twenty-first century. In 1991 she and Pasko Rakic founded the journal *Cerebral Cortex*. As the chief coeditors, they made that journal into the premier publication for basic cortical research.

Patricia Goldman-Rakic received numerous honors and awards. She was elected president of the Society for Neuroscience in 1989; she was elected to the National Academy of Sciences (U.S.) in 1990, the American Academy of Arts and Sciences in 1991, and the Institute of Medicine of the National Academy of Sciences in 1994. She received France's Fyssen Prize in Neuroscience in 1990, the Merit Award of NIMH in 1990, the Lieber Award for the National Alliance for Research on Schizophrenia and Depression in 1991, the Karl Lashley Award of the American Philosophical Society in 1996, the Ralph Gerard Award of the Society for Neuroscience in 2002, and the Gold Medal for Distinguished Scientific Contributions from the American Psychological Association. She was awarded a *doctor honoris causa* from the University of Utrecht in 2000 and an honorary degree from St. Andrews College of the University of Edinburgh in 2003, just a few months before her death.

Goldman-Rakic died at the age of sixty-six on 31 July 2003 from injuries sustained when a car struck her as she was crossing a street in Hamden, Connecticut. At the time of her death, she held appointments at Yale as professor in the Departments of Neurobiology, Psychiatry, Neurology, and Psychology. She was struck down at the pinnacle of her career and died one of the most innovative and dedicated neuroscientists in the modern era of brain research.

BIBLIOGRAPHY

WORKS BY GOLDMAN-RAKIC

With Howard T. Crawford, Linton P. Stokes, Thelma W. Galkin, et al. "Sex-Dependent Behavioral Effects of Cerebral Cortical Lesions in the Developing Rhesus Monkey." *Science* 186 (1974): 540–542.

"Neuronal Plasticity in Primate Telencephalon: Anomalous Projections Induced by Prenatal Removal of Frontal Cortex." *Science* 202 (1978): 768–776.

With Thelma W. Galkin. "Prenatal Removal of Frontal Association Cortex in the Fetal Rhesus Monkey: Anatomical and Functional Consequences in Postnatal Life." *Brain Research* 152 (1978): 451–485.

"Contralateral Projections to the Dorsal Thalamus from Frontal Association Cortex in the Rhesus Monkey." *Brain Research* 166 (1979): 166–171.

With Lynn D. Selemon and Michael L. Schwartz. "Dual Pathways Connecting the Dorsolateral Prefrontal Cortex with the Hippocampal Formation in the Rhesus Monkey." *Neuroscience* 12 (1984): 719–743.

"Circuitry of Primate Prefrontal Cortex and Regulation of Behavior by Representational Memory." In *Handbook of Physiology: The Nervous System: Higher Functions of the Brain,* edited by Vernon B. Montcastle, Fred Plum, and Stephen R. Geiger, 373–417. Bethesda, MD: American Physiological Society, 1987.

"Topography of Cognition: Parallel Distributed Networks in Primate Association Cortex." *Annual Review of Neuroscience* 11 (1988): 137–156.

With Shintaro Funahashi and Charles J. Bruce. "Mnemonic Coding of Visual Space in the Monkey's Dorsolateral Prefrontal Cortex." *Journal of Neurophysiology* 61 (1989): 331–349.

"Cortical Localization of Working Memory." In *Brain Organization and Memory: Cells, Systems, and Circuits,* edited by James L. McGaugh, Norman M. Weinberger, and Gary Lynch, 285–298. New York: Oxford University Press, 1990.

With Michael S. Lidow and D. W. Gallager. "Overlap of Dopaminergic, Adrenergic, and Serotonergic Receptors and Complementarity of Their Subtypes in Primate Prefrontal Cortex." *Journal of Neuroscience* 10 (1990): 2125–2138.

"Regional and Cellular Fractionation of Working Memory." *Proceedings of the National Academy of Sciences of the United States of America* 93 (1996): 13473–13480.

With Amy F. Arnsten. "Noise Stress Impairs Prefrontal Cortical Cognitive Function in Monkeys: Evidence for Hyperdopaminergic Mechanism." *Archives of General Psychiatry* 55 (1998): 362–628.

With Srinivas G. Rao and Graham V. Williams. "Isodirectional Tuning of Adjacent Interneurons and Pyramidal Cells during Working Memory: Evidence for Microcolumnar Organization in PFC." *Journal of Neurophysiology* 81 (1999): 1903–1916.

OTHER SOURCES

Aghajanian, George, Benjamin S. Bunney, and Philip S. Holzman. "Patricia Goldman-Rakic, 1937–2003." *Neuropsychopharmacology* 28 (2003) 2218–2220.

"Award for Distinguished Scientific Contributions: Patricia S. Goldman-Rakic." *American Psychologist* 47, no. 4 (1992): 471–473.

Fuster, Joaquín. M. "Patricia Shoer Goldman-Rakic (1937–2003)." *American Psychologist* 59, no. 6 (2004): 559–560.

Jonides, John. "In Memory of Patricia Goldman-Rakic." *Cognitive, Affective and Behavioral Neuroscience* 4, no. 4 (2004): 407–408.

Nestler, Eric J. "Obituary: Patricia S. Goldman-Rakic (1937–2003)." *Nature* 425, no. 6957 (2003): 471.

Valerie Gray Hardcastle

GOODMAN, NELSON HENRY

(*b.* Somerville, Massachusetts, 7 August 1906; *d.* Needham, Massachusetts, 25 November 1998), *theory of induction and confirmation, logic, scientific methodology, aesthetics, metaphysics.*

Goodman is most famous for his discovery of the new riddle of induction and its consequences for the theory of induction. His famous grue-bleen example shows that contextual and pragmatic factors are crucial for the validity of inductive and counterfactual arguments, because their compellingness varies with the selection of predicates and rules for their application by competent judges. Goodman's second groundbreaking methodological contribution to the inductive sciences is the proposal to model inductive and counterfactual inferences as the partly informal process of producing a coherent whole in "reflective equilibrium." Goodman's work decisively shifted the attention of theorists of induction away from mathematical formalisms (like the probability calculus) toward the pragmatic conditions of nondeductive reasoning.

Biographical Sketch, Wider Influence. Goodman was educated at Harvard University (BSc 1928), and obtained his PhD there in 1941 with a groundbreaking dissertation that was later published as *A Study of Qualities.* From 1929 to 1941 he was director of the Walker-Goodman Art Gallery (Boston), and he performed military service from 1942 to 1945. Goodman taught at Tufts College, the University of Pennsylvania, and Brandeis University before becoming professor of philosophy at Harvard University (1968–1977). Goodman's work displays a remarkable unity of thought, starting out from the early nominalist constructionism in his *The Structure of Appearance* (1951), through the studies in general symbol theory in his *Languages of Art* (1968; largely focused on aesthetics), until the late metaphysics of "worldmaking" in *Ways of Worldmaking* (1978), which propounds a radically pluralist form of constructivism ("irrealism"). Whereas the latter aspects of his work in aesthetics and metaphysics earned him wide popularity even outside philosophical circles, it is often overlooked that they are firmly rooted in his earlier studies of foundational problems in the methodology of the inductive sciences. Most famous among these are his new riddle of induction and his study of counterfactual conditionals.

The Problem of Projectibility. In *Fact, Fiction, and Forecast* (1955, chaps. 1 and 3), Goodman elaborated earlier reflections on the conditions for evaluating inductive inferences and counterfactual conditionals. Regarding the former, he discovered the new riddle of induction by making the following observation. Suppose all emeralds examined so far have been found green, and that there are still some to be discovered, and consider the question whether our knowledge is evidence for the hypothesis that the next, or all emeralds without regard to when they were found, are green. We usually think that it is, tacitly relying on an inference licensing principle like (U): "Whenever some Fs have been observed to be Gs in n% of the cases, then inferring that n% of the remaining Fs are G is admissible."

Goodman's new riddle showed that such general principles allow too many hypotheses to be equally well supported by the evidence. To show this, he stipulated that something is grue if it either has been observed until some time *t* and been found green, or blue otherwise. Clearly, the principle licenses reasoning from the evidential fact that (by definition) all emeralds observed so far were (since green before *t*) grue, to the conclusion that the remaining emeralds are grue as well. However, accepting this generalization commits us to expecting emeralds observed after *t* to be (grue, hence) blue, whereas the original hypothesis commits us to expecting the same emeralds to be green. If the evidence is described in these terms, it seems that our knowledge about green emeralds supports something equivalent to the hypothesis that not all emeralds are green just as much as it supports the rival thesis that all emeralds are green, when the evidence is described in familiar terms. It just seems obvious that the grue hypothesis is not supported at all by our knowledge, but given the example, it becomes unclear why we ought to think this.

The new riddle of induction is to say why some regularities work (i.e., are lawlike or confirmable by their instances) while other, formally analogous ones do not. Goodman's answer was to connect inductive validity and the acceptance of predicate systems. Predicates are expressions for the attribution of properties to particular objects, and predicate systems are sets of predicates that are interrelated in systematic ways. For example, color terms are predicates that are true of objects if they have a certain color. Color terms become a system by rules such as "If a given color predicate applies to a uniformly colored object, then no other color predicate applies to it," which regulate the application of all color terms by relating them to one another in this way, predicate systems afford classifications of objects. Goodman's "grue" calls attention to the fact that our expectations of inductive validity may vary with the ways we classify objects, and so with the kinds of systems of predicates that we apply to a given range of particulars. He calls predicate systems that yield descriptions of experiential input and permit inductive inferences regarding generalizations in ways analogous to principle (U) projectible and comes to the following result: normal inductive methods (i.e., those that allow learning from experience or supporting generalizations by instances) yield adequate results only when the evidence and hypotheses are formulated in projectible predicates. By thus underscoring the inseparability of conceptualization and generalization, Goodman's new riddle challenges methodologists who wish to formulate purely general rules of inductive inference to say what it takes for a given predicate within a given set of alternatives (and empirical statements) to be projectible. Without a general answer to this question, unconstrained inductive methods that allow the projection of any regularity from given evidence will always also allow the projection of grue-like regularities. The concomitant incoherencies, however, make it difficult to avoid that such methods will ultimately license any arbitrary hypothesis on any given evidence.

The main difficulty for finding a general and informative account of projectibility is that it concerns nonformal properties of predicates, but also cannot project traits of known successful predicates to a larger class of predicates, since this assumes the legitimacy of the very kind of inference it is supposed to ground. Goodman himself therefore did not believe that there is a general, noncircular account of projectibility. While this leaves dim hopes for a global "justification" of all inductive inferences, Goodman did believe that our judgments answer to shared local standards of inductive correctness. According to him, the required projectibility verdicts are reached locally in pragmatic procedures that terminate in reflective equilibrium (see below).

Another case of projection studied by Goodman comes to light in the analysis of the truth conditions of counterfactual conditionals (CCs), that is, hypothetical statements of the type "If it had been the case that A, then it would have been the case that B." The importance of analyzing CCs stems from their indispensability, among others, for causal analysis, for resolving decision-theoretic problems (common knowledge), and for modeling reasoning within artificial intelligence research. Just as in prediction we attempt to extrapolate from known to unknown cases, in CCs we attempt to extrapolate from known circumstances to hypothetical ones. Goodman's analysis displayed the partial dependency of such extrapolations on our conceptual commitments. His example was "If match *m* had been struck, then *m* would have lighted"; another was "Had Julius Caesar been in command in Korea, he would have used only nuclear bombs." The first step in his analysis is to regard sentences like these as being of the form "if A, then B," or as ordinary implications.

According to most standard semantics, the truth value (i.e., "true" or "false") of a given sentence is determined by the truth values of its truth-evaluable parts and the way they are put together. This is often expressed by saying that the truth value of the whole is a function of the truth values of its parts and the way in which connectives like "and" or "if-then" combine them. In particular, the rule for a material conditional of the form "if A, then B" is that it is false only when the if-part ("antecedent") is true and the then-part ("consequent") is false. This rule captures an intuitive rule of inference. Suppose we hypothesize that if it rains, then the streets are wet, and suppose that we know that it just rained where we are standing. Were the hypothesis true, we could regard our knowledge of the rain and the hypothesis as sufficient for inferring that the streets are wet. However, were the streets not wet although it rained, we would, without further information, first regard the hypothesis as false.

This rule about the material conditional likewise entails (somewhat less intuitively) that an implication is always true if its antecedent is false. Given these standard semantic assumptions, however, CCs quickly lead to perplexities.

The reason for this is that, usually, at least the antecedent of a CC is a known falsehood (whence the name "counterfactual"). Thus, according to standard semantics, all counterfactual conditionals should be true if their truth were determined by the ordinary truth-function for if-then statements mentioned above and the truth-value of the component statements alone. However, some CCs with a given antecedent are clearly false, and some are in conflict with others: consider "If match *m* had been struck, my grandmother would have been a school-bus" or "If Julius Caesar had been in command in Korea, he would have used only catapults."

Goodman observed that typical CCs can be determined as true or false only with additional (extralogical) facts and assumptions. The needed information concerns (a) particular facts (e.g., background conditions such as that the match was dry, surrounded by sufficient oxygen, struck strongly enough, that Julius Caesar was a Roman emperor), and (b) actual regularities that are supposed to hold between what is described in the antecedent and the consequent, respectively (e.g., all matches struck under the right conditions light, no Roman emperor could use nuclear arms). To yield an interpretation, this additional information has to be (C1) compatible with the antecedent, and (C2) relevant in the sense that with it the antecedent entails the consequent when neither the antecedent nor the additional information alone *would have*. Goodman called such information sets *cotenable* with the antecedent. Since any false statement we posit as antecedent in a CC is in conflict with some truths we know, the cotenable set has to suspend some of what we know. Conversely, such a selection amounts to a decision in which particular facts and which actual regularities applying to the case we are to hold fixed in the hypothetical situation.

Goodman aptly called the regularities that we single out as fixed in a given case lawlike because in effect, they are then not only generalizations about, for example, all known matches under given conditions, but also about what a match is to be like under similar conditions. The problem is to say in a general and informative way on what basis some of the grammatically general statements applying to the antecedent are to be selected as lawlike while others are not. Again, Goodman's analysis undermines hopes for the project of modeling such judgments in a formal mechanism because cotenability judgments themselves depend on judging what would have followed from an information set, that is, other CCs (see the italicized part of C2). Judging CCs as true at all also (via C1) clearly requires attention to our acceptance of whole systems of other CCs. Goodman's analysis thus shows how, by fusing empirical {(a) and (b)} and conceptual {(C1) and (C2)} information, cotenability judgments implicitly articulate our priorities regarding predicate systems. This is most obvious from the fact that typically, factual knowledge alone determines no unique selection of additional information for any given antecedent. The same if-part in most cases makes reference to several mutually incompatible sets of facts and regularities that, for all we know, support the consequent.

The pair of Caesar conditionals illustrates this. Logic, known regularities, and the facts of the matter require only suspending at least one part of our knowledge about Caesar to facilitate the antecedent. While it is open whether we stress that Caesar was a Roman or his brutality to infer either of the (incompatible) consequents, it is clear that applying one of the regularity sets to Caesar excludes applying the other. That is, under invariant cognitive conditions, the same regularity statement can appear, for the same antecedent, either as a law or as capable of being false in a hypothetical situation ("accidental"). How it ultimately appears clearly depends on pragmatic factors like our attitude to other CCs, our interests, and the question we wish to answer. Goodman's answer to the obvious question how rational agreement on CCs (and the lawlikeness of generalizations sustaining them) is possible was that, given our competence in using the language, our empirical and theoretical knowledge, and the available alternatives, some information sets simply are implausible. Once again, having no formal mechanism or global solution does not exclude having good arguments that can locally show why some selections are more reasonable than others.

Reflective Equilibrium. In both cases of projectibility judgments, Goodman pointed to an apparent circularity. In both cases he took certain exemplary cases (grue, Caesar, the match) as a standard to correct and refine general principles like (U) or the general constraints on cotenability (C1) and (C2). Thus (U) is rejected as an unconditional general principle because it licenses "grue" and "green" on the same evidence. But at the same time, the inference to the greenness of the next or all emeralds on the given evidence is regulated by (U) if the familiar predicates are used. The circle is that we cannot judge the adequacy of a fundamental rule without any reference to accepted particular inferences, but we also cannot reasonably accept the relevant particular inferences as good standards without the advantage of any application of a roughly equivalent rule. According to Goodman, this is a "virtuous" circle; in fact, it might be better described as the claim that judgments in inductive and counterfactual contexts are not reducible to mechanical decision methods. Goodman consequently proposed that justifying inductive and counterfactual inferences should be modeled as the process of producing a coherent whole of aligned empirical, normative, and theoretical beliefs together with judgments of particular cases, aimed at reaching a "reflective equilibrium," as opposed to mechanical, "judgment-free" models of inductive practices, the results of such scientific deliberations are not predictable on the basis of given formal patterns of inference alone. Such models do not admit standpoint-free, judgment-free ways to justify particular results of good inductive or counterfactual reasoning, independent of actual conditions of being competent in making inductive and counterfactual judgments in general. Since the latter are open ended, mechanical models are inadequate.

Nonetheless, Goodman was not a methodological nihilist or relativist. Scientific practice is rife with cases where it is more reasonable to discount data as abnormal, biased, or incomplete. In such cases, theoretical knowledge and methodological rules decide against experience. Conversely, Goodman's analysis showed how persistent anomalies of such kinds can come to be taken as symptoms of defective conceptual systems or methodological inadequacies. According to Goodman, we always take some inductive judgments for granted when assessing others, just as we take some results of inductive reasoning (considered judgments) for granted when judging the adequacy of a rule with regard to other results, or when, in unproblematic cases, we apparently just apply the rule to the next case. In this way responding to changes in empirical information can consist in revising theoretical hypotheses, experimental results, or methodological rules whenever there is enough "firm ground" from the remnant established knowledge. Which way is most reasonable in each case will depend on the available alternatives, theoretical expertise, and experimental creativity, and is thus not unconstrained or arbitrary. But knowing which way is most reasonable will in any case involve the deliberative and open-ended activity of going back and forth between all these poles until the whole system of beliefs is reasonably balanced. In a classical quote, Goodman's *Fact, Fiction, and Forecast* puts it thus: "The process of justification is the delicate one of making mutual adjustments between rules and accepted inferences; and in the agreement achieved lies the only justification needed for either."

It is important not to confuse Goodman's methodological point that this is how we can come to evaluate evidence and principles with the different, metaphysical doctrine that empirical correctness depends on the coherence produced by such mutual adjustments. The latter view can lead to an epistemological relativism Goodman never endorsed. The famous Harvard political philosopher John Rawls (1971) coined the term *reflective equilibrium* for the coherent outcome of such justificatory procedures. Under this name, the underlying model of reasoning and justification has become central for decision and game theorists and methodologists, as well as ethicists and political theorists.

BIBLIOGRAPHY

WORKS BY GOODMAN

"A Study of Qualities: An Essay in Elementary Constructional Theory." PhD diss., Harvard University, 1941. Reprinted as *A Study of Qualities.* New York: Garland, 1990.

"A Query on Confirmation." *Journal of Philosophy* 43 (1946): 383–385.

"On Infirmities of Confirmation-Theory." *Philosophy and Phenomenological Research* 8 (1947): 149–151. First important texts concerning confirmation theory.

"The Problem of Counterfactual Conditionals." *Journal of Philosophy* 44 (1947): 113–120. Classical discussion of counterfactuals. Reprinted in his *Fact, Fiction, and Forecast.*

The Structure of Appearance. Cambridge, MA: Harvard University Press, 1951. 3rd ed., Boston: Reidel, 1977.

Fact, Fiction, and Forecast. Cambridge, MA: Harvard University Press, 1955. 4th ed., 1983. His pathbreaking book; chapter 1 discusses counterfactual conditionals and chapter 3 discusses the new riddle of induction.

Languages of Art. Indianapolis: Bobbs-Merrill, 1968.

Problems and Projects. Indianapolis: Bobbs-Merrill, 1972.

Ways of Worldmaking. Indianapolis: Hackett, 1978.

Of Mind and Other Matters. Cambridge, MA: Harvard University Press, 1983.

With Catherine Z. Elgin. *Reconceptions in Philosophy and other Arts and Sciences.* Indianapolis: Hackett, 1988.

OTHER SOURCES

Berka, Sigrid. "An International Bibliography of Works by and Selected Works about Nelson Goodman." *Journal of Aesthetic Education* 25, no. 1 (1991): 99–112. Full bibliography until 1991. Updated bibliography available from http://www.hcrc.ed.ac.uk/~john/GoodmanBib.html.

Douglas, Mary, and David Hull, eds. *How Classification Works: Nelson Goodman among the Social Sciences.* Edinburgh: Edinburgh University Press, 1992.

Elgin, Catherine Z., ed. *The Philosophy of Nelson Goodman: Selected Essays.* 4 vols. New York: Garland, 1997.

"General Topic: Languages of Art." Spec. issue, *Monist* 58, no. 2 (1974): 175–318. Edited by Monroe C. Beardsley; includes replies by Goodman.

McCormick, Peter J., ed. *Starmaking: Realism, Anti-realism, and Irrealism.* Cambridge, MA: MIT Press, 1996.

"The Philosophy of Nelson Goodman," parts 1 and 2. Spec. issue, *Erkenntnis* 12, no. 1/2 (1978): 3–291. Edited by Carl G. Hempel, Wolfgang Stegmüller, and Wihelm K. Essler.

Rudner, Richard S., and Israel Scheffler, eds. *Logic and Art: Essays in Honor of Nelson Goodman.* Indianapolis: Bobbs-Merrill, 1972.

Stalker, Douglas, ed. *Grue!* Chicago: Open Court, 1994.

Axel Mueller

GORENSTEIN, DANIEL

GORENSTEIN, DANIEL (*b.* Boston, Massachusetts, 1 January 1923; *d.* Martha's Vineyard, Massachusetts, 26 August 1992), *mathematics, algebra, group theory.*

Gorenstein was an American mathematician whose main research was in the theory of finite groups, where he focused single-mindedly on the search for simple groups. Besides contributing major theorems himself, he mapped out the path that would lead to the goal of a complete classification, and became the informal leader of a disseminated team which achieved that goal.

Private Life. Born and bred in Boston, Daniel Gorenstein attended the Boston Latin School, from which he entered Harvard College, earning his AB in 1943 and PhD in 1950. His doctoral advisor was Oscar Zariski and his thesis was on a problem in algebraic geometry and its foundations in commutative algebra, a subject that he did not pursue after his first published paper. He married Helen Brav in 1947; they had four children, three girls and a boy. In his obituary of Gorenstein (*The Independent*, London 1992), Michael Collins wrote "He was a short stocky man, who applied the same muscular techniques to his mathematics as to his tennis," and "Gorenstein both worked hard and played hard. […] Research was over by lunchtime. Living in Portland Place [London] in 1972–73 must have been ideal, for he could then devote the rest of the day to seminars and to visits to art galleries, museums, restaurants and the theatre. He collected modern art, with a good eye for artists yet to be recognised, and for the value of the works of those who were."

Career. Soon after he achieved his doctorate Gorenstein became assistant professor at Clark University in Worcester, Massachusetts. He remained there until 1964, when he became professor at Northeastern University in Boston. In 1969 he moved to Rutgers University, New Brunswick, New Jersey, where he remained for the rest of his life, serving as chairman of the mathematics department from 1975 to 1981 and director of DIMACS, the NSF Center for Discrete Mathematics and Computer