A PRELIMINARY CHECKLIST OF ARIZONA SLIME MOLDS

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ABSTRACT

A checklist of 147 species of slime molds is presented for the state of Arizona. This total represents approximately one-tenth of all species known from the eukaryotic slime mold groups. This is remarkable in that a majority of the records here have been derived from studies focusing on arid-lands. The checklist was compiled primarily from records of Arizona slime molds in scientific publications and was supplemented with data from the U.S. National Fungus Collection, the Global Biodiversity of Eumycetozoans database, as well as personal herbaria. Fifteen species, *Arcyria veriscolor* W. Phillips, *Badhamia foliicola* Lister, *Echinostelium elachiston* Alexop., *Hemitrichia leiocarpa* (Cooke) Lister, *Licea variabilis* Schrad., *Lindbladia tubulina* Fr., *Perichaena microspora* Penz. & Lister, *Physarum bitectum* G. Lister, *Physarum confertum* T. Macbr., *Physarum crateriforme* Petch, *Physarum echinosporum* Lister, *Physarum flavicomum* Berk., *Physarum newtonii* T. Macbr., *Stemonitis nigrescens* Rex, and *Trichia alpina* (R.E. Fr.) Myel., are considered as new records for the state, although identifications of these species have not been verified by the authors. The data presented here contribute to our understanding of slime mold biodiversity and biogeography.

INTRODUCTION

The term 'slime mold' has been applied to several groups of organisms characterized by a life cycle that includes motile amoebae-like cells, that normally aggregate to form multinucleate or multicellular structures (assimilative and/or reproductive), and produce sessile or stalked sporulating structures. Although slime molds share this common generalized life cycle, they are not all closely related, and modern phylogenetically based classification schemes place them within five different subgroups of three major eukaryotic clades (see Baldauf 2003). An additional prokaryotic group, the myxobacteria (δ proteobacteria; not treated here), are also similar in that individual cells aggregate and eventually form spores; however, these organisms lack flagella and achieve motility by 'gliding' (Shimkets & Woese 1992, Dworkin & Kaiser 1993).

Historically it has been acknowledged that slime molds comprise distinct groups, and their polyphyletic nature has been speculated for over a century (de

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Bary 1887). Alexopoulos et al. (1996) recognized five separate phyla: the *Labyrinthulomycota* (net slime molds), *Plasmodiophoromycota* (endoparasitic slime molds), *Dictyosteliomycota* (dictyostelid cellular slime molds), *Acrasiomycota* (acrasid cellular slime molds), and *Myxomycota* (true slime molds or myxomycetes). Although the nomenclature surrounding these organisms suggests relatedness to the *Eumycota* (true fungi), they are not contained in the opisthokonts clade (i.e., animals + fungi; Baldauf 2003); however, mycologists have traditionally been involved in their study (Ainsworth 1976). To distinguish the core monophyletic group of slime molds (myxomycetes, dictyostelids, and protostelids) as a distinct group, separate from the fungi, the terms mycetozoans or eumycetozoans has been informally used by some authors (e.g., Olive 1975, Spiegel et al. 1995).

Slime mold diversity is perhaps best reflected in the variety of forms that are exhibited by their fruiting structures. Though minute (many less than 2 mm tall), these forms can be quite beautiful (Fig. 1; and see the *Eumycetozoan Project*, http://slimemold.uark.edu), if one takes the time to examine them closely. The most recognizable slime molds are found within the *Myxomycota*, and this group contains the majority of described species (ca. 1000; Schnittler et al. 2006), their plasmodia (Fig. 1b, multinucleate assimilative phase) can be large and colorful, and their fruiting bodies, unlike those found in other groups (e.g., *Dictyosteliomycota*), are often visible to the unaided eye. Others are also familiar; for example, the 'slug' forming 'social amoeba' *Dictyostelium discoideum* is a well-known model organism used by researchers to study cell differentiation (Alexopoulos et al. 1996). In general, these organisms are phagotrophic microbial predators, the vegetative phase feeding on microscopic organisms such as bacteria, fungi, or protozoans. As with fungi, the substrata (e.g., bark, dung, decaying wood) on which slime molds are found may be of importance as these organisms can be associated with specific macro- or micro-habitats (e.g., 'succulenticolous' myxomycetes can be encountered in arid-lands on decaying succulents, Lado et al. 2002).

Slime molds have been recorded throughout the world and are well known from temperate forests, although they occur in a wide range of habitats – from tropical forests to alpine and arctic ecosystems (e.g., Martin & Alexopoulos 1969, Ing 1994, Alexopoulos et al. 1996, Stephenson & Laursen 1998, Schnittler & Stephenson 2000). Because these organisms require moisture for an extended period of time in order to complete their life cycles, their occurrence in deserts may seem remarkable; however, several studies have documented a notable diversity of slime molds from arid regions around the globe (e.g., Evenson 1961, Faurel et al. 1965, Ramon 1968, Blackwell & Gilbertson 1980a & 1984, Novozhilov & Golubeva 1986, Schnittler & Novozhilov 2000, Schnittler 2001, Lado et al. 2002, Novozhilov et al. 2003, Novozhilov et al. 2006). In these arid systems, slime molds are likely to be encountered on dead plant tissue of cacti and agaves, which can retain moisture long enough to support slime mold growth (Blackwell & Gilbertson 1980a, Ing 1994, Lado et al. 2002). The majority of Arizona slime mold records have originated within studies that focused on arid-lands in general and the Sonoran Desert in particular, and most of these studies have relied primarily on the use of 'moist-chamber cultures' to induce plasmodial and sporulating structures (see Gilbert & Martin 1933, Alexopoulos 1964).

The first accounts of Arizona slime molds come from Evenson (1961), who recorded 63 species that were "…observed in an area that is within a radius of 90 miles of Tucson…." Blackwell and Gilbertson (1980a) again focused on localities near Tucson and reported on 52 species. Within the twentieth century, other reports were sparse (e.g., Olive & Stoianovitch 1966, Cavender & Raper 1968, Ranzoni 1968, Raper & Alexopoulos 1973, Cooke 1985, McGuinness & Haskins 1985, Clark & Haskins 1998); however, records from central and northern Arizona were accumulated and species new to science were reported from the state (e.g., Keller & Brooks 1976a–b & 1977, Blackwell & Gilbertson 1980b, Whitney & Keller 1980, Whitney 1980, Cox 1981). The twenty-first century brought more records from the northern parts of the state. Brian (2000) reported on two species from the Grand Canyon (only one identified to species) and the study of Novozhilov et al. (2003) from the Colorado Plateau brought 48 additional records.

METHODS

The methods used in this paper follow, for the most part, those of Bates (2006). The literature search was aided considerably by the appearance on-line of early editions of journals, such as *Mycologia*, and technology allowing for journal content searches (e.g., JSTOR, http://www.jstor.org; Google Scholar, http://scholar.google.com). On-line searches for slime mold records in the *Planetary Biodiversity Inventories (PBI): Global Biodiversity of Eumycetozoans* database (http://slimemold.uark.edu) and for specimens in the U.S. National Fungus Collections (BPI; Farr et al. 2007) were also carried out. From this effort, 55 species records for Arizona were obtained. A number of species cited from the literature are also deposited as specimens in herbaria (e.g., Blackwell & Gilbertson 1980a). Data from the literature and herbarium databases were supplemented by records acquired from the author's personal herbarium (hb. Bates) and also that of Y.K. Novozhilov (hb. Novozhilov).

A database was compiled from all of the individual records located (303 in total). Each entry in the database cited the source of the record and the binomial as it originally appeared in publication or in a database record. Synonymy, currently accepted names, and the classification system used conform to Lado (2001), the 'On-Line Nomenclatural Information System of the Eumycetozoans (http://www.eumycetozoa.com), and the CABI Index Fungorum (http://www.indexfungorum.org). Entries in the checklist published here are followed by annotations in brackets, which indicate the record source/s for each species included (see *Annotation Key* below). If no previous published report of the species' occurrence in Arizona existed, then the annotation 'NR' indicates a new record. The on-line Checklist of Arizona Macrofungi has been relocated to a new URL (http://www.azfungi.org/checklist) and has been restructured to include slime mold records published here in addition to more than one-thousand species of macrofungi documented previously from the state (see Bates 2006). The on-line checklist will continue to be updated as additional records become available.

RESULTS, DISCUSSION, AND CONCLUSIONS

Records of one hundred forty-seven Arizona slime molds from 14 families, 3 phyla (*Labyrinthulomycota, Dictyosteliomycota*, and *Myxomycota*), and 2 major eukaryotic groups (Chromista and Protozoa) are reported in this checklist. While the majority of these (~90%) have been previously reported from the literature, a total of fifteen species, *Arcyria veriscolor* W. Phillips, *Badhamia foliicola* Lister, *Echinostelium elachiston* Alexop., *Hemitrichia leiocarpa* (Cooke) Lister, *Licea variabilis* Schrad., *Lindbladia tubulina* Fr., *Perichaena microspora* Penz. & Lister, *Physarum bitectum* G. Lister, *Physarum confertum* T. Macbr., *Physarum crateriforme* Petch, *Physarum echinosporum* Lister, *Physarum flavicomum* Berk., *Physarum newtonii* T. Macbr., *Stemonitis nigrescens* Rex, and *Trichia alpina* (R.E. Fr.) Myel., are reported from the state for the first time. These new records are tentative, however, as the authors have not been able to verify the validity of these identifications, most of which originated from the BPI specimen database and *Global Biodiversity of Eumycetozoans* database. Furthermore, it was beyond the scope of this project and the expertise of the authors to confirm identifications for each record; therefore, the checklist should be considered preliminary and some inaccuracies may exist. Despite these faults, we feel that publishing a preliminary checklist such as this serves a purpose in that it provides a starting point from which future studies can precede – errors, once discovered, can then be corrected in the on-line checklist (http://www.azfungi.org/checklist). In the very least, this publication serves to catalog the slime mold literature for the state.

The extent of global slime mold diversity is still poorly known; however, it appears that their numbers are less than fungi, which estimates place at 700,000 to 1.5 million species world-wide, or more (Hawksworth 2001, Schmit & Mueller 2007). Considering that less than 1500 species of slime molds are described (Schnittler et al. 2006), it is remarkable that this checklist, based primarily on studies of arid-lands, contains approximately one-tenth of all known species. On going studies such as the *Tree Canopy Biodiversity in the Great Smoky Mountains National Park* (see Snell & Keller 2003, Keller et al. 2004) and the *PBI: Global Biodiversity of Eumycetozoans* project (see Schnittler et al. 2006) continue to make contributions to our understanding of slime molds and new species are being described; however, comprehensive knowledge of their diversity is still lacking. We hope this paper will encourage further study of these unique organisms within Arizona (or elsewhere) as it is likely that, with concentrated effort and exploration of additional habitats (e.g., mid- to high-elevation mesic forests of the state), new species will be discovered and additional records can be obtained.

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Slime molds Figure 1. Diversity in slime molds (forms visible to the unaided eye): (a) *Mucilago* sp., an example of the spore forming phase of the slime mold life cycle; (b) Slime mold plasmodium, an example of the assimilative phase of the slime mold life cycle; (c) *Physarum* sp. sporangia on wood; (d) *Lycogala epidendrum* sporangia on rotting wood.

PRELIMINARY CHECKLIST OF ARIZONA SLIME MOLDS

□ CHROMISTA
• LABYRINTHULOMYCOTA
LABYRINTHULOMYCETES
LABYRINTHULULALES

Labyrinthulaceae
Labyrinthula terrestris D.M. Bigelow, M.W. Olsen & Gilb. [1]

□ PROTOZOA
• DICTYOSTELIOMYCOTA
DICTYOSTELIOMYCETES
DICTYOSTELIALES

Dictyosteliaceae
Polysphondylium pallidum Olive [6]

• MYXOMYCOTA
MYXOMYCETES
ECHINOSTELIALES

Echinosteliaceae
Echinostelium apitectum K.D. Whitney [20,27]
Echinostelium arboreum H.W. Keller & T.E. Brooks [14]
Echinostelium coelocephalum T.E. Brooks & H.W. Keller [15,17,20,24,27]
Echinostelium colliculosum K.D. Whitney & H.W. Keller [2,20,24,25,27]
Echinostelium corynophorum K.D. Whitney [20,27]
Echinostelium elachiston Alexop. [NR,26]
Echinostelium fragile Nann.-Bremek. [17,24]
Echinostelium minutum de Bary [2,7,12,20,26,27,29]

LICEALES

Cribrariaceae
Cribraria cancellata (Batsch.) Nann.-Bremek. [12,29]
Cribraria violacea Rex [20,27]
Lindbladia tubulina Fr. [NR,29]

Liceaceae
Licea belmontiana Nann.-Bremek. [20,27]
Licea castanea G. Lister [20,27]
Licea denudescens H.W. Keller & T.E. Brooks [20,27]
Licea inconspicua T.E. Brooks & H.W. Keller [20,27]
Licea kleistobolus G.W. Martin [12,20,27]
Licea nannengae Pando & Lado [20,27]
Licea parasitica (Zukal) G.W. Martin [2,20,27]
Licea pedicellata (H.C. Gilbert) H.C. Gilbert [2]
Licea pseudoconica H.W. Keller & T.E. Brooks [2,18]
Licea tenera E. Jahn [20,27]
Licea testudinacea Nann.-Bremek. [20,27]
Licea variabilis Schrad. [NR,26]

Reticulariaceae
Lycogala epidendrum (J.C. Buxb. ex L.) Fr. [5,10,12,26,28,29]
Lycogala flavofuscum (Ehrenb.) Rostaf. [13]
Tubifera ferruginosa (Batsch) J.F. Gmel. [10]

PHYSARALES

Didymiaceae
Diderma effusum (Schwein.) Morgan [2]
Diderma radiatum (L.) Morgan [12,26]
Diderma simplex (Schroet.) G. Lister [2]
Diderma trevelyanii (Grev.) Fr. [12]
Didymium anellus Morgan [2,12,20,27]
Didymium difforme (Pers.) Gray [20,27]
Didymium dubium Rostaf. [2,12,20,27]
Didymium eremophilum M. Blackw. & Gilb. [2,3,4]
Didymium inconspicuum Nann.-Bremek. & D.W. Mitch. [20,27]
Didymium iridis Fr. [2,20,27]
Didymium karstensii Nann.-Brem. [2]
Didymium melanospermum (Pers.) T. Macbr. [12,29]
Didymium mexicanum G. Moreno, Lizarraga & Illana [20,27]
Didymium minus (Lister) Morgan [12]
Didymium nigripes (Link) Fr. [2,23]
Didymium quitense (Pat.) Torrend [20,27]
Didymium squamulosum (Alb. & Schwein.) Fr. [20,27]
Didymium vaccinum (Durieu & Mont.) Buchet [2,12]
Didymium verrucosporum A.L. Welden [20,27]
Lepidoderma carestianum (Rabenh.) Rostaf. [12]
Mucilago crustacea P. Micheli ex F.H. Wigg. [12,26,28]

Physaraceae
Badhamia affinis Rostaf. [2]
Badhamia apiculospora (Hark.) Eliasson & N. Lundq. [20,27]
Badhamia foliicola Lister [NR,26]
Badhamia gracilis (Macbr.) Macbr. [2,4,9,26]
Badhamia macrocarpa (Ces.) Rostaf. [2,12,26]
Badhamia melanospora Speg. [20,27]
Badhamia panicea (Fr.) Rostaf. [2,12]
Badhamiopsis ainoae (Yamash.) T.E. Brooks & H.W. Keller [17]
Craterium leucocephalum (Pers.) Ditmar [2]
Craterium minutum (Leers) Fr. [12]
Fuligo cinerea (Schw.) Morgan [2,20,27,29]
Fuligo intermedia T. Macbr. [10,26]
Fuligo megaspora Sturgis [2]
Fuligo septica var. *septica* (L.) F.H. Wigg. [2,12,29]
Leocarpus fragilis (Dicks.) Rostaf. [12,29]
Physarum auriscalpium Cooke [2,29]
Physarum bitectum G. Lister [NR,29]
Physarum bivalve Pers. [20,27]
Physarum cinereum (Batsch) Pers. [12,20,27,29]
Physarum compressum Alb. & Schwein. [2,12]
Physarum confertum T. Macbr. [NR,29]
Physarum crateriforme Petch [NR,29]
Physarum decipiens M.A. Curtis [20,27]
Physarum didermoides (Ach. ex Pers.) Rostaf. [2]
Physarum echinosporum Lister [NR,29]
Physarum flavicomum Berk. [NR,29]
Physarum galbeum Wingate [12]
Physarum lateritium (Berk. & Ravenel) Morgan [2]
Physarum leucophaeum Fr. [2,20,27,29]
Physarum leucopus Link [2]
Physarum luteolum Peck [2]
Physarum mutabile (Rostaf.) G. Lister [2,12]
Physarum newtonii T. Macbr. [NR,26]
Physarum notabile T. Macbr. [2,12,20,27,29]
Physarum nucleatum Rex [2]
Physarum nudum T. Macbr. [20,27]
Physarum nutans Pers. [12,29]
Physarum ovisporum G. Lister [11]
Physarum pusillum (Berk. & M.A. Curtis) G. Lister [2,12,29]
Physarum straminipes Lister [2,4]
Physarum tenerum Rex [12]
Physarum vernum Sommerf. [2]
Protophysarum phloiogenum M. Blackwell & Alexop. [4,20,27,29]
Willkommlangea reticulata (Alb. & Schwein.) Kuntze [20,27]

Stemonitidaceae
Clastoderma debaryanum A. Blytt. [12,29]
Collaria arcyrionema Rostaf. [12]
Collaria lurida (Lister) Nann.-Bremek. [2,12,19,29]
Colloderma oculatum (Lippert) G. Lister [2]
Comatricha irregularis Rex [12]
Comatricha laxa Rostaf. [2,8,12,20,27,29]
Comatricha nigra (Pers.) J. Schröt. [2,12,29]
Comatricha pulchella (C. Bab.) Rostaf. [2,12,20,27,29]
Comatricha tenerrima (M.A. Curtis) G. Lister [12]
Enerthenema papillatum (Pers.) Rostaf. [20,27]
Lamproderma sauteri Rostaf. [12]
Macbrideola decapillata H.C. Gilbert [20,27]
Macbrideola declinata T.E. Brooks & H.W. Keller [20,27]
Macbrideola scintillans H.C. Gilbert [20,27]
Paradiacheopsis cribrata Nann.-Bremek. [20,27]
Paradiacheopsis fimbriata (G. Lister & Cran) Hertel ex Nann.-Bremek. [20,27,29]
Stemonitis axifera (Bull.) T. Macbr. [10,12]
Stemonitis flavogenita E. Jahn [2,12]
Stemonitis fusca Roth [12,29]
Stemonitis nigrescens Rex [NR,26]
Stemonitis pallida Wingate [12]
Stemonitis smithii T. Macbr. [10]
Stemonitis virginiensis Rex [12]
Stemonitopsis aequalis (Peck) Y. Yamam. [12]
Stemonitopsis typhina (F.H. Wigg.) Nann.-Bremek. [12,29]

Incertae sedis
Kelleromyxa fimicola (Dearn. & Bisby) Eliasson [2,12]

TRICHIALES

Arcyriaceae
Arcyria cinerea (Bull.) Pers. [2,10,12,26]
Arcyria denudata (L.) Wettst. [10]
Arcyria incarnata (Pers.) Pers. [12]
Arcyria insignis Kalchbr. & Cooke [2,12]
Arcyria nutans (Bull.) Grev. [12,26,29]
Arcyria veriscolor W. Phillips [NR,26]

Dianemataceae
Calomyxa metallica (Berk.) Nieuwl. [12]

Trichiaceae
Hemitrichia calyculata (Speg.) M.L. Farr [12]
Hemitrichia clavata (Pers.) Rostaf. [12]

Hemitrichia leiocarpa (Cooke) Lister [NR,26]
Hemitrichia serpula (Scop.) Rostaf. [12,26]
Metatrichia vesparium (Batsch.) Nann.-Bremek. ex G.W. Martin & Alexop. [10,12,26,29]
Perichaena chrysosperma (Curr.) Lister [2,12,29]
Perichaena corticalis (Batsch) Rost. [2,4,12,20,27]
Perichaena depressa Lib. [2,12,20,27]
Perichaena microspora Penz. & Lister [NR,26]
Perichaena quadrata T. Macbr. [20,27]
Perichaena vermicularis (Schwein.) Rostaf. [2,12,20,26,27]
Trichia affinis de Bary [12]
Trichia alpina (R.E. Fr.) Myel. [NR,26]
Trichia botrytis (J.F. Gmel.) Pers. [12]
Trichia favoginea (Batsch) Pers. [10]
Trichia persimilis P. Karst. [12,26,29]
Trichia pusilla (Hedw.) G.W. Martin [12]
Trichia subfusca Rex [20,27]
Trichia varia (Pers.) Pers. [12,26]

PROTOSTELIOMYCETES
PROTOSTELIALES

Ceratiomyxaceae
Ceratiomyxa fruticulosa var. *fruticulosa* (O.F. Mull.) T. Macbr. [12]

Protosteliaceae
Protosteliopsis fimicola (L.S. Olive) L.S. Olive & Stoian. [21,22]

Annotation Key. Annotations [in brackets] follow each taxon. These indicate records that are new for Arizona (e.g., have not previously been published in the literature) and cite the source of each record with a number (see *Literature Cited*):

NR - New Record for Arizona; **1** – Bigelow et al. 2005; **2** – Blackwell & Gilbertson 1980a; **3** – Blackwell & Gilbertson 1980b; **4** – Blackwell & Gilbertson 1984; **5** – Brian 2000; **6** – Cavender & Raper 1968; **7** – Clark & Haskins 1998; **8** – Clark & Haskins 2002; **9** – Clark et al. 2003; **10** – Cooke 1985; **11** – Cox 1981; **12** – Evenson 1961; **13** – Gilbertson et al. 1972; **14** – Haskins & McGuinness 1989; **15** – Haskins et al. 2000; **16** – Keller & Brooks 1976a; **17** – Keller & Brooks 1976b; **18** – Keller & Brooks 1977; **19** – McGuinness & Haskins 1985; **20** – Novozhilov et al. 2003; **21** – Olive 1967; **22** – Olive & Stoianovitch 1966; **23** – Raper & Alexopoulos 1973; **24** – Whitney 1980; **25** – Whitney & Keller 1980; **26** – BPI; **27** – hb. Novozhilov; **28** – hb. Bates; **29** – The *PBI: Global Biodiversity of Eumycetozoans* database, http://slimemold.uark.edu/

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