

Everything Flows: Towards a Processual Philosophy of Biology

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Genidentity and Biological Processes

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Abstract and Keywords

A crucial question for a process view of life is how to identify a process and how to follow it through time. The genidentity view (first proposed by Kurt Lewin and later elaborated by Hans Reichenbach) can contribute decisively to this project. It says that the identity through time of an entity X is given by a well-identified series of continuous states of affairs. Genidentity helps address the problem of diachronic identity in the living world. This chapter describes the centrality of the concept of genidentity for David Hull and proposes an extension of Hull's view to the ubiquitous phenomenon of symbiosis. Finally, using immunology as a key example, it shows that the genidentity view suggests that the main interest of a process approach is epistemological rather than ontological and that its principal claim is one of priority, namely that processes precede and define things, and not vice versa.

Keywords: continuity, genidentity, Hull, David, identity, immune system, individuality, process, symbiosis

1. Introduction

What exactly is a process view of life? Philosophers of biology and biologists who have recently defended such a view (Dupré 2012; Baptiste and Dupré 2013; Dupré 2014) generally oppose *processes* (characterized by constant change) and *things* (characterized by stability and durability). But two major questions should be raised regarding this view:

- (i) What kinds of relationships between 'things' and 'processes' are possible? Is it possible to countenance both 'things' and 'processes' as

categories that describe the living world, or are these two categories incompatible?

(ii) Can a priority claim about ‘things’ and ‘processes’ be made and, if so, on what grounds? Here the question is to determine what comes first—things or processes. Two main types of priority claims can be made: an *ontological* claim (the biological world is actually made of processes, and things are only partial and temporary stabilizations of processes); or one made from an *epistemological* perspective (for us as human beings, the best way to understand the biological world is to get access to it in terms of processes).¹

In this chapter I would like to show that a preexisting view of the biological world, called the ‘genidentity view’, helps—especially in the variant defended by David Hull—to clarify what a process view of life might be. More specifically, the genidentity view is useful because it suggests that (a) the notions of processes and things are both needed in biology, but processes are *prior* to things; and (b) the main interest of adopting a process view is epistemological, not ontological. One key underlying objective of the present chapter will be to address a question that seems decisive for anyone who proposes to conceive of the biological world in terms of processes: what difference does it make, in actual practice, to adopt a process view?

(p.97) Let me start with a preliminary definition of the notion of ‘genidentity’. In a nutshell, the genidentity view, which has been explored in the contexts of psychology, physics, and biology (Lewin 1922; Reichenbach 1956; Hull 1992; Boniolo and Carrara 2004; Pradeu and Carosella 2006b; Guay and Pradeu 2016b), says that the identity through time of an entity X is given by a well-identified series of continuous states of affairs. Of course, this claim is not sufficient in itself; every precise application of the genidentity view requires a clarification of exactly which continuous states are being followed, and why. In the next pages I examine in detail the concept of genidentity, and then I show why it could constitute a decisive building block for the project of developing a process view for biology. After a short reminder of the origins of the concept of genidentity, I describe its centrality in David Hull’s reflections on biological identity. Following this, I suggest an extension of Hull’s view on the basis of recent data that demonstrate the ubiquity of symbiotic interactions in the living world. Finally, I explain why genidentity prompts us to adopt a multilevel and mainly epistemological view on biological processes.

2. What Is Genidentity? And How Can It Be Applied to the Living World?
What constitutes the identity through time of an entity X? For instance, in what sense can I be said to be the ‘same’ as the child I was, a cat the ‘same’ as the kitten it was, or a wave the ‘same’ wave while it is moving through the sea? These questions are particular instances of the more general problem of diachronic identity (or identity through time), undoubtedly one of the most

fundamental and most debated problems of all philosophy. The problem has been raised by major philosophers of the past, including Aristotle, Locke, and Leibniz. More recently, metaphysicians (both ‘perdurantists’ and ‘endurantists’) have offered important analyses of the same problem, for example David Wiggins (2001), Peter van Inwagen (1990), Theodore Sider (2001), and Katherine Hawley (2004).

One very interesting, though often neglected, way to address the problem of diachronic identity is to resort to the concept of genidentity. According to the genidentity view, the identity through time of an entity X is given by a well-identified series of continuous states of affairs. As will become clear in what follows, this view insists on the continuity of states rather than on the prior existence of objects; it conflicts radically with several forms of substantialism; and it is based on an epistemological (rather than ontological) attitude regarding science.

The concept of genidentity was proposed in 1922 by Kurt Lewin (1890–1947), a leading German American psychologist, as a way to better understand identity through time (Lewin 1922). It was neglected by most philosophers of science, but Hans Reichenbach (1891–1953) took it very seriously and explored it further. Indeed, Reichenbach examined different conceptions of genidentity and applied them to several physical cases (Reichenbach 1956).² Today, however, the notion of **(p.98)** genidentity is rarely used in philosophy in general and almost never in the philosophy of science, where the exceptions are few and far between (e.g. Hull 1992; Boniolo and Carrara 2004; Pradeu and Carosella 2006b; Guay and Pradeu 2016b; see also chapters 2, 4, 7, and 11 here).

In its insistence on defining identity as mere continuity, the concept of genidentity echoes in part Locke’s conception of identity. Indeed, in the second edition of his *Essay Concerning Human Understanding*, Locke (1975 [1694]) says that the long-sought ‘principle of individuation’ is to be found in a simple continuity of states. In the case of living things (plants or animals), the identity of a being is, according to Locke, the continuity of one and the same ‘life’. This illustrates what has been said above, namely that genidentity views always need to make clear exactly what states are followed and why (here, the continuity of a ‘life’). Applied to humans, Locke’s view is as follows: ‘This also shows wherein the Identity of the same Man consists; viz. in nothing but a participation of the same continued Life, by constantly fleeting Particles of Matter, in succession vitally united to the same organized Body’ (Locke 1975 [1694]: §6, 331). Interestingly, in his *New Essays Concerning Human Understanding*, a text that constitutes a systematic response to Locke, Leibniz (1916 [1765]) strongly rejects Locke’s conception of identity because, for Leibniz, continuity by itself is insufficient to define identity: ‘By itself continuity no more constitutes substance

than does multitude or number...*Something* is necessary to be numbered, repeated and continued' (Leibniz 1916 [1765]: 169).

Let us call *substantialism* the view according to which the identity of a thing X must be understood as the identity of a substance identified beforehand, and *continuism* the view according to which the identity of a thing X is given by a mere continuity of states (as defended by Locke). Substantialism is defended by Leibniz, but also by many contemporary philosophers, under different forms. One version of substantialism is *essentialism*, which states that what makes the identity of X through time is the fact that a core constituent or characteristic of X remains constant through time. In the case of living things, genetic essentialism says that a living thing remains the same through time in virtue of the fact that it possesses the same genome throughout (Kripke 1980). Another, significantly different version of substantialism is the 'neo-Aristotelian' view defended by Wiggins (2001). According to this view, the identity of a thing X is given by a sortal concept (a category), which defines a specific principle of activity (for example, it is possible to understand the identity of a given thing only by determining that it is, say, a dog and that what defines the identity of a dog is a certain principle of activity, common to all dogs).

I suggest here that the genidentity view constitutes a particularly interesting and fruitful version of continuism (and therefore a view that stands in contrast with substantialism in general), and that it can shed light on the question of the diachronic identity of living things. More precisely, I shall defend the thesis that genidentity is the best way to understand the diachronic identity of a living thing and that it helps to make the concept of biological process more precise. I first explain the centrality of the notion of genidentity in Hull's thinking about the problem of individuality and then I show how his view can be extended to reflect important findings in recent biology, in particular regarding the phenomenon of *symbiosis*.

(p.99) 3. The Inconspicuous Centrality of Genidentity in Hull's Conception of Biological Individuality

David Hull (1935–2010) was undoubtedly one of the most influential philosophers of biology. Hull mentioned the notion of genidentity several times in his writings (Hull 1986, 1992), but these mentions remained largely unnoticed and, intriguingly, most other philosophers of biology did not follow Hull and did not adopt this notion.

How does Hull specifically apply the idea of genidentity? In other words, which states does Hull think one should follow over time in order to understand the identity of a living thing? His answer is that one should follow the continuity of an *internal organization*. Let me try to explain this idea in more detail.

Even before Hull used the notion of genidentity explicitly, the idea behind it was already present in his writings. In particular, that idea underlies the view of identity presented in one of his most famous and influential texts: 'A Matter of Individuality' (Hull 1978). This paper is often seen as a defense of two theses: that species are individuals rather than classes, and that there is no 'human nature', no 'essence' of humanity (indeed, if humans are considered from the species point of view, that is, as tokens of *Homo sapiens*, it is impossible to define what are the necessary and sufficient characteristics that would make a given entity a human). Nevertheless, what in fact constitutes the basis of these two theses is the conception of identity Hull defends; a conception that is also at the heart of what is arguably the most important contribution of that paper, namely the two diagrams drawn by Hull. Let us now see what exactly is the conception of identity held by Hull and why it is important for our argument.

Hull's starting point is that, at least since Aristotle, most philosophers have had a naïve view of biological individuality. Philosophers often use fictitious examples and, when they do actually speak of a living thing, they generally mean an animal, even a higher vertebrate in most cases (a horse, a cat, etc.). In contrast, Hull insists on the importance of using biological examples that are both more realistic and more diverse. According to him, such examples are more interesting, more complex, and in the end more challenging than the fictitious examples and thought experiments favoured by metaphysicians (the same idea is developed in Hull 2001). Taking into account the actual diversity of the living world implies, for Hull, a suspicion towards conceptions of biological individuality based on common sense and intuitive perception. Indeed, common-sense individuation is too strongly biased by our relative size and perception abilities (Hull 1978, 1992). For example, in dealing with many plants, colonial animals, fungi, microbes, and so on, common sense individuation is of no help whatsoever. Some cases have been much discussed in the biological and in the philosophical literature, such as dandelions, aspens, social insects, ascidians, siphonophores, and biofilms (for overviews on these cases, see Pradeu 2012; Bouchard and Huneman 2013; Guay and Pradeu 2016a).

In contrast to common sense and intuitive perception, Hull seeks to offer a biologically precise criterion for the diachronic identity of biological individuals; and he finds this criterion in the idea of continuity of change. According to Hull, organisms and species belong to the same ontological category, as both must be understood as spatio-temporally localized entities. More radically, Hull's thesis is that any organism or any species is a portion of space and time. Every organism has a **(p.100)** starting point and an end, and goes through different but continuous states between these two extremes. Exactly the same is true of every species. For Hull, because living things can undergo massive and unpredictable change, retention of substance (the idea that something of X remains through time) and resemblance (the idea that X looks sufficiently like itself) are useless

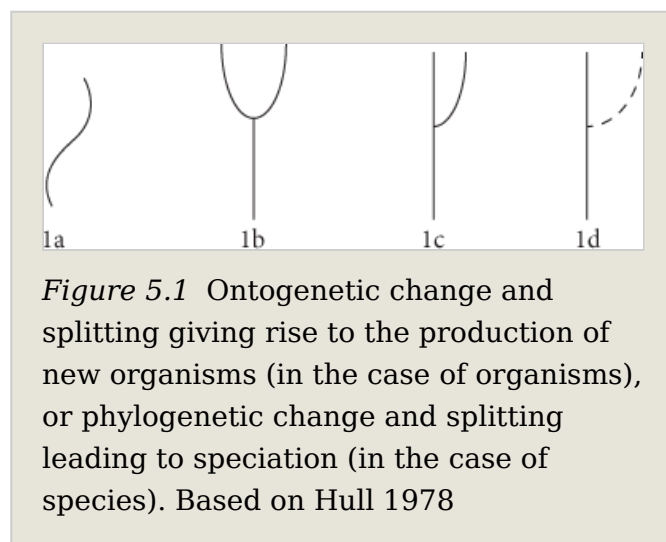
criteria for biological diachronic identity. The only satisfying criterion is continuity of change.

To describe and defend this continuity-based conception of identity, Hull explicitly endorses the notion of ‘genidentity’ in several texts and grounds it in the idea of a continuous *internal organization*:

Three traditional criteria for individuality in material bodies are retention of substance, retention of structure, and continuous existence through time (genidentity). If organisms are to count as individuals, then the first two criteria are much too restrictive. In point of fact, many organisms totally exchange their substance several times over while they retain their individuality. Others undergo massive metamorphosis as well, changing their structure markedly. If organisms are paradigm individuals, then retention of neither substance nor structure is either necessary or sufficient for continued identity in material bodies. The idea that comes closest to capturing individuality in organisms and possibly individuals as such is genidentity. As its name implies, this criterion allows for change just as long as it is sufficiently continuous. The overall organization of any entity can change but it cannot be disrupted too abruptly.

(Hull 1992: 182)

This is the very same conception of identity that underlies Hull’s (1978) fundamental diagrams; see Figures 5.1 and 5.2. These two figures offer a description of structural patterns of change in the living world that are equally applicable to organisms and species.



(p.101) Figure 5.1 illustrates structural changes associated either with *change* in a living entity or with its *splitting* into two living entities. For Hull, a new entity emerges from a given entity if and only if the internal organization of the original entity is strongly disrupted.³ This criterion—the *disruption of internal*

organization—is not always easy

to apply, and by definition the observer often faces a continuum of possible situations, but the examples given by Hull are very helpful. A living entity remains the same (case 1a) even if it undergoes a limited change, or even a radical change, provided that the continuity between these different states can be established (e.g. a caterpillar becoming a butterfly). In contrast, the phenomenon of *splitting* (case 1b) is characterized by a disruption of internal organization: one individual becomes two individuals and the initial individual disappears. Transverse fission in paramecia is an example. In other situations, an individual appears *on* another, preexisting individual, and this new individual becomes progressively autonomous (case 1c). An example is strobilization in certain forms of Scyphozoa (sometimes colloquially called “true jellyfish”). In yet other cases, a small part of an individual gains independence and becomes itself a new individual (case 1d; note that this is a part of an individual—not an individual growing on another, as in case 1c). An example is budding in Hydrozoa (Hydrozoa are Cnidaria that have both a polypoid and a medusoid stage in their life cycles—or at least most of them do). Though classifying all the diversity of real biological phenomena of change and splitting into these four cases would probably prove very difficult, what seems clear and useful is the criterion used by Hull, who asks systematically whether the overall organization of the entity under consideration is disrupted or not. (Importantly, there is transgenerational *material continuity* between a parent and its offspring, but they are characterized by two different *internal organizations*, and it is precisely this criterion that makes the difference between the continuity of one being and the continuity of several beings through reproduction; this issue is addressed in chapter 7.)

Figure 5.2 describes the *merging* of two living entities, or of their parts. To distinguish among the different possible situations, here again Hull uses the disruption of internal organization as a criterion. Two entities can fuse to become one single entity and remain one entity for a significant period of time, so the two initial individuals are lost (case 2a; fusion in amoebas does not constitute an adequate illustration of this case, while the fusion of two germ

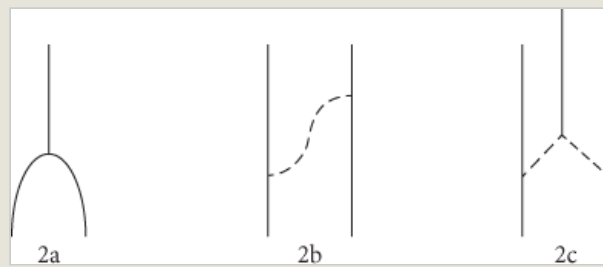


Figure 5.2 Total or partial merging between organisms, or between species. Based on Hull 1978

cells does). In other situations (case 2b), a portion of a first individual becomes a portion of a second individual, the two individuals continue their existence, but both have changed (the first has lost a part, the second has gained a part). Blood transfusion or bacterial conjugation are good examples. In still other situations, a portion of a first individual and a portion of a second individual merge to form a third (new) individual, while the two initial individuals continue their existence (case 2c). Sexual reproduction is a good example. Applied to species rather than organisms, a good example of 2b is introgression and a good example of 2c is speciation by polyploidy (a rather common event in plants, for instance).

(p.102) In conclusion, Hull endorsed the genidentity view. For him, what biologists can and must do to account for the continuously changing identity of any living thing is to follow its changes through time, keeping in mind that it remains the same only as long as its internal organization remains the same or changes progressively.

Naturally, one immediate difficulty faced by Hull's account of biological identity is to offer a precise definition of what 'internal organization' (and its disruption) means. Suggestions to move in this direction will be made in section 5; for now, I would like to show why recent biological data about symbiosis strengthen Hull's line of argument.

4. Why Cases of Symbiosis Strengthen the Genidentity View

As we have seen, Hull claims that, because living entities can change, merge, and split, it is crucial, in order to understand their diachronic individuality, to be able to actually follow them through time. But how frequent are events of merging and splitting in the living world? Though Hull mentions several important examples of fusion and splitting, symbiosis does not play an important role in his demonstration (apart from the rapid mention of the endosymbiotic event that is at the origin of some organelles). Now, research done on symbiosis in the twenty-first century shows that symbiotic events of fusion and splitting are much more frequent than had traditionally been assumed (McFall-Ngai 2002; McFall-Ngai et al. 2013; Gilbert and Epel 2015). In fact, we will see that the pervasiveness of symbiosis proves that Hull's diagrams, which at first sight might seem to concern only a limited number of biological cases, describe situations that are in fact very frequent in nature. Indeed, by taking into account symbioses, one realizes that living things commonly undergo events like a 2a (fusion) or a 2b (integration with continuation)—or, even more frequently, like an 'inverted 1c' (internalization; see Figure 5.3)—and that they can also split more often than is usually thought.

'Symbiosis' can be understood here in the very broad sense of any close and lasting interaction between two biological entities belonging to two different species. This is in accordance with the traditional definition of Anton de Bary, formulated in 1879 (see e.g. Sapp 1994). Adopting this broad definition is important here, as the **(p.103)** definition can cover cases that range from mutualism (in which the fitness of the two partners is increased by the interaction) to commensalism (a neutral interaction) and to parasitism (in which the fitness of one partner increases while the fitness of the other decreases).

Indeed, all these different cases exist among the recently documented examples of symbioses.⁴

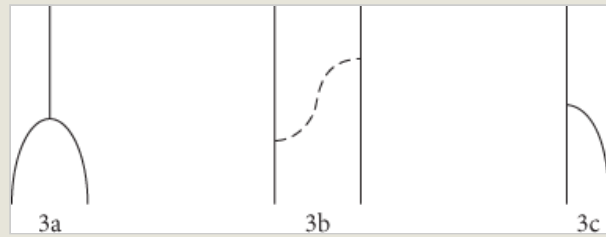


Figure 5.3 Forms of integration of external biological material, at the organism level or the species level. The first case corresponds to Hull's 2a (fusion), the second to Hull's 2b (integration with continuation), while the third case is an inversion of Hull's 1c. The third case (absent in Hull's analysis) can be called 'internalization', and is described in this chapter as an extremely frequent (though long overlooked) phenomenon in nature

Important events of symbiotic fusions occur both at the level of organisms and at the level of species. At the level of organisms, symbioses, long thought to be rather rare, are now considered almost ubiquitous (McFall-Ngai et al. 2013; Gilbert and Epel 2015). Indeed, probably all organisms are hosts of many microorganisms, very often in close and long-lasting associations. Very well documented cases include plants, hydra, cnidarians, sponges, fishes, the squid *Euprymna scolopes*, insects, mice, and humans (Bosch and McFall-Ngai 2011; Nyholm and McFall-Ngai 2014). There is often a co-construction of the host and the microbes, as illustrated by cases such as legume-rhizobia (Oldroyd 2013) or *Euprymna scolopes-Vibrio fischeri* (Nyholm and McFall-Ngai 2004) interactions. In many cases the association is beneficial to one of the partners or to both. In particular, and perhaps counterintuitively, it is frequently the case that interactions with some microbes shape and strengthen the host's immune system (Pradeu and Carosella 2006b; Round and Mazmanian 2009). Very interesting cases are those where some microbes are indispensable for the development of the host (McFall-Ngai 2002; Pradeu 2011). The notion of a *heterogeneous organism* (Pradeu 2010, 2012) captures this very general idea, that all known organisms seem to harbour huge quantities of biological entities belonging to other species and that, in many of them, those biological entities become so integrated into the host's that they can be considered *part* of it.

Which of these cases count as merging events, as described by Hull? The decision, for each, will depend, here again, on the degree of disruption of internal organization. For example, the legume–rhizobia symbiosis offers a clear case of merging, and, more precisely, of internalization (case 3c, which can also be called ‘inverted 1c’). The plant could live without the bacteria, but the recruitment of the bacteria at the root level helps the plant decisively (the rhizobia create ammonia from nitrogen in the air, which is used by the plant to create amino acids and nucleotides), and the bacteria are very significantly transformed during the process, differentiating into bacteroids. The association between the two partners eventually constitutes a unit that displays a high degree of internal organization. In contrast, the colonization of a host by a microbe (be it pathogenic, commensal, or mutualistic) that would not remain for long in the host, would not be transformed by this interaction, and would not, in turn, have a deep effect on the overall organization of the host. Consequently, it would not count as a case of merging.

Symbiotic events of merging also happen at the species level. A nice example is the obligate symbiotic association between aphids and *Buchnera* symbionts (more precisely, *Acyrtosphion pisum* and *Buchnera aphidicola*). Approximately 160–280 million years ago (Shigenobu and Wilson 2011), an aphid ancestor was infected with a free-living eubacterium, and this eubacterium became established within aphid cells. The host and the *Buchnera* endosymbiont became interdependent and **(p.104)** unable to survive without each other. The growth of *Buchnera* became integrated with that of the aphids, which acquired the endosymbionts from their mothers before birth. Speciation of host lineages was paralleled by divergence of associated endosymbiont lineages, resulting in parallel evolution of *Buchnera* and aphids (Baumann et al. 1995). Today the aphid–*Buchnera* association (almost all 4,000 extant species of aphid harbour an obligate *Buchnera* symbiont) constitutes one of the best-documented cases of obligate symbiosis, where neither of the partners can survive and reproduce without the other (Shigenobu and Wilson 2011). In such situations the physiological and reproductive integration between the host and the bacterium is so tight that it makes sense to talk about a single unit, constituted by this association.

Merging events can also happen between a virus and a host species (Pradeu 2016). For example, many parasitoid wasps have integrated a polydnavirus into their genome several million years ago. Such polydnaviruses have a beneficial effect on the parasitoid wasps: they enable them to realize their life cycle by laying their eggs into their hosts, where then their offspring grow, often killing the host progressively in the process. In fact, the wasp eggs can survive and develop only because a virus integrated into the wasp’s genome actively counters the immune defense of the host larva (Edson et al. 1981; Espagne et al. 2004; Bézier et al. 2009). Many specialists consider that the virus has been so tightly integrated into the host genome that it is no longer possible to regard the

virus and the wasp as separate entities (Roossinck 2015; on host-virus mutualisms, see also Virgin et al. 2009).

In many cases, therefore, symbiosis can give rise to new lineages, constituted by the merging of two individuals who belong to different species and subsequently reproduce as new reproductive units. The idea that symbiotic events are crucial in evolution and can even lead to the appearance of new species (i.e. symbiogenesis) is not new (Wallin 1927; Margulis and Fester 1991; Margulis and Sagan 2002), but this phenomenon has recently been illustrated by several examples, including some of those mentioned above. It seems legitimate, in these cases, to use the notions of *heterogeneous species* and *heterogeneous lineages*, on the model of the heterogeneous organism (mentioned above).⁵

What about cases of symbiotic splitting? Taking into account symbioses is likely to lead to a very dynamic view of biological individuality, because many symbiotic interactions change through time. For example, humans are hosts to billions of microbes from birth to old age, but the composition of their microbiome changes significantly through time. Immediately after birth, bacteria colonize the baby upon passage through the birth canal. The microbiota then has a complex history. There is a first period, until approximately the age of one, during which the microbiota has a rather simple composition (*Bifidobacteria* being usually highly abundant in human milk-fed infants); but this changes rapidly and a second period follows during which the microbiota becomes highly diverse (more than 1,000 species, with a clear domination of Firmicutes and Bacteroidetes), indeed unique to each individual, **(p.105)** and stabilizes (see Candela et al. 2012). This is even clearer in the many cases of parasitic symbioses where the association is transient, for example because the parasite leaves the first host in order to colonize a second, or because the host eliminates the parasite via its immune system. Importantly, even a transient interaction between two living things can lead to very significant changes in their respective internal organizations; hence there is no direct link between the robustness and durability of a symbiotic interaction and the extent to which it impacts the internal organization of the partners.

In conclusion, the double phenomena of merging and splitting happen successively in many instances of symbiotic interactions, probably reflecting complex physiological, ecological, and evolutionary exchanges between the two partners. From all the examples examined here it can be concluded that symbiotic events of merging and splitting are extremely frequent in nature, which makes Hull's analyses and diagrams even more useful than they might have seemed when the paper was published in 1978. The ubiquity of symbiosis decisively strengthens Hull's point that genidentity offers the best way to capture the individuality of biological entities through time. Indeed, it seems clear that using an essentialist account based on genetic homogeneity or an account based on similarity would be entirely inadequate. Only the idea of a

continuous change enables us to follow in detail what contributes to the construction of a given living thing; and, here again, the criterion of the degree of disruption of internal organization seems a suitable guide for understanding biological diachronic individuality.

5. How Genidentity Helps Define What an Organism Is

The genidentity view seems very useful if you want to understand biological identity. Nevertheless, it faces a series of important challenges, and in fact it is likely that any process-based view of the living world will also have to meet those same challenges. The basic idea at the heart of the genidentity view is to follow a biological process through time. But how does one choose adequately which processes to follow? And how does one follow them in practice?

In my view, these questions are very important, and the answer to them will depend on who asks them and for what purpose. This is where it becomes clear that one of the main interests of the genidentity view is that it places the emphasis on an epistemological, rather than ontological, approach to processes. I do not think that it is possible to prove the ontological claim that the biological world is ‘really’ made of processes; and, if this is indeed the claim that process philosophers of biology want to make, then they must give an argument for it. However, it is possible to give good arguments in favour of the adoption of an *epistemological* process view and to show that, from this epistemological point of view, the decision to interpret the living world in terms of processes (rather than of already individualized things) makes an important difference to scientific work, because it leads to different perspectives and potentially to different experimental programs.

Biologists will decide which process or processes to follow according to their working questions. For example, one may ask how reproduction is achieved in a given species, or how metabolism is maintained in a cell, or how DNA transcription into RNA occurs. These different processes happen at different levels and involve **(p.106)** many different entities. What is crucial is to decide which process will be followed and which criteria can help us consider that we are dealing with *one* continuous process. This is exactly the question raised by Hull. However, he only did so at a very general level, by talking about the maintenance or disruption of the ‘internal organization’ of an organism or a species. In my view, Hull was on the right track, but the notion of internal organization needs to be defined much more precisely in each specific biological context.

Here I propose to define in precise terms what internal organization is and what its maintenance or disruption entails at the level of an organism (a similar reflection can be produced, and indeed has been produced, at the species level; see e.g. Haber 2016). More specifically, I suggest that immunity helps to offer a more precise conception of genidentity applied to organisms (see also Pradeu

2012: 248–9). In all species (animals, plants, and also prokaryotes), the immune system plays a decisive role in the delineation of the boundaries of the organism because it constitutes a principle of inclusion–exclusion: the immune system is responsible for the rejection or tolerance of any given entity, which means that the immune system determines which entities will be part of the organism and which won't. Importantly, this discrimination mechanism is not based on the traditional 'self' versus 'nonself' distinction, according to which an organism would immunologically reject all foreign entities and would immunologically accept only constituents originating from itself. Actually, every organism harbours huge quantities of genetically foreign entities and triggers, everyday, effector immune responses that target endogenous constituents.⁶

An immunological approach leads to a definition of the organism based on the distinction between two different levels: that of biochemical interactions and that of immune interactions, both necessary to delineate the organism. From that point of view, an organism can be defined as follows:

Definition: Organism = a functionally integrated whole, made up of heterogeneous constituents that are locally interconnected by strong biochemical interactions, and controlled by systemic immune interactions.

(Pradeu 2010: 258; see also Pradeu 2012: 243–6)

This definition means that, when entities interact through regular biochemical interactions and are actively tolerated by the continuous action of an immune system, they are part of a higher-level entity, which should be called an 'organism'. Of course, this definition places a strong emphasis on the role of the immune system in the definition of the organism, but it does so on the basis of the argument that the immune system plays a decisive role in delineating the boundaries of any organism. **(p.107)** This definition rests on the recognition of two layers of interactions (biochemical interactions and immune interactions), which can be seen as a way to make more precise process approaches to the living world. What is suggested here is that there can exist some coalescences of interrelated processes, such as the organism itself, and that following such a coalescence of processes through time might rest on the identification of higher-level processes that control lower-level processes. Thus, an organism can be understood as a local concentration of intertwined biochemical processes under the control of higher-level immunological processes. More generally, it is crucial for a process philosophy to be able to identify not only processes in general, but also 'bundles' of processes (in this case, the organism), as well as to ask how the unity and cohesiveness of these bundles through time is achieved.

The crucial point is that, with the definition of the organism given above, we do not start with a preexisting delineation of the organism and subsequently say that the immune system controls this preexisting delineation. On the contrary,

we start with biochemical and immunological interactions and, from the observation of how these interactions work, we deduce what the boundaries of the organism are. In this view, therefore, what comes first is interactions, and the organism ‘supervenes’ on those interactions. To understand this point fully, it is useful to move away from familiar mammalian examples and to examine more complex cases of biological individuality, in particular colonial organisms. A particularly illuminating case is that of *Botryllus schlosseri* (see Figure 5.4). *Botryllus*, born as a chordate tadpole larva, metamorphs into a sessile, invertebrate juvenile, after which it begins a lifelong, recurring budding process that results in a colony of expanding, asexually derived individuals. The colony is made of genetically identical individuals (zooids) united by a common extracorporeal vasculature. The zooids and the vasculature are embedded in a cellulose-based tunic, and the extracorporeal vasculature ramifies throughout this matrix and at the periphery terminates in finger-shaped projections (**p.108**) called ‘ampullae’. When two colonies meet, an allorecognition reaction occurs, which leads either to vascular fusion or to rejection. Allorecognition is controlled by a single, highly polymorphic locus (the Fu/HC), and the rejection is realized through the triggering of an immune response (Scofield et al. 1982; Nyholm et al. 2006; McKittrick and De Tomaso 2010; McKittrick et al. 2011).

In the case of *Botryllus schlosseri*, as in many other cases of colonial organisms, it is very difficult to say whether what should count as an individual organism is each zooid or the colony as a whole—or perhaps both. In fact, common sense cannot decide between those options. According to the view I have presented, it is the observation of how immune responses occur that tells us what should count as an individual organism. As illustrated in Figure 5.4, immunologically controlled fusion or rejection in *Botryllus schlosseri* occurs at the level of the whole colony, so it is the colony that must count as an individual organism, in accordance with the definition presented above.

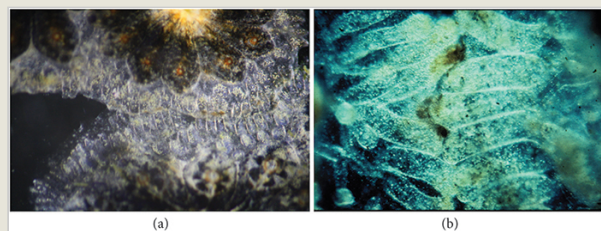


Figure 5.4 Rejection between two colonies of *Botryllus schlosseri*. Panel A shows an example of rejection between two colonies of *Botryllus schlosseri* at the level of the colonies themselves; the brown zones at the point of contact between the ampullae (the finger-like structures at the center of the image) show the starting point of the reaction of rejection. Panel B shows an example of rejection between two colonies of *Botryllus schlosseri* at the much more precise level of the ampullae. Photographs courtesy of Tony De Tomaso, University of California, Santa Barbara

The example of *Botryllus* illustrates one very important advantage of the approach presented here: we start with an indistinct, non-individualized reality, about which common sense and perception have little to say, and it is the decision to follow immunological processes that leads us to conclude, in a scientifically precise way, what counts as an individual entity and what its boundaries are.

6. Genidentity as a Way to Shed Light on the Notion of Biological Process: 'Priority' as the Central Question

I believe that the multilayered genidentity approach developed here can be useful to the current trend towards a processual biology (Dupré 2012; Baptiste and Dupré 2013; Dupré 2014).

First, it emphasizes the importance of an epistemological approach to processes. Though process proponents often think in ontological terms (this is very explicit, e.g., in Baptiste and Dupré 2013), I do not think that they have hitherto offered compelling arguments for this view. With an epistemological approach, the aim is, more modestly, to show that a process view can make a difference to the actual work of biologists, as a question framed in terms of what processes biologists are interested in and how they should follow those processes through time. (A nice example is the argument offered in Dupré and Guttinger 2016.)

Second, this approach clarifies the idea, often expressed by process philosophers, that we live in a world of change. According to the genidentity view, what is interesting is to study how things change, at which pace, and when they start and cease to exist. Within such a perspective change is pervasive, and what is derivative is not change but the apparent absence of change, that is, regularities and sameness, and therefore even apparent stability must be explained in terms of constantly changing processes.

Third and perhaps most importantly, the genidentity view shows that the crucial claim of a process approach is in fact a claim about *priority*. Indeed, a process approach does not emphasize the importance of change itself (substantialist philosophers perfectly admit that every substance changes constantly) so much as it asks **(p.109)** whether the 'thing' or the 'process' comes first; and it answers that things come second, after processes, or derive from them. In other words, the important move of a processual perspective is not, in my view, to go from individuals to processes (by saying, for instance, that individuals are in fact processes), but to go from processes to individuals (as scientists or philosophers, we *decide* to follow some scientifically meaningful processes, and individuals supervene on these processes). This is exactly what I have tried to illustrate in the case of immunology: in this case, it is scientifically identified processes that tell us where the individual lies and what its boundaries are, and not vice versa. We cannot start with the 'thing' *Botryllus schlosseri*, because we just don't know where a *Botryllus schlosseri* starts and ends; the only solution is to start with

processes—namely, as I suggested, biochemical and immune processes—and it is the realization of these processes that tells us where the individual is and what its boundaries are. The example of *Botryllus schlosseri* constitutes in fact a good model for thinking more generally about the individuation of living entities in other species: we cannot assume that we start by identifying an entity and then ask what processes occur in that entity, because we cannot trust our intuitions and perceptions with identifying living entities. So in each case—even in seemingly ‘intuitive’ cases, such as that of humans—it is necessary to start with scientifically well-defined processes—here, immunological processes; and it is those processes that tell us where the individual is and what its boundaries are.

7. Conclusions

The genidentity view seems particularly well suited if we wish to understand the diachronic identity of living things. Given the frequency of events such as extensive structural changes (e.g. through metamorphosis), splitting, and fusion, conceptions of biological identity based on similarity or substance are highly problematic. Hull (1978) perceived this point very well, but we have seen that recent work on symbiosis shows that his view is probably even more compelling today than it was in the 1970s. So the first lesson of the present chapter is that the genidentity view is a very satisfying way to conceive of biological identity.

The second lesson of this chapter is that the genidentity view sheds an important light on process views in biology and philosophy of biology (Dupré 2012; Baptiste and Dupré 2013; Dupré 2014). Indeed, it emphasizes the importance of an epistemological and multilayered approach to processes and suggests that the main claim of a process view is one of priority, namely that processes come first and make it possible to define things, and not the other way around.

Even though the notion of genidentity has not been very popular among philosophers of science, there is still perhaps much that we can learn from it.

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Notes:

⁽¹⁾ On processes in general, and on the opposition between processes and substances, see Seibt 2013.

⁽²⁾ On the different versions of the genidentity concept for Reichenbach, see Padovani (2013) and Guay and Pradeu (2016b).

⁽³⁾ ‘The relevant consideration is how much of the parent organism is lost and its internal organization disrupted’ (Hull 1978: 345).

⁽⁴⁾ For complementary discussions of symbiosis, see chapters 1, 9, 10, and 15.

⁽⁵⁾ On this issue, see also Dupré and O’Malley 2009 and Bouchard 2010. More generally, on the integration of ‘foreign’ genetic material, in particular through horizontal gene transfer, see Doolittle and Baptiste 2007 and Baptiste et al. 2012.

⁽⁶⁾ Much more specifically, the discontinuity theory of immunity that I have constructed with immunologists (Pradeu and Carosella 2006a; Pradeu et al. 2013) reflects directly a genidentity perspective. Indeed, a crucial claim of the most elaborate versions of the genidentity view, including Reichenbach’s (see Guay and Pradeu 2016b), is that what matters to understanding diachronic identity is not the *degree* of change (i.e. how much it changes) but the *rate* of change (i.e. how fast it changes). The discontinuity theory of immunity is based on the principle that the immune system responds to sudden modifications of the antigenic motifs with which it interacts (for further details, see Pradeu 2012).

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