

Simons, P., 1987. Part I is a standard reference for extensional mereology. Parts II and III treat further topics and question some assumptions of extensionality. Has an extensive bibliography.

References and further readings

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Structure

The notion of structure is of central importance to mereology (for the following see also Koslicki 2008, ch. IX). Historical contributions had this clearly in view; for example, as is brought out in Harte 2002, Plato in numerous dialogues grapples with the question of how a whole which has many parts can nevertheless be a single unified object and ultimately endorses a structure-based response to this question (see *Plato*). Wholes, according to Plato's mature views (as developed primarily in the Sophist, Parmenides, Philebus and Timaeus), have a dichotomous nature, consisting of both material as well as structural components; it is the job of structure to unify and organize the plurality of material parts that are present in a unified whole. A similar conception is taken up and worked out further by Aristotle who famously believed that ordinary material objects, such as houses, are compounds of matter (viz., the bricks, wood, etc.) and form (viz., the arrangement exhibited by the material components for the purpose of providing shelter).

In contrast, due to the development in the early 20th century of a theory often referred to as 'standard mereology', based on the work of Stanislaw Leśniewski and Alfred North Whitehead (see also Tarski 1937, 1956; Leonard and Goodman 1940), the notion of structure has been largely absent from more recent mereological frameworks. (A notable exception, however, is the Third Logical Investigation of Husserl 1900-1.) Because the founders of standard mereology were primarily interested in providing a nominalistically acceptable alternative to set theory, according to standard mereology wholes (also known as 'mereological sums', 'fusions' or 'aggregates') are conceived of as completely unstructured entities. On analogy with the axiom of extensionality in set theory, the existence and identity of a mereological sum is

determined exclusively on the basis of the existence and identity of its parts; the arrangement or configuration of these parts is immaterial to the existence and identity of the sum they compose. In fact, because standard mereology does not recognize a distinction analogous to that between subset and membership, mereological sums are, if anything, even more unstructured than sets, since all the entities recognized by standard mereology are of the same ontological type, viz., so-called ‘individuals’. Finally, as a result of its endorsement of the now controversial principle of Unrestricted Composition (according to which any plurality of objects itself composes a further object, viz., their mereological sum), standard mereology is committed to a plenitude of potentially gerry-mandered objects, such as David Lewis’ notorious ‘trout-turkey’, an object composed of, say, the (still attached) upper half of a trout and the (still attached) lower half of a turkey (see Lewis 1986).

Because standard mereology has been and perhaps still is the most well-worked out and widely accepted conception of parthood and composition in recent history, it was thought that, insofar as ordinary material objects are wholes (i.e., composite objects made up of parts), they must therefore be conceptualized as mereological sums in the standard sense. This seemingly universal consensus among contemporary metaphysicians, however, is now beginning to be called into question by the arrival of some dissenting voices, who have turned their attention to the development of alternative non-standard mereological frameworks, and in particular to the re-introduction of the notion of structure into the analysis of parthood and composition, especially as it aims to capture the mereological characteristics of ordinary material objects (see for example Fine 1982, 1994, 1999; Harte 2002; Johnston 2002;

Koslicki 2008; Simons 1987). To these theorists, it seems quite clear that the material objects we encounter in ordinary life and scientific practice cannot have the conditions of identity and individuation that are attributed to mereological sums by standard mereology: for, unlike mereological sums, not only are these objects quite obviously capable of surviving changes with respect to their parts, while mereological sums (like sets) have their parts essentially; but, in contrast to the completely unstructured nature of mereological sums, the existence and identity of these objects is also evidently tied to the arrangement or configuration of their parts. For example, as is pointed out in Fine 1999, a ham sandwich does not in fact come into existence until a slice of ham is placed between two slices of bread; and the ham sandwich does not remain in the existence unless the parts in question continue to exhibit this arrangement. Given the apparent clash between the conditions of identity and individuation of material objects, as we ordinarily conceive of them, and those of mereological sums in the standard sense, there seems to be plenty of room, then, for the development of alternative structure-based mereologies.

One obstacle that has stood in the way of the pursuit of such alternative systems is that the notion of structure, given its traditional affiliation with Platonic forms or Aristotelian essences, in the minds of many contemporary metaphysicians and mereologists inherits much of the philosophical baggage that is associated with its historical precursors. Aristotle already criticized Platonic forms for being so far removed from the sensible particulars whose characteristics they were supposed to explain that they became, in his view, causally inert and explanatorily useless. Plato’s invocation of the participation relation, which was meant to con-

nect Platonic forms to sensible particulars, did not improve the situation, in Aristotle's mind since he found this relation to be utterly unexplained and mysterious. In reaction to the Platonic model, Aristotle made an effort to connect his own explanatory and causal principles much more intimately to the matter/form compounds whose behavior and characteristics they were supposed to make comprehensible. However, in the course of doing so, Aristotle's own conception of form or essence became associated with philosophically loaded notions such as his actuality/potentiality distinction and the accompanying Homonymy Principle (according to which an 'axe' that cannot cut, for example, is an 'axe' in name alone), which in turn made Aristotelian forms or essences acceptable only to philosophers who share his general teleological outlook.

When we look more closely at the various disciplines in which the notion of structure obviously plays a central and significant role, however, we realize that Aristotle's notion of structure as form need not be conceived of as the causally and explanatorily inert metaphysical invention ridiculed by Descartes and others. Rather, in such disciplines as mathematics, logic, chemistry, linguistics and music, for example, we find that the notion of structure is alive and well, whatever exactly its metaphysical status turns out to be. Although the notion of structure, as it is applied in each case, is tailored to the particular concerns of each such discipline, we can nevertheless recognize certain general characteristics that go along with any such domain-specific conception of structure. (The general characteristics I am about to single out will be illustrated shortly by means of examples from particular disciplines.)

First, structures in general are entities which make available 'slots', positions

or nodes for other objects to occupy; in order to be admissible occupants of these positions, the objects in question must satisfy two different sorts of constraints: (i) constraints concerning the type of object which may occupy the position in question; and (ii) constraints concerning the configuration or arrangement which must be exhibited by the occupants of the positions made available by the structure.

Secondly, a particularly noteworthy characteristic of structures or structural features across different domains is that the numerical identity of the particular objects occupying the positions made available within a structure inevitably tends to be immaterial to the question of whether the structure or structural feature in question is implemented; as long as the occupants in question satisfy the two constraints just mentioned, they are considered indistinguishable and hence interchangeable from the point of view of the structure. Thus, the notion of a structure or structural feature should be thought of as going along with a distinction between what is considered to be variable and what is considered to be invariable within a given domain or context; variability, in this connection, amounts to the interchangeability of objects in the domain relative to certain admissible transformations which leave the structural features at issue unchanged.

Finally, in each case, the discipline in question is interested in particular in capturing, usually by means of a system of laws, axioms, and the like, the characteristics and behavior of those features that are taken as invariable, i.e., the structural features within the domain in question. The particular nature of those elements that occupy the positions made available by a given structure, i.e., elements which are considered to be variable within the domain at issue, on the other hand, tends not to lie within the

purview of the significant generalizations formulated by the theory in question, since these elements in any case are taken as interchangeable as far as the structure is concerned, provided that the type and configuration constraints imposed by the structure remain satisfied. I now turn to the illustration of these general principles governing the notion of structure by means of examples taken from particular disciplines. Mathematical Structure. Structures within mathematics are defined as ordered n-tuples consisting of a set of objects (the universe or domain of discourse) along with 'a list of mathematical operations and relations and their required properties, commonly given as axioms, and often so formulated as to be properties shared by a number of possibly quite different specific mathematical objects' (Mac Lane 1996, 174). Widely studied examples of mathematical structures include for example groups, metric spaces, topological spaces, rings, fields, orders and lattices. Mathematical structures can be compared and contrasted by means of various relations, such as embedding, homomorphism, isomorphism, and the like. As any two isomorphic structures satisfy the same axioms and are thus indistinguishable from the point of view of the theory in question, structures are often said to be describable only 'up to isomorphism'.

Logical Structure. A logically valid argument is one that is not only necessarily truth-preserving, but is so in virtue of its logical form or structure: to illustrate, while the first requirement is satisfied in the argument, 'Roses are red; therefore, roses are colored', the second is not. The notion of logical form makes sense only relative to a particular choice of logical vocabulary: for example, because of the meaning assigned to the logical constant, 'and', any instance of the axiom schema $\vdash p \text{ and } q; \text{ therefore } q$ is valid within classical sentential logic. The role of p

and q in this argument schema is merely to mark places that may be occupied by any non-logical expression of the right grammatical category (viz., in this case, a sentence). Thus, as far as the validity of the argument schema in question is concerned, the interpretation of the non-logical vocabulary may vary, while that of the logical vocabulary stays fixed. The inference-rules of a particular logical system aim in particular to describe the role played by the logical vocabulary in generating valid argument patterns.

Chemical Structure. The chemical structure of a compound is determined on the basis of (i) the types of constituents of which it consists, viz., its formula; and (ii) the spatial (i.e., geometrical or topological) configuration exhibited by these constituents. In the 18th and 19th century, it was discovered, in connection with the phenomenon of 'isomers' or 'chiral' ('handed') molecules, that chemical substances which are composed of same constituents, i.e., have the same chemical formula, can nevertheless exhibit dramatically different behavior under certain circumstances, if these constituents are arranged differently. (Cases in point are for example silver cyanate and silver fulminate as well as racemic and tartaric acid.) This discovery led to a three-dimensional conception of molecular shape, which is still to this day widely employed across many of the natural sciences to explain the processes undergone by organic and inorganic compounds.

Linguistic Structure. Linguistic structure bears a remarkable similarity to chemical structure. For example, the syntactic structure of a linguistic compound is similarly determined on the basis of (i) the types of constituents of which it consists (e.g., noun-phrases, verb phrases, modifiers, and the like) as well as (ii) the hierarchical arrangements exhibited by these constituents; the latter is typically

represented by means of a spatial (i.e., geometrical or topological) vocabulary, consisting of such notions familiar for example from the tree-diagrams used within the Chomskyan tradition as 'being to the left of', 'being higher up than', 'being connected via a continuous downward path to' and so on. These two aspects of syntactic structure help explain why linguistic compounds which on the surface look very similar (e.g., 'John is reluctant to leave' versus 'John is likely to leave') may nevertheless exhibit very different behavior under certain transformations (e.g., '*It is reluctant that John leaves' versus 'It is likely that John leaves'). The numerical identity of the lexical items filling the various positions within a syntactic structure is again immaterial from the point of view of the structure, as long as the syntactically relevant features mentioned in (i) and (ii) remain unchanged; thus, insofar as two lexical items belong to the same syntactic category and fit into the same hierarchical arrangements, they are indistinguishable from the point of view of the syntax and are hence interchangeable without affecting the grammaticality of the resulting construction.

Musical Structure. Musical structure, unlike the other examples considered thus far, of course concerns a perceived or phenomenal order, a kind of ordering or organization which comes about when sound waves interact with creatures like us who are equipped with the sort of cognitive apparatus required to hear sound as music. The experience of hearing sound as music sets up in such a hearer certain expectations as to how the tones he hears are going to be organized with respect to the principles of pitch, rhythm, melody and harmony. Relative to certain musical traditions, e.g., the Western tradition of 'tonal music', it is even possible to speak (though somewhat metaphorically no doubt) of a system of

'laws', e.g., the laws of tonality, which constrain how smaller musical units (e.g., tones) may be organized into larger musical wholes (e.g., chords, patterns, motifs, melodies, and the like) relative to the principles of composition that govern a particular musical tradition. The sorts of arrangements into which individual tones enter are again characterized by means of a quasi-three-dimensional vocabulary invoking space and motion, e.g., 'high', 'low', 'fast', 'slow', etc.

The study of structure, as this concept is relevant in particular to the development of non-standard systems of mereology, confronts several important metaphysical questions which at this point remain relatively underexplored especially in the context of the contemporary literature on parthood and composition. (1) *Ontological Category.* To what ontological category do structures belong? Are they objects, properties, relations, or something else entirely? (2) *Grounding Problem.* How is the modal or essential profile of a structured whole connected to the structure that is present within it? That is, what sorts of contributions does the presence of a structure within an object make to the nature of that structured whole? (3) *Mereological Constraints.* What sorts of mereological constraints do structures impose on the wholes they organize? To what extent and in what way do they dictate the mereological make-up of a structured whole? (4) *Individual vs. Species Forms.* What sorts of structural features are shared by the members of a single kind or species? To what extent should structures be thought of as incorporating haecceitistic features that are peculiar to individual members of a kind? (5) *Structural Change.* To what extent can structured wholes change with respect to their structural features? Through what sorts of structural changes can they persist? The resolution of these questions would

contribute much to the advancement of alternative structure-based systems of mereology vis-a-vis standard mereology.

See also >

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Structure of Appearance, Goodman's

The Structure of Appearance (1951, short SA) is perhaps Nelson Goodman's main work, although it is less widely

known than, for example, *Languages of Art* (1986). It is, in fact, a heavily revised version of Goodman's Ph.D. thesis, *A Study of Qualities* (Goodman 1941, short SQ). SA presents 'constructional' system that, just like the constitution system in Rudolf Carnap's *Der logische Aufbau der Welt* (1928), shows how from a basis of primitive objects and a basic relation between those objects all other objects can be obtained by definitions alone. In SA (and already in SQ) Goodman applies a mereological system, the *Calculus of Individuals*, which he developed jointly with Henry Leonard (first published in Goodman and Leonard 1940). The use of mereology allows him to avoid certain technical problems that Carnap's system encounters.

In the *Aufbau*, Carnap investigates the example of a world built up from primitive temporal parts of the totality of experiences of a subject (the so-called 'elementary experiences' or just 'erlebs') and thus faces the problem of abstraction: how can qualities, properties and their objects in the world be abstracted from our phenomenal experiences. Erlebs, which are time slices of the totality of our experiences, can be part-similar with each other in a variety of ways. Perhaps two slices are similar with respect to what is in our visual field at the time in question, or they are similar with respect to what we hear or smell. However, since the time-slices are primitives in the system, we cannot yet even talk about these respects or ways in which the slices should be similar in order to be considered experiences of the same feature (for example, the same color). Carnap's ingenious idea is to group exactly those erlebs together that are mutually part-similar, thereby grouping exactly those that (pre-theoretically speaking) share a property.

Carnap tries to show that by using this method of 'quasi-analysis' all the struc-