[7] Sheer increase in amount of education is not necessarily worthwhile. Thus, Fritz Machlup (*The Production and Distribution of Knowledge in the United States*,, Princeton, 1962) demonstrates how, by increasing the efficiency of American schooling, the amount a child learns between the ages of 6 and 18 could be learnt between the ages of 5 and 15, and that an accelerated programme which brought the school-leaving age down from 18 to 15 might save the United States 10,000 million dollars a year.

[8] Polanyi, M., "The Republic of Science", *Minerva*, **1**, 59 (1962).

[9] This assertion is open to challenge but it is supported by several pieces of evidence, for example: (*a*) in 1960, when an increase in student-numbers to 170,000 was contemplated, the President of the London Mathematical Association at the time calculated that 286 new entrants to the academic profession in mathematics would be required, and that the estimated number available was 14 a year; it might therefore take 20 years to accomplish this recruitment. (*b*) It used to be assumed that by and large a recruit to the academic profession should have a first-class honours degree. About 7 per cent of honours graduates are awarded first-class honours. This is at present an annual output of a little more than 1,000. The need for recruits into the academic profession, excluding replacements, is of the order of 8,000 if student numbers are to rise to 150,0000.

[10] This work is summarized in two publications by the Fund for the Advancement of Education, namely, *Decade of Experiment*, 1951–61 (1961) and *Better Utilisation of College Resources* (1959). See also *Ann. Conf. Higher Educ.* (University of Michigan Official Publ. 61, No. 80, 1959).

[11] Cottrell, T. L., *Univ. Edinburgh Gazette*, No. 33, 20 (1962). Joyce, C. R. B., and Weatherall, M., *Lancet*, ii, 402 (1957); i, 568 (1959).

[12] For the results of experiments on some of these techniques: see Green, E. J., *The Learning Process and Programmed Instruction* (1963). Kay, H., *Research and Experiment in Education*, edit. by Tuck, J. P. (Durham, 1961). Lumsdaine, A. A., *Student Response in Programmed Instruction* (1961). Lumsdaine, A. A., and Glaser, R., *Teaching Machines and Programmed Learning* (1960). Schramm, W., *Programmed Instruction Today and Tomorrow* (1962). Stolurow, L. M., *Teaching by Machine* (1961). Fund for the Advancement of Education, *Teaching by Television* (1961). For a general discussion, see Ong, W. J., *College English*, 245 (1960). There are encouraging signs of a change of heart in some British universities over research into university education. In 1963 the University of Lancaster appointed a Research Fellow in Higher Education, and the University of Essex decided to establish a Research Unit for Higher Education.

[13] *California and Western Conference Cost and Statistical Study* (Univ. Calif., 1956).

[14] Tickton, S. G., *The Year-round Campus Catches on* (Fund for Advancement of Education, 1963).

[15] Ministry of Education, *Statistics of Education*, part 2, 72 (1961).

[16] Sir Peter Venables has been kind enough to give me a breakdown of the refresher courses offered by 67 colleges, including colleges of advanced technology and regional colleges. It is as follows:

Duration	*Courses*
2–7 days	169
2–3 weeks	34
4–6 weeks	18
8–10 weeks	8
3 months	2
6 months	1
9 months	3

Under existing regulations of the Ministry of Education a teacher may be seconded to industry full time for 6 months on full salary, but very little advantage has been taken of this, probably owing to the severe shortage of teachers.

[17] British Postgraduate Medical Federation. *Handbook for the Session* 1962–63 and *Report for* 1961–62 (1962).

SUMMARIES OF ADDRESSES OF PRESIDENTS OF SECTIONS

HIGH-VOLTAGE INSULATION

DR. J. S. FORREST chooses for the subject of his presidential address to Section A (Mathematics and Physics) "High-voltage Insulation".

Insulating materials for high voltages may take the form of a gas, a solid, or a liquid, or a combination of these.

The gas commonly used is air at atmospheric pressure, and by spacing the conductors far enough apart, as in power transmission lines, very high voltages can be insulated. In a uniform electric field the breakdown strength of air is 30 kV/cm, but in practice, especially at large spacings between conductors, the field is usually far from uniform and the breakdown voltage gradient is reduced, for example, to 6 kV/cm for gaps of several metres. For very long gaps, as in lightning, the average gradient is only 1–3 kV/cm. It is interesting to note that the whole range of breakdown voltage of air, from short sparks in the laboratory to lightning flashes of several kilometres in length can be broadly represented by a simple power law:

$$V = 0{\cdot}7\, d^{0{\cdot}85}$$

where V is the peak breakdown voltage in megavolts and d the sparking distance in metres.

If the gas pressure is increased the breakdown voltage increases, reaching a value of 300 kV/cm for nitrogen at a pressure of 315 lb./in.^{2}. With certain electronegative gases, still higher values can be attained; for example, 800 kV/cm for sulphur hexafluoride at a pressure of 215 lb./in.^{2}.

Solid insulating materials will withstand even higher voltages, and, under carefully controlled laboratory conditions, figures of about 8,000 kV/cm have been recorded for the puncture strength of mica. Breakdown in solids may, however, occur at very much lower gradients due to relatively slow processes such as thermal instability and discharge erosion. The breakdown strength of solids is very much less over the surface than through the solid itself, and the surface failure of insulation is much the most frequent cause of trouble in practice. If the surface of the solid is contaminated by moisture and conducting deposits, the breakdown strength is drastically reduced. With porcelain or glass insulation such surface deposits give rise to a very irregular voltage distribution over the insulator, and breakdown, due to surface discharges, may occur at average gradients of only 0·2 kV/cm. With organic insulation, these surface discharges may decompose the material and cause permanent damage. Sometimes the damage takes the form of a conducting path of carbon progressively laid down by the discharges—a phenomenon known as 'tracking'. With other materials carbon is not deposited, but erosion of the material occurs and ultimately causes complete breakdown. These phenomena frequently cause failure in practice at average voltage gradients of less than 1 kV/cm.

Hydrocarbon oils are the commonest insulating liquids; they are used either alone or as an impregnant for solid insulation. Transformer oil has a breakdown strength of about 300 kV/cm, but oil-impregnated paper for high-voltage cable insulation has a breakdown strength of 1,000 kV/cm and represents the highest standard achieved in practical insulation technology. The chlorinated diphenyls also have good insulation properties and, as these liquids are non-inflammable, they are used where there is a serious fire risk.

The practical working stress on high-voltage insulators of all types is only a very small fraction of the electric strength of the insulating material itself under good conditions. Some margin is necessary, but attempts should continue to be made to reduce the gap. Progress can be made by achieving more uniform voltage distribution on large insulators, and by inhibiting cumulative and progressive processes which lead to breakdown.

A PHYSICAL APPROACH TO CHEMICAL STRUCTURE

IN his presidential address to Section B (Chemistry), Prof. J. Monteath Robertson reminds us that the past fifteen years have witnessed extraordinary advances in the power of the physical methods that may be used to investigate chemical problems. During that time the