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Kinds of Impenetrability

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Introduction

It is often believed that no two things or entities can be in the same place at the same time. This intuition however faces many putative counterexamples:

1. *a tree and the molecules that compose it* (Wiggins, 1968): they are distinct (the tree can survive the loss of some molecules, the molecules can survive the death of the tree) and both are at the same place at the same time.

2. *Tibbles-minus-tail and Tib* (Wiggins, 1968): At t1, Tibbles is a cat and Tib a proper part of it which corresponds to Tibbles without its tail. Tibbles and Tib are distinct. At t2, Tibble loses its tail. Then at t2, both Tibbles and Tib are in the same place at the same time.

3. *shadows, rays of light, spots of light, clouds, flames* (Leibniz 1966, II, xxvii, §1; Sanford, 1970a; Shorter, 1977). Two spots of light or shadow on a screen can pass through each other and then continue their trajectory. There is one time at which the two of them are in the same place.

4. *holes* (Casati & Varzi 1994, p. 33; 1996): "holes can also be interpenetrated by other holes...as when you put a chunk of Gruyère with a small hole inside a bigger hole in a bigger piece of Emmenthaler. The former hole does not become part of the latter. Rather, it is partly co-located with it, i.e., exactly co- located with a part of it."

5. *ghosts, angels* (Lewis, 1991, p. 75)[1]. Ghost and angels do not exist, but are conceivable. They can pass through each other, or through walls.

6. *odours, sounds, events, states, processes*. (Swinburne, 1968, p. 16; Sanford, 1970a; Davidson, 1980; Hacker, 1982; Casati and Dokic, 1994): in chords, many notes appear to be in the same place at the same time. More generally, this may be true of many, if not all, events, processes, and states.

7. Multiple colours (Brentano 1979; 1981, p. 72[2]):

[1]Scholastics were sometime mocked because they were discussing how many angels can dance on the head of a pin.

[2]Note that Brentano does not himself endorse the view that multiple colours are cases of compenetration.

8. *physical fields* (Swinburne, 1968, p. 16): physical fields, having no definite boundaries, are often conceived of as overlapping entities.

9. *boundaries* (Brentano, 1988; Chisholm, 1984; Zimmerman, 1996a,b; Smith, 1997): one plausible way to explain contact between different entities is to claim that contact is the superposing of the external boundaries of the entities.

10. *properties of a same bearer*: the redness and the roundness of a red ball are in the same place at the same time.

11. *properties and their bearers*: the roundness of the ball may be in the same place at the same time as the ball itself.

12. *absolute space and the entities located therein* (Aristotle, Physics, IV, 1, 209a5): the ball may be in the same place at the same time as the region it is in[3].

13. *determinables and determinates* (Johansson, 2000) : the property of *being red* may be exemplified in the same place at the same time as the property of *being coloured*.

14. *elements of mixtures* (Sharvy, 1983a,b; Fine, 1996; Simons, 1987, p. 218): the tea and the milk appear to be located in the whole cup at the same time.

15. *social groups* (Simons, 1987; Sheehy, 2006): assuming groups are located where their members are, and that different groups (clubs, committees, parties...) can have the same members, different groups can be located in the same place at the same time.

16. *brentanian substances* (Brentano, 1981): Brentano's late reist ontology construed accidents as wholes which contain substances as their parts. George and happy-George are then two substances which are in the same place at the same time.

Faced with the conflict between our intuition that no two things ever share a place at a time and these counterexamples to it, philosophers usually try to find a happy medium between sticking with the original intuition and rejecting all of its counterexamples or giving up the whole intuition and accepting all the counterexamples. Some counterexamples might be rejected on conceptual grounds : one may deny for instance that absolute space is in the same place that the entities located therein on the ground that absolute space is not itself located. One may also reject the distinct existence of some of the entities put forward in the examples : determinable properties might be nothing else than boolean combinations of determinate ones, spots on a screen may be just four dimensional worms whose passing through each other is a matter of part sharing rather than compenetration, etc. But as long as the conceivability of at least

[3]That empty space would imply two bodies in the same place at the same time was one of Aristote's main argument against absolute space. See Grant (1978) for an history of that argument.

one counterexample is granted, the impenetrability intuition has to be weakened. To this end, one can weaken either the modal force of the impenetrability intuition or its scope. One may claim for instance that things are impenetrable in our world, but grant that the remaining counterexample refers to genuine metaphysical possibilities (although not natural ones). On the other hand, on may claim that the impenetrability intuition does not bear on every entity in the outside world, but only on some of them. Locke, famously, did not want to give up the metaphysical necessity of impenetrability, but agreed to restrict it to entities of the same kind.[4] One other way to restrict the scope of the intuition of impenetrability is to claim that only independent entities (substances, or *things* proper) are impenetrable[5], or that only material entities are.

Those attempts to reconcile our intuition that the entities of the outside world are impenetrable with the putative counterexamples to it all share the assumption that impossibility of co-location constitutes a single unified phenomenon, often dubbed impenetrability. The question is then to determine which entities are impenetrable and which are not. I do not want to address that question here, but to question the assumption that impenetrability, defined as the inability to be in the same place at the same time as another entity, constitutes a simple fundamental property. Before asking which entities are impenetrable or not (if there are any), whether impenetrability is an essential property of matter, of entities of the same kinds, etc., we have to get clear about what impenetrability is. This is especially important if impenetrability comes in different kinds, as I shall argue. For some entities may be impenetrable in one sense, but not in the other.

In the first part of the paper (1-5) I spell out a necessary condition for impenetrability, namely non-penetrability. I spend some time on defining the right kind of co-location that penetrability allows (and that non-penetrability bans). In the second part of the paper (6-11), I argue that complementing non-penetrability in order to get impenetrability gives rise to three conceptual kinds of impenetrability, and claim that two of them are fundamental: dynamic and numerical impenetrabilities.

1 Penetrability

Impenetrability, in the sense that shall interest us here, is related to the impossibility of co-location[6]. If two entities are impenetrable relative to each other, they cannot be in the same place at the same time. But the reverse is not true : impossibility of co-location is not sufficient for impenetrability. Numbers, propositions, or minds, to the extent that they cannot exist in space and time,

[4]

> "We never finding, nor conceiving it possible, that two things of the same kind should exist in the same place at the same time, we rightly conclude that, whatever exists anywhere at any time excludes all of the same kind, and is there itself alone." Locke (2008, II, xxvii, 1)

[5]This is suggested by Sanford (1970b); Shorter (1977) or Simons (1985). This restriction may deal with counterexamples of type 3, 4, 6, 9, 10, 13, 15.

[6]There are other concepts of impenetrability. For instance, Pylyshyn (1999) argues that vision is cognitively impenetrable, being immune from the influence of beliefs, conceptual knowledges, or expectations. The concept of impenetrability that shall concern us here is the concept of spatio-temporal impenetrability.

cannot exist in the same place at the same time as anything else. But this is just because they cannot exist in one place at one time, not because they are impenetrable. Impossibility of co-location is equivalent to non-penetrability and is necessary but not sufficient for impenetrability. Penetrability and non-penetrability are contradictory properties. Penetrability and impenetrability are contrary ones.

The aim of this first part (1-5) is to define non-penetrability. The condition that should be added to non-penetrability in order to get impenetrability will be the topic of the second part (6-12).

In order to define non-penetrability, let us first define penetrability. As a first approximation, two entities are penetrable relative to each other if they can be at the same place at the same time. Penetrability is a symmetrical relation. I shall assume that it is not reflexive : that a thing can be in the same place as itself doesn't imply its penetrability. For penetrability to occur, *two* things have to be able to be in the same place at the same time. Using the following symbols :

$xPEy$:	x and y are mutually penetrable
Rx :	x is a region of space
xL_tr :	x is located at r at t[7]

One can define penetrability as follows :

Penetrability : x and y are mutually penetrable if and only if they are distinct entities that can be located in the same place at the same time.

$xPEy =_{df} x \neq y \wedge \Diamond\exists z(Rz \wedge xL_tz \wedge yL_tz)$

Though penetrability is fundamentally a relation (an entity is always penetrable relative to at least another one), it is most often thought of as a monadic property. Penetrability as a monadic property is a monadic reduction, or derelativisation of the penetrability relation. The relation of penetrability can be derelativised by binding one of its free variables. That variable can be bound either by an existential quantifier, or by a universal one. Let us use the term "relative penetrability" to denote the derelativisation of the penetrability relation by linking one of its variables to an existential quantifier ; and the term "absolute penetrability" to denote the derelativisation of the penetrability relation by linking one of its variable to a universal quantifier. We get the following two relational properties of penetrability :

[7] I choose to index the relation of *being located at* on time and to have a purely spatial concept of region. One other option is to endorse a tenseless concept of location and to relocate the temporal variable in the regions themselves, by speaking of spatio-temporal regions. Still another option is to considere the temporal variable as an independent variable, and to construe the *being located at* relation as a three-places one. The distinction and theses defended below are compatible with each of those three choices.

$PE_{\exists y}x$: x is relatively penetrable
$PE_{\forall y}x$: x is absolutely penetrable

Relative penetrability : x is relatively penetrable if and only if it can be in the same place at the same time as at least one other spatio-temporal entity.

$PE_{\exists y}x =_{df} \exists y[x \neq y \wedge \Diamond \exists z(Rz \wedge xL_t z \wedge yL_t z)]$

Absolute penetrability : x is absolutely penetrable if and only if it can be in the same place at the same time as any other spatio-temporal entity.

$PE_{\forall y}x =_{df} \forall y[(x \neq y) \rightarrow \Diamond \exists z(Rz \wedge xL_t z \wedge yL_t z)]$

An entity which is relatively penetrable, but which is not absolutely penetrable shall be said to be exclusively penetrable :

Exclusive penetrability : x is exclusively penetrable if and only if it cannot be in the same place at the same time as certain but not all other spatio-temporal entities.

$PE_{\exists ! y}x =_{df} PE_{\exists y}x \wedge \exists y[x \neq y \wedge \neg \Diamond \exists z(Rr \wedge xL_t z \wedge yL_t z)]$

Penetrability of an entity, thus defined, is a property that is exemplified at one region at least. One could also distinguish between entities that are penetrable in every region and entities that are penetrable in all regions of space. In the same way, quantifying over times, one could distinguish between entities that are penetrable at at least one time, at some time(s) only, or at all times of their existence. One the whole, penetrability can be relativized to (i) other entities (ii) regions (iii) times. These complications do not play any significant role in what follows, so one may assume for the sake of simplicity and generality that penetrable entities are entities which are penetrable relative to at least one other entity at at least one time in at least one region.

Two entities are co-located if they are in the same place at the same time. Penetrability then amounts to the capacity to be co-located with another entity.

Such definitions however are insufficient, for not all cases of co-location imply the penetrability of the the co-located entities. Consider :

- two fishes can be in the same bowl at the same time. But we do not want to say they compenetrate each other.
- two discs, one yellow and one blue, may be co-located at a green region. But in one reading of this case, the green region itself is not constituted or filled by two surfaces, one blue, the other yellow, but only by one single green one. The two discs just share that simple green part.

According to the definition given above, both the fishes and the discs are penetrable, but this is clearly not the case (or if it is the case, this is not because of what happens in those situations). They are co-located, but not in the right way. I shall call *compenetration* the sub-species of co-location that constitutes the genuine manifestation of penetrability[8]. Like co-location, compenetration is a symmetrical relation. But contrary to co-location, compenetration implies the penetrability of the compenetrating entities. In the present terminology, compenetration is to be distinguished from penetration and interpenetration.

An entity *penetrates* another if it enters or is in a hole in that other entity[9]. Keys penetrates locks, maggots penetrate apples, and apple penetrate mouths (sometimes the hole exists independently of the penetration, sometimes the penetrating entity is causally responsible of the hole it enters in). Penetration is not a symmetrical relation : most often the penetrating entity is not penetrated by the entity it penetrates. But this may happen. When penetration is symmetrical, I shall call it *interpenetration*. Two swarms of bees may interpenetrate, partly or fully. Two gears partly interpenetrate. The way water is in the sponge may be a complex case of penetration rather than a case of interpenetration. Neither penetration nor interpenetration implies the penetrability of the concerned entities. Only compenetration does[10]. Though interpenetration is not needed in order to define penetrability, it is still of interest relatively to the general problem of impenetrability since it is often used for discarding the putative examples of compenetration. One of the most interesting examples of this strategy is the theory of multiple qualities defended by Brentano (1979, chap. 3). Multiple qualities (such as green), are supposed to be mixtures (of yellow and blue in the case green). Brentano argues that green is a not a counterexample to the impenetrability of qualities since in green, yellow and blue are indeed not compenetrating but only interpenetrating. Green should be understood as multiplicity of yellow and blue patches organised in a chequered pattern[11].

In order to make clear what type of co-location is required for compenetration to occur, we have first to be clear about location and its different types.

2 Location

I shall assume substantivalism about space : space exists independently of the entities therein[12]. A *region* is any part of space[13]. No further hypothesis is made on the nature of regions : they can be points, sets of points, pieces of gunk, extended simples ; tridimensional volumes, twodimensional surfaces or one-dimensional lines ; they can be spatially connected or not ; open, closed,

[8]In other terminologies, compenetration is referred to as penetration, interpenetration, superposition, cohabitation, co-location, sharing an address, coïncidence...

[9]Giving a topological definition of holes is beyond the scope of that paper. Non-convexity is not sufficient : the non-convexity of an entity implies only that there is a concavity in it, but not all concavities are holes (Casati and Varzi, 1994, p. 21 sqq.).

[10]One unfortunate consequence of this terminology is that an entity shall not be said to penetrable when it can penetrate another entity (it is penetrable if and only if it can *compenetrate* another entity).

[11]It is only because_those individual patches lie beyond our apperception threshold that whe may have the impression that green is an homogeneous simple colour according to Brentano.

[12]See also Parsons (2007, p. 226) and Hudson (2005, p. 3). Whether the distinctions and theses defended below can be accomodated in a relationist framework is an open question.

[13]One also speaks of place, position, location.

or both. The relation of *being located at* is a relation between an entity and a region. The converse of the relation of being related at is the relation of *being the location of.*

Can regions themselves be the first relata of the the relation of being located at? Can regions be located at regions? This question divides into two. First, can regions be located at themselves, i.e. is the *being located at* relation reflexive? Following Parsons (2007, p. 224) I shall leave that question open since it is not clear that it has strong metaphysical consequences.[14]

Second, one may wonder whether regions can be located at regions other than themselves. I think not. One sometimes says that some regions are located between other regions. But arguably the relation of *being located between* is better understood in terms of the topological notion of betweenness; in any event, it is not the relation of *being located at.* One also says that some regions are located in some larger ones. But arguably, the relation of *being located in* is better understood, for regions, in terms of the mereological relation of "being a part of"; and in any event, it is not the relation of *being located at.* Indeed, to claim that regions can be located at regions other than themselves would be a category mistake: region constitutes space, they are not in space. One clue in favour of that thesis is that it makes little sense to think of a region that moves (assuming that moving consists in changing one's region or place).

One important upshot is that if spatial entities are defined as entities that exist (or can exist) in space, i.e., as entities that can be located at a region (other than themselves), *regions are not spatial entities.* Regions do not exist in space. One may also use the term spatial to designate the entities (or entity) that constitute space, but one should bear in mind that there are two very different senses of "spatial" in play[15]. I shall stick here with the sense of "spatial" according to which only entities that can exist in space (i.e., that can be located at regions) are spatial, so that regions themselves are not spatial. Two fundamental distinctions apply to the relation of location.

The first one contrasts *entire* with *partial* location (Casati and Varzi, 1996, 1999). Consider a fish in a bowl. The fish is entirely located in the bowl to the extent that all its parts are in the bowl. When its fin shows on the surface, the fish is only partly located in the water. The fish is partly located in regions where it is located, but not entirely.

One second fundamental distinction among ways of being located at, which has been however overlooked in the contemporary literature on the topic, is the distinction between *pervasive* and *sporadic* location.[16]When the fish is in the

[14]Casati and Varzi (1999, p. 33) use the reflexivity of the relation of location in order to define regions: "regions are those things which are located at themselves". But someone who rejects the reflexivity of regions could as well define region as "those things at which other things can be located and that can't be located at other things".

[15]The term "causal" displays the same kind of ambiguity. On one reading, causal entities are entities that can be relata of a causal relations. On another reading causal entities are the causal relations themselves.

[16]Casati & Varzi (1996, 1999, p. 120) introduce another nice distinction between tangential and internal location, but fail to notice the distinction between pervasive and sporadic location. Hudson (2005, p. 99) also introduces usefull distinctions in order to account for the location of extended simples, but doesn't clearly distinguish pervasive from sporadic location either. Parsons (2007) is the one who comes closest to the distinction. He introduces the concept of pervasive location, but then he mistakenly equates his concept of pervasive location with Casati and Varzi's concept of partial location(Parsons, 2007, p. 223-4). This mistake may come from his failure to introduce the contrary concept of sporadic location, which led him

centre of the bowl, it is pervasively located (Parsons 2007; 2008) at the point which is the exact center of the bowl. That point is entirely covered by the fish. The fish is sporadically located in the water (even when it is entirely located in it), for certain parts of the water are not locations of the fish. In the same way, the particles that constitute a gas are sporadically located in the container of the gas. The fish is sporadically located in regions where it is located but not pervasively.

These two distinctions give rise to four combinations, which correspond to four determinate modes of location:

- *Partial and sporadic location*: When the fish's fin shows on the surface, the fish is both partly and sporadically located in the water.
- *Entire and sporadic location* : The fish is entirely and sporadically in the bowl.
- *Partial and pervasive location* : When the fish is in the center of the bowl, it is both partly and pervasively at the center point of the bowl.
- *Entire and pervasive location* : The fish is entirely and pervasively located in the hole that would be left if the water were to freeze and if the fish were to disappear. (see table 1)

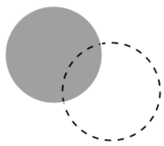
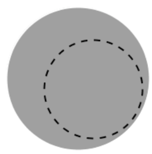
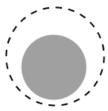
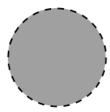
location	*sporadic*	*pervasive*
partial		
entire		

Table 1: Modes of locations
(regions are represented by dotted circles, spatial entities by gray discs)

Entire and pervasive location amounts to what is also called *exact location.* Exact location of a thing is sometimes compared to its *shadow*[17] in absolute space or to its *receptacle*[18].

to contrast pervasive location with entire location.

[17] Parsons, 2007

[18] Sharvy 1983a ; Simons, 1987, p. 215 ; Cartwright, 1975 ; Hudson, 2005, Chap. 2

From those four determinate modes of location, we can define some more determinable ones. *Inexact location* is a contrary of exact location and corresponds to the disjunction of the three first cases. An entity is inexactly located at a region if and only if it is either partly or sporadically located at that region. *Generic location* corresponds to the disjunction of all determinate cases of location. The fish is located in any region that is not "completely free" of the fish (Parsons, 2007). An entity is generically located at a region if and only if it is either exactly or inexactly located at that region. An entity which is not generically located in a region is not located in that region in any sense. (see Figure 1)

$$generic\,location \begin{cases} inexact\,location & \begin{cases} partial\,and\,sporadic\,location \\ partial\,and\,pervasive\,location \\ entire\,and\,sporadic\,location \end{cases} \\ exact\,location & \begin{cases} entire\,and\,pervasive\,location \end{cases} \end{cases}$$

Figure 1: Types of location

Which location concept is the most fundamental ? Casati and Varzi (1999, p. 119) take the concept of exact location as their primitive, and derive from it the notions of partial, entire ("whole") and generic location[19]. Parsons (2007, p. 205) suggests that it may be better to take as primitive the less-demanding notion of generic location (which he calls "weak location"). I shall also take generic location as primitive, and define the specific modes of location as follows[20].

$xL_t^{=} r$:	x is exactly located at r at time t
$xL_t^{\neq} r$:	x is inexactly located at r at time t
$xL_t^{\subseteq} r$:	x is entirely located at r at time t
$xL_t^{\nsubseteq} r$:	x is partly located at r at time t
$xL_t^{\supseteq} r$:	x is pervasively located at r at time t
$xL_t^{\nsupseteq} r$:	x is sporadically located at r at time t
$xL_t r$:	x is generically located at r at time t
xPy:	x is a (proper or improper) part of y

Entire location : x is entirely located at r at t, if and only if each part of x is generically located at r at t.

$xL_t^{\subseteq} r \ =_{df} \forall y(yPx \rightarrow yL_t r)$

[19]The notions of pervasive and sporadic location, can as well be derived from exact location.

[20]Parsons derives the specific modes of location by relying on the concept of overlap. He defines exact location thus :

$xL_t^{=} r \equiv_{df} (\forall s)(r \circ s \leftrightarrow xL_t r)$

I shall not rely on the concept of overlap, but on the more fundamental concept of parts. The definition of exact location I propose is equivalent to Parson's one, but using the concept of part make it easier to grasp.

Partial location : x is partly located at r if and only if (i) x is generically located at r (ii) x is not entirely located at r (*i.e.,* x has at least one part which is not generically located at r).

$xL_t^{\not\subseteq} r \ =_{df} xL_t r \wedge \exists y(yPx \wedge \neg yL_t r)$

Pervasive location : x is pervasively located at r if and only if for each part of r, x is generically located at it.

$xL_t^{\supseteq} r \ =_{df} \ \forall s(sPr \rightarrow xL_t s)$

Sporadic location : x is sporadically located at r if and only if *(i)* x is generically located at r (ii) x is not pervasively located at r *(i.e.,* r has at least one part in which x is not generically located)

$xL_t^{\not\supseteq} r \ = df xL_t r \wedge \exists s(sPr \wedge \neg xL_t s)$

Exact location : x is exactly located at r, if and only if x is both entirely and pervasively located at r (i.e., if and only if for each part of x, there is a part of r at which it is generically located *and* for each part of r there is a part of x which is generically located at it).[21]

$xL_t^{=} r \ =_{df} \ xL_t^{\subseteq} r \wedge xL_t^{\supseteq} r$

Inexact location : x is inexactly located at r if and only if (i) x is generically located at r (ii) x is not exactly located at r (i.e., if and only if either one part of x at least is not generically located in r or one part of r at least is not a generic location for x).

$xL_t^{\neq} r \ =_{df} \ xL_t^{\not\subseteq} r \vee xL_t^{\not\supseteq} r$

Those definitions rely on three assumptions :

1. Parts of regions are necessarily regions (regions are dissective).
2. Parts of spatio-temporal entities are necessarily spatio-temporal entities (spatio-temporal entities are dissective).
3. Any spatial entity has parts corresponding to the parts of the region it occupies.[22]

[21] This notion of exact location is indeed not completely neutral since it implies that the "geometric correspondence principle" (that Simons, 2004, defines as follows : "Any extended object has parts corresponding to the parts of the region it occupes") is true, which Simons denies. If the admission of extended simples indeed relies on the rejection of that principle, it must be granted that that definition is incompatible with the exact location of extended simples.

[22] This latter assumption has been questioned by Simons, 2004, who calls it the "geometric correspondence principle" ("Any extended object has parts corresponding to the parts of the region it occupies"). If the admission of extended simples rely indeed on the rejection of that principle, it must be granted that those definitions cannot be applied to them.

Two interesting relations between those different types of locations are the following. First for x to be pervasively located at a region is for it to have at least one part that is exactly located at that region :

$$\forall x \forall r [x L_t^{\supseteq} r \leftrightarrow \exists z (z P x \wedge z L_t^{=} r)] \tag{1}$$

Second, for x to be entirely located at a region, is for that region to have a part at which x is exactly located :

$$\forall x \forall r [x L_t^{\subseteq} r \leftrightarrow \exists s (s P r \wedge x L_t^{=} s)] \tag{2}$$

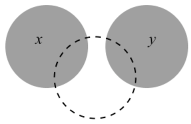
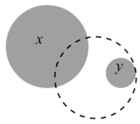
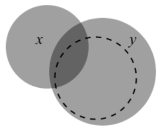
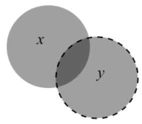
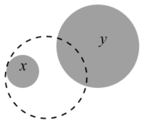
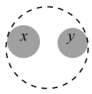
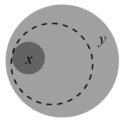
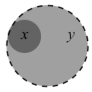
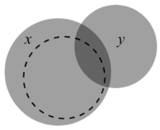
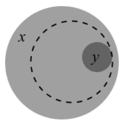
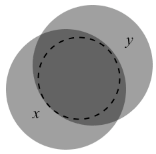
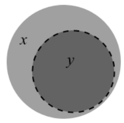
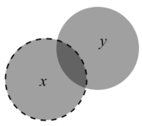
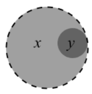
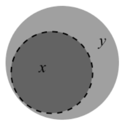
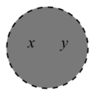
3 Co-location

With those definitions in hand we can now define co-location. Co-location is a three place relation between two spatial entities and a region. Two entities are co-located if and only if they are located in a same region. The most determinable mode of co-location is generic co-location which can be defined as follows :

(Generic) co-location : x and y are generically co-located at t *if and only if* x is generically located at r at t, and y and is generically located at r at t.

$CL_t(x, y, r) =_{df} xL_t r \wedge yL_r t$

Generic co-location can take 16 different determinate forms, which are represented in table 2. Cases represented on the diagonal that goes from the upper-left corner to the lower-right one are cases in which both x and y have the same mode of location. All the other cases have an equivalent case found by symmetry relatively to that diagonal, so that there are in the end only 10 different modes of co-location.

x and y's modes of location	y is partially and sporadically located at r	y is entirely and sporadically located at r	y is partially and pervasively located at r	y is entirely and pervasively located at r
x is partially and sporadically located at r				
x is entirely and sporadically located at r				
x is partially and pervasively located at r				
x is entirely and pervasively located at r				

Tab. 2 – Modes of co-location (regions are represented by dotted circles, spatial entities located therein by gray discs)

4 Compenetration

We can now come back to compenetration : to which mode(s) of co-location should compenetration be identified ? When does the co-location of two entities imply their penetrability ? I want to argue that compenetration amounts to exact co-location. All other cases of co-location are not sufficient for compenetration to occur.[23] All the cases except the one represented in the lower right corner are compatible with the absence of compenetration, and therefore with the impenetrability of x and y.

The four cases represented in the upper left squares correspond to cases in which both entities are sporadically located at r. The case of the two fishes in the bowl is one of them, where both x and y are entirely and sporadically located at r. As the drawings make clear, it is not necessary that compenetration occurs in those cases (no region in dark grey appears in those squares). Sporadic co-location (i.e. the case where two entities are sporadically located at the same place) does not imply compenetration.

It is natural to think then that the two fishes in the bowl do not compenetrate because they are not *pervasively* located in it. One may therefore wonder whether pervasive co-location (cases where two entities are pervasively co-located in the same region) is sufficient for compenetration to occur. Looking at the pictures, even a weaker type of co-location seems sufficient: the pervasive location of *at least one* entity always leads to the occurence of a dark gray patch (i.e. all cases except the four upper-left ones). One may call *spatial overlap* the type of co-location where at least one the the co-located entities is pervasively located at r:

Spatial overlap: x and y spatially overlap if and only if they are co-located at r, and at least one of them is pervasively located at r.

$$x \overset{s}{\bigcirc} y =_{df} x \neq y \wedge \exists r[Rr \wedge xLr \wedge yLr \wedge (xL_t^{\supseteq} r \vee yL_t^{\supseteq} r)]$$

Given the equivalence 1, this amounts to saying that two entities spatially overlap if and only if there is a region (r or a sub-region of r) such that each entity has a part which is exactly located in it. Another equivalent definition of spatial overlap is therefore :

$$x \overset{s}{\bigcirc} y =_{df} x \neq y \wedge \exists r \exists w \exists z(wPx \wedge zPy \wedge Rr \wedge wL_t^{=} r \wedge zL_t^{=} r)$$

Each occurence of a dark gray region corresponds to cases of spatial overlap. Are dark grey regions cases of compenetration ? Not necessarily : they can as well be cases of part sharing. All the cases in which one of the two entities at least is pervasively located in r display that ambiguity, except the case of exact co-location.

Take the blue and and yellow discs which are partly co-located in a green region (i.e. the case of pervasive co-location). Each discs is pervasively located in the green region. Does this imply that the discs compenetrate? The case is ambiguous:

[23]Casati and Varzi (1996, p. 24) defend a close view.

– on a first reading, there is only one colour at the green region: green. Green is a simple colour. Both discs share a common, single, green part. No disc is completely blue or yellow, both are partly green.

– on the second reading, there are two colours at the green region: yellow and blue. Green is a complex colour, a mixture. The discs do not share parts, but have some superposed, compenetrating parts. One disc is completely blue, the other completely yellow.

In both cases, the discs are pervasively and partly located in a common region. But intuitively, only the second case seriously threatens the impenetrability of the discs. This is easier to see why when we take the point of view of the regions. To take up an expression from Hudson (2005, p. 83), in the first case, all regions are *monogamous*: each region is filled by only one simple quality. In the second case, the green region is *bigamous*, so that impenetrability is violated. Pervasive location of one or both co-located entities is not sufficient for compenetration to occur. The question therefore is whether there is one or two parts at the region of the spatial overlap : are w and x identical ? When the answer is "only one", spatial overlap amounts to part-sharing, i.e. mereological overlap.

Mereological overlap : x and y overlap in the mereological sense if and only if they have at least one part in common.

$x \bigcirc y = \exists z(zPy \wedge zPy)$

Mereological overlap is not a case of compenetration, since the shared part is alone in its region. Mereological overlap is a case of partial identity. It is only when there are two different parts at the region of the spatial overlap that we get a case of genuine compenetration[24]. Compenetration can then be defined as follows :

(Generic) Compenetration: x and y (generically) compenetrate each other if and only if they have distinct and exactly co-located (proper or improper) parts.

$xCy =_{df} \exists w \exists z \exists r(wPx \wedge zPy \wedge w \neq z \wedge Rr \wedge wL_t^{=} r \wedge zL_t^{=} r)$

Compenetration, so defined, refers to generic compenetration, and can take different specific forms. *Exact compenetration* occurs when all of the parts of

[24]See Zimmerman (1996b, p. 19) for a clear use of the distinction between compenetration (that he calls interpenetration) and sharing of part. This important distinction is sometimes obscured by the ambiguous us of "coincidence" (see fn. 47). One nice application of this distinction is the distinction between two views about contact (Zimmerman, 1996a) : one that claims that contact is the compenetration of boundaries (a view that was held by Brentano) and another that claims that contact is the mereological overlap of boundaries (a view that was held by Suarez for certain types of contact). Only the first view of contact implies penetrability.

each entities are exactly co-located with parts of the other entity[25]. This is what happens for instance when we consider a green disc as made up of two exactly co-located discs, one green and one yellow.

Exact compenetration: x and y exactly compenetrate each other if and only if they are numerically distinct and exactly co-located.

$$xC^{=}y =_{df} x \neq y \wedge \exists z(Rz \wedge xL_t^{=}z \wedge yL_t^{=}z)$$

Inexact compenetration occurs when two entities compenetrate generically but not exactly. There are two forms of inexact compenetration.

Partial compenetration occurs when *each* compenetrating entity has at least one part that does *not* exactly compenetrate any part of the other. This is what happens for instance in the second reading of the example of the two discs that compenetrate in a green region.

Partial compenetration: x and y partially compenetrate each other if and only if they compenetrate and each of them has a part that does not compenetrate any part of the other.

$$xC^{\cap}y =_{df} xCy \wedge \exists w[wPx \wedge \forall z(zPy \rightarrow \neg wCz)] \wedge \exists s[sPy \wedge \forall t(tPx \rightarrow \neg sCt]$$

Inclusive compenetration occurs when one entity has one part that does not compenetrate any part of the other, and when each part of that other entity compenetrates a part of the first. This amounts to saying that one entity is exactly co-located with a numerically distinct proper part of the other. This happens when a yellow spot on a blue disc is conceived as a yellow disc exactly co-located with a circular portion of the blue disc.

Inclusive compenetration: x inclusively compenetrates y if and only if every part of x compenetrates a part of y, and at least one part of y does not compenetrate any part of x.

$$xC^{\subset}y =_{df} \forall w[wPx \rightarrow \exists z(zPy \wedge wCz)] \wedge \exists s[sPy \wedge \forall t(tPx \rightarrow \neg sCt)]$$

While generic, exact and partial compenetration are symmetrical relations, inclusive compenetration is an asymmetrical one.

To recap, sporadic co-location of two entities does not entail compenetration. Pervasive location of at least one of the two entities in the region of the

[25]Exact compenetration is sometimes called (ambiguously) coincidence, and (less ambiguously) superposition (Simons, 1987, p. 210).

generic co-location, i.e. spatial overlap, is not sufficient either, for spatial overlap can take two forms : compenetration proper or mereological overlap (part sharing). The reason why spatial overlap is not enough for compenetration is that two spatially overlapping entities can be numerically distinct only in virtue of their parts that lie outside the region of the spatial overlap. If so, the region of the overlap is monogamous. The only case in which spatial overlap entails compenetration (bigamy of a region) is when two numerically distinct entities are exactly co-located at a region.[26] Those entities may be parts of wider wholes, in which cases the wholes partially compenetrate. They may be wholes themselves, in which cases those wholes exactly compenetrate. Or one may be a whole and the other a part of a wider whole, in which cases the first whole inclusively compenetrates the second. In any case, exact co-location, and only it, yields compenetration.[27]

5 Non-penetrability

Let us now come back to penetrability. Penetrability is the possibility of compenetration, and should therefore be defined in terms of exact co-location. The first definition of penetrability given above then corresponds to what we shall call exact penetrability.

Exact penetrability: x and y are exactly penetrable if and only if they are distinct entities that can be exactly located in the same place at the same time, i.e. if and only if they can exactly compenetrate.

$xPE^{=}y =_{df} x \neq y \wedge \Diamond\exists z(Rz \wedge xL_t^{=}z \wedge yL_t^{=}z)$

That is:

$xPE^{=}y =_{df} \Diamond xC^{=}y$

Second, two entities are partially penetrable when their partial compenetration is possible:

Partial penetrability: x and y are partially penetrable if and only if is possible that they have numerically distinct exactly co-located proper parts but not possible that they are exactly co-located as whole ; i.e. if and only if they can partially but not exactly compenetrate.

[26]Exact co-location might be equated with complete spatial overlap. If one accepts mereological extensionality (i.e. the identity of entities that share all of their parts. See Varzi (2008) for a recent defense) and assumes that the overlapping entities have no non-spatial parts, then complete overlap cannot take the form of complete mereological overlap, for this would imply the identity of the entities in question (which spatial overlap forbids).

[27]In an aside, note that exact location is required not only in order formulate the genuine puzzle of two things being in the same place at the same time, but also in order to formulate the puzzle of one thing being in different places at one time. That a same thing can be partly or sporadically located at different places at once raises no specific worry. It is only if it is both wholly and pervasively located at different places at onces that a problem appears. In order to capture both our intuitions against compenetration and ubiquity we need to rely on the concept of exact location.

$xPE^{\cap}y =_{df} \Diamond xC^{\cap}y \wedge \neg\Diamond xC^{=}y$

Inclusive penetrability occurs between two entities one of which only can be exactly co-located with a proper part of the other:

Inclusive penetrability: x is inclusively penetrable in y if and only if x can be exactly co-located with a numerically distinct proper part of y but not with y as a whole; i.e., if and only if x can inclusively but not exactly compenetrate y.

$xPE^{\subset}y =_{df} \Diamond xC^{\subset}y \wedge \neg\Diamond xC^{=}y$

Finally generic penetrability, or penetrability *tout court*, refers to the disjunction of all the possible cases of penetrability.

(Generic) Penetrability: x and y are (generically) penetrable if and only if they can have distinct and exactly co-located proper or improper parts; i.e. if and only if they can compenetrate.

$xPEy =_{df} \Diamond xCy$

The former distinctions between absolute, relative and exclusive penetrability apply to the derelativisations of all those four relations of penetrability. For instance, an entity is exactly and absolutely impenetrable if and only if it can be exactly compenetrated by *any* other entity (such an entity would have to be highly deformable and extensible).

$PE^{=}_{\forall y}x =_{df} \forall y\Diamond xC^{=}y$

There is no need here to go through all these combinations. In what follows, in order to remain as general as possible, I shall mean by "x is penetrable", "x is generically penetrable by at least one other entity". This monadic property of relative and generic penetrability covers all the other cases.

(Generic-) Relative penetrability: x is generically and relatively penetrable, or penetrable *tout court*, if and only if there is at least one y with which it can generically compenetrate.

$PE_{\exists y}x =_{df} \exists y\Diamond xCy$

Non-penetrability is the negation of penetrability. Two entities are non-penetrable if and only if they lack penetrability. We shall focus below on generic non-penetrability:

(Generic) Non-penetrability: x and y are (generically) non-penetrable if and only if they cannot compenetrate.

$x \neg PE y =_{df} \neg \Diamond x C y$

The derelativisation of non-penetrability gives rise to relative, absolute, and exclusive non-penetrability. We shall here focus on relative non-penetrability which includes both absolute and exclusive non-penetrability.

(Generic-) Relative non-penetrability: x is generically and relatively non-penetrable, or non-penetrable *tout court*, if and only if it cannot compenetrate y.

$\neg PE_{\exists y} x =_{df} \exists y \neg \Diamond x C y$

6 Impenetrability

One may think that non-penetrability amounts to impenetrability[28]. Penetrability and impenetrability would be contradictory properties. This would suggest that only one of them should have a claim to reality, the other being defined as the lack of first. Some will say that penetrability, being positive, should be considered as the real basic property, impenetrability being only the lack of penetrability; to which others will reply that as far as modal properties are concerned, impossibility is ontologically prior to possibility so that penetrability should be understood as a lack of impenetrability.

But impenetrability cannot be identified with non-penetrability. Though there is some intuitive appeal to the claim that impenetrability is only the modal property of being impossibly compenetrated, that definition is still insufficient for getting impenetrability. Impenetrability is a special case of non-penetrability, and should not be conflated with it. (That impenetrability is a kind of non-penetrability implies that all the distinctions made before between the relations of generic, exact, partial and inclusive non-penetrability, as well as the distinctions between the relative, absolute and exclusive derelativisations of non-penetrability apply to impenetrability as well[29]. Especially, this implies

[28]This is indeed a common view. See for instance Russell (1903, pp. 467, 480), Quinton (1964, p. 341).

[29]Especially, the concept of exclusive impenetrability (impenetrability relative to some other entities only) is introduced by Sanford(1967; 1970a). Following him, Zimmerman (1996b) speaks of objects of a same "impenetrability kinds" in order to refer to entities that are exclusively impenetrable among each other.

that impenetrability is basically a relation, and that speaking of the impenetrability of one entity amounts to ascribe a relational property to it, not an intrinsic one[30].)

One can indeed easily conceive of entities which are unable to compenetrate with any other, without being for all that impenetrable. One clear example is abstract entities, that exist outside space or time, such as (some say) numbers, minds or propositions. Such entities are non-penetrable according to the definition above, but we are not ready to say that they are impenetrable. They lack both penetrability and impenetrability. They may be called a-penetrable. Impenetrability and penetrability are not therefore contradictory properties but contrary ones.[31] How are we then to carve the category of non-penetrability into a-penetrability on the one hand and impenetrability on the other ?

From those examples, an easy way to complete to definition of non-penetrability in order to get impenetrability would be to add that impenetrable entities must be spatio-temporal, i.e. should exist or be able to exist in space and time. In this way we would avoid considering abstract entities as impenetrable. The definition of impenetrability would then look as follows:

Impenetrability : x and y are mutually impenetrable if and only if each of them can exist at least one place at at least one time, but both cannot have exactly co-located parts.

$$xIy =_{df} x \neq y \wedge \Diamond\exists z(Rz \wedge xL_t z) \wedge \Diamond\exists r(Rz \wedge yL_t z) \wedge \neg\Diamond xCy$$

Such a strategy unfortunately can only be a stopgap solution. In addition to abstract entities, there are many other conceivable cases of concrete entities that cannot compentrate without being for that reason impenetrable, and each of them would require a new patch in the definition. For instance:

- Entities that cannot move absolutely. Suppose two entities are located at distant places and are essentially immobile (for reasons independent of. their relation to each other —e.g. there is not repulsive force between them). We are reluctant to say that they are impenetrable relatively to each other, although it is true that they cannot compenetrate.
- Entities that cannot move relatively to each other. Consider the heads and tails of an unbreakable penny. It is impossible for them to compenetrate. But we do not want to call them impenetrable for that reason.
- Separated entities. Suppose space is brain-shaped so that there is only a small path between its two hemispheres. Suppose one entity bigger

[30]The relational character of impenetrability is the crucial premiss of Hume (2000, I, iv, 4)'s famous objection to the concept of material bodies. According to Hume, that concept displays a vicious circularity, for material bodies are defined as impenetrable, and impenetrability can only be defined as a relation between bodies. See Armstrong (1961, p. 184 sqq.), Joske (1967, p. 41 sqq.), Sanford (1967), Robinson (1982, p. 108 sqq.), Mumford (2003, p. 30 sqq.). Fleming (1965) presents a plausible solution to that puzzle.

[31]The same distinction apply to many "negative" dispositions such as being insoluble, ineligible, unbreakable, indescribable, etc. Being unbreakable for instance is not only being impossibly broken. Sunsets are not unbreakable.

than the width of the path is entirely located in the right hemisphere of space, while another entity of the same size is entirelly located in the left hemisphere. Those two entities cannot compenetrate. But intuitively, this is not in virtue of their being impenetrable (but rather in virtue of their size and of the shape of space).

– Protected entities. Suppose God protects some spatio-temporal entity by destroying any other entity that comes too close to it. That entity would be absolutely non-penetrable. But intuitively, it would not be impenetrable for all that.

A Finean move would be to require that for an entity to be impenetrable, it has to be non-penetrable *in virtue of its essence*. This may deal with some counterexamples. For instance, the protected entity of the last example, is non-penetrable not in virtue of its own nature but rather in virtue of the nature of God. Such a move will not do however. First, it still seems insufficient. Take the first case of the immovable entities. They may be immovable in virtue of their nature, because they have regions of space among their essential constituents. We would then have spatially and essentially non-penetrable entities which are not yet impenetrable. Second, that move is too strong for it entails that impenetrability is always a necessary property. Even if it has often been claimed to be an essential property of material entities, one can conceive of some entities that are contingently impenetrable.

Finally, a general worry about patching the definition of non-penetrability with requisites such as "being spatio-temporal" or "essentially" is that such a list may well be very long while intuitively mastering the concept of impenetrability do not requires checking such a long list each time we need to apply the concept. Rather, it seems that the introduction of these new conjuncts is motivated by a quite simpler concept of impenetrability . Even if such a list is needed in the end, there must be some simpler more generic clause that explains why we are spontaneously unsatisfied with the claim that the above examples refer to cases of impenetrability. We have to wonder about that *generic* clause that should be added to the definition of non-penetrability in order to get a good definition of impenetrability.

The answer, I suggest, is to be found in the *dispositional* nature of impenetrability. Impenetrability is not only the modal property of being impossibly compenetrated, but also a *dispositional* property, which means that impenetrable entities tend to display some manifestation in some circumstances (and remain impenetrable even when they do not display it). This, it seems, is a clear difference between impenetrable and a-penetrable entities: there is no way for numbers to manifest their a-penetrability.

What then is the manifestation of impenetrability? That question is a bit tricky for contrary to penetrability which is governed by the modality of possibility, impenetrability, being a kind of non-penetrability, is a disposition governed by the modality of impossibility (if x is impenetrable, then it is impossible for x to compenetrate at least one other entity). One may say that impenetrability is an *incapacitating disposition* (together with unintelligibility, impregnability, inedibility) by contrast to capacitating dispositions such as fragility or agility. In the case of capacitating dispositions, the manifestation is easily specified : it is the actualisation of the possibility that enters in its definition. x is breakable only if it is possible that it breaks. The manifestation of breakability is then the actualization of that possibility, namely the breaking. In the same way, x is penetrable only if it is possible that it compenetrates another entity, therefore compenetration is the manifestation of penetrability. But what could be the manifestation of incapacitating dispositions in general, and of impenetrability in particular ? There is no possibility here to actualize. Two bad candidates for the manifestation of impenetrability are :

- *x's being actually not compenetrated.* If this were the manifestation of impenetrability, then some penetrable entities would also manifest it. Not being compenetrated is often true of penetrable entities as well.
- *x's being necessarily not compenetrated.* This is not true of penetrable entities. But if this is the manifestation of impenetrability, then impenetrability is always manifested. Impenetrability is never latent.

The difficulty of specifying the manifestation of impenetrability arises, I submit, from a failure to distinguish the *manifestation* of a disposition (typically an event[32]) from the *result* of that manifestation (typically a state). The *manifestation* of the disposition of an entity is the way that entity would behave were some circumstances (the stimuli of the disposition) to occur; the *result* of a disposition is the state that ensues. For instance, *x's being breakable* manifests itself in *x's breaking* and results in *x's being (actually) broken.* Accordingly, *x's being (necessarily) not compenetrated* is the result, and not the manifestation of impenetrability. What then, is the manifestation of impenetrability? The right story goes like this:

x's being penetrable manifests itself in *x's entering into compenetration*, and results in *x's being actually compenetrated.*

x's being impenetrable manifests itself in *x's avoiding to enter into compenetration*, and results in *the impossibility of x's being compenetrated.*

The manifestation of impenetrability is the *avoidance of compenetration* and its stimulus is the *threat of compenetration.* When compenetration threatens, impenetrable entities avoid it. We think of impenetrable entities as reacting in certain ways when they are about to compenetrate. This solves our former dilemma: penetrable entity do not avoid compenetration, this behaviour is proper to impenetrable entities; and impenetrable entities do not always avoid compenetration (but only when compenetration threatens). This also helps to understand why numbers, minds, propositions, immovable entities, entities located in disjoint parts of space, or protected entities are not impenetrable: there is no way for them to be threatened of compenetration, and therefore no way for them to avoid it. Being impossibly compenetrated does not entail being disposed to avoid compenetration, for some entities are non-penetrable just because they cannot be about to compenetrate. What all a-penetrable entities have in common is that they are non-penetrable entities that cannot be about to compenetrate.

We are not out the woods yet. It remains to be asked how compenetration can be avoided. Assuming dispositions are individuated by their manifestations (Molnar, 2003), if there are different ways in which compenetration can be avoided there are also different kinds of impenetrability.

[32] The manifestation of disposition is not always an event however, for certain disposition such as forces often manifest themselves in states (maintaining an equilibrium for forces). See Williams (2005) for a defense of "static" disposition, whose manifestation is not a change (Williams however does not mention forces as static dispositions, he seems to believe that accelerations is their only possibly manifestation)

7 Kinematic impenetrability

The most obvious way two objects can be about to compenetrate and avoid it is for them to move towards each other and when coming into contact or sufficiently close to each other, to change their trajectory. One may think that this is the only way to avoid compenetration, but we shall see that there are indeed other kinds of impenetrability. Let us call that kind of impenetrability which manifests itself in a change in the motion of the impenetrable entities *kinematic impenetrability*.

Impenetrability is distinct from *hardness*. Following Locke (2008, II, iv, 4), hardness is the disposition to keep its determinate shape. Hardness is grounded according to Locke in the *cohesion* of the parts of matter[33].

Some impenetrable entities are not hard[34]. As a result, the kinematic manifestation of impenetrability is always a change in motion, but not necessarily a change in the cohesive motion of the impenetrable entities. Impenetrable entities can also split (lose their path-connectedness), or change their shape. Consider two kinematically impenetrable balls moving towards each other. If they are hard, one of them at least will change its trajectory. But they may also be impenetrable but not hard, in which case one or both may break into several parts; or one or both may change of shape; or a combination of those cases. In every case the motion of at least one part of at least one ball changes.

Kinematic impenetrability : x and y are kinematically impenetrable if and only if when compenetration theatens, they avoid it in virtue of some kinematic change(s) in at least one part of at least one of them.

The concept of kinematic impenetrability, as well as the fact that at least some entities in the material world are kinematically impenetrable is to a large extent uncontroversial. Strong disagreement appears, however, as to the *ground* of kinematic impenetrability. In virtue of what do some entities change their state of motion so that they never compenetrate? Here are the three main answers:

1. Kinematic impenetrability is a brute, *ungrounded* disposition.
2. Kinematic impenetrability is grounded on the *dynamic* properties of kinematically impenetrable entities, such as the forces they exert on each other.
3. Kinematic impenetrability is grounded on the *spatial* properties of the kinematically impenetrable entities, such as their extension.

Though 1 seems to be a conceptually sound option, few people have endorsed it[35]. According to that view, some entities just happen to change their motion when they come in the vicinity of each other, without further reason. Such a brute kinematic impenetrability would violate the principle of sufficient reason,

[33] See Sanford (1970b) for a defense of the claim that hardness is also a primary quality according to Locke.

[34] The reverse is also true, some hard entities are not impenetrable. One can think of a perfectly hard ghost that passes through walls.

[35] Price (1961, p. 278) appears to endorse it as far as (family of) sense-data are concerned.

which seems at least true for kinematic changes: there must be some reason why entities are disposed to change their state of motion. A world of kinematically impenetrable entities, where kinematic impenetrability is an ungrounded disposition, would be quite exotic. It can be conceived of in the following way: consider the shadows of billard balls under a vertical light. They behave like the balls: when they come into contact, their motion change so that they avoid compenetration. Contrary to the balls, however, they do not exert any forces on each other. Of course, in the actual world, the kinematic impenetrability of the shadows is grounded in the kinematic impenetrability of the balls they depend on. But in order to conceive this world, we have now to remove the balls and to keep the shadows. Such a world of brutely kinematic entities may be conceivable, but it is certainly far away from ours. The shadows happens to necessarily avoid each other, for no reason apart from their being disposed to do so. Despite the fact that brute kinematic impenetrability represents a genuine metaphysical possibility, this possibility is too exotic to be worth considering at length. Restricting attention to worlds close to ours, kinematic impenetrability has to be grounded.

If kinematical impenetrability is not a free-floating disposition, one can either grounds it on dynamic properties such as forces, or on spatial properties such as extension. In what follows, I argue in favour of the first view: all attempts to ground kinematic impenetrability one purely spatial properties rely on a confusion between kinematic impenetrability and what I shall call numerical impenetrability.

8 Repulsive forces

According to Newton's Second Law of motion, the sum of the forces that acts on a body equals the mass of that body times its acceleration. Mass being constant, the crucial causal factor of accelerations are the forces that acts on the bodies. Newtonian forces are *dynamic* entities (together with mass, energy, momentum or work) by contrast to kinematic entities (such as motion, velocity, acceleration and by extension distances or shapes)[36]. Forces are not reducible to mere spatial or temporal properties and relations, nor to changes in such properties. I shall assume here that they are dynamical relations between bodies, and that part of their essence is to be disposed to cause kinematic changes under circumstances specified by Newton's Second Law[37]. The important point is that according to Newtonian mechanics, changes in motion of bodies are all caused by the forces that act on those bodies.

On such an account, the reason why bodies are kinematicaly impenetrable is that when compenetration threatens, they exert repulsive forces on each other, which cause them to change their motion. Not any repulsive force will do: the repulsive forces involved, must be strong enough to change the relative motions of the bodies. In order for bodies to be kinematically impenetrable, they have to be disposed to exert sufficient forces when there are about to compenetrate.[38]

[36] Heil (1983, pp. 38-38 for such a dynamic/kinematic distinction.)

[37] See Author (2009) for a defense of that view about forces.

[38] This nice story about the ground of kinematic impenetrability is however limited in extension, for it only concerns entities that are able to exert forces, that Newtonian mechanics equates with bodies. It can easily be extended to entities that does not exert forces however if

If so, kinematic impenetrability is a disposition grounded on another disposition, the disposition to exert repulsive forces. Could that other disposition to exert forces be itself a kind of impenetrability? Repulsive forces would have to be themselves ways of avoiding of compenetration. Here is an argument for that claim. Suppose that compenetration threatens not because the two balls come closer to each other, but because, being already in contact, they are heavily pressed against each other. Suppose also that the balls are hard, that the pressure is exerted along the line that joins their centers so that there is no way for them to break or to move away. Surely, the fact that they do not compenetrate in those circumstances should count as a manifestation of their impenetrability. Compare that case with the case in which the very same two balls lie passively in contact of each other. From a kinematic point of view, nothing distinguishes the two cases, while it seems clear that the balls are manifesting their impenetrability in the first case, but not in the second. Replacing the balls by their ghoslty counterparts would end up in compenetration in the first case, not in the second. The manifestation of impenetrability in that case is not a kinematic change, but a dynamic one, namely the appearance of a repulsive force between the balls that counteracts the pressure forces that each ball exerts on the other. Without that repulsive force, the balls would compenetrate.

We found therefore a second kind of impenetrability, whose manifestation consists in dynamic changes. Forces, therefore, are more than grounds for kinematic impenetrability: they are themselves manifestation of another kind of impenetrability. I shall call that kind of impenetrability *dynamic impenetrability*.

Dynamic impenetrability: x and y are dynamically impenetrable if and only if when compenetration threatens, they avoid it by exerting some sufficiently intense repulsive force on each other.

Dynamic impenetrability is more fundamental that kinematic impenetrability. One plausible way to articulate those two kinds of impenetrability is to claim that kinematic changes are not *manifestations* of a *sui generis* kinematic impenetrability, but rather *results* of the manifestations of dynamic impenetrability. Dynamic impenetrability manifests itself in repulsives forces, which may (or may not) cause kinematic changes. (As an aside, the concept of dynamic impenetrability may be used to define solidity: an entity is solid if and only if it is both dynamically impenetrable and hard[39].)

Among people who agree to ground kinematic impenetrability on dynamic one, those who intend to ground in turn dynamic impenetrability on categorical properties part ways with those who think that it is an ungrounded disposition. The first ones, following Newton, usually try to ground the disposition to exert forces in categorical properties such as the mass or charges of bodies.

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one insist that such entities are existentially dependent on the first one, and exactly co-located with them. For instance, one can claim that colour patches are kinematically impenetrable in virtue of qualifying kinematically impenetrable bodies.

[39]See Fleming (1965) for a close suggestion.

Following Kant (2004, Second Chapter)[40], the second ones, sometime called "dynamicists"[41] , consider the disposition to exert repulsive forces as ungrounded.[42]

Be it as it may, forces, have a good claim to ground kinematic impenetrability. However, following Descartes and Hume, many philosophers are suspicious about dynamical entities such as forces, fields or even mass. Rather than relying on such allegedly occult qualities, they intend to ground kinematic impenetrability in the identity of spatial entities.

Those attempts come in two kinds. The first one, which has been notably spell out by Brentano, rely on substantivalism about space and claims that entities are *individuated* by the regions they are located at. The second one, which may have been endorsed by Descartes, rely on relationism about space, and claims that regions are individuated by the body located therein. Both views try to derive kinematic impenetrability from those claims.

9 Spatio-temporal individuation

In a text entitled " The impenetrability of bodies in space rests on the fact that spatial determinations are substantial and individuating"Brentano (1988, p. 150-155) tries to ground impenetrability on the view that impenetrable entities are individuated by the regions they are exactly located at. The following *principium individuationis* of spatio-temporal entities (i.e. of entities that exist in space and time) is endorsed:

Spatio-Temporal *Principium Individuationis* (STPI): x and y are numerically distinct spatiotemporal entities if and only if x and y are exactly located at numerically distinct spatio-temporal regions.

This principle is metaphysical. It is not intended to be read as an epistemic principle that describes the way *we* distinguish those entities. Principles of *individuation*, that spell out the *identity* conditions of things, should be distinguished from principles of *individualization*, that spell out their conditions of *identification* (Denkel, 1991).

[40]See Buroker (1972), Gaukroger (1982)and Warren (2001) for presentations of Kant's dynamicist position. Kant's position is that matter is constituted by a fundamental, ungrounded repulsive or expansive force, that exert from all point of matter toward all side. (One should not be misled by the fact that he calls "expansive *force*", what is indeed clearly a disposition to exert forces. The — dispositional — expansive force is said to react with more or less intensity —actual force— when it is compressed.)

[41]Dynamicists include among others Boscovich (1966), Harre (1970, who is however sceptic relative to the concept of force), Mumford (2003, p. 30 sqq.), Molnar (2003, p. 164), and more generally uhpolder of fields construe as basic dispositions to exert forces. Surprisingly, Newton himself seem to have once endorsed a dynamicist concept of matter in his *De Gravitatione* (see Janiak, 2008), considering dynamic impenetrability as an ungrounded disposition.

[42]Dynamicists usually construe dispositions to exert force as properties intrinsic to there bearer. But since both forces and impenetrability are relations, and that the very notion of *sufficient* repulsive force can only be defined by reference to the intensity and direction of the pressure force applied, fundamental disposition to exert forces may be better construed as a relational or extrinsic disposition. See McKitrick (2003) for a defense of extrinsic dispositions.

The most common metaphysical interpretation of that principle (perhaps the only coherent one) is that spatio-temporal regions are *constituents* of spatio-temporal entities[43]. On such a view, the relation of *being located at* is not a relation between two wholly distinct entities (a spatial entity and a region), but a mereological relation : *x is located at r* is to be understood as *x contains r*, i.e. *r is a part of x*. One intuitive version of that view is that a spatio-temporal entity is a state of affairs consisting in the exemplification of properties by a region at a time. The view that regions are constituent of spatial entities first appeared in Platon (*Timaeus* , 48c-53c). Kim (1976) and Bennett (1988, pp. 88-102) apply it to occurents. Brentano (1981, Appendix)[44], Joske (1967, p. 41 sqq.), Gale (1976), Armstrong (1978, pp. 118-125), Lewis (1994, p. 473), and Sider (2001, pp. 110 sqq. ; 2006) attempt to generalize it to continuants.[45] One reason why this view is more easily applied to occurents than to continuants is that it forbids true motion : if motion is change of location and if locations are constituents of spatial entities grounding their numerical identity, no spatial entity can move without losing its numerical identity. This raises a problem for continuants, but not necessarily for occurents for one can argue that occurents do not move.[46] The key point is that the numerical identity of spatio-temporal regions is taken to be more fundamental than the numerical identity of the entities located in those regions. The identity of regions is also usually taken to be primitive. Let us grant that the STPI is true of some entities at least. How does the impenetrability of those entities follow from it ? Here is Brentano's answer :

> Imagine...two corporeal substances at different places matching each other not only in their temporal determination but also in any other substantial series there might be (rather like two red patches in different places in the visual field). Why should the one not penetrate

[43]One other way to make sense of the STPI would be to claim that though wholly distinct from the regions there are in, the entities falling under its scope are *individually dependent* on those regions. That is, at each time of its existence, a spatio-temporal entity is identity-dependent on the place and time it is exactly located at, though wholly distinct from it. (Such a relation of identity-dependence between wholly-distinct entities may be what certain upholders of tropes rely on in order to account for their particularity). This may have been the view of Locke, 2008, II, xxvii, §3 :

> "From what has been said, it is easy to discover what is so much inquired after, the *principium individuationis* ; and that, it is plain, is existence itself, which determines a being of any sort to a particular time and place, incommunicable to two beings of the same kind."

I do not think that this suggestion makes sense however, for one can always conceive of the spatio-temporal entity apart from the particular region it depends on and wonder about its particularity. If it still particular, then the ground of its particularity do not lie in its dependee. If it is not, then what is particular is indeed the sum of the dependent entity and of its dependee, not the dependent entity *per se*. I shall here assume that such a strategy is a dead-end.

[44]See B. Smith (1989) and D. Schulthess (1999) on that late view of Brentano.

[45]Parsons (2007, p. 227-8) mentions a strong version of this view which merely equates objects and regions and show that his theory of location is compatible with it. Such a view however sounds really odd if one adopt substantivalism about space : objects should be qualified-regions, not bare ones. In the context substantivalism, such a view may rely on an equivocation between thin and thick particulars.

The definitions of location I have endorsed are also compatible with it, as well as with the weaker (and more plausible) view, that identifies objects not with regions but with qualified-regions.

[46]See (Dretske, 1967) for the view that events cannot move.

> the other ? Because there belongs to penetration the duality of the substances involved, but this duality would be immediately abolished if there should cease to be a difference of local determination. For they would then be completely without difference, and thus no longer two. (Brentano, 1988, p. 154)

I agree with Brentano that such a *principium individuationis* entails the *non-penetrability* of the entities that fall under its scope. If places at certain times individuate entities, no two entities can be at exactly at the same place at the same time[47]. But two questions remain to be asked: does such a principle entail the *impenetrability* of those entities? If yes, does it entail their *kinematic* impenetrability?

With regard to the first question, one may raise the following objection: the view that regions are constituents of bodies, to the extent that it forbids the motion of bodies, also forbids their impenetrability. For in order for two bodies to be impenetrable, they have to be not only non-penetrable, but there must also be some way for them to be under the threat of compenetration. Since they cannot move, such entities cannot be about to compenetrate, and cannot avoid compenetration. Therefore they do not exemplify any disposition to avoid compenetration. True, motion can be redefined as the successive exemplifications of similar bundle of properties (redness and roundness for instance) in neighbouring regions. This is the way Brentano (1981, p. 208-211) redefines movement, and this is also the way perdurantists conceive it, on the model of sucessive activation et de-activation of pixels on a screen. But all we get then are spatio-temporal entities that *appear* to be about to compenetrate, but not entities that are really so. There is still room for genuine threats of compenetration in such a picture however. Even in a world where nothing can move, two entities can be about to compenetrate: they may be about to be *created* (or to be "thrown in space" if they were existing outside space before) at the same place at the same time (or one of them may be about to be created at the place at which the other already lies). Such creations of spatio-temporal entities are indeed legion according to the "pixel" view of motion. Following it, for a red patch to move is for it to disappear and for another exactly similar red patch to be created in its immediate vicinity. Motion is a succession of creations and destructions. It can therefore be claimed that compenetration threatens the entities that satisfy the STPI when one entity is about to be created at the very same place where another is exactly located at that time. We should then grant to Brentano that

[47] Sider (2000, p. 589n) wants to deny this on the following ground :

> It might be objected that coincidence would be metaphysically impossible if a certain metaphysics of objects is true : the view that identifies objects with regions of spacetime. But this would be a mistake. It is correct that on this view, no region of spacetime could exactly contain two distinct objects, because no region is identical to two distinct regions. But two overlapping spacetime regions could be considered the trajectories of distinct objects that pass through each other ; the region of overlap would contain a single temporal part common to both objects.

What Sider calls here "coincidence" is ambiguous. It is clear from the context that he takes here the term to be synonymous with "interpenetration" (what I am calling here compenetration, bigamy of a region). He wants to deny that such a Brentanian metaphysics implies the impossibility of compenetration. But he only has an argument for the view that such a metaphysics does not ban part sharing or overlap, which is true, but misses the point for overlap is not compenetration (even partial compenetration).

the STPI do imply the impenetrability of the entities that fall under its scope.

Is this impenetrability of a kinematic kind however? How do the entities that satisfy the STPI avoid compenetration? One shouldn't assume that changing one's motion is the only way to do so. One other crucial way to avoid compenetretation is just to *cease to be*. Suppose again two balls threaten to compenetrate, either because they move toward each other, because they are pressed against each other, or because one is about to be created at the place of the other. They may avoid to compenetrate by ceasing to be (or at least by ceasing to be *in space and time*). Depending on the kind of threat, some or all parts of one or both ball has to cease to be. The *ceasing to be* should here be understood as absolute destruction or annihilation, by contrast to the mere dispersion of parts that sometimes occurs when kinematic impenetrability is manifested. In the present case, entities avoid compenetration neither by a kinematic nor by a dynamic change, but by a numeric change in some or all of their parts, where a numerical change is understood as either a creation *ex nihilo* or a complete annihilation. We shall call this type of impenetrability *numerical impenetrability*[48].

Numerical impenetrability : x and y are numerically impenetrable if and only if when compenetration threatens, they avoid it in virtue of some numerical changes in at least one of the part of at least one of them.

Because of the possiblity of numerical impenetrability, spatio-temporal individuation does not entail kinematic impenetrability. Entities falling under the STPI can also be numerically impenetrable.

One can even argue that the STPI is incompatible kinematic impenetrability. Two entities are kinematically impenetrable relative to each other if and only if they are disposed to change their state of motion in order to avoid compenetrating. The STPI forbids motion. So no no entity that satisfies the STPI can be kinematically impenetrable. Upholder of the STPI however will reply that it is still compatible with kinematic impenetrability *if motion is redefined as a succession of creations and destructions of entities at contiguous places.* Interestingly, this move makes kinematic impenetrability a kind of numerical impenetrability, for it reduces motion to (patterns of) numerical changes. But no all numerical changes will count as motions: mere destruction without replacement, or destruction with a creation at a non-continguous spatio-temporal region will not count as motion for instance. Kinematic impenetrability becomes a kind of numerical impenetrability, but numerical impenetrability cannot be reduced to kinematic one. Therefore, even accepting that ersatz view of motion, the STPI do not entail kinematic impenetrability, for it is compatible with numerical changes that do not constitute motions.

We can conclude that he STPI is indeed compatible with kinematic impenetrability if motion is construed in a fourdimensionist way, but is in any case insufficient to ground it.

[48]One may be reluctant to call "impenetrable" such evanescent entities that cease to be at the first threat of compenetration. But they clearly satisfy the requisites of non-penetrability and avoidance of compenetration essential to impenetrability in the generic sense.

10 Spatial relationism

The second attempt to ground kinematic impenetrability without appealing to forces claims that rather than individuating the spatial entities by the regions they are located at, one should individuate the regions by the entities located therein[49]. This implies to give up substantivalism about space, which we have been assuming so far, in favour of a version of relationism. According to the present proposal, regions are individuated according to the following principle:

principle of individuation for regions: r and s are distinct regions if and only if they are the exact locations of distinct entities.

Here again, that principle should not be read as a principle of individualization for regions, spelling out the way we identify region. It is a metaphysical principle about the very identity of regions. The identity of spatio-temporal entities, sometimes called extended things, is taken to ground the identity of region. Those views also usually considered it as primitive. One plausible metaphysical interpretation of that principle is that spatio-temporal entities are constituents of regions, so that the relation of *x being located at r* is to be understood at the relation of *r having x as an essential part.*

Non-penetrability stems from this principle of individuation. Two entities cannot be in the same place at the same time, because if they were, there would be by definition two differents regions each of them exactly occupy. Such an argument is presented by Wiggins(1968) :

> Space can be mapped only by reference to its occupants, and spatial facts are conceptually dependent on the existence of facts about particulars and the identities of particulars. If space is to be mapped by reference to persisting particulars, then the nonidentity of particulars A and B, both of kind *f*, must be sufficient to establish that the place of A at *t1* $\neq$ the place of B at *t1*.

It is not clear whether Wiggins argument should be read as an epistemic argument about the identification of region, or as a metaphysical argument about their identification. Let us assume a metaphysical reading. Individuation of region by the entities exactly located therein does entail the impossibility of compenetration of those entities, i. e., their non-penetrability[50].

That principle does not entail kinematic impenetrability however, for the very same reason that the STPI does not entail it: compenetration may as well

[49] That second attempt to ground kinematic impenetrability may have been the one Descartes had in mind in his answer to More of the 5th February 1649 Descartes (1953). More objects to him that impenetrability is a second essential property of matter, apart from extension. Descartes answers by trying to show that impenetrability can be derived from extension alone. See See Gabbey (1985) for a discussion of that attempt.

[50] Sanford (1970b)questions Wiggin's argument on the ground that not any individuation of space by its "occupants" will yield the conclusion : regions could as well be individuated by entities not located at them : think of the way we refer to a chess square (considered as a place) by giving a letter and a number (considered as objects) located outside it. Still, Wiggins argument is is sound under the proviso that the individuation of regions satisfies the principle above.

be avoided by destruction. Nothing in the principle itself garantees that the spatio-temporal entities will change their path rather than cease to be (together with their associated regions). Neither the persistance of regions, neither the persistence spatio-temporal entities is entailed by the principle.

One may think that this way of individuating regions is even incompatible with kinematic impenetrability. If motion is defined as a change of location, that principle forbids motion for the reason that bodies, so to speak, always bring their locations with them. There is therefore no way to avoid compenetration by changing one's motion; kinematic impenetrability becomes impossible. However, upholders of this principle may redefine motion as *change of vicinity* rather than change of place (Descartes, 1989, II, 28). A body moves, according that hypothesis, when the bodies in contact with it are changing. Assuming this definition of motion, kinematic impenetrability is compatible with the above principle of individuation of regions.

I conclude that individuating regions by the entities exactly located at them is compatible with kinematic impenetrability (if motion is redefined as change of vicinity), but does not entail it.

11 Impenetrabilities

I argued that kinematic impenetrability, the disposition to change one's motion in order to avoid compenetration can be grounded in the disposition to exert sufficiently intense repulsive forces. I envisaged two metaphysical principles of individuation for spatio-temporal entities and regions and argued that none of them provide sufficient ground for kinematic impenetrability. Those principles do not exclude that the entities about to compenetrate will not destroy each other rather than moving away, for they do not ensure the persistence of those entities.

One may object that dynamic impenetrability, the disposition to exert repulsive forces, does no garantee persistence either. Dynamically impenetrable entities such as fields for instance may be transient. If so, when compenetration threatens, dynamical entities may either change their motion, or vanish. Disposition to exert sufficiently strong repulsive force would no more entail kinematic impenetrability than spatio-temporal principles of individuation do.

This objection misses the point: it is true that force-exerters may not persist, that being disposed to exert forces do not confer any power to survive. But the reason why dynamical entities may cease to be *cannot not lie in the fact that other dynamically impenetrable entities tend to compenetrate them.* Their ceasing to be, if it occurs, has nothing to do with their being about to compenetrate, although it may contingently happen at the same time. What prevents dynamically impenetrable entities to annihilate each other is precisely that they exert repulsive forces of each other. As a consequence, they change their motion before destroying each other. This shield of repulsive force doesn't prevent them from being destroyed by other entities relative to which there are not dynamically impenetrable, or from self-destruction. But it does essentially protect them from all the other entities relative to which they are dynamically impenetrable. Repulsive forces protect both from compenetration and from annihilation, for they hinder the inward motion of outsiders before they go beyond the boundary of the entity. Dynamically impenetrable entities cannot destroy nor compenetrate each other because they first repell each other.

The resulting picture is that there are two fundamental kinds of impenetrability: dynamic and numerical one, each being individuated by a specific kind of manifestation. Dynamically impenetrable entities tend to repell each other; numerically impenetrable entities tend to destroy (annihilate) each other. Those two impenetrabilities are independent on each other: one can conceive of entities that are numerically impenetrable, but not dynamically so. It is beyond the scope of this paper to decide which entities are impenetrable and in which sense, but one may thinks of shadows or flames in this way: when two shadows cross each other, there may be only one shadowed part at the region of their intersection, so that one or both shadows have lost some parts during the crossing. Can we make sense of entities that would be both dynamically and numerically impenetrable? This raises a problem for their incapacity to compenetrate would receive two complete explanations. It would be entailed both by their dynamic and numerical impenetrabilities. But according to the story given above, dynamic impenetrability trumps numerical impenetrability (as well as penetrability): it fordids both the destruction and the compenetration of the concerned entities. The numerical impenetrability of entities that are both numerically and dynamically penetrable is therefore doomed to remain latent. There inability to compenetrate is wholly, but also only explained by their dynamical impenetrability.

This raises a second problem: how can such entities be disposed to destroy each other if it is impossible for them to do so? Doesn't the posession of a disposition imply the possibility of its manifestation? The answer to that worry is that the impossibility of compenetration which results from each type of impenetrability has a distinct modal force. Assuming that numerical impenetrability is grounded on the STPI, it flows entirely from the very identity of impenetrable entities. It is then *metaphysically impossible* for numerically impenetrable entities to be in the same place at the same time[51]. This is not the case for dynamic impenetrability: it is conceivable that an entity which is dynamically impenetrable in one world fails to exert repulsive forces sufficient for avoiding compenetration in other worlds. Dynamic impenetrability is not intrinsic[52]: the degree of repulsive force needed in order to avoid compenetration vary according to the intensity of the attractive or pressure force it has to counteract, and may also vary according to the laws of nature. Consequently, dynamic impenetrability only results in *natural impossibility* of compenetration.

Suppose some entities are both dynamically and numerically impenetrable in our world. In our world and in world close to ours their dynamical impenetrability does all the work and their numerical impenetrability is on stand-by. But in world where the laws of nature are significantly different, their dynamical impenetrability vanishes and their numerical impenetrability takes over. It ensures that in those worlds in which repulsive forces are no more sufficient for changing to relative motion of those entities in the right way, the concerned entities will still remain impenetrable by destroying each other rather than by compenetrating.

We get the following picture (table 3):

[51]The same is true if numerical impenetrability is grounded in the individuation of regions by the entities exactly located therein.

[52]This point was underlined by Leibniz (1966, II, iv, 1) and Kant (2004).

	Dynamic impenetrability	*Numerical impenetrability*
Basis	ungrounded (fields) or grounded in categorical properties such as mass or charge.	spatio-temporal *principium individuationis* (or individuation of regions by the entities located therein)
Manifestation	dynamic change (repulsive force)	numerical change (annihilation)
Result	natural impossibility of compenetration	metaphysical impossibility of compenetration

Table 3: Fundamental kinds of impenetrability

The aim of that paper was only to define impenetrability and to delineate conceptual possibilities, not to decide which entities are impenetrable. The above distinctions between non-penetrability and impenetrability on the one hand, and between dynamic and numerical impenetrability on the other, have however important bearings on that question. It is often assumed for instance (i) that entities that cannot compenetrate are impenetrable, and (ii) that impenetrable entities tend to kinematically avoid each other in virtue of the exercice of repulsive forces[53]. If I am right, none of these step is warranted.

[53]See for instance Mason (2000): "if ever co-location [of objects that cannot be co-located] threatens, repulsive forces there act."

Références

D. M. Armstrong, *Perception and the physical world*. London New York : Routledge & K. Paul Humanities Press, 1961, vol. International library of philosophy and scientific method.

——, *Nominalism and Realism : Universals and Scientific Realism*. Cambridge : Cambridge University Press, 1978.

Author, "Paper," 2009.

J. Bennett, *Events and Their Names*. Hackett Publishing, 1988.

R. G. Boscovich, *A theory of natural philosophy*. Cambridge, Mass : M.I.T. Press, 1966.

F. Brentano, *Untersuchungen zur Sinnespsychologie*. Meiner Verlag, 1979.

——, *The theory of categories*. La Hague : Martinus Nijhoff, 1981.

——, *Philosophical investigations on space, time, and the continuum*, S. Korner and R. M. Chisholm, Eds. New York : Croom Helm, 1988.

J. V. Buroker, "Kant, the dynamical tradition, and the role of matter in explanation," *PSA : Proceedings of the Biennial Meeting of the Philosophy of Science Association*, pp. 153–164, 1972.

R. Cartwright, "Scattered objects," *Analysis and Metaphysics*, pp. 153–171, 1975.

R. Casati and J. Dokic, *La philosophie du son*. Nimes : Editions Jacqueline Chambon, 1994.

R. Casati and A. Varzi, *Holes and other superficialities*. MIT Press, 1994.

——, "The structure of spatial localization," *Philosophical Studies*, vol. 82, no. 2, pp. 205–239, 1996.

——, *Parts and Places : The Structures of Spatial Representation*. MIT Press, 1999.

R. Chisholm, "Boundaries as dependent particulars," *Grazer philosophische Studien*, vol. 10, pp. 87–95, 1984.

D. Davidson, "The individuation of events," in *Essays on Actions and Events*. Oxford : Clarendon Press, 1980, pp. 163–80.

A. Denkel, "Principia individuations," *Philosophical quarterly*, vol. 41, no. 163, pp. 212–228, 1991.

Descartes, *Correspondance avec Arnauld et Morus*. Paris : J. Vrin, 1953.

R. Descartes, *Principes : Traduction française*, C. Adam and P. Tannery, Eds. Paris : Vrin, 1989.

F. Dretske, "Can events move ?" *Mind*, vol. 76, no. 304, pp. 479–492, 1967.

K. Fine, "The problem of mixture," *Form, Matter, and Mixture in Aristotle*, 1996.

N. Fleming, "The idea of a solid," *Australasian Journal of Philosophy*, vol. 43, no. 2, pp. 131–143, 1965.

A. Gabbey, "The mechanical philosophy and its problems : Mechanical explanations, impenetrability, and perpetual motion," *Change and Progress in Modern Science*, pp. 9–84, 1985.

R. M. Gale, *Negation and non-being (Monograph series - American Philosophical Quarterly ; no. 10).* Blackwell, 1976.

S. Gaukroger, "The metaphysics of impenetrability : Euler's conception of force," *The British Journal for the History of Science*, pp. 132–154, 1982.

E. Grant, "The principle of the impenetrability of bodies in the history of concepts of separate space from the middle ages to the seventeenth century," *Isis*, pp. 551–571, 1978.

P. Hacker, "Events and objects in space and time," *Mind*, vol. 91, no. 361, pp. 1–19, 1982.

R. Harre, *The principles of scientific thinking.* [Chicago] : University of Chicago Press, 1970.

J. Heil, *Perception and cognition.* Berkeley : University of California Press, 1983.

H. Hudson, *The metaphysics of hyperspace.* Oxford : Clarendon Press, 2005.

D. Hume, "A treatise of human nature (d. norton & m. norton, eds.)," 2000.

A. Janiak, "Newton's philosophy," *The Stanford Encyclopedia of Philosophy (Fall 2008 Edition)*, 2008.

I. Johansson, "Determinables as universals," *The Monist*, vol. 83, no. 1, pp. 101–121, 2000.

W. Joske, *Material objects.* Macmillan New York : St. Martin's Press, London, 1967.

I. Kant, *Metaphysical Foundations of Natural Science.* Cambridge University Press, 2004.

J. Kim, "Events as property exemplifications. reprinted in supervenience and mind," *Cambridge : Cambridge University Press*, 1976.

G. Leibniz, *Nouveaux Essais sur l'entendement humain*, J. Brunschwig, Ed. Paris : Garnier-Flammarion, 1966.

D. Lewis, *Parts of classes.* Oxford, UK ; Cambridge, Mass., USA : B. Blackwell, 1991.

——, "Humean supervenience debugged," *Mind*, vol. 103, pp. 473–490, 1994.

J. Locke, *An Essay Concerning Human Understanding (Oxford World's Classics).* OUP Oxford, 2008.

F. Mason, "How not to prove the existence of'atomless gunk'," *Ratio*, vol. 13, no. 2, pp. 175–185, 2000.

J. McKitrick, "A case for extrinsic dispositions," *Australasian Journal of Philosophy*, vol. 81, no. 2, pp. 155–174, 2003.

G. Molnar, *Powers : a study in metaphysics*, S. Mumford, Ed. Oxford : Oxford University Press, 2003.

S. Mumford, *Dispositions.* Clarendon Press, 2003.

J. Parsons, "Theories of location," *Oxford Studies in Metaphysics*, vol. 3, pp. 201–232, 2007.

——, "Hudson on location," *Philosophy and Phenomenological Research*, vol. 76, no. 2, pp. 427–435, 2008.

Platon, *Timee, Critias.* Paris : Flammarion, 1999.

H. H. Price, *Perception.* Methuen, 1961.

Z. Pylyshyn, "Is vision continuous with cognition ? : The case for cognitive impenetrability of visual perception," *Behavioral and Brain Sciences*, vol. 22, no. 03, pp. 341–365, 1999.

A. Quinton, "Matter and space," *Mind*, pp. 332–352, 1964.

H. Robinson, *Matter and Sense : A Critique of Contemporary Materialism*, 1982.

B. Russell, *The principles of mathematics.* Cambridge : Cambridge University Press, 1903.

D. H. Sanford, "Volume and solidity," *Australasian Journal of Philosophy*, vol. 45, no. 3, pp. 329–340, 1967.

——, "Does locke think hardness is a primary quality ?" *Locke Newsletter*, vol. 1, pp. 17–19, 1970.

——, "Locke, leibniz, and wiggins on being in the same place at the same time," *The Philosophical Review*, pp. 75–82, 1970.

D. Schultess, "L'individuation selon brentano," *Philosophiques*, 1999.

R. Sharvy, "Aristotle on mixtures," *The Journal of Philosophy*, pp. 439–457, 1983.

——, "Mixtures," *Philosophy and Phenomenological Research*, pp. 227–239, 1983.

P. Sheehy, "Sharing space : The synchronic identity of social groups," *Philosophy of the Social Sciences*, vol. 36, no. 2, p. 131, 2006.

J. M. Shorter, "On coinciding in space and time," *Philosophy*, pp. 399–408, 1977.

T. Sider, “Bare particulars,” *Philosophical perspectives*, vol. 20, pp. 387–397, 2006.

——, “Simply possible,” *Philosophical and Phenomenological Research*, pp. 585–590, 2000.

——, *Four-dimensionalism : an ontology of persistence and time.* Oxford New York : Clarendon Press Oxford University Press, 2001.

P. Simons, *Parts : A Study in Ontology.* Oxford University Press, 1987.

——, “Extended simples : A third way between atoms and gunk,” *The Monist*, vol. 87, no. 3, pp. 371–384, 2004.

——, “Coincidence of things of a kind,” *Mind*, pp. 70–75, 1985.

B. Smith, “The primacy of place, an investigation in to brentanian ontology,” *Topoi*, vol. 8, pp. 43–51, 1989.

——, “Boundaries : An essay in mereotopology,” in *The Philosophy of Roderick Chisholm*, L. Hahn, Ed. LaSalle : Open Court, 1997, pp. 534–561.

R. Swinburne, *Space and time.* Macmillan, 1968.

A. Varzi, “The extensionality of parthood and composition,” *The Philosophical Quarterly*, vol. 58, pp. 108–133, 2008.

D. Warren, *Reality and Impenetrability in Kant's Philosophy of Nature.* Routledge, 2001.

D. Wiggins, “On being in the same place at the same time,” *The Philosophical Review*, pp. 90–95, 1968.

N. Williams, “Static and dynamic dispositions,” *Synthese*, vol. 146, no. 3, pp. 303–324, 2005.

D. Zimmerman, “Could extended objects be made out of simple parts ? an argument for "atomless gunk",” *Philosophy and Phenomenological Research*, vol. 56, No. 1, pp. 1–29, 1996.

——, “Indivisible parts and extended objects : Some philosophical episodes from topology's prehistory,” *The Monist*, vol. 79, no. 1, pp. 148–180, 1996.