operated successfully in New York, but, hampered by Parliamentary actions, it transferred poorly to England.

In the third phase, "system growth," electric power companies encountered what Hughes labels "reverse salients"—loci where progress in one part of the system lagged others. Utilities discovered one such salient when trying to extend beyond the small areas served by direct-current stations. After defining the "critical problem" of power transmission losses over large distances—identification of the problem being the first step in eradicating the salient—engineers in the 1890's introduced alternating-current networks. Despite successful demonstration in 1896 with Westinghouse's Niagara-Falls–to–Buffalo line, alternating current did not immediately win the "battle of the currents." The fight lasted several years and resulted more in a compromise, through the use of conversion devices, than in an immediate victory for alternating current.

By the fourth phase, power systems had acquired substantial "momentum." Polyphase alternating current won widespread acceptance, and a "culture" of uniform engineering and business practice grew around it. Critical problems still arose in this phase—an important one was the elimination of transmission losses due to coronal discharges—but they generally fell within the mainstream development and therefore added to momentum. The concept of momentum helps explain events during World War I. Even though war forced power systems to forgo their drive for autonomous growth and profits in exchange for serving national needs, most reverted to prewar behavior after the conflict.

However useful in this case, the concept of momentum presents problems for Hughes's argument that social factors constitute the most important determinants for technological change. After 1900, the managerial goal of improved load factor (which stemmed in large part from the type of technology employed) became universal. Combined with the huge investment of financial and human resources into one alternating-current technology, it created power systems in different countries that looked alike by the 1920's. Large momentum in the power industry implied that the influence of national style diminished after systems emerged in the 1890's.

During the final stage, which took place after World War I, the inventor-entrepreneurs of earlier days lost control of the systems' growth. In their place, financiers and consulting engineers dominated the enterprise by providing the standardization, coordination, and huge capital resources needed for creating interconnected regional networks. In the United States (and to a lesser extent in England), these new managers exploited the holding company, a relatively new institution. Though mired in scandal in the 1930's, holding companies helped the industry achieve technical and economic efficiency.

Hughes's history of electric power ends in 1930, when utility systems had emerged into their recognizable present forms. After 1930, the author argues, the basic structure of electrification remained qualitatively the same despite the intervening depression, governmental influence on regional systems (such as the Tennessee Valley Authority), and world war. Though some readers may miss reading about later events, few new insights about the evolution of power systems would have been gained. The next period for study, I would maintain, begins in the late 1960's, when the electric power industry suffered severe setbacks, raising questions about the values and principles that had served it well for almost a century. Of course, these comments are not meant as criticisms. Instead, they point to a program of further research that has already begun and that will gain clarity as a result of Hughes's excellent study. While some may quibble with Hughes's conceptual tool of "technological momentum," few will fault his emphasis on the social environment that influences technological change. *Networks of Power* is therefore a book that requires serious study by historians and those interested in the reciprocal impact of technology and society.

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The Plant Cytoskeleton

The Cytoskeleton in Plant Growth and Development. CLIVE W. LLOYD, Ed. Academic Press, New York, 1982. xii, 458 pp., illus. $60.

For some years botanical cytologists postulated the existence of a cytoskeleton in plants, but the direct demonstration of cortical microtubules in elongating root tip cells by Ledbetter and Porter in 1963 marks the beginning of investigation of the plant cytoskeleton as we know it today. The progress made during the intervening 20 years is summarized in this book, which integrates studies at the subcellular level with those at the cellular and organ level. Unfortunately, the micrographs, on which the wealth of cytological information on the cytoskeleton is based, are poorly reproduced. Nevertheless, the chapters are well balanced and authoritative, and the book should prove useful to graduate students and to experts, who will appreciate having the subject drawn together in one volume.

The 15 chapters are divided into four sections that consider the molecular components of the cytoskeleton and the role of the cytoskeleton in wall formation, division, and morphogenesis. Introductory chapters provide general accounts of actomyosin (Jackson) and calmodulin (Schleicher *et al.*) in plants, but the central focus of the book is the microtubule, the cytoskeletal component that has received the most attention to date. A broad discussion of microtubule biochemistry (Hyams) emphasizes that we know very little of the properties of tubulin from higher plant cells. Because the protein is highly conserved it may be reasonable to expect considerable similarity between tubulins of animal and plant origin, but the fact that higher plant microtubules are a thousandfold less sensitive to colchicine than animal microtubules leads us to suspect that there may be significant biochemical differences in the constituent tubulins (Hyams).

Though our understanding of the biochemistry of plant microtubules is meager, we have considerably more information about their cytology, especially about their role in the formation of the cell wall. The original observations showed microtubules oriented parallel to the underlying cellulose microfibrils and suggested that microtubules might regulate cellulose orientation. Numerous studies on this topic are critically reviewed by Robinson and Quader, who conclude that microtubules do indeed participate in the control of cellulose microfibril orientation. Observations of and experimentation on wall formation in the alga *Oocystis* (Robinson and Quader) and in stomatal guard cells (Palevitz) provide specific examples of microtubule involvement in cellulose alignment. Since the orientation of the cellulose microfibrils controls the shape of the cell and since the shape in turn influences tissue morphology, it becomes apparent that microtubules are the prime cellular agents regulating morphogenesis. Hardham shows in the formation of a leaf primordium in *Graptopetalum*, in which a change in cellulose microfibril orientation occurs in certain

epidermal cells, that there is a preceding change in the orientation of the cytoskeletal microtubules. The central role of microtubules in morphogenesis is further underscored by numerous examples of plant cells without walls in which cytoskeletal microtubules control shape directly (Marchant).

How microtubules control cellulose orientation is reviewed by Heath and Seagull, who compare and contrast several models. Many schemes invoke a flow of membrane components (such as cellulose synthetases) driven or aligned by microtubules (Heath and Seagull; Palevitz), but beyond the frequent observation of cross bridges between microtubules and the plasma membrane (Palevitz) very little is known about the interaction of the two. Two chapters emphasize the role of the plasma membrane in structural (Montezinos) and biochemical (Maclachlan and Fèvre) aspects of wall formation. Particles observed in freeze-fracture preparations that are localized with impressions of cellulose fibers provide for interesting speculation about wall formation (Montezinos), but the particles require biochemical characterization before specific models of function can be seriously entertained (Maclachlan and Fèvre).

Although the discussion of the involvement of cortical microtubules in cell wall formation dominates the book, discussions of other aspects of cytoskeletal function contribute importantly to it. Forer reminds us that, in addition to the microtubules, the mitotic apparatus contains components such as actin microfilaments and membranes, that may participate in chromosome motion. The process of cytokinesis and the factors that define the place of the cell plate are thoughtfully reviewed by Gunning, who devotes special attention to the structure and function and the pre-prophase band of microtubules, an enigmatic grouping of cortical microtubules that appears early in mitosis and indicates the place where the cell plate will fuse but disappears long before cytokinesis begins. Here and in chapters by Lloyd and Barlow and by Schnepf the commonly observed polarization of plant cell cytoplasm is emphasized. Specific movements and placements of the nucleus and organelles are controlled in part by the cytoskeleton and may lead to highly asymmetric positioning of cytoplasmic constituents that are essential to a subsequent division and cell differentiation (Schnepf).

The participation of microtubules in a myriad of events raises the crucial but vexing question of how the cytoskeletal elements themselves are controlled. It is amply demonstrated by Lloyd and Barlow that the coordination of cell division and elongation in a complex tissue requires precise control over the positioning and time of activation of the microtubule organizing centers. Several chapters address the nature of such centers from different perspectives. Brown *et al.* review evidence concerning the structure and function of the more discretely delimited microtubule organizing centers, such as centrioles and basal bodies, that are found commonly in lower plants and in all animal cells. A more puzzling situation occurs in higher plants, in which microtubule nucleation appears to be associated with amorphous aggregates from which microtubules radiate (Lloyd and Barlow; Palevitz; Hardham). The discovery of these amorphous structures was an important advance of the last few years, but what they are chemically and how they work await future clarification.

In summary the book provides a thoughtful and up-to-date accounting of the cytoskeleton in plant cells. Nevertheless, one is likely to come away from reading it with a sense of disappointment because the field it reviews leaves so many questions unanswered and has seemed to be so slow in moving into new lines of inquiry and in adopting or developing new techniques. One welcomes the application of immunofluorescent antibody labeling techniques to plant cells (Lloyd and Barlow; Gunning), but this approach is in its infancy and has not yet offered any information leading to new ideas. In short, the excitement that currently surrounds cytoskeletal studies of animal cells is lacking in cytoskeletal studies of plant cells.

Plant cells, largely because of their walls, are difficult objects for biochemical and histochemical studies. Even so the wall may be a blessing as well as a curse. The pattern of cellulose microfibrils impressed upon the wall is the direct product of cytoskeletal activity and can be used to provide important spatial and temporal information about cytoskeletal function. Investigations of the structure and biochemical properties of the plasma membrane, which resides at the interface between the cytoplasmic microtubule and the extracellular cellulose, might produce promising leads and should be pursued with vigor. In general our understanding of the biochemistry of the plant cytoskeleton is badly deficient; quite likely many components, including proteins like erythrocyte spectrin and ankyrin, are present but are unknown.

The book in a sense draws to a close the early stages of cytoskeletal research on plant cells. Further observations of parallel orientation between microtubules and cellulose microfibrils, or studies that show altered cellulose deposition in the presence of anti-microtubule drugs, for example, will be redundant. It is time for fresh ideas and approaches. Although the book is not too helpful in providing direction for future research, it should well serve the important role of informing us of what has been done and may provide valuable suggestions concerning unique botanical systems for new experimentation.

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Photosynthetic Systems

Photosynthesis. GOVINDJEE, Ed. Academic Press, New York, 1982. In two volumes. Vol. 1, Energy Conversion by Plants and Bacteria. xxx, 800 pp., illus. $79. Vol. 2, Development, Carbon Metabolism, and Plant Productivity. xxvi, 580 pp., illus. $59. Cell Biology.

The discussion of photosynthesis in most biochemistry textbooks is dominated by "green plant" or "oxygenic" photosynthesis, which utilizes water as a hydrogen donor and produces oxygen as a byproduct. However, there is a type of photosynthesis that produces no oxygen. It utilizes hydrogen donors other than water, such as hydrogen sulfide, and produces such byproducts as elemental sulfur. Anoxygenic photosynthesis is carried out by a small group of microorganisms known as photosynthetic bacteria. Although studies with these bacteria have had major impacts on our understanding of the mechanism of photosynthesis, they are usually overlooked because the organisms are specialized.

The book under review not only allows the bacterial photosynthetic system to share center stage with its larger, more prominent chloroplast counterpart, it integrates the studies with bacteria into a broad context, describing recent progress concerning molecular aspects of the subject in a manner not available elsewhere.

The book is a comprehensive survey of the subject. The first volume, "Energy Conversion by Plants and Bacteria," considers how light energy is converted into the high-energy products adenosine triphosphate and reduced pyridine nucleotide. The volume discusses the structure of the photosynthetic apparatus, primary photochemistry, electron transport