International Journal of Astrobiology 9 (2): 131–136 (2010)
doi:10.1017/S1473550410000017

On the applicability of dialetheism and philosophy of identity to the definition of life

Vera M. Kolb

Department of Chemistry, University of Wisconsin-Parkside, Kenosha, WI 53141, USA
e-mail: kolb@uwp.edu

Abstract: We have found that the principles of dialetheism, which state that some contradictions (typically at the limits of a system) may be true, and which amply demonstrate the limits of thought and conception, can be valuable in sorting out and clarifying some astrobiological problems that impede our ability to define life. The examples include the classification of viruses as alive or not alive, and the description of the transition zone for the abiotic-to-biotic transition. Dialetheism gives us the philosophical tool to state that the viruses may be both alive and not alive, and that chemical systems may exist that are both abiotic and biotic.

We have extracted some philosophical principles of the identity and have applied them to the identity of living organisms and their life forms. The first and most important idea is that we should define an individual organism via its numerical identity. For each organism its identity will be in relation to itself. As the organism undergoes various changes during its development, and as it transitions from one to the next of its life forms, one can observe numerous qualitative differences between these life forms. Although the life forms change and the organism is in a flux, what remains constant is the numerical identity of the organism. If the organism reproduces, for example by a fission mode, then the daughter cells will have their own numerical identity. We can state that the life of an organism is a sum of all its life forms over the period of time of the existence of the organism. Reproduction, particularly by fission, represents an identity dilemma, but it can be resolved by Gallois' occasional identities theory.

Received 4 December 2009, accepted 3 January 2010, first published online 29 January 2010

Key words: abiotic-to-biotic transition, Aristotelian logic, classification of viruses, definition of life, dialetheism, Hegel's dialectics, life forms, occasional identity, the identity problem, true contradictions.

Introduction and objectives

In this paper we combine, expand and put in a new light our recent preliminary investigations of the application of dialetheism and philosophy of identity to the definition of life as relevant to astrobiology (Kolb 2008, 2009). We utilize philosophy as a tool for the advancement of astrobiology. However, as philosophers are constantly seeking real-life problems for testing their concepts, we hope that more philosophers will become attracted to astrobiology.

This manuscript is composed of two sections. In the first section we address the philosophical concept of dialetheism and in the second one we address the identity problem, in both cases as they relate to the definition of life. The conclusions tie these two sections together.

On the applicability of dialetheism to the emergence of life and the classification of viruses

Life presumably emerged by a transition from an abiotic physico-chemical system to a biotic one. To describe this transition we have considered a model in which life arises from abiotic matter by a quantity-to-quality transition (Kolb 2005). The quantity of the organization and complexity of the abiotic matter gives rise to a new quality, namely life. In an earlier paper we proposed the existence of a transition zone between the abiotic and biotic systems (Perry & Kolb 2004). In this section we show the contradictions that arise from the concept of the transition zone, and a possible way to resolve them via dialetheism.

In our previous work we addressed the problem of the classification of viruses as alive or not alive when reproduction is used as a key factor in defining life (Kolb 2007). In this section we show how this problem can be resolved by an application of dialetheism.

We first provide a short background on the philosophical principles that are important for understanding dialetheism.

From Aristotle to Hegel to Priest: a brief review

Here we give a brief review of the philosophical principles of Aristotle (Gottlieb 2007), Hegel (1970, 1975) and Priest (1995, 2006), which are applicable to our paper.

Most traditional scientific reasoning has a foundation in Aristotle's logic, such as his law of non-contradiction (it is impossible for both *p* and *not-p* to be true; cannot *be* and *not-be* at the same time) (Gottlieb 2007).

Hegel (1970, 1975) introduced his dialectic, in which contradictions can be transcended. Hegel believed that everything contains its opposite, and thus is contradictory. Everything is what it is because of its opposite. The master–slave opposite illustrates the point, because neither master nor slave is meaningful without the other. Hegel's thesis and antithesis are in conflict or contradiction. The solution to the contradiction is a synthesis of a thesis and its antithesis. This is the famous Hegelian triad consisting of a thesis, antithesis and synthesis. We have found Hegel's laws of logic regarding quantity-to-quality transitions valuable when describing the abiotic-to-biotic transition (Kolb 2005). Hegel's dialectics and his laws of logic can successfully explain how a build-up of the quantity of the organization and complexity of the abiotic matter leads to the emergence of new qualities.

Priest, like Hegel, does not follow Aristotelian logic. Priest examines the limits of the mind, thought, concepts, expressions, descriptions, conceptions and knowing. These limits are boundaries that cannot be crossed, and yet they are crossed. Transcendence beyond these limits may create contradictions. Priest believes that some contradictions may be true. Thus, both the statement and its negations could be true. This belief is termed dialetheism (Greek: *aletheia* = truth; *di-aletheia* = a two-way truth). Priest gives a simple, but convincing example of a true contradiction. It is the case of a person leaving the room through an open door to go outside. At some point in this transition, as the person exits the room by passing through the open door, the person will be both inside and outside the room. It is easy to visualize this.

We now provide a background on some problems in defining life, which we will attempt to solve via dialetheism.

Background on some problems in defining life

There have been many attempts to propose a definition of life that would be all-encompassing and relevant to as many diverse life forms as possible. Some definitions of life have favoured the algorithmic and other reductionist approaches, while some others have been more empirical and descriptive of specific life properties, which presumably characterize life more fully. We point the readers to our recent papers (Kolb 2005, 2007), which summarize many of the definitions and cite numerous major references and reviews on the topic. We also recommend two recent papers on the subject (Forterre & Gribaldo 2007; Lazcano 2007).

Despite all the efforts directed towards defining life, we still do not have a satisfactory definition that is universally accepted and applicable to a wide variety of life forms. Most definitions overemphasize the requirement for replication. This leads to the absurd classification of sterile organisms as not alive (Kolb 2007). The definitional requirement that all life forms must engage in independent replication creates a problem in the classification of viruses. As entities that cannot reproduce on their own, viruses must be regarded as entities that are not alive by such a replication requirement. Sometimes the viruses are classified as belonging to a 'twilight zone of life' (Kolb 2007).

The proper definition of life should also include its origins. Most scientists believe that life evolved by the chemical evolution of abiotic matter. However, the understanding of the nature of the transition between the abiotic and biotic is murky at best (Perry & Kolb 2004). Consequently, the description of this transition is difficult.

In the next two sections we show how the application of dialetheism can help us to clarify the classification of viruses and the description of the abiotic-to-biotic transition.

The example of viruses

Viruses may be considered not alive based on the criterion that they cannot reproduce on their own (Miller 2004; Kolb 2007; Raoult & Forterre 2008). The non-reproductive form of viruses would be their virion phase. However, when the virions penetrate the cells of their hosts, they become capable of reproduction with the help of their hosts. In their hosts, viruses act as alive if we accept assisted reproduction as a valid mode of reproduction. Thus, viruses may be considered as being both alive and not alive, depending on the viral forms we consider, namely those before they infect the host and after they start reproducing with the help of the host. This classification, as both alive and not alive, would be a true contradiction. To resolve this contradiction, we can propose that it is not necessarily true that *alive* and *not alive* are the only two options. The option of being *both alive and not alive* may have validity, since it appears to adequately describe viruses. Such an option would be a problem for the Aristotelian law of non-contradiction, but not for dialetheism.

The example of the transition zone between the abiotic and the biotic

One of the central concerns of astrobiology is the nature of the transition from abiotic to biotic states. We have proposed that there is a transition zone between the abiotic and the biotic (Perry & Kolb 2004). We have also described this transition via Hegel's law for quantity-to-quality transitions (Kolb 2005), in which the quantity of the chemical and organizational changes in the prebiotic soup, or in a similar prebiotic system, makes a transition to a new quality, that of life. Various questions arise about this model. At which point is the quantity transformed to a new quality? Not all accumulations of quantity lead to a new quality. When does the quantity of chemical and organizational changes in the prebiotic soup result in the emergence of a new quality, that of the biotic, rather than in the deterioration of complexity or chaos, for example? These questions result from the shortcomings of the Hegelian law, which does not have an explicit predictive power.

We find dialetheism useful in describing the transition from the abiotic to the biotic. The two commonly considered states, those of the abiotic and the biotic, do not have to be necessarily the only two mutually exclusive states. A third state could exist, a transition zone, for example, which has some properties of both states – the abiotic and the biotic. The obvious need for a third category, both *abiotic and biotic*, is usually not explicitly acknowledged, possibly because it violates Aristotle's law of non-contradiction. Instead, linguistic constructions such as 'the transition zone' and 'order at the edge of the chaos', among others, have been used (Perry & Kolb 2004). Yet, such constructs clearly describe conditions that have characteristics of both the abiotic and the biotic. It is dialetheism that points to the need to define such transitional conditions explicitly.

Our case of the abiotic-to-biotic transition is more complicated than Priest's example of a person being both inside and outside the room in the process of transitioning from inside the room to the outside via an open door. The abiotic-to-biotic transition involves the appearance of a new quality, that of life, while in the case of the person leaving the room to go outside, the person's 'essence' does not change. Priest (1995) stated: ' … according to Hegel, something which is changing from being F to not being F is, in the transition, both F and not F'. This describes perfectly the case of the transition zone between the abiotic and the biotic, as having properties of both.

In this section we have provided some answers, but those have generated additional questions. For example, what is a virus? Is it a virion that is best described as not alive, or is it a virus inside the host's cell where it is more appropriately described as alive, since it is reproducing? Similarly, what is a tree? Is it a seed, a sapling or a mature tree? What is the identity of a tree? When we define life, which one of these different entities should we use?

In our previous work (Liesch & Kolb 2007; Kolb & Liesch 2008) we addressed the subject of such entities, which we have termed life forms. Life forms are appropriate for the categorization of viruses and similar entities that fail to reach critical complexity or self-sufficiency, which are usually associated with life. Life forms also characterize living organisms as they undergo changes throughout their life cycles. Some changes between the life forms may involve metamorphosis with drastically different morphological forms, such as those of a caterpillar and its corresponding butterfly.

We now focus on the identity of the life forms and their relationship to the identity of the parent organism. Again, we seek inspiration from philosophy, which has analysed the identity problem in depth.

The philosophical problem of identity and its application to the definition of life

The Ship of Theseus paradox and proposed resolutions

We consider first 'The Ship of Theseus paradox', from a Greek legend described by Plutarch in 75 ACE (Wikipedia 2008b; Plutarch 2009). This paradox raises the question of whether a ship that has all of its parts replaced, plank by plank, remains the same ship. 'The ship wherein Theseus and the youth of Athens returned had thirty oars, and was preserved by the Athenians down even to the time of Demetrius Phalereus, for they took away the old planks as they decayed, putting in new and stronger timber in their place, insomuch that this ship became a standing example among the philosophers, for the logical question of things that grow; one side holding that the ship remained the same, and the other contending that it was not the same' (Plutarch 2009). This paradox involves an inanimate object, but it may also be applied to living organisms. For example, does an organism stay the same despite the cell turnover? Further, does a cell that has its constituent molecules replaced in a catabolic/metabolic cycle remain the same in a fundamental way?

There are several options for addressing the Theseus Ship paradox. Firstly, one may take the Heraclitean view that everything is changing and is in a state of flux (Kahn 1979; Heraclitus 2003). Heraclitus famously stated that: 'Just as the river where I step is not the same, and is, so I am as I am not' (Heraclitus 2003), and 'One cannot step twice into the same river, nor can one grasp any mortal substance in a stable condition, but it scatters and again gathers; it forms and dissolves, and approaches and departs' (Kahn 1979). The Heraclitean option is the correct one for describing living beings, which are constantly changing, but is not very helpful in understanding their identity.

Another proposed solution for the Theseus paradox is to apply Aristotle's causes (Wedin 1999; Wikipedia 2008b). These causes or reasons describe a thing. The formal cause is its plan, or form, or design (what-it-is) (*eidos*), the material cause is the matter the thing is made of (*hyle*), the efficient cause refers to how and by whom the thing is made, namely the artisans and tools, and the final cause is the intended purpose of the thing (*telos*). Thus, one could claim that the Ship of Theseus is the same after the replacement of the planks, because its formal cause and the final cause are the same. The efficient cause is reasonably similar. Although the individual artisans and tools may have been different, they have produced the same results of replacing the old planks with the new ones. According to Aristotle, the efficient cause is the builder, but more exactly the form in the builder's soul; we could assume that this form, a blueprint for the ship, stays the same for various builders. However, the material cause is not the same, since the planks would rot gradually and would be replaced by the new ones, which would also gradually deteriorate. Thus, at any point of time the planks are changing gradually and are not the same. This sort of analysis can be extrapolated to living organisms, but various assumptions need to be made (Kolb 2009). Here, we show only a reasonably straightforward case of the material cause, which in the living organisms would be their cell(s) and/or the chemical compounds within a single cell. These are in flux, both in terms of cell turnover (in some higher organisms) and/or the individual cell's chemical composition at any particular time. Here we could see a parallel with the wooden planks of the Ship of Theseus, which undergo gradual rotting, but are replaced with new ones.

We turn next to another possible way of resolving the Ship of Theseus paradox, by looking at the definition of sameness, which is also called identity Wikipedia 2008a, b). Identity is

https://doi.org/10.1017/S1473550410000017 Published online by Cambridge University Press

whatever makes an entity definable, recognizable and distinguishable from other entities. Things may be qualitatively the same, if they have the same properties. Here we can think about clones, which are the same except for the space they occupy. (In some cases clones may be engineered to exist at different times.) On the other hand, things may be numerically the same if they are 'one'.

Numerical identity appears to provide the answer to our dilemma. An individual organism is numerically the same (it is 'one'), although at any point of time/space it exists as yet another of its life forms, all of which are qualitatively different. We now have the numerical identity as a tool for analysing the identity problem as related to life in more depth. We next look at the identity over time, persistence through change and the space requirement for identity, all of which are directly applicable to the life of an organism.

Philosophers noticed early on that misjudgements of identity are possible, because one thing may be presented in many different forms (Williamson 1998). Examples include a seed, a sapling and a mature tree, and the previously given example of a caterpillar and its butterfly, among others. Persistence through change is illustrated in these examples.

Wittgenstein pointed out the following problem with identity: 'Roughly speaking, to say of two things that they are identical is nonsense, and to say of one thing that is identical with itself is to say nothing at all' (Wittgenstein 1993; Williams 1995). Wittgenstein denies that identity is a relation; if it is then it must hold either between two distinct things or between a thing and itself (Williams 1995). 'To say that A is the same as B, when A and B are distinct, is bound to be false; but to say that A is the same as A is to utter a tautology' (Williams 1995). It is indeed not information rich if we say that one thing is identical with itself in a specific point of time and space. However, if we look at a living being at this moment, in its present space, and compare it with what it was in the past when it was different, and possibly also in a different space, then we must choose how to define its identity. Either we can say that its identity is the same (although the living being was qualitatively different in the past), or it that it is different. In the latter option, the living beings would have to have an infinite number of identities, over a continuum of time and the associated space. This would not be useful either, namely it would say nothing at all. The numerical identity is helpful, because it allows for the living being to remain the same, while being different at different times/spaces. We see here a conceptual link with dialetheism. It is possible to be both 'one' and 'many'.

In the classical views identity can be interpreted as meaning permanence amid change, or as unity amid diversity (Stroll 1967). The problem of identity as permanence is that it cannot accommodate change, while the problem of identity as unity is that we are asking whether the diverse is really not diverse (Stroll 1967). Again, the numerical identity solves the problem. The living being can be 'not diverse', as it is 'one', but it can also be diverse in different times/spaces.

For the identity of life as understood via a spatiotemporal succession of its life forms, the approach by Gallois is particularly fruitful (Gallois 2005). Gallois provides an extensive coverage of identity over time, including synchronic identity, which is the identity holding at a single time, and diachronic identity, which is the identity holding between something existing at one time and something existing at another. Gallois considers the division of an amoeba into two by fission and the identity of the original organism in relation to that of its daughter cells (Gallois 2003). He has produced a solution, which we describe below, and which we believe is definitely usable for biology. Gallois' solution comes from his theory of occasions of identity (Sider 2001; Gallois 2003).

Gallois explored the nature of identity and change and proposed that things can be identical at one time, but distinct at another time. This represents 'occasional identities'. Gallois addressed the case of the dividing amoebas, among other identity problems (Gallois 2003). A concise summary of the identity problem related to the amoeba division and the solution of the problem by the theory of occasional identities are provided by Sider (2001). The first key idea is that the identity can hold temporarily. This is directly relevant to ever-changing living organisms. The second key idea addresses changes in identity during replication. This is explained on an example of the division of an amoeba. An amoeba, referred to as AMOEBA, divides into two. One of the resultant daughter cell amoebas, POND, lives in a pond, while the other, SLIDE, is taken out of the pond and is examined on a microscope slide in a laboratory. The first question is if AMOEBA survives the fission process. If so, does it survive as POND or SLIDE? The solution by Gallois is that POND and SLIDE are numerically distinct after division, but that they were numerically identical before division. After the division there are two amoebas, POND and SLIDE, each of which existed before division. However, there were no two amoebas before division. The identity relation can hold temporarily or occasionally (thus the 'occasions of identity').

We consider the above example of the dividing amoeba further in the biological context. Since AMOEBA continues to function metabolically/catabolically during the division, and since there is no chemical deterioration characteristic of death (such as in death by starvation, for example), AMOEBA can be considered to be alive during the division. The question is what happens to the numerical identity of AMOEBA. At the very moment of fission, AMOEBA splits into two PONDs. These daughter cells initially occupy roughly the same space as AMOEBA. The two PONDs become separated in space when one is taken out of the pond to become SLIDE. POND and SLIDE are two clones, initially qualitatively identical except for the space they occupy. They have separate numerical identities. If SLIDE were not taken out of the pond, we would have POND 1 and POND 2, which would initially occupy approximately the same space as the original AMOEBA, but would separate after AMOEBA's fission by a diffusion process, among other means. These clones would initially be qualitatively identical, except for the space they occupy, but would have different numerical identities. They would soon acquire more qualitative differences, since they would end up living in different spaces in the pond, which would likely differ in the nutritional content and other environmental factors. These factors would influence the development of POND 1 and POND 2 in a different way. It is clear that POND 1 and POND 2 should have different numerical identities, since they are not 'one'. As for the identity of AMOEBA, we have various options. One option is to assume that the numerical identity of AMOEBA ceases to exist when the fission occurs. However, the fission produces two new numerical identities, one for each of the two POND daughter cells. We suggest that a quality-to-quantity transition occurs, in which the accumulation of the qualitative changes in AMOEBA generates a different quantity, that of two new cells with different numerical identities. The old quality associated with AMOEBA is not completely lost, but is preserved in some fashion in the new cells, within their new identities. This would be an application of the Hegelian law of the quality-to-quantity change. More common are cases of the quantity-to-quality change (Kolb 2005).

We propose that the life of an organism is the sum of its life forms over a period of time. We set the integral of time from the birth of the organism to its death. We see that the death boundary may be debatable, since AMOEBA as such does not exist anymore after fission, but it is not dead, as it continues to live in some fashion as PONDs. Should we extend the integral of time to include the life forms of the PONDs and of further offspring? Likewise, the birth boundary has its own complexity. PONDs have existed in some fashion before the division of AMOEBA, but not as two amoebas. They became numerically distinct only after the division. We could consider 'birth' as the time/space of such numerical distinction. Alternatively, we could go back in time to the first common ancestor. This would make our definition of life too broad and not useful. The most practical thing is to go by the numerical identity of each individual live cell, and disregard their origin and the future of their offspring. As for the question of where the numerical identity of POND comes from, we can assume that it is coming from the quality-to-quantity transition in AMOEBA. Thus, the numerical identity can be generated.

Conclusions

We have found that the principles of dialetheism, which state that some contradictions (typically at the limits of a system) may be true, and which amply demonstrate the limits of thought and conception, can be valuable in sorting out and clarifying some astrobiological problems that impede our ability to define life. The examples include the classification of viruses as alive or not alive, and the description of the transition zone for the abiotic-to-biotic transition. Dialetheism gives us the philosophical tool to state that viruses may be both alive and not alive, and that chemical systems may exist that are both abiotic and biotic.

We have extracted some philosophical principles of identity and have applied them to the identity of living organisms and their life forms. The first and most important idea is that we should define an individual organism via its numerical identity. For each organism its identity will be in relation to itself. As the organism undergoes various changes during its development, and as it transitions from one to the next of its life forms, one can observe numerous qualitative differences between these life forms. Although the life forms change and the organism is in a flux, what remains constant is the numerical identity of the organism. If the organism reproduces, for example by a fission mode, then the daughter cells will have their own numerical identity. We can state that the life of an organism is the sum of all its life forms over the period of time of the existence of the organism. Reproduction, particularly by fission, represents an identity dilemma, but it can be resolved by Gallois' occasional identities theory.

Acknowledgment

Thanks are expressed to Joseph Pearson, from the University of Wisconsin-Parkside Philosophy department, for valuable discussions and for providing various references.

References

Forterre, P. & Gribaldo, S. (2007). *Hum. Front. Sci. Program J.* **1**, 156–168.

Gallois, A. (2003). *Occasions of Identity, the Metaphysics of Persistence, Change, and Sameness*, pp. 1–10. 16–19, 25–28, 58–59, 64, 70–77, 101–110, 255–264. Oxford University Press, Oxford.

Gallois, A. (2005). Identity over time. In *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/identity/ (accessed 13 November 2008).

Gottlieb, P. (2007). Aristotle on non-contradiction. In *Stanford Encyclopedia of Philosophy*, Winter 2007 edn, ed. Zalta, E.N. http://plato.stanford.edu/entries/aristotle-noncontradiction (accessed 23 June 2008).

Hegel, G.W.F. (1970). *Philosophy of Nature*, translated by Miller, A.V., pp. 232–272. Oxford University Press, London.

Hegel, G.W.F. (1975). *Logic*, translated by Wallace, W., pp. 123–161, 265–267. Oxford University Press, London.

Heraclitus (2003). *Fragments*, translated by Haxton, B., p. 51. Penguin Books.

Kahn, C.H. (1979). *The Art and Thought of Heraclitus: An Edition of the Fragments with Translation and Commentary*, p. 53. Cambridge University Press, Cambridge.

Kolb, V.M. (2005). *Int. J. Astrobiol.* **4**, 227–232.

Kolb, V.M. (2007). *Int. J. Astrobiol.* **6**, 51–57.

Kolb, V.M. (2008). On the applicability of dialetheism to the emergence of life and the classification of viruses. In *Instruments, Methods, and Missions for Astrobiology XI*, ed. Hoover, R.B., Levin, G.V., Rozanov, A.Y. & Davis, P.C.W. (*Proc. SPIE*, vol. 7097), p. 709713 (1–4). The International Society of Optical Engineers, Bellingham.

Kolb, V.M. (2009). On the applicability of the identity problem to astrobiology. In *Instruments and Methods for Astrobiology and Planetary Missions XII*, ed. Hoover, R.B., Levin, G.V., Rozanov, A.Y. & Retherford, K.D. (*Proc. SPIE*, vol. 7441), p. 74410U (1–7). The International Society of Optical Engineers, Bellingham.

Kolb, V.M. & Liesch, P.J. (2008). Abiotic, biotic, and in-between. In *Instruments, Methods, and Missions for Astrobiology XI*, ed. Hoover, R.B., Levin, G.V., Rozanov, A.Y. & Davis, P.C.W. (*Proc. SPIE*, vol. 7097), p. 70970A (1–6). The International Society of Optical Engineers, Bellingham.

Lazcano, A. (2007). *Chem. Biodivers.* **5**, 1–15.

Liesch, P.J. & Kolb, V.M. (2007). Living strategies of unusual life forms on Earth and the relevance to astrobiology. In *Instruments, Methods, and*

Missions for Astrobiology X, ed. Hoover, R.B., Levin, G.V., Rozanov, A.Y. & Davis, P.C.W. (*Proc. SPIE*, vol. 6694), p. 66941F (1–10). The International Society of Optical Engineers, Bellingham.

Miller, R.V. (2004). Bacteriophage-mediated transduction: an engine for change and evolution. In *Microbial Evolution: Gene Establishment, Survival, and Exchange*, ed. Miller, R.V. & Day, M.J., pp. 144–148. ASM Press, Washington, DC.

Perry, R.S. & Kolb, V.M. (2004). *Int. J. Astrobiol.* **3**, 45–53.

Plutarch (2009). *Theseus*, translated by Dryden, J. The Internet Classics Archive, http://classics.mit.edu/Plutarch/theseus.html (accessed 30 June 2009).

Priest, G. (1995). *Beyond the Limits of Thought*, pp. 3–8, 56–70, 104–105. Cambridge University Press, Cambridge.

Priest, G. (2006). What's so bad about contradictions? In *The Law of Non-Contradiction, New Philosophical Essays*, ed. Priest, G., Beall, J.C. & Armour-Garb, B., pp. 23–38. Oxford University Press, Oxford.

Raoult, D. & Forterre, P. (2008). *Nat. Rev. Microbiol.* **6**, 315–319.

Sider, T. (2001). *Br. J. Philos. Sci.* **52**, 401–405.

Stroll, A. (1967). Identity. In *The Encyclopedia of Philosophy*, vol. 3, ed. Edwards, P., pp. 121–124. Macmillan, New York.

Wedin, M.V. (1999). Aristotle. In *The Cambridge Dictionary of Philosophy*, ed. Audi, R., pp. 44–51. Cambridge University Press, Cambridge.

Wikipedia (2008a). Identity (philosophy). http://en.wikipedia.org/wiki/Identity_(philosophy) (accessed 8 July 2008).

Wikipedia (2008b). Ship of Theseus. http://en.wikipedia.org/wiki/Ship_of_Theseus (accessed 13 November 2008).

Williams, C.J.F. (1995). Identity, the paradox of. In *The Oxford Companion to Philosophy*, ed. Honderich, T., p. 391. Oxford University Press, Oxford.

Williamson, T. (1998). Identity. In *Routledge Encyclopedia of Philosophy*, ed. Craig, E., pp. 675–678. Routledge, New York.

Wittgenstein, L. (1993). Cause and effect: intuitive awareness. In *Philosophical Occasions, 1912–1951*, ed. Wittgenstein, L., p. 412. Hackett Publishing Co., Indianapolis.