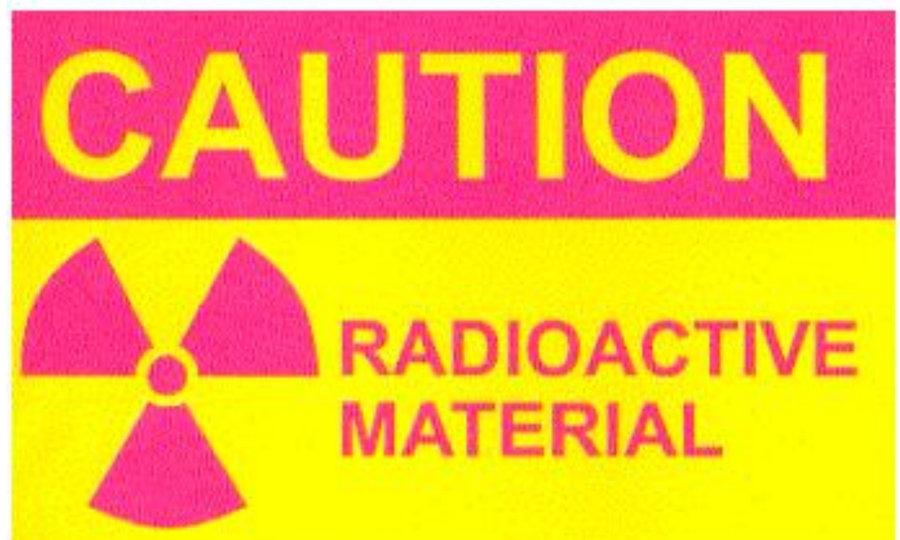
Radiation Safety Talk

UC Santa Cruz

Physics 133

Winter 2018

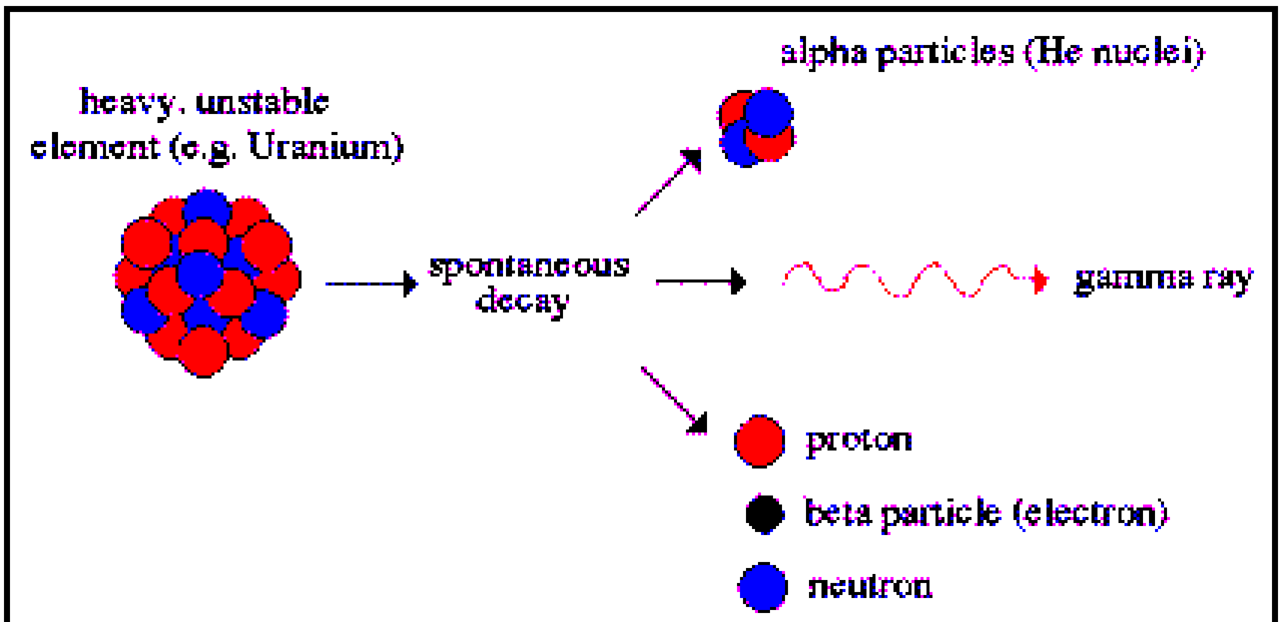


Outline

- Types of radiation
- Sources of radiation
- Dose limits and risks
- ALARA principle
- Safety procedures

Types of radiation

- Radiation is energy transferred through space and matter. Radiation is emitted as waves or particles from unstable atoms



Alpha radiation produces a helium atom and one or more gamma rays

E. R. Crain, https://www.spec2000.net/06-atomicphysics.htm

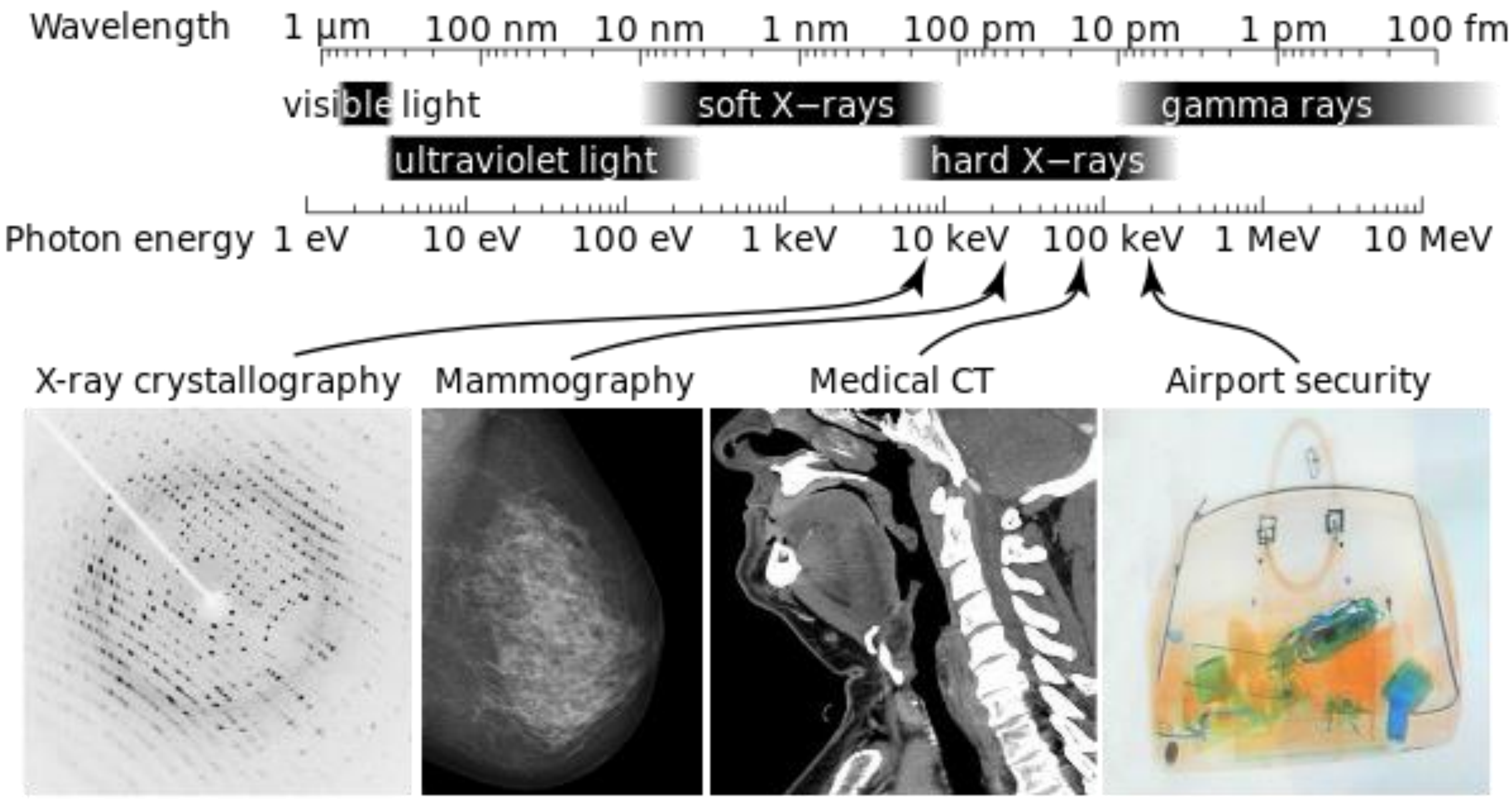
Ionizing radiation

- Ionizing radiation is produced by unstable atoms (which have an excess of mass or energy, or both)
- To reach stability, unstable atoms emit the excess energy/mass in the form of radiation.
- There are 4 basic types:
  - Alpha particles (He nuclei)
  - Beta particles (electrons and positrons)
  - Neutrons
  - Gamma rays (from nuclei) and X-rays (from collisions between electrons and atoms)
- Ionizing radiation is dangerous to humans – it can damage atoms in cells

Gamma radiation and X-rays

- These are the most energetic types of electromagnetic radiation
  - X-rays are ~ 125 eV – 100 keV
  - Gamma rays are > 100 keV
- Penetrating radiation: these can travel many meters in air and centimeters in human tissue. They deposit their energy in cells as they slow down.
- Require dense materials for shielding (e.g. lead or concrete)

Energy ranges of X-rays used in different applications:

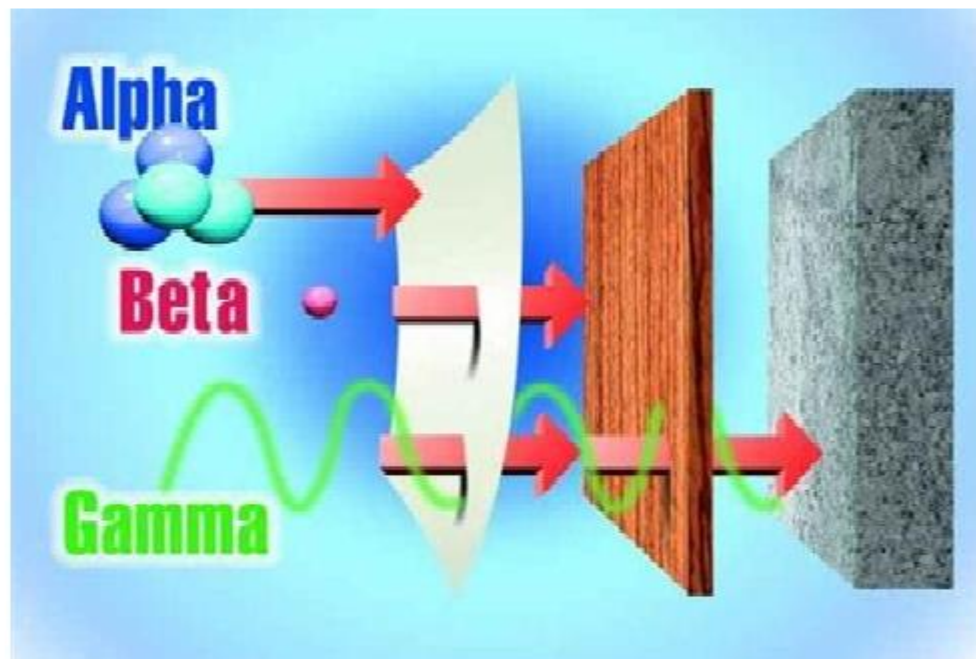


https://en.wikipedia.org/wiki/X-ray#/media/File:X-ray_applications.svg

Note: The millimeter-wave scanners at airports actually use photons with energies of less than 1 eV – they are not actually x-rays!

Beta Particles

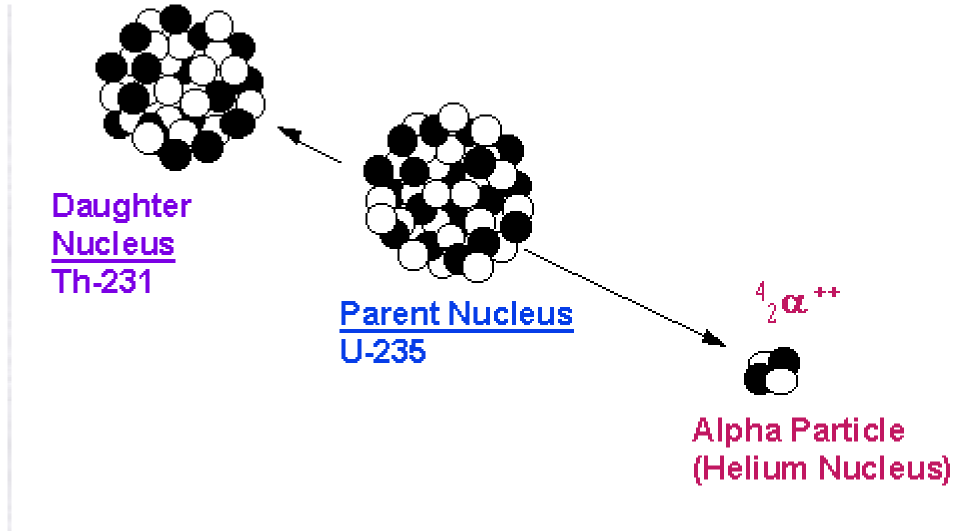
- Can travel meters in air and are moderately penetrating (a few mm in Aluminum)
- Skin contact for a prolonged period can cause injury.
- Beta-emitting contaminants can be harmful if you ingest them.



http://www.keepbanderabeautiful.org/nuclear.html

Alpha Particles

- Least penetrating type of ionizing radiation (travels a very short distance through air)
- Can be stopped by paper or skin



http://www.physics.isu.edu/radinf/alpha.htm

- Can be harmful if inhaled, swallowed, or absorbed through wounds
- We will not be encountering alpha particles in this lab

Units

	Radioactivity	Absorbed Dose	Dose Equivalent	Exposure
Common Units	curie (Ci)	rad	rem	roentgen (R)
SI Units	becquerel (Bq)	gray (Gy)	sievert (Sv)	coulomb/kilogram (C/kg)

https://orise.orau.gov/reacts/guide/measure.htm

- Curie (Ci): non-Si unit of source activity

  1 Ci = 3.7 x 10^{10} disintegrations/second
- Rad: non-SI unit of absorbed dose

  1 rad = 0.01 J/kg absorbed
- Gray (Gy): SI unit of absorbed dose

  1 Gy = 1 J/kg absorbed
- Sievert (Sv): SI unit of dose equivalent
  - Represents the energy absorbed by an infinitesimal mass (dE/dm)

  Sv = Gy x "quality factor"
- Rem: non-SI unit of dose equivalent

  rem = rad x "quality factor"

Quality factor

- The dose equivalent depends on the "quality factor" of a type of radiation

Type of radiation	Quality factor (Q)
X-, gamma, or beta radiation	1
Alpha particles, multiple-charged particles, fission fragments and heavy particles of unknown charge	20
Neutrons of unknown energy	10
High-energy protons	10

http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1004.html

- This factor quantifies the biological damage caused by different types of radiation
- For example, alpha particles are more damaging than gamma rays when the absorbed dose is equal

Unit conversions

Conversion Equivalence

1 curie = 3.7×10^{10} disintegrations per second		1 becquerel = 1 disintegration per second
1 millicurie (mCi)	=	37 megabecquerels (MBq)
1 rad	=	0.01 gray (Gy)
1 rem	=	0.01 sievert (Sv)
1 roentgen (R)	=	0.000258 coulomb/kilogram (C/kg)
1 megabecquerel (MBq)	=	0.027 millicuries (mCi)
1 gray (Gy)	=	100 rad
1 sievert (Sv)	=	100 rem
1 coulomb/kilogram (C/kg)	=	3,880 roentgens

https://orise.orau.gov/reacts/guide/measure.htm

Sources of radiation

- Average annual radiation dose for a person is ~360 millirem. This is from natural background and human-made radiation sources.
- Natural background sources (~300 mrem):
  - Radon gas (~200 mrem)
  - Cosmic radiation (worse on planes!)
  - Radioactive elements in Earth's crust (e.g. Th and U)
  - Radioactive elements in the human body (e.g. potassium-40)

Sources of radiation

- Human-made sources (~60 mrem):
  - Medical x-rays and nuclear medicine (~53 mrem)
  - Consumer products (e.g. smoke detectors, tobacco)
  - Fallout from nuclear weapons testing
  - Nuclear reactors for power generation

Dose limits

- UCSC and federal dose limit for non-radiological workers and visitors is 100 mrem/yr
- Federal dose limit for occupational radiation exposure (radiological workers) is 5000 mrem/yr
- UCSC dose limit for occupational radiation exposure is 500 mrem/yr

Physics 133 Dose

- Our sealed Cs-137 source emits radiation at a rate of 5 μCi (1.85×10^5 disintegrations/sec).
- That comes out to 56 mrem/hr at a distance of 0.5 cm
- At a distance of 30 cm, that comes out to 0.016 mrem/hr

Dose risks

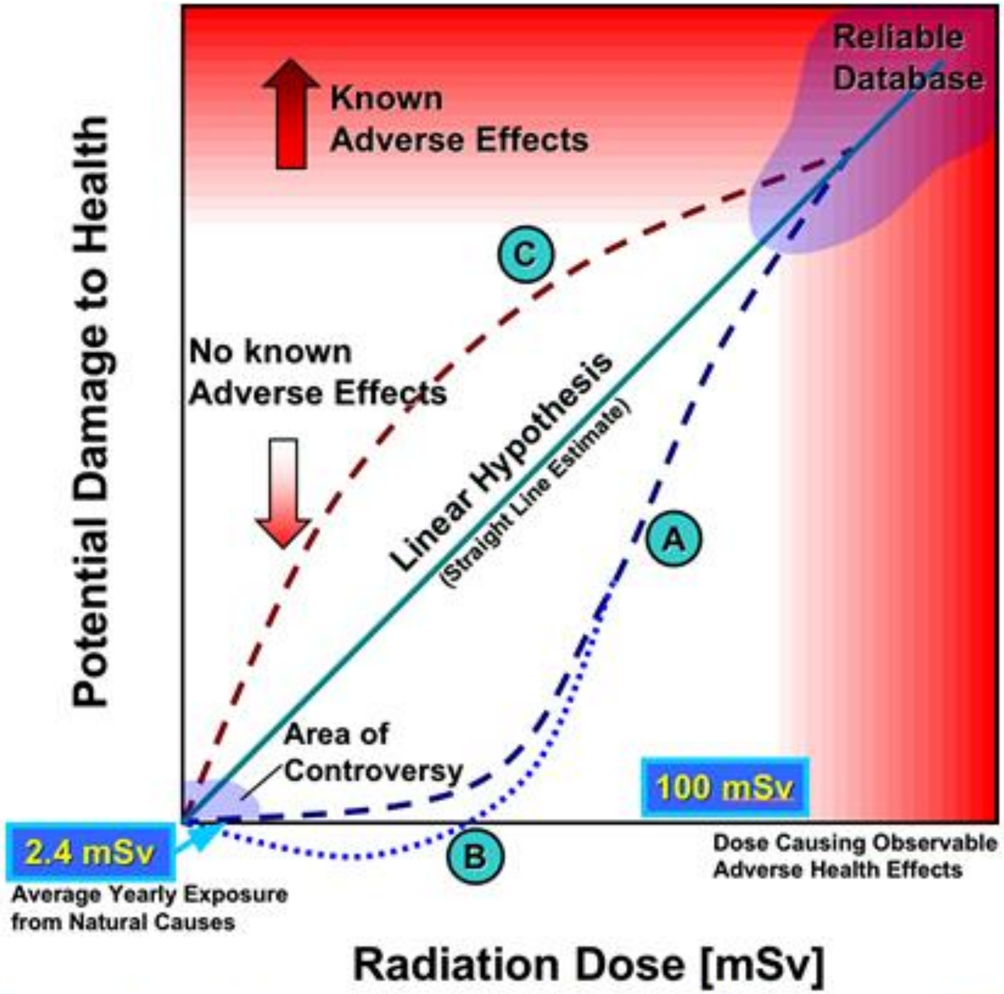


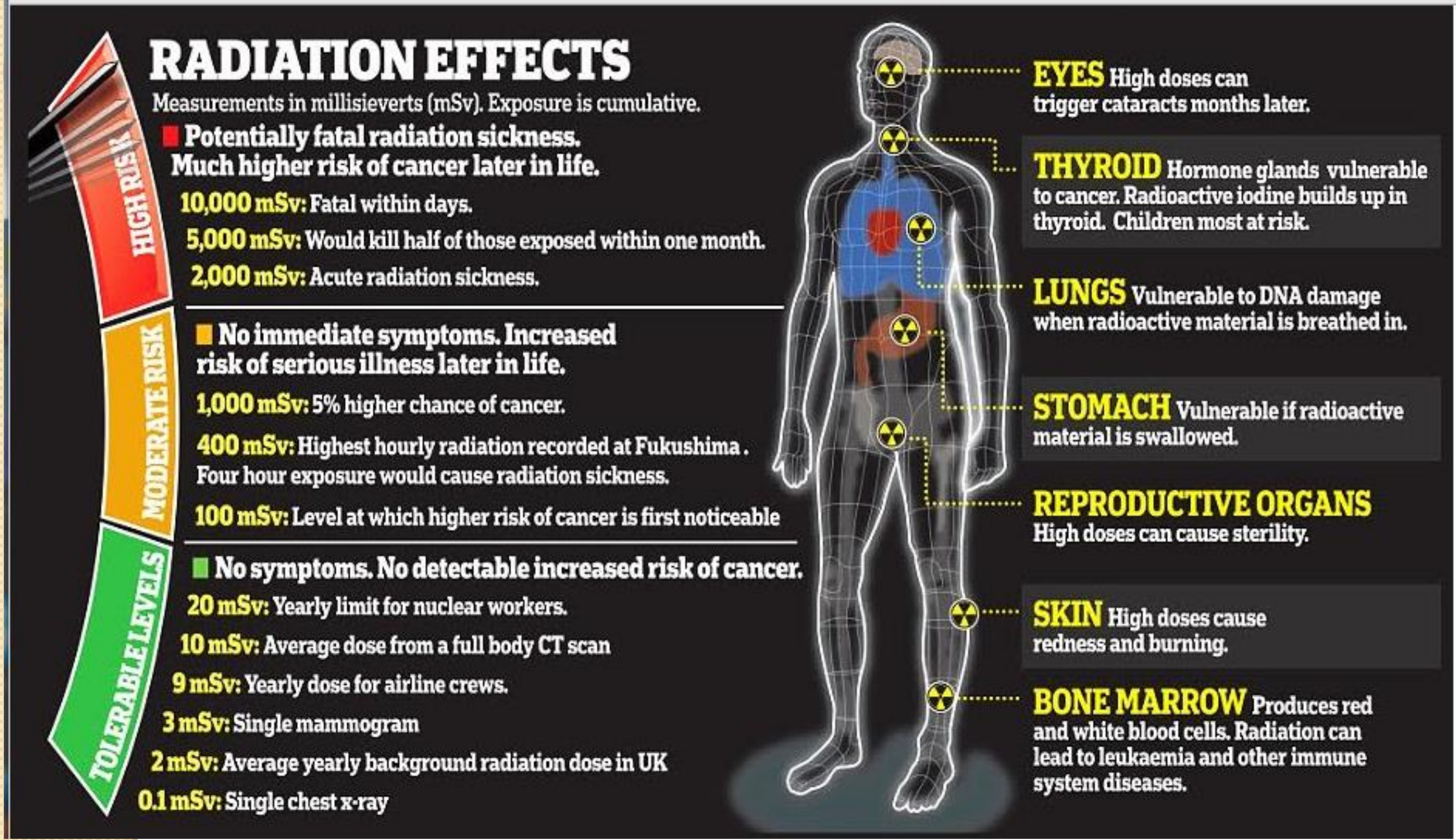
Figure 3 Effect of low dose radiation on health and the linear no-threshold model (hypothetical)

- 1 Sv = 100 rem
- 100 mSv = 10 rem
- The effect of low doses (<10 rem) of radiation is unknown

http://www.yomiuri.co.jp/adv/wol/dy/opinion/earthquake_110502.html

Radiation effects

(1 mSv = 100 mrem)



http://theprofessional-b.blogspot.com/2011/03/effects-of-radiation-on-human-body.html

ALARA principle

- ALARA – while working with radiation, keep your dose As Low As Reasonably Achievable
- Don't stop work altogether! You can minimize the risk using three basic practices:
  - Time
  - Distance
  - Shielding

ALARA

- Time
  - Reduce the amount of time spent near a radiation source.
- Distance
  - Maximize your distance from the source. Radiation exposure follows the inverse square law (Intensity α $1/r^2$), so if you are twice as far away, your exposure will be four times less.
- Shielding
  - Surround the source with appropriate shielding (e.g. lead for x-rays and gamma rays, plastic for neutrons)

Physics 133 safety

- Do not handle the Cs-137 sealed sources more than is necessary
- Do not place the sources near your eye or ingest the sources
- The professor or the TA will check out your source, and check it back in when you are done
- NO EATING OR DRINKING IN THE LAB

Safety Resources

- If you have any questions or concerns, you can contact EH&S radiation safety at (831) 459-3911 or rad@ucsc.edu
- Radiation safety contacts:
  - Eli Port: rad@ucsc.edu
  - Tristan White: twhite2@ucsc.edu

Sources

- UCSC radiation safety website: http://ehs.ucsc.edu/programs/research-safety/radiation/documents/rat.pdf
- Oak Ridge Institute for Science and Education: https://orise.orau.gov/reacts/guide/index.htm
- RS-500 radiation detector website: http://www.oasisllc.com/abgx/radioactivity.htm
- Radiation dose rate calculator: http://www.radprocalculator.com/Gamma.aspx