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Obituary

Yoshihiko Fujita (1932–2005): A pioneer of photoregulation in cyanobacteria

A 2001 photograph of Yoshihiko Fujita

Yoshihiko Fujita, Emeritus Professor of National Institute for Basic Biology (Okazaki, Japan) and Fukui Prefectural University (Obama, Japan), passed away on February 24, 2005 in a hospice which faces the beautiful Mt. Fuji. He had admirably overcome earlier a major operation for advanced esophageal cancer during the 9th International Congress on Photosynthesis in Nagoya (1992). However, the second operation in his last summer was not successful.

Yoshihiko Fujita was born on January 12, 1932 and grew up in Tokyo, Japan. He graduated from the University of Tokyo (Liberal Arts College) in 1955 and began graduate school at the University of Tokyo (Department of Biology). In the beginning of his doctoral course (1957), he received an offer from the Institute for Applied Microbiology (IAM) of the University of Tokyo to be an Assistant Professor in Professor Atsushi Watanabe's laboratory; his duties included curatorship of the IAM Algal Culture Collection. From then on, he acquired a fascination for blue-green algae (cyanobacteria) during his entire life. Very early in his career he re-discovered complementary chromatic adaptation that occurs in certain cyanobacteria. It is a phenomenon where light quality affects the pigmentation of cells, an interesting response that had been earlier discovered by Theodor W. Engelmann in 1883 (Drews 2005). Fujita's extensive physiological investigations on *Tolypothrix tenuis* revealed that the chromatic changes, upon exposure to different wavelengths of light, resulted from the production of phycobiliproteins that were both constitutive (allophycocyanin) and variable (C-phycoerythrin and C-phycocyanin) (Hattori and Fujita 1959; Fujita and Hattori 1960). Later, other structural studies of phycobilisomes revealed that these components were peripheral rod (C-phycoerythrin and C-phycocyanin) and core (allophycocyanin) constituents

of phycobilisomes (cf. Tandeau de Marsac 2003). Moreover, Fujita predicted confidently that the photo-reversible receptor must participate in complementary chromatic adaptation, based on measurement of an action spectrum (Fujita and Hattori 1962, cf. Tandeau de Marsac 2003). Through a series of incisive independent studies, he earned a PhD degree, in Biology, from the University of Tokyo in 1962. The title of his dissertation was 'Photochemical Interconversion between Precursors of Phycobilin Chromoproteins in *Tolypothrix tenuis*' (cf. Fujita and Hattori 1962).

Following the recommendation of the late Hiroshi Tamiya (of the University of Tokyo), Yoshihiko Fujita joined, in 1963, the laboratory of Jack Myers at the University of Texas at Austin as a visiting scientist. He greatly enjoyed his stay in Myers' laboratory and also came to know a number of American photobiologists. Myers was the teacher *extraordinaire* of his whole life and they continued their life-long association and mutually-valued friendship (Myers 2002). In Myers' laboratory, he pursued biochemical studies on photosynthetic redox reactions of the cyanobacterium *Anabaena cylindrica* (Fujita and Myers 1965). During the two-and-a-half year stay in the USA, he became a close friend of the late Chase Van Baalen (University of Texas Marine Science Institute, Port Aransas, USA) and first came to know Elisabeth Gantt (Radiation Biology Laboratory, Smithsonian Institution, Rockville, Maryland; now at the University of Maryland, College Park, USA). Subsequent collaborations between their laboratories and their associates have lasted for decades, and several official international programs ensued. In 1978–1980, Chase Van Baalen visited Japan (Tokyo and Shimoda) and together they launched a Japan–US collaborative project studying the cultured and wild strains of the pelagic cyanobacterium *Trichodesmium*, a genus now recognized as a major oceanic nitrogen fixer. Some years later, Yoshihiko Fujita co-organized, with Elisabeth Gantt, the first Japan–US Symposium on Phycobiliproteins, in Okazaki in October 1982.

After returning to Tokyo in 1967, Yoshihiko Fujita was promoted to be an Associate Professor of a newly-organized laboratory, Marine Biochemistry in Ocean Research Institute of the University of Tokyo. In 1977, he was promoted to full Professor of the laboratory of Marine Physiology at the same institute. During his 15 years at the Ocean Research Institute, he spent over 600 days on research vessels estimating the primary productivity and harvesting planktonic cyanobactertia and eukaryotic microalgae. During this time, he also identified a novel phycourobilin-containing phycoerythrin in the bloom-forming and pelagic cyanobacterium *Trichodesmium thiebautii* (Fujita and Shimura 1974). His laboratory subsequently succeeded in culturing this species in the laboratory (Ohki and Fujita 1982) with the help of Takashi Ishimaru (Tokyo University of Marine Science and Technology).

Eitaro Wada (Program Director, Frontier Research Center for Global Change, Ecosystem Change Research Program, Japan Agency for Marine–Earth Science and Technology, Yokohama), formerly an Assistant Professor of the Marine Biochemistry laboratory, studied under Yoshihiko Fujita as a new comer to his laboratory. He remembers those days as:

> 'I met Fujita-sensei for the first time in 1967 at Gakushi Kaikan, Kanda, Tokyo, when a new Marine Biochemistry laboratory was established in the Ocean Research Institute of the University of Tokyo. At that time I did not talk to him, but my first impression of him was that he was very gentle. From that time on, we breathed the same atmosphere for seven years in managing the lab and the research cruise on the research vessels 'Tansei-maru' and/or 'Hakuho-maru'. It seems to me that he was a colleague on one hand and a gentle respectful brother on the other; he guided me like a teacher. Our cruises covered a very wide area; one time, it covered from latitude 50°N to 15°S along longitude 155°E in the Pacific Ocean, and at another time we looked for a cyanobacterium, *Trichodesmium*, in Kuroshio near the Izu Archipelago and in the East China Sea where Fujita-sensei was crazy about cyanobacteria hunting.
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> There was a drinking spot, Mizumura-ya, near the Ocean Research Institute, and Fujita-san took me there at least once a week. During these times, he taught me the concepts of biology. Since I graduated from the chemistry department and was a new comer to the field of biology, his guidance led me to acquire the fundamentals of biology, which I value to this

day. He became more serious and philosophical with each cup of sak, and his favorite phrase at that time was 'Science is akin to art'.

Fujita-sensei was a tough science teacher, and when things became difficult he relied first on his own initiative and by example persuaded others to follow. It was a meaningful experience for a young scientist. His instruction now serves as my personal estate (treasure) and my guide in science. He always said 'First do your best for science, instead of having a big reputation or getting a high-rank job'.

At Odawara we eternally parted and I shall not meet Fujita-sensei again. I pray for the repose of his soul.'

In the laboratory, Fujita and his coworkers found that the reaction centers in cyanobacteria and red algae did not occur in equimolar amounts, which was different from green algae and land plants (Kawamura et al. 1979). They showed that the stoichiometry between Photosystem (PS) I/Photosystem II varied depending on growth light conditions, i.e., high in cells grown under low light condition and low under high light condition (Kawamura et al. 1979). Coincidently, his mentor Jack Myers found a very similar phenomenon in cyanobacteria grown under chromatic light conditions (Myers et al. 1980; cf. Ghosh and Govindjee 1966). These findings triggered Fujita's new direction.

In 1982, Yoshihiko Fujita with a few colleagues moved to the newly created National Institute for Basic Biology in Okazaki (birth place of Tokugawa, the famous shogun). As a full Professor of the Division of Bioenergetics, he started exhaustive investigations on the photoregulation of stoichiometry in photosystems in the unicellular *Synechocystis* sp. PCC 6714. Red light preferentially exciting PS I induced a low PS I/PS II ratio and orange light exciting PS II induced a high ratio (Fujita et al. 1985, 1987, Fujita and Murakami 1987). These analyses in cyanobacteria revealed that the stoichiometric change between the two photosystems explained the changes in the quantum yield of photosynthetic oxygen evolution in red algae grown under different wavelengths of light (Yocum and Blinks 1958, Brody and Emerson 1959); these two phenomena originated from the same root, i.e., changes in PS I/PS II ratio. This universal topic in all oxygenic photosynthetic organisms occupied him until his first retirement. All the ins and outs of this research were described in his *personal perspective* of the special issue of Photosynthesis Research (Fujita 1997) and his review articles (Fujita et al. 1994, 2001). During these physiological researches, he started to collaborate with physical chemists to investigate the energy transfer processes in cyanobacteria by the time-resolved spectroscopy (Yamazaki et al. 1984).

Elisabeth Gantt stayed in Okazaki for 3 months in 1982. She recalls those days:

'Yoshi Fujita and I came to know one another better after he visited us at the Smithsonian Laboratory when he was goodwill ambassador in photosynthesis from Japan. I never did know if this was one of his assumed roles to spread the word about the original science being done in Japan, or if it was one of his special interests. He was a proud man and a self-generated scientist, which he and many others of his generation had to be to emerge from the ruins of post-war Japan. Over the years, lasting friendships developed between our families, by no small measure through Kyoko his many-talented wife, and many members of our laboratories. While spending a mini-sabbatical in his laboratory we inadvertently tested each other's tolerance. If I arrived at the laboratory at 8:00 a.m. or at 6:30 a.m., Yoshi was there, even if he had just returned hours before from overseas. Coffee, concentrated enough to put espresso to shame, was the first thing he made that as a proper guest I had to share. To this day I have not recovered and I do not indulge in anything stronger than 'American coffee'. By altering my program to early morning library work we came to a happier solution. Sapporo beer at the end of the day was enjoyed by both of us and stimulated discussions on research results, the merits of raw fish, and Japanese versus European poetry, if not necessarily the future of photosynthesis. An appreciation of saké, which Yoshi valued in a friend, has been a lasting enjoyment. Kanpai Yoshi!'

Fujita had been stuck to an 'old-fashioned' physiological approach instead of adopting the 'modern' molecular biological approach, as he himself admitted (Fujita 1997). He has never dis-

closed the real reason for his way of thinking. Our guess is that he thought that molecular biological techniques were not sensitive enough to detect minute quantitative changes in stoichiometry or that one specific gene is not responsible for physiological changes, simply because adaptation to light conditions are very complicated phenomena.

Following his retirement from the National Institute for Basic Biology in 1995, he dedicated himself, until 2002, to educating undergraduates and graduated students at the Department of Marine Bioscience, Fukui Prefectural University (Obama, Japan). His last paper was written there on the fluorescence properties of a diatom *Phaeodactylum tricornutum* grown under different wavelengths of light (Fujita and Ohki 2004).

Recent molecular biological approaches in cyanobacteria by several groups have unveiled some aspects of the mechanism of photoregulation, especially the identification of a strong candidate for a photoreceptor, and have shown some steps of the regulatory cascades. However, genuine elucidation for the whole story of photoregulation *in vivo* including signal-sensing and signal-transduction mechanisms remains unsolved to date (cf. Tandeau de Marsac 2003). The quest for two types of photoregulation in cyanobacteria that were so remarkably advanced by Yoshihiko Fujita needs to be continued; he was a real pioneer in the two major types of photoregulation in the cyanobacterial photosynthetic system.

This tribute to Professor Fujita was invited and edited by Govindjee.

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