



LETTERS

edited by Etta Kavanagh

Don't Sell Social Science Short

THE NEWS OF THE WEEK ARTICLE THAT REPORTS ON SENATOR KAY BAILEY HUTCHISON (R-TX) questioning the need to fund social science research at the National Science Foundation is alarming and shortsighted ("Senate panel chair asks why NSF funds social sciences," 12 May, p. 829). Social science research is at the fundamental core of basic research and has much to contribute to the economic viability of the United States. Twenty years of direct and jointly funded social and ecosystem science research at Colorado State University's Natural Resource Ecology Laboratory has produced deep insights into environmental and societal impacts of political upheaval, land use, and climate change in parts of Africa, Asia, and the Americas. Beyond greatly advancing our understanding of the coupled human-environmental system, the partnership of social and ecosystem science has brought scientists and decision-makers together to begin to develop solutions to difficult problems.

Insights from the social sciences about the vulnerability, sustainability, and resilience of social and environmental systems have greatly increased our understanding of the complex interactions of the world on which we depend. The contributions of social and ecological science for data analyses associated with spatial relationships, transfer of goods and services, valuation, and decision-making processes have improved our understanding of how human activities are altering environmental systems worldwide. These findings have become the core of policy and development decisions used throughout the world.

It is critical that the NSF support social science funding and that, as budget decisions are made, the social science allocation should move forward equally with increases as in other basic and applied research. Failure to do so will further hinder U.S. competitiveness in the future and will slow transfer of knowledge and usefulness to the public.

DENNIS S. OJIMA,* DIANA H. WALL,† JOHN MOORE,‡ KATHY GALVIN, N. T. HOBBS, WILLIAM H. HUNT, KEITH PAUSTIAN, DAVID SWIFT, RANDALL B. BOONE, RICHARD T. CONANT, JULIA KLEIN, LINDSEY CHRISTENSEN, MAHESH SANKARAN, JAYASHREE RATNAM, ED AYRES, HEIDI STELTZER, BREANA SIMMONS, GARY WILLIAMS

Natural Resource Ecology Laboratory (NREL), Colorado State University, Fort Collins, CO 80523-1499, USA.

*Director, NREL

†Past Director, NREL

‡Incoming Director, NREL

Photosynthetic Oxygen Production

UNDERSTANDING LIGHT-DRIVEN OXYGEN PRODUCTION from water by plants and cyanobacteria is one of the greatest challenges in molecular bioenergetics. The essential reaction step is mediated by a Mn_4CaTyr catalytic center. After photon-clocked accumulation of four

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—Ojima *et al.*

oxidizing equivalents, this center abstracts four electrons from two molecules of water in a terminal reaction that has long appeared to be a single reaction step. The hunt for the still ill-characterized intermediates of this complex reaction is on, as recently documented in *Science* (M. Haumann *et al.*, "Photosynthetic O_2 formation tracked by time-resolved x-ray experiments," Reports, 11 Nov. 2005, p. 1019) and *Nature* (1).

The sequence of states leading from the lowest oxidation state of the Mn_4CaTyr -entity, named S_0Y , to the highest, named S_3Y^{ox} , is well characterized. The chemistry from the highest state back to S_0Y under liberation of dioxygen has, however, remained enigmatic. Haumann *et al.* recorded the electron flow from water into Mn_4 by x-ray spectroscopy and found a lag phase of 250- μ s duration. It precedes the known reduction of the center, which occurs in about 1 ms. They interpreted this lag phase in terms of an intermediate, the center still in its highest oxidation state being

partially deprotonated. By UV spectroscopy we previously detected a partially (twofold?) reduced Mn-intermediate. Elevated oxygen pressure ($P^{1/2} = 2.3$ bar) served to push oxygen evolution in the reverse direction (1). Instead of being contradictory, as stated by J. E. Penner-Hahn and C. F. Yocum

in their Perspective ("The photosynthesis 'oxygen clock' gets a new number," 11 Nov. 2005, p. 982), the two data sets supplement each other. Haumann *et al.* identified one non-redox intermediate lying before the rate-limiting step of the reaction cascade, and we detected one redox intermediate located after this step closer to the end (1). Further redox intermediates are expected on the path of this tetravalent electron transfer cascade, of course.

WOLFGANG JUNGE AND JUERGEN CLAUSEN

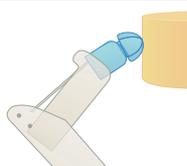
Department of Biophysics, Universitaet Osnabrueck, Room 36/132, Barbarastrasse 11, Osnabrueck D-49076, Germany.

Reference

1. J. Clausen, W. Junge, *Nature* **430**, 480 (2004).

Response

WE AGREE THAT A FULL CHARACTERIZATION OF all of the intermediates in the mechanism of photosynthetic water oxidation will represent one of the great discoveries in bioenergetics. Clausen and Junge's paper (1) was a signal achievement, providing evidence for a chemical intermediate in the formation of oxygen from water; this was modeled as B in the reaction $A \rightarrow B \rightarrow C$, where A is $S_3Y_Z^{ox}$ and C is $S_0Y_Z + O_2$. Clausen and Junge suggested that B might correspond to $S_2Y_ZH_2O_2$, although they noted that this was "only one of several choices" for B (1). Haumann *et al.*'s Report does indeed complement these earlier findings: The existence of an intermediate is confirmed by monitoring directly the redox behavior of the Mn.



There is great interest in determining the chemical identity of the intermediate(s) that exist between $S_3Y_Z^{OX}$ and S_0Y_Z (i.e., the intermediate defined as *B* by Clausen and Junge). Haumann *et al.* provide important insight by defining what the intermediate is not. If the intermediate that Haumann *et al.* describe corresponded to $S_2Y_ZH_2O_2$, it would have a lower edge energy, reflecting the lower oxidation state of the Mn. It was in this context that we described the data as excluding the model put forward by Clausen and Junge; the intermediate that is seen by Haumann *et al.* does not match the properties expected of $S_2Y_ZH_2O_2$. Thus, under the parsimonious assumption that there is only one isolable intermediate between $S_3Y_Z^{OX}$ and S_0Y_Z , the recent data exclude the possibility that this intermediate is $S_2Y_ZH_2O_2$. However, as Clausen and Junge note here, it is possible that the reaction is more complex—e.g., $A \rightarrow D \rightarrow B \rightarrow C$ —with the intermediate seen by Haumann *et al.* corresponding to *D* and the intermediate seen by Clausen and Junge corresponding to *B*. In this case, *B* certainly could be $S_2Y_ZH_2O_2$. To our knowledge, there is at present no evidence for the existence of two intermediates. However, it is possible that future experiments may provide such evidence, supporting the existence of a stable partially reduced intermediate oxidation state of Mn along the route to formation of S_0 and O_2 .

JAMES E. PENNER-HAHN AND CHARLES F. YOCUM

Departments of Chemistry and Molecular, Cellular, and Developmental Biology and the Biophysics Research Division, University of Michigan, 930 North University Avenue, Ann Arbor, MI 48109–1055, USA.

Reference

1. J. Clausen, W. Junge, *Nature* **430**, 480 (2004).

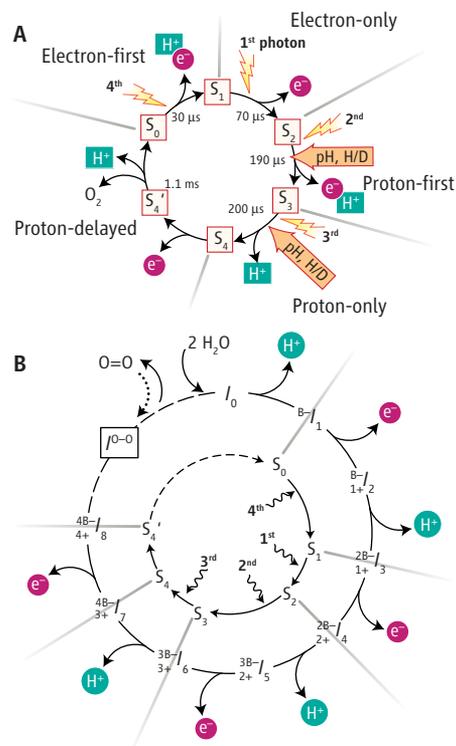
Response

THE INTERMEDIATES OF PHOTOSYNTHETIC OXYGEN evolution described by Clausen and Junge (1) and in our Report (Haumann *et al.*) are distinctly different. For clarification, we discuss a basic model that includes both reaction intermediates. Moreover, the proposed reaction cycle resolves inconsistencies of earlier models and provides a fresh twist in research on oxygenic photosynthesis.

The active site of dioxygen formation is a manganese complex bound to the proteins of Photosystem II (PSII). In 1970, Kok proposed a five-state reaction cycle (2) (S_0 to S_4 in Fig. 1) (Haumann *et al.*; Perspective by Penner-Hahn and Yocum). However, the simplicity of Kok's five-state charge accumulation model and of the more recent, particularly influential hydrogen-atom abstraction hypothesis (3) is generally not met by the intricate experi-

mental results (see panel A of the figure). Clarification may come from the alternative reaction cycle of panel B of the figure.

We have reported evidence for formation of the enigmatic S_4 state by deprotonation so that subsequent electron transfer leads to an additional S_4' state (Haumann *et al.*). Clausen and Junge (1) suggested transient formation of an intermediate state prior to dioxygen release that is stabilized at elevated oxygen partial pressure. In this state, the manganese is reduced in comparison to the S_4 state identified in our Report, and partial water oxidation may have resulted in peroxide formation. Penner-Hahn and Yocum correctly pointed out that this peroxidic intermediate cannot be identical to the S_4 state, but suggested that identity had been claimed in (1).



Reaction cycle of photosynthetic water oxidation in plants and cyanobacteria. (A) Irregular properties [(6), and references therein] of the transitions in the classic S-state model. A complete cycle requires sequential absorption of four photons. For each transition, it is indicated whether an electron is removed from the Mn complex, whether a proton is released from the Mn complex or its ligand environment, and whether the rate constant is sensitive to pH and H_2O/D_2O exchange. (B) Proposed sequence of alternating proton and electron abstraction from the Mn complex. The left subscript and superscript indicate the number of accumulated oxidizing equivalents and bases, respectively.

Rather, we propose that the S_4 state is formed before peroxide formation in a sequence of events that are outwardly convoluted and irregular, but governed by a simple underlying principle: Protons and electrons are removed strictly alternately from the Mn complex. Starting in I_0 , eight successive steps of alternate proton and electron removal lead to I_8 , where four electrons and four protons have been removed. The intermediates from I_0 to I_8 are different from the peroxidic reaction intermediate formed in the $I_8 \rightarrow I_0$ transition, which in panel B of the figure is denoted as I^{O-O} . The alternate proton-electron release explains experimental results straightforwardly, thereby resolving the irregularities of the S-state model. Moreover, the I cycle explains how four successive oxidation steps can proceed without prohibitive increase in the redox potential of the manganese complex (4). A second—and equally crucial—mechanistic role of the four deprotonation events may be the accumulation of bases [Haumann *et al.*; (5)] that serve as proton acceptors in the O_2 -formation step (4).

HOLGER DAU* AND MICHAEL HAUMANN

FB Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany.

*To whom correspondence should be addressed. E-mail: holger.dau@physik.fu-berlin.de

References

1. J. Clausen, W. Junge, *Nature* **430**, 480 (2004).
2. B. Kok, B. Forbush, M. McGloin, *Photochem. Photobiol.* **11**, 457 (1970).
3. C. W. Hoganson, G. T. Babcock, *Science* **277**, 1953 (1997).
4. H. Dau, M. Haumann, *Photosynth. Res.* **84**, 325 (2005).
5. M. Haumann *et al.*, *Biochemistry* **44**, 1894 (2005).
6. W. Junge, M. Haumann, R. Ahlbrink, A. Mulikidjanian, J. Clausen, *Philos. Trans. R. Soc. London Ser. B* **357**, 1407 (2002).

Making Choices Without Deliberating

CONCLUDING THAT DELEGATING THINKING about complex matters to the unconscious is beneficial is, at best, misleading and, at worst, harmful to those making complex and difficult decisions in the real world (A. Dijksterhuis *et al.*, "On making the right choice: the deliberation-without-attention effect," Reports, 17 Feb., p. 1005). Dijksterhuis *et al.* make this conclusion after interpreting data from studies with small student samples making nonrisky choices that have no serious consequences; they find that not deliberating about options with more than four attributes—and yet conscious deliberation about simpler options—led to better outcomes. An equally reasonable interpretation is that conscious deliberation leads to better decisions, but there are barriers to individuals' abilities to make reasoned evaluations of options and, in these instances, unconscious processes will usually result in satisfactory choices (1). There is consid-

erable evidence from randomized controlled trials of patients making risky choices with serious health consequences that decision-aid interventions delivered by health professionals help patients make better choices about options with several attributes (2). Decision aids restructure decision information, reducing the cognitive demands of complex choices and making explicit cognitions and emotions, enabling patients to reason verbally about treatment options (3). The outcome measures used to evaluate good decisions by Dijksterhuis *et al.* are unhelpful when applied to real-world contexts; most individuals do not make choices in accord with normative theories. Decision quality should be operationalized with reference to a theoretical perspective that takes into consideration patients' reasoning about their evaluation of options in accord with their beliefs (4).

HILARY L. BEKKER

Institute of Health Sciences and Public Health Research, University of Leeds, Leeds LS2 9LT, UK.

References

1. J. Baron, *Thinking and Deciding* (Cambridge Univ. Press, Cambridge, 1994).
2. A. M. O'Connor *et al.*, *Cochrane Database Syst. Rev.*, Issue 1, Art. No.: CD001431. DOI: 10.1002/14651858.CD001431 (2003).
3. H. L. Bekker, J. Hewison, J. G. Thornton, *Patient Educ. Counsel.* **50**, 323 (2003).
4. D. Frisch, R. T. Clemen, *Psychol. Bull.* **116**, 46 (1994).

Response

BEKKER'S CONCERN IS BASED ON A GENERALIZATION of our conclusions to a situation we never suggested nor intended and on a misleading portrayal of our data. Our work is on object evaluation, and we tested our hypothesis in the domain of consumer choice. We would not want to equate such choices with a patient's dilemma in choosing (or not) a certain treatment. Patients initially have little or no relevant knowledge when they face a medical decision (they need the help of specialists), whereas consumers of CDs, clothes, or furniture are usually reasonably well informed. Our analysis is of the stage in decision-making at which choosers already have all the necessary information and only need to come to a preference and does not pertain to the earlier stage, when consciousness is necessary (1).

Bekker states that decision quality should not be judged normatively, but with reference to people's own beliefs. This is what we do in our studies. Actual decisions were investigated, and quality of decision was operationalized as postchoice satisfaction.

Bekker also states that we only base our conclusions on student samples making nonrisky choices. However, in our two studies, real decisions were investigated, and in the Report we used actual shoppers rather than students.

Finally, the alternative explanation offered for our data is contradictory in itself. Saying that "conscious deliberation leads to better deci-

sions, but there are barriers to individuals' abilities to make reasoned evaluations of options..." is like saying that consciousness is in principle a good decision-maker, but that it fails to make good decisions, because it, well, just cannot make decisions. After all, we show that unconscious thinkers suffer much less from these "barriers."

AP DIJKSTERHUIS, MAARTEN W. BOS,
LORAN F. NORDGREN, RICK B. VAN BAAREN

Department of Psychology, University of Amsterdam, Roetersstraat 15, 1018 WB, Amsterdam, the Netherlands.

Reference

1. A. Dijksterhuis, L. F. Nordgren, *Perspect. Psychol. Sci.*, in press.

CORRECTIONS AND CLARIFICATIONS

Special Section News: "A one-size-fits-all flu vaccine?" by J. Kaiser (21 Apr., p. 380). In the figure of an influenza virus on page 380, the labels for NA (neuraminidase) and HA (hemagglutinin) should have been reversed.

Reports: "Diels-Alder in aqueous molecular hosts: unusual regioselectivity and efficient catalysis" by M. Yoshizawa *et al.* (14 Apr., p. 251). Due to a nomenclature error, all references to "phthalimides" in the text and Supporting Online Material should instead refer to "maleimides." The chemical structures in the schemes and figures are all correct as drawn.

This Week in Science: "Catch, react, release" (14 Apr., p. 155). The reference to "phthalimides" should instead have read "maleimides."

Technical Comments: "Response to comment on 'ivory-billed woodpecker (*Campephilus principalis*) persists in continental North America'" by J. W. Fitzpatrick *et al.* (17 Mar., <http://www.sciencemag.org/cgi/content/full/311/5767/1555b>). In reference (11), it is stated that "[a]fter studying the evidence at length, the Bird Records Committee of the Arkansas Audubon Society voted unanimously to accept the documentation of ivory-billed woodpecker (www.arbirds.org/ivory_billed_woodpecker.html)." This is incorrect; the Committee did accept the documentation, but the vote was not unanimous.

Policy Forum: "Globalization, roving bandits, and marine resources" by F. Berkes *et al.* (17 Mar., p. 1557). In the third line of the caption on page 1558, "Baja, Mexico" should instead have read "Baja California peninsula, Mexico."

Brevia: "Genetic variation affects de novo translocation frequency" by T. Kato *et al.* (17 Feb., p. 971). The affiliation for all of the authors except Beverly S. Emanuel is incorrect. The authors are at the Division of Molecular Genetics, Institute for Comprehensive Medical Science, Fujita Health University, 1-98 Dengakugakubo, Kutsukake-cho, Toyooka Aichi 470-1192, Japan.

Letters to the Editor

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