Version 2.2

These are steps to reduce household hazards. People are not born knowing that they must brush their teeth to prevent decay, they must learn it. So with household hazards, they must learn how to take care of themselves. Occupants know things about the building and themselves that can be learned nowhere else. Start with the people.

The second step is to keep the household in a certain condition:

- limit moisture related problems,
- limit dust and allergens,
- limit pest borne disease,
- provide local exhaust ventilation and general dilution ventilation to control unavoidable air contaminants,
- provide a comfortable space by limiting hazards like slips, falls, electric shock, drowning and poisons.

Third, limit sources of contaminants like lead, asbestos, combustion fumes, VOCs (Volatile organic compounds) and radon.

Fourth, maintain the house so it continues to provide dry, clean, comfortable and safe conditions.

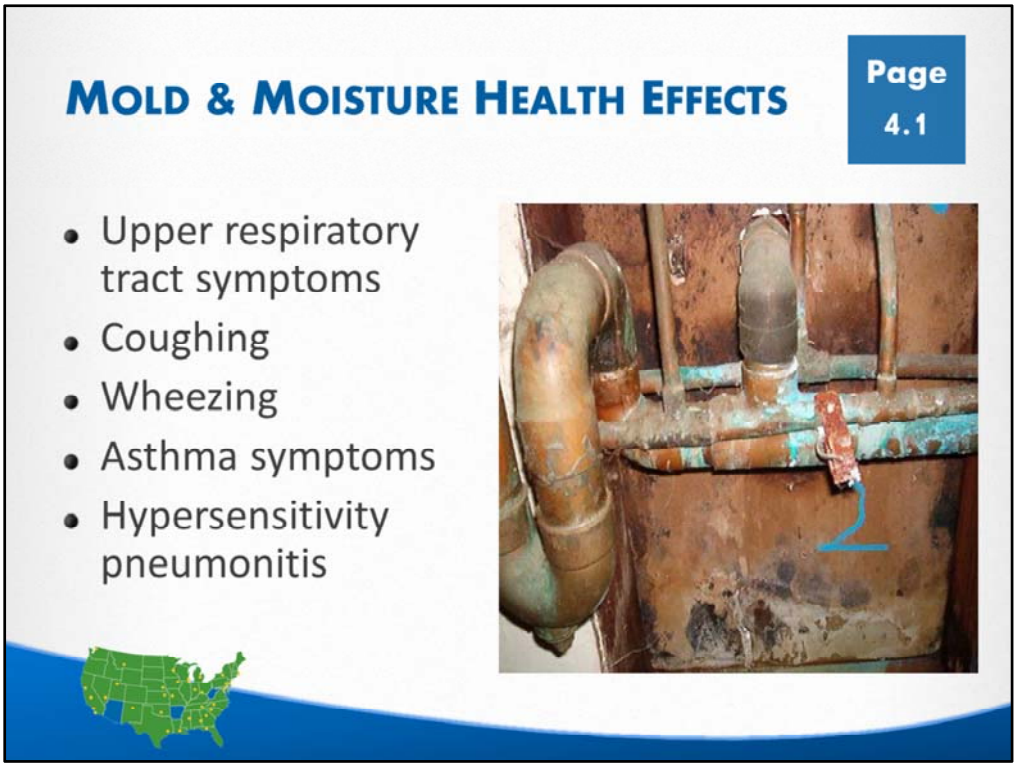
Learning Objectives

Page 4.1

Name three health hazards in the home that are related to excessive moisture.

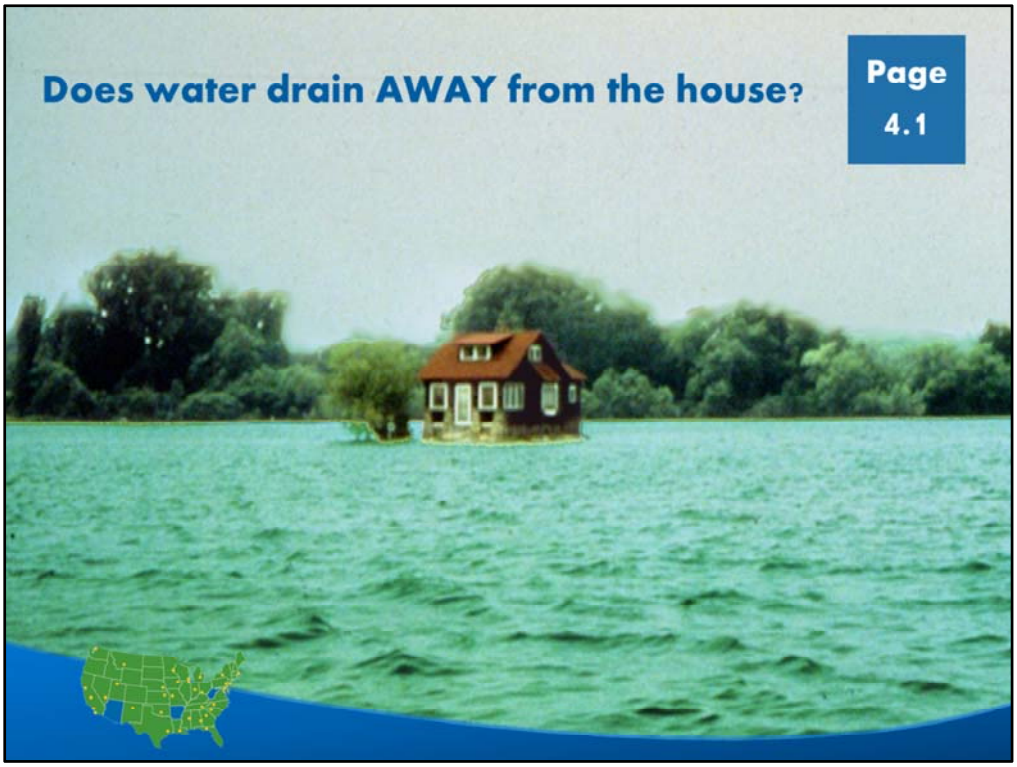
Identify four sources of moisture in the home.

Describe five strategies for controlling moisture in the home.

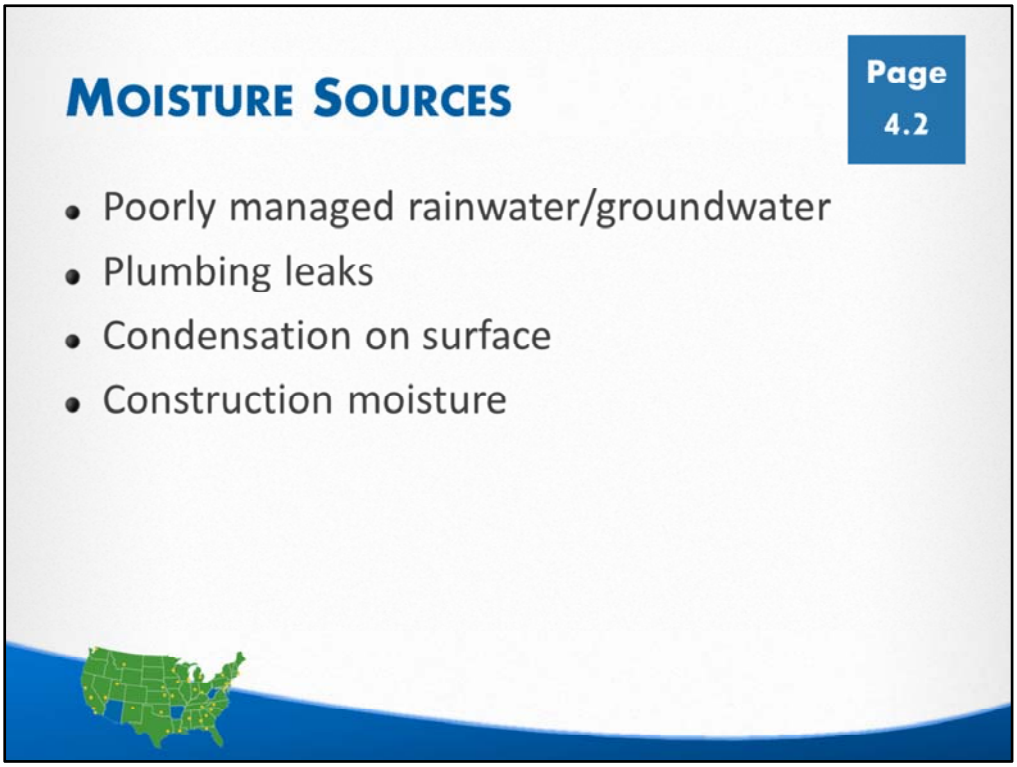


Excess moisture is associated with increased incidence of respiratory disease. For example, moldy apartments have been associated with twice as many reports of respiratory disease. [1] The prevalence of asthma or respiratory symptoms is twice as high for occupants of schools or homes with evidence of dampness problems or molds. In places where there is mold and environmental tobacco smoke there has been a noted 20-40% increase in asthma symptoms or respiratory symptoms. [2]

Molds can trigger asthma attacks in sensitive individual. They can also adversely affect immune system function.



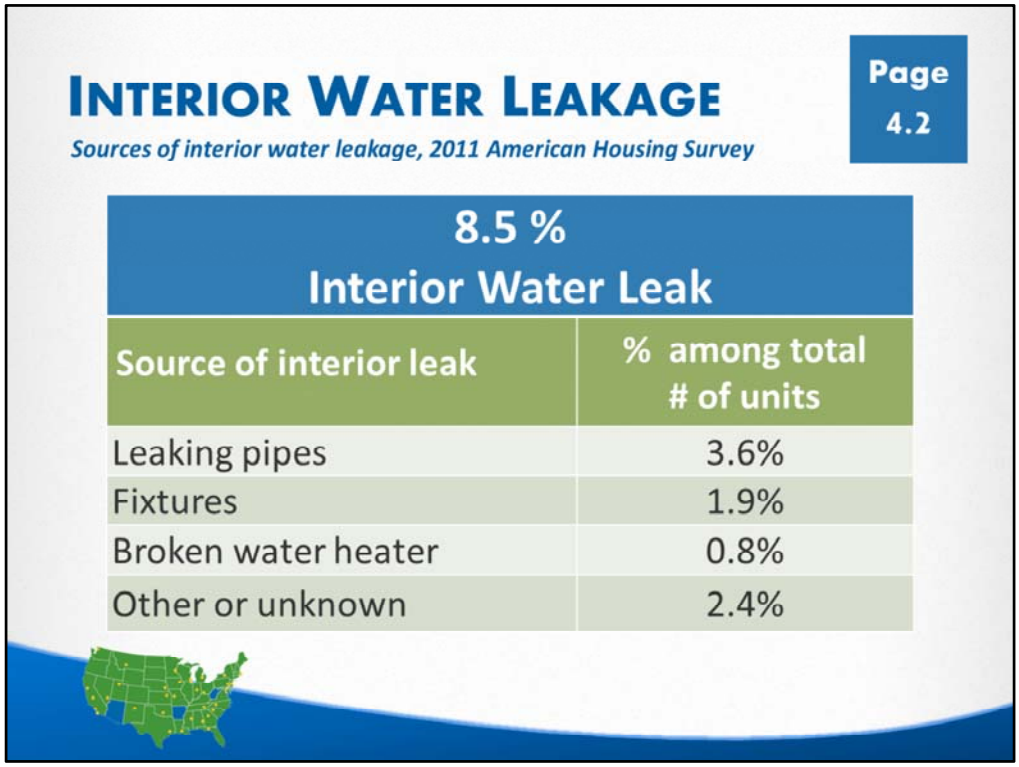
Drainage is the key to rainwater control. The roof, the walls, the windows, the foundation and the site must drain water away from the building. Examine the site to see how rainwater flows. Does the landscape drain water away from the house or towards it? Is there evidence the water table at the site is near the surface? Are there gutters on the house?



Keep things dry. These are the sources of water that have to be controlled to avoid problems.

- Poorly managed rainwater/groundwater
  - Poor roof, wall, window and foundation drainage
  - Defects in rain barriers
- Plumbing leaks
- Condensation on surface
  - Surfaces chilled by mechanical equipment, earth contact, outdoor air contact
- Construction moisture
  - Concrete, wet spray cellulose, gypsum mud

Damp earth in crawlspace



Remember that you looked up the percent of homes with interior water leakage during the Overview section? Here you can see where those leaks come from.

Ask a question - What % of homes had interior water leakage in a 12 month period?

Answer: 8.5% (of 114.9 million homes) had interior water leakage in a 12 month period.

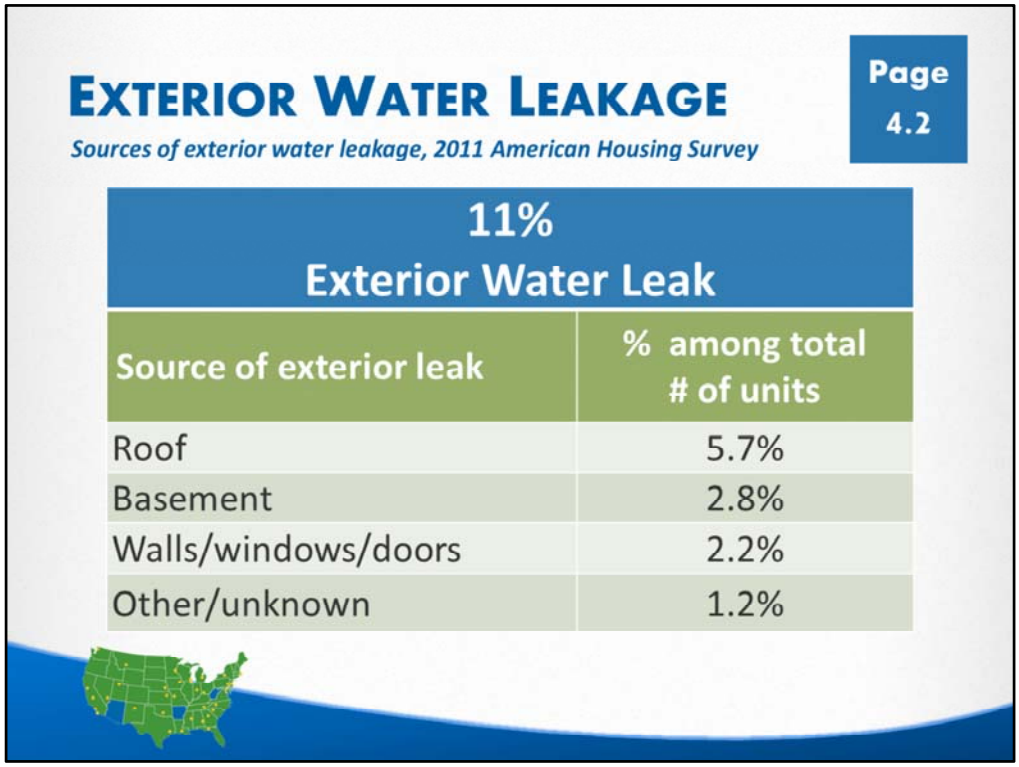
Note that: Worse for renters (11.2%) and those living below poverty (11.0%).

From American Housing Survey – 2011

Ask another question: How many homes does that 8.5% represent?

Answer: Remind people that there were 114.9 million homes in 2011. 8.5% is 9.8 million homes.

Among the total number of occupied housing units:
3.6% had leaking pipes
1.9% had leaks associated with fixtures
0.8% had a broken water heater
2.4% had another problem or an unknown problem



Note that:

Among the total number of occupied housing units - 11% had exterior water leakage in 12 month period

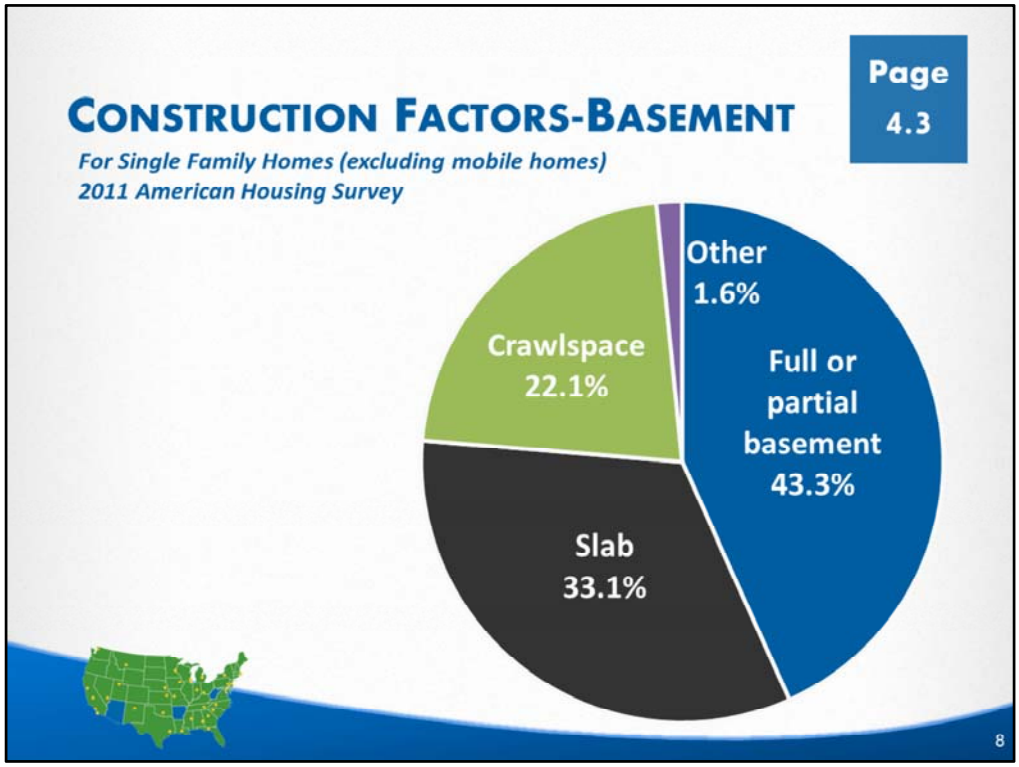
- 5.7% from the roof
- 2.8% from the basement
- 2.2% from the walls, closed windows or doors
- 1.2% from other or unknown source

The problem was worse for:

- Northeast – 16.7%
- Midwest – 13.1%

Ask: How many homes does 11% equal?

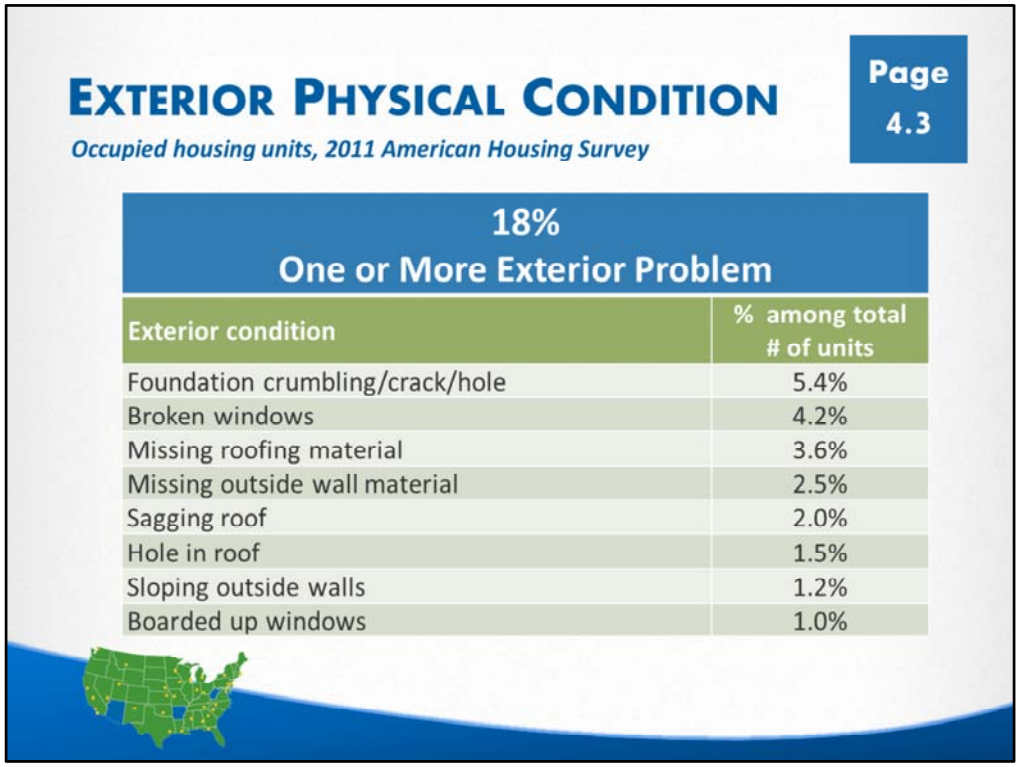
Answer: About 12.6 million homes



Of single family homes excluding mobile homes:

43.3% have full or partial basement
22.1% have crawlspace
33.1% have slab
1.6% have “other”

From American Housing Survey – 2011



Exterior physical condition of homes:

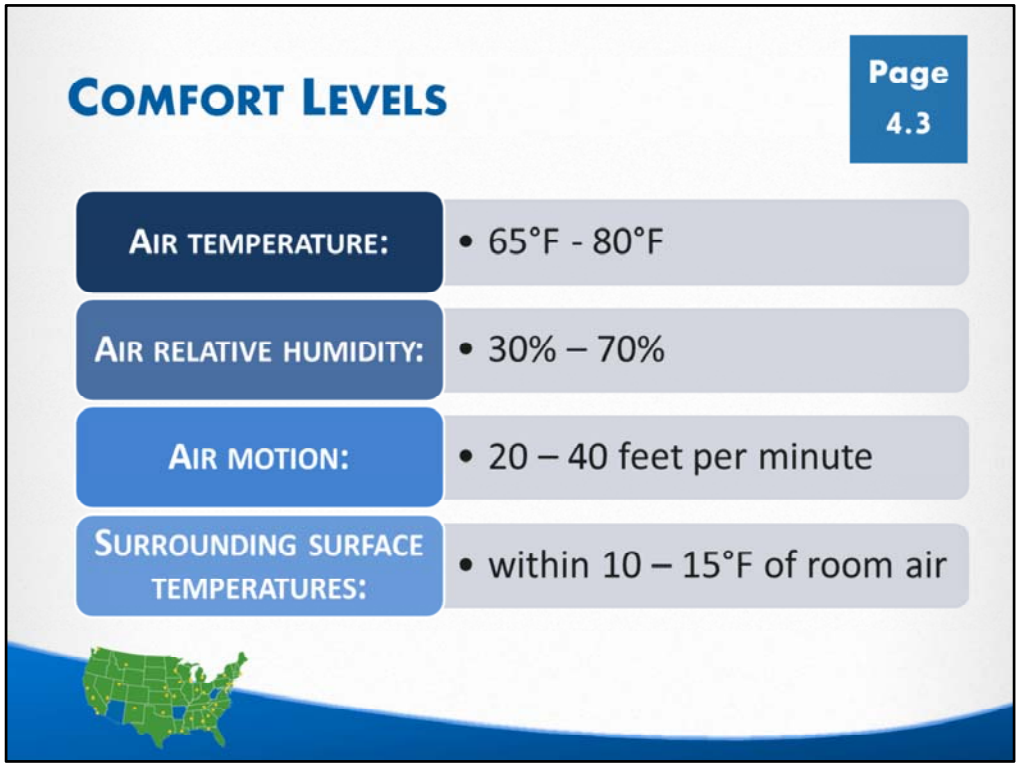
18% of homes have some physical condition contributing to leaks

Overall:

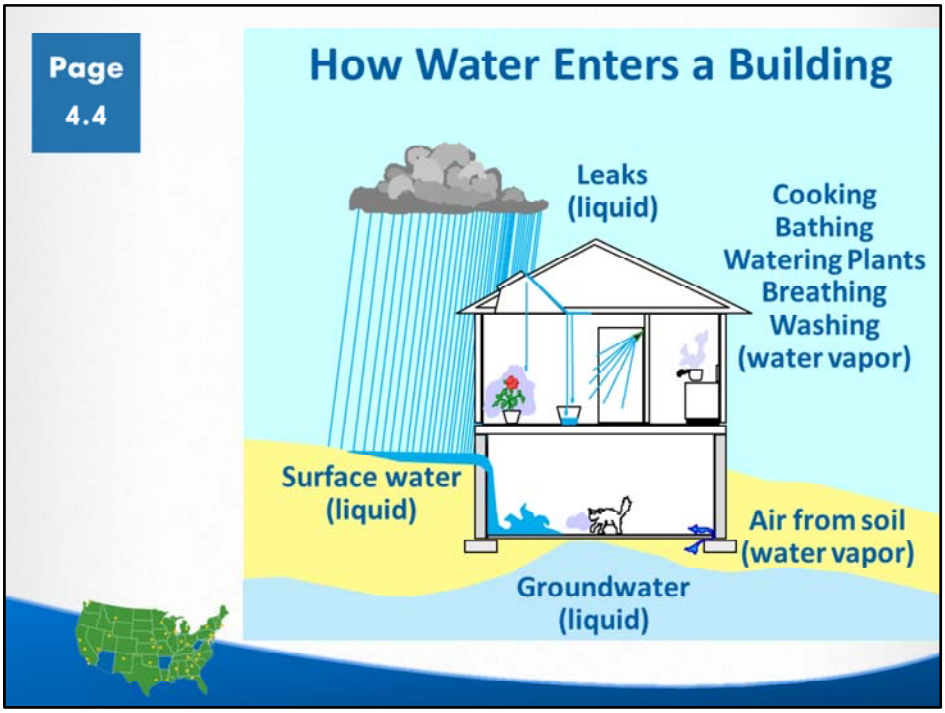
5.4% have foundation crumbling or has open crack or hole.
4.2% have broken windows
3.6% have missing roofing material
2.5% are missing bricks siding or other outside wall material
2.0% have sagging roof
1.5% have hole in roof
1.2% have sloping outside walls
1.0% have boarded up windows

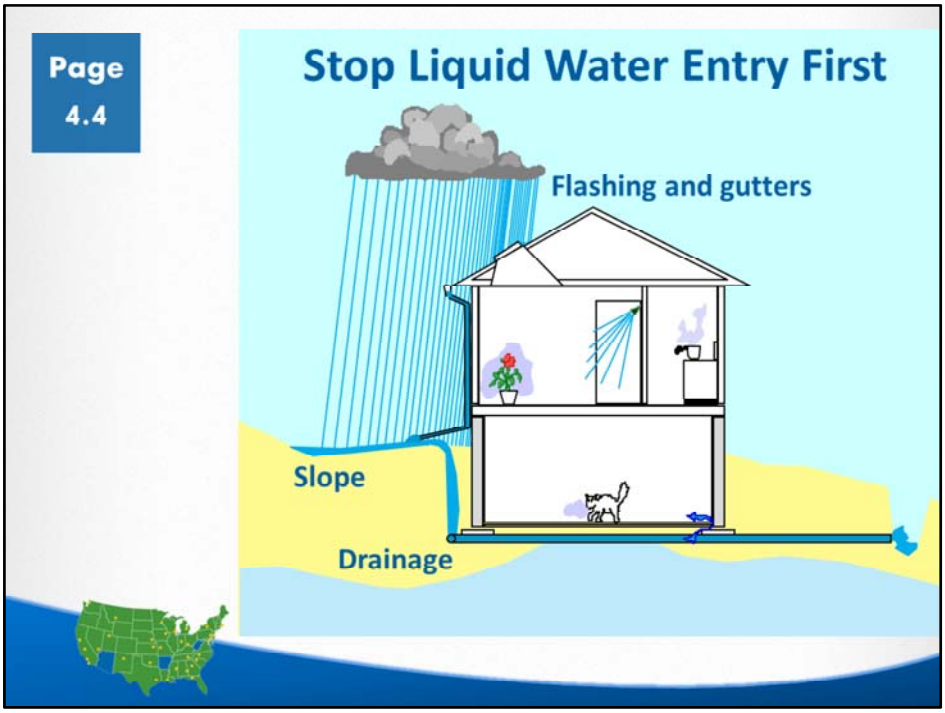
From American Housing Survey – 2011

Note that this excludes multi-unit housing (so you have to subtract those homes from the denominator) and that since conditions are not mutually exclusive (e.g., one can have both broken windows and missing roofing material), the numbers in the table do not sum to 100%.



- Air temperature: 65°F (active) – 80°F (bathing)
- Air relative humidity: 30% – 70%
- Air motion: 20 – 40 feet per minute
- Surrounding surface temperatures: within 10 – 15°F of room air


Page
4.4
How Water Enters a Building
Leaks
(liquid)
Cooking
Bathing
Watering Plants
Breathing
Washing
(water vapor)
Surface water
(liquid)
Air from soil
(water vapor)
Groundwater
(liquid)



Keep out liquid water

- Trace and repair rain leaks, which occur at places where materials join (e.g. an improper flashing detail at a roof/wall joint, no damp proof course in a parapet wall, skylight or equipment curbs).
- Trace and repair surface water and groundwater leaks, which are usually the result of poor or failed drainage detailing (e.g. no capillary break beneath a slab on grade, poorly designed rain gutters, clogged footing drains, poorly graded site).
- Trace and repair plumbing leaks.

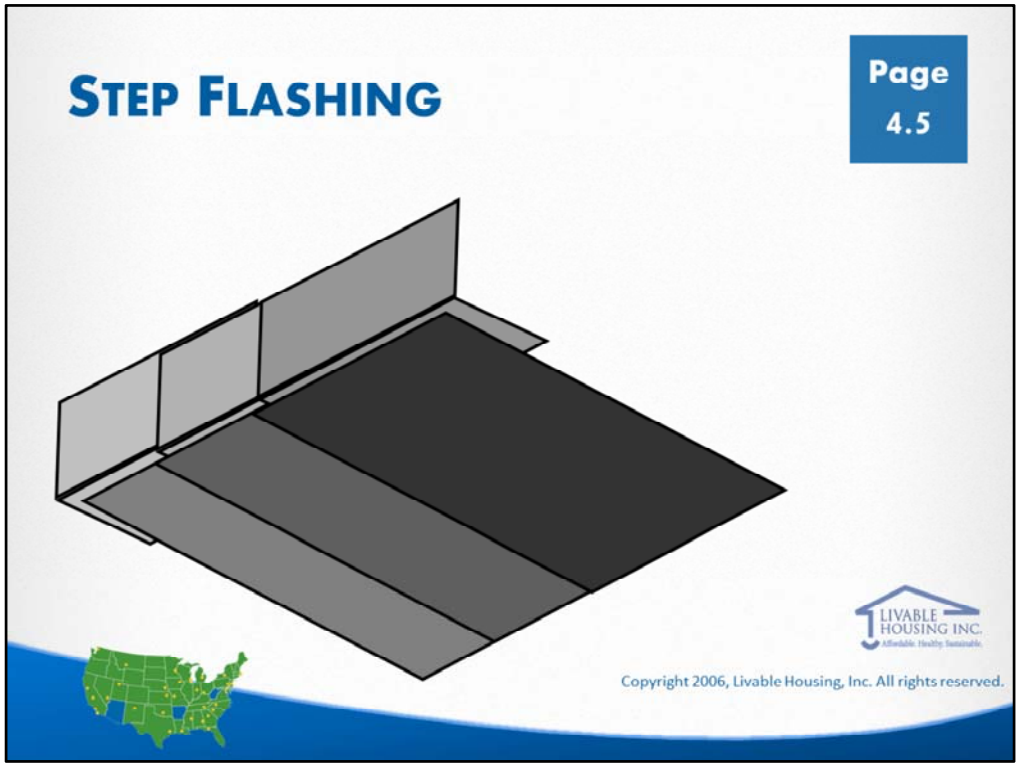
Manage water vapor migration

Outdoor air as a source of water vapor: For example, during cooling seasons, the outdoor air may be hot and humid. If air conditioning systems are not designed to deal with the latent load, thermal comfort problems and condensation in the supply system may result. If the building or rooms, plenums or cavities are running negative in cooling season, thermal comfort problems may result or condensation may occur in the walls, ceilings or plenums of the building.

Combination of wind, capillary suction and sun driven rain as source of wall moisture: A masonry wall which receives direct sun will experience a significant daily temperature swing on the outer surface. If the outer surface of the wall has even a small amount of moisture entering by wind or capillary suction, moisture can accumulate to saturation levels in the masonry if there is an interior layer of low-permeability material (e.g., foil-faced or extruded foam board, vinyl wallpaper). The warmed outer surface of the wall creates a large partial pressure difference that drives the moisture into the wall, then the moisture has no place to go.

Protect indoor chilled surfaces (e.g., chilled water lines, earth contact foundation materials) using insulation and low permeability materials layered to keep water vapor away from chilled

surfaces and locate them so that unconditioned outdoor air will not be drawn across them.



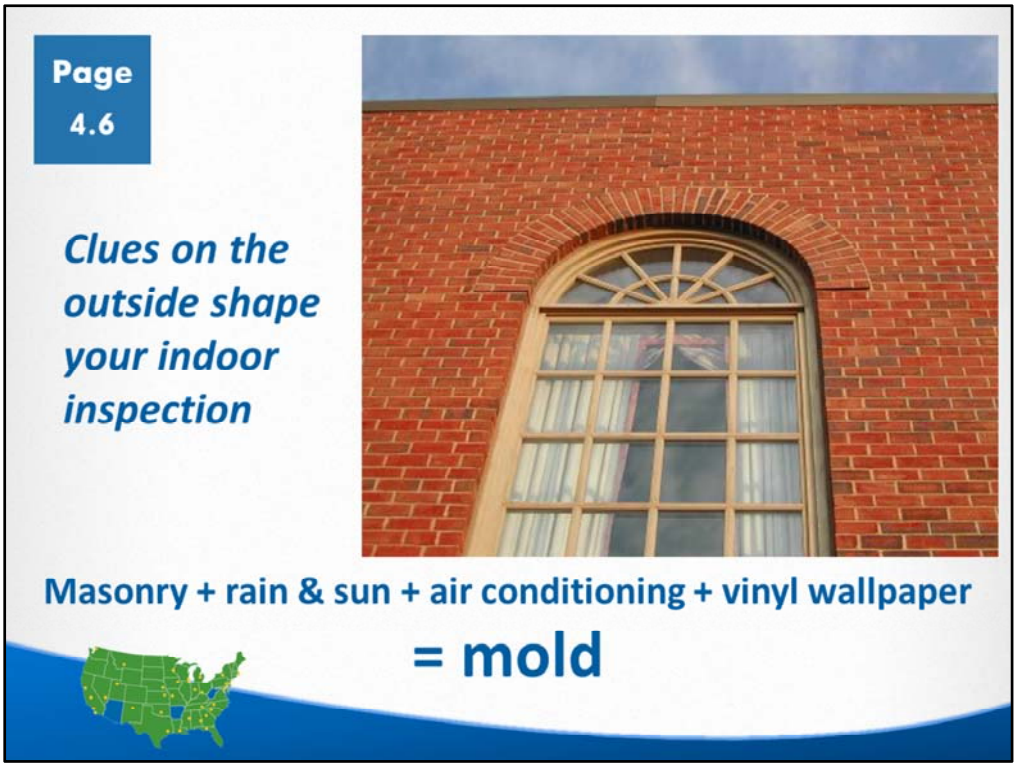
Courtesy of Armand Magnelli of Livable Housing

On the left is a picture of a downspout that dumps all the collected water next to the foundation. The discharge has been crushed by people or lawnmowers.

On the right is a picture of a downspout that goes below grade and extends ten feet from the house with solid pipe where it transitions to another fifteen feet of perforated pipe (protected by filter fabric) creating a leaching system.

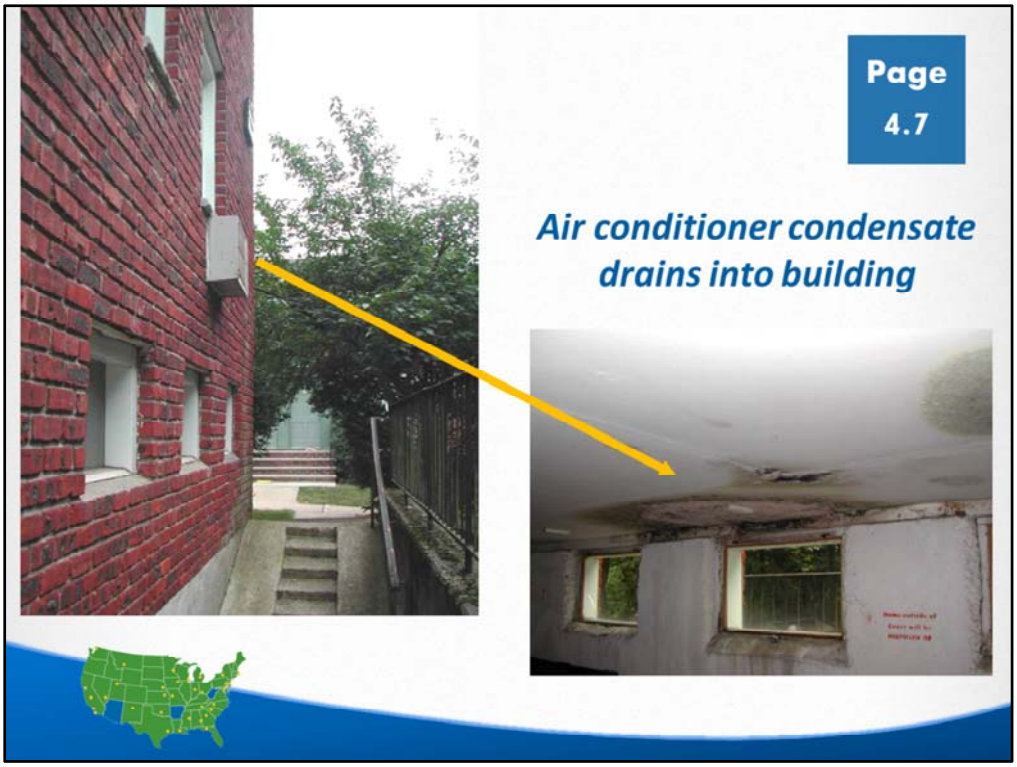
Here is a retrofit method of controlling rainwater from the exterior. EPDM rubber roofing is placed against the foundation wall and extended out below grade. Filter protected drain pipe and porous backfill are used to collect water and drain it away from the foundation. [4]

Moisture damage beneath a window. Windows may leak rainwater at mitered corners and where multiple windows are mulled together. They may leak around the edges where they should be flashed into the wall system. Use window installation methods that prevent such damage. [5]

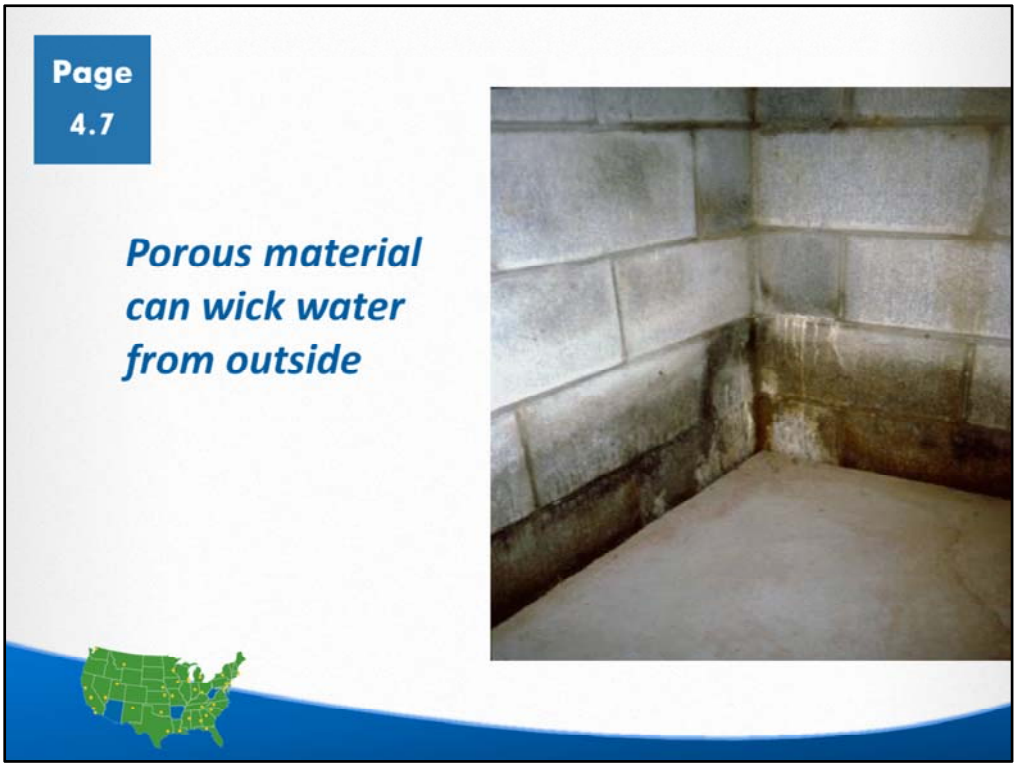


Sidings that absorb rainwater in combination with air conditioning and an interior vapor barrier can result in condensation and mold growth. The brick absorbs rainwater, the sun heats the water, evaporating it and creating very high vapor pressure in and behind the brick. The vapor pressure drives water vapor into the wall. The vapor passes through the wall until it hits an intentional (polyethylene films) or accidental (vinyl wallpaper, chalkboard, mirror) vapor barrier that is chilled by the air conditioned interior. Then the vapor condenses.

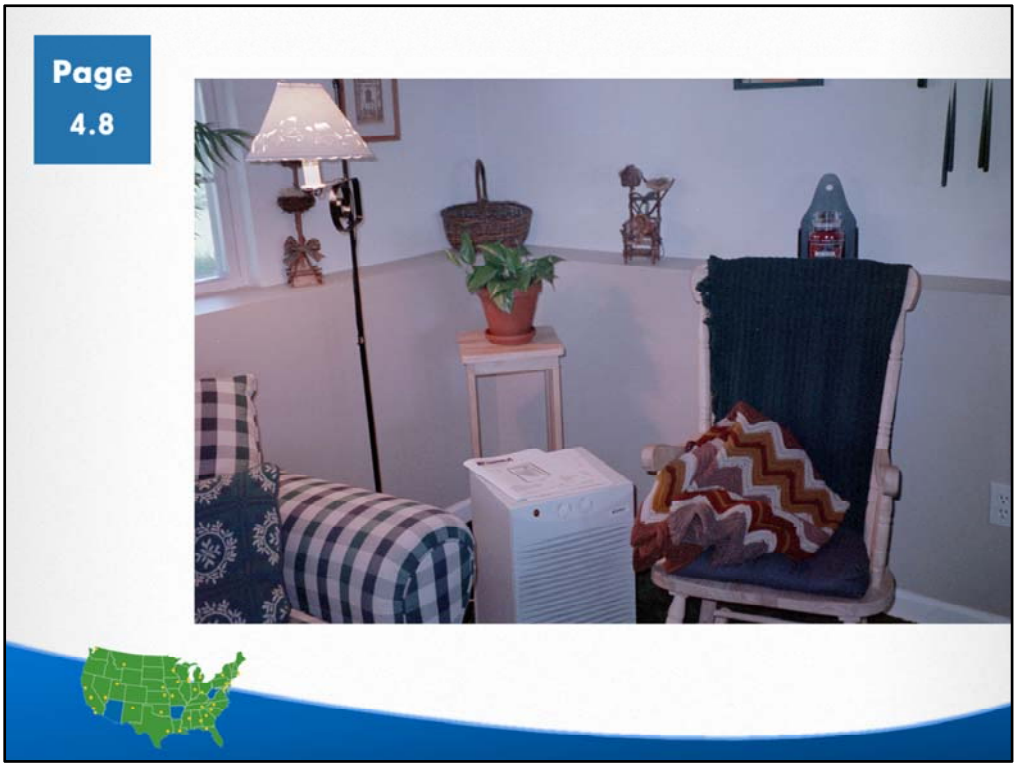
Back venting the brick, using a low perm sheathing and running the building under positive pressure help reduce this problem. Running the building under negative pressure aggravates the problem.



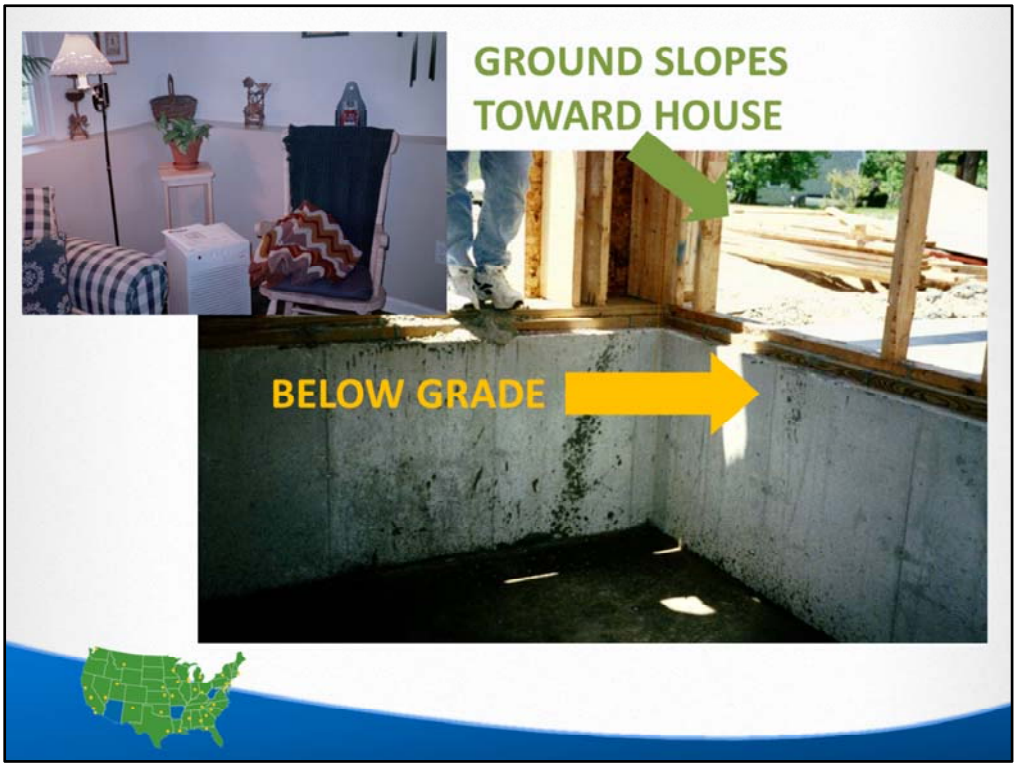
The through-the-wall air conditioner tilts towards the wall. Condensate water from the cooling coil runs into the building rather than out of the building.



The bottom few inches of this wall are damp because water is wicking up through the footing by “capillary suction.” It is only wet a few inches from the slab because the moisture evaporates into the basement. In an unfinished basement this is probably not a problem, but if the wall is finished using paper covered gypsum board, paneling and wooden studs or furring strips, a dark, damp place is created. This provides good conditions for mold growth.



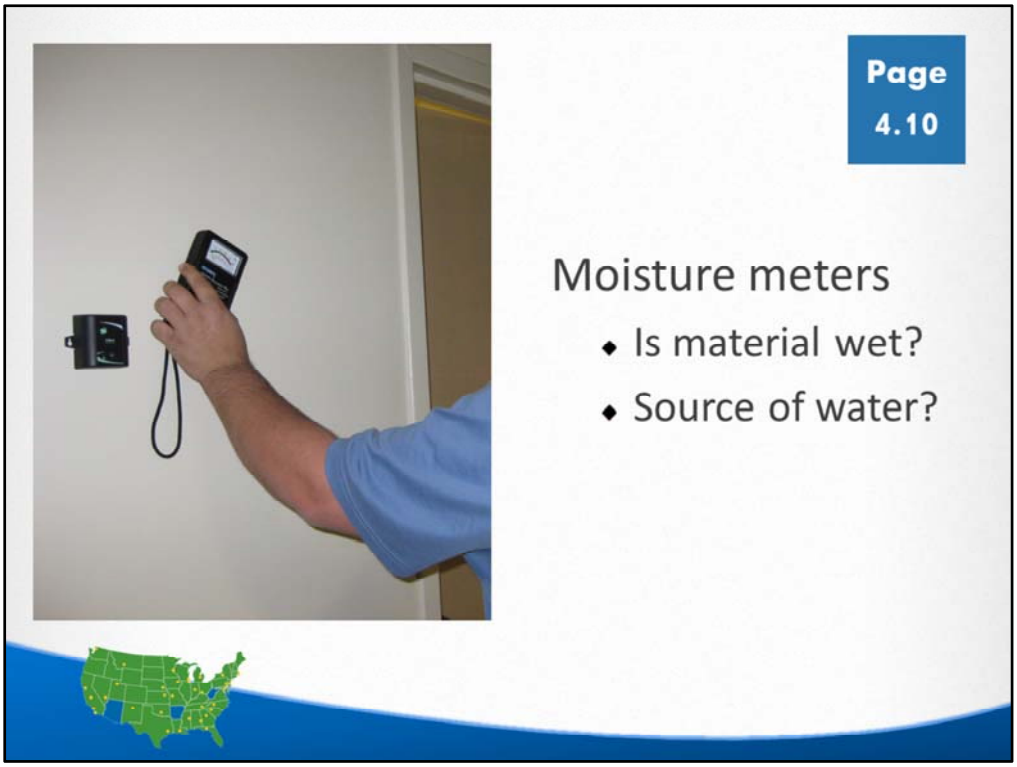
This room smells musty. What do you think is going on? Do you see any visual clues?



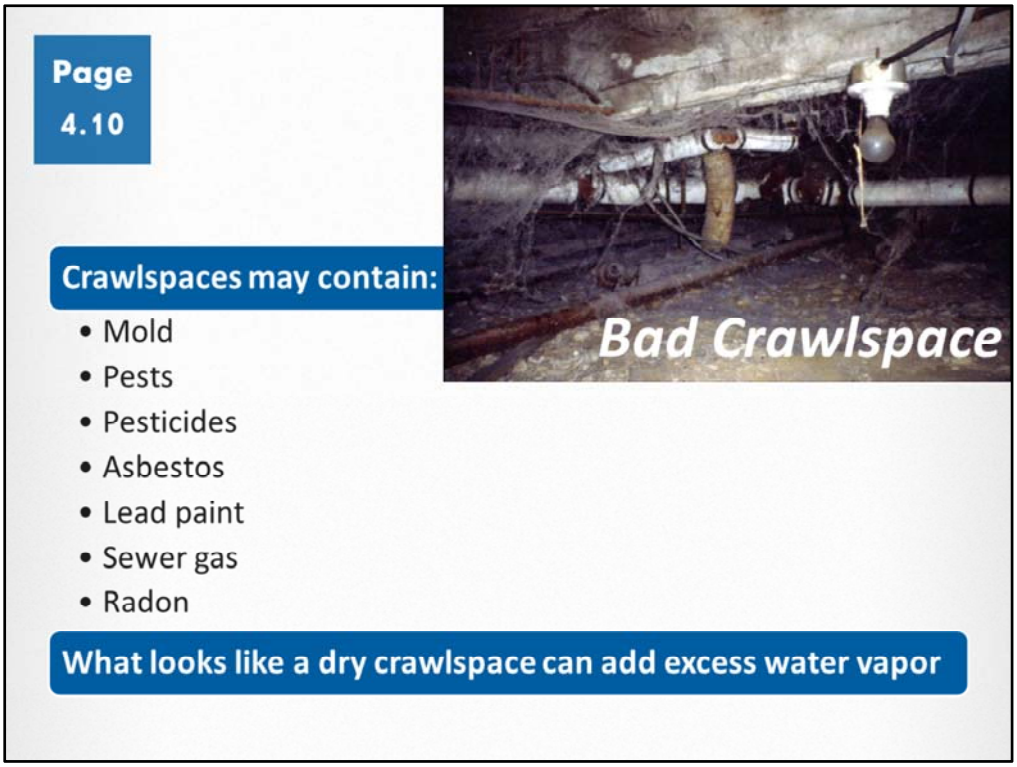
Hidden mold? The insert in the upper left hand corner of the slide shows the previous picture. Notice that the room was a finished room with walls that are partially below grade. The room had no visible mold but smelled musty. Removing the furnishings and finishes revealed significant mold growth.

Molds are organisms that colonize surfaces. They produce large numbers of spores that contain DNA and enough food to start growth. Unless extremely diligent efforts are made to keep surfaces clean on a daily basis, there are mold spores on virtually every surface in a building. Ordinary house dust contains tens of thousands of mold spores per gram. If conditions are right the spore germinates and sends out thread-like hyphae. The hyphae exude enzymes. If there is enough free water available the enzymes go into solution and digest available food. The nutrient solution is absorbed back into the hyphae, more growth occurs, and spores are produced until the colony runs out of food or water.

In the photo above, the wooden flooring seen here from below, is composed of heartwood Douglas fir and sapwood Spruce. The Douglas fir has almost no mold growth on it because there are very few sugars and starches in heartwood. Molds cannot actually digest cellulose and lignin. The sapwood is covered with mold because it is filled with sugars and starches.



The Community Environmental Health Resource Center (CEHRC) has an information sheet on using moisture meters to track water sources. [6]



In many areas the most common problems with crawl spaces are the result of moisture. Poorly managed rainwater and warm, humid outdoor air are the two most common sources of moisture in crawlspaces. During times when the outdoor dew point is higher than the temperature of surfaces in the crawlspace, the ventilating outdoor air actually humidifies the crawlspace. In mixed/humid and hot humid climates ventilated crawlspaces are problematic. During cold weather, ventilated crawlspaces containing plumbing run the risk of pipes freezing.

Crawlspaces are not only a source of moisture, they are a source of other indoor hazards including; mold, radon, bacteria, insects, rodents and pesticides.

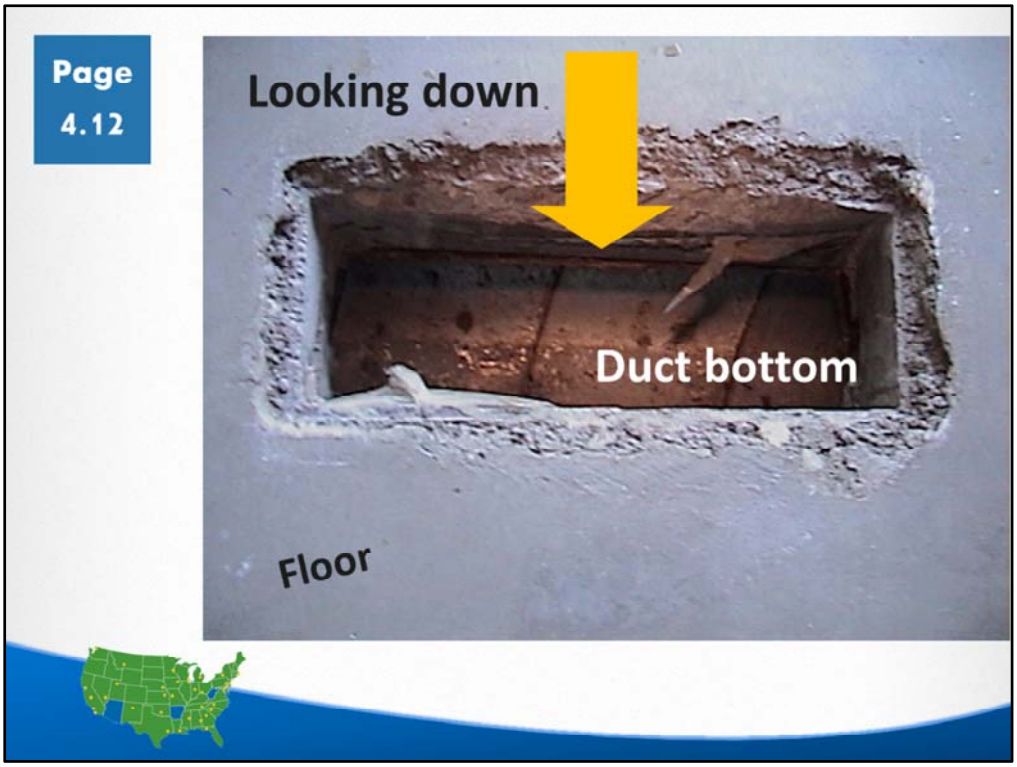
Air from crawlspaces is drawn into the occupied portion of houses by the stack effect during cold weather. When an air handler is running, air can be drawn into the occupied portion of the house. This happens when closed doors separate supply air diffusers from return grilles or when there are leaks on return portions of an air distribution system that are located in the crawlspace.

A study conducted by the EPA in crawlspace houses in Tennessee found that the leakage between the crawlspace and the upper portion of the house averaged 38 square inches for houses without ductwork in the crawlspace and 74 square inches for houses with ductwork in the crawlspace. [7] [CHECK REFERENCE FOR SQUARE INCHES OF WHAT?? UNITS?]

Here is a example of a sealed, insulated crawlspace with good drainage and a vapor barrier covering the soil floor.

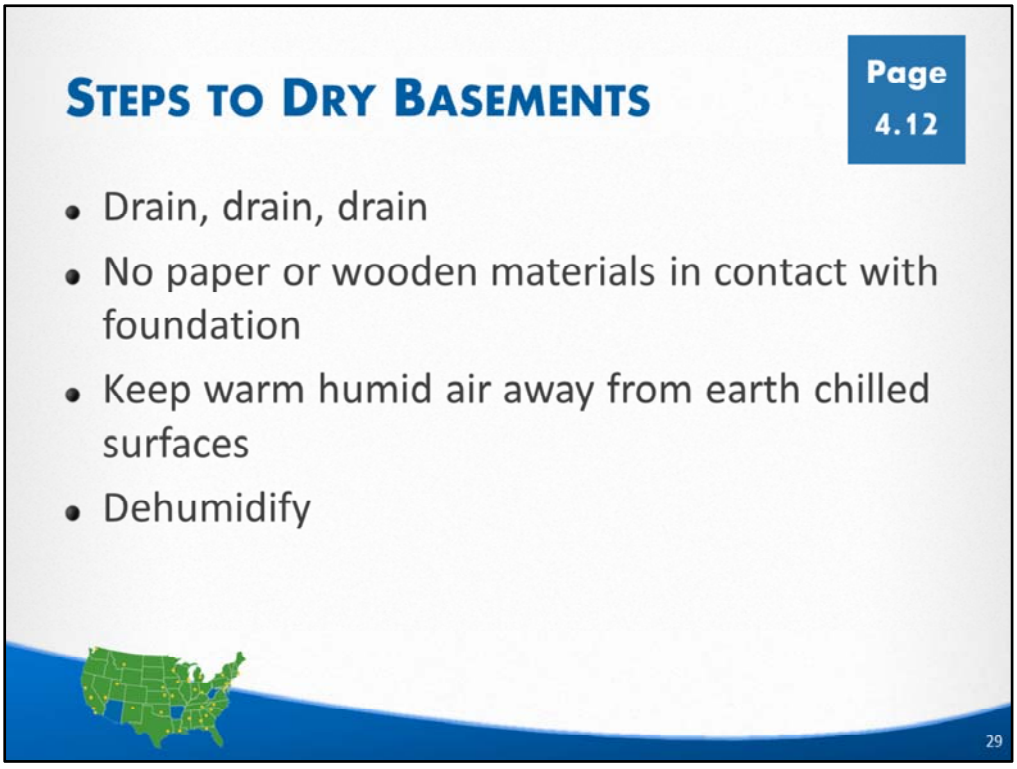
Sometimes there are drainage systems installed, but they have failed. Drain lines must be protected from clogging with silt. Traditionally they were covered with layers of straw or felt paper. In the last thirty years, synthetic filter fabrics have been developed that last longer and provide better filtration. In these photos the sump pump on the left has broken and has not been repaired. The pump on the right would run except the float that turns on the pump is stuck on the plywood cover.

The picture on the right also show an example of how sometimes our efforts to make things "better" actually create more problems. The plywood cover was put into place to prevent injury to children and pets, but the design was no good because it prevented the float working and therefore can result in the basement flooding.



Ductwork beneath the slab is a problem area. Supply or return ducts are sometimes placed beneath the on-grade slab. This is often the lowest point in the building, so the ducts collect any accidental water from plumbing leaks or rainwater leaks. They are not water tight, so water leaks in from outside. If the soil air has high radon levels then they also provide a good transport pathway. When these cause problems it is often best to abandon them and install new heating or cooling distribution systems.

A floor drain in the basement is a good idea. It gives water from a big plumbing or rainwater leak a place to go. Notice the dehumidifier. Below grade spaces often can benefit from a dehumidifier.



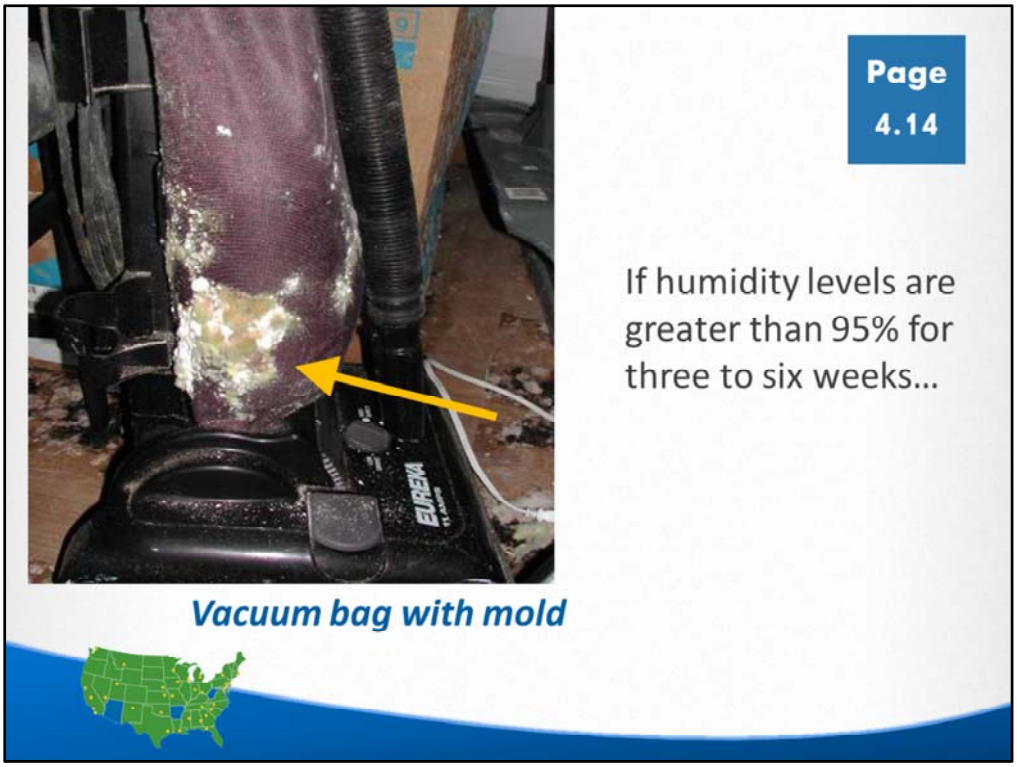
In general, here is what we want to do to keep basements dry.

The next category of problem water is plumbing leaks. When plumbing leaks occur, it is best if they are easy to see, easy to repair and do not wet materials that facilitate mold growth or dry slowly. Wet rooms, such as kitchens, baths and laundry rooms, are the places most likely to have plumbing leaks. Always inspect around toilets, tubs, showers, beneath sinks, clothes washers and dishwashers.

The drain basket and drain trap are vulnerable locations for leaks and vermin entry. Fortunately, they are easily inspected. Put a stopper in the sink and run water to see if the basket leaks. Let the water out to check the trap. Repair by tightening and sealing as needed.

Drain pans are inexpensive ways to reduce the impact of a mechanical leak. They can be used for hot water tanks and for washing machines. Drain pans are not intended to hold the capacity of the appliance. In this instance, the drain pan actually has a leak (see red circle) and should be replaced. Residents need know to check the drain pan for water. Indicators such as alarms or lights are helpful for appliances that are not easily accessible (e.g. water heater in the attic).

The condensation pan beneath a refrigerator may overflow and cause mold growth. Often these pans are heated to evaporate condensate. The heating may have failed. Many people do not realize they should be checked and cleaned periodically.

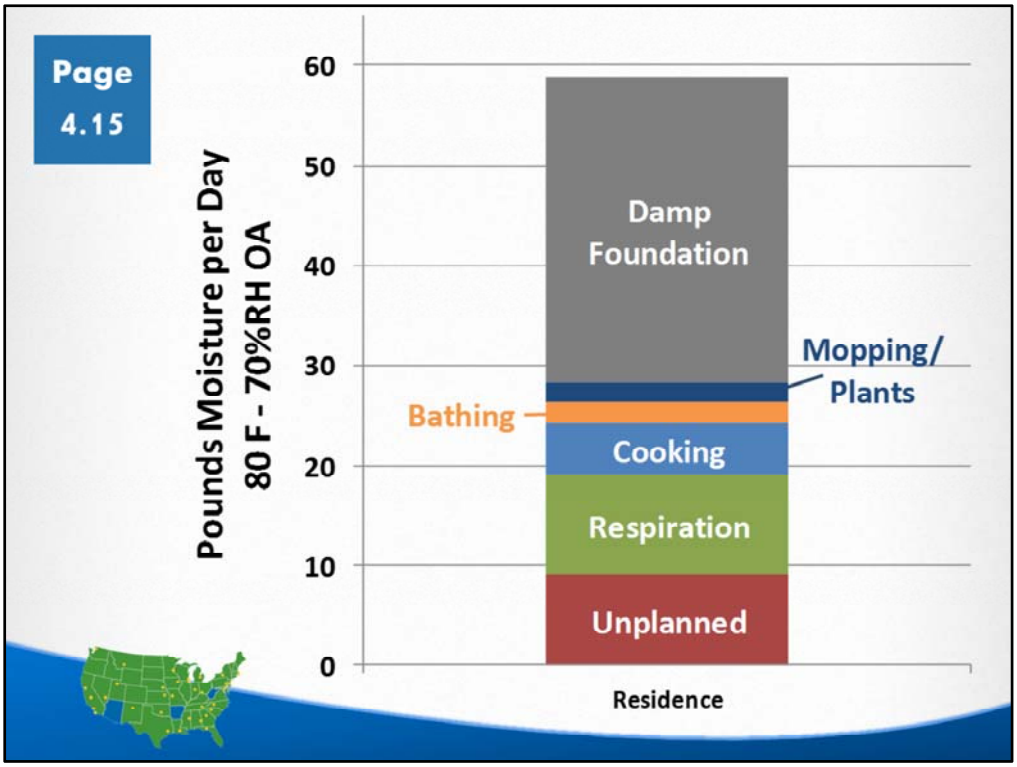


This vacuum was left in a house that was closed up for 6 weeks without air conditioning. The dust on the vacuum cleaner bag served as a food source while the humidity provided the moisture. Mold spores are ubiquitous but don't usually cause a problem unless you have this type of extended high humidity levels.

Chronically high humidity can result in mold growth. While it is true that mold spores generally need a small amount of liquid water to germinate and hyphae tips certainly need liquid water to exude enzymes and absorb digested nutrient, it does not take a lot of liquid moisture. At 90% relative humidity an ordinary surface only needs to be 6 degrees F cooler than the air to be at dew point. In a building, it is likely that there are surfaces a few degrees cooler than house air.

Mold or Mildew?

A question that is frequently asked is what is the difference between mold and mildew? According to wisegeek.com, in common usage, the difference between mold and mildew usually is in their appearance and the surfaces on which they are growing. Mold is often thicker and black, green, red or blue in color, and mildew usually is lighter, powdery and gray or white. Both mold and mildew often grow in moist and warm locations, but mildew is more often found in showers, on paper and on fabrics, and mold is often found on foods and in walls and other permanent structures. (wisegeek.com)



This chart shows sources of humidity for a family of four.

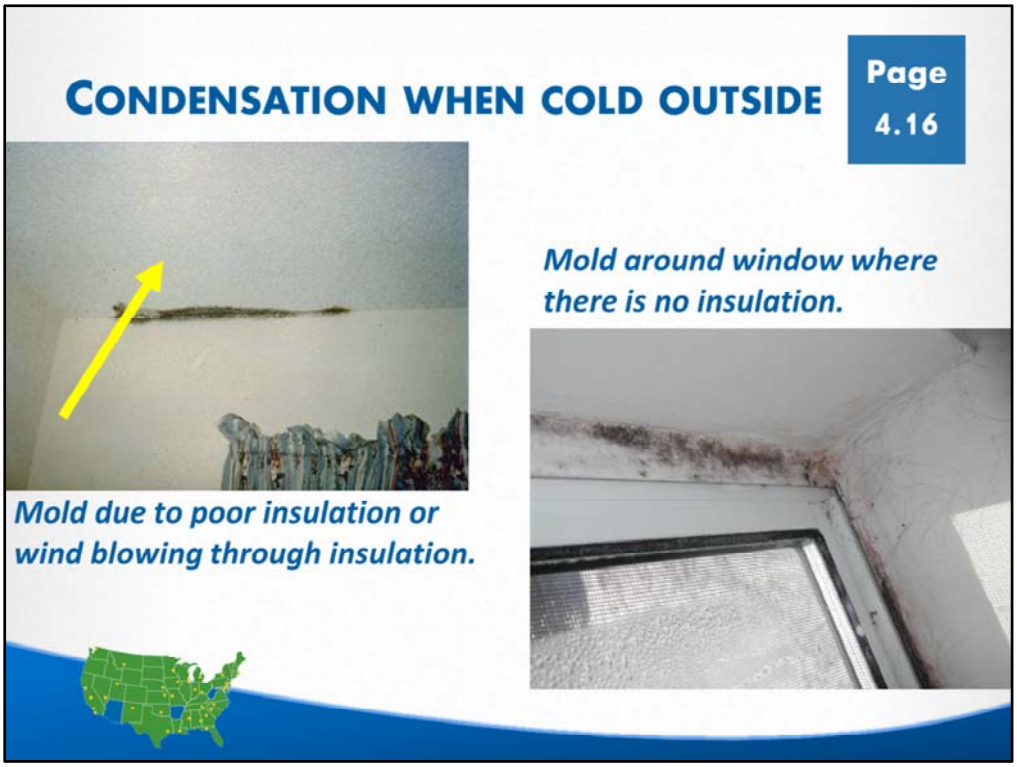
For offices and classrooms, the major source of indoor humidity during warm, humid weather is outdoor air (see chart below). However, as this chart illustrates, for a residence the dominating source could be a damp foundation. If the foundation is dry, the major sources of indoor humidity are respiration, bathing, cooking and outdoor air.

Also, do not overlook the possibility that occupants have introduced a strong humidity source like many aquariums, a constantly boiling stewpot with no ventilation, a humidifier or an indoor spa.

This picture shows condensation and mold growth on the bottom of a toilet tank. Condensation occurs when there is too much humidity and the surfaces are too cool. The tank is cooled by incoming cold water. The water vapor is from outdoor air during warm humid times of the year and from showers. The mold gets nutrient, not from the porcelain, but from paper dust released by tearing toilet tissue. The problem can be avoided by:
- using an insulated toilet
- air conditioning or dehumidifying the house air
- using a mixing valve to supply warm water to the toilet tank.

Air conditioners have cold surfaces such as the cooling coil, the drain pan, the ductwork down stream of the cooling coil and supply diffusers. Mold can grow in all of these locations. Again, there are two parts to fixing the problem. The first is to clean up the mold and the second is to fix the water issue. Cleaning up the mold should be done following guidance from EPA, NYCDOH, and NADCA. [8,9,10]

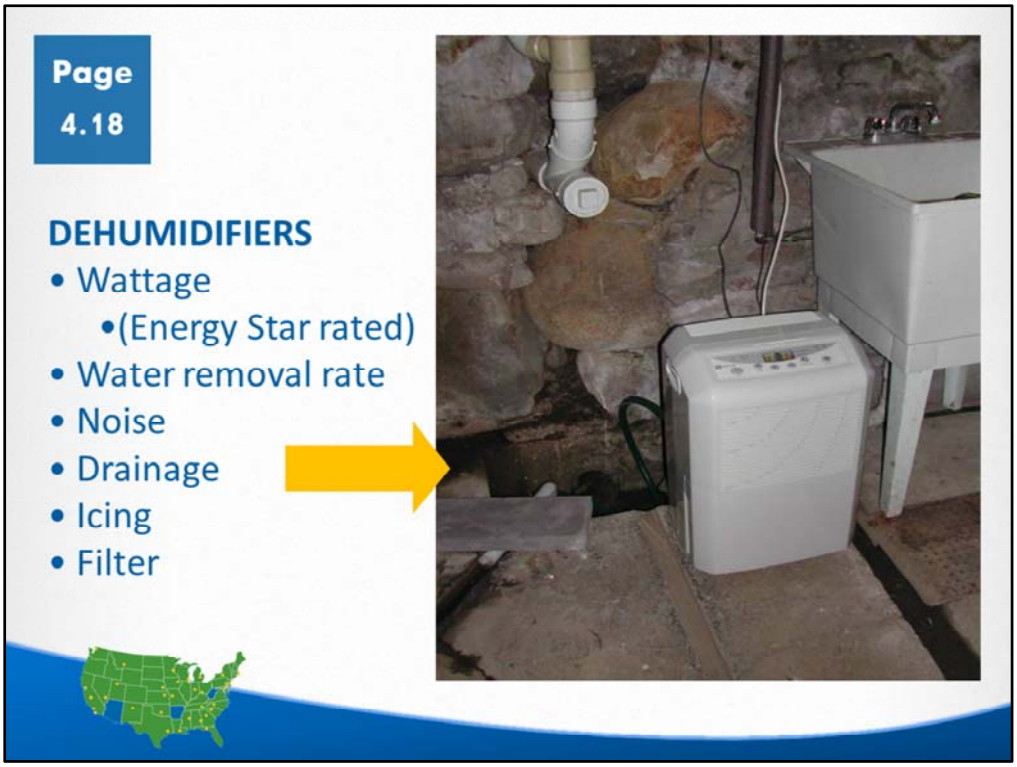
Many residential air conditioners do not have access panels that allow inspection or cleaning of the cooling coils. These should be installed so the coils can be inspected and cleaned. It helps to use higher efficiency filters so there is less dust on the coil.



Here is mold growing on a ceiling that is chilled by wind blowing through the soffit across un-insulated gypsum board. The second picture shows mold around a window where there is poor insulation.

This picture shows a cold water line (seen running up the wall in the background), which condenses water above the ceiling. The water drips down onto the gypsum board ceiling resulting in a straight line of mold growth. All things being equal, mold does not grow in straight lines unless it is fed by a straight line water source.

The recessed light in this photo is an opening directly into the attic. When the light is on the heat from the bulb causes a thermal draft to move even more air into the attic. This light is located over the shower in a bathroom that does not have an exhaust fan. As a result the warm, humid shower air is exhausted directly into the attic.

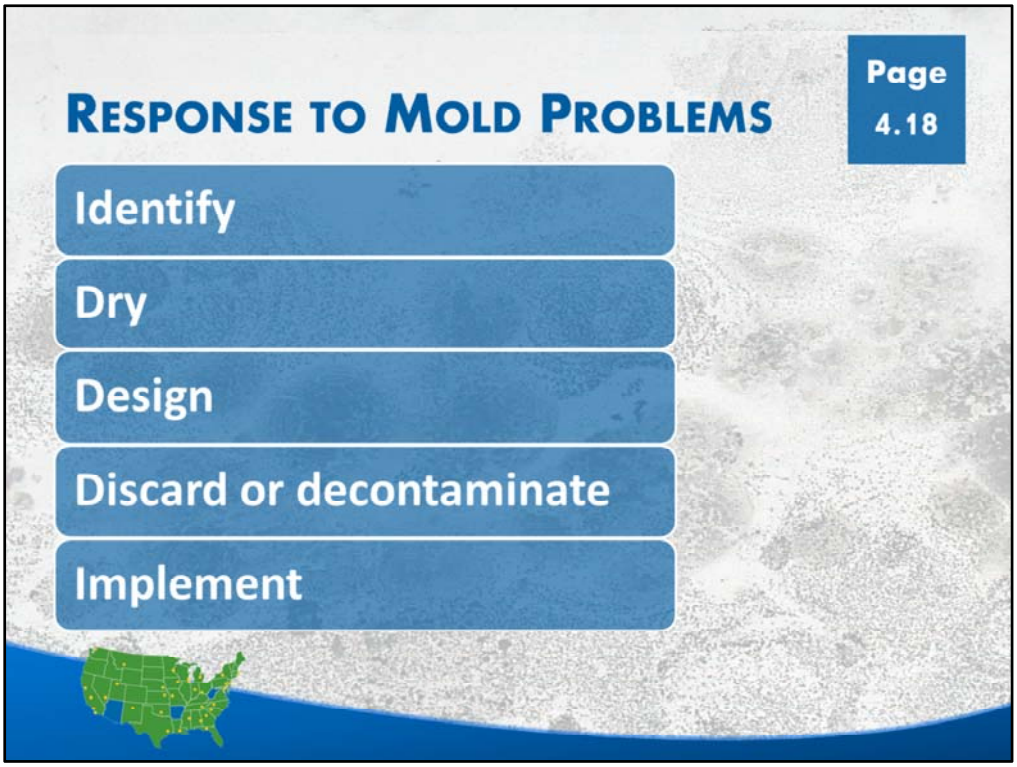


Dehumidifiers are very useful for managing humidity levels in buildings. High humidity in buildings is either the result of warm humid outdoor air entering the building or a strong source of indoor humidity. In the previous slide, the source of humidity was water migrating through the foundation and evaporating into the basement during cold weather. In warm weather, it was both the damp foundation and outdoor air.

When running at least 35% of each hour, air conditioners dehumidify. During part-load conditions they do little or no dehumidification. Dehumidifiers can be very useful in combination with air conditioners in hot humid climates with extended part-load conditions. Dehumidifiers, however, do not cool the air. They ordinarily have supply air temperatures over 90 degrees F.

Characteristics that are desirable in dehumidifiers are:

- Low energy use – some models are Energy Star rated now;
- Quiet operation – many dehumidifiers are too noisy to use in occupied space;
- A direct drain or a condensate pump (otherwise the tank must be emptied several times a day);
- And freeze protection so they can be used in cool spaces like basements or crawlspaces.



IDENTIFY

extent of moisture damage and contamination
dynamics of moisture sources
appropriate containment and worker protection

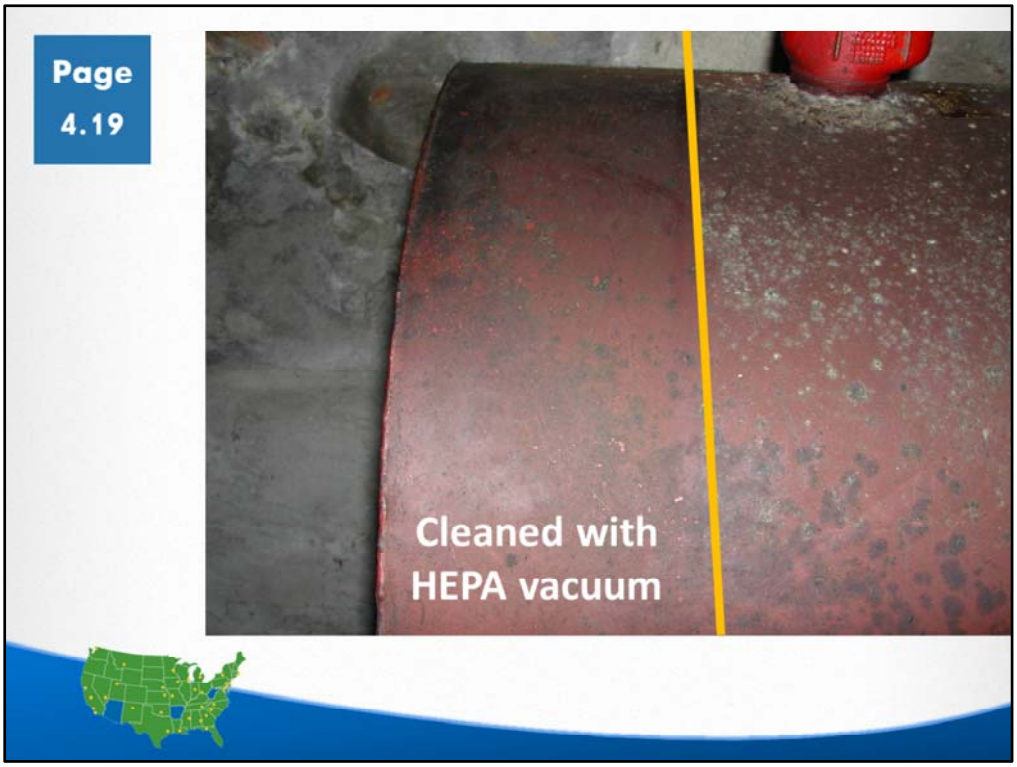
- **DRY** the wet areas in the short term
- **DESIGN**

long term intervention in the moisture dynamics
fungal clean-up procedures and clearance ion methods.
long term intervention in the moisture dynamics
fungal clean-up procedures and clearance criteria

- **DISCARD - DECONTAMINATE** contaminated material
- **IMPLEMENT** repairs and program changes to prevent future problems
- See EPA Guidance

Mold is a contaminant problem and a moisture problem. Both problems must be solved. The solutions are quite different. The mold itself is best removed from the building by cleaning surfaces or by removing contaminated materials. Containment and encapsulation have been used to intervene in exposures. There is no general agreement in the written remediation guidance on the advisability of containment or encapsulatation.

In a previous slide, the attic above the bathroom has mold growing on some of the roof sheathing. A moisture meter is used to test the moisture content of roof sheathing in cold weather. The test locations are only one foot apart and yet the moisture content of the sheathing is very different. The south facing sheathing is drier, because it receives more sun than the north facing sheathing. Notice that the south facing sheathing is free of mold and the north facing sheathing is covered with mold. The source of the moisture is water vapor in the house air. Warm house air is leaking into the attic through cracks and holes in the ceiling. The cold roof sheathing is dehumidifying the warm air from the house. During the day, the water that condensed overnight on the south facing roof is evaporated by the solar heat.

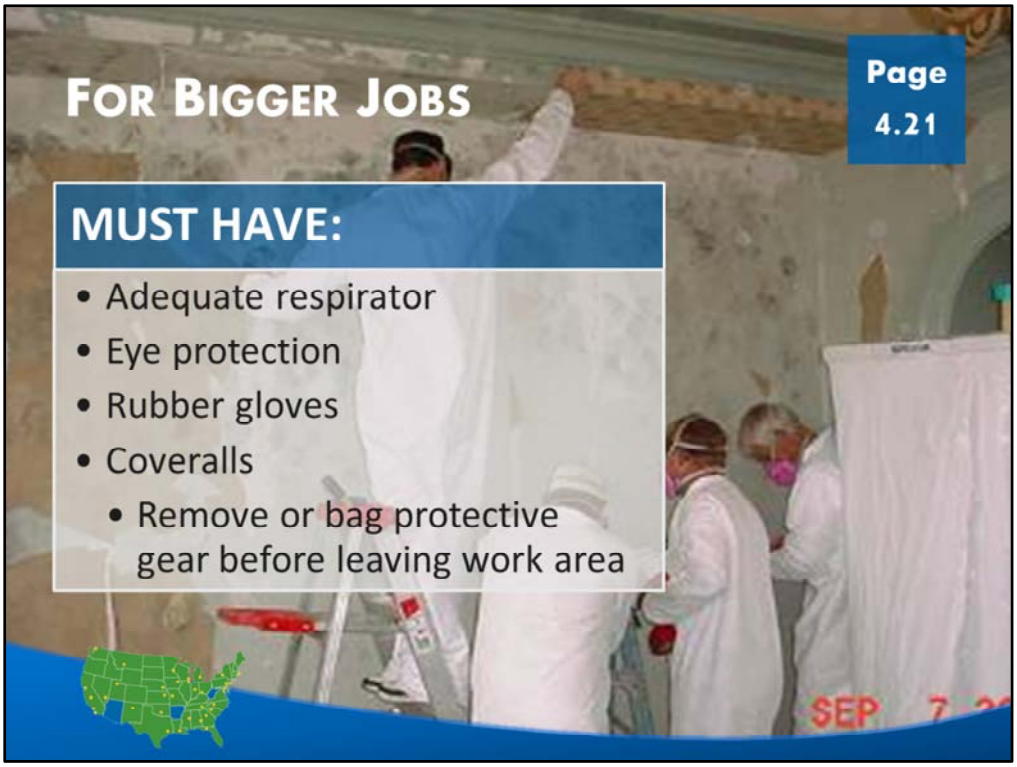


This is an oil tank in a stone basement foundation with high humidity. On the right hand side of the tank the bluish-green spots are colonies of aspergillus species. The mold may be getting nutrient from a layer of dust. On the left hand side the tank has been vacuumed using a HEPA vacuum. A large reduction in spore and hyphae have been made by this simple action. The cleaning was done with the upstairs portion of the house under positive pressure (provided by 1200 cfm window fan). A dehumidifier was installed to maintain humidity at 65% or lower.

Here is a picture of mold growing on painted joint compound in a bathroom. The moisture condenses from the air during showers, in spite of a low volume of exhaust air (around 7 cfm) through the grille. The mold did not grow with one person living in the house, but began shortly after another person moved in.

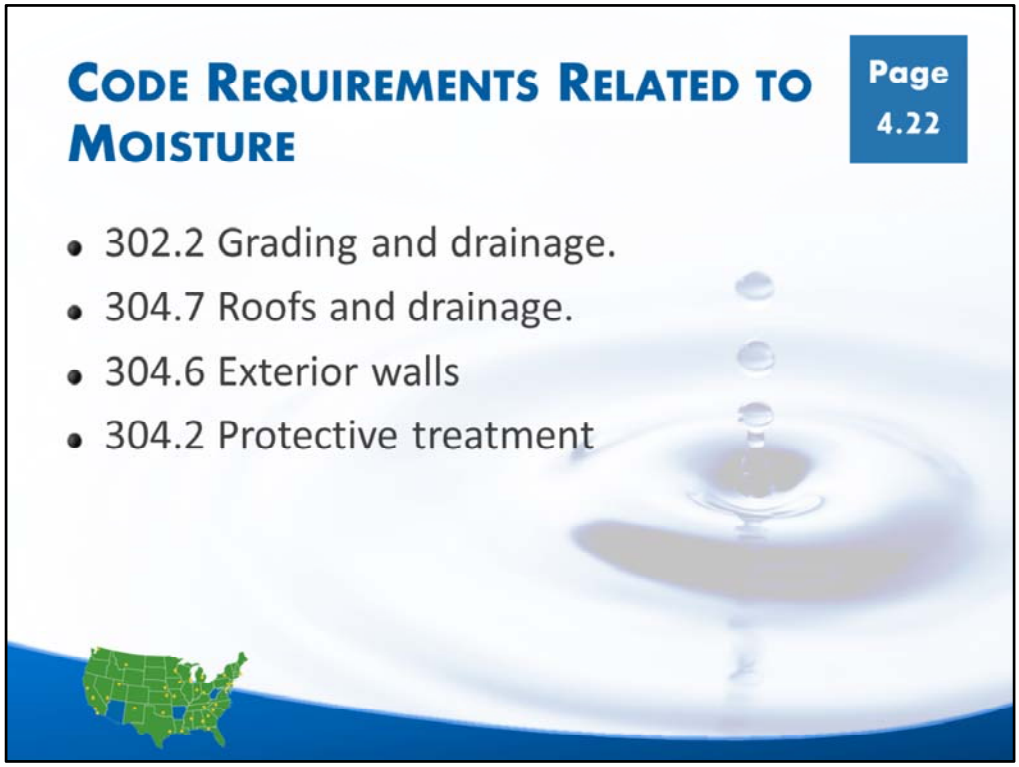
Wiping damp surfaces with water and a small amount of detergent collects any remaining fungal particles. The detergent is needed because the spores of some fungi (e.g. aspergillus and penicillium species) are hydrophobic and pushed off the surface into the air if water without a surfactant is used.

Some experts recommend the used of a pesticide containing borates labeled to kill or prevent mold as a final rinse. Be sure to read the label carefully and follow instructions if you choose this option. Also, check with state agency regulating the licensing of pesticide applicators. While homeowners are usually permitted to treat their own home, other people may need to be licensed or certified by the state to apply any pesticide. See www.epa.gov/pesticides/enforcement/index.htm for more information.



As the size of the area needing remediation increases or if demolition is involved, the chance of larger exposures increases and more worker protection and containment are advised.[8,9,11] Quickly drying things out is an important step, because mold will continue to grow as long as there is moisture and nutrient.

This shows fairly simple containment using spring-loaded poles and polyethylene film.



302.2 Grading and drainage. All premises shall be graded and maintained to prevent the erosion of soil and to prevent the accumulation of stagnant water thereon, or within any structure located thereon.

304.7 Roofs and drainage.

The roof and flashing shall be sound, tight and not have defects that admit rain.

Roof drainage shall be adequate to prevent dampness or deterioration in the walls or interior portion of the structure.

Roof drains, gutters and downspouts shall be maintained in good repair and free from obstructions.

Roofwater shall not be discharged in a manner that creates a public nuisance.

304.6 Exterior walls. All exterior walls shall be free from holes, breaks, and loose or rotting materials; and maintained weatherproof and properly surface coated where required to prevent deterioration.

304.2 Protective treatment.

All exterior surfaces, including but not limited to, doors, door and window frames, cornices, porches, trim, balconies, decks and fences shall be maintained in good condition.

Exterior wood surfaces, other than decay-resistant woods, shall be protected from the elements and decay by painting or other protective covering or treatment.

All siding and masonry joints as well as those between the building envelope and the perimeter of windows, doors, and skylights shall be maintained weather resistant and water tight.

Key Messages

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- Excess moisture creates conditions that can affect health.
- Moisture in the home comes from inside and outside.
- Excess moisture in the home should be prevented through appropriate construction methods and plumbing systems, temperature control, ventilation and proper maintenance.

Learning Objectives

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Name three health hazards in the home that are related to excessive moisture.

Identify four sources of moisture in the home.

Describe five strategies for controlling moisture in the home.