

X-ray Device Safety

For users of
X-ray producing devices
Other ionizing radiation producing devices

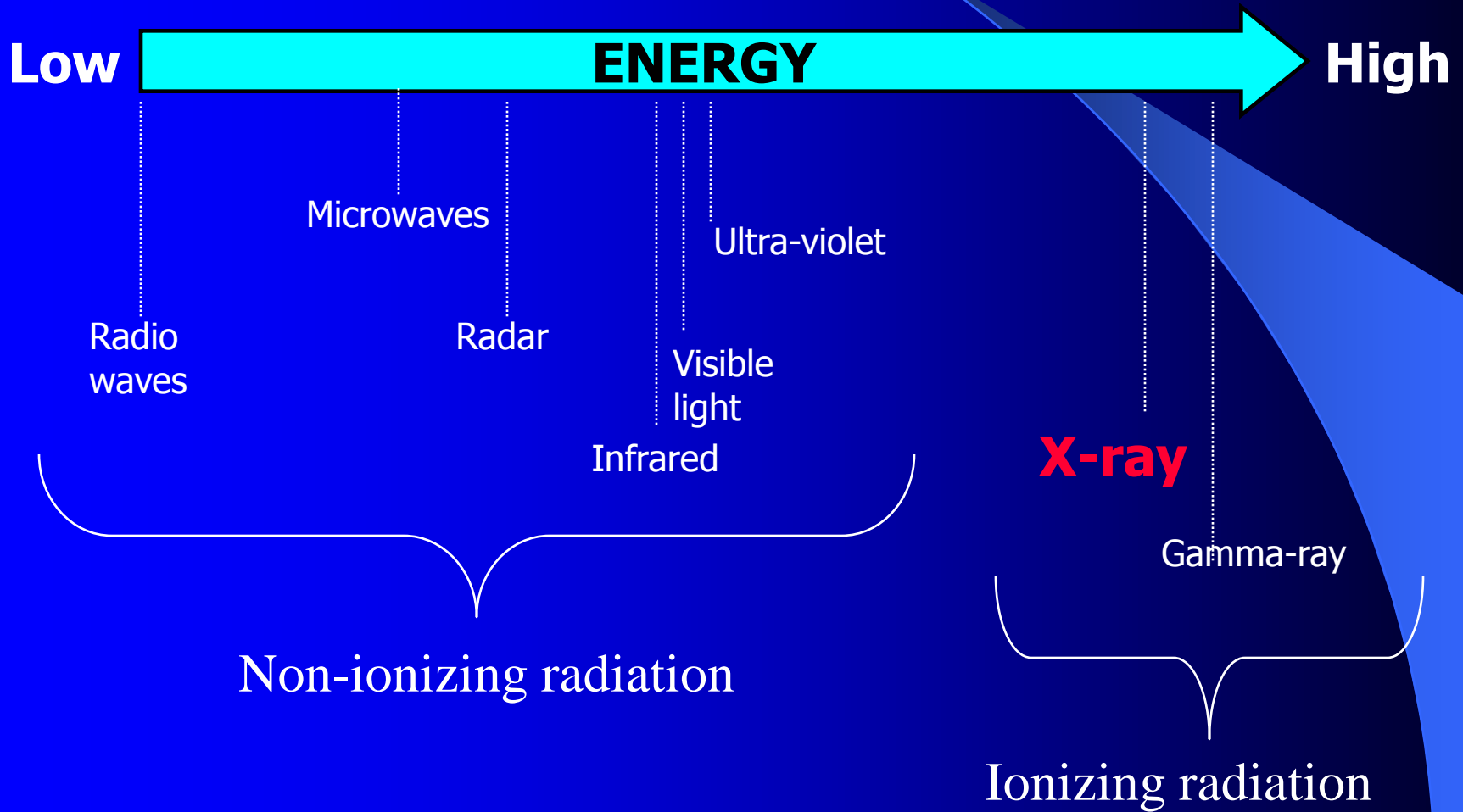
University of Arkansas
Environmental Health & Safety
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What are X-rays ?

X-rays are Electromagnetic waves generated from electron clouds of atoms.

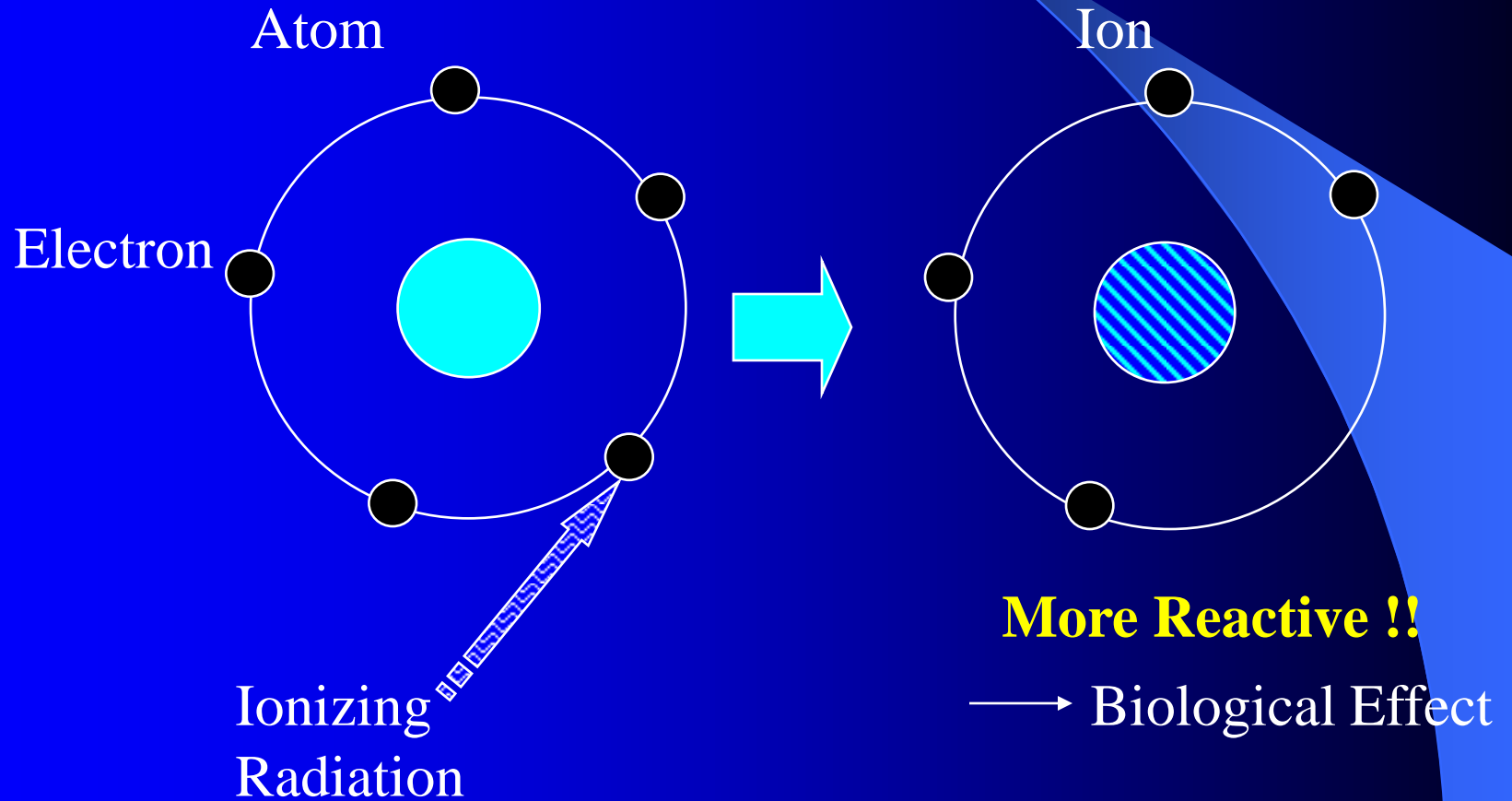
- **No charge**
- **No mass**
- **Travel at the speed of light**
- **Categorized in two groups depend on the energy**
 - Low energy----- Non-ionizing radiation**
 - High energy----- Ionizing radiation**
 - Can cause “ionization”**

Electromagnetic Waves

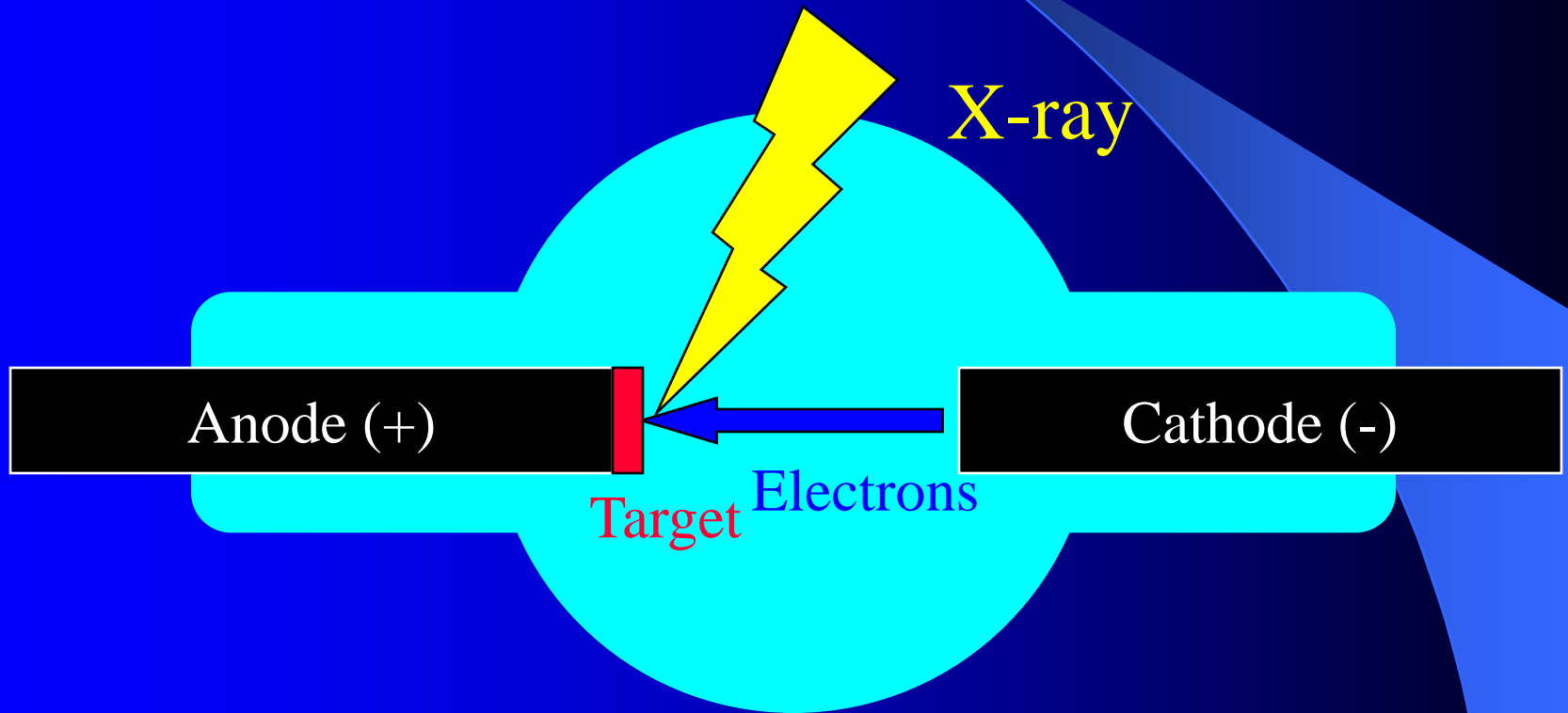


Ionization

Ionization



How are X-rays produced ??



X-ray tube

How are X-rays produced ??

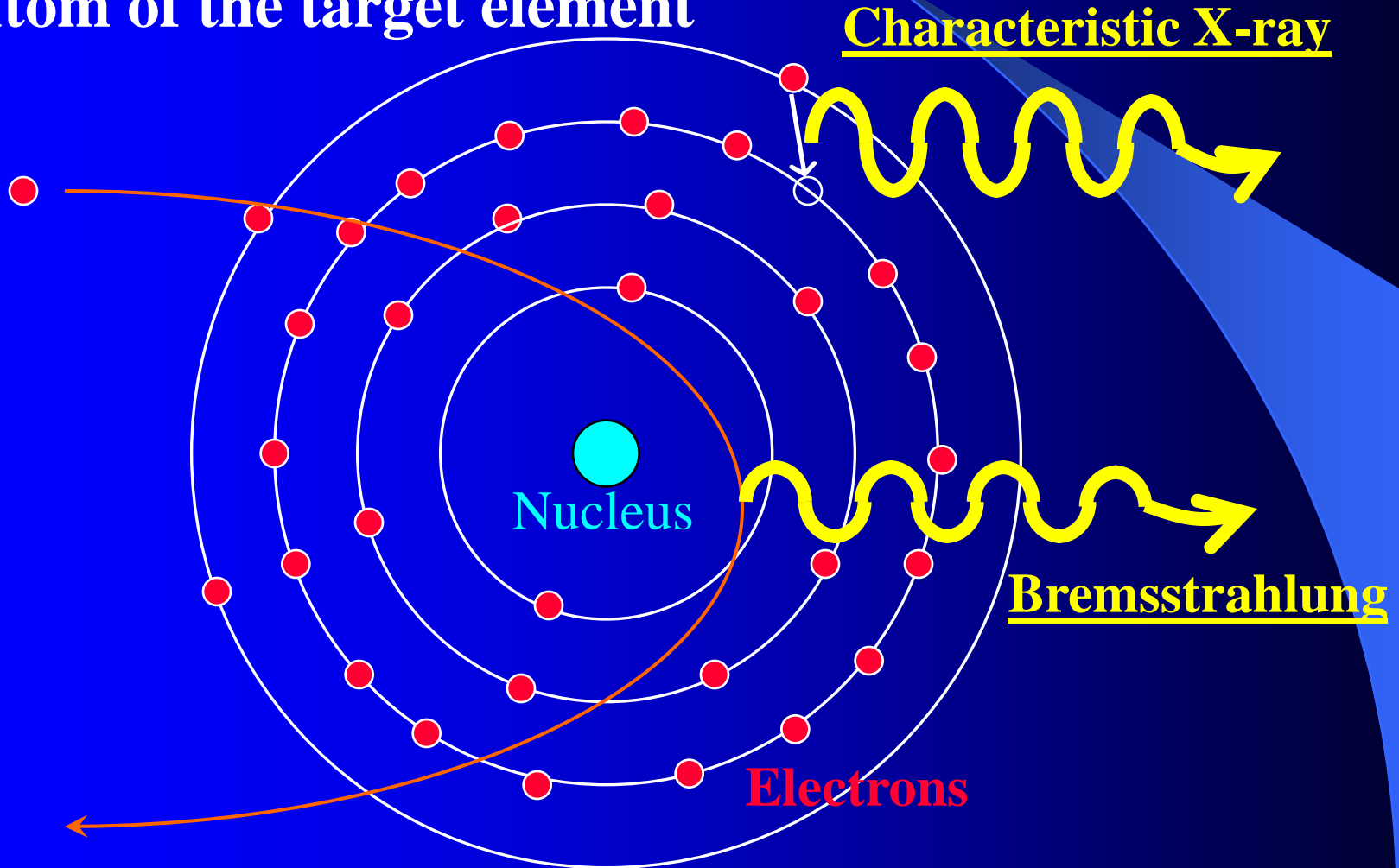
Most X-ray devices emit electrons from cathode, accelerate them with a voltage (vacuum), and let them bombard an target (anode). As a result of interactions of atoms of target elements and electrons, x-ray is produced.

The energy of the x-ray shows different distribution depending on the target material.

During the process, the device emits two different types of radiation.

Where do X-rays come from ?

Atom of the target element



Where do X-rays come from ?

- **Characteristic X-ray**

When the shell of the target atom has vacant, electrons in outer orbit will replace the spot. The energy difference is released as a form of X-ray. The energy shows the peak as energy differences between shells are characteristic of each atom.

Where do X-rays come from ?

- **Bremsstrahlung**

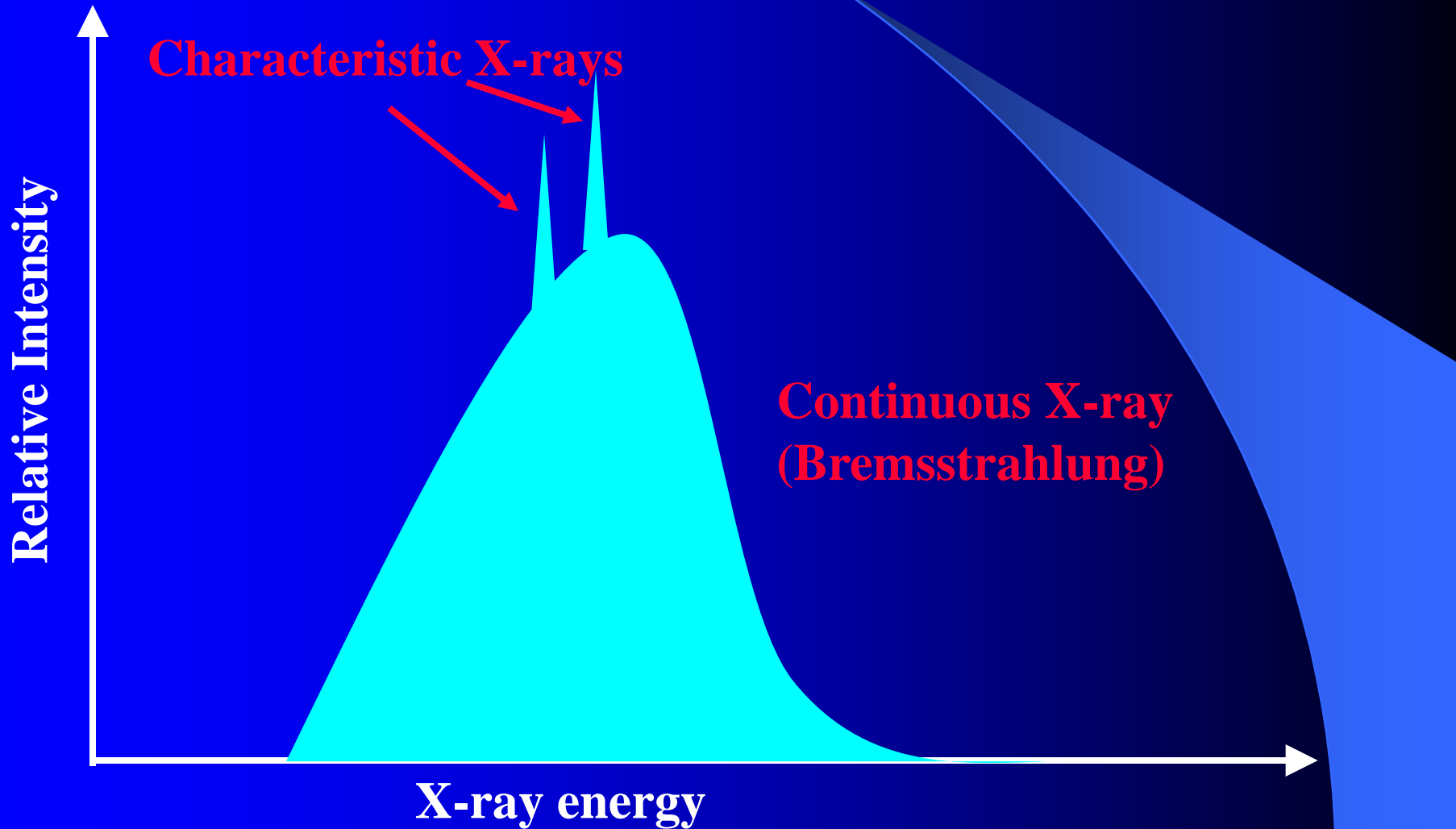
Bremsstrahlung occurs when high energy electrons slowed down near the nucleus. Excess energy (by the deceleration) is released in the form of x-ray(photon).

Bremsstrahlung means “ breaking radiation” in German.

This shows continuous spectrum as each electrons emits different fraction of its energy.

X-ray spectrum

— Example of energy distribution.



X-ray devices

Incidental

- Devices which produce x-rays that are not used as part of a designed purpose

- Computer monitors, electron microscopes, electron beam welders, etc.**
- < 0.5 mR /hour**

X-ray devices

Intentional

– Devices designed to generate x-ray beams for a particular use

- X-ray diffraction, fluorescence analysis**
- Medical x-rays**
- Used in designated room
(shielded, interlocked)**

X-ray devices

ATTENTION !!

Application for radioactive materials/ionizing radiation (X-ray and else) for human subject is not allowed at the University of Arkansas Fayetteville.

Researchers who wishes to use medical devices for human subject research, should consult the RSO before starting the projects.

X-ray device user

Responsible for:

- ❖ **Notifying the RSO of any changes**
(addition, removal, location change, authorized user change ... etc)
- ❖ **Inspection**
(according to the manufacturers guideline)
- ❖ **Ensuring security**
- ❖ **Compliance**
(Federal, State, Institution policies)

Unit

R (Roentgen)

- The unit of radiation exposure in air.

•R (Roentgen)

Defined as the amount of X-ray or gamma-ray that will generate $2.58\text{E}-4$ coulombs/kg-air (STP). Please note that this unit is only applicable to X-ray/gamma-ray field.

Unit

Rad (Radiation absorbed dose)

•Rad stands for Radiation Absorbed Dose. Definition is 1 rem is the amount of radiation that will deposit 0.01J of energy in a kilogram of material (tissue, air, shielding material ...etc). This unit can be used for any kinds of radiation.

•Rad is a traditional unit for absorbed dose. International Unit (SI unit) for absorption dose is Gy (gray). Conversion is $1 \text{ Gy} = 100 \text{ rad}$.

Unit

Rem (Roentgen equivalent man)

- Rem stands for Roentgen Equivalent Man. It can be obtained by multiplying Rad and weighting factor. Different weighting factor is given for different types of radiation. For X-rays, weighting factor is 1. Thus, for X-rays, 1 rem = 1 rad.
- Rem is also traditional unit. SI unit used for rem is Sv (sievert).

Conversion is $1 \text{ Sv} = 100 \text{ rem}$

Unit

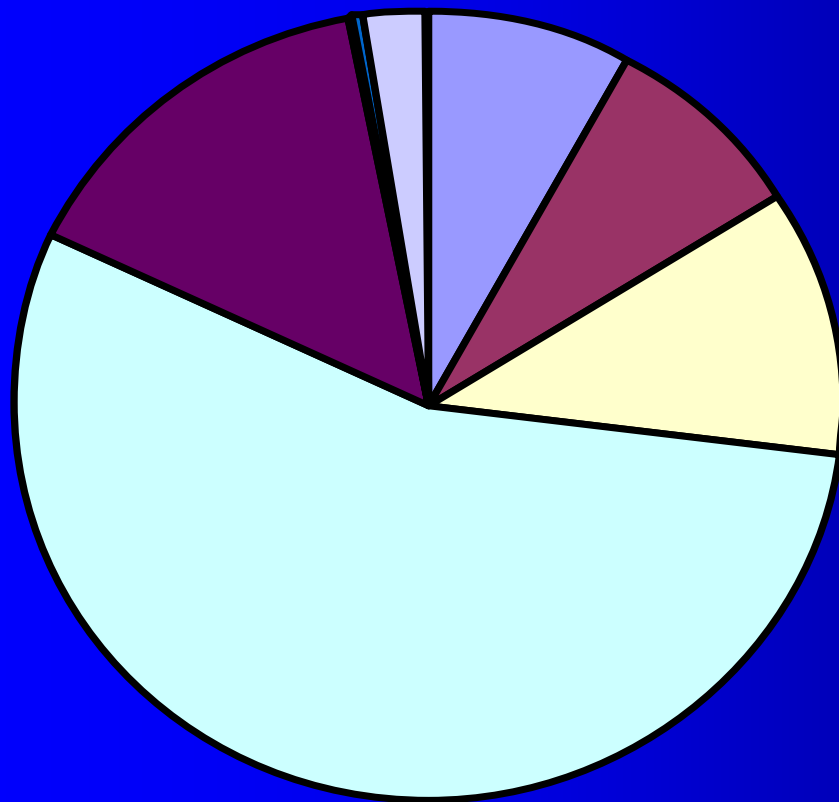
**1R = 0.93rad (tissue),
0.97rad(bone), 0.87rad(air)**

**For a quick estimation of
exposure, it is often
approximated that**

1R=1rad=1rem.

Background radiation

Exposure rate of the average U.S. resident is 360 mrem /year.



■ Terrestrial - 8%

■ Cosmic - 8%

■ Internal- 11%

■ Radon - 55%

■ Medical - 15%

■ Fallout - 0.3%

■ Reactor - 0.1%

■ Others - 2.6%

Natural
82%

Man-Made
18%

Occupational Exposure Limit

Whole Body – 5rem/year

Extremities – 50rem/year

Eye – 15rem/year

Pregnant workers – 0.5rem/gestation period

General public

Limited to 0.1 rem/year (Addition to the background radiation)

Biological Effects

X-ray has a capability to go through skin layers and deposit its energy to the cells deep inside the body.

X-ray has enough energy to ionize atoms, which constructing molecules.

It can break chemical bonds within some critical biological molecules.

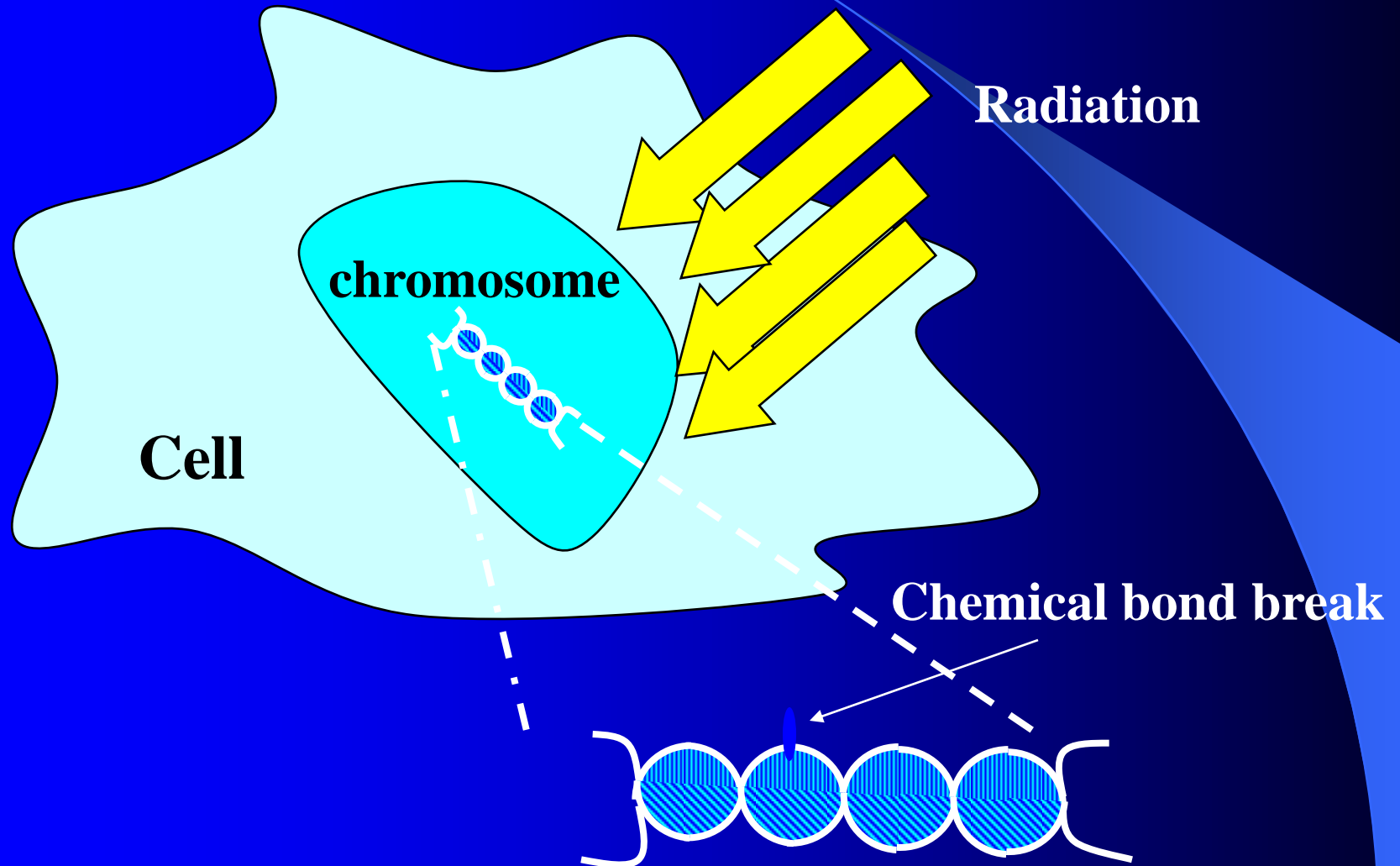
Biological Effects

In some cases, those damaged cells are able to repair themselves. However, when high dose or high dose rate exposure may create non curable damage.

When cells are not recovered, this damage can cause cell injury or even cell death. The effects may passed to daughter cells (with damaged characteristics). The division of this damaged cell may be the first step in tumor/cancer development.

If enough cells in a particular body organ are damaged, the function of the organ may be impaired.

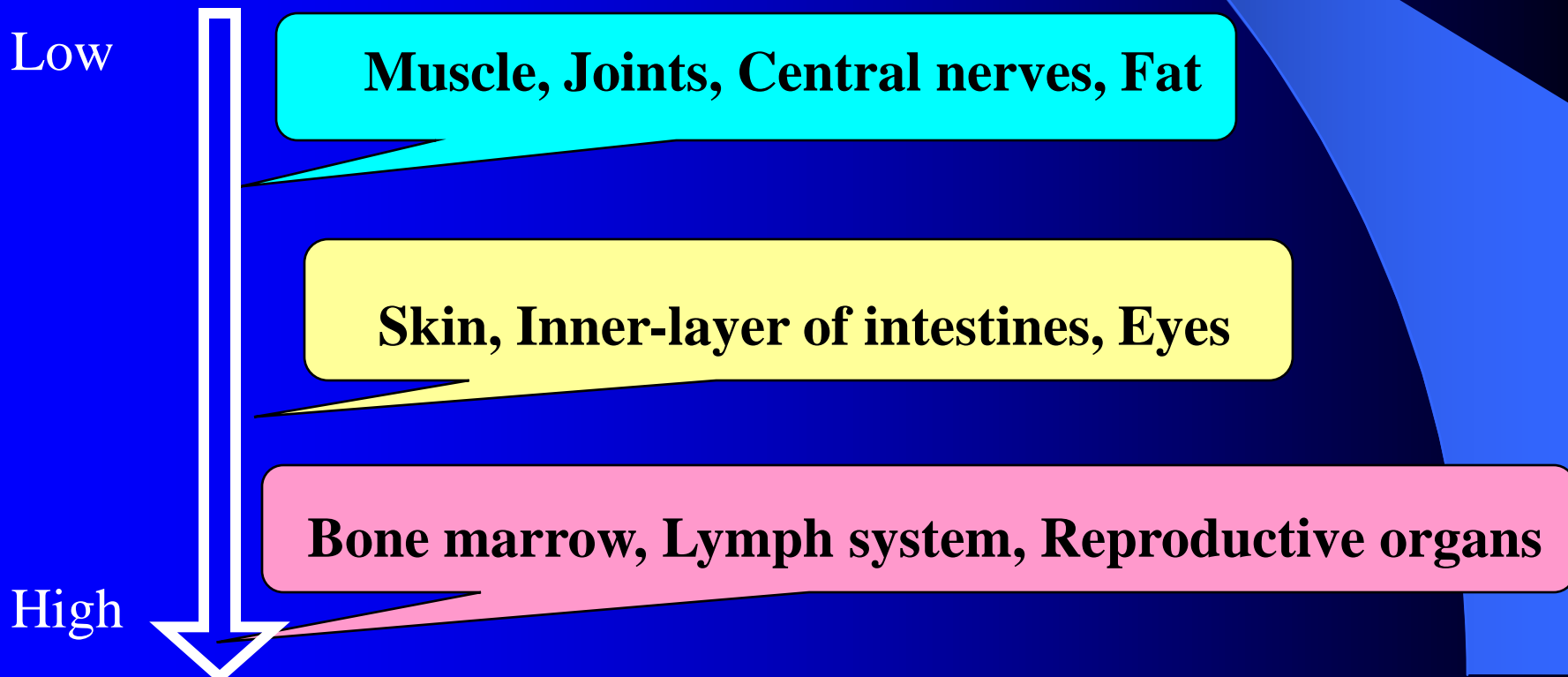
Biological Effects



Biological Effects

Typically young and rapid growing cells are more sensitive to the radiation than grownup cells.

Sensitivity



Biological Effects

Exposure (Acute Dose)

500 rem

- No immediate pain
- Warmth & itching in one day

1000 rem

- Serious tissue damage
- 2nd degree burn
- Blisters, raw open wound (1-3weeks)

Syndrome

Hematopoietic

100 –1,000 rem

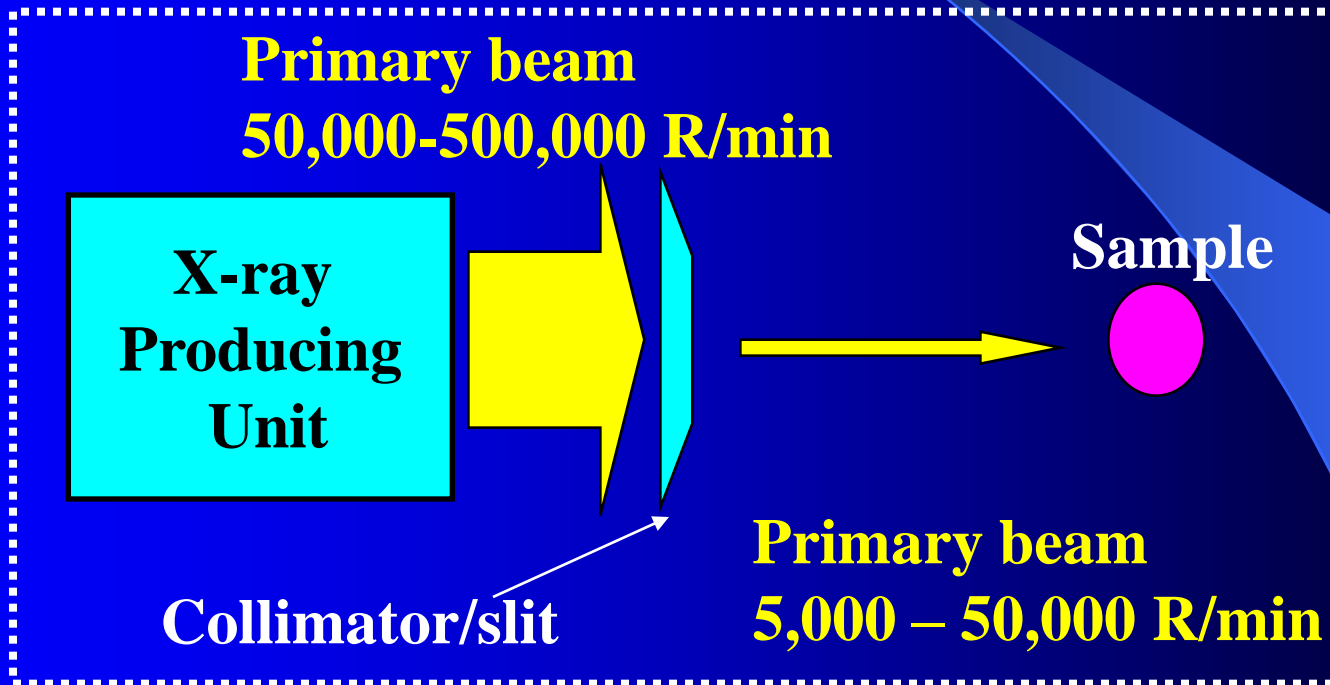
Gastrointestinal

1,000-5,000rem

Central Nervous

5,000 –10,000 rem

Possible exposure rate (X-ray machines)



Secondary beam
Leakage 0.5 - 5 R/hr
Scatter < 10 - 300 mR/hr

Accident cause

Operator Error

Manipulation while x-ray is in operation

- adjustment or alignment of samples/cameras while beam is on

Not use device safety features

- interlocks, shielding of unused port ...etc.

Unauthorized use

- untrained user, unsupervised operation

Machine Error

Safety feature failure

- Shutter, warning light ...etc.

Hazard Prevention

Know X-ray beam status at ALL TIMES !

Use safety features (shielding, shutter, warning sign, etc.)

Do not place any part of your body in the beam.

Make sure the beam is off when maintaining the device or adjusting sample/camera locations.

Do not forget to shield (or cap) unused ports.

Do not operate the device if you are not trained./supervised by trained personnel.

ALARA

ALARA = As low as reasonably achievable

- Main objective of the University of Arkansas, Fayetteville, Radiation Safety Program
- Radiation protection philosophy
- Which should be applied to maintain any dose at levels as low as are practicable



Personal protection

Time : Shorter usage → Less exposure

Distance : Keep your distance (Inverse square law)

Shielding : Shielding material selection
- Bremsstrahlung

Monitoring : Survey meter selection

PPE (Personal Protective Equipment)

Time

- **Planning of experiment**
- **Cold run**
- **Written procedure**



Distance

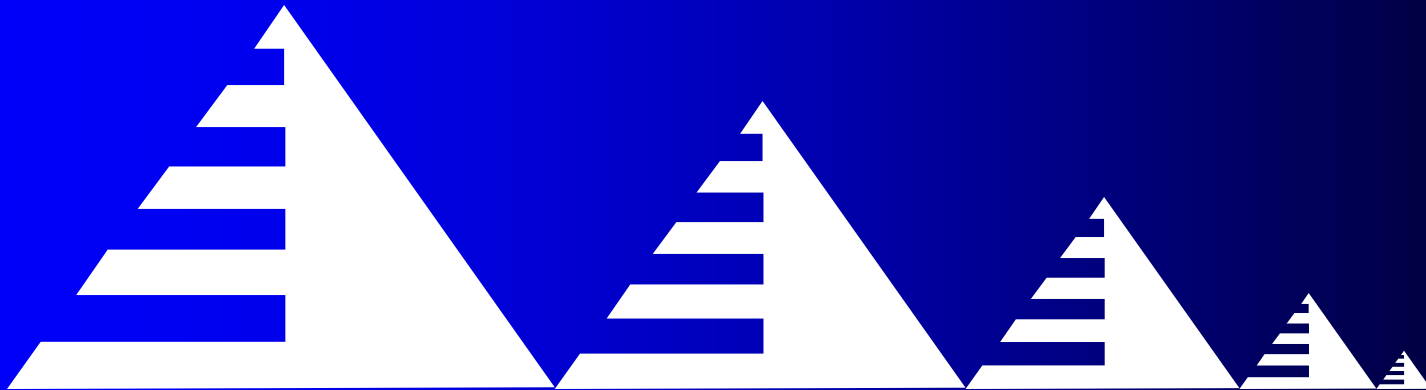
Distance is large factor for reducing exposure

Inverse Square law

“ When you double the distance the exposure rate is decreased by 4 times ”

“ Triple the distance? Half the distance?”

Proper equipment (*e.g.*, tongs)

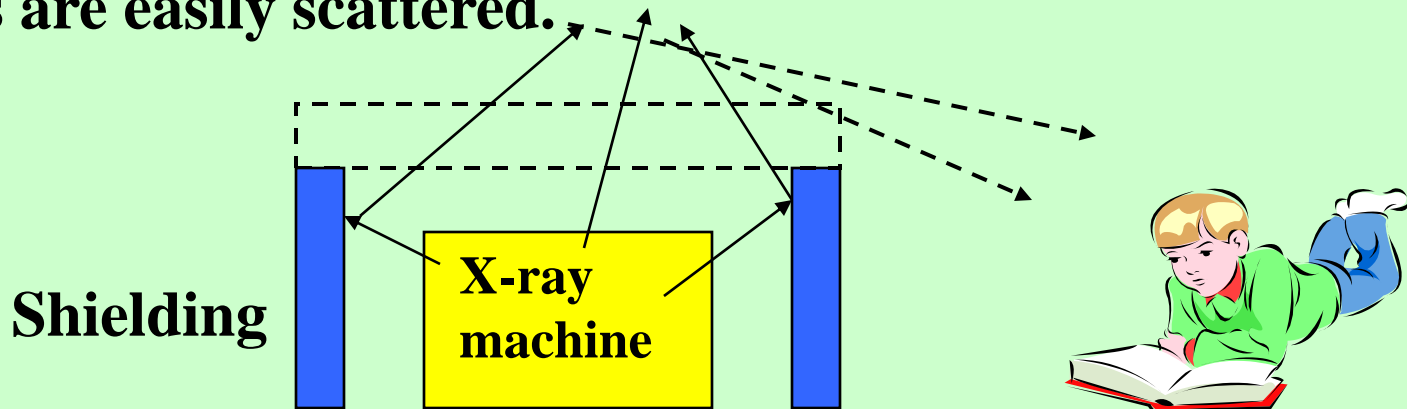


Shielding

Increasing the amount of shielding around a source of radiation will decrease the amount of radiation exposure.

Be sure to shield all directions.

X-rays are easily scattered.



Shielding

For analytical X-ray machines, the manufacturer provides shielding in accordance with the ANSI standard. (see “safety features of devices”)

Use dense material (e.g. Lead glass, lead, steel plate) for the additional shielding.

Rooms

Security

Limit access to authorized personnel only

Notification of hazard presence

Signs, Posting, Warning signs (see next page)

Protection

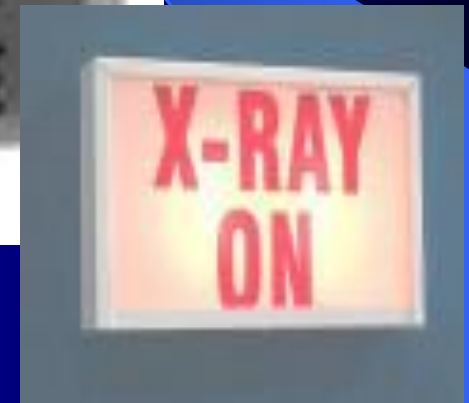
Shielding, Warning signs



Posting, Warning sign



Door sign



Warning sign

Survey

Area

Thin-window GM (Geiger-Mueller) survey meter may be used to

- Check leaking radiation**
- Indicate x-ray production**
- Monitor routine operation**

Ion chamber is used to determine dose rate at the x-ray field.

Both types of survey meters are available at EH&S.

Survey meters are calibrated annually.

Survey

The GM-counters count individual photons(x-ray, gamma-ray) in counts per minute. It can be used to check if the beam is off, when entering the area, if there are any leaking, and other qualitative survey.

The ion chambers response is in R/minute (hour) or mR/minute (hour) and can be used to measure radiation dose rate.

Monitoring

Operator

Use personal dosimeter provided by the RSO.

Body badge type TLD (Thermo Luminescence Dosimeter) is provided for the main users of the X-ray machines. This is sensitive to about 10mrem or higher exposure. TLDs are personal dose monitoring device and do “not” provide any protection.

Safety Features of Devices

Shielding

For analytical X-ray machines, the manufacturer provides shielding in accordance with ANSI N43.2. However it is important to survey the adequacy of the shielding before initial operation. This should be checked routinely.

ANSI N43.2

Anode Current (mA)	Millimeters of Lead		
	50kVp	70kVp	100kVp
20	1.5	5.6	7.7
40	1.6	5.8	7.9
80	1.6	5.9	
160	1.7		

Safety Features of Devices

Shutter

X-ray machine will not generate X-rays when shutter is open. (Avoid accidental exposure while changing samples)

Safety key/Interlock

To prevent unauthorized use, x-ray machine operation requires several steps (key(s) to be in place to switch on the device, etc.)

Warning sign

Indicates on-off status of the X-ray machine

Contact information

- **Office of Environmental Health & Safety**
5-5448
(M-F, 7:30am – 4:00pm)
- **University of Arkansas Police Department (UAPD)**
5-2222
(After hours & Holidays)
- **Radiation Safety Officer**
5-3379

