

# The Cornucopia of Formal-Ontological Relations

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## ABSTRACT

The paper presents a new method for generating typologies of formal-ontological relations. The guiding idea is that formal relations are those sorts of relations which hold between entities which are constituents of distinct ontologies. We provide examples of ontologies (in the spirit of Zemach's classic "Four Ontologies" of 1970), and show how these can be used to give a rich typology of formal relations in a way which also throws light on the opposition between three- and four-dimensionalism.

There are many candidate formal-ontological relations, for instance: identity and difference, parthood and overlap, inherence and dependence, participation and location. Our task in what follows is to provide a principle for generating the complete family of such relations. This will mean providing an account of what formal-ontological relations are, and of how they differ from relations of other types (for instance from static material relations such as *lies on* and *fits into*, from material relational events such as kisses and thumps, from comparative relations such as *is taller than* and *is further from Witwatersrand than*, and from family relations such as *is the brother of* and *is consanguineous with*).

The starting point for our endeavours is a philosophical position which we call realist perspectivalism (Grenon 2003a; Smith and Brogaard 2003). This consists in the view that any given domain of reality can be viewed from a number of different ontological perspectives, all of which can have equal claim to veridicality. Compare the way in which medical science is divided into anatomy and physiology: the former tells us about the structures of the human

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body at some instant of time; the latter tells us about the normal functioning of the human body as it sustains itself in existence through some interval of time. Or consider the way in which linguistic science is divided into synchronic and diachronic linguistics: the former tells us about the structures of a language at some given time; the latter tells us how the language evolves through time. We can consider different perspectives also according to the level of granularity we adopt. Thus we can examine the human body from a molecular, cellular, organ, and whole organism perspective, and each of these can have equal claims to veridicality.

The possibility of a number of equally veridical perspectives does not mean however that any and every perspective is veridical. Perspectivalism is constrained by realism – by the view that there is a way reality is, independent of the perspectives (languages, theories, cultures, measuring instruments) which we human beings adopt.

### *1. Trans-Ontological Perspectives*

Problems arise, however, when we bring two or more such perspectives together. Consider the sentence:

The tumour developed in John's lung over 25 years.

This brings together the two dimensions of structure (tumour, lung) and process (developed in ... over 25 years). Tumours and lungs, like the organism of which they form part, are continuants or endurants; they persist identically through time. Tumour development is an occurrent or perdurant, which means that it is a process which unfolds itself in its successive temporal phases.<sup>1</sup> But what *is* the tumour which persists identically over 25 years? It may well be that no single molecule existing as part of the tumour in an early phase of its existence is such as to remain a part of the tumour in some later phase of its existence. What this means is that for two continuant entities *a* and *b* it is not in general determinate whether *a* is a part of *b*. It is however a generally accepted feature of recent work in ontology that the part relation is used as a crucial organizing tool. The solution, we believe, is to preserve the determinateness of parthood by insisting that continuant entities should be grasped in an ontology always as they exist at some specific instant of time. Continuants, to be sure, are such as to continue to exist; but our ontological assay of this fact involves in every case appeal to a plurality of temporal instants. Oc-

<sup>1</sup> We will here use the terms 'continuant' and 'endurant' on the one hand and 'occurrent' and 'perdurant' on the other hand interchangeably. See Lowe 1998 and Sider 2001 for further background on this topic.

currents, in contrast, call for ontological perspectives which themselves span or extend across corresponding temporal intervals.

Continuants and occurrents accordingly call for two distinct sorts of ontological perspective. Another way of stating this thesis is to point out that, because substantial entities and processes *exist in time in different ways*, there is no ontologically structured perspective – no inventory of reality – under which both can be viewed together. We view John, his lungs, and his tumour, in successive instantaneous snapshots. We view a process of development by spanning an interval of time.<sup>2</sup>

Many philosophers are of course unwilling to take the leap into perspectivalism. They insist, rather, that it is necessary to embrace some one, single perspective. Thus many will embrace either four-dimensionalist or three-dimensionalist perspectives – but in such a way that each is understood in eliminativistic fashion as ruling out the other. We, in contrast, see the need to have both. Exclusivistic four-dimensionalism holds (in our terms) that only processes exist, and that continuants are special kinds of process-things (Quine 1960). Time is then just another dimension, analogous to the three spatial dimensions, and substantial entities are analyzed away as worms or fibres within the four-dimensional plenum. Strictly speaking, therefore, there is for the four-dimensionalist no such thing as Bill Clinton. Rather, there exists within the four-dimensional plenum a continuous succession of processes which are *similar in a Billclintonizing sort of way*. For us, this reduction of Bill Clinton is unacceptable: for a process to Billclintonize is precisely for it to be a part of Bill Clinton's life. Conversely, we think that there is more to dynamic reality than a mere succession of states and more to change than mere discrepancies over time. We therefore reject approaches which seek to eliminate or reduce events and processes by conceiving all reference to such entities as a mere *façon de parler* about what is three-dimensionally acceptable.

Four-dimensionalism brings the signal benefit, from the point of view of rigorous ontology, that its ontology is mereologically determinate. (This means that, given any *a* and any *b*, it is always determinate whether *a* is part of, or overlaps with, or is disjoint from, or is itself *a* whole including *b*.) Indeed, we hold that four-dimensionalism is right in everything it says, but only when it is making assertions about those entities which fall properly within its purview. The four-dimensionalist does indeed offer, from the standpoint of realist perspectivalism, one veridical perspective on reality (the perspective which ap-

<sup>2</sup> Zemach 1970 distinguishes four combinations of modes of being in space and time and four corresponding ontologies. The present paper is very much in the spirit of Zemach, but follows Grenon 2003b in its account of the relations between and across ontologies.

prehends processes and the spatiotemporal regions at which they are located). But we insist that other perspectives are required also; not least the three-dimensional perspectives which capture, for given instants of time, the substances (and other continuant entities) which exist at those times. And then not only is it the case that each such instantaneous three-dimensionalist ontology also enjoys the nice feature that it is mereologically determinate, but also that this same feature is preserved when we embrace both the four- and three-dimensional ontologies simultaneously.

## 2. *SNAP and SPAN*

The realist perspectivalist embraces, not one ontology, but a multiplicity of complementary ontologies – distinct perspectives on reality, each one of which is veridical. We call those instantaneous snapshot-like perspectives on reality which recognize continuant entities SNAP ontologies, for short. Four-dimensionalist perspectives on the reality of processes yield what we shall call SPAN ontologies. (The details of the SNAP and SPAN ontologies are presented in Grenon and Smith 2003 and Grenon 2003c, which in addition present a logical formalization of the framework here presented.)

The entities recognized by SNAP ontologies are marked by the fact that they:

- enjoy continuous existence in time,
- preserve their identity through change,
- exist *in toto* at every moment at which they exist at all.

SPAN entities, in contrast,

- have temporal parts (or they are instantaneous temporal boundaries of entities which have temporal parts),
- unfold themselves phase by phase,
- exist only in their successive phases.

You are a SNAP entity; your life is a SPAN entity. You are three-dimensional; your life is four-dimensional. You persist in time by enduring; your life per-dures.

The classes of entities visible through the SNAP and SPAN perspectives are strictly disjoint from each other because SNAP and SPAN entities enjoy distinct temporal modes of being. The parts, aggregates, and boundaries of SNAP entities are themselves in every case SNAP entities; the parts, aggregates, and boundaries of SPAN entities are likewise themselves SPAN entities. No SNAP entity is ever a part of any SPAN entity and vice versa. It is for this reason that ontological determinacy is preserved when we put SNAP and SPAN ontologies together.

The SNAP/SPAN distinction reflects two distinct modes of being in time. It generates two types of ontology, each of which may be instantiated in selected domains or portions of reality. Each such instantiation is, so to speak, an ontological depiction or ontologically structured inventory of this portion of reality. It carves out and categorizes its constituents in ways which approximate, to different degrees, to the *bone fide* boundaries among those constituents (Smith 2000). This carving out and categorizing can exhibit different degrees of coarseness or refinement. Granularity is yet another dimension along which we may generate a variety of distinct ontological perspectives. This dimension is, so to speak, orthogonal to that which we have considered above, which means that the SNAP/SPAN distinction can be put to work at each level of granularity.

### 2.1. SNAP

Each SNAP ontology is an inventory of the continuants existing at some given time, and is accordingly indexed by the corresponding time instant  $t_i$ . Note that to be a SNAP entity it is neither necessary nor sufficient that an entity be instantaneous. Instantaneous temporal boundaries of processes fall within the scope of SPAN (rather than SNAP) ontologies, and most SNAP entities themselves – including Bill Clinton – endure for extended periods of time.

We can distinguish three kinds of SNAP entities:

1. Independent SNAP entities (substances and their aggregates, the parts, and boundaries thereof).
2. Dependent SNAP entities (qualities, roles, conditions, functions, dispositions, powers, etc.).
3. Spatial regions of 0, 1, 2 and 3 dimensions.

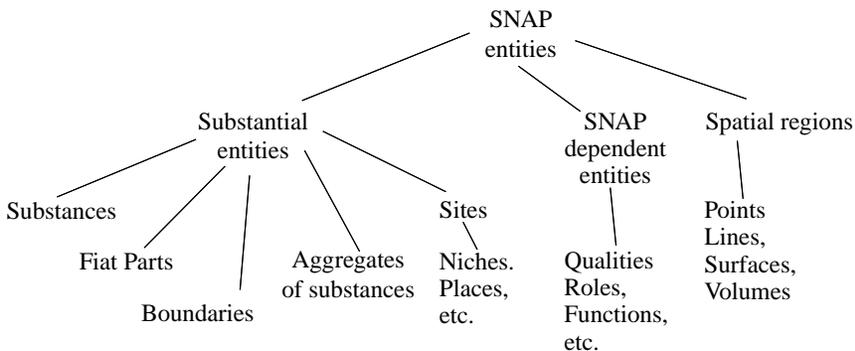


Figure 1. The main categories of SNAP entities.

Examples of independent SNAP entities are: you and me; a bunch of grapes; your head; the boundary of an apple. This category includes also the various types of niche- and cavity-like structures formed by substances and their parts and boundaries, for examples rooms, corridors, buildings, your alimentary tract – entities which fall under the category of what we shall call *sites*, and which are at any given time distinct from, though such as to coincide exactly with, some given spatial region. Spatial regions share with substantial entities the feature of being (specifically) independent.

Examples of dependent SNAP entities are: the specific individual redness of this grape; the specific individual temperature of this cheese; the specific individual function of this pen; the specific individual condition of mild hypertension of this patient extending over many years. Dependent SNAP entities may be either monadic – your mass, the fragility of this glass – which means that they are (specifically) dependent on just one substance; or relational – John’s love for Mary, the electromagnetic charge between these two conductors – when they are (specifically) dependent on a plurality of substances. There is a variety of subcategories of dependent SNAP entities, including *functions* (the function of the canal to enable transportation), *roles* (as student, as captain of a soccer team), *dispositions* (of the vegetables, that they are prone to decay), *powers* (of the refrigerator, to slow the decay of vegetables), plans, liabilities, algorithms, shapes, and so on.

## 2.2. SPAN

In SNAP, time plays the role of external index. In SPAN, in contrast, it exists as part of the domain of the ontology. We can distinguish two kinds of SPAN entities:

1. Processual entities (which include processes in the narrow sense – these are extended in time –, as well as the instantaneous temporal boundaries of processes, here called events).
2. Temporal regions (of dimension T) and spatiotemporal regions of dimensions T+1, T+2 and T+3.

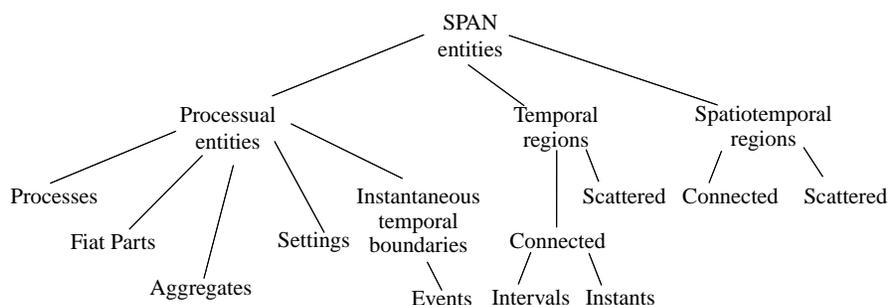


Figure 2. Taxonomy of SPAN entities.

Examples of processual entities are: your life; your neighbour's holiday in Jamaica; your eating of this grape; the rotting of this cheese; the 2002 World Cup.

Processual entities, too, it will be clear, are dependent entities. And just as we can distinguish monadic and relational in the case of SNAP dependent entities, so we can distinguish monadic and relational in the case of processes. Examples of the former are: your getting warmer, my getting hungrier; examples of the latter are: conversations, dancings, wars. Such relational processes join their carriers together into collectives of greater or lesser duration.

Processes have their characteristics by necessity. This means that there are no SPAN entities which stand to processes in a relation analogous to that in which dependent qualities stand to substances in SNAP. The alleged qualities of processes such as pace, intensity, linearity, cyclicity, and so forth, are not extra entities which might have been absent and yet the processes themselves have existed nonetheless. Rather they are moments or dimensions or structural parts within the makeup of the processes themselves. A fast race is a race whose duration is short compared to the distance to be run. In turn, a race is a process which involves a number of participants entering into specific sub-processes (people who are starting to run from certain positions, their running along a certain defined path, their stopping at a second location, and so on). Some types of processes are defined in terms of the types of SNAP entities they involve, such as *changes* in temperature or *displacements* of vehicles. Conversely, we may define a number of types of SNAP entity on the basis of the relations they bear to SPAN entities of specific types. Once we have the type *race*, we can define the type *racer* and the type *racing venue*. Some definitions are even more straightforward, such as that of the type student as a type of substance in which the role of *being-a-student* inheres.

The category of processuals includes not only processes and their boundaries but also the various types of complex structures formed by these – in-

cluding the four-dimensional analogues of corridors, rooms, and alimentary tracts, namely the *settings* in which processes take place (the 5 o'clock train to Long Island, the Afghan winter, Tudor England). Entities of this sort are involved, for example, in making true assertions such as: lobsters have evolved into environments marked by cyclical patterns of temperature change.

Settings are the analogues in SPAN to sites in SNAP. In particular, they are distinct from temporal or spatiotemporal regions (roughly as the concrete is different from the abstract). The largest SPAN ontology is eternalist: it encompasses the whole of time. Other SPAN ontologies extend across only a part of time, and it is even in principle possible to construct a SPAN ontology which extends only over an instantaneous cross-section of spacetime. This will still be a SPAN ontology (it will comprehend within its purview exactly all those instantaneous boundaries at the corresponding moment). Its domain will indeed coincide in a complex way with the corresponding SNAP ontology. But coincidence is not identity. Thus the entities made visible in an instantaneous SPAN ontology have the character of boundaries of entities with larger numbers of dimensions (as *the present moment* is a boundary of the past and *the future*). This is not so for the entities made visible by a SNAP ontology (Smith 1997).

### 3. *Formal-Ontological Relations*

The term 'formal ontology' was first used by Husserl in his *Logical Investigations* (1913/1921), where formal-ontological relations are in addition described as being 'independent of the peculiarity of any material of knowledge'. This means that they are such as to apply, in principle, to any domain of reality whatsoever. Husserl himself provides a list of formal-ontological categories, which includes items such as: *object*, *state of affairs*, *unity*, *plurality*, and so on. These concepts are, like the concepts of formal logic, able to form complex structures in non-arbitrary, law-governed ways, so that by grasping the corresponding laws, we are able to grasp the properties of given structures in such a way as to establish *in one go* the properties of all formally similar structures. This holds in formal ontology just as it holds in formal logic and in mathematics (Smith 1989).

But how, when all of this has been said, are we to determine which ontological categories are the formal ones? Our idea, in its first rough version, which focuses exclusively on formal *relations*, reads as follows (and it presupposes the notion of ontological perspectives that has been outlined above):

Formal relations are those types of relations which can traverse the divides between distinct ontological perspectives. Thus, they are those types of relations which:

1. can traverse the SNAP-SPAN divide (relations which glue SNAP and SPAN entities together)
2. can traverse granularities (for example between the molecular and the cellular levels of granularity)
3. can traverse temporal divides (for example between now and later).

The idea here encapsulated does justice also to the intuition that formal-ontological relations come for free; that they do not add anything to being. Beings are precisely what is captured by the ontologies themselves, which are linked together by the formal relations. Our proposal yields a first rough list of formal relations, above all *dependence*, which is ranked by Husserl among the prime examples of formal relations, and *parthood*, which holds (*inter alia*) between entities captured by ontologies of different level of granularity. *Identity* also counts as a formal relation under 3.

But dependence, parthood, and identity are of course able also to tie together entities within single ontologies. A more careful version of our proposal would therefore read as follows:

Formal relations are those relations that can obtain between entities of distinct ontologies.

The fruitfulness of this idea turns on the fact that it can be used to generate a catalogue of kinds of formal relations, reflecting the kinds of ontologies and of relations between ontologies that have been distinguished at any given stage in the development of the ontological science. A number of parameters can then be used in the construction of this catalogue:

- the ontologies from which the relata derive, expressed as an ordered list, called the *signature* of the relation
- the *arity* of the relation
- the *directionality* of the relation

The principal signatures in the binary case are as follows:

- <SNAP, SPAN>
- <SPAN, SNAP>
- <SNAP<sub>i</sub>, SNAP<sub>j</sub>>, for distinct time indices *i, j*
- <SPAN, SPAN> for SPAN ontologies with different domains or granularities

To see how the machinery works, consider Figure 3. Here any relation which crosses the dotted line – for example connecting spatial regions with processual entities – is a formal-ontological relation by the terms of our theory:

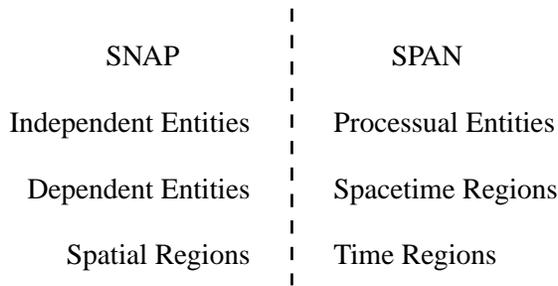


Figure 3. SNAP-SPAN and SPAN-SNAP Relations

This simple idea will prove to be surprisingly powerful in the range of examples of formal-ontological relations it is able to generate.

4. *Relations with Signatures*  $\langle SNAP_i, SNAP_j \rangle$  for  $i < j$ , and  $\langle SPAN, SPAN \rangle$

GENIDENTITY. The formal-ontological relation of genidentity, or in other words the being-such-as-to-have-come-forth-from relation (Lewin 1922), comes in a number of different varieties. If you cut a chunk of matter in two, the sum of the remaining pieces is physically completely genidentical to the chunk before cutting. A new-born baby is biologically partially genidentical to its mother. Genidentity is thus a transtemporal – which for us means transontological – generalization of the relations of identity and part-whole among continuant entities.

Examples of relations with signature  $\langle SPAN, SPAN \rangle$  are relations of successive causality, illustrated where one process causes another later process. But there are also cases of simultaneous causality, as for example where a rise in temperature causes the (simultaneous) increase in pressure (Boyle's law), or where a blood infusion regulates the metabolism in a given patient.

TRANSGRANULAR PART-WHOLE RELATIONS. We can move ontologically from a coarse- to a fine-grained perspective and back again, as occurs for example when some clinical phenomenon prompts us to investigate the features of the underlying DNA, which prompts us in turn to draw new conclusions on the clinical level. Reality admits in this way of a sort of ontological zooming (Bittner and Smith 2002).

The relations crossing ontologies of different levels are pre-eminently relations of part and whole:

John's hair follicles (SNAP) are parts of John (SNAP)  
 These and those molecule (SNAP) are parts of John's hair follicles (SNAP)

Kevin's leg-movement (SPAN) is part of Kevin's running (SPAN)  
 Kevin's flexing of his gastrocnemius (SPAN) is part of Kevin's leg-movement (SPAN)

Note that relations of part and whole crossing SNAP ontologies obtain only if the ontologies in question have the same temporal index, and that such relations crossing SPAN ontologies obtain only if the relevant ontologies temporally overlap.

Other formal relations crossing the granular divide are for example the relation of sustaining-in-being, which holds between certain physiological processes and the organism which they sustain. Note that these processes are not parts of the organism; rather they are parts of the organism's life. In what follows, however, we shall leave such issues of transgranularity aside and assume that the relations with which we deal obtain within and between ontologies of a single granularity.

##### 5. Relations with Signature <SNAP, SPAN>

SEGMENTATION. Our first example of a relation between SNAP and SPAN entities is that of segmentation, sometimes also called individuation. The realm of substances, we can say, is segmented in and of itself; here external boundaries correspond to joints in reality. In the SPAN realm of processes, in contrast, the maxim 'everything is flux' nearly everywhere holds sway. Processes flow seamlessly one into another, and their segmentation is often parasitic upon that of substances, as when we talk of *John's headache*, *Mary's speech*, *Bill's life*. Such segmentation then traverses the SNAP-SPAN divide. This applies first of all on the level of individuals or tokens: where token substances are separated by bona fide boundaries, token processes are in very many cases separated by fiat boundaries only (Smith and Varzi 2000). But an analogous point holds also on the level of types. For there, too, we find a marked opposition between substances and entities in other categories. Substance-types are characteristically sharply delineated from each other (in the way in which the kind *rabbit*, for example, is sharply delineated from the kind *dog*). Process-types, in contrast, are characterized by the fact that they very often form continua, with the possibility of segmentation into distinct types arising primarily in the realm of process artifacts such as weddings and music festivals. It is the Heraclitean nature of the realm of processes which makes attractive, for four-dimensionalists such as Quine (1960, p. 171), ontologies based on the principle of unrestricted gerrymandering.

### 5.1. Relations with Signature <SNAP Independent, SPAN>

PARTICIPATION. The relation of participation is a species of dependence. It holds between a substance and a process: you participate in your life; in each one of your actions; in the history of your nation or regiment. *A runner participates in a race. A voter participates in an election.*

There are different kinds of participation, which we can order along the following dimensions:

- active/passive ( $\pm$  agentive)
- direct/mediated
- complete/partial
  - of subject* (the degree to which the whole subject or only part of the subject participates)
  - of action* (the degree to which the subject is involved in the whole or only in part of the action)
- benefactive/maiefactive ( $\pm$  conducive to the existence of the participating subject) (This last dimension has an obvious relevance to the domain of medical ontology.)

The resulting tree of modes of participation looks roughly as follows:

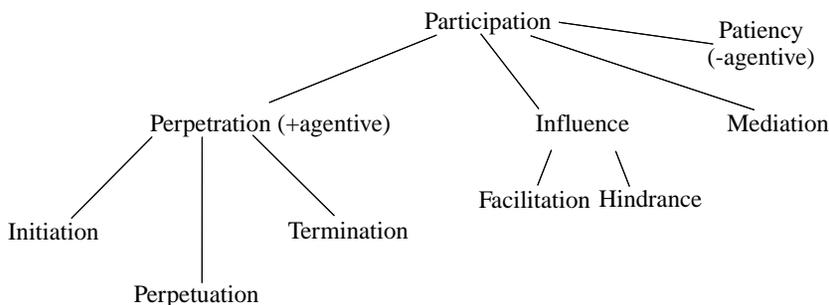


Figure 4: Modes of Participation.

PERPETRATION. A substance perpetrates an action (direct and agentive participation in a process): *the referee fires the starting-pistol; the captain gives the order.*

INITIATION. A substance initiates a process: *the referee starts the race; the attorney initiates the process of appeal.*

PERPETUATION. A substance sustains a process: *the singer sings the song; the charged filament perpetuates the emission of light.* Perpetuation normally presupposes that at an earlier time there has been an entity which entered in the relation of initiation with the process in question. However, perpetrators are of course not by necessity themselves initiators.

TERMINATION. A substance terminates a process: *the operator terminates the projection of the film; the judge terminates the imprisonment of the pardoned convict*. Termination normally presupposes that there has obtained in the immediately prior interval of time a relation of perpetuation. Processes cannot pass from initiation to termination instantaneously. Instantaneous processual entities, including initiations and terminations themselves, are in every case boundaries (events) in processes of longer duration and it is the latter which have initiations and terminations in the strict sense of the terms.

INFLUENCE. A substance has an effect on a process: *the hilly slopes affect the movement of the troops; the politicians influence the course of the war*.

A further closely related class of examples can be distinguished, which do not quite fall within the <SNAP, SPAN> group because they involve terms additional to their two primary relata:

FACILITATION. A substance plays a secondary role in a process (for example by participating in a part or layer of the process): *the catalyst provides the chemical conditions for the reaction; the traffic-police facilitate our rapid progress to the airport*.

HINDRANCE, PREVENTION. A substance has a negative effect on the unfolding of a process (by participating in other processes): *the drug hinders the progression of the disease; the strikers prevent the airplane from departing*.

MEDIATION. A substance plays an indirect role in the unfolding of a process relating other participants: *the Norwegians mediate the discussions between the warring parties; the mailman brings Mary's letter to John*.

PATENCY. A substance is being acted on by a process: *the pistol is being fired; the song is being sung*. This is the dual of agentive participation.

## 5.2. Relations with Signature <SNAP Dependent, SPAN Processual>

REALIZATION. Where participation is a relation between SNAP substantial entities and processes, realization is a relation between SNAP dependent entities and processes. There are three main modes of realization:

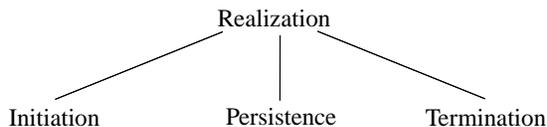


Figure 5. Modes of Realization

Examples are: *the power to legislate is realized through the passing of a law; the role of antibiotics in treating infections is realized via the killing of bacteria*.

There are several kinds of dependent SNAP entity, and we may associate with each some corresponding form of realization. We shall not distinguish formally here between all these variants, but shall only observe the corresponding variety of English terms:

- execution (of a plan)
- performance (of an act, of a symphony)
- expression (of a function, of a character, of an emotion)
- exercise (of a power, of a role)
- actualization (of a disposition)
- utterance (of a sentence)
- application (of a therapy, of a law)
- course (of a disease)
- increase (in temperature)

Realization involves in every case three entities: (1) a substance, (2) a SNAP dependent entity, and (3) a correlated process. (2) then inheres in (1) in virtue of the fact that (1) participates in (3). Material ontology will tell us which types of processes are associated in this sense with each specific type of realization. For instance, your role as a student is realized during processes of registration, of attending lectures, of taking examinations, and so on. Clearly other participants in these processes may realize other, quite different roles.

Note that realization is not the only mode of existence of SNAP dependent entities. Roles, powers, functions, liabilities, and so on may exist without being realized (a teacher is still a teacher even when she leaves the classroom; a screwdriver is still a screwdriver even when it is not being used). In this connection, we may make a further distinction according to which each substantial bearer of a dependent SNAP entity is in a sense participating in a certain default state (a continuous process of non-change), in virtue of the dependent entity which inheres in it. Thus Jacques Chirac will continue to hold office during the whole period of time during which his presidency – a certain social status, a SNAP entity – inheres in him. He is not President only when receiving foreign dignitaries, but also when asleep in bed. Such states are SPAN entities. (Compare the Spinozistic terminology of being in a ‘state of motion or rest’.)

## 6. Relations with Signature <SPAN, SNAP>

### 6.1 Relations between Processes and Substances

INVOLVEMENT. *Involvement* is the most general form of relation between a processual and a substantial entity. It is sometimes simply the converse rela-

tion of participation: as racers *participate in* races, so races *involve* racers. However, there are additional forms of involvement, as for example: wars involve civilians, which denote not agentive participation but rather a passive being *affected by* on the part of the substances involved.

There are a number of sub-types of involvement, illustrated in Figure 6 as follow:

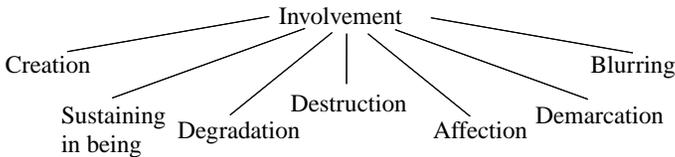


Figure 6. Modes of Involvement.

**CREATION.** A process brings into being a substance: *the declaration of independence creates the new state; the work of the potter creates the new vase.*

**SUSTAINING IN BEING.** A process sustains in being a substance: *the circulation of the blood sustains the body; levying taxes sustains the army.*

**DEGRADATION.** A process has negative effects upon a substance: *eating sugar contributes to the deterioration of your teeth; the flow of water erodes the rock.*

**DESTRUCTION.** A process puts a substance out of existence: *the explosion destroys the car; the falling on the floor destroys the vase.*

**DEMARCATION.** A process creates (fiat or bona fide) boundaries of substances: *the signing of the treaty establishes fixed borders between the two nations; the tracing of the area of the operation performed by the surgeon defines a fiat boundary, the incision defines its bona fide counterpart.*

**BLURRING.** A process destroys the boundaries of substances: *the military stand-off creates the no man's land; the successful transplant obliterates the boundary between original and grafted tissue.*

## 6.2 Relations with Signature <SPAN, SNAP Dependent>

**AFFECTING.** We shall employ the not wholly appropriate term 'Affecting' for this group of relations, with sub-types as depicted in Figure 7:

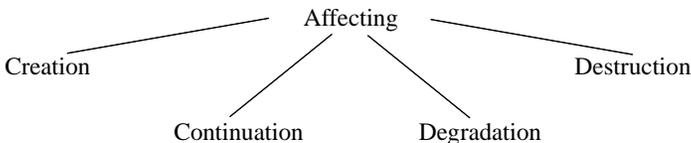


Figure 7. Forms of Affecting.

Examples are: *a warming process yielding a rise in temperature; a tenure process yielding a rise in status.*

CREATION. A process brings into being a dependent entity: *the accident reshapes the car; the baking of the clay gives the vase its rigidity and color.*

CONTINUATION. A process sustains a SNAP dependent entity in existence: *the firing of the fireworks maintains the coloration of the night sky; John's intake of alcohol sustains the rosiness of his cheeks.*

DEGRADATION. A process affects a SNAP dependent entity by lowering its degree: *the opening of the window diminishes the temperature in the room; the impeachment process diminished the status of the President.*

DESTRUCTION. A process destroys or changes a SNAP dependent entity: *the accident destroys the car's shape; the burning of the vase destroys its color; the dishonorable discharge relieved him of his rank.*

## 7. Spatiotemporal Projection

When we talk of John and of his having lived from 1908 to 1988, then we are projecting John onto a certain temporal interval. There is a range of such relations of projecting, including what we might call qualitative projection, when for example warming processes are projected onto temperature scales. Here however we shall concentrate on projection relations involving regions in space and time.

TEMPORAL PROJECTION. Processes are, clearly, projectible onto the axis of time. And a substance is projectible onto a period of time through the mediation of the processes in which it is involved – above all of that process which is its life.

SPATIAL PROJECTION. Processes are projectible, too, onto the (SPAN) spatiotemporal regions in which they occur, as also onto the (SNAP) spatial regions where they start and end. Some processes occur in a given place or area, as in: *the Revolution took place in Paris; the wind blows across the desert.*

The different varieties of projection yield criteria for characterizing processes. Thus a process projects onto:

- its temporal duration,
- the spatio-temporal region it occupies,
- the spatial region it occupies at a given time,
- the sum of its participants at a time,
- the sum of the dependent entities realized through it at a time.

Temporal projection here enjoys a privileged status. This is because it provides the fundamental means for interrelating SNAP and SPAN entities. Each has

its own variety of temporal projection: SPAN entities project directly, SNAP entities indirectly, via their lives, onto temporal intervals. Although *co-temporality* (the relation which holds between entities with identical temporal projections) is a prerequisite for the obtaining of most SNAP-SPAN relations (participation, realization, etc.), there are exceptions, such as memory, some cases of genidentity, and, more generally, all trans-temporal relations between one existing entity and another entity which is either no longer or not yet existing.

## 8. Conclusion

We can now recapitulate our principal thesis as follows:

Formal relations are those relations which are not captured within any single ontology because they are relations which hold (sometimes *inter alia*) between entities in distinct ontologies, for example because they traverse the SNAP-SPAN or the granular divide.

We have shown how this idea can be used to generate a rich inventory of types of formal relations, and we have given examples of relations in each of the various types. There is an objection to this view, which is anticipated in our reference above to ‘ontologies which have been distinguished at any given stage in the development of ontological science’. For this reference would seem to make the repertoire of formal relations depend on which ontologies happen to have been formulated at given times. The rejoinder to this objection is clear: certainly with the advance of ontological science we will *discover* more formal relations; but this does not mean that what formal relations *exist* depends on which ontological theories we happen to have advanced at any given time.

Another objection turns on the fact that there are some relations between the entities in distinct ontologies which are not formal relations, for example comparatives of the form: has more admirers in Warsaw than. The response to this objection is to adopt one final modification of our proposal, which should now read as follows:

Formal relations are those relations which hold (sometimes *inter alia*) between entities which are constituents of ontologies of different types and which are such that, if they hold between entities of given types, then necessarily all entities of those types enter *mutatis mutandis* into those relations.

A final objection is more serious. This is the objection to the effect that our principle for generating formal relations works only if we have a basis of good

ontologies from which to start. The task of formulating criteria of good ontologies is not something we can engage in here. This is not to say that we have nothing to say on this topic; but let it suffice for the moment to remark simply that the better the ontologies with which one starts, the better will be the typology of formal relations which will be generated.\*

## REFERENCES

- BITTNER, T. and SMITH, B. 2002 "A Theory of Granular Partitions" in: M. Duckham, M. Goodchild and M. Worboys, eds., *Foundations of Geographic Information Science*. London: Taylor & Francis Books, 117–151.
- GRENON, P. 2003a "Knowledge Management from the Ontological Standpoint", in: *Proceedings of the WM2003 Workshop on Philosophy and Knowledge Management*, CEUR-WS.org/Vol-85/grenon.pdf.
- GRENON, P. 2003b "The Formal Ontology of Spatio-Temporal Reality and its Formalization" in: H.W. Guesguen, D. Mitra, and J. Renz, eds., *Foundations and Applications of Spatio-Temporal Reasoning (FASTR)*, AAAI Spring Symposium Technical Report Series, AAAI Press, 27–34.
- GRENON, P. 2003c "Spatio-Temporality in Basic Formal Ontology: SNAP and SPAN, Upper-Level Ontology, and Framework for Formalization", IFOMIS Technical Reports Series, 05/03.
- GRENON, P. and SMITH, B. 2003 "SNAP and SPAN: Towards Dynamic Spatial Ontology", *Spatial Cognition and Computation*, 4(1), 69–104.
- HUSSERL, E. 1913/21 *Logische Untersuchungen*, Halle: Niemeyer (2nd ed.). English translation by J. N. Findlay as *Logical Investigations*, London: Routledge and Kegan Paul, 1970.
- LEWIN, K. 1922 *Der Begriff der Genese in Physik, Biologie und Entwicklungsgeschichte. Eine Untersuchung zur vergleichenden Wissenschaftslehre*. Berlin: Borntraeger.
- LOWE, E.J. 1998 *The Possibility of Metaphysics: Substance, Identity, and Time*, Oxford: Oxford University Press.
- QUINE, W.V.O. 1960 *Word and Object*, Cambridge, MA: The M.I.T. Press.
- SIDER, T. 2001 *Four-Dimensionalism: An Ontology of Persistence and Time*, Oxford: Clarendon Press.
- SMITH, B. 1989 "Logic and Formal Ontology" in: J.N. Mohanty and W. McKenna, eds., *Husserl's Phenomenology: A Textbook*, Lanham: University Press of America, 29–67.
- SMITH, B. 1997 "Boundaries: An Essay in Mereotopology", in L.H. Hahn (ed.), *The Philosophy of Roderick Chisholm* (Library of Living Philosophers), Chicago and LaSalle: Open Court, 1997, 534–561.
- SMITH, B. 2001, "Fiat Objects", *Topoi*, 20(2), 131–148.
- SMITH, B. and BROGAARD, B. 2003 "A Unified Theory of Truth and Reference", *Logique et Analyse*, 43(169–170), 49–93.
- SMITH, B. and VARZI, A.C. 2000 "Fiat and Bona Fide Boundaries", *Philosophy and Phenomenological Research*, 60(2), 401–420.
- ZEMACH, E. 1970 "Four Ontologies", *The Journal of Philosophy*, 47, 231–247.

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