each case all the experiments have been successful, and on one occasion only were we troubled by a disturbance due to a note (of about 253 vibrations) when sounded alone. A slight readjustment of the cone, however, eliminated this effect entirely.

Such difficulties make it no easy matter to set up the apparatus in a hurry, and the most I can hope to do this evening is to demonstrate to you the methods of using it. I cannot undertake to make the actual measurements before you.

It is, however, desirable to illustrate the sensitiveness of the apparatus to vibrations of 64 per second, and its insensitiveness to other sounds.

Provided the current of air does not travel directly down the cone, organ-pipes may be blown just outside it without producing any effect. One of Konig's large tuning-forks may be bowed strongly without effect.

If, however, the exciting fork be tuned to 64 vibrations per second, and if it be struck as lightly as possible with the handle of a small gimlet, used as a hammer, the handle having been previously covered with india-rubber, the bands will immediately vanish, though the note produced is often quite inaudible, even to a person whose ear is placed close to the fork.

Let the weights on the fork be shifted so that it makes 63·5 vibrations per second, then the resonating fork beats. and the bands regularly appear and disappear every two seconds.

Having thus explained the construction and working of the apparatus, let me show you how we have tested whether it responds to a difference tone. When the proper rows of holes are opened, the siren will give simultaneously the *c*′ of 256 and the *e*′ of 320 vibrations. The interval is a major third, the difference tone is 64 vibrations. The pitch is determined by the beats between the upper note and a standard tuning-fork which gives *e*′. Sounding the upper note alone no effect is produced on the interference bands, as the beats first appear, then die out, and are finally heard again when the note given by the siren is too high.

It could be shown in like manner that the 256 note alone produces no effect, but if, when the standard fork of 320 vibrations and the upper note of the siren are judged to be in exact accord, the 256 note be also produced, the bands immediately disappear. Sometimes, of course, a small error is made in the estimate of the pitch, and the effect is not instantaneous, but in every case the bands disappear when the beats between the two notes are so slow that they cannot be distinguished.

It is therefore evident that Helmholtz was right when he asserted that the difference tone given by the siren is objective. It exists outside the ear, for it can move a tuning-fork.

(*To be continued.*)

JAMES WATT AND OCEAN NAVIGATION.[1]

IF it be asked what James Watt did during his long, busy, and eventful life to improve ocean navigation, or to adapt the steam engine to the work of propelling ships, I am obliged to reply that I am not aware he personally did anything, or even that he concerned himself much about the matter. He took no active part that we know of in applying or adapting his steam engine to the propulsion of ships. The reason probably was that after his attention was first directed to the subject of the steam engine, or fire engine, in 1759, his whole energy was expended, first in improving the steam engine and making its manufacture commercially successful, and afterwards in executing the orders that came for pumping and other engines that were required for mines and manufactures. In the case of most of the greatest mechanical inventions—Watt's among the number—it has not been the ideas or the inventions by themselves that have brought success, prosperity, or even satisfaction to their owners. These results have had to be painfully and slowly evolved out of long and costly practical demonstrations and experience of the alleged merits of the invention. James Watt toiled, suffered and endured for more than twenty years after his discovery of separate condensation in 1765, before he could see that his steam engine would ever bring him anything but disappointment, loss, and misery. It is highly characteristic, however, of Watt's fertile and original genius, and significant of what he might have done to develop the marine engine at the commencement of its history, had he taken the matter up, that upon the two principal occasions we know of when he applied his mind to the subject, he made very pregnant suggestions. Thus, when Watt sent drawings of his engines to Soho in 1770 for Mr. Boulton to construct one for experiment, and had been told that it was intended to make an engine to draw canal boats, Watt wrote, "Have you ever considered a spiral oar for that purpose, or are you for two wheels?" and to make his meaning clear he sketched a rough but graphic outline of a screw propeller. This is, perhaps, the earliest suggestion of a screw propeller, except that it was proposed by Daniel Bernoulli, the mathematician, in 1752. Again, in 1816, four years after the first Clyde steamboat, the *Comet*, was built at Port Glasgow, when Mr. Watt was upon his last visit to Greenock, he went to Rothesay and back in a steamboat. At that time the engineer did not reverse his engines, but merely stopped them some time before the vessel reached her mooring-place, and let her gradually slow down. James Watt, then an old man of eighty, tackled the engineer of the boat, and showed him how the engine could be reversed. He tried to explain this with the aid of a foot rule, but not being successful in doing it to the complete satisfaction of the engineer, he is said to have thrown off his overcoat and given a practical demonstration. Although Watt never took up the subject of steam navigation and never made a marine engine, still he was in reality its originator, because he discovered and provided the means by which it could be applied with advantage to the propulsion of ships. Each of his great improvements upon the old engine that worked by atmospheric pressure and condensed its steam in the cylinder—such as the separate condenser, the working by steam pressure as well as by pressure obtained by vacuum, the double action of the steam in the cylinder on both sides of the piston, working the steam expansively, the centrifugal governor for automatically regulating the speed of the engine, and many others—was a direct adaptation for marine purposes.

There is one point in the history of shipping at which we can draw a definite line between old and new when changes were made so radical in their nature, and so rapid and universal in their operations, that all which came after is fundamentally different from what existed before. The period of transition falls in the early part of the present century, when the propulsion of ships by steam power was substituted for propulsion by the wind—the motive power that had been employed from time immemorial—and when the material out of which their hulls were built was changed from wood to iron. The lateness of this period and its near proximity to the present, is illustrated by the fact that it was not till after the accession of H.M. Queen Victoria that steamships and ships built of iron came to be regularly employed in ocean navigation. At the close of the first third of the nineteenth century, the over-sea trade of the world was carried on with ships that were all built of wood and propelled by sails. Only about 200 of these were over 500 tons in burden, or much over 100 feet long. Nothing approaching to such a rapid and complete revolution as these two great changes brought about in the dimensions, forms, and all the characteristics and qualities of ships, in the conditions of life on board ship, and in travelling by sea, was ever experienced before in the known history of shipping. All the old ships of which we have any knowledge—and by old ships I mean all that existed prior to the introduction of steam—were built and fashioned entirely by manual power, with the aid of very simple tools; and they were either propelled through the water by manual labour, or by sails that could be worked in the simplest manner by the crew. One of the broadest distinctions between the ships of the past that were built of wood and propelled by sails and those of the present that are built of iron or steel and propelled by steam, is that everything had to be done in the former by the hand of man, without any aid from machine tools or other modern labour-saving and labour-helping appliances. And this was so both in preparing the materials used in building the hull and shaping them to their requisite form, putting them in position, fastening them together, and in working the ship at sea and handling the sails so as to make the pressure of the wind most effective for propulsion. In modern ships, almost everything is, on the other hand, done by steam-power in its various applications. It is by this means the plates which form the hull are first of all rolled

[1] Abstract of the Watt Lecture, delivered by Dr. Francis Elgar at Greenock, on January 18.

and are afterwards cut, drilled, bent to the required form, and many of them riveted; and it is by steam-power also that ships, after they are built, are propelled through the water, steered, pumped and drained, ventilated, lighted, loaded and discharged; the anchor is weighed, guns are trained, loaded and fired, and all the principal working operations are carried on. There could have been no great difference in size between the ships of 2000 years ago and the trading vessels of the last century. It is the application of steam-power to propulsion and to manufacture that has enabled vessels to be produced the dimensions and proportions of which were formerly unapproachable. The employment of iron and steel as the material of construction would have been impossible without the aid of steam-power; and it is the extra strength of hull obtained by these means which enables ships to be built of the large size that has now become common. Steam-power has thus not only furnished a mode of propulsion certain and regular in its action, and enabled ships to make their voyages with little or no regard to wind or weather, but it has, in manufacturing the raw material out of which ships are built, permitted the dimensions to be very largely increased, and that not only without risk and inconvenience, but with very great increase of accommodation, comfort, and safety. It is sometimes thought that the largest ships are essentially more unsafe than those of smaller size; the fact is, increase of size enables a vessel not only to be made easier in her movements at sea and less affected by the waves across which she is travelling, but it also enables the largest ships to be divided into so many separate water-tight compartments as to be practically unsinkable by the action of the heaviest seas, or by the worst effects of a collision. I do not say that all large ships are constructed so as to possess this high degree of safety, but many of the latest ones are, and it is perfectly practicable to obtain in cases where safety is the principal consideration. In small vessels the same degree of safety could not always be obtained. Safety is a quality that can be much increased by growth in dimensions.

Although James Watt may not have helped actively in the application of steam-power to ships, it is really to him and his inventions we have to look as the source whence all the great modern improvements in ocean navigation have been derived. We find in James Watt the typical engineer. He was a great philosopher and a great mechanic. He possessed just the combination of qualities and the temperament requisite to enable a man to ascertain what may be learned of the forces of nature and their mode of operation, and to utilise and apply these in the most direct way for producing a required result. He formed that happy union of what is commonly called the "theoretical" with the "practical" man. For as there was no better practical mechanic than Watt in the country, so was there no more diligent student of the sciences related to the subjects of his work, or a more patient and thorough investigator of the principles or theories upon which it depended. He tested everything by experiment; and it is said that when asked an opinion of a novel invention or proposal, his reply invariably was, "Make a model." But having ascertained by experiment all he could learn of the facts connected with any subject he was investigating, he was never satisfied till these could be explained by some physical law with which they could be shown to accord. His mental attitude towards the great mechanical problems he took in hand was that of one engaged in a close and desperate struggle with nature herself, questioning, cross-examining, testing by experiments, attacking from all sides, and refusing to give in till he had succeeded in discovering the particular secret he required to know. A favourite saying of his was, "Nature can be conquered, if we can but find out her weak side."

We thus see what are the qualities necessary to make a great engineer. They are mechanical skill and experience, scientific knowledge and capacity, great powers of observation and original investigation, energy, patience, and untiring perseverance. There have been great engineers who have exhibited certain of these qualities in a very high degree, but none who possessed all together in such full measure and such harmonious blending as we see in the case of Watt. No one man could otherwise, in a few years, have transformed so rude and imperfect a machine as the steam-engine was when Watt first took hold of it into the most perfect instrument that the working capabilities of the time admitted. The proof of Watt's great power as a mechanic and philosopher combined are to be found in the fact that he perfected in such a short time, within the limitations that were imposed by the quality of the materials and the workmen of the day, the greatest work that has been performed by any engineer of modern times.

We often hear the question asked by anxious parents or aspiring youths: How can my son, or how can I, as the case may be, become an engineer or a naval architect? This is sometimes asked as though the making of an engineer or a naval architect were perhaps a matter of three or four years' work in an office, combined with a certain amount of study of books, or attendance at lectures. There are few persons not belonging to one of the many branches of the engineering profession who know what this question really means. Engineering—and when I say engineering, I include in the term shipbuilding and all other branches of that grand profession, "whereby the great sources of power in nature are converted, adapted, and applied for the use and convenience of man"—engineering has of late become somewhat fashionable, and has attracted the notice of classes in the community who at one time would have despised it as a base, mechanic art, and turned their backs upon it. It has apparently acquired the reputation of being a well-paid profession and of being worth belonging to, in a money sense. To the general body of inquirers who thus look to engineering as offering better financial prospects than the army or navy, than the law, medicine, or the Church—including some who think there might be a chance in that direction after failing to qualify for one of the professions named—let me say that the prospects of success are very remote unless he who enters upon it is gifted with mechanical aptitude and skill, is willing to gain experience by a long course of hard work, and at the same time has the capacity, the taste, and the time for acquiring a sound knowledge of the mathematics and the physical sciences that relate to the particular branch of engineering he may think of taking up. Competition is now very keen in all departments of engineering, and what prizes there may be to strive for in them, can only fall to those who are exceptionally gifted with knowledge, experience, energy, and determination. An ordinary student or apprentice who can only learn what some one teaches him, and has not much faculty for independent observation, or for reflecting upon and discovering the causes of the many things he sees going on all around him, is never likely to be more than a subordinate in the ranks of the profession, a hewer of wood and a drawer of water, for others who have greater power of acquiring knowledge, of thinking for themselves, of observing and investigating closely and accurately the causes of defects and difficulties that arise out of their work, and of devising the necessary means of overcoming them.

If poets "are born and not made," I am sure it is equally the case with a great engineer like James Watt. His wonderful mechanical skill and ingenuity were natural to him, and were the means of determining the course his life would take. But even with all that, it is quite clear he could never have made his great discoveries and improvements had he not been a naturally gifted and diligent student, and acquired all the knowledge that was obtainable at the time of mathematics and natural philosophy. It is true that scientific study alone cannot make an engineer; but with the example of such a great mechanic as James Watt before us, it would be very presumptuous for any to say of himself that his own practical knowledge and judgment are sufficient to make him a fully-qualified engineer without studying what others have said or done upon the subjects of his work, or the physical laws that underlie the whole fabric of his practice and ideas. I would be the last to encourage any young man to suppose that a short course of study, or even great progress in mathematics and the physical sciences, would justify him in thinking himself an engineer; but I am at the same time perfectly sure that no one, however great his mechanical skill and ability might be, could ever become an engineer in the true sense of the term without following Watt's example of studying, thinking, and diligently acquiring all the knowledge of nature and nature's laws he can obtain; and applying such knowledge to the better understanding of the principles which relate to his work, and upon which the degree of success he may achieve in it depends.

One other remark with regard to James Watt. I have spoken of the great benefits we have derived in this country from the application of his steam-engine to ocean navigation by drawing the various parts of the world closer towards us, and converting the sea into a broad highway that unites us to the different continents and islands upon it in a neighbourhood which is becoming nearer and more intimate every year. We often speak complacently of the advantage this is to our own country in particular—of what it has done in enormously increasing the wealth and prosperity of the rich, and ameliorating and brightening the lives of the poor—in promoting the growth of our manufacturing trades—in enabling food to be imported from abroad in large and regular supplies at much cheaper rates than we could produce it ourselves in these islands, and in the great increase of population that the growing prosperity of the country and the easier conditions of life have thus brought about. All this is true, and it represents an extent of change and of progress during a short space of time that we can only look and marvel at, as being due to so large an extent to the results of one man's inventions. But there are other feelings with which we do well to regard the matter besides those of wonder and admiration, and of self-satisfaction with the great prosperity and the numerous advantages the country has reaped. We have been favoured above most other peoples by all these great changes, and have been blessed in very bountiful measure. We must not forget, however, that among the privileges we thus enjoy, that of immunity from danger and harm is not included. There are few pleasures or privileges to be had without alloy; and we now find, as a set-off against the benefits obtained through the improvements in ocean navigation, that we have much greater responsibilities and difficulties in protecting ourselves against danger, and in preserving unimpaired for the future the heritage of power and prosperity that has been handed down to us. The same causes that make ocean navigation easy, swift, and certain for us, make it easier also for any possible enemies to attack us. The great increase of population, due to the recent growth of wealth and prosperity, requires for its existence constant supplies of raw material to be kept up from abroad, in order that our surplus hands may be profitably employed in manufactures, and it requires also large and continuous food supplies from outside in order that it may be fed. Hence the great problem of the time for this country—how to protect ourselves against the dangers and drawbacks of the new state of things, while enjoying for the time its advantages and reaping its rewards; and how to effectually shield the vulnerable points in our armour that have arisen out of changes and improvements which brought so much good in other ways. It is upon the sea that any real danger to England would arise; and upon the sea it would have to be met. Let us hope that the nation which has covered all the seas of the world with its ships will not now fail in energy and enterprise, or be slow in providing and maintaining adequate defence of what it has produced with such success, and out of which it has reaped such rich reward. If we were to fail thus in our duties, and so shirk our responsibilities, the improvements and benefits we owe so largely to the genius of James Watt might, after all, prove a curse instead of a blessing; and we should be unworthy of the country and the race which produced the great engineer who taught his contemporaries, more than one hundred years ago, how to manufacture Power.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—Mr. Francis Gotch, F.R.S., Holt Professor of Physiology in University College, Liverpool, has been elected to the Waynflete Professorship of Physiology, vacated by the appointment of Dr. Burdon Sanderson to be Regius Professor of Medicine. Prof. Gotch is no stranger to Oxford, having been for some years assistant to his predecessor in the Waynflete Chair.

CAMBRIDGE.—Dr. W. S. Lazarus-Barlow, of Downing College, has been appointed Demonstrator of Pathology in the room of Dr. J. Lorrain Smith, who has been elected Lecturer in Pathology at Queen's College, Belfast.

The Examination in Sanitary Science for the University Diploma in Public Health will begin on April 2.

Hitherto one of the conditions which had to be fulfilled before the Science and Art Department made payments to the Committees of schools or classes, for the instruction of students, has been that the parents of a student should not have an income exceeding £400 a year from all sources. A Blue-paper now informs us that the Lords of the Committee of Council of Education have decided to enlarge this limit to £500 per annum. In future, therefore, the student on account of whom a claim is made must belong to the category of "persons in the receipt of not more than £500 a year from all sources, that is, who are allowed an abatement of the income-tax; and their children if not gaining their own livelihood." This example could be followed with advantage by the Technical Education Committees of those County Councils that restrict their Scholarships to competitors whose parents are in receipt of less than £120 a year.

SCIENTIFIC SERIALS.

Bulletin de l'Académie Royale de Belgique, No. 1.—Is the declination indicated by a compass independent of its magnetic moment? by Ch. Lagrange. According to Gauss's theory it may be assumed that the magnetic axis of a magnet lies in the direction of the lines of force of the field, whatever its magnetic moment may be. But in practice it is found that the orientation of a magnet depends upon the strength of its magnetisation. Since these systematic differences are not due to magnetic force, they must be due to some other force, probably a force hitherto unknown. Hence the magnetic chart of the earth calculated by Gauss's theory cannot be considered rigidly correct. A new constant must be introduced, depending upon the declinometer. The author foreshadows an explanation of these facts, based upon the "circulation of the ether," and intimately associated with the physics of the globe.—Double decompositions of vapours, by Henryk Arctowsky. It is not necessary that two substances should be dissolved in water to bring about their mutual decomposition; or their "ionisation," in terms of the electrolytic theory, is not altogether dependent upon water. Freshly sublimated mercuric chloride and flowers of sulphur were placed in small vessels inside a Bohemian glass tube over an organic combustion furnace. A current of pure dry hydrogen was introduced, which on heating formed sulphuretted hydrogen with the sulphur. This gas and the vapour of $HgCl_2$ gave a precipitate of mercuric sulphide on the walls of the tube. This reaction, which is contrary to Berthelot's principle of maximum work, does not take more time than the corresponding reaction in water. To prove that it was a true double decomposition, CO_2 was substituted for the hydrogen, when it was found that the sulphur vapour alone was unable to attack the mercuric chloride.

Bulletin de l'Académie des Sciences de St. Pétersbourg, fifth series, vol. I, No. 4, 1894.—Minutes of proceedings for October last.—On derived functions of superior orders, by N. Sonin (in Russian).—Crustacea Caspia: contributions to the knowledge of the Carcinological fauna of the Caspian Sea, by G. O. Sars (in English, with eight plates). The Gammarideæ are continued, and the following species, mostly new, are described and figured: *Gammarus Warpachowskyi*, *minutus*, *macrurus*, *compressus*, *similis*, *robustoides*, *crassus*, *abbreviatus*, and *obesus*, and *Niphargoides caspius*, Grimm.—On the transformation of Periodical Aggregates, mathematical paper by H. Gyldén (in German).—On Free Energy, by B. Galitzine (in Russian).

SOCIETIES AND ACADEMIES.

LONDON

Royal Society, January 24.—"Notes of an Inquiry into the Nature and Physiological Action of Black-damp, as met with in Podmore Colliery, Staffordshire, and Lilleshall Colliery, Shropshire." By Dr. John Haldane.

Black-damp, sometimes also called choke-damp, or "stythe," is one of the gases frequently found in the workings of coal mines. It is distinguished from fire-damp by the fact that it is not explosive when mixed with air, but extinguishes flame; and from after-damp by the fact that it is not the product of an explosion, but collects in the workings under ordinary conditions. Like after-damp and fire-damp, it produces fatal effects when inhaled in sufficient concentration. A further distinction has been drawn between black-damp and white-damp, which latter is described as capable of supporting combustion, while at the same time acting as a poison when inhaled.

The author has made a number of observations on concentrated black-damp from two pits, the first being in a fiery