

thus the waters of the ocean are in part dragged as a brake along the surface of the earth; and as a brake they must diminish the velocity of the earth's rotation. The diminution though inevitable, is, however, too small to make itself felt within the period over which observations on the subject extend. Supposing, then, that we turn a mill by the action of the tide, and produce heat by the friction of the millstones; that heat has an origin totally different from the heat produced by another mill which is turned by a mountain stream. The former is produced at the expense of the earth's rotation; the latter at the expense of the sun's radiation.

The sun, by the act of vaporisation, lifts mechanically all the moisture out of the air. It condenses and falls in the form of rain,—it freezes and falls as snow. In this solid form it piles upon the Alpine heights, and furnishes materials for the glaciers of the Alps. But the sun again interposes, liberates the solidified liquid, and permits it to roll by gravity to the sea. The mechanical force of every river in the world, as it rolls towards the ocean, is drawn from the heat of the sun. No streamlet glides to a lower level without having been first lifted to the elevation from which it springs, by the mighty power of the sun. The energy of winds is also due entirely to the sun; but there is still another work which he performs, and his connection with which is not so obvious. Trees and vegetable grow upon the earth, and when burned they give rise to heat, and hence to mechanical energy. Whence is this power derived? You see this oxyd of iron, produced by the falling together of the atoms of iron and oxygen; here also is a transparent gas which you cannot now see—carbonic acid gas—which is formed by the falling together of carbon and oxygen. These atoms thus in close union resemble our lead weight while resting on the earth; but I can wind up the weight and prepare it for another fall, and so these atoms can be wound up, separate from each other, and thus enabled to repeat the process of combination. In the building of plants carbonic acid is the material from which the carbon of the plant is derived; and the solar beam is the agent which tears the atoms asunder, setting the oxygen free, and allowing the carbon to aggregate in the woody fibre. Let the solar rays fall upon a surface of sand; the sand is heated, and finally radiates away as much heat as it receives; let the same beams fall upon a forest, the quantity of heat given back is less than the forest receives, for the energy of a portion of the sunbeams is invested in building up the trees, in the manner indicated. Without the sun the reduction of carbonic acid cannot be effected and an amount of sunlight is consumed exactly equivalent to the molecular work done. Thus trees are formed; thus the cotton, on which Mr. Bazely discoursed lately, is formed. I ignite this cotton, and it flames; the oxygen again unites with its beloved carbon; but an amount of heat equal to that which you see produced by its combustion was sacrificed by the sun to form that bit of cotton.

But we cannot stop at vegetable life, for this is the source, mediate or immediate, of all animal life. The sun severs the carbon from its oxygen; the animal consumes the vegetable thus formed, and in its arteries a reunion of the severed elements takes

place, and produces animal heat. Thus, strictly speaking, the process of building a vegetable is one of winding up; the process of building an animal is one of running down. The warmth of our bodies, and every mechanical energy which we exert, trace their lineage directly to the sun. The fight of a pair of pugilists, the motion of an army, or the lifting of his own body up mountain slopes by an Alpine climber, are all cases of mechanical energy drawn from the sun. Not, therefore, in the poetical, but in a purely mechanical sense, are we children of the sun. A man weighing 150 lbs. has sixty-four pounds of muscle; but these, when dried, reduce themselves to fifteen pounds. During an ordinary day's work, for eighty days, this mass of muscle would be wholly oxidised. Special organs which do more work would be more quickly oxidised: the heart, for example, if entirely unsustained, would be oxidised in about a week. Take the amount of heat due to the direct oxidation of a given amount of food; a less amount of heat is developed by this food in the working animal frame, and the missing quantity is the exact equivalent of the mechanical work which the body accomplishes.

I might extend these considerations; the work, indeed, is done to my hand—but I am warned that I have kept you already too long. To whom, then, are we indebted for the striking generalisations of this evening's discourse? All that I have laid before you is the work of a man of whom you have scarcely ever heard. All that I have brought before you has been taken from the labors of a German physician, named Mayer. Without external stimulus, and pursuing his profession as town physician in Heilbronn, this man was the first to raise the conception of the interaction of natural forces to clearness in his own mind. And yet he is scarcely ever heard of in scientific lectures, and even to scientific men his merits are but partially known. Led by his own beautiful researches, and quite independent of Mayer, Mr. Joule published his first paper on the "Mechanical Value of Heat," in 1843; but in 1842 Mayer had actually calculated the mechanical equivalent of heat. In 1845 he published his Memoir on "Organic Motion," and applied the mechanical theory of heat in the most fearless and precise manner to vital processes. He also embraced the other natural agents in his chain of conversation. In 1853 Mr. Waterston proposed, independently, the meteoric theory of the sun's heat, and in 1854, professor William Thomson applied his admirable mathematical powers to the development of the theory; but six years previously, the subject had been handled in a masterly manner by Mayer, and all that I have said on this subject has been derived from him. When we consider the circumstances of Mayer's life, and the period at which he wrote, we cannot fail to be struck with astonishment at what he has accomplished. Here was a man of genius working in silence, animated solely by a love of his subject, and arriving at the most important results, some time in advance of those whose lives were entirely devoted to Natural Philosophy. It was the accident of bleeding of a feverish patient at Jena in 1840, that led Mayer to speculate on these subjects. He noticed that the venous blood in the tropics was of a much brighter red than in colder latitudes, and his reasoning on this fact led him into the labora-