ORIENTAL ALCHEMY

By MASUMI CHIKASHIGE

東洋錬金術

The translation and the publication of this
book are made possible by
the late Prince Arisugawa's Foundation
granted by
H. I. H. Prince Takamatsu
through the recommendation of
the Imperial Academy of Japan.

Alchemy and Other Chemical Achievements of the Ancient Orient

The Civilization of Japan and China in Early Times as Seen from the Chemical Point of View

By

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1936

Sun Po (孫博)

Sun Po(孫博) was born in the *Ho Tung* (河東) district during the Han dynasty. He was an enthusiastic reader and an excellent writer. In his later years he adopted the Taoistic creed and is said to have thereby acquired the power of making grasses and trees burst into flames spontaneously and of diving into water without wetting his clothes. He is credited with being able to heal the sick by merely pointing to the patient and saying "Be whole." He could, it is said, penetrate into a mountain or go through a stonewall as if through an aperture. He retired afterwards to a mountain called *Lin Lu Shan*(林慮山) where he compounded the elixir of longevity and disappeared as a *hsien* (仙). (*Wang Shih Shên*'s (王世貞) *Lieh Hsien Chüan Chuan*(列仙全傳), vol. 5).

NOTE TO THE TRANSLATION

The original Japanese edition of this booklet was published six years ago. About a quarter of the text was devoted to an outline of Western alchemy for the benefit of Japanese readers. In this English version that part has been omitted for obvious reasons, and at the same time some points in the text have been revised and supplemented.

Since the publication of the Japanese edition it has been my ambition to have the work translated into English but unexpected trouble with my eyes has prevented me from entering upon the task myself. My most heartfelt thanks are due, therefore, to my former pupil, Prof. *Nobuji Sasaki*(佐々木申二), who has willingly taken upon himself the laborious work of translation. Now that the English version is completed, I feel as if a load had been taken off my mind, and rejoice in the thought that the booklet will now find a wider circle of readers.

I should like to take this opportunity to express my sincere thanks to the Emeritus Professor *Naoki Kano*(狩野直喜) M.I.A. who helped me with his authoritative knowledge of Chinese classics and also to the Emeritus Professor *Takuji Ogawa*(小川

琢治) M.I.A. who kindly allowed me to make use of his book, *Ching Shih Chêng Lei Ta Kuan Pên Ts'ao*(經史證類大觀本草, a special commentary on the *Pên Ts'ao Ching*). My deep gratitude is also due to Mr. *Li Shu Lin* (李樹林), student of chemistry from Manchoukuo, who assisted me in translating the Chinese texts.

Masumi Chikashige.

October, 1935.

PREFACE

It is a well-known fact, that alchemy was studied and practised in the West in very remote times; but as early, or even earlier, a similar art was practised in the East, especially in China. If *Lao Tsŭ* (老子) can be regarded as the founder of this art, its beginning must have dated from the fifth century B.C., but there is no evidence whatever that he concerned himself with alchemy. Three centuries later, however, during the reign of Emperor *Shih Huang Ti*(始皇帝) the first of the *Ch'in* (秦) dynasty, there appeared two famous alchemists *Hsü Fu*(徐福) and *An Ch'i Shêng*(安期生). Still later, in the second century A.D., a book on materia medica, entitled *Pên Ts'ao Ching*(本草經) was published, and in the century immediately following, in the *Chin* (晉) dynasty, *Ko Hung* (葛洪) made his appearance as the first conspicuous figure in the history of Chinese alchemy. He compiled a comprehensive work, known under the name of *Pao Pu Tzŭ*(抱朴子), *Ko Hung*'s pseudonym. The first half of this work contains an excellent treatise on alchemy. Since it was not until two or three centuries thereafter that Western alchemy began to flourish, it may well be argued that the alchemy of China is older than that of the West.

The ancient Chinese alchemy was the art practised by the *hsien*(仙, those who have attained longevity or immortality by their own art, genii or immortals). Its aim was above all to search for the elixir of life. But since the best elixir ought to contain gold, the art came to include that of gold-making. It is highly interesting to note that Chinese alchemy was born in the attempts at searching for the elixir of life and consequently the idea of the making of gold was rather hidden in the background. This fact stands in vivid contrast to the birth of Western alchemy which was stimulated by the more materialistic wish to make genuine gold or rather an imitation of it from the base metals, while the notion of immortalizing human life was seemingly subordinate. This being so, the gold which should be present in the Chinese elixir as the efficacious ingredient did not always require to be gold which had been produced from other substances—we do not necessarily say from base metals—but might be natural gold purposely added to the drug.

The physical art of the *hsien* is called the art of *lien tan* (錬丹). *Lien* means refining and *tan* means drugs compounded by sublimation, or red substances in general, or more particulary cinnabar, which can easily yield mercury by means of which gold may be obtained. The art of *lien tan* is therefore the art of alchemy. Modern chemistry, however, repudiates the possibility of the mutual transformation of the chemical elements by ordinary laboratory means. From this point of view the idea of the alchemical transmutation of metals is nothing more than a dream. On the other hand the wish of a mortal to live forever is a physical desire which ignores the natural law that life is subject to decay. Thus alchemy seems to be a bygone science which is not worthy of serious consideration. But the human interest in gold will never change and the longing for longevity will remain forever with the human race. Thus the formation of gold by the transmutation of elements has often been discussed by chemists of the present time and modern medical science is much concerned with the secret of rejuvenation. The ancient alchemy was indeed a manifestation of incessant efforts to satisfy certain human desires. The alchemy of olden times was a true science, whether its theories can lay claim to any validity or not. There is a great deal of truth in the dictum of Liebig, that great German chemist, that alchemy was never anything other than chemistry. It is only regrettable that the very existence of Chinese alchemy has hardly been recognised even to-day, while the knowledge of Western alchemy is widespread. Without doubt the Chinese books on alchemy have long since found readers in our country; but the study of them has been left to sinologues and seemingly no one has ever attempted to appreciate the subject from the chemical point of view. In point of fact Oriental alchemy has its own theories, which are of deep interest and which are accompanied by the corresponding experiments. The recipe for obtaining gold from its ores may be regarded as a reasonable one, if only the practical procedure is properly performed.

The achievements of alchemy, especially on its practical side, serve as valuable mile-stones marking the progress of man's knowledge of nature. The same may be said with equal justification of many chemical achievements of a more or less industrial nature. In this respect, above all the art of moulding bronze articles of ancient China and the technical methods of forging swords of old Japan, arts which represent the culminating point of this kind of applied chemistry, may be considered as splendid examples which have no parallel in the whole world.

My interest has been keenly attracted to these subjects for the past twenty years. The present booklet contains the results of my studies, from the chemical stand point, of Chinese alchemy and bronzes and of Japanese swords. When I began my researches, this kind of investigation was entirely new, and I fear I have merely followed the example of *Ch'ên Sheng* (陳勝) and *Wu Kuang* (吳廣), those archetypes of failure. As a matter of course I am fully aware of the faults of omission and inexactitude, and shall be greatly pleased if any of my readers will kindly point out such mistakes as they find, so that they may be amended, and moreover sincerely hope that further development in this domain will be accomplished by other investigators.

My sincere acknowledgements are due to Dr. *Yoshio Yano* (矢野芳雄) and Dr. *Kenkyo Inaba* (稻葉見敬) who kindly performed some of the analyses of the bronze articles, and to Dr. *Teruo Ashida* (足田輝雄) who took the trouble of preparing all of the sectional views of the swords, and last but not least to Dr. *Masahiro Tasaki* (田崎正浩) who kindly drew all the diagrams of the methods of forging swords.

April, 1929.

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INTRODUCTION

The first gleam of the dawn of modern chemistry appeared towards the end of the eighteenth century, and its progress during the past one and a half centuries has been remarkable. It was once thought that before that dawn there was no chemistry of any kind; but the long history of alchemy clearly shows, as Liebig remarked, that alchemy was never anything else than the chemistry proper to its own generation. Some among the alchemists, to be sure, were impostors who mystified the innocent to make their own fortunes. But there were without doubt many earnest students who, actuated by a purely scientific conscience, endeavoured to find truth in the natural changes. Their experimentation, however, did not lead them to any fundamental conclusion such as would indicate to them the right way to proceed further. It is rather a pity that their blind efforts often appear ridiculous or even fraudulent in the light of the advanced sciences of the present day. But just as a rough diamond stands out from among ordinary pebbles, so many of the invaluable achievements of the alchemists, which have formed the basis of modern chemistry, cannot remain hidden, and retain their unfading brilliancy of truth even to-day. That is so with many of the facts they discovered and the articles they produced. On the other hand their theories were generally too vague and sometimes even nonsensical in the light of modern science. Theories, however, are always changing. If a false theory of yesterday can give rise to the birth of a more correct theory to-day, it has done great service to the progress of science. It is by no means justifiable to neglect wholly the services rendered by alchemy because of its false theories.

Commonly, by alchemy is meant the alchemy of the West alone. That obviously is of very ancient origin; but Chinese alchemy is almost as old. Some are even of opinion, judging from the possible early communication between the East and the West, that the Western and the Eastern alchemy had the same origin. Whether that view is correct or not, the history of alchemy should comprise Chinese alchemy as well as that of the West. In marked contrast to the fate of the alchemy of the West, however, that of China flourished and degenerated as such, without promoting itself to the stage of modern chemistry. Moreover the Chinese classics of alchemy are difficult to understand. This is probably the reason why Chinese alchemy has found no mention in Western books.

As to the history of Western alchemy, the main steps in its development are perhaps best given in reverse order. The time between the end of the eighteenth century and the beginning of the nineteenth was the infancy of modern chemistry, which was born from iatro-chemistry. Iatro-chemistry was a modification of alchemy that flourished from the sixteenth to the eighteenth century; abandoning the attempts to transmute base metals into gold, it had as its main aim the study of the elixir of longevity. Before the dawn of iatro-chemistry we have alchemy proper, which had culminated under the prosperous Roman Empire in the fourth century. The Empire inherited alchemy from Greece, which in its turn had imported it from Arabia about the sixth century B.C. Arabia learned it from Persia and Persia from Egypt. Since Egypt had already attained its high civilisation two thousand years B.C. its alchemy also must have been well developed.

The alchemy of the West has thus its source deep in the past. Is Chinese alchemy comparable with it in the remoteness of its origin? According to a book called " A Study of Chinese Alchemy," *Chung Kuo Lien Tan Shu K'ao* (中國鍊丹術考) written by Obed S. Johnson and published in the same year as the present book was written, the alchemy of China is older than that of Greece by four or five hundred years. He even puts forward the theory that the alchemy of Greece was possibly imported from China. It is not easy to see whether that opinion is correct; but I also have long been aware that the dawns of Chinese and Greek alchemy were not far apart. The chronological table given below will facilitate the comparison of the history of the alchemical and the chemical arts of the East and the West (Japan is also included in the table, though the history of her chemistry began far later).

This table gives only a rough idea of the dates. In the sixth century B.C. Western alchemy began to rise while in China there appeared *Lao Tzŭ*, who was a philosopher and is regarded as the founder of Taoism, a religion in which alchemical arts are practised. He lived more than one hundred years earlier than such Greek philosophers as Democritus and Aristotle, who lived in the fourth and the fifth century B.C. From the second century B.C. or the early days of Rome, until the fourth century A.D. Western alchemy flourished. In the same period, however, this art prospered also in China. *Hsü Fu* (徐福) is said to have come to Japan on the expedition which he undertook in search of the elixir of life at the request of the great Emperor *Shih Hung Ti* (始皇帝), the founder of the *Ch'in* (秦) dynasty.[1] *An Ch'i Shêng* (安期生) also lived in this period, although his life is highly legendary. He learned the art of compounding medicines from *Ho Shang Chang Jên* (河上丈人) and sold them in a district near the sea. His contemporaries believed that even in those days he was a thousand years old, and called him "the thousand-year-old." The Emperor *Shih Hung Ti* when on his journey through *Shang Tung* (山東) invited him to talk with him and their talk continued for three days and nights. The Emperor rewarded him with gold and jade of high value, but he threw it all away.[2] Thus he obviously lived during the *Ch'in* Dynasty. But in the Western *Han* Dynasty (西漢), as history tells, we again meet an *An Ch'i Shêng* (安期生), who suggested to *Hsiang Yü* (項羽) a political plan which was rejected by him. Still later, in the reign of *Wu Ti* (武帝) of the *Han* dynasty, a *hsien* (仙) called *Li Shao Chün* (李少君) said to the Emperor, "I used to see *An Ch'i Shêng* (安期生) in a district near the sea. He lives on *chü tsao* (巨棗, jujubes) as large as a *kua* (瓜, melon) and enjoys longevity."[3] Thus we see that *An Ch'i Shêng* is represented in history as having lived as long as a thousand years

1) *Lieh Hsien Ch'üan Chuan*, vol. 2.
2) ibid., vol. 2.
3) ibid., vol. 2.

Period	East			West
	Japan	China	Near East	
3000 B.C.		Materia medica of *Shêng Nung* (神農).	Chemistry of Egypt and Caledonia.	
2000		Bronzes of the *Hsia* (夏) and *Yin* (殷). dynasties.	Babylonia.	
1000		The Six Receipts for Bronze of the *Chou* (周) dynasty.	Phoenicia.	
900			Hebrews.	Greeks.
800	Bronzes and swords of the Divine Period.			
700	Cloth.	The Period of Spring and Autumn.	Persia.	
600	The first Emperor, *Jimmu* (神武).	*Lao Tsŭ* (老子).		Alchemy.
500	Emperor *Suisei* (綏靖).			

400		The Period of Civil Wars.		Democritus.
300				Aristotle, Alexander the Great.
200	Emperor *Kōrei* (孝靈).	The *Ch'in* (秦) and the *Han* (漢) dynasties. *Hsü Fu* (徐福). *An Ch'i Shêng* (安期生).		The Roman Age.
100				
1 A.D.	Emperor *Suijin* (垂仁).			Pliny.
100		*Hsin* (新) and the Later *Han* (後漢) dynasties.		Mercury was obtained from cinnabar.
200		*Pên Ts'ao Ching* (本草經) was published.		Gold-assaying.
300	Emperor *Ōjin* (應仁)	The Three Kingdoms. The Six Dynasties. *Ko Hung* (葛洪).		Gold-plating.
400				Alchemy prospered.
500	Brocade.			

Period	East			West
	Japan	China	Near East	
600	Empress *Suiko*, (推古), The naturalized smiths at *Oshinumi* (忍海) forged swords.	The *Sui* (隋) dynasty.		
700	Empress *Genmyō* (元明). Copper and gold were produced.	The *T'ang* (唐) dynasty.		
800	*Amakuni* (天國) forged swords.[1] Calomel was manufactured in the province of *Ise* (伊勢).			
900	Emperor *Daigo* (醍醐) *Engi-shiki* (延喜式)[2] and *Wamyōshō* (和名抄)[3] were compiled.			
1000		The *Sung* (宋) dynasty.		

1100				
1200				
1300		The *Yüan* (元) dynasty.		
1400		The *Ming* (明) dynasty.		
1500		Bronzes of the *Hsüan Te* (宣德) era.		
1600				
1700		The *Ch'ing* (清) dynasty.		Iatrochemistry.
1800	*Honzō Kōmoku Keimō* (本草綱目啓蒙)[4] and *Chymie-Kaisō* (舎密開宗)[5] were published.			The dawn of modern chemistry.
1900				

1) The first authentic sword-smith.
2) Rules and Regulations compiled in the *Engi* era.
3) Materia medica in Japanese.
4) A Japanese commentary on the *Pên Ts'ao Kan Mu* (本草綱目).
5) A Japanese translation of a Dutch chemical book.

already in the *Ch'in* dynasty and still continuing to live for several hundred years more. Indeed Chinese alchemy was so prosperous in those days that the possibility of the existence of such an extraordinary human being was fully accepted. The third century of the Christian era corresponds to the *Chin* (晉) dynasty of the *Six Dynasties* (六朝), when *Ko Hung* (葛洪) appeared. The book called *Pao Pu Tsŭ* (抱朴子), written by *Ko Hung*, whose life will later be mentioned in detail, is the oldest complete book on alchemy, dealing with the art of gold-making and the compounding of the elixir.

The above table contains also the names of the chemical products according to the date of their first appearance. We see therefore that in our country the metallurgy of bronze was already being practised in the Divine Period, and that there are authentic records of the forging of iron swords and the manufacture of calomel as medicine dated more than a thousand years ago. The method of manufacturing calomel was handed down to the *Meiji* (明治) era and Edward Divers recognized its excellent quality, of which he notified Europe, (Journal of the Society of Chemical Industry, Vol. 13, 1894, p. 18). In the final analysis, therefore, it is evident that the chemistry of the Orient is, so far as its practical side is concerned, by no means inferior to that of the West in the remoteness of its

p. 8—9 *An Ch'i Shêng* (安期生)

origin. As to its theories, there is little to be noticed.

Here I should like to add that in 1919 I published in a Japanese journal "*Shirin*" (史林, the Journal of History published by the Historical Society of Kyoto Imperial University) an essay entitled "The culture of the ancient Orient as seen from the chemical view point." Two papers of almost the same substance were published in "Man," a Monthly Record of Anthropological Science, Vol. 20, 1920, p. 81 and in the Journal of the Chemical Society, Vol. 117, 1920, p. 917. These papers may be read with advantage in conjunction with the text.

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Lao Tzŭ (老子)

CHAPTER I. ALCHEMY IN THE EAST.

1. DISTINGUISHED ALCHEMISTS IN ANCIENT CHINA.

China has a religion called Taoism (道教, teaching of *Tao*) of which *Lao Tzŭ* (老子) is regarded as the founder. He was born in the sixth century B. C. and enjoyed, it is said, almost eternal life, being reborn several times, which is obviously a legend. No achievement which has in any way to do with alchemy is attributed to *Lao Tzŭ*. The teaching of *Lao Tzŭ* itself was not religious in character. It was concerned with the fundamental principle *Tao* (道) or universal truth, which he claimed was the emptiness of nature. But because of the loftiness and abstractness of this principle, the original teaching was more or less incorrectly interpreted and with its gradual popularisation the doctrine finally took on the form of a religion. The masters of Taoism were called *tao shih* (道士). They held certain metaphysical views and compounded medicinal preparations with the aim of supporting them. Here enters in the notion of chemistry or alchemy. Since in the compounding of medicines to produce longevity various materials, inorganic as well as organic were used, the chemistry of the time must have been concerned with a rather wide field of the material world. From the fact that the Chinese alchemists thought that they were able to compound the elixir impregnated with gold from materials which they thought were not auriferous and from their attempts at gold-making for that explicit purpose, we may infer that they accepted, as did the Western alchemists also, the theory of the transmutation of chemical elements. The validity of this theory was, however, not at all questioned by any *tao shih*, as may well be supposed from the fact that the notions of *yin yang* (陰陽) and *wu hsing* (五行), prevailed in China at that time. On the other hand there were many ordinary people who, having realised the impossibility of producing inordinate longevity, ridiculed the art of the immortals or alchemy.

As to the bibliography of Chinese alchemy, *Ko Hung*'s *Pao Pu Tsŭ* is the oldest complete book. We have a still older book entitled *Ts'an T'ung Ch'i* (參同契), which dates from the later *Han* dynasty. This book is without doubt one of the Taoist classics but it is too abstract and esoteric for our study. One may also add *Pên*

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T'ao Hun Ching (陶弘景)

Ts'ao Ching (本草經), a treatise on Chinese materia medica, published towards the end of the *Han* dynasty. This work, upon which *T'ao Hun Ching* (陶弘景) commented in the *Liang* (梁) dynasty, being revised and supplemented much later in the *Ming* (明) dynasty, was re-entitled *Pên Ts'ao Kang Mu* (本草綱目). *Pên Ts'ao Ching* (本草經) may also be looked upon as a treatise on natural history, dealing as it does with minerals and plants in an exhaustive way, and hence may be said to contain something relating to chemistry. A good many other alchemical books can be enumerated but they are all of later date. *An Ch'i Shêng* (安期生), an alchemist, is said to have lived considerably earlier than *Ko Hung* but he left no writings. In the final analysis, only the two works, *Pao Pu Tsŭ* and *Pên Ts'ao Ching* remain as the authentic sources of information on the earlier Chinese alchemy. We now proceed to give some account of the life of *T'ao Hung Ching* and of *Ko Hung*.

T'ao Hung Ching was a native of *Liang* (梁). His name is sometimes differently written 宏景, in order to avoid using the sacred name of the *Ch'ing* (清) dynasty. When young he obtained *Ko Hung*'s *Shên Hsien Chuan* (神仙傳) which stimulated him to search for the art of nurturing life. Having read more than ten thousand books, he retreated to

Mount *Chü Ch'ü Shan* (句曲山) in the province of *Chü Jung* (句容) and assumed the name of *Hua Yang Yin Chü* (華陽隱居, retired master of Mount *Hua Yang*). He was deeply versed in the philosophy of *Yin Yang* (陰陽, the Negative Positive and the Two Contraries)and the principle of *Wu Hsing* (五行, the Five Fundamental Elements), divination by winds, astronomical calculation, geography, the productions of different countries, the medical art and materia medica.

He once constructed a celestial globe, and it is recorded that the Emperor of *Liang* often visited him in the mountain, in order to ask for instruction, so that his contemporaries called him the Prime Minister of the Mountain. At the age of eighty-five he died without suffering or else, as it is said, disappeared as a *hsien* (仙, an immortal)[1]. Among the literati he is well-known by the poem which he composed:

What is there in the mountains?
A mass of fleecy clouds upon the summits,
Only to be enjoyed by myself.
It is not worth presenting to you.

Ko Hung (葛洪), the author of *Pao Pu Tsŭ*, lived earlier than *T'ao Hung Ching*, for he belongs to the *Chin* (晉) dynasty. History says of him that

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1) *Lieh Hsien Ch'üan Chuan*, vol. 5.

he was born in *Chü Jung* (句容) in the ancient state of *Chin* and that his surname was *Chi Ch'uan* (稚川). Being informed that *Chiao Chih* (交趾) yielded a great deal of *tan sha* (丹砂, red sand or cinnabar), he wanted to be the governor of the prefecture of *Chü Lou* (句漏). Setting out with his family, he journeyed as far as the province of *Kuang Chou* (廣州), but the governor *Liu Yo* (劉嶽) of the province would not permit him to travel further. He then remained on Mount *Lo Fou Shan* (羅浮山) and practised the art of the immortals. Upon accomplishing the compounding of the elixir he died *shih chieh* (尸解), that is, disappeared leaving his clothes only.[1] His famous work, *Pao Pu Tsŭ*, is divided into two parts. The first part, called *Nei P'ien* (內篇, the Inner Part), consists of twenty chapters and deals with such subjects as the elixir of life, longevity and immortality and the making of gold. The second part, called *Wai P'ien* (外篇, the Outer Part), consists of fifty chapters and is concerned with mundane matters such as politics, economics and social relations. He assumed the name *Pao Pu Tsŭ*, which was also given to his work. Besides this fundamental work he wrote *Shên Hsien Chuan* (神仙傳) and many other books which amount to several hundreds in number.

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1) *Lieh Hsien Ch'üan Chuan*, vol. 4.

In the fourth chapter of the Inner Part which is termed *Chin Tan* (金丹, the Golden Drug), he describes how the art of the immortals was handed down to him. "Long ago," he says, "when one *Tso Yüang Fang* (左元放) was in deep meditation on Mount *T'ien Chu Shan* (天柱山), there appeared to him a holy man who handed him a book, called *Chin Tan Hsien Ching* (金丹仙經). But before he could compound medicines, he was interrupted by the war which broke out towards the end of the *Han* Dynasty. He then left the mountain and went over to the eastern district of the *Yang Tzŭ Chiang* (楊子江) where he wished to enter a sacred mountain and pursue the art. My great-uncle *Hsien Kung* (仙公) was a diciple of *Yüang Fang* (元放) and received from him *Ta Ch'ing Tan Ching* (大淸丹經) three volumes, *Chiu Ting Tan Ching* (九鼎丹經) one volume, and *Chin I Tan Ching* (金液丹經) one volume. My master *Chêng Hsüan* (鄭玄) was a diciple of *Hsien Kung* who transmitted to him the above-named books. He was poor and could not obtain medicinal materials. I was a servant-student to him for a long time, and then erected an alter on Mount *Ma Chi Shan* (馬迹山), took an oath and received the sacred books. Several secrets were also transmitted to me orally. It is twenty years since I received them, but because of extreme poverty I have done nothing but mourn.

There are rich persons who have accumulated mountains of wealth, yet they do not know that I have this secret of immortality, and even if they were told of it, they would never believe it."

As above mentioned, *Ko Hung*'s death was an extraordinary one, for his corpse disappeared, his clothes alone being left in its stead. It is said in the *Hsien Ching* (仙經), "A man of the highest ability ascends with all his earthly body into heaven; he is called *t'ien hsien* (天仙, heavenly immortal). A man of moderate ability enters a sacred mountain; he is called *ti hsien* (地仙, earthly immortal). A man of the lowest ability first dies and then disappears leaving his clothes only; he is called *shih chieh hsien* (尸解仙, an immortal whose corpse disappears)." To become a heavenly immortal must evidently be the ideal of all those who study the art of the immortals. A sacred mountain probably means a mine, where men of moderate ability may, as a miner does, compound alchemical preparations. One who becomes *shih chieh hsien* (尸解仙) is the least favoured of men. This is certainly because he is of the lowest quality; but such a mode of immortalisation as *shih chieh* (尸解) must always be the fate of everyone, if one is a mortal at all. No mortal ever becomes immortal even though he imbibes the elixir of life. But then if the Taoist also is doomed to the same fate, what is the reward of his long years of patient practice of the art of the immortals? *Hsien Ching* (仙經) wisely teaches that one can become immortal even after death.

What then happened to *Ko Hung?* He could not attain even the rank of an earthly immortal. It is said that his corpse was once coffined, but that on being opened again it was found to contain nothing except the sloughed clothes. Thus he died *shih chieh*. This circumstance was wondered at by his contemporaries and even laughed at, for devoted student of the art as he was, *Ko Hung* could not rise above even the lowest class.

2. THEORIES OF CHINESE ALCHEMY.

Since, as has already been mentioned, an insight into ancient Chinese alchemy can most conveniently be obtained from the *Pao Pu Tsŭ*, this chapter contains many quotations mainly taken from that source.

As already mentioned in the biography of *Ko Hung*, the accounts relating to alchemy are mainly contained in the first part of the *Pao Pu Tsŭ*, wherein are found the theories of longevity, the alchemical processes for compounding various forms of the elixir of life and for making gold and the natural drugs of the immortals.

The aim of the art of the immortals, or alchemy, seems to be divisible into two parts: first and most important, the search for the elixir of immortality, and second and subordinate, the making of gold and the achievement of prosperity. These two aims appear to contradict one another; for in order to attain immortality, one must strictly abstain from all physical desires. Taoism teaches that if one's attitude inclines to material prosperity, the attainment of immortality is impossible. Indeed, in the second chapter, *Lun Hsien* (論仙, An Essay on the Immortals) of the *Pao Pu Tsŭ*, *Ko Hung* deprecates the avarice of his contemporaries and says, "The worldly man blindly toils for wealth and fame and judges others by himself, so that he never believes that the motives of the ancients were honorable." In another part of the same chapter he elaborates this view thus: "The adept in Taoism regards a peerage as an execution cauldron, a seal of office as a mourning dress, gold and jade as dirt, a splendid hall as a prison. How different from those pseudo-alchemists, who, clenching their fists, mouth empty phrases and wait for good luck, or who lead a leisurely life in a gorgeous room, endowed with countless grants, appointed to high office and given a princess for wife, and still are discontented with their power and wealth!"

On the other hand *Ko Hung* deplores his poverty, which prevents him from practising his art, and the indifference of the rich who will not support him. If gold is an excellent medicine for producing longevity, the gold which already exists in the world could be used immediately, and yet he toiled for the express purpose of making gold. Various reasons for this may be gathered from the *Pao Pu Tsŭ*, but it may not be too far-fetched to interpret it as his endeavour as a miner to supply gold to the world by a new process. Thus the apparent contradiction mentioned above may be dispelled by the understanding that the *hsien* ought to produce gold for the sake of mankind, without corrupting his mind.

In the theoretical part, *Ko Hung* discusses the possibility of longevity and immortal life. But since immortality is absolutely denied to us mortals, the possibility of its attainment defies inductive proof. In his argument, therefore, he makes use of ignoratio elenchi. He gives as premise various facts which have no logical relation with what is to be proved, and then by making use of this logical fallacy he concludes that eternal life is possible. This method reminds us of the well-known proverb, " The thief covers his ears while he steals the bell." But it is quite understandable that *Ko Hung* should be at a loss in his logic, to illustrate which some examples of his reasoning are given below from the chapter *Lun Hsien* (論仙).

"Some one asked *Ko Hung* and said, 'Even *Pan Ti* (班狄) could not make a sharp needle of soft stone. Even *Ou Yeh* (歐冶) could not weld a fine blade out of lead or tin. The very gods cannot make possible what is really impossible, the very universe cannot do what cannot be done. How is it possible for us human beings to give constant youth to one who must grow old, or to confer eternal life on one who must die? And yet you say that by the power of alchemy you can cause a cicada to live for a year and an ephemeral mushroom to survive many months. Don't you think you are wrong?' *Pao Pu Tsŭ* answered the question by saying, 'The roaring thunder is inaudible to the deaf, the brilliant sun is invisible to the blind. Is it then right to say the thunder is low and the sun is pale? And yet the deaf say there is no roar; the blind say there is nothing. Still less can they appreciate the harmony of music or the splendour of the Emperor's dress. The deaf and the blind, having defects in their own bodies, can never perceive the activities of the atmosphere and of the heavens, easily perceptible though they are, to say nothing of more subtle things. A mind that has become a prey to imbecility, will reject even *Chou Kung* (周公) and *Confucius*, not to speak of the teaching of the *hsien*. The opposition of life to death or beginning to end is in fact only a general feature of all natural phenomena. When scrutinized in detail, they sometimes reveal that there is no such opposition. Indeed the diversity is boundless, and some things are the same in nature while they appear different. A sweeping law should never be formulated. Things which have a beginning have generally also an end, but there is no universal truth. One says that every thing grows in the summer, while garlic and wheat fade then. One says that every thing withers in the winter, while bamboos and pines flourish in that season. One says that every thing must come to end, if it begins at all, but heaven and earth have no end. It is generally said that life is followed by death, but the tortoise and the crane live forever. In summer the weather ought to be hot, but we have often cool days then. The winter ought to be cold, but we have often mild days in winter. A hundred rivers flow eastward while one large river flows northward. The earth is quiet by nature, but it sometimes trembles and crumbles. Water is cool by nature, but there are hot springs in *Wen Ku* (溫谷). Fire is hot by nature, but there is a cold flame upon *Hsiao Ch'iu* (蕭丘). Heavy matter ought to sink in water, but there are floating hills of stone in the southern sea. Light matter ought to float, but there is in *Tsang Ko* (牂柯) a stream in which a feather sinks. If a generalisation is driven too far, it always ends in error, as these abundant examples show. Thus it is not to be wondered at that the *hsien* does not die like other human beings.'

Condemning this sort of sophistry, someone put further questions to him: 'It may be admitted that the *hsien* differs very much from ordinary men, but just as the pine as compared with other plants is endowed with an extremely long life, so may not the longevity of the *hsien*, as exemplified in *Lao Tsŭ* and *P'êng Tsu* (彭祖) be after all a gift from Nature? We cannot believe that every one can learn to enjoy longevity as they did.' 'Of course the pine,' answers *Ko Hung*, 'belongs to a kind different from other trees. But as to *Lao Tsŭ* and *P'êng Tsu* they are equally human beings. Since they could live long, so also can we. Moreover I have the art of preparing the elixir of life by which one can enjoy everlasting life.' Being still unsatisfied someone protested, 'If the medicine you employ were of the same substance as our own body, it might be efficacious. But as to a medicine of wholly different origin, I shall never be convinced of its efficacy.' *Ko Hung* answered this question and said, 'You may drink an extract of hair and skin, but it will not cure your baldness.

This proves the ineffectiveness of a medicine which is of the same nature as your own body. On the other hand we can live on grain. That is a proof that something of different nature can have medicinal effect. Thus we see that the effectiveness of medicine is independent of whether it is of the same nature as our own body or not.' "

As is obvious from these quotations, the theories of *Ko Hung* are based entirely on conclusions arrived at by false reasoning by analogy.

Ko Hung eagerly searched for further instances of longevity, which are described in the chapter *Tui Su*(對俗, To worldly men). " According to *Yü Ts'ê Chi* (玉策記)), a tortoise a thousand years old is coloured in five colours. Two bones of its frontlet have grown into horns. It understands human speech. It is sometimes found on a lotus-leaf or sometimes under a bush of *shih* (蓍, the divining plant, the stalks of which were used in ancient times for purposes of divination). Fleecy clouds sometimes tortuously hang over the place where it dwells. A crane a thousand years old cries at appropriate times. It can climb a tree while younger cranes can not. It is snow white and its head is entirely red. A pine tree a thousand years old has grown more at the exterior than at the centre, so that when viewed from afar, looks like an inverted umbrella. A serpent enjoys an endless life.

A *mi hou* (獼猴, a monkey) metamorphoses into a *yüan* (猨, a gibbon) at the age of eight hundred years. A *yüan* metamorphoses in its turn into a *chüeh* (玃, a large ape) when five hundred years old. A *chüeh* lives for a thousand years. The life of a *ch'an ch'u* (蟾蜍, a large toad) is three thousand years. Tigers, deer and hares all live for a thousand years. When they are five hundred years old, their hair turns white. In general animals which have lived for five hundred years undergo a change. The fox, the racoon, the *ch'ai* (豺, a ravenous beast, akin to the dog) and the wolf all enjoy a life of eight hundred years, and when they are five hundred years old, they take on a human appearance. The life of a rat lasts for three hundred years, and when it has lived for one hundred years, it turns white. It can divine well through a human medium. It is then called *chung* (仲) and is able to tell anyone's fortune for the following year, and knows what is going on a thousand miles away."

Ko Hung writes further, quoting from *I Wên Chi* (異聞記) compiled by *Ch'ên Chung Kung* (陳仲弓): "There was a certain *Chang Kuang Ting* (張廣定) in the province of *Ying Shui* (潁水). War having broken out in the province, he fled for refuge, after throwing into a hole in a large old tomb his four year old daughter, who was a great encumbrance to him in his flight. The war was suppressed in three years, at the end of which time he returned to his village to find his daughter's remains. But to his great astonishment he found her still alive. In answer to her enraptured parents' questions, the daughter told the secret of her miraculous escape. As she went into the cavity, she said, she found in a corner something alive which was breathing by stretching its neck. She then imitated this manner of breathing, and by this means saved herself from starvation until the day of her rescue. They then looked for the living thing to which they owed so much gratitude and found it to be a tortoise." *Ko Hung* considers that the tortoise knows the art of longevity.

In fine, the point of *Ko Hung*'s theory is this: we mortals can attain longevity or even immortality if we take pains to develop our human nature; for nature is full of such examples. The fostering of life may be achieved in three ways: first, by medicines, second, by the art of breathing, third, by metaphysical thoughts. These points are fully discussed in the Inner Part of the *Pao Pu Tsŭ*. Of these three methods, we are interested only in the first, which will therefore be the subject of the next section.

3. THE MEDICINES OF THE IMMORTALS.

In the eleventh chapter "*Hsien Yao*" (仙藥, the medicines of the immortals, as found in nature) of the *Pao Pu Tsŭ* we find the following statement: —

"The best medicine of the immortals is *tan sha* (丹砂), the next best is *huang chin* (黃金), the next is *pai yin* (白銀), the next are various kinds of *chih* (芝), the next are the *wu yü* (五玉), the next is *yün mu* (雲母), the next is *ming chu* (明珠), the next is *hsiung huang* (雄黃), the next is *ta i wu yü liang* (太乙禹餘糧), the next is *shih chung huang tzŭ* (石中黃子), the next is *shih kuei* (石桂), the next is *shih ying* (石英), the next is *shih nao* (石腦), the next is *shih liu huang* (石硫黃), the next is *shih i* (石飴), the next is *ts'êng ch'in* (曾青), the next is *sung pai chih* (松柏脂), the next is *fu ling* (茯苓), ..."

So many names are given, but we are at a loss when we try to identify them. For in the first place the names of things change in the course of time. Moreover things are often named merely from their appearance, which has nothing to do with their intrinsic nature. In fact these difficulties confronted the alchemist of far by-gone days as they do the investigator of the present time. So

Ko Hung says in the eleventh chapter: "There are many medicinal herbs which have the same name as ordinary grasses, and only the expert can judge whether a herb is genuine or not. We must all be particularly careful in this respect."

We now venture to give some account of the nature of the medicines above mentioned.

Tan sha (丹砂, red sand) means cinnabar, sulphide of mercury, but sometimes, be it noted, even mercuric oxide because of its red colour; for, as will later be mentioned, alchemists thought that cinnabar upon calcination produced mercury, which upon further calcination returned to *tan sha.*

Huang chin (黄金, yellow metal) and *pai yin* (白銀, white silver) require no explanation.

Chu chih (諸芝, various species of *chih* (芝)) are really strange things. They consist of five species: *shih chih* (石芝), *mu chih* (木芝), *ts'ao chih* (草芝), *jou chih* (肉芝) and *chun chih* (菌芝), each species comprising some hundreds of varieties. They are not always organic in nature, although the Chinese character 芝 means fungi, for *shih chih* (石芝), for instance, comprises various sorts of minerals. In short, this part is the most perplexing one, but we shall make some quotations from the chapter "*Hsien Yao.*" Of the first species, *shih chih* (石芝), the following account may be given.

"*Shih hsiang chih* (石象芝) grows in a sacred mountain near the sea or on an island sea shore. It sometimes assumes the form of an animal possessing a head, a tail and four limbs. Its luminosity may be discerned in the dark at a distance of three hundred paces. A large one weighs more than ten pounds, a small one several pounds. It is crushed with three thousand six hundred strokes to powder and a tea-spoonful of it is taken three times a day. The consumption of one pound of it confers on the eater a life of a thousand years, of ten punds, one of ten thousand years." Thus its medicinal power is clearly mentioned, while its actual nature is quite obscure.

Yü chih chih (玉脂芝) is another variety of *shih chih*, "It is found only in dangerous places in a mountain that yields jade. A sort of gem-like fluid flows out, which solidifies to *chih* (芝) in the course of more than ten thousand years. It takes the form of birds or animals, has no definite colouration, resembles generally *shan hsüan shui ts'ang yü* (山玄水蒼玉, a kind of jade) and is as limpid as rock crystal. The powder made from it, when mixed with the extract of *wu hsin ts'ao* (無心草), becomes at once liquid. Anyone who consumes two litres of it may live for a thousand years." From these accounts *yü chih chih* (玉脂芝) is evidently a sort of petrified plant juice, but what it really is remains obscure after all.

In the species of *shih chih* (石芝) such substances as *shih kuei chih* (石桂芝), *shih chung huang tzŭ* (石中黃子), *shih nao chih* (石腦芝), *shih liu huang chih* (石硫黃芝) are enumerated, although in the list given at the beginning of this section, they were mentioned separately from the *chih* (芝). Some account of these medicinal minerals will now be given.

Shih kuei chih (石桂芝) is found in a cave in a sacred mountain. In spite of its external resemblance to *kuei shu* (桂樹, Judas-tree) it is a kind of stone. It is as large as one foot, brilliant in lustre and hot to the taste. By taking one pound of it in the form of powder one can attain the age of a thousand years."

Shih chung huang tzŭ (石中黃子, egg-yellow in stone) is found here and there, most frequently in the mountains near water. The large piece of stone in which it is found embedded is always wet. Several dozen layers must first be removed by hammering, and then one comes to a reddish-yellow liquid resembling the yellow of egg inside the shell. It must be drunk at once, or if allowed to solidify, must be crushed to powder before being taken. One piece of stone contains one or two litres of the liquid. If one drinks six litres of it one may live for a thousand years. It is only regrettable that it is very rare."

" *Shih nao chih* (石腦芝) is seldom found in *hua shih* (滑石, talc.). It resembles *shih chung huang tzŭ*(石中黃子). It may be found in only one out of a thousand large pieces of talc. So long as it is in the stone, it is iridescent and mobile." Thus *shih noa chih* (石腦芝) is evidently a liquid substance, occluded in stone but it is identified with a sort of *seki men* (石綿, asbestos) in a book called *Honzō Kōmoku Keimō* (本草綱目啓蒙) written by *Ranzan Ono*(小野蘭山), a distinguished Japanese physician who lived from 1729 to 1810. Thus at the time when no notion of chemical composition as an essential characteristic of substances existed, the description of their external forms alone was detailed, while their true nature was left untouched. This naturally gives rise to various kinds of misunderstanding in later times.

" *Shih liu huang chih* (石硫黃芝) is found in all the five mountains(*Wu Yo*, 五岳), and is especially abundant in *Chi Shan* (箕山). If eaten, it confers long life. *Shih liu tan* (石硫丹) is described as a red essence of stone, probably a variety of *shih liu huang* (石硫黃)." So much for the description of *shih chih* (石芝).

Mu chih (木芝) is also vaguely described. " The resin of the pine changes into *fu ling* (茯苓), when it is buried under the earth for a thousand years. A small plant grows on *fu ling* when ten thousand years old. This plant, which resembles the lotus and is called *mu wei hsi chih* (木威喜芝) is luminous at night, greasy to touch and incombustible. Whoever bears it, becomes immune from attack by weapons. For example, if it is attached to a hen and that hen placed among a dozen others, and if then, from a distance of a dozen paces a dozen arrows are shot at them, the dozen hens will be injured, while the one bearing the plant will never be hit. Dry and pulverise the plant, take one tea-spoonful three times a day and thus consume one stem and you will live for three thousand years."

One more example of *mu chih* (木芝) may be added. "The root of a thousand-year-old *kua* (栝, Chinese juniper) has the form of a sitting man and is seven inches long. When a cut is made in it, it bleeds. Cover the sole with it, and you can walk on water without sinking. Smear the nostrils with it, and you can dive into water without intrusion of water and stay a long time on the river bottom. Cover the body with it, and you will be at once invisible. If you want to make yourself visible again, you have simply to wipe it off. It is also an efficacious drug. If the disease is inside the belly, cut off one-tenth of a tea-spoonful from the belly of the root; if the disease is outside, cut out one-tenth of a tea-spoonful from the corresponding part of the root and rub it in the part affected. The disease will heal on the spot. Take it in the form of powder and consume ten pounds and you will live for a thousand years."

" *Yün mu* (雲母, mother of clouds or mica) has five varieties which can only be distinguished by examining their colours against the sun, because in the shade the different colour tones are entirely indistinguishable. The variety which is five-coloured and especially bluish is called *yün ying* (雲英). This may be taken in the spring. The reddish variety is called *yün chu* (雲珠) and may be taken in the summer. The whitish variety is called *yün i*(雲液) and may be taken in the autumn. The black variety is called *yün mu* (雲母) and may be taken in the winter. To prepare drugs from the various kinds of mica, it must be liquefied by the aid of *kuei ts'ung shui yü* (桂葱水玉) or by mixing it with saltpetre in a cylinder which is then kept under the earth or it is kneaded with honey to a paste or powdered by hammering in a leather bag after being kept in autumnal dew for one hundred days. Mica is also used in combination with *wu tien ts'ao* (無巔草) and *ch'u hsüeh* (樗血). When eaten for three years, it rejuvenates the old and makes them children again." As the reasons for this efficacy are enumerated its constancy in fire and its durability under the earth.

Ming chu (明珠) is the pearl.

Hsiung huang (雄黃, masculine yellow) is probably orpiment or arsenic sulphide. There is also *tz'ŭ huang* (雌黃, feminine yellow) but it is not mentioned in the medicines of the immortals. "The mineral found in *Wu Tu Shan* (武都山) is very pure. As medicine we value the kinds which are as red as a cock's comb and have brilliant lustre. Other kinds cannot be used as *Hsien* drugs. It may be taken after boiling with water or may be drunk with wine. By the aid of saltpetre it may also be made into a solution, which is then solidified. When mixed with saltpetre, pig's darm and pine-resin it yields a paste which is as white as snow and may be rolled out as thin as cloth. If it is eaten it confers long life and immunity from various diseases, gray hair turns black and fallen teeth grow anew." Thus complete rejuvenation can be attained with this drug. It may contain oxides of arsenic as the products of the oxidation of orpiment by saltpetre, and we know to-day that arsenious oxide when used in proper doses, is efficacious in promoting health but when taken in excess causes immediate death.

Ta i wu yü liang (太乙烏餘糧). According to the *Pên Ts'ao Ching*, the long use of this drug confers on the user resistance against hard weather and starvation, the quality of buoyancy and the ability to fly a thousand miles. It is sometimes identified with *shih nao* (石腦).

Ts'êng Ch'ing (曾青). According to the *Pên Ts'ao Ching*, *ts'êng ch'ing* has an acid taste and is a little cold in nature, is not poisonous and is mainly used as an eye-wash. It is also good for diseases of the joints and the nine passages of the body. When taken long, it produces agility and lasting youth. It changes into gold and copper. It is found in the mountains of *Shu* (蜀) and *Yüeh Sui* (越巂) and may be collected at any time. As to its nature, a book called *Tan Fang Ching Yuan* (丹房鏡源) states that *ts'êng ch'ing* combines with mercury to yield *tan sha* (red sand) and that it is born of copper." It seems to resemble *k'ung ch'ing* (空青) which is formed on fumigating the essence of copper. From these descriptions we may infer that this mineral is either sulphate or basic carbonate of copper. *Honzō Kōmoku Keimō* (本草綱目啓蒙) identifies it with *iwakonjō*(岩紺青, a rock-pigment).

Sung pai chih (松柏脂), *fu ling* (茯苓) and others are all of vegetable nature. Some of them are identifiable, but we have great doubt as to their medicinal value. These points require further study.

In short, only the names of the drugs of the immortals have been handed down to us, while what they really are is well nigh unknowable. Some of them may still exist under other names, while some of the names given to them are still in use for other substances. Moreover it is doubtful whether the drugs are really efficacious. In explanation of the reason why *tan sha* (丹砂, cinnabar) occupies the first place, preceding gold in the list of the drugs of the immortals, the following quotations from the chapter *Chin Tan* may be adduced. "All plants are reduced to ashes upon burning. *Tan sha* when calcined changes into mercury, which turns again into *tan sha* upon further calcination and thus it differs very much from plants. Hence it is able to confer longevity upon man." From this passage it is evident that the first *tan sha* is cinnabar and the second mercuric oxide. They were taken to be the same substance, because they are equally red. "The ordinary man knows little and doubts much. He can never be convinced of the fact that red sand yields mercury, but says, 'Red sand is red in nature; how can it give rise to a brilliant substance?' or '*Tan sha* is a mere stone. Stone always becomes ashes when calcined. How can red sand alone be an exception?' Thus with the ignorant it is very difficult to reason upon such a simple fact. We may well expect that they should laugh at the teaching of the immortals when they hear it."

"Gold may be thrown into the fire and wrought a hundred times without losing anything; it may be buried in the earth without decaying till the end of heaven." It is obvious from these passages that the ancients seem to have noticed the peculiar property of mercury and gold, that they survive a series of chemical reactions, and consequently to have come to the belief that this supreme quality might pass over into the body of the eater, to make it unchangeable and unfading. As will be mentioned in the next chapter, however, gold can remain in the compounded preparation, while mercury is lost during the process, which is indeed fortunate since the resulting drug happens to be free from poisonous mercury. And yet the alchemists believed in the importance of mercury as an efficacious ingredient of the compounded elixir. On the other hand, mercury is essential in the process of making gold. This fact, that mercury played an important rôle in the domain of the alchemy of longevity as well as of gold-making, is probably the reason why mercury is placed before gold in order of medicinal potency. As to the other drugs, some may be more or less efficatious, while others may be formidable poisons.

4. THE ART OF GOLD-MAKING.

i. Recipes for Gold-Making.

As to the theory of the making of gold, we may refer to some passages in the sixteenth chapter of the *Pao Pu Tsŭ,* called *Huang Pai* (黄白, yellow and white or gold and silver), where *Ko Hung* argues the possibility of the transmutation again by using the reasoning of analogy. Nature is full of changes, he says, so why should it be possible that gold and silver alone should not be produced from other substances. May we not, however, venture to suggest that the earlier theories of the transmutation of metals of the East and the West had some fundamental concepts in common? The ancients both of the West and the East thought that all things consisted of a certain small number of fundamental elements or properties. They were distinguished from each other only by their different contents of these fundamental units. So one thing might be transformed into another by changing its composition by proper treatment. That is the reason for the belief in the possibility of producing gold artificially. In the West there originated the strange concept of the Philosopher's Stone as the means by which this transmutation could be effected; but no such curious thing is to be found in the *Pao Pu Tsŭ.* In this book the matter is treated clearly as if gold were produced as a result of complex chemical change. As the Chinese alchemists believed gold to be produced from other substances, they used raw materials which they thought contained no gold and at the end of the alchemical treatments, obtained gold, as they insisted. This is the practical feature of Chinese alchemy. Now the point is whether the process, as viewed from the modern chemical standpoint, is a reasonable one for producing gold. There would be no need to discuss this point if no gold was produced; but since it is insisted that gold was obtained, it may have been, at least very occasionally. Then the raw material must necessarily have contained a certain amount of gold, and we must examine the raw materials to see which of them was really a gold ore. If any gold ore is found among them and the alchemical process employed was in conformity with the principles of modern metallurgy, the alchemy of China will prove to have been an exact science. This certainly would contribute much to the appreciation of Oriental science and art. Keeping these points in view, we now proceed to inquire into the true features of the Chinese art of gold-making. The chapter *Chin Tan* (金丹, Golden Drug) of the *Pao Pu Tsŭ* contains various methods of gold-making; one of them may be given here as an example. "Mix several dozen pounds of each of the following nine substances: *hsiung huang shui* (雄黃水), *fan shih shui* (礬石水), *jung yen* (戎鹽), *lu yen* (鹵鹽), *fan shih* (礬石), *mu li* (牡蠣), *ch'ih shih chih* (赤石脂), *hua shih* (滑石) and *hu fên*

(胡粉)."

The mixture is called *hsüan huang* (玄黃) and since *hsüan* means the colour of the heavens, and *huang*, the colour of the earth, this name may, as I suppose, suggest that the mysteries of Heaven and Earth are contained in this mixture. As to the nine substances we know hardly anything except their names, but the name of a substance without any essential specification such as the chemical composition is very often of no use, because the name of a substance has often changed in the course of time, and also the substance indicated by a name. Our present task is therefore to search for substances which correspond to the nine names. For this purpose we can fortunately make use of some explanatory notes of *Ko Hung* himself and *T'ao Hung Ching*'s commentary on the *Pên Ts'ao Ching.*

Hsiung huang (雄黃) and *hsiung huang shui* (雄黃水). *Hsiung huang* is, as has been mentioned above, orpiment, provided that this mineral was formerly called by the same name as to-day. Orpiment gives *hsiung huang shui* (雄黃水) when dissolved, and the method of dissolving it is given by *Ko Hung:* "A pound of this mineral is placed in a raw bamboo cylinder and then two ounces of saltpetre are added; it is then stoppered with straw at both ends, sealed with *ch'i ku wan* (漆骨丸, an unidentified substance) and kept under genuine vinegar at a depth of three feet." The specification of the depth has presumably to do with the hydraulic pressure which is sufficient to press the vinegar into the cylinder. "The contents of the cylinder dissolve in twenty days." The change which might occur is probably the disintegration of the gangue materials, the orpiment naturally remaining unaffected.

Fan shih (礬石). According to the *Pên Ts'ao Ching, fan shih* is cold in nature and acid to the taste, pale blue in colour and able to change iron into copper. It is therefore probably copper sulphate. When dissolved in water, it gives *fan shih shui* (礬石水). *Fan shih* is usually identified with alunite.

Jung yen (戎鹽). According to the *Pên Ts'ao Ching, jung yen,* also called *hu yen* (胡鹽) is salty to the taste, not poisonous, and is found in *Hu Yen Shan* (胡鹽山), *Hsi Ch'iang* (西羌) and in the northern districts ; it is usually white, rarely blue, red or violet, and melts in summer. These descriptions remind us of rock salt or the carnallite obtainable in a rock salt layer. The principal component of *jung yen* is then sodium chloride mixed with some potassium and magnesium salts.

Lu yen (鹵鹽) is a kind of alkali salts. According to a specialist of the *Pên Ts'ao* this may, however, be identified with *jên chung pai* (人中白). *Jên chung pai* is also called *tien* (澱, precipitate), *ch'ien nien ping* (千年氷) or *wan nien shuang*(萬年霜). This was one of the raw materials employed by the scholars of the art of *hsien* and made from the human urine. It is therefore supposed to be a mixture of ammonium chloride, urea, and other organic substances.

Mu li (牡蠣). This was made by calcination of shells and contains calcium carbonate as the main component.

Hua shih (滑石). If this substance is the same as what we now call by this name, *hua shih* is talc, its main component being acidic magnesium silicate.

Hu fên (胡粉). This substance is white lead. Its main component is basic carbonate of lead.

Ch'ih shih chih (赤石脂, red stone fat). The above-mentioned eight substances have, I believe, been correctly identified. Obviously none of them can be considered as a gold ore. The remaining one *ch'ih shih chih* (赤石脂) now becomes the centre of the problem. In the *Pên Ts'ao Ching* mention is made of five varieties of *shih chih* (石脂) which are distinguished by their colour, namely blue, red, yellow, white and black *shih chih*. According to *Ranzan* (蘭山)'s *Honzō Kōmoku Keimō* (本草綱目啓蒙), *shih chih* is something exuded by stone, it is found in stone or in earth; medicinal power exists mainly in the red and white varieties. Thus *Ranzan* seems to have concentrated too much on the word *chih* (脂, fat) and left *ch'ih shih chih* unidentified. It is also doubtful whether the description of *Ranzan* can be applied to the substance that *Ko Hung* meant. Judging from its name, *shih chih* seems to have a resinous lustre and a greasy feel. In fact *Ranzan* identified the name *hei shih chih* (黑赤脂) with graphite. To return to *ch'ih shih chih* (赤石脂), the *Pên Ts'ao Ching* says, "It is peach-red in colour and becomes lustrous when rubbed with the nail. The variety which is fine grained and adheres to the tongue is the best in quality." The *Tz'u Yüan* (辭源, a Chinese encyclopaedia) says, "*Ch'ih shih chih* is a kind of weathered stone and is found in *Chi Nan* (濟南) and *Wu Chun* (吳郡) and elsewhere; vividly red; it grows again when removed; the best variety adheres to the tongue. In the biography of *Shih Ch'ung* (石崇) in a book, called, *Chin Shu* (晉書) it is stated that *Ch'ung* (崇) painted his house with *chiao* (椒, a spice-plant), while *Wang K'ai* (王愷) used *ch'ih shih chih* (赤石脂) for the same purpose in order to keep pace with him." As may be supposed from this quotation, *ch'ih shih chih* was a costly substance in the time of *Chin*. To-day it is low in price and used as chalk by tailors. I have been told that *ch'ih shih chih* as a drug is now used against diarrhoea by physicians of the Chinese school. Since in this way no decisive conclusion was to be obtained from books, I turned to the investigation of the matter from the chemical view point. All the sorts of *ch'ih shih chih* now obtainable were collected and analysed. They turned out to consist mainly of oxides of iron, mixed with clay or silica. *Ch'ih shih chih* may then be synthesized by mixing clay with finely pulverized red ochre, but since it carries the distinct name *ch'ih shih chih,* it is probably a natural product which grows from a ferriferous mother ore by weathering. In this respect we agree with the *Tz'u Yüan.* Now, ferriferous ore does not always contain gold, but one auriferous rock which can yield a red substance on weathering is a siliceous gold ore. Since the weathering takes place in the part which is exposed to the atmosphere, that is, in the outcrop of the vein, it is possible that an alchemist happened to come across such an outcrop during a journey in search of *ch'ih shih chih.* Thus the assumption that the ancient *ch'ih shih chih* might sometimes contain some gold becomes more probable. Consequently, the high price of *ch'ih shih chih* at the time of *Chin* (晉) may also be understood, for it must have been such a special species, while the *ch'ih shih chih* of to-day can be any low-priced sort of red iron oxide. Such cheap material may not contain gold, though I have not analysed it myself.

It may be added that a gleam of hope of solving this problem still remains in an unexpected direction. This is the actual existence in our country, of a specimen of *ch'ih shih chih* which was collected during the *T'ang* dynasty, that is, only two or three centuries after the *Chin*. Its history is this: This specimen of *ch'ih shih chih* was presented by the *T'ang* Court to our Imperial Family, and having been donated by the Emperor *Shōmu* (聖武) to the *Tōdaiji* (東大寺) temple, it has been kept in good condition for more than a thousand years. We can have the honour of seeing it even to-day in the *Shōsōin* (正倉院) at *Nara* (奈良). In appearance it differs little from the *ch'ih shih chih* on the market to-day, but may we not assume that this *ch'ih shih chih* possibly contains gold? Although we must not be irreverent enough even to think of analysing it, since it is an Imperial Possession, I have ventured with deep respect and actuated solely by my humble desire to benefit science, to wonder whether the secret-key of alchemy could possibly be hidden in it.

ii. Chemical Reactions of Gold-Making.

The nature of each component of *hsüan huang* (玄黃) has become more or less clear by the description given above. With these substances was prepared a paste, called *liu i ni* (六一泥) which was then heated for thirty-six days. As fuel, horse dung was often used, as is stated in the sixteenth chapter of the *Nei P'ien* of the *Pao Pu Tsŭ*. The fact that the dung of an animal was esteemed as fuel, reminds us of the Arabians who think highly of camel dung, and by way of suggestion may throw some light on the question of a possible relationship between Eastern and Western alchemy. After thirty-six days of heating, the compounding of *tan hua* (丹華) was completed. The compounding was regarded as successful if gold was found in the product, there being two ways of testing for gold. The first method was to add a hundred pounds of mercury to two hundred and forty grams of the product and heat the mixture. In this way gold, if it was present, came out into the mercury. The other method was to knead the product with *hsüan kao* (玄膏) into a ball. The nature of the latter substance is not clear, but whatever it may be, since *tan hua* contains metallic lead, gold will remain after the lead has been burnt off. Of the two methods, the former corresponds to the amalgamation process of to-day and the latter to cupellation. It may be suggested that these two processes may in their very beginning have been originated by *hsien* and passed from place to place and from hand to hand in the course of time till at last they were developed into the completed form of the metallurgy of the present day. In this way we come to the belief that the *hsien* did not deceive their contemporaries with false arguments and that the *tan hua* really contained gold sometimes, if not always.

Since everything connected with *hsüan huang* and its treatment is important, the whole text is given here for reference.

第一之丹名曰丹華。當先作玄黃。用雄黃水，礬石水，戎鹽，鹵鹽，礬石，牡蠣，赤石脂，滑石，胡粉，各數十斤。以爲六一泥。火之三十六日成。服之七日。仙。又以玄膏，丸此丹，置猛火上。須臾成黃金。又以二百四十銖，合水銀百斤火之。亦成黃金。金成者藥成也。金不成，更封藥而火之。日數如前。無不成也。

We now proceed to examine the chemical reactions which occur during the heating of *hsüan huang* in order to see whether gold, if it existed at all in the raw material, could be obtained in this way. If we assume *ch'ih shih chih* to be a gold ore, it is an acidic silicate with some gold and iron. In order to separate gold from the mother substance, some sort of basic mineral must be added, so as to cause the silicate to slag. Of the components of *hsüan huang*, those which meet this purpose are the calcium in *mu li* (牡蠣), the copper in *fan shih*

(礬石) and the sodium in *jung yen* (戎鹽), while talc may serve as flux. If therefore the materials were taken in due proportions, the metallurgy of gold must be regarded as possible in the way *Ko Hung* prescribed.

Orpiment, containing arsenic and sulphur, reduces *hu fên* (胡粉) to lead,[1] (and *lu yen* (鹵鹽) might supply organic matter and ammonium salts), which in its turn, as the reaction proceeds, dissolves separated gold, forming a distinct layer. The solidified lead can be worked for gold either by mere roasting or by amalgamation. In this light, the composition of *hsüan huang* may be regarded as appropriate for the metallurgy of gold, the proportions of the mixture being of decisive importance. The metallurgist of to-day would of course choose more reasonable substance, but the ancient alchemist merits the highest praise for having reached such a degree of proficiency without any leading scientific principles.

The orpiment seems also to have had another important mission. The object in compounding *tan hua* (丹華) was not solely to manufacture gold but at the same time to prepare drugs. Gold has no such medicinal power as was once supposed. In order that *tan hua* may be effective in prolonging

1) The reaction, once started by heating, proceeds spontaneously with a considerable evolution of heat.

life, it must contain some other efficacious ingredient and this ingredient seems to come from the orpiment. During the process of compounding, the greater part of the arsenious oxide from the orpiment would escape and only a small portion of it would be left in the product, which must therefore have been an effective medicine when eaten. If it happened to contain a much larger quantity of the oxide, the eater would die on the spot, and in fact there are frequent references in Chinese history to Emperors who died upon taking the drugs of the immortals.

In fine, the conclusion is that the Chinese alchemy of gold-making is not to be regarded as sheer falsehood. The process was a reasonable one, if not perfect, for it employed all the materials necessary for metallurgy, among which was included a substance which might be auriferous. The alchemists, however, did not know where the gold came from and consequently came to the erroneous belief that the gold was produced by transmutation.

iii. Another Recipe for Gold-Making.

We have discussed at sufficient length the methods mentioned in the chapter *Chin Tan* (金丹), and now proceed to deal with another. The sixteenth chapter of the Inner Part, *Huang Pai*(黃白, Gold and Silver) contains among other things a method called *hsiao erh tso huang chin fa* (小兒作黃金法, a method of gold-making for ordinary people). This method seems to be, if it is not certainly, a form of the cupellation process. Two iron cylinders of different sizes were made and well polished. The following substances were then pulverised and mixed intimately to a paste by adding a quantity of vinegar; *ch'ih shih chih* (赤石脂) one pound, saltpetre one pound, mica one pound, *tai chê* (代赭) one pound, sulphur half a pound, *k'ung ch'ing* (空青) four ounces and *ning shui shih* (凝水石) one pound. Of the raw materials here given, *ning shui shih* is, according to the *Pên Ts'ao Ching*, probably table salt bittern. *Tai chê* is, as the same book teaches, like a hen's liver. To-day a substance called *tai chê*, which consists mainly of iron oxide, is used as a pigment. The smaller cylinder was lined internally two-tenths of an inch thick with the paste. Another substance called *liang fei* (良非) was also prepared, in the following way: " Ten pounds of lead is placed in an iron pot and heated from the outside. Three ounces of mercury are added to the molten lead. The first portion that can be taken out of the pot by means of an iron spoon is called *liang fei* (良非). Half a pound of this substance, one pound of mercury and half a pound of *tan sha* are well mixed, until drops of mercury became invisible. The mixture is put into the smaller cylinder and covered with mica. The cylinder is then closed with an iron lid, and placed in the larger cylinder, into which molten lead is then poured until the small cylinder is submerged half an inch from the top. After the cylinders have been heated for three days and nights on a strong fire, the lead being kept molten, a substance called *tzŭ fên* (紫粉, purple powder) makes its appearance. In order to obtain gold from this powder, ten pounds of lead are kept molten in an iron pot for about twenty days, then transferred to a copper pot and further heated to melting. Seven spoonfuls of the powder are then added and stirred in. Gold will appear. In order to make silver, mercury is placed in an iron vessel to which three spoonfuls of the powder are added and after being properly heated, the mixture is thrown into water. Silver will appear."

The full text is given below for reference.

作大鐵筩成。中一尺二寸，高一尺二寸。作小鐵筩成，中六寸。瑩磨之。赤石脂一斤，消石一斤，雲母一斤，代赭一斤，流黃半斤，空青四兩，凝水石一斤，皆合搗細篩。以醯和塗之小筩中。厚二分。汞一斤，丹砂半斤，良非半斤。取良非法，用鉛十斤。內鐵釜中。居爐上，露灼之。鉛銷內汞三兩。早出者以鐵匙抄取之。名曰良非也。攪令相得，以汞不見爲候。置小筩中。雲母覆其上。鐵蓋鎮之。取大筩居爐上，銷鉛注大筩中。沒小筩中，去上半寸，取

銷鉛爲候。猛火炊之。三日三夜成。名曰紫粉。取鉛十斤於鐵器中銷之。二十日上下。更內銅器中。須鉛銷，內紫粉七方寸匕，攪之。旣成黃金也。欲作白銀者，取汞置鐵器中。內紫粉三方寸匕。火令相得，注水中。卽成銀也。

I shall not try to give any explanation of this process. The point is that gold remains after the lead has been roasted away. If the alchemists thought that the lead was transmuted into gold, they were of course mistaken, but there is no cause for wonder if there was gold in the lead from the beginning and this remained unchanged after the complete oxidation of the lead.

CHAPTER II. BRONZE ARTICLES

1. THE SIX RECEIPTS FOR BRONZE

Just as alchemy was in no wise different from chemistry of the degree of perfection appropriate to the age, we recognize another branch of chemistry in more familiar and more widespread arts, in which various chemical goods were produced to satisfy the more practical desires of mankind. Chemistry in this sense existed from very ancient times in China as well as in Japan. In pursuing the historical study of this kind of chemistry, metal articles above all are invaluable, for they have generally been preserved in good condition and thus reveal the undistorted features of the art of manufacturing of each age. In this respect the bronze articles of ancient China and the swords characteristic of Japan provide us with precious materials. Indeed, they indicate the high degree of perfection attained by the chemical art of these countries in very ancient times, so far as these articles are concerned. I have for many years been engaged in the study of metal work of these kinds in their chemical aspects, with a view to contributing to a deeper insight into the cultural history of the Far East. To begin with, some account of Chinese bronzes may be given.

Archaeologists used to divide the history of the progress of human culture roughly into three stages, namely, the Stone Age, the Bronze Age and the Iron Age. Bronze articles are thought to have been in use from tolerably ancient times. This is very reasonable, for copper was found abundantly in the native state and tin as well as copper could be obtained from ores by comparatively primitive methods. The bronze age extended over a vast interval of time, in the course of which artistic skill changed considerably, while each nation fostered the particular arts in which it specially excelled. The Chinese bronzes are indeed unique in their exquisiteness. The *Hsia* (夏) and the *Yin* (殷) dynasty which flourished two thousand years B.C. left us many marvelous master-pieces of bronze-work. Moreover in the tenth century B.C. a book called *Chou Li K'ao Kung Chi* (周禮考工記, the Artificers' Record, the sixth part of the *Chou* Ritual) was published during the *Chou* dynasty.

This book contains the so-called "Six Receipts of *Chin*" (金之六齊), according to which the composition of bronzes is varied stepwise from one to another, their properties changing accordingly. To each kind of bronze is given the names of the articles which may most suitably be made of it. It is interesting to see whether these receipts are reasonable, and whether the bronze works of that age are of the composition prescribed by the "Six Receipts." Such an investigation would enable us to judge how far the chemistry of the *Chou* dynasty had advanced.

An explanation of the "Six Receipts" of *Chin* may first of all be given. The "Six Receipts," literally translated, run as follows: "The *chin* is divided into six, tin occupies one. This is the receipt for bells and tripod-kettles. The *chin* is divided into five, tin occupies one. This is the receipt for axes and hatchets. The *chin* is divided into four, tin occupies one. This is the receipt for halberds and trident spears. The *chin* is divided into three, tin occupies one. This is the receipt for swords. The *chin* is divided into five, tin occupies two. This is the receipt for writing-knives and arrow-heads. The *chin* and tin are half and half. This is the receipt for mirrors." Here the problem is the real meaning of *chin*. *Chin* can generally mean every metal. Of the three metals with which the receipts are concerned, either bronze or copper may be identified with *chin*, for there is no doubt with regard to tin. If *chin* means bronze, however, the last receipt will become meaningless. It must, therefore, indicate copper, at least in the last receipt. It may, however, be reasonable to assume that *chin* has one and the same meaning throughout the receipts. The compositions prescribed in The "Six Receipts," expressed in percentages, will then assume the following figures :

Articles.	Cu	Sn
1. Bells and tripod-kettles	86	14
2. Axes and hatchets	83	17
3. Halberds and trident spears	80	20
4. Swords	75	25
5. Writing-knives and arrow-heads	71	29
6. Mirrors	50	50

It may be of interest to examine the "Six Receipts" in the light of modern metallographical knowledge, and see whether the resulting materials are suitable for the articles mentioned therewith. In the system of the copper-tin alloys, those which contain eight to nine per cent. of tin are still red, but a little harder than pure copper. Such alloys may be used as stamping metal. Bronzes which contain twelve to thirteen per cent. of tin are called gun-metal. They are strong and hard and have a beautiful yellow tint. They were formerly used, as their name indicates, for casting guns, but today they find an extended technical use in other directions. As the content of tin increases to from about fifteen to twenty per cent., the alloys increase in hardness and take on a pale yellow tinge ; the strength decreases but the bronze is not yet too brittle. These alloys are used for casting bells, because such bells ring loud and clear. As the tin content proceeds beyond twenty-five per cent., the colour becomes paler and the brittleness increases. The alloy containing thirty per cent. of tin is called specular metal; it is almost white, as hard as quenched medium steel and has from early times been used for casting mirrors.

As the tin content increases further, the alloy becomes more brittle and less hard and can not be used for any practical purpose. If the tin content far exceeds that of copper, the alloy assumes largely the properties of tin. The alloy called bearing metal, for instance, is abundantly used because of its peculiar properties, but this kind of alloy can no longer be regarded as bronze and must be excluded from the present consideration. In short, the tin content of bronze is limited to the range of from nil to thirty per cent.

Turning back again to the "Six Receipts," we find that they do not include alloys containing less than fourteen per cent. of tin, but these may be regarded as included in the first receipt, or in other words, fourteen per cent. meant the upper limit of the tin content in the first receipt. The articles made of bronze of this range may most profitably be used where strength is the first requisite. Bells ring the clearer the harder the metal is, while brittleness is an enemy of large bells. In this respect the upper limit of the first receipt is in conformity with the modern metallographical view. The receipt for axes and hatchets places the upper limit at seventeen per cent. Since the axe, being a chopping-tool, must be sharp as well as strong, a slightly greater tin content than that of the first receipt is reasonable. Halberds, spears and swords are used rather for cutting and thrusting than for chopping, and consequently the limitation of tin to between twenty and twenty-five per cent. is irreproachable. The bronze containing twenty per cent. of tin is still pale yellow but bronze with twenty-five per cent. of tin is already white and assumes when polished a shining trenchant appearance. In fact it has a tolerably high degree of hardness, the only drawback being that bronze of this kind is rather brittle. This drawback may, however, be remedied by giving the weapons a suitable shape. Thus to the main point of a halberd were added several additional points, while the sword blades were made straight. The bronze of the fifth receipt was used for curved pointed knives for writing on bamboo and arrow-heads. In these articles sharpness is the most important factor while brittleness matters little, because they are of small size. Such bronze may therefore contain as much as thirty per cent. of tin. Lastly, in the receipt for mirrors, equal amounts of copper and tin are prescribed, and with the alloy thus produced, two kinds of mirrors, *chien* and *sui*, were made. *Chien* (鑑) means an ordinary mirror, while *sui* (燧) was a concave mirror for collecting the sun's rays to make fire. As a matter of fact, bronze containing thirty per cent. of tin has been recognized from early times as the best for mirrors, and this is also borne out by modern metallographical investigations. The sixth receipt prescribes too high a percentage of tin. In reality, as long as the tin content is no higher than thirty-two per cent., bronze is pure white and hard, capable of taking the fine polish required for a mirror surface and resistant enough for the surface to remain bright for a long time. Since the alloy with fifty per cent. of tin lacks all these good qualities, the ancient Chinese mirrors could not really have had the actual composition prescribed by the receipt; as shall be shown later, the tin content on analysis did not exceed thirty per cent. Consequently, I venture to suggest that the sixth receipt does not really mean what it says, that the author's rhetoric overpowered his real meaning; that is to say, his pen, inspired by the fine passages of the preceding receipts, was wielded so freely as to give rise to this exaggeration. It would be better not to lay stress on the numerical value itself; the receipt should rather be interpreted as an indication that more tin must be used in the alloy for mirrors than in the one for arrow-heads. Interpreted in this way, all the "Six Receipts" become generally speaking reasonable and correct.

2. METHOD OF ANALYSING BRONZE ARTICLES.

Chemical analysis of the ancient bronzes is necessary in order to see how the standard receipts of the *K'ao Kung Chi* were actually followed by the artisans of old China. As samples for this purpose the bronze objects of the *Chou* dynasty are naturally the most desirable. But if they are inaccessible, those made in the *Han* dynasty, especially in its earlier period, may serve. Fortunately, owing to their high power of resistance against corrosion, bronze articles retain their original features more or less intact even after lying buried in the ground for more than two thousand years, and thus afford really valuable material for investigation. They are often dug up and brought on the market. In my endeavours during the past twenty years to collet such materials I have received valuable aid from various quarters. In this respect I am indebted above all to the Institute of

Archaeology of the Kyoto Imperial University and to Colonel *Mantaro Watanabe* (渡邊滿太郎), at the time attached to the Peking-Government, who have kindly supplied me with various materials otherwise inaccessible. Mirrors in particular were collected from all parts of China, Korea and Japan until the collection included more than one hundred pieces, partly in perfect form, partly fragmental.

In the analysis of bronze articles I have made use of my own method. The excavated bronzes are almost always covered with rust and earthy matter which used to be removed for the purpose of analysis. It depends, however, upon the condition of the article, whether the earthy substances can be completely removed from the surface, and if the rust is removed the composition of the rest differs more or less from the original. For, though bronze is a solid solution of copper and tin, these two metals do not change into rust in exactly the same proportion as that in which they exist in the metal. The more basic copper abounds more in the rust, while the less basic tin remains in the mother substance more or less increased above its original percentage. Thus the analysis of an article freed from its rust does not give its composition in the original unrusted condition. My method was devised to avoid this unfortunate circumstance. The essential point in the method is that the sample with all its rust and adhering earth, is dissolved as a whole and the amounts of metals present in the filtrate are determined. If the residue is not free from metals, these are separated from the earthy matter by a suitable treatment and measured. It is of course best if the sample can be so dissolved by some suitable means that all the metals present go into solution in one process. In this way the correct composition of the original unrusted metal article may be obtained. It may be noted that even with this method no reliable results will be obtained if the sample to be analysed has already lost any portion of its rust. The fault in that case, however, lies in the sample itself and not in the method.

The usefulness of my method is borne out by the following example. As will be mentioned below, some ancient Chinese coins were subjected to analysis by my own method, while the elaborate analysis of such coins was also undertaken by Dr. *Norimasa Koga* (甲賀宣政), an engineer of the Imperial Mint at Osaka, and the results were published in the thirty seventh annual report of the Mint. The results were, on comparison, found to be essentially in agreement. The method adopted by Dr. *Koga* was the usual one, the most perfect and unrusted coins obtainable being employed, specimens which are naturally not accessible to the ordinary investigator, who has to make the best of poor materials. Nevertheless good results can still be obtained with them if suitable precautions are taken in sampling. In this respect my own method is, I venture to think, perfect.

3. THE RESULTS OF ANALYSIS OF BRONZE ARTICLES.

In this section we shall give the results of the analysis of various bronze articles, beginning with those related to the receipt for bells and kettles.

1. Axe head(a). This seems to be an axe used in music and dancing, and not for practical purposes but brittleness is not desirable. The result of the analysis is :

Copper	Tin	Lead	Copper : Tin
92.08	4.94	0.55	95 : 5

The axe here shown was made in the Western *Han* dynasty and is said to have been disinterred in *Lo Yang* (洛陽).

2. Axe head(b). The axe head shown in the photograph is also a work of the Western *Han* dynasty. The analysis gave :

Copper	Tin	Lead	Copper : Tin
92.90	5.54	1.46	94 : 6

The tin content is too low, when compared with the seventeen per cent. of tin prescribed in the receipt for axes and hatchets, but if stress is laid upon strength rather than upon sharpness, the composition may nevertheless be suitable.

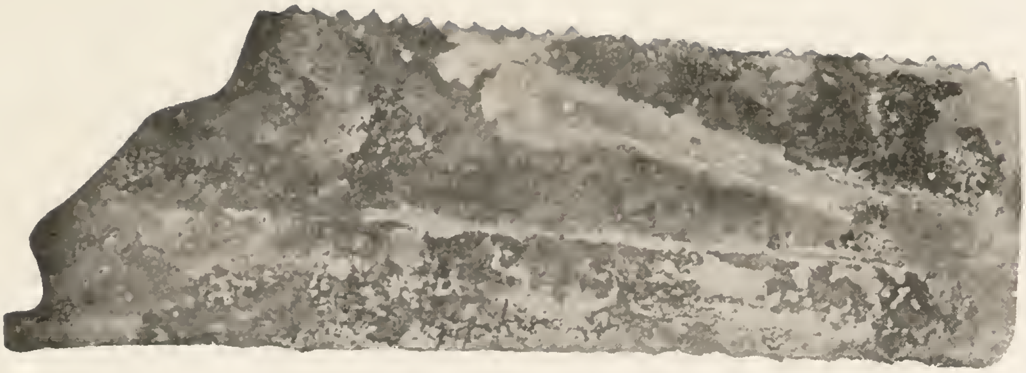
3. Saw. For sawing such material as metal, extreme hardness is necessary, but for the ordinary purpose of sawing wood and bamboo, a strong saw would be more desirable than a hard one. The saw here shown bears out this view, for it is an example of rather low tin content. The analysis gave:

Copper	Tin	Lead	Copper : Tin
80.73	11.23	7.63	88 : 12

4. Ploughshare. In this article also the composition resembles that prescribed in the first receipt.

Copper	Tin	Lead	Nickel	Copper : Tin
71.10	9.54	18.98	0.38	88 : 12

The ratio is almost exactly that which the first receipt requires. The content of lead is rather high; indeed one of the characteristics of Chinese bronze is that it always contains lead. Sometimes the content is so low that it may be regarded as a contamination originating in the tin, but in the examples thus far given, there is so much lead that it is justifiable to assume that the lead was purposely added. This problem will be discussed more fully in the description of the *Han* mirrors; it may merely be suggested here that the higher content of lead is associated with the lower tin content.



Saw

Ploughshare

p, 66=67 (1)

5. The next example is an instrument which was thrust into the ground like a spade, to turn it over. The one shown in the photograph belongs to the Western *Han* dynasty. The result of the analysis is:

Copper	Tin	Lead	Copper : Tin
81.00	13.14	4.65	86 : 14

Lead is present here too. The ratio of copper to tin just corresponds to the proportion given in the first receipt.

6. Bells and kettles. As examples of these articles, we analysed a number of specimens of a particular object called *t'ung to* (銅鐸, a kind of bell with a clapper) which were found in several localities in Japan. The first of them was excavated as early as the *Nara*-period, and they belong to such ancient times that it has so far been impossible to discover who used them. According to the results of the analysis, the tin content is in no way constant and extends over a rather wide range. Some examples are given below.

	Place of excavation unkown	Excavated in the province of *Iga* (伊賀)	Excavated in the province of *Yamato* (大和)
Copper	68.96	87.99	86.49
Tin	15.45	5.66	5.09
Lead	5.63	5.80	8.37
Antimony	8.32	—	—
Iron	0.04	0.12	0.4
Nickel	1.35	—	—
Arsenic	trace	—	—

Many more samples were analysed but the results need not be given. Generally speaking, the older and smaller *t'ung to* contains more tin. Those with around sixteen per cent. of tin comform to the first receipt. A small bell-shaped coin about one inch high, which is said to have been current in the Period of Spring and Autumn was also analysed. The results are:

Copper	Tin	Lead	Antimony	Iron	Nickel	Arsenic	Copper:Tin
67.53	16.52	10.84	1.83	—	0.92	2.36	86 : 14

This ratio is in good agreement with that of the the bell receipt. It may be mentioned in passing that our present private foundries employ bronze containing fifteen per cent. of tin for casting bells, which might suggest that this doctrine of *Chou* has possibly been handed down to our generation. Ancient bells contain also lead, a fact which is worthy of notice. No kettle has yet been subjected to analysis.

7. Weapons. According to the three receipts for weapons the tin content ought to range from twenty to thirty per cent. No such range, however, is to be seen in the results of analysis.

Swords

No.	Copper	Tin	Antimony	Arsenic	Nickel	Iron	Lead	Copper: Tin
1	73.34	19.84	3.80	0.55	2.47	—	—	78:22
2	69.31	12.55	2.30	3.01	3.52	1.37	7.92	84:16
3	66.60	14.13	1.93	trace	2.93	0.09	1.32	84:16
4	71.93	16.19	—	—	1.05	—	10.83	82:18

Spade

Sword (4)

Halberd (2)

p. 68=69 (1)

Halberds

No.	Copper	Tin	Anti-mony	Arsenic	Nickel	Iron	Lead	Copper : Tin
1	73.35	17.84	—	trace	—	—	9.17	80:20
2	73.49	23.11	1.25	—	—	—	1.70	76:24
3	69.56	14.48	—	—	0.10	—	11.86	79:21

The weapons above cited contain tin to the extent of from sixteen to twenty-five per cent. Such bronze varies from pale yellow to white in colour and has a high degree of hardness and sharpness. In this respect, the compositions are suitable for weapons and substantially correspond to those prescribed in the "Six Receipts."

8. Arrow-heads. The following analytical results were obtained for arrow-heads (p. 70).

As the table shows, the tin content of the arrow-heads is generally very high and in some cases attains even thirty per cent., though some of the Japanese arrow-heads are very poor in tin. In this respect the arrow-heads are in conformity with the fifth receipt. The arrow-heads of the *Han* dynasty are tolerably rich in tin but not quite rich enough. In them, the tin appears to be partially replaced by antimony, which probably has the same power as tin of conferring sufficient hardness on the alloy.

9. Knives. We have various kinds of bronze knives; some have a red tinge, which betrays a low content of tin, while some have a black patina

Arrow-Heads

Source	Copper	Tin	Antimony	Nickel	Iron	Arsenic	Lead	Copper : Tin
1 *Han*	74.47	10.82	8.00	3.68	3.03	trace	—	87 : 13
2 〃	73.12	16.15	8.69	2.04	trace	trace	—	82 : 18
3 *Japan*, found in the province of *Tajima* (但 馬)	70.46	21.86	—	0.57	—	1.29	5.82	76 : 24
4 *Japan*, found in the province of *Yamashiro* (山 城)	69.89	23.40	—	1.51	—	—	5.20	75 : 25
5 〃	80.83	8.80	1.04	1.41	—	—	8.62	91 : 9
6 *Japan*, found in the province of *Ueno* (上 野)	67.67	28.11	—	—	trace	—	3.96	70 : 30

which suggests the contrary. The knife here shown was divided into three parts numbered 1, 2, and 3. The analyses of them gave similar results for parts 1 and 2 while the result for part 3 differed considerably from the others.

	Copper	Tin	Lead	Copper : Tin
Mean of (1) and (2)	74.42	22.35	2.62	77 : 23
(3)	83.61	10.69	5.17	88 : 12

From the table we see that the blade is sufficiently hard and strong, since it is of white bronze containing twenty-three per cent. of tin.

10. Culinary articles. Copper-rich bronze, when used for culinary articles soon becomes covered with green rust and gives rise to the danger of verdigris-poisoning. The ancients were seemingly aware of this fact, for the better kinds of culinary articles are made of tin-rich alloys. For example, the analysis of a kind of spoon gave the following composition :

Copper	Tin	Nickel	Copper : Tin
73.77	24.04	2.19	75 : 25.

A fragment of a water pot had the composition :

Copper	Tin	Arsenic	Copper : Tin
77.89	19.35	3.82	80 : 20.

11. Coins. These were generally made of alloys of low quality. Blade money, for example, contains a considerable quantity of lead, probably because

Coins

	Copper	Tin	Lead	Anti-mony	Iron	Arsenic	Nickel	Silver
Bell money	65.53	16.52	10.84	1.83	—	2.36	0.92	—
Knife money	46.22	9.25	43.53	—	0.73	—	—	0.27
〃	38.38	1.66	55.41	—	2.66	0.60	1.03	—
〃	45.93	2.12	48.60	—	—	1.72	1.63	—
〃	42.25	2.12	47.32	—	—	3.28	5.08	—
〃	64.65	6.76	21.25	—	6.41	3.88	3.04	—
Spade money	70.42	9.92	19.30	—	—	—	0.35	—

	Copper	Tin	Lead	Iron	Gold	Silver
Spade money	65.86	14.60	14.00	0.41	—	—
Knife money of *Ch'i* (齊)	55.10	4.29	38.60	1.00	0.001	0.200
Knife money of *Ming* (明)	45.05	5.90	45.82	2.00	—	0.49
〃	48.77	2.44	45.94	0.49	—	0.26
〃	36.85	2.68	58.25	0.98	0.001	0.16

a lead-rich alloy, forming as it does a highly mobile liquid, is most convenient for casting such very thin coins.

Another hypothesis is that lead-rich coins may be of later date, for old lead-free coins are also known (see the thirty-seventh annual report of the Imperial Mint), but a generalisation of that kind is probably too sweeping. It has already been mentioned that there is always some lead in the ancient Chinese bronzes, and it is therefore not justifiable to conclude that lead was maliciously added to the bronze, except when an abnormal excess of lead is found. The number of coins which we were able to analyse was very small; the results are summarized in the table given above.

The table shows that knife money is richest in lead, and indeed that there is sometimes as much lead as copper present. In fact we are often made to wonder whether such a composition was the regular one. Money that contains more lead than copper provokes the suspicion that it is counterfeit; but such a disproportion might possibly occur as a result of unskilful casting. By way of reference, some other examples of analysis are given below, taken from the articles by Dr. *Koga* mentioned above. For these analyses almost perfect coins were used, the rusty matter being previously

Mirrors

Source	Copper	Tin	Lead	Zinc	Iron	Arsenic	Antimony	Nickel	Silver	Gold	Copper: Tin
Han	65.10	25.07	9.12	0.16	0.06	trace	trace	—	—	—	72 : 26
"	66.67	26.57	5.29	0.20	0.81	—	—	0.63	—	—	72 : 28
"	62.15	26.47	5.29	5.00	—	—	1.08	—	trace	—	70 : 30
"	70.11	24.28	5.59	—	0.22	—	—	—	trace	—	74 : 26
T'ang	67.56	27.57	5.43	—	0.37	—	—	—	trace	—	71 : 29
Han excavated in *Japan*	92.99	24.12	3.27	—	—	2.63	—	1.83	—	—	72 : 28
"	67.22	25.44	0.61	6.73	—	—	—	—	—	—	72 : 28
"	65.82	28.72	5.05	—	—	—	—	—	—	—	70 : 30
"	63.63	30.69	0.69	—	—	—	—	—	—	—	69 : 31
Japan 5th century	67.03	22.45	8.99	—	—	—	—	1.52	—	—	75 : 25
Korea	65.37	21.90	9.68	—	—	0.44	2.60	—	—	—	75 : 25

removed. These values are in fair agreement with our own.

12. Mirrors. With regard to the last of the "Six Receipts," since no specimen of *Sui* (燧) have been analysed, the discussion will be confined to *Chien* (鑑, ordinary mirror). Many old mirrors were analysed, about one hundred of which had been pronounced to be *Han* mirrors. All of them except a dozen or so collected by myself, were procured through the kindness of the Institute of Archaeology of Kyoto Imperial University. They had been found in China, Korea or Japan. Only a few of the results are given in the preceding table.

As the table shows, the principal components of the white bronze mirror are copper, tin and lead. The first use of zinc as an intentional addition to the mirror alloy seems to date from the *T'ang* dynasty. The two *Han* mirrors in the table, however, have the exceptionally high zinc content of five to six per cent.; but this fact rather provokes the suspicion that they may be mirrors of the *T'ang* dynasty, produced just before its downfall, and may not indicate an exceptional use of zinc during the *Han* dynasty. A relatively large amount of antimony is found in the Korean mirrors. This may be said to be one of the characteristics of mirrors of this kind, a view which is confirmed by the analyses performed by Professor Collie, who also found antimony as an invariable constituent of Korean mirrors. It may be mentioned in passing that this element has been found in *Han* arrow-heads but in no other bronzes ever analysed. Returning now to the ratio of copper to tin in mirrors, we have met with no example with such a ratio as is required by the sixth receipt. The ratio has the average value of 71 : 29, while in a single case it is even 69 : 31. In short the alloy of the *Han* mirrors is a genuine specular metal, far different from the composition of fifty per cent. of tin. In fact I have only once met with a mirror which contained as much as about forty-five per cent. of tin. This mirror is indeed a rare example that was made by following literally the sixth receipt of the *K'ao Kung Chi.* In reality the best results were obtained by trespassing against the canonical doctrine, or else this is an endorsement of my view that the passage (the *chin* and tin are half and half) is merely the result of rhetorical exaggeration and that it meant in truth that the specular metal should contain the largest permissible amount of tin.

Taking into account the presence of lead, the average composition of *Han* mirrors is

Copper	Tin	Lead.
67	27	6

Several dozens of imitation *Han* mirrors have been

Knife.

Han mirror excavated in Japan.

p. 76=77

cast in my institute in accordance with this receipt, and the nature of our alloy is found identical with that of the *Han* mirrors and not to be distinguished by inspection. Here I should like to cite my paper on this subject published in 1929 (The Proceedings of the Imperial Academy, Vol. 5, p. 347), in which the problem of lead in the *Han* mirrors is also discussed.

" The recipe for mirrors given in the *K'ao Kung Chi* is 50 per cent. Sn to 50 per cent. Cu, and no reference is made to any lead. Fifty per cent. of tin is too much, however, and it must perhaps be understood as meaning that that is the greatest possible quantity of tin needed in casting a mirror. The white bronze with 26–32 per cent. Sn has a homogeneous structure, named ε according to Bornemann,[1] and corresponds in composition to the so-called " specular metal." The lead, which is one of the constant constituents and so great in quantity, has remained a problem ever since. It can not be taken as an impurity, although it does not appear in the ancient recipe and is besides detrimental in bronze-casting owing to its tendency to liquation. Lead seldom occurs in European bronze, which is a marked sign of the difference between it and the oriental bronze. Further experiments, however,

1) Die binären Metallegierungen, p. 32 (1909).

dispel all the mist from these points, as will be clear from what follows.

First, we shall consider the problem from the point of view of equilibrium. For the Sn-Pb system, according to Rosenhain and Tucker (1908/1909), the lead forms a saturated mixed crystal with 16 per cent. Sn, which is segregated to 6 per cent. Sn at room-temperature, while the tin has no solubility for lead, the eutectic being formed at 181°C. Next, for the Cu-Pb system, according to Friedrich and Leroux (1907), and others, the lead-melt gets saturated with 18 per cent. Cu and the copper-melt with 40 per cent. Pb, thus forming two liquid layers at 955°C. On the heat being removed, the copper-melt will crystallise out a saturated mixed crystal containing only 1 or a little more per cent. of lead at 955°C, and when this crystallisation comes to an end, a series of copper-crystals with a lower percentage of lead will continue to separate out from the lead-melt till the temperature drops to 326.9°C, where the crystallisation ends, forming a eutectic at 98 per cent. Pb.

Now, with regard to the ternary system, where these three metals are melted together and allowed to cool, the pure tin will be dissolved in the copper to form the bronze, which must retain some lead in solution as well as in inclosure, properly speaking as a eutectic, according to the rate of cooling and to the quantity of lead present. The lead in solution forming no independent constituent of the structure is harmless, besides that it lowers the solidifying point of the copper to some extent, which must be an advantage in casting as it helps to cause every detail cut in the mould to be revealed. The latter effect will become more and more obvious the greater the quantity of lead used, but the presence of too much lead is evidently detrimental, because it not only makes the structure heterogeneous, but is also liable to liquate on slow cooling. It would therefore be interesting to see how much lead might be used without detriment for the purpose of facilitating the casting. This will also cast some light on the metallurgical question of whether the Chinese really understood the rôle played by lead and used it in proper amounts.

In the preliminary experiments, where a mixture of ca. 66 per cent. Cu and ca. 28 per cent. Sn was melted together with more than 5 per cent. Pb, the latter was seen to have been largely liquated in the bottom part of the ingot. Such was however not the case for an ingot with less than 5 per cent. Pb. The lead which did not liquate must have been retained in both ingots partly in solution and partly as an inclosure. The following table shows the ratio of the lead liquated to that retained in the ingot, as found on analysis with 12 samples containing various amounts of lead and furnace cooled.

Composition of bronze in per cent.		Lead added in per cent.	Lead retained in per cent.
Cu	Sn		
69.3	29.7	1	0.74
68.6	29.4	2	1.95
67.9	29.1	3	2.31
67.2	28.8	4	3.64
66.5	28.5	5	4.38
65.8	28.2	6	3.70
—	—	7	4.99
—	—	8	4.06
63	27	10	4 08
—	—	12	3.70
—	—	15	3.59
—	—	20	4.10

As may be seen from this result, all the lead below 4 per cent. is retained in the ingot entirely uninfluenced by the rate of cooling, but that more than 4 per cent. is segregated on slow cooling, however great the amount taken may be. The average amount of the lead retained is 4 per cent. in nine experiments; this value must be much raised by rapid cooling. That the *Han* mirror contains 5–6 per cent. Pb is certainly not because the Chinese mixed it just in this proportion, but because they threw in a tolerably large amount of it into the molten specular metal in order to facilitate the casting, the 5–6 per cent. Pb being that retained after liquation.

The structure of the alloy with 5 per cent. Pb is shown in the photograph ; the black spots correspond to the lead enclosed. No such spot is present in the pure specular metal. The grain-boundaries of the lead-containing alloy are much more distorted than those of the pure alloy ; but it is not clear, whether this is due to the presence of lead in solution.

In the attempt to make reproductions of the *Han* mirror, several difficulties were encountered in keeping the cast body slag-free and safe from cracking through uneven cooling on account of the back-figures characteristic of the *Han* mirror. They were, however, overcome by using a sand-mould with a riser leading to the bottom and with a very large outlet as shown in the photograph ; besides, the melt should be raised to a temperature above 1200°C and should be more than double the weight of the article to be cast. 5–6 per cent. of lead is added just before the casting, stirring the while. When the mould cools down to a dull red heat, it must be placed in a coke-fire, and left there till the fire goes out. The homogeneous structure may be obtained by slow cooling. Rapid cooling is the cause of the cored structure which has often been met with in *Han* mirrors. The cast article can easily be worked with a grind-stone on a lathe; steel-tools are almost useless because of the great hardness."

In Japan genuine *Han* mirrors have often been excavated, but other kinds of mirrors, which have proved to have been cast in the *Han* fashion in our own country are not infrequently discovered. The Japanese mirror of the fifth century shown in the table, is an excavated mirror of the *Han* type, probably cast by a naturalized *Han* artisan. From the ninth century on we have mirrors of our own fashion. The receipt is given in the *Engishiki* (延喜式, a description of rules and regulations compiled in the *Engi* era), according to which the ratio of copper to tin should be 76 : 24, closely resembling that of the *K'ao Kung Chi*.

In China as well as in Japan, the composition of mirror bronze has changed with the times; the content of tin has decreased while that of zinc has increased. In recent times, the tin content has decreased to almost nil or at most to two or three per cent. Such mirrors should rather be called brass mirrors. In some extreme cases, even zinc is scanty and is replaced by antimony and lead. It is evident that quality has been sacrificed to cheapness and ease of casting.

To sum up, white bronze mirrors of the *Han*

Alloy with 5 per cent. Pb.

Specular metal.

Sand-mould for casting the Han Mirror.

dynasty are supreme in all their principal properties: they are genuinely white, possess high reflecting power without either silvering or tinning and are hard enough to remain uninjured by scratching and so resistant to corrosion that they retain their shining surface for more than a thousand years, even under the ground if only kept dry. This is sufficient testimony that the ancient Chinese people and our ancestors, who could produce such excellent masterpieces of industrial art, were remarkably advanced in the knowledge of chemistry. The art of casting these wonderful *Han* mirrors has been obscure since the end of the *T'ang* dynasty; it is a great pleasure to me that I have lately been able to accomplish the revival of this time-honoured art in my own laboratory.

CHAPTER III. JAPANESE SWORDS.

1. METHODS OF FORGING.

The Bronze Age was followed by the Iron Age. Iron has in its peculiar properties no parallel among the other metals. To make full use of them special knowledge is necessary. While in China the Bronze Age lasted for a tolerably long time, the Japanese became acquainted in comparatively early times with the use of iron articles. They recognised, though only vaguely, three kinds of iron according to their properties. Such knowledge was of course gained by practical experience and they were entirely without any scientific explanation, such as exists to-day, of the true nature of the iron they used. The first kind was wrought iron. Its high melting point makes it unsuitable for casting but its property of softening on heating was utilised to advantage in forging. This kind of iron contains less than 0.1 per cent. of carbon, as our present metallography shows. The second kind of iron was steel. Steel is harder than wrought iron and capable of further hardening by means of quenching from a high temparature; it is known to contain 0.8–0.9 per cent. of carbon. The third kind of iron was cast iron. Its melting point is low enough to permit of its being easily melted and cast, as its name indicates. Its carbon content is less than 4 per cent. Thus a small difference in the carbon content of iron is responsible for a marked difference in its properties; but what is more important is the fact that the comparatively high carbon content of cast iron can be reduced to any desired degree, because the carbon can be burnt away by blowing air against the hot surface of the molten metal. Thus cast iron may easily be turned into one of the other sorts, or more precisely, if the carbon content is decreased gradually, the metal will pass through all the intermediate stages from cast iron via steel to wrought iron. At the present time this process of decarbonisation has been mastered as a result of thorough scientific investigation and the perfection of the necessary mechanical devices makes it possible for any one to make any kind of iron of the highest quality. But this was not so in ancient times. This burning off of carbon in cast iron was performed by the smith. If he came during his long practice to comprehend the secret of the art, he could produce a remarkable sort of steel, which was then turned into a fine blade by a master sword-smith. A sword, if it is a fine blade at all, should neither break nor bend

Old Japanese straight swords

made about 1500 years ago and excavated near
Isezaki-Chō, Gunma-Prefecture.

(a)

The blade is 556 mm long and 32 mm wide.
The handle is 148 mm long.

(b)

The blade is 780 mm long and 43 mm wide.
The handle is broken off.

Sectional view at a. Sectional view at b.
The white parts: soft iron.
The black parts: soft steel.

but cut well. From this state of affairs we can say that a sort of steel industry, though only on a small scale, flourished in old Japan and could produce a kind of steel such as might well excel the products of modern industry. In this respect old Japan contributed much to the chemical achievements of the ancient Orient.

As to the method of forging swords in extreme antiquity, no history nor tradition has been handed down ; but some of the straight swords excavated by archaeologists were once submitted to investigation from which it may be concluded with some justice that they belong to the class of forged swords. For they showed some signs of having been forged by " folding," or even by " combining" different sorts of iron. The art of forging made great progress when in the days of the Prince Regent *Shōtoku* (聖徳, 573–621) it was taught by some naturalised smiths at *Oshinumi* (忍海) and later when Emperor *Gotoba* (後鳥羽, 1180–1239) gave directions to the noted smiths of the various provinces and made them forge at the court. All this concerns the method of forging the so-called *kotō* (古刀, old swords) but this method was lost during the age of civil wars towards the end of the *Ashikaga* (足利) Period. *Shintō* (新刀, new swords) made their first appearance towards the beginning of the *Tokugawa* (徳川) Period and during the *Anei*

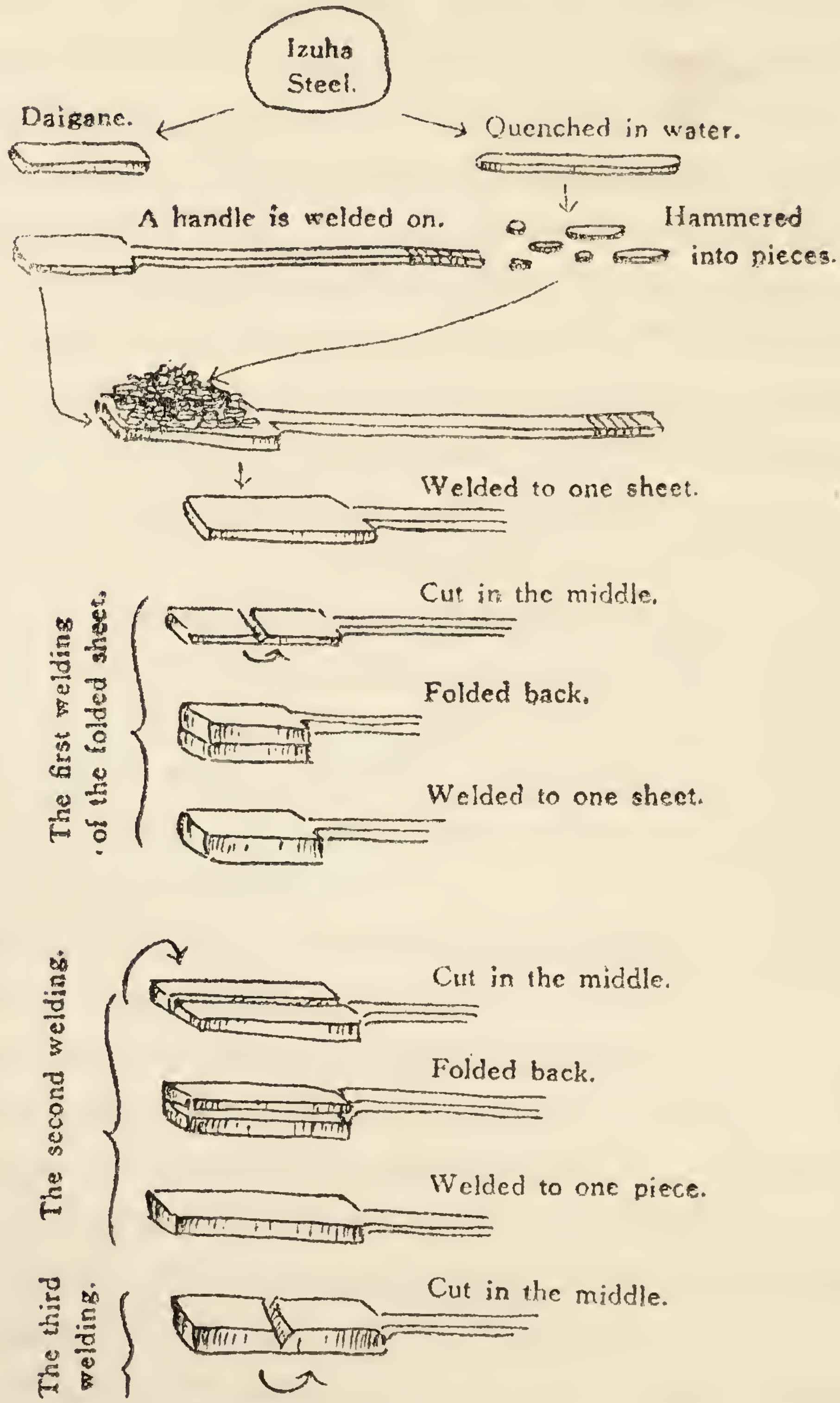
(安永, 1772–1780) era or thereabout *shinshintō* (新々刀, new new swords) began to be turned out. A sword-smith, named *Suishinshi* (水心子) is said to have been the originator of the *shinshintō* school. He was a diligent investigator of the oldest school of sword forging, and thus the once obscured method became clear again; but it did not live long as such, for *Suishinshi* improved it further and gave birth to a new school. The doctrine of the school of *shinshintō* still survives among the sword-smiths of the last days of the *Tokugawa* (徳川) Period.

Some details of the methods of the *shinshintō* school may now be given. Fortunately I am possessed of two valuable writings concerning the *shinshintō* school. One of them is a note taken down from the oral instructions given by Mr. *Nobuhide Takahashi* (高橋信秀) who is an old pupil of the famous sword-smith *Fuyuhiro* (冬廣) of *Wakasa*(若狭) Province and who now lives in Osaka. (This note has been published by the Institute of Metallurgy of the Kyoto Imperial University). The other is an unpublished paper by Dr. *Masahiro Tazaki* (田崎正浩), who learned and practised the art under the guidance of Mr. *Takahashi.* In the following description, it may be added, no special reference will be made to the numerous works recently published by other investigators of swords.

Kawakane (皮金, cover metal). A sword, as exemplified by the swords of antiquity, which was forged simply by repeated folding of a piece of iron, would have the drawback of being apt to break or to bend. In the forging of the *kotō* (古刀, old swords) a greatly improved method called "*awasekitai*" (合せ鍛ひ), which will be fully explained later, was already used. A blade forged by this method acquires a combined structure of properly distributed hard and soft steel. How pieces of different kinds of steel are combined and welded together will be discribed later; but the manner of preparing the constituent steel pieces is of itself an exquisite art. There are probably, of course, various ways of preparing them; one of them will now be described.

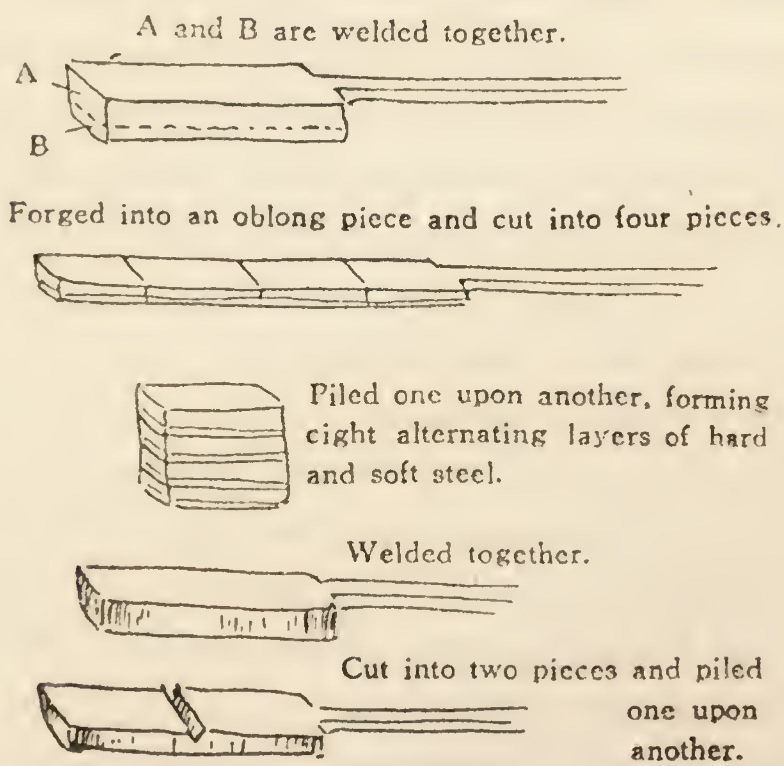
A piece of *Izuha* steel (出羽, a kind of steel) is forged to make the main piece (*daigane*, 臺金). Another piece is heated and thrown into water while hot and then hammered to pieces and placed on the main piece, to which a long piece of iron has been welded as a handle. These are then heated and welded to one sheet. The object of this process is probably to produce the isotropic structure of the resulting steel. This sheet is now cut in the middle, the notch being perpendicular to the direction of the handle. One half is folded over on the other and the two welded together. This process is called the first "welding of the folded sheet."

The first step in forging Kawakane



The sheet is again cut in the middle, the notch this time being parallel to the handle, and after being folded back, the two parts are welded together. This process is the second welding of the folded sheet. This procedure are repeated about ten times, resulting finally in a rectangular sheet which may be termed A. Next, a piece of soft iron is subjected five times to the "welding of the folded sheet" process and forged to the same shape as A with half of its thickness ; the resulting sheet may be termed B. A and B are now welded together and forged into an oblong sheet and cut asunder

The second step in forging Kawakane



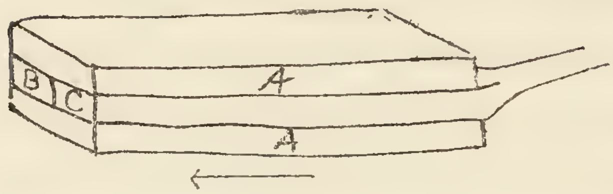
into four equal pieces which are then, instead of being folded back, piled one upon another as shown in the figure and welded together. The resulting sheet is again cut in the middle and two halves piled as before and welded together. This oblong mass now consists of sixteen alternating layers of hard and soft steel. This process is further repeated, the number of the layers being multiplied by each repetition. After say ten repetitions the piece of steel acquires a fine laminated structure, the number of the laminae being as many as sixteen thousand in a layer about one inch thick. In such thin laminae the effect of the diffusion of carbon is predominant, and apt to cause the boundaries of the hard and the soft steel to be obliterated. As a consequence the laminated structure is more or less blurred and sometimes almost indiscernible, especially when the welding was skilfully performed, so much so that it was commonly said among swordsmiths that excessive repetition of the welding process was rather harmful.

However that may be, the oblong piece of steel thus welded is called *kawakane* (皮金, cover metal) and it constitutes mainly the outer part of the blade. *Shingane* (心金, centre metal) is properly composed of soft steel alone, subjected to the "welding of the folded sheet" process repeatedly but not so often as *kawakane*. Medium steel between soft steel and *kawakane* in hardness, or *kawakane* itself may also be used as *shingane*. *Hagane* (刄金, edge metal) is composed of hard steel welded in the same way as *shingane*. Sheets of proper sizes made of these various kinds of steel, which we shall hereafter call, in the order above given, cover-piece, centre-piece and edge-piece, are put together in proper position and welded and forged into a sword.

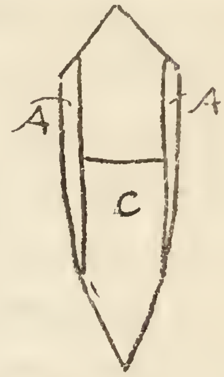
The *Awasekitai* (合せ鍛ひ, forging by combining sheets) method was used from olden times. When forged by this method, a sword can cut well without breaking or bending, and thus possesses in one piece the mutually contradictory but essential elements of a fine blade. This exquisite method was, however, as I suppose, a simple one as used in very ancient times and developed to its present complexity and perfection especially after the dawn of the *shinshintō* school. Some examples of this method will be described below.

1. *Honsanmaitsukuri* (本三枚作り, the standard method of forging with three sheets of iron). The accompanying figure will suffice to give the main idea of this method. Two cover-pieces, one centre-piece and one edge-piece, of which the latter two were welded together beforehand, are used in combination.

These three pieces are piled one upon another and welded together into one piece which is then elongated by hammering in the direction of the



A: cover-piece, B: centre-piece,
C: edge-piece.
Combination of steel pieces.

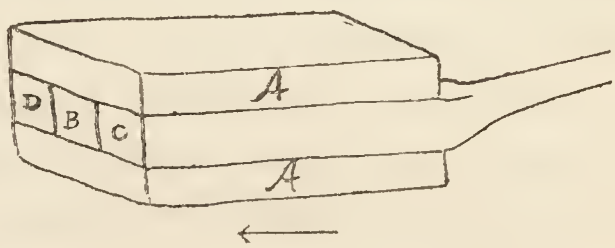


Ideal sectional view.

Honsanmaitsukuri.

arrow into the final shape of the blade. The ideal section of a blade forged by this method ought to be as indicated in the figure, while the real section approaches this more or less according to the skill of the smith.

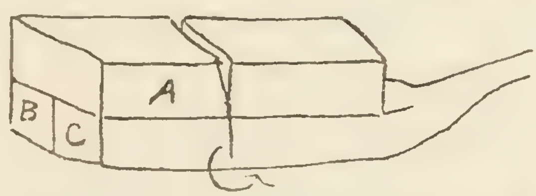
2. *Shihōzume* (四方詰, the method of girding on four sides.) This combination is more complex. In the former one the centre-piece, made of soft



A: cover-piece, B: centre-piece, C: edge-piece,
D: back-piece.
Combination of steel pieces in *Shihōzume*.

iron, constitutes the back of the blade. The sword is therefore exposed to the danger of being cut at the back. In this second method, a piece of medium or hard steel, subjected to the "welding of the folded sheet" process, is specially used as a back-piece, the soft centre-piece being thus protected on all four sides.

3. *Orikaeshi-sanmaitsukuri* (折返三枚作り, the method of forging by folding into three sheets of iron). As shown in the figure the cover-, the centre- and the edge-piece are welded together and cut in the middle, the notch being perpendicular to the direction of the handle, and one half is turned over

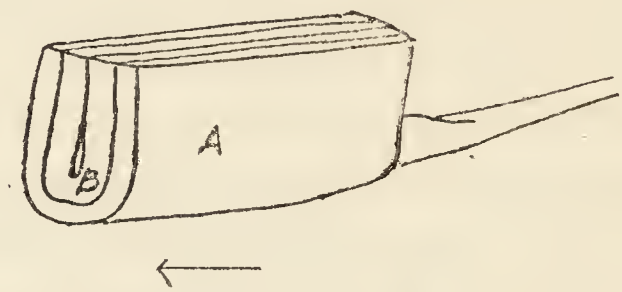


A: cover-piece, B: centre-piece,
C: edge-piece.
Combination of steel pieces in *Orikaeshi-sanmaitsukuri.*

on to the other as shown in the figure, the cover-piece now covering the centre- and the edge-piece from both sides. The finished blade is almost the same as one forged by the first method. Here only one side-piece suffices.

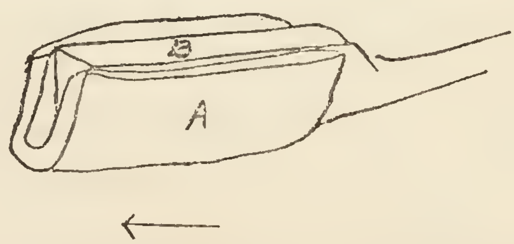
4. *Makuritsukuri* (まくり作り, the method of forging by rolling up). As the accompanying figure shows, one cover-piece, made by welding a piece of hard steel by folding, is used, and can serve as edge also when quenched. This cover-piece and a centre-piece are welded together and bent over, so that

the latter piece is enclosed in the former and these are elongated by hammering to a blade. This method is simple and straight-forward, and was, as I suppose, frequently used in the forging of the "old *Bizen*" swords.



A: cover-edge-piece, B: centre-piece.
Combination of steel pieces in *Makuritsukuri.*

5. *Kōbusetsukuri* (甲伏せ作り). This method resembles the former, and may be gathered from the figure. A centre-piece is welded between the arms of a bent-over cover-piece and hammered out in the direction of the arrow to a blade.



A: cover-edge-piece, B: centre-piece.
Combination of steel pieces in *Kōbusetsukuri.*

2. THE ANATOMICAL INVESTIGATION OF JAPANESE SWORDS.

It is interesting to consider how far the ideal in the forging of swords, the realization of which is to be expected only in the work of master-smiths, has been realized in the now existing Japanese swords. This problem may be attacked by dissecting swords and examining them metallographically, and the swords of the *shinshintō* school are best suited for the purpose, for they are of comparatively later date and the methods of forging are almost clear. Inversely, such an investigation will reveal the methods of the forging of older swords, which were so eagerly discussed by the sword-smiths of about the *Anei* (安永) era. We must, however, refrain from sacrificing too many swords to our investigation, for they are destined to decrease in number as time passes. Moreover it is only by dissecting swords which bear the signatures of master-smiths that valuable results can be obtained, which is obviously a great limitation. Fortunately some fine blades that had run their course in one way or another were placed at our disposal through the kindness of various parties, and these were examined, with the results given below.

1. A sword forged by *Munetsugu Mishina, Tajimanokami* (三品但馬守宗次, about 1750). This sword was forged by the *Shihōzume* method, the second method, as can be clearly seen from the accompanying sectional view. There we see five pieces of steel welded together. Since a cross section of a blade is too large to be investigated at one

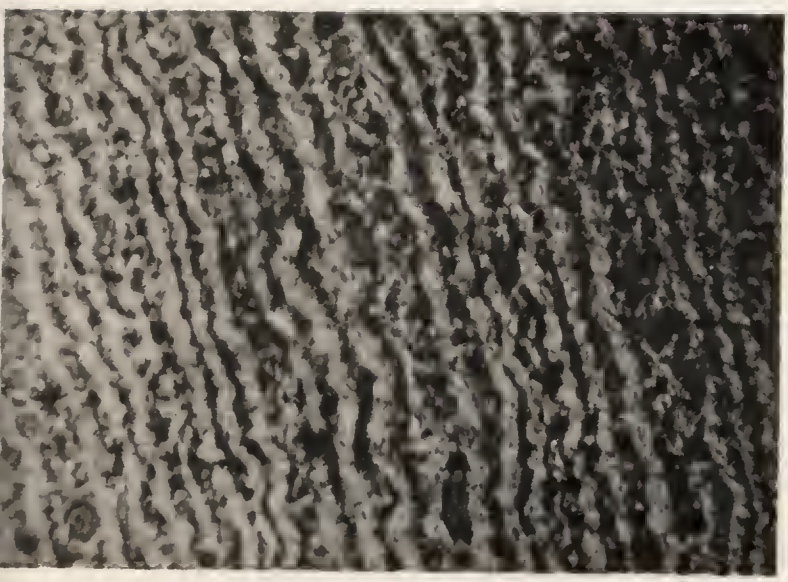
time under a microscope, it must be examined piece by piece, and it is really a tedious task to reduce to a consistent picture the results of micrographical observation of the various parts of the cross section. Dr. *Ashida*, to whom my acknowledgements are expressed in the preface was very painstaking and thorough in making such drawings. The edge has a quenched structure. A layer of ***ni-e*** (沸, scattered spots of martensite on the troostite and sorbite ground) connects the edge to the body of the blade. The back shows the sorbitic structure of hard steel.

2. A sword by *Hisashige Shinryūshi* (眞龍子壽茂), made in August, third year of *Keikō* (慶應, 1867). The result of analysis is given in the accompanying sectional view, which reveals the method of forging to be a kind of *Makuri-kitai*(the fourth method). The forging process is shown diagrammatically.

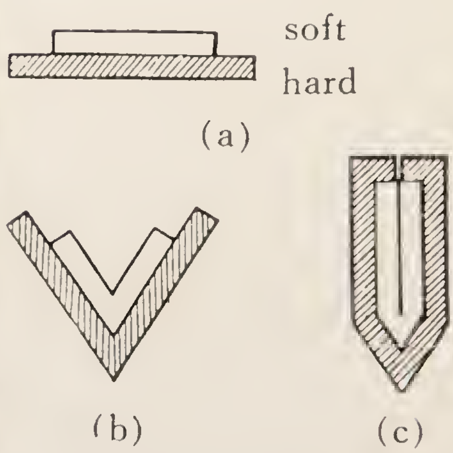
3. A sword by ***Harumitsu*** of the Province of ***Bizen***(備前春光). ***Harumitsu*** was a sword-smith who lived during the *Yeiroku* (永祿) era (1558–1569). As may be seen from the sectional view, the method of forging was probably an old one called *Marukitai* (丸鍛ひ). The supposed process of forging is shown in the figures. A sheet of soft iron is placed between two sheets of hard steel and the whole welded together to one piece, which is then bent over as in

A sword by *Munetsugu Mishima, Tajimanokami.*

A sword by *Shinryūshi Hisashige.*



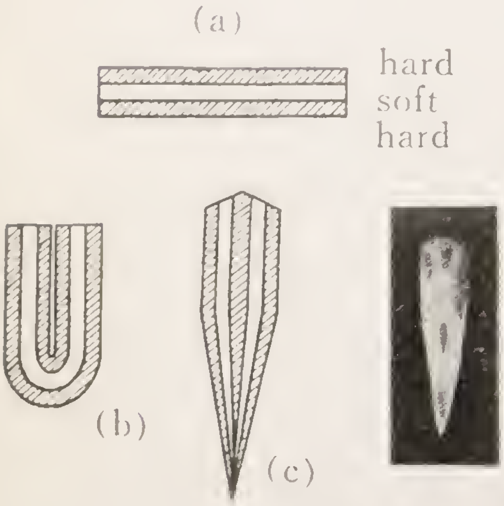
Microphotograph showing the laminated structure of *Kawakane.*



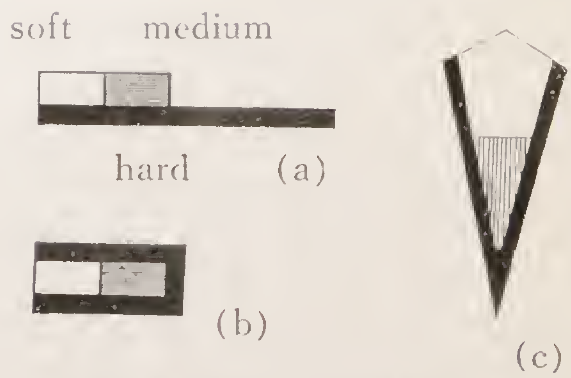
The process of forging.

A sword by *Bizen Harumitsu.*

A sword by *Bizen Sukenaga.*



The process of forging.



The process of forging.

the *Makurikitai* method and then hammered out to a blade. In the sectional view, the parts denoted by *a* and *b* have the sorbitic structure of hard steel, while *c* is soft iron, *d* martensite and *e* *ni-e* (沸).

4. A sword by *Sukenaga* of the Province of *Bizen* (備前祐永). *Sukenaga* was a smith who lived about the *Tempo* (天保) era (1830–1842). In the drawing the part *a* is pure iron, *b* medium steel (0.45 per cent. carbon), *c* hard steel, *d* quenched hard steel, *e* *ni-e*. From this feature of the sectional view we infer a somewhat different style of forging, of the manner shown in the figures. The centre-piece of medium steel is welded to the back-piece of soft iron. These are then enveloped by the cover-piece of hard steel on three sides and forged to a blade. The real cross section differs from the ideal one in the respect that the back-piece has been pushed aside from its ideal position by the cover-piece, which now mainly constitutes the back. The position of the centre-piece is good; the edge and *ni-e* are admirably worked out.

5. A sword by *Kuni ? Rai* (來國 ?, about 1600). The maker of this sword was some one who belonged to the *Rai*-school. The sectional view suggests the *Makurikitai* method. The rather obtuse edge gives an impression of stoutness.

6. A sword by *Tomoshige Fujishima*(藤島友重). *Tomoshige* lived about the *Kōka* (弘化) and *Ganji*

(元治) eras, that is, about 1850. The drawing shows the *Makurikitai* method somewhat distorted.

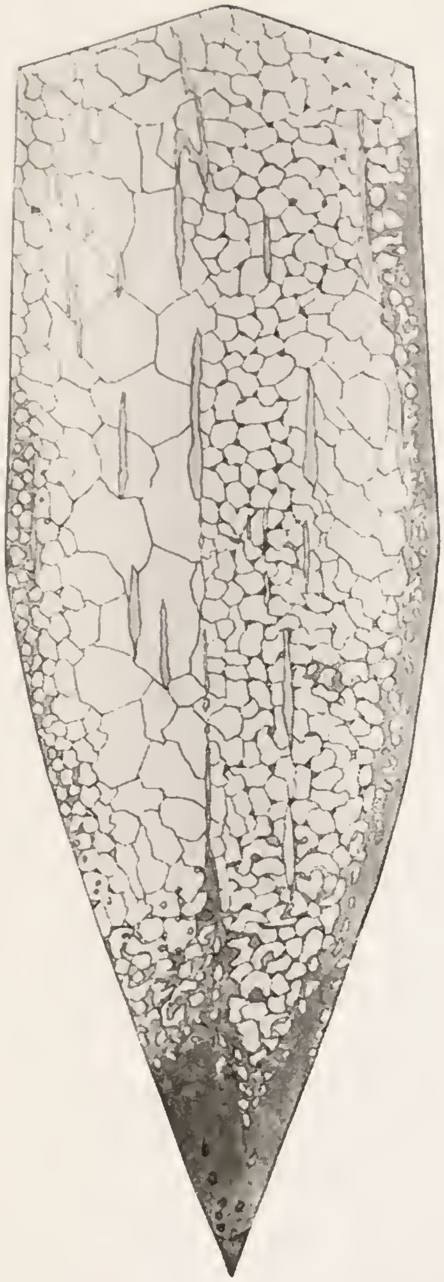
7. A sword by *Jumyō*(壽命). The maker of this sword was *Jumyō* the third, (about 1560). Obviously it was forged by the *Makurikitai* method.

8. A sword by *Kanemoto Seki*(關兼元, abot 1500). This sword bears the engraved signature of its maker but has a flaw developed in the forging. It must have been a votive sword. It is a fine blade, however, and being one of the old swords, it shows in its structure the simple *Makurikitai* method.

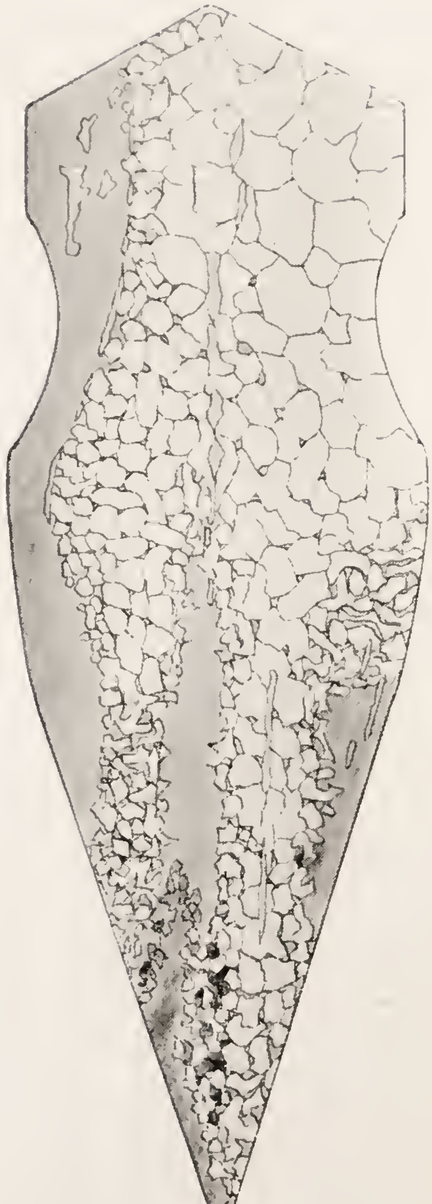
9. A sword by *Masahiro* of the Province of *Sagami* (相州正廣, about 1360). This short sword is one of the masterpieces of *Masahiro* and was kindly donated by Mr. *Kishimoto*, a sword dealer of Kyoto. It is hardly necessary to say that the grains are very fine and the skin is admirable as might be expected from the work of the *Sōshū*(相州)-school which is noted for its repeated welding.

10. A sword worn by the *Shogun Ieshige* (家茂). A tradition says that this sword was found cut in two by another sword in Osaka Castle. The sword has a very fine appearance which is becoming in a nobleman's weapon but is probably inferior in strength to the sword of a wild samurai intended for practical use.

11. A sword by *Tsugitada* of *Aoe* (青江次忠). This sword is a masterpiece made seven hundred



A sword by
Kuni? Rai.



A sword by
Tomoshige Fujishima.

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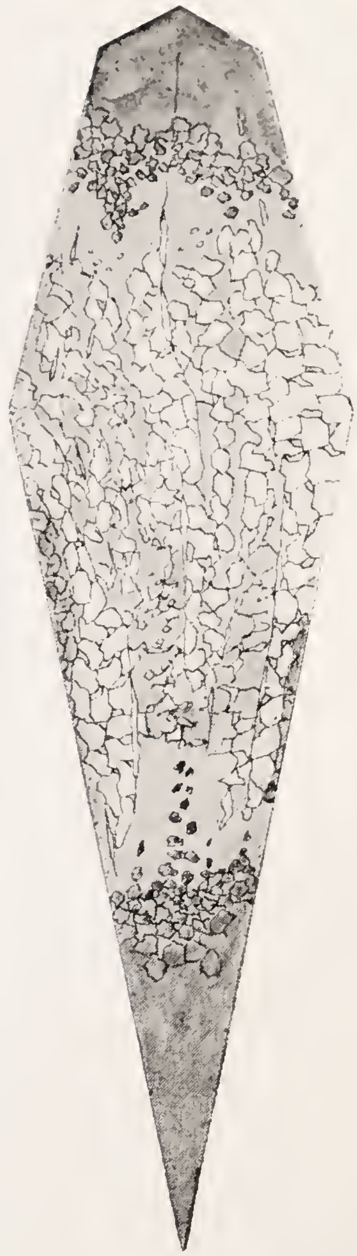
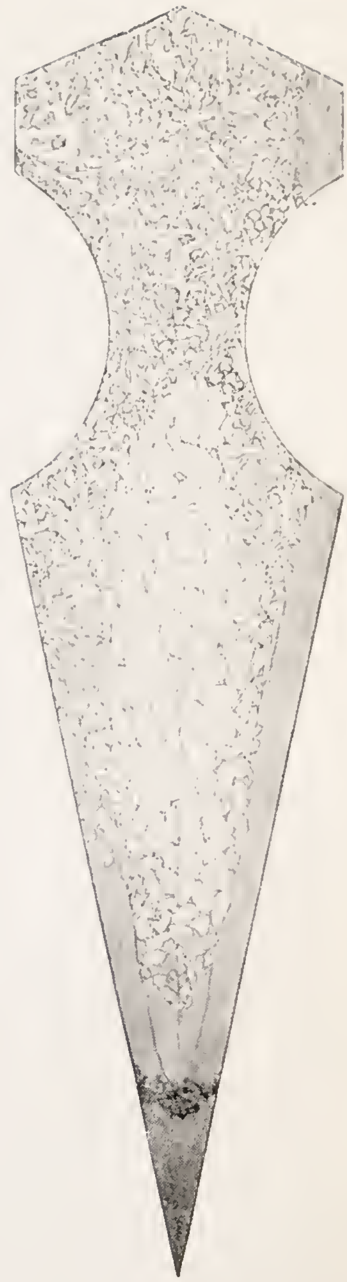


A sword by *Kanemoto Seki*.

A sword by *Jumyō*.

A sword by
Sōshū Masahiro.

A sword worn by
Shogun Ieshige.



A sword by
Tsugitada of *Aoe.*

years ago ; .it has a sharp edge and cuts well. A sword expert when shown it, said that since it has a dry lustre, it must have been through a fire, and in fact on analysis it was found that one face of the blade contained well crystallised ferrite, indicating the characteristic feature of burnt iron ; the other face was untouched. This fact shows that our art of judging swords is fairly reliable.

3. THE SWORDS OF THE NATIVES OF THE PACIFIC COAST.

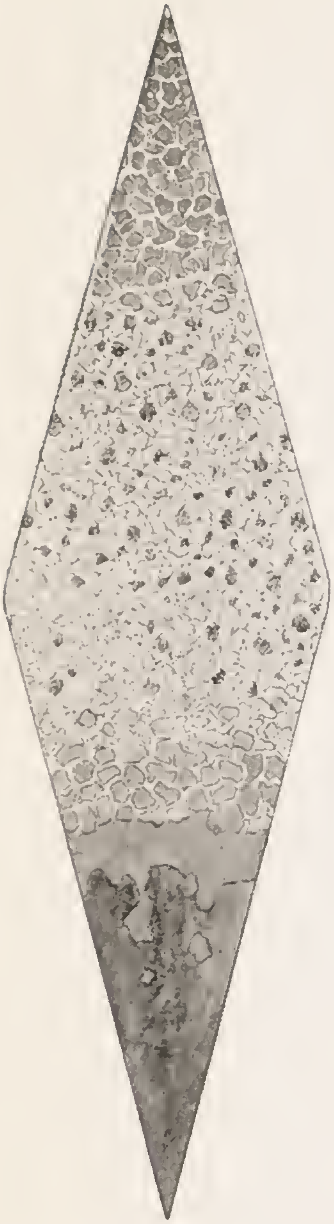
An old proverb says " The best sword stays the war." While the abuse of military power is absurd, a nation without military defence can not exist for a single day. Our country has long been noted for its military power. A good many causes for this might be advanced, but one is certainly the supremacy of its swords. Of the splendid Japanese swords the preceding sections have given an adequate account, and now for the sake of comparison some results of an investigation performed with swords of the natives of the Pacific Coast may be given. The comparison will show how far they are excelled by our own swords, a fact which may suggest not only why our country has maintained its supreme position in the East since the beginning of our history but also how well-versed our ancestors were in this branch of chemistry.

1. A Sword from Java. In this sectional view, the white particles indicate soft steel with 0.3 per cent. of carbon and the shaded particles indicate hard steel with 0.8–0.9 per cent. of carbon. As is evident from the figure, a piece of hard steel is welded to each side of the body, composed of soft iron, and one piece is quenched to form the edge while the other constitutes the back, which is of sorbitic structure. The construction is thus very simple and shows no trace of exquisite welding.

2. A sword from the eastern part of Java. The body is of mild steel with 0.4 per cent. of carbon, to which a thin piece of hard steel is welded. The sword resembles our fish-slice.

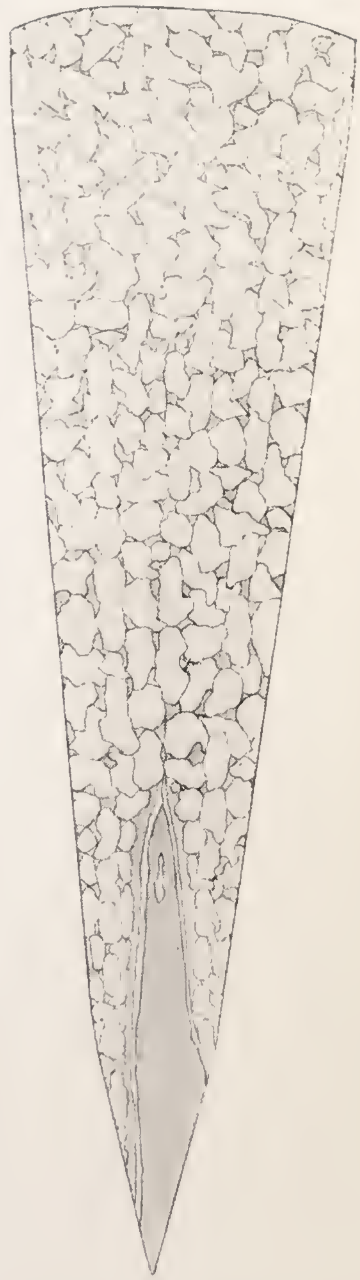
3. A sword from Formosa. This sword consists of the main body, of mild steel with 0.4 per cent. of carbon, and the edge, of hard steel with 0.9 per cent. carbon ; it resembles our heavy kitchen knife and shows no signs of fine treatment.

From these examples we see that none of the natives of the Pacific Coast can rival us in the quality of our swords. This is a reflex of the national vigour and a symbol of our racial predominance. In the days when there were no firearms, our country would never have been conquered either by the natives of the Pacific Coast or by any of the other nations of the whole world.



A sword from Java.

A sword from the eastern part of Java.



A sword from Formosa.

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印刷所　大日本印刷株式會社
東京市牛込區市谷加賀町一丁目一二

發行所　內田老鶴圃
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