Transport and its Indebtedness to Science.[1]

By Sir HENRY FOWLER, K.B.E.

PROBLEMS of transportation have been solved more or less successfully in all ages, and some of them, such as the moving of stones to Stonehenge, etc., still excite our wonder and admiration. Such works, and similar ones of much greater magnitude in the East, could be accomplished by quite crude methods if there was unlimited labour available, and if time were of no consequence. The transportation which aids civilisation is that which cuts down the wastage of power to a minimum and reduces the time occupied in carrying this out. It is here that science has helped in times past, and will help increasingly in the future if we are to go forward. In no other branch is Telford's dictum that the science of engineering is "the art of directing the great sources of power in Nature for the use and convenience of man" so well exemplified, and this utilisation has been carried forward at ever-increasing speed during the last hundred years. If we take the definition of science as "ordered knowledge of natural phenomena and of the relations between them," as given by W. C. D. Whetham in the "Encyclopædia Britannica," we shall easily see how transportation has been dependent upon it.

Transport is mainly dependent upon three things—the method of propulsion, the material available for use, and the path over which traction takes place. I propose to confine my remarks to the first two. Advance in traction really became rapid when methods of propulsion other than those of animals and the force of the wind became available. The greatest step forward—wonderful as some of the achievements of aeronautics have been of recent years—came with the development of the steam engine.

Like most great achievements in the world, it was not a lucky and sudden discovery of one individual, although here as elsewhere we associate the work with the name of one man especially. This has usually been the case, and without wishing to detract from the work of the individuals who are fortunate enough to utilise the ordered knowledge available to the practical use of man, one must not forget the labours of those who have sought out that knowledge and have given it freely to the world, thus placing it at the disposal of the one whose imagination and creative faculty were great enough to see how it could be utilised in the service of man.

The first attempt at traction by using a steam engine was a failure because of the lack of this knowledge. I refer to the work of Jonathan Hulls and his attempt in 1736–7 to apply a steam engine to the propulsion of a boat on the River Avon in Worcestershire. He failed because of the lack of that knowledge, although undoubtedly he possessed the necessary imagination.

Although James Watt is not directly associated with traction, it was his application of science to practical use that finally gave the greatest impulse to transportation that it has ever had. No advance had taken place after Newcomen's engine of 1720 until Watt's work of 1769. His knowledge of Black's work at Glasgow on the latent heat of steam, and his own experiments with the Newcomen model, led to the success of his improvements of the steam engine. His scientific knowledge is clearly shown in his patents and publications, for he dealt with steam jacketing in 1769, with expansive working in 1782, and he devised his parallel motion in 1784. His direct connexion with transport includes the reference to a steam carriage and a screw propeller in 1784, while the firm of Boulton and Watt corresponded with Foulton for a period extending from 1794 to 1805.

Although Cugnot in 1770 and Murdoch in 1786 had made models of vehicles propelled by steam, it was Richard Trevithick with his steam carriage in 1801 and 1803 and ill-fated railway in 1804 who first showed the practical application which could be made. It is probable that the engine which his assistant, Steel, took to the wagon-way at Wylam in 1805 turned the thoughts of George Stephenson to the work that has meant so much for us.

No one can read the early life of the "father of railways" without appreciating that he was from young manhood a searcher after scientific knowledge. The advances he gave to the world of transport were all due to his practical application of the knowledge he had obtained himself or had learned from others. It is so often thought that because the early inventors and engineers of the beginning of last century had not received what we now call a scientific education that they were not in any sense of the term men of science. It must be remembered that at that time the knowledge of natural phenomena was very limited, and it was possible to know much more easily all the information available on a subject than at the present day, when we have such a mass of miscellaneous information to hand on every conceivable subject. It was ordered knowledge which led Stephenson to adopt the blast-pipe of Trevithick. It was the desirability of obtaining ordered knowledge that caused him to carry out those experiments which showed to him the advantages of using rails, and it was the scientific appreciation of the necessity of increased heating surface that made him adopt the suggestion of using tubes through the water space in the boiler of the "Rocket." His appreciation of the advantages of science was shown by his acceptance of the presidency of the Mechanical Science Section (then as now Section G) of the British Association in 1838, and it is interesting to note that one of the earliest grants in Section G was for a constant indicator (for locomotives) and dynamometric instruments in 1842–43, while Stephenson was still alive.

From the time of Stephenson the progress in propulsion on rails by steam locomotives was steady if slow. The investigations for a long while were largely confined to the question of expansion and condensation, and although the results attained were noteworthy in the case of steamships, on the rail there was little advance in the principle of propulsion, although the improvements in materials allowed a steady growth in power and size. Although work was done by compounding and using higher pressures, the greatest

[1] From the presidential address delivered to Section G (Engineering) of the British Association at Liverpool on September 14.

advance came to steam locomotives by the use of superheated steam. This was no new thing, for Papin in 1705 seemed to have an appreciation of its value. As pressures and the resultant temperatures increased there came difficulties with lubrication. With the increased use and knowledge of mineral lubricants Dr. Schmit was in 1895 able to devise methods of using superheated steam which have been of the greatest use to transport and to the community.

In spite of the fact that the idea of the utilisation of steam for giving rotary motion is old, its commercial adaptation in the turbine is modern. Rarely, if ever, has there been such a direct and instantaneous application of science to practice. We are too close at present to the matter to realise what a change has taken place in the world owing to the introduction of the steam turbine. One realises the work done by De Laval, Curtiss, Rateau, and the brothers Ljungstrom, but the name which will always be associated with the steam turbine as firmly as that of James Watt is with the inception of the steam engine is that of Sir Charles A. Parsons. The success of his work is due to his application of scientific principles to the many points of the turbine and its accessories. Apart from its application to marine work, it has made possible the economical production of electrical energy, which is doing so much, and will do so much more in the future, for rail transport.

The last means of propulsion that I can deal with is the internal-combustion engine. This, as we almost universally have it to-day, is the result of the cycle adopted by N. A. Otto in his gas engine in 1876. Here again the engines we have are the result of careful and studied investigation, and the advance made has been so much more rapid than in the case of the steam engine and electrical machinery because of the more advanced state of scientific knowledge.

In relation to transport the work has proceeded on two distinct lines, the Daimler and the Diesel engines. In 1885 Gottlieb Daimler produced the engine associated with his name, which utilises a light spirit supplying a carburetted air for the explosive mixture for the cylinder. The development of this engine has itself proceeded in two directions. In one it has been made very much more flexible and silent in its adaptation to motor-car work, while in the other the great desideratum has been lightness and in association with the improvements in the necessary materials has rendered possible the aeroplane as we have it to-day. In both cases the development to the degree reached has been due to a careful study primarily of the pressures, compression, and composition of the mixture.

The Diesel engine was invented in 1894 by Rudolph Diesel, and works by the injection of oil or pulverised fuel into the engine cylinder. Its development has taken place both on the four- and two-stroke cycle, and although considerable progress has been made with land engines, it has been used chiefly for marine transport.

The internal-combustion engine has not been largely used for rail transport owing to its comparatively high cost of fuel per horse-power and its lack of flexibility. The latter is particularly the case when one remembers the high torque desirable, which can be attained in both the steam and electric locomotives in starting.

The early efforts of Hulls have been mentioned, and it was only natural that the work of Watt on land should be followed by application of the new power available to propulsion on the water. Although the growth after the work of Symington, Fulton, and Bell may have seemed to be slow, it was continuous, and constant experiments and research were made both in marine engines and in their application. Saving of fuel has played a much more important part here than with the locomotive, and since more space was available and greater power required, the advantages of the expansion of steam were rendered more imperative and had greater scope than in the other long-established method of mechanical transport. The great advance came with the turbine, and it is interesting to notice that whereas in early days engines were geared up, most of them now are geared down to the screw. Scientific methods have been applied to all those details of measurement and experiment that have led to transport by sea being carried on at increased speed and with decreased cost per ton carried. The application of liquid fuel and the introduction of Diesel engines, both with the object of increasing the space available for cargo, have been carried out on true scientific lines.

Of transport by road it may be said that its commercial inception came at a time when scientific knowledge was well advanced, and its progress was in consequence more rapid. The development of the motor-car engine is a case of the careful application of the fundamental principle developed with ever-increasing care until we get engines as noiseless, as efficient, as trustworthy, and as flexible as we have them to-day.

Much could be said of the indebtedness of aeronautics to science, but I will only speak of the aeroplane. It was not until the development of the internal-combustion engine that the matter became really practical. The War was naturally a great incentive to the advancement of our knowledge of aeronautics. In the means of propulsion, research has given an engine of such size and so light in weight per horse-power that what was a laboured struggle against the effects of gravity has changed into the ability to rise at considerably more than 1000 feet per minute to heights where the rarefaction of the atmosphere renders it necessary for oxygen for breathing to be obtained artificially. The safety of flying as the result of the work of Busk has rendered the machines stable even in such a medium as the air. There is no greater example of the indebtedness of transport to science than the rapidity with which the possibilities of transport by air have advanced.

The other point I would deal with in some detail is the question of materials. We, to-day, have no basic metal or material which was not known when transport first turned to mechanical methods for assistance. The change which has come about has been as largely due to the advances made in metallurgy as to the inventions in mechanics that have led to the improvements in means of propulsion and in machinery. The early builders of steam engines were not only troubled through inability to get their engines machined properly, but also with the difficulties of obtaining suitable material for the parts they required. Steel has been known for thousands of years, but its rapid and economic production is of very recent growth. It has very truly been said that every great metallurgical discovery has led to a rapid advance in other directions. I will as before deal with the railway as an example.

We can scarcely appreciate now the conditions which existed from a metallurgical point of view on our railways when the British Association first met at Liverpool in 1837. Iron—made laboriously, heterogeneous in character and expensive of production not only in money but also, owing to the heavy character of the methods employed, detrimental to the very character of the workman—was the only material available for the various parts of the mechanism of the locomotive and for the rails. However improved the methods of manufacture were, there could never have been a universal development of rail traction if it had depended upon material made in such a way.

The demand was met at the Cheltenham meeting of the British Association in 1856 when Bessemer made public the invention he had already been working on for two years, which was to ensure a cheap method of production of a material so essential to transport. One should also mention with Bessemer the name of Mushet, whose work helped so materially in getting rid of the red shortness which in the early days gave such trouble. We are apt at the present day to belittle somewhat the work of Bessemer in view of the more improved methods now employed, but his name must for ever stand out as the one who made cheap transport possible. After the use of manganese in one form or the other as a deoxidiser and a " physic " for sulphur, there remained, however, the baneful effect, due to phosphorus, which prevented the use of the ores of more general occurrence. There have been few more epoch-making announcements made at meetings of technical subjects—although this was not appreciated at the time by many of the audience—than S. G. Thomas's announcement of the discovery of the " basic " process, which he made at the meeting of the Iron and Steel Institute in March 1878. His work, associated with that of his cousin, Gilchrist, was the result of close scientific research.

Another investigation which has given great results in transport has been the ever-growing use of alloy steels. For the scientific inception of these we owe a great debt to Sir Robert Hadfield. His first investigations materially affect transport to-day. Mushet had previously worked on self-hardening tool steel containing tungsten, but the work was only carried out on a small scale. In 1882 Hadfield had produced manganese steel. This is a most remarkable product with its great toughness, and is extensively used for railway and tramway crossings, where resistance to abrasion is of great value. This was the first of a remarkable series of alloys which have made possible the motor car and the aeroplane as we have them to-day.

Continuing his investigations, in 1889 Hadfield produced the compound of iron and silicon known as low hysteresis steel. Indirectly, this is of the greatest interest from a transport point of view, for when used in transformers it not only reduces the hysteresis losses, but also allows of a considerable saving in the weight of core material.

From these early uses of alloy steels there has grown up a large number of alloys, many of which are of the very greatest use for various transport purposes. It is not too much to say that the modern aeroplane is the result of the material now at the designers' disposal both for the engine and for the structure itself. The strength of some of the chrome-nickel steels combined with their ductility is extraordinary, and is due not only to the composition of the metal, but also to the results which have been obtained by patient scientific investigations relating to their heat-treatment. Taking one other example, one may quote the use of high chrome steel—for the early investigations into which we owe so much to Brearley, and to its later developments to Hatfield also—for the valves of aeronautical engines, subjected as they are to high temperatures. At one time it looked as if the advantages which follow high compression and its resultant high temperatures might be lost owing to the inability of ordinary steels to resist this heat, but the employment of 13 per cent. chrome steel allowed work in this direction to be continued.

It is not only with steels that we have been benefited so much from research. The case is as marked with light alloys, which have aluminium as a base. The latter itself is the result of investigation along scientific lines, and in aeronautical work particularly much has been done towards giving a metal both light and strong by the work of Walter Rosenhain, F. C. Lea, and others.

It may be said that all I have dealt with up to the present has been the result of special investigation, and that " ordered knowledge " is not of assistance to an everyday engineer. The results I have obtained with the assistance of my colleagues, especially L. Archbutt and H. A. Treadgold, dealing with the solid locomotive crank axle are of interest in this connexion. Not only is the axle subjected to stresses set up by revolving it while it is loaded with the weight of a portion of the locomotive on its axle-bearings and by the steam pressure on the pistons transmitted to the crank-pins, but it has also to withstand the shocks set up by its running on the rails, which cannot be calculated. For about twenty years we have endeavoured to get the knowledge we have obtained into an ordered state, from observation and discussion with the metallurgists attached to the various manufacturing firms. Certain points are obvious, such as the necessity of a good micro-structure, and we can with confidence say that the steel " shall be as free as possible from non-metallic enclosures, and that the micro-structure should show uniformly distributed pearlite in a sorbitic or very finely granular or lamellar condition and be free from any nodular or balled-up cementite. It must also be free from any signs of segregation and from any coarse or overheated structure." (Extract from Midland Railway specification for crank-axle forgings.) Toughness rather than strength is required, and the studied consideration of these points has led to an increased life in miles of the crank axles of the 3000 locomotives owned by the Midland Railway Company, in spite of the fact that they have been constantly growing in size, in pressure on the pistons, and in the work expected from them.

It will be appreciated that the above result, which is unquestionably the result of "ordered knowledge of natural phenomena and the relation between them," is only one example, if perhaps the most marked one, in our experience. A somewhat similar record could, however, be written on locomotive tyres and other matters.

I think I have shown adequately the debt which transport, as well as other branches of our profession, owes to the study of "ordered knowledge." That in the future this will be even more marked than at present, one can say without fear of contradiction. Not only so, but there must be more and more interdependence between science and engineering. More and more as we advance in the knowledge of natural phenomena will the necessity of the practical application of this knowledge on a large scale become necessary, to confirm it and to bring out fresh features.

The Influence of Science on Christianity.[1]

By Canon E. W. BARNES, F.R.S.

IT is a commonplace that all religions, even though their formularies and sacred books seem to guarantee absence of change, are constantly modified. Unless religion is moribund it is dynamic and not static. It is a living process within the spirit of man; and, as such, it is profoundly affected by the ideas and emotions of the community in which it exists. Religious thought and feeling alike are influenced, for good or ill, by contemporary political, social, and intellectual movements. During the last century there has been a movement of human thought as influential and as valuable as that of Renaissance humanism. The assumptions and methods of science have affected the whole outlook of educated men. In particular, those branches of science which are concerned with the domains of physics and biology have radically changed our conceptions both of the structure of the visible universe and of the development of life upon this earth.

The effect of the scientific movement, alike on organised religion and on private faith, has been prodigious. In any circumstances it would have been far-reaching. But unfortunately, representative Christian leaders, with the eager support of their communions, opposed the new scientific conceptions as they appeared. Science was then compelled to fight for autonomy on its own territory; and, as Dr. Hobson says in his recently published Gifford lectures, the result has been a prolonged struggle "in which theology has lost every battle." As a consequence it is now widely believed by the populace that Christianity itself has been worsted.

At least a generation must pass before it is generally recognised that, with regard to religion, science is neutral. Educated men know that the traditional presentation of the Christian faith must be shorn of what have become mythological accretions. But Christianity resembles a biological organism with a racial future. In the struggle for existence it gains strength and power by utilising its environment. It seeks both freedom from old limitations and increased mastery of hostile forces. Amid all change its essential character is preserved, for it rests on historical facts combined with permanent intuitions and continually repeated experiences of the human spirit. The great pioneers, whether in science or religion, are few. Men usually accept both scientific and religious truth at second-hand. The expert speaks with the accent of what seems to us to be unmistakable authority. We make such imperfect tests as we are able to apply to his teaching; and perforce rest content.

We must never forget that all human activity, and not merely those aspects which we call science and religion, rests upon unproved and unprovable assumptions. The existence of such assumptions is often ignored. They are there, none the less. Often lazily and hazily we conceal them under the term "common-sense." Faith, however, is a necessity of existence. Zealots sometimes have contended and still contend that there is a moral value in blind faith. But the modern world, so far as it has fallen under the sway of scientific method, demands that faith shall be reasonable and not blind.

In science we build upon the assumption that the processes of Nature can be represented by schemes that are, to us, rational. There is, we postulate, a unity between Nature's processes and the working of the human mind. The address given this year by the president of the British Association shows how extraordinarily fruitful this assumption has proved to be. But, when we consider the vast domains of science which still remain to be explored, we must grant that the rationality of the universe remains a postulate of reasonable faith. As we pass from science to philosophy and religion, we have to assume the existence of a universal Mind in order to bind together the sequences of phenomena which science observes and describes. Then, as the basis of religious faith, we further assume that the values, which we instinctively deem supreme, express the quality of this Mind to whom all natural process is due. We thus assert that goodness, beauty, and truth are not private values of humanity, but attributes of God.

The different processes of the human mind, thought, will, and feeling, cannot be decisively sundered. As a consequence, the search for truth made by men of science has in our own time profoundly affected our religious outlook. Science has not merely created a new cosmogony against which, as a background, religion must be set. But, as the character of its postulates and the extent of its limitations have become more clear, science has given us a new conception of what we mean by reasonable faith. In so doing, it has strikingly altered the way in which we approach religion. Some old modes of argument and their attendant dogmas have rapidly become obsolete. A great gulf has opened between constructive and merely defensive types of theology. Among religious communions there is, in consequence, much confusion, some bitterness, fear of change combined with recognition of its necessity. The direct influence of science

[1] From a sermon preached in the Lady Chapel of Liverpool Cathedral on Sunday morning, September 16, in connexion with the visit of the British Association to the city.