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Review Article

Max von Pettenkofer (1818–1901) as a Pioneer of Modern Hygiene and Preventive Medicine

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Abstract

Max von Pettenkofer (1818–1901) belonged to the scientific elite of the 19th century. With his stringent search for the laws of nature and his fight for scientific truth, Pettenkofer was the prototype of a modern researcher. In the field of hygiene, he sought ways and means of preserving health and preventing sickness. With his consistent application of the experimental method to the field of public health, Pettenkofer helped the discipline of hygiene to provide precise and reliable answers to sanitary questions. In his experimental work on hygiene, Pettenkofer sought an answer to every imaginable question concerning the connection between the human organism and its environment.

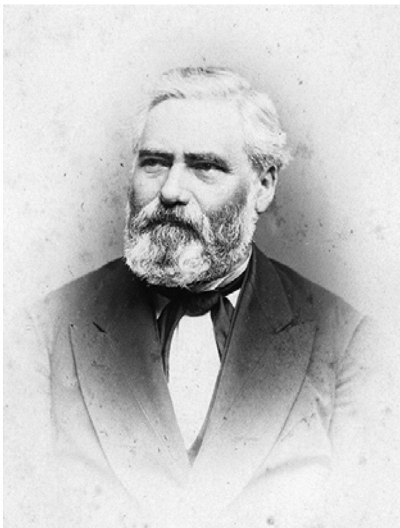
To proceed in this direction, Pettenkofer combined medical expertise with physics, chemistry, technique and statistics. This even today modern "crossover-thinking" made hygiene to the first interdisciplinary medical field. With his Institute of Hygiene, Pettenkofer established 1879 the first centre of competence for hygiene and environment in the world, opening a new era of environmental observation.

In the framework of hygiene, Pettenkofer turned also to questions of nutrition and the quality of foodstuff. The science of hygiene owes to Max von Pettenkofer not only its development and cartography, but also its introduction as an academic discipline. Finally he regarded hygiene also as an economic and cultural feature. His idea about a clean soil in the cities and his promotion of adequate water supply and sufficient sewage networks are linked to his theory of the cholera. Pettenkofer believed that a battle against this epidemic could be won.

Key words: Max von Pettenkofer, Japan, hygiene, cholera, preventive medicine

Max von Pettenkofer belonged to the scientific elite of the 19th century, and he was the prototype of a modern researcher (1). The treatment of individual patients or medical repair work on the sick human organism was not Pettenkofer's goal (2, p. 11; 3, p. 47). From early on he showed a tendency to perceive medical concern for the individual patient in a more general frame of reference.

In the field of hygiene, Pettenkofer found a challenge in keeping with his general concept of medicine, which was not centred on individuals. Pettenkofer did not wait for disease to occur in order to cure it. He sought ways and means of preserving health and preventing sickness. Of course, under the concept of medical policing this task had been recognized already since



Max von Pettenkofer photographed by J. Albert 1872.

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the end of the 18th century. But Pettenkofer turned this former administrative and judicial policy approach into modern hygienic science (4). He gave public hygiene a contemporary methodological consciousness and a modern research instrument.

Hygiene as the first interdisciplinary medical field

Pettenkofer believed that for modern public hygiene, physical, chemical, physiological, technical and statistical findings and facts were essential. Pettenkofer once said, "a physicist who has also seriously studied chemistry and physiology is better suited to teach and research in the field of hygiene than a practical doctor" (4, p. 9). Pettenkofer himself was fascinated by chemistry which he made to the centerpiece of his scientific thought. Pettenkofer had studied pharmacy and medicine at the university of Munich, but he always thought of himself as a medically trained chemist (4, p. 9). Pettenkofer's highly developed understanding of medical-chemical interconnections also formed the basis of his research work in the field of hygiene.

With his version of hygiene, he established the first truly interdisciplinary specialty of medicine. Thus, Pettenkofer is justifiably considered as a pathfinder and pioneer of modern hygienic science. With his consistent application of the experimental method to the field of public health, Pettenkofer helped the study of hygiene produce reliable knowledge. Exactly for this great merit, in 1897 Pettenkofer was awarded with the golden Harben Medal by the British Royal Institute for Public Health (5, p. 190).

For Pettenkofer it was clear that knowledge is the best basis of prevention (6, p. 99–104). In his fundamental research Pettenkofer was concerned with achieving a better understanding of human health. In doing so, Pettenkofer concentrated his thoughts above all on the connections between the human organism and its complete surroundings. For Pettenkofer researching this formed the basic requirement for the successful prevention of disease.

Consequently he insisted that the individual's personal precautions, familiar since antiquity, should be supplemented by arranging the worlds of life and work and the environment to promote health. In his eyes, bad air, unclean water, poor nutrition and unhealthy clothing were to be avoided as much as excesses in ones life style, in order not to become susceptible to illness (7, p. 468–482).

Hygiene—old tradition in scientific terms

That environment and living space influence the health of human population was already suspected in earlier times. In classical Antiquity almost, 2500 years ago, physicians first pointed out factors which must be considered in order to understand good health and illness: besides individual hygiene, life style and nutrition, these included—according to a well-known text in the Hippocratic Corpus—things such as soil condition, climate, water and air. In the classical age, both physicians and the general population were aware of the connection between the physical composition of ground and water, the available food, clothing and living quarters on the one hand, and health risks on the other (8, p. 1). Pettenkofer tied to this old tradition of knowledge.

One would assume that something so obvious had long been studied thoroughly. But on closer examination, Pettenkofer realized that no one could give clear answers to the simplest questions about physiological causal relations. In many of these things, such as the function of clothing for example, the investigators of nature and physicians knew no more than what any layman considered to be common sense (9, p. 180).

What are the real relations between the human organism and its environment, in concise scientific terms? Pettenkofer adressed this question with a keen flair for hygiene. Consequently, it was possible to develop the foundations of an effective preventive approach for dealing with illness and epidemics. Pettenkofer's research into health was not only of immediate use to individuals, but also of potential and long-term benefit to all humanity.

With foresight, Max von Pettenkofer once said, "it is a peculiarity of hygiene, to change its field of research and, within certain limits its field of study, according to time and circumstances" (10, p. 934). Thus, Max von Pettenkofer expressed a feature of our modern school medicine as taught at universities, namely that it is adaptive and research orientated—in contrast to many alternative systems of healing, for example. Hence, Pettenkofer made hygiene receptive to new trends such as work and school hygiene, which became new fields of hygiene and prevention in 1900 (6, p. 104). Whilst Pettenkofer was primarily concerned with the influence of natural factors on human health, the living conditions created by humans themselves came to the fore later, in the 20th century. Behind the term social hygiene stands the insight, that to no lesser extent, social affliction also benefits the spread of disease and bacteria.

Hygiene as an academic discipline

The science of hygiene owes to Max von Pettenkofer not only its development and formation, but also its introduction as an academic discipline.

In 1865, Pettenkofer's efforts led Bavaria to integrate the subject of hygiene into the study of medicine. At all three Bavarian universities Professorships were created for this new compulsory and examined subject. Pettenkofer himself was appointed to the newly created chair for hygiene at the University of Munich (11). Bavaria thus became the first country, in which medical students were consequently educated in sanitation and public health. The first professorship for hygiene was established 1860 for Edmund Parkes (1819–1876) in England, but this was at the Army Medical School in Southampton and not at an university. 1882 hygiene became an examination subject throughout the entire German Empire. Soon no university in Germany was without an institute of hygiene.

For systematic research and teaching on public health issues, Pettenkofer received 1879 his own institute of hygiene (12). Pettenkofer's research and teaching institute, unique in the world at the time, was a model to many other countries. For example, the Hygiene Institute in Munich was the impulse for the founding (1917) of the now world-renowned Johns Hopkins School of Hygiene and Public Health in Baltimore (13, p. 57). With the Institute of Hygiene Pettenkofer established the first centre of competence for hygiene and environment in the world, opening a new era of environmental observation. Top research and practical application were imparted simultaneously under the same roof. The worldwide attraction of the research institution Pettenkofer had created and the fact that many of his students later held professorships or faculty positions in hygiene testify Pettenkofer's wide-reaching influence.

Scholars from Japan

In the past Max von Pettenkofer certainly also contributed greatly to the medical dialogue between Japan and Germany. At the end of the 19th century, a number of young physicians from Japan made a pilgrimage to Munich in order to learn about modern hygiene. At times the Japanese even made up the largest group of foreign guests and researchers at the Institute of hygiene in Munich.

One of the first from the Far East was Masanori Ogata (1845–1919), who returned to Tokyo in 1885 and received a position at the university as well as being in charge of the public health authority (14; p. 151, Letter of Ogata, dat. 3.1.1885). At the University of Tokyo he founded the Institute of Hygiene, which at the School of Medicine now is the Department of Molecular Preventive Medicine. Ogata, also a member of the High Medical Council since 1892, represented Japan at the 1897 International Congress for Hygiene in Moscow (14; p. 208, Letter of Ogata, dat. 11.8.1897). Ogata then organized special courses in hygiene for district doctors in Japan, modelled on the Munich hygiene courses for prospective doctors (14, p. 192, Letter of Ogata dat. 20.6.1892). Ogata occupied himself extensively with the Japanese illness known as "kakke", Beri-Beri (14; p. 158, Letter of Ogata, dat. 25.5.1887). As other members of the University of Tokyo, Jiro Tsuboi and Nakahama were also responsible for spreading Max von Pettenkofer's ideas in Japan (14; p. 163, 174, 181, 186, 190, Letters of Nakahama, dat. 27.4.1888, 1.10.1889, 31.7.1890, 21.5.1891 and 1.1.1892). About 1890, Jiro Tsuboi studied in Munich the "natural ventilation in buildings" (15). Nakahama, for example, founded a research department in 1890 in Tokyo for testing "ground water, humidity, temperature, rainwater etc" (14; p. 182, Letter of Nakahama, dat. 2.9.1890). After graduation at the Tokyo Medical School and while belonging to the Japanese Army, also Mori Ogai (1861–1922) was sent 1884 to Germany to study Hygiene under Pettenkofer. Mori later became Surgeon General of the Army and made especially a great literary career (16).

Hygiene as a field of research

As mentioned before, in his experimental work on hygiene, Pettenkofer sought an answer to every imaginable question concerning the connection between the human organism and its environment. This included such topics as the quality of air and drinking water and the influence of soil on the spread of disease; the hygienic value of cultivating indoor plants; the function of clothing and cleanliness at home and on the street; the ventilation and heating of rooms and so on (12; 17; 18).

As I have already stated, these questions were not entirely new. Before Pettenkofer there had been a whole series of people, who had contributed to the progress of healthcare, in Germany, above all in France and England, where an active sanitation movement had formed around 1830/40 (19; 20; 21, p. 142–143; 22, p. 413–415). In particular England with its practical tradition of hygiene was an inspiration and a role model to Pettenkofer in this field (23, p. 26–27).

Pettenkofer did not invent hygiene. But it is evident that Pettenkofer pioneered the production of reliable knowledge in the field of hygiene using the consistent application of experimental methods. With his hygienic experimental work he gave an exact scientific basis for action previously taken for purely intuitive reasons or considered sensible on empirical grounds.

Thus, Pettenkofer is connected with the modern breakthrough in hygiene and prevention, and in this way Max von Pettenkofer became the "father of modern hygienic science"—as the German Imperial Health Office once called him (Letter of condolence to the Bavarian Academy of Science, dat. Feb. 13, 1901, Berlin; quoted from Münch. med. Wschr. 48, 324 (1901)). In 1897, the Royal British Institute of Public Health awarded Pettenkofer the golden Harben Medal "in recognition of the eminent services he has rendered to the cause of Public Health" (Institute for the History of Medicine, Munich: Pettenkofer Archive 3.4. Letter of the Secretary of the Royal Institute of Public Health, London, to the German Ambassador, dated 19.7.1897).

Pettenkofer's teaching programme

The standard gauge for Max von Pettenkofer's hygiene syllabus was the knowledge that: a healthy life involves clean air, clean water, clean ground, good clothing, a healthy dwelling and good nutrition.

In Pettenkofer's eyes maintaining clean air was one of the most pressing tasks of healthcare. Consequently, in Pettenkofer's practical courses in hygiene one learned that the air must be accurately analysed physically, chemically and microbiologically. Temperature, air pressure and water content were taken into account. With the help of psychrometers and hygrometers, absolute and relative humidity, saturation point and saturation deficit were established. Meteorological observations such as measuring rainfall as well as wind direction and strength completed the picture. Dust particles in the air were examined microscopically with cultures of nutrient solution. Chemical analysis of the air included oxygen, ozone, nitrogen, carbonic acid and carbon dioxide as well as a number of impurities in gas form (12, p. 16–17).

For the quality of indoor air, ventilation and heating were of particular significance (24, p. 104–110; 6, p. 37–74). To study ventilation, rooms were measured and the space and ventilation requirements were calculated. The ventilation size of a room with artificial ventilation was established using an anemometer and in buildings with natural ventilation by measuring carbonic acid (12, p. 17). According to Pettenkofer, the fuller or smaller a dwelling or room is, the greater the necessity of cleanliness and air exchange (24, p. 107–112; 6; 23, p. 36–37).

A product of Pettenkofer's extensive investigations on room climate, the so called "Pettenkoferzahl" (Pettenkofer number), is still used today to assess indoor air quality. Pettenkofer's idea was to use carbonic acid as a benchmark for measuring how hygienic the air in a room is (6, p. 63). It is probably hard for us to imagine today, the air quality in city houses 150 years ago. The fumes from the kitchen and oven, the smell of waxed floors, the stink of all kinds of refuse, the accompaniments of human waste disposal—all this got into the dust filled air in rooms. Pettenkofer discovered and proved that the air in dwellings, schools, lecture theatres, public houses and other localities was a far cry from the atmospheric air quality (24, p. 560–564). Whilst searching for a benchmark for the comparison of indoor and outdoor air quality, it occurred to Pettenkofer that the presence of carbonic acid in both could be easily measured using methods he had himself developed. Through his investigations he discovered that the CO_2 content of the air in many of the places mentioned was more than 0.71%. In the atmosphere only 0.05% carbonic acid were found. From this Pettenkofer derived 0.1% CO_2-concentration a useful standard for good room air (6, p. 63). Carbon dioxide levels served him as a measure of the volatile organic material released by humans (25, p. 319). By taking up questions of interior hygiene, Pettenkofer fortuitously became a precursor of building physics (26, p. 2).

Just as important to Pettenkofer as "clean air" and "good living conditions" was "water quality". Pettenkofer often said: "I myself am a drinking or clean water fanatic" (27, p. 32). According to Pettenkofer, dirty water could, like contaminated air, bad nutrition, unhealthy clothing or individual excesses, disturb the physiological processes in the human body, making an individual more susceptible to disease (28, p. 61). Therefore, Pettenkofer gave the "examination and assessment of water" highest priority. He taught how to take water samples correctly and physically examine water for clarity, colour, temperature, odour and taste. A microscope was used to detect suspended particles. Following a physical examination, water was analysed chemically: qualitatively for chlorine, nitric and nitrous acid, sulphuric acid, lime, magnesia, Ammonia, hydrogen sulphide and metals. Quantitatively, the presence of residues, organic substances, chlorine, nitric acid, ammonia and the hardness were tested. The training programme also included the filtration of drinking water (12, p. 18).

For Pettenkofer, part of the development of a healthy environment was the so-called sanitisation of the soil. In Pettenkofer's opinion, the soil played a significant part in the spread of epidemics such as cholera for example (29, p. 106–110). The examination of soil was thus a principle item in Pettenkofer's hygiene training. On the one hand, natural soil was tested in situ: the surface, form, vegetation and behaviour with water were described. Aspects of ground water relevant to building technology or epidemiology were assessed. The soil temperature and its air, carbon dioxide, water, and fungus content were measured. On the other hand, soil samples were examined using following parameters: porosity, grain size, water content and water capacity, permeability to air and water, absorptive and condensation capacity and the extent of soil contamination (12, p. 18).

Besides dwellings, according to Pettenkofer clothing was also one of mankind's most important inventions (9; 6, p. 3–36). Clothing made it possible for humans to live in all latitudes and spread all regions of the earth. Clothing was the weapon with which humans fought against, and according to Pettenkofer, subdued the atmosphere (11, p. 17 and 35). To understand the physiological significance of our clothing and its interaction with the skin, he examined clothing material microscopically and analysed its physical properties (12, p. 20). This also included searching for poisonous dyes in the clothes. For example, on behalf of the Bavarian Army, Pettenkofer tested anilin blue and black dyes used for military clothes. As it was free of arsenic, Pettenkofer gave its use the green light (30, p. 47).

Nutritional research and security of foodstuff

In the framework of a hygiene understood as encompassing all factors influencing human well-being, Pettenkofer turned also to the daily menu of the people and to questions of nutrition. Together with the chemist Justus von Liebig (1803–1873) and the physiologist Carl von Voit (1831–1908), he was one of the founders of the Munich School of Metabolic Research (31). Pettenkofer's experimental chamber from 1861 for analyzing the exhaled air of human beings was a technical masterpiece (32). It made reliable and accurate quantitative determination of the carbon dioxide in exhaled air possible for the first time (33). Thus in turn meant that, the consumption of fats and carbohydrates in the human organism could be calculated.

Over decades Pettenkofer's measuring procedure remained the system of choice when analysing carbon dioxide in exhaled air. And the results obtained by the so-called "respiration apparatus" provided metabolic research with a solid foundation for scientific nutritional planning. Thus the analysis that Pettenkofer conceived played a key role in the examination of human metabolism (33; 34).

Eventually this research path led to the calculation of costs not only for individual people, but also for patients in hospitals, for the inmates of prisons, for soldier's provisions and also for the dishes served in canteens. Pettenkofer and Voit calculated that a body weighing 70 kg requires nutrients with a caloric value of about 3100 calories each day. This information became known as the Voit-Pettenkofer figure in metabolic research.

But Max von Pettenkofer not only helped modern nutritional research get started, he also looked at the quality of foodstuffs. Successfully he worked for the establishment of control units. As the first Director of the Royal Testing Institute for Food and Drugs, which was founded in 1884 in Bavaria, Pettenkofer made the examination, looking at quality, extraneous additions or adulterations of meat and other stuffs, an important function of hygiene.

Nutrition and the "examination of food" thus belonged to Max von Pettenkofer's hygienic training programme. The components of food and beverages were studied, as well as their alteration through commonly used methods of preparation in kitchens. The methods of conservation were analysed, encompassing the effects of temperature, the importance of airtight seals and water extraction as well as the effects of so-called antiseptic substances. Additives, falsifications, impurities and counterfeits were detected in meat, vegetables, milk and other liquids such as wine and beer (13, p. 19–20).

Pettenkofer as communicator

Max von Pettenkofer had great expectations of hygiene and prevention and consequently demanded a new hygienic environmental consciousness. In principle however, all research had to and still does assume that we cannot guarantee specific results in advance. This also applied to Pettenkofer. As a result, Pettenkofer's abilities as an enlightener and communicator were all the more important.

Pettenkofer demonstrated great ability as a propagandist of his ideas (35). He was not only able, to persuade public decision-makers that his concerns were justified in essential points. In a large number of popular lectures (6; 23; 24; 36) and articles (37–39) he also addressed medical laymen and performed educational work dealing with questions of hygiene. With an extraordinary talent for conveying specialized scientific content in easily understood form, he provided his listeners with a clear picture of a health-promoting lifestyle and encouraged people to modify their behaviour.

In his attempt to make his ideas generally understandable, Pettenkofer realized very early on how significant the problem of communication between experts and society was; a problem that is making itself felt again today in connection with technologies that seem threatening. Pettenkofer knew the goal could not be to make laymen into specialists. But, as Pettenkofer once explicitly noted, to gain the trust of the public, experts must help the population comprehend our world (6, p. 3–4).

Max von Pettenkofer's importance in this respect cannot be overestimated. By publicly addressing commonly held views about natural processes and the connections between disease and our environment, Pettenkofer sensitized the public to environmental problems—to express it in a modern way. In doing so he created the social conditions in which official policy makers could make decisions based on and in keeping with the approaches to solutions which he elaborated.

Hygiene—as an economic and cultural feature

Looking ahead, Pettenkofer realized also the great economic value of public health. He liked to present health problems to the public in terms of economic criteria. In analogy to the discipline of National Economy, he saw in hygiene a kind of "Economy of Health" (2, p. 127; 23, p. 3–10).

For example, he noted that Christian and humanitarian motives were not the only reasons why a community should care about the illness and health of its citizens. According to Pettenkofer, the health of a populace was also a form of capital that produced a high rate of interest. Pettenkofer presented public calculations of the final value of health for the citizenry of a city like Munich. In his cost-benefit evaluation he balanced the expenditure for preventive measures against their usefulness to society and viewed the investment in preventive measures as capital which would gain in interest (23, p. 3–4, 23–44; 18, p. 169–170).

Pettenkofer saw a society's endeavours in the field of preventative health care as a measure of its ability to "play a role in cultural history" (23, p. 3–4). However, the improvements in living conditions Pettenkofer had in mind were never ends in themselves. He simply regarded health as indispensable for the individual's and society's ability to perform. Pettenkofer once stated that the value of our lives depends on our ability and our achievements (23, p. 3–4).

Fighting cholera

As a pioneer of hygiene and preventive medicine, Pettenkofer can not be understood without mentioning his battle against cholera (40). Many of Pettenkofer's most important ideas are linked to cholera, for example his ideas about a clean soil in the cities, his promotion of sanitary reforms, adequate pressurized water supply, and a sufficient sewage network.

Since the second decade of the 19th century Asian dysentery swept rapidly across Europe in several pandemics, spreading fear among the population. In the eighties of the 19th century, even in Japan the people trembled before the epidemic. As a rule 50% of the patients did not survive the illness. Today we know that the cholera pathogen is present in the infected person's stool and that the disease is passed from one person to another through contaminated food or water. The cholera pathogen, the comma bacillus discovered in 1883 by Robert Koch (1843–1910), produces an enterotoxin in the intestines, responsible for all the pathological changes. When Pettenkofer began to study cholera in the mid 19th century, there was great perplexity as to the origins and transmission of this epidemic (41, p. 576–578; 42, p. 330–331).

One group of experts pointed out that cholera spread along the trade and traffic routes, and advocated the theory, that it was contagious. These so-called contagionists said the disease spread through a specific infectious cholera germ that was transmitted either directly or indirectly from those suffering from the disease to healthy persons. Other specialists believed that a cholera poison had its origins outside the body of the ill person. The adherents of this miasmatic theory, as it was called, denied any connection between the spread of the disease, on the one hand, and trade and travel, on the other. They had observed that within the areas affected by the epidemic, many places remained cholera free. For this reason they held the awesome disease to be non-contagious. In the opinion of this so-called miasmatic theory, poisonous earth vapours or rotten fumes or the odour of decay from swampy ground and other sources were responsible for cholera. The epidemic was thus not transmitted by the ill but arose from local conditions.

In fact, the assumption that vapours from rotting material or from the earth were responsible, offered a plausible explanation for the regional and local differences in the occurrence of cholera. However, this theory (sometimes known as localism) provided no answer for the undeniable geographical spread of the epidemic along the trade and travel routes. The contradictions appeared unsolvable. Being a genuine researcher, Pettenkofer regarded it a personal challenge to overcome the existing contradictions and uncover the real truth about the cholera (29, p. 99).

Based on his own epidemiological data, Pettenkofer interpreted the facts as indicating the existence of a cholera germ that bred in the patient's intestine and spread by means of human excrement, but was not contagious. He believed that this germ was incapable of triggering an epidemic by itself, but when combined with certain putrescent materials existing in the soil it produced a highly infectious agent that caused the cholera. Pettenkofer thus developed a cholera theory with no internal contradictions, which, in contrast to previous views, could explain all known facts in one unified etiology. While the uninfectious cholera germ carried the disease from place to place, the actual transmitting material or the true infectious substance was a product of the soil. This could explain why certain places remained free of cholera, even though they lay on the route of the epidemic (29, p. 99–100).

According to Pettenkofer, the process decisive for the spread of the epidemic took place outside the human body, in the ground. Pettenkofer described this process in the soil as a kind of chemical maturing driven by decay and fermentation organisms. But this reaction under the surface required a nutritive solution derived from the organic wastes that ended up in the ground every day. Accordingly, he recommended that the ground be made infertile for maturing the disease's germs. In other words, this meant cleaning the waste material out of the soil. Thus, the goal of a well-considered health policy would have to be to bring enough clean water into the cities and drain waste water away by building new, efficient sewage systems. In this way the ground could be cleansed, protecting people from the dangers of cholera (29, p. 110).

Since there is often confusion about this point, I should like it to be understood: In contrast to English experts of hygiene like John Simon (1816–1904) and John Snow (1813–1858), Pettenkofer believed that it was not drinking water itself that could trigger a cholera epidemic, but rather the huge amounts of water used domestically and industrially, which contaminated the urban soil, thus creating the precondition for the production of the cholera poison in the ground (18, p. 171–173; 29, p. 110–113). Pettenkofer clearly stated that consuming about two liters of drinking water a day could do no harm, due to the disinfecting power of the human stomach.

Nevertheless, as we have seen, Pettenkofer argued for good drinking water. But his arguments were very different from those based on the contagionistic view. Bad drinking water only disturbed the balance of physiological processes, but did not cause an epidemic infection. Pettenkofer obviously underrated the role of drinking water in the spread of an epidemic like cholera.

From a dead end to a golden path

Pettenkofer's plea for clean ground led a number of cities to undertake a series of sanitary reforms (18, p. 169–170; 29, p. 113–115). A sufficient supply of adequately pressurized water was installed, creating the conditions for the type of water closet Pettenkofer often recommended. A capacious and efficient sewage system ensured rapid removal of wastes and faeces, thus eliminating soil contamination and thus protecting people from the danger of cholera. However, this ambitious scheme of cleansing the soil stretched public spending to the limit. Cities had to run up considerable debts whilst house and landowners were required to pay huge connection charges. Consequently, the new hygienic and extremely expensive measures also found numerous opponents. But with his great reputation as scientist, Pettenkofer could explain to the citizens that no unnecessary costs were being imposed. Finally, many municipalities invested great amounts of money in cleaning up the ground and in local sanitary regulations, as Pettenkofer recommended.

A decisive role in the acceptance of Pettenkofer's cholera theory and its practical consequences played economic reasons. The proponents of the contagion theory wanted to stop the spread of the pathogen by using the military forces to close the borders forbidding transport in affected regions (43, p. 243–245). In order to stamp out the disease, they were prepared to accept the collapse of commerce and the destruction of a considerable part of the economic base of whole regions as consequences. The so-called "contagionistic" idea was also dominant in Japan in the eighties. Ogata wrote in a letter to Pettenkofer in 1887, that this idea had caused "ridiculous embargos". Orientated himself in Pettenkofer's epidemic model, Ogata openly fought the transport and trade embargos decreed by the Japanese government (14, 157, Letter of Ogata, dat. 5.4.1887).

The measures recommended by Pettenkofer imposed no restrictions on trade and transport at all. Therefore, representatives of commerce, industry and trade favoured Pettenkofer's point of view, even after Robert Koch's discovery of the cholera bacillus put the contagious theory on an exact basis.

Today we know, measured by its proximity to reality, Pettenkofer's cholera theory was a dead end. Nevertheless, he managed to turn this dead end into an ideal way for fighting epidemics, for the sanitary measurers to combat epidemics that derived from his false theory proved to be extremely effective. With the introduction of effective centralized water supplies and wastewater disposal systems, Pettenkofer indisputably made a tremendous contribution to lowering the death rate and to extending life expectancy.

Truth as an ideal good

Pettenkofer's work was always accompanied by a commitment to the search for the truth about things and the laws of nature. "A true man of science", so he said, "is always concerned primarily with the truth" (44, p. 37). Paradoxically, an especially impressive example of this motto was furnished by Pettenkofer's incorrect theory about cholera, as we have seen.

In his bold fight for the truth in the sciences, Pettenkofer also was not afraid to experiment on himself. On 7th October 1892, during the cholera epidemic in Hamburg, Max von Pettenkofer demonstratively drunk a diluted culture of the cholera pathogen, discovered by his great rival Robert Koch, to endorse his views (45). In contrast to Pettenkofer, Robert Koch believed the Hamburg cholera epidemic was caused by contaminated water. Happily or luckily, Pettenkofer survived this experiment on himself without serious damage and commented with the heroic words (46, p. 12; 42, p. 332):

> "Even if I had deceived myself and the experiment endangered my life, I would have looked death quietly in the eye for mine would have been no foolish or cowardly suicide; I would have died in the service of science like a soldier on the field of honour. Health and life", so Pettenkofer, "are ... very great earthly goods, but not the highest for man. Man, if he will rise above the animals, must sacrifice both life and health for the higher ideals"

Among such ideal goods, Pettenkofer counted "religion, fatherland, law and freedom, science and art, and also truth." These ideas were to be served without reserve (47, p. 22). As an iron-willed researcher, Pettenkofer saw the aforementioned experiment on his own body as part of the intrepid battle for truth in science.

Among mankind's ideal goods Pettenkofer also counted the freedom of thought and research. In his mission for an unrestrained access to truth Max von Pettenkofer 1870 protested vehemently against the new Vatican dogma of Papal infallibility as injurious to freedom of thought and research and dissociated himself from the Roman Catholic Church (1, p. 389; see also 48, p. 16).

Intellectual bequest

With his services in the worldwide promotion of hygiene, Max von Pettenkofer became a pioneer of Hygiene and preventive medicine. As a mastermind in the field of health care, he set trends and his name became synonymous with hygiene. He sensitized humanity to questions of health, hygiene and the environment. By providing such impulses for a health-promoting lifestyle, he made a great contribution to reducing mortality and extending life expectancy. As a man of principle he looked to the future. With his visionary belief in science and technology, Pettenkofer also reminds us of the importance of the value of truth. He regarded truth and freedom of thought as the guarantees of the material and moral perfection of this world. One might say that therein lies the intellectual bequest of the "founder of modern hygienic science."

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In this respect we have to mention for example J. Forster in Amsterdam and later in Strassburg, Fr. Hofmann in Leipzig, K.B. Lehmann in Würzburg, Wolffhügel in Göttingen and M. Rubner in Marburg and Berlin. In foreign countries we have to refer to Isidor Soyka (Prague) or von Fodor (Budapest), Bubnoff (Moskow) and Subottin (Kiew). In Japan, Ogata, Tsuboi and Nakahama were responsible for spreading Max von Pettenkofer’s ideas and became members of the University of Tokyo.