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HISTORY AND BIOGRAPHY

Paul A. Castelfranco (1921–2021): a scientist par excellence, a man of lasting faith, and ever a humanist

R. W. Breidenbach[1] · Ann M. Castelfranco[2] · John Castelfranco[3] · Govindjee Govindjee[4] · Kevin M. Smith[5] · Alan Stemler[6]

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Abstract
We present here the life and the work of Paul A. Castelfranco (1921–2021), a very special person who was not only a top chemist of chlorophyll biosynthesis, but also made major contributions on fatty acid oxidation, acetate metabolism and cellular organization. He led an extraordinary and exemplary life as a human being. We present here both his personal life as well as his scientific life, which is followed by reminiscences by William Breidenbach, Kevin Smith, Alan Stemler, Ann Castelfranco, and John Castelfranco. As the subtitle of this Tribute implies, till the end Paul was a scientist par excellence, an intellectual with unlimited curiosity, a humanist, and a man of enduring religious faith. We all miss him dearly.

Keywords Chlorophyll biosynthesis · δ-aminolevulinic acid · Donald Noyce · Paul Stumpf · Giorgio de Chirico · Photosynthesis

Early life and education

Paul Castelfranco (Fig. 1) was born on October 16, 1921, in Florence, Italy, the son of Giorgio Castelfranco, an art historian with the Administration of Fine Arts, and Matilde Forti, the daughter of a textile manufacturer. He was brought up in a comfortable middle-class home, which was frequented by artists and intellectuals. One of his earliest memories was of the artist Giorgio de Chirico (1888–1978), who taught him how to load and light a pipe. He also frequently recalled spending time at his grandfather's villa at Santa Lucia outside of Prato and helping on the farm with his lifelong friend, Umberto Mannucci. Figure 2 shows two photographs from his early life.

When he was sixteen his life changed abruptly with the enactment of antisemitic race laws since his family was Jewish. His parents reacted to this response of the Italian government to the pact with the Nazi party leader Adolf Hitler (1889–1945) by sending Paul and his sister, Giovanna, to Switzerland. In 1939, Paul and Giovanna immigrated to the United States of America. They arrived in New York at the beginning of a hot summer and continued to California, ending up at the International House near the University of California at Berkeley (UC Berkeley). Paul decided to continue his education by studying agriculture at Bakersfield Junior College. In 1941 he graduated from there and transferred to UC Berkeley, where he majored in chemistry.

After graduating in 1943, he joined the US Merchant Marine and crisscrossed the Pacific and Indian Oceans until the end of World War II, often on a supply ship as part of a military convoy. In 1947, Paul and his sister returned to Italy with the hope of reestablishing their lives there. Their

"Chlorophyll is the pigment that negotiates the cosmic gap between the light of the sun and life on Earth."—Paul Castelfranco.

✉ Ann M. Castelfranco
castelfr@hawaii.edu

✉ Govindjee Govindjee
gov@illinois.edu

1 Department of Plant Sciences, University of California Davis, CA 95616, USA

2 Pacific Biosciences Research Center, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA

3 511 7th Street, Davis, CA 95616, USA

4 Department of Plant Biology, Department of Biochemistry and Center of Biophysics & Quantitative Biology, University of Illinois at Urbana- Champaign, Urbana, IL 61801, USA

5 Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803, USA

6 Department of Plant Biology, University of California, Davis, CA 95616, USA

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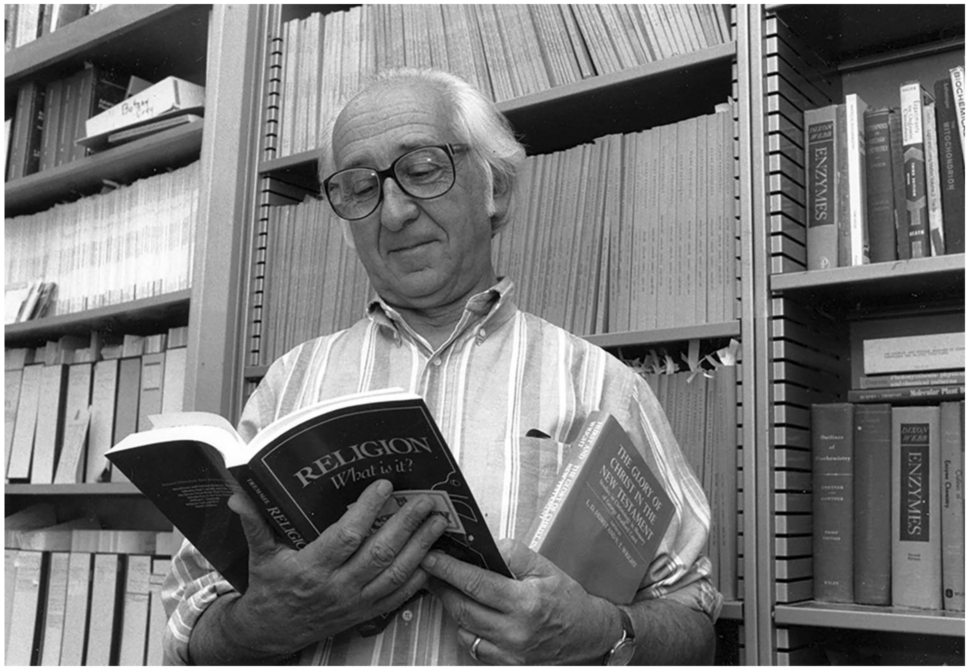

Fig. 1 Paul Castelfranco in his office shortly before his retirement on June 30, 1991. Source: P. Castelfranco (2007)

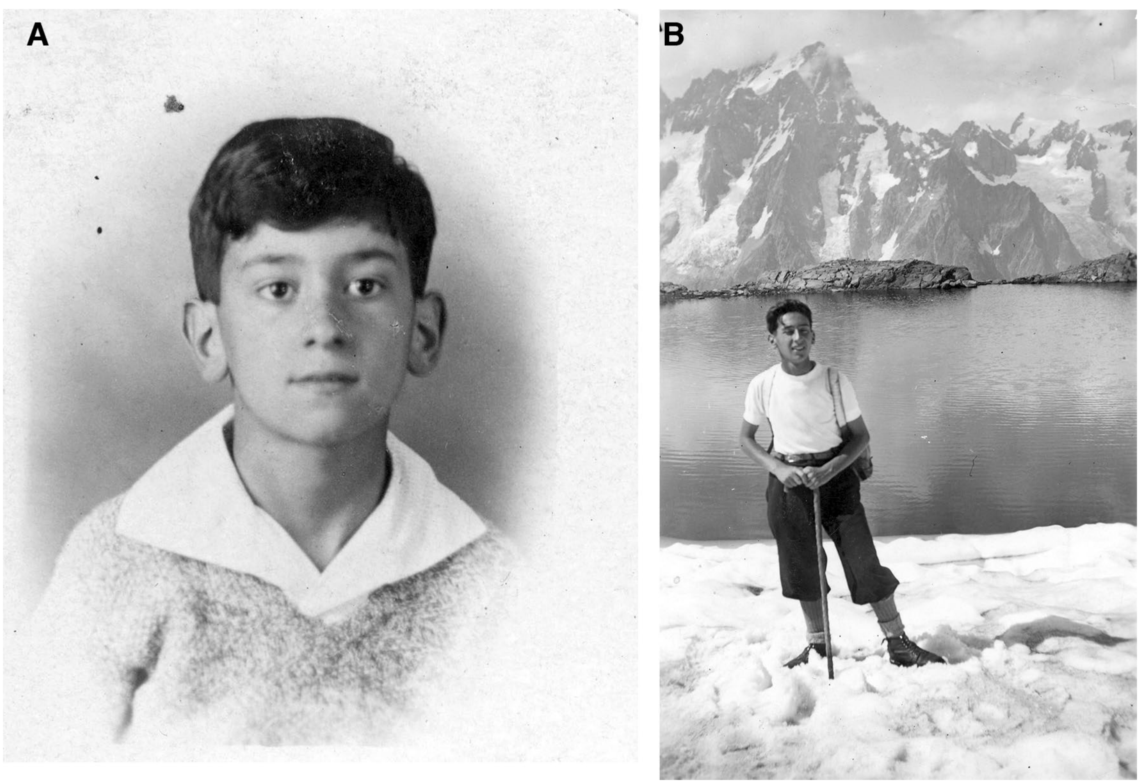

Fig. 2 **A** Paul Castelfranco as schoolboy in ~ 1930. **B** Paul in the Italian Alps in the summer of 1938. Source: Castelfranco Family Archives

parents had survived the war, but the family was in disarray, and it soon became clear that restarting life in Italy was not possible. So, Paul decided to return to UC Berkeley for graduate school.

He joined the laboratory of Donald Sterling Noyce (1923–2004), where he studied the acid-catalyzed condensation of benzaldehyde and acetophenone. This experience kindled an enduring passion for scientific research. After

Fig. 3 Paul Stumpf's laboratory at UC Berkeley in ~ 1954. Back row from left to right: unidentified, Paul Castelfranco, Paul Stumpf. Front: Rebecca Contopoulou. Source: Castelfranco Family Archives

receiving his Master's in Chemistry, Paul entered the Ph.D. program in Agricultural Chemistry. He did his doctoral research with Paul Karl Stumpf (1919–2007) at UC Berkeley on the oxidation of long chain fatty acids in germinating peanut tissues (Fig. 3). In Stumpf's laboratory, Paul characterized the first step in the alpha-oxidation of palmitic acid, in which glycolic acid is oxidized to glyoxylic acid releasing hydrogen peroxide. The released hydrogen peroxide attacked the long chain fatty acid in a peroxidase-type reaction to detach the carboxyl group, as CO_2 (Castelfranco et al. 1955). Paul Stumpf remained his mentor, colleague, and friend for the rest of their lives. Berkeley is also where Paul met Marie Sander, and the two were married in 1954.

Paul became captivated by Christian theology, as well as plant biochemistry, a unique thing. So, after obtaining his Ph.D. in 1954, he enrolled in the Pacific School of Religion in Berkeley, later transferring to Harvard Divinity School in Cambridge, MA where he completed an STB (S*cientiae Theologicae Baccalaureus*) degree in1957 (Fig. 4). In 2002, Paul and Marie endowed a chair in the History of Christianity in the Religious Studies Department (Fig. 5). Paul said in Castelfranco (2007) that "*for me there is no conflict between Religion and Science and there cannot be any, because the belief in a natural order, which is the basis of all the sciences I know, is in itself a religious idea. If I believed in a random universe, a miscellaneous grab-bag of unrelated objects and events, I could not be a scientist*."

From 1957 to 1958, Paul was a postdoctoral researcher in the lab of Alton Meister (1922–1995) in the Biochemistry Department at Tufts Medical School, where he worked on the chemical synthesis of aminoacyl adenylates (Moldave et al. 1959). [We note that Meister did pioneering research on AIDS.] Finally, he served on the Faculty of Botany at the University of California at Davis (UC Davis) from 1958 till 1991 when he retired. While at UC Davis, he, and Neal Gilbert (1924–2020) from the Philosophy Department started the Program in Religious Studies, which is now the Department of Religious Studies with a Ph.D. program. After retiring Paul continued his research for many years as professor emeritus. He passed away on December 1, 2021, at his home in Davis, California.

Research

Paul was a leader in research on the '*Biosynthesis of Chlorophyll*' discovering some of the key steps in the pathway. It was to this area of study that he devoted most of his research career. His major discoveries concern three key steps in the biosynthetic pathway. The first was the discovery of the C-5 (glutamate) pathway for the biosynthesis of 5-aminolevulinic acid (ALA), the first committed precursor in the

Fig. 4 Graduation from Harvard Divinity School, Cambridge, MA in 1957. Paul with his daughter Ann, and wife Marie. Source: Castelfranco Family Archive

Fig. 5 Paul and Marie Castelfranco in their home at the time of the endowment of the Paul and Marie Castelfranco Chair in Religious Studies in 2002. Source: Castelfranco Family Archive

synthesis of porphyrin and chlorophyll (Beale and Castelfranco 1973, 1974). Glutamate is now recognized as the precursor of ALA in most organisms. The next was the discovery of the specific requirement of ATP for the insertion of Mg into protoporphyrin IX to form Mg-protoporphyrin IX (Pardo et al. 1980). Third, was the pathway for the formation of the isocyclic ring, the fifth ring of chlorophyll. Some of this work is described below by Kevin Smith (see his Reminiscence). Paul's later work was concerned with light/dark regulation of the pathway from ALA to protochlorophyllide (Huang et al. 1989; Huang and Castelfranco 1990) and differences between the behavior of the oxidative cyclase in intact chloroplasts and in the reconstituted system made from a membrane pellet and a soluble supernatant component (Whyte and Castelfranco 1993). In 1993, Paul was invited by the Ciba Foundation to give a lecture at a symposium on the "*Biosynthesis of the Tetrapyrrole Pigments*" in which he summarized his laboratory's view on the formation of the isocyclic ring (Castelfranco et al. 1994). At the invitation of Govindjee (one of the authors), Castelfranco (2007) summarized his research on the biosynthesis of chlorophyll, his major and best-known contribution to plant biochemistry; just a few years before, Castelfranco and Beale (2003) provided a detailed complete review on this topic, as well as references to his research. His sense of putting together science and art was brilliant. He used to remark: "*Chlorophyll is the pigment that negotiates the cosmic gap between the light of the sun and life on Earth*." In 2007, Paul received a lifetime achievement award from the Rebeiz Foundation for Basic Research at Champaign, Illinois.

Among the early projects in Paul's laboratory at UC Davis was the study of the subcellular localization of β-oxidation in germinating oily seeds. His first graduate student, Constantin Rebeiz found that the enzyme system for β-oxidation of palmitic acid in peanut cotyledons was extra-mitochondrial (Rebeiz and Castelfranco 1964). This led another graduate student, Bill Breidenbach to the observation that mitochondria pellets from germinating peanut cotyledons resolved into two distinct particles on sucrose gradients and speculated that perhaps there were two classes of mitochondria, one with the expected metabolic features, and one involved in gluconeogenesis in these fatty tissues (Breidenbach et al. 1966; see his Reminiscence below).

What more?

We could not have imagined that on top of all we mentioned above that Paul Castelfranco was a poet, a story writer, as well as a science fiction writer. He wrote several books of poetry and one of short stories (Castelfranco 1986; 1988; 1991; 2003; 2011). Further, he loved the outdoors; he was a great hiker, had the curiosity of a child, and a brilliant imagination. We know well that his students and friends always felt encouraged and inspired when they were with him and even afterwards.

Reminiscences

We provide below remembrances from William Breidenbach (of University of California Davis), Kevin Smith (of Louisiana State University) and Alan Stemler (of University of California Davis) as well as those of his children Ann and John Castelfranco.

1. R. William (Bill) Breidenbach (e-mail: rwbreidenbach@ucdavis.edu)

On Paul Castelfranco: The poet, The philosopher, The scientist, The mentor, and a wonderful friend.

As previously noted, Paul Castelfranco was truly a renaissance man with an exceptionally creative and inquisitive mind, who applied that mind to a broad range of interests from biochemistry to theology. Others in this tribute may describe Paul's pioneering work in the field of chlorophyll biosynthesis and biology, but I will focus on an earlier part of his career.

Paul's Ph.D. thesis in 1955 (in the Biochemistry Department at the University of California Berkeley) under Paul K. Stumpf (1919–2007) first described the α-oxidation of palmitic acid in a supernatant extract from germinating peanut cotyledons, which was published in the Journal of Biological Chemistry (Castelfranco et al. 1955). It was not until the 1970s that others purified and characterized the enzyme, acyl-CoA oxidase, catalyzing this reaction. This is related to oxidation in peroxisomes, which is now a hot topic in medical research (see e.g., Wanders et al 2020).

In1964, he and his first student, Constantin Rebeiz (1936–2019) made the pioneering discovery that in fatty seeds the beta oxidation of fatty acids was extra-mitochondrial (Rebeiz and Castelfranco 1964) unlike animals where the beta oxidation of fatty acids was entirely associated with mitochondria. (For the life and work of Rebeiz, see Govindjee et al. 2020.) C. Rebeiz and P. Castelfranco suggested that this might be related to gluconeogenesis via the glyoxylate bypass in these tissues. That was a prescient speculation, as I will describe later.

At this point I became a student in Paul's lab. I will digress to describe how this came about. It exemplifies Paul's compassion, social skills and understanding of human nature. I had just finished my master's thesis in another laboratory. My master's project was disappointing, revealing mostly negative results, causing me to become depressed. I came to dread coming to the laboratory. At this point it was suggested that I was unsuited to scientific research and should seek another career. Fortunately, I consulted another faculty member, who disagreed with that assessment and suggested that I should talk to Paul Castelfranco, advice that changed my life. Outside of my wife, children and parents, Paul became the most influential person in my life. From my first day, as with all his students, Paul treated me as a colleague rather than an apprentice. Almost daily he would call me or other students to the blackboard in the lab to ask our opinions on some idea or some paper he had read. He often invited me and other students to join him, his friend Grant Noda, Lab Manager for the Botany Department and Grant's counterpart from Biochemistry and Biophysics, for coffee at the Coffee House where we always had stimulating discussions on a wide range of topics. Paul always allowed his students to work independently. He was skilled at observing when a student might be floundering, carefully suggesting how to solve their problem, and then stepping back, allowing them to proceed.

To familiarize me with the laboratory and its protocols, Paul first asked me to work with Tino Rebiez, running experiments investigating the acetylthiokinase activity of germinating peanut cotyledons, particularly with respect to its distribution among the various subcellular constituents (Rebeiz et al. 1965). After a short time, Paul and I began to discuss possible thesis projects for me. During these discussions I suggested that I was interested in how the low levels of oxidative metabolism in dormant storage tissues increased to the relatively high levels observed in these tissues during germination. Paul agreed, even though this question was only peripherally related to his current research. So, I began experiments isolating the particulate fractions from cotyledons at various times during the germination of peanut seeds using sucrose density gradient centrifugation to purify the mitochondria. It was quickly seen that there were two distinct protein peaks with different densities on the gradients and that both increased significantly during germination. During discussions of these results, Paul raised the idea that perhaps there were two types of mitochondria in gluconeogenetic tissues such as peanut cotyledons. This notion had arisen in discussions with Prof. Marré during Paul's visit in Milan about whether there were two kinds of mitochondria, that of Hans Krebs (1900–1981) with the typical citric acid cycle and that of Arthur Kornberg (1918–2007) with the enzymes requisite for gluconeogenesis via the glyoxylate bypass (Breidenbach et al. 1966). While Harry Beevers (1924–2004) and I (see: Breidenbach et al. 1968) received the credit for demonstrating that in fact, the glyoxylate bypass enzymes were associated with the denser of the two particles observed on the gradients, naming them glyoxisomes, Paul's prescient suggestion clearly was the foundation for this finding. Glyoxisomes were subsequently shown to be a specialized form of peroxisome having the extra-mitochondrial β oxidation activity that he and Tino Rebiez had described.

I have one further example of Paul's humility and inquiring mind, before acceding to others, the pioneering observations on tetrapyrrole metabolism, chlorophyll biosynthesis and biology. As a student I took a graduate student seminar course taught by Paul. In that class, Paul emphasized to the students that *no question was stupid*, if sincerely asked because it was something you didn't know or didn't understand. If you didn't know or understand something there were probably others in the audience in the same position. Paul himself adhered to that principle at seminars by other faculty or visitors that he attended.

A sad goodbye to the poet, the philosopher, and the scientist who was my mentor, friend, and colleague. We all miss him dearly.

2. Kevin M. Smith (e-mail: kmsmith@lsu.edu)

I arrived at UC Davis from Liverpool (UK) in August of 1977 as a newly minted Professor of Chemistry. I barely knew anyone on campus outside of the UC Davis Chemistry department, but I did know about Paul Castelfranco because of his groundbreaking work on the C5 (glutamate) pathway to some tetrapyrroles. During the previous 2 years (1975–1976) I had participated, along with Albert Neuberger (1908–1996) and George W. Kenner (1922–1978), in the organization of a Royal Society (London) Conference entitled "A Discussion on the Biosynthesis of Porphyrins, Chlorophyll and Vitamin B_{12}". This was published in full in *The Philosophical Transactions of the Royal Society*, Vol. 273 No. 924, February 1976. During the early planning stages for the discussion meeting, we became aware of the startling 1974 report of an alternative "C5" biosynthetic pathway to δ-aminolevulinic acid and therefore to porphobilinogen, the monopyrrolic universal biological precursor of the porphyrins, chlorophylls and vitamin B_{12}. Paul Castelfranco and Samuel Beale were the originators of this work, and Sam Beale agreed to speak at the meeting. At this point in time, I became aware that Paul Castelfranco was in the Botany Department at UC Davis, where unexpectedly I would arrive 3 years later to join the Chemistry faculty.

Not long after I arrived in UC Davis, Paul showed up at my office in Chemistry. He explained that, like me, he was interested in chlorophyll biosynthesis, and modestly seemed surprised that I already knew about his work with Beale. Paul was welcoming, quietly spoken, thought carefully about what he was saying, and was a complete gentleman. We decided to collaborate on chlorophyll biosynthesis once I had my feet on the ground in California, had secured NSF funding for *Chlorobium* chlorophyll research I had planned, and had some graduate students recruited into my group and trained to do the work. My immediate need was to get results from an already funded NIH R01 grant I had written shortly before leaving the UK; this work was related to structure/function relationships in heme proteins using paramagnetic NMR (in collaboration with Gerd LaMar at UC Davis) and required uniquely and specifically deuterated hemes.

We eventually got our act together (funding, equipment, and students), and in 1984 began a study of the biosynthetic formation of the isocyclic ring (E) in chlorophyll *a* with Paul (see Fig. 6).

Using Castelfranco's organelle-free enzyme system from developing chloroplasts and our synthetic magnesium protoporphyrin (**1**; see Fig. 6) and the magnesium β-ketoester (**2**), Wong et al. (1985) reported that both were efficiently transformed into magnesium 2,4-divinylpheoporphyrin a_5 (**3**). In addition, an intermediate was isolated which we identified as the magnesium β-hydroxyester (**4**). Further, in Walker et al. (1988), we reported that using a cyclase system isolated by Paul and his group from cucumber, the acrylate (**5**) was inactive as a substrate for (**3**), but that synthetic magnesium β-hydroxyester (**4**) was indeed a substrate. Compound (**4**) exists as a pair of enantiomers due to the asterisked chiral carbon in the propionic side chain, but we showed that only one of the two enantiomeric alcohols was a substrate for the cyclase. Then we showed, in Walker et al. (1989), that $^{18}O_2$ was incorporated into (**3**) using detached cucumber cotyledons, establishing that hydration of the acrylate (**5**) was not the source of the new oxygen atom in the β-hydroxyester (**4**) and therefore of the β-ketoester (**2**). The biosynthetic pathway from the propionate in magnesium protoporphyrin IX to the ketoester isocyclic ring E in the intermediate (**3**; Fig. 6), and therefore in chlorophyll *a*, was thus clearly established. Lastly, in Shiau et al. (1991), we published our syntheses of the two possible monomethyl esters of protoporphyrin IX, one of which is the intermediate (**6**). We were able to establish structurally which isomer was which by demonstrating that one (**6**) was a substrate for the cyclase, while the other was not (see Shiau et al. 1991). Attempts to identify the active enantiomer of (**4**) by crystallization and single crystal X-ray diffraction were unsuccessful.

It was a tremendous pleasure to know Paul, as a kind person of calmness, wit, humor and knowledge, and also as a first-rate scientist and a leader in his field. I warmly remember also that my own synthetic organic chemistry graduate students loved going down California Avenue

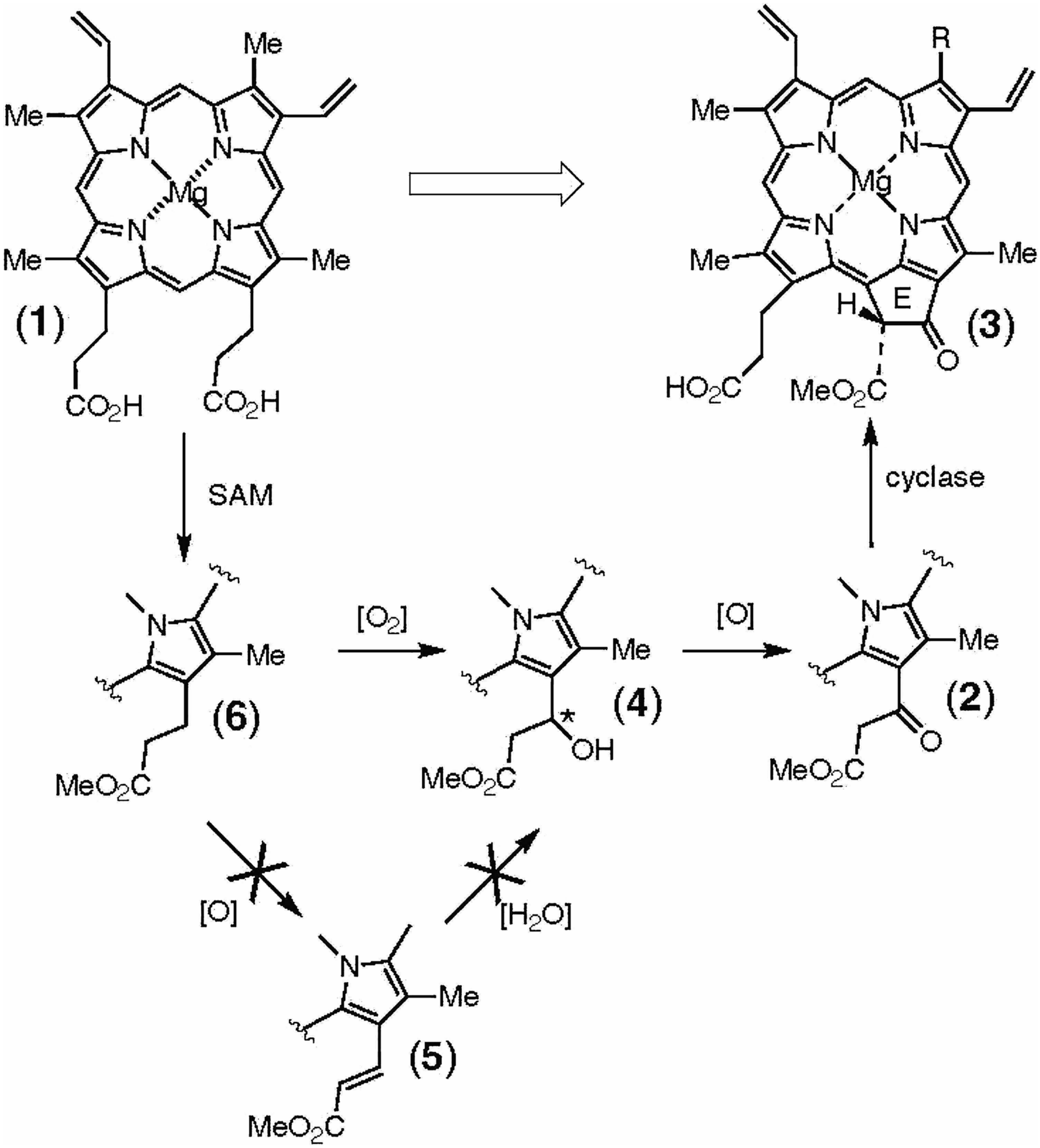

Fig. 6 A scheme for the formation of the isocyclic ring (E) in chlorophyll precursors. The propionic side chain in the lower-right ring of magnesium protoporphyrin IX (**1**) is first esterified to give the methyl ester (**6**) and then mono-oxygenated by atmospheric oxygen to give the alcohol (**4**); this is further oxidized to give the β-ketoester (**2**) which cyclizes to give (**3**). Earlier researchers had suggested that the acrylate (**5**) could be a biosynthetic intermediate which is subsequently hydrated enzymically to give (**4**); this possibility was eliminated as an option by the reported studies (see the text)

from Chemistry to his office in Robbins Hall and interacting with him. We all miss him.

3. Alan Stemler (e-mail: ajstemler@ucdavis.edu)

Getting to know Paul Castelfranco began when I arrived at Davis as a young assistant professor forty short years ago. Time steadily increased my appreciation and admiration of him as a scientist, scholar, historian, philosopher, theologian and, yes, poet. I recall the many conversations we had over the years on topics ranging from the trivial to war and peace and the nature of everything. With the mundane subjects, I could sometimes hold my own. With all the rest, Paul provided the substance, with an endless supply of knowledge and wisdom.

Fig. 7 Alan Stemler (right) about to absorb coffee and wisdom from Paul Castelfranco at UC Davis, ~ 2010, Davis, California. Source: Stemler's Archive

Clearly, Paul Castelfranco led an oversized, diverse, and creative life. He was first and foremost a scientist, with all the requisite curiosity and intellect needed to add to our fundamental knowledge of creation. It is not difficult to appreciate the result of these gifts, and to understand the importance of Paul's research. We owe our existence to living on a green planet, filled with hundreds of thousands of species of plants. Except for a handful of parasitic exceptions, all plants contain chlorophyll, the green pigment that most often meets our eyes. It is this chemical compound, and the light it absorbs, that alone energizes food production to supply the needs of the entire biosphere. There is no substitute for chlorophyll, or the process it initiates and that we call photosynthesis.

But how do plants make this miracle substance? If he were still with us, the answer would be, "Ask Paul Castelfranco." Until retirement, Paul was *the* authority on how plants synthesize chlorophyll. To be sure, uncovering the steps involved in the synthesis, a large, intricate molecule, required the attention of many researchers, but Paul and his laboratory were always central to this monumental effort. Now this knowledge is integral to many related studies and practical applications. He leaves exactly the sort of legacy to which all of us in science aspire.

Paul retired in 1991, at least according to the university's books. In actuality, he never even paused in his thinking and problem solving to reveal the secrets of nature and beyond. I gained the most from Paul's continued creative momentum. He was always interested in my own research that involved a different aspect of photosynthesis. My lab was still open, and Paul was encouraged to come in whenever he felt the urge. Soon we were collaborating on another challenging question. Plants use chlorophyll, and the energy it absorbs is used to attack water molecules. This results in the production of molecular oxygen that presently accounts for all of this vital gas in the earth's atmosphere. However, the chemical mechanism remains elusive despite protracted efforts by some of the best minds in the field. Adding to the confusion, for some unresolved reason, the process of water splitting appears to require a catalytic amount of carbon dioxide, a phenomenon I researched for most of my career. The topic has generated many conflicting ideas, and personal disputes. Paul was undeterred. Here was just another important science puzzle to be solved. He accepted the challenge and produced a detailed theoretical chemical model (Castelfranco 2013; cf. Castelfranco et al. 2007), including a catalytic role for carbon dioxide, which suggests how plants may produce the oxygen we breathe in addition to the food that sustains us. His model, which uses peroxydicarbonic acid cycle, is not yet accepted—future experiments will allow judgment. Figure 7 shows a photograph of Paul and me in California.

4. Ann M. Castelfranco (email: castelfr@hawaii.edu)

More than anyone else my father, Paul Castelfranco, inspired me to become a scientist. For me, he was always an archetypal scientist. He embodied many of the essential characteristics of a successful scientist: creativity coupled with a fertile imagination, a strong belief in his own ideas, and the ability to trust his results. Furthermore, he knew how to construct a rational argument for designing experiments to test a hypothesis or writing a discussion, and, importantly, he had facility for working with his hands in the laboratory. As a child, I loved my father's creativity and imagination, his rational discourse about ideas at dinner, and the belief in the importance of ideas coupled with the concreteness of experimentation. My father could make a Sunday afternoon drive into an "exploration" of the world around us. But more than this, the thing that inspired me was the satisfaction that he always seemed to get from his scientific research. As long as I have known him, his research was a constant that sustained him through difficult periods in his life.

I had the opportunity to work with my father after I graduated from high school, while he was on sabbatical leave in Bristol, England working with Owen Jones. I spent that spring working as a very junior lab assistant. Although my primary function was probably to wash glassware, I learned how to extract chlorophyll and how to make thin layer plates for chromatography (a technique that is probably no longer used), but more importantly it was my first introduction to laboratory research and to the work of a plant biochemist. I remember listening to the conversations of my father and his colleagues and watching how their understanding of the system evolved with the experimental results (Castelfranco and Jones 1975). I started college the next fall, with the intention of becoming a biologist, but I never made it. Instead I ended up as an applied mathematician who spends every day working with biologists.

He was also an inspiring father. A father who taught me many things, things that shaped my life, but also things that have enriched it, such as the beauty of Brunelleschi's architecture from the great dome of the cathedral of Florence to the intimacy of the Pazzi Chapel, the identification of the conifers of the Sierra Nevada, and the appreciation of good cognac.

5. John Castelfranco (email: johncastelfranco@att.net)

My father, Paul Castelfranco, worked intently on the things that were important to him. He loved his research in plant physiology; he loved working together with a group of graduate students and trying to figure out the role played by the various molecular components in a plant cell, and how together they succeeded in capturing energy from the sun.

My sister Ann and I got used to him returning to the lab in the evening to check on experiments, and usually not returning until after we were asleep. Sometimes, joy of joys, there was time for roughhousing, when we would jump on him, get thrown off, and immediately climb back on.

In 1938, when my father was sixteen, the fascist government of Benito Mussolini (1884–1945) enacted antisemitic laws to secure an alliance with Adolf Hitler. These laws were a completely unexpected blow to my father's family. It meant that my grandfather lost his government job, and my father could no longer attend public schools. His parents succeeded in sending him and his sister as refugees to the United States. Perhaps, because of this experience my father understood the importance of knowing what was happening in the world, and of working for social justice, and he communicated this importance to his wife and children. He participated in marches opposing the Vietnam War, and sometimes we joined in these activities.

My father's interest in what was happening in the world expanded into an interest in history, theology, and art. While I was growing up our family had many opportunities to travel; we lived in Milan (Italy), Padova (Italy), and Bristol (UK). And my father did an excellent job of explaining the complex history associated with the palaces, cathedrals, museums, and castles we visited. For example, when we visited the Italian city of Ravenna, we found that there were two baptisteries; charming little round buildings with colorful byzantine mosaics in their domed ceilings depicting Jesus being baptized in the river Jordan. One baptistery was for those who held the orthodox understanding of the Trinity affirmed at the council of Nicaea, and the other for those holding the views of the fourth century theologian Arius. Although I was ten or eleven at the time, throughout that afternoon, my father did his best to explain these two theological positions to me.

My father always wanted to check up on his children and grandchildren and make sure we were alright. After my two sons were born, he would frequently call to see how we were doing.

After he retired from the University of California at Davis, he spent a lot of time writing poetry, his memoirs, and science fiction. One theme he explored in his writing was the immigrant experience and the question, "*How do you adapt to your new homeland, while remaining true to yourself and not becoming fragmented?*" He sometimes used the concept of "entropy" to describe the forces which threaten biological and psychological fragmentation. I conclude with an excerpt from one of his unpublished science fiction novels. The North Star, a ship carrying two intrepid space explorers, Henry Locanio, a human and a remarkable spider named Joe, enters an entropy hole:

> *…As they moved closer to the Center, they became ill, both physically and neurologically ill; both the man and the spider. They stuck to each other for reassurance and comfort, but they were terribly ill, so ill, in fact, that Locanio did not know how to fire a retro-rocket to get out of that hole.*

It was at that point that Juan Pussywillow's message reached the North Star. Locanio put one anti-Entropy helmet on his head and used the other helmet to screen his companion. They both felt immediately better, and Locanio decided to sail on to the Center, which they reached five days later…
On the way out of the Pulsating Entropy, Henry reached an important realization…If you want to overcome the ill effect of extreme Entropy values you must do two things: travel with someone you love and wear your helmet. On hindsight, Locanio decided this prescription was not too surprising; at least not the first part:
Love is order, but an order which is internal and organic, not imposed from the outside in a coercive manner. High Entropy means disorder, anarchy, chaos. Low Entropy means rigidity, autocracy, absolutism. It is not surprising, therefore, that Love conquers both high and low Entropy. Locanio remembered hearing of someone who said: "But the greatest of these is love."

Concluding Remark

The above Tribute outlines the highlights of some of Paul Castelfranco's accomplishments in science as well as his wonderful personal spirit and humanity, and how he affected those around him.[1] lists URLs of websites where the readers can find further information on Paul Castelfranco.

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Author contributions AS initiated the writing of this manuscript and requested GG to coordinate and invite others to participate. GG prepared a basic draft and approached AMC to join. This was followed by the addition of detailed *Reminiscences* by RWB, AMC, JC, KMS and AS. Figure 1 is prepared from P. Castelfranco (2007), Figs. 2, 3, 4, 5 were provided by AMC, Fig. 6 by KMS, and Fig. 7 by AS. All the authors finalized and approved the entire paper. In view of the above, authorship was decided to be in alphabetical order,

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[1] Web sites related to Paul Castelfranco are:
https://www.davisenterprise.com/obits/paul-a-castelfranco/
https://religions.ucdavis.edu/paul-and-marie-castelfranco-chair-0
https://www.researchgate.net/scientific-contributions/Paul-A-Castelfranco-2900551
https://religions.sf.ucdavis.edu/paul-and-marie-castelfranco-lecture-archive
https://video.ucdavis.edu/media/Paul+Castelfranco/0_8ccxalcb

Data availability The data is available.

Declarations

Conflict of interest All the authors declare that there are no conflicts of interest.

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