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FROM SECONDARY SCHOOL TO UNIVERSITY

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The educational system in Britain is not easy to explain largely because it is, in many ways, so unsystematic. The coexistence of private schools (called " public ") with those under government control, through local authorities, gives a variety which one man might call " richness " and another " confusion ". For my immediate purposes, however, this variety is less relevant; and much of what I shall have to say is common to all.

The basic pattern for education leading up to the University expresses itself through the General Certificate of Education, which, for most pupils, forms the crown of their Secondary School career. This examination may be taken at three levels, called Ordinary, Advanced, and Scholarship, and in a variety of subjects.

Speaking roughly, the Ordinary Level examination is taken by pupils at the age of about 16 or 17. The aim is a standard of attainment such as would be expected in a general education without specialist details. Typical subjects are: Use of our own language, English; familiarity with a foreign language, such as French or German; possibly Latin, or Greek; Mathematics; Physics or Chemistry; History; Geography; and so on. It should be noted, however, that pupils do not always sit the examination in the subjects which they intend to take at Advanced level later. This is a matter on which there are very divergent views, and the actual practice varies from school to school. Thus the future mathematican, with mathematics as his best subject in class, may decide not to take his examination at Ordinary level, but to wait two years for Advanced; he will, however, clear off other subjects, like languages, history, geography.

Now begins, for two, or possibly three, years, specialist work in what we usually call the " Sixth Form ". One or more topics are chosen for detailed study, and normally occupy one half to three quarters of school time; the remaining time is given over to more general subjects, like literature, further work in languages, religious instruction, and, possibly, a second onslaught on any subjects failed at the Ordinary Level examination earlier. For a mathematician, the subject itself may occupy all his advanced work; but it is more likely to be supplemented by Physics or some other subject. There exists also a standard grouping in which intending scientists take Mathematics, Physics and Chemistry, with mathematics at a level somewhat lower than that required for full mathematicians.

Candidates for the Advanced Level will often take simultaneously further papers at the Scholarship Level; and here I come to the core of one aspect of my talk. The successful accomplishment of work at this level leads to the award of a *State Scholarship*, whereby the State undertakes (subject to reduction according to the income of the parents) the complete cost of education at one of the Universities.

A good insight into the British mechanism of Education may be gained by looking a little more closely at the State Scholarships. Take first the method of award:

The Ministry of Education of itself holds no examinations. There are eight (or, to be exact, nine counting a somewhat special one recently added) Examining Bodies charged with the conduct of the General Certificate Examinations, and each school is free to deal with whichever one it prefers—or to change from one to another should it wish to do so and should the new choice be willing to accept it. These eight bodies are coordinated by the Secondary Schools Examination Council, through Subject Committees of which Her Majesty's Inspectors act as Chairmen, but each body sets its own syllabus, composes its own examination papers and fixes its own standards of pass or failure. The certificates issued to successful candidates are, however, countersigned by the Minister of Education.

The State Scholarships, in particular, are therefore awarded on the recommendation of these Examining Bodies, and I have never known a case where the Ministry, which provides the actual money, has in any way disputed an award.

Another important point is that the award to a candidate of a State Scholarship does not carry with it any guarantee of admission into a particular University. Each candidate seeks for himself entry into the University of his choice; but it is not by any means certain that that University will be able to take him—though the knowledge that a man has had the ability to obtain a State Scholarship naturally counts in his favour.

We are now at the stage envisaged in my title—" From Secondary School to University ". The pupil has cleared his Ordinary Level work certifying his general education, and his Advanced Level work of a more specialist nature, possibly gaining a State Scholarship to help with his University expenses. The question arises—what influences are the Universities as such bringing to bear on his specialist education ?

(i) The most obvious influence, in many ways, is found in the Scholarships which the Universities themselves provide for intending undergraduates. In particular, the papers set by the Colleges of Oxford and Cambridge have a profound effect because of the number of people anxious to go there. It may, indeed, be argued that this influence is too great, and that the pressure of numbers encourages a standard of papers which becomes so high as to be detrimental to teaching. This is a point where opinions differ greatly, and it is certainly true that the Universities are themselves aware of the danger and try hard to avoid it.

It may be added that the money for these Scholarships is provided by the Universities or Colleges themselves; but the State has, in addition, agreed to supplement such awards from its own resources so as to make them financially as attractive as the State Scholarships.

(ii) An indirect, but very powerful, influence is exercised through the eight Examining Bodies of which I have already spoken. These bodies must get their advisers and examiners from somewhere, and they turn naturally to the schools and universities to obtain them. The council of any one of these bodies will normally include teachers in schools and in universities, and the setting of papers and marking of scripts is undertaken by teams to which members of University Staffs often belong. Thus is formed a very important link to join the schools and universities together and to keep each in touch with what is going on in the other.

(iii) We in Britain are fortunate in the existence of a link in the form of the Mathematical Association, of which teachers in both schools and universities are members. Towards the end of the last century, there was considerable dissatisfaction with the teaching of geometry according to the strict Euclidean ritual, and an Association was founded for the purpose of instituting reforms. This Association later took other branches of mathematics under its wing, and so the Mathematical Association was formed.

The functions of this Association make themselves felt in three main ways:

(a) *The Mathematical Gazette* gives teachers an opportunity to exchange ideas both on the matter and also on the manner of the mathematics that they teach. The section headed " Notes ", for example, enables writers to point out interesting properties that might otherwise escape attention. Another very valuable feature is the extensive series of book reviews, ranging from the most elementary levels up to the most advanced.

(b) The Association meets annually, either at Christmas or at Easter, so that members of schools and universities get the chance to know each other personally and to discuss their problems informally. Talks and discussions, too, take place on a wide variety of topics, and there are few matters concerning the teaching of mathematics which do not feature in the programmes taken over the years;

(c) Most important of all, in many ways, is the Teaching Committee, whose reports on the teaching of various topics are found extremely useful. For example, reports have been

published on the teaching of geometry, of algebra, of arithmetic, of calculus, of mechanics, and so on. A new report, on the teaching of mathematics in the Primary Schools—our most elementary level—is to be issued shortly. The membership of this Committee is drawn from all levels of our mathematical education, and includes teachers in elementary schools, secondary schools, universities, training centres (for the training of people intending to become teachers) and technical colleges. Thus the reports draw on a wide range of experience, and represent a high degree of cooperation in our mathematical education.

I have not said a great deal about the mathematics that is actually taught, for the framework seems to require our first attention, but a few brief remarks may be of interest:

(i) The " Ordinary " level—taken by pupils at about 16-7 years of age—includes algebra, geometry and trigonometry. The syllabus in algebra covers such things as the simplification of algebraic expressions, logarithms, quadratic equations and their application to simple problems. In geometry, the work is entirely Euclidean, though not by any means according to Euclid's own arrangement; it includes the usual elementary properties of angle, length and straight line, and goes up to circles and tangency. In the actual examination, pupils are expected know the proofs of only some 6-8 theorems, though they will, of course, have studied more in the class-room. Proofs by trigonometry are allowed—and, indeed, encouraged. The aim is, as far as possible, to " fuse " the work into a single unity.

(ii) For " Advanced Level " work the subjects of calculus, analytical geometry and mechanics are added. In calculus, the syllabus includes the differentiation and integration of elementary functions, maxima and minima, Maclaurin series, areas, centres of gravity and so on. Analytical geometry reaches the conics referred to their principal axes, and mechanics includes statics and the motion of a particle. In addition, further work in algebra covers such topics as series and the binomial theorem.

(iii) At Scholarship level, the subjects of the advanced level are continued in the natural way, and various fresh topics appear. For example, complex numbers are introduced, and a certain amount of elementary projective geometry.

Throughout the course, we lay great stress on the solution of problems as a supplement to the systematic treatment of " bookwork ". A typical examination question will often contain, as the first half, a well-known theorem to be proved, followed, for the second half, by a problem on it—though usually a pupil is allowed to prove the problem by any alternative method he may be able to devise. It may be added that solving problems is a basic method in our teaching, both at school and at university.

The scheme of work at the start of a university career is naturally very varied. It depends on the particular university selected, and upon the actual course within that university. Speaking very generally, the first year's work serves as a completion of the school course, filling in details which were regarded as " obvious " at school, and carrying technical ability to its fruition. In addition, elementary foundations may be laid for analysis (as distinct from calculus) and vectors introduced.

In some universities—Cambridge, for example—it is possible to omit this more elementary course and to proceed at once to the more advanced parts. In that case, we have linear algebra, analysis, projective geometry, vectors including divergence and curl, as well as more advanced mechanics. This course is hard, and only the better pupils really profit by it—through several others try it with varying degrees of success.

I have tried in this brief outline to give you some idea of the general picture, so that you may be able to see the significance of the details should you meet them later. That picture

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[1] Your may like to see an amusing example of where the solving of problems sometimes gets us. I found the following " solution " in a script:

$$(x+3)(2-x) = 4$$
$$x+3 = 4 \quad \text{or} \quad 2-x = 4$$
$$x = 1 \quad \text{or} \quad x = -2$$

Testing of these solutions by the Axiomatic Method of which we heard this morning shows that *both are correct* !

I add that I have been able to prove that *every* quadratic can be solved in this way, since the equation

$$x^2 - (\alpha + \beta)x + \alpha\beta = 0$$

is also

$$[(1+\alpha) - x][(1-\beta) + x] = 1 + \alpha - \beta\,.$$

is complicated at all stages by the fact that such coordination as exists is very loose, so that standards vary considerably, but I hope that I have said enough to show you the kind of problem that we have to deal with at the school-university stage.

Résumé

DE L'ÉCOLE SECONDAIRE A L'UNIVERSITÉ

La conférence donne un aperçu concret du passage de l'Ecole secondaire à l'Université:

Le « Certificat général d'Education » est accordé par un jury composé de huit comités de professeurs de l'Ecole et de l'Université. Des bourses d'Etat, couvrant les frais d'études, sont octroyées aux candidats qui ont donné satisfaction lors de cet examen. Les universités mêmes donnent aussi des bourses, et les examens qu'elles exigent de passer pour les obtenir, exercent une influence déterminée sur l'enseignement scolaire.

La Société mathématique, qui recrute ses membres parmi le corps enseignant secondaire et supérieur, établit un lien précieux entre l'Ecole et l'Université. Les congrès annuels et le travail du Comité d'enseignement permettent aux membres des contacts personnels utiles et des échanges d'idées. La *Mathematical Gazette*, organe de la Société, aide à consolider ces liens.

(Dans la discussion qui suivit la conférence, on fit remarquer que les examens mentionnés plus haut étaient uniquement écrits; toutefois, on peut demander un entretien aux candidats aux bourses d'Université.)