subsequent oscillations of the discharge take place through the metallic vapours, and not through the air. We find confirmation of this view in a striking experiment which is easily repeated. If a coil of wire be inserted in the spark circuit of a Leyden jar, which may be charged either by a Wimshurst machine or an induction coil, the air lines disappear almost completely, the metallic lines alone remaining. According to our view we should explain the experiment by saying that the coil which adds self-induction lengthens the duration of the discharge, and allows time for the metallit molecules to diffuse properly into the spark gap. A great part of the energy of the current may then do useful work by heating up the metallic molecules instead of those of air. Mr. Hemsalech is at present engaged in investigating the changes in the metallic spectra which accompany the insertion of self-induction.

The first spark passing through the air will give rise to a sound wave which, during the complete time of the discharge, will only travel a few millimetres. We may therefore consider that the mass of metallic vapours suddenly set free is driven by its own pressure into the partial vacuum formed by the heated air. It would seem more correct to liken the process to that of a gas under pressure flowing into a vacuum than to that of a pure thermal diffusion. There is not much difference between these views, and we may take it that in our experiment we have approximately measured the velocity of sound in the metallic vapours. This gives a relation between their temperature and density. If we neglect the differences in the ratio of specific heat, we find approximately

$$V = 80 \sqrt{T/\rho},$$

where T is the absolute temperature and ρ the vapour density referred to hydrogen. Thus for cadmium the average molecular velocity found was 560, and substituting $\rho = 56$ we obtain $T = 2700$, which seems a possible value. Hence we conclude that the molecule of cadmium in the spark cannot have a mass which is much smaller than that directly determined near the boiling point of the metal.

In conclusion we have also taken some photographs in which the slit was directly focussed on the sensitive film without the interposition of the film. The photographs show a straight image of the slit followed by a number of curved bands extending from both poles into the spark gap.

The straight image we consider to be the initial discharge through air creating sufficient heat to fill the space with vapour through which the oscillating discharges may then pass. Our experiments point to the fact that the periodic time was rather too small in our experiments to give the best results. The metallic molecule before it has had time to reach through a sufficient distance was possibly affected in its motion by the subsequent oscillation. We hope to remedy this defect by introducing still higher capacities than those used. Our experiments allow us to give the following approximate numerical data. The air rendered luminous by the first discharge remains luminous for a time of about 5×10^{-7} seconds, the metallic vapours then begin to diffuse and reach the centre of the spark (the gap being 1 cm. long) in a time which in the case of cadmium was about 6×10^{-6} seconds. The periodic time of the oscillations with our six jars and a circuit possessing as little self-induction as possible was about 2×10^{-6} seconds. The metallic vapours remain luminous in the centre of the spark for a longer period than near the poles, the duration of the time during which some luminosity can be traced with a discharge from six Leyden jars is about $1 \cdot 5 \times 10^{-5}$ seconds.

MR. BALFOUR AND PROF. JEBB ON TECHNICAL AND SECONDARY EDUCATION.

TWO important speeches on technical and secondary education were made during last week—one by Mr. Balfour in opening a new hall which has been erected in connection with the Battersea Polytechnic, and the other by Prof. Jebb at Cambridge. The *Times* reports of the remarks made on these two occasions are abridged below.

MR. BALFOUR ON TECHNICAL EDUCATION.

Everybody interested in the least in the progress of education must watch with the profoundest interest the great experiment now being carried on in this metropolis, and not the least in the building where I am now addressing you, in connection with technical education. If I understand the matter rightly, the experiment differs frcm any other efforts in the same direction which have been made, either in this country, in other great centres of population, or on the continent of Europe—in Germany or in Switzerland, or in any other countries which have been pioneers in this matter of scientific and technical education.

Every scheme of education has to be considered from two distinct points of view. We have to consider its effect in qualifying the individual who receives the education for the particular work in life which he has to do. That is the first aspect of it; but there is another aspect not less important, which certainly ought never to be lost sight of, and which is not lost sight of in this institution—namely, the general educational results at which any sound system of education ought to aim. There is the technical side and there is the general side. There is the skill infused in the pupil for following that profession in life which he has selected, or which circumstances have forced upon him; and there is that other and that broader aspect in which all education of every kind is intended to co-operate—namely, the development of the general faculties of mind, eye, and body, and also to make a man or a woman a complete citizen, with all their faculties developed to the highest possible point.

Technical Instruction.

Taking these two aspects in turn, and dealing, in the first instance, with the industrial and technical aspect, I do not feel myself qualified to speak with any authority upon that part of the work of this institution which has to do with handicrafts. I understand that the aim of the institution in this connection is to supply those who are engaged in these handicrafts with more theoretical and general instruction in connection with their special pursuit which is required to enable the people to reach the highest results in that pursuit. I cannot imagine a better object. I am not aware that in other places the same object is pursued systematically and successfully in the same way in which it is pursued in the London polytechnics. After all, it has to be recognised that work is mainly to be learnt in the workshops, and I am convinced that no wise teacher would for a moment attempt to substitute either the lecture-room or experiment-room for that which can be learnt only in the workshop. But unquestionably there are branches of knowledge connected with trades and handicrafts which have a theoretical side which cannot with equal facility be learnt except in a place devoted to that side, and I believe that the work done in this institution in that connection is one of the greatest value, not merely to the pupils, but to the trades and industries which they have elected to follow.

Scientific Education.

But there is another side, and, from a national point of view, perhaps a decidedly more important side than that, and the side I mean is the complete scientific equipment of a student for those professions in which a thorough grounding in science, theoretical and practical, is absolutely necessary if he is to make the most of himself and the most of the profession in which he is engaged. I have always been deeply interested in this aspect of the question, which is the one specially considered in Germany and elsewhere, and the value of which we have perhaps in this country until recent years unduly ignored and neglected. It is an interesting question to ask ourselves how it comes about, and why it comes about, that it is only in the latter half of the nineteenth century that the absolute necessity of this thorough scientific grounding has been recognised in connection with great industrial enterprises. And the real reason I take to be this—that it is only after science has developed to a certain point, and after industry has developed to a certain point, that you can, as it were, successfully and usefully combine the two, and that there is forced upon you the necessity of recognising that almost every advance in theoretical science is reflected in a corresponding advance of industrial enterprise, and in like manner industrial enterprise and the practical application of science is itself from day to day giving birth to new scientific conceptions and new improvements either in the machinery of discovery or in the results of discovery. If anybody wishes to have a concrete illustration of this abstract truth I would ask him to make the following comparison. Take for a moment the career of the greatest man of science that this world has ever seen—I mean Sir Isaac Newson. As far as I know—I speak under correction—neither by Sir Isaac Newton himself, nor by

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any one during his lifetime, were any of his epoch-making discoveries turned to any practical industrial account. So far as I know neither the unparalleled advances he made in the methods of mathematical investigation nor his discoveries in physics, in the laws of energy and the laws of motion, nor his discoveries in the region of light had any important practical bearing upon the industries either of his own country or any other country during his long life. Those discoveries were, for the most part, made while he was comparatively a young man—made, let me tell the younger members of my audience, at that happy time of life between twenty and thirty when the inventive energies are freshest, and when I hope many of them will be able to add to the store of our knowledge; but though those discoveries were made at this early period, and though Newton lived to a very advanced age, the fact broadly, I believe, is that his inventions had no important effect upon the industrial world. Now, compare with the career of Newton the careers of two of the greatest men of science that we have seen in our time—Pasteur and Lord Kelvin—two of the greatest names, I was going to say, in the science of all time, but certainly in the science of the last half of the nineteenth century. Almost every discovery of those two great men found its immediate echo in some practical advantage to the industrial world. It would be a mere impertinence before an audience in which there are many persons incomparably more qualified than I am to speak on those subjects, to dwell upon the details, but the fact is familiar to almost everybody, and the extraordinary additions which both these great men have made in very different spheres to our theoretic knowledge have had an application of incalculable value, either in the department of commercial production, of navigation, or of medicine and therapeutics.

A Plea for Thoroughness.

Can you have a more instructive contrast than I have endeavoured to lay before you between the immediate results of the scientific career of Newton and the scientific career of two of Newton's great successors, and on what does it depend? It depends upon this, that theoretical science and practical production have each on their sides now so advanced, come so close together, are so intertwined, that nothing can happen in one branch which has not its copy in another branch. Theory and practice are now almost different sides of the same shield, and he who advances theory knows probably in his own experience that it will be met in practice, and he who advances practice may rest assured that some of the fruits of his labour will be found valuable to theory. In order to obtain the highest results which we hope may really follow from such training as students obtain in the higher and more difficult branches of science in institutions like this it is absolutely necessary that the training should be thorough. It is absolutely necessary if we in this country are to compete on equal terms with the scientifically trained pupils of foreign polytechnics that the scientific training here must be offered and must be taken—and I believe it to be taken by the pupils here —in the same spirit in which it is taken in Germany or in Switzerland. Whatever else may be said of the system of education there—and do not suppose that I for one hold it up as being superior in every respect to what we have in this country—at all events, the sternest critics must admit that it is thorough in the branches with which it deals; and the man who has got the best out of one highly equipped foreign place of technical instruction does really know not merely the theoretical groundwork, but the whole special detail of the science most nearly concerned with his work in life. That thoroughness is aimed at, and I believe is attained in this institution; and it is for that reason I look forward with such great confidence to the results of the system of education here instituted in its higher branches. For it is the higher branches, mark you, that ought to be on a universal level. Part of the work of a polytechnic is more properly described as secondary education. Part of it must be more than secondary education; and if we fall short of the highest ideal of all we fall short of something which is, I believe, absolutely necessary both from an educational and from a technical point of view.

The General Aspect of Education.

It remains for me to say a word upon the second and more general aspect of education.

I feel that even those students of this institution who come here merely to gain some addition to their knowledge of a special handicraft may carry away something which is of far more importance to them than the mere acquisition of technical skill. They may carry away that broadened knowledge of the laws of nature and the progress of science which, to my mind, is not less liberalising and of not less value in the highest sense of education than the most accurate knowledge of the grammar of a dead language or the works of an ancient civilisation. I make no attack, I need hardly say, on literary education, but I cannot admit that scientific education—even if it be humble in its amount, if it be stopped comparatively early in the career of the learner—is not capable of producing as beneficial educational effects on the taught as any system of education which the ingenuity of the world as has yet succeeded in devising. Let me conclude by saying that I value the great privilege of being asked to take a leading part in this interesting ceremony. I believe that the polytechnic is doing a great work, not merely for the economic, but for the educational future of the country. I believe that in that work this splendid building, which we owe entirely to the liberality of private donors and of liberal companies, is destined in future to play no small part in the lives of those who come to this institution for educational advantages which until twenty years ago were not within the reach of any citizen of this great city.

PROF. JEBB ON SECONDARY EDUCATION.

A meeting of members of the University of Cambridge was held at Trinity College Lodge on Saturday afternoon to consider prospective legislation with regard to secondary education.

Prof. Jebb, M.P., moved the following resolutions: (1) "That this meeting welcomes the Board of Education Bill introduced by the Duke of Devonshire in the House of Lords last August as an important step towards the organisation of secondary education in England." (2) "That, in the opinion of this meeting, the consultative committee proposed in Clause 3 of the Bill should be made permanent, and should contain representatives of the Universities and of the teaching profession." (3) "That, in the opinion of this meeting, it is desirable that a system of inspection and examination conducted by a University, and approved for the purpose by the Board of Education, should be accepted as adequate under Clause 2, section (4) of the Bill." (4) "That copies of resolutions 1, 2 and 3 be forwarded to the Marquis of Salisbury, the Duke of Devonshire, Mr. Balfour, and Sir John Gorst." Speaking to the first proposition Prof. Jebb, in the course of his remarks, said:—

Scope of the Board of Education Bill.

The first duty of a recognised central department will be to take something in the nature of a census or a general survey of our existing educational resources. Such a survey was necessary, because at present, owing to the number of separate and independent agencies at work, there was no means of ascertaining precisely where gaps and deficiencies existed, and where, on the other hand, power was being wasted—though the existence of such evils was sufficiently manifest. The central authority, overlooking the whole field, would be able to determine what parts of the ground were vacant and in what parts of it there was overlapping, and therefore loss of power. The scope of the Bill, confined as it was to setting up a central authority, was limited. He believed this limitation to be a wise one, not merely on Parliamentary grounds, because such a Bill was easier to get through both Houses, but on larger grounds of educational policy. The establishment of a strong central authority, commanding public confidence, would in itself facilitate the creation of local authorities of a satisfactory kind; it would tend towards harmony among the various agencies and interests which claimed representation in the local management of secondary education. Further, the preliminary stock-taking by the central authority of our educational resources—that general survey or census to which he had just referred—was an operation which might with great advantage be performed, or at least begun, before the new local authorities came into active operation, since it would in some respects facilitate their task, and give them the advantage of information which no one of them separately could collect with equal efficiency or comprehensiveness. But there should be no mistake about the fact that the Government, speaking by the mouth of the Lord President on August 1, had clearly recognised the necessity of creating new statutory local authorities for secondary education, and regarded that as the next step to be

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taken. Dr. Jebb next touched upon the uneasiness caused in some quarters by Clause 7 in the revised Directory of the Science and Art Department, issued in 1897, and said a needless fear had arisen lest the clause was designed to forestall the establishment of local authorities by Parliament and to set up voluntary organisations in their place. It was a "temporary and partial expedient." After what the Lord President had said he might say that they had the most explicit and the most completely satisfactory assurances that the Government contemplated following up their creation of a central authority by the creation of local authorities, and that it would be altogether unjustifiable to refuse a welcome to the Board of Education Bill on the ground that its own immediate scope was limited. With regard to the second proposition, Dr. Jebb addressed himself to the desirability of the Consultative Committee of the Board of Education being of a permanent character. They desired that, if not a statutory body, it should, at all events, be a recognised institution, not a merely occasional resource, which might or might not be called into existence by the Minister of the time. In asking for some express recognition of the Universities and the teachers on the Consultative Committee they were merely asking that the Government should not leave to chance a result which would probably occur in any case, and that the committee should always include certain elements which, as would be generally allowed, would be indispensable to its efficiency for the purposes which the Bill contemplated.

Need for a Central Authority.

There existed in England a very large supply of institutions which gave secondary education in some form or other. There were public schools, grammar schools, large and small, of various types, proprietary and private schools, technical colleges and institutes, polytechnics, science and art classes in connection with South Kensington; and at the top of the elementary school system there were the higher grade Board schools, some of which were also schools of science, receiving Government aid; there were also higher grade schools not subject to School Boards, but under voluntary management. These various resources for secondary teaching were controlled by various agencies which had no connection with each other. The central control was divided up between the Charity Commission, the Department of Science and Art, and the Education Department; the Board of Agriculture, too, had certain functions in this respect. The local authorities were no less manifold and disparate. Within the same town or district the local power over secondary education might be shared between a county or borough council, a School Board, various governing bodies, committees under the Science and Art Department, and managers of voluntary schools. The inevitable result was overlapping and waste of power, greater or less in different places, but prevalent in some degree everywhere. Such waste of power meant increased cost to the taxpayer or ratepayer. Economy alone dictated organisation. But organisation was also demanded by regard to the efficiency of our secondary system as a whole, which vitally concerned not only our industrial and commercial interests, but also the general welfare of the nation and the empire.

Organisation of Education Board.

The Board of Education Bill introduced in the House of Lords by the Duke of Devonshire last August was to be again introduced this Session. Its object was to establish a Board of Education for England and Wales, which should take the place of the existing Education Department (including the Department of Science and Art at South Kensington), and should also exercise certain powers now pertaining to the Charity Commission. This Board would have the superintendence of all matters relating to education, both secondary and elementary. It might probably be organised in three departments—one for secondary education proper, one for the more technical branches of science and art teaching and for the control of science and art museums, and a third for elementary education. The object was to establish a single strong central authority which could survey the whole field. At the same time, nothing was more remote from the intention of the Bill than to impose a rigid or bureaucratic system of secondary education on the country. There was no idea of a cast-iron uniformity. The local authorities, which in due course would be created, would have free discretion to deal in their own way with the varying needs and circumstances of their respective localities. The central authority would merely exercise a general supervision, affording guidance and assistance as they might be needed. The Duke of Devonshire indicated, in his speech at Birmingham on January 23, what the first task of the new central authority would be. He said that the literary side of education should not be unduly neglected in comparison with the scientific and the technical. It would be a guarantee for the maintenance of the distinctly liberal studies and of that liberal spirit in education generally which was the very breath of life to secondary schools. Already a very large number of schools, of various sizes and types, had had experience of examination by the Universities, and had been thoroughly satisfied with it. About one hundred secondary schools were represented in the Cambridge local examinations, and about the same or a slightly larger number were examined by the Oxford and Cambridge Joint Board. The cost was very moderate, making the aid of the Universities available for many schools of which the resources were comparatively limited. He could not, of course, speak with any authority as to the manner in which the Government might be disposed to regard the suggestion made in this resolution; but it appeared reasonable to hope and believe that the assistance of the Universities in work for which they had already proved their competence, and which had been done to the satisfaction of the schools, would be accepted by the Education Board of the future. Such assistance would so far diminish the number of new inspectors that would have to be appointed. In conclusion, he would only say that the Board of Education Bill appeared to him, on the whole, to receive a cordial welcome from all who were interested in the welfare of secondary education in this country. The Government had shown itself fully alive to the importance of the question. It had chosen the method of procedure which was recommended by practical considerations, and which was most likely to conduce to effective legislation on sound lines and without unavoidable delay. Dr. Jebb concluded by moving the resolutions *en bloc*, and after short addresses by the Master of Trinity, Mr. Swallow, and Mr. Bryce, M.P., the resolutions were put to the meeting and carried.

EXPERIMENTAL CONTRIBUTIONS TO THE THEORY OF HEREDITY.[1]

IN this, the first part of a paper on reversion, the two following questions are dealt with, viz.: (1) Is there invariably evidence of reversion? (2) May reversion, when it does occur, result in the complete, or all but complete restoration of either comparatively recent or of comparatively remote ancestors? The first question is answered in the negative, but to the second an affirmative answer is given. In support of the view that reversion does not invariably occur, it is pointed out (1) that clear evidence of reversion is rare in the pure-bred offspring of highly prepotent animals, such as Galloway, Aberdeen, Angus, and Shorthorn cattle. And (2) that there is sometimes no evidence of reversion in cross-bred animals. While it is deemed unnecessary to submit evidence of the fact, long recognised by breeders, that the offspring of highly prepotent animals are, as a rule, the image of their parents, it is thought desirable to submit evidence in support of the contention that in cross-bred animals indications of reversion may be wholly wanting. The following experiments bear on this point: (*a*) When a prepotent Galloway bull (which is black and hornless) is crossed with a Highland heifer, the result may be an animal which experts are unable to distinguish from a pure-bred Galloway—there may be neither a trace of the long-horned Highland parent, nor yet any indication of reversion. (*b*) A peculiarly marked skewbald (bay and white) Iceland pony mare, when mated with a whole-coloured bay Shetland pony, produced a foal which in colour, form, and gait is almost identical with the skewbald dam—on no single point does it suggest the bay Shetland sire. (*c*) A nearly black Shetland mare, when mated with a bay Welsh pony, produced a bay foal which in its make, colour, &c., is the image of the sire. (*d*) A pure white fantail pigeon, crossed with a blue pouter hen, yielded a nearly white bird having the form and habits of a pouter, but no suggestion of *Columba livia*, the supposed ancestor of the numerous varieties of pigeons. (*e*) A white Shorthorn crossed with Aberdeen, Angus, or Galloway cattle results in "blue-greys," which,

[1] By Prof. J. C. Ewart, F.R.S. (Communicated to the Royal Society of Edinburgh, December 5, 1898.)

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