North American Mycoflora Project

Without a sequenced specimen it's a rumor
Thanks to

Bob Mara and Jean Lodge (local arrangements)

Karen Hughes (Fesin Website)

David Rust, Else Vellinga, Nathan Wilson for input into the program

NSF Research Coordination Network grant
Fungal Environmental Sampling and Informatics Network

F E S I N

Photo by Clark Orr, Biodiversity Informatics, Great Smoky Mountains National Park
Goals of this meeting are:

1) to outline a white paper targeted for *BioScience*

2) Create a framework to progress toward a mycoflora
Possible title for the paper:

"A North American Mycoflora – you mean we don't already have one of those?” – Erik Lilleskov

“Working toward a North American Mycoflora: an old fashioned idea, whose time has finally come”
A rough outline for the paper

• What is a mycoflora and what can it do for the scientific community?
• Why don't we have one already?
• What do we need to do to produce one?
• What tools or advantages do we have now that make it possible?
• What would a modern mycoflora look like?
• What kind of time scale and funding will be needed to accomplish it?
A rough outline for the paper

• **What is a mycoflora** and what can it do for the scientific community?
• **Why don't we have one already?**
• What do we need to do to produce one?
• What tools or advantages do we have now that make it possible?
• What would a modern mycoflora look like?
• What kind of time scale and funding will be needed to accomplish it?
The long-term goal of this project is to produce a modern, comprehensive mycoflora of macrofungi for North America. This would be a resource that contains monographic treatments of all the macrofungi. It would provide online keys and downloadable applications, up to date distribution maps, links to macroscopic and microscopic images, and links to nucleotide sequences and phylogenetic trees. We are a long way from this goal and will need the help of everyone interested in this project to get there.

The recent push for a North American Mycoflora was been made by articles by Matheny and Vellinga 2009, and Bruns 2011 in the Inoculum, and the call was repeated by Bruns and Beug 2012 in Mclivanea. However, the idea of a mycoflora is hardly a new one (see Petersen's short historical perspective here). Nevertheless we have never really made a serious attempt at producing a Mycoflora in North America. In fact we have never had even a regional mycoflora for any part of the continent. However, we think that the combination of web-based tools, trained citizen scientists, and DNA sequence analysis open up the possibilities for producing the first North American Mycoflora for Macrofungi within our life times.

You may wonder how a mycoflora would be different from the field guides and foray lists already available. **Vouchered herbarium specimens** is a big part of the answer. In any monographic treatment species concepts are anchored to physical specimens. So that when one gives a species description, it is followed by a
A rough outline for the paper

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• Why don't we have one already?
• What do we need to do to produce one?
• What tools or advantages do we have now that make it possible?
• What would a modern mycoflora look like?
• What kind of time scale and funding will be needed to accomplish it?
What will a mycoflora provide?

- Baseline data for conservation
- The first broadly based view of biogeographic patterns in North American Fungi
- A great sequence database for ecological studies
- Enhanced identification tools
- A recruitment tool for the field of mycology at both the professional and the citizen science levels
What do we need to do to create a mycoflora?

- Assemble (and scrutinize) existing herbarium records and literature
- More sampling
- Recruit and train more people
- New sequence acquisition and analysis
- Create modern monographs
- Set some realistic short-term goals and a structure to work toward long-term goals
- Find funding
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- Find funding
Email from Tim Baroni:

“The issue I foresee is gathering a critical mass of workers to produce such a product. North America is a big piece of real estate with a significant number of taxa yet to be described in most all groups of macrofungi.”
Email from Karen Nakasone

“This is something I am interested in but never imagined that it could be done -- too many species and not enough taxonomists. But nothing ventured nothing gained, right? “
How big is the mycoflora?

Global diversity and distribution of macrofungi

How big is the mycoflora?

Based on current names

10,000 macrofungi occur in North America and 65% are unique to the continent
Conclusions of Mueller et al 2007:

Using a list of names to estimate species is not ideal....

However the data sets for each region are often woefully incomplete and most taxonomic groups have not been recently monographed, so numerous cryptic species will likely be uncovered. Therefore, we are confident that our numbers represent very conservative estimates for macrofungal diversity in each region.
What do we need to do to create a mycoflora?

• Assemble (and scrutinize) existing herbarium records and literature
• More sampling
• Recruit and train more people
• New sequence acquisition and analysis
• Create modern monographs
• Set some realistic short-term goals and a structure to work toward long-term goals
• Find funding
Why do we need sequences?

• Allows us to compare across regions and studies
• Allows us to connect current collections to types (and therefore correct names)
• Allows us to connect environmental sequences to organisms
Suillus quiescens - its known distribution is expanded by sequences from pine roots (yellow)
How much sequencing do we need and who will do it?

- 10,000 species X 10 accessions of each = 100,000
- We obviously want to make access to sequencing widely available
- A centralized sequencing facility that gives everyone access to the sequence analysis would be ideal.
Nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for *Fungi*

Conrad L. Schoch\textsuperscript{a,1}, Keith A. Seifert\textsuperscript{b,1}, Sabine Huhndorf\textsuperscript{c}, Vincent Robert\textsuperscript{d}, John L. Spouge\textsuperscript{a}, C. André Levesque\textsuperscript{b}, Wen Chen\textsuperscript{b}, and Fungal Barcoding Consortium\textsuperscript{a,2}

\textsuperscript{a}National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health, Bethesda, MD 20892; \textsuperscript{b}Biodiversity (Mycology and Microbiology), Agriculture and Agri-Food Canada, Ottawa, ON, Canada K1A 0C6; \textsuperscript{c}Department of Botany, The Field Museum, Chicago, IL 60605; and \textsuperscript{d}Centraalbureau voor Schimmelcultures Fungal Biodiversity Centre (CBS-KNAW), 3508 AD, Utrecht, The Netherlands

Edited* by Daniel H. Janzen, University of Pennsylvania, Philadelphia, PA, and approved February 24, 2012 (received for review October 18, 2011)
Dear Tom
We have just received notice that our federal government has hugely reduced support to Genome Canada and this will have very great impacts on our project. **We have decided that we must focus our efforts solely on animals and plants.**

Best wishes Paul [Hebert]
What do we need to do to accomplish this?

• Assemble (and scrutinize) existing herbarium records and literature
• More sampling
• Recruit and train more people
• New sequence acquisition and analysis
• **Create modern monographs**
• Set some realistic short-term goals
• Find funding
What Characteristics Should We Strive for in a Modern Monograph?

- Comprehensive, accurate, current information for the targeted taxa (easily edited)
- Specimen and sequence-based, with lots of cross-links to metadata
- Great keys with lots of illustrations
- Lots of color images
- Portable
- Inexpensive to the users
Fig. 113. *Cinereomyces lindbladii*
cystidioles, d, basidia, e, basidiospores.

I. a, generative hyphae, b, skeletal hyphae, c,
Mapped collections of *Cinereomyces lindbladii* from Mycoportal.org.
KEY TO FAMILIES AND GENERA

1. Spores pale brown to yellowish, with an inner ornamented sporewall and a hyaline outer one ........................................... Ganoderma
2. Spores hyaline to rusty brown, with a simple wall ........................................... 2
3. Tubes separate, but closely packed ........................................... Fistulinia
4. Tubes coherent, hymenophore poroid, lamellate, daedaleoid or hydnoid to strongly incised ........................................... 3
5. Fruitbodies brown, becoming black with KOH, generative hyphae with simple septa, dark brown, acute setae absent or present, cystidia never present ........................................... Hymenochaetaceae
6. Fruitbodies variably colored, if black in KOH, then always with clamped generative hyphae, generative hyphae with clamps or simple septa, dark brown setae never present, cystidia absent or present ........................................... Polyporaceae.

HYMENochaetaeae

1. Spores finely ornamented, fruitbodies small, pendant or stipitate, on dead wood ........................................... Coltriciella
2. Spores smooth, fruitbodies small to very large, resupinate, pileate to stipitate, on dead wood or the ground ........................................... 2
3. Fruitbody more or less centrally stipitate, usually on the ground, setae never present ........................................... Coltriciella
4. Fruitbody resupinate, pileate, sometimes with a lateral, tapering base, setae present or absent ........................................... 3
5. Hymenophore hydnoid to deeply incised ........................................... Hydrochaete
6. Hymenophore distinctly poroid ........................................... 4
7. 4. Hyphal system dimitic with skeletal hyphae, fruitbodies mostly woody and perennial ........................................... Phellinus
8. Hyphal system monomorphic, fruitbodies mostly fragile when dry ........................................... 5
9. Context distinctly dux, upper loose part often separated from the lower dense part by a black zone ........................................... 6
10. Context homogeneous ........................................... 7
11. Setae absent, spores usually abundantly present, ellipsoid and pale yellowish, fruitbodies 5-20 mm thick, on living trees or plants ........................................... Phylloporia
12. Setae present, spores usually difficult to find, cylindrical and hyaline, fruitbodies 1-3 mm thick, on dead wood ........................................... Cyclomyces
13. Spores hyaline to rusty brown in KOH, pileus if present, hirsute, villose to glabrous, normally without a crust ........................................... Inonotus
14. Spores olive brown in KOH, pileus glabrous and with a distinct crust, at least close to the base ........................................... Aurificaria

POLYPORACEAE, CONDENSED KEY TO MAIN SECTIONS

A. Fruitbody more or less centrally stipitate (all species with numerous pilei from a common base belong here) ........................................... 1
1. A. Fruitbody resupinate to pileate, sometimes with a tapering lateral base or stipe ........................................... B
2. Hymenophore irregular, hydnoid, lamellate, daedaleoid to sinuous ........................................... 17
3. Hymenophore with angular to round pores, sometimes slightly split and dentate in the dissepiments ........................................... C
4. Spores ornamented ........................................... 31
5. Spores smooth ........................................... D
6. D. Amyloid or dextrinoid reaction in spores, cystidia or hyphae ........................................... 38
7. D. No amyloid nor dextrinoid reaction in spores, cystidia or hyphae ........................................... E
8. E. Generative hyphae with simple septa ........................................... 47
9. E. Generative hyphae with clamps ........................................... F
10. F. Tubes and context brown, purplish black, orange, brick red or cinna-barr red ........................................... 63
11. F. Tubes and context white, ochraceous, yellow to pale brown ........................................... G
12. G. Cystidia present in hymenium or context ........................................... 80
13. G. Cystidia absent from hymenium or context ........................................... H
14. H. Hyphal system monomorphic ........................................... 85
15. H. Hyphal system di or trinemic ........................................... 93

POLYPORACEAE AND SOME POROID REPRESENTATIVES FROM OTHER FAMILIES

Basidiocarps more or less centrally stipitate

1. Spores ornamented ........................................... 2
2. Spores smooth ........................................... 6
3. Spores amyloid or dextrinoid ........................................... 4
4. Spores non-amyloid ........................................... 5
5. Spores dextrinoid ........................................... Diacanthodes
6. Spores amyloid ........................................... 4
7. Spores coarsely crested, 5-8 μm in diameter ........................................... Bondarzewia
8. Spores finely asperulate, 4-5 μm in diameter ........................................... Amylosorus
9. Spores angular, fruitbody grayish to orange ........................................... Boletopsis
10. Spores globose with pitted walls (Ganoderoid) ........................................... Polyporotus
11. Fruitbody with many pilei from a common base ........................................... 7
12. Fruitbody with a single pileus or a few fused or lobed ........................................... 11
13. Fruitbody globose with numerous small pilei, context brown ........................................... Globifomes
14. Fruitbody stipitate and branched, context white to ochraceous ........................................... 8
ANNOTATED KEY TO PACIFIC NORTHWEST POLYPORES

Prepared for the Pacific Northwest Key Council
by J. Ginns, Vancouver Mycological Society, January 2007

Copyright © 2007 Pacific Northwest Key Council

**Pileus** 2-7 x 2-12 x 1-2 cm, sessile, semicircular to conchate, surface appressed-tomentose, red; **context** red to orange-red, zonate, soft-fibrous or soft-corky; **tubes** 2-6 mm deep; **pore surface** smooth, red; **pores** 2-4 per mm, round to angular, occasionally daedaleoid. **Basidiospores** 4.5-6 x 2-3 μm, oblong-ellipsoid; **context** trimitic, **generatives** with clamps. **Color picture** figure 512 in Lincoff (1994). Note 12.

16b Pore surface not bright cinnabar red

............... 17

17a Basidiocarps resupinate or effuse-reflexed; pores large, 1-3 mm diameter, orange with white edges, soon becoming irpiciform

**Pileus** surface when present orange, rough-fibrillose; **context** orange, soft-fibrous, becoming cherry red with KOH; **tubes** 10-20 mm deep, walls orange with white, irregular, jagged edges. **Basidiospores** 6-10 x 3-4 μm, cylindrical; **leptocystidia** 50-100 x 6-12 μm, cylindrical, walls hyaline, thin; **context** monomitic; **generatives** lack clamps. **Color picture** figure 747 in Lincoff (1994). Note 13.
<table>
<thead>
<tr>
<th>Basidocarp</th>
<th>Color of context or pore surface</th>
<th>Hymenophore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stipitate</td>
<td>Placate</td>
<td>Bursate</td>
</tr>
<tr>
<td>Abertiporus</td>
<td>Albatrellus</td>
<td>Amyloeptis</td>
</tr>
</tbody>
</table>
Our mission is to assemble and share knowledge in order to improve education, health, agriculture, economic development, and conservation throughout the world.

We provide free on-line tools to identify species, share ways to teach and study nature’s wonders, report findings, build maps, process images, and contribute to and learn from a growing, interactive encyclopedia of life that now has 1,225,407 species pages.

Please get involved and join our research and educational projects. — John Pickering
# IDnature Guides

**To start a guide, click on its blue link.**

All guides are under construction and may contain errors.

## Plants
- **Burseraceae**, Peru
- **Famis**, North America
- **Flora, Neotropics**
- **Frullania Liverworts, World**
- **Ginseng genera, World**
- **Grasses, Sedges & Rushes, North America**
- **Laurels, Asia**
- **Leaves, Barro Colorado Island, Panama**
- **Opuntia, New World**
- **Tree genera, Madagascar**
- **Trees, Shrub & Vines, North America**
- **Wildflowers, North America**

## Vertebrates
- **Birds, North America**
- **Frogs & Toads, World checklist**
- **Frogs & Toads, North America**
- **Frogs & Toads, Panama**
- **Lizards, North America**
- **Mammals, North America**
- **Marine Mammals, World**
- **Salamanders, North America**
- **Shorefishes, Tropical eastern Pacific**
- **Snakes, North America**
- **Turtles, North America**

## Fungi
- **Fungi, North America**
- **Graphis, World**
- **Chaetosphaeriaceae**
- **Hysteriaceae**
- **Tubaphaceae**
- **Xylariaceae**

## Other
- **Goldenrod associates**
- **Invasives, North America**
- **Land Snails, Jamaica**
- **Sea anemones**

## Insects
- **Bees (over 70 guides)**
- **Bees – world checklist**
- **Apoid wasps, North American checklist**
- **Bumblebees & mimics, North America**
  - (uses Bombus guide when experienced)
- **Butterflies, North America**
- **Caterpillars, North America**
- **Cicada species, North of Mexico**
- **Crane Fly Flies, Adult**
- **Cricket and katydid species, North of Mexico**
- **Dragonflies, North America**
- **Dung Beetles, North America**
- **Goldenrod associates**
- **Insect orders, World**
- **Ladybugs, North America**
- **Leaf Beetles, Panama & Ecuador**
- **Membracoidea – world checklist**
- **Mosquitoes, North America**
- **Moths, North America**
  - Georgia, Clarke County
- **Ticks, North America**

## Ants – world checklist
- **Ants Ascension Island**
- **Mona Island**
- **Navajo Nation**
- **New Caledonia**
- **Niue**
- **North America**
- **Philippines**
- **Sabah**
- **Samoa**
- **St. Helena**
- **St. Lucia**
- **St. Vincent**
- **Tonga**
- **Tristan da Cunha**
- **Uganda**
- **USNC**
- **Vietnam**
A piece of the Xylariaceae key (by Andy Miller)

1. Stromata, position
   - Horizontal
   - Vertical

2. Stromata, number of perithecia
   - Multiple perithecia in stromata
   - Single perithecium in stromata

3. Stromata, shape
   - Club-shaped
   - Crust-like
   - Cup-like to disc-shaped
   - Flat and bumpy
   - Flat, not bumpy
   - Half-rounded globular mounds
   - Round, ball-shaped
   - Round, pea-shaped
   - Thread-like to hair-like

4. Stromata, color
   - Brown colored brown to grayish-brown
   - Dark brown dark brown to dark gray or black
   - Purplish colored purple to purplish-brown
   - Reddish colored orange to red or dark red
   - White to gray with black dots ostioles

5. Stromata, ostioles
   - Not distinct
   - Papillate
   - Surrounded by a poorly developed circle
   - Surrounded by a well developed circle
   - Surrounded by a white ring

6. Asci, shape
   - Cylindrical
   - Globose to subglobose

7. Ascospore, shape
   - Ellipsoid
   - Subglobose
What Characteristics Should We Strive for in a Modern Monograph?

✓ Comprehensive, accurate, current information for the targeted taxa (readily edited)
✓ Specimen and sequence based, with lots of cross-links to metadata
✓ Great keys with lots of illustrations
✓ Lots of color images
✓ Portable
✓ Inexpensive for the users
✓ Electronic
Can we connect existing web resources together to provide the platform we need?

- Herbarium databases, Mycoportal – primary repository of specimens and analytical tools for geographic information retrieval
- Mushroom Observer – primary entry of images and data for new collections
- Discoverlife.org – primary key interface
- Wikipedia or EOL – primary location for species pages
- Genbank for deposition of sequences, but here we need a database that can be annotated – with crosslinks to specimens
What do we need to do to accomplish this?

- Assemble (and scrutinize) existing herbarium records and literature
- More sampling
- Recruit and train more people
- New sequence acquisition and analysis
- Create modern monographs
- Set some realistic short-term goals
- Find funding
Email from Tim Baroni:

“Money to do this work would serve as an important factor to bring morphological taxonomists into a group effort. We basically have been pushed off of NA to tropical regions in the past two decades to obtain funding to work. Not all bad because we have been finding lots to keep us busy, but unfortunately our numbers are not growing like they need to in order to tackle such a project with any ease.”
What would funding do for us

- Pay salaries for postdocs, students, and professionals to do the work and to train additional people
- Pay for travel for new collecting
- Pay for curation of the specimens
- Pay for web-related construction and upkeep
- Pay for sequencing
- Allow young taxonomists to work in North America and achieve tenure
Funding must be available for Canadian and Mexican parts of the project as well

- From Scott Redhead: “....Canada covers a rather large land mass for North America, and yet I don’t see that much from Canada in the program or among the attendees.”
A rough estimate of funding needs

• Assuming six regional centers for organizing and sequencing collections distributed across the continent

• Each center would need to hire a postdoc, hourly help or student support, pay for travel, pay for sequencing, pay for curation

• Conservatively $300,000/year/center; X 6 centers; = 1.8 million/year; X 10 years = 18 million
How do we find this kind of money?

• We convince others it’s worth it!
• “Others” might include: NSF, Foundations, Individuals
• For existing NSF support - REU supplements, “broader impact outreach” are natural ways to tap into small amounts of money
And without additional funding what can we do?

- We can start with the pieces for which we can find money
- We can coordinate these pieces so that they fit together
Without a sequenced specimen it’s a rumor
### Presentations Today

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<td>registration and breakfast</td>
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<tr>
<td>9:00 AM</td>
<td>Welcome, Introduction, and charge</td>
<td>Tom Bruns</td>
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<tr>
<td>9:30 AM</td>
<td>Mushroom Observer (and EOL) as a repository of images and metadata</td>
<td>Nathan Wilson</td>
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<td>10:00 AM</td>
<td>Group authoring of web content - how to keep quality and accuracy high and</td>
<td>Daniel Mietchen (presenting remotely)</td>
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<td>resolve conflicts: the Wikipedia example</td>
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<td>10:45 AM</td>
<td>Discoverlife.org: Modern Random-access, image-rich keys and beyond</td>
<td>John Pickering</td>
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<td>11:15 AM</td>
<td>Assembling the existing data available in Herbaria</td>
<td>Barbara Thiers</td>
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<td>11:45 AM</td>
<td>The Nordic Mycoflora and thoughts on making large mycofloristic projects</td>
<td>Henning Knudsen</td>
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<td><strong>Examples of ongoing surveys</strong></td>
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<td>Great Smoky Mts. Survey</td>
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<td>NAMA Voucher program</td>
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<td>Potential contributions towards a North American-wide Mycota</td>
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<td>American-wide Mycota from Canada</td>
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<td>2:30</td>
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<td>2:45-3:00</td>
<td>Discussion on Surveys</td>
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<td>3:00-4:45</td>
<td><strong>Examples of Modern monographic or regional taxon oriented work</strong></td>
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<td>3:00</td>
<td>Agaricus</td>
<td>Rick Kerrigan</td>
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<td>Rooting out Phaeocollybia: lessons learned</td>
<td>Lorelei Norvell</td>
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<td>&amp; a second chance.</td>
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<td>Russula in North America</td>
<td>Bart Buyck</td>
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<td>A mycoflora for the Inocybaceae of Australia</td>
<td>Brandon Matheny</td>
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<td>4:00</td>
<td>Large-scale barcoding of fungal collections</td>
<td>Todd Osmundsen</td>
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<td>4:15-4:45</td>
<td>Discussion and Concluding remarks</td>
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<td>5:30-9:00</td>
<td>Dinner and social Kelly’s 196 Crown St</td>
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# Sunday Afternoon Discussion Sessions

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<td>2-3:30 PM</td>
<td>Session 1</td>
<td>Topics Goals and Structure</td>
<td>Else Vellinga, Mike Wood, Ron Petersen</td>
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<tr>
<td></td>
<td>Session 2</td>
<td>Physical logistics (specimen/taxonomy related)</td>
<td>Brandon Matheny, Scott Redhead, Roy Halling, Patrick Leacock, Lorelei Norvell</td>
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<td>Session 3</td>
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<td>David Rust, Karen Nakasone, Bart Buyck, Sharon Cantrell</td>
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<td>Session 4</td>
<td>Web and Database Issues</td>
<td>Barbara Thiers, Nathan Wilson, John Pickering, Scott Bates</td>
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<td>3:30-4:00</td>
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<td>Coffee</td>
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<tr>
<td>4-5:30</td>
<td></td>
<td>Short summary from each group. Discussion of funding Final remarks</td>
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North American Mycoflora Project

Without a sequenced specimen it’s a rumor