

Universal Terminology

CHAPTER 13: PARTONOMY

Partonomy, also called mereology, is the preferred hierarchy of anatomists because it resembles the anatomy atlas, where each figure represents a body part and all its subparts. However, partonomy is formally complex and difficult to implement. Several common relationships applicable to the field of anatomy are similar to the *part_of* relationship, like the *contained_in* relationship, but are actually false friends and lead to representation errors.

This chapter clearly defines the *part_of* relationship and explains how partonomic lists are constructed. The reader will discover the multiple specializations of the *part_of* relationship, with formal definitions and relevant examples.

This document constitutes chapter 13 of the book *Universal Terminology*, which presents a comprehensive documentation on **T_{logy}**.

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13.1 Introduction to the partonomy

The partonomic hierarchy is governed by the *part_of* relationship, relatively familiar to human beings interested in terminology: everyone is clearly capable of identifying an object and distinguishing its several parts. The *LA:pylorus* is indeed a part of the *LA:stomach*. But this approach, seemingly simple, is in fact formally complicated, and it is unrealistic to want to ignore its existing pitfalls without having to face uncomfortable situations, as the following questions illustrate:

- Is a *LA:central retinal artery* part of the *LA:eye*?
- Is blood part of the artery?
- Is the *LA:surface of a tooth* material or immaterial?
- Are the *LA:common digital plantar arteries* part of the *LA:plantar metatarsal arteries*?
- How can a branch of an artery be defined as part of that artery?
- Is a spare tire, the fifth wheel of a car, part of the car?
- Of which *LA:organ system* is a peacemaker part?

A casual user of *T_{logy}* cannot necessarily be sure of the answers.

13.1.1 Past terminologies

In 1998, the first version of Terminology Anatomica (TA98) was published, with the following statement: *The order of presentation of terms naturally follows the anatomy of each system. Indentations and heading styles serve to indicate the relationship between terms.* The *part_of* relationship is not even mentioned. But a simple reading of the TA98 edition immediately shows that the presentation is primarily focused on the partonomic hierarchy. However, a closer examination will sooner or later reveal numerous problems that must be addressed in a modern terminology.

In any case, to do justice to the authors of TA98, and in particular to the chair of its working committee, Professor Ian Whitmore [Whitmore, 1999], it must be said that this version of anatomical terminology represented a major step forward at the moment of its publication. It presented a new, modern classification of anatomical terms, expanded the scope of anatomical terminology internationally, and highlighted the need for a high-quality reference for anatomical terms. We can affirm that *The Universal Terminology* presented here draws heavily on the initial work carried out under the auspices of TA98. This step proved to be fundamental.

However, it is time to move on to the next step. The initial concept was valid when it was published, but it is no longer sufficient in the digitalized society of the 21st century. Ontology has emerged and is no longer an option: it must be at the heart of current and future terminologies. Formal linguistics is another essential tool for managing 50,000 terms in multiple languages. Terminology storage and support today rely on a structured database and validation

software. The days of six-column spreadsheet-style working lists are over. The new terminology is based on formal principles and definitions.

This chapter is part of the book on *Universal Terminology*. This book aims to provide an answer to this problem. It aims to establish the fundamental principles of the new terminology. It provides numerous definitions to justify and limit its development within strict scientific limits. Its main contribution is to **make the terminology independent of any language** and, consequently, to restore the expression of each language on an equal footing. The new terminology depends neither on Latin nor English. This objective has never been stated before, but its practical implementation has demonstrated its feasibility in several languages, including Latin, which cannot be neglected under any circumstances.

In addition to partonomy, it is always necessary to consider taxonomy: these two hierarchies are complementary, and only their parallel presentation allows a complete view of the field of anatomy. Either hierarchy taken in isolation does not allow for the presentation of the essentials of anatomy: taxonomy classifies entities by type, and partonomy provides a spatial distribution of these entities. Fortunately, the publication of the TA98 partonomy enabled another initiative to construct and publish a taxonomy, called the Fundamental Model of Anatomy (FMA). These near-simultaneous efforts provided a comparable body of meaningful data. Any further developments must be presented according to the same principles.

To summarize this section, this Terminologia Anatomica Humana is the direct successor to Terminologia Anatomica (1998) and the Fundamental Model of Anatomy (FMA) [Rosse and Mejino, 2003]. May their authors be recognized for their pioneering roles in the history of anatomical terminology. For completeness, it is worth mentioning the prominent formal role of the Open Biomedical Ontologies (OBO) consortium [Smith and al., 2007].

13.1.2 Around the *part_of* relation

Several authors have studied and described this relationship in various fields. It is beyond the scope of this article to present these developments, which are widely documented in the scientific literature. However, in anatomy, we have a specific context. We can first exclude temporal relationships, which are absent from macroscopic anatomy and most subdisciplines of anatomy, with the exception of embryology, for which an extension would be necessary. We then deal primarily with physical entities, whether material or immaterial. The working context is that of material objects without temporal constraints: this is a much simpler situation than the general situation.

Our approach will unfold in three steps, sufficient for the $\mathbf{T}_{logy}$:

- Define the *part_of* relationship in the context of material entities.
- Extend this definition to immaterial entities.
- Extend this definition to the *branch_of* relationship.

13.1.3 Material part_of

The material part_of relationship concerns the partonomic link between a parent material entity and a child material entity. Fundamentally, we define the relationship by the matter present in both the parent and child entities.

material part_of relationship

The material part_of relationship is (definition) a link between material entities A and B of the form A part_of B, where all the matter of A is matter of B, and where there is some matter of B distinct from A.

This definition is derived from the basic definition given in *chapter 02*.

According to this definition, A and B cannot be equal: A is strictly a part of B. An immediate property of this relation is transitivity. If A is a part of B and B is a part of C, then A is a part of C.

This definition is generic and is inherited by all the specializations described below.

13.1.4 Immaterial part_of

The immaterial part_of relationship concerns the partonomic link between a parent entity, either material or immaterial, and an immaterial child entity. For example, with a material parent, we have: *FR:sternocostal face* part_of *FR:heart*. For example, with an immaterial parent, we have: *FR:abdominal cavity* part_of *FR:abdominopelvic cavity*. Basically, we define the relationship with an immaterial child, which is a space, a surface, a line, or a point defined relative to a parent entity.

immaterial part_of relation

The immaterial part_of relation is (definition) a link between entities A and B of the form A part_of B, where B is a material or immaterial entity, and such that A is an immaterial entity, a space, a surface, an edge, or a point, where every part of A is a part of B, and where there is a part of B distinct from A.

13.1.5 Branch_of

The branch_of relationship concerns the partonomic link between a father and his child in an anatomical subdomain with a dendritic hierarchy, blood vessels, lymphatic vessels, or nerves), typically *LA:arteria thyroidea superior* branch_of *LA:arteria carotis externa*. In this case, we consider each entity as the entire subtree of which it is the trunk; this means that any entity recursively includes the trunk and all its branches. Therefore, since any branch is part of the tree, we join the definition of part_of.

branch_of relation

The branch of relationship is (definition) a link between entities A and B of the form A branch of B, where B' is the entire tree of which B is the trunk and A is part of B'.

The branch of relationship applies only to material entities.

13.2 Foundation of the partonomy

The partonomic hierarchy of a domain generally consists of two types of partonomic lists.

First, there is a set of global lists based on the domain's top objects; the number of top objects varies considerably depending on the domain, from one to several. The domain of anatomy has two top objects.

Second, there are an indefinite number of generic lists, necessary in the presence of set-like entities for certain domain objects; it is preferable not to explicitly prioritize each member of the set, but instead to define a generic partonomy based on the generic entity of the set.

These two aspects create a duality in the partonomy of the anatomy domain, which will be developed below.

13.2.1 Duality of the domain

In the field of anatomy, there are two apex objects and several hundred generic partonomic lists. Indeed, we are faced with the following two apex objects: the female human body and the male human body. They are clearly different, although over 95% essentially undifferentiated, at least in terms of terminology. The difference lies in the 23rd chromosome: where this chromosome is expressed, the body parts may be different. A male body part necessarily belongs to a male individual and a female body part to a female individual. The terminology must be precise and explicit in this regard. Any body part specific to a given gender must be indicated as such wherever it appears.

This was not so clear in previous terminologies. TA98 defined an entity FR:*genital systems* which, like all organ systems in other chapters, is a part of the human body. However, this entity clearly never existed: no human body has ever had two genital systems! Often, terminologies are formally incorrect in this regard, although this peculiarity certainly does not mislead users; but it does prevent the development of formal reasoning engines.

Given that 95% advocated to use a single representation and only report exceptions. This is clearly a pragmatic approach, but it must be carried out with precision. To achieve this, we distinguish three forms of presentation of entities related to the sex chromosome:

- Ordinary entities are simply represented without a gender indicator. This means that such a form simultaneously represents both entities of each sex. A typical example is LA:*stomach*, which represents both the *stomach* ♂ and the *stomach* ♀. There is no terminological need to distinguish these two entities; the representation without a gender indicator is therefore adequate.
- Exclusively male entities are denoted by the masculine sign ♂. Their parents and children are essentially of the same gender. A typical example is LA:*musculus vesicoprostaticus* ♂. In $\mathbf{T}_{logy}$, any exclusively male entity must be denoted by ♂.
- Exclusively female entities are denoted by the feminine sign ♀. Their parents and children are essentially of the same gender. A typical example

PARTONOMIE	
TAH:U13545	corps humain @ inv
TAH:U16330	corps humain féminin ♀ @ SOS
TAH:U16331	corps humain masculin ♂ @ SOS
TAH:U9602	parties du corps humain @ TOS
TAH:U259	système squelettique @ SOS
TAH:U1240	système articulaire @ SOS
TAH:U1623	système musculaire @ SOS
TAH:U2275	système digestif @ SOS
TAH:U2325	dentition @ SOS
TAH:U2765	système respiratoire @ SOS
TAH:U3040	système urinaire @ SOS
TAH:U11401	système du tronc @ SOS
TAH:U3534	glandes endocrines @ XOS
TAH:U3568	système cardiovasculaire @ SOS
TAH:U4860	système lymphatique @ SOS
TAH:U5062	système nerveux @ SOS
TAH:U6876	organes sensoriels @ XOS
TAH:U7382	tégument commun @ SOS
Total	11945 children

Figure 13.1: Representation of the global top partonomy of the field of anatomy, as presented on the $\mathbf{T}_{logy}$ website. In reality, we should see two representations, one for each genus.

is $_{LA}$: *urethra feminina* ♀. In $\mathbf{T}_{logy}$, any exclusively female entity should be indicated by ♀.

Strict discipline is recommended for the three presentation forms mentioned above. This was not the case for TA98; for example, the $_{LA}$: *clitoris* ♀ was not reported as belonging exclusively to the female sex. This requirement may seem too imperative in partonomic lists, since all children of an entity marked with a gender must necessarily be marked with the same gender. But as soon as we consider environments other than partonomics, the risk of error is evident. For example, see in this regard the $_{LA}$: *circular layer* ♀ in the taxonomic list *muscle fiber group*.

13.2.2 Top of global partonomy

There are two global partonomies in the field of anatomy, depending on the genus. For each hierarchy, let's examine the top entities and their articulation with the immediately lower child entities. The top entity is $_{LA}$: *corpus humanum* and the list of its immediate child entities is given in figure 13.1.

Gender representation should be understood as either feminine or masculine. The result is illustrated for the *corpus humanum femininum* ♀, a similar representation exists for the *corpus humanum masculinum* ♂:

$_{LA}$:	<i>female human body</i> ♀
—	$_{LA}$: <i>general anatomy</i> ♀
—	$_{LA}$: <i>skeletal system</i> ♀
—	$_{LA}$: <i>articular system</i> ♀
—	$_{LA}$: <i>muscular system</i> ♀
—	$_{LA}$: <i>digestive system</i> ♀
—	$_{LA}$: <i>dentition</i> ♀

- LA: *respiratory system* ♀
- LA: *urinary system* ♀
- LA: *trunk system* ♀
- LA: *endocrine glands* ♀
- LA: *cardiovascular system* ♀
- LA: *lymphatic system* ♀
- LA: *nervous system* ♀
- LA: *sense organs* ♀
- LA: *common integument* ♀

▼ arteria pudenda interna (par) ♂
• arteria rectalis inferior (par) ♂
• arteria perinealis (par) ♂
• rami labiales posteriores (par) ♀ ♂
• rami scrotales posteriores (par) ♂
• arteria urethralis (par) ♂
• arteria bulbi vestibuli (par) ♀ ♂
• arteria bulbi penis (par) ♂
• arteria dorsalis clitoridis (par) ♀ ♂
• arteria dorsalis penis (par) ♂
• arteria profunda clitoridis (par) ♀ ♂
• arteria profunda penis (par) ♂
• arteria perforans penis (par) ♂
12 children

Figure 13.2: This figure shows the descending partonomy of the FR: *internal pudendal artery*.

13.2.3 Example of list with sex symbols

The following partial partonomy corresponds to the internal pudendal artery (FR: *internal pudendal artery*), from which the figure 13.2 is extracted:

It represents two different partonomies in a single presentation. The user is responsible for ensuring an accurate reading for each genre, as presented below.

Female presentation:

```

internal pudendal artery ♀
├── inferior rectal artery ♀
├── perineal artery ♀
├── posterior labial branches ♀
├── urethral artery ♀
├── vestibular bulbous artery ♀
├── dorsal clitoral artery ♀
└── deep clitoral artery ♀

```

Male presentation:

```

internal pudendal artery ♂
├── inferior rectal artery ♂
├── perineal artery ♂
├── posterior scrotal branches ♂
├── urethral artery ♂
├── bulbous artery of the penis ♂
├── dorsal artery of the penis ♂
├── deep artery of the penis ♂
└── perforating artery of the penis ♂

```

15777		3673	valvulae semilunares pulmonales 	pulmonary semilunar valvules 
76530		3674	# valvula semilunaris pulmonalis 	# pulmonary semilunar valvule 
76531			nodulus valvulae semilunaris 	nodule of semilunar leaflet 
7249		3670	lunulae valvulae semilunaris 	lunulae of semilunar leaflet of 
7250		3671	valvula semilunaris dextra valvae trunci pulmonalis 	right semilunar leaflet of pulmonary valve; right semilunar cusp of pulmonary valve
7247		3672	valvula semilunaris sinistra valvae trunci pulmonalis 	left adjacent leaflet of pulmonary valve; left semilunar cusp of pulmonary valve
			valvula semilunaris anterior valvae trunci pulmonalis 	anterior semilunar leaflet of pulmonary valve; anterior semilunar cusp of pulmonary valve

Figure 13.3: The list presented here is taken from the **root of the pulmonary trunk** at level P4. There are three semilunar valves. All valves appear on the first line in the plural. The three explicit valves are listed on the last three lines of this figure. Between the two, the generic list, beginning with the hash sign #, is inserted. The length of the generic list is defined by indentation; here, it is three lines long.

13.2.4 Generic partonomy

Generic partonomies are numerous and can be found in any partonomic list. A typical example concerns rods: there are several million of them in each retina. In the upper part of the partonomy, we find the eye, the retina in each eye, and, as part of the retina, the rods, represented as a set (plural term), namely the LA: *rods of the retina*, also called EN: *bacilliferous neurons*. But this hierarchy obviously does not list the approximately 100,000 examples present in each retina: no individual rods appear. To describe the partonomy of a rod, it is necessary to create a separate generic partonomy with the rod as the top entity, included in a partonomic list. Such a partonomic hierarchy is completely independent of the higher partonomic hierarchy. However, for practical reasons of presentation, it is convenient to integrate it into the higher list.

Let's examine another detailed example of a generic partonomy concerning the *valvulae semilunares*. The presentation, including the generic partonomy, is shown in figure 13.3. It clearly shows the generic partonomy list, preceded by # valvule semilunaire pulmonaire in the singular and three lines long. This generic list should be considered independent of the current list visible on both sides. It can be displayed alone, out of context. It is presented here solely for pragmatic reasons, after the plural term.

13.3 Bibliography about partonomy

Here we present a review of several articles deemed relevant for introducing partonomy and formally documenting the fundamental hierarchy of terminology. Most of these articles are cited in this chapter. All these references are directly available as PDF files in the list presented at the end of this document.

[Whitmore, 1999]

This article, written by the author of Terminologia Anatomica (1998), should be read as a first reading, before any discussion or critique. It sets the scene in which this terminology appears.

[Rosse and Mejino, 2003]

The Fundamental Model of Anatomy was first introduced by this important article. It encompasses the material objects, from the molecular to the macroscopic level, that constitute the body and associates with them immaterial entities (spaces, surfaces, lines, and points) necessary for the description of structural relationships.

[Rosse and Mejino, 2007]

A formal review of the FMA and its construction.

[Schulz et al., 2006]

Partonomic relationships such as part_of are fundamental for describing the structure of living organisms. While classical partonomy focuses on individual entities, partonomic relationships in biomedical ontologies are generally asserted between classes of individuals. This article offers suggestions for standardizing partonomic relationships in biomedical ontologies.

[Wacholder et al., 1998]

A section of this article focuses on the structure of an anatomical semantic network. Considerations are presented on the ISA relationship as well as the part_of relationship.

[Winston et al., 1987]

A taxonomy of part-whole or meronym relationships is developed. The resulting classification yields six types of partonomic relationships, which are described. Partonomic relationships are also distinguished from other inclusion relationships, such as spatial inclusion and class inclusion, as well as from several other semantic relationships: attribution, attachment, and ownership. This is a basic introduction to partonomies.

[Neuhaus and Smith, 2000]

This article describes what an ontology should be, the goal being for it to be both human-readable and computer-interpretable. An ontology is composed of types (anatomical entities) and relationships such as isa, part_of, or contained_in. This article states: An ontology is much more than a list of terms. It is designed to encapsulate the meaning of these terms in a form that can be analyzed by computers.

[Mejino and Rosse, 2001]

The role of definitions in FMA is examined.

[Mejino and Rosse, 2003]

Part-whole relationships play a particularly important role in this representation. To ensure that knowledge-based applications relying on FMA can reason about anatomy, we have modified and improved the currently available partonomic relationship schemas.

[Smith et al., 2005]

On the ontology of relationships.

13.4 Naming the part_of relations

There are many variations or specializations of the part_of relationship, which will be documented below. A naming convention is necessary to understand their meaning from their name or acronym. In this section, we develop a mandatory way to name partonomic relationships and define their three-character acronyms.

Each relationship is defined by three criteria, plus one or two optional dimension values. This results in names and acronyms composed of three concatenated parts, with the dimension value interspersed. The three parts, defined from left to right, are as follows, given in the order of the extended name followed by the acronym:

- **Child Type:** Values for the material entities Single S, Set T, Mixed X, Pair U, Pset V, and for the immaterial entities Single M, Set N, Mixed Z, Pair P, Pset Q
- **Materiality Transition and Dendronomy:** The values are Of O for a parent/child equal to material/material, Br B for an equivalent dendronomy, Ex E for immaterial/material, and In I for immaterial/immaterial.
- **Parent Type:** The values are identical to those of the child type.

The dimension values correspond to the number of dimensions of the entities involved for volume 3, surface 2, line 1, and point 0. These values are optional.

According to these specifications, a transition between a material pset child and a material singular parent would be named PsetOfSingle VOS. And a transition between an immaterial even child, a surface, and a material even parent would be named PairExPset PEU (or P2EU), as for the LA: *lateral face of testicle*.

Finally, the inverse of a relation is named with the same name preceded by an underscore, for example _SOU.

13.5 Specialization of the part_of relation

Entity types govern the hierarchical relationships of partonomy. Several constraints on relationships arise from the entity types in partonomic relationships. For this reason, to ensure rigorous control of hierarchical relationships, it is necessary to formally define entity types: this was done in Chapter 2, where the part_of relationship is formally defined. Here is a summary of physical entity types, where the term pset is used to mean even set:

- *single S*: material singular entity
- *set T*: material set
- *mixed X*: material mixed set
- *pair U*: material pair
- *pset V*: material pset
- *single M*: immaterial singular entity
- *set N*: immaterial set
- *mixed Z*: immaterial mixed set
- *pair P*: immaterial pair
- *pset Q*: immaterial pset

Part-of relationships apply only to physical entities, which have one dimension. In the following discussion, non-physical entities are not included, although they exist in the taxonomy. They are part of the taxonomy, but are absent from the partonomy and, therefore, are not subject to the part-of relationship.

Physical entity types are based on three independent properties: materiality, parity, and composition. Each of these properties is bivalued: materiality

		origin	
		material = m	immaterial = i
destination	m	1	
	i	2	3

Figure 13.4: Permitted partonomic relationships according to tangible and intangible entities. The transition from an immaterial parent entity to a material child entity does not actually exist: a material entity cannot be part of an immaterial entity! The total number of permitted partonomic relationships is thus reduced to three-quarters of the total. Other relationships are either prohibited or absent from the theory. The figures refer to the detailed tables below.

separates entities into tangible and intangible entities; composition separates entities into singular and composite entities; parity separates entities into even and non-even entities. This diagram defines eight entity types and can be clearly represented as a cube.

Partonomic links must be differentiated according to their origin and destination entity types. Broadly speaking, we can consider two origins and destinations: material and immaterial. The possible links are shown in figure 13.4. Since there are 10 physical types of entities, either as origin or as destination, there are $10 \times 10 = 100$ possible origin/destination pairs that can be realized in $\mathbf{T}_{logy}$. However, not all of them occur in reality: pairs with an immaterial origin and a material destination are prohibited. This leaves a total of 75 possible origin/destination pairs. However, all of these pairs are either not possible or are absent from $\mathbf{T}_{logy}$. As a result, there are 51 pairs that exhaustively describe the partonomic hierarchy. They are all listed and described below.

All links express the fact that the destination entity is part of the source entity. In the partonomic tree, whose root is at the top and leaves at the bottom, all links are considered from the bottom (the part) to the top (the container).

Links are themselves entities. They are considered non-physical entities of the taxonomy. Therefore, they are part of the $\mathbf{T}_{logy}$ and have dedicated entity pages.

In the following descriptions of partonomic links, all links are considered descendants of the part_of relationship. Therefore, since the part_of link is transitive, any composition of part_of links is itself a part_of link. Any link that can be obtained by composing two other existing links will not be documented.

1		parent				
		single	set	mixed	pair	pset
child	single	SOS SBS	SOT	SOX	SOU	✖
	set	TOS	TOT	TOX	✖	TOV
	mixed	XOS	✖	XOX	✖	✖
	pair	UOS UBS	✖	UOX	UOU UBU	UOV UBV
	pset	VOS VBS	✖	VOX	VOU VBU	VOV VBV

Figure 13.5: This figure shows all the partonomic relationships from a parent material entity to a child material entity. Out of a total of 25 possible situations, 25 relationships are instantiated in the $\mathbf{T}_{logy}$. They are represented by their acronym, provided with each definition. This table reads as follows: **child parent relationship**, which gives for the lower left corner: **pset VOS single**

13.6 Material child from material father

This section lists the partonomic links between a parent material entity and a child material entity. In this case, the number of links is limited by the possible origin/destination pairs ($5 \times 5 = 25$), as shown in figure 13.5. However, not all pairs are actually active, and some pairs have two links. The exact number of links is 25.

The additional links result from the existence of a tree-like approach in certain chapters of the $\mathbf{T}_{logy}$, such as for vessels or nerves. It is necessary to define a specialized link for branches equivalent to the part_of link.

In the following descriptions of partonomic relationships, all relationships are considered parts of or specializations of a part_of relationship. The part_of relationship is transitive. This means that if A is part_of B and B is part_of C, then A is part_of C.

13.6.1 SingleOfSingle (Part_of)

SingleOfSingle: SOS

The `SingleOfSingle` relationship (definition) is a `part_of` relationship that applies between a child singular material entity and a parent singular material entity.

Example: *LA:Right atrium* *LA:SingleOfSingle* *LA:Heart*

This is the true `part_of` relationship. At the instance level, this means that a certain amount of matter in the child entity is also matter in the parent entity, and that there is a complement of matter such that the addition of the part and its complement equals the parent entity. The child can never be equal to the parent, or, equivalently, the complement is never an empty entity.

This relationship can then be formally extended to the class level, which is the level of interest of the TAH. If for all *a* and *b* that are instances of entities *A* and *B* at time *t*, and if *b* is part of *a* at the instance level, then *B* is part of *A* at the class level at time *t*. The time dimension is necessary for this statement to be formally true, but this aspect will not be developed here.

An example is *LA:cardia* *LA:SingleOfSingle* *LA:stomach*. There is no doubt that the matter (biological cells) of the *cardia* also belongs to the *stomach* and that some of the matter of the *stomach* is disjoint from the *cardia*.

13.6.2 SingleBrSingle (Branch_of)

Branch_of: SBS

The `SingleBrSingle` relationship (definition) is a `part_of` relationship that applies between a child singular material entity and a parent singular material entity for tree structures.

Example: *FR:azygos vein* *LA:SingleBrSingle* *FR:superior vena cava*

This is an alternative link to the `SingleOfSingle` link above. An intuitive approach would be to say that the child is `SingleOfSingle` of the parent. If *B* is an artery that is a branch of another artery, *A*, it is not directly part of it because they are distinct entities; we cannot directly say that *B* is `SingleOfSingle` *A*.

However, let's slightly modify this *B* `SingleOfSingle` *A* link. We can consider *A'* as the tree of which *A* is the trunk. This immediately follows that *B* `SingleOfSingle` *A'*, since *B* is indeed a branch of the tree *A'*, and therefore a part of this tree. To highlight this difference in the interpretation of *A'* as a tributary tree of *A*, `SingleOfSingle` is replaced by `SingleBrSingle`. In this way, the `SingleBrSingle` relationship becomes a specialization of `part_of` and allows all tree structures to be included in the partonomy. However, in the implementation of the $\mathbf{T}_{logy}$, the `SingleBrSingle` link is always represented by the `SingleOfSingle` link, i.e., `SOS` instead of `SBS`. The same applies to the other links applicable to dendronomy.

This relationship is used exclusively for arteries, veins, and nerves.

13.6.3 SingleOfSet

SingleOfSet: SOT

The SingleOfSet relationship (definition) is a `part_of` link that applies between a child singular material entity and a parent composite material entity.

Example: FR: *prominent vertebrae* LA: *SingleOfSet* LA: *typical cervical vertebrae*

This link is often cited in the scientific literature as a member-of.

It is essentially a set membership relationship, meaning that the child entity is one of the entities comprising the parent set. Due to the definition of anatomical sets, the sum of all member entities of the child set unequivocally defines the parent set.

In the practice of partonomic lists, it should be noted that in the presence of a set entity, it is not necessary to list all its members as descendants to constitute a total partition. This assessment is left to the authors of the T_{logy} . Typically, LA: *amacrine neurons* are detailed in the form of 15 different variants, but in reality there are several dozen. An exhaustive list in this case would go beyond the general scope of interest, which applies to the entire T_{logy} .

It should be noted here that the SingleOfSet link does not exist. Indeed, if we want to extract a singular entity from a pset, we must proceed in two steps: extract a paired entity with PairOfSet, then extract the singular entity with SingleOfPair. We therefore have $\text{SingleOfSet} == \text{SOU} \times \text{UOV}$.

13.6.4 SingleOfMixed

SingleOfMixed: SOX

The SingleOfMixed relationship (definition) is a `part_of` relationship that applies between a child singular material entity and a parent mixed set material entity.

Example: frontal bone422 SingleOfMixed16909 skull bone402

This relationship connects a singular entity to its parent entity, which is a mixed set. It is required to extract a singular entity that is part of a mixed set. It works in conjunction with the SingleOfSet relationship for extracting a singular entity or the SingleOfSet relationship for extracting a paired entity. This relationship is required for mixed sets, as the usual SingleOfSet and SingleOfPair relationships are not allowed here.

13.6.5 SingleOfPair

SingleOfPair: SOU

The SingleOfPair relationship (definition) is a `part_of` relationship between a child unpaired member of a pair and the corresponding parent paired entity, valid for both material and immaterial entities.

Example: LA: *ligamentum teres sinistrum uteri* LA: *SingleOfPair* LA: *ligamentum teres uteri*

This relationship connects a paired entity to any one of its lateral member. In addition to the constitutional and regional partitions, this relationship is known as a lateral partition. Such a partition is always a final explicit partition, without further descendants.

We can observe the following property. If (1) left humerus SOU pair of humeri, in other words, pair of humeri _SOU left humerus (2) pair of humerus heads UOU pair of humerus and (3) left humerus head SOU pair of humerus heads, then (4) left humerus head SOS left humerus.

In other words, the rule is: $\text{SOU} \times \text{UOU} \times \text{_SOU} = \text{SOS}$. What we have proven is that if UOU applies between two pairs, then SOS applies parallel to the left and right of each pair.

13.6.6 SetOfSingle

SetOfSingle: TOS

The SetOfSingle relationship (definition) is a part_of relationship that applies between a child set material entity and a parent singular material entity.

Example: LA: *vertebrae* LA: *SetOfSingle* LA: *vertebral column*

This relationship is necessary when multiple-occurring entities are found within a singular entity. This relationship is not uncommon in AHT, where it expresses plural terms.

It is possible and recommended to avoid this link when possible, and therefore to avoid the presence of a plural, when a collective term exists. Such a term is singular. For example, FR: *small omentum* replaces a term that could be FR: *hepatic ligaments*.

13.6.7 SetOfSet

SetOfSet: TOT

The SetOfSet relationship (definition) is a part_of relationship that applies between a child material set and a parent material set.

Example: LA: *cervical vertebrae* LA: *SetOfSet* LA: *vertebrae*

This relationship is often cited in the scientific literature as subset of.

The SetOfSet relationship is fundamentally a subset relationship, meaning that all child entities are also entities of the parent. The child can never be equal to the parent.

This relationship, along with PsetOfPset and MixedOfMixed, are the only relationships connecting an entity together to another entity of the same type.

13.6.8 SetOfMixed

SetOfMixed: TOX

The SetOfMixed relationship (definition) is a part_of relationship that applies between a child material set and a parent mixed set.

Example: LA:*rostral basal cisterns* LA:*SetOfMixed* LA:*supratentorial cisterns*

This relationship allows the extraction of a set of singular entities as a subset of a mixed set.

13.6.9 SetOfPset

SetOfPset: TOV

The SetOfPset relationship (definition) is a part_of relationship that applies between a child material set and a parent material pset.

Example: FR:*right kidney columns* LA:*SetOfPset* LA:*kidney columns*

This relationship is the equivalent of SingleOfPair for psets: it allows you to extract one of the side members.

13.6.10 MixedOfSingle

MixedOfSingle: XOS

The MixedOfSingle relationship (definition) is a part_of relationship that applies between a mixed child material set and a parent material singular entity.

Example: LA:*cranial bones* LA:*MixedOfSingle* LA:*axial skeletal system*

In this example, the cranial bones set is composed of 15 bones, of which 7 are single entities and 8 are even entities.

This relationship allows a mixed set to be defined as part of a singular material entity.

13.6.11 MixedOfMixed

MixedOfMixed: XOX

The MixedOfMixed relationship (definition) is a part_of relationship that applies between a child mixed material set and a parent mixed material set.

Example: LA:*infratentorial cisterns* LA:*MixedOfMixed* LA:*cranial subarachnoid cisterns*

Any mixed set can be a subset of another mixed set.

13.6.12 PairOfSingle

PairOfSingle: UOS

The PairOfSingle relationship (definition) is a part_of relationship that applies between a child even-numbered material entity and a parent singular material entity, the parent entity necessarily being a median entity.

Example: LA:*lesser wing of the sphenoid bone* LA:*PairOfSingle* LA:*sphenoid bone*

This relationship allows the creation of a first material pair entity in the global partonomy, based on the superior entity of the EN: *human body*. It can be shown that only a median entity can be the parent of a pair entity. From this point in the hierarchy, descendants (except for lateral limbs) can only be pair entities obtained by the PairOfPair relationship.

The sphenoid bone is indeed a median entity.

13.6.13 PairBrSingle

PairBrSingle: UBS

The PairBrSingle relationship (definition) is a part_of relationship that applies between a child pair material entity and a parent singular material entity, in the context of a dendronomy.

Example: LA: *renal artery* LA: *PairBrSingle* LA: *abdominal aorta*

This relationship is the equivalent of PairOfSingle for tree structures.

13.6.14 PairOfMixed

PairOfMixed: UOX

The PairOfMixed relationship (definition) is a part_of relationship that applies between a child paired material entity and a parent mixed material entity.

Example: LA: *parietal bone* LA: *PairOfMixed* LA: *skull bone*

This *member_of* relationship allows you to extract a paired entity from a mixed set, just as SingleOfMixed allows you to extract a single entity from the same mixed set.

13.6.15 PairOfPair

PairOfPair: UOU

The PairOfPair relationship (definition) is a part_of relationship that applies between two pair material entities, which applies a part-of link to each of their members.

Example: FR: *head of the humerus* LA: *PairOfPair* LA: *humerus*

This relationship is simply an extension of the part-of relationship to pair material entities. It is the most common relationship in the partonomy of $\mathbf{T}_{logy}$.

13.6.16 PairBrPair

PairBrPair: UBU

The PairBrPair relationship (definition) is a part_of relationship that applies between two even material entities, in the context of a dendronomy.

Example: LA:*inferior ulnar artery* LA:*PairBrPair* LA:*radial artery*

Example: LA:*thoracoacromial artery* LA:*PairBrPair* LA:*axillary artery*

This relationship is simply an extension of the branch-of relationship to pair material entities.

13.6.17 PairOfPset

PairOfPset: UOV

The PairOfPset relationship (definition) is a part_of relationship that applies between a child paired material entity and a parent pset.

Example: FR:*trigeminal nerve* LA:*PairOfPset* FR:*cranial nerves*

Example: LA:*syndesmosis radioulnaris* LA:*SingleOfSet* LA:*juncturae membri superioris liberi*

This relationship allows you to extract a pair from a set of pairs.

13.6.18 PairBrPset

PairBrPset: UBV

The PairBrPset relationship (definition) is a part_of relationship that applies between a child pair material entity and a parent pset material in a dendromic context.

Example: LA:*fourth plantar metatarsal artery* LA:*PairOfPset* LA:*plantar metatarsal arteries*

13.6.19 PsetOfSingle

PsetOfSingle: VOS

The PsetOfSingle relationship (definition) is a part_of relationship that applies between a child material pset and a parent singular material entity.

Example: LA:*upper limb muscles* LA:*PsetOfSingle* LA:*upper limb muscular system*

This relationship is the equivalent of the set-of relationship, required to create a pset from a singular entity.

13.6.20 PsetOfMixed

PsetOfMixed: VOX

The PsetOfMixed relationship (definition) is a part_of relationship that applies between a child material pset and a parent mixed material set.

Example: LA:*caudal lateral cisterns* LA:*PsetOfMixed* LA:*infratentorial cisterns*

This relationship connects a pair set to its parent entity, which is a mixed set. It is necessary to extract a pair set from a mixed set.

13.6.21 PsetOfPair

PsetOfPair: VOU

The PsetOfPair relationship (definition) is a part_of relationship that applies between a child material pset entity and a parent material pair entity.

Example: LA:*interosseous muscles of the hand* LA:*PsetOfPair* LA:*interosseous space muscle*

13.6.22 PsetBrPair

PsetBrPair: VBU

The PsetBrPair relationship (definition) is a part_of relationship that applies between a child material pset entity and a parent material pair entity for tree structures.

13.6.23 PsetOfPset

PsetOfPset: VOV

The PsetOfPset relationship (definition) is a part_of relationship that applies between a child material pset entity and a parent material pset entity.

Example: LA:*tooth tubercles (pair)* LA:*PsetOfPset* LA:*tooth crown parts (pair)*
This relationship creates the *subset_of* relationship for a pset.

13.6.24 PsetBrPset

PsetBrPset: VBV

The PsetBrPset relationship (definition) is a part_of relationship that applies between a child material pset and a parent material pset in a dendromic context.

13.7 Immaterial child from material father

Not all possible relationships between a child immaterial entity and a parent material entity are realized in the $\mathbf{T}_{logy}$. The absence of relationships does not necessarily mean that this relationship does not exist: it does not currently exist in the $\mathbf{T}_{logy}$, but it may exist elsewhere.

The table 13.6 displays all the relationships found, designated by their acronyms. The relationships that are formally possible but do not exist in the $\mathbf{T}_{logy}$ are represented by a pair of round parentheses.

13.7.1 SingleExSingle

SingleExSingle: MES

The `SingleExSingle` relationship (definition) is a `part_of` relationship that applies between a child immaterial entity and a parent material entity.

Example: $_{LA:}$ *ethmoidal bubble* $_{LA:}$ *SingleExSingle* $_{LA:}$ *ethmoidal labyrinth*.

The sub-relationships of `SingleExSingle` are `Single3ExSingle`, `Single2ExSingle`, `Single1ExSingle`, and `Single0ExSingle`. Specifying the sub-relationship is optional.

This example relationship concerns the location of a three-dimensional immaterial cavity within a material entity. This relationship applies to a volume, a surface, a line, or a point.

13.7.2 SingleExMixed

SingleExMixed: MEX

The `SingleExMixed` relationship (definition) is a `part_of` relationship that applies between a singular immaterial child entity and a parent mixed material set.

Example: $_{LA:}$ *inion* $_{LA:}$ *SingleExMixed* $_{LA:}$ *skull terms*.

The sub-relationships of `SingleExMixed` are `Single3ExMixed`, `Single2ExMixed`, `Single1ExMixed`, and `Single0ExMixed`. Specifying the sub-relationship is optional.

This example relationship concerns the location of a zero-dimensional immaterial point within a material entity. This relationship applies to a volume, a surface, a line, or a point.

13.7.3 SetExSingle

SetExSingle: NES

The `SetExSingle` relationship (definition) is a `part_of` relationship that applies between a child immaterial set and a parent singular material entity.

Example: $_{LA:}$ *gastric dimples* $_{LA:}$ *Set2ExSingle* $_{LA:}$ *mucous membrane of the stomach*.

2		parent				
		single	set	mixed	pair	pset
child	single	MES	✗	MEX	✗	✗
	set	NES	✗	()	✗	✗
	mixed	ZES	✗	()	✗	✗
	pair	PES	✗	PEX	PEU	✗
	pset	QES	✗	QEX	QEU	✗

Figure 13.6: This figure shows all the partonomic relationships from a parent material entity to a child immaterial entity. Out of a total of 25 possible situations, 10 relationships are instantiated in the $\mathbf{T}_{logy}$ and 2 relationships are possible but never present. They are represented by their acronym, provided with each definition. Each relationship formally has 4 sub-relationships dedicated respectively to a volume, a surface, a line or a point. Not all of these sub-relationships are necessarily present in the $\mathbf{T}_{logy}$.

The sub-relationships of `SetExSingle` are `Set3ExSingle`, `Set2ExSingle`, `Set1ExSingle`, and `Set0ExSingle`. Specifying the sub-relationship is optional.

This example relationship concerns the location of two-dimensional immaterial surfaces within a material entity. This relationship applies to a volume, a surface, a line, or a point.

13.7.4 MixedExSingle

MixedExSingle: PES

The `MixedExSingle` relationship (definition) is a `part_of` relationship that applies between a mixed immaterial child set and a singular material parent entity.

Example: *LA:regions of the human body LA:MixedExSingle LA:human body.*

13.7.5 PairExSingle

PairExSingle: PES

The `PairExSingle` relationship (definition) is a `part_of` relationship that applies between a child immaterial pair entity and a parent material singular entity.

Example: *LA:border of uterus (pair) LA:PairExSingle LA:uterus.*

13.7.6 PairExMixed

PairExMixed: PEX

The `PairExMixed` relationship (definition) is a `part_of` relationship that applies between a child immaterial pair entity and a parent mixed set material entity.

Example: *LA:oculomotor nerve groove (pair) LA:PairExMixed LA:external morphology of the midbrain.*

13.7.7 PairExPair

PairExPair: PEU

The `PairExPair` relationship (definition) is a `part_of` relationship that applies between a child paired immaterial entity, which is a parent paired material entity.

Example: *LA:semilunar hiatus (pair) LA:PairExPair LA:ethmoidal labyrinth (pair).*

This relationship allows the creation of a first paired immaterial entity. It can be shown that only median immaterial entities can be parents of paired immaterial entities.

13.7.8 PsetExSingle

PsetExSingle: QES

The PsetExSingle relationship (definition) is a part_of relationship that applies between a child immaterial pset and a parent singular material entity.

Example: LA:*costal incisures* LA:*Pset1ExSingle* LA:*sternum*.

The subrelationships of PsetExSingle are Pset3ExSingle, Pset2ExSingle, Pset1ExSingle, and Pset0ExSingle. Specifying the subrelationship is optional.

13.7.9 PsetExMixed

PsetExMixed: QEX

The PsetExMixed relationship (definition) is a part_of relationship that applies between a child immaterial pset and a parent material mixed set entity.

Example: LA:*cavitates dentis* LA:*Pset3ExMixed* LA:*partes dentis*.

13.7.10 PsetExPair

PsetExPair: QEU

The PsetExPair relationship (definition) is a part_of relationship that applies between a child immaterial pset and a parent material pair entity.

Example: LA:*pleural recesses (pair)* LA:*PsetExPair* LA:*pleura (pair)*.

13.8 Immaterial child from immaterial father

Not all possible relationships between two immaterial entities are realized in the $\mathbf{T}_{logy}$. No mixed immaterial set is observed. Table 13.7 presents all the relationships found.

13.8.1 SingleInSingle

SingleInSingle: MIM

The SingleInSingle relationship (definition) is a part_of relationship that applies between a singular child immaterial entity and a singular parent immaterial entity.

- **Single2InSingle:** A surface is defined as a part of a volume or space.

Example: $LA: vestibule\ of\ the\ larynx$ $LA: SingleInSingle$ $LA: cavity\ of\ the\ larynx$.

- **Single0InSingle:** A point is defined as a part of a volume or space.

Example: $LA: basion$ $LA: SingleInSingle$ $LA: foramen\ magnum$.

The subrelationships of SingleInSingle are Single3InSingle, Single2InSingle, Single1InSingle, and Single0InSingle. Specifying the subrelationship is optional.

This relationship concerns a child entity with a dimension equal to or smaller than that of the parent entity.

13.8.2 SingleInSet

SingleInSet: MIN

The SingleInSet relationship (definition) is a part_of relationship that applies between a singular child intangible entity and a parent set intangible entity.

Example:

$LA: abdominopelvic\ cavity$ $LA: Single0InSingle$ $LA: trunk\ cavities$.

13.8.3 SingleInMixed

SingleInMixed: MIZ

The SingleInMixed relationship (definition) is a part_of relationship that applies between a child singular immaterial entity and a parent mixed set immaterial entity.

Example:

$LA: cranial\ vertex$ $LA: SingleInMixed$ $LA: neurocranial\ regions$.

3

parent

single

set

mixed

pair

pset

single

set

mixed

pair

pset

child

	single	MIM	MIN	MIZ	MIP	()
	set	()	NIN	NIZ	✖	NIQ
	mixed	ZIM	✖	ZIZ	✖	✖
	pair	PIM	✖	PIZ	PIP	PIQ
	pset	()	✖	QIZ	QIP	QIQ

Figure 13.7: This figure shows all the partonomic relationships from a parent immaterial entity to a child immaterial entity. Out of a total of 25 possible situations, 16 relationships are instantiated in the $\mathbf{T}_{logy}$ and 3 relationships are possible but never present. They are represented by their acronym, provided with each definition. Each relationship formally has 4 sub-links dedicated respectively to a volume, a surface, a line or a point. Not all of these sub-relationships are necessarily present in the $\mathbf{T}_{logy}$.

13.8.4 SingleInPair

SingleInPair: MIP

The SingleInPair relationship (definition) is a part_of relationship that applies between a child singular immaterial entity and a parent pair immaterial entity.

Example:

FR: *left lateral pectoral region* LA: *SingleInPair* LA: *lateral pectoral region (pair)*.

This relationship extracts a lateral member from an immaterial pair.

13.8.5 SetInSet

SetInSet: NIN

The SetInSet relationship (definition) is a part_of relationship that applies between a child set immaterial entity and a parent set immaterial entity.

13.8.6 SetInPset

SetInPset: NIQ

The SetInPset relationship (definition) is a part_of relationship that applies between a child set immaterial entity and a parent pset immaterial entity.

Example:

FR: *right occlusal faces* LA: *SetInPset* LA: *occlusal faces (pair)*.

This relationship extracts a lateral set member from an immaterial pset.

13.8.7 SetInMixed

SetInMixed: NIZ

The SetInMixed relationship (definition) is a part_of relationship that applies between a child set immaterial entity and a parent set immaterial entity.

Example:

LA: *caudal basal cisterns* LA: *SetInMixed* LA: *infratentorial cisterns*.

13.8.8 MixedInSingle

MixedInSingle: ZIM

The MixedInSingle relationship (definition) is a part_of relationship that applies between a child mixed set immaterial entity and a parent singular immaterial entity.

Example:

LA: *cranial subarachnoid cisterns* LA: *Single0InSingle* LA: *cranial subarachnoid space*.

13.8.9 MixedInMixed

MixedInMixed: ZIZ

The MixedInMixed relationship (definition) is a part_of relationship that applies between a child mixed-set immaterial entity and a parent mixed-set immaterial entity.

Example:

LA: *facial regions* LA: *MixedInMixed* LA: *head regions*.

13.8.10 PairInSingle

PairInSingle: PIM

The PairInSingle relationship (definition) is a part_of relationship that applies between a child pair immaterial entity and a parent singular immaterial entity.

Example:

LA: *pleural cavity* LA: *PairInSingle* LA: *thoracic cavity*.

The subrelationships of PairInSingle are Pair3InSingle, Pair2InSingle, Pair1InSingle and Pair0InSingle. Specifying the subrelationship is optional.

This relationship concerns a child entity of equal or smaller dimension than the parent entity.

13.8.11 PairInMixed

PairInMixed: PIZ

The PairInMixed relationship (definition) is a part_of relationship that applies between a child pair immaterial entity and a parent mixed set immaterial entity.

Example:

LA: *parietal region* LA: *PairInMixed* LA: *neurocranial regions*.

13.8.12 PairInPair

PairInPair: PIP

The PairInPair relationship (definition) is a part_of relationship that applies between a child paired immaterial entity and a parent paired immaterial entity.

Example:

LA: *cubital fossa (pair)* LA: *PairInPair* LA: *anterior region of the elbow (pair)*.

13.8.13 PairInPset

PairInPset: PIQ

The PairInPset link (definition) is a part-of link that applies between a child pair immaterial entity and a parent immaterial pset.

Example:

LA: *deltoid region (pair)* LA: *PairInPset* LA: *upper limb regions (pair)*.

13.8.14 PsetInMixed

PsetInMixed: QIZ

The PsetInMixed link (definition) is a part-of link that applies between a child immaterial pset and a parent mixed set immaterial entity.

Example:

LA: *caudal lateral cisterns (pair)* LA: *PsetInMixed* LA: *infratentorial cisterns (pair)*.

13.8.15 PsetInPair

PsetInPair: QIP

The PsetInPair link (definition) is a part-of link that applies between a child immaterial pset and a parent immaterial pair entity.

Example:

LA: *plantar surfaces of toe (pair)* LA: *PsetInPair* LA: *foot region (pair)*.

13.8.16 PsetInPset

PsetInPset: QIQ

The PsetInPset link (definition) is a part-of link that applies between a child immaterial pset and a parent immaterial pset.

Example:

LA: *superolateral interlobar grooves (pair)* LA: *PsetInPset* LA: *interlobar grooves (pair)*.

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13.9 Log of updates

12 Sep 2025 Full revision. The source reference file is from now on the French version.

14 Feb 2024 Revision of all specializations of the part_of link.

30 Oct 2023 New section on foundation of partonomic lists, about generic lists.

09 May 2023 Extension of the chapter with a detailed introduction.

04 Apr 2022 Creation of the file.

13.10 Credentials

This document is part of the work *Universal Terminology*, which accompanies the website Terminologia Anatomica Humana. It expresses the vision of the authors of the on the foundations of the science of ontology, supporting the terminology presented here. Although it is as accurate as possible, close to the reality of the terminology database and the software that supports it, approximations, errors, and ambiguities are possible and must be considered beyond their control and intentions.

Any comments regarding the content of the website and its presentation are welcome. An appropriate response will be provided if necessary.

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