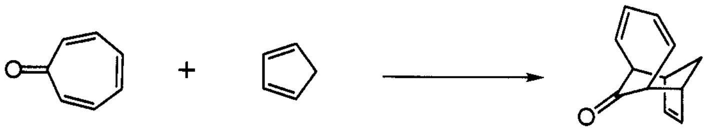
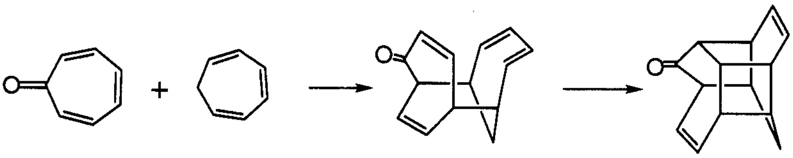
CONTRIBUTIONS OF PROFESSOR SHÔ ITÔ IN ORGANIC CHEMISTRY

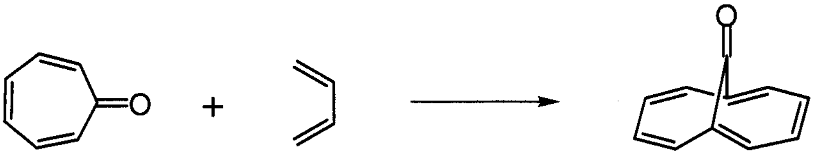
It is my great honor to introduce the research accomplishments of Professor Shô Itô in this special issue of Heterocycles. Professor Itô was born in Tokyo in 1924. He received his early education at Chiba College of Pharmacy (1944) and then studied at Tohoku University (B.S. in 1950). He earned his D.Sc. degree in 1957 under Prof. Tetsuo Nozoe, and did his postdoctoral studies at the University of New Brunswick with Prof. K. Wiesner (1956~1958), and at Harvard with Prof. R. B. Woodward (1958~1959). In 1956 he started his career as an assistant professor in Tohoku University, and was promoted to an associate professor in 1962 and to Professor of Chemistry in 1965. He served as Dean of Faculty of Science from 1979 to 1982. After he retired from Tohoku University in 1988, he successively joined Tokushima Bunri University and served as Dean of Faculty of Pharmaceutical Science for more than 11 years, until his very recent retirement on September 30, 2000.

Professor Shô Itô's research interests has encompassed two diverse areas: nonbenzenoid (novel) aromatics chemistry and natural product chemistry. He is one of the rare chemists who was able to pursue his research simultaneously in two completely different areas. The new frontiers of chemistry on nonbenzenoid seven-membered aromatic compounds, so called troponoid or tropylium chemistry, was initiated by his mentor, Professor Tetsuo Nozoe. Professor Shô Itô started his research career in this field by scrutinizing the non-aromatic behaviors of tropylium compounds; the addition reactions of tropylium compounds with cyclopentadiene and cycloheptatriene were extensively studied and a number of cage compounds were synthesized. One of his most important discoveries was the [6 + 4]π cycloaddition reaction of tropylium compounds such as tropone with cyclo- pentadiene, which comprised the first example of a concerted [6 + 4] cycloaddition reaction (1966).

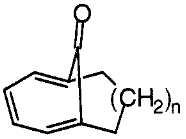

[6 + 4] Cycloadduct

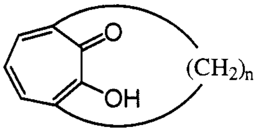

[4 + 6] Cycloadduct

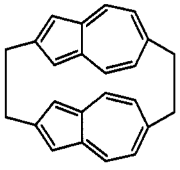
He extended his research in this area to the syntheses of various novel and theoretically interesting compounds and the discovery of their novel molecular rearrangements. The 1,6-methano[10]-annulen-11-one was successfully synthesized in only two steps from tropone through a [6 + 4] cycloaddition reaction, and the absence of appreciable interaction between the 10 π annulene system and the bridged orthogonal carbonyl group was demonstrated (1972).

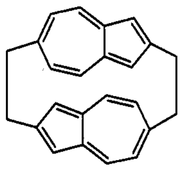


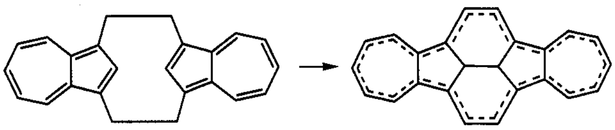
Furthermore, he synthesized highly strained [3], [4], and [5](2,7)troponophanes and tropolonophanes, as well as [2,2](2,6) and [2,2](1,3)azulenophanes, and investigated precisely all their characteristic behaviors, reduced aromaticities, nonplanar structures, and transannular π interactions. In addition he demonstrated that the unique nonplanar tropoquinones as well as the tropoquinophanes possess genuine quinone characters with a higher oxidation potential compared to the corresponding benzoquinones (~1987).

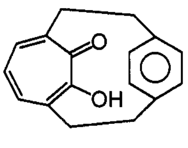


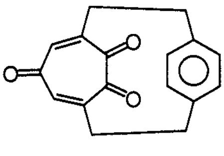


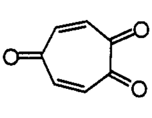


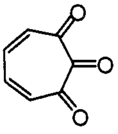


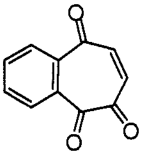


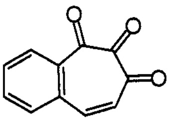




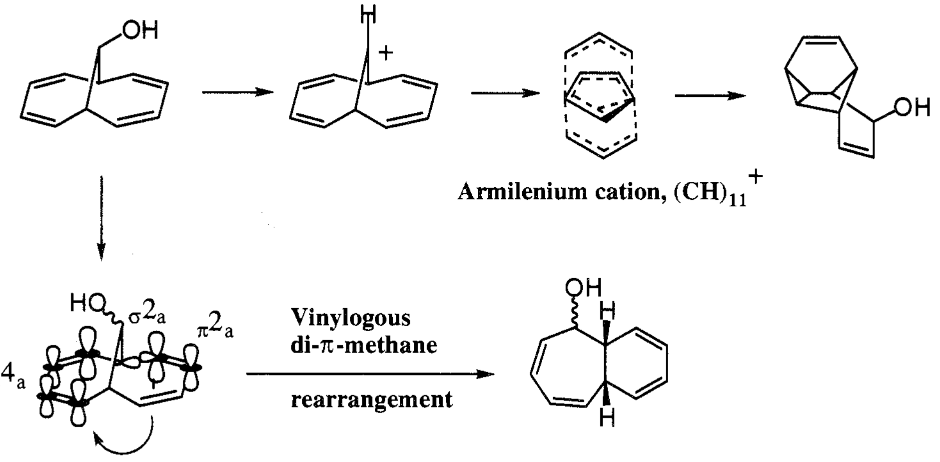




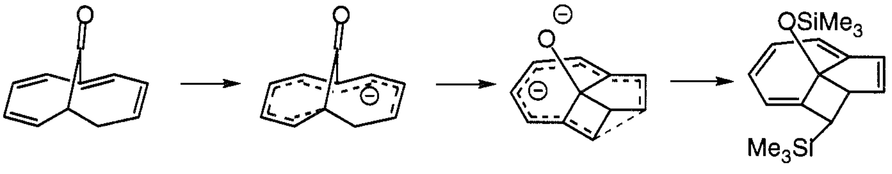


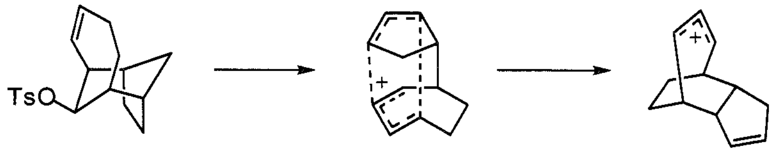


Novel molecular rearrangements of these synthetic molecules were also investigated. Notably, he succeeded in the formation of the [3.5.3] armilenium cation $(CH)_{11}^{+}$ by the treatment of bicyclo[4.4.1]undeca-2,4,7,9- tetraen-11-ol with superacid, which was intriguing in terms of its three dimensional bicycloaromaticity, and moreover discovered thermally induced, concerted vinylogous di-π-methane rearrangement (1968~1985).

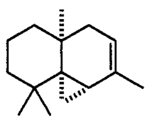


He also elucidated the homoaromaticity of a bicyclic 10 π–anion system and established that such a species undergoes a facile rearrangement to a tricyclic anion system (1983). A novel cationic [3,3] sigmatropic rearrangement was also discovered (1978).

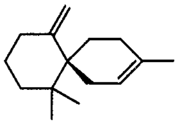




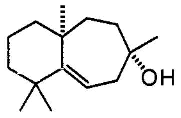
Besides the above nonbenzenoid aromatic chemistry, Professor Shô Itô simultaneously conducted research on natural product chemistry. His career into the natural product chemistry began in early 1960s with isolation and structure determination utilizing new spectroscopic methods, particularly NMR and CD. He has determined the structures of more than fifty-five new terpenoids including sesqui-, di-, and triterpenoids as well as steroidal alkaloids. His elucidation of the stereo-structures of kessyl alcohol and kessyl glycol was one of the earliest successful examples to determine the stereochemistry of natural products by using NMR and CD spectroscopic methods (1963). Representative natural products whose structures were determined by Professor Shô Itô are listed below (1960~1981). He discovered the additivity of substituent effects on the chemical shifts of the methyl signals in the NMR spectra of the oleanane triterpenoids (1969). Furthermore, he established empirical rules on the sign of the π–π* CD of α-cyclopropylketones (1968), epoxyketones (1968), and vinylcyclopropane systems (1982), that are useful for determining their absolute configuration.



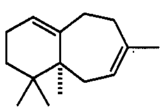
Thujopsene



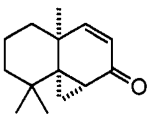
Chamigrene



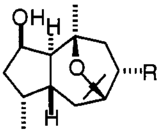
Widdrol



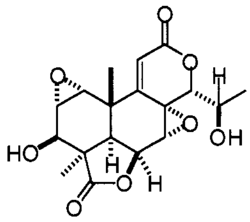
Pseudowiddrene



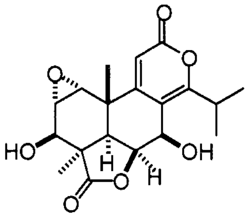
Mayurone



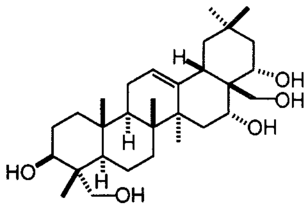
R=H, Kessyl alcohol
R=OH, Kessyl glycol



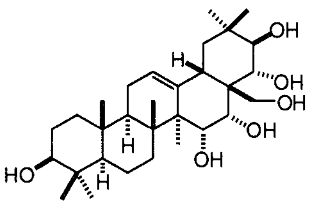
Inumakilactone



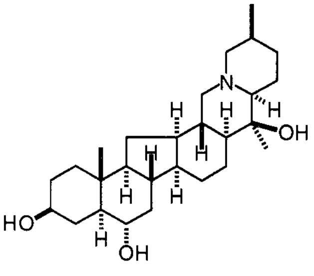
Nagilactone



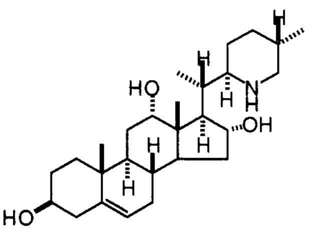
Camelliagenin



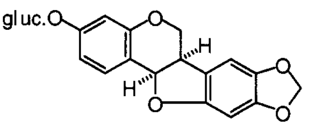
Barrigenol



Verticine

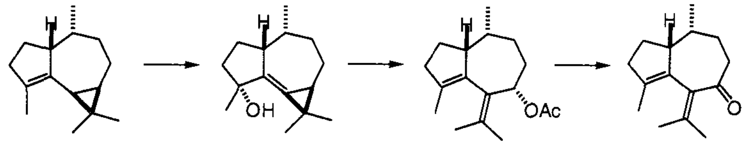


Baikeine



Pterocarpinoid

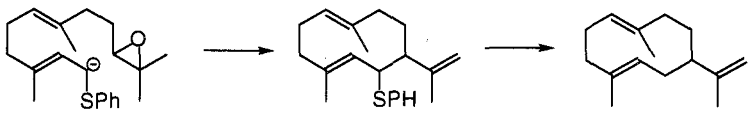
Professor Shô Itô's studies on natural product synthesis commenced with his study on the rearrangements of carbenium ions generated from sesquiterpenoids such as thujopsene, chamigrene, and widdrol in 1960s, as well as the photosensitized oxidation of thujopsene and gurjunene (1969~1972). Most remarkable was the rearrangement of gurjunene into a zierone skeleton *via* a highly strained methylene cyclopropane intermediate in its reaction with molecular singlet oxygen, which allowed him to determine the absolute stereochemistry of zierone. Such transformations strongly suggested a possible biosynthesis pathway to terpenoids.



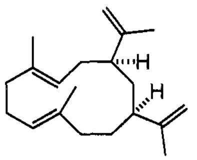
Gurjunene

Epizierone

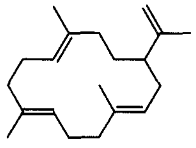
The cyclization of farnesyl and geranylgeranyl cations to monocyclic ions with 10- and 14-membered rings, germacrene and cembrene, respectively, is one of the basic natural biosynthesis pathways. Although some of such monocyclic terpenes had been synthesized, none of the approaches had followed the biogenetic pathway. Professor Shô Itô designed biogenetic-type synthesese of these macrocyclic terpenes through an anion-induced cyclization, according to an inversed electron demand sense, and offered a new, simple and general method for synthesizing macrocyclic terpenoids. Thus, germacrene, cubitene, and cembrene A, a termite trail pheromone, among others were efficiently synthesized (1975~1982).



Germacrene

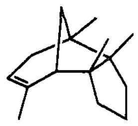


Cubitene

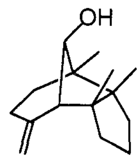


Cembrene A

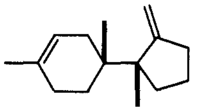
Furthermore, Professor Shô Itô succeeded in the total syntheses of a variety of architecturally novel natural products, as represented below (1979~1995).



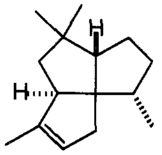
Barbatene



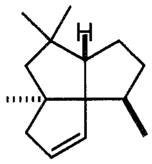
Gymnomitrol



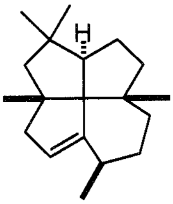
Bazzanene



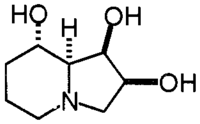
Senoxydene



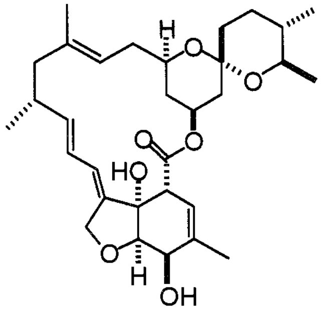
Silphinene



Laurenene



(+)-Swainsonine



Milbemycin α1

During his research on natural product synthesis, he invented a new diastereoselective amination method using the intramolecular conjugate addition reactions of carbamoyloxy unsaturated esters and hetero-olefins, which is useful for the stereocontrolled synthesis of amino sugars and hydroxy amino acids. The stereocontrolling factors were also defined precisely (1984~1989). Moreover, an Aza-Claisen rearrangement of amide enolates was developed for the stereoselective and asymmetric synthesis of 2,3-disubstituted carboxamides (1990~1994). New and more versatile reagent systems for the Mitsunobu reaction and Mitsunobu-type alkylation reactions have also recently been developed (1993~2000).

Thus, Professor Shô Itô has demonstrated his deep insight and research ability in two diverse areas of organic chemistry, nonbenzenoid (novel) aromatics chemistry and natural product chemistry. Furthermore, he has many talents besides chemistry and he has always been an excellent mentor, rich with a warmly human understanding, and is loved not only by his students but also by the students' families. I do hope that he will continue to enjoy and love chemistry, family, friends, and his new life in the Canadian Rocky Mountains.

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