synthetic oils having special and valuable properties will in the long run involve their production from coal even at a higher cost. The purely economic point of view alone will not be sufficient to prevent this development as it does to-day—military, political and fiscal points of view are likely in the near future to make the advent of oil from coal nearer than is generally believed.

Whereas in the United States coal only makes up half of the power production, in Germany it is necessary for 90 per cent. Hence Germany is forced to make oil from coal, the more so as in times of peril she will have no easy access to world supplies without command of the sea.

The position in Great Britain is an intermediate one; with no natural oil we are staking everything on the command of the sea and the ability to continue supplies of oil on an enormous scale. To-day, as for many years past, our industrial supremacy is based on coal.

In any event, under present-day conditions, crude oil production can scarcely keep step with the rate of increase in demand. The share of the United States has declined, though the production of Venezuela, Rumania, Iran and Iraq has assumed greater importance.

There is always a change in the particular oil product required: thus the proportion of gasoline (petrol) to crude oil has risen from 7 per cent in 1913 to 35 per cent in 1931, since when it has slightly declined as the production of heavier gas

oil has increased. The position of oil supplies twenty years hence is obviously one of uncertainty.

In England, where the wood resources are so small, it comes perhaps somewhat as a surprise that 12·8 per cent of the world power supply is produced from wood, the equivalent figure in 1913 being 17·6 per cent. In heavily timbered countries, however, both on the continent of Europe and abroad, wood is still of prime importance. The forests which cover so much of northern Quebec represent to-day what the English Lake District must have looked like before the trees were felled—largely to smelt copper—in the time of Elizabeth: the oft-related destruction of the Sussex woods to smelt iron ore before the discovery of sea-coal is another parallel of what is happening abroad to-day. Scientific attempts are being made to utilize wood and its products in the best manner for a variety of purposes connected with power production and also as a raw material for the paper industry. Actually about half the total wood cut is used as firewood—a quantity estimated at 680 million cubic metres.

At the turn of the nineteenth century, coal seemed to dominate the field and to have pushed all other sources of power into the background. To-day coal, oil and water compete: the situation is determined in the various countries by conditions which have relation to factors not purely economic.

Modern Study of Plants in Relation to Education*

By Prof. E. J. Salisbury, F.R.S.

FROM the cultural point of view, plant life and all that it implies may be regarded as the foundation of a vast extent of human activity and the basis of a large and essential part of every human environment. Because neither we nor the animals could persist without plant life, it follows that much of the present distribution of these organisms over the face of the earth can only be understood in terms of the plant life either of the present or the past. Even man's industrial activities have been largely localized and in part determined by the geographical distribution of vegetation, whether it be that of the forests, of perhaps 280 million years ago, which gave origin to our coal deposits, or the vast extent of grasslands that have determined the location of pastoral communities.

A realization of the widespread demands made upon plant products would probably astonish

many of those who, like Mr. Babitt, find in the mechanistic devices of the age their chief delight. Yet it has been recently estimated that a thousand Ford motor-cars utilize in their manufacture the entire plant yield of more than six hundred acres, and this quite apart from the indirect demands for grazing necessary to furnish the materials of animal origin. Despite the vast areas of the earth's surface devoted to the growth of foodstuffs, of textile fibres, of timber, rubber, tea, tobacco and innumerable other plant products, the plant remains perhaps the least known and appreciated of all man's servants by those who lay claim to any cognizance of their environment.

Even the town dweller can scarcely fail to recognize the indirect contacts of his everyday existence with the activities of agriculture, forestry and horticulture, and, if education is to be interpreted as a means of enabling the individual to

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have an intelligent appreciation of and harmonious relations with his environment, then a knowledge of plant life is manifestly essential to that end. I should almost feel that an apology was necessary for expressing sentiments so trite were I not sure that whatever agreement there may be in theory, our educational curricula bear witness to the neglect of these principles in practice.

The increasing diversity of pursuits in a progressive science is only too liable to be accompanied by an increasing detachment of interests and divergence of expression. Specialization, which should be accompanied by greater co-ordination, is only too frequently the begetter of disintegration rather than synthesis, and the mutual interdependence of one branch on another is lost sight of. One of the main purposes which the British Association should serve is to promote the co-operation between workers in different fields. But we only come together for a short week in each year, and so it is to the universities that we must look mainly for the continuous fostering of a liberal outlook both on science as a whole and within the domains of each particular subject.

In its earlier phases, botany was naturally concerned largely with description, and in such branches as taxonomy, morphology, anatomy, cytology, mycology, palaeobotany and plant geography the descriptive aspect must necessarily play an important part, just as in ecology, physiology, bacteriology and genetics the experimental aspects should predominate. But in all, the cultural value can only be maintained if form and function are closely integrated. Each branch has its own contribution to make in this respect not only to the pure science but also to its applied aspects in agriculture, horticulture, pomology, silviculture and plant pathology. The mere enumeration of these branches, whether pure or applied, envisages the richness of the field we cultivate and the extensive contribution that botany can make towards both the enrichment of the human mind and the well-being of the race. But the accumulation of data in these varied directions of inquiry will only fulfil its full purpose if the many threads are continually woven into the warp and woof of a single fabric.

The retention of plant physiology within the domain of botany has saved us from the worst evils of the study of form unrelated to function. This has also been one of the chief factors which led to that synthetic approach to our subject which concerns the relation of the plant to its surroundings. The supreme value of ecology, however, lies not so much in the attention which it focuses upon the mutual relations of organisms or even upon their relation to the environment, but in the synthesis which ecology achieves, into a

single picture, of so many aspects of botany itself and so many branches of human knowledge. Its high educational and cultural potentiality is an outcome of the fact that it is the very antithesis of that common failing of the human mind to think of different subjects as isolated compartments of knowledge and not as different facets of one and the same jewel.

When we attempt to understand any plant community, the necessary study of the physical environment leads us at once into realms of soil structure, into the physical problems connected with water retention and water movement involving colloid properties and surface action. So, too, the chemist and the meteorologist make their contributions to our concept of the habitat, whilst the bacteriologist, the mycologist and the protozoologist all help us to envisage that teeming population of bacteria, fungi and protozoa in the soil which, by their proper balance, maintain a healthy circulation of chemical products and are a necessity for the maintenance of the supply of raw material for the higher plants and animals.

Since the environment of the present is in some considerable degree the consequence of that of the immediate and sometimes of the remote past, the study of external conditions brings us into contact with the contributions of glaciologists and historians, whilst even the student of 'place names' may materially assist in the reconstruction of those past conditions that in part have determined the present state.

When we turn from the study of the habitat to that of the vegetation which it supports, we are at once confronted with the question as to the extent to which one is in equilibrium with the other.

The morphologist and the anatomist furnish the data upon which we base our judgment as to the degree to which the external form and internal structure have contributed to render the organisms suited to the environments that they frequent. In so far as there is adaptation, whether passive or active, in this respect, to that extent the community is in equilibrium with its surroundings and represents a climax, subject, it is true, to secular change but of a relatively stable character.

The contribution of the systematist is to distinguish between the more critical species and races which exhibit a localization that less meticulous examination might readily ignore and which often have an ecological importance far greater than the Linneons of which they are the segregates. The experimental conclusions of the physiologist in the laboratory must be applied by the ecologist to the elucidation of problems in the field, complicated and often profoundly modified

by the continual operation of the competitive factor.

Finally, knowledge of the life-histories of the constituent organisms, the reaction of the various phases of their development to the environment, their modes of reproduction, their establishment and extension, comprise a mass of knowledge to which many astute observers have contributed and amongst whom the amateur holds an honoured place in our esteem. The *clichés* of the politician with regard to policies could be applied with far more than their usual significance to the ecologist, who might with some reason be described as "exploring every avenue" and "leaving no stone unturned" in his attempt to reveal the causal relations underlying the social organization of plant life; but this all too brief résumé of the contents and contacts of a single branch of botany has, I hope, sufficed to emphasize that the wide range of knowledge invoked by the ecological approach, though constituting its chief difficulty, is the very basis of its cultural value, since it weaves together into a comprehensive whole so many threads of knowledge spun by the specialists upon the wheels of research.

The value of such approach is also obvious in relation to everyday affairs. In any well-considered plan of land utilization of catchment areas the ecological aspects are apt to be ignored. The land surface under its various guises may be likened to a sponge which absorbs the divers forms of precipitation and allows the water with more or less rapidity to find its way into the streams and rivers. But the effectiveness of the land surface for holding back the water varies according to whether it is under high forests, scrub, grassland or is arable. Each type of plant cover has its own absorptive factor and its own resistance to erosion. Furthermore, each vegetation type is not static but dynamic, and its role in this respect changes both with the seasons and with the passage of time. If therefore our land utilization is to be properly conceived, due regard must be had to the proportions in which the various communities, whether natural or artificial, are present. If we are to avoid floods and droughts, we must preserve rural England for practical, as well as æsthetic, reasons. To all this ecologists can contribute valuable help, the more so that with the passage of years the surface of our roads has become better and less absorbent, and our ditches are kept cleaner so that drainage to rivers has generally become more effective and rapid. Hence what sufficed to restrain extreme conditions a hundred years ago would not suffice to-day. Afforestation of the catchment area of the Thames and other rivers would, in the long run, be perhaps far more effective and less costly as a guarantee against

future floods or droughts than grand-scale engineering works, and whilst the former would produce ancillary assets of great value the latter would not.

Prof. F. W. Oliver pointed out, in reference to the reclamation of foreshores, that the plastic plant can and does meet the constantly changing impact of the forces of Nature in a way which the dead material of the engineer cannot hope to emulate, and at a far lower cost. But such biological control demands not only a comprehensive knowledge of the life-histories of the species utilized, but also an appreciation of the environmental factors, dynamic as well as static, that is summed up in the phrase ecological foresight.

Another matter is the much-discussed question of the preservation of natural areas. Owing to the widespread ignorance of biological knowledge, the dynamic character of vegetation is by no means widely realized. There are indeed many educated people to-day who think that to preserve an area all you need to do is to leave it alone. The fact that our open downland, presented to the National Trust, may, if left unhindered, ultimately cease to be downland and become woodland, with the loss perhaps of the very features for which the area was preserved, is for most a novel concept. But an enlightened policy of such control of national reserves and all that this implies will only be possible if the rising generation has been inculcated into a biological mode of thought.

It is probably true to say that no branch of botany could be cited that has not its important practical applications. Botany needs no defence in respect to the practical utility of its pursuit, although it is probably true to say that the majority of those who reap the benefits of its achievements are unmindful of their source. But it is, I feel, the contribution that botanical knowledge can make towards general culture and spiritual contentment that is its chief claim to rank high in our educational scheme.

A sympathetic understanding of botanical thought and progress is essential to a community which is to deal adequately with such national problems as agricultural policy, land utilization, afforestation, drainage and water supply, the preservation of rural areas or the provision of national parks. Only on the foundation of a knowledge of plant life and its requirements can an educated public opinion be built up that will receive and give effect to well-considered legislative action. Moreover, it is perhaps truer of these pressing questions than of most that a sympathetic and informed public opinion is essential to the continued effective operation of any policy however well conceived and enlightened.