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Responding to *Pfiesteria piscicida* (the Fish Killer): Phantomatic Ontologies, Indeterminacy, and Responsibility in Toxic Microbiology

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**ABSTRACT** Based on an analysis of an ongoing scientific–political controversy over the toxicity of a fish-killing microorganism, this paper explores the relationship between responsibility and nonhuman contributions to agency in experimental practices. Research into the insidious effects of the dinoflagellates *Pfiesteria piscicida* (the fish killer) that thrive in waters over-enriched with nutrients, has received considerable attention by both the media and government agencies concerned with public and environmental health. After nearly two decades of research, the question of whether *Pfiesteria* can be regarded the ‘causative agent’ of massive fish kills in the estuaries of the US mid-Atlantic could not be scientifically settled. In contrast to policymakers, who attribute the absence of a scientific consensus to gaps in scientific knowledge and uncertainties regarding the identity and behavior of the potentially toxic dinoflagellates, I propose that an inseparable entanglement of *Pfiesteria*’s identities and their toxic activities challenges conventional notions of causality that seek to establish a connection between independent events in linear time. Building on Karen Barad’s framework of agential realism, I argue for a move from epistemological uncertainties to ontological indeterminacies that follow from *Pfiesteria*’s contributions to agency, as the condition for responsible and objective science. In tracking discrepant experimental enactments of *Pfiesteria* that have been mobilized as evidence for and against their toxicity, I investigate how criteria for what counts as evidence get built into the experimental apparatuses and suggest that the joint possibilities of causality and responsibility vary with the temporalities of the objects enacted. This discussion seeks to highlight a thorough entanglement of epistemic/ontological concerns with the ecological/political relevance of particular experiments. Finally, I introduce a new kind of scientific object that – borrowing from Derrida – I call phantomatic. Phantoms don’t emerge as such, but appear as traces and are associated with specific matters of concern.

**Keywords** causality, intra-activities, indeterminacy, iterability, material agency, phantomatic ontologies, responsibility, temporality, toxic dinoflagellates

## Responding to *Pfiesteria piscicida* (the Fish Killer):

### Phantomatic Ontologies, Indeterminacy, and Responsibility in Toxic Microbiology

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Invisible to both scientist and fish is the creature itself, a bizarre one-celled predator that can appear to transform itself from animal to plant

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and back again. Called *Pfiesteria piscicida*, this killer dinoflagellate captured the attention of scientists worldwide when it emerged 6 years ago (1991) from the murk of North Carolina's coastal estuaries, the phantom suspect in a string of mass killings that destroyed more than a billion fish. (Warrick, 1997)

What might read like a passage from a murder mystery or science fiction novel is the beginning of a report on years of conflict-ridden research into the toxicity of a single-celled microorganism: the dinoflagellate *Pfiesteria piscicida*. Joby Warrick, staff writer of the *Washington Post*, was not alone in finding inspiration in sci-fi literature to describe the scientific findings about this toxic dinoflagellate. While tremendously important to the health of our oceans, dinoflagellates are perhaps best known as contributors to so-called 'harmful algal blooms' (HABs), sometimes referred to as 'red tides'. Most of them, however, are not toxic<sup>1</sup> and no other dinos<sup>2</sup> have been observed to prey on fish. Media reports referring to *Pfiesteria piscicida* as the 'cell from hell', 'killer algae', or 'microscopic monster' proliferated in the late 1990s, when massive fish kills occurred in the estuaries of North Carolina and Maryland (Greer, 1993; Macilwain, 1997).

Until *Pfiesteria* made their first public appearance, most of the fish kills that had increasingly plagued the two largest estuaries of the US were ascribed to unknown causes, or alternatively to 'naturally' occurring conditions of low dissolved oxygen levels (Burkholder, 1998). The term 'phantom dinoflagellate' was introduced into the scientific literature by JoAnn Burkholder and colleagues from the Center for Applied Aquatic Ecology at North Carolina State University, before the dinos were taxonomically baptized *Pfiesteria piscicida* according to their lethal actions: 'piscicida' literally means 'fish killer'. In 1992, Burkholder and colleagues published a *Letter to Nature* with the title 'New "phantom" dinoflagellate is the causative agent of major estuarine fish kills'. In this first of a long series of publications Burkholder et al. (1992) not only announced the 'discovery' of a 'new' toxic microorganism, but also suggested a possible 'cause' for the increasing number of fish kills in North Carolina's estuaries. Linking *Pfiesteria* blooms to water pollutants, predominantly from the flushing of untreated hog waste into North Carolina's estuaries, on one hand, and human health risks<sup>3</sup> associated with the toxic outbreaks on the other, Burkholder et al.'s publications initiated an enduring controversy over the toxicity of *Pfiesteria piscicida*. Since the main nutrient polluters of North Carolina's estuaries also comprise the state's largest industry, the stakes were high in providing evidence for or against *Pfiesteria*'s toxicity. While the declining seafood and tourist industries quickly established *Pfiesteria* as 'a major ecological problem to the economies of several eastern seaboard states' (Gawley & Baden, 1998), the hog and chicken farming industries that line the shores of North Carolina and Maryland's estuaries faced possible regulations concerning their animal waste treatment. Nearly two decades of research, however, could neither decidedly establish nor successfully refute *Pfiesteria* as the 'causative agent' of major estuarine fish kills. The fact that the controversy is still going on and

little has been settled either scientifically or politically is crucial for my approach and arguments to follow.

Policymakers and governmental agencies charged with the review of *Pfiesteria* science attribute the absence of consensus to gaps in scientific knowledge and uncertainties regarding the identity and behavior of the potentially toxic dinoflagellates. How uncertainties in scientific knowledges are produced, manipulated, exploited, or contested in order to influence policy decisions has been widely discussed in Science Studies (Star, 1985; Jasanoff, 1987; Shackley & Wynne, 1996; Wynne, 1996; Lynch, 1998). While indebted to these studies, this paper takes a different approach. Shifting the focus from uncertainties in human knowledges to the materialities of scientific experimentation, I explore how criteria for what counts as ecologically and/or politically relevant get built into scientific experiments. My analysis of the controversy focuses on a few selected experiments that have received considerable media attention as evidence for and against the assertion of *Pfiesteria*'s toxicity. Building on feminist philosopher Karen Barad's (2007) framework of 'agential realism' and Jacques Derrida's spectral logic of time, I offer a reading of these experiments, paying particular attention to how the *temporalization* of the scientific object enables and disables responsibility in scientific practices. Taking seriously that science is a material practice to which not only humans contribute, I propose a notion of responsibility that is attentive to multiple 'histories' and 'agencies' and underpins objectivity in science rather than interfering with it. Rather than considering responsibility as an attribute of individual scientists or as a 'social' responsibility that merely concerns the subsequent uses of scientific results, I develop a notion of responsibility *in* scientific practices as a consequence of fundamental indeterminacies in *Pfiesteria*'s beings and doings. Responsibility in my account entails not a particular response, but an enabling of responsiveness within experimental relations. I argue that responsible experimentation with the fish killers hinges on maintaining *Pfiesteria*'s ability to respond to their experimental probings, that is, their response-ability.

In addition, I suggest that the notion of 'uncertainty' in scientific knowledges is inadequate to describe the scientific-political controversies over identities and actions of *Pfiesteria*. The very idea of an epistemological uncertainty presupposes an *a priori* separation of the epistemological question of 'how we know' from the ontological status of 'what we know', where only the former, that is, our knowledge is allowed to vary.<sup>4</sup> As Bruno Latour (2002: 253) puts it most succinctly, 'the epistemological question limits historicity to humans and artifacts and bans it for nonhumans'. I argue for a move from epistemological uncertainties to ontological indeterminacies that follow from *Pfiesteria*'s contributions to material agency as a condition for responsible and objective science.<sup>5</sup> Discrepant enactments of *Pfiesteria* suggest that how we get to know a species experimentally cannot be separated from the ontological question of what/who they are. Since the fish killers only 'are' in relation to fish, the question is ill-posed if it asks 'who toxic *Pfiesteria* are' before 'what they do' is established.

What Burkholder et al. term 'phantom-like' behavior describes the spontaneous metamorphoses of a usually benign dinoflagellate into a toxic

‘ambush predator’. Under specific environmental conditions, the dinos emerge from sediments, collectively attack fish and disappear from the water column as soon as most of their fish prey is dead. Following Burkholder et al.’s experimental descriptions in some detail, I suggest that the term ‘phantom’ is not just a nickname for the hide-and-seek playing microscopic ambush–predator, but perhaps provides the only way for dinos such as *Pfiesteria* ‘to be’ in scientific nature-culture. In other words, the phantomatic character of the toxic dinos is not only a suitable description of *Pfiesteria*’s ephemeral appearances and disappearances, but also most appropriately describes the very nature of their species beings. I hence call their ontology ‘phantomatic’.

A ‘phantomatic ontology’ is closely allied with Derrida’s (1994) notion of hauntology, which describes the paradoxical existence of a specter as neither being nor non-being, neither present nor absent, neither of the ‘past’ nor of the ‘future’, but which affirms an indeterminate relationship between being and becoming and between ‘past’ and ‘future’. In holding on to the notion of ontology, I try to emphasize the necessity of determinations in scientific experiments. Through a more explicit incorporating of political and ethical concerns into ontological determinations in experimental practices, the notion of a ‘phantomatic ontology’ is an attempt to provide with *Pfiesteria* an alternative to multiple ontologies (Mol, 2002) or uncertain ontologies (Jasanoff, 2005).

With the rise of the study of performances in scientific practices, recently reviewed by Rebecca Herzig (2004), scientific objects have become increasingly lively and active. Nowadays, ‘scientific objects have a history’ (Daston, 2002: 13). Their ‘histories’, however, are often tracked as trajectories that presuppose an already established temporal order. Ironically, along with the displacement of human subjects as the only locus of agency and historicity comes an almost exclusionary focus on the productive forces of scientific practices.<sup>6</sup> Latour (1999, 2002), for example, grants historicity to microorganisms; their history, however, appears as always already a joint laboratory history of humans and nonhumans.<sup>7</sup> What conceptions of temporality and causality are presupposed when the production of scientific objects accounts for effects rather than causes of scientific activities?<sup>8</sup> Is there another way to account for the historicity of scientific objects, other than through their coming into being and passing away (Daston, 2002: 13)? In elaborating on the phantomatic character of the toxic dinos, this paper begins to explore what it could mean for responsibility in experimentation that microorganisms have ‘a history, and not merely a social one’, as Judith Butler puts it (1993: 5).

Expanding upon the taxonomy of possible kinds of scientific objects recently provided by John Law and Vicky Singleton (2005), I propose the phantom as a new kind of scientific object. The phantom is importantly distinct from all those kinds of objects that suggest a specific topology as either fixed, such as the atemporal Euclidean volume, or variable *in* time, such as ‘fluid objects’ that may reshape their configurations in different contexts. Phantoms rather challenge our conception of time as homogenous flow of

self-identical moments, in which a cause by definition precedes its effect. Phantoms are not simply produced, nor are they purely productive, as Law and Singleton's (2005: 347) notion of a 'fire object' – a generator of 'links between presences and absences' – and Hans-Jörg Rheinberger's (1997) 'epistemic things' suggest.<sup>9</sup> Phantomatic movements are shaped by *différance*, where 'the ending *-ance* remains undecided *between* the active and the passive', not just moving but also moved, neither passion nor action, but both (Derrida, 1982: 9, emphasis in original). Phantoms do not emerge 'as such'; they appear as traces and are associated with specific matters of concern. Importantly, a phantom is not an empty signifier, whose meaning is simply deferred until the controversy may become settled. Phantoms are 'agentially real'; they contribute to their own materialization and make demands on us to be accounted for. Responsibility in scientific practices hinges on *how* their 'agencies' are taken into account.

While what I offer here is a study of 'science-in-the-making' (Latour, 1987) in a very literal sense, I am not claiming to follow scientific practices in 'real time', as if such a thing would be possible. Indeed, dino science demonstrates that 'real time' is always already delayed.<sup>10</sup> As Rheinberger puts it, 'a story of what, then, really happened ... presupposes the existence of an undistorted past "out there" that, from a detached present "in here", can in principle be grasped by means of an analysis whose means are supposed not to have been altered by what is going to be synthesized' (Rheinberger, 1999 [1994]: 417–18). At issue in my dino story is precisely the question of how the means of science affect that which it studies. My study is, however, not a 'historical' study from a position of 'reflected anachronicity' (Rheinberger, 1997: 33), since such an approach 'requires the existence of a product ... for assessing the condition of its production' (p. 177). *Pfiesteria* have not achieved a stable identity; their meaning as a species and their toxic relationalities to fish are still at stake.

While risky, the advantage of beginning 'in the middle of things' is that it enables questions not easily accessible from a historical distance or security of knowledge that would enable the pronouncement of a winner of the scientific power-knowledge game and the coming-into-being of an autonomous entity or a product at the end of a research trajectory (Latour, 1999). The absence of a 'product' describes an indeterminate situation that requires a response, that is, taking responsibility for specific relations enacted.

## The Stakes of the Controversy

While journalists contributed their share to the dramatization of the *Pfiesteria* issue, often pitching environmental concerns against agricultural interests, the confrontations among scientists have been no less dramatic. Scientists have accused each other of biases, poor experimental practices, inexperience, and extrapolations beyond their data. Letters to the editor disputing the narratives of previous publications have been as common in newspapers as in scientific journals (Burkholder & Glasgow, 2002; Litaker et al., 2002b;



Drgon et al., 2005; Gordon et al., 2005). While some scientists have articulated strong opinions regarding the management practice of animal waste treatment (Burkholder, 1998), the controversy can hardly be reduced to competing interests regarding environmental regulations. Scientific publications that affirm (Burkholder et al., 2005; Moeller et al., 2007) and contest (Park et al., 2007) *Pfiesteria*'s toxicity continue to alternate. What are the stakes in one of the 'ugliest disputes in environmental science', as one commentator characterized it (Blankenship, 2002)?

During a 1998 Sea Grant briefing, the Director for Research and Advisory Services at the Virginia Institute of Marine Science states for example:

For *Pfiesteria*-related issues the process of science is in the early stages and, although much good research has been conducted, there is a high degree of uncertainty surrounding many issues. Opposing views by scientists are confusing to the public and to policy-makers, but they are the processes of science at work. (Burrison, 1998)

For Burrison, the problem seems to be that the slow-moving process of science cannot keep up with the public policy demands for timely decisions. Implicit in this statement is an assumption that further research would reduce uncertainties and scientists would eventually come to a consensus regarding 'who *Pfiesteria* are', their toxic impact on fish, and associated human health effects. Uncertainties here assume the possibility of certainties as horizon or *telos*, and therefore the possibility of their removal. A decade and several million dollars of federal research funding later,<sup>11</sup> though, we are still faced with what an editor of *Science Magazine* has called 'The *Pfiesteria* Conundrum: More Study, Less Certainty' (Kaiser, 2004).

While the majority of dino scientists and public officials involved have accepted that *Pfiesteria* play an active role in fish kills and also that their increased appearances can be correlated to excessive nutrient loadings,<sup>12</sup> major disagreements remain about the proper identification of *Pfiesteria* and the particular pathways of their toxic effects. Since *Pfiesteria*'s toxicity is highly ephemeral, one of the key 'missing links' appears to be the relation between the 'presence of *Pfiesteria*' and 'actively toxic *Pfiesteria*'.

In 2001, the Centers for Disease Control and Prevention (CDC) charged a multidisciplinary panel with the evaluation of the current state of *Pfiesteria* research. Assuming the possibility of a causal chain from nutrient pollution to the proliferation of *Pfiesteria* to fish deaths and human health effects, the panel recognized 'gaps in scientific understanding with attendant uncertainties for decision makers' concluding that 'sufficient certainty is needed on each of these points' in order 'to provide a basis for protection of the environment and human health' (Samet et al., 2001). The reader of Samet et al.'s summary report is left with no clear idea of what 'sufficient certainty' in establishing this link could possibly mean. And who will judge?<sup>13</sup>

Part of what drives the controversy is that various research teams disagree not about whether *Pfiesteria* can kill fish, but rather about what experimental evidence would establish or refute that the species *Pfiesteria piscicida*

is the ‘causative agent’ of major estuarine fish kills. At stake for the scientists are simultaneously the meaning of ‘causality’ and what counts as ‘good scientific practice’. Both became closely linked to what counts as evidence needed to advance environmental policies.

### *Pfiesteria*’s Entangled Life Histories

‘Unlike most species that are considered to be “harmful algae”, *Pfiesteria* is not an alga according to the classical definition (primitive plant-like organisms)’ (Glibert & Burkholder, 2006). *Pfiesteria* are neither plant nor animal, but can act as both. *Pfiesteria* prey encompasses almost everything available in the water column, ranging from bacteria to fish tissue. Abrupt changes in available nutrition can trigger spontaneous transformations, not only of particular life stages, but also in the dinos’ entire mode of reproduction.

*Pfiesteria* spend most of their life as dormant cysts in sediments of the brackish waters of the mid-Atlantic estuaries. Under certain environmental conditions, the dinos, apparently attracted by a large number of fish, emerge from the sediments and metamorphize into free-swimming zoospores. ‘The toxic zoospores gather together, alter their random swimming pattern into directed movement, doubling their swimming speed in the process, and commence predatory behavior upon the targeted fish’ (Samet et al., 2001: 641). The fish might first be immobilized with the help of one or more neurotoxins before the zoospores begin to consume their cell content. During the killing period, the dinos rapidly reproduce both sexually and asexually. Upon fish death *Pfiesteria* metamorphize into a variety of different shapes. Toxic zoospores may transform into amoebae and sink to the bottom sediments, where they transform again and hide away as motionless, dormant and benign cysts.

According to Burkholder & Glasgow (1997), *Pfiesteria* have an extraordinarily complex ‘life cycle’ with at least 24 distinct life stages occurring in three life forms: flagellated, amoeboid, and encysted (see Fig. 1).

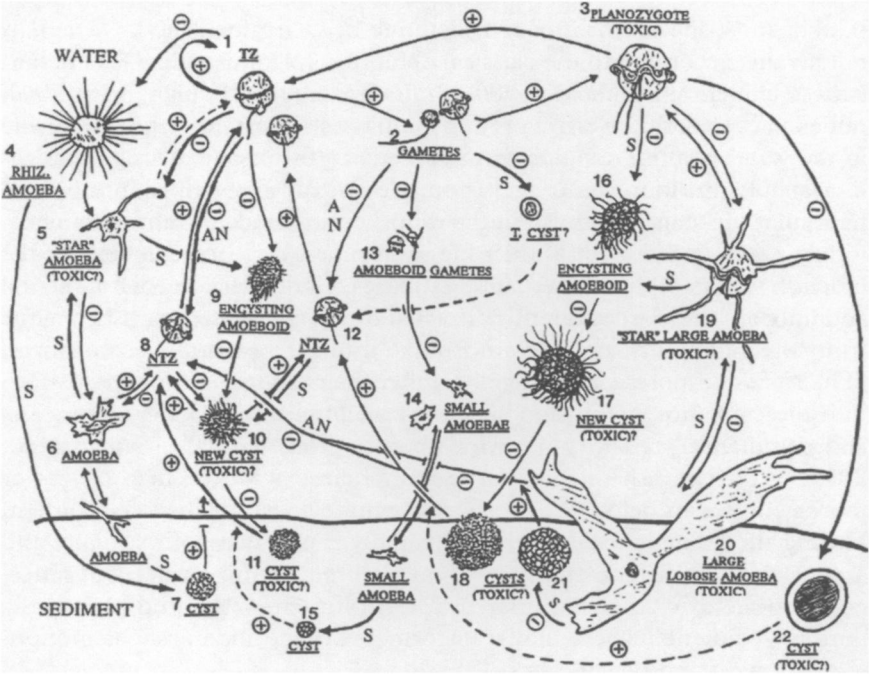
A closer look at the ‘life cycle’ proposed by Burkholder et al. suggests that it is neither a cycle nor a static web or network, nor anything that could be easily translated into a program – an algorithm that runs in linear time. This compilation of multiple experimental findings depicts a superposition of various, partially overlapping temporal and spatial scales that cannot be easily disentangled. Which of the morphs actually belongs to the fish killer is part of the ongoing dispute. In addition to a multidimensional environmental space (different temperature, salinity, organic and inorganic nutrients), *Pfiesteria* inhabit multiple temporalities in this picture. Is there any way to tell where *Pfiesteria* end and their environment begins? Can the ‘environmental’ conditions, indicated by letters and plus and minus signs, be translated into a well-defined spatially bounded ecological niche?

Toxic morphs are neither a subset nor just a temporal performance of the species *Pfiesteria piscicida* under fixed environmental conditions. Rather, this ‘life-history’ simultaneously depicts how one morph responds to various environmental conditions and how changed environmental conditions (for



FIGURE 1

Schematic of the complex life cycle of *P. piscicida* with (+) and without (–) live finfish. Other environmental controls are indicated by: A, presence of flagellated algal prey; N, nutrient enrichment (for example, organic or inorganic nitrogen and phosphorus); S, environmental stress such as shift in salinity, temperature, or physical disturbance. NTZ, nontoxic zoospore. Adapted from Burkholder & Glasgow (1997: 1053) with permission from the American Society of Limnology and Oceanography, Inc.



example, the presence of fish) modify the mode of reproduction and with it the possible kinds of morphs. This is not a mutual determination between organisms and a selective environment. There is no way to tell which morphs are ‘naturally’ part of *Pfiesteria* and which are environmentally induced transformations. Ecological changes (extended in space) that capture moment-to-moment interactions and developmental changes that extend in time are intimately linked. Productive or eco-logical/nomical and reproductive activities cannot be disassociated. The ‘how of making-more’ depends on what the dinos have been eating. Thus, ‘who *Pfiesteria* are’ is not only context- but also history-dependent.

Rather than an ‘organism-niche system’ that is moving through time (Oyama, 1985: 23), *Pfiesteria* might be better described in Rheinberger’s (1997: 227) terms, as ‘an ecohistorical nexus in an environment of potential traces’. Much, however, hinges on how the joining of the ecological and historical is captured. *Pfiesteria*’s life histories cannot be summarized as ‘an ensemble of changing interactions’ (Rheinberger, 1997: 227) – at least not as long as the changes are figured in a temporal framework external to happenings and entities are assumed to pre-exist their actions.

Context-dependent development is, according to biologist Scott Gilbert, a widespread and well-established biological phenomenon. The point I am trying to make here, however, exceeds the assertion of ‘phenotypic plasticity, the ability of an organism to respond to environmental conditions by altering its development’ (Gilbert, 2002). *Pfiesteria*’s life histories do not describe a definable organism that would pre-exist an environment, await its changes to which it can then respond. Rather, the very distinction between internal or innate characteristics and externally or environmentally induced behaviors implodes in *Pfiesteria*’s life-histories. Boundaries between organism and environment do not simply become blurred, but rather the entire process of boundary construction has to be reconfigured in order to account for the entanglements within *Pfiesteria*’s life-histories.

Barad’s notion of ‘intra-activity’ provides the key to such a reconfiguration. In contrast to interactions that suggest connections between independent entities, intra-actions draw attention to the inseparability of individual (human or nonhuman) agencies, conventionally called ‘subjects’ and ‘objects’, ‘bodies’ and ‘environment’ *prior* to experimental enactments. Independent of specific material meaning-making apparatuses toxic *Pfiesteria* remain indeterminate. ‘Bodies do not simply take their place in the world. They are not simply situated in, or located in, particular environments. Rather “environments” and “bodies” are intra-actively co-constituted’ (Barad, 2007: 170).

In addition to an inseparability of ‘organism’ and ‘environment’, spatial (synchronic) and temporal (diachronic) changes in *Pfiesteria*’s life-histories are thoroughly intertwined. There is no moment in time in which *Pfiesteria* could be captured in their entirety. Thus, part of the conundrum that drives the controversy, I suggest, is that the questions ‘who *Pfiesteria piscicida* are’ and ‘what toxic *Pfiesteria* do’ are inseparably entangled. *Pfiesteria*’s beings and doings are complementary in the Bohrian sense, that is, mutually exclusive and simultaneously necessary to assess *Pfiesteria* as fish killers.<sup>14</sup> In other words, the entanglement of *Pfiesteria*’s beings and doings attest to an inherent indeterminacy. Unlike epistemological uncertainties that refer to ‘gaps’ in or incompleteness of human knowledges and allegedly inhibit environmental decision-makings, this indeterminacy is an ontological notion.<sup>15</sup> It is not due to the limitation of ‘our’ knowledge, but concerns the spatiotemporal inseparability of ‘intra-acting components’ within *Pfiesteria*’s life histories. The indeterminacy between *Pfiesteria*’s beings and doings not only affects the ‘what’ of their ‘being now’, but extends across spaces and times. It is not only that their ontology is indeterminate; rather, ontology itself is put into question and hence becomes *phantomatic*.

In contrast to a lack of certainty in human knowledges that presumes an *a priori* distinction between knowledges that must change in time and an object of inquiry that, without history or agency, has no means of varying, this ontological indeterminacy affirms *Pfiesteria*’s contributions to their own materializations. Such an indeterminacy can be ignored but it cannot be removed; it is due to *Pfiesteria*’s material agency, not only to react to an environment, but also to co-produce and transform ‘themselves’ in

relation to ‘their’ environment. What I call material agency<sup>16</sup> in dino science draws from Barad’s account of agency, as ‘an enactment of iterative changes to particular practices ... through the dynamics of intra-activity’ (Barad, 2007: 178). Material agency is not a property of a preexisting thing, nor an effect of human-constructed laboratory experiments in always already unified time, but needs to be taken into account ‘before’ certain dino features materialize.

Emphasizing the joint forces of ‘nature’ and ‘society’ in the materialization of bodies, Barad develops her performative account of agency through a reworking of Butler’s influential theory of gender performativity which accounts for the materialization of sexed human bodies. For Butler, matter is ‘a process of materialization that stabilizes over time to produce the effect of boundary, fixity, and surface we call matter’ (Butler, 1993: 9). Agency lies in the possibility of reiterations left by the gap between regulative ideals and bodies through which norms materialize (Cheah, 1996). Barad critiques Butler’s account of performativity on the grounds that matter is figured ‘as merely an end product rather than an active factor in further materializations’ (Barad, 2007: 66). For my purposes here, the crucial differences between these two performative notions of agency is that Butler’s version hinges on a necessary *incompleteness* of identity formations that posits identities as future horizon or *telos*, while Barad relies on a fundamental *indeterminacy* in the ‘dynamics of intra-activity’. In the absence of a product or future horizon as regulative idea, agency cannot be attributed to gaps between reiterations; the dynamics involved in intra-actions rather requires the re/constitution of time and history.

Agency is a matter of iterable intra-activity, of *différance*, ‘history’, and ‘memory’. Figured as *différance*, as differentiation and temporization conjoined (Derrida, 1982: 8), the kinds of relationship that dynamic intra-activities enable remain inherently indeterminate through space and time. ‘History’ here does not denote a march of human knowledges towards better understandings of passive objects, nor does it come always already synchronized as ‘joint historicity of humans and nonhumans’ (Latour, 2002: 265), rather it entails a ‘coming to terms with the agency of the “objects” studied’ (Haraway, 1991: 198) without guarantee that the ‘name of an action’ will ever transition to a ‘name of a thing’ at the end of a research trajectory (Latour, 1999: 147). An accounting for *Pfiesteria*’s material agency is therefore indissociably linked to a reconfiguration of time and causality.

## Without Fish There Is No Fish Killer

What is most remarkable about *Pfiesteria* is not only that they are capable of spontaneous metamorphoses in response to changing environmental conditions, but also that such a response is triggered by the fish (presumably their excreta) on which they then prey, altering not only their current shape, but their entire mode of reproduction. According to Burkholder & Glasgow (1997), many of the morphs and transformations depicted in the life cycle above (for example, the amoebae) manifest themselves only while *Pfiesteria*

are actively killing fish. There is something like a ‘catch-22’, regarding *Pfiesteria*’s identification as a species and their toxicity as a characteristic property. As the authors of the *Raleigh Report* (1998) observe: ‘An unfortunate and unavoidable circularity exists in that the presence of fish in culture ... is needed both to stimulate and detect toxin activity, hence the stimulus cannot be measured independently of its effect.’ *Pfiesteria* exclusively cultured on algae prey cannot be made to kill fish. Ironically, they need the fish around in order to become their killers. *Toxic Pfiesteria* only ‘are’ in relationship to fish and specific environmental conditions. In simpler terms: without fish there is no fish killer. If you want to know who *Pfiesteria* are by themselves – if that were possible at all – you will inevitably produce *nontoxic Pfiesteria*, but not *Pfiesteria piscicida*, the fish killer.

If their becoming-toxic is part of ‘who *Pfiesteria* are’, what could it mean to affirm ‘*Pfiesteria*’ as the causative agent of fish kills? In other words, can the entanglement between *Pfiesteria*’s beings and doings, their species-identity and toxicity be resolved experimentally? In Barad’s agential realist account of scientific practices this is exactly what (objective) experiments do; they locally resolve an inherent indeterminacy within a phenomenon, in determining the meaning of a cause in relation to its effect. The referent for such ‘causal intra-actions’ is however not a predefined object, but the phenomenon<sup>17</sup> within which ‘agencies of observations’ become differentiated from an ‘object’. An unambiguous differentiation is possible only under the condition of a complete specification of the material-discursive practices that enact what Barad calls an ‘agential cut’ (Barad, 2007: 140). Different ‘cuts’ between ‘object’ and ‘measurement agencies’ establish different phenomena. Responsibility then entails the accounting for the practices that enact a specific cut such that objects-in-phenomena become determined, that is, materialize and matter, and accountability to ‘what is excluded from mattering’ (pp. 184, 205). Mattering implies both materialization and meaning-making (Butler, 1993: 32). Hence, for Barad, scientific practices are meaning-making practices that require accountability to what comes to exist. Responsibility and causality condition each other. In order to accommodate *Pfiesteria*’s specific spatiotemporal entanglements, I reformulate Barad’s notion of responsibility slightly.

Considering that *Pfiesteria*’s life-histories and toxic ‘parts’ thereof constitute an entanglement whose intra-acting ‘components’ are inseparable in space and time, the joint possibility of responsibility and causality will not only depend on *what* materializes, but also on *how* such a cut is enacted in relation to space and time. At issue is not only the mutual entanglement of ‘object’ and ‘measurement agencies’, but also the enactment of their interdependent historicities. In other words, responsible enactments of *toxic Pfiesteria* will have to take *Pfiesteria*’s contribution to their experimental materialization into account. As soon as *Pfiesteria*’s agencies and history-dependency are accounted for, that is, the capability to dynamically change the relationship between ‘self’ and ‘environment’, we are no longer dealing with an indeterminacy that could be resolved in laboratory time. The ghostly undecidability that asserts *Pfiesteria*’s material agency precludes deterministic cause and effect relations in general.

In the following sections, I discuss various experimental enactments of *Pfiesteria* that either: (1) ignore *Pfiesteria*'s contributions to experimental intra-actions; (2) reduce them to context-dependencies and thus oppose *Pfiesteria*'s doings and beings; or (3) take the entanglement of *Pfiesteria*'s history- and context-dependency into account, but leave *Pfiesteria*'s being indeterminate. Assuming different meanings of toxicity and its relationship to causality, discrepant experimental enactments of *Pfiesteria* delimit their response-ability in various ways.

## Toxicity as Absent Property of Atemporal Objects

Fiercely disputing Burkholder's finding, Litaker et al., a group of scientists from the National Oceanic and Atmospheric Administration (NOAA), propose a much simpler life cycle for *Pfiesteria*. Presuming that 'a species life cycle is one of the most fundamental and conservative traits intrinsic to that organism' (Litaker et al., 2002b: 1268), the researchers set out to establish an 'unambiguous identification of *P. piscicida* life cycle stages' (Litaker et al., 2002a: 443). After a careful literature review establishing the possible stages of a *typical* dino life cycle that exhibits both asexual and sexual modes of reproduction, Litaker et al. confirm the existence of similar stages in the *Pfiesteria* life cycle with the help of a new genetic technology. Since genetic probes – or more accurately, those genetic probes that mark a specific ribosomal gene region used for *Pfiesteria* species identification (Tengs et al., 2003) – cannot discriminate between toxic and non-toxic *Pfiesteria*, the researchers assume that *Pfiesteria*'s lethal relation to fish is irrelevant to the 'being' of *Pfiesteria*. To them, what looks like *Pfiesteria* before the experiment becomes *Pfiesteria* after the experiment. The difference is a new molecular visualization technology for identity production, establishing genetic relationships with *in situ* fluorescent-labeled peptide nucleic acid probes (PNAs).<sup>18</sup> Trying to sort out which of the dino morphs they encounter belong to genetically defined *Pfiesteria* and which are supposedly contaminations (organisms belonging to a different species), the researchers let *Pfiesteria*-specific PNA probes penetrate various 'life-stages', such that the fluorescent molecules light up pieces of ribosomal RNA with which the probes are designed to hybridize. Litaker et al. (2002a) present various pictures of dino cells with glowing (in red or green) spots in their bodies and amoebae that don't glow when exposed to *Pfiesteria*-specific probes. Assuming that a genetic relationship, or the lack thereof, between *Pfiesteria* zoospores and amoebae found in fish aquaria would be indicative of *Pfiesteria*'s toxicity, Litaker proclaims, '*Toxic Pfiesteria* life cycle stages that don't exist can't be toxic' (Litaker, quoted in Dewar, 2002).<sup>19</sup> Burkholder and Glasgow (2002: 1265) object that 'they did not show that their strains were killing fish'. Throughout their paper, which the media and a number of scientific reviewers quickly cited as evidence against *Pfiesteria*'s toxicity, Litaker et al. (2002a) state that their clonal *Pfiesteria* cultures were 'maintained on algae or fish', without specifying which of the glowing



morphs corresponds to which cultural condition. For the NOAA team, *Pfiesteria* are fully determined by a correspondence between genes and a particular mode of reproduction. Such a mapping becomes possible when *Pfiesteria*'s material agency is erased. In Litaker et al.'s hands, *Pfiesteria* becomes an atemporal object, which can be genetically identified, but will not be toxic to fish. Not having been able to observe those life stages described as specific to *Pfiesteria*-fish intra-actions, the authors conclude, 'Consequently, any ecological role or potential toxicity ascribed to these specious *P. piscicida* stages should be reexamined' (2002a: 462). Thus, for Litaker et al., toxicity is a property of specific life stages, which must manifest themselves independently of the experimental circumstances, in particular independently of specific culture conditions and *Pfiesteria*'s activity towards fish.

Rather than searching for specific life stages, another research team, Berry et al., looks for genes encoding for substances (polyketide synthase) typical of those found in other toxin-producing dinoflagellates. Unable to find evidence for the existence of these genes within *Pfiesteria*'s genome, they conclude that *Pfiesteria* kill fish, but are not toxic to fish. For Berry et al. (2002: 10972), the demonstration of toxicity 'requires that chemical constituents capable of causing the attributed effect(s) can be isolated from the suspected source ... and subsequently shown to induce the same effect *in vitro*'. Their notion of toxicity assumes causality to constitute a substantive relationship between predefined objects mediated by a chemical substance. Both the organism as producer and the toxin as transmitter have to exist as bounded entities independent of the circumstances of their production. 'The root error', as philosopher Joe Rouse puts it, 'is the presumption that the world somehow already comes naturally composed of discrete objects' (Rouse, 2002: 313).

Both research teams assume that toxicity must be locatable somewhere within the genetically defined organism. Their search for an inherent toxic property simultaneously presumes a specific notion of causality and precludes its establishment. The assumption that a potential for toxicity is given by an essential characteristic inherent to dinos as established by past research on other dinos requires that its expression be independent of environmental circumstances and its effects. Thus, if toxicity were to exist, it must be independent of the environmental circumstances that bring it about. In erasing the means of variation in *Pfiesteria* under altered experimental and environmental circumstances, the existence of *toxic Pfiesteria* is precluded by design. The possibility that *Pfiesteria*'s doings affect their beings is simply ignored. What remains is the universalization of unspecified particular contexts 'unable to be called into account' (Haraway, 1991: 191). In this way, responsibility in experimentation is effaced in both senses of term: in recreating that which was presupposed, the experiments construct the essence of *Pfiesteria*'s beings as atemporal object, foreclosing the dinos' ability to respond and presume that any evidence for *Pfiesteria*'s toxicity requires universal validity that by definition forestalls responsibility.



## Irrelevant 'Core' Reproductive Processes: A Fluid Compromise?

Since it seems to be impossible to follow *Pfiesteria* around in a controlled manner and in 'contaminant-free' cultures while they are killing fish, Parrow et al. (2002) propose that there may be 'core (common) reproductive processes exhibited by *Pfiesteria* spp. zoospores that are largely conserved, regardless of prey type availability and toxicity status'. The authors caution, however, that the significance of their life cycle studies should not be overestimated:

For this study, the need for controlled, contaminant-free cultures with benthic encysted and planktonic stages that could be readily observed under microscopy outweighed the increased ecological relevance possible in fish-fed, actively toxic cultures. Although caution is warranted in over-extrapolation of the importance of research conducted using *Pfiesteria* spp. cultures that have been maintained solely on a diet of algal prey for extended periods (weeks to months), those concerns extend primarily to issues of toxicity and nutrient pollution. (Parrow et al., 2002: 7)

Here, Parrow et al. seem to be pitching the need for reproducibility and controlled experimentation that would allow for 'inferences for [*Pfiesteria*'s] classification' against the ecological relevance of experiments investigating *Pfiesteria*'s toxicity. In contrast to Litaker et al., who sample their aquaria periodically and match the life-stages found to a schema reconstructed from the dino literature, Parrow et al. follow *Pfiesteria*'s developments. In order to do so, they have to pick a beginning in the (life) cycle and make the cells perform in unified time freed from intra-actions with prey. Motile dino cells were isolated from other developmental stages just after they transformed from benthic cysts such that 'flagellated cells excysted into media devoid of prey' (Parrow et al., 2002: 9). By erasing the poly-temporality within the collection of morphs, the experimenters attempt to make *Pfiesteria*'s developments become traceable in laboratory time. *Pfiesteria*'s agencies are not entirely erased as in the case of the atemporal objects discussed above, rather possible variations are circumscribed by specific technologies employed, severely limiting *Pfiesteria*'s response-ability. Ecological relevance is not excluded *a priori* because the focus is on stability and reproducibility, but rather because reproducibility involves a process of synchronization that makes the 'cells live differently in time' (Landecker, 2005).

For Parrow et al. the question is not 'what the true life cycle of *Pfiesteria piscicida* really is' (Coats, 2002). Their approach suggests instead that there might be 'different versions of the object' (Mol, 1999: 77). The researchers maintain that '[a]lthough the cell division of a given dinoflagellate species has been regarded a conserved character (often used as taxonomic trait) ... it is possible that *Pfiesteria* also exhibits variability in cell division' (Parrow et al., 2002: 23). Perhaps this is what Law and Singleton (2005) mean when they speak of a 'fluid object': relations that make up the core reproductive processes change in time and reshape the object when environmental and laboratory circumstances are altered.

By taking into account the circumstances that bring the classifiable dinos about, the scientists could be seen as being accountable for connections made and particular exclusions enacted. While Parrow et al. consider the possibility that changes in *Pfiesteria*'s life cycle may occur under altered nutritional or ecological conditions, they do not consider that the synchronization process, which establishes *Pfiesteria*'s temporality as traceable in laboratory time, erases the nutritional histories on which *Pfiesteria*'s becoming-toxic depends. Toxicity cannot modify life cycle processes over time that only exist under the condition that toxicity is excluded. It is not that *toxic Pfiesteria* remain indeterminate; rather toxicity becomes impossible to affirm. The very assumption of the existence of a conserved entity *before Pfiesteria* become toxic in their encounter with fish precludes a link between *Pfiesteria* and *toxic Pfiesteria*. Thus, what Parrow et al. consider experimentation in a 'highly artificial environment' and perhaps irrelevant for ecological processes, is not irrelevant for the possibility of *toxic Pfiesteria* at all – such an environment *precludes* their existence.

Parrow et al.'s affirmation of a stable 'core' in *Pfiesteria*'s species-being thus depicts potentially *toxic Pfiesteria* maintained with fish as both a temporal modification of classifiable *Pfiesteria* and ontologically distinct from them, namely, that which is necessarily excluded from experiments with algae-fed *Pfiesteria*. The indeterminacy between *Pfiesteria*'s beings and doings is not resolved, but rather affirmed as oxymoron. When *Pfiesteria*'s nutritional history-dependency and with it *Pfiesteria*'s contributions to material agencies are erased, their beings and doings remain opposed within an ecological space that cannot vary in pre-established laboratory time. The significance of core-reproductive processes is established through responsibility towards a particular mode of experimentation, emphasizing contaminant-free culture, and easy reproducibility, thus enabling inferences for *Pfiesteria*'s classification. Thus, limiting their responsibility towards a 'past' of established scientific practices, the researchers minimize *Pfiesteria*'s ability to respond (their response-ability).

As one dino taxonomist notes, 'it is perhaps obvious that a full knowledge of the life cycle of a particular species is critical in order to determine its appropriate placement in the overall scheme of the group as a whole' (Fensome et al., 1999). Steidinger et al. (1996) invented a new family (*Pfiesteriaceae*), genus (*Pfiesteria*) and species (*Pfiesteria piscicida*) for the fish killers. Without connection to anything established, a new species, genus, and family would cease to be meaningful. Anything 'new' must be both familiar and revolutionary, related to the 'past' and radically breaking with it (Derrida, 1988; see also Jasanoff, 2005). The fact that anything 'new' is necessarily aporetic has not prevented scientists from establishing classifications in the past. No classification is innocent, as an extensive literature in Science Studies has shown (Foucault, 1970; Ritvo, 1997; Bowker & Star, 1999; Waterton, 2002; Bowker, 2005; Sommerlund, 2006). Different kinds of classification embed different kinds of priorities and values. But the situation is slightly different here. *Pfiesteria*'s appearances are not merely 'under-determined by nature and logic alone' (Shackley & Wynne, 1995: 124),

a situation that requires scientific assessment about relevant stabilities. *Pfiesteria* do not acquire a stable identity or species-being that could be abstracted from the conditions of their production (see Helmreich, 2009, for related arguments). It is not only that *Pfiesteria* are 'hard to classify'; they are rather unclassifiable as long as classification requires the existence of stable properties independent of specific relations between space and time. As Geoffrey Bowker points out, 'when time itself is a dynamic variable then the naming mechanisms tend to break down' (2005: 145). Thus the main issue here is not so much the politics *in* classification or the co-existence of multiple classification schemes (Sommerlund, 2006), but the politics *of* classification, that is, the perceived requirement of sorting out the 'taxonomic background' as prerequisite for further investigating into *Pfiesteria*'s behaviors. The phantomatic character of the dinos disrupts the entire logic of taxonomy. Toxic phantom dinos shatter the self-evidence of 'our' time.

To summarize, as long as *Pfiesteria piscicida* is considered the name of a species that can be unambiguously characterized by a life cycle and/or genetic probes, *toxic Pfiesteria* remain precluded; they are neither an ecological subset nor a temporal variation of the species, but both at the same time. In other words, as long as the species is assumed to exist *prior* to *toxic Pfiesteria*, *toxic Pfiesteria* incorporate 'two fundamentally incommensurable ontologies' (Bowker, 2005: 186).

Before re/turning to the phantomatic fish killer, whose experimental enactment in the hands of Burkholder et al. does not presuppose an atemporal essence or a core existence that may vary in linear time, a few remarks about discrepant meanings of toxicity employed by the various research teams are in order, as slipperiness in the usage of the term 'toxicity' seems to conceal the fact that the controversy is about the meaning of causality.

## Discrepant Meanings of Toxicity and their Relation to Causality

The scientists' incoherent and sometimes interchangeable usage of the terms 'toxicity', sometimes referring to 'toxi(co)genicity' (producing toxins), and other times to 'ichthyotoxicity' (fish killing) may have contributed a great deal to the controversy over *Pfiesteria*'s 'toxicity'. Various articulations of toxicity imply different notions of causality. While 'ichthyotoxicity' is clearly defined as detrimental to fish, toxi(co)genicity implies the production of a neurotoxin that may also be harmful to humans in addition to fish. The more important distinction for my purposes is that the former suggests toxicity as a harmful or deadly relationship, whereas the latter associates toxicity with an inherent property. Toxicogenicity as employed by Berry et al. (2002) locates the 'cause' of a toxic relationship within the producer of a toxin, which by definition already contains its effect, rendering causality a deterministic relationship. Ichthyotoxicity, conversely, focuses on the effect of a toxic relationship, the dead fish. A cause is then defined as that which can repeatedly induce the same effect. Within that definition, ichthyotoxicity receives two distinct meanings depending on whether toxicity is associated

with a stable relationship or a ‘dynamic activity’. In the former case the existence of well-defined relata is presupposed, such that a ‘causal agent’ can be isolated from its effect *after* the fact and retrospectively defined as that which precedes it. How it might be possible to affirm *Pfiesteria*’s toxicity without presupposing the existence of a causal agent and render experimentation more response-able at the same time is the topic of the rest of this paper. As already suggested, this will entail a reconfiguration of both the notion of ‘dynamics’ and of ‘activity’. First, however, I discuss a protocol for the experimental establishment of causality – when not associated with the production of a toxin – that most dino researchers sought to follow.

## Koch Postulates

The ‘Koch’s Postulates’ are a series of guidelines developed in the late 19th century by German bacteriologist Robert Koch (1843–1910) as a standard for evidence of causation in infectious diseases (Evans, 1976). While their limitations have long been recognized, the ‘Koch Postulates’ are still considered the ‘gold standard’ for causative agency in epidemiology.<sup>20</sup> For a microorganism to count as the cause of a specific disease, the following four criteria must be fulfilled:<sup>21</sup>

Postulate 1: The infectious organism must be present in the diseased host.

Postulate 2: The organism must be isolated from the host and grown in pure culture.

Postulate 3: The pure culture must be shown to induce the disease anew: the isolated organism must be injected into a healthy host and infect the host again.

Postulate 4: The agent must be re-isolated from the experimentally infected animal and shown to be the same as the previously isolated organism.

These Postulates are designed to assess retrospectively whether a given infectious organism has caused a disease. The requirements of the organism’s isolatability and stability presume that what constitutes the organism must be already established and independent of the capability to infect the host. The requirement for ‘pure culture’ assumes that infection happens under all circumstances independent of any environmental variations.

None of these requirements apply to *Pfiesteria* as described above. Since toxicity in *Pfiesteria* is triggered by fish, it cannot be assumed to exist before *Pfiesteria* are exposed to fish. Moreover, *Pfiesteria* are not ‘present’ in the fish, and toxic zoospores can be found in water samples only as long as fish are dying. Soon after fish death, many zoospores transform into benign cysts, which makes it difficult to catch *toxic Pfiesteria* ‘in the act’. Potentially toxic zoospores cannot be entirely isolated from other organisms since endosymbiotic bacteria survive as functional energy reserves in their ‘bellies’, producing nutrition photosynthetically when necessary. *Pfiesteria* zoospores cannot be grown in pure culture since they need to be fed in order to proliferate (Burkholder et al., 2001b). Moreover, healthy fish rarely come alone;

they are accompanied by a microbial consortium that cannot be removed without changing the very meaning of ‘health’ or ‘life’ in fish.<sup>22</sup> More importantly, however, the boundary between ‘organism’ and ‘host’, or between potentially toxic *Pfiesteria* and their environment does not sit still in the transition from live to dead fish. The kind of population of zoospores that may have killed the fish will no longer exist after the fish are dead. When becoming-toxic, individual morphs change shape and reproduce quickly.

Thus, the two main requirements for causality as postulated by Koch – repetition of the ‘infection’ and stability of identity between iterations – are mutually exclusive. Does that mean that causality is in principle impossible to establish? As argued above, the species *Pfiesteria piscicida* and *toxic Pfiesteria* cannot receive meaning at the same time; the experimental circumstances for their enactment are complementary. The relation between *Pfiesteria piscicida* and *toxic Pfiesteria* is one of différance: *toxic Pfiesteria* differ from and defer their species-being. So far I have discussed attempts at identification that precluded the assessment of toxicity and the possibility of a causal relation between *Pfiesteria* and dead fish. Now, I turn to experiments that focus on the repeatability of *Pfiesteria*’s toxic activities, without establishing exactly who *Pfiesteria* are.

### Experimenting with the *Toxic Pfiesteria* Complex: Relating Responsibility as Response-ability to Causality as Inheritance

Burkholder et al.’s adaptations of the Koch Postulates ‘for toxic rather than infectious agents’ entail a reworking of the notion of causality. In order to affirm what is measured and causally connected, a new terminology was required. Burkholder et al. avoid speaking of toxicity as a contingent characteristic of the species *Pfiesteria piscicida*. Her laboratory rather affirms the toxicity of *Pfiesteria*-like organisms (PLOs)<sup>23</sup> that will have become members of the *toxic Pfiesteria* complex, according to their lethal performance in standardized fish bioassays. The experiments define *toxic Pfiesteria* dynamically through deadly intra-actions with certain kinds of fish. Burkholder et al. (2001a) distinguish three agential types of *toxic Pfiesteria*: ‘strains’ that are either actively toxic, potentially toxic, or non-inducible. The last of these can no longer be made to kill fish, whereas the first two are distinguished by how fast and often they kill fish. ‘Time to fish death’ is taken as a measure of the kind of toxicity.

Before *Pfiesteria* are found in action killing fish, it remains inherently undecidable whether the toxicity of a particular ‘strain’ refers to how they have been acting or to how they will be acting towards fish. *Pfiesteria*’s capability to act differently depending on their nutritional histories not only affirms an indeterminacy between ‘organism’ and ‘environment’, but also between ‘past’ and ‘future’ activities.

How *Pfiesteria* have been acting in the ‘field’ can only be inferred from how they continue to act under comparable conditions in endless repetition of the entire procedure. Since *toxic Pfiesteria* are defined as being able to kill

fish, they can only be assumed to ‘be’ of the same kind if they continue to be able to kill fish. In general, it is inherently undecidable whether *Pfiesteria*’s toxicity is occurring for the first time or whether it is coming back. Like a Derridean specter, *Pfiesteria*’s toxicity begins by coming back.<sup>24</sup> *Toxic Pfiesteria* neither precede nor follow their traces.

How then can any relations between the deadly activities in laboratory fish tanks and fish kills in the estuaries be established? In other words, how can the indeterminacy between ‘past’ and ‘future’ in *Pfiesteria*’s toxic activities be resolved? In Barad’s reconfiguration of causality as iterative intra-activity, component ‘parts’ of a phenomenon become differentiated only under the condition of a complete specification of the experimental (material and discursive) circumstances through which a mark on a ‘measurement agency’ (the dying fish) receives meaning as ‘effect’ of a measured object. *Pfiesteria* do not pre-exist ‘their’ toxic relationship to fish; *toxic Pfiesteria* receive meaning only if the ‘intra-actions exhibit repeatable patterns’ (Rouse, 2002: 279). A repetition of the toxic phenomenon is, however, as we will see, precisely what renders an unambiguous differentiation between *Pfiesteria* and their environment impossible. Part of the problem is that *Pfiesteria* are not only context-, but also history-dependent, in which case we are dealing with an entanglement of two indeterminacies – between ‘bodies’ and ‘environment’ and ‘past’ and ‘future’ – that cannot be resolved at the same time. As soon as a ‘time’ as an external parameter that automatically orders events chronologically can no longer be presupposed, the *differentiation* between ‘bodies’ and ‘environment’ depends on what I call *temporalization* – the establishment of a relation between ‘past’ and ‘future’.

## The Fish Bioassays

The fish bioassays are designed to distinguish whether *Pfiesteria* that are able to continue to kill fish in the laboratory have been actively toxic in the field. This becomes possible because the time of separation from proximity to fish critically influences their further ability to kill fish. Actively toxic zoospores rapidly form cysts, but ‘resume lethal activity toward test fish within 4 to 9 days. ... Populations that were not previously in actively toxic mode require considerably longer to kill fish in bioassays (typically 6–8 weeks or more)’ (Burkholder et al., 2001b). *Pfiesteria* have a ‘biochemical “memory” for recent stimulation by live fish’ (*Pfiesteria* Interagency Coordination Workgroup, 2000). Here, ‘memory’ cannot be thought of as an intrinsic property of *Pfiesteria*; it cannot be localized internally to an organism and determined by a genetic sequence. As co-constitutive part of agency, *Pfiesteria*’s memory manifests itself in response to fish; it doesn’t precede but conditions their intra-activity with fish. Memory is not a matter of the past, but re-creates a past each time it is invoked.<sup>25</sup>

In the following procedure described by Burkholder et al., timings are important at every step. The requirement of the Koch Postulates for ‘presence of the organism in the host’ is replaced with an observation of a minimum density of flagellated dino morphs that under a light microscope look



like *Pfiesteria* zoospores. The 'host' is a water sample collected from an estuary where/while a fish kill is still in process. In the laboratory, the water samples are incubated with healthy fish. If the fish continue to die, the water samples are said to contain 'an actively ichthyotoxic population of zoospores *resembling Pfiesteria*' (Burkholder et al., 2001b: 747). From this population of *Pfiesteria*-like organisms that have been killing fish a subpopulation that still look like *Pfiesteria* zoospores when analyzed with the enhanced resolution of scanning electron microscopy (SEM) are isolated from the rest of the water sample and made to reproduce with algae-prey until they acquire a critical zoospore density.

In a 'renewed induction of the disease', algae-cultured *Pfiesteria* zoospores are incubated with healthy fish (accompanied by a consortium of other microbes) and the time to fish death is observed as an initial measure of toxicity. In order to remain actively toxic, the dinos have to be continuously fed with fish. Dead fish in the aquaria have to be replaced with healthy fish. 'Time to fish death' depends on 'the rate of zoospore population increase', which in turn depends on the frequency of fish replacements (Glasgow et al., 2001). In addition, it depends on *Pfiesteria*'s memory of their previous exposure to fish and therefore varies with every iteration. Since *Pfiesteria*'s 'past' relation to fish receives meaning only through the possibility of multiple iterations, enabling *Pfiesteria* to continue to act, the relationship between *toxic Pfiesteria* and fish is not causally fixable at any moment in time.

A second iteration changes not only the 'time to fish death', but also the relation between *Pfiesteria* zoospores and their environment. Control fish cultures that receive algae prey without *Pfiesteria* may delineate *Pfiesteria* zoospores from their environment *before* zoospores are exposed to fish. If maintained under equivalent conditions, the control experiments could define *toxic Pfiesteria* as that which is absent in those aquaria in which fish stay healthy compared with the content of the aquaria in which fish will die. However, as soon as the putative cause receives meaning in relation to its effect – that is, as soon as a population of zoospores begins killing fish – the population of *toxic Pfiesteria* changes both in number (through enhanced fish-assisted reproduction) and kind (through metamorphoses). What may have been contributing to toxicity during a previous kill may now be part of 'its' environment. Repetition of the toxic phenomenon thus continuously modifies the boundary between the putative fish killer and 'its' environment.

As described so far, the situation seems hopelessly circular, and causality, even in Barad's reformulation, seems to be precluded. An unambiguous determination of a boundary between 'object' and 'measurement agency' or, in this case, between '*Pfiesteria*' and 'their environment' would be possible only if repetition would not alter this boundary. The failure to unambiguously enact *toxic Pfiesteria* in the fish bioassays dramatizes what Derrida suggests for all kinds of objects: the 'same' object is only determinable as the same through its alteration (see Derrida, 1988). What seems to be a paradoxical statement might just be matter of our preconceptions of time. A corollary to the 'root error' that assumes the world is composed of

discrete entities is the assumption that time is 'made up of successive linking of presents identical to themselves' (Derrida, 1994: 70).

Repeatability here is better understood in Derrida's terms as 'iterability', which suggests that the very possibility of appearance of a 'mark' as objective measurement result entails its temporalization, that is, the 'object' must be able to continue to act in the absence of its condition of production, whereas any reiteration introduces a difference that undermines its supposed identity. In this way, iterability is constitutive of every mark or object. The point here is not, as Butler's regulative account of performativity may suggest, that the mark must be repeated in order to be effective, rather a mark only *exists* as a mark if repeatability inheres in it.

For Barad, 'causality is an entangled affair: it is a matter of cutting things together and apart' (Barad, 2007: 394). While 'cutting apart' refers to the *differentiation* between 'object' and 'measurement agencies' within a phenomenon, an agential cutting-together is a process that extends the entanglement of a specific phenomenon. In my reading of the *Pfiesteria* experiments, this 'cutting-together' becomes a process of *temporalization* when it relates histories of traces or memories of past relations rather than things. For Barad, an extension of an entanglement engenders a 'new' phenomenon. In my account, this cutting-together constitutes a temporalization as the condition of possibility of the appearance of *the* phenomenon. In joining differentiation with temporalization, I hold on to an undecidability between 'the original' and 'the new'. Temporalization extends a phenomenon through 'time'. However, as long as temporalization presupposes differentiation as a possibility of repetition that guarantees identity prior to the actual repetitions it makes possible, causality as intra-activity is precluded. In other words, temporalization cannot be thought of on the basis of a beginning, an origin, or cause as a discrete event that has been present in the 'past'.

What turns out to be repeatable in these experiments is neither the 'time to fish death' nor the delineation of a 'causative agent' as separable difference from its environment, but a temporal pattern – where the relation between first time and second time to fish death are of particular importance (Burkholder et al., 2001b: 755) – of continued deadly activity towards fish under specific environmental conditions such as water temperature, salinity, pH, oxygen, nitrogen, and phosphate content, and so on.

The results of fish assays do not establish an unambiguous cause of the fish kills in terms of origin, producer, or identity, but the environmental conditions under which '*Pfiesteria*' are able to continue to act, as conditions of possibility for fish kills in the field. In order to establish causality, the environmental parameters must fulfill two complementary requirements: they must be able to relate *actively toxic Pfiesteria* in the laboratory fish tanks to a particular fish kill in the field, that is, temporalize the toxic phenomenon; and they must ensure the repeatability of this relation for a particular set of fish assays.

In order to relate *actively toxic Pfiesteria* in the laboratory to a particular fish kill in the field, the environmental and experimental conditions can

neither be arbitrary nor prescribed as fixed (for example, by measured condition in the field after the fish are dead). They must be both sufficiently constraining, simulating field conditions that are ‘conducive to toxic *Pfiesteria* growth’, and flexible enough such that *Pfiesteria*’s contributions to the temporal pattern of consecutive fish kills continue to matter. Only if the conditions allow for *Pfiesteria*’s memory of previous exposures to fish to influence these patterns is it possible to distinguish between toxic *Pfiesteria* that have been active in the field and those enticed to kill fish in laboratory without memory of previous exposure to fish. If *Pfiesteria*’s activities would just follow the rhythms in which healthy fish are made available, the times to fish death would provide no clue about possible activities in the field. What is required are conditions that enable an *intra-active synchronization* between *Pfiesteria*’s memory and the frequency of the fish-replacement, which manifests itself (paradoxically) in the temporal variability of *Pfiesteria*’s response to fish in every iteration.

As soon as the ‘object of study’ contributes to its own materialization, a cause can no longer precede its effect in linear externalized time. And, as soon as temporal homogeneity can no longer be presupposed – that is, when ‘components’ of a phenomenon are activities that cannot be assumed to already cohere in time – agential differentiations must be accompanied by temporalization – an intra-active process of *synchronization*. Synchronization here does not entail the adjustment or maladjustment of an intrinsic time of the body to the time of the experimental apparatuses – a situation that Bowker and Star refer to as ‘torqued’ (1999). Rather, it is itself an intra-activity composed of temporally heterogeneous activities, enabling the reconstitution of time in the deadly marking of fish. In short, the environmental conditions must be determined in such a way that *Pfiesteria*’s toxic activities in the laboratory are assertable as the future trace of a specific ‘past’ fish kill in the field. The ‘past’ of a fish kill in the field is neither produced nor reproduced in the laboratory, but *inherited*. Inheritance brings forth a past that has never been present as future trace through intra-active synchronization of multiple activities, which becomes possible only under *relevant* environmental and experimental conditions that render the experiments repeatable.

Repeatability of the fish bioassays entails the adjustment of environmental conditions allowing for *Pfiesteria*’s continued toxic response to fish such that they become conditions of possibility for fish kills in the estuaries to which *Pfiesteria* zoospores will have contributed. A successful repetition of the experiments then ensures that these conditions are relevant for an assessment of the link between *toxic Pfiesteria* and the nutrient pollution in the estuaries.<sup>26</sup> In other words, getting the experiments to work responsibly and repeatedly requires attention to the agencies of the object of study – the maintenance of *Pfiesteria*’s response-ability – which in turn necessitates the inclusion of particular matters of concern<sup>27</sup> – the condition that will have enabled particular fish kills in the field – as part of the objective referent, which also establish the ecological and political relevance of the experiments.

While *Pfiesteria*'s history-dependency ensures that their being is constitutively deferred, undermining any attempt to fully identify *Pfiesteria*, it enables a temporal 'connection' between *Pfiesteria*-associated laboratory killings and a particular fish kill in the field. *Pfiesteria*'s memory does not change in time, but changes time itself. The time reconstituted through inheritance cannot simply be reinserted into a causal chain as an additional element, rather it becomes topical – a 'chronotope' in Haraway's (1997: 41) terms – where 'topos' does not simply refer to a place but to a site of engagement or a matter of concern.

Causality as iterable intra-activity thus becomes an inheritance that *temporalizes* the phenomenon in 'cutting together' deadly traces and hinges on the inclusion of specific matters of concern as part of the experimental referent, which renders the experiments repeatable. The fish bioassays don't establish an event that closes a gap between a preconceived 'before' and 'after'. They don't provide the 'missing link' that transforms aspects of the species *Pfiesteria piscicida* into *toxic Pfiesteria*; rather they demonstrate that *toxic Pfiesteria* have always already been killing fish. Actively *toxic Pfiesteria* will have been able to kill fish in the field if 'future' generations continue to kill fish in the laboratory.

Membership in the *Toxic Pfiesteria Complex* is thus not established by any particular presence, but through a continued ability to respond to and kill fish. *Pfiesteria*'s being remains phantomatic. Phantoms always begin in repetition. A phantom is however not simply something that comes and goes, which could be captured scientifically with appropriate timings and improved sampling methods; it cannot be represented or made present; it rather challenges the 'synchrony of the living present' (Derrida, 1982). But a phantom leaves a trace, making demands on us to be accounted for, to be taken into account.

Responsibility then entails not responding to a particular other, who does not exist as such,<sup>28</sup> but the *enabling of responsiveness* within particular relations, which in turn enables and necessitates accountability to an 'extended' phenomenon, that is, to what is at stake in getting the experiments to work. In other words, the epistemic/ontological concern of getting the experiments to work in a reliable manner cannot be dissociated from the ecological/political relevance within responsible practices. *How toxic Pfiesteria* are enacted is thoroughly entangled with *what* comes to matter for environmental decision-making.

## Critiques of the Fish Bioassays

The existence of a multi-species microbial community in the fish aquaria has led to criticism of the fish bioassays as a suitable tool to establish causality between *Pfiesteria* and dead fish. Since the fish bioassays cannot draw an unambiguous boundary between *Pfiesteria* and their environment, they cannot distinguish whether toxicity is generated by *Pfiesteria*-like organisms 'or a result of interactive processes within the complex microbial community' (Gordon & Dyer, 2005: 429). Some researchers suspect that

interactions between *Pfiesteria* and bacteria that either come with the fish or live within certain *Pfiesteria* stages might be important for toxin production (Burkholder et al., 2005). The experiments also do not distinguish whether a water-soluble toxin ultimately kills the fish or whether the fish die from physical attacks by the dinos. These are important open questions, but they do not render the kind of causality established with fish bioassays more uncertain. The matters of concern are different. In particular, investigations of the involvement and effects of a neurotoxin are of great importance when it comes to the assessment of human health risks. In the fish bioassays, the concerns are explicitly with dead fish and the environmental conditions that enable the kills. Dead fish cannot (directly) stand in for human health risks. While the fish bioassays might provide clues about possible means to *prevent* massive fish kills, they do not allow for an assessment of the dangers to human health *after* the fact. There is no guarantee that the kind of causality the fish bioassays establish makes a difference for environmental policies, but perhaps it can change the terms of the negotiations from deferrals due to alleged uncertainties towards arguments over specific matters of concern.

## Concluding Remarks

The quest to remove uncertainties, ‘gaps’ in knowledge, and ‘missing links’ in a causal chain has presumed (without specifying) that what counts as evidence for the establishment of *Pfiesteria*’s toxicity is independent of the experimental questions asked. In each of the cases discussed, what counts as evidence for *Pfiesteria*’s toxicity, their life cycle and possible links between the two, has become part of the experimental apparatus. Who *Pfiesteria* are and what *toxic Pfiesteria* could possibly become crucially depend on the ‘how’ of their enactment.

Discrepant enactments of *Pfiesteria*’s life histories and toxicity are not a matter of epistemological uncertainties or opposing views. Nor did the researchers construct different versions of the object ‘toxic *Pfiesteria*’ that would be simply incomparable. Rather, various laboratory practices have enacted different kinds of objects – the atemporal genetic *Pfiesteria*, the fluid object of reproductive processes, and a *phantom* – exhibiting various degrees of responsibility in enabling and disabling responsiveness. The differences are thus neither epistemological, concerning different perspectives onto the same object, nor ontological, in the sense that multiple ontologies co-exist at the same time (Mol, 2002). Rather, differences here concern the variability of relations through and between space and time. In other words, experimental determinations don’t just constitute ‘subjects’ and ‘objects’, but constitute such divisions in specific spatiotemporal relationships. It is the kind of relationship that matters.

The fish bioassays, I have argued, affirm causality as responsible inheritance; they are both responsible in enabling *Pfiesteria*’s continued response-ability and necessarily relevant to particular matters of environmental concern. These experiments not only account for *Pfiesteria*’s toxic inheritances from field to laboratory, but also constitute an inheritance of



a specific scientific practice. The Koch Postulates are neither rejected nor literally followed, but materially reconfigured – that is, inherited. The indeterminacy between *Pfiesteria*'s being and doings is not resolved but is rather affirmed as entanglement. *Pfiesteria*'s being is not opposable to their doings; it rather remains indeterminate, when the circumstances of 'their' bioactivity are measured. This *ontological* indeterminacy establishes the very condition of possibility for objective and responsible scientific practice. The members of the *Toxic Pfiesteria Complex* are phantomatic; their being remains 'to come'. A move from 'being' as a ground in ontology towards a *phantomatic ontology*, as the condition for responsible and objective science, is not a move from 'being' to 'doings' or 'becomings', rather their relationship itself remains inherently indeterminate and must be reconfigured in every intra-act through specific matters of concern.

Phantoms share with 'fire objects' the acknowledgement that not everything can be brought to presence, but that doesn't turn them into 'a pattern of presences and absences' (Law & Singleton, 2005: 343). Phantoms don't follow the rules of a dialectic that can conceive of difference only as absence; they are neither present nor absent, but spectral, internally split, 'non-contemporary' with themselves (Derrida, 1994: xix), or in Bohrian terms, they are complementary to themselves. Phantoms share with Rheinberger's 'epistemic things' that they are constitutively deferred; their embodiments are their traces. These traces, however, are not 'transformed as time goes on'; phantoms do not become what they have been (Rheinberger, 1997: 181); rather than recurrent, *Pfiesteria*'s movements are reconstituted through inheritance. Phantoms are not 'a machine for making the future' (p. 33), but enable responsibility towards 'a "past" that has never been present, and which never will be, whose future to come will never be a *production* or a reproduction in the form of presence' (Derrida, 1982: 21, emphasis in original). 'As such' a phantom *is* im/possible, and therefore necessitates the making of determinations *here and now*.

Responsibility cannot be reduced to the adherence of preconceived norms of 'good practice', or follow a demand for science 'to be "cutting edge"' (Fortun & Fortun, 2005: 47). On the contrary, responsibility to the past and the future entails an opening-up of possibilities for different kinds of responses – responses that may transform the 'edge' in the making of scientific cuts. In my account, responsibility happens within an entanglement of two indeterminacies between 'object' and 'agencies of observation' and between 'past' and 'future'. At stake is not only a particular content but the very meaning of 'past' and 'future' in scientific practice. The 'past' can no longer be associated with what is already given or known; it rather is a matter of inheritance to which not only humans contribute. The scientific future is not a receding horizon to be populated with an ever increasing amount of human knowledges and technologies, but remains to come. Granting microorganisms a role in agency does not absolve humans from the responsibility to 'perpetually contest and rework [established] boundaries' (Barad, 2007: 205). Agency manifests itself after all as 'an enactment of ... changes to particular practices' (p. 178). Responsibility thus requires the interruption of 'the ordinary course of things, time and history *here-now*' (Derrida, 2002: 249).



## Notes

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1. Among the several thousand described species of dinoflagellates, about 80 are considered to be toxic. This number is constantly increasing (Burkholder, 1998). Many ecologists hold that formerly benign species have become toxic because of altered environments.
2. 'Dino' – short for dinoflagellate, not to be confused with the 'fierce ones', as in dinosaurs – is a Greek verb meaning 'spinning' or 'whirling' and refers to the movement of these micro-critters, which propel themselves through the water with two flagella.
3. Coinciding with fish kill reports were reports by fisherman of skin lesions, disorientation and memory loss (Burkholder, 1998).
4. A division of ontological questions and epistemological approaches to the study of scientific objects has been a matter of recurring debate in Science Studies. According to Sheila Jasanoff (2004), co-productionist approaches in Science Studies have either focused on ontological questions concerning the emergence and stabilization of scientific objects (which she terms 'constitutive co-production') or on conflicting epistemologies within already demarcated domains. The latter, which Jasanoff calls an 'interactional approach' to co-production, is less concerned with 'what is and more with how we know about it' (Hacking, 1999:169, quoted in Jasanoff, 2004: 19).
5. Steve Hinchliffe (2001) makes a similar distinction between uncertainty and indeterminacy.
6. Herzig (2004) argues that when the constitutive contradictions entailed in deconstructive notions of performativity are erased, the studies of scientific performances become linked to notions of production, highlighting 'some extreme forms of capitalist efficiency' (Parker & Sedgwick, quoted in Herzig, 2004: 136). In lieu of human agency, power and capital have become self-moving agents. 'The thing is defined by its movement' (Herzig, 2004: 137). Herzig calls for a renewed attention to the constitutive contradictions entailed in deconstructive notions of performativity. In part, this essay follows Herzig's call. See also Maurer (2000) for an intervention into unexamined 'nature of movement' inherent in narratives of scientific and capitalist progress.
7. This is consistent with Latour's belief in an 'arrow of time' pointing from simplicity towards increasing complexity as network connections expand and all actors gain in activity.
8. As Vicky Kirby (1997: 123) asserts, a real-ization of matter as 'effect[s] reverses the logic of causality but does not contest its linear discriminations of difference as separability'.
9. While 'epistemic things embody what one does yet not know' (Rheinberger, 1997: 28), they are not "merely" epistemic, as Joe Rouse (2002: 338) puts it. They do not follow trajectories towards predefined objects; they rather must be capable of transformations leading to 'unprecedented events.' As scientific objects, they are 'absent in their experimental presence' (Rheinberger, 1997: 28, 134).
10. The fact that 'there can be no single, identically conceived and experienced "real" time' (Weston & Helmreich, 2006) cannot be reduced to an acknowledgement of the multiplicity of times. Rather, any attempt to grasp 'real time' as bounded interval, a spatialized moment, or full presence, can, paradoxically, conceive of the difference that differentiates between 'past' and 'future' moments in time only as absence.
11. In 1997, the Clinton administration established the 'Pfiesteria Research Act', authorizing \$12 million over the following 2 years for *Pfiesteria*-related research (National Oceanic and Atmospheric Administration Legislative Informer, 1997).

12. The authors of the 1998 *Raleigh Report*, a summary of a workshop to assess 'Pfiesteria Research Needs and Management Actions', suggest:

There can be little question that decreases in nutrient loading (both organic and inorganic forms of nitrogen and phosphorus) will reduce eutrophication and, thereby, lower the risk of toxic outbreaks of *Pfiesteria*-like dinoflagellates, hypoxia, and fishkills. However, sufficient scientific information does not exist at present to quantitatively determine causal relationships, with confidence, between specific sources and rates of nutrient inputs (that can be attributed to particular land-use practices) and the occurrence of toxic events attributed to *Pfiesteria piscicida* or the *Pfiesteria*-like organisms (*Raleigh Report*, 1998).

13. Discussing climate change science and policy, Shackley and Wynne (1996) make a similar argument: On one hand 'the scientists' authority may reside precisely in their informal judgments of uncertainty' and on the other hand, there is confidence that the uncertainties will be reduced by further research (pp. 277, 283).
14. See Hayden (2003) for a discussion of a necessary separation of what 'life is' and from what 'life does' for an association of bioactivity with the 'production of value' in plants.
15. The distinction I am making here between uncertainty and indeterminacy derives from Barad's reading of Niels Bohr's interpretation of quantum physics. In his initial (epistemological) formulation of the 'uncertainty principle' in quantum mechanics, Heisenberg first assumed (and later corrected) that position and momentum of a particle cannot be *known* at the same time, because the measurement process would distort an underlying reality in such a way that complementary properties would not be accessible to a human observer at the same time. According to Bohr, on the contrary, 'particles don't *have* determinate values of position and momentum simultaneously' (Barad, 2007: 19). Since the measurement of position and momentum of an object entail mutually exclusive experimental apparatuses, determinate values do not *exist* at the same time. In Bohr's own words, 'in this context, we are of course not concerned with a restriction as to the accuracy of measurement, but with the limitation of the well-defined space-time concepts' (Bohr quoted in Plotnitsky, 2003 [1995]: 24).
16. Such agency is distinct from various other versions of 'material agency' wiggling through the Science Studies literature. Material agency cannot be attributed to 'objects that do things in the world', nor can it be reduced to random unpredictable changes of 'natural forces' or machinic extensions of human productivities (Pickering, 1995: 6–7, 9). Material agency is not situated somewhere external to or outside of a human realm, but displaces the very distinction between human and nonhuman agency. The problem of symmetry between human and nonhuman agencies, which preoccupied much of the actor network theory (ANT), is not an issue here (Callon, 1986), since neither the dinos nor their investigators are preformed entities before they intra-act. *Pfiesteria* are neither actors, nor quasi-objects, which would follow a continuous trajectory of increasing stabilization from existence to essence. The dinos are explicitly not temporally emergent – as long as emergence is figured as happening progressively in an externalized flux of time. When grammar fails and I nevertheless speak of *Pfiesteria*'s agency, it should be kept in mind that the dinos are neither pre-existing subjects nor objects. The same holds for the experimenting humans.
17. A phenomenon is 'an ontological inseparability of agentially intra-acting components' (Barad, 2007: 33).
18. Peptide nucleic acid (PNA) probes are synthetic molecules that contain the same nucleotide bases as DNA, but replace the negatively charged backbone with a neutrally charged peptide backbone. The neutral charge allows them to penetrate the cell more easily than conventional DNA probes (Litaker et al., 2002a).
19. In Burkholder's early experiments, amoeboid morphs played a vital role as participants in *Pfiesteria*'s toxicity. While Burkholder et al. (2001a) still insist that amoebae are part of *Pfiesteria*'s life cycle when exhibiting toxicity, they are no longer judged to play an important role in fish attacks.

20. According to Nancy Krieger (1997), in epidemiology, the notion of a single causative agent was replaced during the mid-20th century by a 'web of causation' taking multiple environmental and social factors into account. Recently however, the view that 'each disease is caused by one agent' has regained prominence since, as one epidemiologist argues, 'the future of epidemiology lies in the search for genetic markers'.
21. The Koch Postulates appear in various versions in the literature. The version presented here follows Glasgow et al. (2001) and the one used by the VIMS researchers (available at <www.vims.edu/env/projects/Pfiesteria/Aphano.html>, accessed 29 December 2009).
22. Parrow et al. (2005) have also conducted 'contaminant free' experiments studying *Pfiesteria*'s intra-action with fish tissue. *Pfiesteria* was observed to feed on fish cells, exhibiting heightened reproductive activities. From such experiments, however, few conclusions can be drawn about *Pfiesteria*'s involvement in fish kills. What would 'killing' mean when the fish are already taken apart?
23. *Pfiesteria*-like organisms (PLOs) refer to zoospores of dinoflagellates that look similar to *Pfiesteria piscicida* zoospores (as previously defined by scanning electron microscopy) under a light microscope (Pfiesteria Interagency Coordination Workgroup, 2000).
24. Derrida insists that 'one can never distinguish between the future-to-come (*l'a-venir*) and the coming back (*revenant*) of a specter' (1994: 38).
25. Ian Hacking (1995: 94) makes a similar argument, restricting it, however, to human memories: 'a new past comes into being once events are recalled and described within a structure of causation and explanation'.
26. The determination of a range of environmental conditions under which *Pfiesteria* maintain their toxicity does not demonstrate a link between the proliferation of toxic *Pfiesteria* and nutrition pollution. However, the knowledge of these conditions is necessary in order to establish such a link in separate experiments.
27. Matters of concern are not to be confused with intentions of particular scientists nor are they solely human affairs. Here, matters of concern are also not relations or associations that replace matters of fact, as Latour (2004) proposes; they neither precede nor follow matters of fact, but rather condition them.
28. Not only does *Pfiesteria*'s phantomatic ontology call into question any securely bounded atemporal existence of these toxic dinoflagellates, but also unsettles the notion of an unbridgeable ontological difference between the 'human' and its 'animal other' on which conventional articulations of responsibility to the 'other' would rely.

## References

- Barad, Karen (2007) *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press).
- Berry J.P., K.S. Reece, K.S. Rein, D.G. Baden, L.W. Haas, et al. (2002) 'Are *Pfiesteria* Species Toxicogenic? Evidence against Production of Ichthyotoxins by *Pfiesteria shumwayae*', *Proceedings of the National Academy of Sciences USA* 99(17): 10970–75.
- Blankenship, Karl (2002) '*Pfiesteria* May or May Not Be Toxic, but the Dispute over the Issue Is', *Chesapeake Bay Journal* 12(7). Available at <www.bayjournal.com/article.cfm?article=785> (accessed 8 August 2007).
- Bowker, Geoffrey C. (2005) *Memory Practices in the Sciences* (Cambridge, MA: MIT Press).
- Bowker, Geoffrey C. & Susan Leigh Star (1999) *Sorting Things Out: Classification and Its Consequences* (Cambridge, MA: MIT Press).
- Burkholder, JoAnn M. (1998) 'Implications of Harmful Marine Microalgae and Heterotrophic Dinoflagellates in Management of Sustainable Marine Fisheries', *Ecological Applications* 8 (Supplement): 37S–62S.
- Burkholder, JoAnn M. & Howard B. Glasgow (1997) '*Pfiesteria piscicida* and Other *Pfiesteria*-Like Dinoflagellates: Behavior, Impacts, and Environmental Controls', *Limnology and Oceanography* 42(5): 1052–75.
- Burkholder, JoAnn M., Howard B. Glasgow, N.J. Deamer-Melia, J. Springer, M.W. Parrow, et al. (2001a) 'Species of the Toxic *Pfiesteria* Complex, and the Importance of Functional Type in Data Interpretation', *Environmental Health Perspectives* 109(S5): 667–79.

- Burkholder, JoAnn M., A.S. Gordon, P.D. Moeller, J.M. Law, K.J. Coyne, et al. (2005) 'Demonstration of Toxicity to Fish and to Mammalian Cells by *Pfiesteria* Species: Comparison of Assay Methods and Strains', *Proceedings of the National Academy of Sciences USA* 102(9): 3471–76.
- Burkholder, JoAnn M., H.G. Marshall, H.B. Glasgow, D.W. Seaborn & N.J. Deamer-Melia (2001b) 'The Standardized Fish Bioassay Procedure for Detecting and Culturing Actively Toxic *Pfiesteria*, Used by Two Reference Laboratories for Atlantic and Gulf Coast States', *Environmental Health Perspectives* 109: 745–56.
- Burkholder, JoAnn M., E.J. Noga, C.H. Hobbs, Howard B. Glasgow Jr & S.A. Smith (1992) 'New "Phantom" Dinoflagellate Is the Causative Agent of Major Estuarine Fish Kills', *Nature* 358 (30 July): 407–10.
- Burkholder, JoAnn M. & Howard B. Glasgow (2002) 'The Life Cycle and Toxicity of *Pfiesteria piscicida* Revisited', *Journal of Phycology* 38(6): 1261–67.
- Burreson, Eugene (1998) 'Science, Uncertainty & Policy (Sea Grant *Pfiesteria* Briefing, 19 October 1998)', Sea Grant News Media Center. Available at <[www.mdsg.umd.edu/~seagrantmedia/news/pfiest101998/burreson.html](http://www.mdsg.umd.edu/~seagrantmedia/news/pfiest101998/burreson.html)> (accessed 18 December 2006).
- Butler, Judith (1993) *Bodies That Matter: On the Discursive Limits of 'Sex'* (New York: Routledge).
- Callon, Michel (1986) 'Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay', in John Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge?* (London: Routledge): 196–229.
- Cheah, Pheng (1996) 'Mattering', *Diacritics* 26(1): 108–39.
- Coats, D.W. (2002) 'Dinoflagellate Life-cycle Complexities', *Journal of Phycology* 38(3): 417–19.
- Daston, Lorraine (2002) 'Introduction: The Coming into Being of Scientific Objects', in Lorraine Daston (ed) *Biographies of Scientific Objects* (Chicago, IL: University of Chicago Press): 1–14.
- Derrida, Jacques (1982) 'Différance', in *Margins of Philosophy* (Chicago, IL: University of Chicago Press): 3–27.
- Derrida, Jacques (1988) *Limited Inc* (Evanston, IL: Northwestern University Press).
- Derrida, Jacques (1994) *Specters of Marx: The State of the Debt, the Work of Mourning, and the New International* (New York & London: Routledge).
- Derrida, Jacques (2002) 'Marx & Sons', in Michael Sprinker (ed.), *Ghostly Demarcations: A Symposium on Jacques Derrida's Specters of Marx* (London: Verso): 249–56.
- Dewar, Heather (2002) 'Scientists Challenge Theory on Toxicity of *Pfiesteria*', *Baltimore Sun* (21 June).
- Drgon, Tomás, Keiko Saito, Patrick M. Gillevet, Masoumeh Sikaroodi & Gerardo R. Vasta (2005) 'Characterization of *Pfiesteria* Ichthyocidal Activity – Authors' Reply', *Applied and Environmental Microbiology* 71(10): 6463–64.
- Evans, A.S. (1976) 'Causation and Disease: The Henle-Koch Postulates Revised', *Yale Journal of Biology and Medicine* 49: 175–95.
- Fensome, Robert A., Juan F. Saldarriaga, F.J.R. "Max" Taylor (1999) 'Dinoflagellate Phylogeny Revisited: Reconciling Morphological and Molecular Based Phylogenies', *Grana* 38(2/3): 66–80.
- Fortun, Kim & Mike Fortun (2005) 'Scientific Imaginaries and Ethical Plateaus in Contemporary U.S. Toxicology', *American Anthropologist* 107(1): 43–54.
- Foucault, Michel (1970) *The Order of Things: An Archaeology of the Human Sciences* (New York: Pantheon).
- Gawley, Robert E. & Daniel G. Baden (1998) 'Detection and Identification of the Toxins from *Pfiesteria* and Related Harmful Algal Blooms', EPA Grant Number: R826655. Available at <[cfpub.epa.gov/ncer\\_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/10/report/0](http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/10/report/0)> (accessed 10 December 2007).
- Gilbert, Scott F. (2002) 'The Genome in Its Ecological Context: Philosophical Perspectives on Interspecies Epigenesis' *New York Academy of Sciences* 981: 202–18.

- Glasgow, Howard B., JoAnn M. Burkholder, M.A. Mallin, N.J. Deamer-Melia & R.E. Reed (2001) 'Field Ecology of Toxic *Pfiesteria* Complex Species and a Conservative Analysis of Their Role in Estuarine Fish Kills', *Environmental Health Perspectives* 109: 715–30.
- Glibert, Patricia M. & JoAnn M. Burkholder (2006) 'Toward an Emerging Consensus on the Ecology of *Pfiesteria*', *Harmful Algae* 5(4): 339.
- Gordon, Andrew S. & B. Dyer (2005) 'Relative Contribution of Exotoxin and Micropredation to Ichthyotoxicity of Two Strains of *Pfiesteria shumwayae* (Dinophyceae)', *Harmful Algae* 4(2): 423–31.
- Gordon, Andrew S., Harold G. Marshall, Sandra E. Shumway, Kathryn J. Coyne, Alan J. Lewitus et al. (2005) 'Letter to the Editor: Characterization of *Pfiesteria* Ichthyocidal Activity', *Applied and Environmental Microbiology* 71(10): 6463–64.
- Greer, Jack (1993) 'Alien in Our Midst? Phantom Algae Suspected in Bay', *Maryland Marine Notes* 11(3). Available at <www.mdsg.umd.edu/MarineNotes/Mar93/> (accessed 7 July 2007).
- Hacking, Ian (1995) *Rewriting the Soul: Multiple Personality and the Sciences of Memory* (Princeton, NJ: Princeton University Press).
- Haraway, Donna (1991) 'Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective', in D. Haraway, *Simians, Cyborgs, and Women: The Reinvention of Nature* (London: Routledge): 183–201.
- Haraway, Donna (1997) *Modest\_Witness@Second\_Millennium.Femaleman@\_Meets\_Oncomouse™: Feminism and Technoscience* (New York: Routledge).
- Hayden, Corinne (2003) 'Suspended Animation: A Brine Shrimp Essay', in S. Franklin & M. Lock (eds), *Remaking Life and Death: Towards an Anthropology of the Biosciences* (Santa Fe, NM: School of American Research Press): 193–226.
- Helmreich, Stefan (2009) *Alien Ocean: Anthropological Voyages in Microbial Seas* (Berkeley, CA: University of California Press).
- Herzig, Rebecca (2004) 'On Performance, Productivity, and Vocabulary of Motive in Recent Studies of Science', *Feminist Theory* 5(2): 127–47.
- Hinchliffe, Steve (2001) 'Indeterminacy In-decisions: Science, Policy and Politics in the BSE (Bovine Spongiform Encephalopathy) Crisis', *Transactions of the Institute of British Geographers*, 26(2): 182–204.
- Jasanoff, Sheila (1987) 'Contested Boundaries in Policy-relevant Science', *Social Studies of Science* 17(2): 195–230.
- Jasanoff, Sheila (2004) 'Ordering Knowledge, Ordering Society', in S. Jasanoff (ed.), *States of Knowledge: The Co-production of Science and the Social Order* (New York: Routledge): 13–45.
- Jasanoff, Sheila (2005) 'In the Democracies of DNA: Ontological Uncertainties and Political Order in Three States', *New Genetics and Society* 24(2): 139–155.
- Kaiser, Jocelyn (2004) 'The *Pfiesteria* Conundrum: More Study, Less Certainty', *Science* 303 (2 January): 25–26.
- Kirby, Vicki (1997) *Telling Flesh: The Substance of the Corporeal* (New York: Routledge).
- Krieger, Nancy (1997) 'Epidemiology and the Web of Causation: Has Anyone Seen the Spider?', *Social Science & Medicine* 39(7): 887–903.
- Landecker, Hannah (2005) 'Living Differently in Time: Plasticity, Temporality and Cellular Biotechnologies', *Culture Machine* 7. Available at <www.culturemachine.net/index.php/cm/article/viewArticle/26/33> (accessed 10 December 2007).
- Latour, Bruno (1987) *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press).
- Latour, Bruno (1999) *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, MA: Harvard University Press).
- Latour, Bruno (2002) 'On the Partial Existence of Existing and Nonexisting Objects', in Lorraine Daston (ed.), *Biographies of Scientific Objects* (Chicago, IL, & London: University of Chicago Press): 247–69.
- Latour, Bruno (2004) 'Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern', *Critical Inquiry* 30(2): 225–48.



- Law, John & Vicky Singleton (2005) 'Object Lessons', *Organization* 12(3): 331–55.
- Litaker, R.W., M.W. Vandersea, S.R. Kibler, V.J. Madden, E.J. Noga, et al. (2002a) 'Life Cycle of the Heterotrophic Dinoflagellate *Pfiesteria piscicida* (Dinophyceae)', *Journal of Phycology* 38(3): 442–63.
- Litaker, R.W., M.W. Vandersea, S.R. Kibler, E.J. Noga & P.A. Tester (2002b) 'Reply to Comment on the Life Cycle and Toxicity of *Pfiesteria piscicida* Revisited', *Journal of Phycology* 38(6): 1268–72.
- Lynch, Michael (1998) 'The Discursive Production of Uncertainty: The OJ Simpson "Dream Team" and the Sociology of Knowledge Machine', *Social Studies of Science* 28(5/6): 829–68.
- Macilwain, Colin (1997) 'Scientists Close in on "Cell from Hell" Lurking in Chesapeake Bay', *Nature* 389 (25 September): 317–18.
- Maurer, Bill (2000) 'A Fish Story: Rethinking Globalization on Virgin Gorda, British Virgin Islands', *American Ethnologist* 27(3): 670–701.
- Moeller, Peter D.R., K.R. Beauchesne, Kevin M. Huncik, W. Clay Davis, Steven J. Christopher, et al. (2007) 'Metal Complexes and Free Radical Toxins Produced by *Pfiesteria piscicida*', *Environmental Science & Technology* 41(4): 1166–72.
- Mol, Annemarie (1999) 'Ontological Politics: A Word and Some Questions', in John Law & John Hassard (eds), *Actor Network Theory and After* (Oxford: Blackwell): 74–89.
- Mol, Annemarie (2002) *The Body Multiple: Ontology in Medical Practice* (Durham, NC & London: Duke University Press).
- National Oceanic and Atmospheric Administration Legislative Informer (1997) NOAA Issue 25 (December).
- Oyama, Susan (1985) *The Ontogeny of Information: Developmental Systems and Evolution* (Cambridge, MA: Cambridge University Press).
- Park, Tae-Gyu, Elanor M. Bell, Imojen Pearce, Parke A. Rublee, Christopher J.S. Belch et al. (2007) 'Detection of a Novel Ecotype of *Pfiesteria piscicida* (Dinophyceae) in an Antarctic Saline Lake by Real-time PCR', *Polar Biology* 30(7): 843–48.
- Parrow, Matthew, JoAnn M. Burkholder, Nora J. Deamer & Cheng Zhang (2002) 'Vegetative and Sexual Reproduction in *Pfiesteria* spp. (Dinophyceae) Cultured with Algal Prey, and Inferences for Their Classification', *Harmful Algae* 1: 5–33.
- Parrow, Matthew W., JoAnn M. Burkholder, Nora J. Deamer & John S. Ramsdell (2005) 'Contaminant-free Cultivation of *Pfiesteria shumwayae* (Dinophyceae) on a Fish Cell Line', *Aquatic Microbial Ecology* 39(1): 97–105.
- Pickering, Andrew (1995) *The Mangle of Practice: Time, Agency, and Science* (Chicago, IL: University of Chicago Press).
- Pfiesteria Interagency Coordination Workgroup (2000) 'Glossary of Pfiesteria-Related Terms', Pfiesteria Interagency Coordination Workgroup. Available at <www.whoii.edu/redtide/pfiesteria/documents/glossary.html> (accessed 8 August 2007).
- Plotnitsky, Arkady (2003 [1995]) 'Complementarity, Idealization, and the Limits of Classical Conceptions of Reality', in Christopher Norris & David Roben (ed.), *Jacques Derrida Vol. 3* (London: Sage Publications).
- Raleigh Report (1998) 'Pfiesteria Research Needs and Management Actions', *The Raleigh Report*, Report No. SRS-19 (Raleigh, NC: The Water Resources Research Institute of The University of North Carolina Raleigh). Available at <www.ncsu.edu/wrri/publications/ralreport.html> (accessed 15 September 2007).
- Rheinberger, Hans-Jörg (1997) *Towards a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, CA: Stanford University Press).
- Rheinberger, Hans-Jörg (1999 [1994]) 'Experimental Systems: Historiality, Narration, and Deconstruction', in Mario Biagioli (ed.), *The Science Studies Reader* (New York: Routledge): 417–29.
- Ritvo, Harriet (1997) *The Platypus and the Mermaid, and Other Figments of the Classifying Imagination* (Cambridge, MA: Harvard University Press).
- Rouse, Joseph (2002) *How Scientific Practices Matter: Reclaiming Philosophical Naturalism* (Chicago, IL & London: University of Chicago Press).



- Samet, Jonathan, Gary S. Bignami, Robert Feldman, William Hawkins, Jerry Neff, et al. (2001) 'Pfiesteria: Review of the Science and Identification of Research Gaps. Report for the National Center for Environmental Health, Centers for Disease Control and Prevention', *Environmental Health Perspectives* 109(S5): 639–59.
- Shackley, Simon & Brian Wynne (1996) 'Representing Uncertainty in Global Climate Change Science and Policy: Boundary-ordering Devices and Authority', *Science, Technology, & Human Values* 21(3): 275–302.
- Shackley, Simon & Brian Wynne (1995) 'Integrating Knowledges for Climate Change: Pyramids, Nets and Uncertainties', *Global Environmental Change* 5(5): 113–26.
- Sommerlund, Julie (2006) 'Classifying Microorganisms: The Multiplicity of Classifications and Research Practices in Molecular Microbial Ecology', *Social Studies of Science* 36(6): 909–28.
- Star, Susan Leigh (1985) 'Scientific Work and Uncertainty', *Social Studies of Science* 15(3): 391–427.
- Steidinger, K.A., J.M. Burkholder, H.B. Glasgow, C.W. Hobbs, J.K. Garrett, et al. (1996) 'Pfiesteria piscicida gen. et sp. nov. (Pfiesteriaceae fam. nov.), a New Toxic Dinoflagellate with a Complex Life Cycle and Behavior', *Journal of Phycology* 32(1): 157–64.
- Tengs, Torstein, Holly A. Bowers, Howard B. Glasgow, JoAnn M. Burkholder & David W. Oldach (2003) 'Identical Ribosomal DNA Sequence Data from Pfiesteria piscicida (Dinophyceae) Isolates with Different Toxicity Phenotypes', *Environmental Research* 93(1): 88–91.
- Warrick, Joby (1997) 'The Feeding Frenzy of a Morphing "Cell from Hell"', *The Washington Post* (9 June): A03.
- Waterton, Claire (2002) 'From Field to Fantasy: Classifying Nature, Constructing Europe', *Social Studies of Science* 32(2): 177–204.
- Weston, Kath & Stefan Helmreich (2006) 'Kath Weston's Gender in Real Time: Power and Transience in a Visual Age', *Body & Society* 12(3): 103–21.
- Wynne, Brian (1996) 'May the Sheep Safely Graze? A Reflexive View on the Expert-Lay Divide', in S. Lash, B. Szerszynski & B. Wynne (eds), *Risk, Environment and Modernity: Towards a New Ecology* (London: Sage Publications): 44–83.

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