I laid the theory before the late Prebendary Webb a few years ago, and some selections from it were published in the *Journal* of the Liverpool Astronomical Society, and, being necessarily incomplete, the extracts were not very intelligible. I have never attempted the settlement of the lunar surface temperature, which is quite beyond me, leaving the same in the hands of Prof. Langley, and have confined myself to the solution of the peculiar and unearthly surfacing we see. This I find best explained by glaciation, under conditions of intense cold, say $-60°$ or $80°$ C., and absence of all gaseous atmosphere.

I quite indorse Capt. Ericsson's conclusions as to the extreme unlikelihood of such a small globe being finally surfaced by igneous agencies, after it had seas of water, atmosphere, and probably *polar caps*.

Neison, in his "Moon," page 41, line 7, distinctly implies that this took place, *i.e.* "that this high temperature could only arise after the practical disappearance of bodies of water from the lunar surface," the rise in lunar temperature being due to solar heat.

I cannot follow Neison in this, and, on the contrary, believe that the temperature has steadily, if slowly, declined, from a period when there was erosion, with air and water. Polar caps then formed, as on our earth and Mars, and extended as the temperature fell, until at last the entire globe was cased in ice, the last portions to glaciate being what we call the equatorial seas.

Like Capt. Ericsson, I look on the craters and walled plains as having been lagoons of water, left here and there as glaciation extended, at places of greater depth, or more likely as submarine volcanic vents, for we see their sites as craterlets and cones after final glaciation.

The aqueous vapour given off from these lagoons would form a local dome-shaped atmosphere that would retard explosive ebullition, and on its reaching the outer limit of critical temperature, would condense and fall as snow; what fell beyond the lagoon margin would pile to form the ring, and the lagoon surface or flow be gradually lowered by its removal.

But I cannot follow Capt. Ericsson in supposing that the water had a centrifugal motion, and acted as a gigantic carving-tool, that sculptured the enormous terraces in Tycho, Theophilus, &c. On the contrary, I look on it as a quiet process, and that all the circular forms, from small craterlets to even such forms as Mare Crisium or Imbrium, with its huge maritime ranges, are due to one cause. The series is complete.

I quite agree with Mr. Darwin that a layer of water vapour would exist (and be visible) over the ice on the moon if only the temperature be high enough; but, at very low temperatures, ice practically does not vaporise even *in vacuo* (see Ganot's "Physics"). Aqueous vapour not being seen, I conclude the temperature is below (say) $-80°$ C. But the most potent argument in favour of my theory is that it reasonably and consistently explains *all* the peculiar features of lunar surfacing, *i.e.* :—

The absence of distinct Polar caps;
The absence of water and aqueous vapour (now);
The absence of distinct colour in details;
The brightness of all raised, rugged surfaces, mountains, cliffs, peaks;
The relative darkness of levels whereon meteoric dust can lie;
The extraordinary circularity of forms, large and small, incomplete, or overlapped;
The cones, whether central or isolated;
The clefts or rills, also strings of craterlets;
The maritime zones, ridges, and banks;
The haze or cloud, and nimbus or rayed brightness;
The dark points seen by Dr. Klein;
Lastly, if not least, the long bright rays.

I do not think I overstate the case when I say that selenographers will find these features consistently solved by the one hypothesis, and no enigmas left.

I cannot ask for space to go into details here, but will forward a short synopsis of the leading features, in case they may be required, arranging them as nearly as may be as in the preceding list. S. E. PEAL

Sibsagar, Assam, October 13

The Astronomical Theory of the Great Ice Age

THE lecture and the letter of Sir Robert Ball, however lucid, do not appear to carry this question further than where Dr. Croll left it. It is easy to understand that when the shape of the earth's orbit was different, winter days might be colder and summer days hotter than now. What the theory at present wants is an exposition of the successive series of effects by which this state of climates would transform the Emerald Isle into a mere Greenland. It is scarcely an explanation to say that "vast fluctuations like these must correspond to vast climatic changes of the kind postulated." We desire to be shown that they will correspond, and that the correspondence will be of the kind required. Taking Sir Robert Ball's own illustration, I am quite ready to admit that his horse alternately starved and crammed will not run a dead heat with one uniformly fed; but in default of experience I should not feel certain that his animal would die of accumulated fat.

We know that there have been past periods of heat-supply more uniform than at present, and periods of wider fluctuation. We see also in geological records ages of vast snow accumulation and ages of rich vegetation near the Pole. We need a demonstration that such wider fluctuations do tend to the one and not to the other; towards snow-accumulation and not towards snow-dissipation. Attempts in this direction have been made, but much seems needed yet. E. HILL

St. John's College, Cambridge, November 23

Meteor

THE large meteor described in NATURE by Mr. P. L. Sclater, was observed here as follows:—

Nov. 17, 7h. 18m.—Fireball many times brighter than Venus. Path from $32\frac{1}{2}° + 45°$ to $158° + 55°$. Motion very slow, duration 7 seconds. Train, but no enduring streak. The fireball, as it gradually descended to the northern horizon, varied greatly in brilliancy, and gave a series of flashes lighting up the sky with great effect. I have occasionally seen larger fireballs, but never observed one more satisfactorily. This meteor was observed at Handsworth, Birmingham; at Crawshaw Booth, Lancashire; and at many other parts of the country. Its unusual brightness seems to have attracted wide notice.

Fireballs from Taurus are often seen at about this epoch; but that of November 17 appears to have belonged to a radiant-point in Aries. W. F. DENNING

Bristol

Freshwater Diatoms in the Bagshot Beds

WILL you kindly favour me with space to ask any of your numerous readers, who may be specially interested, if they can furnish me with any references to published records of freshwater Diatoms being observed in the carbonaceous earthy sands of the Middle and Lower Bagshot Beds of the London Basin? In conjunction with one of my pupils, I have lately subjected many of these green and dark-grey sands and earths to microscopic examination; and our labours have been rewarded by the discovery of a rather extensive unicellular flora, particulars of which will be shortly laid before the Geological Society. Meanwhile, I shall be happy to have the co-operation of other workers in the same field. A. IRVING

Wellington College, Berks, November 28

THE MATHEMATICAL TRIPOS[1]

I.

IT is with the greatest pleasure that I avail myself this evening of the already well-established custom which permits one of our members, once in two years, to address to his colleagues a few general remarks connected with the science that forms our common bond of union. It is not often that a mathematician has an opportunity of laying before his fellow-workers, by word of mouth, any views of his except such as relate to the actual mathematical investigations upon which he is engaged, which, from their very nature, can appeal directly only to the few who have laboured in the same field; and I feel it to be a high privilege to be permitted, in this room, and surrounded by familiar faces, to give expression to my thoughts and hopes upon subjects that are of common interest to us all as mathematicians.

[1] Address delivered before the London Mathematical Society by the President, Mr. J. W. L. Glaisher, M.A., F.R.S., on vacating the chair November 11, 1886.

I have not ventured to attempt any remarks upon the wide region of pure mathematics, or even upon the progress of such portions of it as have attracted the greatest share of interest among ourselves. I have felt that, as one who has resided and lectured in Cambridge for the past fifteen years, the most appropriate subjects for my address would be those upon which my residence in the University during an eventful period, or my experience as a lecturer, might to some extent qualify me to speak. Still, even when so restricted, I have found it no easy matter to decide upon the subjects to which I was most desirous of drawing your attention to-night.

I should like to have spoken at length upon the theory of elliptic functions. For fourteen years I have lectured regularly, each year, upon this subject, and no lectures of mine have been of so much interest to me. I believe that the time is rapidly approaching when the elementary portions of the theory will be regarded as necessarily forming part of the common course of reading of all students of mathematics, so that a familiarity with sn's, cn's, dn's, and their properties will become as essential as the differential calculus to the mathematical equipment of every person who has made mathematics one of his subjects of study.

Quite apart from its far-reaching influence in all branches of pure mathematics and its widespread applications in mathematical physics, there are special reasons which make the theory of elliptic functions a subject of peculiar interest in a course of mathematical studies, and one to which it is important that the student should be introduced as early as possible in his career, whether he be reading mathematics for its own sake, or for the sake of its applications, or for its advantages as a mental training. It is the first mathematical "theory" that he meets with in his reading—meaning by a "theory" a body of theorems and properties of functions so related to each other that the student cannot fail to see from the equations themselves that they form a consistent and remarkable system of facts, worthy of study on their own account, irrespective of any applications of which they may be susceptible. It is true that trigonometry, if regarded as the theory of singly periodic functions, is a theory in this sense, but it is reached by the student at too early a stage for him to be enabled to appreciate the nature and importance of facts that are expressed in the mathematical language of formulæ, and even if it were not so, the manner in which the subject is treated in text-books (the functions being derived from the circle and applied to the solution of triangles, &c., before they are considered analytically) makes it difficult to separate the mathematical theory from its various applications. In analytical geometry, which the student next meets with in his reading, a method of representing curves by equations is explained, and applied to the investigation and proof of properties of conics. In his next subject, differential calculus, he is introduced to new conceptions and processes of the very highest importance and the most fundamental character, and is taught to apply them to the investigation of maxima and minima, tangents and asymptotes to curves, envelopes, &c. Then come the elements of the integral calculus and of differential equations: the former consisting of a few chapters giving methods of integrating various classes of functions, followed by applications to curves and surfaces; and the latter of rules and methods for treating such equations as admit of finite solution.

Not one of these subjects, in the form in which they are necessarily presented to students, is an end in itself or exists for itself: they consist of ideas, methods, processes, and rules, which the student is taught to apply and to understand; they contain the conceptions with which he has to make himself as familiar as with the commonest facts of life, the tools which he is to have ever ready to his hand for use. And in the course of acquiring this knowledge he is made acquainted with numerous connected series of propositions—such as the properties of conics—besides various important results of more purely analytical interest. But all of these developments are presented to him in a form which throws no light upon the manner in which they were originally discovered, and, though the propositions are made to follow one another in clear logical order, the student cannot but be sensible that he is travelling, not along a natural highway, but upon a well-worn road, artificially constructed for his convenience. It is not till he reaches the subject of elliptic functions that he has the opportunity of seeing how, by means of the principles and processes that he has learned, a theory can be developed in which one result leads on of itself to another, in which every system of formulæ suggests ideas and inquiries about which the mind is eager to satisfy itself, and opens to the view fresh formulæ connected by unsuspected relations with others already obtained, so that he cannot resist the feeling that the subject is taking its own course, and that he is merely a bewildered spectator, delighted with the results which unfold themselves before him. He feels that the formulæ are, as it were, developing the subject of themselves, and that his part is passive: it is for him to follow where the formulæ point the way, and be amazed by the new wonders to which they lead him.

It may be that in using this language I am expressing the feelings of a mathematician, rather than those of a student on reading the elements of the subject for the first time; still I am convinced that the attributes I have just referred to are those which distinguish a genuine mathematical theory from a mere collection of useful principles and facts, and that no one can have studied elliptic functions without realising that mathematics is not only a weapon of research but a real living language—a language that can reveal wonderful and mysterious worlds of truths, of which, without its help, the mind could have gained not the least conception. It seems to me, therefore, of the highest importance that the student should be introduced to a real mathematical theory at the earliest stage at which his knowledge will permit of his deriving from it the peculiar advantages which I have mentioned. Thus only can he obtain expanded views or a true understanding of the science he is studying. Higher algebra and theory of numbers afford other conspicuous examples of the perfection that a pure mathematical theory can exhibit, but they do not lie so directly in the line of a general mathematical course of studies. Regarded from this latter point of view, elliptic functions has the additional merit of being a subject whose importance is recognised, on account of its physical applications, even by those to whom the gift of duly appreciating the wonders of pure mathematics seems to have been partially denied.

I should have liked also to have spoken at some length upon another subject that is constantly in my thoughts I mean the pressing need of text-books upon the higher branches of mathematics. Of text-books for use in schools we have an abundance, and each month produces a fresh supply; but it is only occasionally that we have to welcome a work intended for the use of the higher University student or the mathematician. Every one of us must sometimes have felt the want of an introductory treatise that would give the reader the fundamental propositions in some branch of mathematics which exists only in memoirs and papers scattered throughout the wilderness of *Journals* and *Transactions* of Societies. We can scarcely expect to have provided for us, in many high subjects, text-books so admirable and thorough as Dr. Salmons; still I cannot refrain from expressing the hope that in the future the number of advanced mathematical treatises may not be so infinitesimal compared with the number of memoirs as at present. I could mention several subjects that are almost at a standstill, because advance is impracticable for want of avenues by which new workers can approach them. Of necessity the literature of mathematics must always be in the main a journal literature, for the audience addressed is small; but I cannot help feeling that the disproportion between the amount of exploration effected and the attempts made to render accessible the territories explored and conquered might be greater than it is. No one can realise more vividly than I do how vastly more difficult it is to write a book than a collection of memoirs, and how beset with anxieties, for any one who is at all fastidious, is the task of arranging the fundamental properties of any comparatively new subject in clear and logical form. The sustained struggle to attain clearness, exactitude, and thoroughness in the orderly development of a complicated and mutually-connected system of propositions wears out the worker more than thrice the same amount of labour devoted to new investigations with all the fascinating excitement of successes and failures, rewards and disappointments. In writing a memoir, the mathematician begins where he pleases, and confines himself to what has interested him and what he knows he has done well. In composing a book, the author has not only to marshal into order an array of theorems of various kinds, assigning to each its due place and importance, but he has—hardest task of all, perhaps—to confine his treatise within bounds, to keep it from growing to gigantic proportions as his increased study of the subject opens up to him fresh vistas. On the other hand, however, is to be considered the great service he can thus render to his favourite study: an introductory treatise on a subject not otherwise approachable by any direct route, even if it be not of the highest class, may have done far more for its advance than could have been effected by the most brilliant memoir. Time, care, and thought are essential for the preparation of any valuable treatise, and full references to the original memoirs should be always given; if these conditions have been fulfilled, the writer has deserved well of mathematical science.

I have not been able to forbear from making the few preceding remarks upon two subjects on which I have long felt strongly; but I pass now without further delay to the main subject of my address—the Mathematical Tripos. I have thought that, in view of the importance of this examination to our science, and the frequent changes that have taken place recently, this might be a subject of no ordinary interest to our members as well as to myself. Since 1872 change has succeeded change with great rapidity, and there are probably not many outside the mathematical portion of the resident body at Cambridge who are fully aware of the present mode of conducting the examination or of the further changes already sanctioned by the Senate and which take effect next June. It is, indeed, generally known that the list of wranglers, senior optimes, and junior optimes is published in June, at about the same time as many other Tripos lists, instead of by itself in January, and that the senior wrangler is displaced from his throne, and no longer owes his position to the results of the whole examination, so that he is not necessarily—even from an examination standpoint—the first mathematician of his year. So much only is generally known; and it has seemed to me that it might be of interest, considering the influence for good that it is hoped the examination in its new form will have upon the progress of mathematics, to give some account of the successive developments that have taken place in this time-honoured examination, and the causes and efforts that have led to them. The difficulties connected with the placing of all the mathematical candidates of the year in one order of merit, the extension or limitation of the subjects of examination, and various other questions connected with the Tripos, are matters that have been continually discussed and re-discussed in the light of fresh experience by those concerned with the mathematical course of studies at Cambridge, but I may, nevertheless, perhaps be permitted to-night very briefly to refer to some of the familiar arguments in the presence of a more extended audience of mathematicians.

It is convenient to preface the principal remarks I have to make by an outline of the history of the Tripos. In doing so, I must pass very lightly over its origin and early development, as anything approaching to a complete history of its origin and rise in the last century would amount almost to a history of the studies of the University.

At the beginning of the last century, besides certain merely formal disputations, the only exercises required from candidates for degrees were the keeping of acts and opponencies. Each candidate for honours in the course of his third year had to maintain publicly a thesis, the subject of which was chosen by himself, against three opponents, in the presence of one of the Moderators, who acted as umpire. The subjects selected were philosophical or mathematical; the discussion took place in Latin and in logical form. After hearing the discussions, the Proctors and Moderators prepared a final list of candidates qualified to receive degrees. This can scarcely be considered to have been an order of merit, for each of the Proctors and Moderators, and also the Vice-Chancellor, had the right to introduce the name of one candidate into the list whenever he pleased; still, except in the case of the recipients of these honorary degrees, it is probable that the list in the main fairly represented the merits of the candidates. It was divided into three classes, consisting of (1) the wranglers and senior optimes; (2) the senior optimes who had done fairly well but had not distinguished themselves; and (3) *οἱ πολλοί*, or the poll-men. The first class received their degrees on Ash Wednesday, taking seniority according to their order on the list, and the two other classes received their degrees later.

With regard to the origin of the Tripos, Mr. W. W. Rouse Ball, in his interesting sketch of its history,[1] writes:—

"The impressions gathered from these disputations in the schools were necessarily rather vague, and when they became the sole University exercise for a degree they hardly afforded a sufficient basis for an accurate arrangement of the men in order of merit. It was, I believe, to correct this fault that the Senate House examination was introduced, and I am inclined to think that it had its origin about the year 1730. At first it probably consisted only of a few *vivâ voce* questions addressed by the Proctors and Moderators in the week after the schools to those candidates about whose abilities and position some doubt was felt; but its advantages were so patent that within ten or twelve years it had become systematised into a regular examination to which all questionists were liable, although technically it was still regarded as only supplementary to the exercises in the schools. From the beginning it was conducted in English, and accurate lists were made of the order of merit of the candidates; two advantages to which, I think, its final and definite establishment must be largely attributed."

Mr. Ball divides the time during which the exercises in the schools and the Tripos were concurrent into five periods: (1) from 1730 to about 1750, during which time it was probably unauthorised and regarded as an experiment; (2) from 1750 to 1763, during which it was gradually establishing itself,—in the last year of this period it was officially decided that when a candidate's position in the class-list was doubtful the Senate House examination and not the disputation was to be taken as the final test; (3) from 1763 to 1779, during which definite rules were framed and laid down for conducting it; (4) from 1779 to 1827, during which it practically superseded the disputations; (5) from 1827 to 1841, the year in which the disputations were abolished.

The lists published in the Cambridge University Calendars begin with the year 1747, because in that year

[1] "The Origin and History of the Mathematical Tripos," Cambridge, 1880. (Reprinted from the *Cambridge Review*.)

the final lists were first printed and distributed, the names of those who had received honorary degrees being specially marked, so that by simply erasing them the true order of merit of the other candidates could be obtained. The division of the first class into wranglers and senior optimes was first made in 1753.

It was in the third of the above periods, that is, between 1763 and 1779, that the Senate House examination was gradually gaining ground upon the schools in determining a candidate's final place on the list. By means of their acts and opponencies the candidates were divided by the Moderators into eight classes, each class being arranged in alphabetical order; their subsequent position in the class was then determined by the Senate House examination. The first two classes comprised those who were expected to be wranglers, the next four included the other candidates for honours, and the last two consisted of poll-men only. The classes were examined separately and *vivâ voce*. During this period it became the custom to require written answers to the questions. The examiner gave out the questions to the class one by one, giving out a fresh question as soon as he saw that any one had finished the last. The problem papers, which were confined to the first two classes, were given to the candidates in writing, so that they had the whole paper before them at once.

It may be of interest to give a more detailed account of the exercises in the schools during this period, when both the exercises and the examination were in full operation and vigour. The Moderators, having received from the tutors of the Colleges a list of the students who were candidates for honours at the next examination, fixed a day in the Lent term on which each was to keep his act, and assigned to him three opponents. The Respondent, or "Act" as he was then called, selected three subjects which he proposed to maintain, and submitted them to the Moderator, who communicated them to his three opponents, designating them *opponentium primus*, *secundus*, or *tertius*. On the day fixed for the Act the respondent read his thesis in the schools in the presence of the Moderator. The first opponent then mounted the box opposite to that of the respondent and below that of the Moderator, and joined issue with him, opposing the thesis by eight arguments of syllogistic form. The respondent replied to each in turn, and when an argument had been disposed of, the Moderator called for the next in the words *Probes aliter*. When the disputation had continued long enough, the Moderator dismissed the opponent with such words as "*Bene disputasti*," or "*Optime disputasti*," or "*Optime quidem disputasti*," as the case might be. The second and third opponents (who had to oppose the thesis by five and three arguments respectively) entered the box successively, and after disputing were dismissed in the same manner, the whole performance lasting between one hour and two hours. The respondent himself was dismissed with some such phrase as "*Satis et optime quidem tuo officio functus es*." Such compliments gave rise to the classification into senior and junior optimes. In general, "*Optime quidem*" was the highest praise expected even by future wranglers. The distinguished men of the year appeared eight times in the schools, twice as Respondents and twice in each grade of opponency.[1]

[1] Wordsworth, *Scholæ Academicæ* (1877), p. 37. A specimen of an argument, expressed in scholastic form, on the question, "Recte statuit Paleius de Virtute," is given by Wordsworth on p. 39, and the full system of eight arguments (in a disputation of 1784) on the question, "Solis parallaxis ope Veneris intra solem conspiciendæ a methodo Halleii recte determinari potest," is reproduced in detail by Mr. Ball in the appendix to the sketch already referred to. In the latter part of the last century it seems to have been usual for two of the questions to relate to mathematics and the third to moral philosophy. Wordsworth mentions that in 1710-11 it needed all the influence of an enthusiastic Proctor and Moderator to induce a student to keep his act in mathematical questions, but that by the middle of the century the examination was so far crystallising into the *Mathematical* Tripos that a questionist was enabled by academical authority in 1750 to resist the demands of a Moderator to produce one metaphysical question, he having already distinguished himself in mathematical argument. In the early Cambridge University Calendars the three questions given as specimens are: (1) "Recte statuit Newtonus in septima sua sectione Libri primi"; (2) "Iridis primariæ et secundariæ Phenomena solvi possunt ex Principiis Opticis"; (3) "Recte statuit Lockius de Qualitatibus Corporum."

The final establishment of the Mathematical Tripos dates, as remarked by Mr. Ball, from 1779. By the regulations agreed to by the Senate in that year, the Moderators of the previous year were added to the regular staff of examiners, and the system of brackets was introduced. The examination lasted three days (the last of which was devoted to moral philosophy), and on the fourth day a class-list, called "the Brackets," was issued, in which those candidates who were nearly equal were bracketed together. One day was devoted to the "examination of the brackets," by the result of which the names in each bracket were placed in order of merit. There was also a power of challenging, by which a candidate who was dissatisfied with his bracket might challenge any other candidate he pleased to a fresh examination;[1] but it seldom happened that any one rose above or fell below his bracket. From 1779 onwards the examination slowly and surely grew in importance, and the exercises became of less account each year, till they were finally discontinued by the Moderators in 1839. Two years later they were formally abolished by the Senate.

The following account of the Senate House examination in 1802 is abridged from the Cambridge University Calendar of that year:—"On the Monday morning, a little before eight o'clock, the students, generally about a hundred, enter the Senate House, preceded by a Master of Arts, who on this occasion is styled the father of the College to which he belongs. On two pillars at the entrance of the Senate House are hung the Classes [*i.e.* the eight classes into which the candidates have been divided by the exercises in the schools; and a paper denoting the hours of examination of those who are thought most competent to contend for Honours.

"Immediately after the University clock has struck eight, the names are called over, and the absentees being marked, are subject to certain fines. The classes to be examined are called out, and proceed to their appointed tables, where they find pens, ink, and paper provided in great abundance. In this manner, with the utmost order and regularity, two-thirds of the young men are set to work within less than five minutes after the clock has struck eight. There are three chief tables, at which six examiners preside. At the first, the senior Moderator of the present year and the junior Moderator of the preceding year. At the second, the junior Moderator of the present and the senior Moderator of the preceding year. At the third, two Moderators of the year previous to the two last, or two examiners appointed by the Senate. The two first tables are chiefly allotted to the six first classes; the third or largest to the *οἱ πολλοί*." After describing the manner of reading out the questions, the account proceeds:—"The examiners are not seated, but keep moving round the tables, both to judge how matters proceed and to deliver their questions at proper intervals. The examination, which embraces arithmetic, algebra, fluxions, the doctrine of infinitesimals and increments, geometry, trigonometry, mechanics, hydrostatics, optics, and astronomy, in all their various gradations, is varied according to circumstances: no one can anticipate a question, for in the course of five minutes he may be dragged from Euclid to Newton, from the humble arithmetic of Bonnycastle to the abstruse analytics of Waring. While this examination is proceeding at the three tables between the hours of eight and nine, printed problems are delivered to each person of the first and second classes; these he takes with him to any window he pleases, where there are pens, ink, and paper prepared for his operations." At nine o'clock the papers had to be given up, and half an hour was allowed for breakfast. At 9.30 all returned and were examined in the same way till eleven, when the Senate House was again cleared. An interval of two hours then took place. At

[1] In such cases the Moderators called to their assistance the Proctors or other Masters of Arts. About 1770 any Master of Arts was at liberty to examine any of the candidates. Mr. Ball is of opinion that this right was not insisted on after 1785.

one o'clock all returned again and were examined. At three o'clock the Senate House was again cleared for half an hour, and on the return of the candidates the examination was continued till five o'clock. This ended the Senate House examination for the day, but at seven in the evening the first four classes went to the senior Moderator's rooms to solve problems. They were finally dismissed for the day at nine, after eight hours of examination.[1] The work on the next day (Tuesday) was similar to that of the Monday; Wednesday was devoted to logic, moral philosophy, &c. "On Thursday the examinations are resumed, and continued nearly as usual, as on the Monday and Tuesday. At eight o'clock the new classifications, or brackets, which are arranged according to the order of merit, each containing the names of the candidates placed alphabetically, are hung upon the pillars." Fresh editions and revisions of the brackets were published at 9 and 11 a.m. and at 3 and 5 p.m., according to the course of the examination, liberty being given to any man to challenge the bracket immediately above his own. At five the whole examination ended. The Proctors, Moderators, and examiners then retired to a room under the public library to prepare the list of Honours, which was sometimes settled without much difficulty in a few hours, but sometimes not before two or three the next morning. The name of the senior wrangler was generally published at midnight. In 1802 there were eighty-six candidates for honours, and they were divided into fifteen brackets, the first and second brackets containing each one name only, and the third bracket four names.

The examination seems to have been a time of great excitement, and the list was most anxiously awaited. This was the case also before 1779, as appears from the account of the contest between Paley and Frere for the senior wranglership in 1763 and Jebb's account of the examination in 1772.[2]

Various changes took place in the examination in 1808, 1828, 1833, and 1839. In 1808 another day was added: three days were devoted to mathematics, exclusive of the day of examination of the brackets. Each candidate was employed eighteen hours in the course of the three days, of which eleven were devoted to book-work and the remaining seven to problems. By regulations which were confirmed by the Senate on November 13, 1827, and came into operation in January 1828, another day was added, so that the examination extended over four days, exclusive of the day of examining the brackets; the number of hours of examination was twenty-three, the time assigned to problems being the same as in 1808. On the first two days all the candidates had the same questions proposed to them, inclusive of the evening problems, and the examination on those days excluded the higher and more difficult parts of mathematics, in order, in the words of the report, "that the candidates for Honours may not be induced to pursue the more abstruse and profound mathematics to the neglect of more elementary knowledge." Accordingly, only such questions as could be solved without the aid of the differential calculus were set on the first day, and those set on the second day involved only its elementary applications. The classes were reduced to four, determined as before by the exercises in the schools. The regulations of 1827 are specially important, because they first prescribed that all the papers should be printed.[3] They are also noticeable as being the last which gave the examiners power to ask *vivâ voce* questions: after recommending that there be not contained in any paper more questions than well-prepared students have been generally found able to answer within the time allowed for the paper, the Report proceeds: "But if any candidate shall, before the end of the time, have answered all the questions in the paper, the examiners may at their discretion propose additional questions *vivâ voce*."

New regulations were confirmed by the Senate on April 6, 1832, and took effect in 1833. The commencement of the examination was placed a day earlier, the duration was five days, and the hours of examination on each day were five and a half. Thus four and a half hours were added to the whole time of examination, four of which were assigned to book-work and the remaining half-hour to problems. The examination on the first day was confined to subjects that did not require the differential calculus, and on the second and third days only the simple applications of the calculus were included. During the first four days of the examination the papers were set to all the candidates alike, but on the fifth day the examination was conducted according to classes. No reference is made to *vivâ voce* questions, and the examination of the brackets only survives in the permissive form: "That the result of the examination be published in the Senate House on the morning of the Friday succeeding the first Monday in Lent term, at nine o'clock; but if it should happen that the relative merits of any of the candidates are not then determined to the satisfaction of the Moderators and Examiners, that such candidates be re-examined on that day."

Only six years later these regulations were superseded by a new system, which passed the Senate on June 2, 1838, and came into operation in January 1839. By these new regulations another day was added to the examination, which thus lasted six days. The total number of hours of examination was thirty-three, of which eight and a half were given to problems. Throughout the whole examination the same papers were set to all the candidates. The regulations contain no mention of classes, and accordingly the exercises in the schools were discontinued by the Moderators. The permissive rule relating to the re-examination of the candidates (the survival from the brackets) was retained in these regulations in the same form as in those of 1832.

It is very interesting to notice, in the successive regulations, how the *vivâ voce* examination gradually merged into an examination by printed papers, and how, as the examination became more elaborate and exacting, it rendered unnecessary, not only the preliminary exercises in the schools, but also the final examination of the brackets.

Besides the development of the Senate House examination itself, other changes had taken place in the University system during this period of renewed activity. In 1824 the first Classical Tripos examination took place; only those who had already passed the mathematical examination being admissible as candidates. The name "Mathematical Tripos"[1] dates from after this year.

[1] In 1818 the hours for the evening problem paper were 6-10, so that the candidates had ten hours' examination in the day. Originally, as mentioned above, the problems were only set to the first two classes; in 1802 they were open to four classes, and in 1818 to all six classes, *i.e.* to all the candidates for Honours.

[2] Wordsworth (pp. 47 *et seq.*). See also the letters of Gooch, who was second wrangler in 1771 (p. 322).

[3] The words of the report are:—"It is further recommended that the questions from books, which have hitherto been proposed to the classes *vivâ voce*, should, for the future, be printed. And it is hoped that, as by this means the questions proposed in each year will be more generally known, the students may thus be better directed in their reading than they now are, and the mathematical studies of the University become more fixed and definite. An opportunity will also be afforded of ascertaining by an inspection of these papers that the examination embraces a due proportion of each of the ordinary subjects of mathematical study.

"As, however, in proposing this alteration, the intention of the Syndicate is to avoid making any change in the substance of the examination, it is recommended that the examiners be strictly enjoined to insert in these papers such questions only as are at present proposed *vivâ voce*; namely, propositions contained in the mathematical works commonly in use in the University, or simple examples and explanations of such propositions."

[1] There are few matters in the history of the University more curious and interesting than the manner in which the word *Tripos* came to be applied to the Senate House examination, and consequently also to the other final Honour examinations. It is natural to suppose that it is connected with the three classes into which the Honour list was divided, but there is no connection whatever. The history of the name may be given briefly as follows:—In the ceremonies which were performed on Ash Wednesday in the middle of the sixteenth century, at the admission of questionists to be Bachelors of Arts, an important function was executed by a certain "ould bachilour," who was appointed as champion on the side of the University. He had to "sit upon

Previously it had been known as the Senate House Examination, and this name continued long afterwards and for more than thirty years was still printed as a heading to the papers set. It was only as a means of distinguishing it from the Classical and other newer Triposes that the name Mathematical Tripos gradually came into use. By the regulations which took effect in 1828 a totally distinct series of papers were set to the poll-men, who then formed the fifth and sixth classes. The fiction of regarding the poll-list as a continuation of the list of mathematical honours still lingered till 1858, the names being arranged in order of merit in four classes called the fourth, fifth, sixth, and seventh; the fourth class being in theory supposed to be the next class to that of the junior optimes.

(To be continued.)

THE COLOURS OF METALS AND ALLOYS[1]

THIS lecture is published by request, but the author fears that, dealing as it does with the colours of metals, such interest as it may have possessed when delivered will be greatly diminished in the absence of the experiments and diagrams by which it was illustrated.

I begin with no ordinary pleasure the work which has been intrusted to me by the Council of the British Association. It is nearly twenty years since this series of lectures was established. The first, on "Matter and Force," was delivered at Dundee by a brilliant experimenter and one of the most eloquent living exponents of science; it was followed, at Norwich, by a lecture by Prof. Huxley, to whom the nation owes a deep debt of gratitude for his intense sympathy with all who are seeking to widen the bounds of scientific knowledge—to be whose colleague in one of the most important scientific schools of the country is my great good fortune. These lecturers were succeeded by other eminent men, among whom may be mentioned Spottiswoode, Bramwell, and Lubbock. The object of the lectures is to diffuse a knowledge of the operations of Nature, and to add to the number of those who rejoice in her works. Many, therefore, who have spoken to audiences similar to this, have appealed to natural phenomena; and instead of talking to you about the colour of metals, I also should have liked to dwell on the colour of the sea and sky, but Ruskin's works are, I know, often in your hands, and he has told you once for all of the colour of clouds that "there is not a moment of any day of our lives when Nature is not producing scene after scene, picture after picture, glory after glory, and working still upon such exquisite and constant principles of the most perfect beauty that it is quite certain it is all done for us, and intended for our perpetual pleasure."[1] The metallurgist, however, cannot speak with authority on themes such as these; and I have therefore selected a subject which will, I believe, enable me to bring before you important truths affecting a wide range of industrial operations, and at the same time to sustain the true function of art by pointing to the direction in which we may have increased pleasure in things that constitute our most ordinary possessions, and which we use in daily life. First permit me to explain that I intend to include under the title of the lecture any facts which are, in my opinion, connected with the colours of metals and alloys, whether natural to them or produced by artifice, as well as a brief examination of the influence which the colours of metals appear to have exerted on the history of science.

I propose to begin at what will appear to be a somewhat remote starting-point. We say that copper is red, gold yellow, and silver white, but it is by no means certain that the early races of the world had any very clear perception of the difference between these several metallic colours. With regard to early Hebrew and Greek civilisation, Mr. Gladstone has expressed his belief that the colour-sense—that is the power of recognising colour and distinguishing it from mere brightness or darkness—was imperfectly developed, and he considers that "the starting-point is absolute blindness to colour in the primitive man," and he urges that the sense of colour has been gradually developed "until it has now become a familiar and unquestioned part of our inheritance." He adds: "Perhaps one of the most significant relics of the older state of things is to be found in the preference (known to the manufacturing world) of the uncivilised nations for strong and, what is called in the spontaneous poetry of trading phrases, loud colour."[2]

Dr. Magnus holds the view that the colour-sense in man has undergone a great improvement within the last 2000 years, and Prof. Haeckel supports this speculation, but it is opposed by Romanes, who has favoured me with some observations on the subject, in view of this lecture; and it seems to me strange, if savage nations are really deficient in the sense of colour, that the use of such colours as they can get in metals and fabrics, blended, for instance, in a war-club or a pipe-stem, should be so thoroughly "understood" and so discriminatingly employed as we sometimes find them to be. It may further be observed that primitive man may even have derived from his more remote ancestry some power of being influenced by colour, and we are told that the attraction which gorgeous colouring in flowers has for birds and insects, and which colour generally possesses for our nearer ancestors, has been of great importance in the origin of species, and in the maintenance of organic life.

No doubt, in ancient times, there was much confusion between mere brightness and colour, such as is evident in the beautiful sentence in which St. Augustine[3] says: "For this *queen of colours, the light*, bathing all which we behold, wherever I am through the day, gliding by me in varied forms, soothes me when engaged on other things and not observing her." If, however, it were proved that the power of distinguishing the colour of metals was not widely diffused among the Egyptians, Hebrews, and Greeks, it is at least certain that there were individuals of these nations to whom, in very early times, the colour of metals was all-important; and although they may have confused different precious stones under generic names, they certainly appreciated their various colours, and knew, moreover, that by fusing sand with the addition of a small quantity of certain minerals, they could produce artificial gems of varied tints.

a stoole before Mr. Proctours" and to dispute with the "eldest son" (the foremost of the questionists), and afterwards with "the father" (a graduate of the College to which the "eldest son" belonged, representing the paternal character of the College). At this time the only "Tripos" was the three-legged stool on which the Bachelor sat. A century later this Bachelor seems to have become a sort of licensed buffoon, and to have been called "Mr. Tripos," just as a president is sometimes referred to as "the Chair," or a judge as "the Bench." During the 120 years in which the name Tripos or Tripus indicated a personage there are frequent allusions to the humorous orations delivered in the schools by those who filled this office. These were known as Tripos speeches. It is probable that Mr. Tripos ceased to take part in the arguments in the schools between 1730 and 1750, just about the time when the Senate House examination was originating. The Tripos speeches were then replaced by copies of Latin verses, which were circulated on the admission days. These were called Tripos verses. About 1747 the Moderators began the custom of printing Honour lists on the back of the Tripos verses. Thus the list of Honours in the Senate House examination came to be called the Tripos list, so that a man's name was said to stand in such a place in the Tripos of his year, *i.e.* upon the back of the Tripos verses. And, lastly, the name was transferred from the list to the examination, the results of which were published in the list. This account is abridged from Wordsworth's *Scholæ Academicæ*, chap. ii. Wordsworth concludes: "Thus, step by step, we have traced the word *Tripos*, passing in signification, Proteus-like, from a thing of wood (*olim truncus*) to a man, from a man to a speech, from a speech to two sets of verses, from verses to a sheet of coarse foolscap paper, from a paper to a list of names, and from a list of names to a system of examination."

[1] A Lecture delivered on September 3 by Prof. W. Chandler Roberts-Austen, F.R.S., to the Operative Classes in the Town Hall of Birmingham, in connection with the meeting of the British Association.

[1] "Modern Painters," vol. i. part 2, p. 201, 1851.

[2] *Nineteenth Century*, p. 367, 1877.

[3] "Confessions of St. Augustine." Edition edited by E. B Pusey, D.D. (p. 211).