Radiation Safety Institute of Canada
Institut de radioprotection du Canada

Lunch, Learn, & Dance Wellness Webinars

February 25, 2021

Health Effects of Exposure to Radiation

Followed by STEPs Dance

Good Science in Plain Language®

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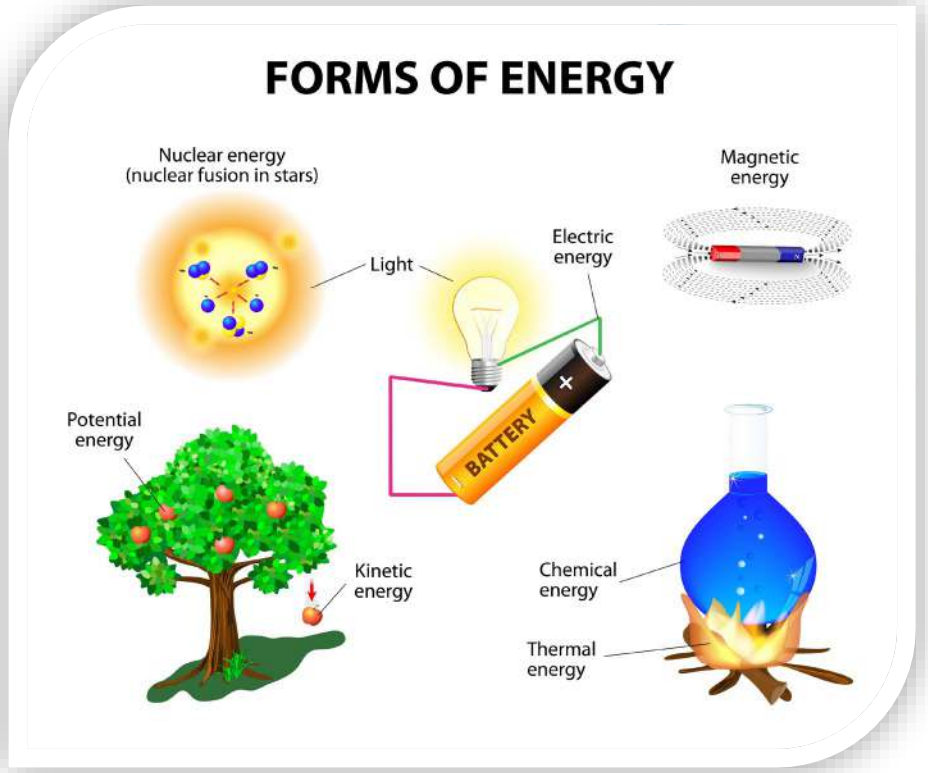
Webinar Functionality

- Audio and video
  - Will be from the presenters only
  - Use computer or telephone (call in)
  - Computer seems to give the best sound quality
- Use the “Chat” feature to enter comments
- Use the “Questions” feature to ask questions
- Posted on webinar page
  - Video, Q&A answers, copy of the slides
- Follow up email will be sent
  - Topics covered, time of attendance
- It may be possible to change your Zoom view if the controls are hiding the closed captioning.

Outline

- What is Radiation?
- Ionizing Radiation
- Health Effects of Ionizing Radiation
- Non-Ionizing Radiation
- Health Effects of Non-Ionizing Radiation
- How Is This Determined?
- Regulators
- For More Information

Matter and Energy



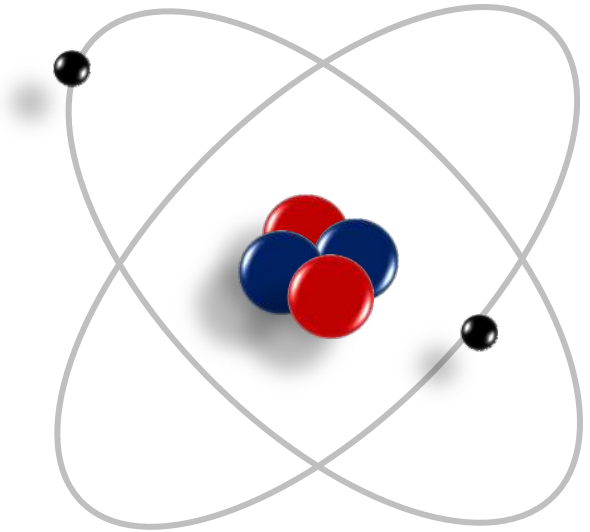
- Matter
  - Has mass
  - Takes up space
- Energy
  - The ability to create change

Radiation and Energy

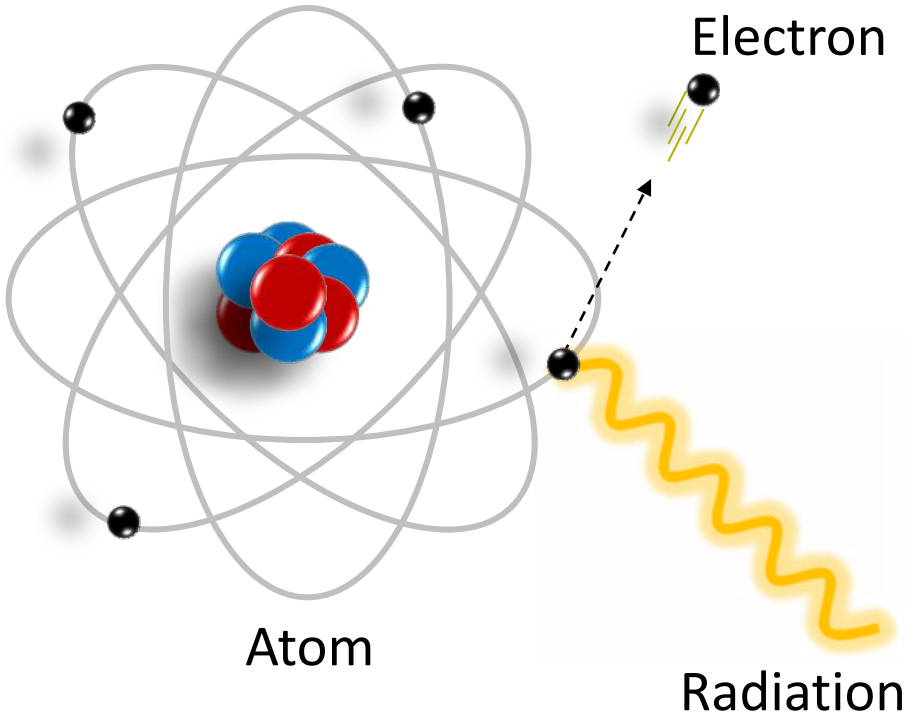
- Radiation
  - Transfer of energy in a straight line
    - Beams of particles
    - Waves
- Radiation will interact differently with matter depending upon
  - Type
  - How much energy it has.

Parts of the Atom

- Atom made up of
  - Protons (+)
  - Neutrons (0) and
  - Electrons (-)
- Nucleus
  - Protons and neutrons
  - At the center
  - Electrons orbit the nucleus



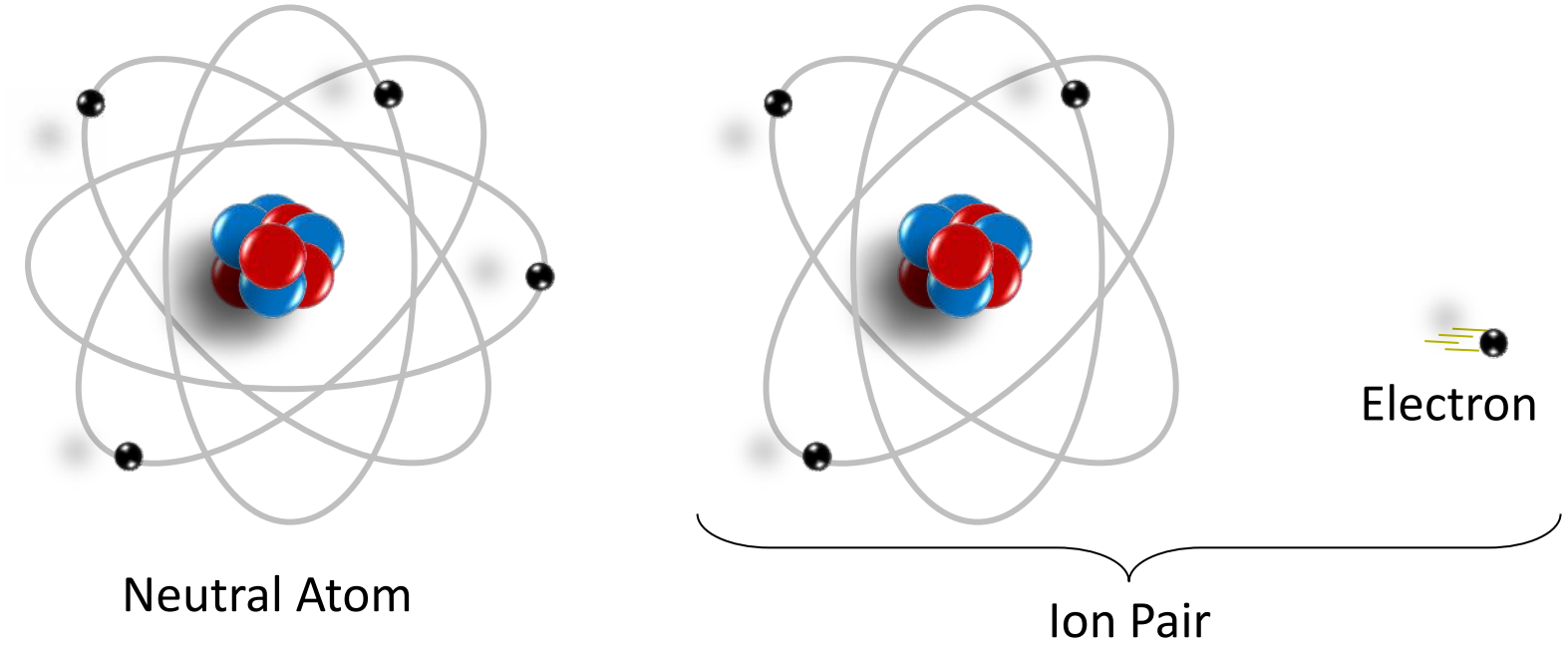
Ionizing Radiation



- When radiation strikes matter, it interacts with the atoms of the matter
- Radiation with enough energy can knock **electrons** out of orbit from the atoms it strikes.

Ionizing Radiation

Radiation that can cause ionization

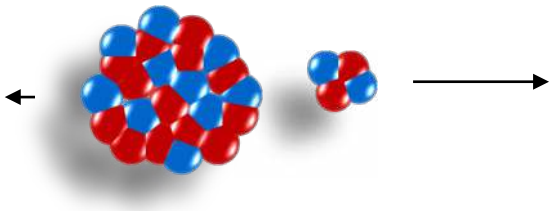


Ionization: the process of creating ions.

Sources of Ionizing Radiation

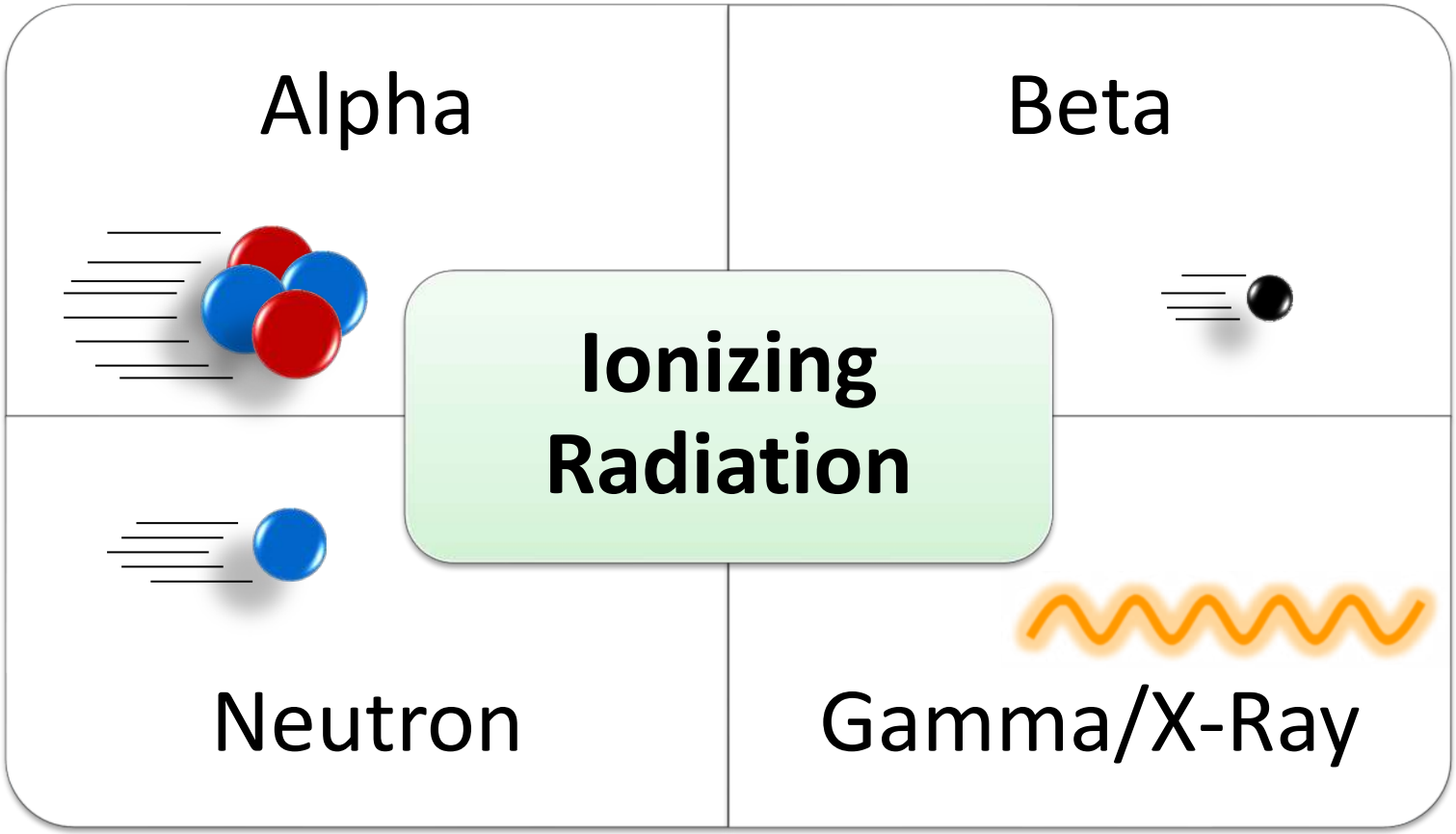
Where does ionizing radiation come from?

Radioactive atoms



Man-made devices

Types of Ionizing Radiation



Radiation Dose

- The effects of radiation depend on the amount of ***energy*** the radiation transfers to your body.
- This transfer of energy results in a radiation ***dose.***

Radiation Dose

Radiation dose is typically measured in Sievert (Sv)

Sieverts take into account how biologically damaging different types of radiation are

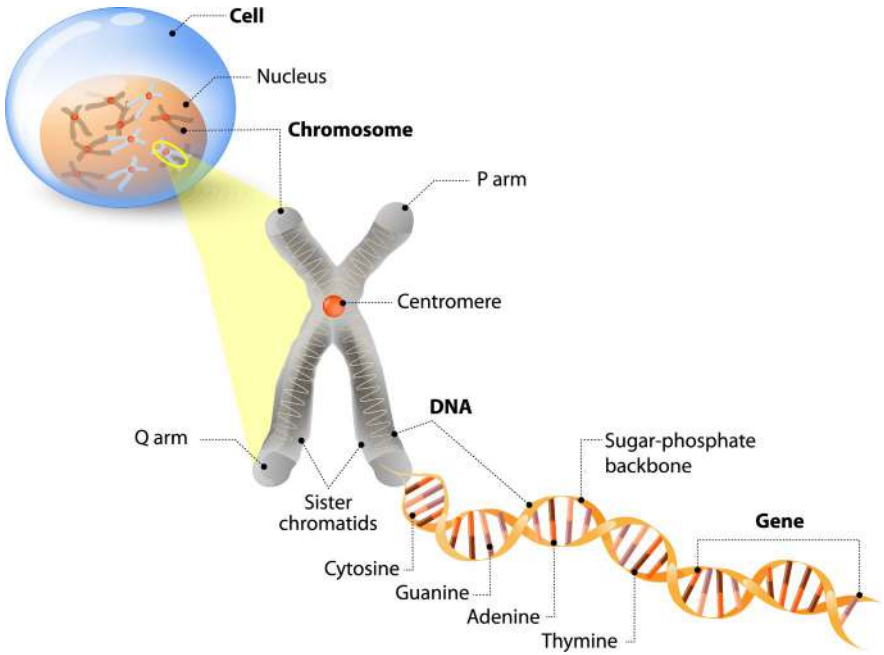
1 Sv is a very large dose.
Typically we use the miliSievert (mSv). 1 Sv = 1000 mSv

Interaction with the Body

- Your body is made up of atoms, like any other material object.
- When radiation strikes it, it can interact.
- Radiation interacts with non-living and living material in the same ways.

Image created using biorender.com

Basic Structure of a Cell



- A cell contains giant molecules called chromosomes.
- Chromosomes contain information required to create another cell identical to the original cell.
- The units of information in the chromosome are called the genes.
- Each gene is a segment of a complex molecule called DNA (deoxyribonucleic acid).

Biological Effects of Radiation

- Interaction of radiation with a cell depends upon the energy and intensity of radiation and exposure time.
- Radiation may ionize the DNA molecule of the cell.
- This may produce alterations in the biological properties of the cell.

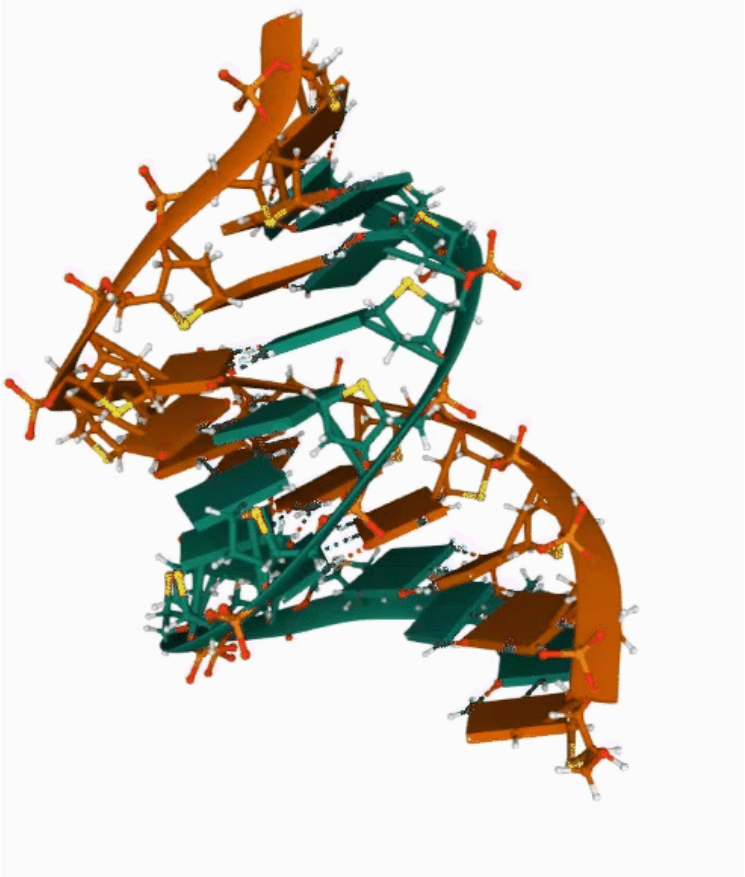
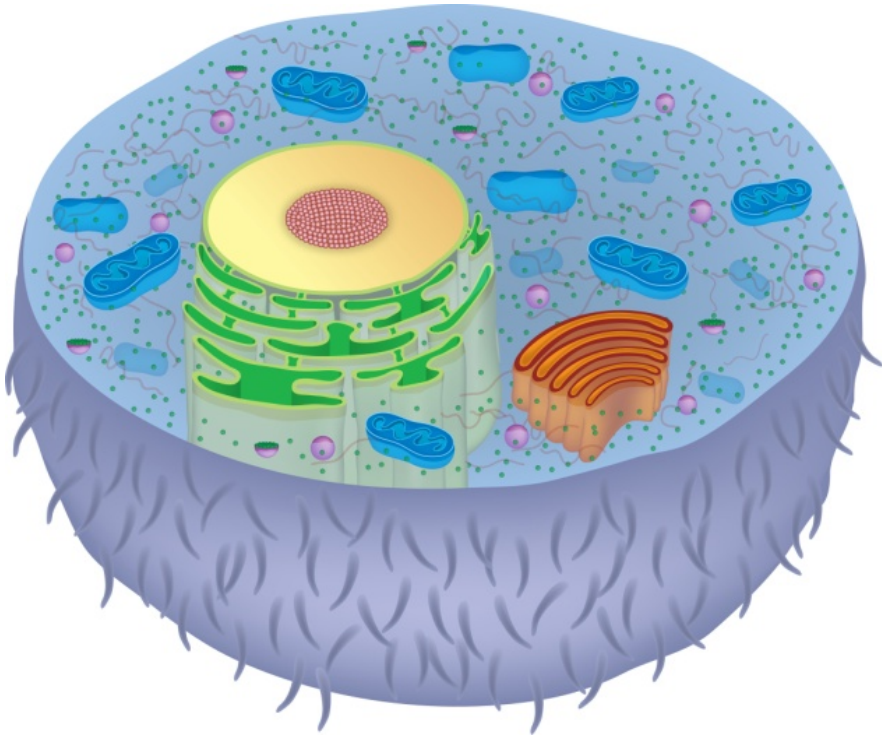


Image from the RCSB PDB (rcsb.org) of the solution structure of fully modified 4'-thioDNA with the sequence of d(CGCGAATTCGCG) (Matsugami, A., Ohyama, T., Inada, M., Katahira, M.) (2007)

Interaction with the Body



- When radiation strikes living tissue, there are a number of possible outcomes:
  - No damage at all
  - Damage to cells that is repaired
  - Damage to cells that leads to cell death
  - Damage to cell chromosomes that is incorrectly repaired ("mutated").

Effect of Radiation on People

Cell mutations caused by radiation could lead to:

Hereditary (genetic) effects

Somatic effects

Hereditary Effects

- Hereditary or genetic effects are potential health effects future generations might experience as a result of our exposure to radiation.

Hereditary Effects

- Radiation alters the DNA molecule in the egg cells of a female or in the sperm cells of a male.
  - This may cause abnormalities in descendants, such as leukemia and developmental delays.
- Hereditary effects have been demonstrated on laboratory animals.
- Hereditary effects have not been proven on human beings yet.

Somatic Effects

Somatic effects are experienced by the person exposed to radiation.

A radiation dose has a certain probability of causing a mutation in a cell, which might cause cells to divide in an uncontrolled manner.

Uncontrolled cell division could lead to cancer, which could be fatal.

Stochastic Somatic Effects

- Radiation exposure increases the likelihood of developing cancer.
- The greater the exposures the greater the likelihood.
- But we cannot be certain that an effect will or will not occur.

Stochastic Somatic Effects

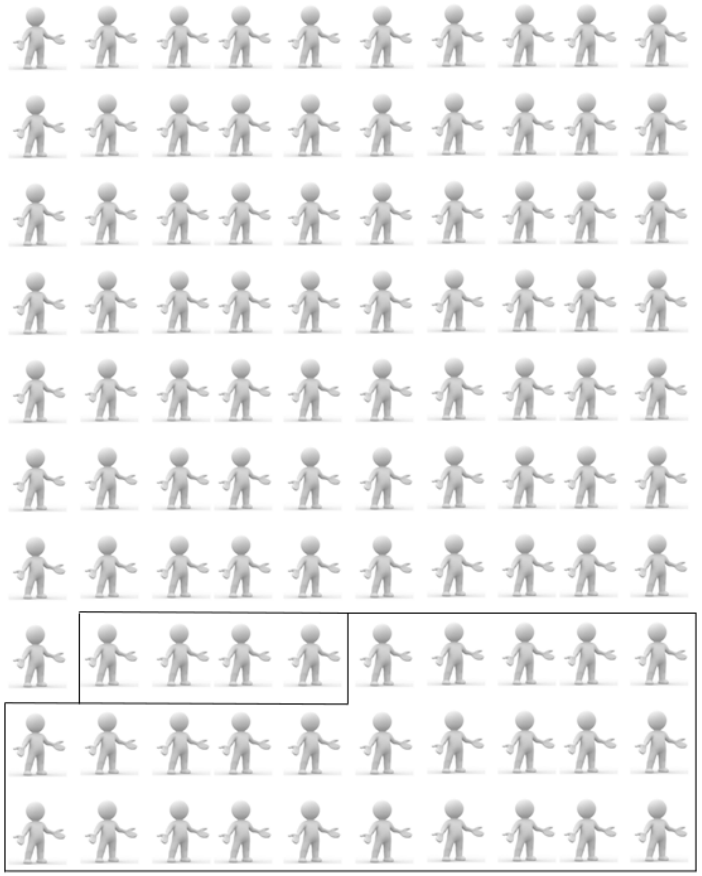
- We know that smoking causes lung cancer.
  - But, Joe smoked sixty a day and lived to be 95!
- Some people develop lung cancer in their life regardless.
  - Only some of these people are smokers.
- Smoking increases the likelihood of developing lung cancer.
  - This is a stochastic effect.

The Risk - Some Numbers

- The risk of developing a fatal cancer as a result of exposure to radiation is approximately 4% per 1000 mSv.
  - Consider a person who worked for 50 years and received 20 mSv per year.
  - This person's total lifetime radiation dose is 1000 mSv.
  - This person will have an extra 4% chance of developing a fatal cancer.

The Risk - Some Numbers

- Approximately 25% of people develop a fatal cancer in their life.
- So, this person's risk of developing a fatal cancer becomes 29% instead of 25%.
- Other professions carry risks too.



Risk of Death for Various Professions

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Profession	Risk of Death per Year
Finance	1 in 60,000
Service	1 in 40,000
Trade	1 in 20,000
2 mSv of radiation per year	1 in 12,000
Government (includes police and fire)	1 in 11,000
Manufacturing	1 in 11,000
Transportation	1 in 4,000
Construction	1 in 3,000
20 mSv of radiation per year	1 in 1,200
Mining	1 in 1,100
Forestry	1 in 900
Fishing and Hunting	1 in 500

From "Canada: Living with Radiation." Reproduced with the permission of the Minister of Public Works and Government Services, 2001.

Occupational Exposures to Ionizing Radiation

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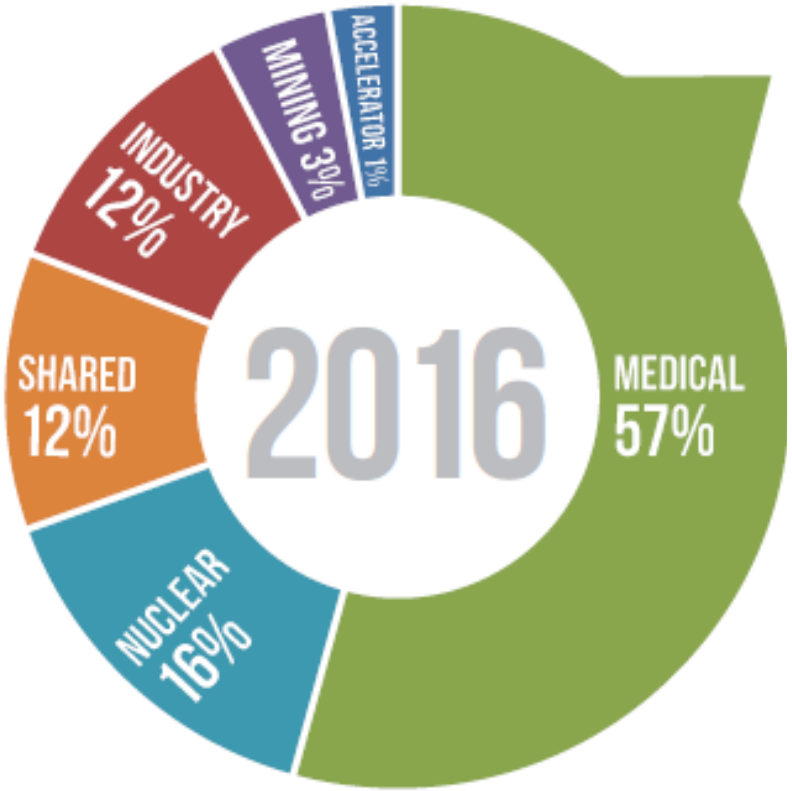
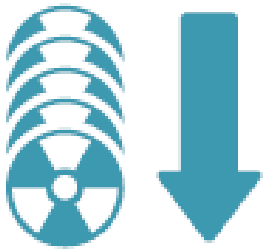


MEAN RADIATION DOSE (2016): 0.2

MILLISIEVERTS (mSv)

The mean dose of ionizing radiation received by Canadian workers has been **decreasing for the past 5 years** and is at its lowest level since the first report was published in 1978.



You can find the full Report on Occupational Radiation Exposures in Canada at: http://publications.gc.ca/collections/collection_2018/sc-hc/H126-1-2017-eng.pdf

Data and Image from https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/occupational-radiation-exposures.html

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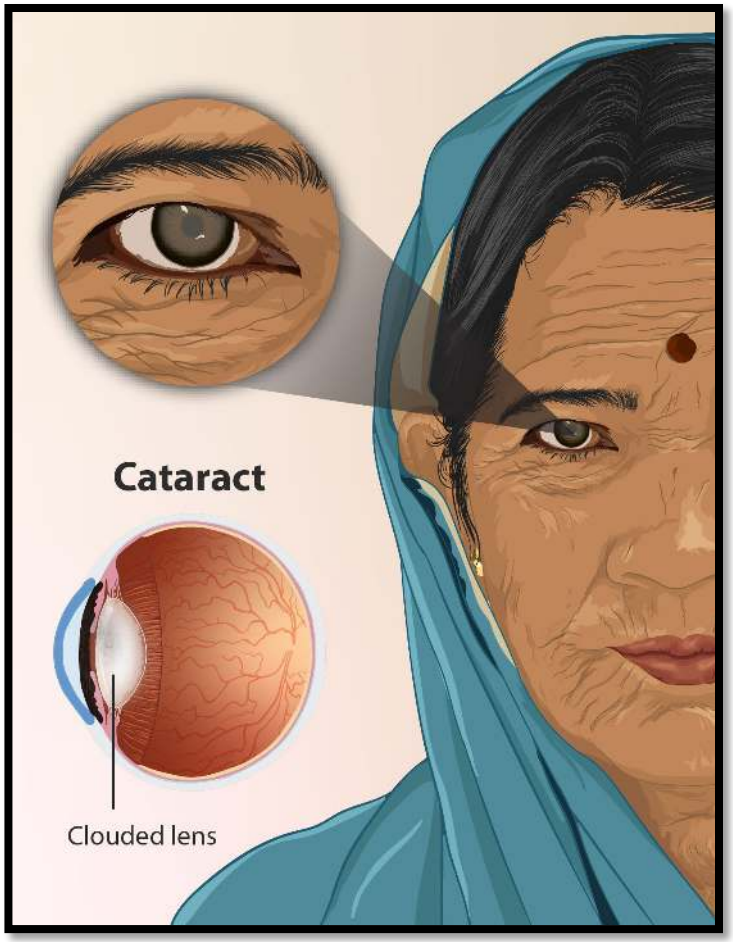
Risk of Death From Accidents

Hazard	Risk of Death per Year
Accidents on the road	1 in 5,000
Accidents at home	1 in 11,000
Accidents at work	1 in 24,000
1 mSv per year (annual dose limit for members of the general public)	1 in 20,000
0.05 mSv per year (maximum emission from nuclear facilities in Canada)	1 in 400,000
0.001 mSv per year (average emission from nuclear facilities in Canada)	1 in 20,000,000

From "Canada: Living with Radiation." Reproduced with the permission of the Minister of Public Works and Government Services, 2001.

Deterministic Effects

- A deterministic effect is one which will certainly result from exposure
- There will be a minimum exposure (threshold) above which the effect will occur
- The severity of the effect will depend on the exposure
  - Example: cataract formation, radiation sickness



Chronic Exposure

Image: Unknown author, Public domain, via Wikimedia Commons

- Exposure to low doses of radiation over months or years
- Deterministic effects
  - Cataracts
  - Nonspecific life shortening
- Stochastic effects
  - Cancer
  - Genetic effects

Acute Exposure

- Exposure to a high dose delivered within seconds, minutes or days
- Possible deterministic effects
  - Blood changes
  - Nausea
  - Diarrhea
  - Hair-loss
  - Malaise
  - Death

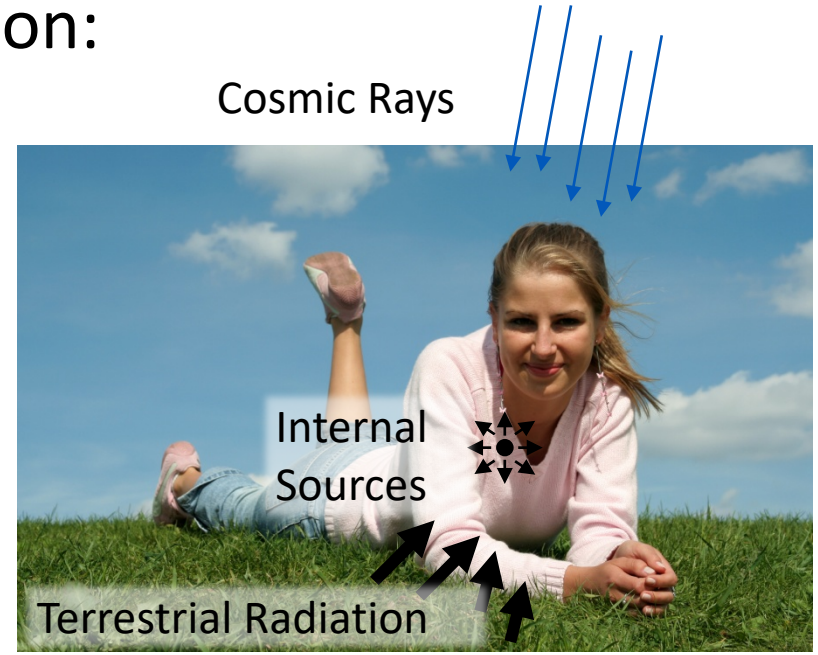
Image by LK Wagner, PhD; Vlietstra et a, CC BY-SA 3.0 via Wikimedia Commons

Acute Exposure

Acute Dose (mGy)	Effect
< 250	No detectable effects
> 3,000	Chance of death 50% and above
> 6,000	Death an almost certainty, time between exposure and death depends on amount of dose

Radiation Exposure

- We are all exposed to radiation:
  - Cosmic radiation
    - sun, space
  - Terrestrial radiation
    - soil, rocks
  - Internally
    - Food, air (radon gas)
  - Medical treatment



- On average, we receive about 2 – 4 mSv per year from background radiation

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Summary of Exposures

Public exposures and threshold effects:

Source or Effect	Effective Dose
Average Dose limit	20 mSv (NEW) 1 mSv (public)
Background Radiation	2-4 mSv/year 0.01 mSv/day
Acute dose which affects the blood	> 250 mSv
4% increased risk of fatal cancer	1000 mSv
Cross country plane ride	0.03 mSv

Medical Exposures:

Source	Effective Dose
Chest X-ray	0.1 mSv
Chest CT	6 mSv
PET/CT scan	25 mSv
SPECT w/ Tc-99m	10 mSv
Mammography (x4)	2-3 mSv
Dental X-rays (x4)	0.04 mSv
Radiation Therapy	Up to 60 Gy (equivalent dose)

Types of Non-Ionizing Radiation

Radio waves

Infrared light

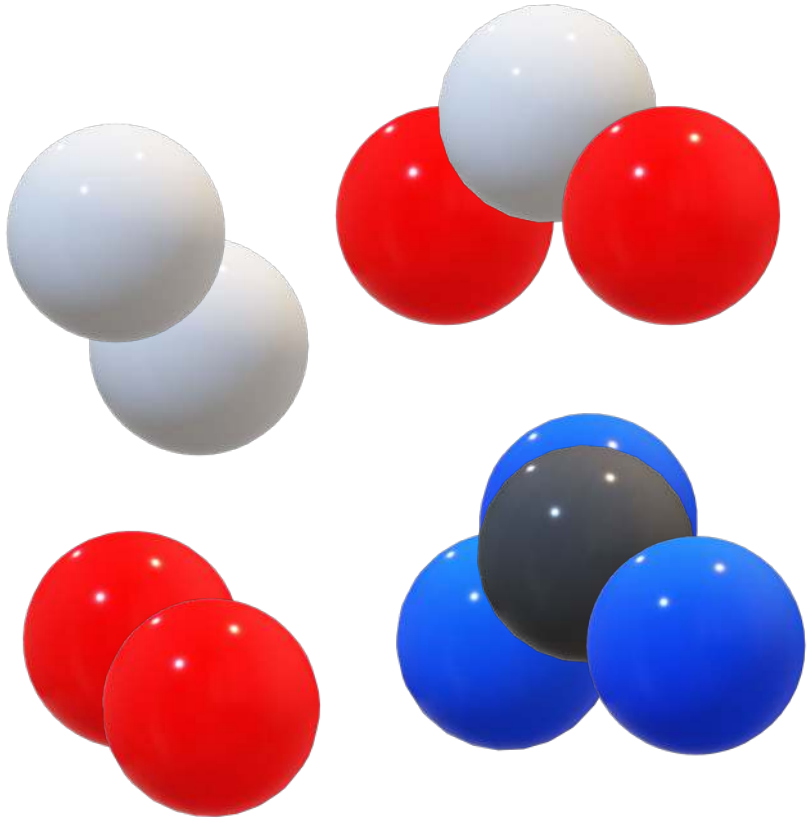
Non-Ionizing Radiation

Visible light

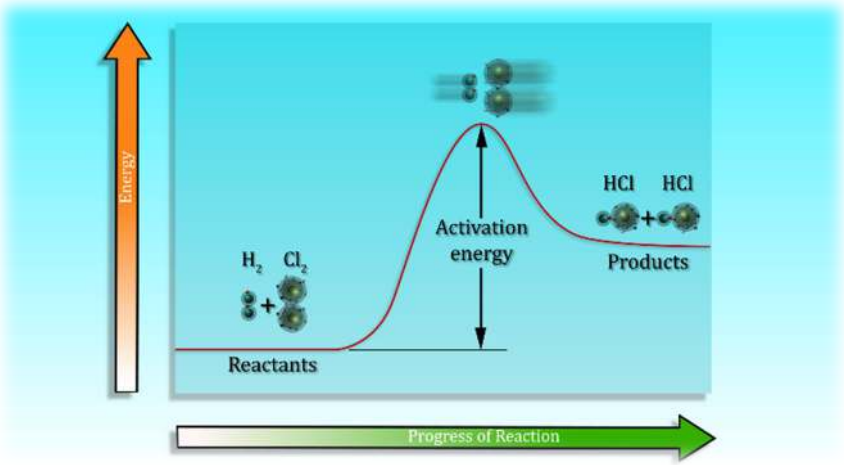
Microwaves

Thermal Effects

- Temperature is a measure of the average kinetic energy of the atoms and molecules in a system, or thermal energy
- Heat is the transfer of thermal energy from one area to another
- If you heat an object, you cause its atoms or molecules to move around more
- Living things are sensitive to temperature changes
  - Change of state
  - Burns
  - Denaturing of proteins
  - Metabolic rates



Photochemical Effects



- Chemical reaction
- Initiated by absorbing electromagnetic radiation
  - Infrared
  - Visible
  - Ultraviolet
- Examples:
  - Photosynthesis
  - Formation of vitamin D
  - Creating long molecules called polymers
  - Degradation
  - Photoreception in the eye

Low Frequency EM Radiation

- Generate electric fields and currents
  - Can interfere with body's fields
  - Low energy levels, unnoticed
  - Over threshold
    - Peripheral vision: faint light flicker
    - Effects similar to static buildup
    - Tingling sensation
    - Very high levels: cardiovascular effects or tissue burns
- Research has not shown chronic exposure has detrimental health effects.

Radiofrequency

- Electromagnetic spectrum in the 100 kHz to 300 GHz in frequency
- Used in
  - telecommunications
    - Mobile phones, base stations, Wi-Fi, 5G, radio, television
  - MRI equipment
  - Microwave ovens
- Research shows effects
  - Heating of exposed tissue
  - Above a threshold: heatstroke, burns

Microwave Oven: Consumer Reports, CC BY-SA 4.0 via Wikimedia Commons

Laser

- Lasers produce a beam of light
  - Same frequency (monochromatic)
  - Same phase (coherent)
  - Travel in the same direction
- Cannot see the beams
- Easily reflected
- Dangers: burns to tissue
  - Eye particularly vulnerable
- Non-beam hazards
  - Fire
  - Generating airborne hazards
- Eye/skin protection

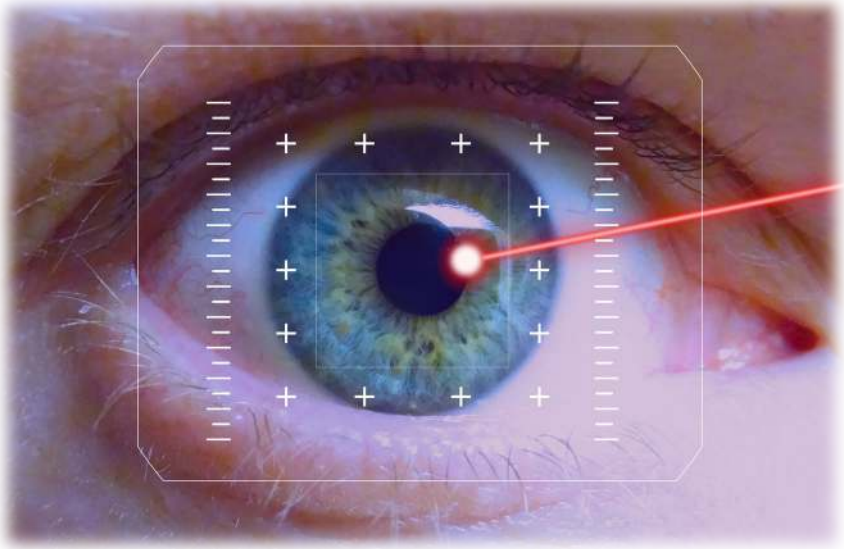


Image royalty free from pxfuel.com

Ultraviolet

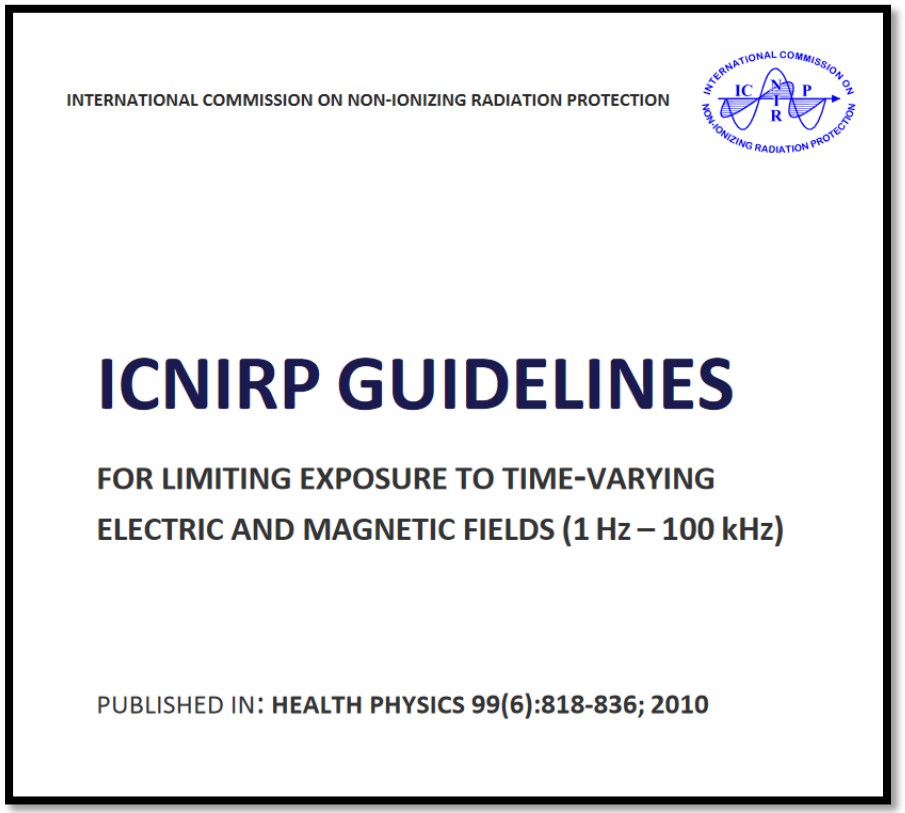
- More energetic than visible light
- Divided into 3 categories
  - Increasing energy
  - UVA, UVB, UVC
- Sunlight
  - UVC and some UVB filtered by atmosphere
- Health effects
  - Heating
  - Photoelectric
  - Ionizing
- Manifest as
  - Acute: Sunburns, Increased melanin production, vitamin D production, local immunosuppression, eye inflammation and retinal damage
  - Chronic: skin wrinkling, skin aging, skin cancer, cataract, retinal degeneration, eye cancer

How Is This Determined?

- Global scientific research
- International agencies compile and make recommendations
  - Low frequency: keep induced currents below normal body
  - Radio/microwave/infrared: prevent effects due to heating
  - Visible, UV: prevent thermal, negative photochemical
  - Ionizing: prevent acute exposure and keep chronic exposure ALARA
- Recommendations include additional safety factors

Example

- International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- Behavioral changes observed
- Threshold determined
- Safety factors:
  - /10 for occupational
  - /50 for public



Regulator

- The Canadian Nuclear Safety Commission (CNSC) regulates the possession and use of all radioactive substances and radiation devices in Canada
  - Owners of radiation sources and devices must have a license from the CNSC
- Equipment which produces non-ionizing radiation are generally under provincial jurisdiction, if they are regulated
  - Most x-ray equipment is provincially regulated
  - Very high energy x-ray units are regulated by the CNSC

Radiation Safety Institute of Canada

- The Radiation Safety Institute of Canada is an independent, not-for-profit organization specializing in radiation safety.

- For further information on all types of radiation contact us at:

1-800-263-5803

info@radiationsafety.ca

www.radiationsafety.ca