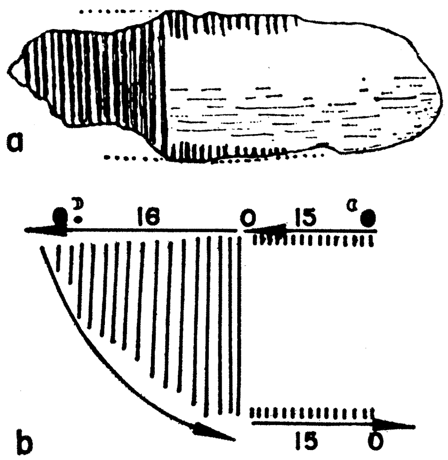

Fig. 3. Engraved reindeer bone from Kulna, Czechoslovakia. [H. Breuil, *Anthropologie* (1925), p. 286, fig. 11]

there is a space and the 4th month begins.

We assume that the mark for one day is lost in the damaged area and supply it. This month then ends on the day of invisibility, which is the longest vertical. The additional lines and "signs," which close the period, may summarize the four months or may be extra days.

The ramifications of the notation on this bone from the Magdalenian period will be presented elsewhere and will include a fuller analysis of the 1-, 2-, and 4-month notational periods, the rapidly evolving use of symbols and other notational techniques, a discussion of the purposes of the nonlunar phrases and of counts that are shorter or longer than a lunar phrase, as well as the reasons for the notational variations of different months.

If we now go backward again some 10,000 to 25,000 years, to the Aurignacian of Western Europe (about 33,500 to 16,500 B.C.) and to the Eastern Gravettian of Central Europe and Russia, we once again find hundreds of notational sequences, many of extraordinary complexity. Figure 3 shows a simple example from Kulna in Moravia, Czechoslovakia. This is a bit of engraved bone without symbols or art work; differentiation of the lunar periods is accomplished by the size of the marks and the direction of the count. The lunar phrasing of the Kulna bone is shown in Fig. 3*b*.

The questions raised by this evidence of lunar notation in the Upper Paleolithic period are many and important. They entail a reevaluation of the origins of human culture, including the origins of art, symbol, religion, rite, and astronomy, and of the intellectual skills that were available for the beginnings of agriculture.

For the first time it now becomes possible to begin the analysis and reconstruction of the culture of *Homo sapiens* in the Upper Paleolithic period. I have begun these tasks with an analysis of all the available published materials and artifacts of the Upper Paleolithic and a first-hand study of many of the artifacts and caves, including a "reading" of over a thousand notational sequences with their associated art and symbol. This is based on a few representative examples and is intended to open the way for a fuller presentation and analysis of the many documents in which the lunar tradition is apparent.

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3. Artwork of Henri Breuil redrawn with permission of Trianon Press, Paris, France.

The Compleat Botanist

Trained botanists with a broad background and a liberal education are urgently needed by society.

A. J. Sharp

My indebtedness, in this speculation about the "compleat" botanist, is clear (*1*). Izaak Walton was not a professional biologist, but he did realize that to be a thorough fisherman one had to understand every angle of angling. It is my thesis that to be a "compleat" botanist one must have a breadth of perspective that permits him to see beyond his own specialty and understand the importance of relationships which exist today not only between the fragments (and I use the word advisedly) of botany but also between plants and the everyday life of man. What I have to say about botany is equally true of zoology and biology in general. And I will be so bold as to substitute often in my discussion the word *biology* for *botany*.

It is wise and healthful in any discipline for the practitioners periodically to reexamine it and themselves. It is clear that the time has come for botanists to take a fresh look at themselves and their science. The current, bitter, internecine discussion concerning the relative validity of modern or molecular biology and classical or organismal biology indicates that we are confused. Worse yet, it is confusing our clients and benefactors, many of whom can see no reason why classical and modern approaches should not supplement each other.

As I understand it, botany is the study of plants in the broadest terms, and ranges from the chemistry of the DNA molecule in the nucleus of a plant cell to the spatial relationship of individuals in a desert community. It includes studies of the chemical and physical natures of the materials and processes in the cells, of the organization of the cells into tissues, of tissues into organs, of the movement of materials into, through, and out of plants. In addition, the botanist is concerned with the plants of the past, with phylogeny, with modern floras, with the relations of plants to all phases of their environment, not excluding man.

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It should be clear to the most naive of our fellowmen that his welfare is dependent upon plants, but man seems far from understanding that fact. Although he is a "newcomer" relative to plants, he constantly treats them without comprehension of their significance. Sears (*2*) reminds us that the earth, around 5 billion years old, produced life only after a period of about 3 billion years and that, from that life, man came after another 2 billion years. This upstart Man (not over 1 million years old and, in civilized form, much younger than that) mistreats the vegetation of the earth and irreparably damages the macrocosm in which his children and grandchildren must live.

I do not have to remind professional biologists that plants are directly or indirectly the source of all food, most clothing, much fuel, and all lumber; that they exert a tremendous control over water supplies, soil, and the production of fish and wildlife; and that, as McKinley (*3*) emphasizes, esthetically and spiritually they are of great value to man. Plants have an enormous impact on man's culture and well-being.

Man, at the same time, exerts an influence on vegetation. He is rapidly destroying large, and often virgin, plant communities, even in remote areas, by saw, bulldozer, fire, and distribution of destructive pests. This devastation must be seen to be understood. The destruction of vegetation and its natural environment is usually accomplished without any thought of what will happen to water supplies, soils, or the general economy of the region affected. Unfortunately, man usually thinks of plants and vegetation only in terms of food, clothing, lumber, and raw materials for manufacture.

Men in primitive groups seem to understand the relationships between themselves and plants better than men in more advanced cultures. There seems to be an almost direct correlation between the degree of civilization of a society and its failure to appreciate this dependence. This lack of awareness is further enhanced when a civilized society changes from an agricultural to an industrial economy. Industrialization seems effectively to isolate the individual from the primary plant resources on which his culture is based. This fact may help explain why botany and botanists are still much more revered in the less-industrialized Latin American countries than in more industrialized countries (*4*).

I have been trying to emphasize the significance of plants to man and, thus, the great importance of botanists to society. Regardless of the recognition afforded us, we can be proud to be botanists. An awareness of our role in our culture imposes a heavy obligation on us to try to do something about the deteriorating balance between human populations and the plant resources upon which they depend. This could be the focal point of much of our teaching and of our research, which should include basic studies as well as applications.

Need for Continuing Research

Long ago research at the general level raised more questions than it answered, and, as the sciences of geology, chemistry, physics, and mathematics developed or matured, botanists turned to them for assistance. No one should infer from this that we have exhausted the problems of a general nature; for most of them remain, demanding constantly more refined and complex answers, not only to the question "How?" but, as recently emphasized by Simpson (*5*), to the legitimate but more fundamental question "What for?" Nor should the great amount of information already accumulated in certain areas mislead one into thinking that research in these areas is no longer needed. As Laetsch (*6*) has indicated, most of the fads (and there seem to be as many fads in biology and botany as there are in women's clothes) subside without solutions being found to most of the basic problems.

As an example of the continuing need for research in the *classical* phases of botany, one could cite the considered opinion of most taxonomists that something less than half of the plant species in the world have been detected and described. It is probable that in this reservoir of "unknowns" are entities of high significance to the understanding of phylogeny and other basic phases of botany. There certainly will be found species of economic importance which may give us new antibiotics or other valuable chemicals, or breeding stock for better or more disease-resistant crops. To discover these species before it is too late is a critical matter, because in the next decade most of the natural areas and many of their species will have been eliminated. I agree with Corner (*7*) that more understanding of the phylogeny and evolution of the flowering plants is to be gained from a study of existing tropical floras than has been given us by paleobotany. Shall we permit this reservoir of evidence to slip through our fingers because we deprecate exploratory and field botany?

Certainly few botanists know the American tropics as does Bassett Maguire, of the New York Botanical Garden, who warns us (see *8*) that the pristine tropical forests of South America are being put to the torch with devastating effect. The destruction, which, he says, at least matches that accomplished by the bulldozer in the United States, is the result of man's migrating from population centers and clearing land for farming. This land is useful for only 2 to 3 years at best. At the end of that time man starts burning new areas. Even the Andes, Maguire says, has felt the impact of this destruction; so far, only the inaccessible Lost World section has escaped. This is the region where four countries meet: British Guiana, Surinam, Brazil, and Venezuela.

The paramount need in the world of biology today, according to Maguire, is an inventory of tropical vegetation. The largest and most important zones not yet inventoried, he notes, are in the tropical areas of the New World. Whereas the flora in the temperate areas have been studied exhaustively, the surface has been only scratched in the hemisphere's tropics, despite repeated expeditions.

Research is still needed in plant geography, where recent findings in regard to geomagnetism and discussions concerning the origins and structure of continents and mountains cause us to question our previous postulates. These findings and discussions, plus our increased knowledge of the mechanics of evolution, make it clear that a reexamination of phytogeography is in order.

I am sure that in every phase of biology there are unsolved problems, whether the field be classical or modern or something in between, such as physiology or genetics. Any investigation of breadth seems to call upon a galaxy of related sciences. How, for example, can one understand physiology without knowledge of anatomy, chemistry, physics, and, in many cases, even taxonomy and ecology? There is a great need for the "generalist," as explained by Storer (*9*). At one time or another each part of biology makes use of nearly all the other phases. And there is no need to use "descriptive" as a derogatory epithet. Each science, even chemistry and physics, describes phenomena, processes, and products, and these descriptions are no less useful for being neither analytical nor mathematical in form.

Should any botanist think he has the final technique or the final answer, may I remind him that science has taught us nothing more clearly in this century than that there are no absolutes and that everything is relative and can be predicted only within certain statistical limits. The nature of living material, because of its tremendous complexity and constant change in a variable environment, is extremely difficult to study and understand. We may remove bits of material from cells, or cells from organisms, and place them in a test tube or a culture dish for analysis or observation, but findings have diminished meaning when the material is dissociated from the organism as a whole, and maximum significance only when the organism is in its natural environment. As Simpson (*5*) has indicated, to our knowledge of physical, chemical, and mechanical principles must be added understanding of the adaptive usefulness of structures and processes to the whole organism and to the species to which the organism belongs, and, in addition, understanding of the ecological function of the species in the communities to which it belongs.

Our knowledge of the recycling of elements or of the capture and routing of energy in a biotic community is relatively in its infancy, and there is demand for new techniques to facilitate such studies. There are many other problems waiting to be solved in all phases of botany and biology. In fact the problems are far more numerous than the available workers.

The Teaching of Botany

So far I have said little about botany as an educational discipline. We need offer no apologies for teaching botany and studying plants, but we may need frequently to remind our students and the public of their dependence on vegetation, their most basic resource. Martin (*10*) stated well the relationship between botany and our social economy and pointed out the value of using this correlation not only in courses in biology but also in such diverse disciplines as history, civics, economics, political science, geography, and social studies in general.

In spite of the fact that a tremendous amount of energy, time, and money has been put into the revision of our biological curricula (a revision which was very much needed), not all of the problems in our beginning courses of botany or biology have been solved. In the minds of many, the emphasis in the revision was on content and the means by which new facts and concepts or relationships could be introduced into already crowded courses. The problem is a critical one and needs our constant attention. It becomes even more difficult when we realize that most of our beginning biology students will become, not professional biologists, but bankers, lawyers, merchants, or housewives. We may have to redefine our objectives, for any approach that fails to teach our citizens to respect plants and vegetation as a necessary and integral part of their environment will doom future generations to intolerable living conditions.

Other aspects of our instruction merit attention. The continuing rapid accumulation of data appalls beginners and "old hands" alike. The easy thing is to specialize from the start. It is difficult to organize a beginning course in the field of biology which will emphasize all the details we wish to include and, at the same time, give the student who takes only the one course a broad view of biology or botany and its ramifications. We must not let each dazzling new fad, whether it be many new species, or gibberellin, or DNA, divert emphasis from the persistent problems of broader relationships. To provide proper instruction in botany is and will continue to be a challenge.

Recently the size of our classes has been increasing (at some institutions suddenly and drastically), mainly because of rapid increase in the number of students and because of misunderstanding on the part of curriculum planners concerning the kind of instruction necessary to a liberal education. Shortages of funds, of space, and of teachers in general or teachers willing to teach in the beginning courses (the granting agencies perhaps help increase the difficulty here), failure to understand the importance of the teacher-student relationship in classes of reasonable size, and the easy availability of closed-circuit television—these are general problems, not restricted to botany. The fact in no way absolves botanists from recognizing them and attempting to do something about them. It may be that some so-called "research men" will have to do some teaching (but if they are poor teachers, let's keep them in research!). Mass instruction tends to produce conformity, for which the pressures are many and heavy. We already see too much of it, not only in our students but also among our colleagues. And not only scholarship, including scholarship in botany but, indeed, as Rickover (*11*) suggests, the maintenance of our way of life requires individuals who can criticize and tolerate criticism, who dare to be independent and different, not in order to attract attention to themselves but because they have the maturity to accept the responsibility of making their own decisions.

Conclusion

In conclusion, let me summarize my feeling about botanists and the position of botany today.

The "compleat" botanist, because his materials are the prime resources of man, must be not only a specialist but at the same time a generalist of the most expansive kind. He must lead the members of a reluctant society to a realization of the importance of plants in most aspects of their daily living. He must teach his students in such a way that they, too, can see the woods *and* the trees, and carry on where he left off. If he must be a specialist, he should see the implications of his specialty for society, and its relation to other bodies of knowledge. He should understand teaching and demand of his charges a healthy skepticism, a tolerance of other points of view, and resistance to the temptation to conform when independent decision is called for. He must realize that diverseness does not imply perverseness and that in biology both classical and modern approaches are necessary. Botany needs taxonomists who understand and utilize chemistry, and biochemists who appreciate taxonomy. Intramural strife is enfeebling to both botanists and botany and must not be allowed to flourish. These are some of the challenges facing botanists today, and they cannot be ignored without penalty.

Finally, I realize, of course, that there is no "compleat" botanist, nor can there be, because no single individual can master all of botanical fact and philosophy. The easy way out is to specialize and "let the rest of the world go by." But we must strive toward the ideal of a broad perspective, for botanists above all others should understand the relationship between society and plant resources and should be able to impart to their students and to society at large the importance of this relationship to the present and future welfare of man.

References and Notes

1. Evidently, it wasn't so clear to some botanists, who asked in all seriousness why I did not edit the title. This perhaps helps emphasize one of the points I am trying to make.
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NEWS AND COMMENT

Nobel Prize in Chemistry Awarded to Crystallographer

An Englishwoman was named last week as the sole recipient of the 1964 Nobel prize for chemistry for her work on the structure of biochemical compounds essential to the understanding and control of pernicious anemia. She is Dorothy Crowfoot Hodgkin, Wolfson research professor of the Royal Society in the Chemical Crystallography Laboratory of Oxford University, England.

Research directed toward understanding the chemistry of life processes has pointed increasingly clearly in recent years to the necessity for detailed stereochemical knowledge, on the atomic scale, of the structure of the molecules involved. These structures are frequently so complicated that attempts to represent them by formulas on paper give little account of the true shape of the molecule and fail to represent important spatial relations. Dorothy Hodgkin's achievement is twofold. She has determined the structure of a very important and complicated molecule, vitamin B_{12}, and some related structures. She has also demonstrated that it is possible to "solve" such complex structures by x-ray diffraction and to think about these complex molecules in "mental stereo." She has contributed to the understanding of vitamin B_{12} chemistry not only by the results of her research, as they became available, but also by her particular three-dimensional viewpoint of the molecular structure. A keen awareness of the potential significance of structure to the chemistry and biochemistry of the molecules in which she has been interested has always been the keynote of Dorothy Hodgkin's work.

A quotation from the Biological Chemistry Section of the *Annual Reports on the Progress of Chemistry* for 1961 gives a simple illustrative example of this type of contribution to an understanding of vitamin B_{12} and its coenzyme. "These [chemical] results could not be rationalized however until x-ray crystallographic analysis [by P. G. Lenhert and D. C. Hodgkin] showed that adenine is present as its riboside and that the riboside is, surprisingly, linked directly to cobalt at C-5′." As in the analysis of the crystal structure of hemoglobin, which was similarly recognized 2 years ago, the research on vitamin B_{12} was conceived and begun over a decade before it came to fruition in a series of papers published in the *Proceedings of the Royal Society, London*, between 1957 and 1962. To quote from one of these, "The very beautiful x-ray photographs obtained soon after vitamin B_{12} crystals were first examined by x-ray methods (in 1948) showed that it was formally possible to solve the structure of the crystals by x-ray analysis." In 1950 the word *formally* meant to most crystallographers that the idea of tackling such a complex molecule was too discouraging. But, nevertheless, the diffraction data were collected from several different derivatives by different co-workers and collaborators during the next 6 years. By the time computer manufacture had begun to catch up with the complexities of nature, and the necessary calculations could be carried out. By 1957 the main features of the structure of $C_{63}H_{88}N_{14}O_{14}PCo + 18\ H_2O$ were solved, and the details were filled out in four more publications in 1959 and 1962. The majority of the earlier computations were made on the National Bureau of Standard's SWAC in Los Angeles, and toward the end a mercury computer was in operation at Oxford.

This chronology of an exciting scientific adventure would be very unpopular with Dorothy Hodgkin if mention were not made of her collaborators in this work—J. Kamper, June Lindsay, M. Mackay, J. Pickworth, J. H. Robertson, Clara Brink (now Mrs. David Shoemaker), J. G. White (who valiantly pursued an independent study in the early stages on a hand calculator at Princeton University), R. J. Prösen, R. A. Sparks, and K. N. Trueblood at the University of California, Los Angeles.

Dorothy Hodgkin is the third woman to win the Nobel prize in chemistry. When the award was announced she was in Ghana with her husband Thomas, who is director of the Institute of African Studies at the University of Ghana in Accra. They have three grown children—Luke, teaching mathematics at the University of Algiers; Elizabeth, teaching in a girls' school in Zambia; and Toby, a voluntary social worker in India. Luke has three children, so Dor-