PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Closing Remarks

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Closing remarks

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I believe this is the first major meeting on plant water relations to be held in Britain since 1964 when the Society of Experimental Biology organized a symposium on 'The state and movement of water in living organisms'. Shortly before that, in 1961, the British Ecological Society chose 'The water relations of plants' as the theme of its annual symposium. When the papers read to us in the last two days are published, we will be able to compare them with their predecessors from a decade ago. In some branches of the subject we will be able to discern impressive progress. In others, we may agree with Tennyson that

'Science moves but slowly, slowly, creeping on from point to point'.

One topic dealt with at some length in the two previous meetings has not been discussed here: the flux of water vapour in the air surrounding leaves and above plant canopies. Although some interesting problems of micrometeorology remain unresolved, the main problem of relating evaporation rate to climate was solved, in essence, by Howard Penman nearly 30 years ago when he used some elegant algebra to combine the conservation of energy and of mass at a water surface. Armed with the Penman formula and its descendants, the meterologist can now say to his ecological colleague: 'tell me the essential parameters of your system and I will calculate the loss of water from your vegetation in any type of weather'.

Our ability to describe and to analyse water flow at the other end of the plant is in a very different state. In fact, I think Professor Tinker suggested that if we could tell him about the flux of water taken up by the root of a plant, he would tell us about the state of water in the soil. This is the converse of the state of knowledge at the leaf/air interface. Once water has been absorbed by the root system, its progress through the plant to the leaf mesophyll seems tortuous and complex. Professor Weatherley and Dr Newman have identified with great care paths of water flow and sites of resistance to flow. But it is disappointing that the validity of the Van den Honert resistance model canot be unequivocally demonstrated. Why is the flow of water through plants proportional to the gradient of free energy in some cases and not in others? When the flow is not proportional to the gradient, calculations of resistance are inappropriate as Dr Penman pointed out in his comments on the papers read by Dr Biscoe and Dr Elston.

In contrast to the formidable problem of root systems which cannot be directly observed without disturbing their natural environment, stomata are comparatively easy to study with a microscope, or a porometer, or a gas exchange system. As a result, the literature on stomatal physiology has burgeoned in the last decade. Professor Raschke and Dr Mansfield took us to the frontiers of the subject by describing how the complex biochemical basis of stomatal behaviour is now being unravelled.

Another aspect of plant water relations where knowledge has advanced substantially in the last decade is the relation between growth, metabolic processes, and water stress. Dr Hsiao showed us a table in which the response of different physiological processes to stress was arranged in order of sensitivity. Dr Boyer dealt in more detail with the relation between stress and CO_2 assimilation and Dr Vaadia discussed the role of specific hormones in mediating and in counteracting the effects of water stress. Identification of the role of specific hormones in plants and the study of their action in relation to water movement has been a major step forward since the early sixties.

Field studies of plant water relations have been greatly stimulated by the development of two types of instrument: porometers for measuring stomatal resistance and the Scholander pressure bomb for measuring the water potential of tissue. Papers read at the British Ecological Society 1961 meeting contain virtually no information about measurements of stomatal resistance or of water potential in the field but Drs Biscoe, Elston and Jarvis have described how such measurements can now be made selecting leaves of different age in a stand and following their behaviour throughout the day. The problem now is not acquiring measurements but knowing how to handle them. Dr Jarvis has suggested a statistical method by which relationships derived in the laboratory or growth room can be fitted to observations in the field. I am convinced that a sensible alternation of experiments in natural and controlled conditions can be most rewarding in ecological studies but until Dr Jarvis can improve the fit between his formulae and his measurements, I shall reserve judgement about the value of nonlinear regression techniques in this context.

To recapitulate, progress in plant water relations over the past decade has been accelerated by the development of new techniques: the diffusion porometer, the pressure bomb, the thermocouple psychrometer, the electron microscope, the scanning electron microscope, and so on. Progress has been inhibited by the absence of techniques: for measuring the turgor pressure of leaves directly, for tracing and measuring the movement of water to roots in undisturbed soil. Progress has been stimulated when the relevant parts of environmental physics, plant physiology and biochemistry have been brought into focus together. But progress has been delayed by a shortage of young scientists with a broad interdisciplinary training. Fortunately, the trend of teaching in many university departments of biology is likely to produce graduates better able to tackle the problems of plant water relations than many of their predecessors.

In conclusion, may I return to Tennyson's vision of the future in 'Locksley Hall'?

> 'Science moves but slowly, slowly, creeping on from point to point
> Slowly comes a hungry people, as a lion creeping nigher,
> Glares at one that nods and winks behind a slowly dying fire'

Even in context, these lines are difficult to interpret but it may be relevant that they were written at the time of the potato famine in Ireland. If the words have any modern relevance, we might wonder whether the fire of scientific enthusiasm is likely to die for lack of financial support. We might also ask whether *we* are the people nodding and winking behind sophisticated research projects while hunger and malnutrition remain an immense global problem.

Many of us here are concerned, directly or indirectly, with agriculture, and although the papers read to us have not been concerned explicitly with water in relation to food production, several speakers have hinted at the connection. Can the antitranspirants described by Dr Mansfield ever be used commercially to conserve water when food is grown in regions where water is scarce? Dr Flowers described how he and his colleagues have been studying the physiological distinction between halophytes and glycophytes in terms of membrane properties. Can this fundamental work provide a basis for increasing the salt tolerance of crop plants growing in saline soils or irrigated with brackish water?

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Dr Boyer summarized experiments on the effects of water stress on photosynthesis and on plant development including the formation of grain. The literature of agronomy is full of reports of how crop yields can be increased by irrigation but relatively little attention seems to have been paid to the effects of stress on the components of yield and on rates of development generally. I believe that more effort ahould be paid to the importance of water supply at critical stages of development. Indian agricultural scientists have been active in this field which they refer to as 'crop life-saving research'. In the past 20 years we have learned how to estimate the *maximum* amount of water that a crop will use. In the next 20 years we should be more concerned with the *minimum* amounts of water (and minimum fertilizer requirements) to achieve adequate yields.

If research on plant water relations can achieve even a few of the objectives considered at this meeting, we may still be able to stop the hungry lion in his tracks.

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