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REVIEWS

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CONTENTS

Kyoto Group of the History of Chinese Science

Shigeru NAKAYAMA*

Rivalling the celebrated project of Joseph Needham's *Science and civilisation in China*, the Kyoto group of the history of Chinese science, organized by Kiyosi Yabuuti, has recently completed a series work of their long-time collaboration.

The pre-history of this group goes back to the pre-War period, when Chūryō Nōda and Yabuuti, as regular staff members of the calendrical science section of the Institute of Oriental Culture at Kyoto, engaged in research into the history of Chinese astronomy and calendrical science with the cooperation of sinologist collegues in the Institute. In 1948, the Institute became affiliated with the University of Kyoto and changed its title to Jinbun Kagaku Kenkyūsho (Research Institute of Humanistic Sciences) and the calendrical science section was converted into a research professorship in the history of science, the function of which was to organize a team research in the history of Chinese science and technology. The post was held by Yabuuti, and under his chairmanship, assisted by Mitsukuni Yoshida, approximately fifteen members, who lived in Kyoto and its vicinity, were invited to join from outside of the Institute. Most of the senior members had teaching or research experience in pre-War China. Since then, with minor changes and recruitment of junior members, this group has been maintained more than twenty years through weekly seminars in which group examination of classical texts has been the main feature.

They started with the reading of *T'ien-kung k'ai-wu* (The exploitation of the works of Nature, Ming encyclopedia of technology), analyzing the text from many angles according to specialities of each member. The research results were published in 1953 under the title *Tenkō kaibutsu no kenkyū* (Studies on the *T'ien-kung k'ai-wu*).

Parallel to the textual study, they made frequent group tours to the workshops of traditional technology still extant in Kyoto and nearby areas. On the basis of these observations at the site, research monographs were produced on traditional technology and industry, such as ceramics, textile and brewery.

Since 1953, the research group decided on investigating Chinese science and technology to follow chronological order since the pre-Han time. Whereas Needham's project attempts to survey vertically throughout history each department of science and technology volume by volume, the Kyoto group used a horizontal arrangement in four volumes. Each volume concentrates on certain periods in Chinese history, and consists of articles written by specialists of the group in each

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subject.   In the second work on medieval China and in later volumes, the format
became much improved, adding an outlook of science and technology in each period
at the opening by Yabuuchi.   English translations of the tables of contents of all
four volumes are given below.   With exceptions of specifically noted items, articles
are written in Japanese.

* Briefly commented by N. Sivin on *Isis* vol. 55, no. 182, 537 p. (1964).

* Briefly commented by N. Sivin on *Isis* vol. 59,5. no. 200, pp. 91-91, (1968).

Activities of Japan's Group for History of Physics*

Tetu HIROSIGE**

After the Second World War there has been continually, though not very actively, proposed in Japan that the history of science should have certain roles in the education of science. It has been argued that the history of science would contribute to the science education by drawing pupil's attention to the human elements in the development of science and thus by awaking in him the interest in learning science. It has also been expected that the study of history of science might offer useful suggestions about how to teach a particular subject by elucidating where did the psychological and conceptual obstacle in understanding a new scientific fact or concept lie in the actual history. Finally, J. B. Conant's proposal to use the case history in order to make student realize the method of science was also recommended.

These discussions certainly have encouraged some attempts to utilize the history of physics in physics education. For example, Prof. M. Watanabe of University of Tokyo, himself a historian of physics, once made a model of the instrument of Galileo's falling body experiment on an inclined plane. Prof. Watanabe tried to carry out the experiment in his course of general physics at Tokyo Women's Christian College. Another historian of physics, Dr. K. Itakura of the National Institute for Educational Research, proposed a teaching method which he named the hypothetico-experimental teaching. Suggested by his study on the history of mechanics, he selected questions which once puzzled or misled those who first studied the subject. He proposed to pose the same questions to a pupil, and to make him suppose the answer and devise an experiment to test the supposed answer. Then the pupil is required to perform the experiment and to examine his supposition by the result of experiment. Itakura's proposal was earnestly welcomed by school teachers.

In spite of these remarkable attempts, the discussions which have been done about the role of history in science education seems to me, in general, unsatisfactory in two respects. First, while the teaching of science at the primary and secondary schools has been discussed rather frequently, the education at university level have been left untouched. It is true that it has sometimes been tried to replace the course

of a science for non science-major student by a lecture on the history of that science. But this could not be considered a sound attempt.   By the regulation of the Ministry of Education, non science-major students in Japanese universitities are required to take certain credits of scientific subject.   As they naturally are not willing to attend scientific lectures, the history of science is expected to moderate their reluctance by diluting the science with humanistic factors.   Thus the history of science is here only a convention.   To be worse, most of those who are making such an attempt are not historian of science, lacking even proper knowledge of the scholarly history of science.   I am afraid that their lectures are in many cases kept on a level of popular story.

We are thus led to the second defect of the former discussions about the history of science in science education.   It is the lack of the background of the genuine history of science.   The reason that the former discussions have been little productive lies, I believe, in the fact that there are, in Japan, few scholarly studies of history of science.   Historians of science who are doing scholarly research are so few that we have little textbooks of history of science written on the scholarly basis in Japan.

These experiences seem to suggest that, in Japan, the most urgent thing to do would be to stimulate the scholarly study of history of science.   Thus I here propose to report on the activity of historians of physics in Japan.

Studies in the history of physics first appeared, except for the study of Japanese efforts during the seclusion age of learning physics and other sciences through Dutch books, in the first years of 1940's, during the Second World War.   In the war time Japanese government attempted to mobilize scientific activity for military purposes like in other countries.   As the science in Japan then was, in general, still in poor stage, various efforts were made, though unsuccessfully, to promote the scientific research and education.   The history of science was called forth because it was expected to contribute to deepen the understanding of the science which, being of western origin, was thought to have been grasped by Japanese superficially. Being encouraged by such a general tendency the History of Science Society of Japan was founded in 1941.   One of the plans which were then attempted in order to promote the history of science was to publish a series of classic papers of various branches of science in Japanese translation.   As a part of it, a book entitled *Theory of Heat Radiation and the Origin of Quantum Theory* was published in 1943.   This book contained a historical introduction by the late Kiyosi Amano as well as the papers by W. Wien, Lord Rayleigh, and M. Planck.   Amano's introduction was in fact an excellent article on the history of the experimental and theoretical researches which led to Planck's discovery of the energy quantum.   It is distinguished from many other articles on the birth of quantum theory by its analysis of the experimentation and of the technological background of researches on heat radiation. Speaking of the social conditions which prompted those researches carried out most vigorously at the Physikalisch-Technische Reichsanstalt in Berlin, Amano argued that they were promoted by the technological problems raised by the rapid

development of German industries after the Franco-Prussian War. He himself was a member of the staff of the Central Bureau of Weights and Measures, a Japanese counterpart of the Reichsanstalt in Berlin, and had undertaken the measurement of heat radiation. His article, though written nearly 30 years ago, may still be highly rated because of its uniqueness.

During several years after the end of the war, strong interest in the history of science was again widely spread among scientists and students. This was caused by the reflection on the weakness of Japanese science which was revealed by the war time experience that Japan's scientific mobilization had produced no remarkable result while that of the allied nations produced the radar, the atomic bomb, and so on. Those who were then interested in the history of science were motivated by the intention to seek the roots of the weakness of Japan's science in its historical background which they thought was very meager compared with that of the science in the west. They also expected that they might discover laws of the development of science which would be effectively utilized as a guide in their scientific research. Many of today's active historians of science in Japan were, in their youth, much influenced by this boom of history of science, though they afterward became aware that such a view of history of science was superficial and that in many cases the advocates of history of science of those days were lacking in the scholarly knowledge and practice of the history of science.

Yet there were a few interesting works in the history of physics. Especially noteworthy were Prof. T. Takabayasi's historio-logical analyses of the science of heat and of the old quantum theory. It was with these background that the textbook of the quantum mechanics by Prof. S. Tomonaga, the Nobel prize winner in theoretical physics, was written. Tomonaga's book was first published in 1948 and later was translated into English* so that western readers may also appreciate its excellence. This book is not, naturally enough, a treatise on the history of quantum mechanics. But the author tries there to show how the present quantum mechanics has been built up instead of trying merely to introduce it in its established form. Thus the author traces the historical development of quantum mechanics, though with arbitrary rearrangements of materials so as to fit the purpose of elucidating as clearly as possible the intricate ways of thinking and of raising questions of many geniuses. The author expects in this way that the book be very helpful in guiding scientists, by stimulating their imagination, in their pursuit for a new theory. The elaborate quasi-historical exposition in this book of the old quantum theory indeed makes the reader realize clearly the physical meaning of the theory considered. Tomonaga's book may surely be regarded as successful a suggestion for the application of the history of physics to physics teaching.

There were, however, in those days no historian of physics in proper sense. Those who wrote or talked about the history of physics were usually professional

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* S. Tomonaga: *Quantum Mechanics, 1. Old Quantum Theory*, North Holland, Amsterdam, 1962; *2. New Quantum Theory*, 1966.

physicists. Consequently their discussions of history of physics were biased by
their professional interest and mode of thinking. In other words, their arguments
either were intended to support their idea in their own field, or rested on an inter-
pretation of historical facts by today's conception disregarding the historical con-
text. With tacit or explicit criticism to these shortcomings the Group for History
of Physics emerged.

At the 1955 annual meeting of the Physical Society of Japan a symposium on
the history of physics was organized. This was the first opportunity in the history
of Japan's physics that historical studies based on the analysis of original sources
were reported before physicists. It was therefore the first sign that the history of
physics was becoming recognized by physicist as an independent discipline. Those
who read papers at this symposium constituted the body which was to be the Group
for the History of Physics.

From 1955 to 1963, the symposium on the history of physics had annually
been organized on the occasion of annual meeting of Physical Society. It was however
still a temporary meeting organized afresh each year. But in 1964 a permanent
section for the history of physics was newly set up in the Physical Society. With
this, it may be said, the history of physics acquired so to speak the citizenship in
the physicists' community.

Six years earlier than this, in 1958, we founded a private journal *Buturigakusi
Kenkyu* (Studies in the History of Physics) which have since been published more
or less regularly. By private journal is meant that it is published without subsi-
diary money from any institution, governmental agency or foundation. It is in
fact a mimeographed circular opened for articles, preliminary reports, memoranda,
book reviews, abstracts, guide to literatures, and so on. Criticism, suggestion, or
request to the historian of physics from the part of physicist is also welcomed.
To illustrate the general tendency of this journal, titles of articles published in recent
numbers are listed below:

Vol. 5, No. 1 (March 1969)

Y. Fujii:	Hantaro Nagaoka as a Geodesist.
K. Yamada:	Dr. H. Nagaoka and the Rise of Optical Industry in Japan.
S. Saito:	Appraisal of the Atom Model of H. Nagaoka.
T. Hirosige:	Relativistic Mechanics in Its Early Days—2.
I. Ohami:	A Memorandum on the History of Medieval Mechanics—2.
S. Kumoi:	On the Title Page of Newton's *Principia*—an addendum.

Vol. 5, No. 2 (Aug. 1969)

N. Hokkyo:	A Note on the "137"
K. Usigome and K. Imaizumi:	Hantaro Nagaoka's Relation to the Physics Abroad.
S. Seto:	Dr. Nagaoka and the Electron Microscope.

T. HIROSIGE: Introduction to the History of Physics. A Suggestion of Reading—3.

K. TSUNEISHI: A Reflection on the Occation of the 10th Aniversary of *Buturigakusi Kenkyu.*

Article Review: P. FORMAN, "The Doublet Riddle and Atomic Physics, circa 1924", *ISIS*, vol. 59, pt. 2. (S. NISIO)

Vo. 5, No. 3 (Oct. 1969)

Abstracts of the Papers read at the 1969 Annual Meeting of the Physical Society of Japan

I. OHAMI: A Flying Instrument in Medieval India.

T. HIROSIGE: Reception of the Theory of Relativity.

T. OGAWA: Historical Description of the Mechanics and its Analysis.

T. TSUJI: Introduction of the Relativity and the Quantum Theory into Japan.

T. KIMURA: Distribution of Ages of the Professors at Physics Departments of the Imperial Universities in Pre-war Japan.

E. YAGI: Development of NAGAOKA's Atom Model—3.

M. WATANABE: Recent Trend in the Newtonian Study.

M. HASHIMOTO: Physics in Japan in the Early Years of Meizi.

T. HIROSIGE: Introduction to the History of Physics. A Suggestion of Reading—4.

Vol. 5, No. 4 (Dec. 1969)

Y. FUJII: Torahiko TERADA's Philosophy of Science.

K. TERAMOTO: Aikitu TANAKADATE and the Measurement of Gravity in the Early Years of Meizi.

E. TAKAHARA: Aikitu TANAKADATE's Geomagnetic Study.

K. HINOTANI: Aikitu TANAKADATE's Work in the Aeronautics.

S. TAKADA: The Life of Max Born.

M. WATANABE: Recent Trend in the Newtonian Study—2.

Article Review: E. A. MOODY, "Galileo and his Precursors" in *Galileo Reappraised*, California, 1966 (M. YOKOYAMA).

Vol. 6, No. 1 (March 1970)

K. SUGAWARA: Japanese Chemists in the Early Years of Meizi.

T. HIROSIGE: Relativistic Mechanics in Its Early Days—3.

J. TAKADA: The Life of Max Born—2.

M. YOKOYAMA: S. STEVIN and the Impossibility of Perpetual Motion.

T. HIROSIGE: Concerning the Hypothesis of van den Broek.

Vol. 6, No. 2 (June 1970)

T. KIMURA and
E. YAGI: NAGAOKA's Laboratory in the Institute of Physical and Chemical Research.—an Interview with Mr. T. Misima.

K. Sugawara: Japanese Chemists in the Early Years of Meizi (1850's to 1880's).

T. Hirosige: Introduction to the History of Physics. A Suggestion of Reading—5.

S. Nakayama: Invasion of Astronomy by Physics.

Book Review: *Historical Studies in the Physical Sciences*, Vol. 1, Philadelphia, 1969 (S. Nisio).

Vol. 6, No. 3 (Sept. 1970)

M. Fukushima: Makita Goto—Science Education in the Early Meizi Era.

T. Hirosige: Introduction to the History of Physics. A Suggestion of Reading—6.

What I Study in the History of Physics:

I. Ohami: Physics in the Ancient India

K. Tsuneishi: Wave Optics from E. Abbe to D. Gabor

M. Yokoyama: Huygens and the Law of Falling Body

M. Yoshinaka: Mechanical Investigations of Galileo

When we first published this journal, we named ourselves Group for History of Physics. The Group therefore manifestly took shape in 1958. The boundary of the Group, however, is not definitely clear. There has been no attempt to define its membership either. It may therefore tentatively be said that those who contribute something to our journal constitute the Group for History of Physics. But the number of historians of physics in a strict sense is smaller than the size of this group. It is larger than one dozen but does not exceed, say, twenty. This is indeed a negligibly small number compared with over eight thousands of members of the Physical Society of Japan. Today the Group for History of Physics, however, has relatively wide influence among physicists. This is because it gathers around it physicist sympathizers of history of physics who pay the subscription for *Buturigakusi Kenkyu*. This journal therefore serves as a medium through which the history of physics is diffused into physicists. Thus far been described only the activity of the Group for History of Physics in the physicists' community. It may also be added that it is one of the most active groups in Japan among the historians of science general.

Retrospecting the past fifteen years, we may summarize the effort of the Group for History of Physics as being directed to two main objects. The first is to develop the scholarly study of history of physics and the second is to promulgate the result of recent studies in the history of physics. As for the first object, number of articles have been published in the *Buturigakusi Kenkyu*, *Kagakusi Kenkyu* (Journal of History of Science, Japan. Official journal of the History of Science Society), and *Japanese Studies in the History of Science* (also official journal of the History of Science Society in western languages). It is however regrettable that many of them are written in Japanese so that it is difficult for western colleagues to read them.

Of the journals named above, the first, the *Buturigakusi Kenkyu*, is also intended to serve for the second object of the Group for History of Physics. This object has been pursued also by meetings at the occasion of each annual meeting of the Physical Society, where we usually have, besides the formal session of history of physics, an informal gathering for free talkings about the history of physics and the physics itself.

The emphasis of our effort has, however, been laid rather on the study of history of physics itself. This is partly because layman's understanding of history of science is generally vulgar and shallow, and on such an understanding they speak of utility or inutility of the history of science. We believe that scholarly history of physics should first be developed before the role of history in physics research or education could effectively be considered. Another reason is that many a physicist shares the prejudice that there is no need to make scholarly study in order to acquire a knowledge of history of physics. They believe that the history of physics could easily be understood without special effort if one has an adequate understanding only of physics. Consequently they would not admit that the history of physics itself is an independent subject of research. Surrounded by such a prejudice, we have decided, instead of begging sympathy or good will of the physicist, to do genuine, scholarly study of history of physics and to make the result of our study speak for itself. Such an effort of the Group for History of Physics has proved to be not fruitless. Recently the history of physics, it seems, has become to receive a certain respect as an independent field of research.

Now through over ten years experience of our activity among physicists, we have learned that most physicists, especially when they are young, could not find adequate means to make approach to the history of physics if they get interested in learning something about history of his own discipline. Lectures given at today's university usually make no reference to the historical background of the subject. Professors themselves, in general, are so busy in following recent publications in their own field that they scarcely have time to read and think about the history. The library of their institute is always troubled with the flood of recent literatures, and consequently historical materials such as old journals and classical books are liable to be piled up disorderly in a distant storeroom. Thus both the scientist and the student are removed away from historical materials. Moreover there is very few universities in Japan which offer a scholarly course of history of physics or other science. The position which the historian of physics holds today is in most cases that for teaching physics. To ameliorate the situation, it therefore seems necessary above all to provide physicists and students with historical materials in a form which is easy for them to approach. As one of the measures to be taken for this purpose the Group for History of Physics has recently edited a series of books which are collection of classic papers translated into Japanese. The series is named *Buturigaku Koten Ronbun Sosyo* (Classical Papers in Physics) and consists of twelve volumes. Its scope is restricted to the generative period of the

twentieth century physics. The titles and contents of each volume were described in the previous issue of this journal.* Thus far 11 volumes have already been published until this December. The remaining, last volume is to be published in the beginning of 1971.

Though this series was first intended for the readings of student, the volumes which were thus far published have been unexpectedly welcomed by physicists. This probably indicates that the interest in history of physics is being aroused among physicists. This interest seems to be rooted in their anxiety. They recently seems to be meditating or skeptical about the significance of their daily practice of investigation, because they feel themselves too busy in pursuing immense but fragmentary data and informations. They want to obtain an integral grasp of their field of research. This tendency has also been strengthened certainly by students' revolt which since 1968 raged through most of Japanese universities. The students' revolt occasioned vigorous discussions about the university reform. These discussions in their turn have motivated some few scientists to reflect on the present situation of their own special field of research against its historical background. Students too have begun to demand that the university education should give them a broad scope of science, not a mere knowledge of detailed technicalities. To meet such a demand a special course of lectures of history of physics is tentatively introduced in some universities. These trends are still in germ, but significant enough.

If in Japan the role of history of physics in physics education is to be considered seriously, it would be expected from now on. But our worry is that we the historians of physics in Japan are too small in number to meet the demand which will probably be made upon us in the near future. The most important problem for us now seems therefore how to attract talented students to the history of physics.

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* T. Hirosige, "Source Books in the Modern Physics," *Jap. Stud. Hist. Sci.*, No. 8 (1969), 17–20.

Philosophy of Science in Japan: 1966-1970

Hiroshi NAGAI*

The following attempt is a general review of the philosophy of science in Japan ·during the latest five years. Regarding the preceding ten years 1956–1965, one can refer to Professor Seizo Ohe's report published in the other periodical (*Ann. Japan Ass. Phil. Sci.*, Vol. 3, No. 3, 1966). Since then an amount of contribution has been made toward our study of philosophy of science.

In connection with a fascinating book *Philosophy in the Scientific Age* (3 Vols., ·ed. by Natsuhiko Yoshida et al., Baifukan, Tokyo, 1964), another worthy one, ·collecting ambitious essays, was issued: *Basis of Science* (ed. by Shozo Ohmori et al., U. of Tokyo P., 1969). In this book mathematicians and natural scientists as well as philosophers act their parts admirably, and they all have precious face-to-face ·discussions on topics such as exactness in mathematics, physical knowledge, and life and consciousness. Nobushige Sawada urges, in the preface to the book, that the common aim of the collaborators is to set a stage for mutual exchange of their ·own views.

Sawada is also the author of *The Structure of Knowledge: Conquest of Dogma and Scientific Thought* (NHK Publishing Co., Tokyo, 1969). In spite of its popularity, Sawada's book may be most interesting; he, in fact, severely criticizes the ·obscurity and sterility of our traditional philosophizing. Shozo Ohmori's article 'Perceptual Scenery and World Picture' in *Basis of Science* is esteemed as most ·conspicuous among his many phenomenalistic essays. From his viewpoint, which he often calls 'the theory of overlapping' of perceptual scenery and scientific world picture, he offers sharp criticism against the arguments brought forward by preoc- ·cupied philosophers.

Shigeo Nagai has issued, with his collaborator Hiroshi Kurosaki, a thorough- going book *Fundamentals of Philosophy of Science* (Yushodo, Tokyo, 1967), in which are explored many basic problems of the philosophy of science by means of the logical method, and is criticized, at the same time, the standpoint of materialistic philosophy. Nagai is chairman of the committee of *Philosophy of Science Society, Japan*, and has edited its annals *Philosophy of Science* (Vol. 1, 1968; Vol. 2, 1969; Vol. 3, 1970).

Hidekichi Nakamura's ambitious book *Basis of the Philosophy of Science* (Aoki Shoten, Tokyo, 1970) treats about the fundamental issues of analytic philo- ·sophy. But Nakamura argues that analytic philosophy has certainly some limits,

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which undoubtedly make materialistic philosophy indispensable for making up·
the shortcomings of that philosophy.

Logico-linguistic analysis must be sound within the scope of explanation of
ready-made scientific theories. But science, in its real phase, should be rather
regarded as research-science of unknown truth than as learning of existing knowledge.
From such a viewpoint Hiroshi Nagai, the present writer, has prudently examined
'metascientific' problems hidden at the very basis of science in the making in his
The Philosophy of Science (Sobunsha, Tokyo, 1966).

Science in general might not be self-sufficient on account of the fact that its
fundamental concepts and principles, and the methods employed in using them
are not always self-evident. For this reason the thoughtful scientist will, indeed,.
sometimes take pause from his research activity to reflect upon the kind of knowledge
he has obtained about the universe he lives in. In this way Hideki Yukawa occa-
sionally lays stress on the point that his own concept of elementary domain is
originally based on a metaphysical idea embraced by the ancient Chinese philosopher
Chuang Tsu. Yukawa's philosophy of physics is displayed, e.g., in his *Creative
Man* (Chikuma Shobo, Tokyo, 1966).

On the other hand, Takahiko Yamanouchi's philosophy of physics is worthy
of notice. In his interesting treatise *On Understanding of Modern Physics: The
World a Physicist Looks at* (Chikuma Shobo, Tokyo, 1970), Yamanouchi gives
the model theory its highest possibilities, and his discussion is really based upon
the precious experience obtained through the many years' study of a veteran phys-
icist. Moreover, his argument is so much brightened in the light of modern logic
that we are likely to be persuaded to approve its plausibility.

Shoji Maehara, a mathematician, is distinguished among our philosophers
of mathematics. Though he is rather an expert in the foundations of mathematics,
he often ventures on discussing the philosophical problems latent in the basis of
mathematics. Some of his thoughtful ideas will be found, e.g., in his article 'The
Exactness of Mathematics' (*Basis of Science*). Furthermore, it must be remembered
that a stimulating debate as to the idea of 'formalization' and 'axiomatization' in
mathematics has recently provoked between Maehara and Setsuya Seki; the latter
is also regarded as one of our leading mathematicians (S. Maehara, 'Philosophy
of Mathematics,' *Jour. Japan Ass. Phil. Sci.,* Vol. 9, No. 2, 1969; S. Seki, 'Philosophy
of Mathematics,' *op. cit.,* Vol. 9, No. 4, 1970). In this controversial debate Seki
seems to interpret every mathematical theory as *façon de parler*, while Maehara may
be very favorably inclined towards a sort of realism.

Chikio Hayashi is a skillful mathematician and has vigorously continued to·
work on statistics. In addition to the intrinsic merit set forth by him in statistical
researches, Hayashi has also paid philosophical attentions toward the foundations
or methodology of statistical mathematics. In his essay 'Basic Problems in Sta-·
tistics' (*Basis of Science*), Hayashi argues that statistics should be defined as system-·
atization of statistical methodology which will be suitable for data analysis. From

his point of view, no existing statistics could satisfy such a demand, because it is used to discuss a formal unification of the things which are quite trivial to the real statistics.   Hayashi has recently completed a voluminous work with his collaborators Isao Higuchi and Tsutomu Komazawa, in which he has clearly summarized his basic ideas of the philosophy of statistics (Preface to *Information Processing and Statistical Mathematics*, Sangyo Tosho Syuppan, Tokyo, 1970).

Ryuichi Yasugi, an eminent biologist, is seriously interested in the philosophical problems of biology, and has exerted all his efforts for clarifying its basic concepts, especially those of the theory of evolution (*History and Methodology of the Theory of Evolution*, Iwanami Shoten, Tokyo, 1965).   In his recent essay 'On the Logic of the Theory of Evolution' (*Jour. Japan Ass. Phil. Sci.,* Vol. 9, No. 2, 1969), Yasugi has appropriately advanced his opinion on the philosophy of evolution theory. Besides Yasugi we can find another biologist Mamoru Iijima who shows his interest in the philosophy of science.   Iijima deserves mention, indeed, as the author of *Between Biology and Philosophy* (Misuzu Shobo, Tokyo, 1969), which has found a welcome from scientists and philosophers.

Our psychologists have seldom done research for the philosophy of science with a few notable exceptions; the cases of Taro Indow and Yoshiharu Akishige are certainly exceptional.   Their elaborate papers are found in the recent issues of our journal and annals (*Jour. Japan Ass. Phil. Sci.* and *Ann. Japan Ass. Phil. Sci.*). Indow is used to stress the salient characteristic achieved by the positivistic method of observation and experiment, which have taken the place of mere meditation; he analyses various kinds of experimental data by using mathematical models. He admits, of course, the limitation of such an approach towards man on account of the impossibility of formulation of human activities.   But, he takes it for granted, at the same time, that in our scientific age, to study human activities is after all essentially tantamount to understanding them in terms of formal models.

Akishige's subject matter is the constancy of perception.   According to him, the real color, shape and quantity of an object are neither given in special impressions nor in an aggregate of them.   Moreover, no memory or reproduction of the previous impressions is even required for that purpose.   Thus he concludes that the constancy of perception really consists in the possibility of constructing an invariance of perception.

The above is a brief description of the general state of discussion on the philosophy of science in Japan during the past five years.   For further particulars, I cannot but hope that my forthcoming article may be found useful for reference: 'Recent Trends in Japanese Research on the Philosophy of Science,' *Zeitschrift für allgemeine Wissenschaftstheorie*, Philosophisches Institut der Universität Düsseldorf, Dezember 1970.

Transmission of Indeterminate Equations
As Seen in an Istanbul Manuscript
of Abū Kāmil

Martin LEVEY*

Abū Kāmil was one of the most creative mathematicians in the medieval Arabic world. It is to his credit that he saw the necessity in his time of fusing the more theoretical Greek approach with the more practical Babylonian algebra. It was in this manner that abū Kāmil proved himself to be a true innovator. As a result of his mathematical procedures, his successors were in a position to forge ahead without profound philosophical difficulties.

Abū Kāmil Shujāᵉ ibn Aslam ibn M. ibn Shujāᵉ (c. 850–930), "the reckoner from Egypt," was the product of a period of intellectual ferment in the Golden Age of the Arabs. After al-Khwārizmī (ca. 825), abū Kāmil is the earliest algebraist of the Islamic period whose writings are still extant. As a result of a different approach to mathematics, abū Kāmil's algebra is much advanced over that of the practical al-Khwārizmī whose roots are almost entirely Babylonian. A comparison of abū Kāmil's *Al-jabr wa'l-muqābala* with the book of the same title by al-Khwārizmī demonstrates the evolution of algebraic method in a fruitful direction.[1] A work of abū Kāmil which contains some indeterminate equations is the *Kitāb al-ṭarā'if fi'l-ḥisāb*. "Book of Rare Things in the Art of Calculation." These problems which show progress are concerned with integral solutions of linear equations.

Another work of abū Kāmil goes more deeply into algebra with solutions for fourth degree equations and for mixed quadratics with irrational coefficients. Only the Latin and Hebrew texts had been known. The Arabic of this text was discovered by Levey in Istanbul in the important Kara Mustafa Library MS 379 as the second treatise.[2]

* State University of New York, Albany, N.Y. (This is a posthumous work of the late Professor Levey who died unexpectedly in August, 1970. We express our deepest sympathy and acknowledge his kind cooporation.—Editorial Committee—)

[1] This has been shown by M. Levey, *The Algebra of Abū Kāmil* (Madison, 1966). This publication includes the text and translation of abū Kāmil's elementary *Al-jabr wa'l-muqabala* "Algebra."

[2] *Ibid.*, p. 9, Cf. H. Suter, *Bibliotheca Mathematica* 10, 15–42 (1909–10) for the German translation. The Italian translation is by G. Sacerdote from the Hebrew in *Festschrift z. 80 Geburtstage M. Steinschneiders* (Leipzig, 1896) pp. 169–194. In Arabic, it is called *Kitāb al-muḥammas wa'l-mu'ashshar*.

As its first treatise, the manuscript has the previously studied elementary algebra. Further, the third treatise is also by abū Kāmil and is the presently discussed one. It is not titled by abū Kāmil but, to use his terminology, it may be called *Kitāb masā'il allatī hiya ghair maḥdūda* "Book on Indeterminate Problems." Brockelmann does not mention this manuscript.[3] A good Hebrew translation is in the great Munich Cod. Heb. 225. The Arabic manuscript which is complete and in excellent condition has been collated with the Hebrew text. The latter is very close to the Arabic both in language and spirit. The Arabic is written in a naskhi hand and runs from fol. 79a to fol. 111a.

In the introduction to the text, abū Kāmil gives an interesting account of his own work in mathematics as well as a description of indeterminate problems.

"I have completed the explanation of what is difficult in many of its parts for mathematicians of our time and for those of whom we have heard among earlier scholars with regard to the rules of the pentagon and decagon, circumscribed or inscribed. Also, I have found the diameter of that circle circumscribing or inscribing a known pentagon or decagon. I have measured the arc of one part in fifteen or the circumference of a known circle, also the length of the side of a regular pentagon or decagon if their areas are known. I have measured the length of the sides of triangles with known areas if they are found in a regular pentagon or decagon. This is besides other subjects which we have indicated in our book.

"But now, I would call attention to many indeterminate problems which some mathematicians call 'the stream,' I consider it as an outlet for many correct answers based upon a logical method and a simple approach. Some of these problems concern mathematics of topics which are not founded upon a definite basis; others are solved by a sound theory and a simple trick which could be of great use. Thanks be to Allah for the way he has helped us through them. He is the ominscient for all which is within our hearts.

"Further, we shall explain much that mathematicians have written in their books and what they have achieved regarding the topics of algebra and mensuration. This will help the reader or observer to obtain a good understanding of what is read as a story or to nearly imitate the writer."[4]

The problems which follow are graduated in difficulty since the treatise is meant to be a teaching text. It is, however, well organized as the following order of examples will show. These are all worked out rhetorically in detail. It must be remembered that, although no notation was used, mathematicians were at that time accustomed to the verbal method and had well trained memories.

The first problem reads, "If one says to you that a square having two roots has added to it five dirhams, then it is a root.[5] What is the square in it?"

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[3] C. Brockelmann, *Gesch. der arab. Litteratur* (Leiden, 1937) S, I, p. 390.

[4] MS, fol. 79a.

[5] $x^2 + 5 = \square = y^2$

$y > x$

" ... If you put down what is possessed, i.e. a square, which has a root called a thing, and add five dirhams to it, then it is a square plus five dirhams. It is necessary that it appear as a root. It is known that its root is larger than the thing for if its square is alone, then its root equals a thing. Then put its root as a thing and a number; it appears from the number that if it is multiplied by itself, it is less than the dirhams that are added to the square. In this problem, it is five dirhams. Then set it as a thing plus a dirham and multiply it by itself; it appears as a square plus a dirham and two things. Take the square plus five dirhams; take away the square plus one dirham from the square plus five dirhams. There remains two things. You equate the four dirhams to give the thing as two and the square as four. If you add five dirhams to it, then it is nine; its root is then three.

"If you put its root as a thing and two dirhams[6] and then multiply it by itself, it gives a square plus four things plus four dirhams which is equal to a square plus five dirhams. Subtract, then, a square plus five dirhams to give four things which is then equal to a dirham, or the thing equals one-quarter of a dirham which is the root of the square. The square is one-half of [one-eighth of] a dirham. If you add five dirhams, then it is five and one-sixteenth,[7] and its root is two and one-quarter dirhams. If you wish let this square be a thing plus a half-dirham or a thing plus one and a half dirhams, or a thing plus one-third dirham, or whatever number you wish to appear after the thing to which it is added. If you multiply it by itself, it is less than five. Then, for that, gather what occurs of this kind."[8]

The next equation,[9] in modern notation,[10] is

$$x^2 - 10 = \square = y^2$$

It is solved by the author as follows,

$$\text{Let } \sqrt{x^2 - 10} = x - 1;$$
$$\text{then } x^2 - 10 = x^2 - 2x + 1$$
$$2x = 11; \; x = 5\frac{1}{2}; \; x^2 = 30\frac{1}{4}$$

Assume $x^2 + 5 = (x + 1)^2$
$$= x^2 + 2x + 1$$
∴ $x = 2; x^2 + 5 = 3^2$ or $x^2 = 4$
Only an integral solution is sought by the author.

[6] $(x + 2)^2 = x^2 + 4x + 4 = x^2 + 5$
$$4x = 1; \; x = \frac{1}{4}; \; x^2 = \frac{1}{2} \cdot \frac{1}{8}$$

[7] Generally, $x^2 + 5 = (x + a)^2 = x^2 + 2ax + a^2$
$$\therefore \quad x = \frac{5 - a^2}{2a}$$
Only positive values are considered and the stipulation is that $a^2 < 5$.

[8] MS, fols. 79a–79b.
[9] MS, fols. 79b–80a.
[10] Cf. Heath, *Diophantos of Alexandria* (London, 1938) pp. 166–167; 205–206.

$$x^2 - 10 = 20\frac{1}{4}; \quad \sqrt{20\frac{1}{4}} = 4\frac{1}{2}$$

Brahmagupta, in the early seventh century, in what is considered the golden age of Hindu algebra, stated the algebraic rule for negative numbers and discussed the so-called Pellian equation $x^2 - Dy^2 = 1$ (or $Dy^2 + 1 = x^2$), and $ax + by = c$ a, b, c, as constants and integers. Brahmagupta went a step further to solve $Nx^2 \pm c = y^2$ in positive integers. This would be the more general equation of the cases of $x^2 + 5 = y^2$ and $x^2 - 10 = y^2$. Brahmagupta obtained a single solution in positive integers of the general equation so that he could derive an infinite number of other integral solutions by making use of the integral solutions of $Nx^2 + 1 = y^2$. If (p, q) is a solution of $Nx^2 \pm c = y^2$ and (α, B) is a solution of $Nx^2 + 1 = y^2$, then by the principle of composition,

$$x = p\beta \pm q\alpha \text{ and } y = q\beta \pm Np\alpha$$

will be a solution of the former. This operation may be repeated to obtain many solutions. Abū Kāmil has a simpler solution since N is made equal to one.

$$x^2 + c = y^2 = (x + a)^2$$

$$\therefore \quad x = \frac{c - a^2}{2a} \quad \text{where} \quad a^2 < c$$

Al-Karajī (ca. 1010) discusses this type of problem.[11]

$$10 - x^2 = y^2; \ 30 - x^2 = z^2$$

Let $x^2 = 10 - x_1^2$

then $20 + x_1^2 = z^2$

Take z so that $x_1^2 < 10$; say $z = x_1 + 3$;

then one has $20 + x_1^2 = x_1^2 + 6x_1 + 9$

$$x_1 = \frac{11}{6}, \ x_1^2 = \frac{121}{36}, \ x^2 = \frac{239}{36}.$$

Specifically, he also works out the same problem of $x^2 + 5y^2$ by letting $y = x + 1$, then solving to get $x = 2$.[12] Leonardo of Pisa[13] (1220) also used the problem $x^2 \pm 5 = y^2$ in his algebra in connection with his number theory development. The strong influence of abū Kāmil upon Leonardo has already been demonstrated conclusively by Levey.[14] Beha-Eddin (ca. 1600) stated one of the seven unsolved problems to be.

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[11] F. Woepcke, *Extrait du Fakhrī...par Alkarkhī* (Paris, 1953) pp. 85, III.

[12] Al-Karajī, p. 84.

[13] B. Boncompagni, *Scritti di Leonardo Pisano* (Roma, 1857–1862), II, p. 253–283; L. Dickson, *History of the Theory of Numbers* (New York, 1952) II, p. 460 for relation to number theory and especially congruent numbers.

[14] M. Levey, *op. cit.*, pp. 6, 217–220.

$$\left\{ \begin{array}{l} x^2 + 10 = \square \\ x^2 - 10 = \square \end{array} \right.$$

This was termed impossible by G.H.F. Nesselmann.[15] Fermat proved that the difference of two biquadrates is never a square.[16] No congruent number can be a square. Leonardo was aware of this but his proof was incomplete.[17]

A similar problem is:

$$x^2 \pm ax = \square$$

In the text, there are $x^2 + 3x = \square$ and $x^2 - 6x = \square$.[18] Diophantos (VI, 12) discusses a right triangle where the general equation $ax^2 + bx = \square$ applies.[19] In abū Kāmil's problems, $a = 1$, making it a simple solution as in the earlier examples. He has a second method:

$$x^2 + ax = \square = k^2x^2 = y^2$$

$$\therefore \quad x = \frac{a}{k^2 - 1}; \, y = \frac{ak}{k^2 - 1}$$

$$ax^2 + bx + c = \square$$

Further, abū Kāmil develops solutions for such equations as:

$$x^2 + 10x + 20 = \square$$
$$x^2 + ax + b = (x + y)^2 = x^2 + 2xy + y^2$$
$$x = \frac{y^2 - b}{a - 2y} \text{ where } y < 5 \text{ and } y^2 < 10$$

Bhaskara II in his *Bījaganita* (1150)[20] mentions the solution of the general indeterminate equation of the second degree. These equations are not treated in Brahmagupta or in other known Indian works before this time. His rules may be shown in the general solution for the problem, "What number being doubled and added to six times its square becomes capable of yielding a square root?"[21]

$$6x^2 + 2x = y^2$$

Multiply through by six and add one to each side to get:

$$(6x + 1)^2 = 6y^2 + 1$$

Then Bhaskara II states that by the method of square-nature, the roots of $6y^2 + 1$

[15] "Essenz der Rechenkunst von Beha-Eddin" (Berlin, 1843) p. 55.

[16] *Oeuvres de Fermat* (Paris, 1891) I, p. 340.

[17] Dickson, *op. cit.*, II, p. 615.

[18] MS, fol. 80a.

[19] Heath, *op. cit.*, pp. 233–235; Cf. Dickson, *op. cit.*, pp. 176ff. in problems on areas of right triangles.

[20] B. Datta and A. N. Singh, *History of Hindu Mathematics* (Bombay, 1962), II, pp. 88, 90, 139.

[21] *Ibid.*, II, pp. 184ff.

are: the lesser 2 and the greater 5, or the lesser 20 and the greater 49. The greater root is equated with the square root of the first side to get the value of x as 2/3 or 8.

Starting with the general equation, $ax^2 + bx + c = y^2$, complete the square to get:

$$(ax + \frac{1}{2}b)^2 = ay^2 + \frac{1}{4}(b^2 - 4ac).$$

Let $z = ax + \frac{1}{2}b$ and $k = \frac{1}{4}(b^2 - 4ac)$.

Then $ay^2 + k = z^2$

If $y = t$, $z = m$ are found empirically as solutions; then another solution is

$$\begin{cases} y = tq \pm mp \\ z = mq \pm atp \end{cases}$$

where $ap^2 + 1 = q^2$

Hence, a solution of $ax^2 + bx + c = y^2$ is

$$x = \frac{-b}{2a} + \frac{1}{a}(mq \pm artp)$$

If $m = ar + \frac{b}{2}$ (i.e., $x = r$ when $z = m$),

then $x = \frac{1}{2a}(bq - b) \pm qr \pm tp$

where $ap^2 + 1 = q^2$ and $ar^2 + br + c = t^2$.[22]

Fermat's Equation

The Pellian equation is related to the general equation $ax^2 + bx + c = \square$. Diophantos and abū Kāmil both discussed types of the Pellian equation; the former treated of the $ax^2 + b = \square$ type and the latter $x^2 + b = \square$.

Fermat's equation, or incorrectly called the Pellian equation, has an infinite number of solutions according to Fermat (1657). This was proved by Lord Brouncker and J. Wallis, and later an improved method was given by L. Euler (1765) for obtaining solutions. Euler was a giant in indeterminate analysis.

Double Equations of the First Degree

Simultaneous equations in the abū Kāmil text range from simple cases to fairly complex quadratics with indeterminate solutions. Similarly, Diophantos (II, 11) solves analogous examples as:

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[22] *Ibid.*, p. 185.

$$\begin{cases} x + 2 = y^2 \\ x + 3 = z^2 \end{cases}$$

He takes the difference between these double equations and resolves it into two factors as 4 and 1/4. Then, the square of half the difference between these factors is taken and equated to the lesser expression. Or, the square of half the sum is equated to the greater.[23] Number 27 of abū Kāmil may be compared with this process. This is briefly stated by the author and will be quoted.

"If one says there is a square which has a root, and if you subtract it from ten of its roots minus eight dirhams, it will have a root. Then, if you take hold of this problem, multiply half of the roots by itself. Then subtract from what is gathered of the dirhams. You divide what remains into two parts for every one root, so then the problem comes out to what you wish of the answer. If you do not divide what remains into two parts for every one root, then the problem cannot be solved. When this is so, multiply half of the roots by itself. The total is like the dirhams or less; then the problem comes out. Multiply half of the roots by itself, and in this problem five becomes twenty-five. Subtract from it the eight dirhams; then it is seventeen. Divide it into two parts so that each part has a root; then they are sixteen and one. Then you say that you wish a square plus sixteen dirhams equals ten roots minus eight dirhams, or a square plus a dirham equals ten roots minus eight dirhams. Then the square you desire comes out to thirty-six. If you wish sixteen, then take a square plus a dirham equal to ten roots minus eight dirhams to give the desired square as eighty-one, and if you wish, one."[24]

The Bakhashālī treatise (ca. 10th cent.) is probably one of the more important in Indian mathematics to give solutions for double equations of the first degree.[25] This text solves:

$$\begin{cases} x + a = y^2 \\ x - b = z^2 \end{cases}$$

Its solution is $x = \left\{ \dfrac{1}{2} \left[\dfrac{a+b}{m} - m \right] \right\}^2 + b$

where m is any integer. In the text, m is taken as 2.

Mahāvīra (9th cent.) was well acquainted with these operations. Brahmagupta (628) improved upon this to solve the general case:

$$\begin{cases} x \pm a = y^2 \\ x \pm b = z^2 \end{cases}$$

Al-Karajī gives the problem:[26]

[23] Heath, *op. cit.*, pp. 146–147.

[24] MS, fol. 90b, $10x - 8 - x^2 = y^2$ or, $y^2 + x^2 - 10x + 25 = 17 = 4^2 + 1^2$ which admits of an infinite number of solutions.

[25] G. R. Kaye, *The Bakhshālī Manuscript* (Calcutta, 1927) p. 149, pp. 42–43.

[26] F. Woepcke, *op. cit.*, p. 86.

$$\begin{cases} x + 10 = y^2 \\ x + 15 = z^2 \end{cases}$$

Nārāyana (1357) gives the solution for the same type of problem:

$$\begin{cases} x + a = y^2 \\ x + b = z^2 \end{cases} \quad \text{where } a > b:$$

Bhaskara II treated the general case:[27]

$$\begin{cases} ax + c = y^2 \\ bx + d = z^2 \end{cases}$$

In the problem

$$\begin{cases} 3x + 1 = y^2 \\ 5x + 1 = z^2 \end{cases}$$

let $y = 3u + 1$; then, in the first equation,

$$x = 3u^2 + 2u.$$

Substitute in the second equation to get $15u^2 + 10u + 1 = z^2$ which may be solved.

Double Equations of the Second Degree

Abū Kāmil gives as a type of double equation:

$$\begin{cases} x^2 + 3x + 1 = y^2 \\ x^2 - 3x + 2 = z^2 \end{cases}$$

It was well known to the Indians who solved many much more difficult problems of the second degree. Bhaskara II solved such types as:

$$\begin{cases} ax^2 + by^2 + e = u^2 \\ cx^2 + dy + f = v^2 \end{cases}$$

and

$$\begin{cases} a^2x^2 + bxy + c^2y^2 = u^2 \\ dx^2 + exy + fy^2 + g = v^2 \end{cases}$$

He also discussed problems of double equations of higher degrees. In abū Kāmil's work, there are no equations higher than the second degree.

At the end of the abū Kāmil text are mainly linear multiple equations of a simple type. These resemble equations found in inheritance problems of other Arabic works. On fol. 104a, there is a relatively unimportant indeterminate problem which would appear as:

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[27] Datta, *op. cit.*, 11, pp. 261ff.

$$\begin{cases} 20x + 15y + 10z = 18 \\ x + y + z = 1 \end{cases}$$

These reduce to

$$10x + 5y = 8 \,.$$

It is necessary at this point to select two positive fractions for x and y such that $x + y < 1$ because of the second equation above.

A somewhat similar problem is on fol. 104b where "A *raṭl* [coin] is valued at five dirhams, another *raṭl* is four dirhams, and ten *raṭls* is one dirham. From all these, obtain a *raṭl* valued at two dirhams. This question has more than a single answer."

At the time of abū Kāmil, Arabic work in indeterminate equations did not come up to the standard set by Hindu mathematicians. It is certain, however, from abū Kāmil's work that the Arabs knew much of the Indian algebra in this area as well as some solutions by Diophantos. Al-Karajī (ca. 1010) improved upon abū Kāmil's treatise not only in those problems discussed by the latter but also in treating algebraic equations of higher than the second degree.[28] Abū Kāmil may have laid the groundwork but it was al-Karajī who repeated many of the formers' examples and elaborated much upon them.[29] Leonardo Fibonacci, in bringing this work to Europe later, repeated many of the same examples. Thus, there is a discernible outline of the growth in knowledge regarding indeterminate equations up to the thirteenth century A.D. The story is still a discontinuous one, however, with much more remaining to be unfolded particularly in the manner in which indeterminate problems affected the development of number theory.

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[28] *Woepcke, op. cit.,* pp. 129ff.

[29] Levey, *op. cit.,* p. 6 for the debt of al-Karajī to abū Kāmil. Cf. also A. P. Juschkewitsch, *Geschichte der Mathematik im Mittelalter* (Basel, 1964) pp. 220ff. For indeterminate equations in Chinese mathematics, see J. Needham, *Science and Civilization in China* (Cambridge, 1959) III, pp. 119ff; D. E. Smith and Y. Mikami. *A History of Japanese Mathematics* (Chicago, 1914) pp. 192, 196, 233, 246.

Newton's *Quantitas Materiae*

Masao WATANABE* and Masakazu YOSHINAKA**

It was more than ten years ago that one of the present authors, Masao Watanabe, published his view concerning Newton's concept of mass revealed in the *Principia*.[1] Commenting on this paper, a different opinion was then presented by Kiyonobu Itakura.[2] Watanabe replied to Itakura later in another paper confirming and strengthening his original point.[3] The present paper will first review this academic dispute, will then refer to John Herivel's more recent work, and will end with the presentation of some of the results of the recent studies made by the present authors.

Newton, in the first of the eight Definitions at the beginning of the *Principia*, defined "the quantity of matter" (*quantitas materiae*) as follows:

> The quantity of matter is the measure of the same, arising from its density and bulk conjointly.[4]

As cited by Florian Cajori, Ernst Mach criticized this definition as being circular, since density can only be defined as the mass of unit volume; but Cajori also noted that Henry Crew held that "it is both natural and logically permissible to define mass in terms of density" at the time of Newton when "the density of water was taken arbitrarily to be unity"; whereas Edmund Hoppe, according to Cajori, assumed that Newton's atoms were of the same size and consequently the densities of bodies were proportional to the numbers of such atoms in equal volumes.[5] Cajori himself was critical of Hoppe's interpretation because it did not accord with Newton's corpuscular idea as described in his *Opticks*.[6] E. A. Burtt, W. C. Dam-

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[1] Masao Watanabe, "Newton's Concept of Mass as revealed in his *Principia*," *Kagakusi Kenkyu* (*Journal of History of Science, Japan*), No. 54, 1960, pp. 1–4.

[2] Kiyonobu Itakura, "Newton's Definition of Mass in *Principia* and Galilei's Atomism in *De Motu*," *Kagakusi Kenkyu*, No. 59, 1961, pp. 29–31.

[3] Masao Watanabe, "Newton's Concept of Mass—A Reply to Dr. Itakura," *Kagakusi Kenkyu*, No. 84, 1967, pp. 191–194.

[4] Isaac Newton, *Mathematical Principles of Natural Philosophy*, Motte-Cajori translation, Berkeley, 1947, p. 1.

[5] Ernst Mach, *Die Mechanik in ihrer Entwicklung* (ed. 8), Leipzig, 1921, p. 188; Henry Crew, *The Rise of Modern Physics*, Baltimore, 1928, p. 124; Edmund Hoppe, *Archiv für Geschichte der Mathematik, der Naturwissenschaften und der Technik*, n.s., Vol. 11, 1929, pp. 354–361 (according to Cajori's Appendix, Newton's *Principles, op. cit.*, pp. 638–639).

[6] Isaac Newton, *Opticks*, 3rd ed., 1721, pp. 375–376 (Cajori, *Ibid.*).

pier, and Max Jammer, on the other hand, suggested that Newton's definition of mass as the product of density and bulk was under the influence of Boyle's law, in which the quantity of the gas under varying pressure was determined by the product of its voluem and density.[7]

The above mentioned might well explain why Newton's definition of mass took that particular form, but did not go deep enough into Newton's concept of mass itself, according to Watanabe.   He claimed, therefore, that Newton's concept must be clarified from Newton's own writings and he suspected that the clue of the matter consisted in the latter part of Newton's comment to Definition I, which reads:

> And the same [quantity of matter] is known by the weight of each body, for it is proportional to the weight, as I have found by experiments on pendulums, very accurately made, which shall be shown hereafter.[8]

These experiments on pendulums are again mentioned in Corollary VII to Proposition XXIV, Book II, that is:

> And by experiments made with the greatest accuracy, I have always found the quantity of matter in bodies to be proportional to their weight.[9]

These experiments are more fully described in Proposition IV, Book III:

> It has been now for a long time, observed by others, that all sorts of heavy bodies (allowance being made for the inequality of retardation which they suffer from a small power of resistance in the air) descend to the earth *from equal heights* in equal times; and that equality of times we may distinguish to a great accuracy, by the help of pendulums.   I tried experiments with gold, silver, lead, glass, sand, common salt, wood, water, and wheat.   I provided two wooden boxes, round and equal: I filled the one with wood, and suspended an equal weight of gold (as exactly as I could) in the centre of oscillation of the other.   The boxes, hanging by equal threads of 11 feet, made a couple of pendulums perfectly equal in weight and figure, and equally receiving the resistance of the air.   And, placing the one by the other, I observed them to play together forwards and backwards, for a long time, with equal vibrations.   And therefore the quantity of matter in the gold (by Cor. I and VI, Prop. XXIV, Book II[10]) was to the quantity of matter in the wood as the action of the motive force (or *vis motrix*) upon all the gold to the action of the same upon all the wood; that is, as the weight of the one to the weight of the other: and the like happened in the other bodies.   By these experiments, in bodies of the

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[7] E. A. Burtt, *The Metaphysical Foundations of Modern Physical Science*, Garden City, N.Y., 1954, p. 241; W. C. Dampier, *A History of Science and its Relations with Philosophy and Religion*, Cambridge, England, 1949, p. 155; Max Jammer, *Concepts of Force*, Cambridge, Massachusetts, 1957, p. 118.

[8] *Principles, op. cit.,* p. 1.

[9] *Ibid.,* p. 304.

[10] Concerning the relationship of the mass, weight, period of oscillation, and the length of a single pendulum. *Ibid.,* pp. 303–304.

same weight, I could manifestly have discovered a difference of matter less than the thousandth part of the whole, had any such been.[11]

Newton analyzed the old problem of falling bodies from an entirely new point of view, namely from the aspect of his new dynamics. He saw that since all falling bodies are in fact equally accelerated so far as the resistance of the air may be neglected, the force which causes this equal acceleraton in each body, which is nothing but the weight of the body, must be proportonal to the quantity of matter or inertial mass in the same body, as may be inferred from Newton's Law II.[12] To see whether a precise proportionality of this kind between weight and mass exists in various sorts of material, he had to appeal to experiments, since there exists no other means than to empirically establish this proportionality. Therefore, Newton performed experiments on pendulums, which may be considered as a far more accurately designed type of experiment on falling bodies. He tried these experiments with various sorts of materials conceivable, including, interestingly enough, wheat, which has weight and falls down like other materials but possibly goes upward also when it sprouts out.

Thus, behind his seemingly circular or equivocal presentation of the definition of mass, there existed a very clear and novel concept of mass, mass as inertial mass, explicitly distinguished from weight. In this connection, moreover, his blurred definition of mass itself as the product of density and bulk of a body may also become intelligible, if we read it together with the following passage of Newton's in Corollary IV to Proposition VI, Book III:

> By bodies of the same density, I mean those whose inertias are in the proportion of their bulks.[13]

Once such a proportionality was empirically established and was proved to conform with the entire system of the theories, then there may have been little practical need to make deliberate distinction between inertial mass and weight or gravitational mass. But, without first conceiving the quantity of matter afresh as the measure of inertia inherent to a body but distinct from its weight, neither the whole establishment of Newtonian dynamics nor the formation of the new concept of weight as universal gravitation would have been possible. The concept of mass here played a really important role.

This very clear and original concept of mass of Newton's own was, however, set forth in a very ambiguous presentation. The reason may have probably been related, at least partly, to the following fact. Although physics is an inductive science by nature and the definitions of physical quantities can be given only operationally, Newton presented his new system of physics in a form of deductive science, such as Euclid's geometry, and started the whole book with "Definitions" and "Axioms, or Laws of Motion." It was therefore necessary for him to supplement these

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[11] *Ibid.*, p. 411.

[12] Newton's own argument to the same effect as to pendulums is seen in his Proposition XXIV and immediately following Corollaries, *Ibid.*, pp. 303–304.

[13] *Ibid.*, p. 414.

Definitions and Laws with closely following comments and Scholia and to give
further explantions in the latter part of his work to show how these defined quantities
and axiomatically presented laws are in reality connected with physical phenomena.
Thus, notwithstanding the clearness of his concept of mass, Newton might well
have written down his definition of mass under the influence of contemporary
ideas of atoms, corpuscles, density, or of Boyle's law.

The above is the substance of Watanabe's paper published early in 1960.[14]
To this paper, Itakura wrote his own comments,[15] in which he stressed the importance
of the influence of atomism on Newton's Definition I and in this connection he held
that Newton's concept of mass was of more gravitational character originating in
atomism, while admitting that Newton had reached to a very clear idea of inertial
mass.

Itakura appealed to Galileo's *De Motu* as evidence.   In this work, Galileo
gave a distinction between apparent weight and "natural and intrinsic weight" of
a body and thought of the latter in connection with the density and the bulk of
matter, where density was related to the number of particles in a given volume of
the matter.[16]   This must have been the common place of atomists of the time
including Newton himself, Itakura argued, and he concluded that Newton's mass
defined in Definition I must have been mass of atomism and mass to be determined
by weight rather than inertia.

To this comment of Itakura's, Watanabe replied somewhat later.[17]   He claimed
that, while he was concerned mainly about how Newton thought of mass, Itakura
was more concerned about how Newton wrote down its definition.   So far as
Newton's concept was concerned, Newton thought of mass unequivocally as inertial,
Watanabe reaffirmed, by citing relevant passages from the text of the *Principia*
and elsewhere, which included the following two passages from different sources:

Definition 15.   Bodies are denser when their inertia is more intense, and rarer
when it is more remiss.[18]

Nor that I affirm gavity to be essential to bodies: by their *vis insita* I mean
nothing but their inertia.   This is immutable.   Their gravity is diminished as
they recede from the earth.[19]

In supplementing the above, Watanabe indicated that if, as Itakura pointed
out, Galileo's theory of matter in his *De Motu* be appropriate to interpret Newton's
definition of mass, then Galileo's descriptions of his experiments on pendulums

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[14] Watanabe (1960), *op. cit.*
[15] Itakura, *op. cit.*
[16] Galileo Galilei, *On Motion and On Mechanics*, tr. by I. E. Drabkin & Stillman Drake, Madison, 1960, pp. 15 & 88 (*Le Opere di Galileo Galilei*, Vol. 1, pp. 252–253 & 318).
[17] Watanabe (1967), *op. cit.*
[18] *De Gravitatione et Aequipondio Fluidorum*, A. R. Hall & M. B. Hall, *Unpublished Scientific Papers of Isaac Newton*, Cambridge, England, 1962, p. 150.
[19] Newton's comment to Rule III, *Principles, op. cit.*, p. 400.

in his *Dialogo* and *Discorsi*[20] must have more pertinence. These experiments can well be the immediate precedent for Newton's, since they are the means Galileo invented to investigate the free fall phenomena more accurately and since the concept of mass there exhibited seems to be anticipating Newton's.

Watanabe now furthered his original view by incorporating Max Jammer's new interpretation as presented in his just published book, *Concepts of Mass*,[21] and he proposed in the same paper that Newton's concept of mass as inertial possibly went down to the level of atoms of which matter was composed. Thus, Newton may have thought of density as the sum of the inertial mass of the constituent atoms or particles in a unit volume of the matter in question, and consequently he defined mass as the product of such density and bulk, which interpretation makes his Definition I more intelligible.

Thus far, the present authors have reviewed two papers of Watanabe's and one related paper of Itakura's. The consequences are in very good accordance with the results of more recent and documented work of John Herivel who has made careful studies of those Newtonian manuscripts which reveal the making of the *Principia*.[22] Herivel points out:

> A brief discussion of the use of pendulum experiments to prove this proportionality occurs at Def. 11 of MS. Xa [1684–85],[23] followed by a much fuller discussion at Def. 7 of MS. Xb [1684–85][24] where the use of *pondus* as an alternative to quantity of matter or mass, even in the absence of any gravitational effects, is brought out much more clearly than in the *Principia*.[25]

Herivel expresses his view concerning Newton's concept and definition of mass as follows:

> However, this flaw in the definition of quantity of matter in no way interfered with the development of Newton's thought in the *Principia*, for when he had to compare the quantities of matter of two bodies he did so by making an appeal to his second law of motion. It is this law, therefore, rather than Def. I, which must be regarded as giving the real, operational definition of mass in Newton's dynamics.
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> As to the original development of the concept, we can be confident that the obvious fact of inertia, or *Vis Insita*, would inevitably have led Newton to attach a measure to it. For example, collision experiments with bodies of

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[20] Galileo Galilei, *Diologue Concerning the Two Chief World Systems*, tr. by Stillman Drake, Berkeley, 1962, pp. 151–152; *Dialogues Concerning Two New Sciences*, tr. by Henry Crew & Fonso de Salvio, New York, 1914, pp. 84–87.

[21] Max Jammer, *Concepts of Mass in Classical and Modern Physics*, New York, 1961, pp. 64–74.

[22] John Herivel, *The Background to Newton's PRINCIPIA*, Oxford, 1965, 337 pp.

[23] "Definition 11" is wholly quoted later in the text of the present paper, p. 33.

[24] This discussion in *De Motu Corporum* is wholly quoted later in the text of the present paper, p. 33.

[25] Herivel, *op. cit.*, p. 25.

equal size, but of different material, revealed that the inertias of such bodies were not entirely determined by their sizes. Two bodies of equal size could have quite different capacities to sustain their states of rest or motion. That he then attempted to give a definition of mass independently of the second law was understandable, though perhaps a trifle unfortunate.[26]

To all that mentioned in the above, the present authors want to add a further and a new conjecture of their own which, they believe, will make Newton's Definition I even more understandable.

This definition of mass in reference to density and bulk has hitherto been explained as mainly owing to the atomistic, or rather corpuscular idea of matter of the time. It may well be so. But, is it not more probable and more immediate to Newton, that he, when making the definition of the quantity of matter, thought of it as the product conjointly of density as intensity and bulk as extension? Such an idea of perceiving a certain quantity as the product of intensity and extension was developed in the tradition of the Merton School,[27] and Newton must have taken it over. In fact, he wrote in his *De Gravitatione et Aequipondio Fluidorum* (MS. Add. 4003) [1664–69]:

> Moreover, the quantity of these powers, namely motion, force, *conatus*, impetus, inertia, pressure and gravity may be reckoned in a double way: that is, according to either intension or extension.
>
> *Definition 11.* The intension of any of the above-mentioned powers is the degree of its quality.
>
> *Definition 12.* Its extension is the amount of space or time in which it operates.
>
> *Definition 13.* Its absolute quantity is the product of its intension and its extension. So, if the quantity of intension is 2, and the quantity of extension 3, multiply the two together and you will have the absolute quantity 6.
>
> Moreover, it will help to illustrate these definitions from individual powers. . . . And the absolute quantity of motion is composed of both the velocity and the magnitude of the moving body. So force, *conatus*, impetus or inertia are more intense as they are greater in the same or an equivalent body: they have more extension when the body is larger, and their absolute quantity arises from both. . . . And the absolute quantity [of pressure] results from the intension of the pressure and the area of the surface pressed . . . , and absolutely speaking the quantity of gravity is the product of the specific gravity and bulk of the gravitating body.[28]

Here, the absolute quantity of motion, impetus, inertia, pressure, gravity, and so on, is thought to be determined by the product of their intensity and extension.

[26] *Ibid.,* pp. 25–26.

[27] Marshall Clagett, *The Science of Mechanics in the Middle Ages*, Madison, 1961, pp. 199–219.

[28] Hall, *op. cit.,* pp. 114–115 & p. 149, (Herivel, *op. cit.,* p. 225 & pp. 231–232).

In a later manuscript, *De Motu Corporum in medijs regulariter cedentibus* (MS. Add. 3965) [1684–85], Newton wrote:

> Definition 11 The quantity of motion is that which arises from the velocity and quantity of a body conjointly. Moreover the quantity of a body is to be estimated from the bulk of the corporeal matter which is usually proportional to its gravity. The oscillations of two equal pendulums with bodies of equal weight are counted, and the bulk of matter in both will be inversely as the number of oscillations made in the same time.[29]

In *De Motu Corporum* (MS. Add. 3965) [1684–85] he said:

> 7. By the heaviness of a body I understand the quantity or bulk of matter moved apart from considerations of gravity as often as it is not a matter of gravitating bodies. To be sure the heaviness of gravitating bodies is proportional to their quantity of matter by which it can by analogy be represented or designated. The analogy can actually be inferred by equal pendulums as follows. The oscillations of the same weight are counted and the bulk of matter in each case will be inversely as the number of oscillations made in the same time. But careful experiments made on gold, silver, lead, glass, sand, common salt, water, wood, and wheat led always to the same number of oscillations. On account of this analogy and lacking a more convenient word I represent and designate quantity of matter by heaviness, even in bodies in which there is no question of gravity.[30]

It should be noticed here that Newton's definition of the quantity of motion in the above quoted Definition 11 is a modification of the one described in the immediately preceding quotation and is already very much similar to Definition II, *Principia*, which reads:

> The quantity of motion is the measure of the same, arising from the velocity and quantity of matter conjointly.[31]

Therefore, on the basis of the following facts:

(1) that the quantity of motion was originally conceived as the product of the velocity as intensity and the magnitude of the body as extension,

(2) that each of such quantities as impetus, inertia, etc. was also thought of to be determined by the product of its intensity and extension,

(3) that the wording of Definition II, *Principia*, quoted in the above is exactly the same as that of its preceding Definition I which defines mass as being inertial and which reads:

> The quantity of matter is the measure of the same, arising from its density and bulk conjointly.[32]

(4) and that the very important pendulum experiments which Newton men-

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[29] Herivel, *op. cit.*, p. 306 & p. 311.

[30] *Ibid.*, pp. 316–317 & p. 319.

[31] *Principles, op. cit.*, p. 1.

[32] *Ibid.*

tioned in his comments immediately following Definition I were already described in the above Definition II of the quantity of motion and this in connection with "the bulk of matter" which in effect implies inertial mass, it may now be very safely inferred that both Definition I and Definition II in *Principia* define the quantity of matter and the quantity of motion respectively as *quantity* in terms conjointly of density or velocity as *intensity* and bulk or quantity of matter as *extension* respectively. This interpretation of the present authors, they believe, certainly makes Newton's Definition I more intelligible and its historical situation clearer.

The Genesis of the Bohr Atom Model and Planck's Theory of Radiation

Tetu Hirosige* and Sigeko Nisio*

1. Introduction

In 1964–65 we considered the origin of Bohr's quantum theory of atomic constitution and concluded as follows:[1]

1. In the first decade of the twentieth century, rather the chemical considera-
    tion afforded the useful foundation for constructing an atomic model than
    the spectrum. J. J. Thomson's positive sphere model, which was the
    most successful theory of atomic structure of the time, aimed at explaining
    the chemical properties of elements. It may also be stressed that Thomson's
    model was the first theory that formulated the two historically important
    notions in the development of atomic model, that is, the notions that the
    chemical properties of an atom were determined by the configuration of
    electrons in the atom, and that the intra-atomic electrons distributed them-
    selves in several rings.

2. Bohr's consideration of atomic constitution was begun with the intention
    to give an explanation of the chemical properties of atoms and molecules.
    In this attempt Bohr inherited the aim as well as the two fundamental
    notions above of Thomson's theory.

3. The common understanding[2] that Bohr formulated his theory by borrowing
    the idea of quantizing the angular momenta of orbital electrons from
    J. W. Nicholson is quite contrary to the fact. Nicholson cannot be said
    to have put forth such a clear idea that the electron orbit would be deter-
    mined by the condition of quantized angular momentum. Furthermore
    Bohr's condition for fixing the electron orbit was not stated in terms of
    the angular momentum.

4. Bohr's actual quantum condition $W = (\tau h/2)\omega$, where W is the amount
    of energy emitted during the binding of an electron by the nucleus, ω the
    number of rotation of the electron on its final orbit, and τ an integral

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[1] T. Hirosige and S. Nisio, "Formation of Bohr's Theory of Atomic Constitution", *Jap. Stud.
Hist. Sci.*, No. 3, 6–28 (1964). T. Hirosige, "On the Background of Bohr's Theory of Atomic
Constitution", *Actes du XIᵉ Congrès international d'Histoire des Sciences*, III, 430–434 (1965).

[2] For example, E. T. Whittaker, *A History of the Theories of Aether and Electricity, II. The
Modern Theories*, Thomas Nelson, London, 1953, pp. 107–109.

number, is inferred to be introduced by an analogy of, or at a suggestion
from, Planck's theory of radiation of 1911–12.

5. Planck's theory is remarkable in its foreshadowing some of the novel
    features of post-Bohr theory of radiation. First, it discarded the classical
    notion that the oscillation of charged particle directly produces the ele-
    ctromagnetic waves. Second, the emission of radiation is regarded as
    an instantaneous and statistical process. Lastly, the emission of radiation
    is suspected to be connected with a binding or a release of the electron.

Recently John L. Heilbron and Thomas S. Kuhn have published an interesting
article on "The Genesis of the Bohr Atom,"[3] using plenty of materials gathered by
the project "Sources for History of Quantum Physics". Making also use of Bohr's
personal correspondences, they have attempted to reconstruct a possible course
of the development of Bohr's thought from his doctoral thesis of 1911 to the com-
position of his renowned paper "On the Constitution of Atoms and Molecules"
of 1913. In their paper they have criticized our assertion about the relation of
Bohr's theory to Planck's theory. Challenged by their criticism, we have recon-
sidered the problem anew by examining also some new materials to which we
formerly did not have access. The following is partly a reply to their criticism based
on this reconsideration. It will also present some new remarks about the problem.

2. Conclusions of Heilbron and Kuhn

The major results of Heilbron and Kuhn's paper may first be summarized as
follows:

1. Throughout all the efforts of Bohr from the year 1911 on, various germs
    of the ideas involved in the 1913 paper may be seen. Especially it is sug-
    gested that the notion of the relation $W \sim h\nu$, where W is the energy and
    ν is the frequency of the system considered, was gradually formed through
    his deep concern with J. J. Thomson's doublet model of atom[4], which was
    introduced in order to explain the photo-electric effect, and also with the
    investigations on the magneton pursued by number of distinguished physi-
    cists since 1911.

2. The influence of Nicholson's theory of spectra is stressed. Through a
    serious struggle with Nicholson's theory, Bohr became to turn his attention
    to the spectrum and reached such an important idea as the existence of
    excited states.

3. Bohr's quantum condition $W = (\tau h/2)\omega$ is concluded to have been obtained
    semi-empirically from Balmer's formula. Namely, Bohr should have
    fixed the factor $1/2$ so as to give a numerical agreement with the Balmer
    formula.

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[3] John L. Heilbron and Thomas S. Kuhn, "The Genesis of the Bohr Atom", *Hist. Stud. Phys. Sci.* **1**, 211–290 (1969) (Hereafter cited as Heilbron-Kuhn)

[4] J. J. Thomson, "On the Theory of Radiation", *Phil. Mag.*, (6) **20**, 238–247 (1910).

4. Consequently, what Bohr called "relation to Planck's theory" is concluded
to be merely an *ad hoc* rationalization to enhance the plausibility of his
theory. Our former paper which attached much importance to Planck's
theory should therefore be criticized.

Of these conclusions of Heilbron and Kuhn, the first is possibly right. We
agree with them in admitting that the investigation on the electron theory of metal
and interests in Thomson's doublet model and the magneton would have formed
the background of Bohr's theory. But we are sceptical about suggesting that
Bohr had formed a clear conception of the theory of atomic constitution since very
early. In his thesis, having derived the Rayleigh-Jeans formula by a quite general
consideration, Bohr asserts that "it therefore seems that it is impossible to explain
the law of heat radiation which agrees with the experience if one retains the foun-
dation on which the electromagnetic theory is based." And he continues: "This
failure has very likely resulted from this, that the electromagnetic theory does not
agree with the real conditions and can only give correct results when it is applied
to a large number of electrons (as in ordinary bodies) or to determine the average
motion of a single electron in a comparatively long time (such as in the calculation
of the motion of cathode rays), but cannot be used to investigate the motion of a
single electron in a short time".[5] It is quite clear that already at this time Bohr
was decidedly convinced of inadequacy of the classical electromagnetic theory.
At the same time, however, it is noteworthy that Bohr does not here mention the
quantum explicitly. Though he cites papers of Einstein (1909) and Planck (1910),
he keeps silence on the necessity of h throughout his thesis. This silence might in-
dicate that at this moment Bohr was not absolutely sure about the inevitability of
introducing h into the problem of atom.

Heilbron and Kuhn's assertion on the influence of Nicholson seems to be tena-
ble. They however do not positively deny the myth that Bohr borrowed the quan-
tum condition from Nicholson. In the paper cited by them Russell McCormmach
reckons the quantization of angular momentum as one of "the various possible
direct influences of Nicholson's work on Bohr's thought."[6] It is evident that Bohr
was possibly influenced by Nicholson when he, in the latter part of his paper, in-
troduced the quantum condition of angular momentum as the basis of considering
the atomic and molecular systems, since he writes that "the possible importance of
the angular momentum in the discussion of atomic systems in relation to Planck's
theory is emphasized by Nicholson."[7] But we would rather like to emphasize again
our former assertion that Bohr's original quantum condition was not borrowed

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[5] N. Bohr, *Studier over metallernes elektrontheori*, Diss., Copenhagen, 1911, p. 103.

[6] R. McCormmach, "The Atomic Theory of John William Nicholson", *Arch. Hist. Exact Sci.*, 3, 160–184 (1966), esp. p. 179.

[7] N. Bohr, "On the Constitution of Atoms and Molecules, Part I", *Phil. Mag.*, (6) 26, 1–25 (1913), esp. p. 15.

from Nicholson.*

    Problems related to Heilbron and Kuhn's conclusions 3 and 4 will be discussed hereafter.

    Heilbron and Kuhn regard the Balmer formula as having afforded Bohr the clue for the final solution.   As a consequence of this view, they interpret Bohr's reference to Planck only as general and formal one.   The interpretation that Bohr's condition $W = (\tau h/2)\omega$ was devised so as to give the Balmer formula is shared also by L. Rosenfeld.[8]   And Bohr himself, in his Rutherford lecture of 1961, states that the idea struck him "in the early spring of 1913 that a clue to the problem of atomic stability directly applicable to the Rutherford atom was offered by the remarkable simple laws governing the optical spectra of the elements."[9]   But one must be cautious in hearing Bohr's statements.   His recollection in later years is often inaccurate.   To take an example, on which Heilbron and Kuhn too make a remark,[10] in the interview conducted by Kuhn for the project of Sources for History of Quantum Physics,[11] Bohr says that the central problem in the earliest study on the Rutherford atom model was the *electromagnetic* instability.   But all the contemporary documents indicate that in those days Bohr was actually concerned with the *mechanical* stability.

    In view of such a circumstance, it seems reasonable presumably to doubt Bohr's story of the Balmer formula.   We should rather rely on Bohr's contemporary writings than his later recollection.   We first note the composition of his 1913 paper. The part I of this paper bears the title "Binding of Electrons by Positive Nuclei" and the quantum condition is introduced in the course of discussing the binding process.   Should this be regarded only as a matter of style of presentation?   As has been documented by Rosenfeld,[12] there was a fight between Bohr and Ruthurford about the length of the paper.   Bohr, impatient in exchanging letters, hurried to Manchester to fight out the issue and succeeded in defending all the composition of his paper against Rutherford's demand that the paper be written as shortly as possible.   Bohr insisted to retain all the lengthy argumentation to its full detail. It is therefore natural to suppose that the discussion of the binding of electron was, for Bohr, not a trivial one but of essential significance.

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    * Recently one of us (Hirosige) had an opportunity to talk with McCormmach, when the latter definitely denied the myth about Bohr's quantum condition.   He told that he regarded it as Nicholson's most important influence that his theory turned Bohr's attention to the new problem, i.e. the spectrum, which Bohr had theretofore disregarded.

    [8] L. Rosenfeld, "Introduction" to N. Bohr, *On the Constitution of Atoms and Molecules,* Munksgaard, Copenhagen, 1963, p. XL.   (Hereafter cited as Rosenfeld)

    [9] N. Bohr, "Reminiscences of the Founder of Nuclear Science and of Some Developments based on his Work" in J. B. Birks (ed.), *Rutherford at Manchester*, Heywood, London, 1962, pp. 114–167, esp. p. 122.

    [10] Heilbron-Kuhn, p. 282, note 160.

    [11] Interviews II (The roman numeral refers to the number of the five interviews with Bohr conducted by the project "Sources for History of Quantum Physics").

    [12] Rosenfeld, p. XLV.   See also N. Bohr, Ref. 9, pp. 127–129.

3. Spectrum or Binding?

As was shown by Rosenfeld,[13] it was at the beginning of February 1913 that Bohr was first acquaninted with, or made to direct his attention to, the Balmer formula at a suggestion of his friend H. M. Hansen.   However, even before that date Bohr had already thought that his theory of atomic constitution was quite near to its completion.   In his number of letters written from the late 1912 to the beginning of February 1913, we see him state that he will soon be able to publish his theory.   On November 4, 1912, Bohr writes to Rutherford that he hopes to finish the paper on the atom in few weeks.[14]   And on January 31, 1913, he again writes a letter to Rutherford and expresses his expectation that he will very soon be able to send his paper on the atom.[15]   Five days later, he writes to his Swedish friend C. W. Oseen that he hopes soon to publish the work on the atom.   He also says that he is in a hurry because the problem seems to him very urgent.[16]   Finally, two days later, in a letter to G. von Hevesy he writes that he has made some progress in the latest time, and hopes to be very soon able to publish his work on the structure of the atom.[17]

The problem with which Bohr was occupied during these days is most likely the binding of electron by a nucleus.   In his Christmas card of 1912 to his brother Harald, he writes his "calculations would be valid for the final, chemical state of the atoms, whereas Nicholson would deal with the atoms sending out radiation, when the electrons are in the process of losing energy before they have occupied their final position."[18]   This passage seems to us to suggest that Bohr was led to the problem of the binding of electron in struggling with Nicholson's theory.   In his letter of January 31, 1913 to Rutherford we find a clearer indication that he was thinking of the binding process.   In that letter he writes that the system considered in his calculation is the one by the formation of which the greatest possible energy has been radiated out, i.e. the atom in its permanent state.   A week later, on 7th February, he clearly states in his letter to Hevesy that he assumes that the atom is formed by a successive binding of electrons and that the energy radiated out during this binding process is proportional to $h\omega$, where ω is the frequency of rotation of the electron in its final orbit.

After the letter above to Hevesy, but before the beginning of March 1913, Bohr was acquaninted with the Balmer formula and on March 6 he sent the first draft of his paper to Rutherford.   In the letter accompanying it he writes that the first chapter of the paper deals with the problem of emission of line-spectra con-

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[13] Rosenfeld, pp. XXXIX–XL.

[14] BSC 6.3 (BSC stands for the Bohr Scientific Correspondence in the Sources for History of Quantum Physics.   The first arabic numeral refers to the film number and the second to the section number).

[15] BSC 6. 3

[16] BSC 5. 4

[17] BSC 3. 3

[18] Rosenfeld, p. XXXVI.

sidered from the viewpoint described in his "former letter."[19] This "former letter"
cannot be but the letter dated January 31. For Rutherford's answer to Bohr's
letter of January 31 is written on February 24, in which he describes recent progress
of the experiments being carried out in his laboratory, and Bohr's letter above of
March 6 begins with his gratitude for hearing about the works under way in Ru-
therford's laboratory. Thus the letter of March 6 is the first letter of Bohr that he
wrote to Rutherford after January 31. Then, that Bohr writes he considers the
problem of spectrum from the viewpoint described in the former letter should be
interpreted to indicate that he has applied his theory in hand to the spectrum.

Together with the consideration in the previous section, this seems to suggest
that by the consideration of the binding process Bohr, before the beginning of
February 1913, had reached the formulation which he then thought as nearly the
completion of his theory and that the progress during Feburary, though, retrospec-
tively, of epoch making importance for the subsequent development of quantum
physics, was only to extend that theory to the spectrum. In the letter of March 6,
Bohr states that from his former point of view it seems possible to give a simple in-
terpretation of the hydrogen spectrum and that the result of calculation is in close
quantitative agreement with experiment. This passage of Bohr's letter is quite in
accordance with our interpretation above. If the Balmer formula afforded him
the decisive clue for the completion of his theory, he would never have written in
such a manner. It seems most natural to read the passage in question as expres-
sing his satisfaction that his theory is strengthened by the success of its application
to the hydrogen spectrum. Thus the Balmer formula may be said to have served
Bohr rather as a confirmation of the theory which he had already had in hand,
than as the final clue for his theory.

Heilbron and Kuhn states that it was "simply to make his model produce the
Balmer formula" that Bohr put the proportional constant K between the kinetic
energy and the frequency of rotation of an electron equal to $h/2$.[20] According
to their version, Bohr is supposed to have proceeded this way: the Balmer formula
$\nu = 3.29025 \times 10^{15}(1/4 - 1/m^2)$ multiplied by h is compared with the expression
of the binding energy of electron $W = \pi^2 m e^4/2K^2$, which Bohr seems to have ob-
tained in his Rutherford memorandum of June or July 1912. Putting $K = \tau h/2$,
he would obtained $W = 2\pi^2 m e^4/\tau^2 h^2$. Divided by h, and if numerical values are
substituted for e, e/m, and h, this gives $3.1 \times 10^{15}/\tau^2$, which agrees with the running
term $3.29025 \times 10^{15}/m^2$ of the Balmer formula within a difference of 7%. Heilbron
and Kuhn suppose that though before this time Bohr had already estimated K at
a value something near to $h/2$, yet he had not been able to make the final decision
about the value of K.[21]* They assert that the Balmer formula was the very clue

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[19] BSC 6. 3
[20] Heilbron-Kuhn, p. 271, note 99.
[21] Heilbron-Kuhn, p. 262, note 130.
* When Hirosige recently discussed the problem of $K = h/2$ personally with Kuhn, the latter

which enables Bohr to decide upon the K. But if this was the case, Bohr would have to come upon both the idea of electron transition and the factor $K = h/2$ at the same time. Does not this seem somewhat acrobatic, if not impossible, however ingenious as Bohr may be?

When interviewed by Kuhn and others, answering the question how did Bohr obtain $K = h/2$, he insists that he obtained it "very very accurately" by a correspondence.[22] He also emphasizes that it was he who first found that there is something in the spectrum. But Bohr's late memories of earlier events are in general unreliable. Above statement too is betrayed by his own words in his lecture delivered at the Physical Society in Copenhagen on December 20 of that crucial year, 1913. In this lecture, after deriving the energy levels of hydrogen atom by a correspondence method, he clearly states that originally he was led to the result not by this method but by an analogy with Planck's oscillator.[23] According to Rosenfeld, Bohr told him more than once; "As soon as I saw Balmer's formula, the whole thing was immediately clear to me."[24] But "whole thing" of what? If we read this as stating that the whole problem of the atomic structure was solved by the Balmer formula, are we not prejudiced by the popular version of the history of quantum theory? There seems to be no reason that prevents us from interpreting this as saying that it was immediately clear how to explain the Balmer formula by the theory he had already constructed. One should carefully free himself from the prejudice that Bohr's theory is the theory of atomic spectra. As was stressed at the beginning of the present paper, Bohr's theory was originally intended to explain chemical properties of the atom.

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told that Heilbron and Kuhn too, at first, had suspected that Bohr would have had a theoretical ground for $h/2$ (See also the note 109 on page 255 of their article). But after they found the footnote which Bohr added afterward in his letter to Hevesy of February 7, 1913, explained Kuhn to Hirosige, they became doubtful about this and finally reached the conclusion that Bohr estimated the value $h/2$ by a numerical consideration. In the footnote in question, Bohr says that the proportional constant between the energy radiated out and the frequency of rotation is not the Planck constant but his constant multiplied by a numerical factor. He adds that this is to be expected from theoretical considerations. Referring to this footnote Heilbron and Kuhn, in their paper, asserts that had Bohr made the final decision $K = h/2$ at this time, he would presumably have specified 1/2 rather than "a numerical factor" (p. 262, note 130). We, however, note that Bohr also writes that it is expected "from theoretical considerations". Anyway how to interpret this Bohr's additional passage is very delicate. But this passage does not seem to us necessarily to prevent us from supposing that Bohr had had a theoretical estimate of K.

[22] Interviews I.

[23] N. Bohr, "Om brintspektret", *Fysisk Tidsskrift* 12, 97 (1914); "On the Spectrum of Hydrogen" in N. Bohr, *The Theory of Atomic Spectra and Atomic Constitution*, Cambridge Univ. Press, London, 1922, pp. 1–19, esp. p. 14.

[24] Rosenfeld, p. XXXIX.

4. Planck's Theory Reexamined

We have conjectured that before the beginning of February 1913 Bohr's theory was, in the sense of its original intention, almost completed and that the consideration of the electron binding played a certain, not trivial, role in those days. If this conjecture is accepted, then Bohr's citation of Planck's papers of 1910–12 ought to be taken seriously. For Bohr indeed declares that in the "first part of the paper the mechanism of the binding of electrons by a positive nucleus is discussed in relation to Planck's theory."[25]

Heilbron and Kuhn's criticism to us consists in this, that Bohr took from Planck's paper only the general idea of the discontinuity of energy, which he could have taken as well, or even better, from Planck's original paper of 1900.[26] We however would like to emphasize that Bohr deals here with the emission of light accompanying the binding of electron, that is, a concrete mechanism of emitting radiation. On the other hand, Planck's original theory of 1900 does not touch the mechanism of emitting radiation. Only the distribution of total energy over individual resonators is considered there. It was in his *Vorlesungen über die Theorie der Wärmestrahlung* of 1906 that Planck first alluded to the mechanism of emitting radiation.[27] But this allusion is merely a vague suggestion that it would be necessary to modify the equation for an oscillator in order to give an electromagnetic foundation of h. It was as late as in 1910–12 that Planck considered the problem in detail.

In 1910, examining Jeans' thorough investigation on the heat radiation, which had shown that the classical theory necessarily leads to Rayleigh's formula, Planck asserted that the equation of motion for an oscillator be modified so that it somehow comprises h.[28] He opposed the theory of light quantum by A. Einstein and J. Stark for the reason that such a theory would imply a retrogression over centuries of the theory of light. He instead proposed to modify the equation of oscillator, leaving the Maxwell equations unchanged, so that the energy of oscillator could change only by an integral multiple of $h\nu$, where ν is the frequency of the oscillator. In making this proposal Planck characterized his position saying that "introducing the quantum of action into the theory, we should be as conservative as possible." But no mathematical formulation was given at this time.

A year later, in February 1911, Planck modified his former view that the energy of oscillator would change discretely by an integral multiple of $h\nu$.[29] According to

[25] N. Bohr, Ref. 7 esp. p. 3.

[26] Heilbron-Kuhn, pp. 268–269, note 145.

[27] M. Planck. *Vorlesungen über die Theorie der Wärmestrahlung,* Leipzig, 1906. Esp. footnote on p. 108.

[28] M. Planck, "Zur Theorie der Wärmestrahlung", *Ann. d. Phys.,* **31**, 758–768 (1910); *Physikalische Abhandlungen und Vorträge,* II, Friedr. Vieweg & Sohn, Braunschweig, 1958, pp. 237–247.

[29] M. Planck, "Eine neue Strahlungshypothese", *Verh. d. Deutsch. Phys. Ges.,* **13**, 138–148 (1911); *Phys. Abh.,* II. pp. 249–259.

the former view, argues Planck, the amount of energy that the oscillator would absorb at a time ought to be at least $h\nu$. This will lead to a difficulty when the radiation field is very weak. For the absorption will not occur at all when the radiation is extremely weak. There is still another difficulty. For the short wavelength of radiation, since the smallest amount of absorbed energy $h\nu$ becomes large and the energy density rapidly falls, the time length required to absorb the whole $h\nu$ will greatly increase. Then, if the incident radiation is suddenly shut off by some cause after the oscillator has begun to absorb the radiation, it is no longer possible for the oscillator to receive the whole energy quantum which is needed to maintain its average energy in an equilibrium. Thus Planck decided to return to the view that the oscillator absorbs the radiation energy continuously. But instead he assumed that the emission of energy by the oscillator takes place discretely. The emission of radiation is supposed to take place in the form of energy quantum, independently of the absorption, and according to a law of chance. The energy of an oscillator at an instant is put

$$U = n\varepsilon + \rho; \quad \varepsilon = h\nu, \quad 0 < \rho < \varepsilon,$$

where n is an integer. If one writes the probability that the oscillator emits a single quantum during sufficiently short time dt as $\eta \cdot n \cdot dt$, it is shown that between the average energy of the oscillator $\bar{U}$ and the energy density of the radiation field u_ν, there is a relation

$$u_\nu = \frac{8\pi\nu^2}{c^3} \left(\bar{U} - \frac{h\nu}{2} \right).$$

Now, if there are N similar oscillators, then

$$U_1 = n_1\varepsilon + \rho_1, \quad U_2 = u_2\varepsilon + \rho_2, \ldots, \quad \ldots$$
$$N\bar{U} = U_1 + U_2 + \ldots.$$

The total number of quanta, $P = n_1 + n_2 + \ldots$, is expressed as

$$P = N \left(\bar{U} - \frac{\varepsilon}{2} \right) \Big/ \varepsilon,$$

where the average value of ρ_1, ρ_2, $\ldots$ has been assumed to be $\varepsilon/2$. If one assumes here that the entropy corresponding to $\bar{U}$ of the oscillator be given by $S = k \log W$, where W is the number of ways to resolve P into a sum of integers n_1, n_2, $\ldots$, the right formula of radiation is easily obtained in a similar way as in the 1900 paper.

Several months later, July 1911, Planck again modified his theory above.[30] In the preceding theory he considered the probability that an oscillator emits a single quantum $h\nu$. Now he argues that this implies that the elementary domains in the phase space having an equal probability are not represented by the energy quantum ε. The purpose of new modification was to make all the values of integral

[30] M. Planck, "Zur Hypothese der Quantenemission", *Sitz. Ber. Preuss. Akad. Wiss.*, Juli, 1911, pp. 723–731; *Phys. Abh.*, II. pp. 260–268.

multiples of ε of the energy of oscillator equally probable. For this purpose Planck assumed that the energy of an oscillator increases continuously but it is radiated out discontinuously, that is, the oscillator radiates out its total energy $n\varepsilon$ with a certain probability η only at each instant when its energy has just reached integral multiples of ε. This theory was developed in full detail in the following year 1912,[31] which we outlined in our previous paper. It should here be noted that the novelty of this theory compared with the previous one consists in its assumption that the oscillator radiates out not a single quantum, but n energy quanta by a single act of emission.

Planck's papers cited by Bohr in the latter's 1913 paper are those of 1910, early 1911, and 1912. It is easily seen that these papers were chosen not arbitrarily but following the development of Planck's theory. In the first 1910 paper Planck posed the problem of the mechanism of emission, in the second paper of early 1911 he introduced the probability into the emission process, and finally in the 1912 paper he developed the formulation in detail by introducing the new hypothesis that an oscillator radiates out its whole energy by a single act of emission. In relation to Bohr's theory, the notion of probability and the assumption of simultaneous emission of more than one quanta are very significant. Bohr in fact states in his 1913 paper: "the essential point in Planck's theory of radiation is that the energy radiation from an atomic system does not take place in the continuous way assumed in the ordinary electrodynamics, but that it, on the contrary, takes place in distinctly separated emissions, the amount of energy radiated out from an atomic vibrator of frequency ν *in a single emission being equal to* $\tau h\nu$, where τ is an entire number, and h is a universal constant."[32] (Italics supplied.) And just at this place he cites three Planck's paper in question. It is, as we have shown above, during mid–1911 to 1912 that Planck's theory took the shape as summarized by Bohr. In two papers of 1900 and 1901[33] Planck only discusses the partition of total energy to each resonator, keeping silence about the mechanism of the emission of light. In the *Vorlesungen* of 1906 the radiation formula is derived in the same manner as in the 1900 and 1901 papers. It was as late as in 1911 that Planck propounded the notion that the emission of light by an oscillator is discrete and probabilistic, and then assumed that not a single but several, all the energy quanta possessed by the oscillator are emitted at a time. Therefore, Planck's theory which Bohr had in mind at his writing the 1913 paper cannot be the original theory of 1900. The conclusion seems inevitable that from Planck's papers of 1911–12 Bohr took the ideas that could not be taken from his earlier papers. We therefore still maintain the view that it was not for the sake of up-to-dateness, as Heilbron and Kuhn

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[31] M. Planck, "Über die Begründung des Gesetzes der schwarzen Strahlung", *Ann. d. Phys.*, 37, 642–656 (1912); *Phys. Abh.*, II, pp. 287–301.

[32] N. Bohr, Ref. 7, esp. p. 4.

[33] M. Planck, "Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum", *Verh. d. Deutsch. Phys. Ges.*, 2, 237–245 (1900); *Phys. Abh.*, I. pp. 698–706. "Ueber das Gesetz der Energieverteilung im Normalspektrum", *Ann d. Phys.*, 4, 553–563 (1901); *Phys. Abh.*, I. pp. 717–727.

suggest,[34] but of substantial significance that Bohr cites Planck's papers of 1910–12.

5. Other Contemporary Theories

Bohr referred to Planck's theory in order to discuss the emission of light by the binding of electron in relation to it. Heilbron and Kuhn, however, suggest that in associating the binding of electron with the emission of light Bohr could follow the widespread view of the time that the emission of the spectral line is connected with the ionization of atom.[35] It seems therefore desirable to examine that widespread view. Heilbron and Kuhn especially mention theories of J. J. Thomson[36] and J. Stark.[37]

Thomson supposes that when an ion and an electron recombine to form the original atom, an energy which is equal to the ionization potential is emitted as a pulse of radiation. This pulse is thought to be radiated out classically by the *bremsung* of electron. The wave length corresponding to the maximum of the energy distribution in the pulse is estimated by having recourse to Wien's displacement law. Finding the temperature corresponding to the molecular kinetic energy which is equal to the ionization potential, λ_{max} of Wien's law at this temperature is calculated. The λ_{max} thus obtained is defined as the wavelength of the pulse emitted. According to Stark, the spectral line is produced when an atom loses one of its valence electrons. Stark supposes that to each spectral line corresponds an oscillator and that this oscillator is the element of positive electricity, the *archion* as he calls, which has been combined with the lost electron when the atom was neutral. Both in Thomson's and Stark's conceptions, the radiation is emitted classically, one by a *bremsung* and the other by an oscillation of positive electric charge. In Planck's theory of 1911–12, on the contrary, the oscillation of resonator is separated from the emission of electromagnetic waves. Radiation is assumed to be emitted independently of the oscillation, according to a law of chance. Right at this point Planck is clearly on the side of Bohr. Heilbron and Kuhn see the decisive difference between Planck and Bohr in the equality, according to Planck's theory, of the frequencies of the emitted radiation and the oscillator. But if the stress is laid on the separation of the oscillation of resonator from the emission of electromagnetic waves, Planck's theory certainly implies a novel idea.*

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[34] Heilbron-Kuhn, p. 269, note 145.

[35] Heilbron-Kuhn, pp. 263–264.

[36] J. J. Thomson, "Ionization by Moving Electrified Particles", *Phil. Mag.*, (6) 23, 449–457 (1912).

[37] J. Stark, *Prinzipen der Atomdynamik, II. Die elementare Strahlung*, Leipzig, 1911, esp. §26; "Zur Frage nach dem Träger und dem Sitz der Emission von Serienlinien", *Jahrb. d. Rad. u. Elekt.*, 8, 231–240 (1911).

* When Hirosige talked with Kuhn, the latter stressed that the break with the classical theory had been evident since Planck first put forward his theory in 1900. With regard to the discreteness of energy, this is certainly true. We however would like to emphasize that for the first time in 1911–12, a mechanism of radiation which was quite alien to the classical electromagnetic theory was proposed by Planck.

The foregoing consideration shows that there is a clear distinction between Planck's theory and other contemporary theories which associate the spectral line with the ionization. Our claim of the influence of Planck's theory, not of the general conception of the time, on the development of Bohr's thought may therefore be justified.

We have thus far regarded Bohr's discussion of the binding of electron in relation to Planck's theory as an actual step of the formation of Bohr's theory. But even when, conceding to Heilbron and Kuhn's argument,[38] we admit that it was for the sake of enhancing the plausibility of the reasoning by which Bohr devised $W = (\tau h/2)\omega$ that he mentioned the relation to Planck's theory, it would still be necessary to give a physical interpretation to the analogy with Planck's theory in order that this analogy would enhance the plausibility of his reasoning. There seems to be no other way than to take the discussion of the binding process seriously if one seeks such an interpretation. As a possible interpretation required, we suggested in our previous paper that Planck's notion of the probabilistic emission of radiation would be related to Bohr's assumption that the frequency of radiation emitted during the binding is equal to $\omega/2$, the average of electron's frequencies of revolution, 0 and ω, in its initial and final orbits. This is of course a conjecture. But the binding of electron seems, as we have stressed earlier, to have been the problem that Bohr was attacking strenuously at the beginning of 1913. And, as was shown above, it was not Planck's original theory of 1900 but his later theory of 1911–12 that could afford a model for considering the emission of radiation by the binding of electron.

In conclusion we reaffirm the essential point of our former view on the possible influence which Planck's theory of 1911–12 would have exerted upon the genesis of the Bohr atom.

6. Concluding Remark

Bohr's theory of atomic constitution of 1913 has long been considered to be the theory of atomic spectra which was to initiate a new stage of the old quantum theory. Our foregoing consideration, however, suggests that the Bohr theory was endowd with a kind of duality. Genetically it was a theory of the chemical properties of atom. But immediately after Bohr had become to believe himself to have completed his theory as such, incidentally the Balmer formula entered into the scene. The Balmer formula forced Bohr to devise a notion of vital importance for the subsequent development of the investigation of the atomic structure, that is, the notion of quantum transition. The development of the atomic theory in the 1910's, however, was not achieved only by the investigation of spectra. Rather the consideration of chemical properties continued to play a major part during

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[38] Heilbron-Kuhn, p. 270.

1910's.[39]   The problem with which Bohr was first occupied did not die out until about 1921, when he published a comprehensive study of the atomic structure in relation to the periodic table.[40]

[39] S. Nisio, "The Role of the Chemical Considerations in the Development of Bohr Atom Model", *Jap. Stud. Hist. Sci.*, No. 6, 26–40 (1967).

[40] N. Bohr, "The Structure of the Atom and the Physical and Chemical Properties of the Elements", in N. Bohr, *The Theory of Spectra and Atomic Constitution*, Cambridge Univ. Press, London, 1922, pp. 61–126. "Atomic Structure", *Nature,* **107**, 104–107 (1921). "Atomic Structure", Ibid. **108**, 208–209 (1921).

Who Invented the Explosives?*

Heizo NAMBO**

Contents

The explosive herein mentioned signifies black powder invented in ancient times. The history of explosive is not so simple as that of nitroglycerin. From the following points of view, I have studied the problem.

    1. Black powder is a mixed explosive, consisting of three elements; potassium nitrate (saltpetre), sulfur and charcoal. In what continent is the natural

saltpetre produced?   Who discovered and made use of it, and who made
'black powder' therefrom?

2.   How many data are there on the development from the invention of black
     powder to the making of fire arms, extending from a point to line, line
     to area and world over.

3.   Can these facts be proved accurately from the literature?   Since 1952,
     when I published the "chronological table of the explosives history in
     Japan" in the Journal of the Industrial Explosives Society, Japan. (vol. 13.
     p. 179–190), I have made efforts to solve this problem and made a chronolo-
     gical table for the gun-powder of ancient times.   Details are in the at-
     tached paper.

Summary

1.   *Discovery of nitre (potassium nitrate)*

     Of the three components of gun powder, sulfur and charcoal are found through-
out the East and West of the world.   But the nitre in the old days, before Christ,
it was discovered only in China as 'earthen nitre', 'river nitre' and 'rock nitre.'
Around in 1600 A.D. in Bihar, India, nitre was discovered by an Englishman,
and has since then been exported at the rate of several thousand tons per year.
Nitre was also produced in other areas including Pakistan, Kirguiz and Turkman,
in USSR., etc.   In Chili, sodium nitrate is produced naturally.   But no relation
to the history of gun powder .   'Earthen nitre' in China is produced in the form
of calcium nitrate in Shan Tung province and is made into the nitre by the action
of wood ash.   'River nitre' is produced in the form of crystal in rivers near Mou
Hsien, Szŭ Chu'an Province.   'Rock nitre' is produced as the ore in Shan Si
Province, etc.

2.   *Utilization of the nitre*

     In the 16th century B.C. "Papyrus Ebers", a pharmacological book, was issued
in Egypt, while in China, 4th century B.C. the 'Wu Ts'ang Shai Ching' were published.
In B.C. 220 nitre and sulfur were described in the 'Chou I Ts'an T'ung Ch'i.'   T'ao
Hang Ching, who wrote the variorum edition of the 'Shên Nung Pên Ts'ao Ching'
(A.D. 502), divided the nitre into pure nitre and plain nitre, and delivered the
former to the alchemist and the latter to the physician.   Thus the pure nitre was
then made.

3.   *Application of the nitre to the alchemy*

     In Egypt, in 275–194 B.C. alchemy was in its prime.   In 220 B.C. in China,
'Chou I Ts'an T'ung Ch'i', the oldest alchemy book, was written by Wei Po
Yang.   In it nitre, and sulfur were described.   In 160–122 B.C. (at the period of
Wu Ti of Early Han), sulfur, charcoal and nitre were described in 'Chun Nan
Tzŭ', a lientan text written by an alchemist Chun Nan Wang Liu An.

4.   *Invention of gun powder by alchemists*

     In China, Shih Huang Ti of Chin searched for a medicine of immortality

beyond the Eastern Sea. Lao Tzŭ started alchemy, and in 220, B.C. Wei Po Yang issued the 'Chou I Ts'an T'ung Ch'i' the first book of Alchemy. In 160–122 B.C., three components of black powder, sulfur, charcoal and the nitre were described in the 'Chun Nan Tzŭ' of Liu An. It proved that the alchemy was a technique for separating the gold and silver from the gold ore including the copper sulphide. In 125–144 A.D., a hut was burnt from the flame of alchemy furnace of I Wei Lao Jên. At the hut of alchemist Chêng Su Yüan, his fire ambassed nitre process (264–322 A.D.) When gold ores and sulfur and orpiment were closely burnt in a vessel of nitre content, by the flame from the furnace he suffered burn on his hand and the hut was burnt down. In the fire-ambassed sulfur process of Sun Ch'en Jên of Tang (<682), two liang each of nitre and sulfur of powders were mixed. They were put into a silver basin, which was then fired by three seed of glcditschia and finally 3 chins of charcoal were added. When summarizing the records of disaster caused by the fire-ambassed alum process of Ch'ing Hsu Tzŭ, we can conclude as follows: When the gold was separated from the silver at low-temperature reaction, by adding the nitre and sulfur to the gold ore in the alchemy furnace for making into gold, explosion occured, by adding the charcoal at the first stage by mistake (which must be added at the final stage). Consequently, in the 2–3rd century A.D. or probably 2nd century B.C. black powder was invented by alchemist accidentally.

5. *Gunpowder in India*

Near Lahore, in West India in 325 B.C. Alexander the Great was defeated by means of thunder bolt made by the Oxydal people on their city walls. It was assumed some explosible matters connected with the saltpetre got there.(4) However no literature was found available on the later development to the invention of explosive or other fire arms.

6. *Experiment making and use of gunpowder (7–9 Centuries)*

Description of the explosion in the 'Chên Yen Miao Tao Yao Lioh' of Chêng Su Yüan in the 4th century aroused the interest of Sui (589–618) and T'ang (618–907) court in making the gunpowder through the topics of alchemists and gold. Yang Ti of Sui made various jests with gunpowder. They have developed fireworks into fire trees and silver flowers of the fireworks in the T'ang Dynasty, while the cracker developed into the fire cracker (850) and probably further into the gunpowder.

About the 10-kingdom, 5-Tai dynasty after the fall of T'ang dynasty, composition of gunpowder was standardized in Chiang Nan. It was about in the Nan T'ang dynasty (937–975), when the nitre was produced in large scale and application to fire arms was developed. At least in Pe Sung (969–1126), gunpowder was applied to the military regime. And from it Pe Sung was able to establish her Dynasty.

7. *Development of the explosive arms (10–13 Centuries)*

Explosive arms were firstly employed by the Pe Sung government for the

military purpose (970, 1045), they built the powder mill and fire arms work in Ta Ming' (Shan Tung) and in Che Chu (Shan Si) respectively (1040). The triple war among the Sung, Chin and Mongols, which began in 1126 explosive arms were first used, by the Sung, but these production areas were occupied by Chin in 1127 and by the Mongols in 1214. The following explosive arms were developed, in the 10th to 13th Century.

a) Fire arrow; Pe and Nan Sung Dynasty.

b) Radiation fire arm; fire burster, fire lance, firing lance (both in Nan Sung), flying fire lance (Chin Dynasty)

c) Explosion fire arms; Fire ball, fire stone ball, thunder ball (Pe Sung), stone ballista, chin pieh pao, chin pien lime bottle, fire ironball, fire stone bomb (Nan Sung), iron bomb, chên t'ien lei (Chin), fire stone ball, chên t'ien lei (Mongols Dynasty)

Powder flask; it was used by the fox hunters.

As for the firing arrow, gun powder cartridge is tied to its front, and it is primered. In relation to the fire lance, bamboo is charged with powder to emit the flame, 20 m long. As for the firing, iron, porcelain, wood, etc. are charged with powder. Safety fuse is fired immediately before firing. Bomb is thrown by crossbow, etc. and explodes after it fall on the ground. 'P'ao' at that time is an arm, in which the powder is wrapped in stone, metal or other materials, and thrown off.

In the reign of Nan Sung, fireworks are used in South China, chiefly in Hang Chou. True fireworks including the fire cracker, fire screen, fire rat, etc. were brought on the market and enjoyed in the palace. In the meantime, the Arabian trading ships seems to have carried them to Arabia.

8. *Propagation of fire arms to Arabia and Europe*

In 1200 B.C., 900 B.C., and 500 B.C., fire arms were used in Troy, Mesopotamia, and Greece respectively. They are, however, incendiaries without such nitre, as the petroleum, sulfur, charcoal, etc. Automatic fire which was used in Rome in 222 is a system that the mixture of quick lime and asphalt is plead into a ball, and water is added to cause a spontaneous ignition. Greek fire, which was used in Constantinople toward 670, consisted of sulfur and resin oil. Both of them are not explosives.

In 1219, Mongolian troops used the poisonous fire can, fire arrow and fire bomb in the battle of Amu river, poisonous smoke ball in the battle of Liegniz in 1241, chên t'ien lei (iron bombs) in the battle of Bagdad in 1258, also iron bomb (chên t'ien lei) in the landing operation in Hakata Bay of Japan in 1274. For the defenders there was no fire arm, since the secret of powder could not be solved.

In a medical book written by Ibn al-Baitar, who died in Damascus, Irak in 1248, nitre was interpreted as the 'snow of China'. In 1249, in a book of an Englishman, Roger Bacon, process for making nitre, "sal petrosus" (earthen nitre process) and the composition of black powder were described. In an Arabian

fire technical book, it is reported that the Moor threw fire arms from ballistas in Nibra, Spain in 1257. Illustration of flying fire arms of Madfa, etc. are also drawn therein. From these facts, it is conceivable that the fire arms were introduced into Europe through Arabia.

In these researches, I have received kind instruction from Assist Prof. Mitsukuni Yoshida, Kyoto University. In addition, I have utilized the works of Dr. Seiho Arima, Fêng Chia Shêng, Chao Tieh Han and Hime. In this connection, I hereby express my hearty appreciation to these researchers. Maps of the explosives history in ancient times shown in Figs. 0, (1), (2) and (3) are the records of places where the powder and fire arms were made and used. I shall be happy, if these data will serve in discovering of ancient gunpowder and fire arms conducted by archaeologists. Composition of the gunpowder, and details of fire arms shall be described in the later part of this article.

(1)   China

Fig. 0.   World Map of the Explosives History
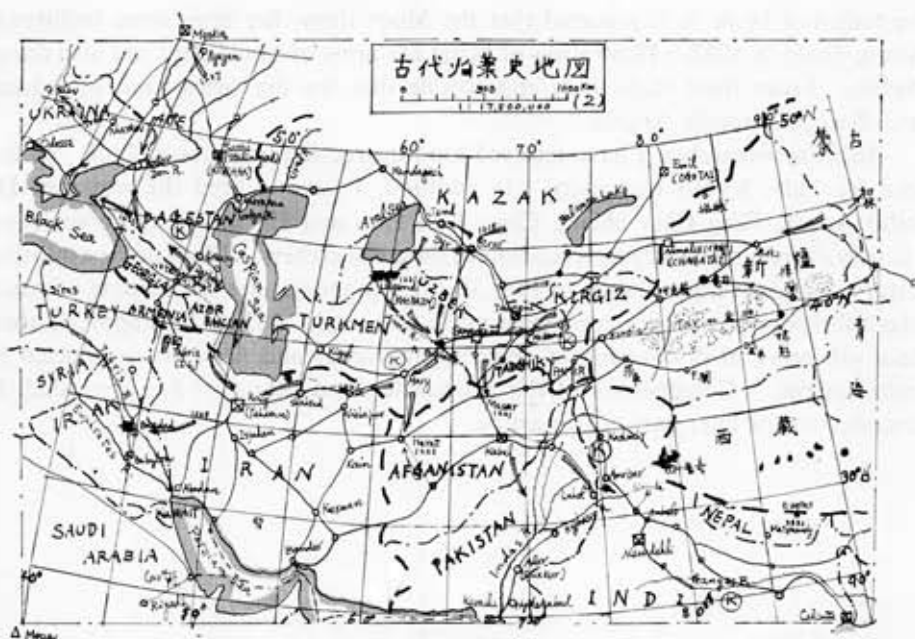
(2) West Asia
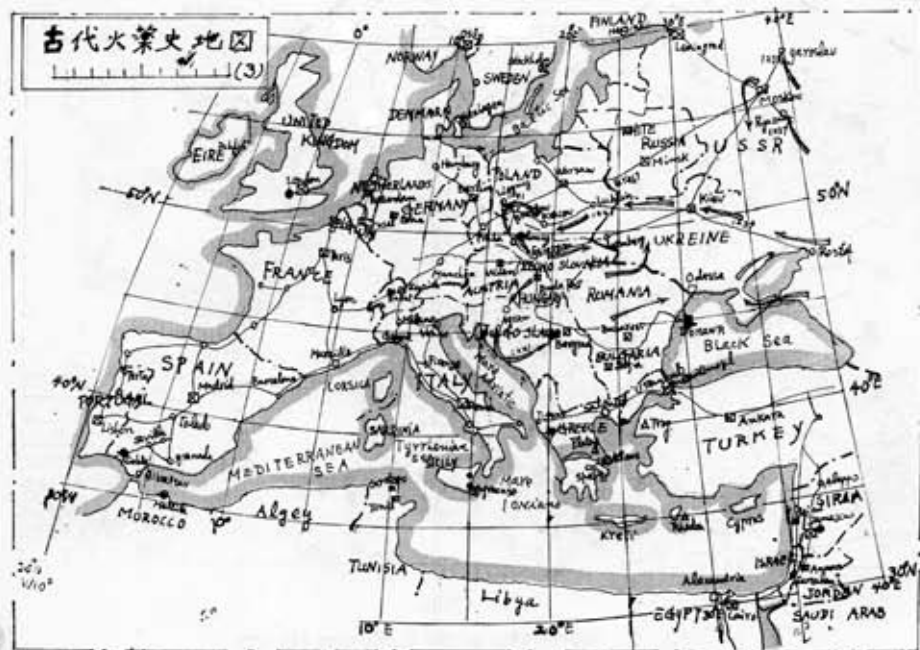
(3) Europe

Fig. 0. World Map of the Explosines History

Literature

No.	Author	Name of the book	Publisher	Year of issue
1.	Mitsukuni Yoshida	Alchemy	Chuo Koron	1963
2.	Suketoshi Yajima	Story of the Arabian Science	Iwanami Bookstore	1965
3.	Koichi Kimura	System Table for the Major Material of China	Print Paper of Kyoto University	1963
4.	Shozo Arisaka	Illustration of Arms History	Technical Engineering Dept. Tokyo University	1916
5.	Kiyoshi Yabuuchi	Story of Tien Kung K'ai Wu	Kosei-sha	1954
6.	Seiho Arima	Origin and Spread of fire arms	Yoshikawa Kobundo	1962
7.	Masanosuke Ito	War History, Volume of the War in the West in Ancient Times	War History Publishing Society	1936
8.	Mitsutomo Yuasa	Chronology of the History of Scientific Culture	Chuo Koron-sha	1950
9.	Taro Harano	History of Chemical Engineering (translation of Fritz Ferchl)	Keio Shobo	1942
10.	Kamei and Mikami	Standard Chronology of World History	Yoshikawa Kobundo	1966
11.	ditto	Standard Map for the World History	ditto	1954
12.	Takeshi Haga	History of the Mining in China	Denzu, Publishing Dept.	1943
13.	Denzo Hiratake	War time Economical Geography in U.S.S.R.	Zaisei Keizai Zihosha	1932
14.		Map for the Distribution of Important Resources in North China	Kitashina Keizai Tsushin-sha	1940
15.	Sanshodo	Map of China	Sanshodo	1939
16.	Shojiro Tanaka (translator)	D'Ohsson's Mongolian History	Iwanami Shoten	1936
17.	Shikita Koyanagi	New and Great Chinese-Japanese Dictionary (Weights and Measures)	Hakubunkan	1940
18.	Takeshiro Kuraishi	Iwanami's Chinese Dictionary	Iwanami-shoten	1963
19.	Yasue Yamada	Mongolian Invasion History (with the appendix)	Tokyo Tsukiji-Kappan Seizosho	1891
20.	Chen Shou's Selection	Sankuochih (Tsin)	Chung Hua Shu Chii	1962

No.	Author	Name of the book	Publisher	Year of issue
21.	Fêng Chia Shêng	Invention of Gunpowder and their propagation to the west	Hua Tung Jen Min Chu Pan Sha	1954
22.	Ch'ao Tieh Han	Invention of Explosives	Quo li li Shi Pa wu kuan	1960
23.	T'ang Shên Hui's selection	Chung Sin Chêng Ho Ching Shih Chêng Lui Pli Yung Pên Ts'ao	Jen Min Weisheng Chu Pan Sha	1952
24.	Ts'ao Kung liang, et al.	Wu⌣Ching Tsung⌣Yao, published in Cheng Te of Ming	Chung Hua Shu Chii, Shan Hai	1959
25.	W. L. Hime	Gunpowder and Ammunition	Longmens Green & Co. London	1904
26.	A. Marshall	Explosives	T. & A. Charchill	1915
27.	Dr. Günther Bugge	Schiess u. Sprengstoff u. die Männer die sie schiessen	Franclische Werke-Geschandlung	1942
28.	W. W. Greener	The Gun and Its Development	London	1899
29.	Nihon Kogyo Kai	Industrial History of Meiji		1929
30.	Oliueira Simoes	Substancias Explosives	Lisboa	1898

Part I

Chronology of the Explosives History in Ancient Times.

Note: Figures in the parentheses indicate the No. of reference book

Judgement: According to the details, the following judgement by author has been passed on;

    ○ Nitre

    ◎ Explosive

    ⦾ Radiation fire arm

    ⊖ Explosion fire arm

    ⊗ A kind of firework

    △ Incendiary (non-explosives)

    × No relation to the explosives

§1. B.C., Discovery of the Nitre, Development of Alchemy and Pharmacy

Century	Judgement	Description

Geological era	○	Natural resource area of the nitre
		China: Earthen nitre (Shan Tung),
		        river nitre (Szu Chuan),
		        rock nitre (Shan Si, Hsian Si, Kan Suan, Ching Hai) (12.14, 6.23)
		India: Bihar province (26)
		West Pakistan (northern region)
		         (Geological map of India)

B.C. 1190±	△	In the battle of Troy, Troy troops defeated the Greek fleet with unquenchable flame and liquid fire.
B.C. 850	△	As the fire arms, incendiaries were used in the battle of Mesopotamia, Irak (27)
500–450	△	In the military tactics of Sun Tzŭ in Wu of Chiang Su, soldiers with fire, pile of fire, transportation of firing arms, materials, troop with fire, and fire work were used, (24) for the attack by fire.
500–470	×	In the military tactics of Fan Li of Yüeh (Che Chiang province), ballista of stone called 'p'ao of stone' was described (24)
429	△	Spartans (Greek) used incendiaries, small wood piece, sulfur and pitch in the battle of Plataena. (7)
460–377	×	Medical books of Hypokrates, a Greek, were completed (8)
410–304	△	Allied navy of Sparta threw shells of sulfur, pitch and pine resin by means of ballista of stone and setting fire to the Athenian fleet (25)
403–221	×	The oldest Chinese pharmaceutical books, 'Wu Tsang Shai Ching' and 'Shan Hai Ching' were published. (3)
325	◎	Alexander troops, which invaded India, were defeated by Oxydarac by means of thunder bolts thrown from the castle wall in the area (east of Lahor) of Hyphases branch of Indus river. (4)
275–194	×	In Alexandria, Egypt, Arabian alchemy was in its prime (1, 2)
220±	○	In the oldest Chinese alchemy book of Wei Po Yang, Chou I Ts'an T'ung Ch'ih', we can find 'siao and liu' which means letters of nitre and sulfur. (1, 6)
160–122	○	In the Chun Nan Tsŭ of Huang‾Pai Shu (alchemy) of Liu An, Chun Nan (Anhui), letters of the "sulfur, charcoal and nitre" are found. (1, 6)
141– 87	◎	In Robert Norton's Gunnery, it is reported that powder was invented in the reign of Vitey (Wu Ti) of China and used in the battle against Kou Nu. (4)

§2.   1–6 Century: Invention of Explosives

Century	Judge-ment	Description
A.D. 125–144	◎	In the 'Tai Ping Kuang Chi', item of Later Han, it is stated as follows: When Iwei Lao Jên made Elixirs 'Tan Yo' Tou Tzŭ Ch'un (a famous man in the reign of Shun Ti of Later Han in his younger age), called upon him. The old man went out for a while. When Tou waked from his sleep near the fireside, big fire broke out from the furnace, flame reached the roof, and the alchemy hut was burnt down. (21)
200±	◯	In the Shên Nung Pên Ts'ao Ching, medical book of Later Han, there are found letters of the "nitre and sulfur" (1, 6)
200	×	In the San Kuo dynasty, Ts'ao Ts'ao of Wei threw stones at the Yüan Shao troops by means of stone throwing vehicle in the battle of Kuan Tu (Shan Si). The latter troops called it the "thunder vehicle", and were afraid of it. (20)
222–235	△	Alexander VI, of the Roman Empire called the "automatic fire", a ball which contains mixture of quick lime and asphalt, a small quantity of water, which cause thermal evolution and then fired. (25)
226–239	⊗	In the reign of Ming Ti of Wei, Ma Kou in Fu Fêng (North China) made firing crackers. (22)
257	△	Chu Ko Tan, who had been surrounded by the Szu Ma Wên Wang (Wei) troops in Shou Ch'un (present Shou Hsien in Anhui province), destroyed the enemy's weapons by means of stone throwing vehicle and fire arrow. (20)
0–305	△	The Romans used the fire arrow, and shot the fire lances from the machine. (25)
300±	◎	In the reign of Western Tsin, 'Chên Yen Miao Tao Yao Lioh' written by Ch'êng Su Yüan (264–322) disclosed the fire ambassed nitre process: When the sulfur and orpiment were closely burnt in a vessel containing the nitre, flame broke out to burn the hand surface and the hut. (21, 22)
317	◯	In the Pao P'o Tzŭ of Ko Hung (Western Tsin), there are found letters of nitre, sulfur and charcoal.
350	△	Aeneus in Roma put the sulfur, pitch, incense, pine resin and tow into an oval wooden container, and threw it on the deck of enemy's ship. In the meantime, Kegetius threw the sulphur, bitumen, rosin and naphtha into the enemy's ship. (25)
502	◯	Tao⁻Hung Ching of Liang (South China) described in correct attention of Shennung Pentsao Ching, the nitre (mother name is Glauber's salt), discriminated between pure nitre and sodium sulphate by means of violet flame, and handed over them to the alchemist and physician respectively. (21)
502–557	×	'Iwei T'ung⁻Kua Yen' of Liang disclosed that "the crackers were used in the New Year". (22)

§3.   7–9 Century: Utilization of Gun-powder

Century	Judge-ment	Description
604– 18	⊗ △	'Wu Yüan' of Lo Chin reported that "Yang Ti of Sui made various jests of powder". In Lo Yang at that time, a magician exhibited various plays. (22)
7– 9 ct.	⊗	In the item, 'T'ang Tai Huahuo Shu' in 'Wu Li Siao Shih' written by Fang I Chih of Ching, fire tree and silver flowers are described. (6)
659	◯	In the 'Sin Siu Pên Ts'ao' (Tang Pên Ts'ao) written by Su Ching et al., plain nitre, saltpetre and sodium sulphate are detailed. (3, 5)
670±	△	On the basis of the advice given by Kallinikos, Heliotrope of Syria, East Roman Empire annihilated the Califate fleet by means of Greek fire made from the sulfur, pine rosin and petroleum. (25)

Century	Judge-ment	Description
< 682	◎	Fire ambassed sulfur process in the 'Tan Ching' written by Sun Ch'en Jên of Tang it disclosed as follows: Two liang (75 g each) of nitre and sulfur were powdered, mixed, put into a silver basin, and 3 pcs. of seed of glcdischia, and 3 chin (1.8 kg) of fine charcoal were added, etc. (1, 21)
683	△	In the battle of Mecca (Saudi Arabia), Kaaba were fired by the incendiary shells of Syrian troops. (25)
712	△	The elephant, on which King Alor (Dahil in West India) rode, was burnt to death by means of naphtha arrows released by the Moslem troops. (25)
808	◎	According to the 'Ch'ien Hung Yung Ch'ên Chih Pao' Chih Chêng' of Ch'ing Hsü Tzŭ (in the reign of Hsien Tsong of T'ang), two liang of nitre and sulfur, each, and 3.5 chien of Monkshood (75:75:13 grams) were used to make a fire ambassed alum process. (21)
813	△	In a struggle within the califate troops, Bagdad (Iraq) was burnt by fire arms released from the Hostile camp. (25)

§4. 10–13 Century: Development of fire arms.

Century	Judge-ment	Description
904	△	Before the end of T'ang, Chêng Fan of Wu Ch'ên, attacked Yü Ch'ang (Nan Ch'ang in Chiang Si at present), fired the Lung Sha Mên with flying fire by ballista. (22)
904	△	The Califate troops, which attacked Salonika (Greek), threw ceramic pots charged with mixture of pitch, pine, rosin and quick lime. It covered the bodies of the enemy and suffocated them to death. (25)
940	△	In a chemistry book written by T'an Ch'iao of Ch'u (Che Chiang) there is a principle of the chemical reaction of Taoist. (22)
940	⊖	At the beginning of the reign of Pe Sung, Hsü Tung in his book 'Chai Shuo' as follows: fire p'ao is a ballista using explosive, fire ball is fired by ballista after the ball is made of powder, tied to the top of arrow, and set by pulling the wire. After this age, nitre was called 'yen siao'. (21)
941	△	East Roman Navy poured from the stern, sea fire liquid made from naphtha, quick lime and sulfur through the tube or syphon, over the Russian fleet, which had attacked Constantinople. (25)
970	⊖	In the 'Sung Shih Ping Chih', it is reported that Feng Chi Shêng et al., developed the fire arrow system, and the Emperor ordered to experiment it. (6)
975	⊖	Ch'ao Sung of Sung used the fire stone ball (huo p'ao) and fire arrows (huo chiang) to overthrow Nan Tang (South China). (21)
1000	⊖	Tung Fu of Sung donated the fire arrow (huo chiang) fire ball (huo ch'iu) and fire dart rocket. (6, 21)
1002	⊖	Shih P'u of Ch'i Chou [Ho Pe] of Sung made fire ball and arrow, which were taken by Chên Tsong. Then the premier observed their test. (21)
1002	×	In the reign of Chên Tsong of Sung, Lo Yung Si invented a hand ballista (portable ballista). (6)
1040	◎	At the time of Jen Tsong of Sung, Pe Sung government built a gunpowder factory in Pien Ching (Haifeng, Honan), and further built the factories for asphalt, petroleum, etc. (6, 21)
1045	◎ ⊖	Pe Sung government issued the Wu Ching Tsung Yao, in which the blending of powder, construction of fire arrow, thorn fire ball, poisonous smoke ball, etc. were described. (they shall be hereinafter described). (24)

Century	Judge-ment	Description
1096– 99	△	In the battle of Nice of the 1st Crusade, Califate troops threw pitch and fatty balls. They shot fire arrows with pitch, sulphur and tow from the wall of Jerusalem. (25)
1126	⊖	Chin besieged Pien Ching, capital of Sung. Ts'êng Chien of Sung repulsed the Chin troops by means of fire arms, fire arrows and firing stone balls; and Li Kang also repulsed them with thunder ball (p'ili p'ao). (21)
1126	×	When the Chin troops besieged Tung Ching (Hai Feng), they arranged no less than 100 ballista seats. Rain of flying stones struck the castle soldiers, and the casualties were as many as 10–20 persons per day. (6)
1127	◎	When Chin captured Pien Ching, capital of Pe Sung, she also occupied Tai Ming (Ho Pe) and Che Chou (Shan Si), production centers of gun powder and fire arms. Therefore, she succeeded in taking over the technique of making the powder (21, 22)
1127±	①	On a chess board dug out of the earth from Lo Yang, two firing balls 'huo p'ao' on every sides of the seats of three persons sitting face to face were drawn. Letter of 'huo p'ao' explosive ball has come from the fire, not from the stone. It seemed to be the articles made after the Nan Sung. (22)
1127	⊗	According to the Tung Ching Mung Hua Lu written by Mêng Yüen Lao, firing crackers immediately thundered, and all the people were surprised. Great fire smoke broke out. Smoke poured out of the mouth of the masked devil. (22)
1129	⊖	Lin Tzŭ Ping of Nan Sung suggested that such fire arms as the stone ballista, fire arrows, etc. should be used on board the ships to defeat the Chin troops on the coast along Fu Kien and Kuang Tung. (21)
1130	①	When Wan Yen of Chin attacked Shan Chou (Shan Ken Honan), Li Yen Shan of Nan Sung defended by means of chin pien pa'o. (21)
1132	①	Li Hêng, besieged Tê An, attacking with long ladder. Ch'ên Kuei, general of the defense army made over 20 fire lances, i.e. long bamboo pipes charged with gun powder, let two men fired them immediately before the use and burnt the enemies of land bridge. (21, 22)
1134	⊖	When Chin invaded Hao Chou [Pêng Yang, An Hui] of Nan Sung, Chin pieh lime bottles with arrow stones were shot out of the castle. (22)
1135	△	Chin fleets attacked Ts'ai Shih Chi on the south shore of the Yang Tzŭ Chiang, Yo Fei made very thin and brittle pottery bottles, which were charged with poison, lime and iron pickles. They were used for sea battle. In the smoke of lime ballista 'hui p'ao', rebelling soldiers could not open their eyes, and were heavily defeated. (22)
1161	△	Wan Yen of Chin troop tried to cross over the Yang Tzŭ Chiang river. Yu Yün Wên of Nan Sung made thunder ball 'pi li p'ao'. Paper cartridge was charged with petroleum and sulfur, and set. When these balls were shot in the sky, they thundered, fell into the water, and ignited to blind and seriously defeat the enemy. (22)
1161– 64	⊖	At the head of a volunteer corps, Wei Shêng of Nan Sung made Hai Chou, [Chiang Su] the base of operation to resist the Chin. He created stone bombs 'huo shih p'ao' and fought the enemy at the distance of 200 pu (360 m). (22)
1160– 90	⊖	In the reign of Shih Tsong of Chin, Tieh Li in Yang Ch'ü Hsien [Tai Yüan, Shan Si] caught foxes by powder flask 'huo fou' using chicken as the lure, and hid himself on a big tree. When the foxes came, he

Century	Judge-ment	Description
		fired the fuse of fire flask, and threw it. When the flask made a great noise, and exploded, he caught the foxes, taking advantage of the confusion of foxes. Although the quality of fire flask was unknown, flask shell was made of paper, and gun powder was wrapped in paper to make the fuse. (21, 22)
1163– 89	⊗	In the reign of Hsiao Tsong of Nan Sung, fireworks 'yen huo' made its debut. The then firing cracker 'p'ao chang' at present is the box fire. After ignition, it went off with the loud explosion, and then various kinds of flowers and ghosts appeared. 'Ping fêng' is a curious screen. Outside the screen, there is a picture where a demon catches the devil. Inside were various kinds of plays after the fuse was ignited. Fire rats 'ti lao shu' came out from underground, firing and dancing around. (21)
Latter half of the 12th century	◎	Chin and Sung government strictly controled the mining of sulfur and nitre, and peoples applied the powder only to amusement. (21)
1214	◎ ⊖	Chin moved its capital southward to Pien Ching (Hai Feng), and the Mongol captured Chung Tu (Pe Ching). In this connection, powder and fire arms expert and techniques in Chin were transferred to the Mongol. (21)
1221	⊖	Chin besieged Ch'i Chou (Ch'i Chun, Hu Pe), arranged 13 sets of stone ballistas, and shot the ironbombs into the castle. Iron bomb 'tieh huo p'ao' was calabash shape, its mouth was small and the bomb was cast of pig iron, 6 cm. After firing the fuse, the length was cut according to the distance to the target, ball burst when it fell on the ground. (21, 22)
1224	⊗	Li Song of Tsung was surprised to see at the firework of a mole 'ti lao shou' in the garden court of the capital, Lin An [Hang chou, Che Chiang]. (22)
1231	⊖	Mongolian general Touloui captured Hochung Fu [San Kuan, Shên Si]. With 3000 garrisons, Pan Ngo K'o took the ships by force and escaped. He destroyed old ships by iron bombs 'chên t'ien lei', when he crossed the channel. (21)
1232	⊖	Yuan troops made 13 rods bamboo ballistas, shot the stone bullets of ball size, levelled the castle wall and set fire the castle by firing stone balls which shot the tinder. (22)
1232	×	Chin Shih Chiang Shen Chuan reported that the 'o p'ao' was made, and cannon ball shot at a distance of over 100 po (180 m) by several men was able to hit the target. (22)
1232	⊖	Mongols second attacked of Nan Ching [Kuei Tê, Ho Nan of Chin] while the Chin used the chên t'ien lei (iron bombs). Iron bombs charged with powder flew off a long way to burst. Their roar was heard 100 Yi (60 Km) off. Fire and heat spread over the area, more than half se (18 m × 18 m). (21, 22)
1232	①	Mongolian soldiers covered with ox hide tunneled their way below the Nan Ching castle. Chin troops killed the Mongolian, hanging the iron bombs on the iron ladders. (22)
1232	①	In the 2nd battle for Pien Ching (Haifeng) of Chin with the Mongol. Chin used the flying fire lances 'fei huo chiang' to burned an area, over 10 Pu (20 m) ahead. Soldiers could not advance. (22)
1233	①	In the battle of Nan Ching (Kuei Te) Chin defeated the Mongol by means of flying fire lances (fei huo chiang). As for the flying fire lance, tube, 2 shaku (0.6 m) long, made of 16 piled sheets of extended yellow paper was charged with willow charcoal, iron slag, porcelain fragment, sulfur, arsenic frost, etc. When it was ignited, flame reached no less than 3 m in front of the lance. (21, 22)

Century	Judgement	Description
1234	⊖	Allied army of Mongol and Sung besieged Ts'ai Chou (Ju Nan Ho Nan). Mongolian troops fired the fire balls 'huo p'ao' to burn the castle. Ai Tsong of Chin hanged himself, and Chin was perished.
1237	⊖	Mongol attacked An Li [Shou Hsien, An Hui] of Nan Sung, fired the fire stone balls 'huo p'ao', to burn the castle. (21)
1257	⊖ ①	In the reign of Li Tsong of Sung, Mongolian troops came up north-ward from Yuehnan (Yünnan—Annan) to surprise Si Nan District of Sung. When Minister Li Tsêng Po inspected Ching Chiang, (Kuei Lin—Kuang Tung) he found 95 sets of iron bombs 'tie huo p'ao', large and small, 95 pcs. of fire arrows and 105 units of fire lance 'huo cuiang'. These were only sufficient for 1100 men in one battle. He immediately ordered to supply from Arsenals. Wherein units of iron bombs found in Ching Chou (Chiang Ling) Arsenal can produce 1000–2000 units of firing stone balls. 10,000–20,000 pcs. of its stock in Siang (Siang Yang) and Ying (Chung Siang) in Hu Pe respectively. (21)
1259	①	In the reign of Li Tsong of Sung in Shou Ch'un (Shou Hsien), shi huo chiang was invented. A fire lance with missile. Large bamboo was made as a tube, the upper part was charged with powder. In this tube, a ball was loaded. After igniting the powder, flame came out and when it vanished the ball was shot out, at the time it made a noise which was heard in a place over 150 po (270 m) distant. (21)
1268	①	Mongolian troops besieged Siang Yang and Fan Ch'êng (Hu Pe) for no less than 5 years. In order to help their allies in Siang Yang, Ch'ang Shun and Ch'ang Ching let 3,000 men get on board 100 boats separately, and gave them fire lance and other arms, then routed the Mongolian troops grouping over Han Shui 120 li (72 km) long, and entered into Siang Yang. (21)
1274	⊖	Ch'êng Siang, Pê Yen of Yuan attacked Sha Yang (Ching men area, Hu pe). As Ch'uan Lu Wang, the defending general did not surrender, Ch'ang Chün Tso, artillery-man laid siege to the castle by means of huo p'ao (fire balls). The sky was immediately covered with smoke and flame and the castle fell.
1276	①	Pe Yen of Yuan ordered to Shih Pi attack Yang Chou (Chiang Tu, Chiang Su). Two men subject to defending general Chiang Ta was stabbed with fire lance. Shih Pi cut the left man by sword and fell. (21)
1277	⊖	When Ching Chiang (Kuei Lin, Kuang Tung) fell, Lou Ling Hsia, defending general of Sung fired a large cannon 'huo p'ao'. The castle walls were destroyed, and 200 garrisons were killed to ash, while a large number of Yuan soldiers outside the castle were also killed. (21, 22)
1279	⊖	Ch'ang Shih Chieh of Sung, and Ch'ang Hung Fan of Yuan fought a sea battle in Yai Shai (on the sea near Aomên, Kuang Tang). Both of them employed 'huo p'ao' during the battle, but Sung was defeated and destroyed. (21)

§5. 13 Century: **Transmission of Chinese Gun powder and fire arms to abroad.**

Century	Judgement	Description
1221	⊖	When Genghis Khan conquered the west, in the battle of Amu River, against Khorazm Empire (South east of Aral Sea and Iran), his troops threw stones by crossbow ballistas to break the castle walls, and used poisonous powder flasks 'du huo fow' fire arrows 'huo chian' and fire stone ball 'huo p'ao' to burn the castle. (16, 21, 26)
1241	⊖	When Patu conquered the West, his troops used poisonous smoke balls in the battle of Wahlstadt near Lignitz in Poland. (21, 16)
1232–1299	⊗	Wu Lin Chiu Shih of Chou Mi reported that "boys in Si Hu (Hong Chou) competed with one another playing the fire crackers, in which

Century	Judge-ment	Description
		the fuses were concealed". Meanwhile fired the rocket ring 'yan chi lun' 'liu sing' ran etc. and the metear 'shui p'ao fêng pi'". (22)
1232–1299	⊗	Mung Liang Lu of Wu Tzǔ Mu of Sung reported that "screen was arranged in the palace hall, picture of catching devil was drawn thereon, fuse was concealed therein. When it ignited, over 100 pcs. of fireworks broke out continuously".
,,	⊗	In the meantime, Siao⁻Ching Yen of Hang Chou reported that there were fire works venders.
,,	⊗	When Chung Yu attended Nu Chou (Kin Hua, Che Chiang), they found 4 experts in the fire work.
1241	⊖	When the Olmütz castle of Moravia (Slovakia at present) was besieged by Monogolian troop of Bhatu, fire arrows were used to burn the temple. (16)
1218–1258	⊗	In the Dynasty of Nan Sung, the royal family played fire works in Lin An (Hang Chou), capital city. Fire crackers and fire works were sold in the market. At this time, Nan Sung made trade by marine with the caliphate countries vigorously. In Kuang Chou, Chao Chou, Chüan Chou and Wen Chou, there were foreign concessions. Gun powder and fire works seem to have been exported to Arabia for making the fire ring, tube fire and China iron (Chi Lun, meteor and iron slag in China). (22)
<1248	◯	According to the medical book written by Ibn al-Baythar (Arab of Spain blood), who died in Damascus in 1248, nitre was interpreted as 'the snow of China' and he made considerably pure quality nitre. (21, 25, 26)
1249	◎ ◯	Roger Bacon of England wrote in his book "Operibus artis et magiae" that the mixing ratio of black powder was 7 (nitre): 5 (sulfur): 5 (charcoal), and gave in detail the refining method for nitre 'sal petrosus'. (25)
1258	⊖	In the battle of Bagdad, Houlague of Yuan used the chênt'ien lei (iron bombs). (21)
1259	⨀	In Nibra, Spain, the Moor (Arab) threw stone and filth by means of stone ballistas, and shot thunder missiles. (25)
1259	⊖	In the battle of Melilla in Morocco, the Moor also used cannons or fire arms.(25)
13th–14th Century	⨀	In a book of tactics in Arabic, there are illustrations of the Titan fire lance and arrow. Some illustrations are shown in the Madfa drawing in Leningrad Museum. We can conclude that it was made of fire lance. (6, 21)
1273	×	When Yuan attacked Siang Yang (Hu Pe), Ismaon, Khorazmian, made the Siang Yang ballista. It is not a true cannon, because it threw stones on the basis of the principle of lever, when manpower of stone ballista is substituted by the heavy stone. (6, 21)
1274	⊖	In the 11th year of Bun-ei age (Japan), when the Yuan troops landed at the Hakata bay, Japan, they shot 'tie p'ao' which means iron bombs, when they retreating from the fight. The Japanese troops surprised t'ien by their thunder and called it 'teppo'. This iron bomb was 'chên ɔ'ien lei', (approx. 18 cm. dia.) (6, 21)
1275	×	Marco Polo, a Venetian arrived in Shan Tu (E 116° N 43°) in April, met the Emperor Shih Siang (Coubilai) of Yuan. He then traveled into China (6, 10) which was 2 years after the attack of Hsing Yang.

Part II. Commentary

1. Nitre in China

1. *Nitre according to Pharmaceutical Books*

As described in Part I, Summary 2, Potassium nitrate was discovered since before Christ. Pharmacological books were published also before Christ.

In the Shên Nung Pên T'sao Ching, which was published in Dynasty of Later Han, one of these pharmaceutical books, there are found letters of 'siao' the nitre and 'sulfur'. (1, 6)

In the Sin Siu Pen Tsao (Nin-naji edition) in 659 A.D. (in the reign of T'ang), there was another letter of 'siao'. In the Chin Shih Chêng Lui Chi Pên Ts'ao (23) selected by T'ang Shên Hui (Pe Sung) in 1082, and the Chung Siu Chên Ho Ching‾Shih Chêng‾Lui Pli‾Yung Pên‾Ts'ao of Ts'ao Hsiao Chung (Pe Sung) in 1116, there are the following descriptions: "Nitre is bitter and cold". It is harmless in the coldest season. "It shakes off the fever of five visera, washes off the conjested bowls, pushes the undigested portion of food out of the bowls, and removes detrimental vapour; if it is kneaded into pellets, and taken dosed continuously, one would feel light in weight", one feels he can become sien ren, who could ascend to heaven. It is also termed the 'mang siao' the sodium sulphate and its resources are in the mountains and valleys of I Chou. Wu Tu, Lung Si and Si Chiang and there was no seasonal restriction with mining.

The phrases in the above quotation marks are the original of the 'Shên‾Nung Pên‾Ts'ao Ching' and the revised Pên Ts'ao and other additional remarks.

In the second place, Tao Yin Chü (50 A.D.) noted as follows: "It has an effect similar to that of 'p'o siao' the plain nitre. Saltpetre found with the po siao is 'siao shih p'o'. They are similar to each other in colour and physical properties. When it is severely burnt, violet flame breaks out and become the ash. This is 'chên siao shih' the true nitre, which before us called 'mang siao'. At present by kneading 'mang siao' the sulphate 'p'o siao' is made.

In the reign of Sung further note as follows: "This is called 'ti shuang' the nitre crystals in earth. Nitre collected in a frost state as the earth in winter is a material different from 'p'o siao' and 'mang siao' the sodium sulphate.

The above I Chou is capital of Minor Han in the Sankuo dynasty. It is a general name of the Ch'êng Tu area, Szŭ Ch'uan province (N 29°, E 103°). Wu Tu the Wu Shai area, Kan Suan province (N 35°, E 105°), Lung Si the Tien Shui area Kan Suan province (N 35°, E 105°), and Si Chiang the western part of Ch'ing Hai province (N 35°, E 95°). (11) From a view point of productive condition, it is the rock nitre hereinafter mentioned.

T'ao Yin Chü is T'ao Hung Ching of Liang. As mentioned in the item, in the year of 502 of the above table, nitre was discrimated from the sodium sulphate by the flame color reaction, and the nitre was handed over to the alchemists. (21)

2. *Making of the Nitre and gun powder*

Although it is a reference book of later year, the T'ien Kung K'ai Wu, (5) written by Sung Ying Sing in Chiang Si province in 1632 at the end of Ming dynasty, it has described as follows: Nitre is produced in China as well as in foreign countries. In China, it is produced chiefly in the northwestern region. When it is sold in the southeastern area, its venders must obtain a license from the government, or punished for illegal sale. Salt vapour made underground seeps out on the ground. When the district is near the water and the layer is thin, it becomes 'yen' (as 't'u siao', earthen nitre in Shan Tung). When it is near the mountain, and the layer is thick, however, it becomes 'siao shih', (as rock nitre in Shan Si). In the north area of Ch'an, Chiang and Chun Shui. After the mid autumn season, man sweeps the ground surface under the floor of his house yard. He takes a small quantity of nitre and refines it. Nitre produced in Szu Chun is called the 'ch'uan siao' (river nitre).

When 'tu siao', an earthen nitre is put into a jar, and kept in water for a night, impurities appears on the water surface. After skimming it off, the solution is put into a kettle, and water is added, boiled and evaporated. The residual solution is poured into a container, and kept over night. The nitre is crystallized. Crystals floating above is called the 'ma ya siao' (means horse teeth shaped nitre). Varieties of nitre are formed in various places. Of them, the impurities are called 'po siao' the plain nitre. After removing impurities, nitre crystals is placed into the water again, and boiled well together with several pieces of laifu, and poured into the chisel. After a night, it is crystallized into 'p'ên siao' the tray nitre. In making gun powder, 'ma ya siao', the sharp crystal nitre and 'pên siao' tray nitre have the same effect. In roasting large quantity, earthen pot is used. When the saltiness is dried fully, nitre is immediately taken up, and powdered. In powdering the nitre, iron runner must not be put into the stone hand mill, because the stone rubbing against the iron makes fire, and causes unforeseen trouble.

It has been written that "sulfur should first be added to the nitre and rubbed, and thereafter add charcoal powder". (5) In the reign of Sung, this process was introduced from Ming to Korea in 1374 to defend against the 'ho k'ou', the Japanese pirates. From the fact that it took three years from 1271 for Marco Polo to travel from Rome to Pei Ching approximately 10,000 km., it was quite conceivable that the overland transportation of nitre, a strategic material, would have been almost impossible. Thus the Arabs and the West cannot use them to make explosives during these periods.

2. Ballista, Stone Ballista and Crossbow in China (Fig. 1)

1. 'P'ao', the ballista can be also understood as the 'p'ao' of every kind. Original p'ao, the ballista means that stone is wrapped in something and thrown at the enemy. It is quite different from the present cannon. Ballista described in the preceding of Fan Li of Yüeh in the Ch'un Ch'iu dynasty (B.C. 620–609) weighed approx. 7.2 kg. Stone was shot by stone ballista, and flew a distance of 500 m.

   2. Stone ballista: in A.D. 200 stone throwing vehicle used by Ts'ao Ts'ao
of Wei at Kuan Tu (N 35°, E 110°) in A.D. 200 was called the "thunder vehicle"
by Yuan Shao. But it was only an expression of the roaring sound. In the Wu
Ching Tsung Yao, there are such words as the 'pao che', cannon wheel, 'tan shao
p'ao', single rod ballista, two-rod ballista, five-rod ballista, 'suan feng p'ao',
cyclonic ballista, 'hu tung p'ao', tiger reside ballista, etc. All of these are stone
ballista made of wood, in which 50–100 men draw one end of the lever using as
many ropes to throw the ballista at the other end.
   As discussed in the book written by Dr. Arima, etc. (6, 12) 'S'iang Yang
ballista', or 'Moslem ballista' is a wooden weight equipped with lever-type
stone ballista, and is not a modern cannon. It will threw a huge stone of 90 kg
in weight and make a hole of 2.1–2.4 m deep, into the ground. Consequently
the Yuan troops brought the Fan Ch'êng and Siang Yang castle garrisons of Sung
to their knees. For his merits, Ismail, Khurazmian was appointed general of the
Army (6, 21, 24). Yuan might have utilized the Moslem cannon, which was used
by the Khurazm troops against the Mongol troops in 1221. I support Dr. Arima's
view (6) that Marco Polo did not take the the part in the plan. He came to China
too late to participate in the attempt.
   3. Crossbow: Three bow crossbow illustrated in the Wu Ching Tsung Yao
(24), is as follows: Three bows are bound together, and one string is drawn
by something like a vise. Arrow fit on to the bowstring is shot, when the set pin is
taken off. It is equivalent to 70 men's power. It can fly one lance and three


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        1                          2                          3
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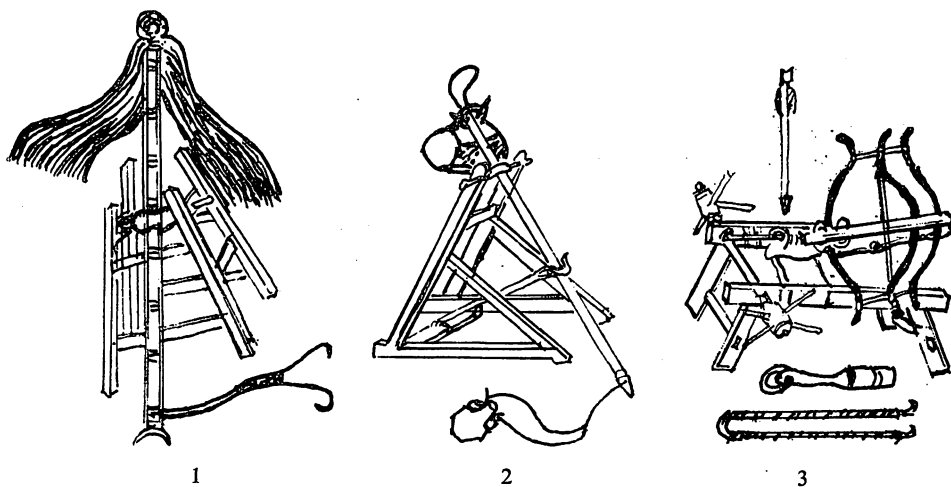
   1. Stone ballista throwing the P'ao (of Pe Sung system)
   2. Weight equipped lever-type stone ballista
       (Hsing Yang ballista or Moslem ballista)
   3. Triple-bow crossbow
          Fig. 1. Various Kinds of Stone Ballistas

sword blades a distance of 500 m. In relation to the explosive arms, D'Ohsson's Mongolian History reported only the fire arrows. But the Mongolian troops reported that they destroyed the capitals in Central Asia and Europe using crossbow ballistas and firing arms of explosives.

3. Development of the Alchemy in China

1. *Alchemy in Western Europe*

The first alchemy was developed in the northern Mediterranean coast of Egypt, chiefly in Alexandria (N 30°, E 30°). About the 3rd century, Zoshimas issued his alchemic, magical and mythical books. Alchemy is a process for making the gold and silver from base metals, 'chemia' in Greek changed into the 'alchemia' in Arabic. It was the age of Ptolemaios dynasty that was supported by the governor general after the death of Alexander the Great. The famous Archimedes's principle (B.C. 282–212) was said to detect counterfeit money. This alchemy was thereafter spread all over Syria and Persia, the territories of Roman Empire and together with the Ching Chiao, it was introduced into China in 634 (at the beginning of T'ang dynasty). At this time, the main international traffic was the "Silk Road". In the east, it led to Chang An via Samarkand, Pamirs and Tun Huang. In the west, it led to Bagdad, Damascas, Constantionople and Roma. In A.D. 97, Kan Ying of Later Han went to Parthia. In A.D. 166, envoy of Marcus Aurelius, the Roman Emperor came to China through the above route.

2. *Alchemy in China*

Shih Huang Ti of Ch'in (B.C. 221–210) searched for the medicine of longevity in Tung Hai. He found out that when food is taken by means of golden tableware, man can enjoy a long life. In the mountains far from the villages, or in huts in valleys, sien ren, men of learning, later scientists and alchemists including Lao Tzŭ, (B.C. 350±) founder of Taoism made every effort to make as much gold and silver as possible. One of the earliest books of alchemy is the Ts'ang T'ung Ch'i of Wei Po Yang (B.C. 220) which discussed the incorporation of three elements, I of confucianism, philosophy of Taoism and the alchemy for making 'tan yo' the elixirs. According to this book, sulfur, mercury, etc. were acted upon the base metals where such five elements including the wood, fire, earth, gold and water, and five colours including blue red, yellow, white and black were added to make 'tan yo' the elixirs.

Later in the reign of Wen Ti of Han, Liu An (B.C. 160–122), King of Chun Nan the alchemy in the Chun Nan Tzu were described as follows: "By means of nitre, sulfur and charcoal, mud was made into gold, and lead into silver". In the Pao P'o Tzŭ, Ko Hung (in Chiang Su (280–340)) of Western Tsin stated that the "part, of chintan relates to the alchemy, and the basic materials for making Tan are, similar in case of Wei Po Yang, mercury and gold" (1, 21, 22). Heating equipment of Tan Yo (alchemy) at that time is as shown in the Fig. 2. The reaction chamber 'Shên Pao' is an oval vessel made of gold of approx. 150 gr. Golden
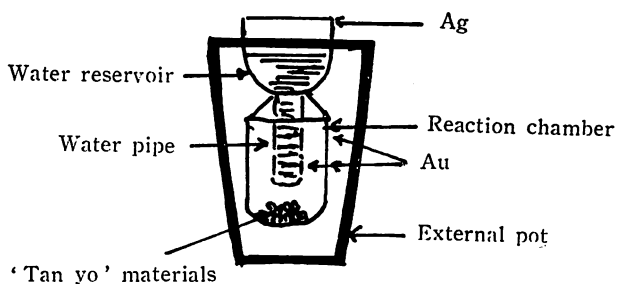
Fig. 2.   Heating equipment of 'Tan Yo' alchemy.

water pipe connecting to the silver water reservoir is inserted into this chamber. Materials are placed in the bottom of the reaction chamber, and fire is put between the chamber and the porcelain or the external earthen pot, to cause the chemical reaction.   As the equipment is cooled by water, the reaction temperature is kept below 100°C (1).   The original objective of alchemy is to separate the gold and silver from the base metal.   In a book of identification issued in 1518, (9) it is described as follows: Separation of gold and silver by nitric acid; separation of gold and copper by a process, heated with sulfur and nitre; Sulfur is enclosed in the wax so as to avoid burning quickly.   Also separation of gold and silver by charcoal leak process, etc.   From these descriptions, it is conceivable that gold and silver were separated from the ore including the copper sulfide.   It was said that when man took a series of 'tan yo' for a long time (say 100 days), he could become a superhuman, who can ascend to heaven, even without wing. Following Tai Tsong of T'ang, 6 or 7 emperors who believed the above legend took these Tan Yo, died young, and it became a great issue.   In this connection it has been transferred from the insoluble mineral substance to soluble remedy.   Thus nitre and sodium sulphate have become the light body medicine (1).

If the alchemy, together with Ching Chiao, comes from Persia as mentioned above (in 638), it would be after the T'ang dynasty.   Therefore, in the reign of Han, Sankuo, Tsin, Nan Pe Chao and Sui before the T'ang alchemy would have been developed independently in China.

4.   Invention of Gun Powder from Alchemy

As previously mentioned, alchemy, where the nitre, sulfur and then the charcoal were added and heated at low temperature, was studied in the reign of Wei Po Yang and Liu An in the 3–2nd century B.C.   But record of explosion was not found. In a section of the Tai Ping Kuang Chien in later Han, the following description was noted (21): When I Wei Lao Jên was making Tan Yo, Tou Tzŭ Ch'un (man in the reign of Shun Ti of Later Han, 125–144 A.D.) called on him.   The old man was away from his hut and some hours passed when Tu woke from his nap, big fire broke out from around the fireplace and flame reached the roof, and burnt the

alchmist's hut to the ground. In the reign of Western Tsin, Ch'êng Su Yüan (264–322 A.D.) wrote a book of alchemy called "Chên Yen Miao Tao Lioh". Fêng Chia Shêng wrote that Chêng was a man after the Chung T'ang Dynasty. (26). Wang Sung Nien described in Sien Yuan Pien Ch'iu that Chêng Su Yuan was a man of the San Kuo dynasty (220–265), while T'ao Hang Ching of T'ang said in the Chên Ling Wei Yeh T'u Li that Cheng was a pupil of Ko Hung and met his death in 322. By employing both views, Ch'ao Tieh Han supposed Ch'êng was alive from 264 to 322 (22). In the above the fire ambassed nitre process it reads as follows: With sulfur and orpiment tightly in a vessel filled with the nitre and set it on fire, flame broke out to burning the hand and the house. In the above two records, the first explosion broke out, and the explosives were invented accidentally without the alchemist's intension. It could be probably in alchemist hut, before 125 to 144 A.D. Although there was no description of charcoal in the three components of powder in the above books, the fire ambassed sulfur process of Sun Ch'en Jên (601–682) of T'ang, and the fire ambassed alum process of Ching Hsü Tzu (808) disclosed that the nitre and sulfur were treated in the same quantity, and charcoal added. Also in the alchemy of Liu An (B.C. 160–122), it was reported that nitre, sulfur and charcoal were used. Accordingly, I suppose the explosion accidents happened to invent the explosives, when the charcoal of the latter process was first added by mistake. Fêng Chia Shêng reported that inflammable chemicals, i.e. explosive was invented at the period of T'ang (21), while Ch'ao Tieh Han concluded that in the reign of Eastern Tsin (264–322) Ch'êng Su Y'uan and that the gun powder was invented without any intention. In consideration of the generation of Tu Tzŭ Ch'un (125–144 A.D.) however, I assumed that the gun powder was invented before 125–144 A.D.

Feng Chia Sheng described as follows (22):

When I Wei Lao Jên was charging, the furnace with nitre, sulfur and ore in the alchemist's hut, Tou Tzu Chun called upon him. Talking with Tou near the furnace, he continued his process. Soon thereafter, he completed his work and fired the furnace. When it operated favorably, Lao Jên went out of the hut, leaving Tu inside. Lao was too late to return (probably he wanted to check something about topic or prepare the meal). Finally Tu took a nap near the furnace. And then suddenly explosion broke out. It might be attributable to that Lao was so deeply engrossed in talking that he carelessly charged the furnace with charcoal to be fed at the next stage, or on the other hand to that Tu charged the furnace with charcoal for fun. There is a possibility of such an accident to happen in the alchemist hut at that time. There is every probability that such an accident would have appeared in other books up to the period of Wei Po Yang, Liu An in 220 B.C. or in 160–122 B.C., who was alchemist. As noted above, alchemist used nitre, sulfur and charcoal in high temp. explosion might happen and gun powder might be invented accidentally before 220 B.C.

5. Development of the Explosives in China

1) 'Pao Chu' the cracker: Various books issued after Eastern Tsin (25–220 A.D.) have disclosed a custom that "each family get up early in the morning of the New Year, full dressed and fires the cracker in the garden to drive out the evil spirits by their thunderous noise". As for the 'p'ao chên chu' the explosion noise of bamboo with several joints are used. When fired, continuous noises are made. At the T'ang Dynasty, it was wrapped in paper, and called "pao chang' the firing cracker (22). The area, south of the Yang Tzŭ Chiang is a bamboo producing region. On festivals, fire-crackers are used even at present.

2) 'Pao Chang' the firing cracker: In Wu Lin Chiu Shih of Chou Mi of Sung, there are found the following phrases: "Boys near the Si Hu compete with one another in setting off firing crackers;" "On new year's eve, firing crackers were used, which had the fuses" (22). These were held on the outskirts of Hang Chou at the Nan Sung Dynasty. In the meantime, the Hui Chi Chih of Nan Sung (1201) reads as follows: "On new year's eve, the noise of fire-cracker is heard"; "Somebody makes explosive from sulfur, and calls it the "firing cracker" because of the thunderous noise it makes". Meanwhile, the Si Hu Yu Hsing says "firing cracker experts make a rotation ring", and the Si Hu Fanch'ang Lu says "five-colored smoke, and set off firing crackers" (22).

3) The Li Huan Yu Pi T'i Yao of Che Pa Ta of Ming says that "Hsien Yüan made 'P'ao' the ballista, Lu Wang made 'Chung' the gun, Ma Kou of Wei made 'P'ao Chang' the cracker, and Yang Ti of Sui made various humours with explosive powder. Feng Chu made 'P'ao Shih, the ballistic stone, and Liu An made 'Yen Siao' the nitre. (22) with these descriptions I feel that the development of explosives started before the Sui period.

4) 'Yen Huo' the fire smoke: In the tactics of Sun Tzŭ (500–450 B.C.) there are found letters of 'Yen Huo'. But these are a kind of straw, grass and fire wood. The Shi Chih the historical record of Szu Ma Ch'ien (97 B. C.) says that "though there are a long range of smoke from the farmers, but actually it was the smoke from their kitchens". (22)

5) 'Feng Huo' the signal fire: According to the military regime of Han, high towers were built in remote places to report the invasion of enemy such as Hu. If any invasion was found, pile of wood set on was fired. The smoke was called 'Sui', the signal fire. In proportion to the number of enemies, its numbers were increased. (22) In Japan, too, in the Nara dynasty, there was a system of fire signals, by which the officials of Dazaifu report to the Yamato dynasty (Nara). in Ono, Kiyama castles, etc. (22)

6) 'Yen Huo' the fire works: The fire works, which seemed to have used the material similar to the explosive, are summarized in this item. 'Hanabi' in Japan is one of them.

Next to later Han Dynasty (52–220 A.D.), San Kuo Dynasty (220–265), Western Tsin (265–316), Nan Pe Chao Dynasty (420–589), Sui (589–618), and T'ang (618–

907) followed. In the San Kuo Dynasty, there is a popular San Kuo Chih, the famous military novel, according to which Chu Ko Kung Ming of Minor Han defeated the Ts'ao Ts'ao troops of Wei by means of sulfur, nitre and inflammable. At the beginning of this historical discussion, the author took interest in this story. But there was no description of explosive in the Correct History of San Kuo Chih written by Chên Shou, authentic history as well as in the complete works of Chu Ko Kung Ming of Fang Ku Tzǔ edition. During this period from 150 to 600 A.D., however, a topic of the explosion accidents developed among the dynasties which had a large number of 'Sien jên' the alchemists to make the gold, militarists and the book scholars. Thus a series of the explosive chemistry greatly developed into fireworks in combination with the cracker and fire cracker among the people that "Yang Ti of Sui made various humours with explosive powder". In Tung Tu (Lo Yang) at that time, various plays including the gulping of swords, puffing of fire by magician, etc. were conducted in the Eastern Han. Fire puffing is not an explosive feat because the fire goes off when the mouth is closed. Anyway, it was conceivable that fire plays were widely conducted.

Su Wei Tao of T'ang was premier of Tsêo T'ien Wu Hou (690–705). In his poem, there was a phrase "Fire tree and silver flower" (21, 6). Although it was impossible to conclude that this phrase meant a firework, it was concluded that it would have been something like firework.

In relation to the skill in fireworks of the T'ang Dynasty, described in the Wu Li Siao Shih of Fang I Chih, I would like to study more details. There has been since the ancient times, a close relation between the military affairs and the fang shu the pharmacist. In the Yin Fu Ching, Ching Tien was shown to the pharmacist. Liu An of Han, Ko Hung of Tsin and Sun Ch'en Jên of T'ang described the military affairs in books of alchemy. In the reign of Suan Tsong of T'ang (754–62), Li Chūan wrote the "Shên Chi Chih Ti T'a Pê Yin Ching", whose first half was a book of tactics, while the latter was a view of pharmacist (prescription of medicines). Like the books of tactics including the Hu Ling Ching of Hsü Tung, Wu Ching Tsung Yao edited by Ts'ao Kung Liang et al. and others. It is considered that, at the later period of T'ang dynasty (at the end of 9th century), the gun powder was dedicated to the militarists on the offer of the alchemists (21). In Yü Ch'ang in 904, there are words of flying vehicle and fire. In the comment of Hsü Tung in 940, there are letters of 'Huo P'ao', 'Huo chiu' and 'Flammable Nitre'. In the alchemy book of T'an Ch'iao in the same year, there is found a principle of chemical reaction of pharmacologist. Tan was later killed by Sung Chi Chiu, pharmacologist of Nan T'ang. In 975, Chao Sung of Sung destroyed Nan T'ang by means of 'Huo Pao' and firing arrows. From these facts, the author has concluded that the gun powder for military use, and the explosive arms, developed chiefly in Nan T'ang (south and north of the Yang Tzǔ Chiang) in the first half of 10th century, was completed by Pe Sung.

6. Development of the gun powder composition after the sung Dynasty

From the former-half volumes, 11 and 12 of Wu Ching Tsung-Yao of Sung, the following table was obtained:

Powder making process.

1) For 'Huo Chiu' the fire balls: Sulfur nest and 'Yen Siao' the nitre are mixed, and pounded into powder. In the meantime, arsenic sulfur, 'Ting fên' powder and lead oxide are sieved, mixed and grounded into powder. In addition, dry lacquer is powdered, while 'Chu ju' the silicious skin of bamboo and 'Ma ju' Skin of hemp are a little toasted, and powdered. Beeswax, rosin, tallow, paulownia seed oil and heavy oil are mixed with one another, prepared, kneaded into ointment, and then mixed with the above-mentioned powder. When this mixture is wrapped in five sheets of paper, and tied up with hemp, 'Huo Ch'iu' the fire ball is made. In addition, melted rosin is put on the powder to make the igniter, which is shot by ballista. It is also used, in discharging when the poisonous smoke ball is discharged.

2) For 'Jili Huochiu' the thorny fire ball: Sulfur, yen siao (nitre), charcoal powder, asphalt and dry lacquer are pounded into powder. Meanwhile, silicious skins of bamboo and hemp are finely cut, and mixed with oil, in which the paulownia seed oil, siao yu oil and wax had been melted, to make the powder. As for the igniter, the materials totalling, 24.25 liang, (0.91 kg) include the paper, 12.5 liang (0.47 kg), hemp 10, lead oxide, 1.25, charcoal powder, 8, asphalt, 2.5 and beeswax, 2.5 are applied to the fire ball.

○ A 1~3   Sung dynasty (China)
■ B 1~11   Ming dynasty (China)
△ C 1~3   Japan
× D 1~9   Europ
□ E 1~2   Japan (present)
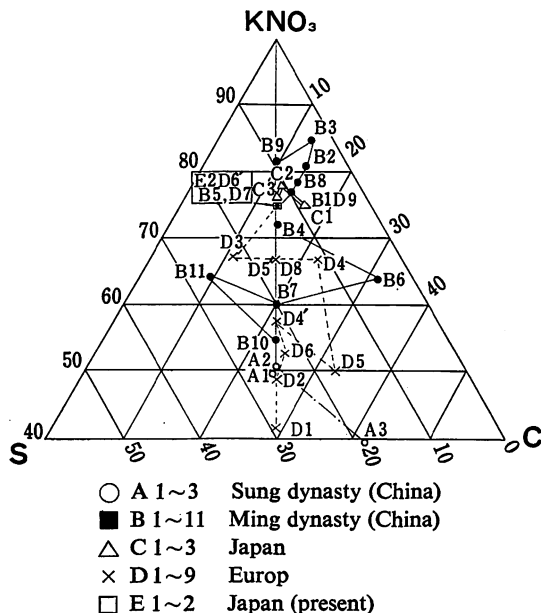
Fig. 3. Composition of Black Powders in various ancient countries

3) For 'Tu yo yen ch'iu' the poisonous smoke ball: Ball weighs 30 kg. Its process is the same as that of fire ball. Hemp rope, 3.6 m long and weigh-. ing 0.8 kg. As for the igniter, the materials totalling 35.75 liang (1.34 kg) including the paper scrap 11.5, hemp akin 10, asphalt 2.5, beeswax 2.5, yellow pill, 1.25 and charcoal powder 8 are pounded to make the outer coating of igniter (246). The literature (30) is the data, when the author investigated in Portugal in 1966 colonel Eng. Material, Filipe Jose Freire Themudo Barata of Lisbon Black Powder Arsenal told me from the old explosives Literature. The Fig. 3 is a triangle or-dinate of the above data shown in terms of nitre, sulfur and charcoal elements. According to this triangle, nitre is 40–50% for the powder in Sung Dynasty in the 11th century, 40–60% for that in Europe in the 13–14th centuries, and less than 50% for that even in the 16th century. In Japan, however, the powder of max.

TABLE 1. Composition of Gun Powder of Pe Sung Dynasty,
China in 1045 A.D.

	Composition	For Fire ball	For thorny fire ball	For poisonous fire ball
Coarse	Nitrate of potash	48.5%	50.0%	38.5%
	Sulfur	17.0%	25.0%	19.25%
	Sulfur nest	8.5%	0	0
	Rough charcoal powder	0	6.25%	0
	Charcoal powder	0	0	6.4%
	Other organics	26.0%	18.75%	35.85%
	Total	100.0%	100.0%	100.0%
	Lot	30.94 kg	30.0 kg	29.2 kg
Detail of other organincs	Asphalt		3.1%	3.2%
	Siao Yu oil		3.1%	3.2
	Wax		3.1	
	Bees wax	0.6%		1.25
	Paulownia Seed oil	0.3		3.2
	Heavy oil	0.6	3.1	
	Rosin	17.8		
	Arsenic yellow	1.2		
	Dry lacquer	1.2	3.15	
	Normal powder	1.2		
	Silicious skin of hemp	1.2	1.6	1.6
	” ” bamboo	1.2	1.6	1.6
	Monkshood			6.4
	Platain bean			6.4
	Wolf poison			6.4
	Arsenic frost			2.6
	Yellow pill	1.2		

TABLE 2. Compositions of Ancient Gun Powders in the World

Nation	A.D.	Original Literature	Powder	No.	Kali nitre	Sulfur	Charcoal	Other comb.	Lite-rature
China	1045	Sung: Wu Ching Tsung Yao	Gun Powder for fire ball	A1	48.5	25.5	——	26.0	24
			,, for thorny fire ball	A2	50.0	25.0	6.25	18.75	,,
			,, for poisonous fire ball	A3	38.5	19.25	6.4	35.85	,,
	-1548	Ming: Chih Siao Sin Shu	By Japanese recipe from 'Ho K'ou'	B1	75.75	10.6	13.65		6
	1597	Ming: Shên Ch'i P'u	For rifle of Southern district	B2	80.66	5.64	13.70		,,
			For igniter	B3	84.0	2.56	13.44		,,
	1606	Ming: Ping Lu	For Sand blasting	B4	71.4	14.28	14.28		,,
			For large European rifle	B5	75.0	12.5	12.5		,,
	1621	Ming: Wu Pei Chih	For bare use	B6	63	5	32		,,
			For igniter	B7	60	20	20		,,
			For propulsion	B8	77	9.5	13.5		,,
	1637	Ming: T'ien Kung K'ai Wu	For bursting	B9	82	9	9		,,
			For detonation	B10	54	23	23		,,
			,,	B11	64	27	9		,,
Japan	1543	Industrial History in Meiji	Tanegashima, early period	C1	75	83	16.7		29
	1569	By Jiyusai, Zuda	After 26 years of introduction	C2	77.6	10.7	11.7		6
				C3	76	12	12		6

Country	Year		Name	No.					
United Kingdom	1249		Roger Bacon	D1	41.2	29.4	29.4		25
France	1338			2	50	25	25		25
Germany	14Ct.			3	66.7	22.2	11.1		6
United Kingdom	1350		Ardernes powder	4	66.7	11.1	22.1		25
"	1480			4'	57.0	21.5	21.5		30
"	1560		White horn common powder	5	50.0	16.7	33.3		25
Sweden	1560			5'	66.6	16.7	16.7		25
Germany	1595			6	52.2	21.7	26.1		25
France	1598			6'	75.0	12.5	12.5		30
United Kingdom	1635	English government		7	75	12.5	12.5		6
"	1647		Nye	8	66.6	16.7	16.7		25
France	1650	Napoleon III		9	75.7	10.8	13.6		25
Japan	1967	Nippon Kayaku Co. Ltd.	Mining black powder	E1	64	18	18		
		"	Sporting black powder	E2	75	12.5	12.5		

potency, approx. 75% in nitre, almost the same as that used at present which has been used since the 16th century, when the gun was introduced into the Tanega-shima Island of Japan. In the Ming Dynasty, which obtained information on powder from prisoner of the Japanese pirate 'Ho Kou', that they made black powder of 75%, and was suprised at its strength (6). Powder introduced into the Tane-gashima Island is not of standard blend in Portugal. I suppose by Japanese litera-ture, Koshiro Shinokawa, could not get the Portuguese composition. It seemed that he worked out a composition of the highest power, when regulating the ratio of the three elements to obtain equal power with the gun powder given.

7. Fire Arms in the 10–13th Century in China

1. *Kind of fire arrows (Fig. 4)*

Fire arrow and firing tube are as follows: The powder tube is tied to the arrow and charged with a combustible agent to shoot the arrow. After the in-vention of gunpowder, powder tube was charged with powder (approx. in 940). In the case of the powder whip arrow, ball shaped powder was made, and fastened to the head of the arrow. After the firing the fuse, arrows were shot into the enemy line with a blast and setting fire the enemy camp. According to Wu Ching Tsung Yao (in 1045), similar to the lance bamboo, 5 cm outer dia. and 1.8 m long, was charged with 200 g of explosives. After the ignition, it was shot, while revolving (6, 21, 22, 24).

2. *Explosive bomb: Fig. 5 shows the explosive bomb of Pe Sung type, and the Fig. 6 that during the period of the triple struggle of Sung, Chin and Mongol. According to the Wu Ching Tsung Yao (24)*

    (1) Fire ball: Ball was made of paper, where piece of stones weighing 2–3 kg was put therein. Beeswax, asphalt and charcoal powder were boiled in the muddy matter, and applied to the periphery of ball. Hemp rope

1	2	3	4
whip type	fire arrow	powder cartridge	fire arrow after
fire arrow		type	gun powder
		fire arrow	invention

Fig. 4. Fire arrows

1 whip type

2 fire ball of pull ignition type

3 thorny fire ball

4 thunder fire ball
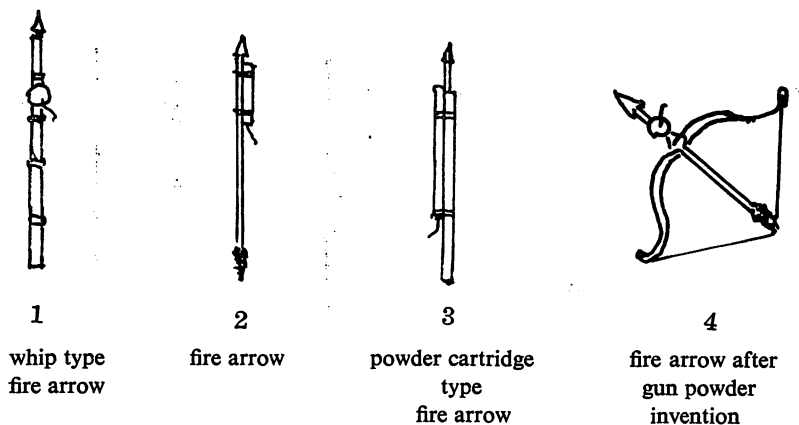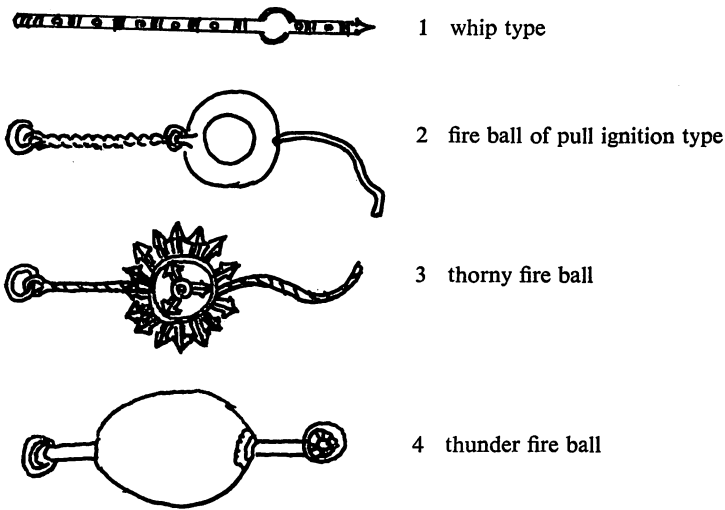
Fig. 5.   Regular fire arrows in Pe Sung

was penetrated through, and in accordance with the distance, the ball
was thrown by holding the head.

(2)   Thorny fire ball: Blade with its three branches and six heads was wrap-
ped in powder, penetrating hemp rope of 3.6 m long.   The ball was
fired by means of paper and miscellaneous agents.   When the ball was
shot, smoke broke out through the hot iron drill.

(3)   Thunder fire ball: Dry bamboo with joint diameter, of 4.5 cm with no
crack was selected.   The joints remained un-pierced.   In this bamboo,
30 hard ceramic pieces were mixed with powder of 2–3 kg, and the ball
was made of inner skin of bamboo.   Both heads were sealed with
bamboo pin, and the igniter was added on the outside of ball.   When it
was fired, thunderous noise was made and its smoke and flame ball
scorch the enemy.

(4)   Poisonous smoke ball: In place of explosive ball, poisonous smoke ball
was used.

Names of the fire arms used at the period of the triple struggle shall be enume-
rated hereunder in chronological order:

Sung;   Huo P'ao 940, Huo ch'iu (paper-wrapped 940), Huo chili (1000),
Ji li huo ch'iu (1045), Tu yao huo ch'iu (1045), Chin pieh p'ao
(1103), fire stone bomb (1161), iron bomb (1257), great cannon
(1277)

Chin;   Iron bomb (1221), Chên t'ien lei (iron bomb 1231, 1232), powder
flask (paper shell, for use in fox hunting) (1160)

Mongol;   'Teppo' (Tieh p'as) used in the Hakata bay (iron bomb, 1274),

cannon (1232, 1237), poisonous powder can (1219, 1241 in Persia and Poland)

In the Chen Chi Tung Hai Ch'iu Fu written by Yang Wan Li of Sung, thunder ball used in the battle of Ts'ai Shih Chi in 1126 was interpreted as follows: It was made from lime and sulfur in a paper tube (paper ballista). After ignition, the ball was thrown up in the sky, and burst to scatter lime and sulphur all over the sky. When it dropped into the water, the lime ignited to set at large the sulfur and the fire destroyed the enemy's boats (21). At the initial explosion, small quantity similar to the gunpowder may have been used. On the whole, however, it would not by any explosive arm.

From the picture of explosive ball on the old chess board excaved out of the earth in Lo Yang, it is conceivable that the word of 'p'ao' the explosive ball has since been used in the Nan Sung period in place of the "ballista" (21).

The "huo foi" powder can was used by fox hunters in the reign of Shih Tsong of Chin 1160–90. According to the record: When the fox appeared from under the tree, the roll cracker was taken from the powder can carried by the hunter, and the fire cracker was thrown at the tree, powder can exploded, and the foxes were in confusion, being surprised at the explosion. It is also commented "Although the quality of fire can is unknown, can shell was made of paper, and the powder wrapped in paper was used for the fuse,—". (22) "As for the fire can, pottery can charged with powder, and the roll cracker set in". (21) It was probably a poaching.

In 1221, Chin troops arranged 13 sets of stone ballistas to shoot 'T'ie huo pao', the iron bomb into the enemy's castle. Iron bomb was calabash-shaped, small opening, a cast of raw iron, 6 cm in dia. When the Yin Sien, which had been cut in proportion to the distance to the target, was ignited, the bomb exploded when it hit the ground. (21, 22) In 1232 when Chin troops used the 'Chên t'ien lei', iron can was filled with powder. When it was ignited, the ballista shot fire, and its thunder was heard hundred li (17 km), and its heat ranged over more than half se (18 m × 18 m) × 1/2. Iron pot a cannon shell, ignited before use and thrown off. It dropped on the ground and exploded. In the mean time, the Mongolian troops advanced below the castle and entrenched themselves. The Chin soldiers hung the Chên t'ien lui on the iron rope, and exploded it in the trenches killing the enemies covered with cattle skin. 'Chên t'ien lei' was officially termed 't'ie huo pao' "iron bomb" (1221), which was of two kinds: calabash-shaped and lid-type (21, 22). In 1232, when the Mongolian troops besieged Pien Ching of Chin they shot the bomb with stone ballista (21). In the arsenal in Ching Chou of Sung in 1257, 1000–2000 pcs. of iron bombs were manufactured monthly, 10,000–20,000 pcs. of iron bombs in Siang Yang and Chung Siang respectively (21). In 1277, when Kuei Lin of Sung surrendered, one unit of the large cannon was taken out. When it fired, a thunderous roar was made, and the sky was filled with smoke, destroying the castle walls. Large number of Yuan soldiers outside the castle wall

were killed with the explosion, while 200 garrison soldiers were burnt to ash. It seems to be a large mine. (21)

In 1219, the first line of Khorazm invasion when Tchinguiz Khan attacked Jend, Otrar and Khodjond (43°–47°N, 60–70°E) of the Sil river, it was reported that the invaders threw combustible materials causing disaster and also the setting up of crossbow ballista. (16) In the same year, crossbow ballista was used, in the Bukhare of the Amu river (40°N., 64°E.). In the battle of Ulghenj at the mouth of the Sil river (45° N., 59° E.), water-soaked mulberry was discharged by means of stone ballista, as there were no stones available. In Nessa in 1220, one battery was built and continuous attack was made upon the enemy for 15 days with 20 crossbow type ballista to make a big break-through openings (16). In the same battle, the Mongolian troops used the poisonous fire cans, fire arrows and Huo pao, the fire bomb (21). In the battle of Nishabour (37° N., 58° E.) in 1221, Khorazimian troops carried 3,000 crossbow ballistas to shoot the sword-blade lances, and 500 ordinary crossbows, while the Mongolian troops carried to the castle 3,000 crossbow ballistas for shooting the lances, 300 ordinary crossbow ballistas, 700 petroleum pot ballistas, 4,000 long ladders, and 2500 carts of stones, and they invaded the castle whole day and night and made 70 breakthrough openings on the castle wall. These ballistas, shown in 3 of Fig. 1, seem to be kinds of crossbows and belong to the Moslem ballistas (Arabian side). (16)

In 1241, when Batou invaded the West, he used poisonous smoke balls in Wahlstadt, Poland (21). Historian in Poland reported as follows: When the Mongolian troops waved a large flag it appeared to be a monster with a X-shaped neck, emitted smoke from the mouth, the bad smell was so intolerable to the Polish soldiers that they suffered heavy casualities (16). In the same year, the Mongol burnt the temple using the fire arrows in the Olmitz castle in Moravia (16).

In the Arabian book in the battle of Bagdad in 1258, the Mongolian troops used iron pot. It seemed to be a kind of Chên t'ien lei or iron bomb. (21)

In 1274 (in the period of Bun-ei in Japan), Yuan troops used the iron bomb (which shall be described hereinafter). As in the above detail in 1160–1230, explosive fire arms used in Sung, Chin and Mongol were shaped as such shown in the Fig. 6, 1–4. It was of iron- or ceramic-made, and termed explosive ball, iron bomb, iron fire bomb, porcelain bomb or Chên t'ien lei. It seems that the stones were shot by crossbow ballistas to destroy the castle walls, while the Chên t'ien lei was thrown into the castle by means of crossbow ballista, in which the fuse was ignited before shooting, the length of the fuse was adjusted in proportion to the distance to the target (21).

Fig. 6 (1) illustrates a copy of the "pictorial tale of Mongolian raid" related by Suenaga Takezaki. It shows the Mongolian arms used by their troops at the landing operation in Hakata bay in 1264. The word "Teppo" would have meant 'Tie p'ao' the iron bomb disclosed by the prisoners of Mongolian troops. According to Dr. Arima's opinion (6) that 'the above arm was not the so-called gun
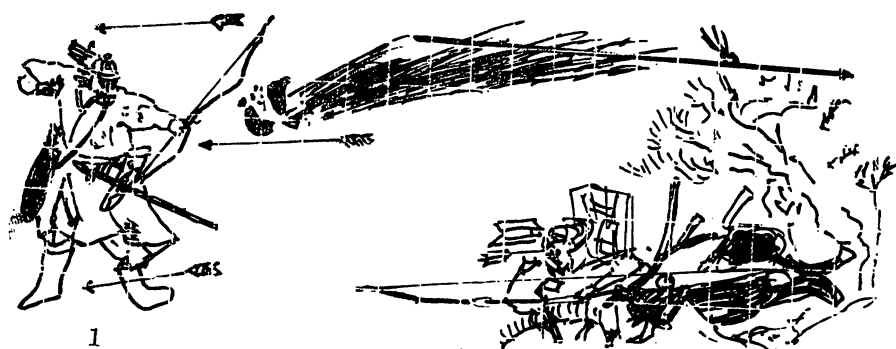
1. Mongolian attack on Japanese with chên t'ien lei

| 2 | 3 | 4 | 5 |
| conbined cap type | pot type | calabash type | ball type |
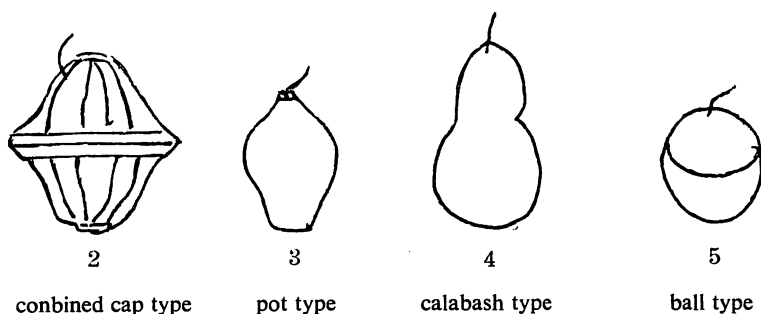
Fig. 6. Various iron bombs and chen lei

of the later period, but the same as the 'chên t'ien lei' when the above picture was observed. It seems that the unexploded scattered shells found in the battle field considered to be dangerous and strange articles, the Japanese troops ordered to dispose it into the Hakata bay without making any investigation. In this connection, it was regretful that the Japanese have idled their time away for about 270 years before the introduction of fire gun into the Tanegashima Island. On the assumption from that of the original drawing scale 1:20, I have tentatively estimated the height of the then soldiers of that period, size of the arms, and the explosive amount of iron bombs in the next Table 3. During this age, the iron bomb was a new arm.

The author calculated the dimension and weight, assuming that the thickness of the iron bomb case was 5 mm, loading density of powder 1.0, Table 4 was obtained. Throwing the iron bomb of 18 cm outer dia. and approx. 7 kg in weight,

TABLE 3. Size of Soldiers and Arms Assumed

Troop	Height of Soldier	Bow	Arrow	Sword	Lance	Iron bomb
Mongolian	1.7 m	1.6–1.4	0.6–0.7	1.0–1.3	2.7–2.1	.18–.20
Japanese	1.5 m	2.4–2.0	0.9–1.1	0.9–1.1	–	–

TABLE 4.

	Iron bomb		case		Powder charge		Total weight
	de cm	di cm	vol liter	wt kg	vol liter	wt kg	kg
1	20	19	0.7	6.5	3.5	3.5	10.0
2	18	17	0.5	3.9	2.5	2.5	6.4
3	16	15	0.3	2.3	1.8	1.8	4.1

1 fire lance

2 fire lance with projectile

3 fire burster of 14 century

4 flying fire lance
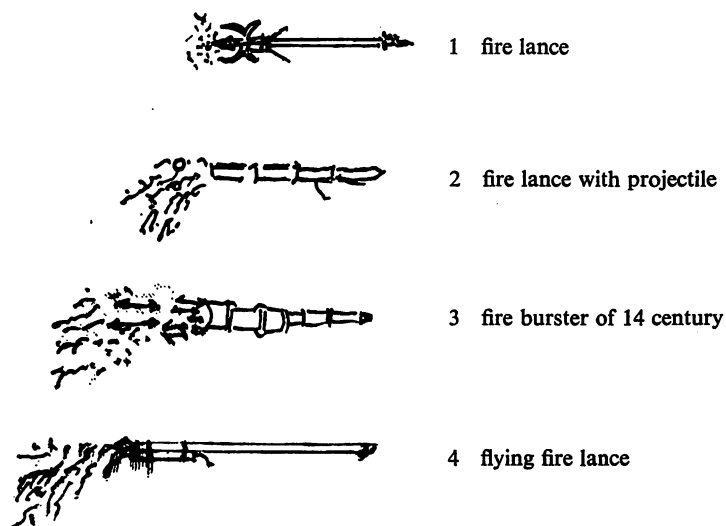
Fig. 7.   Various type of fire lance in China

it seems that crossbow ballista must have been used in the battle, because it must be thrown correctly 200–300 m.   In the picture of Mongolian raid, however, such a ballista was not found.

      Nan Sung: 'Huo t'ung' the fire burster (gun powder in bamboo tube) in 1132; 'Huo chiang' the fire lance (paper cartridge) in 1257 1268, 1276; 'Shi huo chiang' firing lance with projectiles. (bamboo tube with balls) in 1259

      Chin: 'Fei huo chiang' the flying fire lance (paper cartridge) in 1232; 'Huo chiang' the fire lance (paper cartridge), in 1233.

According to reports, the composition of gun powder charged in the long bamboo pipe used by Ch'ên Kuei of Sung in 1132 was not known (21), but in Sung, there were an official gun powder composition (as in Table 1).   After removing the head joint of about 0.6–1.0 m of 4–5 m long bamboo, it was charged with gun powder (approx. 1 kg).   When one soldier would operated the bamboo pole, and the other would fire, or helped him in various works, it could eject flame for approx.

1–2 min. and burn down the long radder.

In 1132, when the Mongolian troops besieged Pien Ching, Chin troops used the flying fire lance.   The fire lance which was used in Kuei Te in the second attack upon Pien Ching in 1133, was a pipe of 60 cm long made of 16 sheets of Chih huang chih.   It was tied on to the lance head, charged with mixture of willow charcoal, iron slug, porcelain powder, sulfur and arsenic frost, and ignited immediately before firing.   It was a flame radiating tube, which can burn an area 20×20 m, and 20 m ahead.   Although there was no description of nitre, there was a possibility that small quantity of nitre was added to reinforce the fire (22).   The fire lance tube was not damaged, even when the powder was completely burnt out at the flame length of 3 m.   In this connection, it was reported that the Chih huang chih could be continuously used, because it was so strong in the alum property which did not burn (22).

Firing lance, which was invented in Shou Ch'un of Nan Sung in 1159, was reported as follows: the upper section of the large bamboo tube was charged with powder and projectiles.   When ignited, flame came out.   After the flame diminished, the projectile was discharged and the noise was heard 270 m off. (21)   It seems that this was a fire gun at the initial stage.   There were some descriptions in the literature of Ming dynasty that the T'ung ch'ung, a copper cannon, was a changed form of the bamboo joint.

8.   Introduction of the Gunpowder and Explosive Arms into Arabia and Europe

1.   *Introduction of explosive arms*

Khorazm, who first took arms against the Mongolian troops invaded the West, had nitre deposit in her land.   But there were no records which can witness the use of gun powder or explosible fire arms.   In these times also in Europe, neither nitre nor explosible fire arms was found.   Only the Mongolian troop had used them in these countries. (16)   The Il Khan Kuo troops, which destroyed the Khorazm and occupied Bagdad in 1258, further captured Damascus and destroyed Syria.   In 1260, however, they were defeated by the Mameluk army of Egypt, and were since then both armies opposed each other.   In 1303, the Egyptian troops finally defeated the Mongolian, and occupied Syria.   During this period, there was a possibility that the explosive arms were delivered to the Arab.   In the battle of Nibra, Melilla in 1259, the Moor used somethings like the explosive arms.

In the 13th–14th centuries, Madofa was made from the fire burster and fire lance with projectile (21).   From the Madofa picture of explosive arms in Arabia, Fig. 8, the followings are conceivable: Outer diameter, 17 cm (inner diameter, 15 cm); length, 30 cm; diameter of bullet, 15 cm; handle length, 1.2 m; explosives, approx. 5 kg; ball is 14 kg (in case of iron), and approx. 5 kg (in case of stone).

In the Arab book of tactics one reads as follows: "As for the 1st type, one short tube was charged with powder and a stone ball was placed at the mouth of the tube.
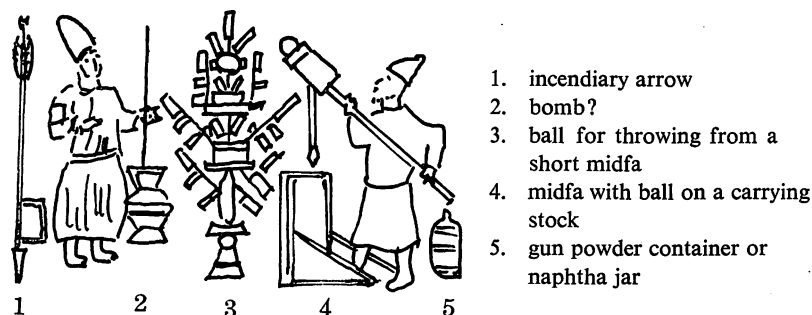
1. incendiary arrow
2. bomb?
3. ball for throwing from a short midfa
4. midfa with ball on a carrying stock
5. gun powder container or naphtha jar

Fig. 8. Explosiness arms in Arabian countries

After ignition, powder was fired and by virtue of this impact, the stone ball was discharged to attack the enemy.   As for the 2nd type, long tube was charged with powder, iron ball was put thereon in the tube.   After plugging the mouth, an arrow was put through.   After ignition of the fuse, powder was fired, and the iron ball jumped out to push the arrow and injure the enemy". (21)

In the records of the 1st–7th Crusades, explosive arms were not reported. (25)

2. *Propagation of gunpowder*

In Lin An (Hang Chou), capital of Nan Sung in 1218–58, the royal family played fire works, the fire crackers and also the fire works were sold in the city (21).   Since the last stage of the Tang regime, Tibet was so powerful that the silk road traffic was interrupted.   In the reign of Nan Sung, seaborne trade through South China, Malay, India and Arabia was very active that there were Arabian concessions in South China, where the explosives and fireworks were introduced to the Arab which became the natural course of the events (21).

The Medical book of Ibn al-Baythar, who died in Damascus, Syria in 1248, first described the nitre making process, calling the nitre as 'snow in China'.   Rogers Bacon (1241–1292) of England described in his book, Operibus artis et magiae that the composition of black powder was nitre 7 (41.2%) sulphur 5 (29.4%) and charcoal 5 (29.4%) and detailed the refining process of sal petrosus (25, 6).   Before the 14th century including the Greek fire and Sea fire it did not contain the nitre (25, 26) therefore they are not explosive powder, but only a chemical incendiary.   In Kyser (literature of Romocki) in 1405, nitre, sulfur, petroleum and sulfamium were reported.   In the Whiteforn's book in 1560, only the nitre, sulfur, pitch terpentine and Bay salt are stated as wild fire (25).

In the Liber Ignium of Marcus Graecus, refining process for the sal petrosus was interpreted.   As this book had a supplement in the later period, the above seemed to be an additonal description in 1225–1300 (25, 9, 6).   Al Hasan al-Rammah (1275–1295), an Syrian (?) said in his book of tactics that the nitre was the fundamental material of fireworks, also described the firing arrow, Nan Ching fire works, explosive tube and Bengal fireworks (9, 2).

Schwarz's opinion, that the black powder was invented or applied to the gun (1350±) has not been confirmed (25–28.6) in that above mentioned literature, (1–28).

9. Postscript

1. In order to define the development of the events, all the years were expressed in terms of Christian Era, and the events have been enumerated in chronological order.   Ages in China are based upon the list of the Chinese name of the chronological eras of the standard chronological table of world history, and the age of the reign of kings.   In relation to the expression in terms of 10 stems and 12 branches, I have assumed that the zero year of Christian era is a Keng Shen year, and had worked out a table of 60–year cycle of Keng Tzu Researches of men, events and ages, also had conformed to the above chronolgical table.

As summerized below, 76 of 101 events described in this essay are based with the literature in China.

Section in the first chronological table	1	2	3	4	5	Total
Number of the event in the world	18	10	9	50	14	101
Number of the event in China	9	7	5	48	7	76

2. In relation to the modernization of names of the places in ancient times, I have conformed to the standard maps of world history (11), and besides shown the approximate longitude and latitude of places.

3. Chinese system of weights and measures are converted into the metric system on the basis of the following table of Great Chinese-Japanese Dictionary (18) which are as follows.

Conversion Table

Weight	Kuan	Chin	Liang	Fun	Chien	Chu
Liang	100	16	1	1/4	1/10	1/24
Gram	3750	600	37.5	9.375	3.75	1.56

Length	Li	Ting	Chien	Chang	Chih	Tsun
Meter	654	109	1.8	3.0	0.3	0.03
Ting	6	1	1/60			
Chang			6.0	10	1.0	0.1

Area	Ting	Tuan	Se	Bu
Bu	3000	300	30	1 (1.8 m × 1.8 m)
m²	10000	1000	100	3.3

4. And translations of Chinese to Japanese are conformed to the Iwanami Chinese Dictionary, present place names to the New World Map issued by Zenkoku Kyoiku Tosho Company and edited by Keiji Tanaka in 1964, and the New World Atlas, the 1967 edition.

5. Development of the gunpowder and explosive arms in the 14th–16th centuries has been chiefly conducted in Europe. In relation to the subject of this article, I have considered it proper to close this article in the 13th century. The following details have been kept for the future.

6. The Mathew's Chinese English Dictionary 1944 was used, in the translation of Chinese to English.

The author was born in Nara City in 1898, graduated from the Explosives Engineering Section of the Engineering Faculty of Tokyo University in 1924, joined the Nippon Kagaku Co., Ltd. The same year, he was engaged in manufacturing dynamite in its Asa Factory, after 1946 worked in its Head Office, and issued the Chronological table of explosives industry in Japan.

Chinese and Japanese glossary

Part I　Proper nouns (Chinese)

A			
Ai Tsong	哀宗	Ch'i Chou	冀州
Akosu	阿克蘇	Chi Chou	蘄州
An Ch'ing	安慶	”　Chun	蘄春
An Hui	安徽	Chi Lin	吉林
An Li	安豐	”　Nan	濟南
An Lu	安陸	Ch'i Tan	契丹
An Nan	安南	Chiang Ling	江陵
An Si	安西	”　Nan	江南
An Yang	安陽	”　Si	江西
Ao Mên (Macao)	澳門	”　Su	江蘇
		”　Ta	姜大
C		”　Tsai	姜才
		”　Tu	江都
Chai Shuo	解說	Chin	晉(山西)，金(滿洲)
Ch'ang An	長安		
Chang Ching	張青	Ch'ih　　(0.3 m)	尺
Ch'ang Chun	長春	Ch'in	秦(陝西のS)
Chang Chüntso	張君佐	Chin hua	金華
Chang Chungching	張仲景	Chinkuo Chih	九國志
Ch'ang Chiang	長江	Ch'iênhung Yungchên	
Chang Hungfan	張弘範	Chihpao Chichêng.	鉛汞用辰至寶集成
Ch'ang Sha	長沙	Chihsiao Shinshu	紀効新書
Chang Shihchich	張世傑	Ch'ing	清
Chung Shun	張順	Ch'ing hai	青海
Chan Kuo Dynasty	戰國時代	Ching Chiang	靜江
Chao	趙(河北W)	”　Ch'êng	京城
”　Chou	潮州	”　Chiao	景教
”　Sung	趙宋	”　Chou	荊州
”　Tiehhan	趙鐵寒	”　Mên	荊門
Che Chiang	浙江	”　Tien	經典
”　Chou	澤州	Ch'ing Hsützŭ	清虛子
”　Pata	這部大	Chingshih Chênglui	
Chên t'ien lei	震天雷	Chi Pênts'ao	經史證類急本草
Chênling Weiyeh T'uli	眞靈位業圖裏	Chou	周
Ch'ên Kuei	陳規	Chou I Ts'ant'ung Ch'i	周易參同契
Ch'ên Shou	陳壽	Chou Mi	周密
Chên Tsong	眞宗	Ch'u	楚
Chênyen Miaotao Yaolioh	眞言妙道要略	Chuko Tan	諸葛誕
Chêng	鄭	”　Liang	諸葛亮
”　Chou	鄭州	Chuko Kungming	諸葛孔明
”　Fan	鄭璠	Chu Hsi	朱熹
Ch'êng Siang	亟相	Chu Tzŭ	朱子
Cheng Suyüan	鄭思遠	Ch'uanlu Wang	串樓王
”　Te	正德	Chun Ho	淮河
Ch'eng Tu	成都	Ch'un Ch'in Dynasty	春秋時代
Chêngchi Tunghai Ch'iufu	誠濟東海鰌賦	Chun Nan	淮南
Ch'i	冀。齋	Chunnan Tzŭ	淮南子
		”　Wang	淮南王
		Chung Ching	重慶

Lao Tzŭ	老子
Later Han	後漢
Li Chüan	李筌
” Hêng	李橫
” Kang	李綱
” Tsêngpo	李曾白
” Tsang	理宗
Liao	遼
Liang	涼。梁
Lihuan Yupi T'iyao	裏還有比提要
Lin An	臨安
Liu An	劉安
Lin Tzuping	林子平
Lo Chin	羅順
” Shai	樂山(四川)
” Yang	洛陽(河南)
” Yungsi	劉永錫
Lou Lun	樓蘭
” Linghsia	婁鈴轄
Lu	魯
Lü Wang	呂望
Lung Shamên	龍沙門
” Si	隴西

M

Ma Kou	馬鈞
Man Chou	滿州
Mêng Yüenlao	孟元老
Ming	明
” Ti	明帝
Minor Han	蜀
Mohammed	謨罕默德（ムハメッド）
Mongols	蒙古，蒙古人
Mou Hsien	茂縣
Mungliang Lu	夢梁錄

N

Nan Chang	南昌(江西)
” Chêng	南鄭(甘肅)
” Chih	南支
” Ching	南京
” Ning	南寧(廣西)
” Sung	南宋
” T'ang	南唐
Nanpe Chao Dynasty	南北朝時代
Ning Hsia	寧夏
Nu Chou	娽州
Nui Mungku	内蒙古

O

Ogotai	窩闊台

P

Pa Tu	拔都
Pan Ngok'o	板訛可
Pao Tou	包頭
Paop'o Tzŭ	抱朴子
Pe Ching	北京
” Sung	北宋
Pê Yen	伯顏
Pên Ts'ao	本草
Pêng Yang	鳳陽
Pien Ching	汴京
Ping Lu	兵錄
P'ing Liang	平涼
” Jang	平壤
P'oyang Hu	鄱陽湖
P'u Chou	蒲州(山西)

S

San Kuan	散關
” Kuo	三國
” ” Chih	三國志
” ” Dynasty	三國時代
Sha Yang	沙洋
Shan Si	山西
” Hai	上海
” ” Ching	上海綴
Shan Tu	上都(内蒙古)
” Tung	山東
Shên Ch'i P'u	神器譜
” Tow	汕頭
Shênchi Chihti T'aipê Yinching	神機制敵大白陰經
Shênnung Pênts'ao Ching	神農本草經
Shih Huang Ti	始皇帝
” Pi	史弼
” Chih	史記
” P'u	石普
” Siang	世相
” Tsong	世宗
Shan Chou	陝州
” Hsien	陝縣
Shên Pao	神寶
” Si	陝西
” Yang	潘陽
Shou	周
” Ch'un	壽春
” Hsien	壽縣

Shuip'ao Fêngpi	水爆風筆
Shun Ti	順 帝
Shuowên Chaitzŭ	說文解字
Shu Chich (Djoutchi)	朮 赤
Si Chiang	西 羌
” Hu	西 湖
Sihu Chihyu	西湖志余
” Fanch'ang Lu	西湖繁昌錄
” Yuhsing	西湖遊幸
Si Ts'ang	西 藏
Siang	襄
” Yang	襄 陽
Siaoching Yen	小經記
Sien Jên	仙 人
Sien Pei	鮮 卑
Sienguan Pienchiu	仙苑編球
Sin Ch'iang	新 疆
” Yang	信 陽
Siensin Pênts'ao	新修本草
Sou Bout'ai	速不台
Su Ching	蘇 敬
Su Weitao	蘇味道
Suan Tsong	蕭 宗
Sui	隋
Sun Tzŭ	孫 子
” Chenjên	孫眞人
Sung	宋
” Ch'ichin	宋齊丘
” Ying Sing	宋應星
Sungshih Pingchih	宋史兵志
Swato	汕 頭
Szŭ Ch'uan	四 川
Szuma Wênwang	司馬文玉
Szu ma Ch'ien	司馬遷

T

Ta Ch'êng	塔 城
” Li	大 理(雲南)
” Ming	大 名(山東)
” Tu	大 都(元)
” T'ung	大 同(山西)
Tan Ching	丹 經
T'an Ch'iao	譚 峭
T'angtai Huahuo Shu	唐代花火術
Tai Hu	太 湖
” Tsang	太 宗
” Yüan	太 原(山西)
Taiping Kuangchi	太平廣記
T'ang	唐
” Shênhui	唐愼徽
Taziks	大食人

Tcha Gatai	察合台
Tchian Guiz Khan	成吉思汗
Tê An	德 安
Tean Snouyü Lu	德安守禦錄
T'ing	町
Ti Hua	迪 化
T'saishih Chi	釆石磯
T'ienkung K'aiwu	天工開物
Tieh Li	鐵 李
T'ien Shui	天 水
T'ao Hungching	陶孔景
T'ao Yinchü	陶陰居
Tou Tzŭch'un	杜子春
Tou Loui	施 留
Ts'ao	曹
Ts'ai	蔡
Ts'ai Chou	蔡 州
Ts'angt'ung Ch'i	參同契
Tsêot'ien Wuhou	則天武后
Tsin	晉
” Cheng	晉 城
Ts'ao Ts'ao	曹 操
” Kungliang	曹公亮
” Hsiagchung	曹孝忠
Ts'êng Chieh	曹 竭
Tu Tsong	度 宗
Tun Huang	敦 煌
Tung Ching	東 京
” Fu	東 福
” Hai	東 海
” Tu	東 都
” Tsin	東 晉
” Ting Hu	洞庭湖
Tungching Yenshun	東京記說
” Munghua Lu	東京夢華錄

U

Uighur	烏孫ウィグル

W

Wan Yen	完 顏
” Sungnien	王松年
Wei	衞(山西)
” Poyang	魏伯陽
” Shêng	魏 勝
Wu	吳(江蘇)
” Ch'ên	吳 臣
” Tai	五 代
” Tu	武 都
” Shai	武 山
” Tzŭmu	吳自牧
Wen Chou	溫 州

Wen Tsong	文宗	" An	延 安(陝西)
" Ti	文帝	Yin	殷
Wen T'ien Siang	文天祥	Yinfu Ching	陰符經
Wulin Chiushih	武林舊事	Yo Chou	岳州
Wutsang Shaiching	五藏山經	" Fei	岳飛
Wupei Chih	武備志	" Yang	岳陽
Wu Yüan	物原	Yü Ch'ang	予昌
Wuching Tsungyao	武經總要	" Lan	于闐
Wuli Siao Shih	物理小識	' Mênkuan	玉門關
		" Yünwên	虞允文
		Yüan Chün	袁軍
Y		" Shao	袁紹
Yai Shai	崖 山(廣東)	" Pishu	苑秘書
Yang Chou	楊州	Yüan	元
" Ch'ü Hsien	陽曲縣	Yüeh	越
" Ti	煬帝	Yüeh Nan	越南
" Tzǔ Kiang	楊子江	Yüan Shih Ch'ihchin	
" Wanli	楊萬里	Hohsi Ch'uan	元史赤䩱合喜傳
Yen	燕	Yün Nan	雲南

Part II   Common

		Bagdad [Irak]	バクダード・報達
		bees wex	蜜蠟, 黄蠟
A		Bengal fire	ベンガル花火
alchemy	鍊丹術。鍊金術 黄白術	bitumen	瀝青
		Bihar [Indo]	ビハール
alchemy furnace	鍊丹爐	black powder	黑色火藥
" book	鍊丹書	blasting explosives	砂用火藥
alchemier, alchemist	鍊丹家	blending (mixing)	配合
alchemist's hut	鍊丹小舍	blasting fire arms	爆炸性の火器
Alexander	アレキサンダー	body enlighting medicine	輕身劑
alum property	礬性	book of tactics	藥方書, 兵書
ancient explosives history	古代火藥史	box fire	箱火
Arab	アラビア人	bow	弓
Arabia	アラビア・阿拉伯	bu (1.8 m×1.8 m)	歩
Archimedes	アルキメデス	bursting powder	直播火藥(炸藥)
arrow ballista	矢砲	" agent	噴火藥
" firing	火箭法	Byzanz [Iran]	ビザンツ
arsenic frost	砒霜 As_2S_3		
asphalt	瀝青	**C**	
attack by fire	火攻	Cairo	カイロ・開羅
" army	攻擊軍	calabash shape	ひさご形
automatic fire	自動火	calcium nitrate	硝酸カルシウム
		Caliph	カリフ
B		Caliphate fleet	サラセン船隊
ball	毬, 砲(古代) 礮, 子窠	cannon ball	砲彈
		" wheel	砲車
ballista	投石機, 投射機 砲(古代)	capselled medicine	甕藥
		casket fire	匣子藥
ballista of stone	投石機 霹靂車, 霹靂砲	carbon dioxide (CO_2)	炭氣(炭酸ガス)

cast iron	生 鐵(鑄鐵)	copper sulphide	硫化銅
ceramic	陶 製	correct attention	集 注
chang (3 meters)	丈	Coubilai	クビライ
charcoal	木炭，炭	crossbow	弩，弩弓
” powder	木炭末	” of 3 bow	三弓弩
” leak process	炭滲法	” type ballista	弩 砲
chên siaoshih	眞消，眞硝石	cracker	爆竹，爆仗(一部)
chên t'ien lei	震天雷		
ch'ien chuen	劍 箭		
chien (1.8 m)	間	**D**	
ch'ien (3.75 g)	錢	Damascus (Irak)	ダマスカス・大馬
chih huang chih	勑黃紙		士 革
chih kuan	紙 管	Dagestan [U.S.S.R.]	ダゲスタン
” p'ao	紙 砲	Dahir	ダヒール
” tung	紙 筒	data	データ
chih (0.3m)	尺	dirts	汚 物
chili nitre	チリ硝石	danger	危 險
chili huoch'iu	葜藥火毬	decision	判 定
chilun	起 輪	devil	鬼
chin (0.6 kg)	斤	detonation fire arm	爆擊火器
chin tan	金 丹	D'Ohsson	ドーソン
chin hua	金 華	dry lacquer	乾 漆
chinpieh p'ao	金汴石	dynamite	ダイナマイト
” huip'ao	金汴灰砲	Dr. Heizo Nambo	南坊平造
chisel	銑	Dr. Seiho Arima	有馬成甫
ch'imo	磁 末		
ch'ing yu	清 油		
ch'iu	毬	**E**	
chronological table	年 表	eastern sea (of China)	東 海
chu	銖(錄貨)	earthen pot	土 釜
chuju	竹 茹	” nitre	土 消(土硝石)
” ts'un	竹 寸	” old rat	地老鼠
chüan p'ao	卷 爆	economic	經 濟
ch'uan siao	川 消	Egypt	エジプト・埃及
ch'uan yo	傳 藥	elixirs	丹 藥
ch'uan huoyo	傳火藥	era of geology	地質時代
ch'ung	銃	establish	建 設
ch'ung k'uei	鐘 鬼	evil aura	邪 氣
city walls	城 壁	excavation	出 土
coiled cracker	捲 爆	excavated (from Lo yang)	(洛陽)出土
combined cap type	合わせ蓋形	explode, explose	爆炸(爆發)
come out from the earth	出 土	explosives	爆發物，火藥
composition	成份，方子，成分	” matter	爆發物
combustible agent	燃燒劑(可燃劑)	” ball	炮，火毬
” matter	燃燒物(可燃物)	” bomb	爆 彈
” firearms	燃燒性的火器	” arms	火藥兵器
composit (mixing)	配 合	” flask	火藥罐
condensed oil	濃 油	” for cannon	火砲藥
confucianism	儒 教	” tube	爆 管
Constantinople (Istanbul)	コンスタンチノプ	explosion	爆發，爆炸
	ル	” accident	爆發事故
copper cannon	銅 銃	” noise bamboo	爆眞竹

explosion fire arm	爆裂兵器
extend yellow paper	敷黃紙
external diameter	外　徑
evil aura	邪　氣

F

fashê	發　射
fayo	發　藥
fach'e	發　機
fashih chi	發石機
〃　　chê	發石車
fanku tzu	仿古字
fang shih	方　士
〃　she	方　術
feihuo	飛　火
〃　chiang	飛火槍
feichi	飛　機
fen　(9.375 g)	分
feng huo	烽　火
ferrous caso	外鐵部皮
fine charcoal	熟　炭
fore arms	火　器
〃　arrow	火矢，火箭
〃　〃　burster	火箭筒
〃　arms of explosives	火藥兵器
fire ambassed alum process	伏火礬法
〃　〃　nitre process	伏火硝石法
〃　〃　sulphur process	伏火硫黃法
fire balls	火毬，火砲
〃　burster	火　筒
〃　bomb	燒夷彈
〃　cracker	爆　仗
〃　dirt rocket	火蒺藜
〃　gun	火砲(後代の鐵砲)
〃　lance	火　槍
fire lance with projectile	突火槍
〃　rat	火老鼠
〃　smoke	烟　火
〃　stone ball	火　砲
〃　tree	火　樹
〃　technical book	火　書
〃　work	煙火，花火
five coolr	五　色
〃　dynasty	五　代
〃　rod ballista	五梢砲
〃　viscera	五　臟
flame length	火焰長
〃　reaction	焰色反應
flint	火石，火道石
flower	花　卉
flying fire	飛　火

flying fire arm	投射火器
flying fire by ballista	發機飛火
〃　　〃　lance	飛火槍
〃　　vehicle	飛　機
fore southern	南方用
foreign settlement	居留地
fuhuang chih	敷黃紙
furnace	竈，かまど
〃　of alchemy	丹藥爐，煉丹爐
fuse	藥線(綫)，導火線

G

Ganges river (India)	ガンジス河
general issimo	元　帥
geographic chart	地質圖
geograph of military economic	戰時經濟地理
Germany	日耳曼・ドイツ
ghost	鬼　怪
go to death	入蒼山，死す
goal	目的地
gold	黃金，金
〃　flower	金　華
great cannon	大火砲
Greek	希臘・ギリシャ
〃　fire	希臘火・ギリシャ火
〃　fleet	ギリシャ船隊
great wall of China	萬里の長城
gun	銃，鳥銃
〃　boat	兵　船
〃　powder	火砲藥，黑色火藥

H

Hakata bay	博多灣
hand ballista	手　砲
hard stoneware	硬質陶器
heating device	加熱裝置
height of body	身　長
Heliopolis	ヘリオポリス人
Heliotrope	ヘリオトロープ
Hime　W.L.	ハイム
ho p'ao	褐　砲
Houlagou	フラーグ
Hsing yang ballista	襄陽砲
hua hui	花　卉
hui p'ao	灰　砲
huo ch'ai	火柴・マッチ
〃　chiang	火　槍
〃　ch'ich	火　器

Liegniz [Poland]	ニーグニッツ	mole (fire rat)	地老鼠
line of fire	火繩，火線	Moor	ムーア人
liu	硫(硫黄)	mou (100 m²)	畝
liu sing	流 星	monkshood	草烏頭・トリカブト
li chu	裏 竹		
lo t'an	柳 炭	Mongolian history	蒙古史
long ladder	雲梯，天橋	″ troop	蒙古軍
″ bamboo pipe	長竹竿	″ invation history	蒙古入寇伏敵編
loose bowel	腸 閉	Morocco	モロッコ
lientan shu	錬丹術	Moslem troop	回教軍
lientan lu	錬丹爐	″ ballista	回回砲
lienchen shu	錬金術	″ fleet	回教徒船隊
		museum	博物館
		mu	木
M		mu hui	木 灰
		″ t'an	木 炭
ma ju	麻 茹	″ t'an mo	木炭末
″ sieh	麻 屑		
″ sheng	麻 繩	**N**	
madfa	マドファ・馬達發		
magician	幻 人	nang yo	甕 藥
Mameluk	馬末婁克・マメリ	Nanching fire works	南京花火
	ウク人	naphtha	ナフサ
map of China	支那地圖	″ thrower	ナフサ矢
mang siao	芒 硝	natural	天然品
Marco Polo	馬可波羅・マルコ	nest hole (projectile)	子 窟
	ポーロ	new revised	新 修
Marcus Aurelius	マルクスオーレリ	new year's eve	除 夜
	ウス	niao chung	鳥 銃
″ gracus	マルクスグレーカ	Nibra [Spain]	ニブラ
	ス	nitre (salt petre)	消，硝石，焰消
materials for alchemy	丹藥材料	″ from river	川 消(硝)
maya siao	馬牙硝(消)	″ ″ the tray	盆 硝(消)
Mecca [Arabia]	メッカ	nitrate crystals on earth	地 霜
Median fire	メジア火	normal powder	定 粉
medicine	藥 材	nu	弩
medicine in capsel	甕 藥	nu kung	弩 弓
mercury	水 銀	nu p'ao	弩 砲
Melilla [Morocco]	メリラ	nung yu	濃 油
memorandum	記 事		
Mesopotamia	美索不達米亞・黒	**O**	
	衣大食國		
meteor	流 星	o p'ao	遏 砲
middle of autumn	中 秋	official fire arms	制式火器
mila	蜜 蠟	oracle	易
military technics	軍事技術	ore of gold	金 鑛
″ tactics	兵 法	original ore	原 鑛
″ regime	兵 制	″ picture	原 圖
″ weapons	兵 器	organic matter	有機物
missfire	不 發	orpiment	雄 黄
missile	ミサイル	old chess board	古家盤
mixed agent	配合劑	outer vessel	外 槽
Mitsukuni, Yoshida	吉田光邦		

Oxydarace [India]	オキダール人	

P

Pakistan	パキスタン	
palace	宮庭，朝庭	
” hall	殿司所	
p'ao	砲，礮，炮	
” cha	爆 作	
” chang	爆 仗	
” chu	爆 竹	
” fa	爆 發	
” kuan	爆 管	
” tan	爆 彈	
” shih	砲 石	
” chênchu	爆眞竹	
p'ao tso	砲 座	
paper ballista	紙 砲	
” cartridge	紙 包	
” pipe	紙 管	
patu	芭 豆	
paulonia seed oil	桐 油	
Peloponesis [Greek]	ペロポネサス	
pellet	膏 藥	
pê hsi	百 戲	
petroleum	猛火油，石油	
” pot	石油壺	
p'ên s'ao	盆 消	
pharmacist	方 士(藥劑士)	
pharmacy	方 術(藥學)	
pharmaceutical book	藥學書	
pi shuang	砒 霜	
pien chien	鞭 箭	
p'ili p'ao	霹靂砲	
” chê	霹靂車	
” huoch'iu	霹靂火毬	
pile of fire	火 積	
pill of immoratality	金 丹	
pine wood	松 樹	
pitch	ピッチ	
ping fêng	屏 風	
play	雜 戲	
platain bean	芭 豆	
Plataea [Greek]	プラテア	
plain nitre	朴 消	
Poland	波蘭・ポーランド	
po (1.8 m)	步	
p'o siao	朴 消	
point	點	
poison	毒 藥	
” of wolf	狼 毒	
poisnous fire can	毒火罐	
” smoke ball	毒藥煙毬	
po siao (plain nitre)	芒 硝	
portable	携帶用	
porcelain	磁 器	
” powder	磁 末	
potentiality	効 能	
pottery	陶，陶器	
” bottle	瓦 罐	
” made	瓦 製	
powder	粉，火藥	
” cartridge	火藥包	
” flask (can)	火 罐	
” fuse	火藥線	
” mill	火藥局	
” tube	火導線	
” of European cannon	西洋大銃藥	
precious	神 寶	
prime minister	宰相，首相	
projectile	彈丸，子窩	
proof	證 明	
propellant	發藥，發射藥	
propulse	發 射	
protecter against devil	鐘 鬼	
pure charcoal	炭 精	
” materials	純 品	
” nitre	眞消，眞硝石	

Q

quick lime	生石灰	

R

radiation fire arm	放射火器	
reaction	反 應	
record	考記，記錄	
red hot iron owl	燒鐵錐	
refine	製鍊，精製	
refining process	精製法	
resin	樹脂，松脂	
Rhodes [Greek]	ローデス	
rifle	ライフル銃	
river nitre	川 消(硝)	
rock nitre	鹽消，熔硝	
rocket ring	烟起輪	
Roger Bacon	羅及倍根・ロジャ・ベーコン	
roll cracker	卷 爆	
rosin	樹脂，松脂	
Roman empire	ローマ帝國	
rotating fire	輪走線	
rough charcoal powder	麁炭木	

royal family	王 室
runner	ランナー
Russia	幹羅思・ロシア
Russian fleet	ロシア船隊

S

saltpetre	火硝，硝石
Salonika [Greece]	サロニカ
scale	縮尺，ものさし
screen	屏 風
sea fire	海火，石油機
seed of glcdishia	サイカチの實
Sevil [Spain]	セビル
shell	砲 彈
Sindo [India]	印 度
silver basin	銀 鍋
” flowers	銀 花(煙火)
sien	銑
” jên	仙 人
siao	消，硝石
” shih	硝 石
siao yu	小 油
signal fire	火道(のろし)，烽火
Silk road	シルクロード
single rod ballista	單梢砲
silicious skin of hemp	麻 茹
” ” ” bamboo	竹 茹
shih p'ao	石砲，矢砲
” tan	石 彈
” kan	十 干
” kuo	十 國
” êrh chih	十二支
” san shaop'ao	十三梢砲
” t'an	石 彈
sin chiang	鐔 槍
shihuo chiang	突火槍
60 year's cycle of Keng Tzŭ	庚子年
shên ch'iep'u	神器譜
“ pao	神 寶
sheng t'ieh	生 鐵
shou p'ao	手 砲
” tan	熟 丹
shuang shap'ao	雙梢砲
shuip'ao fêngpi	水爆風筆
shu'i hui	水 海
” kuan	水 管
” yin	水 銀
siao shih p'o	硝石朴
smoke	煙
” and flame	煙 焰

snow of China	支那の雪(硝石)
soldier with fire	火 人
sodium nitrate	硝酸ソーダ
South China	南 支
sodium sulphate	芒 硝
sparks	火 花
spice and incense	香 料
Spartans [Greek]	スパルタ人
spontaneous ignition	自然發火
strategy	兵法兵機
standard composition	標準配合
standardization	標準化
stone ballista	石 砲
” bomb	火石砲
” bullet	石 彈
stomach	腹
sulphur	硫，硫黃
” nest	窩 黃
suanfeng pao	旋風砲
sword blade	劍 箭
” ” lance	鐔 槍
Syracuse	シラキュース
Syrians	シリア人
Syria	敍利亞 (白衣大食國)

T

tahan	大 寒
tap'ao	大 砲
tahuo p'ao	大火砲
'tanyo' the elixiers	丹 藥
tanyo lu	丹藥爐
t'aochih	陶 製
ɔaohuo	導 火
tao chiao	道 教
taoism	道 教
tallow	清 油
taoist	道 士
t'an ching	炭 精
tan ch'i	炭 氣
10 Kingdom dynasty	十 國
10 years cycle of Kan system	十 干
Teheran [Iran]	テヘラン
3 branch with 6 arrow head	三枝六首
13 rods ballista	十三梢砲
thread	線(綫)
thorng fire ball	蒺藜火毬
throw stone vehicle	發石車
thunder fire ball	霹靂火毬
thunder bolt	雷 火

tiger style ballista	虎蹲砲		unglazed pottery	素燒
tile	瓦		unquenchable flame	
ti lao shou	地老鼠		(liquid fuel)	消えない火
t'iehuo p'ao	鐵火砲			
t'ie p'ao	鐵包			
Tibet [China]	西藏・チベット		**V**	
tien szǎ su	殷司所			
tilei	地雷		various jest	雜戲
ti shuang	地霜		" medicine	雜藥
tinder	火種，火繩		" play	百戲
ting (109 m)	町		Vegetius	ベゲチウス
ting fên	定粉		Venetian	ベニス人
Titan fire arrow	契丹火箭		violet flame	紫青煙，青煙
" " lance	契丹火槍		vicera	臟
tieh p'ao	鐵炮		vessels	容器
total	合計		volume	體積
tow	麻屑			
t'ieh ch'in	鐵球			
" fou	鐵罐		**W**	
" chili	鐵蒺藜			
" jên	鐵刄		wax	蠟
" ping	鐵餅		water pipe	水管
t'ien chiao	天橋		" reservoir	水海
t'oushih chi	投石機		wa chih	瓦製
t'oushê chi	投射機		" fu	瓦罐
t'oushe huo chi	投射火器		weight and measure	度量衡
transport of firing materials	火輻		weikuan huo	葦管火
triangle ordinate	三角座標		winter, wintry	寒
troop with fire	火隊		willow charcoal	柳炭
Troy [Turkey]	トロイ		wo huang	窩黃
tsun	寸		wood	木
tu fu	土釜		" ash	木灰
tu huofou	毒火罐		world history	世界史
t'u siao	土消		wu se	五色
tu yo	毒藥		wushao p'ao	五梢砲
" yen ch'iu	毒藥煙毬		Wutai dynasty	五代
tuan (3300 m²)	段		wutsang	五臟
tubular fire arms	管狀火器			
t'ung ch'ung	銅銃		**X**	
" yu	桐油			
Turkoman [W. Asia]	トルクメン		xian	線，綫
2 rods ballista	雙梢砲			
12 years cycle of			**Y**	
Chi-branches	十二支			
tzu wo	子窩		yen	鹽，煙
ts'u t'anmo	龕炭末		yench'i lun	烟起輪
tz'u ch'i	磁器		yen huo	煙火，烟火
			yen siao	焰硝，鹽硝
U			yenyen	煙焰
			yin huochiu	引火毬
Uighur [West China]	烏孫・ウィグル		yin hua	銀花
undijest	未消化分		yin kuo	銀鍋
			yin sien	引線
			yo t'sai	藥材

| yo hsin | 藥 線 | yüan shih | 元 帥 |
| yo t'ung | 藥 筒 | | |

A Chemical Study on Some Archaeological Samples from Marlik in Iran[1]

Teruko MUROGA*

Introduction

From the archaeological interest, the chemical studies were performed on archaeological samples excavated from Marlik in Iran.

Marlik is located at the northwestern part of Iran (Fig. 1) and it is said to have prospered ca. 900 B.C. and now it remains as ruins.

In 1961, Marlik was excavated by Dr. E. O. Neghaban and his members. The details were published as "Marlik".[2]

Any investigation from the chemical point of view, however, has not been performed on these samples. So, the present paper deals with the results obtained through chemical analyses, in such a manner as to trace the relation between chemi-
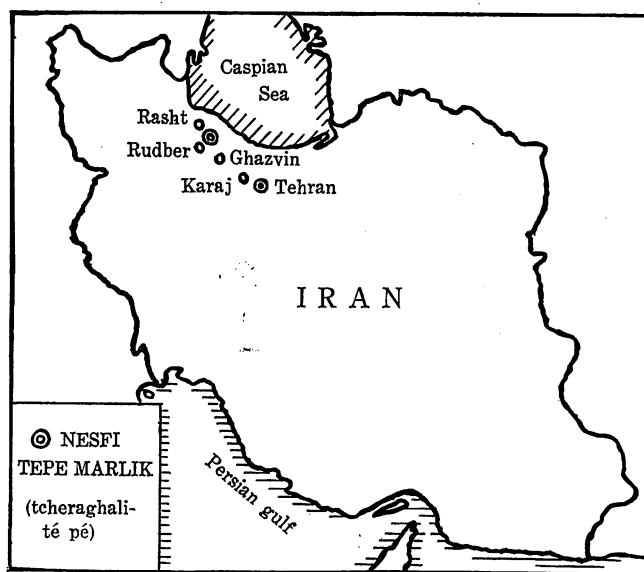
Fig. 1. A map of Marlik.

cal compositions and informations from archaeological and historical points of view.

These samples were offered by Dr. E. O. Neghaban who was a curator of the Iran Bastan Museum, on the occasion of the 5th International Congress of Iranian Art and Archaeology (1968, Tehran).

Materials

No. 1. Shell-like Pottery

In the picture shown in "Marlik"[2], potteries of this kind are linked together with a string through the holes and look like a necklace. This bead is made of unglazed pottery, therefore it is estimated to be a kind of old type beads. The detailed figure is shown in Fig. 2, revealing a brown body upon which white clay has been placed except along radial line. The surface glaze and body are not so hard, therefore it is supposed that it was baked at a lower firing temperature.

10mm
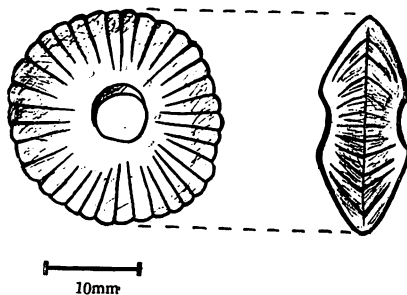
Fig. 2. Schematic diagram of Shell-like Pottery.

No. 2. Bead of Agate

This bead could be estimated to be an agate from the color and external appearance (Fig. 3).

10mm

Fig. 3. Schematic diagram of Bead of Agate.

No. 3. Glass Bead

A layer of weathered surface covers the glass bead. It is easily pulverized. Under the weathered surface layer one can see the blue glass body (Fig. 4).

Fig. 4. Schematic diagram of Glass Bead.

No. 4. Small Lump (Amber)

It looks like a small clod of soil. Under a layer of soil, there is weathered surface beneath which the brown translucent body itself can be seen (Fig. 5).

10 mm
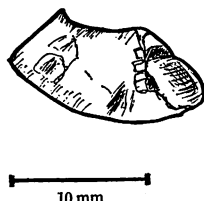
Fig. 5. Schematic diagram of Small Lump.

No. 5. Bronze Button

It is made by metal and its shape looks like a small dish, of which diameter is 11 mm (Fig. 6). At the center of the dish there is a small leg. From these configurations, this metal dish is supposed to be one kind of buttons. The patina surrounds its body and a few places of the edges are chipped. This patina is incrusted not only on the surface but also in its body.

5 mm
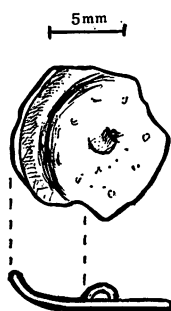
Fig. 6. Schematic diagram of Bronze Button.

No. 6. Mosaic Glass Cup

This mosaic glass cup was restored to the original state, and its picture is shown in Fig. 7. It is made from two kinds of materials, one being green glass, another white paste. The latter is used to make white diaper patterns. The diaper consists of a cross section of small picks bundled together, and looks like a flower of plum. Spaces of these white patterns are filled up with green glass. This mosaic glass has been believed to be the oldest mosaic glass cup ever excavated in the world.
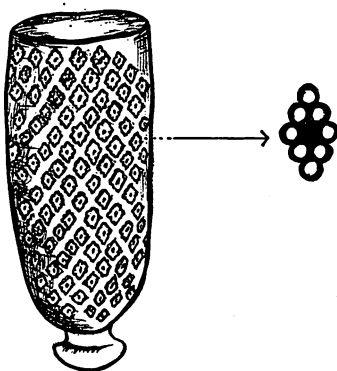
Fig. 7.   Schematic diagram of Mosaic Glass Cup.

Experimental

Semi-quantitative analyses were performed on the archaeological samples by using the internal standard method of emission spectrochemical analysis.

The quantitative analytical methods used especially for the amber were usual manner of the elementary analyses for carbon, hydrogen, nitrogen, sulfur, oxygen and ash.   The quantitative analysis for copper was carried out by the colorimetric determination with 2,2'-Biquinoline.[3]

Results and Discussion

Results of spectrochemical analyses are shown in Table I.   According to the results, in No. 1 sample, the chemical compositions of the glaze are quite similar to its body.

No. 3 Glass Bead: The body of the glass bead was found to belong to the soda-lime glass type.   The bead is not a particular one judging from major components, because more than one hundred archaeological glass samples from Iran are of soda-lime glass type.[4]   A spectrochemical analysis was performed on the weathered layer and its body.   It is of some importance that the contents of such elements as magnesium, sodium and potassium were found to decrease in proportion to the distance from the glass itself, according to the results shown in Table I.

No. 4 Small Lump: The analyses were carried out only inner part of the clod. From the result of the open tube test, it became clear that this material was consisted of an organic substance.

Elementary analyses were performed on this material.   The results are shown in Table II.   As can be seen in the table, the contents of each element are in pretty

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[3] E. B. Sandel, *Colorimetric Determination of Traces of Metals*, Interscience Publishers, Inc., New York (1959) 3rd Ed, p. 407.

[4] T. Muroga, *Bulletin of the Chemical Society of Japan*, Vol. 43, No. 3, p. 581 (1970).

TABLE 1. The Results of Spectrochemical Analyses

Sample \ Element	Fe	Si	Mn	Sb	Mg	Pb	Sn	Ni	Al	V	Cu	Ag	Na	Ti	Co	Ca	K	Cr	Ba	Sr
No. 1. Soil of Hole	++ / ++	++ / ++	+	±	+ / ++	+	±	+	+ / ++	+	+ / ++	±	+	+	+	++ / ++	±	+	+	+
Surface (Glaze)	+ / ++	++ / ++	+	±	++	+	±	+	++	−	+ / ++	±	±	+	+	+ / ++	−	+	+	±
Body	++ / ++	++ / ++	+	±	++	+	±	+	++	±	+ / ++	±	+	+	+	++ / ++	±	+	+	+
No. 3. Weathered Surface	+ / ++	+ / ++	+	−	++	±	+	±	++	−	++	±	+	+	−	++ / ++	−	+	+	+
Body	++ / ++	++ / ++	+	−	++	±	+	±	+	−	++	±	+ / ++	±	−	+ / ++	+	+	±	+
No. 5. Bronze Button	±	+	−	−	±	++	+ / ++	±	±	−	++ / + / ++	++	−	−	−	±	−	−	±	−
No. 6. White	++	+ / ++	+	+	++	±	−	±	++	−	++	±	±	+	±	++ / ++	−	±	±	±
Green	+ / ++	+ / ++	+	+	+	±	±	±	+	−	++ / ++	±	±	+	±	+ / ++	−	±	±	±

$$\begin{smallmatrix}++\\+\\++\end{smallmatrix} > \begin{smallmatrix}++\\++\end{smallmatrix} > \begin{smallmatrix}+\\++\end{smallmatrix} > ++ > + > \pm > -$$

TABLE 2.   The Results of Quantitative Analysis of No. 4 (Amber)

Contents Elements	Analyzed (%)	Literature* (%)
Carbon	70.35	75.48
Hydrogen	9.12	10.30
Oxygen	19.16	12.07
Nitrogen	0.07	0.20
Sulfur	0.0	0.1
Ash	tr	0.85
Total	98.70	99.00

* *Encyclopaedia Chimica*, Vol. 3, p. 673.

good agreement with the contents of amber.[5]   Therefore it may be estimated that this clod is an amber and used as accessory.   As there has been no description about amber in the "Marlik", it seems to be a new finding that amber was excavated from Marlik.

No. 5 Bronze Button: From the results of spectrochemical analyses, this sample contains copper, tin and lead, therefore this was made not of copper only, but of bronze.[6]   The copper content of this metal is 72.13%.   From the shape, this metal may be considered as a sort of button.

No. 6 Mosaic Glass Cup: The green part of the cup is of soda-lime glass, and color origin is copper.   The white part contains much calcium and silica, magnesium and aluminum.   Therefore it is one kind of calcareous substance and plaster.

Besides these samples examined here, golden ornaments, bronze manufactured good and many kinds of jewels were excavated from Marlik.   These facts tell us that ancient Iranian people had achieved a high level in their techniques in the metallurgy and quite advanced techniques of workmanships.

Acknowledgment

Résumé

In 1961, Marlik was excavated by Dr. E. O. Neghaban and his members. Marlik is located at northwestern part of Iran and it remains as ruins.   From this ruins many kinds of materials, gold, silver, bronze, glass beads, amber, agate,

   [5] *Encyclopaedia Chimica* Vol. 3, p. 673, Kyoritsu Shuppan Co., Tokyo, (1964).
   [6] T. Dono, *Nippon Kagaku Zasshi*, Vol. 84, p. 321 (1963).   *ibid.,* Vol. 84, p. 324 (1963).

pottery and clay image, were excavated.

The present paper deals with the results obtained through chemical analyses, in such a manner as to trace the relation between chemical compositions and informations from archaeological and historical points of view.

From the results of chemical analyses, it was concluded that the unglazed beads, the glass beads and mosaic glass cup belonged to the soda-lime glass type. A small metal dish contained 72.13% of copper and small amount of tin and lead. From shape and contents, this metal dish could be thought to be the bronze button. A small lump contained 70.35% of carbon, 9.12% of hydrogen, 19.16% of oxygen, 0.07% of nitrogen and trace of ash, and was concluded to be made of amber. It is the first information that the excavations from Marlik contained amber.

A Brief Chronology of Dr. Heinrich Bürger

Yoshikazu ISHIYAMA*

The personal history and achievements of Heinrich Bürger who engaged in the study of Japan as an assistant of Von Siebold have not yet been cleared up in Japanese historians' circle. The studies of his career are published in many fragmentary reports in Japan, but not in perfect forms. But, while I was investigating many Dutch literatures about Japanese natural history, I fortunately happened to know the life of Bürger by the kind help and suggestions of Dr. Prof. C. G. G. J. van Steenis, director of Rijksherbarium at Leyden, and Mrs. van Steenis.[1] In this report, I will summarize the results of my study in a brief chronology, based on the materials.

1806 (Bunka 3)

Was born at Hameln in Weser (Hanover), on the 20th of January as the seventh son of ten brothers among Samuel Bürger and Eva Meyer are German having Jewish blood. His father was a merchant at Hameln, but he lost his father in his childhood. (There is a version that he was born in the beginning of 1804 at Hameln in Weser,[2] but his birth was not recorded clearly in the church register of Hameln, so it has no distinct source. Therefore I intend to regard the truth that he was recorded in the note of enrollment).

1821 (Bunsei 4)

25 Oct. Was admitted to enter the Göttingen University as a student of the mathematics course.[3]

1822 (Bunsei 5)

Oct. Changed his speciality from mathematics to astronomy.[4]

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* 4–17–1, Tsuzido Higashi Kaigan, Fuzisawa City, Kanagawa Pref. Japan., Syoyo Junior High School.

[1] cf. "Hosei-Sigaku" Mar, 1970 Journal of Hosei Historical Society in Hosei University No. 22 p. 95–113.

[2] [Blumea] vol. XI, No. 2, 1962 "Contribution to the History of Botany and Exporation in Malaysia" M.J. van Steenis-Kruseman. p. 499.

[3] cf. Götz van Selle, Die Matrikel der Georg-August Universität zu Göttingen 1734–1837 No. 28978 and 29536, p. 660.

[4] cf. ibid., p. 676.

1823 (Bunsei 6)

6 Sep. Left Amsterdam for Java and became an apprentice pharmacist at the hospital in Djakarta.[5]

1825 (Bunsei 8)

14 Jan. Was promoted to the 3rd class pharamacist.[6]   In this year, Von Siebold filed an application requiring two assistants for his work to the Governor-General of Dutch East Indie, to satisfy the above request, Dr. Heinrich Bürger and Carolus Hubert de Villeneuve, a painter arrived at Dezima, Nagasaki, Japan.   In December, he was advanced to the 2nd class pharamacist and worked remarkably in the study of physics, chemistry, pharmacology and mineralogy as an assistant of Von Siebold.[7]

1826 (Bunsei 9)

From 15 Feb. to 7 Jul. Followed the annual Edo government courtesy visiting voyage with Joan Willem de Sturler, the chief of Dutch firm and Von Siebold as a clerk.[8] Presented "BATTAGLIA DI ARCOLO" in Italian and a personage picture with an Italian eulogy was written to Katsuragawa Hoken whose name was known as a Botanicus at Nagasakiya, Edo;[9] Was presented Mino paper from Mizukuri Gempo.[10]   The results and the effects resulted from the following researches which he performed in the above voyage were summarized later.

(1)   Measured Japan physically in 1826 and in consequence made contribution to the development of geography.[11]

(2)   Measured Japan geognostically on his way from Nagasaki to Edo in 1826.[12]

(3)   Researched Japan on mineralogy, mine engineering and capital.[13]

In the same year, he translated the treatise with the title "Nippon Kodaishi-Kō" which was given to Von Siebold from his pupil, Mima Junzō, into German under the title of "Chronologie des Japanishen Reiches."[14]

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[5] General State Archives, The Hague, Koloniën 2479, resolution Governor General No. 6. 1823, No. 3.

[6] Itazawa Takeo "Siebold" Zinbutsu-Sōsho Yoshikawa-Kōbunkan Shōwa 35, p. 67, cf. *ibid.* Koloniën 2480, resolution Jan, 14, 1825, No. 1.

[7] cf. *ibid.,* p. 67.

[8] cf. Kure Shūzō "Siebold Edo Sanpu Kiko" Ikoku-Sōsho Shunnansha Shōwa 6, p. 90.

[9] cf. Imaizumi Genkitsi "Rangaku no Ie Katsuragawa no Hitobito" (Zokuhen) Shinozaki-Shorin Shōwa 43, p. 226–227, p. 514.

[10] cf. Kure Shūzō "Siebold Sensei Sono Shōgai Oyobi Kōgyō" 3. Tōyō Bunko Heibonsha Shōwa 43, p. 166.

[11] cf. (6) *ibid.,* p. 81.

[12] cf. *ibid.,* p. 82.

[13] cf. *ibid.,* p. 85.

[14] cf. Nichi-Doku Bunka Kyokaihen "Siebold Kenkyu" Iwanami Shoten, Shōwa 13, p. 206.

1827 (Bunsei 10)

2 Jul. Practised the western clinics as an assistant of Dr. Ph. Fr. Von Siebold for the first time. The patient was a son of Noguchi Gihei, a retainer of the Lord Hosokawa in Higo province, Ritsubei, a twelve-year-old boy. And his illness was the cephalic tumor.[15] In that year, summarized the report concerned with analysis of mineral spring in Japan.[16]

1828 (Bunsei 11)

Sep. Occured the Siebold event. During the period approximately from 1826 to 1828, he translated the "Liu-Kyu-Dan" written by Morishima Chūryō into German under the title of "Beschreibung von Liu-Kyu."[17]

In September of that year, as Siebold was expired from his duty, he was requested to be a successor to Von Siebold by the Governor-General of Dutch East Indie. However, this succession was temporarily postponed due to the occurence of Siebold event.[18] So that in the mean-while he assisted Von Siebold's study of Japan.[19]

1829 (Bunsei 12)

25 May. Was presented the plants "Cephalotaxus drupacea utiemprioris" (Nomen japon, Inugaja) being collected by Kumakichi in Nagasaki a day laborer of Von Siebold[20] and this plant was later distributed to the botanical gardens in European countries.[21]

1 Oct. of that year Heinrich Bürger was commissioned to be a successor to Von Siebold by the Governor-General of Dutch East Indie in public.[22] His position is a government official with the physical research in Japan (Ambtenaar belast met het natuurkundig onderzoek te Japan.)[23]

In the same year, he forwarded the following collection list in Japan to the Governor-General of Dutch East Indie. List of dried plants sent to Batavia. List of some living plants sent from Dezima to Batavia for cultivation in Java.[24]

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[15] cf. (2) *ibid.*, p. 494.

[16] cf. (12) *ibid.*, p. 82.

[17] cf. (14) *ibid.*, p. 248–249.

[18] cf. (15) *ibid.*, p. 497.

[19] cf. (10) *ibid.*, 1. p. 354.

[20] I received a letter (on the Kumakichi) from Prof. Dr. C. G. G. Van Steenis (Director of Rijksherbarium).

[21] cf. (19) *ibid.*, p. 211.

[22] cf. Kure Shūzō "Siebold Sensei Sono Shōgai Oyobi Kōgyō" (Otsuhen) Tōhōdō Taishō 15, p. 305.

[23] cf. Itazawa Takeo "Nichi-Ran Bunkwa Kōshōshi no Kenkyū" Yoshikawa-Kōbunkan Shōwa 36, p. 342.

[24] cf. (18) *ibid.*, Addendum.

1830 (Tempō 1)

Jan. Germain Felix Meijlan, the chief of Dutch firm filed an application to Ohgusa Notono-Kami, a magistrate of Nagasaki province to make Heinrich Bürger accompany with him on the anual Edo government coutesy visiting voyage. However, this application was refused with an intention of the supreme court in the Edo government because he had already joined in the above voyage with Von Siebold in 1826.[25] Consequently, Germain Felix Meijlan started for Edo with Carolus Hubert de Villeneuve, a painter, on his voyage in February of that year.[26] In the same year, he forwarded the following collection list in Japan to the Governor-General of Dutch East Indie.   List of living Japanese plants for the botanical garden at Buitenzorg.   List of Japanese fishes, stuffed mammals and birds, to be sent from Dezima to Batavia 1830, with Chinese and Japanese characters.[27]

1832 (Tempō 3)

May. Left Dezima, Nagasaki and reached Java with a lot of seeds and seedling of plants or vegetables. He was commissioned to cultivate them on the experimental farm, Krawang (Het Establissement van Landobow).[28]

1833 (Tempō 4)

9 June. Participated in the exploration of mineralogy at Padang Uplands located of the west coast of Sumatra as a member of the natural science committee. This research was continued until the end of the year.[29]

27 June of that year He was appointed to the inspector of plants cultivated at Krawang.[30]   The exploration of Sumatra was reported on the newspaper published by Verhandelingen van het Bataviasch Gemootschap. He was a member of the above newspaper office. He also indicated the quantity of copper retained and the amount of copper production in Japanese copper mines on the above mentioned newspaper "Ene beschrijving der Japanische Kopermijnen, en de bereidig van het Koper".[31]

1834 (Tempō 5)

17 Jan. Left Java and rearched Dezima, Nagasaki, Japan and engaged again in the research of Japan (chiefly studied zoology and botany). He forwarded the data collection in Japan to Batavia.[32]

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[25] cf. (9) *ibid.*, p. 514.
[26] cf. (21) *ibid.*, 1. p. 379, (23) *ibid.*, p. 125, "Edo Saiziki" Kan 1. "Koutsyu-Manroku" Dai 9 hen.
[27] cf. (24) *ibid.*, Addendum.
[28] cf. (26) *ibid.*, 1. p. 212.
[29] G. S. A. Kolonien 2550 resolution June 9. 1833, No. 8.
[30] G. S. A. Kolonien 2550 resolution June 27, 1833, No. 2.
[31] cf. (27) *ibid.*, p. 498.
[32] G. S. A. Kolonien 2557, resolution Jan. 17, 1834, No. 1.

Sep. of that year Was recoginized his distinguished services on the study of Japan and was given a decoration as a member of natural science committee (Naturkundige Commissie). Became "Ridder in de Orde van de Nederlandsche Leew".[33]

1835 (Tempō 6)

June. Completed his study in Japan and left Dezima, Nagasaki and reached Java.[34] His study in Japan was succeeded by J. Pierot.

1837 (Tempō 8)

Month is unknown. Married with Anna Cornelia van Daalen (1799–1874).[35] Was requested to study Japan more by the Governor-General of Dutch East Indie. However, he refused this request.[36]

1839 (Tempō 10)

30 Sep. Reappointed to a member of the natural science committee.[37] Von Siebold filled an application so that a bounty would be granted to Heinrich Bürger to the Government of Holland.[38]

1840 (Tempō 11)

Boarded the ship, "Cornelis Hautman" to leave Java. After arriving at Holland, settled down in Amsterdam.[39]

1842 (Tempō 13)

Year is not exact. Met a German poet, Heinrich Heine (1797–1856) through the introduction of H. Wermann in Paris and this meeting was noted in his remembrances title "Geständnisse" of H. Heine.[40]

1843 (Tempō 14)

30 June. The application filed by Von Siebold to grant the bounty of Heinrich Bürger was approved.[41] In that year, he was ordered to wrork in Java by the government of Holland and he served for the governor-general of Dutch East Indie until 1850.

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[33] G. S. A. Koloniën 3954, royal decree Sep. 16, 1834, No. 61.
[34] G. S. A. Koloniën 2855, resolution June 14, 1835, No. 4.
[35] cf. (31) ibid., p. 499.
[36] cf. (35) ibid., p. 499.
[37] Letter from the Minister of the Colonies to the Governor-General date Nov. 30, 1839, No. 4/7676.
[38] cf. (35) ibid., p. 500.
[39] cf. (38) ibid., p. 499.
[40] cf. Doi Yoshinobu, Heine Senshū 14 "Kokuhaku, Kaiso, Yuigon" (Geständnisse) Kaihōsha, Shōwa 23, p. 100–101.
[41] G. S. A. Koloniën 2646, resolution Jun. 30, 1843, No. 9.

The work was to encourage the horticulture under the direction of Von Siebold[.] and C. L. Blume.[42]

1844 (Kouka 1)

Engaged in the transportation of rice, supplying of rice and oil to Bütenbezit-tingen (Outer Possession, i.e. the island outside Java), the work of insurances, the management of mining industry or sugar manufactory.[43]

1845 (Kouka 2)

Published the treatise "Grundriss der Geographie" Breslau and "Hülfs und Nachweisungstafeln" Breslau.[44]

1850 (Kaei 3)

Returned temporarily to Amsterdam and came back to Java again.[45]

1852 (Kaei 5)

Published the treatise "Physikalischer Atlas van 95. Karten" Gotha.[46]

1854 (Ansei 1)

Published the treatise "Die Baudenkmäler aller Völker der Erde" Brüssel und Leipzig 2 vol.[47]

1855 (Ansei 2)

18 Dec. Was authorized to be a naturalized citizen in Dutch.[48]

1857 (Ansei 4)

Jul. Worked remarkably as a resident of Batavia.[49]

1858 (Ansei 5)

25 Mar. Closed his life when he was ?52 year old in Indramaju, Protectorate of England. His wife Anna Cornelia van Daalen settled down there until 1874, the year of her death.[50]

As for the plants, fishes in the Flora Japonica, Fauna Japonica, Bürger's part takes still a great place. His name is often used in honour of his works in these

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[42] cf. (39) *ibid.*, p. 499.

[43] cf. (42) *ibid.*, p. 500.

[44] cf. Catalogue de la Bibliothèque, Apprtée au Japon : Mr. Ph. F. de Siebold pour servir á l'etude des sciences physiques, géographiques, ethnologiques et politiques et de guide dans les recherches et d'ecouvertes scientifiques dans cet Empire Dezima imprimérie néelandaise 1862.

[45] cf. (43) *ibid.*, p. 499.

[46] cf. (44) *ibid.*

[47] cf. (46) *ibid.*

[48] Law of Dec. 18, 1855, Staatsblad 153 (Justitie inv. No. 4862).

[49] cf. (45) *ibid.*, p. 500.

[50] cf. (49) *ibid.*, p. 500.

fields as follows.

(A) *The botany of Japan*[51]

    (1) Aquilegia Buergeriana Sieb. et zucc. (Nomen japon. Yamaodamaki)

    (2) Buergeria stellata Sieb. et zucc. (Nomen japon. Sidekobushi)

    (3) Acer Buergerianum Miquel (Nomen japon. Toukaede)

    (4) Cephalotaxus Buergeri Miquel (Nomen japon. Chyosenmaki)

    (5) Fimbristylis Buergeri Miquel (Nomen japon. Ōtentsuki)

    (6) Lespedeza Buergeri Miquel (Nomen japon. Kihagi)

    (7) Prunus Buergeriana Miquel (Nomen japon. Inuzakura)

    (8) Rubus Buergeri Miquel (Nomen japon. Fuyuichigo)

    (9) Vaccinium Buergeri Miquel (Nomen Japon. Usunoki)

    (10) Desmodium Buergeri Miquel (Nomen japon. Shibahagi)

    (11) Ilex Buergeri Miquel (Nomen japon. Shiimochi)

    (12) Polypodium Buergerianum Miquel (Nomen japon. Nukaboshikuriharan)

    (13) Cephalotaxus drupacea Sieb. et zucc. var Buegeri Maximowicz. (Nomen japon. Chyosenmaki)

    (14) Gentiana scabra Bunge. var Buergei Maximowicz. (Nomen japon. Hosobarindou)

    (15) Maachia amurensis Ruper. var Buergeri Schneid (Nomen japon. Enju)

    (16) Viburnum Japonicum Spreng. (=Viburnum Buergeri) (Nomen japon Hakusanboku)

(B) *The animals of Japan*[52]

    (1) Dictyosoma burgeri van der Hoeven (Nomen japon. Dainangimpo)

    (2) Entatretus burgeri Girard (Nomen japon. Nutaunagi)

    (3) Halaelurus bürgeri Miller. et Henle (Nomen japon. Nagasakitorazame)

    (4) Rhacopharus buergeri Schlegel (Nomen japon. Kazikagaeru)

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[51] Makino Tomitarō, *Makino Nippon Shokubutsu Zukan* Hokuryūkan, Shōwa 32, (An Illustrated Flora of Japan, with the Cultivated and Naturalized plants. By Tomitaro Makino, Dr. Sc.).

[52] "Shin Nippon Doubutsu Zukan" (A New Illustrated Encyclopedia of the Fauna of Japan) Gekan, Hokuryūkan Shōwa 44.

Science Across the Pacific: American-Japanese Scientific and Cultural Contacts in the Late Nineteenth Century*

Masao WATANABE**

Introduction: the Age of Steam and Electricity

The nineteenth century witnessed a remarkable dissemination of science and technology in the Western world and, from the point of view of history of science and technology, may very well be considered the age of steam and electricity. It was in the nineteenth century that the steam engine, already invented and utilized in the eighteenth century, came fully to exhibit its power in promoting the industrial revolution. It was also in this century that newly invented locomotives and steamships revolutionized means of transportation and spurred oceanic navigation. Thus steam replaced the labor of man and beast and the power of water and wind, served to step up the production of mining and manufacturing, drew distant areas together, and accelerated economic circulation and cultural exchange.

Moreover the cuttings and tunnels required for railway construction revealed a great deal of geological information and furnished new knowledge of the past (particularly of fossils), which led in part to the theory of evolution itself.

The discovery of the electric battery by Alessandro VOLTA in 1799 gave, for the first time, a continuous current of electricity. It facilitated the discoveries of electrolysis, the electric arc, the electro-magnet, the induction coil, the dynamo, and the electric motor. The invention of the electric telegraph and telephone followed. A new era of electricity was thus opened. Effective means of communication by electricity, of transportation by steam and later by electricity, were developed with great rapidity. The consequences were particularly remarkable in America, where both need and effectiveness were so great in developing that vast country's lightly populated land.

After settling the Mexican War and securing California as its territory, America's commercial as well as religious interests extended directly across the Pacific to the Far East. Since Japan lay on the line from San Francisco to Shanghai, the requirement of navigation by steam made it imperative to establish coaling stations somewhere in or near Japan. Thus the second paragraph of Chapter I

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of the *Narrative of Perry's Expedition to Japan* reads:

>   Direct trade from our western coast with Asia became, therefore, a familiar
> thought; the agency of steam was, of course, involved, and fuel for its produc-
> tion was indispensable.   Hence arose inquiries for that great mineral agent
> of civilization, *coal*.   Where was it to be obtained on the long route from
> California to Asia?   Another inquiry presented itself: With what far-distant
> eastern nations should we trade?   China was in some measure opened to us;
> but there was, beside, a *terra incognita* in Japan which, while it stimulated
> curiosity, held out also temptations which invited commercial enterprise. . . .
> By some, indeed, the proposition was boldly avowed that Japan had no
> right thus to cut herself off from the community of nations; and that what
> she would not yield to national comity should be wrested from her by
> force.[1]

Commodore PERRY was, in fact, instructed by the American government to secure
from the Japanese government good treatment for distressed American seamen,
some facilities for navigation and trade, and particularly a coaling station.

Japan, secluded for many years from the Western world, was far behind the
recent progress of science and technology.   Therefore when PERRY's fleet steamed
into Tokyo Bay in July 1853, Japan found itself entirely helpless before the "black
ships," which symbolized the power of the new scientific era.   On PERRY's second
visit to Japan in the following year, Japan concluded a peace treaty with America
and on that occasion, PERRY presented to the Japanese a Lilliputian steam locomotive
and an electric telegraph.   Both were demonstrated to and greatly admired by the
Japanese spectators.   Only ten years had elapsed since samuel MORSE telegraphed
his first message between Washington, D.C. and Baltimore.   As the *Narrative of
Perry's Expedition* stated, these gifts appeared in sharp contrast to "the brutal
performance of these wrestlers" (*sumō*), which the Japanese commissioners presented;
and were "a triumphant revelation, to a partially enlightened people, of the success
of science and enterprise."[2]

The age of "Civilization and Enlightenment" was thus opened to Japan.   On
publishing his book, *Seiyō Jijō* (Things in the West, 1866), FUKUZAWA Yukichi,
one of the most potent leaders and eloquent spokesmen of this age, illustrated the
title page with electric wires and poles all around the globe, a steamship, a steam
locomotive, and a balloon, together with eight Chinese characters.   Translated,
they meant "steam ferries people, electricity carries messages."   Also in his *Minjō
Isshin* (Renovation of People's Conditions, 1879) FUKUZAWA emphasized the use
of "the steamship and steam locomotive, electric telegraphy, printing, and the postal
system," saying that these four inventions of the nineteenth century "constitute

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[1] *Narrative of the Expedition of an American Squadron to the China Seas and Japan, per-
formed in the Years 1852, 1853,* and *1854, under the Command of Commodore M. C. Perry, United
States Navy, by Order of the Government of the United States* (Washington, 1856), pp. 75–76.
[2] *Ibid.*, p. 372.

the elements of modern civilization."[3]

It was evident to the Japanese eye that these facilities of modern science and technology were exactly what made Western civilization advance and what the Japanese themselves urgently needed. It was no wonder that great enthusiasm for scientific know-how and for Westernization prevailed in Japan for some time in the early Meiji period.

"Knowledge Shall Be Sought Throughout the World"

The year 1543 saw the publication of the two epochal works in the history of Western science. These were COPERNICUS' *De Revolutionibus Orbium Caelestium* and VESALIUS' treatise, *De Humani Corporis Fabrica,* two great scientific achievements which revolutionized traditional ideas concerning the macrocosm and the microcosm respectively. It was coincidentally in the same year that Japan's first contacts with Westerners occurred, with some Portuguese and Franciscan missionaries from Portugal and Spain. The response of the Japanese people to medical art, astronomy, geography, and to such European products as firearms, clocks, and glasses was immediate and enthusiastic. And by the end of the century, a new religion, Christianity, had been rather widely accepted.

Had Japan continued these contacts, the country might have caught up with the development of Western science and technology. In the 1630's, however, the Tokugawa Shogunate, impelled by a strong desire to preserve its own power, adopted the policy of banning Christianity. Thus all Europeans were excluded except the Dutch. For over two hundred years, one closely supervised Dutch outpost and occasional, licensed Chinese traders were to be Japan's only links with the outside world. Due to the stimulus received in the first contacts with Western science, however, astronomy and particularly calendar-making showed remarkable progress during this period of national seclusion. Also during this period, *wasan* (traditional Japanese mathematics) was to flourish.

In 1720, import of foreign books (except those on Christianity) was permitted by the Shogunate and this policy gave rise to the study of Dutch learning among the Japanese people. The publication in 1774 of *Kaitai Shinsho* (a Japanese translation from the Dutch version of a German treatise on anatomy) was a monumental achievement in the history of the introduction of Western science into Japan. This work so distinctly demonstrated the excellence of Western learning that it was followed by the introduction of Dutch versions of European astronomy, physics, chemistry, and botany, with ever-increasing degrees of interest. Marine almanacs and fragments of Aristotelian cosmology were already known in Japan in the seventeenth century. Then the Copernican system and even Newtonian dynamics were introduced through the Dutch, although the interest of the Japanese astronomers was attracted mainly to calendric aspects of astronomy.

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[3] FUKUZAWA Yukichi, *Minjo Isshin* in *Nihon Kagaku-Gijutsu-Shi Taikei* (History of Science and Technology in Japan), ed. by History of Science Society of Japan, Vol. 1, pp. 489–491.

Dutch learning reached its culmination in the early nineteenth century. INŌ Tadataka, for instance, completed a very accurate map of the Japanese islands, a chart which may be regarded as one of the most remarkable and integrated products of Dutch learning in Japan. At clan schools, Chinese classics had constituted the core of the curricula, but from about the end of the eighteenth century, Dutch learning came to be added and by the middle of the nineteenth century, one-third of all courses of instruction consisted of scientific disciplines. At the same time, the number of scholars of Western learning in Japan increased remarkably.[4]

Owing to the efforts of adherents of Dutch learning, not only the superiority of Western science and technology but also economic and military conditions of Western countries in general were made known to some extent. Once the country was opened, therefore, progressive groups of Japanese leaders readily realized that the most urgent matter was expeditiously and extensively to introduce Western systems of knowledge, technique, industry, army and navy, and political administration. With this need in mind, over ninety students were sent abroad by the Shogunate or by the provincial clans. They were scattered into several countries, such as Holland, England, France, Germany, Russia, and the United States of America.[5] Besides the Dutch language, English, German, and French were also then studied in Japan. Naval and army training schools were organized, an institution devoted to foreign matters was created, and a school of Western medicine was founded by the Shogunate.

With the Meiji Restoration in 1867, traditional Chinese learning was replaced by Western learning, and the *Shōheikō* as the central institution for the study of Chinese classics was soon closed. Governmental policy was formulated to accord with the statement in the so-called Charter Oath that "Knowledge shall be sought throughout the world, so that the foundations of the Empire may be firmly established."

Thus education was to play a particularly important role in the whole process of Meiji development. The government sent many Japanese students to study abroad[6] and employed scores of foreigners to help establish modern education and introduce Western science and technology. In the field of natural science, as is shown in the diagram on page 119, the number of foreign teachers in Japan was greatest in the 1870's; it decreased rapidly during the following decade, when most of them were replaced by Japanese trained abroad. The countries to which the Japanese students were sent were primarily America, England, and Germany and those countries from which most of the foreign teachers of natural science came were

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[4] *Nihon Kagaku-Gijutsu-Shi Taikei, ibid.,* pp. 12–16; Vol. 8, p. 27.

[5] YOSHIDA Mitsukuni, *Nihon o kizuita Kagaku* (Science that built Japan) (Tokyo, 1966), pp. 29–30.

[6] The number of Japanese students sent abroad by the Ministry of Education in the entire Meiji period came to 444. Among them, 268 were in the field of science and technology. (*Ibid.,* p. 30.) In addition to these students, there were many others who went abroad privately or were sent by other government departments.

Number of Foreign Teachers in Natural Science at Collegiate or
Semi-Collegiate Level in Japan during 1860–1895[7]
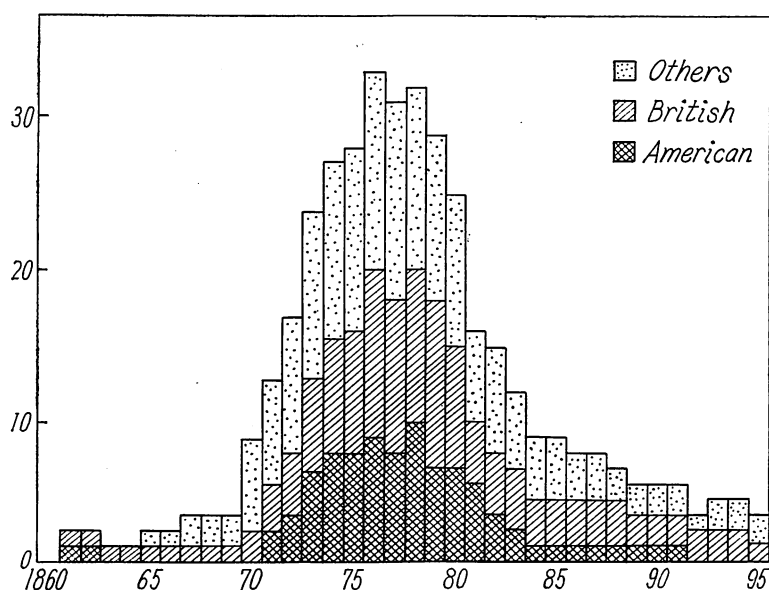
	American	British	German	French	Dutch	Total
Mathematics	5 + (2)	4 + (2)	3 + (3)	4 + (2)	———	16 + (9)
Physics, Astronomy, Geophysics	4 + (5)	8	1 + (2)	5 + (1)	(1)	18 + (9)
Chemistry	5 + (1)	3	7	(3)	1 + (1)	16 + (5)
Physical Geography	3 + (1)	1	5	1	———	10 + (1)
Biology	6	1	3	(2)	———	10 + (2)
TOTAL	23 + (9)	17 + (2)	19 + (5)	10 + (8)	1 + (2)	70 + (26)

Number of foreign teachers in various fields of natural science at collegiate or semi-collegiate
level who were in Japan sometime during the period 1860–1895. Numbers in parenthesis
denote teachers who taught in field indicated in addition to other fields.

America, England, Germany, and France. The table below gives numerical data
for the foreign teachers according to their specialities and nationalities.

These facts and statistics for the early years of Meiji Japan may be an indica-
tion that the English language itself played an important part in the early transmis-
sion of Western science to Japan. In fact, many of the Western books on science
translated and published in Japanese in those days were mainly either of American

[7] These statistics, though not complete, are based on the best available sources and may
very well show general trends. The author would like to acknowledge his debt to Professor YUASA
Mitsutomo for the original form of the statistics.

or of British authorship.

The extensive early American influence on Japan in science was due, first of all, to the leading part which America took in the reopening of Japan. Although England dominated trade at that time, America was more influential in the cultural sphere. Tens of Americans were sent to Japan as missionaries and many of the teachers and technical directors were invited from America. The Dutch-American missionary, Guido H. F. Verbeck (1830–1898), who had been staying in Japan since 1859, and the American educator, David Murray (1830–1905), who was called to Japan in 1873 to serve as educational adviser to the Minister of Education, had a particularly profound influence on the whole Japanese educational system and on the selection of foreign teachers to serve in Japan.[8] This may be counted as the second and more direct reason for the extensiveness of American influence on science in early Meiji Japan.

The following will deal with the introduction of science from America, with its influence on various phases of Japanese intellect, and with the ensuing cultural exchange. Although it is rather difficult to single out purely American-Japanese scientific and cultural influx, the author will try to give some representative cases largely pertaining to the activities of individuals, since the influence was exerted and exchange made mostly through a limited number of individuals in those early years. The field of applied science (for example, medicine and engineering), though very important, will not be treated in detail in this paper.

Achievements in Mathematics and Physical Science

Although most of the fields of natural science in Meiji Japan were first developed under the leadership of foreign teachers, mathematics differed somewhat in this respect. Traditional Japanese mathematics had already been quite highly developed and Western mathematics had also been taught by Dutch officers at the Nagasaki Naval Institute since 1855. During the 1870's two Japanese professors, Kikuchi Dairoku and Fujisawa Rikitaro,[9] rather than foreign teachers, were most active in the field of mathematics. The Mathematical Society of Tokyo, established in 1877, was also the first among the academic societies inaugurated in Japan. It consisted of three groups of Japanese mathematicians, namely, scholars of Japanese mathematics, scholars of newly introduced Western mathematics, and naval and army mathematicians.

The pivotal institution for the introduction of Western science was Tokyo University, established in 1877 as a result of the merger of separate educational institutions originally belonging to the Shogunate. In 1871, an American teacher, Peter V. Veeder, was invited by the Japanese government to teach physics. He

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[8] It was partly the result of advice of Guido H. F. Verbeck that the Meiji Government decided to learn medicine from Germany.

[9] Kikuchi Dairoku (1855–1917) studied in England and Fujisawa Rikitarō (1851–1933) studied in Germany.

continued teaching at Tokyo University until 1878 and published some meteorolog-ical observations and other works during his stay in Japan.[10]   In 1880, an American astronomer, Henry Martyn PAUL, came to serve as the first professor of astronomy at Tokyo University.   In 1883, he returned to the Naval Observatory, Washington, D.C.[11]   The groundwork for teaching and research in physics, however, was laid by an American physicist, T. C. MENDENHALL and by two British physicists, J. A. EWING and C. G. KNOTT.

Thomas Corwin MENDENHALL (1841–1924) was largely self-educated and was a professor of physics and mechanics at the newly founded Ohio Agricultural and Mechanical College (later Ohio State University) in 1878, when he was called to the chair of physics at Tokyo University.   He remained there for three years and helped establish a physical laboratory.   He initiated the measurement of the force of grav-ity in various parts of Japan and determined the mean density of the earth from the results of his measurements in Tokyo and at the summit of Mount Fuji.[12]   The result of his work was the best obtained at that time by the method he employed. Japanese students of physics followed his example and continued the same measure-ments for other parts of Japan, including Hokkaido and Okinawa.[13]

MENDENHALL was one of the main leaders in the early meteorological observa-tions in Meiji Japan.[14]   He served as the director of the newly established mete-orological observatory of Tokyo University.   In his concluding remarks in the "Report on the Meteorology of Tokio for the Year 1879,"[15] he suggested that the observatory should also be equipped with seismographs.   He finished this paper right after a severe earthquake (February 22, 1880) in the Tokyo and Yokohama area and was keenly aware of the need for the scientific study of the earthquake.

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[10] "Some Meteorological Observations in Japan," *Transactions of the Asiatic Society of Japan* (hereafter, *TASJ*), Vol. 5, Part I (Oct. 1876–June 1877), pp. 142–153; "Some Japanese Musical Intervals," *TASJ*, Vol. 7 (1879), pp. 76–85; "Results of Observation of the Visibility of Five of the Principal Mountains Seen from Tokio," *TASJ*, Vol. 7 (1879), pp. 86–89.

[11] Among H. M. PAUL's writings, the following are related to Japan: "Measuring Earth-quakes," *Science,* Vol. 4, No. 96 (1884), pp. 516–518; "Seismological Notes," *Science*, Vol. 5, No. 109 (1885), pp. 199–201; "Recent Gravity Determinations in and near Japan," *Science*, Vol. 6, No. 140 (1885), pp. 319–320.

[12] "Measurements of the Force of Gravity at Tokio and on the Summit of Fujinoyama," *Memoirs of the Science Department, University of Tokio* (hereafter, *Mem. Sci.*), No. 5 (1881), pp. 1–17 with preface. MENDENHALL made use of a Borda pendulum for his measurements because, as he wrote, the Kater pendulum which was available gave only an approximate value.

[13] A. TANAKADATE, R. FUJISAWA & S. TANAKA, "Measurement of the Force of Gravity at Sap-poro," *An Appendix to Mem. Sci.*, No. 5 (1882), pp. 1–21; *Tōyō Gakugei Zasshi* (Journal of Arts & Sciences), No. 12 (Sept., 1882), p. 298.

[14] Among other leaders of Japanese meteorology were the Englishman, H. B. JOYNER, who inaugurated and supervised meteorological observations at Tokyo Metropolitan Observatory founded in 1875; and the German, Erwin KNIPPING, who was famous for establishing the system of weather forecasting and storm warnings at the same institution.

[15] *Mem. Sci.,* Vol. 3, Part 1 (1880), pp. 1–42, preface, plates.

His meteorological report for the next year[16] included magnetic observations, meteorological observations on Mount Fuji, and the historical survey of the fires in Tokyo. This last survey was done by YAMAGAWA Kenjirō, who had been educated at the Sheffield Scientific School of Yale University and later became the first Japanese professor of physics at Tokyo University.

The Japan Seismological Society was founded in 1880. This was probably the first scientific society in the world for the study of seismology. The frequent earthquakes, particularly the one metntioned above, which terrified the foreign teachers in Japan, gave strong impetus to this outcome. Among the foreign teachers, MENDENHALL and two British professors, John MILNE and James Alfred EWING, were influential in organizing the society. The study of seismology was thus initiated and it made amazing progress in Japan in a relatively short time. MENDENHALL retired in 1901 and died in 1924. His bequest to the Imperial Academy of Japan was made the endowment fund for the Mendenhall Commemoration Prize.[17]

MENDENHALL's principal scientific contributions were in the fields of geophysics (gravity, meteorology, and seismology), geodetic survey, and weights and measures. The breadth of his interest was evidenced by his numerous monographs, reports, and papers which covered a wide field, including articles on the history of science, biographies of scientists and educators, and historical accounts related to the state of Ohio. The Japanese translation of his book *A Century of Electricity* (Boston and New York: 1887) was published in Tokyo in 1893.[18] MENDENHALL is mentioned by D. E. SMITH and J. GINSBURG in their book, *A History of Mathematics in America before 1900*, as one of the most prominent among "American mathematicians who gave particular attention to the subject" of the "mathematical problem of the pendulum."[19] He was also the only American physics teacher who served in Japan during the Meiji period and whose name appears in the list of some 1800 Americans considered by the American Institute of Physics as having made significant

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[16] "Report on the Meteorology of Tokio for the Year 1880," *Mem. Sci.,* No. 7 (1881), pp. 1–81, plates.

[17] While in Japan, MENDENHALL published a number of papers, including the following: "An Experimental Solution of a Problem in the Doctrine of Chances," *Proceedings of the American Association for the Advancement of Science,* Vol. 28 (1879), pp. 190–192; "A Japanese Typhoon," *The Popular Science Monthly*, Vol. 18 (1880), pp. 356–361; "On the Determination of the Acceleration due to the Force of Gravity at Tokio," *Transactions of the Seismological Society of Japan,* Vol. 1 (1880), pp. 52–53; "The Wave Length of Some of the Principal Fraunhofer Lines of the Solar Spectrum" *Mem Sci.,* No. 8 (1881), pp. 1–27, plate; while he served as Professor of Electrical Science in the U.S. Signal Corps (1884–1886), MENDENHALL established a systematic collection of data relating to earthquakes. As Superintendent of the U.S. Coast & Geodetic Survey (1889–1894), he was responsible for the development of an improved portable apparatus for the measurement of gravity and according to his plans, a transcontinental series of gravity measurements were made.

[18] *Denki Gakujutsu no Shimpo* (Tokyo, 1893).

[19] D. E. SMITH & J. GINSBURG, *A History of Mathematics in America before 1900* (Chicago, 1934), p. 101.

contributions to physics.

Scientific ability coupled with the pioneer's spirit in this Ohio-born American seemed to have been fully displayed as he managed scientific, educational and administrative matters both in America and in Japan. He was probably best suited for work of this nature, for he was well acquainted with those fields to which physics was to be effectually applied, was proficient in mathematics, and was well experienced in the art of precise measurements. Thus as physicist, educator, and administrator, he rendered distinguished service to his own country as well as to Japan, although in some aspects of teaching physics in Japan he had to be supplemented by other foreign teachers from Europe.[20]

In the field of chemisty, reference should be made to the American teacher William Elliot GRIFFIS (1843–1928) for the uniqueness of the role he played in the cultural contacts between Japan and the United States, although the Dutch chemist, K. W. GRATAMA, and two British chemists, E. DIVERS and R. W. ATKINSON, may be said to have contributed more to the introduction of Western chemistry in Japan.[21]

While a student at Rutgers College, GRIFFIS taught the first Japanese students who were sent there on the advice of VERBECK. Thus, when in 1870 a call came from the Fukui clan in Japan for someone to organize a scientific school on the American principle, GRIFFIS was selected by the Rutgers faculty for that duty. He accepted the appointment and went to Japan. After teaching in Fukui, he was called to Tokyo in 1872 to teach chemistry and physics at the *Nanko*, one of the predecessors of Tokyo University. He remained there till 1874, and returned to America, where he graduated from the Union Theological Seminary in 1877, entered the ministry, and served as pastor of several churches.

GRIFFIS took great pride in the claim that he spent nearly a year "alone in a daimiō's capital far in the interior, away from Western influence, when feudalism was in its full bloom, and the old life in vogue."[22] He devoted much of his life to the work of interpreting Japan to America with voice and pen. His first book, *The Mikado's Empire* (1876) became a mine of information about Japan, including matters scientific and technical. Many other books and articles of his were also concerned with Japan.[23]

While in Japan, GRIFFIS was asked by KATSU Awa to find for the Shizuoka clan "a professional gentleman, regularly educated, not a mechanic or a clerk who has taken to teaching to pick up a living; and, if possible, a graduate of the same school as yourself."[24] Thus, GRIFFIS introduced another Rutgers graduate, Edward Warren

[20] For further information on MENDENHALL's life and activities, see: WATANABE Masao, "Thomas Corwin Mendenhall: Physicist in Japan and America" (in Japanese with English summary), *Kagakusi Kenkyu* (*Journal of History of Science, Japan*), No. 79 (1966), pp. 113–123, including a comprehensive bibliography of MENDENHALL.

[21] Years of stay in Japan as follows: GRATAMA, 1865–1871; DIVERS, 1873–1899; and ATKINSON, 1874–1881.

[22] W. E. GRIFFIS, *The Mikado's Empire* (5th ed.), Preface, p. 9.

[23] GRIFFIS' other writings are too numerous to be listed here.

[24] GRIFFIS, *op. cit.*, p. 527.

CLARK. CLARK taught in Shizuoka and then moved to Tokyo to teach physics and chemistry at *Kaisei Gakko*, one of the predecessors of Tokyo University, during 1873–74. He left two books on Japan, *Life and Adventure in Japan* (1878) and *Katz Awa, the Bismarck of Japan* (1904).[25]

GRIFFIS had a decisive effect on the whole interpretation of history and culture of Japan. In his *Mikado's Empire* he not only presented the history of Japan but also reported his observations on nature and the folklore of Japan. As to some representative aspects of nature in Japan, he wrote:

> The aspects of nature in Japan are such as to influence the minds of its mainly agricultural inhabitants to an extent but faintly realized by one born in the United States. In the first place, the foundations of the land are shaky. There can be no *real* estate in Japan, for one knows not but the whole country may be ingulfed in the waters out of which it once emerged. Earthquakes average over two a month, and a hundred in one revolution of the moon have been known. The national annals tell of many a town and village ingulfed, and of cities and proud castles leveled. Floods of rain, causing dreadful land-slides and inundations, are by no means rare. Even the ocean has, to the coast-dweller, and added terror. Not only do the wind and tempest arise to wreck and drown, but the tidal wave is ever a possible visitor. Once or twice a year the typhoons, sometimes the most dreadful in the dreadful catalogue of destructive agencies, must be looked for. Two-thirds of the entire surface of the empire is covered with mountains—not always superb models of form like Fuji, but often jagged peaks and cloven crests, among which are grim precipices, frightful gulches, and gloomy defiles. With no religion but that of paganism and fetishism, armed without by no weapons of science, strengthened within by no knowledge of the Creator-father, the Japanese peasant is appalled at his own insignificance in the midst of the sublime mysteries and immensities of nature. The creatures of his own imagination, by which he explains the phenomena of nature and soothes his terrors, though seeming frightful to us, are necessities to him, since the awful suspense of uncertainty and ignorance is to him more terrible than the creatures whose existence he imagines. Though modern science will confer an ineffable good upon Japan by enlightening the darkened intellect of its inhabitants, yet the continual liability to the recurrence of destructive natural phenomena will long retard the march of mind, and keep alive superstitions that now block like boulders the path of civilization.[26]

The natural calamities GRIFFIS listed were typical of nature in Japan, especially the earthquake and the typhoon. Thus, once the scientific method of investigation

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[25] Besides these two books, CLARK wrote the following: "International Relations with Japan," *International Review*, Vol. 4, (1877), pp. 51–67.

[26] GRIFFIS, *op. cit.*, pp. 477–478. The quotation is from the second paragraph of the chapter, "The Mythical Zoology of Japan." In following pages, GRIFFIS described the fire dragon, the rain dragon, the wind imp, the thunder-drummer, the earthquake fish, *etc.*

¯was introduced, seismology and the science of the typhoon were to become two specialities of physical science in Japan.

Concerning seismology in Japan, KIKUCHI Dairoku stated in one of his articles published in 1912:

It is not strictly proper to speak of seismology as introduced from the West, for it may be said to have originated in Japan with the investigations of Professors Wagner, Milne, Gray, Ewing, Knott, Sekiya, Omori, and others; but its first invertigators came from Europe, and its methods are those of Western science.[27]

MENDENHALL had already in 1900 made a very felicitous remark:

There is one science which the Japanese have practically made their own. Blessed or cursed (according to how you look at it), by the frequent occurrence of earthquakes, and blessed (certainly) by the presence of a large number of able and enthusiastic students of physical science, Japan has become within twenty years a vast seismological laboratory in which seismic phenomena are being used as they never were before. Indeed, modern seismology had its birth there, and there it has been and is being most carefully nurtured. About twenty years ago there were in Japan a considerable number of foreigners employed as professors of engineering, geology, physics, etc., and of necessity they became interested in the one characteristics natural phenomenon, the unpleasantly frequent manifestations of which none of them will ever forget.[28]

These quotations very adequately describe the growth of a peculiar phase of physical science in Japan as the result of the introduction of the scientific method from the Western world.

Advances in Biological Science

The early influence of American science on Japan was greatest in the field of biological science. Most of the early Japanese leaders in this field had been either educated in American universities or influenced by the American professors who taught in Japan.

The development of Hokkaido, the northern island of Japan, was carried out largely under the guidance of American experts during the Meiji era and their influence was so strong that even today the agricultural landscape there bears a startling resemblance to that of American rural areas. The Sapporo Agricultural College in Hokkaido, predecessor of Hokkaido University, was founded at the suggestion of Horace CAPRON, an American adviser to the Colonization Commission (*Kaitakushi*) of the Japanese government. This college was modelled after Massachusetts Agricultural College, now the University of Massachusetts. William

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[27] KIKUCHI Dairoku, "The Introduction of Western Learning into Japan," *The Rice Institute Pamphlet*, Vol. 2 (1915), p. 94.

[28] T. C. MENDENHALL, "Publication of the Earthquake Investigation Committee—in Foreign Languages, Numbers 3 and 4 Tokyo–1900," *Science*, n.s., Vol. 12, No. 305 (1900), p. 678.

Smith CLARK (1826–1886), President and professor of botany and horticulture of Massachusetts Agricultural College, was invited to be the first president of this new college in Hokkaido.   CLARK presided there for only a year, yet he exerted such a great and lasting influence on Japanese students in both religious and scientific outlook that his name is still remembered by the Japanese people today.   Among the early graduates from this College were MIYABE Kingo and WATASE Shōzaburo, two leading biologists of Japan.

The circumstances differed in Tokyo where Edward Sylvester MORSE (1838–1925) at Tokyo University was influencing Japanese intellectuals.   MORSE was born in Maine, showed special interest in collecting and classifying shells and minerals, and happened to win the notice of Louis AGASSIZ, who was about to start the new Museum of Comparative Zoology at Harvard University.   Thus MORSE became a student-assistant to AGASSIZ at the Lawrence Scientific School, Harvard University, and specialized for three years in conchology.   His study of the brachiopods led him to his undertaking a systematic exploration of the Atlantic Coast from Maine southward and his publication of this research attracted the attention of Charles DARWIN and other European naturalists.   The Pacific Ocean brachiopods with their rich varieties lured MORSE to Japan in 1877 and while there he was invited to teach zoology at Tokyo University.

His tenure in this professorship during the years 1877–79 witnessed the introduction among the Japanese of the theory of evolution and modern methods of collecting and classifying objects of natural history.   He also "collected books and pamphlets for the University Library to the extent of twenty-five hundred volumes and made the beginning of a good scientific collection."[29]   *Memoirs of the Science Department, University of Tokio* was published at his suggestion and the Tokyo Biological Society was established under his strong influence.   This society was to grow into the present Zoological Society and Botanical Society of Japan.   MORSE's students later became the founders of modern zoology in Japan.

One of the greatest achievements of MORSE in Japan was his discovery of shell mounds at Omori, Tokyo, which he first noticed on a train as it travelled through a railroad pass.   His prior experience studying "these deposits along the coast of New England, in company with Prof. Jeffries Wyman"[30] advantageously served him in making this discovery.   He examined these shell mounds of Omori, which consisted of kitchen middens with their pre-historic artifacts, and his students and American colleagues, MENDENHALL and JEWETT,[31] cooperated with him.   MORSE

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[29] E. S. MORSE, *Japan Day by Day* (Boston & New York, 1917), Vol. 1, p. 139.

[30] E. S. MORSE, "Traces of an Early Race in Japan," *The Popular Science Monthly*, Vol. 14 (1879), pp. 257–266 (esp. p. 260).

[31] Frank Fanning JEWETT (1844–1926) was a professor of chemistry at Tokyo University from 1876 to 1880.   After his return to America, he became a professor in Oberlin College, where he remained until 1912.   Among his students at Obserlin was Charles M. HALL, discoverer of the electrolytic method for separating aluminum from its various compounds.   For the shell mound discoveries, see MORSE, *ibid*.

published the results of his investigation in the first issue of *Memoir of the Science Department* and elsewhere. He thus opened the way to the development of archae- ology and anthropology in Japan. His example was immediately followed by two of his Japanese students in their excavation of a shell mound at Hitachi, 73 miles distant from Tokyo, and their report was attached to that of MORSE.[32] MORSE sent Charles DARWIN a copy of the proof-sheets for "A Comparison between the Ancient and Modern Molluscan Fauna of Omori," a chapter in his report. DARWIN showed great interest in it and in his reply to MORSE he wrote:

> Of all the wonders of the world, the progress of Japan, in which you have been aiding, seems to me about the most wonderful.[33]

It was mainly MORSE who introduced the theory of evolution to Japan. He came to Japan only eighteen years after the publication of DARWIN's *Origin of Species*. He not only lectured at the University but also expounded the theory at a series of public lectures in Tokyo and did much to popularize it among Japanese intellectuals at the time when this theory was not as yet universally accepted. Dar- winism, together with Herbert SPENCER's philosophy, which was also introduced to Japan at the same time, attracted contemporary Japanese leaders.[34] Both bio- logical and sociological implications and applications of the notion of the survival of the fittest were, so to speak, an inspiration to them when their own country had to struggle for existence in new international circumstances.

The lively interest of Japanese intellectuals in Darwinism and Social Dar- winism was reflected in academic periodicals of the time, such as *Gakugei Shirin* and *Tōyō Gakugei Zasshi*. In the former were published many articles translated from the originals appearing in *The Popular Science Monthly*, an American journal edited by Edward Livingston YOUMANS (an advocator of SPENCER's thought). The opening article of *Tōyō Gakugei Zasshi*, Volume I (1881), was entitled "How to Apply the Artificial Selection to Obtain Capable Men" and was written by KATŌ Hiroyuki, then President of Tokyo University. Articles of similar sort appeared in the succeeding volumes of the same journal.[35]

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[32] E. S. MORSE, "Shell Mounds of Omori," *Mem. Sci.*, Vol. 1, Part I (1879), pp. 1–36, preface, plates (Japanese translation of the same paper was also published in the same year); "Evidences of Cannibalism in a Nation before the Ainos in Japan," *Tokio Times*, Jan. 19, 1879; and IIJIMA I. & SASAKI C., "Okadaira Shell Mound at Hitachi," *An Appendix to Mem. Sci.*, Vol. 1, Part I (1883), pp. 1–7, preface, plates.

[33] Francis DARWIN & A. C. SEWARD, ed., *More Letters of Charles Darwin*, Vol. 1 (New York, 1903), p. 384.

[34] MORSE's public lectures were translated into Japanese and published in 1883 under the title, *Dōbutsu Shinkaron* (The Evolution of Animals), probably the first book on evolution published in Japan. The following were also influential in spreading the theory of evolution: E. F. FENOLLOSA, American professor of philosophy at Tokyo University; TOYAMA Shōichi, Japanese professor of sociology at Tokyo University, who had studied in England and in America; YATABE Ryōkichi, professor of botany at Tokyo University, who had studied in America.

[35] *Gakugei Shirin* was first published in 1877 and *Tōyō Gakugei Zasshi* in 1881. Japanese

On leaving Fukui for Tokyo and travelling in heavy snow on January 23, 1872,.
GRIFFIS could write and joke:

> We resume our march. . . . The tracks of boar, bear, foxes, and monkeys
> are numerous. It is the hunter's harvest-time. Dressed carcasses are on
> sale in every village. I wonder how a Darwinian steak would taste. "No,.
> thank you; no monkey for me!" is my response to an invitation to taste my
> ancestors. Good people, you need "science" to teach you what cannibals
> you are.[36]

At the time, many of the missionaries and Christian teachers in Japan were uneasy
in seeing evolution popularized there, since it was, they decided, entirely contrary
to the Biblical account of creation. Thus they started a strong campaign of apolo-
getics in Japan.[37]

As for the Japanese, however, they saw practically nothing in the theory of
evolution which contradicted their own philosophy of life, nor were they furnished
with any other systems of scientific knowledge according to which they might crit-
icize this new theory. At the time when ill feeling toward Christianity was still
existent, Darwinism, presented antagonistically to this Western religion, must
have appealed to the Japanese mind. It was ready to accept the newest outcome
of Western science and technology but clung mostly to traditional value systems.
Moreover evolution might have provided justification for modernization and en-
lightenment and, as Dr. SCHWANTES pointed out, it "offered a solution to the
problem of the new *versus* the old: if the future, present, and past were continu-
ous, one developing inevitably out of the other, then respect for ancestors and na-
tional heroes was perfectly compatible with modernization and progress."[38] Under
these circumstances, evolutionary thought, sometimes in its most simplified form
but still armed with the term "scientific," swept over the Japanese mind. It was
to lead critiques on social affairs and was to be invoked to justify powerful
armament.

MORSE was responsible for the early introduction of the theory of evolution to
Japan and, to a considerable degree, for the above situation as well. He did not in-
troduce the elaborate theory of DARWIN but rather presented his own interpretation,.

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students in America had also been exposed to Spencer's philosophy. Even YAMAGAWA Kenjirō,.
for example, while a student at Sheffield Scientific School of Yale University, argued that promotion
of natural science was indispensable for the furtherance of national strength and thus he decided
to major in physics. As he related in his recollections, the whole argument was deduced by a
Spencerian mode of thinking as was presented by YOUMANS in his *Popular Science Monthly*, start-
ed in 1872, when YAMAGAWA entered the Sheffield Scientific School. See WATANABE Masao,
"Kenjirō Yamagawa: a *Samurai* Scientist at Yale University" (in Japanese with English summary),.
Bunkashi ni okeru Kindai Kagaku (Science in the History of Modern Culture) (Tokyo, 1963).

[36] GRIFFIS, *op. cit.*, p. 542.

[37] Robert SCHWANTES, "Christianity *versus* Science: A Conflict of Ideas in Meiji Japan," *The*
Far Eastern Quarterly, Vol. 12, No. 2 (1953), pp. 126–127.

[38] *Ibid.*, p. 125.

which was much simpler. He sometimes did not bring transitional stages under careful consideration but related results too hastily to the supposed causes of evolution. Nor was he adequately cautious when he compared examples in plants and animals with the cases of mankind. Often he interpreted plant or animal phenomena in terms of human affairs and conversely applied the patterns of the former too rashly to the latter. As he was originally a student of AGASSIZ, who was strongly opposed to Darwinism, MORSE was not thoroughly trained in theory of evolution. He also saw evolution as conflicting with Christianity and presented it, in fact, as something quite antagonistic. In doing so, he might have intended to set the Japanese people's mind free from superstitution. He had been brought up under austere religious instruction but did not realize the role of Christianity was to play in Japan in modernizing people's thought. Therefore the effects of his endeavors were probably contrary to his original intentions.[39]

MORSE recommended Thomas Henry HUXLEY as his successor but because of his failing health, HUXLEY could not come. Had he come, the whole story of evolution in Japan might have been somewhat different. Since MORSE thus remained the major figure who introduced evolution to Japan, its effects were limited.

Another American evolutionist in Japan, John Thomas GULICK (1832–1923), although he did not teach at any university, made original contributions to the theory of evolution by his study of shells. He was a son of an American missionary to Hawaii and he himself became a missionary to China and Japan. He was at the same time a specialist in Hawaiian snails. He not only substantiated DARWIN's theory but also took a further important step in post-Darwinian development of the theory of evolution. He made a careful study of the relation between the geographical distribution and the variation of the species of *Achatinellidae* and applied the theory of evolution to account for observed facts. While DARWIN regarded selection by outside environmental forces as the dominant factor in evolution, GULICK showed that there were other factors working as causes of change or evolution. This was the new evidence discovered by GULICK through his study of *Achatinellidae*. As he observed, the power of migration of this particular species was limited to a very extraordinary degree in that they scarcely moved from one tree to another. Nevertheless, there were noticeable differences between this family of snails in one valley and the next and even on one tree and the next. Thus he argued that even in the absence of differences of selection there must be an inherent tendency in check. Therefore he emphasized isolation, or the prevention of mingling, and also many factors that were of internal origin.

While the majority of contemporary Christian leaders and laymen were hesitant in accepting the consequences of the theory of evolution and even in Japan there was controvarsy among missionaries and visting Western teachers as to the validity

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[39] For an evaluation of MORSE's presentation of the theory of evolution in Japan, the author is indebted to Mr. TSUKUBA Hisaharu, in *Nihon Kagaku-Gijutsu-Shi Taikei, op. cit.,* Vol. 15, pp. 168–169.

of what was implied by the Darwinian theory, GULICK saw both science and religion in harmony. He maintained a theory of evolution that emphasized a non-fatalistic self-determination. He felt that future advancement of the race would be determined by the conscious choices by man himself and that the work of the missionary was to spread the influence that leads men to make the best choices. In connection with these thoughts was the ethical incentive to discover and to make known the scientific laws that set the conditions for achieving a better racial and cultural evolution, according to GULICK.

J. T. GULICK lived mainly in Kōbe and Ōsaka. Japanese land snails constituted an additional conchological interest for GULICK. He could observe the similar but more intricate relations of the varieties and localities than those of the Hawaiian Islands he had observed. He lectured on evolution several times at Dōshisha, a Christian school in Kyoto, and on "Evolution in the Organic World" at the Protestant Missionary Conference in the 1880's. His scientific work has come to be reevaluated today, but, in his lifetime, he seems to have exerted relatively little influence on science and thought in Japan. Several reasons for this fact may be cited.

Lack of impact by GULICK was due first, to his modest and quiet personality and second, to his unpretentious scientific attitude. Third, he was stationed in the Kansai area, far removed from Tokyo, the center of modern education as well as of politics. Fourth, he was sent to Japan as a missionary and not as a science teacher. Fifth, Christian educational institutions in Japan did not lay stress on science education, while governmental institutions accentuated the scientific and technological aspects of education. Sixth, the Japanese people in general were eager to learn Western science and technology but were less favorably inclined toward Christianity, as has already been pointed out. Thus E. S. MORSE was quite enthusiastically accepted, but for GULICK, there existed little room to bring his scientific expertness into full play, although his activities in Japan as a missionary bore significance of immeasurable degree.[40]

In the fields of anthropology and archaeology in Japan, again MORSE took the lead. Under his influence, the Tokyo Anthropological Society was organized in 1884, and the teaching of anthropology and paleontology was started at Tokyo University. MORSE not only excavated shell mounds, as mentioned above, but also investigated prehistoric caves and ancient tombs in Japan. One of his books, *Japan Day by Day*, was an excellent record of his travels and observations. It gave the reader vivid descriptions, made by a friendly foreigner, of life in Japan when the country was "little influenced by the modes and manners of foreign

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[40] For information on John Thomas GULICK and his work, see: Addison GULICK, *Evolutionist and Missionary: John Thomas Gulick* (Chicago, 1932); WATANABE Masao, "John Thomas Gulick: American Evolutionist and Missionary in Japan" (in Japanese with English summary), *Kagakusi Kenkyu (Journal of History of Science, Japan)*, No. 77 (1966), pp. 1–15 and "John Thomas Gulick: American Evolutionist and Missionary in Japan" (in English), *Japanese Studies in the History of Science*, No. 5 (1966), pp. 140–149.

countries,"[41] and it contained nearly eight hundred drawings beautifully done by the author. What made him decide to have his material published sooner was, according to his preface, the following argument by William Sturgis BIGELOW in a letter addressed to him:

> The only thing I don't like in your letter is the confession that you are still frittering away your valuable time on the lower forms of animal life, which anybody can attend to, instead of devoting it to the highest, about the manner and customs of which no one is so well qualified to speak as you. Honestly, now, is'nt a Japanese a higher organism than a worm? Drop your damned Brachiopods. They'll always be there and will inevitably be taken care of by somebody or other as the years go by, and remember that the Japanese organisms which you and I knew familiarly forty years ago are vanishing types, many of which have already disappeared completely from the face of the earth, and that men of our age are literally the last people who have seen these organisms alive. For the next generation the Japanese we knew will be as extinct as Belemnites.[42]

MORSE also became well-informed on Japanese pottery and houses, as well as other ethnological aspects of Japanese life. No other collection of Japanese pottery could surpass the one made by E. S. MORSE and deposited in the Boston Museum of Fine Arts. A chance discovery at a china shop in Tokyo, of a saucer resembling a shell, first turned MORSE's attention to Japanese pottery. He looked for and found other examples modelled on shells. He was told by a Japanese friend, however, that these were not famous potteries. Thus "Morse became aware that there was a cult of pottery in Japan and that good pottery was to be recognized by an incised potter's mark."[43] Soon he had a Japanese expert[44] as his tutor of ceramics, with every Sunday afternoon devoted to lessons. Although MORSE had had no aesthetic training, he had a special talent for accurate observation and for skillful drawing.

> ... Morse's camera eye, his uncanny ability to carry an image in his mind with complete fidelity of detail, enabled him to recognize at a glance the unfamiliar hieroglyphs of the various potters' marks. He could not read the Japanese written language, but he could carry in his memory and identify unerringly hundreds of potters' signatures in Japanese characters.

> The third factor that made a ceramics connoisseur of Edward Morse was his passion for collecting. All his life he had a compulsion to collect, catalogue, and classify objects, beginning with the Maine land shells of his boyhood, and this natural impulse had been disciplined and encouraged by the great

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[41] A letter from John G. MORSE, son of E. S. MORSE, to ISHIKAWA Kin-ichi, Japanese translator of *Japan Day by Day*.

[42] William Sturgis BIGELOW (1850–1926), physician, orientalist, and collector of Japanese art. For the quotation, see *Japan Day by Day, op. cit.,* Vol. 1, preface, pp. ix–x.

[43] Dorothy G. WAYMAN, *Edward Sylvester Morse: A Biography* (Cambridge, Massachusetts, 1942), p. 259.

[44] NINAGAWA Noritane.

collector, Agassiz.[45]

Another MORSE book, *Japanese Homes and Their Surroundings* (1885), was republished very recently in America in a paperback edition. MORSE's careful observations of Japanese houses, made three-quarters of a century ago and presented in this book with abundant illustrations of his own, seem to remain so important and reliable a source of information that it must have been worth republication today, when Japanese architectural influence on the modern American home is becoming more evident than ever before.

After returning to America, MORSE took up his lifework as director of the Peabody Museum in Salem, Massachusetts. There he also did a great deal to introduce Japan and Japanese art to the American people. The things he brought back from Japan and deposited in the Peabody Museum make one of the world's finest collections of Japanese ethnological objects. MORSE died in 1925. Since his mentality was encyclopedic and, on occasions, he drew brilliantly using both his hands, the Director of the Wister Institute of Anatomy became interested in the function of his brain. Thus MORSE proposed to contribute it to the Institute "when I am done with it"[46] and there his brain was studied[47] and is still preserved in alcohol.

MORSE recommended competent American teachers to Tokyo University, men like MENDENHALL, Ernest FENOLLOSA, and Charles Otis WHITMAN (1842–1910), who succeeded him at Tokyo University. WHITMAN was another pupil of AGASSIZ and had done his graduate work in Germany.[48] He remained in Japan for a period of two years (1879–1881) and taught embryology, introducing the latest method of microscopic study. His own scientific work in Japan was on the study of leeches.

While his predecessor was a man of gay and expansive personality and was a naturalist (or *hakubutsu-gakusha*) in the broadest sense of the word, WHITMAN was a grave scholar of the more analytical type. He had only four students in Japan, namely, SASAKI Chūjiro, IWAKAWA Tomotarō, IIJIMA Isao, and ISHIKAWA Chiyomatsu, but they all became leaders in the field of biology in Japan. After returning to America, he successively assumed the chairs of Director of Allis Lake Laboratory at Milwaukee, Professor and Head of the Department of Zoology, University of Chicago, and Director of the Marine Biological Laboratory at Woods Hole. His main scientific contributions were in embryology, comparative anatomy, taxonomy,

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[45] WAYMAN, *op. cit.*, pp. 259–260. And thus an American biologist became the supreme authority on Japanese pottery, consultant to the British Museum, the Royal Museum in Desden, the Freer Art Gallery, the Boston Museum of Fine Arts. Japanese pottery, for the first time systematically collected, classified, and catalogued according to the scientific fashion of natural history. His acquisitions were listed and published in *Catalogue of the Morse Collection of Japanese Pottery* (1901).

[46] MORSE's letter to ISHIKAWA Chiyomatsu.

[47] Henry H. DONALDSON & Myrtelle M. CANAVAN, "A Study of the Brains of Three Scholars, Granville Stanley Hall, Sir Wiliam Osler, Edward Sylvester Morse," *The Journal of Comparative Neurology*, Vol. 46, No. 1 (1928), pp. 1–95.

[48] Under Karl G. F. R. LEUCHART at the University of Leipzig.

evolution, heredity, and animal behavior. To him belongs the credit for introducing scientific zoology to America. Among the science teachers in Meiji Japan, WHITMAN may justly be counted as one of the most eminent scientists and investigators.

Both MORSE and WHITMAN were pupils of AGASSIZ and at least three early Japanese professors of zoology at Tokyo University, namely MITSUKURI Kakichi, who succeeded WHITMAN, WATASE Shōzaburō, and GOTŌ Seitarō, were trained at the Johns Hopkins University under William Keith BROOKS, another pupil of AGASSIZ. Thus it is true that "during the latter part of the last century there was hardly an active naturalist in America and Japan who had not either studied under Agassiz or been a pupil of one of his students."[49]

Both YATABE Ryōkichi, who was already professor of botany at Tokyo University when MORSE came to Japan, and MIYABE Kingo, who became a professor of botany at Hokkaido University, had studied under Asa GRAY, another great naturalist in America. GRAY was a pioneer and master in the field of plant geography and of his contributions to this department the most famous was the monograph on the botany of Japan and its relations to that of North America and other parts of the north temperate zone.[50] The collections of plants of Japan and of other Asian regions necessary for his study, GRAY was able to obtain through the scientists who joined PERRY's and other expeditions to the East.

All of the above examples illustrate the deep and extensive influence of American scientists on Japan, particularly in the field of natural history during the early Meiji Period.

Conclusion

From the time of reopening of the country, Japan had made great efforts to catch up with Western countries and in a relatively short time seemed successfully to have introduced modern science and technology. Already in 1874, GRIFFIS could write of the revolt in Saga:

> The days of Old Japan were passed. The era of steam, electricity, and breech-loaders had come. From the national capital darted the telegraphic lightnings. On the wings of steam, the imperial battalions swooped on Saga, as if by magic. The rebellion was annihilated in ten days.[51]

By about 1890, the educational system had been established; academic societies had been founded; scientific terminology had been formulated; academic periodicals were being published; and original works by Japanese scientists which won international reputations had already appeared. For example, there were the theory of typhoon by KITAO Jirō, a physicist trained in Germany, and the study of magneto-

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[49] "Agassiz, Jean Louis Rodolphe," *Dictionary of American Biography,* Vol. 1, pp. 114–122, particularly p. 121.

[50] *Memoirs of the American Academy of Arts and Sciences,* Vol. 6 (1859).

[51] GRIFFIS, *op. cit.,* p. 575.

striction by NAGAOKA Hantarō, a young Tokyo University graduate who later went to Germany for further study.

The tradition of Dutch learning in Japan paved the way and enabled Japanese to make rapid strides in assimilating Western science. Moreover, unlike other Asian countries, there existed a lingual unity in Japan. This made it possible for Japanese to translate the body of Western science efficiently into their own language and to teach and to conduct research. Third, science and technology in the nineteenth century could be explored by individuals. Only a few Western teachers in Japan and Japanese students abroad were able to fulfill the initial task of quickly transmitting modern science into Japan. A century later, such an endeavor would certainly require groups of researchers and technicians working together in factory-like laboratories, with gigantic amounts of research funds.

The influence of American scientists was particularly notable in the fields of natural history and geophysics. These Americans at the same time proceeded even to unknown corners of the country and made observations not only on scientific matters but also on Japanese life in general. Thus they contributed to the introduction of Japanese culture into the Western world, as well as to the introduction of Western science into Japan.

In the late 1880's however, Japanese leaders, impressed by the rise of Germany, switched over from America to Germany to look for their models and tried to follow German examples in almost every aspect of education as well as in constitutional and military affairs. Consequently American influence in natural science declined, to be revived about a quarter of a century ago.

Remarkably rapid as it was, the introduction of Western science into Japan could not be effected without leaving various strains and deformities. Since the modernization of the state was the pressing question, the promotion of national industry and military forces took priority. Scientific activities were commenced primarily at governmental institutions under centralized national authority. Unlike the situation in Western countries, these activities were not necessarily initiated voluntarily by individuals interested in scientific inquiries, but were promoted as parts of national projects spurred on by immediate national needs.

Already before the opening of the country, scholars of Western learning in Japan were well aware of the effectiveness of modern science. Even after direct contact with Western countries was made possible, however, the Japanese people did not fully realize how deeply these disciplines were rooted in Western culture. Consequently, although they were eager to introduce the latest scientific findings, they did not pay much attention to how these could be made to fit their own cultural environment. The frequently used phrase, *wakon-yōsai* (Japanese spirit with Western learning) might well represent the basic attitude of the Japanese intellectuals of the time. Most of the Western teachers, who so much appreciated traditional Japanese culture, did not seem to have thoroughly perceived this shortcoming either.

In this respect, Erwin BAELZ's observation was exceptionally adequate and

penetrating. He had been invited from Germany and taught at the Medical School of Tokyo University for as long as twenty-five years, beginning in 1876. "As a true and warm friend of the Japanese people" he set forth the following criticism, on the occasion celebrating his twenty-fifth year of service in Japan:

> ... So far as I see, a mistaken notion seems to be frequently prevalent in Japan concerning the origin and nature of western science. The Japanese people regard science as a kind of machine which yearly performs a prescribed amount of work and can easily be transferred to any place to have it kept working there. This is a mistake. The western scientific world is not a machine at all, but it is an organism, for the growth of which a certain climate and atmosphere are necessary as is true with the case of all other organisms....
>
> ... The western countries sent many teachers to you, and with zeal did these teacher endeavor to transplant this spirit [of the West] in Japan and to make it adopted by the Japanese people. However, their mission was often misunderstood. They were looked upon as traders of scientific fruits who sell those fruits by the piece, although they were to be and they themselves intended to be the cultivators of the trees of science.... The Japanese people are content only with receiving the most recent developments and do not care to learn the basic spirit which has yielded these results.[52]

As was rightly pointed out, the Japanese people did not quite learn how to be creative in scientific investigations, although they became ever alert to import the newest products of technology. They did not seem fully to have acquired the scientific mind, but retained some conventional modes of mental attitude, such as secretiveness and sectarianism, which hampered exercising open and free discussions among researchers, a means vital to the advancement of scientific knowledge.

Only as most effective tools for the modernization of the country were Western science and technology introduced into Japan, independent from their intrinsic cultural environment and value system. As a result, in Japan there has been an almost complete isolation between the scientific-technological aspect and the cultural-religious aspect of life. The Japanese people did not try to see the newly introduced science in relation to its cultural foundations in the West, nor did they feel it necessary to correlate it adequately to their own traditional culture. Thus it is doubtful whether the Japanese people operated modern science and technology with modern consciousness and modern humanitarianism.

Christianity and science are the two distinguishing features of the Western cultural heritage. It is, however, the result of recent scholarship in the history of scientific thought that the fact was brought to light that Christianity played an important role in the growth of modern science. In the late nineteenth century, this fact was not yet established and, with the rise of Darwinism, science became regarded generally as conflicting with Christianity. Some Western teachers in

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[52] Translation by the present author from Japanese edition, *Baelz no Nikki* (Tokyo: Iwanami Bunko), Part 1(2), pp. 51–52.

Japan therefore taught science regardless of their religious concepts, while others upheld their beliefs and disregarded the theory of evolution. For the most part, the former type of presentation appealed more to the Japanese intellectual leaders, and less religiously motivated Western teachers soon became prevalent, particularly at Tokyo University, although this was not the case with the Sapporo Agricultural College where the inspiration of W. S. CLARK was predominant.

In this peculiar period of intellectual history, science was consequently introduced into Japan all the more independently of the humanities and the religious aspect of the Western culture. Moreover, science was taught only in the scientific departments at governmental institutions. On the other hand, Christian institutions in Japan inaugurated by missionaries (mostly from America) concentrated upon the teaching of humanistic phases of Western learning and did not include science as a major field. Consequently, the gap between scientific discipline and humanistic scholarship was there from the beginning, inherent to the Japanese academic world, and is now part of the more serious gap of the "two cultures" of today.[53] How to close the gap and integrate the divided cultures and specialized frontiers of academic attainments has become the task not only of the Japanese but also of all peoples of the world.

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[53] C. P. SNOW, *Two Cultures and Scientific Revolution* (Cambridge, 1959).

The Growth of Scientific Communities in Japan*

Mitsutomo YUASA**

1. Introdution

The first university in Japan on the European system was Tokyo Imperial University, established in 1877. Twenty years later, Kyoto Imperial University was founded in 1897. Among the graduates from the latter university can be found two post World War II Nobel Prize winners in physics, namely, Hideki Yukawa (in 1949), and Shinichiro Tomonaga (in 1965). We may say that Japan attained her scientific maturity nearly a century after the arrival of Commodore Perry in 1853 for the purpose of opening her ports. Incidentally, two scientists in the U.S.A. were awarded the Nobel Prize before 1920, namely, A. A. Michelson (physics in 1907), and T. W. Richard (chemistry in 1914). On this point, Japan lagged about fifty years behind the U.S.A.

Japanese scientists began to achieve international recognition in the 1890's. This period conincides with the dates of the establishment of the Cabinet System, the promulgation of the Constitution of the Japanese Empire and the opening of the Imperial Diet, 1885, 1889, and 1890 respectively. Shibasaburo Kitazato (1852–1931), discovered the serum treatment for tetanus in 1890, Jiro Kitao (1853–1907), made public his theories on the movement of atomospheric currents and typhoons in 1887, and Hantaro Nagaoka (1865–1950), published his research on the distortion of magnetism in 1889, and his idea on the structure of the atom in 1903. These three representative scientists were all closely related to Tokyo Imperial University, as graduates and latter, as professors. But we cannot forget to mention that the main studies of Kitazato and Kitao were made, not in Japan, but in Germany, under the guidance of great scientists of that country, R. Koch and H. von Helmholtz.

2. Scientific Revolution in JAPAN

During the fifteen years of turmoil, beginning in 1853, when Commodore Perry entered Uraga Harbour, and ending in 1868, when the Meiji Restoration was accomplished, three great men of science came into existence in Japan, namely Kitazato, Kitao and Nagaoka, mentioned in the introductory section of the present

paper. This is a memorable fact for the scientists in Japan.

These three scientists were born and brought up in *samurai* families. A *samurai* (warrior) was a retainer of a *daimyo* or local lord under the Tokugawa shogunate. He was taught the Chinese classics called "*Shisho-Gokyo*" (Four History Books and Five Poetry Books), which were brought to Japan in the Nara Period (the seventh century, A.D.). For more than one thousand years, these classics had been taught to the Japanese both at home and in small-scale private schools, so that they had long become a sort of traditional training for children of *samurai*. These three great scientists, already referred to, must have begun their early education in this way.

The population of Japan towards the end of the Tokugawa period was nearly thirty million, governed by feudal lords called *daimyo* in the shogunate Regime. There were about three hundred feudal lords, under whom education was given to sons of *samurai* in *Han-kō* (Clan Schools) and to children of commercial, labour, farmer or peasant classes in *Terakoya* (small-scale private elementary schools). Hence we may say that Japan at the end of the shogunate government was far from being a savage or barbarous nation, for the inhabitants of the land were given training in the three R's and their culture was based upon a knowledge of Chinese classics. As a whole, they had enough knowledge for their daily life and at the same time they understood higher culture of the Chinese classics. Those who ignore or deny these facts and history, may, in my opinion, find it hard to understand the development of Japan in the past hundred years, especially the rapid formation and tremendous progress of Japan's national scientific communities.

At the beginning of the seventh century, Hōryūji Temple was built which is the oldest wooden building that now exists in the world. In the middle of the Eighth century, a big bronze statue of Buddha was cast in Nara; this was believed to be the largest statue cast at that period in history, because it is 16.2 m in height. The *Kojiki, Nihonshoki*, and *Mannyoshu* (histories and anthology of ancient Japanese poems), are already more than one thousand years old. The *Genji-Monogatari* (Story of Genji), well-known in the world as a long romance, was written by Murasaki-Shikibu who led a court life in the eleventh century.

The intellectual system differed from that of the West, in that it was first imported from China and then perfected under the influence of Buddhism and Confucianism, and spread first among the aristocratic class, Buddhist priests, and the warrior classes. Later, as a result of popular education in the Edo period under the shogunate government, it prevailed even more widely until finally it became part and parcel of the Japanese heritage.

In order to make clear the fact that, as regards modern science, national scientific communities were established in Japan during the century after the arrival of Commodore Perry in 1853, I want to apply to Japanese modern history the historical idea of Scientific Revolution advocated by H. Butterfield in *The Origins of Modern Science* (Cambridge, 1949). There existed in Japan national communities in the

classical sciences which were nearly ten centuries old. I wish to state that the science in these communities was transformed into modern science with the impact of the capitalistic communities of the West. The transformation, as a mater of fact, was revolutionary. But the impact is rather a long story to tell. The beginning of the impact was the first fire-arms (muskets) that came to Japan in 1543 and greatly changed the battle tactics of war lords. Then, nearly four hundred years later, came Commodore Perry whose arrival resulted in the transformation of the older scientific communities.

As is well known, Japan under the Shogunate government had been virtually closed to foreign nations for about two hundred years from 1639–1853. During these years, Nagasaki was the only port where the Netherland traders (Dutchmen) alone were permitted to trade with Japanese people. Nagasaki was then the lean thread of communication to Western culture and civilization. In 1720, when Yoshimune Tokugawa was the eighth *Shogun*, the limitation on the import of foreign books on science and technology was loosened, and the slow development of modern science began in Japan at this date. How the modern science of the West was carried into Japan by way of books is outlined in Fig. 1.

The community which had played the *avant-gard* role in the scientific revolution in modern Japan was a group of Dutch scholars ("*Rangaku-sha*" in Japanese).

In preparing the present investigation, I made use of Heibonsha's *Dai-Jinmei-Jiten* ("Great Biographical Dictionary"), 1955. About 58,000 Japanese are included in this work (Vols. V–VI and IX). Accordingly, 58,000 biographical cards were prepared, from which 1,740 scientists were chosen, and were classified as follows:

1) Scientists born in the 18th century—512 2) Scientists born in the 19th century—696 3) Living scientists born in the 19th century—532

These cards were further classified as follows:

Type F (Feudalism) category includes Oriental scientists such as *Wazan-ka* (Japanese mathematicians), *Honzō-ka* (herbalists), and *Kampō-i* (physicians of the Chinese school). These had almost no connection with Western science.

Type M (Modern) category includes new Western type scientists who contributed to the scientific revolution and who were appointed to important institutional positions, from around the time of the late Tokugawa shogunate era and the beginning of the Meiji era.

Type T (Transition) category includes Dutch scholars (*Rangaku-sha*) who contributed to the scientific revolution within the frame of feudalism and who were not appointed to any institutional position in the modern social structure.

The biographical cards of the scientists born from 1701 to 1900 were divided into forty sections, each section indicating five years; names were included according to the year of birth. Each section was further divided into three groups; Type F, M, and T. The data on each type in each section were divided by the total data for the corresponding section. In this way a series of percentages was obtained.

M. YUASA

Cen-tury	Europe		JAPAN	Type
16	Vesalius (1543) Copernicus (1543)			
1600			Period of ISOLATION (1639–1853)	
17			1639　関　孝和 (Wazan-ka) 貝原益軒 (Honzō-ka) 山脇東洋 (Kampō-i)	(F) (F) (F)
	Newton (1687)			
1700				
18	Linnaeus (1735)		1720　Import of BOOKS (natural science and technology) 1774　『解体新書』　Gempaku SUGITA 1791　Ryoei MOTOKI	(T) (T)
	Lavoisier (1789)		1798　『暦象新書』　Tadao SHITSUKI	(T)
1800	Dalton (1808)		1829　Keisuke ITO (1803–1901) 1839　Yoan UDAGAWA	(M) (T)
19	Darwin (1859)		1853　Komin KAWAMOTO 1868　明治維新　Meiji Restoration 1881　Chiyomatsu ISHIKAWA	(T) (M)
1900			北里栄三郎 (KITAZATO) 長岡半太郎 (NAGAOKA)	(M) (M)
20			1949　湯川秀樹 (YUKAWA)	(M)

Type of scientists: F (Feudalism), T (Transition), M (Modern)

Fig. 1. Flows into Japan of Modern Science of Europe.

Type F ◄——————   ——————► Type T

%

100   80   60   40   20   0   20   40   %

1700

18th Century

Type T

Type F

1774 Kaitai-Shinsho
(modern Anatomy)

1800

19th Century

birth-year
1841~1845
Transition
(F → M)

1841-45

Point

1853 visit of PERRY

Meiji Restoration
(1868)

Type M

Promulgation of Imperial Constitution
(1889)

1900

0   20   40   60   80   100

——► Type M   %
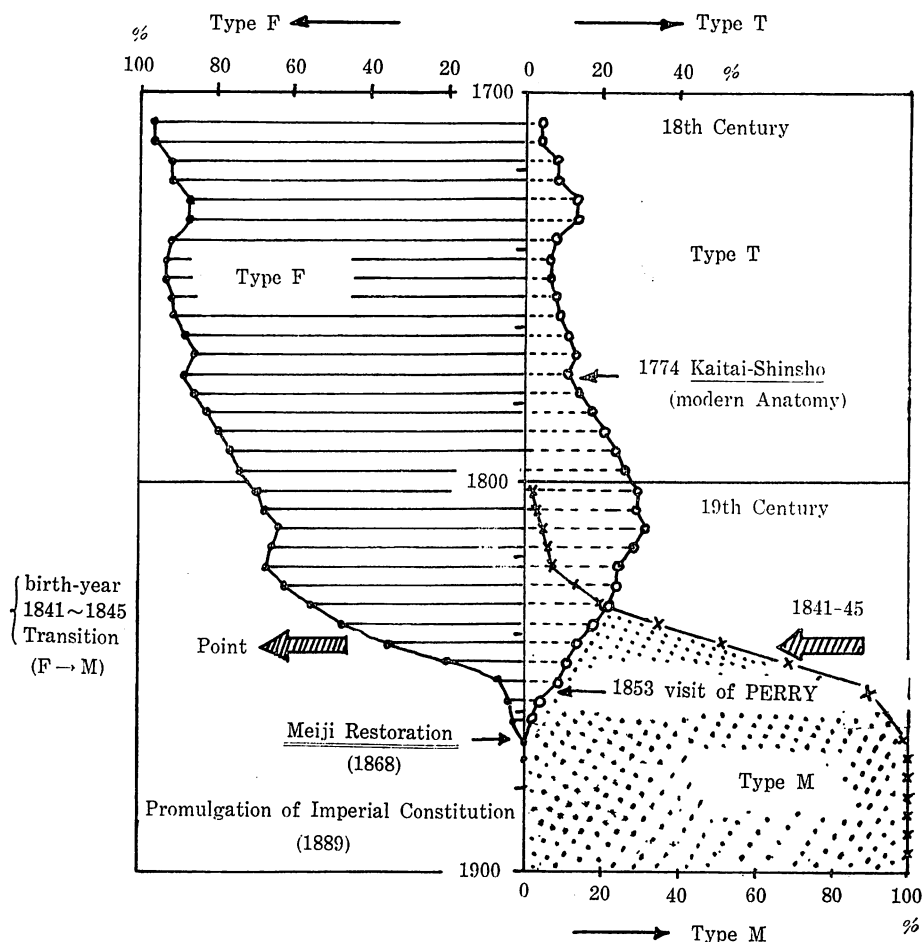
Figure 2. Changes in Type of Japanese Scientists

Type { T .... Transition
       F .... Feudalism
       M .... Modern }

The moving average of the Types F, M, and T from 1701 to 1900 is shown in Fig. 2. This graph shows clearly the shift in types from F (Feudalism) to M (Modern) through T (Transition). We can easily find the age of transference in Fig. 2. This transition point is in the period 1841–1845, and the curves of F and M indicate a great change. The percentages of F and M, at these points, are shown in Table 1.

Figure 2 shows the results of statistical treatments of the birth year, and we find that the time of the transition point has to be shifted.

(a) If it is assumed that a man's occupational interests are decided at the age of 15 (*Genpuku*, or attainment of manhood), we have

TABLE 1.   Changes in Percentages

Birth Year	% of F.	% of M.
1826—1830	72	7
1831—1835	46	23
1836—1840	53	33
1841—1845	44	47
1846—1850	10	72
1851—1855	7	82

$$(1841 \sim 45) + 15 = 1856 \sim 1860$$

(b)   If it is assumed that the alternation takes place at the age of 40 (the so-called "acme of manhood"), we have

$$(1841 \sim 45) + 40 = 1881 \sim 1885$$

The first cabinet based on the European model was organized by Hirobumi Ito in 1885.   Around this year several well-known scientists, including S. Kitazato, I. Kitao, and H. Nagaoka, began to make public their achievements which resulted in international recognition.[1]

3.   Scientific Communities in Edo Period

I would like to explain the beginning and the growth of scientific communities in Japan, not in a strict comparison, but using a metaphor, and state that the whole process is like the life of a butterfly that begins by being an ovum.   As is well known, the butterfly is an insect that undergoes a perfect metamorphosis from an ovum, through a green catterpillar and a cocoon, and then into a mature butterfly.   We wonder how a noxious worm that creeps on the earth can grow into a beautiful butterfly that dances in the air.   Biologists may explain the process of metamorphosis as the effects of *corpora-allata*, a hormone secreted from the prothorax glands.

I have already introduced the idea of scientific revolution in order to explain the life cycle of scientific communities in Japan.   Here I want to make use of the mechanism of metamorphosis in insects and give you the folllowing metaphoric contrasts.

(a)   "Green catterpillar" period: scientific communities in Japan from the ancient days to the Tokugawa or Edo period, mainly founded upon imported classic Chinese culture together with Buddhist culture that had come over the Continent of Asia.

(b)   "Chrysalis" period: scientific communities during the days when Japan was almost closed to foreign culture from 1639–1853.

(c)   "Butterfly" period: scientific communities in present-day Japan since

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[1] Mitsutomo Yuasa: "The Scientific Revolution and the Age of Technology", *Journal of World History*, Vol. IX, No. 2, 1965, pp. 187–207.

the year 1853.

Next, I feel the hormone that effected the above metamorphosis in science in Japan was: *Rangaku* (Dutch Learning or Netherlandish studies). This played the role of a "hormone", which could be identified with Dutch Scholars in Type T in my division made in the foregoing section. It was Type T (Transition) that had made possible the development from Type F (Feudalism) to Type M (Modern Japan).

In the *Rangaku-Kotohajime*, written by Gempaku Sugita in 1815 when he was eighty-three years old, we find the following passages:

"They say that one drop of oil cast into a wide pond will spread out to cover the entire surface. Just like that, in the beginning there were only three of us—Ryotaku Maeno, Jun-an Nakagawa and myself—who came together to make plans for our studies. Now, when close to fifty years have elapsed, the studies have reached every corner of this country, and each year new translations seem to be brought out. This is a case of one dog barking at something, only to be echoed by ten housands dogs barking at nothing. Since I am enjoying longevity, I have the previledge of being delighted and surprised at the great developments to-day. Again and again I am especially delighted at the idea, that when the way is opened wide, doctors in a hundred years, yea, a thousand years, will master real medicine, and that will be of great profit for public welfare. When I think of this, I can not help dancing and springing for joy."[2]

Konyō Aoki (1698–1769) was the first to learn Dutch in Edo, but his studies did not go beyond collecting a few hundred Dutch words. His pupil Ryotaku Maeno went to Nagasaki, where he increased his knowledge of the Dutch languange, and Gempaku Sugita's translation of a Western work on anatomy was dependent on Maeno's knowledge of Dutch. Sugita wished to deliver western learning, hitherto monopolized by the official interpreters of the shogunate, into the hands of the scholars so that they might pursue more profound research, and the word *Rangaku* was first used by this pioneer. The *Kaitai-Shinsho* was published by this group of scholars in 1774. This translation proved to be a turning-point in the importation of Western science in the Tokugawa period. After this date Dutch Learning made rapid advances.

An account of the actual stages in the establishment of modern science in Japan can be given by dividing the period of scientific revolution in the country into three stages, analogous to those of J. D. Bernal.[3]

1st stage (1774–1853), from the publication of *Kaitai-Shinsho* (Anatomy) to Commodore Perry's arrival at Uraga.

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[2] Eikoh Ma (Shimao): "The Impact of Western Medicine on Japan, Memoirs of a Pioneer, Sugita Gempaku, 1733–1817," *Archives Internationales d'Histoire des Sciences*, 1961, pp. 65–84, pp. 253–272.

[3] J. D. Bernal: *Science in History*, London, Watts & Co., 1954, p. 257.

2nd stage (1853–1868), from Perry's arrival to the Meiji Restoration.

3rd stage (1868–1889), from the Meiji Restoration to the promulgation of the Imperial Constitution.

The above stages are to be treated merely as a working hypothesis for now. Moreover, they do not constitute three different periods that may be distinguished clearly one from the other; they are three stages in the single process of change from feudalism to capitalism.

In the 1st stage (1774–1853), the essence of the scientific revolution in Europe was translated into Japanese by way of Dutch, as follows:

A. Vesalius (1514–1564): *De Humani Corporis Fabrica* (1543). The contents of this book were introduced into Japan through *Kaitai-Shinsho* (1774) by G. Sugita and his collaborators.

N. Copernicus (1473–1543): *De Revolutionibus Orbium Caelestium* (1543). The essence of Copernicus' heliocentric theory was introduced through Ryoei Motoki's *Tenchi-Nikyu-Yōhōki* (1791).

I. Newton's dynamics, published as *Principia* (1687), was introduced through Tadao Shitsuki's *Rekishō-Shinsho* (1798).

C. von Linnaeus's theory of biological classification, published as *Systema Naturae* (1735), was introduced through Keisuke Ito's *Taisei-Honzō-Meiso* (1829).

A. L. Lavoisier (1743–1794): *Traité élémentaire de Chimie* (1789). The contents of this work were introduced through Yōan Udagawa's *Seimi-Kaisō* (1839).

J. Dalton (1766–1844): *New System of Chemical Philosophy* (1808). The theory of atoms was introduced through Kōmin Kawamoto's *Kagaku-Shinsho* (1857).

In the 2nd stage (1853–1868), there occurred two major changes. One was the turning of *Rangaku* (Dutch Learning) to military use, and as a consequence of this change, the turning of these studies into government-sponsored learning. The other major change was the shift from Dutch to English studies. After Commodore Perry's arrival, as conditions abroad became better known, a greater need for German, French, and English, rather than Dutch, came to be recognized.

The study of the English language began at Nagasaki in 1809 at the official command of the shogunate government. Six of the Dutch interpreters at Nagasaki began to study English under Dutch trade-station members there, nearly seventy years after Konyō Aoki began his study of the Dutch language in 1740 at the command of the shogunate government. The study of French and German was begun years after that of English.

Bansho-Shirabe-Sho ("Institute for the Study of Foreign Books"), was founded on September 18, 1857. This was the first school in Japan for higher education in Western science. The first students of this school numbered 191, all of whom were sons of *samurai* who were direct retainers of the shogunate government. The

main languange that was taught here was Dutch, but English was taught to some extent at the same time.

The branches of training consisted of science and technology, astronomy, geography, physics, mathematics, chemistry, mechanics, and drawing. This institution later developed into Tokyo Imperial University, which was officially founded by the Meiji government and consisted of faculties of Laws, Letters, and Science. The medical faculty which was contained in the new university developed from the *Shutō-Sho* ("Institute for Vaccination"), which was founded at Otamaga-ike, Edo, in 1858 by medical researchers in the Dutch style. This institute was later called *Seiyō-Igaku-Sho* ("Institute for Western Medical Science") in 1861, and, further on, renamed *Daigaku-Tōkō* ("Eastern School of the University").

The great shift from Dutch studies to English studies was rapidly made, as we have already seen, in the second stage of scientific revolution (1853–1868). A vivid description of this shift is found in *Fukuō Jiden* (1899), an autobiography of Yukichi Fukuzawa. The passage I want to translate and quote in connection with this, tells about his visit to Yokohama on a certain day in 1859.

"Foreigners had set up their shops there. I went to see them, but I could not make myself understood. What I said was not understood by them nor did I know what they said. I cannot read their sign-boards or even the labels on bottles. There were no words that I could understand. I never knew whether the language these foreigners spoke was English or French...I returned from Yokohama in great disappointment. I was quite at a loss. For the past several years I did my best in learning Dutch. My endeavour was all to no purpose. I could not read even the sign-boards of shops. I was greatly discouraged. But I cannot afford to remain discouraged...Their language must have been English. Our country has contracted treaties with foreign nations. From now on, the most necessary language should be English...The next day I made up my mind to learn English and to study everything English."[4]

Fukuzawa's autobiography goes on to say.

"Dutch scholars at the time, I among the rest, all thought that, if the Dutch language which they had worked hard to master, should prove of no use, and they should study English afresh, they would have to experience hard work again. What a useless and vain endeavour they had made! They were like those who have worked hard at learning how to swim for, say, two or three years. Then, all of a sudden, they were told not to swim, but to begin to learn the art of climbing trees. All their former efforts proved vain and useless. I thought of the affair over and over again. It was hard for me to make up my mind."[5]

At the beginning of this section, I compared the period when Japan was closed to foreign nations, and the days when Japan began to learn everything from Western

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4 Yukichi Fukuzawa: *"Fukuō Jiden"*, 1899, Iwanami-Bunko, (in Japanese), 1954, p. 99.
5 *Ibid.,* p. 102.

countries and had become a highly civilized and industrialized nation, the chrysalis and the mature and beautiful butterfly respectively.   Dutch Learning had been of use only in the chrysalis stage of Japan, for it had merely been a phenomenon of the transitional process.   Yet it had played a part ocrresponding to a hormone or *corpora allata* for the "chrysalis" Japan.

4.   Assistance from Foreigners

Modern science came to be firmly rooted in Japan in the 3rd stage of the scientific revolution in Japan, 1868–1889, as mentioned previously.   Science in Japan had, so to speak, achieved a complete metamorphosis from a green caterpillar into a butterfly.   In Tokyo University, which was the centre of activities, a number of foreign professors had given assistance to Japanese researchers.

Bansho-Shirabe-Sho, opened in 1857, changed its official name several times before it came to be called Tokyo University.   These changes of name were aftermaths of the big and rapid changes in the system of government, administration and education before and after the Restoration of Meiji in 1868.   *Yōsho-Shirabe-Sho* (1862)→*Kaisei-Sho*→*Daigaku-Nankō* (1869)→*Dai-Ichiban-Chūgaku* (1872)→ *Tokyo-Kaisei-Gakkō* (1874)→*Tokyo University* (1877).   Tokyo University was founded on April 12th in 1877, after annexing *Tokyo-Kaisei-Gakkō* and *Tokyo-I-Gakkō* ("Tokyo Medical School").   *Tokyo-Kaise-Gakkō* contained, as regular courses, Law, Chemistry, and Mechanics, and, as temporary courses, Polytechnique and Mining.   The Ministry of Education which controlled education throughout the land, recognized the advantages of using one foreign language in the classes to be opened in the new institute of higher education.   When it opened *Kaisei-Gakkō*, it decided to use only English, and temporarily allowed those students who had learned French, German or Dutch to study polytechnique and mining.   And in 1875, classes given in French were changed from politechnique to physics and class numbers were decreased, those in German, altered from mining to chemistry and decreased in number.   After some time, classes in German in chemistry were discontinued because applicants for the course greatly decreased in number.   The Faculty of Science in Tokyo University consisted of six courses, only one course of which, that is, French Physics was given in French and the other five courses— physics, chemistry, biology, and engineering—were taught in English.   Aikitu Tanakadate, who was a physicist, entered *Tokyo-Kaisei-Gakkō* in 1876 and graduated from Tokyo University in 1882.   He wrote about his old class-room life as follows:

> "Students were about 90 in number.   They were divided into three groups called *Ko, Otsu,* and *Hei* Classes, ordinarily called A, B, and C Classes.   The Japanese professors were merely Prof. Yamagawa and Prof. Toyama.   The other teachers were mostly Americans and a few Englishmen and Germans. All the classes were given in English and recitation was the chief method of teaching."[6]

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[6] Aikitu Tanakadate: *Kuzu no Ne*, (in Japanese), Nihon-no Romazi-Sya, 1938, p. 118.

After classes in French physics were discontinued in 1880, all the lessons in the Faculty of Science in Tokyo University were given in English. The Dutch language, which was the only and the first language in the *Bansho-Shirabe-Sho*, opened in 1857, had become less important as diplomatic treaties were made with foreign nations and trade was opened at Yokohama, Kobe, and several other ports after the arrival of Commodore Perry in 1853. According to the statistics in the *Report of the Ministry of Education*, No. II (1874), there were 91 foreign language schools in Japan at the time, including governmental, prefectural and private schools, 82 schools or 91% of which were English language schools.

Table 2 shows the foreign professors in mathematics, astronomy, geophysics, physics, chemistry, geology, biology, and similar sciences during the period from 1860 to 1900.

TABLE 2. Foreign Professors in Japan (1860—1900)

Nationality / Sciences	Great Britain	U.S.A.	Germany	France	Nether-lands	Total
Mathematics	5	4	6	5	—	20
Astronomy	—	—	—	1	—	1
Physics	6	8	2	5	—	21
Geophysics	1	1	2	—	—	4
Chemistry	4	4	5	3	2	18
Geology	1	3	6	1	—	11
Biology	1	4	4	2	—	11
Total	18	24	25	17	2	86

Fig. 3 shows the number of foreign teachers in Japan (in natural sciences alone) over the years from 1860 to 1900. You will be able to understand that the number of foreign teachers was the highest in the 3rd period of the Scientific Revolution in Japan from 1868–1899, as we have mentioned before. The period from 1871–1882, which contains the date of the founding of Tokyo University, 1877, was the highest in number. In the finishing touches of this revolution in science, the Japanese seem to have owed much to the guidance and assistance of these foreign teachers. By 1889 most of these foreign professors returned to their own countries and their successors were selected from among Japanese scientists.

In regard to Modern Technology, it may also be said that the Japanese owe much to technologists from abroad in the same period, *i.e.*, in the 3rd Period of Japan's Scientific Revolution from 1868–1889. Without their assistance, Japan would not have so rapidly made modern technology her own. The *Kōbu-Shō* ("Ministry of Engineering") played the same role in the field of technology as that played by Tokyo University in the field of science. The *Kōbu-Shō* was a ministry of the Government that was organized in 1870 and was abolished in 1885 so as to develop the general organization of the government. However, this ministry
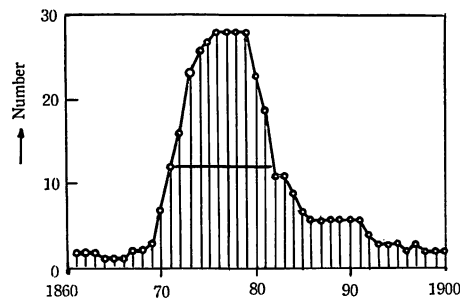
Figure 3. The number of foreign science teachers in Japan (1860–1900)
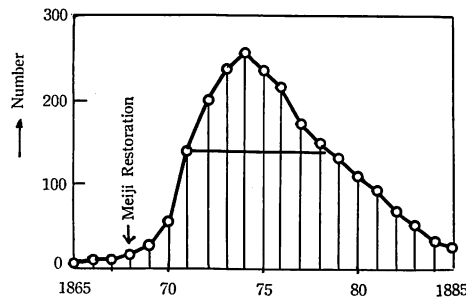
Figure 4. The number of foreign technical advisors (Ministry of Engineering, 1865–1885)

TABLE 3. Settle Accounts of Ministries (1876)

Ministry	Settle Accounts Unit: 1,000 Yen
Foreign Affairs	153
Home Affair	2977
Finance	1560
War	6904
Navy	3424
Education	1695
Engineering	4343
Jurisprudence	1383
Imperial Household	290

had built the bases for the Industrial Revolution in Japan. The first Minister of Engineering (1873–1878) was Hirobumi Ito, who later, in 1885, became the Prime Minister in the first Cabinet organized on the European model. The Ministery of Engineering, though it was a branch of the Cabinet under the charge of a minister, played an important part in the Cabinet in developing Japan into a modern nation, together with the Ministries of Foreign Affairs, Home Affairs, War, Navy, and of Education. As is shown in the Table 3, the sum expended by the Ministry of

Engineering in the settlement report for 1876, was 4,343,000 yen, which was next to the War Office with 6,904,000 yen, the highest amount in the Budget. The Ministry of Engineering, when it was organized in August, 1871, consisted of ten bureaus, *i.e.,* Engineering, Industries, Mining, Railways, Civil Engineering, Light-Houses, Ship-Building, Telegraphy, Iron Foundry, Mechanics, and one office for Survey, and affairs concerning mechanical industries were all controlled by the Ministry.

The various works that were completed by the Ministry of Engineering were, all of them, run by importing and introducing foreign technology, so that scores of foreigners were employed by this Ministry. The number of foreign technical experts who were employed during the 15 years, 1870–1885, when this ministry was in existence, was as follows: Railways (256), Mechanical Engineering (81), Mining (78), Telegraphy (59), Light-Houses (52), School in Mechanical Engineering (21), Building and Repairs (13), School in Arts (7), Primary School under the direct control of the Department of Engineering (5), Crew for the *Meiji-Maru* and for two other ships (175) and others (2). When we calculate the number of foreign technical advisors staying in Japan for each year during the period from the number of years they spent in Japan, the number is as seen in the Fig. 4.

As can be seen in Fig. 4, the number was bigger in 1870–1880, reaching the peak in 1874. This Figure is similar in character to Fig. 3 which tells us of the number of natural science foreign professors in Japan. Judging from this trend, we may say that modern technology took root in Japan, as is the case with modern science, in the 3rd stage of the Scientific Revolution.

The year 1886 saw the promulgation of the Edict Concerning Imperial Universities, and Graduate Schools were established. The Edict Concerning Academic Degrees was promulgated in 1877. The next year, 1888, a total of 25 doctorates were granted—five each in law, literature, science, medicine, and engineering. In Dr. Eri Yagi's paper "The Growth of Modern Science in Japan, 1960", the number of Doctors of Science from 1888–1956 was calculated, and the number was found to have doubled every ten years, showing normal development in the country. She has also considered and found normal the growth in the number of members of the Physico-Mathematical Society of Japan from 1888–1945. (Fig. 5),[7]

1888–1911: Membership $= 37 \exp (0.0064\,n)$
1919–1945: Membership $= 33 \exp (0.0064\,n)$
      (n, being the number of years elapsed from 1877)

These figures may be regarded as proof that in regard to science, national communities have made as normal and regular development as in the countries of Western Europe.

From about the year 1877 when Tokyo University was founded, learned societies were organized, and professors and graduates made up an important part of the

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[7] Eri Yagi: The Growth of Modern Science in Japan, *Abstract of Paper Presented at the New York Meeting of A.A.A.S.,* 1960.
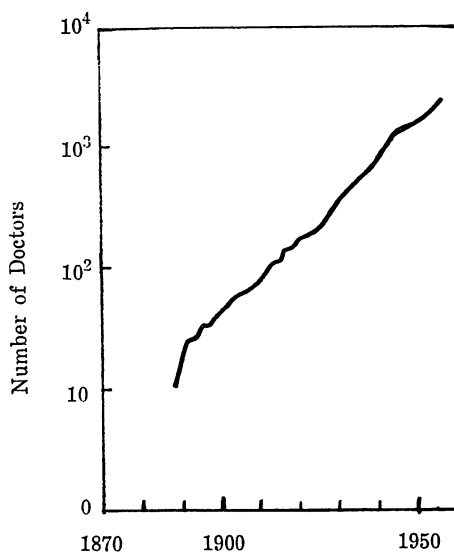
Figure 5.

The number of Doctors of Science in Japan, as function of data (1888–1956)

Number of doctors = 18 exp 0.07 n (n is the number of years elapsed from 1888) from Eri YAGI: "The Growth of Modern Science in Japan," *Abstact of Paper presented at the New York Meeting of A.A.A.S.*, 1960; *Nippon Kagaku-gizyutsusi Taikei* Vol. 7., Tokyo, 1968, p. 547.

membership. All these societies are still going on now, nearly a century after their inauguration. A list of learned societies in the chronological order of their founding runs as follows: Mathematical Society (1877); Medical Society (1877); Chemical Society (1878); Geological Society (1879); Engineering Society (1879); Seismological Society (1880); Botanical Society (1882); Physical Society (1884); Anthropological Society (1884); Mining Society (1885); Veterinary Society (1885); Architectural Society (1886); Agricultural Society (1887); Zoological Society (1888); Electricity Society (1888) etc. By this time, societies had been established in all the branches of basic sciences.

To organize and manage these learned societies, advice from resident foreign teachers and Japanese researchers trained abroad should be highly evaluated. Now I want to report on the establishment of the Seismological Society in Japan, which was the first society of this branch of science in the world. The first general meeting of the Society was held in March, 1880. In February of that year, there was a strong earthquake in Tokyo Bay and damage was done to the Yokohama district where a number of foreign professors lived. This event might have stimulated the founding of the Seismological Society, for nearly a hundfed people gathered together to organize a society for scientific research into earthquakes. The central figure of the society was an Englishman named J. Milne, who was a professor

of Geology and Mining in the *Kōbu-Daigakkō* ("College of Engineering") from 1875–1895. The second meeting of the society was held on April 26, 1880, in which a report was made on an original idea for a seismograph by Prof. Ewing and Gray, who stayed in Japan from 1875 to 1882 and from 1878 to 1881 respectively. The modern scientific and mechanical seismograph was invented in Japan by these two foreign Professors. This was the beginning of seismology in Japan which is now playing an important part in this branch of science.

In concluding this section I want to make a list of foreigners who contributed much to Japanese civilization and culture in the Meiji Period, 1868–1912, classifying them by their nationality and their fields of contribution.

Englishmen and Americans are greatest in number, but, in natural science and medicine, the Germans, and, in Military affairs, the Frenchmen contributed much to Japan in the Meiji Era.

TABLE 4. List of Foreigners in the Meiji Period (1868—1912)

Field of Contribution	U.S.A.	Great Britain	German	France	Nether-lands (Dutch)	Italy	Russia	Others
Laws & Economics	16	4	5	5				1 (Belgium)
Religion	20	7		5			2	1 (Belgium)
Education	17	12	3	4	1		1	1 (Switzerland)
Literature	10	13	4	1		4	1	2 (Austria)
Natural Sience	16	10	11	3			1	2 (Sweden)
Medicine	4	1	16	1	8			
Industry	10		11	2		1		2 (Austria)
Architecture & Civil Engineering	4	6		1	5	1		1 (Canada)
Traffic	2	19		1				1 (Sweden)
Military Afairs	2	1	2	13		1		
Total	101	73	52	36	14	7	5	11

5. Economic Development of Japan

W. W. Rostow has divided the economic growth of Japan into the following stages:

1. the traditional society—the Tokugawa Shogunate Period
2. the preconditions for take-off
3. the take-off—1878~1900
4. the drive to maturity—1940
5. the age of mass-consumption—1955

"The beginning of take-off can usually be traced to a particular sharp stimulus. The stimulus may take the form of a political revolution which affects directly

the balance of social power and effective values, the character of economic institutions, the distribution of income, the pattern of investment outlays and the proportion of potential innovations actually applied."[8]

In underdeveloped countries or non-initiated countries the most important stage in economic development is "Take-off." The Take-off is the interval when the old blocks and resistances to a steady growth are finally overcome. In Japan the epochal change of scientific revolution overlapped in this interval. In the Scientific Revolution (in the 3rd stage, 1868–1889), the whole edifice of the intellectual system, which had been brought from China and cultivated under Buddhism and Confucianism, was overturned and replaced by a completely new system introduced from Europe.

As we have already mentioned, Japan owed her success in introducing a completely new system to the growth of scientific communities of the so-called *Rangaku-sha* (Dutch Scholars) and to advice and assistance from foreign scientists and technicians who came to Japan. In the first half of the Meiji Period Japan started its take-off, and, by the end of the 1960's her GNP has overtaken the civilized countries of Europe and occupies third place in the world next to the U.S.A. and the U.S.S.R. Japan has made a phenonomenal economic development in about a century after the Meiji Restoration, which we might regard as a 20th century miracle. To explain the miracle, I want you to look at two points, where the Japanese have made continuous efforts, but which have not yet been noticed by the people of the world.

1) Technical terminology was put into order and unified.
2) Since Jan. 1, 1959, the metric system has been adopted as the only authorized system of measuring.

(1)   Among the countries of Asia and Africa, it seems that one of the greatest difficulties in introducing modern science was the problem of technical terminology. In order to found scientific communities in a country, it is necessary that technical terminology should be established so that the people may use it in a unified way.

In the first half of the Meiji Period, one of the greatest efforts among Japanese scientists was to unify the technical terminology in each branch of science. To translate a great number of foreign scientific terms into Japanese words and to unify the translated words—this might have been the most difficult work to do. Here I want to show examples of this. The term "gas" is now called "Kitai" in Japanese. But, at the end of the Shogunate Period and in the first days of the Meiji Era, it was called "Kijotai," "Kyoshitsu," "Fukitai" or "Gasutai," all being expressed by using various Chinese characters. As for Strontium, Sr, in Yōan Udagawa's *Sei-mikaisō* (1837), which was the first book in Japan on modern chemistry, it was spelled in Japanese "期多論胃母". The present writer looked up a dozen chemical books published prior to 1886, and the same term was spelled "ストロンチウム," "斯篤論母", "思而", "鎴," or "鎦".

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[8] W. W. Rostow: *The Stages of Economic Growth*, Cambridge, University Press, 1966, p. 36.

In the community of mathematicians, there were *Wazan-ka* of Type F, (Feudalism) and mathematicians of the Western school belonging to Type M, (Modern); to these some elements of the Chinese language using Chinese characters were mixed together. As a result, the chaotic condition of mathematical terms was regarded as a great handicap when elementary schools were opened in Japan in 1872. In 1880 a translation committee was organized in the *Tokyo Sūgaku Kaisha*, (the beginning of the present Mathematical Society of Japan), but the unification of translated mathematical terms was not easily accomplished.

Mathematicians who were not teaching in schools established by the Government organized themselves into *Sūgaku-Kyokai*, which differed from *Tokyo-Sūgaku-Kaisha*. The former group decided the translated terms by vote and made public the results in their magazine entitled "*Sūgaku-Kyokai-Zasshi*." In the second number of this publication we find the following English terms, the Japanese equivalents for which the readers were asked to decide by voting:

○ Mathematics:　　　(1) 数　学. (2) 数理学. (3) 算　学.
○ Arithmetic:　　　　(1) 算　術. (2) 平　算. (3) 数　学. (4) 算数学.
○ Trigonometry:　　　(1) 三角法. (2) 三角術. (3) 三角学. (4) 八線学.
○ Analytical Geometry: (1) 解析幾何学. (2) 代数幾何学. (3) 高等幾何学.
　　　　　　　　　　　(4) 軸式幾何学.

Furthermore, for "Unit", the following Japanese terms were once used:
(1) 単位. (2) 定個. (3) 一個. (4) 一. (5) 数基. (6) 一位度.

How can we expect science and technology, that were developed among foreign nations and countries, to be firmly transplanted to other countries, unless the translated technical terminology is used in vernacular words uniformly in the country, from elementary schools to the highest institutions of learning? The hard work of transplanting foreign science and technology in Japanese land was first begun by the *Rangaku-sha* ("Dutch Scholars") belonging to Type T (Transition), and then, was accomplished by scholars studying the English, German and French languages. In 1870, about a century after the publication of *Kaitai-Shinsho* (1774), the work of unifying translated terms began. We have already seen that learned societies for mathematics, physics and chemistry began to be organized about 1877. The first work for these societies to do was to unify the translated technical terms. As a typical result of this work, we can refer to the following dictionaries published in Japan;

○ Philosophical Terminology (*Tetsugaku-Ji-I*), 1884.
○ Engineering Terminology (*Kōgaku-Ji-I*), 1886.
○ Japanese-English-French-German Dictionary of Physical terms (*Butsuri Gakujutsu-go Wa-Ei-Futsu-Doku Taiyaku Jisho*), 1888.
○ Collection of Translations of Chemical Terms (*Kagaku-Yakugo-shu*), 1891.

These works almost firmly established the terminology of modern science in the Japanese language. These publications were all products of pains-taking efforts. For example, *Tokyo-Kagakukai*, inaugurated in 1878, organized the committee

for unifying technical terms in 1881, but it was ten years before *Kagaku-Yakugo-Shu* ("Chemical Vocabulary") was published in 1891.   The preface of this vocabulary says:

> "Many books on chemistry have already been translated into Japanese.   However, translated terms of various tools, instruments, medicines and technical terms differ with translators, so that a great many inconveniences were felt by scholars who wanted to make use of these books or manuscripts.   We have long regreted these inconveniences.   Our society, therefore, has appointed several members for the task of unifying the translated terms.   As the work was far from being easy, we cannot expect the result to be perfect, but a step forward has been made in the past years, so we here decided to publish the results of the committee members in book-form and title it 'Chemical Vocabulary'."

We might say that national scientific communities could never be organized unless we had a unified technical terminology thanks to the efforts of many scientists.   Technical terminology in Japan began to be unified by the socalled *Rangaku-sha* before the Restoration of Meiji, and then, in 1945, after World War II, the reform of the Japanese language was again attempted in our country.   New Japanese words which will go with the developing science and technology, are expected.

(2)   The establishment of a modern system of measuring is necessary not only for economic activities to keep order in the commercial life of the people, but is also required for the development of science, industry and culture.   A Modern measuring system is needed in expanding commercial markets through a unified system, as well as in forming modern quantative ideas about nature.   The so-called *Shakukan-Hō*, which was used in erecting the famous Hōryūji Temple in the Nara Period, A.D. 607, will not be sufficient in the days of modern science and technology.

Before the Meiji Restoration, the shogunate government divided the land into hundreds of domains of feudal lords.   These domains were practically independent soverein states, and the methods of measuring differed from clan to clan, for there was no standard measure that was used throughout the land.   To illustrate this the *Shaku* was used as unit of measuring length, but there were several kinds of *shaku: Kyoku-shaku, Ina-shaku, Kujira-shaku, Gofuku-shaku, Kyoho-shaku, Secchu-shaku*, and others.   *Shō* was once a unit of cubic mearurement, but it is recorded that there were 70 kinds of *shō* from ancient times.

The metric system, begun in 1799 in France, was adopted by the Dutch people in 1816 and was known comparatively early to the Japanese through the *Rangaku-sha*.   "Japan's Transition to the Metric System" (1967), compiled by the Japan Metric System Promotion Committee, reports the history of the system:

> "It was in 1891 that the regulation of weights and measures was established for the first time in the form of law.   Six years earlier, Japan had already decided to sign the Treaty of the Meter, and the Treaty had been enacted in 1886.   In 1890, Japan received the prototype meter and kilogram from the

International Bureau of Weights and Measures in accordance with the Treaty. In the law of 1891, which came into effect in 1893, the traditional measuring units "*Shaku*" and "*Kan*" were taken as the fundamental units in length and mass. At the same time, the use of the metric system was approved in this law, and the conversion factors between these two systems were also fixed.

"Since then, there have been several amendments in this old law, and in 1909 the units of the foot-pound system were also adopted as legal. Thus, since 1909, Japan has had three measuring systems approved as legal. The actual measurements became more and more complicated and troublesome, and a desire to unify these measuring units arose. In 1919, the Ministry of Agriculture and Commerce set up a Committee for Weights and Measures and Industrial Standards to investigate which measuring system was to be adopted in Japan and to study procedures for promoting the plan. According to the advice of the committee, the Ministry decided to revise the old law and prepared a bill in which the metric system was taken as the unique measuring system. The bill was passed in the Diet in March of 1921, and the revised law was promulgated in April of the same year. The date of enforcement of this law fixed by the Imperial Ordinance was July 1, 1924. But in this same Imperial Ordinance, the use of measuring units other than those of the metric system was also permitted as a transitional measure."

In 1959, all the transitional measures were forbidden by law, and the metric system was legally and exclusively adopted within the realm of Japan. The history of the adoption of metric system in Japan may be regarded as a remarkable case in the history of unifying various measures into the metric system.

We can see, in the short history mentioned above, that the basis for the adoption of metric system was found in the "Take off" period of the Japanese economy, 1878–1900. We may say that this period partly overlaps the 3rd stage in the history of the Scientific Revolution in Japan, 1868–1889. In 1890, in the first Session of the Imperial Diet, a committee was organized for making a Bill proposing a change in the measuring system (or the adoption of metric system). Among the committee members were Dairoku Kikuchi and Kenjiro Yamagawa, both being professors in Tokyo University and well-known scientists of the time. The committee made a Bill, which was later made an Act which unified the old *Shakukan* measuring system on the basis of the metric system.

6. Conclusion

In *The Reorganization of Science and Techonology in Japan* (Report to the National Academy of Sciences, U.S.A., 1947), published by the Scientific Advisory Group that visited Japan after World War II, Japanese science is reported on as follows:

"In the fields indigenous to Japan, such as agriculture, fisheries, and sericulture, the Japanese show outstanding skill, not only in practical methods, but

in the application of recent scientific results. In some subdivisions of these
fields they possibly lead the world. In the fields associated with manufacturing
industries and physical sciences, they have made remarkable progress, in the
past eighty years, in the introduction of western skills and methods of thought.
They still lag behind the United States and England in the development of a
broad base of scientific and technical understanding. Science is still regarded
as the exclusive possession of a privileged few, so that its influence on the life
of the country is limited. This is a condition which time and the democratiza-
tion of political life will tend to cure, and which cannot be suddenly changed by
any type of reorganization. The social sciences, especially as they involve
international comparison in the fields of history, economies, law, literature,
and government, seem to have suffered greatly before and during the war
from lack of freedom, both of speech and of investigation. But evidence exists
of talent and training adequate to provide a basis for recovery of lost ground
and future development now that defeat has lifted bans on free expression
and has prompted critical reconsideration of Japanese social and political
institutions." (General Comments)

Nearly twenty years after the above statement was made, the Japanese economy,
which is often said to have made miraculous progress, now, in 1969, occupies the
third place in the world. Science and technology in Japan, however, in L.D. D.
Corral's words, is "El Rapto de Europa", and rare are the results of Japanese
originality. We have only two Nobel Prize winners in Science, namely, Yukawa
and Tomonaga. J. Jewkes, D. Sawers and R. Stillerman: *The Sources of In-
vention* (1962), points out 50 typical inventions of the 20th century, to which the
Japanese had contributed nothing at all. Japanese are still "Rapto" (enraptured)
of the achievements of the Western World, and have no claim at all to being called
"Homo Kreata" (creators). In typical 20th century big science, present-day Japan
is definitively lagging behind. But the Japanese are not merely following the
steps of the European countries of the 17th–19th centuries. According to reports
made by Herman Kahn and others, Japan in 2000 will be regarded as a promising
country, belonging to the economic grouping that has made high progress, worthy
of being called Visibly Post-Industrial (Fig. 6).[9]

Japan has completed growth from a green caterpillar through a chrysalis into
a beautiful butterfly. From now on, it will create original scientific communities
in the field of social sciences as it heretofore has in the field of natural science and
technology. I wonder if the butterfly will continue to fly higher and higher in the
air. I hope it will.

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[9] H. Kahn and A. J. Wiener: *The Year 2000. A Framework for Speculation on the Next
Thirty-Three Years*, New York, MacMillan, 1967, p. 60.
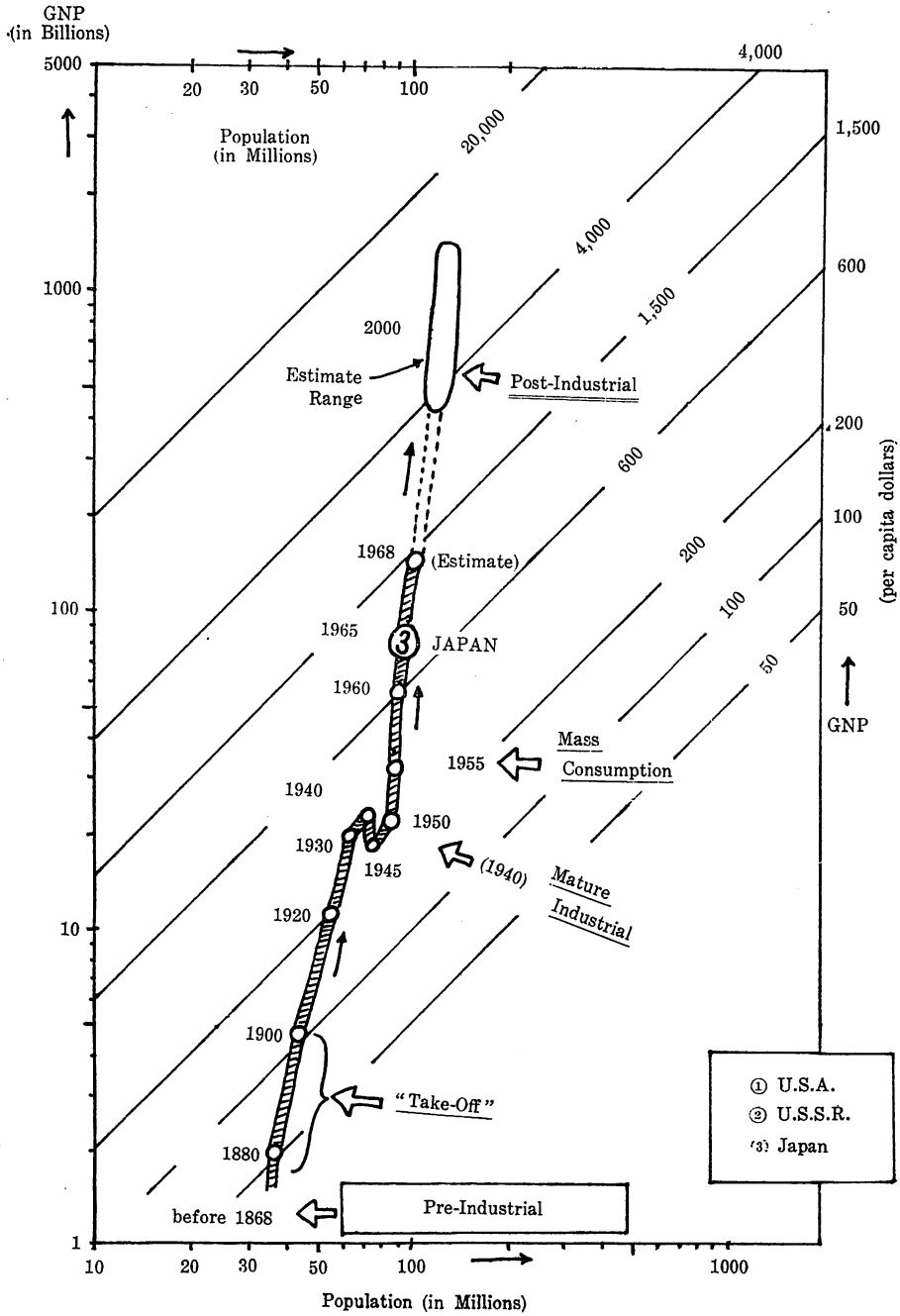
Figure 6. Growth of GNF in Japan (1880–2000)

SOURCES

Fig. 1. Mitsutomo Yuasa: *Kagakushi* (A History of Science), Tokyo, Toyokeizai-Shinpo-Sha, 1961, p. 10.

Fig. 2. *Note* (1), p. 196.

Fig. 3. Mitsutomo Yuasa: *Kagakushi*, p. 105.

Fig. 4. *Ibid.,* p. 106.

Fig. 5. *Note* (7).

Fig. 6. Mitsutomo Yuasa: "The Role of Science and Technology in the Economic Development of Modern Japan", A Figure presented at the *XIIth International Congress of the History of Science*, Paris, 1968.

Table 1. *Note* (1), p. 195.

Table 2. Mitsutomo Yuasa: *Kagakushi*, p. 104.

Table 3. Mitsutomo Yuasa: *Kagaku 50 Nen* (A Fifty Years of Science), Tokyo, Jiji-Tsushin-Sha, 1950, p. 30.

Table 4. Mitsutomo Yuasa: "Kindai Kagaku 100 Nen Shi, 3 (A Hundred Years of Modern Science), Scientific Magazine *Shizen* (in Japanese), Vol. 11, No. 7, p. 75.

Historical Studies in the Physical Sciences, Vol. 1,
University of Pennsylvania Press, 1969; Joseph
Agassi, "Sir John Herschel's Philosophy
of Success," *Ibid.*, pp. 1-36.

The newly issued *Historical Studies in the Physical Sciences* is "an annual journal devoted to the history of the physical sciences in the post-Scientific Revolution period," edited by Dr. Russell McCormmach, Assistant Professor of History and Philosophy of Science, University of Pennsylvania. The editorial board consists of sixteen scholars from six countries, among whom we find the name of Dr. Tetu Hirosige, Nihon University, Tokyo. "Articles may be submitted in foreign languages; if accepted, they will be published in English translation," according to the "Notice to Contributors."

Volume 1 contains the following eight papers:
Joseph Agassi: Sir John Herschel's Philosophy of Success
D. C. Goodman: Wollaston and the Atomic Theory of Dalton
Theodore M. Brown: The Electric Current in Early Nineteenth-
      Century French Physics
S. G. Brush & C. W. F. Everitt: Maxwell, Osborne Reynolds,
      and the Radiometer
Martin J. Klein: Gibbs on Clausius
Tetu Hirosige: Origins of Lourentz' Theory of Electrons and the
      Concept of the Electromagnetic Field
John L. Heilbron & T. S. Kuhn: The Genesis of the Bohr Atom
V. V. Raman & Paul Forman: Why Was It Schrödinger Who
      Developed de Broglie's Ideas?

Among these papers, the present reviewer will take up only the first one, which is the results of Dr. Joseph Agassi's study mainly of John Herschel's work, *Preliminary Discourse on the Study of Natural Philosophy*, London & Philadelphia, 1831.

The time of John Herschel was a period of great transiton in science and scientific thought, owing to the rise of Dalton's atomism, the appearance of electrochemistry and of electromagnetism, the overthrow of Newton's optics, and so on. "Doubts about Newton, about science, and about modes of research and modes of publication all found their way to public attention. Herschel tried to handle them and restore an order of sorts in the scientific community." Agassi proposes that he did so "by publishing his views in a definitive essay about science in general." Thus came out Herschel's *Preliminary Discourse*.

It is composed of three parts. The first is on the nature and advantages of physics. Having first established the value of science, Herschel "launches an attack on those who oppose science as anti-religious and on those who support science from purely utilitarian considerations." He then tells that science is composed of abstract and empirical components, and goes on to the law of causality. Although *a priorist* arguments are contained in Herschel's view, he was much too empiricist to be considered even mildly Kantian, nor was it probable that he ever read Kant. However, Agassi could add that Herschel studied Isaac Watts's *Logic*, 1724, which was once very popular.

The second part of Herschel's book deals with the empirical aspects of science. He discusses prejudices and induction, illustrated by historical examples. "Herschel is one of the last exponents of the orthodox Baconian doctrine of prejudice." "Copernicus, Kepler, Galileo, and Boyle all found some facts, partly due to his own inspiration, but he, Bacon, was the reformer of philosophy, the herald of Newton's success!" "Herschel seems merely to reiterate naively Bacon's view that no real science existed before Bacon, and to present the rest of the history of science as the history of inductive reasoning." Thus his "*Preliminary Discourse* seems to be a modernized version of Bacon's *Novum Organum*." In this work, however, the theory of *independent* tests is almost entirely Herschel's own invention and is a very important contribution to the theory of testing hypotheses, according to Agassi.

The third part of Herschel book is a history of the physical sciences. Beginning with a classification of the sciences, which includes a passage on light, he describes Newton's corpuscular hypothesis. "In defense of Newton's conduct Herschel says that the corpuscular hypothesis had explained all the then known phenomena, including Newton's own discoveries. He was confident that 'had the properties of light remained confined to these, there would have been no occasion to have resorted to any other mode of conceiving it.'" This statement was to be meanwhile refuted by Whewell and by Mach. Herschel also says that the rival hypothesis of Huygens seemed to be less capable of explaining diffraction. Herschel deals with other aspects of history of physical sciences, but the revolution in optics was, Agassi thinks, the major subject of his history.

The nineteenth century may be considered as the century of the philosophy of *success*, according to Agassi. "Herschel's emphasis on success permeates his book. The idea that science is identical with scientific success, intellectual as well as material, is implicit throughout, and explicit in quite a number of places." Herschel might have been "more of an originator than reflector of the philosophy of success," but Agassi has to say that he has too little evidence to support this view of his own. It deserves to be mentioned, in either case, that Herschel's philosophy is identical with Bacon's with but a small difference and Bacon's philosophy of hope is in a way an early predecessor of Herschel's philosophy of success.

Masao Watanabe (University of Tokyo, Tokyo)

Armin Hermann: *Frühgeschichte der Quantentheorie* (*1899-1913*), Physik Verlag, Mosbach in Baden, 1969, 14 × 21 cm, 181 pp.

It is a joy for the historian of the modern physics that Armin Hermann's book has been added to the literatures of the history of quantum physics. We have already possessed excellent histories of quantum theory such as the late Amano's *Theory of Heat Radiation and the Origin of Quantum Theory* and *History of Quantum Mechanics,* and Max Jammer's comprehensive *Conceptual Development of Quantum Mechanics*. Hermann's book, however, claims a unique *raison d'être* of its own.

In the period covered by this treatise, 1899 to 1913, the study of the quantum theory was not yet recognized as an active field of research in the physicists' wrold. Physicists who paid serious attention to the problem were rather few. The interest in the quantum theory was, by and large, restricted, as the author rightly states, within the boundary of German-speaking people. The author critically describes and examines the contributions of eight physicists who in this period were concerned with the quantum theory. They are: M. Planck, H. A. Lorentz, A. Einstein, J. Stark, A. E. Haas, A. Sommerfeld, W. Nernst, and N. Bohr, to each of whom a separate chapter is devoted respectively. A plenty of unpublished materials, large part of which are scientific correspondences of these physicists, have been investigated and are effectively utilized in this book by the author. The quantum theory of this period having been, as characterizes the author, a German subject-matter, he, a German historian of physics, certainly is profitably entitled to do such a work. For example, he presents interesting new findings about the career and the achievement of A. E. Haas who, in spite of being the first to apply the quantum of action to the theory of atomic structure, has been hitherto relatively neglected. This is one of the contributions of this book which a foreign historian would not be able to make without some difficulty.

Among many interesting points presented in this book, of particular interest to the reviewer are the chapters on Planck and Stark.

The author starts the history of quantum theory from the year 1899, not from the year 1900 as might be expected. This choice of date is not without reason. For as early as in May 1899, discussing the validity of Wien's radiation formula, Planck introduced two constants a and b, of which the latter was the equivalent of Planck's constant h and was calculated to be 6.885×10^{-27}. Planck noticed that they were universal constants with the aid of which a natural system of units of physical quantities could be constructed. Planck emphasized this again in

his papers of 1900–01 which introduced the energy element, while, asserts the author, in 1900–01 Planck was not quite aware of the violence of the principle of continuity.   In his deriving the radiation formula using $S = k \log W$, it was entirely out of question to take the limit of ε or $h \rightarrow 0$, because, according to the author, the constant h, being a universal constant, had been, since the previous year, of fundamental importance to Planck.

Thus the author asserts that what was new for Planck in his theory of radiation was not the energy element but the universal constant h.   This is the reason why the author considers the beginning of the history of quantum theory to be in the year 1899.   In this connection, the author also makes a remark about what Planck called "an act of desperation" in his letter to R. W. Wood.   This may be liable to be interpreted as indicating the introduction of a discreteness of the energy. But the author asserts that his historical exposition, together with some writings of Planck, indicates that Planck meant by "an act of desparation" not the discreteness but that he had adopted Boltzmann's probabilistic interpretation of the entropy notwinthstanding the dislike of the atomism openly expressed by him until only a few years ago.

This conclusion is a very probable one.   To the reviewer's regret, however, all the writings of Planck's, adduced by the author as the evidence, are of later date. They are quotations from Planck's Nobel lecture, the essay on the history of the discovery of quantum of action written in 1943, the scientific autobiography, and the letter to Wood dated October 7, 1931.   It is virtually impossible to use writings of Planck himself at the crucial time because all his private papers were destroyed by the War.   But when a later writing is presented as evidence in the historical study, adequate caution may be required.   For example, Planck says in his letter to Wood that he will narrate the psychological side of his investigation. His narration is, however, a retrospective, somewhat logical reconstruction of the course of events, as is evidenced by his reference to the partition of energy between the radiation and the resonators, a problem of which Planck was not yet conscious in 1900.   The reviewer does not mean that the author's conclusion is doubtful.   It seems well supported by circumstantial evidences.   It may however be hoped that the author would have added here some adequate consideration.

Now another point of particular interest is to be discussed.   The author has uncovered many interesting efforts of Stark which have hitherto been neglected in the history of quantum theory.   To take an example, the idea that the energy difference of two positions of intra-atomic electron may be emitted as a spectral line is found to be first stated by Stark in 1908.   What seems to the reviewer especially suggestive is the discussion of the possible influence of Stark on Bohr's theory of atomic constitution.   In 1908, Stark considered a mechanism of the emission of spectral line.   He supposed that the emission was due to binding process of a remote electron by the atom.   The electron captured by the atom was supposed to described an elliptic orbit of large eccentricity.   At each successive perihelion and

aphelion the electron loses some of its energy in the form of radiation because of its large acceleration. Thus the electron, emitting radiations of ever increasing wavelength, successively describes a series of orbits which become smaller and smaller until it settles down in a state of lowest potential energy. Stark presented this idea in a more careful form in his book *Prinzipien der Atomdynamik II* of 1911, a copy of which was in possession of Bohr around the time when the latter was finishing his theory of atomic constitution. Now, the author suggests that Stark's book should have strongly influenced on Bohr in shaping of his theory, because Stark's idea, when applied to the Rutherford atom, will automatically lead to the concept of a family of elliptic orbits characterized by the energy of electron on each of them. To the reviewer this is quite a interesting suggestion. For he, with S. Nisio, once proposed an interpretation of Bohr's first form of the quantum condition that this condition would have been derived by an averaging of the energy which an electron captured by the nucleus might emit with a certain probability during its binding through successive, ever shrinking orbits (No. 3, 1964 of this journal. See also pp. 35–47 of the present volume). The suggested influence of Stark on Bohr will probably corrobarate this interpretation. However, here again, there is lacking any direct and contemporary evidence that Bohr actually derived inspiration from Stark. It therefore cannot be said to be conclusively established, possible though it may be, that Stark directly influenced on Bohr.

Tetu Hirosige (Nihon University, Tokyo)

History of Science Society of Japan (ed.): *Nihon Kagaku-Gijutsu-shi Taikei* (History of Science and Technology in Japan), 25 Vols., 1964~1970.

In 1960, the History of Science Society of Japan planned to publish as its twenty years commemoration publication a series of source books of history of science and technology in Japan since 1850. It was entitled *Nihon Kagaku-Gijutsu-shi Taikei* (History of Science and Technology in Japan).

About one hundred Japanese historians of science and technology participated in this work. The series was started to be published in 1964 and has recently been completed. This is a most comprehensive documental compilation for the recent on the history of science and technology in Japan. It consists of historical surveys, sources and documents with commantary, in Japanese, together with illustrations, in the following twenty-five volumes:

1 Outline History I	10 Education III	18 Mechanical Engineering
2 Outline History II	11 Natural Environment	19 Electrical Engineering
3 Outline History III	12 Mathematical Science	20 Mining & Metallurgy
4 Outline History IV	13 Physical Sciences	21 Chemical Engineering
5 Outline History V	14 Astronomy & Earth	22 Agriculture I
6 Philosophy	Science	23 Agriculture II
7 International	15 Biological Science	24 Medicine I
8 Education I	16 Civil Engineering	25 Medicine II
9 Education II	17 Architecture	

A supplementary volume is planned to be published as an index for the whole twenty-five volumes. While preparing a thesaurus for this index, we noticed that some proper nouns, especially names of scientists, technicians, polititians, and so on, could be keywords indispensable to this kind of historical thesauri. Therefore, we decided to present a part of the draft list of the names in the thesaurus now we are making.

In order to make out the list, all the items in the indices of the twenty-five volumes were written up on a card system. Then, all the cards of personal names were arranged into the order of the Japanese syllabary. We found a certain name appearing in several volumes and several times in one volume. Now, the number indicating in how many volumes a certain name appears is called A, and the number, of appearing times of a certain name through the volumes is called B. By these two values, A and B, we decided to select persons that ought to be listed up in our draft list.

After reducing the repeated cards, we got 5121 Japanese names from 7071 cards, and 1223 foreign names from 1584 cards. The distribution of the numbers of Japanese names evaluated by A and B is indicated in Table 1 and that of foreign names in Table 2. List 1 gives the Japanese names with the value $A \geq 6$, List 2 gives the foreign names valued $A \geq 4$.

We are expecting to make a detailed report of our work in the next issue of this publication.

TABLE 1–A.   Distribution of Numbers of Japanese Persons (N)
in Relation with A-Value

A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
N	4121	602	194	88	49	25	9	13	8	2	4	3	1	1	—	1	5121

TABLE 1–B.   Distribution of Number of Japanese Persons
in Relation with A– and B-Values

B A	1	2	3	4	5	More than 4 or 5	Total
1	2638	808	299	133	84	159	4121
2	—	158	125	96	—	223	602
3	—	—	22	29	—	143	194
4	—	—	—	2	—	86	88

TABLE 2.   Distribution of Numbers of Foreign Persons
in Relation with A– and B-Values

B A	1	2	3	4	5	More than 4 or 5	Total
1	666	190	61	59	23	22	1020
2	—	19	30	20	—	56	125
3	—	—	3	6	—	30	39
4							24
5							4
6			(not counted)				2
7							5
8							2
9							2
Total							1223

List 1

A=16

NAGAOKA Hantarō

A=14

TANAKADATE Aikitsu

A=13

SHIBUSAWA Eiichi

1=12

FURUICHI Kimitake,   KIKUCHI (MITSUKURI) Dairoku, TERADA Torahiko

A=11

FUKUZAWA Yukichi,   NAKAMURA Seiji,

HONDA Kōtarō,   ŌKŌCHI Masatoshi

A=10

SAKURAI Jōji,   TAKAMINE Jōkichi

A=9

ENOMOTO Takeaki   MANO Bunji,   ŌKUMA Shigenobu,

(Kamajiro)   NAGAI Nagayoshi,   WADA Tsunashirō,

KAWAMOTO Kōmin,   OGURA Kinnosuke,   YANAGAWA Shunsan

A=8

ANDŌ Kotarō,   ISHIHARA Atsushi (Jun), TANABE Hajime,

FUJISAWA Rikitarō,   ITŌ Hirobumi,   YUKAWA Hideki,

GOTŌ Shinpei,   KATŌ Hiroyuki,   YAMAKAWA Kenjirō,

HIRAGA Yoshimi,   SUZUKI Umetarō,   YAMAO Yōzō

A=7

IKEDA Kikunae,   OMORI Fusakichi,   WATANABE Kōki

KITAZATO Shibasaburō, TANBA Keizō,   (Kōichirō),

KUHARA Mitsuru,   TEJIMA Seiichi,   YOKOI Tokiyoshi

MIYAKE Hide,

A=6

FUJIOKA Ichirō,   ŌKUBO Toshimichi,   TANAKA Yoshio,

HASHIDA Kunihiko,   OSAWA Kenji,   TATSUNO Kingo,

IGUCHI Ariya,   SAKUMA Shōzan,   TERANO Seiichi,

ISHIKAWA Chiyomatsu, SANO Toshiki,   TOMONAGA Shin-ichiro

KANDA Kōhei,   SANO Tsunetami,   TSUDA Sen,

KOZAI Yoshinao,   SHIDA Rinshirō,   YAGI Hideji,

MORI Rintarō,   SHIMAZU Nariakira,   YATABE Ryōkichi

NAKAYA Ukichirō,   TAKAMATSU Toyokichi,

OGATA Kōan,   TAKETANI Mitsuo,

List 2

A=9

DIVERS, Edward,   WAGENER, Gottfried

A=8

AYRTON, W. E.,   MILNE, John

A=7

CAPRON, Horace,   EWING, James Alfred,   PERRY, John,
EINSTEIN, Albert,   FESUCA, Max

A=6

LYMAN, Benjamin S.   MORSE, Edward Sylvester

A=5

D'RIJKE, J.,   MENDENHALL, Thomas C.,
KNIPPING, Erwin,   NAUMANN, Edmund

A=4

ATKINSON, Robert W.,   HABER, Fritz,   MOREL, Edmond,
BÄLZ, Erwin,   HELMHOLTZ, H. L. F. von,   NEWTON, Isaac,
CURIE, Pierre & Marie,   HEPBURN, James C.,   PERRY, Matthew C.,
DARWIN, Charles R.,   KELLNER, O.,   PLANCK, Max Karl
                                                       E. L.,
DYER, Henry,   KOCH, Robert,   POINCARÉ, Jules H.,
EUCLID,   LENIN, Nikolai,   RUSSELL, Bertrand,
FARADAY, Michael,   LYSENKO, T. Denisowich,   WERNIE, Francois,
GARATAMA, K.,   MAXWELL, James C.,   WIENER, N.

Tetsuo TOMITA   (Patent Office, under the Ministry
                   of International Trades and In-
                   dustries, Tokyo)
Kazutoshi HATTORI (National Diet Library, Tokyo)

News

The History of Science Society of Japan met for its 17th annual meeting on May 2 and 3, 1970, at Shōwachō Campus of St. Andrew's University (Momoyama Gakuin University), Osaka.   The following are the papers, the special lecture, and the symposium presented on that occasion.

May 2

On Ritter's "Butsuri Nikki"	Manpei HASHIMOTO
Early Japanese Translations of Euclid's *Elements*	Takao KURODA
Activities of Japanese Chemists in the Mid-Meiji Period	Kunika SUGAWARA
Women Scientists in Japan (4)	Teruko SEKINE, Aiko YAMASHITA, & Akiko YOSHIMURA
Herb *Pyrola* as Studied in Japan	Aiko YAMASHITA
Methods of Instruction of Japanese Mathematics	Kazuo SHIMODAIRA
Recent Studies of "Sangaku"	Kazuo SHIMODAIRA
Japanese Herbals Mentioned in Thunberg's Books	Yojiro KIMURA
On Indian Atomism (2)	Isao OHAMI
On Huygens' Mechanics	Masahiko YOKOYAMA
Development of Optics, with reference to Abbe Theory	Keiichi TSUNEISHI
H. Nagaoka's Theory of Matter: 1904–05	Eri YAGI
The Origins of the Bohr Atom Reconsidered	Tetu HIROSIGE & Sigeko NISIO
Characteristic X-rays and the Bohr Atom	Segeko NISIO

Special Lecture: Reseraches on the History of Chinese Astronomy

Kiyosi YABUUTI

May 3

Phylogenetic Studies of the Solar Cosmogony	Fukutaro SHIMAMURA
Color Description of the Chinese Herbals	Kenichi MORIMURA
Professionalization of Science in the 19th Century	Shigeru NAKAYAMA
On Evaluation of Information	Susumu IMOTO

The Study of Underdeveloped Economy and the History of Technology

Tatsuya KOBAYASHI

Development of Automobile Industry in Japan	Hiroo KATO

Research Organization in Electrical Industry: 1890–1914

Chikayoshi KAMATANI

Symposium: The Present Japanese Technology: Its Level in the World

A. Reports

Preliminary Remarks	Mitsutomo YUASA
Technology in Minor Enterprises	Masami TAKEUCHI
Technology of Big Machines	Seikan ISHIGAI
Technology of High Quality Materials	Saizo OONO

Table of Contents

Japanese Studies in the History of Science
Nos. 1~8 (1962~1969)

No. 1 (1962)

No. 2 (1963)

Articles

No. 5 (1966)

Articles

No. 6 (1967)

No. 7 (1968)

No. 8 (1969)

Information for Contributors

I. *Manuscripts*

1. Reviews, research surveys, source materials, documents and original papers are acceptable.
2. Articles may be written in English, French, or German.
3. The title and the author's name should be typed on a separate page, with the author's present position indicated in a foot-note.
4. The text should be typed double-space on paper of standard size and weight, about 65 spaces per line and 25 lines per page, with margins of 4 cm. at the top and 3 cm. on the left.
5. All special types, such as italics and Greek letters, should be so designated in red.
6. Notes and references should be compiled at the close and not appear as foot-notes in the text.
7. Figures and tables, other than simple tabulations, should be prepared separate from the text on standard size paper, with their proper locations noted in red.
8. Figures should be drawn in black ink, one figure per page at actual size, and collected together after the text and notes.
9. Tables should be similarly prepared.
10. For each table and figure, the author's name and the page where they appear in the text should be noted in red at the lower right hand corner.
11. Titles and explanations, which are to accompany figures or tables, should be typed, one to a page, with the author's name and the page in the text indicated in red as above.

II. *Procedures*

1. The original manuscript plus one copy should be sent to:
   The History of Science Society of Japan
   Meteorological Research Institute   Branch Office
   Japan Meterorological Agency
   1-3-4, Ōtemachi, Chiyoda-ku
   Tokyo, Japan
2. The following information should also be provided: 1) title, 2) author's name, 3) present position (title, address, phone), 4) home address and phone, 5) preferred address, home or office.
3. One hundred copies will be sent at no charge.
4. Any author who has submitted a manuscript must request permission from the editorial board before sending it to another journal.

III. *Corrections to Proofs*

    1. Only the first proofs will be submitted to the author for correction.

    2. The author must bear the costs that arise from introducing any revisions or additons, including notes in proof.