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DO SCIENTIFIC OBJECTS HAVE A HISTORY?

PASTEUR AND WHITEHEAD IN A BATH OF
LACTIC ACID

Bruno Latour

Translated by Lydia Davis

*But in the real world it is more important that a proposition be interesting than it be true.
The importance of truth is, that it adds to interest.*

*It must be remembered that the phrase actual world is like yesterday and tomorrow, in that it
alters its meaning according to standpoint.*

—Alfred N. Whitehead, *Process and Reality*

In a recent issue of *Common Knowledge*,¹ I followed in some detail the progressive transformation of a tiny piece of Amazonian forest into scientific knowledge. To do so, I multiplied mediations, replacing the huge vertical gap between words and world with a horizontal set of tiny translations from one representational medium to another. In that article, the main activity was from the human side, from the scientists and their instruments, from maps and diagrams and collections. No matter how many intermediary steps I unfolded, those steps were still portrayed by me as a way to gain access to the forest “out there.” More exactly, even though the forest “out there” was reformatted in my paper as a thing circulating “inside” the network of science, this circulating thing could not be imagined otherwise than *passive*. The Boa Vista forest, in itself, was doing nothing.

It is this passivity that I want to try to overcome in this essay. At the risk of taxing the patience of the readers of *Common Knowledge*, I will consider another piece of hard science—borrowed this time, in honor of the centenary of his death, from the story of Pasteur and the history of fermentation. What has made so many modern philosophers and theorists shun realism is the impoverished role assigned by realist philosophers to objects of scientific discovery, which apparently had no other function, no other ontological life, than to wait silently in the dark before shutting the mouths of the human agents discussing them. This silent and silencing function was what irritated, and

¹“The ‘Pédofil’ of Boa Vista: A Photo-Philosophical Montage,” *Common Knowledge* 4 (Spring 1995): 144–87.

with good reason, those who could not believe in unmediated access to truth. In their eyes, science is interesting not because it offers unmediated access to the world, but rather another form of mediation, of transcendence, of truth warmly clothed.

The question I want to ask is whether it is possible to develop a sort of realism that would offer the agents of the world a more interesting role than that of passive object. Strangely, not many philosophers are interested in this metaphysical question. No matter whether they worship or hate science, most thinkers take for granted that scientific objects, accessible or not, behave as realists believe them to behave—that is, in a passive and indifferent manner, wholly impervious to human history. The only alternatives that most philosophers can imagine are animism and anthropomorphism, horrors to which they always prefer the canonical version of objects seen *sub specie scientiae*. A. N. Whitehead is one of the interesting exceptions, and it is his “historical realism,” though largely out of fashion, that I want to use as my guide or goad for this exploration. But since I am only half a philosopher, I need an empirical site in order not to lose myself in questions that quickly become too deep for me: my project, then, will be to imagine how Whitehead would have accounted for Pasteur’s understanding of the discovery of lactic-acid fermentation in 1858.

SOME RECENT CONTROVERSIES IN SCIENCE STUDIES

*The simple notion of an enduring substance sustaining persistent qualities, either essentially or accidentally, expresses a useful abstract for many purposes of life. But whenever we try to use it as a fundamental statement of the nature of things, it proves itself mistaken. It arose from a mistake and has never succeeded in any of its applications.*²

This critique of substantialism, so important for Whitehead, could be shared by numerous historians and sociologists of science, but for very different reasons. In an account of a discovery, one should *not*, according to students of science, refer to a substance external to the human work involved in order to explain its genesis.³ Of course, like Kant, most contemporary historians, in order to avoid the extremes of idealism, do not deny the existence of such a substance, but they wish to emphasize the concrete attributes only of the mind that knows or, in more recent historiography, only of the practice of the scientific group that manipulates and demonstrates the substance within the closed and local precinct of the laboratory.⁴ According to them, in order to

²Alfred N. Whitehead, *Process and Reality: An Essay in Cosmology* (New York: Free Press, [1929] 1978), 79.

³The canonical description of this principle can be found in Harry M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage, 1985).

⁴The most developed examples can be found in Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life* (Princeton: Princeton University Press, 1985), and, more recently, Christian Licoppe, *La Formation de la pratique scientifique* (Paris: La Découverte, 1996).

criticise substantialism, one must quite simply *abstain from giving a role to nonhumans* in the story of a discovery and instead construct the account exclusively with reference to the practices, the places, the instruments, the authorities, the institutions, and the historical events furnished by the context. Such historians hope that a multitude of small determinations when added to one another will count for as much as the always-already-there substance of the old-fashioned accounts of discoveries. However, as Isabelle Stengers has clearly shown in a recent book,⁵ there is something unlikely for the practicing scientist in this approach, something unrealistic, not only in the philosophical sense of the word but also in the common meaning of improbable. Something essential seems missing from the account. Is it precisely essence that is lacking? No, and it is Whitehead's interest to imagine a realism without substance, a radical historical realism ("The Castle Rock of Edinburgh exists from moment to moment, and from century to century, by reason of the decision effected by its own historic route of antecedent occasions.")⁶

It has seemed necessary to some of us to devise what we call in our jargon "principles of symmetry" in order to do justice—without falling back on essentialism—to the feeling scientists and common sense share that something is missing from accounts of science that consider only the human side. The first principle of symmetry demanded that historians judge accounts of discovery fairly by treating on terms of equality scientists who have been wrong and those who have been right.⁷ This principle, which is opposed to the French epistemological tradition that demands one distinguish "out-of date science" from "sanctioned science,"⁸ permitted nice effects of historical drama. The victories of Boyle over Hobbes, of Newton over Descartes, or of Pasteur over Pouchet, no longer differed from the provisional victories of Napoleon over Tsar Alexander, or of Clinton over Bush. The history of science ceased to be distinguished from history plain and simple.

The price paid for this reunification was very high. The principle of limited symmetry does not equalize the possibilities of the victors (rationality) and the vanquished (irrationality) except in that the principle forbids both protagonists access to the very phenomena that they both consider their only reason for being. There is something heroic in this: nature, the symmetrical historians all say with a yogi's asceticism, does not intervene in the interpretations we make with respect to it.

⁵Isabelle Stengers, *L'Invention des sciences modernes* (Paris: La Découverte, 1993).

⁶Whitehead, 43.

⁷See David Bloor, *Knowledge and Social Imagery* (Chicago: University of Chicago Press, [1976] 1991). For a more recent justification, see the preface to the second edition.

⁸See Georges Canguilhem, *Ideology and Rationality in the History of the Life Sciences*, trans. Arthur Goldhammer (Cambridge: MIT Press, [1968] 1988), for an extreme example. See also, more recently, G. Canguilhem, *A Vital Rationalist: Selected Writings*, trans. A. Goldhammer, ed. François Delaporte (New York: Zone Books, 1994).

One can understand the motives of historians who are partisans of symmetry—they are reacting against the abuses of substantialists who are content to explain that victors in the history of science won because they were more rational or had better access to the nature of things. By insisting, for the first time, on the difficulties of the experiment, on the uncertainties of the instruments, on the irremediable localization of the methods, on the ambiguity of interpretations, on the importance of a community of more or less credible colleagues, the constructivist historians find it easy to ridicule those who believe they benefit from immediate access to the real and who take social or cognitive habits that date only from yesterday to be the permanent essence of things.

It is important, however, to avoid pressing asceticism to the point of anorexia, and this is where another, more general, principle of symmetry becomes necessary.⁹ No longer is it a matter of equalizing the possibilities for success of the victors and the vanquished by evenhandedly forbidding both groups access to the real but rather of equalizing by allowing all groups to construct simultaneously and symmetrically both their natural reality and their social reality. Like yogis who have been without food too long and forced to sleep too many nights on beds of nails, one finally allows victors and vanquished alike to gorge themselves on reality and sleep in featherbeds. This shift enables recovery from Kantianism since one no longer has to choose, in order to explain a discovery, between privileged access to the real and determination through thousands of small social or practical causes. One sees in effect that the real as a reserve or anchor against idealism had meaning only by contrast with the knowing mind (or the laboratory, or the paradigm). For every Copernican revolution, there is a counter-revolution and a half. Discoverers establish at once what they are, the world in which they are situated, and the numerous social, practical, and historical causalities compatible with the type of phenomena with which they are populating the collective. The differences among ontological, epistemological, and sociological questions become indistinct. The question becomes: In which socio-natural world do we agree to live? The principle of generalized symmetry does not abolish the principle of limited symmetry, but extends it to questions about nature and about society, and thus allows a new object to appear—the *collective* of humans and nonhumans.¹⁰

This solution, however, does not have the metaphysics of its ambitions. While no longer anthropomorphic, it remains as fragile as the meaning given to the word *collective*. If one means by that word the demiurgic activity of researchers in engendering not only nature but also society and the history in which they are situated, one comes dangerously close to the tales of the absolute idealists that believed they could go “beyond Kant.” Whereas if it is semiotic proliferation that endows humans, nonhu-

⁹See Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge: Harvard University Press, 1993), for a presentation of this principle and its consequences for anthropology.

¹⁰See B. Latour, “On Technical Mediation,” *Common Knowledge* 3 (Fall 1994): 29–64.

mans (i.e., objects in circulation), enunciative positions, and the contexts inscribed in texts with certain properties, then we are awash in discourse, in a sea of positions without subjects, and we drift farther from the realism that we were aiming for. The “superman” of the first (the demiurgic) account is abruptly followed by the “death of man” in the second. In a third account the activity of researchers is a matter of allowing nonhumans to proliferate in society as subjects, in which case we run the risk of naturalizing the whole of history without any longer being able to endow objects with their uncertainty, their transcendence, their “tremolo.” This third account relies on a will to power to anchor discourse and action in biology or in physics.

In order to be sure of escaping these three perils—being trapped in society, in language, or in nature—we must leave behind for a moment the ambiguity of the word *collective* and abandon the notions of actors, actions, subjects, objects, humans, and nonhumans that have provisionally served to enable our escape from Kantianism. Thus we must dare, like Whitehead, to have commerce with metaphysics despite the embargo declared against it by analytic philosophy as well as by constructivism.

HOW PASTEUR STAGES HIS OWN DISCOVERY OF THE LACTIC ACID FERMENT

In 1858, sometime after having discovered the fermentation of brewer's yeast, Pasteur relates, in a celebrated report to the Académie des sciences, the discovery of a yeast peculiar to lactic acid.¹¹ Today, lactic fermentation is no longer an object of discussion, and one can order by mail any quantities of yeast for dairies, creameries, and cheese manufacturers the world over. But one has only to “place oneself in the conditions of the period” to measure the originality of Pasteur's report, and thus the reward he can claim for his pains. In the middle of the nineteenth century, in scientific circles influenced by Liebig's chemistry, the claim that a specific microorganism could explain fermentation amounted to a step backward, since it was through ridding itself of obscure vitalist explanations that chemistry had only just won its laurels.¹² Fermentation could and had been explained, without the intervention of any living thing whatsoever, in a purely chemical way by the degradation of inert substances. In any case, specialists in lactic fermentation had never seen microorganisms inseparably associated with the transformation of sugar:

¹¹The English text is “Pasteur's Study of Fermentation” in *Harvard Case Histories in Experimental Science*, vol. 2, ed. James B. Conant (Cambridge: Harvard University Press, 1957), 453–60. A fuller semiotic analysis of Pasteur's report can be found in my “Pasteur on Lactic Acid Yeast: A Partial Semiotic Analysis,” *Configurations* 1 (January 1993): 127–42. For a general presentation of Pasteur's career, the best source is now Gerald Geison, *The Private Science of Louis Pasteur* (Princeton: Princeton University Press, 1995). In this article, I am concentrating on the text in order to extract from it its various ontologies, and not concerning myself with other material (as I did for the Boa Vista forest; *Common Knowledge* 4:1,144–87) that would connect me more securely to Pasteur's laboratory and method.

¹²For a description of the chemists and their professional ideologies at the time, see Bernadette Bensaude-Vincent and I. Stengers, *Histoire de la chimie* (Paris: La Découverte, 1993).

Until now minute researches have been unable to discover the development of organized life. Observers who have identified some organisms have at the same time found that they were accidental and detrimental to the process.

The facts then seem very favorable to the ideas of Liebig or to those of Berzelius. In the eyes of the former a ferment is an unstable substance that decomposes and thereby excites fermentation in consequence of its alteration which communicates a disintegrating disturbance to the molecular group of the fermentable matter. According to Liebig, such is the primary cause of all fermentations and the origin of most contagious diseases. Berzelius believes that the chemical act of fermentation is to be referred to the action of contact. These opinions gain more credit daily. . . . These works all agree in rejecting the idea of some sort of influence from organization and life as a cause of the phenomena that we are considering. (Emphasis added.)

And Pasteur quietly adds: "I have been led to an entirely different point of view"¹³ The discoverer will appear all the more involved in the process because he will have everyone against him, the unanimous opinion of the chemists as well as the scrupulous research of the specialists. The discoverer does not lift the veil behind which the yeast in lactic fermentation has always been hiding. Like the story of General de Gaulle rising from obscurity to triumph, the discoverer's story can be told as a tale of victory. But Pasteur's act was not the imposition of a framework or vision on powerless matter—though he later posed the problem to himself in these terms (as we shall see). He states, in fact, that he has been *led* to a point of view. His activity consists in allowing himself to be carried along by the "propensity of things," to adopt François Jullien's beautiful expression.¹⁴ Even when Pasteur acts to cause the yeast to emerge, in opposition to the convictions of the rest of the world, he still allows himself to be led by things—thus mingling once again the fate of a subject and an object.

For political and military history, resources exist that allow one to weigh the respective roles of *longue durée*, opportunity, circumstances, chance, individual genius, and finally the attribution of responsibility to a few individual geniuses. However, when it is a matter of accounting for beings who have been invented or discovered, the historian of science becomes more timid, more hesitant than his colleagues. The historian of science accosts one monster more than the historian plain and simple: however great may be the heterogony of factors that history summons, it is never as great as in the history of science, where one must integrate the short life of Pasteur, the longer span of the Second Empire or of chemistry, the even longer existence of alcoholic or lactic fermentations (which go back to Neolithic times), and the existence, infinitely longer,

¹³J. B. Conant, 455.

¹⁴Surprising resonances exist between Whitehead, *op. cit.*, and this admirable book on Chinese philosophy: François Jullien, *The Propensity of Things: Toward a History of Efficacy in China* (New York: Zone Books, 1995).

absolutely longer, of lactic acid yeast, always already present. *Once discovered by Pasteur in 1857*, lactic acid yeast has always already been there, from Neolithic times in the gourds of homo sapiens to the present in the whey that is souring in all the dairies on earth. How should one go about historicizing the creation of a being that seems to overflow its historical framework immediately, to go back through the whole of time and spread through the whole of space? Historians are used to dealing with the *longue durée*, but how to deal with timelessness?

The only solution consists in bestowing historicity on all elements that enter into an account. Young Louis Pasteur of Lille counts as an episode in the destiny, in the essence, in the trajectory of lactic yeast: The absurdity of a premise like this, the scandal it may provoke, is brought home if, instead of to yeast, still close to the agitated history of living things, the premise is applied to gravitation or cosmology. Newton happened to universal gravitation? The European Center for Nuclear Research happened to the Big Bang?

If, once again seeking refuge in the cozy Kantian framework, one were to speak only of *representation*, there would be no difficulty here. Pasteur would be said to transform the ideas that chemists and dairymen have formed "about" lactic fermentation, much as Newton modified our ideas about the action of distant celestial bodies. One would return more easily to history if one remained exclusively among humans with their representations, their visions of the world, their more or less passionate interests. The history of science, social or intellectual, could be deployed, like most of anthropology, with a boldness all the greater because it would be limited to representations alone, leaving the phenomena themselves out of reach. But, given generalized symmetry, we want to reach the phenomena, to emerge from the childhood home of idealism and rediscover, with realism, the risks of ontology without losing the uncertainties of history or the localization of methods.¹⁵ We must therefore explore this path, however bizarre it may appear, and speak of Pasteur as an *event that occurs to lactic acid*.

SEVERAL ONTOLOGIES WITH VARIABLE GEOMETRIES

What seemed absurd in a metaphysics of essence and attributes can become child's play for "an ontology of events and relations."¹⁶ In Whitehead's vocabulary, Pasteur's laboratory appears to us an *occasion* offered to *trajectories* of entities that *inherit* preceding

¹⁵What is involved, in fact, is attributing to the following passage in Kuhn an ontology, where, in his understanding of it, it has a psychosocial meaning: "[T]hough the world does not change with a change of paradigm," he writes, "*the scientist afterward works in a different world*. Nevertheless, I am convinced that we must learn to make sense of statements that at least resemble these. What occurs during a scientific revolution is not fully reducible to a reinterpretation of individual and stable data." Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, [1962] 1970), 121.

¹⁶I am borrowing these terms from the excellent article by John B. Cobb, "Alfred North Whitehead," in *Founders of Constructive Postmodern Philosophy*, ed. David Ray Griffin (Albany: State University of New York Press, 1993).

circumstances by *deciding* to persevere in a new way of being. Certain entities will travel through the laboratory as stabilized practices. This is the case of lactic acid itself:

Lactic acid was discovered by Scheele in 1780 in soured whey. His procedure for removing it from the whey is still today the best one can follow.

In a footnote, Pasteur adds:

First he reduced the whey to an eighth of its volume by evaporation. He filtered it and saturated it with lime to precipitate the phosphate of lime. The liquid was then filtered and diluted with three times its weight of water; into this he poured oxalic acid drop by drop to precipitate all the lime. He evaporated the liquid to the consistency of honey. . . . (Emphasis added.)

Even here, the acid is not presented as a substance durable in time and defined by its attributes but rather by a collection of verbs referring to laboratory gestures. Acid is ultimately a *procedure*, a recipe, and is coextensive with a course of action. The fact that the list of operations is long hardly matters, since each of them is part of the routine of a well-equipped chemistry laboratory. The interlocking of the subprograms does not make the essence fragile because skillful chemists have no trouble understanding the gestures for filtering, evaporating, precipitating, and because they take their arrangement as monolithic.

The same is not true for the yeast that the entire scientific community found so dubious in 1857:

If one examines carefully an ordinary lactic fermentation, there are cases where one can find on top of the deposit of the chalk and nitrogenous material spots of a gray substance which sometimes form a layer on the surface of the deposit. At other times, this substance is found adhering to the upper sides of the vessel, where it has been carried by effervescence. Under the microscope, when one is not forewarned, it is hardly possible to distinguish it from casein, disaggregated gluten, etc.; in short, nothing indicates that it is a separate material or that it originated during the fermentation. Its apparent weight always remains very little as compared to that of the nitrogenous material originally necessary for the carrying out of the process. Finally, very often it is so mixed with the mass of casein and chalk that there would be no reason to suspect its existence. It is nevertheless this substance that plays the principal role. (Emphasis added.)

The very existence of the yeast is in question, as that of lactic acid is not. There are no routinized gestures that would allow one to assure the regular presence of yeast. The entity is defined only by a “degree zero” of existence, appearing as “spots of a gray substance which sometimes form a layer on the surface of the deposit.” One could scarcely exist less! The contrast appears all the stronger in the act of defiance with which the quotation above concludes. In opposition to Liebig and Berzelius, as we have seen, Pasteur was “led to an entirely different point of view.” This thought process

depends on a conversion by which a creature of whom one does not have “reason to suspect its existence” “nevertheless plays the principal role”!

In order to follow how the yeast—criticized by everyone, invisible, a poor spot at the bottom of a glass vessel—will soon become the “only thing responsible” for lactic fermentation, the expressions “subject” and “object” must become, as one may imagine, of little use. Pasteur plays his large part in this affair, as do the yeast, Liebig, and the dairymen. We do not observe a man endowed with faculties discovering a creature defined by attributes. We see a body with multiple and partial members seeking to bring about in its laboratory, through a series of trials, a regular succession of actions:

I am going to show, first of all, how to isolate it and prepare it in a pure state.

I extract the soluble part from brewer's yeast, by treating the yeast for some time with fifteen to twenty times its weight of water at the temperature of boiling water. The liquid, a complex solution of albuminous and mineral material, is carefully filtered. About fifty to one hundred grams of sugar are then dissolved in each liter, some chalk is added, and a trace of the gray material I have just mentioned extracted from a good, ordinary lactic fermentation is sprinkled in; then one raises the temperature to 30 or 35 degrees Centigrade. It is also good to introduce a current of carbonic acid in order to expel the air from the flask, which is fitted with a bent exit tube immersed under water. On the very next day a lively and regular fermentation is manifest. (Emphasis added.)

In the laboratory, the body of Pasteur, careful and skilled, serves as the occasion, the circumstance, the concrescence of the enduring establishment of lactic fermentation. Through gestures (filtering, dissolving, adding), ingredients (brewer's yeast, solution, chalk), fixtures (faucets, receptacles, ovens, tubes), instruments for measuring (thermometers, scales, thermostats), and little tricks of the profession, fermentation becomes visible and stable. At this stage of variation, the essence of fermentation is coextensive with the deployment of practical and local circumstances.

Granting historicity to the yeast, in this instance, goes much further than a simple return to the contingencies of the period in question. It is no longer a matter simply of going back to Pasteur, trembling in his laboratory with fear that he might lose his fermentation and that his yeast might not be a “correlative to life.” The lactic fermentation is also trembling. This controlled manifestation, “lively and regular,” has never happened before, since the world began, to yeast, anywhere. The small laboratory of the dean of the faculty of science at Lille also constitutes a decisive juncture in the trajectory of this fermentation since here it becomes visible and pure. It is no longer only Pasteur who alters his “representation” of the fermentation, but the fermentation itself (in its being, in its history, in its ascents and descents) that modifies its manifestations.

If Pasteur hesitates, the fermentation is also hesitating. Ambivalence, ambiguity, uncertainty, and plasticity bother humans groping their way toward phenomena that

are in themselves secure.¹⁷ But ambivalence (etc.) also accompanies creatures to which the laboratory offers the possibility of existence, a historic opportunity. Fermentation has experienced other lives before now (1857) and elsewhere, but its new concrescence is a unique, dated, localized life made up in part of Pasteur—himself transformed by his second great discovery—and in part of the laboratory. By speaking of events defined in terms of their relations, I am sketching here the history of Pasteur and *his* yeast, of the yeast and *its* Pasteur.

FROM THE EVENT TO THE SUBSTANCE

By describing in this way the shared history of a researcher, a discipline, a laboratory, a fixture, a yeast, and a theory, one does not for all that lose the substance and its attributes, but the meaning of the word *substance* changes profoundly and becomes the gradual attribution of stable properties attached by an institution to a name lastingly linked to a practice, the whole circulating in a relatively standardized network. This transition from the event to the newly defined substance poses a formidable problem of description and interpretation from which Pasteur extricates himself through two apparent contradictions.

At the beginning of his report, the author does not yet know which properties to attribute to which essences. By the end, the yeast possesses the same solidity as that of brewer's yeast, recently discovered. The substance endowed with attributes offers a particular case of the event defined by its relations, a manner of summarizing, of routinizing, of stabilizing, of institutionalizing events. It is as though one began with attributes before coming to an essence. Let us take this transition, rarely studied, between two completely different ontological states summed up in two paragraphs of Pasteur's report:

Let us consider now what are the characteristics of this substance, the production of which goes hand in hand with those phenomena that, taken together, we call lactic fermentation. Viewed as a mass it looks exactly like ordinary pressed or drained yeast. It is slightly viscous, and gray in color. Under the microscope, it appears to be formed of little globules or very short segmented filaments, isolated or in clusters, which form irregular flakes resembling those of certain amorphous precipitates. It can be collected and transported for great distances without losing its activity, which is weakened only when the material is dried or when it is boiled in water. Very little of this yeast is necessary to transform a considerable weight of sugar. . . .

¹⁷It is the mistake of social constructivists to accord *interpretive flexibility* only to researchers actively engaged with the data. To introduce nonhumans would always amount, according to him, to silencing controversies. Inversely, Hacking has no difficulty giving a constructivist reading of social facts since it is understood, once and for all, that they can correspond to nothing but arbitrary, self-realizing prophecies. Ian Hacking, "World-Making by Kind-Making: Child Abuse for Example," in *How Classification Works: Nelson Goodman Among the Social Sciences*, ed. Nelson Goodman, Mary Douglas, and David L. Hull (Edinburgh: Edinburgh University Press, 1992), 180–237.

“Here we find all the general characteristics of brewer’s yeast, and these substances probably have organic structures that, in a natural classification, place them in neighboring species or in two connected families.” (Emphasis added.)

In the first paragraph, the essence is defined only by various trials to which one submits the anonymous “special substance,” recording responses that have recently become stable thanks to the care and skill of the scientist and to the laboratory’s genius loci. Each trial brings a new surprise: “x” can be transported without weakening! So little “x” is needed to transform so much sugar! Still, attributes float without being able to attach themselves to a substratum. One senses in the text Pasteur’s hesitations, scruples, shilly-shallying before a viscous, gray matter that resists dryness and boiling. The trial defines it in all its freshness, as though, to use the vocabulary of semiotics, one could induce *competences* only on the basis of troubling *performances*.

But in the next paragraph, the coalescence has taken place. The “special substance” no longer merely resembles brewer’s yeast, it is no longer merely composed of globules, of irregular flakes. The yeast, now named, becomes a substance and occupies a clearly locatable position in a classification by family and by species. The attributes that floated randomly become the marks of an enduring essence—not simply of a stabilized routine like the lactic acid with which we began.

How can we explain the transition from a long series of hesitant trials to a being summed up in a name? The answer of those historians of science who are inspired by the first principle of symmetry leaves no doubt. Without presupposing an organism, Pasteur never could have reduced up the long list of trials into a single yeast. According to historians of science since Duhem, one has in fact always needed a theory, a prejudice, a presupposition, a conceptual framework, a paradigm, in order to organize data that one can never encounter face to face: the inevitable return to Kant and his sociologist followers. Curiously, Pasteur asks himself the same question and seems to espouse the constructivist thesis before contradicting himself a second time:

All through this memoir, I have reasoned on the basis of the hypothesis that the new yeast is organized, that it is a living organism, and that its chemical action on sugar corresponds to its development and organization. If someone were to tell me that in these conclusions I am going beyond that which the facts prove, I would answer that this is quite true, in the sense that the stand I am taking is in a framework of ideas that in rigorous terms cannot be irrefutably demonstrated. Here is the way I see it; whenever a chemist makes a study of these mysterious phenomena and has the good fortune to bring about an important development, he will instinctively be inclined to assign its primary cause to a type of reaction consistent with the general results of his own research. It is the logical course of the human mind in all controversial questions. (Emphasis added.)

In the purest (French) rationalist tradition, Pasteur insists on the necessity of a theory in order to make facts speak and, in the same breath, brings into play practical

training in chemistry, instinctive inclinations, the “logical course” of the human mind, and personal perspective. He knows that one must follow reason to find the facts. But, in spite of the superficial resemblance to social constructivists, there is nothing in Pasteur’s rhetoric to enchant them because, without fear of contradicting himself, Pasteur goes on to the most traditional realism, and tranquilly affirms:

And it is my opinion, at this point in the development of my knowledge of the subject, that whoever judges impartially the results of this work and that which I shall shortly publish will recognize with me that fermentation appears to be correlative to life and to the organization of globules, and not to their death or putrefaction. Any contention that fermentation is a phenomenon due to contact in which the transformation of sugar takes place in the presence of the ferment without giving up anything to it or taking anything from it, is contradicted by experiment as will be soon seen. (Emphasis added.)

Give me impartial colleagues, he says, and they will recognize what the experiment incontestably affirms—the same experiment that had required after-the-fact presuppositions without which the presence of microorganisms could not be demonstrated. Pasteur ignores this flagrant contradiction and moves from a realist to a constructionist epistemology in much the way that the yeast smoothly moves from event to substance.

Before reading Whitehead, I could not extricate myself from this dilemma. It seemed that we always had to choose between two evils: Whitehead opens a new possibility and allows us to understand why the contradiction is only apparent. Lactic-acid yeast changes its history upon contact with Pasteur and his laboratory. It is quite real, but its historical reality puts it on an equal footing with the researcher and the laboratory in which it is involved. Lactic acid has also changed. The yeast has taken the little push that Pasteur has given it as a historic opportunity to manifest itself by altering its entire trajectory. The yeast proposes, Pasteur disposes. Pasteur proposes, the yeast disposes. Pasteur has not imposed his views on an infinitely plastic form, nor tentatively discovered the resistance of an infinitely robust form; he has given a phenomenon its chance. This is why, writing his report, he sees no contradiction between his realist and constructivist rhetoric, though everything distinguishes them in the eyes of an epistemologist or a social historian. An ontology, even more counterintuitive than that of the social history of science, allows us to follow the common sense of a scientist:

The experimenter, a man of conquest over nature, finds himself ceaselessly at grips with facts that are not yet manifested and exist, for the most part, only potentially in natural law. The unknown in the possible and not in what has been—this is his domain. (Emphasis added.)¹⁸

¹⁸Louis Pasteur, *Oeuvres complètes*, 7 vols. (Paris: Masson, 1939), 7:334.—*Trans. L. Davis*

TESTED BY WHITEHEAD

Why does positing the historicity of all things, even though this solution may in the end be reconciled with common sense, appear at first sight so unlikely, so senseless? Because of our ideas about nature, about transcendence, and about causality, ideas that Whitehead allows, profoundly, to dismiss.

Suppose we were to calculate the ingredients that enter into the composition of lactic yeast of 1857 in order to understand the coproduction of this scientific fact. Once the accounts of discovery in the old mode have been abandoned, along with the more recent accounts of social construction, we must draw up a heterogeneous list that includes, among many other factors, Pasteur, the Faculty of Science at Lille, Liebig, cheesemongers, laboratory apparatus, brewer's yeast, sugar, and lactic yeast. There is no essentialism in this list since each entity is defined only by its relations. If the relations change, the definition changes similarly; the Faculty of Science with and without Pasteur is not exactly the same Faculty; sugar with and without lactic yeast is not quite the same sugar; lactic yeast after and before 1857 is not at all the same yeast.

But history cannot be defined by a simple rearrangement of factors. History is not created from already made ingredients. To avoid the jangling of combinations, the atomism of factors, we must thus recognize in every compound, in every condescence, something more, some radical and unique capacity for innovation—and, to do so, we must accept the fact that events, to deserve their name, are in part without cause. As absurd as that appears, realism demands that one abandon the idea of causality as compulsory movement or as a displacement of forms. The discovery of lactic yeast in 1857 is not due to a dispersal of infinitesimal conditions that defy calculation but of which each, nevertheless, acts as a cause. For there to be history, the yeast-of-1857-at-Lille-with-Pasteur must in part be *causa sui*.¹⁹

Nowhere in the universe does one find a cause, a compulsory movement, that permits one to sum up any event in order to explain its emergence retrospectively. If it were otherwise, one would not be faced with an event, with a difference, but only with the simple activation of a potential, the mere actualization of a cause.²⁰ Time would *do* nothing and history would be in vain. The discovery-invention-construction of lactic yeast requires that it be given the status of a mediation, that is, of an occurrence that is neither altogether a cause nor altogether a consequence, nor completely a means nor completely an end.

Pasteur can be understood as an event occurring to lactic yeast because he is unfore-

¹⁹"All actual entities share with God this characteristic of self-causation. For this reason every actual entity also shares with God the characteristic of transcending all other actual entities, including God." Whitehead, 223.

²⁰This is also the argument of the most Whiteheadian French philosopher, Deleuze. See especially Gilles Deleuze, *Le Plî: Leibniz et le baroque* (Paris: Minuit, 1988), and the remarkable small book by François Zourabichvili, *Deleuze, une philosophie de l'événement* (Paris: Presses Universitaires de France, 1994).

seen, external to the history that until then defined the “society” of the microorganism, its trajectory, its heritage. To find itself in a laboratory, there to be scattered, cultivated, redescribed, purified, diverts the yeast in an unpredictable way. At the same time, the lasting presence of a yeast associated with a fermentation, the chemical activity of a living creature, constitutes, for Pasteur, a decisive branching out of his career and identity. As for the chemists, by accepting Pasteur and his yeast, they become, through a decisive translation, biochemists. No ingredient, as we can see, enters into these relations without changing its nature.

As long as one made nature the kingdom of causes, to speak of a historicity of *things* seemed improbable: inventiveness, flexibility, hesitation, could only come from humans and their painful history. They alone could transcend the brutal realm of objects, affirm their freedom against the viscous constraints of the “practico-inert,” to use Sartre’s expression for the antipodes of freedom. By linking humans and nonhumans, the principle of generalized symmetry causes a small scandal, since it amounts to extending the notion of personhood to creatures of nature—panpsychism, hylozoism—or, on the other hand, to plunging human invention into the more or less predictable game of causes—mechanism, social engineering.²¹

What a difference it would make if all entities left behind, transcended, exceeded to some degree their causes, their histories, their ancestries! The objects of nature no longer offer as their only ontological model the stubborn, obstinate, headstrong, silent demand of substance. Nothing thus prevents us from granting them a role in the fabrication of the human world, and doing so does not require our returning to the old-style realism that social historians rightly fought, nor does it open us to the accusation of granting to nonhumans that intentional personality heretofore reserved for humans. Nature shares with society the same historicity, but the unified whole does not become either immanent or transcendent, impersonal or personal, animated or inanimate. The transcendence necessary to innovation is distributed through all the little uncouplings through which effects leave behind their causes. The history of science becomes once and for all an existentialism extended to *things*. Nature, by becoming historical,²² becomes even more interesting, more realistic.

As for nature’s contrary, culture, it is transformed even more thoroughly, and may be reconciled more completely with common sense. In culture, one is therefore not

²¹The transition from cause-and-effect analysis to a conception of order through disorder has curiously not changed this alternative, despite Ilya Prigogine and I. Stengers, *Entre le temps et l'éternité* (Paris: Fayard, 1988). The notion of emergence, though very Whiteheadian, does not necessarily imply the symmetrical historicization of nature and society.

²²This historicity must not be confused with a transformation in time of particles or living creatures such as are discussed in cosmological or evolutionist accounts as, for instance, Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton, 1989). Inverting the anthropic principle causes scientists to enter the history of things. One not only recounts how the dinosaurs disappeared but also how paleontologists participate in the very history of the dinosaurs—two complementary but distinct historicities.

forever a prisoner of language, locked into conceptual frameworks, forever deprived of all access to things themselves, on which, as for Kant, we could only impose arbitrary categories. Our minds, our societies, our paradigms are no longer so many closed circles. Despite his hesitations, Pasteur does not dictate to the facts how they should speak. He *mingles* with them. He does not discover them any more than he fashions them.

Whitehead pleasantly makes fun of philosophers who believe our minds are connected to the world by the fragile footbridge of perception alone, as though a great city, until then open to the surrounding countryside, had decided to enclose itself gradually behind ramparts, permitting no passage except by way of a narrow postern gate and a shaky drawbridge. All philosophy of knowledge arises, he argues, from this *artificially* maintained fragility, as though the mind constantly risked losing its precious provisions. But if you demolish the ramparts, authorize other passages, open wide the city to the countryside, do away with city taxes, contacts between the mind and the world will not be lacking. There is no risk of an embargo on importations, since, no longer ascetics, we would no longer be obliged to deprive ourselves of summoning the things of nature, which would then be broadly accessible because transcendent like us, historical like us, heterogeneous like us.

By sharing transcendence with objects and gaining access to them through the thousand conduits of language, of practice, of social life, we are no longer bound to file items exclusively under the heading of nature or society or discourse. It is enough to place them in “networks”—but while that word used to be employed in a vague sense, it can have, thanks to Whitehead, the ontology of its ambitions. Every item or circumstance exactly fills, without supplement or residue, its unique spatiotemporal envelope. There exists nothing, not lactic yeast, not universal gravitation, that “would overflow” the historical conditions of its emergence—which does not mean, however, that everything is the result of human work alone, as social constructivists feel always obliged to conclude. Again, we do not have to choose between these two versions. In order for an item or circumstance to extend and thus give the impression of “overflowing,” it requires other historical conditions, other vehicles, other mediations, other underpinnings—each partially causes of themselves.

We would not find this historicization difficult except that we make unconsidered use of the two pairs of adverbs *always/never* and *everywhere/nowhere*. Since the emergence in 1857 of lactic acid, we have concluded that it has *always* been there and that it acts equally *everywhere*. From the time of Pasteur’s destruction of Liebig’s theory about fermentation through degradation of substances, we have concluded that it has *never* been present, *anywhere*—a double exaggeration that makes the history of things coalesce and then obliges one to invent, by contrast, those accounts of discovery that I criticized at the opening of this essay. Because yeast has always existed, a fact unknown before 1857, Pasteur must necessarily have discovered it by lifting a veil that concealed it. But Pasteur, his colleagues, the cheesemongers, the dairies, the historians, must

work hard in order to extend into the past the retrospective presence of lactic-acid yeast. Scientists and historians work like software companies that, for a modest sum, will replace version 2.1 of your program with the new version 2.2, retrofitting all the new advances without (so you hope) endangering your earlier programs. In the case of the lactic-acid yeast, enormous work is necessary also in space as well as time to extend to all dairies and cheese manufacturers the presence, soon “universal,” of lactic yeast. Still more work must be done to eliminate Liebig’s version from history and gradually eliminate it from scientific manuals—until the “discovery” of enzymes, later in the century, which newly reshapes fermentation, Pasteur, Liebig, and the retrospective history of biochemistry. Lactic yeast, in the course of its history, never exaggerates either its existence or nonexistence, its locality or universality. Like other entities, it perseveres in its being, however tiny, in certain places, for a certain time, on condition of existing in common with many others that also decline to acquiesce either to substance or nothingness, but “decide,” at the turning points, on their history. Like fibers, lineages, trajectories, heritages, societies, rhizomes.

I hope that I have shown, as I promised, that Whitehead’s metaphysics allows us to help the philosophy of the history of science—blocked for some time on the question of the role that ought to be given to nonhumans—to take a small step forward. It is perfectly possible to reconcile skepticism and realism, provided historicity be thoroughly granted to nonhumans as well. A little historicity spawns relativism, a great deal engenders realism.