## 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

force, no new creation, takes place; only a communication of disturbed condition from one molecule to another is transpiring, and this process continues until an equilibrium between all the molecules is obtained. All particles of matter are subject to natural affections, or to the energies which nature employs in her processes. The single molecules will remain at rest toward each other so long as they are equally affected or in an equally sensitive condition. But as soon as their affections differ in degree, then a more or less violent endeavor takes place to restore their former equality. The principles of nature are essentially democratic and founded on even justice.

13. All exhibitions of force result from a disturbance of equilibrium. This is equally true in a cosmical as it is in a terrestrial sense. The equilibrium of the universe is preserved by the constant tendency of gravitation to correct regular and irregular perturbations, and thus to maintain, not the equilibrium which attends rest, but which is the result of well-balanced motion. Nature knows no absolute rest—motion is universal. Where rest appears, it is only comparative. The motion of our planet and its life is supported by the light of the sun, which is a never-failing source of energy. Without the sun's influence, the play of all other energies would cease—stagnation and death would result. Owing to that constant flow of energy which is poured upon the planets by the central luminary, their molecular equilibrium is kept uninterruptedly disturbed. Not only is the earth's individual rotation maintained, but it is driven around the luminar center of gravitation, thereby proving that its center of life is not within itself, but outside of it. And by the same energy all minor planetary processes are sustained, more or less remotely, because they are all effects of the central cause.

14. The sun, by virtue of its greater mass, is positive opposite the planet, which, as the lesser quantity, is negative. And since matter is equivalent to force, the sun represents an overwhelming energy compared to the planetary energies. This immense difference constitutes a never-failing source of disturbance to planetary rest. In their mutual endeavor to restore rest and equilibrium, the sun is kept revolving around itself, and the planets are driven on in their swift race; and since equilibrium of rest can never be restored, an equilibrium of endless motion is the result.

15. Force is matter in motion. Mechanical motion proceeds from an outer cause, and is only communicated outwardly—that is, mechanically. If an iron ball is set in motion by powder, that motion is simply communicated or imparted by the expansive force of the gases which have been dynamically evolved by the process of combustion. That dynamical process was initiated by a match or by friction or percussion. The powder explosion takes place because of the disturbed equilibrium of the particles of powder. In a steam engine the elastic power of steam acts upon the piston, and its motion is communicated to various kinds of machinery. The dynamical motion is converted into mechanical motion, and the latter again expends itself in friction, and friction again produces heat and electricity. It does not matter how a force is produced or started, none can ever be lost. When a force is expended apparently, it has only been communicated to some neighboring matter, or has been converted into some other mode of motion. Nor can a new force be produced by any process whatever. When a weight falls ten feet, it has thereby produced a certain amount of mechanical action. But to restore the previous condition of things, the weight has to be raised again to the point of starting, and the same amount of force is expended. When steam is raised as a motive power, it is done through the agency of heat. But heat is the result of a chemical process by which no atom is destroyed; only old combinations are destroyed and new ones are formed. Now this process of combustion is attended by the phenomena of heat, and this heat is converted into mechanical action, and at last back again into heat and electricity. The heat which raised the steam was evolved by that oxydizing process in which carbon and oxygen unite and form carbonic acid. The principle of heat manifests itself through the vehicle of matter, its combinations and decompositions. The principle is universal and invariable. Matter is subject to certain mathematical evolutions, governed by certain laws on mathematical formulas, and these formulas have materialized and expressed themselves in certain fixed motions or modes of action, and these modes are known as heat, light, electricity, magnetism, etc. Now since these material actions of well-defined mathematical principles can only take place by means of matter which is constituted accordingly, and to suit the action, or whose consolidation is fixed by that very action of the spiritual or scientific principle, it follows as a matter of course that the quantity of existing forces is just as invariable as is matter itself.

[To be Continued.]

## MR. MUSHET AND THE BESSEMER PROCESS.

Wrought iron is the pure metal, cast iron contains 2 to 4 per cent of carbon, and steel from $\frac{3}{4}$ to $1\frac{3}{4}$ per cent of carbon. Wrought iron is made by laboriously extracting the carbon from cast iron, and steel is made by restoring a portion of the carbon to wrought iron.

Bessemer's first plan was to remove just enough of the carbon from cast iron to leave it in the state of steel, and thus avoid the round about process of changing the metal first to wrought iron. It is well known that if carbon at a high temperature is brought into contact with free oxygen, the two elements combine to form either carbonic oxide or carbonic acid, and that both of these substances are gases. As one-fifth of the atmospheric air is free oxygen, Bessemer conceived the simple plan of blowing atmospheric air through molten cast iron, to burn out a portion of the carbon contained in the iron.

Mr. Bessemer, on trying his plan, found that it was exceedingly difficult to stop the combustion of the carbon at just the point to leave the metal in a state of steel, and the method now adopted is to continue the operation until the carbon is wholly consumed, and the molten cast iron is added to this wrought iron in such proportion that the mixture will contain the requisite quantity of carbon to form steel.

But there is difficulty in stopping even at the point where the carbon is all consumed. Oxygen has a very strong affinity for iron, especially when the iron is heated, and if on entering the mass it finds no carbon with which to combine, it enters into combination with the iron, forming oxide of iron. Oxide of iron is a brittle substance, and if it is scattered through a mass of iron it destroys the tenacity and value of the metal. It is manifest that the combination of oxygen with the iron is almost certain to commence before the whole of the carbon is consumed, as an atom of oxygen entering the molten mass might meet with an atom of iron before it encountered the last atom of carbon.

This fatal difficulty in the process was effectually overcome by a suggestion of Mr. Mushet, a suggestion which has made the Bessemer process a practical industry. The last number of the *London Engineer*, in a leading editorial on the subject, says:—

"Oxygen, in combining with carbon, produces a gaseous compound, only one-half heavier then air itself; and hence this compound must, of necessity, rise to the surface. But in combining with iron oxygen forms a heavy metallic compound, which is quite as likely to remain secreted in the pores of the melted mass as to float—for in no case can it escape into the air. That this compound is not formed from the first application of the blast is more than probable, because when, by a lucky hit decarburization has been stopped at the right point for steel, the product is much less red short than when the process is continued until all the carbon is exhausted. But however this may be, the danger of burning the iron before it is fully converted remains as distinctly as ever. Mr. Mushet saw it with the eye of a practised metallurgist, and almost as soon as he could have known of Mr. Bessemer's discovery, to wit, in September, 1856, he patented the remedy. His reasoning was rapid and conclusive. There was the oxygen secreted in the iron, and it must be got out. How? By presenting to it a metal more oxidizable than iron—a metal whose own affinity for oxygen would de-oxydize the iron. Such a metal is manganese; and the best vehicle for manganese, in this case, is spathic iron, or spiegeleisen. The best proof of the value of this addition is the fact that it was only after it was made that Bessemer metal took a recognized position in the market.

"Strangely enough, a discovery at once so important has brought no rewards to its author. Mr. Mushet's affairs were in the hands of trustees, and in 1859, three years after the reading of Mr. Bessemer's memorable paper at the Cheltenham meeting of the British Association, his process was looked upon as so hopelessly worthless that his trustees would not pay the £50 stamp to keep alive the patent for a discovery upon which the present value of the Bessemer process mainly depends. So it lapsed, and Mr. Bessemer lost no time in turning his opportunity to account, and how well he has done so is proved by the fact, which he takes no pains to conceal, that his present income from royalties exceeds £100,000 per annum! His royalties are £1 per ton for ingots for rails, £2 a ton for ingots for axles, &c., and £3 per ton for ingots for a higher quality of steel; and these are strictlyenforced against the largest concerns in the land. Even the London and North-Western Railway Company obtain no discount, and if the Ebbw Vale Company have done so it has been in the form of a sale of Martien's curious patent to Mr. Bessemer for £30,000—Martien having parted with it for £500."

### Mechanical Progress.

Under this head the Hartford *Daily Post* pays the following compliment to the SCIENTIFIC AMERICAN:—

"We cannot do a greater service to machinists than to call their attention to a series of illustrated articles on 'Turning Tools' just published in the SCIENTIFIC AMERICAN. They are evidently from the pen of a practical workman, and are invaluable, not only for the accurate illustration, but for truly practical suggestions they contain. Probably on no one thing are machinists so disagreeing as on the proper shape of turning tools, and the proper use to which the varying kinds are applied. Some seldom use a 'bossing' or 'diamond point,' roughing off the work with a 'side tool.' It is an expensive and awkward use of a tool intended and adapted mainly to 'squaring up.' But in grinding tools the master mechanic submits to many annoyances in consequence of the shiftless habit of men who satisfy themselves with touching the point or cutting edge alone upon the stone. By a little care and time spent in properly grinding a tool, much labor is saved the forger, and a tool can be used up to the stock and still kept in shape without once dressing if managed with some degree of care and intelligence. A 'side tool' after being once finished should never be ground on the vertical cutting face. The top and edges alone should be ground and the latter more than the former. Many workmen grind the cutting point of a diamond tool until the back angles are much the highest and then the tool 'gnaws' the work instead of cutting it. A slight rounding of the cutting angle or face of the 'diamond point' will ensure smoother work and retain the edge much longer than where the corner is left a perfect angle. In finishing a shaft for a fit, or for a bearing, the slovenly habit of using the file ought to be entirely abandoned. A water polish with a 'square nosed' tool insures perfect rotundity and gives a better surface than the file and emery can. No more should be removed by this finishing cut than will just obliterate the marks of the bossing tool and leave a good surface. In the article referred to in the SCIENTIFIC AMERICAN the writer approves of the use of 'swan neck or spring tools.' We think their use of doubtful utility. No dependence can be placed upon securing perfect roundness or truth unless the material turned is perfectly homogeneous, a condition which the best iron, and even steel, will rarely fulfill. Instead of allowing for springiness in either the work or the tool, we believe that absolute stiffness and rigidity are indispensable to making a good job. Another bad habit among careless workmen is the use of turning tools indiscriminately on the lathe and the planer. While turning tools must have considerable 'rake,' the planer tools are forged nearly at right angles with the stock."

[By referring to page 34, current volume of the SCIENTIFIC AMERICAN, our readers will see precisely what we said about the use of spring tools.—EDS.

THE King of Siam, whose full name is "Phra Bart Somdetch Phra Paramenpe Maha Monghui Phra Chaum Kiow Chow Yu Hua," recently celebrated his sixtieth birthday, the ceremonies being of the most gorgeous character.