COUNT RUMFORD'S DISCOVER THAT HEAT IS MOTION.

Now that the mechanical theory of heat is being generally accepted by philosophers as an established truth of science, it is peculiarly interesting to recall the manner in which the idea was first suggested to the mind of our countryman, Count Rumford.

"It is described in a paper published in the transactions of the Royal Society for 1798. He was led to it while superintending the operations of the Munich arsenal, by observing the large amount of heat generated in boring brass cannon. Reflecting upon this, he proposed to himself the following questions:—'Whence comes the heat produced in the mechanical operations above mentioned?' 'Is it furnished by the metallic chips which are separated from the metal?'

"The common hypothesis affirmed that the heat produced had been latent in the metal, and had been forced out by *condensation* of the chips. But if this were the case the capacity for heat of the parts of metal so reduced to chips ought only to be changed, but the change undergone by them should be sufficiently great to account for *all* the heat produced. With a fine saw Rumford then cut away slices of unheated metal, and found that they had *exactly the same capacity for heat as the metallic chips.* No change in this respect had occurred, and it was thus conclusively proved that the heat generated could not have been held latent in the chips. Having settled this preliminary point, Rumford proceeds to his principal experiments.

"With the intuition of the true investigator, he remarks that 'very interesting philosophical experiments may often be made, almost without trouble or expense, by means of machinery contrived for mere mechanical purposes of the arts and manufactures.' Accordingly he mounted a metallic cylinder weighing 113.13 pounds avoirdupois, in a horizontal position. At one end there was a cavity three and a half inches in diameter, and into this was introduced a borer, a flat piece of hardened steel, four inches long, 0.63 inches thick, and nearly as wide as the cavity, the area of contact of the borer with the cylinder being two and a half inches. To measure the heat developed, a small round hole was bored in the cylinder near the bottom of the cavity, for the insertion of a small mercurial thermometer. The borer was pressed against the base of the cavity, with a force of 10,000 pounds, and the cylinder made to revolve by horse power at the rate of thirty-two times per minute. At the beginning of the experiment the temperature of the air in the shade and also in the cylinder was 60° F., at the end of thirty minutes, and after the cylinder had made 960 revolutions the temperature was found to be 130° F.

"Having taken away the borer, he found that 839 grains of metallic dust had been cut away. 'Is it possible,' he exclaims, 'that the very considerable quantity of heat produced in this experiment—a quantity which actually raised the temperature of upward of 113 pounds of gun metal at least 70°, could have been furnished by so inconsiderable a quantity of metallic dust, and this merely in consequence of a change in the capacity for heat?'

"To measure more precisely the heat produced, he next surrounded his cylinder by an oblong wooden box in such a manner that it could turn water-tight in the center of the box, while the borer was pressed against the bottom. The box was filled with water until the entire cylinder was covered, and the apparatus was set in action. The temperature of the water on commencing was 60°. He remarks, 'The result of this beautiful experiment was very striking, and the pleasure it afforded amply repaid me for all the trouble I had taken in contriving and arranging the complicated machinery used in making it. The cylinder had been in motion but a short time when I perceived, by putting my hand into the water and touching the outside of the cylinder, that heat was generated.'

"As the work continued the temperature gradually rose; at two hours and twenty minutes from the beginning of the operation, the water was at 200°, and in ten minutes more it actually boiled! Upon this result Rumford observes, 'It would be difficult to describe the surprise and astonishment expressed in the countenance of the bystanders, on seeing so large a quantity of water heated and actually made to boil without any fire. Though there was nothing that could be considered very surprising in this matter, yet I acknowledge fairly that it afforded me a degree of childish pleasure which, were I ambitious of the reputation of a grave philosopher, I ought most certainly rather to hide than to discover.'

"Rumford estimated the total heat generated as sufficient to raise 26.58 pounds of ice-cold water 180° or to its boiling point; and he adds, 'from the results of these computations, it appears that the quantity of heat produced equally or in a continuous stream, if I may use the expression, by the friction of the blunt steel borer against the bottom of the hollow metallic cylinder, was *greater* than that produced in the combustion of nine wax candles, each three-quarters of an inch in diameter, all burning together with clear, bright flames.'

"One horse would have been equal to the work performed, though two were actually employed. Heat may thus be produced merely by the strength of a horse, and in a case of necessity this might be used in cooking victuals. But no circumstances could be imagined in which this method of producing heat could be advantageous, for more heat might be obtained by using the fodder necessary for the support of the horse, as fuel.

"By meditating on the results of all these experiments, we are naturally brought to that great question which has so often been the subject of speculation among philosophers, namely, What is heat? Is there such a thing as an igneous fluid? Is there any thing that with propriety can be called caloric?

"We have seen that a very considerable quantity of heat may be excited by the friction of two metallic surfaces, and given off in a constant stream or flux *in all directions*, without interruption or intermission, and without any signs of *diminution* or *exhaustion.* In reasoning on this subject we must not forget *that most remarkable circumstance*, that the source of the heat generated by friction in these experiments appeared evidently to be *inexhaustible.* (The italics are Rumford's.) It is hardly necessary to add, that any thing which any *insulated* body or system of bodies can continue to furnish *without limitation*, cannot possibly be a *material substance*, and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in those experiments, except it be MOTION."

REMARKS ON THE SUBJECT OF FORCE IN GENERAL.

BY JOHN A. ROEBLING.

[For the Scientific American.]

The subject of Force is now engrossing the attention of scientific men. In the early part of this century the conclusion was arrived at from general reasoning, that all forces in nature spring from one common source, and that correlations exist between the various phenomena which accompany the evolutions of nature's display. Since the year 1842, the publications and experiments of Mayer, Joule, Grove and others have thrown a flood of light upon the nature of force, and the earliest enunciations of the philosophical spirit of this century bid fair to be fulfilled to the letter. The most important truths which may be deduced from the facts but recently demonstrated experimentally, may be stated in general terms as follows:—

1. Force is matter in motion.

2. Matter is an incorporation of force, consequently also of motion.

3. The quantity or mass of matter which constitutes our Earth and atmosphere, is a fixed, invariable quantity. So is the aggregate mass which composes our planetary system. The same is true of each planetary system, and equally true of the whole material Universe. This broad statement may be objected to on the ground that new comets are being formed, that old ones are growing larger, and that meteors are being constantly made and dissolved within our cosmic region and outside of it. The answer is that all these processes take place *within* the realm of material creation and not *outside* of it. If a new comet is formed, it is out of that cosmical matter which constitutes the material universe. And if a comet becomes extinct, its nucleus by that process is simply resolving itself (from some unknown cause) into the original elements of space. The great fact impresses itself upon the human mind that the material creation is a fixed, and, for the time being (but not eternally), an unalterable quantity.

4. The material composing the universe being a constant quantity, and matter being equivalent to force, it follows that the forces of nature, in the aggregate, also form a constant and invariable quantity.

5. From the foregoing, it is evident that no additional forces, no new forces, can be created; neither can the general storehouse of forces, or of matter, be diminished.

6. There is neither creation, in the common sense, nor annihilation, and never has been. There certainly was a beginning, because processes cannot be *eternal* in duration, but they may last an *infinite* period of time. The word *Beginning* must be understood in an ideal or heuristic sense. All material existence constitutes a material process; all processes are governed by an inner unseen cause, and this cause, when traced to its final cause, will be discovered to be totally independent of time and space. To further elucidate this proposition would be out of place in this essay.

7. Since natural existence is only a process, in which a certain invariable quantity of matter or force is employed by the Creator for a certain well defined and well understood purpose, viz: the evolution and growth of rational and sentient beings—the conclusion logically presents itself that all changes and phenomena which are observed in nature are only phases of this process, passing away more or less rapidly. Whether this process involves the gradual evolution of elementary matter out of a chaotic condition, consuming millions of ages for its accomplishment, or whether it is a perpetual, never-ceasing action, as, for instance, the evolution of light and heat by the sun, and the consequent enormous evaporation of the ocean, and accompanying generation of electric and magnetic forces—it makes no difference, because time in the economy of nature is of no account.

8. All phenomena are more or less remote effects of the universal process; on this earth, as well as in our whole planetary system, and equally so in the whole realm of creation. The creative process, which maintains the life of the universe at large, is progressing uninterruptedly, without cessation. To arrest this vast process one single second of time would be annihilation. The pulsation of Universal Causality, which supports the life of the whole, is vibrating through every part, and in perfect accord and unison with that Great Central Mind and Heart which is the final cause of all.

9. Light being the most subtle and also the most universal force known and observed in nature, it may be inferred *a priori* that all other planetary forces either have grown out of it or refer to it, being more or less governed by it. The facts discovered of late years appear to favor the truth of this inference; but long years may pass away before it may become a scientific and experimental demonstration.

10. Heat is a less subtle agency, and admits of more tangible and conclusive experiments. Heat is a centroperipheric force, acting spirally, either expanding or contracting matter in its endeavors to equilibrate with the surrounding temperature.

11. It was stated that *force* is *matter in motion*, and that matter is incorporated force or motion. So long as two contiguous particles or molecules of the same kind of matter are in a quiescent state, or in equilibrium in a dynamical sense, so long will they both remain at rest with reference to each other. But should the thermal, electrical, magnetical, or chemical condition of the one molecule be disturbed, then the equilibrium will cease, and a display of force will result, which display is simply an endeavor to restore the lost equilibrium. If one molecule is set in motion, its condition opposite the other molecule is changed, and the consequence will be that this neighboring molecule is affected in the same way. And so the disturbance will proceed from one molecule to the other, until the whole mass is *uniformly* affected either by heat, electricity, or other kind of energy.

12. In the above phenomena no new evolution of

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