

So that it is actually the power that carbon has of combining with oxygen that is the source of the power obtained when we burn wood or coal; and it is the presence of carbon in these that fit them for the purpose of fuel. Coal contains from 40 to 90 per cent of carbon; and this is why its burning gives to our hands so much power.

But it is not sufficient to say that carbon unites readily with oxygen, and that it is found in trees, to explain why force is given out when the two combine. If I compress a spring, it has power to return to its original extent; if I stretch a piece of indiarubber, it has power to contract to its former size. But it is the compression that gives the spring power to extend again; extension that gives the indiarubber power to contract. So it is the force acting in the tree to withdraw the carbon from the carbonic acid that gives it the power again to combine with oxygen. And this force comes from the sun; for without sunlight the separation of carbonic acid into its constituents does not take place.

Therefore, it is the sunlight that makes wood and coal able to burn; it is the sunlight that enables us to travel by steam, to warm ourselves by fire, to cook our food; it is the sunlight which has given us nearly all the force we have in the world; and it is a solemn thought that a piece of coal is the storehouse of force that fell, millions of years ago, upon the earth—that it has preserved the force until now, that we can take out this force and use it, either now or at any future time. Just as a bottle may contain water to be poured out when wanted, so coal contains force which we can take out at will.

It is the being able to call forth this force, to use it when and how we will, that constitutes power. The driver of a locomotive engine, by turning a handle, makes the huge machine move this way or that at his pleasure—can make it travel as slowly as a tortoise or as swiftly as a swallow. A steam hammer can be made to mould iron almost like putty, or to crack a nut without touching the kernel; the steersman of a vessel can turn it hither or thither at his will, whether it be a tiny skiff or a Clyde steamer; the engineer uses the force of burning coal to pump water out of a mine, to raise coal, to move a railway train, a steamboat, or the numberless machines in a factory. In this way one man, by means of a pulley or a lever, will raise a load that without such aid ten men could not move. All these are instances of the power of man to collect force, to store it up, to accumulate it, to use it at his will; and we may define power as “the intelligent application of force.”

But we must not regard coal or wood as containing a special kind of force; only as having the force, or potential power, which they contain compressed into a very small space, as compared with most other combustible substances. Phosphorus, pitch, potassium, all burn, and in burning give out force; but they do this so rapidly as to be both inconvenient and dangerous. Zinc, iron, and many other substances will burn when sufficiently heated; but the heat required is so great as to be inconvenient for many purposes, and also requires a great expenditure of fuel. Coal burns at a comparatively low temperature, is obtainable in any required quantity at a moderate cost, is easily broken into small pieces, and when burning gives out a considerable force, owing to its containing so much carbon; add to this that it can be moved when cold without any danger, is not likely to catch fire by accident, and may be kept for any period of time without loss or injury; and we see at once why it is so invaluable as fuel, alike for the domestic hearth and the furnace, for giving power to machinery in the mill or at the mine, and for moving trains of carriages upon roads or vessels upon the water.

Nor must we regard burning as the only method of obtaining force. In burning, carbon unites with oxygen so rapidly as to give out force, just as when I clap my hands together I give out force, and the air driven from between them will move any light substance in its way. So when carbon, phosphorus, potassium, or any other substance burns rapidly, force is given out, not as a chemical, but as a mechanical result of the burning. I use the terms chemical and mechanical as they are ordinarily accepted, though I think there can be but little doubt that eventually the distinction will be found to be quite untenable; and chemical result will be found to be identical with mechanical, when we are able to estimate correctly the size and weight of the bodies engaged in the former. That is, it will be found that chemical combinations are but refined examples of mechanics, in which the bodies concerned are of exceedingly small size and exceedingly numerous.

A water-mill is worked by the force of some brook or river; and it would seem that here we had an example of a continuous force, that required no other force to evoke it, of a gain without a corresponding loss. We set up a mill which is worked without any

cost beyond that of the machinery; have we not here a kind of perpetual force which requires no preparation and no repair? The river comes down continuously (unless it be only a summer brook); what force is required to raise it before it falls? For it must be remembered that it is practically the same water that circulates continually from the ocean to the clouds as steam, from the clouds to the earth as rain, and from the earth to the sea as rivers. The rivers fall into the sea, and the rain that forms them falls to the earth by the force of gravitation. But the sea, in rising to the clouds as steam, has to overcome, or to be raised against, this force of gravitation. The sun it is that does this—that overcomes gravitation, so that in raising water from the sea, as steam, to form clouds, the sun gives but another instance of how much we owe to it.

But a mill may be worked by the water in a tidal creek—that is, the waters of a creek may rise and fall with the tide, so as to enable a reservoir to be filled every tide; and the water passing out from this, when the tide has fallen, may be made to work the mill. Has the sun done this? An example is given in the figure, a rough plan of the mill-pond, &c., at Wootton Bridge, in the Isle of Wight. The water in the creek, C, rises every tide, so as to fill the mill-pond, P, which is really only a part of the creek separated by the bridge, B, which is closed underneath by locks opening towards the pond, P. When the tide falls in C, the pond, P, remains full, and (unless the locks are purposely opened) is emptied only by a kind of tunnel, M, which passes through the mill, M, which it is made to work. Are the tides also owing to the action of the sun? Partly they are, but chiefly to that of the moon. The moon is very much smaller than the sun, but, being so much nearer, has more power to move the earth, and the movements caused by the sun or difference of the attractions of the sun and moon result in the rise and fall of the surface of the water, as compared with that of the land, to which we have given the name of tides. The highest tides occur when the sun and moon act in a line; the lowest, when they act at right angles. Whether the force of the moon, like its light, be but derived from that of the sun, is difficult to tell; but if so, then again we are, in the case of a tide-mill, driven to the sun as the origin of force.

Again, an avalanche is but another example of the sun's power. The water raised as steam has been solidified by cold, and an immense accumulation of it sweeps away a village.

I climb a lofty mountain, carrying with me a small stone. I pick up another stone about the same size, and drop both together over the edge of the cliff. One I carried up, the other I found at the top; yet they are alike as to the force they exert upon anything that checks their fall. The one I carried up derived its force from being so carried; whence did the other derive its force? Assuming it to have been where I find it since the formation of the mountain, the question becomes, how was the mountain formed? For whatever force raised the mountain gave to each particular stone of it the power to fall. It is very probable that if we knew accurately the details of the past existence of our globe we should be able to trace the origin of all such force to the sun, just as I can the force that enables me to raise a pebble from the bottom of a hill to its top.

But we must carefully separate in our mind the force exerted and the means by which it is exerted. I throw a stone at a window and break it. My hand, the stone, the window are all as before, except that the stone has moved from one place to another, and that the glass is in pieces. But the size, weight, and nature of all these, whether of my hand, the stone, or the pieces of glass, are all unchanged. The force exerted is something quite independent of all those—something which can be transferred from one to another—which existed before any of them, and will probably outlive all.

It may at first surprise an unthinking person to be told that there is no force in the universe now that has not always existed; that all the vast changes in land and sea, all the storms and earthquakes, all the work of man, from his earliest existence until now, have been but rearrangements of already existing substances, and transfers of already existing force.

This explains the title of “Applied Mechanics:” the knowledge of the action of the laws of gravitation we call the science of mechanics. The study of how the observance of these laws may enable us to build houses, make roads and bridges, procure and prepare for use the materials, whether stones, timber, or metals, for these works—construct machines for spinning, weaving, printing, and performing other processes for fitting for our use the various materials we find around us—contrive engines for pumping, locomotion, moving machinery—is the study how to apply mechanics to useful purposes, and thus obtains the name of Applied Mechanics.