sixpence; and even in the wood sorrel, which, in common with other herbs of shady situations, has relatively few stomata, a single leaflet will probably have between twenty and thirty thousand stomata. Their distribution exhibits a number of interesting features. While in many plants the stomata are confined to the lower surface of the leaf which is the more sheltered in respect to removal of water vapour by evaporation, yet in rosette leaves and mat plants and species of shady damp habitats the stomata may be as numerous or even more so in the skin of the upper surface than the lower. Since the stoma has an elliptical pore bordered by two sausage-like guard cells, upon the turgidity of which the opening or closure of the aperture depends, each pore has a definite axis.

There is a marked difference in the orientation of the stomata in the leaves of most dicotyledonous and monocotyledonous leaves. In the latter all the stomata usually show a parallel trend, while in the former the stomata appear orientated in an irregular way. But close study of such a leaf as that of the lesser celandine will show that, in fact, there is a very high degree of correlation between orientation of the individual stomata and the direction of the adjacent veins. It would, in fact, appear to be highly probable that the orientation of stomata is dependent upon the direction of the stresses occurring in the epidermis during the period that these structures develop. The leaves of monocotyledons, as we have seen, are more nearly comparable to the leaf-stalk and midrib of the dicotyledons, and nearly all the bundles trend in the same direction, so the stresses and strains may be described as polarized. Here we find the stomata parallel just as they are in the epidermis of the leaf-stalks of dicotyledons; but in the lamina of the dicotyledons the bundles are orientated in a network that spreads in all directions, and the orientation of each stoma would appear to be dominated by the resultant of the tensions to which the tissues are subjected.

In the herb Paris, a monocotyledon with unusually irregular venation, the stomata are also irregularly orientated, and in this shade species we may note also that the epidermis no longer functions as a water jacket protecting the chlorophyll tissue beneath, as in the leaves of open habitat species, but itself contains chloroplasts. On the other hand, in some dicotyledonous leaves (for example, *Silene maritima*) where the stresses are polarized in a manner similar to midribs, the stomata exhibit a regular and parallel orientation.

We have previously noted that for any given species the drier the environment, both internal and external, the greater is the density of the stomata. Since, however, only the widest of spacing will preclude mutual interference of evaporation from neighbouring pores, the increased density induced by external conditions has little effect in augmenting the capacity of the leaf to lose water.

The necessity for free gaseous exchange that ensures an adequate supply of carbon dioxide also involves the risk of excessive water-loss. Since the rate of manufacture by the leaves decreases with loss of turgidity both directly and through closure of the stomata, any structural features which retard excessive water-loss and prolong the period of turgidity will increase the food income. Thus transpiration checks may be beneficial even though their influence be slight. The thick waxy cuticle, the dense covering of hairs and the sunken stomata do not stop water loss, but may greatly retard it and so prolong the working period. It is only when the leaf is appreciably wilted that the mechanism of closure of the stomata comes into play as the most important check on water loss.

But if the danger of excessive water-loss is perhaps the most obvious in the mature leaf, the excessive intake of water is possibly the greatest risk in the juvenile condition. It is therefore significant that the parts of the leaf which are the earliest to mature, namely, the leaf tip and the tips of the leaf teeth, corresponding to bundle endings, are the site of groups of permanently open stomata that serve as water pores. From these the water forced out of the vessels escapes as vapour or, in humid conditions, collects as liquid on the leaf teeth like localized dew drops. Sometimes the safety valves are extra floral nectaries, and the nectaries of flowers themselves are to be regarded as specialized derivatives of such safeguards in the reproductive shoot.

OBITUARIES

Prof. Walter Garstang

THROUGH the death of Prof. Walter Garstang on February 23, at the age of eighty-one, zoology has lost one of its most prominent personalities—scholar, investigator and teacher. The son of Dr. W. Garstang of Blackburn, he entered Jesus College, Oxford, as a medical student in 1884, and, abandoning that course, graduated with honours in zoology. In 1888 he was appointed as assistant to G. C. Bourne, the first director of the Plymouth Marine Laboratory, and a few years later became assistant naturalist there. The year 1893 saw him back again in Oxford as Fellow of Lincoln College and lecturer in zoology under Ray Lankester; but in 1897 he was again established in Plymouth as chief naturalist in charge of fishery investigations. In 1901, he directed from Plymouth, and later from Lowestoft, Great Britain's part of the larger international programme of research on the North Sea fisheries. In 1907, the University of Leeds invited him to the chair of zoology—a position which he accepted and continued to hold until 1933, when he retired to Oxford to continue his researches there.

Thus Garstang's zoological career falls into three phases. First come those researches into the morphology and biology of marine invertebrates which were carried out in the early Plymouth and Oxford years when he was laying the foundations of his profound knowledge of the sea. Then followed the application of this knowledge to investigations on fisheries, and his work on the natural history of the plaice of the North Sea will long serve as a model for such research. By extensive age-determinations and measurements, and particularly by liberating vast numbers of marked fish (to be returned when recaptured by fishermen) he studied their natural growth-rates and migrations in different areas. He also transplanted young marked plaice from the crowded nursing grounds of the Dogger Bank, and, by showing that in two years they grew to more than twice the size of those left behind, he pointed the way to a future farming of the sea. Some of his ideas on this subject appear in his Buckland Lectures for 1929. It is not surprising that he became one of the architects of the International Council for the Exploration of the

Sea. Nor is it to be wondered at that he was the able and trusted spokesman for the industry at the then Board of Agriculture and Fisheries—sometimes, it may be said, to the discomfiture of scientific colleagues with whom he did not always see eye to eye.

The quality of independence which he possessed abundantly must surely have accounted for his translation to the chair at Leeds in 1907, for it was then that the Government took over the fishery investigations. Great as were his contributions to marine zoology, both academic and economic, zoology was the gainer by this change. For his virile mind was thereby released to pursue the philosophical and speculative tasks for which he was so patently fitted. It permitted, too, that his personality should be felt and enjoyed by the many generations of his students. He inspired them with a love for the subject, and, more, he made them think and seek for themselves. His class lectures were unique in that they often ignored the channels prescribed by syllabus and became instead a forum in which he argued with himself on his own philosophical speculations. Here were first sown the seeds of his classical re-statement of the biogenetic law. It was in his degree-course lectures, too, that his ideas on larval forms and vertebrate ancestry first appeared. Here it was that he began to build up his logical case for the influence of larval modifications on adult evolution by the process of pædomorphosis, a word of his own coining. During this time he developed a reputation as a world authority on tunicates, and used his knowledge on their morphology to develop his theme on chordate phylogeny.

Garstang never isolated himself from the outside world. Over many years and through his active presidency of the Yorkshire Naturalists' Union, the Leeds Naturalists' and the Leeds Philosophical and Literary Society he stimulated the interest of the amateur biologists of Yorkshire. He was president of Section D of the British Association at the Glasgow meeting in 1929. After retirement, he continued his investigations, and a steady stream of papers appeared right to the end. Before the War he renewed his study of marine animals and particularly of larval forms by visits to Bermuda. His critical grasp of detail emerges in his criticism of modern molluscan nomenclature and, to greater effect still, in the remarkable treatise on the morphology and relations of the Siphonophora, which was published as he was approaching his eightieth year.

Few who go from us will leave behind so much affection and such a sense of gratitude. It is inevitable that his students will remember Garstang for his perpetual youth and his genial kindness. They will think of their visits with him to the marine station which he established at Robin Hood's Bay; of teas in the laboratory at which he and Mrs. Garstang were generous hosts and at which the week's problems were discussed; and of their open house at Meanwood where all students were welcome. He will also be remembered for his interpretation of bird-song—something of a poetic interlude in his scientific work—the enthusiasm for which he easily imparted to those who joined him in this delightful pursuit. It is good to know that he lived always a happy and full life in the midst of a devoted family who shared his interests. His wife, whom he married as Miss Lucy Ackroyd of Newnham College in 1895, died in 1942. They are survived by a son and five daughters.

L. Eastham

Prof. Bailey Willis

'Earthquake Willis', one of the most colourful and widely known figures in American geology, has passed away. The record says he died at the age of ninety-one; but those who, a short while ago, saw him striding jauntily across the Stanford campus, riding his bicycle to the gymnasium, or arguing vehemently with embryo geologists, will tell you that he was still a student eagerly learning his trade. First among the impressions he leaves is one of perennially vigorous, inquiring youth.

A few days before he died, he completed another part of his autobiography, "Friendly China", sequel to "Yankee in Patagonia". Yet his first geological paper appeared sixty-five years before. He graduated in the late seventies as an engineer from Columbia, and for the rest of his days his prime concern was with the mechanics of mountain-building. The colours of his spirited landscape-paintings re-appear in all his writings, as when, discussing mountain arcs, he asked: "Are the wrinkles on our face there because the muscles have pushed or because the flesh has shrunk or the skin expanded ?" It was the physiognomy of the earth's face that specially intrigued him, and not so much the details as the fundamental causes. Let some of his chief papers be recalled. His "Mechanics of Appalachian Structure", dated 1893, remains a classic for development of the concept of competent and incompetent beds and the role of initial dips in folding. His writings on "The East African Plateaus" and on "The Dead Sea" advocate the compressional origin of the great rift valleys; his articles on the coast ranges of California emphasize shearing along faults as a cause of deformation, and compression along deep shears as a cause of vertical uplift.

For him, the theory of continental drift was "a fairy tale, ein Märchen"; no need to invoke it to answer the demands of palæontology when temporary isthmian links might do the same with less affront to his concepts of earth-mechanics. For him, the propulsive force in earth-movements was volume-change at depth, brought on by the rise of 'asthenoliths', blisters of molten rock, developed by decay of radioactive substances scattered irregularly beneath the crust. The earth is growing hotter; the rising blisters expand upward, and their covering rocks, becoming foliated by recrystallization, spread sideways. Discoidal surfaces of shear form in the lithosphere; the disks rise and fall. Metamorphism is no less the cause than the result of orogeny.

These were among the views Bailey Willis championed with vigorous pen and fluent speech, and his travels took him over most of the globe in search of evidence. The same search inspired his large works on the geologic map, the palæogeographic maps, and the index to the stratigraphy of North America.

His training as an engineer led him naturally to seismology. For six years he presided over the Seismological Society of America; his influence had much to do with the important part now played in seismology by Californian institutions. He was greatly concerned with earthquake insurance, and did much to improve the building codes in California. Indeed his reputation grew until he found it hard to allay rumours that he had powers of prediction.

Honours came to him from many lands. He was president of the Geological Society of America and recipient of its highest award, the Penrose Medal.