from that of his pupils by any quality or quantity accurately measurable in absolute units.

It is significant of the recent increased interest in such problems in Great Britain that the National Gallery has installed specialised equipment for the physical investigation and characterisation of its pictures : and this almost simultaneous establishment of two such research departments in London can scarcely fail to have an important bearing on this field of investigation.

The results previously obtained have, perhaps inevitably, given rise to a certain amount of sensational publicity in the Press. This is very regrettable : for not only has it led to popular misconceptions, and to the making of extravagant claims for certain scientific weapons, but also it has tended to suggest that all manner of questions, including the thorny problem of attribution, can be settled rapidly and with certainty by scientific means. The publicity accorded to the occasional detection of art forgeries by examination with X-rays, and with ultra-violet and infra-red radiation, has led many a layman to believe that such methods invariably reveal hidden features of deep significance. In actual practice, nine out of every ten paintings, on X-ray examination, show nothing of significance—or, at least, nothing which can with certainty be interpreted at the present stage of our experience. The outstanding difficulty in investigations of this kind is that of establishing a satisfactory control experiment—a norm for comparison. It should never be forgotten that a work of art, of practically any kind, has to be regarded as a 'living' system, in a state of physico-chemical equilibrium which can be radically altered by factors at present almost unknown—as witness the sudden disintegration of certain Italian frescoes, without warning, after centuries of healthy 'life'. The independent variables controlling such a system are so numerous that it is doubtful whether any given work of art will ever be defined by a set of specific and reproducible conditions. Its very nature is so intensely individual that the cleverest forgery in existence would be an unsatisfactory control for experiment on the original. To generalise on a few striking cases is, if possible, even less permissible here than in the exact sciences : and significant progress will be obtained only after long-continued experiment under carefully controlled conditions. P. D. R.

Origin of the British Flora

LIKE all other biological phenomena, the British flora is determined by two classes of factors, those of history and constitution on one hand, and those of environment on the other. It is obvious that only those species which can at least tolerate the climate of these islands can continue to live here : the discussion held at the Royal Society on March 28 was concerned mainly with the problem of how and when they came. Light was thrown on this subject by contributions not only from taxonomists and students of the geographical distribution of species, but also from ecologists, meteorologists, geologists and archæologists, though it cannot be said that the problem taken as a whole is very close to solution despite the intensified field-work of recent years. We are in fact no farther than the beginning of the laborious collection and analysis of detailed facts which alone can eventually lead to general agreement.

Mrs. E. M. Reid opened with a paper on "British Floras antecedent to the Great Ice Age". In dealing with the Tertiary floras, she showed that that of the London clay has a large preponderance of tropical, mostly Indo-Malayan forms, which she explained by supposing migration to north-western Europe along the shores of the Tethys Sea—that greatly extended 'Mediterranean' which persisted through so many geological ages. The evidence is that some existing British genera, absent from the London Clay, existed in these regions in earlier times (before the London Clay was laid down) and were presumably driven out by this invasion of tropical climate and flora from the south-east, but the floras of later deposits (subsequent to the London Clay) show a steadily increasing percentage of living British genera, culminating in the late Pliocene with 97 per cent. It is generally accepted that the climate and flora of the Cromer Forest bed at the top of the Pliocene were roughly equivalent to those of to-day, and may therefore be taken as the real starting point of the modern flora.

Then came the cold of the Pleistocene with the advance of the great continental ice-sheet from Scandinavia and the formation of glacial systems in the mountains of Great Britain. It is obvious that these conditions must have exterminated or driven southward most of the existing flora, since the ice advanced at one time to the northern edge of the Thames Valley, and later to South Wales. It is now established, however, that there were four successive glaciations in England—though these do not necessarily correspond at all closely with those of the Continent—and correspondingly three interglacial phases. Prof. P. G. H. Boswell, whose work has greatly increased our knowledge of the Pleistocene period in Britain, sketched the history of these successive glaciations. The second reached farthest south in the east (Thames valley), the third and fourth in the west (Bristol Channel). The floras of the interglacial phases when the ice retreated were touched upon by Miss M. E. J. Chandler. During the second (middle) interglacial phase, much of our existing flora was present in eastern England, which was at that time joined to the Continent owing to general elevation of the land. Of the others little is known, and there is no evidence that any interglacial was much warmer than the present climate. 'Nunataks' (ice-free areas surrounded by ice) no doubt existed during the glaciations, but according to Prof. Boswell it is uncertain whether any of these were continuous throughout the Pleistocene, and could thus possibly afford a permanent refuge for Pliocene plants. According to Dr. Raistrick, there were 50 square miles of such ice-free areas in the Pennines, though none in the Lake District mountains. But there is still some difference of opinion on this point. The most generally accepted view is that at any rate the great bulk of the existing flora came into Great Britain from the Continent after the final retreat of the ice.

The main issue of controversy on the effect of the ice age on the British flora lies in the question whether practically the whole vegetation north of the Thames and Bristol Channel was wiped out, except such as could survive in the comparatively narrow strip south of the ice-sheets, or whether a substantial portion at least survived in ice-free 'sanctuaries' and in the south-west from interglacial or even from Pliocene times. In the discussion, Dr. A. J. Wilmott was the protagonist of the latter, Prof. E. J. Salisbury of the former view. Dr. Wilmott's evidence is (1) the occurrence of certain endemic species which are regarded as relics of Pliocene or a warm interglacial period and are very unlikely to have originated in post-glacial times ; (2) the aggregations of rare and local species in unglaciated areas south of the ice-sheet such as Brean Down in Somerset and Torquay, or in unglaciated areas surrounded by ice such as Teesdale and Arran. It seemed to him "inconceivable" that such species would have migrated separately to these areas in post-glacial times, avoiding intervening and equally suitable habitats. They must rather be regarded as relicts which have survived in these places. Prof. Salisbury, on the other hand, argued that these collections of rare species have occupied such areas in post-glacial times because the local conditions are particularly suitable for them. He does not believe that the cumulative effect of very cold conditions during a glacial phase would permit the survival of such species within the boundaries of or in proximity to an ice-sheet, or that any bounds can be set to the post-glacial migration of species within the British Isles, provided the conditions of existence are suitable for their establishment.

The view that relict species surviving the last glaciation may probably be fairly numerous in the British flora was supported by Prof. G. E. Du Rietz, of Uppsala, who gave many examples of species concentrated and isolated in two mountain areas, one in the north and the other in the south of the Scandinavian peninsula ; these can only be interpreted as relict areas, since the nature of the habitat does not in any way explain this localisation of species. He also described Norwegian coastal areas which were free of ice during the Pleistocene and possess remarkable collocations of species, and particularly one in Novaya Zemlya in proximity to the existing ice-sheet and known as "flower hill". These instances taken together greatly strengthen the case for survival close to the ice. Furthermore, he instanced a species of tropical rain forest lichen still found in south-west Ireland, the presence of which he is only able to interpret as a survival from a pre-glacial tropical climate. Prof. Du Rietz confessed himself "rather an extreme advocate" of the theory of survival of pre-glacial relicts, believing that a great part of the oceanic (Atlantic) flora survived in the south-west of the British Isles, though he did not oppose Prof. Salisbury's contention that the distribution of very many species followed the differentiation of climate, and was thus determined by existing environment rather than by the more remote history of the species. Dr. W. Watson cited several examples of Scottish liverworts and lichens occurring in isolated positions in southern England, both in the west and in Norfolk, interpreting these as glacial relicts.

There certainly seems a good deal of evidence derived from the existing distribution of particular species, not only in the British Isles but also on the Continent and in America, for the survival of relicts in particular places, doubtless in more or less specially suitable habitats, from various earlier periods, surrounded by a flora of which they do not form an integral part. But we are still very far from being able to write a convincing history of the extremely complex changes which must have occurred since the Pliocene. Our ignorance of the climates which actually existed in proximity to the ice-sheets is almost complete. We cannot assume that all the unglaciated parts of the British Isles must have been arctic tundra. The evidence from southern Sweden and Esthonia is that the forest zone there came very close to the ice ; and, for all we know, quite mild conditions may have existed in our own south-west, enabling the survival of many 'Atlantic' species, among which may be reckoned the so-called 'Lusitanian' flora, species which occur in south-western Ireland or in south-west England and also in the Iberian peninsula—some being present in and some absent from western France—among which the strawberry tree (*Arbutus unedo*) is perhaps the best known.

Several speakers—for example Miss Chandler, Prof. Boswell, Dr. W. B. Wright, Mr. Butcher and Dr. Hamshaw Thomas—emphasised from different points of view the extreme complexity of the changes and the wide fluctuations of climate and other conditions which must have occurred during the Pleistocene. Other speakers, again, directed attention to factors which are probably of great importance but are often ignored—Dr. Thomas to the importance of precipitation and accompanying humidity of the air, in addition to temperature; Dr. A. S. Watt to soil development, different soil phases limiting the spread of particular species and favouring that of others; Dr. W. B. Turrill to 'ecotypes' within an aggregate species which may all have a general superficial resemblance but in reality differ greatly, both in genetic constitution and in ecological requirements.

Dr. H. Godwin gave a lucid account of the application of the modern technique of pollen analysis to the interpretation of the post-glacial history of the British flora, showing that the succession of forest types in Britain agrees very well in a general way with that recorded from the Continent. It is difficult to judge the time of the first appearance of the dominant trees, but the order in which they spread and attained dominance can be determined with some certainty. The earliest post-glacial forest phase (Boreal) shows dominance of birch and pine and the entry of elm, oak and lime. Later came the alder, and the next climatic period (Atlantic) saw mixed oak-forest and alder dominant. It is now certain also that beech, on the native place of which doubts have been cast, was present in pre-Roman (probably Iron Age) times; and hornbeam has a similar status. Both these records agree well with the late post-glacial spread of the two trees on the Continent. There is also evidence of a second pine forest maximum between the early Bronze Age and the Roman period, and this perhaps corresponds with the Sub-boreal pine maxima in Ireland, Scandinavia and other parts of Great Britain. Not very much is certainly known of the pollen of British interglacial beds, but the presence of spruce—now extinct—has been established, so that extermination of some species at least during the later glaciations appears to be demonstrated.

A. G. TANSLEY.

The Alkali Industry

IN the Hurter Memorial Lecture to the Society of Chemical Industry (*Chemistry and Industry*, 54, 121; 1935), Dr. J. T. Conroy gave a very interesting review of the development of the manufacture of sulphuric acid, alkali, chlorine and allied products since about 1890. This period has seen the disappearance of the Leblanc process and its replacement by electrolytic processes, the Castner and Hargreaves processes developed in Great Britain having features embodied in most successful modern cells except those of the gravity type. The possibility of operating these processes was almost entirely dependent on power production. The original rocking mercury cell has given way to a trough type with many times the capacity of the original unit, and the use of Acheson artificial graphite for the anodes was a material improvement. The high degree of purity of the caustic soda produced by the Castner cell, fitting it for the electrolytic production of metallic sodium, was very helpful to its development. The sodium is the starting material for the manufacture of cyanide. For the last fifteen years the chlorine produced in Great Britain has been electrolytic in origin.

In the ammonia-soda process, improvement in plant and operation has been effected, and processes for the production of sal ammoniac and calcium chloride from appropriate tower and still liquors have been developed.

Although the Leblanc cycle has been superseded, some intermediate products are still important. Sulphuric acid is made by the chamber process, in the operation of which some mechanical improvements have been effected, and on the chemical side the use of nitre has been replaced by ammonia oxidation. Concentration of acid in platinum pans has given way to other types of apparatus and finally to the contact process. It is only with large installations and a demand for high strength acid, such as is necessary in the dyestuffs industry, that the contact process is economical. The use of sulphur has replaced that of pyrites to a large extent since the exploitation of the American deposits by the Frasch process.

The manufacture of saltcake (sodium sulphate) has declined considerably, partly because saltcake is now largely displaced by ammonia soda ash in glass manufacture and partly because the export market demands have been largely met by the recovery of sodium sulphate from residual