Varieties of Parthood

Ontology learns from Engineering

Peter Simons

Trinity College Dublin

Published in

Philosophy and Engineering: Reflections on Practice, Principles and Process

Diane Michelfelder, Natasha McCarthy, David E. Goldberg (eds.)

Dordrecht: Springer, 2013, 151–163.

DOI 10.1007/978-94-007-7762-0_12

Abstract

We survey mereology, the ontological treatment of part and whole, distinguishing its uncontroversial from its controversial principles and lamenting the excesses to which too great an attraction to formal simplicity leads ontologists. As a partial remedy we recommend greater occupation with the range and variety of uses of the concept ‘part’ in engineering, where artifact parts and their configurations are of vital concern. We highlight some of the major linguistic and conceptual difficulties surrounding the concept of part, and distinguish several more specific concepts of part, noting how distinctive enumeration of artifact parts at different phases in their life-cycle leads to the problem of multiple bills of materials. A related and important concept in engineering and elsewhere is that of a material feature. We discuss this and its partial affinity with the part concept.

Keywords

philosophy and engineering, mereology, part, feature, compositio

For Brian, engineer, at 85.

Image the whole, then execute the parts--
Fancy the fabric
Quite, ere you build, ere steel strike fire from quartz,
Ere mortar dab brick!
Robert Browning

1. INTRODUCTION

Ever since the first deliberately chipped hand-axe, humans have produced artifacts with a view to the different functions of their different parts, and ever since the first axe-head was fitted into a wooden handle, they have assembled artifacts out of functionally and structurally diverse components. In the thousands of years since then, artificers, builders and engineers have had daily currency with artifact parts, the wholes they compose, and the ways in which the parts are put together to make the whole. Philosophers by contrast have only very recently thought it worth *analysing* the concept of the part–whole relation. Of course the concept did not escape them: it is too ubiquitous for that. Plato worried about whether some abstract forms had others as parts; Aristotle pointed out that the term '*meros*' (part) has several meanings in ordinary Greek. But the concept of part did not move to centre stage in philosophical discussion until the late 20th century. At the beginning of that century, starting with some observations of Edmund Husserl, (Husserl 1970), logicians, most notably Stanisław Leśniewski (Leśniewski 1916) and Alfred North Whitehead, (Whitehead 1919) developed formal theories of part and whole, for which theories Leśniewski coined the term 'mereology'.

In this paper I review some of the problems and controversies surrounding philosophers' formal treatments of parthood, and will conclude that their views, more prevalent than ever in the philosophical community, are simply too monocultural to account for the wide variety of part-concepts met with and required in applications, most especially in engineering. The moral drawn is that formal theories of parthood must be supplemented and if necessary corrected by empirical information about actual thought and practice outside philosophy, and that one of the best sources for such information is engineering.

2. PHILOSOPHICAL MEREOLOGY

Mereology was developed initially for mathematical purposes: as a nominalistically acceptable substitute for set theory (Leśniewski) or as a logical framework for geometry (Whitehead). By the late 20th century it had become apparent that the standard formal resources of philosophers (interpreted predicate logic and set theory) were insufficient to articulate the variety of problems in ontology and metaphysics (Simons 1987), and mereology became a central instrument in the ontologist's toolkit, so that nowadays a significant proportion of metaphysical disputes turn on matters of mereology. Nevertheless, ontologists have tended to take over the strong algebraic assumptions of the early mereologists (Simons 2007). Partly as a result, a large number of the mereological problems which preoccupy metaphysicians have little or no relevance to engineering practice or theory. Despite this, the concept of part–whole in engineering is not a mere simple application, to be indicated in passing while sticking to the theoretical high road. On the contrary, the mereology of artifacts is rife with problems, for which the philosophical ontologist's mereology is of little or no use. It is the central contention of this paper that until the crucial differences between the "pure" mereology of philosophers and the "applied" mereology of engineers are more carefully articulated, there will continue to be a significant gap between their respective mereologies, rendering these mutually almost irrelevant. It is precisely the job of the *philosopher* to recognize and articulate such differences and to see that philosophical theory, no matter how abstract, does not become wholly detached from real-world considerations.

3. UNCONTROVERSIAL PRINCIPLES OF PARTHOOD

We use the term 'part' in its normal everyday sense, according to which a part is something less than the whole. What this means precisely can be spelled out. Firstly however what it implies is that no part is identical with its whole:

IRREFL If A is part of B, then A is not identical to B

Secondly, that a part of a whole cannot have that whole as a part:

ASYMM If A is part of B, then B is not part of A

Logically, we only need the second principle, since the first follows from it: if A were identical with B they would be alike in all respects, so then B would be part of A. But it is not, so A and B cannot be identical. A crucial formal property of the part-relation is its transitivity

TRANS If A is part of B and B is part of C then A is part of C

Many relations satisfy these principles without being part-relations, for example the less-than relation among numbers. So we need to add more to distinguish the part-relation. This takes a little more work. Here is how we do it. Firstly we define a concept of (mereological) coincidence

Def.COIN A coincides with B if and only (Df.) A is identical with B or A and B both have parts, and they have the same parts.

This allows for the possibility that A and B have the same parts and yet are not identical.

We now use this to define a notion of ingredient

Def.INGR A is an ingredient of B iff (Df.) A is part of B or A coincides with B

So if A is identical with B, A and B are ingredients of one another, by the definition.

Now we define disjointness:

Def.DISJ A is disjoint from B iff (Df.) nothing is an ingredient of both A and B

We are now in a position to say what else we need for A to be part of B: it is the principle of supplementation:

SUPPL If A is part of B then B has a part which is disjoint from A

For example, the frame is part of a bicycle, but other parts such as the wheels are disjoint from the frame.

The principles ASYMM, TRANS and SUPPL are analytically true of the part relation, and diagnostic (constitutive) of it against relations satisfying other formal principles.

4. CONTENTIOUS PRINCIPLES

Philosophers have put forward two mereological axioms that go well beyond the analytic principles constitutive of the part relation. These are mereological *extensionality*

EXT Coincident things are identical

And the principle of universal *composition*

UC Any collection of individuals compose a further individual, called their *mereological sum*.

Taken together these imply that the mereological sum of any collection of individuals is unique.

EXT is a thesis in keeping with standard conceptions of mathematical discourse, and in particular it is analogous to the extensionality principle of set theory, according to which sets with the same elements are identical. Although the less deleterious of the two contentious principles mentioned here, it does have one consequence that is not neutral. Sometimes an object is composed of parts yet we have reasons not to identify it with the sum of these parts. For example a casting is made of a certain consignment of metal. The sum of parts of this metal could have made other things than the casting, but the casting could not not have made anything else: it is what it is. So we want to distinguish the casting from the sum of metal making it up, though they appear to have the same parts. Likewise a dry stone wall is made up exclusively of a number of stones, and it and the sum of the stones have the same parts, but they are not identical since the sum can survive scattering, whereas scattering would destroy the wall.

UC leads more obviously to ridiculous and absurd consequences, for example that there is a whole composed wholly of my left hand and Napoleon's left foot, which therefore did not exist in 1900 but did in 1820 and in 1970. Another weird whole consists of the odd-numbered breaths that Napoleon took between 1810 and 1815, another consists of Napoleon's last breath and the Tower of

Pisa. Yet such bizarre ontological monsters are defended by philosophers on both pragmatic and *a priori* grounds.

To illustrate how how easily the philosophical debate can become divorced from common sense, we may note that two diametrically opposed positions, both anti-common-sense, are now taken seriously in the contemporary ontological literature. One says that there is really only one thing, and it has no parts (monism). The other says that there are only atomic (simple) things, and no complex objects (radical atomism, RAT). Such extremes have been rare since the pre-Socratics (6th C BCE).

A related debate within the literature concerns the question under what conditions a collection of parts compose a whole. This is known as the *special composition question*. (Van Inwagen 1990). UC represents one extreme answer to this question, RAT the opposite extreme. RAT entails that mereology has no meaningful role to play in ontology, since nothing has any proper parts. Its applicability depends on the assumption that there are metaphysical atoms, which may be true, but also may not: as far as mereology and science currently tell us, there is no reason to deny that everything has proper parts without end. The extremes of UC and RAT are so attractive to philosophers that I have known at least one ontologist to have simply switched his alliegance from UC to RAT without adopting any of the many possible intermediate positions, wherein, somewhere, the truth lies.

Mereology with EXT and UC is known as *classical extensional mereology* or CEM (Simons 1987, Ch. 1). Rather than enter into philosophical debate, in the spirit of (perhaps misplaced) ecumenism, let's give proponents of CEM their concept and call it that of the M-part ('M' for 'mereological'). No one to date has convicted it of inconsistency, for the simple reason that it is provably consistent. A world consisting of a single individual with no proper parts (one-element model) satisfies all the principles of CEM. The question is not whether CEM and its M-part concept are consistent, but whether they are useful, whether other concepts of part are needed and/or are preferable.

5. AMBIGUITIES OF 'PART'

One reason why the mereological part concept has been able to gain a near-monopoly of acceptance among philosophers is that there is a subtle ambiguity in the use of the term 'part', not one which was picked up by Aristotle. It turns on the distinction between 'is part of' and 'is *a* part of'. One aspect of this distinction correlates with the distinction between mass terms like ‘paint’ or ‘steel’ and count terms like ‘car or ‘elephant’. Part of a car is the paint on its body, another part is the steel in its body. Neither the paint nor the steel would be called *a* part of the car, unlike its engine, its windscreen, or its steering wheel. Mixtures such as alloys and solutions have different parts, in the mass sense: steel is a mixture of iron, carbon and often other elements. Bronze is a mixture of copper and tin: it has these two parts, in varying proportions depending on the type of alloy. Air is a mixture of nitrogen, oxygen, carbon dioxide, water vapour and other gases, and so on. Each of these gases is part of the mixture. On the other hand the gas in a closed container such as an aircraft in flight has parts that are not the individual components of the mixture. There is (at any one time) the part in the first-class cabin, the part in the economy class cabin, the part in the air-conditioning system, and so on. The term ‘part of’ is in vernacular use more flexible that the term ‘a part of’ and that helps to explain why the mereological or M-part concept is liked by philsoophers: it is more widely applicable. When we say ‘*a* part’ however we typically have some more limited notion of part in mind: a selection of such concepts will be given in the next section.

Both ‘is part’ and ‘is a part’ use the grammatical singular, but ‘part’ can also occur with the plural: ‘the women on the electoral register are an important part of the electorate’ (not ‘part*s* of the electorate’!) This is because when we allow plural terms as well as singular ones, the logic of ‘part of’ holding between plurals is the same as that for ‘part of’ holding among singulars. The women are part of the people but not all of them, the men are another part disjoint from the women, and so on. Very often we can interchange ‘part of’ with ‘some of’, both for plurals and for mass terms. The part of the air in the first-class cabin is some of the air in the aircraft, the women in the electorate are some of the electorate, and so on. For singulars however, instead of ‘some of’ we say ‘one of’. The unstressed pronunciation of ‘some’, pronounced [sm̩], can be used with mass and plural nouns in the way that ‘a’ may be used with singular count nouns:

A man came to the door

Sm coffee was spilt on my keyboard

Sm people came in waving sticks

These show that English, like French, has mass and plural indefinite articles. Incidentally it is highly suggestive that the grammatical term for these in French

Du café a été renversé dans mon clavier

Des gens sont entrés en brandissant des bâtons is ‘partitive’. To date and to my knowledge no one has done a thorough investigation of the grammatical varieties of ‘part’ from a philosophical and linguistic point of view.

Another closely related conception is that of the constitution of an object out of matter or materials, obviously a subject of serious interest to engineers. In ancient times Aristotle proposed that all material things are compounded of two disparate elements: the form and the matter. While this hylomorphic conception of things was decisively rejected for science in the scientific revolution, in everyday terms the notion of matter or materials applies quite naturally. The engine casting is made of alloy, the dry stone wall is made of stones, more complex artifacts are composed of many disparate materials. As standardly understood, the materials of a complex whole are taken in a “mass” way: so much of this, so much of that; whereas the parts of a complex whole are understood in a “count” way: this part, that part and so on. And when we consider materials like glue, paint, weld etc., many artifacts (as indeed organisms) consist both of parts and of materials. The relationships between parts and materials are complex and by no means transparent, and have been largely ignored by ontologists (but cf. Simons 1987.)

6. MORE SPECIFIC PART-CONCEPTS

6.1 Physical Part

One perhaps not wholly determinate concept, but one which is certainly worth using and trying to get more determinate, is that of a *physical* part, or P-part. Consider a metal bar. It might be cut at the centre into two pieces, but suppose it is not. Each of the two halves is a physical part of the whole, even though neither is a detached physical body. By a physical part we mean a part that could if separated from the rest be a physical object in its own right. To a first approximation, a P-part is one which is causally internally connected, but not in general a maximally connected whole. Even such arbitrary parts as the left-hand half of a car are physical parts: were such a car sliced in two (as was once portrayed in a James Bond movie) the left half would become a physical object in its own right. By contrast, the object considered by taking the sections of the bar at 1–2 cm from one end, and 3–4 cm, and 5–6 cm and so on, is not a P-part of the bar, because removing the rest does not give a physical object but several physical objects. Of course we could fuse these together somehow to give one object, but then they compose something *new*, and that’s the point. Of course we may want to distinguish between *connected* and disconnected P-parts: there may be some genuine (not merely topological) basis for that further distinction. For the moment however let’s stick with this first additional concept. All P-parts are M-parts, but not vice versa. M-parts need have no internal causal cohesion whatever: that's one of the things people don't like about them.

6.2 Salient Part

There is also a somewhat vaguely delimited notion of part of something which is in some way *salient*. Call these S-parts. A part may be salient (to a given set of potential observers via one or more sensory modalities) by virtue of its geometric prominence, or its material or qualitative discontinuity from adjacent parts. An example of a salient part (which is always a physical part but not necessarily vice versa) is the lower part of an aircraft fuselage which is painted a different colour from the upper part. For example the upper part may be white and the lower part may be blue. The shape of the line separating the two parts may be deliberately chosen for example to emphasize speed, or to look elegant. Salience in this case indicates that the part is intended to be discerned by observers. But sometimes a part may be salient unintentionally or incidentally, as for example the carburettor bulges on older sports cars sometimes are (of course in time such bulges came to be associated with power and speed, so designers took pains to put them in just to advertise those connotations).

6.3 Engineering Parts: D-A-R-T

Now let's bring engineering into the picture. For any artifact that might be interesting to an engineer, some parts are more important than others. Not all P-parts are important. So call E-parts all parts that are of interest to an engineer. This is not a wholly objective demarcation so again let's try for a bit more precision, in the knowledge that improvement is incremental. Parts play different roles in engineering depending on what stage of the life-cycle of an artifact we are considering. A part which is envisaged as a unitary part during the *design* of an artifact we call a D-part. One which is manipulated as a separate individual during *assembly* we call an A-part. One which is manipulated as a separate individual during *repair* we call an R-part. And finally one which is manipulated as a separate individual during *retirement* we call a T-part ('T' as in 'reTire'). That gives DART as an acronym. It is possible for a given physical individual to play all four roles, D- A- R- and T, in the economy of a complex artifact. A door of an automobile might be an example. On the other hand, the exigencies of design, manufacture, maintenance and retirement mean that there are frequent discrepancies: what is designed as a D-part may come together only incidentally in manufacture, e.g. the braking system of a truck is never manipulated as a unitary separate object. Modular replacement and repair mean that many A-parts are never R-parts: a sealed headlamp unit in an automobile is an R-part of the automobile which has many A-parts (the unit was assembled) but no R-parts (it is replaced as a whole). Discrepancies among the different kinds of part lead to the so-called *Multiple Bill of Materials (BoM) Problem*, which is a practical hurdle facing electronic documentation of the mereology of complex artifacts across their life-cycles. (Simons and Dement 1996).

We are *not* here saying there are four completely new concepts of part: what we are saying is that there are four different *roles* that parts (mostly P-parts) can fill in the life-cycle. And even parts which are not E-parts as here defined may be of at least passing interest to an engineer. Suppose a screw fails to hold a certain slightly friable material because its head is not wide enough, and the material works lose around the head. The engineer will take an interest in the screw head which is, we may suppose, a P-part but not an E-part of the screw (it was turned out of a single piece of material), in that s/he will expect the screw (*not* the head) to be replaced by another with a wider head.

6.4 Functional Part

That brings me to a crucially important role for parts, the most important in regard to engineering, which it is vitally important to recognize and yet surprisingly difficult to make fully precise. That is the idea of a part which performs a unified *function* in the working of the whole artifact. Call this an F-part. For example, the screw head in the example just given is an F-part, since its function is to brace the screw against the material it is intended to hold down. We shall assume then that all F-parts are E-parts, since an engineer has to be interested in function. But as the example shows, an F-part need not be a DART-part (i.e. not any one of those). Some P-parts like the screw head are F-parts, but others are not. The left-hand half of the car is not an F-part. It will not do to invent *ad hoc* "functions" for such parts such as "holding up the right half" just to make anything an F-part. The function has to be describable independently of invoking the part in question. In this case it is not, since the right-hand half is obviously just the mereological complement of the left-hand half. By contrast a function such as "providing forward visibility while shielding occupants from the wind of forward motion" is a description of the function fulfilled by a transparent windscreen (windshield) on a vehicle, and could in principle be fulfilled by some other part or method, e.g. (without considering practical feasibility) a repulsive force-field or forceful cross-draught.

7. MATERIAL FEATURES

There is another general concept associated with material objects (not just artifacts, but natural things as well) which is not a concept of a material part, but which is sufficiently similar and sufficiently important to require treatment here. This is the concept of a *material feature* (Simons 2002). One example is the cross-shaped recess in a screwhead, enabling it to be turned by a suitably shaped driver. Another is the helical thread on the screw with its V- or U-shaped section. Yet another is the hole in a washer or nut, which enables a bolt to pass through it. The teeth of a gear wheel are P- and F-parts of the wheel, but the recesses between the teeth, which allow it to engage with other gear wheels, are material features, not material parts. In general such features as holes, (Casati and Varzi 1994) slots, grooves, recesses, cavities, edges, ledges, ridges, corners, waists, tunnels, surfaces and other interfaces are material features, and as the examples indicate, they are to be found among natural objects just as much as among artificial ones, for example in physical geography or human anatomy.

We cannot here attempt a rigorous formal ontological definition of a material feature, not least because it promises to be complicated and may require several overlapping definitions to cover different cases. But we can offer enough by the way of characterization to make the concept's distinctness and importance clear. We mention four ways in which material features are *like* material parts, and two ways on which they are *unlike* them. Firstly, a material feature is, like a material part, a *located individual*. It is not a general property, or a relation, or a mass of material. As a located individual, it can reasonably be attributed causal powers, at least of a passive nature. A hole, slot, tunnel etc. *permits* the insertion or passage of light, matter, objects, constrained by its surrounding matter. In engineering, that it often its precisely what it is there for. Secondly, like material parts, material features generally have a geometrical *shape*, whether stably or fluctuating over time. Thus engineering drawings, blueprints, and their electronic successors, CAD files, can deal with features like holes in the same way in which they deal with parts, by indicating the boundaries of material parts. Thirdly, in a quite general but intelligible sense, a material feature is *something about* a larger object in much the way that a material part is. For that reason it is tempting in various contexts to describe and think of material features as weird kinds of part, *immaterial parts*. Of course such a conception is inherently confused, but it does signify our recognition of an affinity between parts and features, as well as our need to talk about features and give them their due. Fourthly, material features in engineering can have functions just as much as parts do. As indicated, a hole in a nut is there to allow a bolt to be inserted through it, while the thread on the inside of this hole is there to engage with the thread in the bolt and ensure a secure physical bond between them, as well as (by the threads' matched helical forms) allowing rotation to be converted into pressure exerted along the bolt's central axis in order to hold something firmly between the nut and the bolthead.

Conversely, a material feature is distinguished from a material part in two crucial ontological respects. Firstly, in general a material feature is not *made of* matter in the way in which a material part is. This applies in particular to those features which are obviously in some way concave. Obviously a hole or slot is not made of material like its surrounding matter is, otherwise it would not be there. We form a hole, slot etc. typically by *removing* matter. The hole etc. may be *filled* by something such as air or oil, fuel or hot gas, but that is different. A cavity persists as a feature despite being filled, and indeed its being suitably filled is often the point. The function of a rocket nozzle (the nozzle as material part) is to surround and define a complicatedly shaped cavity (the nozzle as material feature) through which hot expanding gas is designed to flow in a certain way.

Another kind of material feature are *boundaries*, such as a surfaces, edges, ends, tips, points: the outer surface of a sphere, the inner surface of a tube, the cutting edge of a chisel, the end of a rod, the point of a needle. There are two competing conceptions of boundary, one mathematical, one physical. The mathematical conception uses topology and geometry. In this conception a boundary has at least one fewer dimensions than that which is bounds: a surface of a body has two dimensions, and edge one, a point zero. These are very apt for mathematical modeling and for simulation in computer software such as CAD systems. However such boundaries without bulk cannot account for the physical discontinuities and properties of real boundaries among material things, such as refraction, change in the velocity of sound, or surface effects such as optical films. So for engineering purposes, which is what engineering requires, a physical conception of boundary as a thin layer of material with often exceptional properties is more appropriate (Simons 1991).

Secondly, the material feature nevertheless *requires* its adjacent matter in order to be what it is: a tunnel is not nothing (ask a tunnel engineer), but it is nothing without material surrounding it. In the jargon of formal ontology, material features are *ontologically dependent* on their adjacent material. How this dependence works varies slightly from case to case.

It should be obvious even from the few simple examples given here that material features are very important in engineering, almost as important as parts. This, and the utility of CAD modeling, explain the importance of feature-based design in manufacturing engineering, despite the different senses sometimes attached to the term ‘feature’. The preponderance of similarities over dissimilarities between material features and material parts also explains why we are often tempted to consider features as a sort of part. Indeed as the rocket nozzle example indicates, we sometimes use the same word for both a material feature and the material that bounds it and on which it depends, although these are ontologically speaking wholly different entities. We might even want to call material features *quasi-parts* of the objects they depend on. It is worth considering to what extent the various distinctions drawn above among different subspecies of part can be applied to quasi-parts.

8. PROCESSES AND THEIR PARTS

Processes, apart from their ubiquity and importance in nature, or of vital interest to engineers. The operation of any artifact that entails motion or other change involves processes. These include motion of many types, chemical processes such as reactions, physical processes such as changes in temperature, pressure, shape and other parameters, as well as all the processes involved in the manufacture, running, maintenance and retirement of artifacts. Not for nothing is there a whole branch of engineering bearing the name 'process engineering'. According to some philosophers, among whom I count myself, processes are metaphysically more fundamental than enduring things or *continuants* (Simons 2000). That debate is a lively one within philosophy, albeit that for most of the history of western philosophy the idea that continuants are more basic has had the upper hand. The difference between enduring things on the one hand and processes, events and states on the other is that the latter have *temporal* parts or *phases*, whereas the former do not. So a football match or an explosion has earlier and later parts, whereas a chair or a human being does not. Their lives or careers have temporal parts. Both enduring things and processes may have spatial parts: the difference is that the parts of an enduring thing may move around and change wholesale.

There is then clearly room for a mereology of processes, and their countable associates, events. Some events are indeed minutely scrutinized and anatomized, distinguishing their various parts and their relationships: these include crucial historical events like battles and assassinations, catastrophic events like natural disasters and spectacular accidents like the sinking of the *Titanic* or the explosion of the space shuttle *Challenger,* and on a more mundane level, the critical parts of sporting events, and the myriad of crimes investigated by organs of justice. Biographers make it their trade to describe and relate the events in a person's life, itself a whole composed of countless smaller events and processes. We are thus adept, at an intuitive level, at discerning the parts of events and processes. Relatively little thought has however gone into the question whether we can simply adapt the mereology coming from mathematics and logic for processes. In many respects it appears to be easier to do so than to pursue mereology for continuants, which may change their parts over time, either naturally or by repair. There is doubtless much more to be learnt about the ontology and mereology of processes.

9. PARTS AT A TIME

Unlike processes, which just have parts, continuants have parts at a time and over a time. For example a young man has a full head of hair, but in old age he is bald. A house may acquire an extension, or new built-in cupboards. A car requires a new clutch: the old part is taken out and replaced by a new one. And so on. Some parts are permanent: the continuant has them as long as it lives, others are temporary, even intermittently parts. Some artifacts spend more time dismantled into their component parts than assembled into a whole: guns, musical instruments, some complex tools would be examples. Some parts may come into existence by the configuration of other parts, either permanently or temporarily. In general, the ontology of parts at a time and their manifold changes over time, in themselves, in their relation to one another, and in their relation to the whole, is another one of those subjects that appears to be below the interest threshold of most ontologists, while yet being of crucial concern to engineers. Yet it is not without its high theoretical interest. Plutarch, in his *Life of Theseus*, relates how

> The ship on which Theseus sailed with the youths and returned in safety, the thirty-oared galley, was preserved by the Athenians down to the time of Demetrius Phalereus. They took away the old timbers from time to time, and put new and sound ones in their places, so that the vessel became a standing illustration for the philosophers in the mooted question of growth, some declaring that it remained the same, others that it was not the same vessel.

In a twist to the story Thomas Hobbes imagines someone collecting the replaced parts until he has a complete set, whereupon he rebuilds the "original" ship, and the question whether the ship made of the original materials or the ship with the replacement materials is the "real" ship. Pragmatically of course a decision can simply be made on grounds of expediency, tradition or fiat, but the problem is theoretical as much as practical, and illustrates how clarity about the role of parts in a whole at and over a time can help to settle otherwise puzzling disputes.

10. CONCLUSION

Mereology, the formal-logical theory of part–whole and cognate relations, is around a century old. It has been thoroughly incorporated into the toolkit of modern analytic ontology, generally to the benefit of the latter. However the special purposes for which it was originally introduced, which were connected with the foundations of mathematics and physics, endowed it with a number of features which have impeded its neutral application both within and outside philosophy, and have led some ontologists to extreme and implausible positions about what there is. Since part of the point of ontology is to be able to connect with the special sciences, it is to no-one's advantage if the formal theory of part and whole interferes with the standard working assumptions of those sciences, either by unreasonably denying the existence of things everyone normally accepts (such as artifacts composed of many parts), or by propounding the existence of things no-one would normally dream of (such as bizarre mereological hybrids and monsters).

In these circumstances the obvious solution is to pare back the formal account of part and whole to cover only those logical properties that are analytically constitutive of the concept, and to leave everything else open. That allows there to be a variety of more specific part-concepts in which different features are optionally added according to the use in different contexts. That is the route we have recommended. It allows mereology to be more responsive to the needs and practices of different sciences, which benefits both sides: ontologists can bring their drive for conceptual clarity to bear on problems encountered in theory and practice outside their subject, while the rigours of encountering real problems can lend their theories greater robustness.

REFERENCES

Casati, Roberto and Achille Varzi 1994. *Holes and other Superficialities*. Cambridge, MA: MIT Press.

Husserl, Edmund 1970. *Logical Investigations*. Translated by J. N. Findlay. London: Routledge & Kegan Paul. Investigation 3: On the Theory of Wholes and Parts.

Leśniewski, Stanisław 1916. *Podstawy ogólnej teoryi mnogości*. Moscow: Poplawski. Translation: Foundations of the General Theory of Sets, in S. Leśniewski, *Collected Works.* Dordrecht: Kluwer, 1992, vol. 2. 129–173.

Simons, Peter 1987. *Parts.* Oxford University Press.

--- 1991. Faces, Boundaries, and Thin Layers. In: A. P. Martinich and M. J. White (eds.), *Certainty and Surface in Epistemology and Philosophical Method. Essays in Honor of Avrum Stroll*. Lewiston, NY: Edwin Mellen Press, 87–99.

--- 2000. Continuants and Occurrents. *The Aristotelian Society, Supplementary Volume* **LXXIV**, 78–101.

--- 2002. Characters and Features: Individual Attributes and their Kin in Biology and Engineering. *The Modern Schoolman* **59**, 235–252.

--- 2007. Real Wholes, Real Parts: Mereology without Algebra. *Journal of Philosophy* **103**, 597–613.

Simons, Peter and Charles W. Dement 1996. Aspects of the Mereology of Artifacts. In Roberto Poli and Peter Simons, eds., *Formal Ontology*. Dordrecht: Kluwer, 255–276.

Van Inwagen, Peter 1990. *Material Beings*. Ithaca: Cornell University Press.

Whitehead, Alfred North 1919. *Enquiry Concerning the Principles of Natural Knowledge.* Cambridge: Cambridge University Press.