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KOJI NAKANISHI

Transcript of an Interview  
Conducted By

Leon Gortler

at

Columbia University

on

15 February 1985

With Subsequent Additions and Corrections

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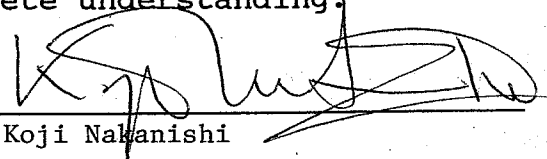
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Koji Nakanishi

(Date) \_\_\_\_\_

28 June 1994

KOJI NAKANISHI

1925 Born in Hong Kong on 11 May

Education

1947 B.Sc., chemistry, Nagoya University  
1954 Ph.D., chemistry, Nagoya University  
(Mentor: Y. Hirata)

Professional Experience

1950-1952 Garioa Fellow, Harvard University (with L.F. Fieser)  
1955-1958 Assistant Professor, Nagoya University  
1958-1963 Professor, Tokyo Kyoiku University  
1963-1969 Professor, Tohoku University, Sendai  
1968-1977 Director of Research, International Centre of Insect  
Physiology and Ecology, Nairobi, Kenya

Columbia University  
1969-1980 Professor  
1980- Centennial Professor  
1987- Chairman, Chemistry Department

1979- Director, Suntory Institute for Bioorganic Research,  
Osaka, Japan

Awards

1954 Award in Pure Chemistry, Chemical Society of Japan  
1968 Asahi Cultural Award  
1978 Ernest Guenther Award, American Chemical Society  
1979 Chemical Society of Japan Award  
1979 E. E. Smissman Medal, University of Kansas  
1979 Centenary Medal, British Chemical Society  
1980 H. C. Urey Award, Phi Lambda Upsilon, Columbia  
University  
1981 Remsen Award, Maryland Section, American Chemical  
Society  
1985 First Research Award, American Society of  
Pharmacognosy  
1986 Alcon Award in Ophthalmology  
1986 Paul Karrer Gold Medal, University of Zurich  
1987 Honorary D.Sc., Williams College

## ABSTRACT

This interview covers the life of Koji Nakanishi from his early education in Egypt to his current work as Professor of Chemistry at Columbia University and Director of the Suntory Institute for Bioorganic research in Japan. He discusses his education in wartime Japan, his fellowship years at Harvard University working with Louis Fieser, a succession of positions at various Japanese universities, and his eventual decision to go to Columbia University. His research on the structure of natural products and, more recently, their mode of action, and the development and use of infrared spectroscopy, NMR, and circular dichroism is discussed in some detail. The interview concludes with a brief discussion of his avocation, magic, and some general comments on the future of organic chemistry.

## INTERVIEWER

Leon Gortler holds an A.B. and M.S. (chemistry) from the University of Chicago and a Ph.D. in chemistry from Harvard University. He has been on the faculty of Brooklyn College since 1962, where he is currently Professor of Chemistry. This interview was conducted as part of Professor Gortler's long range study of the development of physical organic chemistry in the United States.

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1. Y. Hirata, K. Nakanishi, and H. Kikkawa, "Xanthopterin Obtained from the Skins of the Yellow Mutant of Bombyx mori (Silkworm)," Science, 111 (1950): 608-609.
2. Koji Nakanishi, Infrared Absorption Spectroscopy, Practical (San Francisco: Holden-Day, 1962); second edition with P. H. Solomon, Infrared Absorption Spectroscopy (San Francisco: Holden-Day, 1977).
3. Koji Nakanishi, "The Ginkgolides," Pure and Applied Chemistry, 14 (1967): 89-113.
4. F. A. L. Anet and A. J. R. Bourn, "Nuclear Magnetic Resonance Spectral Assignments from Nuclear Overhauser Effects," Journal of the American Chemical Society, 87 (1965): 5250-5251.
5. K. Nakanishi, "The Ecdysones," Pure and Applied Chemistry 25 (1971): 167-195.
6. R. Huber and W. Hoppe, "Zur Chemie des Ecdyson. VII. Die Kristall und Molekülstrukturanalyse des Insektenverpuppungshormons Ecdyson mit der Automatisierten Faltmolekülmethode" [Chemistry of Ecdysone. VII. Determination of the Crystal and Molecular Structure of the Insect Pupation Hormone Ecdysone by the Automatic Bent-Molecule Method], Chemische Berichte, 98 (1965): 2403-2424; P. Karlson, H. Hoffmeister, H. Hummel, P. Hocks, and G. Spiteller, "Zur Chemie des Ecdyson. VI. Reaktionen des Ecdysonmoleküls" [Chemistry of Ecdysone. VI. Reactions of the Ecdysone Molecule], Chemische Berichte, 98 (1965): 2394-2402.
7. K. Nakanishi and N. Harada, Circular Dichroic Spectroscopy: Exciton Coupling in Organic Stereochemistry (Oxford: Oxford University Press, 1983).
8. N. Furutachi, M. Funamizu, K. Nakanishi, D. Grunberger, and I. B. Weinstein, "Structure of the Fluorescent Y Base from Yeast Phenylalanine Transfer Ribonucleic Acid," Journal of the American Chemical Society, 92 (1970): 7617-7619.
9. P. Zanno, I. Miura, K. Nakanishi and D. Elder, "Structure of the Insect Phagorepellent Azadirachtin. Application of PRFT/CWD Carbon-13 Nuclear Magnetic Resonance," Journal of the American Chemical Society, 97 (1975): 1975-1977.
10. I. Kubo, Y. W. Lee, M. Pettei, F. Pilkiewicz, and K. Nakanishi, "Potent Army Worm Antifeedants from the East African Warburgia Plants," Journal of the Chemical Society, Chemical Communications, 24 (1976): 1013-1014.

11. B. Honig, U. Dinur, K. Nakanishi, V. Balogh-Nair, M. A. Gawinowicz, M. Arnaboldi, and M. G. Motto, "An External Point-Charge Model for Wavelength Regulation in Visual Pigments," Journal of the American Chemical Society 101 (1979): 7084-7086.
12. K. Nakanishi, V. Balogh-Nair, M. Arnaboldi, K. Tsujimoto, and B. Honig, "An External Point-Charge Model for Bacteriorhodopsin to Account for Its Purple Color," Journal of the American Chemical Society, 102 (1980): 7945-7947.
13. K. W. Foster, J. Saranak, N. Patel, G. Zarilli, M. Okabe, T. Kline, and K. Nakanishi, "A Rhodopsin is the Functional Photoreceptor for the Phototaxis in the Unicellular Eukaryote Chlamydomonas," Nature, 311 (1984): 756-759.
14. Y. Y. Lin, M. Risk, S. M. Ray, D. Van Engen, J. Clardy, J. Golik, J. C. James, and K. Nakanishi, "Isolation and Structure of Brevetoxin B from the 'Red Tide' Dinoflagellate Ptychodiscus brevis (Gymnodinium breve)," Journal of the American Chemical Society, 103 (1981): 6773-6775.
15. K. Nakanishi, H. Kasai, H. Cho, R. G. Harvey, A. M. Jeffrey, K. W. Jennette, and I. B. Weinstein, "Absolute Configuration of a Ribonucleic Acid Adduct Formed in vivo by Metabolism of Benzo[a]pyrene," Journal of the American Chemical Society, 99 (1977): 258-260.
16. R. C. Bruening, E. M. Oltz, J. Furukawa, K. Nakanishi, and K. Custin, "Isolation and Structure of Tunichrome B-1, a Reducing Blood Pigment from the Tunicate Ascidia nigra L.," Journal of the American Chemical Society, 107 (1985): 5298-5300.
17. H. Kanatani, H. Shirai, K. Nakanishi, and T. Kurokawa, "Isolation and Identification of Meiosis-Inducing Substance in Starfish Asterias amurensis," Nature, 221 (1969): 273-274.



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