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Herman Jan Phaff: professor, mentor, friend and colleague

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Abstract Herman Jan Phaff, the father of yeast ecology, was born in the Netherlands in 1913. In his early years, he spent much time in his family's winery, which sparked his interest in microbes. Trained in the famous Delft tradition, Phaff discovered many unrecognized ecological niches of yeast, such as shellfish, rabbit stomach, frass of bark beetles, tree exudates, cactus roots, Capri figs, sewage, *Drosophila* flies and shrimp. He is also remembered for his pioneering work on the coevolution of yeasts, insects and plants as well as for his work on yeast β -glucanase, which resulted in major advances in the understanding of the nature of the yeast cell wall. Phaff's legacy includes research on pectin degradation by fungal enzymes and the application of molecular approaches to yeast systematics. He discovered and described many yeasts, such as the yeast named in his honor, *Phaffia rhodozyma*, which led to the establishment of a very important industrial fermentation process yielding high concentrations of the pigment astaxanthin, used throughout the world to provide a natural source of this important carotenoid.

Keywords *Phaffia rhodozyma* · Yeast morphology and physiology · Yeast ecology and systematics · Herman J. Phaff (1913–2001)

Introduction

Herman Jan Phaff was born in the Netherlands in 1913. In his early years, he spent much time in his family's winery, which sparked his interest in microbes. As a

student of the great microbiologist Albert Jan Kluyver, at the Technical University of Delft, the birthplace of microbiology, Phaff received his bachelor's degree in Chemical Engineering. His thesis, "The elaboration of extracellular pectin-hydrolyzing enzymes by fungi", was a subject of great importance to the wine industry. He left Holland in 1939, just before World War II, and became a graduate student at the University of California-Berkeley, Division of Fruit Products, later known as the Department of Food Science and Technology. Working as a research assistant in Emil Mrak's laboratory, Phaff began his work on the isolation and identification of yeasts responsible for the spoilage of figs and dates in orchards of central and southern California. Thus began his love affair with yeast ecology. Research for his Ph.D. was done under the supervision of Maynard Joslyn and Horace Barker and followed in the footsteps of his undergraduate work. His thesis was titled "Elaboration of pectic enzymes by *Penicillium chrysogenum*", and in it the inducibility of pectin esterase and polygalacturonase was demonstrated. Herman Phaff became a faculty member in Berkeley in 1943, and it was there that I first met him, in 1950, when I came to that Department to carry out my doctoral studies. Back in those days, Herman taught the course on the taxonomy, ecology and physiology of yeasts with Emil Mrak, who later became the head of the Davis Food Science and Technology Department and Chancellor of UC-Davis. Most of the Department moved to Davis in 1952 but Herman remained in Berkeley for another year. I had the pleasant responsibility of picking him up at the Davis train station three times a week and driving him to Cruess Hall, the Food Science building. His interest in pectic enzymes was very fortunate for me since I also came from a family involved in food fermentation (fermentation of cucumbers into pickles) and was very interested in the softening spoilage of pickles during fermentation. Herman was the first to describe the mechanism of pectin degradation by fungal enzymes. He and I, as his student, employed affinity chromatography for the purification of yeast polygalacturonase on a

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pectic acid column even before the announcement of the discovery by others of this major technique. His studies on yeast pectic enzymes led the way to the discovery by John L. (Jack) Etchells' USDA group at North Carolina State University that cucumber softening during lactic fermentation was caused by yeasts entering the fermentation vats on the vegetables. As a student in both Herman's and Jack's laboratories, I was pleased to have participated in this commercially important research.

A major accomplishment of Herman's was the discovery, with R. Whelton, of nonrespiratory mutants of *Saccharomyces cerevisiae*, some 6 years before Boris Ephrussi's well known publication. Another important contribution was Herman's work on yeast β -glucanase, which resulted in major advances in understanding the nature of the yeast cell wall.

Working with yeasts

Herman is the father of yeast ecology. Trained in the famous Delft tradition, he discovered many previously unrecognized ecological niches of yeast, such as shellfish, rabbit stomach, frass of bark beetles, tree exudates, cactus roots, Capri figs, sewage, *Drosophila* flies and shrimp. He is remembered for his pioneering work on the coevolution of yeasts, insects and plants, being the first to establish that particular yeast species growing in the sap of trees in the Sierra Mountains of California determine the species of *Drosophila* inhabiting the tree. His work on the yeast inhabiting cactus is recognized worldwide as a major achievement in microbial ecology.

Herman was a world authority on yeast morphology, physiology and taxonomy. He was the first to discover and describe many yeasts, of which two species and one genus were named in his honor. He and his student Sally Meyer were the first microbiologists to use the tools of molecular biology to delineate yeast species and to establish evolutionary relationships among these species. This effort was recognized by his UC-Davis Faculty Research Lectureship Award in 1969, at which time, he presented the lecture "Changing Aspects in Yeast Systematics".

Herman's discovery of the yeast named in his honor, *Phaffia rhodozyma*, led to the establishment of a very important industrial fermentation process yielding high concentrations of the pigment astaxanthin, used throughout the world to provide a natural source of this important carotenoid. Astaxanthin is of great use in salmon aquaculture to provide the pink color expected by consumers of this fish. Yeast workers worldwide appreciated his book "The Life of Yeasts", written in 1966 in collaboration with Emil Mrak and colleague Marty Miller. A second revised and enlarged edition was published in 1978 and was later translated into Japanese by Susumu Nagai.

Through Herman's efforts, the Davis campus of the University of California became an international center of yeast research, and his yeast collection has been

utilized by scientists worldwide. I remember well my tasks in Davis, and in Berkeley before that, involving the periodic regrowth on slants of the many cultures in that collection. This important collection of yeast germ plasm containing over 6,000 strains is maintained in Davis by Curator Kyria Boundy-Mills and is known as the Herman J. Phaff Yeast Culture Collection.

Intellectual heritage

Herman was not only an inspiring teacher and friend but also a role model for future academic researchers. He arrived early to work and left late. Because of his example and inspiration, many of his students, coworkers and colleagues near and far were able to achieve international fame for their research. They include, among others, Ahmed T. Abdelal, Don Ahearn, Ed Buecher, Lydia do Carmo-Sousa, Ron Edstrom, Jack Fell, Graham Fleet, Mohamed Foda, Phil Gorin, A. Hagler, Bill Heed, Don Holzschu, Eric Johnson, Elisa Knapp, Andre LaChance, Mike Lewis, Bor-Shiun Luh, Alessandro Martini, Jim Macmillan, Leda Mendonça-Hagler, Marty Miller, Melvin Meyer, Sally Meyer, Demo Pappagianis, Denish Patel, Chet Price, Frank Rombouts, El Tabey Shehata, Moshe Shifrine, Harry Snyder, Masumi Soneda, Frank Spencer, Tom Starmer, Hirosato Tanaka, Tomas G. Villa, R. Whelton, and Minoru Yoneyama. His technicians, Ellen Barker, Gayle Fuson, Mary Miranda, Heather Presley and Joanne Tredick, were well appreciated by Herman and they learned much from this great researcher and teacher.

Herman had an illustrious career of over six decades during which he forged a new science of yeast biology in the interactive fields of systematics, ecology, physiology and biochemistry. Up until the end, Herman continued to be dedicated to studying yeast biodiversity, modernizing his vast collection and making it available to the world. He, his students, and coworkers described over 50 species of yeast in over 300 publications. He was a Charter Member of the American Academy of Microbiology, represented the USA on the International Commission on Yeasts, and was a longtime Editor of the International Journal of Systematic Bacteriology. He also received many honors during and after his lifetime, from the Mycological Society of America, the American Society for Microbiology (J. Roger Porter Award), the US Federation for Culture Collections, the American Society for Enology and Viticulture, the International Commission on Yeast and Yeast-like Organisms, North Carolina State University (John L. Etchells Memorial Lectureship Award), and UC-Davis (Award of Distinction). He was the Editor of the Yeast Newsletter for over 30 years. This publication was a major mechanism for bringing together yeast investigators from all over the world and became the official organ of the International Commission on Yeasts and Yeast-like Organisms of the International Union of Microbiological Societies. A memorable Phaff Symposium took place at the 5th

International Symposium of Yeasts in London, Canada, in 1980. Six years later, Herman was given the honor of presenting his autobiography as the prefatory chapter of the Annual Reviews of Microbiology. Of course, he called it "My Life with Yeasts". In 1996, a special issue of the Journal of Industrial Microbiology was dedicated to Herman in which he contributed the paper "Life with Yeasts during Retirement".

Marinka, Herman's wonderful wife for 37 years, was a major supportive force for him until her death in 1985. Herman's second wife, Diane, was his constant companion until he passed away at the age of 88. Since she was also a musician, she was able to actively share in his love of music.

Herman was an accomplished cellist, a founding member of and performer with the UC-Davis Symphony Orchestra and the Davis Comic Opera Company. He also played in many chamber music groups and was an Honorary Member of the UC Davis Department of Music.

After retiring as Emeritus Professor at UC Davis in 1983, he continued to spend time in the laboratory, collect yeasts in nature, and write until his accidental death in 2001. He loved his work, and had no reason or interest in stopping. We who were the beneficiaries of this man's scholarship, teaching, professionalism and, above all, his deep friendship, owe the success of our careers to Herman Jan Phaff. He taught us how to work hard, be professional, ethical, and, above all, to enjoy our chosen careers!

I will close now with my personal thoughts of Herman on the occasion of his memorial service in Davis on October 29, 2001:

Dear Herman, although I am not a religious man, I believe that you are up there and can receive this message. We met in 1950, not long after I had arrived in Berkeley, a Brooklyn boy without any particular enthusiasm for science. I had been sent to Emil Mrak by Jack Etchells with the goal of making me a food microbiologist. Jody and I drove to California for the first time, and you and I met shortly thereafter. From the beginning, our discussions set me thinking, and I began to appreciate the richness of the scientific life. The excitement that you generated within me as your second student still lives on 51 years later! Like you, I cannot wait to get to the lab in the morning and I drag myself home late in the day. I will never forget our many evenings together in the lab after we had gone home for dinner and then returned for many hours of research and discussion. But I also remember those wonderful parties in your home during which everyone could leave their work behind and simply have fun. You were not only my Professor, but also my dearest friend, my role model and my most important mentor. I will also never forget all those years that we roomed together at the ASM meetings, how we practiced our presentations in front of one another, and all the fun we had at dinners and with our colleagues. You have greatly inspired me, and any heights that I have

reached in science are due to your teaching, your example, and your love. Whenever I will feel in the future that I need a lift, some inspiration, I shall look up at the heavens above and think of you. You were a great scientist, human being and friend, and you will continue to inspire me for as long as I live.

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Chronological list of reviews and book chapters of Herman J. Phaff

- Joslyn MA, Phaff HJ (1947) Recent advances in the chemistry of pectic substances. *Wallerstein Lab Commun* 10:39–56
- Mrak EM, Phaff HJ (1948) Yeasts. *Annu Rev Microbiol* 2:1–47
- Phaff HJ, Mrak EM (1948) Sporulation in yeasts. *Wallerstein Lab Commun* 11:261–279
- Phaff HJ, Mrak EM (1949) Sporulation in yeasts. *Wallerstein Lab Commun* 12:29–44
- Phaff HJ, Joslyn MA (1952) The newer knowledge of pectic enzymes. *Wallerstein Lab Commun* 10:133–147
- Demain AL, Phaff HJ (1957) Recent advances in the enzymatic hydrolysis of pectic substances. *Wallerstein Lab Commun* 20:119–139
- Demain AL, Phaff HJ (1957) Softening of cucumbers during curing. *Agric Food Chem* 5:60–64
- Phaff HJ (1959) The production of certain extracellular enzymes by microorganisms. In: Ruhland W (ed) *Hansdbuch der Pflanzenphysiologie*. Springer-Verlag, Berlin, pp 76–116
- Phaff HJ (1960) *Saccharomycetales; Sporobolomycetales; Malt beverage; Ethyl alcohol; Fat and oil, edible; Distilled spirits; Food microbiology; Wine; Cryptococcales; yeast; Yeast, industrial*. In: McGraw-Hill Encyclopedia of Science and Technology. McGraw-Hill, New York, pp. 1–2; 10–11; 80–81; 89–91; 184–188; 253–256; 423–424; 506–508; 578–579; 599–604
- Phaff HJ (1963) Cell wall of yeasts. *Annu Rev Microbiol* 17:15–30
- Phaff HJ (1966) Alpha-1,4-polygalacturonate glucanohydrolase (endo-polygalacturonase) from *Saccharomyces fragilis*. In: Neufeld EF, Ginsburg V (eds) *Methods in Enzymology*, vol 8, Complex carbohydrates. Academic, New York, pp 636–641
- Macmillan JD, Phaff HJ (1966) Exopolygalacturonate lyase from *Clostridium multifementans*. In: Neufeld EF, Ginsburg V (eds) *Methods Enzymol*, vol 8. Complex carbohydrates. Academic, New York, pp 632–635
- Phaff HJ, Miller MW, Mrak EM (1966) The life of yeasts, 186 pp.; and a 2nd edn. 1978, 341 pp. Harvard Univ Press, Cambridge, USA
- Phaff HJ (1970) Genus *Hanseniaspora* Zikes. In: Lodder J (ed) *The yeasts: a taxonomic study*. North Holland, Amsterdam, pp 209–225
- Phaff HJ (1970) Genus *Nadsonia* Sydow. In: Lodder J (ed) *The yeasts: a taxonomic study*. North Holland, Amsterdam, pp 430–439
- Phaff HJ (1970) Genus *Saccharomycodes* Hansen. In: Lodder J (ed) *The yeasts: a taxonomic study*. North Holland, Amsterdam, pp 719–724

- Phaff HJ (1970) Genus *Saccharomycopsis* Schionning. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 725–732
- Phaff HJ (1970) Genus *Schwanniomyces* Klockner. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 756–766
- Phaff HJ (1970) Genus *Wickerhamia* Soneda. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 767–771
- Phaff HJ (1970) Genus *Bullera* Derx. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 815–821
- Phaff HJ (1970) Genus *Sporidiobolus* Nyland. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 822–830
- Phaff HJ (1970) Genus *Sporobolomyces* Kluver et van Niel. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 831–862
- Phaff HJ (1970) Genus *Kloeckera* Janke. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 1146–1160
- Fell JW, Phaff HJ (1970) Genus *Leucosporidium* Fell, Statzell, Hunter et Phaff. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 776–802
- Foda MS, Phaff HJ (1970) The synthesis of starch-like compounds by *Cryptococcus laurentii*. In: Ahearn DG (ed) Recent trends in yeast research, vol 1, Spectrum. Georgia State Univ, Atlanta, pp 181–198
- Phaff HJ, Ahearn DG (1970) Genus *Rhodotorula* Harrison. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 1187–1223
- Phaff HJ, Fell JW (1970) Genus *Cryptococcus* Kützing emend. Phaff et Spencer. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 1088–1145
- Meyer SA, Phaff HJ (1970) Taxonomic significance of the DNA base composition in yeasts. In: Ahearn DG (ed) Recent trends in yeast research, vol 1, Spectrum. Georgia State Univ, Atlanta, pp 1–29
- Fell JW, Phaff HJ, Newell SY (1970) Genus *Rhodosporidium* Banno. In: Lodder J (ed) The yeasts: a taxonomic study. North Holland, Amsterdam, pp 803–814
- Phaff HJ (1971) Structure and biosynthesis of the yeast cell envelope. In: Rose AH, Harrison JS (eds) The yeasts, vol 2, physiology and biochemistry of yeasts. Academic, London, pp 135–210
- Simpson KL, Chichester CO, Phaff HJ (1971) Carotenoid pigments of yeasts. In: Rose AH, Harrison JS (eds) The yeasts, vol 2, physiology and biochemistry of yeasts. Academic, London, pp 493–515
- Meyer SA, Phaff H J (1972) DNA base composition and DNA-DNA homology studies as tools in yeast systematics. In: Kockova-Kratochvilova A, Minarik E (eds) Yeasts: models in Science and techniques. Slovak Acad Sci, Bratislava, pp 375–387
- Phaff HJ, Macmillan JD (1973) Description of various genera and species of special interest. In: Laskin AI, Lechevalier HA (eds) CRC Handbook of microbiology. CRC, Cleveland, pp 373–389
- Phaff H J (1977) Enzymatic yeast cell wall degradation. In: Feeney RE, Whitaker JR (eds) Food proteins: improvement through chemical and enzymatic modification, advances in chemistry series 160. Amer Chem Soc, Washington DC, pp 244–282
- Macmillan, J.D. and Phaff, H. J. 1978. In: Laskin AI, Lechevalier HA (eds) Yeasts: general survey, CRC handbook of microbiology vol II, Fungi, algae, protozoa and viruses. 2nd edn. CRC, West Palm Beach, pp 207–228
- Phaff HJ, Macmillan JD (1978) Description of various genera and species of special interest. In: Laskin AI, Lechevalier HA (eds) Yeasts: general survey, CRC handbook of microbiology vol II., Fungi, algae, protozoa and viruses, 2nd edn. CRC, West Palm Beach, pp 229–250
- Price CW, Fuson GB, Phaff HJ (1978) Genome comparison in yeast systematics: delimitation of species within the genera *Schwanniomyces*, *Saccharomyces*, *Debaryomyces* and *Pichia*. Microbiol Rev 42:161–193
- Phaff HJ, Amerine MA (1979) Wine. In: Peppler HJ, Perlman D (eds) Microbial technology, vol 2, Fermentation technology, 2nd edn. Academic, New York, pp 131–153
- Phaff HJ, Starmer WT (1980) Specificity of natural habitats for yeasts and yeast-like organisms. In: Skinner FA, Passmore SM, Davenport RR (eds) Biology and activities of yeasts, Soc Appl Bacteriol Symp Ser No 9. Academic, New York, pp 79–102
- Phaff H J (1981) Industrial microorganisms. Sci Am 245:76–89
- Fleet GH, Phaff HJ (1981) Fungal glucans: structure and metabolism. In: Tanner W, Loewus FA (eds) Plant carbohydrates, vol II, Extracellular carbohydrates. Springer, Berlin Heidelberg New York, pp 416–440
- Holdschu DSL, Phaff HJ (1982) Taxonomy and evolution of some ascomycetous cactophilic yeasts. In: Barker JSF, Starmer WT (eds) Ecological genetics and evolution - the cactus-yeast-*Drosophila* model system. Academic, Sydney, pp 127–141
- Starmer WT, Phaff HJ, Miranda M, Miller MW, Heed WB (1982) The yeast flora associated with the decaying stems of columnar cacti and *Drosophila* in North America. In: Hecht MK, Wallace B, Prance CT (eds) Evolutionary biology, vol 14, Plenum, New York, pp 269–295
- Kurtzman CP, Phaff HJ, Meyer SA (1983) Nucleic acid relatedness among yeasts. In: Spencer JFT, Spencer DM, Smith ARW (eds) Yeast genetics, fundamental and applied aspects. Springer-Verlag, New York, pp 139–166
- Phaff HJ (1984) DNA, enzymes and cell wall. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 17–21
- Phaff HJ (1984) Chemical composition of the cell wall. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 22–24
- Phaff HJ (1984) Genus 5. *Coccidiascus* Chatton. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 123–124
- Miller MW, Phaff HJ (1984) Genus 16. *Metchnikowia* Kamienski. In: Kreger-van Rij NJW (ed) The Yeasts: A Taxonomic Study, 3rd edn. Elsevier, Amsterdam, pp 266–278
- Miller MW, Phaff HJ (1984) Genus 17. *Nadsonia* Sydow. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 279–284
- Miller MW, Phaff HJ (1984) Genus 18. *Nematospora* Peglion. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 285–288
- Miller MW, Phaff HJ (1984) Genus 23. *Saccharomycodes* Hansen. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 396–398
- Phaff HJ, Kurtzman CP (1984) Genus 14. *Lipomyces* Lodder et Kreger-van Rij. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 252–262
- Phaff HJ, Miller MW (1984) Genus 6. *Cyniclomyces* van der Walt et Scott. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 125–129
- Phaff HJ, Miller MW (1984) Genus 26. *Schwanniomyces* Klockner. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 423–426

- Phaff HJ, Miller MW (1984) Genus 30. *Wickerhamia* Soneda. In: Kreger-van Rij NJW (ed) The yeasts: a taxonomic study, 3rd edn. Elsevier, Amsterdam, pp 440–442
- Phaff HJ (1985) Biology of yeasts other than *Saccharomyces*. In: Demain AL, Solomon NA (eds) Biology of industrial microorganisms. Benjamin/Cummings, London, pp 537–562
- Phaff HJ (1986) My life with yeasts. *Annu Rev Microbiol* 40:1–28
- Phaff HJ, Starmer WT (1987) Yeasts associated with plants, insects and soil. In: Rose AH, Harrison JS (eds) The yeasts, vol 1, Biology of yeasts, 2nd edn. Academic, Orlando, pp 123–180
- Kurtzman CP, Phaff HJ (1987) Molecular taxonomy. In: Rose AH, Harrison JS (eds) The yeasts, vol 1, Biology of yeasts, 2nd edn. Academic, Orlando, pp 63–94
- Phaff HJ (1989) Trends in yeast systematics. *Yeast* 5:S341–S349
- Phaff HJ (1990) Isolation of yeasts from natural sources. In: Labeda DP (ed) Isolation of biotechnological organisms from nature. McGraw-Hill, New York, pp 53–79
- Bennett JW, Phaff HJ (1993) Early biotechnology: the Delft connection. *ASM News* 59:401–404
- Phaff HJ (1995) Life with yeasts during retirement. *J Indust Microbiol* 14:432–435
- Phaff HJ (1998) Chemotaxonomy based on the polysaccharide composition of cell walls and capsules. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 45–47
- Phaff HJ (1998) *Coccidiascus* Chatton emend. Lushbaugh, Rowton et McGhee. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, p 153
- Lachance MA, Phaff HJ (1998) *Clavispora* Rodrigues de Miranda. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 148–152
- Phaff HJ, Miller MW (1998) *Cyniclomyces* van der Walt et Scott. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 154–156
- Miller MW, Phaff HJ (1998) *Metschnikowia* Kamienski. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 256–267
- Miller MW, Phaff HJ (1998) *Nadsonia* Sydow. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 268–270
- Miller MW, Phaff HJ (1998) *Saccharomyces* E. C. Hansen. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 372–373
- Lachance MA, Phaff HJ (1998) *Sporopachydermia* Rodrigues de Miranda. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 395–399
- Phaff HJ, Miller MW (1998) *Wickerhamia* Soneda. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 409–410
- Miller MW, Phaff HJ (1998) *Phaffia* M. W. Miller, Yoneyama et Soneda. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, p 789
- De Hoog GS, Kurtzman CP, Miller MW, Phaff HJ (1998) *Eremothecium* Borzi emend. Kurtzman. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 201–208
- Demain AL, Phaff H J, Kurtzman CP (1998) The industrial and agricultural significance of yeasts. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 13–19
- Nakase TM, Suzuki M, Phaff HJ, Kurtzman CP (1998) *Debaryomyces* Lodder and Kreger-van Rij. In: Kurtzman CP, Fell JW (eds) The yeasts: a taxonomic study, 4th edn. Elsevier, Amsterdam, pp 157–173