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Authors

Prof. Dr. R. RUBENS. Universiteit Gent. Inwendige Ziekten, afdeling Endocrinologie. Universitair Ziekenhuis. De Pintelaan 185, B-9000 Gent, België.

Prof. Dr. H. BEUKERS. Rijksuniversiteit Leiden. Vakgroep Metamedica, sectie Geschiedenis der Geneeskunde. Postbus 2087, NL-2301 CB Leiden, Nederland.

Prof. Dr. ir. A. VAN CAUWENBERGHE. Universiteit Gent. Laboratorium Regeltechniek. Grotesteenweg-Noord 6, B-9052 Gent, België

Prof. Dr. ir. P. EIJKHOFF. Technische Universiteit Eindhoven, EE Departement, P.O. Box 513, NL-5600 MB Eindhoven, Nederland.

Prof. Dr. G. VANDEN BERGHE. Universiteit Gent. Vakgroep Toegepaste Wiskunde en Informatica. Krijgslaan 281-59, B-9000 Gent, België

Prof. Dr. E. VAN SCHOONENBERGHE. Katholieke Hogeschool Sint-Lieven. Campus Rabot. Gebroeders Desmetstraat 1, B-9000 Gent, België

Prof. Dr. J. VAN HOOF. Universiteit Gent. Faculteit Diergeneeskunde. Diergeneeskundig Toezicht op Eetwaren. Salisburylaan 133, B-9820 Merelbeke, België.

Prof. Dr. P. KOOLMEES. Universiteit Utrecht. Faculteit Diergeneeskunde. Vakgroep Voedingsmiddelen van Dierlijke Oorsprong. Postbus 80175, NL-3508 TD, Utrecht, Nederland.

Prof. Dr. K. HEYDE. Universiteit Gent. Vakgroep Subatomaire Stralingsfysica. Proeftuinstraat 86, B-9000 Gent, België

Prof. Dr. C. ISERENTANT. Universiteit Gent. Vakgroep Subatomaire

Stralingsfysica. Proeftuinstraat 86, B-9000 Gent, België

Prof. Dr. F.GEERARDYN. Universiteit Gent. Vakgroep Psychoanalyse en Raadgevingspsychologie. Henri Dunantlaan 2, B-9000 Gent, België

Prof. Dr. J.QUACKELBEEN. Universiteit Gent. Vakgroep Psychoanalyse en Raadgevingspsychologie. Henri Dunantlaan 2, B-9000 Gent, België

Prof. Dr. DE GIER SOLMS. 4B Hampstead Hill Gardens, London NW3 2PL, England.

GEORGE SARTON CHAIR

of the

HISTORY OF SCIENCES

1998-1999

SARTON CHAIR LECTURES

LAUDATIO HARM BEUKERS

Robert Rubens

As is well known dr.G.Sarton was a very important holistic scientific thinker and writer. Based upon his ideas and works germinated in this university but mainly grown to adulthood in the US, science and knowledge were conceived as being one. Sarton claimed very correctly no science could ever exist without the knowledge of the historical genesis of the idea.

The same argument similarly can state no medical knowledge is conceived without the knowledge of the previous ideas about medicine and therapeutics. The teaching of the history of medicine is considered to be an important element in the formation of the next generation of physicians. The principle already stated by Galenos and retained in the academical world is present in nearly all English and German speaking universities of the world. The traditional Dutch universities still cherish the idea and consider the knowledge of the history of medicine an important part of the medical university curriculum. Our university which was founded in 1817 upon the principles of Leyden university had this course as a main part of the medical formation in the first hundred years of its existence. In the following 50 years the introduction of more and more exact science in the curriculum did eclipse the historical formation. It was only retained as an elective subject and still remains important in the formation of the professions allied to medicine and teachers training. In Leyden it remained a part of the basic curriculum of the formation of the physician.

It therefore gives me great pleasure to introduce to you as proximus in this aula which still reminds us of the ancient relations between Gent and Leyden Prof. H. Beukers, professor in the history of medicine at Leyden University as the laureate of the Sarton Chair for the history of sciences at the proposal of the faculty of medicine.

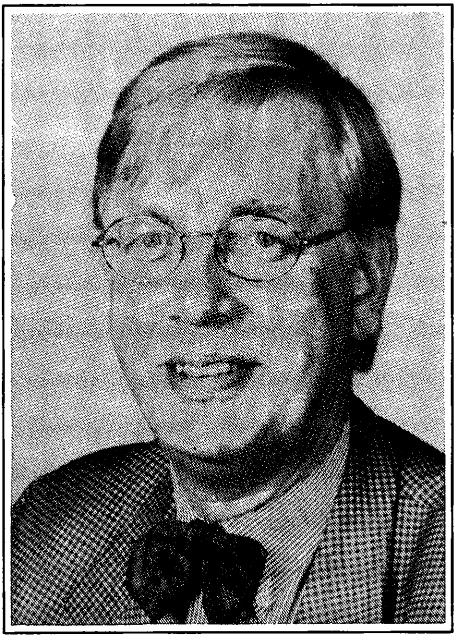
Prof.Beukers was born in 1945 and after medical studies at Leyden university started a research career in the same university. His first subject was biochemistry and in 1978 he obtained his Ph.D. in medical biochemistry. During his research work in basic science Dr.Beukers already became involved in medieval palaeography and codicology. In the second part of his scientific career Dr.Beukers mainly performed original medical historical research. When in 1981 the chair for the history of medicine became vacant he was appointed professor of the history of medicine in the department of metamedica. The last twenty years he produced some 144 papers about the history of medicine, history of the university and the advent of Western medicine in Japan. The important historical relationship existing between Japan and the Netherlands since more than two centuries was his main research subject. His original studies of historical "fontes" and intrinsic knowledge of the Japanese culture and language makes him an internationally recognised expert on the connections between Japan and the Netherlands.

The expertise is well recognised and gave him a visiting professorship in Tokohu University in Japanese culture and studies. Needless to state this honour is seldomly bestowed upon Western researchers.

Besides the important teaching and research responsibilities Prof.Beukers is involved in numerous committees on the history of medicine as well in the university of Leyden, the Dutch Academy of Sciences, the International Society for the History of Medicine.

Prof.Beukers is a member of various editorial boards. He is the general editor of the main journal about the history of medicine, Geschiedenis der Geneeskunde, in the Dutch speaking Netherlands. Furthermore he is the president elect of the European association for the History of Medicine and Health.

Based upon his main research interest Prof.Beukers will now give his lecture about" Red-haired medicine.The introduction and acceptance of Western medicine in Japan", to-morrow he will give his paper concerning Franciscus dele Boë, Sylvius, the founding father of the very important Leyden medical School. It is certainly too frequently forgotten that the contribution of the Dutch intelligentsia to the formation of the scientific medical knowledge at the end of the XVIIth century not only influenced but really moulded total Europe.



RED-HAIR MEDICINE

The Introduction of Western Anatomy in Japan

Harm Beukers

> The more we become aware of Dutch learning, the more strongly we are impressed by their empirical spirit.
> Sugita Gempaku, *Rangaku Kotohajime* (1815)

One of the many contributions of the name giver of this chair, George Sarton, is related to his role in calling attention to the science history of the Muslim world. His real interest was the entire Asian heritage, but, owing to lack of easily accessible sources, Sarton had to restrict himself to materials from the Near and Middle East. Consequently, China and Japan remained 'by far the largest terrae incognitae' in his *Introduction to the History of Science*.[1] Sarton has nevertheless included the limited, but available material related to the science history of the Far East in his monumental work. It strongly illustrates Sarton's concept of a unity of nature, of knowledge, and of humanity as three aspects of a single reality.[2] In that context it is worth mentioning that he gave the first half of the fifth century the title the 'Time of Fa-Hsien' [Fa Xia], the Chinese Buddhist who made a long journey to India (399-414) to collect Buddhist texts. Choosing a Chinese scholar as label for this period, Sarton wanted to express that China "was becoming one of the most important provinces of mankind." And he continued:

Also the name Fa-Hsien suggests Buddhism, which was then in one of its most vigorous phases - a civilizing power equal to Christianity and already spread over an immense area. Moreover, the monk Fa-Hsien was one of the greatest travellers of all ages. There is, however, an essential difference between him and the Christian missionaries who roamed across Europe at the same time; they went out to teach, he went out to learn.[3]

The quotation is, to my opinion, illustrative for Sarton's sincerity to foreign cultures.

The first entry of Japan in the *Introduction to the History of Science* is just in the chapter dedicated to Fa-Hsien, when Sarton referred to the arrival of two Korean physicians, Kon-Bu or Kommu and Tokurai or Duklai, in Japan.[4] Kon-Bu was sent in 418 by the king of Silla (one of the three Korean kingdoms) upon request of the diseased Emperor Ingyō. Tokurai settled in 459 in Naniwa (present Osaka) and founded a medical school, the so-called *Naniwa no kusushi.* This school represented the first step in the introduction of continental, essentially Chinese medicine. Direct contacts between Japan and China existed only from the seventh century when Japanese Embassies or *kentōshi* visited the 'Middle Empire' regularly. In the period 630-838 students accompanied the Embassies to China where they stayed for a long time, initially ten years or more. They returned as specialists of Chinese philosophy, literature and medicine.[5] The beginning of this period coincides with the proclamation of a series of edicts, which gave the period 640-650 the name *Taika* or 'Great Transformation.' That name designates the reforms carried out under Emperor Kōtoku. They aimed for the formation of a centralised state modelled after Sui and T'ang China. For the propagation of learning this implied the establishment of three institutes for higher education in the capital Heiankyō (present Nara), among which the Institute of Medicine *(Ten 'yakuryō)* was responsible for both the training of physicians and the actual medical care. In line with the T'ang medical practice, courses were offered in medicine, botany, acupuncture, massage and exorcism.

The reception of Chinese scientific knowledge was not a mere acceptation of ideas and concepts borrowed from a foreign natural philosophy. The 'Transformation' included the adoption of the Chinese system of writing, despite the fact that both languages had complete different structures. Ancient Chinese is essentially monosyllabic: almost all words consist of one syllable and have no inflections of number, case, tense and the like. The monosyllabicity makes it simple to represent each word by a unique character. This system is, however, not practical to write Japanese, which, in contrast, is characterised by highly inflected words. In the ninth and tenth century a Japanese syllabic script, the so-called *kana* developed, which was more suited to represent spoken Japanese. By then the first Japanese compilations of Chinese medicine had already been published. There had even appeared a work entitled *Daidō ruijūhō* or 'Classified prescriptions from the Daidō-period', a collection of indigenous therapies, which were in danger to be forgotten and which were compiled under imperial order in 808.

Sarton described a comparable process in his Keiser Foundation Lecture on *The Incubation of Western Culture in the Middle East*. Speaking of the "miracle of Arabic science" he stated:

...using the word miracle as a symbol of our inability to explain achievements which were almost incredible. There is nothing like it in the whole history of the world, except the Japanese assimilation of modern science and technology, during the Meiji era.[6]

The year 1868 marked, in the history of Japan, the end of the power of the Tokugawa shoguns and the accession to sovereign power by Emperor Mutsuhito. The young emperor named the period of his reign *Meiji* or 'Enlightened Government,' alluding to an extensive program of modernisation after the Western example. Sarton drew a parallel between the movement in Japan during the second part of the nineteenth century and the situation in the Middle East during the eighth century:

...the intellectual leaders of the Arabs realised the need of Greek science as urgently as the Japanese of two generations ago that of European science. Both had the best of teachers - necessity, compelling necessity. Both had the will and the kind of spiritual energy which overcomes insuperable difficulties...[7]

1. Opening and seclusion

The Taika- and the Meiji-Reforms represent a special phenomenon of Japan's history, *viz,* that the interaction with foreign cultures is marked by measures of the central government to open the country or to close it for foreign influences. Upon this Sugimoto and Swain introduced a scheme of periodisation for the history of scholarship and science in Japan in which periods of cultural influx alternate with periods of isolation and prevalence of domestic developments.[8]

The first wave of Chinese influences is marked by the decision to follow the example of SuiT'ang China (the Taika Reforms of 646) and the decision to cancel the Embassy of 894. The latter decision put an end to the official relations with China and Japan began an era of semi-seclusion. At the end of the ninth century, Japanese culture had developed to such a degree that there was less need to learn from China. Moreover, the T'ang dynasty itself fell at that moment politically into decay. With the exception of a few Buddhist monks voyages to China were henceforth forbidden. At the same time restrictions were imposed on the arrival of Chinese ships.

The second Chinese Wave began about 1401, when shogun Ashikaga Yoshimutsu resumed official relations with the Ming Court. Japan broke its self-imposed seclusion, and merchants expanded their commercial activities to Southeast Asia. They even founded more or less autonomous commercial communities, the so-called *Nihonmachi* or 'Japanese towns' in Burma, Siam, Vietnam, the Philippines, etc. Sophisticated forms of Chinese learning finally rooted in Japan. A variety of Confucian schools was introduced, among which the philosophy of Chu Hsi, the *Shushigaku* - also known as Neo-Confucianism - became more or less the offical ideology in the seventeenth century.

The first Portuguese traders reached the south coast of Kyushu in 1543, and a period of almost a century began in which Japan was also exposed to the first wave of European influences. A crucial role in the exchange of scholarly ideas was given to the Portuguese Jesuits, who arrived in Kagoshima in 1549.[9] As a result of the efforts of Allesandro Valignano, since 1573 Visitador of the Indies, *seminarios* were built in Arima and Azuchi, and a *collegio* in Funai. Due to changes in governmental policy, only the Nagasaki *collegio* and the Arima *seminario* were flourishing in the first decade of the seventeenth century. These schools introduced an advanced educational system, including instruction in elementary European mathematics and sciences. They thus provided the basis for a second Western Wave starting in 1720. In that context the Jesuits' study of the Japanese language should be mentioned. They completed not only the first grammars, but also a Japanese- Portuguese and even a Latin-Portuguese-Japanese lexicon.

European medicine was among the Western influxes in this period. The Jesuit Luis de Almeida, a graduate from Lisbon, founded a hospital for the destitute in Funai in 1557. He introduced European surgery and taught this subject to his helpers. His fellow-Jesuit Christovão Ferreira arrived in 1611. He gave a great impetus to the development of the so-called *Namban geka* or 'surgery of the South-Barbarians' among others by publishing treatises about surgery. He abjured Christianity after heavy tortures in 1633, and lived henceforth under the Japanese name Sawano Chūan. At least two Japanese, Handa Jun'an and Kurisaki Dōki, studied European surgery outside Japan, probably in Macao. Among Japanese *Namban geka* received such a prestige that it could continue its position -under a different name- after the expulsion of the Portuguese.

The first Western Wave came to an abrupt end in the seventeenth century when the political unity was restored under Tokugawa Ieyasu, who was appointed, in 1603, *Seii tai shōgun,* the 'Barbarian-oppressing Generalissimo.' The administrative centre of the Tokugawa family in Edo (present Tokyo) became actually the government centre of Japan. The landlords, *daimyō,* were submitted to a system of restrictions and control in order to prevent a possible revolt against the Tokugawa government. They were, for instance, obliged to maintain a permanent residence at Edo, where they lived - six or twelve months - alternately with their home castles. In that context fitted the system of *metsuke* - in Dutch sources 'dwarskijkers'- who on the one hand recorded any misgovernment by civil servants and on the other hand spied on individuals or factions that were a possible threat to the authorities.

After the establishment of the Dutch and English trading posts at Hirado in 1609 and 1613 respectively, the Japanese authorities realised that it was not necessary to tolerate Christianity in order to maintain trade relations with European nations. They continued the persecutions of European missionaries and their Japanese followers, which had begun already at the end of the sixteenth century, not so much for religious reasons as well as for the political threat of the Christians. The persecutions came to a tragic end with the suppression of the Shimabara rebellion in 1637/8. The Tokugawa government decided, in 1639, to prohibit Christianity completely and to expel all the foreigners with the exception of the Dutch and the Chinese. The Dutch trading post was transferred to Nagasaki at the artificial island Deshima, which previously accommodated the Portuguese. Chinese merchants had only permission to trade exclusively in Nagasaki. That step had only to a limited degree consequences for the second wave of Chinese influences. As a matter of fact it stimulated the study of Chinese sciences and philosophy. Western influences, on the contrary, were initially strongly restricted, with the exception of surgery. The first Western Wave thus came to an end in 1639. From 1720 shogun Yoshimune allowed Western influences (the second Western Wave), when he eased the ban on the importation of certain categories of Western books. The national seclusion-policy was lifted with the treaty of Kanagawa (1854) and the subsequent opening of harbours to foreign ships. A complete turn towards the West occurred only after the aforementioned Meiji-Reforms of 1868.

2. Conditions for exchange

The preceding remarks give a rough outline of the background against which the Dutch-Japanese relations take place. Before going deeper into the introduction of Western medicine in Tokugawa Japan, it is good to recollect Sarton's fundamental ideas, as a demonstration of their value in understanding the exchange processes between different scientific cultures. It involves in particular the concepts of the humanity of science and of the unity of nature.[10]

The former concept is important in evaluating the limits of science. Sarton defined science as "the reflection of nature (of everything that is) by the human mind" and not by "a perfect, godlike mind." Only the latter could make 'perfect science.' Science as exclusive human activity is thus by definition imperfect. Scientific results are always abstractions. Abstraction is a process in which consideration is given to certain aspects or features of a complex whole disregarding the remainder. The limitations imposed on that process are defined by the worldview prevailing in a culture. In other words, they are defined by principles, which are supposed to be common and invariable to the diversity of phenomena, such as the four Aristotelian elements or the Chinese principles *yin* and *yang,* and the Western causality or the Chinese systematic correspondences. The prevailing scientific ideal, such as a strict formalism following mathematics, imposes another type of limitation. The 'humanity of science' implies imperfection and susceptibility to extensions and corrections.

In the confrontation between different scientific systems, exchange will take place only when there is a certain degree of resonance between conceptions, or a similar approach of reality. The postulate of a 'unity of nature' is crucial in that context. It gives the natural sciences their rationale and a certain consistency. Contradictions concerning this aspect, observed between different cultures or within a culture during its historic development, demonstrate more likely the inadequacy of sciences as an activity of the human mind, caught as they are in language, religious beliefs and philosophical ideas. The conditions for a successful introduction of unfamiliar scientific concepts can simply be described with the metaphor of the seed, the soil and the climate. The seed of a new and unfamiliar scientific concept can grow only to full stature in a receptive and fertile soil under favourable climatic influences.

The introduction of Western medicine in Japan occurred under limiting conditions. First and foremost was the language barrier. For the Western traditions the main language was Latin, for the Far Eastern tradition Chinese. Assuming a difference in scientific concepts, this means that Japanese scholars were introduced to unfamiliar ideas for which initially no terminology was available. The linguistic problem was even more complicated. From mid-seventeenth century the confrontation was not between traditional linguistic circles, but between Japanese and Dutch. Portuguese became an important intermediary: it was still the *lingua franca* among sailor nations and the Japanese interpreters had acquired considerable fluency in that language. With the help of the aforementioned dictionaries - in particular the Latin-Portuguesê-Japanese dictionary - problems could be solved, insofar classical medical knowledge was involved.

Next problem was the position of the central authorities. Japan was, from 1639-1854, practically cut off from European influences, except from those via contacts with the Chinese and the Dutch. The former contacts were especially important for the introduction of Western astronomy,[11] the latter for Western medicine. An essential turning point in the contacts with foreigners during the seclusion-period were the *Kyōhō* reforms under shogun Tokugawa Yoshimune in 1720. From that year Western sources were again available for Japanese scholars. This so-called second Western Wave will be discussed in more detail, focussing in particular on the introduction of anatomy.'[2]

3. Material restrictions

Japanese scholars depended for direct scientific contacts with Europeans on the Dutch trading post, since 1641 confined to Deshima. There were usually from ten to fifteen Dutch personnel in residence, including a senior surgeon and his assistant. Until the end of the eighteenth century only two *medicinae doctores* occupied the position of senior surgeon, *viz.* Willem ten Rhijne (Deshima 1674-1676), and Carl Pieter Thunberg (1775-1776). They remained relatively short at Deshima, like Engelbert Kaempfer (1690-1692) who took his degree only after returning from Japan. By far the largest numbers of medical men at Deshima were ship's surgeons. They were in fact artisans specialised in surgery. There was no traditional division of labour between medical doctors and surgeons on board the East-Indianmen. Medical doctors were almost completely missing at the merchant fleet. It meant that ship's surgeons had to treat internal diseases like scurvy, dysentery and typhoid fever. They even had to prepare drugs. Abraham Titsingh, since 1752 Upper-Surgeon of Amsterdam's Admiralty and in that capacity also examiner of ship's surgeons, held the view that a ship's surgeon should not only study physics, chemistry, botany, anatomy and surgery, but also physiology, pathology (i.e. internal medicine), therapy, and pharmacy.[13] These subjects constituted the contents of the - among ship's surgeons popular - handbook *Oost- en West-Indische warande* (1694 and 1734), a translation of the Latin treatises by Jacob Bontius, Willem Piso and Georgius Markgraef on medicine in Asia and America.

Most of the surgeons stayed relatively long in Japan, on an average at least four years. In the first part of the eighteenth century a few surgeons even stayed much longer. The surgeons Willem Wagemans, Doede Everts and Philip Pieter Musculus occupied their position at Deshima for twelve, eleven and eight years respectively. Musculus was expelled because of his knowledge of the Japanese language. One should realise that medical knowledge at Deshima was not limited to the surgeons. Some knowledge was probably not unusual among the higher officials. According to his inheritance, Chief Gijsbert Hemmy possessed a number of books on surgery and anatomy.

Live at Deshima was under strict regulations. The Dutch were under continuous and close surveillance of *ottona* (head of the Deshima ward) and *metsuke,* to mention only a few members of the - compared to the Dutch population - fully overgrown Japanese bureaucracy at the small island. No one could enter or leave Deshima without official permission. The Dutch chief made annually, later once every four years, a visit to Edo. The secretary and the senior surgeon usually accompanied him. During the two or three weeks spent at Edo, the chief was received in audience by the shogun.

Possession of bibles and other Christian books or religious pictures was strictly forbidden. They were impounded on entrance into Nagasaki Bay and were given back only on departure. The importation of Western books, even in Chinese translations, was under severe restrictions. Shogun Yoshimune lifted the ban, as we have seen earlier, with the exception of pure Christian literature. The objective of Yoshimune's measure was to improve knowledge of Western sciences useful for Japan, such as astronomy, medicine and botany. Books became an important source for the propagation of Western sciences. As long as the language was a serious barrier visual information probably played a more prominent role. Surgeons, who generally speaking were not familiar with Latin, had an extensive professional literature in Dutch at their disposal.[14] This was the literature to which Japanese scholars were introduced initially.

It is evident that the opportunities for direct personal contacts between the Dutch and the Japanese were extremely limited. Only two conditions occurred, *viz,* at Deshima with the official interpreters and during the court-journey to Edo with scholars from the court. The latter case refers to the custom that court officials and scholars visited the Dutch in their Edo-residence to inquire about Western sciences or to ask advice in medical questions. The role of interpreters was in these cases of vital importance, as it was when Japanese patients asked for the surgeon's intervention. The interpreters and student-interpreters at Deshima were civil servants, who constituted a kind of guild whose members belong to certain families. It is therefore not surprising that some interpreters gradually specialised in Western medicine. Members of the interpreter families Nishi and Narabayashi, for instance, founded medical schools, that became famous under the names *Nishi-ryūgeka* (Nishi-style surgery) and *Narabayashi-ryūgeka* (Narabayashi-style surgery). The founder of the latter school, Narabayashi Chinzan, translated parts of the Dutch edition of a handbook by the famous French surgeon Ambroise Paré under the title *Kōi geka soden* or 'Classical Tradition of Red [-hair] surgery' (1706). It is one of the first detailed treatises describing wound-treatment, surgical methods, instruments and wound-dressings.

A few Japanese received permission to apprentice to the Deshima surgeon. Some received a diploma after finishing their training. The oldest example, signed by surgeon Daniel Busch, dates 1665. It was granted to Arashiyama Hōan, son of a merchant from Chikuzen (Fukuokaken). He actually received tuition from three surgeons. His book *Shinkokuchihō ruiju tekiden* or 'Explanation of different foreign methods of medical treatment' (1683) was a standard work for many years.

Practitioners of *Namban geka* ('South-barbarian surgery') from the pre-seclusion period sought advantage with 'Dutch surgery', and renamed their practice *Kōmō geka* or 'Red-hair surgery.' Knowledge of this speciality remained confined to small groups, mainly interpreters and court physicians. Compared with the traditional practitioners, their number was relatively small. The group of interpreter-physicians monopolised Western learning more or less. They passed their knowledge on as secrets only available to disciples. Yoshimune's reforms caused a greater availability of Dutch books, and from mid-eighteenth century book importation occurred regularly. Gradually the Nagasaki interpreters lost their monopoly position, also because their preparatory linguistic activities enabled Japanese scholars to translate Dutch books.

4. Anatomy as basis of medicine

Health and disease can in principle be explained by two kinds of theories. One theory expresses these conditions in modalities of the relation between man and his environment. The other theory departs from the state of the physical body.

In the former case the human body is considered as a microcosmic image of the universe, the macrocosm. The health of an individual depends on the interaction with the macrocosm, or more simply said with the environment. A human being is, in this view, an inextricable part of nature. He participates in the cycle of elements and follows the daily changes in nature and the changes of seasons. Diseases are generalised disturbances and the degree of disturbance can therefore be derived from general features such as the pulse or the complexion. Generally speaking there is no interest in the exact anatomical location of the disturbance. Such ideas are characteristic for the classical humoral pathology as it prevailed in Europe under the name Galenism. In this system an equilibrium or harmony between four primary body-fluids (blood, phlegm, yellow bile and black bile) with opposite qualities (warm-cold and moist-dry) determines health and disease.

The principle of equilibrium or harmony is also fundamental in traditional Sino-Japanese medicine. Here it is based on a metaphysical dualism of *yin* (Jap. *in)* and *yang* (Jap. *yō),* the passive and active principles, and the notion that the cyclic changes in nature are characterised by a set of 'Five Phases' (Chin. *wu-hsing;* Jap. *go-gyō).* It is assumed that disorders occur when cyclical functioning of the human body is out of phase with that of the macrocosm. Although the phases are named after material aspects (wood, fire, earth, metal and water) they are primarily used to characterise functions. These functions are related to a kind of material force *ch 'i* (Jap. *ki)* which is more or less comparable with the Western concept of *pneuma.* The *ch 'i* maintains a pattern in the universe dictated by a formal principle *li* (Jap. *ri).* The Five Phases characterize everything in the universe, and are in particular used when relations in space and time are involved. They correlate with such phenomena as the planets, the seasons, the directions, the colours, the tastes, the senses and the organs.

As *yin* and *yang* and the Five Phases are assigned fundamental to all natural phenomena, they thus are basic to the theoretical framework for understanding the human body in health and disease. This is reflected in the binary and fivefold systems into which physiological activities are distinguished. The human body thus consists of two sets of functional systems: the Five Viscera (Chin. *wu-tsang,* Jap. *go-zō,* i.e. organs like the heart and liver where *ki* is stored, and the Six Bowels (Chin. *liu-fu,* Jap. *roku-fu),* i.e. organs like the large and small intestines where *ki* is collected. The Viscera and the Bowels are functionally interconnected and each pair is related to one of the senses. The heart is for instance connected with the small intestine and the ears, and the liver with the gall bladder and the eyes. There are also functional relations with certain areas on the surface of the body. Hence, these points are used in acupuncture, moxibustion and massage. As the *ki* of different organs manifests as rhythmic movement, pulse diagnosis is of great importance. The possibility to obtain at the exterior information about the activities of the inner parts discouraged interests in accurate dissections of the human body.

The classical humoral pathology and the traditional Sino-Japanese medicine are primarily related to the functions and activities of the human body and less to spatial relations and structures in the body. The terminology used for these functions is only loosely corresponding to actual anatomical structures. The opposite is the case with the Western medicine practised by the Deshima surgeons. The focus on the physical structure body was dominant in Western medicine. Andreas Vesalius' book *De humani corporis fabrica* (1543) made anatomy the key-stone of European medicine. It gave medicine a positivistic and materialistic character. As the knowledge of the inner structures became increasingly more accurate, it was more or less self-evident to localise diseases in organs or their parts. Thus developed in European medicine the doctrine of solidism, i.e. the doctrine that diseases are primarily changes in the solid parts of the body. Anatomy was not only important in the development of university medicine. Surgery developed gradually from a simple craft into an anatomy-based science. Anatomy became essential in tuition in the surgeon's guilds. Anatomy textbooks therefore were not missing in the reference library of surgeons.

Anatomy visualises the inner parts of the human body. That visualisation culminated in the seventeenth century in detailing the knowledge of the vascular system, the discovery of the lymphatic system and the discovery of glands.[15] Essential for the propagation of anatomical knowledge is the objective description of inner structures, as are the spatial relations and their objective, realistic representation. The transition from humours to the solid parts implies a changing perception of reality and refers to a general cultural-historical motive.[16]

5. The Ancient Practice School

An important role in preparing a receptive climate for Western medicine was given to the so-called *koihō or kohōha,* the 'Ancient Practice School.' That school is the crownpiece of a process of assimilating Chinese medicine that finally resulted in traditional Japanese

Chinese-style medicine *kampō* (literal: 'Han-method').[17]

The acceptation of Chinese medicine in Japan was, until the sixteenth century, limited to an élite. It was monopolised by a small group, which transferred this knowledge, usually within the family, from one generation to the next. During the sixteenth century Chinese culture began to be rooted in wider strata of society, also because of the rise of a printing and publishing culture. Concerning medicine, focus initially was on medicine from the Ming-period (1368-1644) that was strongly influenced by earlier efforts to unify medical theory during the Chin and Yüan dynasties, better known as Li- and Chu-medicine. Under these influences *goseihōha* or the 'School of the later [i.e. Yüan] age' emerged in Japan. It obtained a dominant position, especially through Manase Dōsan, his private academy *Keiteki-in* and his systematic textbook *Keiteki-shu* (1574). Manase's teachings induced the secularisation of medicine by restricting Buddhist influences on medical theory and practice.

Towards the mid-seventeenth century, *koihō* emerged as a reaction to the dogmatic and metaphysically speculative character of *goseihōha.* The Ancient Practice School advocated a return to ancient medical classics, in particular the *Shang-han lun* (Jap. *Shō-kan ron* or 'Treatise on Cold Injuries') written by the Chinese physician Chang Chung-ching in the third century. The author supposed that fevers pass through six phases and that each phase is characterised by specific symptoms. The treatment depends on the phase in which the disease is. *Shang-han lun* was an attractive book. Compared with other classics, it was easy to read. It gave little attention to theoretical consideration, but emphasised practical, positivist approaches to cures.

The koihō mythologised, so to speak, the past around this treatise in order to introduce a more empirical approach of medical treatment. In China the revaluation of *Shang-han lun* began with the 'Conservative School' of Yu Ch'ang. He published, in 1648, an appraisal of this treatise entitled *Shang lun p'ien* (Jap. *Shō ron hen),* in which he unfolded the original classical purity of *Shang-han lun* by eliminating changes and additions of later editions. The most important influences of *Shang-han lun* in Japan were a renewal of the disease-classification and the adoption of a system of diagnosing diseases in entities - the so-called *shō* - named according the drugs, which will be prescribed for their treatment. The latter system made a more direct relation with medical practice than the more abstract notions from *goseihōha.*

The *koihō* developed a new materialistic pathology, *viz,* that diseases resulted from a disturbance in the circulation of *ki.* One of the founders of Ancient Practice School, Gotō Gonzan, supposed that pathogenic factors caused a stagnation and accumulation of *ki* at certain spots. Diseases were, according this theory, no longer considered as generalised (i.e. affecting the whole body), but as localised disturbances. The School focussed on accurate descriptions of disease-entities and consequently on the methods of medical examination. Next to traditional diagnostic procedures (visual inspection, listening, interrogation and pulsefeeling), much value was set on palpation of the abdomen as method to localize the accumulation of *ki.* The Ancient Practice School did not confine itself to philological analysis of medical classics. On the contrary, these texts were a starting-point for reconsideration of traditional medical theories from an empirical or positivistic position.

6. Early dissections

Gotō Gonzan'pupil Yamawaki Tōyō evidently showed such an empirical attitude. He probably possessed the anatomy-textbook *Konstige ontledingh des menschelijken lichaems* (1659) by Johan Vesling. It is possible that this book raised the question about the value of traditional Chinese concepts concerning the inner structure of the human body, and in particular concerning the *zō-fu* concept. In 1754, a group of Kyoto physicians received permission - for the first time in Japan - to dissect the dead body of a criminal. Yamawaki was among that group. He published his observations in 1759 in a treatise entitled *Zōshi* or 'Description of the Organs' together with a few little detailed anatomical drawings made by his pupil Asanuma Suemitsu. Yamawaki compared the figures from Vesling's book with the situation observed during the dissection and was shocked by the accuracy of the European illustrations, for instance concerning the lobe-structure of the liver.'[18] Yamawaki's objective was not to combat the *zō-fu* concept, but to alter it, making it more into agreement with anatomical observations.

The publication of *Zōshi* led to discussions on the value of anatomical dissections. Yoshimasu Tōdō, one of Yamawaki's colleagues in the Ancient Practice School defended the opinion that anatomical knowledge was completely useless for the treatment of diseases. Sano Yasusada wrote in his *Hi-zōshi* ('Anti-Zōshi', 1760) that observation of viscera in a dead body was meaningless:

What zō really means is not a question of morphology; they are storages of *ki* with different functions. If *ki* is absent, then *zō* is nothing more than an empty container. Nothing can be learned from dissections, because *ki* is missing.

Similar criticisms could not prevent the growing notion that Chinese descriptions of the inner organs were unreliable and that the Dutch anatomy books deserved a closer study because of their greater accuracy. Yamawaki's publication convinced other scholars that anatomical dissections were of value. It inaugurated an era, in which Japanese physicians started to anatomise. Over a decade after *Zōshi* a second anatomical treatise was published, *viz,* the *Kaishihen* or 'On dissection of bodies' (1772) by Kawaguchi Shinnin. It was based on two dissections performed by Kawaguchi himself in Kyoto in 1770. The book had twenty-three drawings, some representing organs in cross-section.'[19]

Only two years later a book was published which is considered as the start of *Rangaku* or 'Dutch studies' in Japan. That book, the *Kaitai shinsho* or 'New Book on Anatomy' (1774) resulted from three years diligent translation work by a group of enthusiastic young physicians, among whom Sugita Gempaku, Maeno Ryōtaku and Nakagawa Jun'an were prominent.[20] The idea to publish this book was not inspired by the need to improve practical medical knowledge. It reflected more a greater interest in the perceptible physical structure of the human body. A genuine curiosity was excited on seeing the figures of two Dutch anatomy books, Johan Adam Kulmus' *Ontleedkundige Tafelen* and Caspar Bartholin's *Anatomia, ofte ontledinge des menschelijcken lichaems.* Sugita Gempaku described this in the autobiographic *Rangaku kotohajime* ('Dawn of Dutch Studies', 1815) as follows:

> Of course, not a word in them could we read, but the structures of internal organs and the skeletal frames illustrated in them appeared very different from those we had seen in books or had heard of in the past. We concluded that these must have been drawn from the real things.[21]

When Sugita obtained the two books, he became "anxious to compare their illustrations with the real things." The three aforementioned Japanese attended the dissection of a female criminal at Kotsugahara (near Edo) in March 1771. They were surprised by the resemblance between the illustrations and the observed structures. Their objective became:

> ...to show to the people that the real structure of the human body was different from the one described in Chinese books.[22]

> The only thought in me then was that a doctor cannot claim his title without first knowing the structures and functions of the internal organs.[23]

The three men decided to translate Kulmus' *Ontleedkundige Tafelen.* From the illustrations in *Kaitai shinsho* it is evident that they also had the anatomy books by Bartholin, Blankaart and Valverde at their disposal.

7. A **broader cultural context**

The publication *of Kaitai shinsho* enabled a greater circle of Japanese physicians to learn about Western anatomy in their own language. The publication of this translation can therefore be considered as the completion of an acceptation process, but not of an assimilation process. In the preceding chapters that acceptation is described as a more or less autonomous development of the medical science in Japan. Like the introduction of anatomy in European medicine, the process in Japan can not be viewed without considering more general cultural-historical influences. Taken into account the wave of well-documented dissections before 1774, i.e. before the real introduction of Western medicine started, this suggests strongly a spontaneous interest of Japanese physicians in morphology. That claim is even stronger when we compare the situation in China. The first translation of a European anatomy book was already available in 1635, but it met little or no response among Chinese doctors.

Observations are not photographic registrations of the outer world; they are interpretations of sense perceptions. Sugita refered to such an interpretative process in his autobiography.[24] The actual post-mortem at Kotsugahara was performed by a ninety-year-old *eta* (a sort of untouchable), who had performed a number of dissections since his youth. The custom then was that he opened the body and pointed out the organs. The attendant doctors simply watched them, and all they could say, was: "We actually viewed the inwards of a human body." For the determination of abnormal situation the doctors had to rely on the dissector's words. In March 1771 too, the old man pointed out various organs. Further he pointed to other structures, remarking:

I do not know what they are, but they have always been there in all the bodies which I have so far dissected.

Comparing them with illustrations in the Dutch books, the young doctors were able to identify them arteries, veins and lymphatics. The old *eta* made gave a remarkable opinion upon this post-mortem:

In my past experience of dissection, the doctors present never showed puzzled or asked questions specifically about one thing or another.

The three doctors evidently perceived the reality of the human body different from their predecessors. The framework of their observations obviously was different.

That difference can partly be attributed to a special interpretation of the principles of Neo-Confucianism. Generally speaking the teachings of Chu Hsi are less transcendental and life denying than Buddhism, and his doctrines encouraged, at least according to some followers, a natural scientific approach. They explained the 'investigation of Things' *(kakubutsu)* and the 'discovery of Heavenly Laws' *(kyūri)* as an encouragement to study 'things' empirically in order to discover their essence. Many books on natural history in the late Edo period included in their title the term *kakubutsu.* Prominent Neo-Confucianists like Hayashi Razan and Kaibara Ekkiken had a great interest in botany. The ultimate goal to study natural sciences was, according some Neo-Confucianists, to demonstrate that all Nature and all mankind were united in the creative will of Heaven. Western sciences thus could be considered as a branch of the 'investigation of Things' which supplemented deficiencies of Chinese Studies. In a sense, Sugita referred to that aspect when he described the, for him unexpected, flourishing of Dutch Studies:

> Looking back now, I see that the Chinese learning took long to develop in this country, because perhaps it was primarily a rhetorical language while Dutch developed fast, because it expressed facts as they were and it was easier to learn. Or, perhaps, it was that Chinese had trained the Japanese mind and had made a foundation whereupon Dutch was able to make a rapid start. I cannot tell. Or, it may be that the time was just ripe for this type of learning.[25]

The latter can be interpreted as a hint to other aspects of the period in which anatomy in Japan emerged. This period, also known as Tanuma period (after the influential senior councillor Tanuma Okitsugu), is characterised by a cultural richness, largely the creation of wealthy merchants in the Kansai area - the area where the first dissections took place. These merchants were relatively free from the rigid codes of the samurai class and could find an outlet for their wealth and energy in creating a new town culture. The domination by the merchant class is responsible for the realism in the new art and literature. It encouraged detailed studies from nature, as can be seen in the naturalistic school of Maruyama Ōkyo from Kyoto. These artists recorded their observations of individual objects - flowers, animals, insects and the like -accurately in sketchbooks. In that respect their work differed from the traditional *kachō-ga* or 'bird and flower painting', where the external form is only indicated to catch the essence of an object. The introduction of Western elements like perspective and shading enabled the new realistic schools to create depth and space around objects. These techniques were essential in drawing anatomical illustrations, as Sugita probably realised. He invited

Odano Naotake, a samurai from Akita, to copy the drawings of Kulmus' anatomy. In that period Odano resided in the house of Hiraga Gennai, a low-ranking samurai, mainly known as a naturalist and student of Western sciences under patronage of councillor Tanuma. Hiraga was a fellow-student of Nakagawa Jun'an and it was through him that Hiraga became acquainted with Sugita Gempaku. Odano and his daimyo Satake Shozan later founded the famous mid-18th-century Akita school of Dutch painting, the *Akita ranga.*[26] The co-operation of Odano with Sugita in the 'Edo-days' resembled the co-operation of the anatomist and the artist common in Renaissance Europe.

8. **Concluding remarks**

The acceptation of Western anatomy was a crucial first step in the acceptation of Western medicine in Japan, since the fundamental difference between eighteenth-century Western and Eastern medicine concerned the emphasis on form and structure. It took almost a century after the publication *of Kaitai shinsho* before Western medicine was accepted, then as part of the general political movement by the Meiji government.[27] In that period came an end to the unique role of the inhabitants of Deshima. At the same time came, so to say, an end to the phantasy images of the foreigners, such as the one by the Shinto propagandist Hirata Atsutane.[28] He depicted the Dutch as people with a fair complexion, big noses, dog's eyes, without heels and long and slender legs, which made them resemble animals. A more generally accepted characteristic was the particular hair-colour. The usual name given to the Dutch was *kōmō-jin* or 'red-haired', suggesting more a demonic being (like the red-haired Buddhist demons) than the actual hair-colour. Whatever the idea behind this name may be, it became the attribute distinguishing the Western contribution to medicine in Japan: *kōmō-geka* or 'Red-Hair Surgery' and *kōmō-igaku* or 'Red-Hair Medicine'. Even Hirata had to admit that, despite their resemblance to animals, their addiction to sexual excess and their short lives, the Dutch:

> ...are a nation given to a deep study of things and to fundamental investigations of every description. That is why they are certainly the most skilled people in the world in fine works of all sorts, and excel in medicine as well as in astronomy and geography.[29]

The influences described in the previous sections demonstrate that realism and scientific objectivity, necessary for a climate receptive for Western anatomy, were not the prerogatives of physicians. They were embedded in broader layers of society. The willingness of physicians with a Confucianist background to accept anatomy was, apart from internal scientific motives, also determined by the realistic view characteristic for a town culture dominated by the merchant class. In that sense the acceptation in Japan is not essentially different from that in Renaissance Europe. Strictly speaking both processes demonstrate Sarton's concept of the unity of nature, of knowledge and of humanity: the cultural context represents the 'humanity of science' and is responsible for its imperfectness. I hope that I made clear that the East has much material available to be used for comparative science history. It is self-evident that such studies need a rejection of thoughts of Western supremacy or self-complacency. In that contexts it still is useful to reflect on George Sarton's 'four guiding principles': the idea of unity, the humanity of science, the great value of Eastern thought and the supreme need of toleration and charity.[30] With this in mind, I am greatly honoured to be appointed to the chair named after the eminent science historian George Sarton!

Notes

1. G. Sarton, 'Remarks on the History of Science in India, Central and Eastern Asia', *Introduction to the History of Science* vol. 1 (Baltimore, 1927) p. 35-37.

2. G. Sarton, 'Four Guiding Ideas', *Introduction to the History of Science* vol. 3, part 1 (Baltimore, 1947) p. 19-26.

3. G. Sarton, *Introduction to the History of Science* vol. 1 (Baltimore, 1927) p. 377.

4. Ibid. p. 393.

5. Mori Katsumi, 'Envoys to T'ang China' [Jap.] *Nihon rekishi shinsho series* (Tokyo, 1962).

6. G. Sarton, *The Incubation of Western Culture in the Middle East* (Washington, 1951) p. 27.

7. Ibid. p. 27-28.

8. M. Sugimoto and D.L. Swain, *Science and Culture in Traditional Japan* (Vermont & Tokyo, 1989).

9. Arimichi Ebisawa, 'The Jesuits and their Cultural Activities in the Far East', *Cahiers d'Histoire Mondiale* 5, 1959: 346-374.

10. Cf note 2.

11. Nakayama Shigeru, *A History of Japanese Astronomy: Chinese Background and Western Impact* (Cambridge, 1969).

12. General information about the history of anatomy in Japan: Ogawa Teizo, 'Meiji mae Nihon Kaibōgakushi' in *Meiji mae Nihon Igakushi* I (Tokyo, 1978) p. 49-249.

13. A. Titsingh, *Geneekconst der heelmeesters tot dienst der zeevaart* (Amsterdam, 1752).

14. H. Beukers, 'De dageraad van de Europese geneeskunde in Japan' in: *Oranda, de Nederlanden in Japan (1600-1868)* (Brussel, 1989) p. 39-48.

15. A.M. Luyendijk-Elshout 'Anatomia Reformata. The Dutch Handbook of Anatomy from the Baroque Period; the Contents and Presentation.', *Nihon Ishigaku Zasshi* 20, 1974: 91-104.

16. J.H. van den Bergh, *Het menselijk lichaam I: het geopende lichaam* (Nijkerk, 1959), and H. Beukers, 'The Role of Anatomy in the Acceptance of Western Knowledge during the Edo period' *Bridge between Japan and the Netherlands* 11, 1996: 359-374 [Jap.: 149-161].

17. Naoki Hirama, 'The Development of Traditional Chinese Therapeutics and its Background in early modern Japan' in: Y. Kawakita, S. Sakai and Y. Otsuka (Eds), *History of Therapy* (Tokyo, 1990) p. 117-156.

18. G. Achiwa, 'On the First Anatomical Chart in Japan', *Japanese Studies in the History of Science* 5, 1966: 193-205.

19. Takamichi Tsusaki, 'Shinnin Kawaguchi und seine Arbeit *Kaishihen'*, *Yokohama Medical Bulletin* 18, 1967: 39-56.

20. A.M. Luijendijk-Elshout,' "Ontleedinge" as underlying Principle of Western Medicine in Japan' in: H. Beukers, A.M. Luijendijk-Elshout, M.E. van Opstall and F. Vos, *Red-Hair Medicine, Dutch-Japanese medical relations* (Amsterdam, 1991) p. 27-36.

21. G. Sugita, *Dawn of Western Sciences in Japan,* translated by Matsumoto Ryōzō (Tokyo, 1969) p. 24.

22. Ibid. p. 43.

23. Ibid. p. 45.

24. Ibid. p. 29-31.

25. Ibid. p. 51-52.

26. C. French, *Through closed doors. Western influence on Japanese art 1639-1853* (Rochester, 1977) p. 123-128.

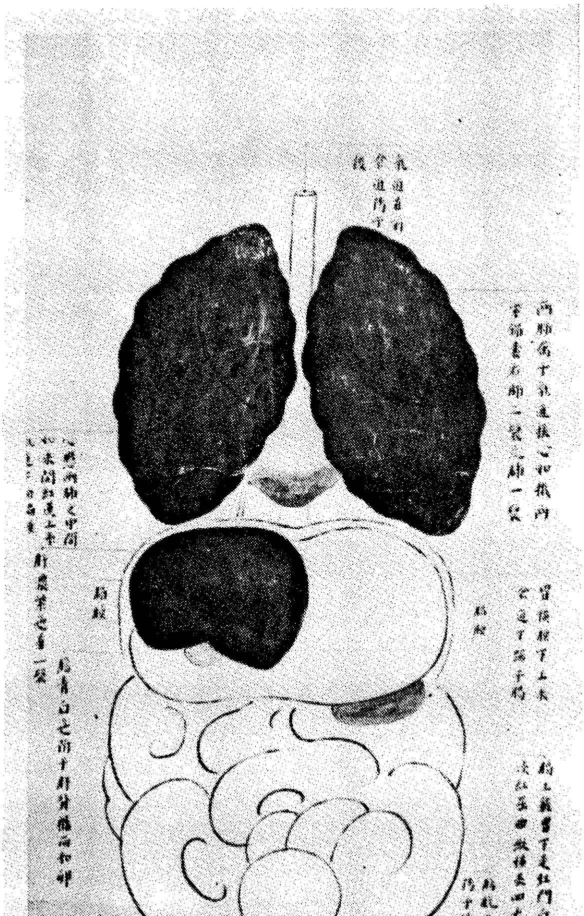
27. H. Beukers, 'The Fight against Smallpox in Japan: the Value of Western Medicine proved' in: H. Beukers, A.M. Luijendijk-Elshout, M.E. van Opstall and F. Vos, *Red-Hair Medicine, Dutch-Japanese medical relations* (Amsterdam, 1991) p. 59-77.

28. D. Keene, 'Hirata Atsutane and Western Learning', *T'oung Pao* 42, 1953: 353-380.

29. Ibid.

30. Cf note 2.

1. Frontal view of the internal organs from *Ton-i-sho* (1302/4), a medical encyclopaedia by the priest-physician Kajiwara Shozen. The drawings were after the Sung-Chinese example (1113) by Yang Chieh based on observations during the famous dissection of a rebel in 1045.



2. Frontal view of the internal organs from *Zōshi* (1759) by Yamawaki Tōyō. He described e.g. the heart as follows: "It looks like a pink lotus that has not bloomed yet. At the top it is connected to the bronchus. The lower part touches the intestines", and the liver as: "Deep purple, and a crease is seen in it."

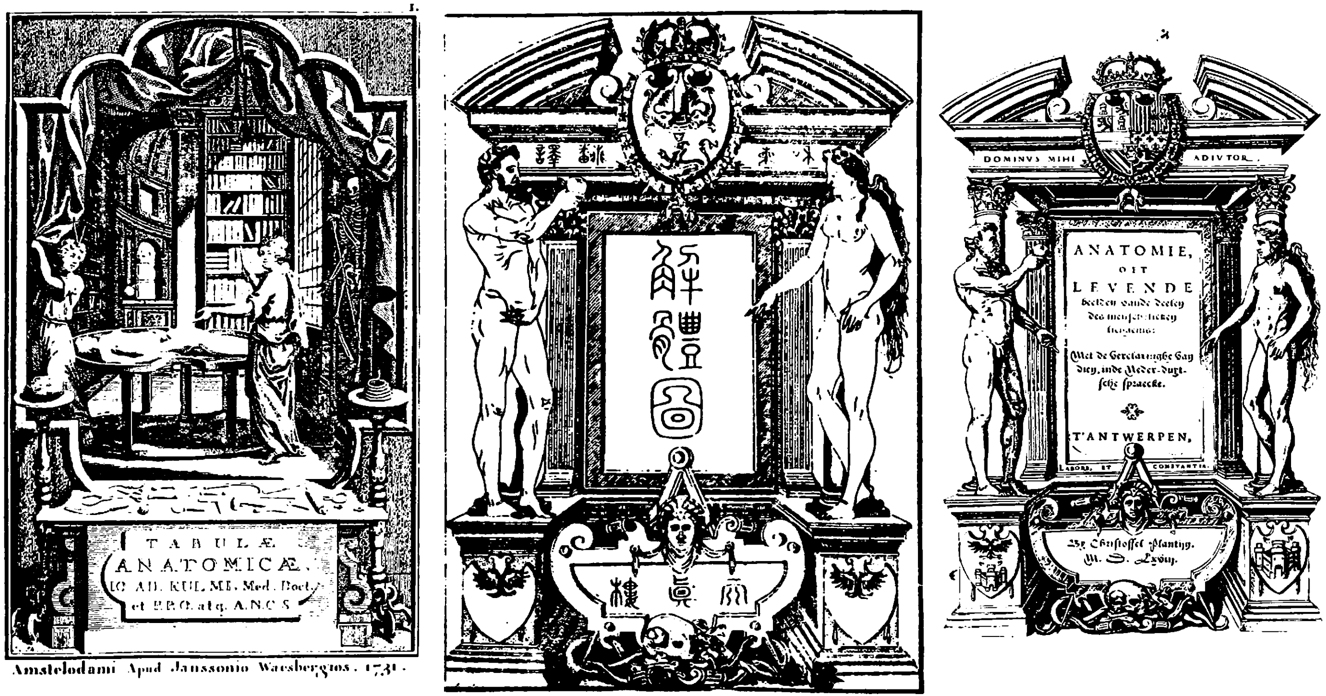


Fig. 3. The *Kaitai shinsho* is primarily based on Kulmus' *Ontleedkundige Tafelen.* Comparison of the frontispiece of the *Kaitai shinsho* (3b) with Kulmus' frontispiece (3a) shows that the translators also had Vervalde's *Anatomie* (3c) at their disposal.

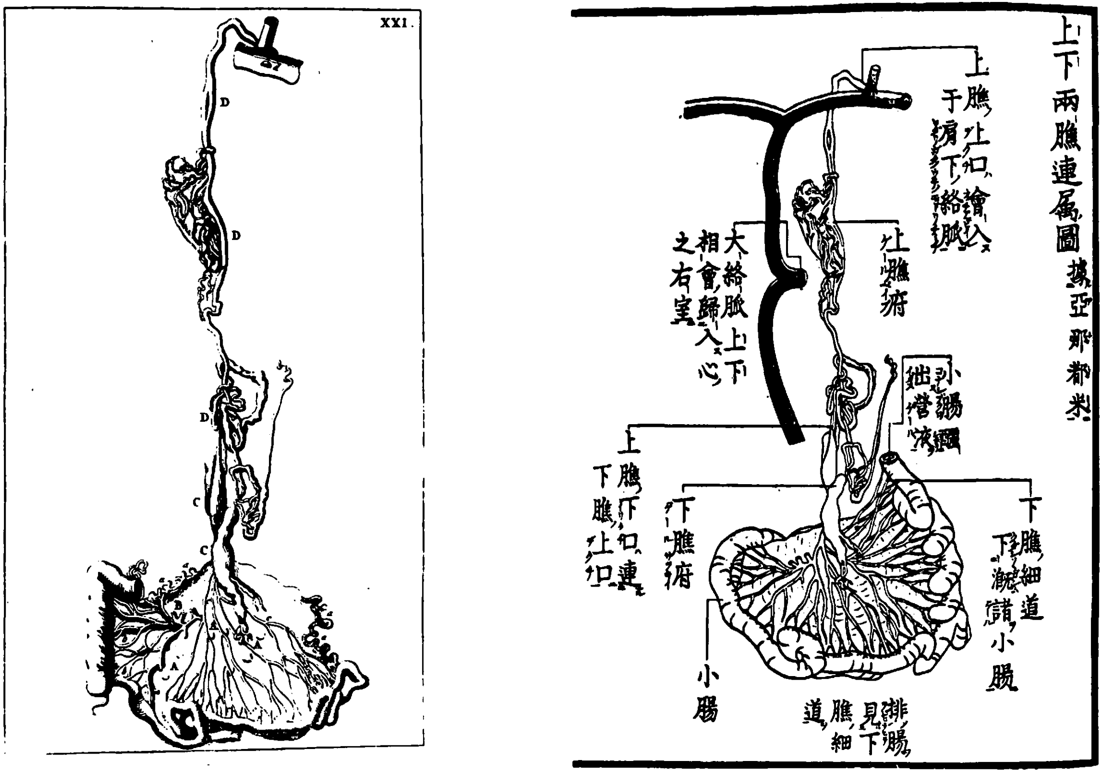


Fig. 4. The illustrations from Kulmus' *Ontleedkundige Tafelen* were the iconographic model for Japanese anatomical illustrations, as can be seen comparing the table representing the intestinal lymphatics and the thoracic duct in Kulmus (left) with the drawing in Mitani Kōki's *Kaitai hatsumō* (1813) (right). Mitami based his work on a dissection performed at Kyoto in 1802.

ACID SPIRITS AND ALKALINE SALTS

The iatrochemistry of Franciscus dele Boë, Sylvius.

Harm Beukers

The second half of the seventeenth century is generally considered as the flourishing-time of the Leiden medical faculty. The ideas prevailing there, are more or less illustrated in the seal of 1670, with which the faculty authenticated its documents (fig. 1).

Prominent in the picture stands a two-headed woman placed against a background with a radiant sun and a colonnade. The woman, wearing a cuirass, has in her left hand a heart with an eye and in her right hand a burning-lens lighting a fire. The colonnade referred to the ideal of the *constantia* or, in the words of the famous humanist Justus Lipsius, the proper and firm strength of mind which does not lead to over-boldness or dejection by external or accidental circumstances. *Constantia* certainly was needed in the turbulent seventeenth-century medicine dominated by the controversies between Galenists and empirically inspired doctors.[1]

The core of Galenism was classical natural philosophy handed down in medical texts and reasoned in the scholastic tradition. Its learned adherents considered medicine as a part of knowledge engaged in regulating human life in accordance with universal principles, thus a philosophy of health. The opponents emphasized the study of nature, "God's book of nature", over scholastic learning. They were more interested in natural history than in natural philosophy. They established a reformed medicine based on Vesalian anatomy and Harvey's physiology. The controversy was not just an intellectual discourse, it had also consequences for medical practice. Galenists emphasized the classical *diaetetica* and the preservation of health. Their opponents, on the other hand, advocated the treatment with the 'chemical' drugs introduced since Paracelsus shook the medical world. The animosity was stirred up, in the seventeenth century, by the discovery of new anatomical structures such as the digestive glands and the lymphatics, but above all by the publication of Harvey's theory of the circulation of blood.

The objects on the seal demonstrate the prevailing idea in Leiden's medical faculty about the way how to obtain true knowledge. Experience played, in that concept, a crucial role. In the seal it is reflected by the burning fire standing for truth and knowledge. The purifying action of fire expels ignorance, falsehood and fallacies. The sun is the source of the fire, and with that the source of truth and knowledge. Its beams make everything visible. They light the fire through a burning-lens and not with a concave mirror. It means that the fire does not originate from a reflection; it arises from converging beams directly derived from the sun. As the eye needs light to see , so the mind or "inner eye" needs divine light. The eye depicted on the heart therefore is the symbol of the enlightenment, the rational intuition. The heart of the woman is protected by a cuirass with Medusa's head. That head sends the ignorant flying. It represents the victory of the ratio. The ultimate asset was not knowledge as such but wisdom. It is shown in the seal by the two heads, since true and positive knowledge proceeds from reflections of past and future matters.

The well-balanced use of experience and reason is expressed with the device *Experientia et Ratione.* It is borrowed from an aphorism of Francis Bacon, *viz,* that much can be expected from a close and pure alliance of the experimental and rational faculties. In the seventeenth century, systematic experimentation played an increasingly important role, since the nature of things gives itself away sooner "under the torments of the art than in its natural freedom." Crucial were so-called *experimenta lucifera* or enlightening experiments aiming at the discovery of true causes.

Franciscis dele Boë, Sylvius brought that subject to the attention of his audience during the inaugural address of 1658.[2] He explained that the perfection of medecine could only succeed when a number of educated men was brought together, who "neglecting all detrimental obstacles of prejudice and partisanship and scorning vain ambitions to suffocate and surpass others by slyness, call and contemplate before the scales of truth, Ratio and Experience, all writings of ancient and recent authors about natural and medical subjects and, at the same time, everything they investigated, considered and observed themselves." Considering this, it is reasonable to suppose that Sylvius was the inspirer of the image on the faculty seal. He was, without doubt, *primus inter pares* in the faculty of that time, since it consisted, after the decease of Florentius Schuyl (teaching *institutiones* and botany: 1664-1669) and Johan van Horne (anatomy: 1651-1670), only of Franciscus Sylvius, Lucas Schacht (medicine: 1670-1689) and Charles Drelincourt (medicine and anatomy: 1668-1697).

Scientific research should, according to Sylvius, not be done as private enterprise. It could only flourish in the joined efforts of like-minded persons. In the oration he had pointed to his earlier efforts, while practising in Amsterdam, to establish a society where physicians would co-operate in view of the progress of medicine. During his professorship, he was able to realize such a co-operation (may be together with his colleague Van Horne) with his students Nicolaas Steno, Reinier de Graaf, Jan Swammerdam en Florentius Schuyl. The latter three published experimental physiological research, which was closely related to

Sylvius' ideas on vital functions.

From its foundation in 1575, the Leiden medical faculty had considered experience the best teacher in education. The students did not only attend the traditional lectures and disputations, but also used more recent educational tools, such as the practical demonstrations and exercises in the botanical garden, the anatomical theatre (both founded in 1592), the Caecilia Hospital (since 1636) and the chemistry, *i.e.* pharmaceutical laboratory (1669). In Sylvius' days Leiden was famous for its clinical teaching. For that purpose twelve beds were available in the Caecilia Hospital.[3] The demonstration of patients there had an exemplary character. It was not the intention to demonstrate a broad spectrum of different diseases. That aspect was still covered by the *consilia,* collections of advices for special diseases by famous physicians that were published combined with relevant case histories.

In that context the frontispiece of Reinier de Graaf's treatise on pancreatic juice deserves special attention (fig. 2). It shows a room where De Graaf demonstrates the contents of the abdominal cavity to two colleagues. In front of the dissection table are animals, including a dog with a pancreas fistula. In the background we see a patient lying in a bedstead. The picture is in fact a reflection about the three pillars on which, according to Sylvius, medical knowledge was based; *i.e.* the observation at the bedside, the dissection of the deceased and the experiments on animals.[4] The first two subjects were part of Sylvius' clinical teaching. In contrast with his predecessors and successors, he used to pay daily visits to the patients, accompanied by the students. In that way the students could much better pursue the development of diseases and the effects of the therapeutical interventions. The clinical rounds in the Caecilia Hospital were not simple demonstrations by the professor. The students had to participate actively. In dialogue with their teacher, they arrived at the diagnosis, prognosis and therapy. The post-mortems performed by Sylvius on patients deceased in the hospital gave the students a deeper understanding of the nature of the pathological changes underlying the clinically observed diseases. The third pillar, animal experimentation, was not an activity taking place within the university, which was primarily a teaching institution. Experiments


G. Wingendorp fe.
REGNERUS DE GRAAF
DE SUCCO PANCREATICO

probably were done at home. Sylvius used three rooms in his house at Rapenburg as laboratory. These laboratories could easily compete with the university *laboratorium chimicum*. The latter had only eight furnaces, while the former counted twenty furnaces.[5]

Franciscus dele Boë, Sylvius

In the preceding part, the name of the Leiden professor Sylvius has been mentioned frequently. It is time to introduce him more in detail.[6] Franciscus dele Boë, called Sylvius, descended from a Protestant family from Cambrai. For religious reasons the family had migrated to Germany, where Sylvius was born in Hanau in 1614. He studied medicine at the universities of Sédan and Leiden. At the latter university he enrolled for the first time on June 4th, 1632. He held a disputation *Positiones variae medicae* under the presidency of Adolphus Vorstius in 1634.[7] After a study-tour to Southern German universities, Sylvius took the doctor's degree in Basel om March 16th, 1637 with a thesis *De animali motu ejusque laesionibus*. He returned to his birthplace and practised medicine for a short period.

In November 1638 Sylvius matriculated again in Leiden. Until 1641, he was active as unsalaried lecturer of anatomy. That course gave him great fame, in particular because of his work on the anatomy of the central nervous system. His *Notae de cerebro* were included in the *Institutiones anatomicae* (1641), the famous textbook by the Danish anatomist Caspar Bartholin. Lucas Schacht mentioned in Sylvius' funeral oration that "many students, and certainly not the worst ones, attended his courses, so that it seemed as if only he could understand and explain anatomy."[8] In this period Sylvius demonstrated the circulation of the blood and convinced the Leiden professors of the truth of Harvey's theory. One of the professors, Johan de Wale changed from a severe opponent into a fervent supporter. He even did experiments, published as *Epistolae duae, de motu sanguinis ad Thomam Bartholinum* (1640), used by Harvey in his defence against Riolan's criticism.

Since there was no prospect of a professorship in Leiden, Sylvius moved to Amsterdam in 1641. After seventeen years practising there, he returned to Leiden again . In 1658 he was appointed professor of medicine, as successor of Albertus Kyper. He officially accepted the chair with the aforementioned inaugural address on September 17th, 1658. Essential elements in his teachings were observations by the students themselves. He invited, in his inaugural oration, students to observe the evidences of his teaching with their own eyes. Clinical teaching in Leiden reached its pinnacle under Sylvius. His death, November 15th, 1672, put an end to a flourishing-time of Leiden's medical faculty, also because Sylvius was considered as the person representing the culmination of iatrochemistry.

In the sixteenth and seventeenth century Galenic traditionalism competed with iatrochemistry. Iatrochemists described vital processes in chemical terms. They based physiology, pathology and therapy on chemical properties and conversions. The system of chemical medicine was not a mere pure theoretical speculation. It had explicit consequences for medical practice. Its intention was the introduction of chemically prepared drugs and the elimination of traditional approaches such as blood-letting and the use of Galenicals. New and more potent drugs, so-called spagyricals, were developed using methods like distillation and maceration. During these procedures the essence, the so-called *arcanum,* was isolated from the inert substance in which it was hidden. Sylvius considered chemistry as "the primary art [to study] natural transformations, which in certain cases - if one would be allowed to say - surpasses Nature itself, and which is not only very useful and pre-eminently necessary for the upbuilding of natural science but also for a true medical science."[9]

It is evident that sixteenth and seventeenth century chemistry was not able to present sufficient support for such interpretations. The ideas of sixteenth century iatrochemists like Paracelsus and Van Helmont were strongly speculative and mystical. Their seventeenth century successor Franciscus Sylvius tried to explain phenomena in terms relatively close to observations and experiments. He also tried to integrate his chemical theories in the so-called *anatomia reformata.* This anatomy included recently discovered structures such as lacteals, thoracic duct and the ducts of digestive glands. These structures actually played a fundamental role in Sylvius' iatrochemistry, which in fact was the adaptation of the humoral pathology to new anatomical and chemical discoveries. Blood remained the most important, life-maintaining substance.

Unfortunately Sylvius did not write a systematic explanation of his medical system. He began writing the *Institutiones medicae* in 1668, but the unauthorized Paris-edition of his courses forced him to stop this work and to concentrate on the edition of the *Praxeos medica idea nova.* He could, however, only complete the first volume (1671). The other volumes, including the appendix, were posthumously published by his former pupil Justus Schrader. This book discusses various diseases and includes much physiology, but not in a systematic order. The basic concepts of Sylvius' system can be found in disputations held under his presidency, in particular the collection entitled *Disputationem medicarum decas* (1663) containing "the primary natural functions of the human body deduced from anatomical, practical and chemical experiments.

Sylvius' physiological chemistry'[10]

Like most iatrochemists, Sylvius payed much attention to the digestive process. The purpose of digestion is "the separation of useful parts from useless parts." To release the useful parts, foodstuffs had to be broken up into components. That process implied the dissolution of bonds between the components. Sylvius supposed two types of binding agents, namely salt and oil. The salt binding was easily broken by water, in contrast with oil, which could only be transformed by fire.

The digestion was divided in two steps. The first step, a fermentation in the stomach, did not result in a complete decomposition into the purest and simplest parts. It was a preparatory process changing the bonds between the component parts of the nutrients in such a way that they easily could be processed in the next step. Sylvius defined fermentation as a process where "the common bond, which keeps all parts in a unit together, is mildly dissolved." The requirements for fermentation were sufficient water (to dissolve the 'salt binding'), moderate heat (to change the 'oil binding'), and a free outlet for gasses originating during the latter change. Recent anatomical discoveries found their niche in this part of Sylvius' physiology. Nicolaas Steno's discovery of the excretory duct of the saliva glands (1660), gave these glands an essential role in Sylvius' concept of the digestion. Saliva provided the large amounts of water and an acid ferment, necessary for the fermentation in the stomach.

The final products of fermentation were "rather pure, simple and less complex, especially liquid parts." They were further digested in the second step, an effervescence taking place in the duodenum. This was the final separation of the purest, more fluid and useful parts from impure, more solid and thick parts of the nutrients. The latter made up the faeces. The former, the so-called *chylus,* constituted the raw material for producing blood. The effervescence was a completely different chemical reaction. Sylvius defined it as: "the dissociation of combined parts and the condensation of parts to be combined, coupled with some kind of perceptible resistance of the parts, which are to be combined and with heat generated by that [process]." The protoype of such a vehement reaction was to combination of an acid spirit, *spiritus acidus,* and an alkaline salt, *sal lixiviosum.*

Acid as well as alkali were generated by the action of fire. It meant, in Sylvius' opinion, that fire particles were intrinsic components of acid and alkali. They were responsible for the sharpness of these substances. Because of the latter quality, he assumed that fire particles had a tetrahedal shape. Fire particles were released during the reaction of an acid with an alkali. Their special shape made fire particles suited to act on other parts and force these parts to move and fly apart. In this way Sylvius explained the agitation, the ebullition and the heat-development accompanying the effervescence. Sylvius supposed an analogous process in the duodenum. The fermented food came here into contact with the *humor triumviratus* or triumviral fluid, consisting of the thin watery part of the saliva, the alkaline bile and the acid pancreatic juice. The reaction of the acid and the alkaline components resulted in a 'subacidic' lymph, which was filtered through the line *[crusta]* of the intestines and passed into the lacteals.

Sylvius' theory was not only based on speculation and reasoning. He adduced also evidence from experiments. *In vitro* experiments supported the basic chemical concepts. In the eighth disputation, he described the preparation of *sal lixivium* from the ashes of burned materials, and in the tenth disputation the preparation *of spiritus acidus* by heating salts in a closed vessel. In both cases the preparation took place through the action of fire. Thus, he proved that fire particles were intrinsic components of acids and alkali. *In vivo* experiments were used to support the hypothesis of the effervescence in the duodenum. The alkaline character of the bile was a common experience, but the acidity of pancreatic juice had to be proven. That was one of the purposes of Reinier de Graafs disputation. He tapped pancreatic juice from a living dog through a fistula connected to the pancreas (fig. 3).

He succeeded after five failures. The taste of the juice was not simple to interprete. Sometimes it was without taste, sometimes salty, sometimes sourish. But the final proof was done with pancreatic juice of a recently deceased boatswain, obtained during a post-mortem. De Graaf never experienced in dogs a more pleasing acid. Another student, Florentius Schuyl, demonstrated *in vivo* the effervescence. He ligated the duodenum of a dog at both sides of the ampulla of Vater, the common outlet of the pancreatic duct and and the bile duct. After three hours the abdomen was opened again. The duodenum was swollen. After opening it, a stinking, brown liquid and gas were produced. Thus an effervescence had taken place.

The latter experiment was only a minor part of Schuyl's *Pro veteri medicina* (1670). In this treatise Schuyl tried to prove that Sylvius' theory was in agreement with the Classics. Evidently, experimental philosphers did not find it beneath their dignity to borrow from historical sources. The publication caused a quarrel with Schuyl's former student Willem ten Rhijne, who thought that much was borrow from his work. Ten Rhijne published two years later *Meditationes in magni Hippocratis textum, de veteri medicina* (1672). This text gave iatrochemistry more or less a classical basis, since it said that all faculties originate from bitter, salt, sweet, acid and astringent present in human beings.

The role of the liver

Sylvius explained the action of the heart with a mechanism analogous to that of the digestion. He postulated a so-called vital effervescence in the right ventricle. Thus, an alkaline and an acid fluid had to encounter there. The endproduct of the digestion, the 'sub-acidic' lymph was carried to the right heart via the lacteals, the thoracic duct, the left innominate vein and finally the superior vena cava. The alkaline part originated from the bile, which - as Sylvius supposed - was partly secreted into the inferior vena cava and transported to the heart. Both fluids met in the right ventricle and caused an effervescence. The fire particles were liberated and penetrated parts of the blood, which were more suitable to their nature, such as oil particles. The reaction had its analogy in the combination of acid spirit of vitriol (sulphuric acid), a volatile (alkaline) salt and oily spirit of terpentine. The heat accompanying the reaction of bile and lymph caused an expansion of the ventricle, which in turn stimulated the heart muscle to contract.

Galenic physiology regarded the liver as the central organ where the blood was formed. The portal vein transported the white nutritive jus or *chylus* from the intestines to the liver. The strong ramifications of the vein created a close contact with the liver matter. The chyle underwent a kind of boiling process leading to the formation of blood and two by-product, *viz,* a 'lighter foam' corresponding to yellow bile and a 'heavier, muddy' substance resembling black bile. The liver therefore was considered the source of three of the four humours. Its central position in the Galenic physiology was, moreover, emphasized by the fact that the liver was the origin of the venous system transporting nutritive blood to all parts of the body.

During the seventeenth century there was a growing criticism on the unique position conferred to the liver. The introduction of Harvey's theory on the circulation of blood (1628) meant that the liver was no longer the central organ from which the veins originated. Aselli's discovery of the lacteals (1622) made clear that chyle was not transported to the liver through the portal vein, but via the thoracic duct to the systemic circulation. Glisson's study of the finer structure of the liver (1654) resulted in a better understanding of its vascular structure, namely that the portal veins and its branches determined the inner structure of the liver. Finally, Malpighi's microscopic examinations (1666) strongly supported the idea that the liver was a gland comparable with the pancreas or the salivary glands. Malpighi classified the liver under the type of glands, which Franciscus Sylvius mentioned *glandulae conglomeratae,* or glands composed of many smaller glands and with a secretory duct. Sylvius distinghuised these glands from the conglobate glands such as the lymph nodes.

In the period passing between the publications of Glisson and Malpighi, there was still discussion about the place were the bile was produced. Sylvius in particular took a rather dissenting position. On July

10th, 1660 he let Peter Sloterdyck defend the disputation entitled *De bilis ac hepatis usu.* Thesis 36 raised the surmise that bile originated as follows from blood in the cystic artery. Particles resembling bile permeate the pores of the membranes covering the gallbladder into the cavity. These particles were there transformed into real bile particles by already excisting bile particles, in a manner comparable to the action of the philosopher's stone. The liver had only two functions. In the first place, it provided the frame-work for the blood-vessels and the bile-ducts: the liver "contained and enclosed the roots of the vena cava, the branches of the portal vein and the bile ducts combined in a common sheath." In the second place, "the gentle heat of its parenchym promoted a profound mixing of bile and blood which flowed back through the aforementioned vein [vena cava]." Sylvius tried to demonstrate the continuity between the bloodvessels and the bile ducts. In the final publication of Sloterdyck's disputation in the *Disputationum medicarum decas,* Sylvius added to the original more theses, describing later experiments. He thought having proved the continuity between the different vascular systems by blowing air into the hepatic bile ducts or the hepatic arteries of deceased patients which he dissected in the Caecilia Hospital.

Sylvius supposed that the bile flowed from the gall-bladder in two directions, namely via the *ductus choledochus* to the alimentary tract and via the *ductus hepaticus* to the liver. The hypothesis found little support. After Malpighi's publication Sylvius had to accept that the bile was no longer produced in the gall-bladder, but in the liver. Malpighi had demonstrated that bile production continued after removal of the gall-bladder. Sylvius' idea concerning the 'inborn heat' in the heart, was so crucial that he sticked to the opinion that bile flowed from the bladder in two directions. In the first volume of his *Praxeos medicae idea nova* (1671), he maintained the 'presumption' that part of the bile flowed back from the gall-bladder to the liver, where it passed into the blood moving to the right ventricle.

The Danish anatomist Thomas Bartholinus, who attended Sylvius' anatomy course in Leiden, thought that his discovery of the lymphatics had undermined Galen's central dogma on the production and movement of the blood in such a way, that one could deprive the liver of its central place among the vital functions. In his book *Vasa lymphatica nuper Hafniae in animantibus inventa* (1653), he wrote that the lymphatics of the liver always held an aqueous fluid, even after a meal. The liver therefore did not collect chyle! Bartholinus concluded chapter eight - entitled "the funeral of the liver after the discovery of the lymphatics" - with a satirical epitaph for "the most prominent cook and ruler of your body, the liver.. She has cooked so long that she, with her bloody rule, boiled herself down."

Sylvius' reaction was unexpected. He wrote Batholin a letter *De epitaphio hepatis* (May 13th, 1661) expressing the opinion that the funeral of the liver was ridiculous and the epitaph not justified: "Those who scoff at the once much honoured organ, should feel ashamed about their not less presumptuous than ridiculous efforts." He supposed that the epitaph was meant as a joke. An organ with such an admirable structure could hardly be without use! Sylvius wondered what function Bartholin assigned to the liver. Few months later Bartholin answered that the main purpose of his treatise was to oppose the idea that blood originated from chyle. He saw the liver only as a filter purifying the blood.

Sylvius' pathology and therapy

Health was, in Sylvius' view, dependent on normal effervescences. Disturbances of this process resulted in disease. Pathological conditions were reduced to two different types: either an excess of acid, an *acrimonia acida,* or an excess of alkali, an *acrimonia lixiviosa.*[11] These abnormal situations were caused by abnormal secretions. An abnormal, *i.e.* sharp acid pancreatic juice gave sharp pains and tensions in the lumbar and the hypochondriac region. An excess of bile induced hot fevers, mainly because bile contained an oily, and therefore inflammable component. Though phlegm made patients frightened. Abnormal lymph caused catarrh and rheumatism. Generally speaking, abnormal secretions freed more fire particles in the heart. These particles intensified the heart action and accelerated the pulse. Sylvius considered the latter sign as pathognomic for fevers. Abnormal effervescences could also be accompanied by excessive exhalations *(halitus).* They caused continuous heat and thus a continuous fever, when the exhalations were bilious. Acid exhalations gave a sensation of cold. For that reason abnormal pancreatic juice caused intermittent fevers.

Sylvius supposed that the disturbances in the blood could be corrected by direct 'chemical interference.' He rejected general measures such as blood-letting. Since diseases were simply based on excesses of acid or alkali, therapy could be reduced to a correction of the excess by drugs of an opposite nature. This implied the use of *alterantia* with a specific character, acid or alkaline. Sylvius also prefered the use of *evacuantia* with specific actions such as, dilution of the blood, mitigation of abnormal effervescences, stimulation of perspiration and interference with flatulence. All these actions were attributed to opium and therefore justified the frequent presciption of the drug.

Sylvius was an active chemist and spent much time in his laboratory to develop new drugs. Well known are his *sal febrifugium* and *sal volatile oleosum.* He prescribed the latter salt frequently. It was an alkaline substance, useful in cases caused by excess of acid. Like all volatile salts it neutralized acid, stimulated respiration and dissolved thick phlegm. Most volatile salts were, however, too sharp and thus unpleasant to use. The 'oily volatile salt', produced by dry destillation of hartshorn, had the advantage that the oily component damped the sharpness of the salt.

Mechanical aspects of Sylvius' iatrochemistry

Sylvius' explanation of the effervescence fitted well in a corpucular, mechanistic view. The actions of fire particles was closely related to their configuration. The changes they caused required direct contact with the substances undergoing transformation. Sylvius also used mechanical concepts to explain other physiological processes. He considered the production of digestive juices, such as the bile or saliva, as a kind of filtration through the pores of the *tunica,* the envelope of a gland. De Graaf specified it as follows: "arteries transfer under the purple blood-substance all kinds of fluid to the glands, each of which letting pass, like sieves, those particles whose size and outer form corresponds best with the shape of the pores; at the same excluding other particles with less resemblance." Filtration and sieving dictated the absorption of chyle from the intestines and the formation of *spiritus animalis* in the brain. It was in fact a general principle: the walls of blood-vessels in different organs had pores of distinct size and shape, letting pass only fitting partcles, so producing the characteristic and specific secretion.

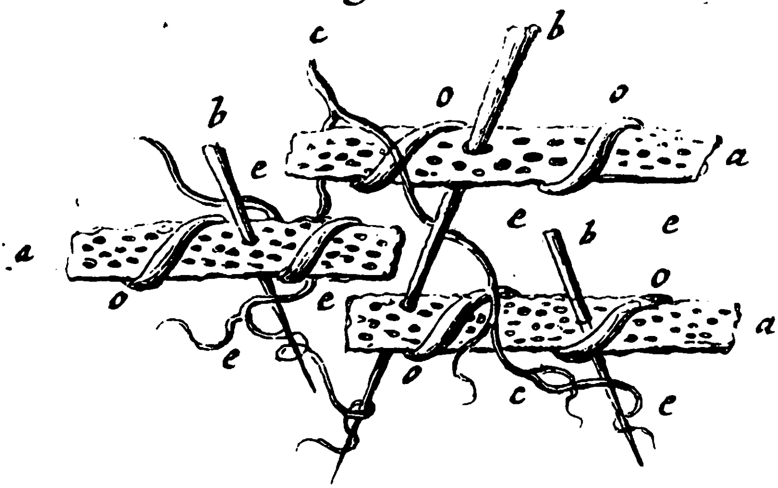
To explain the action of the nervous system, Sylvius maintained the ancient concept of the *spiritus animalis;* the purest and finest substance in the body. The pores of the capillaries in the brain cortex filtered the most spirituous and finest parts from the blood into the white substance. The remaining aqueous parts were collected in the meninges and the ventricles. The nerves carried the animal spirits to all parts of the body. Spirits not used, for instance in muscular actions, were collected from the tissues by the lymphatics and next re-introduced in the blood circulation through the lymphatic system. Lymph particapted in a second circulation used to prevent excessive expenditure of *spiritus animalis.*

Mechanical aspects were also involved in pathological conditions. It usually was a matter of abnormal physical conditions of the body fluids (too tough, too mucous) resulting in obstruction and stagnation in vessels, nerves and glandular ducts. An intermittent fever resulted from stasis of pancreatic juice. An excess of acid was responsible for the coagulation of the juice. Sylvius based this hypothesis on the observation - in a post-mortem - that a blue substance injected in the pancreatic duct did not penetrate all parts of the gland.

Copious meals made the chyle thick and mucous and caused a stasis in the lacteals. These delicate vessels ruptured and their contents accumulated in the abdominal cavity causing the clinical picture of ascites. This abnormal accumulation of fluid could also result from an excess of acid in the blood. In that case excessive binding of bloodparticles created a surplus of serum and phlegm. Therapy included just the dilution of blood, the dissolution of phlegm and the neutralization of acid. For that reason *salia volatilia* could not be missing. Their action was to dissolve tough and mucous substances and to correct acidity.

Sylvius reduced physiological and pathological processes primarily to reactions between acid spirits and alkaline salts. The chemical interpretation did not exclude mechanical aspects, as is shown by Sylvius' interest in the sieving action of the solid parts and the use of 'hydrodynamic' concepts. Followers like Steven Blankaart visualized the bridge between chemical and mechanistic views with the corpuscular interpretation of the fundamental reaction: the sharp, pointed acid was captured in the holes of the alkaline salt (fig.4).

Fig: 8.



Epilogue

Jonathan Swift described in the third part of *Gulliver's Travels* the journey of Lemuel Gulliver, a former medical student at Leiden university, to the country Balnibari. He visited the capital Lagado and its "Academy of Projectors". Gulliver observed there an experiment by the "most ancient student of the Academy" attempting "to reduce human excrements to its original food, by separating parts, removing the tincture which it receives from the gall, making the odour exhale, and scumming off the saliva." This imaginative iatrochemical experiment probably was a persiflage based on Leeuwenhoek's microscopic observations of human excrements.[12] The Academy was "not an entire single building, but a continuation of several houses on both sides of a street." Palomo suggested that this Academy was nothing else than the university of Leiden. The description of the buildings was inspired by the frontispiece of Boerhaave's *Index alter plantarurn* (1720), showing the main building of the university in the background, at the right side the house of the professor of botany, the Physics Theatre and to the left side the printing-office, the chemistry laboratory and the greenhouses. Palomo suggested further that Lagado is derived from the Latin name of Leiden Univerity. In its official bookmark *Academia Lugduno-Batavo* is abbreviated to *Acad. Lugd.,* which is easily transferred into *Lagado.*[13]

If Palomo's suggestion is correct, then Jonathan Swift interpreted Leiden University as an institution accepting a scientific attitude based on experimental philosophy, on experience and experiment. To which the medical faculty added the harmony with the ratio. The device *ratio et experientia* is indicative for this attitude. It was the device chosen by the medical faculty for its seal of 1670. It was also characteristic for Franciscus dele Boë, Sylvius as representative of the first natural scientific period in the history of medicine. Sylvius' iatrochemistry was above all a practice- and research-oriented medicine. He held to the importance of experience in medical practice as well as in experiments, but not without reason. In the disputation defended in 1659 by Ludovicus Meijer he spoke of *Ratione duce ac comite experientia,* reason as companion of experience. Thus, stressing in one of his first disputations the methodological basis of his iatrochemical system.

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SARTON MEDAL LECTURES

LAUDATIO PIETER EIJKHOFF

Achiel Van Cauwenberghe

A good old Dutch saying states "Goede wijn behoeft geen krans" (which means: excellent wine does neither need a wreath nor praise).
Being a graduate judge of wines and a real oenophile, our guest speaker of today will certainly agree with it. Nevertheless, the ceremonial protocol requires that the qualities of the Sarton medalist should be described to some extent by a truthful and reliable witness. Let me try to meet these demands.

Professor Pieter Eijkhoff was born in Den Haag (The Hague) on the ninth of April 1929. I can confirm that this is a real nice day to be born on, as it coincides with my own birthday. Hence, being born under the same lucky stars I do assume that we must have some common characteristics, flavours and tastes.

He studied electrical engineering at the Technical University in Delft (graduating in 1956) and got a doctoral degree (Ph.D.) from the University of California in Berkeley, USA in 1961.
In 1964 he became professor in measurement and control at the Electrical Engineering Faculty of the Technical University in Eindhoven. From 1977 to 1980 he served as Dean of this Faculty.

Together with Åström, Bohlin and Strejc he laid the foundations of "Identification" as a separate discipline. His paper with Åström in 1971 is a classic, still very often cited. His book "System identification, parameter and state estimation" (Wiley 1974/79) has been translated in many languages and is a real "Citation Classic".

Prof. Eijkhoff was very active in many national and international organizations and institutions. Particularly the International Federation of Automatic Control, IFAC for short, was one of his favourites. Indeed, he served as Executive Councilor from 1975 to 1981 and was a leading member of the Publications Managing Board (1976-90), the IFAC Publications Committee (1981-87), the Automatica Editorial Board (1981-87) and the IFAC Awards Committee (1981-87). He is still editor of the IFAC journal "Control Engineering Practice" (since 1992).

He has been awarded many distinctions and honours as e.g. fellow of the Institute of Electrical and Electronics Engineers of the United States of America (1979), honorary professor of Xian Jiaotong University, China (1986), member of the Koninklijke Nederlandse Akademie van Wetenschappen (Royal Dutch Academy of Sciences) since 1988, doctor honoris causa of the Vrije Universiteit Brussel (Free University of Brussels) in 1990. He got the Outstanding Service Award of IFAC in 1990 for "sustained outstanding performance in major leadership positions" and was knighted in the Order of the Dutch Lion in 1991.

As a quality conscious and creative thinker he was very influential and instrumental in many other areas as

- his initiative in medical engineering in Eindhoven
- his endeavours to upgrade the Dutch engineering curriculum, leading to a new curriculum in the Netherlands in 1996.

He was an active advocate of human rights, many years before these became standard on the political agenda.

But all these, although impressive themselves, are not enough to obtain a Sarton medal. Much expertise and interest in the history of sciences is a requisite. And this is certainly the case with Prof. Eijkhoff, who developed a keen interest in the history of electrical engineering in general and control engineering in particular. As such he authored history contributions as

"IFAC 20 years old, 20 years young" (1978)

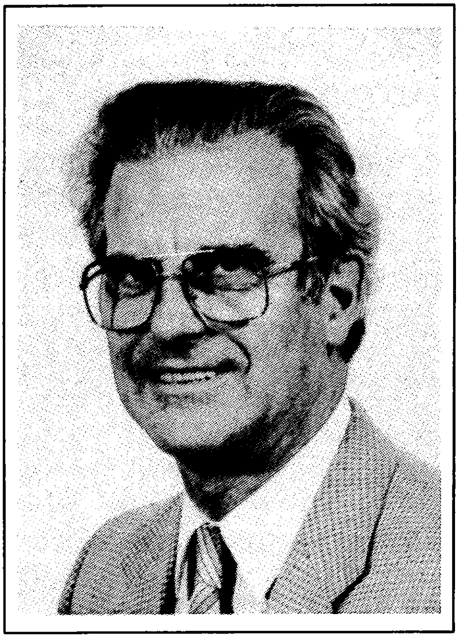
"Highlights from the history of IFAC" (1986) (with Michel Cuénod)

and is actively involved in the Foundation for the History of Electrical Engineering (Fonds voor de Geschiedenis van de Elektrotechniek) at the Technical University in Eindhoven.

He was also the driving force and organizer of many IFAC Symposia. As the origin of "Symposium" (a title of one of Plato's dialogues) was "a convivial meeting with much drinking and other pleasant activities", one could doubt if this contributed to his later activities as oenologist, wine expert and wine identificator. Moreover, he was always a busy photographer of IFAC's scientific and social activities, establishing an outstanding historical record of these events.

During the years, he developed a special relation with China (he was the president of the Netherlands-China friendship society from 1984-1991 and is a renowned and recognized connoisseur of Chinese wines) and Flanders (being interested in Flemish art and science). Of course, both countries can hardly be compared: what we Flemings miss in quantity, we have to make up in quality.

Dear professor Eijkhoff, dear Piet,
I consider it as a big favour to get to know you and your beloved life companion Hanneke, already for many years. I learned to appreciate you as a quiet and honest man, but decisively and relentlessly searching for the truth, as a top quality scientist and a top notch engineer. We developed a warm and fruitful friendship.
How you dealt with uncertainty while identifying sometimes very precarious processes as wine-making and tasting has always risen my interest and stimulated my curiosity. I assume that the audience is equally interested to hear your ideas on the "uncertainty as an assignment: the feedback control principle throughout the ages".



UNCERTAINTY AS AN ASSIGNMENT: THE FEEDBACK CONTROL PRINCIPLE THROUGHOUT THE AGES

Pieter Eijkhoff

Abstract

Since time immemorial man has been trying to fight the uncertainties with which he is confronted during his life. To that end *feedback*, a continuous intervention based on observations, has proved to be a very effective means. Some examples, applications from the distant and the more recent past, are presented. A proper theoretical foundation and the systematic implementation of this discipline in terms of *control theory* and *control engineering*, are only of rather recent origin.
It turns out that the fighting of uncertainty by use of feedback implies the implicit and/or explicit use of a model of the process under consideration. Until now, still some basic questions have been answered only partially. Nevertheless, feedback control has widely been proved and is recognized to be a very effective means in many branches of engineering and in society at large.

Contents

- References

Prologue

'They who know do not speak;
they who speak do not know.'
Lao Zi (580-500 BC)

Since the 6th century BC this saying of the famous Chinese sage has been impressed upon us. You can imagine, dear reader, what a dilemma this presents to a speaker (or writer) ...

Introduction

These lectures are named after George Alfred Leon Sarton (1884-1956), a famous son of the University of Ghent. His whole life was devoted to the history of science. He published extensively and founded two journals: Isis (1912) and Osiris (1936). At the onset of World War I he emigrated to England and then went to the USA. Among other appointments, he was professor of the History of Science at Harvard University (1940-1951). His outstanding devotion to this field is still manifest in the quality and the extent of his publications. In his time he was an illuminating example; so he still is for our generation.

Another name that I would like to mention with respect and appreciation is prof.ir. J.B. Quintyn, who worked at the Ghent University and promoted enthusiastically and ably the 'Museum Wetenschap en Techniek' and its publications.

Uncertainty

'What a man has, so much he 's sure of.'
Miguel de Cervantes (1547-1616)
Don Quixote, book IV, chapter 43

Man has an inborn dislike of uncertainty; much of his efforts have been and are directed to guarantee the perpetual availability of goods and conditions that form the primary breath of life, like: health, food, shelter, ...

Let us evoke our theme by a down-to-earth, every-day experience: taking a shower. Immediately you recognize a goal: to attain a pleasant temperature of the water. By a type of *'control'*, i.e. by adjusting the taps, this goal can be reached ... provided it is being done with some care. If the control action is too impulsive then very unpleasant things may happen.

Translated into technical terms we are dealing with:
- a *process*, which is a general term for a 'cause ⇒effect' relation; in this example the cause is the adjustment of the taps and the effect is the temperature of the water that leaves the nozzle;
- a *controller* that, based on the desired situation on the one hand and the observation/measurement of the actual situation on the other hand, acts in such a way that the difference between wish and actuality is made as small as feasible.

Process and controller together form a *control system*, which may be defined as:

> '*means, natural or artificial, by which a variable quantity, or a set of variable quantities, is caused to conform to a prescribed norm.*' [Enc. Brit., 1998]

The goal or prescribed norm can be of different kinds:

-	**norm**:	to keep a quantity constant
	name:	*regulator system*
	example:	a constant, pleasant temperature of the water during a shower
-	**norm**:	to follow in time a varying quantity
	name:	*servo system*
	examples:	the position on the road when driving a car
-	**norm**:	to bring a quantity from an initial to an end-value in some optimal way
	name:	*optimal control system*
	example:	the task to drive a car from A to B in minimal time or with a minimal fuel consumption

A general scheme for such a feedback control situation is given in fig. 1a, where P and R represent the characteristics of the process and the controller respectively. With adequate mathematical tools it is simple to show that feedback can be instrumental in diminishing the influences on the process output that are caused by:

- disturbances (changes) inside the process P;
- disturbances working from the outside on the process P.

These effects on internal and external uncertainties are elegant and very desirable properties of feedback indeed. Feedback can also affect:

- an unstable process, making it into a stable system;
- a stable process, making it into an unstable system.

In view of the last property, feedback has to be applied with much care and with serious consideration. Feedback can also provide changes in other system characteristics, but a discussion of those effects is outside the scope of these notes.

Another general characteristic of the feedback control situation is given in fig. 1b. The essence is the closed loop in which observations or measurement data, hence *information*, about the process output is being fed back to its input. By this information an *'energy flow'* (or materials flow) is being influenced; so, roughly speaking, 'energy' is being dosed by 'information'.

A few examples from early history

'One must learn by doing the thing;
for though you think you know it
you have no certainty, until you try.'
Sophocles (496-406 BC), Trachiniai

Already the early species of man depended on control actions, e.g. in regulating the fire, which was of paramount importance to him; cf. fig. 2. This implied: observing the fire (process) ⇒ action ⇒ observing again ⇒ if necessary action again, etc. The *'internal'* uncertainties that had to be counteracted include: the kind and the homogeneity of the fuel, its specific heat of combustion, the percentage of moisture. As *'external'* uncertainties we recognize: wind, rain, ambient temperature.

In spite of such uncertainties our early ancestors had various types of norms to approximate: sufficient radiation for ambient heating, adequate heat for cooking or roasting, light for enabling work or light for frightening wild animals, ... The eminent importance of fire and hence the predominance of this specific control action for the ancient people can be judged from many myths (Prometheus et al.). Another proof is the fate of the Vestal Virgins in the ancient Rome who had to maintain the permanent fire. When they neglected the control, and consequently the fire extinguished, the punishment was straightforward: being buried alive!

For an early written report on applications of control we refer to the Iliad by Homer. There we read in chapter 18 about the workshop of Hephaestos:

> *'Female slaves of gold, looking just like real girls, made haste to assist their master. Not only could they speak and move their graceful arms and legs, but they also possessed intelligence and they were gifted enough to do everything the god ordered them to do.'*

For the expert reader it will be clear that this refers to robots that could be programmed by way of speech. Probably they included an expert system based on neural nets ...

Let us look at two examples from the early Chinese development. Zhuang Zi (ca. 369-286 BC) writes about the processes in the human and animal body:

> *'It might seem as if there were a real Governor, but we find no trace of his being... But now the hundred parts of the human body, with its nine orifices and six viscera, all are complete in their places. Which one should one prefer ? Do you like them all equally ? Or do you like some more than others ? Are they all servants ? Are these servants unable to control each other, but need another as ruler ? Or do they become rulers and servants in turn ? Is there any true ruler than themselves ?'* [Ronan, 1978].

He does not give an answer, but the questions are highly pertinent.

An early documented control example that appears in the annals of Chinese history is the **South-pointing carriage**; sometimes it is called 'the first cybernetic machine' [Temple, 1986]; cf. fig. 3. For its origination several dates are mentioned : about 1030 BC, 120 AD or around 250 AD. The purpose of this device was to combat the uncertainty of direction; the figure on the carriage had to point constantly to the south, in spite of all turns that the vehicle is making. This was achieved by the principle which nowadays is called differential gears. When making a turn the two wheels follow paths of different lengths. This difference is changed by the gears into a proper correcting rotation of the pointing figure. It becomes a control system if the loop is closed by a human driver who steers by using the information of the south-pointer or, more automatically, by a carrot which is kept in the proper direction by the south-pointer before the nose of a pulling ox.

The control examples mentioned so far for fighting uncertainty on fire and on direction, include the human being as the controller ('human operator'). The next question is what early examples there are of systems without the need of human intervention: *automatic control systems*. In the excellent book on this topic by Otto Mayr [Mayr, 1970] a number of examples is given, including:

Ktesibios (Alexandria, first half of 3rd century BC) designed a waterclock, in which the flow of water is regulated by a float, swimming in a regulating vessel upstream of the metering orifice. Such a regulation of the fluid flow seems to have been used extensively also in later water clocks.
Philon (Byzantium, second half of 3rd century BC) constructed oil lamps with a vessel in which the level of the fuel is regulated automatically at a constant level in order to get a steady amount of light.
Heron (Alexandria, probably 1st century AD) constructed a mechanism for automatically opening the temple doors when the fire on the altar was lit. He also made several float regulators (e.g. an automatic wine dispenser) using floats and valves.

A real landmark in the early developments of feedback techniques is the oven with an automatic temperature control, invented by **Cornelis Drebbel** (Alkmaar, 1572-1633). Again this is an application used to regulate a combustion process. Fig. 4 shows the original sketch. Its working is as follows: the glass tube D is filled with alcohol and its U-shaped part is filled with mercury. A rise of the inside oven temperature causes an expansion of the alcohol, which is transmitted by the mercury to some bars. These bars close the opening E at the top of the oven, such that the fire will be tempered. If the inside temperature lowers, then the reverse happens and the fire will be fanned. Both the desired temperature and the sensitivity of the control can be adjusted by the geometry of the bars. The first application of this device was an incubator.

Denis Papin (1647-1712) designed a pressure cooker in which the pressure was controlled by a weight-loaded valve (1681).

A few examples from more recent history

A line of early engineering applications of automatic control in Western Europe was used on windmills for two purposes: (1) for keeping the mill continuously and automatically into the wind, and (2) for speed regulation. **Edmund Lee** invented a windmill with fan-tail and self-regulating sails that adjust the sail-surface area to the effective driving force of the wind (patent dated 1745). **Thomas Mead** designed a speed regulator for windmills using a centrifugal pendulum, where the movement of the pendulum is used to control the sail area of the mill (patent dated 1787)

The most celebrated early industrial applications start with the adaptation of the centrifugal or flyball governor by **James Watt** (1736-1819) to a rotating steam engine (1788). The stability problems that were encountered in such applications of feedback were studied by **James Clerk Maxwell** (1831-1879) [Maxwell, 1868]. This started the development of theory on automatic control.

The advent of the radio valve/electronic tube has given rise to a wide variety of circuits in which feedback is being applied. [Bennett, 1993]. In some early cases a *positive* feedback was used to bring the system close to instability, in this way increasing the amplification of the signals of interest. One example is the regenerative amplifier by **Charles S. Franklin** (1913). The radio- and audio-frequency feedback invented by **Edwin Armstrong** (1915) must also be mentioned..
The use of *negative* feedback was extensively studied by Harold S. Black (1934, patent 1937) and **Harry Nyquist** (1932) at Bell Telephone Labs for the design of stable repeaters for transatlantic cables [Bissell, 1997].

Since that time the variety of engineering applications, as well as the recognition of control principles that occur in non-engineering situations, have increased tremendously. A rough and incomplete listing includes:

- fine-mechanical, optical, electronic and mechatronic systems;
- information and communication engineering;
- energy production and -distribution;
- flexible industrial production; automation;
- industrial chemical and physical processes; 'process industry';
- means of transportation on land and sea;
- aero- and space travel;
- scientific instruments;
- climate conditions at home, office, etc;
- household applications;
- agriculture and environmental care;
- biology and medicine;
- economy; sociology, enforcement of the law.

Each of these fields would warrant further discussion, considering the uncertainties encountered and the feedback techniques used for counteracting them.

Models

> *'If a man begin with certainties,*
> *he shall end in doubts;*
> *but if he will be content*
> *to begin with doubts,*
> *he shall end in certainties.'*
> Francis Bacon (1561-1626),
> The Advancement of Learning

Many years ago Conant and Ross Ashby [1970] published an interesting statement: *'Every good regulator must be a model of that system'*. So let us devote some attention to models.

A classical domain where the concept of modelling developed over many centuries was the movement of celestial bodies. For a long time the Ptolemaic model of cycloidal motions stood as a *conceptual* model, mimicking the observed planetary movements. This was rendered out of date by a physical, viz. the Copernican, model that was based on both the motions of the earth (observer) and of the observed planet. The next development was into a *mathematical* model consisting of Kepler's laws, which permits numerical predic-

tions. Further contributions to this modelling by Newton are well known, as well as the explanations by Einstein of some anomaly in the observations.
In fact it was the estimation of planetary orbits based on imperfect observations that inspired **Carl Friedrich Gauss** (1777-1855) to the development of his statistical techniques [Gauss, 1809].

Since that time the growth of the notion of models in modern science and in engineering is tremendous [Popper, 1934]. Models are used for a wide variety of purposes:

- to explain physical laws and insight, based on previous observations;
- to predict future observations;
- to check on the proper performance of a process (fault detection and diagnosis by comparison of the process with a model);
- to derive control signals for influencing the behaviour of a process.

Considering such a wide spectrum of purposes, the intended use of the model is of dominant importance.

Now let us explore in a simple way the relation between feedback and models. Fig. 5 indicates the development of thought in *improving the response of a process.*

a. In mathematical terms P represents the transfer, the relation between the process input u and output y : y = P u.
b. If it were feasible to build a block, a 'model', with the transfer 1/P, the inverse of P, then the total transfer would be 1/P . P = 1, meaning that the output is an exact copy of the input.
c. Here the ∞ sign indicates an 'operational amplifier' with infinite gain; this provides a means to make 1/P.
d. is identical to c. and follows from it by shifting the feedback part of the loop to the process output.

So in principle we have derived a feedback control system, in which the process provides its own model !! This *implicit* model changes automatically if internal uncertainties cause changes in P. Of course the fundamental and practical restrictions imposed by the physical realizability of the inverse of a transfer should be discussed in more detail, but that topic is outside the scope of these notes.
The same type of reasoning using a model can be done for deriving a feedback system which handles external uncertainties that act on the process [Smith,

1958].

From these considerations the reader might accept the statement by Conant and Ross Ashby: *'Every good regulator must be a model of that system'*, although these authors used a different type of reasoning. However, judging from the citation index, that paper received far too little attention; particularly the control engineering community responded below expectation.
Yet since that time, from many research efforts it became clear that the role models play in control systems is an important one [Eykhoff, 1994], for:

- in many types of optimal control theory a perfect a priori knowledge of the process dynamics (model) is required. The early experiences in trying to apply such optimal control schemes lead, generally speaking, to disappointments because no internal uncertainty is considered. However, there proved to be situations in space engineering where the models were good enough (consisting of inertial mechanics, a conservative force field, disturbances that can be calculated). In most down-to-earth applications, however, the complexity of reality, including the disturbances, was not suitable for such optimal control schemes; the optimality of the control is too sensitive to uncertainty, to imperfect modelling.
- more recently, ways were found to include non-perfect models of complex processes for the improvement of the control characteristics. Even in industrial situations with process changes and many disturbances, the explicit use of an approximating model may lead to excellent results, i.e. contributes significantly to the quality of the control, i.e. the uncertainty reduction [Zhu and Backx, 1993]. Cf. also [Schoukens and Pintelon, 1991].

In practice it is not a trivial problem to attain an adequate model of a process. The techniques used to this end are called *process* or *system identification*; it is a way of arriving at knowledge on a complex process, based on partial (uncertain) a priori knowledge and on measured process input and disturbed (uncertain) output signals. The goal is to develop and continuously improve a (mathematical) model that represents the behaviour of the process as far as is feasible [Åström and Eykhoff, 1971; Eykhoff, 1974].
The choice of the type of model is influenced by a priori knowledge. One recognizes: 'white' model (i.e. a priori knowledge available through physical laws, mass balances, etc.) and 'black' model (i.e. no a priori information, but completely based on observations and data handling), as well as hybrid, inter-

mediate or 'grey' models.

The use of system identification can be traced back in early history; an example being the medical diagnosis by Chinese doctors that was practised at least two thousand years ago already; fig. 6. Based on the ethics of that time a physician was not allowed to observe a female patient. For the diagnosis of an illness he had to resort to pulse-feeling only. Even in this early example the essential elements of identification were present: observed 'output signals' served to update and correct the 'model' of the patient that was in the mind of the examining physician. This technique is attributed to **Bian Qiao**, ca. 255 BC.

So far we have met with several kinds of uncertainties: internal changes in the process, external influences on the process, an approximate model of the (complex) process. Relating these uncertainties a fundamental problem statement was given by Fel'dbaum [1960, 1961]. He formulated the concept of *'dual control'*, i.e. the necessity of combining:

- continuous identification of the process to provide a suitable model to the controller for fulfilling adequately the control (e.g. regulation) task;
- continuously controlling the process in order to eliminate as effectively as possible uncertainties working in and on the process.

This leads to a fundamental dilemma: proper control aims at counteracting all disturbances, whereas for proper identification the introduction of extra disturbances (test signals) might be needed. What additional disturbances do we have to apply in order to combat the primary uncertainties? This problem has not yet adequately been solved.

Intermezzo: Chinese and western science and engineering

In the previous sections we made some references to China. So let us digress for a moment. Due to the monumental work of **Joseph Needham** and collaborators [Needham, 1962-1998] now also the non-Chinese speaking part of the earth's population has extensive and high-quality information available on the early development of science, discoveries and inventions in China. This wealth of information has been condensed in an attractive way by **Robert Temple** [Temple, 1986]. Among other things he provides a survey of the time intervals between Chinese inventions or discoveries and their acceptance or recognition in the west. From this we select some spectacular examples:

	Chinese origin:	time interval until the use in Western Europe:
- lacquer; the first 'plastic'	13th century BC	3.200 years
- iron plough	6th - -	2.200 -
- circulation of the blood	6th - -	1.800 -
- compasses	4th - -	1.500 -
- cast iron	4th - -	1.700 -
- steel from cast iron	2nd - -	2.000 -
- paper	2nd - -	1.400 -
- quantitative cartography	2nd - AD	1.300 -
- porcelain	3rd - -	1.700 -
- gunpowder	9th - -	300 -
- printing with movable type	11th - -	400 -

These are only some examples from a long list of amazing achievements. Considering this performance so early in history, one wonders why China was scarcely involved in the development of modern science, including the concepts of automatic control. The following historical characteristics of China and the Western world might offer some base for an explanation:

China

- history until the 17th century
  Tang dynasty (618-907): bureaucratic organisation of the state; an examination system for public officers based on Confucianism, however in dialogue with Buddhism and Taoism; invention of block printing technique.
  Song dynasty (960-1279): more emphasis on the study of actual problems and political economics; invention of printing with movable types.
  Yuan dynasty (1206-1368): expansion of international exchange.
- development in the 17th and 18th century
  Qing dynasty (1644-1911): foreign (Manchu, non-Han) rulers distrust the Chinese; consequently the emphasis lies on stability and status quo; this

leads to intellectual stagnation. Examination system for public officers is based on a rigid interpretation of the nine Confucian classics; new science and technology is completely absent; 'the style was considered more important than the thinking.'

Western world

- history until the 17th century
  Christianity; military-aristocratic feudal system (king - knights - .... farmers and soldiers).
- development in the 17th and 18th century
  advent of the bourgeois entrepreneurs and capitalism; church reformation; rise of modern science: experiments, mathematical formulation, 'mathematical models'.

Apparently the differences in the developments of science in China and the West can be related to the openness of their respective societies in the 17th/18th centuries. In Chinese society many uncertainties were attributed to the degree of harmony between the Emperor, 'Son of Heaven', and Heaven. This had to be secured by performing the right rituals. In the West such uncertainties became subject of scientific approach.

Feedback in society

'No hinge or loop to hang a doubt on.'
William Shakespeare (1564-1616)
Othello, act III

Automatic control has become an important ingredient of technological change, But also the development of technological change is the result of a feedback process. That is indicated in fig. 7.

A *technological change* is effected by decisions based on various types of motives. Those decisions imply the assignment of a bigger or a smaller part of available resources: natural, human (including education), and financial

(capital and capital goods). The motives for such decisions will be based on:
- *physical and cultural needs and desires of man*, as indicated schematically in the figure. Among these needs and desires there are many aspects that are related to 'uncertainty'. Of course this list can be improved on and extended; a hierarchy of 'basic needs' of man is given by **Abraham Harold Maslow** (1908-1970) [Maslow, 1970] which range from low, basic needs to higher, more sophisticated desires:
- the physiological needs
- the safety needs
- the belongingness and love needs
- the esteem needs
- the need for self-actualization
- the desire to know and to understand
- the aesthetic needs.

A person may be confronted with uncertainty at all levels. But only if the uncertainty at more basic levels is small enough, the needs at the next sophisticated level will be of actual importance.

The resulting technological change will manifest itself and will have an impact in different ways. It gives rise to: - *new capabilities* for further development (research-push). Those capabilities can contribute to decisions to start or to continue the work on particular technological changes.

Such technological change also has an influence on the development of: - *new products*. Whether these will be successful or not depends on a type of feed-back: how far do these products satisfy the wishes/demands of man that result from his physical and cultural needs and desires? The degree of acceptance by the 'consumer' (in the broadest sense of the word) will affect the decisions with respect to further development of technological changes.

A technological change can be accompanied by: - *new problems*, e.g. negative incidental effects. Those can be classified with respect to their region of impact. The smallest region is that of the individual who may meet with problems like changes in the type of work, danger to privacy due to the use of computer databases, the dangers on the road, etc. The next region of impact is related to the environment, which is affected by waste, chemicals, heat, etc. As indicated the problems can also extend to still larger regions.

Again a type of feedback will occur: to what degree will the problems be incompatible with the expectations originating from the physical and cultural needs and desires of man? The resulting public opinion will have its influence

on further technological changes too.
Apparently, in principle the feedback paths related to technological change are quite clear. Do they work adequately and are they sufficiently strong to act in an uncertainty-diminishing way? To this question probably each of us has his/her own opinion.

Conclusions

The fight against *uncertainty* is a very basic human drive. Hence the control by way of the feedback principle has been used since very early times. In the beginning man had no choice but to place himself in the control loop as the controller. The *automatic control,* an operation without direct human intervention, developed slowly and incidentally. In the acceleration of this development an important ingredient was the western recognition and use of physico-mathematical models. During part of history China has been lagging in this field.

In these notes many essential aspects of the development had to be neglected. The reader is referred to additional references like: [Åström, 1985; Bennett, 1979; Various authors, 1996].

Now the statement: *'Every good regulator must be a model of that system'* can more and more be recognized implicitly (models hidden in various optimal control schemes) or explicitly (model-based controller) as a leitmotiv.

Certainly not all problems related to uncertainty-suppression have been solved yet; there remains a challenge in incorporating partial knowledge about the uncertainty of the process-changes and about the inaccuracy of the model used, e.g. for answering industrial demands (better quality, efficiency, energy saving, waste prevention, responding to competition).

The fundamental challenge as formulated in 'dual control' still remains open: during operation -

- to reduce the uncertainty of the model through continuous identification action. For this task additional disturbances/testsignals on the process are needed;

- to reduce the uncertainty of the process by counteracting the disturbances through control action.

So some problems are still with us. However, for the time being we can live with this remaining uncertainty. This is testified by an uncountable number of engineering applications and by the recognition of numerous 'natural' types of feedback control (biology, society, economics, ...). A fascinating field of human endeavour !

Epilogue

'When you know something,
to act as one who knows,
and when you do not know something
to acknowledge you do not know
that is real knowledge.'
Kong Zi (Confucius) (551-479 BC)

A fundamental note on coping with uncertainties ...

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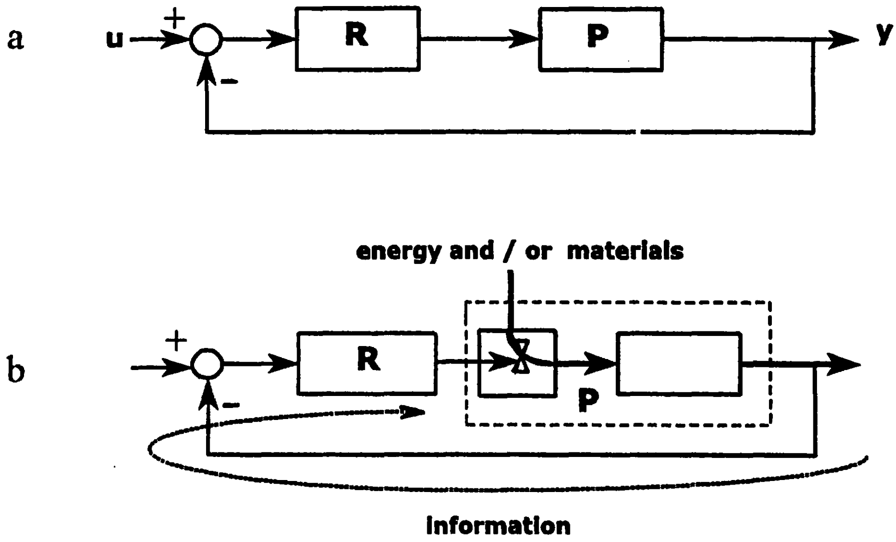
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Fig. 1

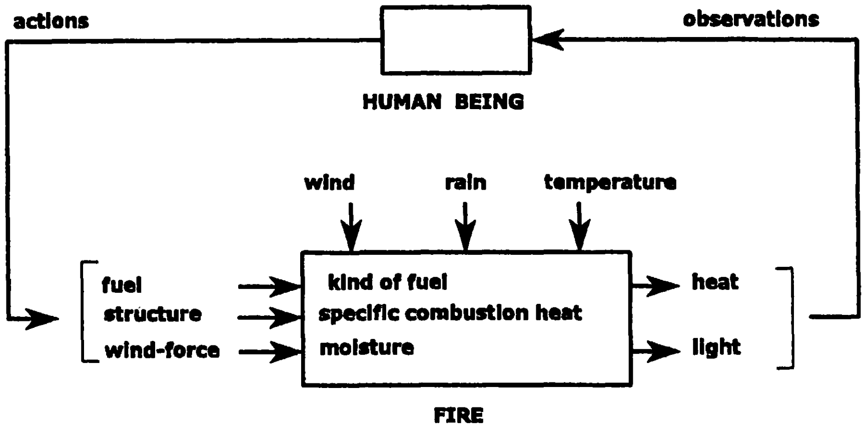

actions
observations
HUMAN BEING
wind
rain
temperature
fuel
structure
wind-force
kind of fuel
specific combustion heat
moisture
heat
light
FIRE

Fig. 2

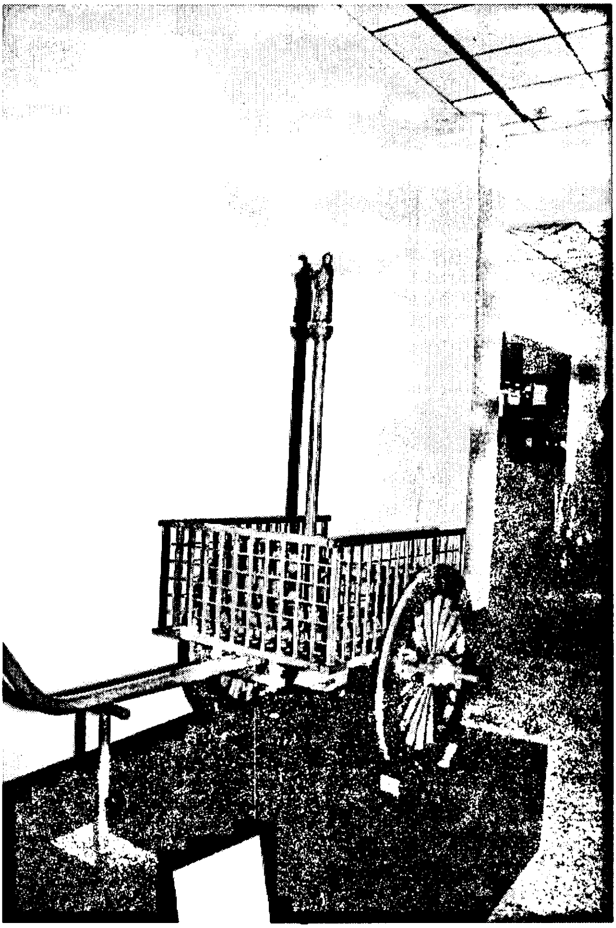


Fig. 3

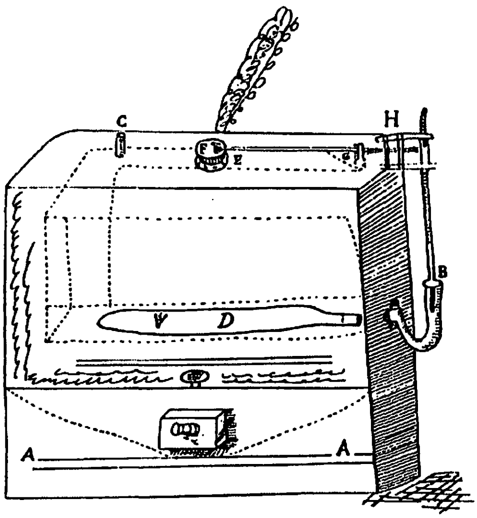


Fig. 4

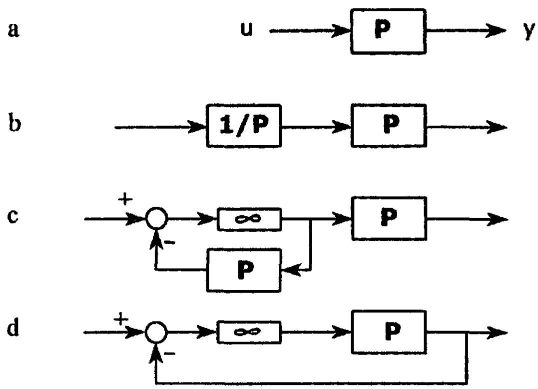
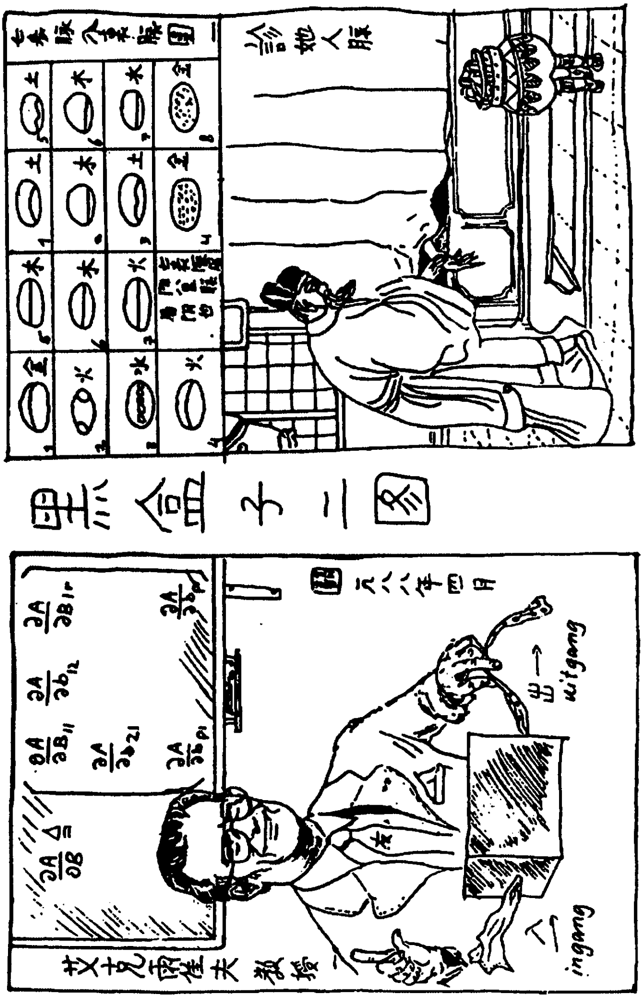


Fig. 5



Identificatie, 1e eeuw

Identificatie, 20e eeuw

Fig. 6

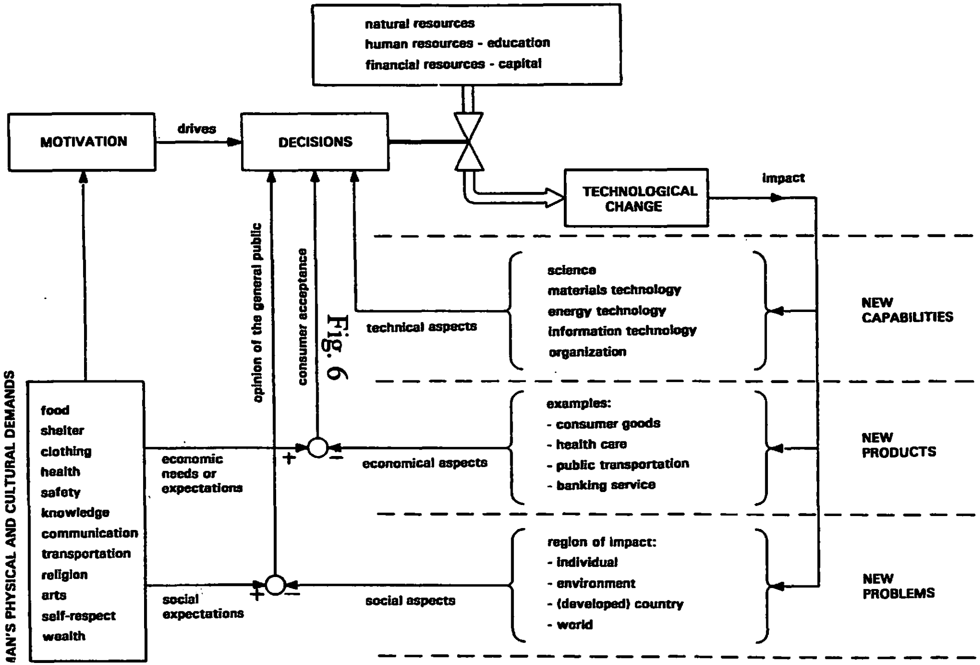

natural resources
human resources - education
financial resources - capital
MOTIVATION
drives
DECISIONS
TECHNOLOGICAL CHANGE
impact
opinion of the general public
consumer acceptance
technical aspects
science
materials technology
energy technology
information technology
organization
NEW CAPABILITIES
examples:
- consumer goods
- health care
- public transportation
- banking service
NEW PRODUCTS
economic needs or expectations
economical aspects
region of impact:
- individual
- environment
- (developed) country
- world
NEW PROBLEMS
social expectations
social aspects
MAN'S PHYSICAL AND CULTURAL DEMANDS
food
shelter
clothing
health
safety
knowledge
communication
transportation
religion
arts
self-respect
wealth

Fig. 6

Fig. 7

LAUDATIO ERIC VAN SCHOONENBERGHE

Guido Vanden Berghe

Eric Van Schoonenberghe was born in Oudenaarde on September 14, 1940 and studied Greek — Latin at Onze-Lieve-Vrouw-College, a secondary school in his hometown.

Afterwards he studied chemistry at the KU Leuven and in 1968 he obtained his doctoral degree in sciences. Later on he also studied brewing technology at KU Leuven. In 1968 he began to teach general and applied biochemistry and microbiology at Hoger Instituut Sint-Lieven, better known as 'Brouwerijschool Sint-Lieven'. He was also responsible for the department of fermentation businesses.

In 1977 he was involved as professor and vice-principal in the establishment of a new school, the Katholieke Industriële Hogeschool Oost-Vlaanderen or KIHO. In 1988 he was task holder of applied scientific research for the VVKHO, Vlaams Verbond van het Katholiek Hoger Onderwijs.

Since the Katholieke Hogeschool Sint-Lieven was established in 1995, he is Head of the Department of Research Coordination and the Department for Continued Education Programs.

Eric Van Schoonenberghe's research activities can be situated in three different fields: food hygiene, analysis of the research done in institutions of higher education and the history of the alcoholic fermentation.

Being responsible for the laboratory of the Landsbond der Belgische Slagers, housed at H.T.I. Sint-Lieven, he mainly focussed on hygiene issues. He acquired an expert knowledge in this field. He published over 50 articles on food hygiene and he participated in hygiene education programs of the Food Education Committee of VLORA (Vlaamse Onderwijsraad), the different education providers, VIZO, VDAB and IVK (Instituut voor Veterinaire Keuring).

Since 1977 he is a permanent member of the Belgian Food Advice Committee.
He is also a founding member of BAMST (Belgian Association of Meat Science and Technology).

In his responsibility of task holder for VVKHO on applied scientific research Eric Van Schoonenberghe studied the research activities at the Flemish catholic institutions of higher education. This study revealed the research expertise and the research capabilities of the institutions of higher education. This analysis was one of the reasons to broaden these institutions' task definition of their research and services and the doctoral possibilities of the graduates of two cycle higher education. Furthermore it stimulated the participation of the institutions of higher education during *Wetenschapsweek* (Flemish Week of Science), the special fund for higher education ex university (HOBU-fonds) and the admission of representatives of the institutions of higher education on the several research boards. Eric Van Schoonenberghe represents the institutions of higher education from all sectors in the steering committee of IWETO (Inventarisatie van het Wetenschappelijk en Toegepast Wetenschappelijk Onderzoek), in the steering committee of the Flemish Week of Science and in the in IWT's (Vlaams Instituut voor Wetenschappelijk en Technologisch Onderzoek) steering committee of small and medium sized businesses.

As professor of the department of fermentation businesses Eric Van Schoonenberghe was relatively active in the scientific and professional life of this sector. For instance, he is a member of the editorial staff of the Dutch magazine *Voedingsmiddelentechnologie* and he is chief editor of the magazine *Cerevisia* that is being published by the brewing departments of the Belgian institutions of higher education and the universities. He is co-founder of the section food and the section history of the KVCV (Koninklijke Vereniging van de Vlaamse Chemici).
The research project he preferred was the study of the history of the alcoholic fermentation process. In this respect he published in magazines in Belgium and abroad and he was asked to speak in several national and international colloquia. Some of the subjects were: the history of mead, the Belgian brewing education, the biochemistry and the technology of alcoholic fermentation and ... gin.
In his book *Jenever in de Lage Landen* (Gin in the Low Countries),

published in 1996 by Stichting Kunstboek, Eric Van Schoonenberghe offers a new view on the genesis of our national distilled drink. In 1997 the book was awarded the Marcel Minnaert Prize, causing the book to be elaborately covered in both the written and spoken press. For instance, the VPRO and VRT3 spent a large topic on it. The book was also the guideline to renew the arrangement of the National Gin Museum in Hasselt of which Eric Van Schoonenberghe is the chairman.

GENEVER (GIN): A SPIRIT DRINK FULL OF HISTORY, SCIENCE AND TECHNOLOGY

Eric Van Schoonenberghe

Introduction

On February 20, 1979 the Court of Justice of the European Communities passed a decree that would be registered by history under the name "Cassis de Dijon". This obliged the former Federal Republic of Germany to indulge the sale in Germany of the French blackcurrant liqueur with an alcohol amount of 20% vol although German law prescribed an alcohol amount of at least 25% vol. From that point onwards all products produced by an European Member State conform its legislation, could be sold in other European Member States. In fear of a declining quality of the traditional products a law concerning the European distilled drinks was drawn up under the pressure of Scottish whisky and French brandy distillers. This led to the promulgation of the Council Regulation (EEC) n° 1576/89 of 29 May 1989, laying down general rules on the definition, description and presentation of spirit drinks.

Describing genever unambiguously appeared to be a difficult task. Genever (shortened by the English to gin) is the national distilled drink of Belgium and the Netherlands and it is also being produced in the North of France (former French Flanders). The Dutch and the Belgians both have a distinctly different view on gin. For example the alcohol amount of the Dutch and the Belgian gin is respectively 35 and 30% vol. Even within Belgium there is a considerable difference in both aroma and taste between a gin from East Flanders and one from Hasselt.

While drawing up the European regulation several questions were asked. Why is gin the national drink of Belgium, the Netherlands and French Flanders, in fact the Low Countries by the sea? Do these gins have a common origin and how was the original composition of gin?

When looking for an answer to these questions we were surprised by the amount of prominent scientists who, through times, have been involved in studying the alcoholic fermentation and the distillation of alcohol. Their research contributed to the development of general and applied chemistry, biochemistry and microbiology. Without exaggeration, alcohol distilleries can be considered the cradle of biotechnology.

The genesis of genever[1]

Until recently the discovery of gin was attributed to the Dutch professor from Leyden, Franciscus de le Boë, Sylvius (1614-1672).[2] This was understandably but wrongly attributed. Understandably, because Sylvius, founder of the iatrochemistry, was particularly trained in the art of distillery and preparation of drugs in which he made abundant use of juniper berries. Wrongly, because the Dutch *States' ordinance on brandy* already levied taxes in 1606 (which was 8 years before Sylvius was born) on all distilled wine, anise, gin or fennel water and alike which were sold as alcoholic drinks. The mentioning of "distilled anise, gin or fennel water sold as alcoholic drinks", has a particular relevance. In the *States' ordinance on brandy* of October 1, 1583 there is still no mention of a tax on the sales of anise, gin nor fennel water. Government still looked upon these drinks as medicinal drinks. The fact that a tax on these medicinal drinks is introduced in 1606 indicates that these drinks are no longer seen as a medicine, but rather as a largely consumed stimulant.[3]

Among these three medicinal waters, gin was the most purchased one, mainly because of the ancient belief in the therapeutic effect of the juniper berry. This belief is shown in several medieval manuscripts praising the medicinal properties of the juniper berry hence turning it into a wonder drug.[4,5] The oldest tracts on juniper berries date from the fourteenth century, most of the tracts date from the fifteenth century. Especially in the German area the amount was high: until now 28 different German tracts on juniper berries are known. Some were translated into Danish, Swedish, Norwegian and Icelandic. The origin of this interest was undeniably to be situated in the Netherlands. Already in the thirteenth century Jacob van Vitri († 1244), from the French Flemish town of Atrecht, wrote an entire chapter about the juniper in his *Historia Orientalis*. Jacob van Vitri was inspired by Pliny the Elder, Avicenna and the Circa Instans. The medicinal properties of juniper berries and juniper oil were also emphasized in *Liber de natura rerum* by Thomas van Bellingen alias Thomas van Cantimpré (1201-ca.1270). Thomas, born in Sint-Pieters-Leeuw near Brussels, became a regular canon in the order of Saint Augustin in the abbey of Cantimpré near the French Flemish Kamerrijk, hence his name. Later on he became a Dominican in Louvain and during several years he was also a pupil of the famous Albertus Magnus (1206-1280) in Cologne. His *Liber de natura rerum* is a compilation of works of ancient masters like Aristotle, Hippocrates, Galen, Avicenna and works like the Circa Instans.

The oldest reference known in Dutch literature to the use of juniper berries in drinks can be found in *Der Naturen Bloeme* by Jacob van Maerlant (1235-1300).[6,7] Jacob wrote this rhyming nature encyclopaedia between 1266 and 1269 in Damme, an outport of the city of Bruges. It is not an original work, but a compilation of earlier books, which he thoroughly compared with each other. His greatest source of inspiration was *Liber de natura rerum*, which had been written a few years earlier by Thomas van Cantimpré. *Der Naturen Bloeme* contains thirteen chapters which the author calls books. In book VIII on trees originating from seeds van Maerlant elaborately describes the properties of the juniper bush (fig. 1). His readers must have known this juniper bush (Juniperus) well because he regularly refers to it in order to describe certain properties of spices. He says for instance, that the cinnamon tree has the same purple leaves as the juniper bush, that the fruit of the sweet chestnut is of nearly the same size as the juniper berry, that the clove tree is as big as the juniper tree and that the wood and the leaves of the pepper tree resemble those of the juniper tree. One gets the same impression when reading the fifteenth century travel story of the pilgrim traveller Knight Joos van Ghistele from Ghent.[8] In his story he always refers to, as a comparison, the juniper bush when describing the innumerable spices and trees he had seen in the Near East, as if it was the standard measure (and he did not know any other plant in his country).

The medicinal properties of the juniper berry are reflected in the following verses of Jacob van Maerlant:

Jeghen buuc evel van leden
So salmen jenewere sieden

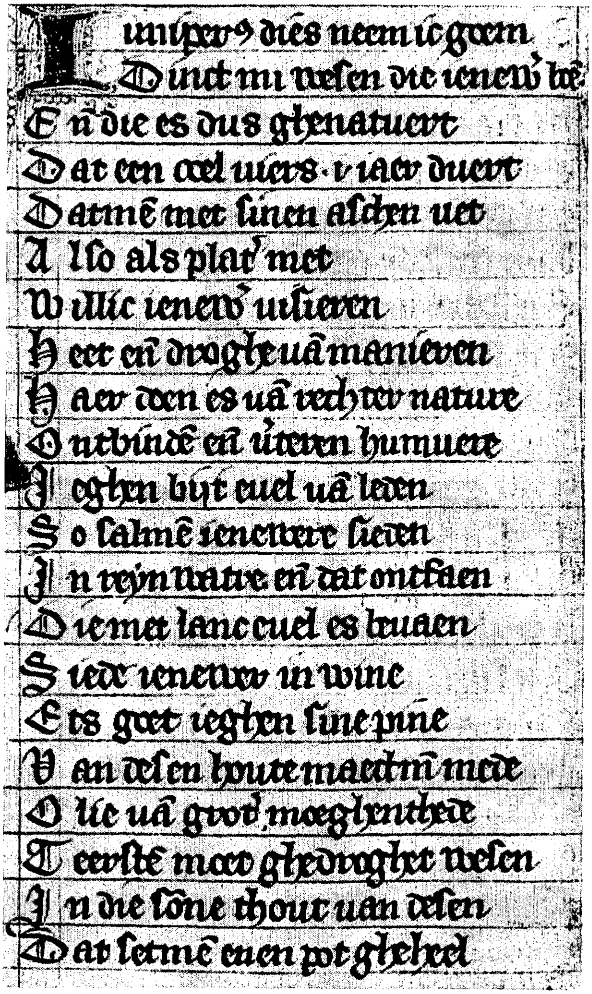


Fig. 1.
Properties of the juniper busch (Juniperus), 13th century.
In: Jacob van Maerlant, Der Naturen Bloeme, Library of the University of Leiden, Ms. BPL 14A., fol. 115[v]

In reynwatre ende dat ontfaen.
Die met lancevel es bevaen
Siede jenewer in wine,
Ets goet jegen sine pine.

In these verses rainwater used to boil juniper berries is recommended to cure abdominal pains. Wine in which juniper berries had been boiled was considered a good remedy for abdominal cramps. This last drink can be seen as a digestive and as the immediate predecessor of the present-day gin. Medicinal wines were also propagated by Jacob's contemporary Arnaldus de Villanova (ca.1255-1311). In his *Liber de vinis*, a book translated several times into Middle Dutch, he describes 28 different medicinal wines.[9] A wine recipe using boiled juniper berries, cannot be found in his work.

According to the fifteenth century Middle Dutch manuscript 697 that is being kept at the academic library of the University of Ghent, juniper berries were also being used during the brewing process of beer.[10] The juniper berries were sun-dried and burnt to powder. That juniper powder was used in order to make bad beer better and to make it resemble Harlem beer. Juniper wood and juniper berries are, still today, being used as a preserver in certain Norwegian beers.

Besides juniper berries also the oil extracted through dry, downward distillation of juniper wood, was being used. This oil was considered to be a work of art and it was used as seasoning or as an ointment. Jacob van Maerlant called this oil a *medicine rike* (a rich medicine) and advised its use to combat fever, epilepsy, arthritis and abdominal cramps.[6] Jacob believed the juniper oil to be good for digestion and effective in suppressing melancholy. The preparation and the use of this oil is also described in *Herbarijs* and in *Den Herbarius in Dyetsche*, the first Dutch book printed on medicinal herbs which has been published in 1484 in Louvain by Jan Veldener.[11,12] That book advises bathing in rainwater in which juniper berries are boiled to treat skin disease and stomachache. The same advice is given in the fourteenth century Middle Dutch translation of the Circa Instans.[13]

In several fifteenth century tracts on the plague the smoke of burning juniper berries en burning juniper wood is being used to clear the "evil air" of the rooms in which plague victims had been staying.[14,15] In his *Cruydeboeck* (Antwerp, 1554) Rembert Dodoens will still advise the use of smoke of burning juniper wood and burning juniper berries to fight the plague and vermin.

The juniper berry tract *Sequuntur propietates et virtutes granorum juniperi et olei granorum* is innovative.[4] The tract, a part of manuscript n° 618 of the Wellcome Historical Medical Library in London, was written in 1496. It is partly written in Latin and partly written in Middle Dutch. Some recipes in the manuscript come from the practice of Jan Spierinck, the personal physician of the Duke of Brabant. Jan Spierinck was also attached to the University of Louvain of which he was the dean in 1457, 1462 and 1479. Jan Spierinck was a strong advocate of the use of indigenous drugs which he preferred to exotic ones. The juniper berry tract calls upon doctor Hubertus, hence it was called the juniper berry tract of doctor Hubertus. Supposedly, doctor Hubertus was an ambulant physician who, like he himself wrote, resided in an inn in 's-Hertogenbosch. The tract excels in simplicity and its sense for details. Hubertus attaches great importance to the type of juniper berry: the berries from the Orient are better than those from the Occident. Furthermore the berries need to be ripe and black. Therefore they should be plucked between two name days of the Holy Mother: August 15 and September 8, during the constellation of Virgo. Hubertus abandons the traditional way of administering the juniper berry. Instead of boiling it in wine, he leaves the berries to macerate during one night in *aqua vitae* or in *clareyt*, a strong wine mixed with honey and herbs. Afterwards the juniper berries are sun-dried. The *aqua vitae (aqua ardens)* and the sun enable the juniper berry, thanks to its hot and dry nature, to reach the fourth or highest degree. Such berries were very good to dissolve and digest cold and moist humours. Eating five to six of such berries in the morning before breakfast and at night before going to bed, could prevent and/or fight the most important diseases (twenty are being named). In other words, it was a true panacea. The same ailments can also be cured using oil distilled from juniper berries: this also is an innovation of doctor Hubertus. The oil is acquired by squashing the juniper berries, sprinkling them with *aqua vitae* and then distilling this. In 1552 Philippus Hermanni describes a recipe of juniper berry water in *Een Constelijck Distileerboec* that strongly resembles a recipe of doctor Hubertus.[16] According to Hermanni the juniper berry water can be consumed for digestive disorders, colds, the plague and bites of venomous animals. It can also be used to wash out bites.

The late fifteenth century manuscript Sloane 345, fols. 51^r-51^v that is being kept at the British Museum in London is also of considerable importance.[4] It contains two brandy recipes which are not mentioned with the medicinal waters, but which are included with the kitchen recipes. The title *Gebrande wyn te maken* (making brandy wine) is accompanied by the note *de aqua vina* in the margin and next to the title of the second recipe *Een ander manyr om brande wyn tmaken* (an other way to make brandy wine) it reads *de aqua vitae*. The fact that the brandy recipes could be found among the kitchen recipes and also the fact that the terminology *aqua vitae* is replaced by brandy, inclines us to believe that by the end of the fifteenth century the drug *aqua vitae* has become a stimulant called brandy. The levy of the tax on brandy first issued in the Netherlands in Amsterdam in 1497 confirms that suspicion.[18] In the recipe *Gebrande wyn te maken*, brandy is distilled out of a mixture of wine and beer. Nevertheless the author adds that in order to be medicinal, the brandy can only and solely be distilled from wine. The medicinal properties of a brandy distilled from wine can be enhanced by adding several ingredients. These herbs are properly proportioned wrapped in a little piece of cloth, immersed in the brandy and jointly distilled. As ingredients are mentioned sage leaves, nutmeg, clove and *gorsbeyn of dameren*. Several authors think these terms refer to ashes (*dameren*) of frog bones (*gorsbeyn*).[17] Gors is probably a corruption of the spelling of the words *ghurst, gurst or goist* which in several Middle Dutch texts are synonymous with juniper and *beyn* can be read as *beyen* or berries. *Gorsbeyn of dameren* would in fact be juniper powder which, in that time, was often used to stabilise beer and it was also used in medicinal recipes. Flavouring brandy with herbs, berries and seeds was already introduced at the end of the fifteenth century.

In the sixteenth century the consumption of brandy rises rapidly. Many cities introduce taxes on brandy, which is increasingly being distilled from beer and mead. This resulted from the disappearance of the vineyards in our regions following the bad harvest between 1511 and 1524 and the so-called cold wave that could be felt around 1540 and extensively from 1590 onwards.[19] Hence wine became more scarce and expensive. However, the upper class continued to drink brandy from wine while the commoner resorted to drinking cheaper brandy distilled from beer and mead. Already in 1552 a physician from Antwerp, Philippus Hermanii protested against the growing consumption of brandy distilled from beer in *Een Constelijck Distileerboec* and in 1588 the pastor Casper Jansz. Coolhaes (1536-1615) did so in *Van seeckere seer costelijcke wateren.*[16,20] According to these authors brandy from grains has less flavour, wine destillate is the only healthy one, one can only speak of brandy if it is distilled from wine, and grains can only be used for the purpose of making bread. Notwithstanding these warnings the production and consumption of brandy made from beer and mead rise enormously in the second half of the sixteenth century. The distillers no longer process the beer, but they immediately use the grain, mainly rye and wheat. These grains are left to germinate first, allowing the starch to transform easily into fermentable sugar during mashing. After the sugar's fermentation into alcohol distillation happens twice to three times hence obtaining corn brandy or malt spirit.

In 1588 the Northern Low Countries (Republic of the Seven United Netherlands) get severed from the Southern Low Countries. In the Southern Low Countries the archdukes Albert and Isabella issue an edict in 1601, because of the excessive brandy consumption, prohibiting the production, sales and consumption of brandy from grains, apples and putrid pears (fig. 2). This prohibition will remain operative during the entire 17th century. In the Northern Low Countries distillation can freely continue; this results in a sensational development of the malt spirit production in the ports (especially Schiedam) with sufficient grain supply. The upper class appreciates less the malt spirit's organoleptic characteristics than brandy distilled from wine. This urges the producers to aromatise the malt spirit, especially with the juniper berry flavour. This is also the origin of a speciality, viz. distillers produce malt spirit while liquor distillers are involved in aromatizing it. Hasselt, which is not a part of the Southern Low Countries but which belongs to the Principality of Liège, must not abide by Albert and Isabella's edict. Therefore it continues to distil brandy and "wachtelwater", its own kind of gin.[21]


ORDONNANTIE
ende
PLACCAET
VANDE EERTZHERTOGHEN TEGEN
d'abuyſen dier geſchieden in ſommige plaetſen, ende Landen van herwvertſouer, deur dē ommatigen drāck ende ſlete vande Ghebrande-wynen, anderſins gheheetē Leuende-wateren, ende ander gelycke diſtillatien.

TOT BRVESSEL,
By Rutgeert Velpius, Boeck-vercooper ende Drucker vanden Houe, inden gulden Arent by t'Hoff, 1601.
Met Priuilegie.

Fig. 2.
Edict of the archdukes Albert and Isabella prohibiting
the production and sales of brandy from grains (March 20, 1601).
Library of the University of Gent.

With the introduction of the government of the Austrian Habsburger family the Southern Low Countries are allowed to recommence their distilling activities.[22] Moreover, distilling is even stimulated to re-energise the dying agricultural sector. When producing alcohol out of grains a valuable additional product is obtained, namely draff. This non-volatile residue remains in the still after distillation and consists of chaff, remainders of flower and yeast. This draff, rich in proteins and cellulose, is valuable food for cattle and pigs. The manure obtained was used to fertilise the fields so increasing the corn yield. This early ecological cycle was implemented in many farms (especially in East Flanders). Distilling activities were allowed under Austrian Habsburger rule if one disposed of a patent paying a yearly contribution regardless of the production volume. This led to expeditious, multiple and neglectful distilling: the tax had already been paid anyway! The farmers used thick mashes which were very sensitive to burning and there was no sufficient separation of the foreshots and the feints from the middle run. Furthermore the farms had a larger interest in the draff than the alcohol which seldom was flavoured with juniper berry although this brandy was already called gin. In 1752 the government established its own public distillery in Waasten (Warneton), a small village near the linguistic border between Hainaut and West Flanders. Dutch distillers who produce gin the Dutch way (viz. aromatised with juniper berries) were being lured and they were asked to pass on their expertise to the agricultural distillers. It did not go beyond the well-meant attempts. Up until this day some distillers in East and West Flanders are still producing gin which does not contain any juniper berries.[23]

(Grain) distilleries: the cradle of biotechnology[1,24,25]

The oldest reference to distilling known in Dutch literature can be found in the manuscript *Der Naturen Bloeme* written in Damme between 1266 and 1269 by Jacob van Maerlant.[6] In his voluminous oeuvre he only wrote once about distillation and miraculously enough – or is it not a coincidence – it concerned the dry distillation of juniper wood out of which juniper oil is extracted.
Jacob van Maerlant described the distillation process in the following verses:

Van desen houte maectmen mede
Olie van groter moeghenthede
Teersten moet ghedroghet wesen
In die sonne thout van desen
Dan setmen enen pot gheheel
In daerde diep ghenoech een deel
Ende enen andren op sinen mond
Ende die ydel oec ter stont
Die hevet in den bodem een gat
Vol van den houte lechmen dat
Ende stoppet boven so tien tiden
datter ghene lucht uut mach liden

Dan maect man an den pot een vier
Also staerc ende also fier
Dat dat hout binnen versmacht
Also coemt met groter cracht
Uut dien houte een lettelkijn
Olien diere en fijn
In den nedersten pot tier stede

These verses describe a 'pot-on-pot' process that was already described by Dioscorides in the first century and was later called *distillatio per descensum* or downward distillation. About the *distillatio ascensum* or the upward distillation Jacob van Maerlant does not say a word. Nevertheless he must have known this classical way of distilling because he describes several applications of *rosen watre*, a distillate of freshly plucked rose petals. Van Maerlant for instance writes about nard boiled with sugar in rose-water and says it is good against *hertvanc en syncopsis* (anxiety and fainting) while mint with rose-water prevents *spuwen en syncopsis* (vomiting and fainting). These little remedies make us spontaneously think of the drop of *eau de Carmes* on a lump of sugar, which is still being used against oppression.

The West copied the use of rose-water from the Arabs to whom the invention of the distillery art is attributed. The cradle of this art stood in Alexandria where Greek and Egyptian scholars established the Alexandrian higher institution. Among their assistants were Maria the Jewess (2nd Century), Zosimos (ca.350-ca.420) and Synesios (ca.365-ca.415). The invention of the distilling instrument and the water-bath (bain-marie) was attributed to Maria the Jewess. She probably knew the work of Aristotle (384 BC-322 BC) and Dioscorides (1st Century AC) who described for the first time a primitive form of distilling. For example: in his *Meteorologica* Aristotle tells about the sailors who boiled see water, caught the vapour in a sponge and obtained potable water after squeezing it. (In his book *Dageraad ofte Nieuwe Opkomst der Geneeskonst* Van Helmont (1578-1644) talks about sponge water meaning in fact distilled water)[26]. Dioscorides, the personal physician of Emperor Nero, describes in his *Materia medica* how the solid, vermilion cinnabar (mercury sulphide) is transformed into a silver-white liquid (mercury). In order to obtain this effect he heats the cinnabar in a ceramic jar to which a lid with an internal channel is attached. The mercury vapours condense on the lid and flow into the channel. After having cooled off the mercury is removed out of the channel and it is used as a medicine.

The distillation instrument of Maria the Jewess was made out of copper, glazed ceramics or glass and consisted of three elements: the cucurbit (boiling kettle), the alembic (still-head) and a phial (receiving flask). The alembic, equipped with an internal gutter or rim with an outlet-tube (spout), was attached to the boiling kettle. The distillate ran through the spout into the phial. This phial was an elegantly shaped bottle with a long neck and a small belly. From the 10th century and later the "alembic" does not refer any longer to the still-head, but to the entire distillation instrument.

The alembic of Synesios is to this day the oldest known depiction of an alembic (fig. 3).

It is described and pictured in a 15th century manuscript (2327 fol. 33^v) that is being kept at the *Bibliothèque Nationale* in Paris.[27] It was certainly possible to obtain rose-water using that distillation instrument. The main substance of rose-water, the geraniol, boils at 230 °C and is sufficiently cooled in this air-cooled alembic, condensed and then collected. For ethanol production (boiling point 78 °C) this alembic was not adequate since the ethanol vapours were insufficiently cooled and hence left the alembic largely as vapour. This deficient cooling process was the reason why the Arabs were unable to prove the existence of alcohol. Thus the Arabs did not use the word *al kuhl* to refer to ethanol, but they used it to refer to the fine, black antimony sulphide powder that the Eastern women used to colour their eye lids. It is Paracelsus (1493-1541) who was the first to use the word alcohol to describe wine spirit or ethanol.

The knowledge of the Alexandrian alchemists was refined and completed by Arab savants like Djâbir (ca.722-ca.803), Rhazes (865-932), Abû Al-Qâsim or Albucasis (936-1013) and Avicenna (980-1037). Djâbir (Ge-

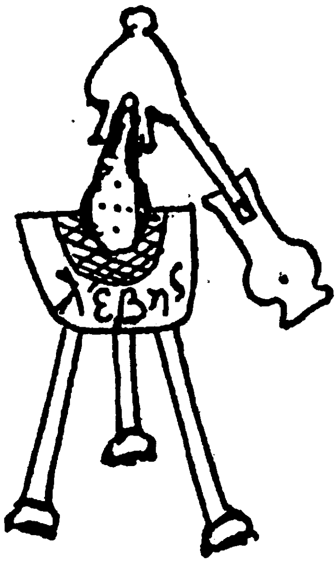


Fig. 3.
Alembic of Synesios, 4th century.
Bibliothèque Nationale de Paris, Ms. 2327, fol. 33^{v}.

ber in Latin) used the alembic to study *ghosts*, which are volatile mineral substances like mercury, sulphur and ammonium chloride and mineral acids like hydrochloric acid, sulphuric acid and nitric acid. Rhazes, Albucasis and Avicenna however, were more interested in distilling medicinal waters.

Through crusades and Moorish settlements in Sicily and Spain the Western world came into contact with the Arab culture and science. In the twelfth and thirteenth centuries the translation schools of Toledo and Salerno translated many alchemist writings from Arabic to Latin. Doing this they left many Arabic words un-translated, words that later on were also assimilated in Dutch. Some examples: alembic *(al anibcq)*, derived from the Greek word *ambix* (vase) and the Arabic article al; alcohol *(al kuhl)*; elixir *(al iksir)*; alcali *(al qali)*; alchemist *(al khemia)*.

Presumably there was already knowledge of some form of wine distillate, called *aqua*, in the 8th century. The manuscript *Mappae clavicula* would indicate such notion, although in the form of a cryptogram.
From the 12th century onwards the distillation of wine is gaining interest. A small tract on *De aqua ardente* is known of Magister Salernus who pertained to the famous medical school of Salerno. It was probably written between 1140 and 1160. Salernus says that an inflamable liquid can be obtained out of wine, in the same way rose-water is made. Before distilling he adds salt and tartar to the wine. We know now that these salts do not only bind water but that they also help to expel alcohol which increases the alcohol concentration of the distillate. To raise the flammability of the distillate sulphur was added, a recommendation from the *Liber ignium ad carburendos hostes* that was presumably written by Marcus Graecus in the 11th century.

One century later, around 1280, Thaddeo Alderotti (1223-1303) wrote one of the most influential tracts on wine distillery: *De virtutibus aquae vitae et eius operationibus*. This Florentine physician (hence his name Thaddeus Florentinus) was a professor at the university of Bologna. He was the first to equip the copper still-head with a spiral spout which was continuously cooled with running water. This cooling made it possible to strongly increase the alcohol concentration of the distillate. He did not only improve the distillation equipment but also the distillation methods: when half of the wine had already been distilled, the procedure was stopped. Then the distillate was distilled for the second time processing 7/10 of the liquid. Thaddeus Florentinus believed that the distillate was not only very inflammable, but that it also had several powers: it was used as a medicine, as *aqua vitae*, and in the *alkimia* (chemistry) it was used as a solvent, a means of fixing and extracting.

The knowledge of Thaddeus Florentinus was disseminated all over Europe via universities and monastic orders. Arnaldus de Villanova (ca.1255-1311) and Johannes de Rupescissa (ca.1300-1365) played a prominent role in this dispersion. Both of them belonged to the fraticelli, a franciscan sect which advocated complete poverty and used the alchemy to search for the mystic gold and the production of medicines. The Spaniard Arnaldus de Villanova wrote the *Liber de vinis* of which several versions in Middle Dutch exist , the oldest dating from the 14th century. [9] The book is not only about medicinal wines, but also about *water of life* in which he leaves multiple spices to macerate. However de Villanova does not describe the distillation process. The Frenchman Johannes de Rupescissa does. In his *De consideratione quintae essentiae omnium rerum* he writes about the preparation of a non-perishable *quinta essentia*, the Elixir of Life that can assure eternal life. It is multiple distilled *aqua ardens* that without interruption is being heated, vaporised in the circulatorium and then ascends, cools and condenses. Its force can even be increased by dipping two golden coins in the *aqua ardens* while being heated. Johannes de Rupescissa, whose work was also translated into Middle Dutch, does not only relate about wine distillation but also about distillation of minerals, metals and mineral acids.[28] In this case it is not about the transmutation of base metals into gold with the help of the Philosopher's Stone, but it is about the application of metals and mineral acids in medicine.

It is far from a coincidence that many Latin written chemical tracts were translated into Middle Dutch. In the Low Countries existed a strong alchemy tradition. Jacob van Maerlant knew alchemy but he was no fan. In his book XII of his *Der Naturen Bloeme* he resists the transmutation: he states that it is only to the Lord to give eternal life.[6] He is also suspicious of the many alchemic writings without an author. It is possible he feared Church. For the Church argued that eternal life could only be provided for by the sacraments, not by the Elixir of Life. The Church mainly aimed at the franciscan monks who counted several alchemists among their members. In 1323 the Church forbade them to practise the art of alchemy on penalty of excommunication.[29]

The mingling of alchemy and religion is very obvious in Constantinus' *Bouc der heimelicheden van mire vrouwen alkemen* and in Gratheus' title-less manuscript.[29] Both tracts have been written in Middle Dutch and are being kept in the *Österreichische Nationalbibliothek* in Vienna. Although in the tracts the date 1224 appears, a graphological study indicates that it was probably written in the 14th century. They are of the utmost importance because up to this day they are the oldest Western illustrated alchemy tracts known. Constantinus' tract deals with the transformation of mercury. To the man living in the Middle Ages the transformation of solid, red mercury sulphide into fluid, silver-white mercury was a truly miraculous event. A solid *stone* was transformed into a volatile *spirit* after being heated in a distillation flask and then after letting it cool off it turned into a *liquid*! The resurrection of Christ and the transformation of bread and wine into the body and blood of Christ could be explained in an analogue way. Gratheus' tract contains peculiar representations with among other things Christ's face surrounded by a circle of different chemical vases (fig. 4). So far, they are the oldest, although very primitive representations of distilling flasks that can be found in alchemic literature.

Besides the speculative alchemists in search of gold, there were also very practical alchemists in the Low Countries who used the latest insights in chemistry and chemical techniques in the most diverging production procedures following the traditional methods. A lot of attention was spent on gaining and purifying base materials like salammoniac, alum, ammoniac-borax, sodium carbonate, salt and potash. These base materials soon became commercial goods and they were transported from one country to another. At the beginning of the fourteenth century the production of three 'more recent' chemical products was started: saltpetre, alcohol and mineral acids.[30] The production of alcohol and mineral acids had only become possible thanks to the improved distillation technique. The three new products themselves created new technologies and trades, for instance saltpetre and alcohol were applied during the production of gunpowder. The mineral acids like nitric acid and sulphuric acid made the division of silver and gold possible, which gave origin to the fine-metallurgy. Alcohol was not only used as a means of extracting or as a solvent of medicinal substances, but also as a universal solvent for things like oils, lacquers and some paints, smell and taste additives.

The production and the use of explosive, burning or inflammable chemicals led to the promulgation of a series of new rules.[31] For instance regulation n° 36 of the *Keure van Deelmans* (Bruges, 1305) prohibited to burn *wijnas* (grape-vine charcoal) within the city to prevent fire risk. The greyish white grape-vine charcoal obtained through evaporating and calcining grape marc in open stone jars, contains a high concentration (40-60%) of potash, besides the carbon. This preparation method resulted in a new Dutch name for *wijnas*: "potas" of which the Latin derivative potassium. This grape-vine charcoal was probably used to produce gunpowder, a mixture of saltpetre, sulphur and carbon. In the accounts of the city of

Fig. 4.
Christ's face surrounded by a circle of different chemical vases, 14th century. Tract of Gratheus, Österreichische Nationalbibliothek, COD. 2372, fol. 61r.

Bruges of 1345 (fol. 141, n° 10 and 11) we can read that the city purchased saltpetre, sulphur, powder of black amber and turpentine but also an alembic from master Niclaeis Bollaerd. Presumably the alembic was used to distil turpentine, hence obtaining camphor. The powder from the black amber was used to increase the inflammation ability of the gunpowder while the camphor held all powder together and reduced the gunpowder-smoke. These additives were mixed with the gunpowder in an alcoholic solution. In the city accounts of Bruges of 1476 (fol. 12v) an indication can be found that wine was being distilled to make gunpowder: *levende watre omme poedre te makene* (water of life to make gunpowder). Who was responsible for distilling the water of life is not known. What we do know is that distilling was already a profession there in 1447 because a certain *Baptiste de Gambaro, stokere* (distiller) was summoned in the courts of Bruges.

The water of life also called *aqua ardens or aqua ignea*, could be poured from the town walls onto the enemies, hence burning them. The preparation of *aqua ignea* is already described in a 14th century chemical tract, *Boec van .XIJ. goeden wateren* that is being kept in the *Koninklijke Bibliotheek* in Brussels (manuscript 4260-4263, fol. 32^r). *Aqua ignea* is obtained through distilling in an alembic of white wine to which almizadir (ammonium chloride), sulfuris (sulphur), tartari (wine stone) and salt were added.[32]

Also dating from the 14th century is the first Middle Dutch tract *Aqua vite, dats water des levens of levende water* (manuscript 15624-15641, fols. 6^v-8^r, *Koninklijke Bibliotheek* in Brussels).[33] Until now it is the oldest Dutch publication known about alcohol (fig. 5). The author of this alcohol tract is unknown, but it is a fact that in 1351, two years after the pest epidemic broke out in the Low Countries, Johannes de Aeltre (Jan van Aalter) copied the document. A dialectic study reveals that the author must be of West Flemish origin. The production of *aqua vitae* goes as follows: a jar of 9 *stopen* (1 stoop in Bruges amounts to about 2.23 litres) is filled with wine and equipped with an alembic. The jar and the alembic are glued together with flour and egg white. The wine is boiled and the inflammable part of the distillate is caught in a recipient made of glass. The inflammation ability is regularly checked by immersing a piece of cloth in the distillate from time to time: as long as the cloth remains burning, the distillate is collected. After the first distillation the jar is cleaned and refilled with the last distillate. The distillation process is repeated up to 4 and 5 times. *Aqua vitae* could be used to treat the most divergent diseases. The medicinal characteristics of it could be reinforced by adding different spices, berries and seeds. *Aqua vitae* was also used to concentrate wine and preserve foods from putrefaction. Furthermore Van Aalter also writes about the *aqua vitae* characteristic to float on oil. To the man of the Middle Ages who had always seen that oil was able to float on water, the phenomenon of water of life floating on oil was equally miraculous. The most important characteristics are mentioned here below:

Het doet oec den mensche droefheit vergeten
Ende maecten van hertten vro ende oec stout ende coene.
(It makes people forget about sadness

and it makes the hearts happy and brave.)

These euphoric properties turn the medicine *aqua vitae* into the stimulant *brandy* over a period of one century.

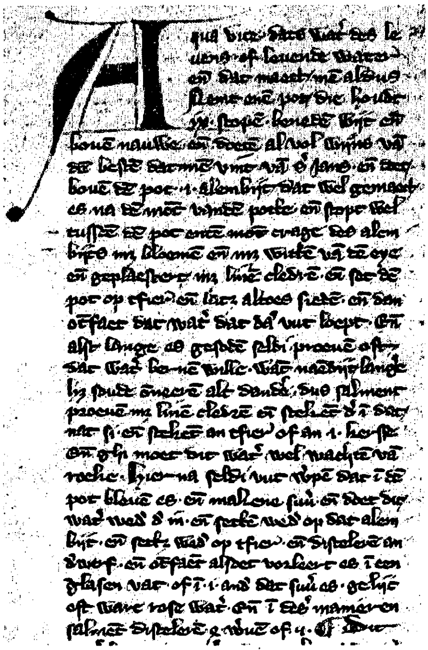


Fig. 5.
Aqua vite, dats water des levens..., 1351.
Koninklijke Bibliotheek Albert I, Ms. 15624-15641, fol. 6^V.

In the second half of the 14th century many Middle Dutch *aqua vitae* tracts resembling the one of Jan van Aalter, are issued.[17,28] The late 15th century recipe *Gebrande wyn te maken* (making brandy wine) (manuscript Sloane 345, fols. 51^r-51^v, British Museum in London) is really innovative.[17] The basic ingredient is wine, diluted wit Hamburg beer, at the time considered to be the best beer available. The dilution can not happen at random, but most be dosed to a thickness equal to that of buttermilk. We know now that this dilution is important to be able to remove the alcohol from the liquid in an effective way. To prevent burning the mixture was stirred until just before the boiling point; then the still-head is attached to the jar with a mixture of egg white and chalk or buckwheat-floor. Afterwards wet towels are put on the still-head and the cooling-coil is immersed in a tank of water. This improved the rectification and the alcoholic vapours are better cooled and condensed, hence increasing the alcohol concentration. Checking the alcohol amount still happens as it did in the times of Jan van Aalter: when a piece of cloth immersed in the distillate catches fire, it is considered to be alright.

It is not strange that many artists were interested in alchemy. For alchemists disposed of the technical procedures that were useful to goldsmiths, potters, glassblowers and painters. For instance, we know that the painters Jan van Eyck (ca.1390-1441) and Leonardo da Vinci (1452-1519) were experienced and skilled alchemists. Famous writers like Giorgio Vasari and Carel van Mander think that the revolutionary oil painting procedure invented by Jan van Eyck, existed thanks to his knowledge of alchemy.[34,35]
There is even a sketch known of a distillation instrument by Leonardo da Vinci and also in his literary work we can read: *since varnish is made from the juniper wood's resin, the varnish can be dissolved in the distilled product after distillation of the resin.*[29]
The distillation of turpentine from the larch or other conifers' resin is described in the 15th century Middle Dutch manuscript Sloane 345, fols. 40^{v}-43^{r}.[17]It also mentions how to prepare *quicsilver* from cinnabar, acetic acid from wine vinegar and *aqua fortis* from alum, saltpetre and green vitriol. For the condensation of the mercury fumes ice cubes were already being used. These distillates were being used by the goldsmiths: mercury was used to dissolve gold and with *aqua forti*s (strong water or nitric acid) it was possible to separate gold and silver. *Aqua fortis* was used during etching. For this purpose the artist covered the copper plate with an acid-repressing layer of wax, resin or tar. The drawing was carved into the etching layer and then the copper plate was dipped into a bath of *aqua fortis*, which eroded the etching lines.
Painting recipes can be found in the late 15th century manuscript 517 of the Wellcome Historical Medical Library in London. For instance, fol. 64^{v}

reveals the recipe of a "water" with which you can dye a cloth in greenish blue or yellow. To obtain this effect a crushed mixture of saltpetre, blue vitriol, alum and Spanish green were distilled. The first water distilled coloured the cloth greenish blue, the next yellow. This recipe illustrates how far the art of distillation had evolved at the end of the 15th century.[36]

Around the same period during which the recipe *Gebrande wyn te maken* was written, the first printed booklet on medicinal waters is published in Augsburg in 1476: *"Hienach volget eyn nüczliche materi von manigerley aussgeprannten wassern wie man die nüczen und prauchen sol zu gesuntheyt der menschen"*. The booklet (15 pages folio) was written by the physician Michael Puff von Schrick (ca.1400-1473), professor at the university of Vienna. The booklet deals with the preparation and the medicinal characteristics of medicinal waters. Furthermore it contains a chapter on *geprannten Wein* (distilled wine) highlighting its medicinal properties. In fact, the booklet does not disclose any new knowledge and the author was mainly inspired by Alderotti's work and Middle Dutch texts.

From now on books on distilled waters are being continuously published. For instance, in 1500 the *Liber de arte distillandi de simplicibus oder das Buch der rechten Kunst zu Distillieren die eintzigen Dinge*, a book by the physician and pharmacist from Strasbourg, Hieronymus Brunschwijgk (ca.1450-1512), is issued. The book consists of three parts and was partly written in Latin and partly written in German. The first part describes distillation instruments and furnaces and contains 79 illustrations. That is why the book has enormous relevance to the history and the distilling techniques. The second part is a herbal and it presents a adjusted distillation method for each plant. The third part is about the medicinal properties of the distillates. In 1512 Hieronymus Brunschwijgk published a more elaborate work: *Liber de arte distillandi de compositis*. The addition mainly covered the preparation of distillates out of herbs, berries and seeds. Both books would continue to be thé works on medicinal water preparation. Several reprints and translations followed. For example in Brussels in 1517 a translation of the booklet is published by Thomas van der Noot with the title *Die distellacien ende virtuyten der wateren*. The Dutch translation contained only 104 pages instead of the original 230 pages. Perhaps the restriction happened due to financial reasons, because books were very expensive at that time. It is largely the technical part that had been shortened: did the translator think or know that the distillation techniques were sufficiently known in the Low Countries?

In Antwerp in 1520 Willem Vorsterman publishes *Dit is die rechte conste om alderhande wateren te distilleren ende oock van die virtuten van alle ghedistileerde wateren seer goet ende profitelyck.* It is a pharmaceutical manual (48 pages) that can be considered as an appendix to the book of Hieronymus Brunschwijgk. In the introduction the writer describes the alembic and the furnace. The alembic is made of lead (something that will be prohibited later) or glazed pottery and it consists of a *scotele*, a dish in which the crushed herbs are placed and a *cleyn torreken*, a small still-head with a spout that can be put on the dish. The alembic itself is put on a *cleyn ooveken*, a small furnace under which a good fire without any smoke is made. The preparation of *aqua vitae* out of wine is not discussed. However the author does praise the many properties of this water of life and he calls it *ghemeynlyc vrouwe van alle medecinen* (common wife of all medicines). He does add the phrase *alsment drinct bi maten* (if it is consumed with measure).

In Antwerp in 1552 Jan Roelands publishes *Een Constelijck Distileerboec* written by the physician and Antwerp resident Philippus Hermanni. The book was such a best-seller that it was reprinted several times in the same city: in 1558 by Simon De Cock and in 1570 by Guilliaem van Parijs. After the disintegration of the Low Countries in 1585 the book was published in Amsterdam in 1612 and 1622 by Broer Jansz. The reason for this was the prohibition rule of the archdukes Albert and Isabella following excessive use of alcohol which had made distilling of corn brandy in the Southern Low Countries illegal and which had caused the distillers to flee northwards. The main focus in *Een Constelijck Distileerboec* is on the preparation of botanical, animal and mineral medicinal waters. Philippus writes in chapter XXI about the way to prepare juniper water or aqua juniperi.

Fig. 6.
Alembic for the production of brandy, 1552.
In: Philippus Hermanii, Een constelijck Distileerboec,
Antwerpen, 1552.

For this purpose juniper berries are crushed, sprinkled with wine and then distilled. The book also contains a small, decorated tract of the master himself about how to distil brandy (fig. 6). This tract cannot be matched and will be considered thé manual for distillers during many years and it will contribute to the explosive growth of the malt spirit industry in the Northern Low Countries. The tract starts with the description of a furnace. Its construction's concept is such that with a minimum of coal or peat a maximum heating efficiency is obtained. The copper distillation kettle is hanging detached in the furnace allowing the fire's warmth to heat up the kettle's sides sticking out of the furnace. A small grid makes a small hearth that can be fanned with adjustable air holes. To alleviate the work an automatic supply of coal and peat is provided. The size of the copper distillation kettle depends on the amount of fermented mash one wants to distil. According to the representation in the book, the still-head fitting on the kettle can have the form of a cone (the so-called Rosenhut) or a water-cooled onion shaped still-head (the so-called Moor's head). Philippus Hermanni gives much attention to the cooling of the vapours. He writes about *spirits* or forces of wine, which are driven out by the heat. It is the first time in Dutch literature that alcoholic vapours are called *spirits*. To obtain a maximal cooling of the alcohol vapour the copper pipe attached with a mixture of egg white and flour to the spout of the still-head, has to run through a barrel filled with water. The size of the distillation kettle determines the size of the cooling barrel. When a kettle of two *amen* or more is used (1 aam is about 135 litres), the cooling barrel has to be eight or nine *amen*. For a small kettle of ten or twelve *potten* (1 pot is about 1.15 litres) a cooling barrel of a *quart* (1 quart is about 57 litres) suffices.

Although Philippus Hermanni advises the use of *oprechten welrieckenden wijn* (wine with a good smell), it is admissible to use wine that *lanck oft onclaer gheworden is* (turbid wine) because of economical reasons as long as it has not turned sour. Because the sweeter the wine, the stronger and better the brandy will be. Philippus warns for the many impostors who use other substances than wine like grape marc, beer yeast and *diergelijcken onreynicheyt* with which he is probably referring to turbid beer and alcoholic drinks made from fruit.
Besides the tools and base materials Philippus also describes the distillation procedures. For instance, only two thirds of the kettle is filled with wine. Next the kettle, still-head and pipe are attached to each other. The distilling itself has to happen slowly because the slower the procedure, the better the brandy will turn out. The concentration of the distillate is checked with a taste test. Philippus makes a distinction between the best brandy and brandy. The best brandy is obtained by collecting only the strong fraction when distilling the wine. The residue of different distillations is gathered and distilled again hence obtaining brandy.

From numerous publications appears that the art of distillery reached a high during the second half of the 16th century. In this respect the Dutch took the lead. For example we know of several books on the preparation of medicinal waters and in the majority of the books on agriculture and api-culture we can find a chapter on the preparation of brandy from wine, mead or cider.[37,38]

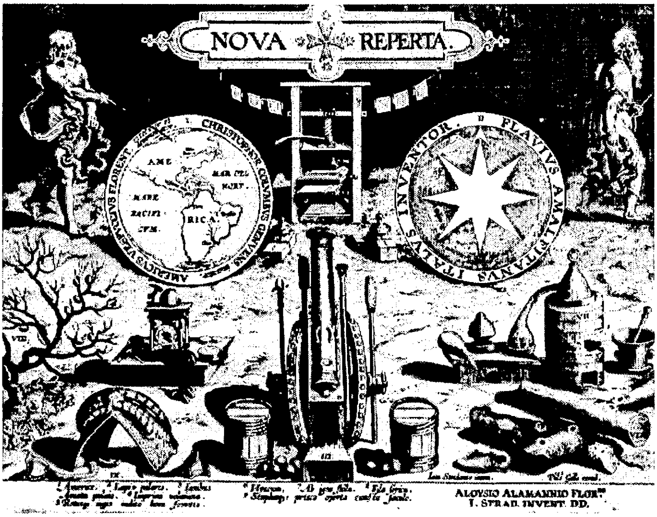


Fig. 7
Nova reperta (new inventions), end 16th century.
Engraving by Jan van der Staet (Stradamus), Amsterdam

In the engraving *Nova reperta* (New inventions), made at the end of the 16th century by the Fleming Jan van der Straet (Stradanus) the nine most important discoveries of the late Middle Ages and the Renaissance period are illustrated: one is the alembic (fig. 7). When one studies the paintings of that time, one concludes that mainly painters (Pieter Brueghel de Oude, Jan Steen, David Teniers de Oude, Jan van der Straet, Jeroen Bosch), engravers (Pieter van der Borcht, Maarten de Vos) and writers (Erasmus) from the Low Countries tackle the subject of alchemy and alchemy chambers.[29]

When, in 1585, the union of the Low Countries disintegrated many distillers swarmed off to all parts of the world. They can be traced in several cities of the Northern Low Countries where they participated in the expansion of the malt spirit industry. This consisted of many so-called four-casks distilleries. Once in twenty-four hours 4 casks with grain mashes were made, 4 were fermenting and 4 others were being distilled. These casks had an average size of 13 barrels (1 barrel being 232 litres).

The distillation took place in two wash stills of about 6.5 barrels with cooling tanks and the rectification in an alembic of about 4 barrels. When the distillery expanded there was simply added a second (or a half) four-casks distillery. In such a distillery work 3 to 4 labourers.[3]

We also encounter distillers from the Southern Low Countries in Berlin, Cologne and Nürnberg where they established grain distilleries, much to the dismay of the local distillers.[25,39] In France we can find them on the island Île de Ré and in La Rochelle where they produce *brandevin* (just as brandy derived from the Dutch word *brandewijn*).[40] In the town of Cognac they establish the first distillery of cognac.[41] Still reminding this is the Quai des Flamands by the Charente. In 1604 the consuls of Bergerac met to discuss the plan *de faire venir certains hommes flamands pour faire une grande quantité d'eau-de-vie et à ces fins dresser leurs fourneaux.*[42] In London resides a strong colony of protestant refugees from the Netherlands (in 1570 there number exceeded 6000!) with among them distillers who produced brandy (also derived from the Dutch word brandewijn) and gin (geneva or Dutch courage).[43] The book *The Whole Art of Distillation* was written in 1692 by W.Y-worth, a physician born in Schiedam and citizen of Rotterdam, and illustrated by the Flemish engraver M. vander Gucht. The Dutch established rum distilleries in Brazil and Barbados and in 1644 they established the first North American grain distillery in Staten Island.[44,45]

The world trade in brandy was completely monopolised in the first half of the 17th century by the Dutch and the sailors of the United East and West Indian Company were the biggest consumers...[46] The brandy was transported in barrels the volume of which was globally expressed in *viertels* and the alcohol strength in *Hollandse proef (Dutch test)*. Until the 17th century there were several ways to determine the alcohol amount. A brandy had only been rightly distilled if

- it completely burned without leaving any humidity behind,
- a piece of cloth immersed in it did not burn up,
- an oil drop sank in it,
- a drop of it put on a hand evaporated entirely,
- a bucket filled with it completely burned up,
- camphor melted in it.

In the 17th century one was familiar with the gunpowder test: a spoonful of gunpowder was showered with brandy and held in a burning candle. If he brandy contained too much water, the gunpowder did not catch fire. The most used checking method however, was the *Hollandse proef (Dutch test)*. This implied filling more than the half of a small bottle with brandy and shaking it vigorously. This shaking formed many little bubbles of air. If the brandy was too strong, the bubbles would rise very quickly; if, on the contrary, it was too weak the bubbles disappeared slowly and the brandy became white. If the brandy was *op proef* (on proof, about 50% vol alcohol) a *kleyn schuymjen* (some foam) appeared in the middle and the bubbles did not disappear quickly.[47] This Dutch checking method was accepted all over Europe; it would only disappear in the 19th century when the hydrometer was introduced.

How corn brandy was produced in the 17th century, can be read in *Den Volmaekten Brandewijnstooker en Distilateur*. The book was written by J.K.B.P. (Jacob Bols?) and published in Maastricht in 1794. A second revised edition titled *Een uytvoerig en omstandig bericht van de nieuw ontdekte distilleerkonst* was published in Amsterdam in 1736. On the matter of the preparation of corn brandy the author refers to the recipe *Koorn-Brandewyn uyt Koornvruchten te maeken* by Johann Rudolf Glauber (1604-1668). This German physicist and chemist settled in Holland in 1648 and died 20 years later in Amsterdam. He was possessed by the art of distillery and exercised this art in a very practical manner. His contemporaries called him the Paracelsus of distillery art. In 1648 he published his *Furni novi philosophici oder Beschreibung der neu erfundenen Destillierkunst* in Amsterdam and in Leyden: this work was reprinted several times. Glauber developed an iron alembic for the industrial production of nitric acid. This led to the establishment of distilleries that were able to produce over 10,000 kg of nitric acid (aqua fortis) a year and by adding hydrogen chloride were able to prepare aqua regia (fig. 8).

The nitric was very popular among European engravers at the time and it was known by the name of *Hollands zuur* (Dutch acid). Glauber is also considered to be the inventor of the vapour distillation: he boils water in a retort and allows the vapour to effervesce through a barrel filled with wine. The steam carries the volatile alcohol and the vapours leaving the barrel are cooled in a spiral tube, immersed in a cooling barrel. In a different setting up he lets the vapours run through a battery of cooling barrels thus obtain

Fig. 8
De Stoockerey van Gerrit Kraandyk en Cie, manufacture
of aqua fortis and aqua regis, 1732.
Engraving by Abraham Zeeman, Amsterdam.

ing different alcohol fractions (fig. 9). This invention is nevertheless soon to be forgotten and will come into vogue again during the first industrial revolution. Until then the distillers continue to cherish their alembics.

The first industrial revolution does not leave the distillers unaffected. Stimulated by B. Thompson Rumford, in England around 1802 steamers are used to heat the grain mashes. In this respect a distinction is made between direct and indirect heating. When heating indirectly the mashtuns are equipped with a steam-jacket or with an internal, spiral steam tube. When heating directly the mash is heated by direct steam injection, also called living steam. In large distilleries steam engines were used to drive the malt mills, steam pumps, mixers and lifting machines; all these tools made manual labour easier and speeded up the production.

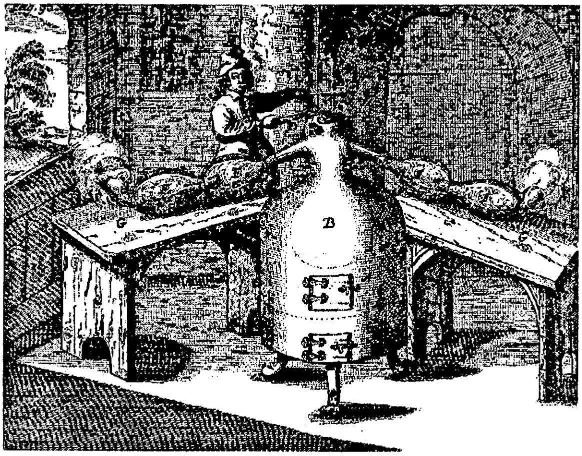


Fig. 9
Alembic with dephlegmators, 1666.
In: J.R. Glauber, *Von den Dreyen Anfangen der Metallen*, Prague, 1666.

Of even more importance than the heating of the mash and the driving of the machines, was the introduction of the continuous working steam column. In this area the French inventors were very important. In a period of 30 to 40 years the transition of the classic alembic to the continuous working steam column had been achieved.[24,48,49,50]

The first substantial step in this respect was the invention in 1780 of *le chauffe-vin* by the brothers Argand. Between the alembic and the water containing cooling barrel, they placed a barrel with wine not yet distilled. They made the cooling spiral run through the wine barrel first and only then through the cooling barrel. The vapours condensed in the cooling spiral running through the wine barrel hence preheating the wine. The use of this heat exchanger led to a considerable fuel saving and a reduction of the distillation time. Thus the invention of the Argand brothers was called *cuve de vitesse*. The heat exchanger could also be used to distil a thick grain mash; then the heat exchanger was provided with a mixer that prevented the sedimentation of flour particles, chaff and yeast cells.

The next significant step was made in 1801 by Edouard Adam who took over the ideas of Glauber. Adam boiled wine in an alembic and then let the vapour effervesce through three egg-like containers filled with wine (fig. 10). Next the damp was condensed in a closed cooling spiral that was placed in two drums arranged on top of each other. The upper vessel was filled with wine and thus preheated. The lower vessel contained cooling water. The damp carries the volatile wine alcohol along in the egg-like containers hence enriching the damp with alcohol. The great advantage of Adam's distillation device was that it was possible to produce a high alcohol concentration using little fuel.

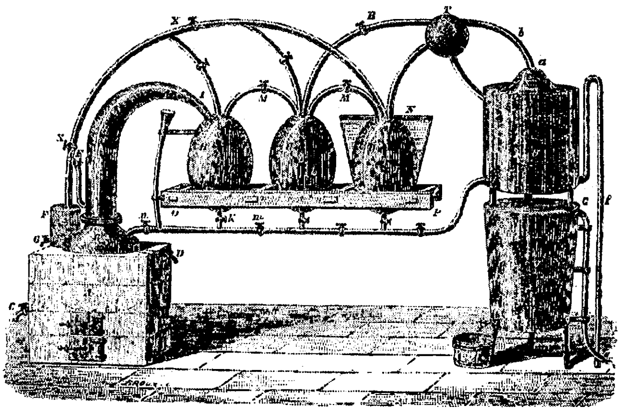


Fig. 245. — Appareil distillatoire d'Édouard Adam, breveté en 1805.

Fig. 10
A simple Adám still, 1805.
In: L. Figuier, *Les merveilles de l'industrie*, Paris.

In 1805 Isaac Bérard took a patent on a *appareil distillatoire propre à retirer du vin dans une seule opération de l'eau-de-vie épreuve d'Hollande, de l'esprit trois-cinq, trois-six, à la volonté du fabricant.* Bérard placed a condenser between the alembic and the cooling barrel (fig. 11). The condenser was cooled in a water trough and consisted of two parallel, horizontal, cylindrical tubes which had been internally compartimented with perforated plates. When running through the condenser the least volatile part of the vapour was condensed. The non-condensed vapour contained more alcohol and was made liquid in the cooling barrel. The condensate, rich in water and poor in alcohol, ran back to the alembic. From the title of Bérard's patent it appears that at the beginning of the 18th century the strength of brandy was still indicated in the *Hollandse proef* like it had been the custom to do so since the 17th century. An *eau-de-vie of trois-cinq* means that three parts of this eau-de-vie diluted with two parts of water result in an alcoholic solution with a strength of the standard Dutch gin (*Hollandse proef*).

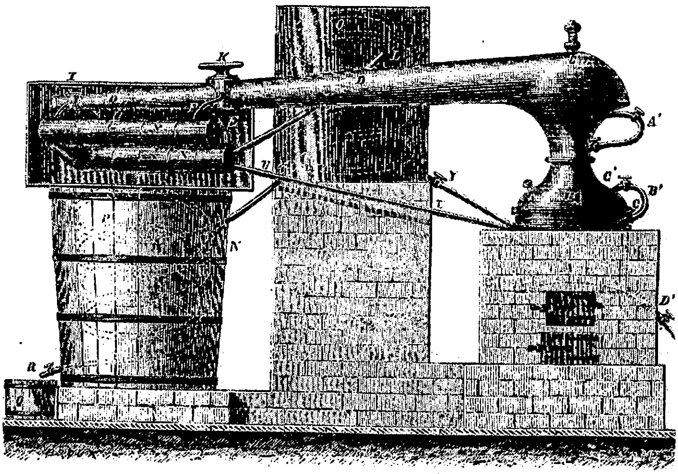


Fig. 251. — Deuxième appareil d'Isaac Bérard.

Fig. 11
The Bérard apparatus, 1805.
In: L. Figuier, *Les merveilles de l'industrie*, Paris.

In 1813 Jean Baptiste Cellier-Blumenthal took a patent on a continuous working steam column. He had discovered this when investigating the production of granulated sugar out of sugar beets. It was the German chemist Andreas Margraff who demonstrated in 1747 that beets contained crystallizable sugar. Forty years afterwards Karl Archard succeeds in preparing beet sugar and with the support of king Frederic II of Prussia he opens the first European sugar factory. Germany is the first European sugar producer but it is swiftly surpassed by France. The reason for this was the English blockade of the continental ports. Consequently the cane sugar from the colonies was no longer obtainable. Napoleon promised a premium of 1 million French francs to the inventor of a good method to produce on an industrial scale white granulated sugar from beets. Like others, Cellier-Blumenthal also tried to refine beet sugar with alcohol, a method already described for the refinement of sugars from grapes and honey. However for this procedure large quantities of alcohol needed to be vaporised, which encouraged Cellier to develop a distillation instrument that could produce even faster and more economically than the devices of Adam and Bérard. He combined Adam's principles (enriching vapours relatively poor in alcohol through contact with an alcoholic liquid) and Bérard's (enriching vapour by controlled partial condensation and by removing the condensate). Cellier located a vertical column consisting of two parts on the alembic. The upper part, the rectifying column, was equipped with different perforated plates; the lower part, the distillation column, contained plates with bubble caps. Cellier let the wine stream downward out of the supply tank with height control, through a small and large condenser, into the rectifying column. The wine streaming downwards came into contact with the ascending vapours out of the steam-heated alembic filled with wine. The good contact between the downward-streaming wine and the ascending vapours produced a continuous condensation and evaporation. The vapours leaving the rectifying column were very rich in alcohol and were being cooled in the condensers while in the meantime the wine was being preheated. The non-volatile wine fraction, the *vinasse* ran down the column and left it at the bottom.

To construct this steam column Cellier called upon the Parisian machinery builders Derosne and Cail. Cellier's steam column was soon copied and some like Baglioni from Bordeaux claimed the paternity of the invention of the steam column. This issue was taken to court and Baglioni lost. Irritated by all these trials Cellier left Paris in 1820 and settled in Koekelberg near Brussels.

Cellier also had success abroad. In 1817 the German professor Johann Pistorius took a patent on an instrument that allowed him to distil thick grain and potato mashes. In England in 1830 Aeneas Coffey patented a steam column that is very suitable to distil grain mashes. The German and English instruments were able to produce industrial alcohol in one step. (These steam columns, primarily Coffey's, will later also be used to distil petroleum). In France and in Belgium industrial alcohol was produced in two steps. First wine or an other alcoholic liquid was distilled to an alcohol percentage of 50-52% vol and consequently rectified to 80% vol, which was the industrial standard at the time.

In Belgium there was a lot of interest in the steam column.[51] The fact that Cellier-Blumenthal had settled in Koekelberg in 1820 was certainly one of the reasons. Also his later friendship with king Leopold I had a stimulating effect. Leopold I, who owned a potato distillery in Niederfülbach, Saxony, was very interested in Cellier's work. In Belgium Cellier mainly worked with the coppersmiths Delattre, Dubois and Camal from Brussels. In 1828 Cellier performed tests in the distillery Dooms in Lessen together with coppersmith Dubois. He rebuilt his steam column, developed for wine distillation, so it would be suitable to distil thick grain mashes. For instance, he replaced the perforated plates in the rectifying column by plates with bubble caps in order to obstruct the column less. In 1829 he installed a steam column in the sugar refinery / distillery Van Volsem in Halle and in 1830 one in the distillery Claes in Lembeek. This steam column was entirely satisfactory and meant a real breakthrough in the world of distillery, where it was known by the name *la colonne belge* (fig. 12). This column that could mostly be found in industrial distilleries, was made out of red copper and contained depending on the distiller's wish 12, 14 or 20 dishes. In Belgium, Cellier also collaborated with Pierre Savalle with whom he had been friends since 1813. This French engineer spent a large part of his life in Belgium and owned three sugar refineries with distillery. The story goes that Cellier and Savalle escaped death by a hair's breadth when an explosion happened during a test distillation. This incident would have driven Savalle to look for a steam control, research he ended successfully in 1857. François Savalle, born in Louvain in 1838, assisted his father and inherited the sugar refineries with distilleries and the construction workshop Savalle et Cie when he died in 1864 in Lille. F. Savalle built numerous steam columns, which were not only used in industrial distilleries and agricultural distilleries, but also in the emerging petroleum industry.

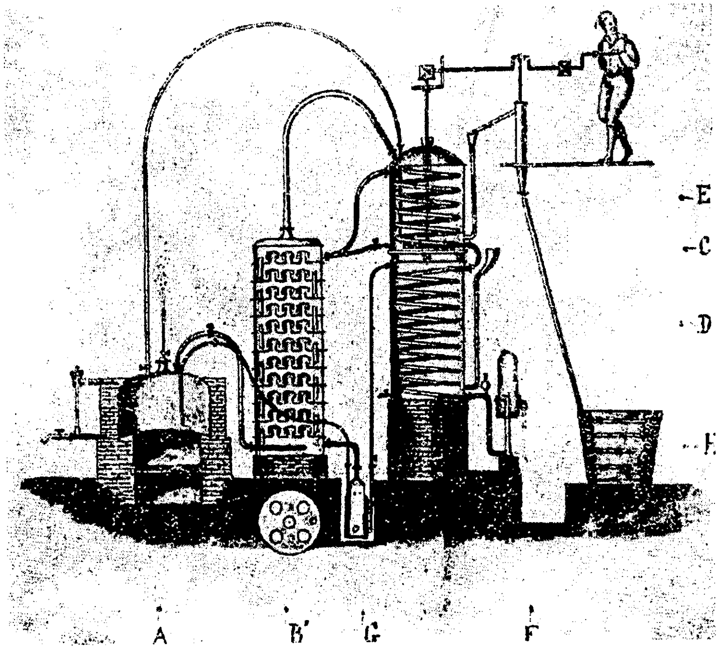


Fig 12
The Cellier column (La colonne belge), 1841.
Brevet de perfectionnement n° 816, 30 août 1841, Brussels.

The most impressive industrial distillery was Louis Meeus' distillery *De Sleutel* in Wijnegem (fig. 13). It was established in 1869 but its roots were in the Antwerp distillery *Het Anker* which dated from 1753. During the world exibition in Antwerp in 1895 the distillery had a prestigious stand and important business figures were revealed at that time.[52] The company had a build-on surface of 20,543 m² and disposed of a steam engine park that supplied 1,084 h.p. The grain was brought in by ship and stored in one of the 19 silos. These silos were four storeys high and could contain 50,000 hl of grain. The malt-house had a malting floor of 8,000 m² and the green malt was dried in an one-layer kiln equipped with mechanical turners. The company had 12 grain mills. The unmalted grain was released with steam under pressure in cylindroconical Henze-cones. The saccharification took place in lying macerators rotating on their axe. The fermentation process took 48 hours and took place in one of the 34 copper tubs of 120 hl,

equipped with an internal cooling spiral. The company had 11 different distillation columns to separate volatile from non-volatile components. The rectification was done with alembics (for gin) or rectification columns (for spirits). It was possible to produce 50,000 litres of alcohol of 50% vol on a daily basis. The year after its establishment the company already produced 7,154 hl of alcohol at 50% vol.
The production rose continuously and in 1884 it mounted to 101,359 hl. The company had its own steam vessel, l' *Etoile*, which transported gin from Wijnegem to Antwerp where the enterprise had large warehouses. Part of the gin production was exported to Coruna, Rio de Janeiro, Liberia, Sourabaya, Dunedin, Sydney, Hongkong and Melbourne. In 1884 42,665 tons of imported grain was consumed, 3,600 pieces of cattle were fatted, 1,300 of which in stables of their own, 574,000 hl of manure was sold and 25,998 francs of taxes was daily paid. The company employed 250 workers, had its own fire brigade and even a factory chapel.

Since the previous century the steam column has known no substantial changes. However it has become bigger, made out of rustproof steel, computer-controlled and more energy economical.[53] Today the largest distilleries are in Brazil where colossal amounts of water-free alcohol are being produced as fuel for vehicles as part of the *Programa Nacional do Alcool.*[54] In this respect distilleries were built which starting from the fermented cane sugar molasses can produce up to 240,000 litres of water-free alcohol per day!

Despite the introduction of heat pumps and the distillation under increased pressure distillation remains very energy-consuming (10 to 13 MJ per litre water-free alcohol) and (at the current rate) the use petrol of is cheaper. Therefore a less expensive separation technique is being searched, possibly it will be the membrane technology. For the production of pure industrial alcohol this might be possible; for the manufacture of the more complex strong drinks this is not for tomorrow, not even for the day after.

Fig 13
Louis Meeus' distillery *De Sleutel*, Wijnegem (Antwerp), beginning 20th century. Postcard, Nationaal Jenevermuseum, Hasselt.

Alcoholic fermentation: the cradle of biochemistry and microbiology[55,56]

The phenomenon that grape juice or some other sweet liquid starts to bubble up spontaneously during a shorter or longer period of time to finally end up being a drink that has a fuddling effect, has intrigued many researchers throughout the centuries. Although the art of making wine, beer, mead and other alcoholic drinks has been existing for centuries, the insight in yeast and the fermentation process was not to be gained until the 19th century. The study of yeast and the fermentation process is one of the most interesting chapters in the history of science. Many famous scientists were interested in the phenomenon of alcoholic fermentation and their research is part of the origin of general and applied biochemistry and microbiology, a scientific discipline nowadays referred to as biotechnology.

Until the 15th century the alchemists believed that fermentation (*fermentatio*) was being caused by a ferment (*fermentum*). They compared the ferment with the Philosopher's Stone: just like the Philosopher's Stone transformed base metals into gold, such did the ferment to the dough, made it rise and transformed grape juice into wine. Although one was not familiarised with the true nature of the ferment, knowledge of the fermentation parameters was relatively well managed. In a 15th century beer recipe (Ms. 697, fols. 72-84, Library of the University of Ghent) the use of *heve* (yeast floating on the surface) and *onderghist* (flocculated yeast) is already being mentioned. These different types of yeast are first being tempered in *werse* (wort) and only then the inoculated yeast is casked and mixed with the chilled grain mash. The chilling continues until *bloet leau* (body temperature). The fermentation process (*liggen heffen*) takes three days.[10]

In the first Dutch bee book *Van de byen, hare wonderlicke oorspronc, natuer, eygenschap, crachtige, ongehoorde ende seltsame wercken* two recipes to make mead can be found.[38] The bee book, first published in 1597 by Jan Claesz. in Leyden, was written by Theodorus Clutius (1550-1598) in the form of a dialogue with the famous botanist Carolus Clusius (1526-1609) from the French Flemish town of Atrecht (present-day Arras). In 1593 the board of governors of the university of Leyden entrusted Clusius with the planning of the *Universiteyts Kruyt-Hof*. Clusius was not very mobile so he had Theodorus Clutius (Dirk Outgaerz Cluyt), who was a pharmacist in Delft, assist him. Their mead recipes show that they had a profound knowledge of the fermentation parameters. For example 90 parts of white honey are boiled down and skimmed off with 10 parts of clean river water. This result in a triple effect: the mead must becomes sterile, the sugar concentration rises and the proteins solidify. The sterilisation of the must does not only prevent flavour deviations following infections, but together with the increased sugar concentration it leads to an increased alcohol formation. Skimming of the coagulated proteins prevents the yeast from getting foul and results in a clear mead. The choice of white honey is remarkable: we know now that honey contains less proteins and hence produces less turbidity. Boiling down the mead must to the density desired is being checked with an egg: as soon as the egg starts to float the boiling process is stopped. After being chilled the mead must is put in a drum and it is mixed with brewer's yeast. The drum has to be full at all times, so it must be refilled in order to allow the yeast to remove all non-soluble substances, which improves the clarity and taste of the mead. After the primary fermentation process the drum is closed causing an anaerobic maturing, so excluding an acidification by acetic acid bacteria.

In the 16th and 17th centuries the iatrochemists advocated the use of *spiritus vini* for making medicinal tinctures and extracts. The most important representatives are Paracelsus (1493-1541), Joan Baptista van Helmont (1579-1644) and Franciscus de le Boë, Sylvius (1614-1672).
Paracelsus joins the alchemists and writes his *Paragranum* in 1530: "the alchemist proceeds like a baker making bread with flour and leaven". Paracelsus is the first to call *spiritus vini* alcohol, a term which will be largely introduced by Herman Boerhaave (1688-1738).
Joan Baptista van Helmont broadens the term *fermentatio*. According to this Flemish scholar from Vilvoorde fermentation (*fermentatio*), digestion (*digestio*) and putrefaction (*putrefactio*) are similar phenomena. In his *Dageraad ofte Nieuwe Opkomst der Geneeskonst*, published in 1660 by his son, van Helmont argues that every change needs a specific ferment (*heve*).[26] During these change warmth is released. It is not the heat that activates the ferment like Libavius (1540-1616) argues, but it is the *drift des zaets* (passion of seed). This seed or *semen* gives it specificity to each body. During the fermentation process van Helmont finds a *siedende bobbelinghe* (seething bubbles), a *windt* (wind) that he can see and hear. Above the bung of a drum filled with fermenting wine must he collocates the head of an alembic. Much to his surprise he notices that this "wind" cannot be condensed and therefore it cannot be a wine ghost. He compares this what he calls *bobbelinghe* with the effect of acids on rock, a process during which *windt* is also released. The same winds which he calls gas, also appear in the human abdomen and in Spa water and are being formed when burning wood (a century later the Scot Mac Bride will show this gas to be carbon dioxide).

The French Fleming Franciscus de le Boë, Sylvius, professor at the university of Leyden, does not quite agree with van Helmont. For instance, in his book *Opera medica* (Geneva, 1698) Sylvius makes a clear distinction between the phenomenon of releasing gas when an acid is affecting limestone and the phenomenon of fermentation. He calls the first phenomenon *effervescentia* or effervescence. It goes together with the origin of a new compound. This is not the case with *fermentatio* or the fermentation which resembles more a disintegration.[56]

Antoni van Leeuwenhoek (1632-1723) was the first to see living yeast cells.[57] This cloth trader from the Dutch town of Delft was familiar with the use of lenses to check the quality of cloth. He developed a technique to polish lenses and with these he built little single microscopes. With some of them he accomplished to magnify 500 times. In 1680 he looks at yeast cells from wine and beer and he draws them as congealed bulbs. He does not consider them to be alive (but he does view bacteria as such) but as congealed bulbs originating from elements used in the preparation of wine and beer. The yeast cells isolated from beer seem bigger to him than those from wine or syrups he had been given by a pharmacist from Delft.

According to the English physician Thomas Willis (1621-1675), professor at Oxford university, a ferment is an element which transfers its inner movement onto other fermentable elements. The German physician and chemist Georg Ernest Stahl (1660-1734), professor at the University of Halle, shared this opinion. In his work *Zymotechnia fundamentalis* (1697) he states that the fermentation process is a kind of reaction during which the ferment collides with fermentable elements. This produces larger elements to be broken down into smaller, ever more stabile elements. This mechanical fermentation theory was advocated by many, partly because of the enormous prestige Stahl enjoyed. For he was the inventor of the phlogiston theory which stated that elements release a substance, phlogiston, when being burned (oxidation). The influential professor from Leyden, Hermann Boerhaave (1668-1738) also advocated this mechanical fermentation theory.

The French chemist Antoine Lavoisier (1743-1794) destroyed both Stahl's phlogiston theory and his fermentation theory.[58] On the basis of weight determinations he concluded that sugar is half transformed into alcohol and half into carbon dioxide during the fermentation process. He saw sugar as an oxide (*oxide végétal*). During the fermentation process of the sugar a part of the oxygen would compound with a part of the carbon forming carbon dioxide. With hydrogen and oxygen the rest of the carbon would produce alcohol. In 1815 French chemist Joseph Gay-Lussac (1770-1850) formulated these ideas in an equation:

$$C_{12}H_{24}O_{12} = 4\ CO_2 + 4\ C_2H_5OH$$

In 1828 his fellow countryman J.B. Dumas (1800-1884) argued that this was not a matter of sucrose (wrongly written like $C_{12}H_{24}O_{12}$ by Gay-Lussac) but one of glucose. He corrected this equation into:

$$C_6H_{12}O_6 = 2\ CO_2 + 2\ C_2H_5OH$$

The Austrian Christian Erxleven was the first to state that yeast is a living organism in 1818. More or less two decades later this statement is agreed with by the Frenchman Charles Cagniard Latour (1777-1859) and in 1837 the Germans Theodor Schwann (1810-1882) and Friedrich Kützing (1807-1893). Among these three Schwann excelled because his vitalistic fermentation theory relied on tests. Moreover he had quite a status because of the discovery of animal and plant cells about which he declared that the cell was the smallest unit of a living organism. Schwann demonstrated that boiled, sugar containing liquids started to ferment when they were being exposed to air. Furthermore he found that air looses its fermentation ability when it is being heated in a flame or washed in concentrated sulphuric acid. Following these tests he concluded that fermentation is not caused by oxygen but rather by a living organism that can be destroyed by heat or concentrated acids. He called this organism *Zückerpilz or Saccharomyces*. Kützing, who did his research on acetic acid bacteria, concluded with analogue findings.[56]

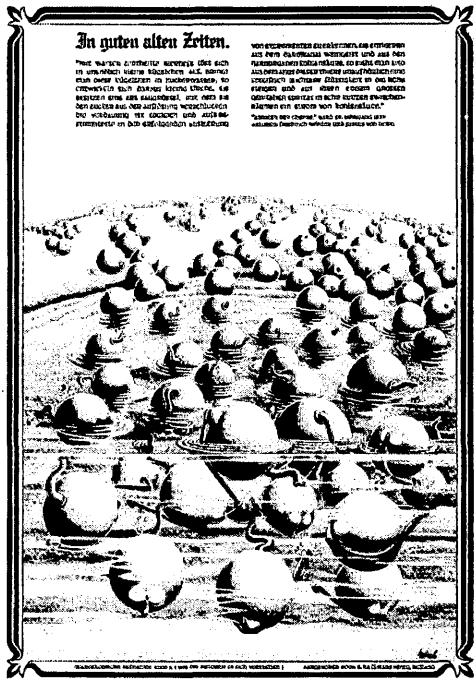


Fig. 14
Cartoon representing "living" yeast cells, F. Wöhler and J. von Liebig, 1839.
In : Annalen der Chemie 29 (1839)

This vitalistic fermentation theory was strongly opposed by J.J. Berzelius (1779-1848), Friedrich Wöhler (1800-1882) and Justus von Liebig (1803-1873). These men were far from unimportant: in 1813 the Swedish professor Berzelius introduced the modern chemistry notation system. In 1828 the German professor Wöhler succeeded in synthesising urea and in doing so he laid the foundation of organic chemistry. His friend and fellow countryman von Liebig, professor at the university of Giessen is being regarded as one of the greatest chemists ever.

In 1839 Wöhler and Liebig published a cartoon (fig. 14) representing yeast cells as small, globular creatures. They had a little trunk to suck up sugar, an anus to discharge alcohol and genitalia to secrete carbon dioxide...[59]
Berzelius stated in 1839 that yeast was a lifeless, organic catalyst and Von Liebig shared this opinion. Both were familiar with the work of A.P. Dubrunfaut, a distiller from Lille, who wrote in 1824 how gluten, a nitrogen containing element in germinating grain, was able to break down quickly and entirely starch into fermentable sugars (in 1833 Payen and Persoz will demonstrate that gluten contains a diastase, able to liquefy and saccharify starch).[60] Dubrunfaut observed that the gluten worked best at a temperature of 62,5 °C and that the activity decreased when temperatures increased and finally it disappeared at 75 °C. Therefore he stimulated the use of a thermometer and he checked the efficiency of the saccharification with iodine: starch gives a blue colour with iodine. When the starch decomposition is finished the red-brown colour of iodine is recovered.
Berzelius' chemical fermentation theory also relied on the analogy between the fermentative conversion from alcohol into acetic acid and the catalytic oxidation of alcohol into acetic acid in the presence of colloidal platinum. According to Von Liebig the conversion of sugar into alcohol and carbon dioxide is catalysed by a nitrogen containing element. The speed at which it happens is influenced by temperature, degree of acidity and the presence or absence of inhibitory factors like heavy metals.

In 1857 the Frenchman Louis Pasteur (1822-1895) joins the vitalistic fermentation theory of Schwann.[61] This happened after being asked by a distiller from Lille, Bigo, father of one of his students, to study a fermentation of molasses that had got out of hand. For several weeks Pasteur took different samples in Bigo's distillery and he analysed these in his laboratory (fig. 15).

He demonstrated that in fermentations that had gone wrong not only alcohol had been formed, but also lactic acid, something that did not happen with healthy fermentations. Under the microscope he also found that in bad fermentations besides spherical-shaped yeast, many smaller rod-shaped and other globular ferments could be seen. By adjusting the composition of sugar solutions Pasteur managed to direct the fermentations in the right

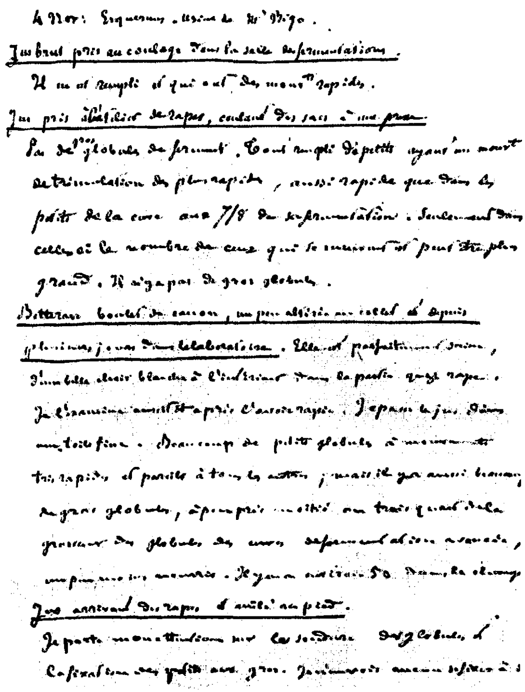


Fig. 15
Notes of Louis Pasteur in the distillery Bigo,
Esquermes (Lille), 1856, November 4.
Collection Pasteur Vallery-Radot.

direction. For instance, he proved that yeast cells develop easier in acid sugar solutions, while lactic acid ferments develop easier in neutral sugar solutions. Besides that, Pasteur also found that apart from alcohol and carbon dioxide an equal amount of glycerol and succinic acid is formed and that yeast cells absorb ammonium salts from the fermentation liquid. ANALOGUE testing led to the proposition that every fermentation process is triggered by a specific living organism and that every micro-organism needs a specific nutrient for it. Pasteur also looked for the causes for infections occurring during the fermentation process. He proved that the air contains a lot of micro-organisms. To do this he sucked air through a sterile filter of cotton and then he added this contaminated filter to a sterile infusion. This resulted in the development of micro-organisms, something which did not happen when the aspirated air was heated first. Sterile infusions could be kept in open glass recipients indefinitely if only the long neck was sufficiently bent downwards (U-trap) so the air, but not the germs could end up in the infusion. With these tests Pasteur managed to enfeeble the theory of generatio spontanea that claimed germs could spontaneously be generated from non-life matter. During his research on butyric acid fermentation in 1876 Pasteur discovered the existence of micro-organisms which were only able to stay alive in absence of oxygen: *la vie sans air*. Pasteur thought that these anaerobic micro-organisms got their oxygen and energy from the degradation of organic matter. Some micro-organisms, the so-called facultative anaerobic, dispose of two energy supplying mechanisms. Pasteur demonstrated that yeast is inclined to form alcohol in an environment lacking oxygen, while in an environment filled with oxygen it is more likely to focus on multiplying (the Pasteur effect). These new insights in the fermentation process led to practical applications which Pasteur disclosed in his *Etudes sur le vin* (1866) *and Etudes sur la bière* (1876).

The study of yeast and fermentation was accelerated in 1879 when the Danish researcher Emil Hansen completed a method to breed pure yeast cultures and in 1897 when the German chemist Eduard Buchner isolated the first yeast-free ferment, the zymase.[62]

Emil Hansen was tied to the laboratory of the Carlsberg brewery in Copenhagen. In the same laboratory worked also Kjeldahl who was the first who knew how to dose a protein. Hansen developed a special slide with cavitations and using this he succeeded in isolating one single yeast cell out of a mixture of yeast cells under the microscope. Afterwards he cultivated the desired amount of these yeast cell. This technique had many advantages: from now on it was possible to work with any type of yeast like with a chemical reagent, hence enabling the registration of its specific chemical, cytological and morphological characteristics. For instance, specific colourings would indicate cell parts like the cell wall, the cell nucleus, the mitochondria, the vacuole, glycogen kernels and oil drops. It is observed that the cell's look (thickness cell wall, size of the vacuole, presence of glycogen kernels...) can be influenced by nutrition (both a lack and a surplus thereof), temperature and oxygen. This can explain the pleomorphism of some types of yeast. One demonstrates that the cell nucleus mainly consists of chromatine parts which causes the multiplication and caries the hereditary characteristics. It is observed that yeast does not only procreate asexually through budding, but also through sexual spores. Through fermentation and assimilation tests the system of the fermentation process is implemented. This scientific knowledge is being directly applied in breweries and later on also in yeast and spirit factories. Progressive brewers check their fermentation culture on cleanliness and viability. The determination of the fermentation rate and the fermentation degree is being introduced.

The isolation of the fermentation enzymes out of the living yeast cells was a mere coincidence. In 1897 E. Buchner (1860-1917) was studying the medicinal effect of yeast proteins. He washed the yeast with water, added sand and kieselguhr, crushed the cell membranes and finally he squeezed the moist mass under high pressure. The liquid obtained resulted to be very subject to putrefaction. Bearing in mind the fact that fruit could be conserved by adding sugar, Buchner added a certain amount of sugar to the juice. Much to his amazement this sugar began to ferment. Buchner concluded that the fermentation had been caused by fermentation enzymes which he called zymase. The fermentation ability of the juice varied strongly, which was brought about partly by the amount of enzymes in the yeast used, partly by the lability of the free zymase. Zymase was not a secretory product of the yeast, but appeared within the yeast cell and its composition seemed to be strongly connected with the yeast cell's growth. Furthermore, the fermentation activity seemed to be connected with the yeast cell's metabolism and energy management. By discovering the zymase, Buchner reconciled Pasteur's vitalistic fermentation theory and von Liebig's chemical fermentation theory: fermentation demands a living organism (Pasteur) that operates through a nitrogen containing catalyst (von Liebig).

The zymase discovery stimulated chemical research into alcoholic fermentation. Relatively soon was found that zymase was not only able to ferment glucose, but also fructose, mannose, sucrose and maltose. The research mainly focused on the degradation of glucose, a process that was also studied in mammalian muscles. Parallel with the study of anaerobe degradation of glycogen to lactic acid (glycolysis) ran the study of the change of glucose in alcohol and carbon dioxide. The results obtained from the study of alcoholic fermentation contributed to the solution of the problems encountered when studying glycolysis and vice versa. The study of glycolysis and alcoholic fermentation was done between 1900 and 1950. Many known researchers were involved in this study: for instance A. Harden, W.J. Young, C. Neuberg, H. Euler, G. Embden, O. Meyerhof, O. Warburg, K. Lohman, C. and G. Cori and J. Parnas.[62,63]

In 1905 the British researchers Harden and Young did a dialysis of the cell free fermentation juice on parchment. They concluded that the dialysed juice and the dialyse water were not able to trigger fermentation of the glucose separately, but they did so when jointly used. The non-dialysable component (the protein or enzyme complex) was heat sensitive, the dialysable component (the co-enzyme) was not. (In 1933 H. Euler identified the co-enzyme as being nicotinamide adenine dinucleotide or NAD^+). Harden and Young found that apart from the enzyme complex and the co-enzyme fermentation also needed phosphates. They demonstrated that CO_2 production from glucose starts very rapidly, but that it suddenly slows down unless an inorganic phosphate is added. They detected a disappearance of the added phosphate during the fermentation when they were unable to precipitate it with uranium acetate. They concluded that the inorganic phosphate is converted into organic phosphate and succeeded in isolating a hexose diphosphate. In 1913 Embden proved this to be the fructose-1,6-diphosphate. (Later on Robinson isolated the glucose-6-phosphate and Neuberg the fructose-6-phosphate). Harden and Young proposed the following correction of the Gay-Lussac and Dumas equation:

$$2\ C_6H_{12}O_6 + 2\ H_3PO_4 = 2\ CO_2 + 2\ C_2H_5OH + 2\ H_2O + C_6H_{10}O_4(PO_4H_2)_2$$

When the alcoholic fermentation was coming to an end, the phosphate was released again under the influence of a phosphatase, which indicated that the phosphate was part of a continuous cycle.

Progress in organic chemistry made it possible to isolate and identify other fermentation products. Some researchers argued that the transformation of glucose in alcohol and carbon dioxide happened through lactic acid which would be changed into formic acid and acetaldehyde. Consequently the formic acid would disintegrate in carbon dioxide and hydrogen and this would reduce the acetaldehyde to alcohol:

$$CH_3\text{-}CHOH\text{-}COOH = CH_3\text{-}CHO + H\text{-}COOH$$

$$H\text{-}COOH = CO_2 + H_2$$

$$CH_3\text{-}CHO + H_2 = CH_3\text{-}CH_2OH$$

However, Harden and Young rejected this point of view because they were unable to show the presence of any lactic acid in alcoholic fermentations. In 1907 Wohl stated that glucose, by dehydration, was changed into a "hypothetical molecule" which then disintegrated in glyceraldehyde and methyl-glyoxal:

$$CH_2OH\text{-}CHOH\text{-}CHOH\text{-}CHOH\text{-}CHOH\text{-}CHO = H_2O + CH_2OH\text{-}CHOH\text{-}CHOH\text{-}CH_2\text{-}CO\text{-}CHO$$

$$CH_2OH\text{-}CHOH\text{-}CHOH\text{-}CH_2\text{-}CO\text{-}CHO = CH_2OH\text{-}CHOH\text{-}CHO + CH_3\text{-}CO\text{-}CHO$$

In 1907 P. Mayer contested this hypothesis because methylglyoxal could not be proved and was not fermentable. In 1910 E. Buchner and O. Meisenheimer proved that glyceraldehyde was fermentable and that is was easily transformable into its fermentable isomer ketose, the dihydroxyacetone. A. von Ledebew said in 1911 that the glyceraldehyde and the dihydroxyacetone before being fermented, were phosphorylated. Also in 1911 C. Neuberg was able to determine the presence of pyruvic acid (pyruvate). Under the influence of an enzyme he called carboxylase, the pyruvic acid is transformed into acetaldehyde and carbon dioxide. The acetaldehyde is then with hydrogen reduced to alcohol using a reductase:

$$CH_3\text{-}CO\text{-}COOH = CH_3\text{-}CHO + CO_2$$

$$CH_3\text{-}CHO + H_2 = CH_3\text{-}CH_2OH$$

In 1911 C. Neuberg formulated a scheme of the glucose disintegration putting forward methylglyoxal and pyruvic acid as the central components of the fermentation (fig. 16). In 1913 G. Embden argued that the fructose-1,6-diphosphate was changed into two triose phoshates, viz. the dihydroxy-acetone phosphate and the D-glyceraldehyde-3-phosphate. In 1927 O. Meyerhof demonstrated that glucose was transformed in the presence of adenosine triphosphate (ATP) and a hexokinase into glucose-6-phosphate. Early 1930 several researchers found that adding fluoride to the fermentation fluid led to an accumulation of 2-phosphoglycerate and 3-phosphoglycerate. Furthermore, the concentration of fructose-1,6-diphosphate was raised because of an addition of iodoacetate. In 1932 L. Fischer succeeded in synthesising the D-glyceraldehyde-3-phosphate and proving its fermentability. This research data allowed G. Embden and O. Meyerhof to compose their Embden-Meyerhof cycle in 1933. Although the individual steps were known, the research was continued. In 1935 H. Euler and O. Warburg demonstrated that nicotinamide adenine dinuleotide (NAD^+) played a role in the transformation of D-glyceraldehyde-3-phosphate into 1,3-diphospho-D-glycerate. The same O. Warburg proved in 1937 that ATP was formed when transforming 1,3-diphospho-D-glycerate into 3-phospho-D-glycerate and phospho-enol-pyruvate into pyruvate. This meant that the energy released when changing glucose into alcohol and carbon dioxide was partly released in warmth and was partly stored in the form of ATP. Also in 1937 K. Lohmann and P. Schuster declared that the heat stable thiamine played a role in the decarboxylation of pyruvate to acetaldehyde and carbon dioxide. Negelein and Bromel isolated the labile 1,3-diphospho-D-glycerate in 1939. This allowed the statement that by 1940 the Embden-Meyerhof cycle was entirely known.

The formation of the higher alcohols (fusel alcohols) was studied in 1905 by F. Ehrlich. Yeast forms these higher alcohols out of amino acids in accordance with:

$$R\text{-}CH(NH_2)\text{-}COOH + H_2O \Rightarrow R\text{-}CH_2OH + CO_2 + NH_3$$

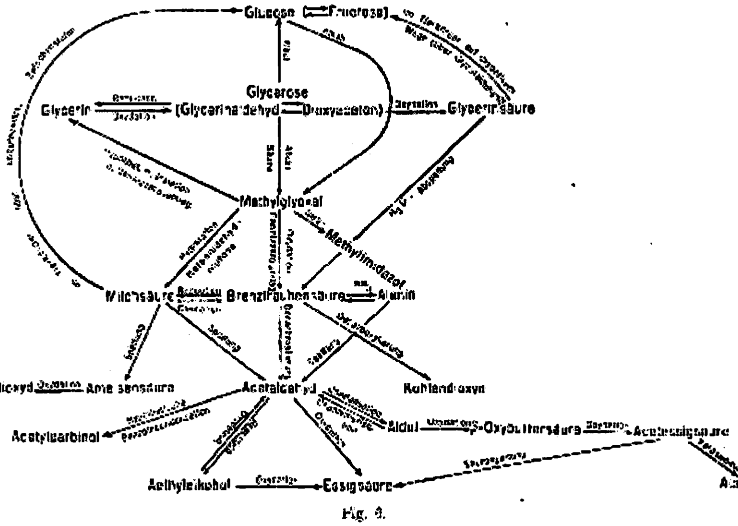


Fig. 16
The C. Neuberg scheme of the glucose fermentation, 1911.
In: H. Euler & P. Lindner, *Chemie der Hefe und der alkoholischen Gärung*, Leipzig, 1915.

So leucine results in iso amyl alcohol, isoleucine gives the optic active amyl alcohol and valine gives isobutanol. These kinds of alcohol can be oxidised to acids which will form fats when combined with glycerol. Thus Ehrlich demonstrated already in 1905 the connection between carbohydrate, protein and fat metabolism.[62]

Up to this day yeast (or is it because of the alcohol?) is still a favourite subject of many researchers. So it is no mere coincidence that *Saccharomyces cerevisiae* was one of the first micro-organisms of which the entire genetic information was listed. The complete DNA sequence of this yeast was deciphered in an international project. On one of the sites of the Max-Planck-Gesellschaft many results are summarised .(http://speedy.mips.biochem.mpg.de/mips/yeast/).

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LAUDATIO PETER KOOLMEES

Jan Van Hoof

Sarton Medalist Petrus KOOLMEES was born in Gouda in the Netherlands on March 26, 1954. After his secondary studies at the St. Antoniuscollege in Gouda, he was employed for a short time (1971-1973) - and at very young age - as a chemical laboratory assistant in industry.

He very soon displayed an interest in the university work environment and in 1973 was employed in the Department of General Medicine and Large Animal Surgery in the Faculty of Veterinary Medicine of the University of Utrecht. In the meantime he continued his studies and in 1977 was awarded the 'MBO' (Intermediate Vocational Education) degree in Bionics and in 1979 the 'MBO' degree in Histology at the Gijsen Institute in Utrecht. After his transfer to the Department of Veterinary Food Sciences ('VVDO') in the same faculty, this training enabled him to take on the position of histological analyst (1975-1986).

From 1986 to 1990 he was first a technical assistant and then head technician, and since 1990 he has been a researcher and project leader in the same department. During this period he resumed his studies, this time, however, turning his interests to a totally different discipline: history. In 1989 he obtained the Secondary School Teaching Certificate in History (1st level) from the *Hogeschool Midden Nederland* in Utrecht and a degree in History from the Faculty of Arts and Sciences of the University of Utrecht, specializing in economic and social history.

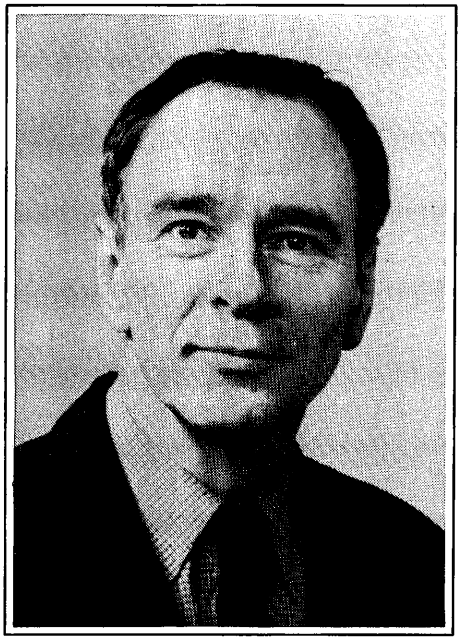
Under the direction of his promoters, Prof. Jan van Logtesti.jn, former Chairman of the Department of Veterinary Food Sciences, and Prof. J. van Zanden of the Department of History in the Faculty of Arts and Sciences at the University of Utrecht, he undertook an extensive study of the origin and development of the (chiefly municipal) slaughterhouses and of meat inspection. His special interest for this field first took form in the publication in 1991 of his book *Vleeskeuring en Openbare Slachthuizen in Nederland*

1875-1985 ("Meat Inspection and Public Slaughterhouses in the Netherlands, 1875-1985").
This research also led to Petrus Koolmees being awarded a doctorate by the University of Utrecht after defending his dissertation entitled *Symbolen van Openbare Hygiëne* ("Symbols of Public Hygiene") on March 6, 1997.

Dr. Koolmees is the author and co-author of numerous scientific publications, not only in the field of the history of veterinary public health, but also in the field of the hygiene, histology and technology of meat and meat products. Besides his scientific responsibilities in the Faculty of Veterinary Medicine, Dr. Koolmees is also a member of the Board of the Dutch Veterinary Historical Society. In addition, he is a member of the editorial staff of *Argos*, the bulletin of the Veterinary Historical Society and an active member of the Board of Curators of the University Museum in Utrecht.
He is a member of the World Association for History of Veterinary Medicine, from 1988 onwards. In 1998 he became board member and president-elect of this association.

Our faculty has made an unusually fortunate choice with the nomination of Dr. Koolmees as a Sarton medalist. Not only does Dr. Koolmees totally fit the profile established by the Sarton Committee in awarding the medals, but he is also living proof that with dedication and perseverance the saying still holds that "the sky is the limit".

At the same time, the scientific work of Dr. Koolmees fully illustrates the fact that our knowledge of the past is an important tool in evaluating the present and orienting ourselves toward the future.



THE DEVELOPMENT OF VETERINARY PUBLIC HEALTH IN WESTERN EUROPE, 1850-1940

Peter Koolmees

Introduction

Many aspects of public hygiene that are enjoyed today were developed during the course of the nineteenth century. Sanitary measures, such as waterworks, sewerage, garbage disposal, and food inspection, that are more or less taken for granted in the western world, are often virtually unknown in many underdeveloped countries. This is one of the reasons why the origin and development of public health services is an important theme in general history. During the past few decades, an international network has developed that consists of many historians, sociologists and physicians who have studied various aspects of public health care in the past (Goudsblom, 1986; Labisch 1998; Porter, 1994; De Swaan, 1988). Within this well-established discipline, attention to issues of veterinary public health has thus far remained rather limited, in spite of the fact that there is a considerable overlap between the public health care provided by physicians and veterinarians. This is particularly true with respect to zoonoses and the quality control of food of animal origin. Much attention has been paid to the role of physicians and chemists in safeguarding food quality and hence in improving public health (Hanssen & Wendt, 1965; Hutt & Hutt, 1984). The contribution made by veterinarians to food quality control is, however, often underestimated (Rosser, 1991).

The history of veterinary public health has predominantly been recorded by veterinarians. Pioneers in the field, such as Schwabe (1984) and Steele (1978), have described developments from antiquity onwards, whereas Grossklaus (1991) and Schönherr (1990) have studied scientific and technical progress in veterinary public health throughout the last century. These studies mainly deal with the recognition of animal disease problems as they have affected public health, and with the establishment of national and international organisations. They pay little attention to the development of meat hygiene and the related social and economic factors.

In essence, a modern society cannot function properly without a well-developed veterinary infrastucture, within which the production and supply of safe foods of animal origin is one of the main tasks. This infrastructure, as we know it today, is usually taken for granted by society; public attention generally only focuses on it in the event of food poisoning scandals. The availability and supply of safe and sound foods, such as dairy products and meat, as a matter of course has only been established through a slow and laborious process. What are the main elements that constitute this veterinary infrastructure? The oldest and most important ones are veterinary state supervision, state veterinary services and laws pertaining to cattle disease and zoonoses control. These measures gave veterinarians important responsibilities for maintaining animal health and helping to maintain livestock production. A second important element is the extensive network of practitioners who supply primary veterinary care. Further to these elements, the veterinary infrastructure requires well-organised professional associations and literature, research institutes, legal protection of the profession and institutionalised education. Finally, all veterinary tasks involving food hygiene, such as scientifically and legally based meat inspection, should be mentioned. Before veterinarians were able to carry out these tasks and the responsibility for these tasks were entrusted to veterinarians, both the process of professionalisation and the scientific progress of veterinary medicine was necessary (Fisher, 1997; Swabe, 1997).

In order to obtain a greater insight into the way in which modern meat hygiene developed in Western Europe, particularly in the Low Countries, during the period between 1850 and 1940, this paper will focus on two issues. Firstly, it will explore which social groups played a significant role in the process of instituting the sanitary reform of the municipal meat supply by establishing mandatory meat inspection by expert veterinarians and developing public slaughterhouses. Secondly, it will examine the role of the local and national authorities. How did the authorities direct their policy between the economic interests of meat producers and butchers on the one hand and the care for the urban environment and protection of consumer's health on the other? Theoretically, these questions concerning the development of meat hygiene cohere with the broader problem of the modernisation of society, the formation of the modern welfare states (Ashford, 1988; Porter, 1994), and of collective sanitary provisions and the so-called 'civilising offensive' (Goudsblom, 1986; De Swaan, 1988). This offensive was initiated and guided by the elite and was aimed at bringing lower social groups to a higher cultural level and promoting the civic spirit. It is interesting to examine the extent to which meat hygiene played a role in the civilising offensive. Firstly, a review of the social-economic and ideological context of the meat supply during the period 1850-1940 will be given. On the basis of this, the increasing need to involve mandatory meat inspection and public abattoirs in the meat supply chain can be explained.

Meat consumption

From the middle of the nineteenth century onwards, there was a gradual transition from a traditional rural society to a modern welfare state. This process of modernisation was accompanied by characteristic changes including strong population growth, urbanisation, economic growth, industrialisation and a gradual rise in the standard of living. These changes caused a shift in the food consumption pattern, among others an increase in meat consumption. This was particularly the case in industrialised countries like Great Britain, France, Belgium and Germany, where the situation of the working class improved. The British market was crucial to meat exporters, and the removal of custom barriers after 1842 provided a powerful incentive for potential suppliers. Due to extensive livestock farming, new transport possibilities and innovations in cooling and freezing technology, meat exports from sparsely populated countries, such as Argentina, the USA, New Zealand and Australia to Europe, increased. A large-scale international meat trade consequently developed (Diederiks et al., 1994; Perren, 1978). Within Europe, coutries like Denmark and the Netherlands specialised in dairy and meat exports. As a result of increasing domestic demand for meat and ample opportunities for meat and meat product exports, cattle breeding and meat production in the Netherlands expanded from 1870 onwards. This was realised by intensive livestock farming based on the use of fertilisers, increased animal feed production, developments in cattle breeding, the organised struggle against animal diseases and improved veterinary care.

Akin to the more industrialised neighbouring countries, a quantitative and qualitative improvement in diet occurred in the Netherlands and the democratisation of meat consumption gradually began. In this sense, democratisation means that meat was no longer an exclusive food for the rich, but that sufficient meat and more different kinds of meat were consumed by the majority of the population (Den Hartog, 1980). Between 1850 and 1930, the annual per capita meat consumption in the Netherlands increased from 27 to 50 kg. Beef consumption doubled between 1850 and 1900; from then on pork became the main constituent of the total meat consumption. In the course of the nineteenth century, increased scientific knowledge of the chemical composition of food and the need for different nutrients became available. Food of animal origin was considered more nutritious than vegetable foods. Meat and bread were beleived to be the main components of a healthy diet. In the second half of the nineteenth century, food scientists stated that 90 kg of meat per year was the minimum quantity to guarantee optimum nutrition; this was the amount included in soldiers' diets. From 1918 onwards, less emphasis was placed on meat consumption and a more varied diet was advised under the maxim of 'a little bit of everything, but not too much of anything'. The recommended amount of meat dropped from 90 to 45 kg annually.

It is interesting to see the kind of ideas that existed about the relationship between health, welfare and meat consumption between 1850 and World War I. In 1847, the Dutch chemist Gerrit Jan Mulder pointed out that the lack of proteins of animal origin in the one-sided diet of the working class and poor resulted in a bad health and a lack of physical strength. The physician E.C. Büchner stated that a population deprived of meat would become weak and hence, produce moderate labour and soldiers. In England, the level of meat consumption remained high throughout the entire nineteenth century. This was noticed with envy by other European countries. The seemingly effortless manner in which Great Britain created its enormous Indian Empire was contributed to the high meat consumption of the British and the vegetarian diet of the Indians. Due to their consumption of meat, the Englishmen were thought to have more physical power, endurance and intelligence. In his well-known handbook on meat inspection, Robert von Ostertag also stressed the importance of meat in the diet to maintain productivity. He cited sources that stated that the weakness, low industriousness and effeminacy of men from Southern

Italy were related to their very low level of meat consumption. Although less extreme, these ideas still persisted during the period 1900-1940. (Fig. 1)

Fig. 1
Advertisement from the 1930's to promote meat consumption (De Vee- en Vleeshandel 51, 1966, 306)

For instance, it was argued that European nations with the highest meat consumption had not only generated the most successful colonists, but had also produced the most technological innovations. The future thus belonged to the meat eating nations. (Brouwer, 1946; Büchner, 1855; Koller, 1941; Von Ostertag, 1899).

Meat supply

Such notions provide an explanation for why not only food scientists, physicians and veterinarians, but also politicians, economists and military attached great importance to a high level of meat consumption. This would promote physical and mental health, thereby positively affecting productivity. Consequently, societal authorities insisted on more meat being included in the diet. A prerequisite to this was improvements in both the quantity and the quality of meat. A review of the meat supply reveals that the soundness of meat, particularly cheap meat that was usually consumed by the working class people, left much to be desired. Before the emergence of urban societies with cattle and meat markets, consumers provided themselves with meat. In the countryside, home slaughtering remained common until well into the twentieth century, when refrigeration was introduced into households. In most cities, animals were slaughtered by butchers in small, privately owned butcheries. From the late Middle Ages, the slaughtering, selling and inspection of meat was regulated by butcher guilds and the local authorities. After the French Revolution the guilds were abolished, and local meat inspection and meat trade regulations were disregarded. From around 1870 onwards, population growth and urbanisation went hand in hand with an expanded network of these small butcheries, where slaughtering often took place under poor hygienic conditions. The city Utrecht, for instance, with a population of about 100,000 in 1890, had 144 registered private butcheries and 370 'shops' where meat was sold, and a market for cheap meat and sausages. In addition, meat from knackers' yards was marketed or processed into pies and sausages and sold to labourers and the poor. Often this involved meat from animals infected with anthrax, tuberculosis, trichinosis and tape-worms, as well as meat from animals that had died. A mere four inspectors were appointed to carry out meat inspection (Koolmees, 1997).

It is clear that under these circumstances consumers were left almost unprotected from fraud and the adulteration of meat and meat products, and the calamities that followed, were almost inevitable. This was even more the case since the chain between producers and consumers became longer, more complicated and extended beyond the reach of the eye by the development of a large-scale international meat trade and meat industry.

Poor hygienic conditions characterised meat and sausage processing due to a lack of hygiene awareness. Furthermore, a major impediment to the re-introduction of meat inspection was that veterinary research findings initially supported the conviction that meat from diseased animals was not harmful to humans. The increasing amount of butcheries represented a nuisance for the citizens. The transport and slaughtering of animals, as well as the storage and transport of offal within the city walls, deteriorated the urban environment. From 1850 onwards, numerous outbreaks of trichinosis and meat poisonings occurred, infecting hundreds and killing dozens of people. Consequently, local and national authorities were increasingly confronted not only with complaints about the filth and problems that butcheries caused in the urban centres, but also about the poor quality of the meat offered (Van Daalen, 1987; Poulussen, 1987). The mass outbreaks of meat-borne diseases alarmed the authorities and clearly demonstrated the need for meat hygiene control. From 1850 onwards, governments in Western Europe were more or less forced to pay more attention to a public health policy related to the meat supply.

The role of hygienists

Improvement of the urban environment and meat trade and meat inspection regulation became a regular issue in local and national politics. Increased meat production and consumption necessitated a large-scale supply of sound meat. However, radical measures with respect to organisation and hygiene were needed to accomplish this. A programme was available which contained the two key factors for effective meat inspection: mandatory inspection by professional veterinarians and centralised slaughtering in public abattoirs located on the outskirts of towns. Well before the 1860s, health boards had already come to this conclusion. In fact, at the end of the eighteenth century, the well-known Paris Council for Public Hygiene had drawn up such a programme, and mandatory meat inspection in public slaughterhouses had been recommended by both the French chemist Antoine Lavoisier and the German physician Johann Peter Frank. Inspired by the body of thoughts of the Enlightenment and the French Revolution, these scientists formulated comprehensive programmes for sanitary reform in order to improve public health. Realisation of such programmes would require active state interference for the general welfare by means of a centralised bureaucracy. These ideas of the French hygienists were published among others in the Encyclopédie méthodique and spread rapidly among the bourgoisie. The local and national health boards that were established in France around 1800, and in which the bourgoisie was well represented, tried to realise public health programmes (Fowler la Berge, 1975; Moreau, 1916).

Following the French example, health boards were established in most larger towns in Belgium from 1848, and in the Netherlands from 1854 onwards. Within these boards the so-called hygienists, a group of progressive physicians, engineers, physicists, chemists, lawyers, veterinarians, and civil servants, played a predominant role. Their great accomplishment was to turn public health into a political issue. From the middle of the nineteenth century onwards, the hygienists wanted to improve the poor social conditions of a large part of the population. They tried to realise this by means of professionalisation and a scientific approach to public health care. Local and national health boards served as their forum. The spread of hygienic awareness led to a change in the attitude of local and central authorities who gradually took more trouble to improve public hygiene (Houwaart, 1991). Due to their knowledge in the field of food hygiene, veterinarians participated in these health board from the outset. Together with physicians, veterinarians, as a new group of professionals, contributed significantly to the creation of the social infrastructure in the field of public health (Koolmees, 1997).

Veterinarians and meat hygiene

In the first half of the nineteenth century, there was essentially no scientifically-based meat inspection in Western Europe. Hardly any veterinarians were involved in meat inspection. The untrained meat inspectors that were appointed in the larger towns were entirely committed to empirical knowledge. From 1850 onwards, veterinarians involved in health boards advised on all matters concerning veterinary public health due to their specific knowledge of zoonoses and their ability and training in recognising diseased animals. They focussed on a scientifically and legally based form of meat inspection, research on meat poisonings, humane slaughtering methods, and regulations for the collection and destruction of waste from slaughterhouses and butcheries. However, physicians played a predominant role in these boards. In their view, veterinarians lacked scientific knowledge and were responsible for healthy livestock only. Therefore, the protection of the public health, including meat inspection, should remain in the competent hands of physicians. Initially, it was mainly physicians who wrote about the subject meat hygiene. Nevertheless, in various countries, a number of veterinarians started to publish on the subject, claiming this new field of professional activities for themselves. In their books and articles, these authors stressed the importance of veterinary medicine for society as a whole. They argued that it was important not only for a prosperous livestock industry, but also because of its value in safeguarding the healthy quality of foods of animal origin, and thus the workforce of the working class (Koolmees et al., 1999; Von Reeken, 1861). Sticker (1890-91) spoke for the veterinary profession when he argued that the theoretical aspects, as well as the practical execution, of meat inspection should be part and parcel of veterinary activities since the emergence of meat inspection had coincided with the emergence of veterinary medicine. According to him, it was veterinarians who extended the science of meat inspection, while the practical execution of meat inspection is equal to the pathological anatomy of animals. Finally, he argued that meat inspection should belong to the veterinary sphere because it supports animal disease control, also carried out by veterinarians. The efforts of veterinarians to gain veterinary public health as a new field were strongly supported by the different national veterinary medical associations. Such associations were established, for instance, in Denmark (1807), Switzerland (1813), the Netherlands (1862), Belgium (1864), Germany (1864), France (1879) and England (1883) (Grimm, 1968; Mammerickx, 1987). In the Netherlands, a comprehensive report on the (bad) state of meat inspection was published in 1894 by the Dutch Veterinary Medical Association. (Fig. 2)

The veterinary associations recognised the potential for job opportunities in meat inspection services and public slaughterhouses and a possible broadening of the legal basis of the veterinary profession. These claims, however, required a scientific basis of meat inspection.

DE KEURING VAN VEE EN VLEESCH
IN NEDERLAND.

RAPPORT

UITGEBRACHT DOOR

het Hoofdbestuur van de Maatschappij ter bevordering der
Veeartsenijkunde in Nederland

INHOUDENDE

**de resultaten van het onderzoek naar den
toestand der keuring van vee en
vleesch hier te lande.**

UTRECHT
J. L. BEIJERS
1894.

Fig. 2
Title page of the report on meat inspection in the Netherlands, published in 1894 by the Dutch Veterinary Medical Association.

After the foundation of veterinary schools at the end of the eighteenth century, veterinary science developed. In these schools research was conducted on questions related to the transmission of animal diseases by the consumption of meat from infected animals. Research findings soon showed that meat from animals infected with cattle plague posed no threat for human health. More and more cases where meat from diseased animals was consumed without any detriment to human health were described. This led to the one-sided conviction that all meat from animals suffering from different diseases was not harmful to humans. If only such meat was heated long enough, no danger could occur. Thus, research findings at veterinary schools initially led to a drawback in the care for a proper meat inspection.

The standing of meat inspection as a veterinary discipline increased, when the scientific backgrounds of several diseases related to meat consumption were discovered one after the other. Firstly, there were the findings in the field of parasitology. The cycle of tapeworms was discovered in the 1860s and, by incision, meat inspectors were able to conduct a preventive control. (Fig. 3) The occurence of parasites declined, especially where trichinella control was instituted. From 1880 onwards, meat hygiene research obtained a more scientific character and bacteriological meat research carried out in slaughterhouse laboratories ensued. (Fig. 4) The pioneering work of Louis Pasteur (1822-1895), Robert Koch (1843-1910) and others, such as Auguste Chauveau (1827-1917), Otto Bollinger (1843-1909), August Gärtner (1848-1934), Emile van Ermenghem (1851-1932), Daniel Salmon (1850-1914), Jan Poels (1851-1927), and their discoveries in the field of bacteriology, including the aetiology of meat poisonings, were decisive for the further development of meat inspection. Between 1890 and 1900, a number of meat-borne pathogens were isolated (Van Logtestijn et al., 1987; Mossel & Dijkmann, 1984; Von Ostertag, 1939). The veterinary and medical debate and disagreement over the 'germ-theory' and the precise aetiology of those diseases that were seen as a threat either to human or animal health lasted for decades. The major subject in this debate was bovine tuberculosis, of which the aetiology was a matter of scientific dispute until the 1920s (Romano, 1997; Worboys, 1992).

During the second half of the nineteenth century, the traditional empirical meat inspection was transformed into an applied veterinary science. Research findings were published in handbooks and professional literature, and theoretical and practical meat inspection became part of the veterinary curriculum. Special courses for veterinarians and training programmes for lay-inspectors were organised at veterinary schools and slaughterhouses. Some of the handbooks and guidelines used for education and inspection by veterinarians and lay-inspectors in the Low Countries are listed below.

Fig. 3
A Dutch meat inspector at work (G. R. Leighton & L. M. Douglas: The meat industry and meat inspection, Vol. 3, London 1910)

-Baillet, L., (1876). Traité de l'inspection des viandes de boucherie, considérée dans ses rapports avec la zootechnie, la médecine vétérinaire et l'hygiène publique. Asselin, Paris.
-Baránski, A., (1880). Praktische Anleitung zur Vieh- und Fleischschau: für Stadt- und Bezirksärzte, Thierärzte, Sanitätsbeamte, sowie besonders zum Gebrauche für Physikats-Candidaten. Urban & Schwarzenberg, Wien. In 1883 this book was translated into Dutch by F.C. Hekmeijer.

Fig. 4
Bacteriological meat research at the Amsterdam abattoir laboratory in 1900 by the director Dr. D. van der Sluijs and his assistant (Archives of the Department of the Science of Food of Animal Origin, Faculty of Veterinary Medicin, Utrecht University)

-Gerlach, A.C., (1875). Die Fleischkost des Menschen vom sanitären und marktpolizeilichen Standpunkte. Hirschwald, Berlin.
-Greuve, J.K. de, (1846). Handleiding voor landlieden, slagters en veehandelaars, bij het beoordeelen van den gezonden of ziektentoestand van het slagtvee, ter voorkoming van de nadeelige gevolgen, die het gebruik van ongezond vleesch en spek voor de menschelijke gezondheid hebben kan. M. Westerman & Zoon, Amsterdam. (Fig. 5)
-Harrevelt, H.G. van, (1905). Handleiding voor de vleeschkeuring. J.G. Broese, Utrecht.
-Hertsen, E. van, (1873). De l'inspection sanitaire des viandes de boucherie. H. Boissel, Rouen. (Fig. 6)
-Ostertag, R. von, (1892). Handbuch der Fleischbeschau für Tierärzte, Ärzte und Richter. Verlag F. Enke, Stuttgart. This book was reprinted many times

HANDLEIDING

VOOR

Landlieden, Slagters en Veehandelaars,

BIJ HET BEOORDEELEN VAN DEN GEZONDEN OF ZIEKTENTOESTAND

VAN HET

SLAGTVEE,

TER VOORKOMING

VAN DE NADEELIGE GEVOLGEN, DIE HET GEBRUIK
VAN ONGEZOND VLEESCH EN SPEK VOOR DE

MENSCHELIJKE GEZONDHEID

HEBBEN KAN.

DOOR

J. K. de Greuve,

Rijks-Veearts van de eerste Klasse, eersten rang, en beëedigd
Keurmeester van het Vee en van het Vleesch te Amsterdam.

NIEUWE UITGAVE.

TE AMSTERDAM, BIJ
M. WESTERMAN & ZOON.

1846.

Fig. 5
Title page of the manual for meat inspection by the Dutch veterinarian J. K. de Greuve from 1846

DE

L'INSPECTION SANITAIRE

DES VIANDES DE BOUCHERIE

PAR

E. VAN HERTSEN

Ancien Médecin Vétérinaire du Gouvernement,
Inspecteur en chef de l'Abattoir de Bruxelles, Président de la
Société Vétérinaire du Brabant, etc.

Mémoire couronné par la Société Vétérinaire de la Seine-Inférieure et de l'Eure,
au Concours de 1869.

Prix : 2 francs.

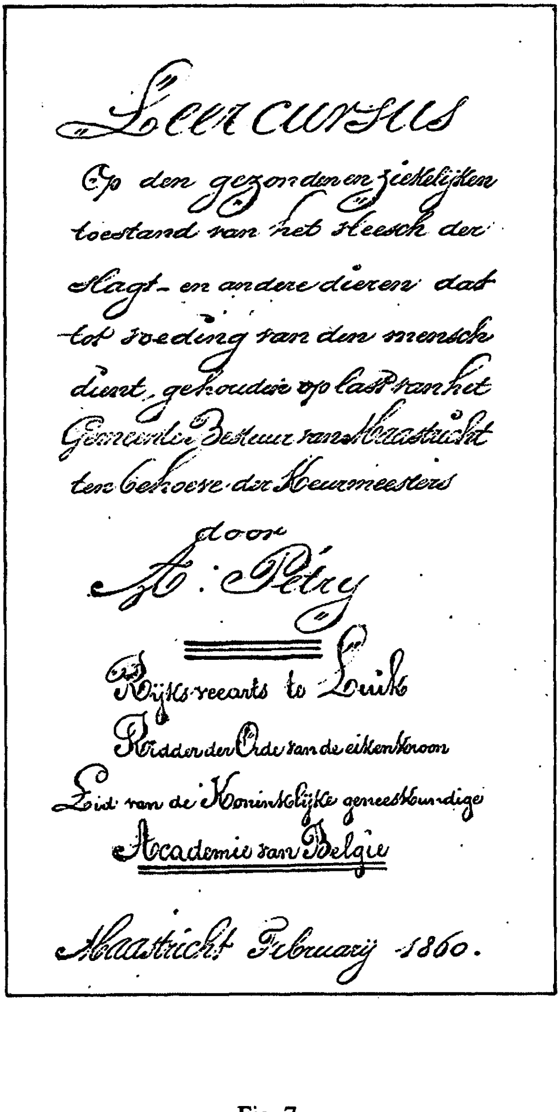
ROUEN

IMPRIMERIE DE HENRY BOISSEL

RUE DE LA VICOMTÉ, 55

1873

Fig. 6
Title page of the treatise on meat inspection by the Belgian veterinarian E. van Hertsen from 1873.


Leercursus

Op den gezonden en ziekelijken toestand van het vleesch der slagt- en andere dieren dat tot voeding van den mensch dient, gehouden op last van het Gemeente Bestuur van Maastricht ten behoeve der Keurmeesters

door

A. Pétry

Rijks veearts te Luik

Ridder der Orde van de eikenkroon

Lid van de Koninklijke geneeskundige Academie van Belgie

Maastricht Februarij 1860.

Fig. 7
Title page of a course in meat inspection given by the Belgian veterinarian Antoine Pétri (Maastricht, 1860)

and translated into English and Russian. Until World War II it was the leading handbook on meat hygiene.

-Pétry, A., (1860). Leercursus op den gezonden en ziekelijken toestand van het vleesch der slagt- en andere dieren dat tot voeding van den mensch dient, gehouden op last van het Gemeente Bestuur van Maastricht ten behoeve der keurmeesters. Maastricht. (Fig. 7)

-Villain, L. & Bascou, V., (1885). Manuel de l'inspecteur des viandes. G. Carré, Paris.

National and international associations for professional veterinary food inspectors came into being. Meat hygiene became an important issue for the international veterinary congresses that were organised from 1863 onwards, the Office International d'Hygiène Publique and the Office International des Epizooties (OIE) that were established in Paris in 1907 and 1921, respectively (Schwabe, 1984). All these factors contributed to the development of a professional meat inspection corps in Western Europe. Towards the turn of the century, the extension of the role of veterinarians to public health was gradually accepted by the medical profession and by society as a whole. Veterinarians had succeeded in providing an adequate answer to the mounting concerns for the more strictly public health aspects of the meat trade. The extension of their professional activities was laid down in veterinary legislation. Given that this legislation had a significant impact on the health and physical well-being of the whole of society, it elevated the responsibilities of those who performed the job of enforcing it, above and beyond the charge of just taking care of animal health.

Slaughterhouses and 'slaughter-warrant'

When we compare the implementation schedule of centralised slaughtering in public abattoirs (public or municipal slaughterhouses) and mandatory meat inspection of some West European countries, considerable differences can be identified. From 1795 onwards, attempts were made in a few Dutch towns to establish public slaughterhouses. These attempts, however, failed. As for slaughterhouses, Napoleonic France was the

European leader in this area; until well into the nineteenth century, the Parisian abattoirs (built in 1810-1814) were regarded as exemplary. The butchers of Paris, and later of all larger French cities, were forced to slaughter their animals in the new public slaughterhouses, while the small, privately owned butcheries were all closed down. The French example was followed in some European countries, especially in Belgium. (Table 1) From around 1880, Germany, Switzerland and Austria-Hungary took the lead in building modern slaughterhouses from a technical, as well as a hygienic, point of view. England, Spain, the Netherlands and the Scandinavian countries lagged behind (Linters, 1988; Moreau, 1916). (Table 2)

City	Number	Year	City	Number	Year
Paris	5	1814	Brussels	1	1842
Orléans	1	1821	Liverpool	1	1844
Maastricht (B)	1	1824	Marseille	1	1848
Rome	1	1825	Vienna	2	1851
Lunéville	1	1827	Edinburgh	1	1851
Bordeaux	1	1828	Lyons	1	1852
Rouen	1	1830	Bois-le-Duc (NL)	1	1852
Hasselt (B)	1	1832	Glasgow	1	1853
Toulouse	1	1832	Anjou	1	1855
Venlo (B)	1	1837	Mechlin	1	1856
Geneva	1	1841	Valencia	1	1858
Hamburg	1	1841	Genoa	2	1859

Table 1: Cities in Western Europe where public slaughterhouses were established during the period 1814-1860 (Koolmees, 1997).

In general, there was a strong opposition to public slaughterhouses from butchers in all West European countries. Having played an essential role in the municipal meat supply for centuries, the butchers feared that the public slaughterhouses would limit their profession considerably. For one thing, they would be forced to slaughter their cattle at the public abattoir under supervision. The competency of municipal authorities to establish a public slaughterhouse and to prohibit private slaughtering, the so-called 'slaughter-warrant', became a politically contentious issue in the nineteenth century. In a number of countries, this matter was settled by a national nuisance act. Most local authorities hesitated in establishing municipal slaughterhouses due to the large financial expenditure required, possible increases in meat prices, and the question of profitability. Competition for local financing also came from other large and expensive projects in the field of sanitary reforms. In the lengthy debates between supporters and opponents of municipal slaughterhouses, two factions could be distinguished: hygienists with their demand for an adequate meat inspection allied with animal protectionists, and citizens with nuisance complaints about the private butcheries versus a coalition of butchers and meat traders whose independence was threatened by the establishment of municipal abattoirs. At first, economic interests and the objections of the butchers outweighed the arguments concerning public health and pollution put forward by the hygienists. By the turn of the century, the growth of socialism tipped the balance in most West European countries. Ultimately, though, the decision to establish a public slaughterhouse mostly depended on the financial position of the municipality and hence, from general economic fluctuations (Koolmees, 1997).

The enactment of the Dutch Meat Inspection Law in 1919 stimulated the building of public slaughterhouses indirectly, since this act involved hygienic requirements concerning furnishing and equipment of private abattoirs, butcher's shops etc., and the obligation for local authorities to establish a meat inspection service. Many existing privately-owned butcheries could not meet these new requirements, leading the authorities of many cities to build public slaughterhouses in order to institute an adequate meat inspection service. Between 1883 and 1940, the Netherlands were covered by a network of 86 municipal slaughterhouses. Apart from the positive influence of the Meat Inspection Act, it was mainly the favourable financial position of the cities in the period 1922-1929 that contributed to this rapid spread of public slaughterhouses. From the total number of veterinarians, an increasing number found employment in slaughterhouses and meat inspection services. As a result of centralised slaughtering under professional supervision, meat inspection became much more effective. The number of infections with parasites was effectively diminished, tuberculosis was better detected and the number of home slaughterings decreased (Koolmees, 1997).

Country	Year	Number	Inhabitants/abattoir
France	1905	912	45,000
Germany	1903	839	51,000
Austria-Hungary	1908	337	142,000
Poland	1903	330	76,000
Scotland	1908	124	36,000
Switzerland	1905	101	34,000
Belgium	1908	91	74,000
England	1905	84	345,000
Spain	1898	26	711,000
Denmark	1908	11	227,000
The Netherlands	1903	11	464,000
Luxemburg	1903	7	33,000
Norway	1907	3	733,000

Table 2: Number of public slaughterhouses in some European countries and inhabitants/abattoir ratio around the beginning of the twentieth century (Koolmees, 1997).

State interference

During the second half of the nineteenth century and the first decades of the twentieth century, municipal slaughterhouses developed as public institutions, established at the expense of society, in which butchers were obliged to slaughter their cattle under stringent supervision to protect the consumer from unsound meat, and to put an end to the nuisance and pollution associated with the numerous, privately-owned butcheries. In many West European countries, the supply of sound meat was improved considerably by the network of municipal slaughterhouses and meat inspection legislation. As mentioned earlier, there was a difference between the period in which state control of the meat supply and quality of meat was instituted in various countries. This can be explained by the different political economy that was adopted by each nation. In the nineteenth century, Britain and the Netherlands lagged behind compared to other countries due to the prevailing liberal doctrine of free trade and the restriction of state interference. Attempts by the hygienists to restore regular meat inspection, failed due to the authorities' belief that consumers were their own best food inspectors. As with aid to the poor and other segments of public health care, meat inspection was considered a task best left to the private sector. Meat inspection was unattractive for another, more practical reason: it would hinder meat exports and free trade in meat and meat products. Due to the increased political influence of socialists, more attention was gradually paid to the responsibility of the central government to implement social legislation as part of the modernisation process of society towards the turn of the century. In the Netherlands, the slaughter-warrant was instituted by the nuisance acts of 1875 and 1901, while the national meat inspection act became effective from 1922 onwards. In Britain, however, attempts to establish meat hygiene legislation on a national level failed until 1966.

In countries with a strong tradition of centralisation, state interference in agriculture and public health to improve social and economic welfare was more common. Within the framework of a public health policy aimed at protecting the health of the individual and society, the slaughter-warrant was instituted much earlier. Meat inspection acts also became operative at a much earlier stage in Belgium (1891), Luxemburg (1892), Germany (1903), Sweden and Norway (1895), France and Spain (1905) Austria-Hungary (1908), Switzerland (1909), and Denmark (1911) (Mammerickx, 1967; Von Ostertag, 1910; Theves, 1991). In these countries, state interference increased since national governments were more willing to spend public money on the creation of a social infrastructure, including food quality control (Fisher, 1993; Kestens, 1990; Koolmees et al., 1999).

Meat hygiene and the civilising offensive

Apart from the improvement of the urban environment and the supply of sound meat, municipal slaughterhouses contributed in another way to the so-called 'civilising offensive'. This offensive was initiated by the elite and was aimed at bringing the lower social groups to a higher cultural level; one in which virtues like sobriety, industriousness, orderliness, devotion and morality played a central role. One of the objectives of the offensive was the prevention of cruelty to animals. Further, it was no longer considered appropriate that civilised citizens should be confronted daily with cruel slaughtering scenes. Towards the turn of the last century, a gradual change in mentality concerning man-animal relationships occurred, resulting in more attention to animal welfare (including that of slaughter animals) among authorities. Slaughtering became invisible, disappearing from the public view to behind the walls of public slaughterhouses.

Animal protectionists drew the public's attention to cruelty to slaughter animals performed by butchers in their butcheries. The usual slaughtering methods without stunning, especially the Jewish method of slaughter, were criticised. Until the turn of the century, traditional methods without pre-slaughter stunning prevailed in most butcheries and slaughterhouses. Veterinarians also paid little attention to animal welfare in slaughterhouses; they were more concerned with realising meat inspection legislation. After 1900, the situation improved markedly by the technical development and introduction of stunning equipment and by the fact that local authorities had to institute regulations for the use of the newly established public slaughterhouses. In most slaughterhouses, in a number of countries in North-western Europe, humane slaughtering methods were introduced in the first decades of the twentieth century. Shooting masks, (Fig. 8) captive bolt guns and spring pistols replaced mallets, throat cutting, pole-axing and neck stabbing. This was due to the propaganda of the animal protection societies and the efforts of the veterinarians appointed as directors op public slaughterhouses. Legislation controlling slaughtering methods was instituted in several national meat inspection acts (Koolmees, 1991; MacNaghten, 1932).

Conclusions

In the course of the nineteenth century, Western Europe bore witness to a gradual change from decentralised slaughtering and inspection in numerous small butcheries to the centralisation of these activities in public slaughterhouses. In initiating and guiding this fundamental change, the so-called hygienists played a predominant role. Veterinarians were represented in the group of hygienists that moulded the social infrastucture in the field of public health care into a concrete form. They contributed to the scientific development of meat inspection, particularly in the field of parasitology and bacteriology. As a new domain of professional activities, municipal slaughterhouses and meat inspection played an important role in

Fig. 8
Shooting mask used at the Amsterdam abattoir (Het Leven Geïllustreerd 12, 1917, 845)

the professionalisation process of the veterinary profession. Under national meat inspection acts, responsibility for a large segment of public health was entrusted to this profession. Arguably, this can be considered the final step in the social emancipation of the veterinary profession.

Local and national authorities were forced to harmonise the economic interest of meat producers with caring for the urban environment and health of the citizens. Confronted with these conflicting interests, governments found a way out by following the advice of health boards to institute mandatory centralised slaughtering in municipal slaughterhouses under professional supervision. Based on the liberal ideology of free trade and self-help state interference in the meat supply chain remained limited in the nineteenth century. From the turn of the twentieth century onwards, central governments felt more responsible for the supply of sound foods of animal origin and spent more public money in the veterinary infrastucture which was created to improve food quality control.

Meat hygiene and slaughterhouses played an important role in the civilising offensive. Regarding these aspects, this offensive was quite successful, since pollution in the cities decreased, the supply of sound meat improved markedly, and humane slaughtering methods were introduced.

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LAUDATIO CHRISTINE ISERENTANT

Kristiaan Heyde

Prof. Iserentant is a well-known professor of physics to the students of the first year chemistry and geology but she is very well known to most people present here through her many initiatives in which the students and the whole educational physics program takes a central position. Yesterday still, she was active working at the introductory days for incoming high-school students. Today, one of the Sarton medals is given to her.

Prof. Iserentant was born on november,4 in 1940 in Bruges. She started studies in physics at the "State University of Gent" and took the degree of 'licentiaat' in physics in 1962. She started research at the 'Natuurkundig Laboratorium', together with Prof. Robbrecht, on the issue of magnetic properties in solid state physics. More specifically, she studied Jahn-Teller structures in deformed perovskites and this resulted in a Ph.D. degree in Physics in 1967.

In 1973, she got the title of 'werkleider', in 1983 she was promoted to the degree of associate professor and became professor of physics in 1991.

Very soon, a substantial interest for the history and use of instruments in physics developed with a major accent on the extensive set of instruments from the late professor of physics, prof. Verhaeghe, and of the physics professors at the University of Gent even before that period. Because of her interest in having this large set of instruments conserved, a very large part of the various instruments dating from the early years of physics teaching at the University of Gent has been conserved (1920-1930) in optimal conditions. It now forms an essential part of the present museum of sciences at the University of Gent.

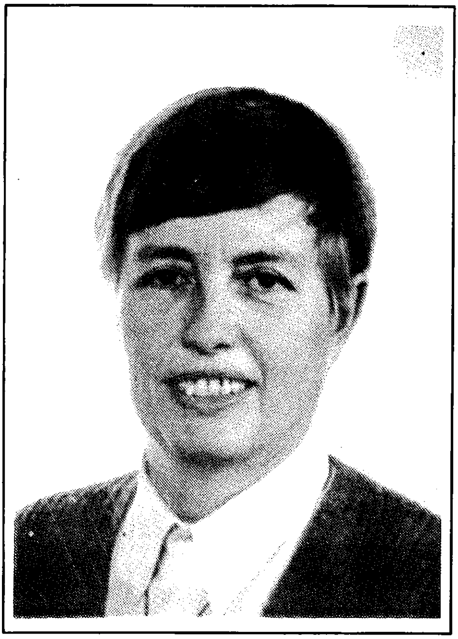
Prof. Iserentant has put up an extraordinary amount of energy in order to bring the work of the late professor Joseph Plateau, world famous physicist from the University of Gent, in the forefront at various exhibitions. A selection of what she accomplished in this context encompasses eg the mini-exhibition about J. Plateau put up at the meeting of the Belgian

Physical Society in 1983, her highly-appreciated contribution to the exhibition "Between art and knowledge" on the occasion of 175 years of the University of Gent, and this with a public collection of scientific apparatus of Plateau. She contributed in an essential way in setting up the 'travelling' exhibition "From Mercator to Frimout" in the framework of the Flemisch science weeks, and this in the period 1994-1995. During those weeks, she was coordinating the activities within the Faculty of Sciences. Her very promotion in all those activities contributed a lot in order to widen the inheritance of J.Plateau and his many contributions to physics into a broad region of society, far beyond the smaller borders of the physics community. She also contributed to the exhibition "Joseph Plateau - Physicist and Artist" in the context of the 21st. International Filmfestival, in 1994, which was presented in the 'St.Pieters abdij' and was essential in setting up an exhibition, entitled "The scientific and cultural inheritance of J. Plateau" that was organized in the Museum for Sciences at the University of Gent. In these various ways, Prof. Iserentant has contributed a lot into bringing to a wider public the interrelationship between the hard facts of physics and the artists aspects that was generated through the work of the late and world-recognized Gent physics professor J. Plateau. Here determinative role in bringing this task to a good end cannot be underlined strongly enough.

Something I should not forget to mention here is the very fact that Prof. Iserentant has been playing and still holds a key-role in bringing the young university students in contact with the realm of physics. This she has done through her large teaching duties (just ask any student in the first or second year of chemistry and geology), through a very large set of activities like the organization of the 'abituriëntendagen' (introductory and orientation days for students from high-school) since 1988, the active work in setting up the Flemish Physics olympics, also since 1998 and, at present, as coordinator for the Flemish Science Weeks within the Faculty of Sciences. In bridging the gap between the early history of physics and the present-day new evolution in physics, she often used the role-model played by J. Plateau and his heritage, as collected for a large part by herself, when explaining to the younger students. I am sure that using this method, Prof. Iserentant has made many of those students at ease with various concepts of physics and conveyed to them the idea that many present-day applications (like the transistor, CD-player, magnetic gadgets, internet,..) are strongly related to basic ideas laid out many years before.

Dear Christine, those many tasks you have carried out with large devotion and strong persistence are so characteristic for your spontaneous way of working. I just quote a few examples but there are for sure a much larger number to be put up here: your 'mission' visits to the LUC in 'Limburg' to present the physics program of the University of Gent, your guidance to the always new generation of incoming young students in their first contacts with our university and with the Faculty of Sciences, the fact you gave the students a broader vision beyond the more specific physics training, your organizational work and talents in setting up a wide spectrum of activities like the physics olympics, and, last but not least, your restless efforts in spreading out the work of J. Plateau to an audience, as large as possible. No one ever tried, in vain, to ask your help or support in those many aspects that are too often put under the common word of 'service work' but of which, every single person present here, knows for sure that this was done with 100% of full commitment and enthousiasm, with 'love' for your 'physics'.

Today, all these elements are brought under the spotlight with the presentation of the Sarton medal.



FROM POLE TO POLE: MAGNETIC INSTRUMENTS AND THEIR TIME

Christine Iserentant

I. Introduction

May I start this introduction by referring to the book From *Pole to Pole* by Sven Hedin (1865-1952)[1]. He was a great explorer, and I have borrowed the title of his book for this address.

"Once upon a time, there was a traveller who was forty-five years old. Twenty-five years ago he began his exploration of the world. At that time, he had just graduated and his knowledge was still rather basic…
However, a quarter of a century had passed… and he wondered how he could celebrate the twenty-fifth anniversary of this first journey…
Could there be a better way of celebrating than to turn his mind back to Asia, and to reminisce about everything he had seen and experienced. I invite everybody, present here today, to accompany me on a journey of recollection from one part of the world to the other, from Europe through Asia and back home. I will be your guide. I will lead you through the magnificent continent which filled twenty-five years of my life. And when we come back home and people ask us where we have been, then our answer will be: "From Pole to Pole".

II. From the Chinese to the European Pole: the magnetic compass

In the early history of modern science, the magnetic compass was considered one of the most important inventions of all times. The compass was crucial to shipping, more in particular for the naval powers in Western Europe. Even nowadays, it remains a crucial instrument for navigation. However, only few people know that the compass is of Chinese origin. Moreover, the invention had nothing to do with shipping.

In Europe as well as in China, legends were told about lodestone. And yet, only the Chinese were able to develop the science of magnetism. It originated in the "fengshui" or geomancy[2], a particular form of fortune-telling, that departs from natural phenomena.

Geomancy was probably developed in the period of the Battling States, about the third century B.C. During and after the Han-dynasty this resulted in the actual creation of the compass (200 B.C. – 220 A.D.). The first practitioners of geomancy used a fortune-telling board consisting of two parts: a square plate that represented the Earth with a rotating disc attached. This disc represented the celestial sphere. Later, certainly in the first century A.D., people recognised that a complete celestial disc was not necessary. From now on, it was sufficient to use a spoon with its typical Chinese shape, representing the Beidou (the "northern spoon") : the seven clearest stars of the sign of the zodiac: the Big Bear (Ursa Major). In the course of the year, the 'tail' of the bear, matching the handle of the spoon, turns around the pole. In that way, the direction of the handle could indicate the seasons. Actually, this was a first step towards the development of dials.

Over the years, the Earth-plate was made out of bronze instead of wood. Thus, the spoon could turn around more easily. By using lodestone for manufacturing the spoon, people discovered the lodestone's natural tendency to direct itself according to a north-south axis.

Finally, the board of the fortune-telling device represented the Earth and the polished circle in the middle the sky. Chinese cyclical characters stood for the eight most important wind directions: north, north-east, east, etc. In addition, the smaller twenty-four points' graduations of the compass (every fifteen degrees) as well as the twenty-eight moonhouses – the base of the Chinese astronomy - were individually marked. As we have already mentioned, the handle of the spoon indicated south. This tradition lived on for many centuries in the use of the Chinese compass rose, whereas the European versions always indicated north.

The Chinese further investigated the properties of lodestone in a pure scientific way. This resulted in some sensational discoveries. Magnetic polarity was just one example.

Thus, they came to the conclusion that a magnet that floated on water was just as helpful as a spoon. This method was developed in the course of the second century B.C. The Chinese also made use of 'compasses' – if I may already use this word - made out of lodestone in the shape of a fish. Or, they placed the magnet in a wooden fish or turtle that floated on the water surface. Examples are also known of turtle-compasses with 'dry suspension'. Most noticeable is the fact that the floating type of compass remained very popular in China, whereas the dry type only became widely accepted as a consequence of the European maritime influence.

The various types of 'compasses' are described in the encyclopedia: "Guide through the forest of things" by Chen Yuanjing, compiled between 1100 – 1250 A.D.

About the fourth century A.D., the Chinese found that iron needles could get magnetised by rubbing them against a lodestone. Such needles were attached to a silk thread and indicated north and south, just as the magnet itself would have done.

Such process of magnetisation was for the first time unambiguously mentioned in "Pen Chats on the banks of the pond of dreams", written around 1088 by astronomer, engineer and official Shen Kuo. In his work, he also refers to another, vital - Chinese - discovery, namely that of magnetic declination: the fact that north and south pole indicated by a compass do not exactly match the geographic, astronomical poles. The Chinese were acquainted with this phenomenon from about 1050 A.D., probably even a century earlier. In Europe, on the contrary, this phenomenon remained unknown till about the middle of the fifteenth century. Hence, the discovery of the magnetic declination, traditionally attributed to Columbus, was already known in China four centuries earlier.

All the discoveries mentioned above are much indebted to geomancy. In navigation, the magnetic needle was for the first time used in 960 A.D., at the time of the commencement of the Song-dynasty. Once the use of the compass became common practice in Chinese shipping, this knowledge reached the European continent within a century.

III. Europe had to re-discover the compass

Ancient Greece[3-5]

Ancient Greece was familiar with the fact that, after friction, amber could attract small objects. On the other hand it was also well known that a certain mineral had the particular feature of attracting small pieces of iron. Such mineral was found in large quantities in Magnesia, a region east of Thessalia, Mid-Greece. The name 'magnet' is probably derived hereof. One of the first references to magnetism in Western history appears in the work 'De Rerum Naturae" by the Roman poet Lucretius, from the first century B.C. (? 98-55 B.C.)

The power to attract small parts of iron was the only distinguishing characteristic of lodestone, known at that time. However, over the centuries, beliefs about the lodestone power grew. In the thirteenth century Bartholomew the Englishman hailed its medicinal properties in his encyclopedia :

> *This kind of stone (the magnet) restores husbands to wives and increases elegance and charm in speech. Moreover, along with honey, it cures dropsy, spleen, fox mange, and burn. ... When placed on the head of a chaste woman (the magnet) causes its poisons to surround her immediately, (but) if she is an adultress she will instantly remove herself from bed for fear of an apparition.*

The Middle Ages (Petrus Peregrinus)[3-6]

Petrus Peregrinus, also called Peter the Pilgrim, was a western pioneer in experimental physics, more particularly in the field of magnetism. He was born and raised in Méricourt, Picardy. Later, he was a member of the army of Charles I of Anjou, King of Sicily. In the army, he probably served as an engineer. During the siege of the city of Lucera, Petrus Peregrinus had enough time to write on his experiments on magnetism. We know this from the letter he wrote to one of the soldiers he became friends with. This "Epistola de Magnete" dated from August eight, 1269.

Apparently, Petrus had shaped a piece of lodestone into a sphere. In his letter, he described how he placed a magnetic needle on various parts of the ball and drew lines showing the direction of the needle. As a result, he obtained a number of lines, circling the ball. He found that the lines crossed in two points, directly opposed to each other on both ends of a diameter of the ball. He realised that the lines matched the meridians of the celestial sphere and corresponded to those of the Earth. He accordingly called these points poles. Moreover, he extended this concept to both ends of the magnetic 'needle'. In some simple experiments he also found that similar poles repel, whereas unlike magnetic poles attract each other. All of these experiments were performed outside the walls of the city of Lucera, the besieged city where people were starved for convincing them to another religion.

This epistola is very important as a historical document because of the fact that Peter the Pilgrim was one of the first European experimental scientists. In his Opus Magnus, the English Franciscan friar and famous philosopher, Roger Bacon (1214 –1294), refers to Peter the Pilgrim as such a scientific pioneer. Petrus Peregrinus was indeed one of the first, if not the first, to emphasize that "experience, rather than argument is the basis of certainty in science"[6)].

William Gilbert[3-6)]

Until the end of the sixteenth century, Peregrinus fell into oblivion. Actually, the history of the scientific study of electricity and magnetism dates from William Gilbert (1540-1603). Three hundred and thirty years had passed before someone else would take up the task of moving the subject of magnetism's mystery out of the realm of superstition into that of science. After that, it took another century for scientists to become aware of the reality of magnetism. In retrospect, we should also take into account that only then the concept of science –as we understand it nowadays came into being.

But, let us go back to China for a moment. Throughout the centuries, China was the cradle of many great inventions[8]. However, from the beginning of the seventeenth century onwards, the rise of modern science would cast a shadow on these early developments. Modern science differed in two main ways from all that preceded. First of all, mathematics was used to express theories and hypotheses on nature. And secondly, these were combined with accurate observations and experiments.

Scientific and technological developments in China never knew dark Middle Ages. In Europe on the contrary, after the essential scientific contribution in the era of Ancient Greece - until the second century A.D.-,scientific knowledge sank to a low. Only the Renaissance (1300 - 1600 A.D) would be able to rise Europe from that low point. In China, on the other hand, there was a steady rise in scientific evolution.

How can this be explained? One of the reasons was probably that Chinese bureaucracy recruited the brightest intellectuals of the country. In addition, there were also some other factors that help to explain this fact. The uninterrupted development of Chinese science and technology never resulted in a revision of the philosophical basis. There never was a drastic revolution that could outbalance the traditional ways of thinking. In China, the traditional order was preserved. Obviously, this was not the case on the European continent. In these parts, there was no continuous evolution in ways of thinking. After a long period of stagnation, intellectual concepts underwent a number of fundamental changes. This resulted e.g. in the Reformation: a profound reform of the traditional religious ways of thinking, which had the effect of a major Earthquake. Independent ways of thinking get a chance, and adventurous commercial enterprises expanded their activities. Daring explorative expeditions were undertaken and new commercial routes were set out.

Let us reflect now on William Gilbert. He was born in Colchester (England, Essex), studied medicine at Cambridge University and afterwards, he held the exercise of his duty in London. He became the personal physician of Queen Elisabeth I and was a contemporary of William Shakespeare. While he fulfilled his obligations at Court, Gilbert carried out the very important investigations that have earned for him the title of "Father of Magnetism". He elaborately wrote on this in his book: "De Magnete, Magneticisque corporibus et de magno magnete tellure", (On magnets, magnetic bodies and on the great magnet, the Earth) published in London in 1600[9]. In general, this work is considered as being the first modern scientific treatise.

In his book, he illustrated how, on the basis of experiments, one could draw certain reliable conclusions concerning the characteristics of magnets and of the Earth. Indeed, he found that the Earth itself was a magnet and that the magnetic needle's characteristic of indicating the north-south direction

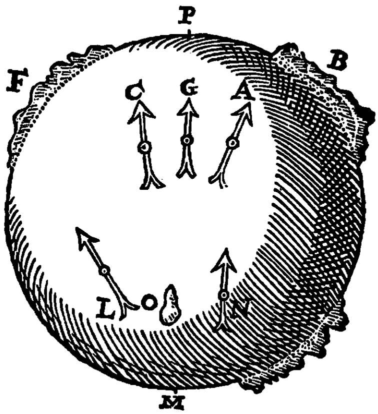


Fig.1. One of W.Gilbert's irregular terrellae with versoria.

was not caused by influences from the celestial sphere. His "Terrellae" (spheric magnets made from lodestone) displayed all magnetic effects of the Earth itself. A "versorium" (we call it now a magnetic needle) suspended above a "terrella", took a position which was known as inclination and declination (Fig. 1).

An instrument used to measure the inclination was first mentioned in a work published in 1581 by Robert Newman: "The Newe Attractive". A drawing of such a device is also found in the work of Gilbert. The experiments with terrellae had led Gilbert to the conclusion that lines which joined those places on Earth, where the inclination is the same, correspond to the lines of latitude. Gilbert also expressed the idea that a circle of inclination would be a more reliable means for navigation at sea than an ordinary compass. However, seamen soon detected that there could be substantial changes in inclination in places on the same latitude. Gilbert's prime idea was consequently abandoned.

The fact that a compass needle would not exactly indicate the north-south direction –as derived from astronomical observations- was already known a long time before Gilbert. The first marks of declination were found on sundials, produced in Nüremberg around 1450. The marks were used to orient the dials with a magnetic compass. A historically important corollary of the variability of declination was Christopher Columbus' discovery of America in 1492, partly by serendipity.

As he normally did on any great exploration, Columbus took along a good lodestone, which was carefully guarded, and a supply of spare compass needles. These would be remagnetized with the lodestone if they lost their ability to seek north. Columbus's ships headed westward according to the compass. However, this was not the geographic west. During their voyage they had –without knowing it- passed the point where the deviation of the magnetic pole was zero. This means that the magnetic pole and the geographical pole lay in the same direction. Once beyond this point, the magnetic north lies west of the geographical north instead of east, as it was the case in Spain at that time. This mistake caused his ships to sail further southward than would otherwise have been the case. This was important, because the sailors had made their captain Columbus to accept to head back to Spain if no land had been sighted within a certain time. If the ships would have sailed accurately westward, they would not have encountered land within that time, and Columbus would not have become famous.

The first numerical reference of declination is found from a measurement in Rome around 1510[10)]. In the following decades, similar measurements were carried out all over Europe. This is how the variability of declination was confirmed. The first map of declination was drawn in 1536 by the hand of Alonzo de Santo Cruz.

The fact that declination was place dependent strengthened the hopes of determining a position at sea by means of magnetic measurements. The knowledge of the world-wide variation of declination was of crucial importance for a naval power such as England. For two years –1698 till 1700- Edmund Halley (1656-1742) carried out declination measurements all over the North- and South-Atlantic Ocean. To do so, he made use of a specially designed and equipped ship, 'The Paramour', financed by the Royal Society, and later under the patronage of the king. The results of the expedition were published is 1701. The first isogonic map of the Atlantic Ocean was thus designed[11)].

IV. The Birth of Electromagnetism[3-5)]

W. Gilbert died in 1603. In the course of the seventeenth century only little progress was made, both in the field of electricity and magnetism. In the eighteenth century however, considerable progress was made in the study of charged bodies, the field of research now known as electrostatics. For a long time, the knowledge of electricity and magnetism has been restricted to a number of isolated facts. Only some two hundred years after Gilbert's death the link between electricity and magnetism would become clear.

Obviously, for the scientific study of any physical phenomenon, two conditions should be fulfilled. First a large quantity of material should be at hand on which experiments can be carried out. Secondly, measuring instruments were needed to give quantitative information on the phenomenon. What was needed here, were large quantities of electricity, strong magnets and instruments that could determine the various features of electricity and magnetism on a purely quantitative basis. Only then would experimentation begin in earnest.

A number of discoveries resulted in an almost endless list of new, practical applications. It was discovered by Peter van Musschenbroeck (1692-1761) that electricity can be stored in what we now call Leyden jars. The force between electrical charges could be measured by means of a torsion balance, designed by Charles-Augustin Coulomb (1736-1806). It was discov-

ered that larger *currents*, flowing electricity, could be generated by larger voltaic cells.
These discoveries brought along that some curious minds considered the use of voltaic cells for studying magnetic effects.

H.C. Oersted[6)]

Hans Christian Oersted (1777-1851), a Danish physicist, was strongly inspired by Immanuel Kant's unifying idea that physical experiences can be related to a unique force. In addition, Oersted was convinced that there had to be a link between electricity and magnetism. That was what he was looking for. Indeed, Oersted was the first to note that the orientation of a compass needle changed when, near to the compass, an electric current went through a wire. He revealed his findings of this key experiment in a four-page Latin publication: "Experimenta circa effectum conflictus electricia in acum magneticum" (Experiments concerning the effects of an eletrical conflict on a magnetic needle), July 21, 1820. The discovery of electromagnetism, the connection between electricity and magnetism, was a fact. Oersted had demonstrated that electricity could generate magnetism.

Soon enough, the implications became clear. Oersted's results operated as a fermentation process. Within a few months, numerous successes had been achieved. One of the pioneers was Andre-Marie Ampère (1775-1836).

A.M. Ampère[6)]

When Ampère became acquainted with Oersted's findings, he immediately started a thorough experimental study of this new phenomenon. For instance, he recorded that wires carrying currents exerted forces on each other (unit of current intensity: ampère). He also found that when a current was sent through a spiral wire (solenoid), this wire behaved as a magnet. One of his friends, François Arago (1786-1853) was the first to put an iron core inside the solenoid, which apparently increased the magnetic effect. The iron core behaved as a magnet every time the electric power was turned on. Ampère wondered if it were possible that the magnetism of the Earth originated in currents inside the Earth.

Undoubtedly Ampère's most important contribution lies in the fact that he was the first one to proclaim the idea that magnetism is caused by 'electricity in motion'.

Galvanometers[12-16)]

Oersted's discovery provided a means for the detection of a current by its magnetie effect. Instruments based on this principle are called galvanometers.

The Museum for the History of Science of the University of Gent houses a large number of these instruments. On their own, they offer scope for an interesting study.

The simplest type of galvanometer consists of a single wire coil, with a compass needle placed in the middle. The instrument is adjusted so that the plane of the coil is in the magnetic meridian. A weak current causes but a small deflection. The geomagnetic field attempts to keep the needle in its original position. Thus, it came down to increasing the sensitivity of the instruments. This could be obtained by raising the effect of the current, and by weakening the influence of the geomagnetic field.

By winding the wire several times round the magnet, the effect was multiplied by a large factor. The German J.S. Schweigger (1779-1857) was the first to actually realise such set-up. This construction was called a 'multiplicator'.

The second way to increase the sensitivity of the apparatus consisted of adding a second magnetic needle of about the same strength. This was done by Nobili in 1830. The needles were mounted in the same vertical plane, but with their similar poles turned in opposite directions, the so-called astatic system. In that way, the influence of the Earth was more or less neutralised.

On figure 2 the core of such a galvanometer is shown. We clearly see the multiplicator and the astatic system. Usually, a circular plate with graduation is placed underneath the upper needle. To increase the sensitivity of the instrument even more, a small mirror is attached to the thread. The mirror reflects a beam of light on a scale (mirror galvanometer).

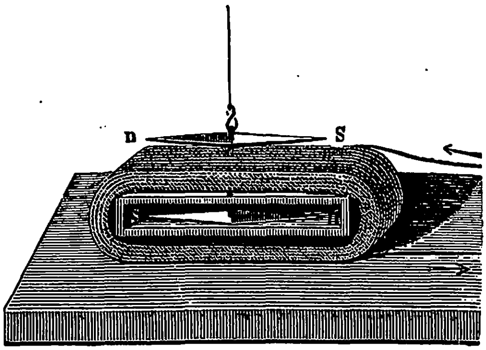


Fig.2. The core of a galvanometer with multiplicator and astatic system

In the instruments mentioned above, the coil (multiplicator) took up a fixed position. Later, the coil itself could spin : hence the name moving coil galvanometer. The subsequent volt- and ampère-meters were based on the same principle. One of the first, and definitely the most famous moving coil galvanometer was the meter designed by the engineer M. Deprez (1843-1918) and professor A. d'Arsonval (1851-1940). Their first model contained a large, vertically installed horseshoe magnet. Attached to a thread, a small coil is suspended inside the magnetic field. When the electric current flows through the circuit, the coil will turn, in accordance with the laws of electromagnetism. However, it will also be impeded by the torsion of the thread. Usually, the apparatus was placed underneath a bell-glass. Later, a number of other improvements resulted in very sensitive and accurate instruments.
Galvanometers helped to save the live of thousands of frogs. Indeed, before the invention of the galvanometer, galvanic electricity was detected by means of the contraction of frog's legs.

Telegraphy[17)]

Electromagnetism was first applied in the field of telegraphy. Ampère suggested already in 1820 that a magnetic needle placed on a very remote point of a circuit could be used to transfer signals. He proposed to set 30 needles into motion by means of 2x 30 wires. In 1828, the Frenchman de Saint-Amand suggested however to use only one needle and to code the alphabet via the number of deviations of the needle. His proposal was ignored.

In 1832 the German physicists Karl Friedrich Gauss (1777-1855) and Wilhelm Weber (1804-1891) were the first to create an efficient telegraphic line about 2.5 km long, between the astronomy observatory in Göttingen (Gauss) and Weber's physics laboratory. The line was used to exchange data through a mirror galvanometer. They soon realised that the system was a useful tool to exchange coded messages.

Telegraphy was given incentives from various areas. The introduction of telegraphy was heaven-sent for the railways as both efficiency and safety increased. Adolphe Quetelet (1796-1874) (a teacher and good friend of Joseph Plateau (1801-1883)) contributed to the introduction of telegraphy in Belgium. Belgium's first electric telegraph service was installed along the railway line Brussels-Antwerp. On 9 September 1846 this connection was open to the public and people could go and see the working of the instrument if they were willing to pay 1 franc per person.

It was only in 1845 that the 1-needle-telegraph was introduced. Such a type of telegraph was in fact a large galvanometer with an astatic needle-pair, such as the one designed by Nobili, but it was positioned vertically. A positive current made the needle deflect to the right, a negative current to the left (cf. the Frenchman's idea in 1828). Later on, people switched to Morse (left = point, right = stripe). It might be interesting to know that the last bastion of commercial radiotelegraphy in Morse, namely connecting ships and coastal stations, came to an end on 31 January 1999.

V. The Discovery of Electromagnetic Induction - M. Faraday[3-7][18]

Experiments thus proved the link between magnetism and electricity in motion. Briton Michael Faraday (1791-1867) made headway with his law of induction in 1831. He stated that a changing magnetic field generated an electric current in a circuit. In a way, this boils down to the opposite of Oersted's observation.

Michael Faraday is one of the fairy tales of science: originally he was an apprentice-bookbinder, but he became one of the greatest scientific researchers and he received nearly all the important scientific awards of that period.

Faraday never received any formal education. His school education was basic. He couldn't fully grasp the mathematics in Ampère's papers. But he had an intuitive feeling for the processes of nature. Furthermore, he was also extremely talented in choosing the right experiments. The blacksmith's son had marvellous hands and nature was a challenge to him. He was a scientific Casanova.

Faraday's life was science. His leading characteristic was reliance on facts derived from experiments. "Without experiments, I am nothing." he wrote. Experimenting was in fact the only thing in which he excelled. But he had one tremendous advantage: his observations were not hampered by biased ideas about the results. Actually, electromagnetic induction had already been observed by Ampère nine years earlier, but to Ampère the effect, although noted, was simply ignored. It was not what he was looking for and he failed to recognize its significance.

Fortunately, Faraday provided us with a detailed report of his research. The descriptions are of particular interest, as they were written at the time of the experiments. To a certain extent, this allows us to grasp his working strategies and to comprehend how he came to his conclusions.

Giving a short overview of Faraday's scientific research is a hopeless task. Faraday started to work for Sir Humphry Davy, a great chemist, thanks to his interest in chemistry. Apart from his electrochemical experiments, three of his physical results would influence history dramatically.

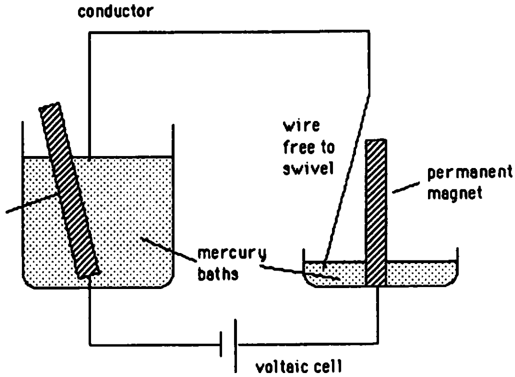


Fig.3. A sketch showing the apparatus Faraday used to demonstrate the mechanical effects of electric currents

First, in 1821 Faraday discovered that an electric current could generate mechanical action. This experiment is schematically shown on figure 3 : when a current flows in the circuit, the suspended magnet at the left rotates around the wire firmly fixed in the bowl of mercury. Simultaneously, the current carrying wire at the right rotates about the permanent magnet anchored in another bowl of mercury. This concept formed the basis for the present electric motor.

This type of engine developed rather quickly. In 1839, a boat was propelled along the river Neva at a rate of 4 km/h by means of an electric motor. In this initial period, the current for the motors was produced by batteries or voltaic cells, sometimes up to seventy units. The construction of powerful motors required high electromotive forces to feed the electromagnets. As long as no better power source than an ordinary chemical cell was developed, this remained impossible. The cost played a role as well. The price of electrical power was about 60 times higher than the power produced by steam engines. However, the construction of more efficient dynamos –

Ampère laid the basis for this – soon resulted in the production of cheaper electricity.

Indeed, on 17 October 1831, Faraday concluded that the mechanical motion of a magnet in the vicinity of a closed circuit could generate an electric current, but only during the time the magnet was moving. Eleven days later he inverted the procedure. Instead of moving a magnet trough a coil of wire, he arranged that a conductor in the form of a copper disc should be made to turn between the poles of a magnet. For this purpose he used the great horse-shoe magnet that is still to be seen at the house of the Royal Society. Between the axis and the rim of the disc a current was induced when the disc was turning. So the dynamo was born: mechanical energy of motion could be converted into electrical energy. Faraday then built the first primitive electric generator. The Belgian Zénobe Gramme (1826-1901) constructed the first serviceable dynamo in 1871[17)].

Also in 1831, Faraday made a third crucial discovery which had a great influence on history: he showed that electric current could be induced in a circuit by changing the current in a nearby circuit. This observation announced the birth of the transformer and the induction coil. At the same time and independently from Faraday, the American scientist Joseph Henry (1791-1878) also discovered this effect, but he published his findings only later. Thanks to the induction coil, a very high electromotive force could be generated, starting from current provided by a couple of voltaic cells. Men finally had a useful high-tension generator and this meant farewell to all friction machines. The German instrument maker Heinrich Ruhmkorff (1803-1877) designed the first efficient instrument[17)]. Ruhmkorff's coil played a crucial role in many areas: in the medical world, for the study of electric discharges in rarefied gases (especially X-rays) and also in telecommunication. Even today the coil of Ruhmkorff generates the spark required to ignite the mixture of gases in an internal combustion engine.

To round off this chapter on Faraday, it might be interesting to point out again that – in contrast to what was generally accepted till then – *time* was a factor which had to be taken into account when explaining physical phenomena, as induction required varying currents and varying fields.

VI. All electromagnetic phenomena explained - J.C. Maxwell[3-6]

The Scot James Clerck Maxwell (1831- 1879) crowned the work in 1873. His four fundamental, mathematical laws describe all electromagnetic phenomena and form the foundation for the physics of the 20th century. In his "Treatise on Electricity and Magnetism"[19], he came to the astonishing conclusion that – to use Faraday's terminology -electric and magnetic forces travel with the speed of light. This involved that light had to be an electromagnetic phenomenon. This conclusion meant a fantastic breakthrough. After centuries of research, magnetism, electricity and light turned out to be connected. Moreover, Maxwell postulated the existence of electromagnetic waves of the same nature as light waves. Heinrich Rudolf Hertz (1847 –1894) proved the authenticity by means of experiments, which introduced the foundation for wireless telecommunication.

The quest for an explanation of the fascinating force exhibited by the lodestone culminated in the discovery that an electrical current created magnetic fields. A logical step was to consider circular currents to be responsible for magnetism in the world of atoms and molecules in order to explain the properties of lodestone and permanent magnets : in the beginning of the 20th century, the atomic theory of matter supported this hypothesis.

VII. Final journeys

As final journeys, I would like to dilate on the importance of magnetism in daily life and in some other fields of science, apart from the applications already mentioned.

Magnetic recording[20]

In 1998, magnetic recording celebrated its hundredth anniversary. Initially magnetic recording developed slowly, even though its technology is omnipresent today. The underlying physics were unknown, applications were slow to emerge, and business and politics stifled development.

Today, magnets store much of the world's information: data on computer discs, videos and tapes for leisure activities, messages on telephone answering machines, and data on credit cards. All such media store words, numbers, images and sounds as invisible patterns of north and south poles.

During the last decades, magnetic memories and audio taping have played an influential role in society and political life. Some famous U.S. presidents might confirm.

It was at the end of the 19th century that people started using magnetic material to record and reproduce the human voice. In 1898 the Danish engineer Valdemar Poulsen patented an apparatus, the so called telegraphone. He demonstrated the principle by means of a steel piano wire stretched across the laboratory. Poulsen spoke into a telephone mouthpiece connected to an electromagnet sliding along the wire. The device converted his words into electric signals of diverse intensities which in turn were sent to the magnet. The varying magnetic field was then imprinted along the steel wire. By replacing the mounthpiece by a receiver and by sliding again the electromagnet along the wire, the apparatus functioned in the opposite way. Poulsen improved his invention by e.g. wrapping up the steel wire around a cylinder. In the beginning people were rather sceptical about Poulsen's telegraphone. In the U.S.A., an office specialised in patents disapproved of the telegraphone, because the apparatus conflicted with "all common laws on magnetism". Apparently not all laws on magnetism were commonly known at that time, because Poulsen's invention functioned properly. However, in 1900 the telegraphone became a tremendous success during the exhibition in Paris. One of the visitors was the emperor of Austria, Franz Joseph, who recorded a message which still exists and which is the oldest magnetic recording.

What hampered the development of this invention for such a long time, half a century to be more precise? The answer is plain, namely a combination of business interests and technical factors. An example: the American Telephone & Telegraph Company was opposed to the telegraphone because they were convinced that they would lose 1/3 of their business interests if the customers would realise that their conversations might be recorded. A kind of remark that sounds familiar.

There were of course also technical problems which obstructed the sophistication of the apparatus. But there was more. Of the few telegraphones which had been sold in the U.S.A, several of them had been installed in two transatlantic wireless stations on the East coast which were then operated by German companies. It was also known that the German Navy had purchased telegraphones for its submarines. Consequently, at the outbreak of the first World War, the two transmitting stations were suspected to pass on military information to German submarines in the Atlantic Ocean. This might have been at the origin of the torpedoing of the British liner Lusitania near the Irish coast, because Germans used the telegraphone for high-speed transmissions.

In Europe, magnetic recording fared much better. An intermediate stage in the development was e.g. the Blattnerphone which was already in use by the BBC in 1931. It was a huge machine: height: 1.5m, width: 1.5m, depth: 0.5m and weight: approximately 1 ton. The recording-medium was a steel ribbon, approximately 3 mm wide, which passed the record and reproduction heads at a speed of 1m/s. A tape of 1.5 km was needed for a recording of half an hour. Two men were required to insert the reels.

In certain countries this type of apparatus remained in use until 1945. The exceptional length of the heavy steel tapes clearly impeded further development. Fortunately, Fritz Pfeumer, an Austrian chemist, improved the system in 1927: he invented a paper tape coated with magnetic particles in powder form. We are all familiar with the modern product which has been derived from this principle.

Let us reflect once more on the scientific world. Many phenomena in which magnetism plays a role can be discussed. Some of these issues are dealt with below.

The drift of the continents[21)22)]

One example is the drift of the continents. The German climatologist Alfred Wegener (1880 –1930) formulated his first theory on the basis of biological and geological arguments. This theory, alike any other, had its opponents and advocates. Once, all continents were believed to have formed one block (Pangea). This supercontinent was ripped into pieces, and the pieces would have drifted away as rafts on the Earth's crust. But where did these immense forces, necessary for the movement of the continents, originate?

From the moment geologists and physicists started to cooperate, a better insight in this matter could be obtained. In the 50s, a palaeo-magnetic research indicated that ancient magnetic poles witnessed from various continents diverged with age, which indeed illustrated the relative movement of the continents. However, the question remained: how?

During the second World War, the American Navy had developed aeromagnetic measurement techniques for detecting submarines. The techniques were later converted into marine magnetometers which were towed at the rear of a ship. Around 1955 these modern proton precession magnetometers were dragged along the bottom of the sea (accuracy: $0.5\gamma = 0.5\ 10^{-9}$ Tesla!). The results were astonishing. Magnetic anomalies formed zebra-like parallel ribbon patterns, parallel to the ridges. They were soon correlated with reversals of the sense of the magnetic field of the Earth. The sea-floor spreading theory was born, heralding plate tectonics, the most profound revolution in Earth Sciences (fig.4).

Intense magnetic fields[23-25)]

To have an idea of the order of magnitude of the magnetic field intensity, it is worth noting that the strength of the Earth magnetic field amounts to $0.5\ 10^{-4}$T. This field occupies an intermediate position between galactic fields, which extend over vast distances but amount to only a few thousandths of the Earth magnetic field, and fields in the vicinity of atomic nuclei, which occupy tiny volumes of space but may exceed 100T. Magnetic fields generated in the laboratory have surpassed atomic fields in both intensity and volume. The need for very intense magnetic fields to serve as extreme research environments is shared by almost all the major divisions of physics : high-energy physics, plasma physics, solid-state physics, geophysics and even biophysics.

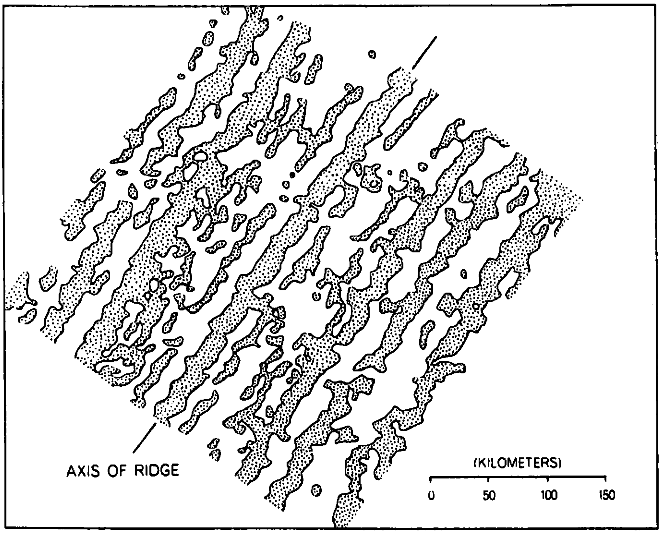


Fig.4. Example of anomaly pattern discovered in ocean floors, particularly along mid-ocean ridges. The pattern is strikingly symmetrical. The parallel bands in which the Earth's field is stronger (stippled) or weaker (white) than the regional average are oriented along the ridge's axis. The magnetic bands are produced by bands of rock with "normal" and "reversed" magnetism.

Several giant electromagnets were built around the first World War, one of which is the well-known magnet of Bellevue, France, weighing 120 tons and built in 1927. The windings around the iron core are 1.90 m in diameter. The generation of a field of 5T within a volume of 20 cm^3 consumed a power of 100 kW. For all practical purposed 3T represents however the limit of magnetic field intensity for such type of magnets.

Fields exceeding 3 T however are more expediently generated in iron-free solenoids. This involves enormous currents, thousands of ampères, which confronts scientists with a first main problem, namely heat. The generation of intense magnetic fields is the only process customarily performed at zero efficiency : nearly all of the energy dissipated in a magnet coil is removed as heat. A second problem is the mechanical force exerted by a magnetic field on an electric current. This force is the magnetic equivalent of pressure. At 25 T the pressure reaches the yield strength of copper, with the result that an ordinary copper coil, no matter how well constrained, will begin to flow like a liquid. The National Magnet Laboratory at MIT (Massachusetts Institute of Technology) managed to produce the most intense continuous magnetic field in this way with a 25 T solenoid. The magnet contains 3 tons of copper and has an outside diameter of approximately 1 m. At full power it consumes 16 million watts of electricity and 7500 l water per minute!

Superconductive magnets, which are available now at reasonable prices, solved the problems of the enormous power and need for cooling.

Magnetic fields in space[4)]

Magnetism was also fundamental to our understanding of astronomic phenomena. Everything we know about the remote universe was derived from a study of electromagnetic waves, such as light, X-rays, radio-waves, ultra-violet and infrared radiation. The discovery of magnetism in astronomical objects is based on an effect observed by Pieter Zeeman (1865 – 1943) in 1896. An effect which has been named after him. Today there are a dozen of telescopes in the world that do nothing else but measure the Zeeman splitting of light from the sun, in order to measure magnetic fields in and around sun-spots. These reveal that the sun's basic field amounts to the double of the field of the Earth, that it runs north-south and that it reverses its direction every 22 years. The magnetic fields in sun-spots can be 1000 times stronger. Pairs of spots appear to act as the north and south poles of huge magnets hundreds of times the size of the Earth. The fields in pairs of sun-spots also change their relative polarity with the eleven-year sun-spot cycle. Magnetic stars are known, with fields ranging from 10^{-2} T to 3,5 T. Magnetic fields are also present between stars. Magnetism in space influences there various physical processes, ranging from the genesis of stars to the evolution of galaxies. Their origin remains mysterious.

VIII. Conclusion

In conclusion I would like to stress that our present knowledge in magnetism is the product of several generations. Knowledge certainly is a living and growing phenomenon. We can only grasp a living organism if we are acquainted with its inheritance and upbringing. No one can acquire a valuable scientific knowledge while ignoring how ideas have been achieved. Wolfgang Goethe (1749 – 1832) befittingly wrote: " The history of science is science in its own."...[27)]

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Prof. Dr. Mark De Gier Solms received the Sarton Memorial Medal in 1996 (cfr. Sartoniana vol. IX, p. 99) and was interviewed by Prof. F. Geerardyn and Prof. J. Quackelbeen.

PSYCHOANALYSIS AND NEUROSCIENCES. A PARTICULAR PARCOURS INTERVIEW WITH MARK LEONARD DE GIER SOLMS[1]

Filip Geerardyn and Julien Quackelbeen

Question: Can you tell us of your current professional occupation, what it is that you do and where?

Mark Solms: At this moment I am working in three different contexts, by which I mean clinical contexts. I am working in the division of neurosurgery in the *Royal London Hospital*. There I am involved in the diagnostic work up of the patients, presurgical and postsurgical. I am also involved in the diagnostic work up of neurological patients. And my specific area of expertise in that setting is understanding the neuropathological implications of mental changes. I don't know how much you know about this sort of thing but there is a whole medical specialisation concerning the understanding of the neurological correlates and implications of mental changes in, for example, memory, personality, ability to conceptualise and operate in space, the higher visual functions, the tactile agnosias, all of speech and language, calculation, and so on. All of these different aspects of mental life have specific ways of breaking down with specific lesions to specific parts of the brain, and also to some extent their specific pathological processes, in other words specific diseases. It is not only a matter of anatomy, where the lesion is, but also the type of pathology. You can make a contribution to the diagnostic work up for example of dementing patients by a careful, clinical examination of the quality of the mental change in the patient. Broadly speaking this goes under the heading of behavioral neurology.

Question: You do have some publications in this field?

Mark Solms: Yes, I can give you an example. A particularly fascinating case I published in, I think it was 1988, in the journal *Cortex*, an Italian neuropsychological journal.[2] Well, in fact what happened first of all was when I was examining the patient, I gave him a very complex design to draw for me. It is called the complex figure of...

Question: Of Rey?

Mark Solms: Yes, oh, you know it ? It tells you many things and there are many questions which arise on the basis of how the patient performs on this task, and then you investigate those possibilities further. So this patient did this drawing. Well, depending on what the clinical question is and what it is that you are particularly investigating you would go in one or another direction. I mean, on a test like that the patient can perform poorly for many different reasons. But this patient did not do a particularly unusual drawing. It was more or less what one would have expected from a patient with his lesion, which was a frontal lobe abscess; he had frontal sinusitis, it is an infection of the sinuses in this part of the skull over here and as a result he developed a brain abscess in the frontal lobe, and the surgeons had drained the abscess, and now this was an investigation of how his recovery was proceeding after the operation. And the patient did this drawing which, as you know, is a very complicated drawing. He did it in a slightly haphazard way which is what you expect with frontal lobe lesions. The patients are slightly disinhibited, they have a more lackadaisical attitude to their own performances. And I then asked the patient to draw the thing again from memory.

Question: From memory?

Mark Solms: Yes, which is the typical paradigm with this test. You do not warn the patient that you are going to ask him to do that. I just asked him to draw it, took it away and then said "Now can you draw it for me again". And without batting an eyelid, the patient drew the thing again, the Rey complex figure, but he rotated it through 180 degrees so it was completely upside down and reversed. And when he did this I was astonished because if you try and do that deliberately, especially after brain surgery, it would be very very difficult. And yet he had done this with ease. It was clearly an automatic occurrence. It was not something that he was trying to do. And then from there I investigated the problem further and discovered that this patient in fact experienced episodes in which the entire visual scene was inverted. Perceptually he would see the world upside down, which is a truly remarkable and unbelievable symptom.

And then it was a matter of investigating further the possible causes of this and looking into the literature; and I found 21 or so previous cases going back to 1840-something, with exactly the same clinical picture being described. We know very little about the brain mechanisms involved in the inversion. At the level of the eye you invert the image of what you see and then this is projected in a topographic, an exact topographic relation to the back of the brain. With modern imaging techniques it has been demonstrated that there is an inverse, inverted representation of the image perceived, directly mapped onto your striate cortex. And then something happens to that image in the further processing of it. If you can draw this kind of connection between the conscious perception of the world and the physiological representation of the perceptual process, something somewhere gets reinverted which in this patient had broken down. The most natural inference that one would make with a patient who is literally seeing the world upside down is that it has something to do with these mechanisms. So this paper that I am mentioning to you was an investigation of that patient.

However my most important piece of purely neuroscientific research is a study of the neurological organization of dreaming.[3] I investigated the effects on the dream process of damage to different parts of the brain in 361 patients. This study led me to some unexpected discoveries of which I am really proud! For example, I found that the most important parts of the brain contributing to the psychological processes of dreaming are located in the higher cortical regions — not in the primitive brainstem structures that regulate the physiological processes of REM sleep. In fact I observed many patients with damage to those brainstem structures who continued to dream normally, and conversely, all of the patients in whom dreaming ceased completelly as a result of these neurological illness suffered higher cortical lesions, in the parietal and frontal lobes.

My second field of interest is closely related to that study. Traditional behavioral neurology and neuropsychology such as it has developed since the end of last century is interested in the exploration of the representation of mental functions in physical tissue. Scientists are concerned with the question of how mental functions are represented in the tissues of the brain, a question which has clinical relevance but also enormous scientific implications for us, and philosophical implications for that matter. However, the problem is that have concentrated almost exclusively on higher functions, on what they call higher functions, which from a psychoanalytical point of view means superficial cognitive functions, the conscious functions or preconscious functions at best. Things like language, in the sense that they use the term, which is really the behavioral aspects of language and at most an analysis down to its grammatical structure. And visual perception, recognition processes, visual recognition processes, calculation, spacial reasoning, these sort of things.

Like I said, the problem is that they have always focused only on those higher functions. And I think, together with a number of other colleagues, that there is a need for us to understand more about the deeper aspects of mental life and how they relate to the brain. And there have recently been developments in this direction. People like Damasio, whom perhaps you know, and others are beginning to try and incorporate these aspects of mental life into behavioral neurology, to explore the neurological correlates of deeper mental functions.

Now, this is the second area that I am working in. I am working in a children's clinic. It is a psychoanalytic clinic in fact, traditionally, but it has been a clinic which has always taken on unusual kinds of problems. They have studied, in analysis, blind children, children with severe diabetes, physically handicapped children. This is the *Hampstead Clinic*, or the *Anna Freud Centre* as it is now called. What we have set up there now is a service for children to come where there is any doubt about whether their behavioural symptoms have a neurological component to them or not. Many children with learning problems and with strange emotional difficulties, where the question arises, the diagnostic question in the first instance: "Is there something wrong with this child's brain ?". And we offer a diagnostic service there, contributing to the decision about "is this child's brain normal or not ?" and then as a second step beyond that, by taking some of these patients into analytic treatment.

What we are particularly interested in obviously is the patients in which we find that there is a neurological abnormality, and taking these patients into analytic treatment. This provides us with insights into the psychological consequences and the psychological correlates of their brain lesions in relation to these deeper aspects of mental life. So, we consider not only the diagnostic aspect. Into that same service we are also taking children with known neurological disease, cases in which it is definite that there is a lesion, that there was a tumour or one or another disease process. Mostly we are taking in epileptic children, and we study these children analytically trying to get to an analytic understanding in the classical sense of the word, a truly analytical understanding of what the mental correlates are of that physical disease process. I mention children because it is the children's clinic that I am working at, but my wife and colleague Karen Kaplan Solms and I have done similar studies with adult patients also. And as the developmental aspects belong to a psychoanalytic psychology, it is important for us to study these problems in all ages of the developing mind.

The third aspect is purely psychoanalytic work. At the *Hampstead Clinic* I have private consulting rooms and I see psychoanalytic patients. When I say private consulting rooms in fact I only have very few private patients. Most of the patients that I am seeing in analysis are either derived from these other groups that I mentioned, but also, because I am just recently qualified. I am treating patients from the London Clinic of *Psychoanalysis* which were my training patients and whom are still in analysis with me.

Question: Can you tell us something about the whole of your curriculum. We started with the ending. Could you start with the beginning? You are of South African extraction, I believe. Apart from the name of Mark Solms you also have a few other names. The question has been put to me of how do we actually call him and what do the names in between mean?

Mark Solms: Well, the name of Solms is a very old German name. The first records of my family who originally came from the Braunfels area near Frankfurt in Germany date from 1126. From there the family spread in just that little area: from Braunfels to Laubach and Lich in the north, and in the south down as far as Frankfurt itself. The vast majority of my family still lives in that area, and in fact there is quite a well-known analyst in Vienna, Wilhelm Solms. I do not know if you know him. He was from the branch of my family which was originally in Frankfurt, the Solms-Rödelheim branch. But he now lives in Austria. He is my only relative in this field.

In 1838, two Solmses left Germany. One went to America and one went to South Africa. As you know there were enormous political uncertainties at that time for the aristocracy in Europe. I presume that it was related to these uncertainties that these young men went out to the New World. The one who went to America only stayed there briefly. Apparently his fiancée was very unhappy with the environment and he went back to

Germany. But my family stayed in South-Africa and they remained a very small family in South-Africa. Around the time of the First World War, because of the German colonisation of what is now known as Namibia, a lot of my family were there, because it was a German cultural environment. But others were in South-Africa proper which was at that time a British colony.

So the war in Europe was played out on colonial territory between these two protectorates, the colony of Britain which was South-Africa and the colony of German which was Sudwes Afrika. My family split then at that time between those who supported the English and those who supported the Germans. My branch of the family supported England in the war. So, from that point onwards, from the First World War onwards, my little branch of the family became English speaking whereas the rest of my family in South Africa speaks Afrikaans. There is a white population who predominantly speak either English or Afrikaans; a funny little division. So, that is the story about where my name comes from.

I do not know if you want me to tell you anything of my individual biography, from where I was born. Perhaps it is more my education that you are interested in. Well, the school I went to was *Pretoria Boys* which is in Pretoria as the name indicates. Then I went to *University of Witwatersrand* in Johannesburg, which is nearby. My first degree was in the humanities. I did a bachelor's degree in which my major subject was history of art. And in fact I was particularly interested in African art.

Question: The tribal African art?

Mark Solms: Yes. I think probably the origin of my interest in the history of science comes from that training in the history of art. And it was only then that I moved to the sciences and eventually to the medical school. I was very fortunate to have professor Saling, whose name appears on a number of my early publications, as my mentor, and who interested me in this field which I have been describing to you — the field of neuropsychology. My main experience, and I think which has also been very important for the direction that my work has taken, is that there are such enormous clinical needs in a Third World country like South-Africa, that those of us who had a social conscience about the political situation in South-Africa felt very guilty about just pursuing research interests and just pursuing academic interests.

In various ways, members of my social circle tried to make a contribution to the political struggles that were going on. It was not in my nature to become involved in anything publically political. It was more my nature to make a contribution, more on the human level. So I worked at the *Baragwanath Hospital*, which is the name of the largest hospital in Africa, and in the southern hemisphere. It is in Soweto, just outside Johannesburg. There I saw literally hundreds and hundreds of patients, which is the sort of experience that I think perhaps a hundred years ago physicians like Charcot at the Salpêtrière had. This sea of humanity and an immensely varied clinical experience and exposure to an immense number of cases is a great advantage I think for clinical training. And at the same time in that way I was, hopefully, I believed, making some contribution also on the human level, because I was not paid for the work that I did at that hospital.

I also worked at the *Johannesburg Hospital* in the neurology department and the neurosurgery department, which was the main academic hospital in that area. Then we had a subsection of a teaching hospital, called the *Eden Vale Hospital*, where we had a neurological rehabilitation unit. My wife and I started the work with adults that I mentioned to you earlier at that hospital.

You know if you are working in an acute case setting, you see a patient, you make a contribution to the diagnosis, or to the prognostication, or the post-operative work up or the home management of the case, and then you do not see the patient again, perhaps for a few months, perhaps never again. But in a rehabilitation setting, the patient is living there and you see the patient every day. And you are then forced to recognise that the brain lesion has not just changed the patient's language or just changed their visual perception or just left them with a paralysis: it has changed their whole life. It has changed everything about them as a person. And I think that was a very important influence also on the direction that my research interests have taken, which is that there I was confronted in a very practical way, with having to somehow come to grips with the fact that the entire personality of the patient is affected by a brain lesion. And in trying to understand these patients, we first very naively, not having had an education in this, started trying to apply psychoanalytical concepts and methods to try and get a better understanding of the way in which they had changed. One of the main reasons why I left South Africa was my recognition that there was something about this science, psychoanalysis, which made it very different from for example neurological science. It is not something that you can just learn by working with patients and reading books. One has to undergo an analysis oneself. There was no possibility of that in South-Africa.

Question: What was your first contact with psychoanalysis?

Mark Solms: Well, my first contact with psychoanalysis was again through my mentor, Michael Saling. His father was an internal physician from Berlin who during the war came with the Jewish refugees from Germany to South-Africa which at that time was a British colony.

Question: He came directly from Germany to South-Africa?

Mark Solms: No, his father, Michael Saling's father left Germany in 1938 and went to South Africa and I think he must have had a knowledge and interest in psychoanalysis. And his son who was my teacher, Michael Saling, imparted to me this interest in psychoanalysis that he had, an intellectual interest in psychoanalysis. And the first contacts I had with psychoanalysis were Freud's monograph *On Aphasia* and his *Project*.[4] These were two books that Michael Saling, my professor, recommended to me to read, which he thought were outstanding contributions to neuroscience, the aphasia monograph as an outstanding analysis of the problem of aphasia in itself and the *Project* as an outstanding intellectual masterpiece. And it was through those two works and especially through the *Project* at that time that I thought: "This is something that I have to understand more about." And then I read Freud systematically after that. But we were very isolated out in South-Africa because it was impossible to really pursue a proper education in psychoanalysis. It was just a matter of reading and I read as much as I could.

Question: Do you mean there were no analysts in South-Africa?

Mark Solms: At that time, no. Not at all. Up till 1989 I had no formal education in psychoanalysis.

Question: But there was a possibility to be trained as a psychoanalyst?

Mark Solms: No, that was not possible.

Question: Fritz Perls was not there?

Mark Solms: Fritz Perls... Well, you are going back a long way. Fritz Perls was no longer in South-Africa at that time and also — as far as I know — was no longer a psychoanalyst. But Wulf Sachs came from Berlin, well, from Russia via Berlin — he was analyzed in Berlin — and he moved to South-Africa in the 1920's. And he took a number of people into analysis, including Ann Hayman and Sadie Gillespie who are still currently members of the *British Psychoanalytical Society*. He took five people into analysis and he formed an IPA recognised study group. And they would have then been the nucleus of a future *South African Psychoanalytic Society*. Fritz Perls was a member of this group. But Wulf Sachs died suddenly and unexpectedly, and while all of his patients were still in analysis with him; none of them had yet qualified. So, all of them had to transplant themselves to London in order to complete their analysis and their training. And because of the nature of psychoanalysis which is such a slow process and which you cannot really plan, they said: "Well, I am going to just be here for three years and then I shall go back. I have to just see where it takes me." It happened that these people did not go back to South-Africa. As a direct consequence of Wulf Sach's death, psychoanalysis disappeared in Britain. It is a remarkable fact that in the *British Psychoanalytical Society* — I am not sure how big it is, maybe about 300 members — 18 are South African. Around about 18. Probably it is an oversimplification to say: "It is just because of Wulf Sachs' death". Because of the way in which things then developed in South-Africa after 1948. With the Apartheid government, it became more and more of an unanalytical atmosphere. It was really impossible to function as a psychoanalyst in that society. People who left South-Africa, as they had to in order to train in psychoanalysis, were then able to see what they previously would perhaps not have been able to see, and that made it very difficult for them to go back.

Question: Are things still like this?

Mark Solms: Well, it has been like that until 1987, I think, or thereabouts. One analyst moved to South-Africa. Her name is Aubertin, Katherine Aubertin, trained in Paris, she was a patient of André Green. And just after I had gone to London and had interviews to apply for psychoanalytic training which I did in 1987, or perhaps it was late 1986, somewhere around there, she had just arrived in South-Africa then. She was not sure whether she was going to stay or not. At that time she was just having a look to see if it was possible for her to live there. And I had already started the ball rolling of going to England and so I did do that. But I must mention this, that during that period, for about three and a half years, before I applied for training in London, so in other words from about 1983 onwards, I did have a sort of an analysis. I entered into an analytic psychotherapy with a psychiatrist in Johannesburg by the name of George Warren. He had himself been analyzed by a member of the *British Psychoanalytic Society*, so I had at least an inkling of what psychoanalysis was about and the motivation to want to do more and to have a proper analysis.

Question: A good introduction...

Mark Solms: Yes. I in fact only started my formal analytic education in 1989.

Question: And now you are recognised as an analyst in England?

Mark Solms: Yes, I qualified from the institute in January this year.

Question: I would like to return to your publications. Do you also have typically psychoanalytic publications apart from your historical studies?

Mark Solms: Apart from historical and theoretical studies and translations I published nothing in psychoanalysis. No clinical publications. That is not through lack of interest in purely psychoanalytic matters. It is more out of a recognition out of my not yet being in a position really to contribute. But I hope in future years to do so.

Question: Just harking back to the stoppages in your career..., according to your curriculum I believe you have also been given a number of honours, or should I say research scholarships to perform scientific research. Could you tell us something about that, what the most important are?

Mark Solms: Well, I won a few prizes from my own university. During my studies I was the best scholar on a number of occasions and I won prizes for that but these were not financial prizes, just a certificate of acknowledgement from the university itself. Then I received small amounts of funding, again from my own university. Nothing dramatic. I won one scholarship which was called the *Henry Bradlow Scholarship* which had a financial aspect to it as well. But our university, the *Witwatersrand University*, was also, unlike most of the South African universities, a very socially conscious university and very aware of its position. A lot of the funds of the university which in a European university would have gone to supporting graduate students and young researchers, went towards supporting underprivileged students at the undergraduate level. You know, at that stage, schools were separated between white and black schools and the pupils from the black schools were at an enormous disadvantage. And unless the university did something to help them to come into the universities, then we would just be perpetuating what the government was doing. So most of the resources of our university, then and still now, have gone into the funding of that sort of work. I had to rely on private funding, my own funds first of all. And then when it came to my wanting to train in psychoanalysis I received a very generous scholarship from what is called the *South African Foundation for Scientific Study and Research* which is a private foundation endowed by an industrialist who himself underwent an analysis in his youth and who felt immense gratitude to psychoanalysis for what it had done for him. So that foundation gave me a research and study grant which enabled me to move to London. Since then I had funding from the *Simenauer Foundation* which is again a private foundation that was endowed by a German analyst. Presumably for historical reasons he wanted to leave his money to the *British Psychoanalytical Society* rather than to German societies. That was a very large grant that he gave to our institute and they gave some of it to me. The other research funding that I have had has been from the *Freud Literary Heritage Foundation* in New York which is chaired by doctor Kurt Eissler.

Question: How did you arrive at the whole collection of the so-called pre-analytic writings? How did you come to assume or receive this assignment?

Mark Solms: Well, I think that was in quite an amusing way. I read Frank Sulloway's book, probably in about 1980 or 1981, and there is a footnote in that book in which he mentions that Freud's pre-analytic writings as he called them, are going to be published at last and that was going to make an enormous difference.[5] So I looked into his bibliography at the back of his book, because at that stage I was developing an interest in psychoanalysis from my own background in neurological sciences. And I had read Freud's *Project* which my professor had recommended to me and I had read the aphasia book. I thought: "Well, I want to read more". And so, here was a collected edition of Freud's neurological writings, so "let me get it". So I looked in the bibliography and I saw to my disappointment that it was not yet out and that they did not give a date. It was forthcoming, still to be published. But at least it mentioned that the *Hogarth Press* was the publisher. So I waited patiently until about 1983, but it never appeared. I kept on asking my local academic bookseller to keep an eye out for this and as soon as he saw the announcement he was to let me know. But it never came. So eventually I wrote to the *Hogarth Press*, and John Charlton was a director, the director responsible for Freud editions, and I asked him when this edition was going to appear, and told him that I was getting impatient. He told me then, which I did not know being out in South-Africa, that the editor Erwin Stengel, the editor of that edition, had died and he had not completed it, and that they had abandoned the idea of doing it. And it is not surprising to me that they had to abandon the idea of doing it, first of all because I have subsequently seen Stengel's material and it was very far from ready to be published as a proper scholarly edition of Freud's neurological writings, but also if you do not have somebody like Erwin Stengel who was an analyst and a neurologist and who has knowledge of German and of English, it is very hard to continue the work. There really are very few people who have those basic necessary qualifications. I said to John Charlton that I would be very grateful if he would let me have a look at least at what Stengel had done, because this area was of particular interest to me, given the direction that my work was then beginning to take. At first he was anxious about letting me see this material. And so I gradually got to know him and went and saw him in London and spoke to him about this. And the idea gradually developed from me being a potential buyer of this collected series, to my taking over the responsibility of editing it. And so they gave me all of Stengel's material. And then at the same time I became aware of the fact that Paul Vögel in Frankfurt had been working also on an edition, a German edition of Freud's neuro-scientific works for *the Fischer Verlag*. He was also a neurologist. He was not a psychoanalyst but he was very admiring of Freud and, again like me, he had come to know Freud through his neurological writings. He wrote a number of papers on Freud's *On Aphasia* in which he pointed out to neurological audiences the great value of this work. He also had died before he could finish the work. In fact he lost his eyesight and so he could not complete it and then he died. *Fischer Verlag*, on hearing that I had now taken over the project in London, proposed to combine forces with us and I took over the project for them too, and we turned it into a single project. So all of professor Vogel's work was made available to me also. So I had a leg up from then onwards to be able to continue the work with the foundations at least having already been laid.

Question: So you are now the editor, both of the German and the English editions?

Mark Solms: Yes.

Question: How is the job getting on ? You announced it for 1999?

Mark Solms: Yes. As I have said, the work that was done by my predecessors was made available to me. So I think that when you date what I have been doing, the time span that I am working in is not what would otherwise have been the case. I did not have to start from scratch. I already had this material to begin with. And in the case of the German edition, that was quite considerable material. For example, the entire anatomical works and the entire cocaine papers, had already been edited by Vogel and by his assistant, Frau Ingeborg Meyer-Palmedo, who had done a lot of work tracing all the sources, copying them, checking the quotations and that sort of thing. And that has been over years. I mean, they had been working since the 70's. And so was professor Stengel in London, working since the 70's. I formally took on the project in 1989. I signed the contracts with the publishers and began the actual work. There was a lot of spade work that I had to do because a lot of material had been discovered since then, since Stengel and Vögel had been working on it. A lot of new material had been discovered; I had to collect all of that together and there was also work which both of them had not been aware of and which I had to get. These really are very obscure publications, many of them. Inevitably the last ones are the most obscure and the most difficult to get. And I also had very complex contractual negotiations to get through, which sounds like something which is peripheral to a project of this sort but in fact it is a big part of the reality of trying to do a scholarly edition of Freud. It is a minefield of legal issues, copyrights and other complexities. There is material that is restricted, there is material that is held and copyrighted by one person, other material by another person and different publishers... I spent nearly a year on just dealing with that sort of things. And by 1990 I started actually doing the translations and the editing. At this point now, in 1995, I have completed the first translation of everything. So I now have an English translation of the entire works and I have editorial notes that I have been taking as I have been going along. Of course I have also had to collect the vast literature on Freud's neuroscientific works. That is actually a very big body of literature, which I have had to collect in order to be able to compile the editorial introductions and the footnotes. Now at this point I am about to start back from the beginning again, to improve on the translations, to make final corrections and then to work up the editorial apparatus, and it is that that I am expecting to take another four years to complete. So that is where things stand. Recently I have also been asked to take executive editorial responsibility for a forthcoming revised edition of the 24-volume *Standard Edition of the Complete Psychological Works of Sigmund Freud*, so that has impeded my rate of progress on the *Neuroscientific Works* as well.

Question: What, of all that you have done so far, do you consider the most important ? If, say, you had to present someone with your three most important publications, studies, merits, what would these be?

Mark Solms: Well, I would have to say that my most important work has not been done yet. I am in a position at this point to know what I am going to be doing in the next few years, because of course I have started on all of this. And I think that the most important work is first of all what we have been discussing: Freud's neuroscientific writings, the publication of these works, and incidentally I must mention that although they will appear in simultaneous English and German editions, French and Italian editions have also been agreed. The *PUF* are doing the French edition and in Italy it is *Borrengeri* who is doing the Italian edition. And there are scholars who are beginning to work on that. They will be translating my editorial work into their languages and obviously the Freud texts too. I think that this is not only going to be important historically, to have this information and these works available. I think it can have an impact also on the status of psychoanalysis now and on the future of psychoanalysis. I think if we have a better understanding of where these concepts come from and how they relate to neurology.., which is not a simple matter... but Freud was very well aware of the complexities and he thought very deeply on these problems, and this comes out from these neuro-scientific writings, one can see. I think, I hope that this will stimulate an interest in the relationship between psychoanalysis and neuroscience and in that way contribute to the scientific development of psychoanalysis in relation to these problems. The situation is very different in America from what it is here in Europe. I think that psychoanalysis is in quite a serious crisis in relation to developments in the neurological sciences in America. And I am hoping that by making these works available in English, especially in America, we can prevent too crass and too quick an answer of how we can relate psychoanalysis to neuroscience, which I think is the way things seem to be going in America, where it has been heading in a direction which is very detrimental to psychoanalysis. I am hoping that by introducing the complexity of Freud's vision of these things into that debate in America, I am hoping that this will reinvigorate a proper psychoanalytical understanding of these problems, and in that way influence research directions in America. Mentioning America, I think that relates to the second most important work that I am doing. Since 1993, I have been going to New York once a month. We have a research group there, it is at the *New York Psychoanalytic Institute* and it is called the *Neuroscience Research Group*, headed by doctor Arnold Pfeffer. I have been meeting with this group monthly and presenting lectures to them on the relationship of psychoanalysis to contemporary neurological science. How can we, as psychoanalysts, understand and make use of current advances in neurological science ? What is the meaning of all of this to us ? How can we assimilate it ? Should we be assimilating it ? If so, what aspects and in what ways should we be assimilating all of these enormous developments which I really think, in spite of all of the problems with them from our point of view, psychologically and psychoanalytically, I think that there can be no doubt that there have been enormous advances in our knowledge. I think if psychoanalysis is going to remain at the vanguard of thinking in mental science, we have to somehow take account of these developments. And by being invited to give these lectures in New York, I was given the opportunity to consider these problems. First of all I gave a series of 8 lectures, starting in, I think it was September 1993.

When you ask what is one of my most important works, I think this is one of my most important works, but it is only going to appear in print in about 1997. Each lecture deals with a different part of the brain, considering it in relation to psychoanalysis. What do we know of this part of the brain, what does that mean to us in psychoanalysis. The last lecture is a view of the brain as a whole in relation to psychoanalysis. But also in that lecture series I have discussed methodological problems and historical problems and so on. Those will be published in a monograph series by the *Journal of the American Psychoanalytic Association*. In that series only four monographs were published and they stopped it in the early 1960's. Now they are restarting the series and these lectures will be the fifth monograph in that series, published by *International Universities Press*. And that will come, hopefully in 1996, but probably only the next year.

If I can mention a third thing, I think that the third most important work that I am involved with is the work arising from what I mentioned we started in South-Africa already, that is conducting actual psychoanalytical investigations of patients with damage to different parts of the brain. Using a psychoanalytic method to understand these patients opens a whole new world, to be able to really appreciate what the internal life of these patients is like. It is absolutely fascinating. But I think also scientifically that is a very important direction for us to go in, in order to be able to, on a rational basis, understand how our concepts, in all their complexity and subtlety, how they relate to the tissues of the brain. And as I was saying in the discussion after my lecture yesterday, I think that these case studies are the beginnings, I would hope, of a new research trend in psychoanalysis. Now those case studies I am publishing also, together with my wife, who saw most of those patients. In fact I saw only a few of them, she saw more of them than I did. That will be published by *Karnac Books* in London and *International Universities Press* in New York, but we are still busy editing those.

Notes

[1] On the occasion of the *International Conference on Freud's Pre-Analytical Writings* (1877-1900) at Ghent University, 12-15 May 1995.

[2] M. SOLMS, K. KAPLAN-SOLMS, M. SALING, P. MILLER, Inverted Vision after Frontal Lobe Disease, *Cortex*, 1988, 24, pp. 499-509.

[3] M. SOLMS, *The Neuropsychology of Dreams: A Clinico-Anatomical Study*, Lawrence Erlbaum Associates: in press.

[4] S. FREUD, *Zur Auffassung der Aphasien. Eine kritische Studie* (1891b), Frankfurt am Main, Fischer Verlag, 1992, 168 pp. [English translation: *On Aphasia. A Critical Study*, New York, International University Press, 1953, xv + 105 pp.] S. FREUD, Entwurf einer Psychologie, (1950c), G.W, Nachtragband, 1987, pp. 373-477. [English translation, Project for a Scientific Psychology, S.E., vol. I, pp. 281-387.]

[5] F. SULLOWAY, *Freud, Biologist of the Mind*, London, Burnett Books, 1979, 612 pp.

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