A Trope Nominalist Theory of Natural Kinds

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Abstract

In this chapter, I present the first systematic trope nominalist approach to natural kinds of objects. It does not identify natural kinds with the structures of mind-independent entities (objects, universals or tropes). Rather, natural kinds are abstractions from natural kind terms and objects belong to a natural kind if they satisfy their mind-independent application conditions. By relying on the trope theory SNT (Keinänen 2011), I show that the trope parts of a simple object determine the kind to which it belongs. Moreover, I take the first steps to generalize the trope nominalist theory to the natural kinds of complex objects.

1. Introduction

All objects at the different levels of complexity divide into natural kinds. The salient and commonly discussed *prima facie* examples are the natural kinds of fundamental micro-particles (e.g., electron, down quark), the natural kinds of complex objects studied by physics and chemistry (e.g., helium atom, water molecule), the natural kinds of chemical substances (e.g., water, ethyl alcohol), and the natural kinds of living organisms (e.g., polar bear, human). The classification of objects into natural kinds is useful because the members of a natural kind are usually similar in various distinct respects and behave in similar ways in the same kind of circumstances. Moreover, it seems that objects are necessarily members of *some* natural kind and we are able to individuate them only as members of a natural kind.

In this chapter, I outline the beginnings of a trope nominalist theory of substantial natural kinds (i.e. natural kinds of objects). The theory is novel in two different ways. First, it is the first contemporary attempt to develop a systematic trope nominalist approach to substantial natural kinds. Second, the present theory is *nominalist* (or, conceptualist/nominalist): unlike its main rivals, *Neo-Aristotelian* (Lowe 1998, 2009, Ellis 2001) and *Reductive Realist* (Hawley & Bird 2011) theories, it does not identify natural kinds with the structures of mind-independent entities (objects, universals or tropes) or with separate (e.g., supervenient) entities.[1] According to the present theory,

[1] Thus, natural kinds are not considered as supervenient "free lunches" or "pseudo-additions", cf. Simons (2003) and Keinänen (2008) for criticism of this type of ideas.

natural kinds are abstractions from natural kind terms with certain determinate application conditions. Objects belong to a natural kind if they satisfy these conditions, which are certain mind-independent facts about objects and depend on their level of complexity.

Tropes are particular properties (such as the charge –e of an electron) and relations (the distance of 1m between certain distinct objects). According to trope theories (i.e. the trope bundle theories of substance), all fundamental entities are property and relation tropes.[2] Individual objects and all other entities (e.g., processes) are constructed by means of aggregates of tropes. Trope theories assign to property tropes the standard category features of the fundamental concrete particulars but typically differ in the conditions the tropes constructing a substance must fulfil.[3] According to *trope nominalism*, properties and relations are tropes and there are no universals. Thus, trope nominalism is a wider term; in addition to trope theorists, substance trope theorists (Martin 1980, LaBossiere 1994, Heil 2006) advocate trope nominalism.

One of the main reasons to postulate tropes is to answer *the contemporary problem of universals*: to give an account of the shared features of objects, i.e. the type identities between objects with respect to perfectly natural properties such as determinate masses, charges or lengths. According to the trope theoretic answer, two (simple) objects share a determinate feature (e.g., a specific electric charge) if and only if they possess exactly similar tropes (-e charge tropes).[4] The main motivation of the present theory of natural kinds is to generalize the trope theoretic answer to *the traditional problem of kind universals*: assuming that all fundamental entities are tropes, to account for the division of objects into natural kinds.

The most developed recent metaphysical theories of substantial natural kinds are all in the Realist camp: the *Neo-Aristotelian* (Lowe 1998, 2006, 2009, Ellis 2001) theories identify natural kinds with *substantial kind universals* and the *Reductive Realist* theory of Hawley and Bird (2011) with complex *Russellian property universals*.[5] In order to provide a trope nominalist alternative, the present approach uses the natural kind terms with certain application conditions, which replace natural kinds, as its main tool. The theory of natural kinds will adopt a bottom up approach and start with the natural kinds of simple objects (or, simple substances) and then proceed to more complex objects. Moreover, it relies on the trope bundle theory of simple substances (SNT) developed by the author (Keinänen 2011).

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[2] Among the recent trope theorists are Campbell (1990), Simons (1994, 1998), Denkel (1996), Maurin (2002), Morganti (2009a), Ehring (2011), Keinänen (2011) and Keinänen & Hakkarainen (2010, 2014).
[3] Cf. Keinänen (2011: sec. 3) for a short overview of the alternative trope theories.
[4] According to certain trope theories (Simons's Nuclear Theory and the SNT), only simple substances are trope bundles. Most features of complex objects are accounted for by means of the tropes possessed by their proper parts.
[5] *Russellian property universals* (advocated, e.g., by Russell (1912) and Armstrong (1978, 1997)) are directly instantiated by objects. The existence of tropes is denied. We can contrast them with the property universals having tropes as their instances (advocated, e.g., by Lowe (1998, 2006, 2009) and Ellis (2001)).

Despite certain much-discussed examples (cf. above), metaphysicians have given mutually incompatible characterizations of natural kinds. We can make a useful distinction between the *abundant* and the *sparse conception of natural kinds*. The advocates of the *abundant conception* typically admit of all of the above listed kinds as examples of natural kinds.[6] By contrast, Brian Ellis (2001: 19-21) argues for the *sparse conception*, according to which all natural kinds must fulfil certain specific criteria. Before we can provide a trope nominalist *theory of natural kinds*, we must specify what the natural kinds forming the *explananda* of our theory are as opposed to the artefactual or conventionally defined kinds.

The structure of this chapter is as follows. In section 2, I describe the different roles metaphysicians have assigned to natural kinds. On that basis, in section 3, I begin with the construction of the trope nominalist theory by the natural kinds of simple substances. In section 4, I take the first steps to generalize this account to more complex objects. Finally, section 5 concludes the chapter.

2. What are natural kinds?

Metaphysicians have introduced properties for several distinct purposes, or property roles (cf. Lewis 1983, Oliver 1996, Swoyer & Orilia 2011). Similarly, they have given to substantial natural kinds several different roles or functions to answer different philosophical problems. The following four seem to be the most important:

(a) *Semantic theory*: natural kinds are referents of natural kind terms (Kripke 1980, Lowe 2009, cf. Beebee & Sabbarton-Leary 2010).

(b) *Philosophy of Science*: natural kinds facilitate inductive inferences and have a central role in scientific explanation (Boyd 1999, 2010, Hawley & Bird 2011, Bird & Tobin 2012).

(c) *Metaphysics of Science*: the members of a natural kind possess the basic dispositional properties and the fundamental laws of nature concern the behaviour of every member of some kind K (Ellis 2001, Lowe 2009).

[6] Boyd (1999, 2010) advocates the abundant conception of natural kinds but Hawley and Bird (2011) seem to stay neutral between the abundant and the (more) sparse conceptions.

(d) *Kinds determining identity conditions*: every object necessarily belongs to some (sufficient general) natural kind that determines its identity conditions (Wiggins 2001, Lowe 1998, 2009).

It is consistent to postulate entities in some ontological category, for example, the category of kind universals, identify them with natural kinds and assign to them all or most of the above functions. Nevertheless, before we even consider such a move, we must be able to spell out which of the above functions give us reason to introduce kind-like natural (or, mind-independent) divisions among objects as contrasted with the man-made divisions.

In connection with functions (c) and (d), we clearly introduce natural divisions. First, we must identify natural kinds satisfying function (c) by the best *a posteriori* means. Ellis's and Lowe's theories differ in detail. According to both of them, it is the distinctive feature of substantial natural kinds (in contradistinction with the artefactual or conventionally defined kinds) that they are characterized by a set of property universals and subject to certain laws of nature. According to Ellis (2001), these property universals are determinate kinds of the property tropes the objects belonging to the substantial kind instantiate. Thus, they are intrinsic properties of these objects. Moreover, the properties of the fundamental natural kinds are dispositional and supposed to act as truthmakers of certain basic laws of nature.[7] Second, function (d) builds on the insight that objects are necessarily instances of some natural kind. Since objects have certain determinate identity conditions only as members of a natural kind, we can identify an object only as a certain kind of object, by reference to the natural kind to which it belongs.

If an advocate of substantial kind universals accepts functions (c) and (d), she assigns them to kind universals. First, natural kind universals are assumed to determine the identity conditions of their instances (Loux 1978, Lowe 1998, 2006, 2009, 2010). If there are objects, there must be kind universals and some division of objects into natural kinds. Second, because of being instances of a certain definite kind universal, objects have a set of properties. Kind universals are assumed to collect these properties, which act as truthmakers of laws of nature (Ellis 2001; Lowe 2010: sec. 6). Correspondingly, the properties of the fundamental (or, comparatively fundamental) objects seem to be intrinsic to their bearers and truthmakers of the fundamental laws.

Functions (a) and (b) have a broader range of application than functions (c) and (d). First, if natural kinds are the bearers of the properties making the fundamental laws true, the classification of objects by means of the corresponding kind terms facilitates inductive inferences

[7] According to Lowe (2009, 2010), kind universals are characterized by property and relation universals, which make true the statements of the corresponding laws of nature. Laws of nature are normative in their character. Whether or not they allow of exceptions depends on the kind of objects to which they apply.

concerning objects. Similarly, the fundamental laws of nature have a central role in scientific explanation. Nevertheless, the converse need not hold. We can introduce kinds with the help of some man-made or context relative criteria but the corresponding kind terms can still facilitate scientific explanation and our inductive practices (Bird & Tobin 2012: sec. 1). Second, if there are kind universals acting in roles (c) and (d), they are referents of certain *selected* natural kind terms. Unless we *define* natural kind terms as terms that refer to natural kinds (or, alternatively, as terms that pick up kind-like natural divisions among objects), there seems to be no guarantee that all natural kind terms manage to refer to natural kinds (or, pick up kind-like natural divisions) (cf. Beebee & Sabbarton-Leary 2010: 4).

Brian Ellis (2001: 19-23) sets six constraints on natural kinds, with the help of which we are supposed to be able to specify the real natural kinds as contrasted with the conventionally defined kinds. As he identifies natural kinds with kind universals, they are also purported to lay down the conditions in which we are entitled to introduce a kind universal. Although formulating comparatively *a priori* principles for the identification of natural kinds, Ellis is both *fallibilist* and *a posteriori* realist with respect to natural kinds: natural kinds must be identified by the best scientific theories. Here, I am confined to listing four of the constraints and I leave out two, which I consider less important (namely, the specification and hierarchy requirements) (Ellis 2001: 19-21):

(i) *Objectivity*: natural kinds are distinguished by their objectivity, they are independent of us. The division of objects into natural kinds is drawn by nature, not by us.

(ii) *Categorical distinctness*: since the distinctions between natural kinds are independent of us, they must be sharp and cannot be gradual. Were the boundaries between natural kinds gradual, we should ultimately draw them, they could not pre-exist in the mind-independent reality.

(iii) *Essentiality requirement*: the distinctions between natural kinds are based on facts about their essential nature or structure, not on how we find it useful to classify them. As a consequence, the members of a natural kind have their kind-determining features necessarily. Conversely, necessarily, if an object has the kind determining features of kind K, it is also a member of K.

(iv) *Intrinsic difference*: the identities of natural kinds must be based on the intrinsic properties of their members. The kind distinctions cannot be based on accidental circumstances. Because all relational differences are accidental, all kind distinctions must be grounded on the intrinsic differences between the members of the kinds.

The *Objectivity* constraint forms a reasonable basis for the talk about natural kinds: the division of objects into natural kinds is independent of us. It is drawn by nature, not by our classificatory system.

According to Ellis, natural kinds must also fulfil constraints (ii) – (iv) but several theorists contest this (cf. Mumford (2004: ch. 7; Hawley & Bird 2011: secs 4, 6). In limits of this chapter, I defend a weaker thesis that the natural kinds of comparatively simple objects (i.e. micro-particles and their composites) fulfil constraints (iii) and (iv). First, the kind determining features of the members of the kind individuate each of these kinds: for example, a particle having a different mass or charge than electron would be a different kind of micro-particle or a molecule having a different molecular structure than a water molecule would be a different kind of molecule. Consequently, the kind determining features are necessary to the members of the kind.

Second, Ellis makes a stronger claim that natural kinds are individuated by the intrinsic features of their members (constraint (iv)). Ellis's defence of the claim is unconvincing for a natural kind might have relations among the features necessary to the members of the kind. Nevertheless, the fundamental objects (i.e. the basic particles) appear to be powerful particulars: they possess a set of intrinsic features which are all dispositional (cf. Ellis 2001: 215; Mumford 2006). The composites of these objects (atoms, molecules) have a certain kind of intrinsic structure determined by the causal powers of their parts and certain intrinsic causal powers. Relative to these features, the spatio-temporal location and other extrinsic features are accidental and changeable. Therefore, it is a plausible hypothesis that the intrinsic features also individuate the natural kinds of micro particles and their composites.

I adopt the following strategy in constructing the trope nominalist theory of natural kinds: I start with the natural kinds of micro-particles and their composites, which are best candidates to fulfil criteria (i), (iii) and (iv). Nevertheless, I must leave the discussion of the possible natural kinds not fulfilling (iv) (the non-intrinsic natural kinds) to some other occasion.

3. Natural kinds of simple substances

The current Standard Model of quantum physics gives us *prima facie* examples of simple substances (i.e. micro-particles that do not have further particles as their proper parts). They divide into specific natural kinds such as down quark and electron, which are sub-kinds of more general kinds (quark and lepton). The trope theory SNT, which has been defended elsewhere (Keinänen 2011, Keinänen & Hakkarainen 2010, 2014), is a trope bundle theory of simple substances: all complex objects are constituted by simpler objects and all property tropes are parts of the simple objects, that is, objects that do not have further objects as their proper parts.

Let us consider the fundamental micro-particles such as electrons and quarks as examples of simple substances, although this interpretation of physical reality can be challenged.[8] They all have a certain set of necessary intrinsic features (a determinate rest mass, electric charge and spin quantum number). Moreover, the quark constituents of a proton or neutron possess one of the three colour charges constantly exchanging them with each other.[9] The SNT introduces nuclear tropes, either one nuclear trope or two or several tropes rigidly dependent on each other to determine the necessary features of a powerful particular (such as a down quark or an electron).[10] If there is more than one nuclear trope, they must fall under distinct determinables. For instance, it seems that a down quark has a mass trope of 4.8 MeV, charge trope of -1/3e and a spin quantum number trope in its trope nucleus. Contingent tropes, which many different kinds of substances must also have, are one-sidedly rigidly dependent on the nuclear tropes. Colour charge tropes of a quark are good candidates. Property trope *t* is a part of substance *i* if and only if *t* is rigidly dependent only on its nuclear tropes. Simple substances are dependence closures of tropes: they are trope aggregates in which all of the rigid dependencies of the member tropes are fulfilled (Keinänen 2011: 436 ff., 446-7).

We are now in a position to argue that the nuclear tropes of powerful particular *i* are naturally unified and determine the (most specific or nearly the most specific) natural kind to which *i* belongs. The argument proceeds in four steps. First, I argue that the nuclear tropes are sufficiently naturally unified to form the trope nucleus of a powerful particular. Second, I have assumed just above that the nuclear tropes fall under certain determinates (e.g., charge trope of -1/3). I now argue that the nuclear tropes belong to certain determinate kinds because of being the tropes they are without need to introduce further entities. Third, I specify (in exact terms) what the natural kinds of powerful particulars are. Finally, I show (again in exact terms) that the nuclear tropes of substance *i* determine the (most specific or nearly the most specific) natural kind K to which *i* belongs.

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[8] According to certain interpretations of quantum mechanics (the so-called Received View), the quantum micro-particles do not have determinate identity conditions, which is a standard category feature of substances. Morganti (2009b) gives an alternative interpretation explaining the same facts about the state dependent properties of two or more particle systems as the Received View but which does not reject the conception of particles as substances, cf. *ibid* for further discussion.

[9] The physical facts about basic particles allow of slightly different ontological interpretations: according to Simons (1994), spin quantum number and spin direction constitute two distinct properties but Morganti (2009a) takes them as aspects of a single property (spin).

[10] Let "≤ " be a relation of improper parthood between entities (cf. Simons (1987: 112) for the definition) and "E!" the predicate of (singular) existence. Trope *e* is *strongly rigidly dependent* on trope *f*, if $SRD(e, f) \equiv \neg(\Box E!f) \wedge \Box((E!e \rightarrow E!f) \wedge \neg(f \leq e))$ holds.

According to the SNT, the nuclear tropes of a simple substance are both rigidly dependent on each other *and* form an individual (the *n-bundle*) that is in the basic spatio-temporal relations. The location of the *n-bundle* determines the location of the nuclear tropes. Consequently, the existence of nuclear tropes entails that they are co-located (Keinänen 2011: 438-440). Hence, the nuclear tropes are both rigidly dependent on each other and necessarily spatio-temporally co-located. Because the location of the nuclear tropes determines the centre of influence (spatio-temporal location) of a powerful particular, they are naturally unified.

In order to accomplish the second task, I defend a nominalist account of determinate (and, determinable) kinds of tropes elsewhere. Here, I am confined to outlining some of its main features.[11] According to it, quantity trope *t* falls under determinate D (is a –e/3 trope) if and only if kind term D applies to *t*. Kind term D applies to *t* if and only if *t* is in a relation of 1:1 proportion ("exact similarity") to *any* actual D-trope, which can be used to fix the reference of kind term D. Trope *t* is in an ungrounded internal relation of 1:1 proportion to any actual D-trope because of being the trope it is (bestowed with a particular nature of a D-trope). As a consequence, trope *t* makes true the claim that *t* is a D-trope. Therefore, trope *t* also determines determinate kind D to which it belongs.

Third, I briefly motivate and then present a trope nominalist account of natural kinds of simple substances. The motivation takes a form of an eliminative argument: the identification of natural kinds with the abstractions from kind terms is preferable to the alternative accounts of natural kinds. The further main alternative accounts available to a trope nominalist are (A) – (D):[12]

(A) Substantial natural kind K is a plurality of K-objects.

(B) Substantial natural kind K is a sum of K-objects (a concrete individual).

(C): Substantial natural kind K is a set of K-objects (an abstract individual).

(D) Substantial natural kind K is an abstraction from the plurality of K-objects.

We can immediately reject alternative (B): even if such an individual as the sum of all K-objects existed (which is dubious), a natural kind has instances but is distinct from the sum of its instances (i.e. a scattered individual). Given that objects belonging to a natural kind exist, also their plurality exists. However, according to alternative (A), a unity (or, an individual, i.e. a natural kind) is

[11] The argument for the identification of determinate kinds with kind terms applying to tropes has exactly the same form of eliminative argument as the argument for the identification of substantial natural kinds with kind terms below.

[12] Alternatives (A) – (D) correspond to the different possible approaches to the determinate kinds of property tropes. For instance, Williams (1953) favours (C). Williams's (1986) *Painless Realism* is a representative of approach (A). Simons (2008) puts forth approach (D) with respect to determinate kinds of tropes: they are abstracta under the equivalence relation of exact similarity between tropes.

identical with a plurality of entities, which is incoherent.[13] After the rejection of (A), it might appear attractive to identify natural kinds with sets of their instances, that is, abstract individuals. Nevertheless, the postulation of sets involves two serious problems. First, it would introduce a further category of entities and entail that trope theory is qualitatively less economical than originally considered (i.e. a two-category ontology of property and relational tropes). Second, the postulation of abstract entities such as sets would contradict the sound nominalist maxim that all entities are concrete.

Thus, we are left with alternative (D). According to it, only the plurality of the concrete K-objects has a mind-independent existence. Natural kind K (electron) is a result of abstraction from all K-objects (electrons), which are in an equivalence relation to each other (have exactly the same kind-determining features). There is no unity of a kind in the world but the unity of a natural kind is a result of an abstraction, to consider the distinct kind members as a single natural kind.[14] The main problem of alternative (D), which it shares with the other extensional characterizations of natural kinds (i.e. (A)-(C)), is that it binds a natural kind to the actual plurality of its members. Nevertheless, natural kind K can have different numbers of members as its instances – there is no necessary connection between a kind and some particular group of its members.

Instead of introducing *possible objects* to solve this problem, the present theory identifies substantial natural kinds with the abstractions from kind terms applying to objects. We can assume that there is a group of the tokens of a natural kind term with certain determinate application conditions, a group of natural kind term tokens exactly applying to K-objects (e.g., electrons). Natural kind K (electron) is an abstraction from these kind term tokens, that is, a result of considering these different kind terms a single natural kind. Object *i* is an instance of kind K if and only if kind term(s) K applies to *i*. As an abstraction from kind terms kind K is distinct from its instances and does not have any necessary connection to some specific group of its instances.

In order to make this schematic description more precise, I now give the application conditions of certain kind terms specifying the natural kinds of simple substances. I first discuss the natural kinds necessary to a simple substance, which I call *primary kinds*:

[13] Williams's (1986) *Painless Realism* attempts reconcile the talk about a plurality of tropes and a single universal by relying on the "rules of counting": depending on such rules, we can talk either about a single universal or a plurality of exactly similar tropes. However, *pace* Williams, if identity is univocal, a plurality of distinct entities is not one entity (individual). Referring to our ways of talking about entities does not help us out of this distinction.

[14] Here, the key idea is to introduce a new object (property, natural kind) by means of abstraction principle, cf. Rosen (2012: sec. 6) for details. Further, the trope nominalist denies the existence of the new object. Rather, our ability to talk about it is a result of our applying the abstraction principle to the objects belonging to the equivalence class.

(PK) Kind term of primary kind K applies to simple substance *i* if and only if *i* satisfies the following conditions *a.* and *b.*:

a. Object *i* has nuclear tropes $x_1, \ldots, x_n$.
b. Tropes $x_1, \ldots, x_n$ belong to determinate kinds $D_1, \ldots, D_n$.

Condition (PK) is formulated in terms of certain kinds of tropes and we need not make reference to any *individual* tropes. The nuclear tropes specified in clause a. must fall under certain determinates $D_1, \ldots, D_n$. For instance, the kind term "down quark" applies to object *i* if and only if *i* has a mass trope of 4.8 MeV, a charge trope of -1/3e and a spin quantum number half trope in its trope nucleus.

Finally, we can show in the special case of primary kinds that the nuclear tropes $t_1,\ldots, t_n$ of simple substance *i* determine natural kind K to which *i* belongs. First, the nuclear tropes are tropes of certain determinate kinds $D_1, \ldots, D_n$ because of being the tropes they are (cf. above). Second, certain simple substance *i* exists because its nuclear tropes $t_1, \ldots, t_n$ exist. Third, because nuclear tropes $t_1,\ldots, t_n$ exist, substance *i* exists and kind term K applies to *i* (condition (PK)). Thus, tropes $t_1, \ldots, t_n$ make jointly true the claim that *i* belongs to kind K.[15] Since natural kind K is an abstraction from the kind terms applying to *i*, tropes $t_1,\ldots, t_n$ also determine the natural kind to which *i* belongs.

There are two main ways to modify (PK) in order to obtain other natural kinds than primary kinds. First, we get higher natural kinds as follows: we modify clause *b* to involve tropes belonging to certain determinable kinds. For instance, powerful particular *i* is a quark because it necessarily has tropes belonging to certain determinable kinds, namely, some mass trope, some charge trope, some spin quantum number trope and some colour charge trope among its constituents. Here, it does not matter whether the individual tropes of a certain kind are necessary or contingent to substance *i* because it necessarily has tropes belonging to these *determinable kinds*. Thus, necessarily, *i* has tropes that make true the claim that *i* belongs to higher kind K'.[16]

Second, assuming that the primary kinds are not the most specific natural kinds, we obtain more specific natural kinds by modifying clause *a* to involve the tropes contingent to a substance to determine the features necessary to kind K. Such natural kind is contingent to *i*. If there

[15] The plurality of nuclear tropes exists if and only if all of the nuclear tropes exist. Nuclear tropes make jointly true proposition *p* if and only if their plurality makes *p* true. I adopt the following familiar entailment principle for joint truthmaking: if a plurality of entities makes proposition *p* true, then the existence of the plurality entails that *p* is true, cf. Mulligan *et al.* 1984: sec. 6.

[16] According to the SNT, if substance *i* has contingent tropes, the nuclear tropes of *i* are generically dependent on the tropes that belong to the determinable kinds of the contingent tropes. Moreover, necessarily, there is a trope of the corresponding determinable kind rigidly dependent on the nuclear tropes of *i*. Therefore, *i* necessarily has tropes that belong to each of these determinable kinds as its parts.

is more than one contingent trope of substance *i* determining contingent natural kind K to which *i* belongs, the tropes must be naturally unified. We can modify the SNT to introduce such naturally unified tropes contingent to a simple substance (Keinänen 2011: 447).

I now anticipate one criticism a Neo-Aristotelian can level at the present account and provide a brief answer to it in the case of simple substances. It remains to be shown that we can generalize the trope nominalist answer to complex objects. According to this criticism, an object is necessarily an instance of some kind universal K, which determines its identity conditions (cf. role (d)). We need to introduce an object as an instance of a kind universal to even consider it as an entity with determinate identity conditions.[17] Because the present theory *presupposes* that an object can have determinate identity conditions without being an instance of a kind universal, it fails.

The present theory indeed assigns determinate identity conditions to objects without introducing substantial kind universals. We introduce *substantial kind terms* to identify objects and to distinguish them from other objects. As for instance, Wiggins (2001) and Lowe (2009) have argued, objects are identified only as members of some natural kind. Certain substantial kind terms (or, sortal notions), under which objects fall, carry with themselves information about the identity conditions of the objects. However, this point is limited to concern *identification* (or, individuation in epistemic sense).[18] According to the SNT, the nuclear tropes *individuate* (in metaphysical sense) simple substance *i* and determine its identity conditions (Keinänen & Hakkarainen 2014: sec. 3.2). As I argued just above, the nuclear tropes of *i* make true the claim that substance *i* is of kind K. Substantial natural kinds (i.e. natural kind terms) have a central role in (epistemic) identification: we identify substances as certain kinds of substances and their constituent tropes as properties of a certain kind of substance (*op. cit.*: sec. 4). We need no substantial kind universals to determine the identity conditions of simple substances because nuclear tropes determine them.

4. Generalization to complex substances

In this section, I take the first steps to generalize the trope nominalist theory to more complex objects. I restrict my approach to *perfectly intrinsic natural kinds*, that is, the kinds fulfilling Ellis's requirements (i), (iii) and (iv). More specifically, I concentrate on (stable) atoms. In their case, object's membership in a natural kind has an explanation in terms of the features and spatial

[17] Lowe (2009: 3) states this contention in two theses: first, that "particular objects are individuable and identifiable only as particulars of this or that *sort* or *kind* – there are no 'bare particulars'", second, that "individuals and kinds are ontologically on an equal footing, at least in the sense that neither may be reduced to the other…", which he takes as a corollary of the claim that the notions of individual and kind are mutually dependent.

[18] Cf. Keinänen & Hakkarainen (2014: sec.1) for the distinction between *identification* (i.e. individuation in epistemic sense) and *individuation* (i.e. individuation in metaphysical sense). Cf. also Lowe (2003).

arrangement of its proper parts. Atoms are a straightforward case of complex objects also for the following reason: if certain kinds of proper parts exist, their spatial arrangements do not generate different kinds of complex objects (atoms). On the present approach, certain kinds of simpler objects compose a complex natural object because they are *naturally unified* due to their relative locations and causal powers generating certain kinds of causal processes connecting objects.[19] A complex object belongs to natural kind K (e.g., helium atom) because it has certain kinds of simpler objects as its K-necessary proper parts (necessary to it as a member of K).

Since I have not presented any exact trope theoretic account of causal processes and spatiotemporal relations, the present approach will remain somewhat schematic. *Prima facie*, the spatiotemporal location of the constituent objects is accounted for by means of relational tropes connecting certain trope bundles or trope bundles and space-time points.[20] Second, dispositional property tropes, usually belonging to the same determinable kind (e.g., electric charge) and occurring in pairs, generate causal processes (electric attractions and repulsions) between objects. We can describe the action of such processes in terms of the action of the attractive and repulsive forces (such as Coulomb force and strong nuclear force) on objects.[21] A stable complex micro-particle such as hydrogen or helium atom forms a prime example of a complex natural object. It remains stable due to the operation of strong nuclear force (the nucleons exert on each other) and Coulomb force (binding the nucleon(s) and the orbiting electron(s)) in quantum mechanical context.[22] In order to break the balance ("a low energy state of the system") and decompose the complex object, we must import further energy to the object (system).

The present approach provides us with an *a posteriori* explanation of the composition of a complex natural object in terms of location and causal powers of its proper parts; we need not postulate any further entities. According to it, the stability of composition is in many cases an Ellis-

[19] Thus, we can provide a *series type answer* to Peter van Inwagen's (1990: sec. 7) *special composition question*, an answer whose exact content depends on the kind to which the simpler objects and the object composed belong. See Silva (2013) for a recent defence of the series type answers against van Inwagen's criticisms.

[20] The SNT accounts for the spatiotemporal location of simple substances by means of relational tropes that connect the parts of distinct simple substances (the N- and C-bundles) or these parts of simple substances and space-time points, cf. Keinänen 2011: sec. 3. The location of simple substances determines the location of all complex objects they compose.

[21] Following Ellis (2001), I have argued that the monadic tropes of simple substances are dispositional (Keinänen 2011). The more accurate quantum-mechanical description of the processes generated by these tropes is in terms of the exchange of virtual particles ("force-carrier bosons").

[22] In order to simplify presentation, I have omitted the current description of strong nuclear force in terms of gluon exchange ("colour force") between the quark constituents of nucleons. Similarly, certain quantum-mechanical facts (e.g., that an electron is a wave-particle whose energy is quantized) constitute a central part of the physical explanation of why an electron retains its stable "orbit" unless further energy is imported.

intrinsic feature of the complex object: it remains composed in a certain way unless external forces are exerted on it.[23]

The identification of natural kinds of these complex objects (i.e. atoms) needs further consideration. In chemistry, the primary division of chemical elements into natural kinds (i.e. the distinct elements) is in terms of the nuclear charge (i.e. the number of protons) of the respective atoms. This division reflects the fact that chemical elements with a certain atomic nuclear charge remain stable in chemical reactions and that we can predict the main lines of the behaviour of the element on the basis of nuclear charge.[24] Atoms divide into natural kinds, that is, the atoms of the different kinds of elements, on grounds of their nuclear charge. Moreover, there is a finer division of atoms into natural kinds on grounds of their nuclear charge and nuclear mass, namely, the atoms of the different atomic isotopes of the element.[25]

Hence, as complex natural objects atoms divide into natural kinds on the basis of their necessary structure as members of the respective natural kind K (e.g., hydrogen or helium atom), the K-necessary structure, for short. The K-necessary structure amounts to having a certain number of certain kinds of objects (i.e. a proton or protons and neutrons) as K-necessary parts. Second, the structure remains stable in chemical reactions. Third, because of the stability of the K-necessary structure of the stable atomic nuclei, we can identify the respective atoms through many standard changes by means of their K-necessary parts. However, intrinsically unstable atoms seem to be capable of remaining in existence through the change of natural kind.[26] Even if we accept this, we can put forth a tentative proposal that atoms are individuated by the fact that they have a certain number of nucleons (neutrons or protons) as their necessary parts.[27]

Before I provide the application conditions of natural kind terms, I specify the conditions in which a plurality of certain kinds of simpler physical objects forms an intrinsically stable complex object (an individual):

[23] According to Ellis's (2001: sec. 1.4) *causal notion of intrinsicness*, feature *F* is possessed intrinsically by object *i* if and only if *i* would display *F* in the absence of any accidental (e.g., external) forces that might otherwise affect the features that would be displayed by *i*. The present approach does not apply to the atoms having an intrinsically unstable nucleus, which are inclined to decay in some period.

[24] See Hendry (2013: ch.4). Hendry defends microstructuralism with respect to chemical elements, that is, that elements have "a microstructural essence" specified by their nuclear charge (the number of protons in atomic nuclei).

[25] Cf. Hendry (2013: ch.4, sec. 3) for a brief discussion of the effects of isotopic variation on the behaviour of the corresponding chemical elements and their compounds.

[26] Brian Ellis (2001: 238) argues that, as an individual, an (intrinsically unstable) atom emitting an electron in a β^--decay remains in existence but changes its natural kind. The individual atom continues to exist since it retains the number of its nucleons, and, thus, most of its mass, although one of its nuclear neutrons is replaced with a proton. If we accept this, β^+-decays and electron captures offer us similar examples of atom's changing its natural kind.

[27] According to this proposal, atoms would not maintain their existence through the fission processes not preserving the number of nucleons (e.g., α-decays) because such fissions radically change the structure of atomic nucleus. Moreover, they change the number of atoms.

(CC) If objects i_1 ,...,i_n satisfy the following conditions, they *form an intrinsically stable individual*, that is, complex object *i*:

a. Objects i_1,...,i_n belong to certain natural kinds K_1,...,K_n and have certain determinate causal powers as members of these kinds.
b. If objects i_1,...,i_n of kinds K_1,...,K_n are in certain relative spatial locations, their causal powers generate certain kinds of causal processes and i_1 ,...,i_n mutually interact by means of the processes.
c. Objects i_1,...,i_n are in the required relative spatial locations, mutually interact and retain their relative locations (in certain limits) due to their mutual interaction unless external forces are exerted on them.

Condition (CC) is meant as a schematic formula: we would need a larger survey of *a posteriori* examples to deal with the intrinsically unstable objects (such as the uranium atoms of any specific isotope). Moreover, an ontologically more detailed account of composition would require a trope theory of causal processes and spatio-temporal relations.

Whilst the trope constituents of simple substances (powerful particulars) determine their causal powers (cf. above), we can assume that most causal powers (e.g., electric charges) of complex particles (such as neutrons, protons and atoms) are determined by the tropes possessed by their proper parts. The SNT introduces relational tropes to determine the causal powers of complex individuals not determined by the fundamental property tropes.[28]

According to clause *b*, the proper parts of a complex object must mutually interact, usually by means of one or more different kinds of causal processes. In the case of atoms, the relevant processes are the two basic physical interactions (strong and electro-magnetic interactions), which are generated by the electric charges and colour charges of their fundamental parts.[29] *Prima facie*, assuming that the parts of a complex physical object exist during some interval, the complex object must demonstrate stability among its parts in order to exist and remain in existence. Clause *c* purports to cash out the stability condition in terms of relative spatial locations: due to the relevant causal processes (here, strong nuclear force and Coulomb force), the constituent objects retain their relative location (in certain limits) provided that no external forces affect them.

[28] Morganti (2009b) argues that the state-dependent properties of the systems of two- or more quantum particles (or, the groups of such particles) are best considered as emergent inherent properties of the groups of these particles ("systems"). The SNT introduces relational tropes to account for the corresponding state-dependent properties, cf. Keinänen 2011: 434.
[29] For the sake of brevity, I omit the characterization *weak interaction* and the role it plays.

Finally, the trope nominalist theory identifies (a perfectly intrinsic) natural kind K of complex objects with an abstraction from the kind terms having certain determinate application conditions:

(CK) Kind term K specifying a natural kind of complex objects fulfils the following two conditions:

> a. Kind term K applies to complex object *i* if and only if *i* has objects x_1 ,..., x_m belonging to certain natural kinds K_1,...,K_m as its proper parts. Object *i* has no more objects belonging to these natural kinds as its parts.
>
> b. The application conditions of K in the actual world, which clause a. specifies, fix the application conditions of K in every possible world.[30] Thus, kind term K has exactly the same application conditions in every possible world.

Condition (CK) relies on the fact that object *i* has proper parts, that is, it forms a natural unity in accordance with condition (CC) or a similar clause. If a complex object (e.g., a helium-4 atom) fulfils condition (CC), it has a certain kind of structure, that is, its proper parts interact in a certain way and are in certain spatial relations. For instance, some proper parts of a helium-4 atom (neutrons and protons) are arranged in the atomic nucleus, some are the orbiting electrons.

Kind term K applies to object *i* if and only if *i* has a certain definite number of objects belonging to certain natural kinds as its proper parts (clause a). This specifies the application conditions of K in the actual world. The kind term has the same application conditions in every possible world (clause b), cf. note 30. Complex object *i* belongs to natural kind K if and only if kind term K applies to *i*.

Condition (CK) suffices to explain K-necessity of certain kinds of proper parts to object *i*. Assume that *i* is a helium-4 atom, that is, the natural kind term “helium-4 atom” applies to *i*. This kind term “helium-4 atom” applies to *i* if and only if it has two protons and two neutrons as its proper parts (clause a). In every possible world in which “helium-4 atom” applies to *i*, it has exactly these nucleons as its proper parts (clause b). Hence, necessarily, if *i* exists and is a helium-4

[30]According to Haukioja (2012: sec. 3), the semantics of many kind terms can be explained by considering them as *actuality-dependent expressions*. A term T is actuality-dependent if and only if it applies, in non-actual worlds, to the thing(s) which possess the properties which realize the *applicability role* associated with term in the actual world, (2012: 406). Roughly, the features of objects due to which the term applies to these objects realize the applicability role of the term. Here, I apply the idea of actuality-dependence to the kind terms specifying the natural kinds of complex objects.

atom, *i* has two neutrons and two protons as its proper parts. The K-necessity of certain kinds of proper parts to an instance of natural kind K is thus explained by recourse to the semantic properties of kind term K, that is, that the features of *i* due to which K applies to *i* in any possible world are the same due to which it applies in the actual world.

On the present approach, the location and causal powers of the proper parts of an atom explain why the parts constitute a certain kind of stable (or, comparatively stable) structure. Thus, the stability of the K-necessary structure has a bottom up explanation in the case of atoms. If natural kind K is contingent to its instance *i*, the K-necessary structure cannot individuate it. Nevertheless, if the above suggestion is correct, an atom is individuated by means of its proper parts: it has certain simpler objects (nucleons) as its necessary parts, or, at least, necessarily, a certain number of certain kinds of simpler objects as its parts.[31]

In the limits of this chapter, answering the question what makes true the claim that a complex object *i* is a member of natural kind K remains schematic. In order to illustrate the main lines, let us consider the claim "*i* is a helium-4 atom". On grounds of clause (CK), we can infer that it is made jointly true by the truthmakers of the claims about its K-necessary proper parts: first, that they belong to certain natural kinds (neutron, proton), second, are spatiotemporally related in a certain way, and third, are connected by certain causal processes. The truthmakers of these statements are the property tropes making true the claim that certain kinds of powerful particulars (d- and u-quarks) exist, the relational tropes accounting for the spatiotemporal location of the powerful particulars, relational tropes accounting for the emergent causal powers of the groups of these powerful particulars and the entities (tropes) constituting the relevant basic causal processes that connect the powerful particulars.

5. Conclusion

In this chapter, I have outlined a trope nominalist theory of natural kinds of simple substances and the beginnings of the generalization of the same theory to complex objects. According to the trope nominalist theory, natural kinds are not mind-independent entities but abstractions from natural kind terms with certain determinate application conditions. I argued against the rival nominalist attempts to identify natural kinds with any mind-independent entity or with groups of mind-independent entities (section 3). Moreover, since natural kinds are *abstractions* from natural kind

[31] Depending on the identity conditions of its constituent nucleons and quarks, the atom has either certain definite nucleons (quarks) as its necessary parts or, necessarily, a certain number of nucleons (quarks) as its parts.

terms, every token of a kind term with exactly the same application conditions specifies the same natural kind.

Further, I outlined the application conditions of the kind terms specifying the natural kinds of simple substances. I discussed three different kinds of cases: first, the *primary kinds*, or, the most specific natural kinds necessary to a simple substance, second, the (possible) contingent natural kinds more specific than the primary kinds, and third, more general natural kinds than the primary kinds. By relying on the trope theory SNT, I showed that, in each of these cases, the trope parts of simple object *i* determine the natural kind to which *i* belongs.

In section 4, I took the first steps to generalize the trope nominalist theory to the natural kinds of complex objects. I used stable atoms as an example. Simpler objects must be sufficiently naturally unified to compose a complex object. I explained the natural unification in terms of causal processes connecting the parts of a complex object due to which the parts retain their relative locations (in certain limits). Moreover, I discussed the application conditions of the kind terms specifying the natural kinds of atoms. They apply to a complex object because it has a certain number of certain kinds of simpler objects as its parts. While the specific kinds are contingent to some particular atom, it seems to have determinate identity conditions as a member of the general kind. Finally, property and relation tropes (instantiated by the simple or more complex objects) suffice determine the natural kinds to which these complex objects belong.

Here, I cannot take up a detailed comparison of the present theory to its main rivals. However, I mention three reasons of why it is preferable to them. First, all complex entities the present theory introduces are objects; all tropes are simple and we need not postulate complex properties. Hence, unlike the reductive realist theory of Hawley and Bird (2011), the present theory does not have a larger task of explaining of how the composition of properties is correlated with the composition of objects. Second, the trope nominalist theory avoids the postulation of substantial kind universals. Above, I argued that simple substances are individuated by their nuclear tropes. If the necessary parts can also individuate complex objects in a similar manner (cf. the example of atoms above), we need not postulate substantial kind universals to determine the identity conditions of complex objects. Third, in the case of simple substances, the present theory need not introduce further entities (such as kind universals or laws of nature) to collect (or, unify) the necessary properties of natural kind K.[32]

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