MI132 - Principles of Imaging and Equipment

Unit 5 – Photon Interactions with Matter 2022-2023

Reading Hospital School of Health Sciences
Medical Imaging Program

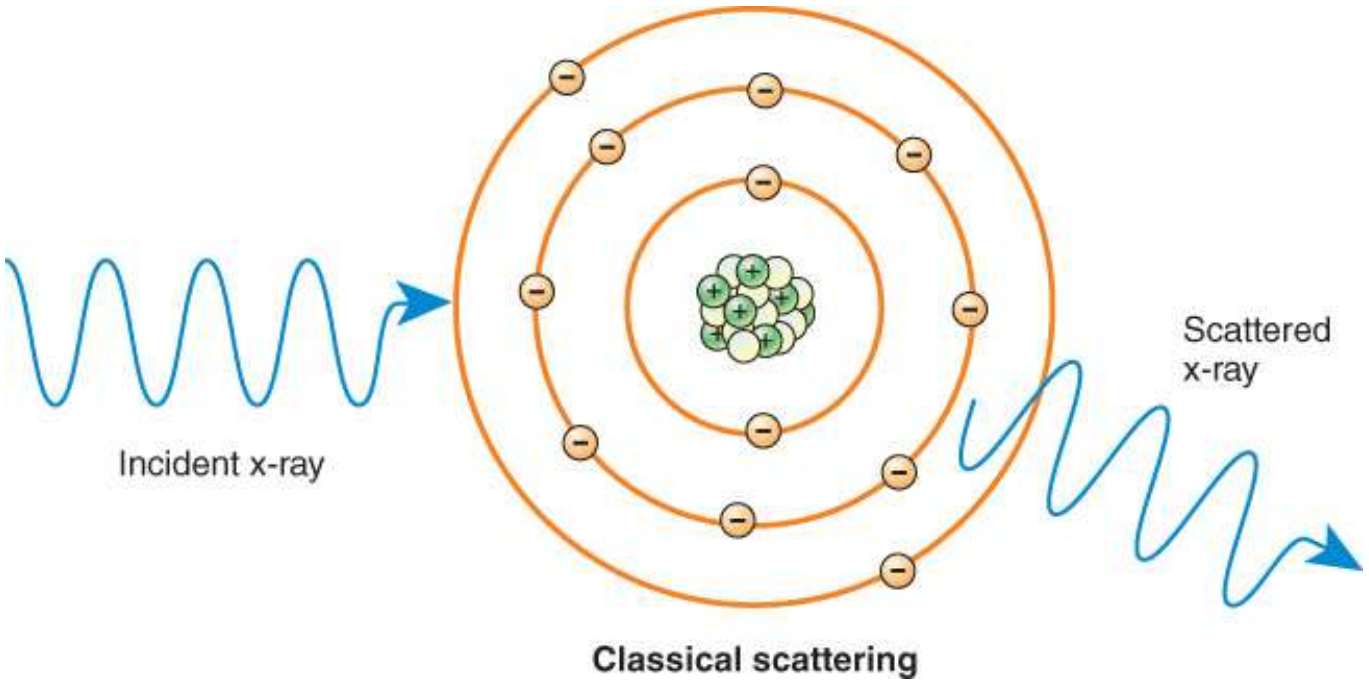
Learning Objectives

1. Describe interactions between x-ray and matter in the diagnostic energy range (Photoelectric, Compton and Coherent), including production, energy, effects on patient dose, and effects on image quality.

What 3 interactions with matter occur within the diagnostic range?

- X-rays interact with matter in five ways:
  - *Classical interactions*
  - *Compton scattering*
  - *Photoelectric effect*
  - Pair production
  - Photodisintegration

Describe how Classical Interactions occur:

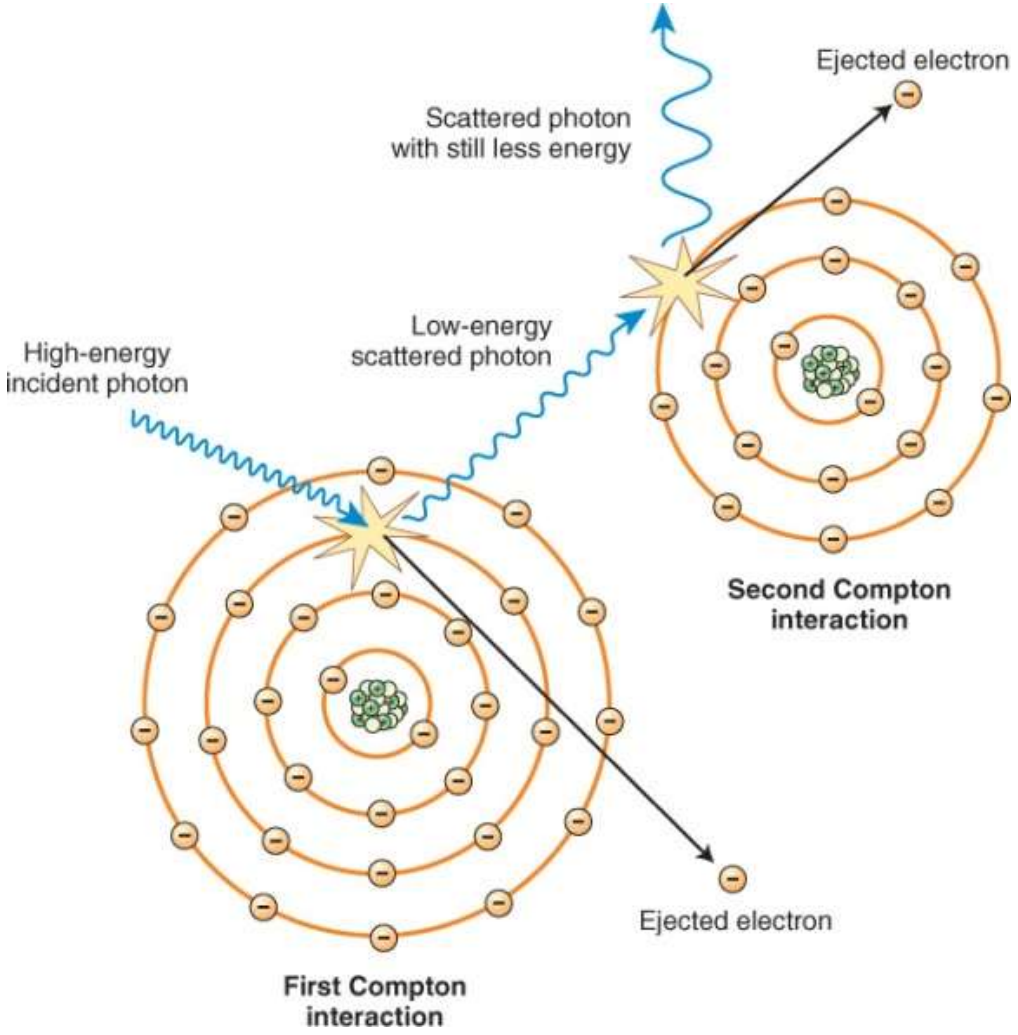


What impact do Classical Interactions have on image creation and patient dose?

- No significant impact to the image
- Adds slightly to patient dose

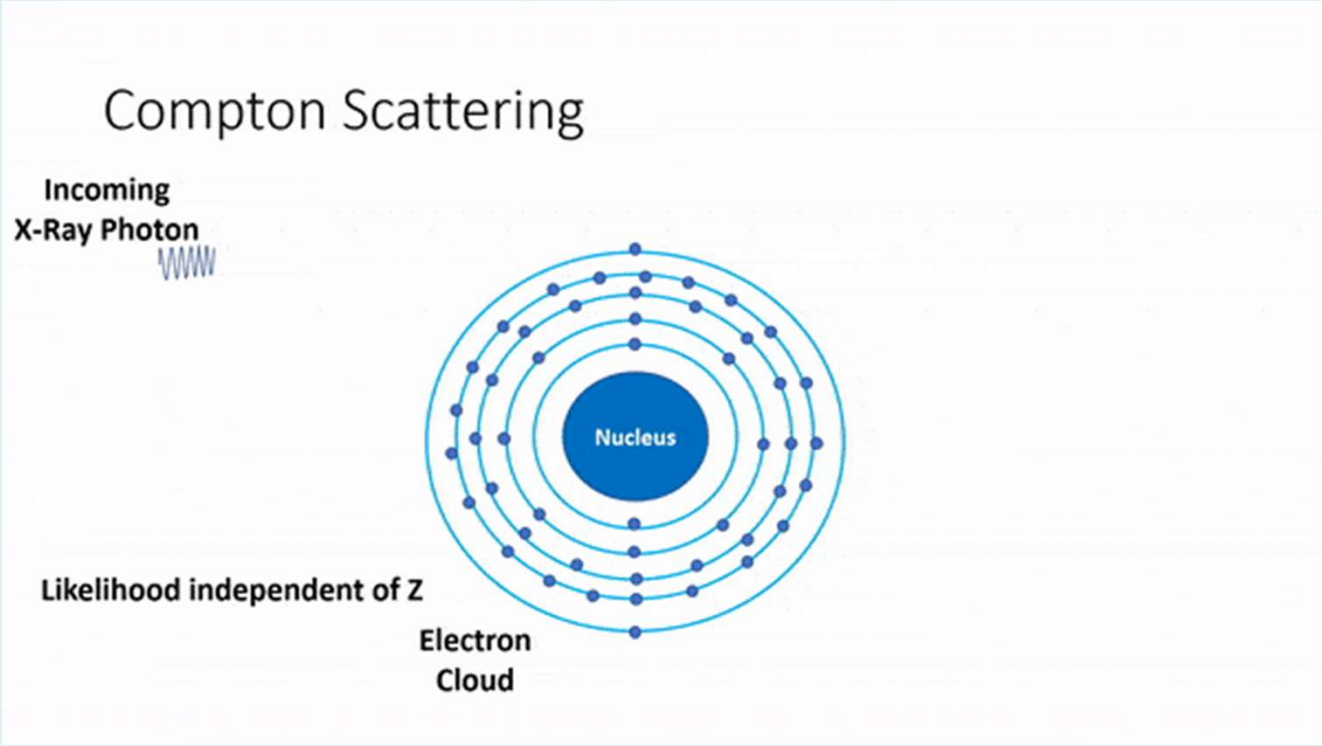
Describe how Compton Interactions Occur

- Split into groups and draw a Compton interaction

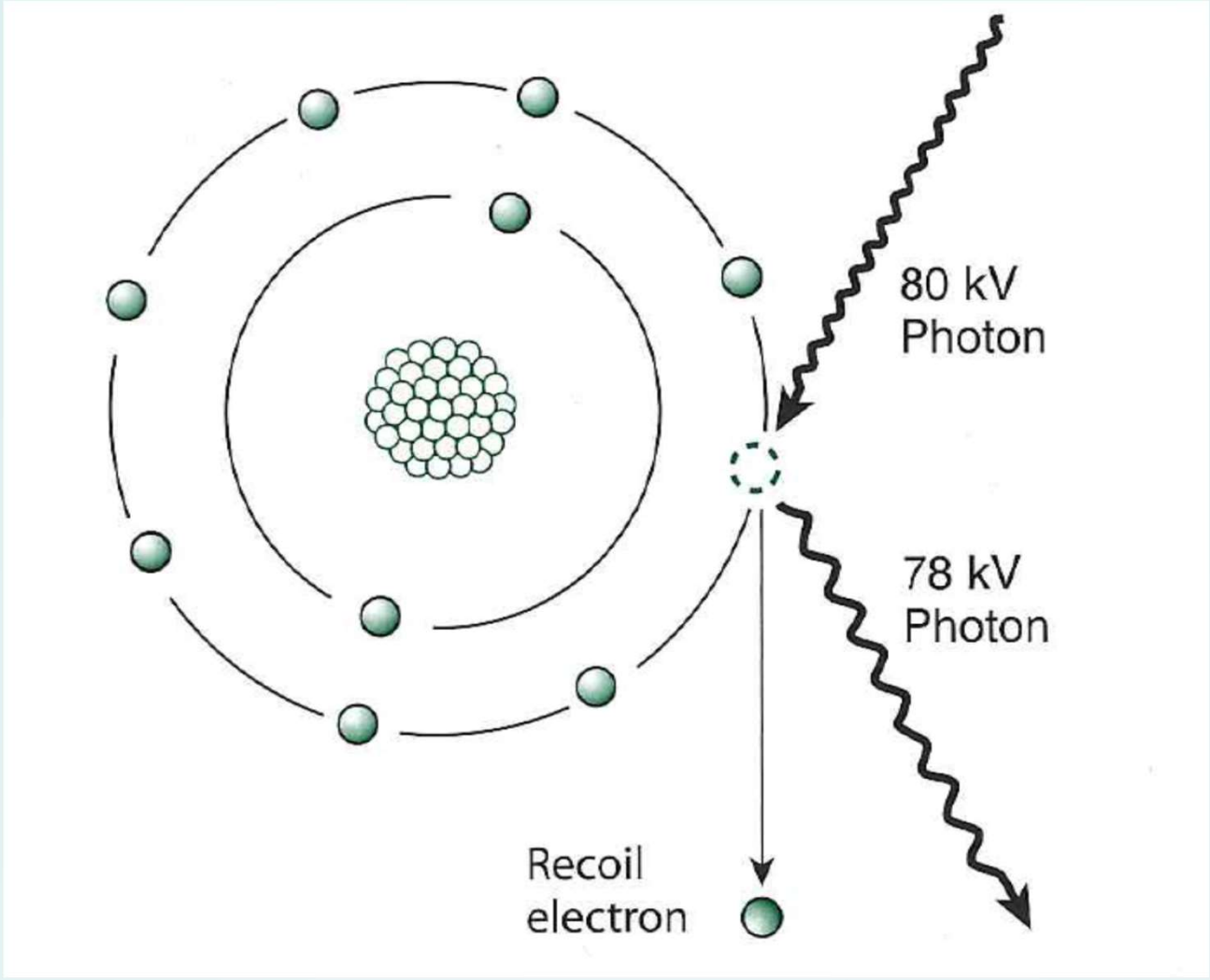


What 3 things occur during Compton Interactions?

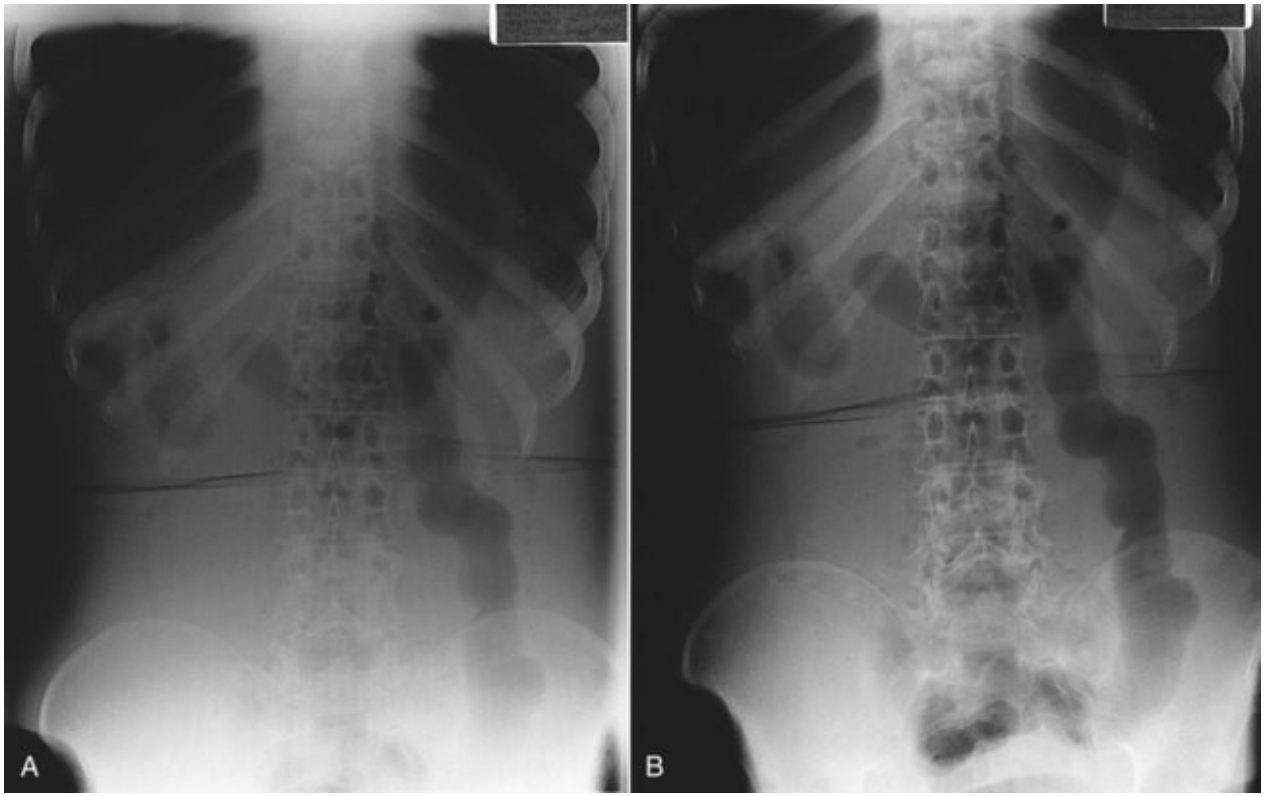
1) Ionizes the atom making it unstable
2) ejected electron - compton/ electron or secondary with enough energy to go through own interactions
3) incident photon directed in new direction = compton scatter



- Scattered photon:
  - Will have less energy than incident photon
  - Can scatter in any direction
  - Will retain at least two thirds of incident photon energy


80 kV
Photon
78 kV
Photon
Recoil
electron

What impact does Compton Scatter have on image quality and occupational exposure?



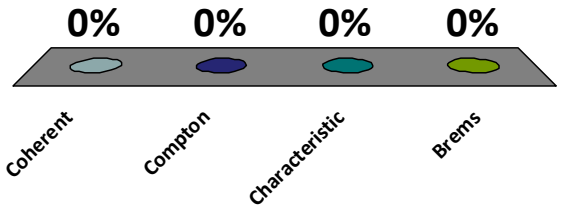
Which of the following x-ray interactions with matter occur only at *low* energy ranges?

★A. Coherent

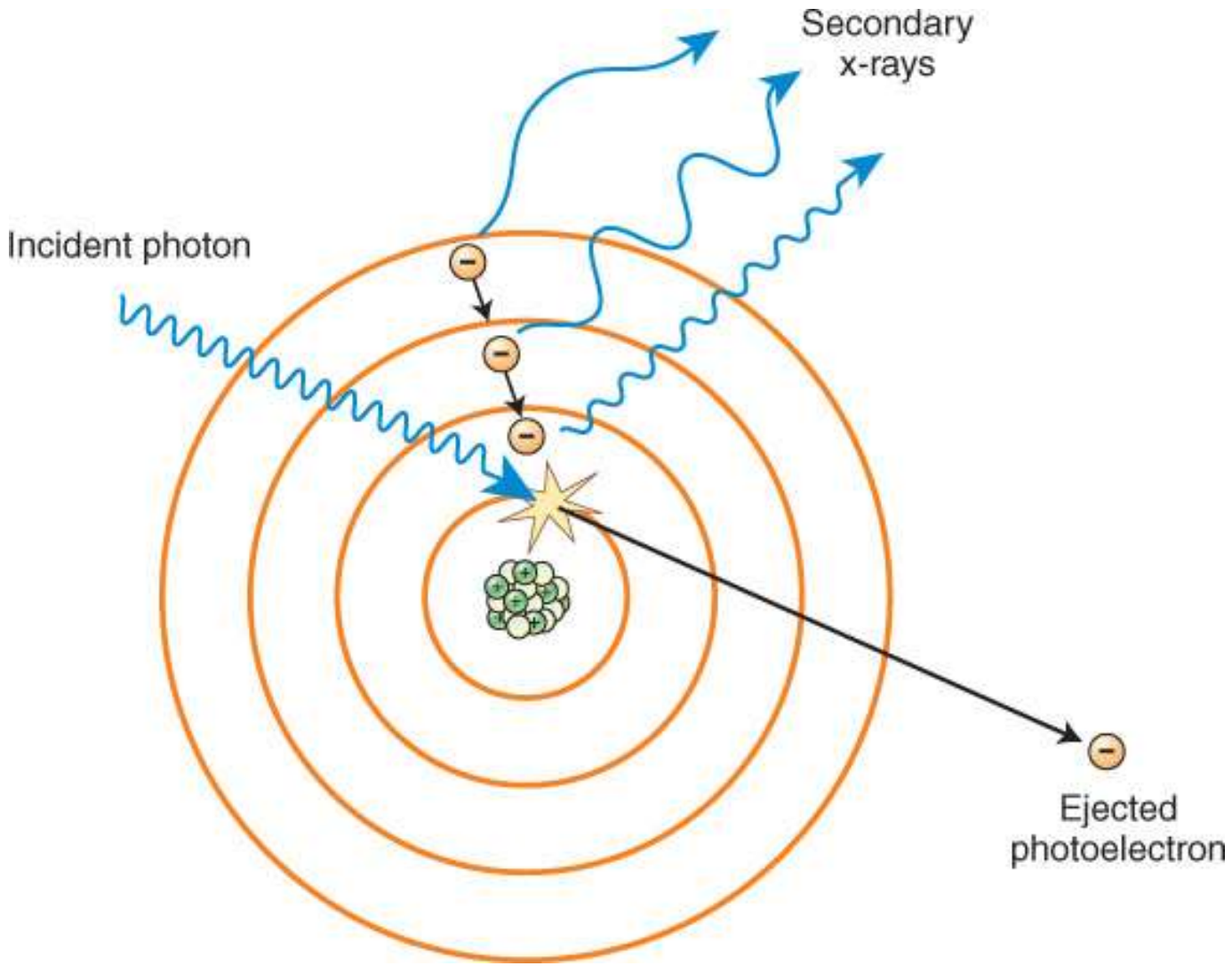
B. Compton

C. Characteristic

D. Brems

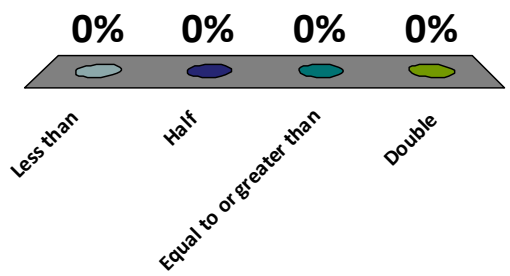


Describe Photoelectric Interactions



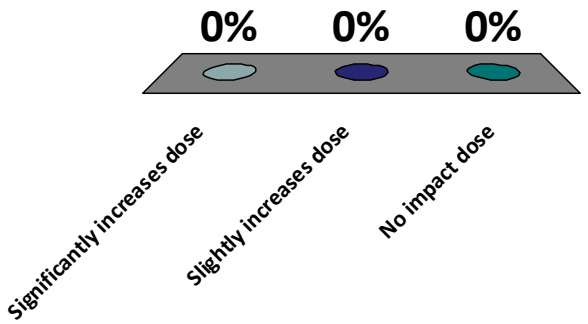
During a photoelectric interaction, the incident x-ray energy must be _____ the inner-shell binding energy of the tissue atom??

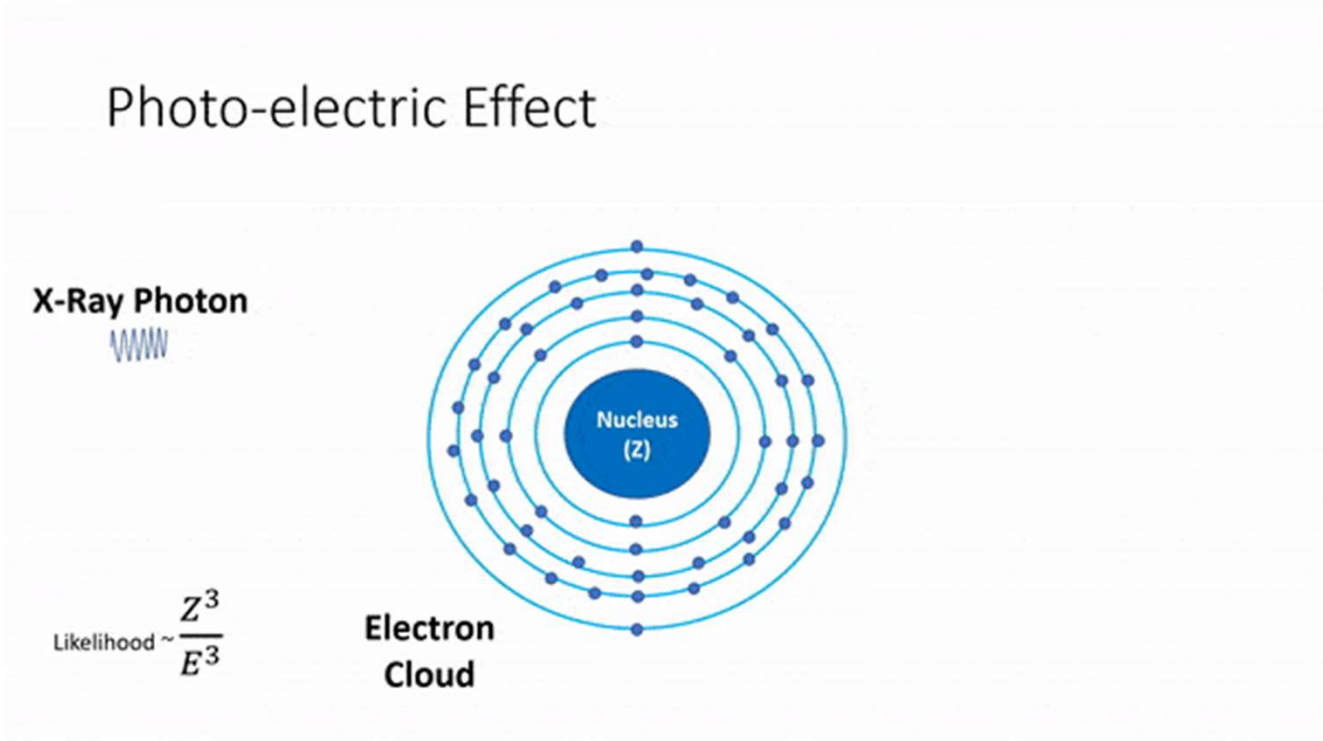
A. Less than
B. Half
C. Equal to or greater than
D. Double



What impact do Photoelectric Interactions have on patient dose?

A. Significantly increases dose
B. Slightly increases dose
C. No impact dose

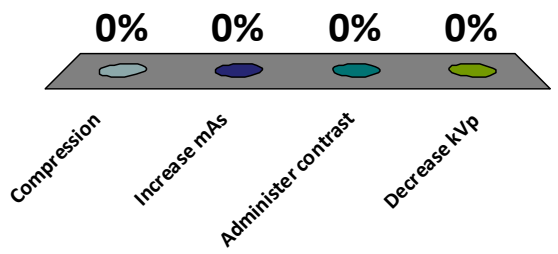




- The ejected electron is called a **photoelectron**
  - Energy it possesses will be the difference between incident photon energy and binding energy of the orbital electron.
  - It has enough kinetic energy to undergo interactions of its own before filling a vacancy in another atom elsewhere.

What can be done to increase the likelihood that a photoelectric effect will occur if it is needed to view a particular structure?

A. Compression
B. Increase mAs
C. Administer contrast
D. Decrease kVp

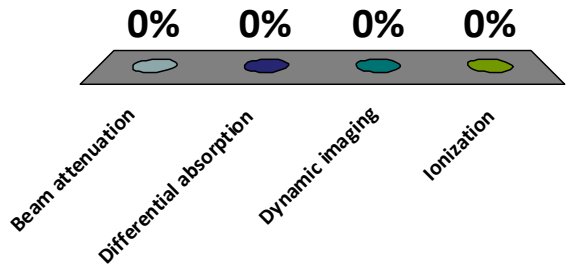


What else impacts the probability that a Photoelectric Interaction will occur?

- increase atomic number of the tissue atoms = increase in interactions
- increase in energy decreases interactions

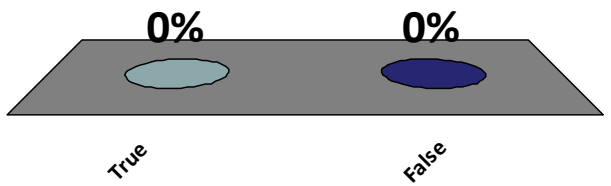
X-rays can eject electrons from atoms. This is known as:

A. Beam attenuation
B. Differential absorption
C. Dynamic imaging
D. Ionization



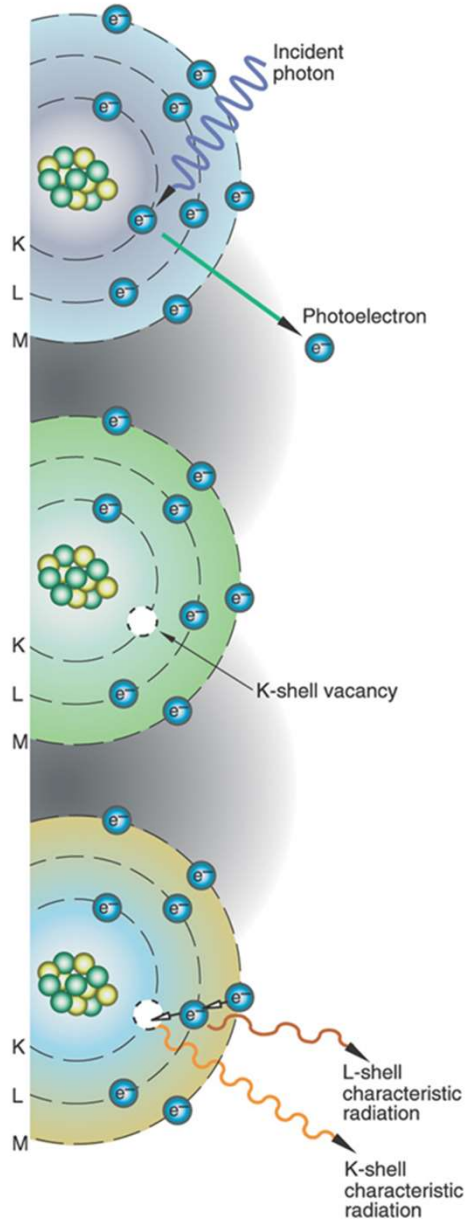
Secondary radiation occurs after every ionizing event?

A. True
B. False



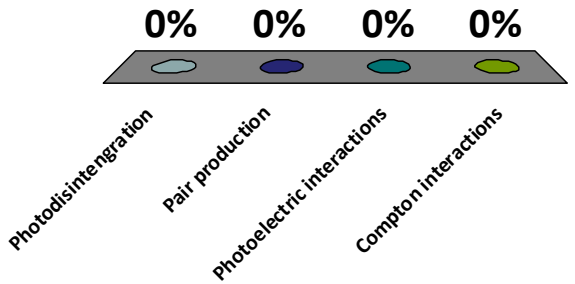
What is Secondary Radiation?

- Follows ionizing events in the body
- Orbital electron vacancy filled by another electron resulting in a release of energy in the form of a **secondary x-ray photon**
- Energy released is very minimal since associated binding energies of body tissues is low
  - Contribute to **patient dose**
  - Not to image production



Which of the following is a major source of occupational exposure?

A. Photodisintengration
B. Pair production
C. Photoelectric interactions
D. Compton interactions



Which interaction in the diagnostic range involves total absorption of the incident photon?

A. Pair production

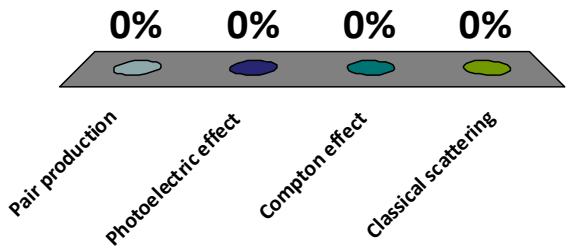
B. Photodisintegration

C. Compton effect

D. Photoelectric effect

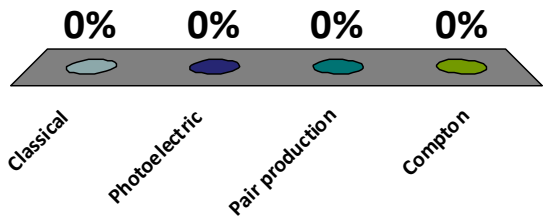
Which interaction, within the diagnostic range, does not involve the removal of an orbital electron?

A. Pair production
B. Photoelectric effect
C. Compton effect
D. Classical scattering



Which of the following contributes to image fog?

A. Classical
B. Photoelectric
C. Pair production
D. Compton



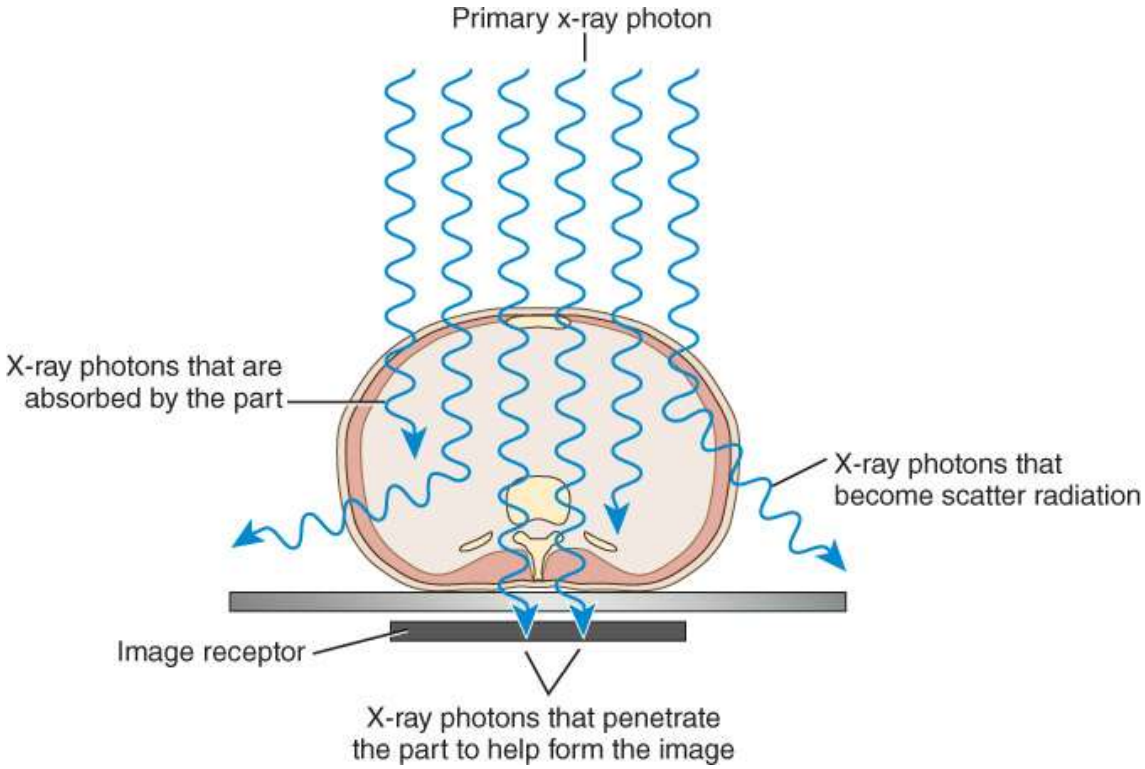
Learning Objectives

1. Relate differential absorption to x-ray beam interactions with the human body and image formation.
2. Describe the x-ray interactions termed photoelectric effect and Compton effect.
3. Describe the process of radiographic image formation.
4. Explain the process of beam attenuation.
5. Identify the factors that affect beam attenuation.
6. State the composition of exit radiation.
7. State the effect of scatter radiation on the radiographic image.
8. Explain the process of creating the various shades of gray in the image.

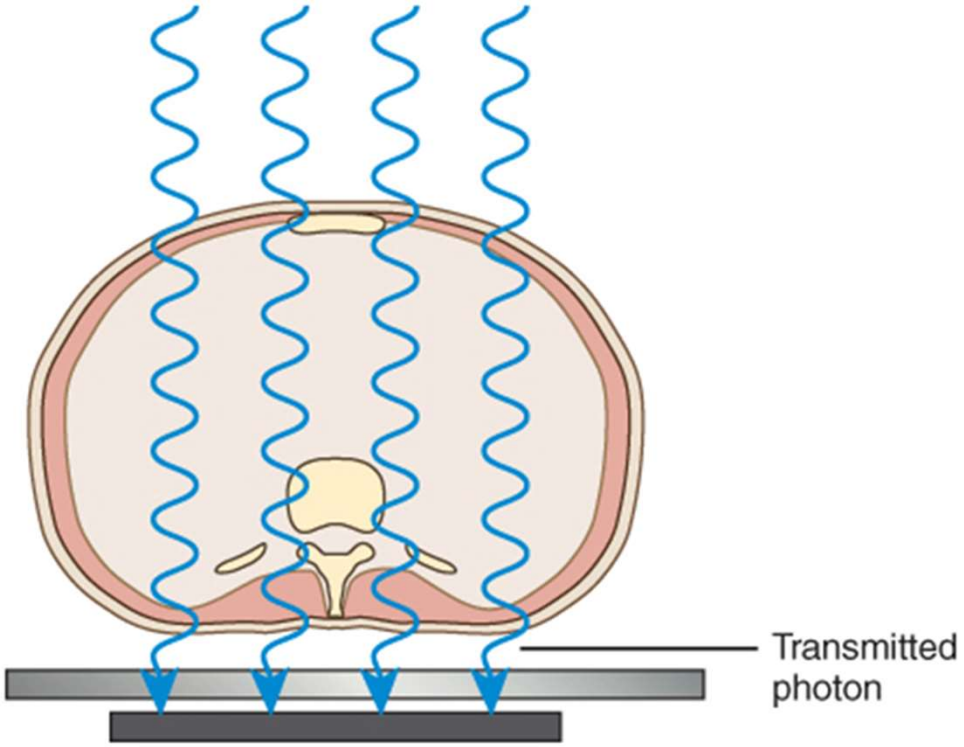
Producing An Image

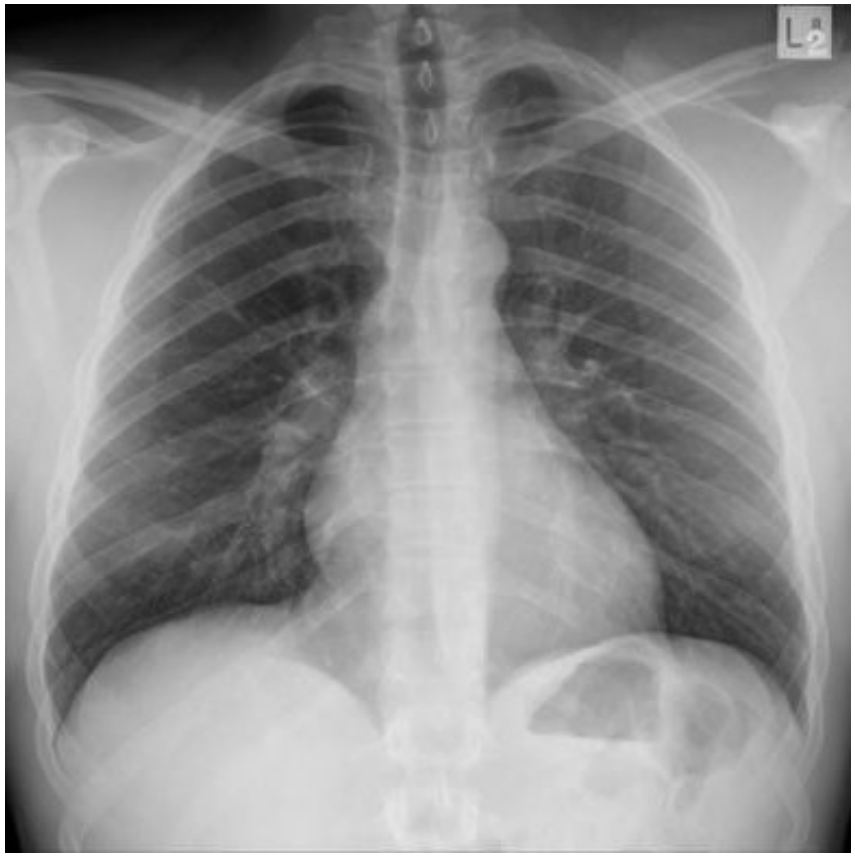
- X-ray photons must pass through tissue and interact with an IR.
- Quantity and quality of the primary x-ray beam affects its interaction within the body's tissues.
- Composition of the anatomic tissues affects the x-ray beams interaction/attenuation.
- Radiation that exits the patient is composed of varying energies and interacts with the IR to form the latent/invisible image.

Define Differential Absorption



What is the difference between transmission and absorption?





Beam Attenuation

- Reduction in the energy or number of photons in the primary x-ray beam
- Occurs as a result of the photon interactions with the atomic structures that compose the tissues

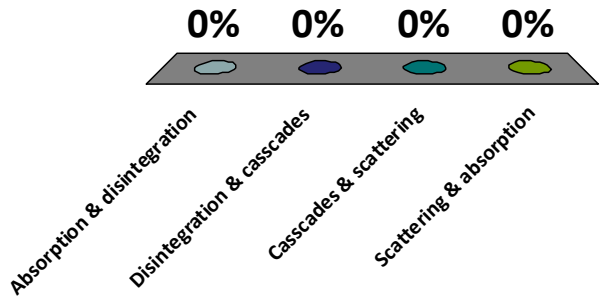
What two processes occur during beam attenuation in the diagnostic range?

A. Absorption & disintegration

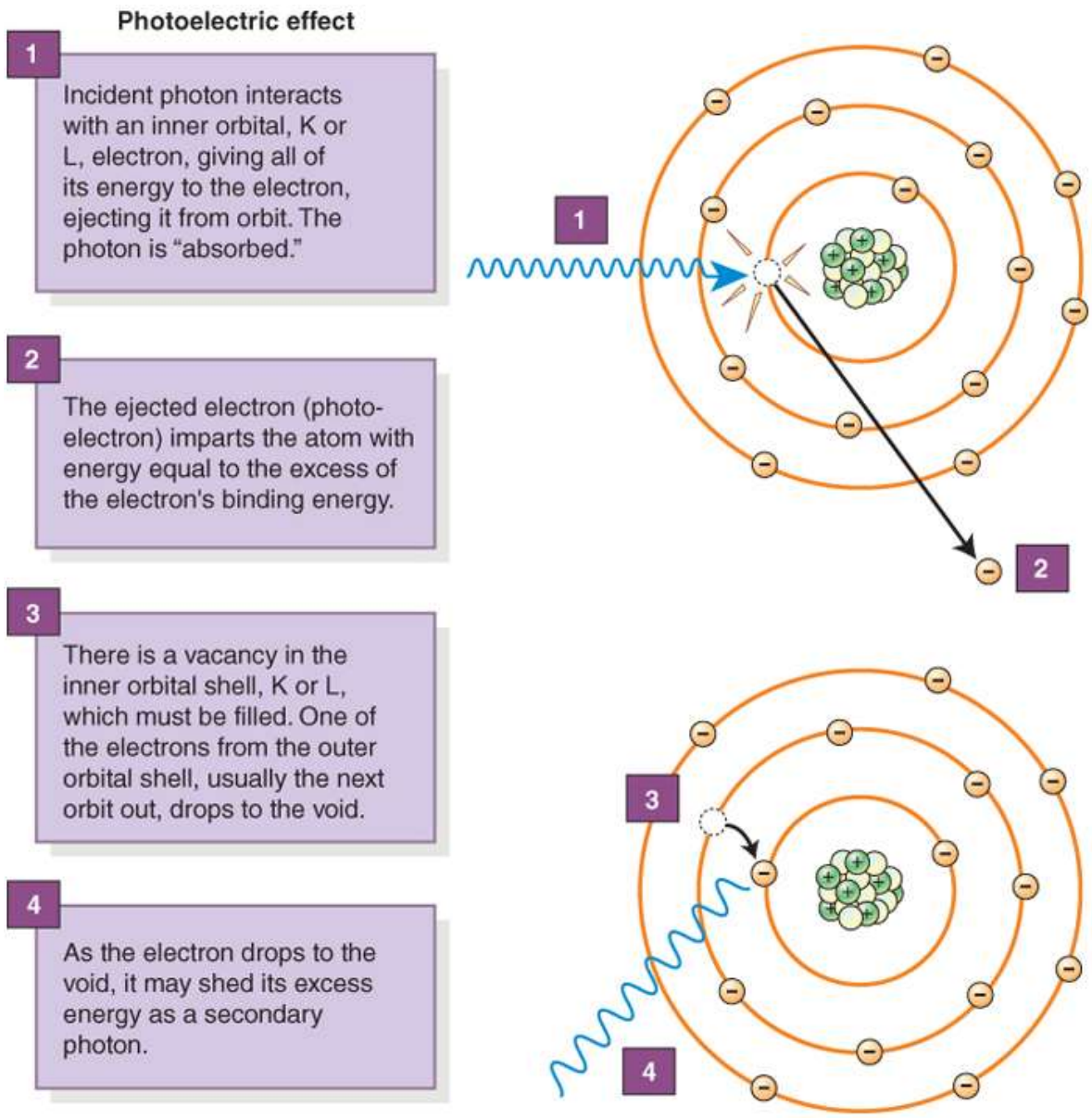
B. Disintegration & casscades

C. Casscades & scattering

★ D. Scattering & absorption



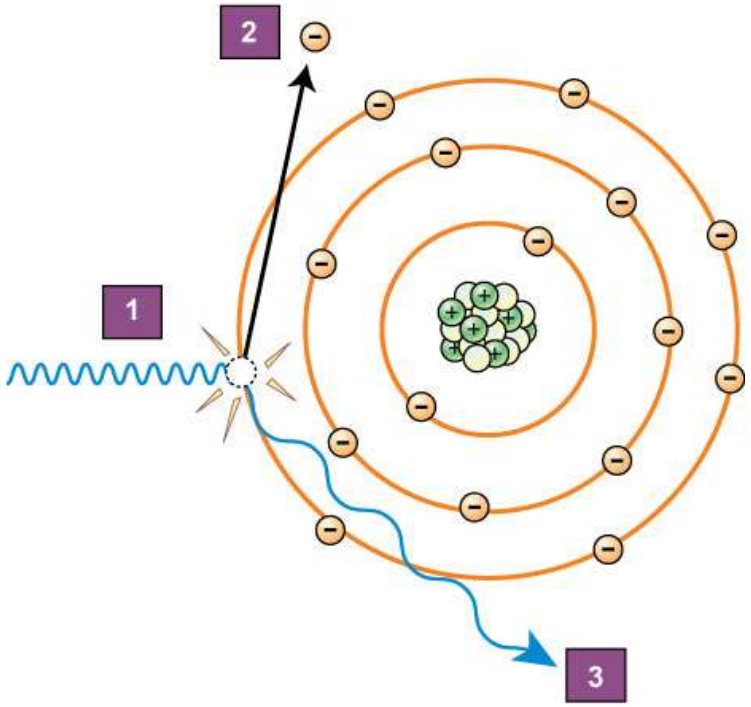
Absorption

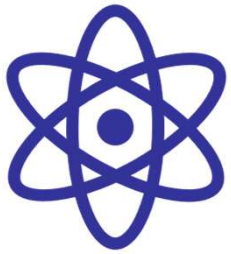


Scattering

Compton effect

1. Photon interacts with an outer orbital electron, imparting some of its energy to the electron, ejecting it from orbit.
2. The ejected electron (Compton electron) leaves the atom with an energy equal to the excess imparted by the photon.
3. The photon continues on an altered path, scattered, with less energy (longer wavelength) than before the collision.

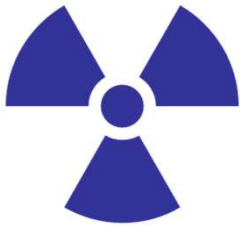




Coherent scattering

Low-energy x-rays

Typically, do not interact with IR



Scattered photons

Do not contribute any useful information

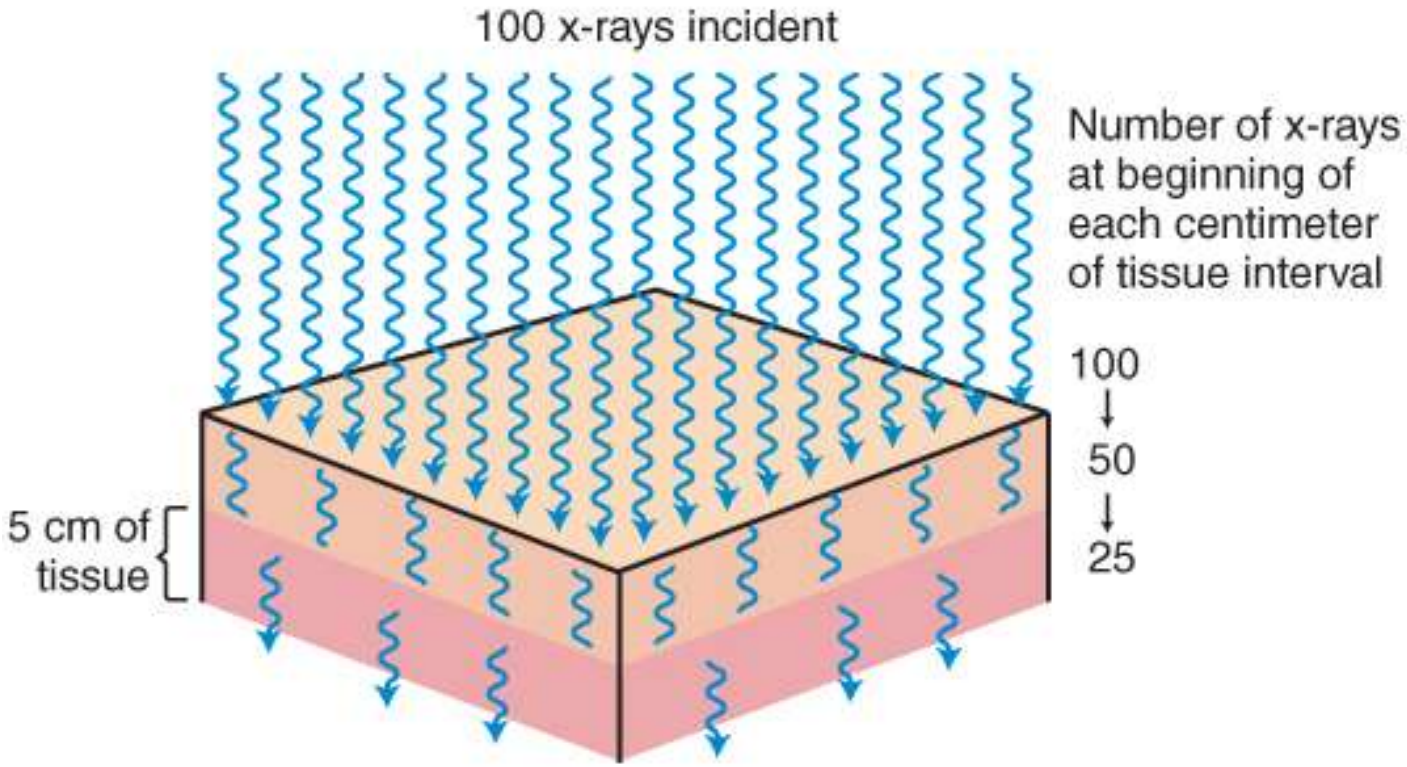
Contribute to the radiation exposure of the patient and others

What 4 factors affect beam attenuation?

- Tissue Thickness
- Type of Tissue
- Tissue Density
- Beam Quality

Tissue Thickness

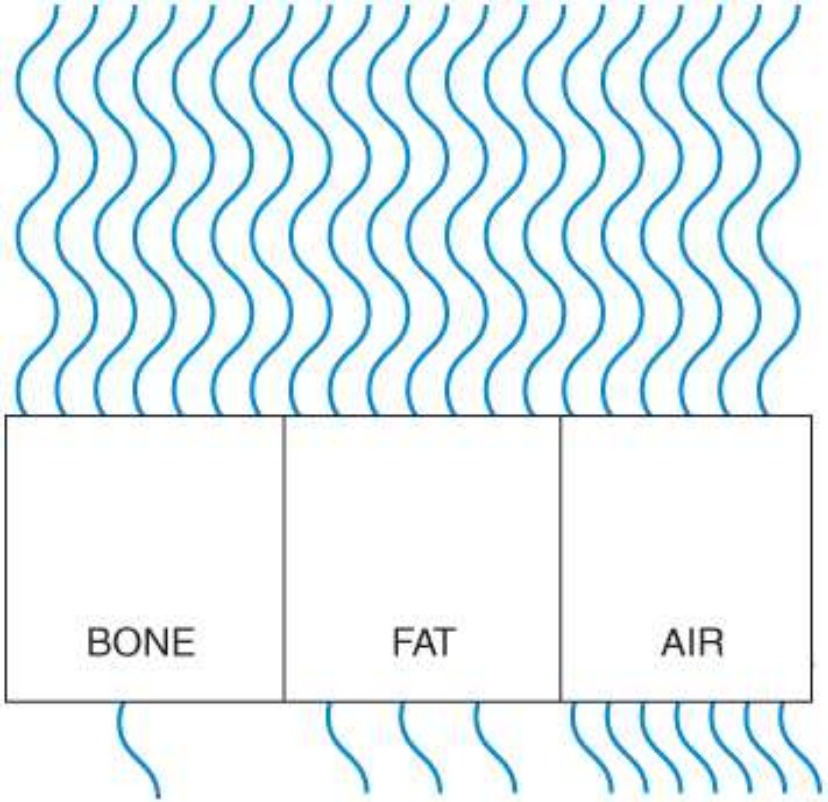
- How does increasing tissue thickness increase beam attenuation?



Will bone, muscle, fat, or air have a great impact on beam attenuation? Why?

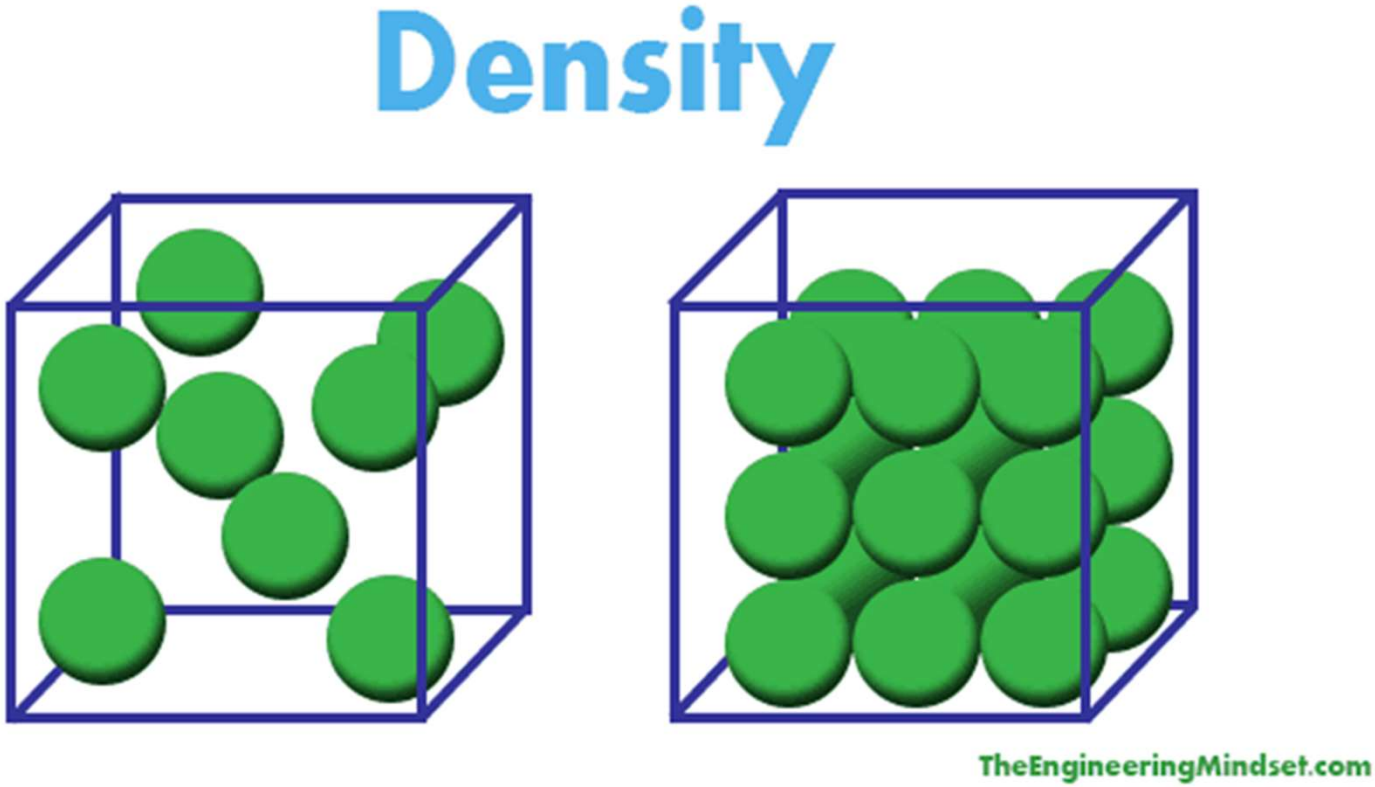
Type of Tissue

- Higher atomic numbers indicate more particles for x-ray photons to interact with



Tissue Density

- Atomic particles that are more dense or compact attenuate the x-ray beam more.
- Bone, muscle, fat, and air account for most of the beam attenuation in the human body.
- Measured in kg/m^3



What impact does beam quality have on beam attenuation?

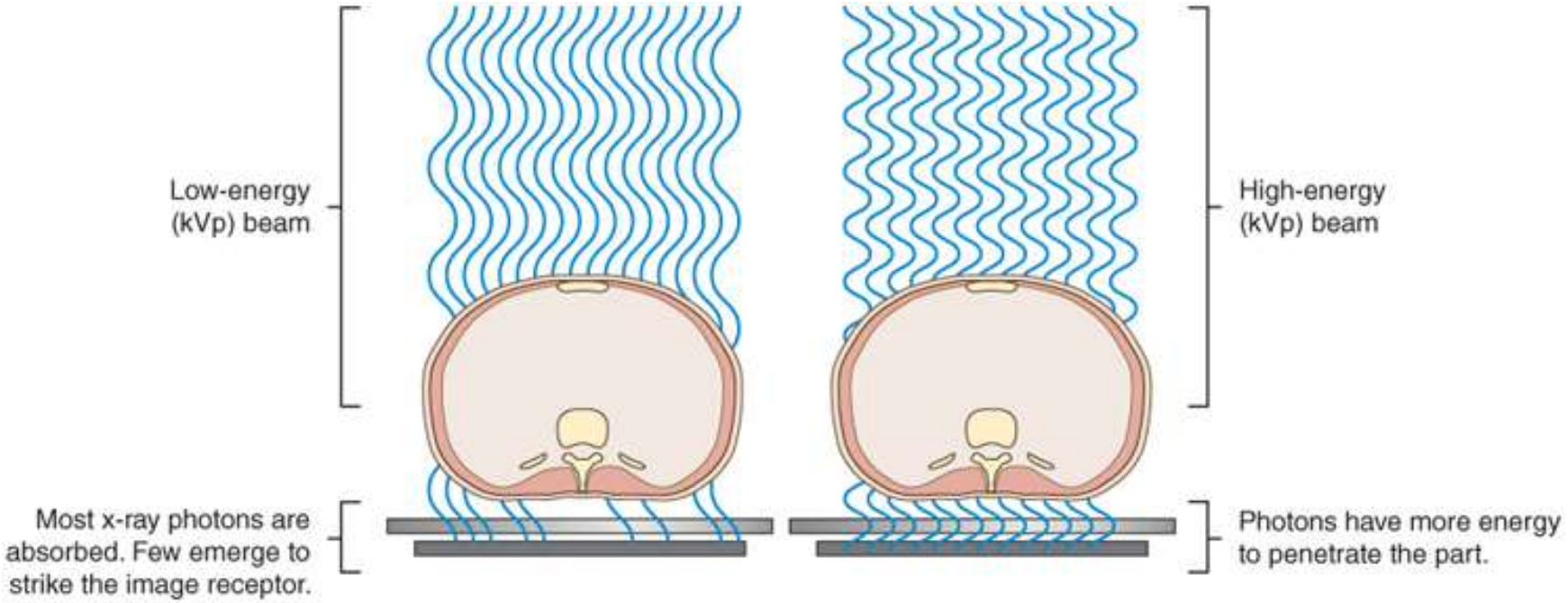
Higher-Penetrating X-rays

- Shorter wavelength with higher frequency
- More likely to be transmitted

Lower-Penetrating X-rays

- Longer wavelength with lower frequency
- More likely to interact with the atomic structures and be absorbed

Beam Quality (Cont.)



Split into groups and complete the chart without using your textbook.

Factor	Beam Attenuation	Absorption	Transmission
Tissue Thickness			
Increasing thickness	↑	↑	↓
Decreasing thickness	↓	↓	↑
Tissue Atomic Number			
Increasing Atomic Number	↑	↑	↓
Decreasing Atomic Number	↓	↓	↑
Tissue Density			
Increasing tissue density	↑	↑	↓
Decreasing tissue Density	↓	↓	↑
X-ray Beam Quality			
Increasing beam quality	↓	↓	↑
Decreasing beam quality	↑	↑	↓

What impact does scatter radiation have on the image?

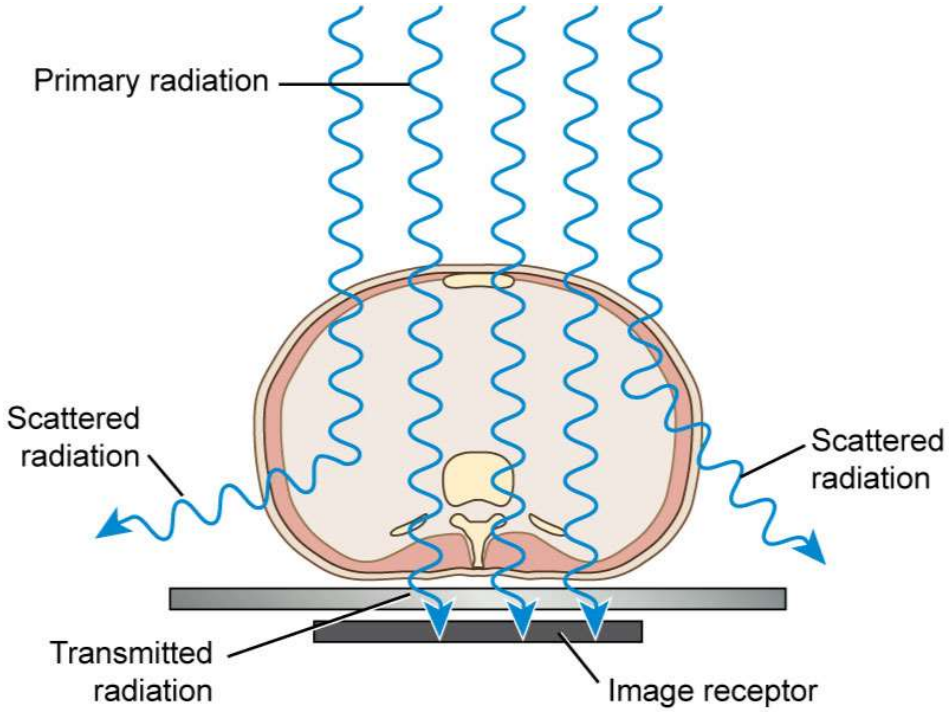
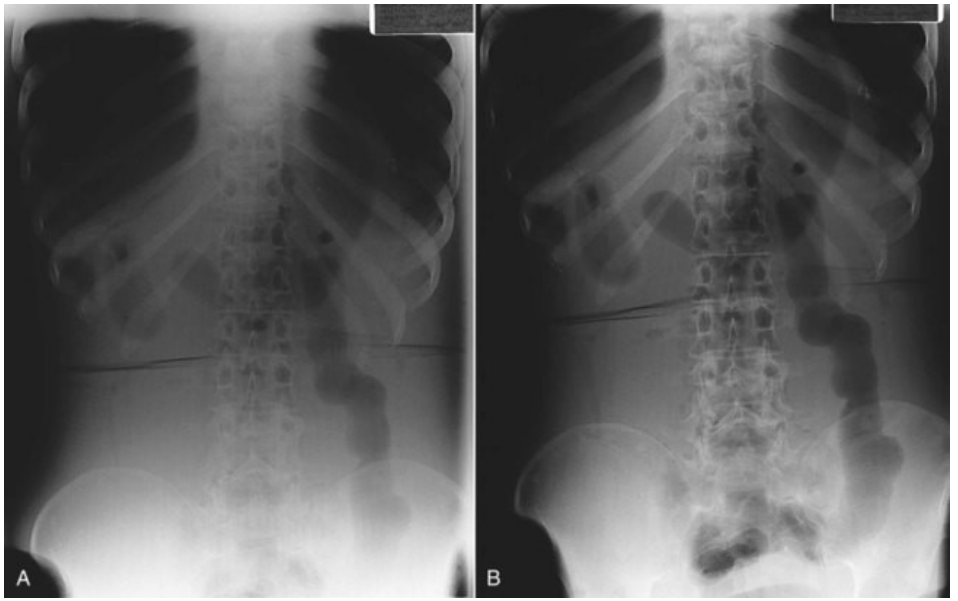
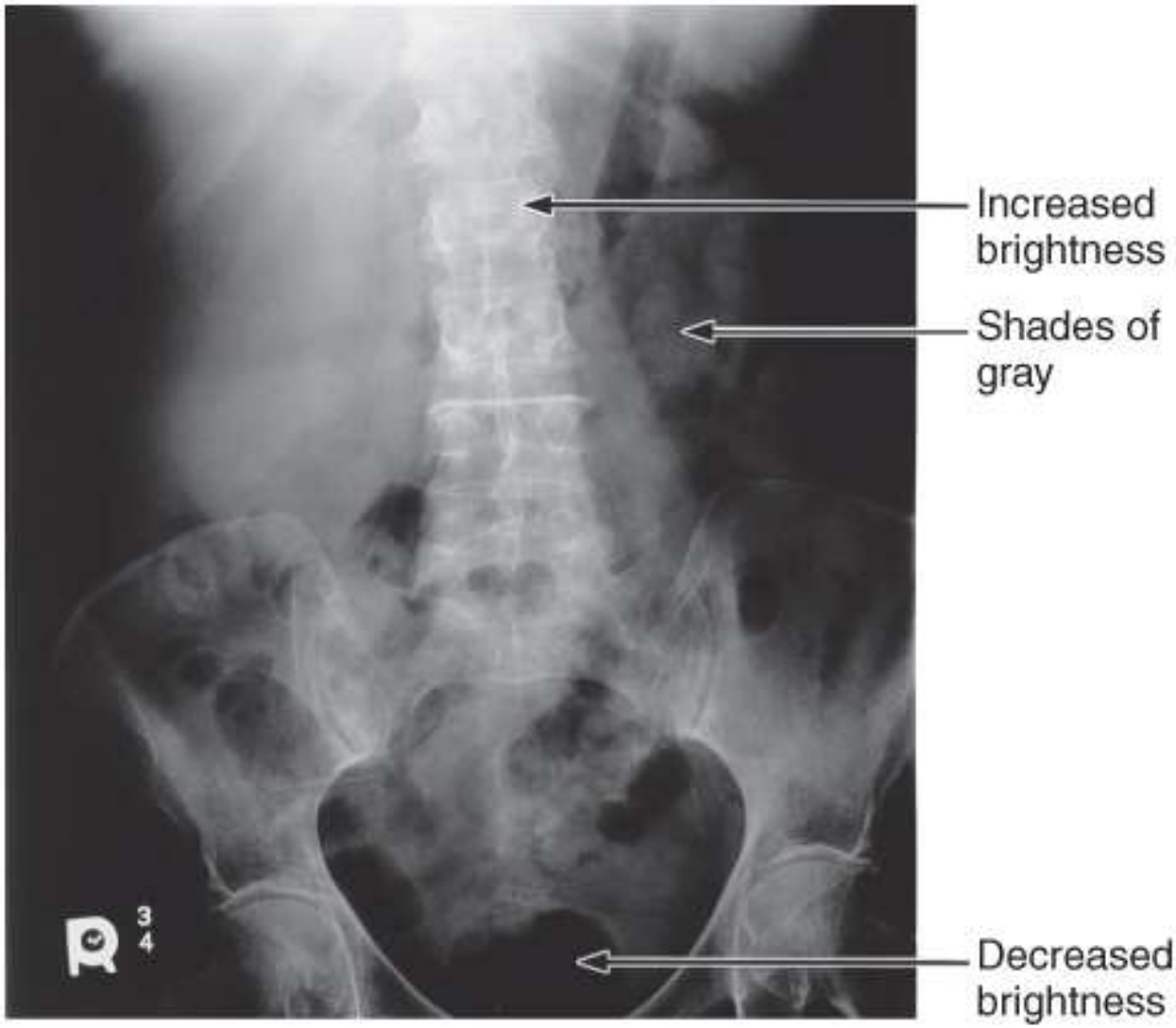


Fig. 8-6. **Exit Radiation Radiographic Densities.** When the attenuated x-ray beam leaves the patient, the remnant x-ray beam is composed of both transmitted and scattered radiation.



Imaging Effect (Cont.)

Shades of gray or brightness recorded in the radiographic image make tissue visible.



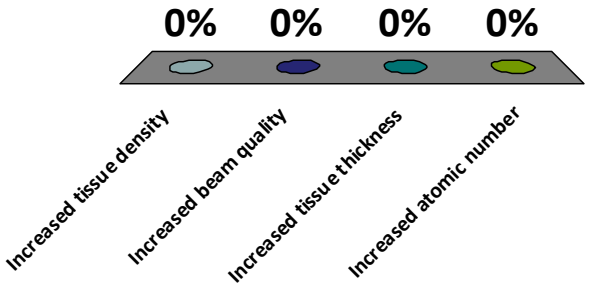
Factors that decrease x-ray absorption include:

A. Increased tissue density

B. Increased beam quality

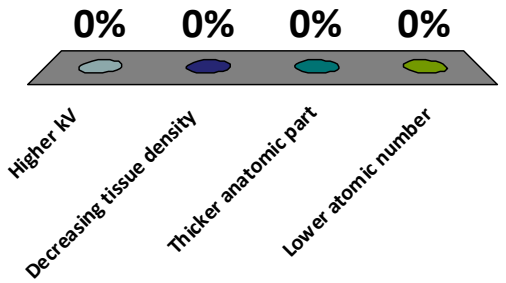
C. Increased tissue thickness

D. Increased atomic number



Which of the following will increase beam attenuation?

A. Higher kV
B. Decreasing tissue density
C. Thicker anatomic part
D. Lower atomic number



Happy Halloween!