

# Magnetism as a tool in biology

**Magnetic techniques can be useful in many types of biological research**

Dietrick E. Thomsen

Magnetism is a property of atoms. Sometimes it makes itself macroscopically evident when the magnetic fields of the atoms in a piece of matter line up in one direction and a natural or artificial magnet results. More often the magnetism of atoms is not grossly evident, but can be sensed by appropriate means.

When magnetism is applied to biology both the atomic and gross aspects of it can come into play. The magnetism of atoms and their nuclei can be used to study the physics and chemistry of biologically important substances; the gross magnetism of sizable bodies can be used as an aid in investigating physiological processes or in carrying out medical therapy.

One example of the use of magnetism in physicochemical studies is the investigation of hemoglobin, myoglobin and various enzymatic proteins with the Mössbauer effect. Dr. C. E. Johnson of the University of Liverpool in England described some of these experiments at a recent Conference on Magnetism and Magnetic Materials in Miami Beach.

Mössbauer effect is the name for the so-called recoilless emission or absorption of gamma rays by atomic nuclei. Nuclei emit or absorb gamma rays when their internal energy changes from one value to another. If the atom involved is in a gas, it will recoil when the gamma ray is emitted or absorbed. This is because the principle of conservation of momentum requires that the momentum of the emitted ray be balanced by a momentum of the atom in the opposite direction and that the momentum of the absorbed ray be preserved as a momentum of the absorbing nucleus.

Some of the energy involved in the interaction will go into the momentum of the atom, and since this may vary,

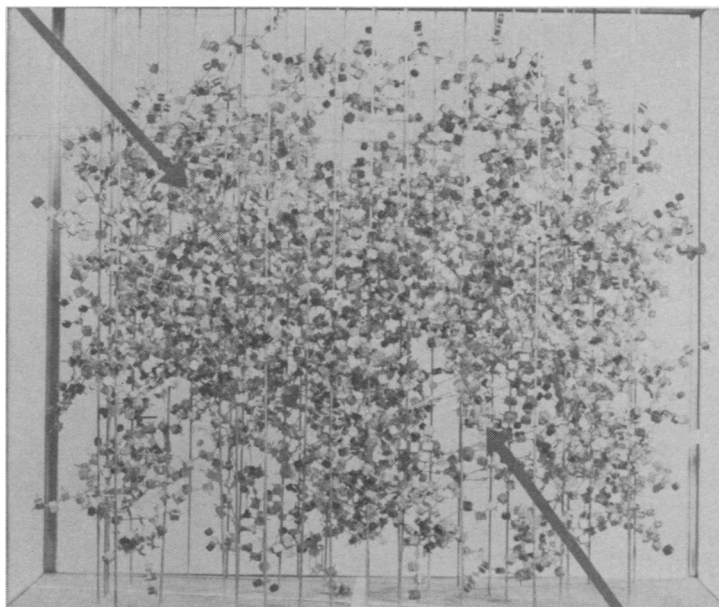
it is not possible to use the absorption or emission spectra of gamma rays from gases to determine the exact amounts of energy involved in the internal changes of the nucleus. But if the atom is bound in a crystal, the recoil involves the whole crystal. Since the crystal is massive compared with a single atom, the recoil necessary to conserve momentum is slight, almost nothing. Thus nearly all the energy in the interaction passes between the gamma ray and the internal energy of the nucleus, and the gamma-ray spectra of solids can be used to determine the exact energies involved in the nuclear transitions.

Since the energy states of the nucleus are influenced by the magnetic state of the atom, Mössbauer studies can be used to determine magnetic properties of the atom. And where magnetic changes are involved in their chemical activity much can be learned about that.

Many biological substances, such as hemoglobin and myoglobin, form large crystals. The important chemical activity of these substances is carried on not by the whole molecule but by a few active atoms. In hemoglobin, for example, four iron atoms do all the work involved in taking up oxygen and transporting it to cells.

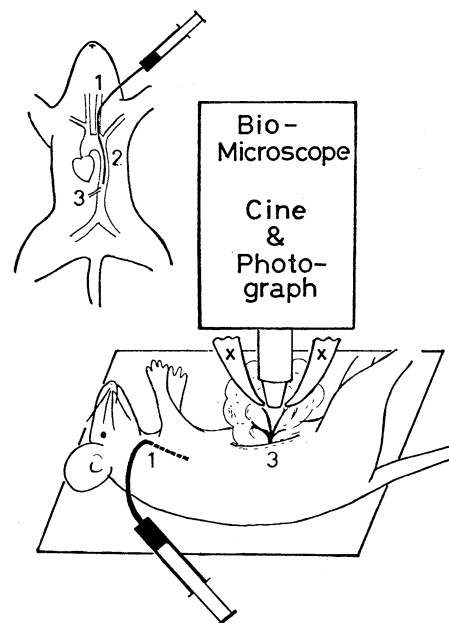
Similar characteristics are found in the so-called iron-sulfur proteins, whose structures play roles in photosynthesis, metabolism and nitrogen fixation. One of these proteins that has been extensively studied is spinach ferridoxide, a substance found in spinach leaves.

In spinach ferridoxide the enzymatic activity is concentrated on the iron atoms, of which there are two per molecule. Investigation can therefore concentrate on the state and structure of the iron atoms, and much can be learned even without knowing the de-



M. Murayama

*The complex hemoglobin molecule's four iron atoms are the key to its main chemical activity.*



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*Magnetic pellets for vascular research.*

tailed structure of the whole molecule, which is extremely difficult to determine.

It was found, for example that in the oxidized state the molecule is non-magnetic; in the reduced or deoxydized state it is magnetic. In reduction, one electron is transferred to the two iron atoms, and the question was whether it belonged entirely to one of them or was shared by both and how this affected the magnetism.

Study shows that the electron goes to one, not both, of the atoms and that the magnetic fields of the two atoms are pointed in opposite directions. Thus in the oxidized state, when both atoms have equal numbers of electrons,

## ... physiochemistry

the two magnetic fields are equal and cancel, and the over-all field is zero. In the reduced state one atom has the extra electron, and the result is a net field.

The electrons and how they move determine the chemical bonds that can form, and such studies should throw light on the complicated chemistry of these proteins, especially how they can exist in either of two oxidation states: ferrous (divalent) and ferric (trivalent).

Magnetic bodies much larger than single atoms, called ferromagnetic fine particles, can be used as a contrast material in studies of small blood vessels, according to Dr. K. Konno of Tohoku University in Sendai, Japan, who has performed experiments with Drs. T. Nakamura, T. Morone, N. Tsuya and M. Hatano.

**In X-rays** small blood vessels do not show up well against surrounding tissue. To get good pictures of them a contrast material that absorbs X-rays more strongly than the tissue must be introduced. In the magnetic pellets such a material is combined with a magnetic one.

The pellets are injected into the blood vessels where pictures are wanted. When a magnet is applied to the outside of the body the pellets clump together in aggregations that outline the vessel. Both still and motion pictures can be taken with this method, says Dr. Konno. The method has been successful in experimental pictures of blood vessels in rat intestines. Dr. Konno says it could be useful in such fine structures as kidneys, brain and pancreas.

Because of problems in getting the pellets out of the blood stream once they are in, experimentation must be confined to animals for the present, says Dr. Konno.

**On removal** of the external magnet, blood flow recovers, but as long as the pellets remain in the blood the possibility of embolism or iron poisoning remains. Possible methods to remove the pellets include recycling the blood through an external apparatus that strains out the pellets or providing pellets that will be dissolved by the blood and excreted.

Another contrast method that Dr. Konno and his co-workers have experimented with introduces gold-plated magnetic rings into the right ventricle of the heart by means of a catheter. When these are in place, pictures can show the thickness of the ventricle wall. This method can be useful, he says, in diagnosing pulmonary disease that causes thickening of the ventricle wall. The rings can be removed, he says, and experimental subjects show no side effects. □

## books OF THE WEEK

**ACOUSTIC NERVE TUMORS:** Early Diagnosis and Treatment—J. Lawrence Pool, Arthur A. Pava and Elliott C. Greenfield—Thomas, C. C., 1970, 2nd ed., 232 p., illus., \$13.50. Monograph describes symptomatology and various tests which can establish early diagnosis, and discusses recent developments in surgical and postoperative management.

**BEYOND THE IVORY TOWER:** The Frontiers of Public and Private Science—Sir Solly Zuckerman—Taplinger, 1971, 244 p., illus., \$7.95. Biologist and British government science adviser addresses himself to the goals and respective jurisdictions of pure science and its practical (or political) applications.

**BRUNELLESCHI:** Studies of His Technology and Inventions—Frank D. Prager and Gustina Scaglia—MIT Press, 1970, 152 p., photographs, drawings, \$10. Monograph deals with the Renaissance architect's concepts of design and construction, and the history and influence of his patented machines.

**CLINICAL LABORATORY COMPUTERIZATION—**Arthur F. Krieg and others—Univ. Park Press, 1971, 125 p., illus., \$8.50. Nontechnical manual for clinical pathologists and hospital administrators, designed to help with the planning of an economic and reliable system for transmitting reports.

**THE COMPUTERIZED SOCIETY:** An Appraisal of the Impact of Computers on Society Over the Next Fifteen Years—James Martin and Adrian R. D. Norman—Prentice-Hall, 1971, 560 p., photographs, diagrams, \$10.95. Two professional data processors provide a view of the future against a background of interconnecting machines and data banks, discussing their potential, threats to society and safeguards needed.

**DRUGS AND SCHOOLCHILDREN—**R. S. P. Wiener—Humanities Press, 1970, 238 p., tables, \$7.50. A sociological investigation of matched groups of London teenagers, drug-users and non-drug-users. The book describes methodology of the research, the results obtained, and suggests recommendations.

**ELECTRONIC MUSICAL INSTRUMENTS—**Norman H. Crowhurst—TAB Bks., 1971, 191 p., diagrams, \$7.95; paper, \$4.95. Describes electronic tone production, amplification of traditional instruments, modifiers, fully electronic instruments, and speaker systems.

**AN END TO POLITICAL SCIENCE:** The Caucus Papers—Marvin Surkin and Alan Wolfe, Eds.—Basic Bks., 1970, 324 p., \$7.95. Essays critical of American politics and American political science, presented by a group of young university teachers and graduate students conversant with the current realities of their disciplines.

**ENGINEERS' SALARIES:** Special Industry Report 1970—Engineering Manpower Commission—Engineers Jt. Council, 1970, 136 p., graphs and tables, \$35. Gives basic salary information on engineering graduates in the United States.

**EXPERIMENTAL MESON SPECTROSCOPY—**Charles Baltay and Arthur H. Rosenfeld, Eds.—Columbia Univ. Press, 1971, 664 p., photographs, diagrams, \$15. Collection of articles on experimental research concerning particle properties, including some theoretical research.

**EXPERIMENTS WITH MICROSCOPIC ANIMALS—**Philip Goldstein and Jerome Metzner—Doubleday, 1971, 245 p., illus., \$7.95. A book of research ideas for the amateur scientist and student, describes projects centering around protozoa, nematodes, hydra and microfauna of the soil.

**KLONDIKE '70:** The Alaskan Oil Boom—Daniel Jack Chasam—Praeger, 1971, 184 p., photographs, \$6.95. An eyewitness account of how oil and the prospect of oil is affecting the region, describes the hazards of living and working at the drilling sites, the claims of the natives, the controversy over transport schemes and the stakes involved.

**MARRIAGE AND MENTAL HANDICAP—**Janet Mattinson—Univ. of Pittsburgh Press, 1971, 231 p., \$6. Study based on interviews with 32 couples of which both parties are mentally handicapped and have been patients for short or long periods at a British mental hospital.

**THE MYSTERY OF HEREDITY—**John J. Fried, foreword by Norton Zinder—Day, 1971, 180 p., illus., \$6.95. Tells the story of the step-by-step discovery of the chemical nature of genetic material, how it is organized, how it reproduces and how it functions.

**NECKACHE AND BACKACHE—**E. S. Gurdjian and L. M. Thomas, Eds.—Thomas, C. C., 1970, 231 p., illus., \$8. Proceedings of workshop sponsored by the American Association of Neurological Surgeons and the National Institutes of Health; topics range from lumbar disc disease, degenerative causes, osteoporosis, to injuries, X-ray evaluation and trauma.

**NILPOTENT RINGS—**Robert L. Kruse and David T. Price—Gordon & Breach, 1970, 127 p., diagrams, \$12.50; paper, \$6. Reference work for researchers, emphasis is on the structure of nilpotent rings and algebras.

**PESTS AND DISEASES OF TROPICAL CROPS AND THEIR CONTROL—**G. Fröhlich, W. Rodewald and others, transl. from German by H. Liebscher, Ed. and F. Koehler—Pergamon, 1970, 371 p., color plates, \$19. Presents an overview of tropical and subtropical field crop pests and their control, from bananas and citrus, cacao and coffee, to maize, soya bean, sugar cane and rubber tree.

**THE PRODUCTION AND HAZARDS OF A HYPERBARIC OXYGEN ENVIRONMENT—**Proceedings of 1968 Symposium, London—G. S. Innes, Ed.—Pergamon, 1970, 121 p., photographs, diagrams, \$5.50. Papers deal with the advantage and risks of hyperbaric treatment, and with the principles involved in the clinical application of hyperbaric oxygen.

**RELIABILITY MATHEMATICS:** Fundamentals, Practices, Procedures—Bertram L. Amstader—McGraw-Hill, 1971, 408 p., diagrams, \$17.50. Designed to fill the needs of design and test engineers, reliability personnel and program managers, offers practical approaches and criteria for selection and application of the various mathematical methods.

**THE ROLE OF THE AGED IN PRIMITIVE SOCIETY—**Leo W. Simmons—Archon Bks., 1970, 317 p., maps, \$10. Unabridged reprint of 1945 study.

**SONS AND DAUGHTERS OF MOM—**Philip Wylie—Doubleday, 1971, 227 p., \$5.95. The author of GENERATION OF VIPERS continues his lively polemic by commenting on the "now" generation, the TV generation, squares and radicals, education, the sex revolution, pot, and ecology as a rallying point.

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