

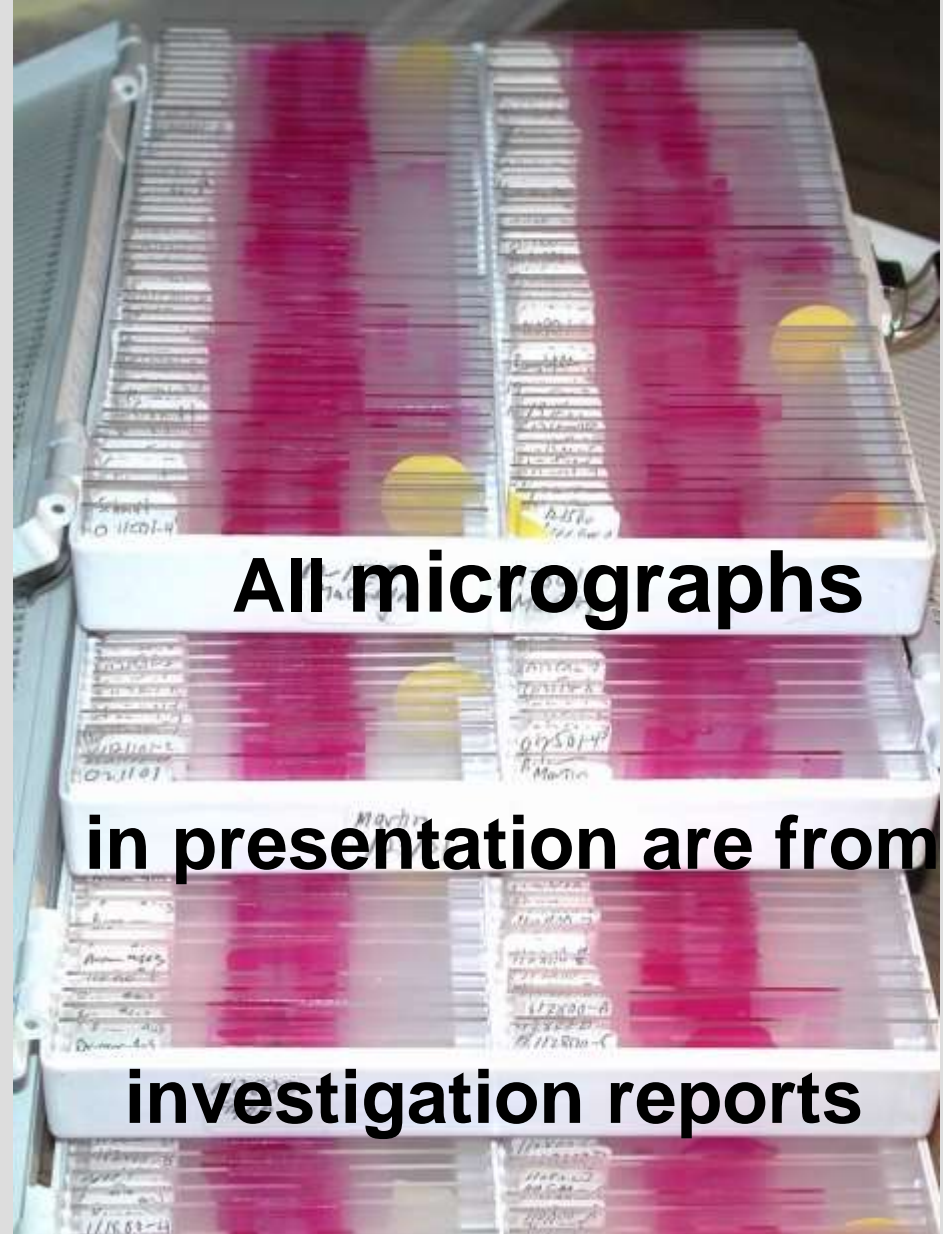
Some Surprising Sources of IAQ Problems; Novel Ways to Sample Mold

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**Since 1992
MIAI has completed
more than 4,000
building inspections,
including more than
2,000**

**“sick building
investigations.”**

**We have taken and
analyzed by
microscopy over
35,000 air and dust
samples.**



All micrographs

in presentation are from

investigation reports

Outline

Odors

Allergenic Dust

Appliances

Carpets and Rugs

Pets and Pests

Fiberglass and SPF Insulation

Actinomyces

Mechanical Equipment

More Case Studies

ODORS

House with Library Stench



House with Library Stench



Odor strongest at outlet in library



Clapboard removed from exterior wall of library

Odor was so bad that library was sealed off from rest of house with plastic

You can use a window exhaust fan to depressurize! (don't have to use a blower door)

A close-up photograph of an electrical outlet. The outlet is a standard two-pronged type with a grey faceplate. Behind the outlet, there is a significant amount of dark, granular material, which are shrew droppings. There is also some light-colored, fibrous material and some dried leaves or debris scattered around the base of the outlet. The outlet is mounted on a light-colored wall.

**Shrew droppings
behind electric outlet**

Odors: DRAINS

Client 26 years in home, experiencing eye problems (iritis, conjunctivitis), worst in master bathroom; OK if stays out of master bedroom



Odors: Drains

Client 26 years in home, experiencing eye problems (iritis, conjunctivitis); saw 2 eye docs; worst in master bathroom; OK if stays out of master bedroom



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Odors: Drains

No odor in bathroom at time of site visit but drain slime smelled strongly of hydrogen sulfide (bacteria reduce sulfur in hair)



Cleaned drain with bleach, odor and symptoms gone

Dead animals are often the source of odors in homes, particularly dead mice

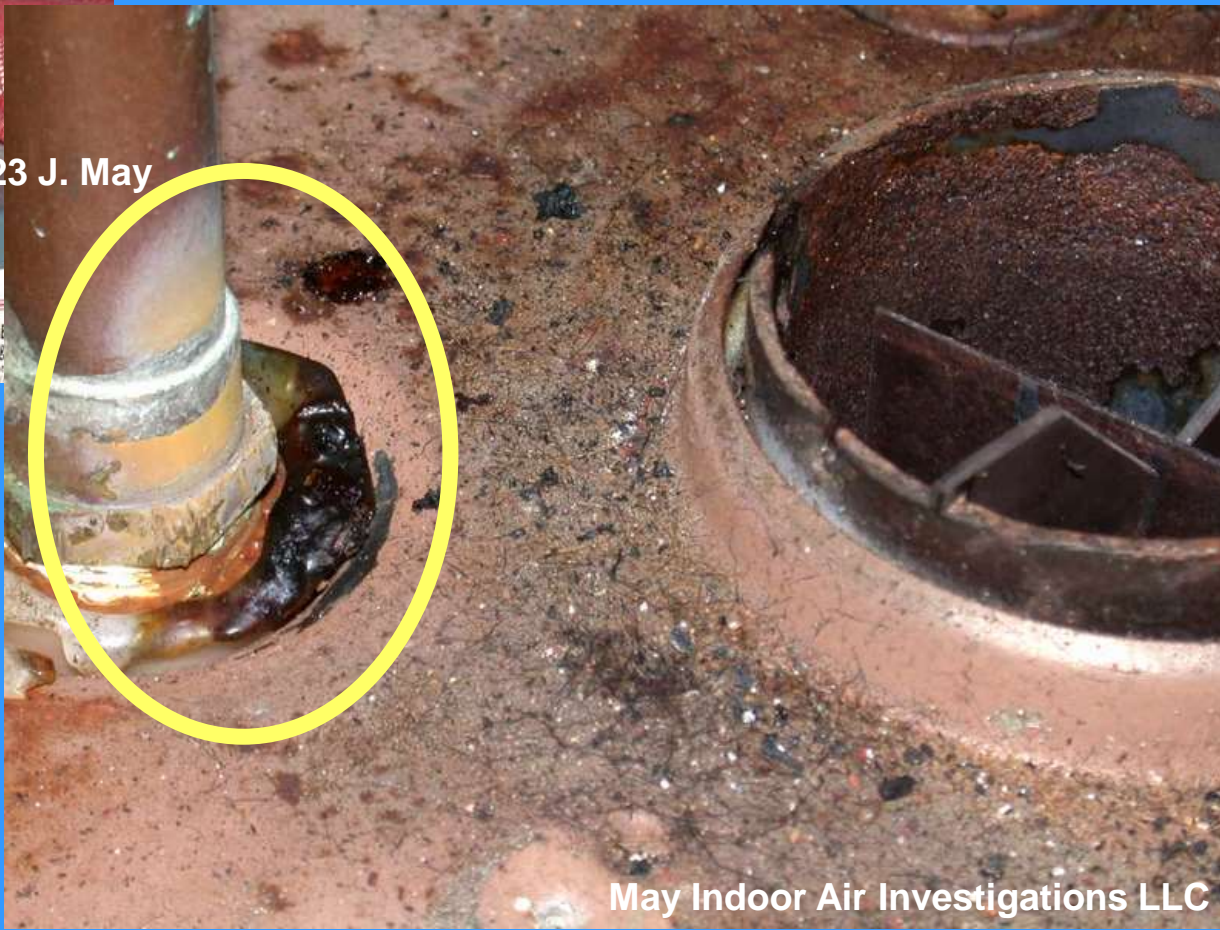
Here is one unusual case of an odor in a basement when the water heater ran; a hissing sound was heard when water dripped intermittently from the vent pipe onto the top of the heater suggesting a blocked vent!

Basement with awful an odor when water heater running



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Vent pipe removed:
charred plastic
gasket and oxidized
copper visible




Basement with awful an odor when water heater running

A close-up photograph of a circular metal vent cover. The interior of the vent is filled with dark, charred debris and several small, brown, skeletal remains of a squirrel, including what appears to be a skull and some bones.

Charred remains
of squirrel at
bottom of vent

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A photograph showing the interior of a vent. The top of the vent is filled with a large, brown, rotting mass of squirrel remains, including fur, skin, and skeletal parts, surrounded by dark, charred debris.

Rotting remains
of squirrel in top
of vent

Why do basements stink?

**Powerful ammonia odor in basement
with vinyl flooring on concrete**

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**Microbial growth under
vinyl flooring**

**Problem: Which Surface is Off Gassing
and causing the odor in a room?**

**You can put a window fan on exhaust
and depressurize the room and sniff, sniff**

Or

**You can have the client set up
aluminum foil/paper towel test**

1.



Foil/Paper Towel Test for Surface Odor

2.



3.



4. Sniff paper outdoors

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**Problem: Testing a Wall Cavity for
Mold without
Making a Hole**

Musty Odor in Baby's Room

Room is depressurized with
window fan on exhaust



... so air sample is taken at electric outlet

Musty Odor in Baby's Room

Vacuum out loose dust first using adapter box with HEPA vacuum



Sample-box adaptor
With Air-O-Cell cassette



Sample-box adaptor
with rope caulk at
perimeter openings

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Sample-box adapter
Burkard sampler



Musty Odor in Baby's Room



Skin scale

**Air is full of Pen/Asp spores so drywall is moldy;
remediation needed**

Do You Need to Worry about Building-Cavity Mold?

Many wall cavities have suffered from moisture infiltration

Musty odors can penetrate drywall and plaster but spores cannot

Spores must have a pathway such as an electrical or other opening in wall cavity where there is air at higher pressure than in room (pressure differences often caused by wind)

House with very musty entry hall but no visible mold

No gutter above entry balcony



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Brick veneer



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House with very musty entry hall

**No interior stains!!!
No visible mold**

Drywall over door stunk!



House with very musty entry hall

Elevated moisture content in drywall under 2nd floor window over entry



No odor at 2nd floor over entry!!

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Small gap in caulk under window

Remediation of house with very musty entry hall



Basement



Remediation of house with very musty entry hall



ALLERGENIC DUST

Do You Need to Worry about Building-Cavity Mold?



Gaps in hall flooring

Client with severe mold allergies could not occupy second-floor condo after bathroom renovation in 140 year-old home



Do You Need to Worry about Building-Cavity Mold?



**Billowing poly
in bedroom
and hall of 140
year-old two
family**

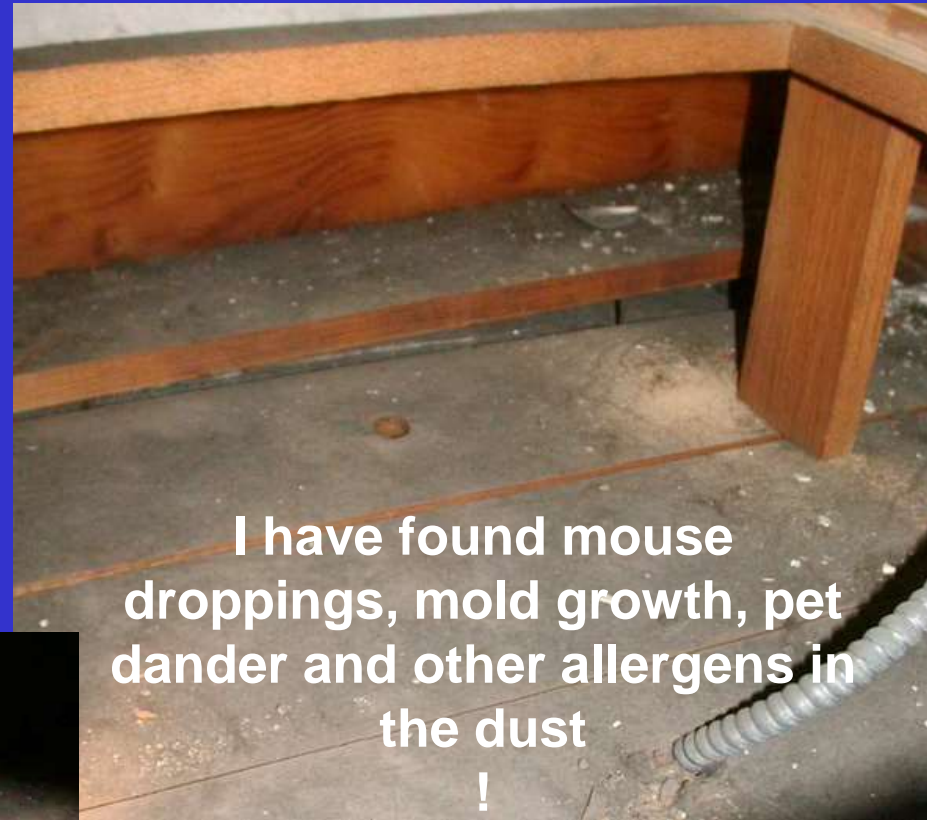
**Passive air flow
from ancient
floor cavity
with decades of
allergens**



**Client with severe mold allergies
could not occupy second-floor unit
after bathroom renovation**

Built-in dressers

Remove the bottom drawer for a surprise



I have found mouse droppings, mold growth, pet dander and other allergens in the dust !

HAVE SPACE UNDER DRAWERS CLEANED AND SEALED



Pocket Doors in Older Homes



Cavities impossible to clean
Seal openings and do not use

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**Air is compressed and allergens aerosolized
when door is pushed into wall cavity**

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APPLIANCES

Refrigerators

Stinky washing machines

Dryers

Dishwashers

Dehumidifiers

Humidifiers

Refrigerators are not always full of edibles

Refrigerators can be bioaerosol sources



Several clients' symptoms were alleviated after the refrigerator was cleaned

APPLIANCES

Stinky washing machines



**Always keep washer and detergent drawer open between loads !!!
Operate a Lasko 200-watt heater for a few hours to dry interior**

APPLIANCES

Stinky washing machine

Bottom of outer tub



Bottom of inner tub



Appliances generate air flows that accumulate and aerosolize potentially- allergenic dust

Dryer

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Refrigerator from drip pans

Lint can carry allergenic enzyme residues from detergents

Dishwasher Mite Infestation!

Insulation on
dishwasher

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Tape sample of dust

Dust-mite
fecal
pellets in
dust

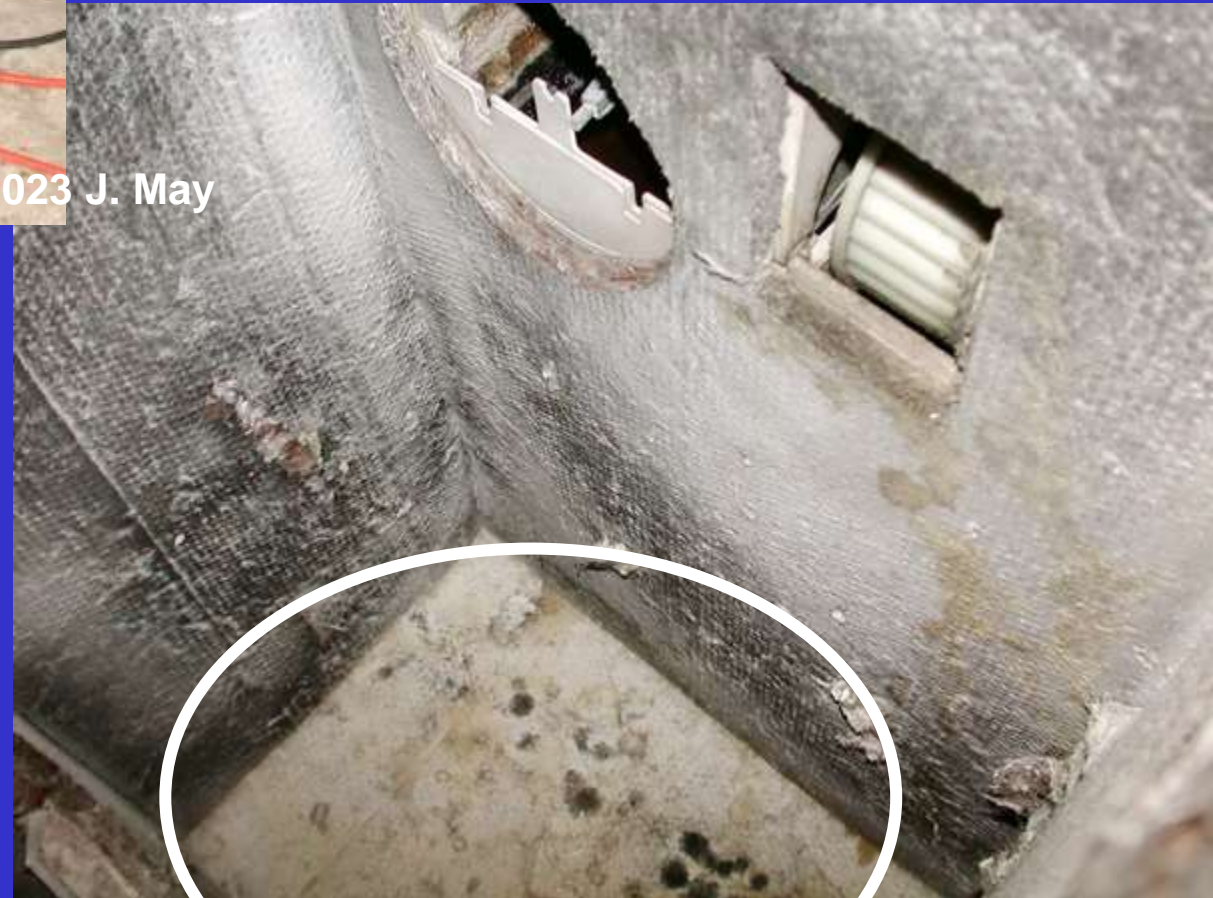
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APPLIANCES

Central Humidifiers



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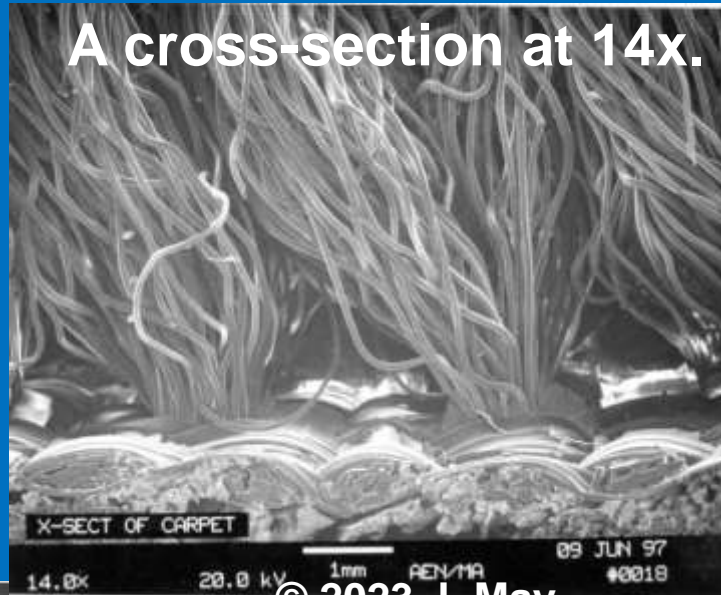
Dehumidifiers

Have inadequate filtration

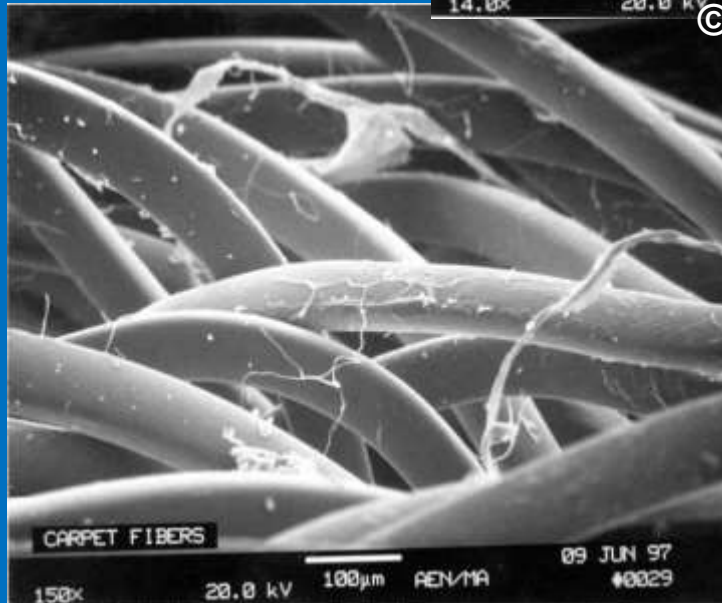
CARPETS AND RUGS

SEM of a Smelly, Almost New Carpet

Below left:
tops of fiber loops
with hyphae and
cellulose strands
at 150x.



Below right:
growing spores
and hyphae on
carpet fiber at
2000x



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“Pat” sampling a rug With Brukard Sampler



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FIND THE SOURCE

New way to “pat” sample

Any Mini-Vacuum can be Used

VACUUM CLEANER



**“Pat” Sampling Using a
Mini-Vacuum and an
Air-O-Cell cassette**

Keyboard
Cleaning

Auto
Detailing

PC
Dusting

Home
&
Office

CE RoHS FC

“Equipment” for Sampler



**Air-O-Cell cassette
(glass removed)**



**Tygon tubing
(1/2" ID, 5/8" OD)**



Vacuum tube



balloon



**3/4 to 1/2 inch copper
reducer fitting**

Also: 1/2 inch clear tape

Mini-vac sampler



**Cut end of balloon
to make “gasket”**



**Place gasket
over tube end**



Mini-vac sampler



Assembled adapter



**Cassette and adapter
attached to vacuum
via tubing**

Mini-vac sampler



**Cover slip removed
from interior of cassette**

**Cut about 4-inch length of 1/2 inch
clear tape; fold over at ends
to make tabs**

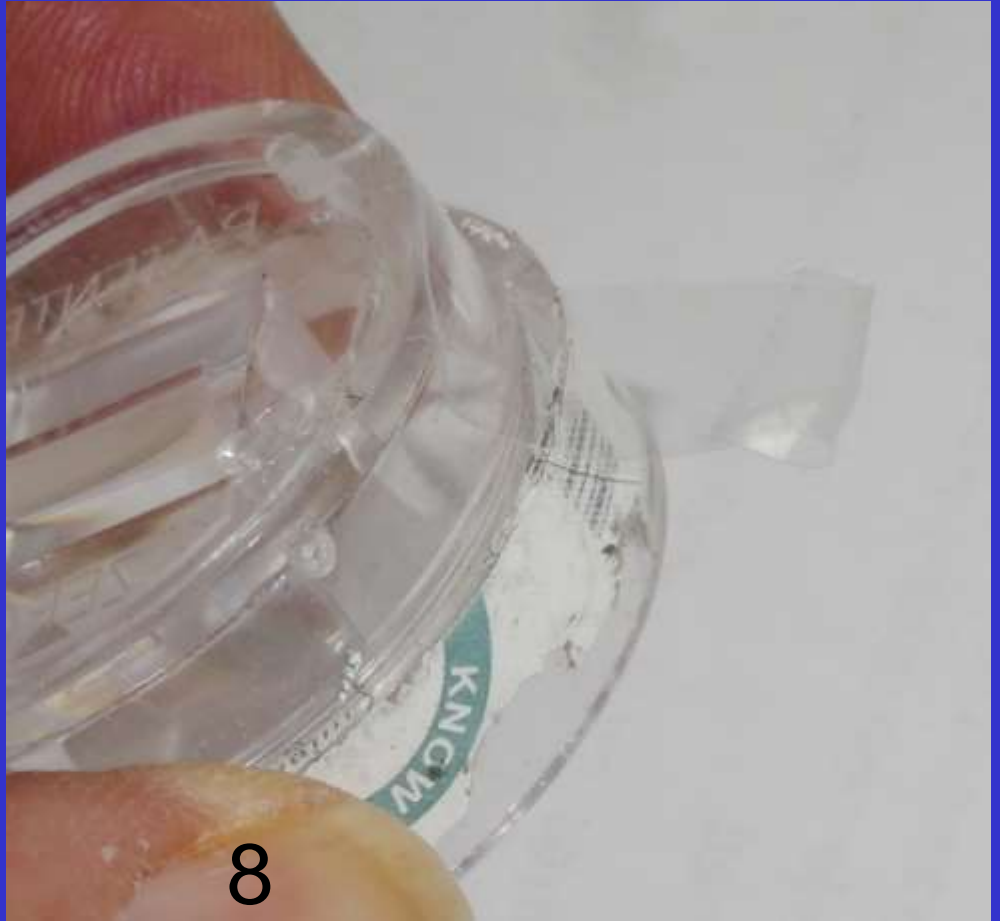


1/2 inch clear tape pulled taut

Mini-vac sampler



7



8

Press tape down sides

Replace top in holder

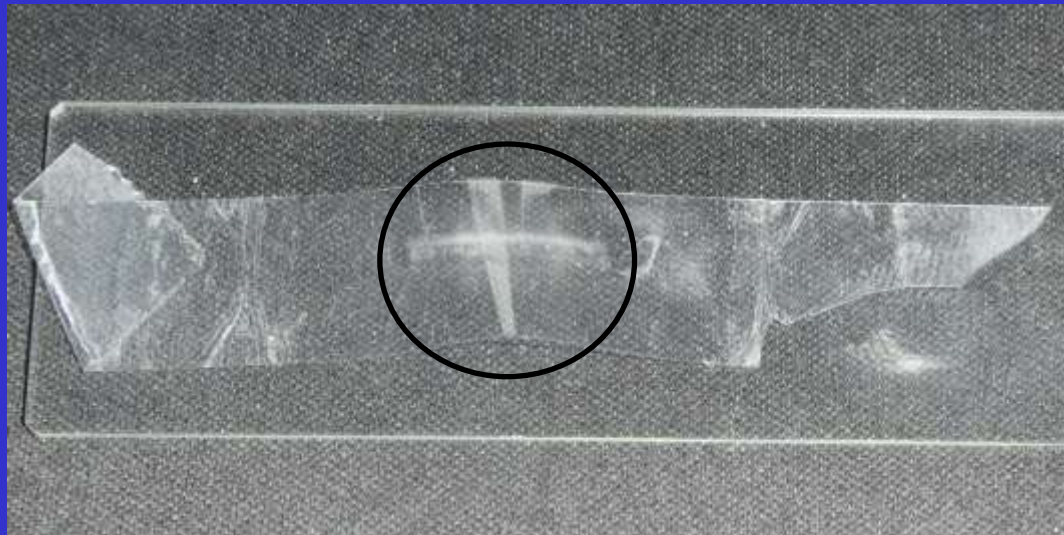
Mini-vac sampler



Pat surface with spatula to aerosolize dust;
simultaneously operate vacuum

Length of testing device can be extended
with 1/2-inch copper tubing

Mini-vac sampler



Place tape on glass slide with
sample area arched

Remove tape carefully by pulling tab;
avoid creasing




Ship in slide holder

A photograph of a child's bedroom. In the foreground, a large, fluffy lion plush toy sits on a light-colored, patterned rug. To the right, a zebra plush toy stands near a dark wood dresser. In the background, a giraffe plush toy is visible. A white crib is on the left, and a white trash can is near the dresser. The room has wooden flooring and a white wall.

**3 year-old
child's
bedroom**

**Chronic coughing,
wakefulness at
night, parents get
little sleep for 3 years**

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A photograph showing a close-up of a rug made from numerous vertical strips of cowhide, sewn together. The strips are in various shades of brown, tan, and grey. In the upper left corner, a person's foot wearing a purple sock is visible. In the lower left corner, a yellow plush toy paw with black stripes is visible. The rug is laid on a light-colored wooden floor.

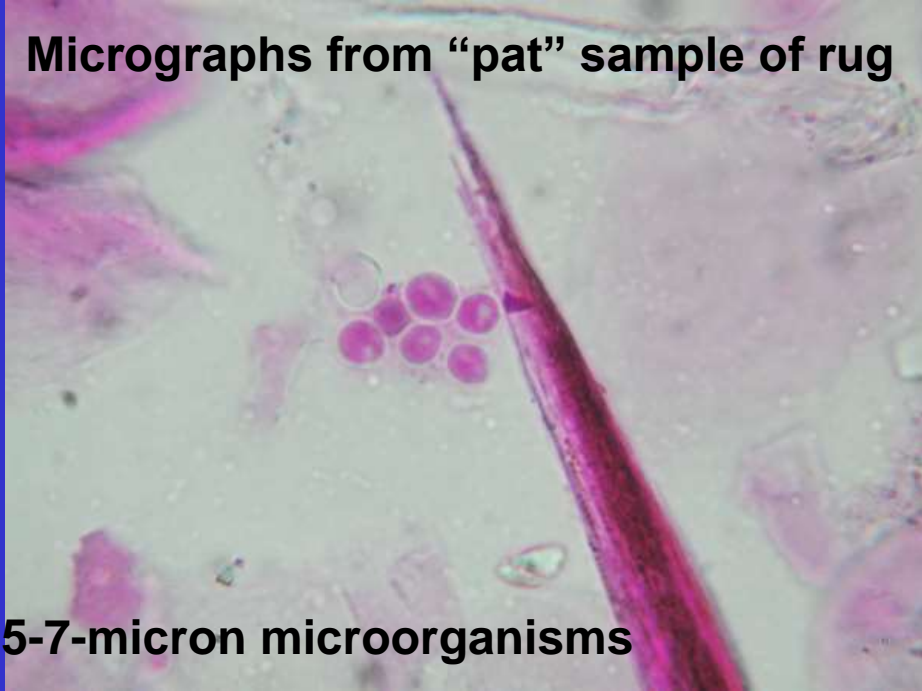
New rug made of cowhide strips sewn together was placed in baby's room at time of birth

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Rugs

Micrographs from "pat" sample of rug



5-7-micron microorganisms



5-7 -micron microorganisms



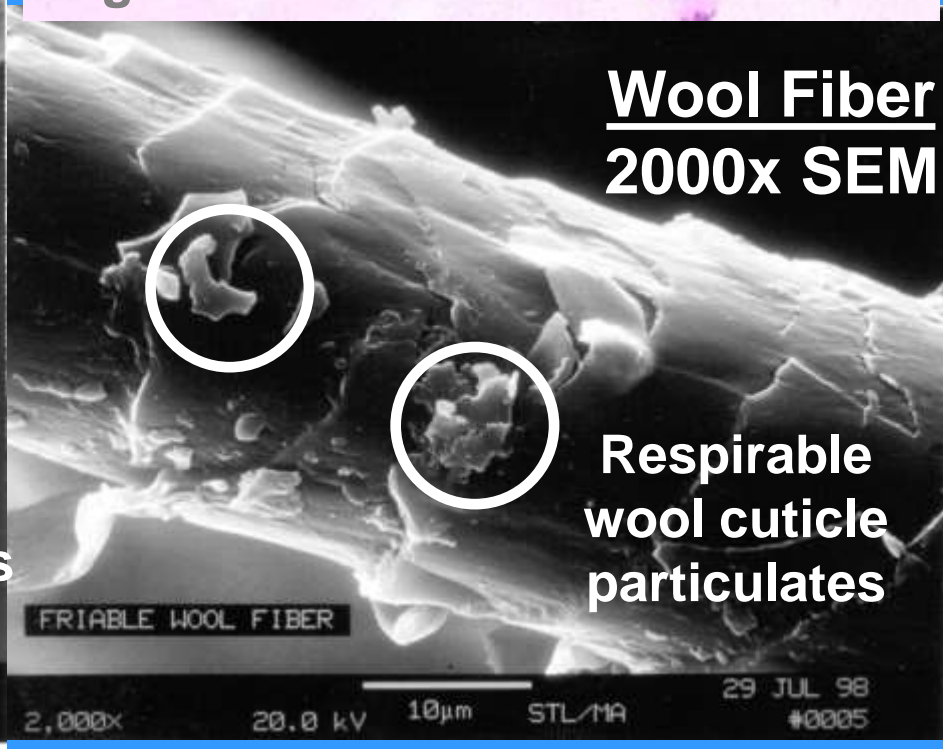
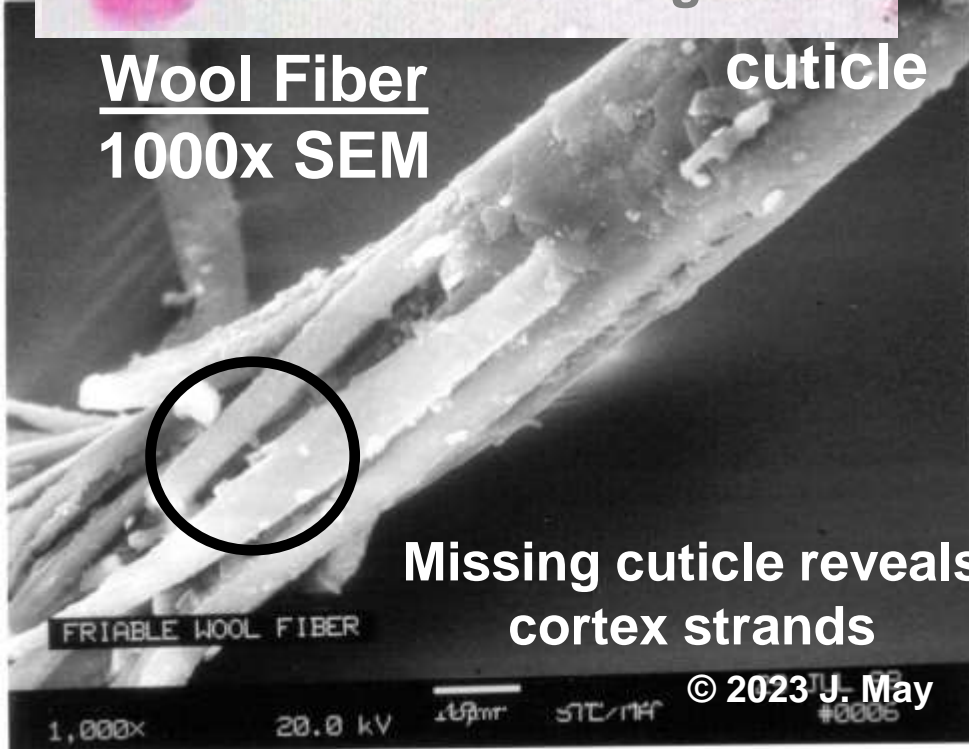
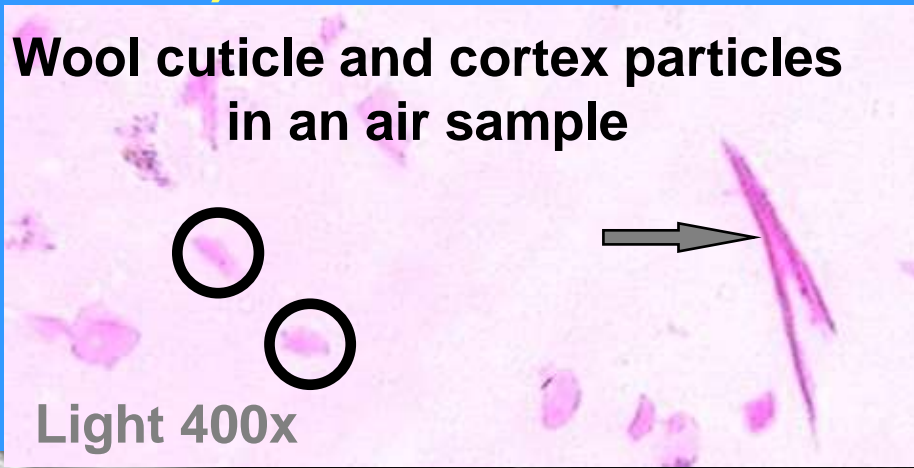
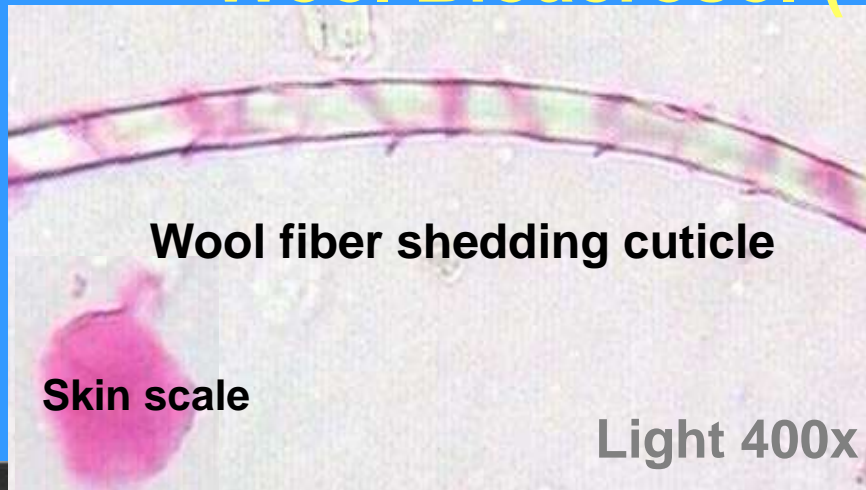
5-7-micron microorganisms

Rug was severely contaminated with microorganisms, probably yeast

Parents complained to manufacturer and company rep arrived next day to remove rug and refund \$3,000

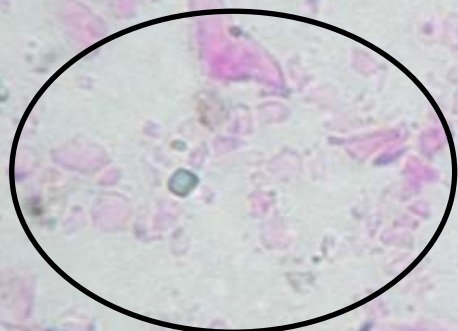
Child and parents slept through night after removal

Wool Bioaerosol ("dander") Can Be an Irritant



“Pat” sample from wool rug

Respirable wool cortex



Respirable wool cuticle

Skin scale

**Wool bioaerosol
can only be
detected by
microscopy.**

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Over

30,000 /m³

in one office

**(associated with eye irritation
and coughing)**

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**Cuticle stained
on wool fiber**

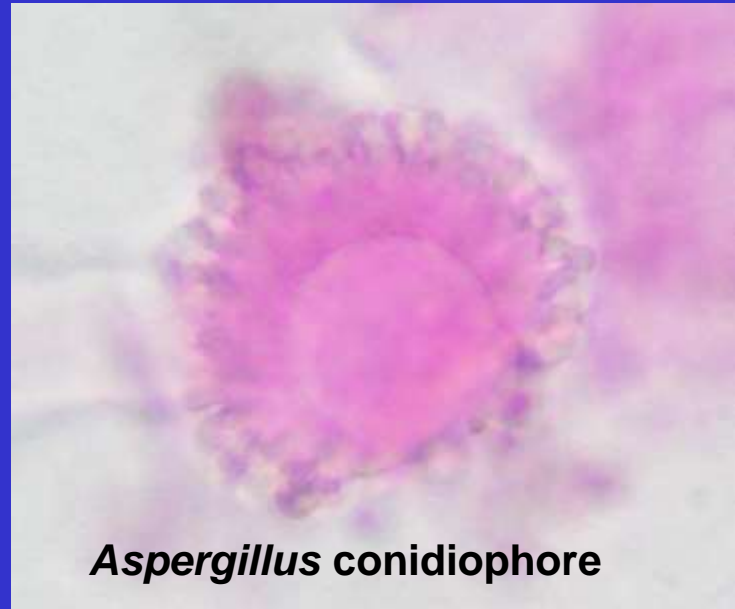
**No labs identify wool-cuticle or wool-cortex particles
(Google search only came up with my books and articles)**

Pillows “pat”



“Pat” sample of pillow

Daughter with allergies and asthma



Aspergillus conidiophore



Bacteria clump



Cluster *Eurotium* spores

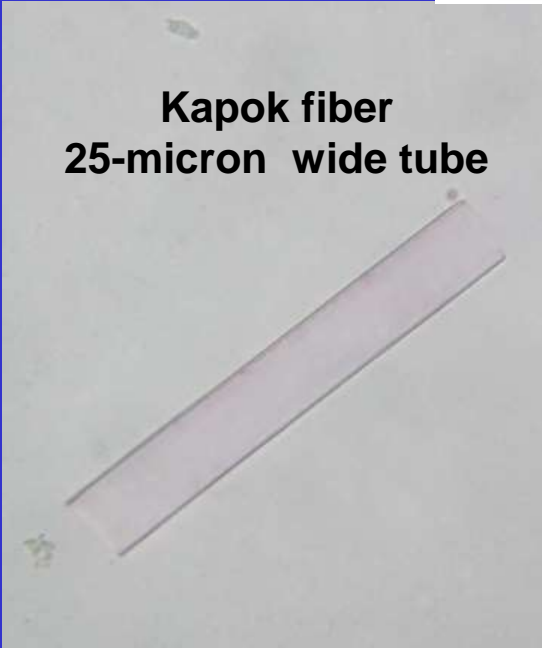
Pillow “Pat” Sample

Kapok is supposed to be mold resistant fiber

Pillows and mattresses are stuffed with kapok



Kapok fiber
25-micron wide tube



Kapok fiber containing hyphal fragment



PETS AND PESTS

Pet Allergy

There about 100 million dogs and cats in U.S.


From 15 percent to 30 percent of people with allergies have allergic reactions to cats and dogs.

Cat allergies are about twice as common as dog allergies.

Frequent exposure to birds can cause bird “allergy.”

Dogs can acquire asthma.

Source: AAFA



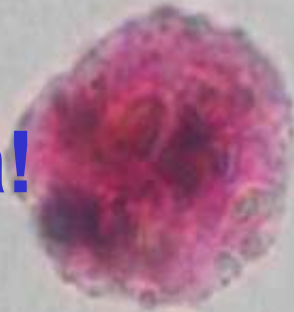
**You probably change
your sheets once a week.**

**When was the last time you
washed the dog bed?**

**Mite infestations are common
in pet beds.**

“Pat” Sample from a Dog Bed

Dogs get asthma!



← Dust-mite dropping

Dog (and cat) fur can have mite allergens!

Dog dander



Every Animal has a
“Dust Aura”

There is nothing spiritual about this aura!
Clothing, hair and fur are full of dust

**Skin scales, dander particles are
aerosolized with every move**

**People and pets exude allergens from
their environment**

**Most pet allergen in schools is
from children's clothing**

Every Animal has a **Dust Aura**

More than just dander.....

“Home Life: Factors Structuring the Bacterial Diversity Found within and between Homes”

**Dunn RR, Fierer N, Henley JB, Leff JW, Menninger HL (2013) PLoS ONE 8(5): e64133.
doi:10.1371/journal.pone.0064133**

“We found that the presence of dogs had a significant effect on bacterial community composition in multiple locations within homes as the homes occupied by dogs harbored more diverse communities and higher relative abundances of dog-associated bacterial taxa.”

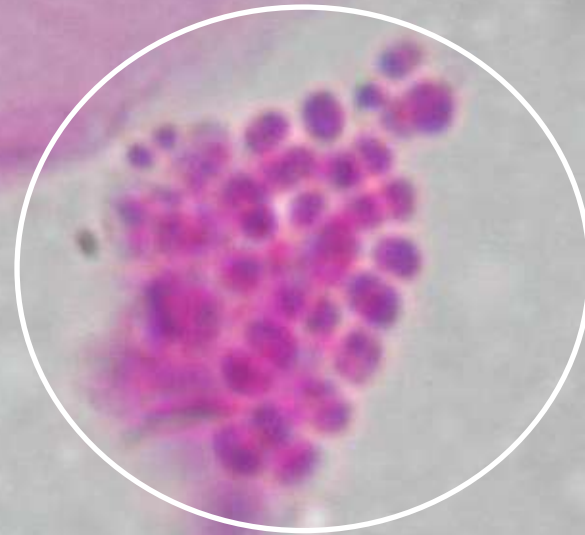
In another study of bacterial DNA, individuals in an isolation room could be identified by sampling their bacterial bioaerosol emissions!

Microscopy:

Bacteria cluster from carpet (1,200x)

Found more commonly in homes with dogs

Skin scale



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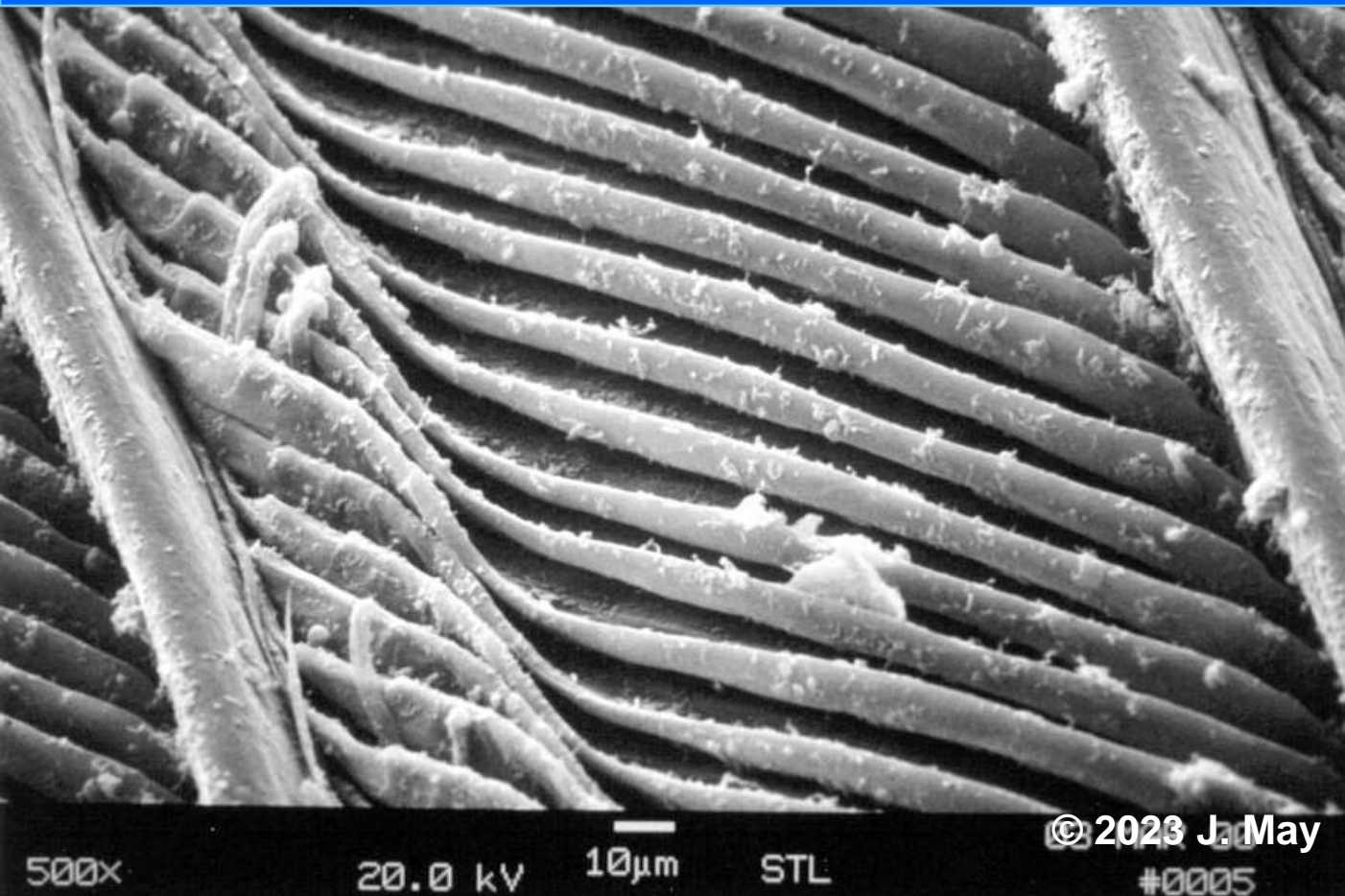


“Birds”

Feathers and down can be large sources of bird bioaerosol (“bird bloom”) which (along with other avian proteins) are irritating and/or allergenic.

Evaluating Allergic Responses to Bird Allergens. Lopata A, Schinkel M, Current Allergy & Clinical Immunology, June 2004, vol 17, No.2

Cockatiel Feather with Bird Bloom



SEM of Cockatiel Feather with "Bird Bloom" (4000x)

Keratin granules

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Large numbers of keratin granules were in the air of the home. The client had hypersensitivity pneumonitis.

wing

4,000x

20.0 kV

10µm

STL

03 MAR 00

#0006

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Bird Bioaerosol ("Bird Bloom" and dander)

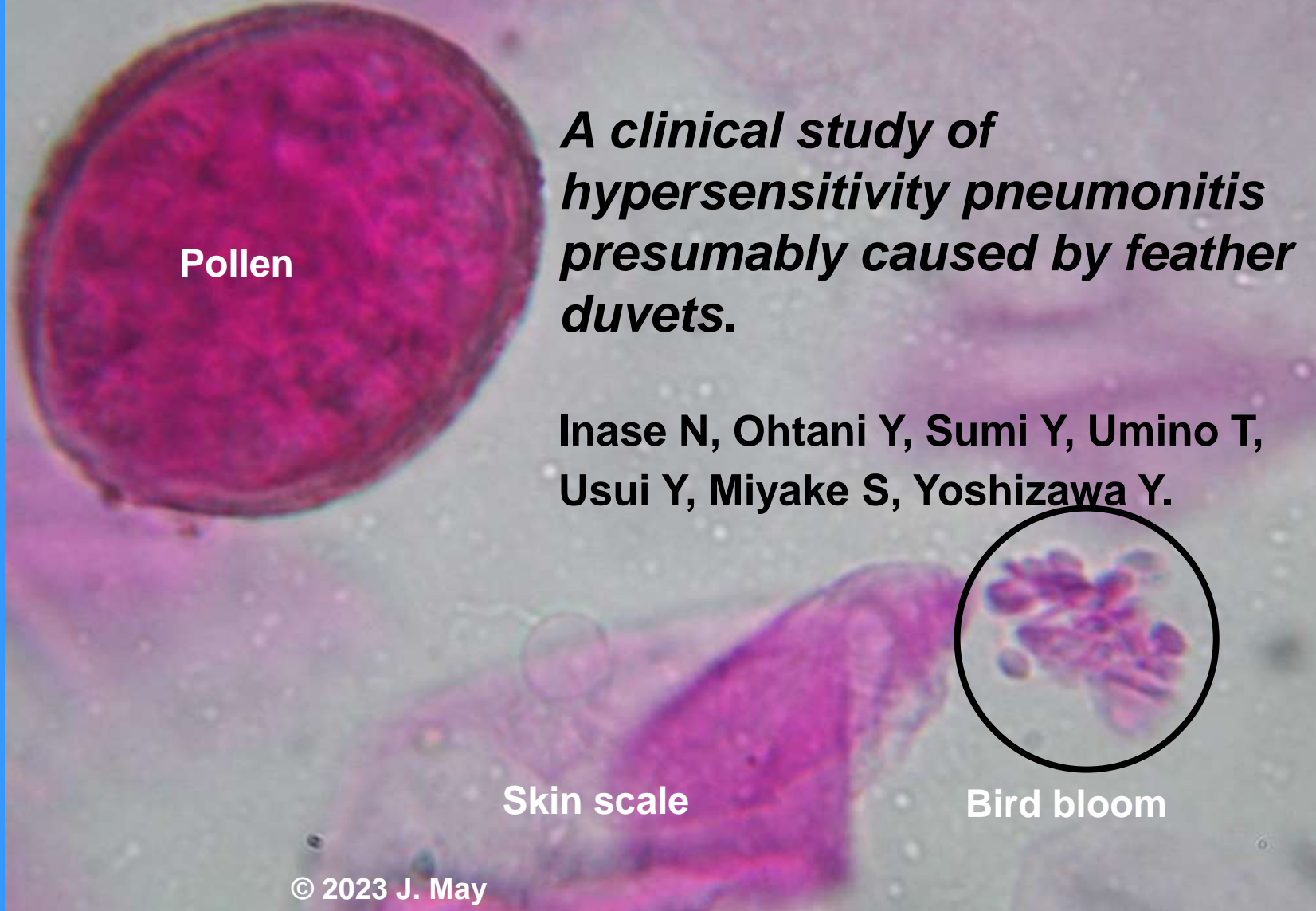
Bird dander

**Keratin granules
1-3 microns**

From a quilt 1,000x

Feather-Pillow Bioaerosol and “Duvet Lung”

Ann. Allergy Asthma Immunol. 2006 Jan;96(1):98-104.



A clinical study of hypersensitivity pneumonitis presumably caused by feather duvets.

Inase N, Ohtani Y, Sumi Y, Umino T, Usui Y, Miyake S, Yoshizawa Y.

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**Client developed
hypersensitivity pneumonitis
(HP) after receiving quilt**

**Client mailed
feather quilt to
office**

Hypersensitivity pneumonitis (HP) is a life threatening illness caused by exposure to bioaerosol particles generally smaller than 4 microns

HP (sometimes called bird-fancier's lung) is difficult to diagnose and causes cough and severe shortness of breath due in part to progressive fibrosis of lung tissue

Bird bloom particles ~2 microns



**Bird Bioaerosol
("Bird Bloom"
and dander) carry
bird antigens**

Bird dander

From HP client's quilt 1,000x

**Bird bloom consists
of keratin (protein)
granules ~2 microns
Can reach alveoli
in lungs**

Other studies:

High levels of bird antigen after 18 months in one home*.

HP from exposure to house dust with bird antigen from prior owner.**

HP from a feather duvet.* “Duvet Lung”**

*Craig, T.J., Hershey, J., Engler, R.J., et. al., 1992, “Bird antigen persistence in the home environment after removal of the bird,” *Ann. Allergy*, vol. 69, no.6, pp 510-12.

**Greinert, U., Lepp, U., Becker, W., 2000, “Bird Keeper's lung without bird keeping,” *Eur. J. Med. Res.*, vol.5, no.3, p.124.

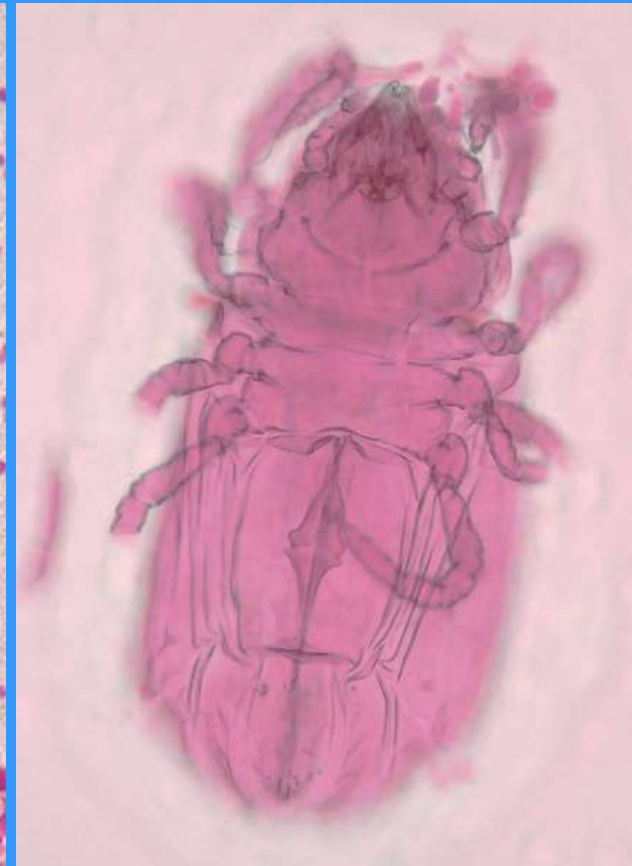
***Haitjema, T., van Velzen-Blad, H., van den Bosch, J.M., 1992, “Extrinsic allergic alveolitis caused by goose feathers in a duvet,” *Thorax*, vol.47, no.11, pp. 990-1.

**No labs identify bird dander or bird bloom
(Google search only came up with my book!)**

“Allergenic” Bioaerosol

- Mites, mold and other bugs**

Allergy testing to mites does not detect allergy to mold-eating mites



Mold-eating microarthropod fecal pellets

full of *Aspergillus* spores

Looks like mold

Mite and mite fecal pellets from dust around kitchen-sink rim

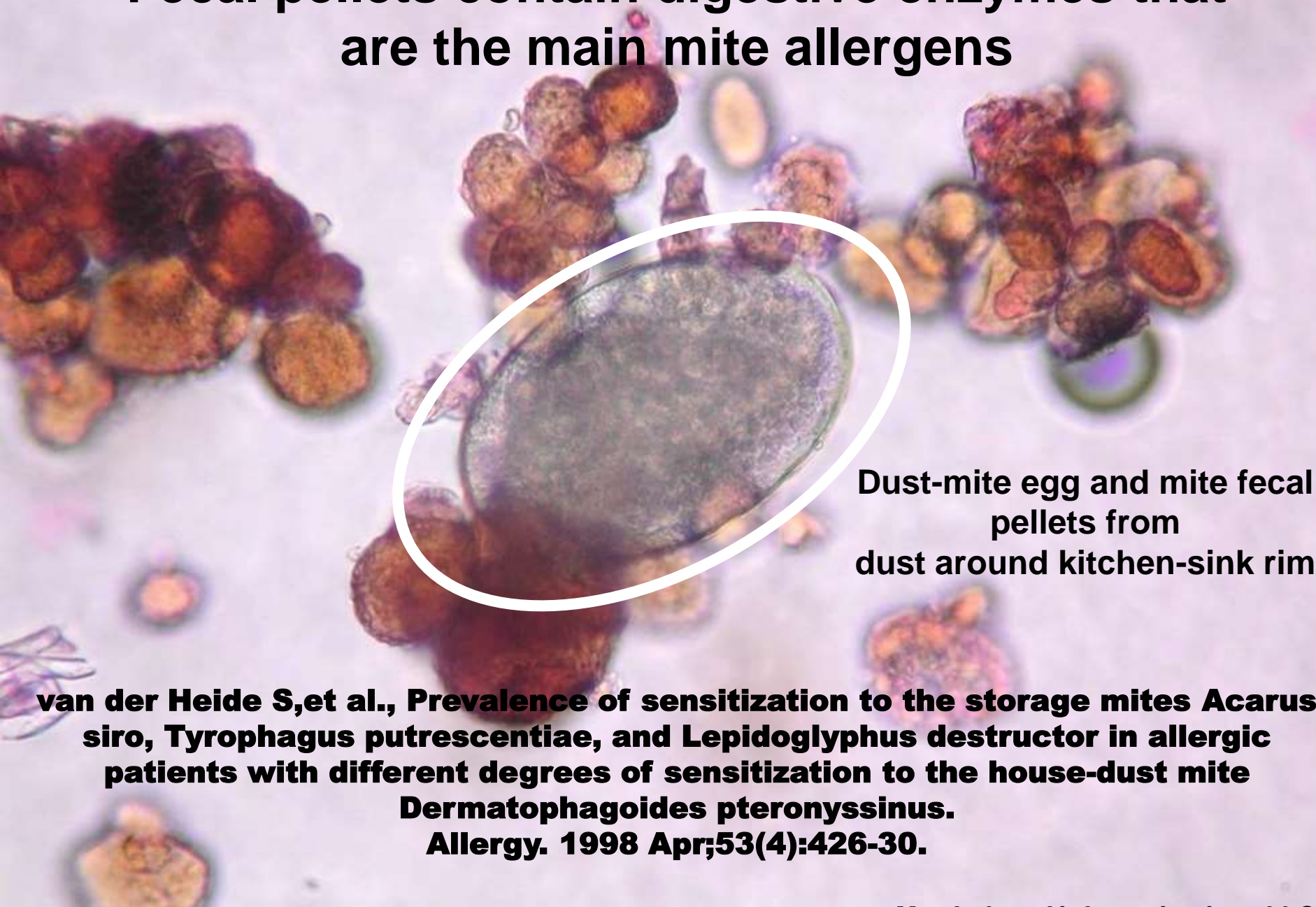
(probably *Acarus* mite)

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Fecal pellets contain digestive enzymes that are the main mite allergens



Dust-mite egg and mite fecal pellets from dust around kitchen-sink rim

van der Heide S, et al., Prevalence of sensitization to the storage mites *Acarus siro*, *Tyrophagus putrescentiae*, and *Lepidoglyphus destructor* in allergic patients with different degrees of sensitization to the house-dust mite *Dermatophagoides pteronyssinus*. *Allergy*. 1998 Apr;53(4):426-30.

Wool-moth larva:



Allergy to Wool Moths

Adult wool moth



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Baldo, B.A., Panzani, R.C. 1988. Detection of IgE antibodies to a wide range of insect species in subjects with suspected inhalant allergies to insects. *Int. Arch. Allergy Appl. Immunol.*, 85(3):278-87.

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A fecal pellet consisting of partially digested fibers is in the larger circle. Individual rug fibers in the digestive tube can be seen (small circle).



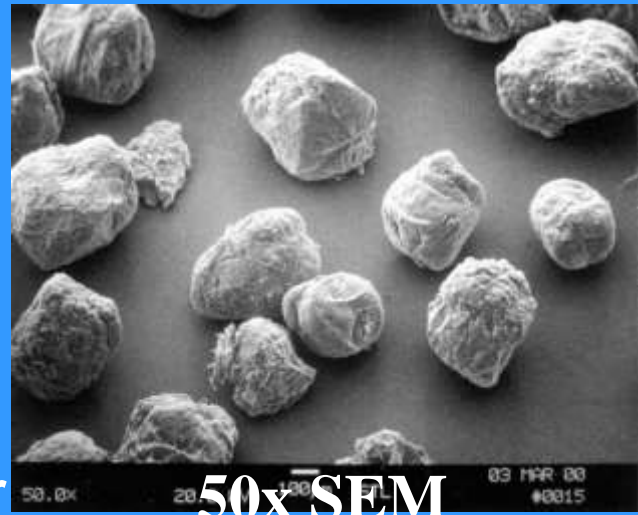
Wool-moth larval fecal pellets in rug



Wool Moth Fecal Pellets



Low power light

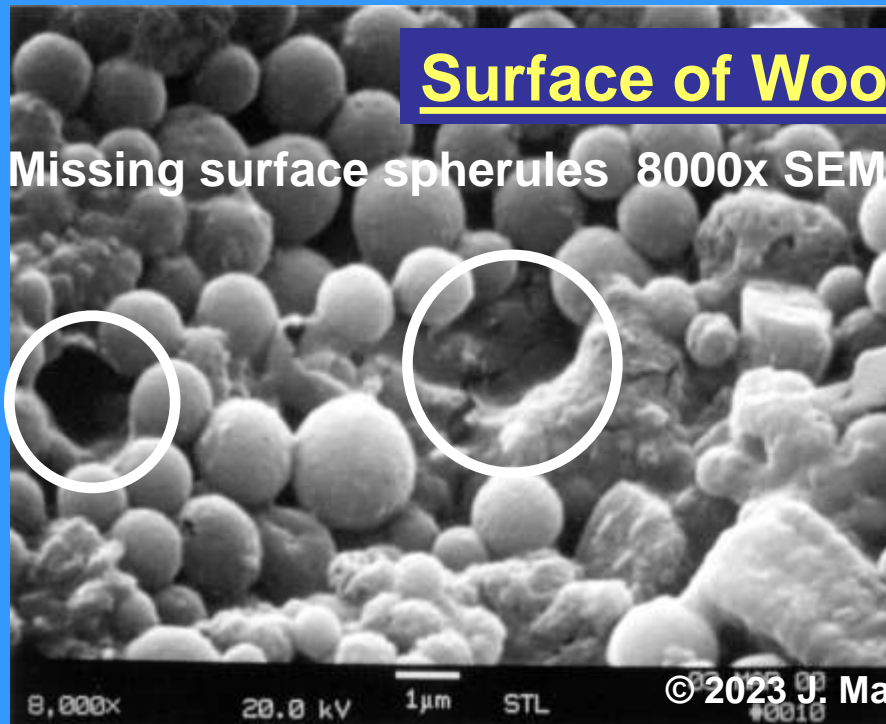


50x SEM

Pellet Color Depends on Fiber Color

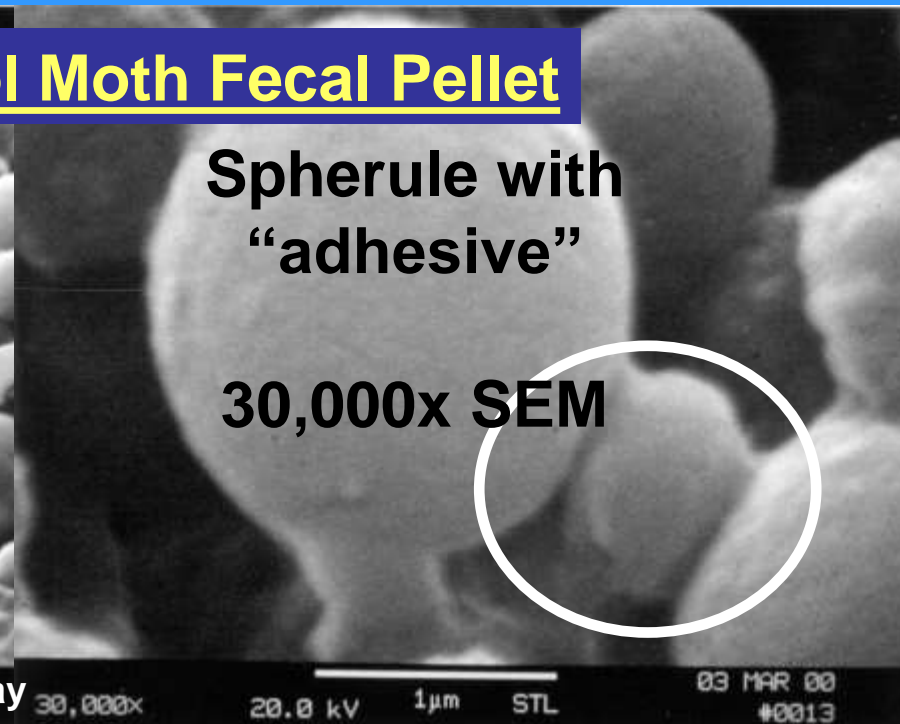
Surface of Wool Moth Fecal Pellet

Missing surface spherules 8000x SEM

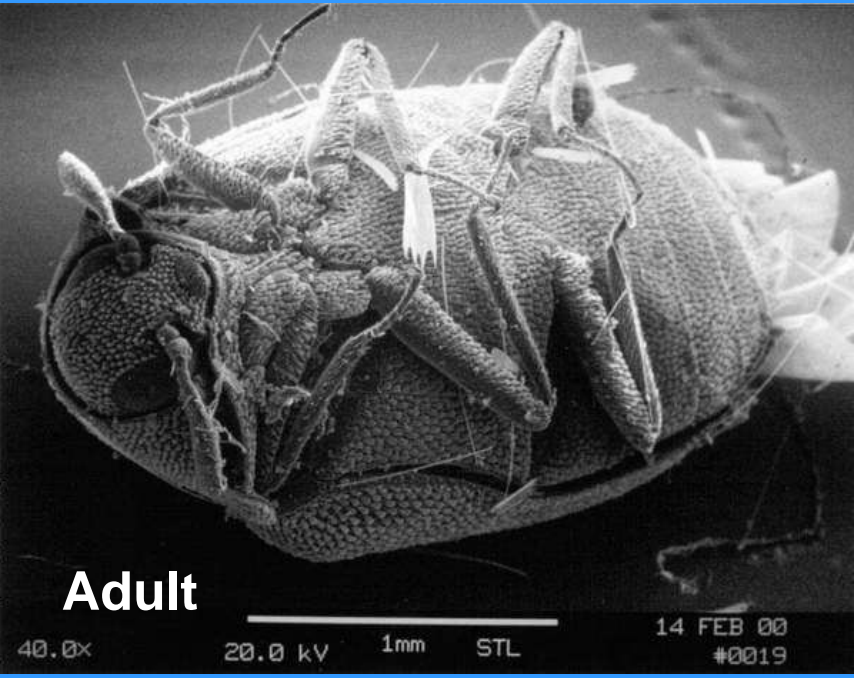


Spherule with
“adhesive”

30,000x SEM



Allergy to carpet beetles, common indoor pests



Adult



Larva



Larva (headless)

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Cuesta-Herranz, J. et al. (1997): Asthma caused by *Dermestidae* (black carpet beetle); a new allergen in house dust. *J. Allergy Clin. Immunol.*, 99: 147-149.

Brito FF, Mur P, Barber D, Lombardero M, Galindo PA, Gómez E, Borja J. Occupational rhinoconjunctivitis and asthma in a wool worker caused by *Dermestidae* spp. *Allergy*. 2002 Dec; 57(12):1191-4.



Beetle larval hair



Animal hair with larva bites

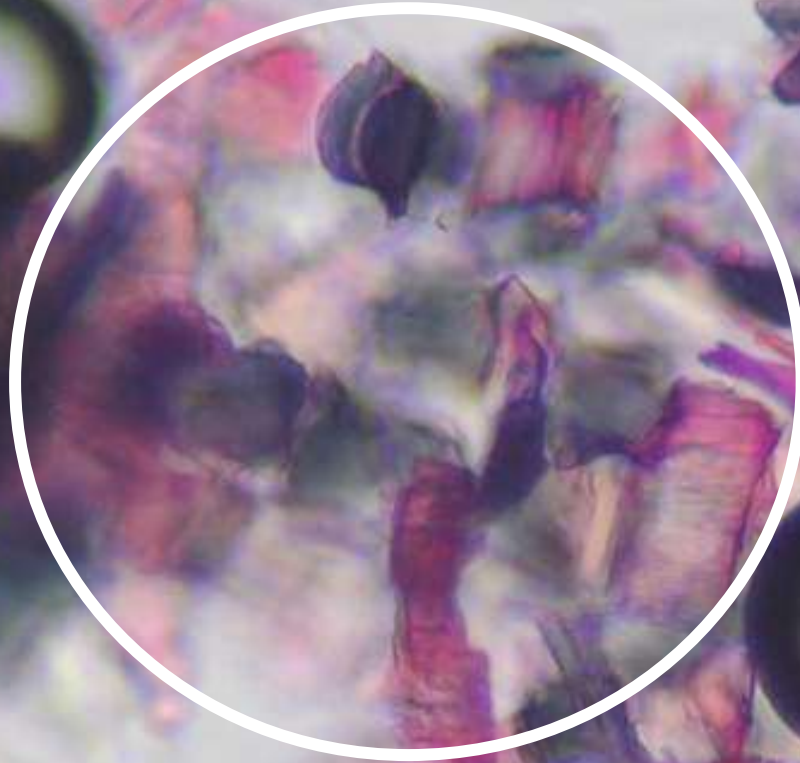


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Allergy to carpet beetles

**Chewed wool fragments
from a crushed fecal pellet**



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No labs identify carpet-beetle fecal pellets

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Book Lice

Allergy to book lice

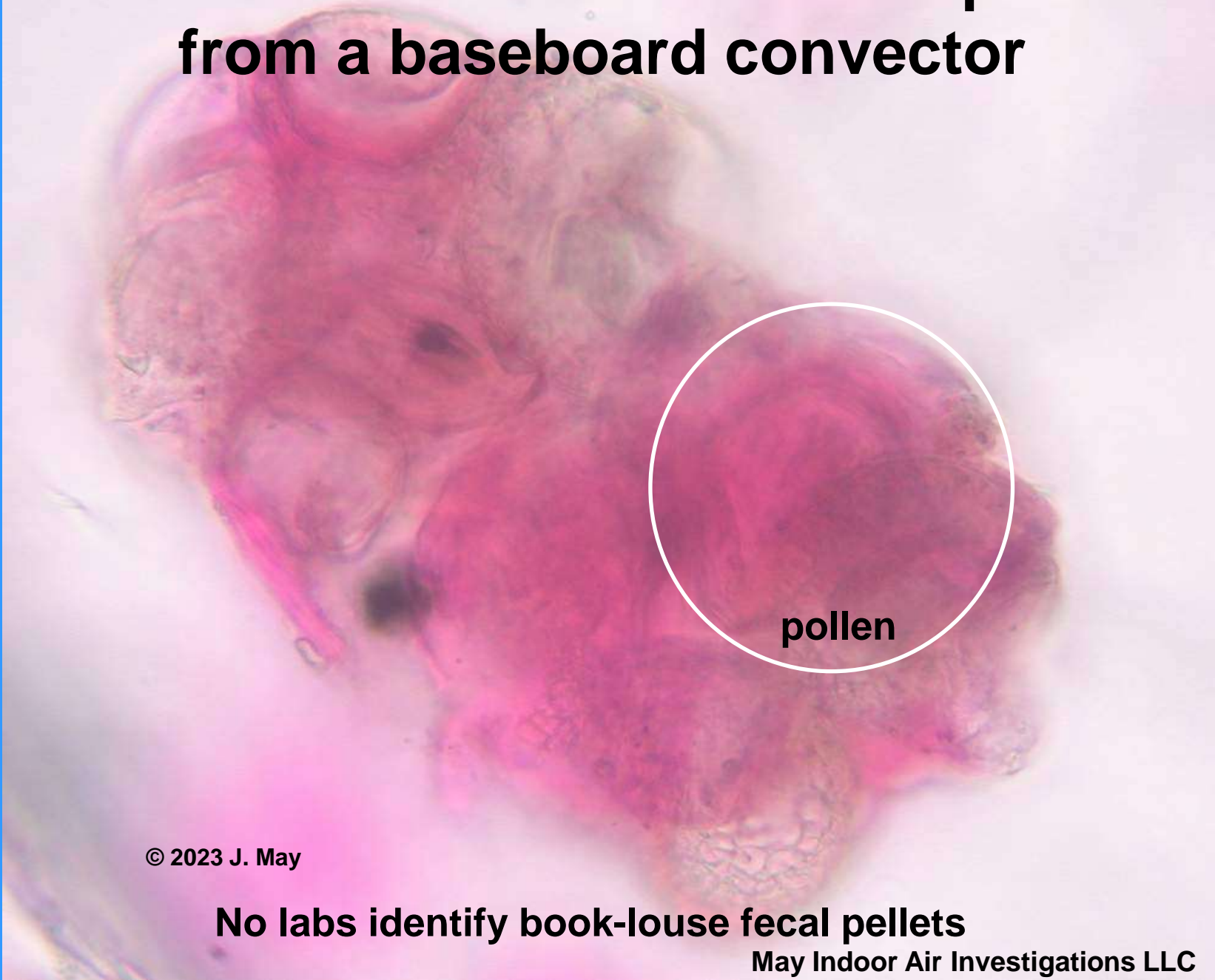
Musken, H., Franz, J-Th., Fernandez-Caldas, E., Masuch, G., Maranon, F. Bergmann, K-C. 1998. Psocoptera. Allergologie, 21: 381-382.



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Book lice are very common, barely visible indoor pests

125-micron insect fecal full of pollen from a baseboard convector



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No labs identify book-louse fecal pellets

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**Allergic to
HOUSE DUST???**

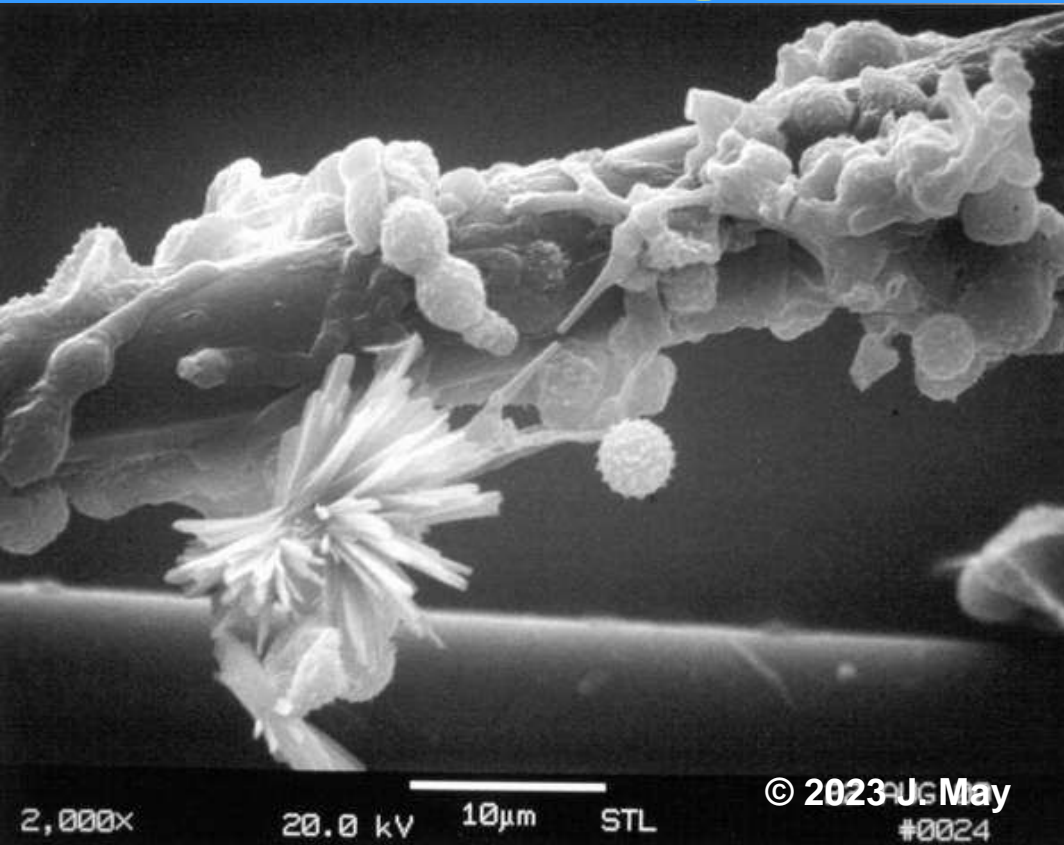
Now you know why!

FIBERGLASS and SPF INSULATION



**Condensation on
bulb and
insulation, mold
on framing**

Mold in exposed, basement fiberglass insulation




can be a major source of mold exposure

Surface Pat Sample for Fiberglass Insulation

Press Petri dish gently against insulation two or three times;
Incubate at room temperature for about a week.



If there is mold growth in the insulation,
dozens of similar colonies will grow.

The image shows the interior of a new duct, likely made of metal, with a layer of spray-polyurethane foam (SPF) lining the walls. The foam is a light brown color and appears to be in the process of being applied or has just been applied, as there are some irregularities and a small piece of debris visible on the surface. The duct is illuminated from the side, creating a bright highlight along the bottom edge.

Is There a Dust Risk from Spray-Polyurethane Foam (SPF)?

**Interior of new duct in house
addition built with SPF**

A microscopic image of duct dust. The background is a light, grainy surface. Numerous spherical particles of various sizes are scattered throughout, many with a distinct purple or blue outer ring and a lighter center. Some particles are elongated and fibrous. A black circle highlights a specific cluster of three small, pinkish-purple spherical particles.

Unknown Dust Risk in Duct Dust: All spheres are SPF droplets from duct dust

Chain of 3 *Penicillium* mold spores



Many respirable droplets
with all SPF chemicals
including TCCP

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No labs identify SPF droplets!

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Owner vacated home due to symptoms from SPF chemical off gassing



Master-bedroom
fireplace mantel
covered with dust

Home also had serious SPF- dust problem

**Air Sample from
Home with SPF**

**Dust risk?
SPF contains
about 12% TCCP
flame retardant**



Skin scale

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ACTINOMYCETES

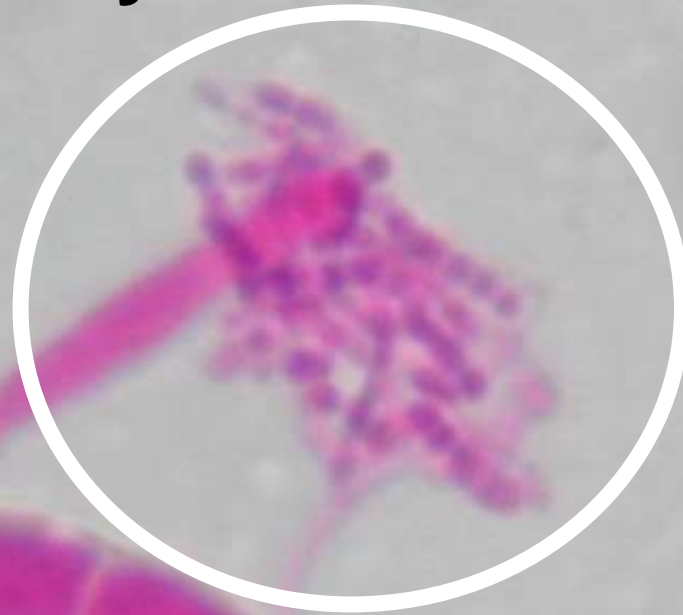
Actinomycetes growing in a toilet



Actinomycetes are microorganisms that require high-moisture conditions!

They are often found growing in dust on foundations

Actinomycetes



Mold hyphae

Actinomycetes are a genus of bacteria that grow like molds with hyphae and spores.

Actinomycetes

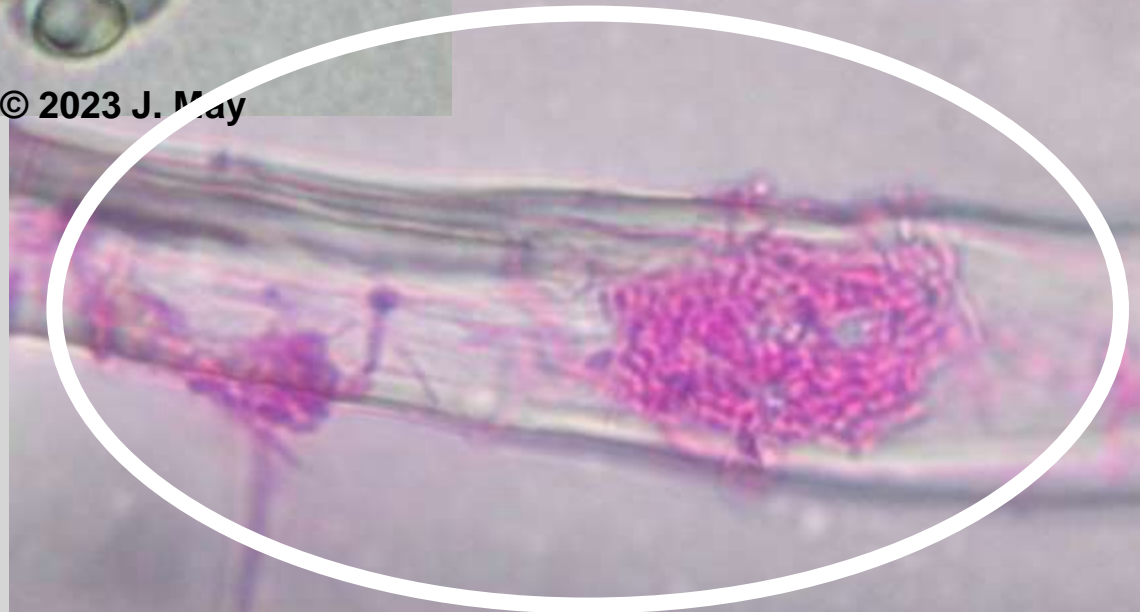
Inhalation exposure to thermophilic actinomycetes is the cause of “farmer’s lung” a type of hypersensitivity pneumonitis (HP).

Actinomycetes →
in basement air

← Eurotium mold spores

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Actinomycetes on
cellulose fibers →
are very common on
foundation
walls.



Actinomycetes in basement air

1,000x


Penicillium or *Aspergillus* →
spore chain

Actinomycetes →

Skin scale

Actinomycetes not reported on by most labs!

MECHANICAL EQUIPMENT

A close-up photograph of a steam convector. The top surface is heavily covered with a thick layer of grey dust and mold. A copper pipe runs diagonally across the top right. Below the dust, a black circular pressure cap is visible on a metal fitting. The background is dark and indistinct.

**Choral singers
lost voices during
rehearsal in
basement church
room**

**CASE STUDIES:
Convector silenced the
chorus**

**Dust on the bottom a steam
convector. This dust can be
30% mold, growing in
sawdust, skin scales and
animal dander.**

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All Tight Buildings Must Have Fresh Air

**Many will use air-to-air heat
exchangers for ventilation.**

HRVs need maintenance

92-150
DAMPER DOOR
DATE: 8/25/99

↑
This Side Towards Door
UP
CORE CLEANING
Remove, Rinse & Return
as Indicated Above

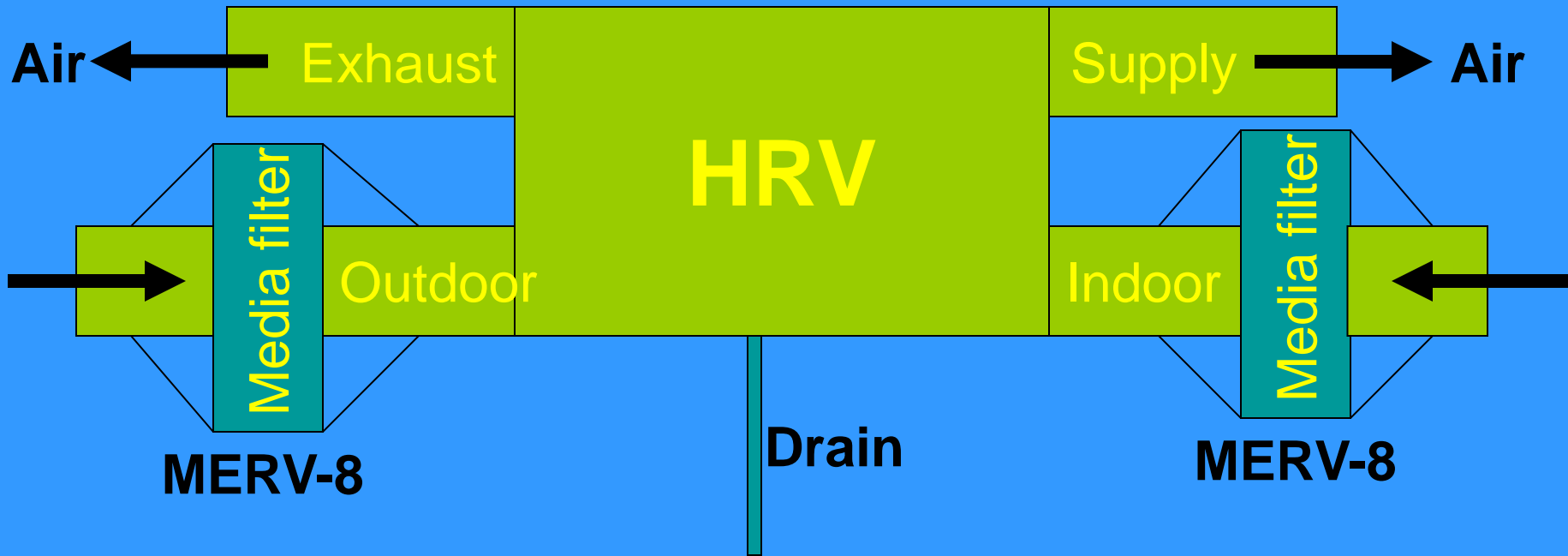
Fresh-Air Intake Side

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HRVs Must Not Have Exposed Fibrous Liner

Surfaces must be cleanable

A Temporary Solution: HRV with external, in-line filtration



MORE CASE STUDIES

Odor and Allergies in exercise room



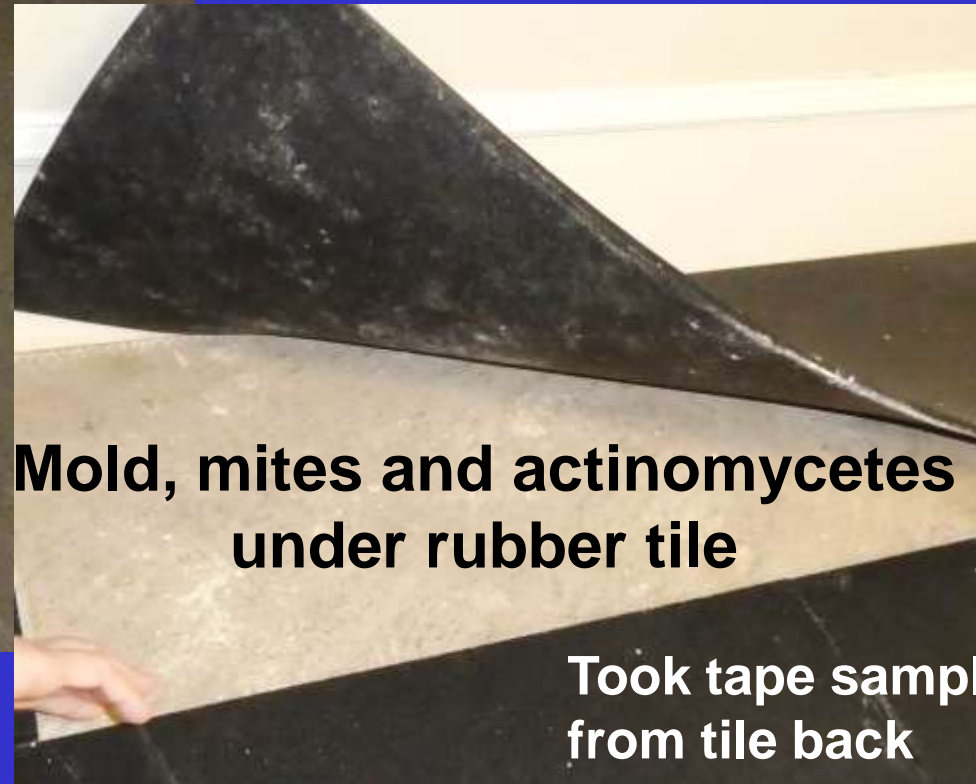
Rubber tile floor

Odor and Allergies in exercise room



Dust at seam

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Mold, mites and actinomycetes
under rubber tile

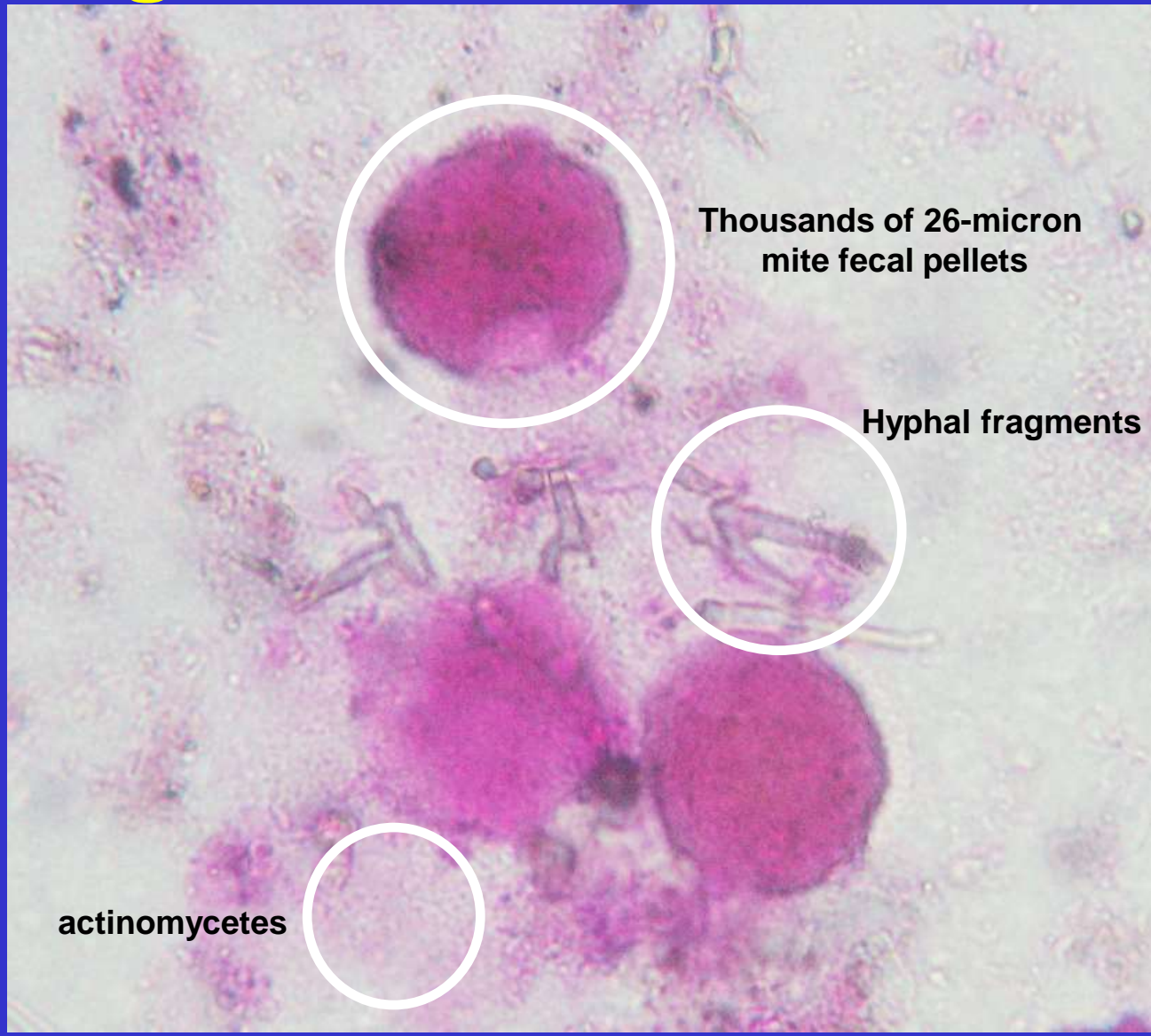
Took tape sample
from tile back

Odor and Allergies in exercise room

Results of tape sample



350-micron mite

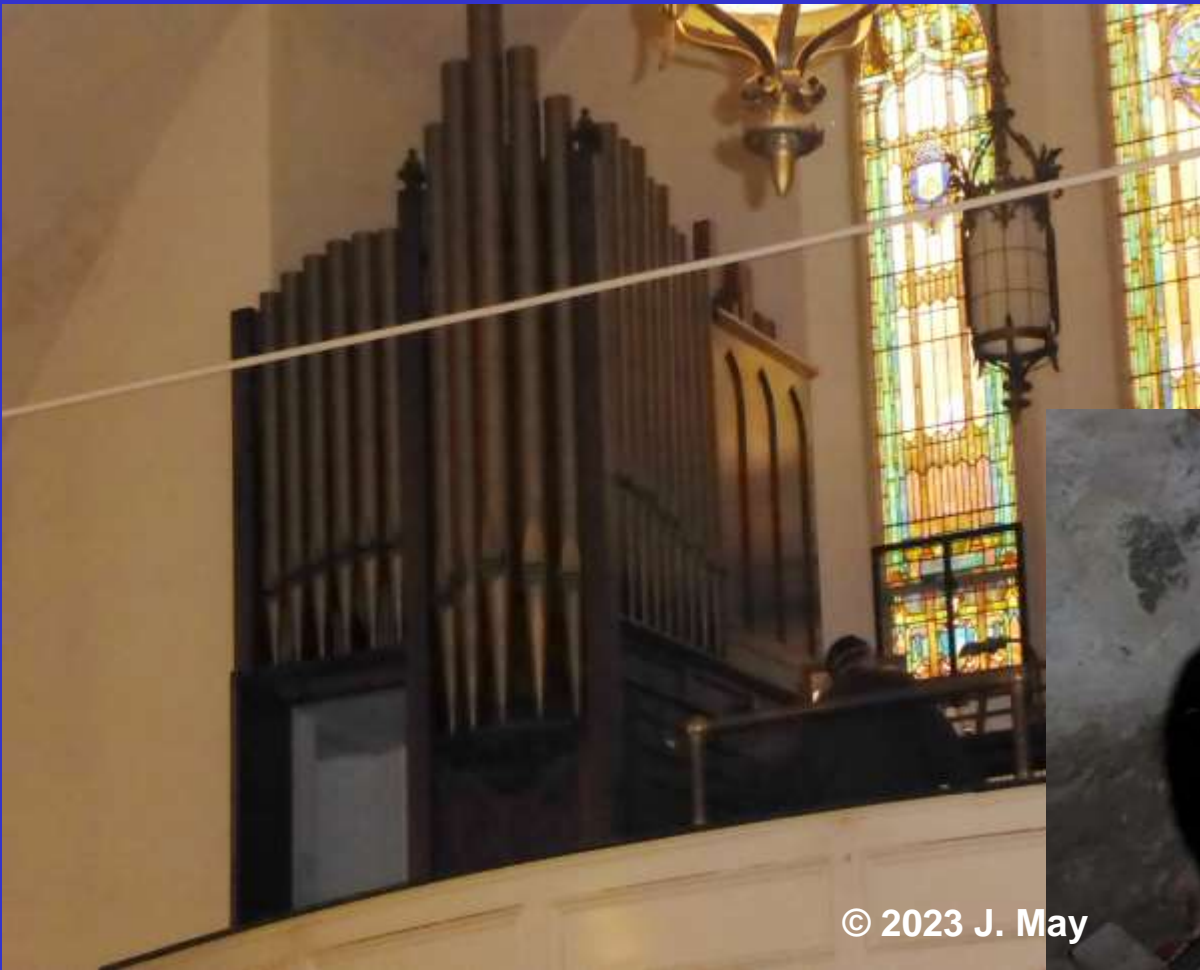


Thousands of 26-micron mite fecal pellets

Hyphal fragments

actinomycetes

Church Organs Can Be an Allergen Source



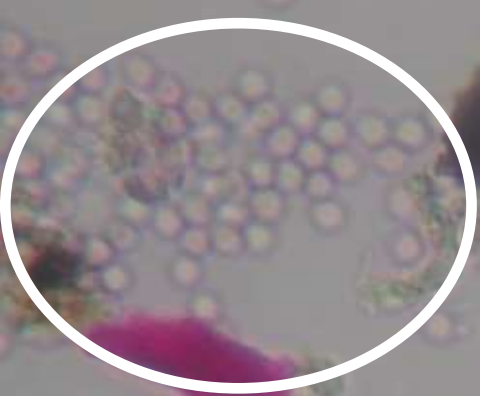
**Sanctuary air fine
prior to organ playing;
very allergenic
after music started!**

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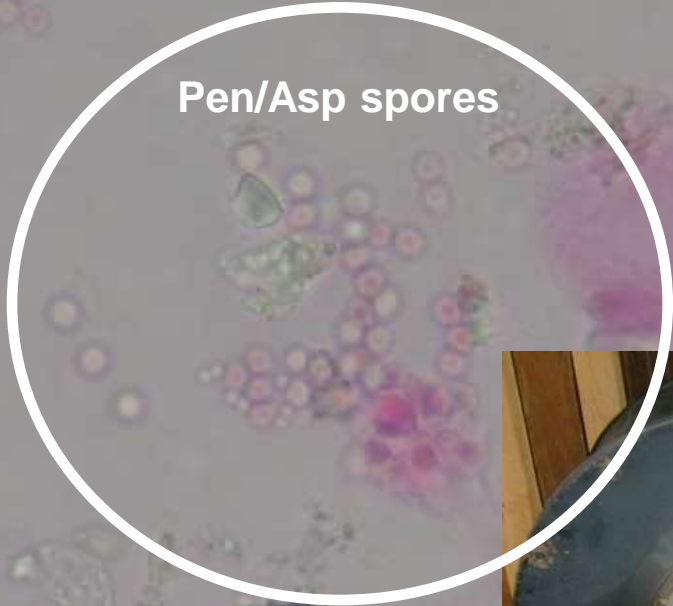


Organ blower in moldy basement closet

Church Organs Can Be an Allergen Source



Pen/Asp spores



Air sample from blower closet

Is this a common problem in old churches?

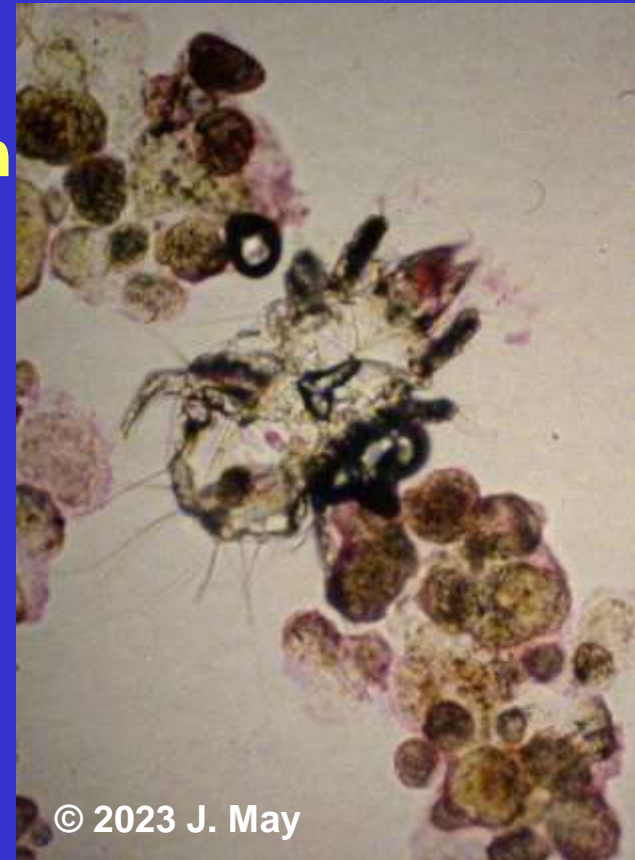


Blower in another "sick" church

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Case Study: Retired Surgeon

- 70+ year-old, referred by allergist.
- Mild asthma and disabling rhinitis.
- Experienced sudden symptoms in den
- 25 gallon tropical fish tank in den.



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- Fish food flakes all around tank and on cover.
- Live dust mites crawling around fish tank.
- Underside of tank cover covered with mite fecal pellets.

CASE STUDIES: Hidden ceiling mold



Adaptive re-use of mill building into lofts

Client experiencing eye and respiratory irritation

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Wide gaps between ceiling planks the source of irritating dust



Hidden ceiling mold

Dust from ceiling crack
was sampled



Penicillium conidiophore

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Microarthropod fecal pellet full of spores

Multiple layers of factory
flooring had been wet
by roof leaks for decades

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Fiber with mold growth

CASE STUDIES: Hidden ceiling mold



***Stachybotrys* mold grew between the planks and exited with the dust**

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Client moved out but continued to sensitized

Conclusions:

- **Dust can be an enormous mixture of allergens from many sources.**
- **Many of these allergens cannot be readily detected by today's testing.**
- **Clean-looking fibrous insulation can be the source of mold and mite allergens.**

Conclusions:

- **No dust is a must!**
- **There are more unknowns than knowns, so believe the sufferers.**

Conclusions:

Air Sampling Alone Does not Identify
Bioaerosol Sources

Culture testing only detects live spores
but dead spores remain allergenic

Source Sampling Can Identify
Bioaerosol Sources

Microscopy rules!

What is the Source????

Before remediation, the source must be identified!

Contrary to the EPA,

Sampling is often necessary

Air cleaners are not a substitute for source removal.



Bibliography

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Questions

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