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宮地重遠：田宮博士，Avron 博士の追悼講演

S. Miyachi: Memorial lectures in honor of Prof. Tamiya and Prof. Avron

第15回　国際植物学会のサテライトミーティングとして International Phycology Forum が筑波大学で行われた。その期間中の1993年8月24日に "Special Evening in Honor of Professors Tamiya and Avron" を行い，光合成と微細藻類の研究に卓越した業績を残された両先輩を偲んだ。両氏は，光合成と微細藻類の発育生理に関しては世界的な業績を残されているが，象牙の塔にこもらず，微細藻類の利用（大量培養）に努力し勝れた成果を上げられたという共通点を持つ。

Special Evening では，ドイツ・マールブルク大学の H. Senger 教授が田宮博士について，イスラエル・海洋研究所の A. Ben-Amotz 教授が Avron 博士について記念講演を行い，引き続き Memorial Banquet に移行した。多くの出席者の要望により，記念講演の原稿を再録することができたことは，この Special Evening の主催者として大きなよろこびである。(113 東京都文京区本郷2-35-10 海洋バイオテクノロジー研究所)

Hiroshi Tamiya, an homage to an outstanding scientist and a remarkable personality

H. Senger (Phillipps-Universität Marburg, Germany)

It is a great honor and pleasure for me to be asked and to make this contribution in memory and admiration for Professor Hiroshi Tamiya, late Director of the Tokugawa Institute for Biological Research and of the Institute of Applied Microbiology of the University of Tokyo. I recognize with appreciation that the audience of the International Phycology Forum is joined by the former co-workers and students of Hiroshi Tamiya, Professors Oh-Hama, Hase, Kanai, Miyachi, Mitsui and others.

I had the privilege to cross the path of Hiroshi Tamiya and to experience this outstanding scientist as a fatherly friend for 20 years. It was 35 years ago when I started my PhD work under the guidance of Professor André Pirson at the University of Göttingen. My task was to perform a mathematical analysis of syncronized cultures of *Chlorella* and investigate the mechanism of synchrony. Two publications were handed out to me as an introduction to the field:

From John Burlew: "Algal culture from laboratory to pilot plant" the Article by Tamiya, Shibata, Sasa, Iwamura and Morimura: "Effect of diurnally intermittent illumination on the growth and some cellular characteristics of *Chlorella*". And the publication by Tamiya and co-workers: "Correlation between photosynthesis and light-dependent metabolism in the growth of *Chlorella*", which appeared in a special volume of Biochemica and Biophysica Acta in memory of Professor Otto Warburg. It was the new method of synchronizing all cells in a mass culture by intermittent illumination, introduced by Tamiya and co-workers, which attracted the recognition of scientists all over the world: Cook, Edmonds, Hastings, Sorokin and Sweeny in the USA; Hauschild and Krotkov in Canada; Huogenhout and Zeuthen in the

Netherlands; Nichiporowich and Spektorow in Russia; Petropolus in Greece; Kylin in Sweden and in Germany the groups around Pirson in Göttingen, Egle in Frankfurt and the Kohlenstoffbiologische Anstalt in Dortmund. But what was so intriguing and so exciting about the synchronous cultures? On the one hand they provided an excellent tool to study the life cycle of a cell by using a mass culture in which all cells were in the same stage of development at the according time of sampling. Metabolic events could be correlated with the life cycle and biosynthetic pathways could be analysed in respect to their natural interrelationship. On the other hand the mechanism of synchronization itself was a fascinating puzzle. It turned out that the change from darkness to light triggered the beginning of the life cycle and determined the time of cell division and separation of daughter cells. According to Bünning's nomenclature of circadian rhythms the trigger was called "Zeitgeber". The time between the Zeitgeber and the simultaneous separation of mother cells into daughter cells turned out to be endogenously fixed and species specific. But before going into details of the synchronous cultures of microalgae the "life cycle" and the scientific oeuvre of Hiroshi Tamiya shall be considered.

90 years ago Hiroshi was born as the sixth and last child of his family in Osaka. His father was a medical doctor who received his training from a Dutch physician. The microscope in his father's office and even more the influence of his 14 years older brother Takeo, who later become the first president of the National Cancer Center, determined young Hiroshi's wish to become a biologist. Consequently he entered the Imperial University of Tokyo. There he became acquainted with Professor Keita Shibata, the creator of Physiological Chemistry of Plants and founder of Acta Phytochemica. (By the way, an issue of the Acta Phytochemica of those days cost ¥2.3, equivalent to $1.3). Shibata obviously recognized the outstanding talents of Hiroshi and supported him generously. He introduced Hiroshi to the Marquis of Tokugawa and Hiroshi became a member of the Tokugawa Research Institute. At the age of 23 years Hiroshi graduated and published his first paper in the same year in the Journal of Bacteriology: "A new apparatus for intermittent observations of physiological changes in cultures of microorganisms". In this paper he analysed by mathematical evaluation the change in surface to volume of a culture during intermittent sampling and he designed several culture vessels to minimize the changes. This paper indicated already the continuous interest in culture techniques and his strict attention to the growth conditions of the organisms with which he worked.

The second publication appeared in the same year in Acta Phytochemica: "Untersuchungen über die adsorptiven Eigenschaften von Zellulose". In this contribution he investigated the absorption characteristics of cellulose in which he presented fundamental data which might be considered as basis for subsequent development of chromatography.

These two first papers published in the

English and German languages already indicated Hiroshi's interest in international communication. Subsequently he published his papers mainly in German, English and French and only occasionally in Japanese. Until the end of World War II the majority of his 42 publications were written in German and thereafter in English. In his publication he proved to be a master of the German language.—It was the marquis of Tokugawa who took along young Hiroshi on a trip to the USA and Germany. Hiroshi stayed for a longer period on the island of Helgoland in the North Sea. Here he was not only active to learn about marine algae, but he also practiced his German (by the aid of a young girl, Kätchen) and frequently attended the local bowling club. Hiroshi later told me that among the many awards and recognitions he received, the Honorable Membership of the Helgoland Bowling Club, was one of those he liked most. This indicated a remarkable side of Hiroshi Tamiya. To become a member of the Helgoland Bowling Club you must have a remarkable ability to consume and endure lots of high percentage rum. And Hiroshi was always ready for a good drink with his friends and students. Other colleagues present in the audience would be able to make many more contributions about happy hours under this aspect. The conversation during such events were most relaxed and the borders between the highly decorated Professor and young colleagues and students rapidly disappeared.

However, going back to his scientific career, one can recognize distinct "*Scientific periods*" characterizing the research of Hiroshi Tamiya.

The *first period* was entirely devoted to the metabolism of the mold *Aspergillus oryzae* (also known as Koji), the microorganism widely used in brewing. Tamiya's interest extended from designing experimental instrumentation, theoretical evaluation, biochemical and physiological studies to a compilation of the bibliography of *Aspergillus* over a period of 200 years. These studies on the relationship between substrate and energy metabolism are still valid today.

In the *second period*, which slightly overlapped with the first, he studied various aspects of cytochrome biochemistry. His interest in this topic resulted on the one hand from studies of his teacher Professor Keita Shibata, but on the other hand to an even larger extent from his admiration of Otto Warburg, who had received the Nobel Price for his discovery of the *gelbes Atmungsferment* in 1931. Later Hiroshi got engaged in heated arguments about cytochrome action with Otto Warburg, however, this did not influence his personal relationship and admiration for him. This indicated another remarkable side of Hiroshi Tamiya. He could get into firey arguments and scientific controversies, but this would never harm or influence his human and personal relationship or friendship.

By using the primitive hand-spectroscope of those days and by applying elaborate reaction kinetics he elucidated the sequence in the respiratory cytochrome chain in yeast.

Beside the investigations attributed to his "scientific periods" Tamiya developed a new micro-calorimeter, published on peroxydases in algae, worked with chemiautotrophic sulfur bacteria and studied the relationship between turgor pressure and osmotic parameters in higher plants.

The *third period* of research started during World War II. This is the broad field of photosynthesis.—If we relate back to those times, only the formula of photosynthesis and a few wrong assumptions existed. Warburg believed that photosynthetic O_2 would derive from CO_2, Bayer proposed that carbohydrates were formed via formaldehyde and dark reactions were summarily called *Blackman reactions*. Nobody could interpret the *red drop* of photosynthetic oxygen evolution published by the Dutch Botanist Engelmann, nor did other scientists pay attention to the proposal of the German physical chemist, Kautsky, that 2 photosystems existed in the photosynthetic apparatus, as he deduced from his studies on fluorescence kinetics. With this type of background Tamiya entered the field of photosynthesis research with a publication on: "The content of heavy isotopes in photosynthetic oxygen" and a review on: "The mechanism of photosynthesis".

Tamiya and his co-workers first concentrated on the use of inhibitory techniques for analyzing the photosynthetic mechanism. They also applied intermittent illumination in order to separate light and dark reactions of photosynthesis. In a strong argument with Robert Emerson on the influence of intermittent light on photosynthesis, Tamiya and co-workers could show that maximum yield of photosynthesis depended on the length of the dark period between saturating flashes and on the temperature provided during the experiment. The photosynthetic research of Tamiya's group never ended and it is most successfully continued by his successors and students.

By this time Tamiya had amost completely turned away from fungi and was working with microalgae instead. *Chlorella*, a unicellular green alga, became his favorite organism. Obviously, he was again inspired by Otto Warburg, who introduced *Chlorella* into the studies in photosynthesis.

A *fourth period* of research started after the end of World War II. Concerned about the shortage of food in the world, Hiroshi Tamiya made his contribution to help solving the problem by introducing new methods for mass cultures of microalgae. In the already quoted book of Burlew, Tamiya and co-workers published an article: "Pre-pilot-plant experiment on algal mass culture", in which they demonstrated a pilot plant for mass cultures of *Chlorella* which was situated in the back of the Tokugawa Research Institute. Improvement in cultivation of mass cultures was pursued by Tamiya successors to high perfection. As a spin-off of the research on

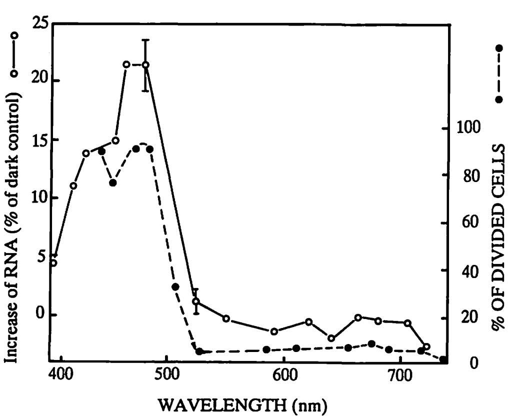

Fig. 1. Wavelength dependent induction of cell division in a mixotrophic synchronous culture of *Chlorella pyrenoidosa* in the presence of 5×10^{-6} M DCMU (after Senger and Bishop, Plant & Cell Physiol. **7**, 441, 1966) and of RNA formation in an achlorophyllous mutant (C-1.1.10.31) of *Chlorella pyrenoidosa* grown heterotrophically (after Senger and Bishop, Biochim. Biophys. Acts, **157**, 417, 1968).

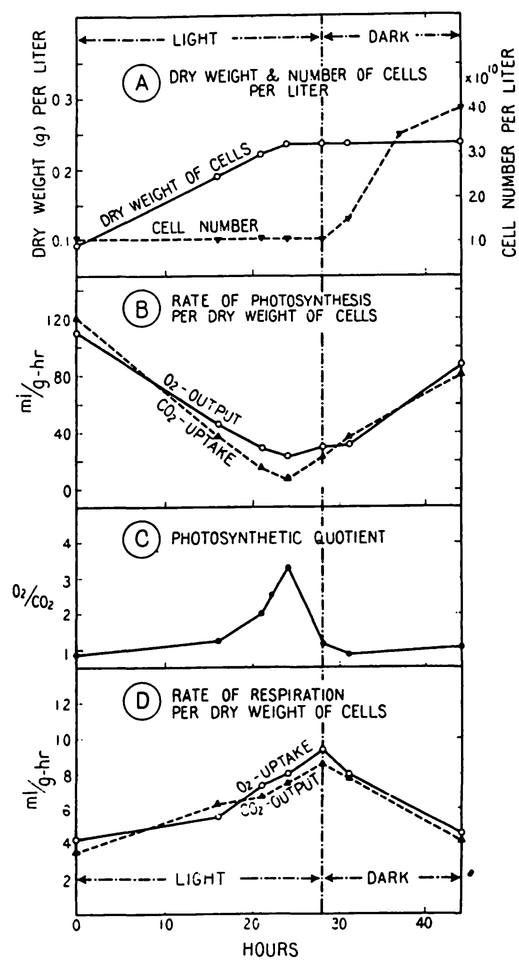

Fig. 2. Changes in photosynthetic and respiratory activities during the synchronous life cycle of *Chlorella ellipsoidea* (Nihei, Sasa, Miyachi, Suzuki and Tamiya, Arch. Mikrobiol. **21**, 156, 1954).

mass culture maintenance the *fifth period* concerned with synchronous cultures of microalgae started.

Concerning this topic I met Hiroshi Tamiya for the first time. In 1959 Professor Tamiya visited the Department of Plant Physiology of the University of Göttingen and I was asked by Professor Pirson to present my research data. My knees were a little bit shaky when I had to report to the master of synchrony. However, I was confronted with a warm hearted man who asked a lot of questions and discussed in a very fair and friendly way. He was in agreement with my mathematical analysis of group-synchronization and my interpretation of mixitrophic cultures to prove that the endogenous time factor was not coupled to the photosynthetic apparatus. But we got into an argument about the temperature dependence of the endogenous time factor. I found a prolonged life cycle upon change from 30 to 20°C. Tamiya insisted that the endogenous life cycle had to be more or less temperature independent. The solution to the controversy was that cells had to be adapted to the according temperature for a longer period to demonstrate life cycles of more or less the same length at different temperatures.

The nature of mechanism underlying the endogenous time factor in green algae is still unsolved. The only thing we know about it is the fact that blue light triggers the induction of cell division and the formation of total RNA (Fig. 1).

Almost completely solved is the nature of the changes in the photosynthetic apparatus during the life cycle of green algae. Already in one of their first papers about synchronous cultures Nihei, Sasa, Miyachi, Suzuki and Tamiya reported about "Change of the photosynthetic activity of *Chlorella* cells during the course of their normal life cycle" (Fig. 2). These changes in the photosynthetic apparatus have been the subject of many investigations and publications. The molecular mechanism of these changes seems to be elucidated by now (Fig. 2).

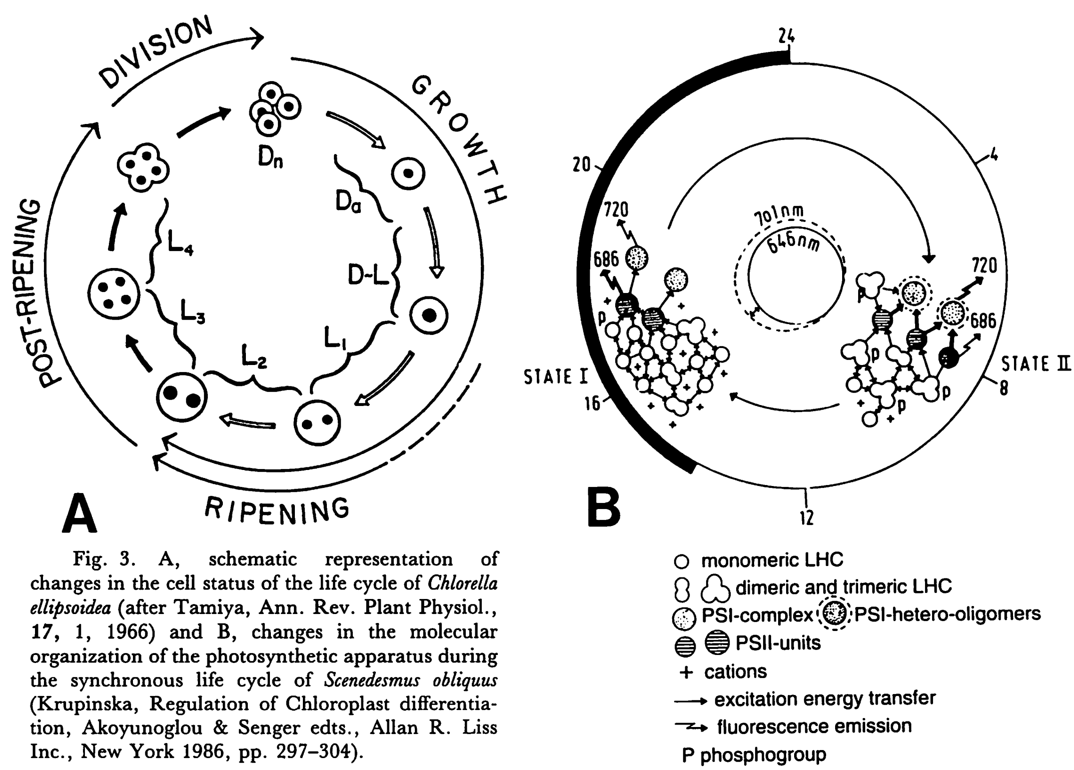

Fig. 3. A, schematic representation of changes in the cell status of the life cycle of *Chlorella ellipsoidea* (after Tamiya, Ann. Rev. Plant Physiol., 17, 1, 1966) and B, changes in the molecular organization of the photosynthetic apparatus during the synchronous life cycle of *Scenedesmus obliquus* (Krupinska, Regulation of Chloroplast differentiation, Akoyunoglou & Senger edts., Allan R. Liss Inc., New York 1986, pp. 297–304).

In an invited review article on synchronization Tamiya presented a scheme of the life cycle (Fig. 3a). We could finally supplement this life cycle with an explanation about the mechanism underlying the change in the photosynthetic apparatus (Fig. 3b). Research with synchronous cultures has accompanied my scientific career ever since it was initiated by the pioneering discovery by Tamiya and his co-workers.

An additional aspect in the life of Hiroshi Tamiya was his ability and dedication as a promotor of basic science and creator of international relationships. He was an appointed member of the editorial board of the highly reputed "Archiv für Mikrobiologie" even before he finished his PhD. He served also on the editorial boards for Biochemica and Biophysica Acta, for the Journal of General and Applied Microbiology, Photochemistry and Photobiology and Plant and Cell Physiology. He was part of the group which established the National Science Council of Japan after World War II. He served as President of the Japanese Biochemical Society and was Vice President of the International Biological Programme. He was council member of the: International Association of Plant Physiology, National Committee of Microbiology of Japan, Japan Radioisotope Association, and last but not least, Japan Association for Philosophy of Science.

In 1958 he was the driving force in founding the Japanese Society of Plant Physiologists, and he was the promotor in issuing its scientific organ, Plant and Cell Physiology. In the foreword of the first issue he says: "Contribution to plant physiology in the world at large is the cardinal mission of the Society".

And as the motto he chose the words from the English mathematician and philosopher Alfred North Whitehead: "The art of progress is to preserve order amid change, and to preserve change amid order. Life refuses to be embalmed alive. The more prolonged the halt in some unrelieved system of order, the greater the crash of the dead society".

Both citations could as well be considered to be the motto of Hiroshi Tamiya's life as a scientist.

The author index of the first issue of Plant and Cell Physiology already includes the names of many later well known and internationally reputed scientists who were more or less connected with the work of Tamiya. Indeed, the first article is written by Shigetoh Miyachi, one of his most successful disciples, who succeeded him as director of the Institute of Applied Microbiology and who is now chairman of this Memorial Lecture.

In recognition of his outstanding scientific contributions, for the fact that he opened Japanese plant physiology to the western world and his promotion of collaboration and friendship between Japanese and foreign scientists Hiroshi Tamiya was highly rewarded. He was appointed Honorable Member of the German Academy of Science (Leopoldina) and of the German Botanical Society. He became corresponding member of the American Society of Plant Physiologists and of the Botanical Society of America. Numerous also were the honours and awards he received in Japan.

In 1963, I had meanwhile moved to the University of Tübingen, the Faculty of Science, the first one established in a German University, celebrated its centenary. On this occasion the faculty recognized Hiroshi Tamiya as the outstanding scientist and personality to be honored by the granting of an "Honorary PhD" (Dr. h. c.).

Fig. 4. Photograph taken at the meeting of the Japanese Society of Plant Physiologists 1980. From left, Hiroshi Tamiya, the author, Eiji Hase, Yoshio Masuda and Shigetoh Miyachi.

The following was written in the laudation: "To the outstanding Botanist, who promoted plant physiology and microbiology as well by his skillful art of experimentation, in recognition of his merits as a researcher, teacher and example for a whole generation of students, as well as in thankful appreciation of his permanent attempt to improve international collaboration."

After the official celebration a happy drinking party with staff and students took place, which will be remembered by everybody who participated. Later the students crowned Hiroshi and lifted him high on a chair and carried him through the university hall.

Years later, when I gave a seminar on synchronous cultures in the Institute of Applied Microbiology, it was one of the rare occasions that Hiroshi returned to his former Institute and vivaciously took part in the discussion.

I saw Hiroshi for the last time in 1980 during a meeting of the Japanese Society of Plant Physiologists (Fig. 4). I had also the honor and pleasure to spend a most memorable evening in his house and to enjoy the company of his charming wife Nabuko and his daughter.

In 1983, on the occasion of his 80th birthday the University of Tübingen presented him the silver medal of the University. In his letter of thanks he expressed his wish to come again to Germany. This wish was not to be fulfilled.

In Germany we have a proverb, saying that somebody is not dead as long as his memory is alive. I hope that my homage to Hiroshi Tamiya, an outstanding scientist and fatherly friend to me, will ensure to keep his memory alive.

The Pioneering Biotechnological Path of the Late Prof. Avron, Dunaliella: (Volvocales, Chlorophyta); from Glycerol to β-carotene

Ami Ben Amotz (The National Institute of Oceanography, POB 8030, Haifa, Israel)

Prof. Mordhay Avron died untimely during heart surgery in March 1991, in the USA. Prof. Avron was born in 1931 in Tel Aviv, Israel (Table 1), finished elementary and high schools in Israel, and continued onto a high level of education in the USA. His graduate studies were concentrated around selected aspects of plant physiology with a broader view of agriculture. Shortly following completing his post-doctorate studies in the USA, the young scientist returned to Israel and joined the Weizmann Institute of Science. From 1958 to 1991, Prof. Avron was a member of the Weizmann Institute of Science progressing over all academic levels to be full Professor on 1966, and over most of the institute administration positions, to be promoted the deputy President of the Weizmann Institute for a long peiod from 1968 to 1991.

The first phase of Prof. Avron's scientific activity was devoted to photosynthesis and bioenergetics, an area where he succeeded and climbed all the way to the top with many publications, monographs, book reviews, books and conferences. His specific contribution to the photosynthetic field is in the photosynthetic electron transport systems and the related photophosphorylation machanism, as associated with ion transport bioenergetics.

I met Prof. Avron in 1968 on looking forward to initiation of my graduate studies. Being already a student on *Dunaliella*, the meeting with Prof. Avron and the invitation to continue my doctorate studies under his supervision led eventually to a very fruitful

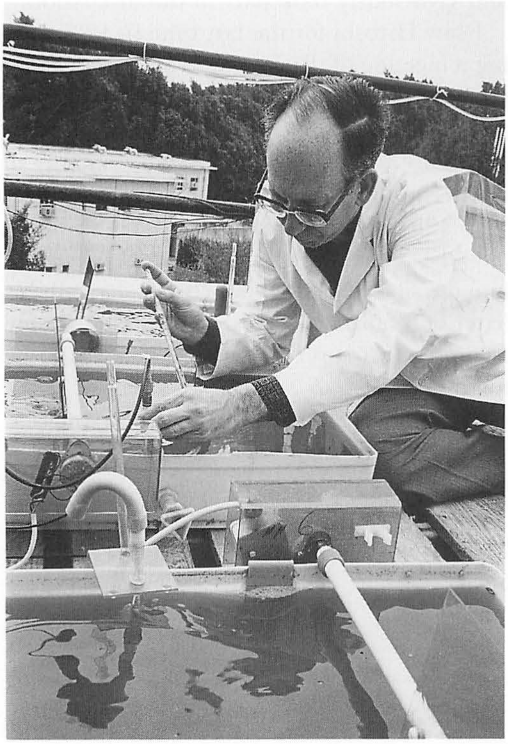

Fig. 1. Prof. Mordhay Avron at the Dunaliella outdoor microponds unit at the Weizmann Institute of Science.

and productive study on *Dunaliella*. The second phase of Prof. Avron's research, the *Dunaliella* Era, as being called, was a fascinating and illuminating period of collaberation in pure and applied science into the hidden life of the most halotolerant eukaryotic organism known: *Dunaliella*. Subsequently to the basic studies, applied photosynthsis was emerged for photosynthetic solar energy conversion and utilization for the production of algal valuable commercial products. Idea emerged from idea, topic followed topic, slowly together from the laboratory test-tube through bottles, carboys, indoor microponds, miniponds, and outdoor pilot plants to a successful biotechnological commercial industry of *Dunaliella*. Many friends and scientists were involved in the *Dunaliella* Era, contributing to different related research areas and for the massive accumulated devotion which was used to develop the project, but the leading person was Prof. Avron with impressive inspiration, guidance, and energetic enthusiasm.

A few milestones are well recognized in the history of *Dunaliella*, and each one is well associated with Prof. Avron's contribution and devotion. The deciphering of osmoregulation in *Dunaliella*, including the halotolerance machinery of the alga, basic glycerol biosynthesis and later interlaced cycles (Figure 2) of glycerol accumulation and elimination, the related membrane phenomena and ion transport, were all excitingly and intensively investigated, initially through classical methodology and subsequently by modern NMR techniques.

The high β-carotene producing strain, *Dunaliella salina* var. *bardawil*, a fascinating eukaryotic organism, was intensively studied step by step for carotenogenesis in the laboratory for a few years to elucidate the β-carotene present biosynthetic pathway (Figure 3). A significant breakthrough was made on transfer of this alga from the laboratory to the outdoor unit on the roof of the Ulman biochemistry building at the Weizmann Institute, a step which marked the period of biosolar energy conversion and applied photosynthesis. At the set of 10 microponds and one 5 m^2 pond of *Dunaliella*, most of the research on the integration of science and engineering has been done since 1976. The so called "*Dunaliella* garden" was the only place where Prof. Avron could be found daily, including Saturdays and holidays, in his attempt to escape the administrative office work and the telephone and focus on truly applied photosynthesis with no interference. The *Dunaliella* garden was used to investigate and test many ideas, schemes, views and concepts, season after season, year after year, to reach the goal of modern algal biotechnology applying economical biosolar energy conversion through the *Dunaliella* photosynthetic mechinery. The *Dunaliella* garden turned out to be an internationally most famous site for many visitors of the Weizmann Institute.

The accumulated knowhow of the mini pilot plant of the Weizmann Institute was transferred continuously to the *Dunaliella* com-

Table 1. MORDHAY AVRON 1931-1991

1931	Born, Tel-Aviv, Israel.
1953	B. Sc. Honors, Univ. of California, Los Angeles, CA, USA
1955	Ph. D in Plant Physiology (Supervisor: Prof. J. B. Biale) Univ. of California
1955–1958	Post-doctoral Fellow (with A. T. Jagendorf) McCollum-Pratt Institute, Johns Hopkins Univ., Baltimore MD, USA.
1958	Research Associate, Biochemistry Dept., Weizmann Institute of Science, Rehovot, Israel.
1963	Associate Professor, Biochemistry Dept., Weizmann Institute of Science.
1966	Professor, Biochemistry Dept., Weizmann Institute.
1966–1969	Head, Dept. of Biochemistry, Weizmann Institute of Science
1968–1969	Acting Director General, Weizmann Institute of Science
1970–1975	Chairman, Israel National Council for Research & Development.
1971–1972	Visiting Professor, Biology Dept., Brandeis Univ., Waltham MA, USA.
1973–1976	Dean, Faculty of Biochemistry-Biophysics, Weizmann Institute of Science.
1976–1977	Visiting Senior Investigator, Dept. of Plant Biology, Carnegie Institution of Washington, Stanford, CA., USA.
1977	Visiting Professor, Molecular Biology Institute, Univ. of California, Los Angeles, CA USA
1978–1985	Deputy President, Weizmann Institute of Science.
1979–1985	Chairman of the Board, Miles-Yeda Inc., Rehovot, Israel
1980–1981	Chairman, Council of University Presidents in Israel.
1982–1985	Chairman of the Board, Yeda Research and Development Co., Rehovot, Israel.
1985–1991	Head, Willstatter Center for Research in Photosynthesis, Weizmann Institute of Science.
1985–1986	"Distinguishing Visiting Investigator", Roche Institute of Molecular Biology, Nutley, NJ, USA.
1986–1991	Dean, Faculty of Biochemistry Biophysics, Weizmann Institute of Science.
1989–1991	Deputy President, Weizmann Institute of Science.

mercial plant in Eilat, south of Israel, always guided by the personal involvement of Prof. Avron, his tireless driving force and his consistene conviction. The joint efforts were gradually developed to the present modern NBT, Nature Beta Technologies, Ltd., a plant of *Dunaliella* on a total pond area of 50,000 m^2, of modern intensive cultivation, harvesting and processing of *Dunaliella*-rich β-carotene.

The analysis identification of the highly fat soluble 9-cis steroisomer of B-carotene in *Dunaliella bardawil* initiated a new momemtum in the pure and applied science of *Dunaliella*, with topics verying from biosynthesis to molecular biology of B-carotene and, most interesting, the implications of natural B-carotene in nutrition and medicine. The high fat solubility of the 9-cis B-carotene was strongly supported by Prof. Avron's enthusiasm to conduct nutritional and clinical studies initially in chicks, chickens, and other laboratory animals grown on diets supplemented with *Dunaliella bardawil*, and later in humans taking tablets or capsules. One topic was personally close to Mordhay's heart. Through may visits and check-ups at the Cardiology Institute at Tel Aviv Hospital, and overviewing the diagnostic clinical difficulties of the cardiovascular fat plaques, Prof. Avron suggested to color the plaques with natural β-carotene through a diet rich in *Dunaliella* for a successive identification by laser beam and finally for demolition of the colored plaque by high laser irradiation. This project which was constructed and built up through the vitality of Prof. Avron led to many other nutritional and medical treatments of humans with natural β-carotene. The scope of Prof. Avron's work is very wide and covers many different aspects of *Dunaliella*. I would like, therefore, to illustrate three examples representing the unique personality of Mordhay as a true scientist and a real *Dunaliella* investigator.

A) Mordhay studied each topic in depth, not

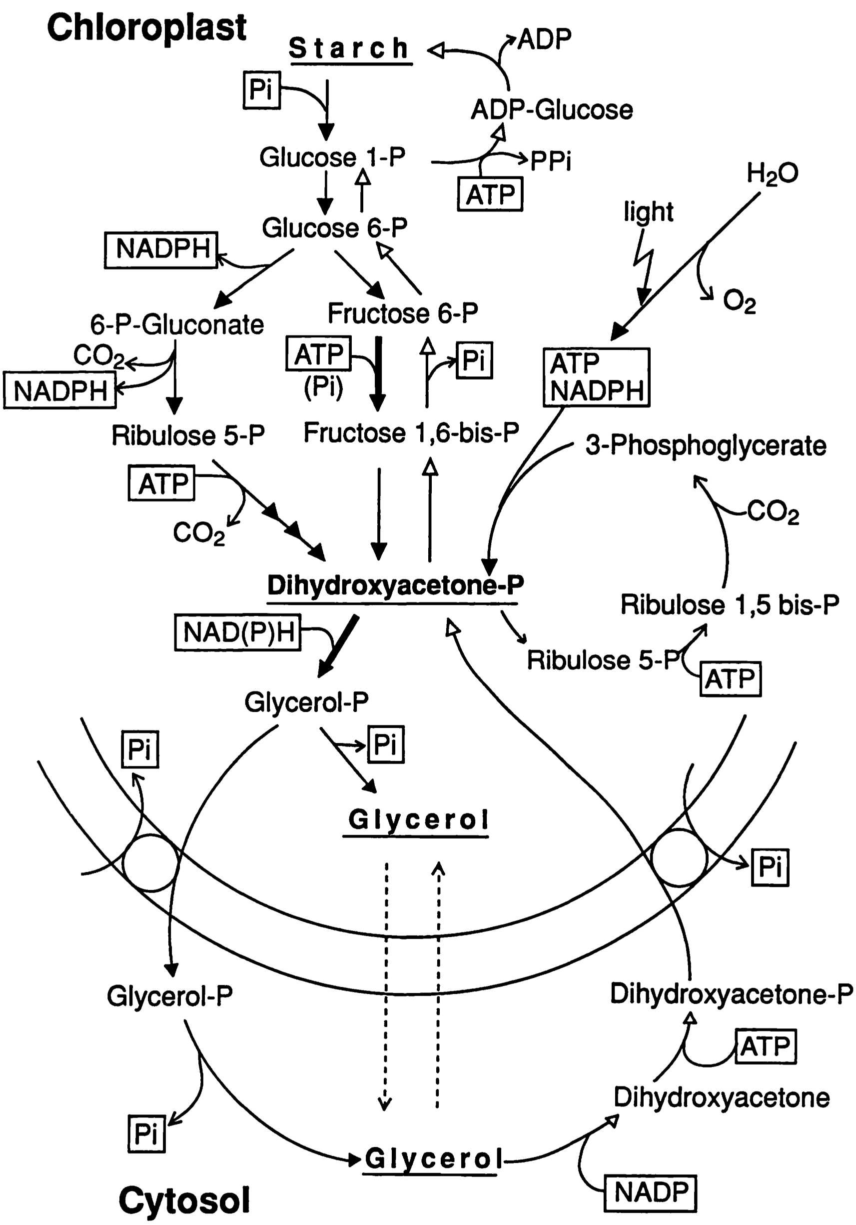

Fig. 2. A proposed metabolic pathway for glycerol metabolism in *Dunaliella*.

leaving any detail unclarified nor uncertainty unresolved. The electron micrograph of *Dunaliella bardawil* originally made in 1981 passed yearly charges by the investigating eyes of Prof. Avron. Thus illustrating this aspect over a period of 10 years, since 1981. Initially, we identified the cell organelles, then cut out the grey background, a cut which led to a long period of discussion whether the scissors at the graphic unit damaged the photograph by cutting the cell membrane or the surface coat with a compromise on a new scissors cut at a distance from the membrane. Later, identification or misidentification of the assumed eye spot were question marked, to lead to the last change made by Prof. Avron shortly before his leaving for the USA in February 1991 year from "eye spot" (?) to "lipid

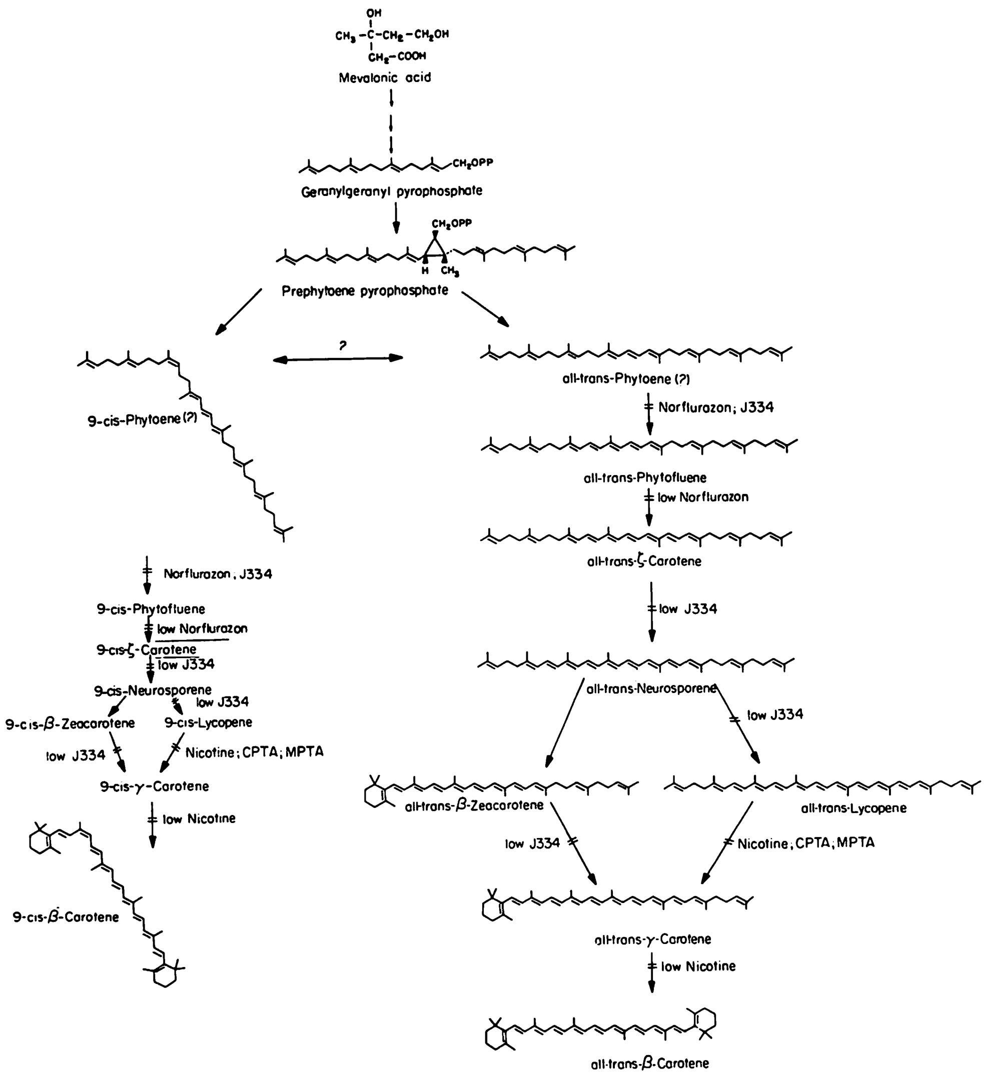

Fig. 3. Postulated pathway of all-trans and 9-cis B-carotene biosynthesis in *Dunaliella bardawil.*

globule" (Figure 4).

B) Prof. Avron was the other extreme of the so-called absent-minded professor. He was very well organized and arranged, and was the only person I know that used the same *Dunaliella* sun protection hat for over 15 years, and more well known, the same personal pen, without losing them.

C) The high dedication and devotion of Prof. Avron to the *Dunaliella* project was well expressed in his enthusiastic cooperation with many special requests dealing with matters not related to science, such as his acceptance of the Japanese tradition and customs on visiting the mother company of NBT, Nikken Sohonsha Co. in Japan. Prof. Avron followed his Japanese colleagues through the night Japanese hospitality, singing Karaoke personally with the microphone at the nightclub. As Prof. Avron said, "I hoped that the pianist would not find the musical notes of any Israeli song, but to my surprise the pianist started to play the Israeli national anthem Hatikvah and followed my poor singing in front of all the guests in the night club".

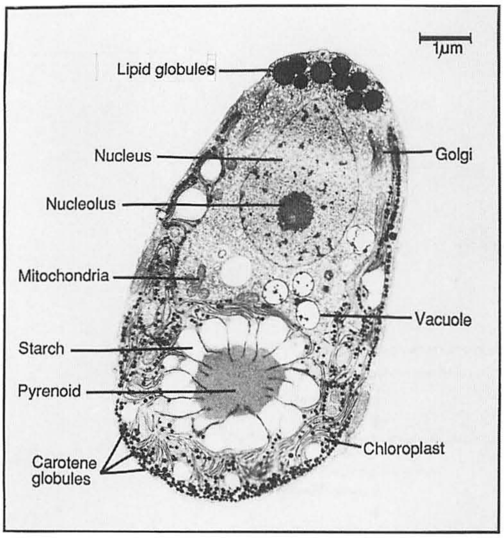

Fig. 4. Electron microgrph of *Dunaliella bardawil*.

Similarly, he played Pachinko, an electronic gambling game, with all dedication, to win surprisingly a very high score to the cheers of the participants, who named Prof. Avron as the Weizmann Institute professor with the golden finger. The close cooperation between Prof. Avron of the Weizmann Institute and Nikken Sohonsha Co., Japan, paved the way to the successful export of *Dunaliella* from Israel to Japan under the well-known distributed poster titled "Shalon *Dunaliella*".

Shortly after the death of Prof. Avron, frineds and colleagues gathered and decided to commemorate his name, through intensive research on all aspects of *Dunaliella*. The "*Dunaliella* Club" at the Weizmann Institute includes a few faculty members and many devoted students, and is used as the framework and a scientific center for exploiting the developed knowhow towards the establishment and expansion of the commercial joint *Dunaliella* biotecnology venture- an honorary memorial symbol to Professor Avron.