

**Hungate R E.** *The rumen and its microbes.* New York: Academic Press, 1966. 533 p.  
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This book integrates the numerous publications on rumen microbiology and physiology into a coherent quantitative account of the rumen microbes and their habitat and shows that the summed activity closely resembles the productivities of the individually studied components in the healthy and diseased rumen. [The *SCI*® indicates that this book has been cited in over 1,480 publications.]

## Ruminations on the Rumen

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February 23, 1990

During thesis work at Stanford University on cellulose digestion by protozoa in termites, I had become aware that certain ciliate protozoa in the rumen were also reported to be cellulolytic. This I confirmed experimentally with clone cultures.<sup>1</sup> Then, at the University of Texas, by using rumen fluid as one-third of the culture medium and increasing the buffering capacity with bicarbonate and CO<sub>2</sub> gas to give a pH of about 7, at the same time excluding air, I isolated the cellulolytic bacteria and showed them to be the most important cellulose digesters in the rumen.

Studies on the metabolism of the protozoa and bacteria disclosed hydrogen gas as an important product in many cultures, but it could not be detected in the rumen, only methane and CO<sub>2</sub>, indicating that H<sub>2</sub> was only an intermediate. I postulated that it was used to reduce CO<sub>2</sub> to methane, yet methane was not formed in dilution series fed an 80 percent CO<sub>2</sub>-20 percent H<sub>2</sub> gas mixture. I thought perhaps enough oxygen remained in the medium to poise its oxidation-reduction potential

at a level too high to allow growth of methanogenic bacteria. When the gas mixture was passed through finely divided palladium black, this catalyst reduced traces of O<sub>2</sub> to water, and in these cultures Paul H. Smith could show at Washington State University that methane formed even in the very high dilution tubes.<sup>2</sup> This was an important development, and, combined with the direct inoculation of habitat dilutions into habitat-simulating melted agar medium (immediately solidified and incubated at appropriate temperature), it greatly increased our ability to isolate many microbes in the stringently anaerobic habitats in which methane formed.

But this and other findings were just by-products of the rumen studies. The great contribution was that investigators could now obtain both qualitative and quantitative information on microbes in stringently anaerobic ecosystems. From additional studies in my laboratory at the University of California, Davis, extended by my students, research associates, and others throughout the world, enough reliable information on the rumen ecosystem was obtained to permit its complete description in *The Rumen and Its Microbes*. It tells how the ruminant foods are taken up by the microbial population in the continuous fermentation system<sup>3</sup> that is the rumen and how they are converted into microbial bodies that constitute the protein used by the host, at the same time digesting the fiber and fermenting the solubilized carbohydrates to produce gases and the acetic and butyric acids and other products absorbed and oxidized by the ruminant to meet its energy needs.

As a single author, I could prepare from the over 2,200 references a more coherent and better-integrated account than would otherwise have been possible. An illustration of the impact of my rumen studies is in the preface to the multiauthored volume *The Rumen Microbial Ecosystem*,<sup>4</sup> for which I have written an introduction; the editor cites me in the preface as "the father of rumen microbiology."

1. Hungate R E. Further experiments on cellulose digestion by the protozoa in the rumen of cattle. *Biol. Bull.* 84:157-63, 1943. (Cited 70 times since 1945.)
2. Smith P H & Hungate R E. Isolation and characterization of *Methanobacterium ruminantium* n. sp. *J. Bacteriology* 75:713-8, 1958. (Cited 130 times.)
3. Adams S L & Hungate R E. Continuous fermentation cycle times. Prediction from growth curve analysis. *Ind. Eng. Chem.* 42:1815-8, 1950. (Cited 25 times.)
4. Hobson P N, ed. *The rumen microbial ecosystem.* London: Elsevier Applied Science, 1988. 527 p.