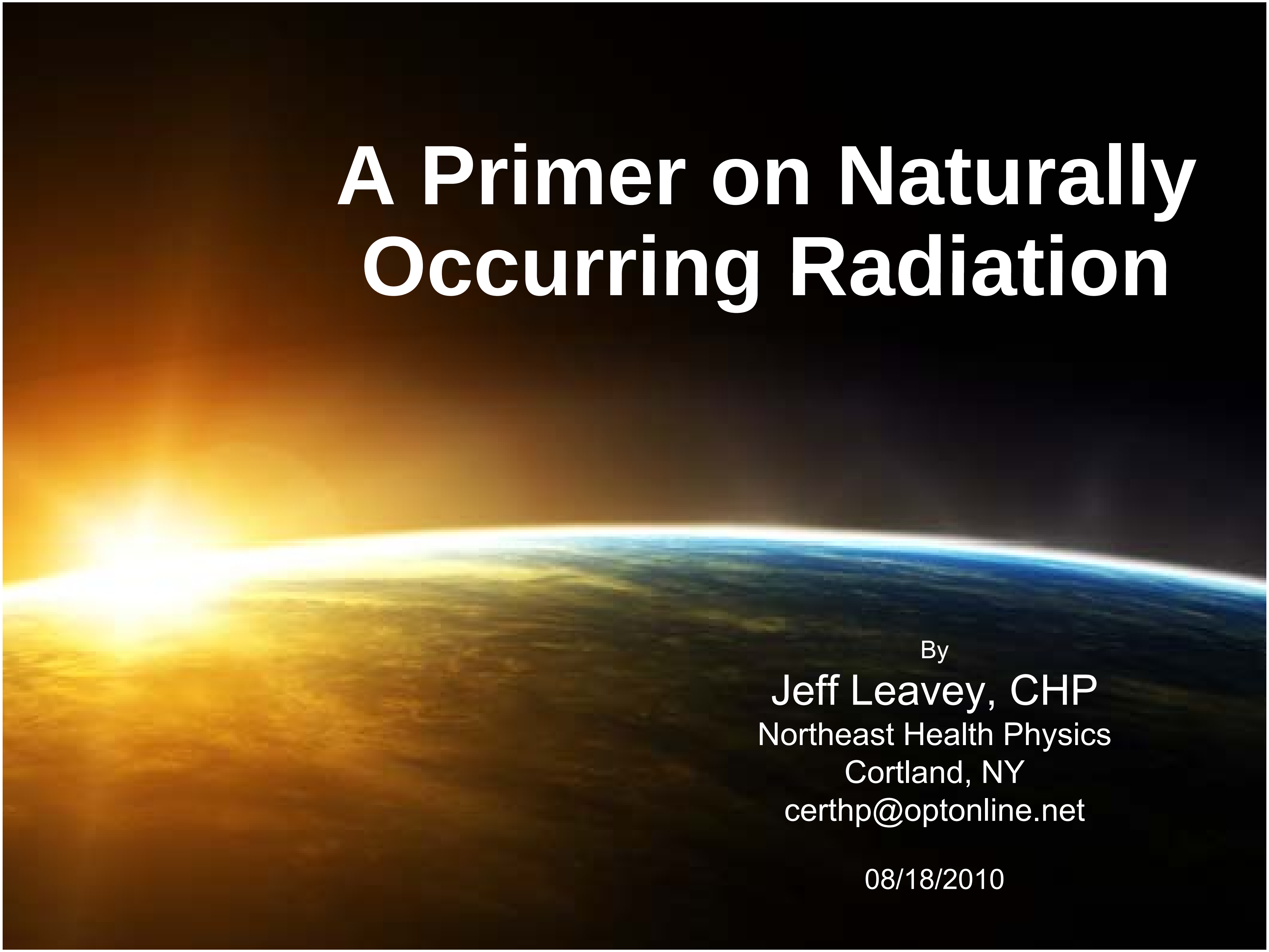
A Primer on Naturally Occurring Radiation



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08/18/2010

First, The Fine Print…

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My Goals

- Provide an understanding of what radiation is
- Explain terms and definitions you will come across
- Give points for comparison
- Review some data about drilling
- Help with "Where do we go from here?"

Tonight's Discussion
Part 1

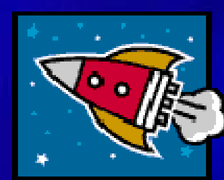
- The atom
  - Protons, neutrons, and electrons – OH MY!
- What is radiation?
- How do we measure radiation?
- Where does radiation come from?
- How does radiation affect me?

Tonight's Discussion
Part 2

- What is in the shale?
- What is around drill sites?
- What could get into water?
- What if I have radon in my home?
- Questions?

High Tech Content Warning

High tech content will have



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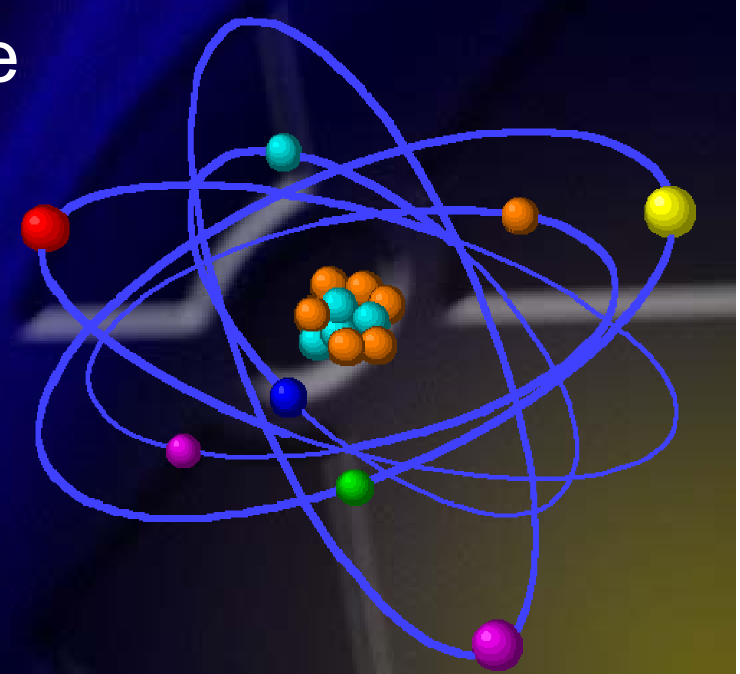
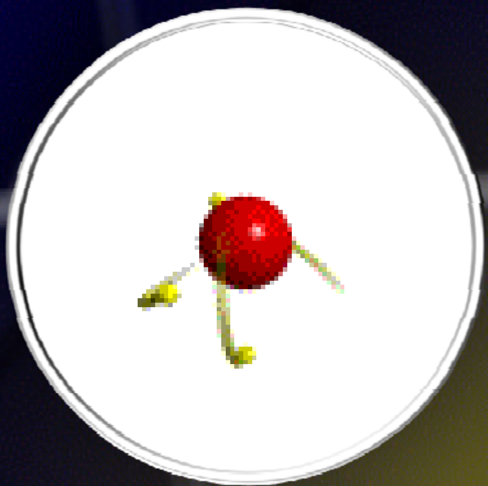
The Atom

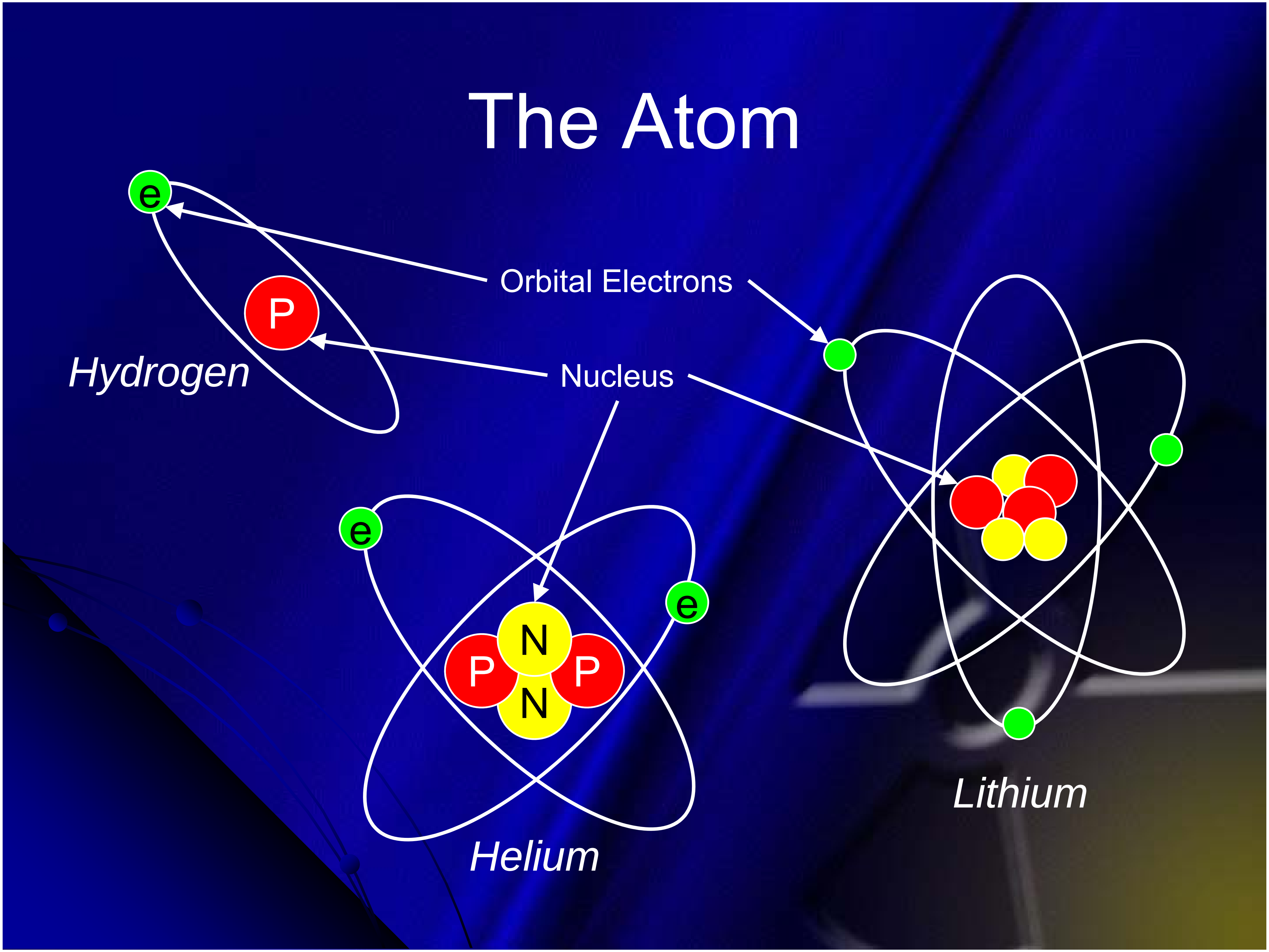
- Basic model
  - Central nucleus surrounded by electrons
- Nucleus
  - Protons – +1 electric charge
  - Neutrons – 0 charge

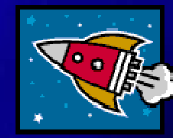


The Atom

- Electrons
  - "Cloud" around the nucleus
  - Have a -1 charge
  - Much smaller than proton or neutron
  - There is one electron in "orbit" for each proton in the nucleus




The Atom
e
P
Hydrogen
Orbital Electrons
Nucleus
e
N
P
P
N
e
Helium
Lithium

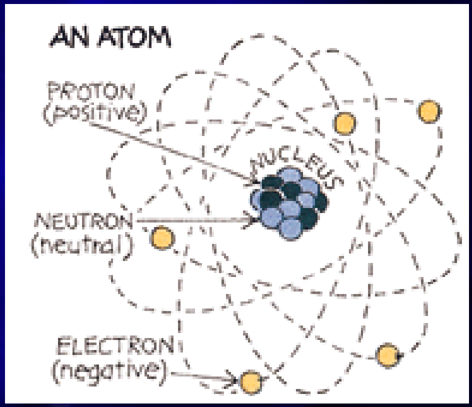


The Atom

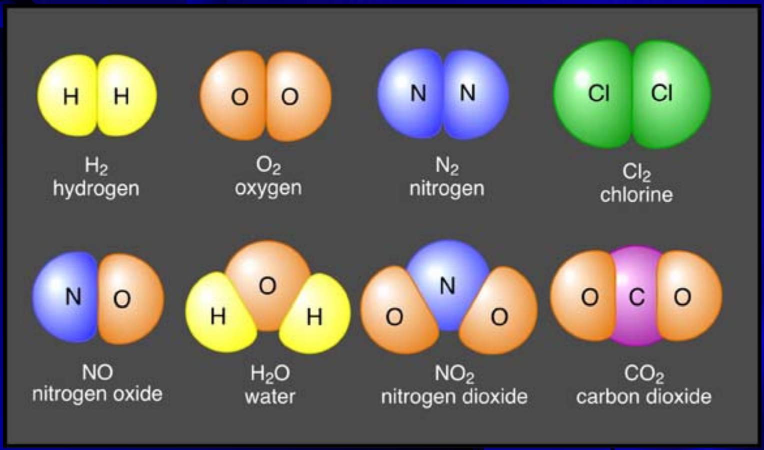
- Number of protons determines the element
  - 1 proton = Hydrogen
  - 86 protons = Radon
  - 88 protons = Radium
  - 92 protons = Uranium
- Number of neutrons determines the isotope
  - U-238 – 92 protons, 146 neutrons
  - U-234 – 92 protons, 142 neutrons
- Isotopes are a different “flavors” of an element

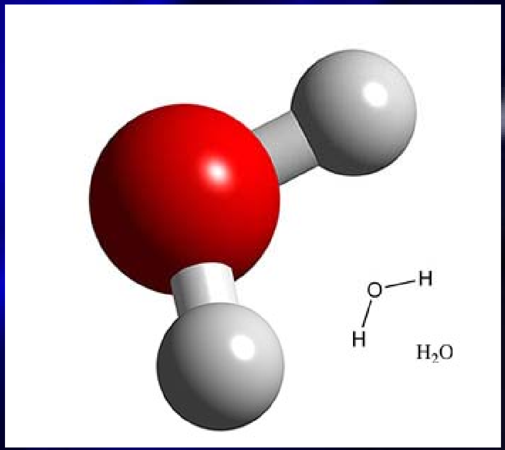
Atoms Are Building Blocks

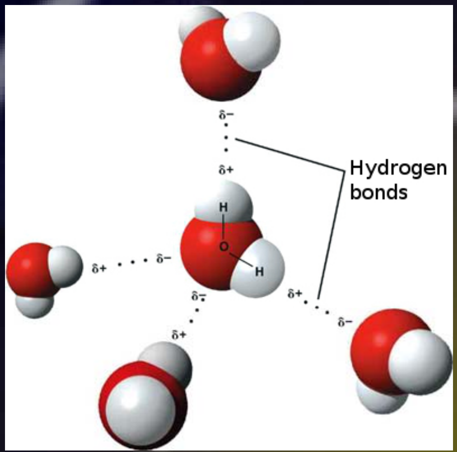
- Remember the basic model of the atom?



- Groups of atoms make molecules by sharing electrons

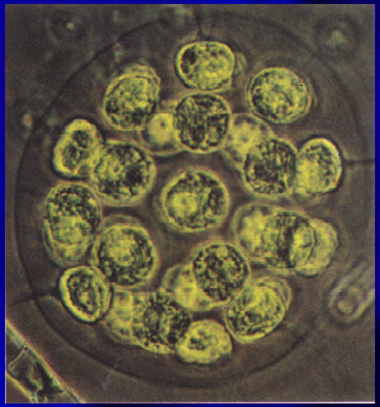






Atoms Are Building Blocks

- Large groups of molecules make up cells



- Large groups of cells make up different organs

- Groups of organs make up US!

What is Radiation

- Radiation – is energy emitted by objects

- Examples
  - Radio – antennas emit RF radiation
  - Microwave ovens – microwave radiation
  - Hot objects – ovens emit IR heat radiation
  - The Sun – visible and UV light radiation

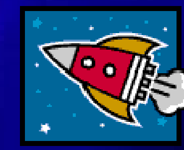
  - Atoms – emit particle and x-ray radiation

What is Radiation

- ALL types of radiation can be harmful at inappropriate levels
  - Too much IR – heat burns
  - Too much UV – sun burn, increased risk skin cancer
  - Too many x-rays – increased risk of cancers

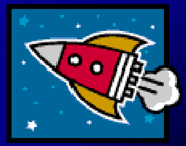
- The harm depends on the dose

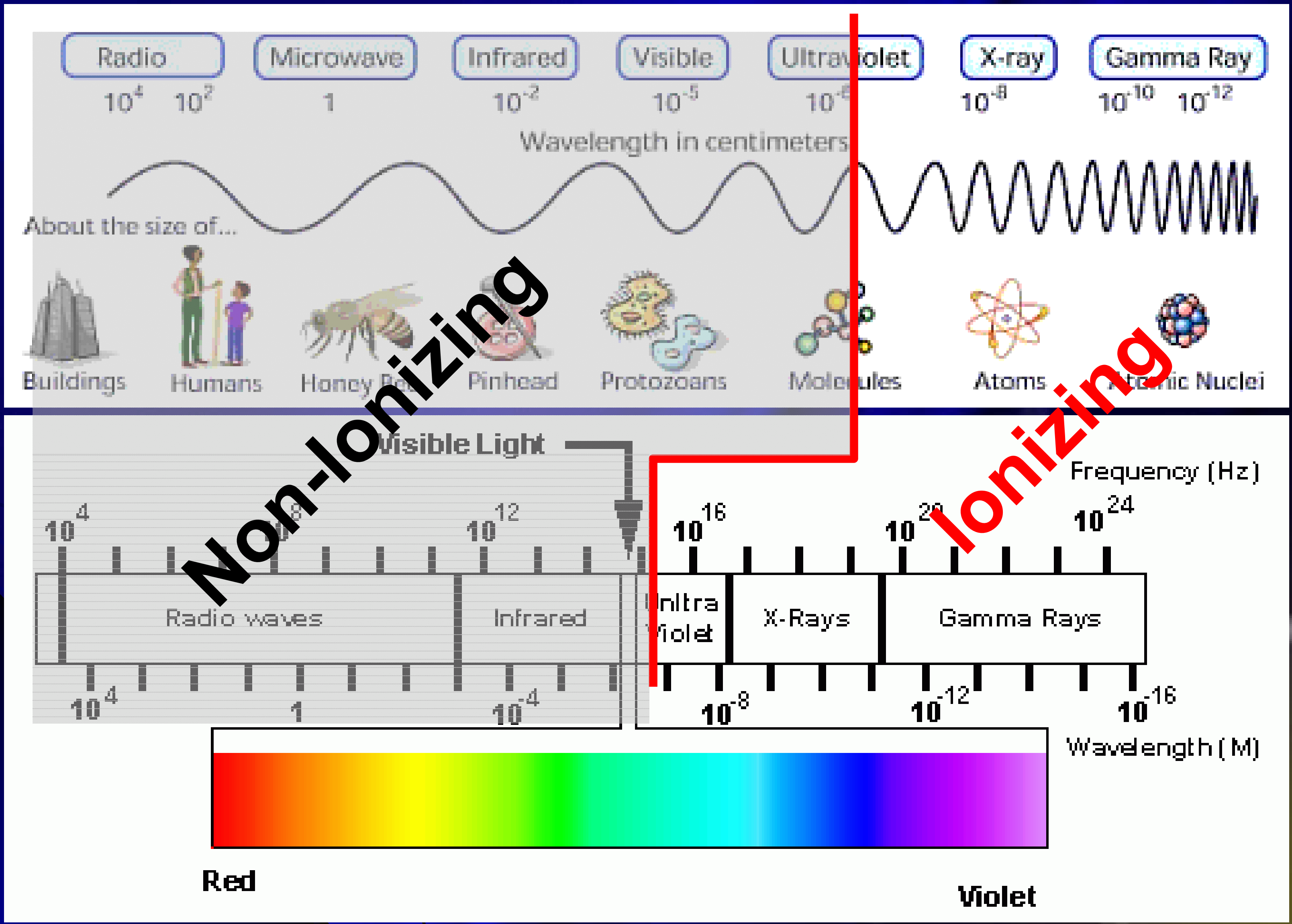
What is Radiation



- Two categories of radiation
  - Non-ionizing   or
  - Ionizing (also called nuclear radiation)
- Non-ionizing – cannot directly break molecules apart
- Ionizing – can break molecules apart

What is Radiation





Four Major Types of Radiation

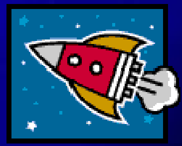
- Alpha (α) – high energy particle from heavy radioactive elements, high dose internally (U, Th, Ra)
- Beta (β^-) – electron from nucleus of light radioactive elements (H-3, C-14, K-40)
- Gamma or x-ray (γ) – high energy light beyond the UV
- Neutron (*n)* – particle emitted from fission or high energy reactions (reactors, high energy accelerators)

What is Radiation

Exposure to radiation <u>does not</u> make you radioactive

How Do We Measure Radioactivity

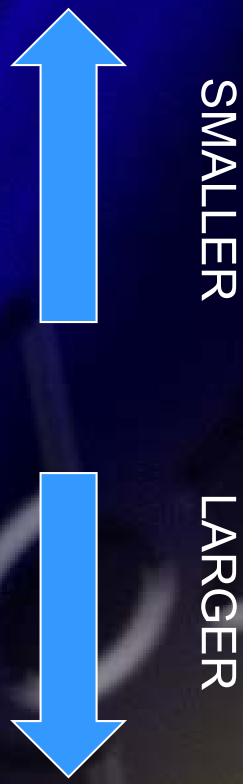
- Inches and centimeters to measure distance …
- Radioactive material
  - USA uses Curies (Ci)
  - US DOT and international – Becquerels (Bq)
- 1 Curie = 37 billion decays per sec
- 1 Becquerel = 1 decay per sec



Radioactivity Units

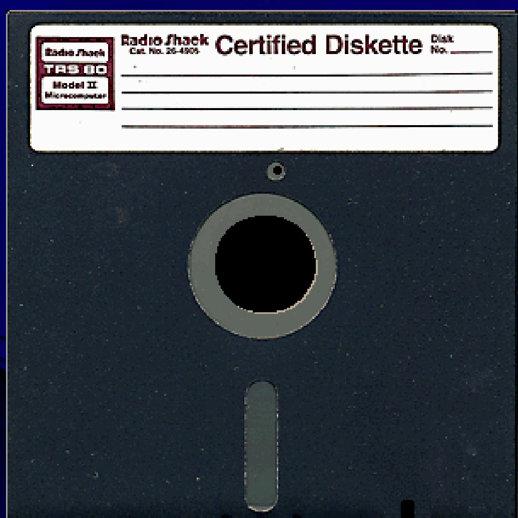
- Scientific notation review
  - Pico *p* – 1 trillionth, 10^{-12}
  - Nano *n* – 1 billionth, 10^{-9}
  - Micro μ or *u* – 1 millionth, 10^{-6}
  - Milli *m* – 1 thousandth, 10^{-3}

  - Kilo *k* – 1 thousand, 10^{3}
  - Mega *M* – 1 million, 10^{6}
  - Giga *G* – 1 billion, 10^{9}
  - Terra *T* – 1 trillion, 10^{12}



Radioactivity Units

- Familiar scientific notation examples



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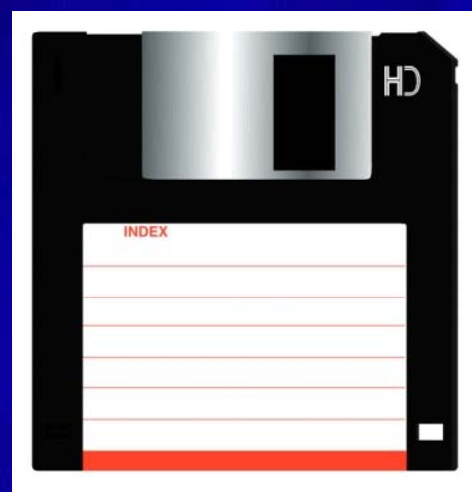
360,000 bytes



3.5 inch Floppy
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Hard Drive
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Radioactivity Units

- Radioactivity examples

Check Source
1 μCi
0.000 001 Ci

Lab and Hospital Sources
5 mCi
0.005 Ci

Irradiator
1 to 50 kCi
1,000 to 50,000 Ci

Radioactivity Units

- Relative scale of radioactivity levels

PicoCuries pCi Enviro Levels	MicroCuries μCi Small Amount Generally Low Hazard	MilliCuries mCi Moderate Amount Moderate Hazard	Curies Ci Large Amount Potentially Large Hazard
Becquerel Bq Enviro Levels	KiloBecquerel kBq Small Amount Generally Low Hazard	MegaBecquerel MBq Moderate Amount Moderate Hazard	GigaBecquerel GBq Large Amount Potentially Large Hazard

SI Units for Radiation Dose

0.1 uSv	1 uSv	10 uSv	100 uSv
0.01 mrem	0.1 mrem	1 mrem	10 mrem

1 mSv	10 mSv	100 mSv	1 Sv
100 mrem	1 rem	10 rem	100 rem

Conversion between grays (absorbed dose) and rads are the same as between sieverts and rems. 1 gray = 100 rad

SI Units for Activity

1 Bq	37 Bq	1 kkBq	37kBq	1MBq
27 pCi	1 nCi	27 nCi	1 uCi	27 uCi

37 MBq	1 GBq	37 GBq	1 TBq	37 TBq
1 mCi	27 mCi	1 Ci	27 Ci	1000 Ci

Common Prefixes for SI Units

Sub multiples

10^{-3}	milli	m
10^{-6}	micro	u
10^{-9}	nano	n
10^{-12}	pico	p

Multiples

10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

Some Conversion Factors

1 pCi = 0.04 decays / sec

1 decay / sec = 27 pCi

1 Bq = 1 decay / sec

1 ppm = 1 milligram / kg

1 ppm U-238 = about
12 decay / sec per kg
336 pCi / kg
5 decay / sec per lb
147 pCi / lb

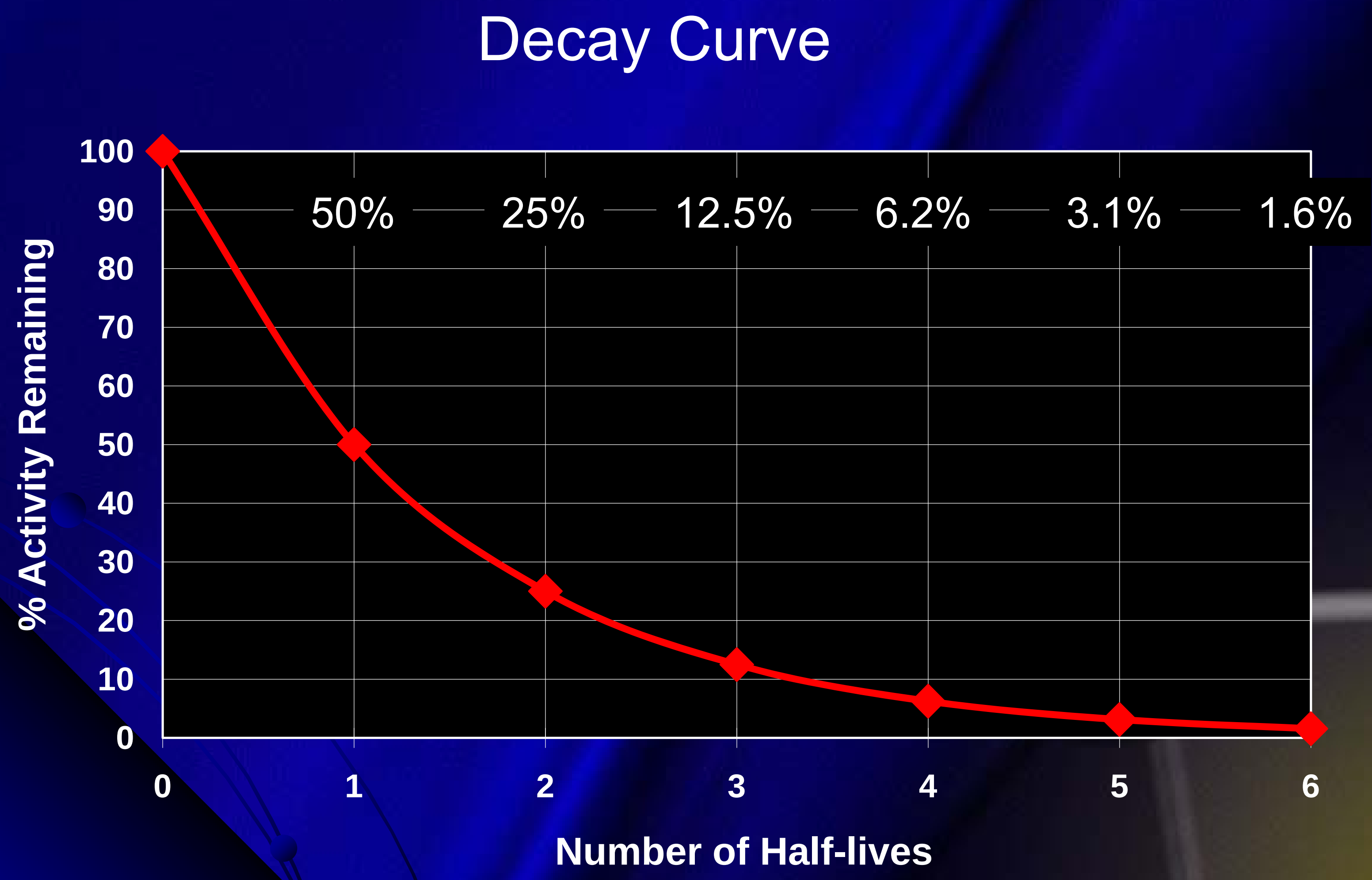
1 g = $1 bill
2.5 g = 1 new penny

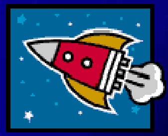
Radioactivity Units

- Half-life – $T_{1/2}$
  - Amount of time for ½ of activity present to decay away
  - Widely varying from less than 1 sec to billions of years

Cs-137	30.07 years	H-3	12.3 years
Tl-201	3.04 days	C-14	5700 years
Rn-222	3.8 days	U-238	4,470,000,000 yrs

Radioactivity Units





Radioactivity Units

- Activity is NOT an indication of source physical size
  - 1 Ci of Co-60 = 0.03 ounces (short half-life)
  - 1 Ci of Th-232 = 10 tons (very long half-life)
- Short half-life = more intense radiation
- Long half-life = longer to wait for it to disappear

Radiation Dose Units

- Radiation dose measured using
  - Radiation Equivalent Mammal – rem
  - 1 rem = 1000 millirem
- International units
  - Seivert – Sv
  - 100 rem = 1 Sv

Radiation Dose Units

- NRC and NYDOH dose limits
  - Rad workers – 5000 mrem / yr total
  - General public – 100 mrem / yr total
  - Medical exposures NOT counted

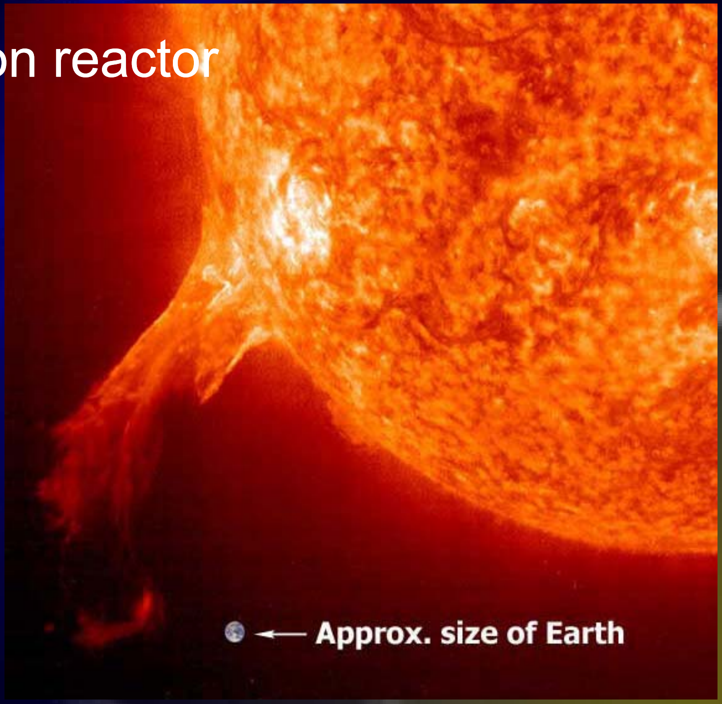
  - Environmental release limits from DOH and DEC
    - Air and water
    - DEC limits effluents to 50 mrem / yr

Our Background Radiation Environment

- Our world and universe are naturally radioactive
- Radiation is constantly being produced
- More than 60 naturally occurring radioactive elements, few are significant
- Three major sources
  - Cosmic – from space
  - Terrestrial – from the earth
  - Man-made – artificially made

Our Background Radiation Environment

- Idaho State University
  - http://physics.isu.edu/radinf/natural.htm
- Cosmic radiation
  - Our Sun and every star is a nuclear fusion reactor
  - High energy radiation interacts with our atmosphere
  - Global source of Carbon-14 and Hydrogen-3



Our Background Radiation Environment

- Carbon-14
  - In all living things – including humans
  - About 6 pCi / gram in organic matter
  - Humans contain about 0.1 μCi (100,000 pCi) (3700 decays/sec)
- Hydrogen-3 (Tritium)
  - All water contains some H-3, drinking water less than 270 pCi/L (10 d/sec per L)
  - Ocean water about 0.02 pCi/L
  - EPA limit 20,000 pCi/L (about 1% of background dose)

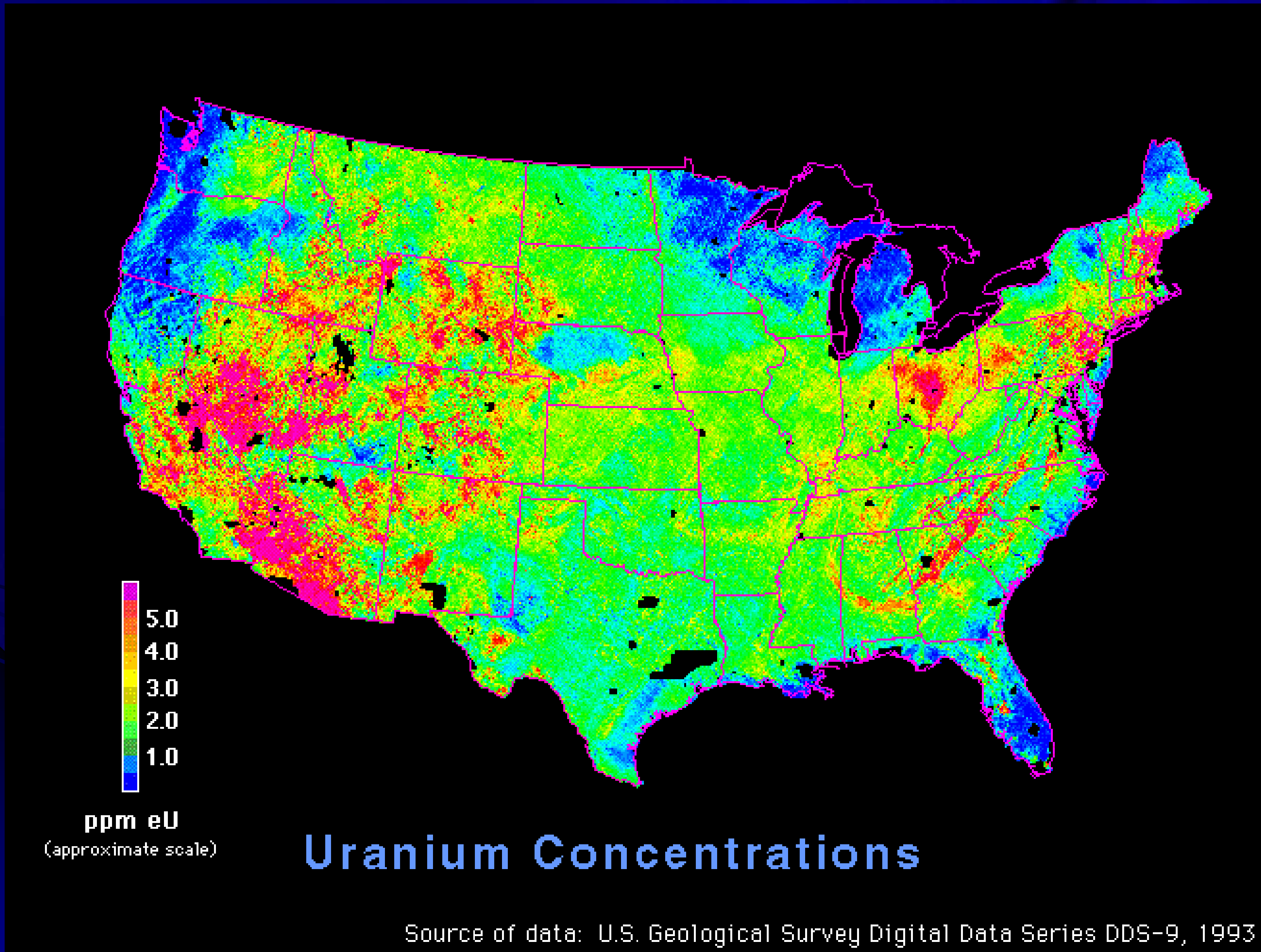
Our Background Radiation Environment

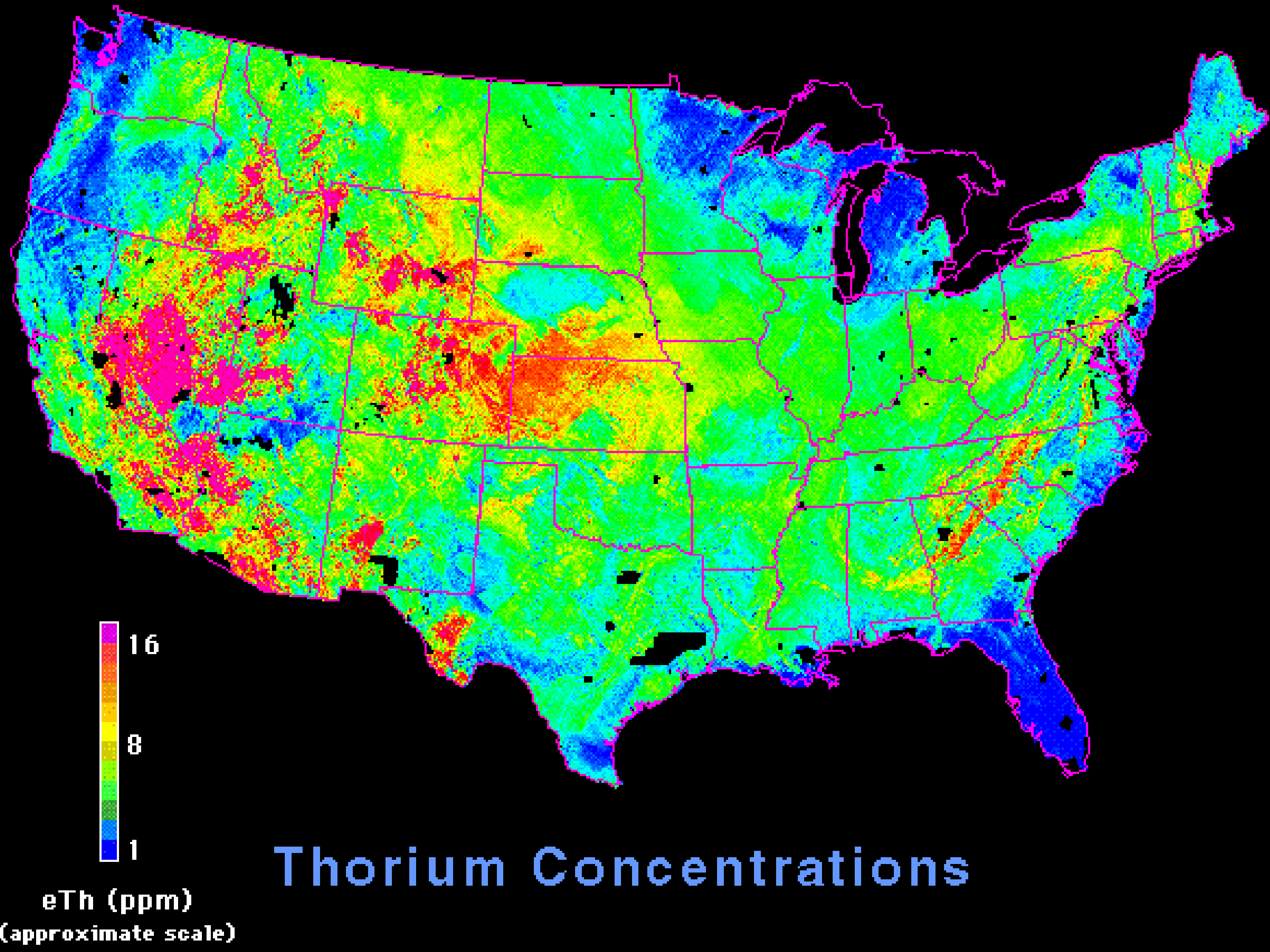
Calculated cosmic ray doses to a person flying in subsonic and supersonic aircraft under normal solar conditions

Route	Subsonic flight at 36,000 ft (11 km)			Supersonic flight at 62,000 (19 km)		
	Flight duration (hrs)	Dose per round trip		Flight duration (hrs)	Dose per round trip	
		(mrad)	(µGy)		(mrad)	(µGy)
Los Angeles-Paris	11.1	4.8	48	3.8	3.7	37
Chicago-Paris	8.3	3.6	36	2.8	2.6	26
New York-Paris	7.4	3.1	31	2.6	2.4	24
New York-London	7.0	2.9	29	2.4	2.2	22
Los Angeles-New York	5.2	1.9	19	1.9	1.3	13
Sydney-Acapulco	17.4	4.4	44	6.2	2.1	21

Our Background Radiation Environment

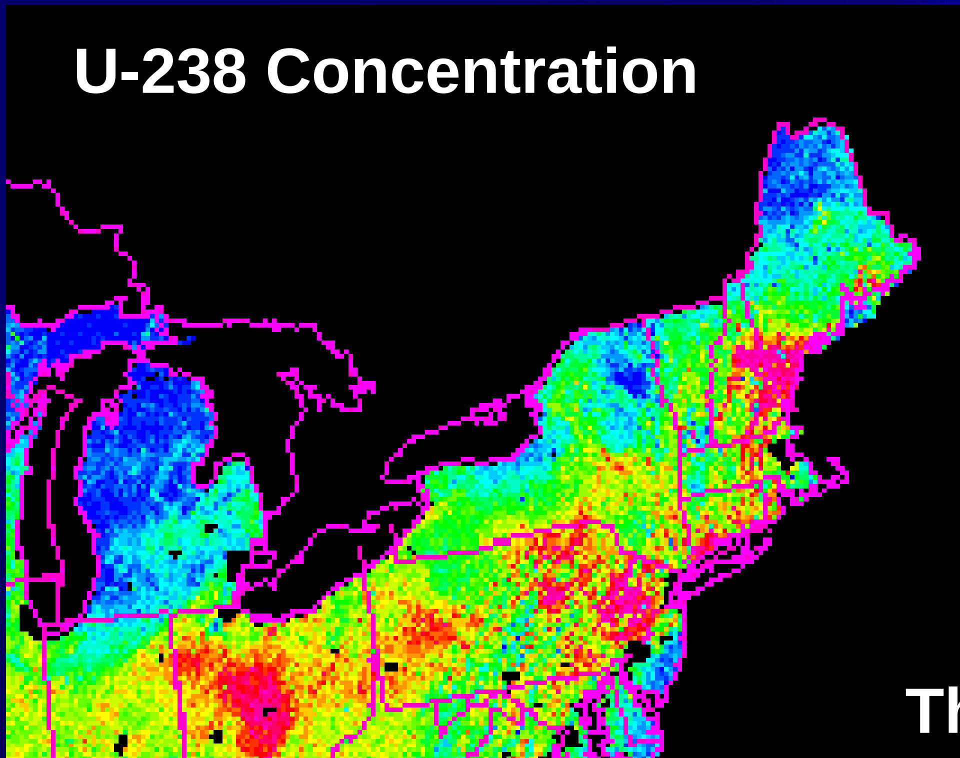
- Terrestrial radiation
  - Radioactive elements are part of our planet
  - Primarily Uranium-238 and Thorium-232 in rocks and soils, and Potassium-40
  - Great variation in concentrations
  - Decay of U and Th creates radium and radon
  - Potassium is important for human health

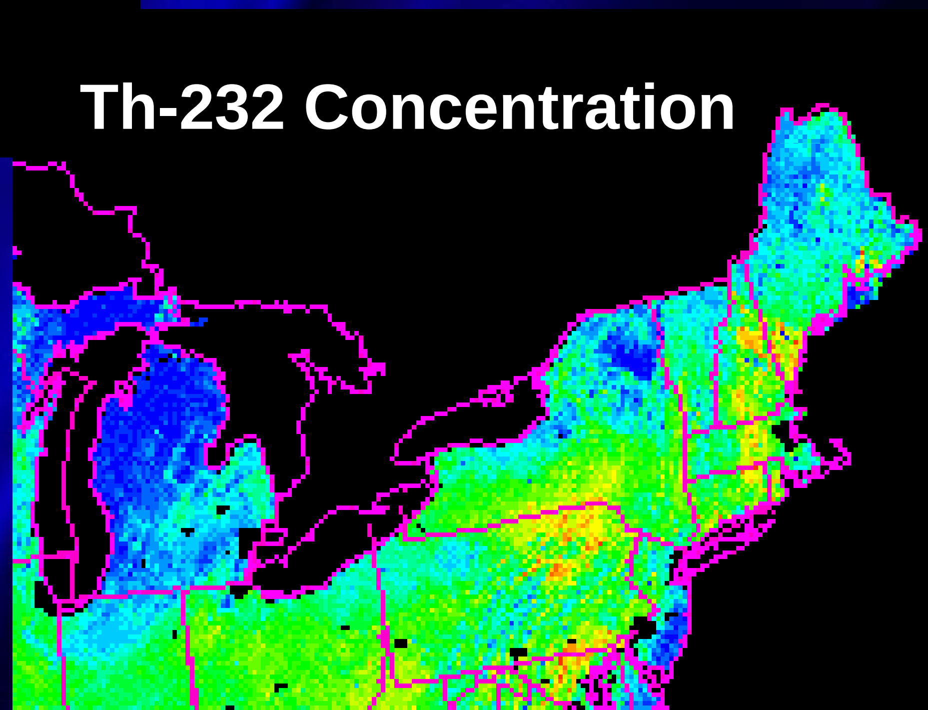

5.0
4.0
3.0
2.0
1.0
ppm eU
(approximate scale)
Uranium Concentrations
Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

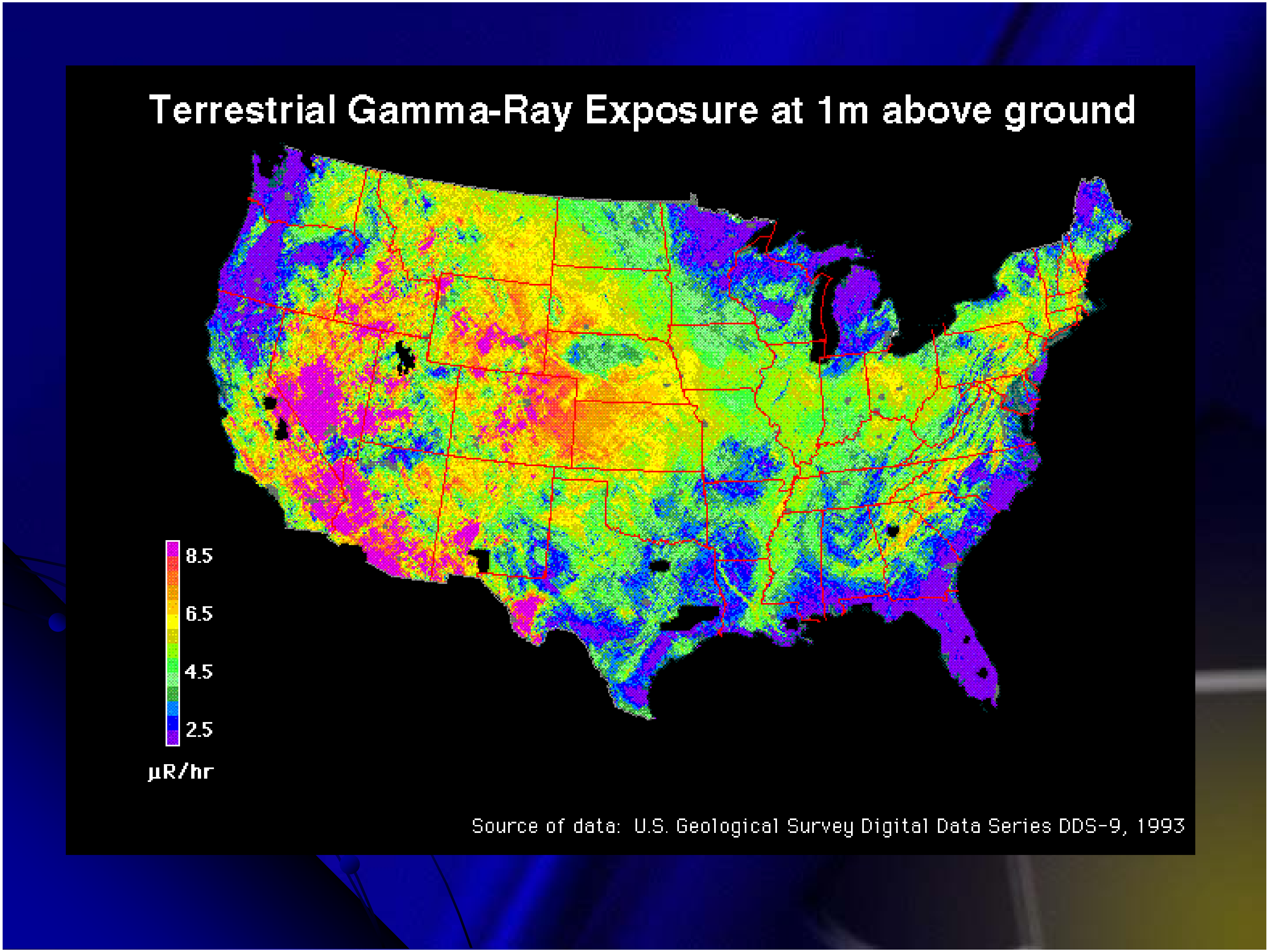


Thorium Concentrations

Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

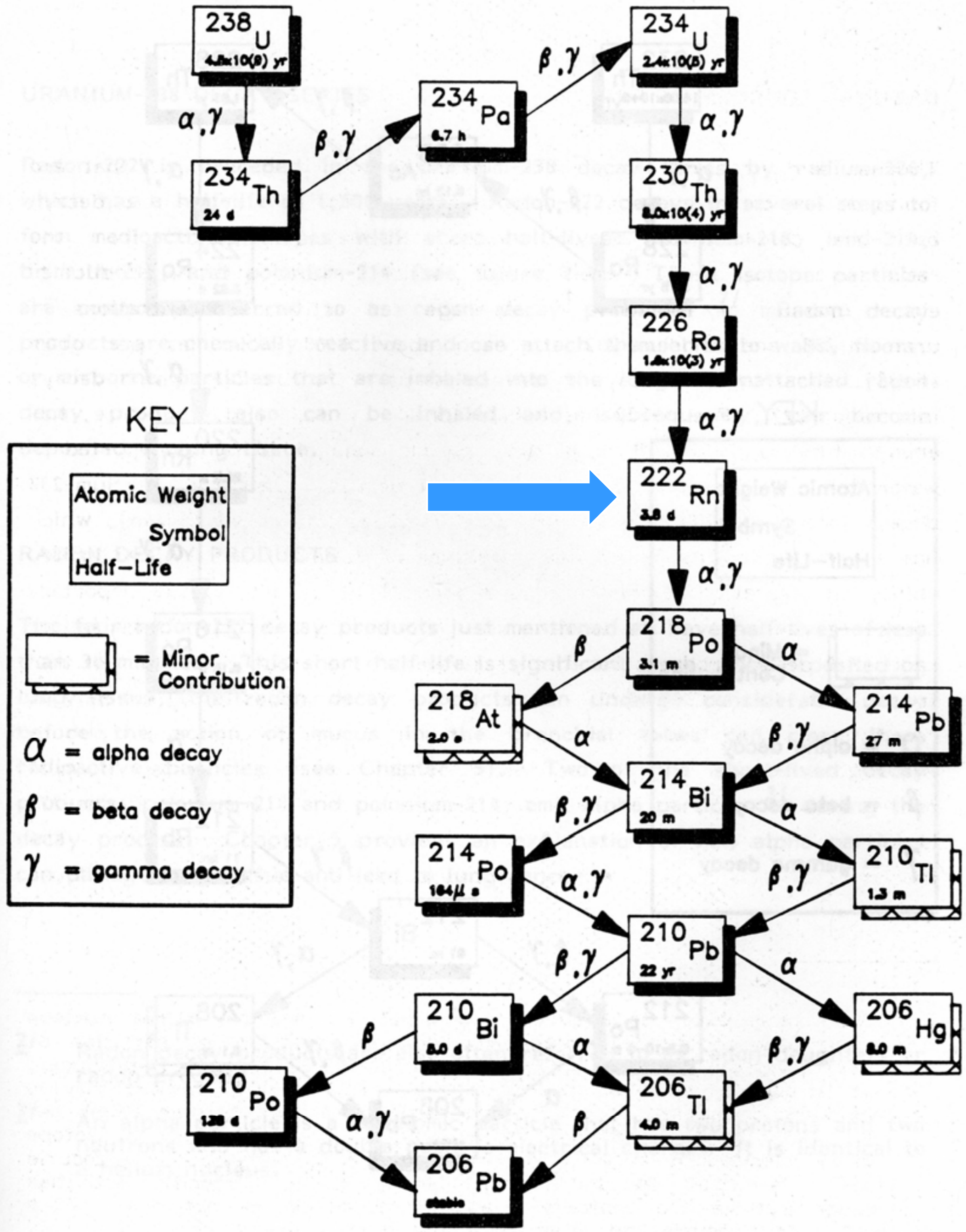

U-238 Concentration


Th-232 Concentration


Terrestrial Gamma-Ray Exposure at 1m above ground
8.5
6.5
4.5
2.5
µR/hr
Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

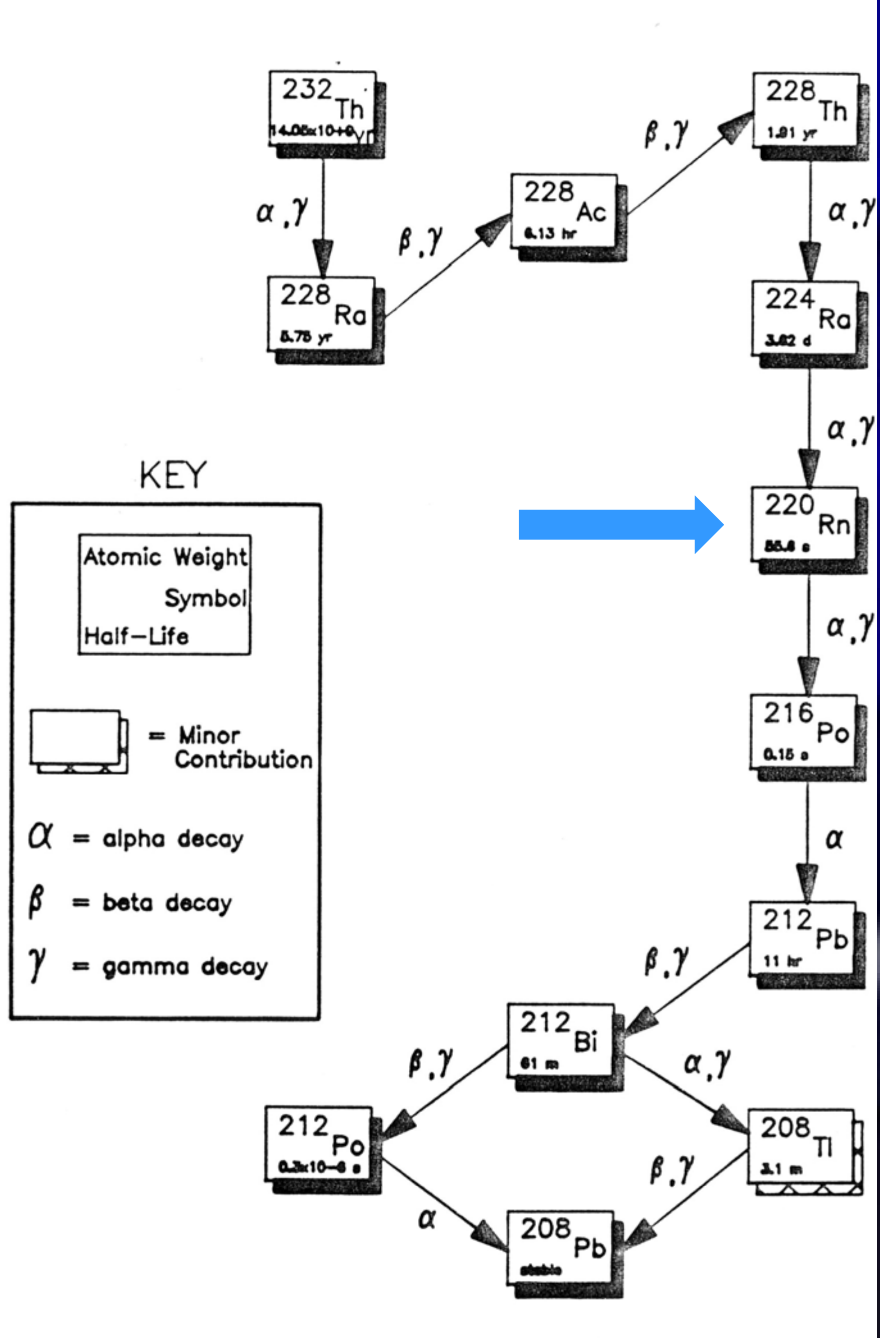
Our Background Radiation Environment

- Why are U-238 and Th-232 important?
  - Both live for a very long time
    U-238 – 4,470,000,000 yr half-life
    Th-232 – 14,100,000,000 yr half-life
  - Both have several decay products that are radioactive
  - Both create Radium and Radon
- More about Radon later….



SOURCE: Putnam, Hayes & Bartlett, Inc., September 1987.

Thorium–232 Decay Series



SOURCE: Putnam, Hayes & Bartlett, Inc., September 1987.

Our Background Radiation Environment

- U-238
  - Average soil concentration is about 2 ppm, granite is about 2 to 20 ppm, and richer deposits up to 50 – 1000 ppm
  - A 10 ft x 10 ft x 1 ft deep garden contains about 12 μCi (440,600 d/sec) using the avg soil concentration
  - Granite counter tops – wide variation in U content and radon release, limited testing generally not found issues
  - In humans – about 30 pCi (1 d/sec) of U and Ra, about 3 pCi of Th

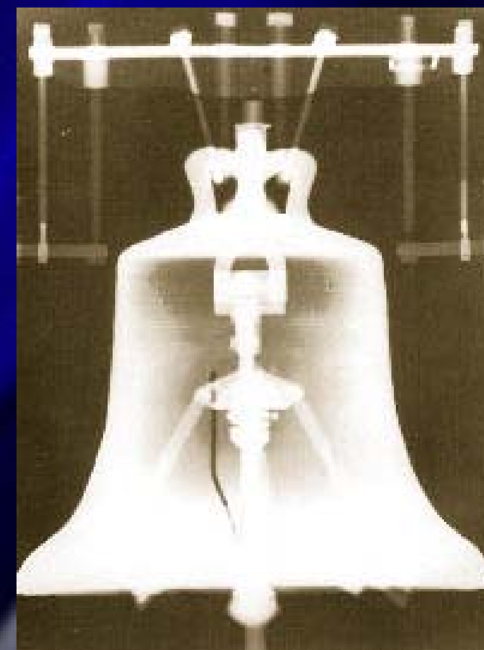
Our Background Radiation Environment

- K - 40
  - In soil, about 20 pCi/gm
  - Potassium is important for human health
  - 1/100 of 1% of all Potassium is K-40
  - We contain about 0.12 μCi (4,400 d/sec)
  - Salt substitutes are KCl, 1 g packet = 433 pCi
  - Some foods are naturally high in Potassium (and Radium)

	Banana	Brazil Nuts	Carrots	White Potatoes	Beer	Red Meat	Raw Lima Beans
K-40 (pCi/kg)	3,520	5,600	3,400	3,400	390	3,000	4,640
Ra-226 (pCi/kg)	1	1000 - 7000	0.6 - 2	1 – 2.5	------	0.5	2 - 5

Our Background Radiation Environment

- Man-made sources
  - Medical and health care
    - Diagnostic x-rays (dental, chest, etc.)
    - Treatment, radiotherapy
    - Nuclear medicine
    - The largest contributor to our background

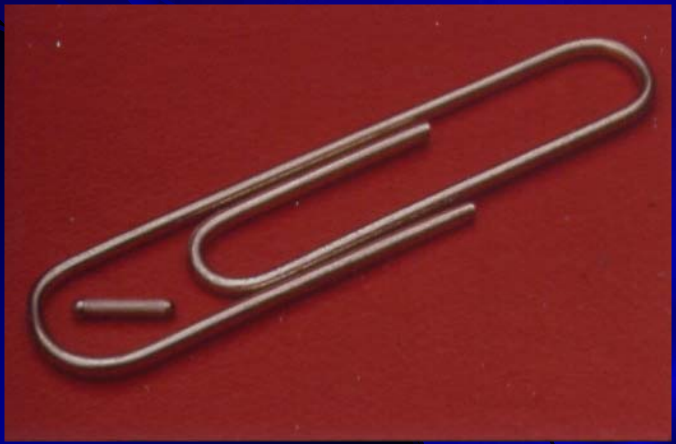


Radiation Sources in Health Care

- X-ray, accelerators

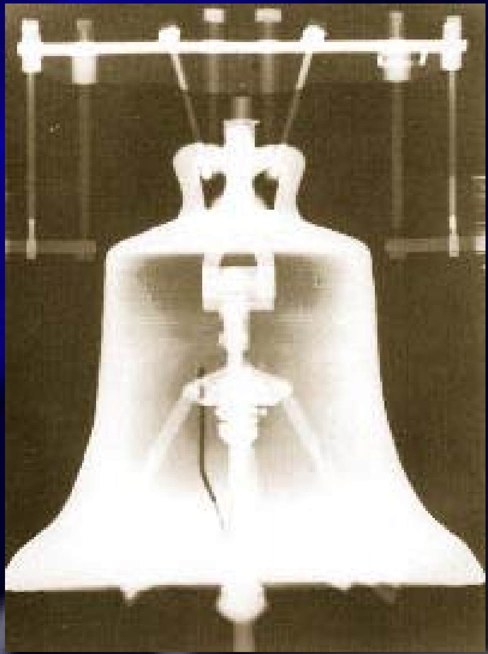
Radiation Sources in Health Care

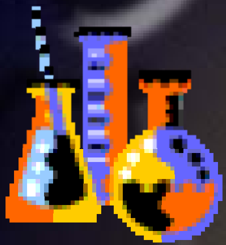
- Sealed sources
  - Co-60, Ir-192
- Radioactive materials
  - F-18
  - Tc-99m
  - I-131
  - Tl-201



Our Background Radiation Environment

- Business and industrial
  - Radiography
  - Process controls (e.g. thickness, level, flow control)
  - Research and development



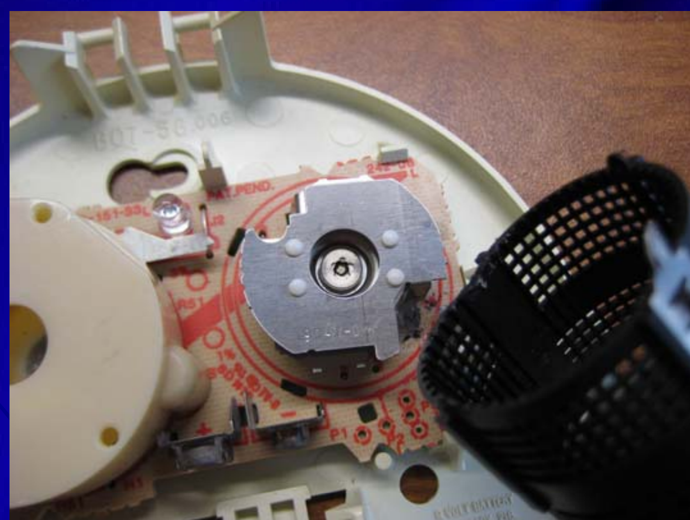


Radiation Sources in Industry

- Radioactive material sources
  - Cs-137, Co-60, AmBe, Ir-192

Radiation Sources in Industry

- Unsealed sources
  - Po-210, Am-241, H-3



Radiation Sources in Industry

- Research and development

Our Background Radiation Environment

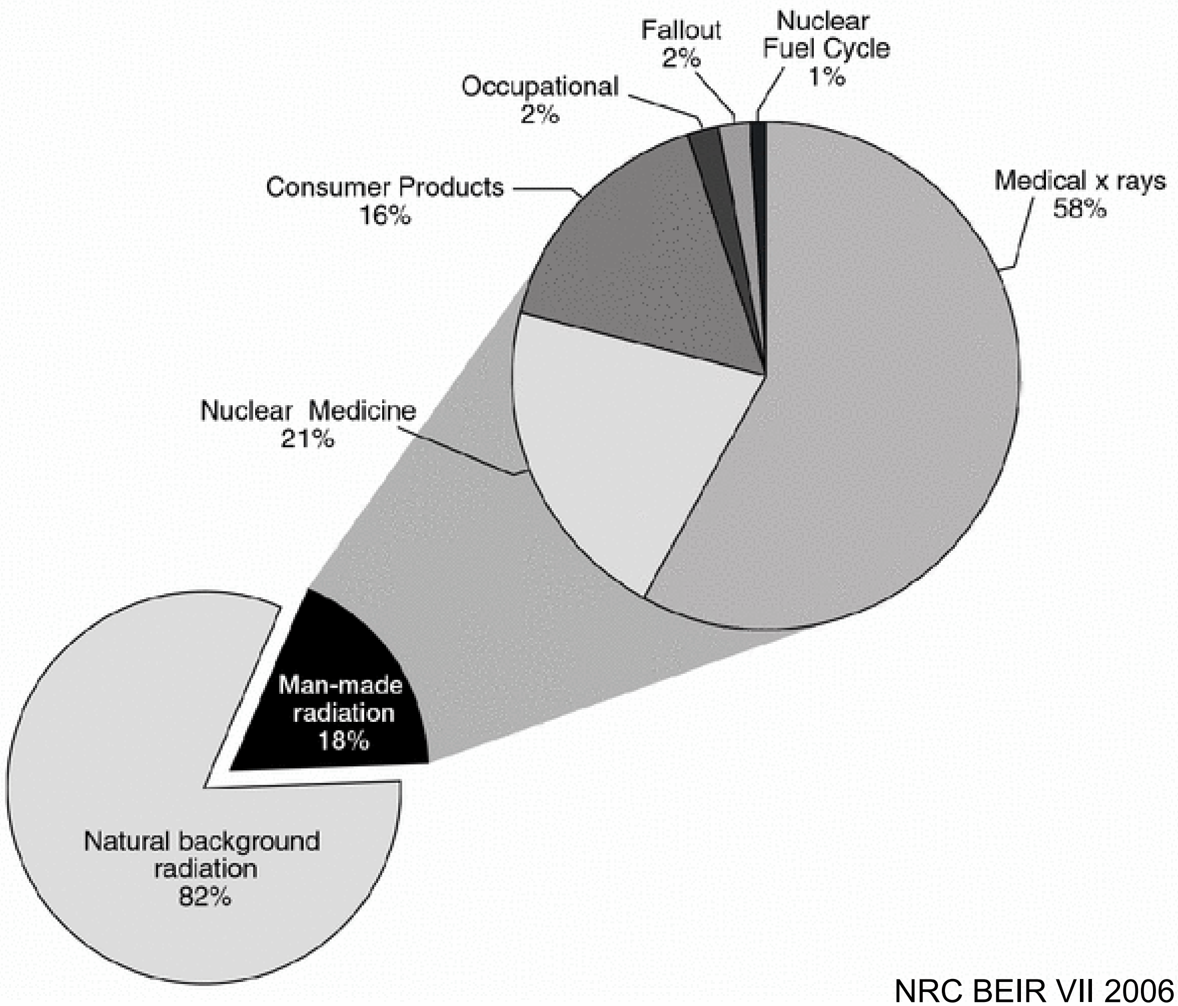
- Consumer products examples
  - Smoke detectors – Am-241
  - Jewelry, cloisonne – U
  - Antique glass – U
  - Old watches, clocks – Ra-226
  - Old tube-type TV power supplies – x-rays
  - Some dishware (Fiestaware) – U
  - Camping gas lantern mantels – Th
  - Tobacco products – U, Pb, Po

Radiation Exposure Comparison Charts

Exposures from Natural Background or Consumer Products	Potential Dose
Airplane ride at 39,000 feet	0.5 mrem/hour
Dose from weapons fallout in the United States (approximated)	1 mrem/year
Dose from building materials	3.5 mrem/year
Average annual dose from radioactive materials in consumer products in the United States	10 mrem/year
Radon in drinking water	1-6 mrem/year
Natural radionuclides in the body, such as ^{40}K and ^{14}C	39 mrem/year
Terrestrial background radiation on the Atlantic Coast	16 mrem/year
Terrestrial background radiation in the Rocky Mountains	63 mrem/year
Cosmic radiation at sea level	26 mrem/year
Cosmic radiation in Denver, Colorado	50 mrem/year
Cosmic radiation in Leadville, Colorado	125 mrem/year
Average cumulative natural background in the United States	300 mrem/year

Exposures from Medical Procedures	Potential Dose
Mammogram	6 mrem/exposure
Chest x-ray	8 mrem/exposure
Hand/foot x-ray	10 mrem/exposure
Head/Neck x-ray	20 mrem/exposure
Average annual dose from medical procedures in the United States	50 mrem/year
Lumbar spinal x-ray	127 mrem/exposure
Upper gastrointestinal (GI) series	245 mrem/exposure
Lower gastrointestinal (GI) series	405 mrem/exposure
Bone scan (^{99m}Tc)	440 mrem/exposure
Thyroid diagnostic exam (^{131}I)	590 mrem/exposure
Heart perfusion diagnostic exam (^{201}Tl)	1,040 mrem/exposure
Tumor diagnostic exam (^{67}Ga)	1,220 mrem/exposure
Thyroid dose from diagnostic exam (^{131}I)	1,960,000 mrad/exposure
Average breast tissue dose following lumpectomy for breast cancer	4,750,000 mrad total
Average tumor dose from therapeutic nuclear medicine	5,000,000 mrad total
Average prostate tissue in treatment for prostate cancer	6,600,000 mrad total
Average tumor dose from brachytherapy for some prostate cancers	15,000,000 mrad total

Our Background Radiation Environment



NRC BEIR VII 2006

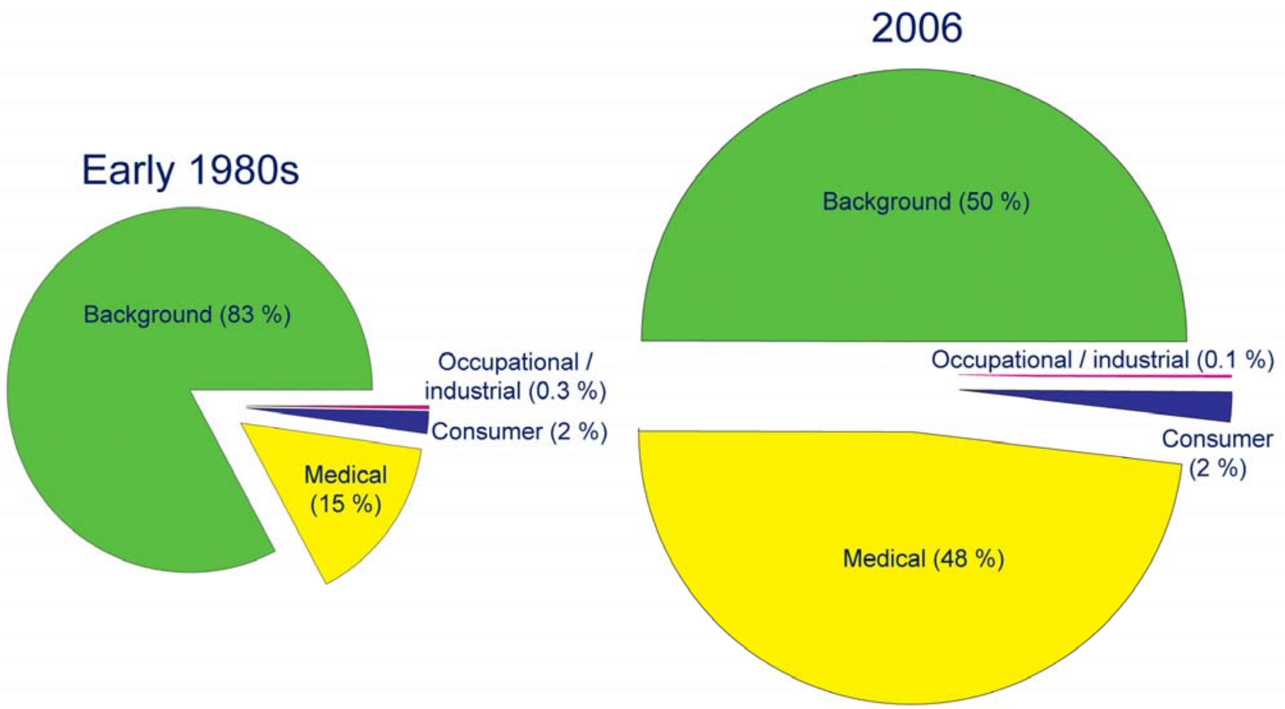
About 360 mrem/yr in the US total

About 240 mrem/yr from natural

Our Background Radiation Environment

NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*

2009



	Early 1980s	2006
Collective effective dose (person-Sv)	835,000	1,870,000
Effective dose per individual in the U.S. population (mSv)	3.6	6.2

Estimate your personal annual radiation dose.

We live in radioactive world – humans always have. Radiation is part of our natural environment. We are exposed to radiation from materials in the earth itself, from naturally occurring radon in the air, from outer space, and from inside our own bodies (as a result of the food and water we consume). This radiation is measured in units called millirems (mrems). The average dose per person from all sources is *about* 360 mrems per year. It is not, however, uncommon for any of us to receive far more than that in a given year (largely due to medical procedures we may undergo). International Standards allow exposure to as much as 5,000 mrems a year for those who work with and around radioactive material.

FACTORS	COMMON SOURCES OF RADIATION	YOUR ANNUAL DOSE (mrems)
WHERE YOU LIVE	**Cosmic radiation** (from outer space) Exposure depends on your elevation (how much air is above you to block radiation). Amounts are listed in mrem (per year). At sea level..........26 mrem; 0 - 1000 ft..........28; 1-2000 ft..........31; 2-3000 ft..........35 mrem; 3-4000 ft..........41; 4-5000 ft..........47; 5-6000 ft..........52; 6-7000 ft..........66 mrem; 7-8000 ft..........79; 8-9000 ft..........96 [Elevation of cities (in feet): Atlanta 1050; Chicago 595; Dallas 435; Denver 5280; Las Vegas 2000; Minneapolis 815; Pittsburgh 1200; St. Louis 455; Salt Lake City 4400; Spokane 1890.]	____ mrem
	Terrestrial (from the ground) If you live in a state that borders the Gulf or Atlantic Coasts, add 16 mrem If you live in the Colorado Plateau area (around Denver), add 63 mrem If you live anywhere else in the continental US, add 30 mrem.	____ mrem
	House Construction If you live in a stone, adobe, brick or concrete building, add 7 mrem	____ mrem
	Power Plants If you live within 50 miles of a nuclear power plant, add 0.01 mrem If you live within 50 miles of a coal-fired power plant, add 0.03 mrem	____ mrem
FOOD WATER AIR	**Internal Radiation***** From food (Carbon-14 and Potassium-40) & from water (radon dissolved in water)	40 mrem
	From air (radon)	200 mrem
HOW YOU LIVE	Weapons test fallout (less than 1)* ....1 mrem	1 mrem
	Jet Plane Travel ....0.5 mrem per hour in the air	____ mrem
	If you have porcelain crowns or false teeth** ....0.07 mrem	____ mrem
	If you wear a luminous wristwatch ....0.06 mrem	____ mrem
	If you go through luggage inspection at airport ....0.002 mrem	____ mrem
	If you watch TV* ....1 mrem	____ mrem
	If you use video display terminal (computer screen)* ....1 mrem	____ mrem
	If you have a smoke detector ....0.008 mrem	____ mrem
	If you use a gas camping lantern ....0.2 mrem	____ mrem
	If you wear a plutonium-powered pacemaker ....100 mrem	____ mrem
MEDICAL TESTS	**Medical Diagnostic Tests – Number of *millirems per procedure*** X-Rays: Extremity (arm, hand, foot, or leg).........1 Dental.........1 Chest.........6 Pelvis/hip ......65 Skull/neck..... 20 Barium enema.....405 Upper GI......245 CAT Scan (head and body)..........110 Nuclear Medicine (e.g., thyroid scan)........14	____ mrem
YOUR ESTIMATED ANNUAL RADIATION DOSE		____ mrem

* The value is less than 1, but adding a value of 1 would be reasonable.

** Some of the radiation sources listed in this chart result in an exposure to only part of the body. For example, false teeth or crowns result in a radiation dose to the mouth. The annual dose numbers given here represent the "effective dose" to the whole body.

*** Average values.

Primary sources for this information are National Council on Radiation Protection and Measurements Reports: #92 Public Radiation Exposure from Nuclear Power Generation in the United States (1987); #93 Ionizing Radiation Exposure of the Population of the United States (1987); #94 Exposure of the Population in the United States and Canada from Natural Background Radiation (1987); #95 Radiation Exposure of the U.S. population from Consumer Products and Miscellaneous Sources, (1987); and #100 Exposure of the U.S. Population from Diagnostic Medical Radiation (1989).

AMERICAN NUCLEAR SOCIETY

About 360 mrem / yr in the US

See also:

http://www.epa.gov/rpdweb00/understand/calculate.html

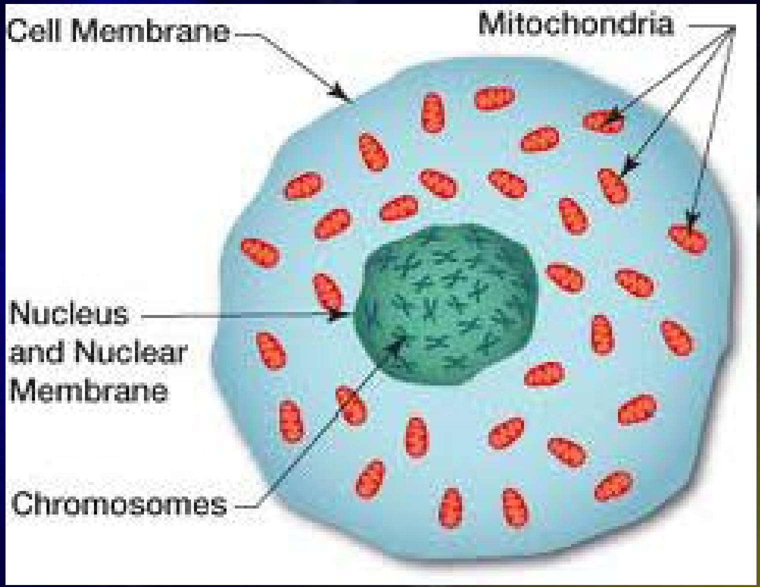
for EPA's on-line calculator

How Does Radiation Affect Me

- Ionizing radiation effects have immediate and long term parts
- At high doses, immediate effects are most important
- At low doses, long term risks are important
- Environmental exposures are low dose
  (the focus of this talk)

How Does Radiation Affect Me

- Ionizing radiation can break molecules apart
- Breaks can happen anywhere in the cell and/or DNA



Simple Cell Model

How Does Radiation Affect Me

- Cells make and break molecules under very controlled conditions as part of life
- Radiation breaks molecules uncontrollably
- High levels of uncontrolled breaks causes damage to cells
- We are constantly exposed to background radiation

How Does Radiation Affect Me

- Cells have repair mechanisms
- Very high ability for complete repair
- Some cells die
- Even fewer cells have defective repairs in DNA leading to risk of cancer

How Does Radiation Affect Me

- Overall cancer risk from radiation
- Of 100 people, 42 will develop cancer
- One cancer (star) may result from 10,000 millirem above natural background, excluding radon

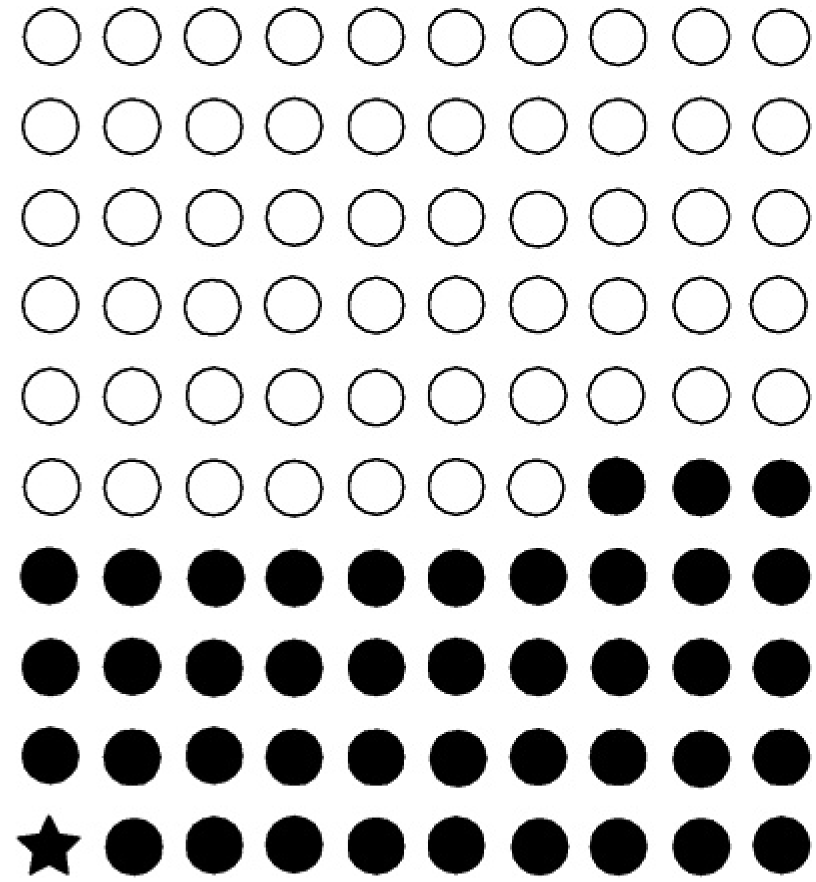
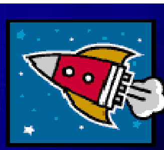


FIGURE PS-4 In a lifetime, approximately 42 (solid circles) of 100 people will be diagnosed with cancer (calculated from Table 12-4 of this report). Calculations in this report suggest that approximately one cancer (star) per 100 people could result from a single exposure to 0.1 Sv of low-LET radiation above background.

BEIR VII 2006



How Does Radiation Affect Me

- National Research Council BEIR VII June 2006
  - Overall cancer incidences, uncertainties ± x2 to x3
  - 1 to 3 in 1000 per rem above background – 0.3% risk
  - 420 in 1000 from all other causes – 42% risk
- Cancer deaths
  - American Cancer Society 2005 – 2009
  - Approx 34% of incidence rate, averaged
  - Approx 66% overall survival rate

How Does Radiation Affect Me

- Radon risk

RADON RISK IF YOU SMOKE

Radon Level	If 1,000 people who smoked were exposed to this level over a lifetime*. . .	The risk of cancer from radon exposure compares to**. . .	WHAT TO DO: Stop Smoking and. . .
20 pCi/L	About 260 people could get lung cancer	◂ 250 times the risk of drowning	Fix your home
10 pCi/L	About 150 people could get lung cancer	◂ 200 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 120 people could get lung cancer	◂ 30 times the risk of dying in a fall	Fix your home
4 pCi/L	About 62 people could get lung cancer	◂ 5 times the risk of dying in a car crash	Fix your home
2 pCi/L	About 32 people could get lung cancer	◂ 6 times the risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 20 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be lower.

EPA Citizens Guide To Radon 2005

How Does Radiation Affect Me

- Radon risk

EPA Citizens Guide To Radon 2005

RADON RISK IF YOU'VE NEVER SMOKED

Radon Level	If 1,000 people who never smoked were exposed to this level over a lifetime*. . .	The risk of cancer from radon exposure compares to**. . .	WHAT TO DO:
20 pCi/L	About 36 people could get lung cancer	◂ 35 times the risk of drowning	Fix your home
10 pCi/L	About 18 people could get lung cancer	◂ 20 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 15 people could get lung cancer	◂ 4 times the risk of dying in a fall	Fix your home
4 pCi/L	About 7 people could get lung cancer	◂ The risk of dying in a car crash	Fix your home
2 pCi/L	About 4 people could get lung cancer	◂ The risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 2 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be higher.
*Lifetime risk of lung cancer deaths from *EPA Assessment of Risks from Radon in Homes* (EPA 402-R-03-003).
**Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports.

How Does Radiation Affect Me

Radiation vs. Other Health Risks

Health Risk	Avg Days Life Lost	Health Risk	Avg Days Life Lost
Smoking 20 cigarettes per day	2370 (6.5 yrs)	Medical diag x-rays (US avg)	6
Overweight 20%	985 (2.7 yrs)	All catastrophes	3.5
All accidents combined	435 (1.2 yrs)	1 rem occupational dose	1
Auto accidents	200		
Home accidents	95		
Drowning	41		
Nat BKG Radiation (calc)	8		

How Does Radiation Affect Me

Radiation vs. Other industries

Health Risk	Avg Days Life Lost	Health Risk	Avg Days Life Lost
All Industries	74	Construction	302
Trade	30	Mining & Quarrying	322
Manufacturing	43	0.65 rem/yr for 30 yrs (calc) (1984)	20
Service	47	0.23 rem/yr for 30 yrs (calc) (2003)	7
Government	55		
Transp & Utilities	164		
Agriculture	277		

How Does Radiation Affect Me

Short List of 1 in 1 Million Risk of Dying

Smoking 1.4 cigarettes (lung cancer)
Radiation dose of 10 mrem (cancer)
Eating 40 tablespoons of peanut butter (liver cancer)
Eating 100 charcoal broiled steaks (cancer)
Spending 2 days in New York City (air pollution)
Driving 40 miles in a car (accident)
Flying 2,500 miles in a jet (accident)
Canoeing for 6 minutes (accident)

What Is In The Shale

- Definitions vary
- NORM – Naturally Occurring Radioactive Material – as nature intended
- TENORM – Technologically Enhanced Naturally Occurring Radioactive Material – human activity that changes the natural presence or concentration of NORM

What Is In The Shale

- Black shale contains Uranium and Thorium
- Some reports state Marcellus contains higher levels of U than other shales
  (e.g. Resnikoff in http://www.rwma.com/Marcellus Shale Report 05-18-2010.pdf)
- Also present are K-40 and U decay products (see the decay chain presented earlier)

What Is In The Shale

- U-238 content

Resnikoff et al

Table 1. Uranium Content and Depth of Marcellus Shale in Four Cores

Location of the Core	Depth of Sample (feet)	Uranium Content (ppm)
Allegheny, NY	7342 – 7465	8.9 – 67.7
Tomkins County, NY	1380 – 1420	25 – 53
Livingston County, NY	543 – 576	16.6 – 83.7
Knox County, OH	1027 – 1127	32.5 – 41.1

- 1 ppm U-238 = 0.7 pCi/g, 83 ppm = 58 pCi/g
- Soil avg about 2 ppm, avg background in cores 4 ppm
- Primary concern is Radium

What Is In The Shale

- Why is Radium of such concern?
  - Soluble in waters used in drilling
  - Continues to evolve in brine water effluent over life of well
  - Behaves like Calcium in the body – bone seeker
  - Emits high dose alpha radiation
  - Bone marrow is radiation sensitive
  - Retained in the body for a very long time
  - Plates out creating scale buildup and possible external exposure concern

What Is In The Shale

- K-40 content
- NY DSGEIS range 14 to 23 pCi/g
- Recall 433 pCi/g in salt substitute
- K-40 not a concern
  - Non-radioactive decay product (decays to Argon)
  - Much higher levels in human environment
  - Much lower hazard beta radiation

What Is Around Drill Sites

- Drill sites
  - NY DSGEIS surveyed 28 sites, essentially background general radiation levels
  - External gamma dose rates from scale build up at mature oil sites ranges up to 30 mrem/hr (IAEA TCS40)
  - Cuttings – U and Th remain in mineral formations as solids, very low mobility

  - Concern remains with Radium in produced waters

What Could Get Into Water

- EPA drinking water standard

Regulated Contaminants		
Regulated Radionuclide	MCL	MCLG
Beta/photon emitters*	4 mrem/yr	0
Gross alpha particle	15 pCi/L	0
Combined radium-226/228	5 pCi/L	0
Uranium	30 µg/L	0

*A total of 168 individual beta particle and photon emitters may be used to calculate compliance with the MCL.

EPA 2001

What Could Get Into Water

- Radium and Radon naturally found in well water from U close to ground water sources
- Radium will go where hydrofracturing chemicals will go
- Proper techniques preventing chemical contamination will also address radiological contamination

TENORM Wastes

- No doubt – a serious concern
- DEC Draft study lacking dose assessments and pathway analysis – DEC April 1999 NORM study should be done for Marcellus region
- Realistic modeling of waste production and thorough evaluation of all disposal methods (1999 study only mentions road spreading as most common)
- Use actual experience from other oil and gas producing states – find the best practices
- The technology exists for safe handling and disposal

Radon

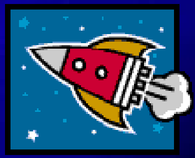
- Radon
  - Naturally occurring radioactive gas
  - From the decay of Radium
  - Odorless and colorless
  - Decay products more important than gas itself
  - Decay products emit alpha radiation leading to high dose to lung tissue

Radon

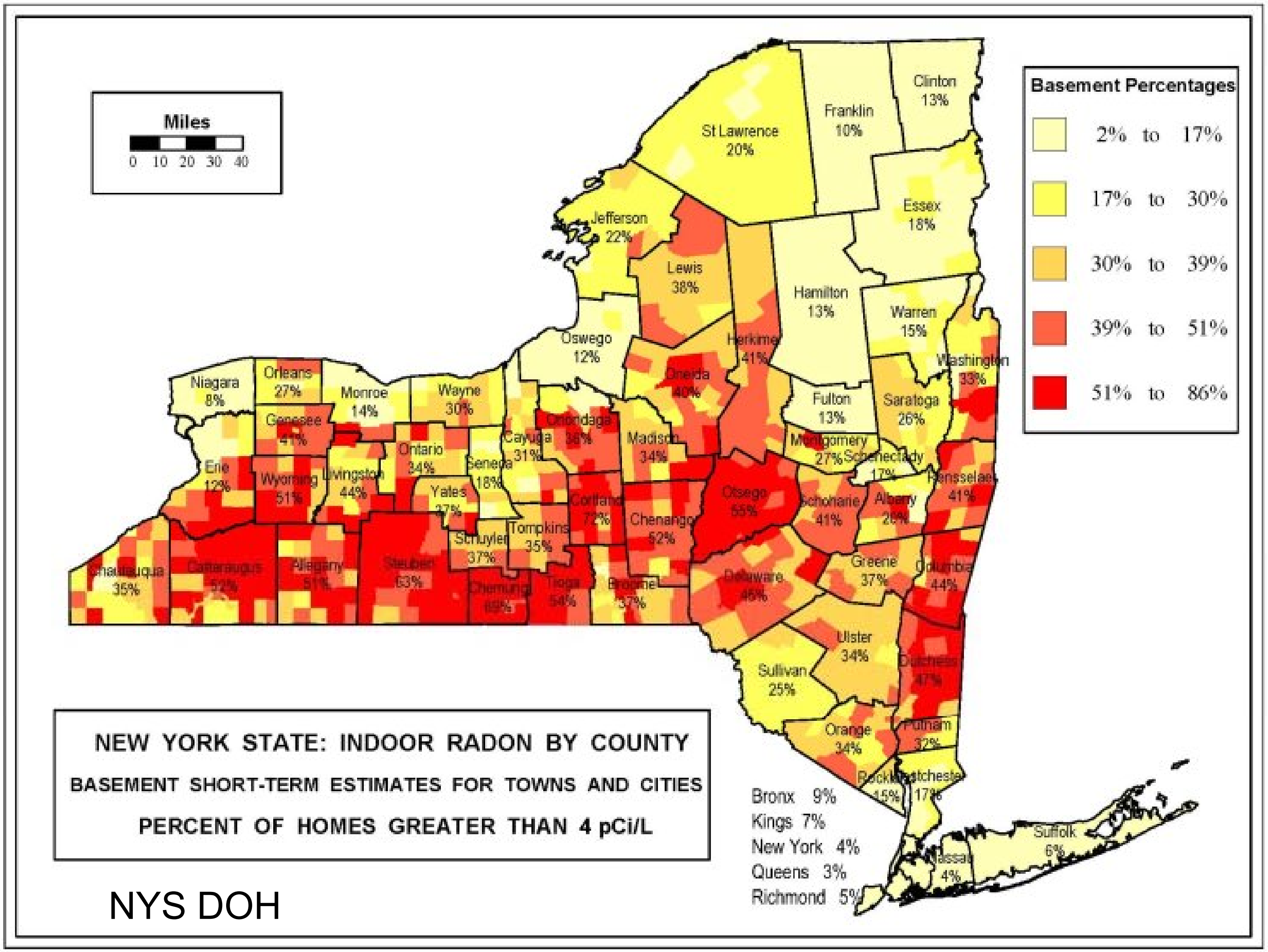
- EPA Radon action level
  - 4 pCi / L of air
  - LONG TERM AVERAGE

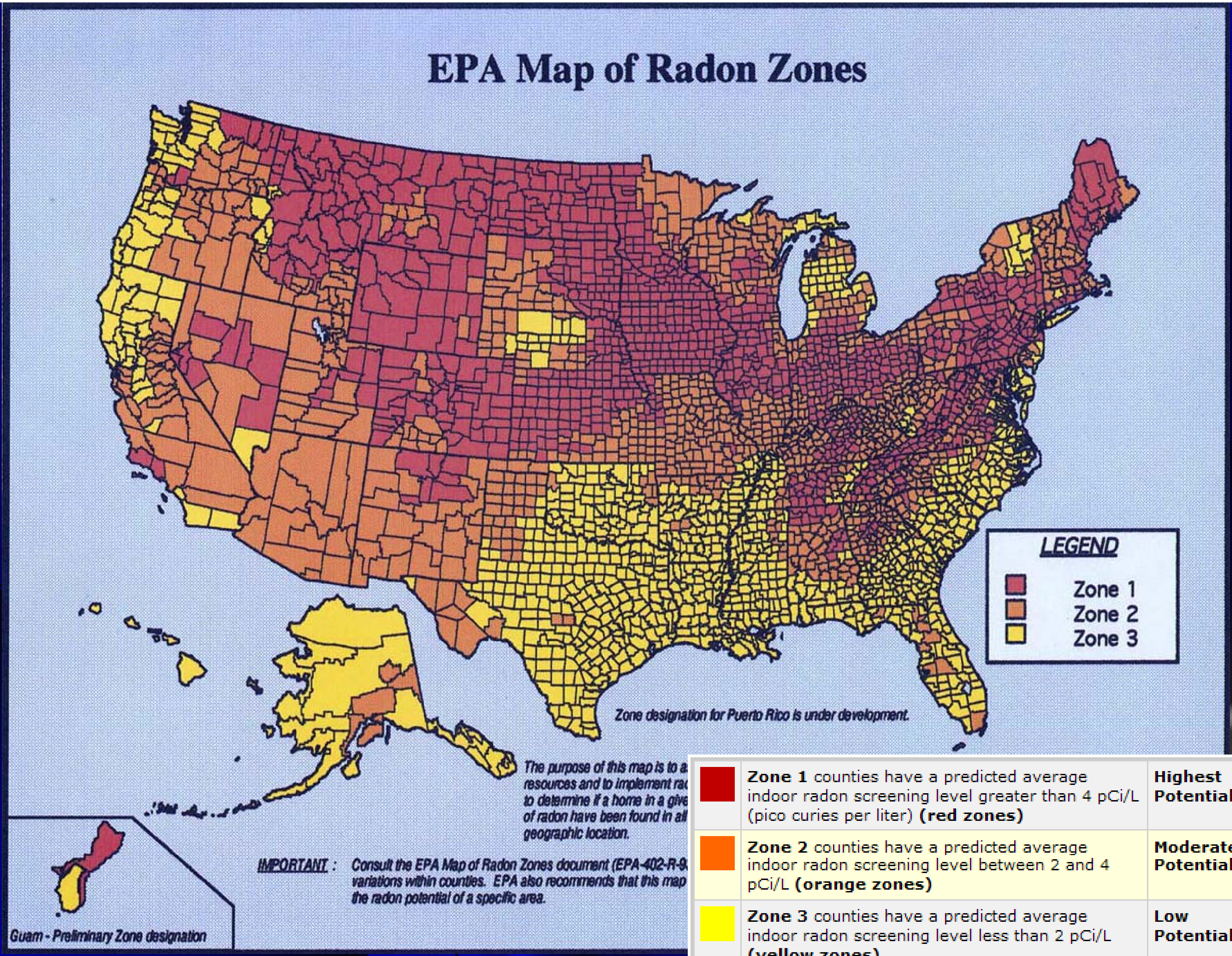
  - Perform several short term tests or one long term test
  - More info to come

Radon

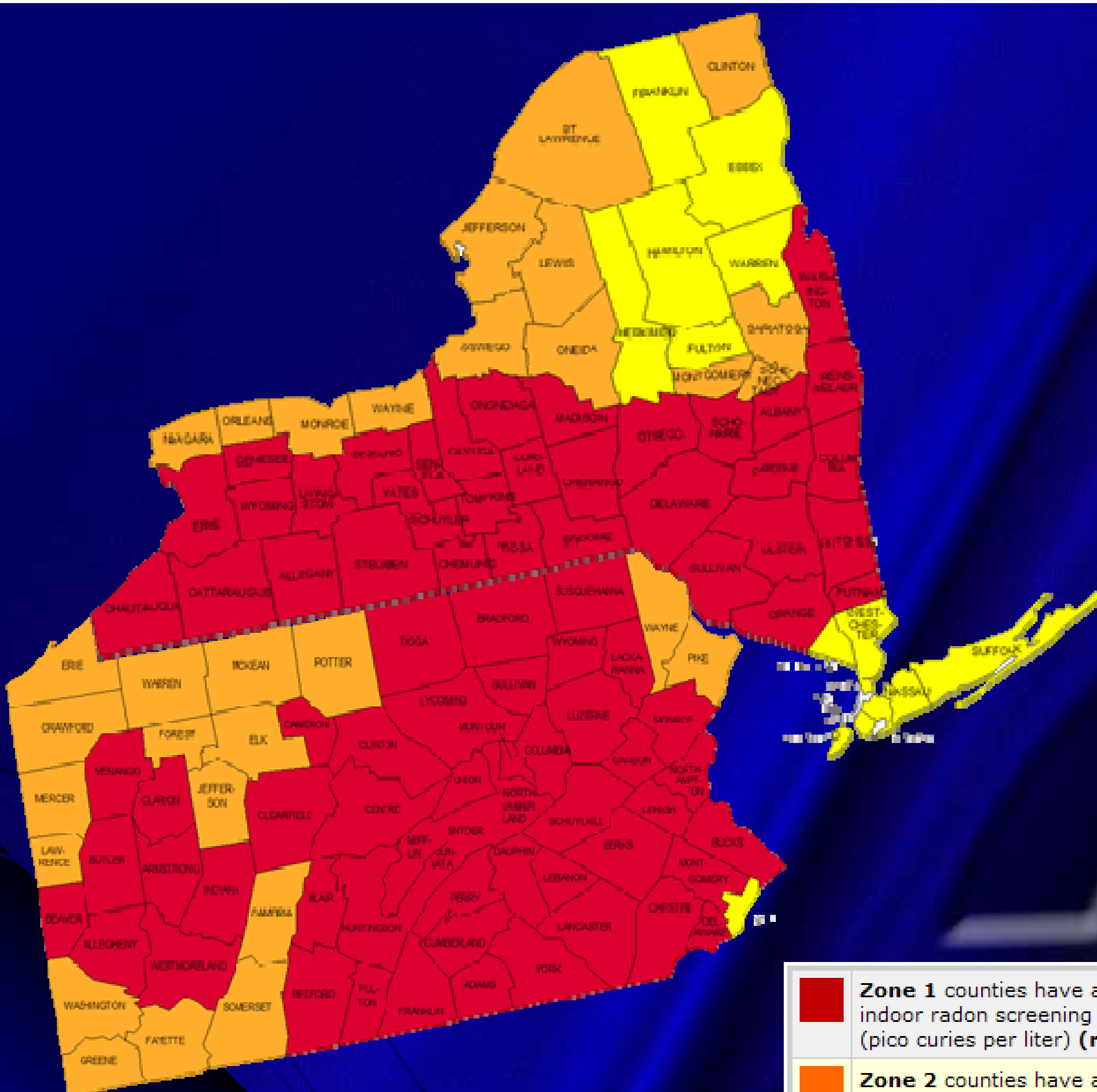


- Radon
  - 4 pCi/L is 370 mrem/yr to lung (UNSCEAR2000)
  - Assumes 7000 hrs occupancy (80%)
  - 40% equilibrium with decay products (ICRP65)
  - Alpha quality factor of 20


Miles
0 10 20 30 40
Basement Percentages
2% to 17%
17% to 30%
30% to 39%
39% to 51%
51% to 86%
St Lawrence 20%
Franklin 10%
Clinton 13%
Essex 18%
Jefferson 22%
Lewis 38%
Hamilton 13%
Warren 15%
Oswego 12%
Herkimer 41%
Washington 33%
Niagara 8%
Orleans 27%
Monroe 14%
Wayne 30%
Oneida 40%
Fulton 13%
Saratoga 26%
Genesee 41%
Onondaga 36%
Cayuga 31%
Madison 34%
Montgomery 27%
Schenectady 17%
Ontario 34%
Seneca 18%
Erie 12%
Wyoming 51%
Livingston 44%
Yates 37%
Cortland 72%
Otsego 55%
Schoharie 41%
Albany 26%
Rensselaer 41%
Chenango 52%
Tompkins 35%
Schuyler 37%
Chautauqua 35%
Cattaraugus 52%
Allegany 51%
Steuben 63%
Chemung 69%
Tioga 54%
Broome 37%
Delaware 46%
Greene 37%
Columbia 44%
Ulster 34%
Dutchess 47%
Sullivan 25%
Orange 34%
Putnam 32%
Rockland 15%
Westchester 17%
Suffolk 6%
Nassau 4%
Bronx 9%
Kings 7%
New York 4%
Queens 3%
Richmond 5%
NEW YORK STATE: INDOOR RADON BY COUNTY
BASEMENT SHORT-TERM ESTIMATES FOR TOWNS AND CITIES
PERCENT OF HOMES GREATER THAN 4 pCi/L
NYS DOH



	Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L (pico curies per liter) **(red zones)**	**Highest Potential**
	Zone 2 counties have a predicted average indoor radon screening level between 2 and 4 pCi/L **(orange zones)**	**Moderate Potential**
	Zone 3 counties have a predicted average indoor radon screening level less than 2 pCi/L **(yellow zones)**	**Low Potential**



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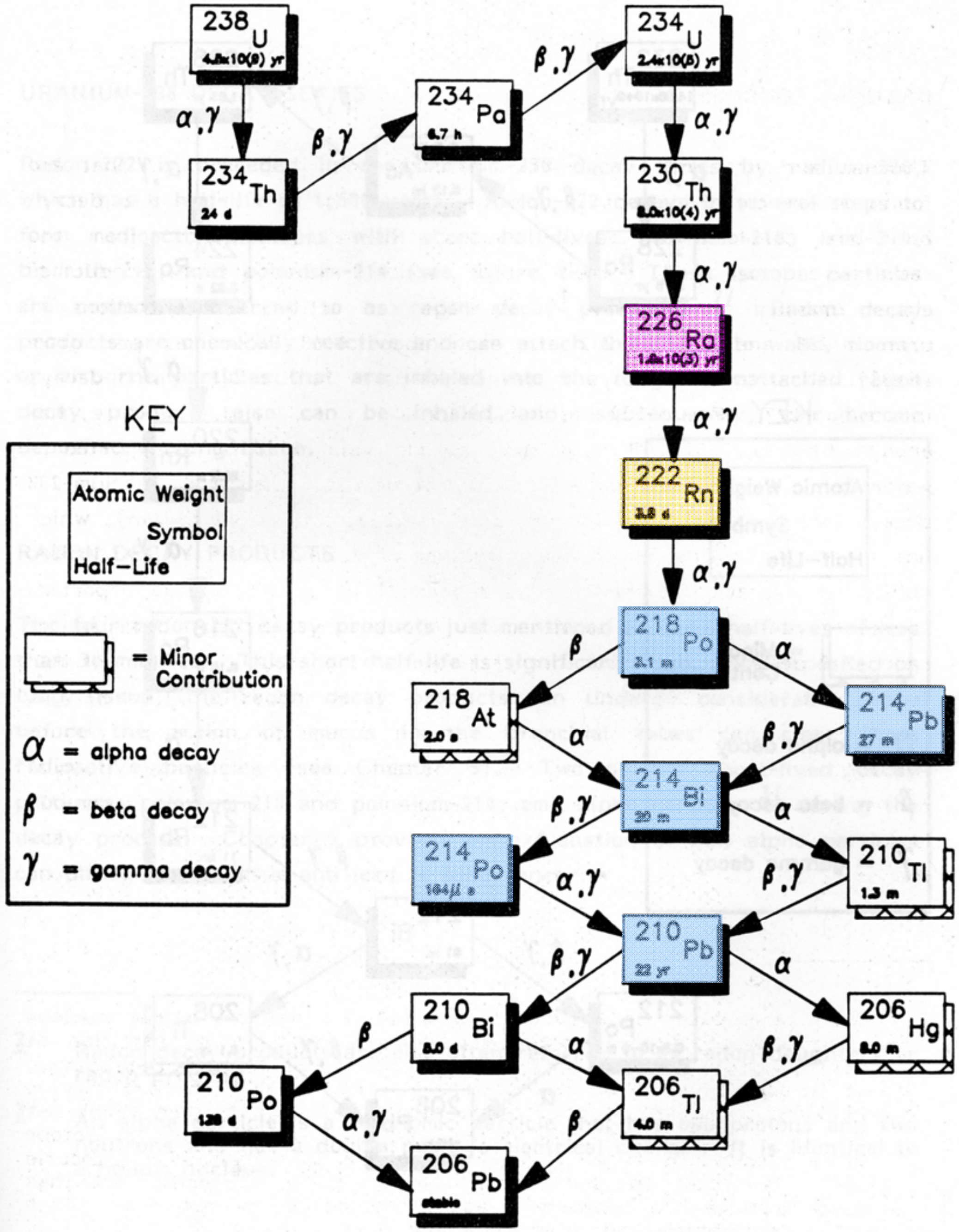
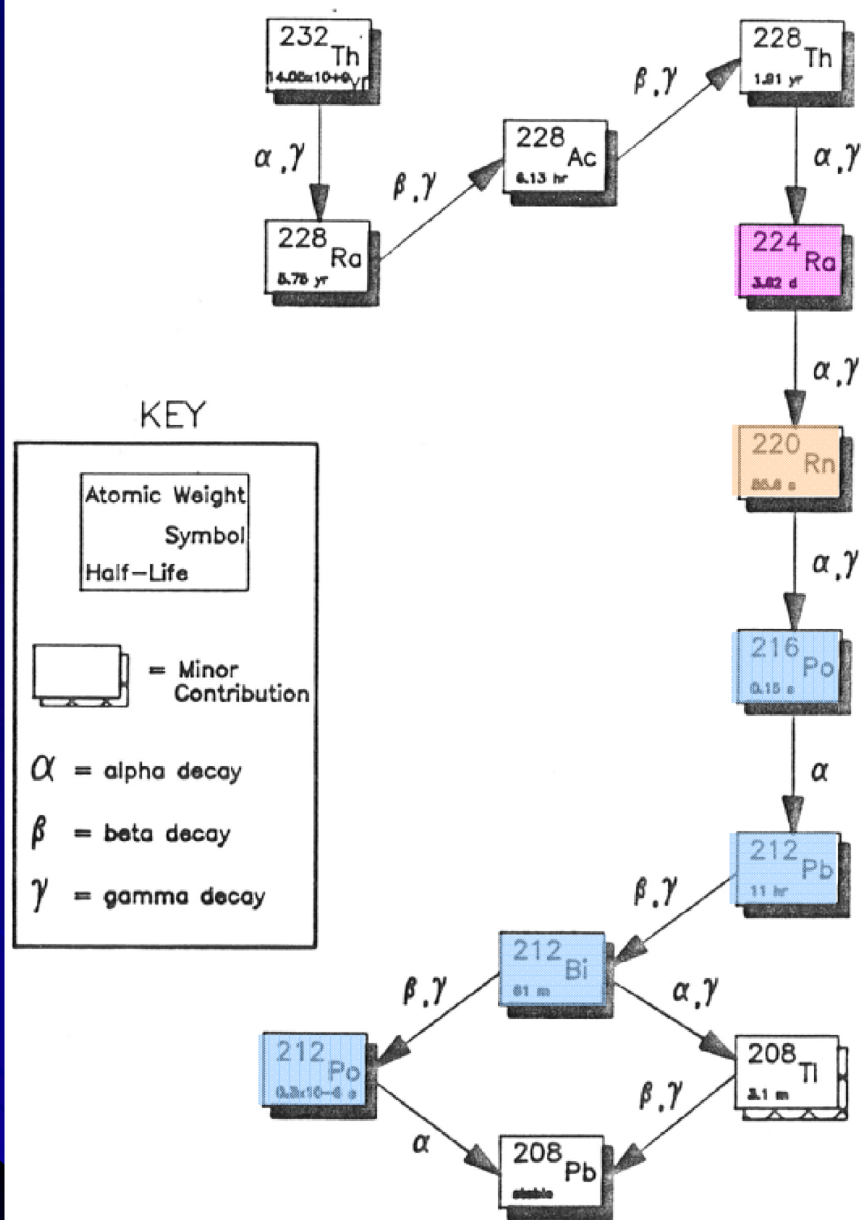


SOURCE: Putnam, Hayes & Bartlett, Inc., September 1987.

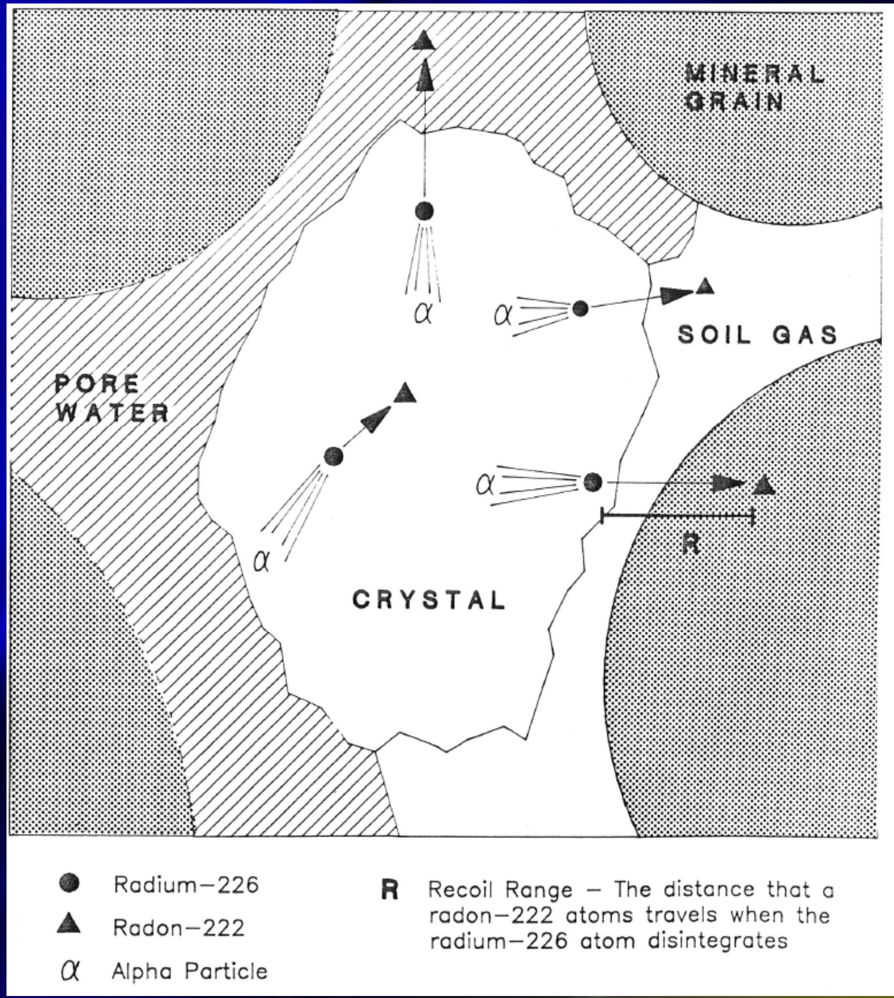
Thorium–232 Decay Series



SOURCE: Putnam, Hayes & Bartlett, Inc., September 1987.

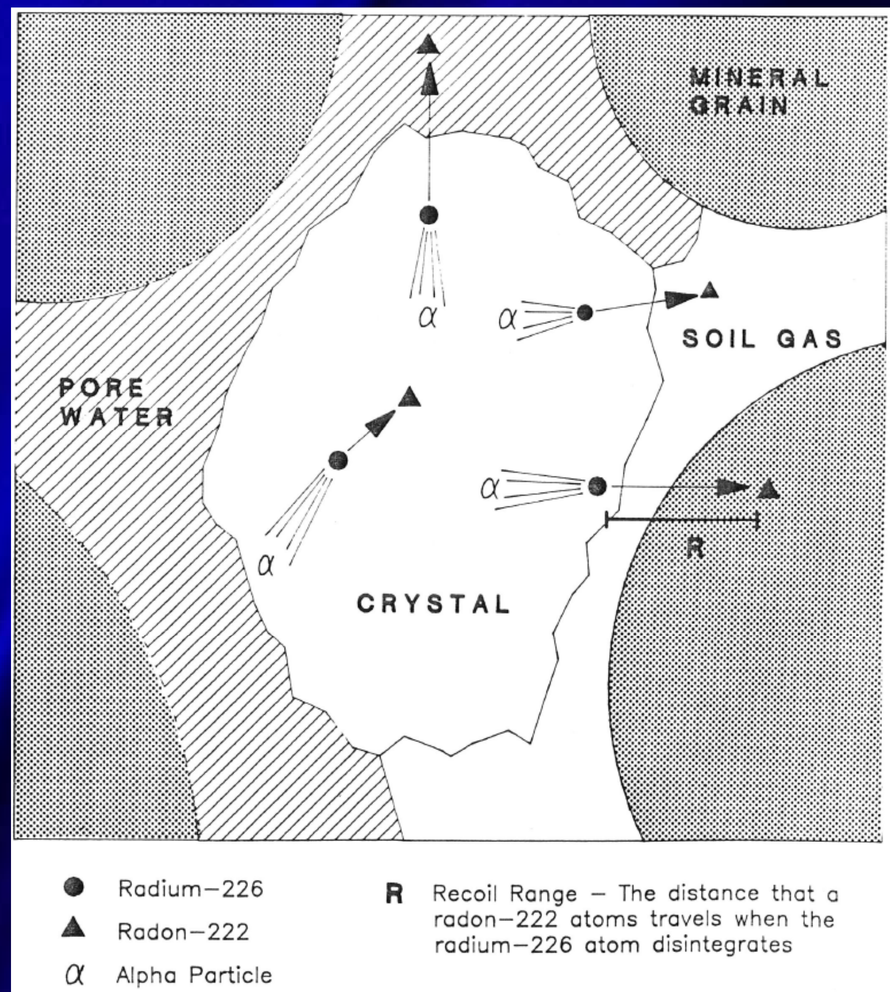
Radon

- Soil is a grainy mixture of minerals, organic material and water
- Soil grains have large surface areas
- Radon near grain surface contributes to free radon gas



Radon

- Moisture content important
- 0% ~30% enhances Rn emanation, over ~30% emanation decreases
- Typical surface emanation rate ~0.5 pCi/sec per m^2



Radon

- In stagnant soil gas space Rn diffuses 1 – 2 meters before decay
- Most indoor Rn comes from 10’s of meters away

- ***Subsoil pressure gradients cause Rn movement***

Radon

- General trends
  - Soil density ↑ → emanation rate ↓
  - Rock/soil fissures or cracks ↑ → emanation rate ↑
  - Atmospheric pres ↑ → emanation rate ↓
  - Wind speed ↑ → emanation rate ↑
- Typical outdoor concentration 0.1 – 0.3 pCi/L

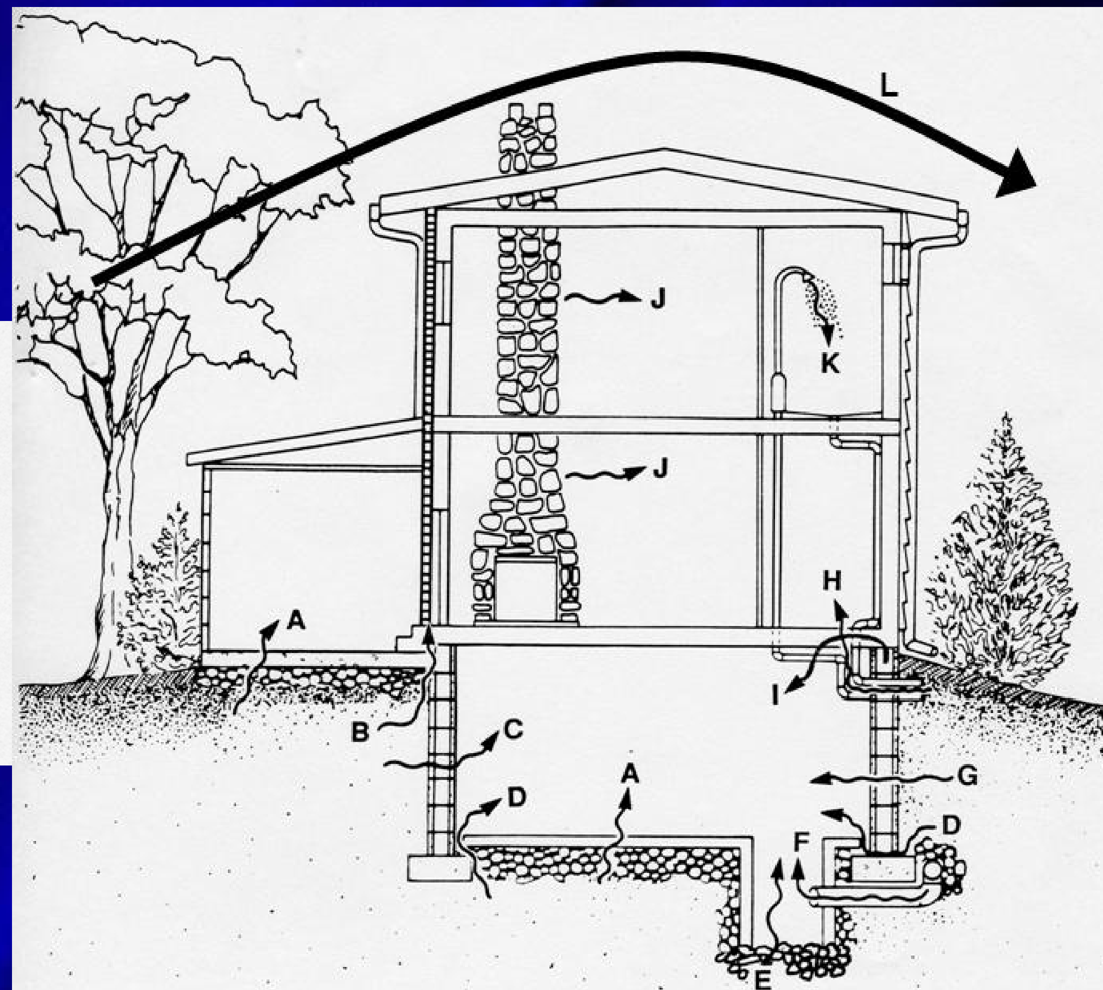
Radon

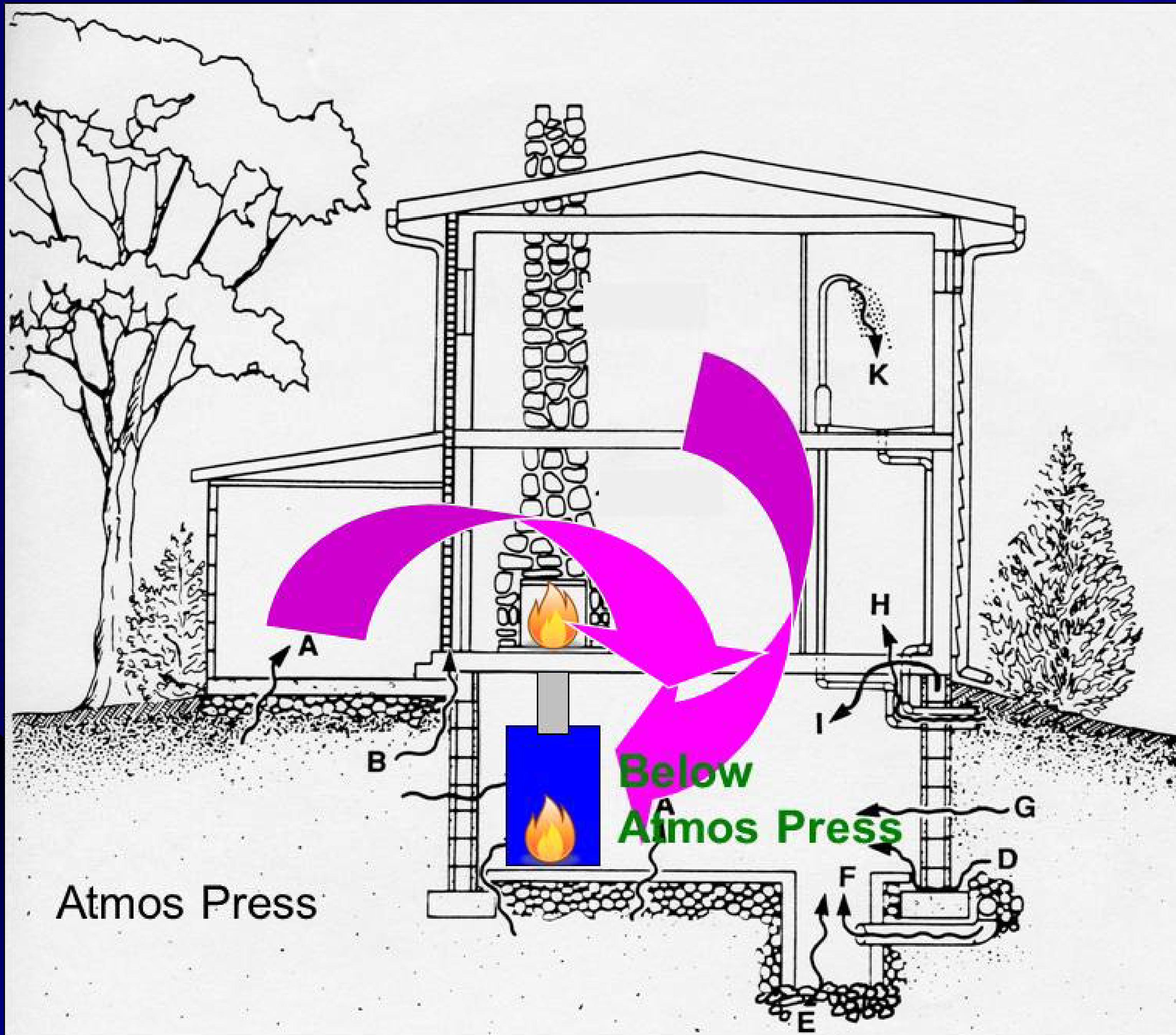
- Sub-soil pressure gradients cause bulk Rn movement into the home, not diffusion
- Houses with basements more susceptible due to large surface area contact with soil
- Chimney effect primary cause
  - Furnace, boiler, fireplaces, general heating, etc.

Radon

MAJOR RADON ENTRY ROUTES

A. Cracks in concrete slabs
B. Spaces behind brick veneer walls that rest on uncapped hollow-block foundation
C. Pores and cracks in concrete blocks
D. Floor-wall joints
E. Exposed soil, as in a sump
F. Weeping (drain) tile, if drained to open sump
G. Mortar joints
H. Loose fitting pipe penetrations
I. Open tops of block walls
J. Building materials such as some rock
K. Water (from some wells)
L. Wind

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Radon

- EPA has found
  - Avg basement ~0.5 – 2.5 pCi/L
  - Drinking (well) water ~240 pCi/L
- Roughly 1000 – 10,000 pCi/L in water yields 1 pCi/L in air
- Natural gas ~20 pCi/L
- Overall ~95% from soils/rocks, ~5% from water, and minor other sources

Radon

- Outdoor Radon
  - Not a concern – rapid dilution in air around drilling and waste sites

- Radon in gas
  - Not a concern – follows gas and combustion products
  - Leaking gas lines more hazardous
  - Leaking CO more hazardous

Measuring Radon

- Rn gas measured in pCi per liter of air
- Rn decay products measured in Working Levels (WL)
  - Borrowed from mining industry
  - 1 WL = total potential α particle energy emission of 1.3×10^5 MeV = 100 pCi/l Rn-222 in equilibrium
  - Cumulative exposure WL Month (WLM) is 1 WL for 170 hrs (occupational)
  - 1 WL for public at home for 16 hr/day, 30 days is equivalent of ~3 WLM

Measuring Radon

- Because Rn is a gas, decay products are particulate, EPA assumes 40% equilibrium
  - 1 WL = 250 pCi/l of Rn-222 in homes
  - 4 pCi/l = 0.016 WL
  - EPA assumes ~40%, research shows wide variability, closer to ~20%
  - Charged decay products plate out
  - Recall that decay products more important than Rn gas itself

Radon Effects

- Attached vs. unattached fractions
  - First decay product Po-218 may attach to ambient particles, remain unattached, or plate out onto surfaces
  - If attached, ~0.1 – 0.5 μm particle sizes, inhaled and retained in nasal-pharyngeal region
  - If unattached, more hazardous, drawn in deeper, attaches to tracho-bronchial region

Radon Effects

- Upper bronchial bifurcations site of exposure
  - Site of most unattached deposition
  - Most dose from Po-218, Po-214 α's – penetrates mucosal lining
  - Basal cells under epithelium appear to be site of cancer induction

Radon Risk

- Only effect attributed to Rn is lung cancer

Table D1: Lifetime risk of lung cancer death by radon level for never smokers, current smokers, and the general population.

Radon Level[a] (pCi/L)	Lifetime Risk of Lung Cancer Death from Radon Exposure in Homes		
	Never Smokers	Current Smokers	General Population
20	3.6%	26.3%	10.5%
10	1.8%	15.0%	5.6%
8	1.5%	12.0%	4.5%
4	0.7%	6.2%	2.3%
2	0.4%	3.2%	1.2%
1.25	0.2%	2.0%	0.7%
0.4	0.1%	0.6%	0.2%

[a] Assumes constant lifetime exposure in homes at these levels.
[b] Estimates are rounded to the nearest tenth of a percent. No indication of uncertainty should be inferred from this practice.

Never smoker less than 100 cigarettes

EPA Assessment of Risks from Radon in Homes [EPA 402-R-03-003]

Radon Risk

- Some points:
  - Smoking is synergistic
  - Risk estimates vary by factor of 2 to 3
  - Rn-220 (thoron) less concern, shorter half-life

Radon Testing

- Measure Rn or decay products?
  - Decay products responsible for lung dose
  - Rn pCi/L less dependent on building occupation or use, may give better estimate of hazard
  - Calibration devices available for Rn, not decay products

  - Rn measurement sufficient for screening

Radon Testing

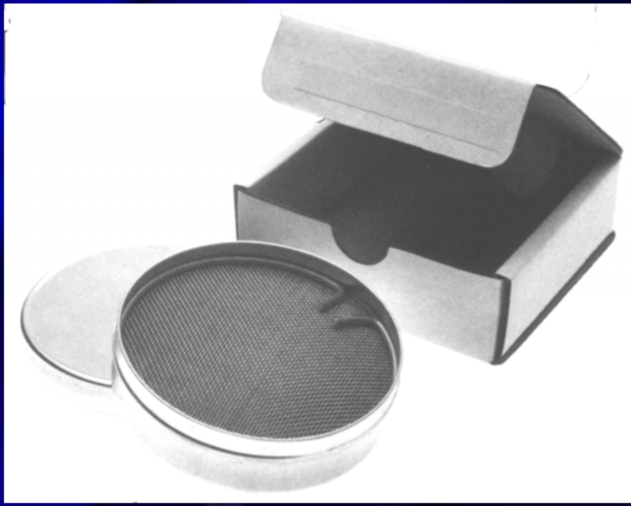
- How to measure
  - Follow manufacturer's instructions
  - Highest readings in lowest living level
  - Basements are NOT a living level, unless capable of being finished or finished for such purpose
  - Homes right next to each other can have dramatic Radon differences

Radon Testing

- Professional electronic detector
  - Draws air samples for 1 – 2 days
  - Grab sample – short term measurement

No product endorsement is implied

Radon Testing

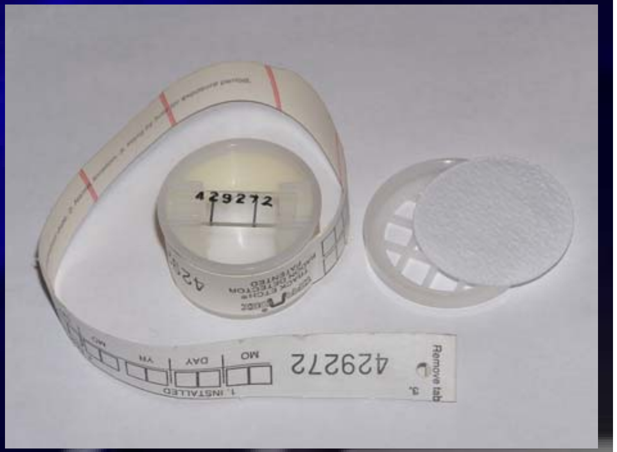


- Charcoal canisters
  - Most common, cheap
  - Short term test, 2 – 5 days
  - Avoid humid days and rooms like kitchens and baths
  - Seal thoroughly and return promptly, time is important
  - Rn adsorbed, decay products equilibrate, perform gamma spec
  - Available at reduced cost from NYS DOH

No product endorsement is implied

Radon Testing

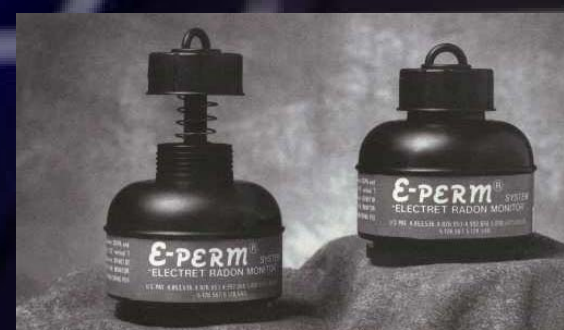
- Alpha track etch
  - Long term integration possible 1 – 12 months
  - Unaffected by environment
  - Alphas leave tracks in plastic
  - Counting tracks per area calibrated back to concentration
  - Version available for water
  - About $30 ea (Radon Testing Corp of America – RTCA)



No product endorsement is implied

Radon Testing

- Electronic passive integrating
  - Electrets and solid state
  - Short to long term
  - Rn decay detected electronically and recorded
  - EPA assumptions built in to provide Rn or in some electronic devices WL
  - Similar placement to charcoal



No product endorsement is implied

Radon Mitigation

- Mitigation methods
  - Remember EPA action level is ***long term*** average over 4 pCi/L – do more than 1 short term test
  - See EPA web site for a large amount of information on measuring and mitigation
  - Start with least invasive, least cost and retest
  - **Goal: reduce pressure differences between inside and outside**

Radon Mitigation

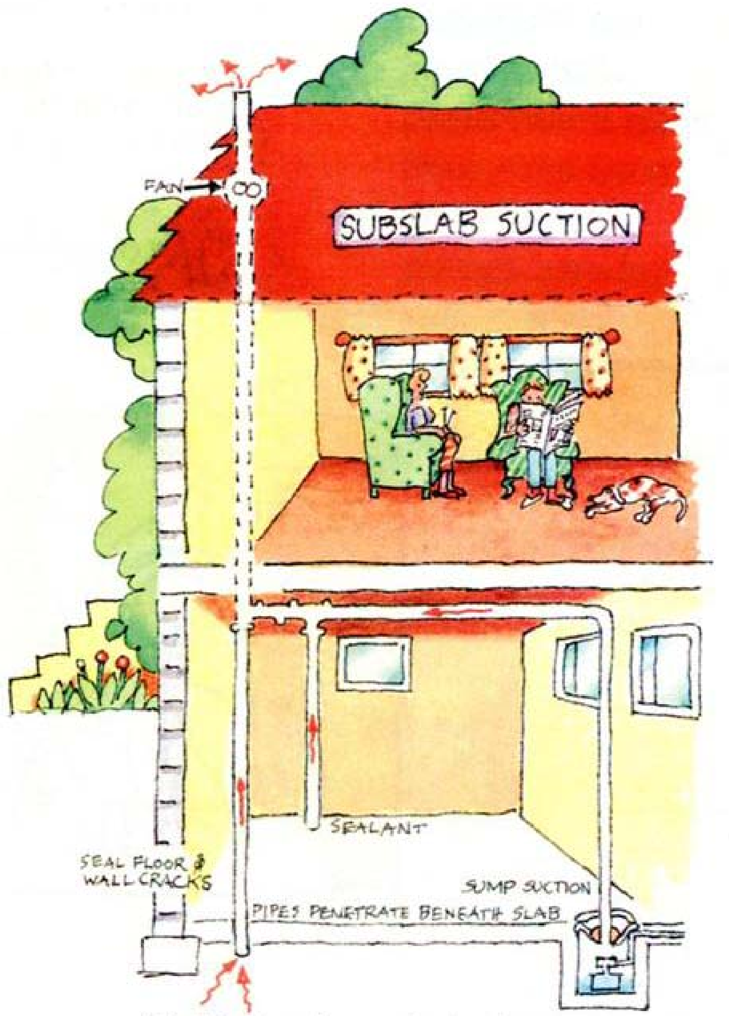
- Do first:
  - Ventilate basements and crawlspaces
  - Supply outside air (e.g. 4 inch flexible pipe) to furnace, fireplace and/or dryer location
  - Seal all cracks and joints – caulk, grout
  - Cover and seal sumps, all bare soil
  - Re-test

Radon Mitigation

- Try second:
  - Pressurize house (fans)
  - Seal / paint cinderblock, poured and brick walls with epoxy paint, cement paint, etc.
  - Fill block wall openings at top
  - Re-test

Radon Mitigation

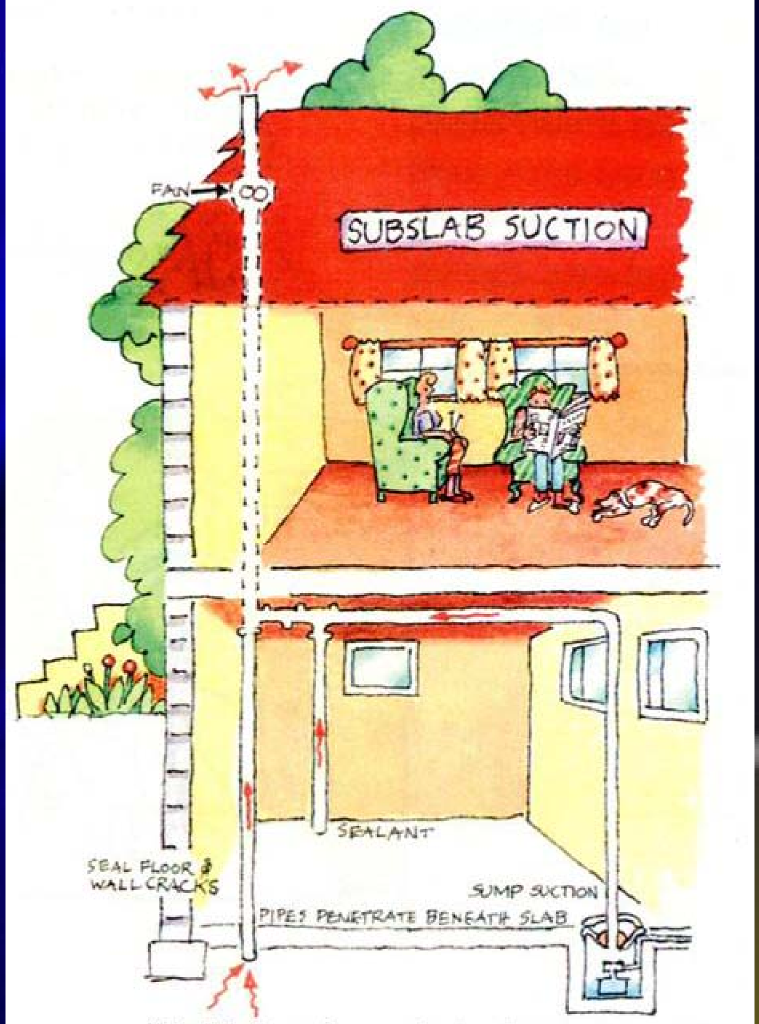
- Try third:
  - Sub-slab ventilation
  - Foundation ventilation
  - Both reduce pressure under slab or crawl space below that in basement
  - Fan blows gas outside
  - Re-test



Note: This diagram is a composite view of several mitigation options. The typical mitigation system usually has only one pipe penetration through the basement floor; the pipe may also be installed on the outside of the house.

Radon Mitigation

- For water
  - Activated charcoal filters, reverse osmosis for Radon and Radium
  - Aerate or charcoal filtration for Radon



Note: This diagram is a composite view of several mitigation options. The typical mitigation system usually has only one pipe penetration through the basement floor; the pipe may also be installed on the outside of the house.

Radon Mitigation

- Other methods
  - Air ionizers or ion generators can be very effective for attached and unattached decay products – charges particulates to attract decay products
  - Air filters or electrostatic filters – effective for attached decay products

Radon Final Comments

- Test now before drilling starts
  - Base line to monitor future changes
  - Find and fix high Radon levels
- Test air and water

Final Comments

- Radiation is natural
- While Marcellus shale is richer in U than others, a lot more radioactivity is present in the environment naturally
- Radium is the primary concern for waste disposal

Final Comments

- Drilling technology is mature – proper technique protects ground water
- Incidents will occur – technology exists to address impacts
- Further study of PA env monitoring and additional pathway analysis needed


Thank You !!!
Questions ???
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