

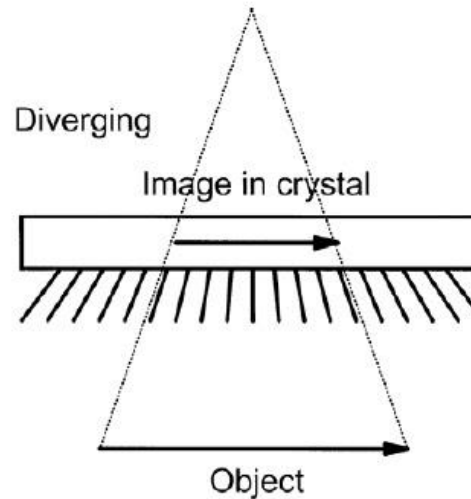
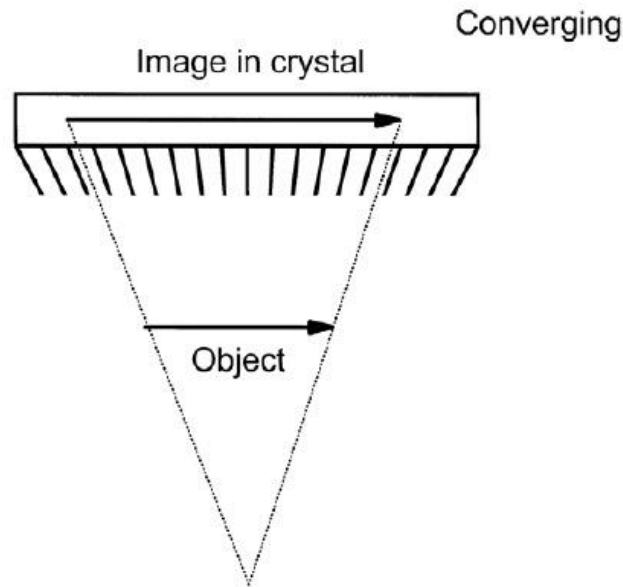
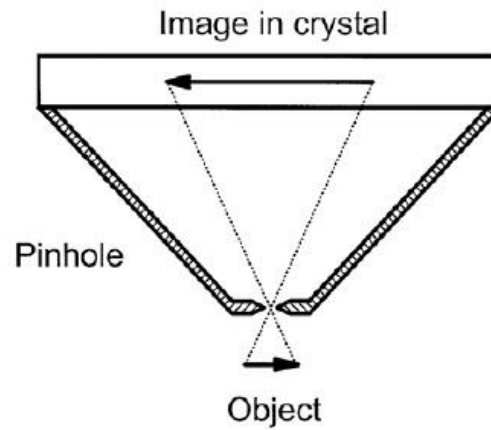
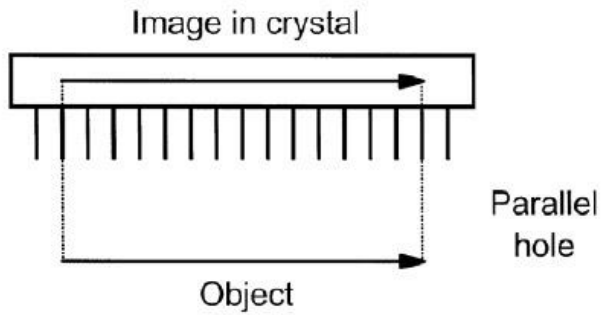
جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم الفيزياء الحياتية

الاجهزة الطبية

X-ray Machine Control and Safety

Mohammed Qasim Taha

Collimators



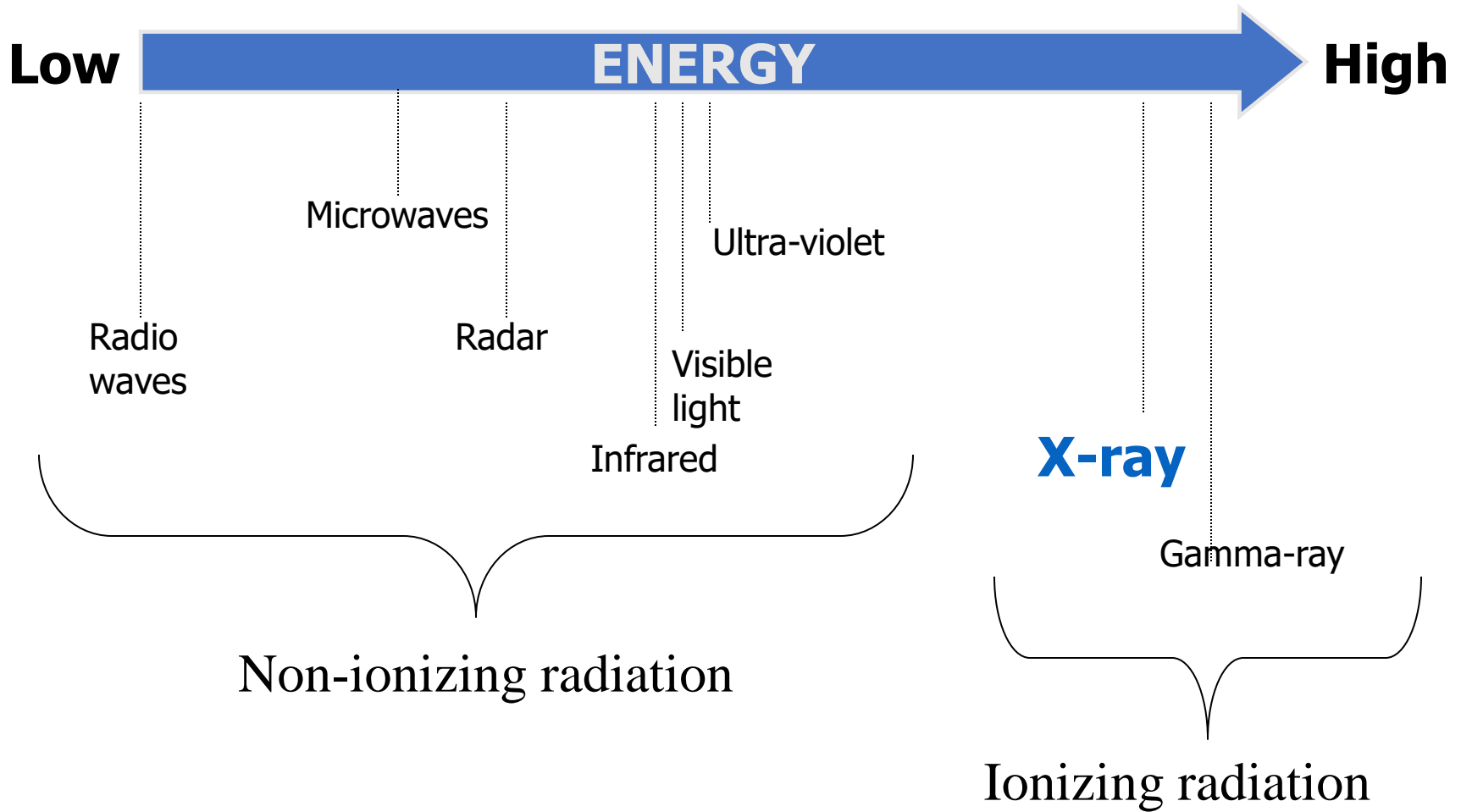
The choice of a particular type of collimator is basically dictated by the size of organ to be imaged

What are X-rays ?

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

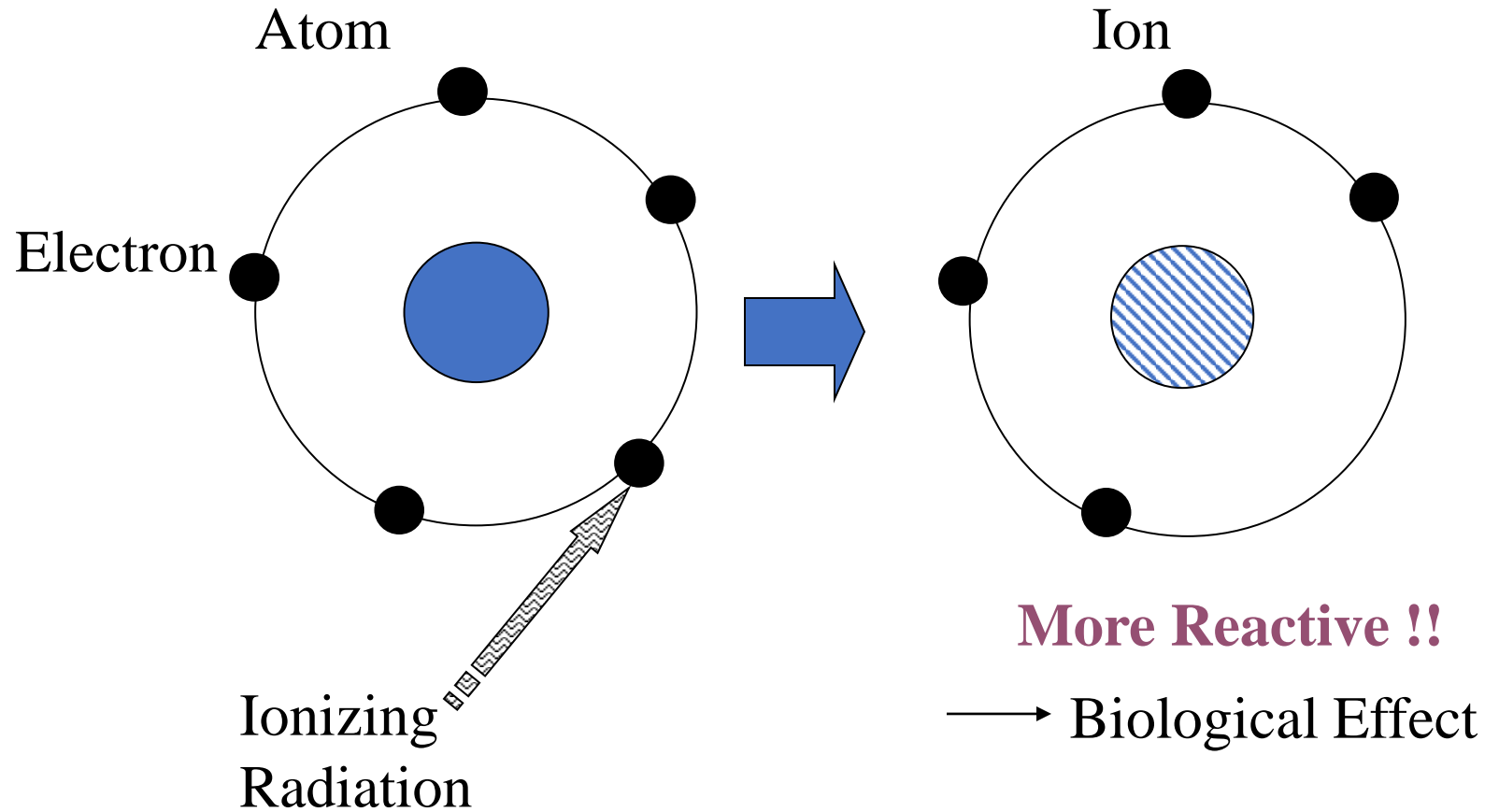
- No charge
- No mass
- Travel at the speed of light
- Categorized in two groups depend on the energy
 - Low energy----- Non-ionizing radiation
 - High energy----- Ionizing radiation
 - Can cause “ionization”

Electromagnetic Waves

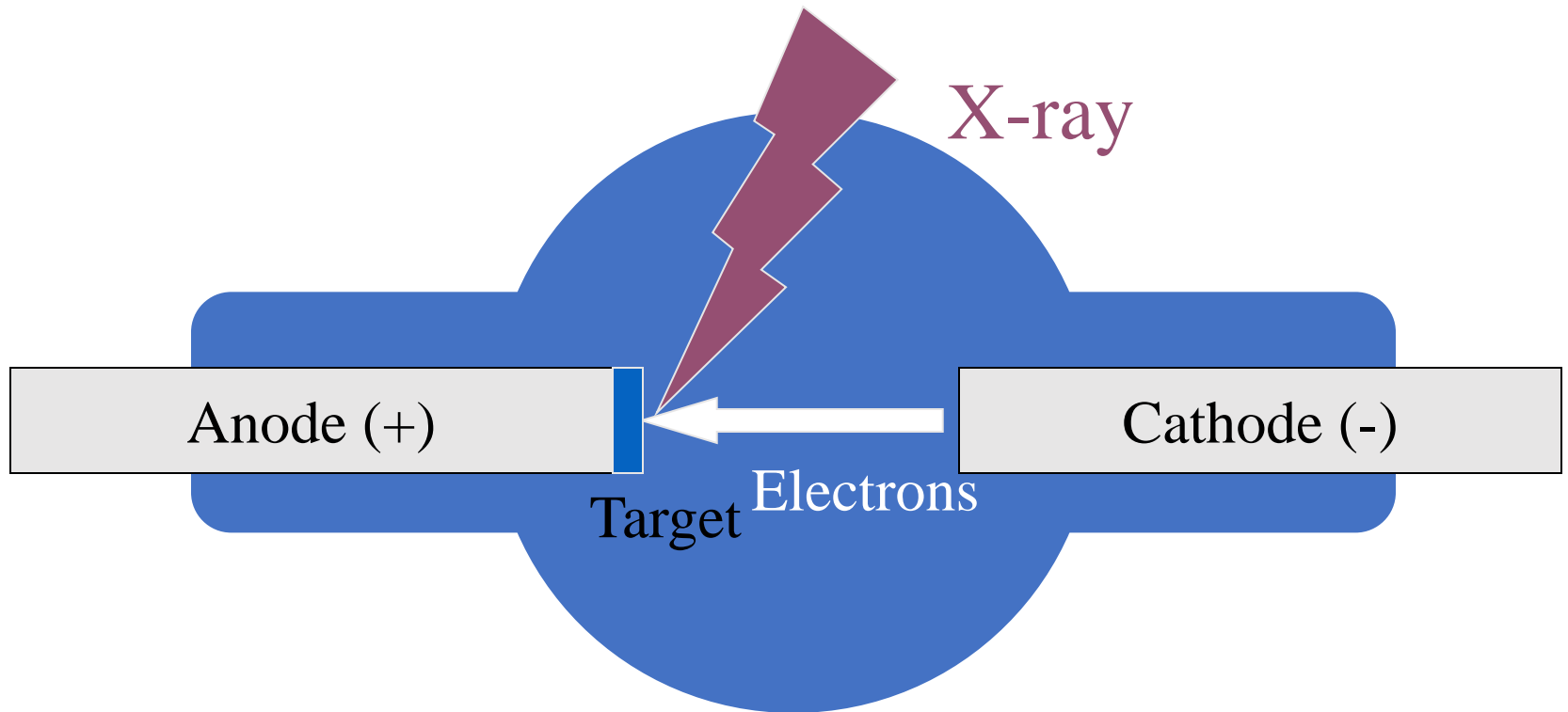


Ionization

Ionization



How X-rays produced ??



X-ray tube

How X-rays produced ??

1. X-ray devices emit electrons from cathode, accelerate them with a voltage (vacuum), and let them bombard an target (anode). $\text{mAs} = \text{mA} * \text{time}$
2. As a result of interactions of atoms of target elements and electrons, x-ray is produced.
3. The energy of the x-ray shows different distribution depending on the target material.
4. During the process, the device emits two different types of radiation.

Where do X-rays come from ?

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

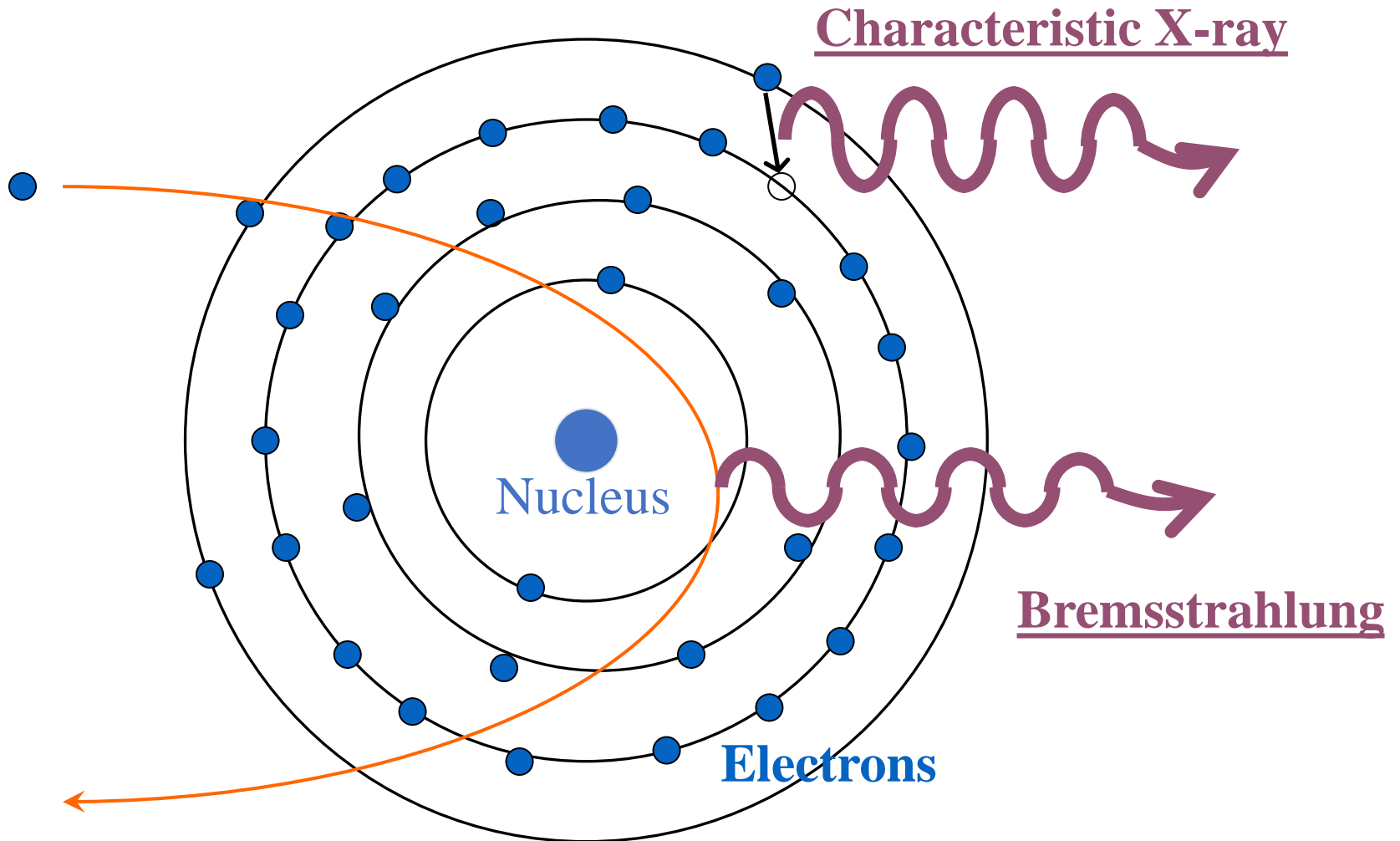
- **Bremsstrahlung:** occurs when high energy electrons are slowed down near the nucleus. Excess energy (by the deceleration) is released in the form of x-ray (photon).

Bremsstrahlung means “breaking radiation” in German.

This shows CONTINUOUS SPECTRUM as each electron emits different fractions of its energy.

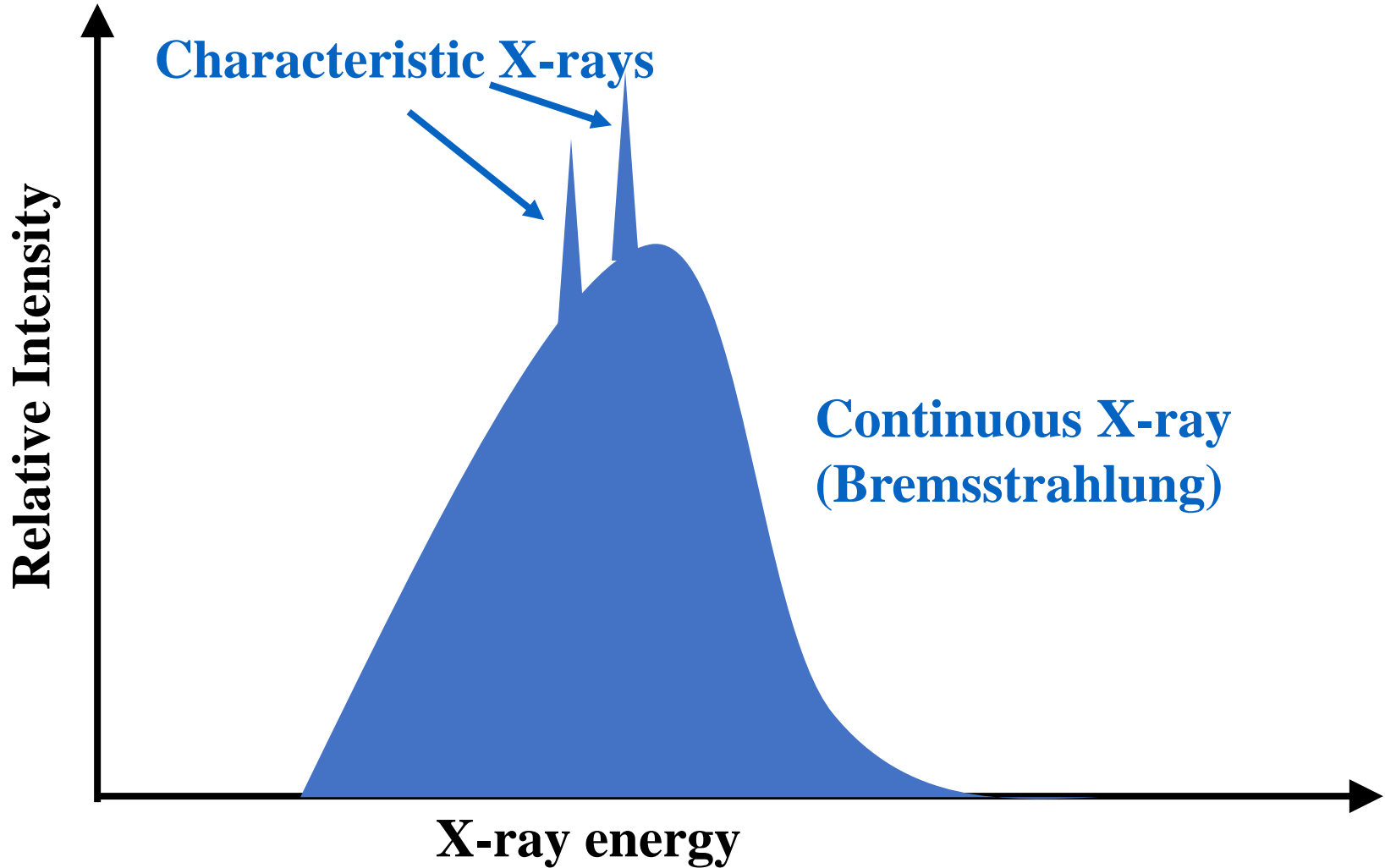
Where do X-rays come from ?

Atom of the target element



X-ray spectrum

— Example of energy distribution.



Units

R (Roentgen)

- The unit of radiation exposure in air.
- Defined as the amount of X-ray or gamma-ray.

Rad (Radiation absorbed dose)

- **Rad** stands for **Radiation Absorbed Dose**.
- 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 Gy = 100 rad**.

Unit **Rem (Roentgen equivalent man)**

- **Rem** stands for **Roentgen Equivalent Man**. It can be obtained by multiplying Rad and weighting factor.
- **1 rem** is the amount of radiation that will deposit 0.01J of energy in a kilogram of material (tissue, air, shielding material ...etc).
- Different weighting factor is given for different types of radiation.
- Rem is also traditional unit. SI unit used for rem is Sv (sievert). **Conversion is $1 \text{ Sv} = 100 \text{ rem}$**

Units Conclusion

X-rays weighting factor is 1. Thus, for X-rays, 1 rem = 1 rad.

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

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

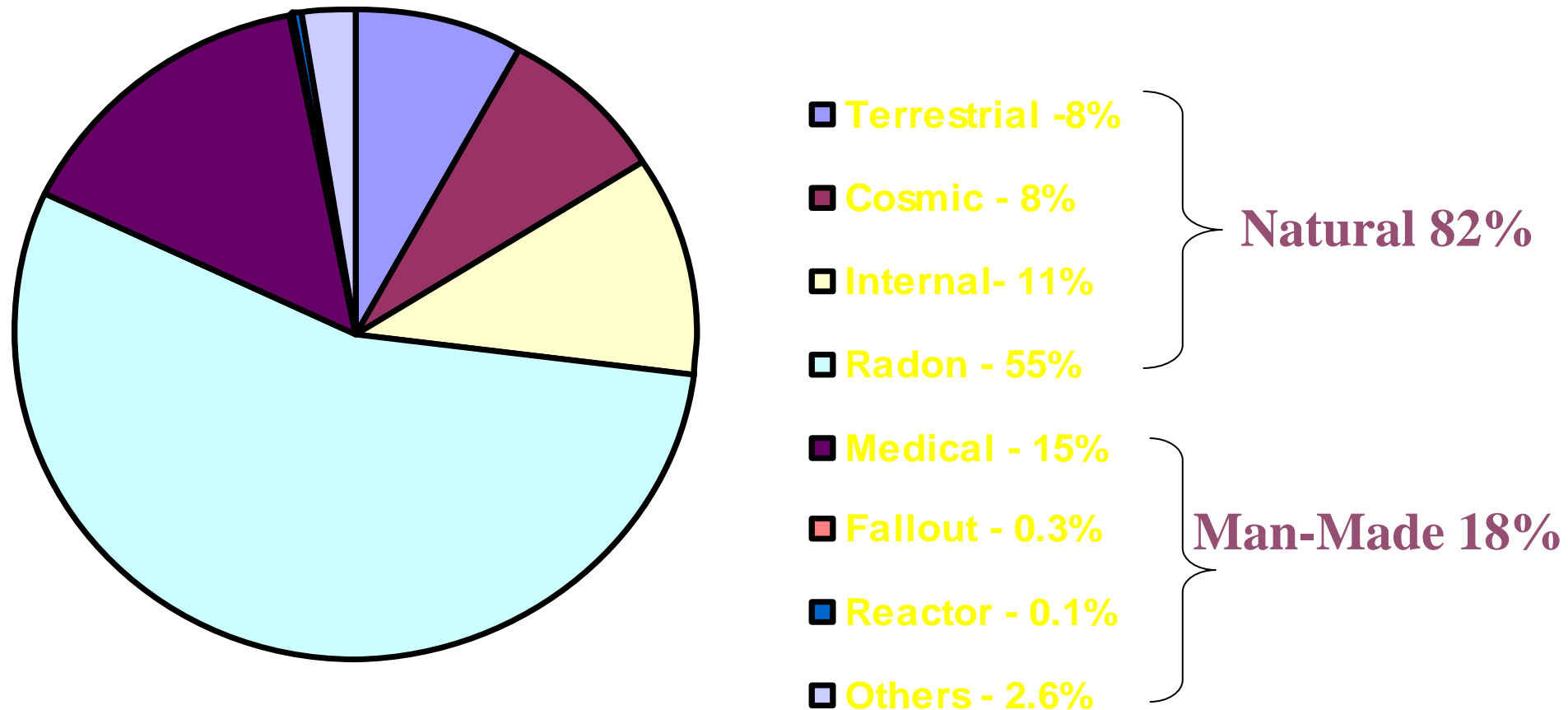
1R = 1rad = 1rem.

X-ray Generation

Incidental X-Ray	Intentional X-Ray
<ul style="list-style-type: none">• Devices which produce x-rays that are not used as part of a designed purpose	<p>Devices designed to generate x-ray beams for a particular use</p>
<p>Examples:</p> <ul style="list-style-type: none">• Computer monitors, electron microscopes, electron beam welders, etc.• < 0.5 mR /hour	<p>Examples:</p> <ul style="list-style-type: none">• X-ray diffraction, fluorescence analysis• Medical x-rays• Used in designated room (shielded, interlocked)

Background radiation

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



Common Radiation Exposure (General Population)

Exposure Source	Dose(conventional)	Dose (SI)
Flight from LA to NY	1.5 mrem	.015 mSv
Dental X-ray	9 mrem	.09 mSv
Chest X-ray	10 mrem	0.1 mSv
Mammogram	70 mrem	0.7 mSv
Background Radiation	620 mrem/year	6.2 mSv/year

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)

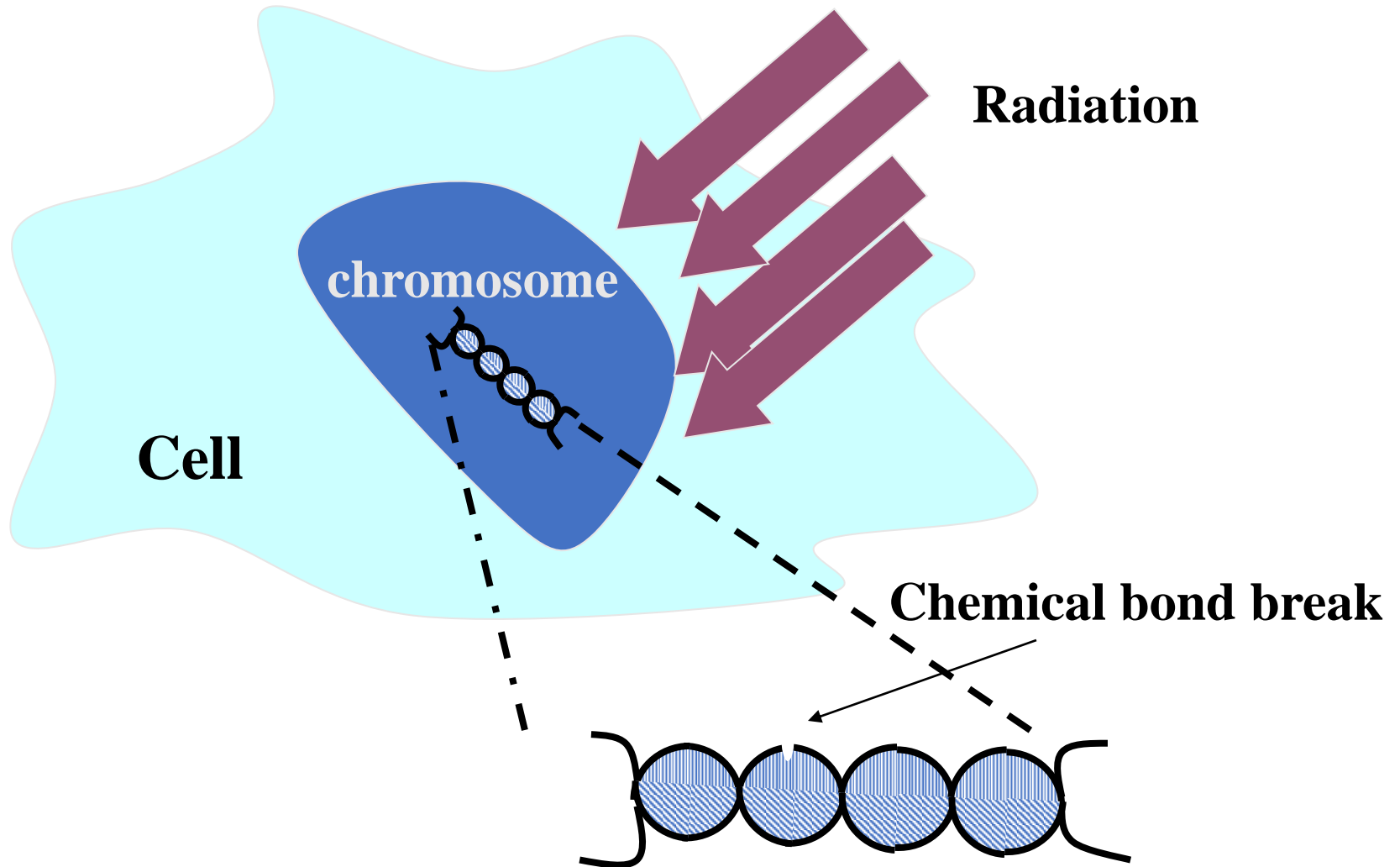
Biological Effects

1. X-ray has a capability to go through skin layers and deposit its energy to the cells deep inside the body (Cell separation).
2. X-ray has enough energy to ionize atoms, which constructing molecules.
3. It can break chemical bonds within some critical biological molecules (DNA).
4. When the cell absorb the energy it can be heated and moving and subsequently uncontrolled separation (cancer)

Subsequences

1. 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.
2. 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.
3. If enough cells in a particular body organ are damaged, the function of the organ may be impaired.

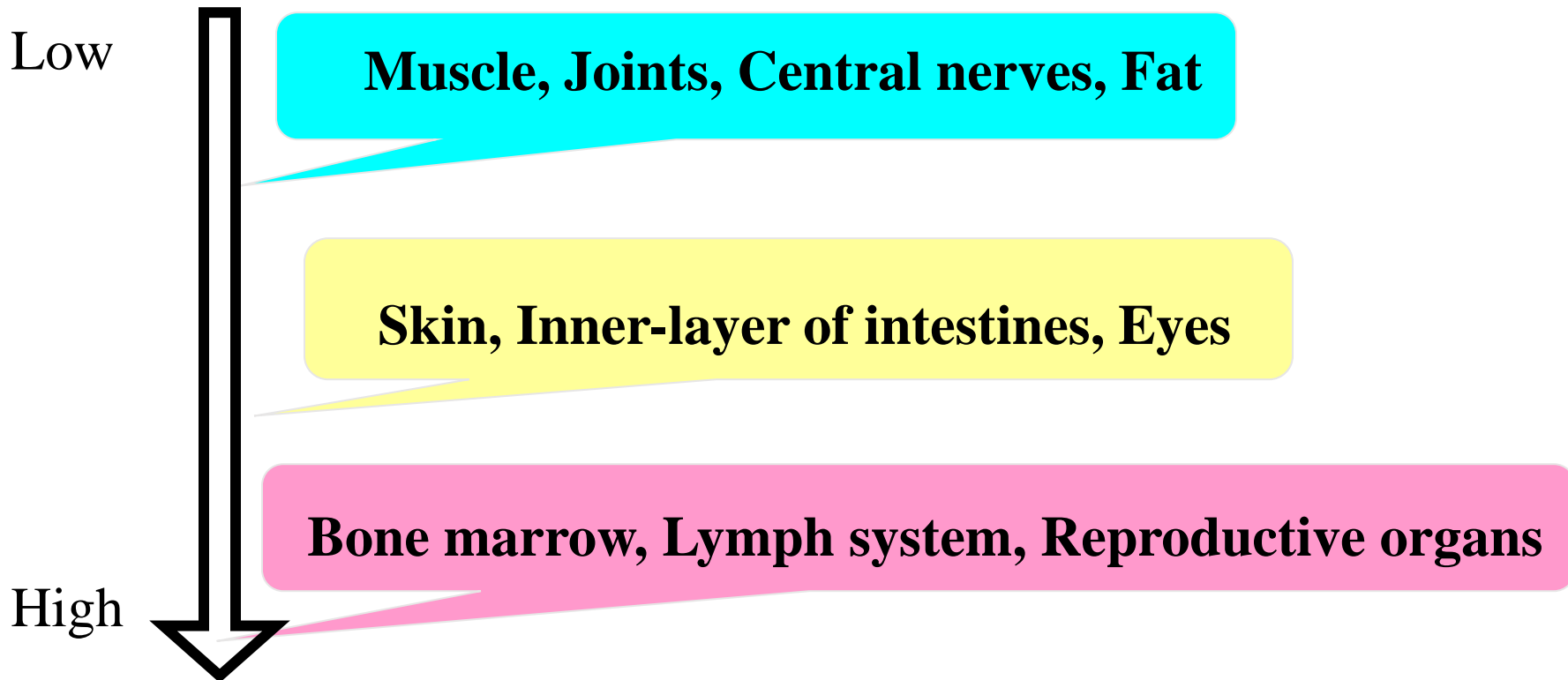
Biological Effects



Biological Effects

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

Sensitivity Flowchart



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)

Organs Limits

Blood

100 –1,000 rem

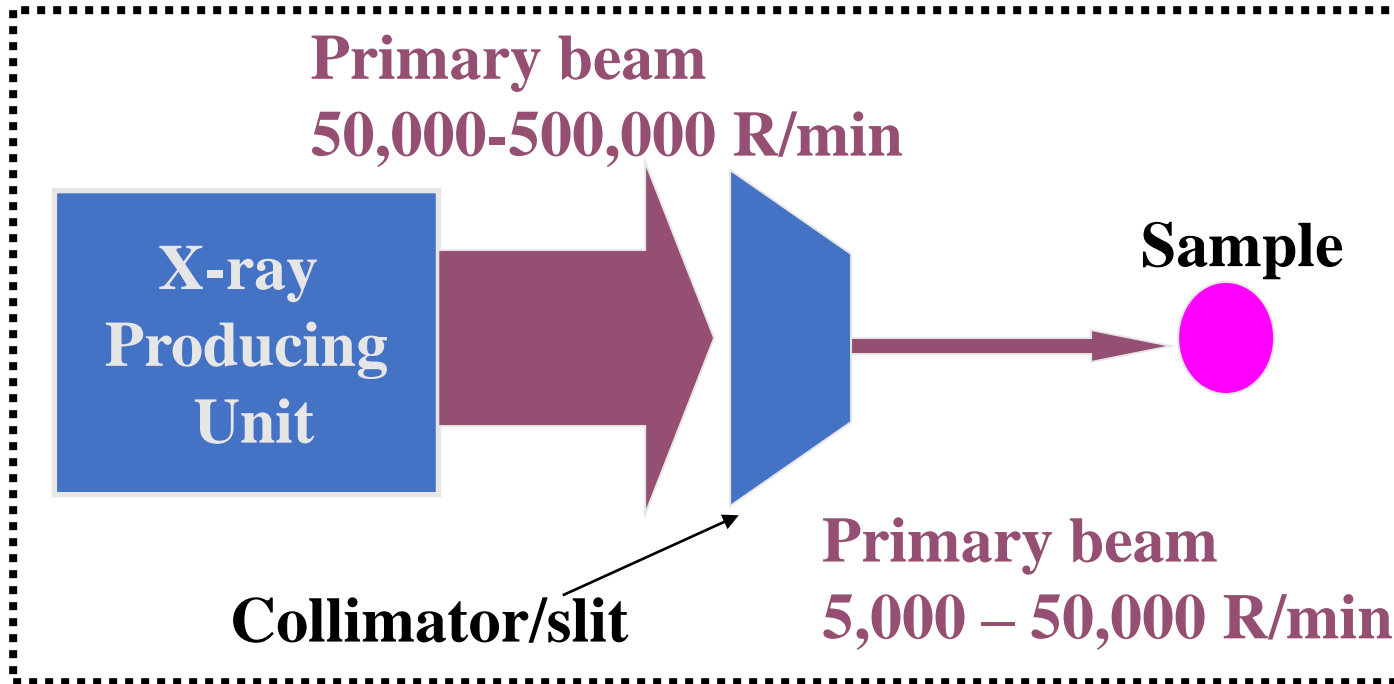
Digestion system

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 Errors

Operation Error

1. Manipulation while x-ray is in operation :adjustment or alignment of samples/cameras while beam is on
2. Not use device safety features
3. Unauthorized use :untrained user, unsupervised operation

Machine Error

Safety feature failure

- Shutter, warning light ...etc.

Hazard Errors 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.

Personal Protection

1. **Time** : Shorter usage → Less exposure
2. **Distance** : Keep your distance (Inverse square law)
3. **Shielding** : Shielding material selection
4. **Monitoring** : Survey meter selection
5. **PPE** (Personal Protective Equipment): Isolation clothes

Distance

Distance is large factor for reducing exposure

Inverse Square law

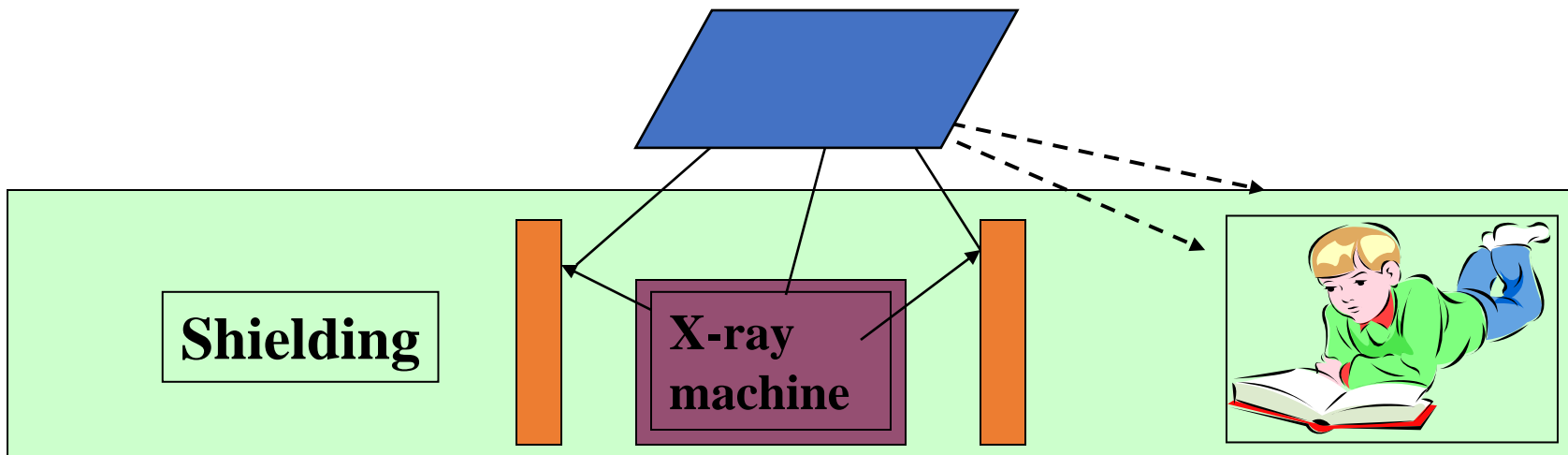
“When you double the distance, the exposure rate is decreased by 4 times”



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 safety standards.

Using dense material (e.g. Lead glass, lead, steel plate, Barium shields) 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

Safety Features of Devices:

1- 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 : Radiation Safety for X-Ray Diffraction

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	7.9
160	1.7	5.9	7.9

Safety Features of Devices

2- Shutter (Safety Key)

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

3- Safety Key/Interlock (Password/ Finger-print)

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

4- Warning sign

Indicates on-off status of the X-ray machine