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Biomagnetics: An Interdisciplinary Field Where Magnetics, Biology, and Medicine Overlap

Shoogo Ueno

Kyushu University, Teikyo University, and University of Tokyo, Japan

Biomagnetics is an interdisciplinary field where magnetics, biology and medicine overlap. It has a long history since 1600, when William Gilbert published his book *De Magnete*. Recent advances in biomagnetics have enabled us not only to detect extremely weak magnetic fields from the human brain, but also to control cell orientation and cell growth by extremely high magnetic fields. Pulsed magnetic fields are used for transcranial magnetic stimulation (TMS) of the human brain, and both high frequency magnetic fields and magnetic nanoparticles have promising therapeutic applications for treatments of cancers and brain diseases such as Alzheimer's and Parkinson's. On the imaging front, magnetic resonance imaging (MRI) is now a powerful tool for basic and clinical medicine. New methods of MRI based on the imaging of impedance of the human body, called impedance MRI, and the imaging of neuronal current activities in the human brain, called current MRI, are also being developed.

This lecture focuses on the advances in biomagnetics and bioimaging obtained mostly in our laboratory in recent years. The lecture describes: (1) a method of localized magnetic stimulation of the human brain by TMS with a figure-eight coil; (2) magnetoencephalography (MEG) to measure extremely weak magnetic fields produced from brain electrical activity using superconducting quantum interference device (SQUID) systems; (3) impedance MRI and current MRI; (4) cancer therapy and control of iron-ion release from, and uptake into, ferritin, an iron-storage protein, by using both high frequency and pulsed magnetic fields and magnetic nanoparticles; and (5) magnetic control of biological cell orientation and cell growth by strong static magnetic fields. These new biomagnetic approaches will open new horizons in brain research, brain treatment, and regenerative medicine.



Shoogo Ueno received the B.S., M.S. and Ph.D. (Dr. Eng.) degrees in electronic engineering from Kyushu University, Fukuoka, Japan, in 1966, 1968, and 1972, respectively. Dr. Ueno was an associate professor with the Department of Electronics, Kyushu University, from 1976 to 1986. From 1979 to 1981, he spent his sabbatical with the Department of Biomedical Engineering, Linköping University, Linköping, Sweden, as a guest scientist. He subsequently served as a professor in the Department of Electronics, Kyushu University (1986-1994) and in the Department of Biomedical Engineering, Graduate School of Medicine, University of Tokyo (1994-2006). In 2006 he retired from the University of Tokyo as professor emeritus. Since 2006 he has been a professor with the Department of Applied Quantum Physics, Graduate School of Engineering, Kyushu University, and is also dean of the Faculty of Medical Technology, Teikyo University, Fukuoka.

Dr. Ueno is a Fellow of the IEEE (2001) and of the American Institute for Medical and Biological Engineering (2001). He is a Fellow and Member-at-Large of the Governing Council of the International Academy for Medical and Biological Engineering (2006). He was an elected member of the IEEE Magnetics Society Administrative Committee (2004-2009). He was President of the Bioelectromagnetics Society (2003-2004), Chairman of the International Union of Radio Science's Commission K on Electromagnetics in Biology and Medicine (2000-2003), President of the Japan Biomagnetism and Bioelectromagnetics Society (1999-2001), President of the Magnetics Society of Japan (2001-2003), and President of the Japanese Society for Medical and Biological Engineering (2002-2004). He received the *Doctor Honoris Causa* from Linköping University, Linköping, Sweden (1998). He was a 150th Anniversary Jubilee Visiting Professor at Chalmers University of Technology, Gothenburg, Sweden (2006), and a visiting professor at Simon Fraser University, Burnaby, Canada (1994) and Swinburne University of Technology, Hawthorn, Australia (2008).

Contact: Prof. Shoogo Ueno, Department of Applied Quantum Physics, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka, 812-8581 Japan; telephone: +81 92 642 7552; fax: +81 92 642 7525; e-mail: ueno@athena.ap.kyushu-u.ac.jp; Faculty of Medical Technology, Teikyo University, Fukuoka, 4-3-124 Shinkattachi-machi, Omuta-shi, Fukuoka, 836-8505 Japan; telephone: +81 944 57 8333; Fax: +81 944 55 7703; e-mail: ueno@fmt.teikyo-u.ac.jp.