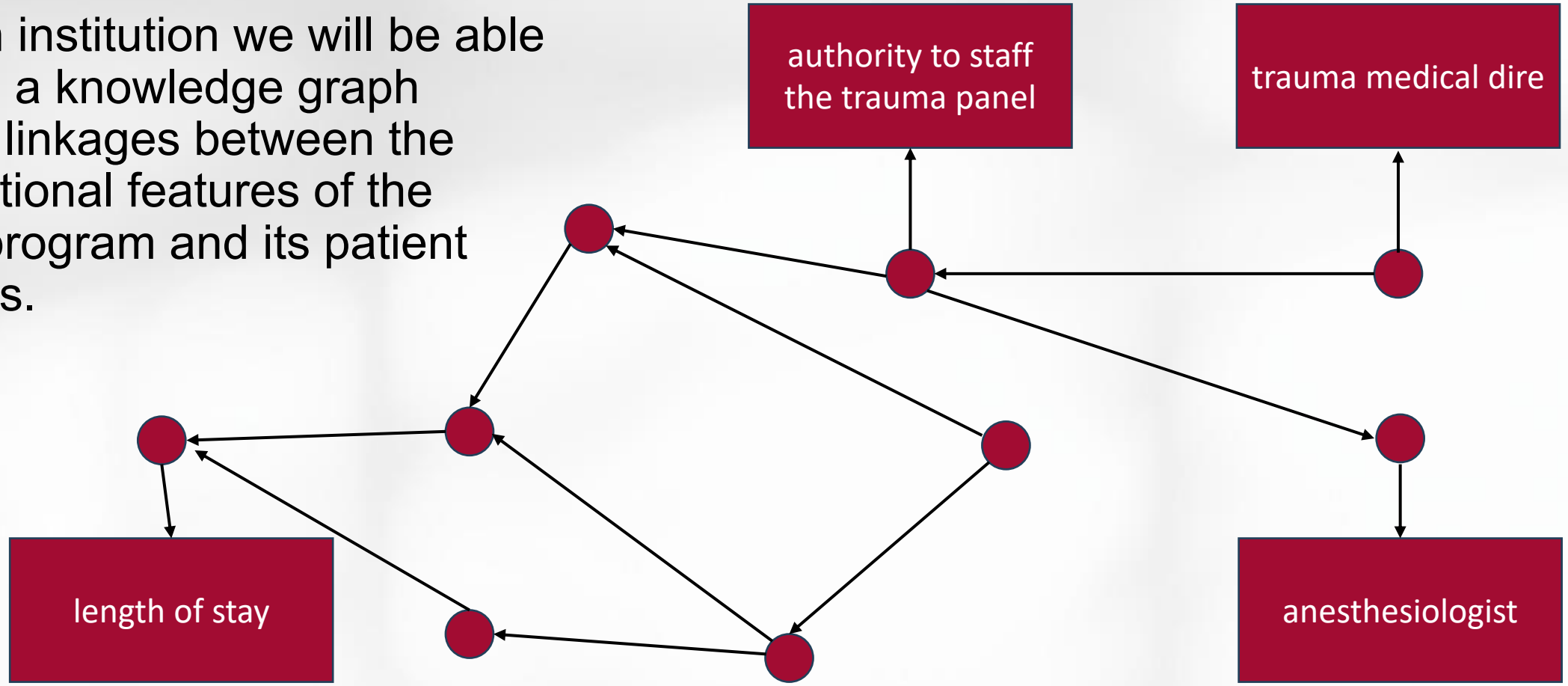
A collection of knowledge graphs

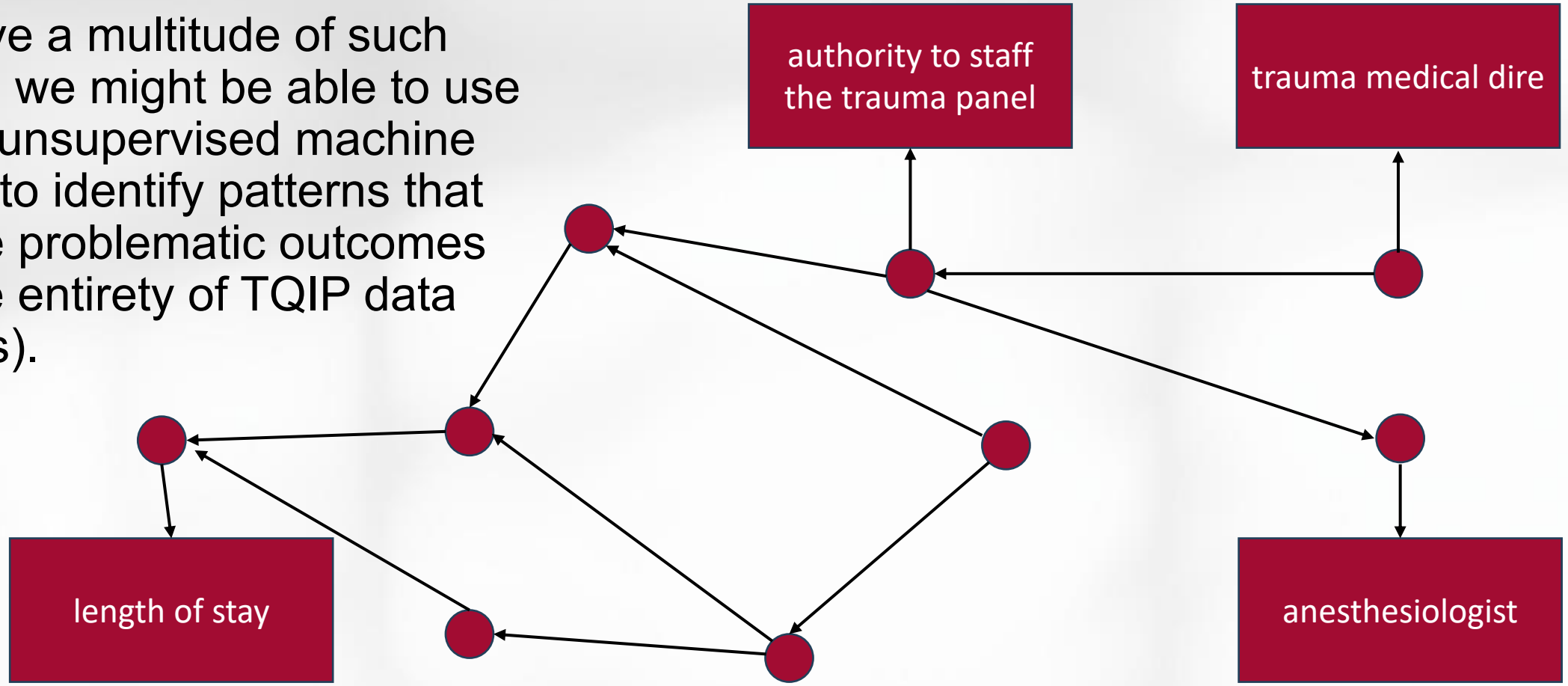
For each institution we will be able to create a knowledge graph showing linkages between the organizational features of the trauma program and its patient outcomes.



This network is hypothetical! To build those, we need the results of Aim 1!

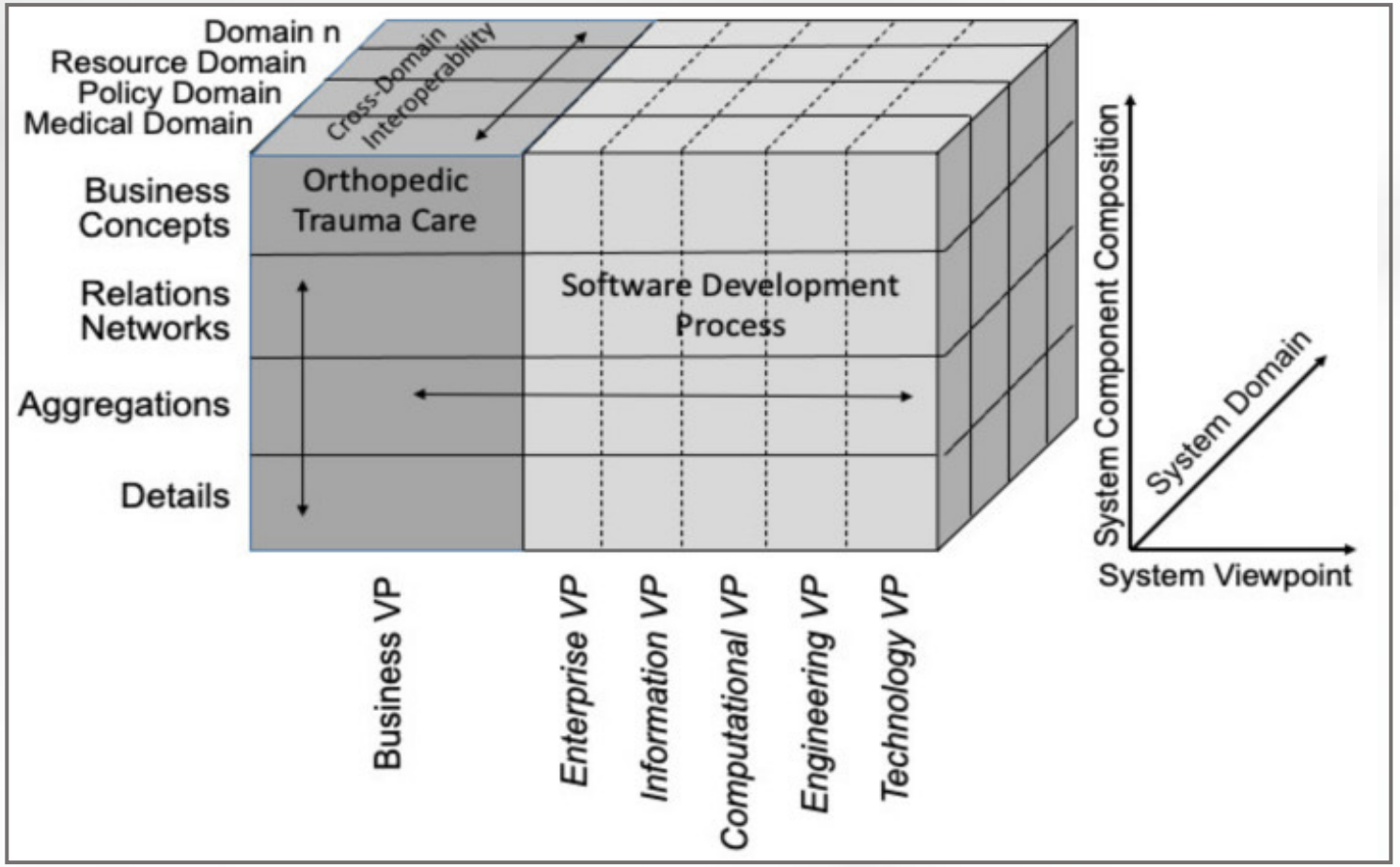
From TIPTOE to machines learning…

If we have a multitude of such patterns, we might be able to use those in unsupervised machine learning to identify patterns that generate problematic outcomes (over the entirety of TQIP data elements).



This network is hypothetical! To build those, we need the results of Aim 1!

We still need to implement a principled approach to addressing all needs for integration of business processes and information structure.



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