W3C Workshop Rule Interoperability

Use Case

Interoperating between ontology and rules for identifying brain anatomical structures

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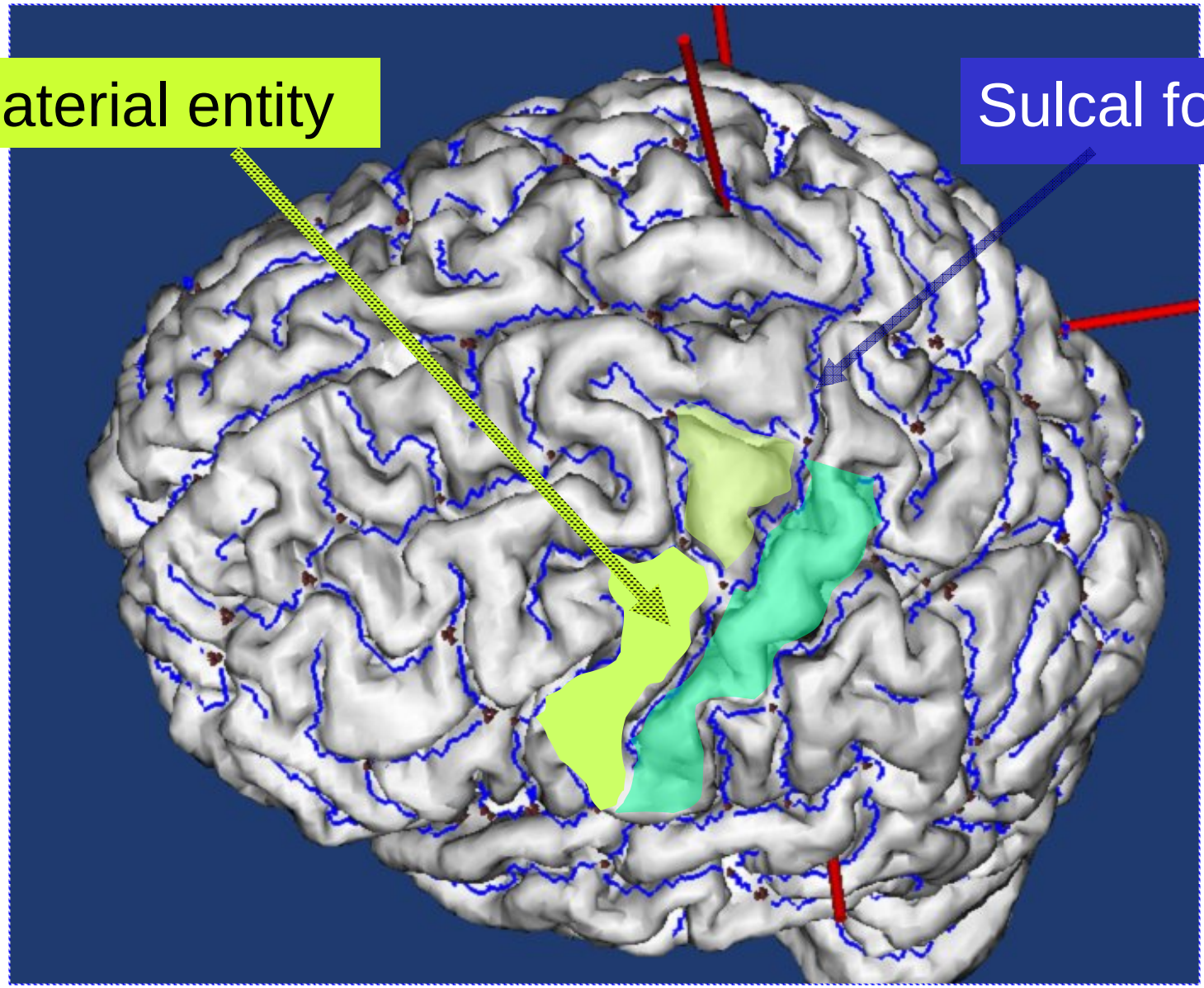
Sharing and reuse

- Sharing anatomical knowledge
- Anatomy plays a central role in medicine
  - applications
    - Computer assisted interpretation of 3D MRI images
    - Decision support in (neuro)surgery
    - Intelligent data retrieval in the Semantic Web

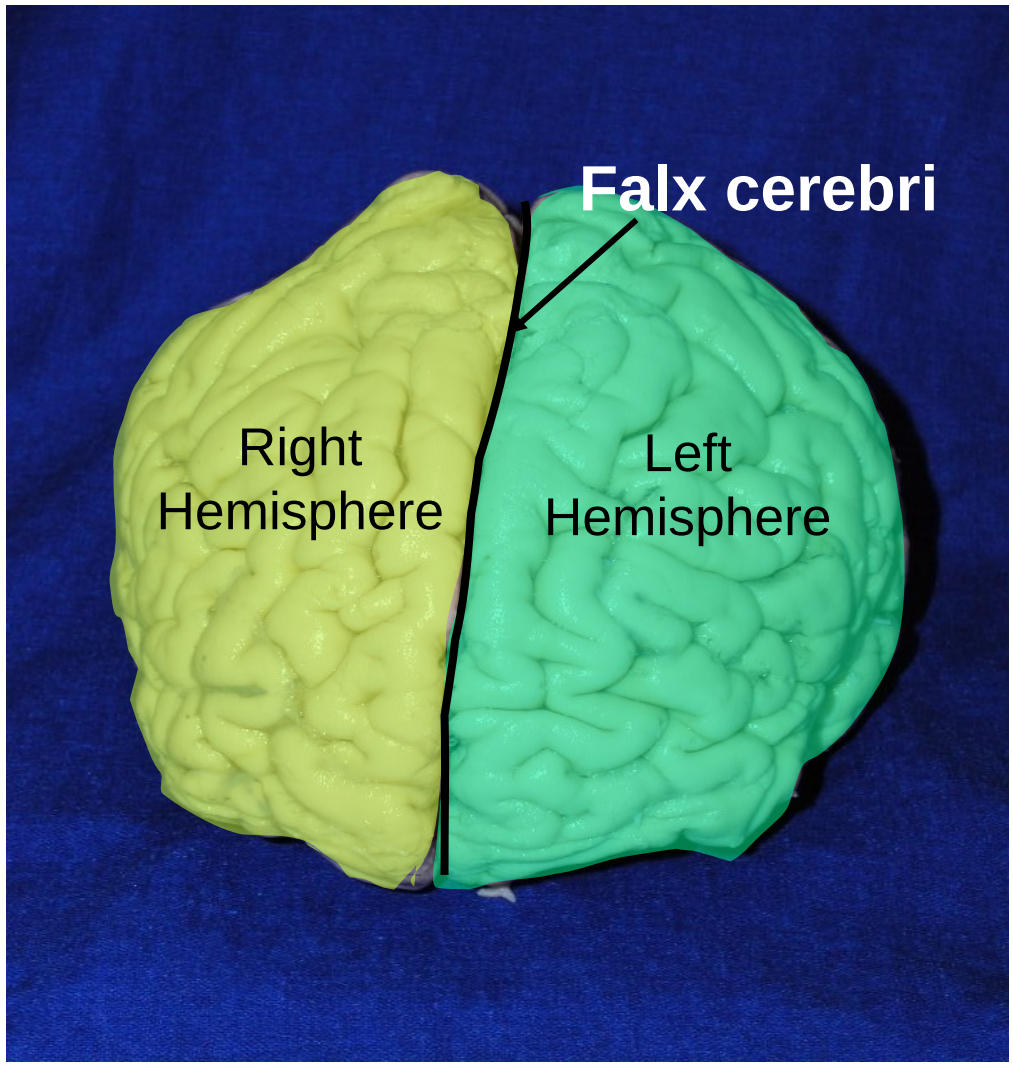
    etc.

Brain



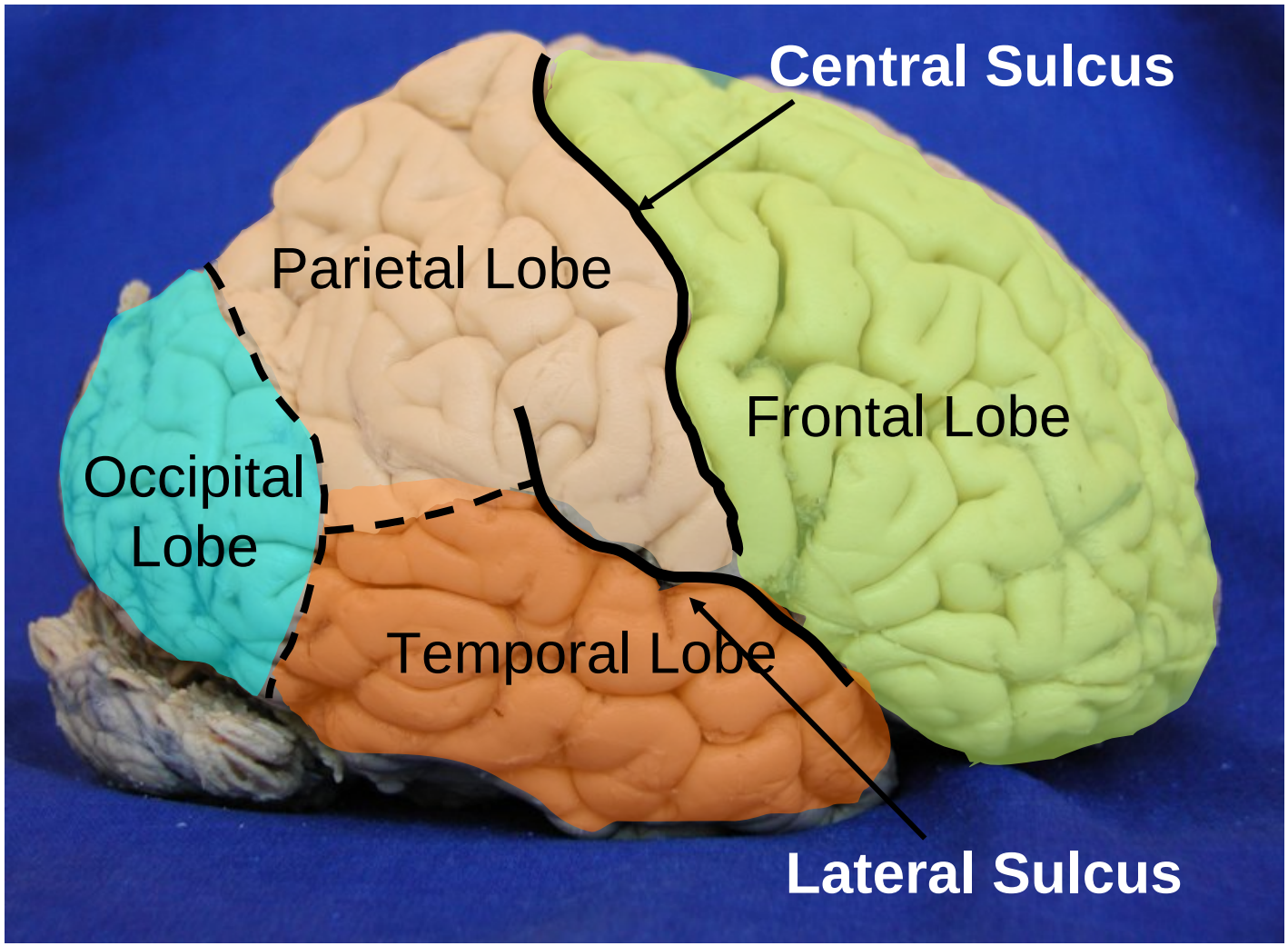
Hemispheres

- bounded by "Falx Cerebri"



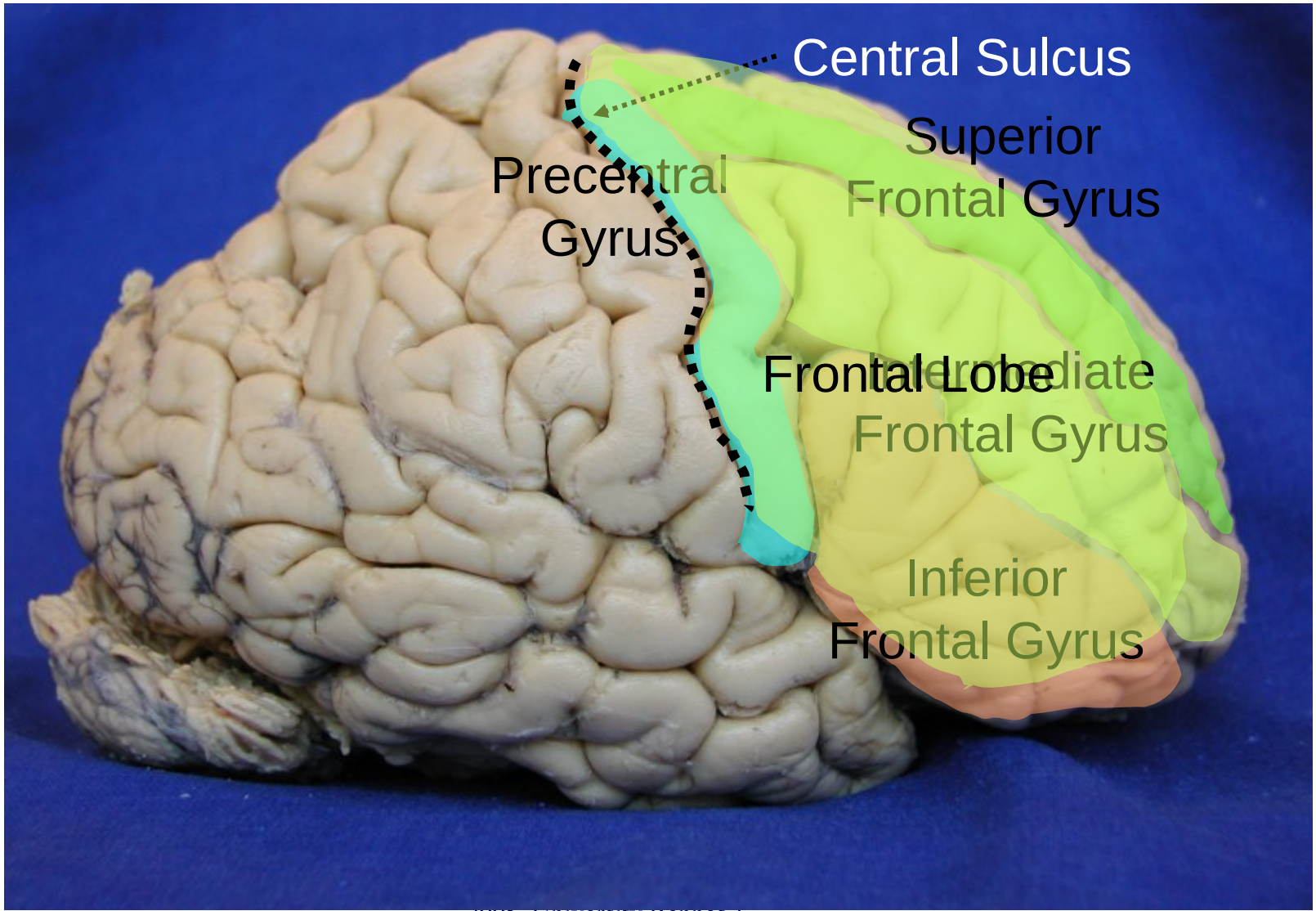
Lobes

- bounded by sulci or lines



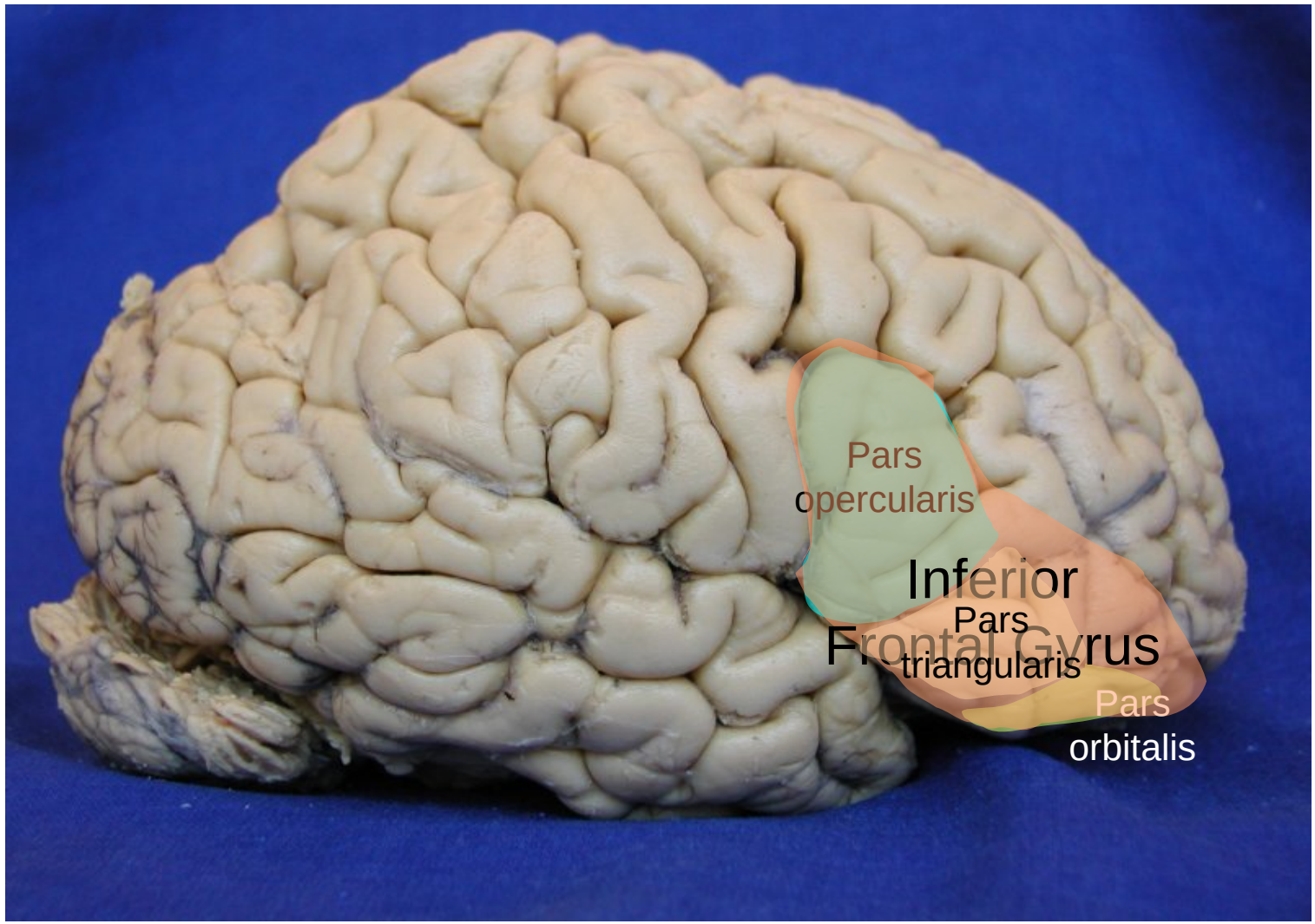
Gyri

- bounded by sulci

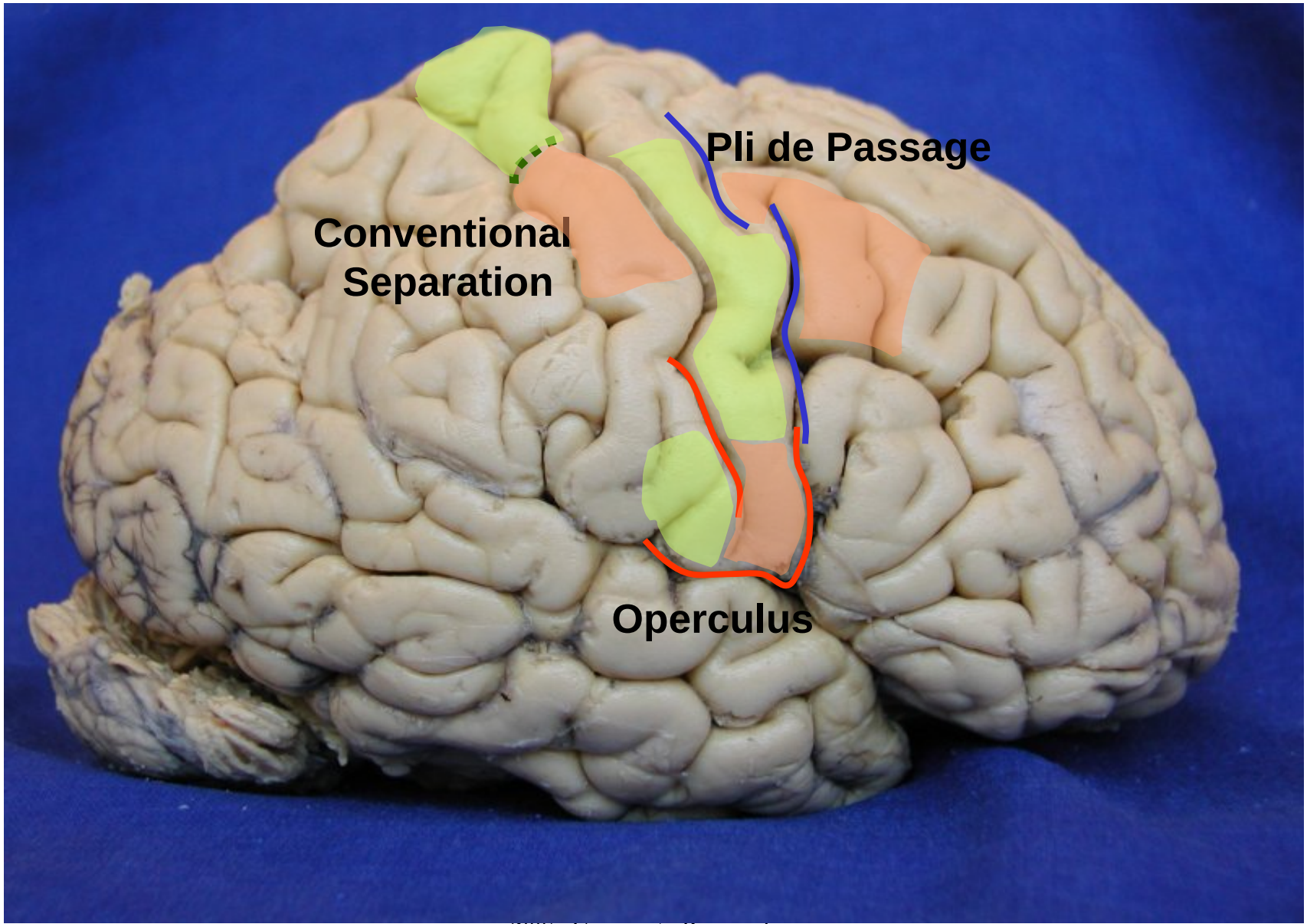


Pars

- bounded by sulcus segments

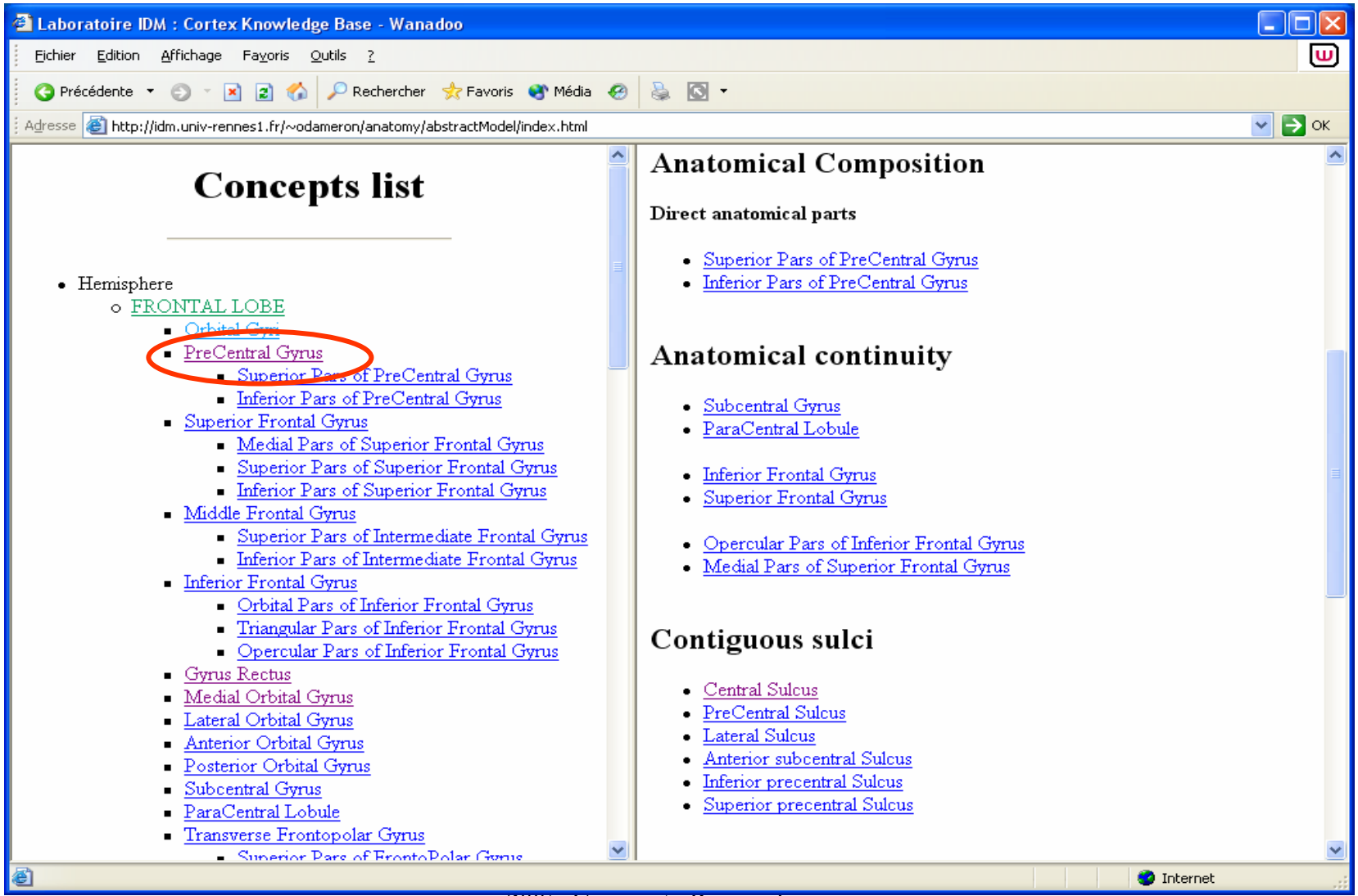


Connections

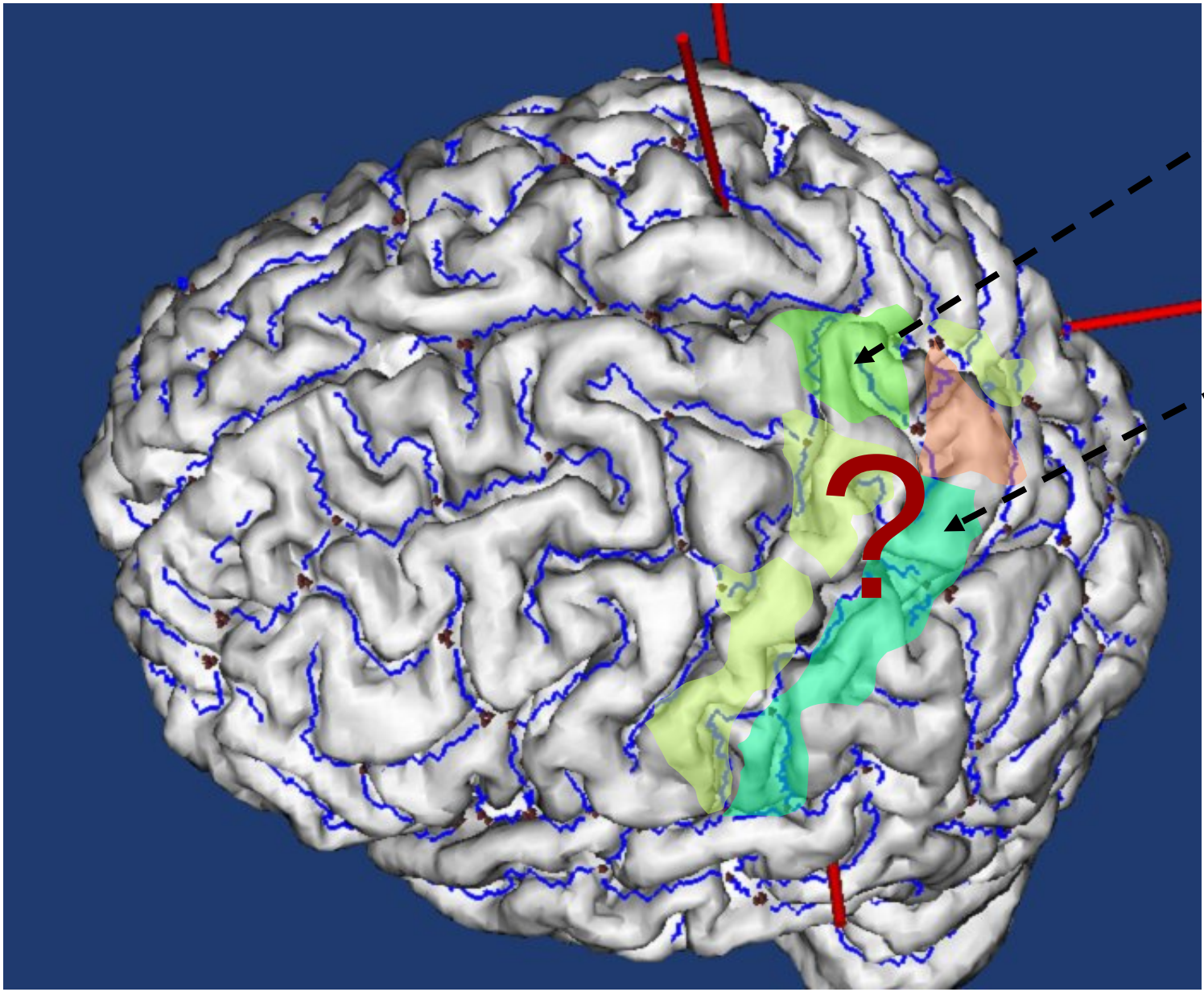


Brain Anatomy 0ntology

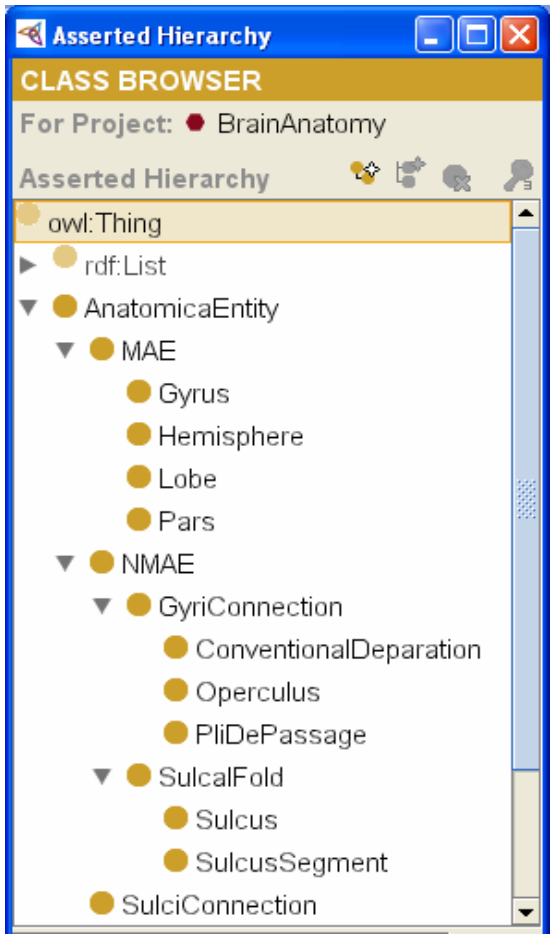
- http://idm.univ-rennes1.fr/~odameron/anatomy/abstractModel/index.html

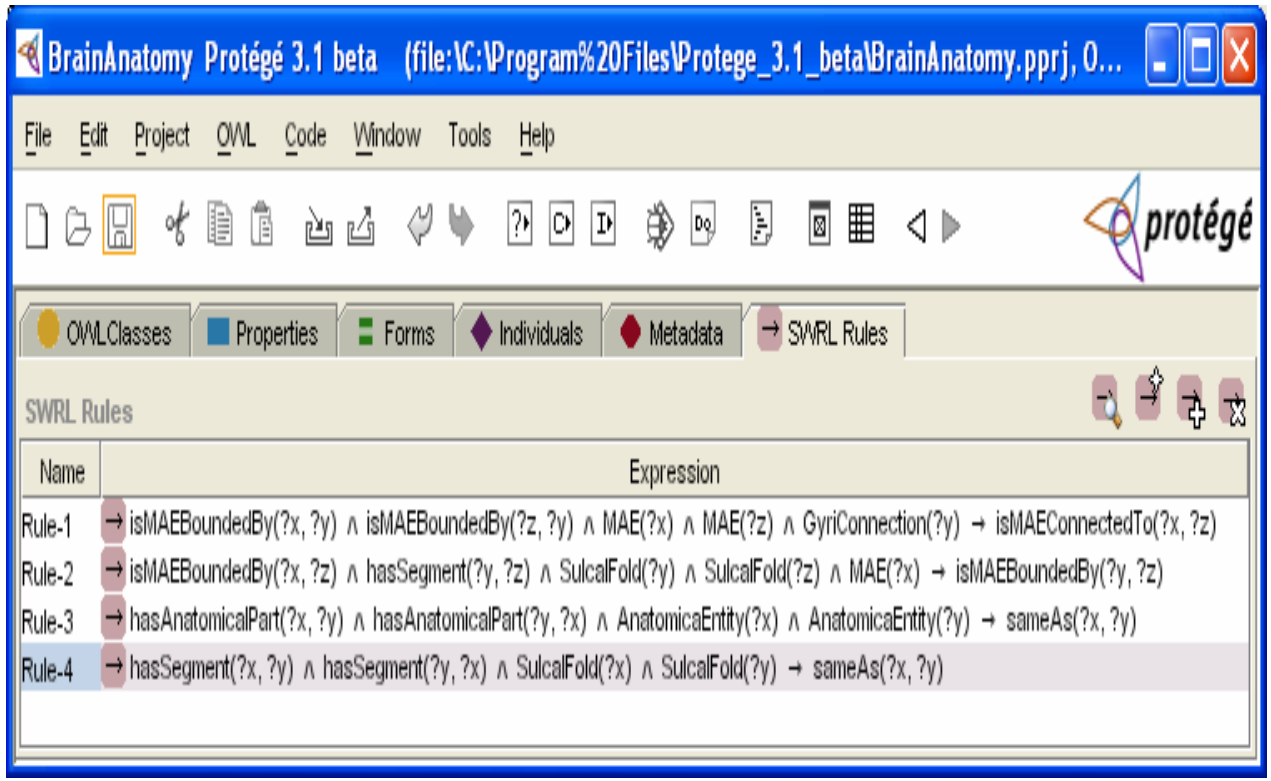


Labeling the gyri and sulci in MRI images



INTEROPERATING BETWEEN ONTOLOGY and RULES





Rule Base

- Dependencies between properties
  - Ontology properties
    - Mereological
    - Spatial
    - Mereological and spatial
  - Ontology and other domain properties
- Queries

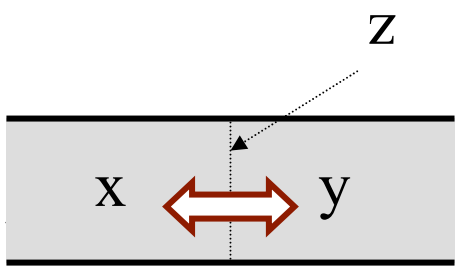
Topological dependency

- If two entities have a common boundary, they are connected

isConnectedTo(?x,?y) ←

isBoundedBy(?x,?z)

Λ isBoundedBy(?y,?z)



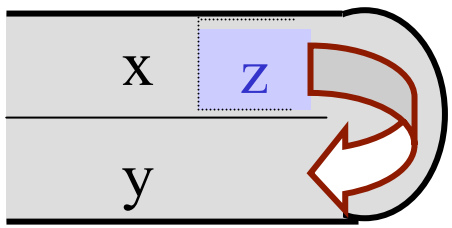
Propagation of connection along part-of

- If a part of a gyrus is connected to another gyrus, the two gyri are connected

isConnectedTo(?x,?y) ←

hasPart(?x,?z)

Λ isConnectedTo(?z,?y)

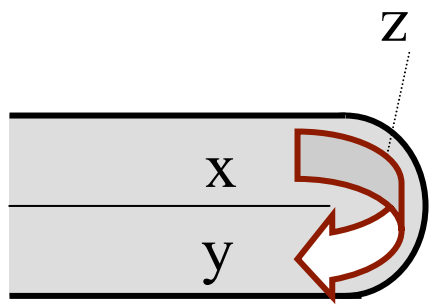


Other domain properties

- if there is a connection relation between entities, they are connected

isConnectedTo(?x,?y) ←

connectsMAE(?z,?x,?y)



Query

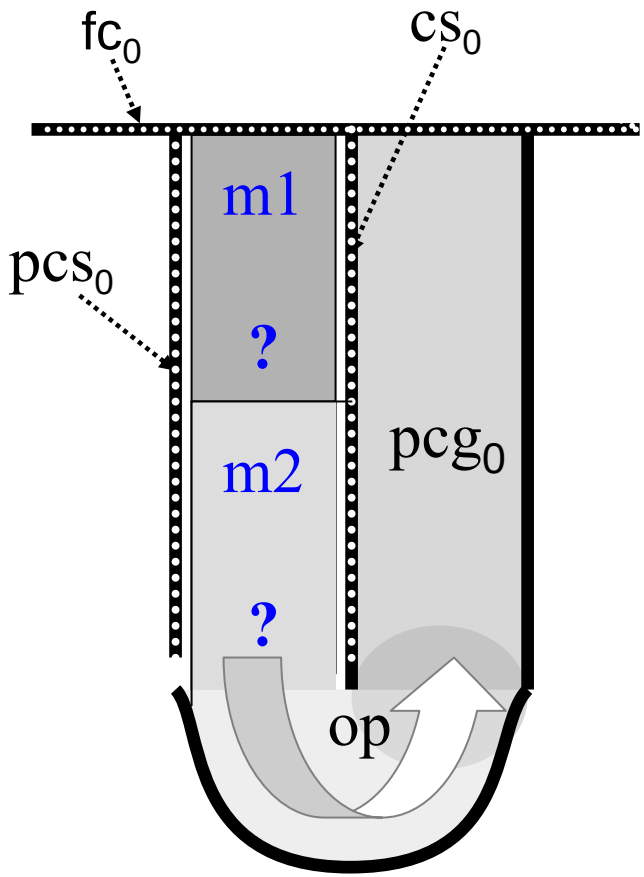
- For given items $\mathbf{m_i}$ of a region under study, find all the possible instances of anatomical entities $\mathbf{?x_i}$ they are part of ?

$$\mathbf{Q\ (?x_1, \ldots, ?x_n\ ) :- \bigwedge_{i=1,n} AE(?x_i) \wedge hasPart(?x_i, m_i)}$$

- **Answering queries with ontology and rules**

Very simple example

- Current facts
  - **boundedBy(m1,fc_0)**
  - **boundedBy(m1,cs_0)**
  - **boundedBy(m1,pcs_0)**
  - **connects(op,m2,pcg_0)**
  - **falxCerebri(fc_0)**
  - **centralSulcus(cs_0)**
  - **preCentralSulcus(pcs_0)**
  - **AE(op)**



- Query

$Q(?x_1)$:- AE $(?x_1) \wedge$ hasPart $(?x_1, m_1) \wedge$ hasPart $(?x_1, m2)$

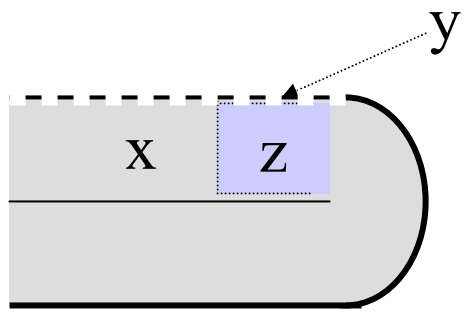
all the possible instances of AE which **m_1** and **m_2** can be part of ?

(1) Rules

isBoundedBy(?x,?y) R1 ←

hasPart(?x,?z)

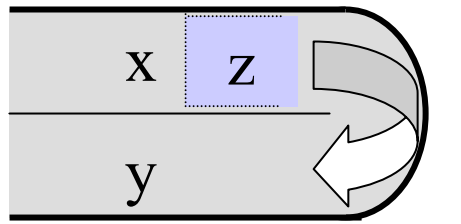
Λ **isBoundedBy(?z,?y)**



isConnectedTo(?x,?y) R2 ←

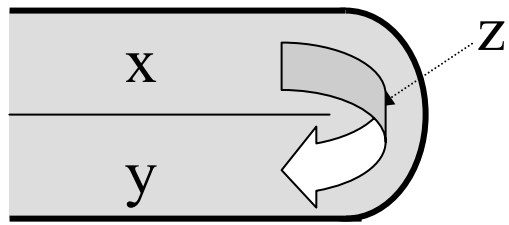
hasPart(?x,?z)

Λ **isConnectedTo(?z,?y)**



isConnectedTo(?x,?y) R3 ←

connects(?z,?x,?y)



Rules reasoning

(1)

isBoundedBy(g_0,cs_0) R1 ←

hasPart(g_0,m1)

Λ **isBoundedBy(m1,cs_0)** ← facts

… … …

isConnectedTo(m2, pcg_0) R2 ←

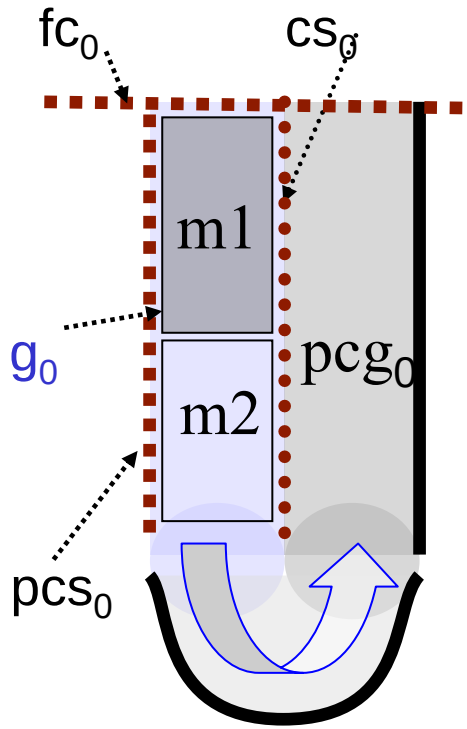
connects(op,m2,pcg_0) ← facts

(4)

isConnectedTo(g_0, pcg_0) R3 ←

hasPart(g_0,m2)

Λ **isConnectedTo(m2, pcg_0)**

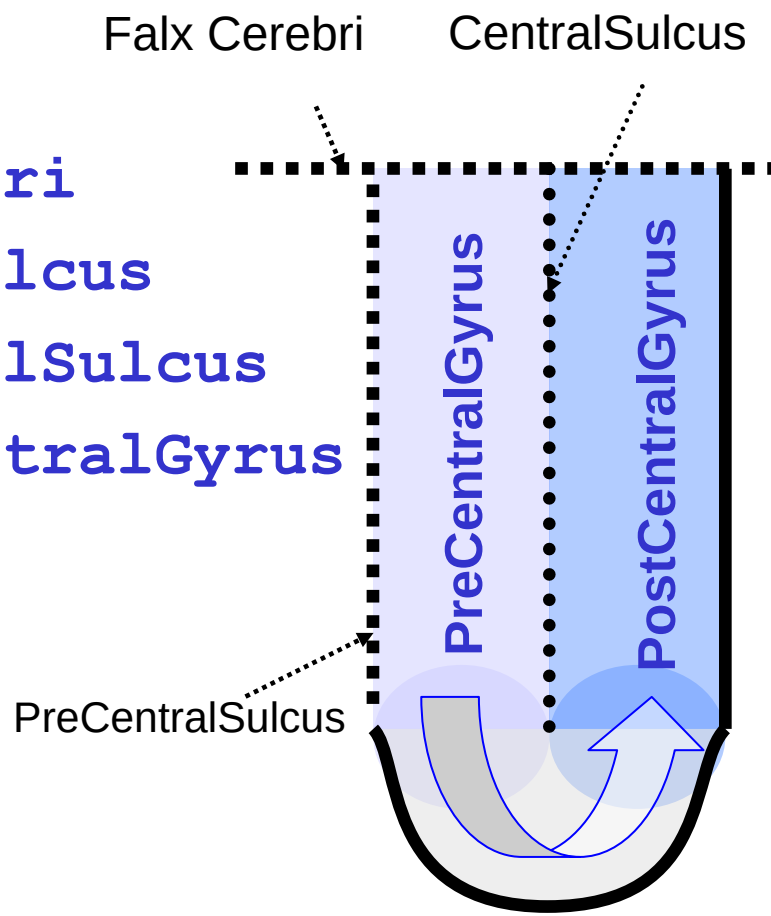


(2) Ontology

PreCentralGyrus ≡

- **Gyrus**
- **=1 isBoundedBy FalxCerebri**
- **=1 isBoundedBy CentralSulcus**
- **=1 isBoundedBy PreCentralSulcus**
- **=1 isConnectedTo PostCentralGyrus**

etc.



Ontology reasoning

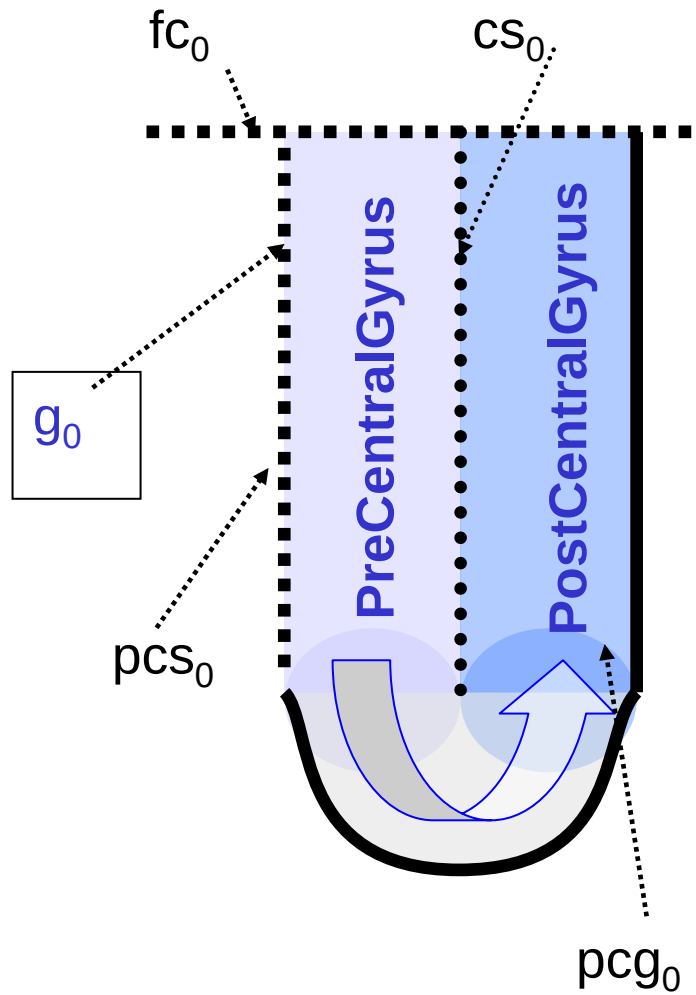
(1) **isBoundedBy(g_0, cs_0)**

(2) **isBoundedBy(g_0, fc_0)**

(3) **isBoundedBy(g_0, pcs_0)**

(4) **isConnectedTo(g_0, pcg_0)**

$\Rightarrow$ g_0 instance of PreCentralGyrus



Test Case

- Annexes
  - Ontology
  - Other domain relations
  - Rules

"Sharable" rule base

Rule 9: isMAEContiguousTo(m1,m2) ← separatesMAE(s,m1,m2) Λ MAE(m1) Λ MAE(m2) Λ SF(s)

/Propagation of MAE boundary (i.e. a first sulcal fold) to a second sulcal fold containing the first/
Rule 10: isMAEBoundedBy(m,s) ← isMAEBoundedBy(m,ss) Λ hasSegment(s,ss) Λ SF(s) Λ SF(ss) Λ MAE(m)

/Propagation of MAE boundary (with a first material entity) to a second material entity containing the first, only if the boundary is not contained in the second material entity/
Rule 11: isMAEBoundedBy(m,s) ← isMAEBoundedBy(sm,s) Λ hasAnatomicalPart(m,sm)
Λ isNotContainedIn(s,m)
Λ (SF(s) V gyriConnection(s)) Λ MAE(sm) Λ MAE(m)

/Propagation of contiguity to parts/
Rule 12: isMAEContiguousTo(m1,sm2) ← isMAEContiguousTo(m1,m2) Λ hasAnatomicalPart(m2,sm2)
Λ isMAEBoundedBy(m1,s) Λ isMAEBoundedBy(m2,s) Λ isMAEBoundedBy(sm2,s)
Λ MAE(m1) Λ MAE(m2) Λ MAE(sm2) Λ SF(s)

/Propagation of contiguity (to a first material entity) to a second material entity containing the first/
Rule 13: isMAEContiguousTo(m1,m2) ← isMAEContiguousTo(m1,sm2) Λ hasAnatomicalPart(m2,sm2)
Λ hasNoCommonParts(m1,m2)
Λ MAE(m1) Λ MAE(m2) Λ MAE(sm2)

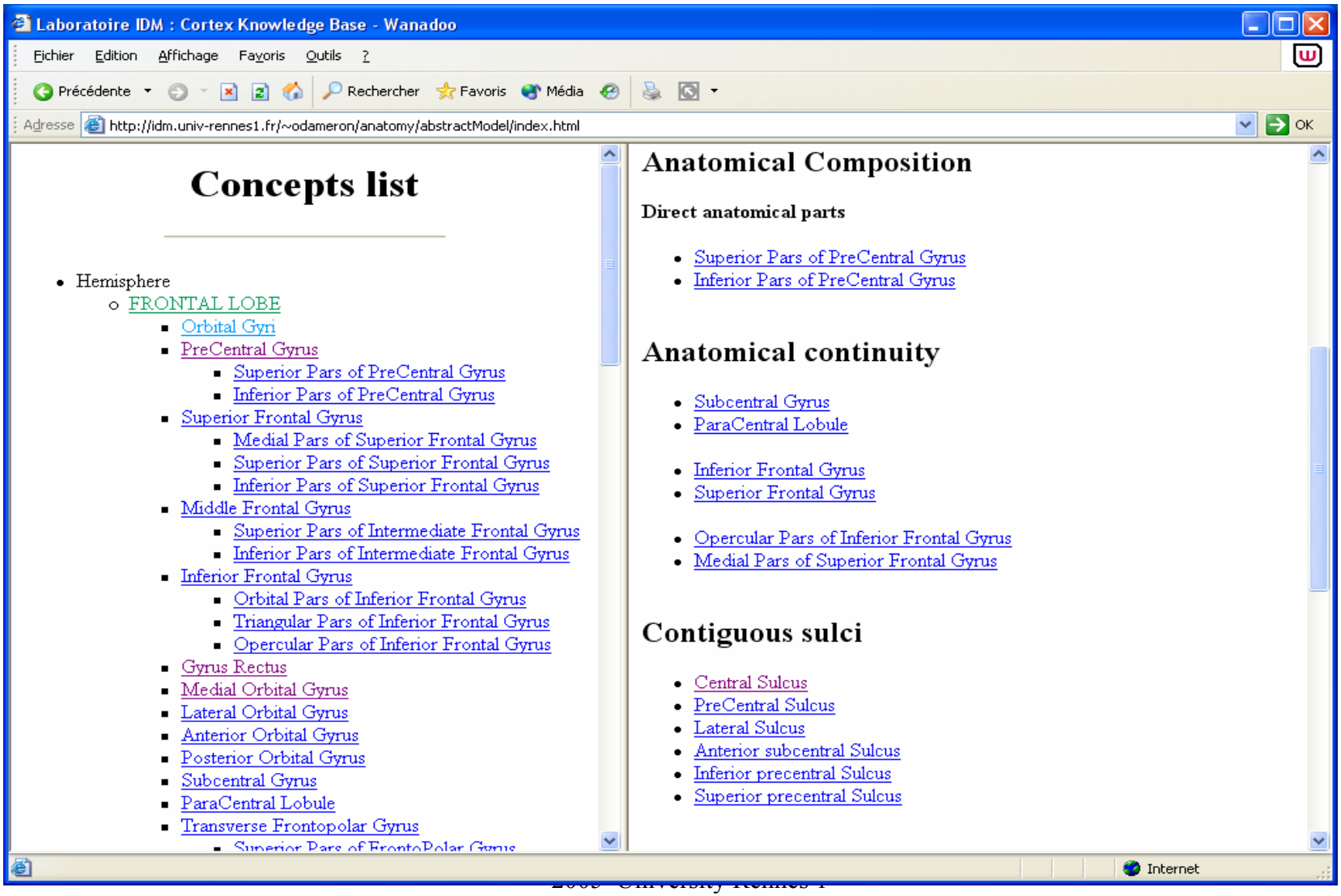
/Propagation of MAE separation to parts/
Rule 14: separatesMAE(s,m1,sm2) ← separatesMAE(s,m1,m2) Λ hasAnatomicalPart(m2,sm2) Λ isMAEBoundedBy(sm2,s)
Λ SF(s) Λ MAE(m1) Λ MAE(m2) Λ MAE(sm2)

/Propagation of MAE separation (of a first material entity) to a second material entity containing the first/
Rule 15: separatesMAE(s,m1,m2) ← separatesMAE(s,m1,sm2) Λ hasAnatomicalPart(m2,sm2)
Λ hasNoCommonParts(m1,m2)
Λ SF(s) Λ MAE(m1) Λ MAE(m2) Λ MAE(sm2)

/Propagation of MAE separation (i.e. a first sulcal fold) to a second sulcal fold containing the first/

Full Brain cortex anatomy ontology

http://idm.univ- rennes1.fr/~odameron/anatomy/abstractModel/index.html



Potential requirements

- Ontology Web language
  1. OWL DL expressiveness (or sublanguage)
  2. Extended by qualified cardinalty constraints
- Rule Web language
  3. ontology concepts and roles in rule body and head as unary or binary predicates in atoms.
  4. “ordinary” domain relations, not ontology concept nor role, in body and head atoms.
  5. n-ary predicates in body and head atoms
  6. queries expressed by n-ary predicates
  7. “safe” rules, i.e. a variable that occurs in the head also occurs in the body

Candidate technologies

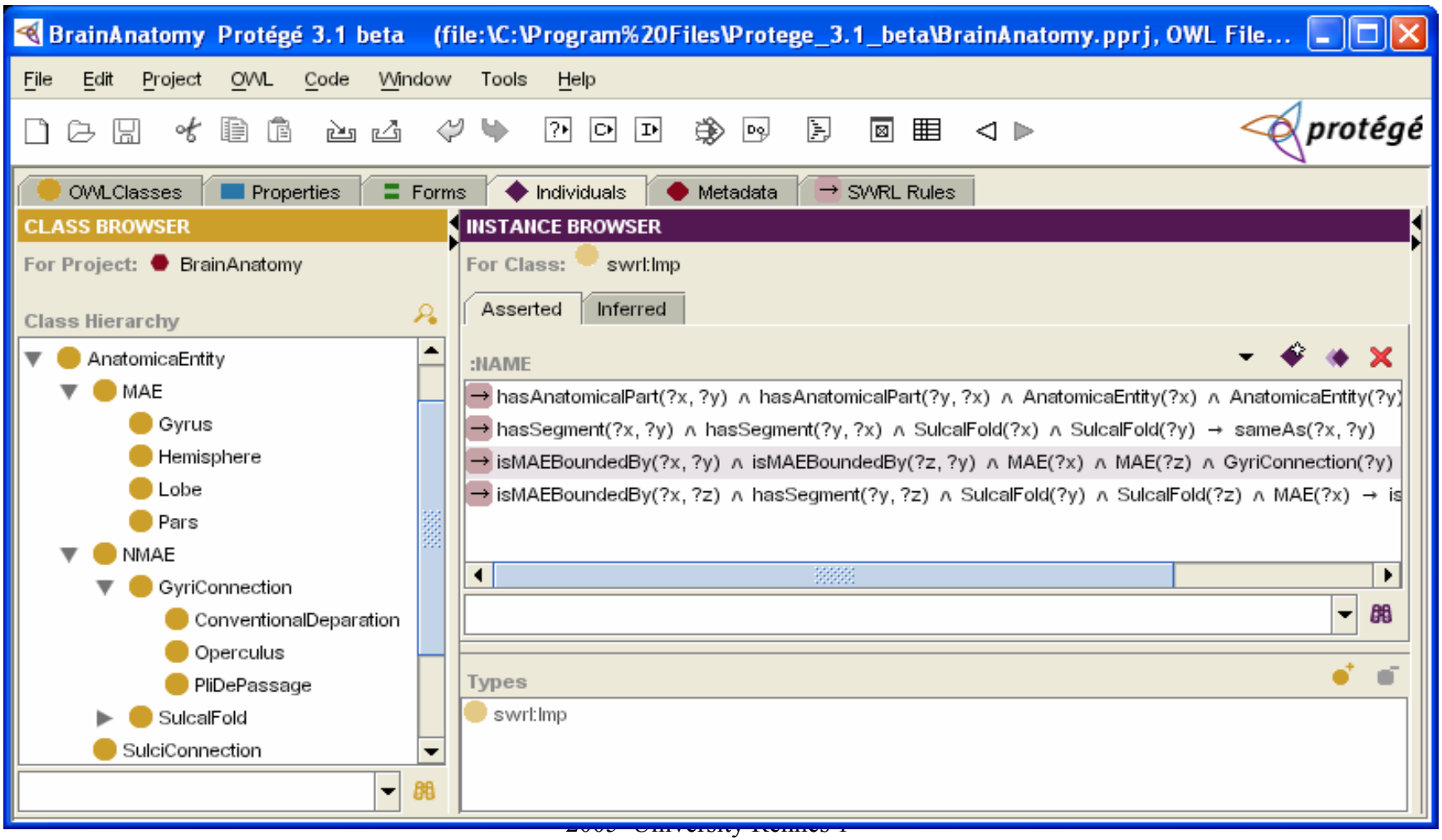
Any language extending OWL DL with rules

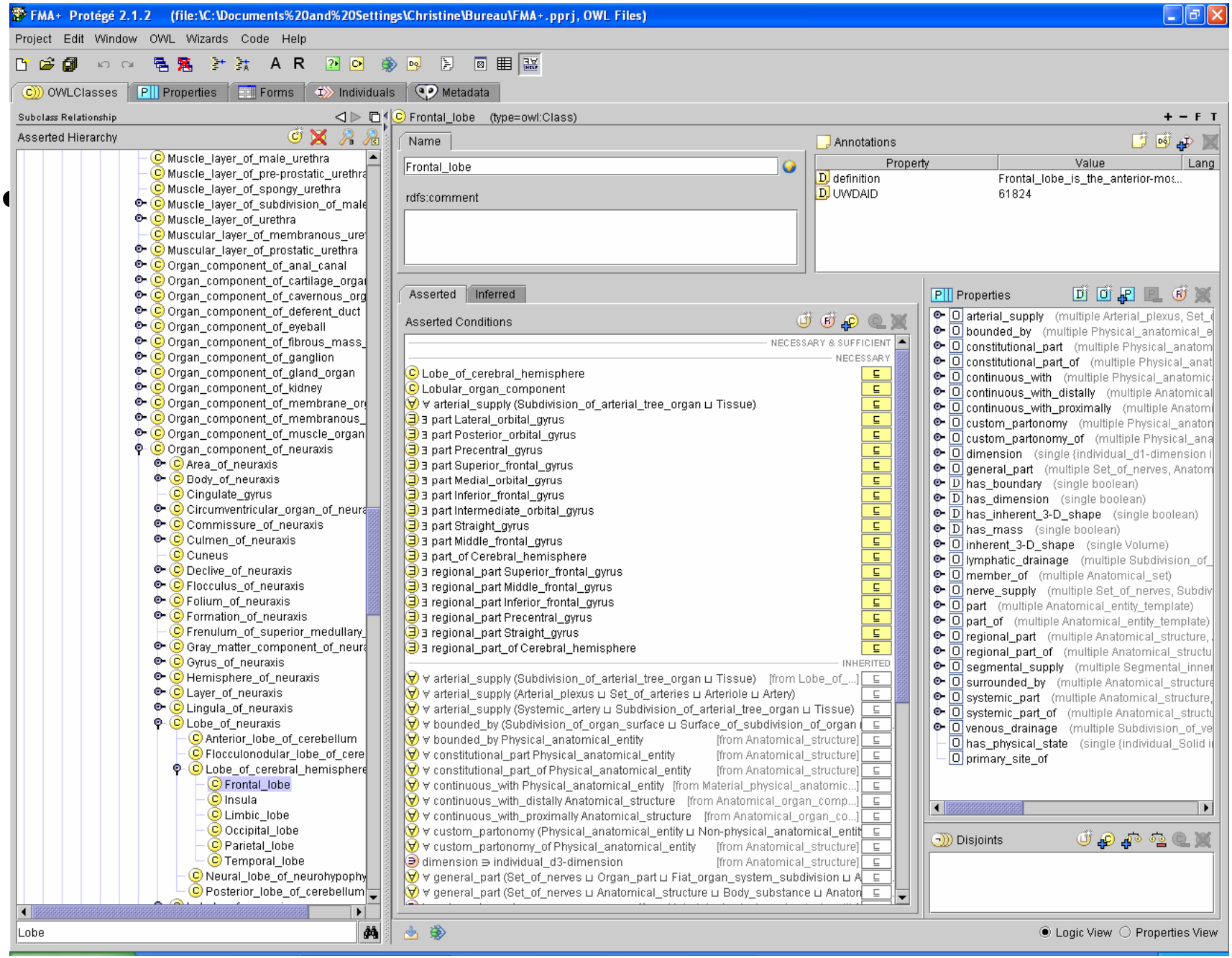
1. To represent all the knowledge described in the ontology and rule annexes, as naturally as possible
2. To **interoperate between rules and ontology** for reasoning
3. To indicate properties (decidability, completeness, correctness) that are guaranteed

Workshop Protégé With Rules, July 18th, Madrid

- *In conjunction with the 8th International Protégé Conference*
- *Supported by the RuleML Initiative*

www.med.univ-rennes1.fr/~cgolb/Protege2005/ProtegeWithRulesCFP.htm




FMA+ Protégé 2.1.2 (file:\C:\Documents%20and%20Settings\Christine\Bureau\FMA+.pprj, OWL Files)
Project Edit Window OWL Wizards Code Help
OWLClasses Properties Forms Individuals Metadata
Subclass Relationship
Asserted Hierarchy
Muscle_layer_of_male_urethra
Muscle_layer_of_pre-prostatic_urethra
Muscle_layer_of_spongy_urethra
Muscle_layer_of_subdivision_of_male
Muscle_layer_of_urethra
Muscular_layer_of_membranous_ure
Muscular_layer_of_prostatic_urethra
Organ_component_of_anal_canal
Organ_component_of_cartilage_orga
Organ_component_of_cavernous_org
Organ_component_of_deferent_duct
Organ_component_of_eyeball
Organ_component_of_fibrous_mass_
Organ_component_of_ganglion
Organ_component_of_gland_organ
Organ_component_of_kidney
Organ_component_of_membrane_or
Organ_component_of_membranous_
Organ_component_of_muscle_organ
Organ_component_of_neuraxis
Area_of_neuraxis
Body_of_neuraxis
Cingulate_gyrus
Circumventricular_organ_of_neura
Commissure_of_neuraxis
Culmen_of_neuraxis
Cuneus
Declive_of_neuraxis
Flocculus_of_neuraxis
Folium_of_neuraxis
Formation_of_neuraxis
Frenulum_of_superior_medullary_
Gray_matter_component_of_neura
Gyrus_of_neuraxis
Hemisphere_of_neuraxis
Layer_of_neuraxis
Lingula_of_neuraxis
Lobe_of_neuraxis
Anterior_lobe_of_cerebellum
Flocculonodular_lobe_of_cere
Lobe_of_cerebral_hemisphere
Frontal_lobe
Insula
Limbic_lobe
Occipital_lobe
Parietal_lobe
Temporal_lobe
Neural_lobe_of_neurohypophy
Posterior_lobe_of_cerebellum
Lobe
Frontal_lobe (type=owl:Class)
Name
Frontal_lobe
rdfs:comment
Annotations
Property
Value
Lang
definition
Frontal_lobe_is_the_anterior-mos...
UWDAID
61824
Asserted
Inferred
Asserted Conditions
NECESSARY & SUFFICIENT
NECESSARY
Lobe_of_cerebral_hemisphere
Lobular_organ_component
∀ arterial_supply (Subdivision_of_arterial_tree_organ ⊔ Tissue)
∃ part Lateral_orbital_gyrus
∃ part Posterior_orbital_gyrus
∃ part Precentral_gyrus
∃ part Superior_frontal_gyrus
∃ part Medial_orbital_gyrus
∃ part Inferior_frontal_gyrus
∃ part Intermediate_orbital_gyrus
∃ part Straight_gyrus
∃ part Middle_frontal_gyrus
∃ part_of Cerebral_hemisphere
∃ regional_part Superior_frontal_gyrus
∃ regional_part Middle_frontal_gyrus
∃ regional_part Inferior_frontal_gyrus
∃ regional_part Precentral_gyrus
∃ regional_part Straight_gyrus
∃ regional_part_of Cerebral_hemisphere
INHERITED
∀ arterial_supply (Subdivision_of_arterial_tree_organ ⊔ Tissue) [from Lobe_of_...]
∀ arterial_supply (Arterial_plexus ⊔ Set_of_arteries ⊔ Arteriole ⊔ Artery)
∀ arterial_supply (Systemic_artery ⊔ Subdivision_of_arterial_tree_organ ⊔ Tissue)
∀ bounded_by (Subdivision_of_organ_surface ⊔ Surface_of_subdivision_of_organ
∀ bounded_by Physical_anatomical_entity [from Anatomical_structure]
∀ constitutional_part Physical_anatomical_entity [from Anatomical_structure]
∀ constitutional_part_of Physical_anatomical_entity [from Anatomical_structure]
∀ continuous_with Physical_anatomical_entity [from Material_physical_anatomic...]
∀ continuous_with_distally Anatomical_structure [from Anatomical_organ_comp...]
∀ continuous_with_proximally Anatomical_structure [from Anatomical_organ_co...]
∀ custom_partonomy (Physical_anatomical_entity ⊔ Non-physical_anatomical_entit
∀ custom_partonomy_of Physical_anatomical_entity [from Anatomical_structure]
dimension ∋ individual_d3-dimension [from Anatomical_structure]
∀ general_part (Set_of_nerves ⊔ Organ_part ⊔ Fiat_organ_system_subdivision ⊔ A
∀ general_part (Set_of_nerves ⊔ Anatomical_structure ⊔ Body_substance ⊔ Anaton
Properties
arterial_supply (multiple Arterial_plexus, Set_(
bounded_by (multiple Physical_anatomical_e
constitutional_part (multiple Physical_anatom
constitutional_part_of (multiple Physical_anat
continuous_with (multiple Physical_anatomic
continuous_with_distally (multiple Anatomical
continuous_with_proximally (multiple Anatomi
custom_partonomy (multiple Physical_anaton
custom_partonomy_of (multiple Physical_ana
dimension (single {individual_d1-dimension i
general_part (multiple Set_of_nerves, Anatom
has_boundary (single boolean)
has_dimension (single boolean)
has_inherent_3-D_shape (single boolean)
has_mass (single boolean)
inherent_3-D_shape (single Volume)
lymphatic_drainage (multiple Subdivision_of_
member_of (multiple Anatomical_set)
nerve_supply (multiple Set_of_nerves, Subdiv
part (multiple Anatomical_entity_template)
part_of (multiple Anatomical_entity_template)
regional_part (multiple Anatomical_structure,
regional_part_of (multiple Anatomical_structu
segmental_supply (multiple Segmental_inner
surrounded_by (multiple Anatomical_structure
systemic_part (multiple Anatomical_structure,
systemic_part_of (multiple Anatomical_structu
venous_drainage (multiple Subdivision_of_ve
has_physical_state (single {individual_Solid i
primary_site_of
Disjoints
Logic View
Properties View