Shelter: How Houses Work

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There are places on earth where the outdoor air is pleasant on the skin day after day – Mediterranean isles, sub-Saharan tropical steppes; some Pacific or Caribbean Islands; and portions of the California coast. Many people live in less hospitable climates and they respond by dressing to protect themselves from the sun, rain, wind and snow. Buildings make it possible for us to create a paradise climate inside even when it is miserably cold, hot, humid or dry outside. Here's how it works.

The roof, walls, windows, doors, and foundation enclose a hunk of air and form the primary protection from rain, wind and sun; from air that's too cold, too hot or too humid and from annoying animals and insects who want to eat our food, bite us, or move in.

Having enclosed some space we can keep it comfortable by adding or removing heat, adding or removing humidity, and removing air contaminants released indoors using mechanical equipment – furnaces, boilers, air conditioners, exhaust fans, chimneys humidifiers and dehumidifiers, and windows.

Enclosure

Rain lands on roofing, siding, windows, doors, foundations and the surrounding landscape. When things are working right the rainwater drains down and away from the house and causes no damage to the building. That's why roofing, siding, windows, doors and foundations are normally made of materials that can get wet and dry out without growing mold, decaying or deteriorating.

Keep it Dry: Use Gravity to Drain Water Away From the Building

We don't install these materials so they are watertight like a swimming pool. We install them so they shed water by gravity. Each layer overlaps the layer below like a rain suit – hat overhanging the jacket collar; jacket outside the pants and pants outside the boots. Imagine the alternative of tucking your raincoat into your pants, now the water runs into your pants.

For a house:

- A cap covers the top row of shingles; each succeeding row of shingles covers the row below; the bottom row covers a drip edge so rainwater will drip into gutters or down to the ground without hitting the wall; an overhang protects the siding below;
- Wooden clapboards overlap each other as we go lower down the wall;
- Rainwater leaks through the clapboard at the joints, so tar paper or house wrap is attached to the wall beneath shingle style collecting and draining any rain that leaks through behind the clapboards;
- Clapboards and tar paper above a window overlap flashing; that diverts rain water from the top of the window to a drip edge overhanging the window;
- Window drains rain to the sill which slopes to a drip edge overhanging the clapboards below; beneath the sill is a pan flashing that catches rain that seeps past the sill at corners and mulls and drains it out where it overlaps the tar paper on the wall below;
- Clapboards and the tar paper overlap the edge of the floor and the top of the foundation so rain drains off onto the landscape surrounding the house;
- Landscape slopes away from the house, draining water away; this point is crucial for keeping rainwater out of foundations – rainwater must not puddle against the building;
- Gutters and downspouts are pitched so that water runs away from the building and are clear of debris;
- If the house has a basement or crawlspace (a hole in the ground), the foundation wall is coated with damp proofing to keep water out of the wall as it seeps downward until it comes to the footings where there is a drainage system made up of stone pebbles, perforated pipe and a filter to keep fine bits of dirt from clogging the stones and pipe;
- The drainage system at the footing drains water away from the lowest spot in the building – the basement or crawlspace floor – to an even lower point downhill, a storm drain or to a sump where it is pumped away.

The result is that when rain or snow land on a house it is kept a safe distance from damaging the house or dripping on the people inside.

Keep it Comfortable: Seal Holes and Use Insulation

To protect us from the wind and from hot, cold, humid or dry air we need a fairly airtight house. The basis for air tightness is provided by the solid materials we use to keep the house from falling down or to finish the inside– plywood, Oriented Strand Board (a composite of wood), gypsum board, foam board, concrete, concrete blocks. Air molecules leak through the cracks between these materials and through the holes we make to install pipes, ducts and wires. The crucial finishing touch to improve air tightness is to seal these holes. We do it with things like caulks, canned foam, and tapes. Solid materials do a good job of keeping out large unwanted guests – cattle, bears, dogs and people. However rats, mice, bats, roaches, ants can easily fit through small gaps. In fact, mice can squeeze through a 3/8 inch hole and cockroaches need only a glimmer of light to fit through.

When it is very hot or cold outdoors the indoors can lose or gain so much heat through the solid materials that it becomes too hot or too cold. Anyone who has been in an attic in summer knows that when the sun hits the roof, it gets very hot in the attic. The sun heats the shingles and the shingles pass the heat on to the plywood by conduction. Materials like blown cellulose, spun fiberglass or plastic foams (sprayed or boards) are used to insulate the enclosure, drastically cutting the amount of heat that passes through by conduction. Insulation makes the cold side of a wall colder and the warm side warmer. Look at how the indoor and outdoor surface temperatures change when we alter the insulation in a wall when it's cold out-- assume that the outside temperature is 20 degrees Fahrenheit and the inside temperature is 72 degrees Fahrenheit.

Construction Type	Outside Clapboard Temp.	Inside Gypsum Temp.
Metal stud no insulation	29 °F	35 °F
No insulation	24 °F	55 °F
Wood studs no insulation	22 °F	66 °F
Insulated wall cavity	21 °F	69 °F

The bit of gypsum board touching the steel stud is cool enough that condensation would occur if the indoor relative humidity is 22% or higher. It's likely that there would be condensation problems at each stud. Particularly on walls that did not get any sunlight – the sun would warm the stud each day, drying out the gypsum board.

Keep it Comfortable: Add Heat

To make the enclosure more comfortable we need to add heat when it is cold outside, remove heat when it is warm outside, and remove irritating contaminants that are generated or brought inside. Sometimes, we may want to add or remove humidity.

Many houses are heated using furnaces or boilers. Most furnaces and boilers burn oil or gas to produce heat. Furnaces heat up air and a fan blows the hot air into the rooms of a house. The furnace fan sucks in the same amount of air that it blows out. It draws air from the paths of least resistance. The warm air is blown through ductwork and into rooms through grilles called *supply diffusers*. It sucks air back through ducts and grilles called return grilles. Sometimes there is a return in each room that has a supply diffuser and the fan circulates air through the rooms. Sometimes there are fewer returns, located in the living space and the returns suck air not only from the rooms where they are located but also from other rooms through gaps under doors and through cracks and holes in the rest of the enclosure. Furnaces all have air filers to keep the heat exchangers from being covered with dust.

Boilers heat water and circulate hot water or steam through the rooms to heat them. Boilers deliver hot water or steam through pipes to radiators and baseboard convectors in each room. Unlike warm air furnaces every room with radiator or convector has a return that brings the cooled water or condensed steam back to the boiler. This fact and the small size of pumps, pipes and valves makes it easy to zone hot water systems to provide comfort in each room.

All houses are partly heated by things inside the building that accidentally release heat – cook stoves, light bulbs, televisions, computers, irons, refrigerators, and people. Each person in the home adds as much heat as about a 100 watt bulb. The accidental heat sources are called *internal gains.* The more airtight and the better a house is insulated the smaller the amount of heat that must be added to keep it warm when it is cold outside. When it is hot outside and we are trying to cool the house, the heat from the internal gains must be removed.

Keep it Comfortable: Add Cooling

When it is hot outside we want to cool the house. Houses are cooled by preventing heat from entering them or by removing heat from them.

Heat enters a house from the outside through windows as sunlight and by infrared radiation; as hot outdoor air leaking in accidentally or drawn in as

part of the ventilation system; and through the solid walls and ceilings by conduction from the warm outside air and sun-heated siding and roofing. To reduce the heat entering from outside we can shade the house with trees, awnings, overhangs and porches; use windows that are better insulated and reject infrared radiation; and air seal and insulate the enclosure. Heat is released inside the house by the internal gains. We can reduce those by using more energy efficient lighting and electric appliances.

Heat can be removed from a house by circulating cool air through the rooms. If indoor air is warmer than outdoor air, a house can be cooled by ventilation with outdoor air. Buildings have used ventilation for thousands of years. We can open windows or use fans. If the outdoor air is too hot or humid we can use air conditioning systems to cool the house air by circulating house air through coils that are chilled by refrigeration equipment. Air conditioners may be individual units in one or more rooms or may be a central system that circulates air through ducts, diffusers and grilles. Air conditioners may have both the evaporation and condensing parts of the cooler in the same unit – like window air conditioners or may have separate units for the condenser and the evaporated like ductless split air conditioners or central air conditioners.

Air conditioners all circulate room air through cold coils using fans. The air must be filtered to protect the coils from dust in the air. Air conditioning coils often are colder than the dew point (the temperature when water forms) of the air passing through – so water condenses on the coil. The units must dispose of the condensed water. Many of them collect the condensed water in a pan and remove it through drain lines to the outside of the house. Some heat the water and evaporate it into the outdoor air or the indoor air. Because they sometimes remove water from the house air, air conditioners may also be dehumidifying the house. In order for an air conditioner to effectively dehumidify a house they must have a coil cooler than the dew point of the indoor air; run long enough for condensate to accumulate and drain into the drain pan and collect the condensate and remove it from the building. If the air conditioner is too large it does not run long enough to dehumidify. Air conditioners need to run at least 25 minutes in each hour before they really dehumidify.

Air conditioners may chill the indoor air below the dew point of the outdoor air. Objects in the house that are below the outdoor air dew point will accumulate water if they happen to be bathed in outdoor air accidentally drawn into the building. If the cold supply air blows on an object it may lower the temperature of the object below the dew point of the indoor air. This is most likely if the air conditioner is not dehumidifying very well. In either case this may be caused by humid outdoor air that is accidentally drawn into the building. In air conditioned buildings ventilating air may be

wetting, rather than drying the building. It is important that air conditioned buildings are air sealed.

In climates that have both a heating and cooling season it is fairly common to heat and cool using heat pumps. Heat pumps are refrigeration systems that can switch the direction of flow so the coil inside the house air handler can either be condensing the refrigerant and heating the indoor air or evaporating the refrigerant and cooling the indoor air. The outside coil will be either dumping heat to or collecting heat from the outdoor air or from ground water.

Keep it Well Ventilated

We ventilate houses for five reasons:

- to remove air contaminants
- to remove moisture
- to remove heat
- provide make-up air for furnaces, hot water tanks, driers, etc.
- provide fresh air for breathing

Appliances can create contaminants and heat. To minimize these sources we vent to the outside (exterior exhaust) our showers, boilers, stoves, ovens, clothes dryers, hot water heaters. We *exhaust vent* the source. Chimneys, kitchen exhaust hoods, ducted dryer vents and ducted bath exhaust fans all pull moisture and contaminants outside. Mechanical exhaust fans do this in an energy efficient manner if Energy Star® appliances are used. The other sources - people, furnishings, and spray cans – are dealt with by general ventilation as air moves out through holes, cracks, door and windows.

At the end of it, this is how houses work – we enclose a hunk of air and make it comfortable by heating, cooling, ventilating and sometimes dehumidifying. Our breathing, use of appliances and lifestyles can create energy, heat, moisture, humidity and contribute to water problems which can make a house wet, hot, attractive to pests and uncomfortable. The solution is to let the building work as well as it can to keep our homes dry, comfortable and well ventilated AND respond quickly to problems we see (flood from rain storm), smell (musty, mold, stale air) and hear (plumbing leak, critters in attic).