*Photosynthesis Research* **61:** 193–196, 1999.



# Obituary

**Therese Marie Cotton-Uphaus (1939–1998)**

Therese Cotton was born in Peru, Illinois, but grew up close by in La Salle. Her father, Joseph Brongel, was a watchmaker and her mother, Christine, was a primary school teacher. Her father's sense of how things worked and her mother's dedication to education certainly had a profound influence. Therese began her scientific career after completing her A.B. degree (1961) in Chemistry at Bradley University, where she received the Distinguished Alumnus Award in 1997. Her first assignment was as a research assistant working on corn proteins and corn starch at the USDA Northern Regional Research Laboratory in Peoria, Illinois. In 1966, she was hired as a Scientific Assistant in the Chemistry Division at Argonne National Laboratory by Joseph Katz. She was determined to become an independent scientist, and in 1971 became a 're-entry' graduate student, working jointly with Paul Loach at Northwestern University and Joseph Katz at Argonne where she carried out most of her graduate research. She was proud of how her children not only 'chipped' in to help her at home but also became independent so she could achieve her goal. Her parenting style was similar to how she would later train her students. She emphasized how things worked, encouraged logical reasoning to solve problems, and stressed independence. She was fair and non-judgmental, as she was with everyone who knew her. Her daughters considered her 'their best friend' despite the fact that her free time was largely work-related. We were also struck early on by her dedication, drive, creativity, and sincerity. She never lost these qualities, nor her quick wit and warm sense of humor, even throughout a protracted illness during the last four years of her life.

As a graduate student, Therese carried out extensive spectroscopic investigations of chlorophyll *a* that led to the publication of five out of her seven most highly cited papers (Cotton et al. 1974, 1978; Katz et al. 1978; Shipman et al. 1976a,b). This work still provides the most detailed understanding of chlorophyll aggregation, interactions and ligation. She had great enthusiasm for her research and could tell the chlorophyll aggregation-state just by looking at the color of the sample. She joked about making a necklace out of quartz cells containing chlorophyll in different solvents having varying degrees of hydration and displaying different colors. Indeed, Therese Cotton was considered one of the leading experts on chlorophyll spectroscopy and chemistry.

After earning her PhD, Therese worked as a postdoctoral fellow with Richard Van Duyne at Northwestern University. During this time she further developed her skills in spectroscopic methods, particularly in resonance Raman and electrochemistry. The powerful combination of spectroscopy with electrochemistry allowed for examination of radical ions formed during the early stages of photosynthetic electron transport. She maintained her interest in porphyrins by examining bacteriochlorophyll interactions using various Raman techniques (Cotton and Van Duyne 1981). Therese also published the first surface-enhanced Raman scattering (SERS) study on proteins (cytochrome *c* and myoglobin), and the paper has stood as her second most highly cited work (Cotton et al. 1980). Throughout her career, she very effectively applied these advanced techniques to study a number of biological and chemical problems.

At age 40, Therese, as an Assistant Professor in the Chemistry Department at the Illinois Institute of Technology, began her highly productive and successful academic career. After five years, she moved on to the University of Nebraska as an Associate Professor and was promoted to Professor four years later. Subsequently, she moved to Ames, Iowa to accept a joint position as Senior Chemist at the Ames Laboratory and Professor of Chemistry at Iowa State University. She continued her fruitful collaboration with her husband, Robert Uphaus, who became a staff Chemist at the Ames Laboratory when they moved to Iowa. Their professional collaboration started early at Argonne (Uphaus et al. 1970) examining chlorophyll–pheophytin interactions, but their later work together, starting in the mid 1980s (Uphaus et al. 1985), focused on structural studies of Langmuir-Blodgett pigment, dye, and protein films using surface-enhanced Raman scattering spectroscopy. Several papers examined effects of distance, molecular orientation, and molecular recognition (Cotton et al. 1986, 1990; Kim et al. 1988) with an eye on biosensor technology (Kim et al. 1989). Their last of 16 papers together (Uphaus et al. 1997) used Langmuir-Blodgett and X-ray diffraction techniques to physically measure the dimensions of the isolated Photosystem II (PS II) reaction center complex. This work was critical in resolving a long-standing controversy regarding the aggregation-state of the complex *in situ* – it turned out to be dimeric.

Therese distinguished herself by her clever and unique applications of resonance Raman and SERS techniques. Besides the Langmuir-Blodgett film work mentioned above, her development of SERS as a probe of structure in isolated proteins, protein complexes, and membranes is considered pioneering. She developed surface-enhanced Raman scattering methods to examine structure and electron transport properties in isolated redox proteins and intact membranes. In the early 1980s, she started to apply Raman techniques to the study of intact photosynthetic complexes (Cotton and Van Duyne 1982), an interest that she would maintain for the rest of her career. Much of this involved studies of bacterial reaction center and antenna systems, but she also had an interest in examining structural and functional aspects of the plant photosynthetic apparatus. Therese was the first to apply vibrational spectroscopy to the study of PS II, the $O_2$-evolving apparatus, and the problem of identifying functional Mn (Seibert and Cotton 1985; Seibert et al. 1988). Her work was also the first to show that carotenoids could be detected near both surfaces of the thylakoid membrane (Picorel et al. 1992), but only on the cytoplasmic side of the bacterial chromatophore membrane (Picorel et al. 1988, 1990). These results were later confirmed with the publication of the crystal structures of LHC II (Külhbrandt et al. 1994) and LH2 (McDermott et al. 1995). She also showed that cytochrome $b_{559}$ in the PS II reaction center complex was structurally located next to CP47 (Picorel et al. 1994), one of the reaction center core proximal antenna complexes. Only within the last few years have others started to carry on this line of work using FTIR, another vibrational spectroscopy. Also over the years, she examined other types of proteins including glucose oxidase, FAD, P-450, phycocyanin, phytochrome and her stand-by cytochrome *c*; RNA; as well as many dyes and model compounds.

Continuing her traditional interest in advancing SERS spectroscopy, Therese, particularly with her colleague George Chumanov, recently suggested a new type of SERS-active substrate. The approach was to covalently attach nanosize silver or gold particles to a glass surface, producing well-controlled films that could be optimized for the most efficient excitation of plasmon resonances. This is a required prerequisite for the enhancement of Raman scattering at surfaces (Chumanov et al. 1995). The substrates prepared in such a way exhibit a high degree of reproducibility and can be used directly, without any pretreatment, for the SERS spectroscopy. These have been successfully used in SERS studies of membrane complexes and other biomolecules yielding spectra with an exceptionally good signal-to-noise ratio. Needless to say, this approach provides new opportunities for the development of a commercial SERS substrate, a dream of many in analytical Raman spectroscopy.

Therese was active in six professional societies and held offices in five of them. She was Associate Editor of Photochemistry and Photobiology from 1989 to 1992 and was honored with the Lester W. Strock Award by the American Chemical Society in 1997. She was also selected as the Maria Goeppert Mayer Distinguished Scholar at Argonne in 1995, and subsequently, returned to work at Argonne during part of 1996 and 1997. Therese was very happy at this point to be back at Argonne to be able to work in the lab without the usual interruptions. She spent long hours thinking about new direction for her research and was particularly enthusiastic about the potential for applying EPR techniques to examine radical trapping sites at silver particle surfaces. She was the first to show permanent charge separation at low temperature in small metallic colloids and roughened metal (unpublished results). During this period, Therese was working to beat ovarian cancer with the same diligence that she applied to her science. Often she would pose questions and suggest treatments that would send her physicians to the library. This did not affect her enthusiasm for her research, and her energy until the last two months seemed to have no limits. Up until the very end, she was happy to discuss the latest results and make suggestions as to how to improve manuscripts in preparation.

Therese was a very generous and modest individual, always ready to acknowledge the contributions of her mentors and collaborators. She was an inspiration to many and, in particular, a role model for women. During one of her last conversations, she expressed concern that she had not ‘formally’ worked to encourage women in science. We hope she understood when told that many women were positively affected by her example, including the daughters of one of us. With her strong determination, she was able to enjoy a successful academic career even though she did not take the conventional direct route. In 1997, Dean Eastman, Director of Argonne National Laboratory, highlighted Therese’s career as an example during remarks he made in an address to welcome young women attending a career conference. For advice, he quoted Therese who offered the simple phase, ‘never give up’. For Therese, this was not just an often-repeated phrase; this was her life. Her scientific career was testament to this and she literally traveled around the world trying to find a route to recovery from cancer. She continued to work closely with students and colleagues during these difficult times and unselfishly helped other cancer victims. Even while she herself was facing an uncertain future, she sought out others through her Church and spent a lot of her minimal free time with people who needed her. She was very proud of her children who were constantly at her side while she was bedridden the last two months. Her six grandchildren were of particular importance to her, and she made an extraordinary effort to see them as often as possible during her travels. Her children pointed out to us that her heavy science-related travel schedule was actually a ‘big plus’ because on many occasions she would take them along. Her life was not always easy. She had to surmount the loss of a son, Gregory, to a terrible car accident and the premature death of her husband Bob five years ago. Her warm personality, devotion to her family and Science, and her particular humor helped her overcome these tragedies. She will be missed by all of us whom she touched.

Michael Seibert[1]
Marion Thurnauer[2]

[1]National Renewable
Energy Laboratory
Golden, CO 80401, USA
[2]Chemistry Division
Argonne National Laboratory
Argonne, IL 60439, USA

## References

Chumanov G, Sokolov K, Gregory B and Cotton TM (1995) Colloidal metal films as substrates for surface enhanced spectroscopy. J Phys Chem 99: 9466–9471

Cotton TM, Trifunac AD, Ballschmiter K and Katz JJ (1974) State of chlorophyll *a in vitro* and *in vivo* from electronic transition spectra, and the nature of antenna chlorophyll. Biochim Biophys Acta 368: 181–198

Cotton TM, Loach PA, Katz JJ and Ballschmiter K (1978) Studies of chlorophyll–chlorophyll and chlorophyll–ligand interactions by visible absorption and infrared spectroscopy at low temperatures. Photochem Photobiol 27: 735–749

Cotton TM, Schultz SG and Van Duyne RP (1980) Surface-enhanced resonance Raman scattering from cytochrome *c* and

myoglobin adsorbed on a silver electrode. J Am Chem Soc 102: 7960–7962
Cotton TM and Van Duyne RP (1981) Characterization of bacteriochlorophyll interactions *in vitro* by resonance Raman spectroscopy. J Am Chem Soc 103: 6020–6026
Cotton TM and Van Duyne RP (1982) Resonance Raman scattering from *Rhodopseudomonas sphaeroides* reaction centers adsorbed on a silver electrode. FEBS Lett 147: 81–84
Cotton TM, Uphaus, RA and Möbius D (1986) Distance dependence of surface-enhanced resonance Raman enhancement in Langmuir-Blodgett dye multilayers. J Phys Chem 90: 6071–6073
Cotton TM, Kim J-H and Uphaus RA (1990) Spectroscopic and electrochemical studies of oriented monolayers on electrode surfaces. Microchem J 42: 44–71
Katz JJ, Shipman, LL, Cotton TM and Janson TR (1978) Chlorophyll aggregation: Coordination interactions in chlorophyll monomers, dimers, and oligomers. In: Dolphin D. (ed) The Porphyrins, Physical Chemistry, Vol V, pp 401–458. Academic Press, New York
Kim J-H, Cotton TM and Uphaus RA (1988) Electrochemical and Raman characterization of molecular recognition sites in self-assembled monolayers. J Phys Chem 92: 5575–5578
Kim J-H, Schufeldt DM, Cotton TM and Uphaus RA (1989) Monolayer molecular recognition sites as a basis for biosensor development. In: Hong FT (ed) Molecular Electronics, Biosensors and Biocomputers, pp 329–337 Plenum Press, New York
Kühlbrandt W, Wang DN and Fujiyoshi Y (1994) Atomic model of plant light-harvesting complex by electron crystallography. Nature 367: 614–621
McDermott G, Prince SM, Freer AA, Hawthornthwaite-Lawless, AM, Papiz MZ, Cogdell RJ, and Isaacs NW (1995) Crystal structure of an integral membrane light-harvesting complex from photosynthetic bacteria. Nature 374: 517–521
Picorel R, Holt RE, Cotton TM and Seibert M (1988) Surface-enhanced resonance Raman scattering of bacterial photosynthetic membranes. J Biol Chem 263: 4374–4380
Picorel R, Lu T, Holt RE, Cotton TM and Seibert M (1990) Surface-enhanced resonance Raman scattering spectroscopy of bacterial photosynthetic membranes: Orientation of the carotenoids of *Rhodobacter sphaeroides* 2.4.1. Biochemistry 29: 707–712
Picorel R, Bakhtiari M, Lu T, Cotton TM and Seibert M (1992) Surface-enhanced resonance Raman scattering spectroscopy as a surface topography probe in plant photosynthetic membranes. Photochem Photobiol 56: 263–270
Picorel R, Chumanov G, Cotton TM, Montoya G, Toon S and Seibert M. (1994) Surface-enhanced resonance Raman scattering spectroscopy of Photosystem II pigment–protein complexes. J Phys Chem 98: 6017–6022
Seibert M and Cotton TM (1985) A Surface-enhanced Raman signal associated with functional manganese in oxygen-evolving Photosystem II membranes. FEBS Lett 182: 34–38
Seibert M, Cotton TM and Metz JG (1988) Surface-enhanced Raman scattering spectroscopy: Probing the lumenal surface of Photosystem II membranes for evidence of manganese. Biochem Biophys Acta 934: 235–246
Shipman LL, Cotton TM, Norris JR and Katz JJ (1976a) An analysis of the visible absorption spectrum of chlorophyll *a* monomer, dimer and oligomers in solution. J Am Chem Soc 98: 8222–8230
Shipman LL, Cotton TM, Norris JR and Katz JJ (1976b) New proposal for structure of special-pair chlorophyll. Proc Natl Acad Sci 73: 1791–1794
Uphaus RA, Cotton TM and Katz JJ (1970) Simple spectrophotometer cell for strongly absorbing solutions. Rev Sci Instr 41: 1515–1516
Uphaus RA, Cotton TM and Möbius D (1985) Surface-enhanced resonance Raman spectroscopy of synthetic dyes and photosynthetic pigments in monolayer and multilayer assemblies. Thin Solid Films 132: 173–184
Uphaus RA, Fang JY, Picorel R, Chumanov G, Wang JY, Cotton TM and Seibert M (1997) Langmuir-Blodgett and X-ray diffraction studies of isolated Photosystem II reaction center monolayers and multilayers. Photochem Photobiol 65: 673–679