RADON and Alpha Radiation Exposure

A historical perspective of radon, **Alpha Radiation** biology and household radon levels in the greater Calgary area

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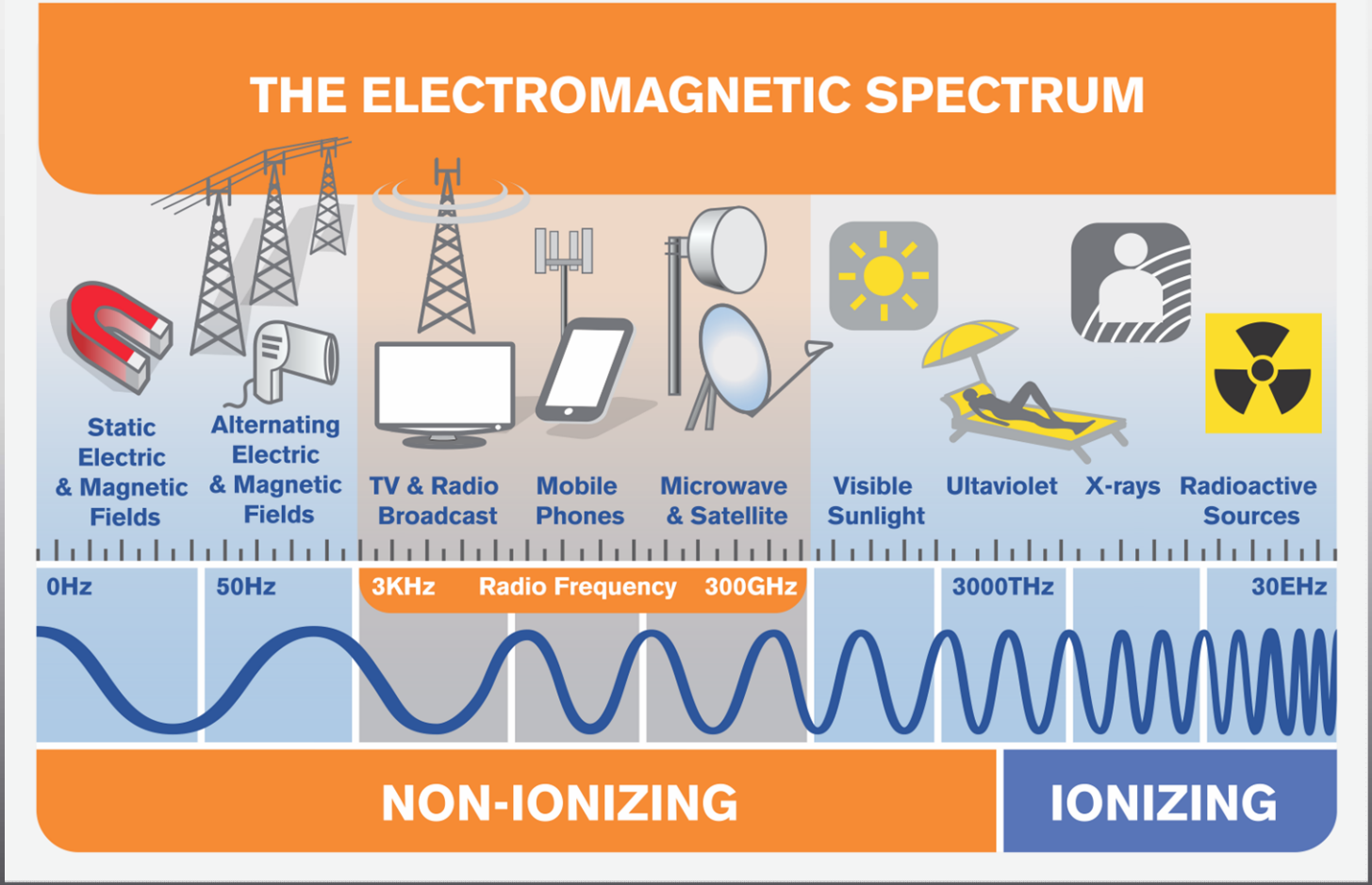
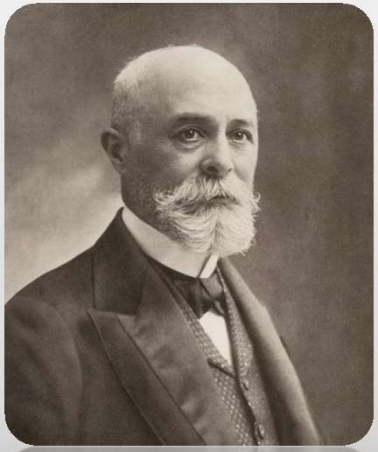
What is Radiation?



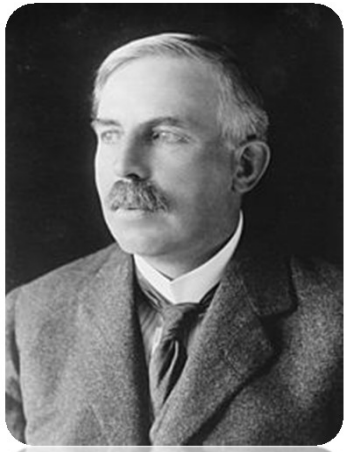
http://emfguide.itu.int/emfguide.html

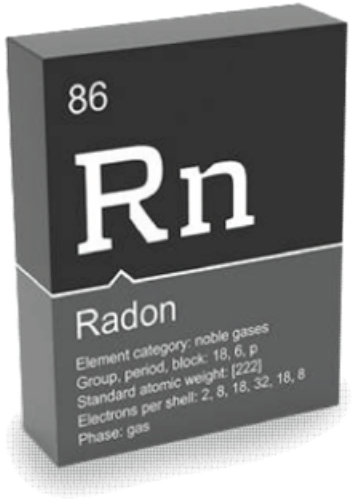
Radiation Discovery



• 1896 – **Henri Becquerel** discovers radioactivity in uranium salts

• 1898 – **Marie Curie** describes radiation from thorium, polonium and radium





• 1903 – **Ernst Rutherford** discovers **radon** and defines α radiation as beams of helium nuclei

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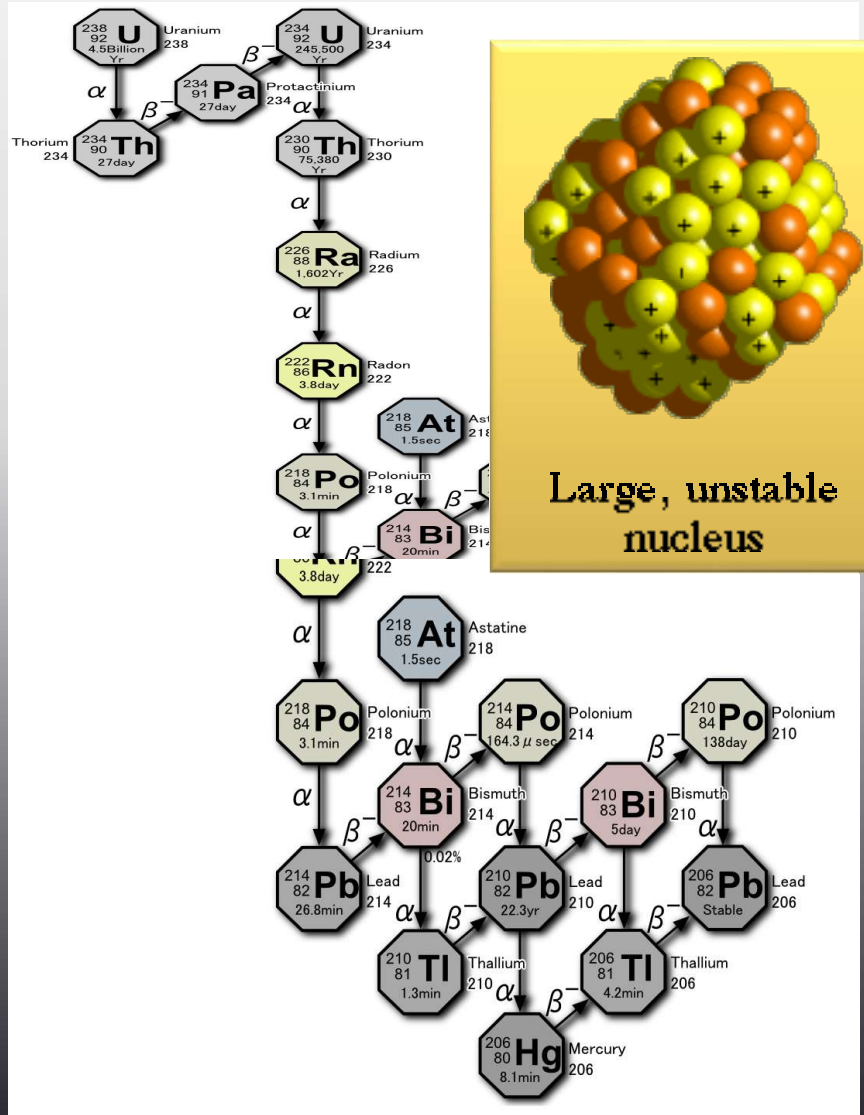
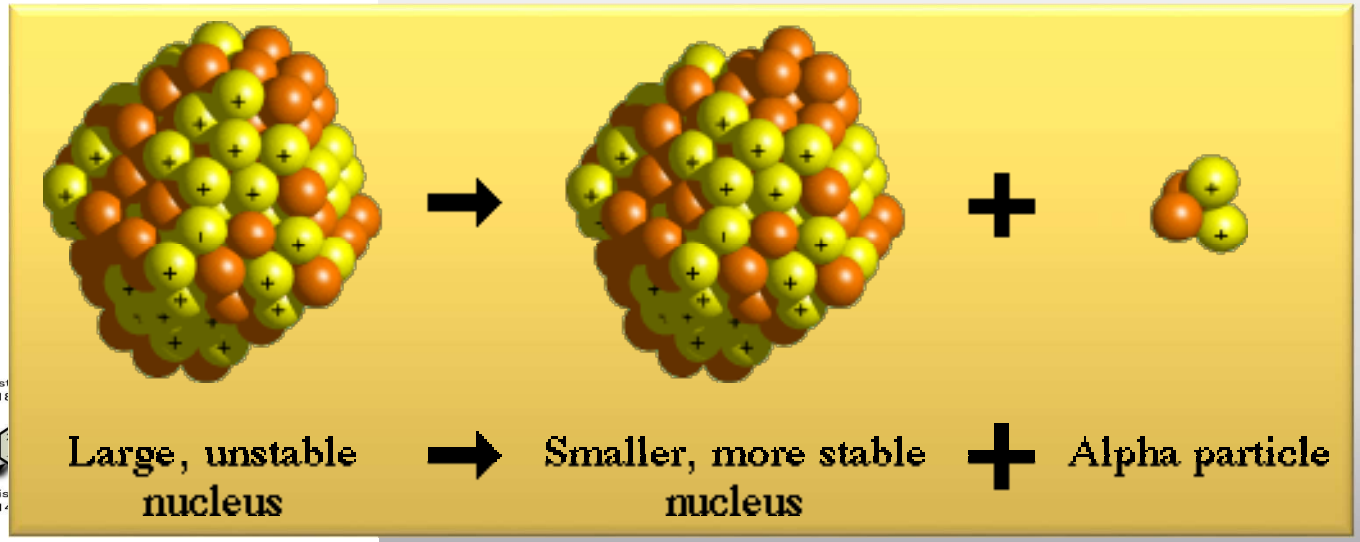
Radon = α-particle radiation

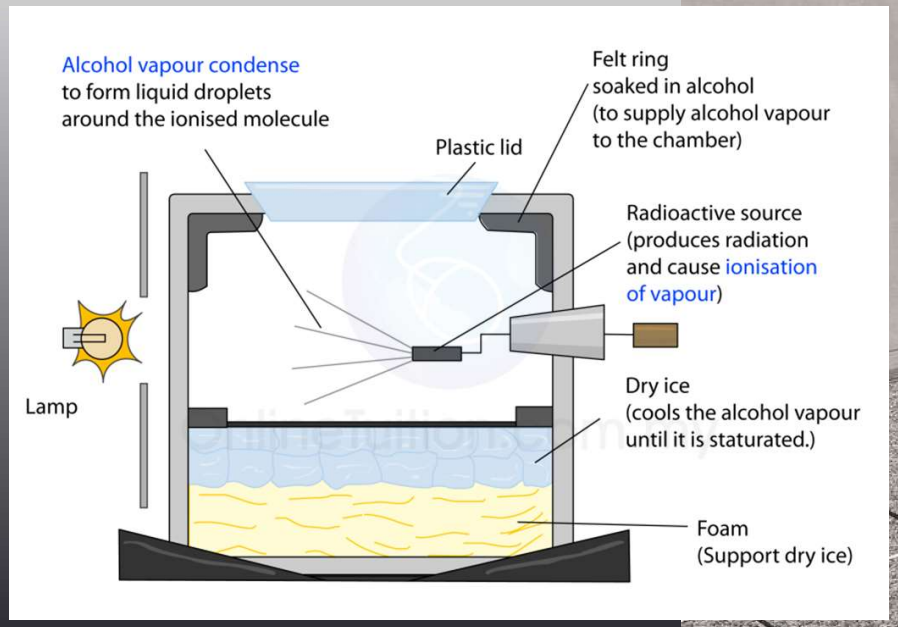


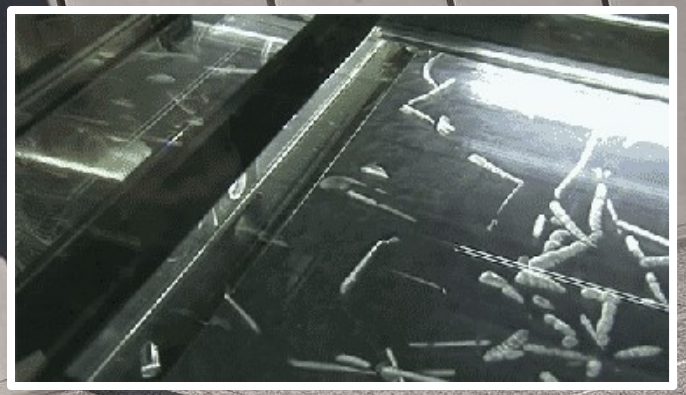


FOUR alpha particles are emitted per atom of decaying radon

Seeing the Invisible

- **Radon is odourless and colourless.**
- Alpha particle tracks can be **seen** using a few tricks





Ernest Rutherford

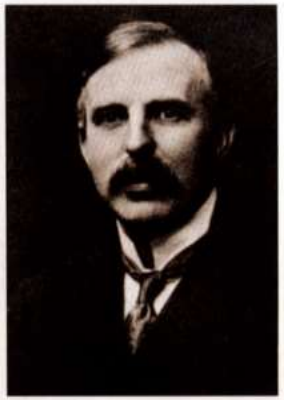
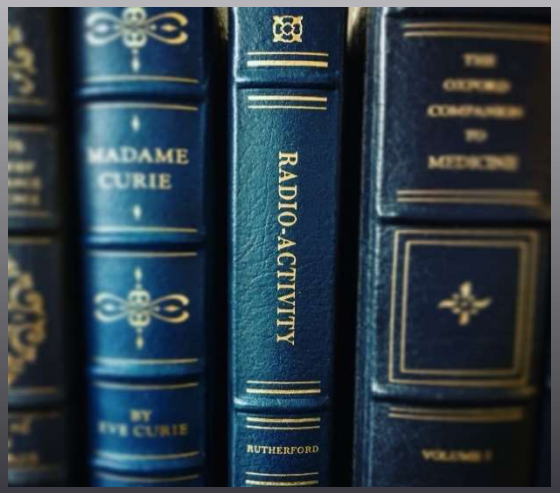
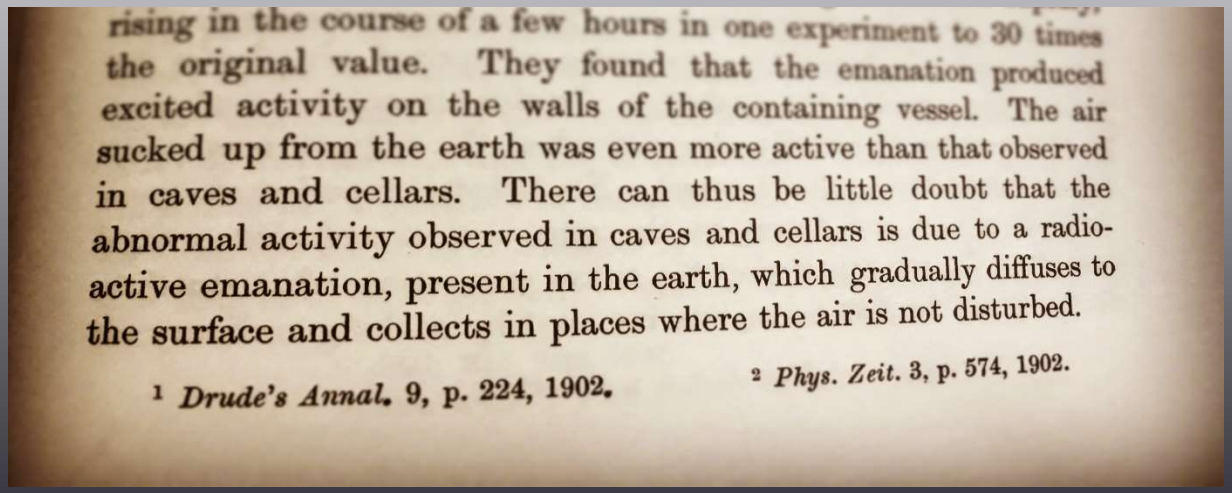


Figure 1. Two scientists in the literature associated with the discovery of radon. Right: Ernest Rutherford (1871–1937), Macdonald Professor of McGill University, Montreal, Canada (portrait at the Dept. of Physics, McGill University). Rutherford first characterized emanation of a radon isotope (from thorium) as a gas and an element, and should be credited with the discovery of radon. Left: Friedrich Ernst Dorn (1848–1916), Geheimer Regierungs-Rat Professor of Friedrichs Universität, Halle (Saale). (Portrait at the University of Halle; photograph by the authors). He was the first to observe emanation from radium specifically (the etymological source of the name "radon"), but his observations were subsequent to Rutherford's work.

- Ernest Rutherford (McGill University – TEAM CANADA!) first characterised radon as "**the radium emanation**"





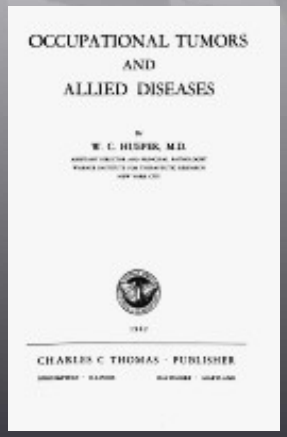
rising in the course of a few hours in one experiment to 30 times the original value. They found that the emanation produced excited activity on the walls of the containing vessel. The air sucked up from the earth was even more active than that observed in caves and cellars. There can thus be little doubt that the abnormal activity observed in caves and cellars is due to a radio-active emanation, present in the earth, which gradually diffuses to the surface and collects in places where the air is not disturbed.

[1] *Drude's Annal.* 9, p. 224, 1902.

[2] *Phys. Zeit.* 3, p. 574, 1902.

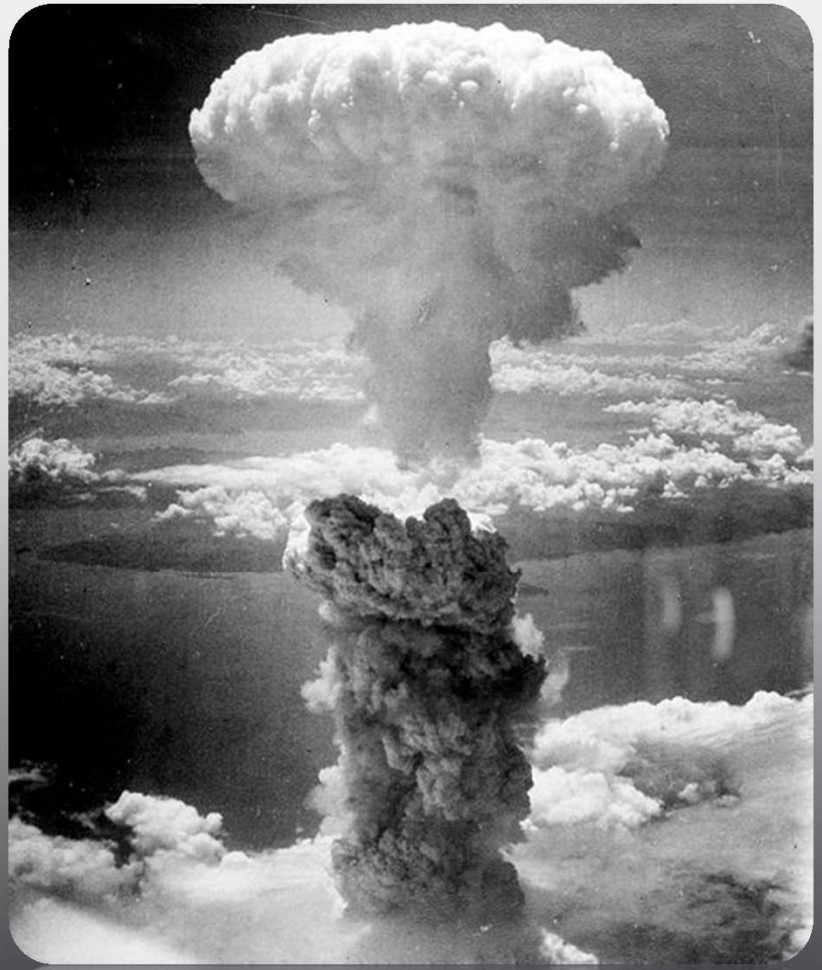
Wilhelm Hueper

In 1942, Wilhelm C. Hueper, concluded that **radon gas caused lung cancers** that killed >50% of all European miners within 10-20 years of employment.

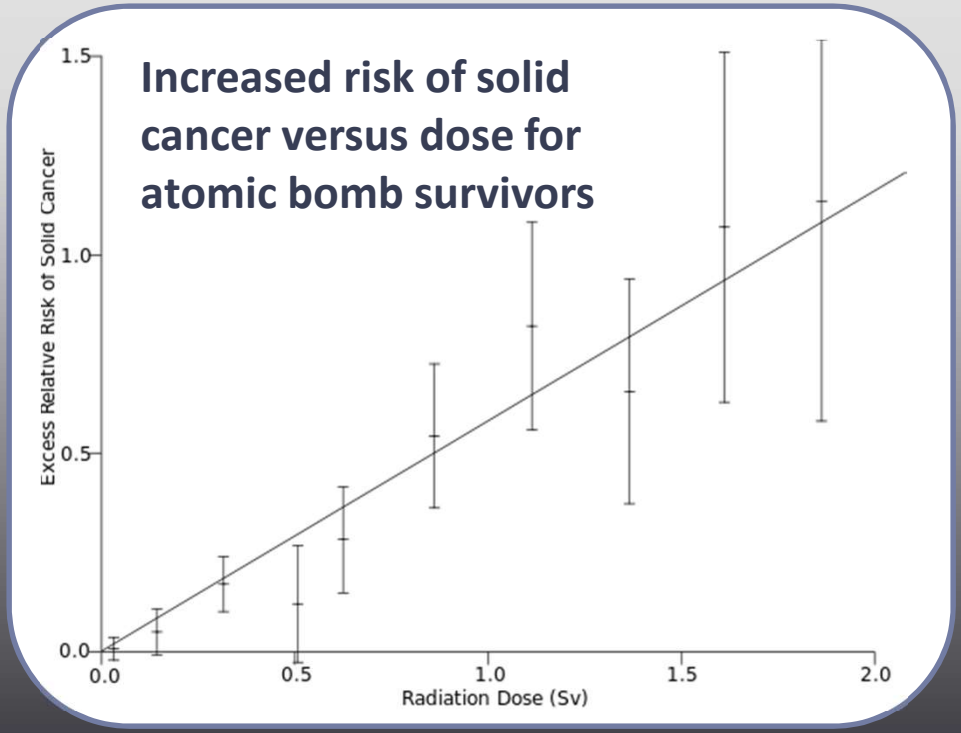


He issued **unheeded warnings** worldwide, including Canada, but was blocked from further work in this area by the *Manhattan Project*.

The Atomic Bombings



The atomic bombings at end of WWII were the first **large population cases** of ionizing radiation exposure.



Radon Cancer Therapy

- In the 1950-60's, in Canada, **radon** was being examined as a type of **radiotherapy**.

Later abandoned…

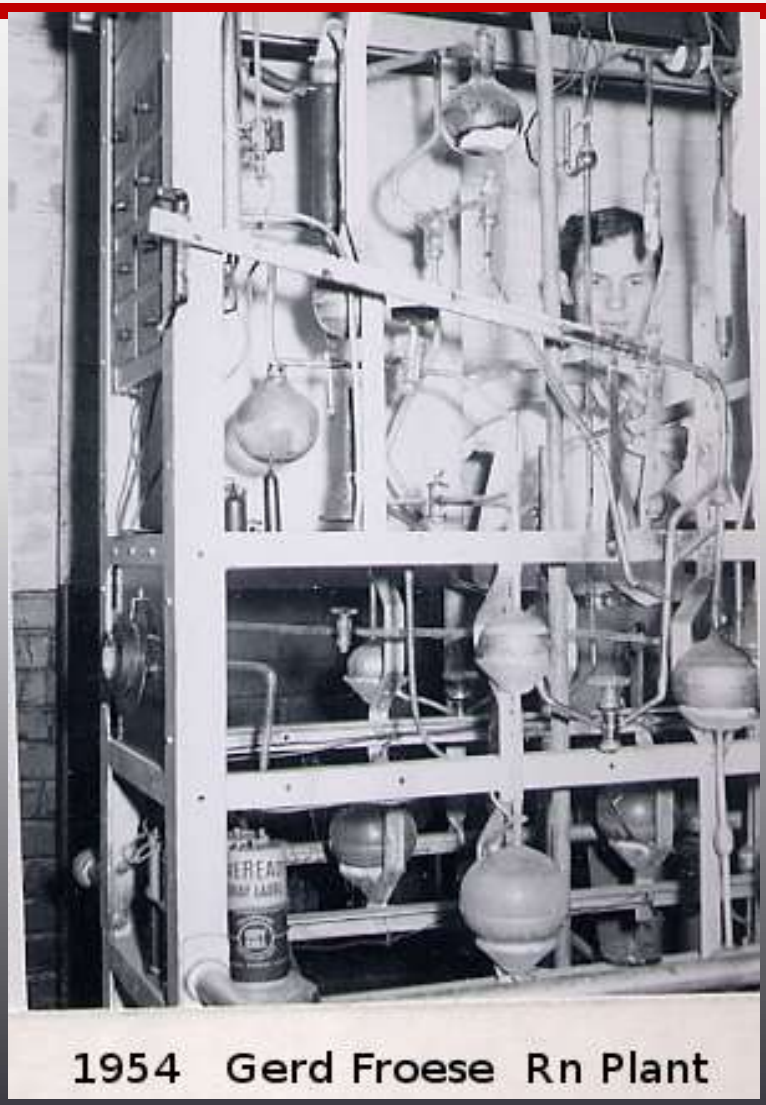
From Ann Report of Sask. Cancer Comission 1962

RADON PLANT

The Emanation Plant or Radon Plant operated by the Cancer Commission was closed down in January, 1962 after 31 years of service. The plant was used to collect the radioactive gas, radon, in very small gold tubes or "seeds" which were then used for cancer treatments in the Regina and Saskatoon Clinics and also in centres outside Saskatchewan. This method of treatment has now been superseded by the use of grains of radioactive gold.

The Radon Plant was constructed in 1931 under the supervision of the late Professor E. L. Harrington, first Consulting Physicist to the Commission. Professor Harrington was a keen glass-blower and he, himself, assembled most of the elaborate system of glass flasks, tubing and valves. The plant contained more than 500 milligrams of radium and it was with considerable anxiety that Professor Harrington approached the problem of getting the radium bromide solution into the plant. However, he was able to call on a chemist, Dr. J. W. T. Spinks, now President of the University of Saskatchewan, and the operation was performed without a hitch. The radon gas formed in the radioactive decay of radium was collected above the radium solution and pumped off at intervals of two to four days. After purification by removal of hydrogen, oxygen and carbon dioxide, the radon was compressed into fine gold tubing which was subsequently cut into various short lengths to give seeds of various radioactive strength. For certain treatments the radon was collected in thin glass bulbs or in a vaseline ointment.

The two properties of radon which determine its particular use in cancer therapy are its radiations and its half-life. The useful radiations from both radium and radon deposits come from radioactive daughter products which are common to both. Therefore, the radiations from radium and radon can be considered to be identical. The half-lives, however, are very different, radium having a half-life of 1,600 years and radon having a half-life of 3.8 days. In a radium treatment, the radium is removed after the prescribed dose has been delivered which takes 2



1954 Gerd Froese Rn Plant

Elliot Lake Miners

- The first major link between radon and lung cancer was observed in Canada, in 1950-70s **Elliot Lake Uranium Miners**.

By 1974, the Ontario Royal Commission on the Health and Safety of Workers in Mines found that Elliot Lake uranium miners were experiencing **twice as many lung cancers as expected**.

Stanley Watras

- Dec. 14, 1984, at the new Limerick nuclear power plant in Montgomery County, Pennsylvania, employee **Stanley J. Watras**, set off the radiation

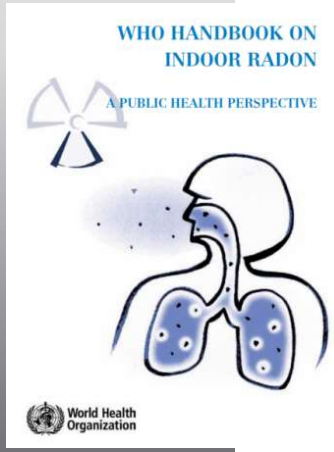
The Watras house tested at an astounding 99,900 Bq/m3 of radon.

The discovery of residential radon spurred U.S. government agencies to take action.

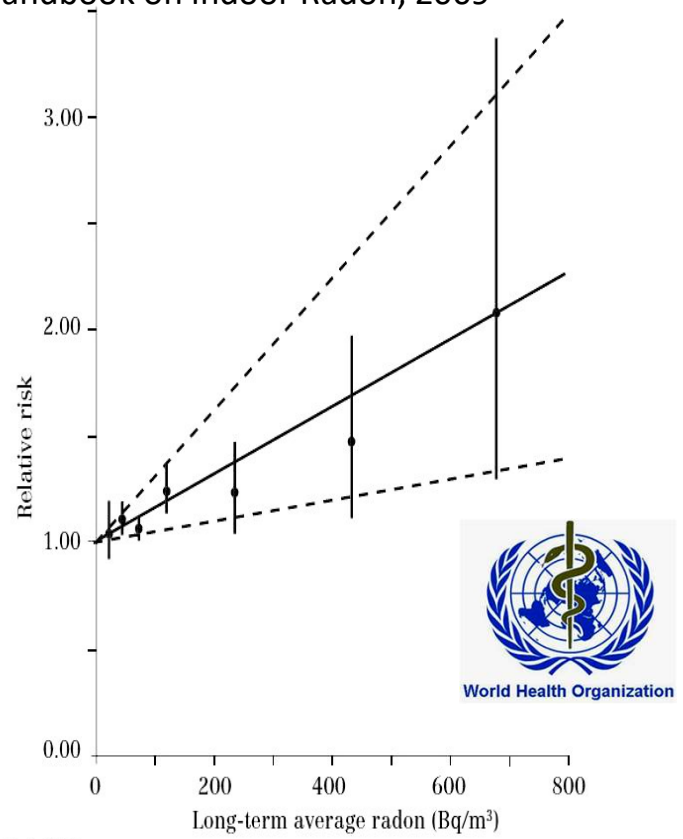
Radon: a leading cause of lung cancer

- UN study concluded relative risk of lung cancer increases ~16% for every 100 Bq/m^3.

100 Bq/m^3 = one hundred particles of alpha radiation emitted *every second* per cubic metre of air



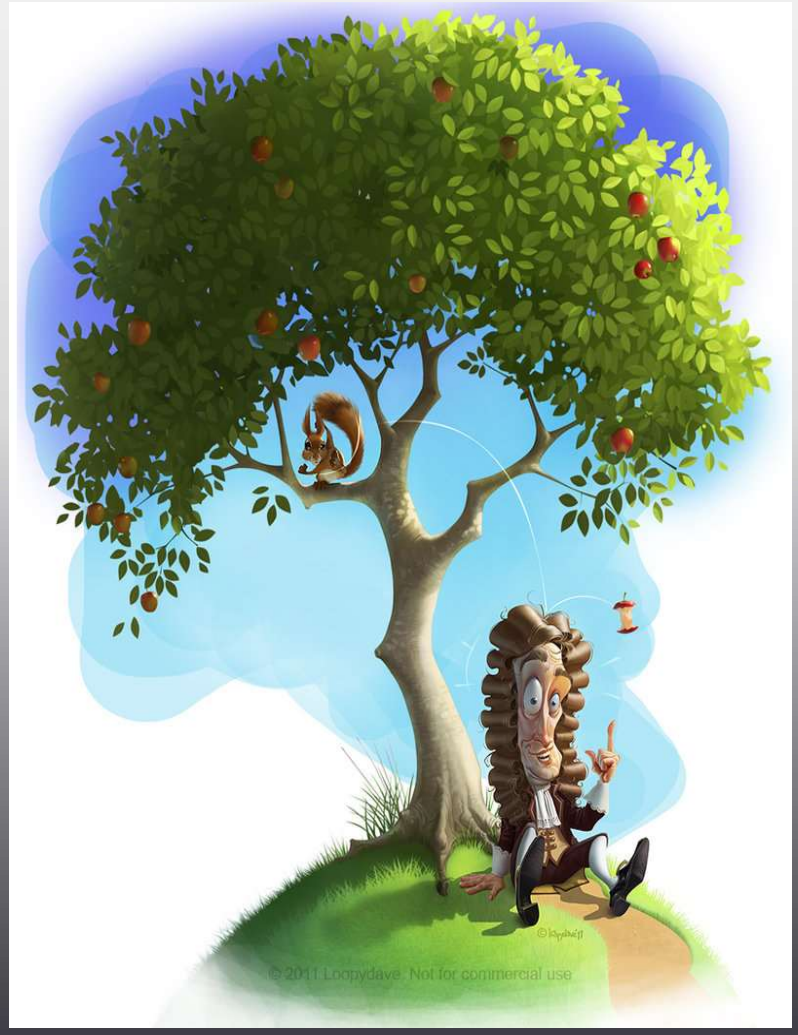
WHO handbook on indoor Radon, 2009

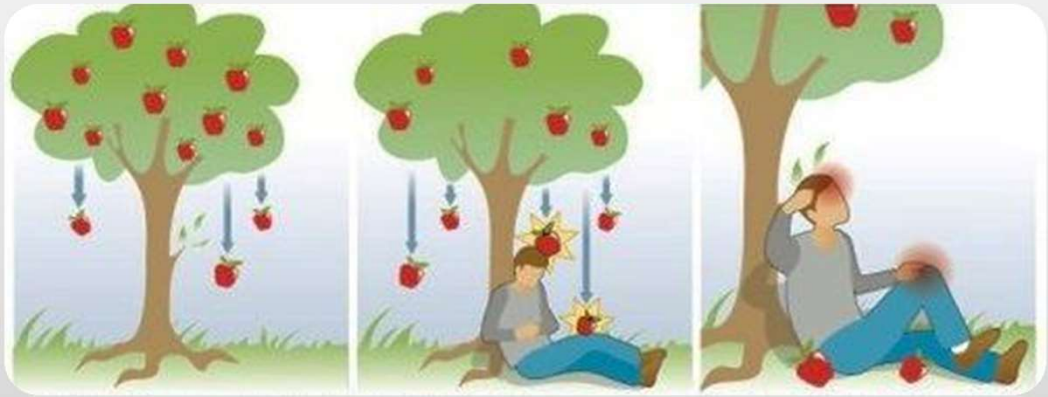


Source: Darby et al. 2005
Relative risks and 95% confidence intervals are shown for categorical analyses and also best fitting straight line.
Risks are relative to that at 0 Bq/m^3.

Figure 1. Relative risk of lung cancer versus long-term average residential radon concentration in the European pooling study

Units of Radiation





Becquerel (Bq)

An absolute measure of radioactivity.

Equivalent to 1 radioactive disintegration (particle emission) per second

Gray (Gy)

The dose of radiation absorbed by the 'object'.

Equivalent to 1 joule of energy per kilogram

Sievert (Sv)

The dose absorbed by a body which has an effect.

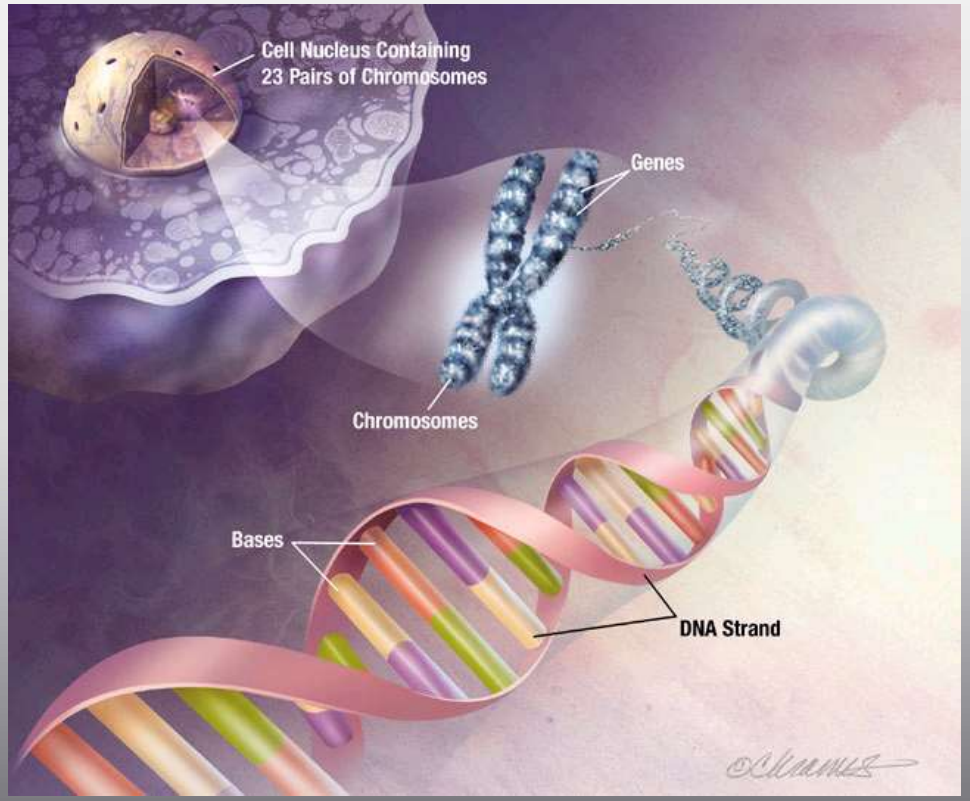
Can be same as Gray.

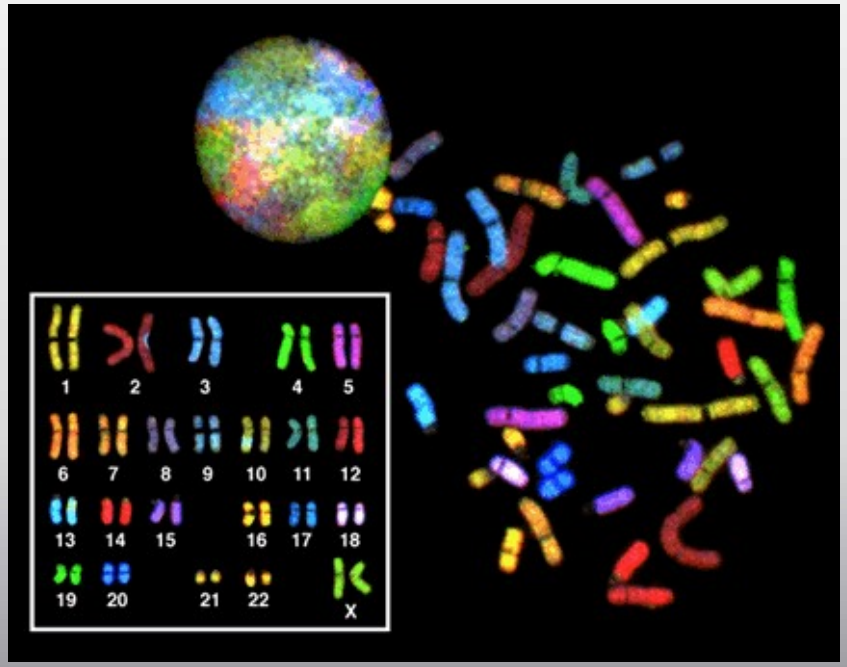
Radiation Dosages

10.000	*Acute radiation poising – death within weeks*
6.000	*Typical dose received by Chernobyl nuclear plant workers who died within one month of accident*
3.000	*Survival rate approximately 50 percent*
2.200	*Reading found near tanks used to store radioactive water at Fukushima plant, Sep 3, 2013*
1.000	*Causes radiation sickness and nausea, but not death. Likely to cause fatal cancer many years later in about 5 of every 100 persons exposed*
700	*Vomiting, hair loss within 2-3 weeks*
500	*Allowable short-term dose for emergency workers taking life-saving actions*
400 per hour	*Peak radiation level recorded inside Fukushima plant four days after accident*
350 per lifetime	*Exposure level used as criterion for relocating residents after Chernobyl accident*
250	*Allowable short-term dose for workers controlling 2011 Fukushima accident*
100	*Lowest level linked to increased cancer risk*
20 per year	*Average limit for nuclear industry workers*
10	*Full-body CT scan*
2.4 per year	*Person's typical exposure to background radiation*
0.01	*Dental x-ray*

Graphic: EUROfusion

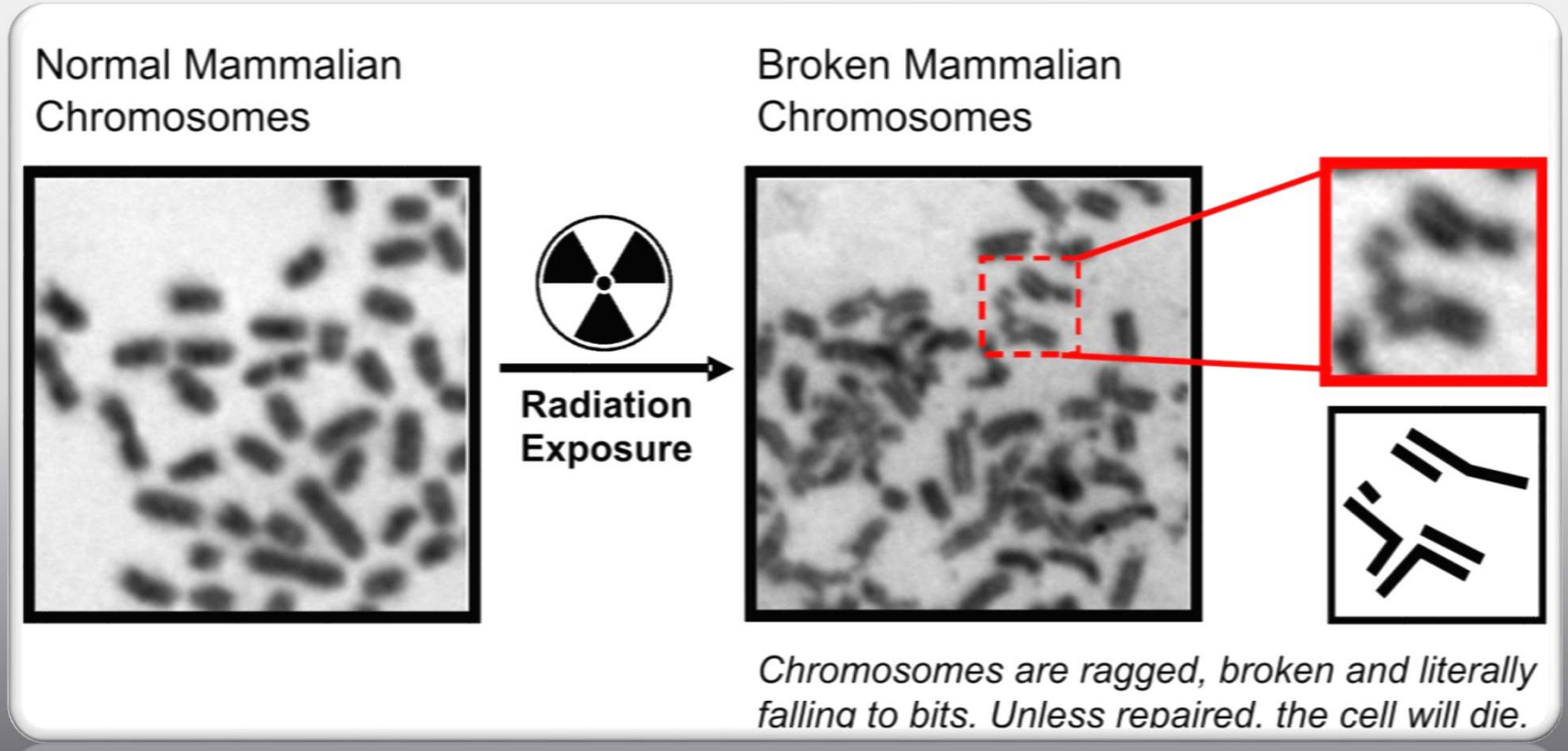
It’s also all about our DNA





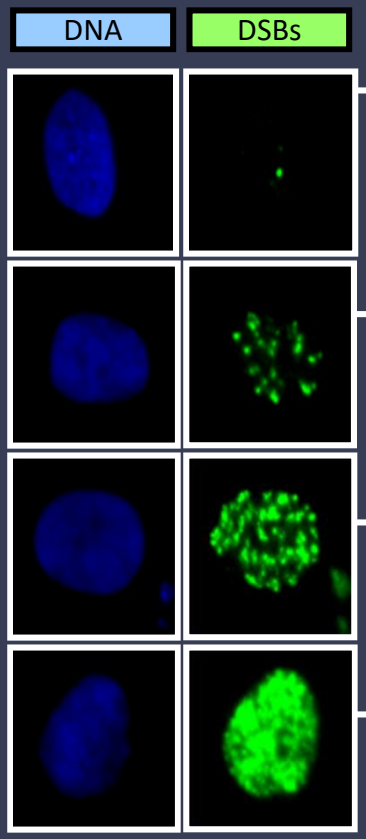
All our DNA is found in our 2 copies
(one from mom, one from dad)
of 23 unique chromosomes.

DNA Breaks



Life, Mutation or Death?

Outcome depends on IR dose



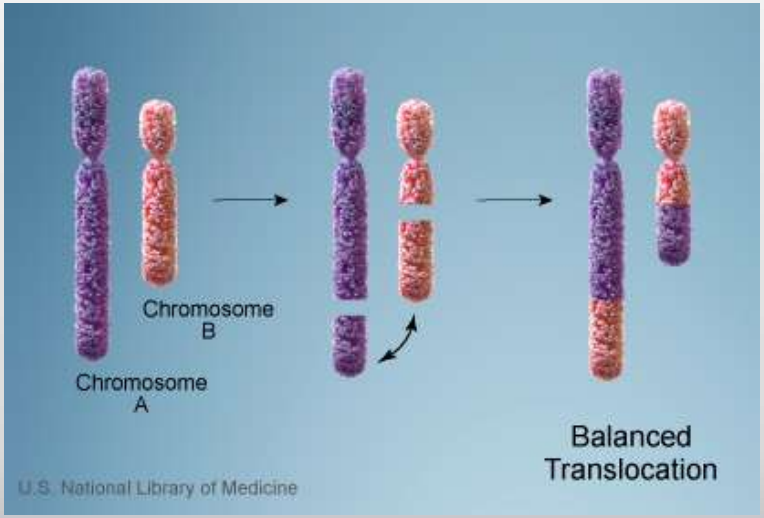
25 mSv IR = 0.5-1 DSB/cell
(low risk of cancer, +1% to lifetime risk)

250 mSv IR = 5-10 DSB/cell
(significant increase in risk of cancer)

2,500 mSv IR = 50-100 DSB/cell
(radiation poisoning, cancer >95% sure)

25,000 mSv IR = 500-1000 DSB/cell
(death is inevitable)

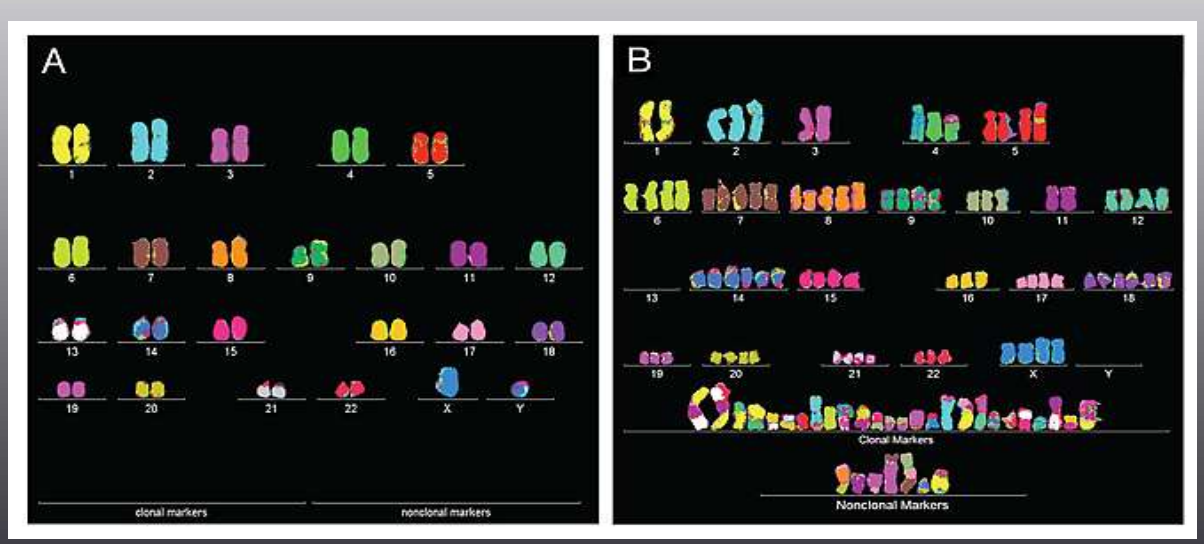
DNA damage = Mutation



DNA damage is usually repaired by our cells correctly.

However, errors are made...

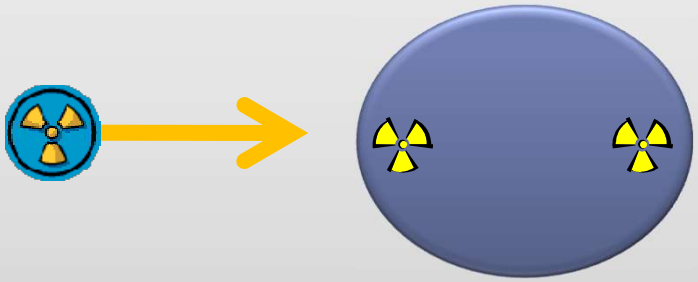
↑ DNA damage = ↑ error = genetic mutation = cancer



A = normal cell
B = cancer cell

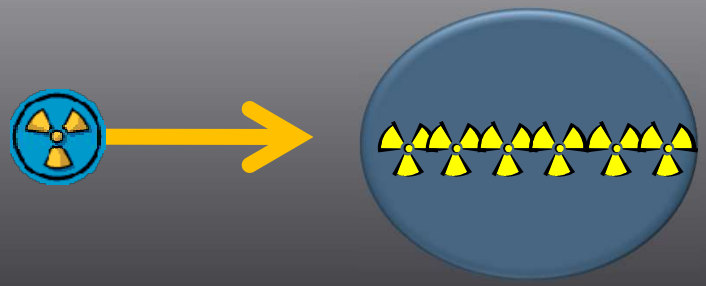
High versus Low LET

Low LINEAR ENERGY TRANSFER (LET) IR



Resulting damage to DNA is more widely spaced, and is comparatively 'easier' to repair

High LINEAR ENERGY TRANSFER (LET) IR

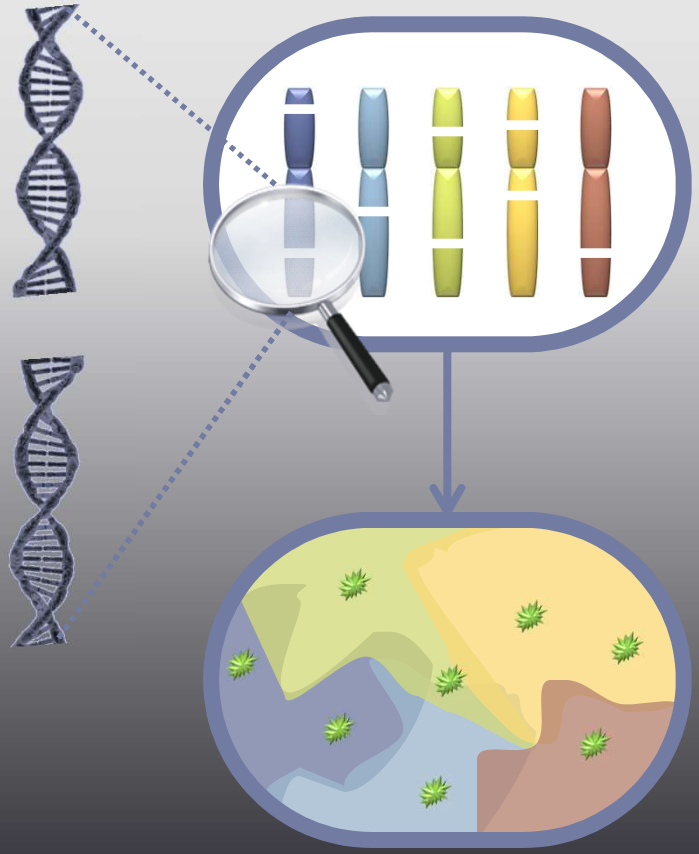


Resulting damage to DNA is clustered together, and is much more challenging to repair accurately.

α-particles = clustered DNA damage

The **CLUSTERING** of DNA damage can impact the accuracy of DNA repair substantially.

Relatively straight-forward rejoining

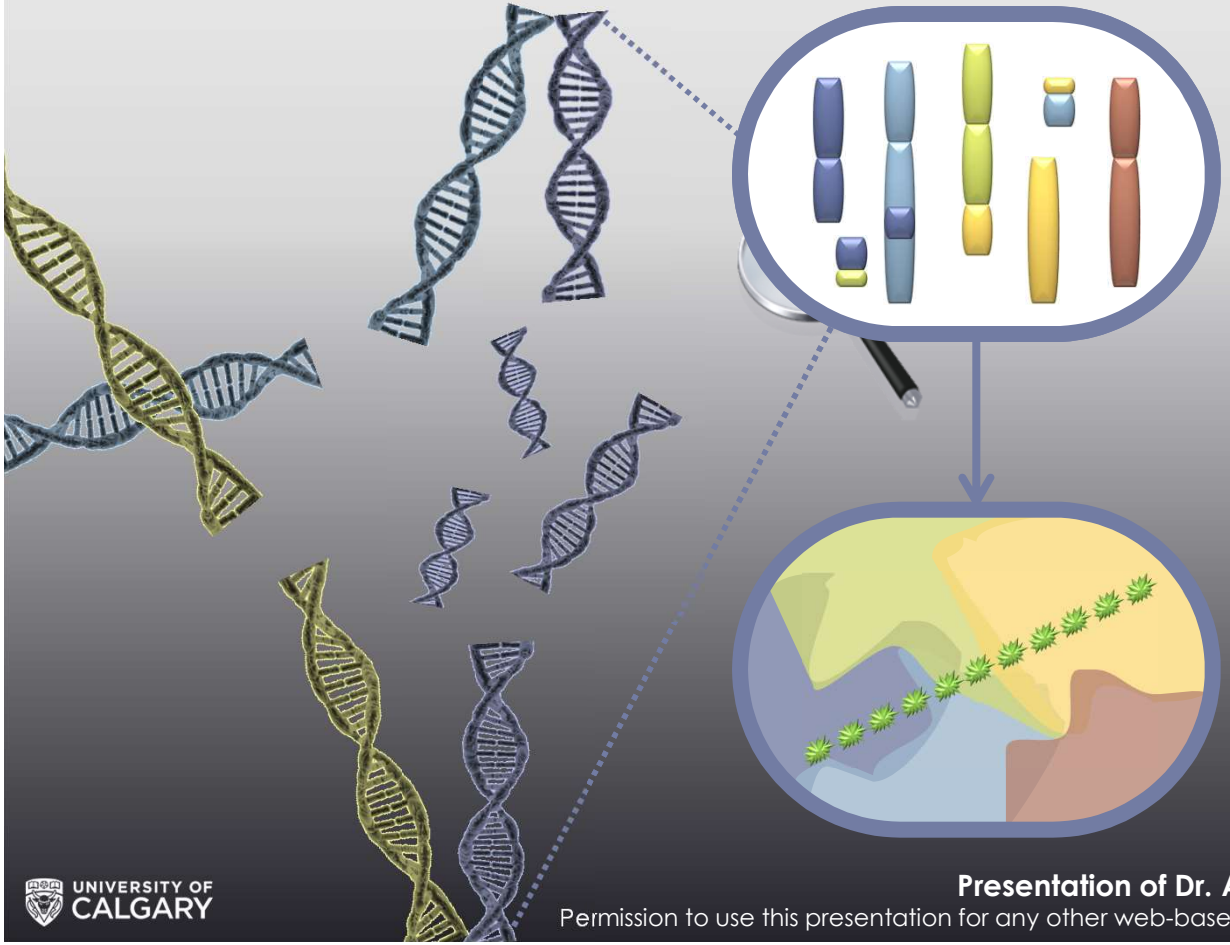


Low LET IR

During interphase, our chromosomes largely exist within independent 'territories', but do overlap to a degree.

α-particles = Clustered DNA damage

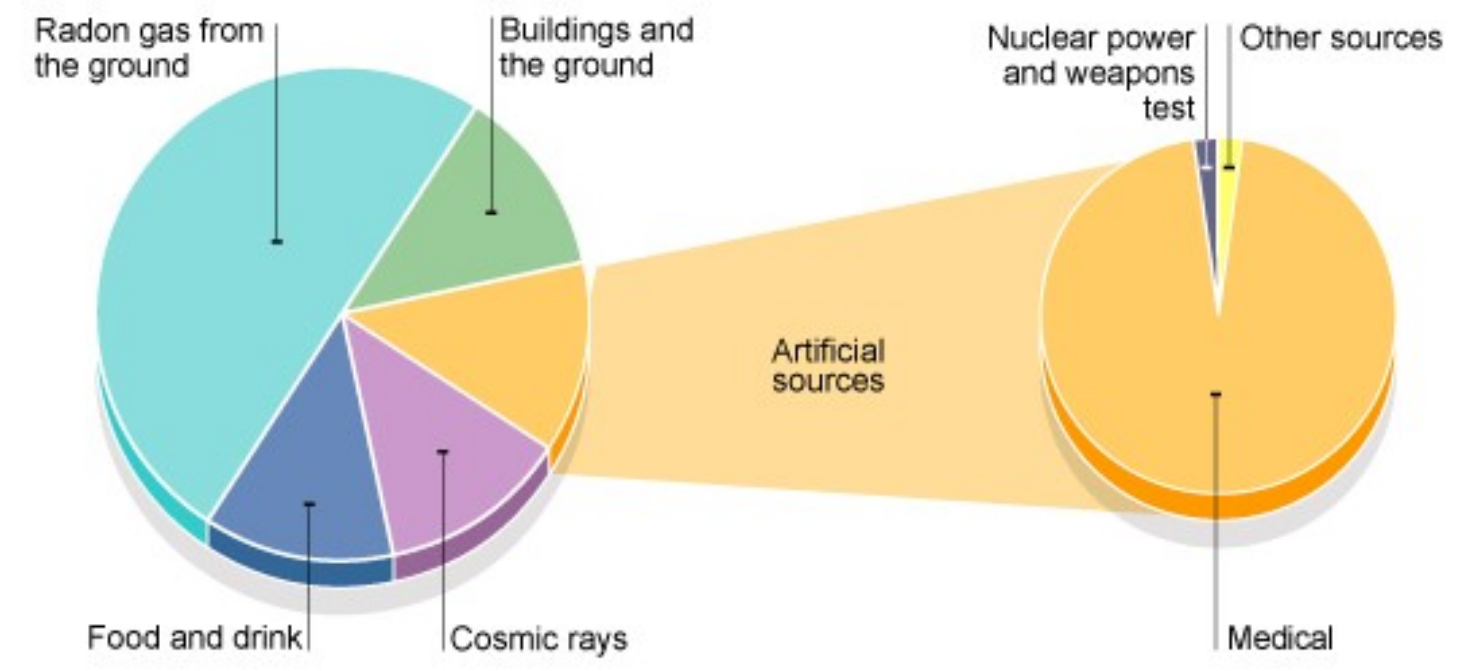
The **CLUSTERING** of DNA damage can impact the accuracy of DNA repair substantially.



Severe fragmentation and proximity of breaks from multiple chromosomes makes accurate re-joining difficult

High LET IR

Radiation Exposure



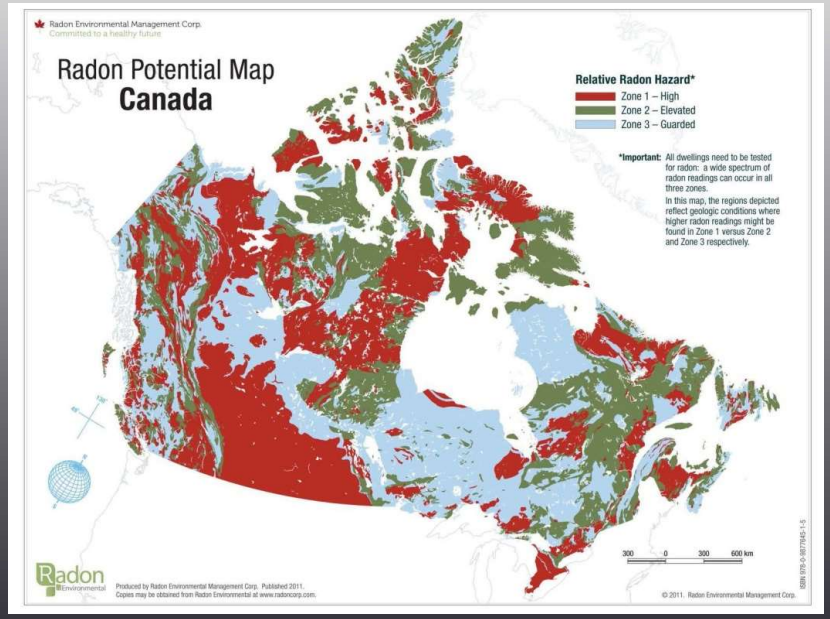
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atoms_radiation/nuclearradiationrev1.shtml

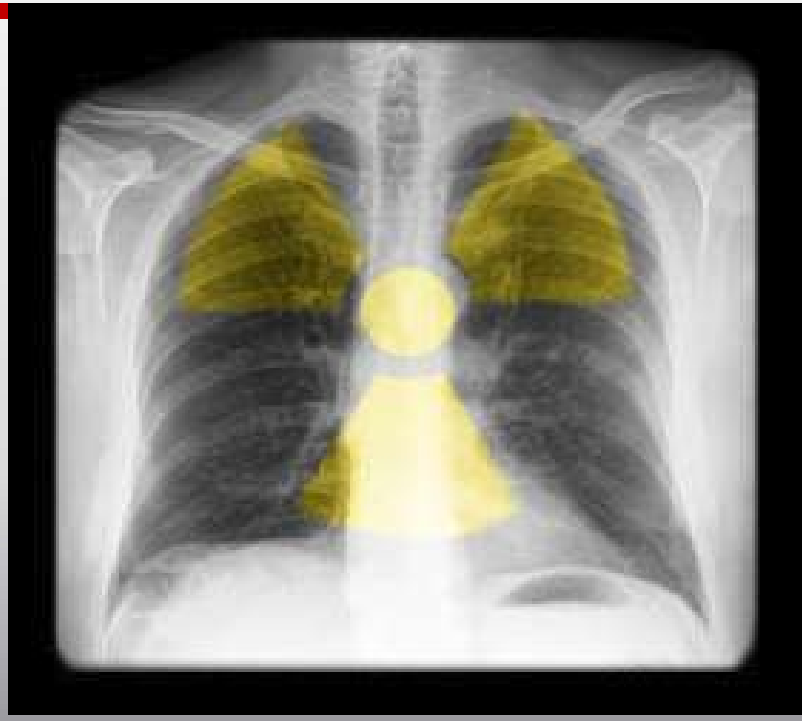
- As a society, we have never been exposed to more sources of ionizing radiation than we are today.
- **Radon remains the single greatest exposure source.**

Radon: a leading cause of lung cancer

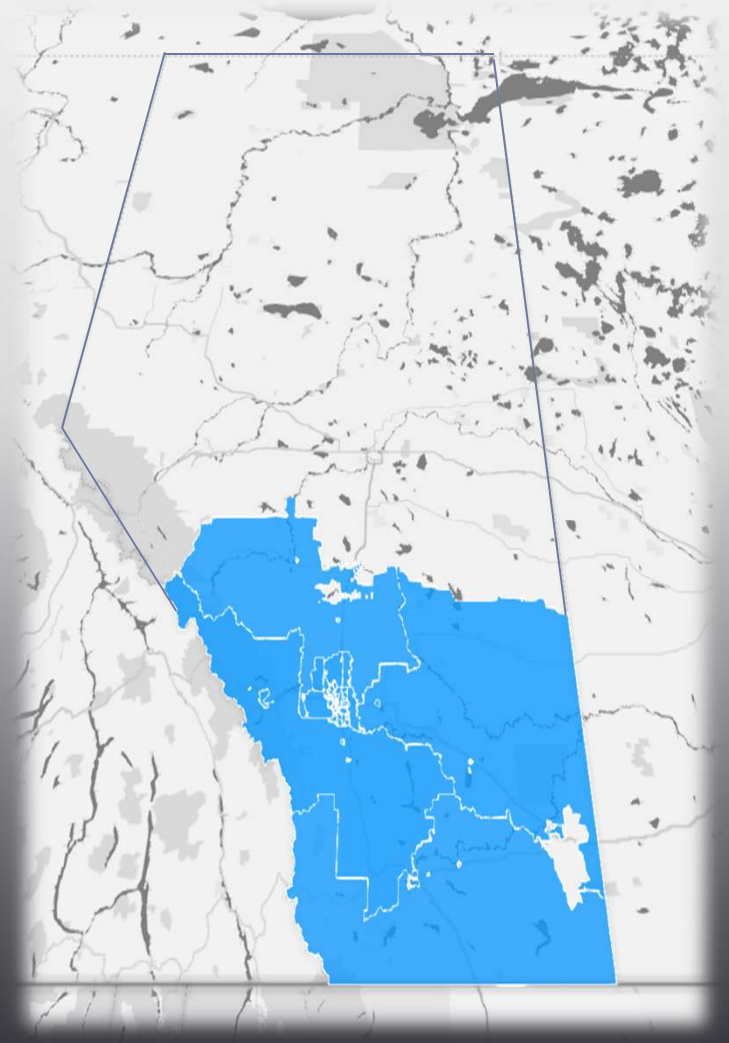
In Canada: 1,000-4,000 new lung cancer/year are caused directly by radon inhalation.

- ~3,200 Canadian deaths/yr
- ~21,000 American deaths/yr





Radon Gas in Southern Alberta



Between 2013 and 2016, we tested radon levels in 2,382 homes across Southern Alberta

Calgary
Okotoks
High River
De Winton
Redwood Meadows
Chestermere
Airdrie
Cochrane
Bragg Creek
Canmore

All tests were conducted for >90 days between Oct-April.

Radon Gas in Southern Alberta

Alpha track radon detectors were purchased by "citizen scientists" i.e. members of the public willing to participate in the study. Care was taken to inform user how to place them properly.

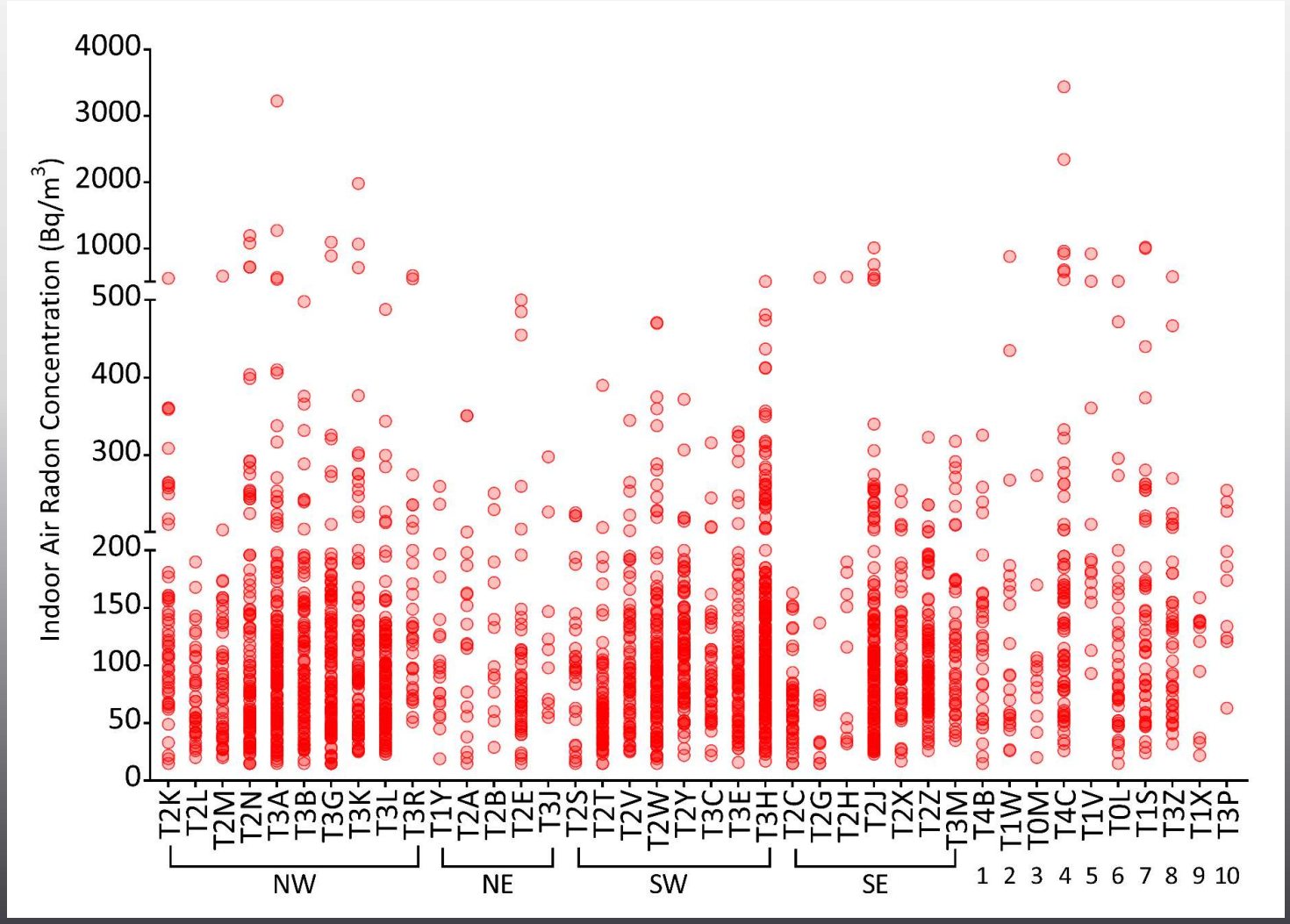
Place the radon detector in the lowest lived-in level of your home.

By lived-in we mean; where you or your family spend a minimum of 4 hours per day.

For some this may be the basement with a rec room or bedroom, for others it will be on the ground floor.

Presentation of Dr. Aaron Goodarzi for 2017 CARST annual meeting.

Radon Gas in Southern Alberta



From: Stanley FKT, Zarezadeh S, Dumais C, Dumais K, MacQueen R, Clement F, Goodarzi AA. A comprehensive survey of household radon gas levels and risk factors in Southern Alberta. Canadian Medical Association Journal Open. 2017; Vol.5(1) E255-E264

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Alberta Health Services

12.4% of homes are over 200 Bq/m³ = about 57,500 homes or roughly 150,000 residents.

No areas examined have 100% homes below the maximum acceptable guideline. Therefore, no 'safe' areas.

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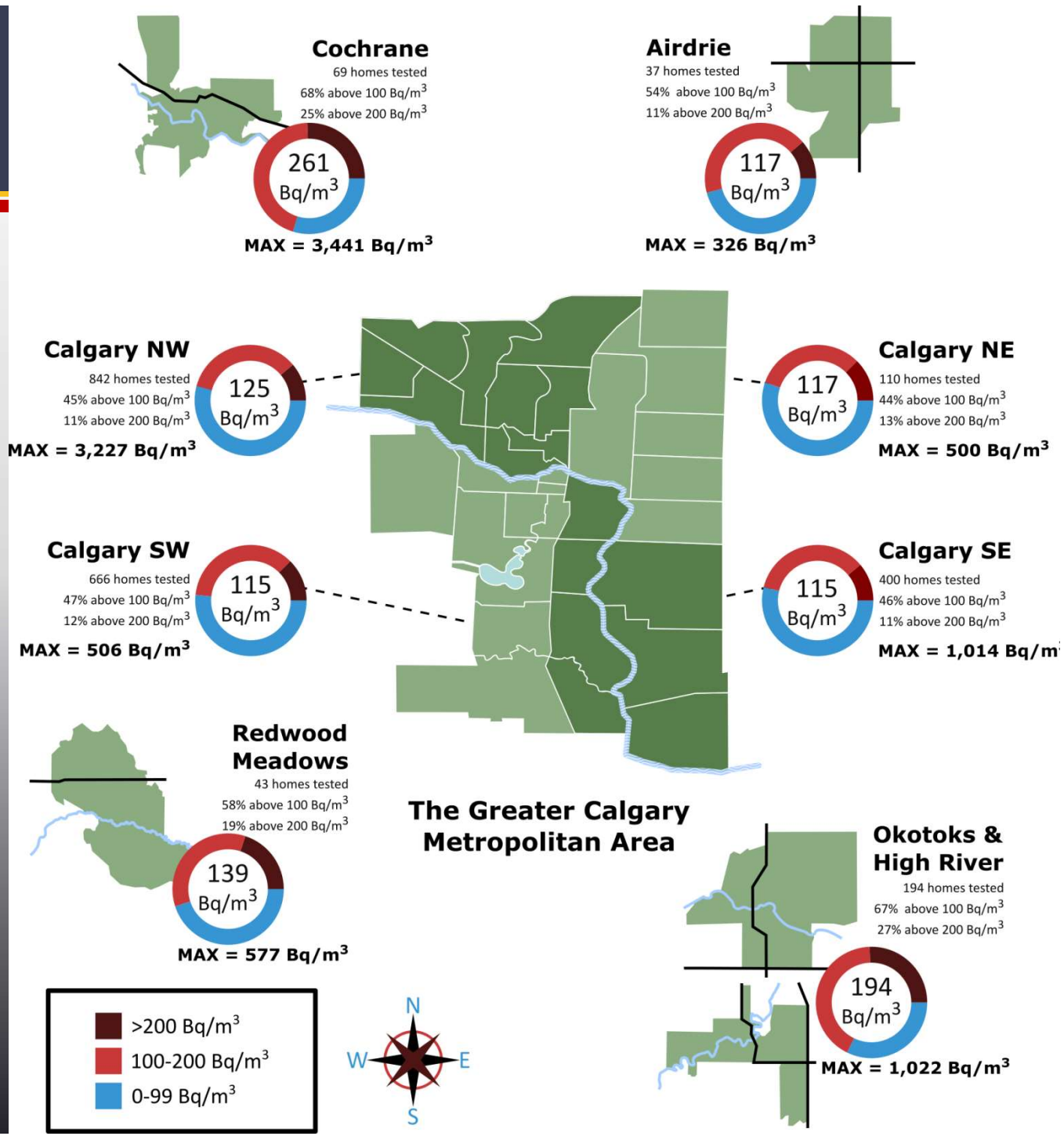

Radon Gas in Southern Alberta

Our Study vs the Health Canada Study

	<200 Bq/m^3	200-599 Bq/m^3	>600 Bq/m^3	n
HC - Calgary	92%	8%	0%	86
S. Alberta	87%	12%	1%	2382

- The percentage over the 200 Bq/m^3 level is 50% higher than previously estimated
- Based on 2016 figures that's an additional 50,000 people
- 200 Bq/m^3 leads to a 32% increased relative risk of lung cancer

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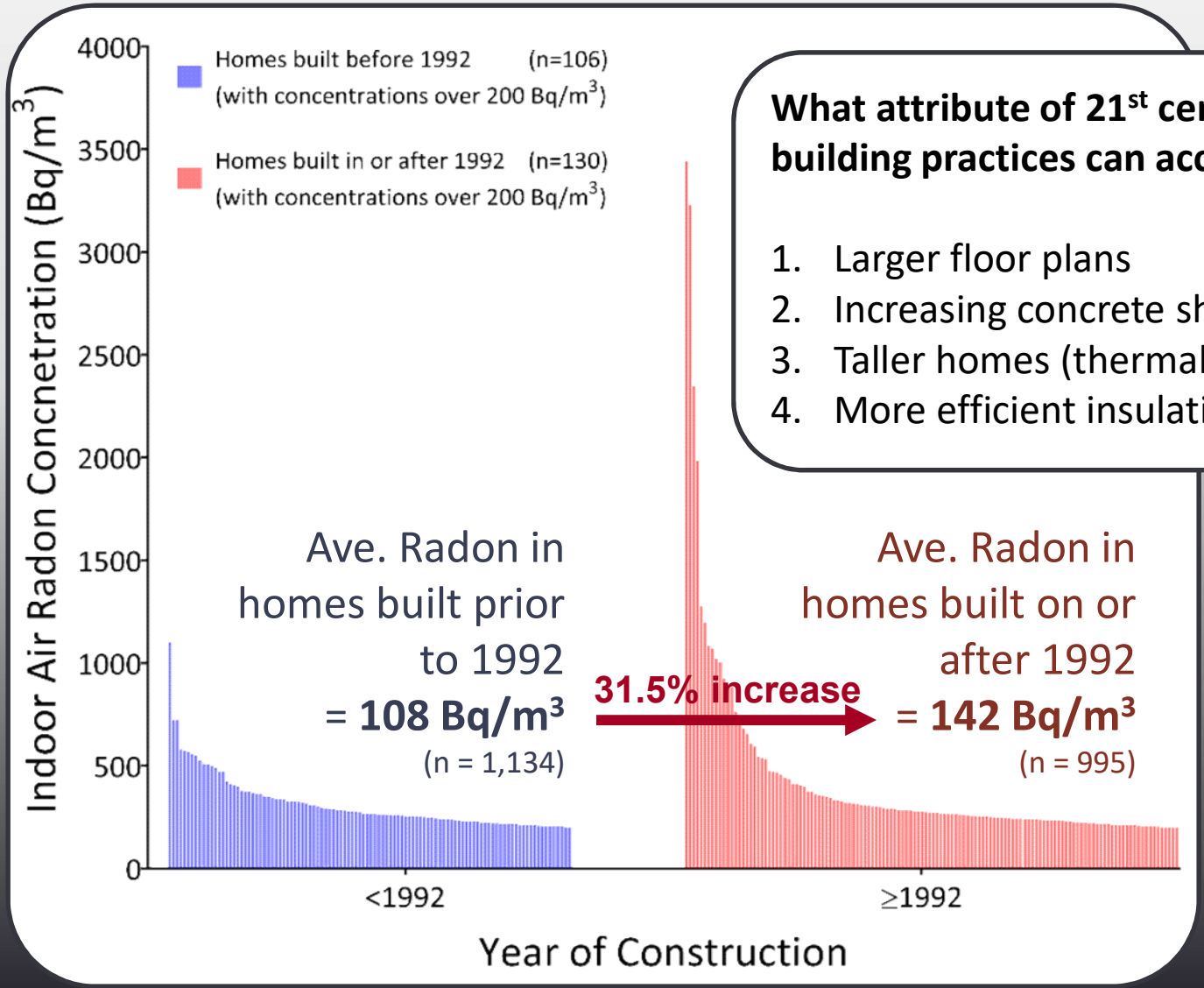

What attribute of 21st century Alberta building practices can account for this?

1. Larger floor plans
2. Increasing concrete shrink
3. Taller homes (thermal stack effect)
4. More efficient insulation

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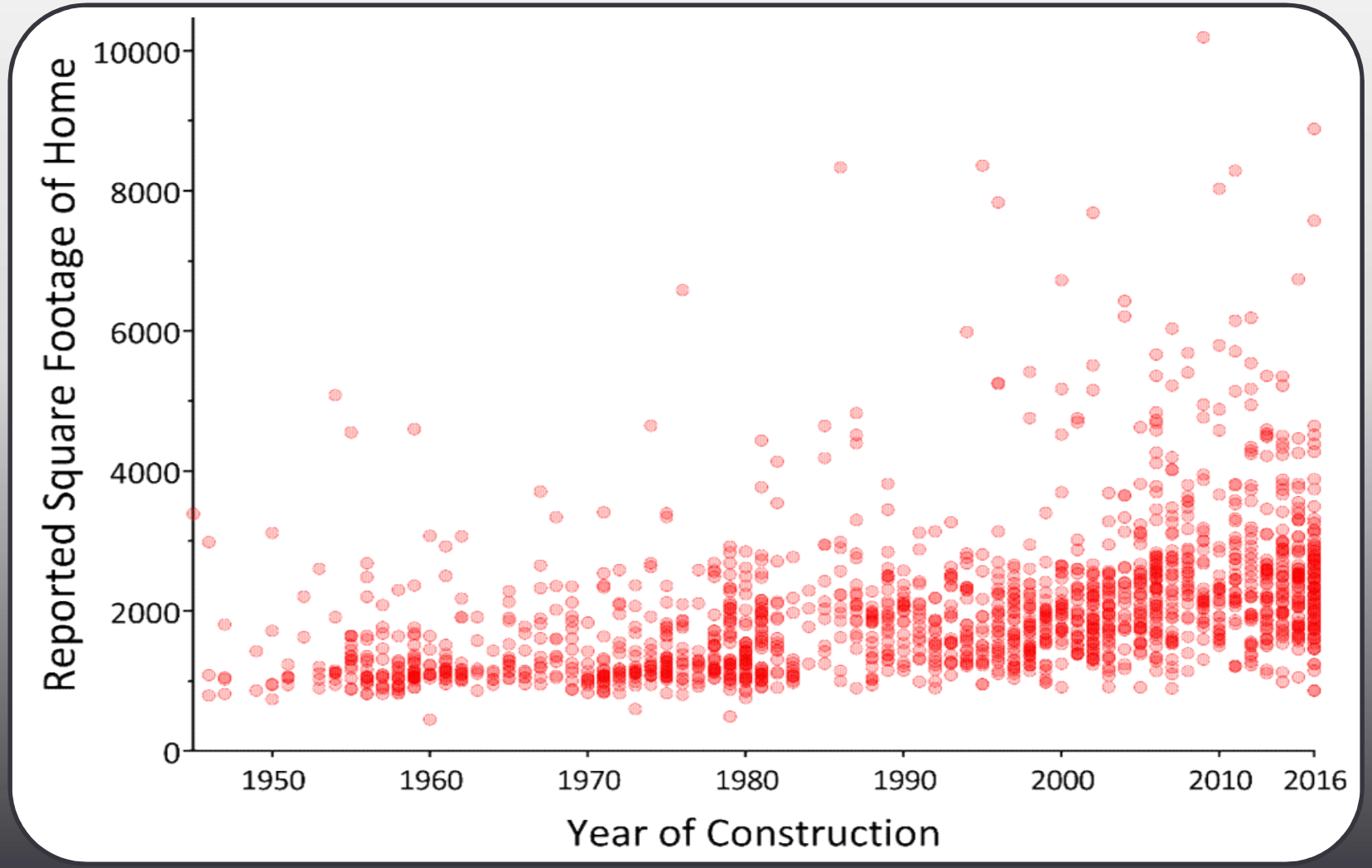

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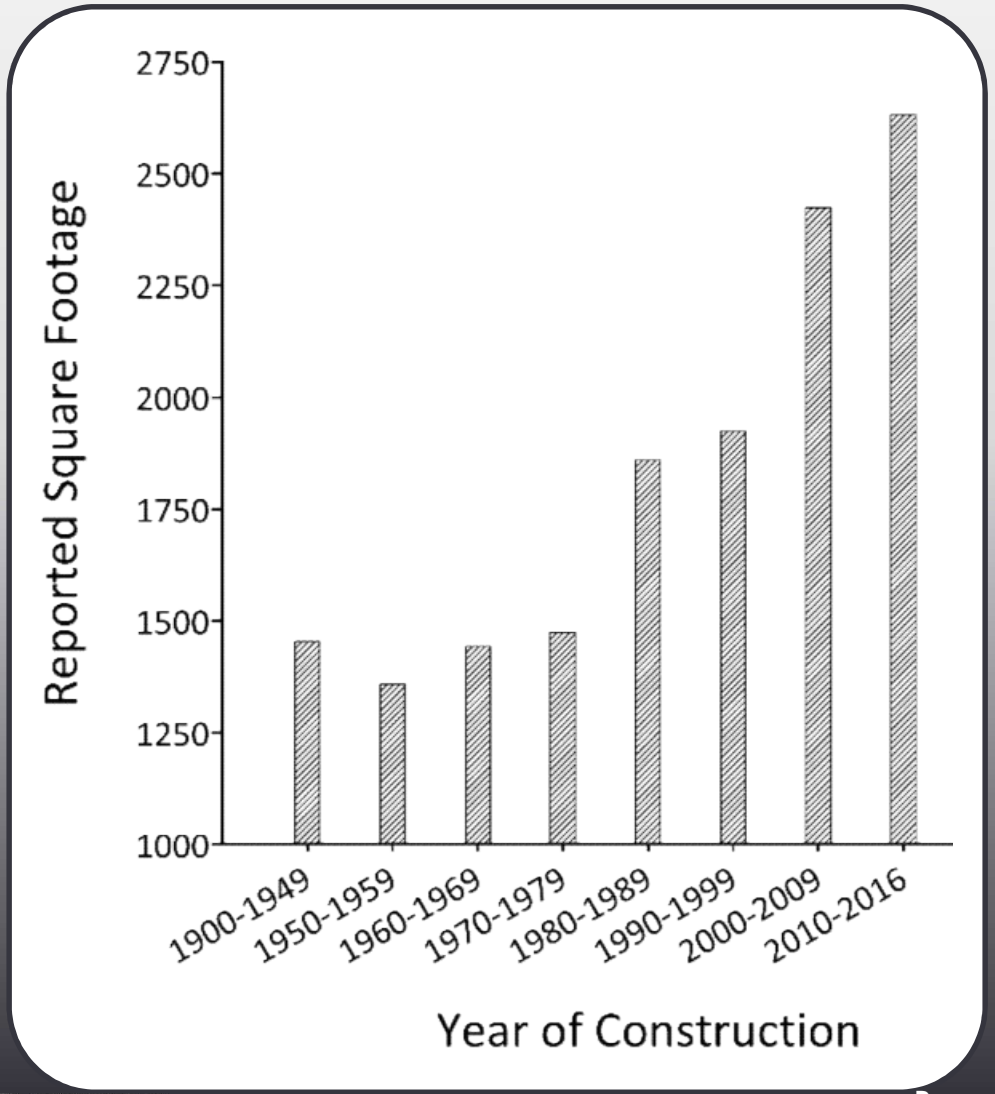
Radon Gas in Southern Alberta



LARGER FLOOR PLANS MEAN LARGER FOUNDATION SLABS

Concrete shrinks by a fixed percentage per square foot, with larger slabs shrinking more and producing LARGER GAPS between the slab/wall.

Larger gaps = larger space for radon entry.

Made worse if joint design for sealing slab/wall join points do not accept movement.

Radon Gas in Southern Alberta

CONCRETE IS SHRINKING MORE NOW THAN IN THE PAST

Good quality aggregates for concrete are increasingly scarce, and the use of recycled concrete with admixtures (such as fly ash or blast furnace slag) is on the rise.

Compared to most of the 20th century, concrete used today is shrinking more per area, hence producing ever larger slab/wall gaps that permit MORE RADON to enter the building.

Presentation of Dr. Aaron Goodarzi for 2017 CARST annual meeting.

Radon Gas in Southern Alberta

Our houses are also a lot TALLER now than they were in the past.

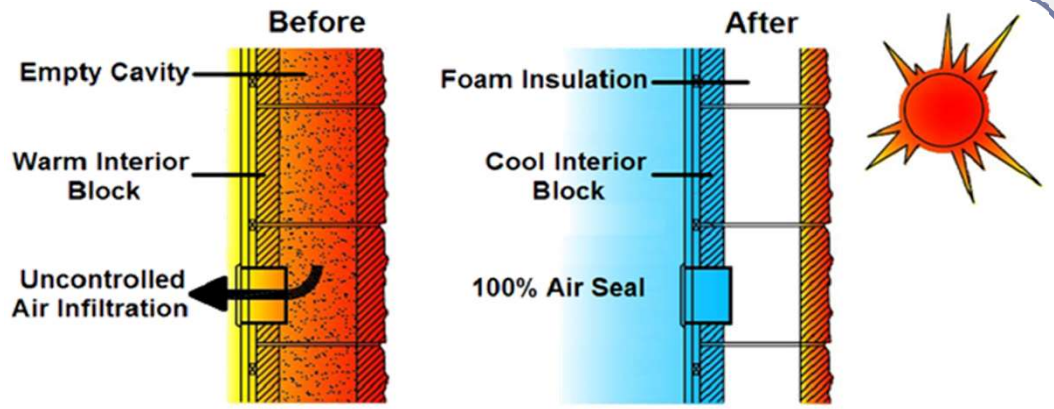
Chances are, if you have a 'newer' home, it has a 2-storey foyer and/or vaulted rooms and/or +10ft ceilings.

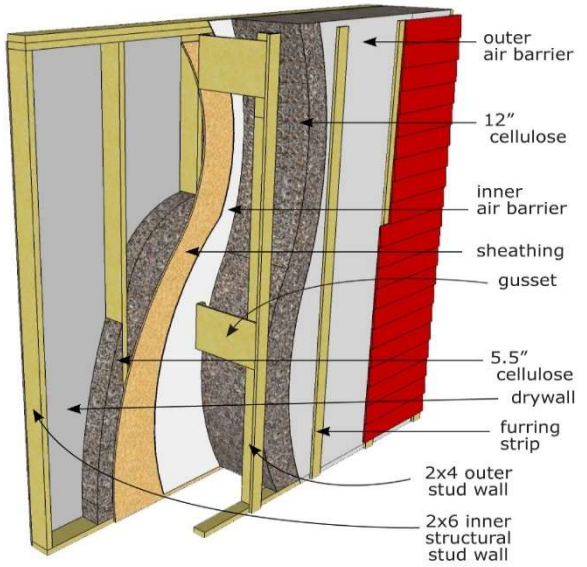
Radon Gas in Southern Alberta

AS WE MAKE OUR HOMES ENERGY EFFICIENT, WE ARE TRAPPING THE AIR

Energy-efficient home retrofits are designed to create an AIR SEAL to reduce heat loss through walls and the roof.

This is great, but unless a compensatory ventilation system is coupled with the install, it is essentially a radon concentrator.





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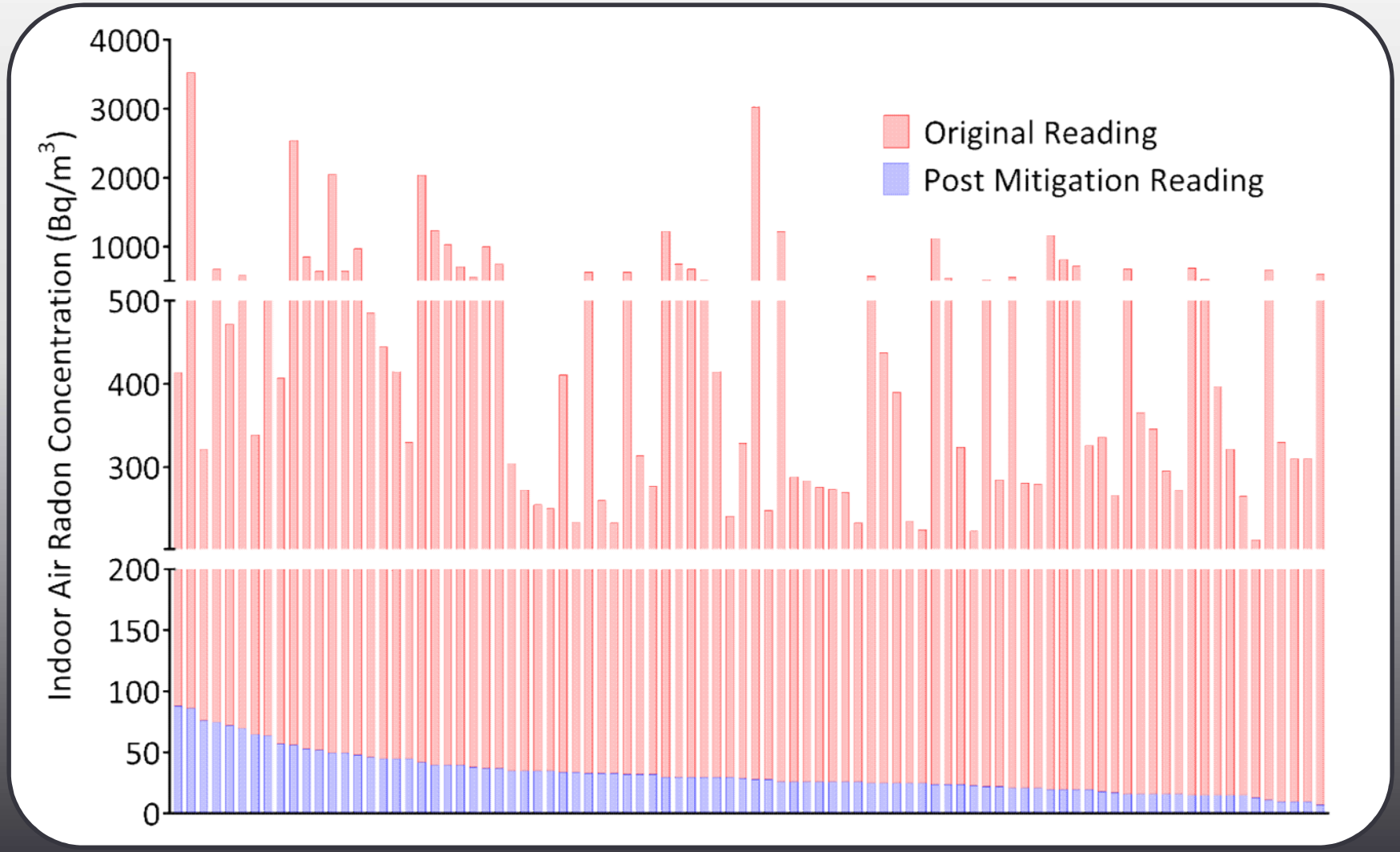

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Health Economic Consequences

- 2,150 lung cancer cases in Alberta annually and 16% (350) are attributed to radon
- Direct costs paid by the Alberta healthcare system $24,055/person
- Studies indicate that indirect costs are as much as direct costs
- Factoring this, total Alberta costs of radon-induced lung cancer are estimated to be at least $17 million/year

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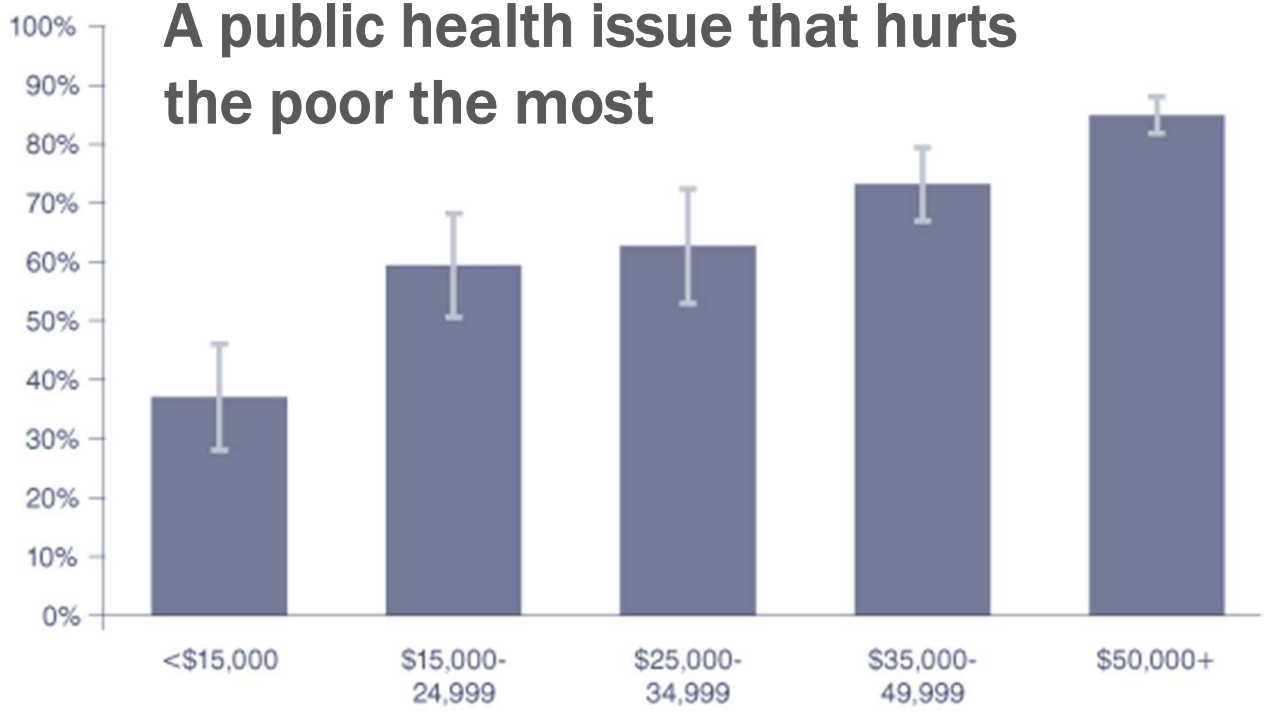
Health Economic Consequences

- Less awareness in lower income brackets
- Cost of tests
- Cost of Mitigation
- Lack of legislation for rental property



Source: Indiana Business Research Center, using Behavioral Risk Factor Surveillance System data from the Colorado Department of Public Health and Environment

Health Economic Consequences

- In Alberta, an estimated 28,140 people will be diagnosed with cancer in 2030,
  - 17,000 in 2015
- the rapidly growing and aging population will cause this drastic jump
- WHO suggests prevention as the most cost-effective, long-term strategy for controlling cancer

Radon Gas in Southern Alberta

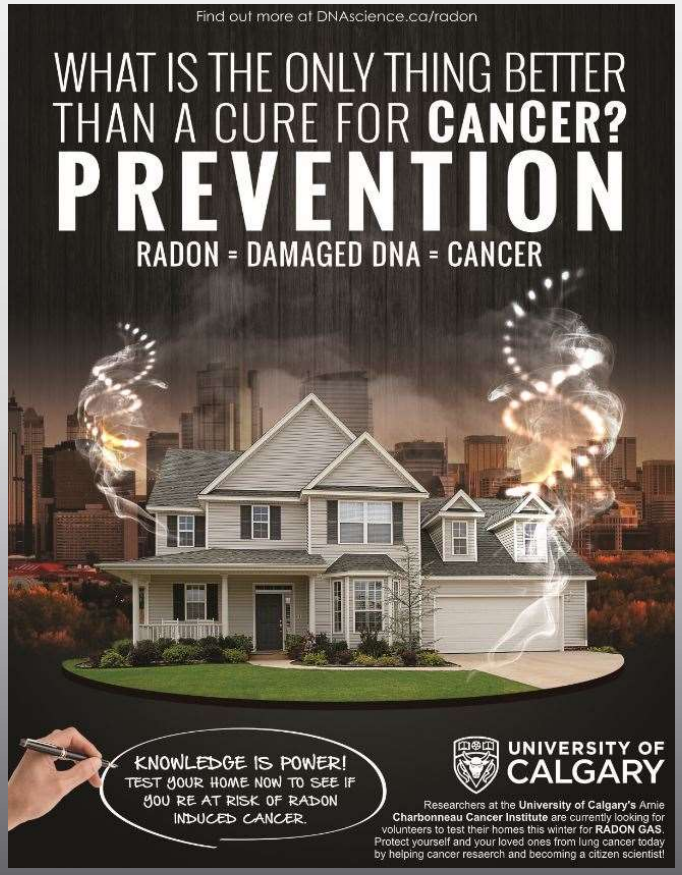
4 in 8 Calgary homes over the WHO radon limit of 100 Bq/m^3

1 in 8 homes over 200 Bq/m^3, carrying a 32% increase in lung cancer risk

Readings range from 0 – >3,000 Bq/m^3, no reliable 'safe' areas

Mitigation is effective

ACKNOWLEDGEMENTS



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