

# Keratinophilic fungi associated with free-living mammals and birds

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**Summary** A concise list of records of keratinophilic fungi mainly isolated from hair [in mammals] or feathers [in birds] of asymptomatic animals or from their nests is given. Their frequency of occurrence and different ecological aspects of the association of keratinophilic fungi with wild vertebrates are also discussed.

**Key words** Keratinophilic fungi, Mammals, Birds

'Keratinophilic' (i.e., often occurring on keratinous substrates) and 'keratinolytic' (keratin-decomposing) fungi should be differentiated. Some keratinophilic fungi namely do not digest keratin and live off components other than the keratin of the keratinous structures [1-4]. In this review, only the keratinolytic fungi (KF) are treated. Non-keratinolytic keratinophilic fungi found on wild vertebrates range among members of the genera, e.g., *Acremonium*, *Alternaria*, *Arcuadendron*, *Chaetomium*, *Chrysosporium* (*C. luteum*, *C. merdarium*, *C. olivaceum*, *C. pruinatum*, *C. inops*), *Cladosporium*, *Curvularia*, *Geomyces* (*G. pannorus*), *Gliomastix*, *Gymnascella* (syn. *Arachniotus*; *G. aurantiaca*, *G. citrina*, *G. dankaliensis*, *G. hyalinosporea*, *G. marginosporea*, *G. nodulosa*), *Gymnoascus* (*G. reessii*), *Myxotrichum*, *Pseudogymnoascus*, *Scopulariopsis* or *Sepedonium*. Many of them are cellulolytic.

Only free-living homoiotherm (endotherm) vertebrates including, e.g., feral pigeons, have been involved in this survey, whereas domestic animals, captive wild animals, and those living in zoological gardens or farms have been omitted.

## Species of keratinolytic fungi associated with wild vertebrates

Teleomorph genera of KF associated with free-living mammals or birds are classified in two families of the ascomycetaceous Onygenales: *Arthrodermataceae* (*Arthroderma*, *Ctenomyces*) and *Onygenaceae* (*Amauroascus*, *Aphanoascus*, *Apinisia*, *Auxarthron*, *Oncocladium*, *Onygena*, *Shanorella*, *Uncinocarpus*). Anamorphs involve *Arthrographis*, *Chrysosporium*, *Malbranchea*, *Microsporium*, *Trichophyton*, *Monodictys* and *Myriodontium* [5-11].

In the following concise list of records of KF species, the isolates were obtained from hair (in mammals) or feathers (in birds) of asymptomatic animals, unless otherwise indicated. The paragraph 'Ref.' (References) lists published records and the 'Coll.' (Collections) additional KF strains deposited in culture collections, which were isolated from wild vertebrates.

***Amauroascus albicans*** (Apinis) von Arx

Syn. *Arachniotus albicans* Apinis.

Ref. Rodents (*Microtus arvalis*, *Apodemus flavicollis*, *A. agrarius*, *A. sylvaticus*) in Czechland and Yugoslavia [12]. Bird feathers, nests (*Tyto alba*, *Passer domesticus*, *P. montanus*) and pellets (*Asio otus*, *Merops apiaster*) in England, Czechland and Yugoslavia [13-15].

***Aphanoascus durus*** (Zukal) Cano et Guarro

Syn. *Gymnoascus durus* Zukal, *Keratinophyton durum* (Zukal) Currah.

Coll. UAMH 3671: hedgehog, Ivory Coast (M. P. English).

***Aphanoascus fulvescens*** (Cooke) Apinis

Syn. *Anxiopsis stercoraria* (Hansen) Hansen, *A. fulvescens* (Cooke) de Vries.

Occasional skin lesions in mammals including man.

Ref. Mammals (*Erinaceus europaeus*, *Sorex araneus*, *Neomys anomalus*, *Clethrionomys glareolus*, *Microtus arvalis*, *M. subterraneus*, *Apodemus agrarius*, *A. flavicollis*, *A. sylvaticus*, *Tatera indica*, *Millardia melitana*, *Oryctolagus cuniculus*, *Dama dama*, *Sus scrofa* - lesions) in India, Czechland, Slovakia, Yugoslavia, Denmark, Belgium and France [12,16-20]. Birds (*A. anser*, *Anas platyrhynchos*, *Fulica atra*, *Phasianus colchicus*, *Tringa glareola*, *Tyto alba*, *Ficedula hypoleuca*, *Phylloscopus collybita*, *Panurus biarmicus*, *Turdus merula*, *Phoenicurus ochruros*, *S. serinus*, *Emberiza schoeniclus*, *Passer domesticus*, *P. montanus*, *Corvus monedula*, *P. pica*) and their nests (*Podiceps cristatus*, *P. nigricollis*, *P. ruficollis*, *Ixobrychus minutus*, *Aythya fuligula*, *Larus ridibundus*, *Columba livia*, *Streptopelia decaocto*, *Tyto alba*, *Anthus trivialis*, *Motacilla alba*, *Ficedula albicollis*, *P. collybita*, *Acrocephalus arundinaceus*, *Turdus philomelos*, *T. merula*, *Lanius collurio*, *Parus major*, *P. ater*, *Hirundo rustica*, *Delichon urbica*, *R. riparia*, *Carduelis chloris*, *Fringilla coelebs*, *P. montanus*, *Sturnus vulgaris*) in England, Czechland, Yugoslavia and Denmark [14,15,17,21-25]. Bird pellets (*Bubo virginianus*, *Tyto alba*, *Asio otus*, *Falco tinnunculus*, *Merops apiaster*) in England, Czechland, Yugoslavia, Denmark and Canada [9,14,15,17, 26,27].

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***Aphanoascus keratinophilus*** Punsola et Cano

Anam. *Chrysosporium keratinophilum* (Frey) Carmichael.

Ref. Mammals (*Crocidura russula*, *Sorex sp.*, *Talpa europaea*, *Clethrionomys glareolus*, *Microtus arvalis*, *Apodemus flavicollis*, *A. sylvaticus*, *Tatera indica*, *Rattus rattus*, *R. norvegicus*, *Mus platythrix*, *Funambulus palmarum*, *Bandicota indica*, *Oryctolagus cuniculus*) in Germany, Czechland, Slovakia, Yugoslavia, India, Nigeria and France [12,16,19,20,28,29]. Birds (*Anas platyrhynchos*, *Aythya fuligula*, *Larus argentatus*, *Lagopus lagopus*, *Phasianus colchicus*, *Dendrocopos major*, *Columba livia*, *Galerida cristata*, *Sylvia curruca*, *Phylloscopus collybita*, *P. trochilus*, *Acrocephalus scirpaceus*, *Turdus philomelos*, *T. merula*, *Parus major*, *Passer domesticus*, *P. montanus*, *C. carduelis*, *S. serinus*, *Sturnus vulgaris*, *Corvus monedula*, *P. pica*) and their nests (*P. puffinus*, *Streptopelia decaocto*, *Tyto alba*, *D. major*, *G. cristata*, *Hirundo rustica*, *Delichon urbica*, *R. riparia*, *Motacilla cinerea*, *Muscicapa striata*, *Ficedula albicollis*, *Sylvia atricapilla*, *P. collybita*, *T. merula*, *Prunella modularis*, *Phoenicurus ochruros*, *Lanius collurio*, *P. major*, *P. ater*, *Sitta europaea*, *Carduelis chloris*, *C. cannabina*, *S. serinus*, *Fringilla coelebs*, *P. domesticus*, *P. montanus*, *S. vulgaris*, *C. monedula*) in England, Czechland, Yugoslavia, Russia and France [14,15,21,24,25,30-33]. Bird pellets (*Falco tinnunculus*, *Asio otus*, *Merops apiaster*) in England, Czechland and Yugoslavia [14,15,27].

***Aphanoascus reticulisporus*** (Routien) Hubalek

Syn. *Anixiopsis reticulisporea* Routien.

Anam. *Chrysosporium* sp.

Ref. Rodents (*Apodemus flavicollis*), Yugoslavia [12]. Birds (*Passer domesticus*, *Corvus monedula*) and their nests (*Carduelis cannabina*, *C. monedula*) in Czechland, Yugoslavia and India [14,15,34].

***Aphanoascus terreus*** (Randhawa et Sandhu)

Apinis

Syn. *Keratinophyton terreum* Randhawa et Sandhu.

Anam. *Chrysosporium indicum* (Randhawa et Sandhu) Garg.

Ref. Mammals (*Suncus murinus*, *Neomys anomalus*, *Apodemus agrarius*, *A. flavicollis*, *A. sylvaticus*, *Mus platythrix*, *M. musculus*, *Tatera indica*, *Rattus rattus*, *R. norvegicus*, *Cricetomys gambianus*, *Funambulus palmarum*, *Cervus elaphus*, *V. vulpes*) in Romania, Germany, India, Czechland, Yugoslavia, Nigeria [12,16,25,29,35,36]. Birds (*Cygnus olor*, *A. anser*, *Fulica atra*, *Phasianus colchicus*, *Tringa glareola*, *Larus ridibundus*, *Streptopelia turtur*, *Upupa epops*, *Parus major*, *C. coccyzoides*, *Passer domesticus*, *P. montanus*), their nests (*Podiceps nigricollis*, *Ixobrychus minutus*, *Anas strepera*, *Falco tinnunculus*, *F. atra*, *V. vanellus*, *L. ridibundus*, *Tyto alba*, *Hirundo rustica*, *Turdus philomelos*, *T. merula*, *Carduelis chloris*, *P. montanus*, *Emberiza citrinella*) and pellets (*Asio otus*) in Czechland, Yugoslavia and India [14,15,24,34,37].

Coll. UAMH 2557: *Milvus migrans*, Queensland, 1965 (R.G. Rees H427), UAMH 3226: dead bird, California, 1969 (J. W. Carmichael).

***Apinisia queenslandica*** Apinis et Rees

Syn. *Chrysosporium articulatum* Sharapov.

Ref. *Passer domesticus*, India [38].

Coll. UAMH 4320: *Sicista betulina*, Novosibirsk, Russia, 1974 (V. M. Sharapov VKM-F2116) = CBS 662. 78. UAMH 4709: *Apodemus agrarius*, Novosibirsk, Russia, 1974 (V. M. Sharapov VKM-F2117) = CBS 663. 78.

***Arthroderma benhamiae*** Ajello et Cheng

Anam. *Trichophyton mentagrophytes* (Robin) Blanchard. Three anamorph varieties of this zoophilic dermatophyte are associated with free-living vertebrates:

*T. m.* var. *mentagrophytes*;

*T. m.* var. *quinckeanum* (agent of classical mouse favus);

*T. m.* var. *erinacei* (= *T. proliferans* English et Stockdale).

*T. m. mentagrophytes* is an important zoophilic dermatophyte transmissible to humans principally from mammals, especially rodents [39-44], but also kangaroos [45,46]. Wild rodents are reservoirs for *T. mentagrophytes* in agroecosystems.

Ref. Mammals (*Erinaceus europaeus* - lesions, *Talpa europaea*, *Sorex araneus*, *Ondatra zibethicus* - lesions, *Myocastor coypus* - lesions, *Arvicola terrestris*, *Microtus agrestis*, *M. arvalis*, *M. oeconomus* - lesions, *M. pennsylvanicus*, *Clethrionomys glareolus*, *C. rutilus*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Peromyscus gossypinus*, *P. polionotus*, *P. maniculatus*, *Dipodomys ordii*, *Rattus norvegicus*, *R. rattus*, *R. exulans*, *Funambulus palmarum*, *Mus musculus*, *Meriones erythrorurus*, *Sigmodon hispidus*, *Hystrix africaeaustralis*, *Sciurus carolinensis*, *S. vulgaris* - lesions, *Lepus europaeus* - lesions, *L. americanus* - lesions, *Sus scrofa*, *Cervus elaphus*, *Odocoileus virginianus*, *Capra ibex*, *B. bison*, *Canis lupus*, *C. latrans*, *Procyon lotor* - lesions, *M. mephitis*, *Mustela nigripes*, *Taxidea taxus*, *V. vulpes*, *M. meles*, *Macropus major*, *Wallabia* spp., *Trichosurus vulpecula*, *Didelphis marsupialis*, *D. virginianus*, *Glossophaga soricina*, *Pteronotus psilotus*) in USA, Australia, New Zealand, Egypt, Africa, Azerbaijan, Romania, Slovakia, England, Russia, Germany, Italy, France, Austria, Croatia, Poland, India, Nigeria, Columbia [20,25,28,29,35,36,41,42,44-77]. Birds (*Tympanuchus phasianellus* - favus, *Fulica atra*, *Sylvia curruca*, *Emberiza schoeniclus*), USA and Czechland [25,64,78].

Coll. UAMH 3490: *Passer montanus* nest, Bzenec, Czechland, 1971 (Z. Hubalek 909A). 552A: an abandoned (and by rodents visited) nest of *Anas strepera* near Pohorelice, Czechland, 1970 (Z. Hubalek, confirmed by L. Sigler).

*T. m. quinckeanum* (Zopf) Smith et Austwick causes favus in mice, less often in fox, squirrel, domestic mammals (e.g., cat) and humans. Wild mice have been described as a cause of human favus in, e.g., Australia, Hungary, Yugoslavia and Russia [54,61,79-81].

Ref. Isolated from wild rodents during epizootics of favus in Hungary [80] and S. Australia [79].

*T. m. erinacei* (Smith et Marples) Padhye et Carmichael causes skin disease in hedgehogs (England, France, Israel, New Zealand), transmissible to humans [63,82-84].

Ref. Mammals (*Erinaceus europaeus* - skin lesions on the head especially on ear lobes, *E. albiventris*, rarely in *Apodemus sylvaticus*, *Microtus agrestis*, *Mus musculus* and *Rattus norvegicus*) in New Zealand, England, Austria, Italy, Israel and Kenya [56,63,67,74,85-93]. Also in hibernating hedgehogs and their nests in England [94]. Two of eight marked wild *E. europaeus* become infected (presumably through bodily contact) in Bushy Park (London) during the study period of about 15 months [90]. Generally, 20-25% of *E. europaeus* are infected in England. Pathogenicity of the fungus for hedgehog is low, but the infection usually persists throughout life.

***Arthroderma borellii*** (Moraes, Padhye et Ajello) Padhye, Weitzman, McGinnis et Ajello

Syn. *Nannizzia borellii* Moraes, Padhye et Ajello.

Anam. *Microsporium amazonicum* Moraes, Borelli et Feo.

Ref. Rodents (*Oryzomys* sp., *Proechimys cayenensis*) in Brazil [95-96].

***Arthroderma cajetani*** (Ajello) Weitzman, McGinnis, Padhye et Ajello

Syn. *Nannizzia cajetani* Ajello.

Anam. *Microsporium cookei* Ajello. Probably identical [97] is *A. racemosum* (Rush-Munro, Smith et Borelli) Weitzman, McGinnis, Padhye et Ajello [basonym *Nannizzia racemosa* Rush-Munro, Smith et Borelli, anam. *Microsporium racemosum* Borelli].

Ref. Mammals (*Erinaceus europaeus*, *Sorex araneus*, *Neotoma floridana*, *Microtus arvalis*, *Clethrionomys glareolus*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *A. microps*, *Peromyscus gossypinus*, *P. polionotus*, *P. nuttalli*, *Mus musculus*, *Sigmodon hispidus*, *Reithrodontomys humulis*, *Rattus rattus*, *R. norvegicus*, *R. assimilis*, *R. lutreolus*, *Melomys cervinipes*, *Sciurus vulgaris*, *Sylvilagus floridanus*, *Oryctolagus cuniculus*, *Didelphis marsupialis*, *Isoodon macrourus*, *Trichosurus vulpecula*, *Perameles nasuta*, *Macropus major*, *Pseudocheirus laniginosus*, *Aepyprymnus rufescens*, *M. mephitis*, *Procyon lotor*, *M. meles*) in USA, New Zealand, Czechland, Slovakia, Yugoslavia, Romania, Germany, England, France, Italy, Venezuela, Brazil and Australia [12,19,28,35,41,51,52,57,63,64,67,69,72,100-105]. Birds (*Anas acuta*, *A. platyrhynchos*, *A. crecca*, *Aythya ferina*, *Fulica atra*, *Sterna hirundo*, *Larus argentatus*, *Alectura lathamii*, *Columbiformes*, *Cuculiformes*, *Turdus merula*, *Parus major*, *C. coccothraustes*, *Passer montanus*, *Sturnus vulgaris*, *Emberiza schoeniclus*, other *Passeriformes*) and their nests (*Delichon urbica*, *P. major*, *Corvus monedula*) in Australia, England, Czechland and Russia [14,15,21,31,32,106].

Coll. UAMH 3282: 'rat', Mysore, India, 1969 = CDC B359.

***Arthroderma ciferrii*** Varsavsky et Ajello

Anam. *Chrysosporium georgii* (Varsavsky et Ajello) van Oorschot.

Syn. *Trichophyton georgiae* Varsavsky et Ajello.

Ref. Mammals (*Clethrionomys glareolus*, *Apodemus flavicollis*, *A. sylvaticus*, *Oryctolagus cuniculus*) in Yugoslavia, Czechland, Austria and France [12,20,74]. Birds (*Columba livia*, *Merops apiaster*, *Dendrocopos major*, *R. riparia*, *Acrocephalus scirpaceus*, *Turdus merula*, *Aegithalos caudatus*, *Parus cyanus*, *P. major*, *P. caeruleus*, *P. palustris*, *Passer domesticus*, *P. montanus*, *Sturnus vulgaris*, *Corvus frugilegus*, *Carduelis cannabina*), their nests (*Anas platyrhynchos*, *Hirundo rustica*, *Delichon urbica*, *R. riparia*, *Muscicapa striata*, *P. phoenicurus*, *Parus ater*, *Sitta europaea*, *P. domesticus*, *P. montanus*, *Sturnus vulgaris*) and pellets (*Asio otus*) in Czechland, Yugoslavia, Russia and France [14,15,22-25, 32,33,107].

Coll. UAMH 1677: hedgehog (M. J. Marples). UAMH 2535: *Didelphis marsupialis*, Georgia, USA, 1958 (S. McKeever) = ATCC 44005. UAMH 2560: *Rattus assimilis*, Queensland, 1965 (R. G. Rees H432). UAMH 4016: wild mouse 1976 (L. Kapica 11).

***Arthroderma cuniculi*** Dawson

Ref. Mammals (*Oryctolagus cuniculus* burrows and hair, *Neomys anomalus*, *Crocidura russula*, *Clethrionomys glareolus*, *Microtus arvalis*, *Apodemus flavicollis*, *A. sylvaticus*, *Rattus norvegicus*, *R. assimilis*, *Melomys cervinipes*, *M. lutillus*, *Hydromys chrysogaster*, *Uromys caudimaculatus*, *Isoodon macrourus*, *Trichosurus vulpecula*, *Perameles nasuta*, *Schoinobates volans*,

*Pseudocheirus laniginosus*) in Scotland, Australia, Yugoslavia, Czechland and France [12,20,103,108]. Birds (*Climacteris leucophaea*, *Phasianus colchicus*, *Parus major*, *Passer domesticus*), their nests (*Prunella modularis*, *Turdus merula*) and pellets (*Asio otus*) in England, Australia, Czechland, Yugoslavia and India [14,15,30, 34,106].

***Arthroderma curreyi*** Berkeley

Ref. Mammals (*Oryctolagus cuniculus* burrows and hair, *Erinaceus europaeus*, *Sorex araneus*, *Neomys anomalus*, *N. fodiens*, *Crocidura suaveolens*, *C. russula*, *Talpa europaea*, *Clethrionomys glareolus*, *Microtus arvalis*, *M. subterraneus*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Rattus rattus*, *R. norvegicus*, *R. assimilis*, *R. conatus*, *R. lutreolus*, *Melomys cervinipes*, *M. lutillus*, *Hydromys chrysogaster*, *Uromys caudimaculatus*, *Isoodon macrourus*, *Trichosurus caninus*, *Perameles nasuta*, *D. dama*, *Rhinolophus ferrumequinum*) in Great Britain, Australia, Yugoslavia, Czechland, Denmark, France [12,17,20,56,64,103,108]. Birds (*Phasianus colchicus*, *P. perdix*, *Alectura lathamii*, *Monarcha trivirgata*, *Pitta versicolor*, *Colluricincla megarhyncha*, *Psophodes olivaceus*, *Tringa glareola*, *Scolopax rusticola*, *Larus ridibundus*, *Tyto alba*, *Columba livia*, *R. riparia*, *Motacilla alba*, *Acrocephalus palustris*, *A. scirpaceus*, *A. schoenobaenus*, *Sylvia communis*, *Phylloscopus collybita*, *Turdus merula*, *T. philomelos*, *T. iliacus*, *Erithacus rubecula*, *Luscinia megarhynchos*, *Prunella modularis*, *T. troglodytes*, *Parus major*, *P. caeruleus*, *Panurus biarmicus*, *Sitta europaea*, *C. coccothraustes*, *Carduelis cannabina*, *C. spinus*, *Fringilla coelebs*, *Passer domesticus*, *P. montanus*, *Sturnus vulgaris*, *Corvus corone*, *C. monedula*, *P. pica*, *Garrulus glandarius*, *Emberiza citrinella*, *E. schoeniclus*), their nests (*Anas platyrhynchos*, *A. strepera*, *P. colchicus*, *Fulica atra*, *L. ridibundus*, *Hirundo rustica*, *R. riparia*, *Muscicapa striata*, *Ficedula albicollis*, *T. merula*, *T. philomelos*, *P. major*, *S. europaea*, *P. domesticus*, *P. montanus*) and pellets (*Asio otus*) in England, Australia, Czechland, Yugoslavia, Denmark, Italy and France [13-15,17,21,24,25,30,31,33,67,106, 109,110].

***Arthroderma flavescens*** Rees

Anam. *Trichophyton flavescens* Padhye et Carmichael.

Ref. Birds (*Trichoglossus moluccanus*, *Halcyon sancta*) in Queensland [106,111].

***Arthroderma fulvum*** (Stockdale) Weitzman, McGinnis, Padhye et Ajello

Syn. *Nannizzia fulva* Stockdale.

Anam. *Microsporium fulvum* Uriburu, closely related to *M. gypseum* (*Microsporium gypseum* complex) [112] and usually not differentiated in ecological studies. See *Arthroderma gypseum*.

***Arthroderma gloriae*** Ajello

Anam. *Trichophyton gloriae* Ajello.

Ref. *Mustela frenata*, USA [64].

***Arthroderma grubyi*** (Georg, Ajello, Friedman et Brinkman) Ajello, Weitzman, McGinnis et Padhye

Syn. *Nannizzia grubyia* Georg, Ajello, Friedman et Brinkman.

Anam. *Microsporium vanbreuseghemii* Georg, Ajello, Friedman et Brinkman. Possibly identical to *M. gallinae* (Megnin) Grigorakis [97]. Occasional infections in dog, cat and man.

Ref. Mammals (*Ratufa indica*, stray *Felis catus*, *Sciurus vulgaris*) in India, Italy and Czechland [64,113,114].

***Arthroderma gypseum*** (Nannizzi) Weitzman, McGinnis, Padhye et Ajello, and

***Arthroderma incurvatum*** (Stockdale) Weitzman, McGinnis, Padhye et Ajello

Syn. *Nannizzia gypsea* (Nannizzi) Stockdale, and *N. incurvata* Stockdale, respectively.

Anam. *Microsporium gypseum* (Bodin) Guiart et Grigorakis.

In ecological studies, these two teleomorph species (and *A. fulvum*), i. e. the *Microsporium gypseum* anamorph complex, are usually not differentiated. *Microsporium gypseum* is a typical geophilic dermatophyte, causing infrequent skin infections in mammals including man and in domestic and caged birds.

Ref. Mammals (*Erinaceus europaeus*, *Sorex araneus*, *Crocidura leucodon*, *Suncus murinus*, *Clethrionomys glareolus*, *Microtus arvalis*, *M. subterraneus*, *Apodemus flavicollis*, *A. sylvaticus*, *Peromyscus gossypinus*, *P. polionotus*, *Sigmodon hispidus*, *Reithrodontomys humulis*, *Mus platythrix*, *M. musculus*, *Rattus norvegicus*, *R. rattus*, *R. assimilis*, *Melomys lutilius*, *Arvicanthus niloticus*, *Tatera indica*, *Meriones hurriane*, *Sciurus carolinensis*, *Lepus europaeus*, *Oryctolagus cuniculus*, *D. dama*, *Rupicapra rupicapra* - lesions, *Isodon macrourus*, *Didelphis marsupialis*, *Procyon lotor*, *M. mephitis*, *Macropus major*, *Wallabia rufogrisea*) in USA, Czechland, Egypt, England, Slovakia, Germany, Australia, Romania, Philippines, Italy, France, India and Nigeria [16,19,28,29,36,41,46,50-53,55,64,66,67,69,71,72,100,103,115-120]. Birds (*Apteryx australis*, *Alectura lathami*, *Trichoglossus chlorolepidotus*, other *Psittaciformes*, *Passer domesticus*, *P. montanus*, *Garrulus glandarius*), their nests (*Turdus merula*, *T. philomelos*, *Carduelis cannabina*) and pellets (*Corvus frugilegus*) in England, Australia, Czechland and New Zealand [14,15,30,31,63,106].

***Arthroderma insingulare*** Padhye et Carmichael

Anam. *Trichophyton terrestre* Durie et Frey (often red-pigmented strains). See also *Arthroderma quadrifidum*.

Ref. Birds (*Aythya fuligula*, *A. apus*, *Hirundo rustica*, *R. riparia*, *Phylloscopus collybita*, *Locustella luscinioides*, *Acrocephalus arundinaceus*, *A. schoenobaenus*, *S. serinus*, *Passer domesticus*), Czechland [25].

Coll. UAMH 3431: rodent, Czechland, 1967 (M. Otcenasek, 'T. terrestre - red') = CDC X-751.

***Arthroderma lenticularum*** Pore, Tsao et Plunkett

Anam. *Trichophyton terrestre* Durie et Frey. See also *A. quadrifidum*.

Ref. Small mammals (*Neomys anomalus*, *Crocidura suaveolens*, *Apodemus flavicollis*) in Yugoslavia and Czechland [12]. Birds (*A. apus*, *Acrocephalus arundinaceus*, *A. scirpaceus*, *A. schoenobaenus*, *Sylvia curruca*, *Phylloscopus collybita*, *Lanius collurio*, *Parus major*, *P. caeruleus*, *Passer domesticus*, *P. montanus*, *Emberiza citrinella*), Czechland and Yugoslavia [14,15,25].

***Arthroderma melis*** Krivanec, Janeckova et Otcenasek.

Anam. *Trichophyton melis* Krivanec, Janeckova et Otcenasek.

Ref. Burrows with nests of *M. meles* and *V. vulpes*, Czechland [12].

***Arthroderma multifidum*** Dawson

Ref. Lagomorphs (*Oryctolagus cuniculus* hair and burrows) in Scotland and France [20,108], and rodent nests in Slovakia [19]. Birds (*Rallus aquaticus*, *Riparia riparia*, *Motacilla flava*, *Sylvia borin*, *Acrocephalus scirpaceus*, *A. schoenobaenus*, *Passer domesticus*, *P. montanus*, *Corvus monedula*) and their nests (*Delichon urbica*, *R. riparia*, *P. montanus*), Czechland and Yugoslavia [14,15,25,31].

Coll. UAMH 2783: *Thomomys talpoides* burrow, Edmonton, 1967 (D. Remington).

***Arthroderma obtusum*** (Dawson et Gentles) Weitzman, McGinnis, Padhye et Ajello

Syn. *Nannizzia obtusa* Dawson et Gentles.

Anam. *Microsporium nanum* Fuentes. A zoophilic dermatophyte, causing skin disease in pig, man, and wild monkeys (in Africa).

Ref. A wild mouse in Germany [28].

***Arthroderma otae*** (Hasegawa et Usui) McGinnis, Weitzman, Padhye et Ajello

Syn. *Nannizzia otae* Hasegawa et Usui.

Anam. *Microsporium canis* Bodin. A zoophilic dermatophyte, often detected in domestic or stray cats and dogs, but very rarely in free-living wild mammals.

Ref. Mammals (*Urocyon cinereoargenteus*, *Rattus rattus*, *R. norvegicus*, *Mus musculus*), USA and Italy [64,66,67].

***Arthroderma persicolor*** (Stockdale) Weitzman, McGinnis, Padhye et Ajello

Syn. *Nannizzia persicolor* Stockdale.

Anam. *Microsporium persicolor* (Sabouraud) Guiart et Grigorakis. A zoophilic species, transmissions from rodents to man were described [122].

Ref. Mammals (*Neomys anomalus*, *Sorex araneus*, *Clethrionomys glareolus*, *C. gapperi*, *Microtus arvalis*, *M. agrestis*, *M. oeconomus*, *Apodemus sylvaticus*, *A. flavicollis*, *Peromyscus maniculatus*, *C. cricetus*, *Eliomys quercinus*, *Pipistrellus pipistrellus*), with occasional skin lesions in *Clethrionomys* and *Microtus* voles, in England, France, Canada, Yugoslavia, Austria, Italy, Czechland and Slovakia [12,20,60,67,68,72-74,104,116,117,122-129]. Birds (*Acrocephalus scirpaceus*, *A. schoenobaenus*) in Czechland [25].

Coll. UAMH 2557: fork-tailed kite, Australia (R. G. Rees H427).

***Arthroderma quadrifidum*** Dawson et Gentles

Anam. *Trichophyton terrestre* Durie et Frey. Syn. *T. thuringiense* Koch. Red-pigmented isolates of *T. terrestre* might be mildly pathogenic for small mammals [56].

Ref. Mammals (*Erinaceus europaeus*, *Sorex araneus*, *S. alpinus*, *Neomys fodiens*, *N. anomalus*, *Crocidura suaveolens*, *C. leucodon*, *C. russula*, *Talpa europaea*, *Ondatra zibethicus*, *Clethrionomys glareolus*, *Microtus arvalis*, *M. agrestis*, *M. subterraneus*, *M. pennsylvanicus*, *M. ochrogaster*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Peromyscus maniculatus*, *P. polionotus*, *Onychomys leucogaster*, *Dipodomys ordii*, *Erethizon dorsatum*, *Micromys minutus*, *Mus musculus*, *Rattus norvegicus*, *R. rattus*, *R. assimilis*, *Sciurus niger*, *Lepus europaeus*, *L. americanus*, *O. cuniculus*, *Capreolus capreolus*, *Cervus elaphus*, *D. dama*, *Odocoileus virginianus*, *O. hemionus*, *Antilocapra americana*, *Canis latrans*, *Vulpes fulva*, *V. vulpes*, *Mustela vison*, *Taxidea taxus*, *M. meles*, *P. putorius*, *Trichosurus vulpecula*) in New Zealand, Great Britain, Czechland, Romania, Russia, Germany, Australia, USA, Italy, France, Slovakia, Yugoslavia, Denmark, Austria and Poland [12,17,19,20,28,35,36,41,56,61,63,64,66-70,72,74,76,85,100,103,108,115,119,130]. Birds (*Anas platyrhynchos*, *A. acuta*, *A. strepera*, *A. querquedula*, *A. crecca*, *A. clypeata*, *Aythya ferina*, *A. nyroca*, *A. fuligula*, *Mergus albellus*, *Falco tinnunculus*, *Fulica atra*, *C. coturnix*, *L. lagopus*, *Phasianus colchicus*, *Larus argentatus*, *Tyto alba*, *Merops apiaster*, *Columba livia*, *Dendrocopos major*, *R. riparia*, *Motacilla flava*, *M. citreola*, *Locustella naevia*, *Acrocephalus scirpaceus*, *A. schoenobaenus*, *Phylloscopus collybita*, *Saxicola torquata*, *Turdus merula*, *T. philomelos*, *Erithacus rubecula*, *Luscinia megarhyn-*

chos, *Phoenicurus ochruros*, *Lanius collurio*, *Aegithalos caudatus*, *Parus major*, *P. caeruleus*, *P. palustris*, *P. cyanus*, *Carduelis cannabina*, *C. carduelis*, *C. chloris*, *S. serinus*, *Passer domesticus*, *P. montanus*, *Sturnus vulgaris*, *Corvus corone*, *C. monedula*, *C. frugilegus*, *P. pica*, *Emberiza citrinella*), their nests (*Ixobrychus minutus*, *A. fuligula*, *P. colchicus*, *Hirundo rustica*, *R. riparia*, *Sylvia atricapilla*, *P. collybita*, *T. philomelos*, *T. merula*, *Prunella modularis*, *E. rubecula*, *L. collurio*, *P. major*, *P. palustris*, *Sitta europaea*, *Fringilla coelebs*, *C. chloris*, *C. cannabina*, *P. domesticus*, *P. montanus*, *S. vulgaris*, *E. citrinella*) and pellets (*Falco tinnunculus*, *Asio otus*) in England, Czechland, Yugoslavia, Russia and France [14,15,21-25,27,30-33,109,110,130].

***Arthroderma simii*** Stockdale, Mackenzie et Austwick

Anam. *Trichophyton simii* (Pinoy) Stockdale, Mackenzie et Austwick.

Ringworm in primates including man, dog and fowls (India, Africa, Brazil). Relatively often in animal hair and poultry feathers but not yet reported from wild birds.

Ref. Mammals (*Papio papio*, *Suncus murinus*, *Tatera indica*, *R. rattus*, *Mus platythrix*, *Funambulus palmarum*, *Bandicota indica*, *Nesokia indica*, *Millardia melatada*, *Meriones hurriane*) in Guinea and India [16,131,132]. Also reported from an asymptomatic *Microtus arvalis* in E. Bohemia, Czechland but mating studies of the isolate with *A. simii* were unsuccessful [114].

***Arthroderma tuberculatum*** Kuehn

Rare human infections have been described.

Ref. Mammals (*Rattus rattus*, *Dipodomys ordii*, *Melomys cervinipes*, *Isoodon macrourus*, *Macropus major*, *Pseudocheirus laniginosus*) in Australia and USA [64,70,103]. Birds (*Alectura lathamii*, *Trichoglossus chlorolepidotus*, other *Psittaciformes*, *Dendrocopos major*, *A. apus*, *Hirundo rustica*, *R. riparia*, *Acrocephalus scirpaceus*, *A. schoenobaenus*, *Phylloscopus collybita*, *Remiz pendulinus*, *Turdus americanus*, *Parus major*, *Aegithalos caudatus*, *Passer domesticus*, *P. montanus*, *Sturnus vulgaris*, *Emberiza citrinella*), their nests (*Tyto alba*, *Delichon urbica*, *R. riparia*, *Ficedula albicollis*, *P. phoenicurus*, *Parus palustris*, *Sturnus vulgaris*, *P. montanus*) and owl pellets in USA, Australia, Czechland, Yugoslavia, Russia and India [14,15,23-25,32,34,37,106,133].

***Arthroderma uncinatum*** Dawson et Gentles

Anam. *Trichophyton (Keratinomyces) ajelloi* (Vanbruseghem) Ajello.

A typical geophilic dermatophyte, causing rare skin infections in mammals including man.

Ref. Mammals (*Erinaceus europaeus*, *Talpa europaea*, *Clethrionomys glareolus*, *Microtus arvalis*, *M. pennsylvanicus*, *M. subterraneus*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Mus musculus*, *Rattus rattus*, *R. norvegicus*, *Sciurus vulgaris*, *Lepus eropaeus*, *Oryctolagus cuniculus*, *Trichosurus vulpecula*, *D. dama*, *B. bison*) in New Zealand, Australia, Czechland, Scotland, England, Slovakia, Germany, USA, Romania, France, Yugoslavia, Italy and Poland [12,17,19,20,28,36,41,60,63,64,67,69,72,76,98-100,103,105,108,115,124,134]. Birds (*Phasianus colchicus*, *Passer domesticus*), their nests (*Delichon urbica*, *Muscicapa striata*, *Erethacus rubecula*, *Prunella modularis*, *Turdus merula*, *T. philomelos*, *Carduelis chloris*, *C. cannabina*, *Passer montanus*) in England, Czechland, Yugoslavia and Japan [14,15,21,30,31,135].

***Arthrographis kalrae*** (Tewari et Macpherson) Sigler et Carmichael

Syn. *Oidiodendron kalrai* Tewari et Macpherson. Onychomycosis and skin lesions in humans sporadically.

Coll. UAMH 4164, 4165: *Setonyx brachyurus* (wallaby) hair, W. Australia, 1978 (R. McAleer).

***Auxarthron umbrinum*** (Boudier) Orr et Plunkett

Syn. *Myxotrichum brunneum* Rostrup, *Auxarthron brunneum* (Rostrup) Orr et Kuehn.

Anam. *Malbranchea albolutea* Sigler et Carmichael.

Ref. Mammals (*Erinaceus europaeus*, *Apodemus sylvaticus*, *Rattus rattus*, *R. norvegicus*, *Cricetomys gambianus*) in Denmark, Macedonia, Bosnia and Nigeria [12,17,29]. Birds (*Phasianus colchicus*, *Passer domesticus*) and their nests (*R. riparia*, *Turdus merula*) in Czechland and Denmark [14,15,17].

Coll. UAMH 161, 162: *Neotoma micropus* (lungs), Texas, 1949 (C. W. Emmons A4718 & A 4966). UAMH 1587: *Thomomys burrow*, California, 1961 (O. A. Plunkett 350). UAMH 4434: badger burrow soil, Queensland, 1981 (L. Sigler).

***Auxarthron zuffianum*** (Morini) Orr et Kuehn

Syn. *Gymnoascus zuffianus* Morini.

Ref. Mammals (*Thomomys burrow*, *Tatera indica*, *Mus platythrix*, *Meriones hurrianae*, *Clethrionomys glareolus*, *Microtus arvalis*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*) in USA, India, Yugoslavia and Czechland [5,12,16]. Bird pellets (*Merops apiaster*), Yugoslavia [14,15].

***Chrysosporium evolceanui*** (Randhawa et Sandhu)

Garg

Ref. Mammals (*Neomys anomalus*, *Crociodura leucodon*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Glis glis*, other rodents) in Australia, Germany, Yugoslavia and Czechland [12,26,36,103]. Birds (*Turdus merula*, *Passer domesticus*, *Sturnus vulgaris*, *Corvus monedula*) and their nests (*Delichon urbica*, *Turdus philomelos*, *Carduelis chloris*, *C. monedula*) in Czechland, Yugoslavia and India [14,15,25,34].

Coll. UAMH 1361: *Apodemus* sp., England (M. J. Marples E32). UAMH 2554: *Tyto alba*, Queensland, 1965 (R.G. Rees H201). UAMH 2555: *Ocyphaps lophotes* (crested pigeon), Queensland, 1965 (R. G. Rees H440). UAMH 2556: *Phalacrocorax*, Queensland, 1964 (R.G. Rees H239). UAMH 2770: rabbit, Alberta, 1967 (D. Remington).

***Chrysosporium lobatum*** Scharapov

Coll. UAMH 4321: mouse hair, Rostov, Russia, 1969 (V. M. Sharapov VKM-F2120) = CBS 666.78. UAMH 3434: *Passer domesticus* feathers, Valtice, Czechland, 1970 (Z. Hubalek) = G. F. Orr O-3278 = CBS 276.77.

***Chrysosporium lucknowense*** Garg

Ref. Rodents (*Apodemus flavicollis*, *A. agrarius*) in Yugoslavia and Czechland [12].

Birds (*Anas* sp., *Psittacula krameri*, *Phasianus colchicus*, *Parus major*, *Passer domesticus*) in Czechland and India [14,15,38].

Coll. CBS 251.72: feather, California, 1972 (G.F. Orr).

***Chrysosporium mephiticum*** Sigler

Coll. UAMH 791: feathers, California (G. F. Orr O-564). UAMH 2559: *Haliastur sphenurus*, Queensland, 1965 (R. G. Rees H428).

***Chrysosporium tropicum*** Carmichael

Teleom. *Aphanoascus* sp. [8].

Ref. Mammals (*Sorex araneus*, *Neomys anomalus*, *Crociodura suaveolens*, *Suncus murinus*, *Clethrionomys glareolus*, *Microtus arvalis*, *Apodemus flavicollis*, *A. sylvaticus*, *A. agrarius*, *Mus musculus*, *M. platythrix*,

*Oryzomys* sp., *Tatera indica*, *Rattus norvegicus*, *R. rattus*, *Funambulus palmarum*, *Bandicota indica*, *Nesokia indica*, *Millardia melitada*, *Cricetomys gambianus*, *Meriones hurriane*, *Oryctolagus cuniculus*) in Australia, Brazil, India, Yugoslavia, Czechland, Slovakia, Nigeria and France [12,16,19,20,29,95,103]. Birds (*Anas platyrhynchos*, *A. acuta*, *A. strepera*, *A. crecca*, *A. querquedula*, *A. clypeata*, *Aythya ferina*, *A. fuligula*, *Mergus albellus*, *Fulica atra*, *Chlidonias nigra*, *C. coturnix*, *Phasianus colchicus*, *Columba livia*, *Athene noctua*, *Upupa epops*, *Dendrocopos major*, *Motacilla flava*, *Locustella naevia*, *Acrocephalus schoenobaenus*, *Phylloscopus collybita*, *Luscinia svecica*, *Turdus merula*, *Erithacus rubecula*, *Luscinia megarhynchos*, *Phoenicurus ochruros*, *Lanius collurio*, *Remiz pendulinus*, *Parus major*, *P. caeruleus*, *C. carduelis*, *C. cannabina*, *S. serinus*, *Passer domesticus*, *P. montanus*, *Sturnus vulgaris*, *Corvus corone*, *C. monedula*, *C. splendens*, *P. pica*, *Emberiza schoeniclus*), their nests (*Podiceps ruficollis*, *Ixobrychus minutus*, *Larus ridibundus*, *Streptopelia decaocto*, *Tyto alba*, *A. apus*, *Ficedula albicollis*, *Acrocephalus scirpaceus*, *T. philomelos*, *T. merula*, *P. major*, *P. ater*, *C. cannabina*, *C. chloris*, *Fringilla coelebs*, *P. montanus*, *S. vulgaris*) and pellets (*Falco tinnunculus* - as *Aleurisma* sp., *Asio otus*, *Merops apiaster*) in England, Czechland, Yugoslavia, Russia and India [14,15,23-25,27,31,32,34,37,38].

***Ctenomyces serratus*** Eidam

Ref. Mammals (*Macropus major*, *Neomys anomalus*, *Tatera indica*, *Mus platythrix*, *Meriones hurrianae*, rodent nests) in Australia, Germany, India, Yugoslavia, Czechland and Slovakia [16,12,19,28]. Birds (*Anser anser*, *Anas clypeata*, *P. perdix*, *Phasianus colchicus*, *Francolinus pondicerianus*, *Coturnix* spp., *Galloperdix spadicea*, *Alectura lathami*, *V. vanellus*, *Merops apiaster*, *Upupa epops*, *Acrocephalus scirpaceus*, *Turdus merula*, *Carduelis cannabina*, *C. spinus*, *S. serinus*, *Passer domesticus*, *Sturnus vulgaris*, *Corvus monedula*), their nests (*P. puffinus*, *Anas platyrhynchos*, *Aythya ferina*, *P. colchicus*, *Larus ridibundus*, *Columba livia*, *Delichon urbica*, *T. philomelos*, *T. merula*, *C. carduelis*, *C. chloris*, *C. cannabina*, *S. serinus*, *Fringilla coelebs*, *P. domesticus*, *P. montanus*, *C. monedula*) and pellets (*Asio otus*, *M. apiaster*) in England, Czechland, Yugoslavia, India and Australia [13-15,21,23-25,30,37,67,106,109,110,136].

***Malbranchea arcuata*** Sigler et Carmichael

Ref. Rodents (*Apodemus flavicollis*, *A. sylvaticus*) in Macedonia and Bosnia [12].

Coll. UAMH 3844, 3845: *Merops apiaster* pellets in a nest, Pesirevo, S. R. Macedonia, 1968 (Z. Hubalek 232B & 236A). UAMH 3842: *Corvus monedula* feathers, S. R. Macedonia, 1968 (Z. Hubalek 153A).

***Malbranchea fulva*** Sigler et Carmichael

References: *Passer domesticus*, India [34].

***Malbranchea pulchella*** Saccardo et Penzig

Ref. Rodents (*Apodemus flavicollis*) in Yugoslavia [12]. Birds (*Passer domesticus*), their nests (*Sturnus vulgaris*) and pellets (*Corvus frugilegus*) in Czechland and India [14,15,34,37].

***Microsporium gallinae*** (Megnin) Grigorakis

Syn. *Trichophyton gallinae* (Megnin) Silva et Benham.

Teleom. *Arthroderma* sp. Very closely related or identical is *Arthroderma grubyi* [97].

A zoophilic dermatophyte causing favus in poultry, but only rarely reported in wild birds, primates including man, domestic mammals and not at all in wild mammals.

Ref. Favus in four wild *P. perdix*, Germany [137], and in a *Lyrurus tetrax*, Finland [138].

***Microsporium ripariae*** Hubalek et Rush-Munro

Teleom. *Arthroderma* sp. The species is related to, but different from, *Microsporium fulvum* [97].

Ref. Feathers and nests of *Riparia riparia* in Czechland [14,15,139].

***Monodictys levis*** (Wiltshire) Hughes

Ref. *Falco tinnunculus* pellets, England [27].

***Myriodontium keratinophilum*** Samson et Polonelli

Coll. IMI 235783: *Sorex araneus*, England, 1979 (A. Wright 528/78). UAMH 3435: *Phasianus colchicus* feathers, Valtice, Czechland, 1970 (Z. Hubalek) = G. F. Orr O-3297.

***Oncocladium flavum*** Wallroth

Syn. *Actinodendron verticillatum* (Smith) Orr et Kuehn, *Gymnoascus verticillatus* Smith.

Anam. *Malbranchea flava* Sigler et Carmichael.

Ref. Insectivores (*Neomys anomalus*) in Bosnia [12]. Birds (e.g., *Falco berigora*) in England and Australia [13,106].

***Onygena equina*** (Wildenow) Persoon

Coll. DAOM 124593: owl pellet, Australia. Wat-38: owl pellet, England (R. Watling).

***Onygena piligena*** (Schumacher) Fries

Syn. *Onygena corvina* Albertini et Schweinitz.

Ref. Rodents (*Apodemus sylvaticus*), Yugoslavia [12]. Pellets of birds of prey (*Asio otus*, other owl species, *Falco tinnunculus*) in Czechland, Japan and England [27,140,141].

Coll. 604: crow remains, Belgium. UAMH 3795: bird remains = CBS 152. 73. DAOM 48905: feather, British Columbia. MICH: mouse remains, Michigan (Smith). FH 7320: owl casting, USA (Thaxter).

***Shanorella spirotricha*** Benjamin

Ref. Birds (a crow, and *Monarcha trivirgatus*), USA and Australia [13,106].

Coll. UAMH 3116: owl pellet, Utah, 1963

(R. K. Benjamin RSA 1424). RSA 1517: owl pellet, California [9].

***Trichophyton phaseoliforme*** Borelli et Feo

Ref. Rodents (*Proechimys cayennensis*, *Heteromys anomalus*, *Rattus rattus*) in Venezuela [142].

***Trichophyton verrucosum*** Bodin

Only sporadic records of this important zoophilic dermatophyte are known in wild mammals but virtually never in birds. Sparrows (*Passer* spp.) have been suspected to carry the fungus from farm to farm.

Ref. Mammals (*Odocoileus hemionus*, *Talpa europaea* - lesions, *M. musculus* - lesions, *Apodemus sylvaticus*) in USA, Germany, Czechland, Australia and Poland [75,76,119,143,144].

***Uncinocarpus reesii*** Sigler et Orr

Anam. *Malbranchea* sp.

Ref. Rodents (*Rattus rattus*), Australia [103]. Birds (*Streptopelia decaocto*, *Parus major*, *Passer domesticus*, *Corvus monedula*, *P. pica*) and their nests (*Columba livia*, *Delichon urbica*, *Carduelis cannabina*, *C. monedula*) in Yugoslavia and Czechland, as *Auxarthron* sp. [14,15].

Coll. UAMH 4689: *Hirundo rustica* nest, Russia (V. M. Sharapov) = CBS 668.78.

***Uncinocarpus uncinatus*** (Eidam) Currah

Syn. *Myxotrichum* (*Gymnoascus*) *uncinatum* (Eidam) Schroeter.

Coll. RSA 425: owl pellet, California [9].

## Ecological aspects of the association of keratinophilic fungi with wild vertebrates

### Frequency of fungal species

The list presents a total of 52 species of KF. Table 1 summarizes published reports of KF isolated from free-living mammals, birds, and their nests or pellets. There is a certain bias in the records since about 7,000 of the mammals were examined selectively for the presence only of pathogenic dermatophytes (especially *T. mentagrophytes*), and non-pathogenic KF isolates were discarded. It is therefore not surprising that *A. benhamiae* is (together with *A. quadrifidum*) the most frequent species reported. Other KF species very often found in wild vertebrates include (in the decreasing order of frequency) *A. curreyi*, *C. tropicum*, *A. cajetani*, *A. uncinatum*, *C. serratus*, *A. ciferrii*, *A. gypseum* + *incurvatum* (*M. gypseum* complex), *A. keratinophilus*, *A. fulvescens*, *A. terreus* and *A. tuberculatum*.

**Table 1.** Reported isolations of individual species of KF from wild mammals and birds

	Mammals		Birds	
	Hair	Nests, burrows	Feathers	Nests, pellets
Total examined:	25,838	137	4,155	804
<i>Amauroascus albicans</i>	6	-	1	9
<i>Aphanoascus durus</i>	1	-	-	-
<i>A. fulvescens</i>	43	1	49	139
<i>A. keratinophilus</i>	90	1	57	93
<i>A. reticulisporus</i>	1	-	92	2
<i>A. terreus</i>	67	-	119	36
<i>Apinisia queenslandica</i>	2	-	4	-
<i>Arthroderma benhamiae</i> :				
<i>T. m. mentagrophytes</i>	1257	-	5	2
<i>T. m. quinckeanum</i>	>10	-	-	-
<i>T. m. erinacei</i>	182	14	-	-
<i>Arthroderma borellii</i>	8	-	-	-
<i>A. cajetani</i>	299	4	39	4
<i>A. ciferrii</i>	67	-	106	97
<i>A. cuniculi</i>	53	13	33	11
<i>A. curreyi</i>	216	2	289	64
<i>A. flavescens</i>	-	-	2	-
<i>A. glorieae</i>	1	-	-	-
<i>A. grubyi</i>	3	-	-	-
<i>A. gypseum, incurvatum, fulvum</i> ( <i>M. gypseum</i> complex)	207	1	28	11
<i>A. insingulare</i>	1	-	18	-
<i>A. lenticularum</i>	4	-	24	-
<i>A. melis</i>	-	2	-	-
<i>A. multifidum</i>	6	10	14	9
<i>A. obtusum</i>	1	-	-	-
<i>A. otae</i>	5	-	-	-
<i>A. persicolor</i>	472	2	3	-
<i>A. quadrifidum</i>	981	3	259	231
<i>A. simii</i>	99	-	-	-
<i>A. tuberculatum</i>	10	-	136	45
<i>A. uncinatum</i>	103	7	9	182
<i>Arthrographis kalrae</i>	1	-	-	-
<i>Auxarthron umbrinum</i>	17	2	3	2
<i>A. zuffianum</i>	12	1	-	3
<i>Chrysosporium evolceanui</i>	23	-	28	5
<i>C. lobatum</i>	1	-	1	-
<i>C. lucknowense</i>	3	-	8	-
<i>C. mephiticum</i>	-	-	2	-
<i>C. tropicum</i>	142	1	322	60
<i>Ctenomyces serratus</i>	73	1	160	56
<i>Malbranchea arcuata</i>	4	-	1	1
<i>M. fulva</i>	-	-	11	-
<i>M. pulchella</i>	1	-	11	2
<i>Microsporium gallinae</i>	-	-	5	-
<i>M. ripariae</i>	-	-	3	2
<i>Monodictys levis</i>	-	-	-	2
<i>Myriodontum keratinophilum</i>	1	-	1	-
<i>Oncocladium flavum</i>	1	-	3	-
<i>Onygena equina</i>	-	-	-	2
<i>O. piligena</i>	2	-	4	5
<i>Shanorella spirotricha</i>	-	-	2	2
<i>Trichophyton phaseoliforme</i>	10	-	-	-
<i>T. verrucosum</i>	6	-	-	-
<i>Uncinocarpus reesii</i>	1	-	13	6
<i>U. uncinatus</i>	-	-	-	1

### Mammals vs. birds

Rees [103,106] compared the frequency of occurrence of keratinophilic fungi between wild mammals and birds in Australia. Mammals were more often contaminated (21%) than birds (4%). However, only a few species (*A. cajetani*, *A. cuniculi*, *A. gypseum*) were significantly more common in mammals, while *A. tuberculatum* was more frequent in birds, and *C. serratus* was especially numerous in gallinaceous birds. Hubalek *et al.* [12] found that the proportion of KF isolated was the same between wild mammals and birds caught in Czechland and Yugoslavia, i. e., 18% of the total fungi. However, some genera (*Auxarthron*, *Malbranchea*, *Uncinocarpus*) and species (*A. curreyi*, *C. evolceanui*, *C. tropicum*, *M. arcuata*) were more frequent in mammals whereas other fungi in birds (*Aphanoascus*, *Ctenomyces*, *Microsporium*). Table 1 gives some idea of the distribution of KF between wild mammals and birds. KF species more frequently reported in mammals than in birds have been *A. benhamiae*, *A. borellii*, *A. cajetani*, *A. gypseum*, *A. otae*, *A. persicolor*, *A. simii*, *A. uncinatum*, *A. umbrinum*, *A. zuffianum*, *T. phaseoliforme* and *T. verrucosum*. On the other hand, KF species relatively more often reported in wild birds than in mammals have been *A. fulvescens*, *A. keratinophilus*, *A. reticulisporus*, *A. terreus*, *A. ciferrii*, *A. curreyi*, *A. insingulare*, *A. lenticularum*, *A. tuberculatum*, *C. evolceanui*, *C. lucknowense*, *C. tropicum*, *C. serratus*, *M. fulva*, *M. pulchella*, *M. gallinae*, *M. ripariae*, *O. piligena*, *S. spirotricha* and *U. reesii*.

### Host species

Pugh [30,109,110,136] and Pugh & Evans [21] observed affinity of *A. curreyi* to blackbirds and other *Turdus* spp., and that of *C. serratus* to galliform species, especially to the partridge. Pugh & Evans [145] further observed that feather fats of different bird species (blackbird, pheasant, pigeon) influence in diverse ways (i.e. stimulate, inhibit, or do not affect) the growth of some KF *in vitro*. For instance, *A. curreyi* was stimulated with feather fat obtained from blackbirds or pheasants but slightly inhibited with that from pigeons; *A. uncinatum* was markedly stimulated by pheasant, and inhibited by pigeon, feather fat. However, Hubalek [14] isolated *A. curreyi* quite frequently not only from *Turdidae* but also from birds of some other avian families, notably gulls and wetland birds. *T. m. erinacei* and *T. terrestre* 'red' are species closely associated with hedgehog, in fact its 'skin residents' [56]. Affinities of *A. persicolor* to *C. glareolus* and of *T. m. mentagrophytes* to *A. sylvaticus* have been repeatedly ascertained in Europe [20,72,73,124-126]. *A. keratinophilus*, *A. curreyi* and *A. cuniculi* have occurred more often on *C. glareolus* than on *A. sylvaticus* [20]. A significant association between *A. simii* and *Tatera indica* was observed in India [16]. Interestingly, *M. ripariae* has only been isolated from sand martins, and not from other avian species [14,15,139]. *A. ciferrii* was the dominant species in sparrows (*Passer* spp.), while *A. fulvescens*, *A. keratinophilus* and *C. tropicum* were distributed relatively equally among bird species [146]. However, *A. ciferrii* was also recovered very often from feathers of rooks [32].

### Host population density

Morris & English [89] found a greater frequency of *T. m. erinacei* in hedgehogs in New Zealand (47%) than in Great Britain (20%) and ascribed it to the higher population density of hedgehog in New Zealand compared to that in U. K.

### Host age and sex

Morris & English [89] recovered *T. m. erinacei* more often from male and adult hedgehogs than from female and juvenile animals. Mariat *et al.* [72] isolated *A. persicolor* and *T. mentagrophytes* more frequently from male than female rodents. Humpolickova & Otcenasek [25] found KF more frequently in adult birds than in the juveniles, and in males more than in females. Sarangi & Ghosh [34] observed a higher frequency of *A. terreus*, *A. reticulisporus* and *C. tropicum* in male than in female house sparrows, and in young than in adults; only *C. evolceanui* was more frequent in adults than in juvenile birds.

### Feathers/hair vs. nests

A few KF (*A. curreyi*, *A. quadrifidum*) occurred more frequently on feathers than in nests of birds whereas some other species (*A. fulvescens*, *A. uncinatum*) were more frequent in nests than in the plumage [15]. Table 1 indicates *A. fulvescens*, *A. keratinophilus*, *A. ciferrii*, *A. multifidum*, *A. quadrifidum*, *A. uncinatum* and *U. reesii* as KF relatively more frequent in bird nests than on feathers.

### Geographic area

Certain differences in keratinophilic mycoflora of wild vertebrates have been found between certain areas [103,124]. For instance, *A. simii* occurs enzootically in restricted areas of India [16]. Chabasse *et al.* [20] observed a different frequency of KF on small mammals within three geographic areas in France. Climatic and mesoclimatic conditions (e.g., coastal vs. continental areas) may play a role [34].

### Habitat

Many mycologists observed different frequencies of KF on wild vertebrates in various habitats [124].

#### Water vs. terrestrial habitats

*A. keratinophilus*, *A. cajetani*, *A. ciferrii*, *A. cuniculi*, *A. multifidum*, *A. quadrifidum*, *A. tuberculatum*, *A. uncinatum*, *Auxarthron* spp., *C. evolceanui*, *C. tropicum*, *C. serratus* and *M. ripariae* were isolated more frequently from terrestrial birds than from waterbirds. On the other hand, *A. fulvescens* and *A. terreus* were more frequent in waterbirds than in terrestrial birds [14,15].

#### Urban, rural and exoanthropic habitats

No significant differences in KF on small mammals were detected between urban and rural habitats in Germany [28]. On the other hand, Morris & English [89] recovered *T. m. erinacei* more often from hedgehogs in urban (17%) than in rural (9%) habitats, and as many as 47% of hedgehogs were infected in Bushy Park, London. Also Pesterev & Stadukhin [77] isolated *T. m. mentagrophytes* significantly more frequently from small mammals in man-inhabited areas than in exoanthropic habitats. Hubalek [15] recovered *A. quadrifidum*, *C. tropicum* and *C. serratus* more frequently in synanthropic birds whereas *A. terreus* prevailed in exoanthropic ones. Sharapov & Kuzmina [32] isolated more KF from birds living in intravillan habitats than from those in woodland and moorland. KF have been more often recovered from synanthropic mammals and birds than from exoanthropic animals [32,37,77,103,106]. In Italy, *M. canis* was isolated from synanthropic rodents but not from exoanthropic animals [67].

#### Woodland vs. openland habitats

*A. curreyi* was significantly more frequent in forest birds whereas *A. tuberculatum* prevailed in the birds of

open landscape [15]. Also Humpolickova & Otcenasek [25] isolated KF less frequently from birds living in woods than those occurring in other habitats in Czechland.

### Contact with the soil

Vertebrates with frequent contact with the soil generally harbour more KF than those without it [32,34,37]. Most importantly, virtually no KF were detected in 313 bats (Chiroptera) examined [67,106]. *A. fulvescens*, *A. ciferrii*, *A. cuniculi*, *A. multifidum*, *A. quadrifidum*, *A. tuberculatum*, *C. evolceanui* and *C. serratus* were significantly more often recorded in birds with frequent (active) contact with the soil, whereas only *A. curreyi* predominated in birds without pronounced contact with the soil [15].

### Seasonal distribution

The minimum occurrence of most fungi is generally in summer, whereas the peaks are often observed in autumn, and spring or winter in the temperate climatic zone. In India, most KF were isolated from house sparrows during the monsoon period, while the minimum was detected in summer [34]. Pesterev & Stadukhin [77] recovered *T. m. mentagrophytes* from small mammals more frequently in April and October than in other months. Buchvald *et al.* [69] isolated *A. quadrifidum* and *A. uncinatum* from *Microtus arvalis* in Slovakia more frequently in September than in May. A similar result was obtained [20] with *A. quadrifidum* on rabbit in France. Otcenasek (pers. comm.) found a peak of the occurrence of keratinophilic fungi (mainly *A. quadrifidum*) on small mammals in autumn (October–November) and a minimum in summer in S. Moravia; the same situation was found in birds' nests [147]. *Arthroderma* spp. (*A. ciferrii*, *A. quadrifidum*, *A. tuberculatum*) were most frequent in house sparrows in winter and spring, whereas *Aphanoascus fulvescens* seemed to prevail in late summer and winter, and *C. tropicum* and *C. serratus* in summer [23]. In the nests of tree sparrows, the summer and winter peaks were also observed for *A. fulvescens*, and spring and/or autumn peak for *A. keratinophilus*, *A. quadrifidum*, *A. tuberculatum*, *A. ciferrii*, *C. serratus*, *A. curreyi*, *A. terreus* and *C. tropicum* [147].

### Humidity

Pugh & Evans [21] isolated most KF from avian nests with a water content below 20%, but Hubalek *et al.* [146], Hubalek [24,151] and Hubalek & Balat [147] recorded KF more often in nests with >15% of water, and markedly hygrophilic (hygro-tolerant) spp. were *A. keratinophilus*, *A. fulvescens* and *A. terreus*. Covered avian nests (i.e. those in hollows, nests boxes, buildings) obviously provide better conditions for KF than open nests [31]. *A. keratinophilus*, *A. cajetani*, *A. ciferrii*, *A. cuniculi*, *A. multifidum*, *A. quadrifidum*, *A. tuberculatum*, *C. evolceanui*, *C. tropicum*, *C. serratus* and *M. ripariae* all prevailed in birds nesting in hollows or in well-covered nests lined mainly with keratinous material whereas only *A. terreus* and *A. curreyi* were more frequent in birds breeding in open nests [14,15,107]. Also Humpolickova & Otcenasek [25] found that the nests in holes harbour KF more frequently than those on the ground and on trees.

### Acidity

The influence of pH on the distribution of KF in birds' nests was ascertained by Pugh [30] and Pugh & Evans [21] who found *A. uncinatum* and *C. serratus* to be an acidophilic (acidotolerant) and an alkalophilic (alkalo-

tolerant) species, respectively, while *A. quadrifidum* preferred neutral to alkaline conditions. *A. keratinophilus* and *A. fulvescens* are alkalotolerant, they occur significantly more often in bird nests under neutral or alkaline conditions with pH>6.5, whereas *A. uncinatum* and *A. curreyi* are acidophilic (acidotolerant) species [146-148]. *A. uncinatum* only occurs infrequently in bird nests and even less so on birds and mammals in contrast to the soil; on the other hand, it is very common in arable and acid soils [31,106,145]. The pH value of feathers fluctuated between 4.4 and 6.8 (mean 5.7) in house sparrow during the year; in the breeding season, the range was 6.1 to 6.8 [23]; Pugh [30] recorded pH 5.5-7.3 (range) and 6.5 (mean) of feathers from various birds. There are no data about pH values of the hair of wild mammals.

### Substrate

The composition (keratin, plant material, etc.) of birds' nests was found to be an important factor in the distribution of KF [146,147], as well as the breeding stage, i.e., the presence of eggs, young or abandoning the nest after fledging. For instance, *A. keratinophilus* occurs more frequently in deserted and older nests than in those inhabited by birds, and *C. serratus* has a higher affinity to feathers than to hair in the nest lining [146].

## Pathogenic keratinophilic fungi in wild homoiothermous vertebrates

A majority of species of the ecological group of keratin decomposing fungi are true saprophytes but some species are potentially pathogenic for homoiotherm verte-

brates. The host and/or substrate preference has allowed a simple classification of the pathogenic KF (dermatophytes) into three ecological groups: anthropophilic, zoophilic, and geophilic species [149]. A more detailed ecological classification of the dermatophytes has been suggested [150]. The virulence of keratinolytic fungal pathogens, associated with wild mammals and birds, varies widely from opportunistic agents causing dermatomycosis (skin, hair or nail disease) only rarely (e.g., *T. ajelloi*, *A. tuberculatum*, *M. cookei*, *A. fulvescens*) to those more virulent (e.g., *M. gypseum*) and up to obligate pathogens (e.g., *T. mentagrophytes*, *T. verrucosum*, *M. gallinae*).

Zoophilic (and geophilic) dermatophytes associated with wild vertebrates (and their prevalent wild or stray hosts in parentheses) are *T. mentagrophytes* var. *mentagrophytes* (rodent), *T. m. var. quinckeanum* (mouse), *T. m. var. erinacei* (hedgehog), *T. verrucosum*, *T. simii* (monkey, fowl), *M. canis* (cat, dog), *M. gypseum* (rodent), *M. persicolor* (vole), *M. gallinae* (fowl). Human ringworm is contractable from wild rodents (*T. m. mentagrophytes* and var. *quinckeanum*, *M. persicolor*), hedgehog (*T. m. var. erinacei*), stray cats or dogs (*M. canis*, *M. persicolor*) and monkeys (*T. simii*).

It is important that pathogenic but also saprophytic KF may be carried on birds' feathers or mammals' fur over long distances. For instance, *A. fulvescens*, *A. tuberculatum* and *M. ripariae* were isolated from the plumage of a number of migratory birds [14,15]. This is significant not only epizootiologically, but also evolutionary, for genetic mixing of fungal populations in diverse parts of the world.

### References

- Bolliger A. Water extractable constituents of hair. *J Invest Derm* 1951;17:79-84.
- Vanbreuseghem R. Keratin digestion by dermatophytes: a diagnostic method. *Mycologia* 1952;44: 176-182.
- Griffin DM. Hair as a substrate for non-keratinolytic fungi. *Nature* 1959;183:1281.
- English MP. The saprophytic growth of non-keratinophilic fungi on keratinized substrata, and a comparison with keratinophilic fungi. *Trans Br Mycol Soc* 1965; 48:219-235.
- Orr GF, Kuehn HH, Plunkett OA. A new genus of the Gymnoascaceae with swollen peridial septa [*Auxarthron*]. *Can J Bot* 1963;41: 1439-1456.
- Padhye AA, Carmichael JW. The genus *Arthroderma* Berkeley. *Can J Bot* 1971; 49: 1525-1540.
- Sigler L, Carmichael JW. Taxonomy of *Malbranchea* and some other hyphomycetes with arthroconidia. *Mycotaxon* 1976;4: 349-488.
- Van Oorschot CAN. A revision of *Chrysosporium* and allied genera. *Stud Mycol* 1980; 20: 1-89.
- Currah RS. Taxonomy of the Onygenales: Arthrodermataceae, Myxotrichaceae and Onygenaceae. *Mycotaxon* 1985;24: 1-216.
- Weitzman I, McGinnis MR, Padhye AA, Ajello L. The genus *Arthroderma* and its later synonym *Nannizzia*. *Mycotaxon* 1986;25:505-518.
- Cano J, Guarro J. The genus *Aphanoascus*. *Mycol Res* 1990; 94: 355-377.
- Hubalek Z, Rosicky B, Otcenacek M. Fungi on the hair of small wild mammals in Czechoslovakia and Yugoslavia. *Ces Mykol* 1979;33: 81-93.
- Apinis AE. Revision of British Gymnoascaceae. *Mycol Papers (CMI)* 1964; 96: 1-56.
- Hubalek Z. Fungi associated with free-living birds in Czechoslovakia and Yugoslavia. *Acta Sc Nat Brno* 1974;8: 1-62.
- Hubalek Z. The distribution patterns of fungi in free-living birds. *Acta Sc Nat Brno* 1974; 8: 1-51.
- Gugnani HC, Wattal BL, Sandhu RS. Dermatophytes and other keratinophilic fungi recovered from small mammals in India. *Mykosen* 1975;18: 529-538.
- Onsberg P. Some dermatophytes and other keratinophilic fungi from Denmark. *Mykosen* 1979;22: 15-20.
- Vanbreuseghem R, De Vroey C. Dermatophytic infection by *Anixiopsis stercoraria* in a wild boar (*Sus scrofa*). *Mykosen* 1980;23: 83-187.
- Volkova A. Keratinophilic fungi in rodents' burrows and in their surroundings (in Slovak). *Ces Mykol* 1985; 39: 97-105.
- Chabasse D, Guiguen C, Couatarmanac'h A, Launay H, Reecht V, De Bievre C. Contribution à la connaissance de la flore fongique kératinophile isolée des petits mammifères sauvages et du lapin de garenne en France. *Ann Parasit Hum Comp* 1987; 62: 357-368.
- Pugh GJF, Evans MD. Keratinophilic fungi associated with birds. I. Fungi isolated from feathers, nests and soils. *Trans Br Mycol Soc* 1970; 54:233-240.
- Hubalek Z, Balat F. The survival of microfungi in the nests of tree sparrow (*Passer montanus* L.) in the nest-boxes over the winter season. *Mycopathologia* 1974;54: 517-530.
- Hubalek Z. Seasonal distribution of fungi on house sparrows. *Trans Br Mycol Soc* 1976; 66:509-516.
- Hubalek Z. Occurrence of keratinolytic fungi in nests of tree sparrow (*Passer montanus* L.) in relation to the substrate moisture (in Czech). *Ces Mykol* 1976; 30: 106-109.
- Humpolickova V, Otcenacek M. Keratinophilic fungi from the feathers of free-living birds. *Folia Parasitol* 1981;28: 179-186.
- Massee G, Salmon E. Coprophilous fungi. II. *Ann Bot (Lond)* 1902;16: 57-93.
- Watling R. The fungal succession on hawk pellets. *Trans Br Mycol Soc* 1963; 46: 81-90.

28. Hoffmann R, Kolipp D, Koch HA. Die Bedeutung von Mäusen und anderen Kleinsäugetieren für die Verbreitung von Dermatophyten und anderen keratinophilen Pilzen. *Mykosen* 1970;13: 583-587.
29. Okafor JI, Gugnani HC. Dermatophytes and other keratinophilic fungi associated with hairs of rodents in Nigeria. *Mykosen* 1981;24: 616-620.
30. Pugh GJF. Associations between birds' nests, their pH, and keratinophilic fungi. *Sabouraudia* 1966;5: 49-53.
31. Otcenasek M, Hudec K, Hubalek Z, Dvorak J. Keratinophilic fungi from the nests of birds in Czechoslovakia. *Sabouraudia* 1967;5: 350-354.
32. Sharapov VM, Kuzmina VS. Keratinophilic fungi on birds of Western Siberia (in Russian). *Mikol Fitopatol* 1976; 10: 380-384.
33. Chabasse D, Guiguen C. Flore keratinophile isolée du plumage des pigeons de ville à Bordeaux. *Bull Soc Fr Mycol Med* 1986; 15: 161-164.
34. Sarangi S, Ghosh GR. Survey of keratinophilic fungi inhabiting *Passer domesticus* in two districts of Orissa, India. *Mycopathologia* 1991;114: 109-116.
35. Alteras I, Nesterov V, Ciolofan I. The occurrence of dermatophytes in wild animals from Roumania. *Sabouraudia* 1966; 4: 215-218.
36. Kaben U. Verbreitung und Epidemiologie der Dermatophyten tierischen Ursprungs. *Mykosen* 1967;10: 47-60.
37. Sur B, Ghosh GR. Keratinophilic fungi from Orissa, India. II. Isolations from feathers of wild birds and domestic fowl. *Sabouraudia* 1980;18: 275-280.
38. Dixit AK, Kushwaha RKS. Occurrence of keratinophilic fungi on Indian birds. *Folia Microbiol* 1991; 36: 383-386.
39. Rozental AS, Vinitzkovska JL. Trichophytosis in wild mice as a source of human trichophytosis (in Russian). "Ocherki po gibkovym zabollevaniyam kozhi" (Medgiz, Moskva) 1955: 65-68.
40. Kleibl K. Significance of a tularemia epizootic in the distribution of dermatomycosis caused by *Trichophyton mentagrophytes* (in Russian). *Vest Derm Vener* 1963;37: 32-35.
41. Chmel L, Buchvald J. Small rodents as reservoirs of trichophytoses. In "Recent Advances of Human and Animal Mycology" (Chmel L, Hegyi E., Gentles J. C., Eds.): 1967; 121-126. Publ. House SAV, Bratislava.
42. Pesterev PN, Boshakov VA. Hedgehog as a source of human infection caused by *Trichophyton mentagrophytes* (in Russian). *Vest Derm Vener* 1972; 46, no. 9: 74-76.
43. Sharapov V. M. Natural focality of trichophytosis caused by *Trichophyton gypsum* (Bodin) Blanchard. *Vest Derm Venerol* 1974; 8: 70-75.
44. Lunder M, Lunder M. Tinea corporis durch ein Eichhornchen übertragen. *Mykosen* 1982;25: 391-192.
45. Donald G. F. (1960). Tinea contracted from kangaroos. *Med J Aust* 1960;1: 852-853.
46. Connole MD. Review of animal mycoses in Australia. *Mycopathologia* 1990;111: 133-164.
47. Delameter ED. The squirrel as a new host to a ringworm fungus. *Mycologia* 1939;31:519-526.
48. Errington PL. Observations on a fungus skin disease in Iowa muskrats. *J Am Vet Med Asso* 1942; 3: 195-201.
49. Adams L, Salvin SB, Hadlow W. J. Ringworm in a population of snowshoe hares. *J Mammal* 1956;37: 94-99.
50. Smith WW, Menges R. W., Georg LK. Ecology of ringworm fungi on commensal rats from rural premises in southwestern Georgia. *Am J Trop Med Hyg* 1957; 6: 81-85.
51. Menges RW, Love GJ, Smith WW, Georg LK. Ringworm in wild mammals in southwestern Georgia. *Am J Vet Res* 1957; 18: 672-677.
52. Mc Keever S, Kaplan W, Ajello L. Ringworm fungi of large wild mammals in south western Georgia and northwestern Florida. *Am J Vet Res* 1958; 19: 973-975.
53. Mc Keever S, Menges RW, Kaplan W, Ajello L. Ringworm fungi of feral rodents in South Western Georgia. *Am J Vet Res* 1958;19: 969-972.
54. Donald GF, Brown G. *Trichophyton mentagrophytes* and *T. mentagrophytes* var. *quinckeum* infections in South Australian mice. *Aust J Derm* 1964; 7: 133-140.
55. Taylor WW, Radcliffe F, Van Peenen PFD. A survey of small Egyptian mammals for pathogenic fungi. *Sabouraudia* 1964; 3:140-142.
56. English MP. The ecology of some keratinophilic fungi associated with hedgehogs. *N Z Med J* 1964; 63: 586-591.
57. Marais V, Oliver DL. Isolation of *Trichophyton mentagrophytes* from a porcupine. *Sabouraudia* 1965; 4: 49-51.
58. Azimov IM. Carriers of *Trichophyton mentagrophytes* (in Russian). *Veterinaria* 1965; 42: 22-23.
59. Grose E, Marendelle CJ. Species of *Sporotrichum*, *Trichophyton* and *Microsporium* from Columbian bats. *Trop Geogr Med* 1966;18: 260-263.
60. English MP. Ringworm in wild mammals. *J Zool (Lond.)*. 1967;153: 556-561.
61. Stepanishcheva ZG, Malkina AJ, Poyarkova NN. Various mice species as carriers of *Trichophyton gypsum* and *T. rosaceum* (in Russian). *Vest Derm Vener* 1967; 41: 55-58.
62. Austwick P. K. C. (1968). *Mycotic infections*. *Symp Zool Soc Lond* 1968;24: 249-271.
63. Smith JMB, Rush-Munro FM, Mc Carthy M. Animals as a reservoir of human ringworm in New Zealand. *Austr J Dermatol* 1969;10: 169-182.
64. Knudtson WU, Robertstad GW. The isolation of keratinophilic fungi from soil and wild animals in south Dakota. *Mycopathologia* 1970;40: 309-323.
65. Al-Doory Y, Moore JA. *Trichophyton mentagrophytes* infection in a raccoon. *Mycopathologia* 1971; 45: 189-192.
66. Mantovani A, Morganti L. Ricerche sui dermatofiti dei mammiferi in Italia. *Vet Ital* 1971;22: 460-471.
67. Mantovani A, Morganti L, Battelli G, Mantovani A, Pogliayen G, Tampieri Vecchi G. The role of wild animals in the ecology of dermatophytes and related fungi. *Folia Parasitol* 1982;29:279-284.
68. Houin R, Rouget-Campana Y, Le Fichoux Y, Lancastre F, Bazin JC, Deniau M, Bolognini J. Isolement de *Trichophyton mentagrophytes* (Robin) Blanchard 1896. *Nannizia persicolor* Stockdale 1967 et *Trichophyton terrestre* Durie et Frey 1957, du pelage de rongeurs. *Ann Parasit Hum Comp* 1972;47:421-429.
69. Buchvald J, Klobusicky M, Chmel L. Zur Frage des Überlebens der Fadenpilze im Biotop des Feldes vom Gesichtspunkt des Naturherdes der mykotischen Infektionen. *Mykosen* 1972;15: 275-283.
70. Orr G. F. Kuehn H. H. Notes on Gymnoascaceae. II. Some Gymnoascaceae and keratinophilic fungi from Utah. *Mycologia* 1972;64:55-72.
71. Lewis E, Hofe GL, Bigler WJ, Jefferies MB. Public health and urban grey squirrel: mycology. *J Wildl Dis* 1975; 11:502-504.
72. Mariat F, Chatelain J, Rouffaud MA. Etude sur la contamination par les champignons dermatophytes d'une population de petits mammifères sauvages en Alsace. *Mycopathologia* 1976;58: 71-78.
73. English MP, Bayley JA. Dermatophytes in a population of bank voles and woodmice. *Mycopathologia* 1978;66:67-71.
74. Otcenacek M, Hubalek Z, Sixl W. Survey of dermatophytes in the hair of small mammals from Austria. *Folia Parasitol* 1980;27:83-87.
75. McAleer R. Zoophilic dermatophytes and their natural hosts in Western Australia. *Med J Aust* 1980;2: 506-508.
76. Banaszkievicz H. Über die Pilzflora im Fell von kleinen Nagetieren aus der Umgebung von Warschau. *Mykosen* 1985;28: 520-523.
77. Pesterev PN, Stadukhin OV. Basic carriers of *Trichophyton mentagrophytes* var. *gypseum* in the Sverdlovsk region. *J Hyg Epidem* 1987;31: 259-267.
78. Knudtson WU, Boddicker ML, Robertstad G. Isolation of *Trichophyton mentagrophytes* from favus in a grouse. *Bull Wildl Dis Asso* 1969; 5: 141.
79. Brown GW, Suter I. I. Human infections with mouse favus in a rural area of South Australia. *Med J Aust* 1969;2:541-543.
80. Szathmary S. Ausgedehnte menschliche Mausefavus-Epidemie in der ungarischen Tiefebene. *Mykosen* 1966;9: 50-63.
81. Ozeovic L. Wild animals as reservoirs of human pathogenic dermatophytes. *Zbl Bakt A* 1980;246: 369-380.
82. English MP, Evans CD, Hewitt M, Warin RP. "Hedgehog ringworm". *Br Med J* 1962;1:149-151.
83. Marples M. J., Smith JMB. The hedgehog as a source of human ringworm. *Nature* 1960;188: 867-868.
84. Quaife RA. Human infection due to the hedgehog fungus, *Trichophyton mentagrophytes* var. *erinacei*. *J Clin Pathol* 1966;19:177-178.
85. Marples MJ, Smith JMB. *Trichophyton terrestre* as a resident in hedgehog skin. *Sabouraudia* 1962;2: 100-107.
86. Smith JMB, Marples MJ. *Trichophyton mentagrophytes* var. *erinacei*. *Sabouraudia* 1963;3:1-10.
87. English MP, Smith JMB, Rush-Munro FM. Hedgehog ringworm in the North Island of New Zealand. *N Z Med J* 1964;63:40-42.
88. La Touche CJ, Forster RA. Spontaneous infection in the hedgehog (*Erinaceus europaeus*) by a variety of *Trichophyton mentagrophytes* (Robin) Blanchard. *Sabouraudia* 1962;2: 143-145.
89. Morris P, English MP. *Trichophyton mentagrophytes* var. *erinacei* in British hedgehogs. *Sabouraudia* 1969;7: 122-128.
90. Morris P, English MP. Transmission and course of *Trichophyton erinacei* infections in British hedgehogs. *Sabouraudia* 1973;11: 42-47.
91. Collinge CA, Stockdale PM, Gregory MW. A mycological study of *Arthroderma benhamiae* from the Central African hedgehog. *Sabouraudia* 1974;12:227-232.
92. Takashio M. Contribution à l'étude d'*Arthroderma benhamiae* var. *erinacei* et de souches isolées du hérisson africain *Erinaceus albiventris* Wagner. *Bull Soc Fr Mycol Med* 1975;4: 47-50.
93. Kuttin ES, Beemer AM, Gerson U. A dermatitis in a hedgehog associated with *Sarcoptes scabiei* and fungi. *Mykosen* 1977;20: 51-53.
94. English MP, Morris P. *Trichophyton mentagrophytes* var. *erinacei* in hedgehog nests. *Sabouraudia* 1969;7:118-121.
95. Moraes M, Borelli D, Feo M. *Microsporium amazonicum* nova species. *Med Cutan (Barcelona)* 1967;2: 281-286.
96. Moraes M, Padhye AA, Ajello L. The perfect state of *Microsporium amazonicum*. *Mycologia* 1975;67: 1109-1113.
97. Kawasaki M, Aoki M, Ishizaki H. Phylogenetic relationships of some *Microsporium* and *Arthroderma* species inferred from mitochondrial DNA analysis. *Mycopathologia* 1995;130: 11-21.
98. Marples MJ. Some extra-human reservoirs of pathogenic fungi in New Zealand. *Trans Roy Soc Trop Med Hyg* 1961;55:216-220.
99. Marples MJ. Non-domestic animals in New Zealand and in Rarotonga as a reservoir of the agents of ringworm. *N Z Med J* 1967;66: 299-302.
100. Otcenacek M, Dvorak J. Morphology, parasitic activity and ecology of *Trichophyton terrestre* Durie et Frey (in Russian). *Vest Derm Vener* 1965; 39: 32-36.
101. Borelli D. *Microsporium racemosum* nova species. *Acta Med Vener* 1965;12: 148-151.
102. Castro RM. *Microsporium cookei*. Frequencia de seu isolamento em roedores silvestres brasileiros. *Rev Inst Med Trop S Paolo* 1965;7:87-88.

103. Rees RG. Keratinophilic fungi from Queensland. I. isolations from animal hair and scales. *Sabouraudia* 1967;5: 165-172.
104. English MP. Ringworm in a group of wild mammals. *J Zool (Lond)* 1971;165: 535-544.
105. McAleer R. Keratinophilic fungi on four animal groups. *Aust Vet J* 1980; 56: 387-390.
106. Rees RG. Keratinophilic fungi from Queensland. II. Isolations from feathers of wild birds. *Sabouraudia* 1967;6: 14-18.
107. Hubalek Z. *Trichophyton georgiae* Varsavsky et Ajello, from birds in Czechoslovakia and Yugoslavia. *Sabouraudia* 1970;8: 1-3.
108. Dawson CO. Two new species of *Arthroderma* isolated from soil from rabbit burrows. *Sabouraudia* 1963;2:185-191.
109. Pugh GJF. Dispersal of *Arthroderma curreyi* by birds, and its role in the soil. *Sabouraudia* 1964;3: 275-278.
110. Pugh GJF. Cellulolytic and keratinophilic fungi recorded on birds. *Sabouraudia* 1965;4: 85-91.
111. Rees RG. *Arthroderma flavescens* sp. nov. *Sabouraudia* 1967; 5:206-208.
112. Stockdale PM. The *Microsporium gypseum* complex (*Nannizzia incurvata* Stockd., *N. gypsea* (Nann.) comb. nov., *N. fulva* sp. nov.). *Sabouraudia* 1963; 3:114-126.
113. Morganti L, Padhye AA, Ajello L. Recovery of *Nannizzia grubyia* from a stray Italian cat (*Felis catus*). *Mycologia* 1975;67:434-436.
114. Ditrich O, Otcenasek M. *Microsporium vanbreusreghemi* and *Trichophyton simii* in Czechoslovakia (in Czech). *Ces Mykol* 1982;36:236-242.
115. Otcenasek M, Dvorak J. The isolation of *Trichophyton terrestre* and other keratinophilic fungi from small mammals of South-Eastern Moravia. *Sabouraudia* 1962;2: 111-113.
116. English MP. *Trichophyton persicolor* infection in the field vole and pipistrelle bat. *Sabouraudia* 1966;4:219-222.
117. English MP. The nature of *Trichophyton persicolor* infection in the bank vole and the interpretation of the results of sampling techniques. *Sabouraudia* 1967; 5:295-301.
118. Alteras I, Nesterov V, Ciolofan I. Infection by *Microsporium gypseum* in the chamois (*Rupicapra rupicapra*). *Sabouraudia* 1968;6: 138-139.
119. Dvorak J, Otcenasek M, Hubalek Z. Die Dermatophytenflora Ostböhmens. *Mykosen* 1969;12: 183-190.
120. Reyes AC, Fontanilla E, Lopez S, Arenas F. Murine rodents and shrews in Manila and suburbs as reservoirs of ringworm fungi. *Acta Med Philip* 1970; 7: 10-14.
121. Krivanec K, Janeckova V, Otcenasek M. *Arthroderma melis* spec. nov. - a new dermatophyte species isolated from badger burrows in Czechoslovakia. *Ces Mykol* 1976;31: 91-99.
122. Badillet G. Das *Microsporium persicolor*, ein nicht selten verkannter Dermatophyt Hautarzt 1978;29: 10-14.
123. English MP. Ringworm in wild mammals: further investigations. *J Zool (Lond.)* 1969;159:515-522.
124. English MP, Southern HN. *Trichophyton persicolor* infection in a population of small wild mammals. *Sabouraudia* 1967; 5:302-309.
125. Badillet G, Gillot B, Pietrini P, Espinosa-Villegas ME. *Microsporium persicolor* chez l'homme et chez l'animal. *Bull Soc Fr Mycol Med* 1972; 1: 11-14.
126. Houin R, Le Fichoux Y, Puel F, Rouget-Campana Y. Etude mycologique de petits mammifères de l'Est de la France. *Bull Soc Fr Mycol Med* 1972;1:161-164.
127. English MP, Kapica L, Maciejewska J. On the occurrence of *Microsporium persicolor* in Montreal, Canada. *Mycopathologia* 1978;64:35-37.
128. Ditrich O, Otcenasek M. Mycological and ecological study of *Microsporium persicolor* (in Czech). *Ces Mykol* 1983; 37: 42-48.
129. Vollekova A. *Microsporium persicolor* and other keratinophilic fungi in soil and rodent burrows (in Slovak). *Biologia* 1984;39:899-904.
130. Otcenasek M, Dvorak J, Kunert J. Ein Beitrag zur Kenntnis der sogenannten "roten Stamme" von *Trichophyton terrestre*. *Derm Wschr* 1967;153: 656-663.
131. Mariat F, Tapia G. Denombrement des champignons keratinophiles d'une population de cynocephales (*Papio papio*). *Ann Parasit Hum Comp* 1966; 41: 627-634.
132. Gugnani HC, Shrivastava JB, Gupta NB. Occurrence of *Arthroderma simii* in soil and on hair of small mammals. *Sabouraudia* 1967;6: 77-80.
133. Kuehn HH. Observations on Gymnoasceae. VIII. A new species of *Arthroderma*. *Mycopathologia* 1960;13: 189-197.
134. Alteras I. A short review on dermatophytoses of animals in Romania. *Mycopathologia* 1971;43: 17-23.
135. Takatori K, Hasegawa A. Isolation of keratinophilic and nonkeratinophilic fungi from birds' nests (in Japanese). *Trans Mycol Soc Jap* 1981; 22: 347-352.
136. Pugh GJF. Fungi on birds in India. *J Ind Bot Soc* 1966; 45: 296-303.
137. Schlegel M. Favuskrankheit (Hühnergrind). *Berl Tierarztl Wschr* 1909; 25: 689.
138. Patiala R. On fungus disease in game. *Riistat Julk [Papers on Game Research]*. 1951;6:21-22.
139. Hubalek Z, Rush-Munro FM. A dermatophyte from birds: *Microsporium ripariae* sp. nov. *Sabouraudia* 1973;11: 287-292.
140. Pilat A. A revision of species of the genus *Onygena* in Czechoslovakia (in Czech). *Ces Mykol* 1956;30: 141-148.
141. Tubaki K. Imperfect stage of *Onygena corvina* and its perithecial formation under culture. *Bull Nat Sci Mus Tokyo* 1960;5: 36-43.
142. Borelli D, Feo M. *Trichophyton phaseoli-forme*, nova species. *Med Cutan (Barcelona)* 1966;1:165-172.
143. Honess RF, Winter KB. An observation of ringworm on a mule deer caused by *Trichophyton faviforme*. *Bull Dis Wildl Wyoming* 1956;9:32.
144. Koch HA. Zur Ökologie von *Trichophyton verrucosum* Bodin 1902. *Proc Int Symp Med Mycol Warsaw* 1965; 75-79.
145. Pugh GJF, Evans MD. Keratinophilic fungi associated with birds. II. Physiological studies. *Trans Br Mycol Soc* 1970;54:241-250.
146. Hubalek Z, Balat F, Touskova I, VIK J. Mycoflora of birds' nests in nest-boxes. *Mycopathologia* 1973;49: 1-12.
147. Hubalek Z, Balat F. Seasonal distribution of keratinophilic fungi in the nests of Tree Sparrow (*Passer montanus* L.). *Zbl Bakt II* 1976; 131: 179-197.
148. Hubalek Z. Influence of pH on the occurrence of fungi in birds' nests. *Z Allg Mikrobiol* 1976; 16: 65-72.
149. Ajello L. Present day concepts of the dermatophytes. *Mycopathologia* 1962;17: 315-324.
150. Otcenasek M, Dvorak J. Ecological classification of dermatophytes. *Mykosen* 1975;18: 425-434.
151. Hubalek Z. Influence of substrate moisture on the occurrence of fungi in birds' nests. *Z Allg Mikrobiol* 1976; 16: 221-227.