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FROM THE HISTORY OF SCIENCE IN GDANSK

AT THE THRESHOLD OF MATURITY*

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About Thermometry. To facilitate the understanding of Fahrenheit's achievements for those who have nothing to do with the school physics, let us have a look at the basics of thermometry. It is not as easy as it seems. The difficulties emerge already at the stage of definitions. Thermometry is the art of measuring temperature, but how to define temperature in such a way that it would be understandable to a not prepared reader? "Scalar physical quality, characterizing the thermodynamic state of equilibrium of a thermodynamic system, a parameter of a state, that is a measure of kinetic energy of gas molecules" – these precise definitions require a lot of additional information. Let us add that temperature belongs among the so called basic values, that do not need to be defined, yet we have to be able to measure it precisely and reliably, and for this we need to establish its units (measurement means comparing with values of the same size, that we accept as a unit). This is what Fahrenheit achieved in the field of thermometry.

The problem of proper measuring of temperature seems stranger by the fact that we feel the differences with our own senses. Putting our hand into water we feel immediately whether it is hot or cold, with the whole range of intermediate states – cool, lukewarm, ice cold, very cold, very hot, *etc.* The following experiment shows, however, how unreliable our impressions are: if we put one hand in cold, and the other hand in hot water, and then we put both hands into warm water, the hand which had been in hot water will feel it as cold, and the one that had been in cold water will feel it as hot. It is only after some time that the impressions become similar for both hands.

We introduce temperature in order to be able to characterize the warmth of bodies in numbers. The hotter bodies are the ones of higher temperature, the

* The following pages are taken from the book "Dzieciństwo i młodość Daniela Gabriela Fahrenheit" (The Childhood and Youth of Daniel Gabriel Fahrenheit) by Andrzej Januszajtis, which appeared in 2002.

colder ones are those of lower temperature. If we put together bodies of different temperatures, then energy, called heat, flows from the hotter to the colder body. The exchange lasts until the two temperatures become equal. This is what happened in our experiment. The heated hand gave away its heat to water, the cold hand took heat from water till the temperature of hands and water was equal. This state is called thermal equilibrium. This way we notice the difference between temperature and heat. The condition of the flow of heat is the difference in temperature. This resembles in some way the flow of current (that is the flow of electric charge): in a conductor the condition for the flow of current is the difference of potentials (voltage). In the thermal phenomena temperature plays the role of potential.

In order to be able to measure temperature, one must use such physical quantity that changes with it – for example volume. Changes in volume that depend on temperature are called thermal expansion (more precisely volumetric, as there is also linear thermal expansion, that is thermal changes in length). It can be most easily observed in gases, as their expansion is biggest – it was already known in the ancient times. So it is not strange that the first instruments for estimating changes in temperature: qualitative ones, called thermoscopes (without the scale), and quantitative ones – thermometers (with a number scale), were filled with air. The first modern thermoscope, constructed around 1595 by Galileo, had the shape of a glass ball with a narrow pipe, whose end was put in water. When the ball is heated, the air contained in it expands and escapes into water through the pipe, creating bubbles. If we cool down the ball now, the air contracts. Inside the thermoscope negative pressure is created, which causes sucking water into the pipe. The height of the water thread in the pipe can be the measure of temperature of the air in the ball. In 1604 Cornelius Drebbel (1572–1633) conducted a similar experiment in Holland. Transforming thermoscope into thermometer by adding the scale onto the pipe is attributed to Santorio Santori (1561–1636), the professor of the University in Padua, working for some time as a doctor also in Croatia. His thermometer from 1612 had a long, twisted pipe with a scale, and at its upper end there was a small bubble that a patient would take into his hand or mouth. The lower end of the pipe was immersed in water. The change in the level of water in the pipe allowed to measure the temperature of the patient in the degrees of any scale (optional). This was then compared to the temperature of a healthy person. This was at the same time the first doctor's thermometer, of course a very unreliable one. The name "thermometer" was introduced in 1624 by a certain Leurechon – a Frenchman judging by the surname.

The next step was using the thermal expansion of fluids. Ethyl alcohol in the first place, that is most suitable for that purpose. Here the first person to use it was probably Giovanfranco Sagredo (1571–1620), who wrote about it in the summer of 1615. The pipe of his thermometer was probably open at the top. The first closed thermometer was to be invented in 1641 or 1642 by the Prince of Tuscany Ferdinand II (1621–1670). It was later improved by the scientists from Experimental Academy (Academia del Cimento), working in the years 1657–1667 in Florence. These so called Florence thermometers looked like thermoscopes, with the difference that the glass ball was at the bottom, and the pipe at the top. After filling them with alcohol tinted red, the top part of the pipe was closed. Probably some of the air was extracted from it first. The scale was marked by colorful glass beads attached to the pipe – black ones for degrees, white ones for tens, and blue ones for hundreds. The scales of 50, 60, 70 and 100 degrees were used. When higher sensitivity was necessary the pipe was lengthened and then took a spiral shape.

The Florence thermometers were popular all over Europe. With time the glass beads were replaced with lines and numbers engraved on a brazen scale. To be able to compare the readings, at least approximately, as the beginning of the scale was chosen the lowest winter state of the thermometer, and as the top border – the highest state observed in summer. The distance between them was divided into an appropriate number of degrees. With time a 180-degree scale emerged, in which the bottom border was minus 90°, and the top one – plus 90°. Zero, lying in the middle of the way between them, was the medium temperature. In spite of all the attempts and similar construction, the readings of these thermometers were not comparable. To get rid of this defect some scientists suggested using the known constant points (temperatures) of freezing and boiling of water. Among them were Christiaan Huygens (1629–1695), already in 1665, then Isaac Newton (1642–1727) in 1701, and Guillaume Amontons (1663–1705) in 1702. In 1687 Newton wrote about the stability of the latter point in his epoch-making work "Mathematical Principles of Natural Philosophy". As we could already see, Rømer also tried to do so, yet the first thermometers of comparable readings, basing on two or even three constant points, were constructed only by Daniel Fahrenheit.

One of the constant points was the blood temperature of a healthy person that is so controversial today. Let us not exaggerate with criticizing, though! Assuming the body temperature as the reference point is not a worse action than assuming a foot, elbow or inch (the width of the thumb) as the length measures. In such cases the most important is not choosing the size or unit, yet the ability of reproducing it. Fahrenheit, before getting rid of the "blood warmth" point, reproduced it with the aid of at least two other constant points: the point of water freezing, realized by the mixture of water with ice, and the temperature obtained by adding to it a certain amount of sea salt or ammonium chloride, which he assumed to be the 0 on the scale.

We should add here that establishing the point of water boiling, suggested by many physicists, using alcohol thermometer was impossible, as ethyl alcohol boils at a lower temperature than water. Among other things here is the reason why Rømer, Fahrenheit and others stuck to the "point of blood warmth" for such a long time, while calibrating their thermometers. This ended when mercury was used as thermometer fluid, as it boils at a much higher temperature than water. This was also introduced by Daniel Fahrenheit.

But let us not anticipate things. As for now, our scientist is still in Copenhagen. He produces thermometers with the modernized (denser) Rømer's scale. As his anonymous biographer describes "he undertook numerous tiring trips, both by land and by sea, had discussions with the most famous mathematicians in Denmark and Sweden, sent his devices to Island, Lapland and many other places, from where he was sent the results of observations made by interested people... it is also known that in 1709 during harsh winter he noticed some extraordinary phenomena with the help of his devices". This sending away thermometers was to find the lowest temperature observed, which Fahrenheit wanted to assume as 0 on his scale, after reproducing it in his laboratory with the help of a special mixture. It is possible, as the temperature of freezing of mixtures depends on their constitution. We can observe it every year in winter: Splashing salt over ice or snow in the street lowers the freezing temperature and causes them to thaw even in the temperatures below 0 in the surrounding. The constitution at which temperature is lowest is called eutectic, and its temperature is called eutectic point. Fahrenheit was the first one to use eutectic compositions. As it seems, he was looking for the lowest possible temperature, something like an absolute zero. Also in these attempts he was a pioneer.

It is highly possible that Fahrenheit also sent one of his thermometers to Gdansk. Michael Hanow in his meteorological charts gave temperatures measured with the use of "a Fahrenheit thermometer, very famous in Gdansk for its accuracy, which was already in use in 1709. It has been a custom for a long time now to send someone to the house of the owner Wilhelm Wilke, to see there how cold it is".

Back in Gdansk. The 1709 started with the omnipotent cold, from which all the nut trees and vine died, not one watermill was operating, crank stocks and horse mills had to be working, animals in the forests were dying, together with numerous fish in the waters, the sea was covered with ice 9 miles into it, sledges were used for some 24 weeks, and no ship could sail into the Gdansk harbor till the 11^{th} of May". This was the situation in Gdansk, and probably in the whole region. Among Fahrenheit's biographers there are disputes whether he came here then to measure the record low temperatures himself, or, as he used to do, he only sent a thermometer, asking someone to register them. According to some authors this is where he found his cold pole – the zero in his scale. If it were, however, true that he did not visit Gdansk at that time, there could only be one reason for that – he did not want to face his guardians, on whose decisions he was still dependent. The Chełmno law, still in force in Gdansk in those days, was clear: "each young man should have a guardian till the age of 25, and till then he should be forbidden to do anything about his own welfare without his guardians' consent", and he surely lived against that law. If he was in touch with his sibling he probably knew that in 1707 one of the guardians – Daniel Nützmann – died. He was succeeded by Martin Friedrich Beyer from Potsdam (1665–1727). All that could have influenced their opinions, yet Daniel Gabriel probably preferred not to risk. He could also have been put off by the plague coming from the inside of the country, one of the most fatal ones in the history of the city.

The murrain started in May, after the low temperatures ended. In June there were 319 dead, in July – 1300, in August – 6139, in the first week of September – 2205, in October 1900. During the whole year there were 24533 deaths in the city, and 8066 in the suburbs. Among others, all the friars of the Reformati Order in Chełm (a suburb) were dead. This meant a real depopulation for a city that had 61 thousand inhabitants. Just for comparison: in the previous year there were 1956 dead, and in the following one – 1784. During the epidemic there was a lack of coffins, so they had to be brought from as far as Tczew! The post started working again in March of 1710, and then, after the epidemic stopped, Daniel decided to come back to Gdansk. He was 23 then, and he could probably be a bit less afraid of the guardians. The epidemic turned the hierarchy of values upside down. In the face of the tragedy other problems seemed less important.

Meeting the sibling must have been a very moving ceremony. Brother Ephraim was already 21 years old, preparing to enter adult life, similarly to 20-year-old Anna Concordia, and 19-year-old Konstantin. The youngest of them – Elisabeth was 16 and was no longer a child, either. They all survived the plague. Seeing the sibling, however a happy event, was not the only aim of Daniel Gabriel's coming to Gdansk. It was very important for him to placate the guardians, and, after becoming of age, to get the rest of the inheritance that belonged to him, shrunk by the sums he had borrowed in Amsterdam to finance his scientific trips and experiments. At the beginning of 1711, when he was to become 25 as was required by the law, they came to an agreement. Gabriel von Bömmeln, his godfather, who was the mayor since 1708, might have helped to settle the matters earlier than expected. At the same time Ephraim, who was 23 at that time, was also considered to be of age.

"Ephraim Fahrenheit, son of the deceased Daniel Fahrenheit, faced the S.G. (*iudicium bannitum* – a kind of court), and, with the certification of his guardians – Bruno Plander and Martin Friedrich Beyer that he is a mature man at the age of 23, has been behaving well till now, and will probably be able to take care of his matters by himself, has been acknowledged to become of age, so the aforementioned Ephraim Fahrenheit is capable of taking care of his own matters. If anyone wanted to stand against it or forbid him to do so, the court will help him, as the law states (issued on 28 January 1711). So in front of the Noble Court of the Right City came Daniel Gabriel Fahrenheit and the mentioned Ephraim Fahrenheit and came to an agreement after the Distinguished Bruno Plander, Beniamin Hedding and Martin Friedrich Beyer were their guardians and took care of their welfare inherited from their mother and father. So the presented ones agree that they received proper knowledge, bills, dowry and instructions from them, with which they feel satisfied, and thank the guardians for the care. With this the presented ones certify that they will not hold or let be held any court matter against the guardians in any of the clerical or secular courts, in the country or abroad, now or in the future (issued as above)".

It may seem that the young scholar, finally self-reliant and financially independent, would devote himself to his passion immediately and continue his research. This did not happen, however, although we do not know why. Instead of doing so, he devoted himself to merchant business together with his brother Ephraim. That may have been caused by the pricks of conscience for his family. Or maybe the money he received was too small and there was a chance to multiply it? Whatever the reasons he traveled with the merchant business to Kurland and Livland. He had to travel through Königsberg, where on 10 February 1711 he signed an authorization for his brother to transfer his participation in the real estate to his name. Another document was issued on 20 May in Mittau (today Jelgava, south of Riga). According to it Ephraim was fully entitled to represent him in all the property cases, to collect money, to sell property, *etc.* Daniel Gabriel signed the document as "merchant journeyman in the Royal City of Gdansk". These are the only proof of his merchant business. We do not know if there were any profits from it, and how big they were. In 1712 he is back in Gdansk, where he cooperated with professor Paul Pater. He surely also took part in his sister's wedding, who in that year at St. Mary's Church married Heinrich Weiland, 7 years older than herself. From the ten children born in this family 5 died in their childhood. The first four were buried in the grave number 362, the fifth one (in 1727) in the grave number 431, mentioned as "their grave". The following sentence clarifies the situation of the remaining ones: "Heindrich Weyland was buried at the Corpus Christi Church, as he became poor and died in Siedlce district". The burial register of the Corpus Christi Church gives us the precise date: "4 December 1729, Weiland from Siedlce, a man". The burial ceremony cost 7 fl 10 groszy. There is no data concerning the reasons for the family's impoverishment.

Pater's School. Paul Pater was one of the most unusual educationalists that worked in Gdansk. Of a German origin, he was born in 1656 in Wierzbowo in Spisz that belonged to Hungary at that time (today to Slovakia). After graduating the Wrocław (Breslau) gymnasium he studied classical languages, philosophy, history and mathematics in Leipzig and Jena. Since 1688 he was teaching mathematics at the gymnasium in Toruń. He also built optical devices. In 1703 he presented king August II with a polemoscope built by himself. The device, today called a periscope, was invented in 1637 by the great Gdansk astronomer – Jan Hevelius (1611–1687). The king thanked Pater by assigning him a patent allowing him to print calendars all over the northern Poland, which ensured additional income. The North War, during which Toruń was under siege by Charles XII, made him leave. At first he intended to go back to Wrocław, but he visited Gdansk first to see the treasures of the famous Council Library, existing since 1596, and… he stayed. In the beginning he earned his living by giving private lessons of astronomy, geography and Latin style. In 1705 he became a professor of mathematics at the Academic Gymnasium. He held this position till the end of his life. He died in 1724. He left 28 publications and no fewer than 18 annual volumes of calendars. He ordered a Latin inscription to be put on his grave: "Here lies Paul Pater, the professor of mathematics, who did not have to fight with illness in his life, did not have to become angry or lustful. He left the life as a bachelor in 1724, on the 7th of September".

In his classes with students he emphasized practical skills and applied knowledge – mechanics and technology. He considered "mechanics to be the most useful branch of knowledge for the whole humankind", and he thought that "all those who believe that exercises in mechanics are not worthy of a free mind, are wrong". As it was difficult to bring his ideas into life at the Academic Gymnasium, he also gave private courses. In 1711, after prolonged attempts, ha was finally allowed to open a printing house, in which he organized "A Mathematical – Mechanical Publishing House". This was the firs technical school in Poland. It was situated at Żabi Kruk Street, probably at number 39, marked in the property registers with the sentence "for the use by Gymnasium".

What was the connection between Fahrenheit and Pater? In the anonymous note about his life, which we had already called upon here a few times, we can only read: "In 1711 he went to Kurland and Livland, from where he came back in 1712 and was in close friendship with the mathematics professor Paul Pater". Some light in that matter is also brought by a promotion leaflet entitled "A well thought over information about the newly opened Mathematical-Mechanical Publishing House of

Art by professor Paul Pater in Gdansk", issued in 1714, yet concerning the previous years of the school's existence. Let us have a look at two of the thirteen points it mentioned.

"4. As concerns the main matter of this Publishing House, and who among the teachers manages the teaching, since the Author opened the House with his own finances, he manages it himself, and supervises not only over those working in the printing house, but also all other exercises… He also teaches himself in the mornings the useful skill of counting, in terms of coins, measure and weight, geometry, how to draw figures and shapes on paper, and then how to measure the points and squares in the open space with the help of special measuring devices. He also shows geography and the use of the sky and the globe, with their construction and use in the maps of the country and astronomy, to be able to see easily both the planets and stars in the sky. Many of the afternoon hours, on the other hand, are used for the mechanical exercises, for which he is especially gifted, and in which he practiced himself since his youth with the most famous masters in Wrocław, Nürnberg, Augsburg and Leipzig […]

9. There is a special room where lenses are polished under the supervision of an experienced mechanic, and telescopes, microscopes, magic lanterns, thermometers and other useful optical devices are made. The same master demonstrates how to skillfully make pipes (tubes) of wood or cardboard for telescopes and microscopes, and how to make them shine according to the Italian fashion by applying bone marrow or lake varnish. One can also see there how to turn on the lathe small hand or pocket telescopes, subtle microscopes, snuffboxes, *etc.*, made of metal, ivory, amber, horn and rare species of wood with screws. They also teach there how, with the help of some devices and dividing heads, to make easily and quickly astronomical, lunar or sundial clocks, conveyors, rules, quadrants, armillary spheres, dividers, *etc.*, of silver, brass and other materials. Those who have already mastered the art of turning and woodwork are also shown how to construct musical instruments such as flutes, harpsichords, harps, according to the requirements of the organ masters. From the civil and military architecture they teach the basics and rules: how to prepare different models of churches, palaces, fortresses, pavilions, fountains, voice tubes (!), of metal, plaster, wood or cardboard, according to various scales. From statics they teach the basics, understanding and the differences in the weight of teeth, gears, screws, bearings and other main devices, and how it happens that it is possible to lift a load of many quintals with the use of a pound".

We do not know who that "experienced mechanic" was, under whose supervision the pupils learnt the machining and constructing the devices, thermometers among others, but the facts let us suppose it could have been Fahrenheit – already then a master in their construction. Apart from that, cooperating with a professor 30 years older than himself must have been very fruitful. He learnt to appreciate mathematics that used to be his weak point. He probably even learnt more of it. In his lectures Pater used what he called "his own mathematical method", based on the works of the great English and French naturalists, such as Hooke, Harvey, Bacon and Cartesius. He did not mention Newton, yet taking into consideration the lively contacts between Gdansk and England, he must have heard about his Principia.

Professor Pater must have been for the students – and also for Fahrenheit – the model of a hard working person. In winter he got up at 4 in the morning, and in summer at 2, and he immediately started working. As many other scholars, he was known for his absentmindedness. His thoughts circulated around "mathematical-mechanical" problems. In spite of his many eccentricities he was liked by the students, who protected him against the accusations of the school authorities. Among the things listed after his death there were many ready and not yet finished optical devices made by his pupils and probably by Fahrenheit himself.

On the way. In the annexes to the property registers there are two entries that had not been known till recently. They bring new light at the final period of our scholar's stay in the country. They are both similar and concern handing down the property share that he inherited to his sibling. Under the date 17 June 1713 we can read: "Daniel Gabriel Fahrenheit, ready for his trip, states that the 1/5 of his property in Ogarna Street Fol. 18A goes to his sister Anna Concordia, wife of Heinrich Weyland, to be her own, agreeing for it to be transferred to her also in his absence".

The other entry from 15 July of the same year concerns the building on the Granary Island.

"Daniel Gabriel Fahrenheit, ready for his trip, states that the 1/5 of the half of the "Kur" (Cock) granary by the Long Riverside Fol. 5A, crossing to (the street) Behind Long Riverside Fol. 20A, together with the encumbrance, goes to his brother Ephraim Fahrenheit to be his own, agreeing for it to be transferred to him also in his absence".

As has already been mentioned, the house in Ogarna Street Fol. 18A is the later number 39. In 1787 the main owner was Jaan Gerlach. In the case of the granary it must be remembered that the name "Long Riverside" initially concerned the riverbank of the Granary Island, and only in the second half of the 17th century was transferred to the other side of the Motlawa. In the property registers the old names were kept longer. The section of Chmielna Street from Stągiewna Street till the "Long Way" granary (ruined at present) on the north edge of the headland still in the 18th century was called "Behind the Long Riverside". The address of the "Kur" (Cock) granary since 1854 is: Chmielna Street 21.

So, as we can see, in the summer of 1713 Fahrenheit got rid of his property in Gdansk and transferred the rights to it to his brother and his already married sister and prepared to leave, probably for good. The books do not mention it, yet we can presume that he obtained some informal financial compensation. We do not know the exact date of his departure, yet since he was "ready for his trip" in June and July, he probably did not wait till the November storms, but set off earlier. To certify that we can mention the till now neglected information by Grischow, according to which our scholar was supposed to be in Berlin already in 1712 and 1713, and study there under a young mathematician – Barnsdorf. In one of the later letters Fahrenheit himself wrote: "At the beginning of 1713, shortly before setting off from Berlin, I researched the expansion of quicksilver in the thermometer made of Potsdam glass (that is practically the same as the Czech one)". This means that before the final leave in the autumn of 1713, he traveled to Germany for a short period of time, probably at the turn of 1712/1713. He came into contact with the glass-works in

Potsdam then. During his stay in Berlin he used this glass to make the first in the world quicksilver thermometer and researched the heat expansion of quicksilver. It was probably then that he got to know Barnsdorf who taught him mathematics, which I would rather associate with the second stay in the city. The subject of these lessons was higher geometry, with special interest in cone sections.

Separation with his homeland meant for Daniel Gabriel saying goodbye to the memories of the childhood ended by the tragedy and of the difficult youth years. At the age of 27 he was an independent, mature man, fully aware of his already substantial achievements and the way ahead of him. He could not have known the future, yet he believed in himself, his own resourcefulness and intuition. He was entitled to expect to succeed in life.

The formal severing any connections with the merchant profession and entering the way of science was the authorization for his brother Ephraim, signed at the city court in Berlin on 12 March 1714. This meant transferring the symbolic duties of the oldest of the sibling – the head of the family – to his 25-year-old brother. Two years later Ephraim was the merchant journeyman in Gdansk, in 1729 he was the citizen and merchant of Riga. He died in 1738 in Königsberg. Similarly to Daniel Gabriel, and the youngest one – Konstantin, who died in 1741, he also remained a bachelor. Of all the sibling only Anna Concordia got married and had children. She became a widow in 1729. We do not know the date of her death.

Translation: Anna Kucharska-Raczunas