

## 21. TROPE BUNDLE THEORIES OF SUBSTANCE

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### 21.1 Introduction

This chapter is an opinionated introduction to contemporary theories according to which substances or objects are bundles of tropes. “Substance” and “object” are taken as interchangeable in this context. Substances are spatiotemporally located, particular, and persisting individual entities that bear properties. Substances can be illustrated by ordinary objects like trees, dogs, and houses, but some theories consider elementary particles better examples of substances (such as electrons and quarks).

Tropes are natures, which may be taken either primitively or derivatively. Moreover, tropes are particulars, although different trope theorists have different conceptions of particularity. We think the best examples of particular natures are basic physical quantities like determinate electric charges, but some other theorists take colors and shapes as tropes (too). Tropes are simple: if tropes have parts, all these parts are tropes and it is standardly assumed that substances are ultimately constructed out of mereologically simple tropes. Nonetheless, tropes are parts, as will be seen below. Tropes form the only fundamental ontological category. They are also considered as located in spacetime. Finally, tropes are individuals: they have numerical identity and are unities (each trope is one entity).

In his *The Elements of Being* (2018a[1953]), D.C. Williams coined the term “trope” for the ontological category of simple or thin particular natures (“occurrences of essences”). In addition to constructing substances out of tropes, he introduced tropes to eliminate the fundamental object-property dichotomy (2018a[1953]: 30–31) and hence substances and properties as fundamental ontological categories. The trope bundle theories considered in this chapter follow Williams’ insight: they take tropes to form the sole fundamental ontological category. Therefore, these theories eliminate substances as a fundamental category. Accordingly, this category is (formal ontologically) analyzed reductively. This results in a ground-breaking insight by Williams: analyzing substances and inherence (that is, a substance having a particular property) reductively go hand in hand in trope bundle theories. Therefore, we examine analyses of substances as trope bundles from the point of view of analyses of inherence, too.

The first and most important question for each trope bundle theory is then the problem of unification: how are individual tropes unified into an individual substance? This unification can be considered synchronically, diachronically, and counterfactually. Second, since a substance is spatiotemporally located, we need an explanation about how the tropes that are its parts determine its location. Third, our best science suggests that many substances are members of natural kinds but there are only a limited number of these natural kinds (e.g., kinds of elementary particles). Accounting for this is a reasonable requirement for trope bundle theories. Relatedly, the number of the kinds of tropes constructing substances is also restricted. Why this is so is a further question involved in the substance construction out of tropes. As will be seen below, different theories give different answers, with their merits and problems, to these questions.

Each of these trope bundle theories introduces exactly one fundamental ontological category, which gives categorial ontological economy and parsimony with respect to different kinds of formal ontological relations.<sup>1</sup> Categorial ontological economy in the service of solving key metaphysical problems is a good reason to hold a trope bundle theory (cf. Ehring 2011: 45ff.).

In what follows, we start by discussing Williams' and Keith Campbell's (1990) paradigmatic trope theories, especially as they pertain to substance, and highlight some problems with these theories (Section 21.2). This sets us up, in Section 21.3, to present two recent developments of trope bundle theory that attempt to address these problems (Ehring 2011; Maurin 2002). These recent developments maintain, like the paradigmatic theories, that non-relational tropes are existentially rigidly independent beings. Hence, we label them *independence theories*. Finally, in Section 21.4, we present two alternative trope bundle theories that suppose non-relational tropes are dependent existents, *dependence theories*, namely, Arda Denkel's (1996, 1997) Saturation theory and our Strong Nuclear Theory.

## 21.2 Paradigmatic Trope Theories

Williams outlined a systematic trope theory in which tropes are considered existentially independent fundamental entities. According to him, substances are mereological sums of *concurrent*, that is, spatiotemporally exactly co-located tropes. In the beginning chapters of his *Abstract Particulars* (1990), Campbell develops further the idea of tropes as particular natures, members of a single fundamental category, and independent existents. There are some interesting differences between Williams' and Campbell's

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<sup>1</sup> Formal ontology is the branch of metaphysics that analyzes ontological categories by ontological forms (forms of being), which correspond to different formal ontological relations like being a part of or being existentially dependent on (Hakkarainen and Keinänen 2023b).

views, which we will discuss later in this section. Nevertheless, Williams' and Campbell's trope theories are usually grouped together under the label of "classical trope theories" (Fisher 2018, 2020; Maurin 2023). We begin this section by describing the common ground of their views.

Williams and Campbell use the terms "abstract" and "concrete" in a fashion that deviates from the currently standard use: spatiotemporal versus non-spatiotemporal. Tropes are "*abstract*" in the specific sense of being able to be exactly spatiotemporally co-located (concurrent, compresent) with other tropes. Substances are mereological sums of mutually co-located tropes, which thereby "monopolize" their locations (Campbell 1990: 3; Williams 2018a [1953]: 28–29). Substances are "*concrete*" in the sense of monopolizing their locations.<sup>2</sup> For instance, suppose that substance *i* is a micro-particle which is constituted by three determinate quantity tropes,  $t_1$ ,  $t_2$ , and  $t_3$ . Let us say  $t_1$  is a -e charge trope,  $t_2$  a determinate mass trope, and  $t_3$  a spin trope. One may now propose the following *analysis of inherence*:

[CI]: Trope *t* is a property of substance *i* if and only if *t* is a part of *i* and *t* is exactly spatiotemporally co-located with *i*.

Thus, substance *i* has -e charge trope  $t_1$  as its property because  $t_1$  is a part of *i* and is exactly spatiotemporally co-located with *i*. Both Williams (2018a[1953]: 30–31) and Campbell (1990: 59) accept a similar analysis to [CI], although they present it as a part of an analysis of *exemplification*, that is, of objects' possessing properties as general entities.<sup>3</sup>

Thus, the advocates of paradigmatic trope theories assume that tropes are particular natures, fundamental particulars, and individuals (that is, countable unities with numerical identity), which have some specific spatiotemporal location. The additional assumption is that every plurality of mutually exactly co-located tropes forms a certain kind of individual, namely, their mereological sum. Moreover, any such mereological sum is a substance (cf. Campbell 1990: 21; Williams 2018a[1953]: 29–30). In standard cases, substances are complex individuals typically constituted by two or several tropes. However, free individual tropes are allowed for and they are limiting cases of inherence, objects having exactly one property.

There are several interesting differences between Williams' and Campbell's trope theories. First, according to Williams (2018b[1960]: 52–55), every substance is an occupant of a four-dimensional manifold (place-time), which he calls a "plime" (Fisher

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<sup>2</sup> See Fisher (2020: 44–45) for a detailed description of Williams' abstract/concrete distinction.

<sup>3</sup> We distinguish between exemplification, i.e., an object possessing general properties (universals or their substitutes), and inherence, i.e., an object having properties taken as particulars.

2020: 45). Williams also adopts a four-dimensionalist conception of persistence: substances and tropes exist at different times by dividing into temporal parts (Williams 2018b[1960]: 53). Because he adopts classical extensional mereology, Williams can also construe temporally extended tropes as mereological sums of their temporal parts (Williams 2018a[1953]: 29). By contrast, Campbell (1990: 3, 24, 131) seems to leave open the possibility that temporally persisting substances divide into temporal parts and occasionally considers substances and tropes as if they were endurants (Campbell 1990: 132, 141). Campbell's view is perhaps best interpreted as leaving open the question of whether tropes/substances are endurants, perdurants or exdurants.

Second, Williams and Campbell disagree, at least as a theoretical ideal, about the existence of relations. Williams (2018c[1963]: 108ff) considers spatiotemporal relations credible examples of external relations. It seems that we need to introduce entities additional to their relata such as particular relations to account for the holding of these relations. According to Campbell (1990: ch. 5), preserving trope theory as a one-category ontology requires that we find non-relational truthmakers for all relational truths, including contingent ones.

The third difference between Williams' and Campbell's views is perhaps the most interesting. According to Williams (2018a[1953]: 28), concurrence is a "limiting value of location", namely, exact spatiotemporal co-location. If one adopts this view, one might think that the spatiotemporal relations that determine the relative locations of tropes also determine which tropes are concurrent with each other. The way in which Campbell formulates his trope theory in the first 58 pages of his *Abstract Particulars* is consistent with taking compresence as a limiting value of location as suggested by Williams in the case of concurrence. Nevertheless, toward the end of *Abstract Particulars*, Campbell starts to treat compresence as a fundamental relation connecting tropes which are parts of a single substance. Campbell considers such relations of compresence the best candidates for particular relations, which one is obliged to postulate unless one is willing to introduce specific field tropes (Campbell 1990: 58–59, 69, 130–133). Of the recent trope theorists, Anna-Sofia Maurin (2002) and Douglas Ehring (2011) follow the later Campbell by taking compresence as primitive (see Section 21.3 below).

If successful, Williams' paradigmatic trope theory would constitute a metaphysician's paradise because of its simplicity and categorial ontological economy. There is only one fundamental ontological category (tropes), which is determined by comparatively transparent formal ontological relations such as identity and parthood. By analyzing inherence by means of parthood and exact co-location, trope theory avoids the fundamental dichotomy between characterizing (properties) and characterized entities (substances). An account of the spatiotemporal location of tropes, which is required in any case, provides us with substances having certain properties in different locations as a by-product.

Nevertheless, Williams' paradigmatic trope theory faces a series of difficulties. First, both Williams and Campbell are Humean trope theorists who thus deny existential dependencies between wholly distinct individual tropes that constitute a substance. According to them, it is a matter of contingent fact that tropes standardly occur in "concurrent/compresent groups" (Campbell 1990: 21; cf. Williams 2018a[1953]). However, there is "an explanatory gap" between this official view and the fact that we encounter things belonging only to a limited number of natural kinds. If the building blocks of physical reality (e.g., fundamental particles) are trope bundles, they seem to be constituted by a very limited set of different kinds of tropes determining their natural kind. It seems that, minimally, the trope theorist should be able to say which kind of explanation – metaphysical or, perhaps, empirical – would shed light on the issue of why substances are constituted only by a highly restricted number of different kinds of tropes in a limited number of combinations. Another closely related problem is that, while allowing for free-floating individual tropes, paradigmatic trope theories have not given any answer to the question of why we do not encounter such beings in actual physical reality.

Second, because he takes substances as mereological sums of co-located tropes and analyzes inherence by means of [CI], Williams' paradigmatic trope theory rules out mutually co-located substances such as mutually co-located micro-particles. This is a serious limitation as it binds the trope theoretical account of substances to our commonsense intuitions about macro-objects as rigid impenetrable physical bodies. However, co-located micro-particles are possible if not actual (cf. Keinänen 2011: 433). Trope metaphysics aiming at some conception of micro-particles or, more generally, substances that do not fulfill the standards of macroscopic impenetrable bodies cannot rule out mutually co-located substances.

Third, Williams is explicitly committed to the perdurantist view of persistence of tropes and substances. By this move, he avoids the standard problem addressed to an endurantist trope theorist of specifying the persistence conditions of a substance over some period of time (that is, the temporal identity conditions of a substance) by means of endurant tropes. Nevertheless, four-dimensionalism (perdurantism or exdurantism) is not without its problems and one might ask whether it is possible to develop a viable endurantist trope bundle theory.

Finally, Williams admits the need to introduce relations to account for (at least) spatiotemporal locations of tropes. However, the claim that relations considered particulars (particular relations) are *sui generis* entities adhering to two or more objects/tropes reintroduces the primitive distinction between *characterizing* and *characterized* entities in trope theory. It also undermines the goal of constructing a one-category trope ontology. In order to preserve this goal, the trope theorist should eliminate relations from their ontology (as Campbell (1990) attempted to do) or else attempt to

generalize the analysis of inherence to *adherence*.<sup>4</sup> For reasons of space, we set aside problematic issues concerning relations and will concentrate on the first three issues in this chapter (for more on particular relations, see Chapter 22, this volume).

### 21.3 Independence Theories

In the final two sections of this chapter, we assess different trope bundle theories on the basis of their being capable of solving these first three difficulties posed to paradigmatic trope theories. We begin with two trope theories inspired by Campbell's trope theory, Maurin's (2002) and Ehring's (2011) accounts. We label them "independence theories" because they, like Williams and Campbell, strive to construct substances without introducing existential dependencies between standard, non-relational tropes.

As does Campbell (1990), Maurin (2002: ch. 2) calls the relation that binds tropes together so as to form a single substance "compresence" and considers it an external relation between tropes (Maurin 2002: 129, 133). In other words, it holds contingently between its relata. Maurin (2002: 163–166) introduces the relations of compresence considered particulars that account for the holding of compresences between tropes. Maurin (2010, 2011) further defends the idea of compresences as particular relations that necessarily relate their relata in a certain specific way if they exist.<sup>5</sup>

Ehring (2011: ch. 4) rejects existential dependencies between wholly distinct tropes. He takes compresence to be a *sui generis* type of relation which is not reducible to anything else and thus not reducible to spatiotemporal co-location. If the substances constituted by the mutually compresent tropes are spatiotemporal, compresence entails co-location, but the converse does not hold (Ehring 2011: 98). Because he takes compresence as *sui generis* in this way, Ehring can allow for mutually co-located substances.

Like Maurin (2002: 163–168), Ehring binds the tropes constituting a substance by means of compresence relations considered particulars, which hold contingently between their relata. Nevertheless, Ehring (2011: 119–135) considers compresences as "self-relating relations", which are themselves parts of the bundles of mutually compresent tropes.<sup>6</sup> Compresence relations are instantaneous. Ehring (2011: 46–50) claims that tropes provide the best explanation for the phenomenon of qualitative persistence in terms of

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<sup>4</sup> Cf. Keinänen (2018: sec. 2). Here, adherence stands for the formal ontological relation between a particular relation and its relata ("relating").

<sup>5</sup> Cf. Keinänen (2018) and Hakkarainen and Keinänen (2023a).

<sup>6</sup> Moreover, Ehring (2011: 123) rejects relata specific particular relations Maurin introduces, but we ignore this difference in this chapter.

trope endurance. In other words, tropes are endurants that explain persistence of properties in time and serve as mediators of the physical connection between causes and effects (Ehring 1997: ch. 5; Ehring 2011: 48). Given that substances are constituted by enduring non-relational tropes and the fact that compresence relations exist instantaneously, the resulting substances are instantaneous (Ehring 2011: 100–107). Thus, Ehring uses trope bundle theory to combine his endurantist conception of tropes with four-dimensionalism about substances: substances are perdurants or exdurants.<sup>7</sup>

Assuming perdurantism with respect to substances, if a substance exists longer than an instant, it is constituted by distinct instantaneous adherences of distinct relations of compresence to a certain group or groups of enduring tropes. Thus, what we might take as a single substance having slightly different properties at different times is actually a series of trope bundles bound together by distinct compresence relations. Like Williams, Ehring avoids what is generally considered a problem for all trope/universal bundle theories, namely, to provide diachronic identity conditions for enduring substances that can change their properties (Ehring 2011: 100). By the same token, Ehring introduces enduring tropes. According to him, they provide us with the only viable account of qualitative persistence (Ehring 2011: 66).

Therefore Ehring's trope theory avoids a potential problem of a perdurantist trope ontology: to specify the conditions in which a sequence of instantaneous stage-like tropes constitute a temporally continuous trope. Nevertheless, like paradigmatic trope theories, Ehring's theory also has "an explanatory gap" between individual tropes and their contingent compresences, on the one hand, and the arrangement of tropes only into certain kinds of substances, on the other. If the explanation is supposed to be empirical, the trope theorist should be able to specify what kind of explanation it is.<sup>8</sup>

Recall that for the purpose of allowing for mutually co-located substances and to avoid the second difficulty that we posed to paradigmatic trope theories, Ehring considers compresence a *sui generis* relation not reducible to spatiotemporal co-location. The introduction of primitive compresence would entail the following analysis of inherence by means of compresence:

[CAI]: Trope *t* is a property of substance *i* if and only if *t* is a part of *i* and *t* is compresent with all and only the other parts of *i*.

Because of the transitivity of compresence and the fact that a bundle of mutually compresent tropes constitutes a substance, [CAI] entails that *t* is a property of *i* if and only if *t* is compresent with *i*.

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<sup>7</sup> Ehring (2011: 105) ends up preferring exdurantism to perdurantism, but due to space, we ignore this subtlety in his theory.

<sup>8</sup> See Schaffer (2003) for an attempt to provide such explanation.

The problematic status of [CAI] becomes apparent if one asks what compresence is. Ehring answers that it is primitive and not reducible to exact spatiotemporal co-location. According to Ehring, in the case of tropes existing in space and time, compresence entails co-location at a time. Compresence has three basic functions in Ehring's trope theory: first, to unify tropes into a single substance; second, to account for the spatiotemporal co-location of concrete tropes constituting a substance; and third, to make substances (trope bundles) instantaneous and located at a point of time. Nevertheless, our main worry is that it is unclear whether compresence is intelligible enough. Even in the case of primitives, one needs to be able to say something with affirmative content to make them sufficiently intelligible. Particular compresence relations are assumed to relate tropes in a primitive compresent way to unify tropes which are parts of the same substance (Ehring 2011: 98). In Ehring's trope theory, the two additional functions are by-products of this basic function.

Unifying is the role that substrata play in some theories alternative to trope bundle theory. It is supposed to be the nature of compresence relations to play this basic role. This leaves us in the dark about the nature of compresence relations, except perhaps that they are entities introduced to replace substrata. In addition, in [CAI], the primitive adherence of the relations of compresence to non-relational tropes replaces the inherence of the latter to a substratum or substance. We have argued elsewhere that adherence (i.e., a particular relation relating two or more entities) is an even more problematic primitive formal ontological relation than inherence (Hakkarainen and Keinänen 2023a; cf. Lowe 2016). For these two reasons, Ehring pays a high price for allowing for co-located substances and the other suggested benefits of primitive compresence.

#### **21.4 Dependence Theories**

According to what we call "dependence theories", (some or all) tropes are existentially dependent beings; tropes are rigidly or generically dependent on certain or certain kinds of distinct tropes that are not their proper parts. Dependence theories construct substances by means of modal existential dependencies between all distinct non-relational tropes constituting substances, whereas independence theories do not invoke such dependencies. Irrespective of their existentially dependent status, tropes are considered fundamental entities in dependence theories. Unlike stronger dependence relations such as identity dependence or essentialist ontological dependence, these modal existential dependence relations are not considered to have any direct bearing to the fundamentality of their relata. The former, but not the latter, introduce asymmetric



determination relations (like the identity conditions of entity  $x$  being determined by the identity conditions of  $y$ ) between dependent existents and their dependees.<sup>9</sup>

Denkel's (1996, 1997) *Saturation theory* constructs substances by means of a single relation he calls "saturation". Any trope  $t$  falls under some determinable  $D_1$  (color, mass, charge, etc.) and is, necessarily, saturated by additional tropes falling under certain additional determinables  $D_2, \dots, D_n$ . Saturation entails co-location at a time. Substances are pluralities of tropes which saturate each other completely.

Although Denkel considers saturation a primitive substance-making relation, it can be analyzed by means of spatial co-location at a time and generic dependence.<sup>10</sup> To illustrate this, we may take Matteo Morganti's (2009) application of *Saturation theory* to fundamental micro-particles. According to Morganti, every fundamental trope  $t$  falling under a certain specific determinate (such as a -e charge trope) is generically dependent on tropes falling under certain distinct determinables (such as some mass trope, some spin trope). Moreover, these additional tropes are co-located with  $t$  at certain moment(s) of time. Micro-particles are aggregates of mutually fully saturated tropes, that is, aggregates of mutually co-located tropes in which all their generic dependencies are fulfilled. Morganti considers a conception of trope bundling that is based on generic dependencies to be superior to every conception based on rigid dependencies (cf. below) because it allows for "substantial changes" in Denkel's sense, that is, migration of tropes from a particle to a new particle replacing the earlier one: every trope, say a -e charge trope of a muon, can continue its existence but start out accompanied by different kinds of tropes falling under the same determinables (such as mass and spin). For instance, a -e charge trope of a muon can continue its existence and come to be a part of a trope bundle that forms an electron (see Morganti 2009: 189–190 for a similar example).

In the version of the theory considered above, Saturation theory takes tropes as endurants. Like in Williams' paradigmatic trope theory, substances are mereological sums of mutually co-located tropes. By restricting the formation of trope bundles by means of generic dependence, Saturation theory seems to provide a partial explanation for why tropes figure only as parts of substances (cf. micro-particles in the example above) belonging to a limited group of natural kinds. Moreover, like Ehring, the advocate of Saturation theory might consider substances perdurants leaving the burden of explaining the qualitative continuity in the world to endurant tropes. However, because it analyzes inherence by means of [CI], Saturation theory rules out mutually co-located

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<sup>9</sup> See Tahko and Lowe (2020) for an excellent discussion of different kinds of dependence relations.

<sup>10</sup> See Keinänen (2005: 352–369; 2011: 430–431) for discussion.

substances. The second major drawback of this view is that it offers no detailed account of the contingent relations that make tropes parts of a single substance.

Peter Simons (1994) presents what he calls *Nuclear Theory* according to which substances are built from tropes solely by means of formal ontological relations of rigid and generic dependence.<sup>11</sup> In standard cases, there is a group of mutually rigidly dependent tropes forming the tropes necessary to a substance, its nuclear tropes. Moreover, there might be additional tropes on which the nuclear tropes are generically dependent. Tropes are parts of a substance by being rigidly dependent on its nuclear tropes. Substances are aggregates of tropes in which all their rigid dependencies on distinct tropes are fulfilled; their dependence closures. Unlike other trope theories discussed in this chapter, Nuclear Theory does not constrain the relative spatiotemporal locations of tropes constituting a substance in any manner (cf. Keinänen 2011: 431–433). Therefore, it remains a schematic construction which can be supplemented in different ways to bring tropes together into a single location, in order to function as properties of a substance. For instance, Simons (2000: 148–149) suggests that the nuclear tropes of a substance usually take the same location as a matter of contingent fact. However, he does not develop this idea any further.

The *Strong Nuclear Theory* (SNT), which we have defended in a series of articles,<sup>12</sup> is inspired by Simons (1994). However, it takes a slightly different line than all the trope theories described above. In SNT, the main strategy is, first, to construct different kinds of trope bundles by means of the formal ontological relation of rigid dependence. As in Simons (1994), substances are identified with dependence closures of tropes with respect to their rigid dependencies. Second, for the purpose of the analysis of inherence, SNT provides an account of the spatiotemporal location of tropes relative to the location of the entire substance. Here, the basic idea is that certain pluralities of tropes constitute individuals (that is, singular entities) that stand in basic spatiotemporal relations. The locations of these trope bundles determine the locations of individual tropes.

According to SNT, tropes divide into different types depending on how they stand in the relation of rigid dependence:

[NT]: Trope  $t$  is a nuclear trope if and only if  $t$  is rigidly dependent on certain distinct tropes which are also rigidly dependent on  $t$ , or alternatively,  $t$  is not rigidly dependent on any other trope.

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<sup>11</sup> The formal ontological relation of rigid dependence is characterized modal-existentially and as follows:  $RD(e,f) = \neg(\Box E!f) \ \& \ \Box((E!e \rightarrow E!f) \ \& \ \neg(f \leq e))$ .

<sup>12</sup> Hakkarainen (2018); Hakkarainen and Keinänen (2017); Keinänen (2011, 2018); Keinänen and Hakkarainen (2010, 2014).

[CT]: Trope  $t$  is a c-trope if and only if  $t$  is rigidly dependent on certain nuclear trope(s), but the converse does not hold. Trope  $t$  is not rigidly dependent on any other trope.

Intuitively, nuclear tropes are necessary properties of a substance. Examples of nuclear tropes are -e charge, certain determinate mass, or spin tropes necessary to a micro-particle. On the other hand, c-tropes are tropes contingent to a substance such as spin direction or color charge tropes contingent to a micro-particle.

To achieve these results, SNT states that every plurality of nuclear tropes constitutes an individual, an n-bundle. Similarly, each c-trope and the nuclear tropes on which it is rigidly dependent form a further individual, a c-bundle. Distinct nuclear tropes necessarily fall under distinct determinables (mass, charge, spin, etc.), which brings certain qualitative diversity to most substances. If a given trope  $t$  is a part of simple substance  $i$  (a substance that does not have any other substances as its proper parts),  $t$  is either the single nuclear trope of  $i$  or  $t$  is rigidly dependent on the nuclear tropes of  $i$ , which individuate substance  $i$ .

Nevertheless, we still need an account of the location of tropes relevant to the analysis of inherence. Here, SNT proposes that n-bundles and c-bundles, not individual tropes, are the minimal entities that occur in the basic spatiotemporal relations. The spatiotemporal location of an n-bundle determines the location of its constituent nuclear tropes. Similarly, the location of an n-bundle determines the location of the substance in which it occurs as a part. The n-bundles form functional unities with a certain qualitative diversity: groups of different kinds of tropes necessary to a substance that determine its causal powers – like mass, spin, and charge tropes. Necessarily, they are co-located with each other and the substance if and only if they exist.

Similarly, the location of each c-trope is determined by the location of the c-bundle in which it occurs as a part. If we assume that both tropes and the substances they constitute are endurants, SNT needs a separate account of the location of every c-bundle in relation to the location of the n-bundle of a substance. We have argued elsewhere that every c-bundle of a substance is spatially co-located with the n-bundle at each moment in which they both exist (Keinänen 2011: sec. 3).

According to SNT, aggregates of tropes closed under rigid dependence are simple substances: substances that do not have other substances as their proper parts. A simple substance typically contains an n-bundle as its part and, possibly, some c-bundles as its proper parts. On this basis, we obtain the following analysis of inherence in SNT:

[AI]: Trope  $t$  is a property of substance  $i$  if and only if, necessarily, if  $t$  exists,  $t$  is a part of  $i$ , and  $t$  is exactly co-located with  $i$  at every moment of  $t$ 's existence.

In the limiting case,  $t$  is a nuclear trope and exactly spatiotemporally co-located with  $i$ . However, if  $t$  is a c-trope, its temporal location is a proper or improper part of the temporal location of  $i$ , but  $t$  is spatially co-located with  $i$  during the time of its existence. Nuclear tropes and c-tropes fulfill the conditions of [AI] in relation to the simple substances they constitute. Like [CI], [AI] provides us with a reductive analysis of inherence. According to [AI], spatial co-location, or in the case of nuclear tropes, spatiotemporal co-location is not sufficient for inherence. Additionally, [AI] states that, necessarily, if  $t$  exists, substance  $i$  exists, and  $t$  is a part of  $i$ . Since these claims are consequences of  $t$ 's being rigidly dependent on the nuclear tropes of  $i$  and a new account of the determination of the location of tropes, SNT analyzes inherence in terms of co-location, parthood, and rigid dependence.

SNT provides new answers to the three problems that plague paradigmatic trope theories. First, in the standard case, tropes are parts of a certain kind of substance determined by its nuclear tropes. Here, the explanation of why tropes are properties of certain kinds of substances is assumed to be metaphysical and determined by the existential dependencies between tropes. Second, SNT allows for mutually co-located substances, which should be a possibility allowed for in any trope bundle account of fundamental substances. Finally, by means of c-bundles, SNT can provide a trope theoretical conception of enduring substances, which are identical through change of contingent tropes. Nevertheless, SNT is not committed to endurantism: in a perdurantist version of SNT, it is enough to suppose that the locations of c-bundles are determined by the locations of n-bundles and that these locations are instantaneous.<sup>13</sup>

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