Handout 1
2007
BIO 329

Non-adapted agents of mycosis:

Saprobe:	Commensal:	Endosaprobe:
Niche outside human	Niche on human	Niche inside human
Healthy host: strong non-specific defence; compromised host: opportunism	No confrontation with immune system	Healthy host: little confrontation with immune system; compromised host: opportunism
Example: *Aspergillus fumigatus*	Example: *Malassezia furfur*	Example: *Candida albicans*

Mycosis does not contribute to fitness;
Vitality factors

Agents of mycosis with various degrees of adaptation:

Facultative pathogen:	Obligatory pathogen:	Human-adapted infectious agent:
Strategy: transmission mammal / environment	Strategy: transmission mammal / mammal	Strategy: transmission human / human
Healthy human: moderate virulence	Healthy human: high virulence	Healthy human: low virulence
Example: *Histoplasma capsulatum*	Example: *Trichophyton verrucosum*	Example: *Trichophyton rubrum*

Fitness is increased by use of mammal vector;
Virulence factors

8. Diagrammatic representation of host relationships in fungi.

Table 7. Possible ecology of pathogenic fungi.

Name:	Saprobic niche:	Animal reservoir:
Blastomyces dermatitidis	wood ?	dog
Coccidioides immitis	desert soil	rodent
Cryptococcus neoformans var. *neoformans*	wood	pigeon
Cryptococcus neoformans var. *gattii*	wood	koala
Emmonsia parva	desert soil	rodent
Histoplasma capsulatum	bat dung, guano	?
Paracoccidioides brasiliensis	wood ?	armadillo
Penicillium marneffei	soil	bamboo rat
Sporothrix schenckii	wood	?

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Letter to the Editor

Terminology Changes Needed for Descriptions of *Pneumocystis carinii* Infection

Historically, descriptions of *Pneumocystis carinii* pneumonitis have presumed a protozoan parasite etiology, rather than the fungal etiology indicated by the microscopic and molecular biological evidence. The recent article entitled "T- and B-Lymphocyte-Independent Formation of Alveolar Macrophage-Derived Multinucleated Giant Cells in Murine *Pneumocystis carinii* Pneumonia" by Hanano et al. (6) perpetuates this erroneous classification by casually referring to *P. carinii* as a parasite with intracystic bodies and trophozoites and using the term infestation (commonly reserved for parasites). In its broadest sense, parasite denotes a plant or animal that lives in or on another living organism and obtains some advantage from this association (3). Thus, *P. carinii* could be called a parasite, but using this term in conjunction with trophozoite, intracystic bodies, and infestation implies classification of *P. carinii* as a protozoan parasite. The inappropriateness of applying the term nuclei to *P. carinii* has already received comment (1).

P. carinii continues to resist culture in artificial media, and some genera of fungi are difficult to differentiate from protozoan parasites in tissues sections (5). Chronic and active but minimal inflammation, absence of an eosinophilic infiltrate, one or more life forms, a yeast-like stage, association of organisms with reactive macrophages and multinucleated giant cells, requirement for special histochemical stains to visualize the organism in tissues sections, and the ultrastructural features of *P. carinii* are characteristics found more often with fungal infections than with a protozoan infestation. Demonstration of DNA homology of *P. carinii* with ustomycetous red yeast fungi (4, 8) has provided important, if not definitive, evidence for reclassifying *P. carinii* infection as a mycotic infection. Although some references continue to tentatively classify *P. carinii* with protozoans and indicate the possibility of a fungal or uncertain status (3, 5), the weight of evidence is with those who have embraced *P. carinii* within the fungal kingdom (7). In keeping with this taxonomic reclassification, the tissue forms of *P. carinii* should not be referred to by using parasitic terms such as sporozoite, trophozoite, cyst, or intracystic bodies (2).

We propose that the biomedical community should adopt terminology for *P. carinii* that is more applicable to other nonhyphal fungi. Presumably, the thick-walled body (formerly, the cyst) typically identified in tissue sections by silver stains should be referred to as the ascus (sometimes referred to as a sporangium, or spore case). The asci contain eight spores or endospores (formerly the intracystic bodies or sporozoites), which are then released to become yeast cells (formerly, trophozoites). Environmental conditions will determine if the spores immediately germinate into yeast cells (typically stained in tissue by Giemsa stain) or enter an ex vivo dormant phase typical of spores (not yet demonstrated for *P. carinii*).

Although details of the life cycle and mode of transmission of *P. carinii* are uncertain, adoption of a more generic terminology applicable to fungi seems reasonable. This change in terminology will enhance communication between investigators who are immersed in the pneumocystosis field and the uninitiated who sporadically encounter *P. carinii*. Only continued confusion can be expected if authors and journals perpetuate, intentionally or inadvertently, terminology that suggests *P. carinii* is a parasite rather than a fungus-like organism.

REFERENCES

1. **Beals, T. F.** 1991. Appropriate terminology for the features of *Pneumocystis carinii*. Acta Cytol. 35:250–251. (Letter.)
2. **Cushion, M. T., J. J. Ruffolo, and P. Walzer.** 1988. Analysis of the developmental stages of Pneumocystis carinii in vivo. Lab. Invest. 58:324–331.
3. **Dorland, N. W.** 1994. Dorland illustrated medical dictionary, 28th ed. The W. B. Saunders Co., Philadelphia, Pa.
4. **Edman, J. C., J. A. Kovacs, H. Masur, D. V. Santi, H. J. Elwood, and M. L. Sogin.** 1988. Ribosomal RNA sequences show *Pneumocystis carinii* to be a member of the fungi. Nature 334:519–522.
5. **Gardiner, C. H., R. Fayer, and J. P. Dubey.** 1988. An atlas of protozoan parasites in animal tissues, USDA handbook no. 651. U.S. Department of Agriculture, Washington, D.C.
6. **Hanano, R., K. Reifenberg, and S. H. E. Kaufmann.** 1996. T- and B-lymphocyte-independent formation of alveolar macrophage-derived multinucleated giant cells in murine *pneumocystis carinii* pneumonia. Infect. Immun. 64:2821–2823.
7. **Makimura, K., S. Y. Murayama, and H. Yamaguchi.** 1994. Detection of a wide range of medically important fungi by the polymerase chain reaction. J. Med. Microbiol. 40:358–364.
8. **Wakefield, A.E., S. E. Peters, S. Banergi, P. D. Bridge, G. S. Hall, D. L. Hawksworth, L. A. Guiver, A. G. Allen, and J. M. Hopkin.** 1992. *Pneumocystis carinii* shows DNA homology with the ustomycetous red yeast fungi. Mol. Microbiol. 6:1903–1911.

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Authors' Reply

In their letter, Schuh et al. emphasize the fact that *Pneumocystis carinii* is a fungus rather than a protozoan. We are fully aware of the fungal affiliation of *P. carinii*, as genetic studies cited by Schuh et al. have demonstrated. We admit to have been tangled in the maelstrom of commonly applied terminology and in this sense rather welcome efforts undertaken to address different developmental stages of this peculiar organism appropriately. Accordingly, we are in favor of changing the terms "trophozoites" and "intracystic bodies/sporozoites" to "yeast cells" and "(endo)spores," respectively. However, substitution of the term "cyst" for "ascus" should be treated with caution. In the fungal kingdom the ascus is not merely any spore case but a specialized form of such a structure typically exhibited by the fungal class *Ascomycetes*, the generation of which is strictly associated with sexual reproduction. Within the ascus, the karyogamy of gametes occurs, followed by meiosis and endogenous formation of haploid meiospores (contrasting exogenous generation of exospores or conidiospores). To our knowledge, there are no reports of definitive sexual reproductive processes in *P. carinii*, even though it was implicated by the suggested finding of synaptonemal complexes in a proposed "early precyst" developmental stage (1). It was further hypothesized that asexual cyst cycles also take place in the life span of the fungus (1). If this were so, terming the cyst an

ascus is, strictly speaking, incorrect. To our knowledge, *P. carinii* has not been definitely allocated a place within the class *Ascomycetes*, yet. Currently, it is believed to fit somewhere between ascomycetes and basidiomycetes (3). Until these questions are settled unambiguously, including the identification of gametes, we would propose the rather general term term "sporangium" more appropriate to describe the cyst.

Certainly, like all living cells, *P. carinii* also has nuclei. There are various ultrastructural studies in the literature showing exactly that. The authors may want to reread the letter by Beals that they have cited. Correctly, Beals reasoned the terming of "dark dots" on cysts (sporangia) that have been silver stained as nuclei to be inappropriate. By using other staining techniques such as Giemsa, nuclei of trophozoites (yeast cells) as well as cysts (sporangia) with intracystic bodies (spores) can be visualized very well, as stated just a few lines further down in his report.

The definition of a parasite as cited by Schuh et al. does not seem reasonable. Whether or not an organism can be denoted as a parasite depends solely on its life style, which is by no means restricted to plants and animals. A parasite is an organism that lives on or in another organism and draws its nourishment therefrom (2). Apart from plants and animals, there are definite parasitic representatives of bacteria and fungi. It seems extraordinarily surprising that a medical dictionary would not consider pathologically important organisms such as fungi as parasites. Surely, a fungus such as *Trichophyton rubrum*, which causes athelete's foot, must essentially be recognized as being parasitic. Other important parasitic fungi infest plants, the most famous of which is *Phytophthora infestans* (potato blight), which caused a devastating famine in Ireland in the last century. *P. carinii* exhibits profound parasitic properties by invading the pulmonary compartment of immunocompromised individuals. In this sense, the term "infestation" in association with this organism is justifiable. Incidentally, Dorland Illustrated Medical Dictionary, cited by Schuh et al., very well includes fungi as parasites (27th ed., parasite > plant parasite); however, fungi were probably erroneously classified as members of the plant kingdom ("vegetable kingdom," according to this dictionary).

REFERENCES

1. **Matsumoto, Y., and Y. Yoshida.** 1984. Sporogony in *Pneumocystis carinii* synaptonemal complexes and meiotic nuclear divisions observed in precysts. J. Protozool. 31:420–428.
2. **Stedman's medical dictionary 26th ed.** 1995. Williams & Wilkins, Baltimore, Md.
3. **Van der Peer, Y., L. Hendricks, and A. Goris.** 1992. Evolution of basidiomycetous yeasts as deduced from small ribosomal sub-unit RNA sequences. System. Appl. Microbiol. 15:250–258.

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HIV-POSITIVE INDIVIDUALS

CD4+ T-cells		Clinical categories		
		A Asymptomatic, acute (primary) HIV or PGL	B Symptomatic, not (A) or (C)	C AIDS
No.	%			
1. ≥500/μl	>28	A1	B1	C1
2. 200-499/μl	14-28	A2	B2	C2
3. <200/μl	<14	A3	B3	C3

PGL, persistent generalized lymphadenopathy.

A. Asymptomatic HIV infection
Persistent generalized lymphadenopathy
Acute (primary) HIV infection with accompanying illness or history of acute HIV infection

B. Candidiasis, oropharyngeal (thrush)
Candidiasis, vulvovaginal; persistent, frequent, or poorly responsive to therapy
Cervical dysplasia (moderate or severe)/cervical carcinoma in situ
Constitutional symptoms, such as fever (38.5°C) or diarrhea lasting >1 month
Herpes zoster (shingles), involving at least two distinct episodes
Pelvic inflammatory disease, particularly if complicated by tubo-ovarian abscess
Peripheral neuropathy

C. Candidiasis of bronchi, trachea, or lungs, esophageal
Cervical cancer, invasive
Coccidioidomycosis, disseminated or extrapulmonary
Cryptococcosis, extrapulmonary
Cryptosporidiosis, chronic intestinal (>1 month's duration)
Cytomegalovirus disease (other than liver, spleen, or nodes)
Cytomegalovirus retinitis (with loss of vision)
Encephalopathy, HIV-related
Herpes simplex: chronic ulcer(s) (>1 month's duration); or bronchitis, pneumonitis, or esophagitis
Histoplasmosis, disseminated or extrapulmonary
Isosporiasis, chronic intestinal (>1 month's duration)
Kaposi's sarcoma
Lymphoma
Mycobacterium avium complex or other species; disseminated or extrapulmonary
Mycobacterium tuberculosis, any site (pulmonary or extrapulmonary)
Pneumocystis carinii pneumonia
Pneumonia, recurrent, any cause
Salmonella septicemia, recurrent
Toxoplasmosis of brain
Wasting syndrome due to HIV

Table 14–1 *The Systemic Mycoses*

	Primary Pathogenic Fungus Infections	(Opportunistic) Fungus Infections
Diseases	Histoplasmosis ✚ Blastomycosis*✚ Paracoccidioidomycosis* Coccidioidomycosis	Aspergillosis Candidiasis ✚ ~~Mucormycosis~~ Zygomycosis Cryptococcosis* ✚
Host	Normal	Abrogated
Portal of entry	Primary infection pulmonary	Various
Prognosis	99% of cases resolve spontaneously (mainly for histoplasmosis & coccidioidomycosis)	Recovery depends on severity of impairment of host defenses
Immunity	Resolution imparts strong specific immunity	No specific resistance to reinfection
Host response	Tuberculoid granuloma; also mixed pyogenic	Depends on degree of impairment — necrosis to pyogenic to granulomatous
Morphology in tissue	All agents show dimorphism to a tissue form	No change in morphology†
Distribution	Geographically restricted (Endemic)	Ubiquitous

*These diseases have significant exceptions to the usual patterns.
†*Candida* sp. is found as mixed yeasts and mycelial elements in tissue.

Rippon Crescens book/BC

+AIDS-related mycosis (common)

Systemic = invasion of deeper tissues, organs and organ systems. CNS, blood, kidney, heart, liver, etc; mostly of pulmonary origin.

Table I
Growth Phases of Dimorphic Zoopathogenic Fungi[a]

In vivo group	Fungus	Saprophytic phase	Parasitic phase
Yeasts	*Ajellomyces (Blastomyces) dermatitidis*	Septate hyphae; white or beige, fluffy or glabrous colonies; microconidia; cleistothecia and ascospores in sexual state	Budding yeasts, size 8–20 μm; neck between mother cell and daughter bud very broad
	~~*Emmonsiella*~~ *A. capsulatus (Histoplasma capsulatum)*	Septate hyphae; white or tan, fluffy or flat colonies; microconidia and tuberculate macroconidia; cleistothecia and ascospores in sexual state	Budding yeasts, size 2–4 μm; neck between mother cell and daughter bud very narrow
	Paracoccidioides brasiliensis	Septate hyphae; white to beige, glabrous, leathery, flat, raised, or velvety colonies; no characteristic conidia; sexual state unknown	Budding yeasts, size variable, 2–30 μm or more; buds one to many per mother cell with neck between mother cell and daughter bud very narrow
	Sporothrix schenckii	Septate hyphae; white, black, or gray, glabrous or fuzzy, wrinkled colonies; conidiogenesis similar to that of some *Ceratocystis* species; sexual state unknown	Budding yeasts, size variable, 2–10 μm or more; sometimes cigar-shaped and up to 30 μm long; buds one to many per mother cell
Interconverting yeasts and hyphae	*Candida albicans*	Budding yeasts predominate, size 4–6 μm; smooth and creamy, white colonies; true hyphae, pseudohyphae, and chlamydospores not infrequent under certain environmental conditions; sexual state unknown	Mixtures of true hyphae, pseudohyphae, and yeasts
	Exophiala werneckii	Budding yeasts predominate in young cultures, size 6–12 μm; septate hyphae arise in older cultures, many intermediate forms; white, gray, or green-black, glabrous or fuzzy colonies; sexual state unknown	Mixtures of hyphae and yeasts
	Wangiella dermatitidis	Budding yeasts predominate in young cultures, size 6–8 μm; septate moniliform and true hyphae arise in older cultures; phialoconidia and annelloconidia; sexual state unknown	Mixtures of hyphae and yeasts; thick-walled, swollen cells and occasional multicellular (sclerotic) forms
Isotropic forms	*Phialophora verrucosa* and other chromoblastomycotic fungi	Septate hyphae; green-brown to green-black, fluffy colonies; phialoconidia, annelloconidia, etc.; sexual state unknown	Sclerotic bodies, which represent swollen, thick-walled cells and thick-walled, septated, multicellular forms
	Chrysosporium parvum var. parvum; C. parvum var. crescens	Septate hyphae; clear to white, glabrous to tufted colonies; smooth or spiny aleurioconidia; sexual state unknown	Adiaspores, which represent very swollen aleurioconidia; size varies from 10 to 400 μm in diameter; growth in tissue only by enlargement
	Coccidioides immitis	Septate hyphae that yield arthroconidia on fragmentation; white, tan, or brown, glabrous or fluffy, smooth or wrinkled colonies; arthroconidia typically barrel-shaped with disjuncters; sexual state unknown	Spherules, which represent very swollen arthroconidia that produce numerous endospores; size of spherules at maturity 30–60 μm in diameter; endospores formed by septation of cytoplasm

[a]Modified from Szaniszlo *et al.* (1983).

From Sz 9 ; pg. 6-7

TABLE 6–1. Five-Kingdom Classification of Living Things*

Kingdom	Characteristics	No. of Phyla	Representative Organisms
I. Monera	Prokaryotic (anucleate), no nuclear membrane, no mitochondria, no mitotic apparatus, single circular chromosome; direct cell division, primarily by binary fission. Nutrition ingestive, absorptive, chemosynthetic, photoheterotrophic or photoautotrophic. Unicellular, filamentous or mycelial. If motile, flagella has one microtubule containing flagellins, operated by a rotary motor embedded in bacterial cell wall. No sterols in cell membrane. Diaminopimelic acid (DAP) lysine synthesis.	14	Bacteria, myxobacteria, actinomycetes, cyanobacteria (blue-green algae).
II. Protoctista	Eukaryotic (nucleate), nuclear membrane, more than one chromosome, heterotrophic or photoautotrophic nutrition, premitotic or mitotic division, DAP lysine biosynthetic pathway, unicellular or multicellular. If motile, cilia or undulipodia (formerly called flagella) consisting of tubulin-containing microtubules arranged in a 9+2 or 9+0 array, forming a shaft (axoneme) inserted in a kinetid (kinetosome) and associated fibrils and tubules. Undulipodia whiplash or tinsel type. Plastids and mitochondria.	3	Protozoans, mycetozoans (slime molds), brown algae, red algae, green algae, hypochytrids, oomycetes, chytrids.
III. Fungi	Absorptive nutrition, unicellular or mycelial, haploid or dikaryotic organisms lacking kinetids and never undulipodiated at a stage in life cycle. Cell walls with chitin-chitosan with β-glucan, mannan, α-glucan, chitin-mannan, or galactosamine-galactose polymers. L-α-aminoapidic acid (AAA) lysine biosynthetic pathway.	2	Zygomycota, Dikaryomycota (Ascomycotina, Basidiomycotina), lichens
IV. Plantae	Photoautotrophic, highly differentiated, often with long diploid phase. DAP lysine pathway, developing from nonblastular embryos.	9	Liverworts, mosses, ferns, conifers, seed plants, and so forth.
V. Animalia	Heterotrophic, multicellular, diploid blastula.	32	Coelenterates, flatworms, mollusks, insects, reptiles, birds, mammals.

*Modified from Whittaker, R. H. 1969. Science, *163*:150–160.

only zoospore group thought to be in main line of fungal phylogeny.
Chytridiomycota

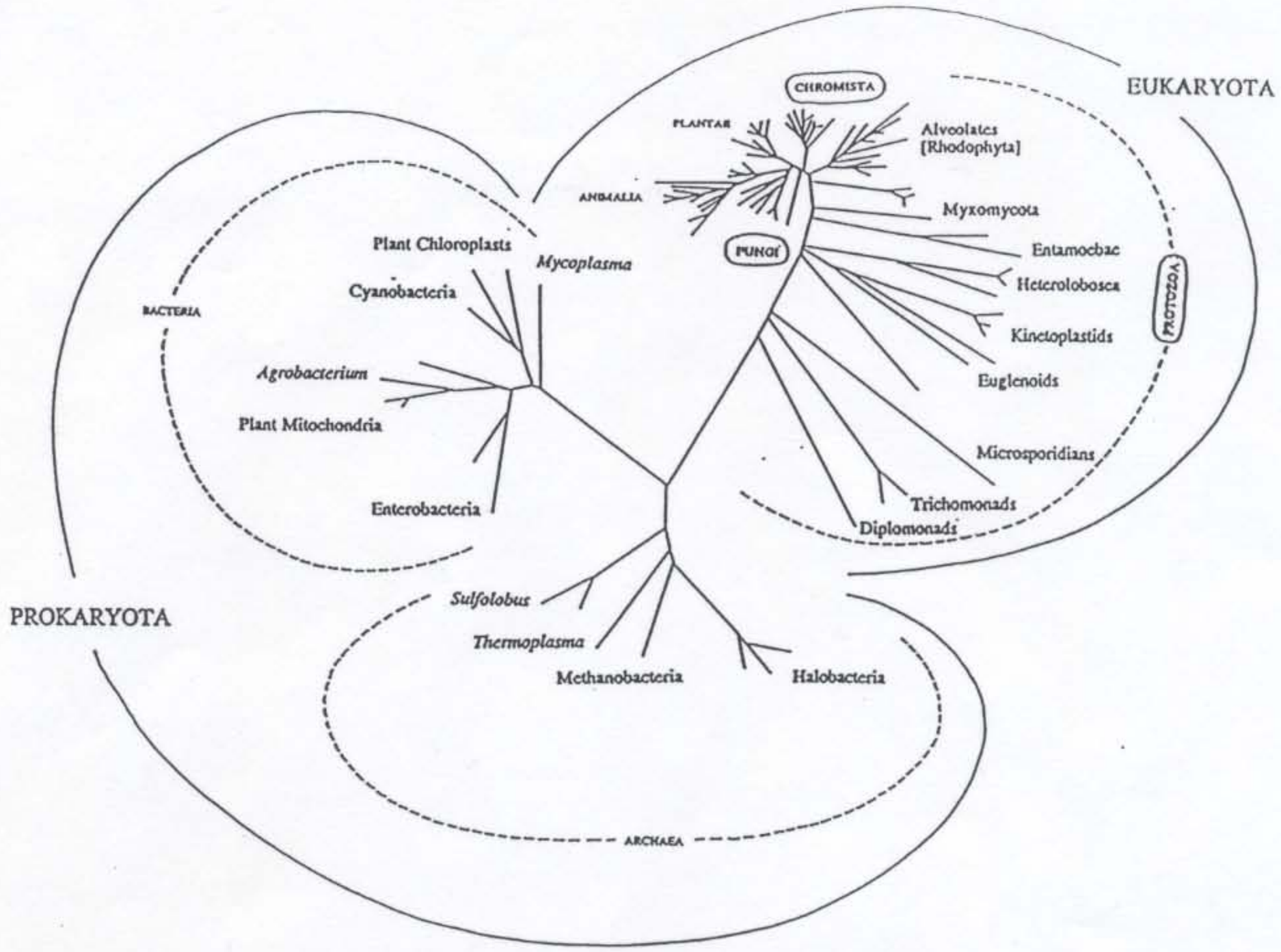

Fig. 31. An inferred unrooted phylogenetic tree of eukaryotes based on a distance analysis of all positions that can be unambiguously aligned among complete 16S-like rRNA molecular sequences from 75 taxa, modified from Patterson & Sogin, *in* Hartman & Matsumo (Eds) (*On the origin and evolution of prokayryotes and eukaryotes*, 1992). Shows relative positions of the Domains *Eukaryota* and *Prokaryota* and the kingdoms including fungi (Kingdom names ringed).

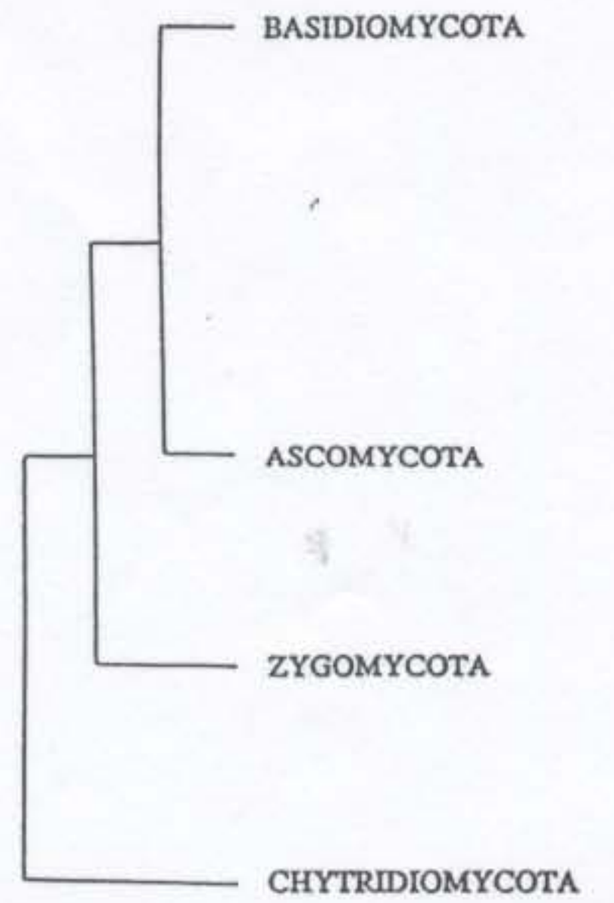

Fig. 32. Diagnostic unrooted phylogenetic tree showing relative positions of the phyla recognized in Kingdom *Fungi* by 18S-r RNA molecular sequences. Note that the confidence values are low for the *Chytridiomycota* + *Zygomycota* linkages. Simplified from Bruns *et al.*, 1992; Cavalier-Smith, 1993.

TABLE 4. Proposed classification of higher categories including fungi[1]

Bessey (1950)	Kriesel (1969)	Ainsworth *et al.* (1973)	v. Arx (1981)	Dictionary (1983)	Kreisel (1988)
	PROTOBIONTA	**FUNGI**	**MYCOTA**	**FUNGI**	**MYXOMYCOTA**
		Myxomycota	**Myxomycota**	**Myxomycota**	Acrasiomycetes
Mycetozoa	[Myxomycota excluded from Fungi]	Acrasiomycetes	Acrasiomycetes	Ceratiomyxomycetes	Ceratiomyxomycetes
		[Labyrinthulales]	Plasmodiophoromycetes	Dictyosteliomycetes	Myxomycetes
		Myxomycetes	Labyrinthulomycetes	Acrasiomycetes	Plasmodiophoromycetes
		Plasmodiophoromycetes		Myxomycetes	Protosteliomycetes
Class Phycomyceteae	**Eumycota**	**Eumycota**		Plasmodiophoromycetes	
	[Chytridiomycetes excluded from fungi]	*Mastigomycotina*	**Oomycota**	Labyrinthulomycetes	**LABRYINTHULOMYCOTA**
		Chytridiomycetes	Oomycetes		Labyrinthulomycetes
		Hyphochytriomycetes	Hyphochytriomycetes	**Eumycota**	
		Oomycetes		**Mastigomycotina**	**OOMYCOTA**
Division Carpomyceteae	[Oomycetes included as a Class of	*Zygomycotina*	**Chytridiomycota**	Chytridiomycetes	Hyphochytridiomycetes
		Zygomycetes	Chytridiomycetes	Hyphochytriomycetes	Oomycetes
Class Ascomyceteae	Chrysophyta (Algae)]	Trichomycetes		Oomycetes	
		Ascomycotina	**Eu-Mycota**	**Zygomycotina**	**CHYTRIDIOMYCOTA**
'The Pyrenomycetes'	Zygomycetes	Hemiascomycetes	Zygomycetes	Zygomycetes	Chytridiomycetes
	Endomycetes	Plectomycetes	Endomycetes	Trichomycetes	
	Ascomycetes	Discomycetes	Ustomycetes		**EUMYCOTA**
Class Basidiomyceteae	*Euascomycetidae*	Pyrenomycetes	Ascomycetes	**Ascomycotina**	Ascomycetes
Subclasses:	*Loculoascomycetidae*	Loculoascomycetes	Basidiomycetes	[No Classes recognized]	Basidiomycetes
Teliosporae	Basidiomycetes	Laboulbeniomycetes	Deuteromycetes		Endomycetes
Heterobasidiae	*Phragmobasidiomycetidae*	*Basidiomycotina*		**Basidiomycotina**	Teliomycetes
Hymenomyceteae	*Hymenobasidiomycetidae*	Teliomycetes		Hymenomycetes	Trichomycetes
'Gasteromycetes'	*Gasteromycetidae*	Hymenomycetes		Gasteromycetes	Ustomycetes
		Gasteromycetes		Urediniomycetes	Zygomycetes
		Deuteromycotina		Ustilaginomycetes	[Deuteromycetes]
The Imperfect Fungi		Blastomycetes			
Moniliales		Hyphomycetes		**Deuteromycotina**	
Sphaeropsidales	Endomycetes imperfecti	Coelomycetes		Coelomycetes	
Melanconiales	Ascomycetes imperfecti			Hyphomycetes	
	Basidiomycetes imperfecti				

[1]In some cases only the principle ranks are included for simplicity.
[2]Phyla including fungi only detailed here.
[3]Listed as classes in an unnamed phylum for plasmodial slime moulds.
[4]All lichen-forming fungi together with their photobionts.

Cavalier-Smith (1991)	Kendrick (1992)	Barr (1992)	Margulis (1993)	Moore (1994)	Dictionary (1995)
PROTOZOA	**PROTOCTISTAN FUNGI**	**PROTOZOA**	**PROTOCTISTA**	**FUNGI**	**PROTOZOA**
Mycetozoa	Myxostelida	Myxomycota	Acrasea[2]	*MASTIGOMYCETIA*	Acrasiomycota
	Dictyostelida	Plasmodiophoromycota	Chytridiomycota	Oomycota	Dictyosteliomycota
	Labyrinthulida		Dictyostelida	Saprolegniomycetes	Myxomycota
	Plasmodiophorida		Hyphochytriomycota	Peronosporomycetes	Myxomycetes
	Chytridiomycota		Labyrinthulomycota	Hyphochytriomycota	Protosteliomycetes
	Hyphochytriomycota		*Myxomycota*[3]	Chytridiomycota	Plasmodiophoromycota
	Oomycota		Oomycota	*ZYGOMYCETIA*	
			Plasmodiophoromycota	Zygomycota	
CHROMISTA		**CHROMISTA**	*Protostelida*[3]	Trichomycota	**CHROMISTA**
Heterokonta		Heterokonta		*ASCOMYCETIA*	Hyphochytriomycota
		Pseudomycotina		Euascomycota	Labyrinthulomycota
		Oomycetes		Hemiascomycota	Oomycota
		Hyphochytriomycetes		*BASIDIOMYCETIA*	
		Labyrinthista		Basidiomycota	
		Labyrinthulea		*Homobasidiomycotina*	
				Hymenomycetes	
				Heterobasidiomycotina	
				Heterobasidiomycetes	
FUNGI	**EUMYCOTAN FUNGI**	**EUMYCOTA**	**FUNGI**	Teliomycetes	**FUNGI**
Archemycota	Dikaryomycota	Ascomycota	Ascomycota	Ustomycota	Ascomycota
Chytridiomycetes	Ascomycotina	Basidiomycota	Basidiomycota	*DEUTEROMYCETIA*	Basidiomycota
Trichomycetes	Basidiomycotina	Chytridiomycota	Deuteromycota	Deuteromycota	Basidiomycetes
Zygomycetes	Zygomycota	Zygomycota	Mycophycophyta[4]	Coelomycetes	Teliomycetes
Ascomycota			Zygomycota	Hyphomycetes	Ustomycetes
Basidiomycota				Agonomycetes	Chytridiomycota
				Blastomycota	Zygomycota
				Ascoblastomycetes	Trichomycetes
				Basidioblastomycetes	Zygomycetes

A Kingdom-Level Phylogeny of Eukaryotes Based on Combined Protein Data

BIO 329
Handout 1a

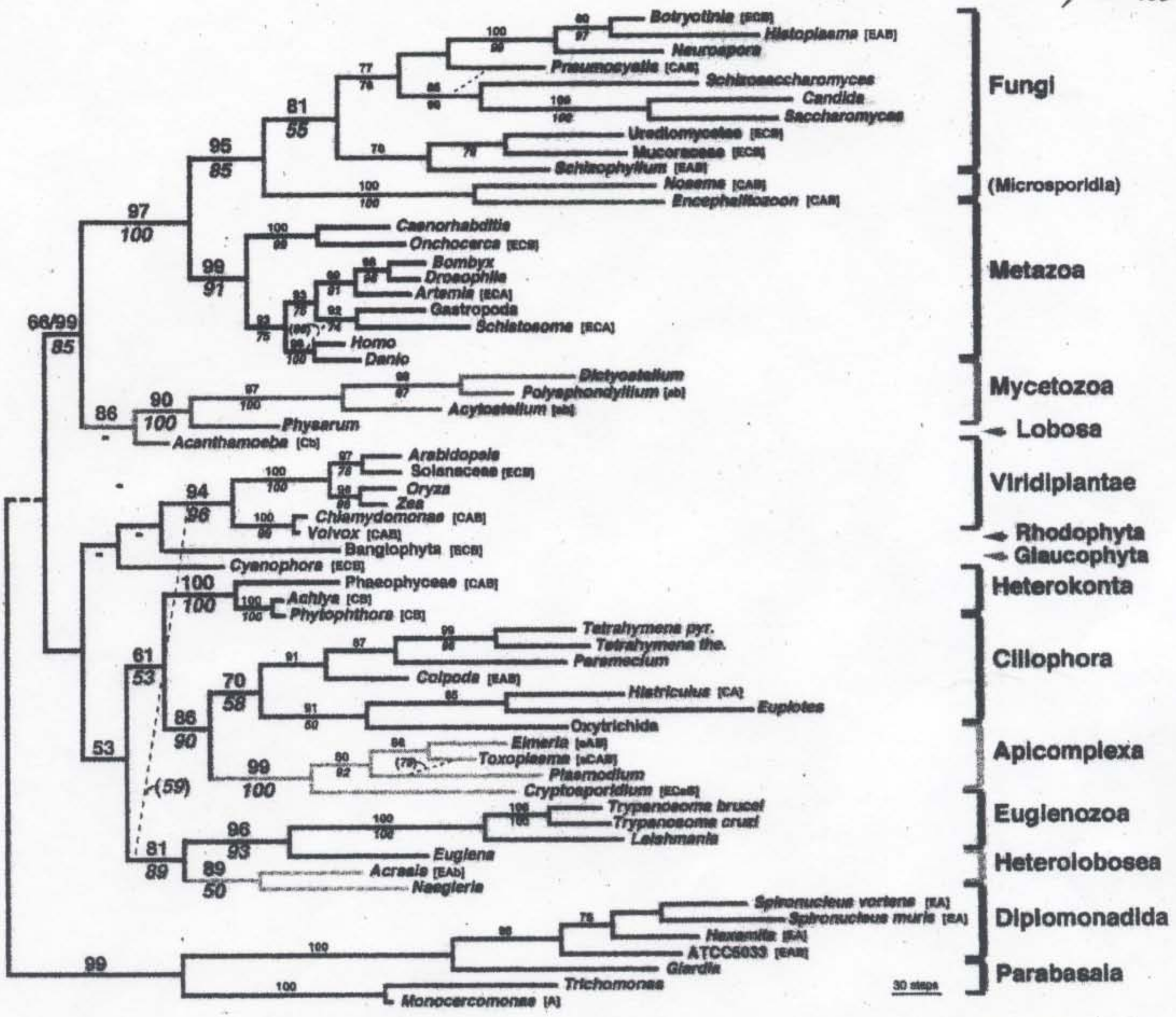

Fig. 1. A kingdom-level phylogeny of eukaryotes, based on combined protein sequences. The tree shown is one of two shortest trees found by parsimony analysis of concatenated EF-1α, actin, α-tubulin, and β-tubulin amino acid sequences (*44*). The tree is 5056 steps long with branches drawn to scale as indicated (*43*, *45*). Bootstrap values >50% are shown above and below the lines, respectively, for amino acid parsimony (aaBP) and maximum likelihood analyses of second codon–position nucleotides (ntBP). Parenthesis indicate the aaBP for the grouping of animals + fungi plus lobosa + mycetozoa in analyses omitting Bangiophyceae and *Cyanophora* (see text). Dashes (–) below lines indicate nodes not tested in the ntBP analyses shown [Bangiophyceae, *Cyanophora*, and *Acanthamoeba* omitted; see text (*29*)]. For taxa with missing data, the sequences used are indicated in brackets to the right of taxon names in uppercase and lowercase letters for complete and partial sequences, respectively (E = EF-1α, C = actin, A = α-tubulin, B = β-tubulin). The lowest common taxonomic designation is given for sequences combined from different taxa. The shortest trees differ only in their placement of *Pneumocystis*, as shown by the thin dashed line; all other slanting dashed lines indicate alternative groupings found with ntBP >50%. The horizontal dashed line (**left center**) indicates tentative placement of the Diplomonadida and Parabasalia (*46*).

Baldauf et al., Science 290 (2000) 973.

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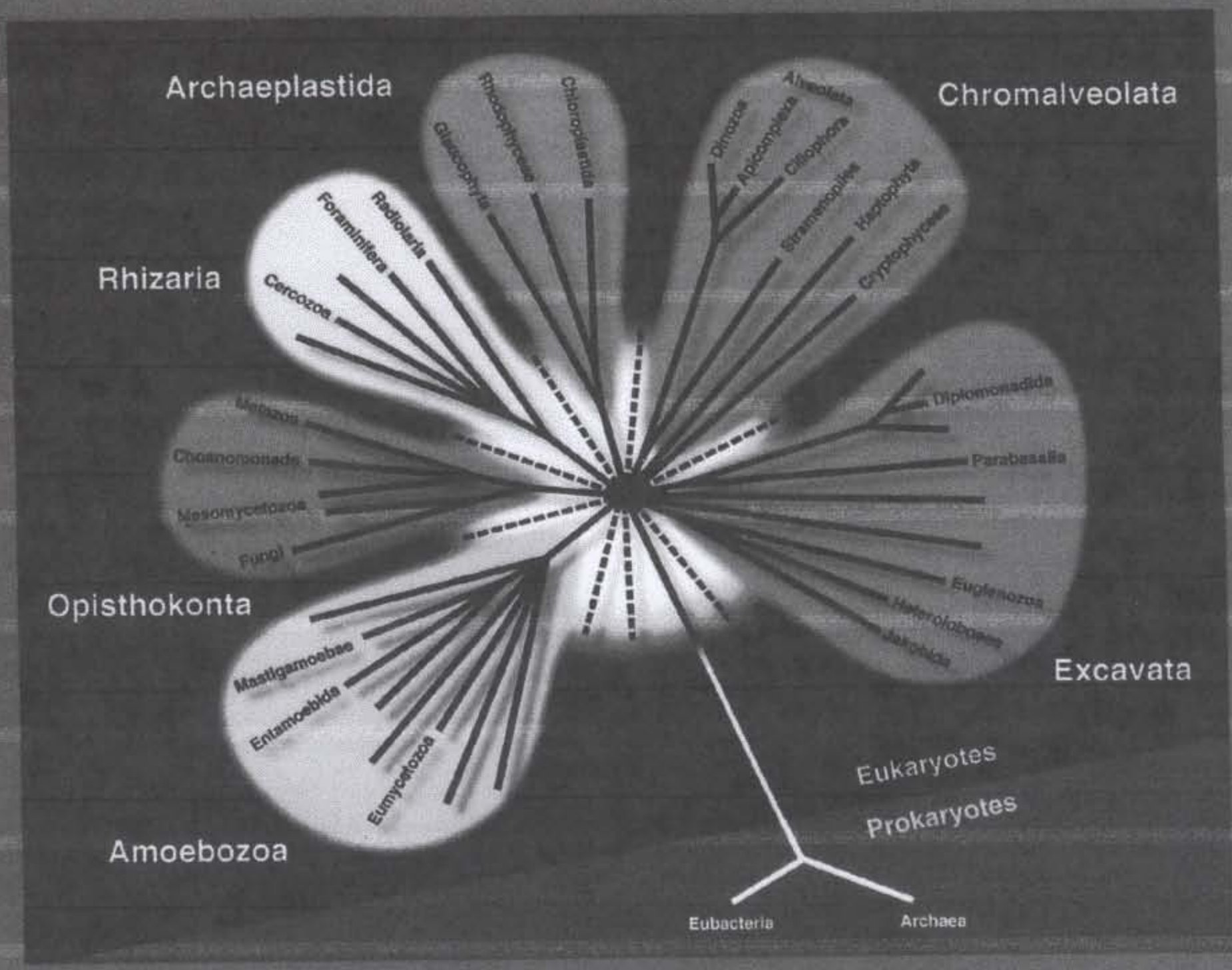

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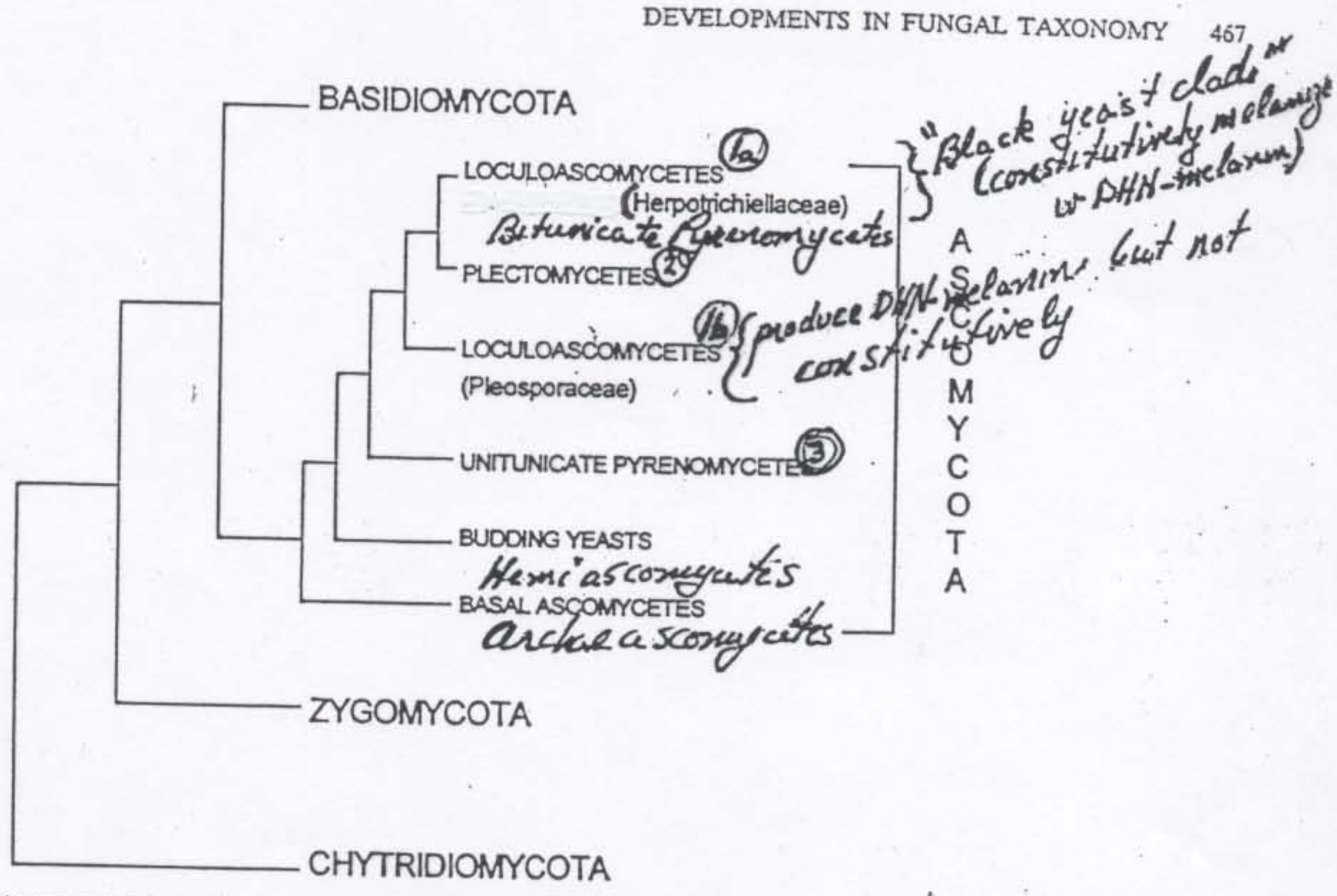

FIG. 5. Diagnostic unrooted phylogenetic tree showing the relative positions of fungal clades of clinical importance by ISS rRNA sequences.

1a. Loculoascomycetes I; Chaetothyriomycetes (?)
1b. Loculoascomycetes II; Dothideomycetes (?).

From Guarro, et al., Clin. Microbiol. Rev. 12(1999) 454-500.

From Atlas of Clinical Fungi' 2nd ed. (on Reserve; pg 4) 2000.

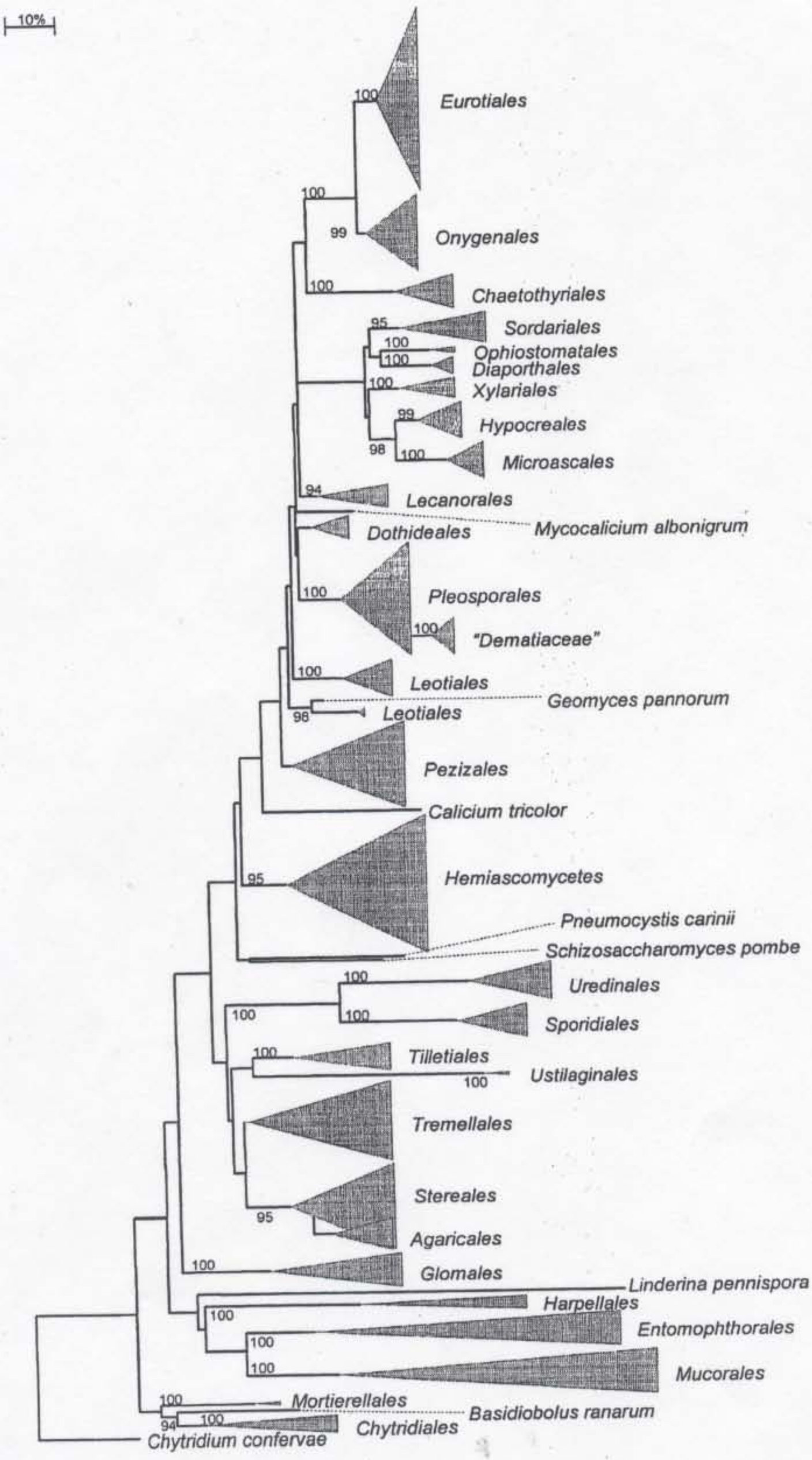

Fig. 3. Phylogenetic tree of the *Eumycota*, mainly showing the members which have been implicated in diseases of human and animals. The tree is based on 414 near-complete SSU rDNA sequencesaligned by Y. van de Peer, using Neighbor joining algorithm with Kimura correction. Bootstrap values >90 from 100 resampled datasets are shown. The tree is highly unbalanced, since of large groups with high biodiversity, e.g., *Dothideales* and *Pezizales*, only relatively few members have been sequenced; well-known order such as the *Eurotiales* are over-represented. Some orders, like the *Pezizales*, are heterogeneous so that they appear several times in the tree; others could not be resolved, e.g., the *Agaricales* being paraphyletic to the *Stereales*. A few individual taxa are attributed with difficulty to any order, such as *Geomyces pannorum*, *Pneumocystis carinii* and *Basidiobolus ranarum*. Note that in the *Zygomycota* the number of species is low but the mutual distances are enormous (compare also Fig. 13 on p. 61).

Table

A Basic Nomenclatural Overview For Some Fungal Infections

Infections
Infections caused by molds
Black fungi Chromoblastomycosis Mycetoma Phaeohyphomycosis Nonblack fungi Aspergillosis Dermatophytosis Hyalohyphomycosis Mycetoma Zygomycosis Dimorphic fungi Blastomycosis Coccidioidomycosis Histoplasmosis Paracoccidioidomycosis Penicilliosis (in part hyalohyphomycosis) Sporotrichosis
Infections caused by yeasts
Candidiasis Cryptococcosis Pityriasis versicolor
Infections caused by fungi whose classification is uncertain
Lobomycosis Rhinosporidiosis
Immune and Toxic Diseases Associated With Fungal Products
Asthma and allergy Poisoning by fungi Mycetism Mycotoxicoses