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Moisture and Leak Investigations

Tools and Instruments
Typical Inspection Equipment:
Screwdrivers, needle-nose pliers, flashlight, camera, etc.

Flame mirror with mirror glass doubled taped

Mirror

Wash bottle

NO HOSING!!!!!!

Syringe or dropper

Why you need a mirror

Top of pipe

Bottom of pipe

MOISTURE AND LEAK INVESTIGATIONS

Patterns of liquid flow
Patterns of condensation
Relative humidity (RH)
Dew point
Measuring moisture content of wood

Case studies of moisture and health problems in homes


Observation and pattern recognition are important parts of moisture diagnostics.
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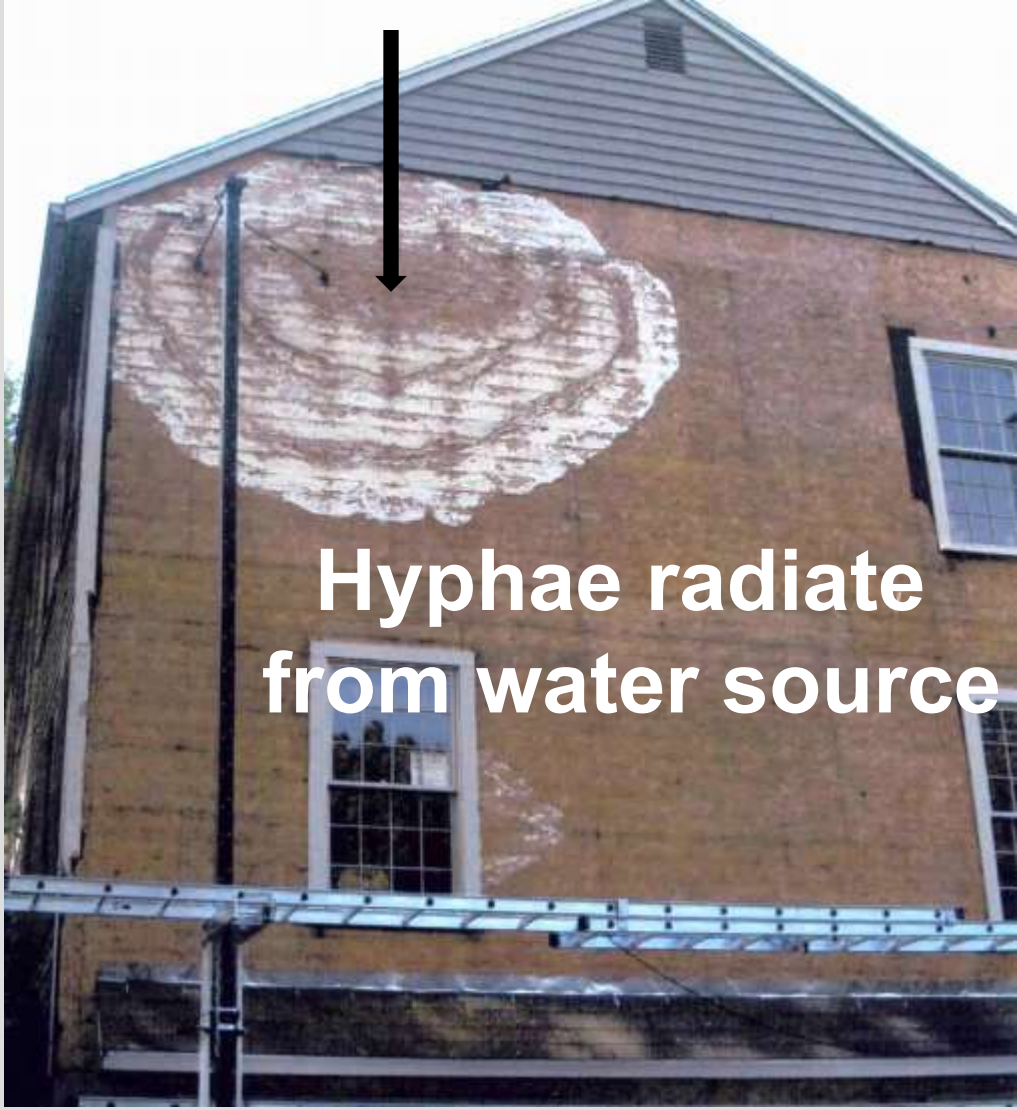

Masonite siding removed

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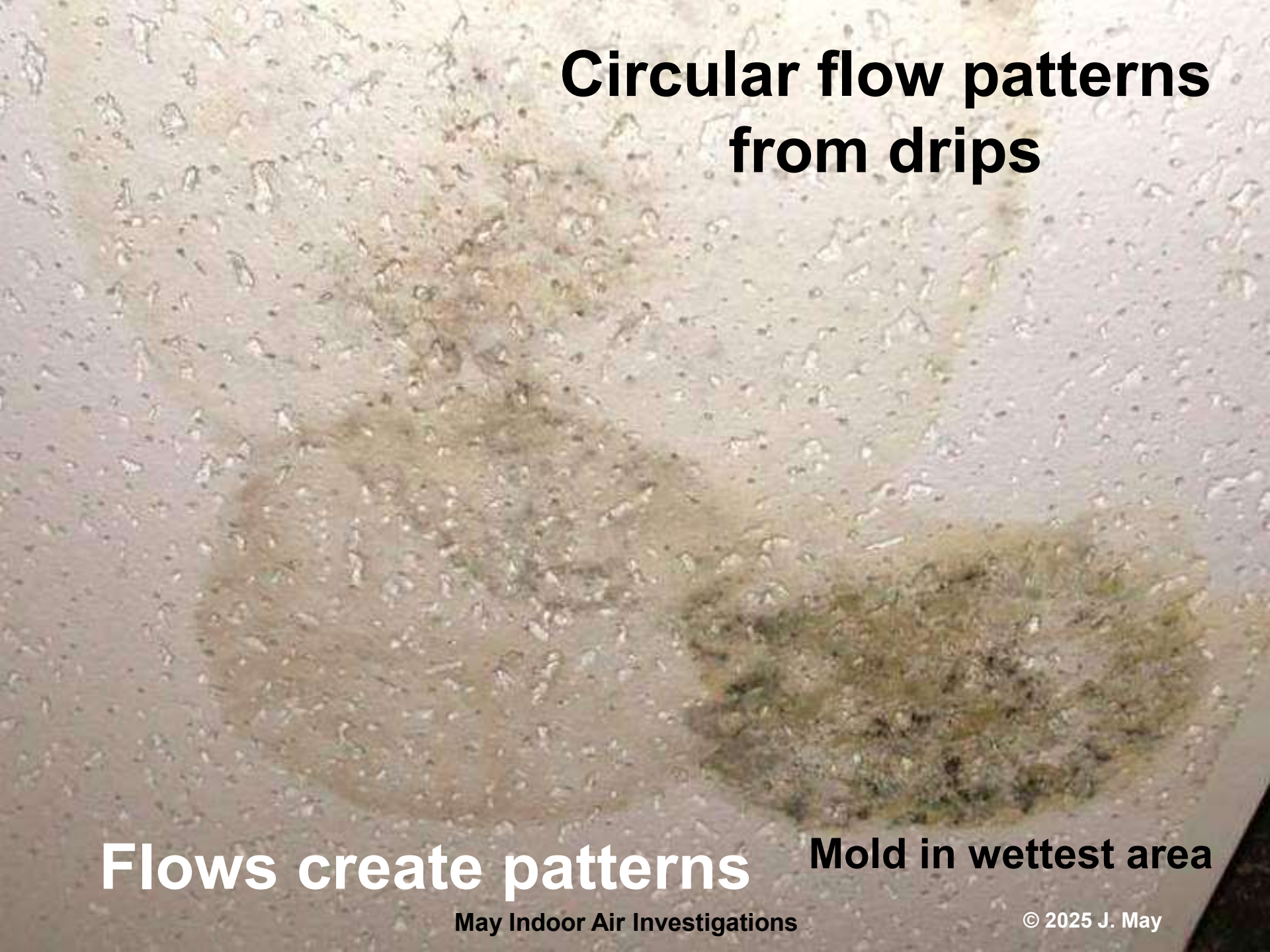
Masonry Patterns

Water flows through the limestone joints.
Efflorescence/freeze/thaw damage


Circular flow patterns from drips
Flows create patterns
Mold in wettest area
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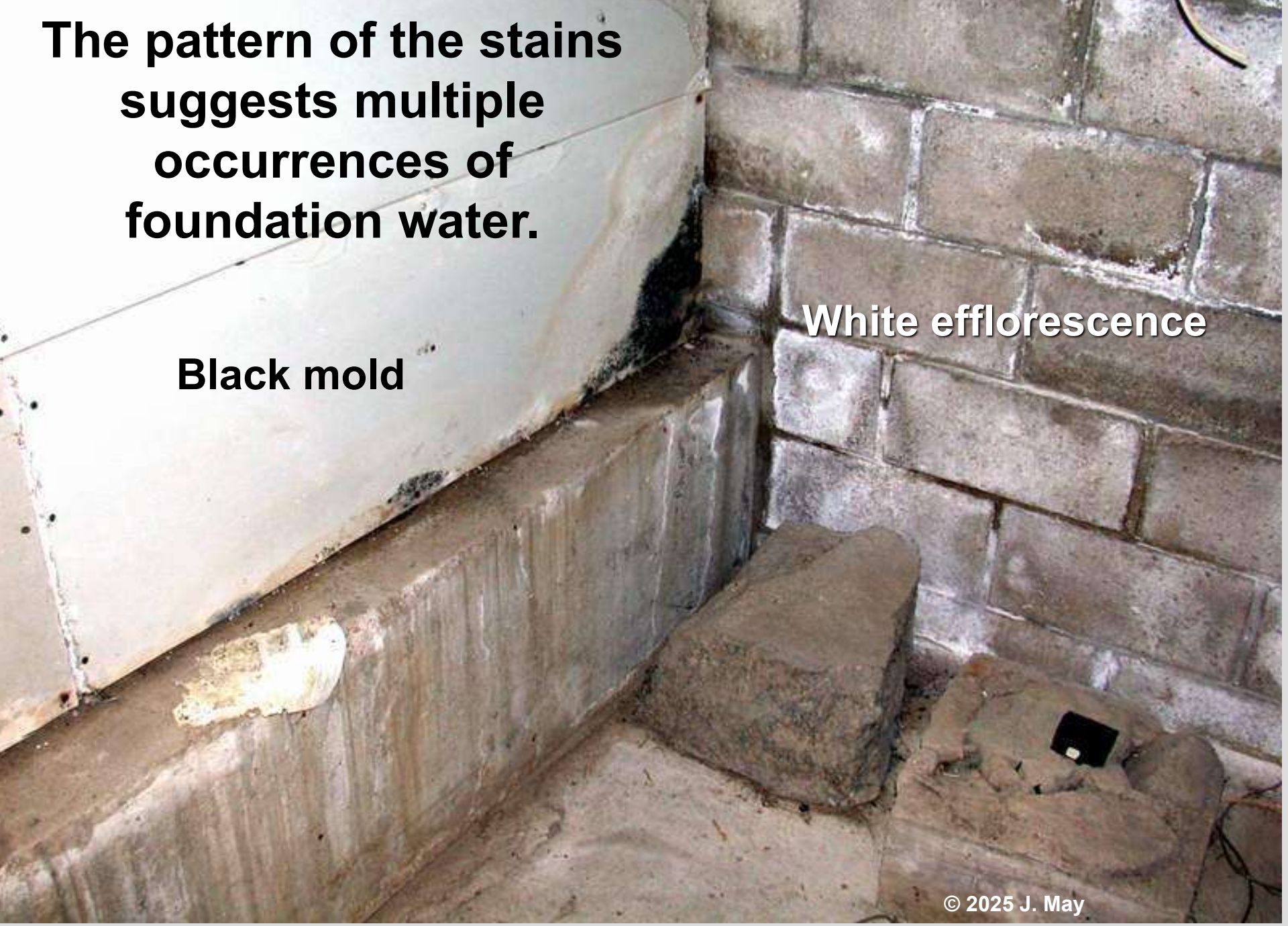
The pattern of the stains suggests multiple occurrences of foundation water.
White efflorescence
Black mold
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Liquid flows can make obvious stain patterns.

Water vapor moves with air.

Air flows are more subtle.

To understand water vapor behavior:

Dew Point

Relative humidity (RH)

Condensation occurs at cooler surfaces.

Roof ice patterns from radiational cooling

Clapboard heat loss at studs

Black mildew at the studs above…

but absent at some studs below!

Moisture Content

RH is a measure of how much vapor is in the air compared to the maximum amount of vapor the air can hold at a given temperature.

RH depends on temperature.

If you heat air, the RH decreases.

If you cool air, the RH increases.

Measuring RH

Digital Thermo-hygrometer

Try Fluke 971

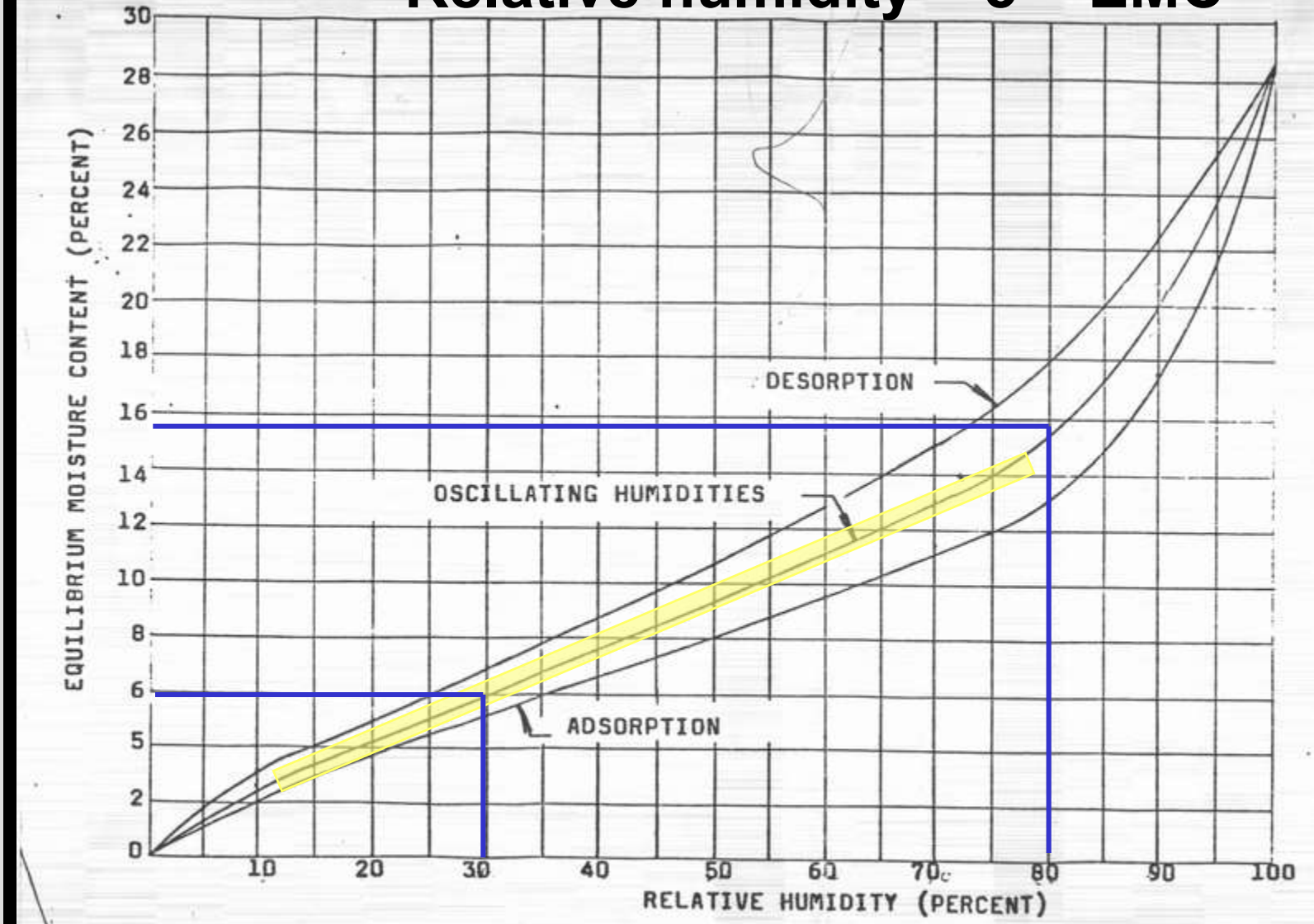
Inexpensive instruments are very inaccurate.

Fluke 971: RH,T, dew point

There is a relationship between the relative humidity (RH) of the air and the moisture content (MC) of materials.

Surfaces are in equilibrium with the relative humidity.

Relative humidity ÷ 5 ~ EMC



TYPICAL HYSTERESIS LOOP FOR WOOD

Measuring Moisture Content (MC) of Wood

Types of meters:

Electrical resistance
Electrical impedance
Radio-frequency absorbance

The Moisture Content of Wood

Pin probe Meter

Measures electrical resistance

“Calibrate” with finger check

Short probe, shallow penetration

Metal conducts so looks wet!

Salts conduct so look wet!:

fire retardant salts

salty ocean spray

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Pin probe

Long probe
Penetration
Probe insulation

Wall cavity MC
Side of work box
Move in slowly
Fiberglass
Sheathing back

Aluminum VB
Salts:
Cellulose insulation

Measures impedance

Conducting carbon pads

Quantitative for wood:
% MC

Drawback:

Can’t measure narrow spaces

Tips:
Hand test before/after

Tramex moisture encounter

Three scales:

Quantitative for wood:
% MC

Qualitative for other

Drywall/roofing is most sensitive

Plaster/brick is least sensitive

Tramex moisture encounter

Test in a thick book:

detecting wet paper towel
detecting aluminum foil

Salts, metals conduct so appear to be wet

OK for asphalt shingles but not membrane roofing

Tramex moisture encounter

Is Ice Wet??

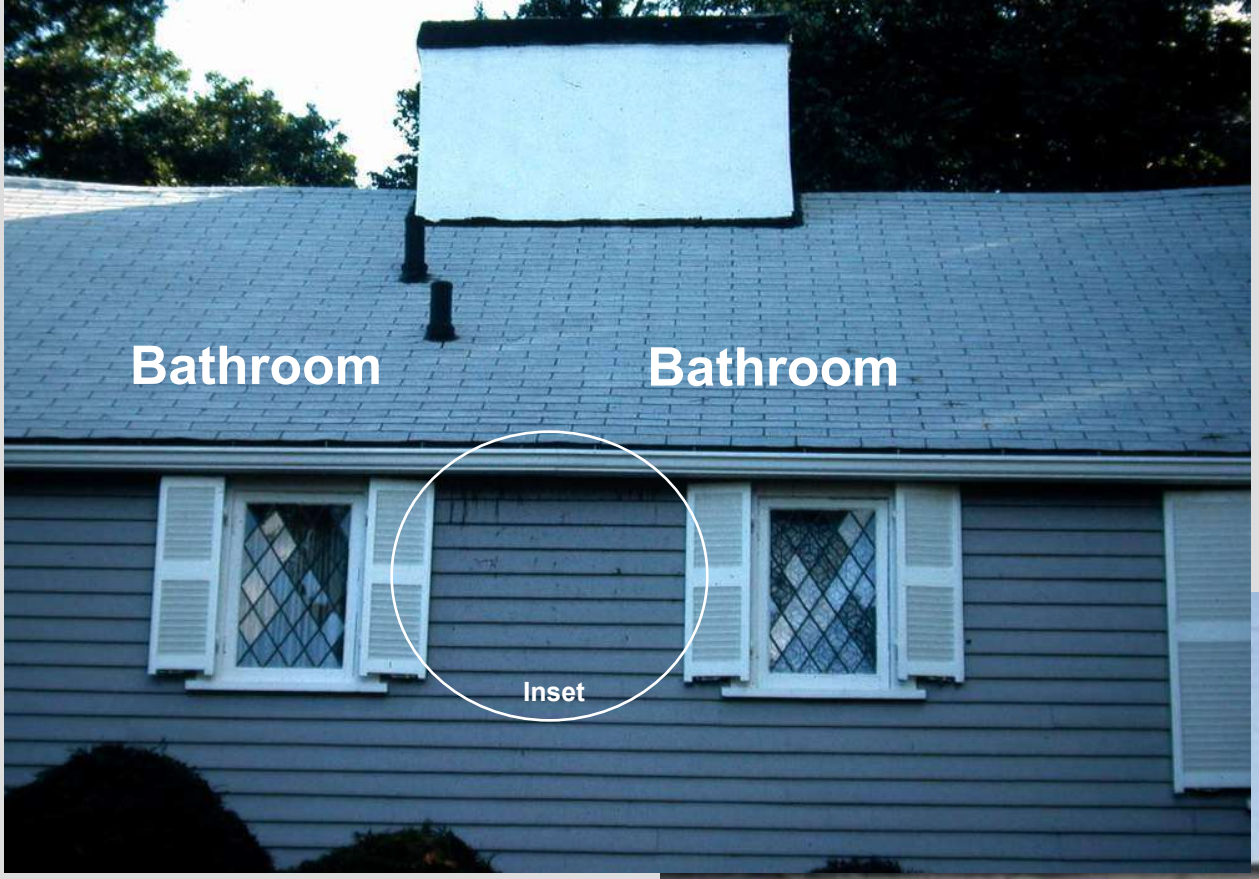
NO!!!

To test moisture content of exterior wood in winter, wood must be above freezing.

Frozen, water-logged wood is dry!

CASE STUDIES

Water leaks and water vapor cause rot, mold, rust and paint peeling.



The homeowner called the paint contractor back.

There was a new roof and a year-old coat of paint. What was causing the blisters?

Crack at Top of Chimney

A water-filled blister appeared in the front of the stucco.

Water was added to the crack.

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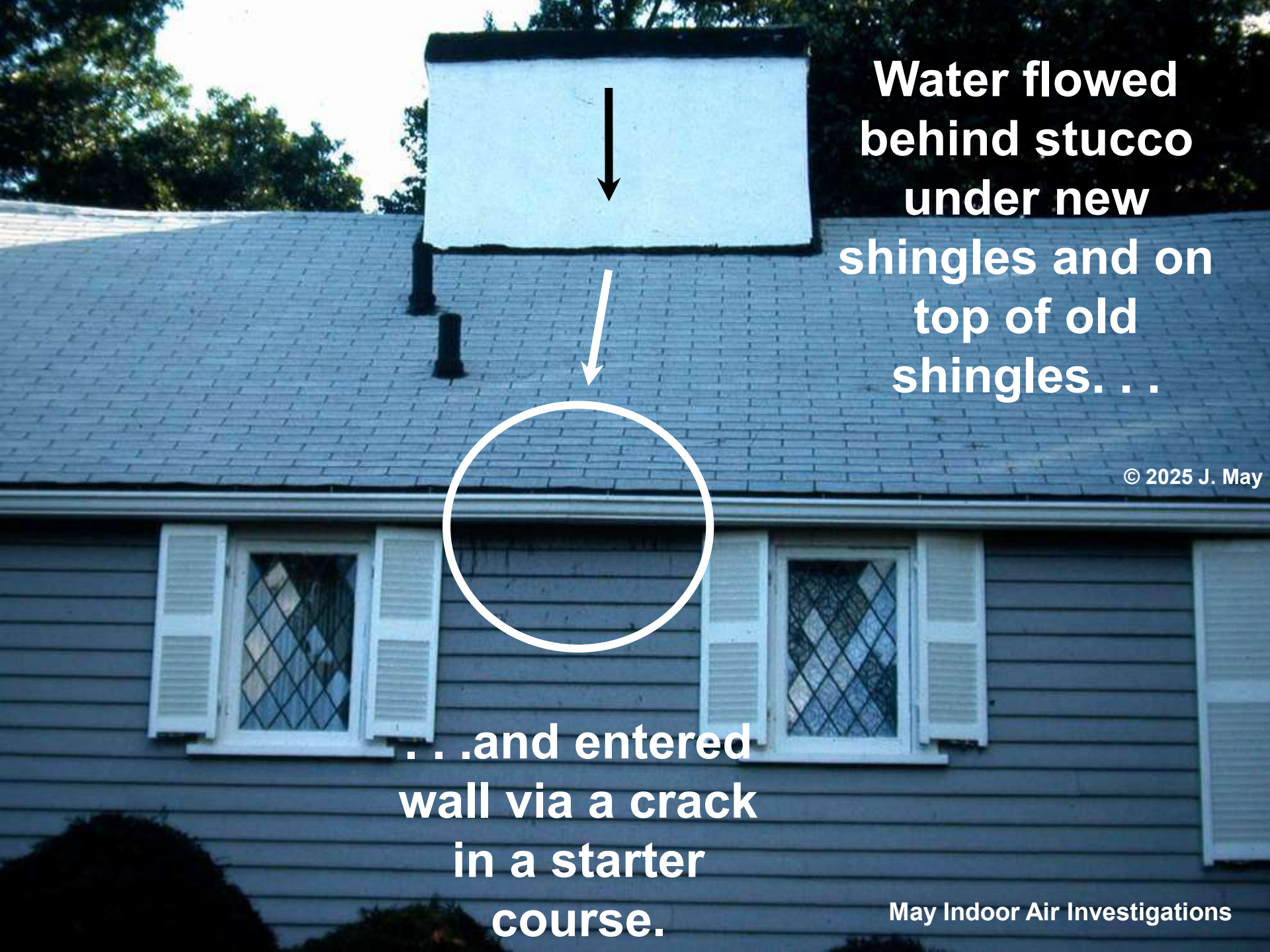
Water flowed behind stucco under new shingles and on top of old shingles. . .
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. . .and entered wall via a crack in a starter course.
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Back of house with first-time water entry
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Wet wallpaper
1st flr DR

Water on floor
2nd flr under window

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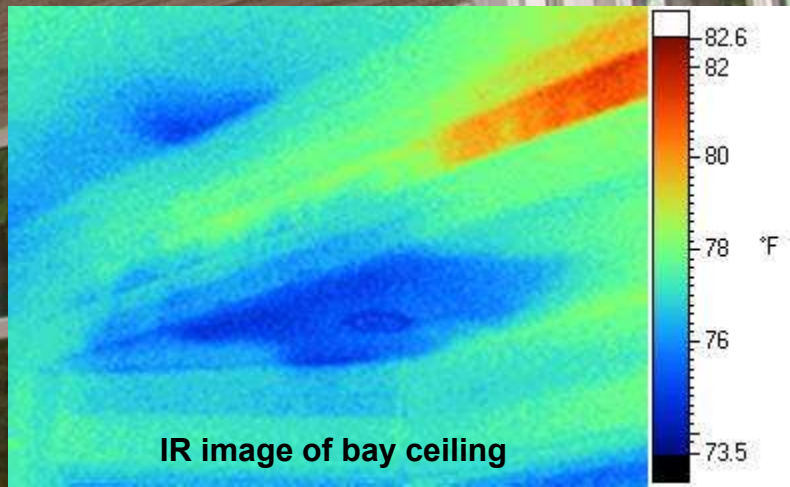
Water exited the light fixture

Was bay roof leaking?



IR image of bay ceiling

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Moisture in window

Gutter above window overflowed in heavy rain

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My drip edge to keep water away from doorway during heavy rain/overflow

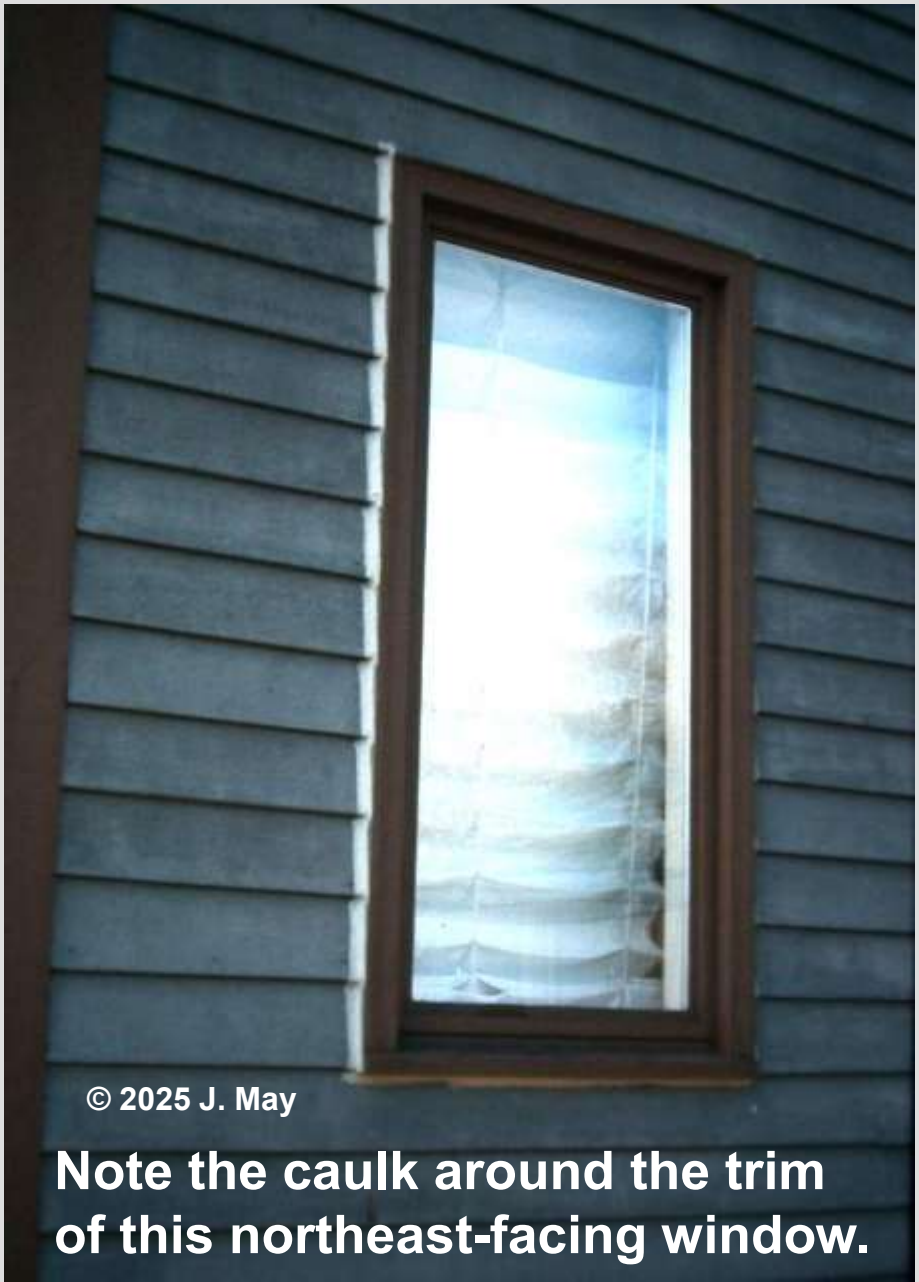
Fifteen years of Gutter Neglect in PA

Builder was sued in court

Above: the decayed sheathing was under the siding.

Remind your clients to keep their gutters and downspouts clean.

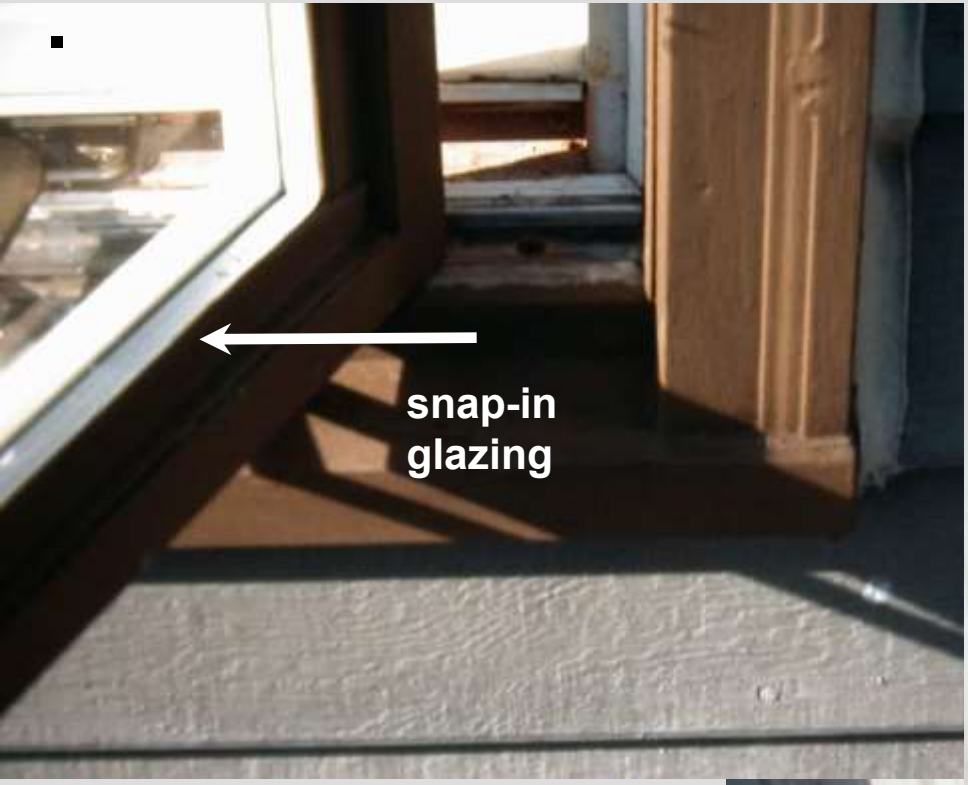
The Window That Wouldn’t Stop Leaking



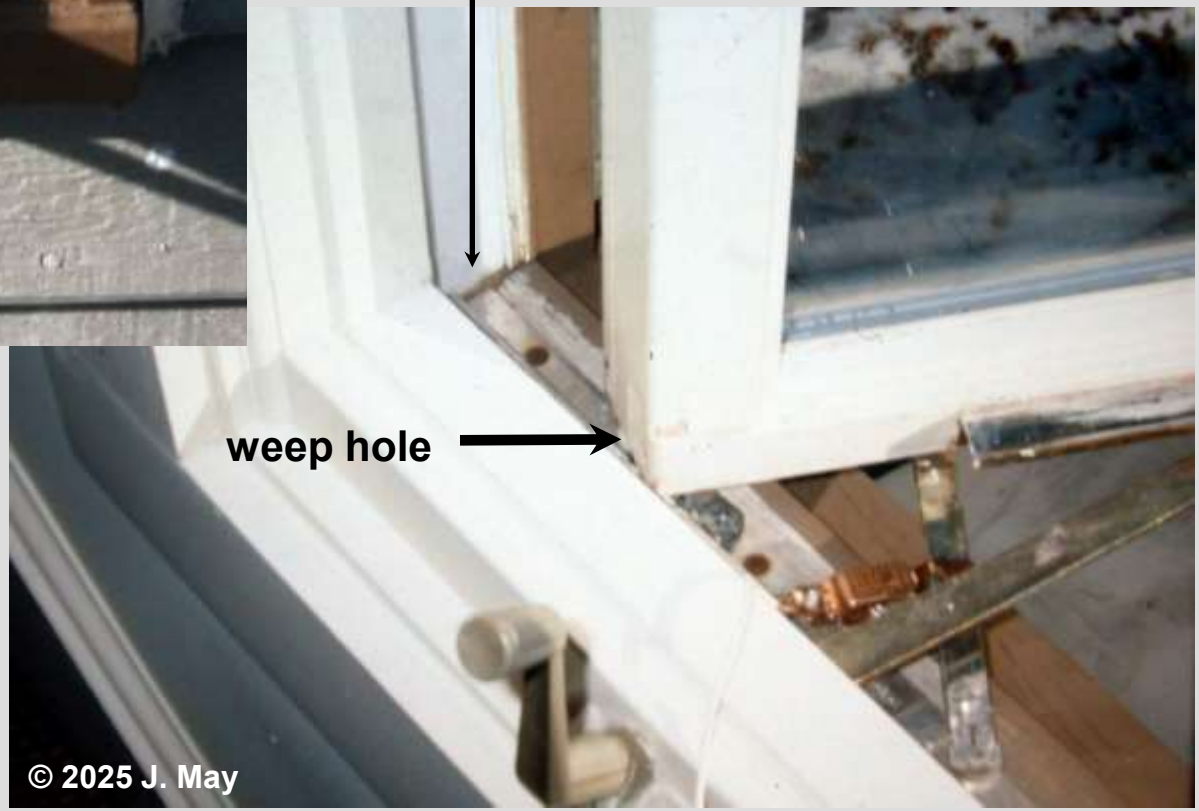
Note the caulk around the trim of this northeast-facing window.

Inside, the wallpaper under the window was all stained from the leaks.

Wind-blown rain flowed down the window. .



Water entry at leaky joint



Visible and Concealed Wall Decay

At the home above, pests and both insect and wood decay led to powerful, musty indoor odors. Water entered the wall between the separate window units.

The Leaky Wall that Damaged Newly Finished Oak

There was a long crack in the mortar joint a few courses above the window.

Leaky Wall

It only took a few ounces of water.

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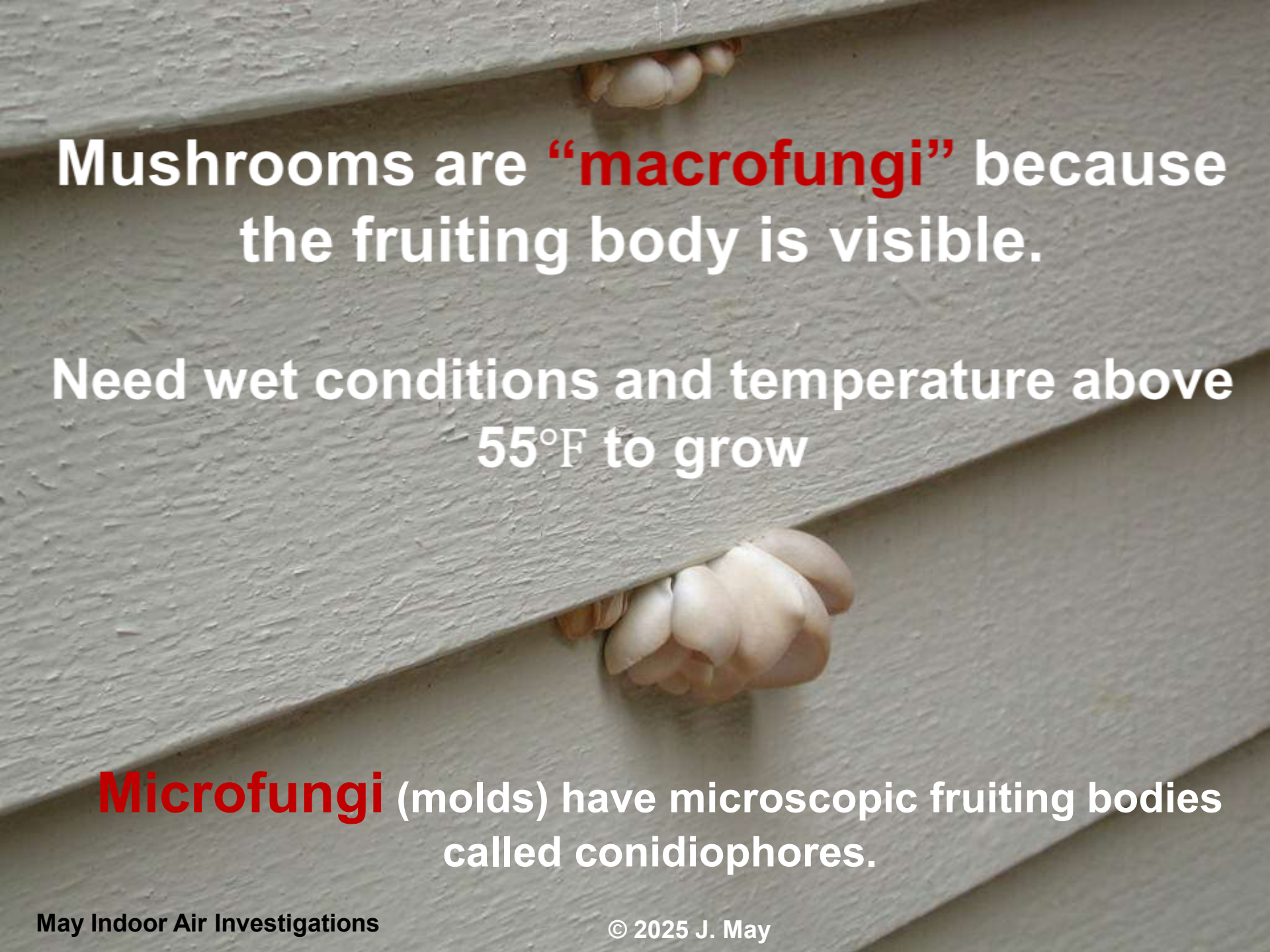
Design Flaws and Construction Defects

Lead to the growth of fungi:

Macrofungi
and
Microfungi


Mushrooms are "macrofungi" because the fruiting body is visible.
Need wet conditions and temperature above 55°F to grow
Microfungi (molds) have microscopic fruiting bodies called conidiophores.

Microfungi

The fruiting bodies (conidiophores) of microfungi may be colored, but the structures are too small to be seen by eye.

Cladosporium mold on a basement door.

Above: *Aspergillus* mold on the front door of a split-level home.

Is There A Design Problem Here?


Is There A Design Problem Here?
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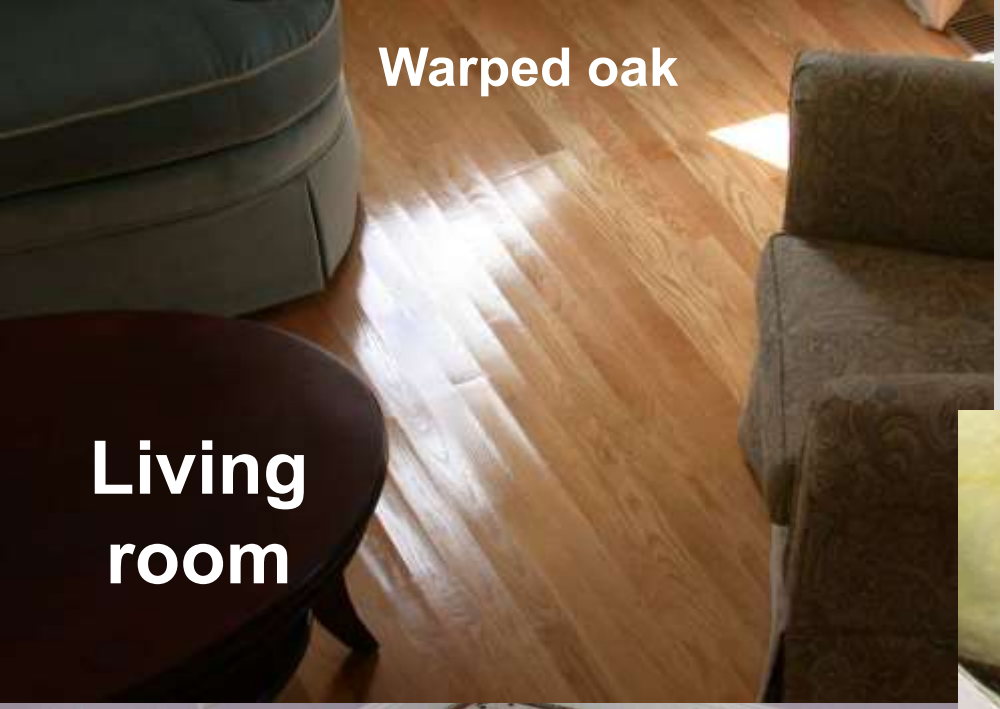
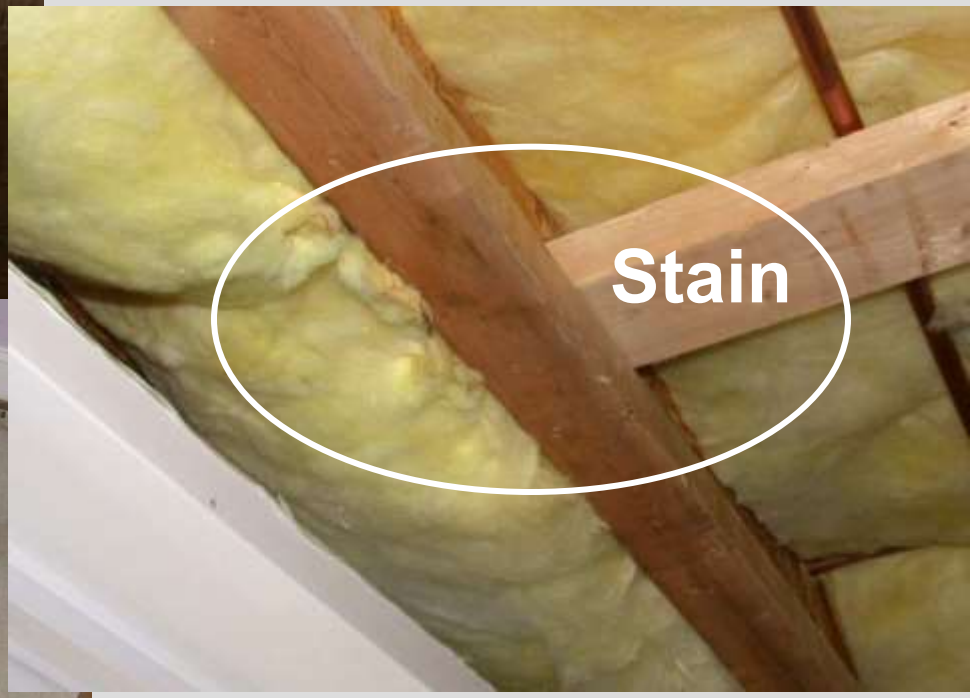
Is There a Design Problem Here?





Basement

Baby with respiratory issues removed from room

Is There a Design Problem Here?

Wet insulation and OSB in second-floor baby's room in corner of house

Home with Bad Siding Installation

No flashing strips under clapboard joints

Nails driven in too far

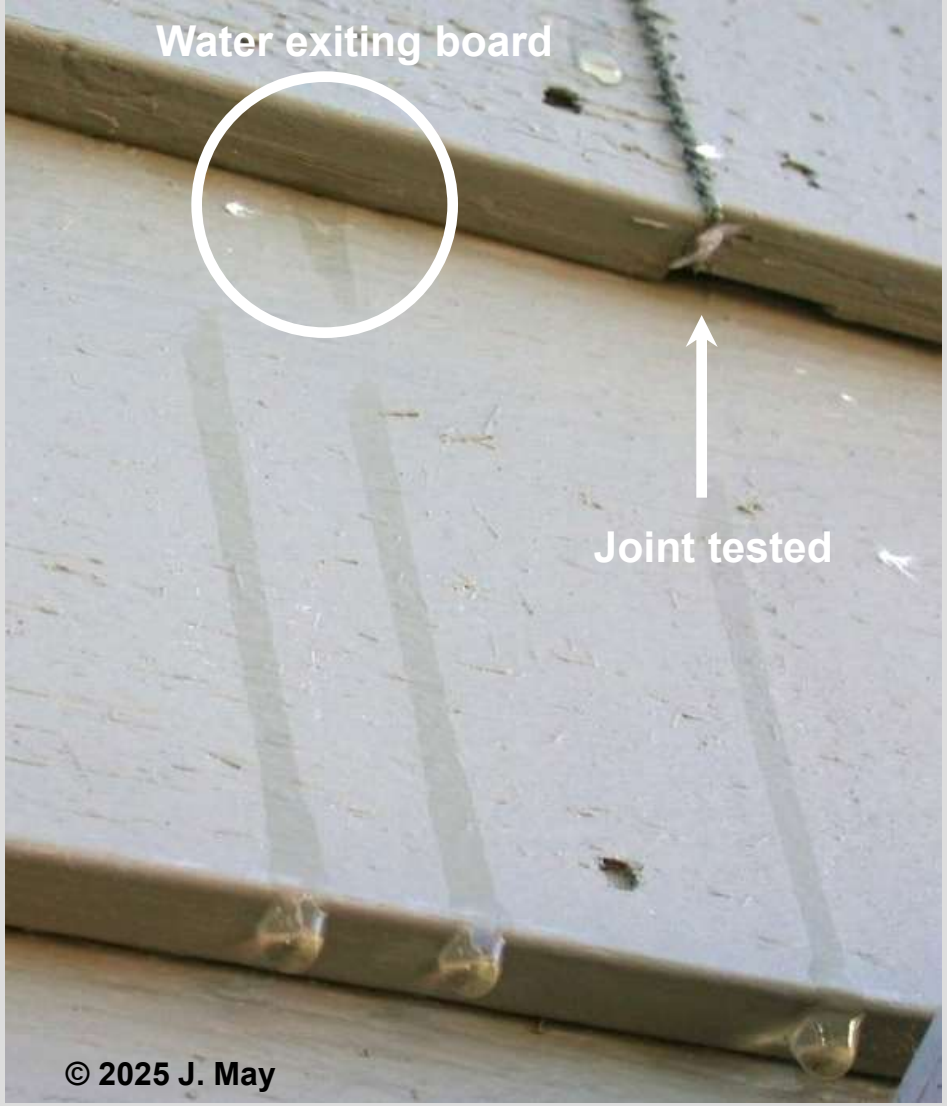
Exposed wood grain at nail depressions not painted

Leak Test at Clapboard Joint

Unfilled nail heads, too deeply set; fibers take in water also!

The resulted was wet sheathing. . .

Flash under clapboard joints!



Northeast-facing Bedroom Wall

Northeast-facing Bedroom Wall

All the interior drywall was removed.

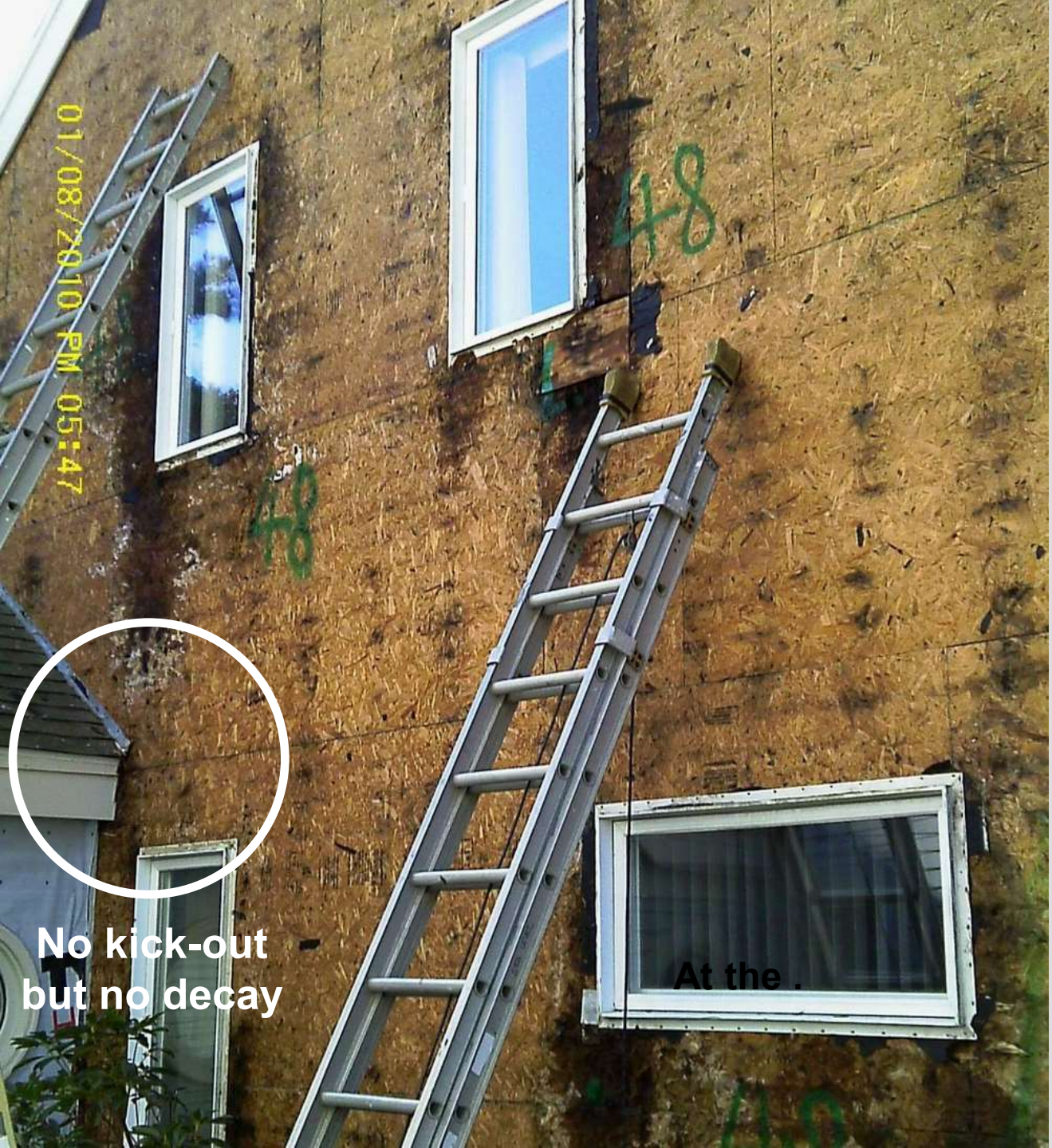
Both macrofungi and microfungi were growing on the OSB. The fungal growth-pattern suggests that water entered the wall from the exterior at the studs (nails and joints) and the window jamb joints.

A Bedroom OdorComplaint
Due to Concealed Wall Decay

Concealed Wall Decay

Visibly decayed clapboards

Return sloped improperly at bottom edge



Concealed Wall Decay

- Window-pitch effect on flow
- Staining at nail penetrations

Concealed Wall Decay

Water flows by capillary action behind OSB at joint.

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Concealed Wall Decay

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Build with ample overhangs

Gutters

Kick-out flashings

Don’t set nails in too deeply

House with very musty entry hall but no visible mold

No gutter above entry balcony

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House with very musty entry hall

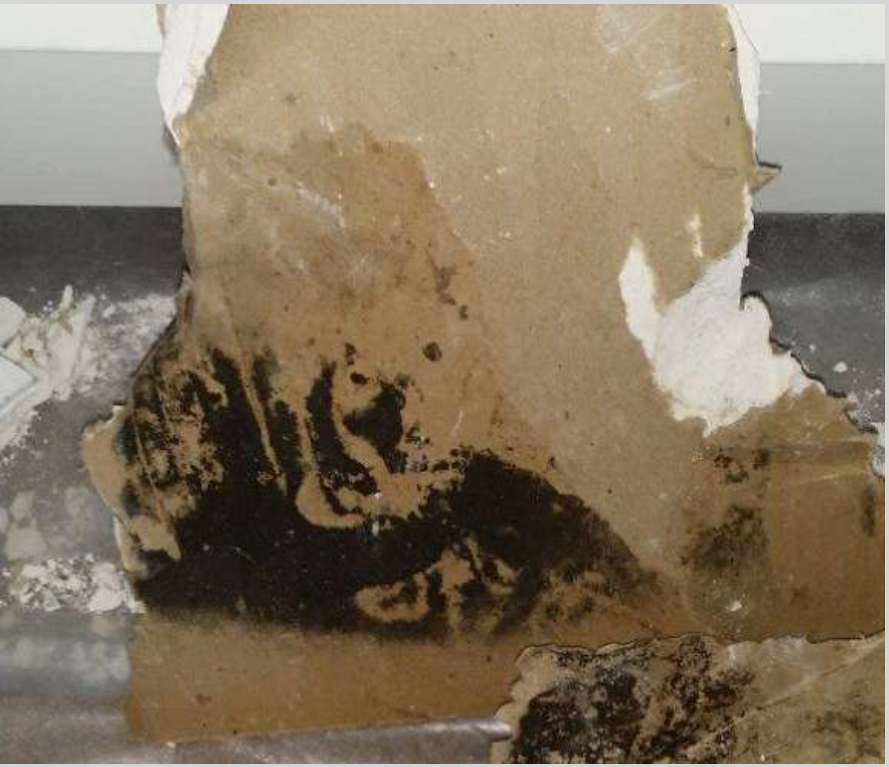
House with very musty entry hall

No odor at 2nd floor over entry!!

Remediation of house with very musty entry hall

Basement

Remediation of house with very musty entry hall



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Gulf-Coast House Completely Re-sided

Decayed sheathing

No roof overhang or gutters!

Gulf-Coast House Completely Re-sided

This house must have overhang or gutters!

Great Design...

A Two Year-old House with a Serious Decay Problem

Above rear deck

Discoloration due to cedar extractive stains is characteristic of water entry behind the clapboards.

Below rear deck

Bottom views of leak test

Great Design...

Gutters at different levels met at a corner under a roof valley. Neither collected the valley water.

A Two Year-old House with a Serious Decay Problem

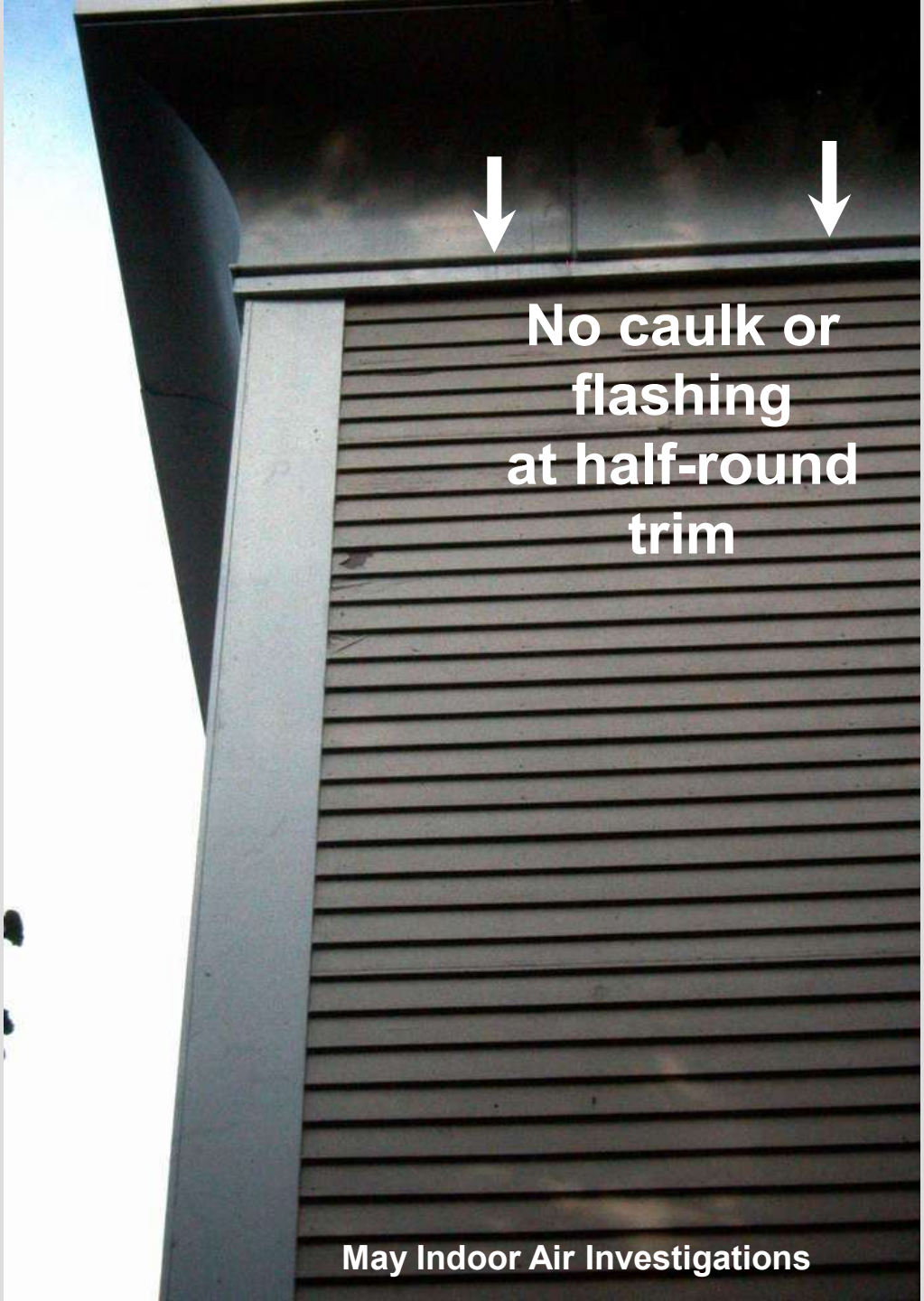
The OSB sheathing was rotted by decay fungi and there was mold growing on the housewrap.

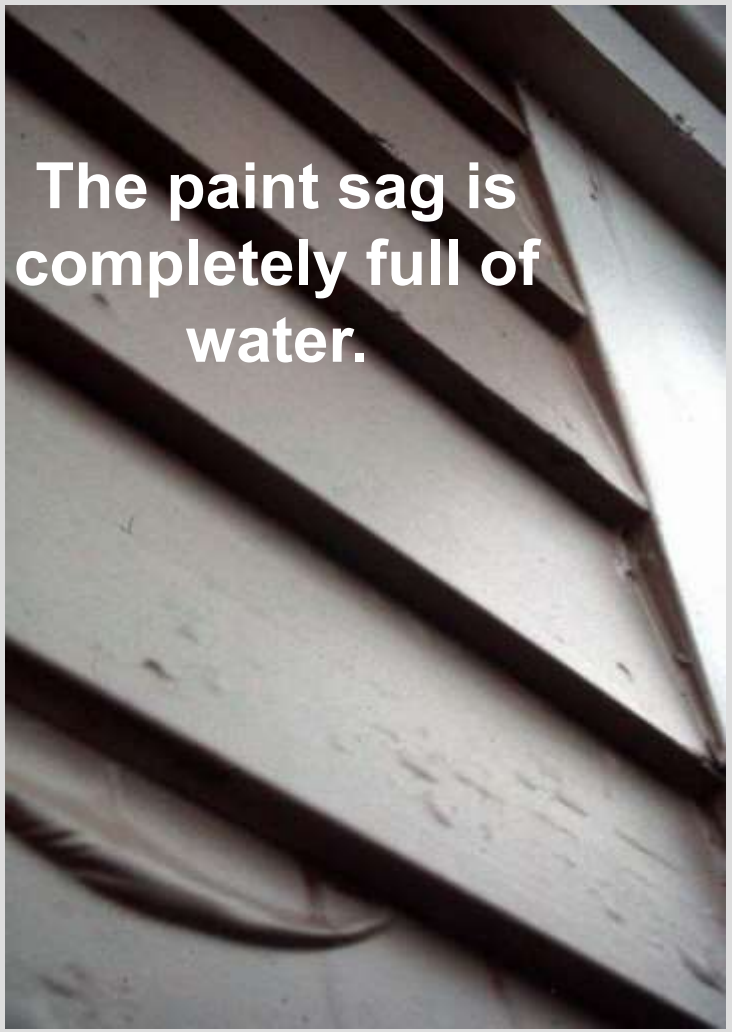
A Two Year-old House with a Serious Decay Problem

There were basement-ceiling stains in the corner.

A ceiling tile was removed. The framing and back of the OSB were covered with white hyphae from macrofungi. Green microfungal growth was also present.

This condo was on the cover of “Architecture Magazine”. . .



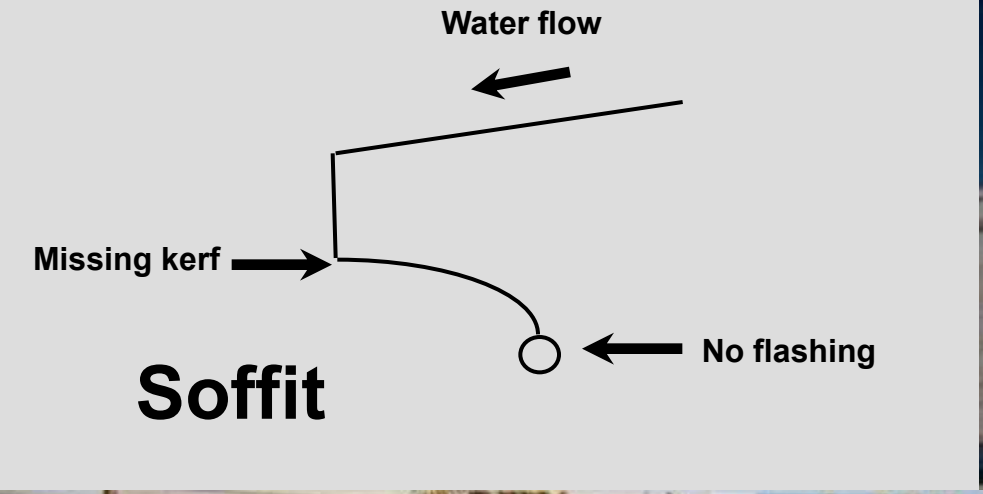


. . . for its award-winning soffit design!

Year 1

Year 2

Eight years after construction, all the siding was replaced.



Originally, there was no flashing or caulk at the half-round trim beneath the soffit, which shed roof water down the concave curve and into the wall.

Grade surfaces so that water flows away from the foundation.

The most common causes of excess basement water are poor dispersal of roof water and improper grading.

Excess humidity is a frequent cause of mildew and odors.

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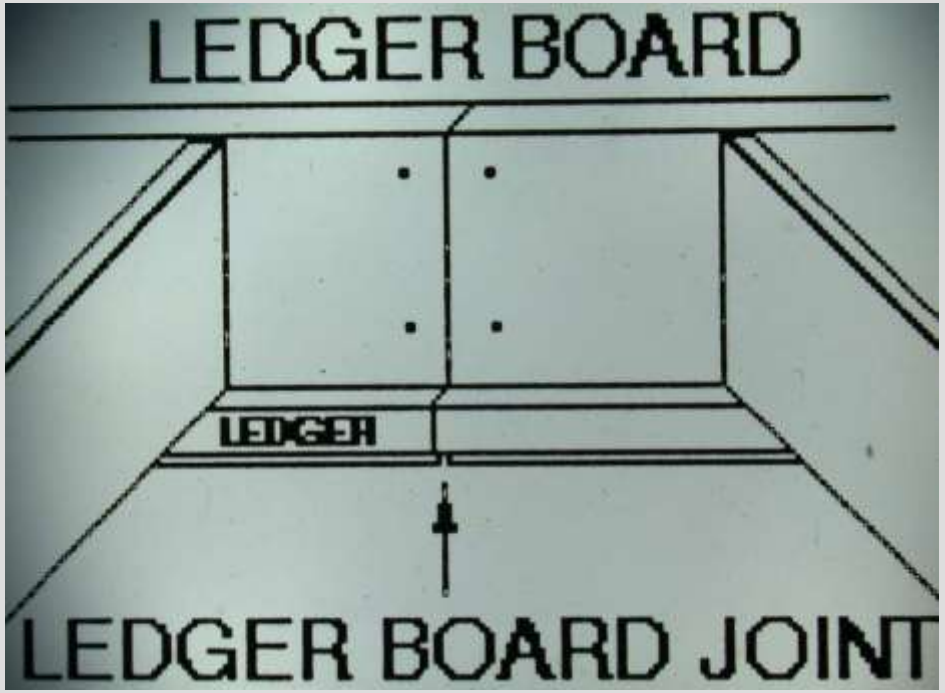
Conspiracy Design...

Portabella By-the-Sea:

A four-unit condo complex on the North Carolina Coast

Mushroom at a three year-old building

Portabella By-the-Sea

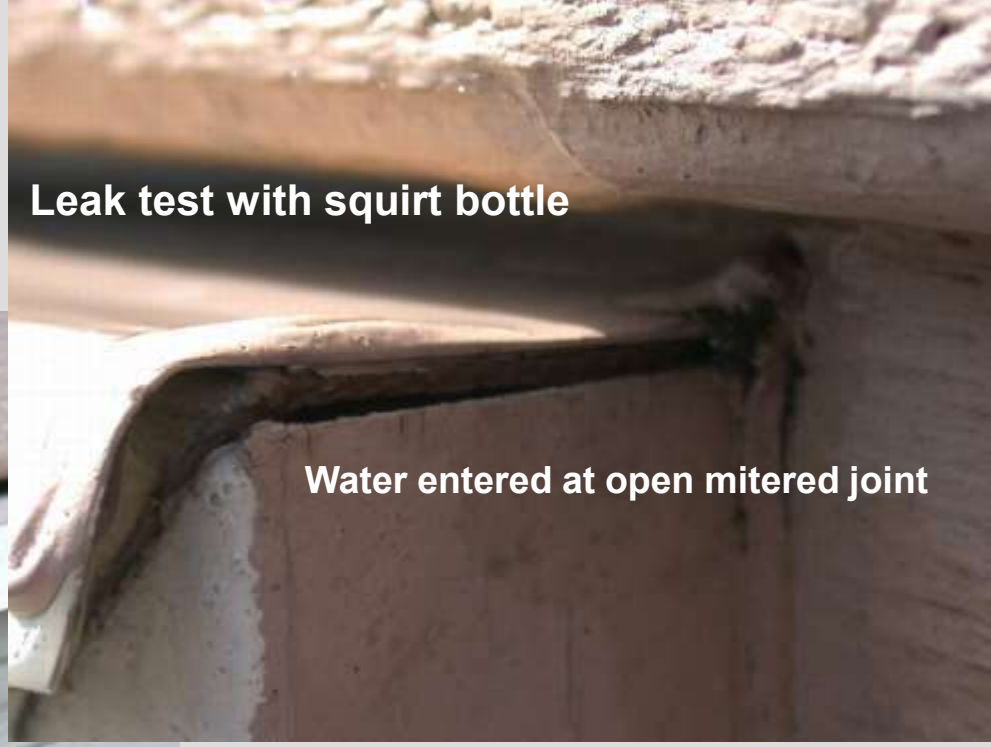


The severe decay at the three year-old building was due to water penetration at a joint and a lack of flashing at the deck ledge.

Drip Caps Should Be Bent Down!!!!!

NOT UP!!!!!

Water soaks up the back of the clapboard and runs to the ends of the flashing, and in this case, into the mitered joints, and down the wall behind the trim.



Water from the drip-cap test came out of the wall!

The end of the exterior for an eight year-old house.

Cedar extractive stains

← Leak-test water exiting siding below mitered joint

A puff-ball fungus!

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The decayed casing from the left side of the window was removed.

Even the framing lumber at the side of the window was rotted. The rough window opening was never flashed.

Obscure Moisture and Mold Sources with Significant health Impacts

Central Air Conditioning
Window Air Conditioners
Humidifiers
Dehumidifiers
Frost-free refrigerators

Anywhere there is wet dust and air flow!!

Microorganisms will grow in the dust and allergens will be aerosolized

"Symptoms, Sources and Solutions In 600 Sick Structures"

(Part II of "Sampling, Results & Remediation in 300 'Sick Homes,'"
***Bioaerosols, Fungi and Mycotoxins* (1999), E. Johanning, ed.)**

Reports from 600 "sick house syndrome" (SHS) homes were compared to randomly selected reports from 300 homes inspected as part of pre-purchase agreements.

"Symptoms, Sources and Solutions In 600 Sick Structures"

In Boston area:

- **19% of homes have central A/C**
- **38% of SHS homes have central A/C**

Conclusion: You are twice as likely to have SHS if you have central A/C

Many studies have shown a correlation between SBS and Central Air Conditioning

Mold contamination and air handling units. J Occup Environ Hyg. 2007 Jul;4(7):483-91
Wilson SC, Palmatier RN, Andriychuk LA, Martin JM, Jumper CA, Holder HW, Straus DC.

Fungal contamination of air conditioning units in operating theatres in India. J Hosp Infect. 2005 May;60(1):81-4. Kelkar U, Bal AM

Aeroallergen sensitization in pediatric allergic rhinitis in Singapore: is air-conditioning a factor in the tropics? Pediatr Allergy Immunol. 2004 Aug;15(4):340-3. Kidon MI, See Y, Goh A, Chay OM, Balakrishnan A. Rheumatology, Immunology and Allergy Service, KK Children's Hospital, Singapore.

Upper respiratory symptoms associated with aging of the ventilation system in artificially ventilated offices in São Paulo, Brazil. Chest. 2002 Aug;122(2):729-35. Graudenz GS, Kalil et al.

Association of air-conditioning with respiratory symptoms in office workers in tropical climate. Indoor Air. 2005 Feb;15(1):62-6. Graudenz GS, Oliveira CH, Tribess A, Mendes C Jr, Latorre MR, Kalil J.,

Relationships between air conditioning, airborne microorganisms and health Bull Acad Natl Med. 1999;183(2):327-42; discussion 342-4. Parat S, Perdrix A, Baconnier P.

Heterotrophic bacteria in an air-handling system Appl Environ Microbiol. 1992 Dec;58(12):3914-20.. Hugenholtz P, Fuerst JA. Department of Microbiology, University of Queensland, Brisbane, Australia.

Mold contamination of automobile air conditioner systems. Ann Allergy. 1990 Feb;64(2 Pt 1):174-7. Kumar P, Lopez M, Fan W, Cambre K, Elston RC. Department of Medicine, Louisiana State University Medical Center, New Orleans.

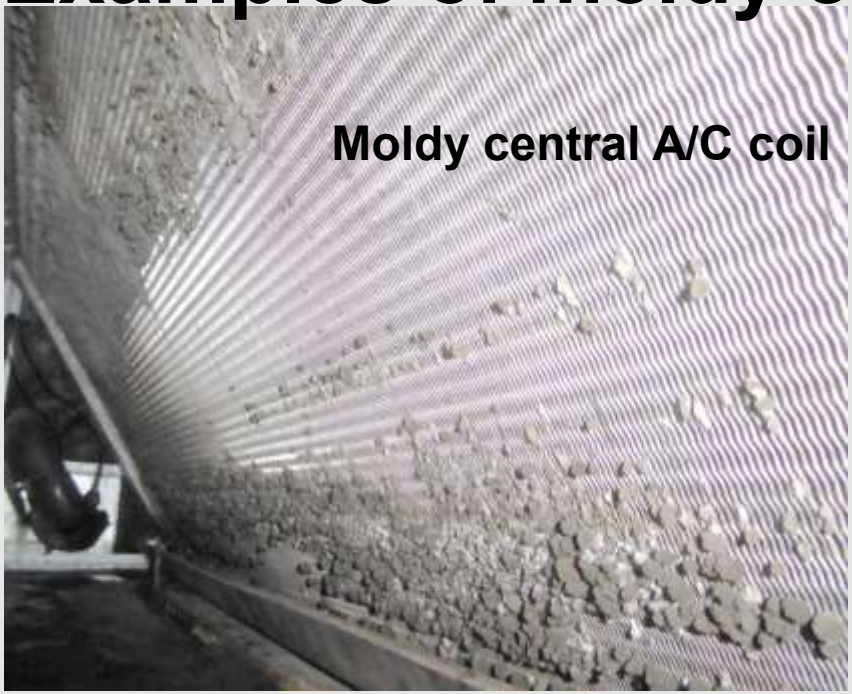
“Symptoms, Sources and Solutions In 600 Sick Structures”

81% had elevated levels of airborne spores

Most common genera found included

Cladosporium
Aspergillus
Penicillium

Examples of moldy condensing equipment



Microbial growth on coils and fibrous liners is a leading cause of sick building syndrome (SBS)

Contaminated HVAC systems can cause allergies, asthma and even life-threatening illnesses like hypersensitivity pneumonitis

Wet materials can be the source of allergenic fungal spores

Sources can include HAVC systems and wet building materials

Spores from decay fungi (macrofungi) and molds (microfungi) in wall cavities do not necessarily cause indoor spore exposures

Questions??

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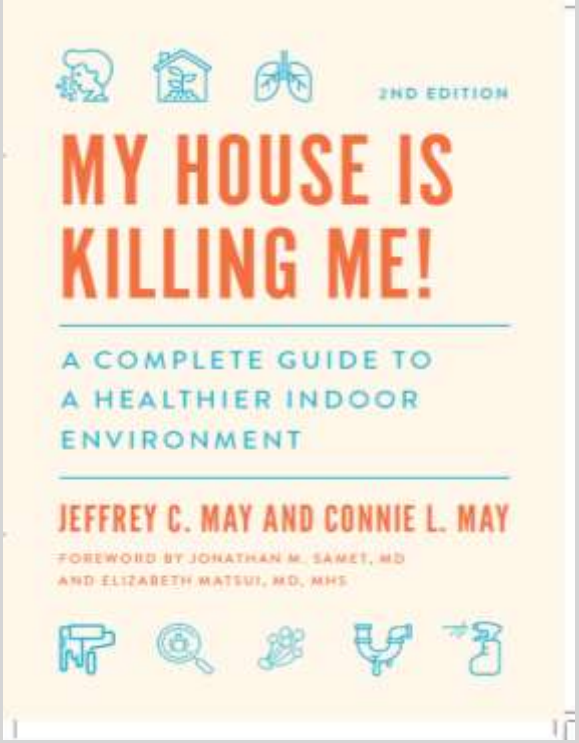
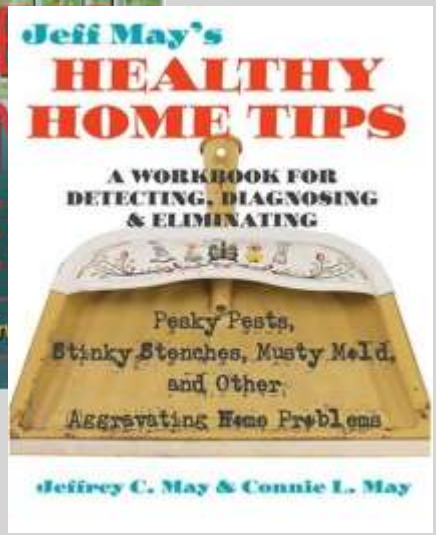


2020
Second edition

2001

2004

2006



2008

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