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HISTORY & BIOGRAPHY

Happy 95th birthday to Pierre Joliot, a brilliant scientist and a wonderful friend

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Abstract

It is both a privilege and a pleasure to celebrate the upcoming 95th birthday of Pierre Joliot, one of the most influential figures in modern photosynthesis research. Across more than seven decades of scientific activity, Pierre has transformed our understanding of oxygenic photosynthesis through pioneering studies of oxygen evolution, excitation-energy transfer, photosynthetic electron transport, and membrane bioenergetics. His discoveries helped establish fundamental concepts that continue to guide contemporary research, including the now-classic period-four oscillation of oxygen evolution and the mechanistic framework underlying the Kok–Joliot model of water oxidation. Pierre Joliot is also part of one of the most remarkable scientific families in history. The Curie–Joliot family has been associated with three Nobel Prizes and generations of groundbreaking discoveries that have shaped both physics and chemistry. Yet Pierre's own scientific accomplishments stand firmly on their own merit and have earned him an enduring place among the pioneers of photosynthesis research. In this tribute, we briefly discuss the origins of the Joliot and Joliot-Curie names, summarize Pierre's education, scientific career, leadership roles, and honors, and highlight selected contributions that have profoundly influenced our understanding of photosynthesis. Above all, we celebrate a scientist whose curiosity, creativity, rigor, and humanity have inspired colleagues, students, and friends around the world.

Keywords: Curie–Joliot scientific legacy; electron transport; oxygen evolution; photosynthesis; Photosystem II; Pierre Joliot.

Introduction

On March 12, 2027, Pierre Joliot will celebrate his ninety-fifth birthday. This milestone provides an opportunity not only to reflect on an extraordinary scientific career but also to honor a life devoted to discovery, education, public service, and the advancement of science. Pierre was born on March 12, 1932, in Paris, France, to Irène Curie and Frédéric Joliot, both Nobel laureates whose scientific achievements helped shape twentieth-century science. He later married Anne Joliot, herself a distinguished scientist and long-time collaborator. Together, they built a family deeply committed to scientific inquiry. Their two sons, Marc Joliot and Alain Joliot, also pursued successful scientific careers, continuing a tradition of intellectual curiosity and achievement that spans multiple generations.

Few scientific families have had such a profound impact on modern science. Pierre's grandparents, Marie and Pierre

Highlights

- Celebrates the Curie–Joliot legacy spanning four generations of Nobel science
- Reviews Joliot's landmark discoveries in photosynthetic energy conversion
- Highlights seven decades of leadership, innovation, and lasting scientific impact

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Curie, received the 1903 Nobel Prize in Physics, shared with Henri Becquerel, for their pioneering investigations of radioactivity (*see* Table 1). Marie Curie was subsequently awarded the 1911 Nobel Prize in Chemistry for her discoveries of radium and polonium and for her pioneering studies of radioactive substances. In 1935, Pierre's parents, Irène and Frédéric Joliot-Curie, received the Nobel Prize in Chemistry for their discovery of artificial radioactivity, a breakthrough that transformed nuclear science and ultimately contributed to important medical applications, including advances in cancer diagnosis and treatment.

Despite this extraordinary family heritage, Pierre Joliot never relied upon a famous name to define his scientific identity. Rather, through originality, perseverance, and scientific insight, he established himself as one of the world's leading investigators of photosynthesis and biological energy conversion. His discoveries fundamentally changed our understanding of how photosynthetic organisms harvest light, transfer electrons, split water, and generate the oxygen that sustains life on Earth.

Before discussing Pierre's scientific achievements, it is worth briefly noting the history of the Joliot and Joliot-Curie names. The combined surname "Joliot-Curie" was first popularized by the eminent French physicist Paul Langevin (1872–1946), a close friend of Marie Curie. Langevin encouraged the use of the combined name to recognize the scientific partnership of Irène Curie and Frédéric Joliot. Pierre's parents embraced this shared surname as a symbol of their collaborative work and mutual contributions to science. Following the death of Irène Joliot-Curie in 1956, Frédéric sought, with Pierre's agreement, to formally adopt "Joliot-Curie" as the family name. However, Frédéric's untimely death in 1958 occurred before the legal process could be completed. As a result, Pierre retained the surname "Joliot". Although history records him under that name, his scientific career reflects the best traditions of both the Joliot and Curie families: intellectual curiosity, experimental excellence, public engagement, and a lifelong commitment to scientific discovery.

As we celebrate Pierre Joliot's ninety-fifth birthday, we honor not only a pioneering scientist but also a colleague, mentor, teacher, and friend whose influence has touched multiple generations of researchers. His work continues to illuminate the field of photosynthesis, just as his generosity, wisdom, and enthusiasm continue to inspire those fortunate enough to know him.

Education, academic appointments, scientific leadership, and honors

Education and early scientific formation: Pierre Joliot began his scientific career in 1954 at the Centre National de la Recherche Scientifique (CNRS) in Paris, France, an institution with which he would remain associated throughout much of his distinguished career. Two years later, in 1956, he earned a Licence ès Sciences in Biology from the Faculty of Sciences of the University of Paris. This prestigious degree, historically known as the Licence ès Sciences Naturelles (or Sciences de la Vie), provided rigorous training in biology, physiology, genetics, and cell biology and served as the foundation for his future contributions to photosynthesis research.

In 1960, Joliot completed his doctoral studies at the University of Paris under the supervision of René Wurmser (1890–1993), a pioneering biophysicist whose influence helped shape Pierre's quantitative and mechanistic approach to biological research (Joliot 1996). Even at this early stage, Joliot displayed the combination of experimental creativity and analytical rigor that would later characterize his scientific career.

Academic Appointments and Scientific Leadership: Pierre Joliot's scientific achievements led to a succession of increasingly influential appointments within the French research system. In 1974, he was appointed Research Director at the CNRS, one of the highest scientific positions within France's premier research organization. This appointment formally recognized his growing international reputation as a leader in photosynthesis and bioenergetics research.

In 1981, Joliot was elected Professor at the Collège de France, where he held the Chair of Cellular Bioenergetics (Bioénergétique Cellulaire) until 2002. Founded in 1530, the Collège de France is among the world's most prestigious academic institutions, and appointment to one of its chairs is widely regarded as one of the highest honors in French intellectual life. Through

Table 1. Nobel Prizes in the Curie–Joliot family.

Year	Laureate(s)	Nobel Prize	Citation/Contribution	Relationship to Pierre Joliot
1903	Marie Skłodowska Curie, Pierre Curie, and Henri Becquerel	Physics	For their pioneering investigations of the phenomenon of radioactivity, establishing the foundations of radiation physics.	Grandparents (Marie and Pierre Curie)
1911	Marie Skłodowska Curie	Chemistry	For the discovery of the elements radium and polonium, the isolation of radium, and studies of the nature and compounds of radioactive elements.	Grandmother
1935	Irène Joliot-Curie and Frédéric Joliot-Curie	Chemistry	For the discovery of artificial (induced) radioactivity, enabling the production of radioactive isotopes and laying the foundation for numerous applications in medicine, biology, and nuclear science.	Parents

his lectures and research, Joliot influenced generations of scientists while continuing to advance the frontiers of photosynthesis research. Following his retirement, he was named Professor Emeritus in 2003.

Beyond his own laboratory, Pierre Joliot played a major role in shaping scientific policy and research administration in France. Between 1983 and 1985, he served on the Higher Council for Research and Technology, advising on national scientific priorities. From 1985 to 1986, he served as Scientific Advisor for Research and Technology to French Prime Minister Laurent Fabius, contributing directly to national science policy.

Pierre Joliot's leadership extended throughout the French academic system. In 1986, he chaired the Scientific Committee on Forest Decline Research. From 1987 to 1992, he served as Head of the Department of Biology at the École Normale Supérieure (ENS-Ulm), one of France's most selective and influential institutions of higher learning. He subsequently served as a member of the National Committee for Research Evaluation and the Scientific Council of the CNRS (1989–1994) and later chaired the Scientific Council of the École Normale Supérieure de Lyon (1993–1997).

Joliot's commitment to science also extended to scientific ethics and institutional leadership. He served as Administrator of the Institut de Biologie Physico-Chimique (IBPC) in Paris from 1994 to 1996 and later directed major research activities associated with the institute. From 1998 to 2001, he was President of COMETS, the CNRS Ethics Committee for Science, where he helped guide discussions on scientific integrity and social responsibility in research. From 2003 to 2007, he served as President of the Rothschild Foundation for the Development of Scientific Research. Taken together, these appointments reflect not only Pierre Joliot's scientific stature but also the trust placed in his judgment, leadership, and vision by the broader scientific community.

International recognition and scientific honors: Pierre Joliot's discoveries transformed our understanding of photosynthesis and biological energy conversion, earning him widespread international recognition. Throughout his career, he received many of the highest distinctions available to scientists in France and abroad. Among his earliest major honors was the Pollicard-Lacassagne Prize, awarded in 1968 in recognition of his pioneering research. This was followed in 1970 by the Charles F. Kettering Award for Photosynthesis Research, one of the most prestigious international awards in the field of photosynthesis.

A landmark moment in Joliot's international recognition came in 1979 when he was elected a Foreign Associate of the United States National Academy of Sciences (NAS). Election to the NAS is among the highest honors accorded to a scientist and is reserved for individuals whose research has had a profound and lasting impact on their discipline. Only a small number of foreign scientists are elected each year, underscoring the significance of this distinction.

Additional honors followed in rapid succession. In 1980, he received the Prix du Commissariat à l'Énergie Atomique, followed by an award from the Institut de France in 1982. During the same period, he was awarded the CNRS Gold Medal, the highest scientific distinction granted by France and an honor reserved for researchers whose work has profoundly advanced science at the national and international levels. Joliot's influence extended throughout Europe as well. He was elected to Academia Europaea in 1989 and received recognition from the European Academy of Sciences, Arts and Letters in 1993. These distinctions reflected not only the scientific importance of his discoveries but also his role as one of the leading figures in European science.

National service and civic recognition: Pierre Joliot's contributions transcended the scientific community and were recognized by the French Republic itself. In 1994, he was appointed Commander of the Ordre National du Mérite and was also honored within the Légion d'Honneur, France's highest order of merit.

Pierre Joliot's continued engagement with public policy and ethics was evident through his service on the French National Consultative Ethics Committee for Life and Health Sciences from 2008 to 2009. This appointment reflected the respect he commanded not only as a scientist but also as a thoughtful voice on issues at the intersection of science and society.

In 2012, Joliot was promoted to Grand Officer of the Legion of Honour, one of the highest civilian distinctions in France and a rare recognition bestowed upon individuals whose lifetime achievements have brought exceptional distinction to the nation.

A career of exceptional distinction: Few scientists combine pioneering scientific discovery, academic leadership, public service, and international recognition to the extent achieved by Pierre Joliot. His career spans more than seven decades and has left a lasting imprint on photosynthesis research, French science, and the international scientific community. The honors he has received are not merely acknowledgments of individual discoveries; they reflect a lifetime dedicated to advancing knowledge, mentoring future generations, and serving science at the highest level.

Selected scientific contributions

Methodological innovations and the measurement of photosynthesis (1950s–1960s): Pierre Joliot's pioneering contributions to photosynthesis research began with the development of innovative experimental approaches for studying photosynthetic electron transport and oxygen evolution. During the 1950s, he designed highly sensitive spectroscopic and amperometric techniques that allowed *in vivo* measurements of oxygen exchange and electron transfer with unprecedented temporal resolution (Joliot 1956). At a time when photosynthetic measurements relied largely on relatively slow manometric methods, Joliot's instrumentation provided access to events occurring on the millisecond timescale and opened new possibilities for investigating the kinetics of photosynthesis under changing illumination conditions (Joliot 1965a,b; Joliot *et al.* 1966).

These methodological advances became the foundation for much of his subsequent scientific work. The ability to follow rapid oxygen evolution and electron-transfer reactions in real time (Joliot 1965a,b) enabled Joliot and his collaborators to uncover fundamental mechanisms that govern photosynthetic energy conversion. Many of the conceptual advances that followed can be traced directly to the experimental capabilities provided by these innovative techniques.

Photosynthetic induction, oxygen evolution, and chlorophyll fluorescence (1960s): One of Pierre Joliot's earliest scientific interests was understanding how photosynthetic organisms respond when transitioning from darkness to illumination. Following his initial observations of oxygen exchange in the green alga *Chlorella pyrenoidosa* (Joliot 1959), he performed a series of elegant experiments that revealed the existence of distinct photochemical activation phases during photosynthetic induction (Joliot 1961a,b).

The above-mentioned studies provided important insights into the regulatory processes that govern oxygen evolution in Photosystem II. Particularly significant was Joliot's exploration of the relationship between oxygen evolution and chlorophyll fluorescence, including the phenomenon known as the Kautsky effect. His work demonstrated that fluorescence and photosynthetic activity are intimately connected (Delosme *et al*. 1959) and helped establish chlorophyll fluorescence as a powerful tool for probing photosynthetic function (Joliot *et al*. 1971). In many respects, Pierre Joliot was among the earliest pioneers to recognize and quantify the relationship between chlorophyll fluorescence and photosynthetic electron transport, work that continues to influence fluorescence-based approaches used throughout plant biology today.

Connected photosynthetic units and excitation energy transfer (1960s–1970s): Another major contribution emerged from the landmark work of Anne Joliot and Pierre Joliot (1964), which provided compelling evidence that Photosystem II reaction centers do not function as completely independent units. Their experiments demonstrated that excitation energy can be shared among neighboring photosynthetic units, resulting in sigmoidal rather than simple exponential kinetics of oxygen evolution.

The findings mentioned above challenged the prevailing view of isolated photosynthetic units and provided a quantitative foundation for later concepts describing excitation-energy migration within photosynthetic membranes. This work helped establish what would later become known as "lake-type" models of photosynthetic organization, in which excitation energy can move among adjacent Photosystem II complexes. This conceptual framework has remained influential in studies of photosynthetic membrane organization and photoprotection and continues to inform modern interpretations of chlorophyll fluorescence kinetics.

The Kok–Joliot model and the mechanism of water oxidation (1960s–1970s): Among Pierre Joliot's most celebrated achievements was his role in elucidating the mechanism of photosynthetic oxygen evolution. Using flash-induced oxygen measurements, Joliot demonstrated that oxygen production exhibits a characteristic period-four oscillation, with oxygen yields reaching maxima after specific flashes (Joliot 1968, Joliot *et al.* 1969). These experiments provided critical evidence that the water-splitting reaction proceeds through a series of discrete oxidation states (Joliot *et al*. 1968). They also revealed the importance of phenomena such as misses and double hits in determining oxygen-evolution yields (Barbieri *et al.* 1970). Together with the theoretical framework developed by Bessel Kok and colleagues (Kok *et al.* 1969), these studies led to what is now widely known as the Kok model of water oxidation. Given Joliot's central experimental contributions, many investigators appropriately refer to this framework as the Kok–Joliot model.

More than fifty years later, the concepts emerging from these experiments remain central to our understanding of Photosystem II and oxygen evolution (Joliot and Kok 1975), and have been repeatedly validated by structural, spectroscopic, and computational studies. Few discoveries in photosynthesis research have demonstrated such an enduring influence.

Electron transport, membrane organization, and bioenergetics (1980s–1990s): In subsequent decades, Pierre Joliot expanded his research interests beyond oxygen evolution to broader questions of photosynthetic electron transport and membrane bioenergetics. Studies with colleagues and collaborators provided important insights into the structure and function of photosynthetic complexes in both oxygenic and anoxygenic organisms, including the purple bacterium *Rhodobacter sphaeroides* (Joliot *et al*. 1989). At the same time, Joliot and collaborators, particularly Jean-Marc Lavergne, developed influential theoretical and experimental analyses of electron transport under limiting light conditions and the diffusion of electron carriers within photosynthetic membranes (Lavergne *et al*. 1989, Lavergne and Joliot 1991). These studies significantly advanced our understanding of the dynamic interactions among photosynthetic complexes and the physical principles governing energy conversion in biological membranes.

Continuing contributions to photosynthetic physiology: In more recent years, Pierre Joliot's interests have broadened to encompass a wide range of topics in photosynthetic physiology. His work has addressed the *in vivo* function of the cytochrome b_6f complex, the organization of photosynthetic supercomplexes, linear and cyclic electron transport (Joliot and Joliot 2002, 2005), and supramolecular membrane protein assemblies in photosynthesis and respiration electron transport in photosynthetic bacteria; *see* Joliot *et al.* (1989, 1993) and Jungas *et al.* (1999).

Pierre Joliot's scientific research, 2010–2019: Although Pierre Joliot's scientific interests evolved over the course of a career spanning more than seven decades, a common theme remained constant: the pursuit of fundamental mechanistic understanding through rigorous experimentation, quantitative analysis, and a relentless focus on the underlying physical principles governing biological energy conversion. From his earliest studies of photosynthetic oxygen evolution and electron transport to his later investigations of membrane organization, cyclic electron flow, and photoprotection, Joliot repeatedly demonstrated how carefully designed experiments could reveal the fundamental processes that sustain life through the conversion of solar energy. This intellectual continuity was particularly evident during 2010–2019, when he returned to many of the central questions that had guided his research for more than half a century. Building upon a lifetime of pioneering investigations into photosynthetic energy transduction, he continued to explore how photosynthetic organisms regulate electron transport, coordinate energy conversion, and adapt to changing environmental conditions. His studies of the dynamic balance between linear and cyclic electron transport pathways helped clarify how plants optimize ATP and reductant production while maintaining photochemical efficiency under fluctuating light conditions (Joliot and Johnson 2011). These investigations reflect his enduring fascination with the mechanisms that govern the movement of electrons through the photosynthetic apparatus and the strategies by which organisms maintain energetic homeostasis in a constantly changing environment.

During the 2010–2019 period, Joliot also made important contributions to our understanding of non-photochemical quenching and the role of proton gradients in regulating photoprotective responses (Joliot and Finazzi 2010), alternative electron transport pathways involving the plastoquinone terminal oxidase (Trouillard *et al.* 2012), and the mechanisms controlling cyclic electron flow around Photosystem I (Nawrocki *et al.* 2019). Collectively, these studies have advanced our understanding of how photosynthetic organisms balance efficient light harvesting with the need to dissipate excess excitation energy, thereby protecting the photosynthetic machinery while maximizing energy conversion efficiency.

Perhaps most remarkably, Joliot has remained actively engaged with some of the most exciting developments in contemporary photosynthesis research well into his ninth decade. His participation in the discovery and characterization of chlorophyll *f*-containing photosystems capable of driving photochemistry beyond the traditional red limit of oxygenic photosynthesis (Nürnberg *et al.* 2018) has expanded our understanding of the energetic boundaries of photosynthetic life and illustrated the continued relevance of his scientific insight to emerging frontiers in the field.

Taken together, the above-mentioned contributions represent a fitting culmination of an extraordinary scientific journey that began with the development of highly sensitive oxygen-measurement techniques and the elucidation of the mechanisms underlying photosynthetic oxygen evolution. By seamlessly bridging classical bioenergetics with modern molecular, biophysical, and systems-level approaches, Joliot's later studies have reaffirmed the central themes that had guided his research throughout his career: the capture, conversion, regulation, and efficient utilization of solar energy in living systems. More broadly, they exemplify the enduring power of quantitative experimentation to reveal fundamental biological principles and stand as a testament to Pierre Joliot's profound and lasting influence on our understanding of photosynthetic energy transduction.

A tribute to Pierre Joliot: We conclude this tribute by presenting two recent photographs of Pierre Joliot (Fig. 1). Together, they capture two complementary aspects of a remarkable scientific life. In the right photograph, Pierre is shown outdoors, thoughtfully admiring the leaves of plants that perform oxygenic photosynthesis – the process that sustains nearly all life on Earth by producing the oxygen we breathe and much

Fig. 1. Two photographs of Professor Pierre Joliot reflecting the two complementary dimensions of his life's work. *Left*: In his laboratory, where he conducted many of the pioneering experiments that established him as one of the world's leading photosynthesis researchers. *Right*: Enjoying nature outdoors among the plants whose oxygen-evolving processes fascinated him throughout his scientific career. Together, these images capture a lifetime devoted to understanding how sunlight, water, and living organisms sustain life on Earth. Source: Joliot family archives.

of the food we consume. The photograph, on the left, shows him in his laboratory in Paris, where for decades he pursued fundamental questions about how light energy is converted into chemical energy. These images beautifully symbolize a lifelong journey of scientific discovery: one that has connected careful observation of nature with rigorous experimentation and deep intellectual *curiosity.* They remind us that behind the many awards, honors, and landmark discoveries stands a scientist whose fascination with the natural world remains undiminished.

Appendix is a perspective of Pierre Joliot in his own words – it brings before us his 'humility'– to say the least.

Appendix. My recollections: Pierre Joliot (e-mail: pjoliot@ibpc.fr)

For my personal history, when I began research, I have the feeling that, for others, around me, I was just the son, or, the grandson of a well-known family, and, it seems [to me that] nobody outside my lab paid attention to what I was doing – including the Late Eugene Rabinowitch (1903–1973), who once visited our lab, for two weeks. However, the Late Bessel Kok (1918–1979), in 1955, 12 years after the beginning of my research, was the first scientist of international reputation to be interested in my work, not just in my name. (*See* a special issue: In appreciation of Bessel Kok, by Govindjee and Renger (1993), for a mention of the visit of Bessel Kok to my lab in France, in which a part of my story is mentioned.)

During this period, I missed meeting Lou Duysens (1921–2015), since I was busy at home due to the birth of our first son, Marc. When Bessel Kok invited me to be at the 19th Brookhaven symposium (Energy Conversion by Photosynthetic Apparatus), in 1966, I had the same feeling, but I was happy to be just Pierre Joliot. Curiously, it was during my first visit to Urbana, in the early 1970s, that Rabinowitch took time to understand my research work, although an important part of it was already in progress when he had visited me earlier in Paris, and seemed, then, not to care what I was saying!

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