On the Discoveries of Robert Emerson

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Christmas, 2020

From the Archives of the University of Illinois at Urbana-Champaign

- **Dr. Robert Emerson Running Photosynthesis Experiments |**
- **(Dec. 1948)**

Robert Emerson's Discoveries in Photosynthesis included

*Photosynthetic Unit: hundreds of chlorophyll molecules per reaction center

*Minimum quantum requirement: 8-12 quanta per oxygen molecule

* The "Red Drop" ; "Enhancement" Effect: Two Light Reactions and Two Pigment Systems in Oxygenic Photosynthesis

References

#Govindjee (2004) Robert Emerson, and Eugene Rabinowitch: Understanding Photosynthesis. Lillian Hoddeson (editor). "No Boundaries: University of Illinois Vignettes", Chapter 12, pp. 181-194. University of Illinois Press, Urbana and Chicago.

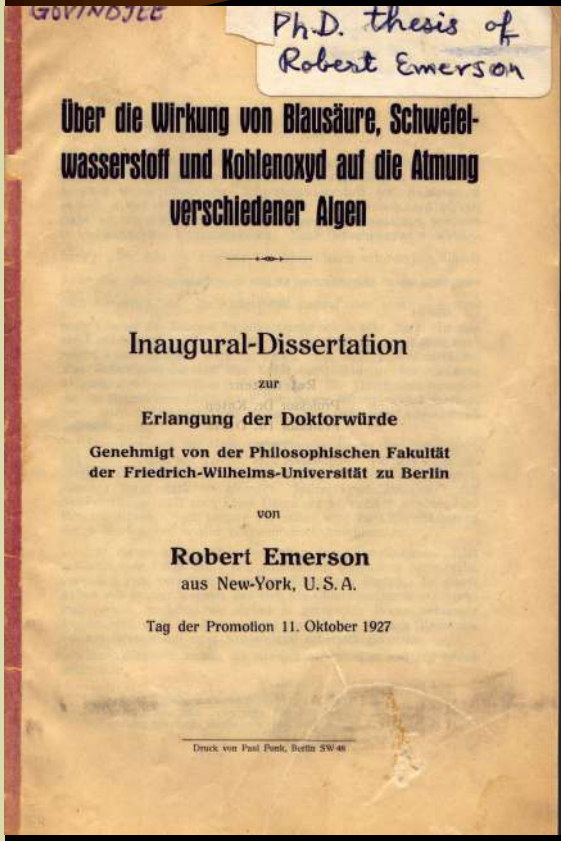
#Govindjee [G] (2018) Robert Emerson's 1949 Stephen Hales Prize Lecture: "Photosynthesis and the World". Journal of Plant Science Research 34 (2): 119-125.

#Govindjee G (2021) Robert Emerson, a major contributor to Photosynthesis, had pioneered research in Respiration in the 1920s, under Otto Warburg. Journal of Plant Science Research 36(1-2): 1-4.

Bob Emerson's grand uncle was Ralph Waldo Emerson (Lincoln, Mass). Bob lived at Urbana on 806 W. Main Street

Robert Emerson: MS in Zoology (1925, Harvard); PhD in Botany (1927, Berlin)

- *Born in New York City, 1903
- *His father was Haven Emerson, Head of NY City Public Health
- * He loved Ice skating/figure skating
- *Pacifist and Democratic socialist; Quaker& worked in Japanese Concen. --camp on Guyayule
- *PhD Advisor:OttoWarburg/Comm; 32 page thesis on Cyanide -insensitive respiration in Chlorella—English translation is now available


Ph.D. thesis of Robert Emerson

Über die Wirkung von Blausäure, Schwefelwasserstoff und Kohlenoxyd auf die Atmung verschiedener Algen

Inaugural-Dissertation

zur

Erlangung der Doktorwürde

Genehmigt von der Philosophischen Fakultät der Friedrich-Wilhelms-Universität zu Berlin

von

Robert Emerson

aus New-York, U.S.A.

Tag der Promotion 11. Oktober 1927

Druck von Paul Funk, Berlin SW 68

Emerson's 1927 thesis has now been translated and published in Dr. C.P. Malik's journal Pl SciRes

Hartmut Lichtenthaler and Lars Olof Björn (2020) English translation of the 1927 doctoral thesis (in German) of Robert Emerson, a pioneer in Photosynthesis. Journal of Plant Science Research 36 (1-2), 5-24

Govindjee (2020) Robert Emerson, a major contributor to Photosynthesis, had pioneered research in Respiration in the 1920s, under Otto Warburg. Journal of Plant Sci. Research 36 (1-2), 1-4

Also available at: http://www.life.illinois.edu/govindjee/

Robert Emerson
A skilled glassblower, and an artistic carpenter

Robert Emerson (1903-1959): at his desk in 157 Natural History Building, Urbana, IL

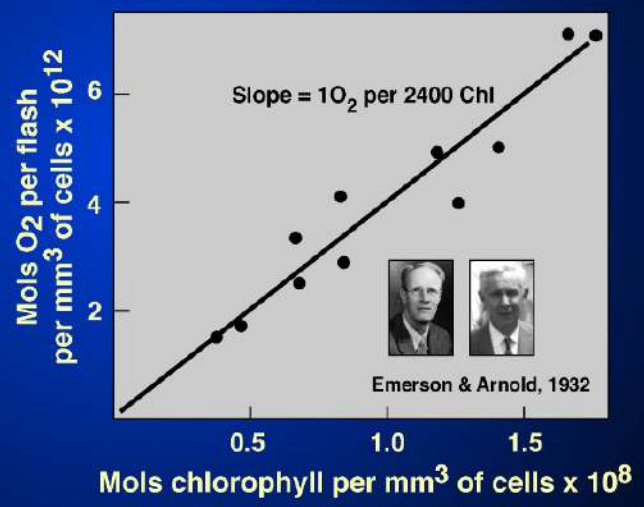
- ***Discovery of Photosynthetic Unit (1932)**
- ***Minimum quanta needed per oxygen molecule are 8-12 (1941-1958), not 3-4**
- ***The Red Drop (1943); Enhancement Effect and two light reaction/two photosystem concept (1957-1959)**

William Arnold (1904-2001) was Emerson's first student (as an undergraduate)

- ***Photosynthetic Unit, with his Professor, Emerson (1932)**
- ***Dicoverer of Delayed Light Emission in plants (with Bernie Strehler) (1951)**
- ***Excitation energy migration (with Meek, 1956)**
- ***Thermoluminescence in plants (1957)**
- ***Solid -state picture of Photosynthesis (with Rod Clayton: first charge sep. at 1K, 1960)**

Choules L & Govindjee (2014) Stories and photographs of William Arnold (1904-2001): A pioneer of photosynthesis. Photosynth. Res. 122:87–95

The 1932 discovery of "Photosynthetic Unit" (2400 Chlorophylls per Oxygen)

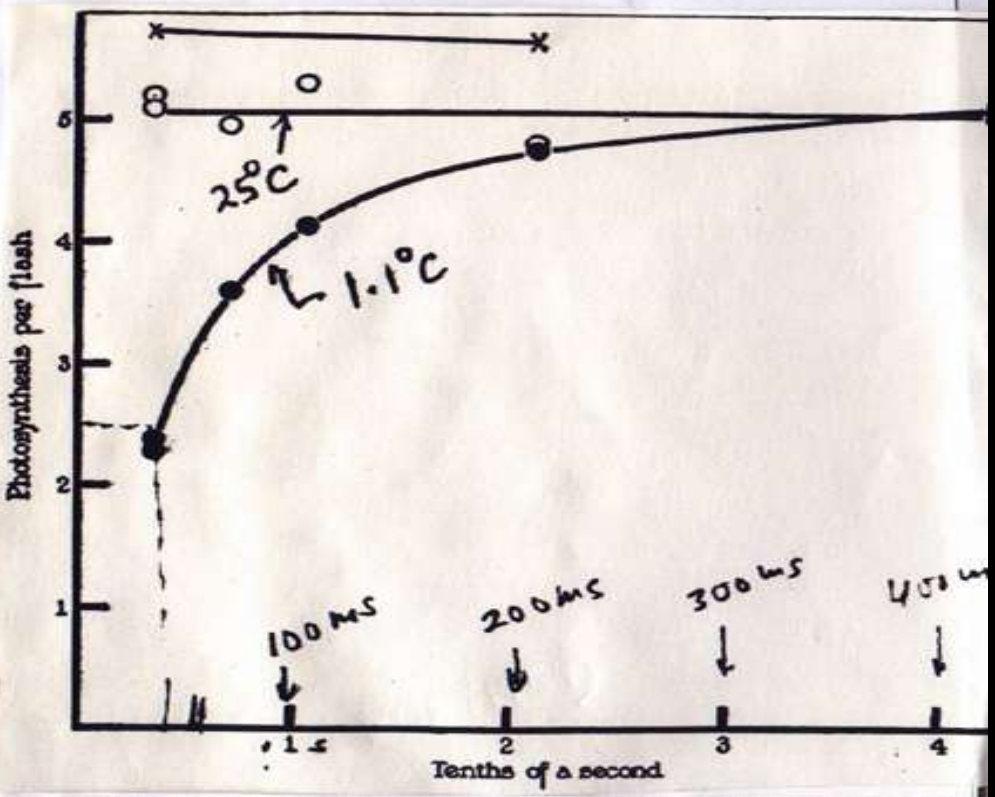


- *We need only suppose that for every 2,480 molecules of chlorophyll there is present in the cell one unit capable of reducing one molecule of carbon dioxide each time it is suitably activated by light*

William Kerckhoff Labs of the Biological Sciences, Cal Tech . William Arnold; Stacy French (had worked with Emerson and Warburg) and Hans Gaffron (had also worked with Warburg). Photo of Room 105

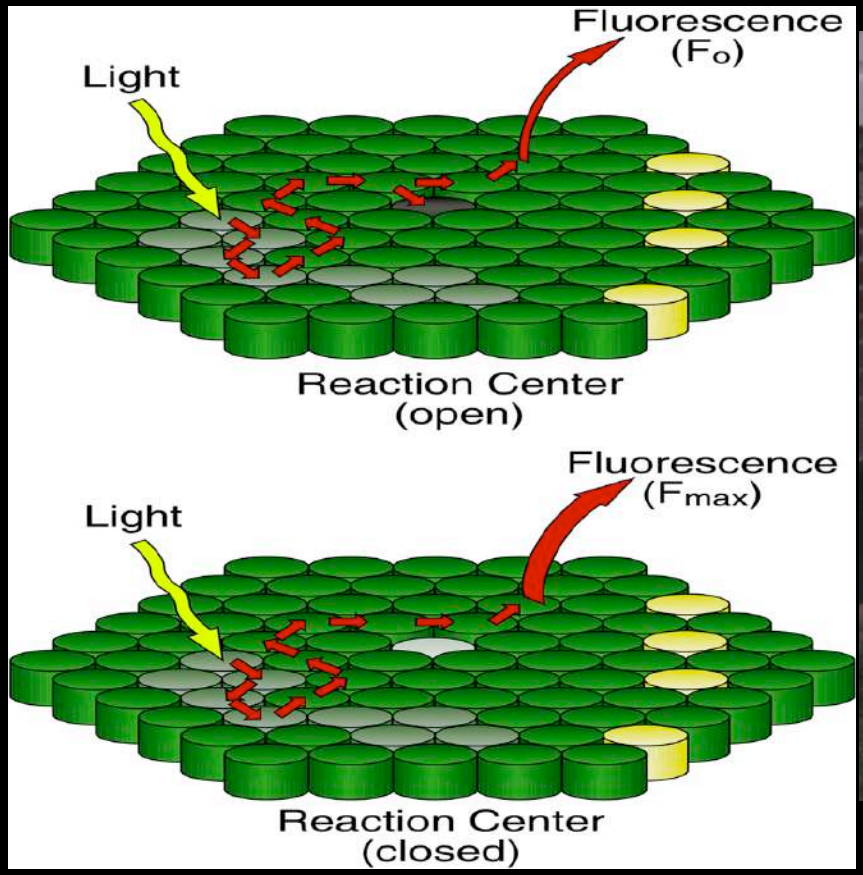
Light and Dark Reactions (halftime, ~30ms at 1C)

Robert Emerson and William Archibald Arnold (1932)



The "Blackman reaction" (as used by Otto Warburg) has a half time of about 30 ms at 1.1 C, and reaches the maximum at ~ 400 ms; it is much faster than 30 ms at 25 C as it already reaches the maximum by 30 ms.

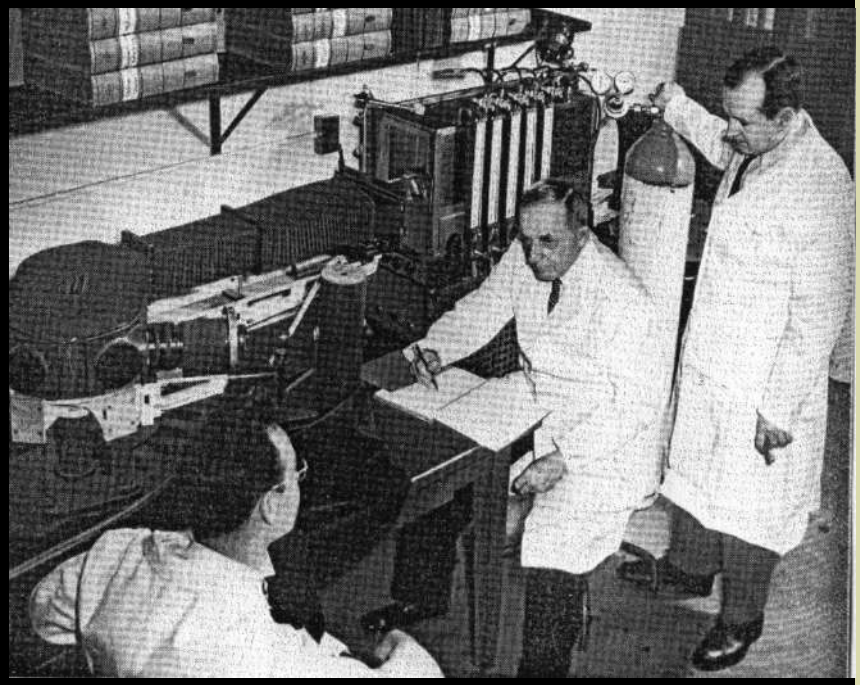
- ***Hans Gaffron (1902-1979):*** **The 1936 "Concept of Excitation Energy Transfer" and a "Photoenzyme"; in the 1940s, he discovered hydrogen evolution and hydrogen uptake by algae**



Otto Warburg (1883-1970):Emerson's "Professor"

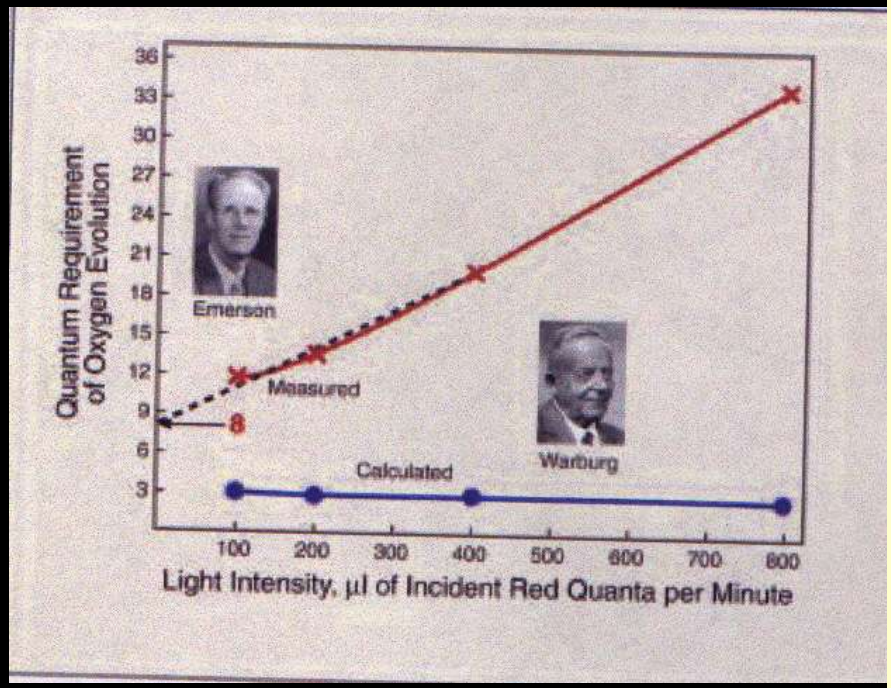
- ***1931 Nobel Prize in Physiology and Medicine: respiratory enzymes**
- ***The minimum quantum requirement for 1molecule of O_2 in photosynthesis is 3-4 (1923-1969); the photolyte hypothesis**
- ***Discoverer of many phenomena in photosynthesis (including "light-induced respiration"; role of chloride and of bicarbonate in Hill reaction).**

Otto Warburg (publications in 1949 and 1950)



- ***At NIH, Warburg did experiments confirming Emerson's 8-10 quanta for cells in a-bicarbonate buffer (statement is hidden)—**
- ***But not in acid culture medium where he obtained a value of 4. Emerson showed these, in 1955, to be due to " transient artifacts"**

The battle was over (1969): Warburg passed away in 1970

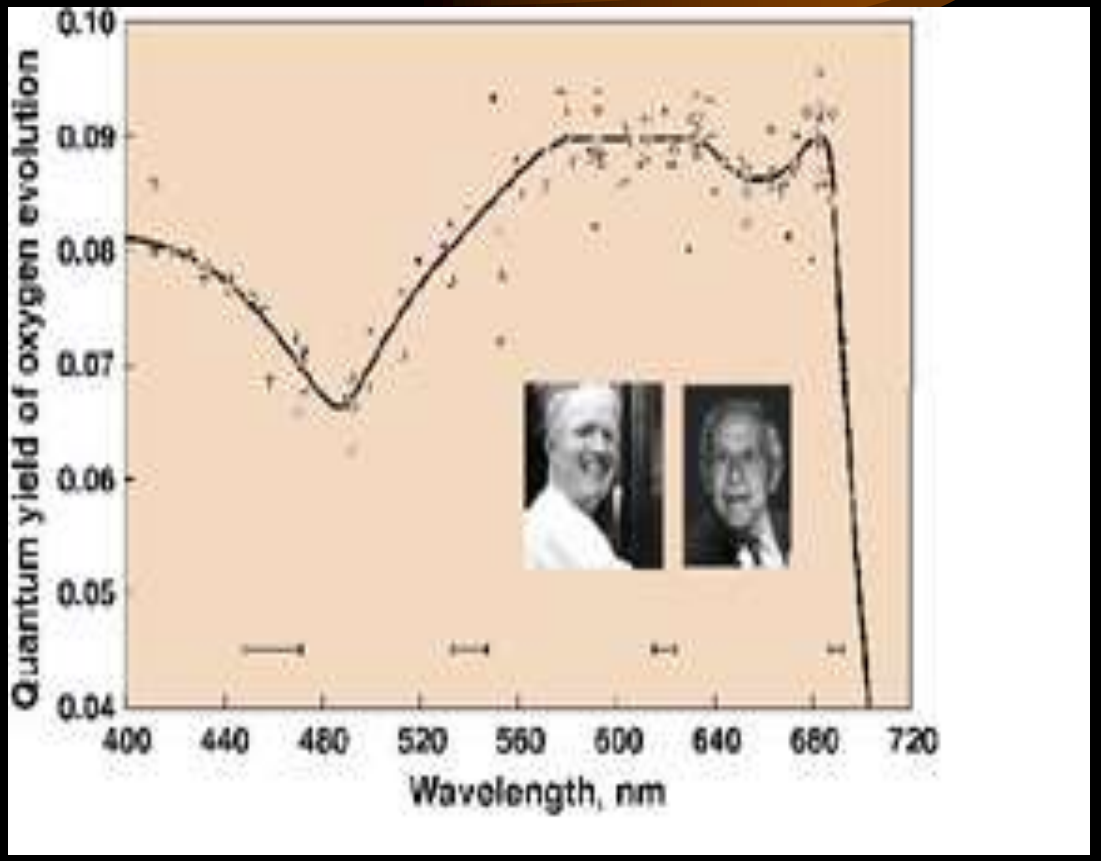


- **Warburg, Krippahl and Lehman (1969) measured a minimum quantum requirement of 12 at the lowest intensity they used, but calculated a value of 3 using an ingenious "photolyte" "trick" See: Govindjee (1999) Photosynth Res 59: 249-254.**

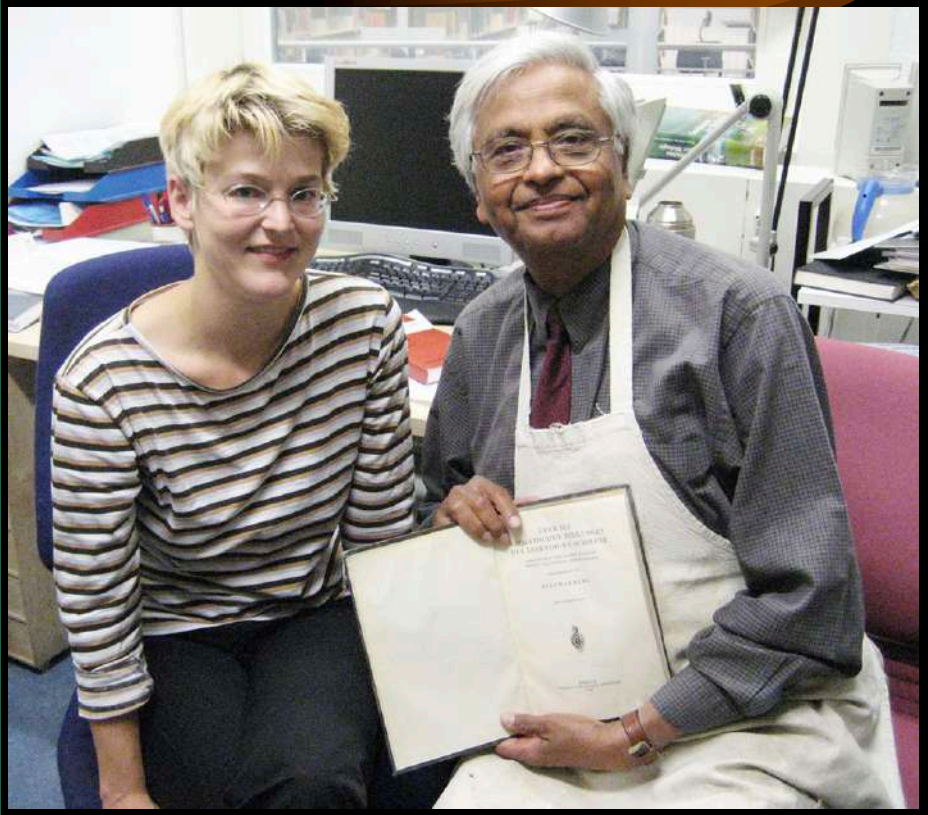
After' Emerson's death in 1959, and at meetings (once in 1963 in France) and beyond, Warburg was heard saying that "Now, the problem is solved"; "Emerson did not use the right conditions: young synchronous cultures ; 10 % CO_2 ; and blue catalytic light and thus he had the wrong results". Rajni and I finally decided to check it all out and in 1968 showed , under these conditions, that the minimum quantum requirement (per oxygen molecule) is TWELVE, NOT FOUR.. Warburg did NOT cite this paper in his 1969 paper….

R. Govindjee, E. Rabinowitch, and Govindjee (1968)Maximum Quantum Yield and Action Spectra of Photosynthesis and Fluorescence in Chlorella.Biochim. Biophys. Acta 162: 530-544.

The Red Drop in the Quantum Yield of Photosynthsis was discovered at Carnegie Inst, Stanford (1943)



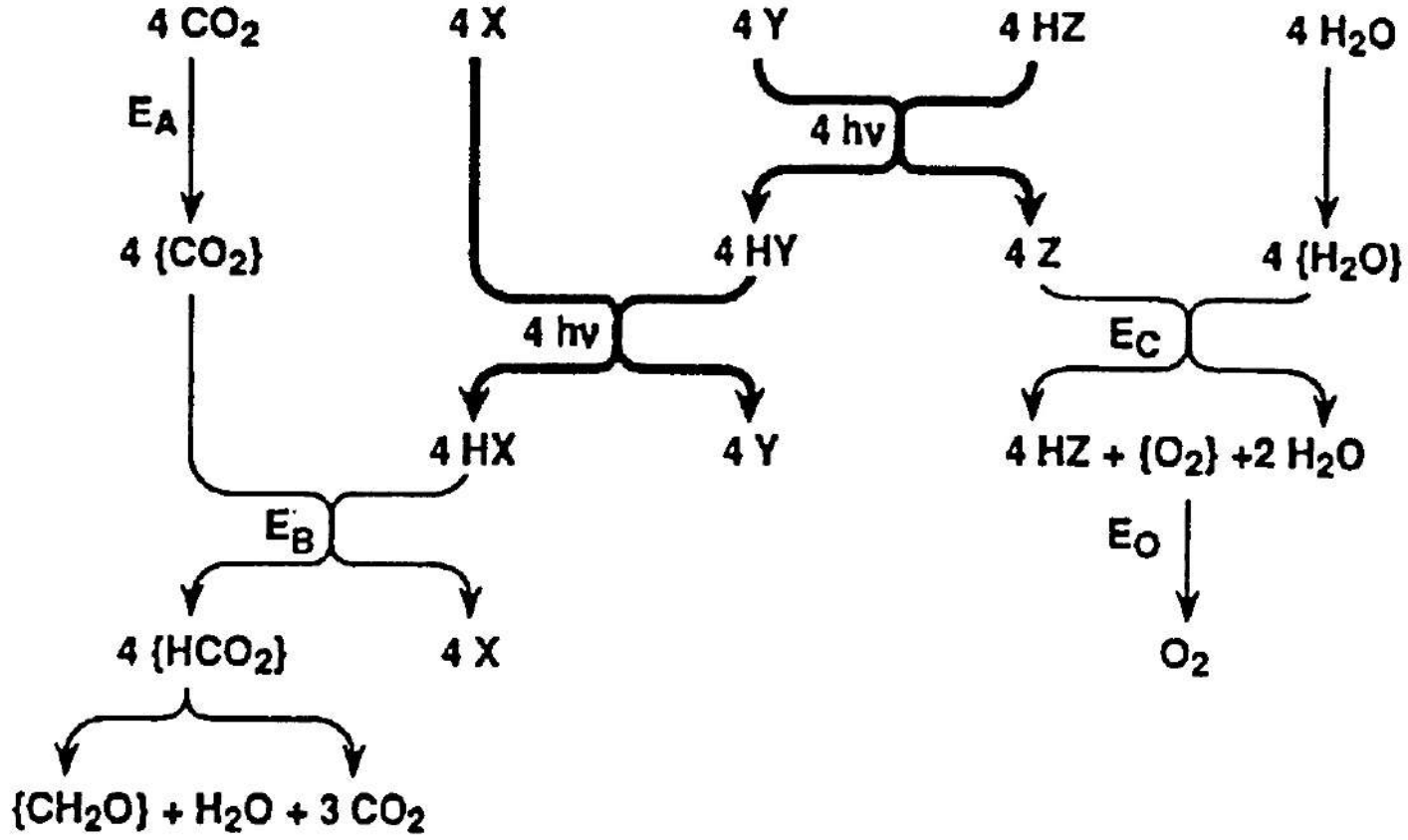
Please read the 2011 book of Nickelsen and Govindjee to know all about the controversy between Emerson and Warburg



Eugene Rabinowitch (1901-1973)
277 Morrill Hall, Urbana, 1967

- ***Masterpiece treatise on Photosynthesis (1945-1956)**
- ***Discovered Photogalvanic Effect (1940s)**
- ***First quantitative measurements on lifetime, and quantum yield of Chl fluorescence (1956-1958)**
- ***Messiah of Peace, & Science & Society in the World**
- ***Govindjee, G.C.Papageorgiou and Rajni Govindjee (2019) Eugene I. Rabinowitch: A prophet of photosynthesis and of peace in the world. PSRES 141 (2): 143-150**

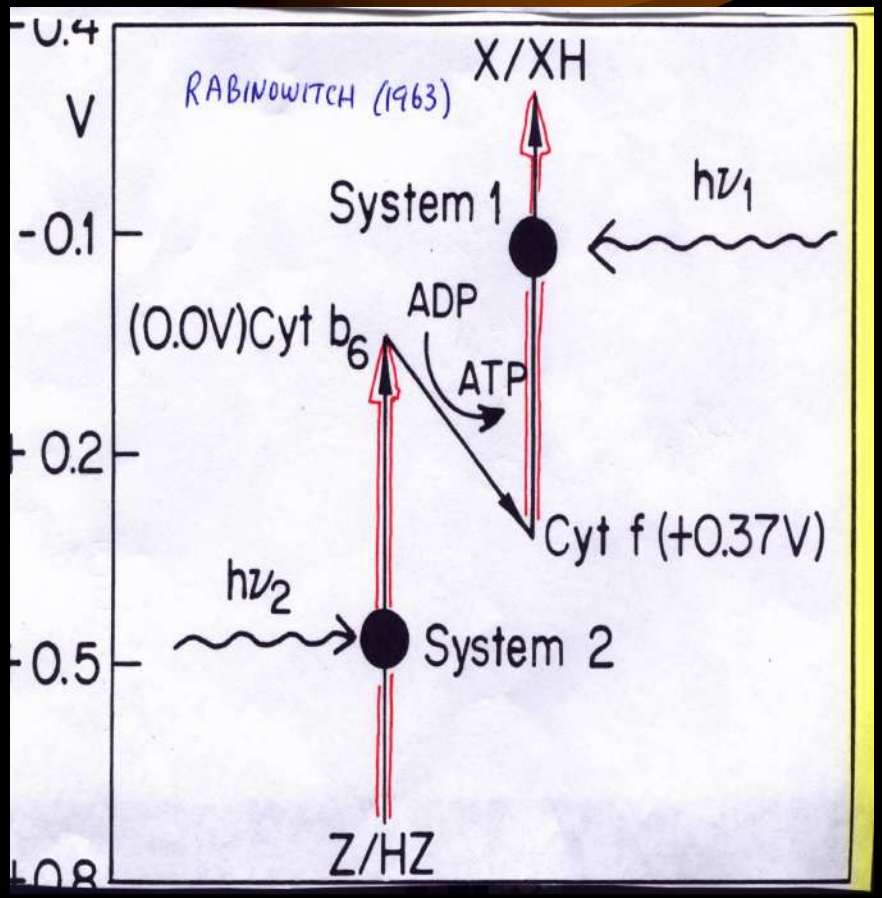
Scheme # 7.V on p. 162 (Rabinowitch, 1945) to explain 8 quanta/oxygen (based on Franck &Herzfeld,1941)



Eugene Rabinowitch (1956, 1963)

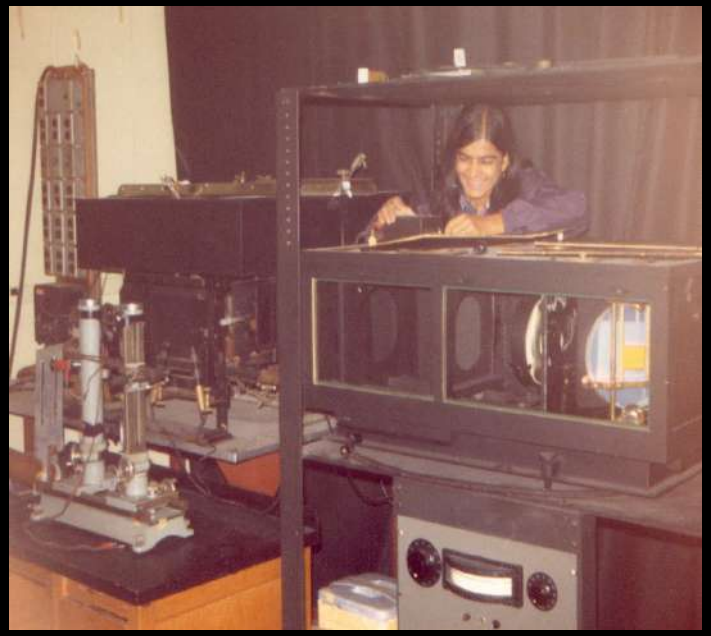
- **Eugene wrote….”since two quanta will be needed to transfer each of the four required H atoms (or electrons), first from water to the cytochrome, and then from the cytochrome to the final acceptor.**

  (p.1862,Vol.II,part 1,para 2, lines 15-19, 1956)



#Where was Emerson Enhancement Effect discovered? *University of Illinois at Urbana (left)*

#What instrument was used?: *See below (right)*

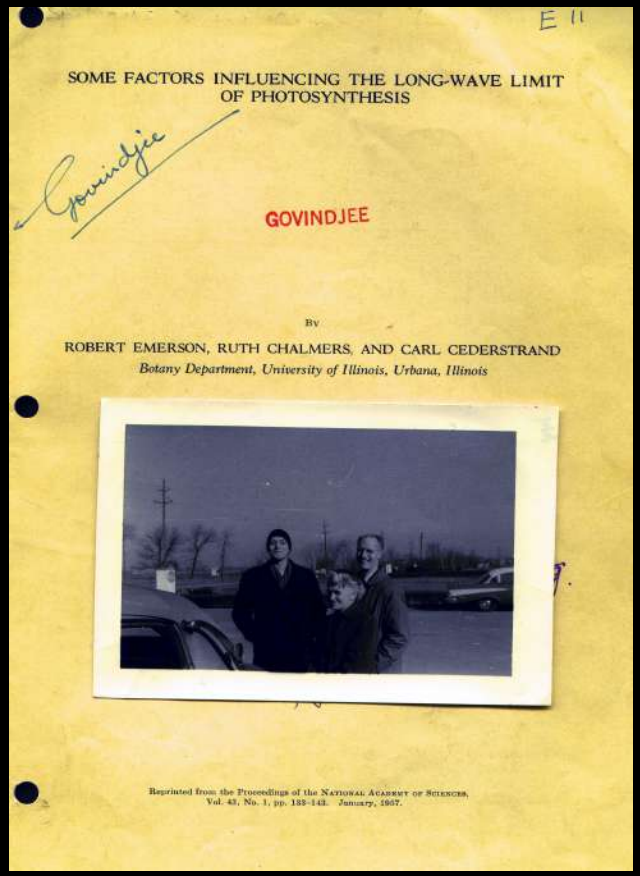


A Glimpse of Bob Emerson's instruments

Setup for giving the second beam of light; Emerson used Hg Cd lamp to get fixed selected wavelengths of light , and he used a monochromator to get "far red" light (the first beam). I will tell you soon what I did!

A 1958 Party in Urbana:Tom&MaryJeanne Bannister;Ruth Chalmers;Tita Emerson; Eugene Rabinowitch;Rajni Varma - Govindjee; Robert Emerson; Marcia & Steve Brody

The first paper on the Enhancement Effect: a 1957 PNAS paper



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SOME FACTORS INFLUENCING THE LONG-WAVE LIMIT OF PHOTOSYNTHESIS

Govindjee

GOVINDJEE

By

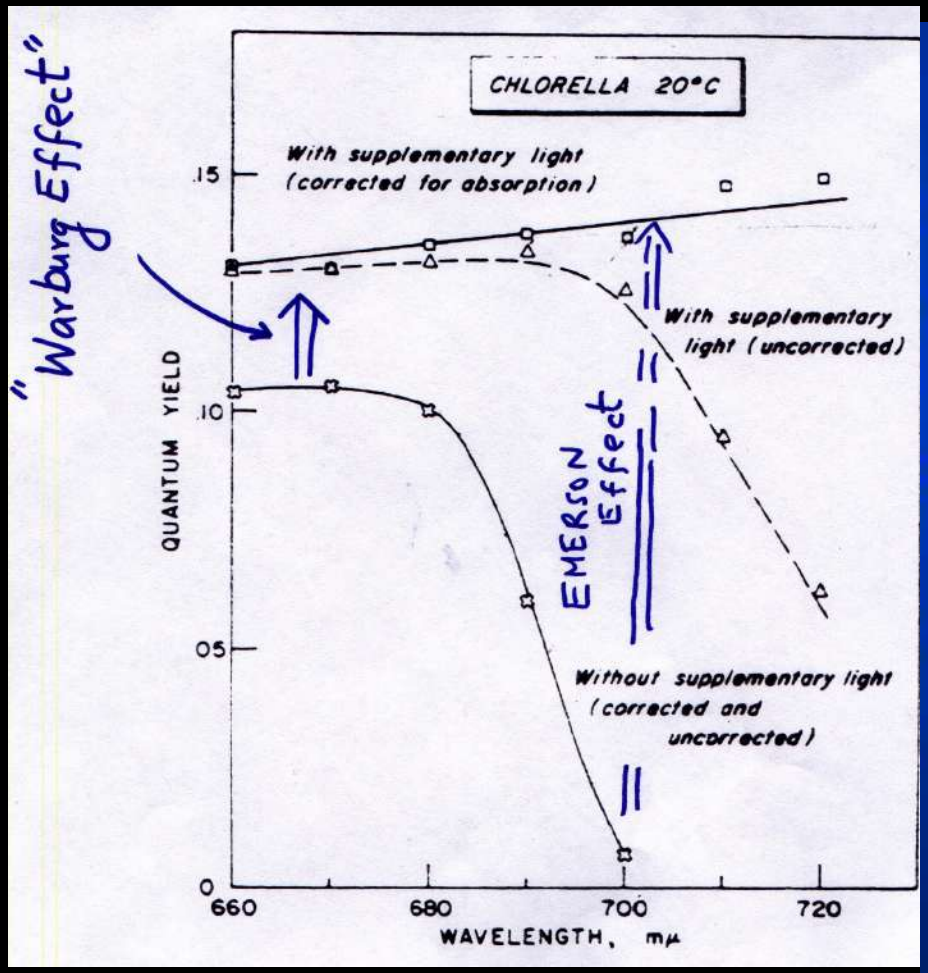
ROBERT EMERSON, RUTH CHALMERS, AND CARL CEDERSTRAND

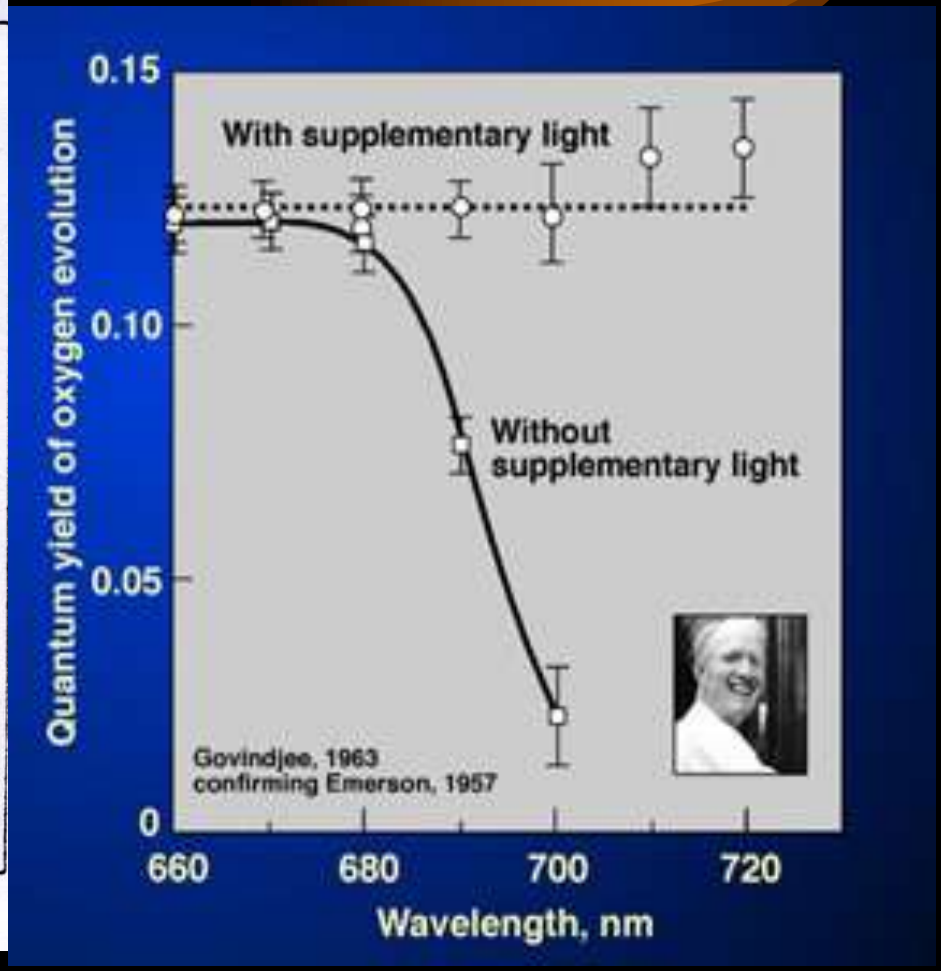
Botany Department, University of Illinois, Urbana, Illinois

Reprinted from the Proceedings of the National Academy of Sciences, Vol. 43, No. 1, pp. 133-143. January, 1957.

- The photo that is added on the cover of this classical paper shows Emerson's coauthors (Carl Cederstrand and Ruth Chalmers) (Photo, 1958)

The Emerson Enhancement Effect (1957)

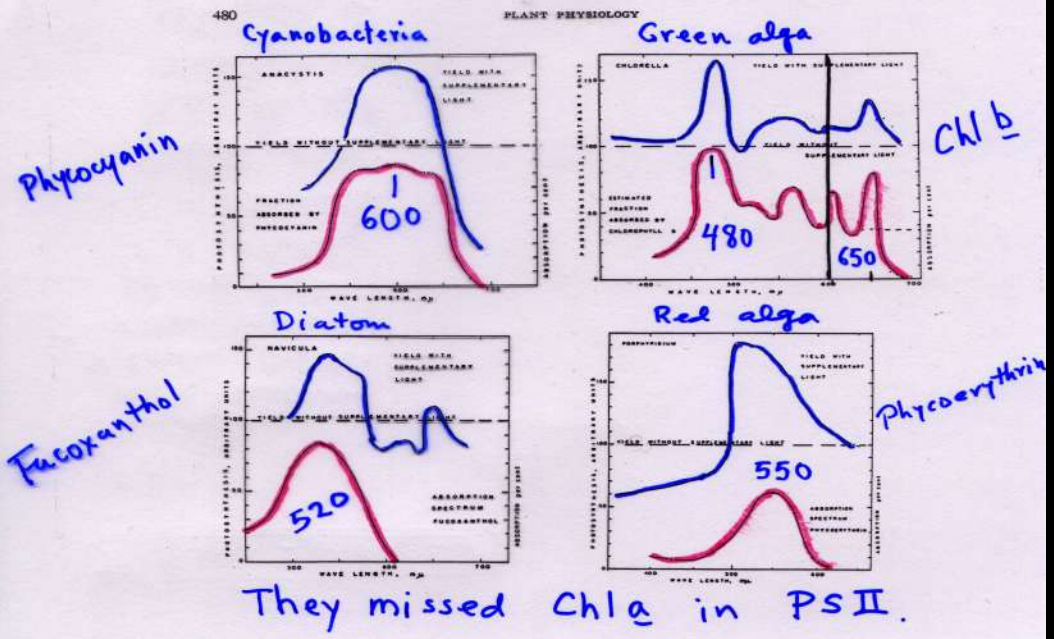




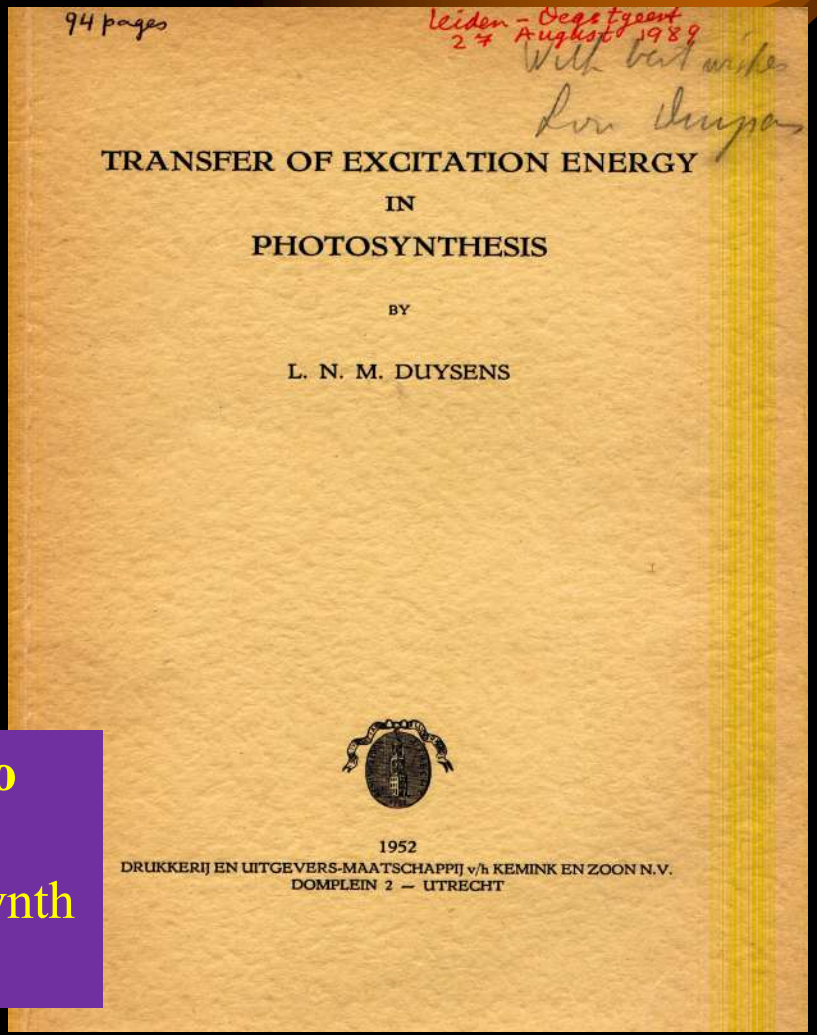
Action Spectra of the Emerson Enhancement Effect (1958;left): Rajni, Emerson and Chalmers-Bloomington, Indiana (right). Photo by Govindjee

THE EMERSON EFFECT

Robert Emerson and Ruth V. Chalmers (1958) "Speculations Concerning the Function and Phylogenetic Significance of the Accessory Pigments of Algae". The Phycological Society of America News Bulletin, Vol.XI, No. 35, 1958, pp. 51-56.

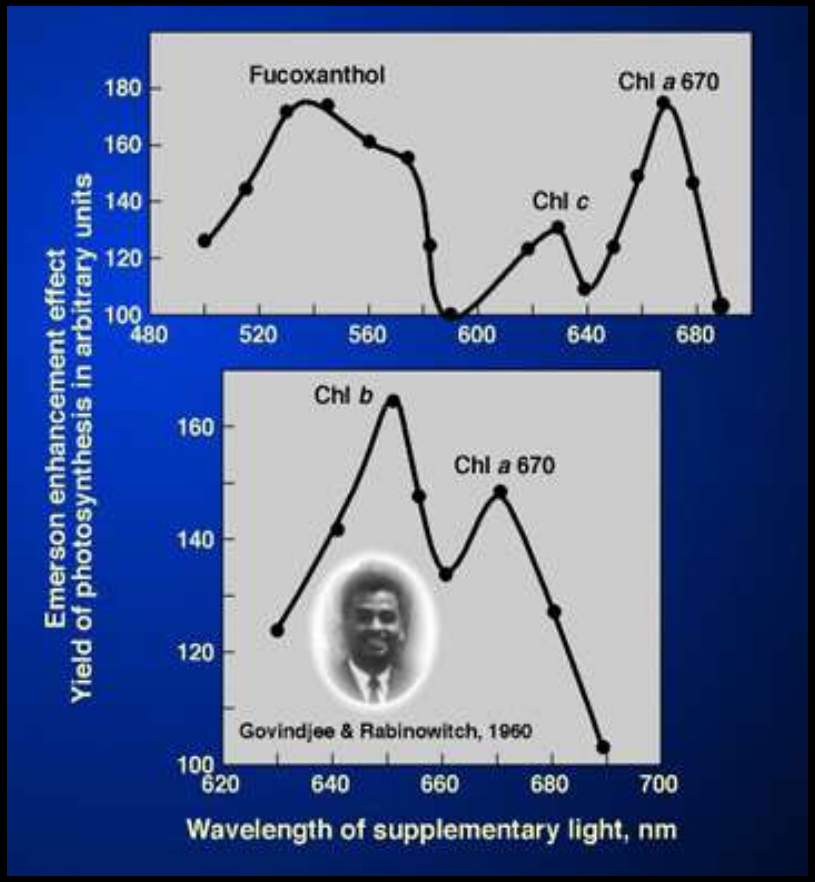


Emerson's conclusion that Chl a runs one system and accessory pigments another made no sense because Lou Duysens had shown in 1952 that the latter transfer energy with high efficiency to Chl a



Govindjee, Pulles MPJ (2016) **Louis Nico Marie Duysens (1921-2015)A leading biophysicist of the 20th century.** Photosynth Res 128:223-234

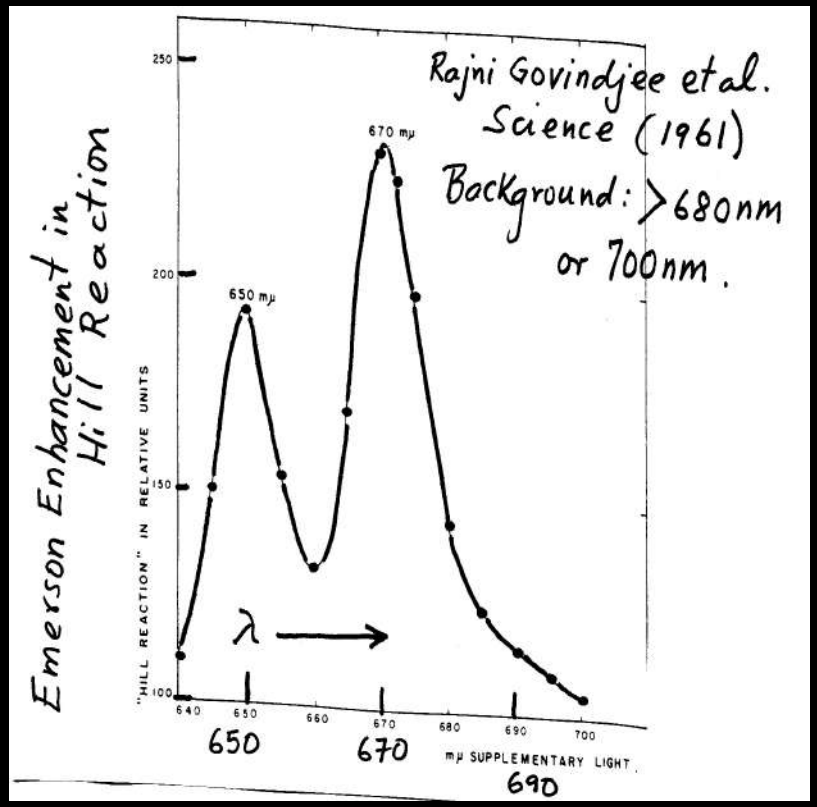
In 1960, the role of Chlorophyll a in the short-wave system (PSII) was discovered (Govindjee & Rabinowitch, Science). In addition, we discovered, also in 1960, the quenching of blue-light excited Chl a fluorescence by far-red light (PSI), another evidence of "two-light effect".

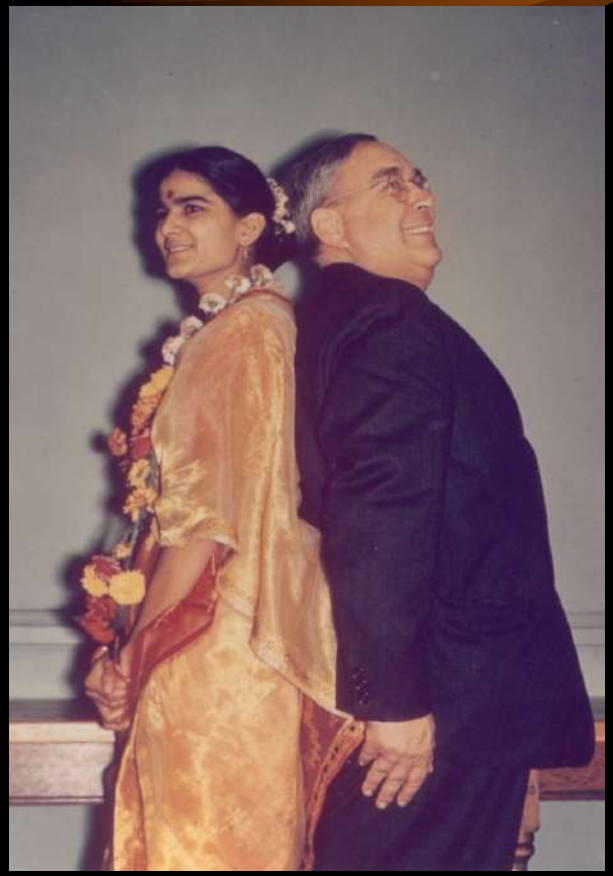


Lawrence Blinks (1900--1989); a laboratory is named after him at Hopkins Marine Station

- ***1950: Development of Haxo and Blinks Oxygen electrode, and action spectra of photosynthesis**
- ***1955-1957: Chromatic transients in algae..Blinks related it to respiration (citing Emerson 1941)**
- ***He gave a very boring lecture at the 1972 Gatlinburg conference when Bessel Kok and I chatted in the back**

Rajni Govindjee showed (1961) that the Enhancement Effect was in the Hill Reaction. Thus, it could not be in respiration as Blinks thought. In 1962, with George Hoch, she and I discovered enhancement in NADP reduction.

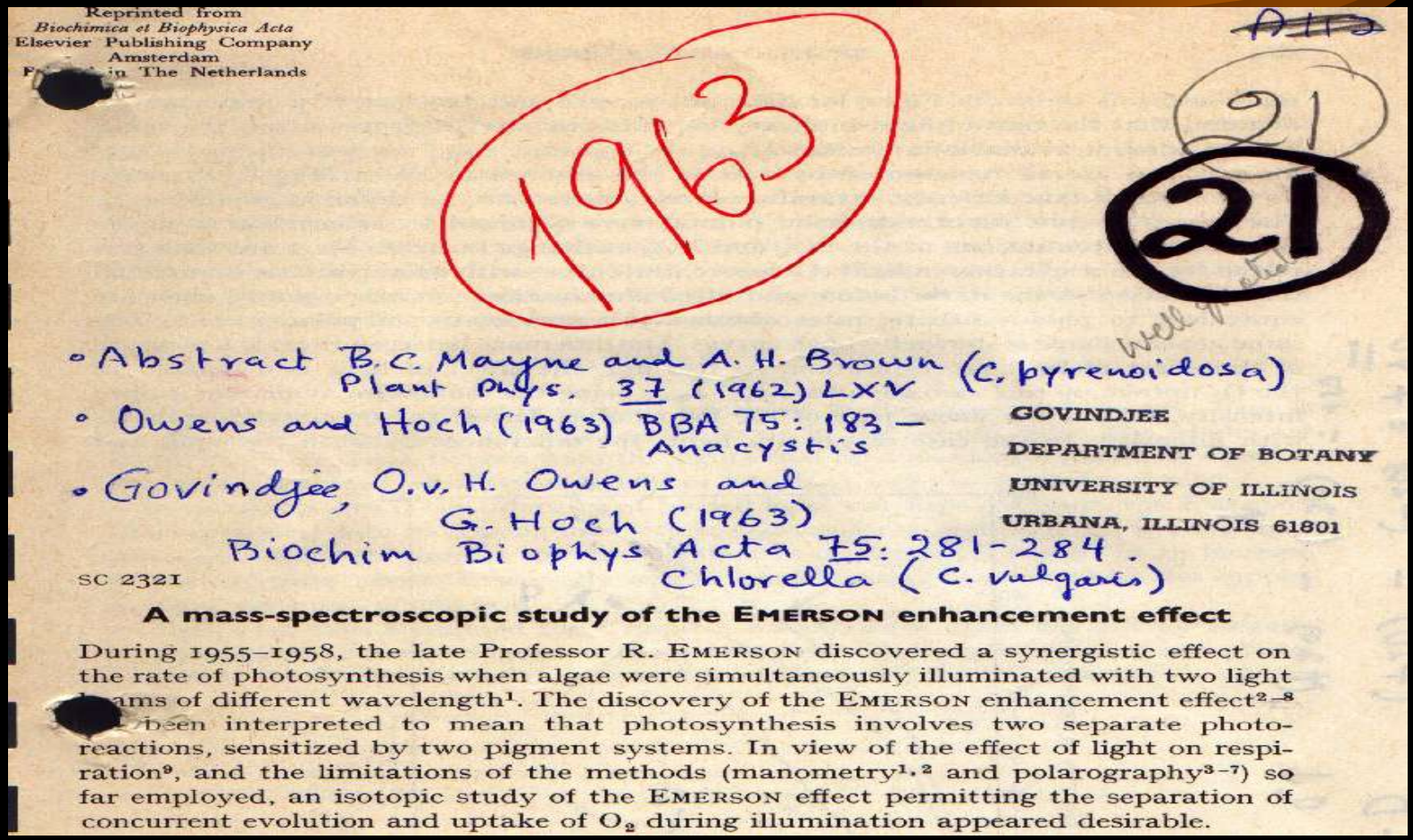




A 1961 photograph in Sweden – where we presented our PhD thesis work at the International Biophysical Society Meeting

Rabinowitch is shown here reading a Swedish newspaper; it was at this meeting that we presented our results showing that the Two Light Reactions are RUN by different spectral forms of chlorophyll and that the two light effect was in photosynthesis, not respiration

During 1962-1963, George Hoch, Olga v.h. Owens, soon joined by Govindjee, showed by oxygen-18 mass spectrometry, that the two-light effect was indeed in photosynthesis.



Reprinted from
Biochimica et Biophysica Acta
Elsevier Publishing Company
Amsterdam
Printed in The Netherlands

1963

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- Abstract B.C. Mayne and A.H. Brown Plant Phys. 37 (1962) LXV (C. pyrenoidosa)
- Owens and Hoch (1963) BBA 75: 183 — Anacystis
- Govindjee, O.v.H. Owens and G. Hoch (1963) Biochim Biophys Acta 75: 281-284. Chlorella (C. vulgaris)

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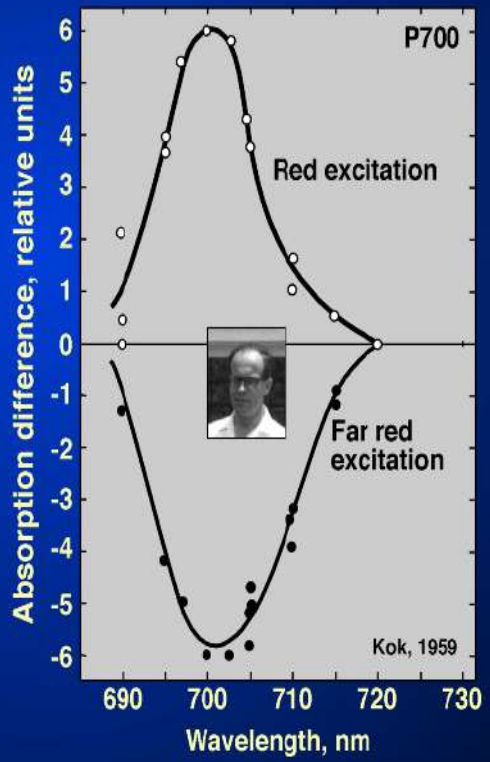
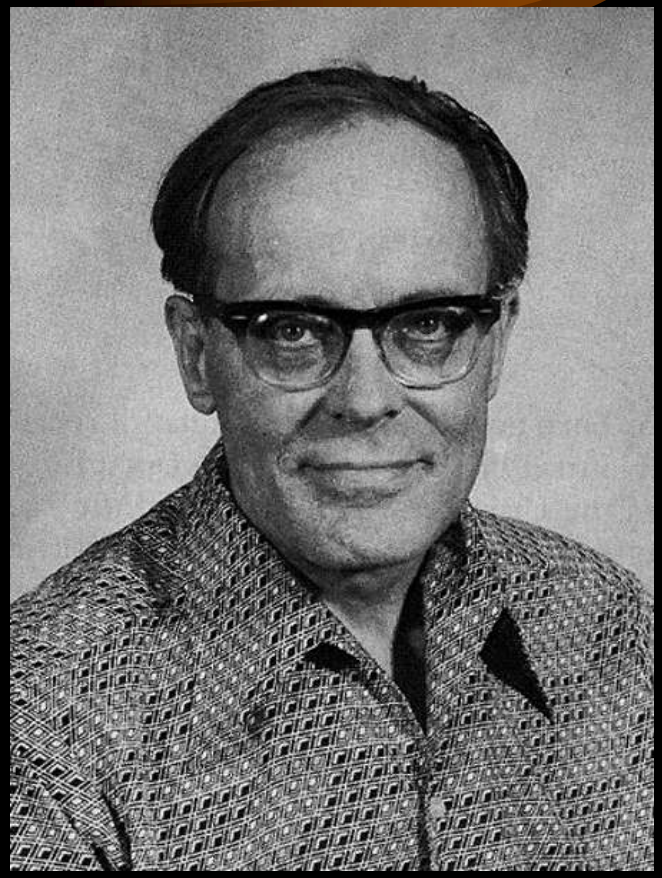
SC 2321

A mass-spectroscopic study of the EMERSON enhancement effect

During 1955–1958, the late Professor R. EMERSON discovered a synergistic effect on the rate of photosynthesis when algae were simultaneously illuminated with two light beams of different wavelength[1]. The discovery of the EMERSON enhancement effect[2–8] has been interpreted to mean that photosynthesis involves two separate photoreactions, sensitized by two pigment systems. In view of the effect of light on respiration[9], and the limitations of the methods (manometry[1,2] and polarography[3–7]) so far employed, an isotopic study of the EMERSON effect permitting the separation of concurrent evolution and uptake of O_2 during illumination appeared desirable.

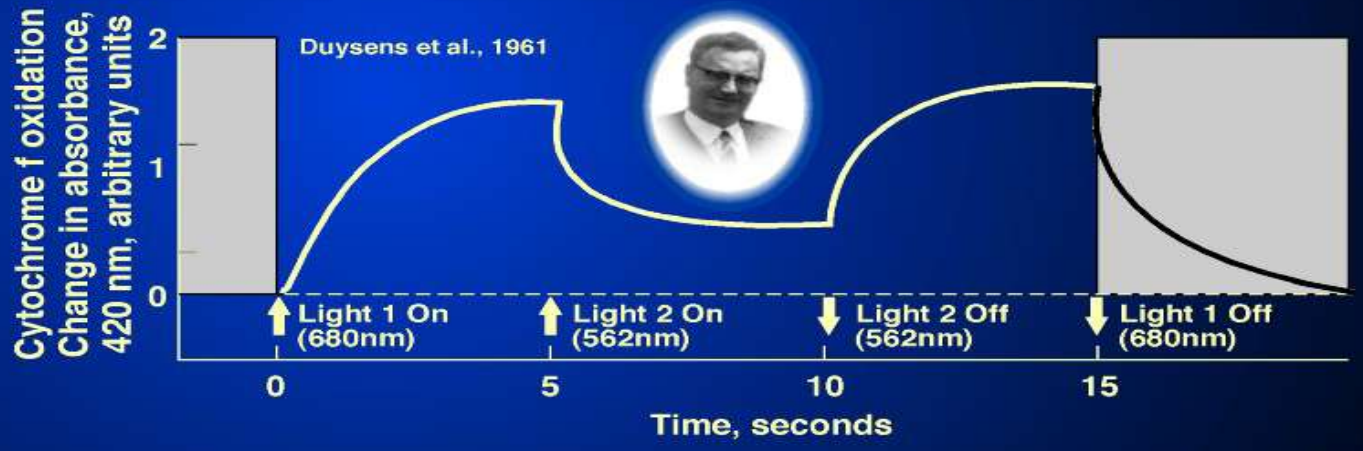
Bessel Kok (1918-1979) had discovered P700 in 1956-1957; in 1959, he showed the two-light effect





Lou Duysens and Jan Amesz's 1961 key experiment in Porphyridium

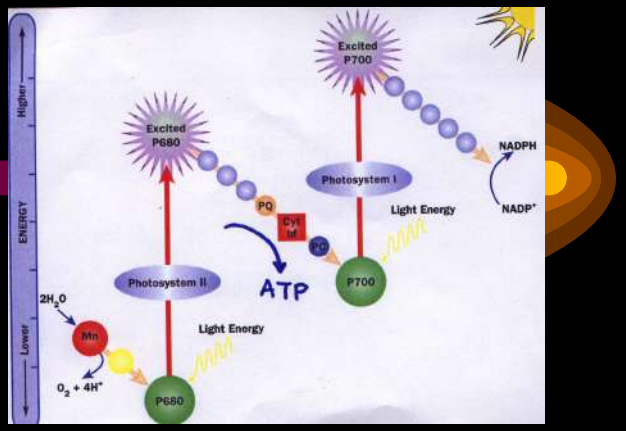
Duysens (right) Bob Knox (left)in Rochester



Robin Hill (1899-1991)

- ***Discoverer of the “Hill Reaction”; cytochromes.**
- ***His 1960 “Z” scheme became famous**
- ***" In the end, when everything is settled, few of us perhaps will really desire to look back at it at all"**

More on the Z-Scheme



- ***During 1959, there were several schemes and discussions in a book "Light Life"; Hill was there, but said nothing**
- ***Robin Hill, published the first "Z" Scheme (theory) with Fay Bendall (1960) in Nature**
- ***During 1961, there were several schemes (with experimental data) published in NATURE by Lou Duysens & Jan Amesz; Horst Witt; and Dan Arnon.**

Reaction Center of PSII, P680 (1965-1969)

THE ROLE OF CHLOROPHYLL IN PHOTOSYNTHESIS

by EUGENE I. RABINOWITCH and GOVINDJEE

SCIENTIFIC AMERICAN
JULY 1965
VOL. 213, NO. 1 PP. 74-83

Sonderabdruck aus der ZEITSCHRIFT FÜR NATURFORSCHUNG Band 22 b, Heft 6, 1967
Verlag der Zeitschrift für Naturforschung, Tübingen

A Second Chlorophyll Reaction in the Electron Chain of Photosynthesis
— Registration by the Repetitive Excitation Technique —

G. DÖRING, H. H. STIEHL, and H. T. WITT

Max-Volmer-Institut, I. Institut für Physikalische Chemie der Technischen Universität Berlin

(Z. Naturforschg. 22 b, 639—644 [1967]; eingegangen am 25. April 1967)

New absorption changes with a life time of $2 \cdot 10^{-4}$ sec at ~690 nm probably represent the chlorophyll-a light reaction in photosynthesis which promotes the cleavage of water.

Sonderdruck aus der ZEITSCHRIFT FÜR NATURFORSCHUNG Band 24 b, Heft 9, 1969
Verlag der Zeitschrift für Naturforschung, Tübingen

Properties of the Photoactive Chlorophyll-a_{II} in Photosynthesis

G. DÖRING, G. RENGER, J. VATER, and H. T. WITT

Max-Volmer-Institut, I. Institut für Physikalische Chemie, Technische Universität Berlin

(Z. Naturforschg. **24 b**, 1139—1143 [1969]; eingegangen am 10. Mai 1969)

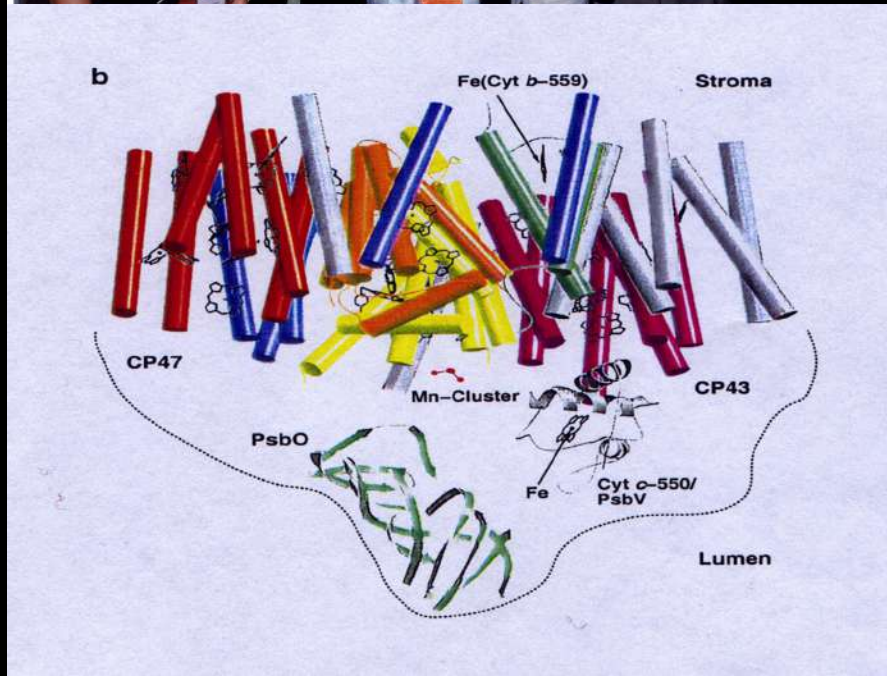
1. The complete difference spectrum of the reaction of the photoactive chlorophyll-a_{II} is presented.
2. The reaction of excited chlorophyll-a_{II} is of the type of a sensitizer. It is not engaged directly in the electron transfers. This is in contrast to the photoactive chlorophyll-a_{I} which is an electron donor in its excited state.
3. The chlorophyll-a_{II}-reaction can be separated from the overall reaction by heating chloroplasts 5 min at 50 °C.
4. Chlorophyll-a_{II} is the reaction center of the well-known poison DCMU.
5. Properties of chlorophyll-a_{II} are depicted in Tab. 1. They are compared with those of chlorophyll-a_{I} and the O_2-evolution system.

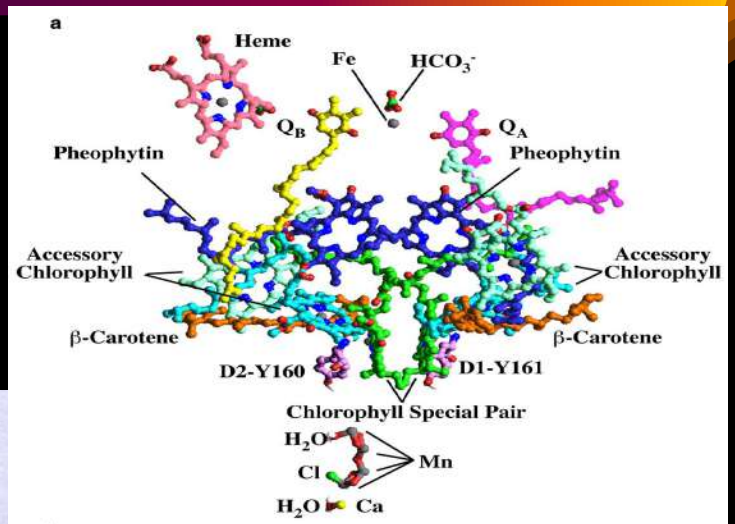
Question of P680 being an artifact

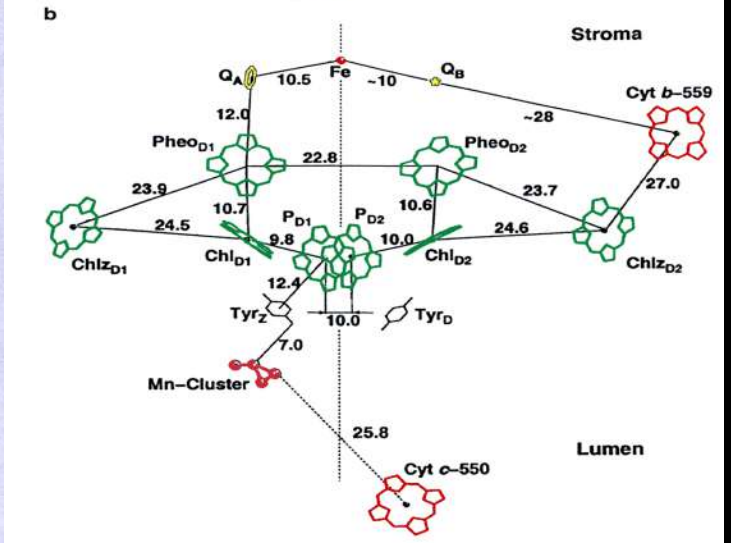
- *Warren Butler raised this question
- * In 1970, Rajni and I, with Guenter Doring, proved that it was not an artifact

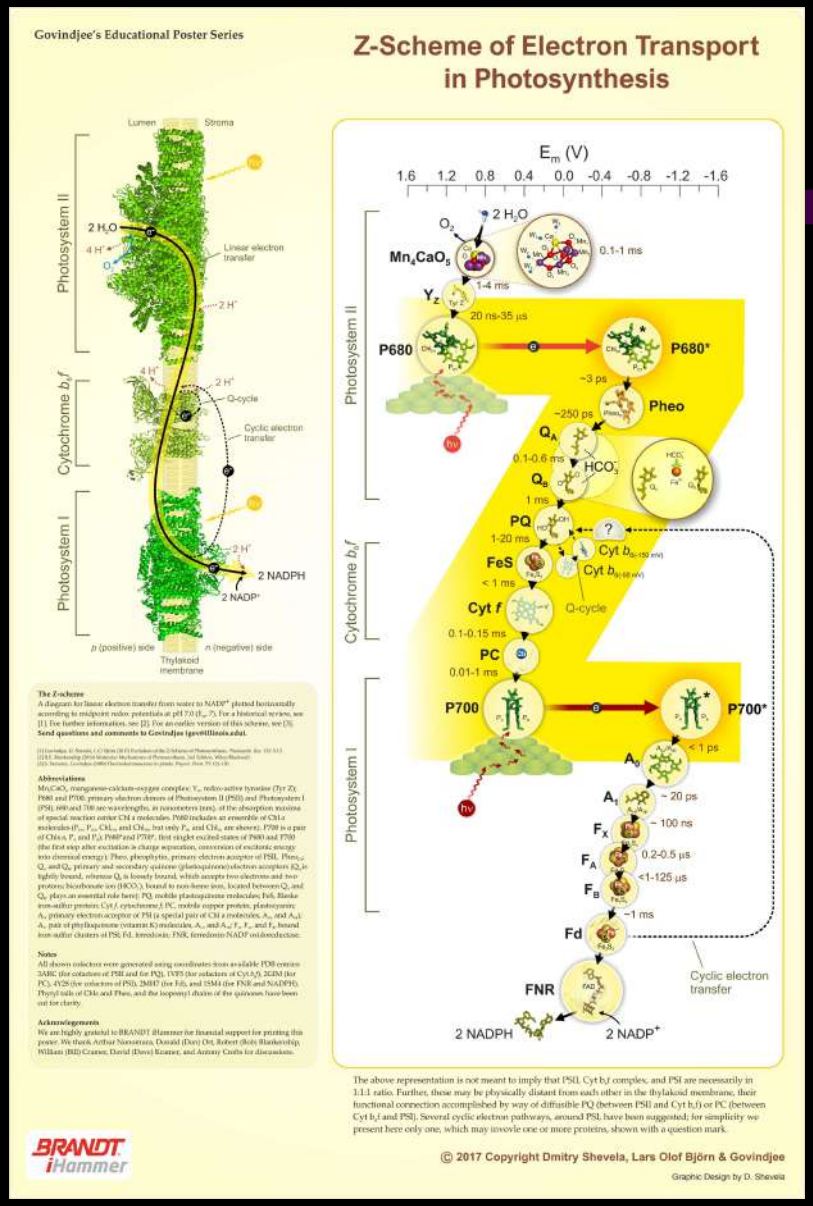
- Govindjee, G. Doering, and R. Govindjee (1970) The Active Chlorophyll *a* II in Suspensions of Lyophilized and Tris-Washed Chloroplasts. Biochim. Biophys. Acta 205: 303-306.

The Photosystem II Reaction Center (see Zouni et al., Nature, 2001)-now, we know a lot more– another lecture









Govindjee, Shevela D and Björn LO

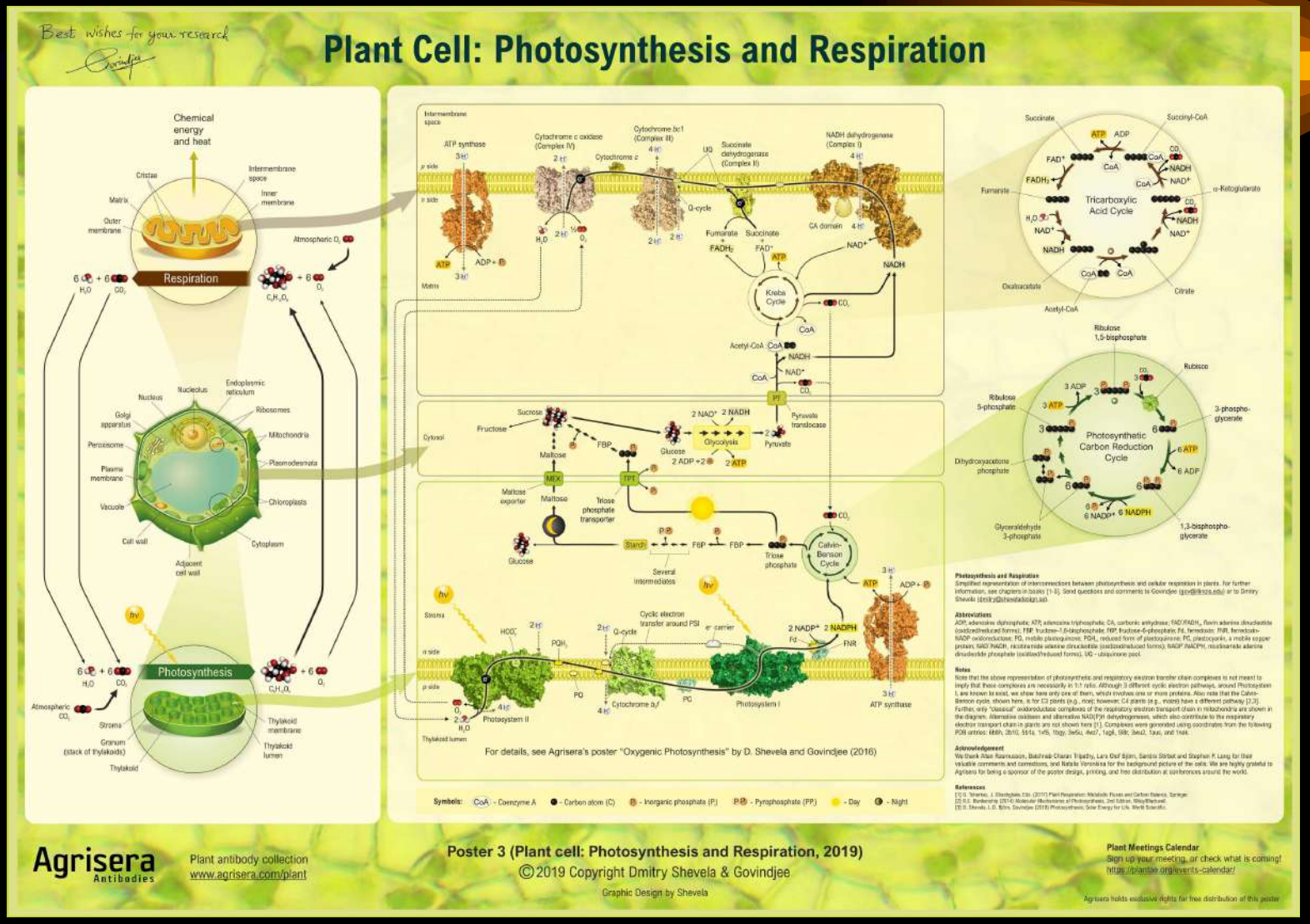
(2017)

Evolution of the Z-scheme of photosynthesis. Photosynth Res 133:5-15.

(There has been tremendous progress since Emerson's discoveries, and scientists are focusing on them)

Beyond Photosynthesis, there is Respiration and More

Just to impress on you the complexity : NOT for reading- another lecture- there is "Respiration" and more!



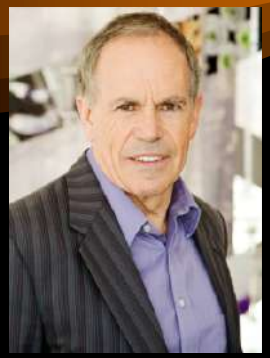
This presentation is dedicated to our first professor Robert Emerson (1956-1958) , with whom we have no single publication!

- The picture shows Robert Emerson with his students (from a class he taught) at a party in Urbana, IL

Robert Emerson Memorial Award

Each year a graduate student is chosen, based on academic credentials,and write-up, to get this award; the student chosen in 2019 was Rachel Moran

Robert Emerson Professor of Plant Biology: Donald R. Ort (left)



See his web site: https://sib.illinois.edu/profile/d-ort

During 1999- 2008, another influential professor Steve Long (right) held this professorship; listen to him on a Youtube:

https://youtu.be/XYXJeZdzpZE

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