Epilogue

The investigation initiated by the nineteenth-century chemists to explain photosynthesis came to a preliminary conclusion around 1960, when a sophisticated, molecular-level model of the mechanism was developed. The problem—how to explain the light-driven production of carbohydrates and oxygen from carbon dioxide and water in green plants—had troubled scientists for more than a century. The solution included an intricate cyclic path, the prerequisites of which, namely, reducing equivalents and chemically usable energy in the form of adenosine triphosphate (ATP), were produced during the course of two photochemical reactions operating in series and dependent on two different pigment systems.

The story of how this solution was reached was described in this book with an emphasis placed on the internal dynamics of the modelling process; and it was suggested that several recurrent heuristic strategies can be identified that characterise the methodology of the researchers under study. It may be worthwhile to summarise some of the central features that emerged and might be of wider applicability. The modelling of a complex mechanism, such as photosynthetic carbon dioxide assimilation, was presented as being a collective enterprise. The functional decomposition of the mechanism, a widespread strategy in dealing with complexity as we know from William Bechtel and Robert Richardson, was correlated to the division of labour between several research groups, which *cooperated informally* with one another.[1] No central agency organised this process; rather, the different groups defined their own contributions to the overall project depending on their research interests and skills. Most scientists specialised in certain experimental techniques and applied them to a limited range of issues within photosynthesis research, at the same time keeping a close eye on the (complementary) work of other researchers in the field. The more complex the issue turned out to be, the more subgoals were identified (corresponding to functional subunits of the mechanism) and the more diversified the community became.

---

[1] Starting in the 1950s, the locations of the different processes also were considered, although it was not yet part of the primary focus of research (differing from the elucidation of other biological mechanisms, as studied by, e.g., Bechtel and Richardson).

K. Nickelsen, *Explaining Photosynthesis,* History, Philosophy and Theory
of the Life Sciences 8, DOI 10.1007/978-94-017-9582-1

Decomposition of the mechanism into functional units—the *modularisation* of the process, as it is referred to in this study—helped individual researchers to focus on one specific aspect or partial process of photosynthesis, while the rest of the mechanism was left untouched. Alternatively, people imported the conception of one subprocess from the literature, while working on the rest. Early on in photosynthesis research, for example, the synthesis of carbohydrates from formaldehyde was treated as such a module: it was accepted as a self-sufficient element, which most researchers integrated into their various models of the first stages of the mechanism. The most extreme example of modularisation, which eventually resulted in the construction of two distinct partial models of photosynthesis, involved the separation of the "dark" reactions of photosynthesis from the "light" reactions. Although these two partial processes were closely interrelated, and known to depend on each other, from about 1940 they were no longer studied as a single unit. This conceptual separation coincided with a disciplinary separation: while the "dark" reactions became the domain of bio*chemistry*, the "light" reactions developed into one of the favourite research themes of bio*physics*.

The integration of experimental results into an explanatory model that adhered to accepted theory, remained a challenge. One of the most important heuristic strategies to meet this task was identified in this study as the *transfer of causal knowledge* from one field to another. This is, in effect, very similar to what Lindley Darden referred to as schema instantiation; although, it might concern only much smaller items than full schemata. The strategy is interpreted here as the tentative classification of a new situation as being similar to a type of situation that had already been elucidated. This was particularly useful in cases where it was impossible to undertake difference tests to find out more details about the involved causally relevant factors, mainly because of the lack of appropriate methods—such as in nineteenth-century chemistry, when hardly anything was known about photosynthesis except for the identity of the raw materials and the end products. The chemists, hence, started from what they knew about the reaction paths of the raw materials in vitro and tried to transfer these interaction patterns to the mechanism of photosynthesis. This strategy continued to be an extremely powerful tool, for example in elucidating the course of the dark reactions of photosynthesis around 1950: by then, intermediate compounds were identified by means of radiotracers and paper chromatography; but how these compounds interacted, had to be inferred from the body of knowledge assembled in other systems.

This type of reasoning is sometimes referred to as "reasoning by analogy" and enjoys a rather bad reputation among philosophers, due to the fact that it is obviously fallible. At the same time, it is a widespread heuristic move in scientific practice. If phenomena are observed, the underlying mechanisms of which are known in similar contexts, one might suppose that a very similar mechanism would satisfactorily explain the problem at hand. In photosynthesis research, either only a couple of factors and their interaction were transferred from one epistemic context to another or even full modules of the mechanism under study. It was frequently accompanied or followed up closely by a phase of empirical investigation in order to ascertain whether the assumed explanation did, in fact, hold. Yet, even if this empirical search did not go anywhere, scientists sometimes retained the tentatively transferred elements if their theoretical foundation and the explanatory value was persuasive enough. The long-held belief in the accuracy of the formaldehyde model of photosynthesis (which was exclusively based on the knowledge gained in artificial systems), despite the failure of scientists to demonstrate that formaldehyde was formed in plants, is a case in point.

Beyond conceptual knowledge of the mechanism, other elements of knowledge were also transferred to photosynthesis research, including new explanatory approaches, theoretical notions of a general nature or the application of new methods and instruments. Frequently, it was not the photosynthesis researchers themselves, who actively sought to import knowledge from other fields to photosynthesis studies when they found themselves in an impasse (although there were exceptions, such as the intensive search of the literature for potential chemical intermediates of photosynthesis that Martin Kamen and Sam Ruben undertook when they started their tracer studies). Rather, new pieces of knowledge were imported mostly by scientists who were experts in other areas (such as atomic physics, physiology and radiation chemistry), who had diverged from their original path of research to make a quick contribution to photosynthesis studies: *research opportunists*, as they were called in this book, in a somewhat provocative choice of term. Some of them returned to their original specialty, while others—unexpectedly for themselves—stayed in the field.

Finally, it was repeatedly emphasised that the group of photosynthesis researchers, as a whole, usually pursued a range of different modelling options concurrently. This *pluralism of alternatives* is particularly prominent in phases of high uncertainty, such as, for instance, the nineteenth-century search for a chemical pathway or the attempts to determine the maximum quantum yield of the process. Whenever important issues were at stake, while the available knowledge was meagre, a premature restriction of alternative options, in the light of what appeared promising at the time, was judged to be unwise. This strategy was applied to fundamentally diverging options (such as the chlorophyll complex model versus models including the photosynthetic unit concept) as well as to "local" alternatives (such as whether 2-phosphoglyceric acid (2-PGA) or 3-PGA was the first product of thermochemical carbon dioxide reduction). This implies that at no point there was one "winning" model, not even in 1960; it were always families of different model variants that were being discussed. The debate about the origin of photosynthetic oxygen provides a fine example of the persistent pursuit of alternatives. From the early nineteenth century onwards and well into the 1930s, the standard notion was that the oxygen originated from the carbon dioxide. However, researchers also explored the possibility that the oxygen might have, in fact, originated from the water. Not many scientists had much faith in the latter hypothesis, but it was still a viable option that they could not afford to ignore. In the end, it proved correct; but, to this day, the possibility has not been excluded that some of the photosynthetic oxygen might still result directly from carbon dioxide reduction.

How were these different options pursued? It is little surprising, although intricate in detail, that existing model suggestions were constantly modified in the light of new experimental findings or theoretical developments (although in photosynthesis research the latter initiated far less frequently a process of reconsideration than new empirical results). Researchers might add factors to the model, replace or redefine earlier ones or revise full sequences; construe alternative pathways to produce an effect or insert intermediate functional modules that had so far been neglected, and so on. Recall, for example, Robert Emerson and William Arnold's 1932 finding that in photosynthesis only one molecule of oxygen was produced per couple of thousand molecules of chlorophyll. At the time, the standard model included the assumption that oxygen was produced by the direct interaction of chlorophyll molecules with the molecules of carbon dioxide, in a one-to-one relationship, which was clearly in conflict with the new data. The community reacted in a number of ways. At first, most of the scientists seriously doubted the validity of the data. James Franck, for example, was convinced for a long time that Emerson and Arnold had not stimulated the system to operate at its maximum efficiency. Others, including Emerson himself, tried to account for the data by introducing new factors to the standard model—such as the suggestion that an enzyme which was only present in very low concentrations might be involved in oxygen evolution. And a third, more radical group, notably headed by Hans Gaffron and Kurt Wohl, postulated that fundamental changes concerning the action of chlorophyll be made to the standard model. They proposed that, instead of one chlorophyll molecule acting on one molecule of carbon dioxide, thousands of light-absorbing molecules might be "cooperating" in photosynthesis. All these alternatives were pursued, although Franck's and Emerson's more conservative approaches were strongly favoured. Gaffron and Wohl's modification implied that a previously unheard-of mechanism operated in photosynthesis; so that, although the assumption would have explained the data, most scientists considered their idea ill-founded. Nobody was able to imagine how this cooperative mechanism might function. The situation only changed when the concept of energy resonance transfer was brought up and applied to photosynthesis studies.

This reluctance on the part of researchers to revise or drop long-held model assumptions, that is, a certain *epistemic inertia*, was widespread in the episode under study. As a rule, scientists tended to respond to new data or revised theoretical knowledge by trying to modify and expand the existing models as moderately as possible. It was only when these efforts constantly failed that the group abandoned certain model families. This dropping of a model variant from the stage was, more often than not, a rather unspectacular event: nobody stopped to "falsify" the hypotheses in question, such as, for example, the existence of a complex binding of carbon dioxide to chlorophyll, which had been part of the generally accepted knowledge from 1870 until far in the 1930s. Researchers simply chose to spend their time on more productive issues, even if they were not aware of the difficulty, in fact impossibility, to prove a particular causal hypothesis implied in the mechanism definitively wrong. Take the maximum quantum yield controversy, neither Emerson nor anyone else was able to demonstrate the irrelevance of the eccentric experimental conditions that Otto Warburg and Dean Burk had advanced. Alternative pathways, incompletely understood module composition, imperfectly realised set-up and so on, could always have had an effect. All Emerson could do (and did, as far as he was able to) was to demonstrate the relevance of certain conditions for certain results and then draw inferences as to why these results of Warburg's did not reflect the maximum quantum yield of actual photosynthesis. If this proved impossible, if none of the alternatives to a contested part of the mechanism could positively be established (as was the case in the search for formaldehyde), the only option open to researchers was to wait until either the question had lost its relevance or new methods emerged. This point was reached when Kamen and Ruben used their new radioactive tracer technique to look for formaldehyde. They were as unable to find formaldehyde as their predecessors, but they found a lot of other compounds that opened up the path to more promising model alternatives.

Having so far reflected on the epistemological side of the modelling process, it needs to be underlined that the modelling of the photosynthesis mechanism was an enterprise that hinged on the mastering of experimental practice. This can most clearly be demonstrated by the fact that photosynthesis researchers spent so much time and energy on algae culturing. The more experiments they carried out using algal cells, the more intricate details they discovered about the complex metabolic reactions of these organisms. The physiological state of the algae turned out to be one of the most decisive influencing factors on the cells' photosynthetic performance. From the 1930s onwards, most researchers chose to work with a standard strain of *Chlorella* which Emerson had originally introduced to the field; and the exchange of information on experimental organisms and recipes for culturing media made up a large part of the correspondence of the actors. It is very likely that chemists such as Melvin Calvin, biophysicists such as Louis N. M. Duysens and even plant physiologists of later generations were no longer familiar with the reasons for the choice of species (*Chlorella* or *Scenedesmus*), or of specific algae cultivation techniques. They continued with established tradition not only because they trusted their predecessors' skills and decisions but also to ensure that their results could be compared with earlier findings. In this sense, experimental organisms such as *Chlorella* really did "incorporate" experimental knowledge: they were needed to satisfy the constant conditions of the experimental set-up; although, perhaps, nobody knew exactly which of their many properties influenced the mechanism in what ways. The same held true for other aspects of experimental practice. The importance of tacit knowledge is impressively demonstrated by the fact that the actors often sought to solve controversies by conducting experiments together: there might always be aspects of the know-how of an experimenter that are crucial to the outcome of the experiment; yet, they might be so self-evident to the experimenter herself that it does not even occur to her to explain these details—unless, of course, a controversy arises.

The difficulties of experimental practice and the need to master the pertinent methods explain why scientists were so conservative, not only in their support of model hypotheses but also in terms of research techniques and explanatory approaches: Warburg and many others investigated *Chlorella* cells manometrically in certain media for most of their working lives. The fact that researchers jumped from one theme or field to another, as Warburg did, was clearly prompted by the strategy to exploit the technique's possibilities in as many disciplines as possible. And Warburg, in particular, was a very successful advocate of the technique's advantages. Many of the central figures in twentieth-century photosynthesis research had learned manometry while they were fellows or members of Warburg's institute; and upon leaving they brought this technique to other places. Searching for kinetic information by manometrically measuring the process soon replaced the mainly stoichiometrically guided (and largely unsuccessful) hunt for chemical intermediates. And once the choice of technique had been made, and some standard experiments carried out with it, researchers kept to it—not the least, as to be able to compare experimental outcomes.

Yet, having emphasised the power of heuristics, methods and strategies, one must not forget that a great many of the paths thus pursued led nowhere. Warburg is a marvellous example of a protagonist whose models and hypotheses soon proved untenable, although his methods and techniques were of lasting impact. On the other hand, there were unexpected discoveries that no heuristic rule could have foreseen—for example, when Emerson set out to investigate the influence of blue light on the gas exchange of *Chlorella* cells and found instead the enhancement effect on photosynthetic efficiency. In some phases, research activity was high and methodically uncontroversial, while the actors felt they were conceptually stuck. This was the case, for example, in the 1930s, when existing model alternatives were continuously worked on, without the scientists having any idea as to where the different paths would eventually lead (if anywhere). There were experimental findings that failed to arouse the conceptional interest they would have deserved, such as the red drop of photosynthesis that Emerson and Lewis had come across in 1943; whereas there were instances of explanatory breakthroughs that were discarded as empty speculation, such as the suggestion of the photosynthetic unit by Gaffron and Wohl in 1936. The aim of this book was not to construct another grand narrative of discovery. The aim was to bring exactly those intricate details to the fore that undermine the very idea of such a narrative, that is, present the highly diverse approaches to elucidating the mechanism of photosynthesis, only some of which were to last; and to try and identify some recurrent heuristic strategies that scientists utilised when they were confronted with the inherent complexity of their subject matter: plants in light and darkness.

References

Allen, G.E.: Life Science in the Twentieth Century (Cambridge History of Science). Cambridge University Press, Cambridge (1975)

Allen, M.B., Arnon, D.I., Capindale, J.B., Whatley, F.R., Durham, L.J.: Photosynthesis by isolated chloroplasts III. Evidence for complete photosynthesis. J. Am. Chem. Soc. **77**, 4149–4155 (1955)

Allen, M.B., Whatley, F.R., Rosenberg, L.L., Capindale, J.B., Arnon, D.I.: Photosynthetic carbon dioxide fixation by broken chloroplasts. In: Gaffron, H., Brown, A.H., Stacy, F.C., Livingston, R., Rabinowitch, E.I., Strehler, B.L., Tolbert, N.E. (eds.) Research in Photosynthesis: Papers and Discussions Presented at the Gatlinburg Conference, October 25–29, 1955, Interscience Publishers, pp. 288–295 (1957)

Allen, M.B., Whatley, F.R., Arnon, D.I.: Photosynthesis by isolated chloroplasts: VI. Rates of conversion of light into chemical energy in photosynthetic phosphorylation. Biochim. Biophys. Acta **27**, 16–23 (1958)

Amesz, J.: The two photosystems of photosynthesis. In: Kung, S.-D., Yang, S.-F. (eds.) Discoveries in Plant Biology, vol. 2, pp. 1–13. World Scientific Publishing, Singapore (1998)

Andersen, H.: A field guide to mechanisms, part I & II, Philosophy Compass **9**, http://philosophy-compass.com/sections/philosophy-of-science/. Accessed 19 Feb 2015. (2014)

Angelico, F., Catalano, G.: Sulla presenza della formaldeide nei succhi delle piante verdi. Gazzetta Chimica Italiana **162**, 563–566 (1913)

Ankeny, R., Leonelli, S.: What's so special about model organisms? Stud. Hist. Philos. Biol. Biomed. Sci. **42**, 313–323 (2011)

Anonymous: (1907a) Assimilation, Meyers Grosses Konversationslexikon, vol. 1, 6th edn. Bibliographisches Institut: Leipzig., p. 890

Anonymous: (1907b) Bolometer, Meyers Grosses Konversationslexikon, vol. 3, 6th edn. Bibliographisches Institut: Leipzig., p. 184

Anonymous: Grünes Geheimnis. Der Spiegel **48**, 88–89 (1961)

Arnold, W.A.: A calorimetric determination of the quantum yield in photosynthesis. In: Franck, J., Loomis, W. E. (eds.) Photosynthesis in Plants, pp. 273–276. Iowa State College Press, Ames (1949)

Arnold, W. A.: Life: a collection of probable or improbable events. In: Augenstine, L.G. (ed.) Bioenergetics. Considerations of processes of absorption, stabilization, transfer, and utilization (Proceedings of a symposium sponsored by the U.S. Atomic Energy Commission held at the Brookhaven National Laboratory, October 12–16, 1959), Academic Press, New York/London, pp. 324–325 (1960)

Arnold, W.A.: Experiments. Photosynth. Res. **27**, 73–82 (1991)

K. Nickelsen, *Explaining Photosynthesis,* History, Philosophy and Theory of the Life Sciences 8, DOI 10.1007/978-94-017-9582-1

Arnold, W., Kohn, H.I.: The chlorophyll unit in photosynthesis. J. Gen. Physiol. **18**, 109–112 (1934)

Arnold, W., Oppenheimer, J.R.: Internal conversion in the photosynthetic mechanism of blue-green algae. J. Gen. Physiol. **133**, 423–435 (1950)

Arnon, D.I.: Extracellular photosynthetic reactions. Nature **167**, 1008–1010 (1951)

Arnon, D.I.: (1954a) Photosynthesis by isolated chloroplasts. Nature **174**, 394–401

Arnon, D.I.: (1954b) Photosynthesis by isolated chloroplasts II. Photosynthetic phosphorylation, the conversion of light into phosphate bond energy. J. Am. Chem. Soc. **74**, 6324–6329

Arnon, D.I.: The chloroplast as a complete photosynthetic unit. Science **122**, 9–16 (1955)

Arnon, D.I.: Localization of photosynthesis in chloroplasts. In: Gaebler, O.H. (ed.) Enzymes: Units of Biological Structure and Function, pp. 279–313. Academic Press, New York (1956)

Arnon, D.I.: Conversion of light into chemical energy in photosynthesis. Nature **184**, 10–21 (1959)

Arnon, D.I.: Photosynthesis 1950–1975: changing concepts and perspectives. In: Trebst, A., Avron, M. (eds.) Photosynthesis I: Photosynthetic Electron Transport and Photophosphorylation, pp. 7–56. Springer, Berlin (1977)

Arnon, D.I.: The discovery of photosynthetic phosphorylation. Trends Biochem. Sci. **9**, 258–262 (1984)

Arnon, D.I.: Photosynthetic CO_2 assimilation by chloroplasts: assertion, refutation, discovery. Trends Biochem. Sci. **12**, 39–42 (1987)

Arnon, D.I.: The discovery of ferredoxin: the photosynthetic path. Trends Biochem. Sci. **13**, 30–33 (1988)

Arnon, D.I., Allen, M.B., Whatley, F.R.: Photosynthesis by isolated chloroplasts IV. General concept and comparison of three photochemical reactions. Biochim. Biophys. Acta **20**, 449–461 (1956)

Arnon, D.I., Whatley, F.R., Allen, M.B.: Triphosphopyridine nucleotide as a catalyst of photosynthetic phosphorylation by chloroplasts. Nature **180**, 182–185 (1957)

Arnon, D.I., Whatley, F.R., Allen, M.B.: Assimilatory power in photosynthesis. Science **127**, 1026–1034 (1958)

Aronoff, S., Calvin, M.: Phosphorus turnover and photosynthesis. Plant Physiol. **23**, 351–358 (1948)

Avron, M., Jagendorf, A.T.: Some further investigations on chloroplast TPNH diaphorase. Arch. Biochem. Biophys. **72**, 17–24 (1957)

Axelrod, B., Bandurski, R.S., Greiner, C.M., Jang, R.: The metabolism of hexose and pentose phosphates in higher plants. J. Biol. Chem. **202**, 619–634 (1953)

Bach, A.: Contribution á l'étude des phénomènes chimiques de l'assimilation de l'acide carbonique par les plantes á chlorophylle. Comptes Rendus de l'Académie des Sciences **116**, 1145–1148 (1893)

Badin, E.J., Calvin, M.: The path of carbon in photosynthesis. IX. Photosynthesis, photoreduction and the hydrogen-oxygen-carbon dioxide dark reaction. J. Am. Chem. Soc. **72**, 5266–5270 (1950)

Baeyer, A.von.: Über die Wasserentziehung und ihre Bedeutung für das Pflanzenleben und die Gährung. Berichte der Deutschen Chemischen Gesellschaft zu Berlin **3**, 63–75 (1870)

Baeyer, A.von.: Erinnerungen aus meinem Leben 1835–1905, Vieweg, Braunschweig (1905)

Baeyer, A.von.: Adolf von Baeyer: Biography. Nobel Lectures, Chemistry 1901–1921. Elsevier Publishing Company, Amsterdam. http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1905/baeyer-bio.html. (1966). Accessed 18 Feb 2014

Bailer-Jones, D.: Creative strategies employed in modelling. A case study. Found. Sci. **4**, 375–388 (1999)

Bailer-Jones, D.: Modelling extended extragalactic radio sources. Stud. Hist. Philos. Mod. Phys. **31**, 49–74 (2000)

Bailer-Jones, D.: Scientific Models in Philosophy of Science. University of Pittsburgh Press, Pittsburgh (2009)

Baker, S.M.: Quantitative experiments on the effects of formaldehyde on living plants. Ann. Bot. **27**, 411–442 (1913)

Ball, E.G.: Oxidative Mechanisms in Animal Tissues, A Symposium on Respiratory Enzymes, pp. 16–32. University of Wisconsin Press, Madison (1942)

Ballou, C., Barker, H.A.: William Zev Hassid (1899–1974). Biogr. Mem. Natl. Acad. Sci. **50**, 196–231 (1979)

Bannister, T.T.: The careers and contributions of Eugene Rabinowitch. Biophys. J. **12**, 707–718 (1972)

Barker, H.A.: Radioactive carbon in bacterial metabolism: something old and something new. In: Kaplan, N.O., Robinson A. (eds.) From Cyclotrons to Cytochromes: Essays in Molecular Biology and Chemistry, Academic Press, New York, pp. 67–75 (1982)

Barker, H.A., Hungate, R.E.: Cornelis Bernardus Van Niel (1897–1985). Biogr. Mem. Natl. Acad. Sci. **59**, 389–423 (1990)

Barltrop, J.A., Hayes, P.M., Calvin, M.: The chemistry of 1,2-dithiolane (trimethylene disulfide) as a model for the primary quantum conversion act in photosynthesis. J. Am. Chem. Soc. **76**, 4348–4367 (1954)

Bartha, P.: By Parallel Reasoning. The Construction and Evaluation of Analogical Arguments, Oxford University Press, Oxford (2010)

Bassham, J.A.: Melvin Calvin (1911–1997). Photochem. Photobiol. **65**, 605–606 (1997)

Bassham, J.A.: Mapping the carbon reduction cycle: a personal retrospective. Photosynth. Res. **76**, 35–52 (2003)

Bassham, J.A., Calvin, M.: The path of carbon in photosynthesis. In: Pirson, A. (ed.) Handbuch der Pflanzenphysiologie, pp. 884–922. Springer, Berlin (1960)

Bassham, J.A., Benson, A.A., Calvin, M.: The path of carbon in photosynthesis VIII. The rôle of malic acid. J. Biol. Chem. **185**, 781–787 (1950)

Bassham, J.A., Benson, A.A., Kay, L.D., Harris, A.Z., Wilson, A.T., Calvin, M.: The path of carbon in photosynthesis. XXI. The cyclic regeneration of carbon dioxide acceptor. J. Am. Chem. Soc. **76**, 1760–1770 (1954)

Baumgartner, M., Graßhoff, G.: Kausalität und kausales Schliessen. Eine Einführung mit interaktiven Übungen. Bern Studies in the History and Philosophy of Science, Bern (2004)

Baur, E.: Über die Genesis der Kohlenhydrate. Naturwissenschaften **1**(20), 474–477 (1913)

Bay, Z., Pearlstein, R.M.: A theory of energy transfer in the photosynthetic unit. Proc. Natl. Acad. Sci. U S A **50**, 1071–1078 (1963)

Bechtel, W.: Biochemistry: a cross-disciplinary endeavour that discovered a distinctive domain. In: Bechtel, W. (ed.) Integrating Scientific Disciplines, pp. 77–100. Martinus Nijhoff, Dordrecht (1986a)

Bechtel, W.: The nature of scientific integration. In: Bechtel, W. (ed.) Integrating Scientific Disciplines, pp. 3–52. Martinus Nijhoff, Dordrecht (1986b)

Bechtel, W.: Discovering Cell Mechanisms: The Creation of Modern Cell Biology. Cambridge University Press, Cambridge (2006)

Bechtel, W., Abrahamsen, A.: Explanation: a mechanist alternative. Stud. Hist. Philos. Biol. Biomed. Sci. **36**, 421–441 (2005)

Bechtel, W., Richardson, R.C.: Discovering Complexity. Decomposition and Localization as Strategies in Scientific Research. Princeton University Press, Princeton (1993)

Beckel, A.L., Haywood, C.N.: Breaking new waters. A century of limnology at the University of Wisconsin, vol. (Special Issue), Transactions of the Wisconsin Academy of Sciences, Arts and Letters (1987)

Bendall, D.S.: Robert Hill. Biogr. Mem. Fellows R. Soc. **40**, 141–171 (1994)

Bendall, D.S.: The unfinished story of cytochrome *f*. Photosynth. Res. **80**, 265–276 (2004)

Bendall, D.S., Walker, D.A.: Obituary: Robert (Robin) Hill (1899–1991). Photosynth. Res. **30**, 1–5 (1991)

Benson, A.A.: Identification of ribulose in $^{14}CO_2$ photosynthesis products. J. Am. Chem. Soc. **73**, 2971–2972 (1951)

Benson, A.A.: Tracers in biology. In: Kaplan, N.O., Robinson, A. (eds.) From Cyclotrons to Cytochromes: Essays in Molecular Biology and Chemistry, pp. 59–65. Academic Press, New York (1982)

Benson, A.A.: Following the path of carbon in photosynthesis: a personal story. Photosynth. Res. **73**, 29–49 (2002a)

Benson, A.A.: Paving the path. Annu. Rev. Plant Biol. **53**, 1–25 (2002b)

Benson, A.A.: Last days in the Old Radiation Laboratory (ORL), Berkeley, California, 1954. Photosynth. Res. **105**, 209–212 (2010)

Benson, A.A., Calvin, M.: The dark reductions of photosynthesis. Science **105**, 648–649 (1947)

Benson, A.A., Calvin, M.: Carbon dioxide fixation by green plants. Annu. Rev. Plant Physiol. **1**, 25–42 (1950)

Benson, A.A., Calvin, M., Haas, V.A., Aronoff, S., Hall, A.G., Bassham, J.A., Weigl, J.W.: C^{14} in photosynthesis. In: Franck, J., Loomis, W.E. (eds.) Photosynthesis in Plants, pp. 381–401. State College Press, Ames (1949)

Benson, A.A., Bassham, J.A., Calvin, M., Goodale, T.C., Haas, V.A., Stepka, W.: The path of carbon in photosynthesis. V. Paper chromatography and radioautography of the products. J. Am. Chem. Soc. **72**, 1710–1718 (1950)

Benson, A.A., Bassham, J.A., Calvin, M.: Sedoheptulose in photosynthesis by plants. J. Am. Chem. Soc. **73**, 2970 (1951)

Benson, A.A., Bassham, J.A., Calvin, M., Hall, A.G., Hirsch, H.E., Kawaguchi, S., Lynch, V., Tolbert, N.E.: The path of carbon in photosynthesis. XV. Ribulose and sedoheptulose. J. Biol. Chem. **196**, 703–716 (1952a)

Benson, A.A., Kawaguchi, S., Hayes, P., Calvin, M.: The path of carbon in photosynthesis. XVI. Kinetic relationships of the intermediates in steady state photosynthesis. J. Am. Chem. Soc. **74**, 4477–4482 (1952b)

Bergia, S., Navarro, L.: Recurrences and continuity in Einstein's research on radiation between 1905 and 1916. Arch. Hist. Exact Sci. **38**, 79–99 (1988)

Besse, I., Buchanan, R.B.: Plant ferredoxin: a multifunctional electron carrier protein with an unusual genealogy. In: Kung S.-D., Yang S.-F. (eds.) Discoveries in Plant Biology, vol. 2, pp. 137–156. World Scientific Publishing, Singapore (1998)

Beyerchen, A.D.: Emigration from country and discipline: the journey of a german physicist into American photosynthesis research. In: Ash, M.G., Söllner, A. (eds.) Forced Migration and Scientific Change, pp. 71–85. Cambridge University Press, Cambridge (1996)

Bhagvat, K., Hill, R.: Cytochrome oxidase in higher plants. New Phytol. **50**, 112–120 (1951)

Bishop, N.I.: The influence of the herbicide, DCMU, on the oxygen-evolving system of photosynthesis. Biochim. Biophys. Acta **27**, 205–206 (1958)

Bishop, N.I.: The reactivity of a naturally occurring quinone (Q-255) in photochemical reactions of isolated chloroplasts, Proc. Natl. Acad. Sci. U S A **45**, 1696–1702 (1959)

Blackman, F.F.: Optima and limiting factors. Ann. Bot. **19**, 281–295 (1905)

Blinks, L.R.: Chromatic transients in photosynthesis of red algae. In: Gaffron, H., Brown A.H., French C.S., Livingston R., Rabinowitch E.I., Strehler B.L., Tolbert N.E. (eds.) Research in Photosynthesis, pp. 444–449. Interscience Publishers, New York (1957)

Blinks, L.R.: Action spectra of chromatic transients and the Emerson effect in marine algae. Proc. Natl. Acad. Sci. U S A **46**, 327–333 (1960a)

Blinks, L.R.: Chromatic transients in the photosynthesis of green, brown, and red algae. In: Allen, M.B. (ed.) Comparative Biochemistry of Photoreactive Systems, pp. 329–341. Academic Press, New York (1960b)

Blinks, L.R.: Relation of photosynthetic transients to respiration. Science **131**, 1316 (1960c)

Blinks, L.R.: Winthrop John Vanleuven Osterhout (1871–1964). Biogr. Mem. Natl. Acad. Sci. **44**, 213–249 (1974)

Boberlin, U.: Photochemische Untersuchungen von R. Bunsen und H. Roscoe im Vergleich mit den Arbeiten J. W. Drapers und W. C. Wittwers: Die Anfänge der quantitativen Photochemie im 19. Jahrhundert, Köster. Berlin (1993)

Bogen, J.: Causally productive activities. Stud. Hist. Philos. Sci. Part A **39**, 112–123 (2008)

Boitreux, R.: Sur la nutrition du Trichoderma viride (Pers.) á partir du formol libre. Comptes Rendus des Séances de la Société de Biologie **83**, 737–738 (1920)

Bonner, J.: James Bonner (1910–1996). Interviewed by Graham Berry, March 13–14, 1980 (1980)

Boorse, H.A., Motz, L., Weaver, J.H.: The Atomic Scientists: A Biographical History. Wiley (1989)

Born, M., Heisenberg, W., Jordan, P.: Zur Quantenmechanik. II., Zeitschrift für Physik **35**, 557–615. (1926) (English translation in: van der Waerden, B.L. (ed.) Sources of Quantum Mechanics. Dover Publications, 1968))

Borsook, H.: Interview by Mary Terrall. Pasadena, California. (Oral History Project, California Institute of Technology Archives; permanent URL: http://resolver.caltech.edu/CaltechOH:OH_Borsook_H). Accessed May 2014 (1978)

Bourdieu, P.: The peculiar history of scientific reason. Sociol. Forum **6**, 3–26 (1991)

Bredig, G.: Katalytische Ameisensäuresynthese unter Druck und ein photochemisch-katalytisches Assimilationsmodell. Vortrag, Chemiker-Zeitung **38**(57), 186–187 (1914a)

Bredig, G.: Welche Zwischenprodukte entstehen bei der Assimilation der Kohlensäure durch die Pflanze? Die Umschau **18**, 362–364 (1914b)

Bredig, G.: Gleichgewicht der Kohlensäurereduktion. Vortrag, Chemiker-Zeitung **12**(72), 72–73 (1915)

Brock, W.H.: Justus von Liebig: The Chemical Gatekeeper. Cambridge University Press, Cambridge (1997)

Brodhun, E.: Die Physikalisch-Technische Reichsanstalt. Fünfundzwanzig Jahre ihrer Tätigkeit. Naturwissenschaften **1**(14), 321–325 (1913)

Brody, S.S.: We remember Eugene. Photosynth. Res. **43**, 67–74 (1995)

Brody, S.S.: Fluorescence lifetime, yield, energy transfer and spectrum in photosynthesis, 1950–1960. Photosynth. Res. **73**, 127–132 (2002)

Brody, S.S., Rabinowitch, E.I.: Excitation lifetime of photosynthetic pigments in vitro and in vivo. Science **125**, 555 (1957)

Brown, H.T.: The reception and utilisation of energy by a green leaf. Nature **71**, 522–526 (1905)

Brown, H.T., Escombe, F.: Static diffusion of gases and liquids in relation to the assimilation of carbon and translocation in plants. Philos. Trans. R. Soc. Lond., Series B **193**, 223–291 (1900)

Brown, H.T., Escombe, F.: Researches on some of the physiological processes of green leaves, with special reference to the interchange of energy between the leaf and its surroundings. Proc. R. Soc. Lond., Series B **76**(507), 29–111 (1905)

Brown, A.H., Frenkel, A.W.: Photosynthesis. Ann. Rev. Biochem. **22**, 423–458 (1953)

Brown, A.H., Fager, E.W., Gaffron, H.: Kinetics of a photochemical intermediate in photosynthesis. In: Franck J., Loomis W.E. (eds.) Photosynthesis in Plants, pp. 403–422. Iowa, State College Press (1949)

Buchanan, R.B.: The life of Daniel I. Arnon. Photosynth. Res. **46**, 3–6 (1995)

Buchanan, R.B.: Daniel I. Arnon (1910–1994). Biogr. Mem. Fellows R. Soc. **80**, 2–3 (2001)

Buchanan, B.B., Wong, J.H.: A conversation with Andrew Benson: reflections on the discovery of the Calvin-Benson cycle. Photosynth. Res. **114**, 207–214 (2013)

Buchanan, R.B., Douce, R., Lichtenthaler, H.K.: Andrew A. Benson. Photosynth. Res. **92**, 143–144 (2007)

Burian, R.M.: Comments on Rheinberger's "From experimental systems to cultures of experimentation". In: Wolters G., Lennox, J.G., McLaughlin, P. (eds.) Concepts, Theories and Rationality in the Biological Sciences, pp. 123–136. University of Pittsburgh Press (1995)

Burk, D., Hearon, J.Z., Caroline, L., Schade, A.L.: Reversible complexes of cobalt, histidine, and oxygen gas. J. Biol. Chem. **165**, 723–724 (1946)

Burk, D., Hearon, J.Z., Levy, H., Schade, A.L.: Reversible oxygenation of cobaltodihistidine to oxy-bis(cobaltodihistidine) and comparisons with other metal-amino acids, oxyhemoglobin, and oxyhemocyanin. Fed. Proc. **6**, 242–242 (1947)

Burk, D., Hendricks, S., Korzenovsky, M., Schocken, V., Warburg, O.: The maximum efficiency of photosynthesis: a rediscovery. Science **110**, 225–229 (1949)

Burk, D., Cornfield, J., Schwartz, M.: The efficient transformation of light into chemical energy in photosynthesis. Sci. Mon. **73**, 213–223 (1951)

Butlerov, A.M.: Bildung einer zuckerartigen Substanz durch Synthese. Annalen der Chemie und Pharmazie **120**, 295–298 (1861)

Cahan, D.: An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871–1918. Cambridge University Press, New York (1989)

Callon, M.: Four models for the dynamics of science. In: Jasanoff, S., Markle, G.E., Petersen, J.C., Pinch, T. (eds.) Handbook of Science and Technology Studies. Sage, London, pp. 29–63 (1994)

Calvin, M.: Chemical and photochemical reactions of thioctic acid and related disulfides. Fed. Proc. pp. 697–711 (1954)

Calvin, M.: The path of carbon in photosynthesis. Science **135**, 879–889 (1962)

Calvin, M.: The Path of Carbon in Photosynthesis, Nobel Lectures, Chemistry 1942–1962, pp. 618–644. Elsevier Publishing Company, Amsterdam (1964)

Calvin, M.: Forty years of photosynthesis and related activities. Photosynth. Res. **21**, 3–16 (1989)

Calvin, M.: Following the Trail of Light. A Scientific Odyssey. American Chemical Society, Washington, D.C (1992)

Calvin, M., Bassham, J.A.: The photosynthesis of carbon compounds. W. A. Benjamin Inc., New York (1962)

Calvin, M., Benson, A.A.: The path of carbon in photosynthesis. Science **107**, 476–480 (1948)

Calvin, M., Massini, P.: The path of carbon in photosynthesis. XX: the steady state. Experientia **8**, 445–457 (1952)

Caneva, K.L.: Robert Mayer and the Conservation of Energy. Princeton University Press, Princeton (1993)

Carson, S.F., Foster, J.W., Ruben, S., Barker, H.A.: Radioactive carbon as an indicator of carbon dioxide utilization. V. Studies on the propionic acid bacteria. Proc. Natl. Acad. Sci. U S A **27**, 229–235 (1941)

Chance, B.: Commentary on the paper Chance & Wlliams (1956). Cit. Class. Comment. **49**, 232 (1983)

Chance, B.: The stopped-flow method and chemical intermediates in enzyme reactions—a personal essay. Photosynth. Res. **80**, 387–400 (2004)

Chance, B., Williams, G.R.: Respiratory enzymes in oxidative phosphorylation. I-IV., J. Biol. Chem. **217**, 383–393, 395–407, 409–427, 429–438 (1955)

Chance, B., Williams, G.R.: The respiratory chain and oxidative phosphorylation. Adv. Enzymol. **17**, 65–134 (1956)

Chance, B., Williams, G.R., Holmes, W.F., Higgins, J.: Respiratory enzymes in oxidative phosphorylation. V. J. Biol. Chem. **217**, 439–451 (1955)

Chodat, R., Schweizer, K.: Nouvelles recherches sure les ferments oxydants. IX. De l'emploi de la peroxydase comme réactif de la photolyse par la chlorophylle. Archives des Sciences Physiques et Naturelles **39**, 334–338 (1915)

Clayton, R.K.: Molecular Physics in Photosynthesis. Blaisdell, New York (1965)

Clayton, R.K.: Research on photosynthetic reaction centers from 1932 to 1987. Photosynth. Res. **73**, 63–71 (2002)

Clegg, R.M., Sener, M., Govindjee: From Foerster resonance energy transfer to coherent resonance energy transfer and back. In: Alfano, R.R. (ed.) Optical Biopsy VII. Proceedings of SPIE, SPIE Press, pp. 7561–82 (2010)

Consden, R., Gordon, A.H., Martin, A.J.P.: Qualitative analysis of proteins: a partition chromatographic method using paper. Biochem. J. **38**, 224–232 (1944)

Craig, P.: Centennial History of the Carnegie Institution of Washington. Vol. IV: The Department of Plant Biology, Cambridge University Press, Cambridge (2005)

Craver, C.F.: When mechanistic models explain. Synthese **153**, 355–376 (2006)

Craver, C., Darden, L.: In Search of Mechanisms. Discoveries Across the Life Sciences. University of Chicago Press, Chicago/London (2013)

Creager, A.N.: Nuclear energy in the service of biomedicine: The Atomic, U.S. Energy Commission's Radioisotope Program, 1946–1950. J. Hist. Biol. **39**, 649–684 (2006)

Creager, A.N.: Life Atomic. A History of Radioisotopes in Science and Medicine. University of Chicago Press, Chicago/London (2013)

Creager, A.N.H., Lunbeck, E., Wise, M.N. (eds.): Science Without Laws: Model Systems, Cases, Exemplary Narratives. Duke University Press (2007)

Czapek, F.: Biochemie der Pflanzen, 2., revised edn. Fischer, Jena (1913)

Darden, L.: Theory Change in Science. Strategies from Mendelian Genetics, Oxford University Press, New York/Oxford (1991)

Darden, L.: Strategies for discovering mechanisms: schema instantiation, modular subassembly, forward/backward chaining. Philos. Sci. **69**, S354–S365 (2002)

Darden, L.: Thinking again about biological mechanisms. Philos. Sci. **75**, 958–969 (2008)

Darden, L., Craver, C.F.: Strategies in the interfield discovery of the mechanism of protein synthesis. Stud. Hist. Philos. Biol. Biomed. Sci. **33**, 1–28 (2002)

Dascal, M.: The study of controversies and the theory and history of science. Sci. Context **11**, 147–154 (1998)

Davenport, H.E.: Ascaris Haemoglobin as an indicator of the oxygen produced by isolated chloroplasts. Proc. R. Soc. Lond., Series B **136**(511), 281–290 (1949)

Davenport, H.E.: Cytochrome components in chloroplasts. Nature **170**, 1112–1114 (1952)

Davenport, H.E.: Coenzyme reduction by illuminated chloroplasts. Biochem. J. **73**, 45–46. (1959) (Proceedings of the Biochemical Society)

Davenport, H.E.: A protein from leaves catalysing the reduction of metmyoglobin and triphosphopyridine nucleotide by illuminated chloroplasts. Biochem. J. **77**, 471–477 (1960)

Davenport, H.E., Hill, R.: The preparation and some properties of cytochrome f. Proc. R. Soc. Lond., Series B **139**, 327–345 (1952)

Davenport, H.E., Hill, R.: A protein from leaves catalysing the reduction of haem-protein compounds by illuminated chloroplasts. Biochem. J. **74**, 493–501 (1960)

Davenport, H.E., Hill, R., Whatley, F.R.: A natural factor catalysing reduction of methaemoglobin by isolated chloroplasts. Proc. R. Soc. Lond., Series B **139**, 346–358 (1952)

Deichmann, U.: The expulsion of German-Jewish chemists and biochemists and their correspondence with colleagues in Germany after 1945: the impossibility of normalization? In: Szöllösi-Janze M. (ed.) Science in the Third Reich, pp. 243–280. Berg, Oxford/New York (2001a)

Deichmann, U.: Flüchten, Mitmachen, Vergessen. Chemiker und Biochemiker in der NS Zeit. Wiley VCH, Weinheim (2001b)

Delbrück, M.: Oral History Interview with Carolyn Harding, CIT, p. 55 (Permanent URL: http://resolver.caltech.edu/CaltechOH:OH_Delbruck_M). Accessed 19 Feb 2015 (1978)

Demeter, S., Govindjee: Thermoluminescence in plants. Physiologia Plantarum **75**, 121–130 (1989)

Dent, C.E., Fink, K., Fink, R.M.: Application of filter paper partition chromatography to radioactive tracer studies. Nature **160**, 801–803 (1947a)

Dent, C.E., Stepka, W., Steward, F.C.: Detection of free amino acids of plant cells by partition chromatography. Nature **160**, 682–683 (1947b)

Dmetrievsky, O.D., Ermolaev, V.L., Terenin, A.N.: Direct measurement of the lifetimes of chlorophyll and analogous pigments in various media. Doklady Akademii Nauk **114**, 468–470 (1957)

Dohrn, A.: Aus Vergangenheit und Gegenwart der Zoologischen Station zu Neapel. Deutsche Rundschau **72**, 275–298 (1892)

Dole, M., Jenks, G.: Isotopic composition of photosynthetic oxygen. Science **100**, 409 (1944)

Dorner, R.W., Kahn, A., Wildman, S.G.: The proteins of green leaves. VII. Synthesis and decay of the cytoplasmic proteins during the life of a tobacco leaf. J. Biol. Chem. **229**, 945–952 (1957)

Dutrochet, H.R.J.: Mémoires pour servir á l'Histoire anatomique et physiologique des Végétaux et des Animaux, J.-B. Bailliére, Paris (1837)

Dutton, H.J.: Carotenoid-sensitized photosynthesis: quantum efficiency, fluorescence and energy transfer. Photosynth. Res. **52**, 175–185 (1997)

Dutton, H.J., Manning, W.M.: Evidence for carotenoid-sensitized photosynthesis in the diatom *Nitzschia closterium*. Am. J. Bot. **28**, 516–526 (1941)

Dutton, H.J., Manning, W.M., Duggar, B.M.: Chlorophyll fluorescence and energy transfer in diatom *Nitzschia closterium*. J. Phys. Chem. **47**, 308–313 (1943)

Duysens, L.N.M.: Transfer of light energy within the pigment systems present in photosynthesizing cells. Nature **168**, 548–550 (1951)

Duysens, L.N.M.: Transfer of excitation energy in photosynthesis, Ph.d. University of Utrecht, Netherlands (1952)

Duysens, L.N.M.: Reversible changes in the absorption spectrum of Chlorella upon irradiation. Science **120**, 353–354 (1954a)

Duysens, L.N.M.: Reversible photo-oxidation of a cytochrome pigment in photosynthesizing *Rhodospirillum rubrum*. Nature **173**, 692–693 (1954b)

Duysens, L.N.M.: Role of cytochrome and pyridine nucleotide in algal photosynthesis. Science **121**, 210–211 (1955)

Duysens, L.N.M.: Energy transformations in photosynthesis. Annu. Rev. Plant Physiol. **7**, 25–50 (1956)

Duysens, L.N.M.: Investigations in the photosynthetic mechanism of purple bacteria by means of sensitive absorption spectrophotometry. In: Gaffron, H., Brown, A.H., Stacy, F.C., Livingston, R., Rabinowitch, E.I., Strehler, B.L., Tolbert, N.E. (eds.), Research in photosynthesis: Papers and discussions presented at the Gatlinburg Conference, October 25–29, 1955, Interscience Publishers, pp. 164–173 (1957)

Duysens, L.N.M.: Cytochrome oxidation by a second photochemical system in the red alga *Porphyridium cruentum*. In: Christensen, B.C., Buchmann, B. (eds.) Progress in photobiology. Proceedings of the 3rd international Congress in photobiology, Copenhagen, 1960 Elsevier, Amsterdam, pp. 135–142 (1961)

Duysens, L.N.M.: The discovery of the two photosynthetic systems: a personal account. Photosynth. Res. **21**, 61–79 (1989)

Duysens, L.N.M., Huiskamp, W.J., Vos, J.J., van der Hart, J.M.: Reversible changes in bacteriochlorophyll in purple bacteria upon illumination. Biochim. Biophys. Acta **19**, 188–190 (1956)

Duysens, L.N.M., Amesz, J., Kamp, B.M.: Two photochemical systems in photosynthesis. Nature **190**, 510–511 (1961)

Eaton-Rye, J.: Govindjee at 80: more than 50 years of free energy for photosynthesis. Photosynth. Res. **116**, 111–144 (2013)

Edge, D.: Competition in modern science. In: Frängsmyr T. (ed.) Solomon's House Revisited. The Organization and Institutionalization of Science, pp. 208–232. Science History Publications, Canton (1990)

Edsall, J.T. (ed.): History of Bioenergetics. Special issue of the journal *Molecular and Cellular Biochemistry*. Papers from a Conference held at the American Academy of Arts and Sciences, Oct. 11–13, 1973 (1974)

Einstein, A.: Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. Annalen der Physik **17**, 132–148 (1905)

Einstein, A.: Über die Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung. Verhandlungen der Deutschen Physikalischen Gesellschaft **11**, 482–500 (1909)

Einstein, A.: Nachtrag zu meiner Arbeit: "Thermodynamische Begründung des photochemischen Aequivalentgesetzes". Annalen der Physik **38**, 881–884 (1912a)

Einstein, A.: Thermodynamische Begründung des photochemischen Aequivalentgesetzes. Annalen der Physik **37**, 832–838 (1912b)

Emerson, R.: A review of recent investigations in the field of chlorophyll photosynthesis. Ergebnisse der Enzymforschung **5**, 305–347 (1936)

Emerson, R., Arnold, W.: The photochemical reaction in photosynthesis. J. Gen. Physiol. **16**, 191–205 (1932a)

Emerson, R., Arnold, W.: A separation of the reactions in photosynthesis by means of intermittent light. J. Gen. Physiol. **15**, 391–420 (1932b)

Emerson, R., Chalmers, R.: Transient changes in cellular gas exchange and the problem of maximum efficiency of photosynthesis. Plant Physiol. **30**, 504–529 (1955)

Emerson, R., Chalmers, R.: Speculations concerning the function and phylogenetic significance of the accessory pigments of algae. Phycol. Soc. Am. News Bull. **11**, 51–56 (1958)

Emerson, R., Green, L.: Nature of the Blackman reaction in photosynthesis. Plant Physiol. **12**, 537–545 (1937)

Emerson, R., Lewis, C.M.: Factors influencing the efficiency of photosynthesis. Am. J. Bot. **26**(10), 808–822 (1939)

Emerson, R., Lewis, C.M.: Carbon dioxide exchange and the measurement of the quantum yield of photosynthesis. Am. J. Bot. **28**, 789–804 (1941a)

Emerson, R., Lewis, C.M.: The photosynthetic efficiency of phycocyanin in Chroococcus and the problem of carotenoid participation in photosynthesis. J. Gen. Physiol. **25**, 579–595 (1941b)

Emerson, R., Lewis, C.M.: The dependence of the quantum yield of Chlorella photosynthesis on wave length of light. Am. J. Bot. **30**, 165–178 (1943)

Emerson, R., Rabinowitch, E.I.: Red drop and role of auxiliary pigments in photosynthesis. Plant Physiol. **35**, 477–485 (1960)

Emerson, R., Stauffer, J.F., Umbreit, W.W.: Relationships between phosphorylation and photosynthesis in Chlorella. Am. J. Bot. **31**, 107–120 (1944)

Emerson, R., Chalmers, R.V., Cederstrand, C.N.: Some factors influencing the long-wave limit of photosynthesis. Proc. Natl. Acad. Sci. U S A **43**, 133–143 (1957)

Engelhardt, V.A.: Ortho- und Pyrophosphat im aeroben und anaeroben Stoffwechsel der Blutzellen. Biochemische Zeitung **227**, 16–38 (1930)

Engelhardt, V.A.: Myosine and adenosinetriphosphatase. Nature **144**, 668–669 (1939)

Erlenmeyer, E.: Das Wasser als Oxydations- und Reductionsmittel. Berichte der Deutschen Chemischen Gesellschaft **10**, 634–635 (1877)

Euler, H., Euler, A.: (1906a) Über die Bildung von i-Arabinoketose aus Formaldehyd. Berichte der deutschen chemischen Gesellschaft **39**, 45–51

Euler, H., Euler, A.: (1906b) Zur Kenntniss der Zuckerbildung aus Formaldehyd. Berichte der deutschen chemischen Gesellschaft **39**, 39–45

Evans, M.C., Buchanan, R.B., Arnon, D.I.: A new ferredoxin-dependent carbon reduction cycle in a photosynthetic bacterium. Proc. Natl. Acad. Sci. U S A **55**, 928–934 (1966)

Ewart, A.J.: On the function of chlorophyll. Proc. R. Soc. Lond., Series B. **89**, 1–17 (1915)

Fager, E.W.: Investigation of the chemical properties of intermediates in photosynthesis. In: Franck, J., Loomis, W.E. (eds.) Photosynthesis in Plants, pp. 423–436. State College Press, Ames (1949)

Fangerau, H.: Spinning the Scientific Web. Jacques Loeb (1859–1924) und sein Programm einer internationalen biomedizinischen Grundlagenforschung. Akademie Verlag, Berlin (2010)

Fantini, B.: The history of the stazione zoologica Anton Dohrn. An outline, S.Z.A.D. Napoli: Activity report 1998/99, Zoological Station Anton Dohrn, Naples, pp. 71–105 (2002)

Fenton, H.J.H.: The reduction of carbon dioxide to formaldehyde in aequous solution. J. Chem. Soc., Trans. **91**, 687–694 (1907)

Fink, R.M., Fink, K.: Radiocarbon and filter paper chromatography. Science **107**, 253 (1948)

Finlay, M.R.: Growing American Rubber: Strategic Plants and the Policies of National Security. Rutgers University Press, New Brunswick (2009)

Fischer, E.: Über die Verbindungen des Phenylhydrazins mit den Zuckerarten. III. Berichte der deutschen chemischen Gesellschaft **21**, 988–991 (1888)

Fischer, E.: Synthese der Mannose und Lävulose. Berichte der deutschen chemischen Gesellschaft **23**, 370–394 (1890a)

Fischer, E.: Synthese des Traubenzuckers. Berichte der deutschen chemischen Gesellschaft **23**, 799–805 (1890b)

Fischer, E.: Synthesen in der Zuckergruppe. Berichte der deutschen chemischen Gesellschaft **23**, 2114–2141 (1890c)

Fischer, E.: Synthesen in der Zuckergruppe I (Vortrag, gehalten in der Sitzung der Deutschen chemischen Gesellschaft am 23. Juni 1890), Untersuchungen über Kohlenhydrate und Fermente, Springer, Berlin, pp. 1–29. [Originally published in *Berichte der deutschen chemischen Gesellschaft* 23, 2114 (1890)] (1909)

Fischer, E., Passmore, F.: Bildung von Acrose aus Formaldehyd. Berichte der deutschen chemischen Gesellschaft **22**, 359–361 (1889)

Florkin, M.: A History of Biochemistry. Part IV. Early Studies on Biosynthesis, Vol. 32 der Comprehensive Biochemistry. Elsevier, Amsterdam (1977)

Florkin, M.: A History of Biochemistry. Part V: The Unravelling of Biosynthetic Pathways, Vol. 33A der Comprehensive Biochemistry. Elsevier, Amsterdam (1979)

Franck, J.: Elementary processes of photochemical reactions. Trans. Faraday Soc. **21**, 536–542 (1925)

Franck, J.: Emil Warburg zum achzigsten Geburtstage. Naturwissenschaften **14**(11), 203–207 (1926)

Franck, J.: Emil Warburg zum Gedächtnis. Naturwissenschaften **19**(50), 993–997 (1931)

Franck, J.: Beitrag zum Problem der Kohlensäure-Assimilation. Naturwissenschaften **23**, 226–229 (1935a)

Franck, J.: Remarks on photosynthesis. Chem. Rev. **17**, 433–438 (1935b)

Franck, J.: Photosynthetic activity of isolated chloroplasts. Rev. Mod. Phys. **17**, 112–119 (1945)

Franck, J.: An interpretation of the contradictory results in measurements of the photosynthetic quantum yield and related phenomena. Arch. Biochem. **23**, 297–314 (1949)

Franck, J., Gaffron, H.: Photosynthesis, facts and interpretation. Adv. Enzymol. **1**, 199–262 (1941)

Franck, J., Hertz, G.: Über ZusammenstöÃŸe zwischen Elektronen und den Molekülen des Quecksilberdampfes und die Ionisierungsspannung desselben. Verhandlungen der Deutschen Physikalischen Gesellschaft **16**, 457–467 (1914)

Franck, J., Herzfeld, K.F.: An attempted theory of photosynthesis. J. Chem. Phys. **5**, 237–251 (1937)

Franck, J., Herzfeld, K.F.: Contributions to a theory of photosynthesis. J. Phys. Chem. **45**, 978–1025 (1941)

Franck, J., Levi, H.: Beitrag zur Untersuchung der Fluoreszenz in Flüssigkeiten. Zeitschrift für Physikalische Chemie **B27**, 409–420 (1935a)

Franck, J., Levi, H.: Zum Mechanismus der Sauerstoff-Aktivierung durch fluoreszenzfähige Farbstoffe. Naturwissenschaften **23**, 229–230 (1935b)

Franck, J., Rabinowitch, E.I.: Some remarks about free radicals and the photochemistry of solutions. Trans. Faraday Soc. **30**, 120–130 (1934)

Franck, J., Rosenberg, J.L.: A theory of light utilization in plant photosynthesis. J. Theor. Biol. **7**, 276–301 (1964)

Franck, J., Teller, E.: Migration and photochemical action of excitation energy in crystals. J. Chem. Phys. **6**, 861–872 (1938)

Franck, J., French, C.S., Puck, T.T.: The fluorescence of chlorophyll and photosynthesis. J. Phys. Chem. **45**, 1268–1300 (1941)

French, C.S.: The rate of CO_2 assimilation by purple bacteria at various wave lengths of light. J. Gen. Physiol. **21**, 71–87 (1937)

French, C.S.: Robert Emerson, investigator of photosynthesis. Science **130**(3373), 437–438 (1959)

French, C.S.: Light, pigments and photosynthesis. In: McElroy, W.D., Glass, B. (eds.) Light and Life, pp. 447–474 . The Johns Hopkins Press, Baltimore (1961)

French, C.S.: Fifty years of photosynthesis. Annu. Rev. Plant Physiol. **30**, 1–26 (1979)

French, C.S., Anson, M.L.: Oxygen production by isolated chloroplasts. Am. J. Bot. **28**, 12s (abstract) (1941)

French, C.S., Young, V.K.: The fluorescence spectra of red algae and the transfer of energy from phycoerytherin to phycocyanin and chlorophyll. J. Gen. Physiol. **35**, 873–890 (1952)

Frenkel, A.W.: Light-induced phosphorylation by cell-free preparations of photosynthetic bacteria. J. Am. Chem. Soc. **76**, 5568–5569 (1954)

Frenkel, A.W.: Reflections. Photosynth. Res. **35**, 103–116 (1993)

Frenkel, A.W.: Photosynthetic phosphorylation. Photosynth. Res. **46**, 73–77 (1995)

Freudenthal, G.: A rational controversy over compounding forces. In: Machamer, P., Pera, M., Baltas, A. (eds.) Scientific Controversies. Philosophical and Historical Perspectives, pp. 125–142. Oxford University Press (2000)

Friedmann, H.C.: From "Butyribacterium" to "E. coli": an essay on unity in biochemistry. Perspect. Biol. Med. **47**, 47–66 (2004)

Frigg, R., Hartmann, S.: Models in science. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/spr2006/entries/models-science/. (2012)

Förster, T.: Energiewanderung und Fluoreszenz. Naturwissenschaften **33**, 166–175 (1946)

Förster, T.: Ein Beitrag zur Theorie der Photosynthese. Zeitschrift für Naturforschung **2b**, 174 (1947)

Förster, T.: Fluoreszenz organischer Verbindungen. Vandenhoeck & Ruprecht, Göttingen (1951)

Fruton, J.S.: Molecules and Life. Historical Essays on the Interplay of Chemistry and Biology. Wiley Interscience, New York (1972a)

Fruton, J.S.: Molecules and Life. Historical Essays on the Interplay of Chemistry and Biology. Wiley-Interscience, New York (1972b)

Fruton, J.S.: Proteins, Enzymes, Genes: The Interplay of Chemistry and Biology. Yale University Press, New Haven (1999)

Fuller, R.C.: Forty years of microbial photosynthesis research: where it came from and what it led to. Photosynth. Res. **62**, 1–29 (1999)

Gaffron, H.: Biochemische Zeitschrift **264**, 251–271 (1933a)

Gaffron, H.: Über den Stoffwechsel der schwefelfreien Purpurbakterien. Biochemische Zeitschrift **260**, 1–17 (1933b)

Gaffron, H.: Über die Kohlensäure-Assimilation der roten Schwefelbakterien. Biochemische Zeitschrift **269**, 447–453 (1934)

Gaffron, H.: Inwiefern ist Sauerstoff für die Kohlensäureassimilation unentbehrlich? Naturwissenschaften **23**, 528–528 (1935)

Gaffron, H.: Studies on the induction period of photosynthesis and light respiration in green algae. Am. J. Bot. **27**, 204–216 (1940)

Gaffron, H.: Van Niel's theory: thirty years Aater. In: Gest, H., San Pietro A., Vernon, L.P. (eds.) Bacterial Photosynthesis, pp. 3–14. Antioch Press, Yellow Springs (1963)

Gaffron, H.: Resistance to knowledge. Plant Physiol. **20**, 1–40 (1969)

Gaffron, H., Fager, E.W.: The kinetics and chemistry of photosynthesis. Annu. Rev. Plant Physiol. **2**, 87–114 (1951)

Gaffron, H., Wohl, K.: Zur Theorie der Assimilation. Naturwissenschaften **24**, 81–90, 103–107 (1936)

Gaffron, H., Brown, A.H., Stacy, F.C., Livingston, R., Rabinowitch, E.I., Strehler, B.L., Tolbert, N.E. (eds.): Research in photosynthesis: papers and discussions presented at the Gatlinburg conference, October 25–29, 1955, Interscience Publishers, Baltimore (1957)

Gamboa, S.: In defense of analogical reasoning. Inf. Logic **28**, 229–241 (2008)

Gest, H.: History of the word 'photosynthesis' and evolution of its definition. Photosynth. Res. **73**, 7–10 (2002)

Gest, H.: Samuel Ruben's contributions to research on photosynthesis and bacterial metabolism with radioactive carbon. Photosynth. Res. **80**, 77–83 (2004)

Gest, H.: A personal tribute to an eminent photosynthesis researcher Martin D. Kamen (1913–2002). In: Govindjee, Beatty, J.T., Gest, H., Allen, J.F. (eds.) Discoveries in Photosynthesis, pp. xxvii–xxviii. Springer, Dordrecht (2005)

Gest, H., Blankenship, R.E.: Time line of discoveries: anoxygenic bacterial photosynthesis. Photosynth. Res. **80**, 59–70 (2004)

Gest, H., Kamen, M.D.: Studies on the phosphorus metabolism of green algae and purple bacteria in relation to photosynthesis. J. Biol. Chem. **176**, 299–318 (1948)

Gibson, R.J.H.: A photoelectric theory of photosynthesis. Ann. Bot. **22**, 117–120 (1908)

Giere, R.N.: Controversies involving science and technology: a theoretical perspective. In: Machamer, P., Pera, M., Baltas, A. (eds.) Scientific Controversies. Philosophical and Historical Perspectives, pp. 125–150. Oxford University Press, Oxford (2000)

Glennan, S.: Mechanisms and the nature of causation. Erkenntnis **44**, 49–77 (1996)

Glennan, S.: Rethinking mechanistic explanation. Philos. Sci. **69**, S342–S353 (2002)

Glennan, S.: Modeling mechanisms. Stud. Hist. Philos. Biol. Biomed. Sci. **36**, 443–464 (2005)

Goenner, H.: Einstein in Berlin 1914–1933. Beck, Munich (2005)

Goenner, H., Castagnetti, G.: Einstein and the Kaiser Wilhelm Institute for physics: Institutional aims and scientific results, Preprint No. 261, MPI for the History of Science, Berlin (2004)

Goldman, A.: Social epistemology. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/spr2006/entries/models-science/. Accessed 16 March 2014 (2010)

Goldman, A.: A Guide to Social Epistemology, Social Epistemology: Essential Readings, pp. 11–37. Oxford University Press, Oxford/New York (2011)

Govindjee: Sixty-three years since Kautsky chlorophyll *a* fluorescence. Aust. J. Plant Physiol. **22**, 131–160 (1995)

Govindjee: On the requirement of minimum number of four versus eight quanta of light for the evolution of one molecule of oxygen in photosynthesis: a historical note. Photosynth. Res. **59**, 249–254 (1999)

Govindjee: Lighting the path: a tribute to Robert Emerson (1903–1959), PS2001 Proceedings: 12th International Congress on Photosynthesis, Brisbane, CSIRO Publishing, Melbourne (2001)

Govindjee: Chlorophyll *a* fluorescence: a bit of basics and history. In: Papageorgiou, G.C., Govindjee (eds.) Chlorophyll *a* Fluorescence: A Signature of Photosynthesis, Vol. 19 der Advances in Photosynthesis and Respiration, pp. 1–42. Springer (2004a)

Govindjee: Robert Emerson and Eugene Rabinowitch: understanding photosynthesis. In: Hoddeson, L. (ed.) No Boundaries: University of Illinois Vignettes, pp. 181–194. University of Illinois Press, Urbana (2004b)

Govindjee: Celebrating 20 years of historical papers in photosynthesis research. Photosynth. Res. **87**, 151–158 (2006)

Govindjee: Sam Aronoff. Am. Soc. Plant Biol. Newsl. **37**, 21–22 (2010)

Govindjee, Björn, L.O.: Dissecting oxygenic photosynthesis: the evolution of the Z-scheme for thylakoid membranes. In: Itoh, S., Mohanty, P., Guruprasad, K.N. (eds.) Photosynthesis: Overviews on Recent Progress and Future Perspective, pp. 1–27. I.K. International Publishers, New Delhi (2012)

Govindjee, Fork, D.: Charles Stacy French (1907–1995). Biogr. Mem. Natl. Acad. Sci. **88**, 1–29 (2006)

Govindjee, Govindjee, R.: Introduction to photosynthesis. In: Govindjee (ed.) Bioenergetics of Photosynthesis, pp. 1–50. Academic Press, New York (1975)

Govindjee, Krogmann, D.: Discoveries in oxygenic photosynthesis (1727–2003): a perspective. Photosynth. Res. **80**, 15–27 (2004)

Govindjee, Rabinowitch, E.I.: Two forms of chlorophyll *a* in vivo with distinct photochemical functions. Science **132**, 355–356 (1960)

Govindjee, R., Thomas, J.B., Rabinowitch, E.I.: "Second Emerson effect" in the Hill reaction of Chlorella cells with quinone as oxidant. Science **132**, 421–421 (1960)

Govindjee, Owens, O., Hoch, G.: A mass spectroscopic study of the Emerson enhancement effect. Biochimica et Biophysica Acta **75**, 281–284 (1963)

Govindjee, R., Rabinowitch, E.I., Govindjee: Maximum quantum yield and action spectra of photosynthesis and fluorescence in Chlorella. Biochim. Biophys. Acta **162**, 530–544 (1968)

Govindjee, Amesz, J., Knox, R.S.: Photosynthetic unit: Antenna and Reaction Centers (Special issue dedicated to William Arnold). Photosynth. Res. (1996)

Govindjee, Beatty, J.T., Gest, H., Allen, J.F. (eds.): Discoveries in Photosynthesis. Springer, Dordrecht (2005)

Govindjee, Björn, L.O., Nickelsen, K.: Evolution of the Z-Scheme of electron transport in oxygenic photosynthesis. In: Lu, C. (ed.) Research for Food, Fuel and Future: 15th International Conference on Photosynthesis, pp. 835–841. Zhejiang University Press (2012)

Grafe, V.: Über ein neues specifisches Formaldehydreagenz. Oesterreichische botanische Zeitschrift **56**, 289–291 (1906)

Grafe, V., Vieser, E.: Untersuchungen über das Verhalten grüner Pflanzen zu gasförmigem Formaldehyd. Berichte der deutschen chemischen Gesellschaft **27**, 431–446 (1909)

Grafe, V., Vieser, E.: Untersuchungen über das Verhalten grüner Pflanzen zu gasförmigem Formaldehyd II. Berichte der deutschen chemischen Gesellschaft **29**, 19–26 (1911)

Graßhoff, G.: Die Kunst wissenschaftlichen Entdeckens. Grundzüge einer Theorie epistemischer Systeme, habilitation treatise, University of Hamburg (1994)

Graßhoff, G.: Modelling the astrophysical object SS433: methodology of model construction by a research collective. Philosophia Naturalis **35**, 161–199 (1998)

Graßhoff, G.: Normal star observation in late astronomical babylonian diaries. In: Swerdlow, N.M. (ed.) Ancient Astronomy and Celestial Divination (Dibner Institute Studies in the History of Science and Technology), pp. 97–147. MIT Press, Cambridge (1999)

Graßhoff, G.: Inferences to causal relevance from experiments. In: Dieks, D., González, W.J., Hartmann, S., Uebel, T., Weber, M. (eds.) Explanation, Prediction and Confirmation, Vol. 2 der The Philosophy of Science in a European Perspective, pp. 167–182. Springer, Berlin (2011)

Graßhoff, G., May, M.: Causal regularities. In: Spohn, W., Ledwig, M., Esfeld, M. (eds.) Current Issues in Causation, pp. 85–114. Mentis, Paderborn (2001)

Graßhoff, G., May, M.: Hans Krebs and Kurt Henseleit's laboratory notebooks and their discovery of the urea cycle: reconstructed with computer models. In: Holmes, F.L., Renn, J., Rheinberger, H.-J. (eds.) Reworking the Bench: Research Notebooks in the History of Science, pp. 269–294. Kluwer Academic Publishers, Dordrecht (2003)

Graßhoff, G., Casties, R., Nickelsen, K.: Zur Theorie des Experiments. Untersuchungen am Beispiel der Entdeckung des Harnstoffzyklus, Educational Materials, Bern Studies for the History and Philosophy of Science, Bern (2000)

Groeben, C.: The Naples Zoological Station at the Time of Anton Dohrn: Exhibition and Catalogue. In Collaboration with Irmgard Müller. Stazione Zoologica, Naples (1975)

Groeben, C.: Catalysing science: The *Stazione Zoologica di Napoli* as a place for the circulation of scientific ideas. In: Groeben, C., Kaasch, J., Kaasch, M. (eds.) Places of Biological Research, pp. 53–64. Verlag für Wissenschaft und Bildung, Berlin (2005)

Gromet-Elhanan, Z.: Mordhay Avron, 1931–1991. J. Bioenerg. Biomembr. **24**, 520–521 (1992)

Guttman, L., Hess, D.C., Myers, F.E., Wolfe, H.C.: Foster Frederick Rieke 1905–1970. J. Appl. Phys. **41**, 3911 (1970)

Haber, F., Willstätter, R.: Unpaarigkeit und Radikalketten im Reaktionsmechanismus organischer und enzymatischer Vorgänge. Berichte der Deutschen Chemischen Gesellschaft **64**, 2844–2856 (1931)

Haberlandt, G.: Vergleichende Anatomie des assimilatorischen Gewebesystems der Pflanzen. Jahrbuch für wissenschaftliche Botanik **13**, 74–188 (1881)

Haberlandt, G.: Physiologische Pflanzenanatomie. Engelmann, Leipzig (1884)

Hall, T.S.: History of General Physiology, 2 vols. University of Chicago Press, Chicago. Originally published as: Ideas of Life and Matter, 2 vols. (University of Chicago Press, 1969) (1975)

Hall, V.M.D.: The role of force or power in Liebig's physiological thought. Med. Hist. **24**, 20–59 (1980)

Hatch, M.D.: I can't believe my luck. Photosynth. Res. **33**, 1–14 (1992)

Hatch, M.D.: C_4 photosynthesis: discovery and resolution. Photosynth. Res. **73**, 251–256 (2002)

Hatch, M.D., Slack, C.R.: Photosynthesis in sugar cane leaves: a new carboxylation reaction and the pathway of sugar formation. Biochem. J. **101**, 103–111 (1966)

Hatch, M.D., Slack, C.R., Johnson, H.S.: Further studies on a new pathway of photosynthetic CO_2 fixation in sugarcane and its occurrence in other plant species. Biochem. J. **102**, 417–422 (1967)

Haxo, F.T., Blinks, L.R.: Photosynthetic action spectra of marine algae. J. Gen. Physiol. **33**, 389–421 (1950)

Hearon, J.Z.: The configuration of cobaltodihistidine and oxy-bis(cobaltodihistidine). J. Natl. Cancer Inst. **9**, 1–11 (1948)

Hearon, J.Z., Burk, D., Schade, A.: Physicochemical studies of reversible and irreversible complexes of cobalt, histidine, and molecular oxygen. J. Natl. Inst. **9**, 337–377 (1949)

Heilbron, J.L., Seidel, R.W.: Lawrence and his Laboratory: A History of the Lawrence Berkeley Laboratory. University of California Press, Berkeley (1989)

Heilbron, J.L., Seidel, R.W., Wheaton, B.R.: Lawrence and his Laboratory: Nuclear Science at Berkeley. University of California Press, Berkeley (1981)

Hendricks, S.B.: A discussion of photosynthesis. Science **117**, 370–373 (1953)

Henning, E.: Otto Heinrich Warburg—Der "Kaiser von Dahlem". In: Treue, W., Hildebrandt, G. (eds.) Berlinische Lebensbilder. Bd. 1: Naturwissenschaftler, pp. 299–316. Colloquium Verlag, Berlin (1987)

Hentschel, K. (ed.): Physics and National Socialism. An Anthology of Primary Sources. Birkhäuser, Basel (1996)

Hentschel, K.: Die Mentalität deutscher Physiker in der frühen Nachkriegszeit (1945–1949). Synchron, Heidelberg (2005)

Herken, G.: Brotherhood of the Bomb. The Tangled Lives and Loyalties of Robert Oppenheimer, Ernest Lawrence, and Edward Teller. Henry Holt, New York (2002)

Hesse, M.B.: Models and Analogies in Science. Sheed and Ward, London (1963)

Hill, R.: Oxygen evolved by isolated chloroplasts. Nature **139**, 881–882 (1937)

Hill, R.: Oxygen produced by isolated chloroplasts. Proc. R. Soc. Lond., Series B **127**(847), 192–210 (1939)

Hill, R.: The cytochrome *b* component of chloroplasts. Nature **174**, 501 (1954)

Hill, R.: The biochemists' green mansions: the photosynthetic electron-transport chain in plants. In: Campbell, P.N., Greville, G.D. (eds.) Essays in Biochemistry, vol. 1, pp. 121–151. Academic Press, London (1965)

Hill, R., Bendall, F.: Crystallisation of a photosynthetic reductase from a green plant. Nature **187**, 417 (1960a)

Hill, R., Bendall, F.: Function of the two cytochrome components in chloroplasts: a working hypothesis. Nature **186**, 136–137 (1960b)

Hill, R., Bhagvat, K.: Cytochrome oxidase in flowering plants. Nature **143**, 726 (1939)

Hill, R., Bonner, W.D.: The nature and possible function of chloroplast cytochromes. In: McElroy, W.D., Glass, B. (eds.) Light and Life, pp. 424–435. Johns Hopkins Press, Baltimore (1961)

Hill, R., Hartree, E.F.: Hematin compounds in plants. Annu. Rev. Plant Physiol. **4**, 115–150 (1953)

Hill, R., Scarisbrick, R.: (1940a) Production of oxygen by iulluminated chloroplasts. Nature **146**, 61–62

Hill, R., Scarisbrick, R.: (1940b) The reduction of ferric oxalate by isolated chloroplasts. Proc. R. Soc. Lond., Series B **129**(855), 233–255

Hill, R., Scarisbrick, R.: The haematin compounds of leaves. New Phytol. **50**, 98–111 (1951)

Hirsch, R.E., Rich, M., Govindjee: A tribute to Seymour Steven Brody: in memoriam (November 29, 1927 to May 25, 2010). Photosynth. Res. **106**, 191–199 (2010)

Hofman, U., Baumgartner, M.: Determinism and the method of difference. Theoria **71**, 155–176 (2011)

Hofmann, K.A., Schumpelt, K.: Bildung von Formaldehyd und anderen organischen Stoffen aus Ameisensäure. I. Mitteilung: Selbstreduktion der Formiate. Berichte der Deutschen Chemischen Gesellschaft zu Berlin **49**, 303–317 (1916)

Holmes, F.L.: Lavoisier and the Chemistry of Life: An Exploration of Scientific Creativity. University of Wisconsin Press, Madison (1985)

Holmes, F.L.: Intermediary Metabolism in the Early Twentieth Century. In: Bechtel, W. (ed.) Integrating Scientific Disciplines, pp. 59–76. Martinus Nijhoff (1986)

Holmes, F.L.: Hans Krebs: The Formation of a Scientific Life, 1900–1933. Oxford University Press, New York (1991)

Holmes, F.L.: Investigative Pathways: Patterns and Stages in the Careers of Experimental Scientists. Yale University Press, New Haven (2004)

Holt, A.S., French, C.S.: Isotopic analysis of the oxygen evolved by illuminated chloroplasts in normal water and in water enriched with $^{1}8O$. Arch. Biochem. **19**, 429–435 (1948)

Homann, P.H.: Hydrogen metabolism of green algae: discovery and early research – a tribute to Hans Gaffron and his coworkers. Photosynth. Res. **76**, 93–103 (2002)

Hon, G., Goldstein, B.R.: Centenary of the Franck-Hertz experiments. Annalen der Physik **12**, A179–A183 (2013)

Hopkins, F.G.: On current views concerning the mechanisms of biological oxidation (with a foreword on the institutional needs of biochemistry). Skandinavisches Archiv für Physiologie **49**, 33–59 (1926)

Hopkins, F.G.: The dynamic side of biochemistry. In: Needham, J., Dunn, W., Baldwin, E. (eds.) Hopkins and Biochemistry: 1861–1947, pp. 136–159. Hefner and Sons, Cambridge (1949)

Hoppe, B.: Structural development of experimental methods in the researches on gas-exchange and photosynthesis. In: Hoppe, B. (ed.) Biology Integrating Scientific Fundamentals: Contributions to the History of Interrelations Between Biology, Chemistry, and Physics from the 18th to the 20th Centuries, Vol. 21 der Algorismus: Studien zur Geschichte der Mathematik und der Naturwissenschaften, pp. 10–30 . Institut für Geschichte der Naturwissenschaften, Munich (1997a)

Hoppe, B. (ed.): Biology Integrating Scientific Fundamentals: Contributions to the History of Interrelations between Biology, Chemistry, and Physics from the 18th to the 20th Centuries. Institut für Geschichte der Naturwissenschaften, München (1997b)

Horecker, B.L., Smyrniotis, P.Z.: The enzymatic formation of sedoheptulose phosphate from pentose phosophate. J. Am. Chem. Soc. **74**, 2123 (1952)

Horecker, B.L., Smyrniotis, P.Z.: The coenzyme function of thiamine pyrophosphate in pentose phosophate metabolism. J. Am. Chem. Soc. **75**, 1009–1010 (1953)

Horecker, B.L., Hurwitz, J., Weissbach, A.: Pentose phosphate and carbon dioxide fixation with spinach extracts. J. Am. Chem. Soc. **76**, 3611–3612 (1954)

Hungate, R.E.: Obituary: Cornelis B. van Niel (1897–1985). Photosynth. Res. **10**, 139–142 (1986)

Huzisige, H., Ke, B.: Dynamics of the history of photosynthesis research. Photosynth. Res. **38**, 185–209 (1993)

Höxtermann, E.: Photosynthese- und Stoffwechselforschung in der Geschichte der Botanik an der Berliner Universität (1810 bis 1945), number 27 in Beiträge zur Geschichte der Humboldt-Universität zu Berlin, Humboldt University, Berlin (1991)

Höxtermann, E.: Fundamental discoveries in the history of photosynthesis research. Photosynthetica **26**, 485–502 (1992)

Höxtermann, E.: Otto Heinrich Warburg (1883–1970). In: Jahn, I., Schmitt, M. (eds.) Darwin & Co. Eine Geschichte der Biologie in Portraits, vol. 2, pp. 251–274. Beck, Munich (2001)

Höxtermann, E.: (2007a) A comment on Warburg's early understanding of biocatalysis. Photosynth. Res. **92**, 121–127

Höxtermann, E.: (2007b) Der Stoffwechsel: die Chemie des Lebens. Zur Geschichte der Biochemie. In: Höxtermann E., Hilger, H.H. (eds.) Lebenswissen. Eine Einführung in die Geschichte der Biologie, pp. 143–177. Natur & Text, Rangsdorf

Höxtermann, E.: unpublished, Berliner Botaniker in der Geschichte der Biochemie, Submitted as habilitation thesis, 1993; Biology Department, Friedrich Schiller University Jena (1993)

Höxtermann, E., Sucker, U.: Otto Warburg, number 91 in Biographien hervorragender Naturwissenschaftler, Techniker und Mediziner. Teubner, Leipzig (1989)

Illari, P.M., Williamson, J.: Mechanisms are real and local. In: Illari, P.M., Russo, F., Williamson, J. (eds.) Causality in the Sciences, pp. 818–844. Oxford University Press, Oxford/New York (2011)

Illari, P., Williamson, J.: What is a mechanism? Thinking about mechanisms across the sciences. Eur. J. Philos. Sci. **2**, 119–135 (2012)

Illari, P.M., Russo, F., Williamson, J.: Why look at causality in the sciences? A manifesto. In: Illari, P.M., Russo, F., Williamson, J. (eds.) Causality in the Sciences, pp. 3–22. Oxford University Press, Oxford/New York (2011)

Jacob, C.: Philosophy and biochemistry: research at the interface between chemistry and biology. Found. Chem. **4**, 97–125 (2002)

Jacoby, M.: Über den Formaldehyd als Übergangsstufe zwischen der eigentlichen Assimilation und der Kohlenhydratbildung in der Pflanze. Biochemische Zeitschrift **101**, 1–6 (1919)

Jacoby, M.: Über den Formaldehyd als Übergangsstufe zwischen der eigentlichen Assimilation und der Kohlenhydratbildung in der Pflanze II.. Biochemische Zeitschrift **128**, 119–121 (1922)

Jaenicke, L.: Horst Tobias Witt (1922–2007). Ahnherr der biophysikalischen Photosyntheseforschung in Deutschland. BIOspektrum **7**, 815–816 (2007)

Jagendorf, A.T.: Oxidation and reduction of pyridine nucleotides by purified chloroplasts. Arch. Biochem. Biophys. **62**, 141–150 (1956)

Jagendorf, A.T.: Chance, luck and photosynthesis research: an inside story. Photosynth. Res. **57**, 215–229 (1998)

Janko, J., Strbánová, S.: Interrelations of biology, physics, and chemistry in historical perspective, number 23 in Acta historiae rerum naturalium necnon technicarum, Prague (1991)

Jencks, W.P., Wolfenden, R.F.: Fritz Albert Lipmann (1899–1986). Biogr. Mem. Fellows R. Soc. **46**, 335–344 (2000)

Johnson, J.A.: The Kaiser's Chemists. Science and Modernization in Imperial Germany. University of North Carolina Press, Chapel Hill (1990)

Johnston, H.: A Bridge not Attacked. Chemical Warfare Civilian Research During World War II. World Scientific Publishing, River Edge (2003)

Jost, W.: Kurt Wohl. Berichte der Bunsengesellschaft **67**, 347–348 (1963)

Jörgensen, I., Stiles, W.: A review of recent work on the pigments of the green leaf and the processes connected with them. New Phytol. **15**, 176–193, 205–232 (1916a)

Jörgensen, I., Stiles, W.: A review of recent work on the pigments of the green leaf and the processes connected with them. Part II. New Phytol. **16**, 24–45, 77–104 (1916b)

Junge, W.: Protons, proteins and ATP. In: Govindjee, Beatty, J.T., Gest, H., Allen, J.F. (eds.) Discoveries in Photosynthesis, pp. 571–595. Springer (2005)

Junge, W., Rutherford, A.W.: Obituary: Horst Tobias Witt (1922–2007). Nature **448**, 425 (2007)

Kalckar, H.: Phosphorylation in kidney tissues. Enzymologia **2**, 47–52 (1937)

Kalckar, H.: Origins of the concept oxidative phosphorylation. Mol. Cell. Biochem. **5**, 55–62 (1974)

Kalckar, H.: 50 years of biological research: from oxidative phosphorylation to energy requiring transport regulation. Annu. Rev. Biochem. **60**, 1–37 (1991)

Kalckar, H.M.: The nature of energetic coupling in biological systems. Chem. Rev. **28**, 71–178 (1941)

Kamen, M.D.: Some remarks on tracer researches in photosynthesis. In: Franck, J., Loomis, W.E. (eds.) Photosynthesis in Plants, pp. 365–380. State College Press, Ames (1949)

Kamen, M.D.: Early days in CO_2 fixation: some brief comments on the Berkeley experience. Mol. Cell. Biochem. **5**, 99–101 (1974)

Kamen, M.D.: Radiant Science, Dark Politics. A Memoir of the Nuclear Age. University of California Press, Berkeley (1985)

Kamen, M.D.: Onward in a fabulous half century. Photosynth. Res. **21**, 139–144 (1989)

Kamp, A.F., Riviére, J.W. M.L., Verhoeven, W. (eds.): Albert Jan Kluyver: His Life and Work. Biographical Memoranda, Selected Papers, Bibliography and Addenda. North-Holland Publishing Company, Amsterdam (1959)

Kandler, O.: Über die Beziehung zwischen Phosphathaushalt und Photosynthese: I. Phosphatspiegelschwankungen bei *Chlorella pyrenoidosa* als Folge des Licht-Dunkel-Wechsels. Zeitschrift für Naturforschung **5b**, 423–437 (1950)

Kandler, O.: Über die Beziehung zwischen Phosphathaushalt und Photosynthese: II. Gesteigerter Glucose-Einbau im Licht als Indikator einer lichtabhängigen Phosphorylierung. Zeitschrift für Naturforschung **9b**,625–644 (1954)

Kandler, O.: Über die Beziehung zwischen Phosphathaushalt und Photosynthese: III. Hemmungsanalyse der lichtabhängigen Phosphorylierung. Zeitschrift für Naturforschung **10b**, 38–46 (1955)

Katz, E.: Chlorophyll fluorescence as an energy flow meter for photosynthesis. In: Franck, J., Loomis, W.E. (eds.) Photosynthesis in Plants, pp. 287–292. State College Press, Ames (1949)

Kautsky, H., Hirsch, A.: Neue Versuche zur Kohlensäureassimilation. Naturwissenschaften **19**, 964–964 (1931)

Kautsky, H., Hirsch, A., Davidshöfer, F.: Energie-Umwandlungen an Grenzflächen. VI. Mitteilung: Kohlensäure-Assimilation (1.). Berichte der Deutschen Chemischen Gesellschaft **65**, 1762–1770 (1932)

Kautsky, H., de Bruijn, H., Neuwirth, R., Baumeister, W.: Energie-Umwandlungen an Grenzflächen. VII. Mitteilung: photo-sensibilisierte Oxydation als Wirkung eines aktiven, metastabilen Zustandes des Sauerstoff-Moleküls. Berichte der Deutschen Chemischen Gesellschaft **66**, 1588–1600 (1933)

Kautsky, H., Hirsch, A., Davidshöfer, F.: Der Einfluß der Kohlensäure auf das Fluoreszenz-Verhalten lebender Blätter. Biochemische Zeitschrift **277**, 250–260 (1935)

Kay, L.E.: The Molecular Vision of Life: Caltech, The Rockefeller Foundation and The Rise of the New Biology. Oxford University Press, New York (1993)

Keilin, D.: A comparative study of turacin and haematin and its bearing on cytochrome. Proc. R. Soc. Lond., Series B **100**, 129–151 (1925a)

Keilin, D.: On cytochrome, a respiratory pigment, common to animals, yeast, and higher plants. Proc. R. Soc. Lond., Series B **98**, 312–339 (1925b)

Keilin, D.: The History of Cell Respiration and Cytochrome. Cambridge University Press, Cambridge (1966)

Keilin, D., Dixon, M., Hill, R.: The absorption spectrum of the component *c* of cytochrome. Proc. R. Soc. Lond., Series B **109**, 29–34 (1931)

Keilin, D., Hill, R.: Estimation of haematin iron and the oxidation-reduction equivalent of cytochrome *c*. Proc. R. Soc. Lond., Series B **114**, 104–109 (1933)

Kennedy, E.P.: Herman Moritz Kalckar (1908–1991). Biogr. Mem. Natl. Acad. Sci. **69**, 148–165 (1996)

Kennedy, E.P.: Hitler's gift and the era of biosynthesis. J. Biol. Chem. **276**, 42619–42631 (2001)

Kimpflin, G.: Présence du menthal dans les végétaux vertes. Comptes Rendus de l'Académie des Sciences **144**, 148–150 (1907)

Kimpflin, G.: Essai sur l'assimilation photochlorophyllienne du carbone. A. Rey Imprimeur-éditeur de l'Université, Lyon (1908)

Kitcher, P.: The division of cognitive labour. J. Philos. **87**, 5–22 (1990)

Kitcher, P.: Patterns of scientific controversy. In: Machamer, P., Pera, M., Baltas, A. (eds.) Scientific Controversies. Philosophical and Historical Perspectives, pp. 21–39. Oxford University Press, Oxford/New York (2000)

Klein, M.J., Kox, A.J., Schulmann, R.E.: The Swiss Years: Correspondence, 1902–1914, Vol. 5 der The Collected Papers of Albert Einstein. Princeton University Press, Princeton (1993)

Klein, M.J., Kox, A.J., Renn, J., Schulmann, R.: The Swiss Years: Writings, 1912–1914, Vol. 4 der The Collected Papers of Albert Einstein. Princeton University Press, Princeton (1995)

Kleinkauf, H., von Döhren, H., Jaenicke, L.: The Roots of Modern Biochemistry: Fritz Lipmann's Squiggle and its Consequences. Walter de Gruyter, Berlin (1988)

Klemm, F.: Baeyer, Adolf Johann Friedrich Wilhelm Ritter von, Neue Deutsche Biographie (NDB), vol. 1. Duncker & Humblot, Berlin (1953)

Klingenberg, M., Müller, A., Schmidt-Mende, P., Witt, H.T.: Changes in absorption during photosynthesis in the ultra-violet spectrum. Nature **194**, 379–380 (1962)

Kluyver, A.J., Donker, H.J.L.: Die Einheit in der Biochemie. Chemie der Zelle und Gewebe: Zeitschrift für die Probleme der Gärung, Atmung und Vitaminforschung **13**, 134–139 (1926)

Knox, R.S.: Electronic excitation transfer in the photosynthetic unit: reflections on work of William Arnold. Photosynth. Res. **48**, 35–39 (1996)

Kohler, R.E.: The background to Otto Warburg's conception of the Atmungsferment. J. Hist. Biol. **6**(2), 171–192 (1973a)

Kohler, R.E.: The enzyme theory of life and the origins of biochemistry. Isis **64**, 171–192 (1973b)

Kohler, R.E.: Rudolf Schoenheimer, isotopic tracers, and the dynamic state. Hist. Stud. Phys. Sci. **8**, 257–298 (1977)

Kohler, R.E.: From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline. Cambridge University Press, Cambridge (1982)

Kohler, R.E.: Partners in Science. Foundations and Natural Scientists 1900–1945. University of Chicago Press, Chicago (1991)

Kok, B.: On the reversible absorption change at 705 nm in photosynthetic organisms. Biochimica et Biophysica Acta **22**, 399–401 (1956)

Kok, B.: Light induced absorption changes in photosynthetic organisms. Acta Botanica Neerlandica **6**, 316–336 (1957)

Kok, B.: Light induced absorption changes in photosynthetic organisms II. A split beam difference spectrophotometer. Plant Physiol. **34**, 184–192 (1959)

Kok, B.: Efficiency of photosynthesis. In: Pirson, A. (ed.) Handbuch der Pflanzenphysiologie, pp. 566–633. Springer, Berlin (1960)

Kok, B.: Does photosynthesis require the interaction of two photochemical steps?, Recent advances in botany, Volume II: From lectures and symposia presented to the IXth International Botanical Congress, Montreal, August, 1959, University of Toronto Press, Toronto, Canada, pp. 1071–1072 (1961a)

Kok, B.: Partial purification and determination of oxidation reduction potential of the photosynthetic chlorophyll complex absorbing at 700 mμ. Biochimica et Biophysica Acta **48**, 527–532 (1961b)

Kok, B., Hoch, G.: Spectral changes in photosynthesis. In: McElroy, W.D., Glass, B. (eds.) Light and Life, pp. 397–423. Johns Hopkins Press, Baltimore (1961)

Kornberg, H.L.: John Rodney Quayle (1926–2006). Photosynth. Res. **89**, 59–62 (2006)

Kortschak, H.P., Hartt, C.E., Burr, G.O.: Carbon dioxide fixation in sugarcane leaves. Plant Physiol. **40**, 209–213 (1965)

Krebs, H.: The discovery of carbon dioxide fixation in mammalian tissues. Mol. Cell. Biochem. **5**, 79–94 (1974)

Krebs, H.: Otto Warburg: Zellphysiologe, Biochemiker, Mediziner 1883–1970, Grosse Naturforscher; 41, Wissenschaftliche Verlagsgesellschaft. Stuttgart (1979)

Krebs, H., Henseleit, K.: Untersuchungen über die Harnstoffbildung im Tierkörper. Hoppe-Seyler's Zeitschrift für physiologische Chemie **210**, 33–66 (1932)

Krebs, H.A., Johnson, W.A.: Metabolism of ketonic acids in animal tissues. Biochem. J. **31**, 645–660 (1937)

Kresge, N., Simoni, R.D., Hill, R.: The discovery of ferredoxin and its role in photosynthesis: the work of Anthony San Pietro. J. Biol. Chem. **280**, e48 (2005)

Krogmann, D.W.: The golden age of biochemical research in photosynthesis. Photosynth. Res. **63**, 109–121 (2000)

Kuhn, H.G.: James Franck (1882–1964). Biogr. Mem. Fellows R. Soc. **11**, 51–74 (1965)

Larkum, A.W.D.: Contributions of Henrik Lundegårdh. Photosynth. Res. **76**, 105–110 (2003)

Latour, B., Woolgar, S.: The cycle of credibility. In: Barnes, B., Edge, D. (eds.) Science in Context: Readings in the Sociology of Science, pp. 35–43. MIT Press, Cambridge (1982)

Latour, B., Woolgar, S.: Laboratory Life. The Construction of Scientific Facts. Princeton University Press, Princeton (1985)

Laudan, L.: Science and Values. The Aims of Science and Their Role in Scientific Debate. University of California Press, Berkeley (1984)

Laurence, W.L.: Atomic key to life is feasible now, New York Times (9 October 1945) p. 6 (1945)

Laurence, W.L.: Dawn Over Zero. The Story of the Atomic Bomb. Knopf, New York (1946a)

Laurence, W.L.: Is atomic energy the key to our dreams? Saturday Evening Post (13 April 1946) pp. 9–10, 36–37, 39, 41 (1946b)

Löb, W.: Zur Kenntnis der Assimilation der Kohlensäure. Landwirtschaftliche Jahrbücher **35**, 541–578 (1906)

Lehmann, J.: Kohlenstoff-14 und die Assimilation des Kohlendioxids. Chemie in unserer Zeit **2**, 67–73 (1968)

Lehninger, A.L.: Phosphorylation coupled to the oxidation of dihydrophosphopyridine nucleotide. J. Biol. Chem. **190**, 345–359 (1951)

Lemmerich, J.: Aufrecht im Sturm der Zeit: Der Physiker James Franck (1882–1964). Verlag für Geschichte der Naturwissenschaften und Technik, Diepholz (2007)

Levitt, L.S.: Photosynthesis as a photoelectric phenomenon. Science **118**, 696–697 (1953)

Levitt, L.S.: The role of magnesium in photosynthesis. Science **120**, 33–35 (1954)

Liebig, J.: Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie. Vieweg & Sohn, Brunswick (1840)

Liebig, J.: Chemistry in its Applications to Agriculture and Physiology, 2nd, enlarged edn. Taylor & Walton, London (1842)

Liebig, J.: Die Wechselwirthschaft. Annalen der Chemie und Pharmazie **46**, 58–97 (1843)

Lineweaver, H., Burk, D.: The determination of enzyme dissociation constants. J. Am. Chem. Soc. **56**, 658–666 (1934)

Lipman, T.O.: Vitalism and reductionism in Liebig's physiological thought. Isis **58**, 167–185 (1967)

Lipmann, F.: Metabolic generation and utilization of phosphate bond energy. Adv. Enzymol. **1**, 99–162 (1941)

Lipmann, F.: Wanderings of a Biochemist. Wiley-Interscience, New York (1971)

Loach, P.: A remembrance of Melvin Calvin. Photosynth. Res. **54**, 1–3 (1997)

Loeb, J.: Studies in General Physiology. The University of Chicago Press, Chicago (1905)

Loew, O.: Über Formaldehyd und dessen Condensation. Journal für praktische Chemie **33**, 321–351 (1886)

Loew, O.: Einige Bemerkungen über Formose. Berichte der deutschen chemischen Gesellschaft **20**, 141–144 (1887)

Loew, O.: Über die Condensation des Formaldehyds unter verschiedenen Bedingungen. Berichte der deutschen chemischen Gesellschaft **21**, 270–275 (1888)

Loew, O.: Über Bildung von Zuckerarten aus Formaldehyd. Berichte der deutschen chemischen Gesellschaft **22**, 470–478 (1889)

Lohmann, K.: Über die Pyrophosphatfraktion im Muskel. Naturwissenschaften **17**, 624–625 (1929)

Loomis, W.E.: Historical introduction. In: Pirson, A., Ruhland, W. (eds.) Handbuch der Pflanzenphysiologie, vol. 5, Teil 1, pp. 85–114. Springer, Berlin (1960)

Losada, M., Trebst, A.V., Arnon, D.I.: Photosynthesis by isolated chloroplasts XI: CO_2 assimilation in a reconstituted chloroplast system. J. Biol. Chem. **235**, 832–839 (1959)

Lundegårdh, H.: On the oxidation of cytochrome *f* by light. Physiologia Plantarum **7**, 375–382 (1954)

Machamer, P., Darden, L., Craver, C.F.: Thinking about mechanisms. Philos. Sci. **67**, 1–25 (2000)

Macrakis, K.: Surviving the Swastika. Scientific Research in Nazi Germany. Oxford University Press, New York (1993)

Magee, J.L., Witt, T.W., Smith, E.C., Daniels, F.: A photocalorimeter. The quantum efficiency of photosynthesis in algae. J. Am. Chem. Soc. **61**, 3529–3533 (1939)

Mann, T.: David Keilin, 1887–1963. Biogr. Mem. Fellows R. Soc. **10**, 183–205 (1964)

Manning, W.M.: Photosynthesis. In: Hugh, S.T. (ed.) Third Report of the Committee on Photochemistry: Reprint and Circular Series of the National Research Council, number 108, pp. 117–156. National Academies Press (1938)

Manning, W.M., Stauffer, J.F., Duggar, B.M., Daniels, F.: Quantum efficiency of photosynthesis in *Chlorella*. J. Am. Chem. Soc. **60**, 266–274 (1938)

Maquenne, L.: Action de l'ozone sure les carbures. Bulletin de la Société Chimique de Paris **37**, 298–300 (1882)

Martin, A.J.P., Synge, R.L.M.: A new form of chromatogram employing two liquid phases. Biochem. J. **35**, 1358–1368 (1941)

Maruyama, K.: The discovery of adenosine triphosphate and the establishment of its structure. J. Hist. Biol. **24**, 145–154 (1991)

Mauskopf, S.H., Schmaltz, T.M. (eds.): Integrating History and Philosophy of Science: Problems and Prospects. Springer, Dordrecht (2011)

May, M.: Kausales Schließen. Eine Untersuchung zur kausalen Erklärung und Theorienbildung, dissertation, University of Hamburg (1999)

Mayaudon, J.: Study of association between the main nucleoprotein of green leaves and carboxydismutase. Enzymologia **18**, 345–354 (1957)

Mayaudon, J., Benson, A.A., Calvin, M.: Ribulose-1,5-diphosphate from and CO_2 fixation by *Tetragonia expansa* leaves extract. Biochimica et Biophysica Acta **23**, 342–351 (1957)

Mayer, J.R.: Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel. Drechsler, Heilbronn (1845)

Mazé, P.: Recherches sur l'assimilation du gaz carbonique par les plantes vertes. Comptes Rendus de l'Académie des Sciences **171**, 1391–1393 (1920)

McElroy, W.D., Glass, B. (eds.): Light and Life. Johns Hopkins Press, Baltimore (1961)

McMullin, E.: Scientific controversy and its termination. In: Engelhardt, H.T., Caplan, A.L. (eds.) Scientific Controversies. Case Studies in the Resolution and Closure of Disputes in Science and Technology, pp. 49–91. Cambridge University Press (1987)

Melis, A., Buchanan, R.B.: A Tribute to Daniel I. Arnon, Photosynthesis Research 46 (1–2). (Special issues dedicated to Daniel Arnon) (1995)

Mendelsohn, E.: The political anatomy of controversy in the sciences. In: Engelhardt, H.T., Caplan, A.L. (eds.), Scientific Controversies. Case Studies in the Resolution and Closure of Disputes in Science and Technology, pp. 93–124. Cambridge University Press, Cambridge (1987)

Metz, C.B., Clapp, P.L. (eds.): The Naples Zoological Station and the Marine Biological Laboratory. Symposium Supplement to the Biological Bulletin, vol. 168, No. 3 (1985)

Mitchell, P.: Chemiosmotic coupling in oxidative and photosynthetic phosphorylation. Biochem. J. **79**, 23B–24B (1961a)

Mitchell, P.: Coupling of phosphorylation to electron and hydrogen transfer by a chemi-osmotic type of mechanism. Nature **191**, 144–148 (1961b)

Moore, B., Webster, T.A.: Synthesis of formaldehyde from carbon dioxide and water by inorganic colloids, acting as transformers of light energy. Proc. R. Acad. Lond., Series B **87**, 163–176 (1913)

Morrison, M.: Where have all the theories gone? Philos. Sci. **74**, 195–228 (2006)

Mortenson, L.E., Valentine, R.C., Carnahan, J.E.: An electron transport factor from *Clostridium pasteurianum*. Biochem. Biophys. Res. Commun. **7**, 448–452 (1962)

Morton, O.: Eating the Sun. How Plants Power the Planet. Fourth Estate, London (2007)

Moses, V., Calvin, M.: The path of carbon in photosynthesis XXI. The identification of carboxy-ketopentitol diphosphates as products of photosynthesis. Proc. Natl. Acad. Sci. U S A **44**, 260–277 (1958)

Moses, V., Moses, S.: The Calvin Lab: Bio-organic chemistry group at the University of California, Berkeley, 1945–1963. An oral history conducted 1995–1997. Regional Oral History Office, The Bancroft Library, University of California, Berkeley (2000)

Myers, J.: Evidences for a specific participation of chlorophyll *b* in photosynthesis, Recent advances in botany, Volume II: From lectures and symposia presented to the IXth International Botanical Congress, Montreal, August, 1959, University of Toronto Press, Toronto, Canada, pp. 1073–1076 (1961)

Myers, J.: Conceptual developments in photosynthesis. Plant Physiol. **54**, 420–426 (1974)

Myers, J.: Bessel Kok (1918–1979). Biogr. Mem. Natl. Acad. Sci. U S A **57**, 124–149 (1987)

Myers, J.: The 1932 experiments. Photosynth. Res. **40**, 303–310 (1994)

Myers, J.: In one era and out the other. Photosynth. Res. **73**, 21–28 (2002)

Myers, J., French, C.S.: (1960a) Evidences from action spectra for a specific participation of chlorophyll *b* in photosynthesis. J. Gen. Physiol. **43**, 723–736

Myers, J., French, C.S.: (1960b) Relationships between time course, chromatic transient, and enhancement phenomena of photosynthesis. Plant Physiol. **35**, 963–969

Nachmansohn, D.: Biochemistry as part of my life. Annu. Rev. Biochem. **41**, 1–28 (1972)

Needham, J., Dunn, W., Baldwin, E. (eds.): Hopkins and Biochemistry: 1861–1947. Hefner and Sons, Cambridge (1949)

Nef, J.U.: Dissoziationsvorgänge in der Zuckergruppe (Zweite Abhandlung). Über das Verhalten der Zuckerarten gegen Aetzalkalien. Annalen der Chemie **376**, 1–119 (1910)

Nef, J.U.: Dissoziationsvorgänge in der Zuckergruppe (Dritte Abhandlung). Annalen der Chemie **403**, 204–383 (1913)

Nickelsen, K.: Wissenschaftliche Pflanzenzeichnungen—Spiegelbilder der Natur? Botanische Abbildungen aus dem 18. und frühen 19. Jahrhundert. Bern Studies in the History and Philosophy of Science, Bern (2000)

Nickelsen, K.: Botanists, draughtsmen and nature. The construction of eighteenth-century botanical illustration. Stud. Hist. Philos. Biol. Biomed. Sci. **37**, 1–25 (2006a)

Nickelsen, K.: Draughtsmen, Botanists and Nature. The Construction of Eighteenth-Century Botanical Illustrations. Archimedes, Kluwer Academic, Dordrecht (2006b)

Nickelsen, K.: Otto Warburg's first approach to photosynthesis. Photosynth. Res. **92**, 109–120 (2007)

Nickelsen, K.: Ein bisher unbekanntes Zeitzeugnis—Otto Warburgs Tagebuchnotizen Feb.–April 1945. NTM. Zeitschrift für Geschichte der Naturwissenschaften, Technik und Medizin **16**, 103–115 (2008a)

Nickelsen, K.: From leaves to molecules: botany and the development of photosynthesis research. Ann. Hist. Philos. Biol. **12**, 1–40 (2008b)

Nickelsen, K.: The construction of a scientific model: Otto Warburg and the building block strategy. Stud. Hist. Philos. Biol. Biomed. Sci. **40**, 73–86 (2009)

Nickelsen, K.: "For Methods go to Naples": Die Stazione Zoologica Anton Dohrn. In: Schmundt, H., Véc, M., Westphal, H.(eds.), Mekkas der Moderne. Pilgerstätten der Wissensgesellschaft. Böhlau. Wien. Böhlau (2010)

Nickelsen, K.: From the Red Drop to the Z-scheme of photosynthesis. Annalen der Physik **524**, A157–A160 (2012a)

Nickelsen, K.: The path of carbon in photosynthesis: how to discover a biochemical pathway. Ambix **59**, 266–293 (2012b)

Nickelsen, K.: Kooperation und Konkurrenz in den Naturwissenschaften. In: Jessen, R. (ed.) Konkurrenz in der Geschichte. Praktiken—Werte—Institutionalisierungen, pp. 353–379. Campus, Frankfurt (2014)

Nickelsen, K., Govindjee: The Maximum Quantum Yield Controversy: Otto Warburg and the "Midwest-Gang". Bern Studies in the History and Philosophy of Science. Bern (2011)

Nickelsen, K., Graßhoff, G.: In pursuit of formaldehyde: causally explanatory models and falsification. Stud. Hist. Philos. Biol. Biomed. Sci. **42**, 297–305 (2011)

Nickelsen, K., Graßhoff, G.: Concepts from the bench: Krebs and the urea cycle. In: Hon, G., Schickore, J., Steinle, F. (eds.) Going Amiss in Experimental Research, pp. 91–117. Springer, Dordrecht et al. (2008)

Nishimura, M.S., Whittingham, C.P., Emerson, R.: The Maximum Efficiency of Photosynthesis. Carbon Dioxide Fixation and Photosynthesis, pp. 176–210. Cambridge University Press, Cambridge, (1951)

Ochoa, S.: Chemical transformations in photosynthesis. Fed. Proc. **9**, 551–553 (1950)

Ochoa, S., Vishniac, W.: Carboxylation reactions and photosynthesis. Science **115**, 297–301 (1952)

Ochoa, S., Veiga Salles, J.B., Ortiz, P.J.: Biosynthesis of dicarboxylic acids by carbon dioxide fixation. III. Enzymatic synthesis of igr-malic acid by reductive carboxylation of pyruvic acid. J. Biol. Chem. **187**, 863–874 (1950)

Ohmura, T.: Oxidative and photosynthetic phosphorylation. Nature **176**, 467–468 (1955)

Oppenheimer, J.R.: Internal conversion in photosynthesis (Abstract). Phys. Rev. **60**, 158 (1941)

Osterhout, W.J.V.: A method for studying respiration. J. Gen. Physiol. **1**, 17–22 (1918)

Osterhout, W.J.V.: Comparative studies on respiration. VII. Respiration and antagonism. J. Gen. Physiol. **2**, 1–3 (1919)

Osterhout, W.J.V.: Jacques Loeb. J. Gen. Physiol. **8**, ix–lix (1928)

Osterhout, W.J.V., Haas, A.R.C.: On the dynamics of photosynthesis. J. Gen. Physiol. **1**, 1–16 (1918)

Osterhout, W.J.V., Haas, A.R.C.: The temperature coefficient of photosynthesis. J. Gen. Physiol. **2**, 299–304 (1919)

Pauli, W.: Wissenschaftlicher Briefwechsel mit Bohr, Einstein, Heisenberg u. a., Vol. 3: 1940–1949. Springer, Berlin (1993)

Pauly, P.J.: Controlling Life: Jacques Loeb and the Engineering Ideal in Biology. Oxford University Press, New York (1987a)

Pauly, P.J.: General physiology and the discipline of physiology, 1890–1935. In: Geison, G.L. (ed.) Physiology in the American Context, 1850–1940, pp. 195–208. American Physiological Society, Bethesda (1987b)

Pearl, J.: Causality: Models, Reasoning, and Inference. Cambridge University Press, Cambridge (2000)

Pearlstein, R.M.: Photosynthetic exciton theory in the 1960s. Photosynth. Res. **73**, 119–126 (2002)

Pfeffer, W.: Pflanzenphysiologie. Ein Handbuch der Lehre vom Stoffwechsel und Kraftwechsel in der Pflanze, 2., revised and amended edn. Engelmann, Leipzig (1897)

Pietro, A.S.: Memories: from protein synthesis to photosynthesis. Photosynth. Res. **96**, 185–199 (2008)

Pirson, A.: Sixty years in algal physiology and photosynthesis. Photosynth. Res. **40**, 207–221 (1994)

Pirson, A., Krollpfeiffer, I., Schaefer, G.: Leistungsfähigkeit und Fehlerquellen manometrischer Stoffwechselmessungen. Marburger Sitzungsberichte **76**, 3–27 (1953)

Pollacci, G.: (1902a) Intorno all' assimilazione clorofilliana delle piante. Seconda memoria. Atti dell'Istituto Botanico dell'Universitá di Pavia **8**, 1–66

Pollacci, G.: (1902b) L'assimilation chlorophyllienne. Deuxiéme memoire. Archives Italiennes de Biologie **36**, 446–448

Pollacci, G.: Elettricitá e vegetazione. Parte I. Influenz dell' elettricitá sulla fotosintesi clorofilliana. Atti dell'Istituto Botanico dell'Universitá di Pavia **13**, 1–152 (1907)

Porter, G.: Some reflections on the work of Theodor Förster. Naturwissenschaften **63**, 207–211 (1976)

Portis, A.R., Parry, M.A.J.: Discoveries in Rubisco: a historical perspective. Photosynth. Res. **94**, 121–143 (2007)

Prebble, J.: The discovery of oxidative phosphorylation: a conceptual off-shoot from the study of glycolysis. Stud. Hist. Philos. Biol. Biomed. Sci. **41**, 253–262 (2010)

Prebble, J., Weber, B.: Wandering in the Gardens of the Mind: Peter Mitchell and the Making of Glynn. Oxford University Press, Oxford/New York (2003)

Pringsheim, E.G.: Julius Sachs: Der Begründer der neueren Pflanzenphysiologie, 1832–1897. Fischer, Jena (1932)

Pringsheim, E.G.: Ernst Georg Pringsheim: Eine autobiographische Skizze. Medizinhistorisches Journal **5**, 125–137 (1970)

Quayle, J.R., Fuller, R.C., Benson, A.A., Calvin, M.: Enzymatic carboxylation of ribulose diphosphate. J. Am. Chem. Soc. **76**, 3610–3612 (1954)

Rabinowitch, A.: Founder and father. Bull. Atomic Sci. **61**, 30–37 (2005)

Rabinowitch, E.I.: Photosynthesis and Related Processes. Vol I: Chemistry of Photosynthesis, Chemosynthesis and Related Processes In Vitro and In Vivo. Interscience Publishers, New York (1945)

Rabinowitch, E.I.: Photosynthesis and Related Processes. Vol II, 2: Kinetics of Photosynthesis (continued); Addenda. Interscience Publishers, New York (1956)

Rabinowitch, E.I.: Robert Emerson (1903–1959). Biogr. Mem. Natl. Acad. Sci. **25**, 112–131 (1961)

Rabinowitch, E.I.: The Mechanism of Photosynthesis, Studies on Microalgae and Photosynthetic Bacteria, vol. 373, pp. 112–121. University of Tokyo Press, Tokyo (1963)

Rabinowitch, E.I., Govindjee: Different forms of chlorophyll *a* in vivo and their photochemical function. In: McElroy, W.D., Glass, B. (eds.) Light and Life, pp. 378–386. Johns Hopkins Press, Baltimore (1961)

Racker, E., de la Haba, G., Leder, I.G.: Thiamine pyrophosphate, a coenzyme of transketolase. J. Am. Chem. Soc. **75**, 1010–1011 (1953)

Reinhardt, C.: Shifting and Rearranging. Physical Methods and the Transformation of Modern Chemistry. Science History Publications, Sagamore Beach (2006)

Reinke, J.: Über aldehydartige Substanzen in chlorophyllhaltigen Pflanzenzellen. Berichte der deutschen chemischen Gesellschaft **14**, 2144–2150 (1881a)

Reinke, J.: Studien über das Protoplasma. III. Der Process der Kohlenstoffassimilation im chlorophyllhaltigen Protoplasma. Untersuchungen aus dem botanischen Labor der Universität Göttingen **2**, 197–202 (1881b)

Reinke, J.: Theoretisches zum Assimilationsproblem. Botanische Zeitung **40**, 289–297, 305–314 (1882)

Renger, G.: Horst Tobias Witt (1922–2007). Photosynth. Res. **96**, 5–8 (2008)

Rheinberger, H.-J.: Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube. Stanford University Press, Stanford (1997)

Rhodes, R.: The Making of the Atomic Bomb. Simon and Schuster, New York (1986)

Rhodes, R.: Dark Sun. The Making of the Hydrogen Bomb. Simon and Schuster, New York (1995)

Rich, P.: Special issue dedicated to Robin Hill. Photosynth. Res. 34 (3) (1992)

Rieke, F.F.: On the quantum efficiency of photosynthesis. J. Chem. Phys. **7**, 238–244 (1939)

Robinson, G.W.: Excitation transfer and trapping in photosynthesis. Brookhaven Sympos. Biol. **19**, 16–48 (1967)

Roelofsen, P.: On the metabolism of the purple sulphur bacteria. Proc. R. Acad. Sci. Amst. **37**, 3–12 (1934)

Roll-Hansen, N.: Experimental method and spontaneous generation: the controversy between Pasteur and Pouchet, 1859–64. J. Hist. Med. Allied Sci. **34**, 273–292 (1979)

Rosenberg, J.L.: The contributions of James Franck to photosynthesis research: a tribute. Photosynth. Res. **80**, 71–76 (2004)

Rossiter, M.W.: The Emergence of Agricultural Science. Justus Liebig and the Americans, 1840–1880. Yale University Press, New Haven (1975)

Rouge, E.: Recherche des premiers produits de l'assimilation chlorophyllienne du carbone. Journal Suisse de Pharmacie **59**, 1–9 (1924)

Rürup, R.: Schicksale und Karrieren. Gedenkbuch für die von den Nationalsozialisten aus der Kaiser-Wilhelm-Gesellschaft vertriebenen Forscherinnen und Forscher, (in collaboration with Michael Schüring). Wallstein, Göttingen (2008)

Rüskamp, W. (ed.): Eine vollkommene Närrin durch meine ewigen Gefühle. Aus den Tagebüchern der Lotte Warburg 1925 bis 1947, Druckhaus Bayreuth (1989)

Ruben, S.: Photosynthesis and phosphorylation. J. Am. Chem. Soc. **65**, 279 (1943)

Ruben, S., Kamen, M.D.: (1940a) Photosynthesis with radioactive carbon IV. Molecular weight of the intermediates and a tentative theory of photosynthesis. J. Am. Chem. Soc. **62**, 3451–3455

Ruben, S., Kamen, M.D.: (1940b) Radioactive carbon in the study of respiration in heterotrophic systems. Proc. Natl. Acad. Sci. U S A **26**, 418–422

Ruben, S., Kamen, M.D.: Long-lived radioactive carbon: C14. Phys. Rev. **59**, 349–354 (1941)

Ruben, S., Hassid, W.Z., Kamen, M.D.: Radioactive carbon in the study of photosynthesis. J. Am. Chem. Soc. **61**, 661–663 (1939a)

Ruben, S., Kamen, M.D., Hassid, W.Z., DeVault, D.C.: Photosynthesis with radio-carbon. Science **90**, 570–571 (1939b)

Ruben, S., Kamen, M.D., Hassid, W.Z.: Photosynthesis with radioactive carbon II. Chemical properties of the intermediates. J. Am. Chem. Soc. **62**, 3443–3450 (1940a)

Ruben, S., Kamen, M.D., Perry, L.H.: Photosynthesis with radioactive carbon III. Ultracentrifugation of intermediate products. J. Am. Chem. Soc. **62**, 3450-34-51 (1940b)

Ruben, S., Randall, M., Kamen, M.D., Hyde, J.L.: Heavy oxygen as a tracer in the study of photosynthesis. J. Am. Chem. Soc. **63**, 877–879 (1941)

Sabalitschka, T., Riesenberg, H.: Über die Ernährung von Pflanzen mit Aldehyden. II. Biochemische Zeitschrift **144**, 545–550 (1924a)

Sabalitschka, T., Riesenberg, H.: Über die Ernährung von Pflanzen mit Aldehyden. III. Biochemische Zeitschrift **144**, 551–555 (1924b)

Sabalitschka, T., Riesenberg, H.: Über die Ernährung von Pflanzen mit Aldehyden. IV. Biochemische Zeitschrift **145**, 373–378 (1924c)

Sachs, J.: Über den Einfluss des Lichtes auf die Bildung des Amylums in den Chlorophyllkörnern. Botanische Zeitung **20**, 365–373 (1862)

Sachs, J.: Über die Auflösung und Wiederbildung des Amylums in den Chlorophyllkörnern bei wechselnder Beleuchtung. Botanische Zeitung **22**, 189–294 (1864)

San Pietro, A., Lang, H.M.: Accumulation of reduced pyridine nucleotides by illuminated grana. Science **124**, 118–119 (1956)

San Pietro, A., Lang, H.M.: Photosynthetic pyridine nucleotide reductase I. Partial purification and properties of the enzyme from spinach. J. Biol. Chem. **231**, 211–229 (1958)

Schickore, J., Steinle, F. (eds.): Revisiting Discovery and Justification: Historical and Philosophical Perspectives on the Context Disctinction. Springer, Dordrecht et al. (2006)

Schleifer, K.-H.: Professor Dr. Dr. h.c. mult. Otto Kandler: distinguished botanist and microbiologist. Bull. BISMiS **2**, 141–148 (2011)

Schmitt, F.F.: Socializing epistemology: an introduction through two sample issues. In: Schmitt, F.F. (ed.) Socializing Epistemology. The Social Dimensions of Knowledge, pp. 1–28. Rowman & Littlefield, Lanham, Maryld./London (1994)

Schoenheimer, R.L.: The Dynamic State of Body Constituents. Cambridge University Press, Cambridge (1940)

Schoenheimer, R.L., Rittenberg, D.: Deuterium as an indicator in the study of intermediary metabolism. I. J. Biol. Chem. **111**, 163–168 (1935)

Schoenheimer, R.L., Rittenberg, D.: Deuterium as an indicator in the study of intermediary metabolism. XI. Further studies on the biological uptake of deuterium into organic substances, with special reference to fat and cholesterol formation. J. Biol. Chem. **121**, 235–253 (1937)

Scholl, R.: Causal inference, mechanisms, and the Semmelweis case. Stud. Hist. Philos. Sci. Part A **44**, 66–76 (2013)

Scholl, R., Nickelsen, K.: Discovery from a causal point of view: Oxidative phosphorylation and the Calvin-Benson cycle. History and philosophy of the life sciences (2015). In print

Schüring, M.: Minervas verstoßene Kinder. Vertriebene Wissenschaftler und die Vergangenheitspolitik der Max-Planck-Gesellschaft. Wallstein, Göttingen (2006)

Schroeder, H.: Die Hypothesen über die chemischen Vorgänge bei der Kohlensäure-Assimilation und ihre Grundlagen, Fischer. Jena (1917)

Schroeder, H.: Methoden zur Bestimmung der Assimilation der Kohlensäure aus der Luft und aus dem Wasser. In: Abderhalden, E. (ed.) Handbuch der biologischen Arbeitsmethoden, vol. 3, pp. 653–714. Urben & Schwarzenberg, Berlin (1928)

Schulmann, R., Kox, A.J., Janssen, M., Illy, J.E.: The Berlin Years: Correspondence, 1914–1918, Vol. 5 der The Collected Papers of Albert Einstein. Princeton University Press, Princeton (1998)

Seaborg, G.T., Benson, A.A.: Melvin Calvin (1911–1997). Biogr. Mem. Natl. Acad. Sci. **75**, 2–21 (1997)

Seidel, R.W.: Accelerating science: the postwar transformation of the Lawrence Radiation Laboratory. Hist. Stud. Phys. Sci. **13**, 375–400 (1983)

Shen, Y.-K., Wei, J.-M.: The discovery of photophosphorylation. In: Kung, S.-D., Yang, S.-F. (eds.) Discoveries in Plant Biology, vol. 2, pp. 105–114. World Scientific Publishing, Singapore (1998)

Shevela, D., Eaton-Rye, J., Shen, J.-R., Govindjee: Photosystem II and the unique role of bicarbonate. A historical perspective. Biochimica et Biophysica Acta **1817**, 1134–1151 (2012)

Simoni, R.D., Hill, R.L., Vaughan, M.: The use of isotope tracers to study intermediary metabolism: Rudolf Schoenheimer. J. Biol. Chem. **43**, e1–e2 (2002)

Singleton, R.: Heterotrophic CO_2-fixation, mentors, and students: the Wood-Werkman reactions, J. Hist. Biol. **30**, 91–120 (1997)

Sloan, P.R.: Biophysics in Berlin. In: Sloan, P.R., Fogel, B. (eds.) Creating a Physical Biology: The Three-Man Paper and the Origins of Molecular Biology, pp. 77–124 . University of Chicago Press, Chicago (2009)

Smith, C.: Force, energy, and thermodynamics. In: Nye, M.J. (ed.) The Cambridge History of Science. Vol. 5: The Modern Physical and Mathematical Sciences, pp. 289–310. Cambridge University Press, Cambridge (2003)

Solomon, M.: A more social epistemology. In: Schmitt, F.F. (ed.) Socializing Epistemology. The Social Dimensions of Knowledge, pp. 111–134. Rowman & Littlefield, Lanham, Maryld./London (1994a)

Solomon, M.: Social empiricism. Noûos **28**, 325–343 (1994b)

Solomon, M.: Social Empiricism, MIT Press (2001)

Spath, S.B.: C. B. van Niel and the Culture of Microbiology, 1920–1965, Thesis (Ph. D.), University of California, Berkeley (1999)

Spoehr, H.A.: Photochemische Vorgänge bei der diurnalen Entsäuerung der Succulenten. Biochemische Zeitschrift **57**, 95–111 (1913)

Spoehr, H.A.: The Theories of photosynthesis in the light of some new facts. Plant World **19**, 1–16 (1916)

Spoehr, H.A., McGee, J.M.: Studies in Plant Respiration and Photosynthesis. Carnegie-Institution, Washington (1923)

Stachel, J., Cassidy, D.C., Renn, J., Schulmann, R. (eds.): The Collected Papers of Albert Einstein. Vol 2: The Swiss Years: Writings, 1900–1909. Princeton University Press (1989)

Stemler, A.J.: The bicarbonate effect, oxygen evolution, and the shadow of Otto Warburg. Photosynth. Res. **73**, 177–183 (2002)

Stepka, W., Benson, A.A., Calvin, M.: The path of carbon in photosynthesis: II Amino acids. Science **108**, 304 (1948)

Stiles, W.: Photosynthesis: The Assimilation of Carbon by Green Plants. Longmans/Green, London (1925)

Stoklasa, J., Zdobnicky, W.: Photochemische Synthese der Kohlenhydrate aus Kohlensäureanhydrid und Wasserstoff in Abwesenheit von Chlorophyll. Biochemische Zeitschrift **30**, 433–456 (1911)

Stoll, A.: Über den chemischen Verlauf der Photosynthese. Naturwissenschaften **20**, 955–958 (1932)

Stowe, B.B.: Kenneth V. Thimann (1904–1997). Proc. Am. Philos. Soc. **143**, 502–509 (1999)

Strehler, B.L.: The luminescence of isolated chloroplasts. Arch. Biochem. Biophys. **34**, 239–248 (1951)

Strehler, B.L.: Photosynthesis—energetics and phosphate metabolism. In: McElroy, W.D., Glass, H.B. (eds.) Phosphorus Metabolism II, pp. 491–502. Johns Hopkins Press, Baltimore (1952)

Strehler, B.L.: Firefly luminescence in the study of energy transfer mechanisms II: Adenosine triphosphate and photosynthesis. Arch. Biochem. Biophys. **43**, 67–79 (1953)

Strehler, B.L.: Halcyon days with Bill Arnold. Photosynth. Res. **48**, 11–18 (1996)

Strehler, B.L., Arnold, W.A.: Light production by green plants. J. Gen. Physiol. **34**, 809–820 (1951)

Strehler, B.L., Hendley, D.: Continuous measurement of photosynthetic phosphorylation with the firefly luminescence assay system. In: McElroy, W.D., Glass, B. (eds.) Light and Life, pp. 601–608. Johns Hopkins Press, Baltimore (1961)

Strehler, B.L., McElroy, W.D.: Purification of firefly luciferin. J. Cell Compd. **34**, 457–466 (1949)

Strehler, B.L., Totter, J.: Firefly luminescence in the study of energy transfer mechanisms I. Substrate and enzyme determination. Arch. Biochem. Biophys. **40**, 28–41 (1951)

Sucker, U.: Das Kaiser-Wilhelm-Institut für Biologie. Seine Gründungsgeschichte, seine problemgeschichtlichen und wissenschaftstheoretischen Voraussetzungen (1911–1916). Steiner, Stuttgart (2002)

Tabery, J.: Synthesizing activities and interactions in the concept of a mechanism. Philos. Sci. **71**, 1–15 (2004)

Tagawa, K., Arnon, D.I.: Ferredoxin as electron carrier in photosynthesis and in the bacterial production and consumption of hydrogen gas. Nature **195**, 537–543 (1962)

Tamiya, H. (ed.): Mechanism of Photosynthesis (Fifth International Congress of Biochemistry. Moscow, 10–16 August 1961. General Editor: Sissakian, N.M. Vol. VI). Pergamon Press, Oxford (Polish Scientific Publishers, Warsaw) (1963)

Tanada, T.: The photosynthetic efficiency of carotenoid pigments in *Navicula minima*. Am. J. Bot. **38**, 276–283 (1951)

Teich, M.: Ferment or enzyme: what's in a name? Hist. Philos. Life Sci. **2**, 193–215 (1981)

Teller, E.: Memoirs: A Twentieth-Century Journey in Science and Politics. Perseus Publishing, Cambridge (2001)

Thimann, K.V.: The absorption of carbon dioxide in photosynthesis. Science **88**, 506–507 (1938)

Thorhaug, A., Berlyn, G.: A tribute to Lawrence Rogers Blinks (1900–1989): light and algae. Photosynth. Res. **100**, 129–141 (2009)

Thunberg, T.: Über einen neuen Weg von der Kohlensäure zum Formaldehyd. Ein Beitrag zur Theorie der Kohlensäureassimilation. Zeitschrift für Physikalische Chemie **106**, 305–312 (1923)

Timofeeff-Ressovsky, N.W., Zimmer, K.G., Delbrück, M.: Über die Natur der Genmutation und der Genstruktur, Nachrichten der Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-Physikalische Klasse **1**, 189–245 (1935)

Todhunter, I. (ed.): William Whewell, D.D., Master of Trinity College, Cambridge; An Account of his Writings with Selections from his Literary and Scientific Correspondence. Macmillan, London (1876)

Tolmach, L.J.: Effects of triphosphopyridine nucleotide upon oxygen evolution and carbon dioxide fixation by illuminated chloroplasts. Nature **167**, 946–948 (1951a)

Tolmach, L.J.: The influence of triphosphopyridine nucleotide and other physiological substances upon oxygen evolution from illuminated chloroplasts. Arch. Biochem. Biophys. **33**, 120–142 (1951b)

Toon, A.: Models as Make-Believe. Imagination, Fiction and Scientific Representation. Palgrave (2012)

Trebst, A.V., Manuel, L., Arnon, D.I.: Photosynthesis by isolated chloroplasts X. Dependence of carbon dioxide assimilation on the photochemical reactions of chloroplasts. J. Biol. Chem. **234**, 3055–3058 (1959)

Trebst, A.V., Losada, M., Arnon, D.I.: Photosynthesis by isolated chloroplasts XII: inhibitors of CO_2 assimilation in a reconstituted chloroplast system. J. Biol. Chem. **235**, 840–844 (1960)

Underwood, E.A.: Lavoisier and the history of respiration. Proc. R. Soc. Med. **37**, 247–262 (1943)

Usher, F.L., Priestley, J.H.: The mechanism of carbon assimilation. II. The photolytic decomposition of carbon dioxide in vitro. Proc. R. Soc. Lond., Series B **78**(518), 318–327 (1906a)

Usher, F.L., Priestley, J.H.: A study of the mechanism of carbon assimilation in green plants. Proc. R. Soc. Lond., Series B **77**(518), 369–376 (1906b)

van Niel, C.B.: Photosynthesis in Bacteria, Contributions to Marine Biology, vol. 3. Stanford University Press, pp. 161–169 (1930)

van Niel, C.B.: On the morphology and physiology of the purple and green sulphur bacteria. Archiv für Mikrobiologie **3**, 1–112 (1931)

van Niel, C.B.: Photosynthesis of Bacteria. In: Harris, R.G. (ed.) Cold Spring Harbor Symposia on Quantitative Biology, vol. 3, pp. 138–150. The Biological Laboratory, New York (1935)

van Niel, C.B.: The bacterial photosynthesis and their importance for the general problem of phtosynthesis. Adv. Enzymol. **1**, 263–328 (1941)

van Niel, C.B.: The education of a microbiologist: some reflections. Ann. Rev. Microbiol. **21**, 1–30 (1967)

Vernon, L.P., Zaugg, W.S.: Photoreductions by fresh and aged chloroplasts: requirement for ascorbate and 2, 6-dichlorophenolindophenol with aged chloroplasts. J. Biol. Chem. **235**, 2728–2733 (1960)

Vierhaus, R., Brocke, B. vom. (eds.): Forschung im Spannungsfeld von Politik und Gesellschaft. Geschichte und Struktur der Kaiser-Wilhelm-/Max-Planck-Gesellschaft. Deutsche Verlags-Anstalt, Stuttgart (1990)

Vinogradov, A.P., Teiss, R.V.: Isotope composition of oxygen from different sources. Doklady Akademii Nauk SSSR **33**, 497–501 (1941)

Vinogradov, A.P., Teiss, R.V.: Novel determination of the isotope composition of oxygen in photosynthesis. Doklady Akademii SSSR **56**, 57–58 (1947)

Vishniac, W., Ochoa, S.: Photochemical reduction of pyridine nucleotides by spinach grana and coupled carbon dioxide fixation. Nature **167**, 768–769 (1951)

Vishniac, W., Ochoa, S.: Fixation of carbon dioxide coupled to photochemical reduction of pyridine nucleotides by chloroplast preparations. J. Biol. Chem. **195**, 75–93 (1952a)

Vishniac, W., Ochoa, S.: Phosphorylation coupled to photochemical reaction of pyridine nucleotides by chloroplast preparations. J. Biol. Chem. **198**, 501–506 (1952b)

von Gerhard, F.: Hans Kautsky (1891–1966). Chemie in unserer Zeit **15**, 197–200 (2004)

von Mohl, H., Wilhelm, M.: Untersuchungen über die anatomischen Verhältnisse des Chlorophylls. Gustav Bähr, Tübingen (1837)

von Mohl, H.: Dr. Justus Liebigs Verhältniss zur Pflanzenphysiologie. Fues, Tübingen (1843)

Walker, D.: Energy, Plants and Man. Oxygraphics Limited, Sheffield (1992a)

Walker, D.A.: Robert Hill. Photosynth. Res. **34**, 337–338 (1992b)

Walker, D.A.: One thing leading to another. Photosynth. Res. **46**, 45–46 (1995)

Walker, D.: Tell me where all past years are. Photosynth. Res. **51**, 1–26 (1997)

Walker, D.A.: "And whose bright presence"—an appreciation of Robert Hill and his reaction. Photosynth. Res. **73**, 51–54 (2002)

Walker, D.A.: From Chlorella to chloroplasts: a personal note. Photosynth. Res. **92**, 181–185 (2007)

Warburg, E.: Über die Bildung des Ozons bei der Spitzenentladung in Sauerstoff, Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften (Berlin). Phys.-math. Klasse (**II**), 712–721 (1900)

Warburg, E.: Einige Bemerkungen über photochemische Wirkung II. Verhandlungen der Deutschen Physikalischen Gesellschaft **11**(21), 654–660 (1909)

Warburg, E.: Über den Energieumsatz bei photochemischen Vorgängen in Gasen. II, Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften (Berlin) pp. 216–225 (1912)

Warburg, E.: Über den Energieumsatz bei photochemischen Vorgängen in Gasen. III, Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften (Berlin) pp. 644–659 (1913)

Warburg, E.: Über die Anwendung der Quantenhypothese auf die Photochemie. Naturwissenschaften **5**(30), 489–494 (1917)

Warburg, E.: Quantentheoretische Grundlagen der Photochemie. Zeitschrift für Elektrochemie **26**, 54–59 (1920a)

Warburg, E.: Die Quantenregeln in der Photochemie. Naturwissenschaften **12**(47), 1058–1063 (1924)

Warburg, E., Leithäuser, G., Johansen, E.: Über das Vakuumbolometer. Annalen der Physik **24**, 25–42 (1907)

Warburg, O.: Beobachtungen über die Oxydationsprozesse im Seeigelei. Hoppe-Seyler's Zeitschrift für physiologische Chemie **57**, 1–16 (1908)

Warburg, O.: Beiträge zur Physiologie der Zelle, insbesondere über die Oxydationsgeschwindigkeit in Zellen. Ergebnisse der Physiologie **14**, 253–337 (1914)

Warburg, O.: Über die Geschwindigkeit der photochemischen Kohlensäurezersetzung in lebenden Zellen. I. Biochemische Zeitschrift **100**, 230–270 (1919)

Warburg, O.: Über die Geschwindigkeit der photochemischen Kohlensäurezersetzung in lebenden Zellen. II. Biochemische Zeitschrift **103**, 188–217 (1920b)

Warburg, O.: Theorie der Kohlensäureassimilation. Naturwissenschaften **9**, 354–358 (1921)

Warburg, O.: Versuche über die Assimilation der Kohlensäure. Biochemische Zeitschrift **166**, 386–406 (1925)

Warburg, O.: Methodische Vorbemerkungen. In: Warburg, O. (ed.) Über den Stoffwechsel der Tumoren. Arbeiten aus dem Kaiser-Wilhelm-Institut für Biologie, Berlin-Dahlem, pp. 1–11. Springer, Berlin (1926)

Warburg, O.: Über die katalytischen Wirkungen der lebendigen Substanz, Über die katalytischen Wirkungen der lebendigen Substanz. Arbeiten aus dem Kaiser-Wilhelm-Institut für Biologie, Berlin-Dahlem, pp. 1–13. Springer, Berlin (1927)

Warburg, O.: Über den Quantenbedarf der Kohlensäureassimilation. Naturwissenschaften **33**, 122–122 (1945)

Warburg, O.: Kohlensäureassimilation I. Der Quantenbedarf der Photochemischen Reduktion der Kohlensäure. In: Kuhn, R. (ed.) Naturforschung und Medizin in Deutschland 1939–1946. Vol. 39: Biochemie, pp. 201–210. Dietrich, Wiesbaden, (1947)

Warburg, O.: Assimilatory quotient and photochemical yield. Am. J. Bot. **35**, 194–204 (1948)

Warburg, O.: Ein-Quantenmechanismus der Photosynthese. Angewandte Chemie **63**, 282–283 (1951)

Warburg, O.: Energetik und Photosynthese. Naturwissenschaften **39**, 337–341 (1952)

Warburg, O.: Photosynthesis. Experiments at the Max Planck Institute for cell physiology, Berlin-Dahlem. Science **128**(3315), 68–73 (1958)

Warburg, O., Burk, D.: 1-Quanten-Mechanismus und Energie-Kreisprozess bei der Photosynthese, Naturwissenschaften **37**, 560 (1950a)

Warburg, O., Burk, D.: The maximum efficiency of photosynthesis. Arch. Biochem. **25**, 410–443 (1950b)

Warburg, O., Christian, W.: Isolierung und Kristallisation des Proteins des oxydierenden Gärungsferments. Biochemische Zeitschrift **303**, 40–68 (1939)

Warburg, O., Krippahl, G.: Hill-Reaktionen. Zeitschrift für Naturforschung B **13**, 509–514 (1958)

Warburg, O., Lüttgens, W.: Experiment zur Assimilation der Kohlensäure. Naturwissenschaften **32**, 161–161 (1944a)

Warburg, O., Lüttgens, W.: Weitere Experimente zur Kohlensäureassimilation. Naturwissenschaften **32**, 301–301 (1944b)

Warburg, O., Negelein, E.: Über den Energieumsatz bei der Kohlensäureassimilation. Zeitschrift für Physikalische Chemie **102**, 235–266 (1922)

Warburg, O., Negelein, E.: Über den Einfluss der Wellenlänge auf den Energieumsatz bei der Kohlensäureassimilation. Zeitschrift für Physikalische Chemie **106**, 191–218 (1923)

Warburg, O., Uyesugi, T.: Über die Blackmansche Reaktion. Biochemische Zeitschrift **146**, 486–492 (1924)

Warburg, O., Burk, D., Schocken, V., Hendricks, S.: The quantum efficiency of photosynthesis. Biochimica et Biophysica Acta **4**, 335–349 (1950)

Warburg, O., Geleick, H., Briese, K.: Über die Messung der Photosynthese in Carbonat-Bicarbonat-Gemischen. Zeitschrift für Naturforschung **7b**, 141 (1952)

Warburg, O., Krippahl, G., Schröder, W.: Katalytische Wirkung des blaugrünen Lichts auf den Energieumsatz bei der Photosynthese. Zeitschrift für Naturforschung **9b**, 667–675 (1954)

Warburg, O., Krippahl, G., Schröder, W.: Wirkungsspektrum eines Photosynthese-Fermentes. Zeitschrift für Naturforschung **10b**, 631–639 (1955)

Warburg, O., Krippahl, G., Lehman, A.: Chlorophyll catalysis and Einstein's law of photochemical equivalence in photosynthesis. Am. J. Bot. **56**, 961–971 (1969)

Warner, C.H.: Formaldehyde as oxidation product of chlorophyll extracts. Proc. R. Soc. Lond., Series B **87**, 378–385 (1914)

Wassink, E.C., Kersten, J.A.: The absorption spectrum and the role of carotenoids in the photosynthesis of diatoms. Enzymologia **12**, 3 (1946)

Weber, B.: Glynn and the conceptual development of the chemiosmotic theory: a retrospective and prospective view. Biosci. Rep. **11**, 577–617 (1991)

Weber, M.: Philosophy of Experimental Biology. Cambridge University Press, Cambridge (2005)

Weber, M.: Experiment in biology. In: Zalta, E.N. (ed.) The Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/spr2012/entries/biology-experiment/. Accessed 2 June 2013 (2012)

Weigert, F.: Die chemischen Wirkungen des Lichts. Enke, Stuttgart (1911)

Weigert, F.: Der Ausnutzungsfaktor der Lichtenergie, Zeitschrift für wissenschaftliche Photographie. Photophysik und Photochemie **11**, 381–394 (1912)

Weissbach, A., Horecker, B.L., Hurwitz, J.: The enzymatic formation of phosphoglyceric acid from ribulose diphosphate and carbon dioxide. J. Biol. Chem. **218**, 795–810 (1956)

Weller, S., Franck, J.: Photosynthesis in flashing light. J. Phys. Chem. **45**, 1359–1373 (1941)

Werner, P.: Otto Warburg. Von der Zellphysiologe zur Krebsforschung. Neues Leben, Berlin (1988)

Werner, P.: Ein Genie irrt seltener. Otto Heinrich Warburg, ein Lebensbild in Dokumenten. Akademie Verlag, Berlin (1991)

Werner, P.: Otto Warburgs Beitrag zur Atmungstheorie: Das Problem der Sauerstoffaktivierung. Basiliskenpresse, Marburg (1996)

Werner, P.: Learning from an adversary? Warburg against Wieland. Hist. Studies Phys. Biol. Sci. **28**(1), 173–196 (1997)

Werner, P.: Humboldt als Vermittler: Schleiden und Mohl contra Liebig. Hist. Philos. Life Sci. **23**, 213–257 (2001)

Werner, P., Holmes, F.L.: Justus Liebig and the plant physiologists. J. Hist. Biol. **35**, 421–441 (2002)

Werner, P., Irmscher, A. (eds.): Fritz Haber. Briefe an Richard Willstätter 1910–1934. VWR Engel, Berlin (1995)

Whatley, F.R.: Photosynthesis by isolated chloroplasts: the early work at Berkeley. Photosynth. Res. **46**, 17–26 (1995)

Whatley, F.R., Allen, M.B., Arnon, D.I.: Cofactors of photosynthetic phosphorylation. Plant Physiol. **32**, iii (1957) (Suppl.)

Whatley, F.R., Allen, M.B., Rosenberg, L.L., Capindale, J.B., Arnon, D.I.: Photosynthesis in isolated chloroplasts V. Phosphorylation and carbon dioxide fixation by broken chloroplasts. Biochimica et Biophysica Acta **20**, 462–468 (1956)

Wheaton, B.R.: The Tiger and the Shark. Empirical Roots of Wave-Particle Dualism. Cambridge, UP (1983)

Wiesen, J.: The Richard Willstätter controversy: the legacy of anti-semitism in the west-German chemical industry. In: Lesch, J.E. (ed.) The German Chemical Industry in the Twentieth Century, pp. 347–366. Kluwer, Dordrecht (2000)

Wildman, S.G.: Early events along the trail leading to identification of Rubisco. Protein Sci. **1**, 303–304 (1992)

Wildman, S.G.: Discovery of Rubisco. In: Kung S.-D., Yang, S.-F. (eds.) Discoveries in Plant Biology, vol. 1, pp. 163–173. World Scientific Publishing, Singapore (1998)

Wildman, S.G.: Along the trail from Fraction I protein to Rubisco. Photosynth. Res. **73**, 243–250 (2002)

Wildman, S.G., Bonner, J.: The proteins of green leaves. I. Isolation of enzymatic properties and auxin content of spinach cytoplasmic proteins. Arch. Biochem. **14**, 381–413 (1947)

Willstätter, R.: Zur Erklärung der Photoreduktion von Kohlensäure durch Chlorophyll. Naturwissenschaften **21**, 252–253 (1933)

Willstätter, R.: Aus meinem Leben. Von Arbeit, Musse und Freunden, 2 edn. Verlag Chemie, Weinheim (1973)

Willstätter, R., Stoll, A.: Untersuchungen über Chlorophyll. Methoden und Ergebnisse. Springer, Berlin (1913)

Willstätter, R., Stoll, A.: Untersuchungen über die Assimilation der Kohlensäure. Sieben Abhandlungen. Springer, Berlin (1918)

Wilson, A.T., Calvin, M.: The photosynthetic cycle. CO_2 dependent transients. J. Am. Chem. Soc. **77**, 5948–5957 (1955)

Wimsatt, W.: Complexity and organization. In: Schaffner, K.F., Cohen, R.S. (eds.) PSA 1972. Proceedings of the Philosophy of Science Association, Reidel, Dordrecht, pp. 67–86 (1972)

Witt, H.T.: Untersuchungen der Photosynthese bei Anregung mit Blitzlicht. In: Pirson, A. (ed.) Handbuch der Pflanzenphysiologie, pp. 634–674. Springer, Berlin (1960)

Witt, H.T.: Functional mechanism of water splitting photosynthesis. Photosynth. Res. **29**, 55–77 (1991)

Witt, H.T., Müller, A., Rumberg, B.: Experimental evidence for the mechanism of photosynthesis. Nature **191**, 194–195 (1961a)

Witt, H.T., Müller, A., Rumberg, B.: Oxidized cytochrome and chlorophyll in photosynthesis. Nature **192**, 967–969 (1961b)

Wohl, K.: The mechanism of photosynthesis in green plants. New Phytol. **39**, 33–64 (1940)

Wohl, K.: On the mechanism of photosynthesis in purple bacteria and green plants. New Phytol. **40**, 34–55 (1941)

Wood, H.G., Werkman, C.H.: The utilization of CO_2 by the propionic acid bacteria in the dissimilation of glycerol. J. Bacteriol. **30**, 332 (1935)

Wood, H.G., Werkman, C.H.: The utilization of CO_2 in the dissimilation of glycerol by the propionic acid bacteria. Biochem. J. **30**, 48–53 (1936)

Wood, H.G., Werkman, C.H.: The utilization of CO_2 by the propionic acid bacteria. Biochem. J. **32**, 1262–1271 (1938)

Woods, D.D.: Albert Jan Kluyver (1888–1956). Biogr. Mem. Fellows R. Soc. **3**, 109–128 (1957)

Woodward, J.: What is a mechanism? A counterfactual account. Philos. Sci. **69**, S366–S377 (2002)

Wurmser, R.: Recherches sur l'assimilation chlorophyllienne. Archives de Physique Biologique **1**, 33–141 (1921)

Wurmser, R.: La loi de l'équivalent photochimique dans la photosynthèse chlorophyllienne. Le Journal de Physique et le Radium **7**, 33–44 (1926)

Wurmser, R.: Oxydations et réductions. Presses Universitaires de France, Paris (1930)

Yodh, A.G., Tromberg, B.J.: Celebrating Britton chance. J. Biomed. Opt. **5**, 115–118 (2000)

Zallen, D.T.: The "light" organism for the job: Green algae and photosynthesis research. J. Hist. Biol. **26**, 269–279 (1993a)

Zallen, D.T.: Redrawing the boundaries of molecular biology: the case of photosynthesis. J. Hist. Biol. **26**, 65–87 (1993b)

Index

K. Nickelsen, *Explaining Photosynthesis,* History, Philosophy and Theory of the Life Sciences 8, DOI 10.1007/978-94-017-9582-1