U.S. Department of Agriculture
Forest Service General Technical Report SO-10

Interrelationships among microorganisms, bark or ambrosia beetles, and woody host tissue: an annotated bibliography, 1965-1974

S.J. Barras and T.J. Perry

Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture

1975

INTERRELATIONSHIPS AMONG MICROORGANISMS, BARK OR AMBROSIA BEETLES, AND WOODY HOST TISSUE: AN ANNOTATED BIBLIOGRAPHY, 1965-1974

S. J. Barras and T. J. Perry[1]

Of the many factors that influence the development of scolytids within woody hosts, the least understood are the interrelationships of insects, microorganisms, and host trees. Only limited information is available concerning the biological, ecological, and physiological parameters of the associations, but the final result is the destruction of valuable timber resources. Broad classes of symbiosis have recently been recognized but are still not fully understood. Symbiosis here denotes not only direct interactions between insects and microorganisms but also refers to microorganism-woody tissue interactions that often influence insect development and survival.

By compiling this bibliography, we hope to stimulate further research into these interrelationships, which must be comprehended before a thorough understanding of scolytid development is possible. The bibliography represents a collection of articles and abstracts from many disciplines; the entries were compiled both during our own research and after an extensive review.

We included papers and abstracts about the biology and physiology of specific microorganisms (bacteria, yeasts, and fungi) associated with bark and ambrosia beetles and items concerning the maintenance of these associations. Also included are papers about pathogenic associations, nutrition, and other biochemical interactions. Microbial taxonomic papers are presented only to provide information on the synonomy of organisms.

[1] Barras is research entomologist and Perry is biological technician, Forest Service—USDA, Southern Forest Experiment Station, Pineville, La. The authors acknowledge the assistance of Michael Dunn in preparing the bibliography and thank Dr. H. S. Whitney and Dr. R. C. Wilkinson for reviewing the manuscript.

We have included pertinent literature published since Francke-Grosmann's 1967 review "Ectosymbiosis in Wood Inhabiting Insects." Papers published before 1967 but not included in her review are also cited. We have excluded literature related to Dutch elm disease because of previous extensive reviews (Laut and Schomaker 1974, Peacock 1973).[2]

All articles and abstracts were examined in entirety—either as originally printed or as reprints or copies. When available, abstracts of the papers were reviewed to determine their suitability for this publication and were revised or expanded to satisfy the requirements of an annotated bibliography. The entries and the index are as comprehensive as possible to offer readers of various interests a system for identifying pertinent information. We hope that researchers in diverse fields will find the bibliography useful.

We regret inadvertent omissions and would welcome having them called to our attention.

1. Abrahamson, L. P., H-M Chu, and D. M. Norris. 1967. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. II. THE ORGANS OF MICROBIAL TRANSPORT AND PERPETUATION IN *TRYPODENDRON BETULAE* AND *T. RETUSUM* (COLEOPTERA: SCOLYTIDAE). Ann. Entomol. Soc. Am. 60: 1107–1110.

   Mycangia were the prothoracic-pleural type and resembled those of other Trypodendron *species. Secretions released into the mycangium may contribute to ambrosia cell growth in symbiontic fungi.*

[2] Laut, J. G. and M. E. Shomaker. Dutch elm disease—a bibliography. Colorado State Forest Service, Colorado State University. 95 p. 1974.

Peacock, J. W. Research on chemical and biological controls for elm bark beetles. Proc. IUFRO Meeting on Dutch Elm Disease. St. Paul, Minn. (in press). 1973.

2. Abrahamson, L. P., and D. M. Norris. 1966. THE MYCANGIA OF *XYLOTERINUS POLITUS* (SAY). Univ. Wisc. For. Res. Note 129, 4 p.
Two distinct pairs of mycangia were found in adults. One was a prothoracic-pleural type found only in females, and the other opened into oral cavities of both sexes.

3. Abrahamson, L. P., and D. M. Norris. 1966. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. I. THE ORGANS OF MICROBIAL TRANSPORT AND PERPETUATION OF *XYLOTERINUS POLITUS*. Ann. Entomol. Soc. Am. 59: 877–880.
Reports more details about mycangia. Different fungi were isolated from each type of mycangia (see Abrahamson and Norris, No. 2 above). A complex of fungi is involved in the nutritional utilization of natural wood substrates.

4. Abrahamson, L. P., and D. M. Norris. 1969. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. IV. AMBROSIAL FUNGI ASSOCIATED WITH *XYLOTERINUS POLITUS*. J. Invertebr. Pathol. 14: 381–385.
Two primary ambrosia fungi from mycangia of X. politus *were isolated and described. One was cultured from the oral mycangia of both male and female adults and was tentatively identified as a new species of* Raffaelea. *The other was from the prothoracic-pleural mycangia of the female only and was not identified.*

5. Abrahamson, L. P., and D. M. Norris. 1970. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES (COLEOPTERA: SCOLYTIDAE). V. AMINO ACIDS AS A SOURCE OF NITROGEN TO THE FUNGI IN THE BEETLE. Ann. Entomol. Soc. Am. 63: 177-180.
Nonprotein acids in the adult female of Xyleborus ferrugineus *were qualitatively similar to those in most endopterygotes. Proline, valine, and alanine were the major constituents in the free amino acid pool. The soluble peptide and amide portion contained relatively large quantities of threonine and valine. Glycine was the most abundant amino acid in the protein residue.*

6. Andrieu, S., J. Biguet, and S. Massamba. 1971. ETUDE IMMUNOLOGIQUE COMPAREE DE *SPOROTHRIX SCHENCKII* ET DES SOUCHES SAPROPHYTES VOISINES. [A COMPARATIVE IMMUNOLOGICAL STUDY OF *SPOROTHRIX SCHENCKII* AND OF RELATED SAPROPHYTIC STRAINS.] Sabouraudia 9: 206-209.
Strains of fungi with Sporothrix *conidial arrangement were taken from human sporotrichosis or from natural habitats and were compared by agar-gel precipitation. Three strains from natural habitats produced a* Ceratocystis *sexual form.* C. stenoceras *is a perfect state of* S. schenckii, *which causes sporotrichosis.*

7. Arx, J. A. von, and G. L. Hennebert. 1965. DEUX CHAMPIGNONS AMBROSIA. [TWO AMBROSIA FUNGI.] Mycopathol. Mycol. Appl. 25: 309–315.
Describes a new genus, Raffaelea. R. ambrosiae *from galleries of* Platypus cylindrus *is the fungus originally described as* Sporothrix *sp. Also discusses the association between* Ambrosiella xylebori *and* Xyleborus compactus.

8. Ashraf, M., and A. A. Berryman. 1969. BIOLOGY OF *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE) ATTACKING *ABIES GRANDIS* IN NORTHERN IDAHO. Melanderia 2: 1–23.
Aspergillus flavus *and* Penicillium *sp. were isolated from parent galleries and larval mines.* A. flavus *was also isolated from dead larvae. It was not determined if these fungi were saprophagous or entomophagous.*

9. Baker, J. M., and D. M. Norris. 1968. A COMPLEX OF FUNGI MUTUALISTICALLY INVOLVED IN THE NUTRITION OF THE AMBROSIA BEETLE *XYLEBORUS FERRUGINEUS*. J. Invertebr. Pathol. 11: 246–250.
Paired oral mycangia present in both sexes of stock culture beetles contained a complex of fungi, yeast, and bacteria. Fusarium solani *was the dominant fungal symbiote, but a* Cephalosporium *sp. and a* Graphium *sp. were also isolated. Each fungus grew as ambrosial propagules that either provided nutrients not already present in the diet or concentrated nutrients essential to reproduction.*

10. Barras, S. J. 1967. THORACIC MYCANGIUM OF *DENDROCTONUS FRONTALIS* (COLEOPTERA: SCOLYTIDAE) IS SYNONYMOUS WITH A SECONDARY FEMALE CHARACTER. Ann. Entomol. Soc. Am. 60: 486–487.
A transverse ridge or callus on the surface of the exoskeleton covers the outer wall of the mycangium and extends around the pronotum like a collar. The mycangium is a useful female sex character for callow and mature adults.

11. Barras, S. J. 1970. ANTAGONISM BETWEEN *DENDROCTONUS FRONTALIS* AND THE FUNGUS *CERATOCYSTIS MINOR*. Ann. Entomol. Soc. Am. 63: 1187–1190.
In the laboratory, C. minor *acting alone was detrimental to* D. frontalis *development in loblolly pine bolts. In nature, interactions of other beetle-associated microorganisms and* C. minor *may inhibit the antagonism.*

12. Barras, S. J. 1973. REDUCTION OF PROGENY AND DEVELOPMENT IN THE SOUTHERN PINE BEETLE FOLLOWING REMOVAL OF SYMBIOTIC FUNGI. Can. Entomol. 105: 1295–1299.
In loblolly pine bolts, lack of mycangial fungi or of the normal complement of mycangial and ectodermal fungi caused a significant decrease in number of progeny, progeny per gallery, progeny per cm of gallery, and ratio of increase. Initial emergence of progeny was delayed 13 to 24 days. Absence of fungi had no effect on the number of successful attacks, the length of ovipositional gallery, and the number of egg niches per cm of gallery.

13. Barras, S. J., and J. D. Hodges. 1969. CARBOHYDRATES OF INNER BARK OF *PINUS*

TAEDA AS AFFECTED BY *DENDROCTONUS FRONTALIS* AND ASSOCIATED MICRO-ORGANISMS. Can. Entomol. 101: 489–493.
Glucose, fructose, and sucrose were the only sugars detected in inner bark treated with a southern pine beetle-microorganism complex and two beetle-associated fungi. C. minor *caused a 68 percent decrease in reducing sugars after 16 days, but a basidiomycete mycangial fungus required 36 days to cause a 64 percent reduction. A similar decrease in sucrose was observed. Results indicated that both fungi influenced the carbohydrate pool available to the insect, but* C. minor *had a more rapid effect on the C:N ratio.*

14. Barras, S. J., and T. Perry. 1971. *LEPTOGRAPHIUM TEREBRANTIS* SP. NOV. ASSOCIATED WITH *DENDROCTONUS TEREBRANS* IN LOBLOLLY PINE. Mycopathol. Mycol. Appl. 43: 1–10.
A Leptographium *fungus associated with the black turpentine beetle* (D. terebrans) *is described for the first time. The name* Leptographium terebrantis *sp. nov. is proposed.*

15. Barras, S. J., and T. Perry. 1971. GLAND CELLS AND FUNGI ASSOCIATED WITH PROTHORACIC MYCANGIUM OF *DENDROCTONUS ADJUNCTUS* (COLEOPTERA: SCOLYTIDAE). Ann. Entomol. Soc. Am. 64: 123–126.
Females have a well-developed mycangium and males, a pseudomycangium. Two types of gland cells were associated with the mycangium: one had an efferent cuticular tubule previously unreported but similar to Tenebrionidae defensive gland cells; the other was a columnar cell found previously with other mycangia. A Verticicladiella *sp. near* huntii *was contained by 60 percent of the female mycangia but was not associated with the male pseudomycangia.* Penicillium decumbens, P. spinulosum, *and yeasts were associated with both males and females.*

16. Barras, S. J., and T. Perry. 1972. FUNGAL SYMBIONTS IN THE PROTHORACIC MYCANGIUM OF *DENDROCTONUS FRONTALIS* (COLEOPTERA: SCOLYTIDAE). Z. Angew. Entomol. 71: 95–104.
An undescribed Sporothrix *and a basidiomycete were the predominant fungi in the attacking female. Other microorganisms such as* Ceratocystis minor, Penicillium *spp., and yeasts may occasionally occur in callow adults, but only yeasts were still present in attacking beetles. The chemical regime of the mycangium selectively favors* Sporothrix *sp. and the basidiomycete.* Sporothrix *isolate is a highly modified anascigerous form of* Ceratocystis.

17. Barras, S. J., and J. J. Taylor. 1973. VARIETAL *CERATOCYSTIS MINOR* IDENTIFIED FROM MYCANGIUM OF *DENDROCTONUS FRONTALIS*. Mycopathol. et Mycol. Appl. 50: 293–305.
A detailed description of the fungus and a discussion of its symbiotic relationship to the insect. A fungus in the adult female produced an anascigerous Sporothrix *sp. in various media. After prolonged growth on potato glucose agar, the fungus produced a type of* Ceratocystis minor.

18. Basham, H. G. 1968. PATHOGENICITY OF SOME BLUE-STAIN FUNGI IN THE GENUS CERATOCYSTIS. Phytopathology 58: 1042.
Abstract of paper for American Phytopathological Society. Loblolly pines were inoculated with pure cultures of Ceratocystis *species. Several pathogenic isolates of* C. ips, C. minor, C. montia, *and* C. pilifera *caused a penetrating stain in sapwood and killed trees. All except* C. pilifera *are associated with pine bark beetles. Dye conduction tests revealed no dye in stained sapwood of dead seedlings.*

19. Basham, H. G. 1970. WILT OF LOBLOLLY PINE INOCULATED WITH BLUE-STAIN FUNGI OF THE *GENUS CERATOCYSTIS*. Phytopathology 60: 750–754.
Pathogenicity of C. ips, C. minor, C. montia, *and* C. pilifera *appeared related to their capacities to penetrate living sapwood. Blockage of water conduction caused wilting. Vigor of the saplings, as measured by crown class or stem diameter, appeared inversely related to susceptibility to pathogenic isolates. A zone of phenols and resins was noted in the region of fungal invasion of resistant trees but not in trees killed by the fungi.*

20. Batra, L. R. 1963. ECOLOGY OF AMBROSIA FUNGI AND THEIR DISSEMINATION BY BEETLES. Trans. Kans. Acad. Sci. 66: 213–236.
Discusses mycangia as repositories for plant pathogens and the role of the ambrosial mass in insect nutrition. Ambrosia fungi were associated with 20 beetle species. Both the specific and dominant ambrosia fungus and propagative bodies of nonspecific fungi were present in insect tunnels. Most foreign fungi were the yeasts and yeast allies Ceratocystis *spp.,* Fusarium *spp.,* Aspergillus, Penicillium, *and* Trichoderma lignorum. *Ambrosia fungi were stored in mycangia during hibernation and disseminated during burrowing in early spring. Ambrosia cells from tunnels and mycangia of related beetles were morphologically similar but showed cultural differences. Limited multiplication of fungi occurred in the mycangia of some beetles.*

21. Batra, L. R. 1966. AMBROSIA FUNGI: EXTENT OF SPECIFICITY TO AMBROSIA BEETLES. Science 153: 193–195.
Beetles may feed on more than one species. Yeast-like ambrosia propagules in the mycangia are from conidia and ascospores picked up by callow adults while in the tunnels.

22. Batra, L. R. 1967. AMBROSIA FUNGI: A TAXONOMIC REVISION, AND NUTRITIONAL STUDIES OF SOME SPECIES. Mycologia 59: 976–1017.
Provides keys to genera and species of all known ambrosia fungi associated with ambrosia beetles. The ambrosia phase occurs in insect tunnels and mycangia of Scolytidae, Platypodidae, and Lymexylidae (Coleoptera). Primary ambrosia fungi belong to four genera of Tuberculariaceae (Ambrosiella, Raffaelea, Monacrosporium, *and* Phial-

ophoropsis) *and two of Endomycetales* (Ascoidea *and* Endomycopsis).

23. Batra, L. R. 1971. TWO NEW HEMIASCOMYCETES: *PICHIA CROSSOTARSI* AND *P. MICROSPORA*. Mycologia 63: 994-1001.
Gives cultural and taxonomic characteristics of two new species found in association with the ambrosia beetle Crossotarsus wollastoni *from Kakanakote, Mysore, India. The yeasts may be an auxiliary source of nutrition. Cultural and taxonomic characteristics of the yeasts are presented.*

24. Batra, L. R. 1972. ECTOSYMBIOSIS BETWEEN AMBROSIA FUNGI AND BEETLES—I. Ind. J. Mycol. Plant Pathol. 2: 165–169.
Reviews previously described associations between ambrosia beetles and fungi. Describes primary and auxiliary ambrosia fungi and discusses specificity of associations. Ectosymbiosis represents a mutualistic mode of life where one symbiont cannot live without the other.

25. Beanlands, G. E. 1967. THE EFFECTS OF BARK MOISTURE ON *POLYGRAPHUS RUFIPENNIS* (COLEOPTERA: SCOLYTIDAE) ADULTS AND THEIR DEVELOPING BROODS. Can. Entomol. 99: 561–564.
Adults and immature stages reared in white spruce bark with high moisture levels had decreased survival and rate of development after 40 days. High moisture may have increased fungal growth and the rate of bark decomposition.

26. Becker, G. 1971. PHYSIOLOGICAL INFLUENCES ON WOOD-DESTROYING INSECTS OF WOOD COMPOUNDS AND SUBSTANCES PRODUCED BY MICROORGANISMS. Wood Sci. and Technol. 5: 236–246.
Describes reactions of various species of Coleoptera and Isoptera to attractive or repellent compounds in wood species or substances produced by fungi. Insect nutrition depends on wood nitrogen compounds, which can be increased by the presence of fungi.

27. Berryman, A. A. 1969. RESPONSES OF *ABIES GRANDIS* TO ATTACK BY *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 101: 1033–1041.
Resistant trees produced secondary resin in cells of the phloem parenchyma and formed callus tissue and traumatic resin cavities at the cambium-sapwood interface. Vulnerable trees had limited resinosis that could not prevent invasion by the insect-fungus complex.

28. Berryman, A. A. 1972. RESISTANCE OF CONIFERS TO INVASION BY BARK BEETLE-FUNGUS ASSOCIATIONS. BioScience 22: 598–602.
Discusses mainly western bark beetles with limited information on mycangia. Infection of the inner bark or cambium produces a resistant or hypersensitive reaction causing a wound periderm to form around the necrotic lesion. Resistant trees may produce compounds toxic to fungi (terpenes, polyphenols). Callus formations contain traumatic resin canals or cavities that eventually curtail the fungus. Failure of the hypersensitivity reaction causes massive necrosis of host tissue and may kill the tree.

29. Bevan, D. 1962. THE AMBROSIA BEETLE OR PINHOLE BORER *TRYPODENDRON LINEATUM* OL. Scot. For. 16: 94–99.
In conifer logs of western Scotland, the ambrosia fungus (unidentified) that provides food for the brood is inoculated into tunnels by the female at the time of gallery construction. The originally white mycelium turns black in the entrance and main tunnel after the eggs hatch; then the larval niches change color. Following pupation, tending parents leave, having kept the gallery clean for larvae by cropping back the fungus.

30. Biévre, C. de, and C. Jourd'huy. 1974. ETUDE COMPARATIVE DES PHOSPHOLIPIDES DE PLUSIEURS SOUCHES DE *CERATOCYSTIS STENOCERAS* ET DE *SPOROTHRIX SCHENCKII*. [COMPARATIVE STUDY OF THE PHOSPHOLIPIDS FROM SEVERAL FORMS OF *C. STENOCERAS* AND OF *S. SCHENCKII*.] C. R. Acad. Sci. Paris Ser. D. 278: 53–55.
Characterizes phospholipids from several forms of C. stenoceras *(wild and mutant sources) and* S. schenckii. *Phospholipid compositions indicate similarity between the two species. All fungal stocks contained cardiolipin, phosphatidylethanolamine, phosphatidyl N methylethanolamine, phosphatidylserine, phosphatidylcholine, lysophosphatidylethanolamine, and lysophosphatidylcholine. The wild source (asigerous) of* C. stenoceras *(1013) contained some phosphatidylinositol; anasigerous mutants (parasitic and nonparasitic) and* S. schenckii *did not.*

31. Bletchly, J. D., and M. G. White. 1962. SIGNIFICANCE AND CONTROL OF ATTACK BY THE AMBROSIA BEETLE *TRYPODENDRON LINEATUM* (OLIV.) (COL. SCOLYTIDAE) IN ARGYLLSHIRE FORESTS. Forestry 35: 139–163.
Parent beetles introduce spores of specialized fungi where eggs are laid to provide the major part of brood nutrition. Fungi can survive only when wood remains green. In processed logs, both fungi and larvae die as timber dries.

32. Borden, J. H., and M. McClaren. 1970. BIOLOGY OF *CRYPTOPORUS VOLVATUS* (PECK) SHEAR (AGARICALES, POLYPORACEAE) IN SOUTHWESTERN BRITISH COLUMBIA: DISTRIBUTION, HOST SPECIES, AND RELATIONSHIP WITH SUBCORTICAL INSECTS. Syesis 3: 145–154.
Occurs primarily where annual rainfall is less than 60 inches. Main host trees are Pseudotsuga menziesii *and* Pinus ponderosa, *but the fungus was also found on* Pinus contorta *and* Abies amabilis, *which is a new host record. Both occurrence and density were strongly correlated with Douglas-fir beetle* (Dendroctonus pseudotsugae) *attacks on host trees the previous year.* Temnochila virescens *var.* chlorodia, *a predator of subcortical insects, is probably a vector of* C. volvatus.

33. Brader, L. 1965. BETEKENIS VAN DE AMBROSIA-SCHIMMEL VOOR DE ONTWIKKELING VAN *XYLEBORUS COMPACTUS* EICHH., DE ZWARTE TAKKENBOORDER VAN KOFFIE (COLEOPTERA, SCOLYTIDAE). [IMPORTANCE OF AMBROSIA FUNGI FOR THE DEVELOPMENT OF *XYLEBORUS COMPACTUS* EICHH., THE BLACK COFFEE TWIG BORER.] Entomol. Ber. 25: 32.
Biology, symbiosis.

34. Bright, D. E., Jr. 1968. REVIEW OF THE TRIBE XYLEBORINI IN AMERICA NORTH OF MEXICO (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 100: 1288–1323.
All are ambrosia beetles. Adults bore into woody tissues of host plants and feed on the ambrosial fungi lining tunnel walls. Coniferous and deciduous trees and shrubs of all sizes are attacked.

35. Bright, D. E., Jr., and R. W. Stark. 1973. THE BARK AND AMBROSIA BEETLES OF CALIFORNIA. COLEOPTERA: SCOLYTIDAE AND PLATYPODIDAE. Bull. Calif. Insect Surv. 16, 169 p. Univ. Calif. Press, Berkeley.
Limited information on the following beetle-fungus associations: Platypus wilsoni-Tuberculariella ambrosiae, Scolytus ventralis-Trichosporium symbioticum, Dendroctonus brevicomis-*blue stain fungus*, Trypodendron lineatum-Monilia ferruginea, Xyleborus dispar-*ambrosial fungus*, X. saxeseni-*ambrosial fungus*, Monarthrum scutellare-Monilia brunnea *and* Gnathotrichus sulcatus-*ambrosial fungus.*

36. Buchner, P. 1965. ENDOSYMBIOSIS OF ANIMALS WITH PLANT MICROORGANISMS (TRANSL. FROM GERMAN). 909 p. John Wiley and Sons, Inc., New York.
Reviews and updates early literature of insect-fungus transmission devices and insect-associated symbionts. Discusses Coleopterous bark-boring beetles Myelophilus minor, Ips acuminatus, Trypodendron, Xylosandrus, Anisandrus dispar, Xyleborus fornicatus, X. mascarensis, X. pfeili, Hylecoetus dermestoides, H. lugubris, Platypus cylindrus, Scolytus *and* Dendroctonus. *The bacterial symbionts in mycetocytes of the Ipidae showed significant form differences that varied according to mycetocyte location.*

37. Butin, H., and G. Zimmerman. 1972. ZWEI NEUE HOLZVERFÄRBENDE *CERATOCYSTIS*-ARTEN IN BUCHENHOLZ (*FAGUS SYLVATICA* L.). [TWO NEW WOOD STAIN *CERATOCYSTIS*-ARTEN IN BEECHWOOD (*FAGUS SYLVATICA* L.).] Phytopathol. Z. 74: 281–287.
Description of two new species isolated from galleries of Xyloterus domesticus. C. bacillospora *sp. nov. is characterized by rod-shaped spores;* C. torulosa *sp. nov. is similar to* C. distorta, *but sizes of ascospores and* Cladosporium-*like conidia differ. Both ascomycetes cause light brown discoloration of beechwood.*

38. Campbell, R. N. 1958. NUTRIENT REQUIREMENTS FOR THE PRODUCTION OF PERITHECIA BY *CERATOCYSTIS VARIOSPORA* AND OTHER SPECIES. Am. J. Bot. 45: 263–270.
Abundant perithecia resulted when the ratio of nitrogen in asparagine and calcium nitrate mixtures was 1:3. The fungus can utilize nitrate nitrogen when an organic nitrogen source furnishing an amino or amide group is available for the formation of essential amino acid precursors. C. pluriannulata, C. piceae, C. pilifera, *and* C. ips *produced more perithecia on the asparagine-nitrate medium than on the asparagine or calcium nitrate media;* C. coerulescens *produced fewer perithecia than the others.*

39. Chansler, J. F., and D. A. Pierce. 1966. BARK BEETLE MORTALITY IN TREES INJECTED WITH CACODYLIC ACID (HERBICIDE). J. Econ. Entomol. 59: 1357–1359.
Fast acting herbicides containing cacodylic acid (dimethylarsenic acid) significantly reduced broods of Dendroctonus adjunctus, D. obesus, *and* D. ponderosae *in naturally infested trees. The chemical was injected directly into the sap stream near ground level. Application was made soon after the attack before most of the eggs had hatched.*

40. Chapman, J. A. 1965. A REVIEW OF THE RELATIONSHIPS BETWEEN FUNGI AND SCOLYTID BEETLES—A SUMMARY. Pages 32-38 *in* Proc. 13th West. Int. For. Dis. Work Conf., Kilowna, B. C.
Briefly reviews bark and ambrosia beetles known to have specific associations with microorganisms and shows need for more information. The symbiotic relationship between the ambrosia beetle and its fungus should be demonstrated by removing the fungus from the insect and subsequently replacing it. The relationship between bark beetles and blue stain fungi is not presently understood.

41. Chapman, J. A., S. H. Farris, and J. M. Kinghorn. 1963. DOUGLAS-FIR SAPWOOD STARCH IN RELATION TO LOG ATTACK BY THE AMBROSIA BEETLE, *TRYPODENDRON*. For. Sci. 9: 430–439.
Both attacked and unattacked logs contain little or no starch. Immature and adult beetles feed primarily on a symbiotic fungus, which utilizes starch, sugars, or other nutritional substances in wood cells. Discusses assumption that beetles have evolved a behavior pattern for selecting logs suitable for fungal growth.

42. Chu, H-M, D. M. Norris, and L. T. Kok. 1970. PUPATION REQUIREMENT OF THE BEETLE, *XYLEBORUS FERRUGINEUS*: STEROLS OTHER THAN CHOLESTEROL. J. Insect Physiol. 16: 1379–1387.
Aposymbiotic insects that utilized cholesterol or lanosterol as the sole sterol source for producing eggs and initial larval growth failed to pupate during consecutive broods. When ergosterol or 7-dehydrocholesterol was the only sterol source, insects consistently produced normal progeny. The insect feeds naturally on symbiotic fungi that contain ergosterol. Lumisterol and vitamins D_2 *and* D_3 *were antagonistic to progeny production and survival. At the* C_{16} *position, the three chemicals differed from acceptable sterols.*

43. Cobb, F. W., Jr., M. Krstic, E. Zavarin, and H. W. Barber, Jr. 1968. INHIBITORY EFFECTS OF VOLATILE OLEORESIN COMPONENTS ON *FOMES ANNOSUS* AND FOUR *CERATOCYSTIS* SPECIES. Phytopathology 58: 1327–1335.
Constituents from ponderosa pine oleoresin reduced growth of C. minor, C. schrenkiana, C. pilifera, *and* F. annosus, *but not of* C. ips. *Colony character, pigmentation, and sporulation were also affected. When fungi were removed from vapors other than heptane, the colonies grew normally. Inhibition was sometimes greater when components were incorporated in the substrate. Effects on spore germination were not as great as on germ tube elongation. Terpene components may influence tree resistance to infection, especially in conjunction with accumulation of phenols.*

44. Cobb, F. W., Jr., and W. D. Platt. 1967. PATHOGENICITY OF *VERTICICLADIELLA WAGENERII* TO DOUGLAS FIR. Phytopathology 57: 998–999.
Fungal isolates from Douglas-fir and ponderosa pine can infect seedlings of both species. Severe foliage discoloration was noted in pine. The xylem discoloration pattern tends to follow the annual rings vertically and tangentially, but not radially as do blue-stain fungi.

45. Coulson, R. N., T. L. Payne, J. E. Coster, and M. W. Houseweart. 1972. THE SOUTHERN PINE BEETLE *DENDROCTONUS FRONTALIS* ZIMM. (COLEOPTERA: SCOLYTIDAE) 1961-1971. Tex. For. Serv. Publ. 108, 38 p.
Reviews 11 references on microbes.

46. Crane, J. L., and J. D. Schoknecht. 1973. CONIDIOGENESIS IN *CERATOCYSTIS ULMI*, *CERATOCYSTIS PICEAE*, AND *GRAPHIUM PENICILLIOIDES*. Am. J. Bot. 60: 346–354.
Establishes the new hypomycete genus Pesotum *for* C. ulmi *(associated with* Scolytus multistriatus*) and* C. piceae, *based on their conidial states. Rejects the lectotype specimen* Graphium penicillioides *as the conidial state.*

47. Curtis, C. R. 1967. RESPONSE OF FUNGI TO DIURNAL TEMPERATURE EXTREMES. Nature 213: 738–739.
Several species were treated to diurnal temperatures of –94°C to 23 ± 2°C for 35 days to simulate Martian extremes. The Ceratocystis *spp. showed no growth on soil plates during testing but afterwards developed on potato dextrose agar at 25°C and did not differ morphologically from stock cultures. Names no species.*

48. Davidson, R. W. 1966. NEW SPECIES OF *CERATOCYSTIS* FROM CONIFERS. Mycopathol. Mycol. Appl. 28: 273–286.
Four of five new species were associated with bark beetles: Ceratocystis abiocarpa *from galleries of* Ips *sp. in Engelmann spruce and* Dryocoetes *sp. in subalpine fir;* C. nigrocarpa *in logs infested with* Scolytus *sp., on late larvae of* Dendroctonus brevicomis *in ponderosa pine logs, and on adults of* I. oregoni; C. leucocarpa *in* Ips *galleries in sugar pine and in dead ponderosa pine; and* C. minuta-bicolor *in* Ips *spp. galleries in spruce, firs, pines, and other conifers. The fifth species,* C. seticollis, *was isolated only once—from ambrosia beetle galleries in a hemlock stump.*

49. Davidson, R. W. 1971. NEW SPECIES OF *CERATOCYSTIS*. Mycolgia 63: 5–15.
Five were isolated: Ceratocystis francke-grosmanniae *from larval galleries of* Hylecoetus dermestoides *in oak from Germany,* C. olivaceapini *from* Dendroctonus *sp. on ponderosa pines in Arizona and New Mexico,* C. distorta *from ambrosia beetles occasionally infesting spruce and fir in North America,* C. gossypina *from insect galleries in pines from North America, and* C. sparsa *from bark beetle galleries in white spruce from Alaska.* Ceratocystis gossypina *var.* robusta *was isolated from insect-infested pine in southern New Mexico.*

50. Davidson, R. W., H. Francke-Grosmann, and A. Käärik. 1967. A RESTUDY OF *CERATOCYSTIS PENICILLATA* AND REPORT OF TWO AMERICAN SPECIES OF THIS GENUS FROM EUROPE. Mycologia 59: 928–932.
C. penicillata *from* Ips typographus *was different from both* C. europhioides *and* C. huntii. C. bicolor *was isolated from* Ips*-infested spruce logs near Stockholm, Sweden.*

51. Davidson, R. W., and R. C. Robinson-Jeffrey. 1965. NEW RECORDS OF *CERATOCYSTIS EUROPHIOIDES* AND *C. HUNTII* WITH *VERTICICLADIELLA* IMPERFECT STAGES FROM CONIFERS. Mycologia 57: 488–490.
Gives extended ranges for the species and presents further records for association of C. huntii *with* Ips pini *and* Dendroctonus *species.*

52. DeGroot, R. C. 1972. GROWTH OF WOOD-INHABITING FUNGI IN SATURATED ATMOSPHERES OF MONOTERPENOIDS. Mycologia 64: 863–870.
Three wood-decay fungi (Lenzites saepiaria, Peniophora gigantea, *and* Schizophyllum commune), *one blue-stain fungus* (Ceratocystis minor), *and one deuteromycete* (Trichoderma viride) *were grown in l-α-pinene, d-α-pinene, l-limonene, d-limonene, p-cymene, dl-camphene, mycrene l-β-pinene, and terpinolene.* C. minor *was inhibited the least by all but p-cymene (not present in living pines) and terpinolene;* T. viride *was inhibited the most. Natural selection for terpene-tolerant variants of the fungi may occur. D-α-pinene limits invasion of southern pine sapwood by* C. minor.

53. DeMars, C. J., Jr., D. L. Dahlsten, and R. W. Stark. 1970. SUVIVORSHIP CURVES FOR EIGHT GENERATIONS OF THE WESTERN PINE BEETLE IN CALIFORNIA, 1962-1965, AND A PRELIMINARY LIFE TABLE. Pages 134-146 *in* Studies of the Population Dynamics of the Western Pine Beetle, *Dendroctonus brevicomis* LeConte (Coleopetera: Scolytidae). Edited by R. W. Stark and D. L. Dahlsten. Univ. Calif. Div. Agric. Sci., Berkeley.
Diseased insects were not prevalent, but Beauveria bassiana *and an* Isaria *sp. were isolated from dead larvae and may have caused some of the unexplained mortality.*

54. Doane, C. C. 1959. *BEAUVERIA BASSIANA* AS A PATHOGEN OF *SCOLYTUS MULTISTRIATUS*. Ann. Entomol. Soc. Am. 52: 109–111.
Most frequently encountered pathogen. Infected up to 6.5 percent of overwintering larvae in trees and killed 97 percent of the larvae in one epizootic. In the laboratory, 99 percent of the larvae died in 5 days.

55. Doane, C. C. 1960. BACTERIAL PATHOGENS OF *SCOLYTUS MULTISTRIATUS* MARSHAM AS RELATED TO CROWDING. J. Insect Pathol. 2: 24–29.
One to four "last stage larvae" per unit space were confined on bark treated with Serratia marcescens *or sterile water. Mortality increased with number of larvae per unit space in both treated and untreated bark. Untreated larvae usually died from bacteria already on the integument. In 3 days, mortality of treated larvae (4 per unit space) was 92 percent, and control mortality was about 60 percent. Two other bacteria,* Aerobacter scolyti *and* Escherichia klebsiellaeformis, *caused comparable mortality in identical tests.*

56. Dowding, P. 1969. THE DISPERSAL AND SURVIVAL OF SPORES OF FUNGI CAUSING BLUESTAIN IN PINE. Trans. Br. Mycol. Soc. 52: 125–137.
Airborne dispersal is probably not responsible for most infections. Conidia of Ceratocystis *spp. (including* C. minor*) were rarely dislodged from their sticky heads by dry air currents but were readily dislodged by and carried on mist and splash droplets. Ascospores were carried only as large discrete masses in a few splash droplets. Conidia separated in water but lost viability rapidly on exposure to sunlight, ultraviolet light, and humidities below 95 percent r.h. An outer shell of dried spores and mucilage protected the inner mass of spores from desiccation and provided some protection from irradiation.*

57. Dowding, P. 1970. COLONIZATION OF FRESHLY BARED PINE SAPWOOD SURFACES BY STAINING FUNGI. Trans. Br. Mycol. Soc. 55: 399–412.
Ceratosystis *spp. (including* C. minor*) produced few air-borne spores. Most transmission to host tissue is by animal vectors—often bark beetles. Spores must be carried into sites protected from ultraviolet light and desiccation.*

58. Eckersley, A. M. 1934. SOME SAP-STAINING ORGANISMS OF *PINUS RADIATA*, D. DON, IN VICTORIA, AUSTRALIA. Proc. R. Soc. Victoria 46: 179–194.
Describes two forms of Ceratostomella (= Ceratocystis) *that may link the American* C. pilifera *with the European* C. coerulea, *both of which may be variants of the same species,* C. coerulea.

59. Entwistle, P. F. 1964. INBREEDING AND ARRHENOTOKY IN THE AMBROSIA BEETLE *XYLEBORUS COMPACTUS* (EICHH.) (COLEOPTERA: SCOLYTIDAE). Proc. R. Entomol. Soc. Lond. Series A. 39(4-6): 83–88.
Galleries are initiated by single adult females and differ in form according to host plant species. Eggs are laid over an extended period, and larvae feed on an ambrosia fungus that grows on gallery walls and that develops communally with eggs and pupae.

60. Eusebio, M. A. 1968. GROWTH OF FIVE STAINING FUNGI AND STAIN DEVELOPMENT IN PINE SAPWOOD. Philipp. J. For. 20: 69–91.
Estimated optimum temperatures for growth on malt agar and blocks of white pine were 24° C for Ceratocystis coerulea, Leptographium lundbergii, Alternaria tenuis, *and* Cytospora pini, *and 28° C for* Ceratocystis ips. *Fungi developed primarily in parenchyma cells, but at the ray crossing, the mycelium passed through the parenchyma walls and through pits in the adjacent tracheids to reach the lumens.*

61. Farmer, L. J. 1965. THE PHLOEM-YEAST COMPLEX DURING INFESTATIONS OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE. Diss. Abstr. 26: 1304–1305.
A phloem-yeast complex including at least four species comprises food for developing larvae of Dendroctonus ponderosae. *Economically damaging outbreaks of the beetle will not occur without the complex, since larvae feed only in yeast-infected areas. Yeasts may rapidly convert host material to simpler molecules, such as amino acids and vitamins, needed in the larval diet. Eight yeast were isolated from the lodgepole pine-mountain pine beetle complex:* Hansenula holstii *and* Pichia pini, *found in phloem and on larvae;* H. capsulata, Endomycopsis scolyti, Candida tenuis, *and* C. rugosa *found in phloem only; and* C. silvicola *and* C. curvata, *associated with the beetle in California.*

62. Farris, S. H. 1965. REPOSITORIES OF SYMBIOTIC FUNGUS IN AMBROSIA BEETLE *MONARTHRUM SCUTELLARE* LEC. (COLEOPTERA: SCOLYTIDAE). Proc. Entomol. Soc. B.C. 62: 30–33.
Adult females transport symbiotic fungi in mycangia, which are enlargement of the forecoxal cavities similar to those described by Batra (1963) for other members of the genus. Male beetles do not have these structures.

63. Farris, S. H. 1965. A PRELIMINARY STUDY OF MYCANGIA IN THE BARK BEETLES, *DENDROCTONUS PONDEROSAE* HOPK., *DENDROCTONUS OBESUS* MANN., AND *DENDROCTONUS PSEUDOTSUGAE* HOPK. Can. Dep. For. Bimon. Prog. Rep. 21(5): 3–4.
Notes fungoid material at various locations on the body of adults, usually in the teneral stage. Mycangia had no associated gland cells or mucus secretions.

64. Farris, S. H. 1969. OCCURRENCE OF MYCANGIA IN THE BARK BEETLE *DRYOCOETES CONFUSUS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 101: 527–532.
First record of mycangia in the genus Dryocoetes. *Both sexes contained paired oral pouches between the base of the mandibles and the ventral tentorial arm. Staining showed fungoid material in pouches but no associated gland cells. A related species,* D. affaber, *showed no fungal pouches. The pres-*

ence of mycangia in both sexes ensures inoculation of feeding tunnel and egg galleries.

65. Faulds, W. 1973. DISCOLOURATION ASSOCIATED WITH *PLATYPUS* WOUNDS IN LIVING *NOTHOFAGUS FUSCA*. N. Z. J. For. Sci. 3: 331–341.
Staining may be a tree response to toxic substances produced by the microorganisms. Two fungi from insect tunnels in red beech (Ceratocystis *sp. and* Endomycopsis platypodis) *and a nonsporulating fungus isolated from nearby tunnels, caused stains when inoculated into drilled holes resembling insect attack. Length of stains varied with microorganisms.*

66. Findlay, W. P. K. 1959. SAP-STAIN OF TIMBER. For. Abstr. 20: 1–7.
Mentions sapwood staining fungi not included in Francke-Grosmann's 1967 review. Fungi are often associated with bark beetle attacks. Discusses mode of infection and development of stain. Ceratocystis *species are the most important causes.*

67. Finnegan, R. J. 1967. NOTES ON THE BIOLOGY OF THE PITTED AMBROSIA BEETLE, *CORTHYLUS PUNCTATISSIMUS* (COLEOPTERA: SCOLYTIDAE), IN ONTARIO AND QUEBEC. Can. Entomol. 99: 49–54.
The male cuts the gallery and egg cradle and deposits spores of ambrosia fungi from specialized repositories in its thorax; the females lay eggs in a fungus mat and plugs the entrance with ambrosia mycelium.

68. Francke-Grosmann, H. 1966. ÜBER SYMBIOSEN VON XYLO-MYCETOPHAGEN UND PHLOEOPHAGEN SCOLYTOIDEA MIT HOLZBEWOHNENDEN PILZEN. [ON THE SYMBIOSIS OF XYLO-MYCETOPHAGOUS AND PHLOEOPHAGOUS SCOLYTOIDEA WITH WOOD-INHABITING FUNGI.] Holz und Org. Int. Symp. Berlin-Dahlem (1965) 1: 503–522.
Labels as "phloeomycetophagous" some bark-inhabiting beetles that have mycetangia (same as mycangia of Batra 1963) and feed as larvae on phloem colonized by specific fungal associates. Ten species of bark-breeding beetles had mycetangia that contained fungi: Ips acuminatus, Dendroctonus frontalis, D. brevicomis, D. mexicanus, D. parallelocollis, D. adjunctus, Myelophilus minor, Hylurgops palliatus, Hylastes ater, *and* H. cunicularius. *Proposes* Ceratocystis minor *as the main fungus of the* frontalis *and* brevicomis *mycetangia, but no cultures were made. Fungal flora are useful as food for juvenile beetles.*

69. Francke-Grosmann, H. 1967. ECTOSYMBIOSIS IN WOOD INHABITING INSECTS. Pages 142-205 *in* Symbiosis vol. 2, Edited by S. M. Henry. Academic Press, New York.
A comprehensive review (277 citations). Includes review of fungal transmission organs (mycangia) and covers four groups of insects: ambrosia beetles (xylomycetophagous Scolytoidea), bark-feeding bark beetles (some phloeophagous Scolytidae), ship timberworms (Lymexylidae), and wood wasps (Siricidae and Xiphydriidae).

70. Franklin, R. T. 1970. OBSERVATIONS ON THE BLUE STAIN-SOUTHERN PINE BEETLE RELATIONSHIP. J. Ga. Entomol. Soc. 5: 53–57.
Relationship between blue-stain fungi and southern pine beetle is not beneficial to beetles reared in a laboratory. Larvae made elongate mines and did not grow in the blue-stained inner bark. Parent beetles avoided stained areas when possible, though oviposition did not appear affected. Of over 190 egg niches, only 42 larvae matured and transformed into beetles. Fungi may reduce nutritive value of inner bark and may even be toxic or repellent to larvae and repellent to adults.

71. French, J. R. J., and R. A. Roeper. 1972. OBSERVATIONS ON *TRYPODENDRON RUFITARSIS* (COLEOPTERA: SCOLYTIDAE) AND ITS PRIMARY SYMBIOTIC FUNGUS, *AMBROSIELLA FERRUGINEA.* Ann. Entomol. Soc. Am. 65: 282.
Reports the first isolation of the fungus from the beetle and describes a hibernating site of the insect—within a basidiomycete sporophore. Blue stain (Ceratocystis *sp.) was observed in the three attacked trees but was not evident in the basal 4 feet of boles with galleries. Mycangia appeared identical in structure and size to those of* T. lineatum.

72. French, J. R. J., and R. A. Roeper. 1972. INTERACTIONS OF THE AMBROSIA BEETLE, *XYLEBORUS DISPAR* (COLEOPTERA: SCOLYTIDAE), WITH ITS SYMBIOTIC FUNGUS *AMBROSIELLA HARTIGII* (FUNGI IMPERFECTI). Can. Entomol. 104: 1635–1641.
Two biassays of various insect stages demonstrated the pleomorphic nature of the fungus and the importance of the ambrosial form for the growth and development of postdiapause adults and larvae. In culture, postdiapause adults and pupae cause a change from the mycelial to the ambrosial form. Without the ambrosial form, oviposition and pupation did not occur. The ambrosial form may be induced by a secretory product of the insect.

73. French, J. R. J., and R. A. Roeper. 1972. *IN VITRO* CULTURE OF THE AMBROSIA BEETLE *XYLEBORUS DISPAR* (COLEOPTERA: SCOLYTIDAE) WITH ITS SYMBIOTIC FUNGUS, *AMBROSIELLA HARTIGII*. Ann. Entomol. Soc. Am. 65: 719–721.
The first recorded rearing of a temperate zone scolytid on a fungus of the genus Ambrosiella. *Prediapause beetles failed to oviposit. Postdiapause adults produced a single generation when reared* in vitro *with its symbiotic fungus* Ambrosiella hartigii.

74. French, J. R. J., and R. A. Roeper. 1973. PATTERNS OF NITROGEN UTILIZATION BETWEEN THE AMBROSIA BEETLE *XYLEBORUS DISPAR* AND ITS SYMBIOTIC FUNGUS. J. Insect Physiol. 19: 593–605.
Uric acid was the main nitrogenous product found in excreta and hindguts of beetles, larvae, and pupae (range 7·6-14·8 μg uric acid per beetle). No ninhydrin-positive compounds were found in excreta. Concentration of ammonia-nitrogen in the various life stages averaged between 0·70 and 1·13

μg NH_3-N per beetle. Comparative concentrations of soluble proteins and free amino acids suggested that the fungus in the mycangia was formed from free amino acids of the insects. During the period of emergence, flight, and attack of new hosts, females had more than double the concentration of soluble proteins found the rest of the year. Free amino acids had the lowest values recorded during this period (March-October).

75. Frye, R. H., and N. D. Wygant. 1971. SPRUCE BEETLE MORTALITY IN CACODYLIC ACID-TREATED ENGELMANN SPRUCE TRAP TREES. J. Econ. Entomol. 64: 911–916.
The treatment was fatal to Dendroctonus rufipennis *and prevented brood development. Blue stain development was very light in treated trees and heavy in untreated ones.*

76. Funk, A. 1965. THE SYMBIOTIC FUNGI OF CERTAIN AMBROSIA BEETLES IN BRITISH COLUMBIA. Can. J. Bot. 43: 929–932.
Monilia ferruginea, M. brunnea, *and* Tuberculariella ambrosiae *n. sp. are the symbiotic fungi of* Trypodendron lineatum, Monarthrum scultellare, *and* Platypus wilsoni, *respectively. Isolations were from mycangia of beetles and from insect galleries.*

77. Funk, A. 1970. FUNGAL SYMBIONTS OF THE AMBROSIA BEETLE *GNATHOTRICHUS SULCATUS*. Can. J. Bot. 48: 1445–1448.
Describes three species of fungi originally found in beetle mycangia and tunnels in Douglas-fir from British Columbia: Ambrosiella sulcati *sp. nov.,* Raffaelea sulcati *sp. nov., and* Graphium *sp. Yeasts were always present but were not identified.*

78. Furniss, M. M., and P. W. Orr. 1970. DOUGLAS-FIR BEETLE. U. S. Dep. Agric. For. Pest Leafl. 5 (rev.), 4 p.
Death results from girdling effect of egg galleries and larval mines. Beetles introduce various fungi, which hasten death by clogging the sap-conducting system.

79. Giese, R. L. 1966. THE BIOECOLOGY OF *CORTHYLUS COLUMBIANUS* HOPKINS. Holz und Org. Int. Symp. Berlin-Dahlem (1965) 1: 361–370.
*Ten microorganisms were isolated from galleries over a 4 year period. Male beetles have a prothoracic mycangium that stores and transmits a new yeast (*Pichia *sp.), which assumes complete dominance in egg cradles and provides the entire nutrient mass for the larval stages. The yeast is the only organism that can be isolated from the egg chamber.* Ceratocystis *sp. becomes evident in the egg chamber following completion of the pupal stage.*

80. Giese, R. L. 1967. THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE). V. A DESCRIPTION OF THE MYCETANGIA. Can. Entomol. 99: 54–58.
These structures lie immediately below the integument of the pronotum, one in each ventrolateral region. Each mycetangium (= mycangium) is a coiled tube that is 4.69 ± 0.35 mm in length, that is cream-colored, and that opens into the anterior coxal cavity. Mycetangia occur only in males and provide the overwintering storage site and transmission mechanism for associated microorganisms. Smears and cultures of the mycetangia were positive for ascospores and vegetative cells of the yeast Pichia *sp., which coincides with the microsymbiote dominant in developmental chambers of the larvae.*

81. Gouger, R. J. 1972. INTERRELATIONS OF *IPS AVULSUS* (EICHH.) AND ASSOCIATED FUNGI. Diss. Abstr. 32: 6453–B.
No mycangium was detected in the insect. Transmission of associated fungi may be accomplished by spores and yeast cells that either adhere to the exoskeleton or pass through the intestinal tract. Ectosymbiotic fungi consistently associated in winter and spring were Ceratocystis ips *and two yeasts*—Hansenula holstii *and* Pichia pini. *One or both yeasts or their associated bacteria may cause wild broods to be larger and to develop more rapidly than aseptic broods reared with or without* C. ips.

82. Graham, K. 1967. FUNGAL-INSECT MUTUALISM IN TREES AND TIMBER. Ann. Rev. Entomol. 12: 105–126.
Discusses various insect and fungoid mutualists and new aspects of isolating and culturing symbiotes. "Mutualism" implies an advantageous association between individuals of different species and precludes mere coexistence, competition, or benefit to only one associate. The genus Ceratocystis *occurs widely with both phloem-eating and wood-boring (ambrosial) species. Suggests need for information to determine if blue-stain fungi render the phloem more suitable as a habitat or as a food medium for bark beetles.*

83. Griffin, H. D. 1968. THE GENUS *CERATOCYSTIS* IN ONTARIO. Can. J. Bot. 46: 689–718.
A key to 60 species based mainly on ascospore characteristics. The bark beetles Ips pini *and* Orthotomicus caelatus *may be the principal vectors for several species including* Ceratocystis ips *and* C. minor.

84. Guerrero, R. T. 1966. UNA NEUVA ESPECIE DE HONGO IMPERFECTO ASOCIADO CON EL COLEÓPTERO *PLATYPUS SULCATUS* CHAPUIS. [NEW IMPERFECT FUNGUS ASSOCIATED WITH THE COLEOPTERA *PLATYPUS SULCATUS* CHAPUIS.] Patol. Veg. 3: 97–103.
Describes a new fungus Raffaelea santoroi *associated with* Platypus sulcatus. *Samples were from Argentina. Fungus was obtained by rasping gallery walls in* Eucalyptus camaldulensis *and* Laurus nobilis; *also found in expelled larval sawdust particles of* Quercus robur.

85. Happ, G. M., C. M. Happ, and S. J. Barras. 1971. FINE STRUCTURE OF THE PROTHORACIC MYCANGIUM, A CHAMBER FOR THE CULTURE OF SYMBIOTIC FUNGI, IN THE SOUTHERN PINE BEETLE, *DENDROCTONUS FRONTALIS*. Tissue and Cell 3: 295–308.
Fungi are cultured and transported to new host trees within a mycangium consisting of a cuticular invagination along the endothoracic fold. Two types of gland cells secrete into the mycangial lumen: one may provide the basic nutrient medium, and

the other may inhibit weed fungi and favor the growth of the symbiotic crop.

86. Hare, R. C. 1969. EFFECTS OF *CERATOCYSTIS MINOR* (HEDGC.) HUNT, THE BLUE-STAIN FUNGUS CARRIED BY *DENDROCTONUS FRONTALIS* ZIMM. ON BEETLE-RESISTANT AND -SUSCEPTIBLE PINE SPECIES. Final Rep. FS-SO-1401-5.18. U.S. Dep. Agric. For. Serv. South. For. Exp. Stn. Gulfport, Miss. 11 p.
Six year old shortleaf, loblolly, and slash pines were inoculated with pure cultures of C. minor *to determine if resistance to the beetle is correlated with resistance to the fungus. None of the trees died. Five months later,* C. minor *was reisolated 1 foot above the inoculated area.* C. minor *is not the primary cause of death in beetle-infested trees.*

87. Harrar, J. G., and R. P. Ellis. 1940. THE BIOLOGY OF A SPECIES OF *BEAUVERIA* FROM THE SOUTHERN PINE BARK BEETLE (ABSTR.). Proc. Va. Acad. Sci. 1: 211.
This unidentified Beauveria *was isolated from larvae and was found to be pathogenic to healthy larvae. Growth characteristics, reproductive structures, and nutritional requirements were studied to evaluate its potential as a biological control agent. No data were presented.*

88. Harrar, J. G., and J. G. Martland. 1940. THE ETIOLOGY OF THE *BEAUVERIA* DISEASE OF *DENDROCTONUS FRONTALIS* (ABSTR.). Proc. Va. Acad. Sci. 1: 211.
Isolates of Beauveria *sp. from the southern pine beetle were used in histological studies of infection in larvae. Reports mode of infection, action within the host, and methods of fructification.*

89. Harrar, J. G., and J. G. Martland. 1940. A FUNGOUS PARASITE OF THE PINE BARK BEETLE (ABSTR.). Phytopathology 30: 8.
Many dead or dying larvae in shortleaf pines from eastern Virginia were found infested with both fungi and nematodes. Monosporous cultures showed that the fungus was probably a Beauveria.

90. Hedgecock, G. G. 1906. STUDIES UPON SOME CHROMOGENIC FUNGI WHICH DISCOLOR WOOD. Rep. Mo. Bot. Gard. 17: 59–114.
Gives keys and descriptions of several Ceratostomella *spp. (=* Ceratocystis*),* Graphium *spp., and other wood staining fungi. The presence of blue staining fungi in the tunnels of some wood boring beetles indicates that the insects carry conidia or ascospores.*

91. Heller, R. C. 1968. PREVISUAL DETECTION OF PONDEROSA PINE TREES DYING FROM BARK BEETLE ATTACK. Pages 387-434 *in* Proc. 5th Symp. on Remote Sensing of Environment. Univ. Mich., Ann Arbor.
Aerial sensors have not been successful in detecting attacked trees before discoloration, and ground observations are inadequate for appraising the success of an attack. The best method of evaluation is to examine the xylem for the blue stain fungus Ceratostomella *spp. (=* Ceratocystis *spp.). Color transparencies revealed three times as many dying trees as ground observations.*

92. Helms, J. A., F. W. Cobb, Jr., and H. S. Whitney. 1971. EFFECT OF INFECTION BY *VERTICICLADIELLA WAGENERII* ON THE PHYSIOLOGY OF *PINUS PONDEROSA*. Phytopathology 61: 920–925.
Discussion of the fungus with emphasis on its tendency to predispose trees to bark beetle attack. Fungus-infested pines > 20 cm d.b.h. usually die from root disease following attacks by Dendroctonus brevicomis *or* D. ponderosa. *Although seedlings showed no visual symptoms 1 month after inoculation with the fungus, dramatic decreases in net photosynthesis and transpiration occurred along with marked increases in foliar water stress and stomata closure.*

93. Himes, W. E., and J. M. Skelly. 1972. AN ASSOCIATION OF THE BLACK TURPENTINE BEETLE *DENDROCTONUS TEREBRANS*, AND *FOMES ANNOSUS* IN LOBLOLLY PINE (ABSTR.). Phytopathology 62: 670.
A total of 1,438 insects in various stages of development were removed from roots and lower boles of infested trees and were incubated at 23°C for 14 days on pine discs. The fungus was isolated from 11.5 percent of these insects. The Oedocephalum *form of the fungus was found in 9 of 130 larval galleries. None of the 13 canals produced by adults was positive. The insect is a likely vector.*

94. Hinds, T. E., and P. E. Buffam. 1971. BLUE STAIN IN ENGELMANN SPRUCE TRAP TREES TREATED WITH CACODYLIC ACID. U.S. Dep. Agric. For. Serv. Res. Note RM-201, 4 p. Rocky Mt. For. Exp. Stn., Fort Collins, Colo.
One year after treatment blue stain development was negligible and bark beetle development poor in trap trees treated 4-8 weeks and felled 2-4 weeks before peak flight. Leptographium engelmannii *was isolated from 95 percent of the blue stain samples.* Ceratocystis olivacea, C. coerulescens, C. *sp. and* Graphium *spp. were less consistent.* C. coerulescens *was isolated from 80 percent of the brown stain samples associated with ambrosia beetles. Incipient decay in stain areas of felled trees was evident and was caused by the sap rot fungus* Fomes pinicola *and two unidentified sp.*

95. Hinds, T. E., and R. W. Davidson. 1972. *CERATOCYSTIS* SPECIES ASSOCIATED WITH THE ASPEN AMBROSIA BEETLE. Mycologia 64: 405–409.
Describes a new species Ceratocystis retusi, *which has brown perithecia and long, flexuous ostiolar filaments. This species and* C. brevicollis *were commonly found in Colorado in pupal cells of the aspen ambrosia beetle* Trypodendron retusum.

96. Hodges, J. D., S. J. Barras, and J. K. Mauldin. 1968. AMINO ACIDS IN INNER BARK OF LOBLOLLY PINE, AS AFFECTED BY THE SOUTHERN PINE BEETLE AND ASSOCIATED MICROORGANISMS. Can. J. Bot. 46: 1467–1472.
Bolts infected with an ascomycete (Ceratocystis minor)*, with a basidiomycete mycangial fungus (SJB 122), or with the beetle-microorganism complex brought about no qualitative changes in free*

amino acids but produced changes in protein-bound ones. Concentration of most free amino acids and soluble nitrogen decreased, but that of most protein-bound amino acids, insoluble nitrogen, and total nitrogen increased.

97. Holst, E. C. 1936. *ZYGOSACCHAROMYCES PINI*, A NEW SPECIES OF YEAST ASSOCIATED WITH BARK BEETLES IN PINES. J. Agric. Res. 53: 513–518.
Describes and reports distribution of a new yeast (Pichia pini) *isolated from specimens and galleries of* Dendroctonus brevicomis *and* D. frontalis *and also associated with* Ips grandicollis, I. avulsus, *and* I. calligraphus.

98. Holt, W. R. 1961. *METARRHIZIUM ANISOPLIAE* (METCHNIKOFF) SOROKIN INFECTING LARVAE OF THE BLACK TURPENTINE BEETLE. J. Insect Pathol. 3: 93–102.
Reports probable new host record for a fungus isolated from full grown larvae under the bark of a loblolly pine stump in southern Mississippi.

99. Hoog, G. S. de. 1974. THE GENERA *BLASTOBOTRYS, SPOROTHRIX, CALCARISPORIUM* AND *CALCARISPORIELLA* GEN. NOV. Studia Mycol. (Netherlands) 7: 1–84.
The genus Blastobotrys, comprising only one species, *is described. The genus* Sporothrix *is enlarged to include 24 species: six are new; three are new combinations; 13 are conidial states of* Ophiostoma; *one is excluded.* Calcarisporium *is restricted to one species.* Calcarisporiella *is described.* Ceratocystis, *an Ascomycete genus, is divided into two separate genera based on the morphology of the conidial states:* Ceratocystis sensu stricto *comprises species with* Chalara, Chalaropsis, *and* Thielaviopsis *conidial states; most species of* Ceratocystis auctt. *have* Sporothrix, Verticicladiella, *and* Graphium *states and are here classified in* Ophiostoma.

100. Hosking, G. P. 1972. *XYLEBORUS SAXESENI*, ITS LIFE HISTORY AND FLIGHT BEHAVIOR IN NEW ZEALAND. N. Z. J. For. Sci. 3: 37–53.
Rate of development is influenced mainly by ambrosia fungi (unidentified) and indirectly by climatic factors and physiological condition of the host.

101. Howe, V. K., A. D. Oberle, T. G. Keeth, and W. J. Gordon. 1971. THE ROLE OF MICROORGANISMS IN THE ATTRACTIVENESS OF LIGHTNING-STRUCK PINES TO SOUTHERN PINE BEETLES. West. Ill. Univ. Bull. 50(3), 44 p. Ser. Biol. Sci. 9.
Of 577 yeasts, fungi, and bacteria isolated from bark beetle galleries and exposed inner bark of struck loblolly pines (Pinus taeda), *214 yeasts and 207 hyphal fungi were identified to species, and 12 bacteria to genera. Olfactometer tests indicated that the microorganisms produced no volatile substances attractive to the insect.*

102. Islas, S. F. 1974. OBSERVACIONES SOBRE LA BIOLOGIA Y EL COMBATE DE LOS ESCARABAJOS DESCORTEZADORES DE LOS PINOS: *DENDROCTONUS ADJUNCTUS* BLF. Y *DENDROCTONUS MEXICANUS* HPK. EN ALGUNAS REGIONES DEL ESTADO DE MEXICO. [OBSERVATIONS ON THE BIOLOGY AND CONTROL OF PINE BARK BEETLES: *DENDROCTONUS ADJUNCTUS* BLF. AND *D. MEXICANUS* HPK. IN SOME REGIONS OF THE STATE OF MEXICO.] Bol. Tech. 40, 35 p. Inst. Nac. de Invest. For. Mexico City, D.F.
Various fungicides (especially modifications of the Bordeaux type) gave from 25 to 50 percent recovery if trees were treated during the first week of attack; little or no fungal growth was observed. Resistant trees produced yellowish-white resin pitch tubes. A "special substance" in the resin impedes the development of associated fungi. A biological control study with Metarrhizium anisopliae *was incomplete.*

103. Jouvenaz, D. P., and R. C. Wilkinson. 1970. INCIDENCE OF *SERRATIA MARCESCENS* IN WILD *IPS CALLIGRAPHUS* POPULATIONS IN FLORIDA. J. Invertebr. Pathol. 16: 295–296.
In laboratory cultures, chromogenic strains were consistently isolated from both live and dead I. calligraphus, *but mortality was less than 1 percent per generation. Mature larvae and pupae associated with teneral adults in loose old bark had a higher incidence of the bacteria than larvae and pupae associated with parent adults in tight fresh bark; teneral adults had a higher incidence of bacteria than parent adults.*

104. Kabir, A. K. M. F., and R. L. Giese. 1966. THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE). II. FUNGI AND STAINING ASSOCIATED WITH THE BEETLE IN SOFT MAPLE. Ann. Entomol. Soc. Am. 59: 894–902.
Graphium *sp. near* rigidum, Ceratocystis pluriannulata, Fusarium tricinctum, F. oxysporum, F. solani, Pichia *n. sp.*, Gliocladium roseum, *and* Rhizoctonia *sp. were isolated from galleries of* Corthylus columbianus *and associated stains in* Acer saccharinum. *The white pseudomycelial mat of* Pichia *sp. is very conspicuous in egg chambers during egg and larval stages, and the larvae depend solely upon it for food. Optimum growth temperature was 65°-85°F for the* Ceratocystis *and 65°-75°F for the* Pichia. *Only* Ceratocystis *grew at 40° or 90°F. No stain developed in sapwood blocks inoculated in the laboratory.*

105. Kaneko, T. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. I. GROWTH AND DEVELOPMENT OF TWO SPECIES OF SCOLYTID BEETLES REARED ON STERILIZED TEA PLANTS. Jap. J. Appl. Entomol. Zool. 9: 211–216.
Xyleborus compactus *and* X. germanus *were successfully reared in test tubes. Steam-sterilized substrates were tea twigs for* X. compactus *and tea roots or twigs for* X. germanus. *Growth rate and size of maturing broods varied with fungal growth, which is determined by wood condition.*

106. Kaneko, T. 1967. SHOT-HOLE BORER OF TEA PLANT IN JAPAN. Jap. Agric. Res. Q. 2: 19–21.
The fungus associated with Xyleborus germanus *and* X. compactus *has two stages, the stored spore stage, which occurs in the mycangia, and the culti-*

vated spore stage, which occurs in the galleries. Virgin females with their associated ambrosia fungi produce haploid males; in the absence of fungi, no reproduction takes place.

107. Kaneko, T., and K. Takagi. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. IV. PARTHENOGENESIS OF *XYLEBORUS GERMANUS* BLAND. IN RELATION TO THE *GERMANUS* AMBROSIA FUNGUS. Jap. J. Appl. Entomol. Zool. 9: 303–304.
Beetle has a polygamous social organization with a sex ratio of about 10:1 (female to male). All adult females (mated and nonmated) provided with the ambrosia fungus reproduced. Noncopulated females produced only male progeny; mated females produced both female and male progeny.

108. Kaneko, T., and K. Takagi. 1966. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. VI. A COMPARATIVE STUDY OF TWO AMBROSIA FUNGI ASSOCIATED WITH *XYLEBORUS COMPACTUS* EICHHOFF AND *XYLEBORUS GERMANUS* BLANDFORD (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 1: 173–176.
Both the tea root borer X. germanus *and the tea twig borer* X. compactus *reproduced normally following artificial exchanges of their symbiotic ambrosia fungi. The fungi appeared morphologically and physiologically alike with the exception of different optimum temperatures of sporulation in cultivated spores.*

109. Kaneko, T., Y. Tamaki, and K. Takagi. 1965. PRELIMINARY REPORT ON THE BIOLOGY OF SOME SCOLYTID BEETLES, THE TEA ROOT BORER, *XYLEBORUS GERMANUS* BLANFORD, ATTACKING TEA ROOTS, AND THE TEA STEM BORER, *XYLEBORUS COMPACTUS* EICHHOFF, ATTACKING TEA TWIGS. Jap. J. Appl. Entomol. Zool. 9: 23–28.
The optimum temperature for mycelial growth of ambrosia fungi was 23°C for X. germanus *and 26°C for* X. compactus. X. germanus *was reared completely through one generation and partially through another on autoclaved wood colonized by the ambrosia fungus. When the fungus grew on agar-based media, the insect did not develop.*

110. Kimmey, J. W., and R. L. Furniss. 1943. DETERIORATION OF FIRE-KILLED DOUGLAS-FIR. U.S. Dep. Agric. Tech. Bull. 851, 61 p.
Most fungi causing wood stain belong to the genus Ceratostomella (= Ceratocystis). *The Douglas-fir beetle is a carrier of* Ceratostomella pseudotsugae (= Ceratocystis minor), *which influences the early stage of sapwood deterioration. The Douglas-fir beetle is the most important insect pest that attacks fire-killed timber. The beetle opens the bole to other agents of deterioration and may accelerate the establishment of fungi. Three species of ambrosia beetles,* Trypodendron bivittatum, Gnathotrichus retusus, *and* G. sulcatus, *cause degrade by making pinholes and by introducing blue-stain fungi.* Platypus wilsoni *occasionally causes pinholes but is not economically important.*

111. King, B., and H. O. W. Eggins. 1972. SOME OBSERVATIONS ON DECAY MECHANISMS OF MICROFUNGI DETERIORATING WOOD. Pages 145-151 *in* Biodeterioration of Materials, vol. 2. Edited by A. H. Walters and E. H. Hueck-van der Plas. John Wiley & Sons, New York.
Discusses 33 species of fungi, including many mold and blue stain, commonly associated with attacked green wood. Growth rate patterns correlated with utilization rates of starch and cellulose agar and with liquification of pectin gels. Ceratocystis pilifera, *which grew quickly and was highly amylolytic, cleared cellulose agar and liquified pectate gels.* C. coerulescens *grew more slowly, was less active, and showed maximum cellulolytic activity.* C. ulmi *and* C. picea *were slow growing and showed slight cellulolytic activity.*

112. Koch, A. 1963. ON THE ROLE OF THE SYMBIONTS IN WOOD-DESTROYING INSECTS. Recent Progress in Microbiol. 8: 151–161.
Discusses symbionts of various insect groups: Ipidae, Platypodidae, Lymexylonidae, Siricidae, Anobiidae, Cerambycidae, and Lyctidae. The symbionts provide or supplement necessary vitamins and proteins and participate in the nitrogen metabolism of their hosts, whose metabolic by-products are used by the symbionts.

113. Kok, L. T., D. M. Norris, and H-M Chu. 1970. STEROL METABOLISM AS A BASIS FOR A MUTUALISTIC SYMBIOSIS. Nature 225: 661–662.
Ergosterol was the only sterol produced by the mutualistic fungus Fusarium solani, *associated with the beetle* Xyleborus ferrugineus, *in pure culture on a chemically defined sterile substrate. Ergosterol was adequate for continued growth, development, and reproduction of the fungus-free beetle. The insect is apparently unique in its use of cholesterol for egg production and larval growth but not for pupation.*

114. Kotýnková-Sychrová, E. 1966. MYKOFLÓRA CHODEB KŮROVCŮ V ČESKOSLOVENSKU. [THE MYCOFLORA OF BARK-BEETLE GALLERIES IN CZECHOSLOVAKIA.] Česká Mykol. 20: 45–53.
Thirteen pathologically important species of fungi (11 Ceratocystis *species,* Leptographium lundbergii, *and* Graphium pycnocephalum) *were isolated from galleries of bark beetles of the genera* Ips, Hylurgops, Xyloterus, Pityogenes, Dryocoetes, *and* Myelophilus.

115. Kulman, H. M. 1964. PITCH DEFECTS IN RED PINE ASSOCIATED WITH UNSUCCESSFUL ATTACKS BY *IPS* SPP. J. For. 62: 322–325.
Unsuccessful attacks produced vertical bark scars and catfaces on red pine in Virginia and West Virginia. The scars lay directly over wood surface depressions, which were above pitch defects buried under one to eight annual growth rings. The defects were composed of Ips *nuptial chambers and egg galleries. The failure of some attacks may be explained by an absence of blue stain in the wounds.*

116. Le Fay, A., J. E. Courtois, A. Thuillier, C. Chararas, and S. Lambin. 1969. ÉTUDE DES OSIDASES

DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. [THE STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND ITS MICROBIAL FLORA.] C. R. Acad. Sci. 268: 2968–2970.
Extracellular microbes in the digestive tract of the insect are Achromobacter superficialis, A. delicatulus, *and* Candida pulcherina. *The microbial flora contain several oxidases. The insect possessed various enzymes that enabled it to degrade numerous oligosaccharides and polysaccharides. The activity of these enzymes is less important and less varied in the microbes than in the insect.*

117. Le Fay, A., J. E. Courtois, A. Thuillier, C. Chararas, and S. Lambin. 1970. ÉTUDE DES OSIDASES DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. I. ÉTUDE DE LA FLORE MICROBIENNE ET COMPARISON DE SES OSIDASES AVEC CELLES DE L'INSECTE TOTAL. [STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND OF ITS MICROBIAL FLORA. I. STUDY OF THE MICROBIAL FLORA AND COMPARISON OF THEIR OXIDASES WITH CELLS OF THE WHOLE INSECT.] Ann. Inst. Pasteur 119: 483–491.
Two bacteria (Achromobacter *spp.) and one yeast* (Candida *spp.) isolated regularly from the alimentary canal of* I. sexdentatus *had various enzymes that were less important and diversified than those of the insect at all developmental stages. Enzymes included glucosidases, galactosidase, amylase, pectinase, and cellulase.*

118. Le Fay, A., A. Thuillier, C. Chararas, and J. E. Courtois. 1969. INFLUENCE DE LA DESTRUCTION SÉLECTIVE DE LA FLORE MICROBIENNE SUR L'ACTIVITÉ DE DEUX OSIDASES CHEZ L'INSECTE XYLOPHAGE *IPS SEXDENTATUS*. [INFLUENCE OF THE SELECTIVE DESTRUCTION OF THE MICROBIAL FLORA ON THE ACTIVITY OF TWO OXIDASES ON THE XYLOPHAGOUS *IPS SEXDENTATUS*.] C. R. Acad. Sci. 268: 3130–3132.
In adults reared on wood impregnated with antibacterial and antifungal substances, two bacteria and a yeast in the digestive tube of the insect were selectively destroyed by inhibitory substances. No significant modification of the enzymatic activity of pectin and hydroxyethyl cellulose occurred in insects with ingested antibiotics, antibacterial agents, or antifungal agents. The microbial flora apparently function as accessories in elaborating the two oxidases in the total enzymatic complex.

119. Le Fay, A., A. Thuillier, J. E. Courtois, and C. Chararas. 1970. ÉTUDE DES OSIDASES DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. II. INFLUENCE DE LA DESTRUCTION SÉLECTIVE DE LA FLORE MICROBIENNE SUR L'ACTIVITÉ DE PECTINASES ET DE CELLULASES ACTIVES EN MILIEU FAIBLEMENT ACIDE CHEZ UN INSECTE XYLOPHAGE. [STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND OF ITS MICROBIAL FLORA. II. INFLUENCE OF THE SELECTIVE DESTRUCTION OF THE MICROBIAL FLORA ON THE ACTIVITY OF PECTINASES AND CELLULASES ACTIVE IN A WEAKLY ACID MEDIUM WITHIN A XYLOPHAGOUS INSECT.] Ann. Inst. Pasteur 119: 745–751.
Beetles were reared on Scots pine logs treated with antibiotics to selectively kill Achromobacter superficialis, A. delicatulus *and* Candida pulcherina *symbionts in insect digestive tracts. No significant change in enzymatic activity was noted with pectin and hydroxyethyl cellulose as substrates; thus, the symbionts are of little importance in providing enzymes.*

120. Lekander, B., and E. Rennerfelt. 1955. UNDERSÖKNINGAR ÖVER INSEKTS-OCH BLÅNADSSKADOR PA SAGTIMMER. [INVESTIGATIONS OF DAMAGE CAUSED BY BARK BEETLES AND BLUEING FUNGI IN SAW TIMBER.] Medd. Statens Skogsforskningsinstitut. 45(8): 1–36.
Surveys the most important blueing fungi [including Cladosporium, Pullularia, *and* Ophiostoma (= Ceratocystis)] *spread either by air or by forest insects; also discusses the most damaging insects that transmit stain in Sweden. Insects are* Blastophagus minor *and* Ips acuminatus *on Scots pine,* I. typographus *on Norway spruce, and* Trypodendron lineatum *on pine and spruce.*

121. Liese, W. 1970. ULTRASTRUCTURAL ASPECTS OF WOODY TISSUE DISINTEGRATION. Ann. Rev. Phytopathol. 8: 231–258.
Pullularia pullans *and* Ophiostoma (= Ceratocystis) coeruleum *are discussed. Passive penetration of the cell wall by blue stain fungi is by means of a transpressorium. Coaction of mechanical forces and enzymes produced at the tip of the transpressorium probably occurs. Further widening of the canals did not occur nor were there any visible changes in cell wall structure. The blue stain fungi derive nutrients from parenchyma cells.*

122. Liese, W. 1971. THE ACTION OF FUNGI AND BACTERIA DURING WOOD DETERIORATION. Int. Pest Control 1: 20–24.
Some blue stain fungi causing sapwood discoloration grew inside ray cells and derived nutrients from parenchyma cells. Since no enzymes are produced that can degrade a cell wall, the fungus enters by mechanical pressure. Bacteria are found in parenchyma cells of sapwood, whose contents provide easily accessible nutrition; the bacteria generally have a lower and more restrictive lytic activity than fungi, and cell wall deterioration is therefore prolonged.

123. Livingston, R. L. 1971. ASPECTS OF THE RELATIONSHIP BETWEEN THE FIR ENGRAVER *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE) AND CERTAIN ASSOCIATED FUNGI. Ph.D. Thesis. Wash. State Univ. (Diss. Abstr. 32: 2777B.)
Trichosporium symbioticum *has been isolated from*

phloem, larval mines, internally from larvae, and externally from pupae, and from both parent and emerging adults. An unidentified yeast was found associated with larvae and adult beetles. Both fungi were consistently found together. Specialized organs (mycangia) for transport of fungi were located in the head of male and female beetles. Observations on the benefit of the fungus to the beetle proved inconclusive.

124. Livingston, R. L., and A. A. Berryman. 1972. FUNGUS TRANSPORT STRUCTURES IN THE FIR ENGRAVER, *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 104: 1793–1800.
Beetles were examined by serial paraffin sections and scanning electron microscopy. In both male and female adult beetles, small cup-shaped pits covering the top and portions of the side of the head consistently contained fungal spores and usually contained a wax-like material in which the spores were imbedded. This material was probably produced by secretory cells of the epidermis.

125. Lowe, R. E., R. L. Giese, and M. L. McManus. 1967. MYCETANGIA OF THE AMBROSIA BEETLE *MONARTHRUM FASCIATUM*. J. Invertebr. Pathol. 9: 451–458.
Females contain paired, saclike mycetangia (= mycangium) that lie dorsal to the prothoracic coxal cavities. These large specialized organs for storage and transport of the ambrosia fungus spores are apparently lined with sclerotized cuticular material, and the posterior portion is heavily musculatured. A tube extends from each mycetangium to an external opening in the procoxal cavity. One section of the organ wall adjacent to the tube lacks sclerotization and contains a series of cells and ducts that terminate in pores within the mycetangia. These may be secretory cells that provide the matrix surrounding the spore aggregates.

126. Lu, K. C., D. G. Allen, and W. B. Bollen. 1957. ASSOCIATION OF YEASTS WITH THE DOUGLAS-FIR BEETLE. For. Sci. 3: 336–343.
Isolations were made from galleries, exoskeletons, and alimentary tracts. The species isolated—either alone or mixed—were: Saccharomyces pastoria, Candida parapsilosis, C. mycoderma, *and* Hansenula capsulata. *Together, the four species were attractive to the beetle; separately,* S. pastoria *was significantly attractive,* H. capsulata *gave inconclusive results, and the other two species were rejected by the beetle.*

127. MacCallum, B. D. 1922. SOME WOOD-STAINING FUNGI. Trans. Brit. Mycol. Soc. 7: 231–236.
Graphium penicillioides *was considered as a stage in the life-history of* Ceratostomella piceae (= Ceratocystis piceae). *The fungus was observed on* Pinus sylvestris *attacked by* Hylesinus piniperda.

128. MacLean, D. B., and R. L. Giese. 1967. THE LIFE HISTORY OF THE AMBROSIA BEETLE *XYLOTERINUS POLITUS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 99: 285–299.
Callow adults first reverse their position in the egg cradles, then begin feeding on an ambrosial fungus that lines the walls of the cradle and is as yet unidentified. The fungus was found consistently in active larval cradles and is probably the main larval food source.

129. MacLean, D. B., and R. L. Giese. 1968. FUNGI ASSOCIATED WITH *XYLOTERINUS POLITUS* (SAY) (COLEOPTERA: SCOLYTIDAE). J. Invertebr. Pathol. 10: 185–189.
Aspergillus flavus *was isolated from overwintering adult females of* Xyloterinus politus *along with* Penicillium *sp.,* Fusarium *sp., and an unidentified bacteria.* A. flavus *isolates from the prothorax were probably from the mycetangia. An unknown fungus, probably the main larval food source, was isolated and described from the cradles and galleries of actively feeding larvae. Pre-emergent adults feed on the fungus lining the old larval cradles; such behavior may cause the introduction of viable spores into the mycetangia.*

130. Mariat, F. 1971. ADAPTATION DE *CERATOCYSTIS* A LA VIE PARASITAIRE CHEZ L'ANIMAL-ETUDE DE L'AQUISITION D'UN POUVOIR PATHOGENE COMPARABLE A CELUI DE *SPOROTHRIX SCHENCKII*. [ADAPTATION OF *CERATOCYSTIS* TO PARASITIC LIFE IN THE ANIMAL - STUDY OF THE ACQUISITION OF ITS PATHOGENIC ABILITY AS COMPARED TO THAT OF *SPOROTHRIX SCHENCKII*.] Sabouraudia 9: 191–205.
Ceratocystis stenoceras, *usually parasitic on plants, was pathogenic for the hamster and mouse. Unicellular forms grown at 35° C produced lesions in some animals. Passaged strains were always more virulent than wild ones, did not form perithecia, and are considered to be stable, asexual pathogenic mutants. They produced triangular, pigmented spores and are indistinguishable from* S. schenckii *in morphology, physiology, and pathogenicity. The experimentally produced disease was similar to experimental sporotrichosis. The presence of cigar-shaped and asteroid bodies suggests that* Ceratocystis *may cause spontaneous sporotrichosis.*

131. Mason, R. R. 1967. DYNAMICS OF *IPS* POPULATIONS AFTER SUMMER THINNING IN A LOBLOLLY PINE PLANTATION: WITH SPECIAL REFERENCE TO HOST TREE RESISTANCE. Ph.D. Thesis. Univ. of Mich. 152 p. (Diss. Abstr. 27: 2215–B.)
Reasserts that the blue stain fungus Ceratocystis ips *is invariably found within the galleries and chambers of* Ips avulsus *and* Ips grandicollis. *The exact nature of the relationship between the fungus and the beetle remains unclear.*

132. Mathre, D. E. 1964. EFFECT OF *CERATOCYSTIS IPS* AND *CERATOCYSTIS MINOR* ON THE FREE SUGAR POOL IN PONDEROSA PINE SAPWOOD. Contrib. Boyce Thompson Inst. 22: 509–511.
Free sugars are most prevalent in the ray parenchyma cells, where fungal hyphae are most abundant. Fructose was apparently utilized by both fungi since it was abundant in uninfected sapwood but was not present in infected wood. Large quantities of xylose appeared in wood infected with C. minor, *but very little was found in wood in-*

fected with C. ips or in noninfected wood. Hemicellulolytic enzyme activity may account for the presence of xylose. The presence of detectible galacturonic acid and mannitol suggests that pectolytic and dehydrogenase activity may also occur.

133. Mathre, D. E. 1964. PATHOGENICITY OF *CERATOCYSTIS IPS* AND *CERATOCYSTIS MINOR* TO *PINUS PONDEROSA*. Contrib. Boyce Thompson Inst. 22: 363–388.
The fungi were pathogenic to small (<9 cm d.b.h.) ponderosa pines. Death resulted more quickly (<20 days) when inoculation covered 40-cm bands of sapwood rather than 10- or 20-cm bands. Trees inoculated in small patches and needle holes to simulate beetle attacks usually showed resistance to infection, probably because of copius resin flow. Dye studies showed that water is conducted around but not through infected areas of sapwood. Pathogenicity may involve entry of air into the sapwood.

134. Mathre, D. E. 1964. SURVEY OF *CERATOCYSTIS* SPP. ASSOCIATED WITH BARK BEETLES IN CALIFORNIA. Contrib. Boyce Thompson Inst. 22: 353–362.
Ceratocystis minor was isolated from old galleries of Dendroctonus brevicomis and D. monticolae; C. ips was isolated from galleries and adults of D. valens, Ips confusus, and I. oregonis, and from galleries only of D. monticolae, I. ponderosae, and I. emarginatus; C. schrenkiana was associated with attacks of D. valens and D. monticolae; C. montia, with D. jeffreyi and D. monticolae; and C. minuta, with I. confusus and I. emarginatus. Inoculations of the sapwood of small (<9 cm d.b.h.) ponderosa pine with C. ips, C. minuta, and C. schrenkiana killed the trees after various periods of time.

135. Mathre, D. E. 1964. STUDIES ON THE PATHOGENICITY TO PONDEROSA PINE OF *CERATOCYSTIS* SPP. ASSOCIATED WITH BARK BEETLES IN CALIFORNIA. Ph.D. Thesis. Univ. of Calif., Davis. 61 p. (Diss. Abstr. 27: 349B.)
The pathogenicity of some blue-stain fungi was tested to determine the role of these fungi in the death of beetle-attacked trees. Trees successfully attacked by bark beetles usually die within a few weeks to several months. The exact cause of death has not been fully established. Since mechanically girdled trees will live 1 or more years, the girdling action of the beetles does not explain the rapid death of the tree. The almost constant association of blue-staining fungi with bark beetles suggests that these fungi may be a cause of tree death.

136. McCambridge, W. F. 1974. IDENTIFYING PONDEROSA PINES INFESTED WITH MOUNTAIN PINE BEETLES. U.S. Dep. Agric. For. Serv. Res. Note RM-273, 2 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.
Describes characteristics of successfully attacked trees. Blue stain infection of wood under the bark is indicated by a dull blue color. A long, narrow strip of infection is usually not fatal, but infection well distributed around the tree and accompanied by fine insect frass or brood indicates a fatal attack.

137. McCowan, J. C., and J. A. Rudinsky. 1958. BIOLOGICAL STUDIES ON THE DOUGLAS FIR BARK BEETLE. Weyerhaeuser Timber Co. For. Res. Note 11, 21 p. Millicoma Forest Tree Farm, Coos Bay, Oregon.
Many Dendroctonus larvae die of starvation. Ceratostomella pseudotsugae (= Ceratocystis minor) and other fungi introduced by adult beetles cause decomposition of the cambium and render it unsuitable as larval food. A secondary enemy, Dryocoetes pseudotsugae, was abundant in windthrown trees infested with Douglas-fir beetles and particularly noticeable in trees with heavy blue stain and high larval mortality. The stain accompanies ambrosia beetles, which cause damage by constructing long winding tunnels into sapwood and heartwood.

138. Meiffren, M., and M. Belin. 1960. ESSAI DE TRAITEMENT MIXTE INSECTICIDE ET FONGICIDE CONTRE LE SCOLYTE DES RAMEAUX DU CAFÉIER *XYLEBORUS MORSTATTI* HAGED. [TEST OF MIXED INSECTICIDE AND FUNGICIDE TREATMENT AGAINST THE SCOLYTID OF COFFEE BRANCHES *XYLEBORUS MORSTATTI* HAGED.] Rev. Café, Cacao. Thé. 4: 150–158.
When the insect bores into branches and excavates a gallery, a canker often forms on all sides of the entrance. Several hundred isolations revealed the following fungi in decreasing order of frequency: Colletotrichum coffeanum, Pestalozzia coffeicola, Botryodiplodia theobromae, Fusarium decemellulare, F. lateritium, Aspergillus sp., and Penicillium sp. C. coffeanum, which with P. coffeicola is an agent of anthracnose, accounted for 80 percent of the isolations either alone or in associations with other species.

139. Miller, D. L., and A. D. Partridge. 1974. ROOT ROT INDICATORS IN GRAND FIR. U.S. Dep. Agric. Plant Dis. Rep. 58: 275–276.
Roots of normal, discolored, and dying grand fir (Abies grandis) were examined along with aboveground signs and symptoms as predictors of root rot, primarily Armillaria mellea. Bark beetle galleries or discolored foliage were the only effective indicators of the root rots. Of the root-rotted trees, 75.71 percent had new bark beetle galleries and 74.29 percent had yellow or red foliage. 98.15 percent of the bark beetle damage was in trees with advanced root decay.

140. Miller, J. M., and F. P. Keen. 1960. BIOLOGY AND CONTROL OF THE WESTERN PINE BEETLE. U. S. Dep. Agric. Misc. Publ. 800, 381 p.
Reviews published and unpublished reports on the insect with 14 reviews related to fungi, bacteria, or yeasts. The yeast Saccharomyces pini (= Pichia pini) was a constant associate of larvae and adults. S. pastori rendered the phloem attractive to the insect. Yeast fermentation caused changes in the nutrient content of the phloem but produced no pathogenic bacteria or viruses in association with the insect. Two unidentified fungi were suspected of being pathogenic. One blue-stain fungus [Ceratostomella ips (= Ceratocystis ips)] was specific to the insect and apparently influenced the host tree response. Reports growth of decay fungi during and following insect attack.

141. Molnar, A. C. 1965. PATHOGENIC FUNGI ASSOCIATED WITH A BARK BEETLE ON ALPINE FIR. Can. J. Bot. 43: 563–570.
Most alpine fir mortality from attacks by Dryocoetes confusus *was caused by fungi, which were probably carried into trees by the beetles. Of three* Ceratocystis *and one* Graphium, *the most virulent fungus was* C. dryocoetidis *as a* Verticicladiella *imperfect form, but tree death occurred only when necrotic lesions coalesced. Following inoculation with* C. dryocoetidis, *Engelmann spruce and lodgepole pine appeared resistant, a fact which may explain the infrequency of successful* D. confusus *attacks on these hosts.*

142. Moore, G. E. 1970. ISOLATING ENTOMOGENOUS FUNGI AND BACTERIA AND TESTS OF FUNGAL ISOLATES AGAINST THE SOUTHERN PINE BEETLE. J. Econ. Entomol. 63: 1702–1704.
Describes a method of eliminating saprophytic fungal overgrowth so that internal and nonsporulating organisms can be detected in diseased insects. Isolated fungi were Beauveria bassiana, Aspergillus flavus, Fusarium solani, Penicillium *spp.*, A. niger, *and* Trichoderma *spp. In pathogenicity tests where the first three fungi and one* Penicillium *sp. were inoculated into the beetles, all inoculated insects died in 6-10 days. Bacterial isolates from diseased beetles were* Serratia, Pseudomonas, Aerobacter, *and* Bacillus *spp.*

143. Moore, G. E. 1971. MORTALITY FACTORS CAUSED BY PATHOGENIC BACTERIA AND FUNGI OF THE SOUTHERN PINE BEETLE IN NORTH CAROLINA. J. Invertebr. Pathol. 17: 28–37.
Pathogenic microorganisms were responsible for 22 percent of the mortality of brood insects collected during sampling periods from 1966-1968. Bacteria isolated from moribund and dead beetles included Serratia marcescens, Pseudomonas aeruginosa, P. fluorescens, Bacillus thuringiensis *var.* thuringiensis, B. cereus *and* Flavobacterium *spp.; fungi isolated from both the exterior and interior of the beetles included* Beauveria bassiana, Aspergillus flavus, Cephalosporium *sp.*, Fusarium solani, Metarrhizium anisopliae, Paecilomyces *sp.*, *and* Scopulariopsis *sp.*

144. Moore, G. E. 1972. MICROFLORA FROM THE ALIMENTARY TRACT OF HEALTHY SOUTHERN PINE BEETLES, *DENDROCTONUS FRONTALIS* (SCOLYTIDAE), AND THEIR POSSIBLE RELATIONSHIP TO PATHOGENICITY. J. Invertebr. Pathol. 19: 72–75.
Microflora of 250 healthy larvae and adults were determined by aseptically excising portions of the fore-, mid-, and hindguts and culturing them on agar. Six genera of bacteria and five genera of fungi were recovered from 178 insects. The most frequently isolated bacteria were Aerobacter aerogenes, Alcaligenes faecalis, *and* Serratia *spp.* Aspergillus *spp. and* Penicillium *spp. were the most frequent fungi, and* Candida *sp. was the only yeast recovered. Seven of the species were identical with facultative or conditioned pathogens recovered from diseased beetles in other studies.*

145. Moore, G. E. 1972. PATHOGENICITY OF TEN STRAINS OF BACTERIA TO LARVAE OF THE SOUTHERN PINE BEETLE. J. Invertebr. Pathol. 20: 41–45.
Pathogenicity was determined by inoculating healthy larvae orally. All but the three Bacillus *spp., which were previously isolated, were from both healthy and diseased beetles. The* Bacillus *spp.* (B. cereus, B. thuringiensis *var.* thuringiensis, *and* B. thuringiensis *var.* kenyae), Pseudomonas aeruginosa, P. fluorescens, *and* Serratia marcescens *were all from diseased beetles and were pathogenic.* Alcaligenes faecalis *and* Aerobacter aerogenes, *both from diseased beetles, and* A. faecalis *and* S. marcescens, *from healthy beetles, were not pathogenic.*

146. Moore, G. E., and R. C. Thatcher. 1973. EPIDEMIC AND ENDEMIC POPULATIONS OF THE SOUTHERN PINE BEETLE. U.S. Dep. Agric. For. Serv. Res. Pap. SE–111, 11 p. Southeast. For. Exp. Stn., Ashville, N. C.
Defines differences between epidemic and endemic populations of the southern pine beetle in two distinct geographical areas. Beetle populations may be lowered by encouraging the development of pathogenic organisms.

147. Morgan, F. D. 1967. *IPS GRANDICOLLIS* IN SOUTH AUSTRALIA. Aust. For. 31: 137–155.
Beetles introduced several fungi into inner bark and sapwood of Pinus radiata. *Fungi always associated with* Ips grandicollis *were* Diplodea pinea, Ceratocystis ips, *and certain yeasts.* D. pinea *and* C. ips *caused sapwood discoloration. When inoculated in sufficient quantity,* C. ips *contributed to the deaths of infected trees.*

148. Moya-Borja, G. E. 1971. SOME ASPECTS OF THE BIOLOGY AND NUTRITION OF FOUR SPECIES OF *XYLEBORUS* AMBROSIA BEETLES. Ph.D. Thesis. Univ. of Wis. 143 p. (Diss. Abstr. 31: 7350B.)
Serial sagittal sections of adults of X. posticus, X. corniculatus, *and* X. cuneatus *revealed one pair of oral mycangia for each sex. Intact oral mycangia were readily observed microscopically in callow adults of* X. ferrugineus *and* X. posticus. Fusarium solani, Cephalosporium *sp.*, Graphium *sp.*, *an unidentified yeast, and an unidentified bacteria were isolated from mycangia of all four species and comprise their microbial complex.*

149. Nakashima, T. 1971. NOTES ON THE ASSOCIATED FUNGI AND THE MYCETANGIA OF THE AMBROSIA BEETLE, *CROSSOTARSUS NIPONICUS* BLANDFORD (COLEOPTERA: PLATYPODIDAE). Appl. Entomol. Zool. 6: 131–137.
A single spherical mycetangium is located at the back of the preoral cavity of the adult female. Sponge-like tissue containing fungal material surrounds the sphere. Absidia glauca *was isolated from fluid in the preoral cavities of all females. In a few specimens,* Cephalosporium mycophilum, C. acremonium, Chaetomium indicum, *and several bacteria were also isolated.*

150. Nakashima, T. 1972. NOTES ON THE MYCETANGIA OF THE AMBROSIA BEETLES,

PLATYPUS SEVERINI BLANDFORD AND *P. CALAMUS* BLANDFORD (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 7: 217–225.
Female adults of both species have several hundred integumentary, pitted mycetangia on the pronotum, whereas male adults have only a few of the pits. The main mycetangia of the male adult of P. severini *are enlarged forecoxal and mesocoxal cavities not found in females.*

151. Neužilová, A. 1956. PŘÍSPĚVEK K ZNALOSTI CIZOPASNÝCH HUB KŮROVCŮ *IPS TYPOGRAPHUS.* [A CONTRIBUTION TO THE KNOWLEDGE OF THE PARASITIC FUNGUS OF *IPS TYPOGRAPHUS.*] Preslia 28: 273–275.
Examination of the bark beetle revealed four entomophagous Beauveria *forms:* Beauveria bassiana, B. globulifera, *and* B. densa *have been frequently found in insects, but the fourth,* Spicaria farinosa, *is from an undescribed host. Mass cultures of* B. globulifera *produced good sporulation, and the fungus was utilized for successful control of the pest* Gnorimoschema ocellatellum.

152. Nilsson, T. 1973. STUDIES ON WOOD DEGRADATION AND CELLULOLYTIC ACTIVITY OF MICROFUNGI. Studia For. Suec. 104, 40 p. R. Coll. For., Stockholm.
Cavity formation, cell wall erosion, and cellulose clearing were observed in 160 fungus species, including 13 Ceratocystis *species* (brunneociliata, cana, clavata, coerulescens, crassivaginata, ips, minor, minuta, olivacea, piceae, pilifera, tetropii, *and sp. A). Two species* (piceae *and sp. A) produced cavities in secondary cell walls of birch* (Betula verrucosa) *wood fibers, but only* piceae *caused cavities in pine* (P. silvestris). Cellulolytic *activity was noted in* cava, piceae, *and* tetropii.

153. Nisikado, Y., and K. Yamauti. 1934. CONTRIBUTIONS TO THE KNOWLEDGE OF THE SAP STAINS OF WOOD IN JAPAN. II. STUDIES ON *CERATOSTOMELLA PINI* MÜNCH, THE CAUSE OF A BLUE STAIN OF PINE TREES. Ber. Ohara Inst. Landwintsch. Forsch. 6: 467–490.
Describes and illustrates the fungus Ceratostomella pini (= Ceratocystis minor), *which was found on* Pinus densiflora *and* Pinus thumbergii. *It attacked felled trees and those already weakened by bark beetles.*

154. Nobuchi, A. 1972. THE BIOLOGY OF JAPANESE SCOLYTIDAE AND PLATYPODIDAE (COLEOPTERA). Rev. Plant. Prot. Res. 5: 61–75.
Xylomycetophagy is a highly specialized feeding habit prevalent in the tribes Xyloterini and Xyleborini of the subfamily Ipinae, in some of the Scolytidae, and in all species of the Platypodidae that occur in Japan. Included are species of the genera Neohyorrhynchus, Sueus, Trypodendron, Indocryphalus, Xylosandrus, Xyleborus, Cnestus, Scolytoplatypus, Platypus, Crossotarsus *and* Diapus. *Spores of a symbiotic fungi are carried by beetles in specialized structures on or within their bodies; therefore safe transport of the fungus to new galleries is assured. Tunnels extend directly through bark into sapwood or heartwood. Both larvae and adults feed on ambrosia fungi growing on gallery walls.* Xyleborus seriatus *is the only species that feeds on the ambrosia fungi growing between the bark and sapwood. Damage to trees and logs is assessed according to depth and density of galleries made by invading blue-stain or wood-rotting fungi and by the black, fungus-stained galleries of the ambrosia beetles.*

155. Nobuchi, A. 1973. THE PLATYPODIDAE OF JAPAN. Bull. Gov. For. Exp. Stn. Toyko 256: 1–22.
All 18 recognized species of Platypodidae are ambrosia beetles with monogamous social organization. The mycangia of Crossotarsus niponicus, Platypus calamus, *and* P. severini *have been described previously. Ambrosia beetles in this family and a few genera of the Scolytidae cause mechanical damage to green logs, and they facilitate the invasion of blue-stain or wood-rotting fungi. Provides keys to all species and mentions geographical distribution and host plants.*

156. Nord, J. C. 1972. BIOLOGY OF THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE), IN GEORGIA. Ann. Entomol. Soc. Am. 65: 350–358.
The fungus Ambrosiella xylebori, *isolated from active galleries and from mycangia in male adults, may be the primary ambrosia fungus lining channels of the gallery and brood cells. It is the most luxuriant fungus in the newly excavated portions of the gallery and provides food for larvae and presumably adults.*

157. Norris, D. M. 1966. THE COMPLEX OF FUNGI ESSENTIAL TO THE GROWTH AND DEVELOPMENT OF *XYLEBORUS SHARPI* IN WOOD. Holz und Organismen. Int. Symp. Berlin-Dahlem (1965) 1: 523–529.
Investigated fungal symbionts and associates of seven species of ambrosia beetles in the genera Xyleborus, Trypodendron, Monarthrum, *and* Xylcterinus; *the species may attack* Betula, Populus, Quercus, Theobroma, *or* Ulmus. *Symbionts and associates of* Xyleborus sharpi *attacking* Theobroma *or* Ulmus *were emphasized. One species each of* Botryodiplodia, Fusarium, Paecilomyces, *and* Candida *was isolated from most ovipositional tunnels or brood galleries of* X. sharpi, *but other fungi were rarely isolated. When this beetle was reared on the nonhost species* Ulmus americana, *the same four fungi were isolated from galleries containing brood. These consistent findings indicate that the four fungi are probably essential for many ambrosia fungus complexes.*

158. Norris, D. M., and J. K. Baker. 1967. SYMBIOSIS: EFFECTS OF A MUTUALISTIC FUNGUS UPON THE GROWTH AND REPRODUCTION OF *XYLEBORUS FERRUGINEUS.* Science 156: 1120–1122.
Beetles developed from asymbiontic eggs through the adult stage on a sterilized meridic diet (I), but the resulting adults oviposited viable eggs only when a mutualistic fungus (Fusarium solani) *was inoculated into the diet. This ambrosia fungus probably synthesizes chemicals essential to insect reproduction. On another diet (II), beetles with*

bacterial symbionts still required the ambrosia fungus for reproduction. This fungus was consistently isolated from oral mycangia in the beetles and was transported to galleries constructed by the insects.

159. Norris, D. M., and J. M. Baker. 1968. A MINIMAL NUTRITIONAL SUBSTRATE REQUIRED BY *FUSARIUM SOLANI* TO FULFILL ITS MUTUALISTIC RELATIONSHIP WITH *XYLEBORUS FERRUGINEUS*. Ann. Entomol. Soc. Am. 61: 1473–1475.
Beetles given a minimal nutritional diet of cellulose, agar, water, and the fungus Fusarium solani *produced no progeny because the diet did not provide adequate nutrition for the fungus, which in turn was not adequate to ensure beetle reproduction. The addition of chemicals such as Wesson salts, sodium nitrate, wood vitamins, and dextrose resulted in a chemically defined substrate required by the symbiotic fungus to fulfill its mutualistic role as provider of the nutritional requirements of the ambrosia beetle,* X. ferrugineus.

160. Norris, D. M., J. M. Baker, and H-M Chu. 1969. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. III. ERGOSTEROL AS THE SOURCE OF STEROL TO THE INSECT. Ann. Entomol. Soc. Am. 62: 413–414.
Without a mutualistic fungus, Xyleborus ferrugineus *pupated in the second generation on test diets containing 0.2 g of ergosterol. Cholesterol at 0.2 g per diet batch was not an adequate source of sterol in the second fungus-free generation. Sterol requirements lacking in the diets of the first generation apparently were met by carry-over of such nutrients from the previous generation (stock culture), whose diet contained fungus.*

161. Norris, D. M., and H-M Chu. 1970. NUTRITION OF *XYLEBORUS FERRUGINEUS*. II. A HOLIDIC DIET FOR THE APOSYMBIOTIC INSECT. Ann. Entomol. Soc. Am. 63: 1142–1145.
Specimens of X. ferrugineus *were cultured in test tubes, freed of ectosymbiotes, and observed for development and for nutritional and physiological needs. Two holidic diets, one containing 10 amino acids and the other 18, were assessed for nutritional adequacy. Both were adequate, but the diet containing 10 amino acids was better. Ergosterol is the source of sterol. Reproduction is arrhenotokous, and fertilized females yield progeny with a spanandrous sex ratio.*

162. Norris, D. M., and H-M Chu. 1971. MATERNAL *XYLEBORUS FERRUGINEUS* TRANSMISSION OF STEROL OR STEROL-DEPENDENT METABOLITES NECESSARY FOR PROGENY PUPATION. J. Insect Physiol. 17: 1741–1745.
The aposymbiotic female Xyleborus ferrugineus *transmitted ergosterol or ergosterol-dependent metabolites necessary for progeny pupation. Transmission was apparently transovarial. Sterol for immature development was required in the progeny diet. When maintained on a diet containing cholesterol, maternal females were no longer able to transmit chemical components necessary for progeny pupation.*

163. Olchowecki, A., and J. Reid. 1974. TAXONOMY OF THE GENUS *CERATOCYSTIS* IN MANITOBA. Can. J. Bot. 52: 1675–1711.
Presents keys to 70 species, including 50 that occur in Manitoba, and divides them into four groups based on ascospore characteristics: Minuta, Ips, Fimbriata, and Pilifera. Keys to species for each group are based additionally on the following: character of the perithecial neck; size, color, and ornamentation of the perithecial base; presence and nature of the ostiolar hyphae; character of the conidial state; and character of the mycelia in culture. Twenty-five new species are described, and descriptions of the conidial states of three species are provided for the first time.

164. Olofinboba, M. O., and J. R. S. Lawton. 1968. AN INVESTIGATION INTO THE BIOLOGY OF THE BLUE-STAIN ORGANISM IN *ANTIARIS AFRICANA*. J. Inst. Wood Sci. 21: 6–20.
Describes experiments showing which part of the tree is susceptible to fungal development. The causal organism is Botryodiplodia theobromae, *which colonizes the wood by entering from vessels into adjacent vasicentric parenchyma, where rapid development occurs. The fungal hyphae then penetrate ray parenchyma and other xylem cells and greatly deplete the carbohydrate content of the wood.*

165. Ordish, G. 1966. PINE BARK BEETLE IN HONDURAS. Span 9: 121–123.
Discusses outbreak of Dendroctonus *spp. and suggests that the beetle's relationship with* Ceratocystis *blue stain is not symbiotic, commensal, or parasitic according to the usual definitions of these conditions; the insect merely transports the fungus to suitable host material.*

166. Osgood, E. A. 1957. A BIBLIOGRAPHY ON THE SOUTHERN PINE BEETLE, *DENDROCTONUS FRONTALIS* ZIMM. U.S. Dep. Agric. For. Serv. Res. Pap. SE–80, 19 p. Southeast. For. Exp. Stn., Asheville, N. C.
Fourteen references from 1929–1949 are given for fungi associated with the insect.

167. Parker, A. K. 1957. *EUROPHIUM,* A NEW GENUS OF THE ASCOMYCETES WITH A *LEPTOGRAPHIUM* IMPERFECT STATE. Can. J. Bot. 35: 173–179.
Describes a new species, Europhium trinacriforme, *and discusses a method for culturing on artificial media the perithecia found on the trunks of dead and dying* Pinus monticola.

168. Partridge, A. D., and D. L. Miller. 1972. BARK BEETLES AND ROOT ROTS RELATED IN IDAHO CONIFERS. U.S. Dep. Agric. Plant Dis. Rep. 56: 498–500.
Examinations of root rots caused mainly by Armillaria mellea *showed a significant association between rotting and the presence of bark beetles. The relationship was particularly evident in Douglas-fir, grand-fir, and ponderosa pine. The bark beetles were not identified.*

169. Pawsey, R. G. 1968. OBSERVATIONS ON BLUE-STAIN AND PIN-HOLE BEETLES, AND THEIR CONTROL, UN UNPEELED LOGS OF

PINUS CARIBAEA IN TRINIDAD. Commonw. For. Rev. 47: 211–224.
Chemical treatment of logs (log-ends and whole-logs) immediately after felling was not effective in controlling blue-stain. Whole-log spraying with 1.0 percent gamma B.H.C. in dieseline gave excellent control of pin-hole beetle damage, and there was evidence of an inverse relationship between resin production from cut ends of logs and blue-stain development. Bark beetles were not associated with blue-stain.

170. Peleg, B., and D. M. Norris. 1972. BACTERIAL SYMBIOTE ACTIVATION OF INSECT PARTHENOGENETIC REPRODUCTION. Nat. New Biol. 236: 111–112.
In Xyleborus ferrugineus, *both natural oocyte maturation and haploid parthenogenesis depend on bacterial symbiotes in the insect. The symbiotic bacterium isolated was placed in the genus* Staphylococcus *(see following paper).*

171. Peleg, B., and D. M. Norris. 1972. SYMBIOTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. VII. BACTERIAL SYMBIONTS ASSOCIATED WITH *XYLEBORUS FERRUGINEUS*. J. Invertebr. Pathol. 20: 59–65.
Transovarially transmitted bacterial symbionts in the genus Staphylococcus *were isolated from the gut lumen of all beetle stages and were shown to invade the oocytes. The invasion was associated with initiation of nuclear division when the oocytes, unfertilized by sperm, were surrounded by the follicular wall in the ovariole. With such an oocyte activation, the bacterium apparently supercedes the sperm and enables the beetles to reproduce parthenogenetically.*

172. Peleg, B., and D. M. Norris. 1973. HAPLOID VERSUS DIPLOID *XYLEBORUS FERRUGINEUS*. I. LARVAL INSTARS, DEVELOPMENT, AND MORPHOGENESIS OF THE METATHORACIC WING. Ann. Entomol. Soc. Am. 66: 180–183.
Xyleborus ferrugineus *reared on stock cultures of fungal and bacterial symbionts had three instars for both haploid and diploid larvae. No marked differences were observed in the time required for larval development. The first distinct difference was observed in the metathoracic wings of the pupa: adult females possessed well-developed wings and were strong flyers, but the adult males had degenerate metathoracic wings and could not fly.*

173. Peleg, B., and D. M. Norris. 1973. OÖCYTE ACTIVATION IN *XYLEBORUS FERRUGINEUS* BY BACTERIAL SYMBIONTS. J. Insect Physiol. 19: 137–145.
This ambrosia beetle exhibits arrhenotokous parthenogenesis, in which the unmated female normally lays eggs that yield haploid male progeny. By invading and activating the oöcytes, bacterial symbionts may enable the beetles to reproduce asexually. Antibiotics incorporated in a sodium benzoate- or in an asorbic acid-based meridic diet significantly reduced oviposition and number of progeny of ectosymbiotic fungus-free virgin females. Bacteria were not found in the primary oöcytes of nonovipositing treated females, but when placed on an antibiotic-free diet, the females regained fertility. Their eggs contained many symbionts that were transmitted transovarially.

174. Peplinski, J. D., and W. Merrill. 1974. NONSURVIVAL OF *CERATOCYSTIS FAGACEARUM* IN FRASS OF OAK BARK BEETLES AND AMBROSIA BEETLES. Phytopathology 64: 1528–1530.
Viable propagules of the fungus were not present in the frass of oak bark beetles (Pseudopityopthorus *spp.) or ambrosia beetles* (Xyleborus saxeseni, X. xylographus, *and* Xyloterinus politus) *in Pennsylvania oaks. The oak bark beetle appears to carry the fungus internally, either in the digestive tract or in special structures such as mycangia. The percentage of effective vectors is lower than 0.4 percent, a fact that may explain the slow spreading rate of oak wilt.*

175. Person, H. L. 1931. THEORY IN EXPLANATION OF THE SELECTION OF CERTAIN TREES BY THE WESTERN PINE BEETLE. J. For. 29: 696–699.
An initial weak attraction occurs, caused by the formation of volatile oils such as aldehydes or esters—by-products of respiratory fermentation or abnormal enzyme activity in subnormal trees. These oils attract beetles from the immediate vicinity, and the beetles introduce a yeast into the inner bark. The yeast produces a fermentation strong enough to attract other beetles from a wider radius.

176. Phaff, H. J., and L. D. Carmo-Sousa. 1962. FOUR NEW SPECIES OF YEAST ISOLATED FROM INSECT FRASS IN BARK OF *TSUGA HETEROPHYLLA* (RAF.) SARGENT. Antonie van Leeuwenhoek 28: 193–207.
These yeasts were isolated from insect frass in Pacific coast hemlock and were described as Sporobolomyces singularis, Bullera tsugae, Cryptococcus skinneri *and* Candida oregonensis. Sporobolomyces singularis, *a nonpigmented species, required an amendment of the genus definition. The yeasts are probably transmitted by* Scolytus tsuga.

177. Phaff, H. J., and M. Yoneyama. 1961. *ENDOMYCOPSIS SCOLYTI*, A NEW HETEROTHALLIC SPECIES OF YEAST. Antonie van Leeuwenhoek 27: 196–202.
The natural habitat of the new species is in frass or in larvae or adults of two species of bark beetles: Scolytus ventralis, *which attacks* Abies, *and* S. unispinosus, *which attacks* Pseudotsuga.

178. Pitman, G. B. 1965. CERTAIN FACTORS AFFECTING COLONIZATION OF PONDEROSA PINE BY *IPS CONFUSUS* (LE CONTE) (COLEOPTERA: SCOLYTIDAE). Ph.D. Thesis. Oregon State Univ., Corvallis, Oregon, 217 p. (Diss. Abstr. 26: 598.)
Inoculation with the blue staining fungus Ceratocystis ips *indicated that the microorganism was aiding colonization and brood development only by reducing moisture movement and oleoresin exudation in the outer sapwood.*

179. Reid, R. W., and D. M. Shrimpton. 1971. RESISTANT RESPONSE OF LODGEPOLE PINE TO INOCULATION WITH *EUROPHIUM CLAVIGERUM* IN DIFFERENT MONTHS AND AT DIFFERENT HEIGHTS ON STEM. Can. J. Bot. 49: 349–351.
For lodgepole pines inoculated at monthly intervals between May and October, the number of trees showing a fully resistant response reached a maximum in early July and then gradually declined. When resistant lodgepole pine trees were inoculated at intervals of 6 feet starting at the groundline, the resistant response was greatest in the lowest 20 feet.

180. Reid, R. W., H. S. Whitney, and J. A. Watson. 1967. REACTIONS OF LODGEPOLE PINE TO ATTACK BY *DENDROCTONUS PONDEROSAE* HOPKINS AND BLUE STAIN FUNGI. Can. J. Bot. 45: 1115–1126.
Europhium *sp. and* Ceratocystis montia *were consistently isolated from* D. ponderosae (= D. monticolae) *and from their galleries and adjacent stem tissue. Secondary resinosis is largely responsible for tree resistance to bark beetles and blue-stain fungi. Resistance did not depend on the absence of the two fungi because both were present in successful and in unsuccessful beetle attacks. Following attacks, the amounts on nonconductive sapwood were about equal in resistant and susceptible trees, but the sapwood of resistant trees was soaked with resin. In successful attacks, the sapwood was not soaked but was colonized by blue-stain fungi.*

181. Rexrode, C. O., H. M. Kulman, and C. K. Dorsey. 1965. BIONOMICS OF THE BARK BEETLE *PSEUDOPITYOPHTHORUS PRUINOSUS* WITH SPECIAL REFERENCE TO ITS ROLE AS A VECTOR OF OAK WILT, *CERATOCYSTIS FAGACEARUM*. J. Econ. Entomol. 58: 913–916.
Parent beetles left the trees 10 to 12 days after they had constructed egg galleries. In laboratory studies, parents emerged after completing their galleries, made new attacks on fresh twigs, and fed on buds. With the spermatization technique, 2 to 20 percent of the emerging parent beetles collected in the field carried the oak wilt fungus and could therefore serve as vectors. Parents were more likely vectors than their offspring, which emerged only after the trees had become dry or were overrun by other fungi.

182. Reynolds, P. E., W. H. Smith, and K. F. Jensen. 1972. EFFECT OF CONSTANT AND FLUCTUATING TEMPERATURES ON THE *IN VITRO* GROWTH OF *CERATOCYSTIS* SPECIES. Trans. Br. Mycol. Soc. 59: 1–9.
Isolates of C. adiposa, C. pluriannulata, C. minor, C. coerulescens, *and* C. pilifera, *all from the Southeastern United States, and 14 isolates of* C. ulmi *were tested at constant 5°C increments from 15° to 35°C, with fluctuating treatments administered by varying the temperature 3°, 6°, and 9°C above and below the constant temperatures.* C. minor *grew relatively slowly at all temperatures tested but grew best at a constant 25°C and at 6° fluctuations about a 25° mean.*

183. Richards, A. G., and M. A. Brooks. 1958. INTERNAL SYMBIOSIS IN INSECTS. Ann. Rev. Entomol. 3: 37–56.
Gives a general account of internal symbiosis in insects and includes some definitions. Discusses the origin of symbiotic associations, the anatomy of hosts, and the effects of symbiotic microorganisms on insects. The Scolytids are not mentioned.

184. Richmond, J. A., C. Mills, and E. W. Clark. 1970. CHEMICAL CHANGES IN LOBLOLLY PINE, *PINUS TAEDA* L., INNER BARK CAUSED BY BLUE STAIN FUNGUS, *CERATOCYSTIS MINOR* (HEDG.) HUNT. J. Elisha Mitchell Sci. Soc. 86: 171.
Investigates changes in free amino acids, carbohydrates, and fatty acids (free and triglyceride) in inner bark of loblolly pine infected with the blue stain fungus and in uninfected inner bark. Free and triglyceride fatty acids of the fungus were also analyzed. Uninfected bark showed decreases for all properties observed. Five weeks after incubation, infected bark revealed a 36 percent decrease in the amino nitrogen content, an 80 percent decrease in carbohydrates, a three-fold decrease in triglyceride fatty acids, and a seven-fold increase in free fatty acids. The major free and triglyceride fatty acids of both the injected bark and the pure fungal cultures were identical. Infected bark revealed large amounts of resin acids.

185. Robinson-Jeffrey, R. C., and R. W. Davidson. 1968. THREE NEW *EUROPHIUM* SPECIES WITH *VERTICICLADIELLA* IMPERFECT STATES ON BLUE-STAINED PINE. Can. J. Bot. 46: 1523–1527.
Perfect states of all three species are similar; species separation is based on differences between the imperfect states. Europhium clavigerum, E. aureum *and* E. robustum *exhibit* Verticicladiella *imperfect forms, and a previously described* E. trinacriforme *was distinguished by its* Leptographium*-like form. Cleistothecia of the perfect state, were found on bark, sapwood, and in old beetle galleries of infested, blue-stained pines, including lodgepole, ponderosa, limber, and western white pine.* E. clavigerum *was found on all hosts and was isolated directly from the mountain pine beetle and* Ips *species,* E. robustum *was found on ponderosa pine and isolated from ambrosia and* Dendroctonus *beetles (no species given), and* E. aureum *was recorded on lodgepole pine only.*

186. Rösch, R., W. Liese, and H. Berndt. 1969. UNTERSUCHUNGEN ÜBER DIE ENZYME VON BLÄUEPILZEN. I. CELLULASE-, POLYGALAKTURONASE-, PEKTINESTERASE-, UND LACCASE-AKTIVITÄT. [STUDIES ON THE ENZYMES OF BLUE-STAIN FUNGI. I. CELLULASE, POLYGALACTURONASE, PECTINASE AND LACCASE ACTIVITY.] Arch. Mikrobiol. 67: 28–50.
Ceratocystis minor, Aureobasidium pullulans, *and* Alternaria humicola *were cultivated in an unbuffered nutrient solution with glucose or carboxymethyl cellulose as carbon source. When culture filtrates were used to detect cellulase, polygalactu-*

ronase, pectinesterase, and p-diphenoloxidase, each fungus produced all four enzymes. With glucose as the carbon source, the acidity increased at the beginning of fungal growth, whereas with carboxymethyl cellulose, the pH values immediately became neutral. The glucose solution produced more cellulase than the carboxymethyl cellulose one.

187. Rudinsky, J. A. 1961. FACTORS AFFECTING THE POPULATION DENSITY OF BARK BEETLES. Proc. 13th IUFRO-Cong. vol. 1, Sect. 24–11, 13 p.
Population levels of bark beetles are determined by abiotic factors such as climate, oleoresin pressure, water conduction, moisture, and temperature, and biotic factors such as parasites, predators, and fungi. Dendroctonus pseudotsugae *in Douglas-fir and* D. brevicomis, D. monticolae, *and* Ips confusus *in ponderosa pine become primary insect pests when the abiotic and biotic interrelationships are disturbed and when host conditions are suitable. Douglas-fir, infected with* Fomes pini *and exhibiting less than 1.5 atms of oleoresin exudation pressure were successfully invaded by the Douglas-fir beetle. A blue-stain fungus* (Ceratocystis *sp.*) *obstructs water conduction and lowers tree resistance to beetle attack, but* D. brevicomis *is able to overcome ponderosa pine without the usual development of blue-stain fungi.*

188. Rudinsky, J. A., and P. Svihra. 1971. THE PATTERNS OF WATER CONDUCTION IN CONIFERS. Acta Inst. For. Zvolen, Czech. 2: 369–383.
Trees under great or prolonged water stress are successfully invaded by the Douglas-fir beetle, but during rainy or cloudy weather, water balance is usually restored. High oleoresin exudation pressure then induces resinosis; the resin flow in the gallery system made by parent beetles and developing larvae stops the feeding, repels the beetles, and prevents further spread of blue-stain fungi. The tree then recovers.

189. Rumbold, C. T. 1929. BLUE-STAINING FUNGI FOUND IN THE UNITED STATES. Phytopathology 19: 597–599.
Forest trees not infested with Dendroctonus *or* Ips *had the greatest variety of blue-stain fungi. Trees infested with either of these beetles contained the blue-stain fungus specific for that beetle.*

190. St. George, R. A., and J. A. Beal. 1929. THE SOUTHERN PINE BEETLE: A SERIOUS ENEMY OF PINES IN THE SOUTH. U. S. Dep. Agric. Farmers' Bull. 1586, 18 p.
Contains an early statement associating a blue-stain fungus with trees killed by the beetle.

191. Salonen, K. 1966. OBSERVATIONS ON *IPS SEXDENTATUS* (BOERN.) (COL., SCOLYTIDAE) AS A BLUER OF TIMBER AT INARI (INL) IN THE SUMMER OF 1965. Ann. Entomol. Fenn. 32: 88–96.
Extensive blue stain was recorded in Scotch pine sapwood associated with attack and larval development of I. sexdentatus *in Finland. Depth of staining ranged from 0.1 to 15.0 mm and appeared to be controlled by the amount of moisture in the sapwood. Stain fungi appeared to be* Tuberculariella ips *and* Ophiostoma brunneo-ciliatum. *When the temperatur was near 0°C, fungal development ceased.*

192. Saunders, J. L., and J. K. Knoke. 1967. DIETS FOR REARING THE AMBROSIA BEETLE *XYLEBORUS FERRUGINEUS* (FABRICIUS) *IN VITRO*. Science 157: 460, 463.
Female ambrosia beetles were reared successfully on an artificial diet when their associated fungus, a species of Fusarium, *was not inhibited.*

193. Saunders, J. L., J. K. Knoke, and D. M. Norris, Jr. 1967. ENDOSULFAN AND LINDANE RESIDUES ON THE TRUNK BARK OF *THEOBROMA CACAO* FOR THE CONTROL OF *XYLEBORUS FERRUGINEUS*. J. Econ. Entomol. 60: 79–82.
Describes chemical treatments to control a vascular wilt incited by the fungus Ceratocystis fimbriata, *generally associated with* Xyleborus ferrugineus. *Endosulfan residue sufficient for beetle control remained 20 weeks after treatment. Lindane residue diminished rapidly after 4 weeks.*

194. Saunders, J. L., D. M. Norris, and J. K. Knoke. 1967. INSECT-HOST TISSUE INTERRELATIONS BETWEEN *XYLEBORUS FERRUGINEUS* (COLEOPTERA: SCOLYTIDAE) AND *THEOBROMA CACAO* IN COSTA RICA. Ann. Entomol. Soc. Am. 60: 419–423.
Wood deterioration was retarded in beetle-infested zones. The fact that a wood preservative was produced by either the beetle, the associated fungi, or the host may indicate an evolved provision for maintaining conditions satisfactory for brood development. Infested trunks supported development for 2-3 months after an infestation by the vascular pathogen Ceratocystis fimbriata, *which caused foliage wilt.*

195. Savory, J. G., R. G. Pawsey, and J. S. Lawrence. 1965. PREVENTION OF BLUE-STAIN IN UNPEELED SCOTS PINE LOGS. Forestry 38: 59–81.
Effective control of blue-stain degrade in logs can be accomplished only by treating the logs with chemicals that prevent attacks by bark beetles—the transmittors of Ceratocystis *spp. and other bluing fungi. Whole-log treatments with a combined fungicide and insecticide in a water emulsion [2 percent Santobrite (active ingredient 90 percent sodium pentachlorophenate), 2 percent borax, and 0.75 percent gamma BHC] applied to the point of run off gave very good protection for 3 months. End treatments with fungicides followed by whole-log treatments with insecticides were also effective.*

196. Schmitz, R. F., and J. A. Rudinsky. 1968. EFFECT OF COMPETITION ON SURVIVAL IN WESTERN OREGON OF THE DOUGLAS-FIR BEETLE. For. Res. Lab. Res. Pap. 8, 42 p. Ore. State Univ., Corvallis, Oreg.
Attacks ceased when the temperature dropped below 50°F or during rain. No differences were observed in the number of eggs laid at different attack densities (one to three attacks per square foot), but maximum brood survival occurred at densities of 1.0 to 1.9 attacks per square foot. The larvae avoided areas of the phloem that contained white

fungal mats or the blue stain fungus; thus, the direction of the larval mines is controlled in part by fungal growth. Intraspecific competition was a factor in natural control, but interspecific competition was not.

197. Schneider, I. A., and J. A. Rudinsky. 1969. MYCETANGIAL GLANDS AND THEIR SEASONAL CHANGES IN *GNATHOTRICHUS RETUSUS* AND *G. SULCATUS*. Ann. Entomol. Soc. Am. 62: 39–43.
Fungus repositories of the male beetles are relatively primitive but contain a glandular epithelium. The gland cells are activated at the end of hibernation and secrete through funnel-shaped openings into the lumen of the mycetangium during the flight period. Development of the symbiotic fungi is synchronized with that of the glands. Fungus cells passively gain entrance into the mycetangium by beetle movement in the gallery at the end of hibernation; the cells proliferate in the presence of the secretion and are disseminated in the new galleries. By the time the beetles are preparing brood gallery, the gland cells are depleted and begin to deteriorate.

198. Scott, D. B., and J. W. Du Toit. 1970. THREE NEW *RAFFAELEA* SPECIES. Trans. Br. Mycol. Soc. 55: 181–186.
The principal fungi occurring in symbiosis with two ambrosia beetles in South Africa are described and assigned to newly described species in Raffaelea. R. albimanens *sp. nov. and* R. hennebertii *sp. nov. are associated with* Platypus externedentatus, *and* R. arxii *sp. nov., with* Xyleborus torquatus.

199. Shepherd, R. F., and J. A. Watson. 1959. BLUE STAIN FUNGI ASSOCIATED WITH THE MOUNTAIN PINE BEETLE. Can. Dep. Agric. For. Biol. Div. Bimon. Prog. Rep. 15(3): 2–3.
Blue-stain fungi (unidentified) are usually introduced into a green tree at the time of attack by adult beetles, which the fungi help to establish by reducing resin flow and blocking water movement in the tree. This study indicates that the fungi probably reduce resin production by utilizing the cell contents and stored food of parenchyma cells, which conduct the food from the phloem into the sapwood. The fungi restrict water conduction by destroying the ray parenchyma cells, which partially control water movement.

200. Shrimpton, D. M. 1973. EXTRACTIVES ASSOCIATED WITH WOUND RESPONSE OF LODGEPOLE PINE ATTACKED BY THE MOUNTAIN PINE BEETLE AND ASSOCIATED MICROORGANISMS. Can. J. Bot. 51: 527–534.
Describes the lodgepole pine response to sapwood invading fungi vectored by bark beetles. First, an initial flow of oleoresin escapes into adjacent tissues from resin ducts severed by the attacking beetles; next, a synthesis of monoterpene occurs within parenchyma cells adjacent to the beetle gallery; finally, sugars and fatty acids are utilized by the fungi. The total amount of terpene increased to levels well above those normal for sapwood and heartwood. All components found in the response were normal constituents of heartwood. Free acids, phenolics, and neutral components increased much more slowly than terpenes and achieved a final concentration about equal to that in heartwood. Free sugar levels decreased. No unusually high or low levels of any compound were observed in response to the wound, except for a high level of phellandrene.

201. Shrimpton, D. M. 1973. AGE- AND SIZE-RELATED RESPONSE OF LODGEPOLE PINE TO INOCULATION WITH *EUROPHIUM CLAVIGERUM*. Can. J. Bot. 51: 1155–1160.
The reactions of 530 trees between 8 and 140 years old were classified as resistant or nonresistant after a summer inoculation with E. clavigerum, *the fungus associated with the mountain pine beetle. Trees between 31 and 50 years old had the greatest frequency of potentially resistant individuals. The youngest (age 10-30) and oldest (age 90-120) trees showed a decreasing frequency of resistant individuals. Trees potentially capable of preventing bark beetles from colonizing their stem tissues generally had better diameter growth and thicker phloem than nonresistant trees.*

202. Shrimpton, D. M., and R. W. Reid. 1973. CHANGE IN RESISTANCE OF LODGEPOLE PINE TO MOUNTAIN PINE BEETLE BETWEEN 1965 AND 1972. Can. J. For. Res. 3: 430–432.
In 1965, lodgepole pines near Radium, B.C., were graded for resistance to mountain pine beetles by evaluating their response to inoculation with a blue-stain fungus normally transported by the beetle. Trees surviving the first treatment were inoculated again in 1972, and the resistance of each was reevaluated. Most trees graded nonresistant in 1965 had died by 1972; whereas, most trees originally rated resistant were still alive and were again rated resistant.

203. Shrimpton, D. M., and J. A. Watson. 1971. RESPONSE OF LODGEPOLE PINE SEEDLINGS TO INOCULATION WITH *EUROPHIUM CLAVIGERUM*, A BLUE STAIN FUNGUS. Can. J. Bot. 49: 373–375.
Point inoculations of the fungus in 4-6 year old seedlings produced resinous reactions similar to those observed in mature trees following artificial or natural introduction of the fungus with the mountain pine beetle. No blue stain developed in the sapwood of any of the inoculated seedlings. Sixty days after inoculation, the resinous tissues of the seedlings contained 58 percent β-phellandrene, 22 percent 3-carene, 12 percent β-pinene, 4 percent camphene, 2 percent α-pinene, and traces of other terpenes. The phenolics identified were pinosylvin, pinosylvin monomethylether, pinobanksin, and pinocembrin. Identical compounds are present in mature trees showing resistant reactions.

204. Shrimpton, D. M., and H. S. Whitney. 1968. INHIBITION OF GROWTH OF BLUE STAIN FUNGI BY WOOD EXTRACTIVES. Can. J. Bot. 46: 757–761.
*Two blue-stain fungi (*Ceratocystis montia *and* Europhium *sp.), both commonly associated with mountain pine beetle attacks on lodgepole pine,*

evoked a resinous reaction in sapwood of resistant trees. Both fungi were inhibited in vitro *by the resinous sapwood, but nonresinous sapwood stimulated fungal growth. The fact that acetone extracts and volatile substances from resinous and nonresinous sapwood inhibited fungal growth suggests that inhibitors are present in both but that the degree of inhibition is determined by the amount of inhibitors present.* C. montia *is apparently important in establishing an initial infection court for the complete fungal complex carried by the beetle.*

205. Spaulding, P. 1961. FOREIGN DISEASES OF FOREST TREES OF THE WORLD. U. S. Dep. Agric., Agric. Handb. 197, 361 p.
Lists pathogenic diseases of forest trees according to causal agents (viruses, bacteria, and fungi); also lists hosts, pathogenicity, and range. Of the seven Ceratocystis *species listed, five* (C. ips, C. minor, C. pilifera, C. tetropii, *and* C. ulmi) *are said to be associated with bark beetles.*

206. Stark, R. W., and J. H. Borden. 1965. OBSERVATIONS ON MORTALITY FACTORS OF THE FIR ENGRAVER BEETLE, *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). J. Econ. Entomol. 58: 1162–1163.
Data obtained from dissection of 505 Scolytus ventralis *galleries in three white fir trees accounted for 78.6 percent larval mortality. Predation and competition contributed 65.8 percent, parasites 4.9 percent, and a fungus, 7.9 percent. The fungus identified as* Oedocephalum *sp., contributed to the deaths of two trees. It is not known if the fungus is "entomogenous," since the genus is reportedly saprophytic on plant material; however, the fungus was found colonizing complete larvae.*

207. Stark, R. W., and F. W. Cobb, Jr. 1969. SMOG INJURY, ROOT DISEASES AND BARK BEETLE DAMAGE IN PONDEROSA PINE. Calif. Agric. 23: 13–15.
Photochemical oxidants (smog) caused serious injury to ponderosa pine in the San Bernardino Mountains of southern California. Smog injury apparently renders the trees more susceptible to attack by two destructive forest insects, the western pine beetle (Dendroctonus brevicomis) *and the mountain pine beetle* (D. ponderosae). *Photochemical oxidant injury to ponderosa pine reduces the oleoresin yield, the rate of resin flow and oleoresin exudation pressure, the moisture content of sapwood and phloem, and the phloem thickness, all of which are important in defending trees against bark beetles. Infection of the trees by root disease fungi, particularly* Fomes annosus *and* Verticicladiella wagenerii, *produced similar injuries along with the resulting increases in bark beetle attacks.*

208. Stevens, R. E., D. B. Cahill, C. K. Lister, and G. E. Metcalf. 1974. TIMING CACODYLIC ACID TREATMENTS FOR CONTROL OF MOUNTAIN PINE BEETLE IN INFESTED PONDEROSA PINES. U. S. Dep. Agric. For. Serv. Res. Note RM-262, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Careful timing is critical in the post-attack application of cacodylic acid against beetle brood. Although bluestain development was initially used as one of the guidelines for determining the optimal time to apply the acid, the chances for successful beetle control are poor by the time bluestain is detectable. The length of the larval mines is the best indicator of when to apply the acid, which should be introduced into infested trees before the mines exceed 0.5 inch.

209. Stevens, R. E., C. A. Myers, W. F. McCambridge, G. L. Downing, and J. G. Laut. 1974. MOUNTAIN PINE BEETLE IN FRONT RANGE PONDEROSA PINE: WHAT IT'S DOING AND HOW TO CONTROL IT. U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM–7, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Beetles have a 1-year life cycle. They attack new trees in midsummer and carry a blue stain fungus that hastens tree death. Successfully attacked trees die almost immediately but do not fade for nearly a year. Combined programs of direct control, logging of infested trees, preventative silviculture, and individual tree protection are proposed as suitable control methods.

210. Struble, G. R. 1937. THE FIR ENGRAVER BEETLE, A SERIOUS ENEMY OF WHITE FIR AND RED FIR. U. S. Dep. Agric. Circ. 419, 15 p.
Within 4 to 6 days after the start of an egg gallery, a yellowish-brown discoloration of the cambium layer appears, extending vertically from each side of the gallery. The fungus that causes the stain is Trichosporium symbioticum, *which spreads in advance of the feeding larvae and dries the cambium layer.*

211. Strzelczyk, A., and A. Lamprecht. 1972. BADANIA NAD GRZYBAMI POWODUJACYMI SINIZNE DREWNA SOSNOWEGO. [STUDIES ON THE BLUE-STAINING FUNGI OF PINE WOOD.] Acta Mycol. 8: 239–247.
Describes studies to determine interactions among fungi and to evaluate the susceptibility of these fungi to commonly used fungicides. Blue-staining fungi from the genera Pullularia, Hormiscium, *and* Homodendrum *were strongly inhibited by* Trichoderma *strains, but strains of* Ophiostoma (= Ceratocystis) *were less susceptible to inhibition by this antagonist. Sodium pentachlorophenolate—even at low doses—proved to be a much stronger fungicide than sodium orthophenylphenolate.*

212. Takagi, K. 1967. THE STORAGE ORGAN OF SYMBIOTIC FUNGUS IN THE AMBROSIA BEETLE *XYLEBORUS RUBRICOLLIS* EICHHOFF (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 2: 168–170.
The adult female has a pair of sac-like pockets (mycangia) containing fungal cells, located at the base of the mandibles beneath the labrum. Lining the inner surface of the mycangia are smooth cilia formed by scales or lines spaced at regular intervals. Gland-like structures covering the mycangia walls were observed but were not described in detail.

213. Takagi, K., and T. Kaneko. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. II. SPORE STORAGE ORGAN OF TEA ROOT BORER, *XYLEBORUS*

GERMANUS BLANDFORD. Jap. J. Appl. Entomol. Zool. 9: 247–248.
The organ consists of a shallow dorsal pouch in the intersegmental membrane between the pronotum and mesonotum. The stored spores are spherical and are smaller than those from galleries of the host plant. They are laid tightly in the sac at the breeding period, but few are present during overwintering. Fungus propagation probably occurs during the pre-breeding period.

214. Takagi, K., and T. Kaneko. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. III. SPORULATION OF *XYLEBORUS GERMANUS* AMBROSIA FUNGUS. Jap. J. Appl. Entomol. Zool. 9: 298–300.
The ambrosia fungus was essential to beetle development. Spores within the mycangium were readily detected in all seasons but winter and were morphologically different from those in the galleries. The optimum temperature range for sporulation of spores cultivated from gallery walls was so narrow (20-25°C) that the growth of the beetle was indirectly limited by the effect of the soil temperature on the fungus in the tea roots.

215. Taylor, J. J. 1970. A COMPARISON OF SOME *CERATOCYSTIS* SPECIES WITH *SPOROTHRIX SCHENCKII*. Mycopathol. Mycol. Appl. 42: 233–240.
Sympodulosporogenous conidial states of C. minor, C. montia, C. multiannulata, C. narcissi, C. nigrocarpa, C. perparvispora, *and* C. pilifera *were found to be morphologically indistinguishable from the conidial state of the form-genus* Sporothrix. *Cultural, morphological, and serological characteristics and virulence of the species in mice were compared to demonstrate the close similarity between the* Ceratocystis *spp. conidial states and* S. schenckii. *The first three characteristics of the* Ceratocystis *spp. were either the same or varied similarly as those observed among* S. schenckii *strains, the only exception being that* Ceratocystis *spp. hydrolyzed starch and* S. schenckii *did not. Mouse virulence tests showed slight variations in the sizes and shapes of sympodulospores and yeast-like budding forms, but no significant differences were observed.*

216. Toriello, C., and F. Mariat. 1974. ÉTUDE COMPARÉE DES POLYOSIDES DES CHAMPIGNONS *CERATOCYSTIS STENOCERAS* ET *SPOROTHRIX SCHENCKII*. COMPOSITION CHIMIQUE ET ANALYSE IMMUNOLOGIQUE. [A COMPARATIVE STUDY OF THE POLYSACCHARIDES PRODUCED BY THE FUNGI *CERATOCYSTIS STENOCERAS* AND *SPOROTHRIX SCHENCKII*. CHEMICAL NATURE AND IMMUNOLOGICAL PROPERTIES.] Ann. Microbiol. (Inst. Pasteur) 125A: 287–307.
Similar polysaccharides were synthesized by a strain of C. stenoceras, *by an asexual mutant of the same fungus pathogenic for animals, and by a strain of the hyphomycete* S. schenckii. *Both somatic and metabolic polysaccharides contained more mannose than rhamnose. Chemical and antigenic analysis showed that the three fungi are closely related.*

217. Upadhyay, H. P., and W. B. Kendrick. 1974. A NEW *GRAPHIUM*-LIKE GENUS (CONIDIAL STATE OF *CERATOCYSTIS*). Mycologia 66: 181–183.
Conidia of the Ceratocystis *most often disseminated by insect vectors such as bark beetles are introduced to the vector by the stalked spore drop. The multifarious conidial states forming spore drops have been separated into the genera* Verticicladiella, Graphium, Leptographium, Pesotum, *and the new genus* Phialographium.

218. Vaartaja, O. 1963. FUNGI ASSOCIATED WITH INSECTS IN PINE TREES. Page 11 *in* Woods and For. Dep. South Aust. Annu. Rep. 1961–62, Edited by B. H. Bednall, Adelaide.
Diplodia pini, Ceratocystis ips, *and several unidentified fungi and yeasts were common to* Ips grandicollis *and* Pinus radiata *near Adelaide, Australia.*

219. Vaartaja, O. 1967. THE COMMON FUNGAL ASSOCIATES OF THE BARK BEETLE, *IPS GRANDICOLLIS*, IN *PINUS RADIATA* IN SOUTH AUSTRALIA. Aust. For. Res. Inst. 2(4): 40–43.
Reports the first record of Ceratocystis ips *on* Pinus radiata. *Plantings of nonstained bark and wood from infested trees of parent galleries and of older galleries with larvae and adults showed that* C. ips *was intimately (>50 percent) associated with the insect. The fungus was often isolated from the* Leptographium *fruiting structures on bark or wood, and* C. pilifera *was occasionally isolated from this habitat.* Macrophoma sabinea *was associated (>50 percent) with nonstained bark and wood on infested trees. Unidentified yeasts were commonly (>50 percent) associated with new galleries, larvae, and adults. No Basidiomycetes were isolated.*

220. Vasil'ev, O. A. 1968. K VOPROSU OB ISPOL' ZOVANII ANTAGONIZMA GRIBOV I BAKTERII DYLA ZASHCHITY DREVESINY. [USING THE ANTAGONISM OF FUNGI AND BACTERIA FOR THE PROTECTION OF WOOD.] Nauch. Tr. Leningrad Lesotekh. Akad. 110: 28–33 [Bio. Abstr. 88862, 1968].
An unidentified bacterial strain from sapwood of rafted pine logs and a fungus, Trichoderma viride, *either suppressed or completely stopped the growth of eight species of blue-stain fungi including* Ceratocystis minor. *Both organisms might be used to develop methods of protecting coniferous trees against wood staining fungi.*

221. Verrall, A. F. 1939. RELATIVE IMPORTANCE AND SEASONAL PREVALENCE OF WOOD-STAINING FUNGI IN THE SOUTHERN STATES. Phytopathology 29: 1031–1051.
Seven fungi found to cause major stain damage in southern trees were Endoconidiophora coerulescens, Ceratostomella (= Ceratocystis) pluriannulata, Diplodia natalensis, *and* Graphium ridigum *in hardwoods and* C. pilifera, C. ips, D. natalensis, *and* Diplodia *sp. in pines. Highest incidences of* D. natalensis *occurred during the hot summer months:* C. pilifera *and* E. coerulescens *occurred*

most frequently during cool months. C. ips, Diplodia *sp.,* C. pluriannulata, *and* G. rigidum *showed little seasonal fluctuation.*

222. Vité, J. P., and J. A. Rudinsky. 1962. INVESTIGATIONS ON THE RESISTANCE OF CONIFERS TO BARK BEETLE INFESTATIONS. XI. Int. Kongr. Entomol. Wein 1960. Sonderdr. Verh. II: 219–225.
Trees infected with the fungus Fomes pini were *more susceptible to mountain pine beetle attacks than uninfected ones because the oleoresin exudation pressure of diseased trees was only about half that of healthy ones. Disturbances in the normal water relation may diminish the exudation of oleoresin from the interconnected capillary system of resin ducts and may cause abnormally decreased turgidity that predisposes ponderosa pine to beetle attack.*

223. Von Schrenk, H. 1903. THE "BLUING" AND THE "RED ROT" OF THE WESTERN YELLOW PINE, WITH SPECIAL REFERENCES TO THE BLACK HILLS FOREST RESERVE. U. S. Bur. Plant. Ind. Bull. 36, 40 p.
Bluing after an attack by Dendroctonus ponderosae *is caused by the fungus* Ceratostomella (=Ceratocystis) pilifera, *which was not isolated from alimentary canals, feces, or live beetles during a limited dissemination study. The red rot disease, caused by* Polyporus ponderosus, *is not vectored by beetles but by spores in the air. Both fungi contribute to wood deterioration.*

224. Walt, J. P. van der, and E. E. Nel. 1968. *CANDIDA EDAX* SP. N. Antonie van Leeuwenhoek 34: 106–108.
Three strains of the yeast were isolated from frass recovered from deserted subcortical insect galleries in Sclerocarya caffra *growing near Groblersdal in the Transvaal.*

225. Walt, J. P. van der, and D. B. Scott. 1971. *PICHIA AMBROSIAE* SP. N., A NEW AUXILIARY AMBROSIA FUNGUS. Antonie van Leeuwenhoek 37: 15–20.
This new species was isolated from the linings of freshly opened tunnels and from the larval cradles of the xylomycetophagous scolytids, Platypus externedentatus, P. sampsoni, *and* Xyleborus torquatus. Pichia ambrosiae *may be a common component of the ectosymbiontic flora of these beetle species, which infest both indigenous and exotic trees in the coastal region of northern Natal.*

226. Walt, J. P. van der, and D. B. Scott. 1971. *SACCHAROMYCOPSIS SYNNAEDENDRA*, A NEW YEAST FROM SOUTH AFRICAN INSECT SOURCES. Mycopathol. Mycol. Appl. 44: 101–106.
Describes a new species isolated in northern Natal from walls of tunnels excavated by Platypus externedentatus *in* Tabernaemontana ventricosa *and from tunnels of* Xyleborus *sp. in* Rapanea melanophloeos *and* Nuxia floribunda, *near Knysna, Cape Providence.*

227. Walt, J. P. van der, and D. B. Scott. 1971. *PICHIA XYLOPSOCI*, A NEW YEAST FROM SOUTH AFRICAN INSECT SOURCES. Mycopathol. Mycol. Appl. 44: 321–324.
The species was recovered from tunnels excavated by the beetle, Xylopsocus capucinus, *in* Ficus sycomorus *and* Celtis africana, *on the north coast of Natal.*

228. Walt, J. P. van der, D. B. Scott, and W. C. van der Klift. 1971. FIVE NEW *TORULOPSIS* SPECIES FROM SOUTH AFRICAN INSECT SOURCES. Antonie van Leeuwenhoek 37: 461–471.
Five new yeast species, Torulopsis dendrica, T. philyla, T. silvatica, T. insectalens, *and* T. nemodendra, *were recovered from Cerambycid, Platypid, and Scolytid beetle infestations in indigenous trees in Natal and the Cape Province in South Africa.*

229. Walt, J. P. van der, D. B. Scott, and W. C. van der Klift. 1971. FOUR NEW, RELATED *CANDIDA* SPECIES FROM SOUTH AFRICAN INSECT SOURCES. Antonie van Leeuwenhoek 37: 449–460.
Four new yeast species (Candida hylophila, C. dendronema, C. silvanorum *and* C. entomophila) *were recovered from Bostrichid, Cerambycid, Scolytid, and Platypid beetle infestations of indigenous trees in the Transvaal, Natal, and the Cape Province in South Africa.*

230. Weiser, J. 1970. THREE NEW PATHOGENS OF THE DOUGLAS FIR BEETLE, *DENDOCTONUS PSEUDOTSUGAE: NOSEMA DENDROCTONI* N. SP., *OPHRYOCYSTIS DENDROCTONI* N. SP., AND *CHYTRIDIOPSIS TYPOGRAPHI* N. COMB. J. Invertebr. Pathol. 16: 436–441.
Three new protozoan parasites and a fungal parasite were found in Douglas-fir beetles. Knowledge of diseases of bark beetles is based chiefly on a few studies of diseases occurring in European scolytids. Protozoan infection rates are low, and the fungus Beauveria bassiana *in adults causes sporadic, nonspecific infection. Bacteria usually appear only in larvae exposed to extreme physical conditions. Laboratory tests indicated that these associated bacteria do not cause mortality except when applied in very high dosages.*

231. Wertz, H. W., J. M. Skelly, and W. Merrill. 1971. *CERATOCYSTIS FAGACEARUM* NOT TRANSMITTED BY AMBROSIA BEETLES. Phytopathology 61: 1185–1187.
Monarthrum fasciatum, Xyleborus saxeseni, *and* X. xylographus *did not attack or transmit* Ceratocystis fagacearum *to healthy red oak seedlings, saplings, or mature trees.* Xyloterinus politus *attacked healthy red oaks of all ages and tunneled into the xylem but did not transmit the pathogen.*

232. Whitney, H. S. 1971. ASSOCIATION OF *DENDROCTONUS PONDEROSAE* (COLEOPTERA: SCOLYTIDAE) WITH BLUE STAIN FUNGI AND YEASTS DURING BROOD DEVELOPMENT IN LODGEPOLE PINE. Can. Entomol. 103: 1495–1503.
Describes the physical association between the beetle and its associated microorganisms: the blue-stain fungi Ceratocystis montia *and* Europium clavigerum *and the yeasts* Pichia pini, Hansenula capsulata, *and* H. holstii. *The association was investigated in single broods reared in bolts of lodgepole pine* (Pinus contorta *var.* latifolia). *Eggs*

about to hatch and first-instar larvae were always contiguous with the microorganisms; newly laid eggs and larvae of the second, third, and fourth instars were not. During pupation, blue-stain fungi and yeasts colonized pupal chamber walls; when contacted by tenerals, the microorganisms were transferred to a new generation of insects. The necessity for physical contact between the insect and the microorganisms supports the hypothesis of their symbiotic relationship.

233. Whitney, H. S., and R. A. Blauel. 1972. ASCOSPORE DISPERSION IN *CERATOCYSTIS* SPP. AND *EUROPHIUM CLAVIGERUM* IN CONIFER RESIN. Mycologia 64: 410–414.
Dispersal by resin is probably important for inoculation and infection of these fungi in coniferous hosts. Cirri of the following fungi dispersed into single ascospores in pine or fir resin: Ceratocystis bicolor, C. fimbriata, C. ips, C. major, C. minor, C. minuta, C. minuta-bicolor, C. montia, *and* C. pilifera; *ascospore masses of* Europhium clavigerum *dispersed in the same manner. Only* C. fimbriata *and* C. pilifera *did not disperse in water. Cirri of* C. leucocarpa *dispersed in water but not pine resin, and those of* C. montia *dispersed in 12 of 25 substances tested and germinated on water agar only when resins, water, and undecane were used as dispersing agents. Germination of* C. minor *was not inhibited on water agar when either ponderosa pine or white fir resin was the dispersing agent. Describes a technique for obtaining single ascospore cultures following dispersal in resin; the method should be useful for investigating genetic variability.*

234. Whitney, H. S., and F. W. Cobb, Jr. 1972. NONSTAINING FUNGI ASSOCIATED WITH THE BARK BEETLE *DENDROCTONUS BREVICOMIS* (COLEOPTERA: SCOLYTIDAE) ON *PINUS PONDEROSA*. Can. J. Bot. 50: 1943–1945.
Three fungi—Ceratocystis nigrocarpa, *an unidentified hyphomycete, and an unidentified basidiomycete—were isolated from extensive nonstained areas of sapwood; the two unidentified fungi were also present in the thoracic mycangium of the female beetle. Nonstaining fungi may assist in the disruption of the conducting system of ponderosa pine attacked by the beetle and may contribute to tree death.* C. minor *was isolated from scattered patches of blue-stained sapwood. The staining fungus* C. minor *and the three nonstaining fungi appeared to be mutually exclusive.*

235. Whitney, H. S., and S. H. Farris. 1970. MAXILLARY MYCANGIUM IN THE MOUNTAIN PINE BEETLE. Science 167: 54–55.
A mycangium was located in the cardines of male and female Dendroctonus ponderosae, *but no gland cells were reported with the structure, which resembled mycangia in several species of* Trypodendron *ambrosia beetles. Blue-stain fungi and yeasts associated with beetle attacks were cultured after being isolated from the mycangia of 32 unsexed insects. Five mycangia contained the blue-stain fungus* Ceratocystis montia, *and 16 contained* Europhium clavigerum, *also a blue-stain fungus; 4 contained* Trichoderma *spp.; 3 contained* Penicillium *spp.; and 2 contained* Cladosporium *spp.; 18 contained yeasts (mainly* Pichia pini, Hansenula capsulata, *or* H. holstii); *3 mycangia yielded only yellow bacterial colonies, and 2 did not yield any microorganisms. Some mycangia that yielded the blue-stain fungi also yielded one or two yeasts, but the two blue-stain fungi were never found in the same mycangium; the nonstaining fungi were usually solitary.*

236. Wickerham, L. J. 1960. *HANSENULA HOLSTII*, A NEW YEAST IMPORTANT IN THE EARLY EVOLUTION OF THE HETEROTHALLIC SPECIES OF ITS GENUS. Mycologia 52: 171–183.
Hansenula holstii *is the most primitive heterothallic species of the genus, and its counterpart among the homothallic species is* H. capsulata. *Both are found in coniferous trees and bark beetles;* H. holstii *is associated with* Dendroctonus engelmanni. *Neither yeast forms diploid cells in nature, but both can be induced to do so in the laboratory.*

237. Wickerham, L. J., and K. A. Burton. 1961. PHYLOGENY OF PHOSPHOMANNAN-PRODUCING YEASTS. I. THE GENERA. J. Bacteriol. 82: 265–268.
Primitive yeasts of the genera Hansenula, Pichia, *and* Pachysolen *are transported to their sap substrate by bark beetles. The yeasts produce extracellular phosphorylated mannans, which through their adhesive quality enable the yeasts to adhere to insects boring through the bark. The yeasts in turn provide food for beetles and their brood. This relationship between the yeast and the beetle is one of balanced symbiosis.*

238. Wilcox, W. W. 1970. ANATOMICAL CHANGES IN WOOD CELL WALLS ATTACKED BY FUNGI AND BACTERIA. Bot. Rev. 36: 1–28.
Reviews papers describing the actions of blue-stain and mold fungi in timber. Many such fungi are transmitted to the trees by insects but apparently cause little damage to the structure of the wood they inhabit. Hyphae may be present in most wood elements and are usually most numerous in ray parenchyma cells. Penetration is primarily through pits; hyphae pass directly through the torus, but bore hyphae bore holes through tracheids and fibers, a more complex process than pit penetration. Bore hyphae are smaller than the other hyphae and may actually form from an appressorium. Penetration through pits tori and the cell walls may be primarily mechanical.

239. Wilkinson, R. C. 1968. REPRODUCTION AND DIET IN THREE SPECIES OF *IPS* BARK BEETLES. Page 83 *in* Fla. Inst. Food and Agric. Ser. Ann. Res. Rep., Univ. of Fla., Gainesville.
The yeasts Hansenula holstii *and* Pichia pini, *isolated from* Ips avulsus, *suppressed the growth and spore production of the blue stain fungus* (Ceratocystis ips), *also carried by this beetle. Of the 12 fatty acids identified by chromatographic analysis of* Ips calligraphus *life forms, C16 and C18:1 compounds were present in highest concentrations.*

240. Wilson, M. 1922. THE BLUING OF CONIFEROUS TIMBER. Trans. Roy. Scot. Arboric. Soc. 36: 82–92.

Reviews early information on blue-stain fungi. In Pinus ponderosa *severely attacked by* Dendroctonus ponderosae, *the blue coloration of the wood appeared to spread from the beetle holes, perhaps because the beetles form channels for hyphae to pass more deeply into sapwood.*

241. Wood, D. L. 1972. SELECTION AND COLONIZATION OF PONDEROSA PINE BY BARK BEETLES. *In* Insect/Plant Relationships. Edited by H. F. van Emden. Symp. R. Entomol. Soc. London 6: 101–117.
Cites four references and reviews current knowledge on associations of Dendroctonus brevicomis *with several* Ceratocystis *spp. and yeasts. States that most studies of host resistance have ignored the phytopathogen-host tree relationships and argues that effects of physio-chemical properties of the host on the beetle and the pathogen must be considered.*

242. Wright, E. F., and R. F. Cain. 1961. NEW SPECIES OF THE GENUS *CERATOCYSTIS.* Can. J. Bot. 39: 1215–1230.
Describes and illustrates four new species of the genus Ceratocystis (C. europhioides, C. brunneocrinita, C. falcata, *and* C. sagmatospora). *Many fungi in this genus possess dark-colored hyphae that cause blue stain discoloration. Beetles associated with these fungi are agents for dispersing spores.*

243. Yearian, W. C., R. J. Gouger, and R. C. Wilkinson. 1972. EFFECTS OF THE BLUESTAIN FUNGUS, *CERATOCYSTIS IPS,* ON DEVELOPMENT OF *IPS* BARK BEETLES IN PINE BOLTS. Ann. Entomol. Soc. Am. 65: 481–487.
The bluestain fungus Ceratocystis ips *was consistently associated with and transmitted by* Ips avulsus, I. calligraphus, *and* I. grandicollis, *all infesting* Pinus *species in Florida. In typical slash pine logs* (Pinus elliottii *var.* elliottii) *containing blue-stain innoculated and stain-free* I. avulsus *populations, no significant differences were found in egg gallery length, brood size, brood composition, pupal weight, or fecundity. Similar results were usually obtained with* I. calligraphus *and* I. grandicollis. *Bluestain-free populations of all three species were reared successfully through three to four successive generations in fungus-free slash pine logs. Oviposition was inhibited when pine logs were inoculated with* C. ips *8 days prior to the introduction of adults.*

244. Zimmerman, G. 1973. DIE PILZFLORA EINIGER IM HOLZ LEBENDER BORKENKAFER. [THE FUNGI OF SOME WOOD-INHABITING BARK BEETLES.] Mater. Org. 8: 121–131.
Ambrosiella hartigii, Fusarium javanicum, Ceratocystis *sp.,* Penicillium citrinum, Penicillium *sp.,* Trichoderma viride, Aspergillis *sp., and a* Sphaeropsidales *fungus were isolated from* Anisandrus dispar *galleries in* Acer pseudoplatanus; F. javanicum *was often isolated apart from the* Ambrosiella *fungus.* Ceratocystis bacillospora, C. torulosa, C. piceae, Ambrosiella ferruginea, Gliccladium roseum, Torula *sp.,* Penicillium *sp.,* T. viride, Graphium penicillioides, Graphium *sp., a* Sphaeropsidales, *and* Bjerkandera adusta *were isolated from* Xyloterus domesticus *in* Fagus sylvatica. Ascoidea hylecoeti, C. bacillospora, Ceratocystis *sp.,* G. penicillioides, Graphium *sp., bacteria, yeasts, and a* Sphaeropsidales *were isolated from galleries of* Hylecoetus dermestoides *in* F. sylvatica. The fungus F. javanicum *caused a pathogenic reaction in the shoots of tomato plants.*

Author Index

Subject Index

Barras, S. J., and T. J. Perry

1975. Interrelationships among microorganisms, bark or ambrosia beetles, and woody host tissue: an annotated bibliography, 1965-1974. South. For. Exp. Stn., New Orleans, La. 34 p. (USDA For. Serv. Gen. Tech. Rep. SO-10)

About 250 references, with comprehensive subject index.

Additional keywords: Symbiosis, Coleoptera, *Dendroctonus*, conifers, bacteria, fungi.

Barras, S. J., and T. J. Perry

1975. Interrelationships among microorganisms, bark or ambrosia beetles, and woody host tissue: an annotated bibliography, 1965-1974. South. For. Exp. Stn., New Orleans, La. 34 p. (USDA For. Serv. Gen. Tech. Rep. SO-10)

About 250 references, with comprehensive subject index.

Additional keywords: Symbiosis, Coleoptera, *Dendroctonus*, conifers, bacteria, fungi.