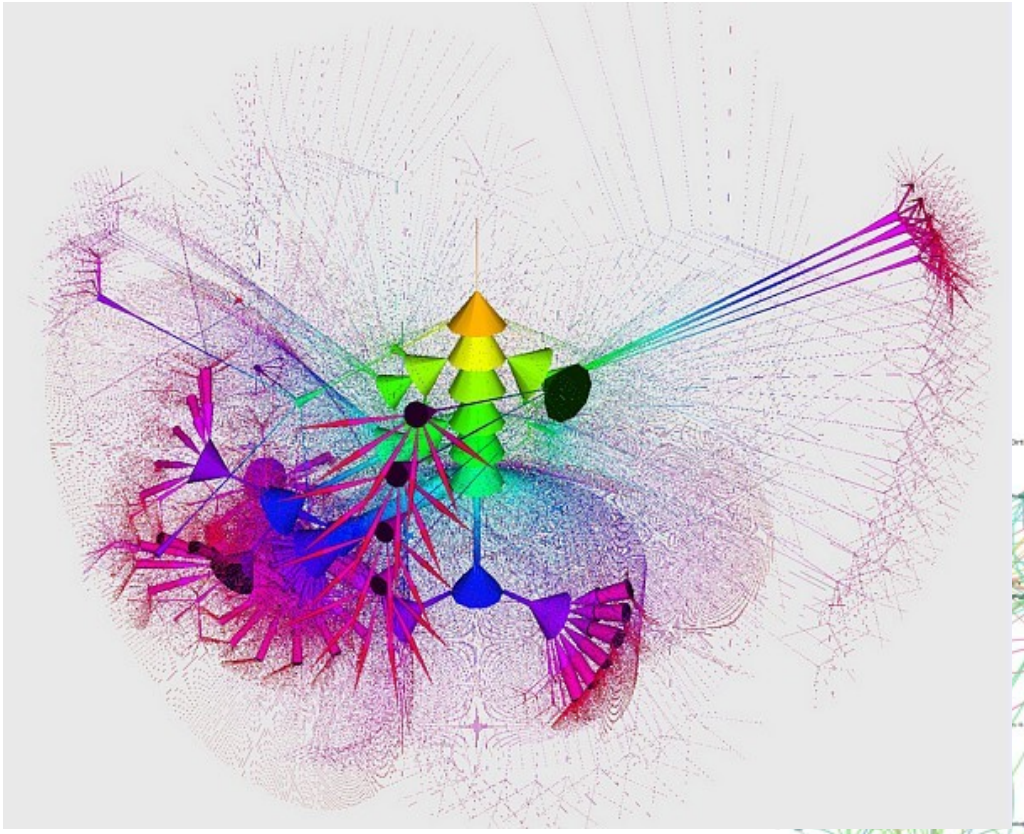
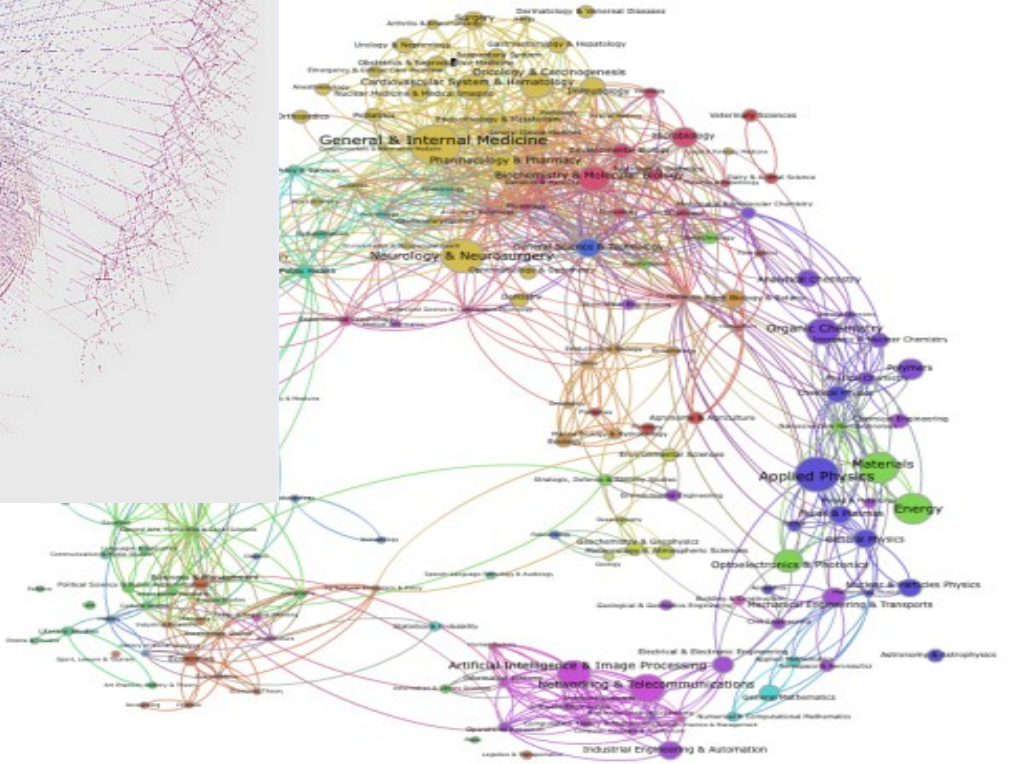
« Shall we

build ontologies regarding neuroscience facts

or are human sentences sufficient ? »





From knowledge to data : towards a formal representation of computational neuroscience known facts.

Models studied in computational neuroscience are fed up with facts obtained from the large literature reporting knowledge obtained from biological experimentation. Such knowledge is put in words, leading to phenomenological descriptions of the underlying behaviors. Then, a part of this information is put in equations and in distributed algorithms to check some quantitative or qualitative aspects of the presumed global understanding. Surprisingly enough, this work is mainly realized like by craftsmen, and more or less by intuition.

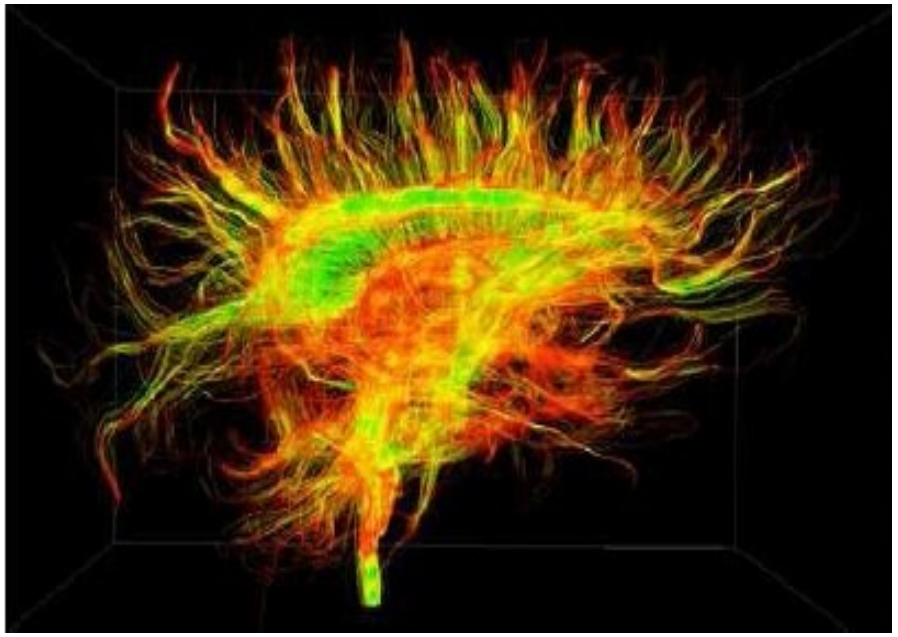
Other domains of knowledge have taken into account recent and powerful developments regarding semantic representations and introduce an intermediate framework between knowledge-in-words and knowledge-in-equations: knowledge-in-facts. From very large and heterogeneous corpus like Wikipedia turned in DBpedia semantic data base, to very specialized fields of knowledge formalized as ontologies, it is clear that powerful methodological tools are now available to manage the data at a higher scale, beyond what "one" brain can handle manually, allowing to take larger corpus into account, but also to apply more rigorous methods on such semantic data.

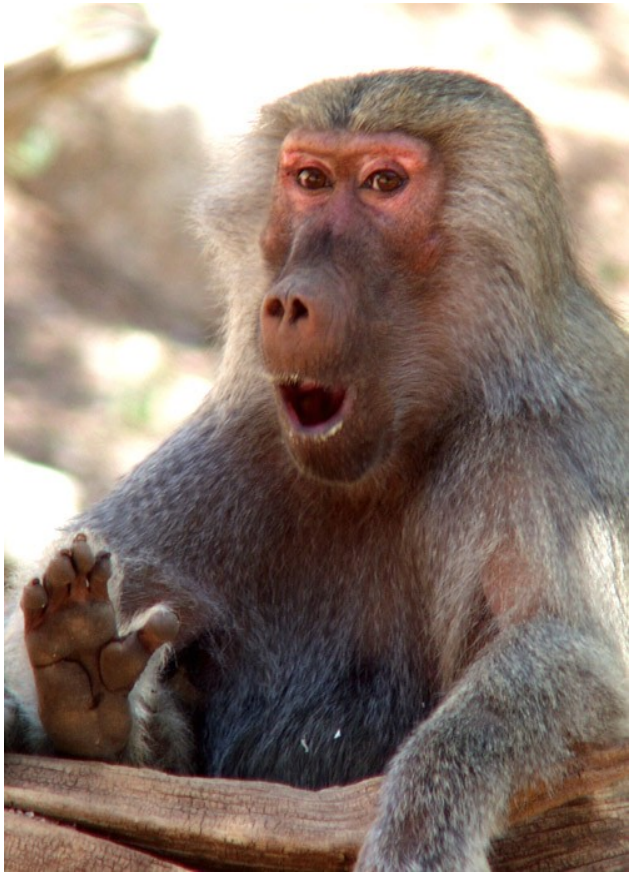
https://team.inria.fr/mnemosyne

Mnemosyme is modeling ``biological intelligence´´

Computational Neuroscience
Cognition
Memory
Mnemosyne
Brain & Body
Complex systems

Using a systemic approach.





thierry.vieville@inria.fr

Modeling comp. Neuro. with ontologies ?

- ✔ ***Let us start***
  - ✔ ***Looking at WikiPedia***
  - ✔ ***Annotating a PDF paper***

- ✔ ***Let us see***
  - ✔ ***What's already there***
  - ✔ ***What's missing here***

- ✔ ***So what & what for ?***

- ✔ ***On-to-lo-g… what ?***
  - ✔ *Data as a graph*
  - ✔ *Facts as triplets*
  - ✔ *Logic as objects*

- ✔ *A “turtoise” langage*

Let us start looking at http://en.wikipedia.org/wiki/Striatum

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia

Interaction
Help
About Wikipedia
Community portal
Recent changes

Striatum

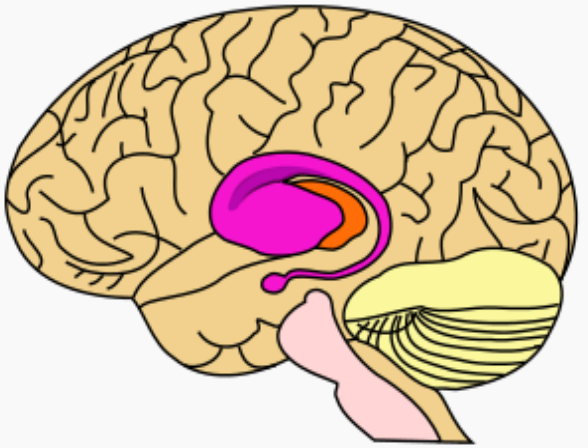
From Wikipedia, the free encyclopedia

"Neostriatum" redirects here. For the avian brain region formerly called the neostriatum, see nidopallium.

The **striatum**, also known as the **neostriatum** or **striate nucleus**, is a subcortical (i.e., inside, rather than on the outside) part of the forebrain. It is the major input station of the basal ganglia system. The striatum, in turn, gets input from the cerebral cortex. In primates (including humans), the striatum is divided by a white matter tract called the internal capsule into two sectors called the caudate nucleus and putamen. The term **corpus striatum** occasionally refers to the striatum combined with the globus pallidus, a structure closely related to the putamen, and the lenticular nucleus refers to the putamen together with the globus pallidus.[1]

Functionally, the striatum helps coordinate motivation with body movement. It facilitates and balances motivation with both higher-level and lower-level functions, such as inhibiting one's behavior in a complex social interaction and fine-motor functions of inhibiting small voluntary movement.[2]

Brain: Striatum



purple=caudate and putamen, orange=thalamus

At the bottom

V · T · E Human brain, cerebrum, Interior of the cerebral hemispheres—Rostral Basal ganglia and associated structures (TA A14.1.09.321-552, GA 9.832-837) [show]

V · T · E Brain and spinal cord: neural tracts and fasciculi [show]

V · T · E Anxiety disorder: Obsessive-compulsive disorder (F42, 300.3) [show]

Categories: Cerebrum | Basal ganglia

Let us start looking at http://en.wikipedia.org/wiki/Striatum

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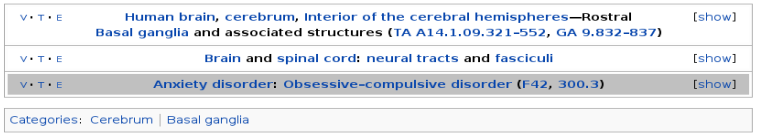

v · t · e	Human brain, cerebrum, Interior of the cerebral hemispheres—Rostral Basal ganglia and associated structures (TA A14.1.09.321-552, GA 9.832-837)		[hide]
Basal ganglia	Grey matter	Corpus striatum	***striatum***: Putamen · Caudate nucleus
			lentiform nucleus: Putamen
			Globus pallidus (GPe · GPi)
		Ventral striatum	Nucleus accumbens · Olfactory tubercle · Islands of Calleja
		Other	Amygdala · Claustrum
	White matter		Semioval center
			Internal capsule (Anterior limb
			Genu · Posterior limb · Optic radiation)
			Corona radiata
			External capsule · Extreme capsule
			Pallidothalamic tracts: Thalamic fasciculus (Ansa lenticularis
			Lenticular fasciculus) · Subthalamic fasciculus
Rhinencephalon	Grey matter		Anterior olfactory nucleus · Anterior perforated substance · Olfactory bulb
	White matter		Olfactory tract (Medial olfactory stria · Lateral olfactory stria) · Olfactory trigone
Other basal forebrain	Grey matter		Substantia innominata (Basal optic nucleus of Meynert) · Nucleus of diagonal band
	White matter		Diagonal band of Broca · Stria terminalis
Archicortex: Hippocampal formation/ Hippocampus anatomy	Grey matter		Hippocampus proper: CA1 · CA2 · CA3 · CA4
			Dentate gyrus: Fascia dentata
			Subiculum
	White matter		Alveus · Fimbria · Perforant path · Schaffer collateral

M: CNS	anat (n/s/m/p/4/e/b/d/c/a/f/l/g)/phys/devp	noco (m/d/e/h/v/s)/cong/tumr, sysi/epon, injr	proc, drug (N1A/2AB/C/3/4/7A/B/C/D)

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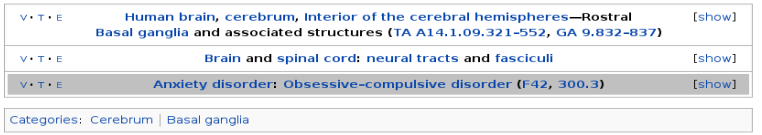

Sensory/ ascending	**PCML**		1°: Pacinian corpuscle/Meissner's corpuscle → Gracile fasciculus/Cuneate fasciculus → Gracile nucleus/Cuneate nucleus 2°: → *sensory decussation*/*arcuate fibers* (Posterior external arcuate fibers, Internal arcuate fibers) → Medial lemniscus/Trigeminal lemniscus → Thalamus (VPL, VPM) 3°: → Posterior limb of internal capsule → Postcentral gyrus
	Anterolateral/ pain	**Fast/lateral**	1° (Free nerve ending → A delta fiber) → 2° (Anterior white commissure → **Lateral and Anterior Spinothalamic tract** → Spinal lemniscus → VPL of Thalamus) → 3° (Postcentral gyrus) → 4° (Posterior parietal cortex) 2° (**Spinotectal tract** → Superior colliculus of Midbrain tectum)
		Slow/medial	1° (Group C nerve fiber → **Spinoreticular tract** → Reticular formation) → 2° (MD of Thalamus) → 3° (Cingulate cortex)
Motor/ descending	**Pyramidal**		*flexion:* Primary motor cortex → Posterior limb of internal capsule → Decussation of pyramids → **Corticospinal tract (Lateral, Anterior)** → Neuromuscular junction
	Extrapyramidal		*flexion:* Primary motor cortex → Genu of internal capsule → **Corticobulbar tract** → Facial motor nucleus → Facial muscles *flexion:* Red nucleus → **Rubrospinal tract** *extension:* Vestibulocerebellum → Vestibular nuclei → **Vestibulospinal tract** *extension:* Vestibulocerebellum → Reticular formation → **Reticulospinal tract** Midbrain tectum → **Tectospinal tract** → muscles of neck
	Basal ganglia		*direct:* 1° (Motor cortex → **Striatum**) → 2° (GPi) → 3° (Lenticular fasciculus/Ansa lenticularis → Thalamic fasciculus → VL of Thalamus) → 4° (Thalamocortical radiations → Supplementary motor area) → 5° (Motor cortex) *indirect:* 1° (Motor cortex → **Striatum**) → 2° (GPe) → 3° (Subthalamic fasciculus → Subthalamic nucleus) → 4° (Subthalamic fasciculus → GPi) → 5° (Lenticular fasciculus/Ansa lenticularis → Thalamic fasciculus → VL of Thalamus) → 6° (Thalamocortical radiations → Supplementary motor area) → 7° (Motor cortex) *nigrostriatal pathway*: Pars compacta → **Striatum**
Cerebellar	**Afferent**		Vestibular nucleus → **Vestibulocerebellar tract** → ICP → Cerebellum → Granule cell Pontine nuclei → **Pontocerebellar fibers** → MCP → Deep cerebellar nuclei → Granule cell Inferior olivary nucleus → **Olivocerebellar tract** → ICP → Hemisphere → Purkinje cell → Deep cerebellar nuclei
	Efferent		Dentate nucleus in Lateral hemisphere/pontocerebellum → SCP → **Dentatothalamic tract** → Thalamus (VL) → Motor cortex Interposed nucleus in Intermediate hemisphere/spinocerebellum → SCP → Reticular formation, or → **Cerebellothalamic tract** → Red nucleus → Thalamus (VL) → Motor cortex Fastigial nucleus in Flocculonodular lobe/vestibulocerebellum → **Vestibulocerebellar tract** → Vestibular nucleus
	Bidirectional: Spinocerebellar	**Unc. prop.**	lower limb → 1° (muscle spindles → DRG) → 2° (Posterior thoracic nucleus → **Dorsal/posterior spinocerebellar tract** → ICP → Cerebellar vermis) upper limb → 1° (muscle spindles → DRG) → 2° (Accessory cuneate nucleus → **Cuneocerebellar tract** → ICP → Anterior lobe of cerebellum)
		Reflex arc	lower limb → 1° (Golgi tendon organ) → 2° (**Ventral/anterior spinocerebellar tract**→ SCP → Cerebellar vermis)

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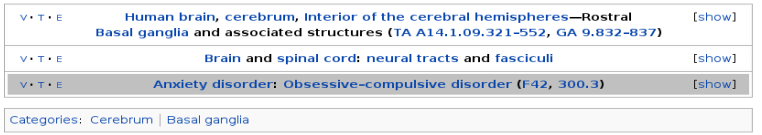

- **This is no more *knowledge* but *data*.**
- **This is no more for *human* but *algorithms*.**

- ***Words are defined :***
  - ***By an identifier***
  - ***As instance of classes (e.g. a brain-structure)***
  - ***In relations to other words (e.g. connected to)***
  - ***Though properties with values (e.g. a numeric value)***

- ***Not all knowledge is reduced to data***
  - ***But almost all well-defined anatomical facts : yes !***

Let us try annoting a PDF paper .

"Ganglion cells are output neurons of the retina, integrating visual information through a network of specific cells (amacrine, bipolar, horizontal). Their axons, corresponding to the optic nerve, carry the information outside the retina, without reciprocal connection (no feedback).
In the human eye, there are about 125 millions of photoreceptors (including more than 100 millions rods) and 1.5 millions of ganglion cells (GC), but the connectivity is uneven: some GC receive from less than 10 photoreceptors, others from thousands. More precisely, there are four kinds of ganglion cells: midget GC (80% of the GC) towards the parvocells in the thalamus; parasol GC (10% of the GC) towards the magnocells in the tha-

@RDF{
retinal-cell has-sub-class photo-receptor , horizontal-cell , bipolar-cell , amacrine-cell , ganglion-cell.
photo-receptor has-sub-class rod , cone.
visual-field human:horizontal-value 160deg.
visual-field human:vertical-value 135deg.
fovea-field human:value 3deg.
fovea human:same-as macula.
rod human:count 100e6.
rod light-sensitivity low.
rod color-sensitivity none.
rod foveal-density negligible.
cones human:count 25e6.
cones light-sensitivity high.
cones color-sensitivity high.
cones foveal-density high.
ganglion-cell has-sub-class midget-ganglion-cell parasol-ganglion-cell bistratified-ganglion-cell photosensitive-ganglion-cell.
midget-ganglion-cell human:count 1.2e6.
parasol-ganglion-cell human:count 1e5.
bistratified-ganglion-cell human:count 1e5.
photosensitive-ganglion-cell human:count low.
midget-ganglion-cell is-a parvocellular-cell.
midget-ganglion-cell projects-onto thalamus-LGN.
parasol-ganglion-cell is-a magnocellular-cell.
parasol-ganglion-cell projects-onto thalamus-LGN.
bistratified-ganglion-cell projects-onto thalamus-LGN.
bistratified-ganglion-cell projects-onto superior-colliculus.
photosensitive-ganglion-cell projects-onto suprachiasmatic-nucleus..

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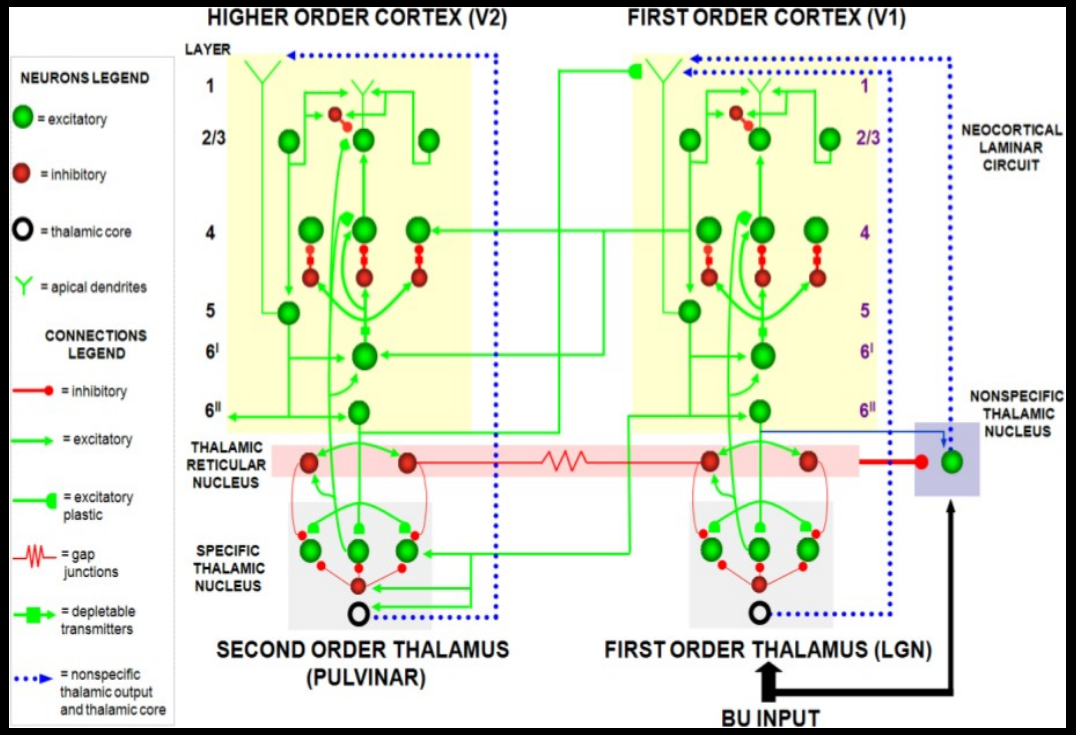
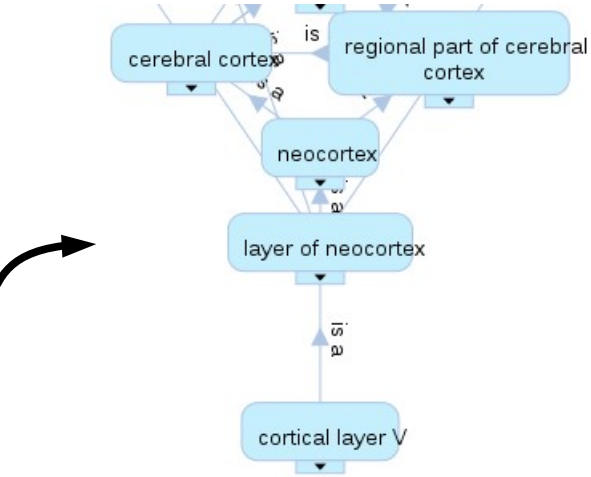
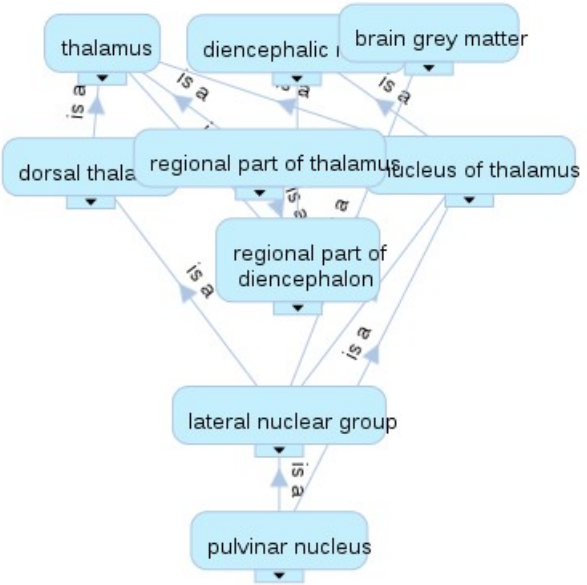
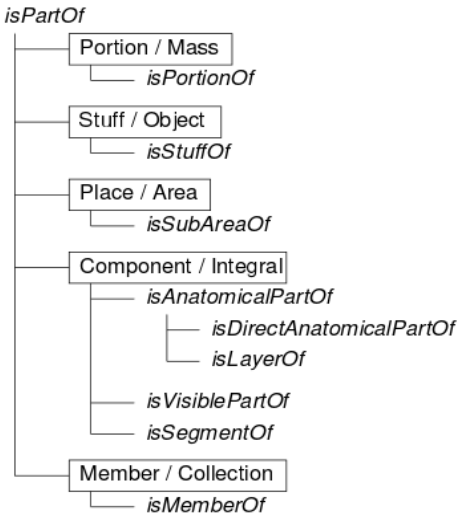








Let us try annoting a PDF paper .

- **This is no more *sentences* but *facts*.**

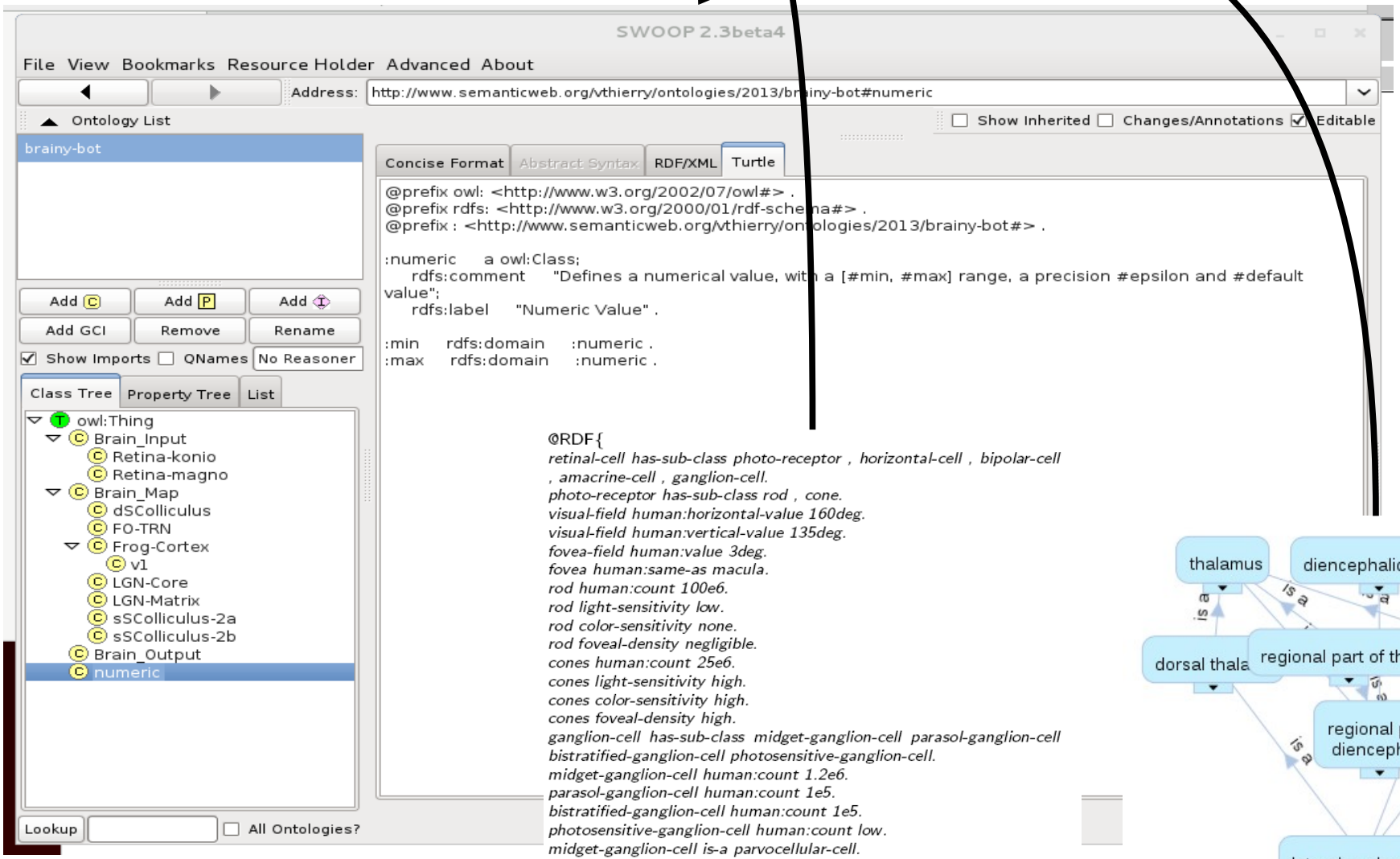
  ~~Syntax~~ → a.k.o. Semantic

- **Clearly this must be**
  a human task, not an meaningless algorithm.

  - **Which information is pertinent ?**
  - **How should the data be structured ?**
  - **What is the implicit information here ?**
    - **e.g. which contextual information to add ?**
  - **What about knowledge put in graphics ?**

Let us try annoting a PDF paper .

Using an ontology editor to manage/design the collected semantic data



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rod color-sensitivity none.
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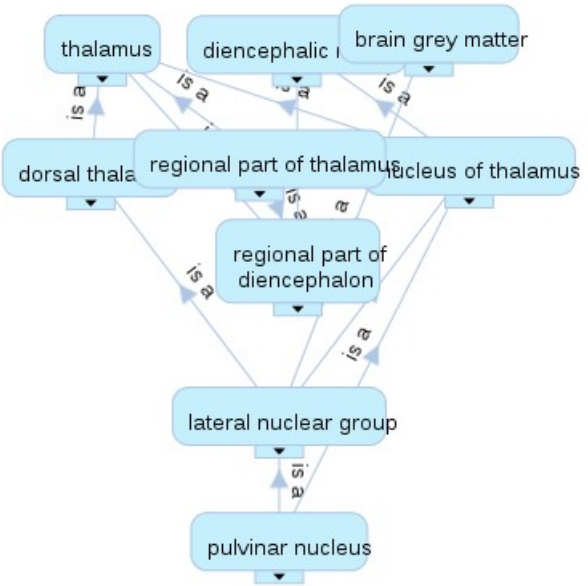

What for ?

- ✔ ***Specify vocabulary and known facts*** **:**
  (qualitative data + quantitative values).

- ✔ ***Fix facts*** **: not only "talk about" them, including**
  - ✔ **Contradictory** (either-or assumption)
  - ✔ **Fuzzy** (fuzzy value, irreductible verbal info)
  - ✔ **Unknown** (wildcard value or fact)

- ✔ ***Data/Facts inference/representation***

- ✔ ***Code parameterization***

Graphical representation.

Automatic code input generation.

What for ?

Explicit the link between facts and model.

- ✔ ***Data inference/representation***
  - ✔ *Offers new views on the collected knowledge,*
  - ✔ *Allows modeling at the “conceptual” level,*
  - ✔ *Checks biological statement coherence/consequence,*
  - ✔ *Generate well-defined falsifiable assumptions.*

- ✔ ***Code parameterization:***
  - ✔ *guaranty the reproducibility of numerical experiments,*
  - ✔ *avoid hidden implementation ad-hoc tricks,*
  - ✔ *change the order of magnitude of the numerical exploration.*

Modeling now reproducible !

Modeling comp. Neuro. with ontologies ?

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  - ✔ *Facts as triplets*
  - ✔ *Logic as objects*

- ✔ *A “turtoise” langage*

What ? The "fact" layer

A semantic description of some knowledge ?
It is a

labeled directed multi-graph,

i.e., a fully distributed set of information atoms.

✔ *Each atom of information is a triplet*

✔ *the subject is the resource to describe,*
✔ *the predicate is the property type of the description,*
✔ *the object is the value of the property.*

Example : The «sky has the color blue» writes : sky color blue.

What ? The "fact" layer

subject verb object

R.D.F.
Resource Description Format

- ✔ *Such a piece of information*
  - ✔ *Defines meta-data over a document.*
  - ✔ *Corresponds to text annotation.*

- ✔ *Each "token" is a*

Uniform International Resource Identifier

- ✔ *while object can also be a value or "literal"*

(i.e., string, numerical value (number, date, …))

Lesson 1.1: tokens.

- ✔ *Each token is a <U|RI>*
  - ✔ *It must have a universal identifier (no ambiguity)*
  - ✔ *It may have a local denomination (usability)*
  - ✔ *It includes international char (e.g.: español, français, …)*

@let evs <http://ncicb.nci.nih.gov/xml/owl/EVS/Thesaurus.owl#>

@let prefix: <http://host/domain/>

yields `prefix:name` ↔ `<http://host/domain/name>`

Which striatum ?

(EVS) Entreprise Vocabulary System

Lesson 1.2: litterals.

- ✔ *Strings are enclosed between double quotes "…",*
  - ✔ while '\"' denotes a double-quote within a string,
  - ✔ and ""…"" encloses multi-line strings.
  - ✔ Have langage tag (e.g., @cl, @fr)

- ✔ *Numerical values have meta-data* with
  - ✔ an explicit *physical-unit*,
  - ✔ bounds : *minimal-value*, *maximal-value*,
  - ✔ a *defaut-value*,
  - ✔ A precison *epsilon-value* (e.g. type)

Contextual value
(e.g., in cat or human)

Only ! Because:

Fuzzy value:
(high|low|negligible|none)

- ✔ *Compounded information is defined by a syntax*
  - ✔ e.g.., a regular-expression,
  - ✔ b*ut* decomposes into atomic triplets

concave response

$$(x;k) \to \log(1+k\,x)/k$$

Lesson 1.3: phrases.

The construct

subject a object

with the verb “a” defines a subject type

✔ Token may have several types

The construct

subject verb_1 object_1 ; verb_2 object_2 .

(i.e. ``subject verb_1 object_1 . subject verb_2 object_2 .``)

defines a property set, i.e. t-uple of information .

The construct

subject verb object_1 , object_2 .

(i.e. ``subject verb_1 object_11 . subject verb_1 object_12 .``)

subject verb (object_1 , object_2) .

defines a set or collection (i.e. sequence) of values.

Lesson 1.4: reusing data.

The construct:

@use <URI>

allows to “import” data:

it states that the given turtoise document
has to be merged to this one
before considering these declarations.

This *document* <URI> is defined via the construct:

@let <> <URI>

What ? The "fact" layer

✔ *A well-founded atomic definition of a re-usable data token.*

✔ *Obvious to read/write from any software.*
✔ *Obvious to "tag" when reading a document.*
✔ *Recognized as a basic standard.*

✔ *Decidable algorithms of knowledge managements*
  ✔ *derive from "graph methods".*

✔ *A menagerie of tools to manipulate the data*
  ✔ *editing, data-basing functions, querying, re-formatting*

✔ *The "Turtle" syntax (here its "Turtoise" dialect) allows you, human, to efficiently read/write that.*

What ? The "logic" layer

- ✔ *A class lattice :*
  - ✔ *A class defines a concept, i.e. a category of individuals.*
  - ✔ *Classes combine with operators.*

- ✔ *A property lattice :*
  - ✔ *States relationships between individuals of a given class.*
  - ✔ *Relates an instance of a class to another instance.*
  - ✔ *Can have class or littreral as object.*

- ✔ *Individuals.*

- ✔ *Ontologies are set of class + property*
  - ✔ *They organise into "stores"*

- ✔ *Queries allow to*
  - ✔ *Retrieve initial data*
  - ✔ *Derived new information*

Is data coherent ?

Is assumption falsifiable ?

... / ...

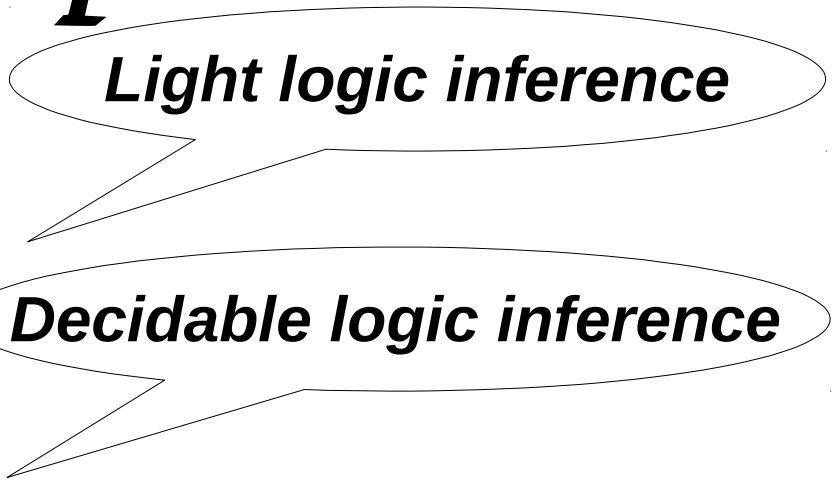
Lesson 2.1: Defining classes.

human a class.
human sc mammalian.

✔ states that human is a class and a sub-class of mammalian.

- ✔ “thing”/”nothing” is the superclass/subclass of all classes
- ✔ classes form a lattice (nocycle, transitivity, …)
- ✔ class names are distinct from others namespaces
- ✔ litteral values are individuals of the `string`, `number` classes

Lesson 2.2: Class operators.



boy and male, kid.
teen or boy, girl.
bad not gentle.

✔ Defines new classes by intersection (conjunction), union (disjunction), complement.

boy ne girl.

✔ States that the two classes have no intersection.

my_brothers are Bod, Carl, David.

✔ Defines a class by enumeration of individual.

Lesson 2.3: Properties.

- ✔ A `property` states relationships between individuals of a given class.
- ✔ It relates an instance of a class to another instance of a class.
- ✔ It is declared using the `a property` verb/object.
- ✔ Properties form a lattice, using the `sp` (`sub-property of`) verb.

- ✔ `**domain**` verb: class to which the property can be applied.
- ✔ `**range**` verb: class that the property may have as value.
- ✔ `**min**` verb: The minimal cardinality (i.e. at least N distinct values).
- ✔ `**max**` verb: The maximal cardinality.
- ✔ `**some**` verb: At least one value must belong to the given class.
- ✔ `a **symmetric**` verb-object: The property is a symmetric.
- ✔ `a **transitive**` verb-object: The property is a transitive.
- ✔ `a **functional**` verb-object: The property has only one value.
- ✔ `a **unambiguous**` verb-object: It defines a unique identifier.
- ✔ `**inverse**` verb: The property is the inverse of another.
- ✔ `**has**` verb: The property has the given value.

Lesson 2.4: Property limits.

- ✔ Property names must be disjoint to other namespaces.
- ✔ Property range can have litteral values.
- ✔ Domain and range can be conjunction/disjunction of classes
- ✔ The `some` verb means
  - ✔ `some-values-from` if the the object is a class and
  - ✔ `has-value` if the object is an individual .

But:

- ✔ The `min` and `max` cardinality constraints are global.

- ✔ For “light logic inference”, no feature:
  - ✔ `has`, `max` for transitive properties, `has-value`
  - ✔ `min` and `max` cardinality beyond `0` or `1`

Lesson 2.5: Individuals.

.

- ✔ Invididuals
  - ✔ Belongs to a class
  - ✔ Have property taking values
  - ✔ Can be set as `eq` or `ne` (equal or different)

- ✔ *What's suprising here ?*

  - ✔ **Typing** (i.e. defining what can be “done” with the individual)
    - ✔ The type is a *property* and may have several value,
    - ✔ The notion of *class* captures the idea of category.

  - ✔ **Property ≠ category** and
  - ✔ It is not “attached” to a class but lives in a lattice,
  - ✔ Has several values and . . domain (unless functional),

What ? The "logic" layer

✔ *Summarizing :*

- ✔ *An "integrated view" of concepts and properties,*
  - ✔ *as modular as object-oriented description*
  - ✔ *with a minimal formalism:*

- ✔ *A simple tool but with universal use.*
  - ✔ *A stratified power of expression up to the 1st order logic,*
  - ✔ *With inference and validation algorithms tuned to the used semantic,*
  - ✔ *With a direct "readable" mapping as a semantic graph.*

Modeling comp. Neuro. with ontologies ?

- ✔ ***Let us start***
  - ✔ ***Looking at WikiPedia***
  - ✔ ***Annotating a PDF paper***

- ✔ ***Let us see***
  - ✔ ***What's already there***
  - ✔ ***What's missing here***

- ✔ ***So what & what for ?***

- ✔ ***On-to-lo-g… what ?***
  - ✔ *Data as a graph*
  - ✔ *Facts as triplets*
  - ✔ *Logic as objects*

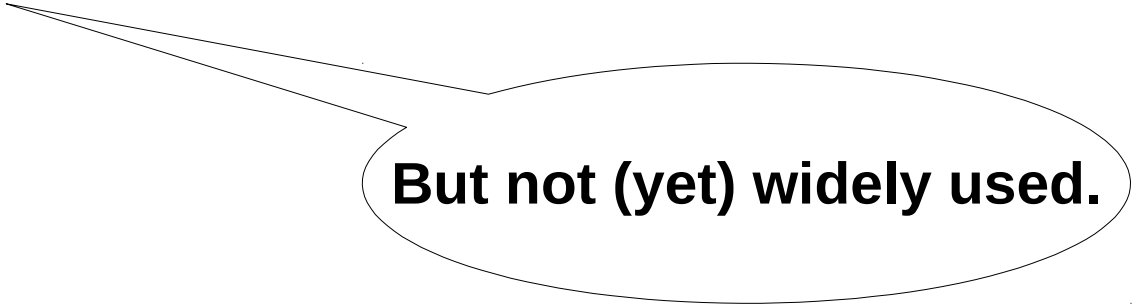
- ✔ *A “turtoise” langage*

What's is already there ?

- **Tagging and Folksonomy of publications**
  - **e.g. http://www.citeulike.org**

- **XML parameterization initiatives**
  - **http://brainml.org**
  - **http://www.neuroml.org**
    - **Used in VirtualRetina or neuralensemble.org**

- **+ standardization of the terminology**
- **+ clarification of specification (model choice, parameters)**
- **+ interoperability between software**



What's is already there ?

- **Wikipedia hierarchical anatomical data**
  - **Regions, Connections, Anatomical data.**

- **The Brain Architecture Management System**
  - **Brain Parts (gray matter regions, major fiber tracts, and ventricles),**
  - **Cell Types, Molecules,**
  - **Connections (between regions and cell types),**
  - **Relations (between parts identified different neuroanatomical atlases).**

- **The bio-ontology portail**
  - **Thesaurus (vocabulary)**
  - **Linked (clinical, physiologicla, …) data**
  - **Query and inter-ontologies connections**

Anatomy and clinical data

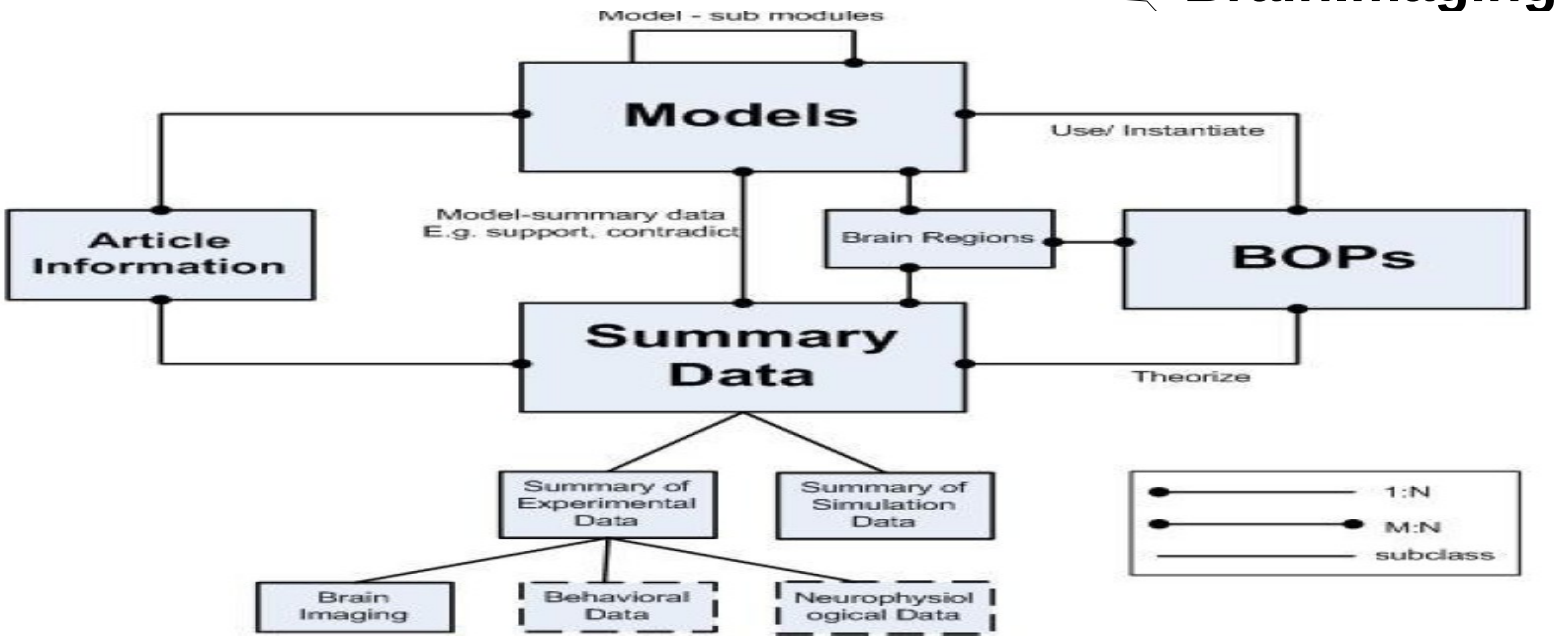
What's is already there ?

- **Brain info :**
  - http://braininfo.rprc.washington.edu
  - BrainInfo#NeuroNames
- **Neuro lex :**
  - http://neurolex.org/wiki/Main_Page

Vocabulary.

- **The Brain Operation Database :**
  - http://bodb.usc.edu/bodb/search

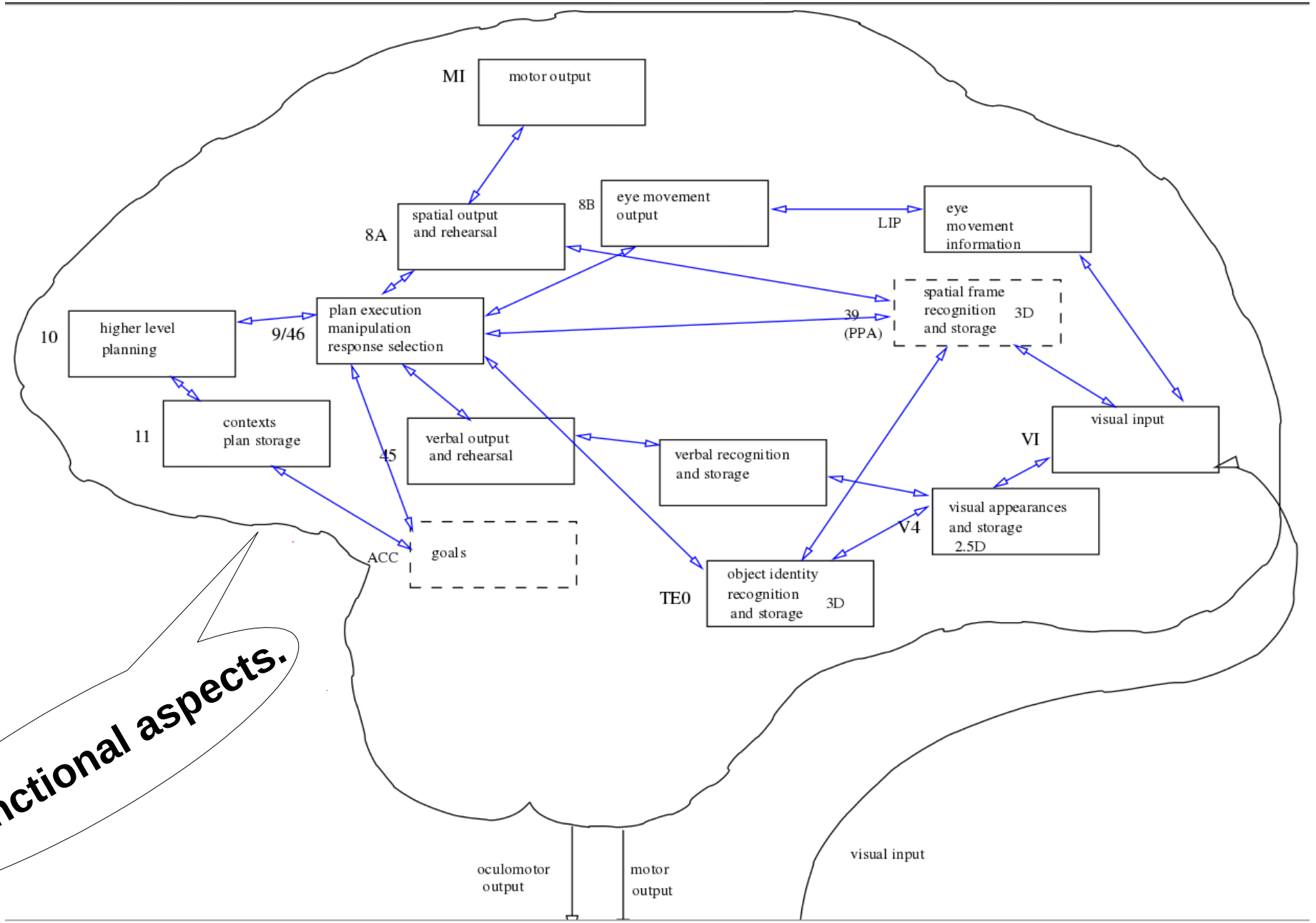
Article +
Models +
BrainImaging data.



What's is already there ?

- Using Semantic [. for .] an Ontology of Brain-Cortex Anatomy
  - Olivier Dameron et al Stanford, Inria Rennes, 200x
- Foundations for an ontology of brain areas, circuits and functions
  - Bénédicte M Batrancourt, CRIM Paris ; CNS'2013
- Cognitive Ontologies Mapping structure and function of the brain from a systemic view
  - Jaime Gomez, U. Polytechnica Madrid, 2008
- And also
  - Ontology of the ventricular system in relation with schizophrenia
    - Santos, Sallet, Cohn et al
  - A developmental ontology for the mammalian brain,
    - Puelles, Watson et al
  - Ontology for neuropsychology and cognitive psychology
    - Bond

What's is not already there ?



The functional aspects.

So what ?

- ✔ ***The finality:***
  - ✔ ***build systemic bio-plausible models***
    - ✔ ***for cognitive functions.***

- ✔***The goal:***
  - ✔***collect biological facts in a formal way***
  - ✔ ***so that :***
    - ✔ ***Knowledge is well-defined,***
    - ✔ ***Algorithms can process them.***

- ✔***The tool:***
  - ✔ ***Ontology in order to describe knowledge to be put in models.***

So what ?

what is the targeted knowledge ?

- ✔ **Architecture:**
  - ✔ *multi-scale brain structures and connections***.**
- ✔ **Terminology:**
  - ✔ *brain anatomical and functional element names.*
- ✔ **Data:**
  - ✔ *quantitative and qualitative facts on each element.*

✔ ***In a nutshell :***

information put in a model and its simulation code.

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That's it.

But : Does the brain use and/or compute ontologies ?

Good news : this is not the question.