# Enabling RadLex with the Foundational Model of Anatomy Ontology to Organize and Integrate Neuro-imaging Data

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## Abstract

*In this study we empowered RadLex with a robust ontological framework and additional neuroanatomical content derived from a reference ontology, the Foundational Model of Anatomy Ontology (FMA)[1], with the intent of providing RadLex the facility to correlate the different standards used in annotating neuro-radiological image data. It is the objective of this work to promote data sharing, data harmonization and interoperability between disparate neuro-radiological labeling systems.*

## Introduction

Huge amounts of neuro-imaging data are being produced by different groups and they are recorded using disparate parcellation schemes and naming conventions, thereby resulting in incompatible terms that make correlation of data difficult to achieve. Current neuro-imaging terminologies lack the semantic framework to explicitly declare the precise meanings of the terms and therefore data and information represented by the terms cannot be readily associated and applied across different studies. RadLex[2] (Radiology Lexicon from RSNA) is a controlled terminology for radiology that seeks to provide the semantics for correlating the diverse terminologies used for annotating neuro-imaging data. In this work we leveraged the FMA to re-structure and reinforce the anatomical domain of RadLex so that it can incorporate, accommodate and correlate the different annotation terminologies.

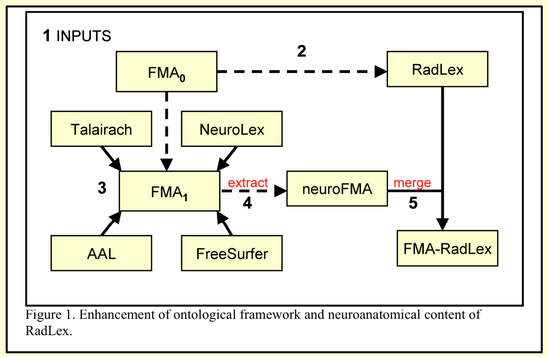


Figure 1. Enhancement of ontological framework and neuroanatomical content of RadLex.

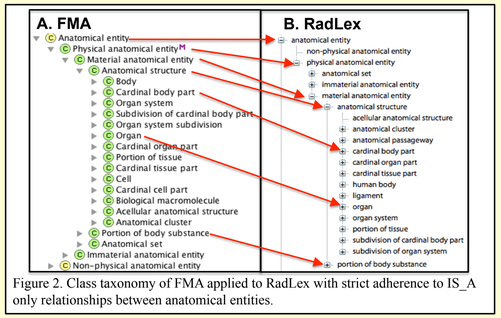


Figure 2. Class taxonomy of FMA applied to RadLex with strict adherence to IS_A only relationships between anatomical entities.

## Materials and Methods

Enabling the neuroanatomy ontology of RadLex involved five major steps (shown in Figure 1):

**1.Select** FMA, RadLex, Talairach Daemon Atlas[3], FreeSurfer atlas[4], Anatomical Automatic Labeling atlas (AAL)[5] and NeuroLex[6] as inputs to the system;

**2.Apply high level class taxonomy** of the FMA to re-organize the anatomy axis of RadLex[7];

**3.Enhance** the neuroanatomy content of the FMA to include the intended semantics of the different terminologies for annotating neuroimaging data;

**4.Extract** the enhanced neuroanatomy component of the FMA, the NeuroFMA, as an ontology "view" for incorporation into RadLex;

**5.Merge** the extracted NeuroFMA with the ontologically re-organized RadLex .

## Results

***Enhancement of Anatomy Taxonomy of RadLex***. Adoption of the ontological framework of the FMA assures a consistent Aristotelian-type inheritance taxonomy for RadLex (Figure 2). The derived ontology provides explicit semantics for RadLex terms .

***Enhancement of Neuroanatomy content of FMA***. Classes and spatio-structural relations were added in the FMA to accommodate and represent the entities referenced by the different annotation terminologies (Figures 3 and 4). Explicit ontological representation therefore allowed for the correlation of the different terms by using FMA properties such as IS_A and PART_OF (Figure 5).

***Extraction of neuroanatomical "view", NeuroFMA, for incoporation into RadLex.*** View extraction is performed via a procedural program that is written in JAVA, utilizing the Protégé ontology API. Rather than creating a view by starting from an empty ontology and then adding classes, the process starts with a complete copy of the FMA and then eliminates everything not required in the NeuroFMA (Figure 6).

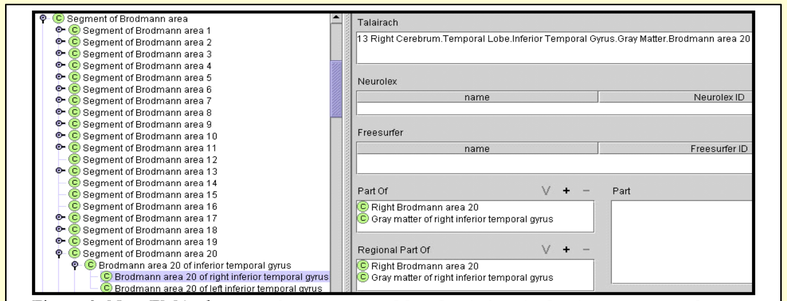


Figure 3. New FMA class `Brodmann area 20 of right inferior temporal gyrus` has been entered to accommodate the Talairach term.

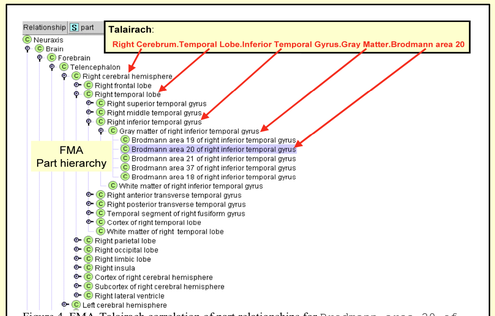


Figure 4. FMA-Talairach correlation of part relationships for `Brodmann area 20 of right inferior temporal gyrus`.

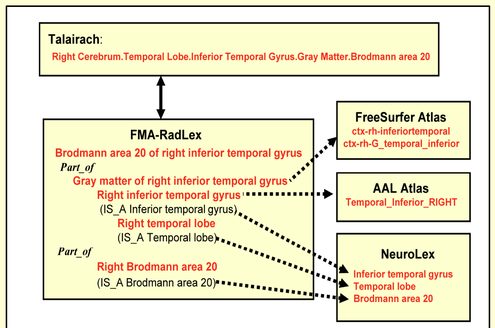


Figure 5. Correlation of neuroanatomical entities referenced by different terminologies.

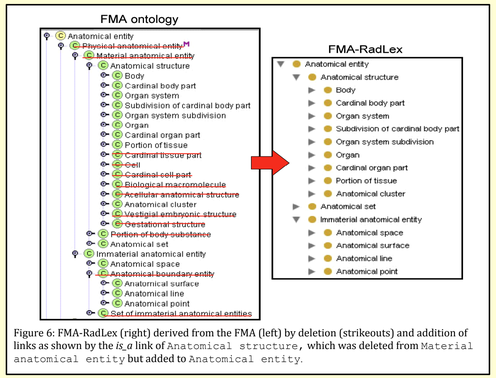


Figure 6: FMA-RadLex (right) derived from the FMA (left) by deletion (strikeouts) and addition of links as shown by the *is_a* link of `Anatomical structure`, which was deleted from `Material anatomical entity` but added to `Anatomical entity`.

***Merging of NeuroFMA into RadLex.*** Technical details for this step are beyond the scope of this presentation. However we found that we could coalesce classes from the two ontologies in RadLex. The merging produced "FMA-like" structure to RadLex. A total of 12,579 classes and 33,361 property values were imported into RadLex from the NeuroFMA. It would have been very difficult and time-consuming to implement these changes manually.

## Conclusion

We have shown how the ontological framework of the FMA explicitly defined the entities represented by the different parcellation and naming schemes and by doing so it becomes possible to ascertain the relationships which correlate these terms, a prerequisite step for sharing and harmonizing data. We have started using the ontology to annotate fMRI datasets and derive inferences about relationships between the datasets[8].

### Acknowledgment

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### References

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