Canons against Calorics

Benjamin Thompson, Bavarian Minister of War, went into the workshop to supervise the production of new cannons. As you may notice, Benjamin Thompson is not really a common Bavarian name, and actually, Thompson was not a Bavarian citizen but he was born in the British colonies in North America. At the time he was entering the workshop there were no more British colonies in North America – the events were are going to discuss took place by the end of the 18th century. During the American Revolution, Thompson had acted as a spy for the British, consequently he had to leave when things turned out to end bad for them. Why a North American could become the Bavarian Minister of War is a completely different story and should not bother us here. But evidently, the supervision of the production of weaponry was amongst the duties of a Minister of War, at least in those days. Europe was at the Edge of War, the French Revolution and the following Empowerment of Napoleon put a threat to all European rulers, and thus there would be war – well, in fact there was already military conflict. Consequently, new cannons were needed, and consequently, Benjamin Thompson had to go to the workshop to make sure that the work was going efficient and that the quality of the weapons was as expected.

When Thompson stood in the workshop, he immediately felt anger raise as most of the workmen stood around waiting. “What is going on?” he addressed one of the waiting workers (actually he said “Was ist hier los?”, but for the sake of the story we will translate the entire discussions into English). The worker bowed and then replied “Sir, we are waiting for the drill to be sharpened”. To understand this response, you have to ask yourself how a cannon is produced. When you imagine a cannon (like one used by pirates or in ancient fortifications), it can be described as a metal barrel with a long, centered hole in it. Now you may think that this can be casted like this, but actually (at least at the time of our story) the metal cylinder had to be casted and then the borehole had to be drilled – actually this was supposed to be going on at the workshop at this time. Now, to drill the hole into the barrel, two horses were constantly turning a large and heavy metal axis that had one end sharpened and served as a drill. Of course, there was some mechanism that made sure that the hole was drilled in the very center of the barrel, but these details are not relevant to our story. But you can imagine that the axis was heavy, and to remove it from the barrel, bring it to the workbench where it could be sharpened again, and bring it back in place was no simple task. Moreover, evidently the sharpening of such a large drill would take quite some time.

Thompson felt not really satisfied by the response of the workman, as he had been to the workshop the day before, had found the same situation, and on his request had received the same response. Such a response may have been acceptable once, but not on two days in a row. Consequently he demanded to see the worker in charge of the tools and inquired why it took that long to sharpen the drill. To his amaze-ment, he learned that the drill was not still in the process of being sharpened but the procedure had to be started once again. The workman pointed out that some drills had broken, and even though new ones were to be made, for the time being the workers had to interrupt the process of drilling the hole in the cannon from time to time.

To Thompson, this appeared not really acceptable – workers standing around waiting for a tool to be prepared were not his idea of efficiency. Thus, he demanded that the workers should work with a blunt drill whilst the other one was still sharpened. Yet, they refused by arguing that the metal would become too hot and the quality of the barrel would diminish. Thompson became irritated – this does not seem to make sense from his scientific understanding of heat. He was well aware that heat could be excited by friction, however, to his understanding (and also to the one of all other scientists he knew – and he knew a lot of scientists) this was due to the substance of heat being pressed out of the materials that were rubbed. Consequently, after some time of rubbing materials against each other, all substance of heat should be pressed out – so why could these craftsmen argue that the cannon would get hotter all the time? Thomp-son felt that this issue deserves some more of his attention, so he mumbled to the workers ‘Work on, and be more efficient’ and went back to his carriage to go home, thinking about this problem.

The next day, an energetic Thompson appeared at the workshop where the men were drilling the hole into the cannon. To their amazement, Thompson ordered them to stop. He told them to get a blunt drill and place it in the machine. When the workers looked at themselves puzzled, Thompson felt that some explanation was needed:

“We are going to carry out a scientific experiment. I want to determine how much heat can be generated through the friction of a blunt drill and the cast metal of the cannon.”

Well, actually this explanation did not seem to be working too well, as the expression in the faces of the workers did not seem to change. Thus, Thompson ordered them to get on as he advised them. They replaced the drill with one that was blunt, they brought some water to cool the metal, and they started making the horses walk again in their usual circle. After a while, Thompson noted that the metal became warm, and after some more time, it did not only become warm, it became hot. When Thompson had the impression that the iron was too hot to be touched with the naked hand, he ordered the workers to use the water to cool the metal and to continue working. After a while, he noticed that the water was getting warm, and after some more time, the water was getting hot, and in the end, the water showed little bubbles and was about to begin to boil. Thompson told the workers to stop, and to get back to their work as the experiment was over. He could see some puzzlement in their faces, but this time their feelings corresponded to his own – even though for entirely different reasons. How could it be that so much heat was in the metal that it seemingly was never squeezed out completely? But if heat was a substance, it had to be limited in its amount. Thus, if it was unlimited, it could not be a substance but had to be …

Rumford went home as something came to his mind. He recalled that he had been reading about an ancient Greek concept of matter being formed out of little particles, and that these particles were supposed to be in permanent motion. At home, he consulted his bookshelf and found the book he was looking for. Democritus had developed this idea, but his theory was rejected by Aristotle, and thus scholars had believed until then that heat is a material substance. Even though modern scholars had been able to overthrow the Aristotelian worldview, the notion of heat being a substance was still the key idea to describe the related phenomena. Only recently, the French chemist Lavoisier had extremely successfully established a new chemical system, in which the substances of light (lumic) and heat (caloric) were identified as elements. But Rumford’s cannon-boring experiment seemed to disprove a material theory of heat and to show that heat was instead something immaterial. Rumford went to his desk and started to write down his findings. He knew that his claim would meet severe opposition. Therefore, he decided that he would not publish his paper in Paris, instead, he would send it to London to the Royal Society. As he was a member, and knew that he had an excellent reputation amongst the influential members of this learned society, they would certainly publish his paper, even if there were not fully convinced. At the same time, he would also prepare a German version of the paper and submit it to the Annalen der Physik, the recent-ly founded German journal which was becoming the main reference in the physical sciences.

Rumford smiled while he was writing, but then an idea crossed his mind. How could it be that the workers seemingly knew that the heat produced in the friction was not finite? And he recalled his disbelief the day before – would other scientists believe his claim and abandon the material theory of heat?

Rumford’s papers, both the German and the English one, were published in 1798. However, despite his efforts to establish his mechanical theory of heat, other scientists kept the understanding of heat being a substance, being caloric. Even though no one contradicted his experimental findings, scientists kept relying on the material theory of heat for more than three decades after the publication of Rumford’s papers.

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