

SNOMED-CT

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Ontologies and Semantic Web
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(Have You noticed ... ?)

- COVID vaccination certificates refer to
 - code of COVID-19 disease/agens
 - [840533007](#)
 - code of COVID-19 vaccine
 - [1119349007](#)

Vaccination certificate Certifikát o provedené vakcinaci

Disease or agent targeted (*Cílená nemoc nebo agens*)
SARS-CoV-2 (ICD 11 XN109, SNOMED CT 840533007)

Vaccine/prophylaxis (*Vakcína/Profylaxe*)
mRNA vakcína proti onemocnění COVID-19
COVID-19 mRNA Vaccine, Severe acute respiratory syndrome coronavirus 2 mRNA only vaccine product(SNOMED CT 1119349007)

Vaccine medicinal product (*Vakcína*)
Comirnaty

Vaccine marketing authorisation holder or manufacturer
(*Výrobce nebo držitel rozhodnutí o registraci vakcíny*)
BioNTech Manufacturing GmbH

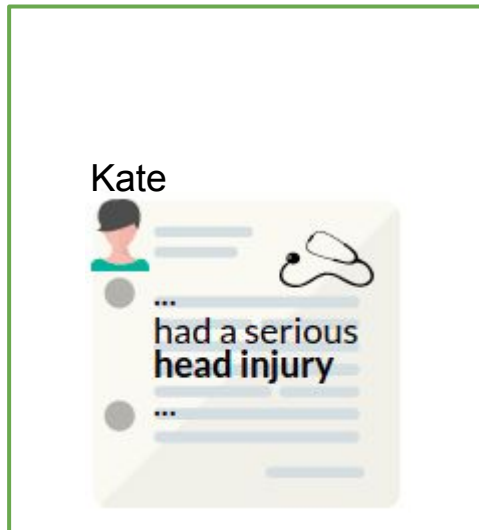
Number in a series of vaccinations/doses and the overall number of doses in the series
(*Pořadové číslo dávky/počet dávek*)
1/2

Date of vaccination (*Datum vakcinace*)
2021-05-25

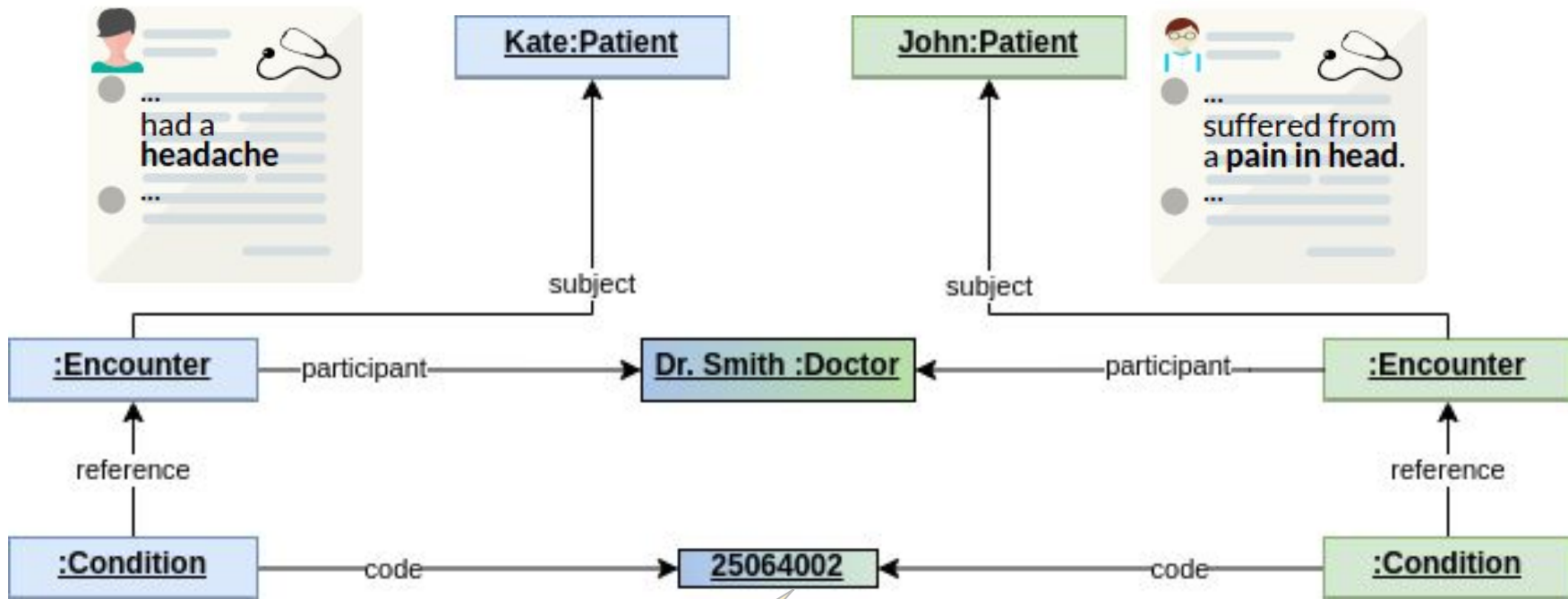
Member State of vaccination (*Členský stát*)
CZ

Certificate issuer (*Vydavatel certifikátu*)
Ministry of Health of the Czech Republic / Ministerstvo zdravotnictví České republiky

- Which patients had some problems with head manifested by a pain?
- What is the Kate's history of problems related to head?



Which patients had some problems with head manifested by a pain?

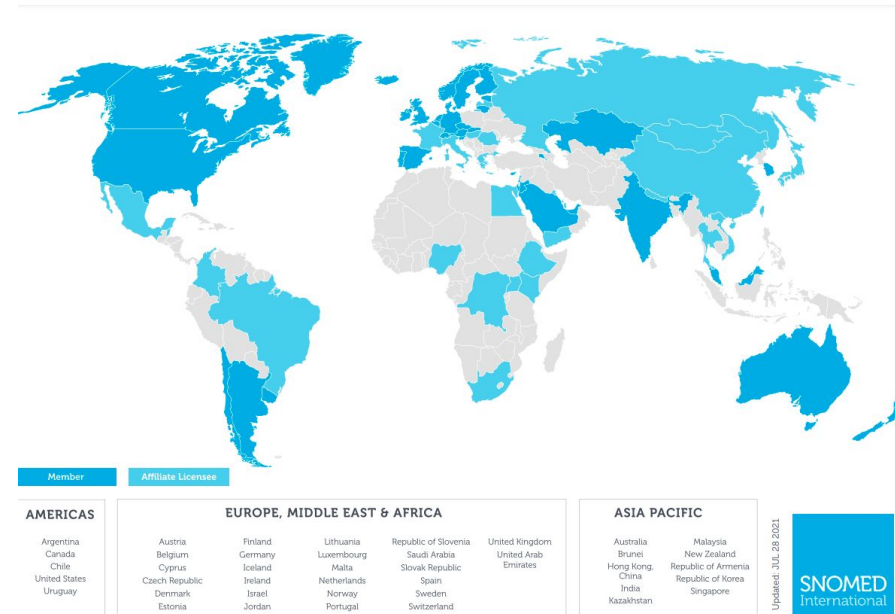


Headache (finding)

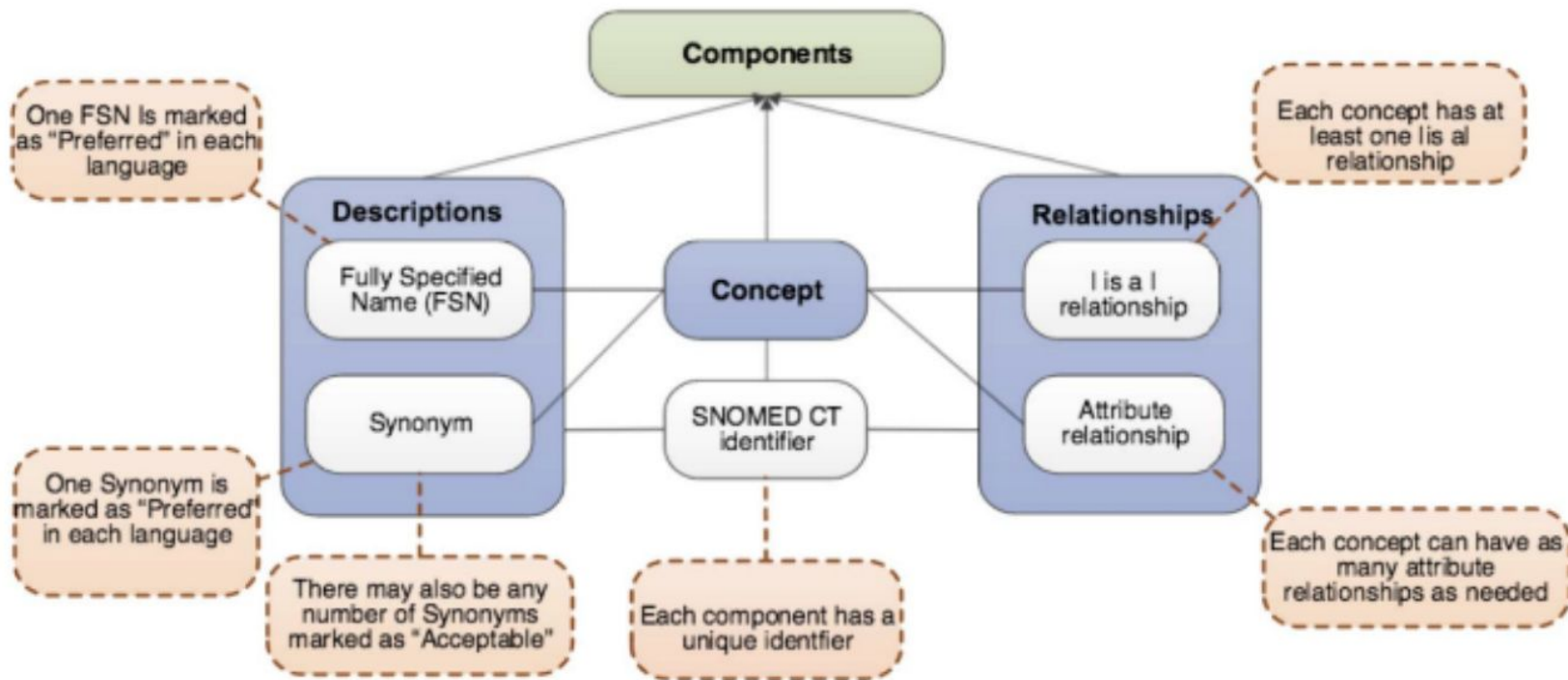
- SCTID: 25064002
- synonym 'Headache'
- synonym 'Pain in head'
- ...

About SNOMED-CT

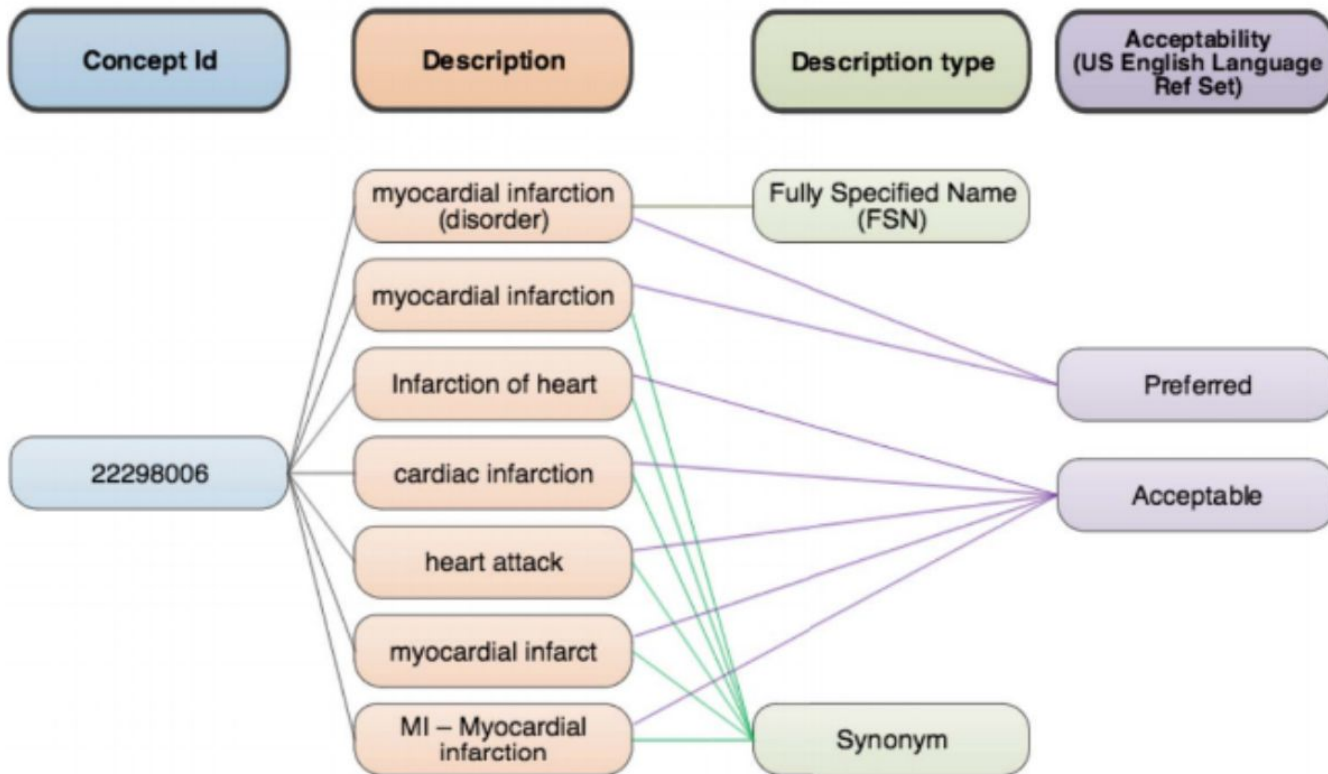
- Systematized **NO**menclature of **MED**icine – **C**linical **T**erms
- multiple inheritance clinical terminology
- developed, curated and distributed by SNOMED International
 - 40 member states (including Czech Republic)
- as of July 2022 - international edition
 - 350k+ clinical concepts



SNOMED-CT components



SNOMED-CT descriptions



SNOMED-CT concept structure

super concepts
(generalizations)

Parents

- ☰ Head finding (finding)
- > ☰ Pain finding at anatomical site (finding)

FSN (fully specified name)
- human-readable identifier

relationships
- links to other concepts

SCTID:
- unique ID of a
SNOMED-CT
concept

● Headache (finding) ☆

SCTID: 25064002

25064002 | Headache (finding) |

- en Headache (finding)
- en Headache
- en Cephalalgia
- en Cephalgia
- en Cephalodynia
- en HA - Headache
- en Head pain
- en Pain in head

Finding site - Head structure

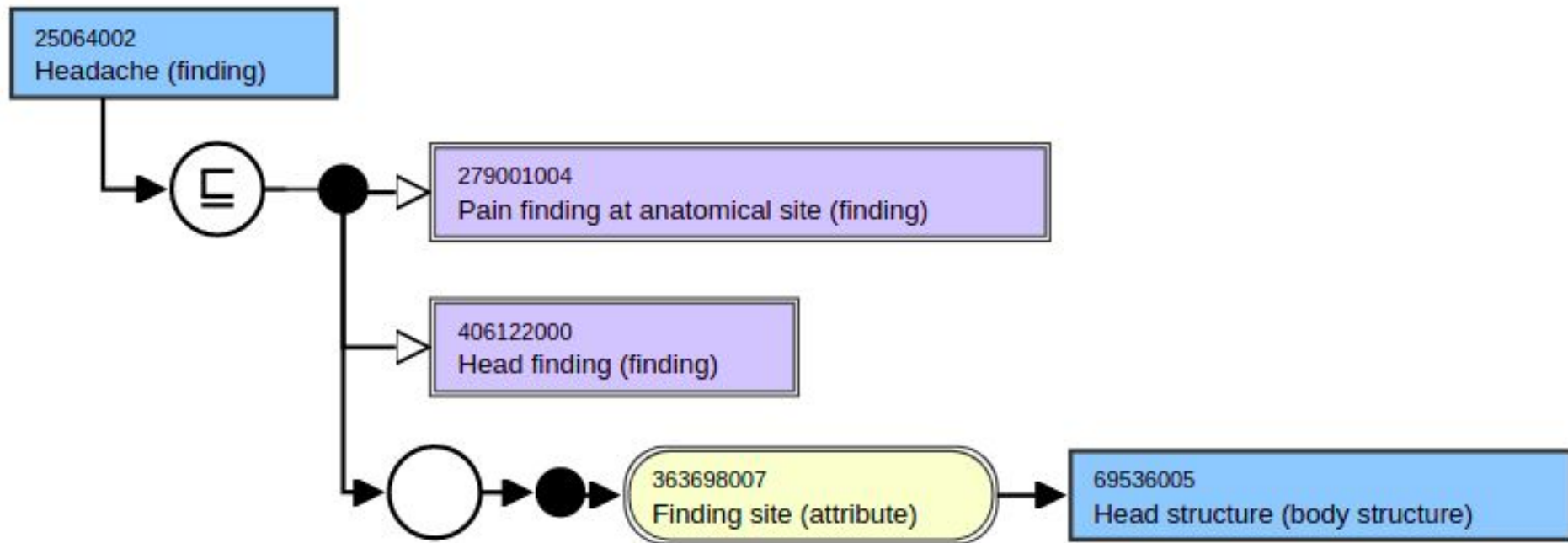
Synonym
- language-specific names -
PREFERRED/ACCEPTABLE

Children (35)

- > ☰ Acute headache (finding)
- ● Aural headache (finding)
- ● Bilateral headache (finding)

sub concepts
(specializations)

SNOMED-CT concept diagram



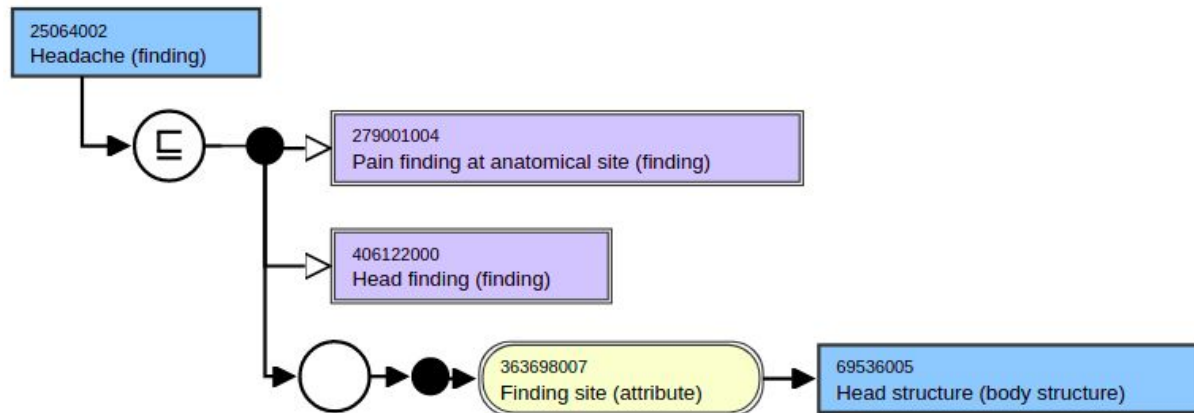
SNOMED-CT in OWL

"Headache (finding)" $\sqsubseteq \exists$ FindingSite . HeadStructure

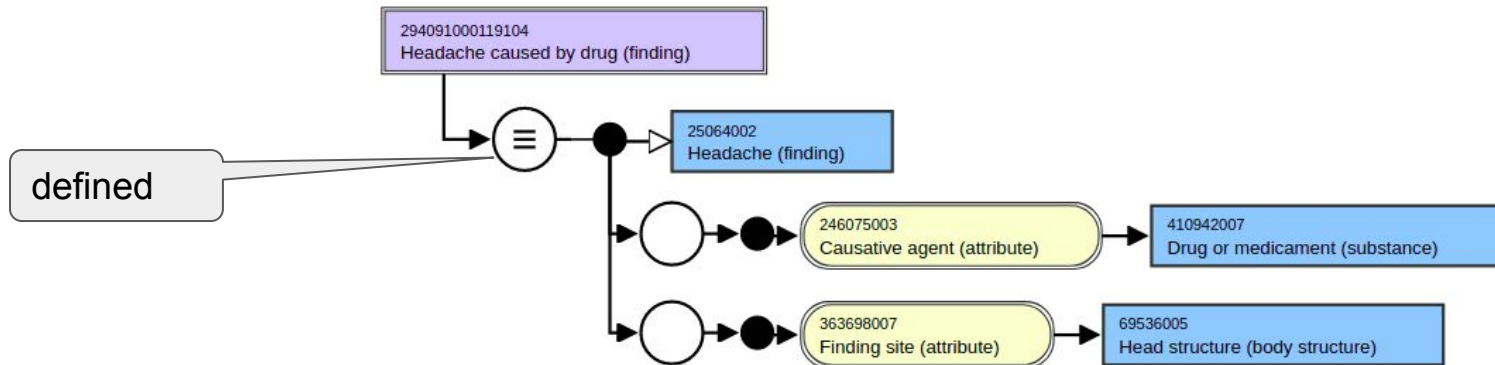
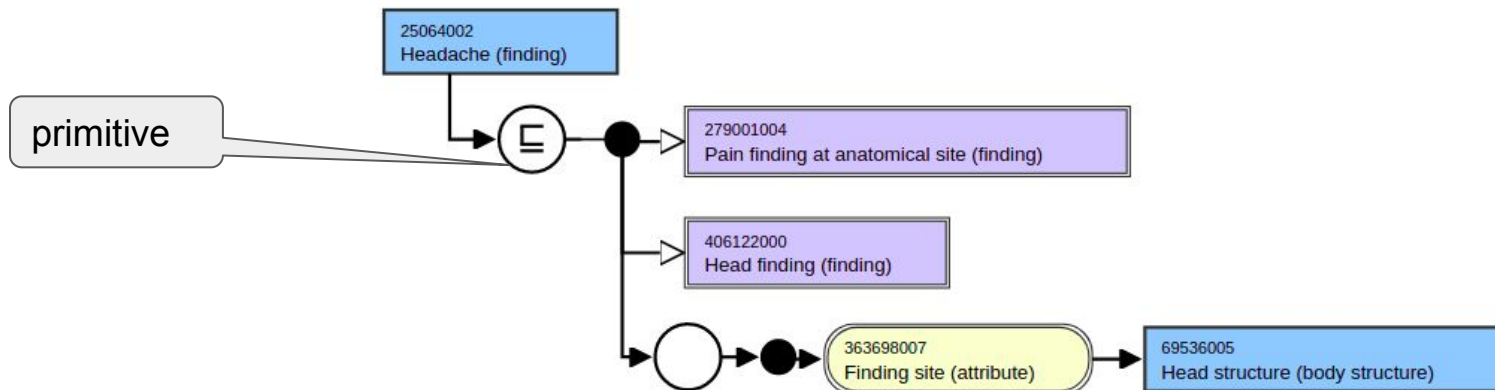
"Headache (finding)" \sqsubseteq "Head finding (finding)"

"Headache (finding)" \sqsubseteq "Pain finding at anatomical site (finding)"

...



Defined vs. Primitive Concepts



Description Logic Intermezzo

- SNOMED-CT - expressible in description logics EL++
- EL++ is expressible in the OWL 2 EL profile
- EL++ reasoners are used to classify SNOMED-CT
(e.g. the [ELK reasoner](#))
- reasoning in EL++ is polynomial and does not require satisfiability checking

Description Logic EL++

Name	Syntax	Semantics
top	\top	$\Delta^{\mathcal{I}}$
bottom	\perp	\emptyset
nominal	$\{a\}$	$\{a^{\mathcal{I}}\}$
conjunction	$C \sqcap D$	$C^{\mathcal{I}} \cap D^{\mathcal{I}}$
existential restriction	$\exists r.C$	$\{x \in \Delta^{\mathcal{I}} \mid \exists y \in \Delta^{\mathcal{I}} : (x, y) \in r^{\mathcal{I}} \wedge y \in C^{\mathcal{I}}\}$
concrete domain	$p(f_1, \dots, f_k)$ for $p \in \mathcal{P}^{\mathcal{D}_j}$	$\{x \in \Delta^{\mathcal{I}} \mid \exists y_1, \dots, y_k \in \Delta^{\mathcal{D}_j} : f_i^{\mathcal{I}}(x) = y_i \text{ for } 1 \leq i \leq k \wedge (y_1, \dots, y_k) \in p^{\mathcal{D}_j}\}$
GCI	$C \sqsubseteq D$	$C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$
RI	$r_1 \circ \dots \circ r_k \sqsubseteq r$	$r_1^{\mathcal{I}} \circ \dots \circ r_k^{\mathcal{I}} \subseteq r^{\mathcal{I}}$

Normalized TBox

- $A \sqsubseteq B$
- $A_1 \sqcap A_2 \sqsubseteq B$
- $A \sqsubseteq \exists r.B$
- $\exists r.A \sqsubseteq B$

Normalization takes a general TBox and creates a normalized TBox (preserving classification results):

$$\exists r.A \sqcap \exists r.\exists s.A \sqsubseteq A \sqcap B$$

can be normalized to

$$\exists r.A \sqsubseteq B_1 \quad B_1 \sqcap B_2 \sqsubseteq B_0 \quad \exists s.A \sqsubseteq B_3 \quad \exists r.B_3 \sqsubseteq B_2 \quad B_0 \sqsubseteq A \quad B_0 \sqsubseteq B$$

Reasoning in EL++

rule	if	then	note
CR1	$\{\}$	$A \sqsubseteq A$	
CR2	$\{\}$	$A \sqsubseteq \top$	
CR3	$\{A_1 \sqsubseteq A_2, A_2 \sqsubseteq A_3\}$	$A_1 \sqsubseteq A_3$	
CR4	$\{A \sqsubseteq A_1, A \sqsubseteq A_2, A_1 \sqcap A_2 \sqsubseteq B\}$	$A \sqsubseteq B$	convexity
CR5	$\{A \sqsubseteq \exists r.A_1, A_1 \sqsubseteq B_1, \exists r.B_1 \sqsubseteq B\}$	$A \sqsubseteq B$	

Reasoning in EL++ - Example

$\{ A \sqsubseteq \exists r.A, \quad \exists r.B \sqsubseteq B_1, \quad T \sqsubseteq B, \quad A \sqsubseteq B_2, \quad B_1 \sqcap B_2 \sqsubseteq C \}$

$\models A \sqsubseteq T$ (CR2)

$\models A \sqsubseteq B$ (CR3)

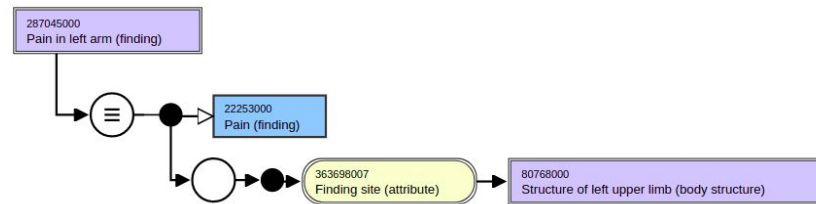
$\models A \sqsubseteq B_1$ (CR4)

$\models A \sqsubseteq C$ (CR5)

**End of
intermezzo.**

Classification of SNOMED-CT

- for defined concepts infers their children
- 287045000 | Pain in left arm |
- before classification - 0 children
- after classification - 11 direct children (26 total)



- ≡ Chronic pain of left upper limb (finding)
- ≡ Joint pain in left hand (finding)
- ≡ Pain of amputation stump of left upper limb (finding)
- ≡ Pain of left acromioclavicular joint (finding)
- ≡ Pain of left forearm (finding)
- ≡ Pain of left shoulder blade (finding)
- ≡ Pain of left sternoclavicular joint (finding)
- ≡ Pain of left upper arm (finding)
- ≡ Pain of left upper limb co-occurrent and due to ischemia (disorder)
- ≡ Repetitive motion disorder of left hand (disorder)
- ≡ Repetitive motion disorder of left shoulder (disorder)

Reference Sets (RefSets)

- a subset of components (**concepts**, **descriptions** or **relationships**), optionally equipped with additional attributes
- use-cases
 - Ordered lists of components
 - Sets of associations between components
 - Mapping between **SNOMED CT concepts** and other systems codes, classifications, or knowledge resources.
 - Language translations to concepts

Reference Sets (RefSets)

Description file
(International release)

conceptId	id	typeId	term
22298006	751689013	900000000000003001 Fully specified name	Myocardial infarction (disorder)
22298006	37436014	900000000000013009 Synonym	Myocardial infarction
22298006	37442013	900000000000013009 Synonym	Cardiac infarction
22298006	37443015	900000000000013009 Synonym	Heart attack
22298006	37441018	900000000000013009 Synonym	Infarction of heart
22298006	1784872019	900000000000013009 Synonym	MI - Myocardial infarction
22298006	1784873012	900000000000013009 Synonym	Myocardial infarct

90000000000509007 | United
States of America English language
reference set|

refsetId	referencedComponentId	acceptabilityId
90000000000509007	751689013	90000000000548007 Preferred
90000000000509007	37436014	90000000000548007 Preferred
90000000000509007	37442013	90000000000549004 Acceptable
90000000000509007	37443015	90000000000549004 Acceptable
90000000000509007	37441018	90000000000549004 Acceptable
90000000000509007	1784872019	90000000000549004 Acceptable
90000000000509007	1784873012	90000000000549004 Acceptable

Content

- combined metadata with data (like in RDF)
- **SNOMED CT Model Component** is healthcare agnostic

- ▼ ● SNOMED CT Concept (SNOMED RT+CTV3) 350935
 - ▶ ● Body structure (body structure) 39815
 - ▶ ● Clinical finding (finding) 114783
 - ▶ ● Environment or geographical location (environment / location) 1838
 - ▶ ● Event (event) 3215
 - ▶ ● Observable entity (observable entity) 9727
 - ▶ ● Organism (organism) 32282
 - ▶ ● Pharmaceutical / biologic product (product) 23214
 - ▶ ● Physical force (physical force) 170
 - ▶ ● Physical object (physical object) 13660
 - ▶ ● Procedure (procedure) 58617
 - ▶ ● Qualifier value (qualifier value) 11107
 - ▶ ● Record artifact (record artifact) 502
 - ▶ ● Situation with explicit context (situation) 4794
 - ▶ ● SNOMED CT Model Component (metadata) 1816
 - ▶ ● Social context (social concept) 4422
 - ▶ ● Special concept (special concept) 635
 - ▶ ● Specimen (specimen) 1726
 - ▶ ● Staging and scales (staging scale) 1622
 - ▶ ● Substance (substance) 26986

Expression Constraint Language (ECL)

- language to express concept model/to query SNOMED-CT

Symbol	Name	Version	Notes
	Pipe	1.0	Used on either side of a concept's term for human readability
*	Any	1.0	Retrieves all concepts in the substrate
^	Member of	1.0	Retrieves all (active) members of a reference set identified by a specified reference set concept
<	Dendant of	1.0	Retrieves all descendants (subtypes) of the specified concept <i>excluding</i> the concept itself
<<	Dendant or self of	1.0	Retrieves all descendants (subtypes) of the specified concept <i>including</i> the concept itself
<!	Child of	1.1	Retrieves all children (immediate subtypes) of the specified concept <i>excluding</i> the concept itself
<<!	Child or self of	1.4	Retrieves all children (immediate subtypes) of the specified concept <i>including</i> the concept itself
>	Ancestor of	1.0	Retrieves all ancestors (supertypes) of the specified concept <i>excluding</i> the concept itself
>>	Ancestor or self of	1.0	Retrieves all ancestors (supertypes) of the specified concept <i>including</i> the concept itself
>!	Parent of	1.1	Retrieves all parents (immediate supertypes) of the specified concept <i>excluding</i> the concept itself
>>!	Parent or self of	1.4	Retrieves all parents (immediate supertypes) of the specified concept <i>including</i> the concept itself
AND	Conjunction	1.0	Retrieves the intersection of the results of each sub-expressions
OR	Disjunction	1.0	Retrieves the union of the results of each sub-expressions
MINUS	Exclusion	1.0	Retrieves the members of the first expression and excludes the members returned by the second expression
:	Refinement	1.0	Used before one or more attribute-value pairs to refine the set of concepts retrieved
[1..3]	Cardinality	1.0	Used to indicate the minimum and maximum number of occurrences of attributes or relationship groups
R	Reverse flag	1.0	Retrieves the set of attribute values (i.e. destination concepts) of a specified attribute for a specified set of concepts
.	Dot notation	1.1	Retrieves the set of attribute values (i.e. destination concepts) of a specified attribute for a specified set of concepts
/* */	Comment	1.1	Allows comments to be added within the text of an expression constraint
{{ }}	Description filter	1.5	Filters the result set, by matching only on concepts which have a description with a matching term, language, type, dialect and/or acceptability
{{ D }}	Description filter	1.5	Filters the result set, by matching only on concepts which have a description with a matching term, language, type, dialect and/or acceptability
{{ C }}	Concept filter	1.6	Filters the result set based on the definition status, module, effectiveTime and active status of each concept

Expression Constraint Language

- What are the types of pain that can occur in the left arm (including the concept itself)?

```
<< 287045000 | Pain in left arm |
```

- What are the types of pain that can occur in the left arm?

```
< 287045000 | Pain in left arm |
```

- What are the finding sites of types of pain in left arm?

```
<< 287045000 | Pain in left arm | . 363698007 | Finding Site |
```

Expression Constraint Language

- What can occur on head?

```
< * : 363698007 | Finding Site | = 69536005 | Head |
```

- What can occur on head or its part?

```
< * : 363698007 | Finding Site | = << 69536005 | Head |
```

- What are the types of paralytic syndromes caused by a cardiovascular finding

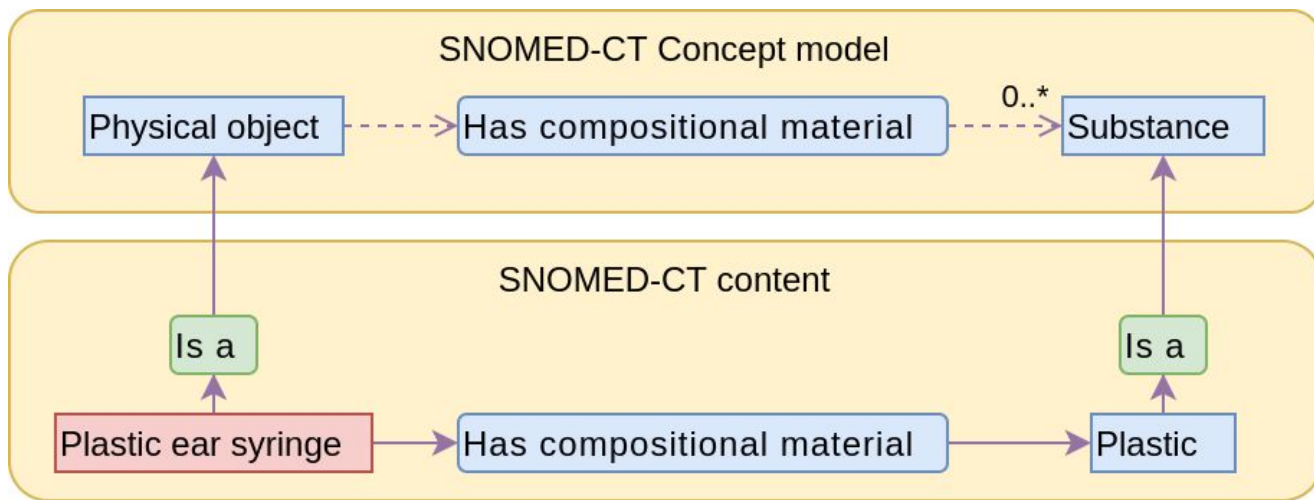
```
<< 29426003 | Paralytic syndrome | : << 42752001 | Due to | = << 106063007 |  
Cardiovascular finding|
```

- Which concepts belong to the CTV3 map

```
< ^ 900000000000497000 | CTV3 simple map reference set |
```

Machine readable concept model (MRMC)

id	effectiveTime	active	moduleId	refsetId	referencedComponentId
b3a823ef-aba5-4cf5-be9a-6c9808ad58b9	20200731	1	900000000000012004	723561005	840560000
domainId	grouped	attributeCardinality	attributeInGroupCardinality	ruleStrengthId	contentTypeId
260787004	0	0..*	0..0	723597001	723596005



- set of files in RF2 format
- snapshot
 - currently valid version
- delta
 - changes w.r.t last snapshot
- full
 - snapshot and all deltas

SnomedCT_InternationalRF2_PRODUCTION_20210131T120000Z.zip

Delta

...

Full

...

Snapshot

Terminology

sct2_Concept_Snapshot_INT_20210131.txt

sct2_Description_Snapshot-en_INT_20210131.txt

sct2_Identifier_Snapshot_INT_20210131.txt

sct2_Relationship_Snapshot_INT_20210131.txt

sct2_sRefset_OWLEExpressionSnapshot_INT_20210131.txt

sct2_StatedRelationship_Snapshot_INT_20210131.txt

sct2_TextDefinition_Snapshot-en_INT_20210131.txt

Refset

Content

der2_cRefset_AssociationSnapshot_INT_20210131.txt

der2_cRefset_AttributeValueSnapshot_INT_20210131.txt

der2_Refset_SimpleSnapshot_INT_20210131.txt

Language

der2_cRefset_LanguageSnapshot-en_INT_20210131.txt

Map

der2_iisssccRefset_ExtendedMapSnapshot_INT_20210131.txt

der2_sRefset_SimpleMapSnapshot_INT_20210131.txt

Metadata

der2_cciRefset_RefsetDescriptorSnapshot_INT_20210131.txt

der2_ciRefset_DescriptionTypeSnapshot_INT_20210131.txt

der2_cisssccRefset_MRCMAttributeDomainSnapshot_INT_20210131.txt

der2_cRefset_MRCModuleScopeSnapshot_INT_20210131.txt

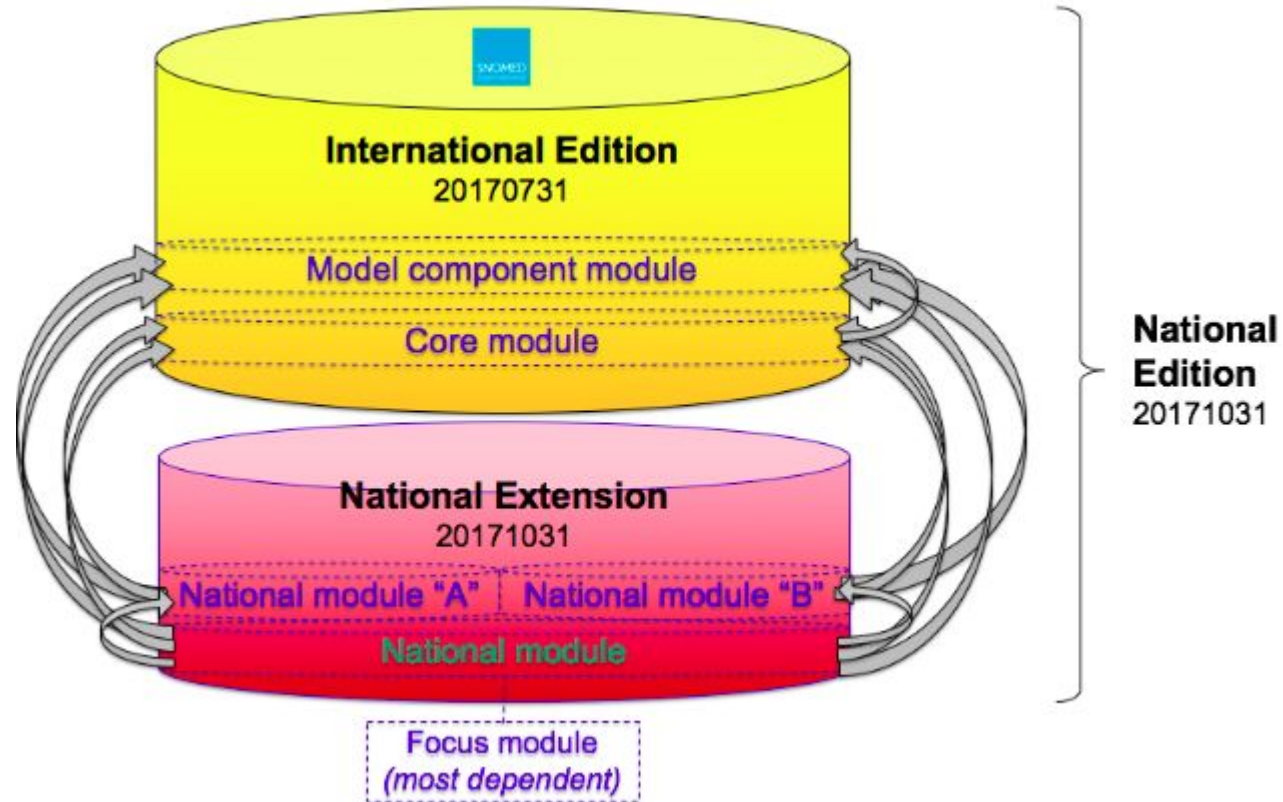
der2_sssccRefset_MRCMAttributeRangeSnapshot_INT_20210131.txt

der2_ssRefset_ModuleDependencySnapshot_INT_20210131.txt

der2_sssssssRefset_MRCMDomainSnapshot_INT_20210131.txt

Editions and Extensions

- each country can create its own extension to the international edition
 - custom concepts
 - custom refsets
 - translations



Reference

1. SNOMED International, <https://www.snomed.org/>, cit. 8.12.2021
2. FHIR, profile Condition <https://www.hl7.org/fhir/condition.html> , cit 8.12.2021
3. Franz Baader, Sebastian Brandt, Carsten Lutz: *Pushing the EL Envelope*. *IJCAI 2005*: 364-369