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Transubstantiation in Science. Review of Anglea Creager, Elizabeth Lunbeck, and M. Norton Wise, *Science Without Laws: Model Systems, Cases, Exemplary Narratives*; Jessica Riskin, *Genesis Redux: Essays in the History and Philosophy of Artificial Life*

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**Abstract**

These two volumes made me think about transubstantiation, the process through which something retains its form, color, and shape, yet becomes, *in reality*, something else. The usual example is the transformation of bread and wine into the body and blood of Christ, in the Roman Catholic ritual of the Eucharist. Transubstantiation is a standardized miracle (the repetitive, guaranteed miracle of the Mass, offered four times a day). The miracle requires dense layers of social and rhetorical labor, and in this sense, it is not unlike the work of using models in *Drosophila* genetics, plate tectonics, or primatology. But I have something a bit grander in mind.

**Disciplines**

History of Religion | History of Science, Technology, and Medicine | Liturgy and Worship

## Transubstantiation in Science

BY SUSAN LINDEE\*

ANGELA N. H. CREAGER, ELIZABETH LUNBECK, AND M. NORTON WISE, eds. *Science Without Laws: Model Systems, Cases, Exemplary Narratives*. Durham, NC: Duke University Press, 2007. 287 pp., illus., index. ISBN 978-0-8223-4046-1. \$22.95 (cloth).

JESSICA RISKIN, ed. *Genesis Redux: Essays in the History and Philosophy of Artificial Life*. Chicago: University of Chicago Press, 2007. xv + 389 pp., illus., ISBN 978-0-226-72080-7. \$25.00 (cloth).

These two volumes made me think about transubstantiation, the process through which something retains its form, color, and shape, yet becomes, *in reality*, something else. The usual example is the transformation of bread and wine into the body and blood of Christ, in the Roman Catholic ritual of the Eucharist. Transubstantiation is a standardized miracle (the repetitive, guaranteed miracle of the Mass, offered four times a day). The miracle requires dense layers of social and rhetorical labor, and in this sense, it is not unlike the work of using models in *Drosophila* genetics, plate tectonics, or primatology. But I have something a bit grander in mind.

My invocation of transubstantiation reflects the subjects explored in the papers collected in these volumes, and the spookiness that they collectively conjure. These include an intimidating little praying monk, memorably described by the sculptor Elizabeth King; the almost magical prisoner's dilemma in Mary Morgan's deft and refreshing perspective; divine sex ratios in Eliot Sober's study; and angels who build chess-playing machine-humans in Adelheid Voskuhl's contribution. Bernadette Bensaude-Vincent introduces us to immortal nanobots, and Carlo Ginsburg looks at biblical justifications for colonial relations. Clifford Geertz explores rituals as personalized model systems for anthropologists,

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*Historical Studies in the Natural Sciences*, Vol. 39, Number 2, pps. 248–257. ISSN 1939-1811, electronic ISSN 1939-182X. © 2009 by the Regents of the University of California. All rights reserved. Please direct all requests for permission to photocopy or reproduce article content through the University of California Press's Rights and Permissions website, <http://www.ucpressjournals.com/reprintinfo.asp>. DOI: 10.1525/hsns.2009.39.2.248.

nodding to his own fate—linked forever to a Balinese cockfight—and to that of the Roman Catholic Victor Turner, similarly identified with his ethnography of the Ndembe *mukanda*. Immortality, magic, biblical injunction, ghosts, rituals, and prayers are threaded through these essays in almost disorienting ways. Producing the Eucharist and producing science both engage with the scary demilitarized zone between the material and the spiritual.

The things that act on history in *Science Without Laws* and *Genesis Redux* retain form yet become in reality something else, not just standing in for other things, but functionally becoming phenomena that are distant, extremely large, highly complex, or emotionally and politically charged. Models become the empirical data that justify other models; robots become “caregivers,” whether they care or not; virtual body language provides a way to research the meaning of embodiment; fake dilemmas undermine practical experience. Models are sometimes the things signified in an effort to understand faraway events (or distant in time as in Naomi Oreskes’s account of geological models), and made things imitate and possibly trick human observers (Embodied Conversational Agents who perform small talk in Justine Cassell’s study, or Shakespeare’s Hermione, who pretends to be an automaton, in Scott Maisano’s paper). Perhaps the imitation of life by models and automata stirs up ghosts, angels, and immortality, both for the technical experts and for the anthropological and historical observers who consider it in broader contexts. In these stories about what people do with stuff, we see how symbolic force travels with material things.

The stated goal of the Creager, Lunbeck, and Wise volume is to reopen questions about relationships between natural and human sciences by considering the representative and representational functions of simpler or smaller models of events too large or too complicated to study directly. The editors also express an interest in what looks portable, how things are transformed, and what makes anything relevant to anything else. They pay unique attention to what is concrete, physical, and material in modeling, rather than to its philosophical and theoretical implications, and emphasize the use of models or exemplars in a wide range of disciplines including history and anthropology. “We want to show how the model-systems approach so pervasive in biology compares with the use of cases, exemplars and related methods in other fields. . . . it appears that many of these approaches grew up in response to the challenge of producing something like lawlike knowledge in disciplines in which laws seemed incapable of capturing the specificity and complexity of organisms, geological processes, or human productions.” (4) They ask how these different kinds of substitutions raise related analytical problems, and they suggest that approaches

that have helped us to understand fruit flies and mice can be applied productively to fuzzy things like ritual, baboon troops, or psychoanalytic narrative, to reconfigure our understanding of the nature/culture boundary. Their ability to toy with our sense of what constitutes a model has produced a volume that is provocative in its juxtapositions. The papers range widely from the biologist E. Jane Albert Hubbard's cheerful and uninflected story of the potential benefits of model organisms, to John Forrester's disturbing account of voyeurism as a form of specificity in modeling in the human sciences.

The canonical model in biology, of course, is a small living thing that shares some relevant traits with the subject of interest.<sup>1</sup> As Rachel Ankeny's essay suggests, the creation of the original descriptive model often reflects specific scientific interests that cohere around an organism that presents "natural" opportunities for scientific cultivation. The nematode worm *C. elegans* entered laboratories in the 1960s, offering a potential model for developmental studies of the nervous system. The model was refined and reshaped over time to conform to its intended uses. The "wild type" (the unwittingly ironic moniker for the standardized version created and used in the laboratory) may be a necessary fiction, she suggests, constructed through descriptive models that idealize whatever aspect of the organism is considered important to its use. But when interests and priorities change, models often stand still, and once a model is stabilized, it is less open to being disrupted by the peculiarities of any particular organism. The use of model organisms involves a messy interplay between the original descriptive models and the questions that interest researchers at any given time. Ankeny's paper fits recognizably within the rich literature on model organisms that has developed over the last twenty years, and contributes a keen perspective on the philosophical quandaries of case-based reasoning.

But how do these questions look when they are applied to living organisms that are not in the laboratory? In her study of the ways that the baboon troop became a model for human society, Susan Sperling explores the baboon troop

1. Some of the texts exploring how animals matter to science and culture include Robert E. Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994); Karen Rader, *Making Mice: Standardizing Animals for Biomedical Research, 1900–1955* (Princeton: Princeton University Press, 2004); Donna Haraway, *Primate Visions: Gender, Race and Nature in the World of Modern Science* (New York: Routledge, 1990). From a somewhat different perspective, see Leo Slater, "Malarial Birds: Modeling Infectious Human Disease in Animals," *Bulletin of the History of Medicine* 79, no. 2 (2005): 261–94; and on corn, see Nathaniel Comfort, *The Tangled Field: Barbara McClintock's Search for the Patterns of Genetic Control* (Cambridge, MA: Harvard University Press, 2003).

“ranging across the savannahs of postwar anthropology” (74) and the “cosmological slot” (75) that these troops have come to occupy, as representatives of primitive human society. In a familiar story, addressed by Donna Haraway and in later work by others, the behaviors of baboons were confidently read into the gender system so that baboons had a “division of labor” which replicated social arrangements called into question by postwar feminism. The model system, in this case, required a fairly selective set of questions and observations. Some things about baboons had to be studiously ignored in order for them to represent primitive human society.<sup>2</sup> But this may, as Ankeny suggests, be the norm in model systems.

Mary Morgan’s account of the development of the Prisoner’s Dilemma (PD) as a model system turns this problem the other way around. The model has no “natural” existence that can challenge anyone’s theories—indeed, it involves imagining situations that are unlikely and even bizarre in some formulations—yet it stirs up trouble anyway for those who take it seriously.<sup>3</sup> The PD was described and named by the Princeton mathematician Albert Tucker in a popular lecture in 1950. He did not invent the game, which had already been explored at RAND, but he provided an enduring narrative to explain it: Two suspects are taken into custody and separated. The district attorney gives each of them the choice of either confessing or not confessing to the crime which the police are sure they have committed. Neither will know what the other chooses to do, but if neither of them confesses, the district attorney says he will book them on some trumped-up minor charge, and they will receive minor punishment. If they both confess, they will be prosecuted but he will recommend less than the most severe sentence. But if one confesses and the other does not, the confessor will receive lenient treatment for turning state’s evidence, while the

2. See also Gregory Radick, *The Simian Tongue: The Long Debate about Animal Language* (Chicago: University of Chicago, 2008); Donald Dewksbury, *Monkey Farm: A History of the Yerkes Laboratories of Primate Biology, Orange Park, Florida, 1930–1965* (Lewisburg, PA: Bucknell University Press, 2005); Amanda Rees, *Natural Born Killers? Infanticide and Field Primatology* (Chicago: University of Chicago Press, forthcoming).

3. Morgan offers the following particularly disorienting variant on the dilemma: “You, your spouse and your mother are kidnapped by mad scientists and placed in a room with a strange machine. All three of you are bound immobile to chairs. In front of you is a push button within reach. A machine gun looms in front of your spouse and mother, and a menacing clock ticks away on the wall. One of the scientists announces that if you push the button, the mechanism will aim the gun at your mother and shoot her dead. If you don’t push it within sixty seconds, it will aim and fire at your spouse.” (160) She is quoting W. Poundstone, *Prisoner’s Dilemma: John von Neumann, Game Theory, and the Puzzle of the Bomb* (New York: Doubleday, 1992), 265.

latter will be subjected to the most vigorous penalties possible. The problem is that if both prisoners attempt to maximize their individual gain (by turning state's evidence, in the hope that their collaborator will deny involvement in the crime), they both end up with a worse outcome than if they had collaborated in denying the crime.

However peculiar in its precise social details (do district attorneys do this sort of thing?), the PD became an important focus of research in neoclassical economics, and Morgan shows that the model retained its utility even though it undermined the discipline's fundamental rationale. Despite all expectations, from Adam Smith onward, results from experimental tests of the PD suggested, repeatedly, that the invisible hand was probably not benevolent. Rational economic man, who inhabits economic theories, unfortunately seems to act "rationally" in the PD cases in ways that produce penalties rather than rewards. Economists themselves recognized their own dilemma and Morgan explores how they turned "their favorite creature into a caricature" (165) as they tried to preserve both his rationality and the benevolence of his self-interest (*Homo economicus* is male). Theoretical and experimental accounts of the PD did not cohere and economists gradually came to a point of cognitive dissonance, holding and supporting two conflicting beliefs: that individuals left to pursue their own self-interest will necessarily reach mutually beneficial outcomes, and that this does not necessarily occur. Morgan notes that the apostrophe matters, with "Prisoner's Dilemma" used by economists when they are referring to individual rationality, and "Prisoners' Dilemma" used to refer to the problem of invisible hand outcomes. The development of the PD game suggests that it is a model much like a fly. It is a simplified, small exemplar that is expected to illuminate larger systems, and while it does not come from nature, it brings into these larger systems its own partialities and limitations.

For Naomi Oreskes, larger systems, including global political systems, modulate the models. The development of modeling in geology provides a striking case study of patronage, as geology moved from historical to predictive models and from the comfortable domain of neutral science to the highly charged political world of nuclear risk. In some ways this is a widely recognized transition, reflected across many disciplines that had militarized over the course of the twentieth century.<sup>4</sup> But Oreskes provides a detailed and documented account of the

4. David Edgerton provides an account of some elements of the impact of militarization on science in his *Warfare State: Britain 1920–1970* (Cambridge: Cambridge University Press, 2006); also see his "British Scientific Intellectuals and the Relations of Science, Technology and War" in *National*

striking way models were constructed in response to the militarization of geology. The change in the way *models* were constructed is particularly striking in geology. Traditionally geological models were intended to replicate processes in earth history, involving tabletop experiments with pressurized layers of clay or cloth that imitated the earth's crust under pressure. As the need to imagine nuclear waste disposal became a part of the field's social and political role, geologists began to model events that they would not and could not experience. Instead of a deep past, geologists became overseers of a deep future, producing predictions that could never be tested by those who made them. What kind of models are these? In Amy Dahan Dalmedico's account, climate modeling has similarly surreal qualities. In theory, a model of climate change can be tested for accuracy by comparison with observed climate. But in the transition from meteorology to climatology, occurring in the same period as the transition for Oreskes's geologists, simulations acquired stronger evidentiary status. Models themselves came to generate input for other models, and the climate scientists, like the geologists, began to approach problems of the deep future. To do this, Dahan Dalmedico suggests, they drew on methods not unlike those on display in these volumes: anti-reductionism, transdisciplinarity, disunification.

Creager, Lunbeck, and Wise have pulled together a range of commentaries on modeling. They propose a broad definition of modeling in which there are some shared qualities among models across the humanities, the social sciences, and even the physical sciences. As they note, models even in the laboratory sciences are rarely mirrors of reality. They play a foundational role in some disciplines—genetics among them—and model systems in these sciences often have parallel lives, within the laboratory and outside it. Fruit flies, for example, hang out around fruit and seek out humanized habitats all on their own, as my colleague Robert Kohler reminded us long ago.<sup>5</sup> The parameters critical to *Drosophila's*

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*Military Establishments and the Advancement of Science and Technology*, ed. Paul Forman and Jose M. Sanchez-Ron (New York: Spring, 1996). My student Roger Turner's work on the relationships between the rise of air power and the intellectual world of meteorology is directly relevant, because meteorology as a science was transformed by the need to understand the upper atmosphere. See Roger Turner, "Teaching the Weather Cadet Generation: Aviation, Pedagogy, and Aspirations to a Universal Meteorology in America, 1920–1950," in *Intimate Universality: Local and Global Themes in the History of Weather and Climate*, ed. James R. Fleming, Vladimir Jankovic, and Deborah R. Coen (Sagamore Beach, MA: Science History Publications, 2006), 141–73. See also Christopher Simpson, *Science of Coercion: Communication Research and Psychological Warfare, 1945–1960* (New York: Oxford University Press, 1996), and Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, NJ: Rutgers University Press, 2005).

5. Kohler, *Lords of the Fly* (ref. 1).

scientific value have changed over time, Marcel Weber suggests in his paper in this volume, and the fly is presumably a repository of future (at this point unclear) information that could lead to another biosocial redesign. But something similar is true of stories about prisoners, of climate measurements, of narratives of sexual excitement, and of historical case studies. They have meanings not wholly encompassed by expert interpretations, and what they can teach us changes with time. Models are both made and discovered, constructed and revealed.

*Genesis Redux* might be seen as a more narrow examination of a particular kind of model, focusing on the questions raised by artificial things that mimic or model or stand for “life.” Modern concerns with artificial intelligence and emotionally manipulative robotic creatures are the well-recognized and much-discussed examples of such things, but the subjects here include other forms of mimicry and substitution, such as automata, mandrakes, nanotechnology, and virtual aquaria. Editor Jessica Riskin has framed the essays partly in terms of what they do not do: They are not just about devices, reducing life to a device, or continuities between the curious automata of Fontana and other early engineers, and contemporary notions of replicants or artificial intelligence. Instead, she proposes, the collection explores the “changefulness and contingency of all views of life and mind.” (3) Tellingly, Bensaude-Vincent proposes that the field of biomimetics rests on circular logic that seems to appear and reappear in these essays: Biological objects are described as machines, and then used as models for making machines that are expected to mimic biology.

There are seven papers here dealing in one way or another with automata (some of them excellent), but I was most intrigued by the playful “Perpetual Devotion” in which Elizabeth King explores a sixteenth-century praying machine made in Germany or Spain. The sixteen-inch monk wears a rough robe and runs by a wind-up mechanism contained in its body. Almost entirely preserved in its original form in the National Museum of American History, the monk (still) walks, strikes its breast, and brings a cross to its lips in a trancelike repetitive motion. King reports that “everyone who sees the monk in action agrees that it is intimidating” and when it was removed from one of the museum’s galleries “some of the staff were actually relieved.” (274) Though some questions remain about its origins, it is possibly associated with the saint San Diego del Alcalá; the clockmaker Juanelo Turriano; and the grievous illness of the actual Don Carlos, whose story forms the basis for Verdi’s opera. King’s approach to the monk is literary and thoughtful, as she asks what this moving object meant to those who made it and what it means to us today. She draws on David Freedberg’s work on images that bled or wept real tears and that

produced a strong devotional response in witnesses, a response that Freedberg calls “reconstitution.”<sup>6</sup> In his account, this reconstitution is performed by the believing observer, who fills in the gap between sign and signified. Holy things, he notes, are not metaphorical. They do not represent or exemplify something else. Rather, they are actually the thing itself, just as the bread and wine are emphatically *not symbols* in the Catholic sacrament of the Eucharist. A *statue* of the Virgin is the virgin, Freedberg suggests, and he wishes to extend this process of constitution and reconstitution to other domains, to suggest that general emotive responses to objects (to anything that stirs up feelings, perhaps like the little monk) are implicated in “the transference of spirits to inanimate objects,” producing the “degree of life or liveliness believed to inhere in an image.” (276) The presumption of a life-granting force within the body that is not reducible to material explanation thus plays tricks on us. Material and visual things pick up spirits as they move, weep, and inquire about real estate.

REA (Real Estate Agent) is a “near human” virtual real estate agent whose words, body language, and patterns of speech were developed based on five years of behavioral research with real estate agents and their clients. In Justine Cassell’s account, “the result was a virtual woman who tried to sell a home to whomever approached her.” (353) Cassell, like King, is interested in the ways that human beings respond to things that are “alive enough” to produce an emotional response. Embodied Conversational Agents like REA do not have bodies at all. They are cartoon-like, often life-sized depictions of virtual humans that are projected on a screen, with images of bodies that look more or less human, and with some conversational repertoire and apparent autonomy. As a communications scholar and computer scientist, and director of the ArticulationLab research group at Northwestern University, Cassell has focused her research on figuring out how to maximize this kind of human-virtual emotional engagement by studying how body language works and applying her results to virtual bodies. Her “partial and imperfect” (349) imitations of human behavior have taught her how much there is to imitate. The group’s effort to create a conversational agent that would give people directions was “ridiculous” and violated “our intuitions about how direction-giving should look.” (348) REA, who had to try to sell houses, was more subtle and could perform human face-to-face conversation with a better range of responses, hand gestures, and timing. Some people found her comfortable and trustworthy and actually engaged her in prolonged small talk. The irony of using

6. David Freedberg, *The Power of Images: Studies in the History and Theory of Response* (Chicago: University of Chicago Press, 1989).

disembodied images to experiment with the informational content of body language shines a light on the gap that concerns King (and Freedberg in her reading) between sign and signified. Reading the visual “body” language of a disembodied real estate agent involves reconstitution and the transference of “spirits.” Even small talk is deep in the forest of symbols.<sup>7</sup>

In her introduction, Riskin identifies the long tradition of attempts to create something that is both artificial and alive as an effort to “sound the Sistine gap.” (1) That’s her term for the open space between the index fingers of God and Adam in Michaelangelo’s portrait of creation, on the ceiling of the Sistine Chapel. Turning the human mind into a machine is almost the complete opposite of turning a simple thing like unleavened bread into the body of a god. In transubstantiation bread moves up into the realm of eternal purity and transcendence; it becomes the body of the Savior. In the creation of intelligence that is not human, spirit and mind become ropes and pulleys. Bread moves up; the mind moves down; but they both move across Riskin’s gap and the essays collected here suggest how haunted that space has been.

Even those hoping that the mechanical can dispel the mystical have been disappointed: The fifteenth-century engineer Giovanni Fontana, in Anthony Grafton’s paper, designed automata as part of a disenchantment project. Fontana’s plans for a moving, winged she-devil, Grafton suggests, were part of a larger project to treat magical traditions with mechanistic skepticism. Supposedly wonderful or supernatural objects were not omens, Fontana proposed, but illusions that he could replicate. His drawing of a she-devil, which could supposedly breathe fire, was much like the devils that appeared in fifteenth-century frescoes in Rome. Yet it mechanistically operated with pipes and ropes. Underneath an exterior that could easily mislead a crowd was a simple work of human ingenuity. The engineer, then, was a practitioner of new arts that could replicate and thereby undermine the supernatural.

Grafton’s account is persuasive, but Fontana and his peers freighted these automata with weight they could not bear. The machines were supposed to dispel the spirits, to prove that there was nothing to fear, but the trick does not al-

7. Geertz makes the somewhat elegiac claim in the Creager, Lunbeck, and Wise volume that “elaborate, inclusive ritual systems pacing the whole or greater part of life and directing its course are hardly prevalent in the contemporary world (though caste may be one example, sharia another). The forest of symbols has been everywhere thinned or cut down, and it is a good deal more difficult to see what use there might be in looking into the sort of dispersed and peripheral ritual—from Halloween and birthday parties to the Super Bowl and loyalty oaths—that does exist. What are we to make of our own conjurations and passages?” (220)

ways work. The human origins of made things that can engage us in small talk are not reassuring. Artificial intelligence and care-giving robots for the elderly have spooky properties, producing social experience and empathy, even when we know that the robots are just things, just machines made by people. And the mechanistic and quantitative solidity of climate models that build on other climate models, and of geological predictions that can never be tested, make them more strange, rather than less. The mechanisms start to look non-mechanistic: the numbers cascading into the distant future start to look like dreams. At the moment of consecration, the host still looks like bread, but it has become, by consensus, something else entirely.