Healthy Home Assessments: Principles and Practice

Building Science Principles and Residential Systems

Building Science Principles

- The Building Envelope
- Heat Transfer
- Air Movement
- Moisture Transfer
- Material Source Strength

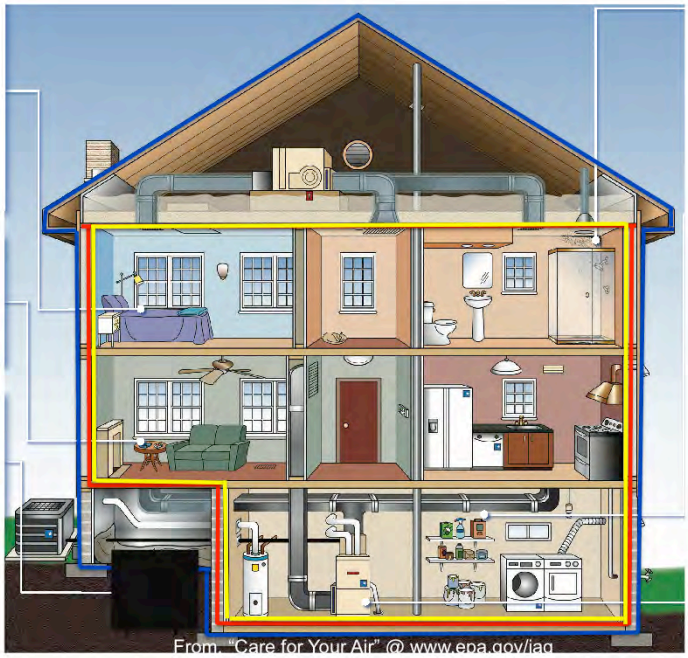
The 4 P's of Healthy Homes*

- People – Occupants, especially Sensitized individuals
- Pollutants – Chemicals, particles, biologicals
- Pathways – intentional (doors, windows, ducts), unintentional (wall cavities, chases, penetrations)
- Pressure – natural, mechanical

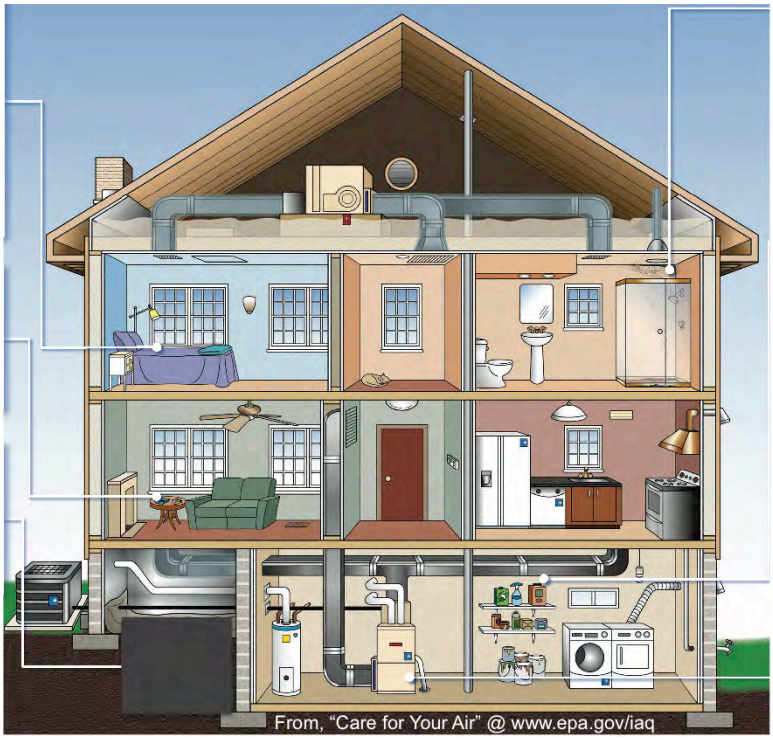
*From "Building Science Fundamentals" – Joe Lstiburek, Ph.D., P.Eng.

Building Enclosure

- Water Barrier
- Thermal Barrier
- Air Barrier



Fire
or
Heat



Heat Flow

- Conduction
- Convection
- Radiation

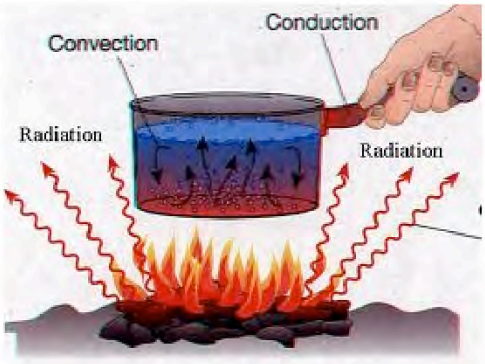
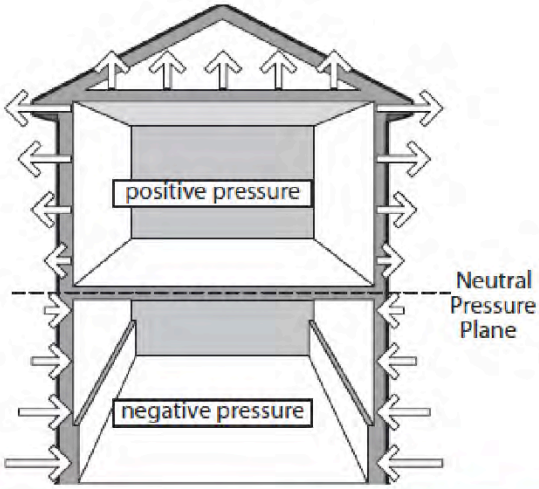


Image from University of Wisconsin

Temperature and Air Movement

- The higher the temperature (the hotter the air), the faster molecules move and the less dense the air becomes.
- Less dense (warmer) air is more buoyant and rises, while denser (cooler) air is less buoyant and falls.

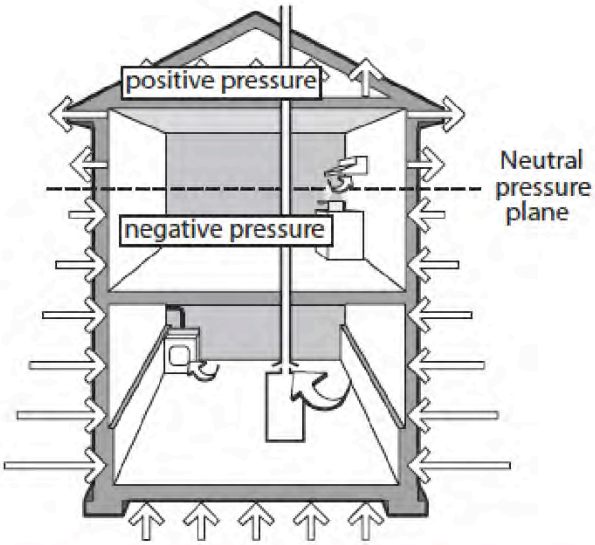
Stack Effect



The stack effect is caused by the relative buoyancy of warmer air. Warmer air's upward force exerts an outward pressure. Airflow, through holes in the home's top, creates suction at lower levels, pulling air in. Arrows indicate the direction and intensity of air pressure.

From, "Residential Energy",
John Krigger & Chris Dorsi
© 2009, Saturn Resource Management.

Chimney and Exhaust Pressures



The chimney, clothes dryer, and kitchen exhaust fan exhaust air from the home, putting most of the home's volume under negative pressure.

From, "Residential Energy",
John Krigger & Chris Dorsi
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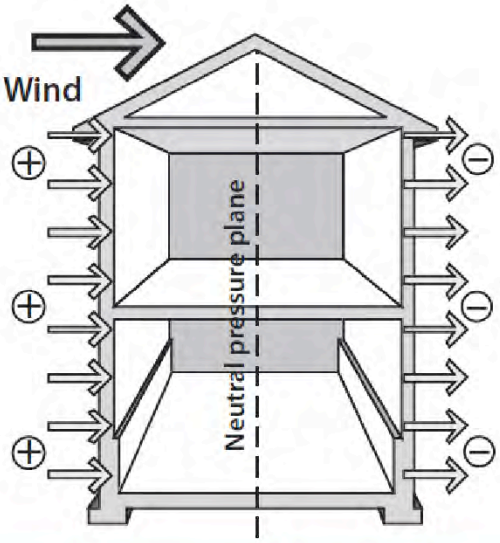
Wind Effect



Wind creates a positive pressure on the windward side of the home and negative pressures on leeward side with reference to the home's interior. Wind pressures push and pull air through holes in the building shell.

From, "Residential Energy",
John Krigger & Chris Dorsi
© 2009, Saturn Resource Management.

Keep it Ventilated
Air Movement Principles

Remember, air moves:

- From high pressure to low pressure
- Follows path of least resistance

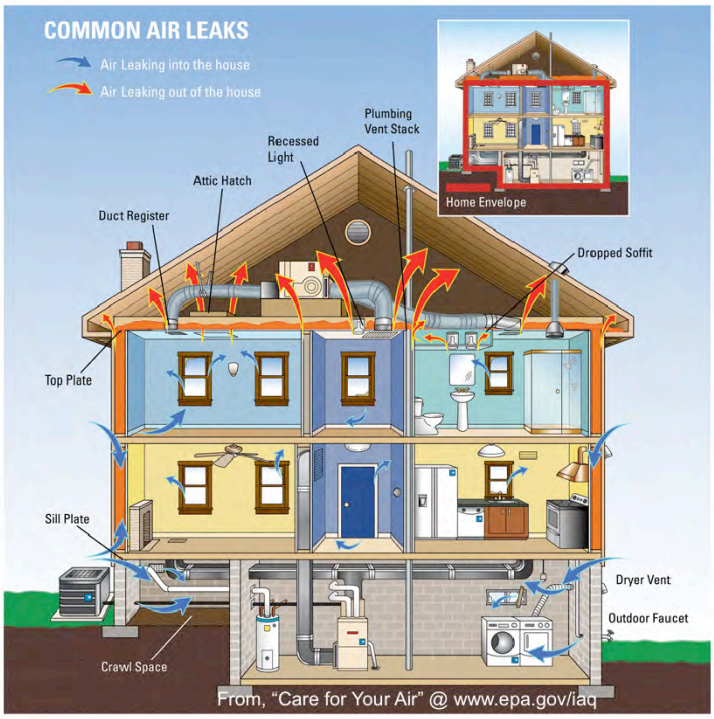
Recognize:

- Air pressure drives air movement (wind effect)
- Mechanical sources (fans) create air pressure

Look for sources of air movement:

- Think both seasonal and chronic (year-round)
- Sources often hidden

Air


COMMON AIR LEAKS
Air Leaking into the house
Air Leaking out of the house
Home Envelope
Plumbing Vent Stack
Recessed Light
Attic Hatch
Duct Register
Dropped Soffit
Top Plate
Sill Plate
Dryer Vent
Outdoor Faucet
Crawl Space
From, "Care for Your Air" @ www.epa.gov/iaq

Pressure Drives Airflow

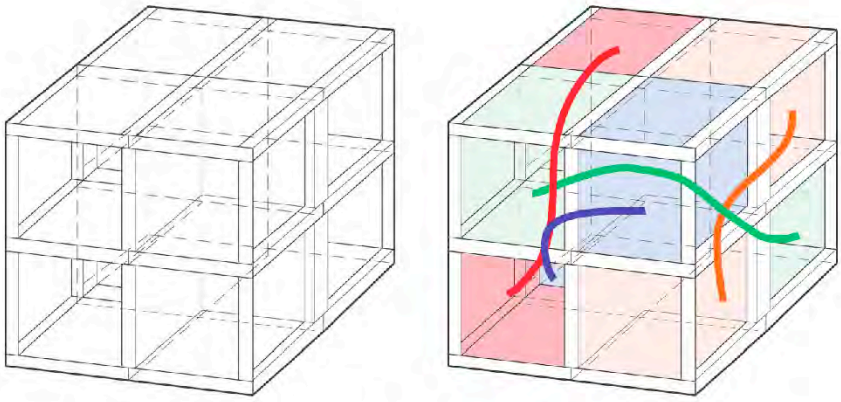
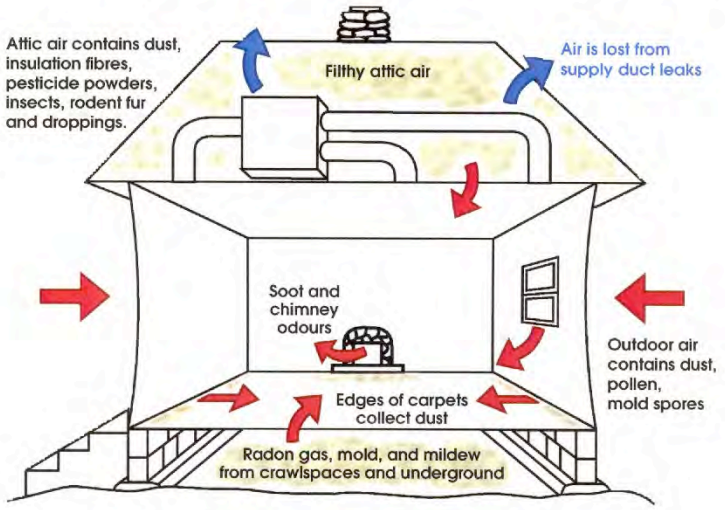


Figure 1: Three-dimensional multi-layer multi-cell analogue (left) with air pressure fields connecting non-contiguous spaces illustrated (right)

From, "Pressure in Buildings", Joe Lstiburek,
Building Science Digest, © 2006, Building Science Press.

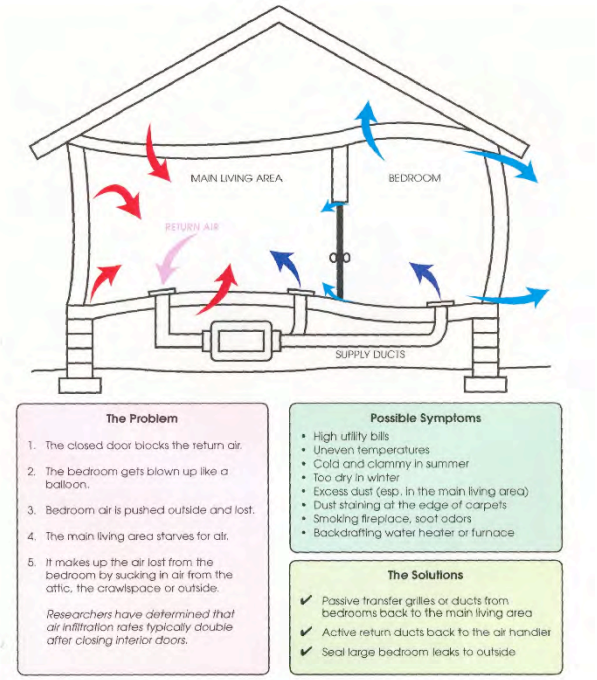
How Supply Duct Leaks Bring in Dust



Supply Leaks "Depressurize" Your Entire House
(air going out must be replaced by air coming in)

From, "Healthy Home Guy", http://www.healthyhomeguy.com

Closing Interior Doors Imbalances System



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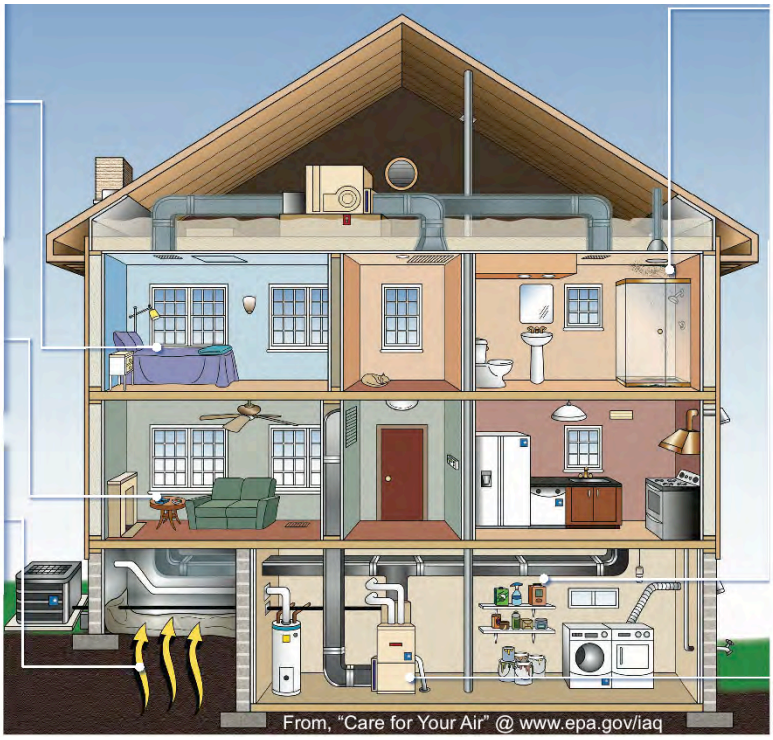
Water



Moisture

- Water enters buildings through three main mechanisms:
  - Bulk Water Sources
  - Water Vapor Diffusion
  - Air Infiltration
- In some cases water vapor can be created by or exacerbated by poorly designed, installed or maintained HVAC systems
- Different materials have different moisture source strengths

Moisture Balance in Buildings

Four factors affect moisture balance:

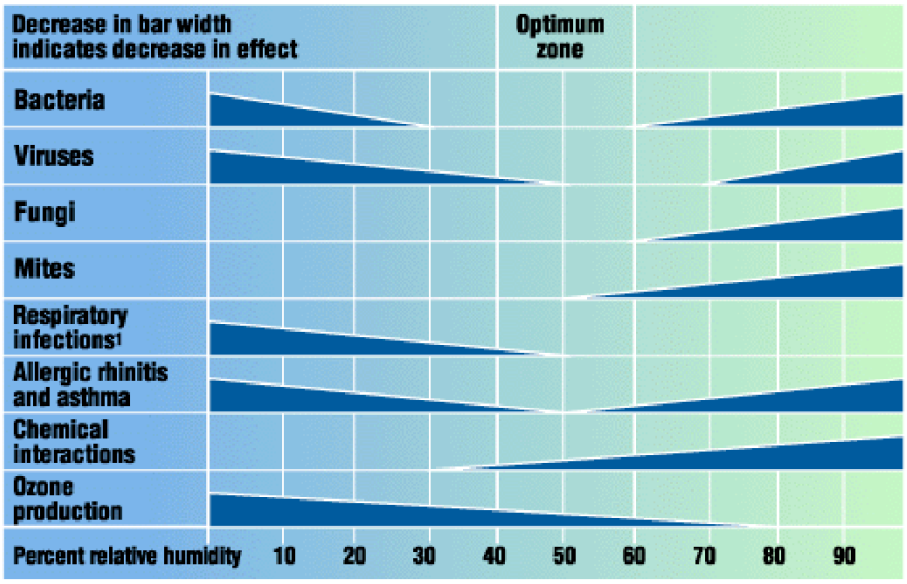
- Source strength of components
- Temperature
- Moisture transfer rate
- Circulation-ventilation rate

Humidity

- **Humidity** is a measure of water vapor in the air. Water vapor results from evaporation as water molecules escape the surface of liquid water below boiling point.

- **Relative Humidity -** Ratio of water vapor in the air compared to fully saturated air at the same temperature. It is abbreviated as “RH” or in equations; Φ relative humidity is relative to temperature.

Effect of Room Relative Humidity on Selected Human Health Parameters

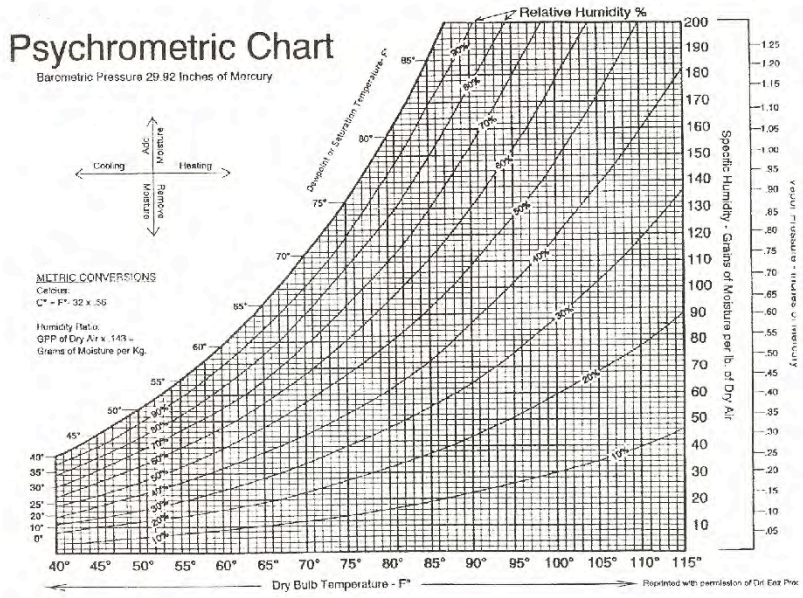


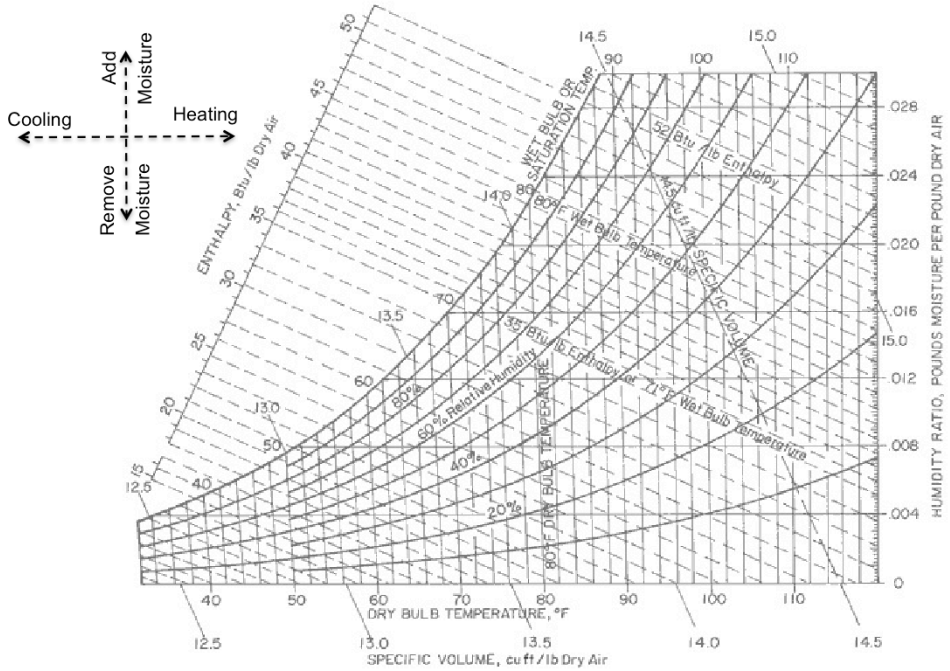
[1] Insufficient data above 50% R.H.
Source: Sterling (1984) ASHRAE Transactions V. 90, Part 2.

Psychrometrics

- **Psychrometrics** is the study of the physical and thermodynamic properties of air-water vapor mixtures. Atmospheric air and small amounts of moisture exist in the same spaces all around us and can be looked at as a mixture of dry air and water vapor.

- **Thermodynamics** is the study of a substance's energy related properties.


Psychrometric Chart
Barometric Pressure 29.92 Inches of Mercury
Relative Humidity %
Dewpoint or Saturation Temperature - F°
Cooling
Heating
Add Moisture
Remove Moisture
METRIC CONVERSIONS
Celsius:
C° = F° - 32 x .56
Humidity Ratio:
GPP of Dry Air x .143 =
Grams of Moisture per Kg.
Specific Humidity - Grains of Moisture per lb. of Dry Air
Dry Bulb Temperature - F°
Reprinted with permission of Dri Eaz Prod



Psychrometric Chart

Class Problem

$T_{\text{Dry Bulb}} = 80^{\circ}$

RH= 70%

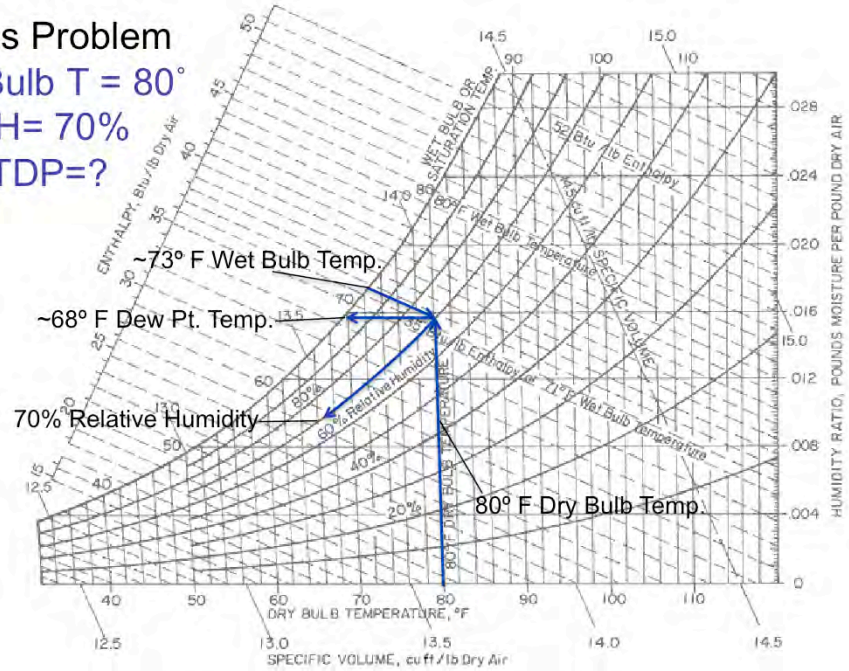
$T_{\text{Dew Point}}$= ????

Class Problem

Dry Bulb T = 80˚

RH= 70%

TDP=?



Psychrometric Chart

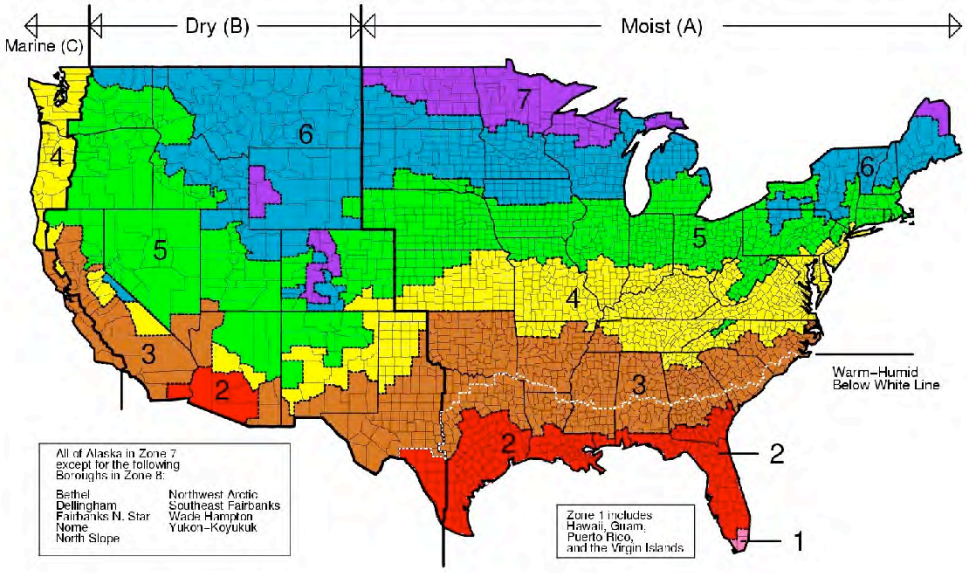
Psychrometric Rule of Thumb

-For every 20ºF drop in temperature the relative humidity doubles, until 100 % RH (saturation) reached.

therefore,

-For every 20ºF rise in temperature the relative humidity is reduced by half, until <10% RH is reached.

Homes are Designed for Regions



Original from US Energy Inform. Admin. (USEIA). Data at:
http://www.eia.gov/consumption/residential/maps.cfm

Keep it Dry Assessment Principles

Start by looking for moisture sources

- Think both seasonal and chronic (year-round)

Look/check for cool spots

- Where it's cool, air moves more slowly, more accumulation because less evaporation

Remember, moisture moves from:

- Hot to Cold
- Wet to Dry

Temperature and relative humidity of surfaces really what matters

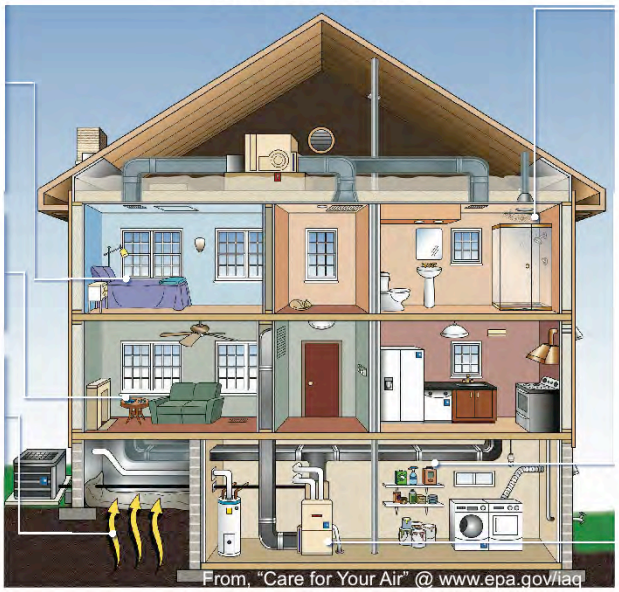
- Condensation Temperature
- Water Activity (a_w)

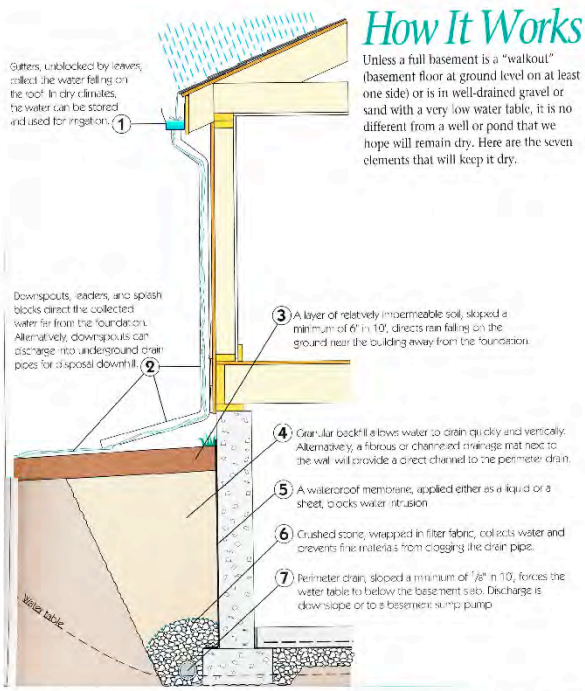
The more closed the system the more these principles apply.

Fungal Amplification - Principles

- Each building material represents a unique set of nutrients and, water activity (a_w) or sufficient available water, that affect how much and what kind of molds will grow.
- In general, for most of North America, there are mold species that are common, and mold species that are unique to a region.
- In many cases, mold species can be common to a building material type, regardless of the region.
- Bacteria require moisture saturated conditions, molds require damp conditions to grow and colonize a material.

Residential Systems Overview





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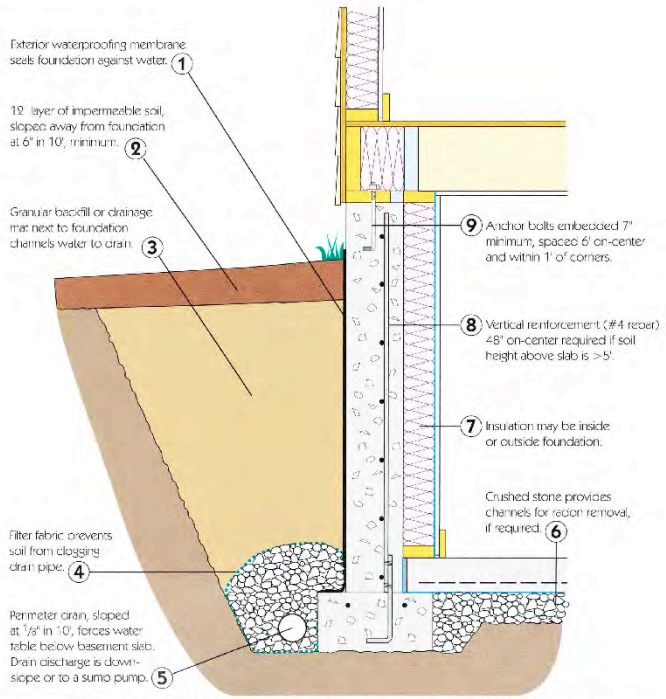

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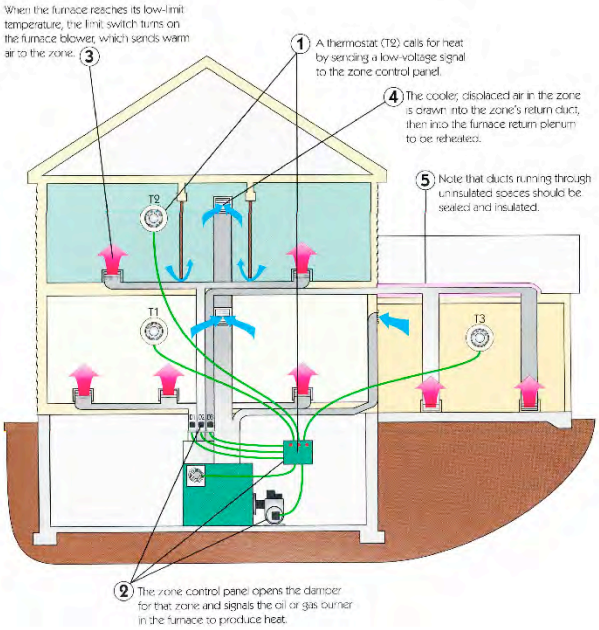
Forced Air System in Homes



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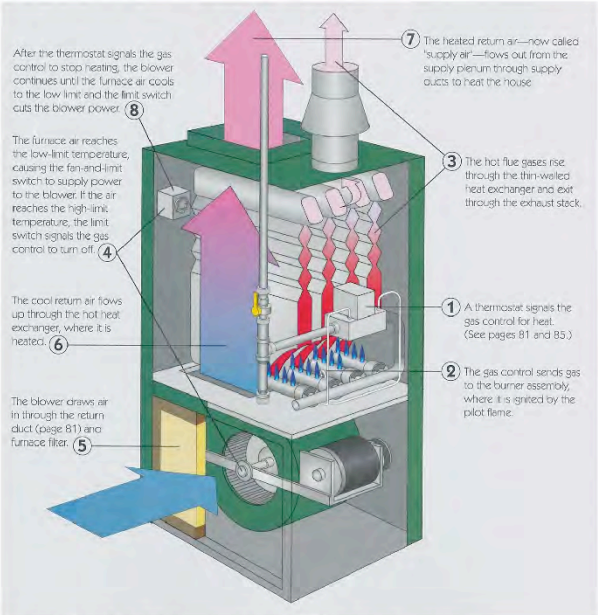
Home Ventilation Basics

Gas Furnace



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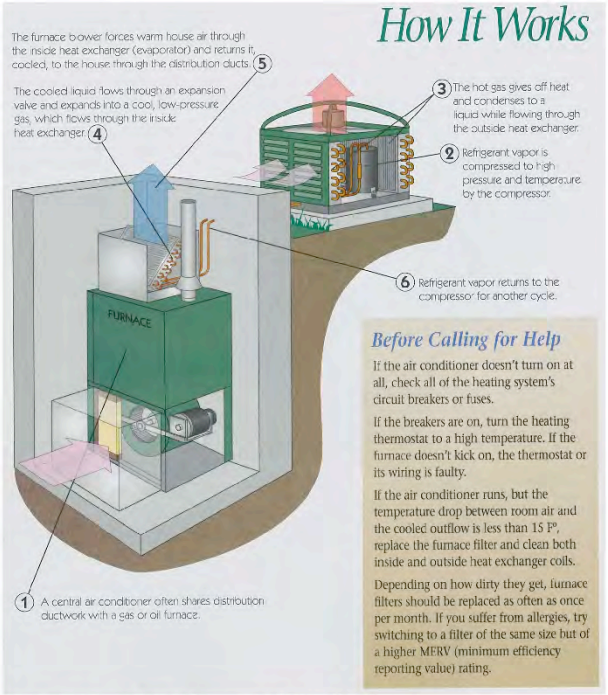
Home Ventilation Basics

Central Air Conditioning



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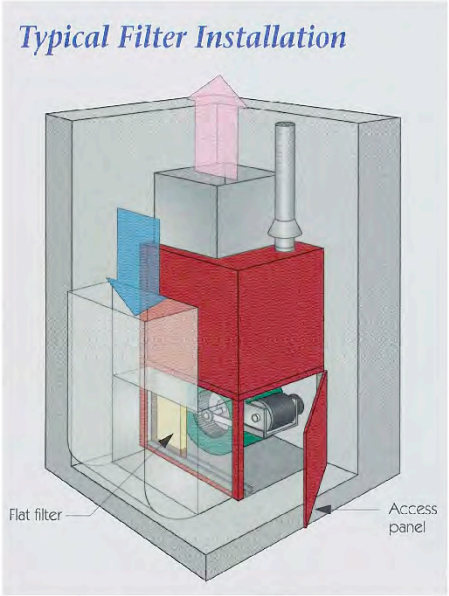
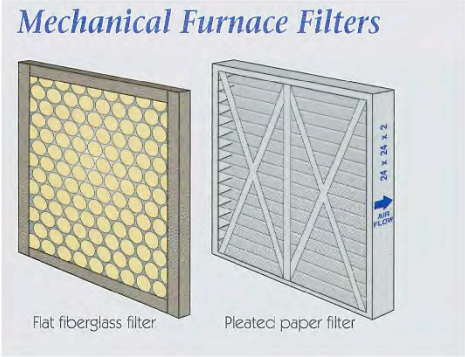
Home Ventilation: Basics*



Filtration



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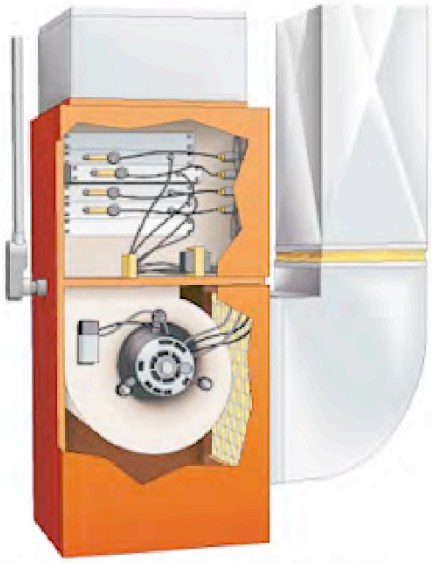
Home Ventilation Basics



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Mechanical & Appliance Assessment

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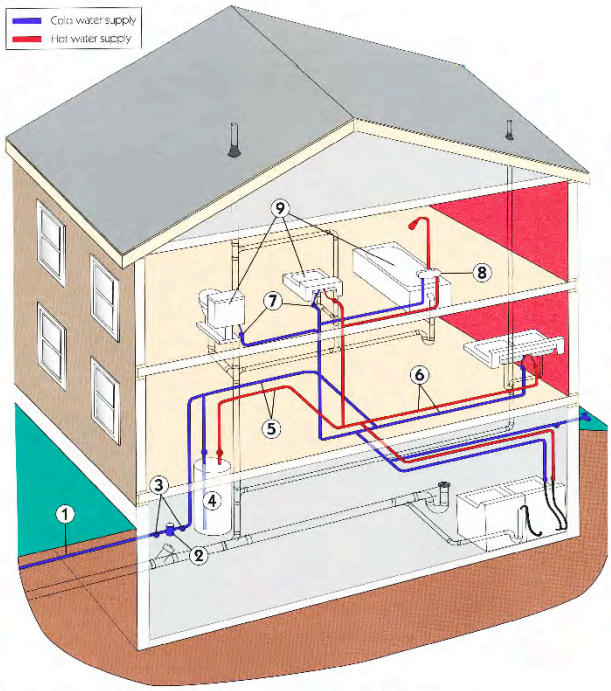
Water Supply System in Homes



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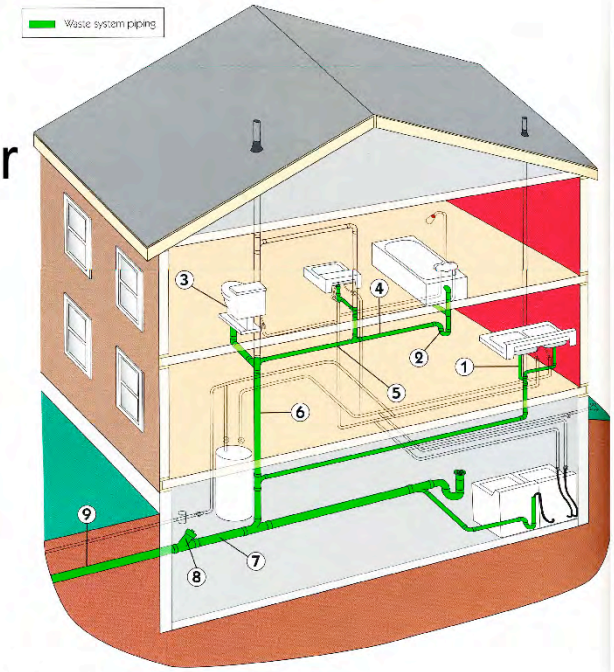
Waste Water System in Homes



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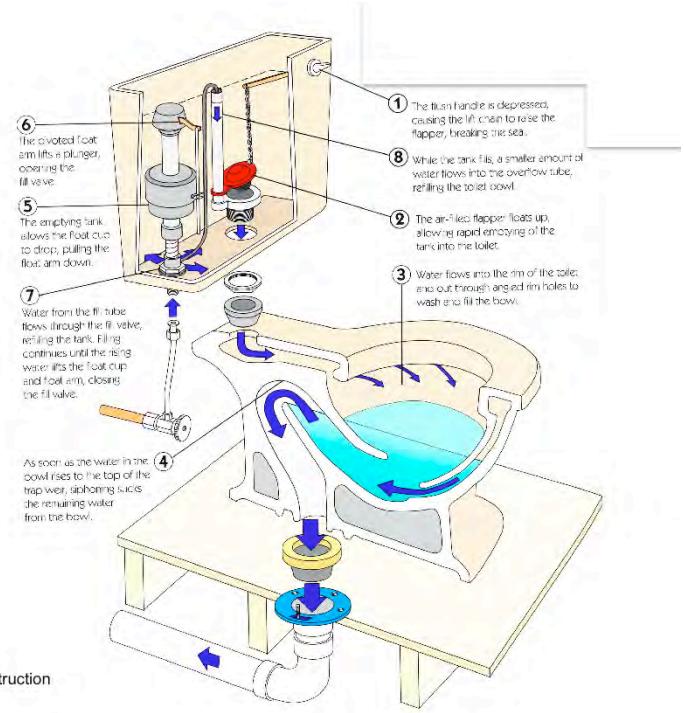
How A Toilet Works



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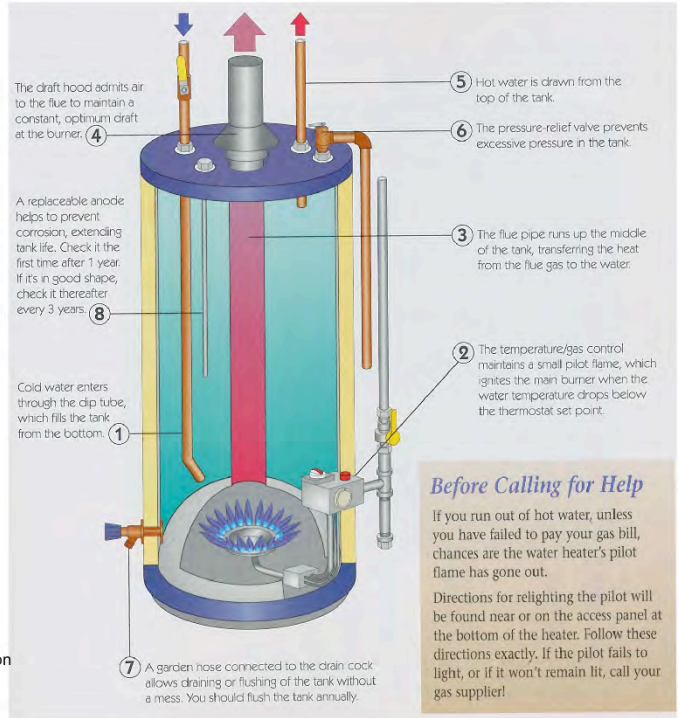
Hot Water Heaters-Gas/LP*



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Hot Water Heaters- Gas/LP

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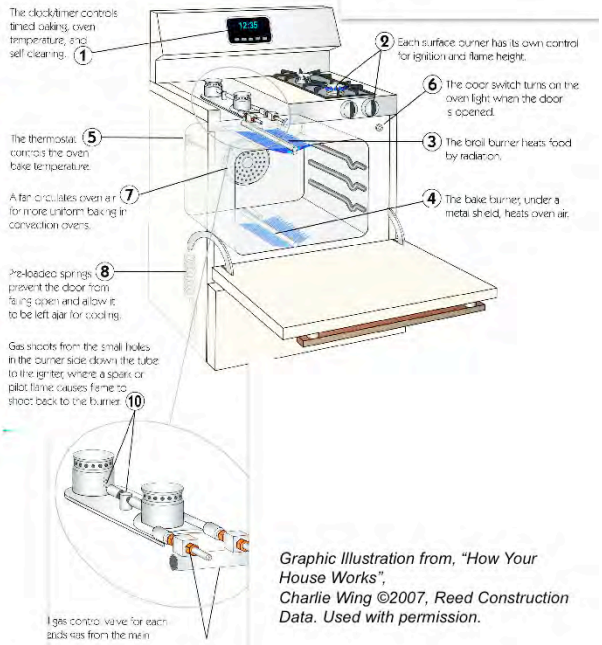
Gas Stove

Photo courtesy of the Center for Environmental Health, Children's Mercy Hospital, © 2010.



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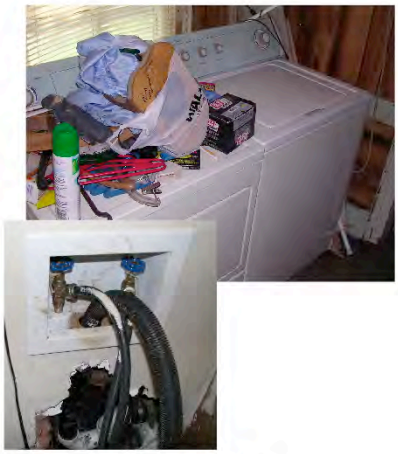
Washing Machine



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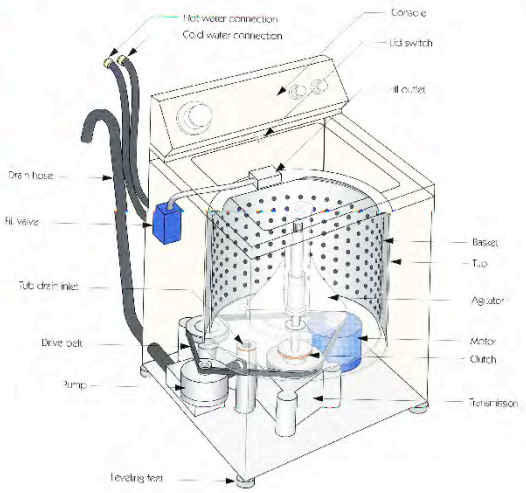

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Gas Dryer

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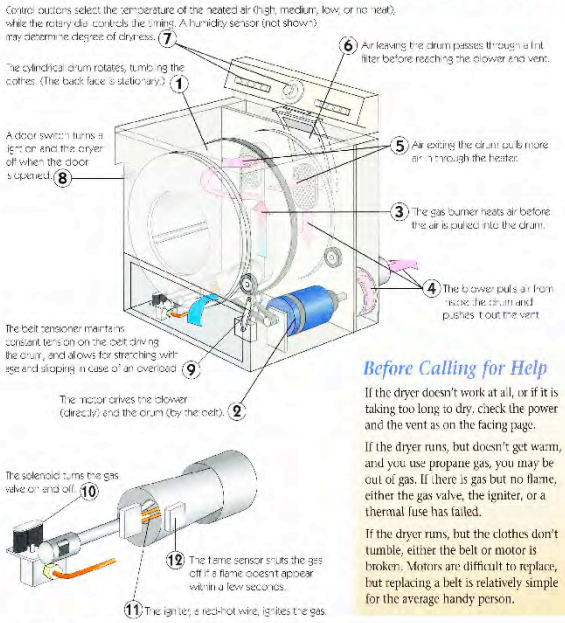
How It Works



Before Calling for Help

If the dryer doesn't work at all, or if it is taking too long to dry, check the power and the vent as on the facing page.

If the dryer runs, but doesn't get warm, and you use propane gas, you may be out of gas. If there is gas but no flame, either the gas valve, the igniter, or a thermal fuse has failed.

If the dryer runs, but the clothes don't tumble, either the belt or motor is broken. Motors are difficult to replace, but replacing a belt is relatively simple for the average handy person.

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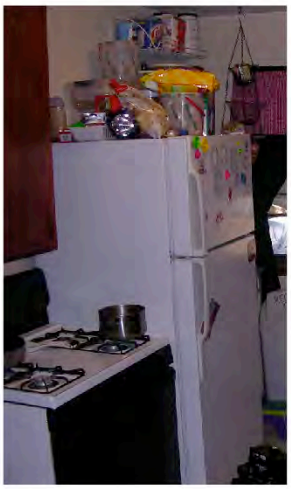
Refrigerator



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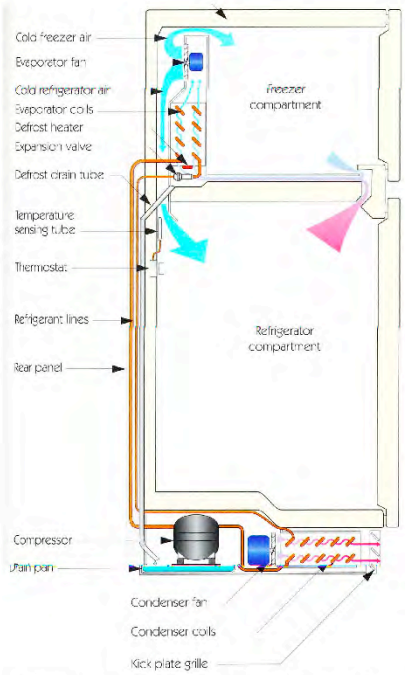

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Questions?