CC/NUMBER 44
NOVEMBER 3, 1986

This Week's Citation Classic®

Kirk T K. Effects of microorganisms on lignin.
Annu. Rev. Phytopathol. 9:185-210, 1971.
[Forest Products Laboratory, USDA Forest Service, Madison, WI]

This paper reviewed the literature through 1970 on the microbial degradation of lignin. The article's conclusions made it clear that relatively little was known in 1971 about any aspect of its biodegradation except that the mode of decomposition must be different from that of other biopolymers. [The *SCI*® indicates that this paper has been cited in over 135 publications.]

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August 19, 1986

This review article was my first publication after joining the US Forest Products Laboratory. The request to write it came from the Editorial Board of the *Annual Review of Phytopathology* on my first day of work. I had just returned to the US from a 1½-year postdoc in the lab of Erich Adler in the Department of Organic Chemistry, Chalmers University of Technology, Göteborg, Sweden. Adler (who died in December 1985) had established himself as the leader in the characterization of lignin, developing methods still in use today and identifying and quantifying the various substructures of the complex lignin polymer. At Chalmers, I worked closely with three of Adler's advanced students, Knut Lundquist, Gerhard Miksche, and Sam Larsson, all of whose names are well known to lignin researchers. The ambience in the lab was exemplary and the standards impeccable. I had gone to Chalmers after having completed graduate research on the fungal degradation of lignin under Arthur Kelman, Ellis Cowling, and Sam Tove at North Carolina State University (NCSU). The background gained at NCSU and at Chalmers made evaluating the literature straight-forward.

This article has been widely cited for several reasons, I think, primarily having to do with the timing. It was the first review of the field after the chemical structure of lignin had been clarified—mainly by Karl Freudenberg in Germany[1] and Adler in Sweden.[2] The article was also the first "modern" review by one who had studied both lignin chemistry and microbiology. I like to think that the review brought some order to a rather confounding literature; it was apparent that much of the research up to 1970 had been flawed, usually because adequate methods and materials had not been available to the investigators and because of the incomplete knowledge of the lignin structure.

The review questioned previous conclusions concerning which microorganisms (besides wood-decaying fungi) degrade lignin, as well as the conclusions from the few biochemical studies that had been done. Some of the best studies of lignin biodegradation had involved characterizations of the polymer after partial degradation by fungi—studies that made it clear that the process is oxidative. The review pointed out that the oxidative mode of degradation must be quite different from the hydrolytic biodegradative mechanisms seen with all other major biopolymers, a conclusion that has been abundantly borne out by subsequent research.

In the 15 years since the review was published, interest in understanding how lignin is biodegraded has greatly increased, in large part because of the potential applications of bio-ligninolytic systems—mainly in the pulp and paper industry—and in part simply because of the intrinsic scientific challenge: lignin biodegradation has proved to be a unique and most interesting process. Many of the unknowns in 1971 have now been clarified through efforts in at least 25 laboratories. The higher basidiomycetous decay fungi seem indeed to be Nature's major lignin-degraders, and much is known about what they do to lignin and how they do it. Notably, after a decade of underpinning research, the first lignin-degrading enzyme, a potent extracellular peroxidase from the fungus *Phanerochaete chrysosporium*, was discovered in 1983.[3,4] Since then, the field has truly entered the realm of biochemistry and, very recently, molecular biology as well. Many questions still remain, of course, but the biotechnical potential of ligninolytic organisms and their enzymes and the scientific challenge continue to spur scientists to find the answers.

It is indeed pleasant to think that my early review article has had an impact. It is still being cited, and, although correct, it is certainly dated. Researchers would do better to use more recent ones.[5-7]

1. **Freudenberg K & Neish A C.** *Constitution and biosynthesis of lignin*. Berlin: Springer, 1968. 129 p.
2. **Adler E.** Lignin chemistry—past, present and future. *Wood Sci. Technol.* 11:169-218, 1977. (Cited 95 times.)
3. **Tien M & Kirk T K.** Lignin-degrading enzyme from the hymenomycete *Phanerochaete chrysosporium*. *Science* 221:661-3, 1983.
4. **Glenn J K, Morgan M A, Mayfield M B, Kuwahara M & Gold M H.** An extracellular H_2O_2-requiring enzyme preparation involved in lignin biodegradation by the white-rot basidiomycete *Phanerochaete chrysosporium*. *Biochem. Biophys. Res. Commun.* 114:1077-83, 1983.
5. **Chen C-L & Chang H-M.** Chemistry of lignin biodegradation. (Higuchi T, ed.) *Biosynthesis and biodegradation of wood components*. San Diego: Academic Press, 1985. p. 535-56.
6. **Higuchi T.** Degradative pathways of lignin model compounds. *Ibid.* p. 557-78.
7. **Kirk T K & Shimada M.** Lignin biodegradation: the microorganisms involved and the physiology and biochemistry of degradation by white-rot fungi. *Ibid.* p. 579-605.

18-6