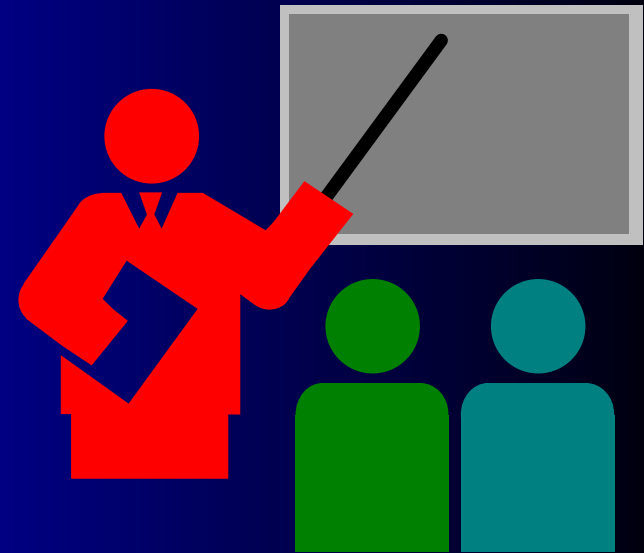
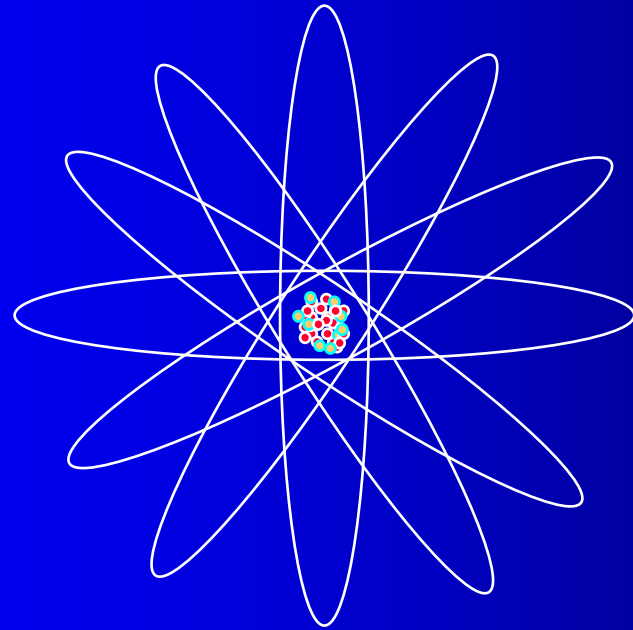


Why view these Radon slides?

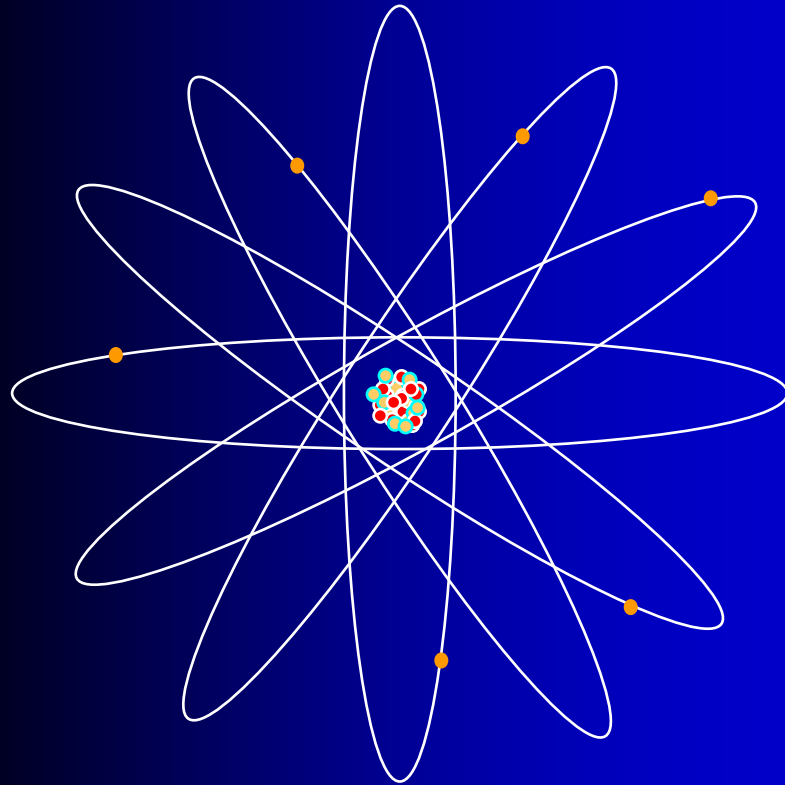
- *Protect your family's health*
- *Learn how to do a radon test*
- *Understand the science*
- *Learn about mitigation methods*
- *Be informed*



Introduction to Radon & Radioactivity



A Simple Model of an Atom



An atom is composed of:

a Nucleus in the Center of the Atom

which is composed of:

- Protons and • Neutrons

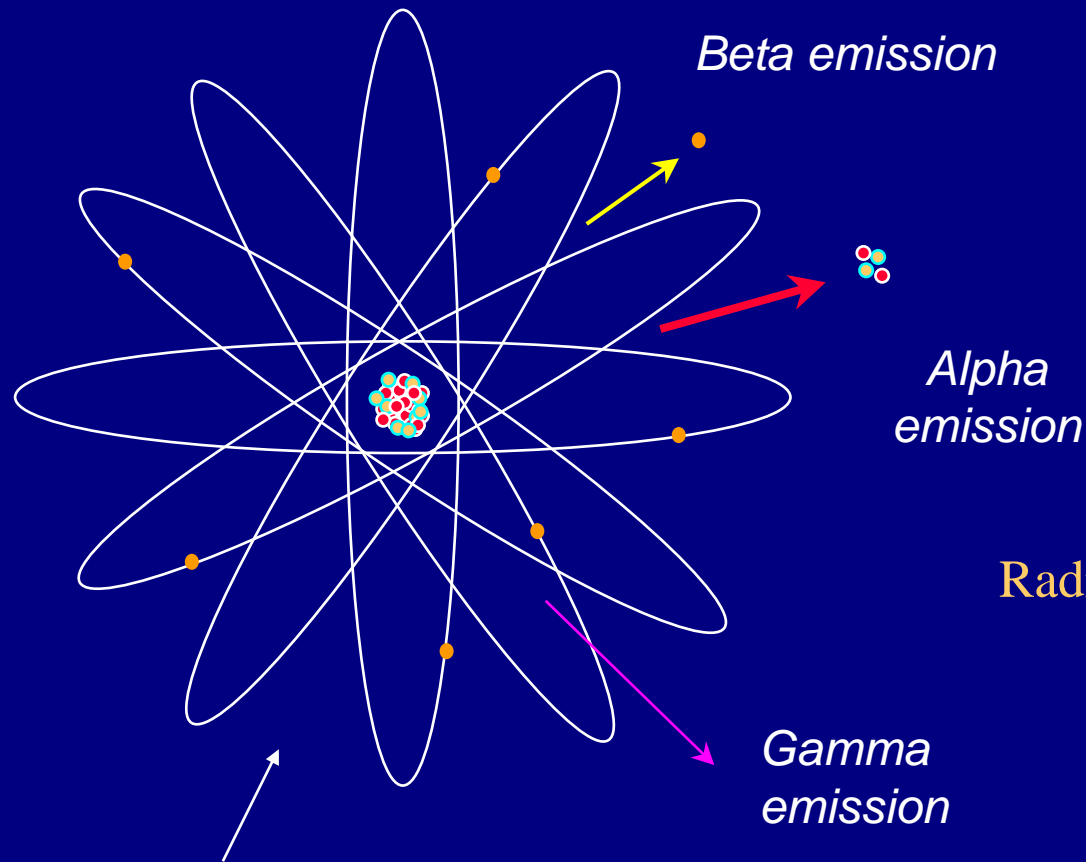
Orbiting around the Nucleus are:

- Electrons

The positive charge of the protons holds the negatively charged electrons in orbit

If the nucleus was the size of a baseball, the electrons, the size of a dust particle, would be a hundred yards to a mile away !!

Radioactivity means an atom occasionally gives off energy or a particle



Atomic Weight is the total count of protons and neutrons in the nucleus

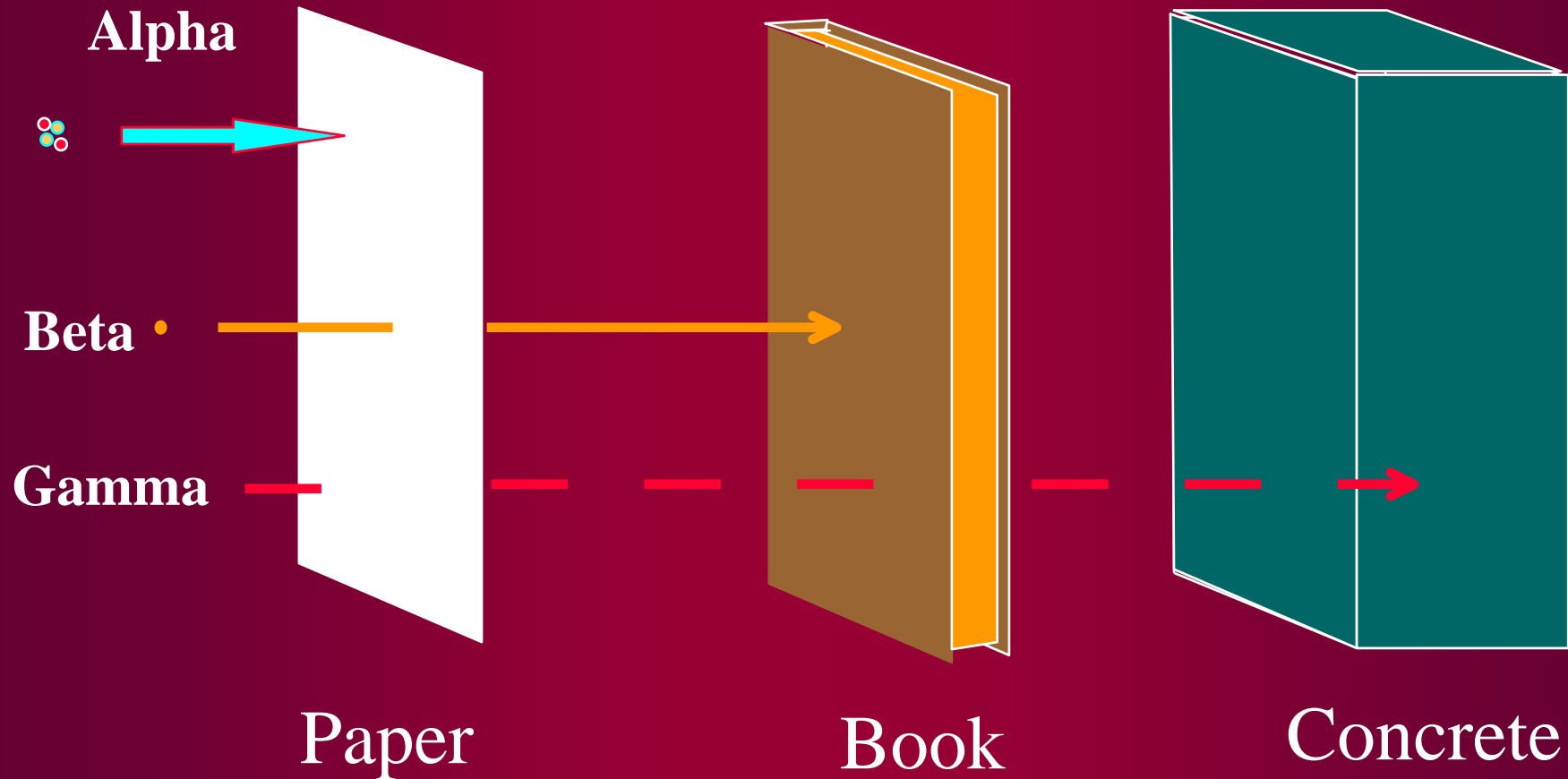
The energy emission is called a **radioactive decay**

Alpha particle has 2 proton's & 2 neutrons

Radioactive decay changes the proton count of the nucleus

The number of protons **Atomic Number** defines the element (lead, bismuth, etc)

Penetrating Power of Alpha - Beta - Gamma



An alpha particle is 20 times more damaging
But it travels the least distance (only a few inches)

Radioactive Elements are identified by:

the Energy
given off

or

the Decay Rate
(Half Life)

1
half life



50 %
remaining

2
half lifes



25 %
remaining

3
half lifes



12.5 %
remaining

4
half lifes



6.3 %
remaining

**Half life is the amount of time required for
half the element to decay.**

Half of the Uranium 238 has decayed away since the earth was formed 4 billion years ago

Uranium 238 (4 Billion yrs)



Radium 226 (1620 yrs)



Radon 222 (3.8 days)



Polonium 218 (3 min)



Bismuth 214 (20 min)



Polonium 214 (u sec)



Lead 210 (20 yrs)

Radon Decay Products

The half life of each element is listed in the brackets

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The atomic mass (number of protons and neutrons) is listed after the element's name

**All the elements in the decay chain
of Uranium 238 are solid particles
except Radon**

Radon is a NOBLE GAS

**Which means it does not
stick or cling to anything and it is:**

***Naturally Occurring
Colorless, Odorless, Tasteless
and free to float through the soil
and up into our homes before
it decays into radon decay products***

Radon is measured in pCi/L units

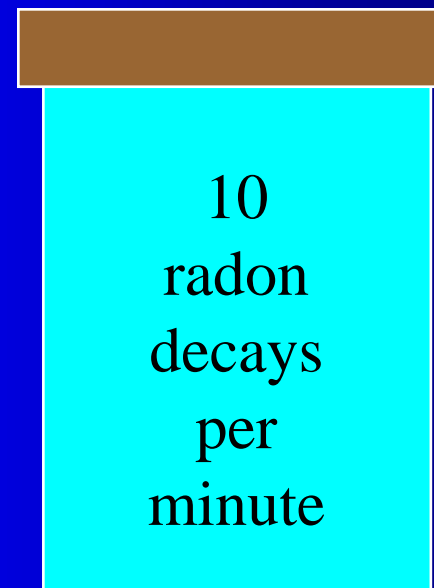
Pico is a Trillionth

Curie comes from Madame Curie

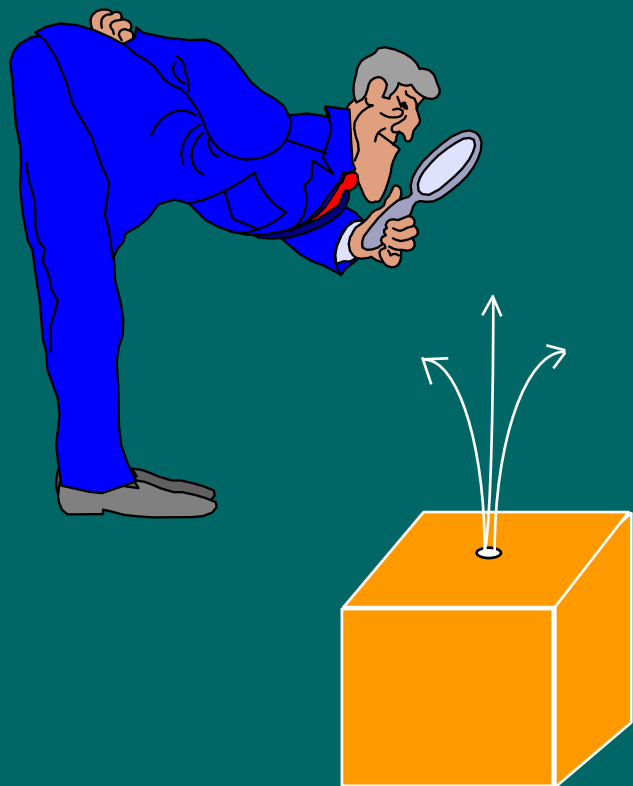
Madame Curie discovered
a gram of radium produce
37 billion decays per second

One PicoCurie or a trillionth
of a curie equals
2.22 decays per minute

A one liter jar
with 4 pCi/L has:



How little is 4 pCi/L ?

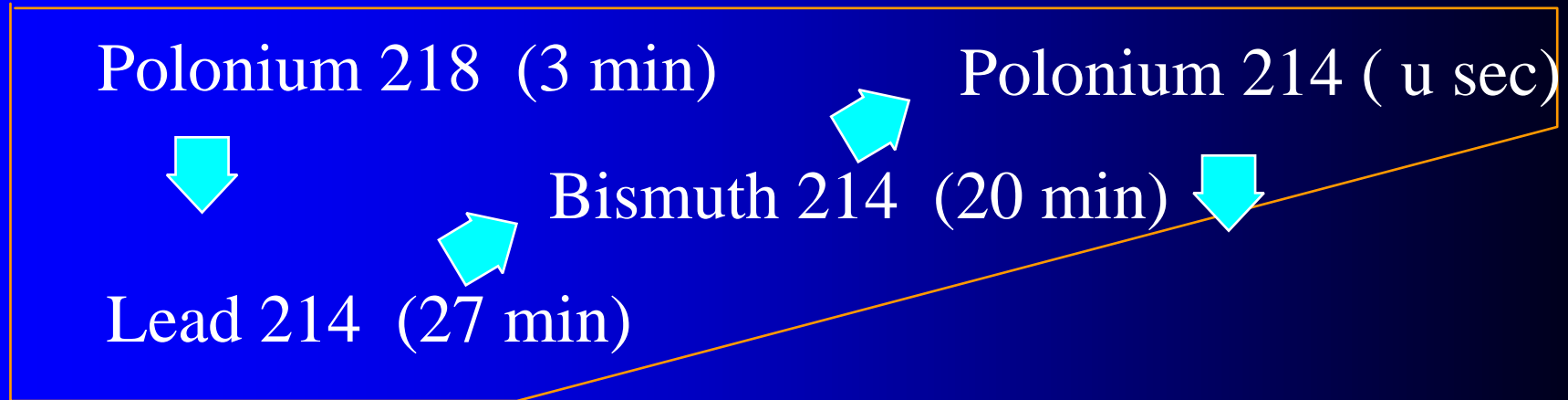


One Cubic
Inch Box

If 10 million molecules per second was escaping, it would take 1 million years to empty this box

Only 2500 radon atoms are needed to reach 4 pCi/L in this one cubic inch box

Characteristics of Short Lived Radon Decay Products (RDPs)



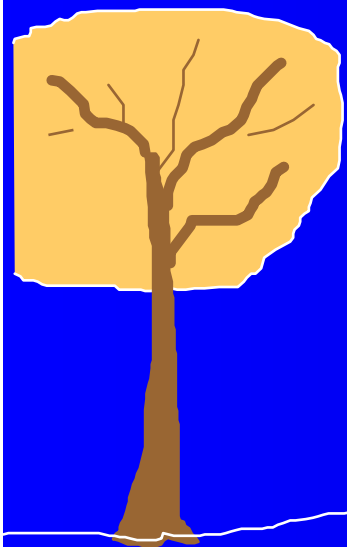
They are sticky particles

Two Polonium's emit Alpha Particles

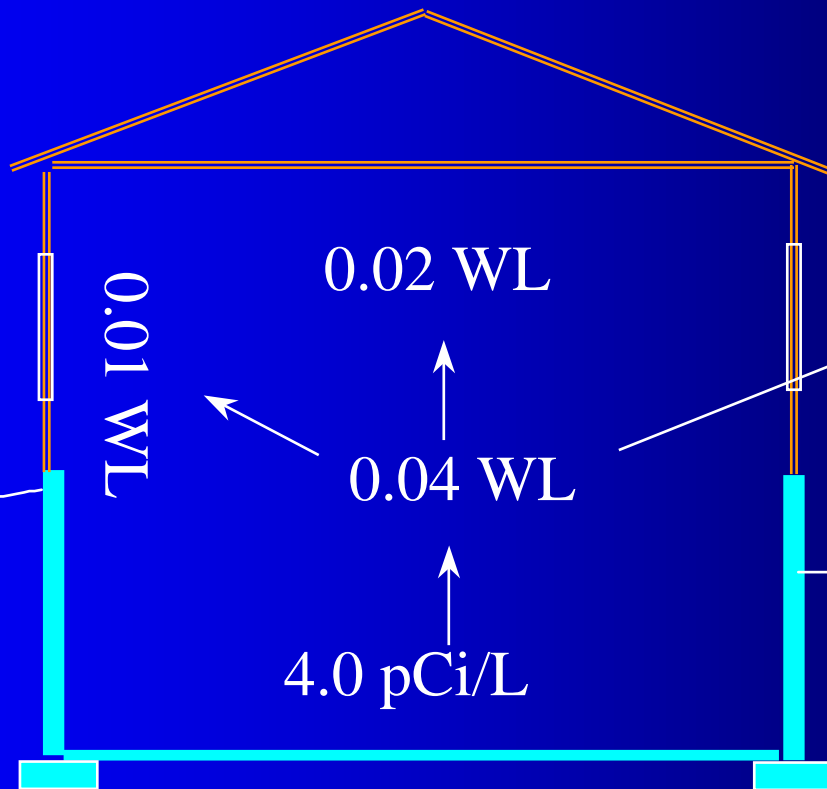
20 times more dangerous than Radon

Measured in units of WL (working level)

Radon Decay Products released from the decay of Radon are measured in units of WL



Some RDPs stick to objects in the room



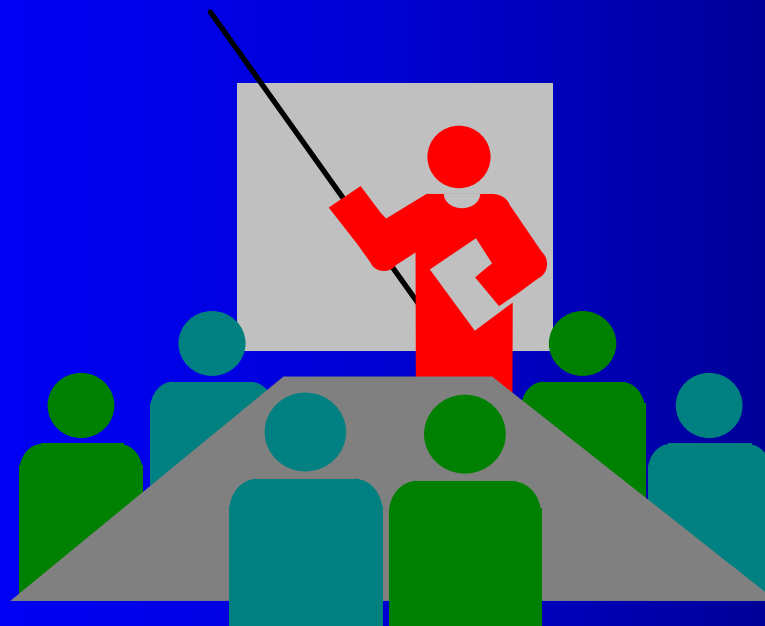
Some RDPs escape to the outside

0.01 WL

About 1/2 the RDPs remain in the air

4.0 pCi/l produces about 0.02 WL in the air

Health Affects from Radon & Radon Decay Products



History of Radon

1400's

Underground miners were dying from an unknown lung disease

1879

Lung Cancer first identified in European miners

1950's

Connection made between Lung Cancer and RDPs

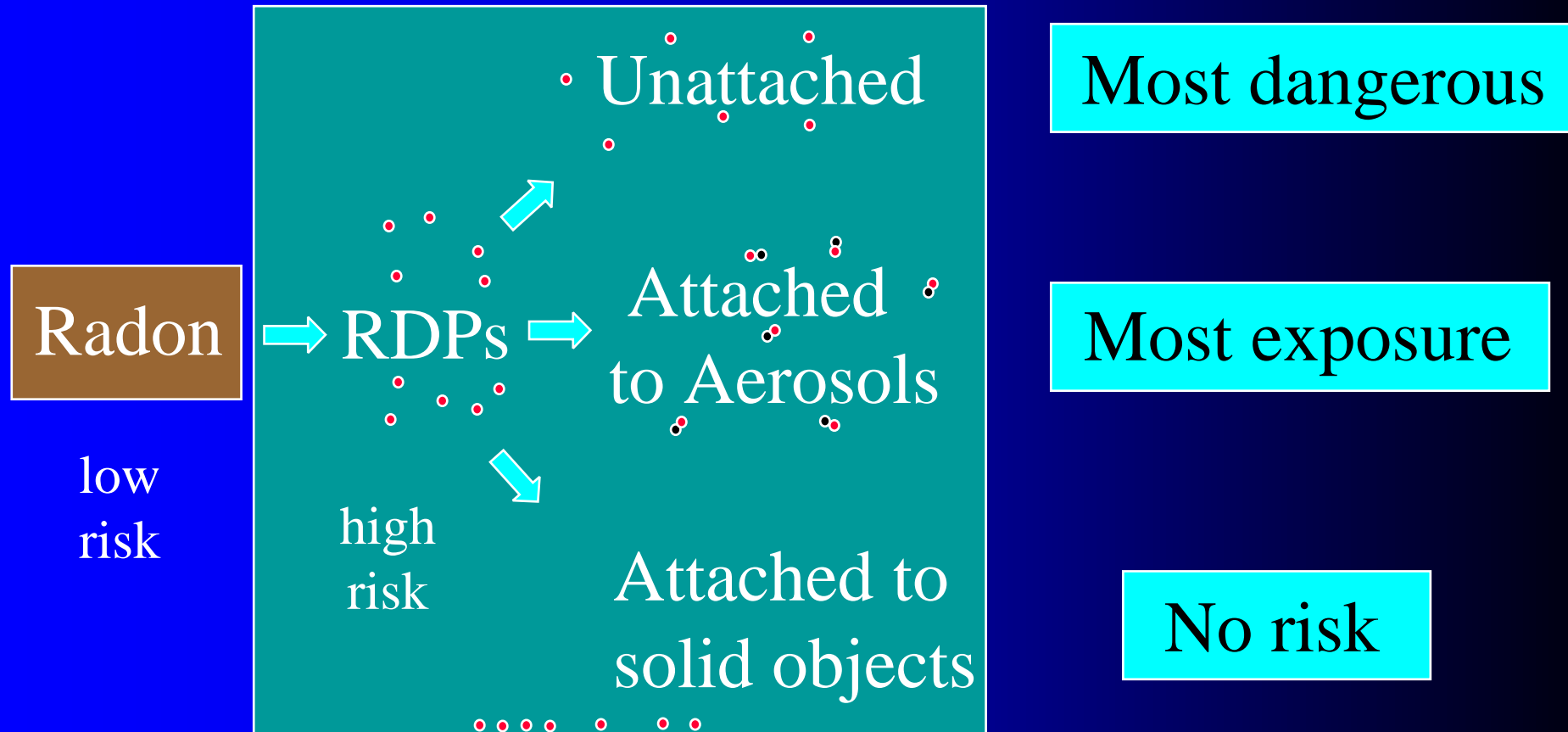
1984

Extremely high radon found in Pennsylvania home (2700 pCi/L)

1999

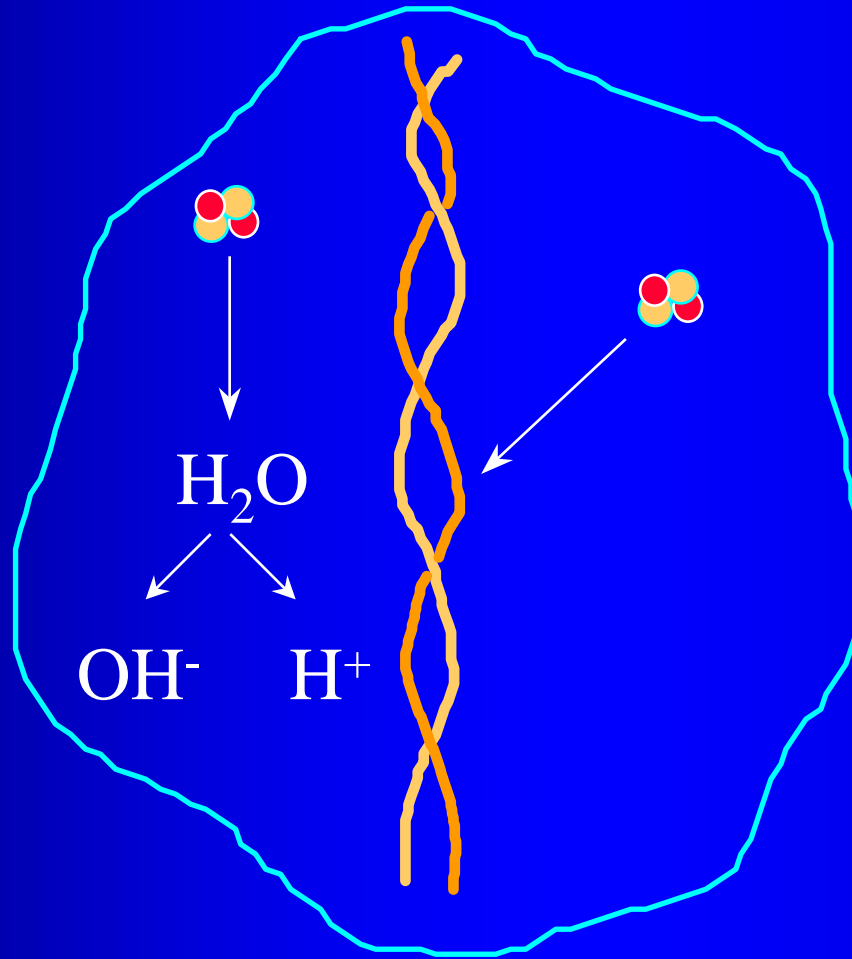
BEIR VI says about 18,500 Americans die each year from exposure to radon

The Radon Decay Products (RDP's) produced by radon are the primary health risk?



Alpha emissions from Radon and Radon Decay Products damage Lung Cells

An alpha particle striking the cell can cause free radicals to be formed in the cell fluid



Double strand DNA can be split by an alpha particle

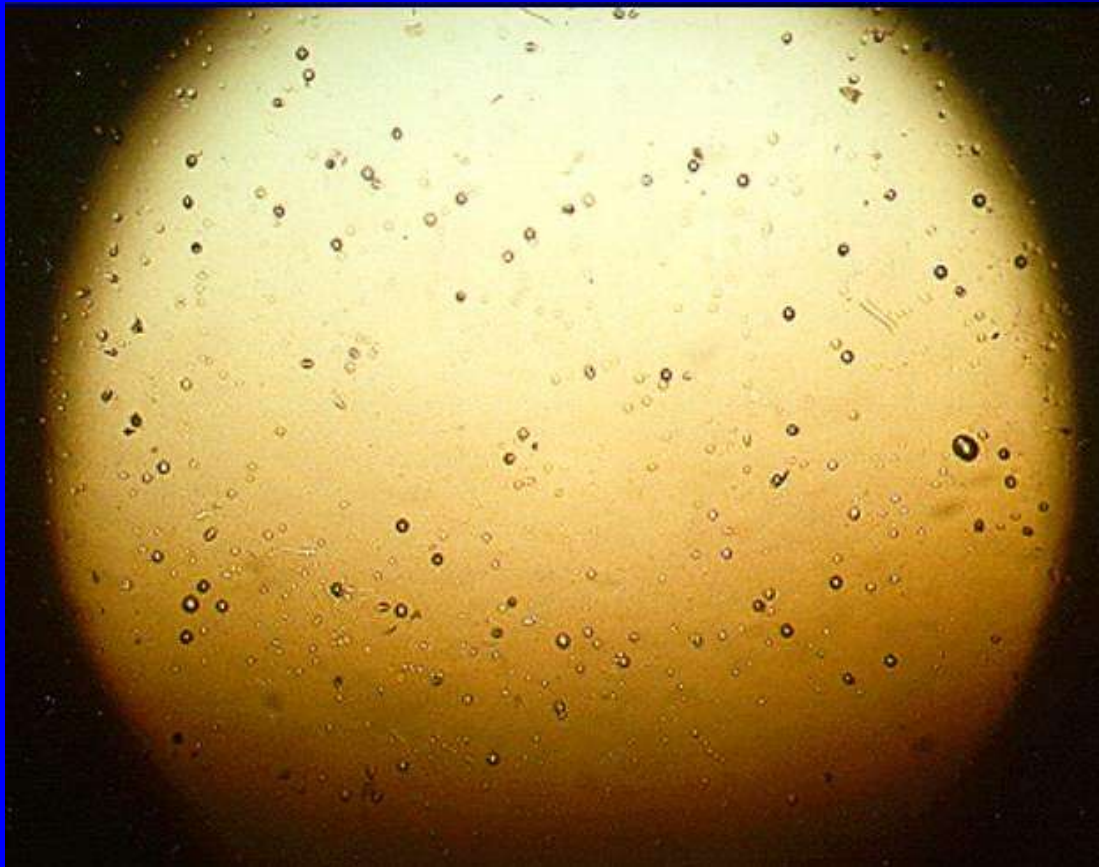
A Lung Cell struck by an alpha particle will:

Die or

Heal itself or

become Cancerous

This is a micro-scope view of plastic that has been struck multiple times by alpha particles from radon and radon decay products



This kind of damage is what your lungs receive from exposure to radon and radon decay products

Photo by Dr. Jim Burkhart

© WPB slideshow

**Radon risk is best determined by
actual people studies**

Miner Studies

Scientists believe the miner studies provide the best determination of radon risk because of the number of miners exposed to radon even though miners are mostly male smokers exposed to other pollutants

Case Control Studies

This is the best type of study but expensive because it requires a large carefully sampled group of lung cancer patients and a similar group who do not have lung cancer

Geographic Studies

Studying the lung cancer rate by area is not considered a good study

1988 BEIR IV study of 22,190 miners with 360 Lung Cancers

Lifetime average pCi/L	Expected lung cancer	Observed lung cancer	Relative increase
0	17	21	No change
1-2	39	46	No change
2-5	19	41	Double
5-10	13	40	Triple
10-20	11	39	3.5 times
36-96	15	66	Four times
96-200	5	45	Nine times

Notice that lung cancer rates doubled when miners were exposed to the equivalent of 2 to 5 pCi/l over a lifetime

'94 Swedish Case Control Study

**1360 Swedes with lung cancer.
2847 Swedes without lung cancer**

Averaged 27 years of Lived-in Radon measurements

Less than 4 pCi/L average = no excess lung cancer

4 to 10 pCi/L average = 30% increased lung cancer

Greater than 10 pCi/L average = 80% increased lung cancer

Sleeping with windows open = no excess lung cancer

Lung Cancer is the leading cause of Cancer deaths

164,000 new cases of Lung Cancer in 2000.

There has been a dramatic increase of Lung Cancer in Woman

Lung Cancer symptoms are so general that 75% of the time it has spread to other organs by the time it is detected

Only 15% of lung cancer victims survive 5 years

Radon causes Lung Cancer for 16,000 smokers and 2500 non-smokers per year.

Radon is responsible for 22% of non-smoker lung cancer

2nd hand Smoke causes 3000 deaths/yr and Asbestos 2000/yr

26% of the population smokes - 90% would like to quit but can't

Carcinogen Ratings

Class A

(demonstrated cancer causing) asbestos
tobacco smoke, benzene, **RADON**

Class B

(probable cancer causing) DDT,
alar, PCB, chewing tobacco, cholesterol

Class C

(limited animal evidence)

Class D

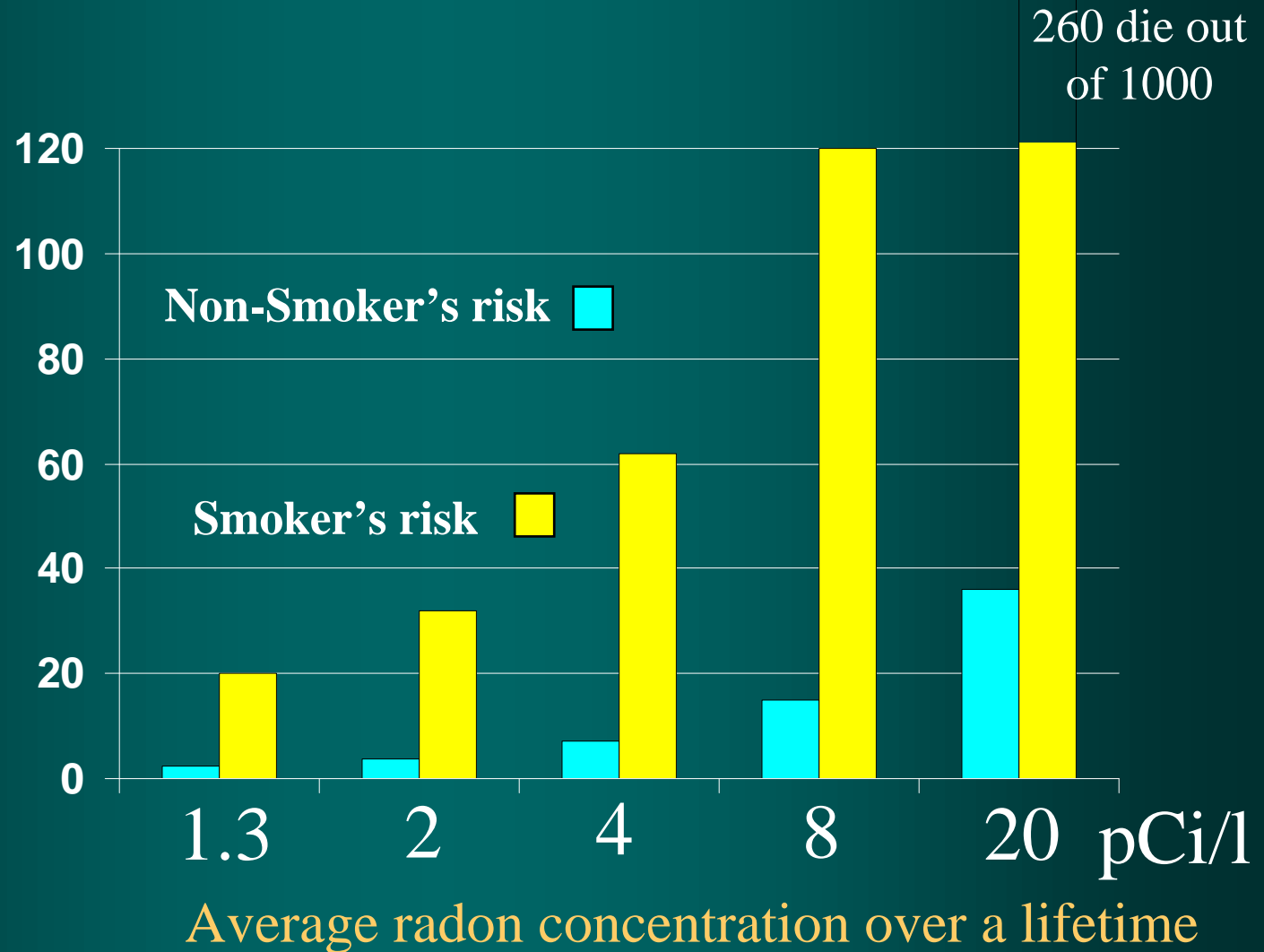
(inadequate evidence)
saccharin

There are Four Factors necessary for a “Class A” carcinogen rating and Radon has all of them

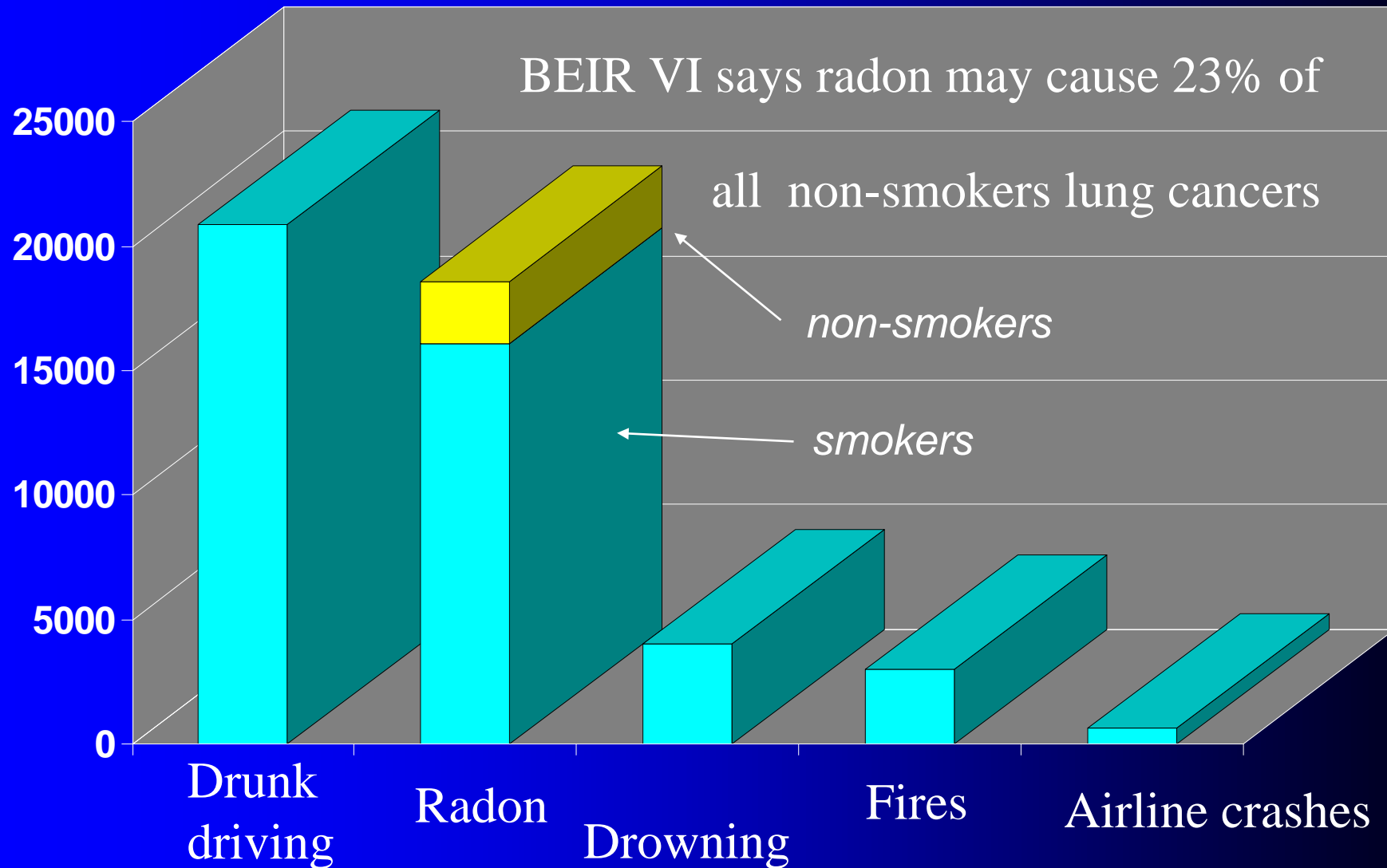
- Physical Model of how it happens
(alpha damage to lung cells)
- Animal studies showing an effect
(animals exposed to radon had a higher rate of lung cancer)
- Occupational or Residential studies
(miner studies and case control studies show a connection)
- Opportunities for exposure
(more time spent indoors with house sealed up)

EPA has calculated how many many people would die of lung cancer if:

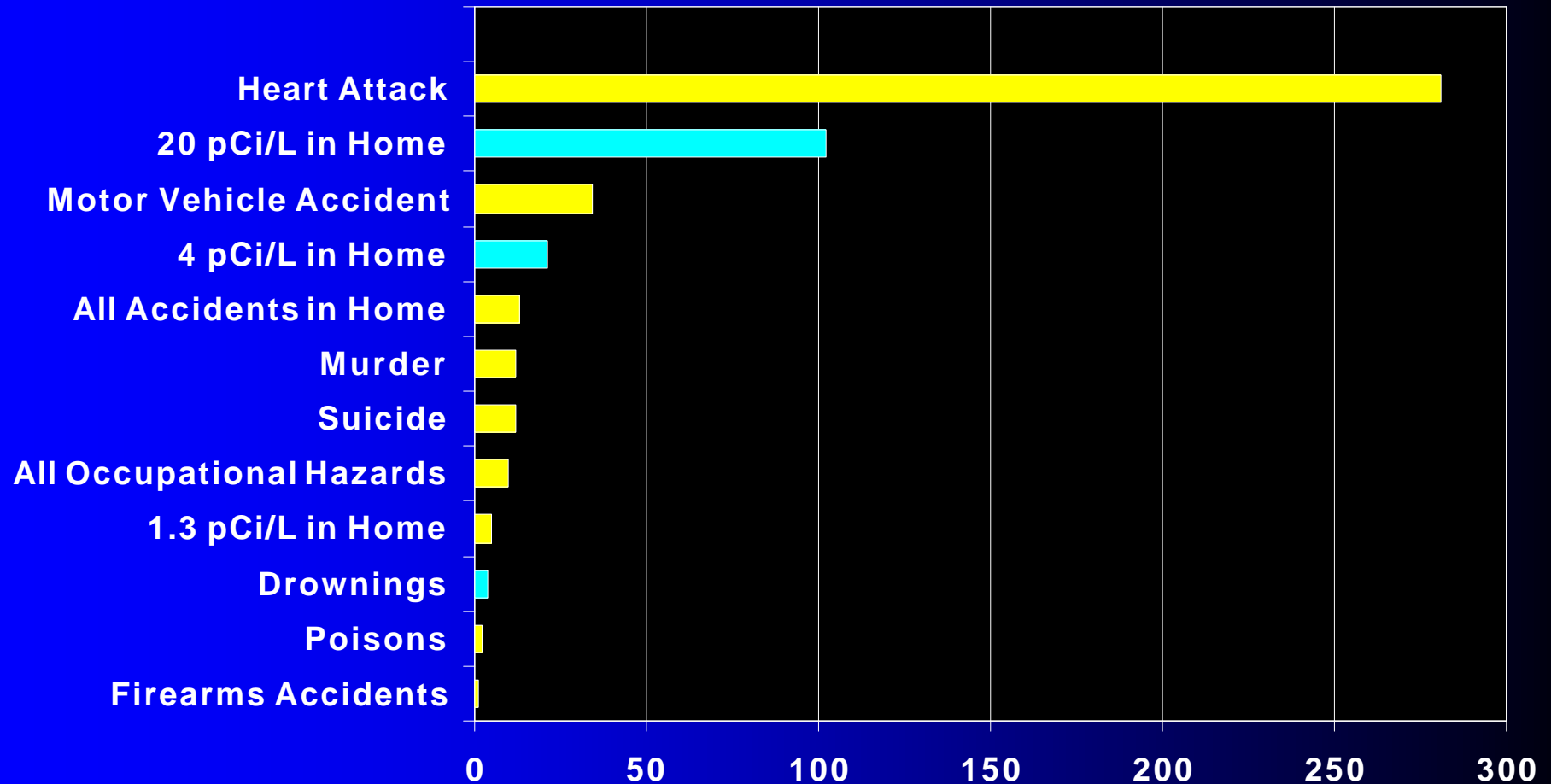
Number of people who would die of lung cancer if a 1000 of them were exposed to these amounts of radon for a lifetime



Comparison to other causes of Death



Comparison of estimated deaths annually per 100,000 persons for different causes

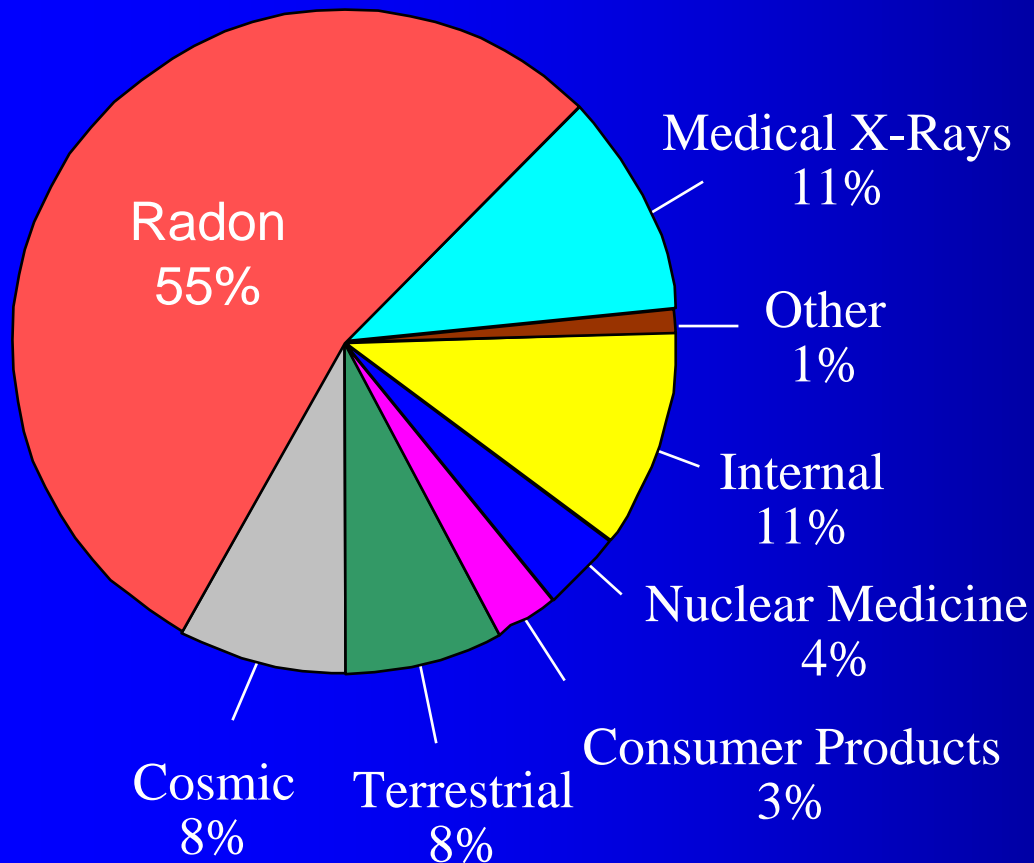


Jacobsen, c1990, University of Michigan

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Sources of Radiation Exposure to the U.S. Population

Radon exposure is based on an average indoor exposure of 1.3 pCi/L



Radon is by far the greatest single source of radiation to the general public.

These Organizations consider Radon to be Dangerous

American Lung Association

American Medical Association

Environmental Protection Agency

National Academy of Sciences

US. Surgeon General

American Cancer Society

EPA and Surgeon General
recommend that everyone
test their home for radon

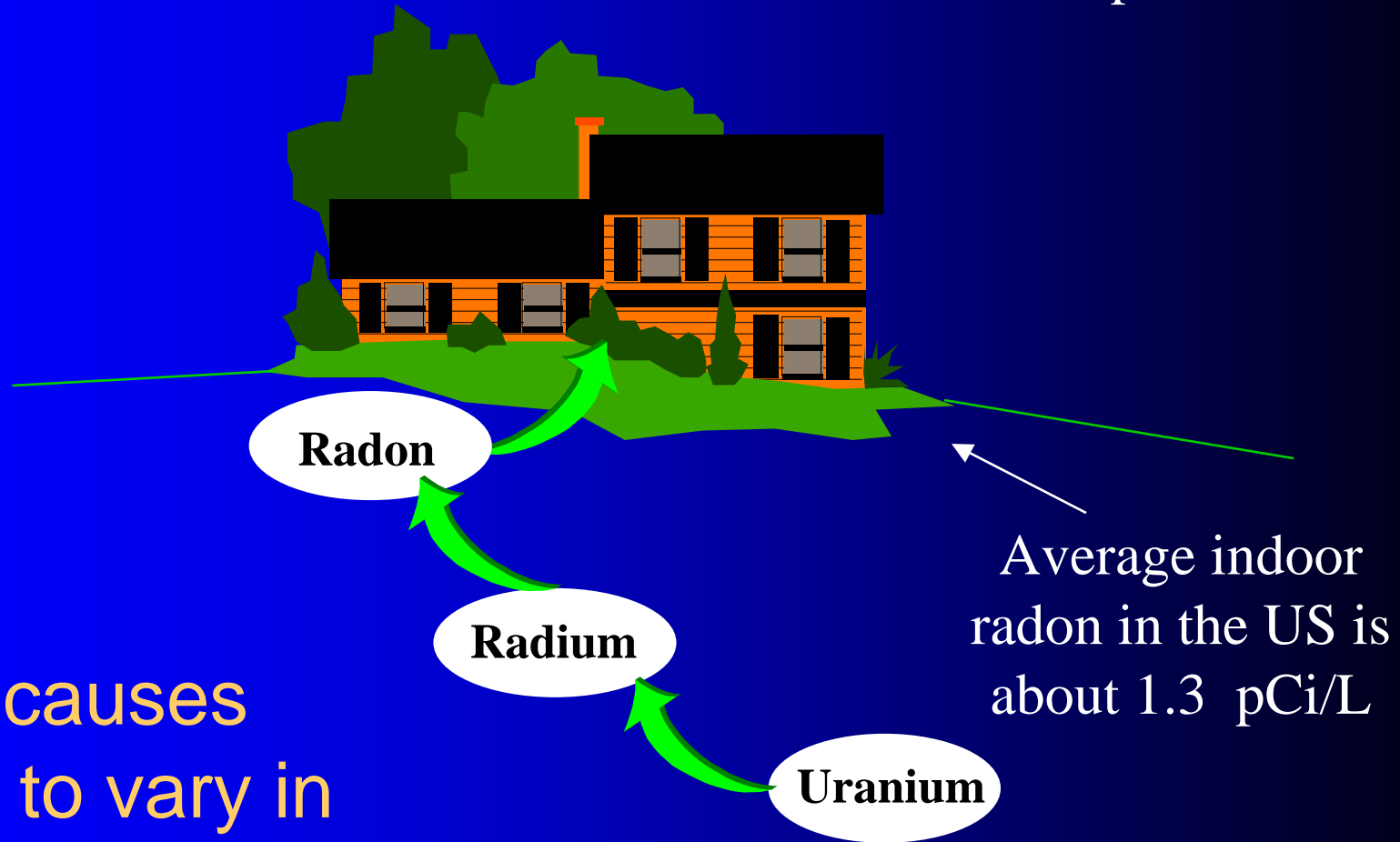
and



If your home
is above 4 pCi/L, Fix It

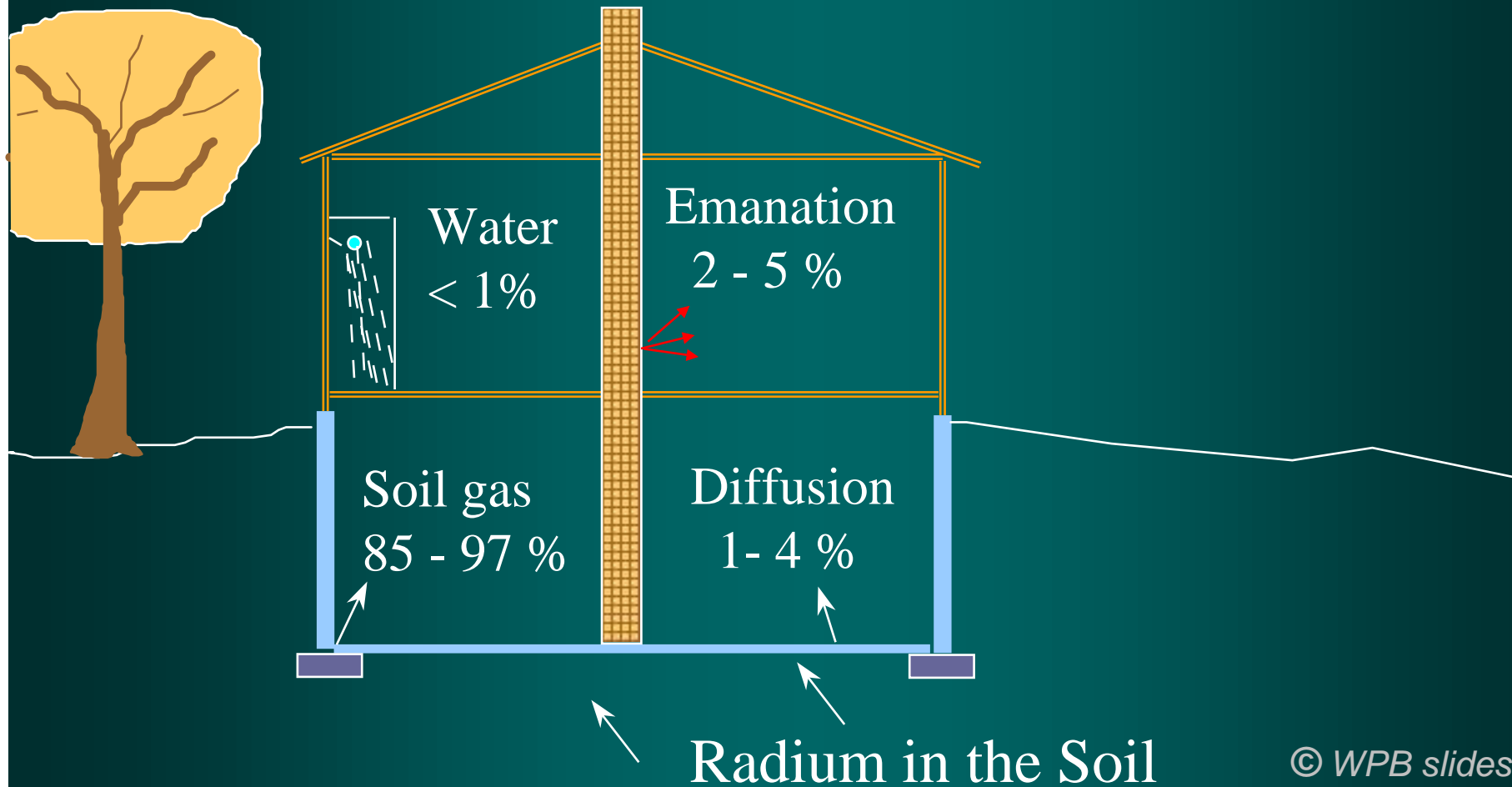
Radon Entry & Behavior

Average outdoor radon in the US is about 0.4 pCi/L

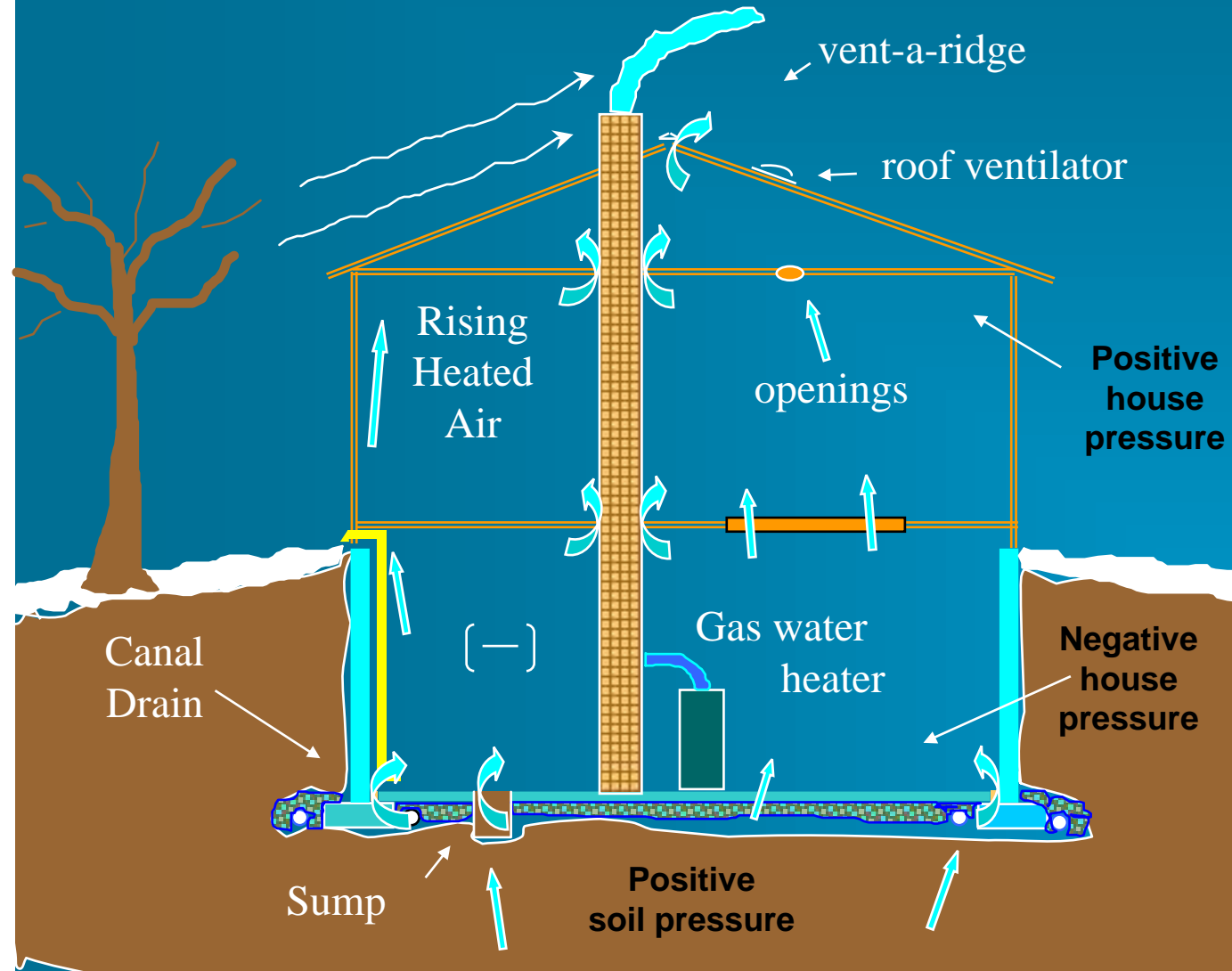


What causes radon to vary in vacant & occupied houses

Radon gets into our homes in several ways



Warm air escapes out the top of our homes in the heating season (stack effect)

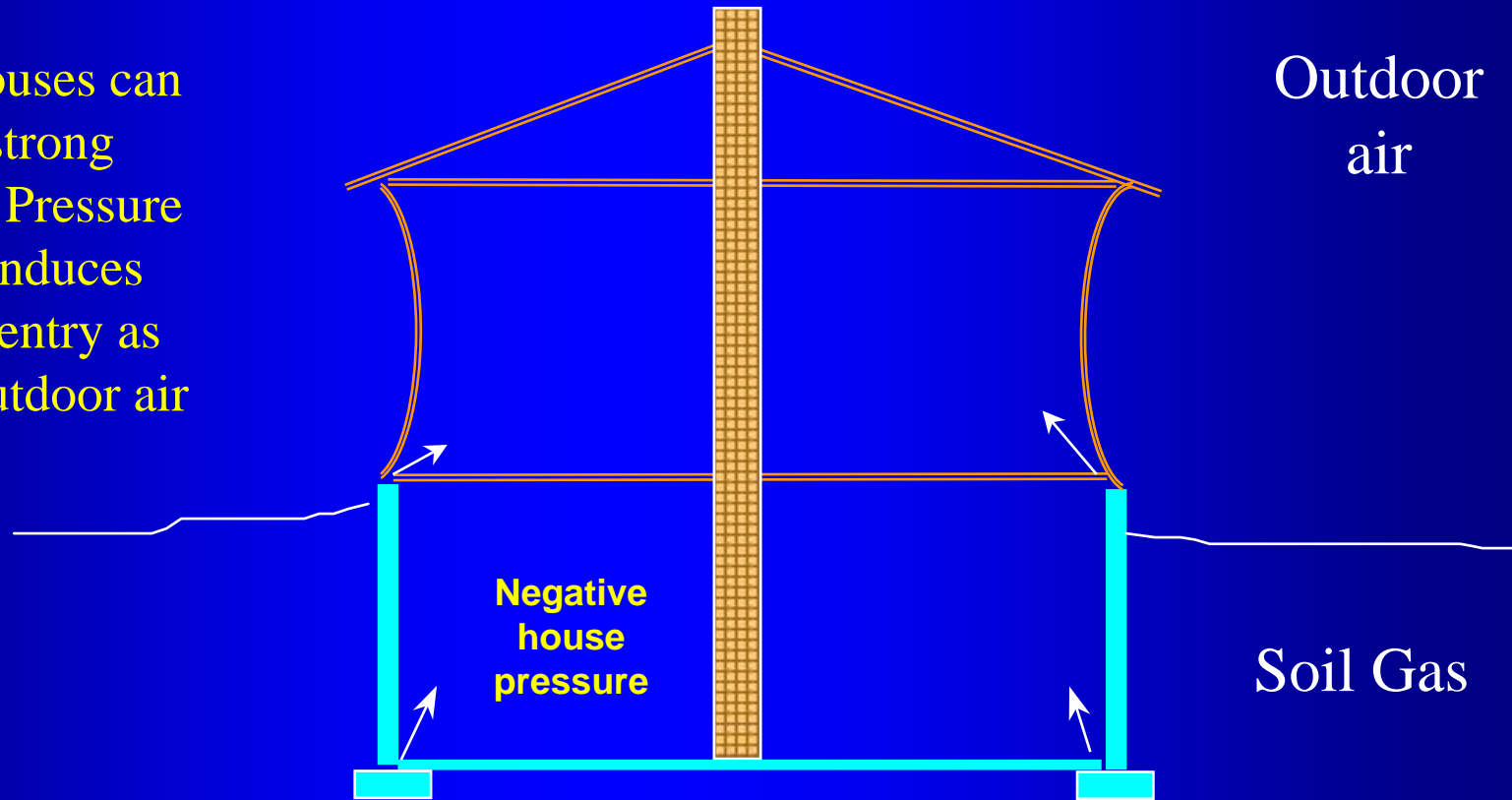


The escaping warm air creates negative house pressure in the lowest level of the house

The negative house pressure draws in radon laden soil gas

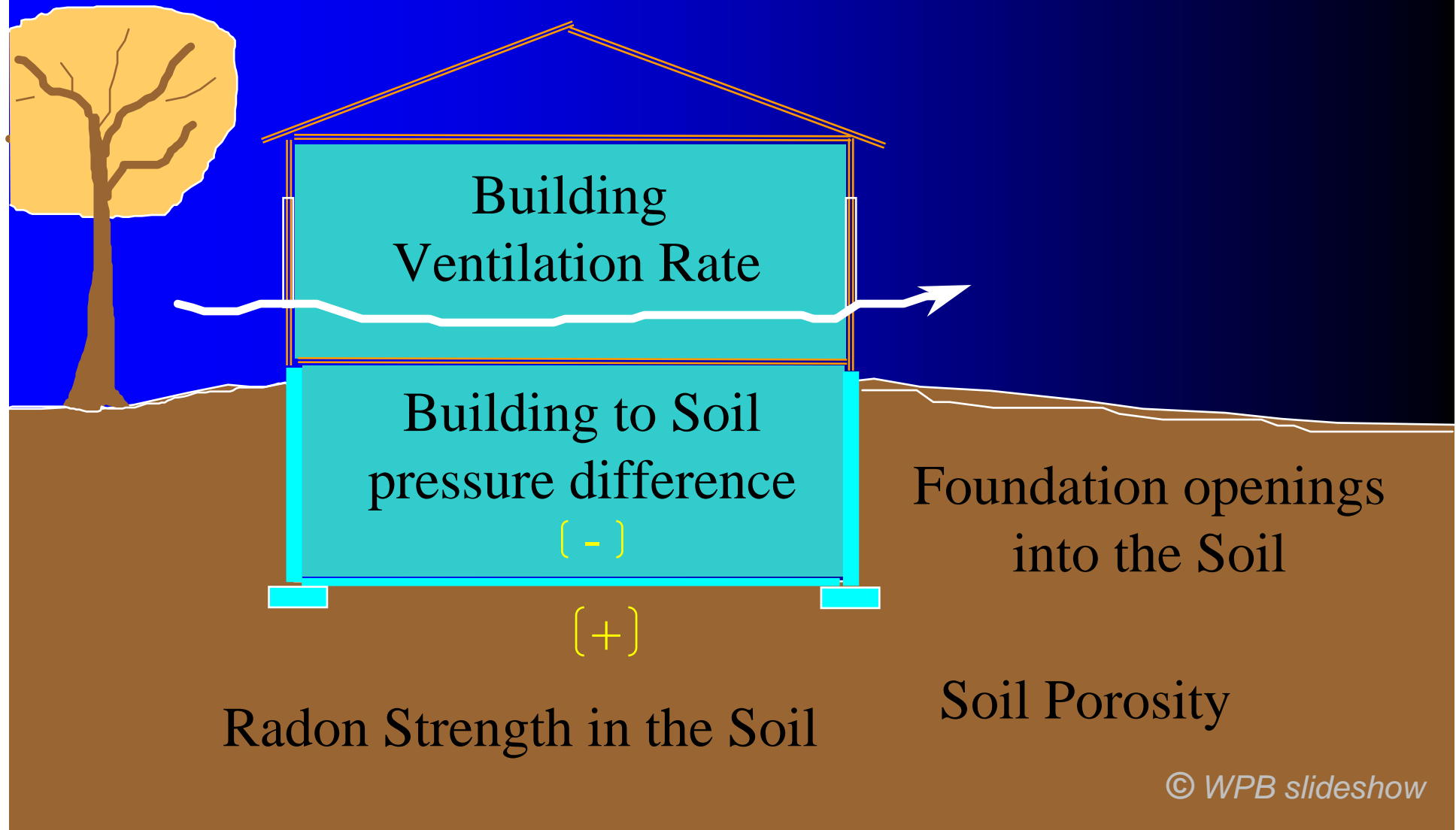
A drafty house can still have radon

Drafty houses can have strong Negative Pressure which induces soil gas entry as well as outdoor air

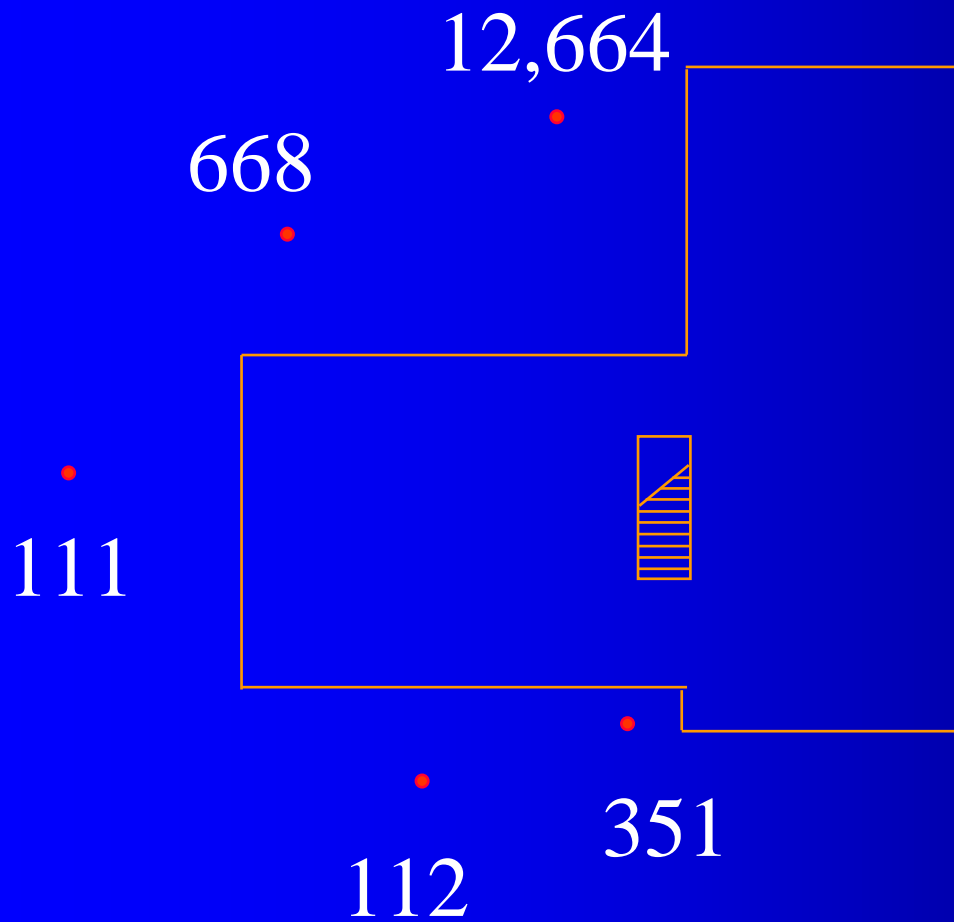


There is no correlation between house age or house ventilation levels and radon levels

Indoor Radon Levels depend on these factors:



There can be large variations in radon levels in the soil



• 77,194

• 89,100

These were actual radon levels measured in the soil around a home in NJ

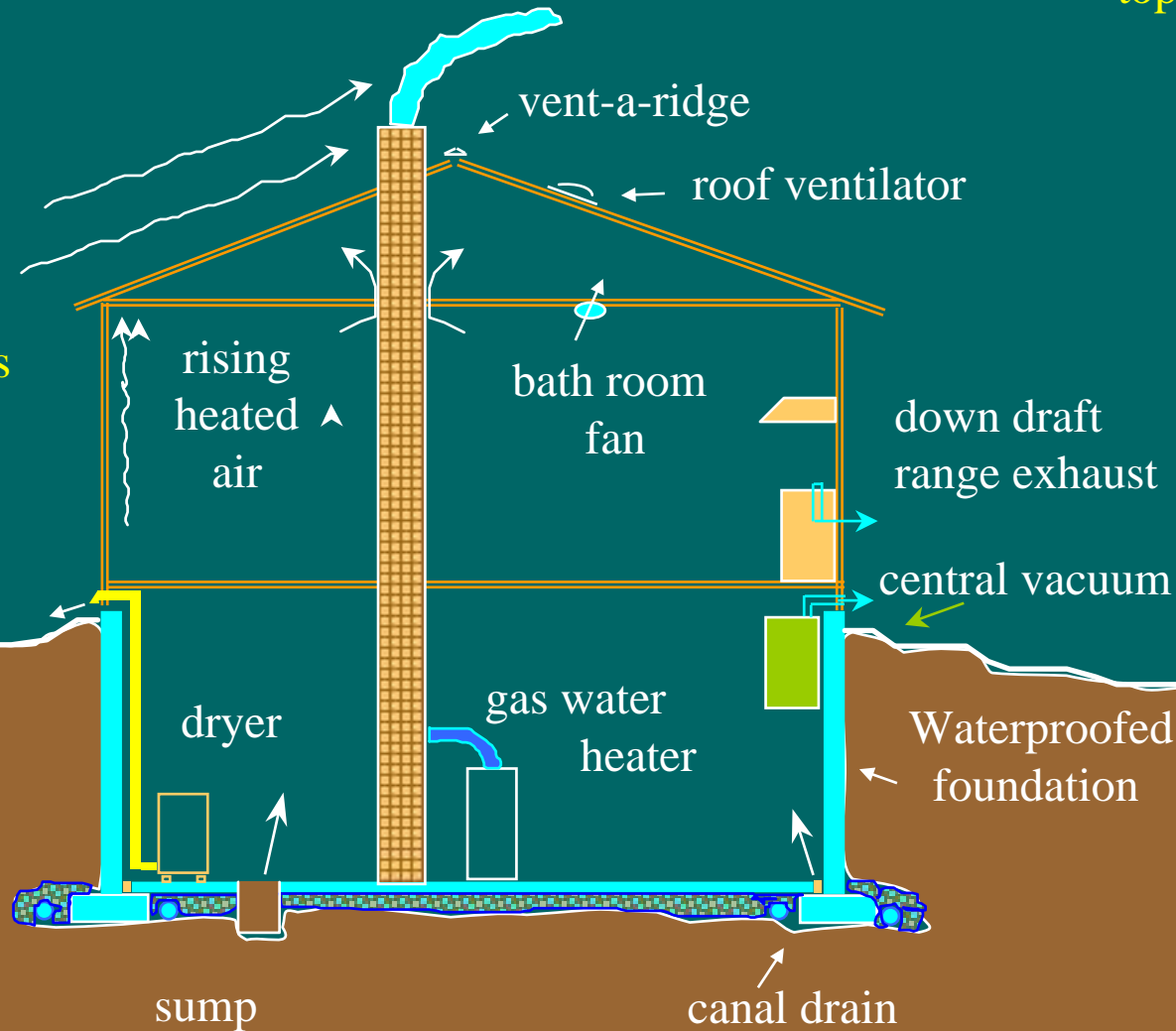
Houses act like Soil Vacuum Cleaners

Warm air
escapes out the
top of the house

Mechanical
equipment
exhausts air

Most houses
have no
mechanical
outdoor air
supply

Tight walls
keeps
pollutants
inside



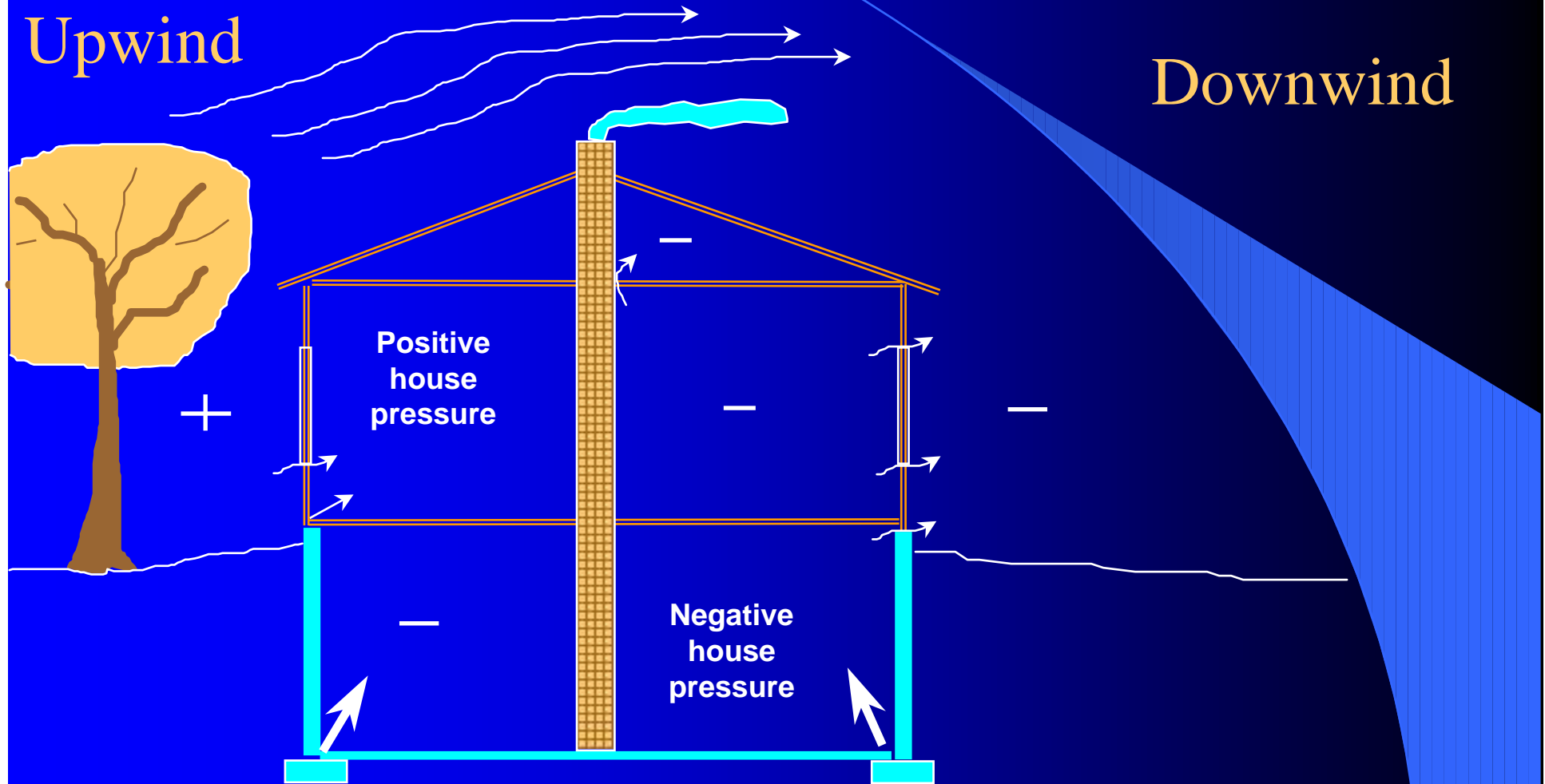
Common household appliances can cause negative pressures inside a home

	<u>Typical exhaust</u>
Air tight wood stove	30 cfm
Combustion Appliance	20 – 70 cfm
Bathroom Fan	25 – 90 cfm
Clothes Dryer	100 cfm
Wood Fireplace	170 cfm
Downdraft range exhaust	300 – 400 cfm

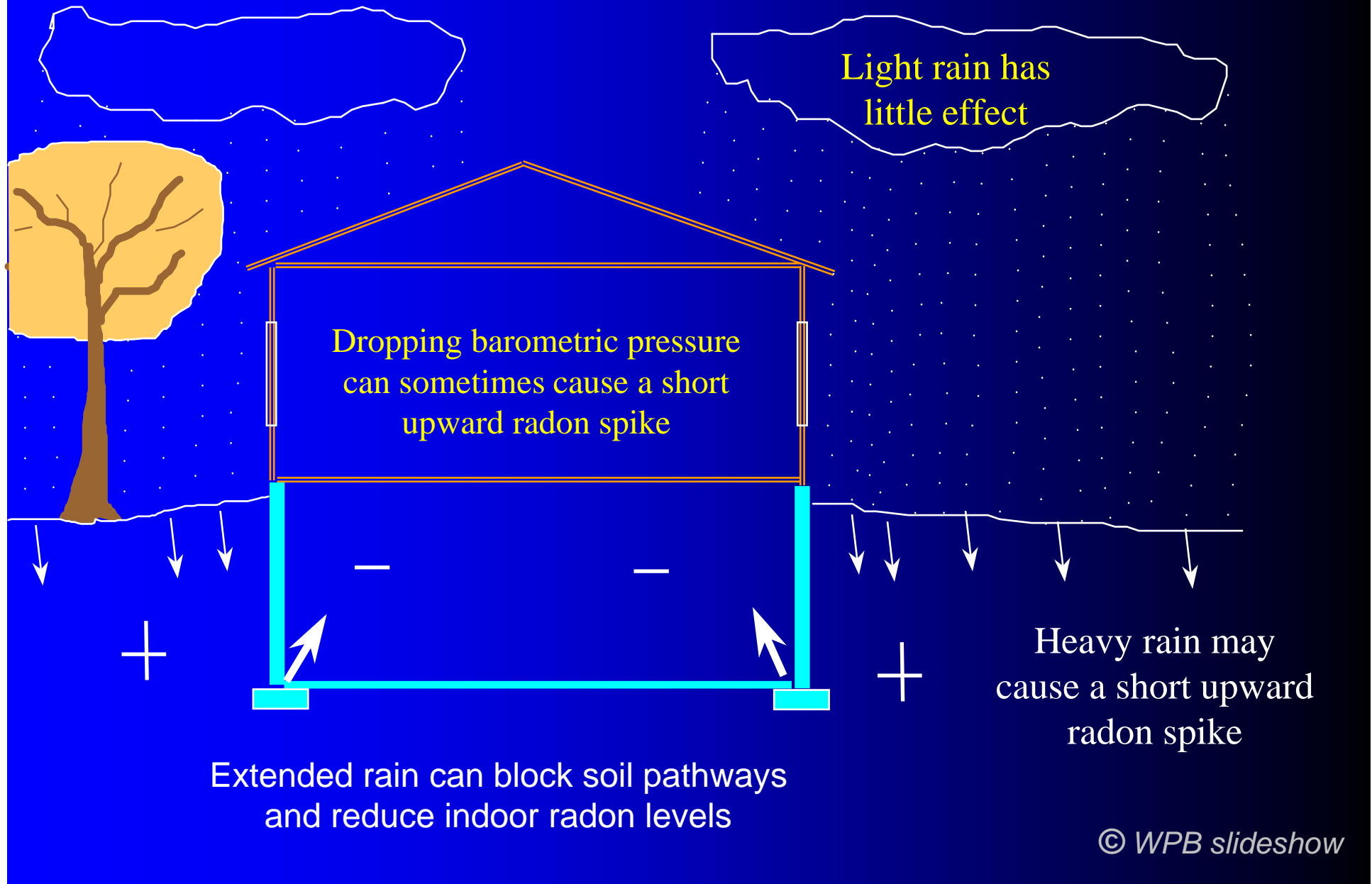
cfm is airflow in cubic feet per minute

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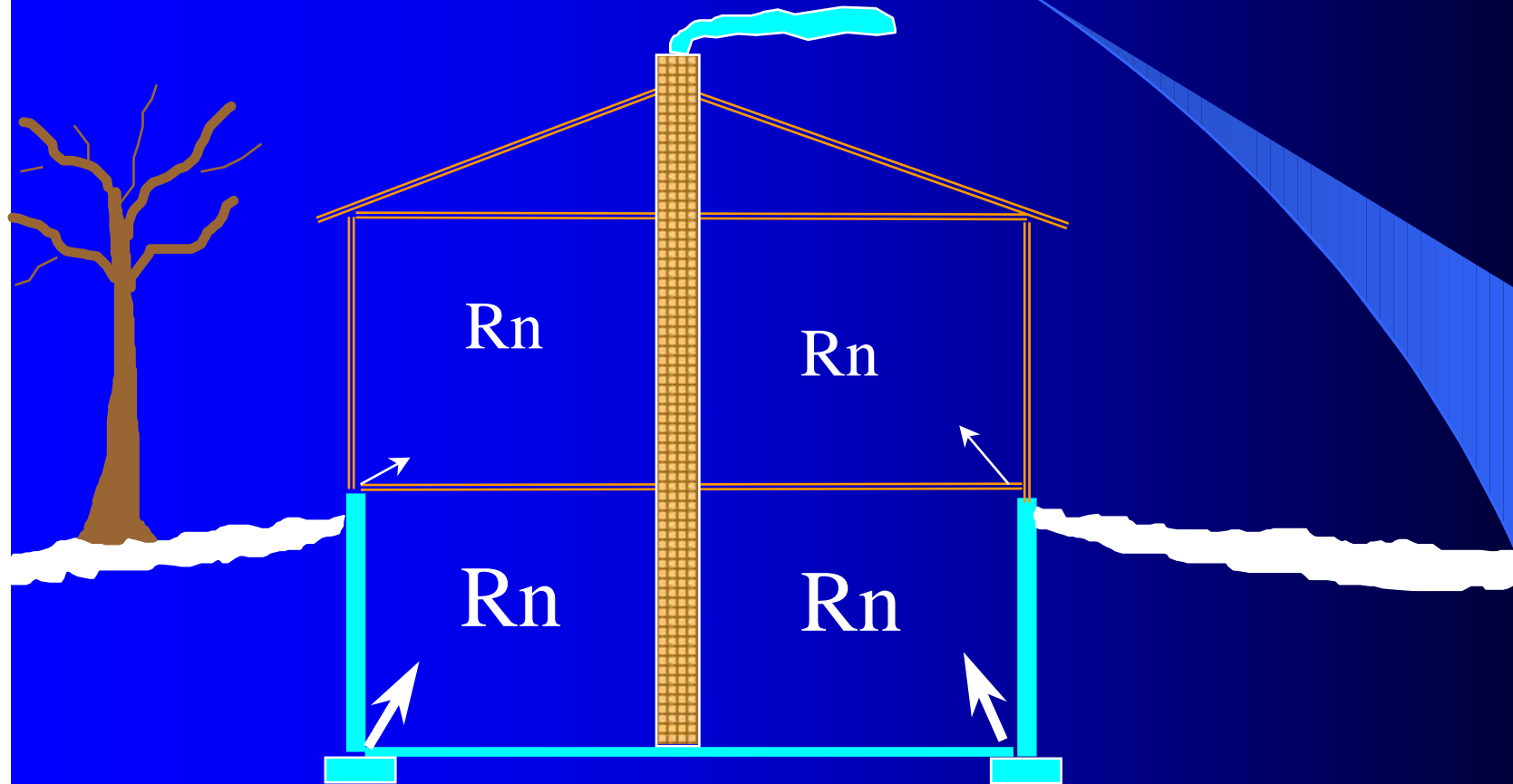
Strong wind can affect the radon levels



Heavy rain may also affect radon levels

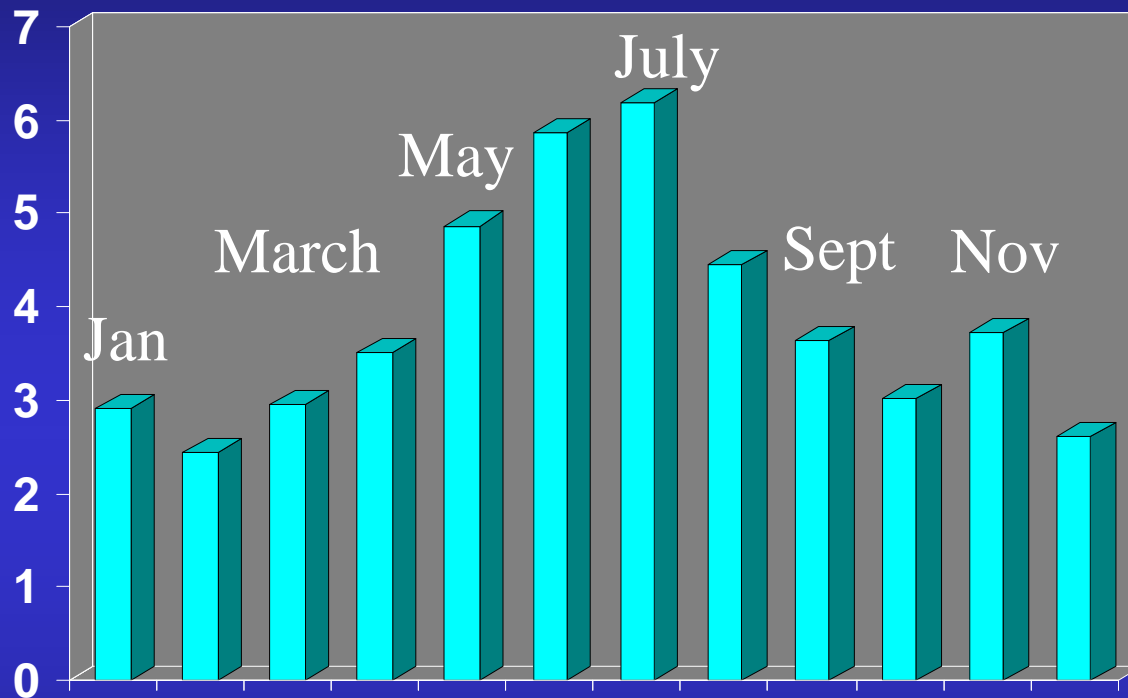


Radon Levels are typically higher during the heating seasons



Some houses have higher basement levels in the summer

First floor tends to have 2 times to 6 times lower radon levels than the basement



This data is based on multi-level radon tests done in 871 Pennsylvania homes

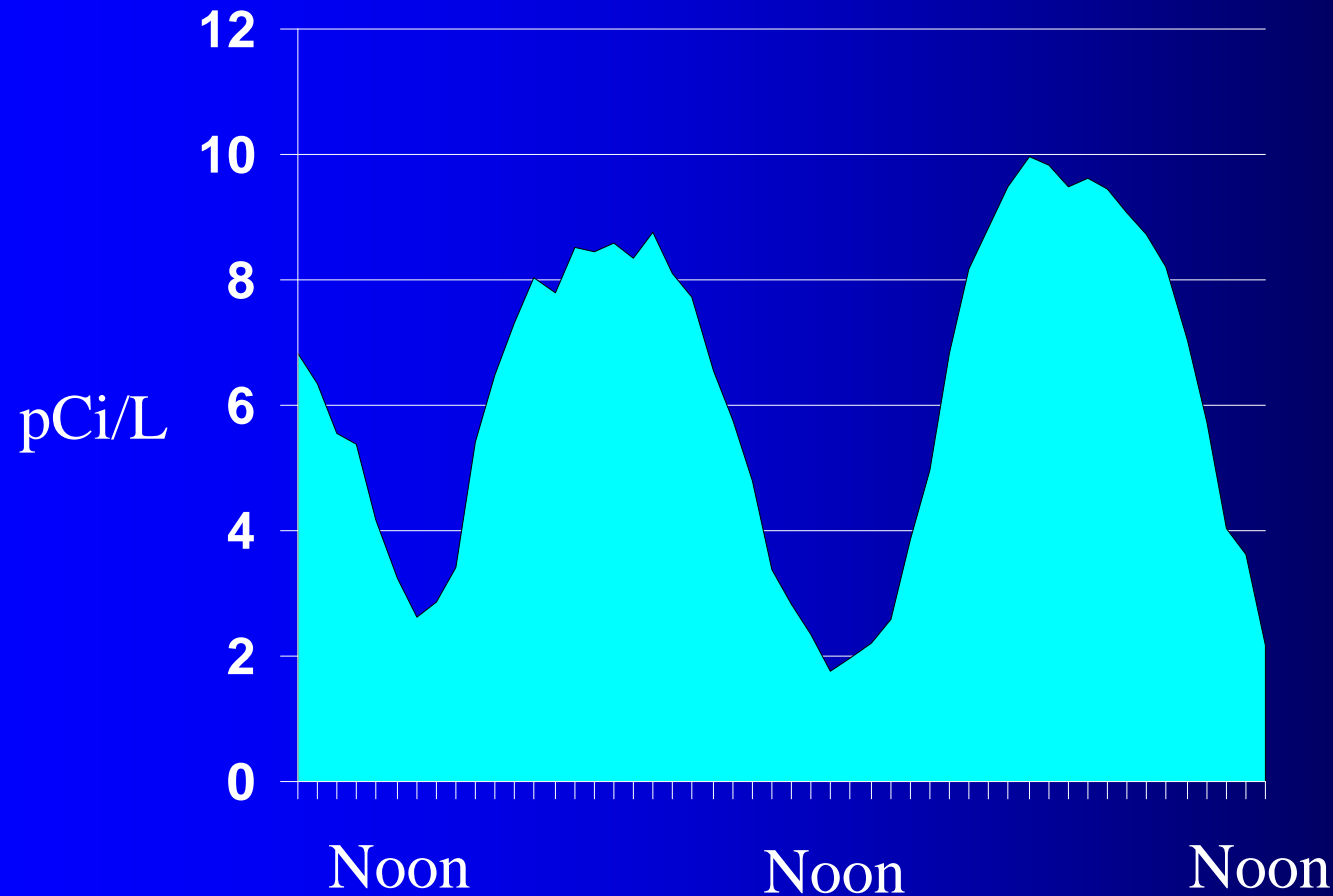
In the Summer the 1st floor is 4 to 6 times lower than the basement

In the Winter the 1st floor is 2 to 3 times lower than the basement

The difference between floors is greater during the summer

Radon levels fluctuate Hour by Hour

Usually radon levels are higher at night and lower during the day



This graph depicts common Diurnal Variation

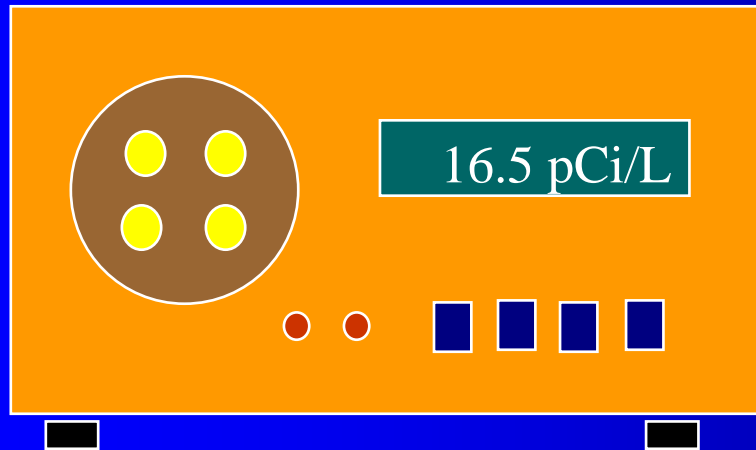
Daily radon variation is usually greater in the summer

Radon Measuring Devices



Two generic types of test devices

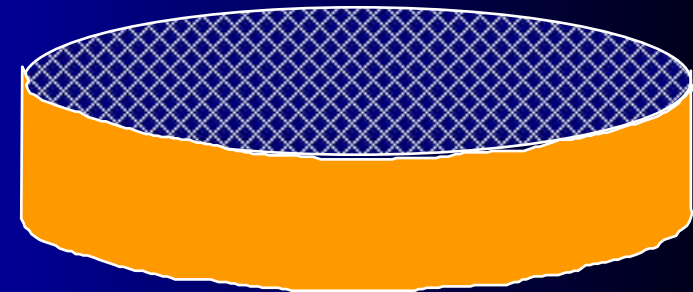
Continuous Radon Monitor or CRM



CRM provides:

radon levels hour by hour
&
tamper resistant features

Passive Detector



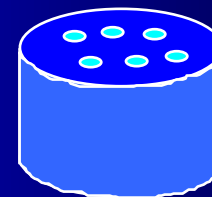
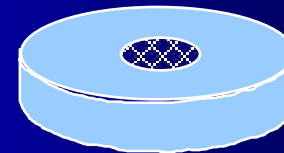
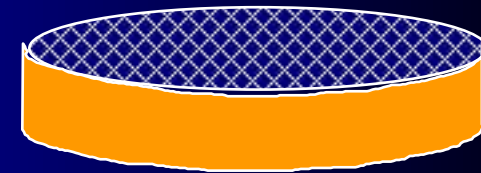
Passive detectors:

provide only a
single average result
&
are less expensive

Both methods can be accurate

Four Types of Passive Detectors

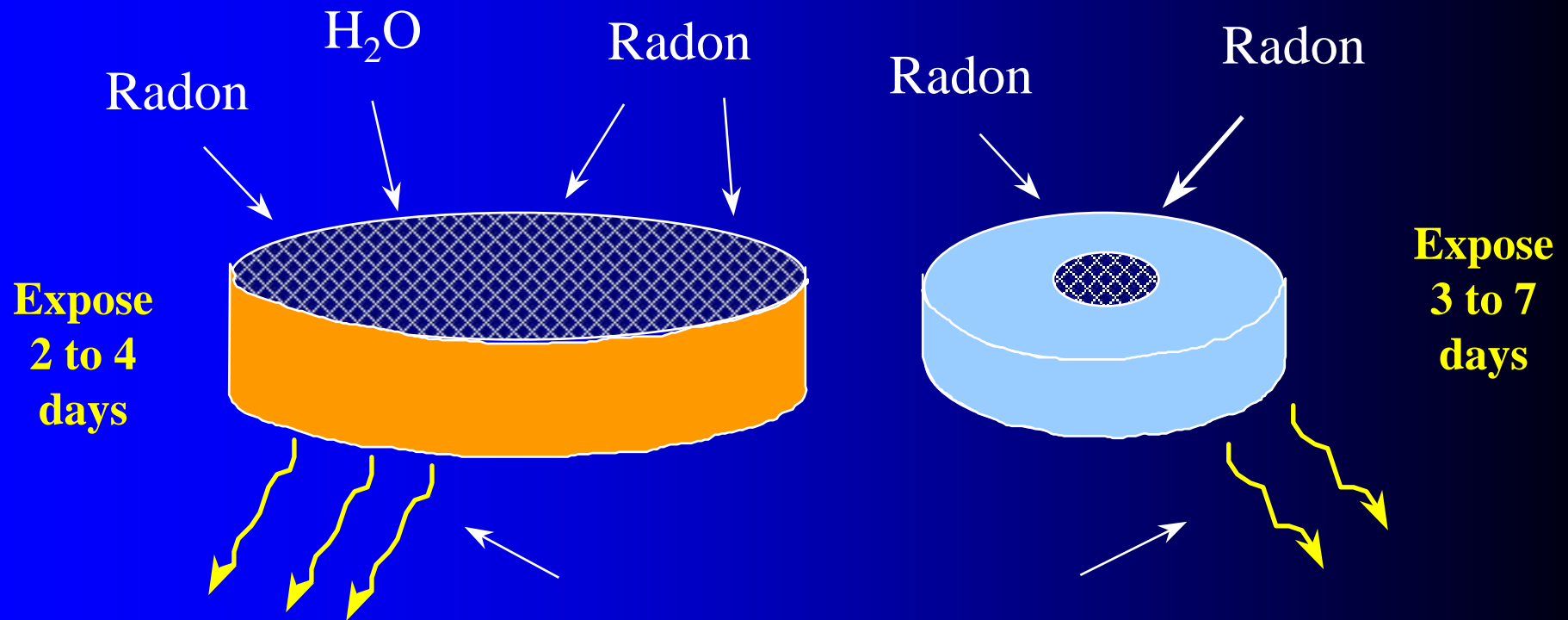
- **Open Face Charcoal**
(2 - 4 day exposure)
- **Diffusion Barrier Charcoal**
(3 - 7 day exposure)
- **Electret Ion Chamber**
(2 - 7 days or 90 - 365 days exposure)
- **Alpha Track Detector**
(90 - 365 day exposure)



Activated Carbon Charcoal Detectors

Open Face

Diffusion



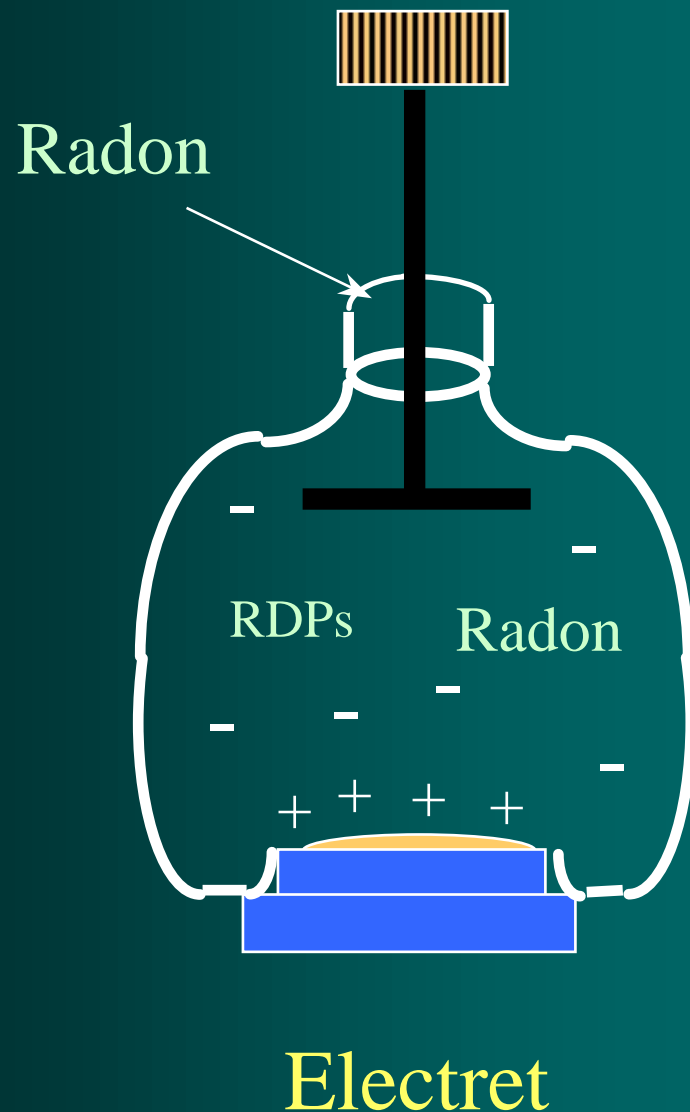
Lab measures gamma from decay of RDP's

Detector must be returned to the lab promptly

Charcoal Detector characteristics

- Easy to use
- Least expensive
- Long shelf life
- Lab analyzes the results
- Has reasonable accuracy
- Must expose a specific amount of time
- Open Face are sensitive to high humidity

Electret Ion Chamber (EIC) characteristics



The decay of Radon & Radon Decay Products inside the chamber causes ionization. This causes the electret to lose volts

Electret voltage is read before & after exposure to determine the radon levels

Electret Ion Chamber (EIC) characteristics

EIC's have demonstrate good accuracy
but it's always best to expose Duplicates

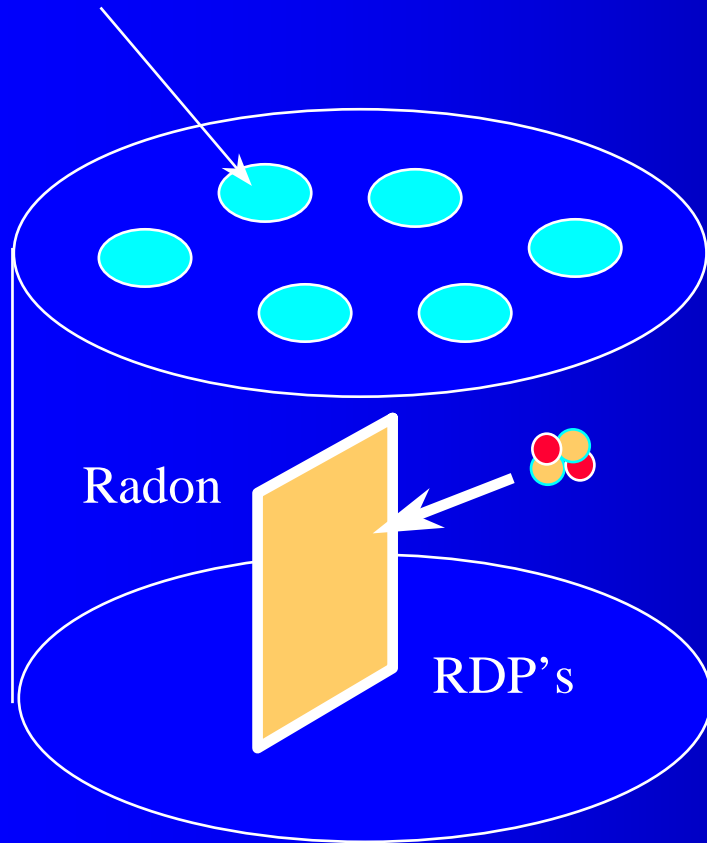
EIC's are more tamper resistant than charcoal detectors

Can vary exposure from 2 to 365 days
depending on chamber size & electret

The testing company analyzes the result.

Alpha Track Detectors

Radon entry



Alpha particles from decay of Radon and RDP's damage the plastic chip

Marks are enhanced at the laboratory and counted to determine the average radon level

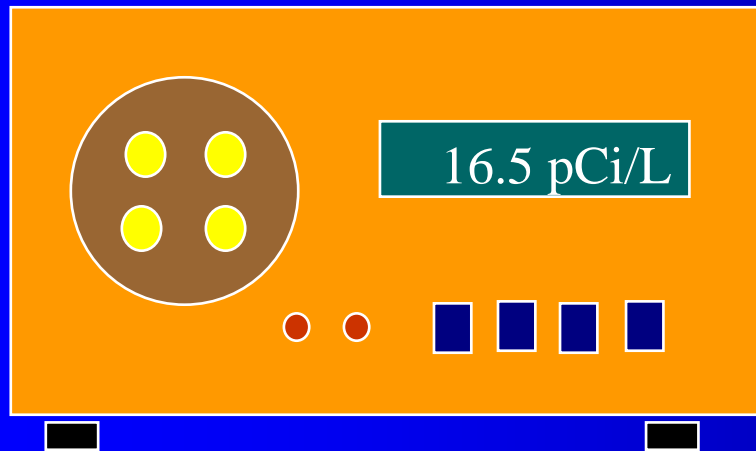
Alpha Track characteristics

Alpha Tracks can measure the average radon levels over 90 to 365 days

They are not affected by the testing environment

Cannot be used for short term tests

Continuous Radon Monitors (CRMs)



CRMs record hour by hour radon variation by counting alpha emissions from Radon or Radon & RDPs

Some CRMs can also monitor hourly temperature, barometric pressure, motion, humidity etc.

Are CRMs the best choice for Real Estate testing ?

CRM's can have Tamper Resistant features

CRM's have demonstrated excellent accuracy

CRM's can indicate the impact of
weather on test results

What are Remote calculated CRM's ?

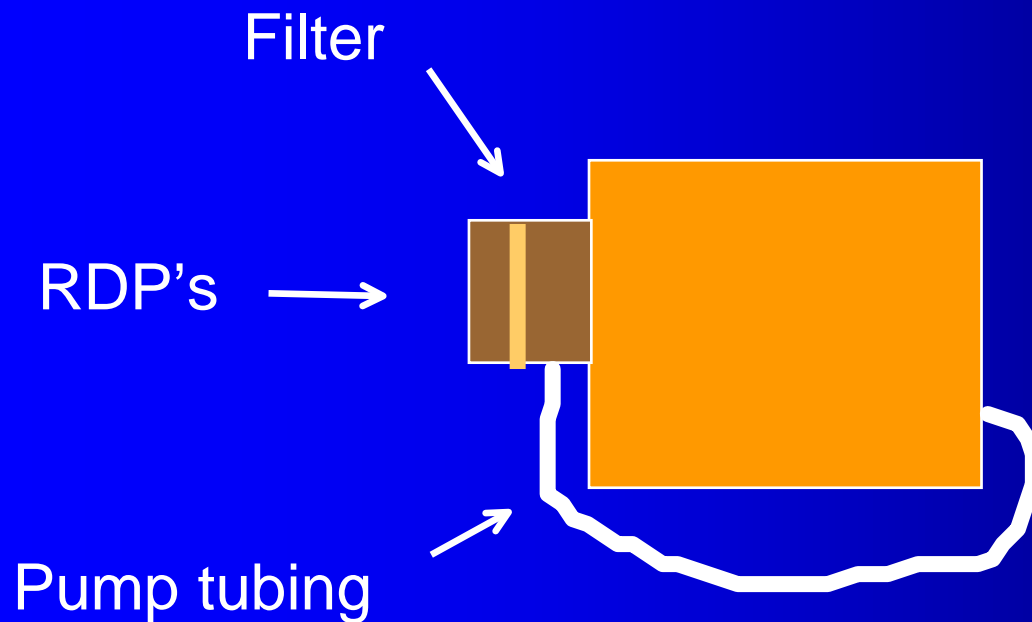
A tester leases
a CRM from
an Equipment Supplier

The tester modems the CRM data to
the equipment supplier who faxes
results back to the Tester's office

Grab Samples & Sniffer tests

- Grab samples and sniffer tests are used primarily by mitigators to diagnose radon entry
- These are diagnostic measurements that cannot be used to determine the need for mitigation

Continuous Working Level Monitors (CWM)



CWM's measure alpha decays from RDPs collected on a filter

CWM only measure radon decay products (WL) not Radon (pCi/L)

CWM's can measure very low concentrations



How can you determine a Tester's qualifications ?

Is Tester state certified ?

In non-certifying states they should be NEHA or NRSB listed

www.radongas.org & www.nrsb.org

Does Tester use tamper resistant features?

Does Tester obtain a signed
“Non-interference Agreement”?



You can always test your own home

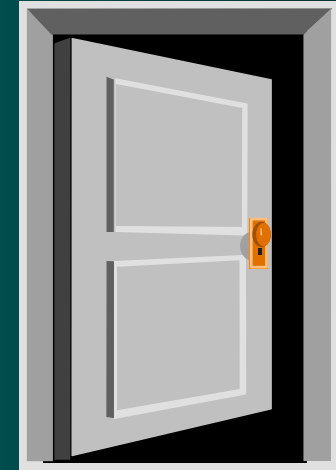
You can purchase charcoal detectors or long term alpha tracks via the internet, calling a supplier or from a local hardware or building supply store

Just follow the instructions. After exposing the detectors, promptly mail them back to the laboratory

Measuring Radon

*The EPA specifies
the following
Testing Conditions
be followed*

Short-term measurements
require
Closed House Conditions
for
12 hours prior to the start of the test
and all during the test



- Fireplace damper closed
- Window air conditioners set to recycle only
- All windows & doors closed except for normal entry and exit
- Attic fans are OK but don't use window or whole house fans

Minimum test period is 2 days

Short Term test is 2 - 7 days
with closed house conditions

while a

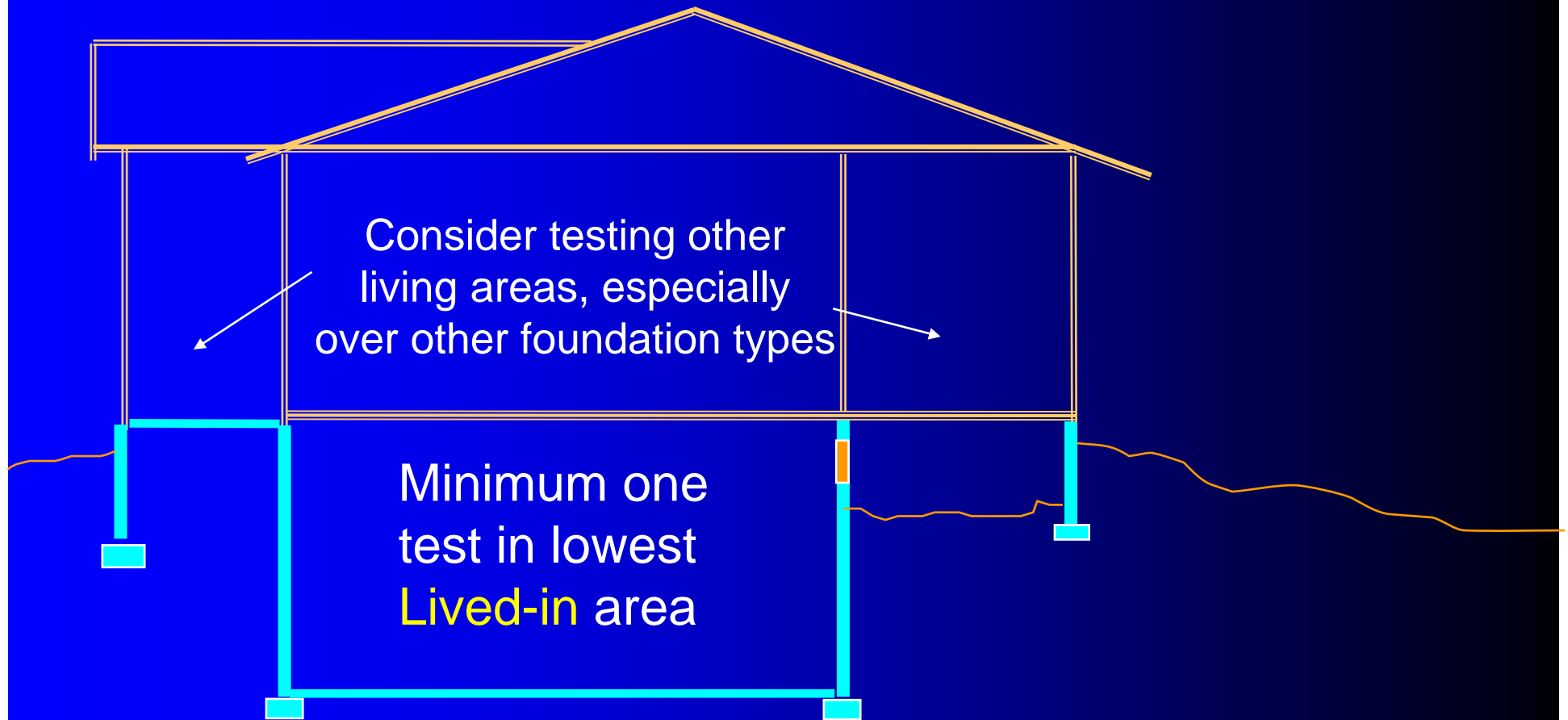
Long Term test is 3 to 12 months
& does not require Closed House conditions

94% of the time Short Term tests provide the
same mitigation decision as a Long Term test

Consider Retesting if :

- Test conditions were not maintained
- Extended heavy Rain or Winds speeds greater than 25 mph for longer than an hour (a Severe Storm)
- One test result is less than 4 pCi/L and the other is greater and the greater is twice the level of the lesser result
(Duplicate results of 2.5 pCi/L & 6.0 pCi/L)

What rooms should be Tested ?



For Real Estate transactions test the **Lowest Livable Area**

What does “Lowest Livable” mean ?

- | Lowest area of the home that could be used as a playroom, family room, workshop or office without needing major structural change such as a concrete floor or more headroom.
- | If a basement only needs a carpet for children to play in, it is considered Livable
 - | A small furnace room is not Livable

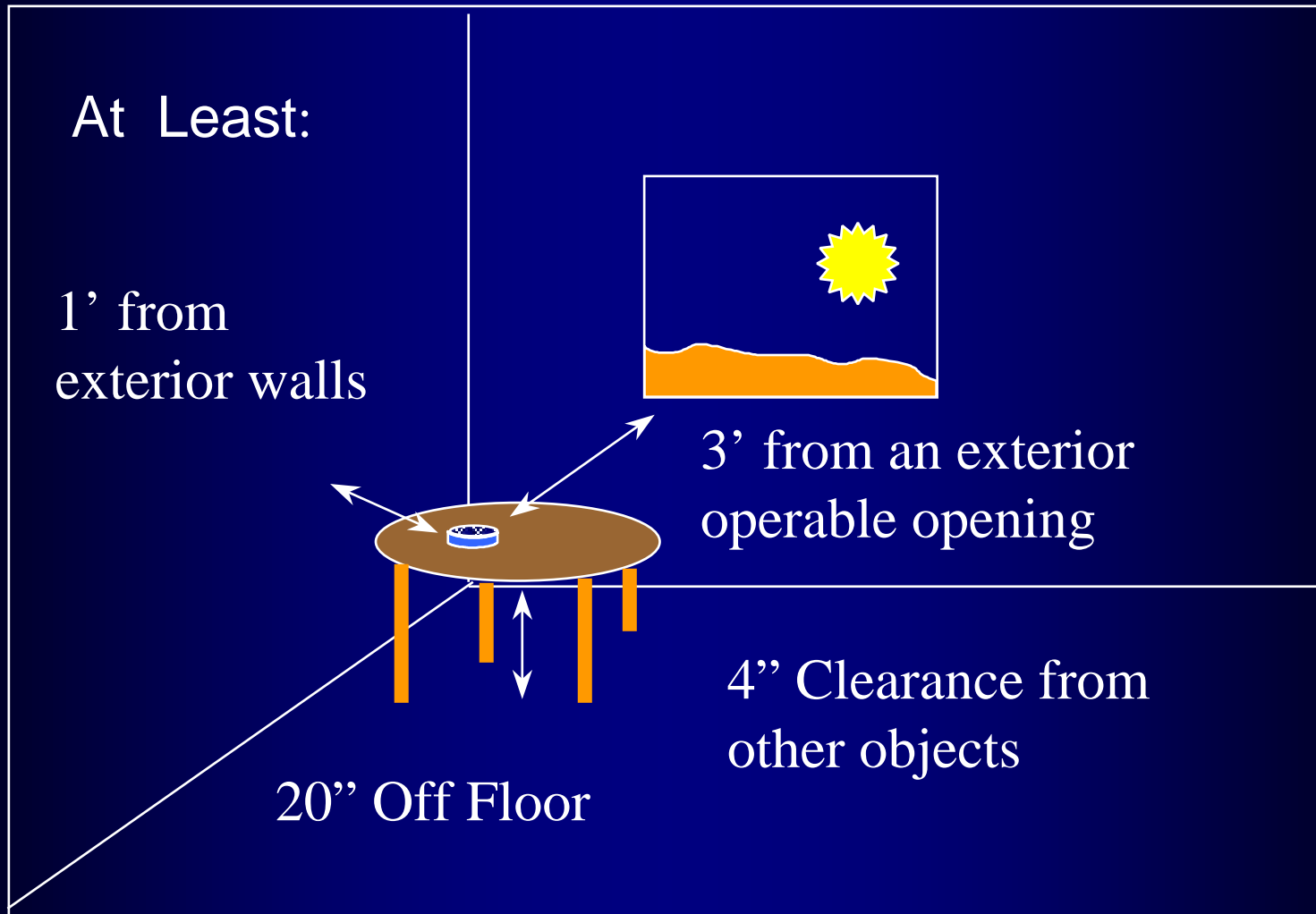
Do NOT test:

Closets, Bathrooms,
Kitchens, Storerooms, Garages,
Crawl Spaces, or Attics

You can test:

Bedrooms, Family Rooms,
Living Rooms, Dining Rooms,
Office, Study, Playroom, or Workshop

How far must a Detector be from windows & doors ?



Consider exposing two detectors at the same time. (Duplicates)

- Duplicate radon results will vary. Duplicate results greater than 4 pCi/L should be within 10% to 30% of each other
- If duplicates have a greater variation than this, contact the Tester or the laboratory
- The lower the radon levels, the greater the percentage variation between duplicate results

Commercial Buildings

***EPA* has not defined workplace radon levels.**

4 pCi/L action level is typically used

Use School Testing protocols for commercial buildings

Radon fix typically involves HVAC equipment

Mitigators need commercial experience

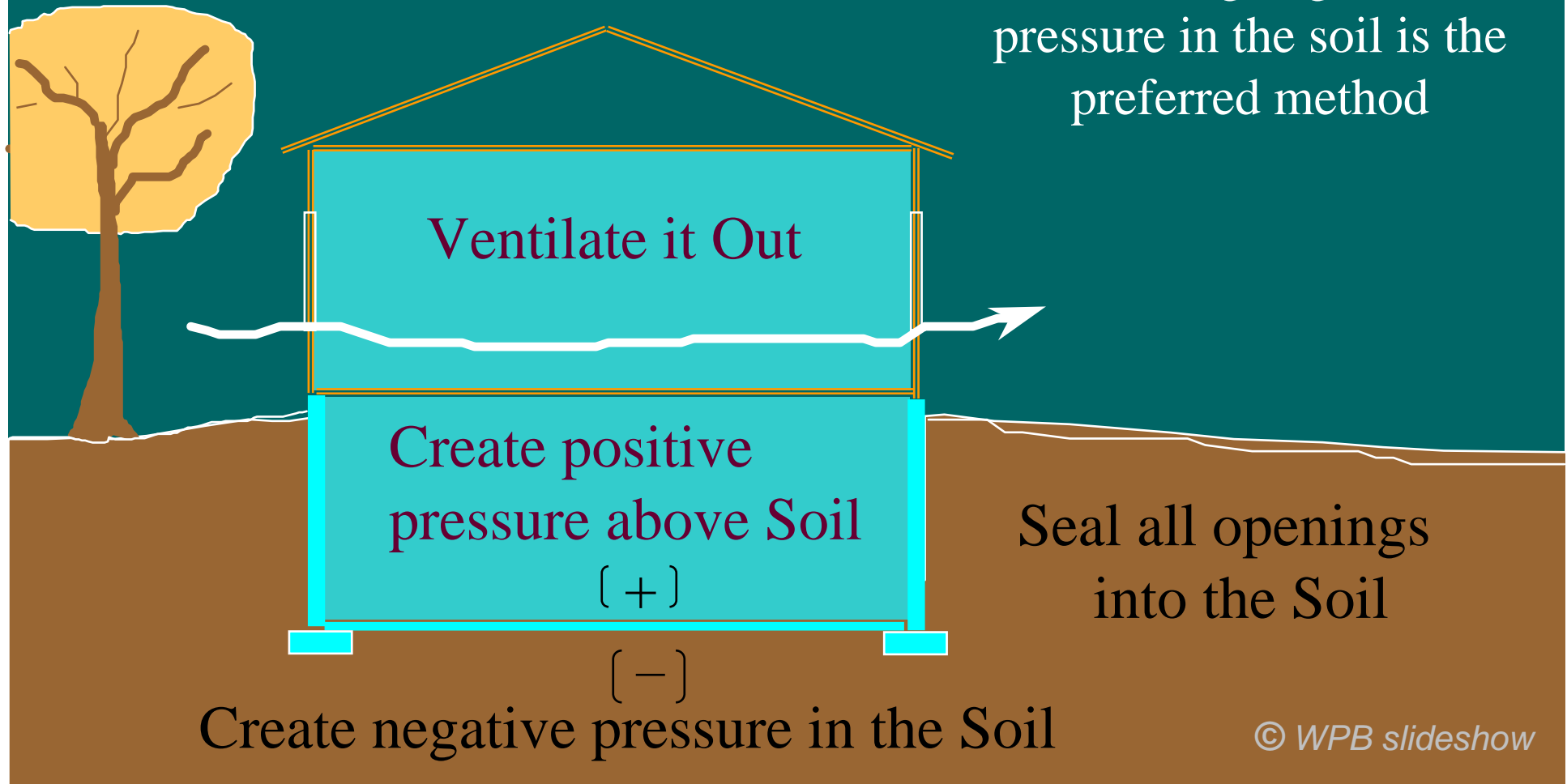
School Testing Protocols

- Test all rooms in contact with the soil
- Test the whole building at the same time
- Test during occupied days (work week)
- Maintain closed building conditions
- HVAC should be operating normally

Radon Mitigation

Four Mitigation Methods

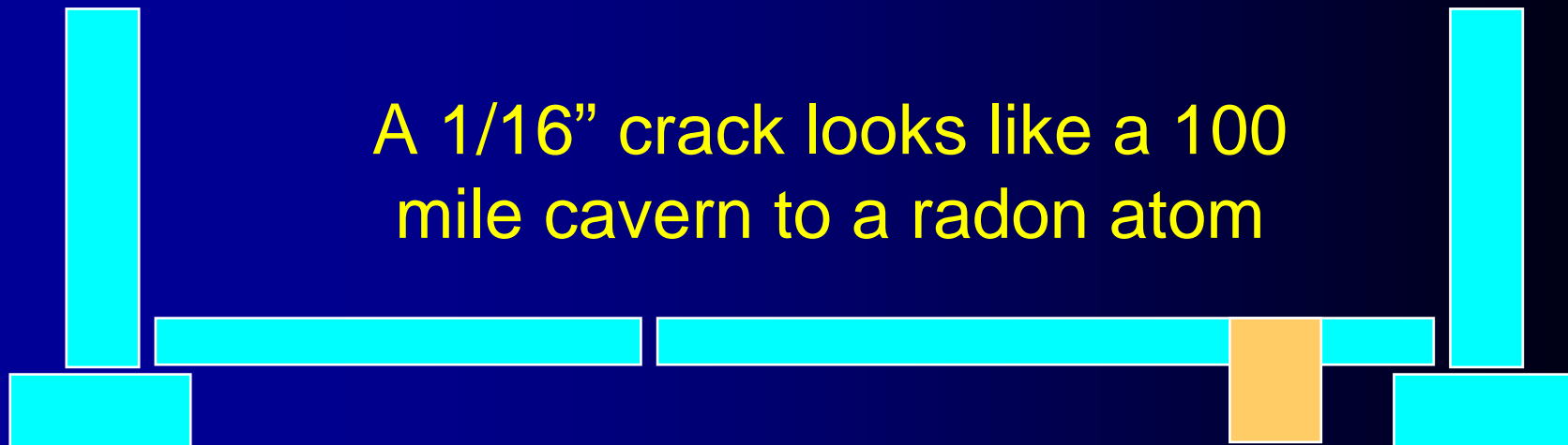
Creating negative pressure in the soil is the preferred method



Sealing an open sump pit will usually not reduce Radon Levels ?


One research project found it only took the equivalent of ten feet of a 1/16" crack in the basement floor to maintain radon levels above the Guideline

A 1/16" crack looks like a 100 mile cavern to a radon atom



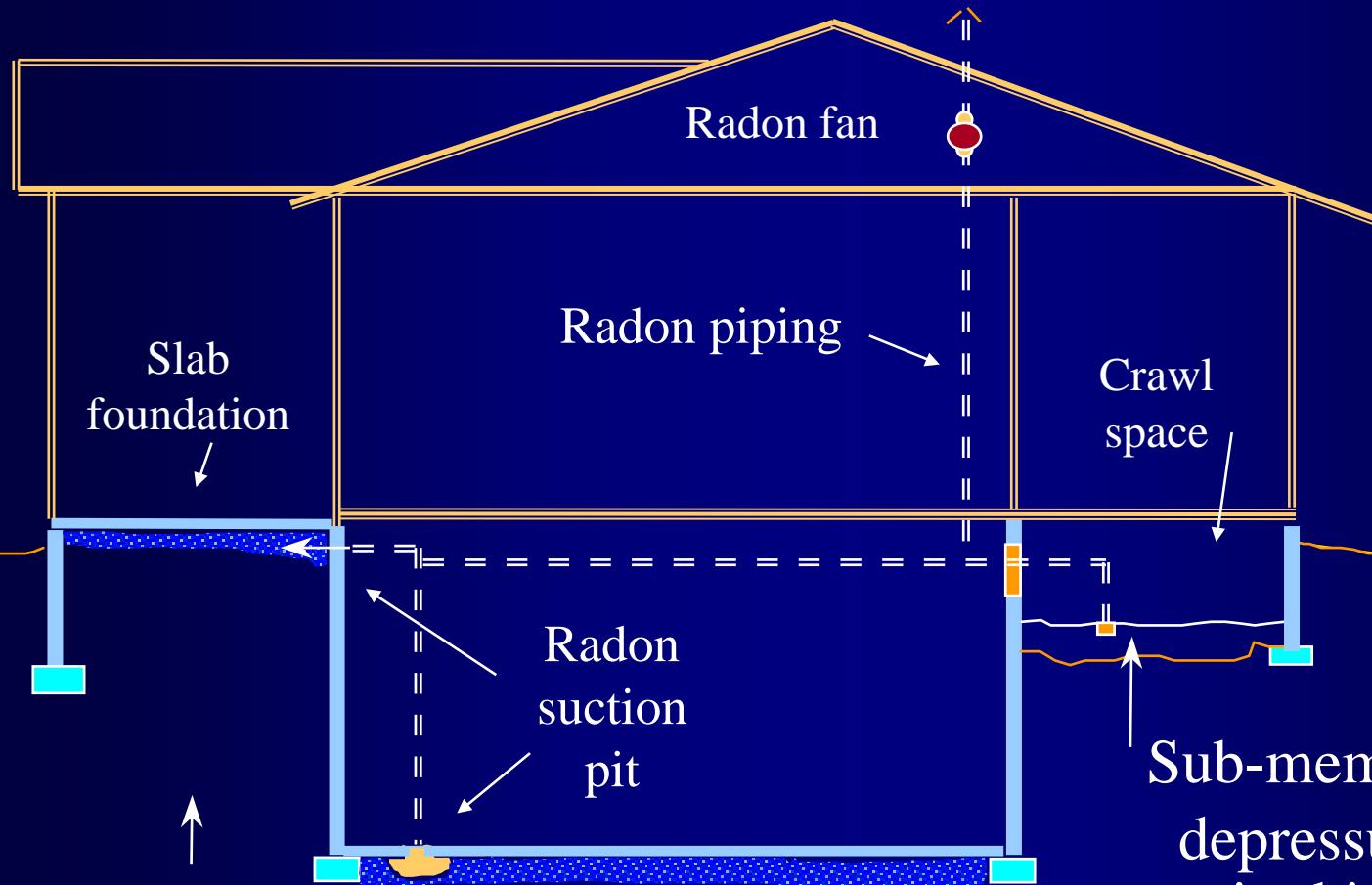
Can Radon Sealing cause a water problem?

A properly installed radon system should not cause a water problem nor will it typically fix a wet basement.



**Caution:
Flooding
during
heavy
rains**

Active Soil Depressurization (ASD)



Air is pulled from under each slab and from under a crawl space membrane

Sub-slab depressurization under concrete slabs

Sub-membrane depressurization in this dirt floor crawlspace

Where must the Radon Fan be located?

Good location

- **Outside**
- **House Attic**
- **Garage Attic**

Not OK

- **Basement**
- **Crawl Spaces**
- **Below grade**

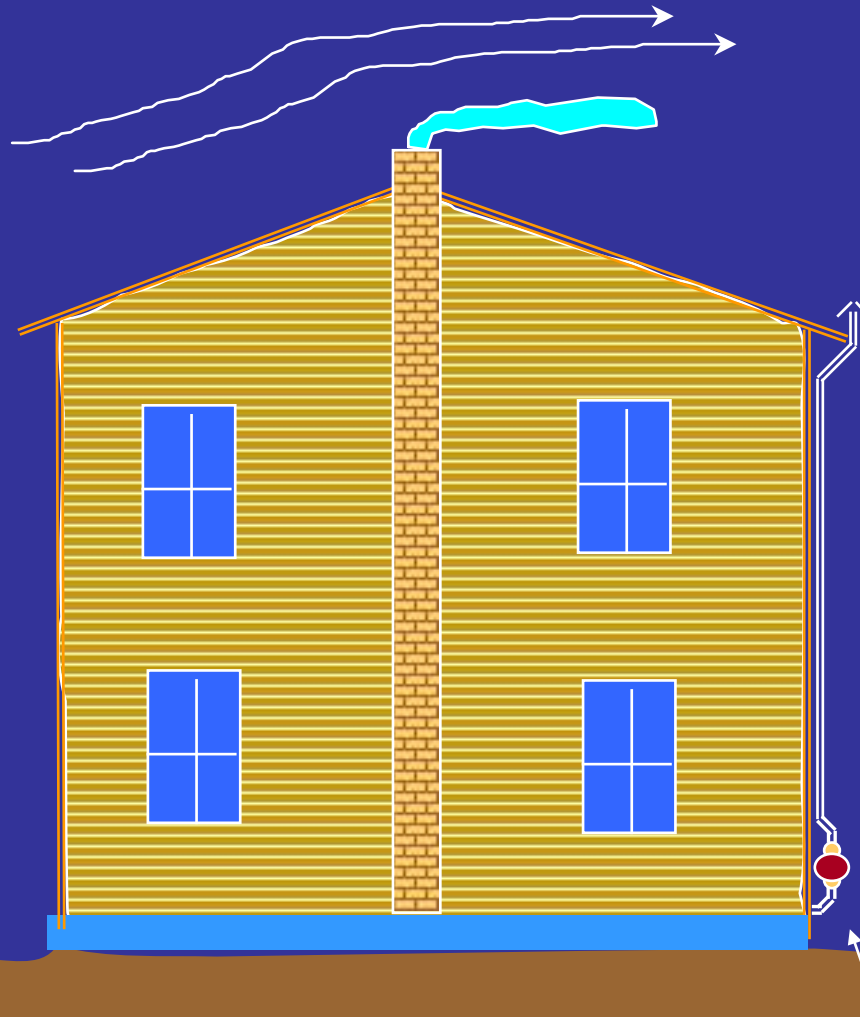
Radon Exhaust Requirements

Radon Exhaust must be:

above the edge of roof

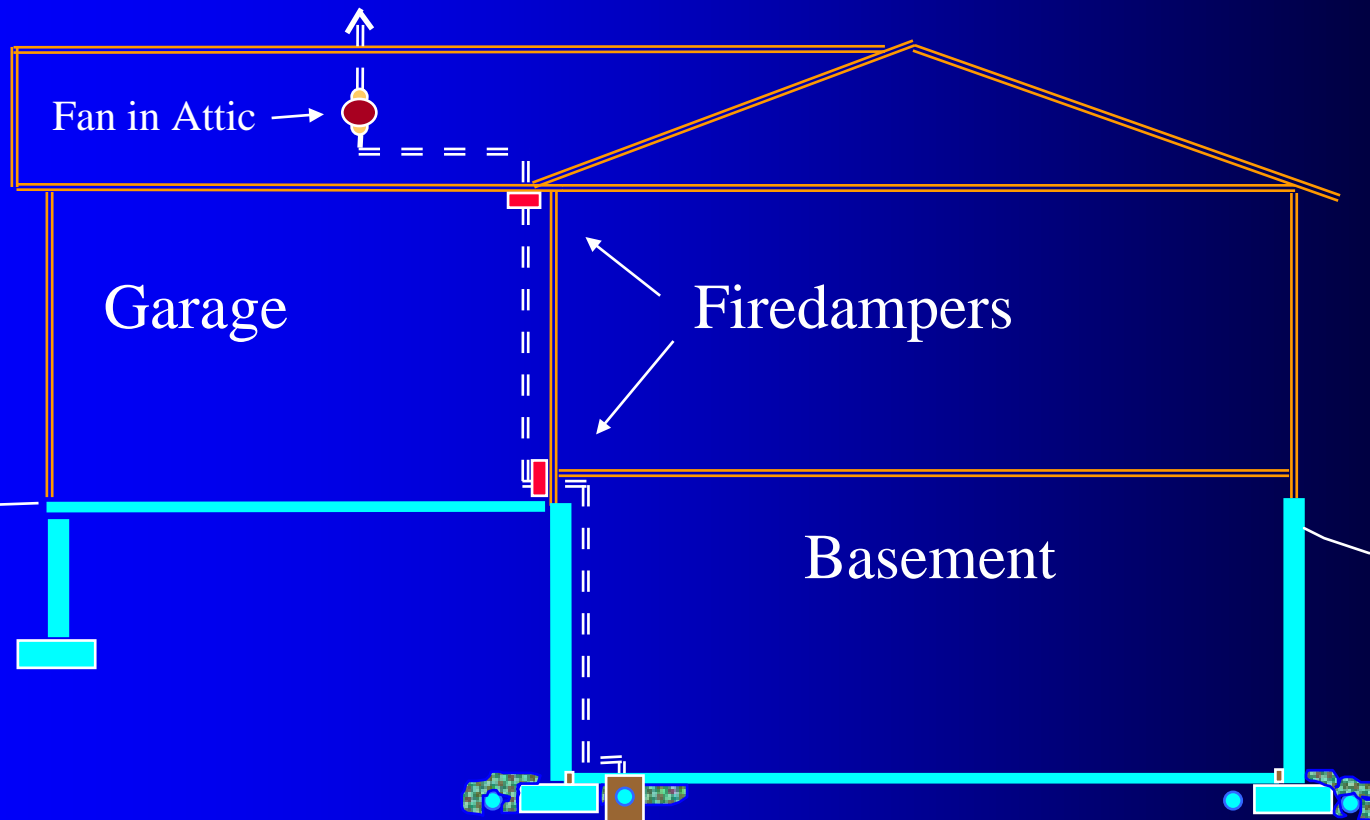
2' higher than
windows within 10'

Minimum 10' off
the ground



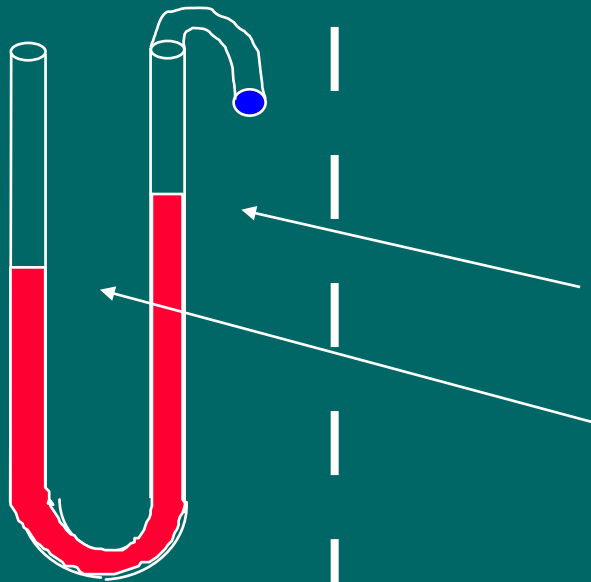
Radon fan

The wall between garage and house is typically a Firewall and needs fire protection



Fan powered radon systems must have a vacuum gauge or other indicator

If oil is level,
system is off or stopped



The difference in oil levels indicates the strength of the vacuum in the system

Note: Vacuum gauge does not indicate Radon Levels

Radon System must have a Label

Radon Reduction System

Installer's:

Name

Phone Number

Certification id #

EPA recommends

Re-testing every 2 Years

There should be an information package
attached to the radon pipe

Gas appliances require a Backdraft Test

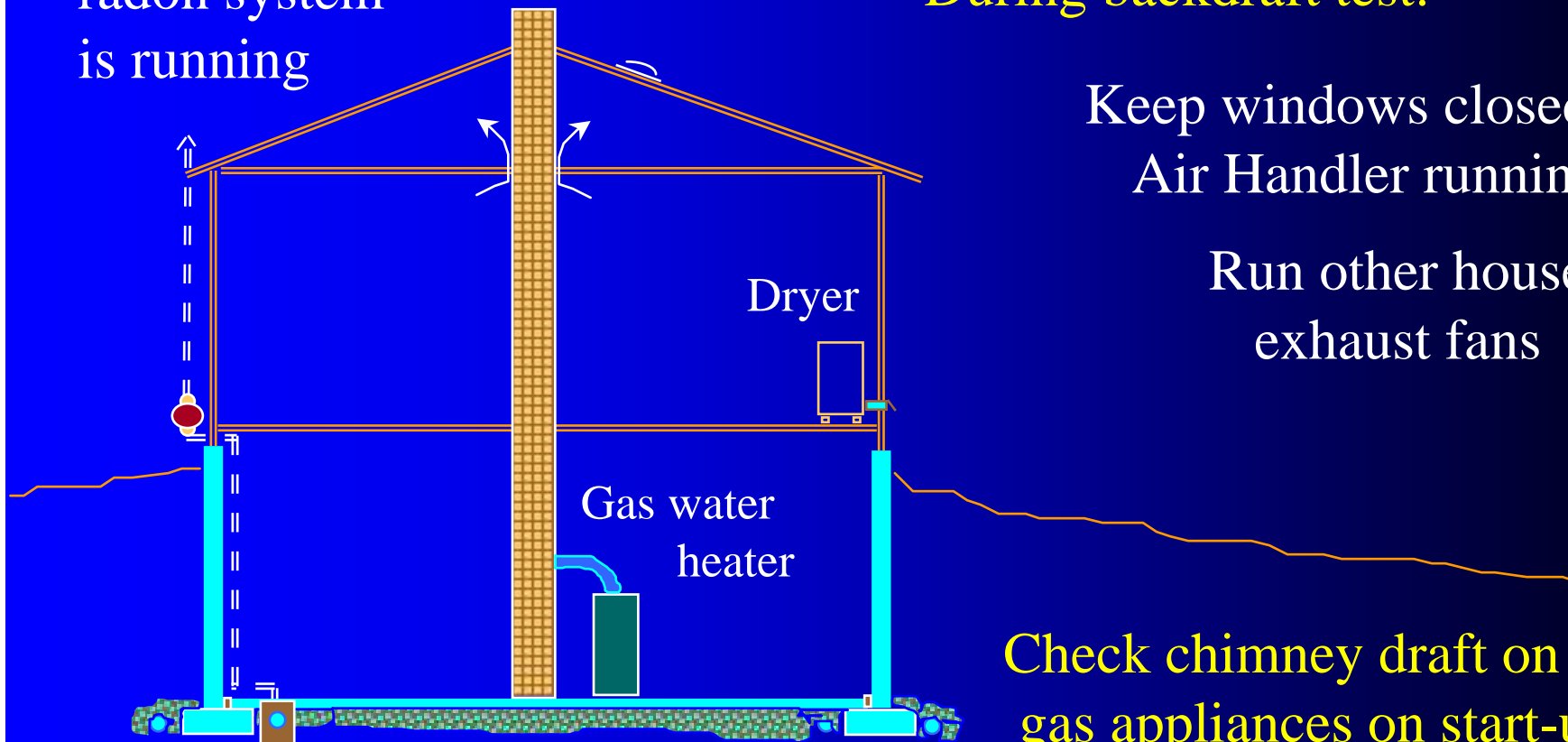
Check backdraft after radon system is running

During backdraft test:

Keep windows closed & Air Handler running

Run other house exhaust fans

Check chimney draft on all gas appliances on start-up



Post Mitigation Testing

- Do a Short-term test within **30 days**
- Wait **24 hours** before starting the test
- Place short term test in the previous test location
- An independent re-test is Best

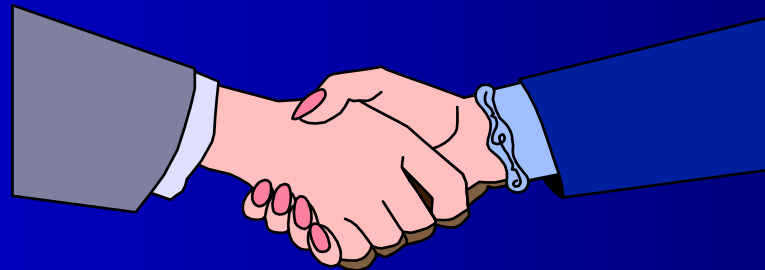
How do you know if a Mitigator is qualified ?

Mitigator must be Certified by the State
or in non certifying states he should be listed
with NEHA or NRSB

www.radongas.org & www.nrsb.org

Does the Mitigator have referrals ?

Will the Mitigator be in business and provide
good service over the length of their warranty ?



Radon in Water

Issues to be

familiar with

EPA states in the
“Home Buyers & Sellers
Guide to Radon”:

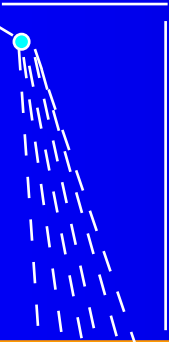
“If you have tested the air in
your home and found a radon
problem, and your water comes
from a well, have the water tested.”

Radon comes out of the water when you:

- Expose the water to air
 - Taking a shower
- Agitate the water
 - Doing the laundry
- Heat the Water
 - Using the Dishwasher

It takes a lot of radon in the water to raise the radon levels in the air?

If radon in water is 10,000 pCi/L then:



A 10 minute shower will raise bathroom to about 30 pCi/L

Average water use in an average size house will raise the overall radon average 1 pCi/L

Radon in Water Health Risk

Primary Risk is the increased radon in the air from water usage

10,000 pCi/L in the water raises the average radon in air about 1 pCi/L

There is a small risk of stomach & other cancers from ingestion of water with radon

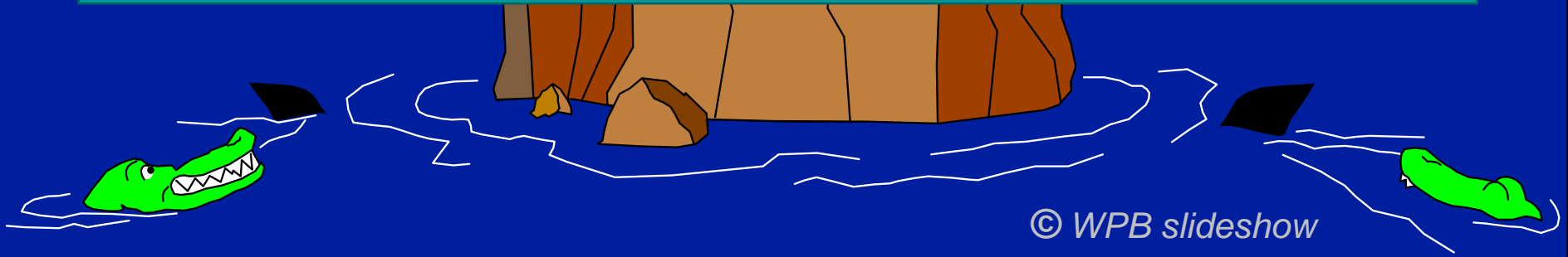
There are no Federal Guidelines

States



EPA

EPA has suggested two options:
An MCL of 300 pCi/L or
an AMCL of 4000 pCi/L if the state has
a Multi-media radon in Air Program



Percentage of Pennsylvania community wells that would not pass a 3000 pCi/L standard

Communities w/ground water systems	25 to 499 people	500 to 3299 people	3300 to 10,000 people	more than 10,000 people
# in PA	1,336	362	65	41
percentage above 3000 pCi/L	7 %	4 %	4 %	5 %

Testing the Radon in Water

- | Order radon in water test kits over the internet
- | A water sample is collected from fresh cold tap water & shipped to analysis laboratory
- | A certified tester can also provide this test for a cost similar to testing the radon in the air

Radon in Water can be reduced with:

- | **Granular Activated Carbon (GAC)**
5' tall tank(s) filter the water
Cost about \$900 - \$1,500

- | **Aeration System**
Radon is bubbled out of the water
Cost about \$3,500 - \$4,500

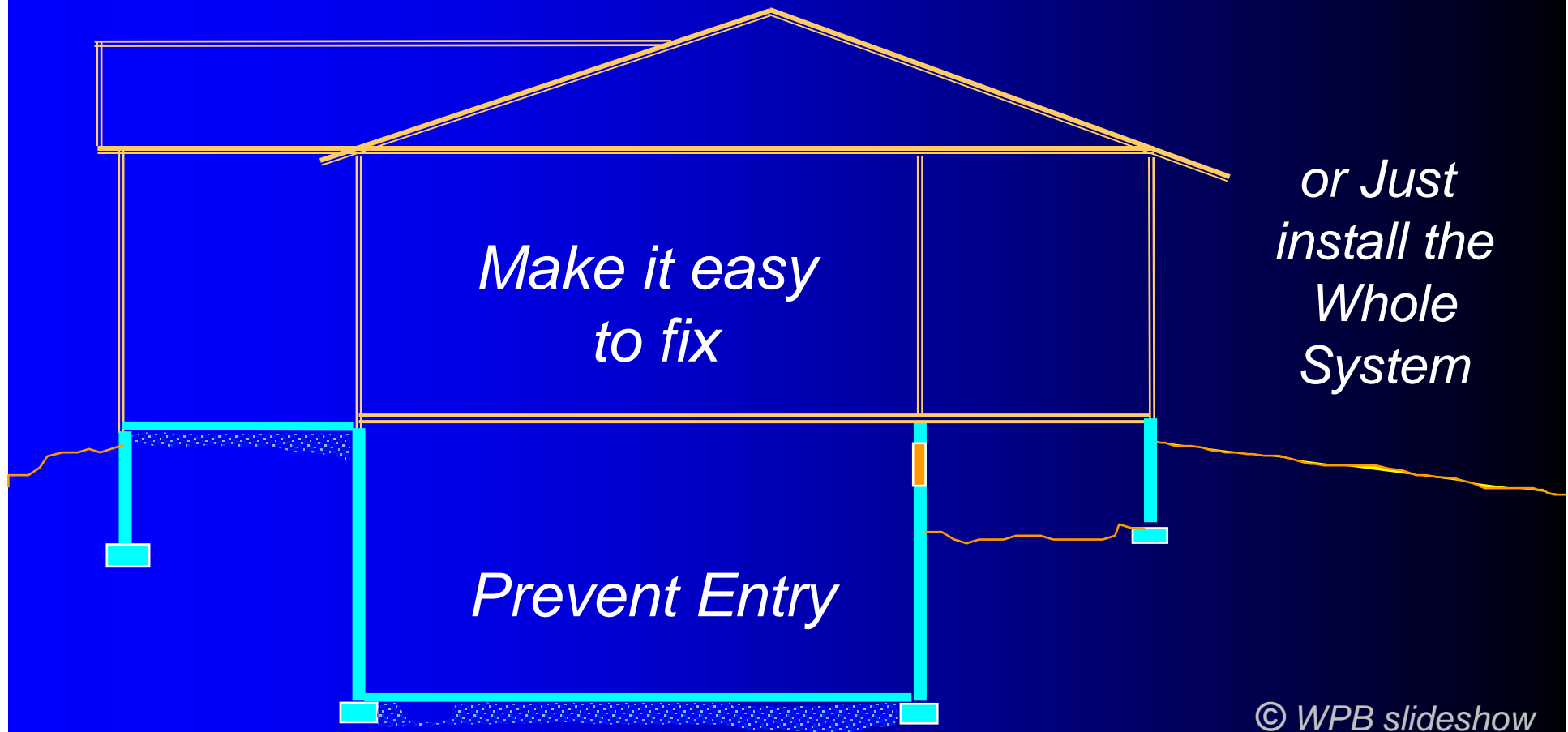
Concerns about using Granular Activated Carbon

- Other contaminants can reduce system performance
- GAC can emanate gamma if radon in water is very high
- GAC should only be used for levels below 20,000 pCi/L
- Carbon needs to be replaced every 1 - 5 years

Some Aeration concerns

- System must discharge above roof
- System needs cleaning at least once per year
- Can have Bacteria growth during non-use periods
- Radon removal, however, is excellent

New Construction and Radon



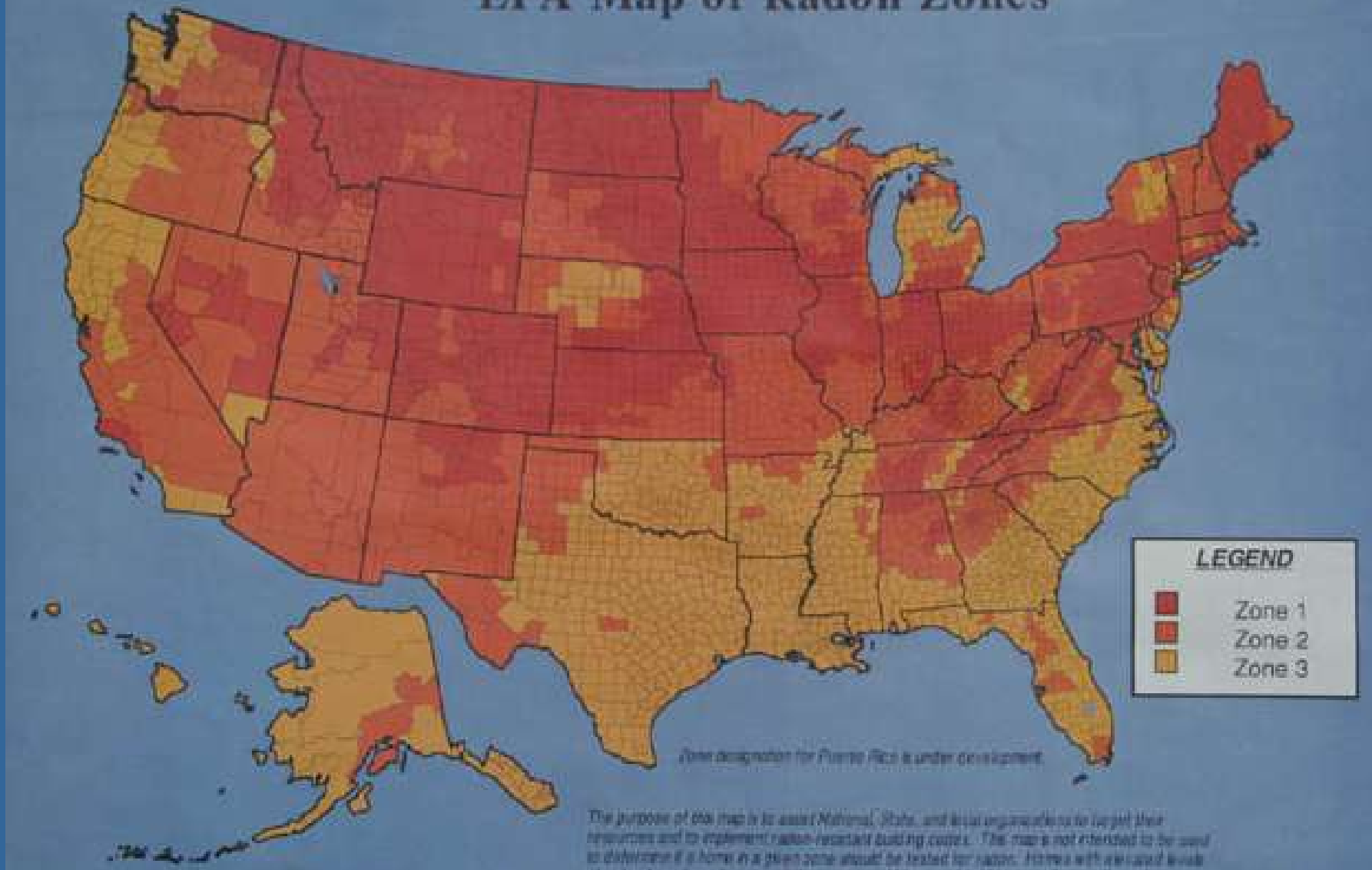
Should land be tested before construction ?

- The soil can be tested but it is not commonly done
- A strong radon source from the soil could be easily missed
- It is better to use the cost of pre-construction soil testing for radon resistant features

EPA has defined Radon Zones

- | Zone 1 - expect 4.0 pCi/L or greater
- | Zone 2 - expect 2.0 to 4.0 pCi/L
- | Zone 3 - expect 2.0 pCi/L or less

EPA Map of Radon Zones



For more detailed state maps go to: www.epa.gov/iaq/radon/zonemap.html

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Recommendations for Zone 1

3" or 4" Passive vent to roof

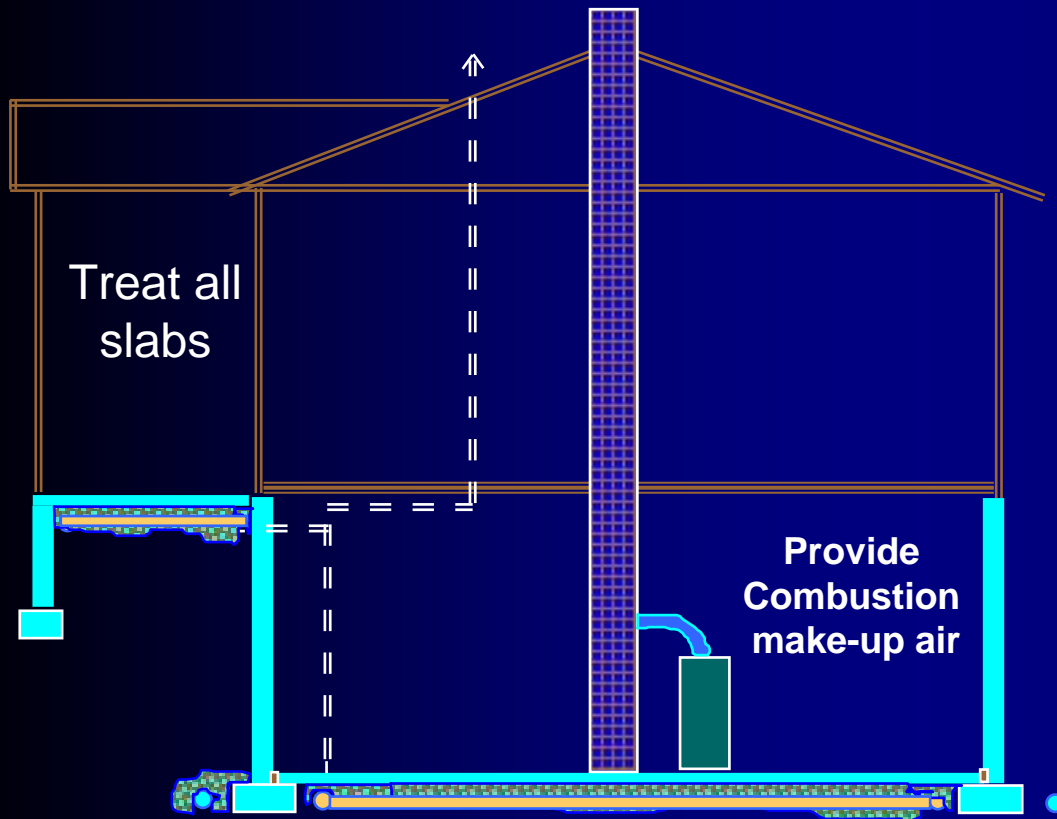
Leave adequate room for fan installation

Have attic wiring for the fan

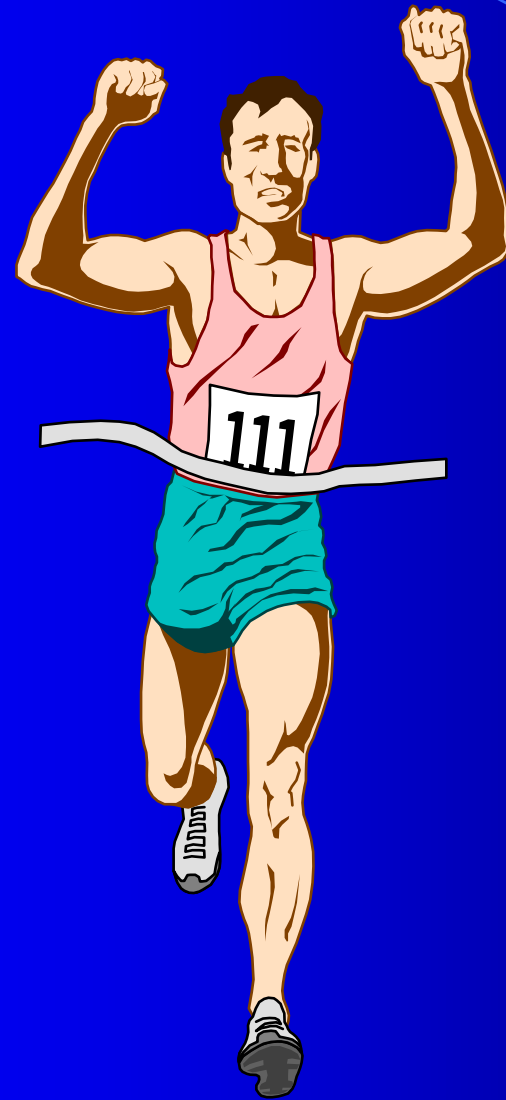
Seal the Sump pit

Do not install channel drains

Minimize concrete cracks & openings



Run perforated piping under all slabs



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