Challenges in Reconciling Different Views of Neuroanatomy in a Reference Ontology of Anatomy

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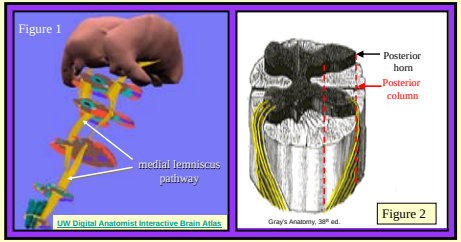
ABSTRACT

A fundamental requirement for integrating different neuroscientific data is a well-structured ontology that can incorporate, accommodate and reconcile different neuroanatomical views. It is a prerequisite for the integration of neuroscientific information across multiple scales and formats. Here we describe the challenges in creating such an ontology, and, illustrate how the Foundational Model of Anatomy (FMA) can be that ontology.

INTRODUCTION

The need to integrate the vast amount of neuroscientific data through neuroanatomical as well as general anatomical ontologies is well recognized[1]. However, most such application ontologies lack the principled structure needed to reconcile the plurality of views of neuroanatomy. We have previously shown[2] that the *Foundational Model of Anatomy* (FMA) *Ontology*[3] possesses the semantic framework for incorporating terms from NeuroNames (NN) and Terminologia Anatomica (TA), which are two of the most widely used terminologies. In the process of incorporating these terminologies we have identified a number of challenges that must be addressed in order to create a reference ontology that can reconcile and align different views.



PROBLEMS

1) Ontological inconsistencies.

A. Lack of explicit definition.

Gray matter, which consists predominantly of cell parts (*somas*), not cells, cannot be regarded as *tissue* if tissue is defined as a collection of cells. The same is true for the recognized functional pathways or tracts which consist only of *neurites* [Figure 1].

B. Ambiguous treatment of immaterial entities.

- *Fourth ventricle* is regarded as a 3-D space and yet it is given parts that are 3-D objects like *choroid plexus* and *ependyma*.
- Depending on operational needs, *sulcus* is represented as 1-D line in one application and a 3-D space in another. The same is true for *gyrus* which is a 2-D surface in one use and a 3-D object in another.

C. Misrepresentation of anatomical set.

The *basal ganglia* is implicitly represented as a single unit when in fact it is a *set of nuclei*.

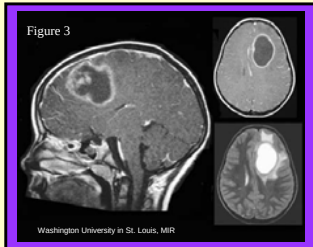
D. Incomplete and misleading descriptions.

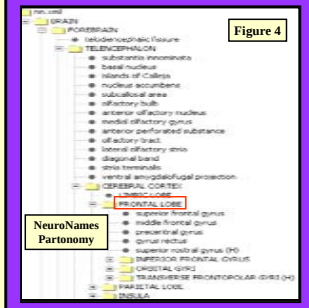
- *Posterior spinocerebellar tract* is not an exclusive part of the *medulla*. It extends from *L2* or *L3 segment of the spinal cord* to the *medulla* and the *vermis of cerebellum*. Therefore it has *spinal*, *medullary* and *cerebellar* segments.
- "Horn" is the shape of spinal gray matter that is based on 2-D sections but in 3-D it is a "column" [Figure 2].

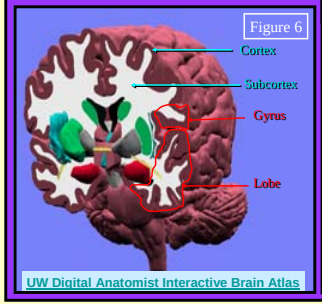
2) Representing multiple levels of granularity. Some terminologies primarily target cells, and others macroscopic entities; none, however, span the spectrum of granularity levels in the nervous system.

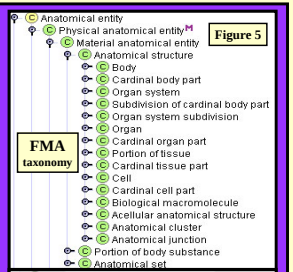
3) Reconciliation of diverse contexts. Different disciplines of neuroscience represent and define neuroanatomical entities in accord with the needs of specific applications:

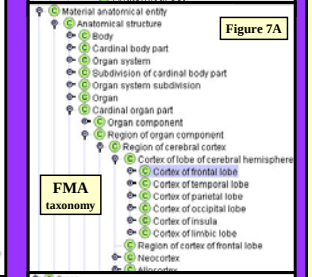
- neurosurgeons and neuroradiologists consider the *frontal lobe* to include both the *cortex* and the underlying *cerebral white matter* [Figure 3 which shows a *glioblastoma*], while neuroscientists limit their functional view of a *lobe* to the *cortex* [Figure 4].
- clinically, "dorsal column" is used to mean the *dorsal funiculus* (white matter), while anatomically the "dorsal column" is used to mean the *dorsal horn* (grey matter).

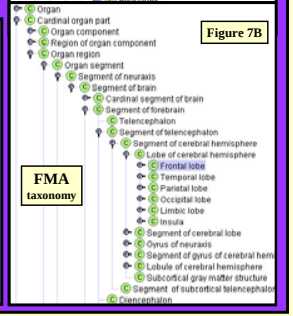












SOLUTIONS

The FMA is a disciplined approach rooted in the top-level nodes of the ***Basic Formal Ontology***[4] and based on a set of guiding principles. It provides a framework that has the facility to resolve many of the issues presented:

1) **Ontological inconsistencies** are addressed by using formal definitions of high level types to assure proper taxonomic type assignment. For example, in the FMA `Gray matter` and `white matter` are assigned not as type `Tissue`, but as type `Cell part cluster`.

2) **Granularity** is automatically addressed since the FMA taxonomy already encompasses objects from macromolecules to gross structures [Figure 5].

3) **Reconciling disparate and diverse contexts** remains a difficult challenge, but explicit representations of the types of neuroanatomical entities and their structural relationships within each context can help. As one example based on the FMA partition of the brain as illustrated in Figure 6, we created the type `Cortex of frontal lobe` [Figure 7A] to accommodate the NeuroNames view and reserve the name `Frontal lobe` [Figure 7B] for the volumetric structure used by clinicians. We are currently working to apply these principles on a larger scale.

ACKNOWLEDGMENT

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