



Three Phase CEUs &
SCS Continuing Education
Presents:

Topics in Radiography
Volume I

by
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Forward

The premise behind the creation of this partnership is to provide imaging professionals with access to high quality yet affordable continuing education units (CEUs). Please feel free to share this with your colleagues and have them contact John Fleming at (727) 796-0397 for information regarding the submission of these 12 CEUs for credit with the Florida Department of Health and the American Registry of Radiologic Technologists. Thanks for your support and be sure to look for additional courses to be developed in the near future by Three Phase CEUs and SCS Continuing Education.●

Course Abstract & Objectives:

The objective of this home study course is to provide the learner with a computer based tutorial that will provide them with the means to learn selected topics in radiographic anatomy, imaging and radiobiology. After completion of this home study course, the participant will be able to correctly label the radiographic anatomy of the lower extremity, identify the salient characteristics of radiographic intensifying screens, identify the salient properties of automatic exposure control (AEC) devices, acquire a working knowledge of diagnosing radiographic artifacts, acquire salient information regarding general cell biology in order to build a foundation for learning how ionizing radiation affects the human body, have a working knowledge of the most common radiologic units, and acquire a working knowledge of radiation protection for the radiographer and the patient. A 100 question mastery test will be administered at the end of the tutorial to ensure that competency of the material has been achieved.

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Toes, Foot, Ankle & Calcaneous

Toes	Foot	Ankle	Calcaneous
PA, Oblique & Lateral	1. AP 2. Oblique 3. Lateral	1. AP 2. Oblique 3. Lateral	1. Lateral 2. Tangential

Routine Toe:



AP



Oblique



Lateral

Routine Toe:



AP



Oblique



Lateral

1. Tuft or Nail Bed
2. Growth Plate
3. Interphalangeal Joint
4. Sesamoid Bones
5. 1st Metatarso-phalangeal Joint

AP Foot:



AP Foot:

1. Lateral Malleolus
2. Cuboid
3. Base of the 5th Metatarsal
4. Head of the 5th Metatarsal
5. 4th Metatarsophalangeal Joint
6. Interphalangeal Joint of the 1st Digit
7. Sesamoid Bone
8. 2nd Metatarsal
9. Medial Cuneiform
10. Navicular



Internal Oblique Foot:



Internal Oblique Foot: (Magnified)



Internal Oblique Foot: (Magnified)

1. Calcaneus or Os Calcis
2. Cuboid
3. Base of the 5th Metatarsal
4. Shaft of the 4th Metatarsal
5. 2nd Metatarsophalangeal Joint
6. Sesamoid Bones
7. Lateral Cuneiform
8. Navicular
9. Talus



Lateral Foot: (Poorly Positioned)

1. The Tibia and Fibula should be aligned to ensure that they are directly superimposed.
2. The Metatarsals should also be directly superimposed.



Lateral Foot: (Properly Positioned)



Lateral Foot: (Properly Positioned)

1. Shaft of the Tibia
2. Talus
3. Navicular
4. Superimposed Cuneiforms
5. Superimposed Metatarsals
6. Sesamoid Bones
7. Base of the 5th Metatarsal
8. Cuboid
9. Calcaneus or Os Calcis

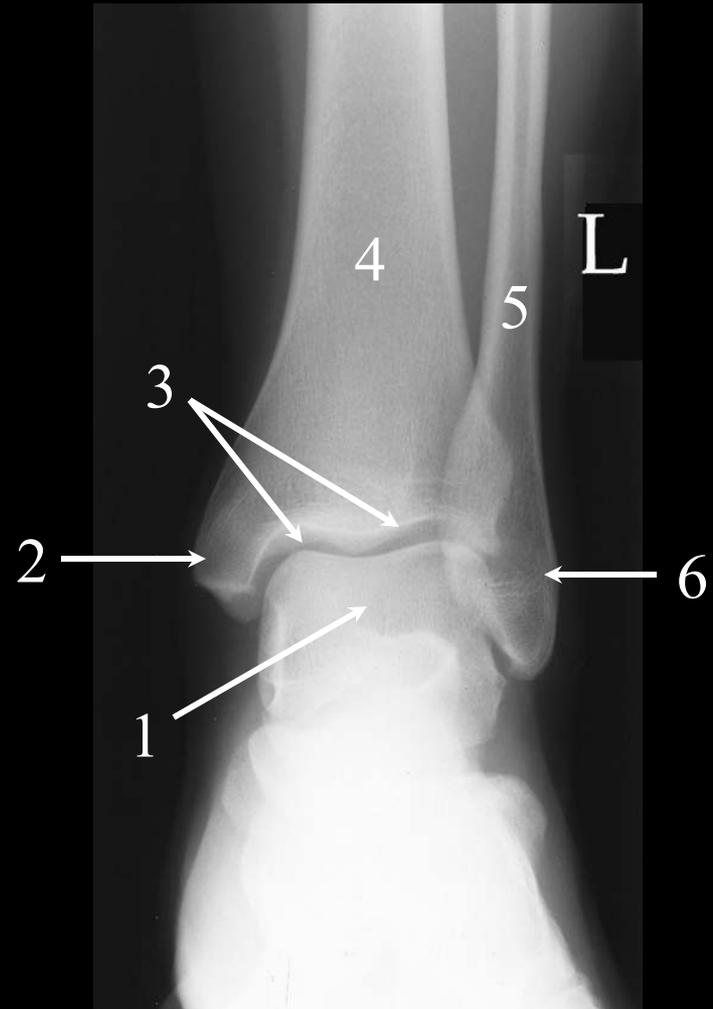


AP Ankle:



AP Ankle:

1. Talus
2. Medial Malleolus
3. Ankle Joint or Mortise
4. Shaft of the Tibia
5. Shaft of the Fibula
6. Lateral Malleolus



Internal Oblique Ankle:



Internal Oblique Ankle:

1. Navicular
2. Tarsal Sinus
3. Medial Malleolus
4. Shaft of the Tibia
5. Lateral Malleolus
6. Talus
7. Calcaneus or Os Calcis



Lateral Ankle:



Lateral Ankle:

1. Shaft of the Fibula
2. Shaft of the Tibia
3. Talus
4. Navicular
5. Cuboid
6. Calcaneus or Os Calcis

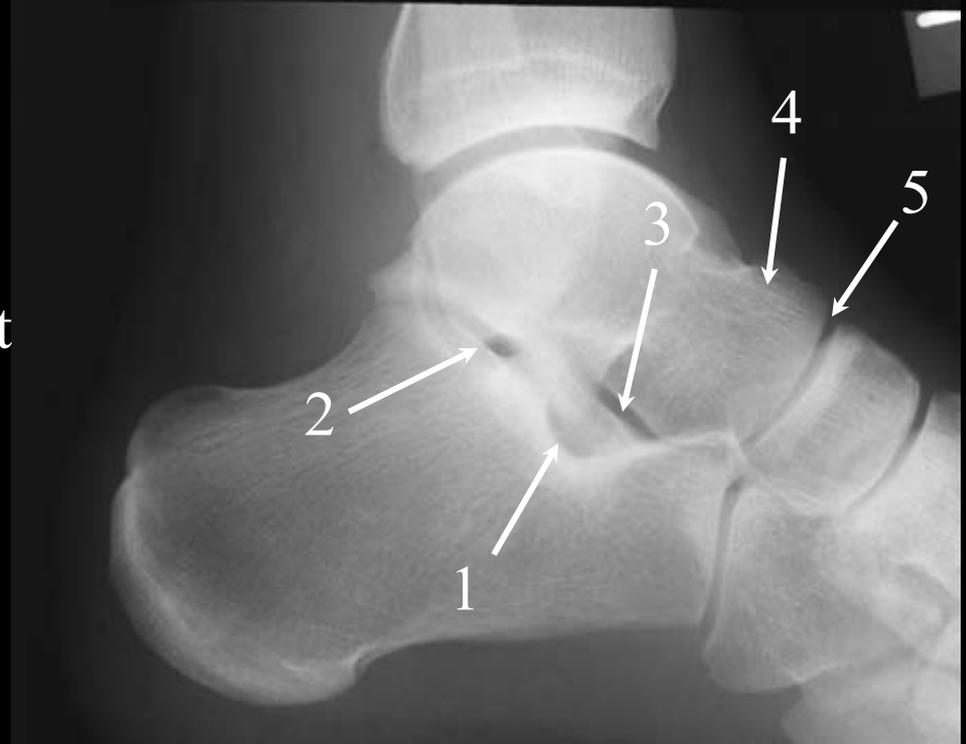


Calcaneus: Lateral



Calcaneus: Lateral

1. Tarsal Sinus
2. Subtalar Joint
3. Talocalcaneonavicular Joint
4. Head of the Talus
5. Talonavicular Joint



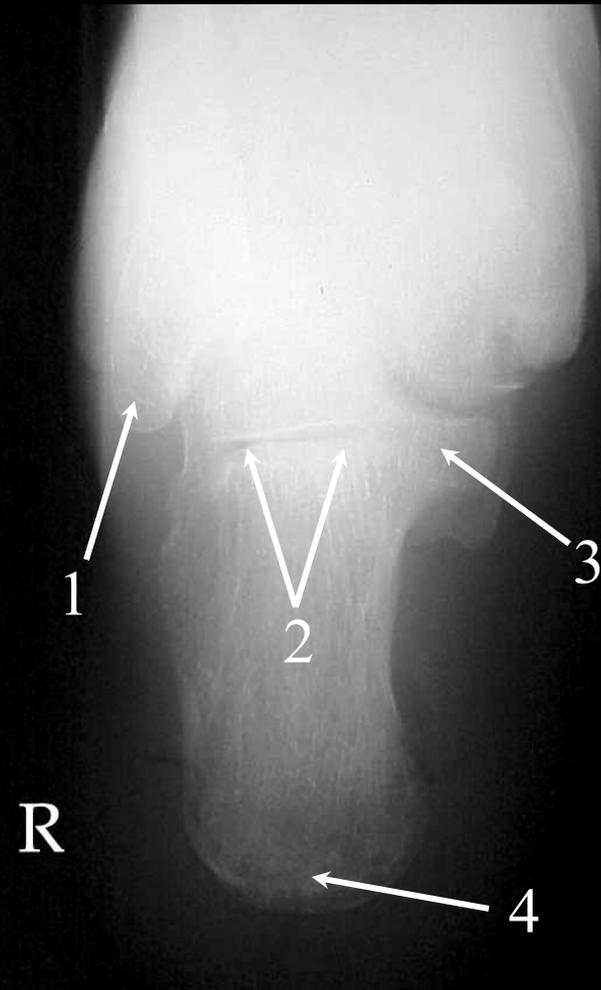
Calcaneus: Tangential



R

Calcaneus: Tangential

1. Fibula
2. Talocalcaneal Joint
3. Sustentaculum Tali
4. Tuberosity of the Calcaneus



Knee & Patella

Knee

- 1. AP**
- 2. Internal Oblique**
- 3. External Oblique**
- 4. Lateral**
- 5. Tunnel**

Patella

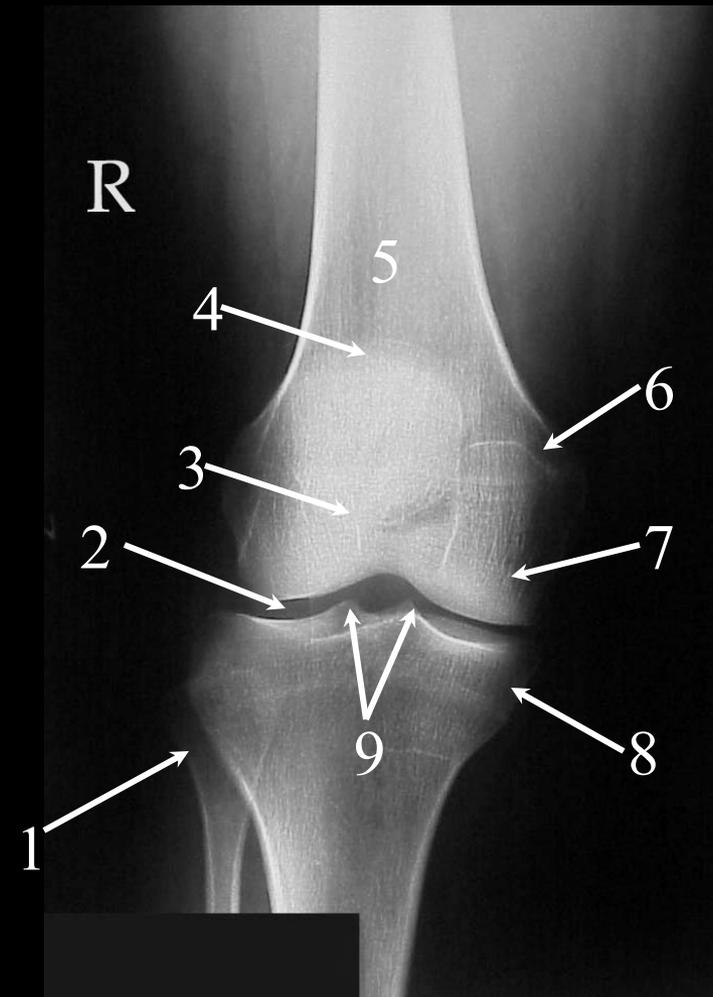
- 1. PA**
- 2. Lateral**
- 3. Tangential**

AP Knee:



AP Knee:

1. Head of the Fibula
2. Tibial Plateau
3. Apex of the Patella
4. Base of the Patella
5. Shaft of the Femur
6. Medial Epicondyle of the Femur
7. Medial Condyle of the Femur
8. Medial Condyle of the Tibia
9. Intercondylar Eminence

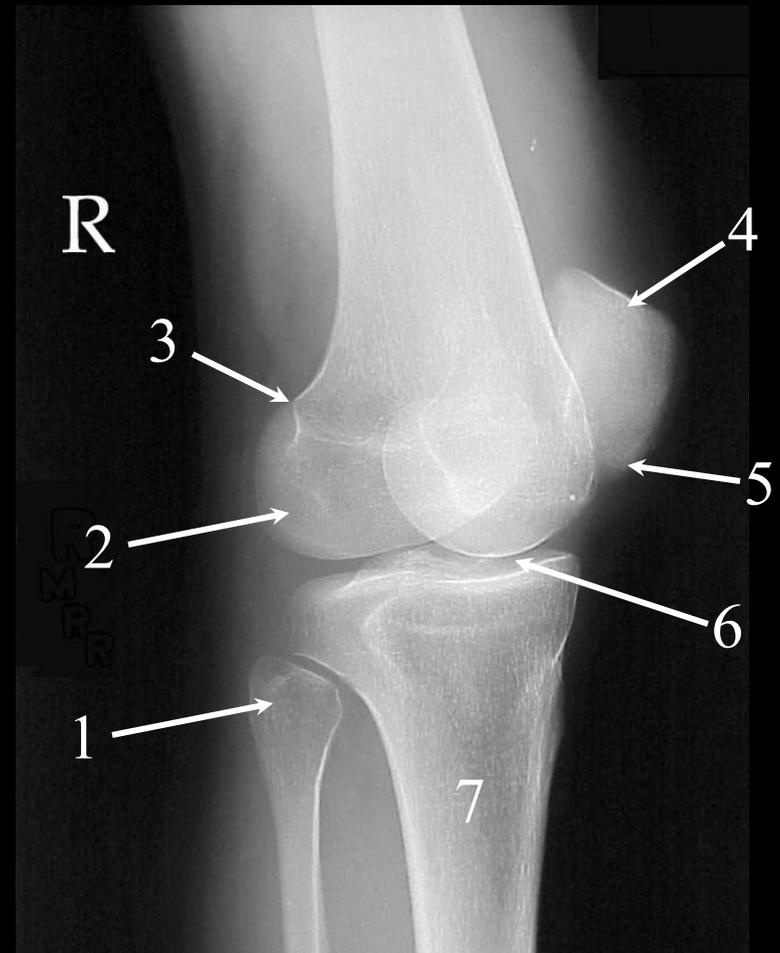


Internal Oblique Knee:



Internal Oblique Knee:

1. Head of the Fibula
2. Lateral Condyle of the Femur
3. Lateral Epicondyle of the Femur
4. Base of the Patella
5. Apex of the Patella
6. Intercondylar Eminence
7. Shaft of the Tibia

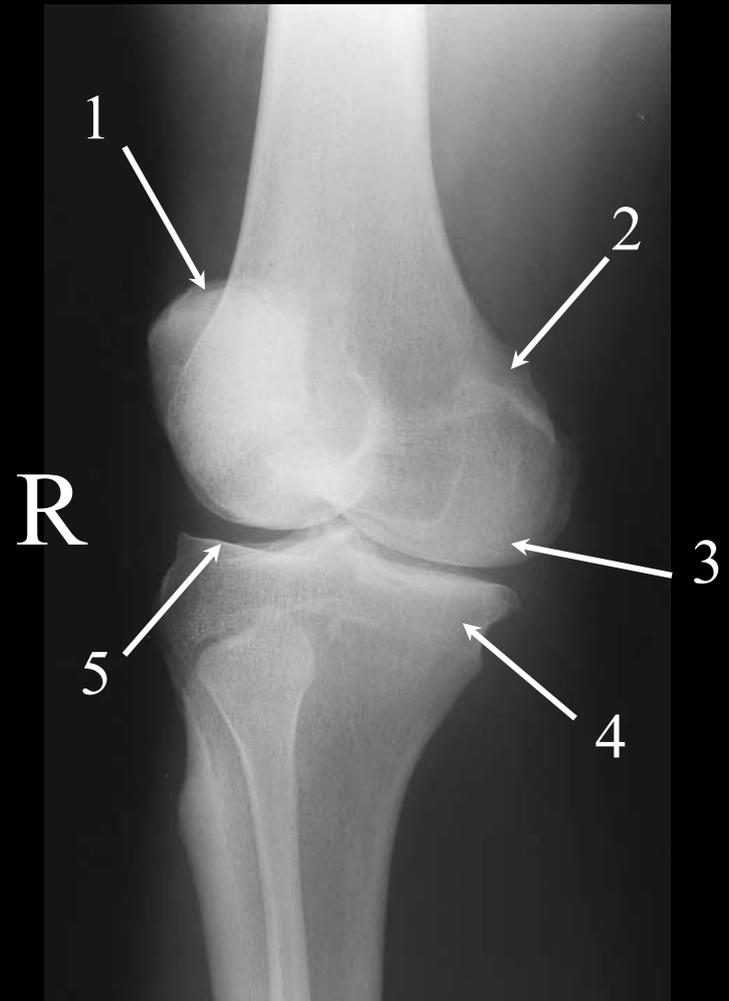


External Oblique Knee:



External Oblique Knee:

1. Base of the Patella
2. Medial Epicondyle of the Femur
3. Medial Condyle of the Femur
4. Medial Condyle of the Tibia
5. Lateral Tibial Plateau



Lateral Knee: (Poorly Positioned)

The arrows are pointing to the medial and lateral condyles of the femur. They should be perfectly superimposed on a true lateral of the knee.



Lateral Knee: (Properly Positioned)

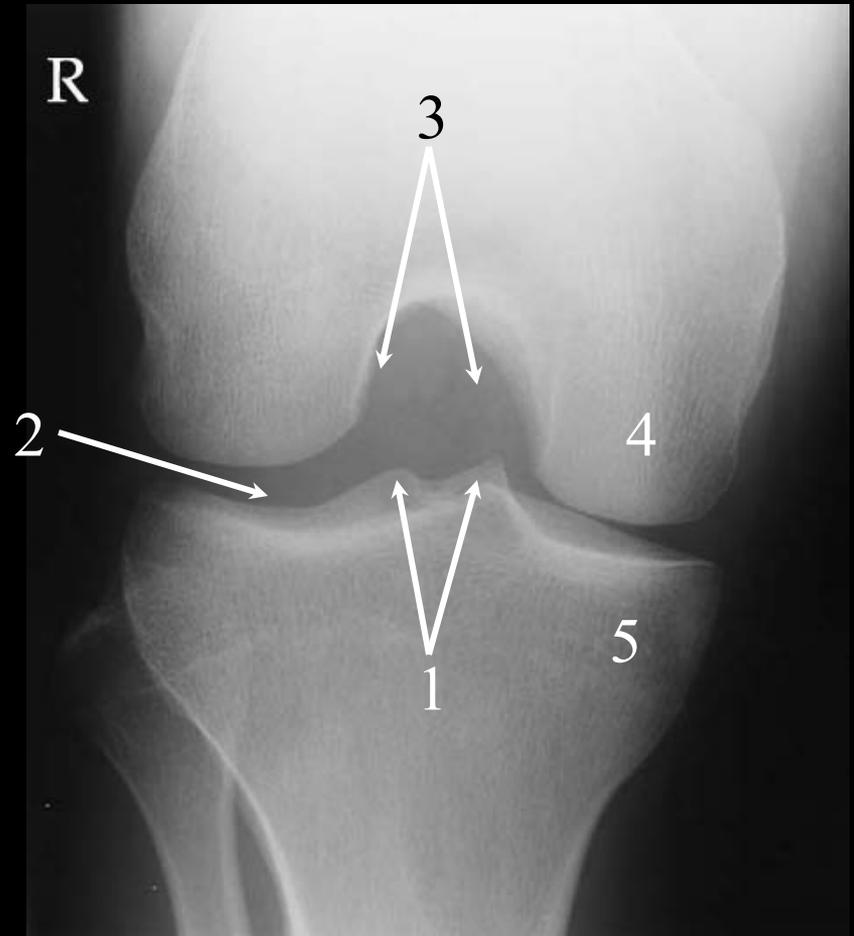


Intercondyloid Fossa or Tunnel Knee:



Intercondyloid Fossa or Tunnel Knee:

1. Intercondylar Eminence
2. Tibial Plateau
3. Intercondylar Fossa
4. Medial Condyle of the Femur
5. Medial Condyle of the Tibia



PA Patella:



PA Patella:

1. Base of the Patella
2. Apex of the Patella

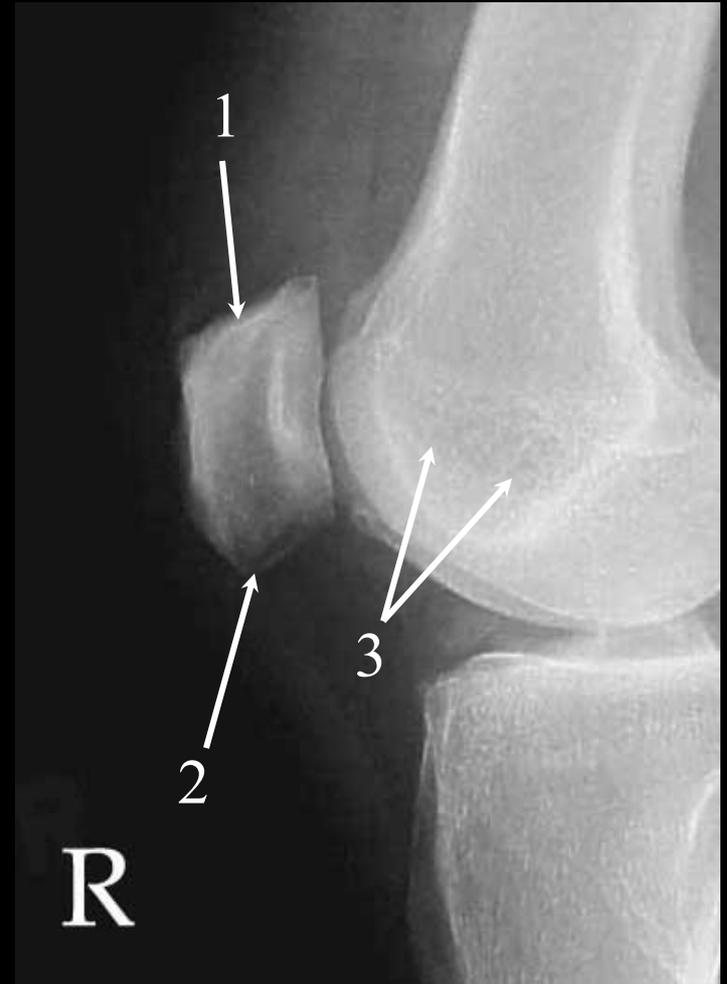


Lateral Patella:



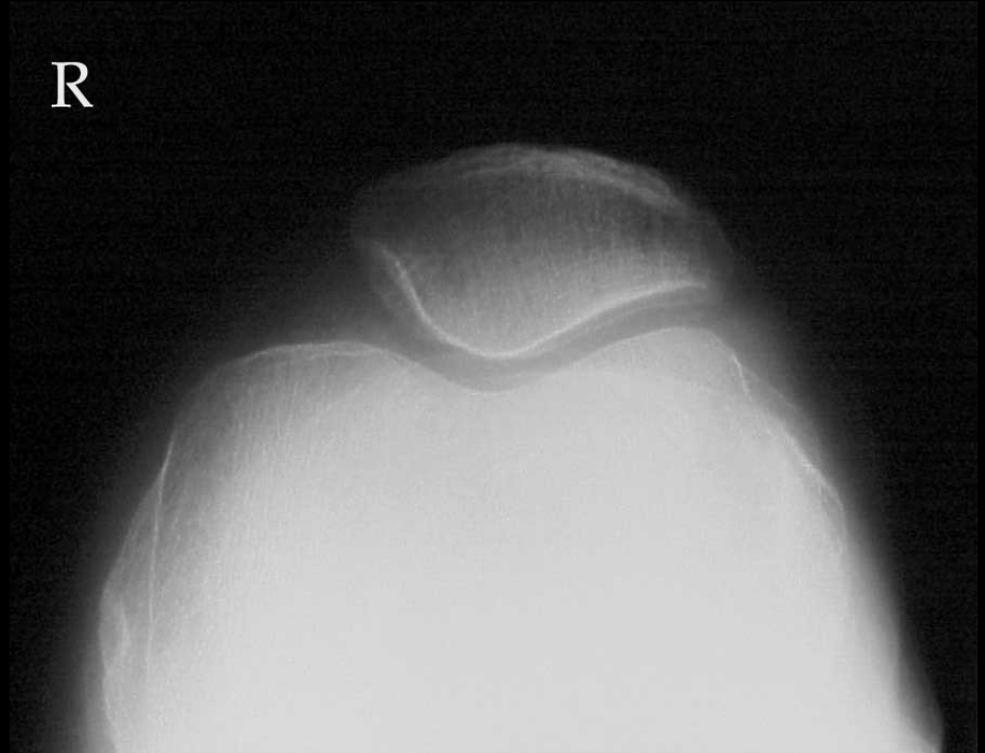
Lateral Patella:

1. Base of the Patella
2. Apex of the Patella
3. Ludloff's Spot



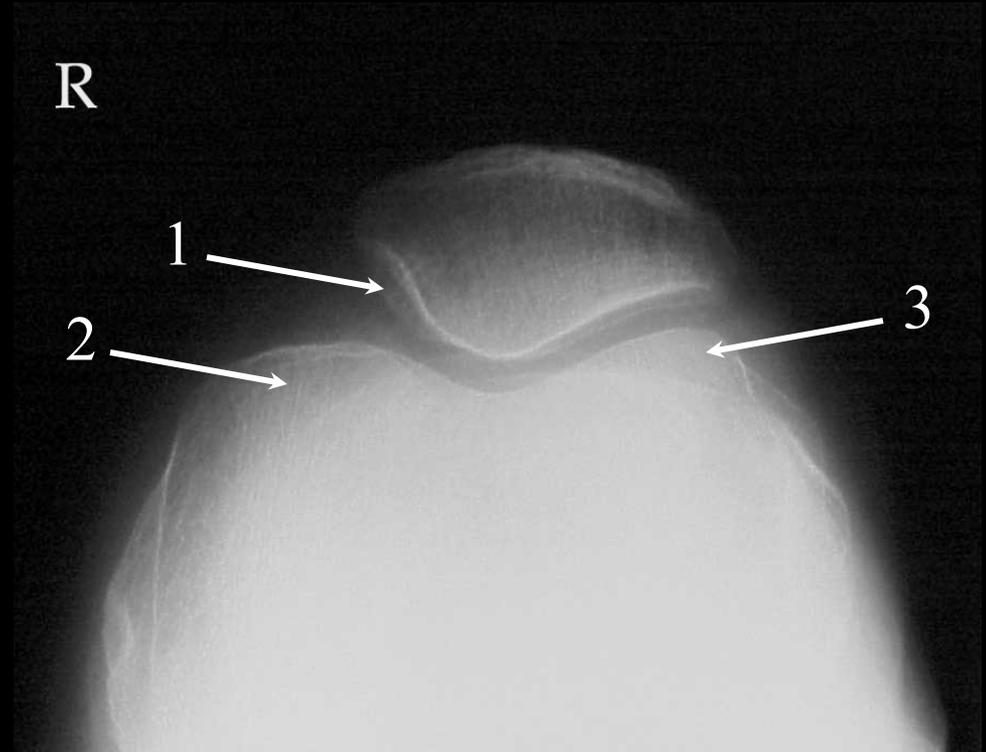
Tangential Patella:

R



Tangential Patella:

1. Medial Articulation Facet
2. Medial Condyle of the Femur
3. Lateral Condyle of the Femur



Hip, Pelvis & SI Joints

Hip

- 1. AP Hip**
- 2. Frog Hip**
- 3. X-Table Lateral Hip**

Pelvis

- 1. AP**

Sacroiliac Joints

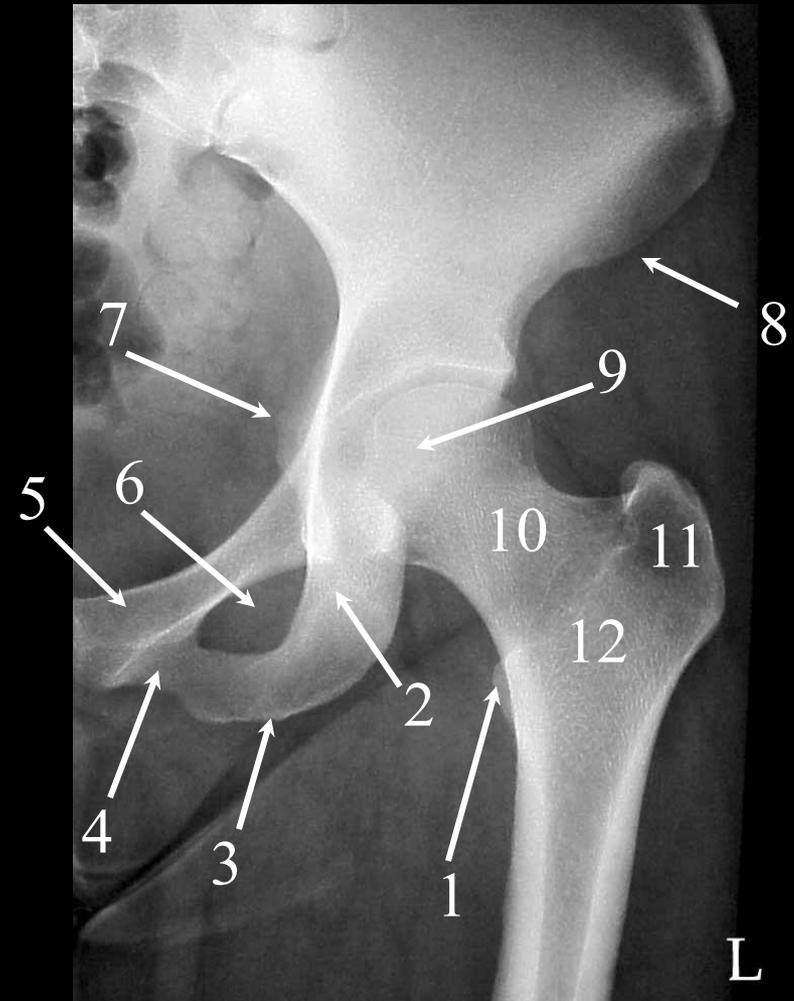
- 1. AP Axial Projection**
- 2. Posterior Oblique**

AP Hip:



AP Hip:

1. Lesser Trochanter
2. Body of the Ischium
3. Ischial Tuberosity
4. Inferior Ramus of the Pubis
5. Superior Ramus of the Pubis
6. Obturator Foramen
7. Ischial Spine
8. ASIS
9. Head of the Femur
10. Neck of the Femur
11. Greater Trochanter
12. Intertrochanteric Crest

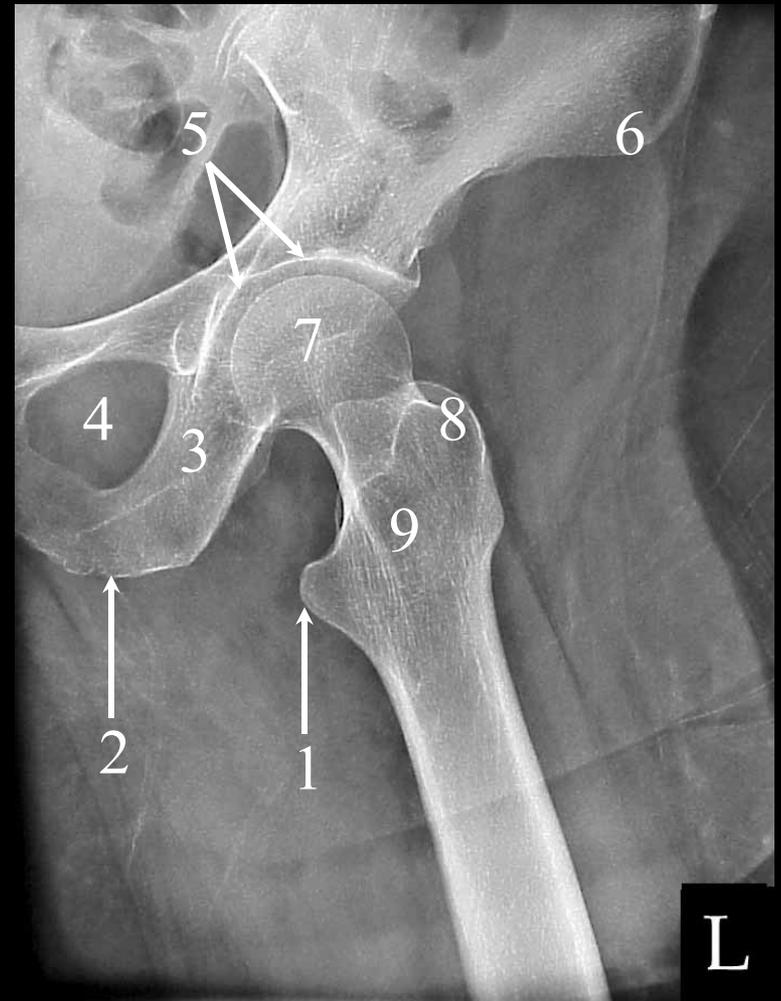


Frog Hip:

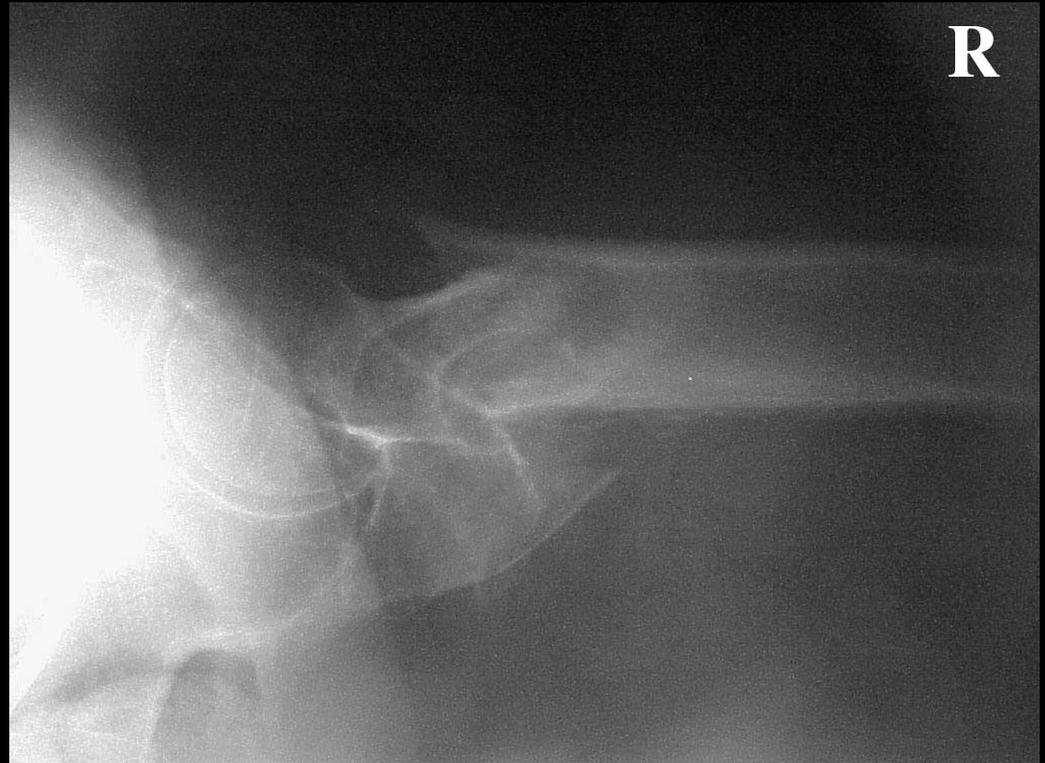


Frog Hip:

1. Lesser Trochanter
2. Ischial Tuberosity
3. Body of the Ischium
4. Obturator Foramen
5. Acetabulum
6. ASIS
7. Head of the Femur
8. Greater Trochanter
9. Intertrochanteric Crest

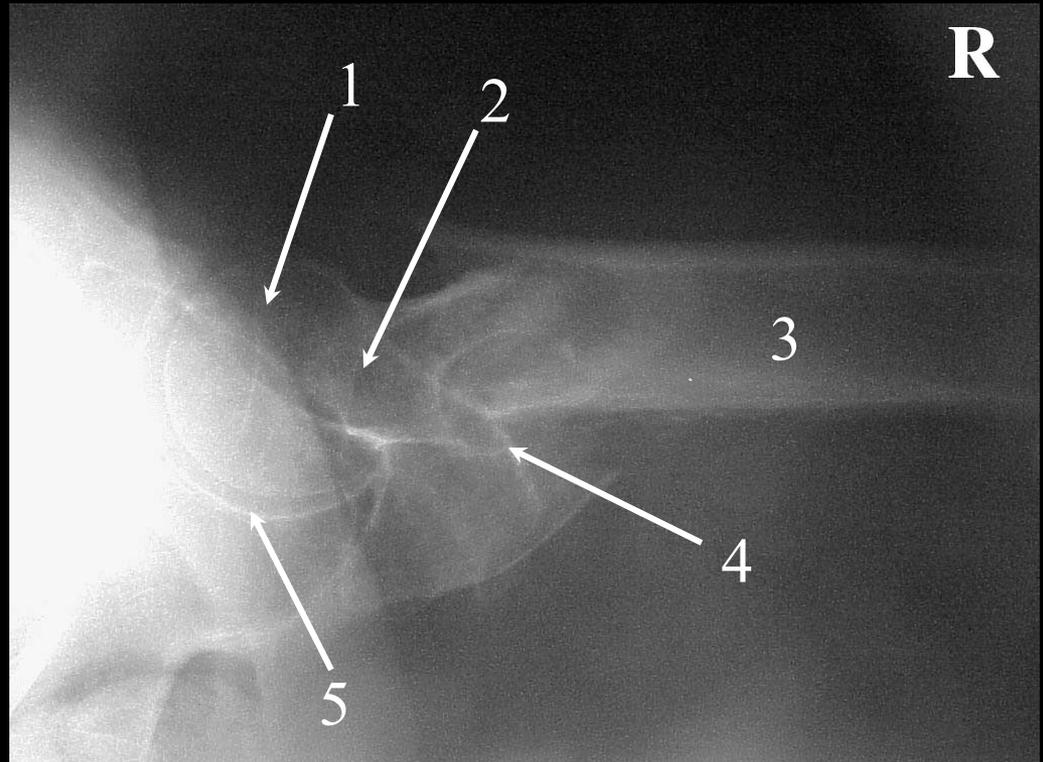


X-Table Lateral Hip:



X-Table Lateral Hip:

1. Head of the Femur
2. Neck of the Femur
3. Shaft
4. Fracture
5. Acetabulum

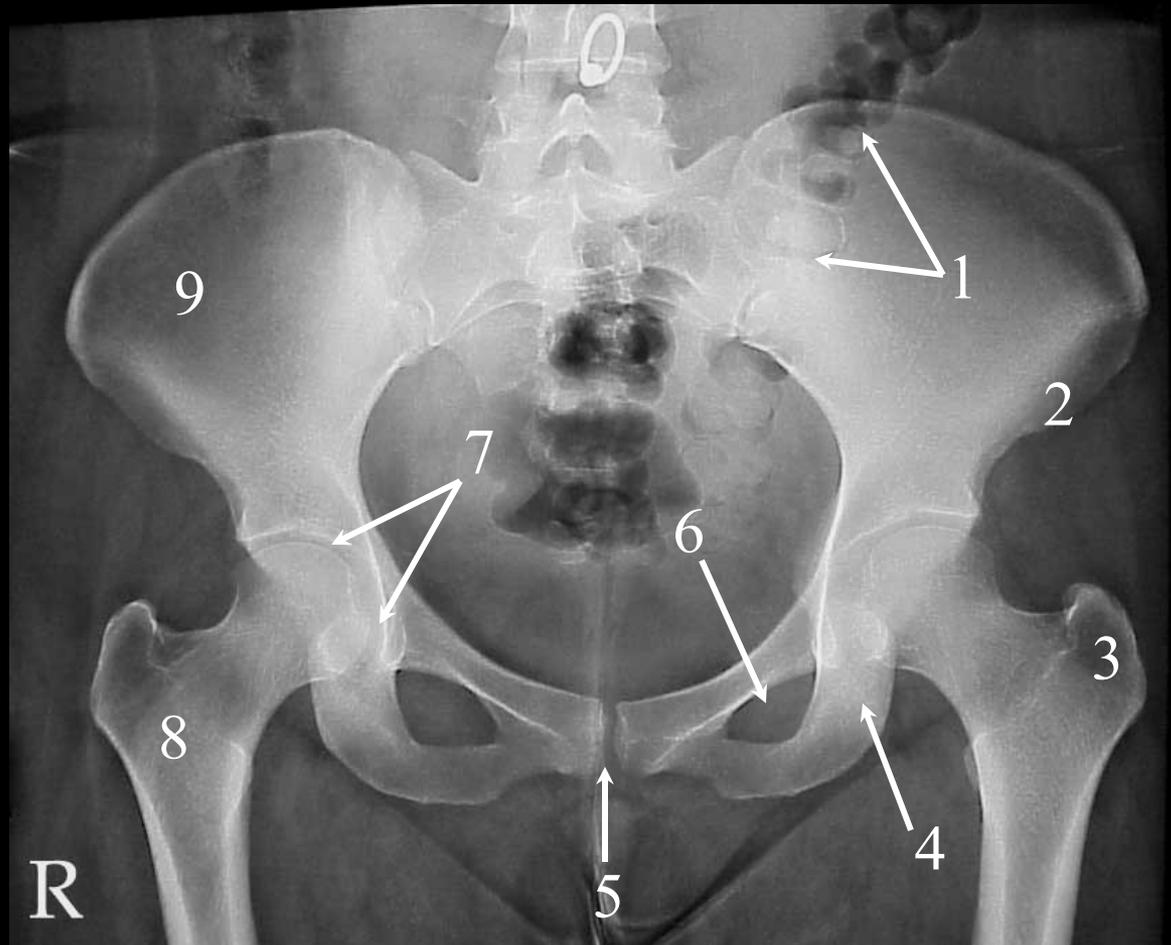


AP Pelvis:



AP Pelvis:

1. Air in the Descending Colon
2. ASIS
3. Greater Trochanter
4. Body of the Ischium
5. Symphysis Pubis
6. Obturator Foramen
7. Acetabulum
8. Intertrochanteric Crest
9. Ala or Wing of the Ilium

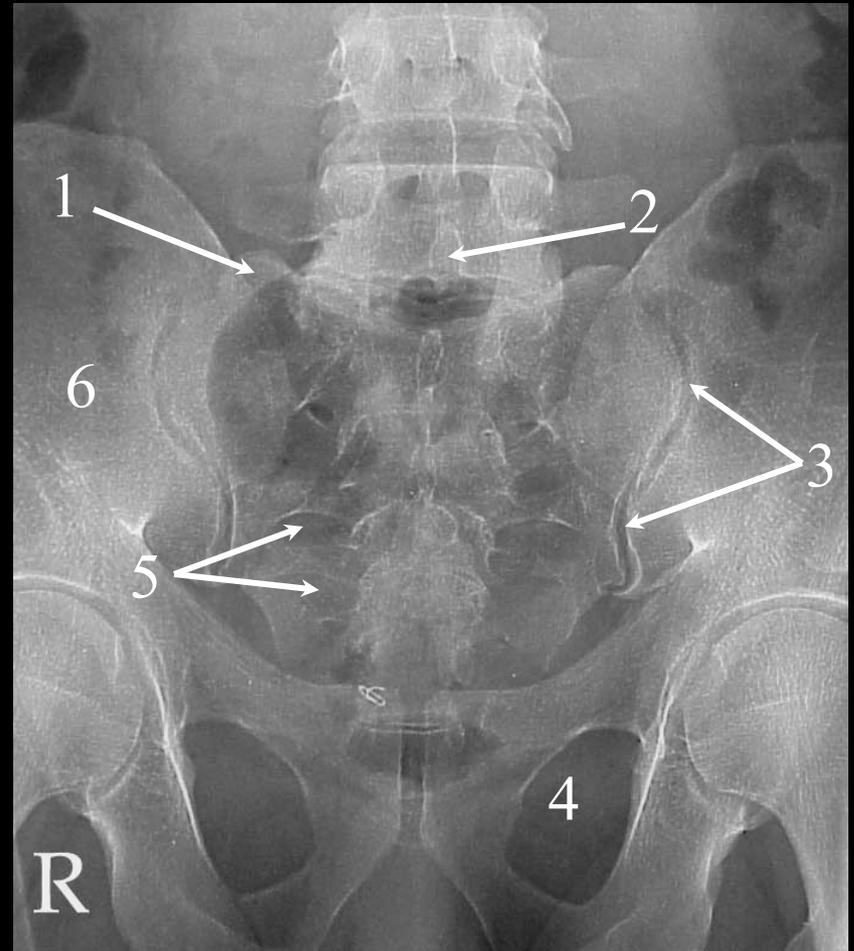


Sacroiliac Joints: AP Axial Projection



Sacroiliac Joints: AP Axial Projection

1. Superior Articular Process of the Sacrum
2. Spinous Process of L5
3. Left S.I. Joint
4. Obturator Foramen
5. Anterior Sacral Foramina
6. Right Ala of the Ilium

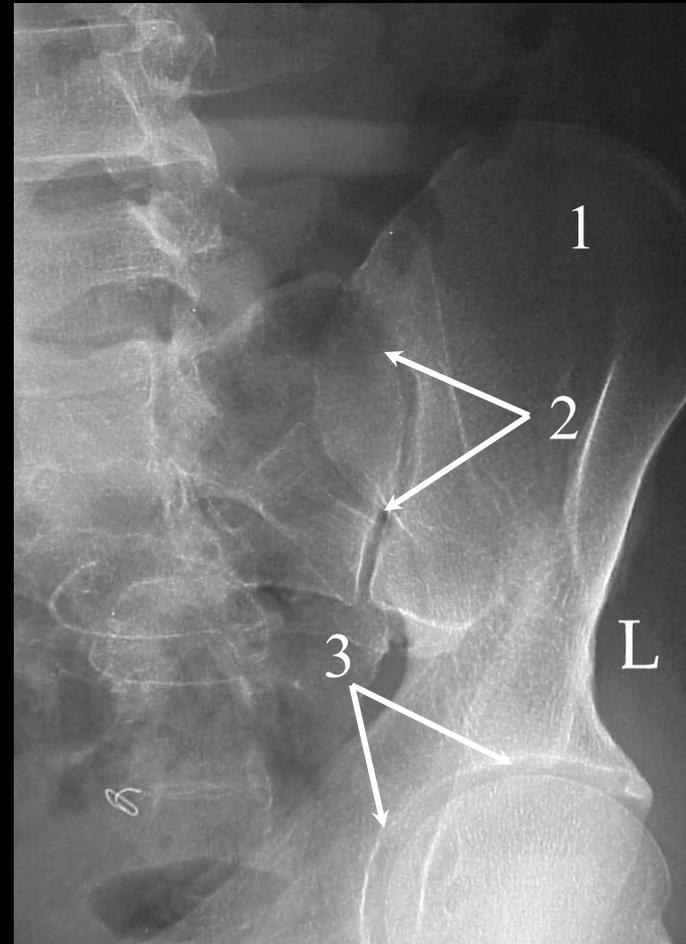


Sacroiliac Joints: RPO



Sacroiliac Joints: RPO

1. Left Ala of the Ilium
2. Left S.I. Joint
3. Left Acetabulum



Preface to the Intensifying Screens Unit:

The design of this section employs a bulleted format as opposed to the more traditional method of using standard paragraphs. The expository nature of the material is very well suited for this style of delivery. Furthermore, the bulleted format will facilitate the learner's ability to quickly reference the material when answering the mastery test questions.

Radiographic Screens

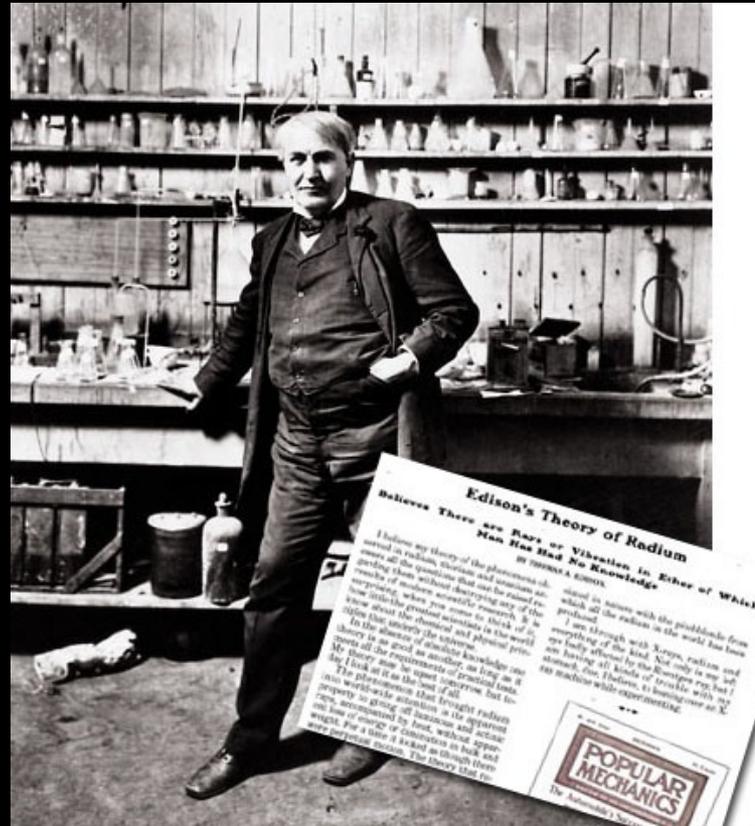
- 1. The History & Benefits of Screen Use**
- 2. Screen Construction**
- 3. Light Emission**
- 4. Factors Affecting Screen Speed & Resolution**
- 5. kVp vs. Screen Speed**
- 6. Absorption vs. Conversion Efficiency**
- 7. Speed Class/Relative Speed (RS) System**
- 8. Screen Care**

The Discovery of Screens:

- Intensifying screens are employed to facilitate a reduction in patient exposure to ionizing radiation.
- In the year 1896, Thomas Edison experimented with nearly 8,500 different combinations of elements in order to find the best combination that could produce fluorescence when exposed to x-rays.

The Discovery of Screens:

Thomas Edison Born 2/11/1847 Died 10/18/1931



POPULAR MECHANICS, OCTOBER 1903

Photo by U.S. Department of the Interior, National Park Service, Edison National Historic Site

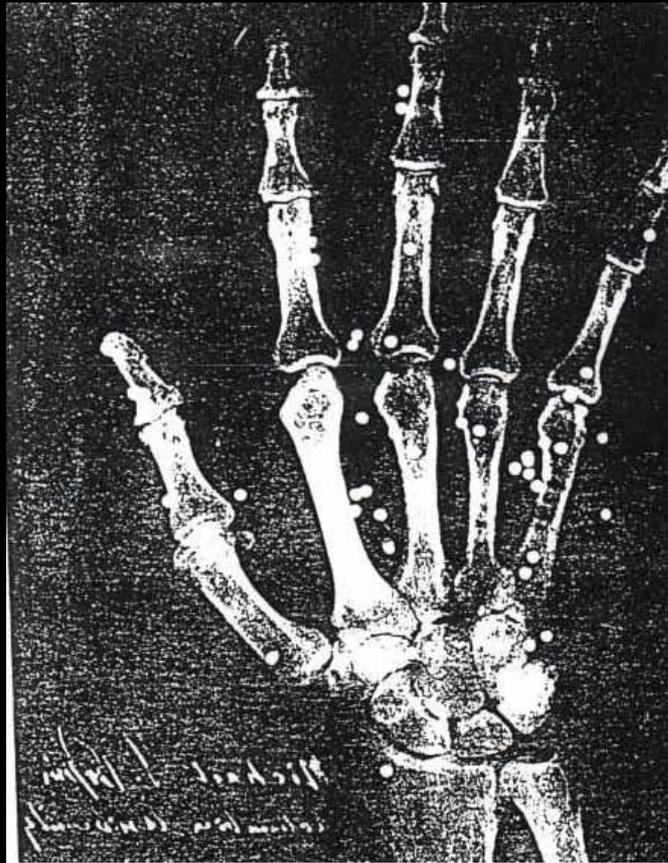
The Discovery of Screens:

- In that same year, Professor Michael Pupin of Columbia University sandwiched together a photographic plate and one of Edison's fluorescent screens and used this combination for medical diagnosis.

This new combination of materials reduced the exposure times from an hour down to just a few seconds.

Pupin produced a famous image of a hand that had numerous buckshot pellets and thus demonstrated to the world the potential diagnostic power of the x-ray.

The Discovery of Screens:



This is the first Reoentgenogram (X-RAY) done by Michael Pupin on January 2, 1896. This original X-ray involved a surgical case which a man's hand was full with buckshots. The surgeon asked Pupin to identify places where the buckshots are present for surgery.

The Benefits of Screen Use:

- Employing intensifying screens will reduce the beam intensity required to produce an image and thus, will provide the potential for reducing the exposure time.

A reduction in exposure time will reduce the likelihood of motion on the the image receptor.

In regards to image production, motion is one of the worst artifacts that the radiographic image can possess.

The next slide demonstrates the loss of image resolution that results from motion.

The Benefits of Screen Use:

L



As this lateral chest demonstrates, motion is the worst attribute that a radiograph can possess. By virtue of their ability to reduce the exposure required to produce optimal film densities, screens have the potential to reduce motion on radiographs.

The Benefits of Screen Use:

- Since there is a reduction in beam intensity, there will also be a reduction in overall patient dose.

The reduction in patient dose is estimated at 100 fold.

This is one of the most important characteristics of screen use.

- Furthermore, the reduction in beam intensity will also increase the expected life of the tube and thus, reduce the cost of tube replacement.

The Benefits of Screen Use:

- Another important option that screen use provides is the potential to use the small focal spot.

The reduction in technique can be accomplished by reducing the mA required to produce the image.

If the mA is reduced to below 200, there is the potential for using the small focal spot on most x-ray machines.

This will greatly improve image resolution and produce a higher quality study.

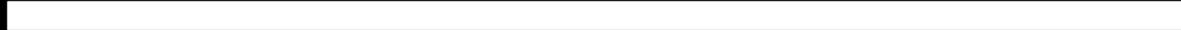
Intensifying Screen Construction:

- The diagram on the next slide consists of a cross-section of half of a typical cassette.
- Each layer of the screen will be discussed in subsequent slides.

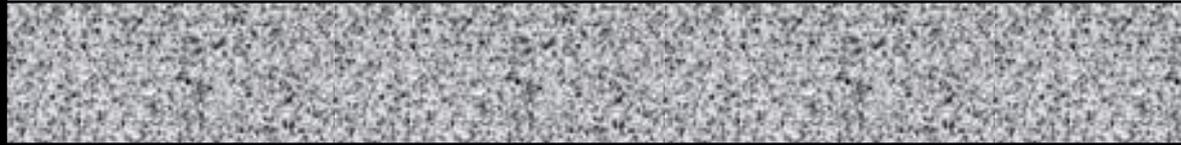
Intensifying Screen Construction:



Radiographic Film



Protective Coat or T-coat



Phosphor Layer



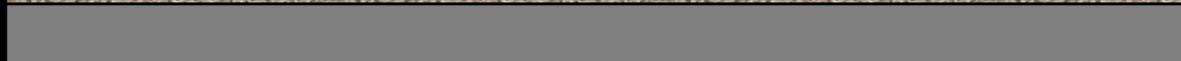
Reflective Layer



Screen Base



Pressure Pad



Lead Backing



Cassette Backing

Intensifying Screen Construction:

- The cassette (front and back) is made of a low atomic number material that is designed to help reduce exit beam attenuation.
- The **lead backing** is located on the bottom of the cassette only.

Its purpose is to absorb scatter radiation emanating from below the image receptor.

This radiation is called backscatter radiation and may occur when very high kVp techniques are employed

Backscatter radiation contributes nothing but noise in the form of fog to the image and is objectionable.

Intensifying Screen Construction:

- The the **pressure pad** is made of either contact felt or a spongy material (foam rubber) that is designed to ensure proper film-screen contact.

Improper film-screen contact will result in image degradation and is also objectionable.

This is sometimes called the pressure pad or supportive backing.

- The **screen base** provides the mechanical support for the phosphor layer and is approximately 1 mm thick.

It is made of polyester and is very difficult to damage.

Intensifying Screen Construction:

- The **reflective layer** is made of a mirror-like material and is found in some cassettes.

Light is emitted isotropically (in all directions) by the phosphor crystals found within the screen emulsion.

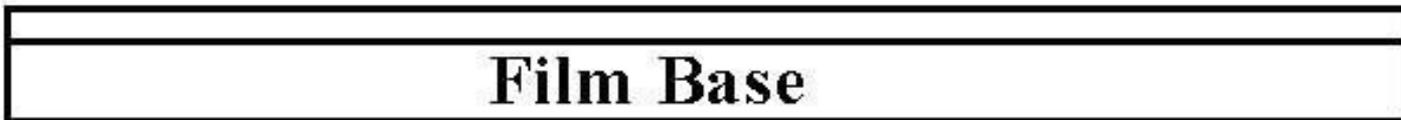
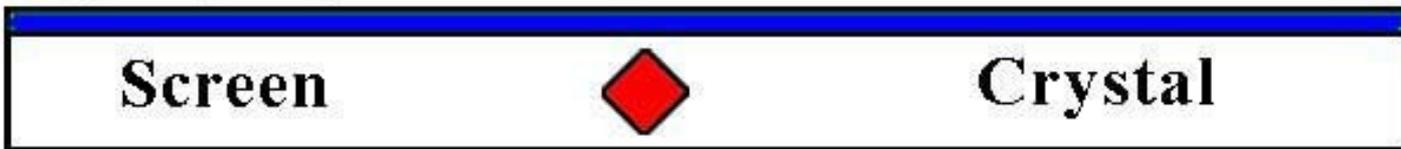
Therefore, some of the useful light is emitted in a direction away from the film and is lost.

The reflective layer redirects a portion of this light back towards the film where it is used to help create the latent image.

This process helps increase screen speed but in doing so, the overall image resolution is reduced as noted in the next diagram.

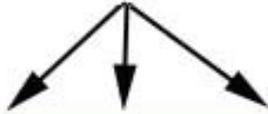
Intensifying Screen Construction:

Reflective Layer

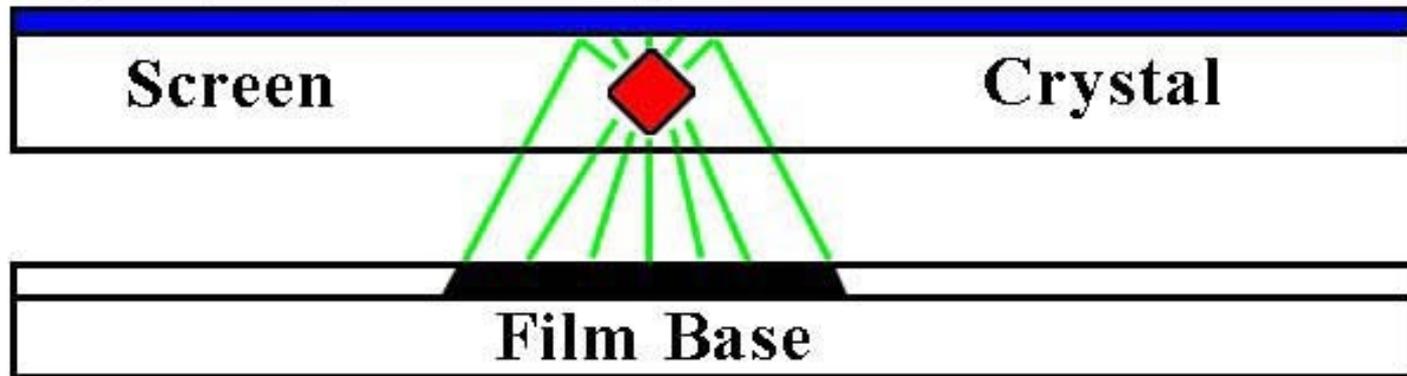


Intensifying Screen Construction:

Reflective Layer



When the x-ray strikes the phosphor (crystal), light is emitted isotropically. Light that is emitted away from the film is reflected back towards the film emulsion thus increasing screen speed. However, a loss of detail occurs because this process spreads the patient information over a wider area of the film emulsion.



Intensifying Screen Construction:

- The **screen phosphor layer** contains high atomic number fluorescent crystals that facilitate the absorption of the exit beam.

Modern rare earth (RE) intensifying screens are primarily made of compounds that contain lanthanum and gadolinium.

Some screens may also be made of terbium and yttrium compounds.

Intensifying Screen Construction:

- The surface of the phosphor layer is covered with a tough plastic called the **protective coat or tough coat (T-coat)**.

It is designed to provide resistance to abrasion and waterproofing.

It is approximately 20 to 25 micrometers thick.

The T-coat is completely clear to ensure that light emitted by the screen phosphors is not attenuated.

The film comes in physical contact with the T-coat within the cassette.

Light Emission:

- **Luminescence** occurs when a material emits visible light in response to some outside stimulation.
- The two types of luminescence are as follows:
 1. **Fluorescence** occurs when the material only emits light during stimulation.

This is desirable for intensifying screen phosphors.

2. **Phosphorescence** occurs when the material continues to emit light following stimulation.

This is objectionable for screen phosphors and is called screen lag or afterglow if it occurs.

Light Emission:

- The process of producing light within the intensifying screen is very similar to characteristic x-ray production within the x-ray tube.
- When the screen phosphors are stimulated by an x-ray, the outer shell electrons absorb this energy and are partially dislodged from their normal position in the electron cloud.
- This creates a temporary hole within the atom.
- The dislodged electron will then fall back into its original position and release the absorbed energy in the form of a light photon (electromagnetic radiation).
- A single x-ray will create thousands of light photons in this manner.

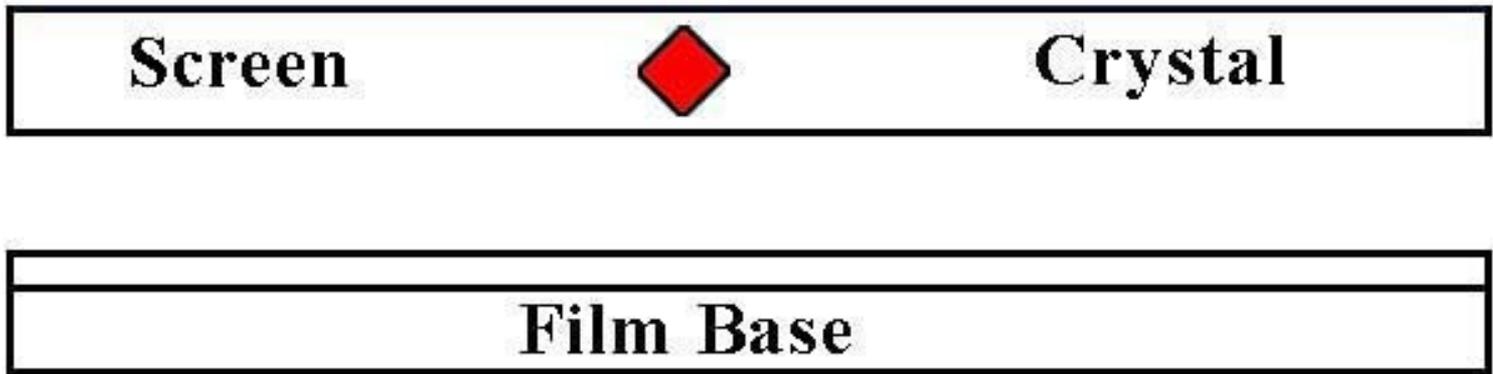
Light Emission:

- **Spectral matching** is the process of matching the light sensitivity of the film to the wavelength (color) of the light that is emitted by the screen.
- Rare earth intensifying screens can either emit a green or a blue-violet light.
- Therefore, green or blue-violet sensitive film must be used accordingly.

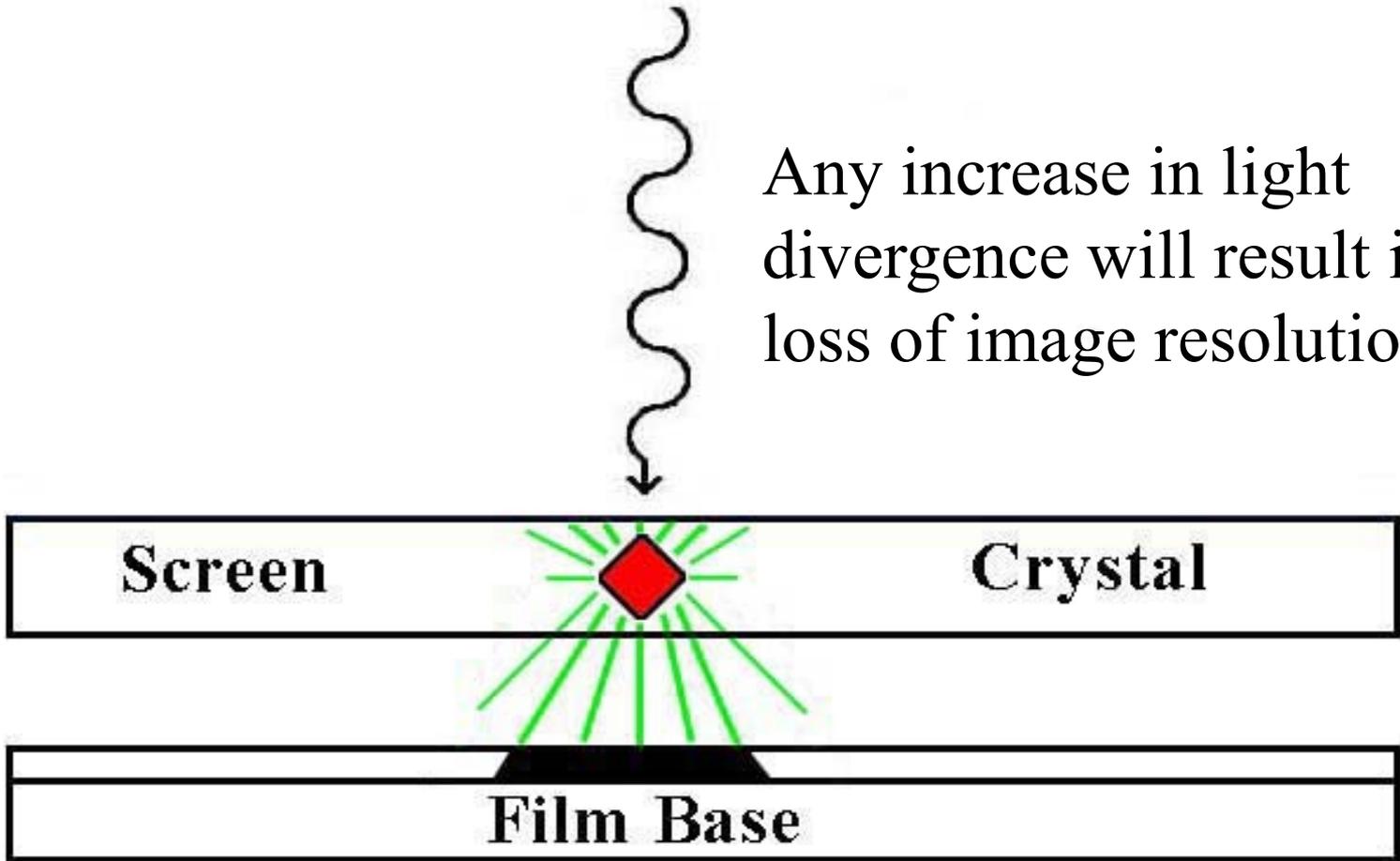
Factors Affecting Screen Speed & Resolution:

- **Resolution** refers to the maximum number of line pair/mm that a screen is capable of recording.
- The process of transferring information from the exit beam to the screen and then to the film decreases resolution.
- Anytime you have an increase in light photon divergence, you will have a decrease in resolution.
- The diagram on the next slide illustrates this concept.

Light Photon Divergence vs. Screen Resolution:



Light Photon Divergence vs. Screen Resolution:



Factors Affecting Screen Speed & Resolution:

- As mentioned earlier, some screens employ the use of a **reflective layer**.
- This mirror-like layer will reflect light photons diverging away from the film back towards the film.
- This process will increase screen speed but it will sacrifice image resolution by increasing penumbra.

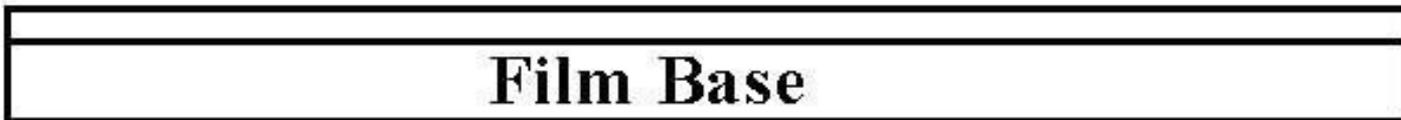
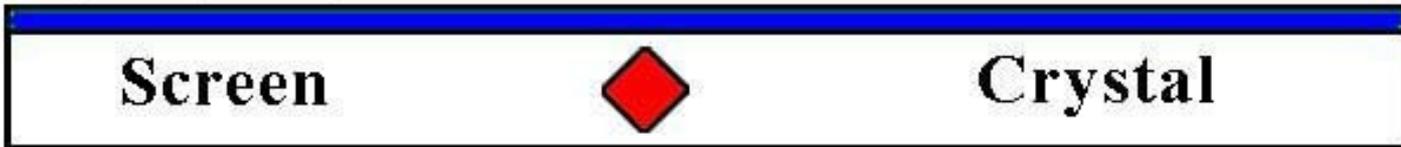
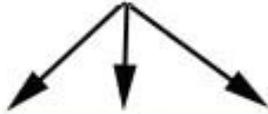
Penumbra is the term employed to describe image unsharpness.

Umbra, on the other hand, describes image sharpness.

- Ultimately, the reflective layer will cause more light divergence and thus, more penumbra.
- The diagram on the next slide will illustrate this process.

Factors Affecting Screen Speed & Resolution:

Reflective Layer

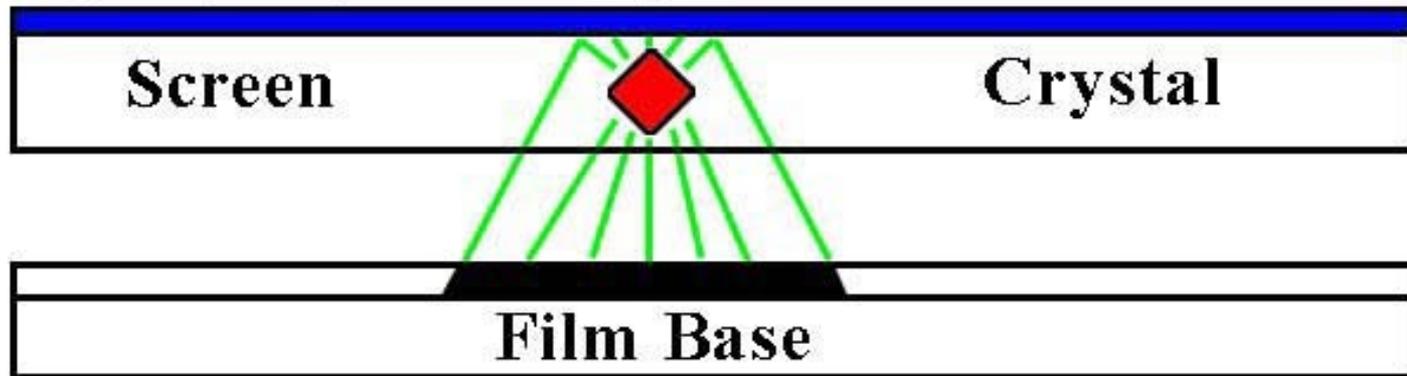


Factors Affecting Screen Speed & Resolution:

Reflective Layer



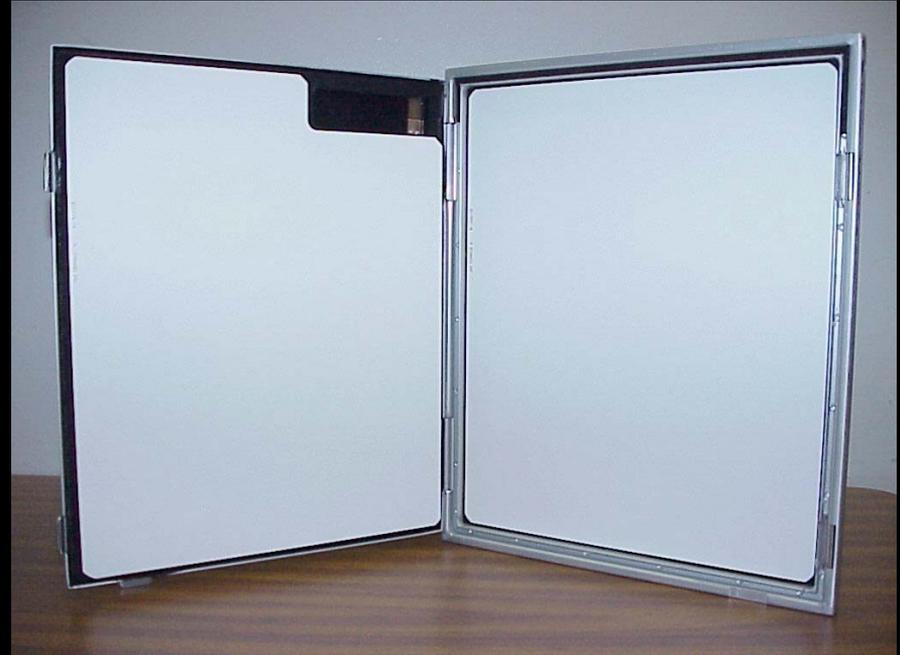
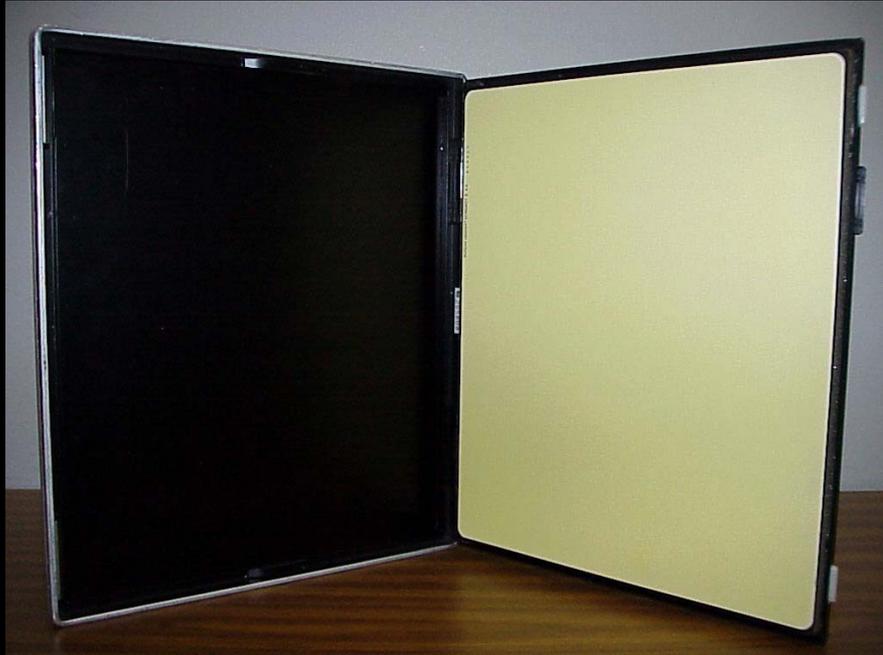
When the x-ray strikes the phosphor (crystal), light is emitted isotropically. Light that is emitted away from the film is reflected back towards the film emulsion thus increasing screen speed. However, a loss of detail occurs because this process spreads the patient information over a wider area of the film emulsion.



Factors Affecting Screen Speed & Resolution:

- **Dyes** are incorporated into some screens in order to reduce screen speed and increase resolution.
- They are often employed in extremity cassettes.
- Dyes absorb light photons that are emitted at large angles to the film.
- This light divergence results in a decrease in detail on the image because the patient information is “spread” over a wider area of the film.
- Dyes ultimately reduce screen speed and therefore, higher technical factors must be employed to produce the proper film density.
- The addition of a dye will increase patient dose.

Screens With & Without Dyes Added:

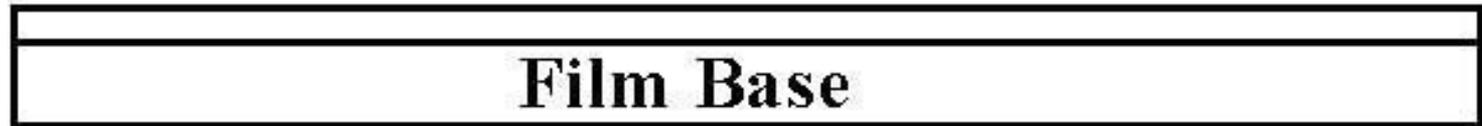


The addition of a dye will increase image resolution but a higher dose is required which increases patient dose.

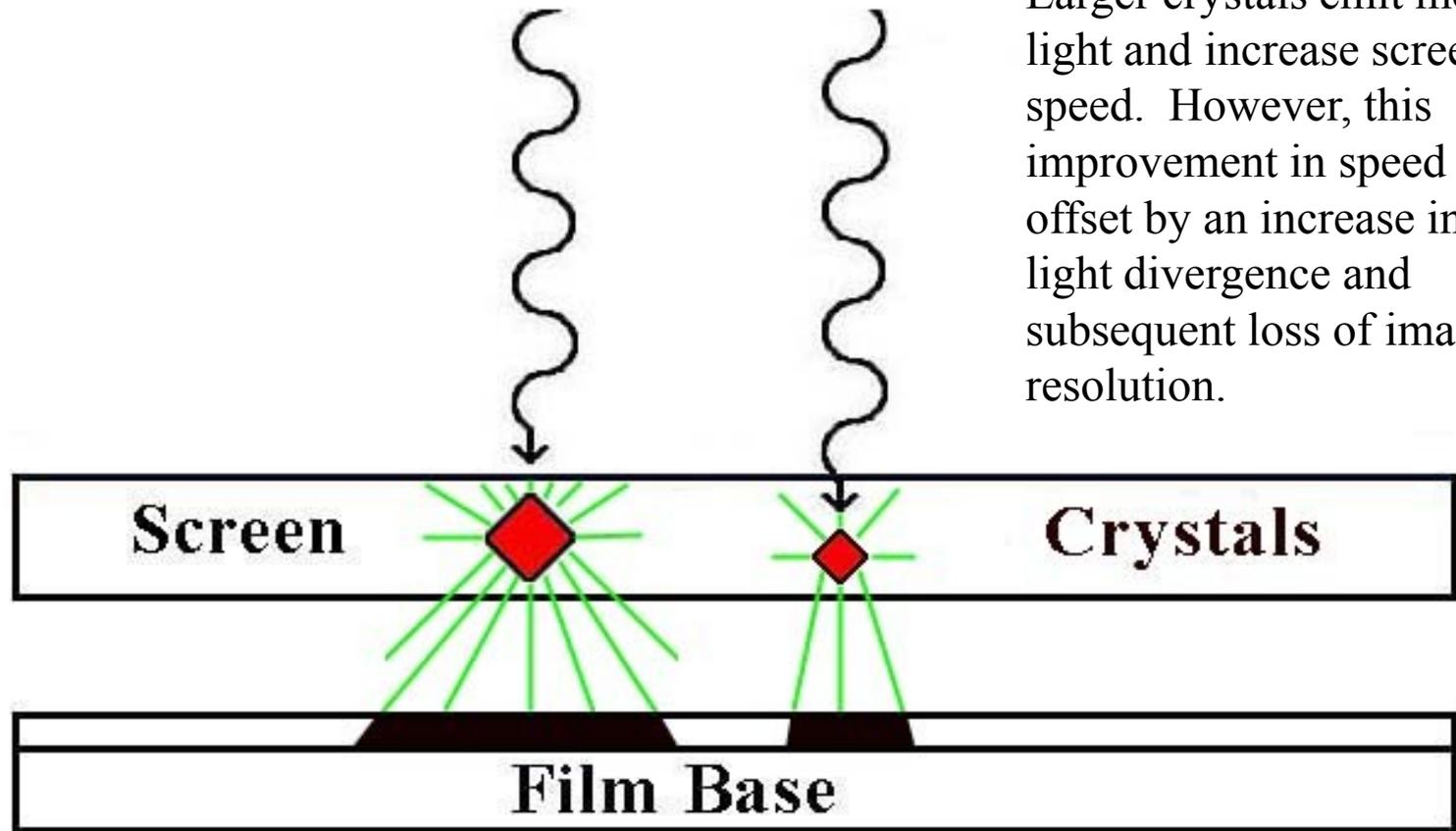
Factors Affecting Screen Speed & Resolution:

- Phosphor crystal size also plays a role in overall screen speed and resolution.
- This is a somewhat antiquated means to increase screen speed.
- Larger crystals will increase the absorption efficiency of screens but sacrifice image resolution due to the increase in penumbra production.
- The diagram on the next slide illustrates this process.

Crystal Size vs. Speed & Resolution:



Crystal Size vs. Speed & Resolution:



Larger crystals emit more light and increase screen speed. However, this improvement in speed is offset by an increase in light divergence and subsequent loss of image resolution.

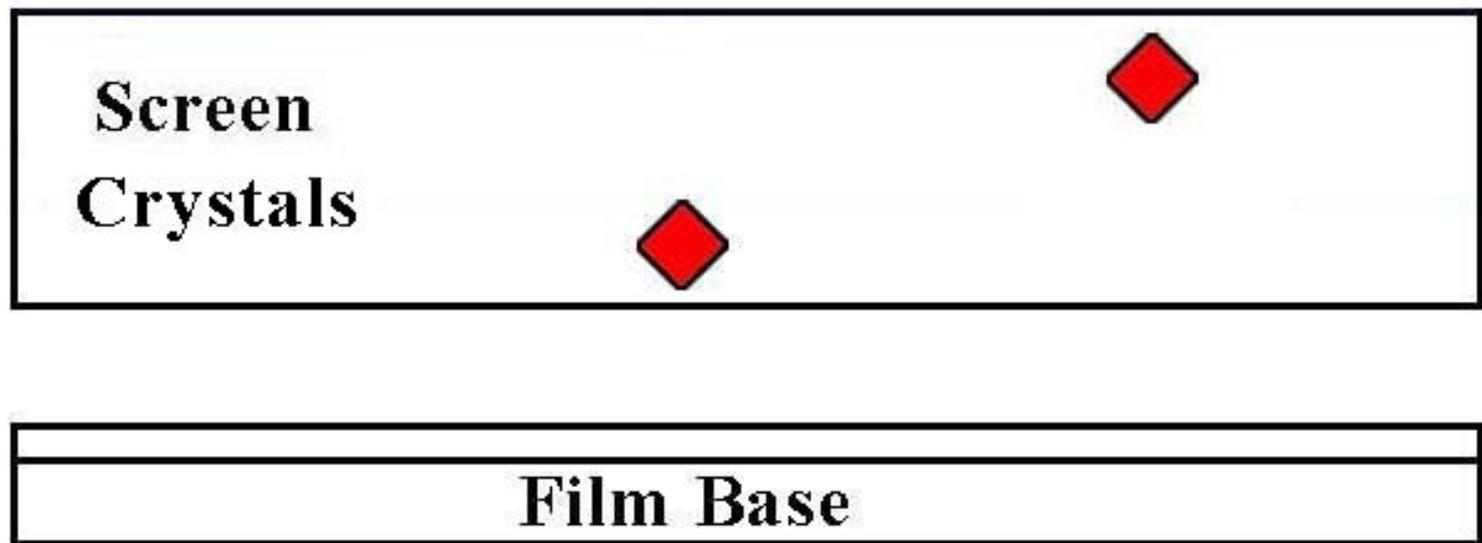
Factors Affecting Screen Speed & Resolution:

- Increasing the thickness of the phosphor layer is another method that manufacturers can employ to increase screen speed.

This will effectively increase the absorption efficiency of the screen as there will be an increase in crystal concentration per cubic millimeter of emulsion.

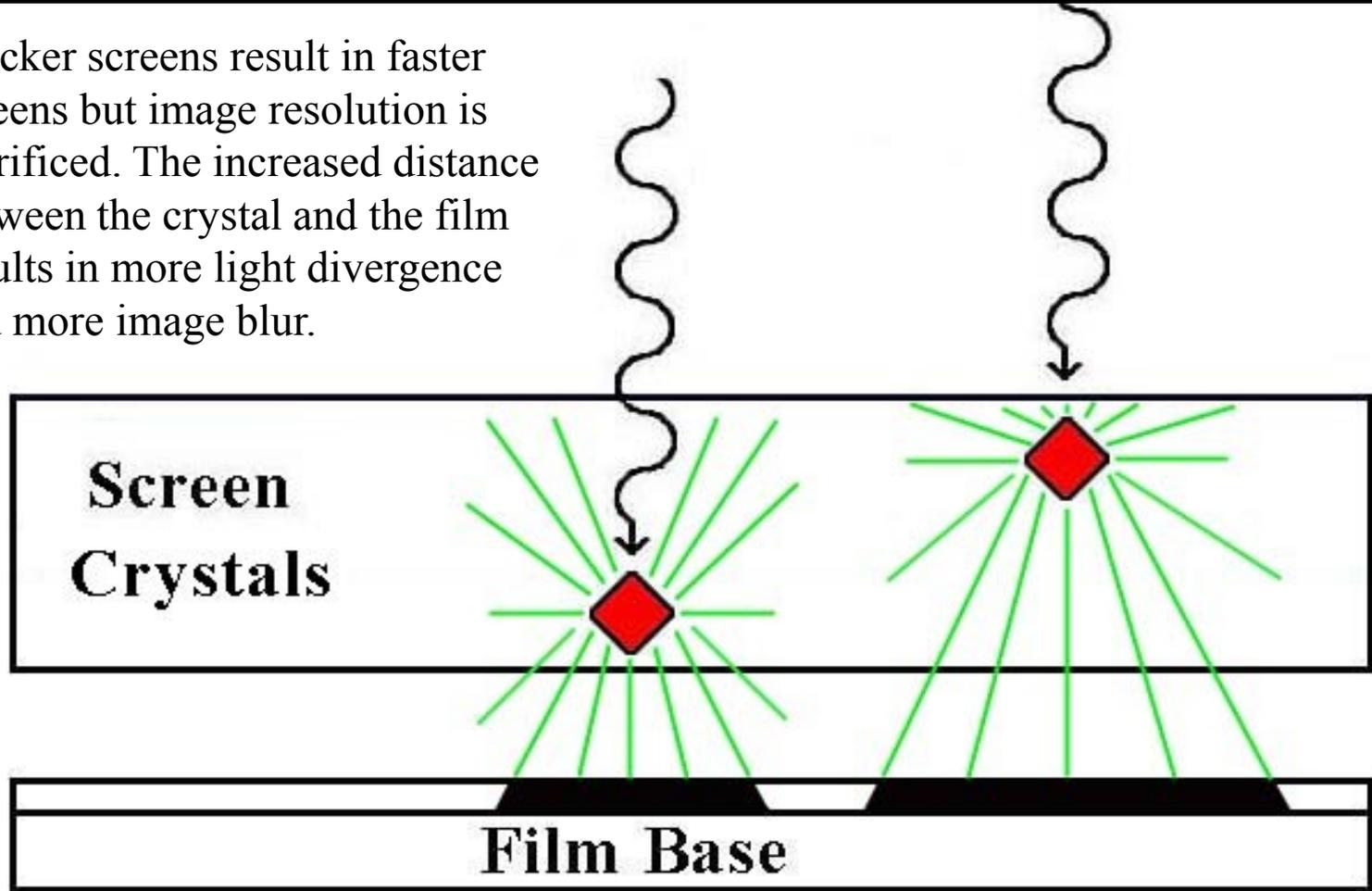
- Once again, however, there is a subsequent loss of image resolution.
- Crystals are essentially placed further from the film and this results in more light divergence and thus, more penumbra or image blur.
- The diagram on the next slide illustrates this process.

Screen Thickness vs. Speed & Resolution:



Screen Thickness vs. Speed & Resolution:

Thicker screens result in faster screens but image resolution is sacrificed. The increased distance between the crystal and the film results in more light divergence and more image blur.



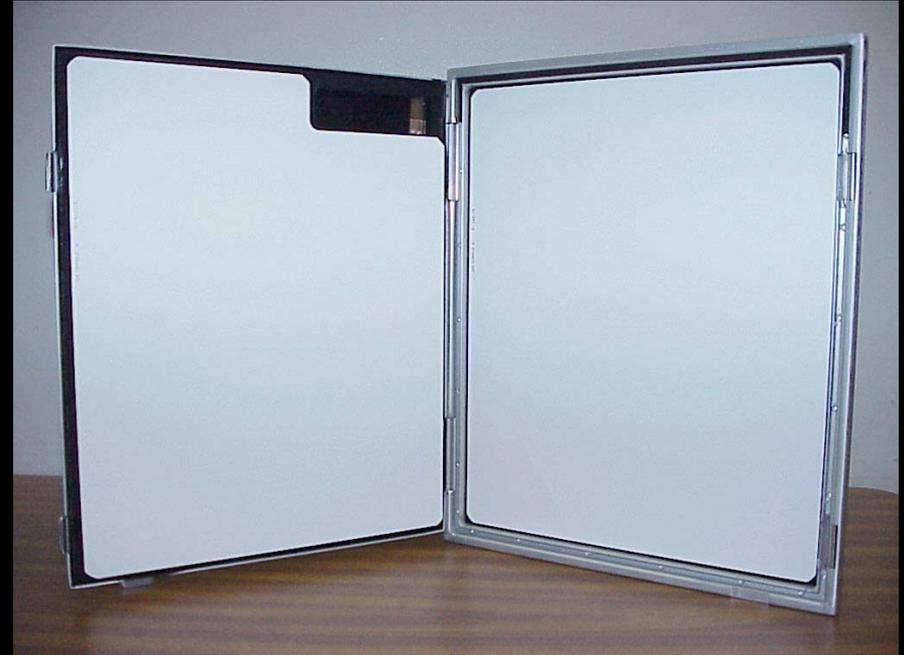
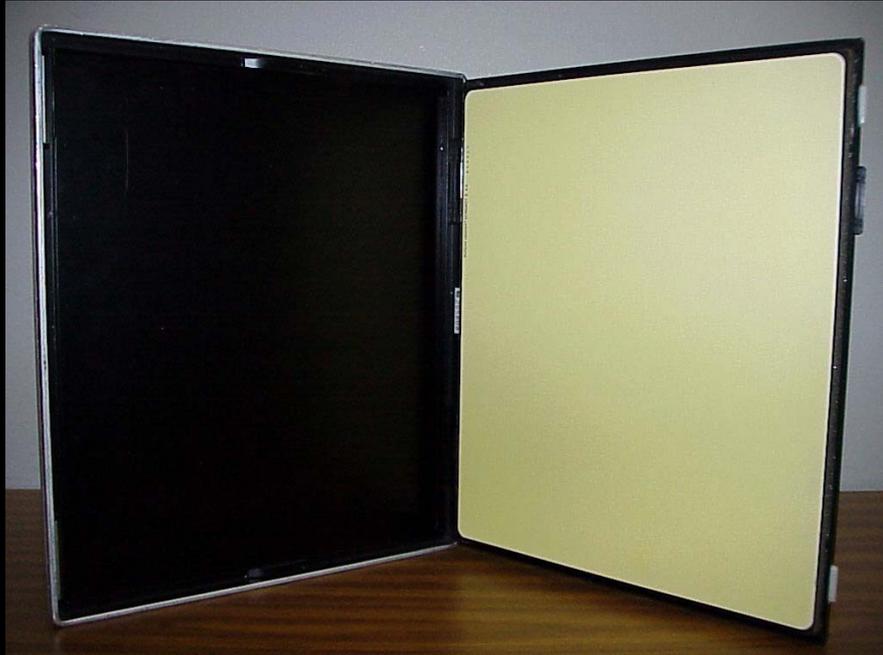
Factors Affecting Screen Speed & Resolution:

- Manufacturers can also change the number of screens that a cassette can possess.
- For example, some extremity cassettes only have one screen.
- These special cassettes require the use of single emulsion film as opposed to **duplitized film** (double emulsion).

This will greatly reduce the overall speed of the cassette and thus result in a higher patient dose.

However, image resolution is enhanced due to less blur.

Factors Affecting Screen Speed & Resolution:



Single Screen with a Dye
Produces Higher Resolution

Double Screen

Absorption vs. Conversion Efficiency:

- **X-ray absorption efficiency** is the ability of the crystals within the phosphor layer to absorb x-ray energy.
- Rare earth screens absorb approximately 50 to 60% of the exit beam via the photoelectric effect.

For comparison, antiquated calcium tungstate screens have an absorption efficiency of between 20 to 40%.

Absorption vs. Conversion Efficiency:

- The **K-edge effect** of RE screens refers to the binding energy of the k-shell electrons and its effect on x-ray absorption and ultimately light production.

Binding energy is the amount of energy required to hold an electron in its orbit around the nucleus of an atom and it is measured in kiloelectron volts (keV).

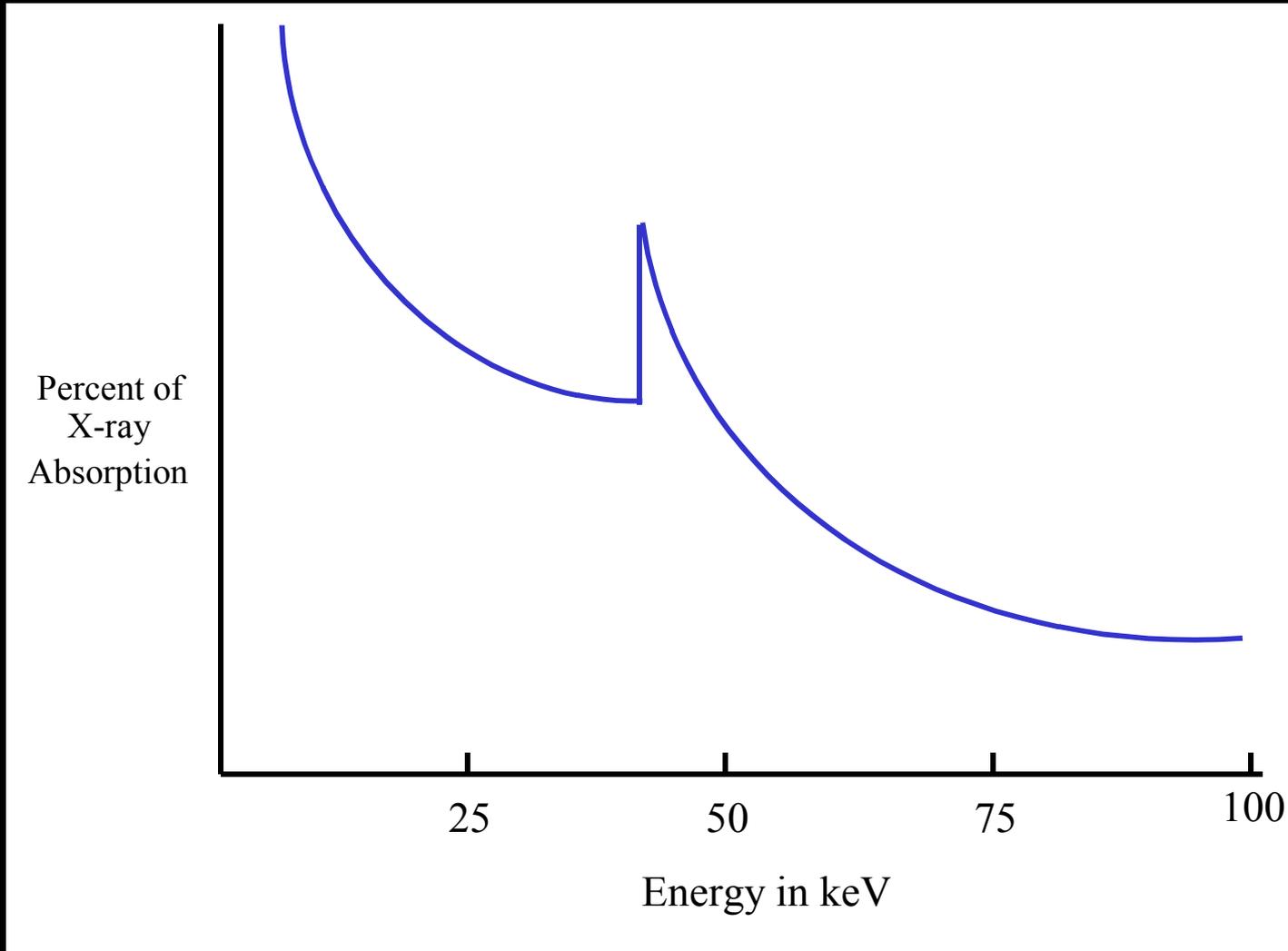
Using the Bohr atomic model, the K-shell is the innermost shell and since it is closest to the nucleus, it has the highest binding energy of all of the shells.

Absorption vs. Conversion Efficiency:

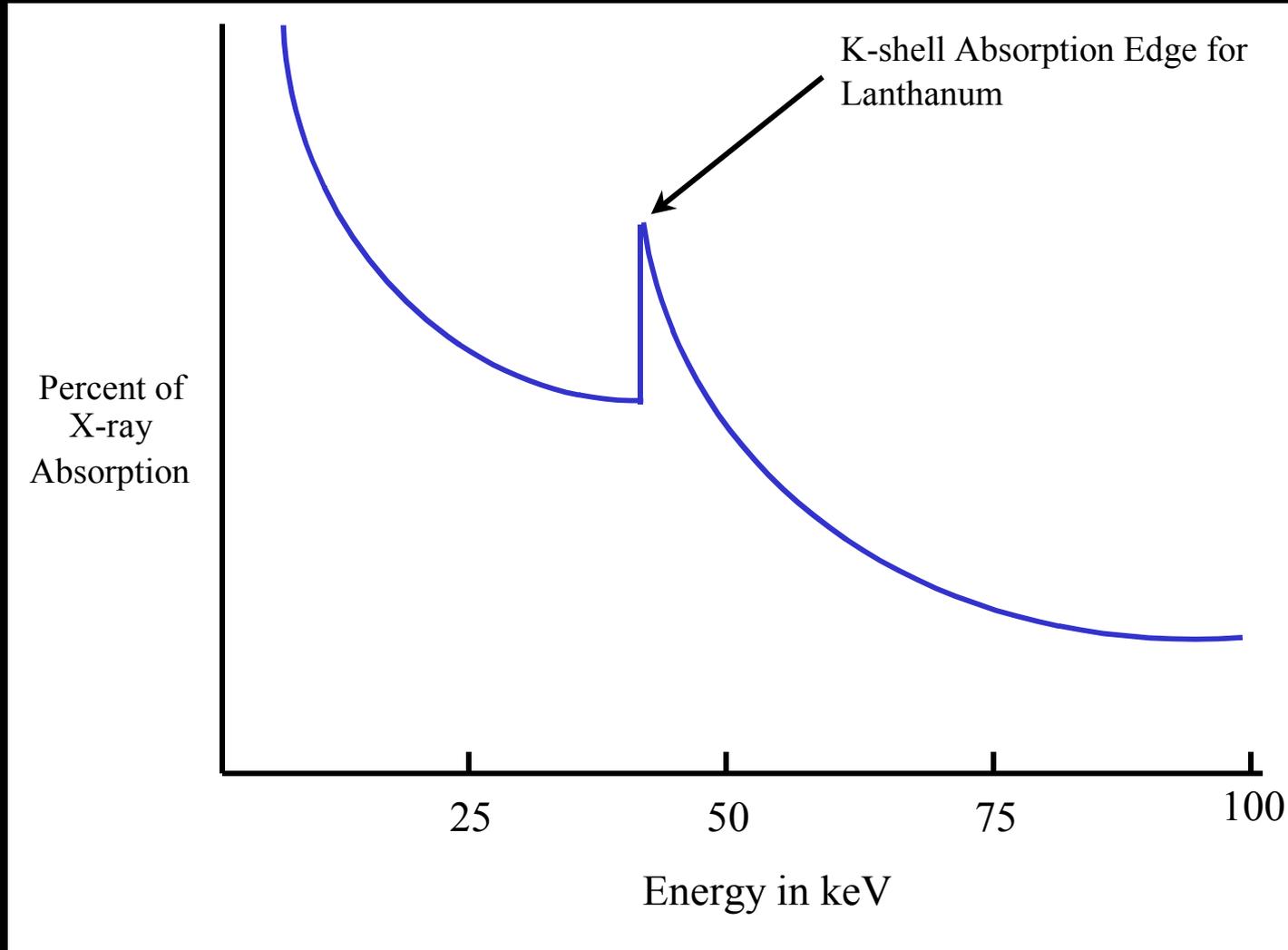
- Calcium tungstate screens have a K-edge binding energy of 69 keV.
It would take an incident x-ray possessing at least 69 keV to ionize this electron.
- The K-edge binding energy for the RE phosphor, lanthanum is 39 keV.
- The average energy of the primary beam at 100 kVp is approximately 33 keV (one third of the kVp).
- The average energy of 33 keV is much closer to the K-edge of lanthanum (39) than that of calcium tungstate (69).

The close proximity of these energy levels results in higher x-ray absorption and more light production.

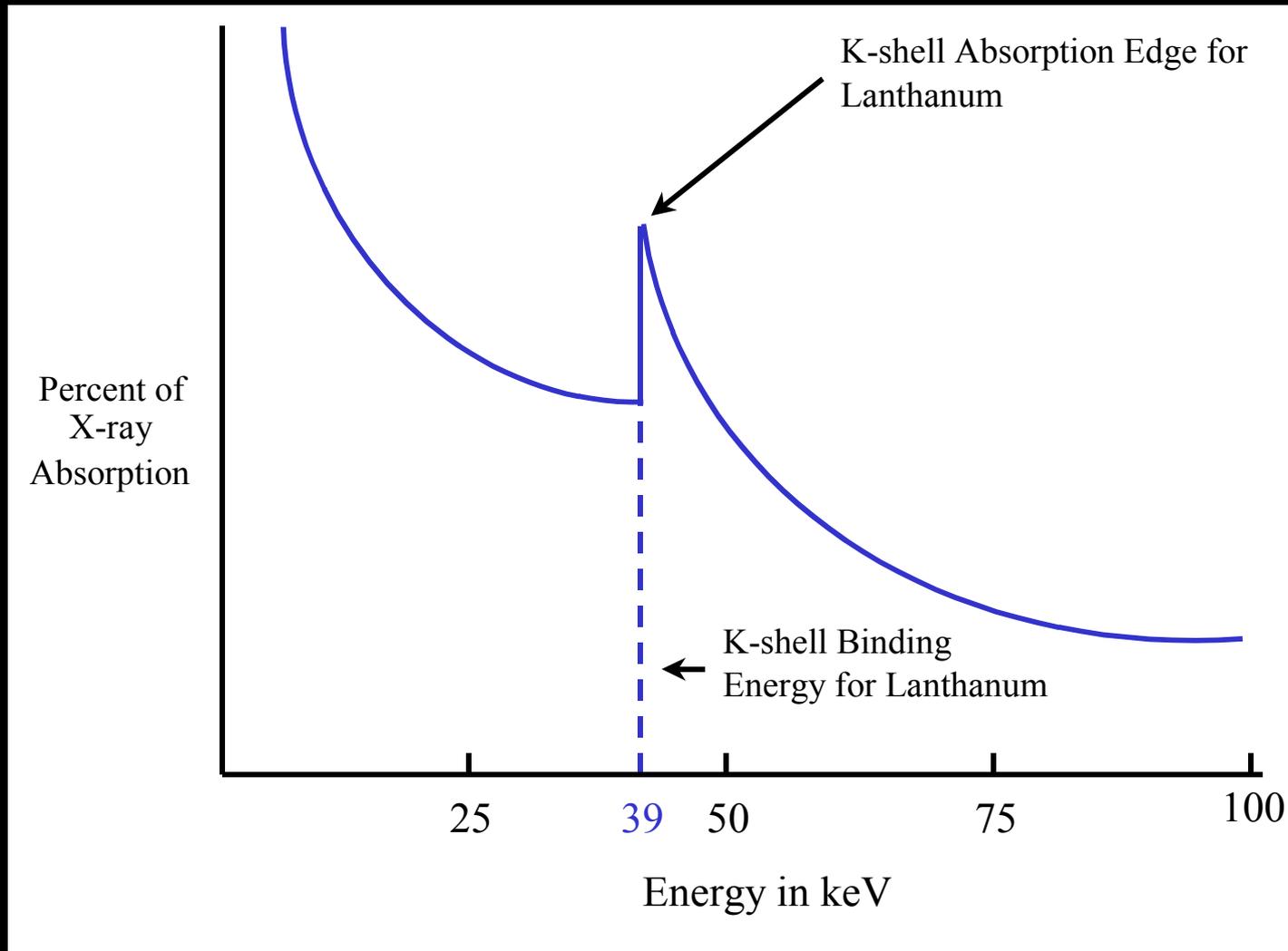
K-edge Effect of RE Screens:



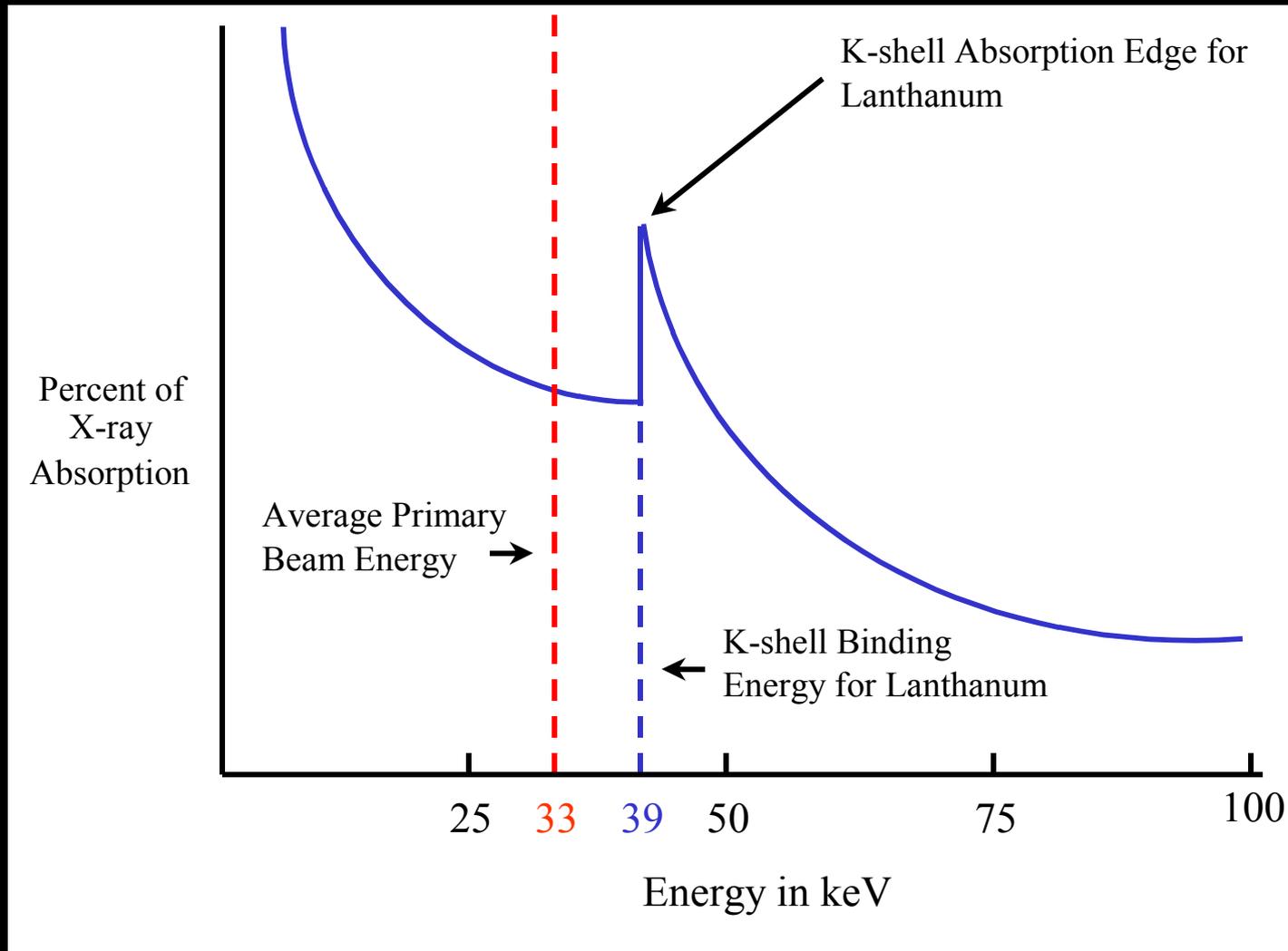
K-edge Effect of RE Screens:



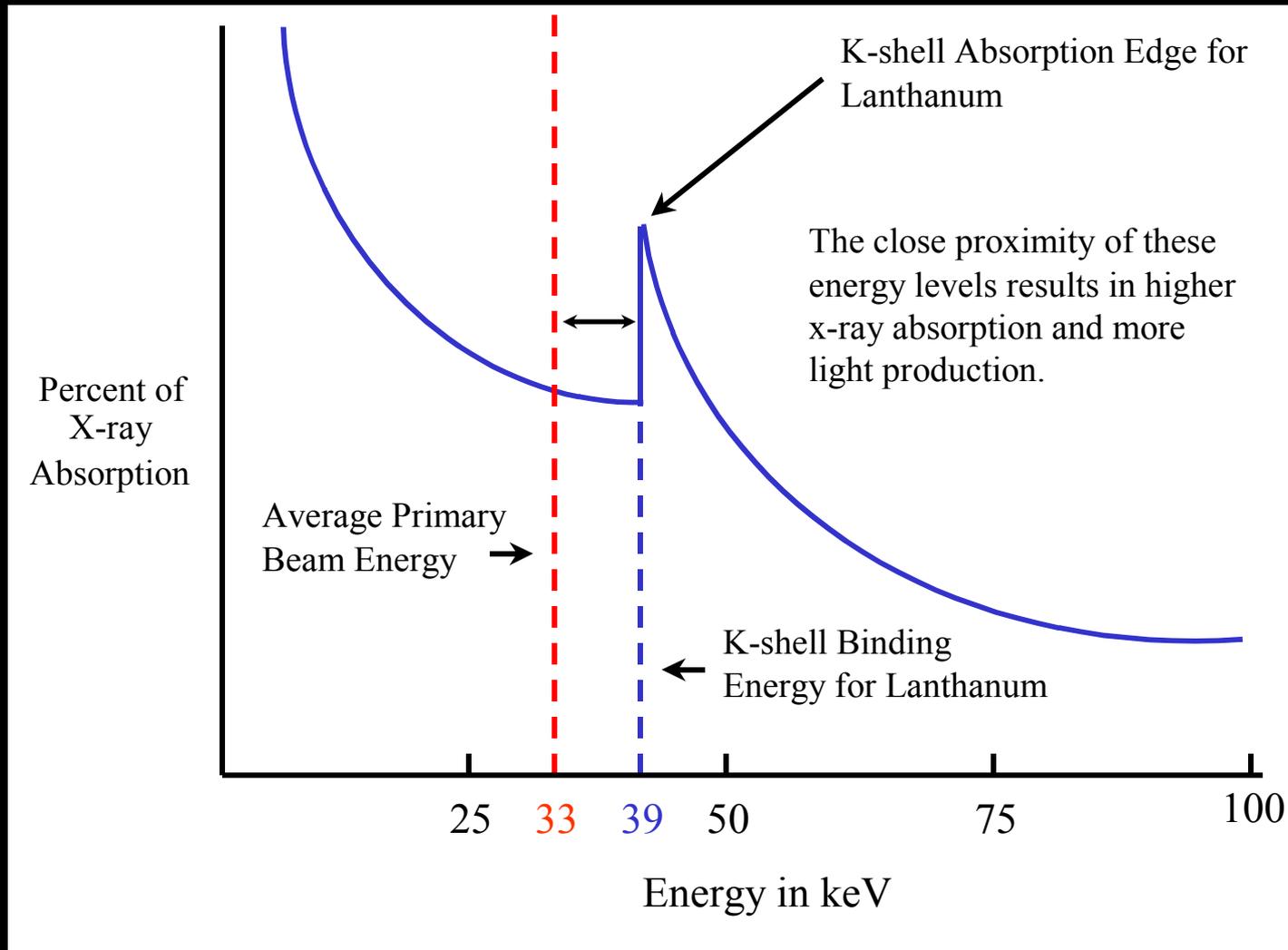
K-edge Effect of RE Screens:



K-edge Effect of RE Screens:



K-edge Effect of RE Screens:



Absorption vs. Conversion Efficiency:

- **Phosphor density** also plays a role in absorption efficiency.
- The physical shape of the RE phosphors allows them to be “packed” into a smaller area than calcium tungstate phosphors.
- This increase in volume will result in more exit beam absorption.
- To summarize, RE screens possess a lower K-shell absorption edge and a higher density that combine to enhance exit beam absorption via the photoelectric effect and this ultimately results in more light photon emission.

Absorption vs. Conversion Efficiency:

- **X-ray conversion efficiency** is the ability of the phosphors to convert x-ray energy into light.
- As this ability increases, the patient dose decreases.
- Rare earth phosphors have a nearly 20% conversion efficiency.
The remaining 80% is lost as heat.
For comparison, calcium tungstate screens only have a 5% conversion efficiency with 95% lost as heat.
- The superior absorption efficiency (60%) and conversion efficiency (20%) of RE screens results in a 2 to 8 fold reduction in patient dose over calcium tungstate screens while maintaining comparable resolution.

kVp vs. Screen Speed:

- kVp has the ability to affect the quantity of light production in intensifying screen phosphor materials.
- Calcium tungstate crystals emit light photons that have approximately 3 eV of energy each.

The 3 eV photon will produce a blue-violet light.

Even though kVp changes, the phosphor crystal will always emit a 3 eV light photon thus ensuring that the crystal will always produce a blue-violet light.

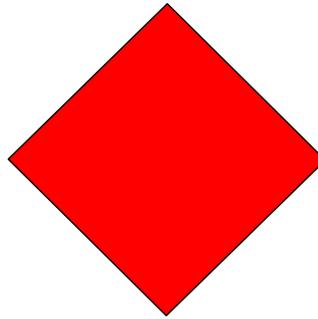
If the energy of the light photon were to change with changes in kVp, the screen would emit a different color light and spectral matching would be lost.

kVp vs. Screen Speed:

- If a calcium tungstate crystal is struck by a 60 kVp (60,000 volts) x-ray, its energy would be divided into 20,000 light photons at 3 eV each if 100% of the incident x-ray energy were absorbed.
- However, as we learned earlier, calcium tungstate crystals can only absorb 5% of the incident x-ray energy.
- Therefore, only 1,000 light photons at 3 eV each would be produced according to the following calculation:
$$20,000 \times 5\% \text{ absorption efficiency} = 1,000 \text{ light photons at } 3 \text{ eV each}$$
- The remaining 95% of the incident energy of the x-ray is lost as heat according to the law of the conservation of energy.
This law states that energy can neither be created nor destroyed but it can change from one form to another.
- The diagram on the next slide illustrates this process.

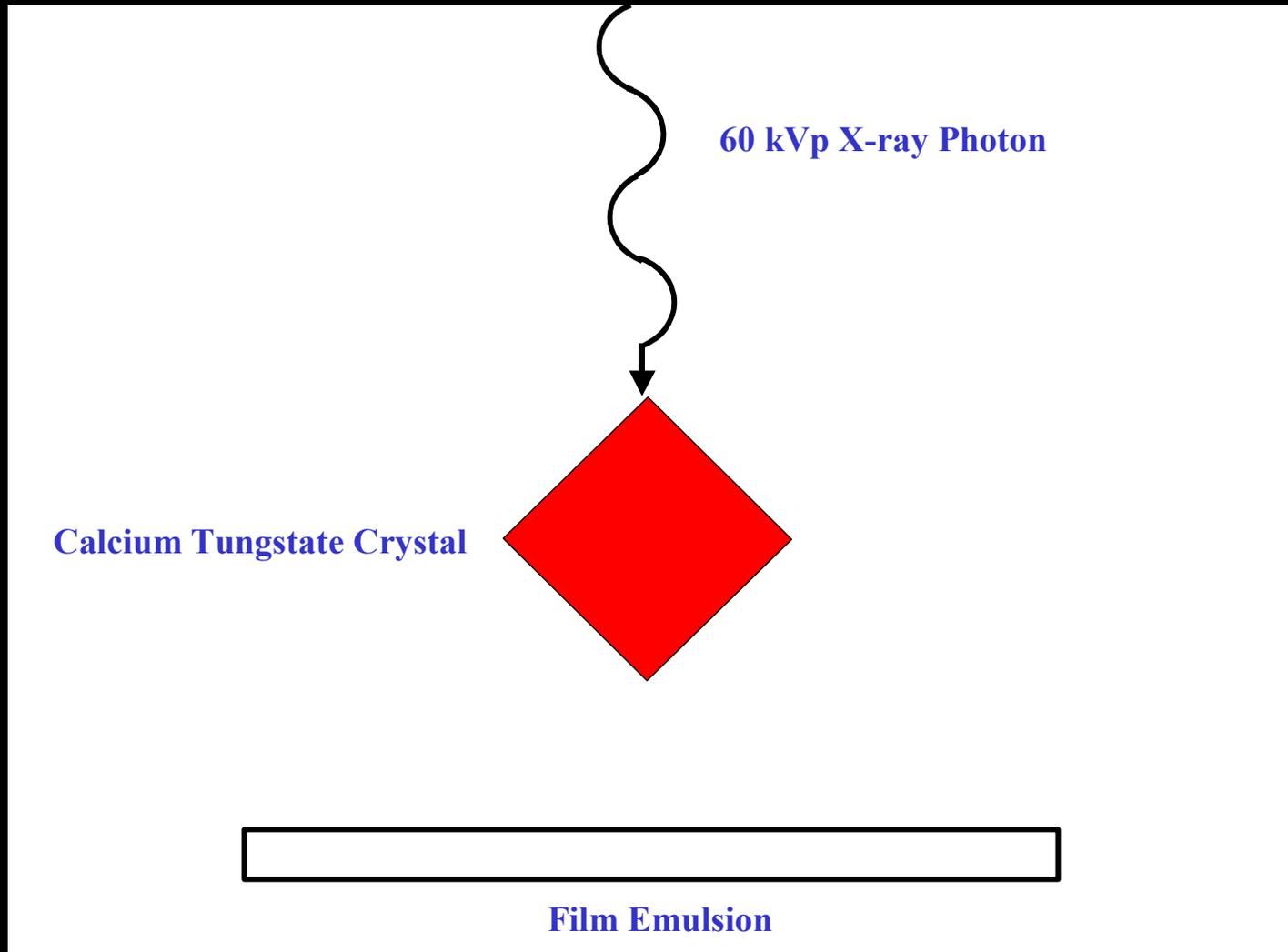
kVp vs. Screen Speed:

Calcium Tungstate Crystal

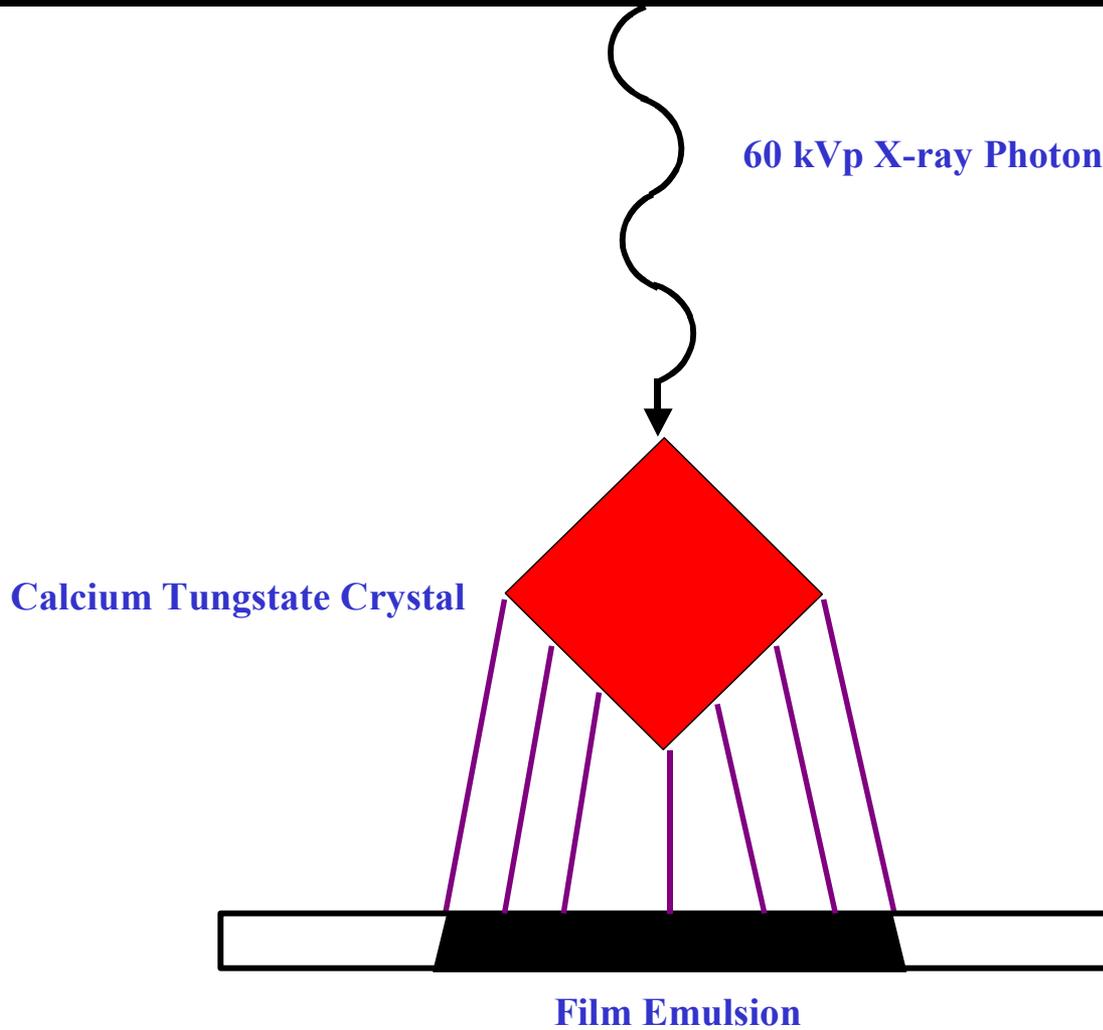


Film Emulsion

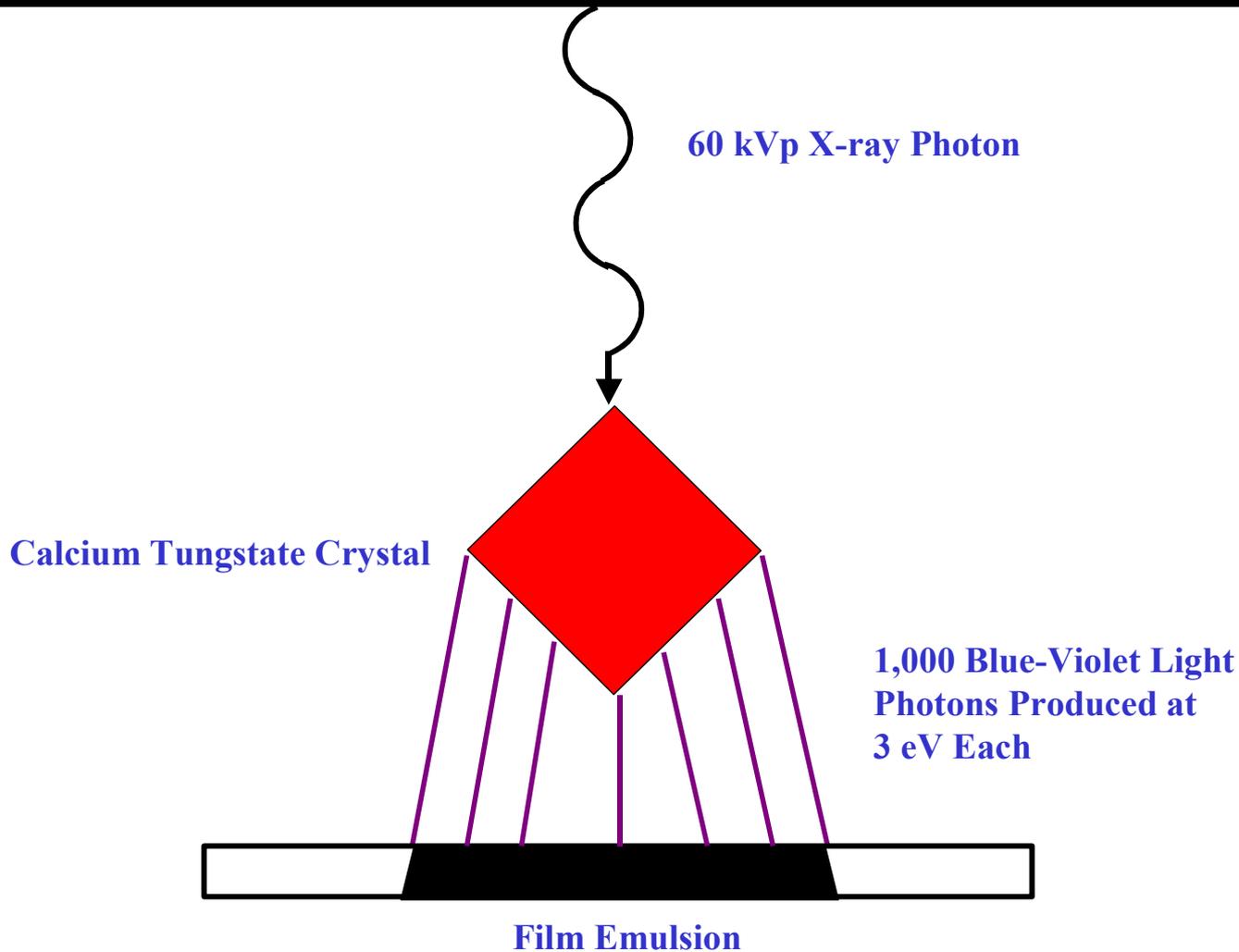
kVp vs. Screen Speed:



kVp vs. Screen Speed:



kVp vs. Screen Speed:



kVp vs. Screen Speed:

- To take this a step further, if another calcium tungstate crystal is struck by a 120 kVp x-ray, 2,000 light photons would be produced each at 3 eV each.

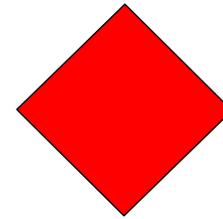
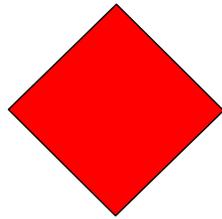
$120,000 \text{ Volts} / 3 \text{ eV} = 40,000 \text{ light photons at } 3 \text{ eV each.}$

$40,000 \times 5\% \text{ absorption efficiency} = 2,000 \text{ light photons produced at } 3 \text{ eV each.}$

- As kVp is increased, the quantity of the light produced by the screen is increased thus making the screen glow brighter.
- As you can see, light photon production is kVp dependent.
- This concept is illustrated on the next slide.

kVp vs. Screen Speed:

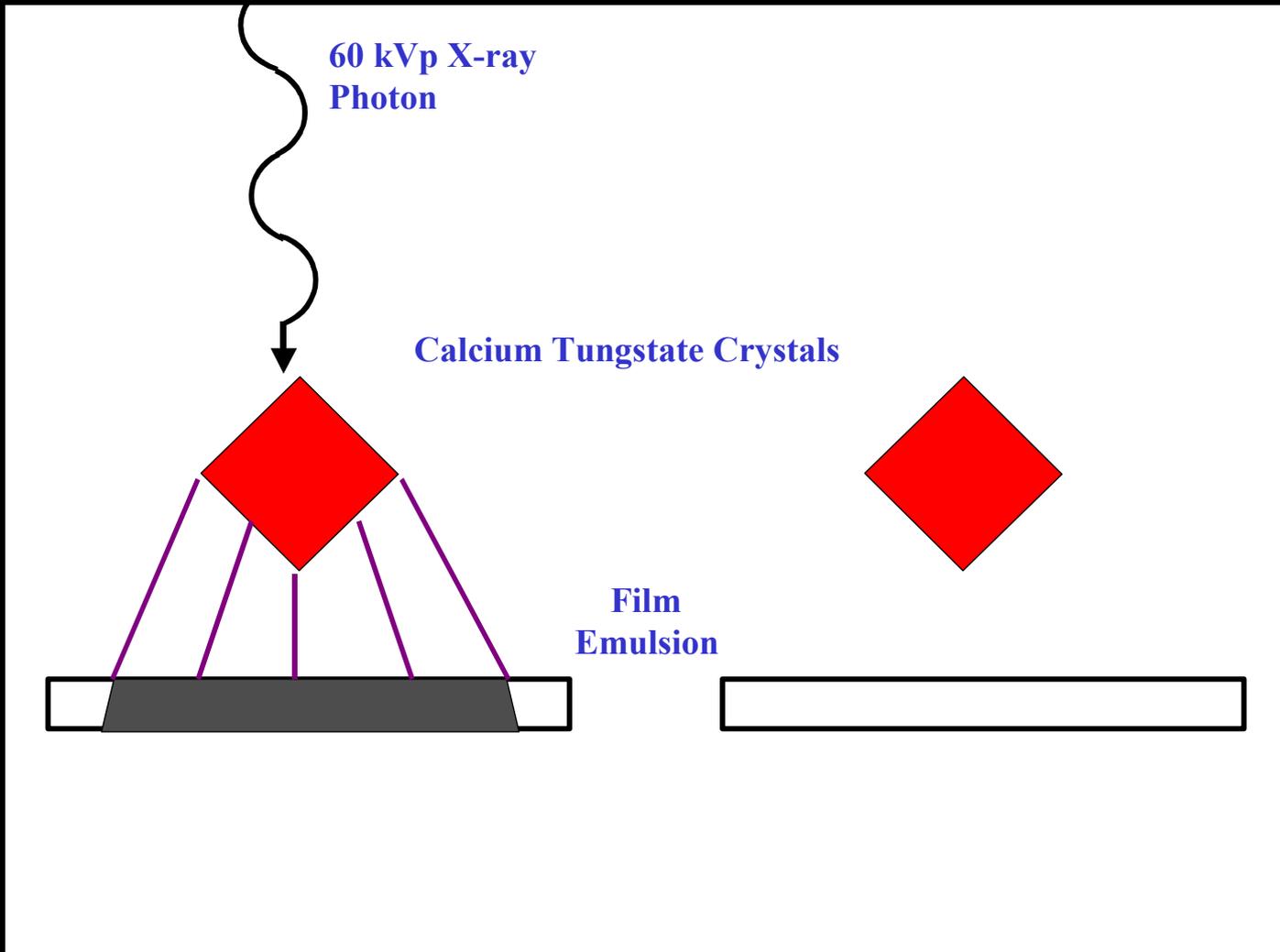
Calcium Tungstate Crystals



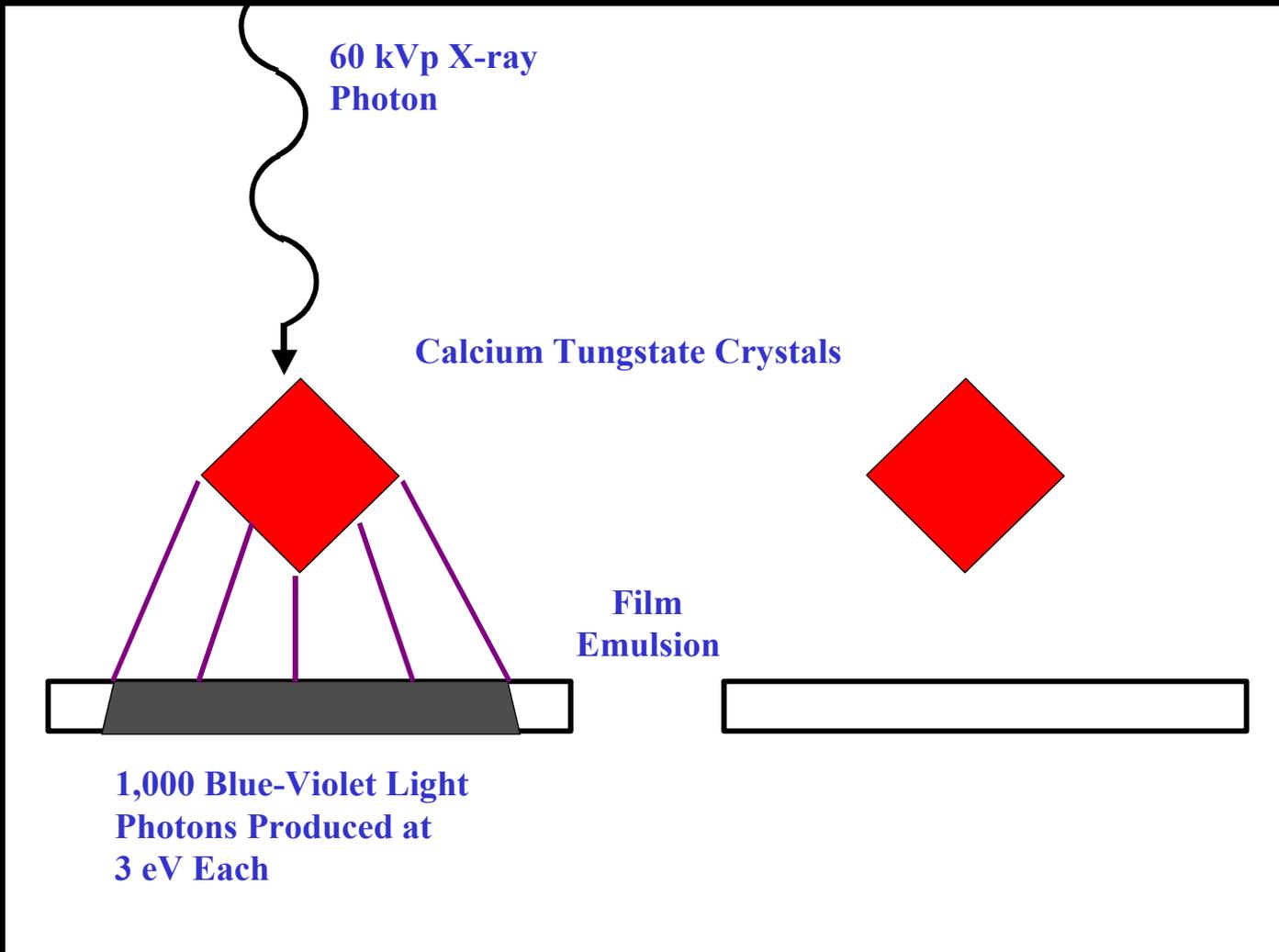
**Film
Emulsion**



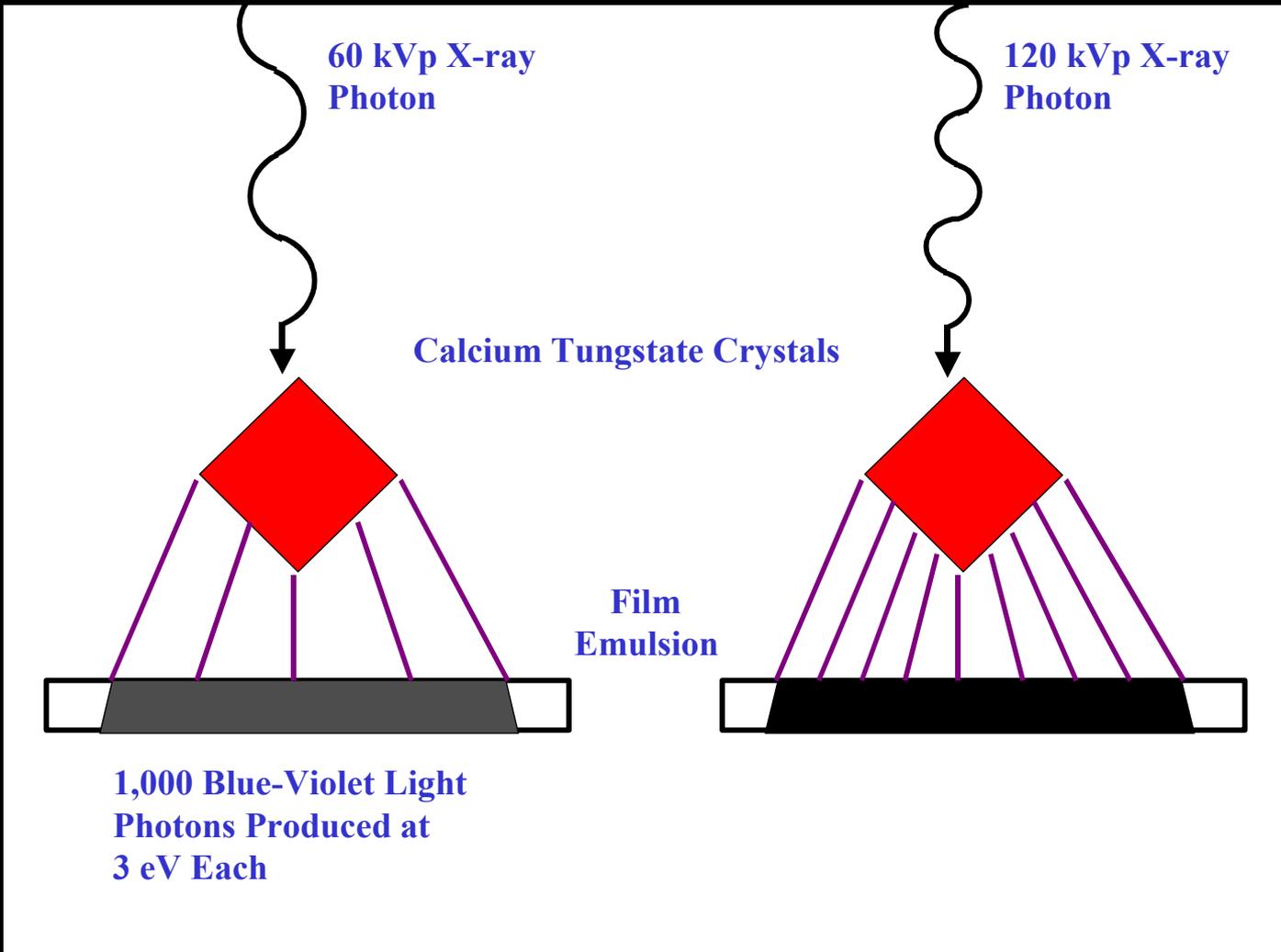
kVp vs. Screen Speed:



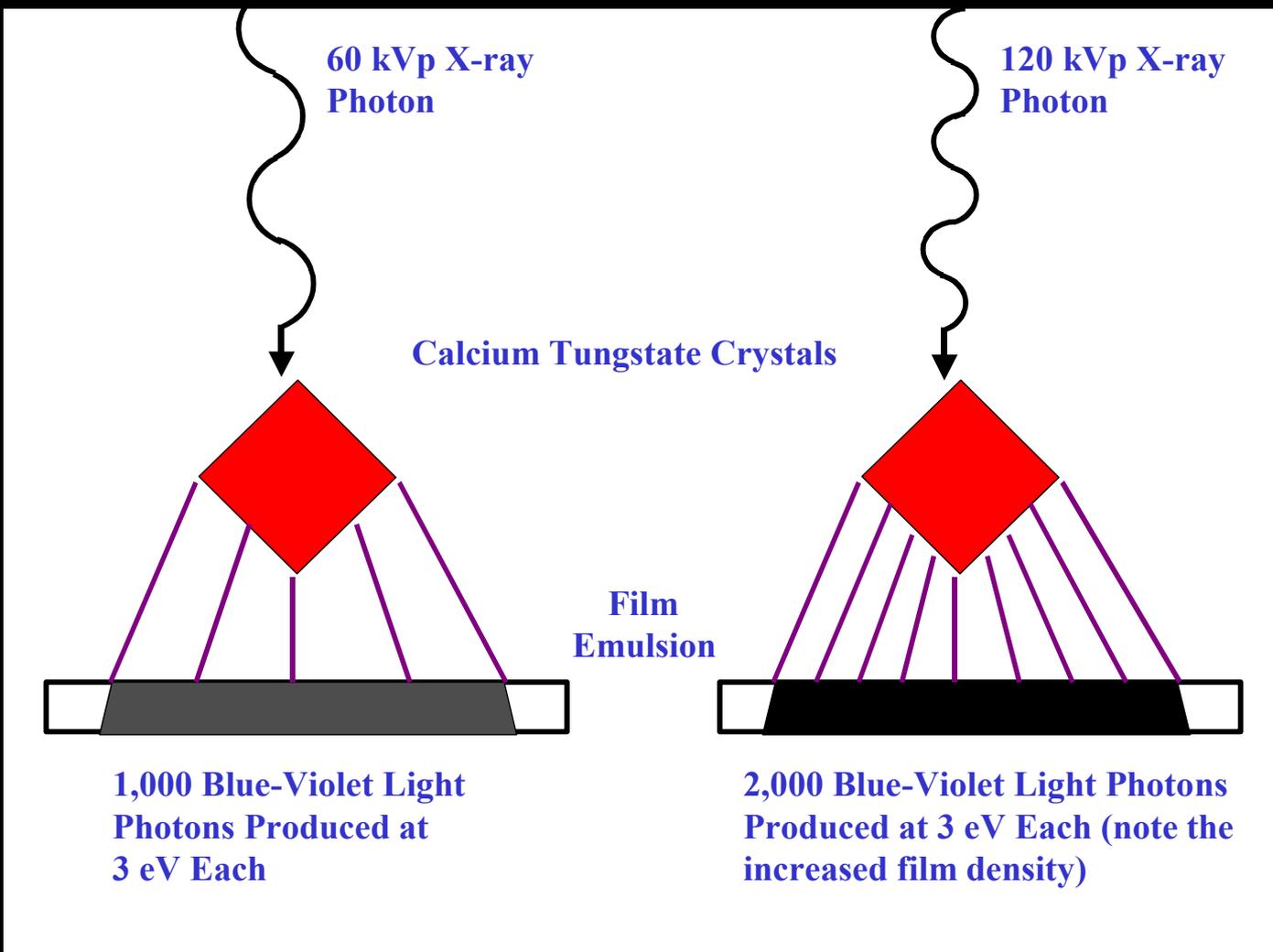
kVp vs. Screen Speed:



kVp vs. Screen Speed:



kVp vs. Screen Speed:



Relative Speed (RS) System:

- **Screen speed** is defined as the ability emit light and ultimately film density following exposure to x-rays.
- Faster screens will produce more light and therefore require less dose to produce optimal film densities.

Faster screens will reduce patient dose but image resolution is, unfortunately, sacrificed.

- The **relative speed (RS) System** was designed to classify screens according to their speed.
- The system revolves around the antiquated calcium tungstate “Par” speed screen.

This was considered to be an average speed screen and was designated a value of 100.

Relative Speed (RS) System:

- When RE screens are paired with the appropriate film, their speed values are rated according to the following scale:

Screen Speed

50 to 100

200

400

600 to 800

1200

Descriptive Name

Extremity or Detail

Medium

Regular

High Speed

(This screen is not used due to the excessive levels of quantum mottle that are produced.)

Relative Speed (RS) System:

- A 100 RS film-screen combination would require four times more beam intensity to produce the same film density as a 400 RS film-screen combination.
- The increase in patient dose is offset by a decrease in quantum mottle and an increase in resolution.

Quantum mottle is caused because there is an insufficient quantity of x-rays striking the screen.

The net result is a grainy radiographic appearance.

This can occur with high RS film-screen systems as there is a significant reduction in requisite technique.

A decrease in screen speed and an increase in mAs will alleviate this issue.

Intensifying Screen Care:

- Screens should be cleaned once a month but this can be extended for as long as 2-3 months in slower departments.
- Traditionally, technologists employ the use of small 2 x 2" gauze sponges and a special electrostatic cleaning solution to properly clean screens.

This solution is specifically designed to not leave chemical residues on the surface of the screen or cause static charges to accumulate.

The screen should be allowed to thoroughly dry before it is closed.

- The following slide provides an example of the artifacts that can be produced by a dirty screen.

Intensifying Screen Care:



The numerous white specks on this radiograph are the result of artifacts found on the screen. Screen artifacts produce areas of decreased density because the light that would normally be emitted by the screen is blocked by the artifact. The black densities were produced by algae in the wash tank during processing.

Intensifying Screen Care:

- The **wire mesh test** can be employed to determine proper film-screen contact.
- Improper contact can occur as the result of a warped cassette or a worn out pressure pad.
- Following exposure of the test device, you should stand back 2 to 3 meters from the film and look for areas that appear blurry and have a decrease in density.

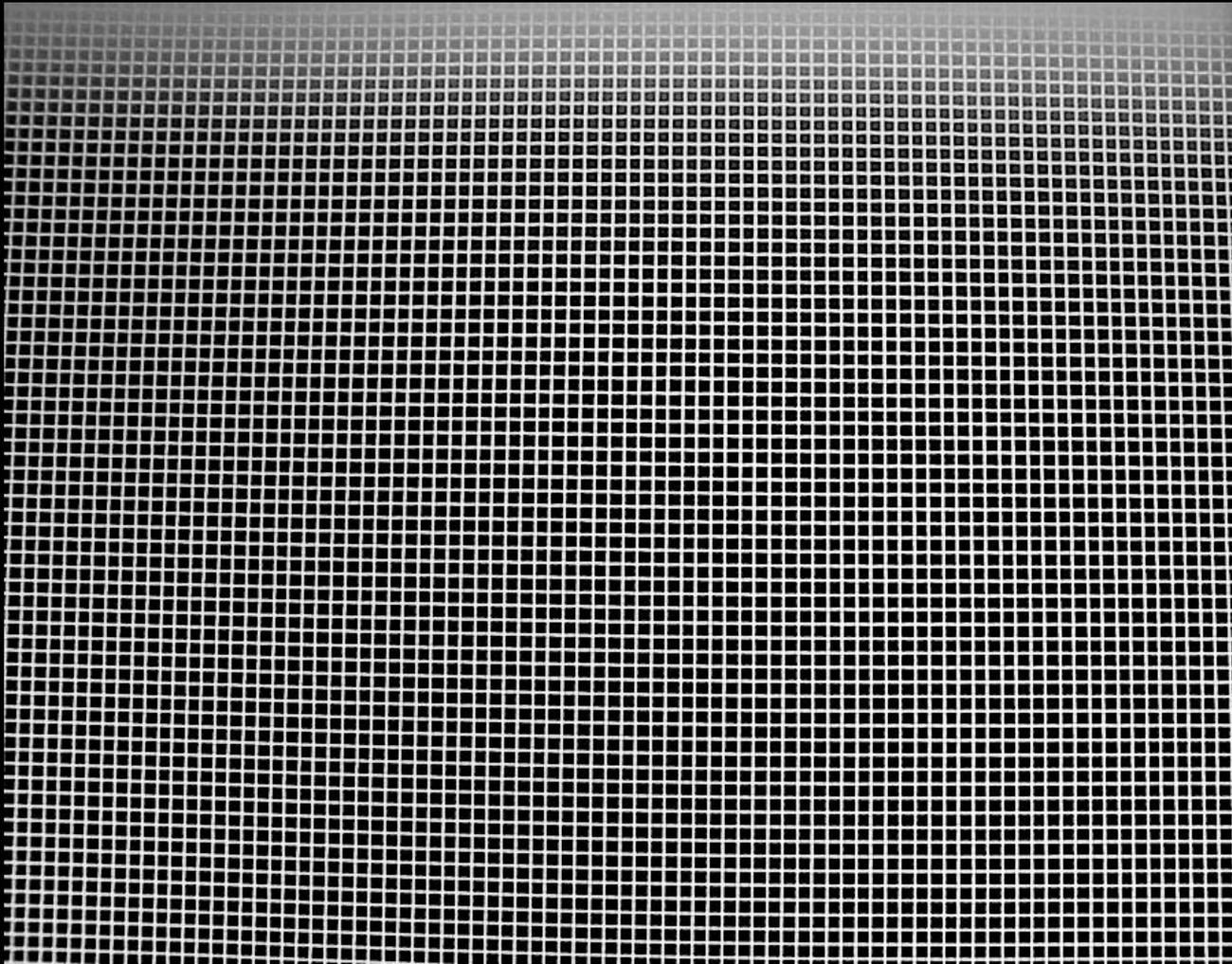
This decrease in density is due to the fact the light photons that are exiting the screen now have a greater distance to travel.

The net result is image blur and a loss of density as evidenced on the following slides.

Intensifying Screen Wire Mesh Test by Kodak:



Intensifying Screen Wire Mesh Test by Kodak:



The region of poor film-screen contact is located across the top of this image. Note the image blur and loss of density.

Preface to the Automatic Exposure Control (AEC) Device Unit:

The design of this section employs a bulleted format as opposed to the more traditional method of using standard paragraphs. The expository nature of the material is very well suited for this style of delivery. Furthermore, the bulleted format will facilitate the learner's ability to quickly reference the material when answering the mastery test questions.

Automatic Exposure Control (AEC) Devices

- 1. Why use an AEC Device?**
- 2. Phototimer AEC Device**
- 3. Ionization Chamber AEC Device**
- 4. Radiographer Responsibilities**
- 5. Advantages & Limitations of AEC Devices**

Why us an AEC Device?

- An AEC device employs a radiation detector to terminate an exposure after a predetermined density has been achieved on the image receptor (cassette/film).
- Most often, the radiographer is responsible for setting the optimum kVp, chamber, density control button (DCB) and either the table or wall image receptor.

The mAs employed for the exposure is determined by the AEC device.

Parameters are set by a service specialist which determine the optimum optical density according to the type of film/screen combination that is employed and the radiologist preferences.

Why us an AEC Device?

- When a manual technique is employed, the dose that reaches the image receptor can only be estimated by the radiographer.

In other words, manual techniques determine the dose that exits the tube and can only estimate what actually reaches the image receptor.

As a result, this process relies heavily on the experience and expertise of the radiographer.

- On the other hand, an AEC device measures the exit beam that reaches the image receptor and will terminate the exposure only after a predetermined film density has been achieved.
- It cannot be emphasized enough, however, that proper patient positioning is imperative for this process to be effective.

Phototimer AEC Devices:

- The **phototimer** is not the most common type of AEC device but it will be examined first.

A phototimer is sometimes referred to as either a photomat or a photomultiplier tube type of AEC device.

- The following steps describe the process of how a phototimer operates:

After setting the appropriate technical factors on the console and properly positioning the patient, an exposure is made.

The primary beam will be attenuated as it passes through the patient forming the exit beam.

The exit beam will pass through the image receptor (cassette) and it will strike a fluorescent screen.

Phototimer AEC Devices:

The screen will emit light in proportion to the number of x-rays that it receives from the exit beam.

The light photons will then strike a **photomultiplier tube** (PMT) which is also sometimes called a photocathode.

The PMT generates an electric signal that is stored in a device called a **capacitor**.

After a maximum, predetermined charge is met in the capacitor, it will discharge through the **thyatron** (thyristor).

- The thyatron sets the maximum charge that the capacitor can hold.
- If it is set to hold a greater charge, a darker density will be achieved on the finished radiograph.

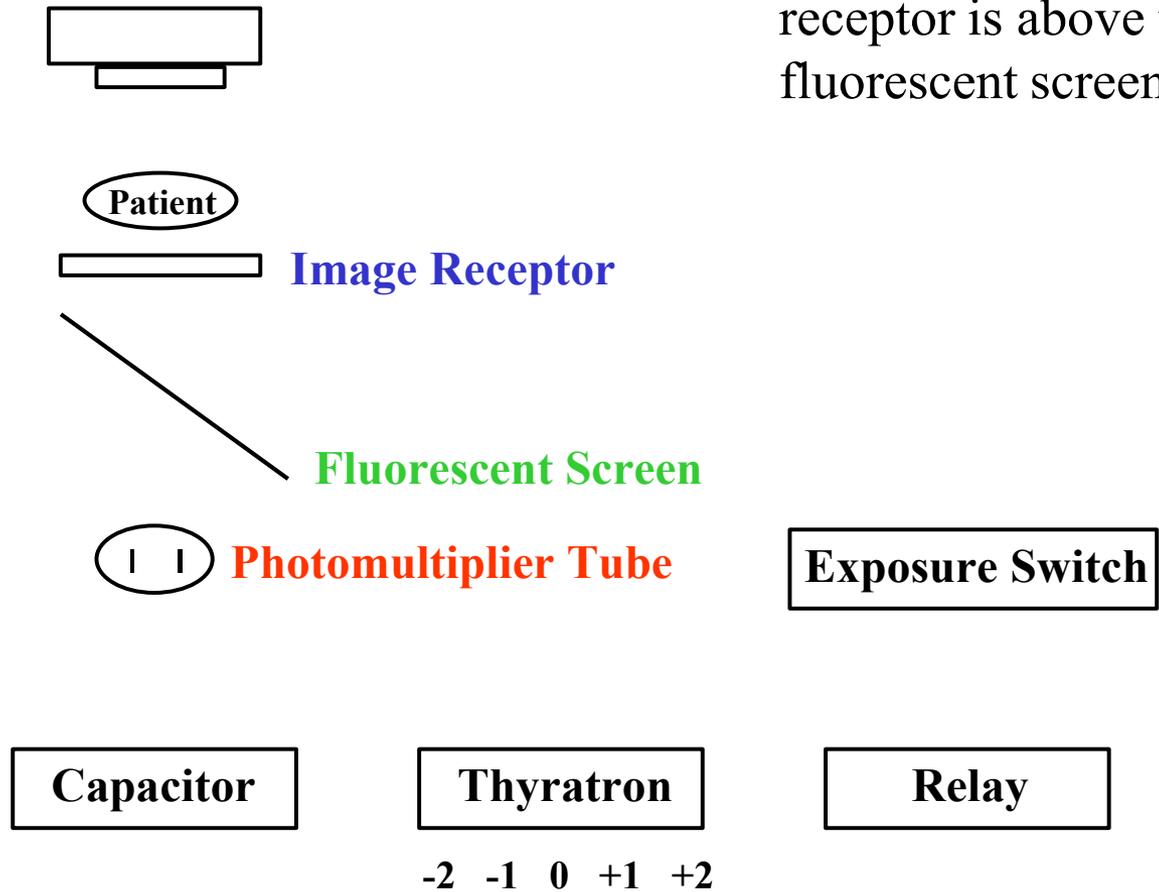
Phototimer AEC Devices:

- As a result, film density can be manipulated by the radiographer by adjusting the maximum charge that the capacitor can hold.
- This is accomplished by changing the density control button (DCB) on the console.
- Generally, changing the DCB to a +1 or a -1 setting will increase or decrease the film density by 25% respectively.
- This adjustment of density may be required on very small or very large patients.

Finally, the electric signal that exits the thyatron will travel to the relay which opens the circuit and terminates the exposure.

The diagram on the next slide illustrates this process.

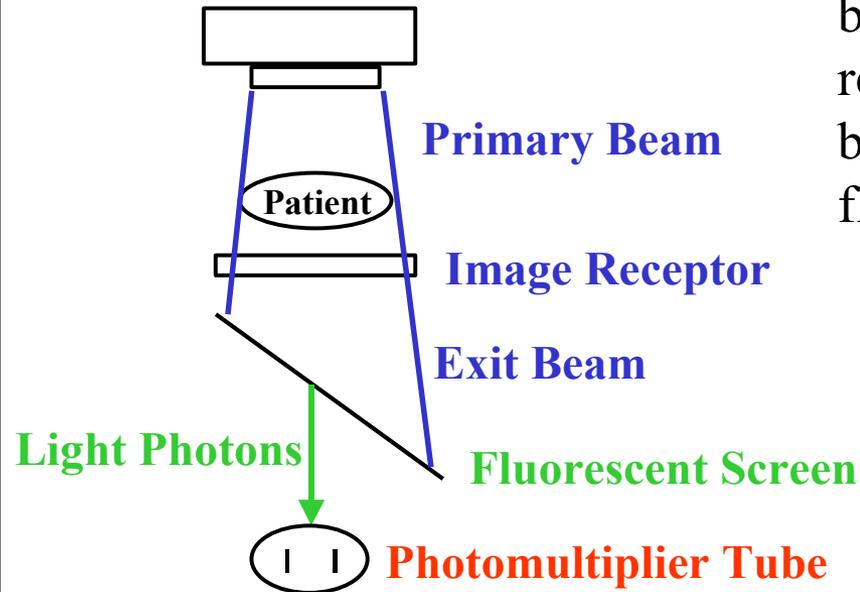
Phototimer AEC Devices:



Note that the image receptor is above the fluorescent screen.

-2 -1 0 +1 +2

Phototimer AEC Devices:



The density has already been placed on the image receptor before the exit beam reaches the fluorescent screen.

Exposure Switch

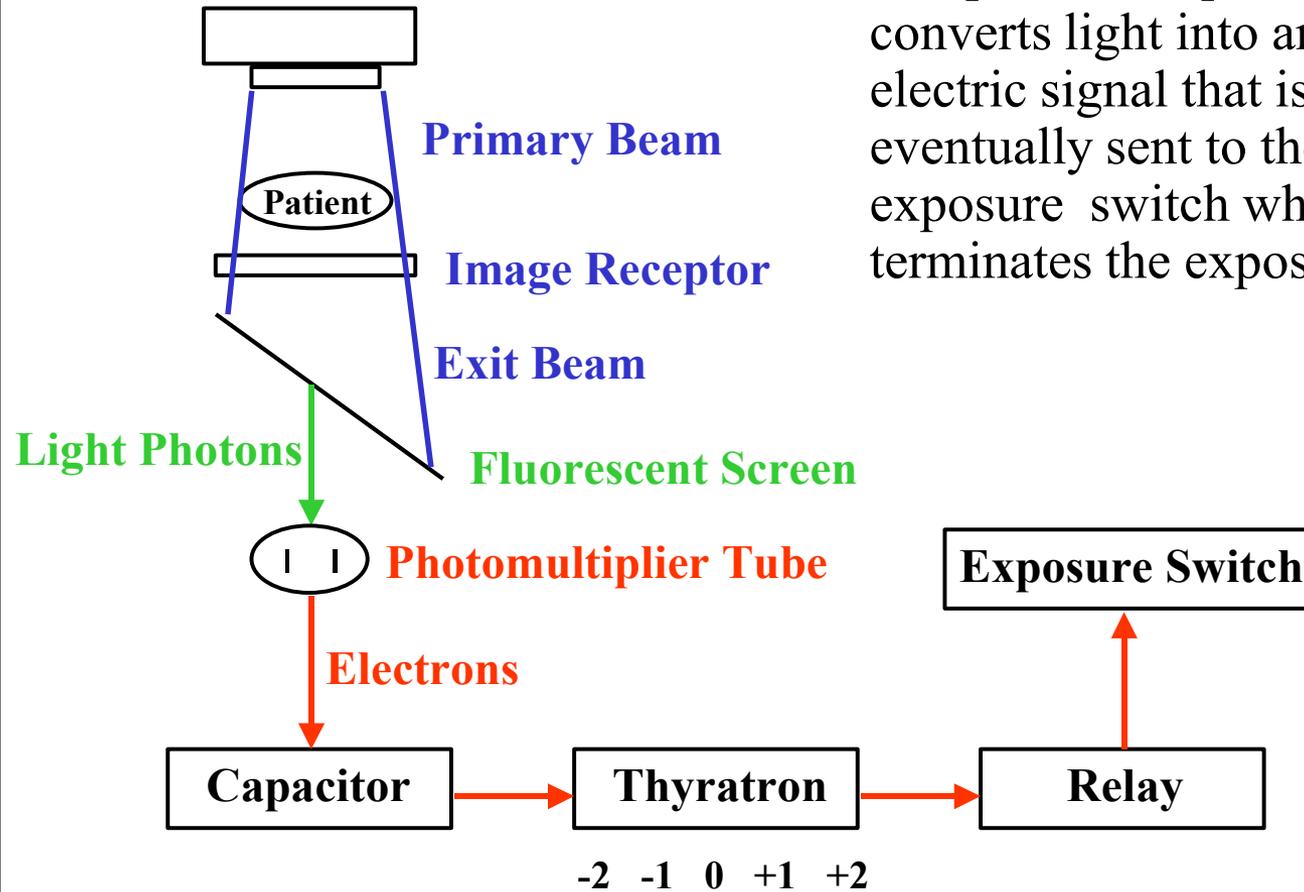
Capacitor

Thyratron

Relay

-2 -1 0 +1 +2

Phototimer AEC Devices:



The photomultiplier tube converts light into an electric signal that is eventually sent to the exposure switch which terminates the exposure.

Ionization Chamber AEC Devices:

- An **ionization chamber** is the most commonly employed AEC device and the following steps describe how it functions:

After setting the appropriate technical factors on the console and properly positioning the patient, an exposure is made.

The primary beam will be attenuated as it passes through the patient forming the exit beam.

The exit beam will strike a flat, **parallel plate ionization chamber** that is filled with a gas that is easily ionized by x-ray exposure.

The next slide contains pictures of an actual ionization chamber.

Ionization Chamber AEC Devices:



This is an ionization chamber that has been removed from the bucky.

Ionization Chamber AEC Devices:



This is an ionization chamber that has been removed from the bucky.



The ionization chamber is found below the grid and above the cassette in a bucky as indicated by the black arrows above.

Ionization Chamber AEC Devices:

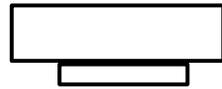
As the electrons (negatively charged) are liberated from the gas, they are attracted to a positively charged anode plate.

The charges are collected in a **capacitor** which discharges through the thyatron after a maximum charge has been met.

Finally, the electric signal that exits the **thyatron** will travel to the relay which opens the circuit and terminates the exposure.

The diagram on the next slide illustrates this process.

Ionization Chamber AEC Devices:



Ionization Chamber

Image Receptor

Capacitor

Thyratron

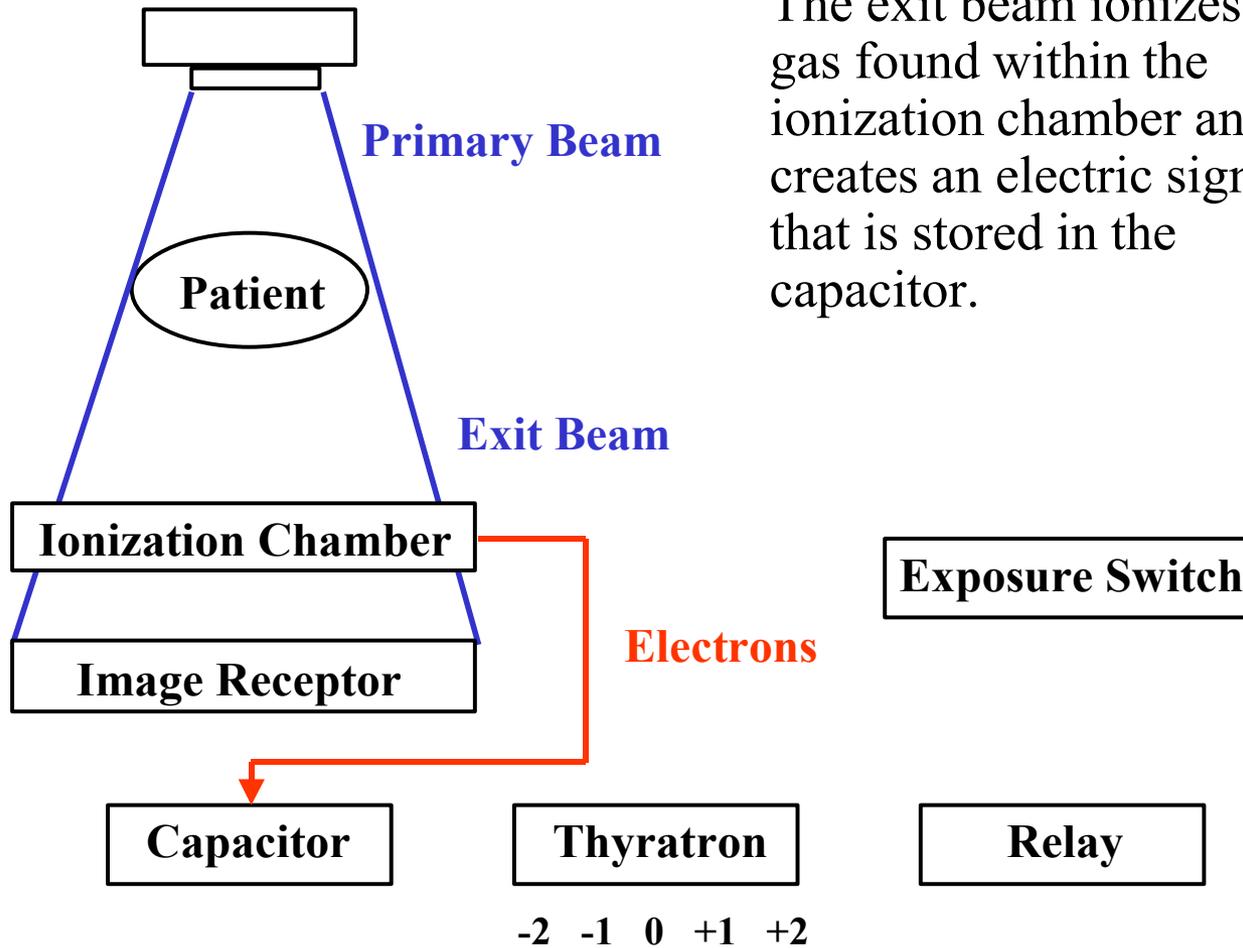
-2 -1 0 +1 +2

Exposure Switch

Relay

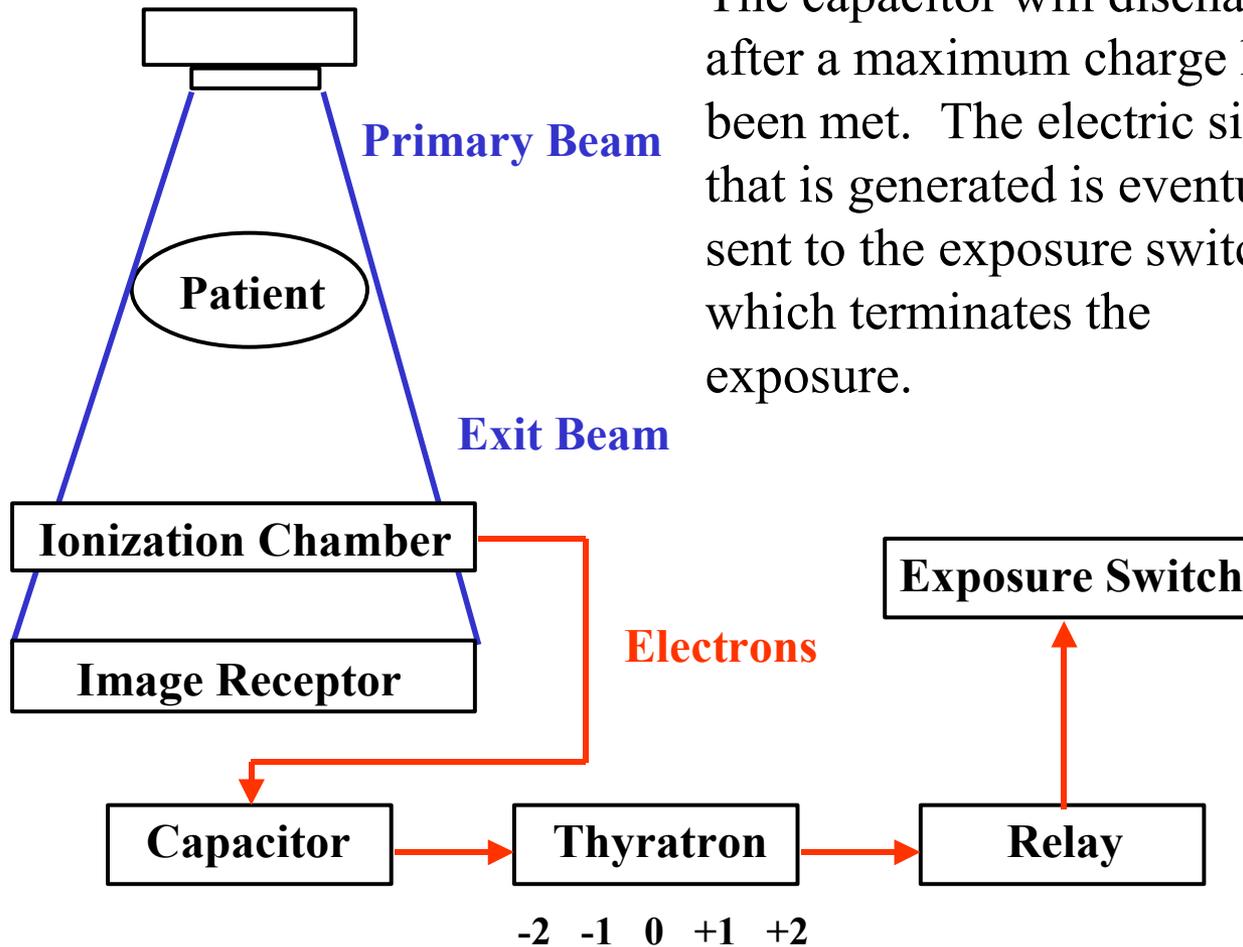
Note that the image receptor is below the ionization chamber.

Ionization Chamber AEC Devices:



The exit beam ionizes the gas found within the ionization chamber and creates an electric signal that is stored in the capacitor.

Ionization Chamber AEC Devices:



The capacitor will discharge after a maximum charge has been met. The electric signal that is generated is eventually sent to the exposure switch which terminates the exposure.

Radiographer Responsibilities:

- The following is a list of factors that must either be set or considered by the radiographer when employing an AEC device:

All AEC devices require that the **optimum kVp** be set.

Some machines also require that the mA to be manually set.

- The mA is generally set between 200 to 400 or higher if a shorter exposure time is required.

A **back-up mAs** is required by some machines.

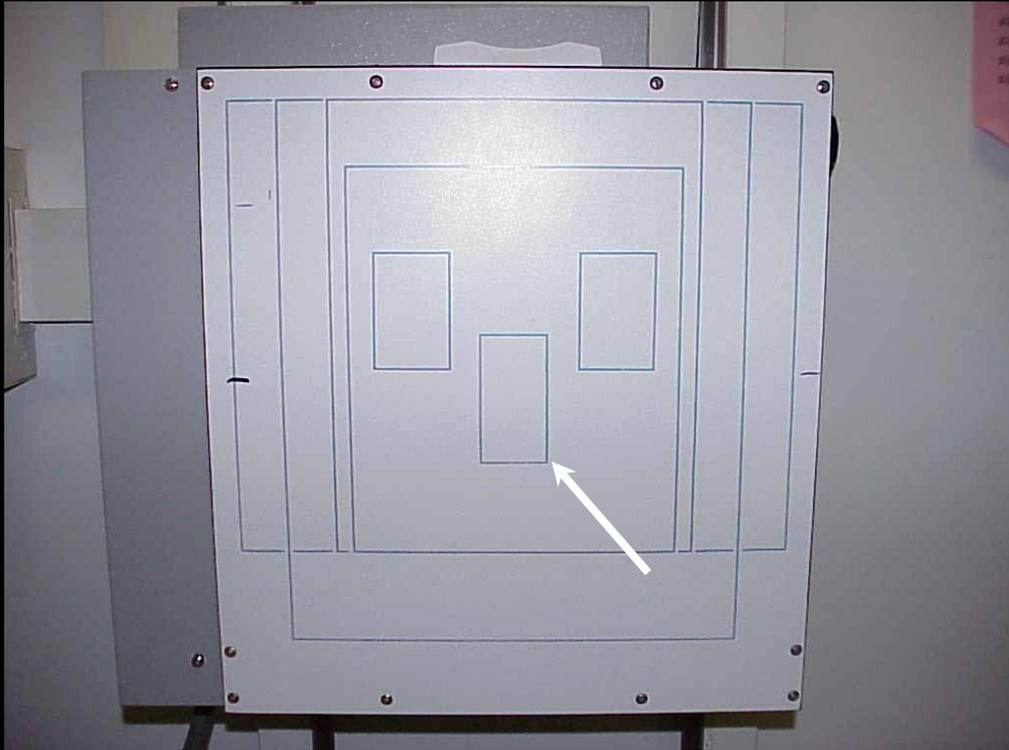
- This is the maximum mAs that the machine will be allowed to deliver during the exposure.
- It is recommended that it be set at 1.5 times the expected mAs.
- This is a safety feature that is designed to protect the patient from overexposure and the x-ray tube from excessive use.

Radiographer Responsibilities:

The correct **chamber** or radiation detector must be set in order to obtain the proper optical film density.

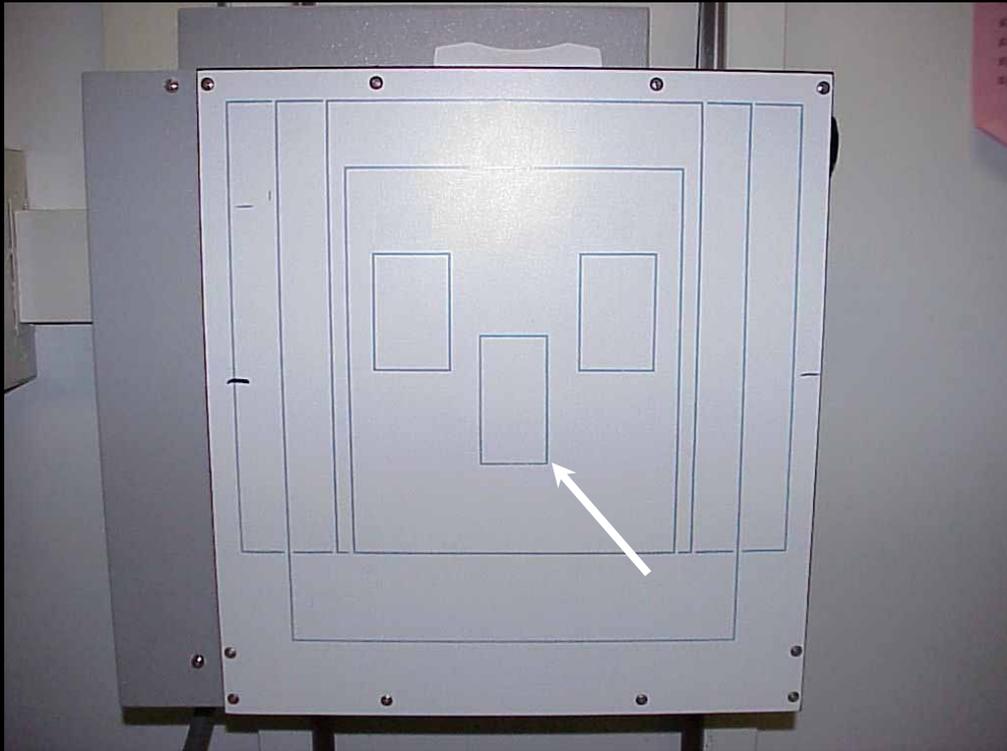
- There are three chambers (cells) to choose from and the chamber over the anatomy of interest should be selected.
- For example, a PA chest radiograph requires that the outside chambers be selected because they lie over the lung fields.
- If the center chamber were mistakenly selected, the radiation detector employed to set the technique would lie below the sternum, thoracic spine and mediastinal structures.
- The AEC device would then terminate the exposure based on these much thicker structures causing the lung fields to be overexposed.
- The next three slides demonstrate this concept.

Radiographer Responsibilities:

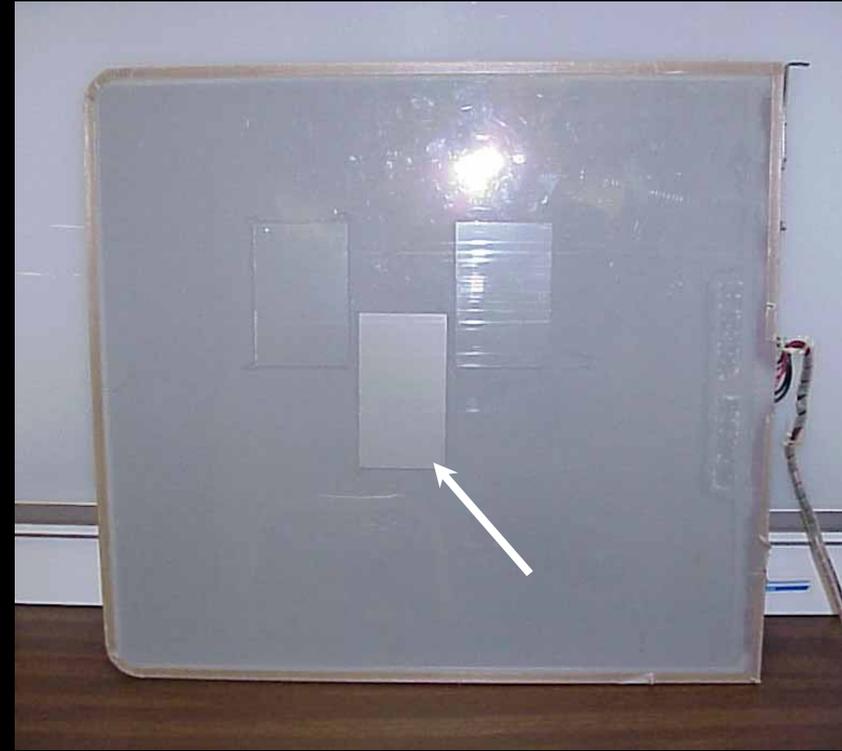


The chamber choices are clearly marked on the outside of the bucky.

Radiographer Responsibilities:

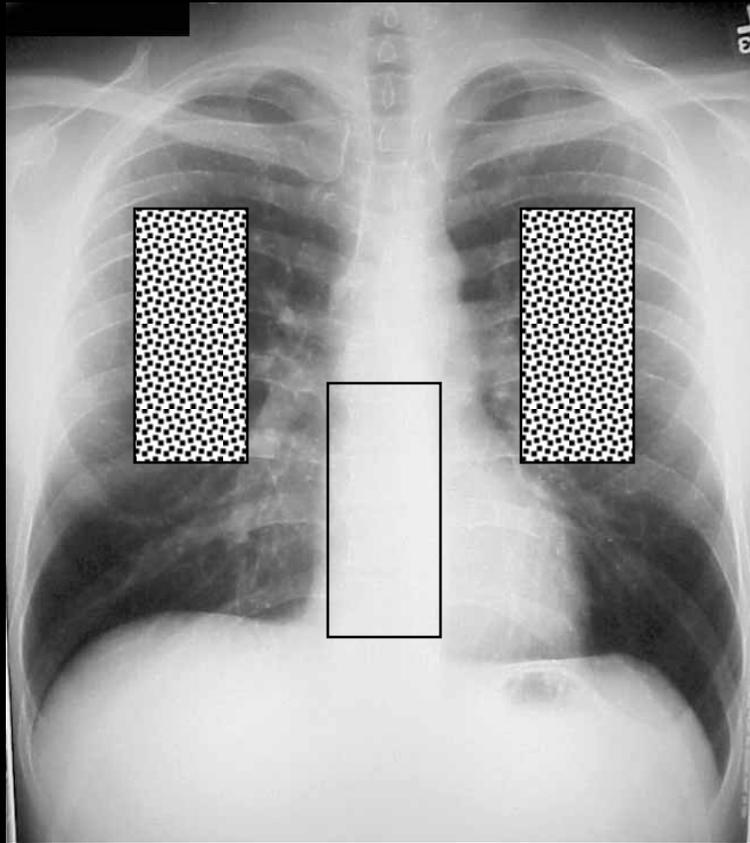


The chamber choices are clearly marked on the outside of the bucky.



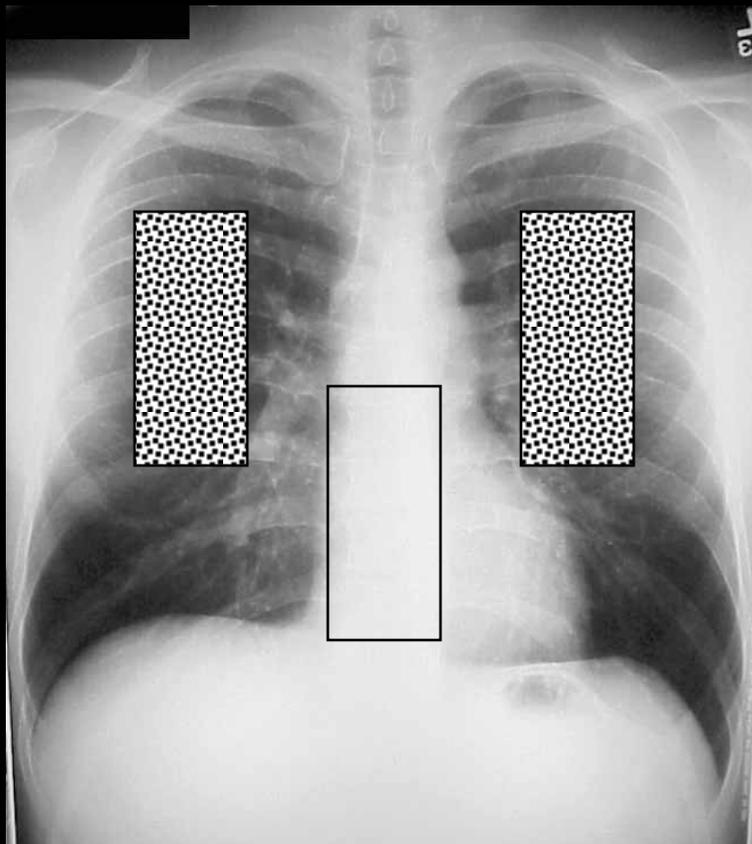
Each chamber corresponds to a radiation detector that is located within the ionization chamber.

Radiographer Responsibilities:

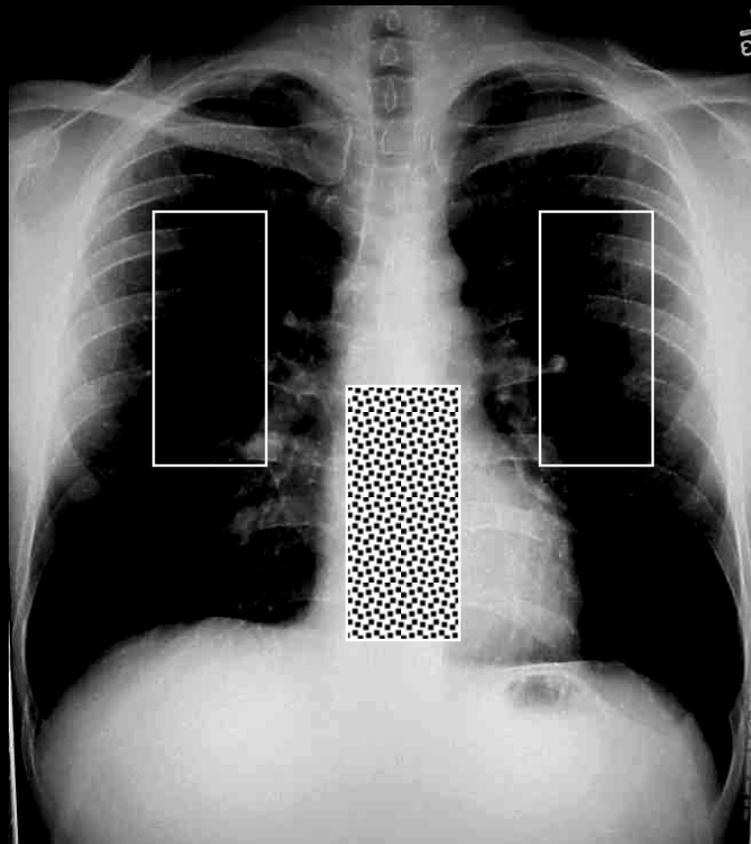


When the side chambers are employed, optimum film density can be achieved.

Radiographer Responsibilities:

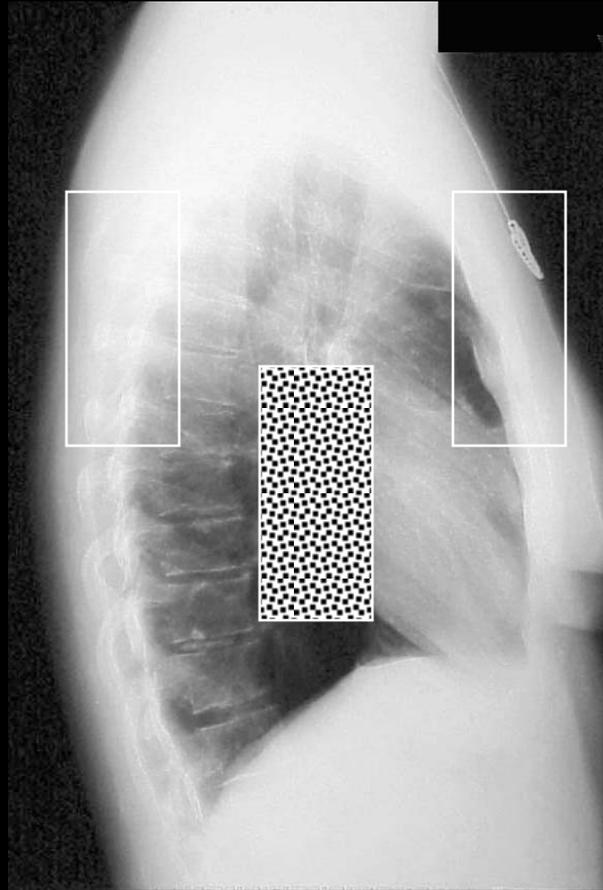


When the side chambers are employed, optimum film density can be achieved.



The lung fields become overexposed when the center chamber is selected.

Radiographer Responsibilities:



A lateral chest, on the other hand, would require that the center chamber be selected because the anatomy of interest is more centrally located.

Radiographer Responsibilities:

The **density control button** (DCB) is generally set to “0” unless the patient is very small or large.

- Each increment will usually change the film density by 25%.
- Keep in mind that it takes a minimum of a 30% change in density to be detected by the human eye.
- Therefore, changing to DCB to +1 may not make an appreciable difference in optical film density.

Most machines also require that the table or upright bucky be manually selected.

- As an added safety measure, some modern x-ray equipment contain sensors that detect which one is being employed prior to the exposure.

Advantages of AEC Devices:

- If used properly, consistent optical film density can be attained from patient to patient.
- There is also the likelihood of reduced repeats due to technique errors.
- Additionally, the proper use of AEC devices can improve the efficiency of the radiographer and lead to more efficient patient flow through the department.

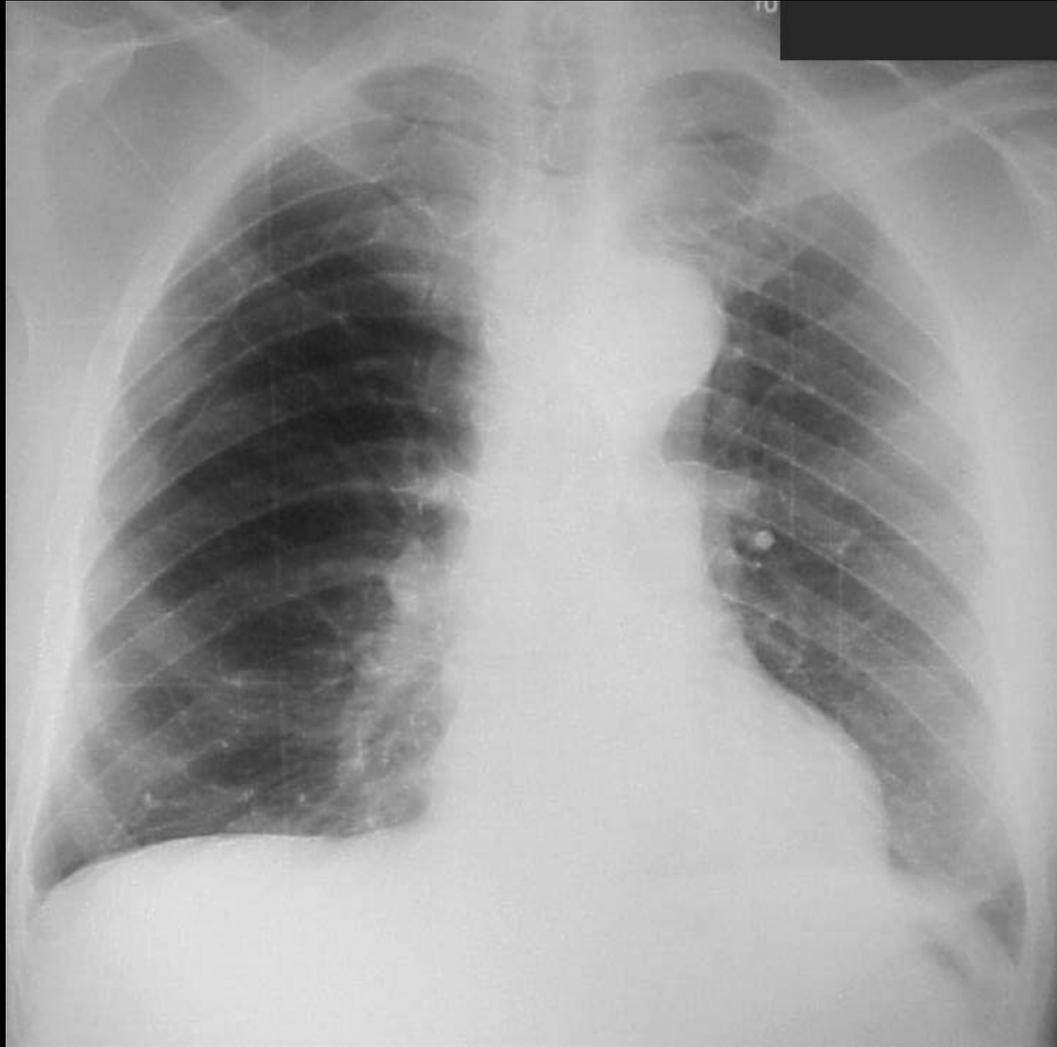
Limitations of AEC Devices:

- The same film/screen system must be employed at all times.
A service specialist is required to adjust the capacitor and thyatron if a new film and or screen is to be employed.
- The radiographer must be an expert at positioning the patient to ensure that the body part of interest is overlying the selected chamber.
If this is not done, the proper density will not be achieved on the radiograph.
- The correct kVp, chamber, back-up mAs and DCB must be selected.
- Proper collimation must be employed to ensure that scatter radiation does not have an adverse affect on the radiation detectors.
Increased levels of scatter will usually result in an underexposed radiograph because the radiation detector will discharge prematurely.

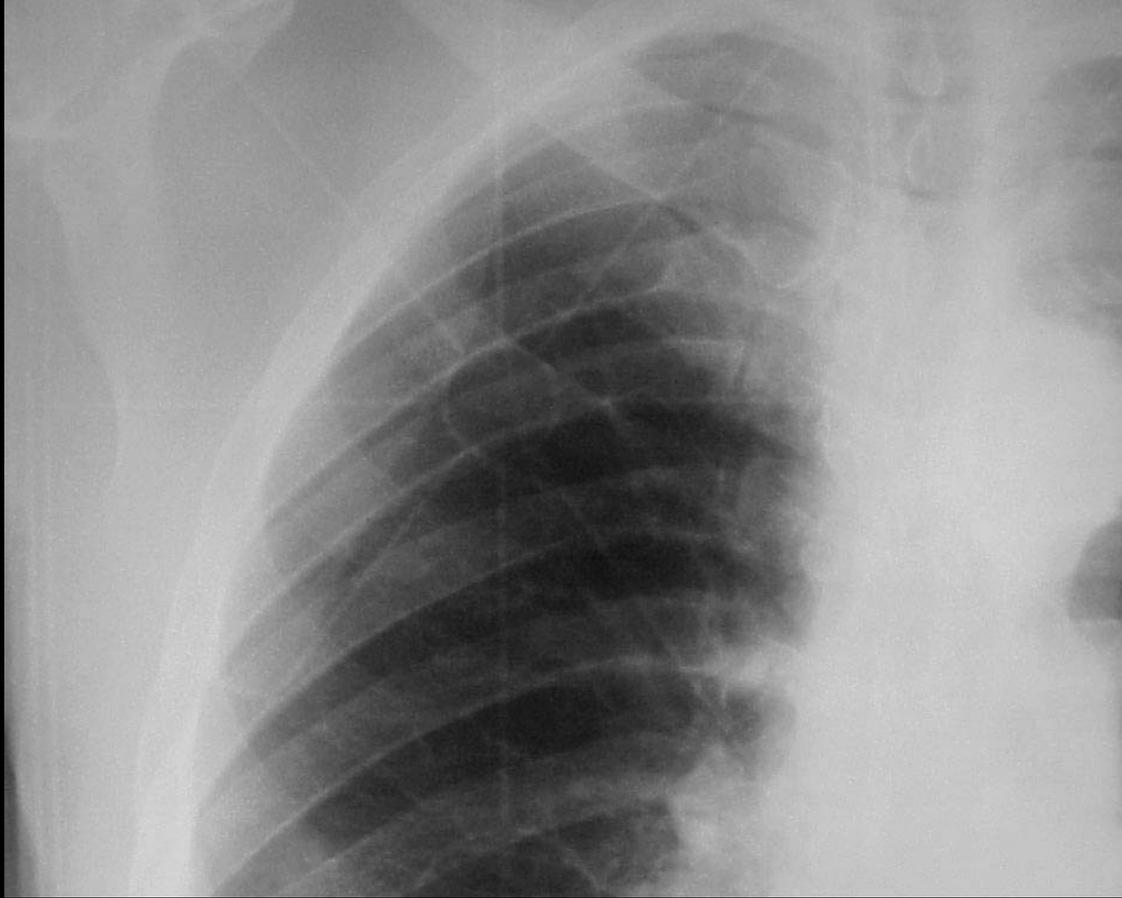
Diagnosing Radiographic Artifacts

- 1. Screen Artifacts**
- 2. Processor Artifacts**
- 3. Darkroom**
- 4. Grid Artifacts**
- 5. Exposure Artifacts**
- 6. Patient Artifacts**

Screen Artifacts:

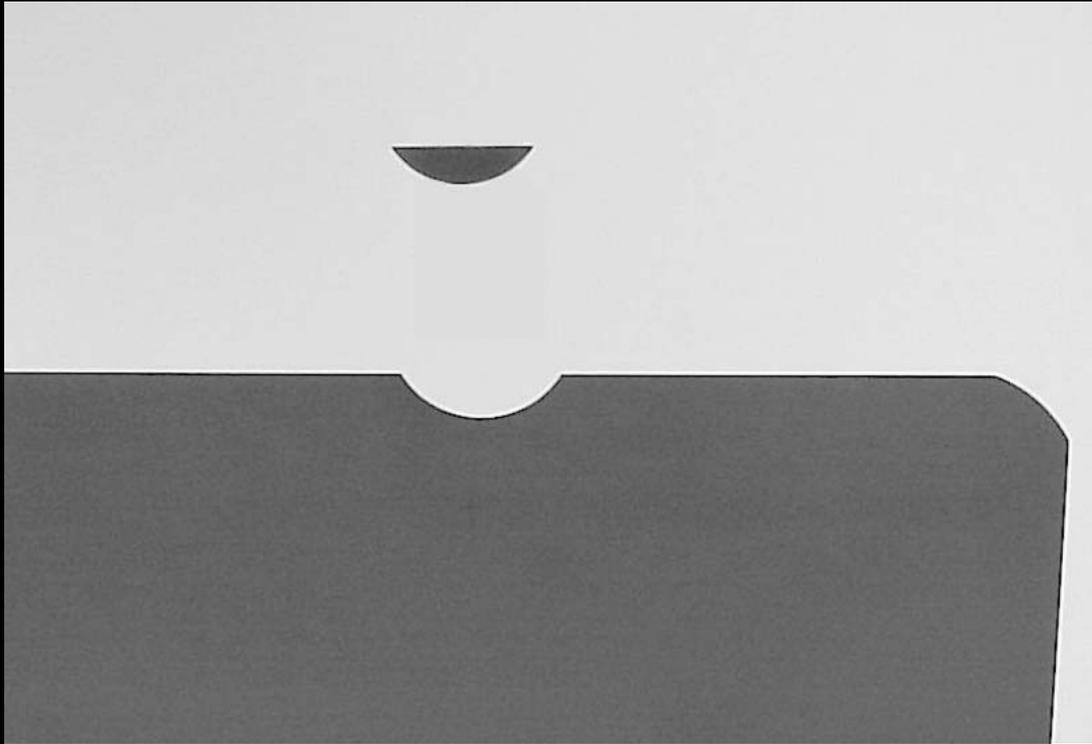


Screen Artifacts:



This cassette was placed upside down inside the bucky. The pattern that is displayed on the image is from the design of the cassette back.

Screen Artifacts:



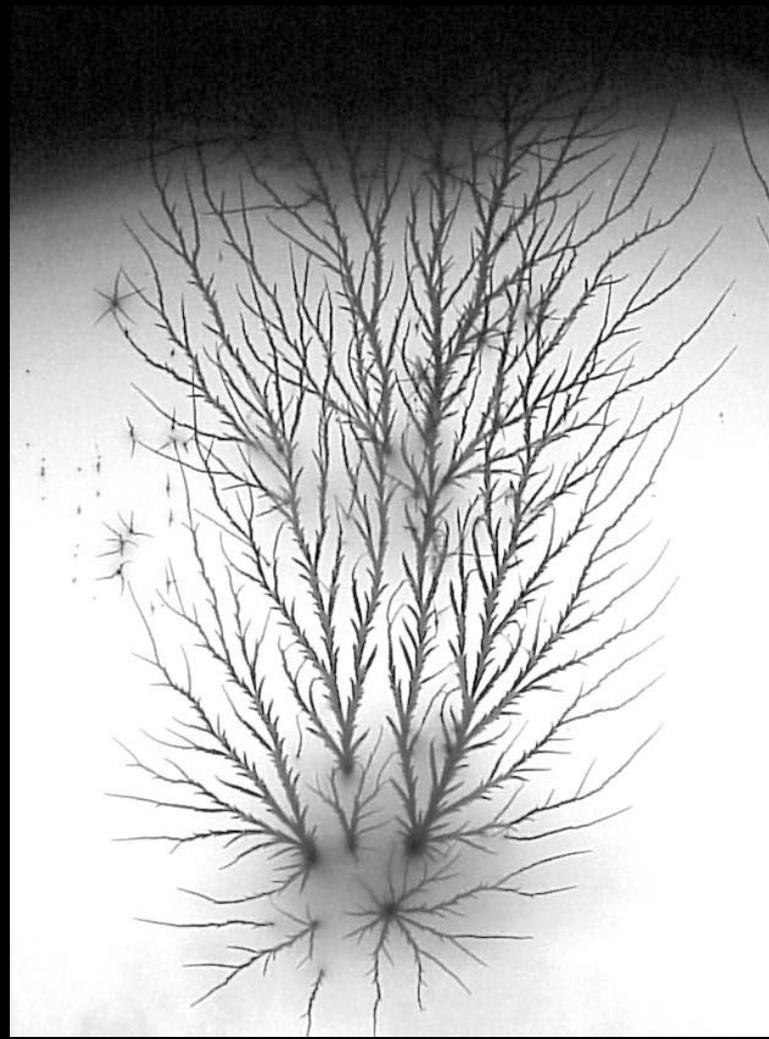
Some film manufacturers take a notch out of specialty film to help radiographers differentiate it from the regular film. This small notch was not properly removed at the factory and found its way into a cassette thus making the artifact found on the previous slide.

Processing Artifacts:

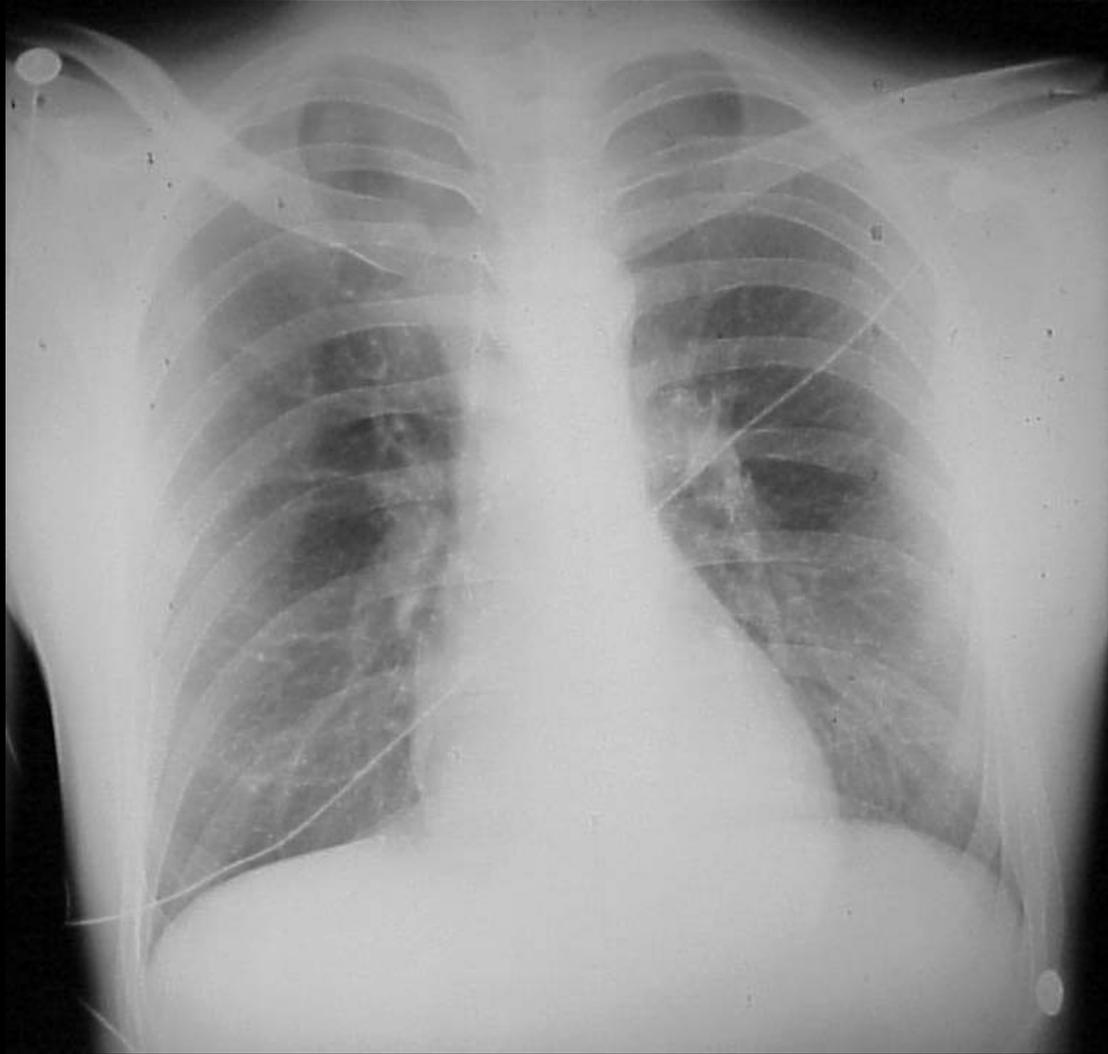


Static charges may accumulate on radiographs as the result of low humidity. This is especially prevalent during the winter months. The three types of static are crown, tree and smudge. This radiograph possesses tree static. The following slide provides an additional example of static.

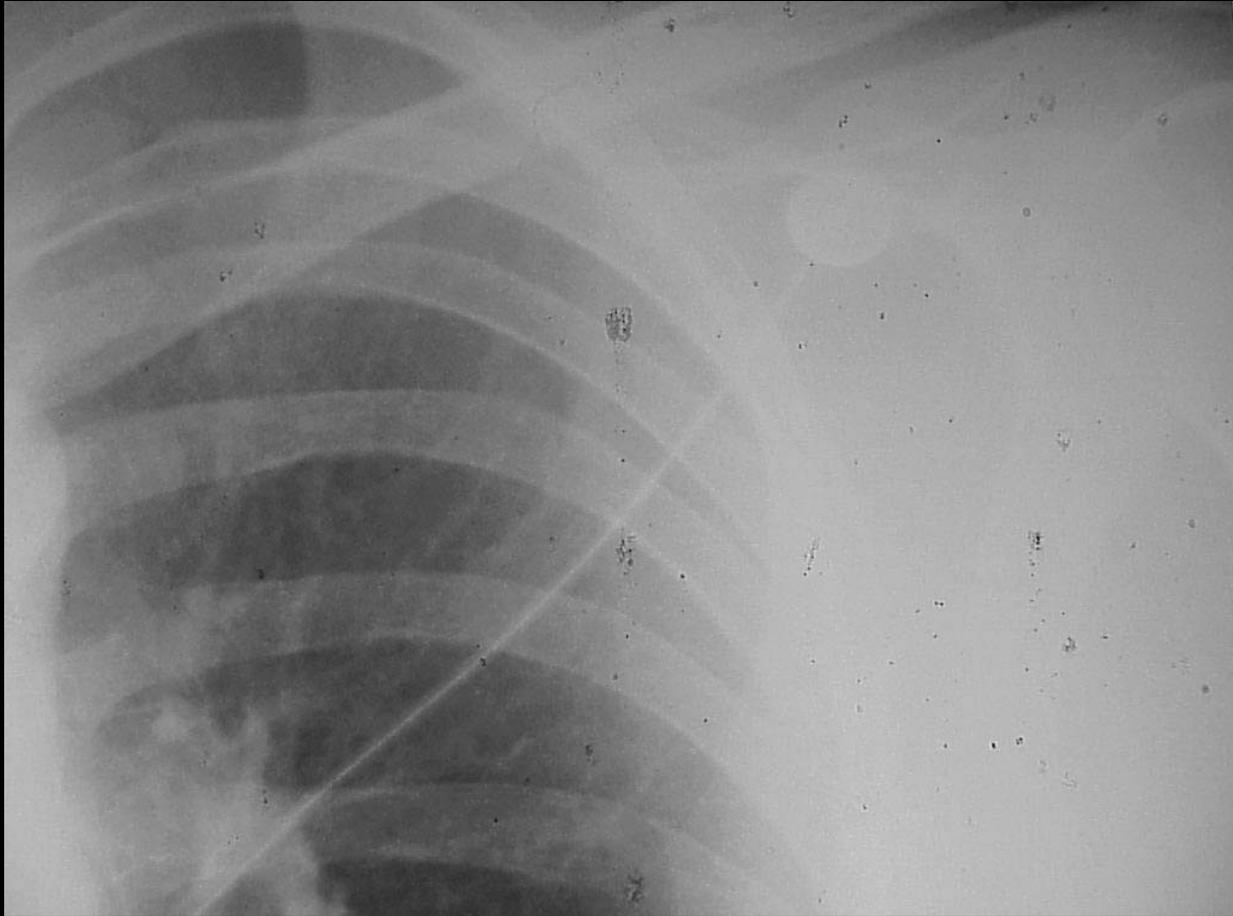
Processing Artifacts:



Processing Artifacts:



Processing Artifacts:

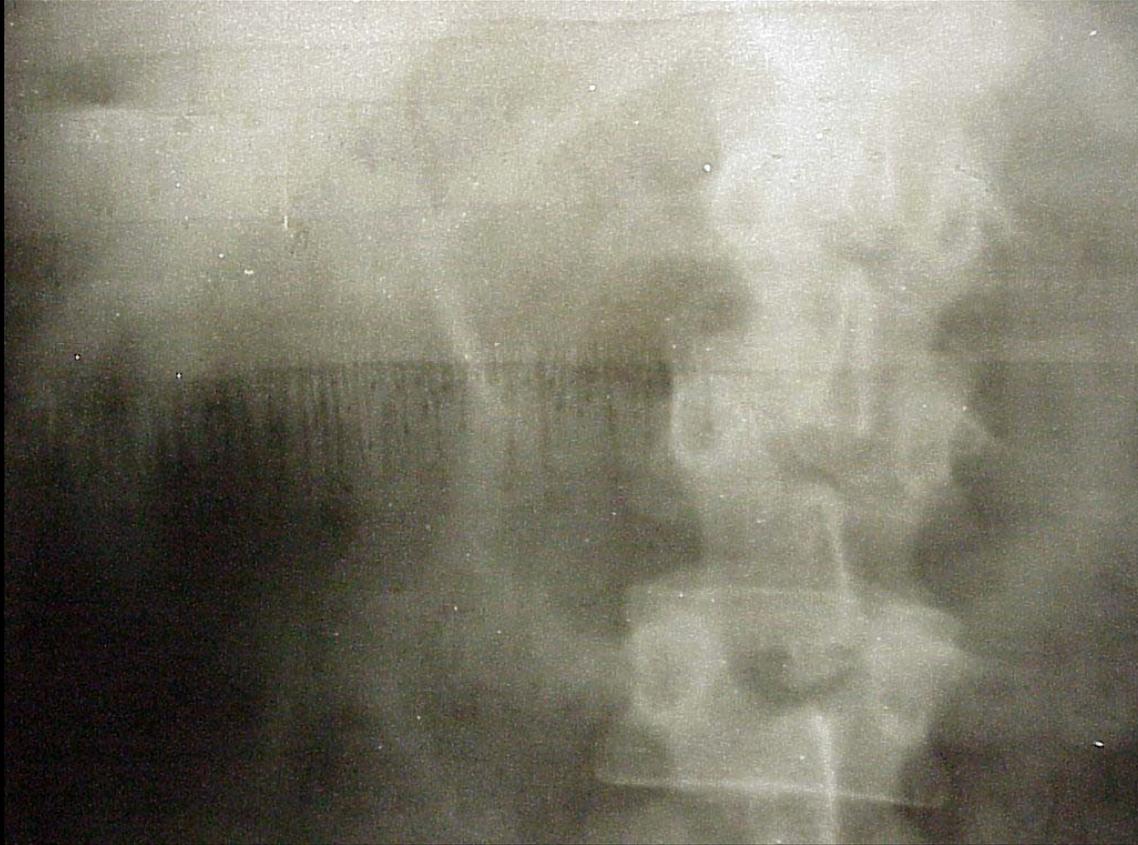


The artifacts found on this radiograph are the result of algae growth in the wash tank of an automatic processor. While the film is in transit through the wash tank, algae may attach to the emulsion and leave these black flaky densities.

Processing Artifacts:



Processing Artifacts:



The wash tank was empty when this film was processed. It came out of the processor and had a greasy feel to it because the excess chemistry was not removed. With time, the film turned this yellowish-brown color which is an indication that the film was not properly washed.

Processing Artifacts:



This radiograph become lodged in the processor and had to be manually removed. Since the film emulsion was porous, it was very easily scratched by the guide shoes as it was pulled out.

Darkroom Artifacts:



Can you identify the artifact found at the bottom of this film? It suddenly began appearing on all of the radiographs that were being processed.

Darkroom Artifacts:



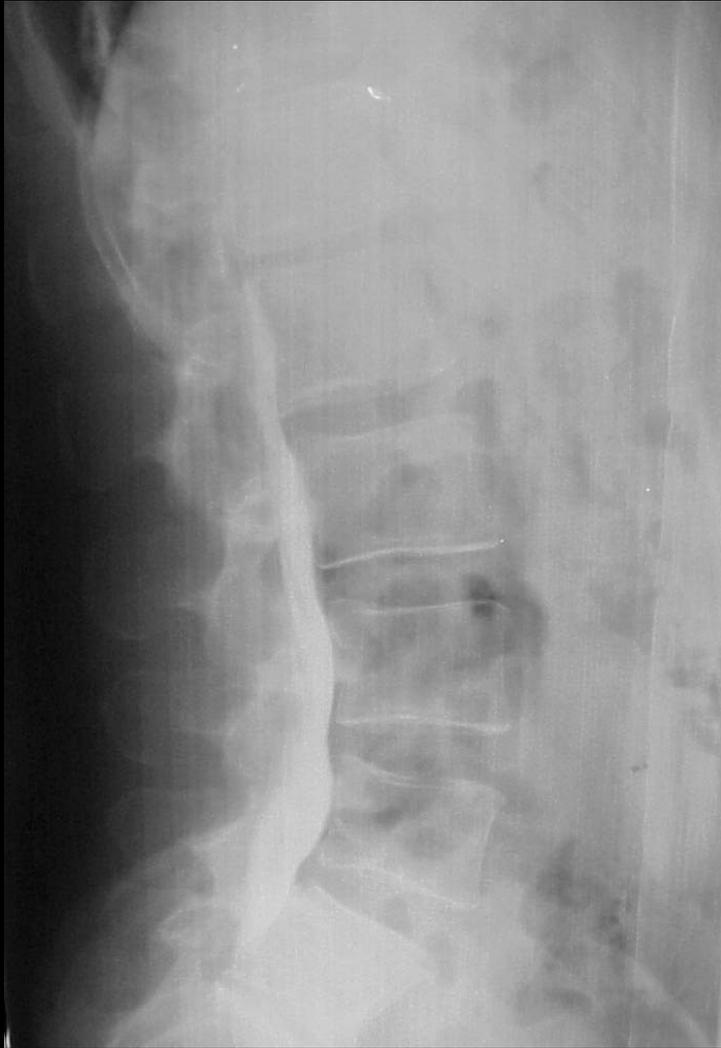
What if I magnified it
for you?

Darkroom Artifacts:



An actual picture of the darkroom began appearing on all of the radiographs that were being processed. As it turns out, one of the screws that secured the handle of the film bin came out and allowed a small amount of light to enter the film bin. Essentially, the film bin became a camera and it placed this “picture” of the darkroom on all subsequent films. Very cool.

Grid Artifacts:



From the radiographer's perspective, taking the x-table lateral lumbar radiograph at the end of a myelogram can sometimes prove to be challenging. This is true because great care must be taken to properly position the grid in order to ensure that there is no grid cut-off.

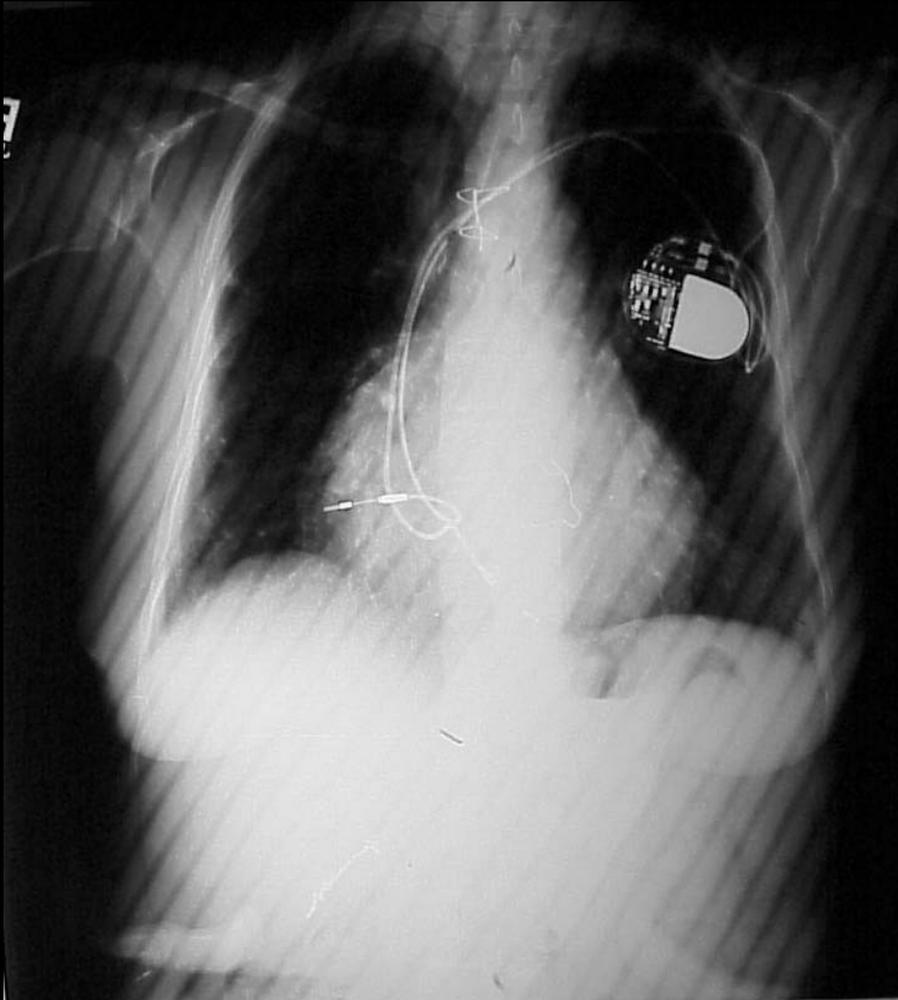
Unfortunately, the vertical lines and loss of density on this radiograph is the result of improper grid positioning.

Grid Artifacts:



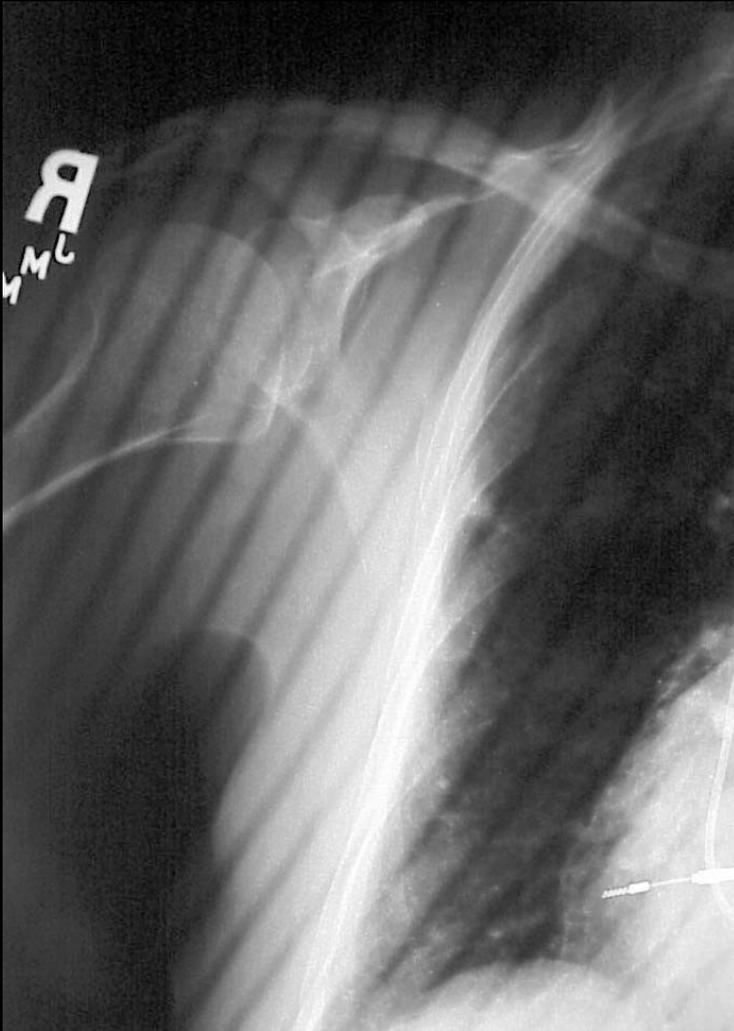
This is the repeated radiograph following proper grid placement. As you can see, a diagnostic study has been achieved.

Grid Artifacts:



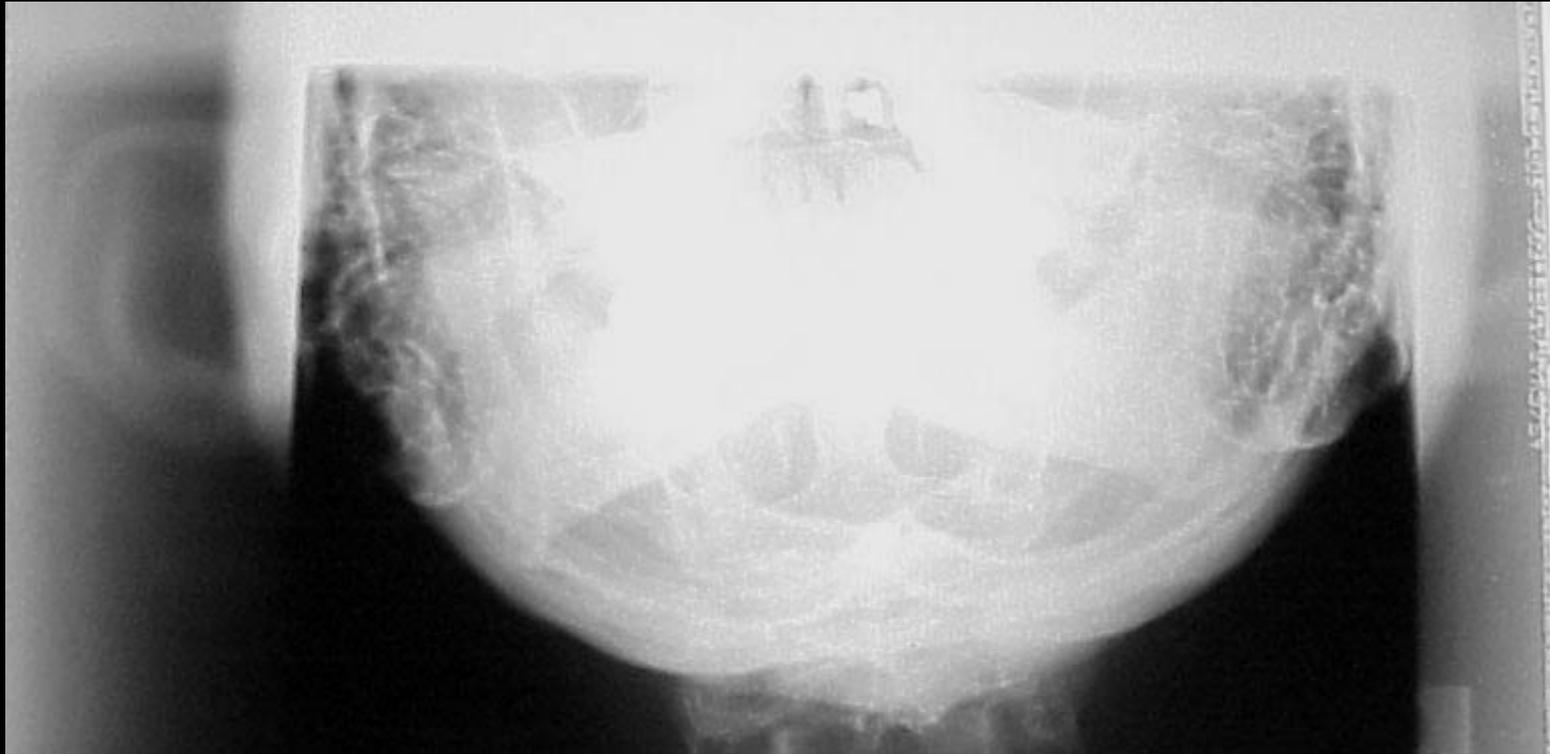
This is a very unusual artifact. Do you recognize it?

Grid Artifacts:



In this case, the radiographer mistakenly placed a cassette that already contained a grid into the bucky. Essentially, this strange pattern was created by taking a radiograph through two focused, parallel grids

Exposure Artifacts:



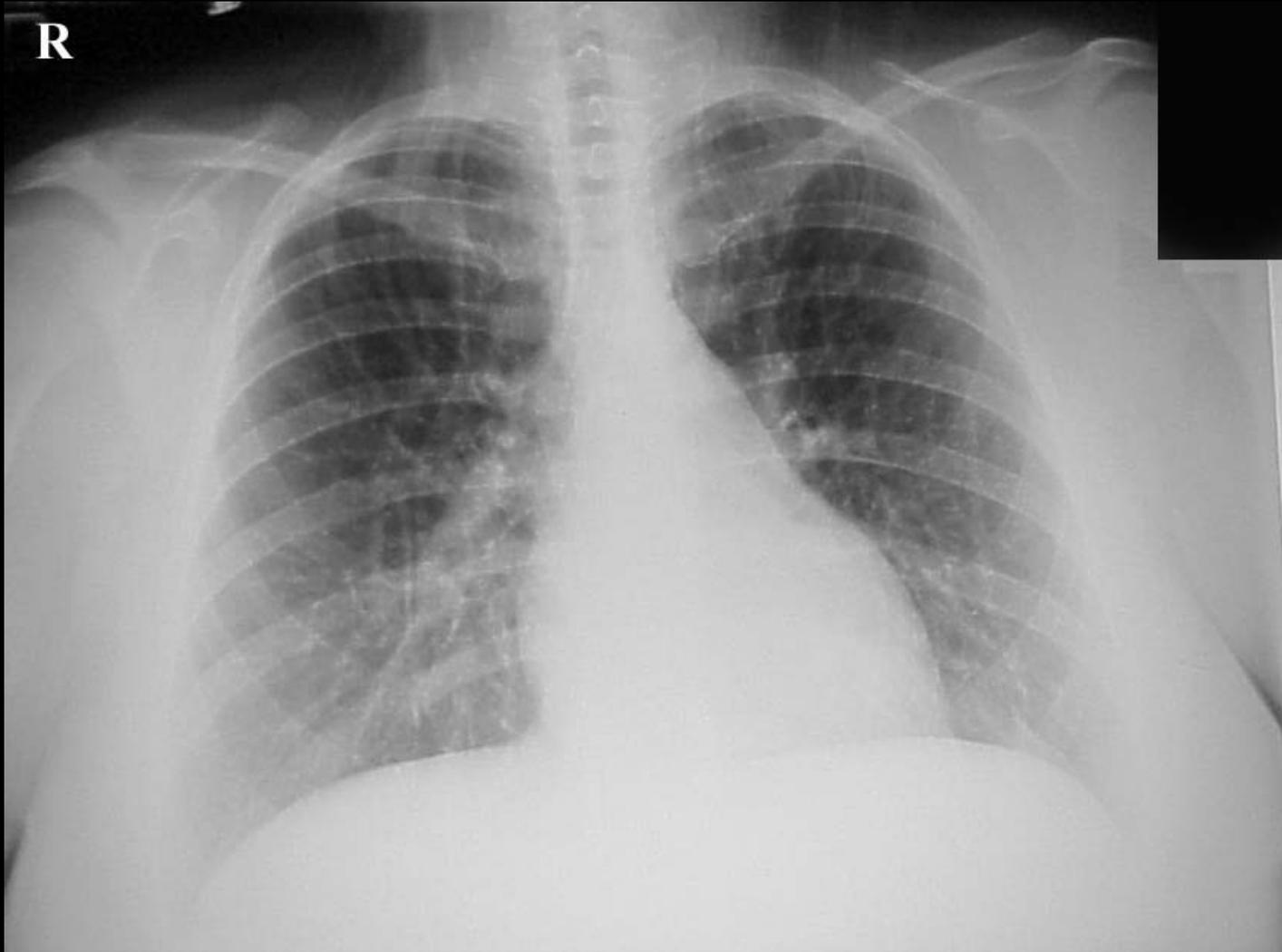
Have you ever noticed how the patient's ears sometimes appear on a Fuchs's Method or an odontoid when you have close collimation? This is often confused with being produced by scatter radiation. Since radiation scattered by the patient cannot form an image, how does this ghosting affect appear? As it turns out, it is the result of off-focus radiation that is produced within the tube and it can contribute to as much as 25 to 30% of the total primary beam.

Patient Artifacts:

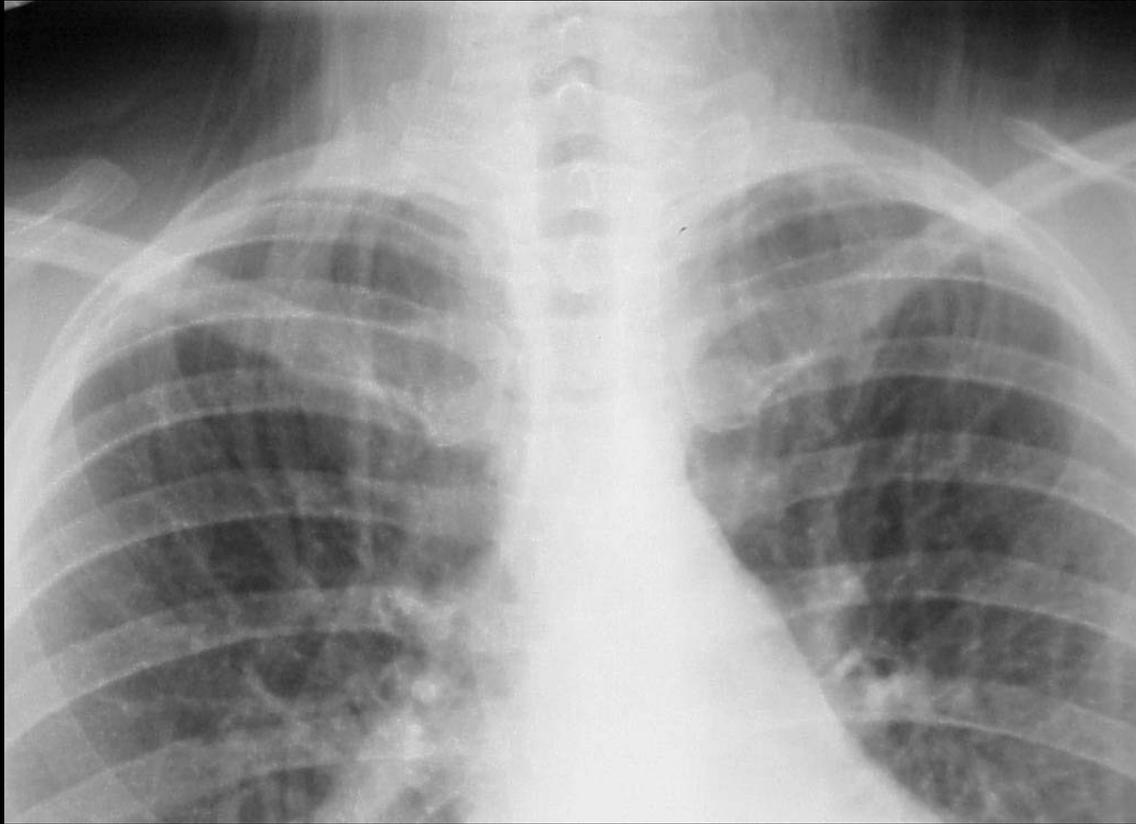


This artifact occurred because the patient had an ice pack left on their knee during the study.

Patient Artifacts:



Patient Artifacts:



This artifact was produced because the patient had wet hair and it was allowed to hang down into the field of interest during the exposure.

Patient Artifacts:



This PA skull radiograph was double exposed with a spot film for a BE.

Of course, the patient was accused of having shi_ for brains!!!

Patient Artifacts:



Patient Artifacts:



When this film came out of the processor, we were sure that there was something in the sheet, table pad or the patients gown that would cause these artifacts but, we could not find a thing. Upon explaining our predicament with the patient, we came to find out that the patient had a type of acupuncture done where the needles are not removed and are left in permanently. How about an MRI sir?

Preface to the Cell Biology Unit:

The design of this section employs a bulleted format as opposed to the more traditional method of employing standard paragraphs. The expository nature of the material is very well suited for this style of delivery. Furthermore, the bulleted format will facilitate the learner's ability to quickly reference the material when answering the mastery test questions.

Cell Biology

- 1. Molecular Composition of the Body**
- 2. Cell Structure**
- 3. Cell Division: Mitosis**
- 4. Cell Division: Meiosis**

Molecular Composition of the Body:

- Molecules found in the human body can be divided into two basic categories.
- The first major category is called **inorganic compounds**.

Inorganic compounds do not contain carbon and they are essential in order to maintain homeostasis within the body.

-**Homeostasis** refers to the body's ability to maintain a relatively constant state of well-being.

Water (H₂O) is the most abundant inorganic compound and molecule, for that matter, found in the body.

Approximately 80% of the body's mass consists of water.

Other inorganic compounds found within cells and in the body include salts (electrolytes), acids and bases.

Molecular Composition of the Body:

- The second major category is a group of macromolecules called **organic compounds**.

Macromolecules are nothing more than very large molecules.

All organic compounds contain carbon and they also play a very important role in maintaining homeostasis.

There are four major categories of organic compounds found in the body.

Proteins make up approximately 15% of the body's mass.

-They are made of different combinations of amino acids that are bound by peptide bonds.

-Enzymes, hormones and antibodies are all examples of proteins that are found in the human body.

Molecular Composition of the Body:

The second category of organic compounds is called **carbohydrates** or saccharides.

- They are commonly referred to as sugars and starches.
- Carbohydrates provide fuel for cellular metabolism.

The third category of organic compounds is called **lipids** or fats.

- Lipids are composed of a combination of glycerol and fatty acids.
- Lipids not only serve as the body's means of insulation, but they can also be used as an alternate source of energy.

Molecular Composition of the Body:

The fourth and final category of organic compounds is called **nucleic acids**.

- DNA and RNA are made of nucleic acids and they contain the hereditary information of the cell and organism.
- They are composed of a combination of small structures called nucleotides.
- Nucleotides are made up of a complex combination of deoxyribose (sugar), phosphate and nitrogenous bases.
- The individual components of a nucleotide are held together by hydrogen bonds.

Molecular Composition of the Body:

- The four nitrogenous bases are broken down into the following two categories:

Purines

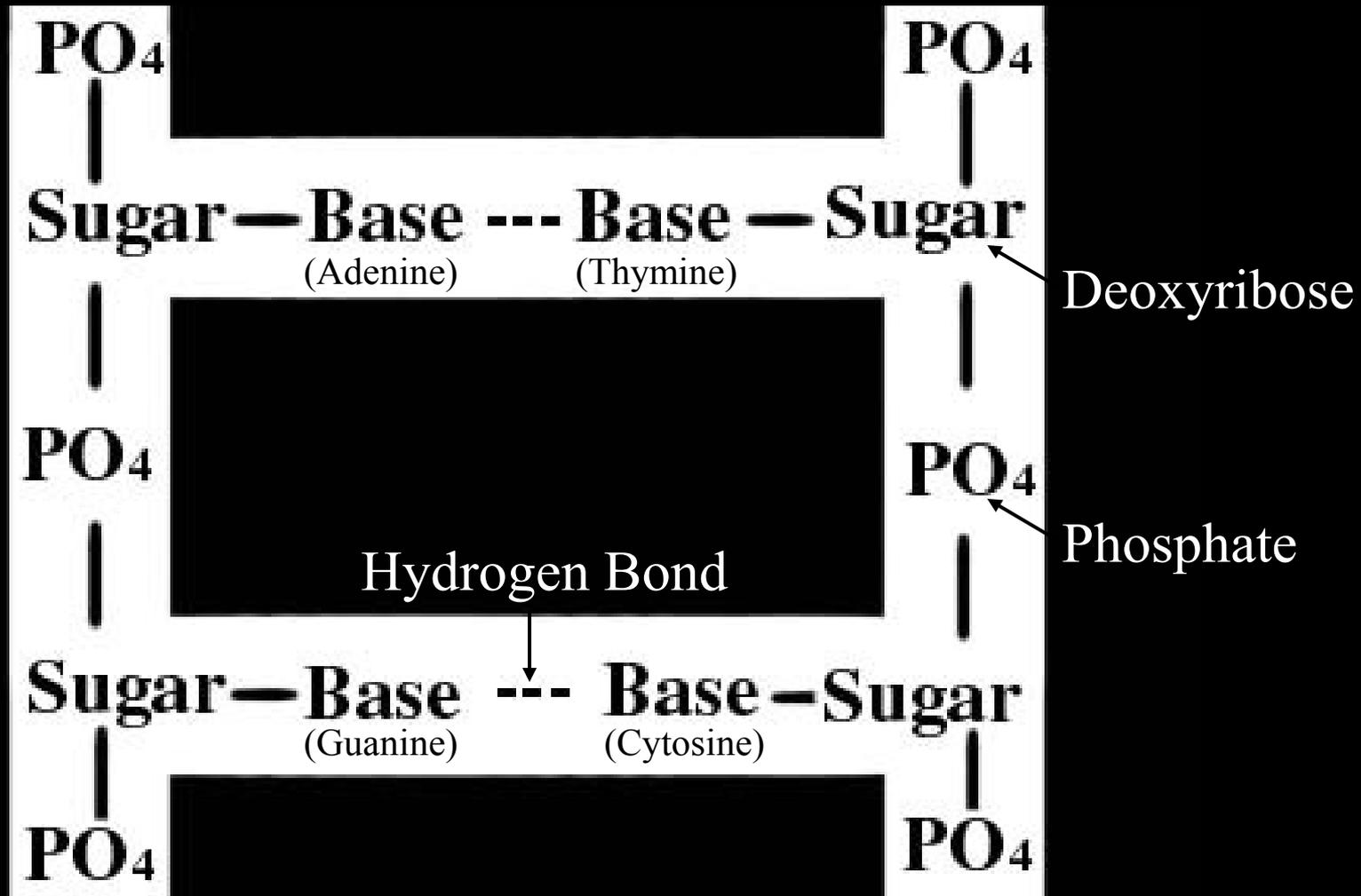
Pyrimadines

adenine.....thymine

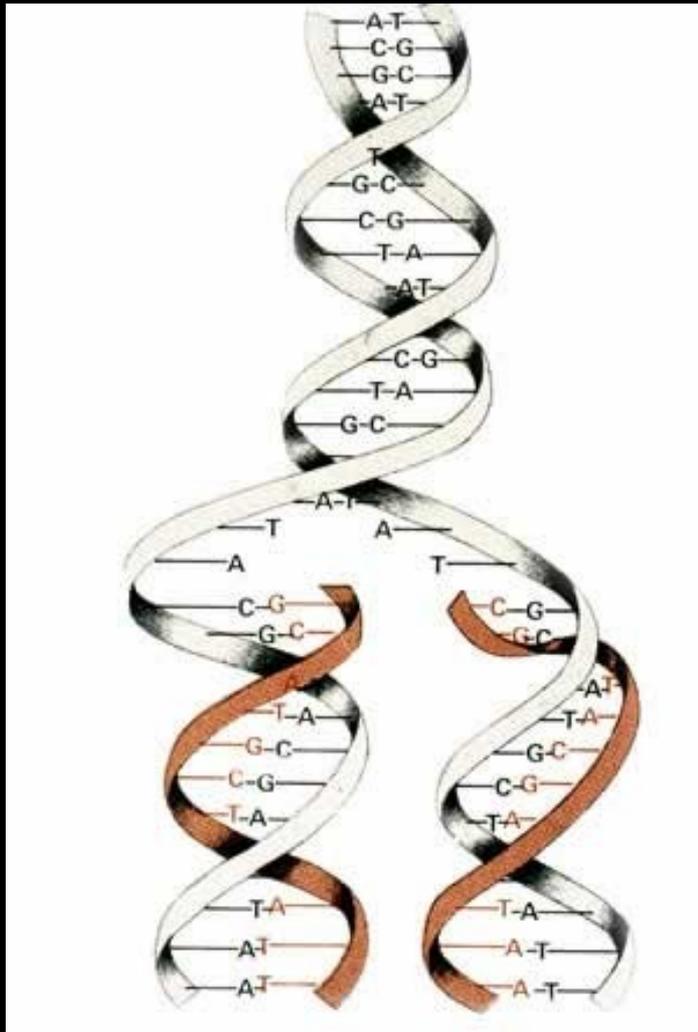
guaninecytosine

- Adenine will only combine with thymine and guanine will only combine with cytosine.
- The DNA macromolecule looks like a ladder that has been twisted to form a spiral staircase.
- The diagrams on the next two slides illustrate this configuration.

Molecular Composition of the Body:



Molecular Composition of the Body:



This diagram is illustrating DNA synthesis during cell division but, it also demonstrates the spiral staircase appearance of a DNA macromolecule.

Molecular Composition of the Body:

- Chromosomes have two **chromatids** (arms) that are attached by a centrally located **centromere**.
- When the cell is not actively dividing, the chromatids of each chromosome form long, thin strands called **chromatin**.
- However, during cell division, the chromatin shortens and thickens to reform the chromatids.
- In regards to the hierarchy of genetic material, a chromosome can be broken down into smaller segments of genetic material called **genes**.
- Genes are responsible for the transfer of hereditary information.
- Genes can then be broken down even further into individual strands of DNA.
- In summary, the hierarchy is as follows:
Chromosomes...Genes...DNA (smallest unit of genetic material)

Cell Structure:

- The **cell membrane** is the outermost portion of the cell and consists of two thin layers.

The cell membrane is selectively permeable in that it determines what is allowed in and out of the cell.

- **Protoplasm** is the organic material that comprises all living matter.
- **Cytoplasm** is protoplasm that is found within the cell membrane and outside the nuclear membrane of a cell.
- **Nucleoplasm** is protoplasm that is found within the nuclear membrane of a cell.

Cell Structure:

- **Organelles** are the many small organs that perform specific functions within the cell.
- **Mitochondria** are bean-shaped organelles within the cytoplasm.
They are known as the powerhouse of the cell as their function is to produce energy for cell use.
- The **endoplasmic reticulum (ER)** consists of a network of tubes or channels that are closely associated with the nucleus.
The ER is essentially the transport system from the nucleus to the cytoplasm.
- **Ribosomes** are small, round structures that are the site of protein synthesis.
They are either attached to the endoplasmic reticulum (rough ER) or are loose within the cytoplasm.

Cell Structure:

- The **golgi apparatus/bodies/complex** consists of a series of tubules that extend from the nucleus to the cell membrane.

It is essentially an area where proteins are packaged for transport out of the cell.

- **Lysosomes** are small sacs that contain the digestive enzymes of the cell.

They are commonly referred to as the digestive system of the cell as their primary function is to breakdown cellular debris.

- **Centrosomes** are located near the nucleus of the cell and they contain two centrioles.

Centrioles are cylindrical structures that spindle fibers attach to during cell reproduction.

Cell Structure:

- The **nucleus** is centrally located within the cell and it contains the genetic material (DNA) of the cell.

It is surrounded by a double walled membrane called the **nuclear envelope**.

The **nucleolus** is also located within the nucleus and it contains and stores RNA.

Cell Division: Mitosis Introduction

- There are two types of cells found in the human body.
 - Genetic cells** are the reproductive cells of the body and they divide by a process known as meiosis.
 - Somatic cells** are all cells in the body except the genetic cells and they divide by a process known as mitosis.
 - Somatic cells contain 46 chromosomes which is also known as the diploid number or $2n\#$.
- The process of **mitosis** consists of the following five distinct stages:
 - Interphase (G_1 , S, G_2)
 - Prophase
 - Metaphase
 - Anaphase
 - Telophase

Cell Division: Mitosis

- **Interphase** consists of the following:

Gap 1 (G₁) is a resting phase where the cell contains the diploid number ($2n\#$) of 46 chromosomes.

DNA synthesis (S) is the next phase where the DNA unwinds and joins with new phosphates, sugars and bases to create two identical strands of DNA.

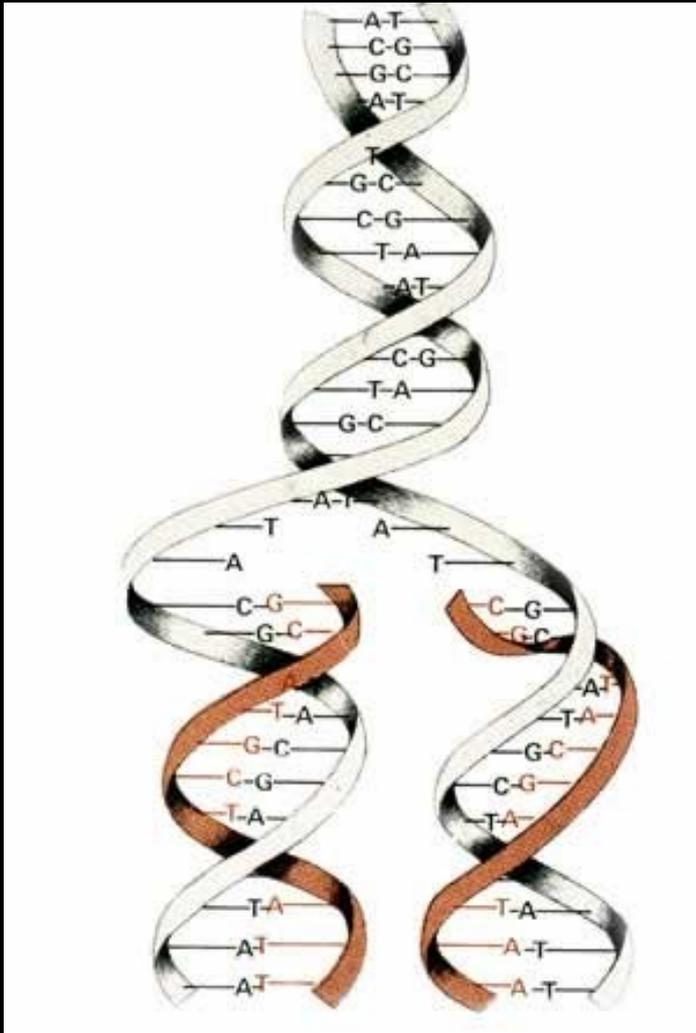
- Each chromosome now has two chromatids attached at the centromere.

- The nucleus now contains 92 chromosomes ($4n\#$) which is twice the normal amount of genetic material.

Gap 2 is a resting phase prior to the cell entering the next phase of mitosis (prophase).

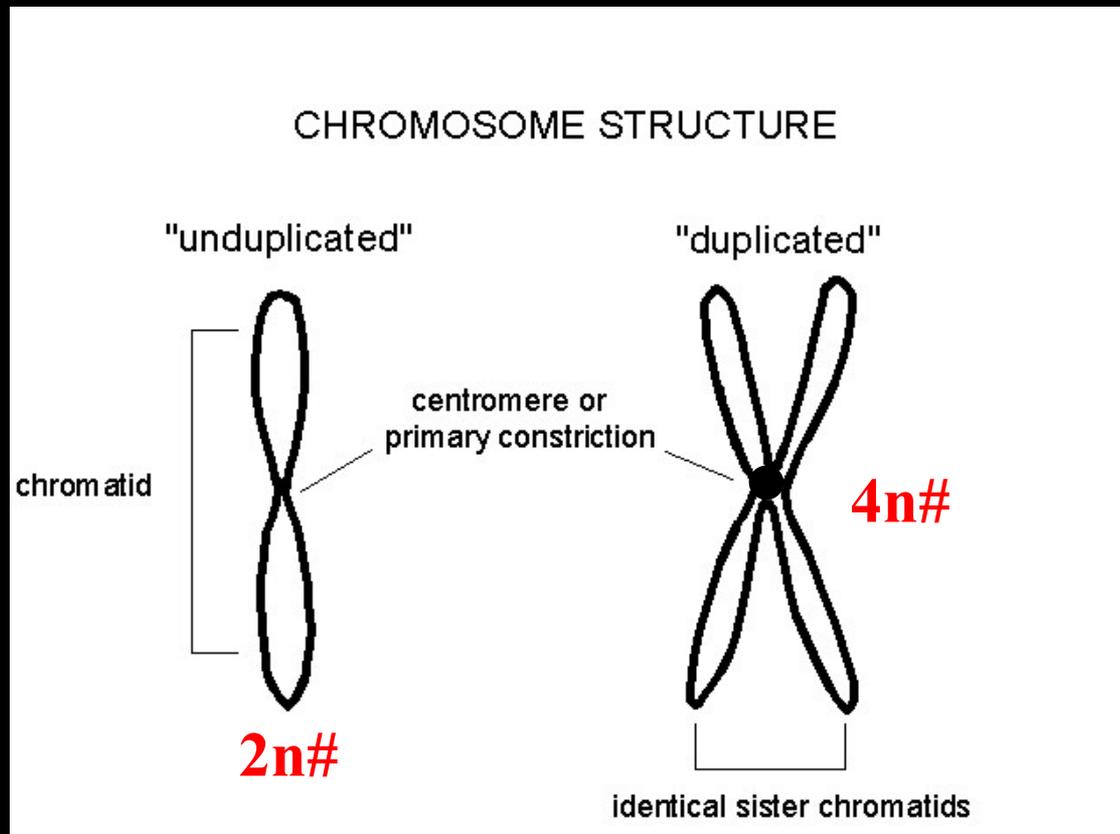
The diagrams on the next two slides illustrate DNA synthesis during interphase.

Mitosis: Interphase (DNA Synthesis)



This diagram illustrates how the DNA macromolecule unwinds and separates at the bases. New bases, phosphates and sugars attach to form two identical strands of DNA. The $4n$ of 92 chromosomes will be present within the cell.

Mitosis: Interphase (DNA Synthesis)



Following DNA synthesis, the $4n\#$ of 92 chromosomes will be present within the cell. Additionally, each pair of chromatids will be attached at the centromere.

Cell Division: Mitosis

- **Prophase** is characterized by the following events:

The chromatin shortens and thickens to take on the characteristic **chromatid** appearance as demonstrated on the previous slide.

The **nuclear membrane** dissolves and disappears.

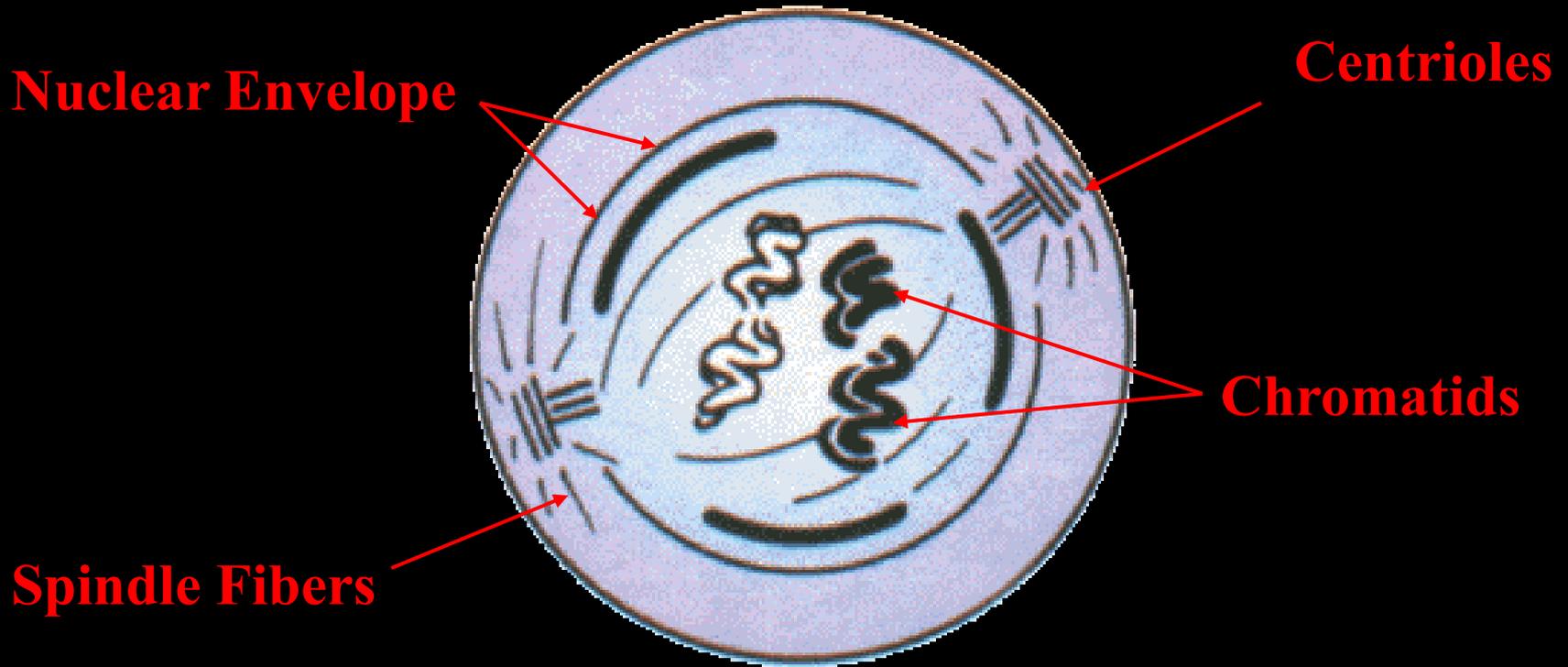
The **centrioles** separate and move to opposite ends of the cell.

Mitotic spindle fibers initially appear between the centrioles.

-These delicate fibers extend from each pole of the cell.

The next slide illustrates this process.

Mitosis: Prophase



During prophase, the chromatin shortens to form chromatids, the nuclear envelope disappears, the centrioles migrate to opposite ends of the cell and spindle fibers appear.

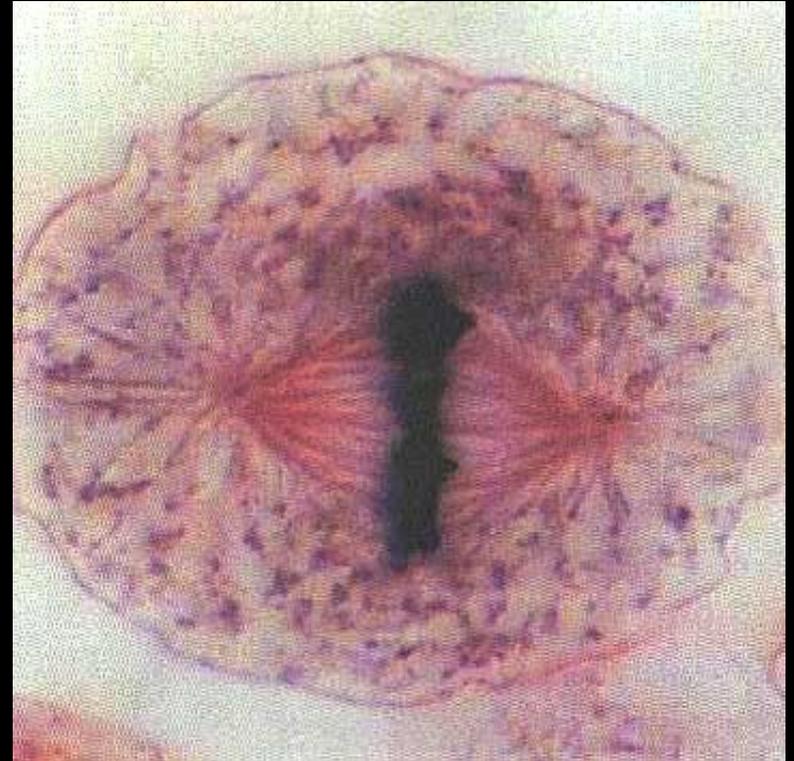
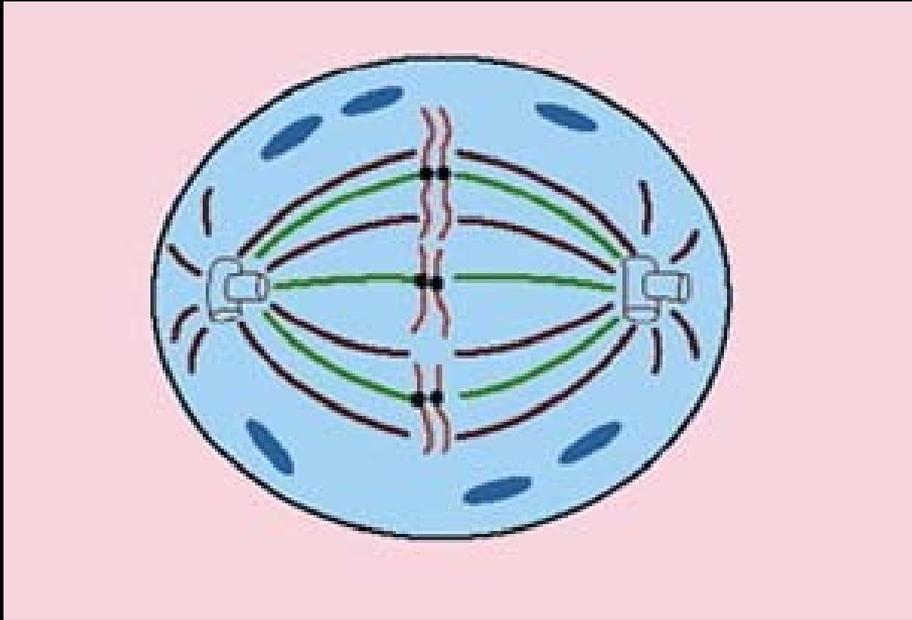
Cell Division: Mitosis

- **Metaphase** is characterized by the following events:

The centromere of each chromosomes, which contains four chromatids, attaches to a spindle fiber at the equatorial plate of the cell.

The next slide illustrates this process.

Mitosis: Metaphase



During metaphase, the chromosomes align themselves along the equatorial plate of the cell and attach to a spindle fiber.

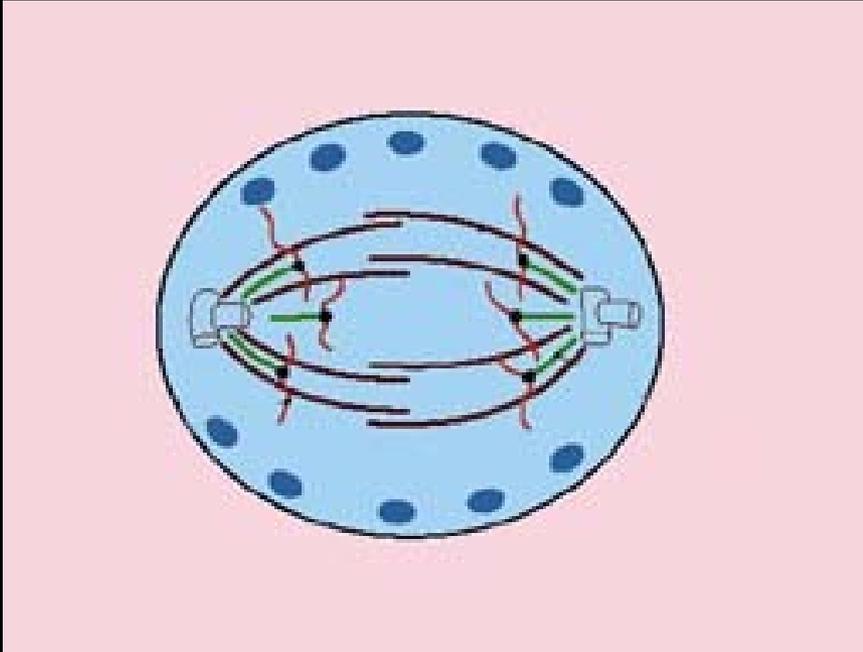
Cell Division: Mitosis

- **Anaphase** is characterized by the following events:

The centromere duplicates and the chromosomes begin to migrate to opposite ends of the cell.

The next slide illustrates this process.

Mitosis: Anaphase



During anaphase, the centromere duplicates and the chromosomes begin to migrate to opposite ends of the cell.

Cell Division: Mitosis

- **Telophase** is characterized by the following events:

The chromatids of each chromosome convert back to chromatin by becoming longer and thinner.

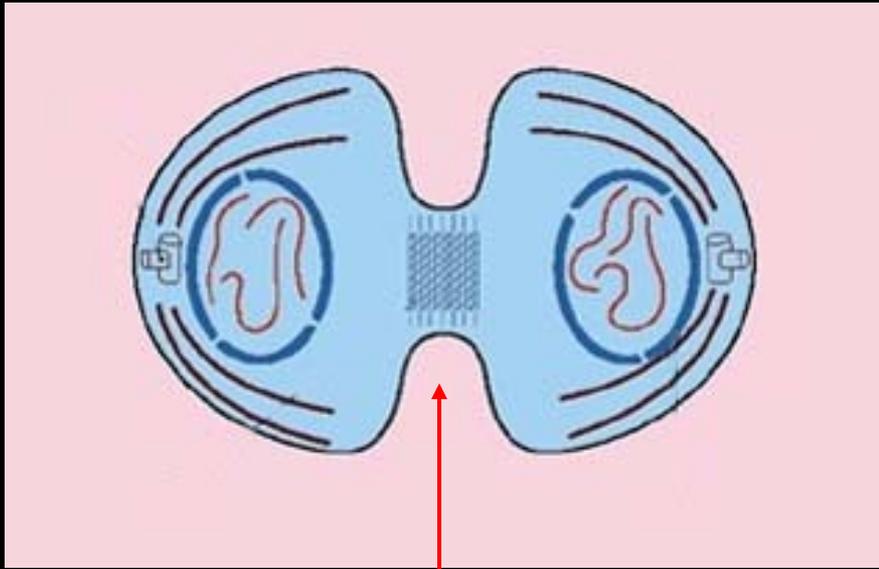
The nuclear membrane reappears around the genetic material.

A **division furrow** appears as the cytoplasm and organelles are divided between the two daughter cells by a process called **cytokinesis**.

Each daughter cell now contains the required diploid number of 46 chromosomes.

The next slide illustrates this process.

Mitosis: Telophase



Division Furrow



During telophase, a division furrow appears and the organelles and cytoplasm are equally divided between the two daughter cells by a process called cytokinesis. Also, the nuclear membrane reappears around the genetic material.

Cell Division: Meiosis

- **Genetic cells** are the reproductive cells of the body.

The spermatocyte is the male genetic cell and the oocyte is the female reproductive cell or egg.

The male and female reproductive cells each contain 23 chromosomes which is the **haploid number** or $n\#$.

When they join during fertilization, the **diploid number** ($2n\#$) of 46 chromosomes will be achieved.

- Genetic cells are produced within the body by a process called **meiosis**.

This is commonly referred to as a **reduction division** where a genetic cell starts with the $2n\#$ of chromosomes and goes through two mitotic-like divisions to produce four daughter cells that possess the desired $n\#$ of chromosomes.

Cell Division: Meiosis

- The following steps occur during **meiosis I**:

During interphase, the DNA is replicated to the $4n\#$ of 92 chromosomes and this is followed by the regular phases of mitosis.

The end result is two daughter cells that have the $2n\#$ of chromosomes.

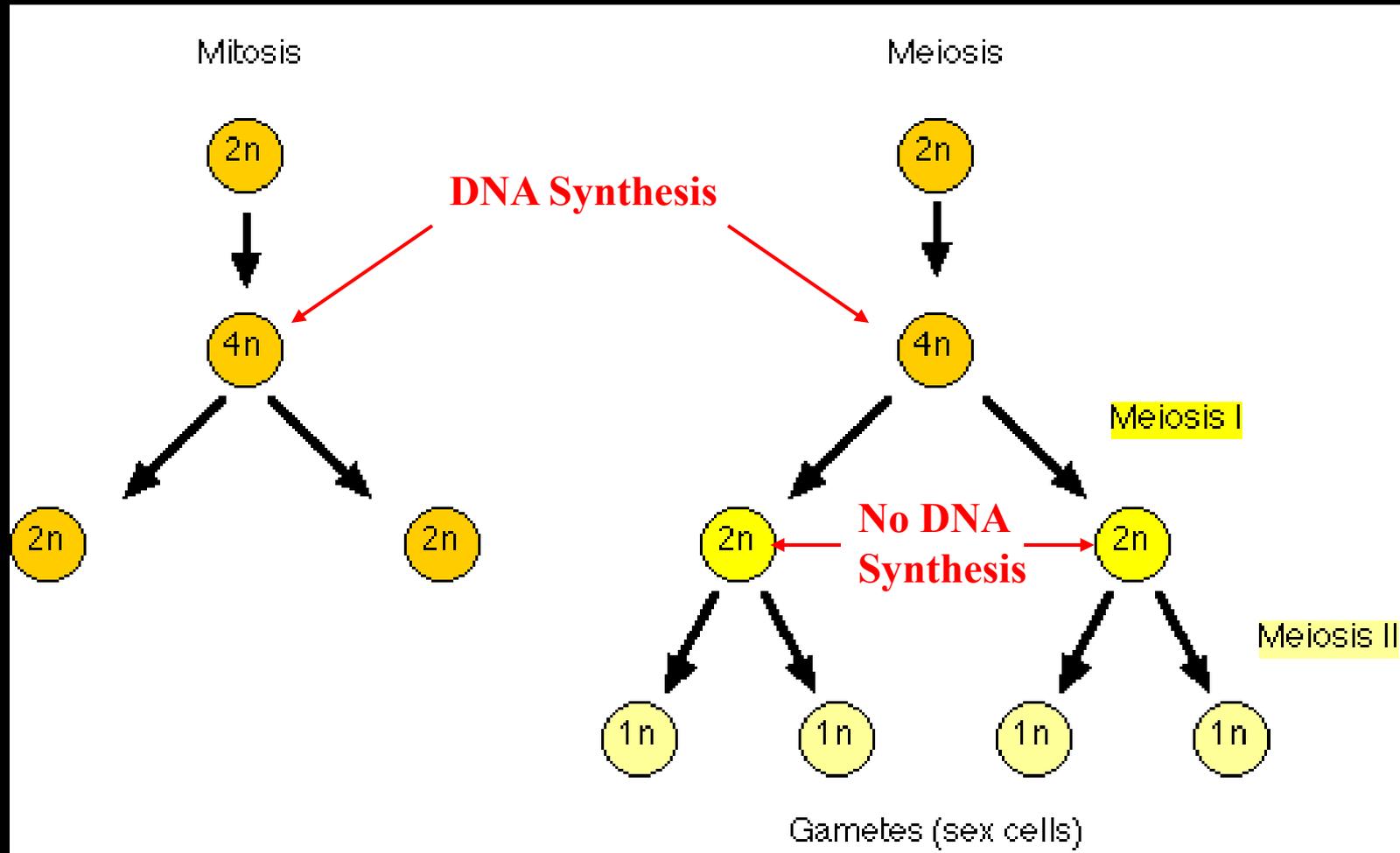
- The following steps occur during **meiosis II**:

During interphase the DNA is NOT replicated.

This is followed by the regular phases of mitosis and the end result is four daughter cells that contain the $n\#$ of chromosomes.

The next slide contains a diagram that compares the stages of mitosis to meiosis.

Cell Division: Mitosis vs. Meiosis



Preface to the Radiologic Units Component of the Tutorial:

The design of this section employs a bulleted format as opposed to the more traditional method of employing standard paragraphs. The expository nature of the material is very well suited for this style of delivery. Furthermore, the bulleted format will facilitate the learner's ability to quickly reference the material when answering the mastery test questions.

Radiologic Units

- 1. Introduction to Radiologic Units**
- 2. Radiation Intensity in Air**
- 3. Unit of Absorbed Dose**
- 4. Quantity of Radioactive Material**
- 5. Unit for Dose Equivalence (H)**

Introduction to Radiologic Units:

- In 1990, the National Council on Radiation Protection and Measurements (NCRP) recommended that the International System (SI) of Units be adopted in the United States.
- SI units are an extension of the metric system and replaced the Traditional or Conventional System of Units that were used in the U.S.
- Both systems will be described in this unit.

Radiation Intensity in Air:

- The conventional unit used to describe a quantity of radiation intensity in the air is called the roentgen (R).

The roentgen is used to measure a quantity of ionizations that occur in a volume of dry air after exposure to either x-rays or gamma rays.

One roentgen is equal to 2.58×10^{-4} C/kg.

It is important to note that x-ray tube output is measured in mR (1R = 1000 mR).

Furthermore, the roentgen refers to x-ray and gamma ray interactions with air and not to particulate exposure (Beta or Alpha Particles).

Radiation Intensity in Air:

- The SI system simply describes radiation intensity in air by using coulombs per kilogram (C/kg).

It is equal to an electric charge (ionizations) of 1 coulomb produced in a kilogram of dry air as the result of exposure to either x-rays or gamma rays.

Unit of Absorbed Dose:

- The conventional unit of absorbed dose per unit of mass is the rad.
It is defined as 100 ergs of energy being absorbed by 1 gram of absorbing material.
$$1 \text{ rad} = 100 \text{ ergs/g.}$$

An erg is a unit used to describe energy and work.
The rad is the unit most often employed to describe radiation exposure to the patient.
- The SI unit for absorbed dose is the gray (Gy).
It is defined 1 joule of energy being absorbed by 1 kilogram of absorbing material.
$$1 \text{ Gy} = 1 \text{ J/kg}$$

A Joule is the SI unit used to describe energy and work.

Unit of Absorbed Dose:

- The following guidelines can be employed to convert units of absorbed dose between the conventional and SI system:

$$1 \text{ Gy} = 100 \text{ rad}$$

If you need to convert from units of Gy to units of rad, simply multiply the quantity of Gy by a factor of 100.

$$10 \text{ Gy} = 1,000 \text{ rad}$$

$$100 \text{ Gy} = 10,000 \text{ rad}$$

On the other hand, $1 \text{ rad} = 0.01 \text{ Gy}$

If you want to convert from units of rad to units of Gy, simply divide the quantity of rad by a factor of 100.

$$1,000 \text{ rad} = 10 \text{ Gy}$$

$$10,000 \text{ rad} = 100 \text{ Gy}$$

Quantity of Radioactive Material:

- The conventional unit used to describe a quantity of radioactive material is the Curie (Ci).

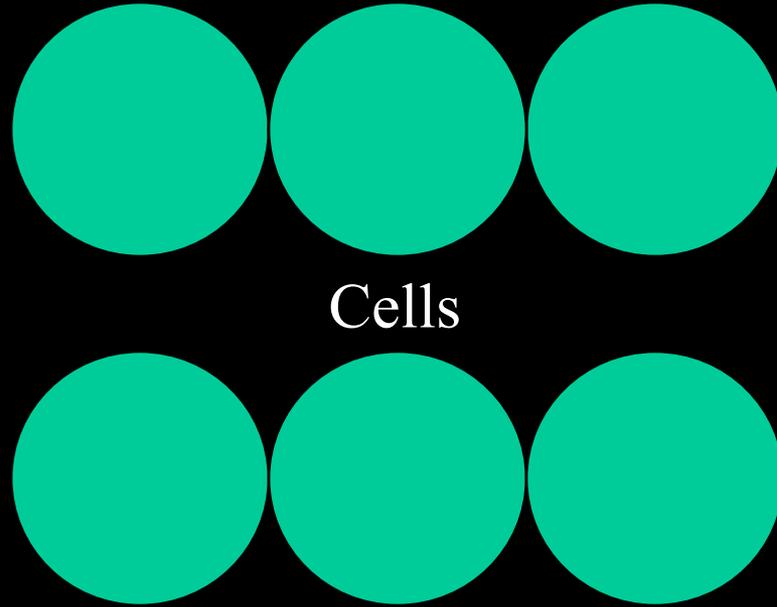
This unit refers to the actual quantity of radioactive material and not to the radiation that is emitted.

- The SI unit for a quantity of radioactive material is the becquerel (Bq).

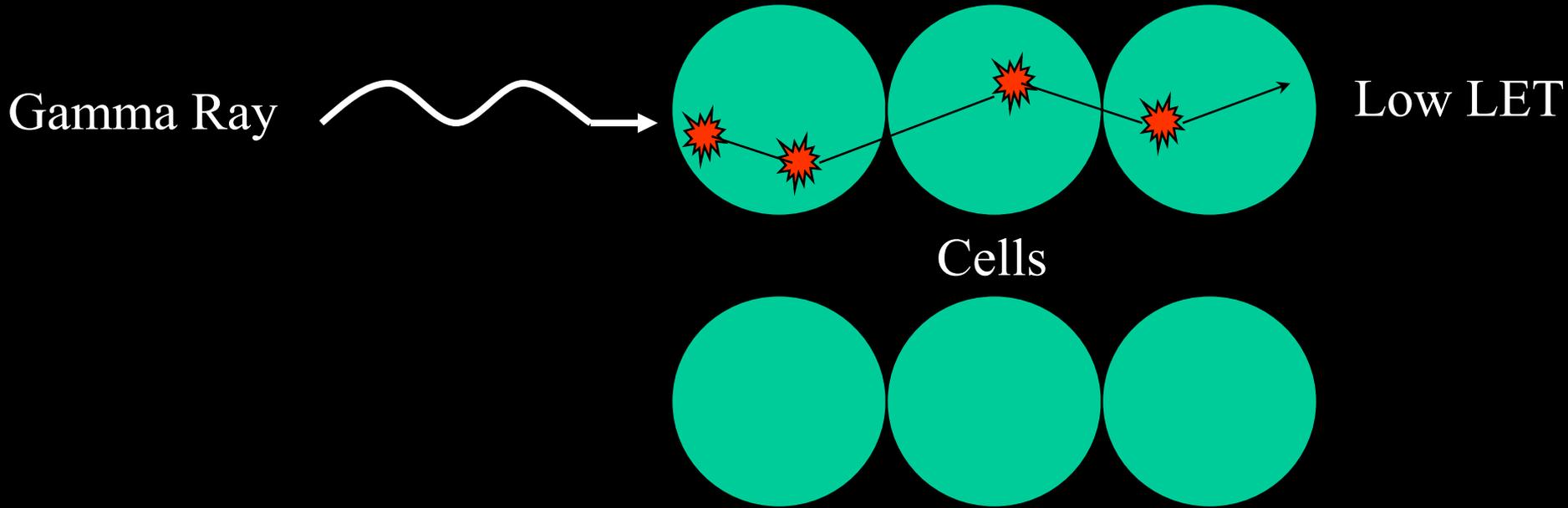
Unit for Dose Equivalence (H):

- As ionizing radiation (x-rays & gamma rays) and particles (alpha, beta & neutrons) travel through matter, ionizations occur.
- As these ionizations occur, energy is transferred from the radiation or particle to the matter.
- This energy transfer can cause biologic damage in living tissue.
- This process is referred to as linear energy transfer or LET.
- The more energy that the radiation or particle possesses, the more likely that it will pass right through matter and cause little if any ionizations to occur (energy transfer).
- On the other hand, the more mass that it possesses increases the likelihood that there will be a transfer of energy at the point of impact with matter and therefore, more ionizations (energy transfer) will occur.
- The next slide illustrates the concept of LET.

Unit for Dose Equivalence (H):

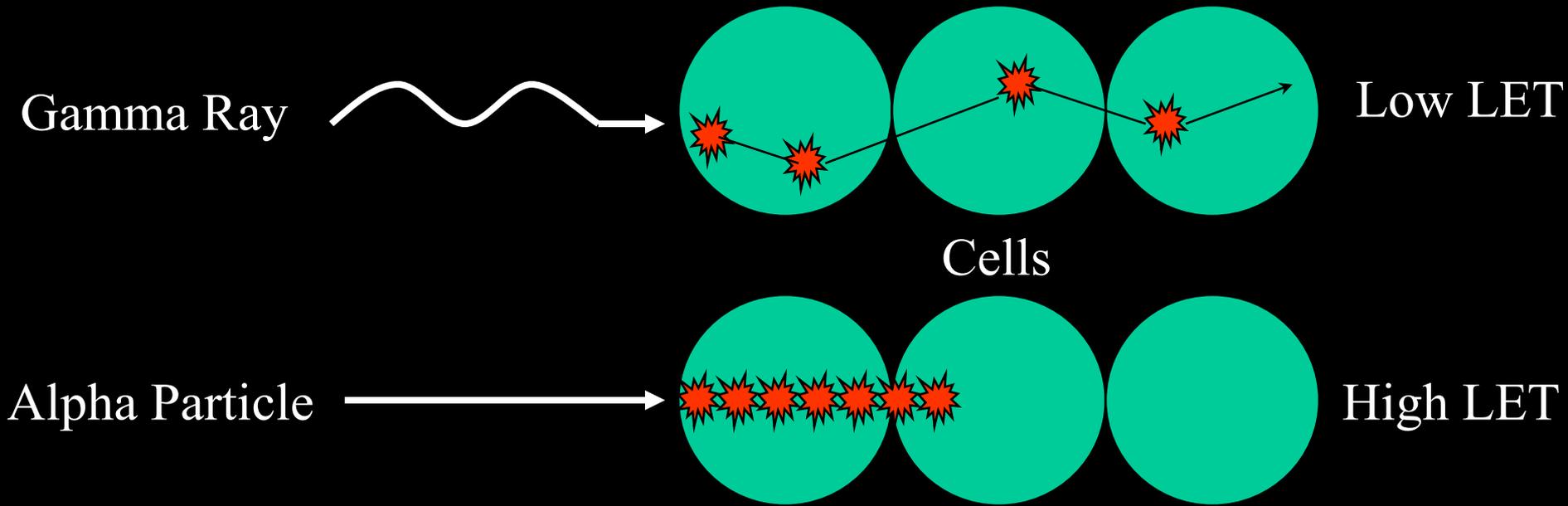


Unit for Dose Equivalence (H):



The gamma ray is sparsely ionizing and retains most of its energy when it exits.

Unit for Dose Equivalence (H):



The gamma ray is sparsely ionizing and retains most of its energy when it exits.

The alpha particle has less energy and a higher mass and as a result, it very quickly loses its energy as it tries to penetrate the cells. Therefore, the alpha particle would have a much higher LET than the gamma ray.

Unit for Dose Equivalence (H):

- The list below ranks different types of radiations and particles according to their LET values.
- Keep in mind that this list is based on their energy levels and mass values.
- For example, alpha particles have a low energy level and a high atomic mass and therefore, possess the highest LET.

Highest LET	Alpha Particles (can be stopped by paper)
	Neutrons
	Beta Particles
	X-rays (no atomic mass)
Lowest LET	Gamma Rays (highest energy level & no mass)



Unit for Dose Equivalence (H):

- As you can see, different types of ionizing radiation and particles can cause varying amounts of biologic damage due to their different LET values.
- Therefore, a system to create a level playing field was developed to address different LET values and their biologic effects on living cells.
- Dose equivalence (H) is equal to the absorbed dose (rad) times a quality factor (Q) and is represented by the following formula:

$$H = \text{rad} \times Q$$

Unit for Dose Equivalence (H):

- A quality factor is employed to compensate for the different LET values of ionizing radiation and particles.
- The scale is as follows:

Dose	Quality Factor
1 rad of x-rays or gamma rays	1
1 rad of neutrons	5 to 20
1 rad of alpha particles	20

- According to the scale above, 1 rad of alpha particles will be 20 times more damaging to cells than 1 rad of x-rays.
 - This is because alpha particles have a much higher LET than x-rays due to their low energy and high atomic mass.

Unit for Dose Equivalence (H):

- The conventional unit for dose equivalence is the rem and it is the unit employed on dosimetry reports.
- The rem is equal to the absorbed dose in rad times the quality factor.

$$H \text{ in rem} = \text{rad} \times Q$$

- The sievert (Sv) is SI unit for dose equivalence and it is equal to the absorbed dose in gray times the quality factor.

$$H \text{ in Sv} = \text{Gy} \times Q$$

Unit for Dose Equivalence (H):

- The following is an example of how to calculate dose equivalence:

Calculate the total exposure that a patient would receive if he/she were exposed to the following doses of ionizing radiation and particles: 50 rad of x-rays ($Q = 1$), 10 rad of neutrons ($Q = 10$), and 5 rad of alpha particles ($Q = 20$)

Use the following formula: Dose in rad x $Q = H$ in rem

H for x-ray exposure: $50 \times 1 = 50$ rem

H for neutron exposure: $10 \times 10 = 100$ rem

H for alpha particle exposure: $5 \times 20 = 100$ rem

Total H = 250 rem

The patient's total, weighted exposure was 250 rem.

Unit for Dose Equivalence (H):

- The following guidelines can be employed to convert units of dose equivalence between the conventional and SI system:

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

If you need to convert from units of Sv to units of rem, simply multiply the quantity of Sv by a factor of 100.

$$10 \text{ Sv} = 1,000 \text{ rem}$$

$$100 \text{ Sv} = 10,000 \text{ rem}$$

On the other hand, $1 \text{ rem} = 0.01 \text{ Sv}$

If you want to convert from units of rem to units of Sv, simply divide the quantity of Sv by a factor of 100.

$$1,000 \text{ rem} = 10 \text{ Sv}$$

$$10,000 \text{ rem} = 100 \text{ Sv}$$

Preface to the Radiation Protection for the Radiographer & the Patient Unit:

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Radiation Protection for the Radiographer & the Patient

- 1. Introduction to Radiation Safety**
- 2. Dose Limits for Radiographers and Patients**
- 3. Genetically Significant Dose**
- 4. Stochastic vs. Nonstochastic Effects**
- 5. Guidelines for Dose Reduction**

Introduction to Radiation Safety:

- There are many issues that must be addressed when considering radiation protection for the patient and health care workers.
- Some of these issues deal with annual dose limits for radiographers, designing radiographic rooms to protect the patient and personnel, and setting technical factors that will produce diagnostic radiographs while keeping the patient dose to a minimum.
- These three areas of radiation protection will be closely examined in subsequent sections of this tutorial.
- Additionally, contributions from national organizations that provide guidelines for radiation safety will also be examined.
- The next slide will begin our discussion on radiation safety by introducing the dose limit concept for occupationally exposed individuals.

Dose Limits for Radiographers:

- The **National Council of Radiation Protection and Measurement (NCRP)** is the government organization that sets dose limits for occupationally exposed individuals.
- The NCRP bases some of its guidelines on a report that was published by the **Committee on the Biologic Effects of Ionizing Radiation (BEIR)**.
- The BEIR V report states that the health risks from exposure to ionizing radiation were approximately three to four times greater than what was previously stated in their 1980 report.
- The models found on the following slides can be employed to illustrate their findings.

Linear, Nonthreshold Dose-Response Curve:

- **Dose-response curves** are employed to illustrate the risk of exposure to ionizing radiation.

These curves refer to the fact that for every *dose* of ionizing radiation, there will be some biologic *response* or effect.

- The following is a list of characteristics of the **linear, non-threshold dose-response curve**:

It consists of a straight line passing through the origin.

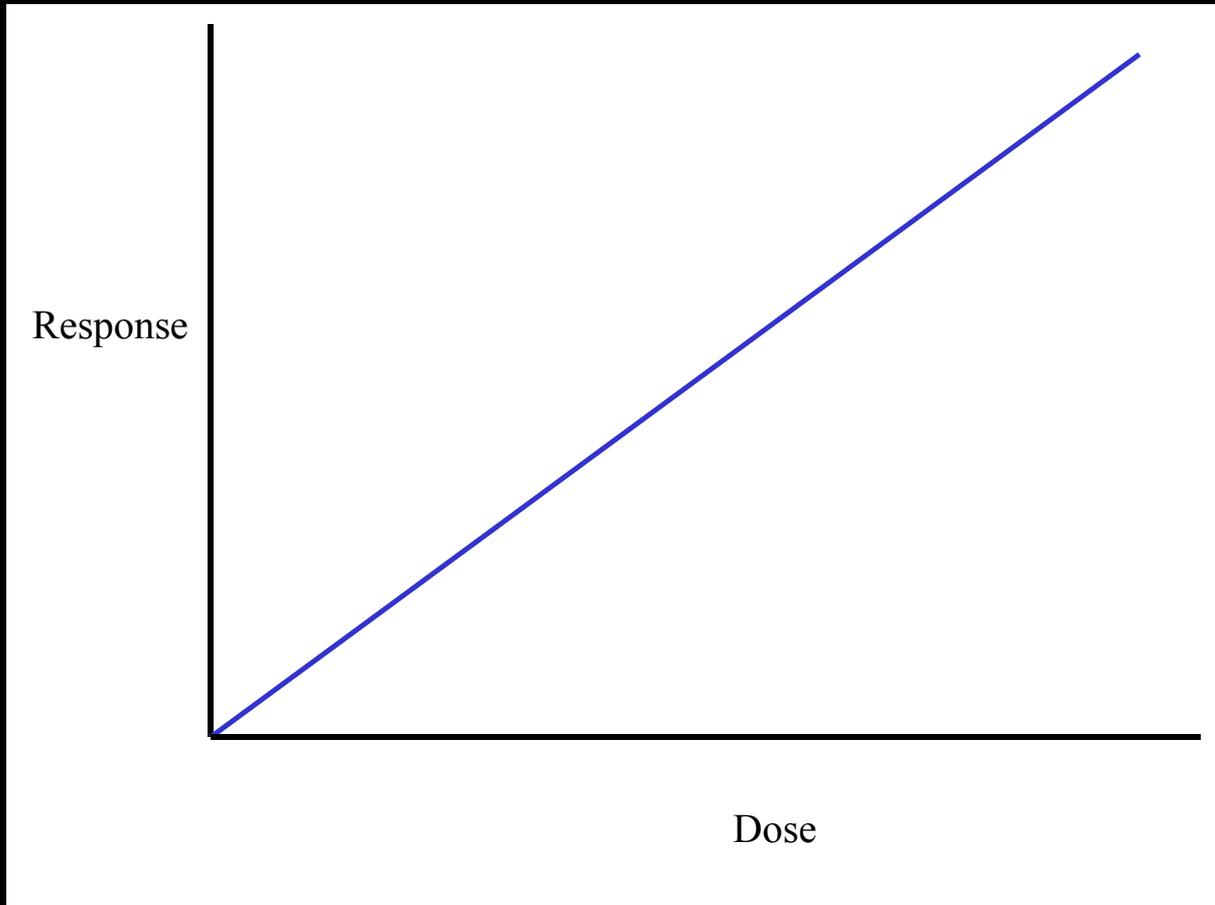
Any dose, regardless of size will induce a response.

An equal increase in dose will yield an equal increase in response.

It is thought to overestimate the tissue damage as a result of exposure to ionizing radiation.

The following slide illustrates this concept.

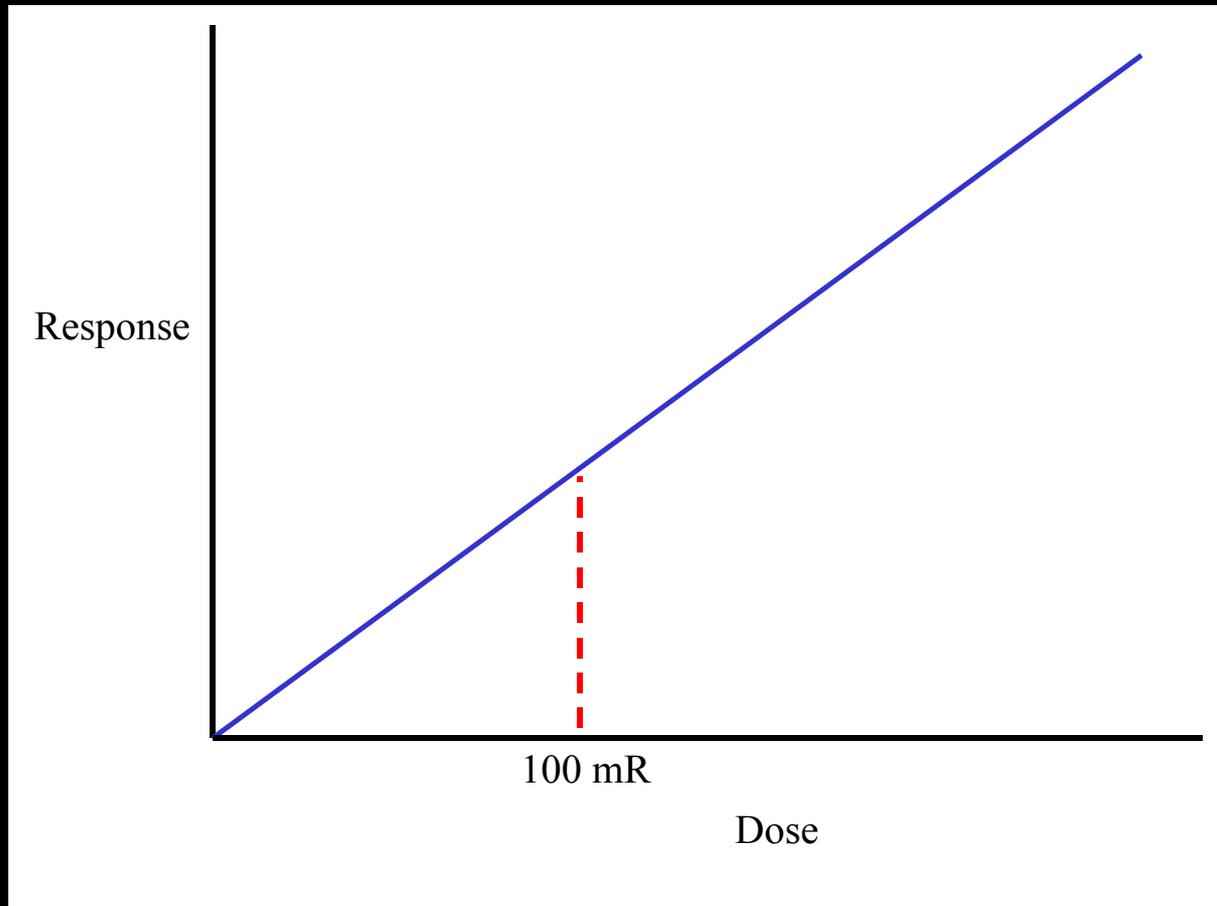
Linear, Nonthreshold Dose-Response Curve:



This dose-response curve illustrates that any dose, regardless of size, will induce a response.

It must be emphasized that this is a hypothetical example of dose-response relationships.

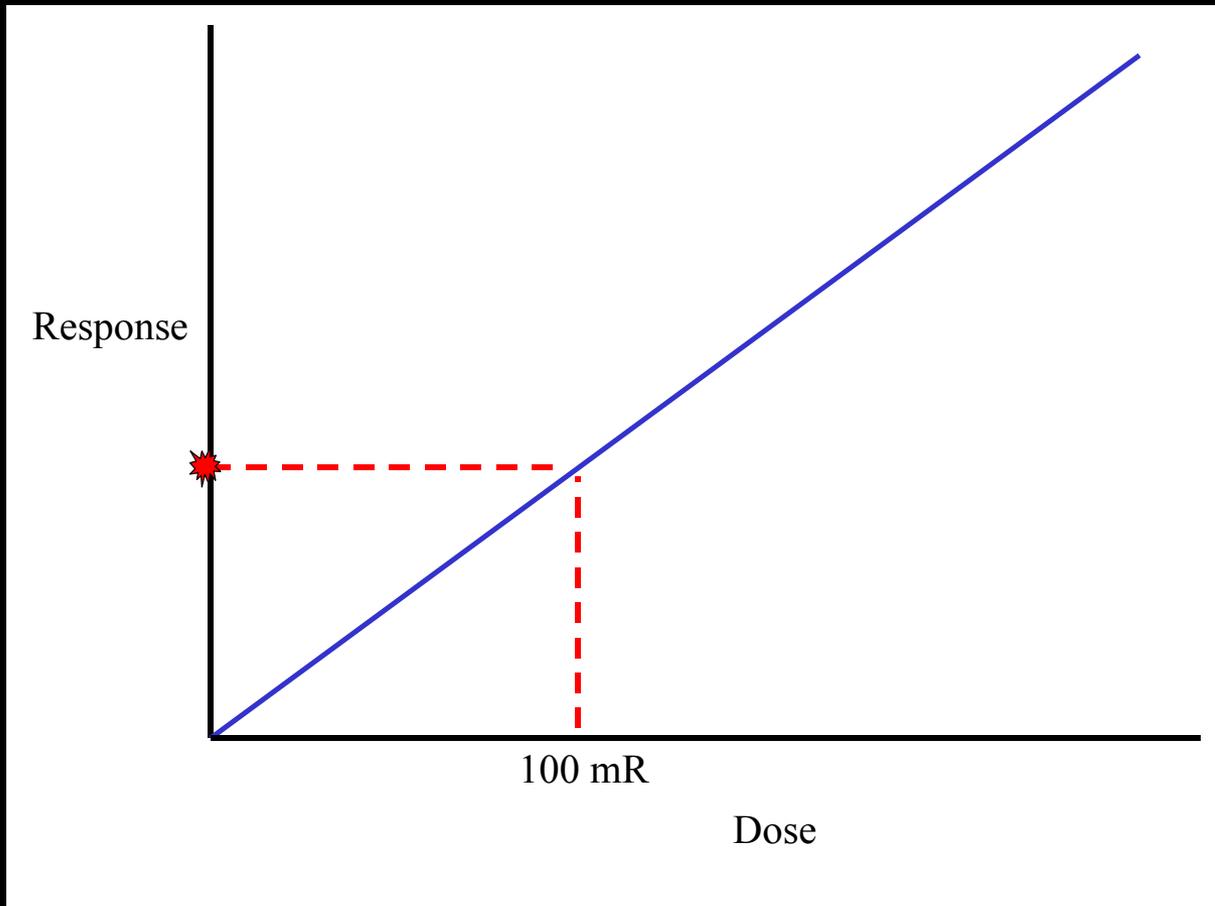
Linear, Nonthreshold Dose-Response Curve:



This dose-response curve illustrates that any dose, regardless of size, will induce a response.

It must be emphasized that this is a hypothetical example of dose-response relationships.

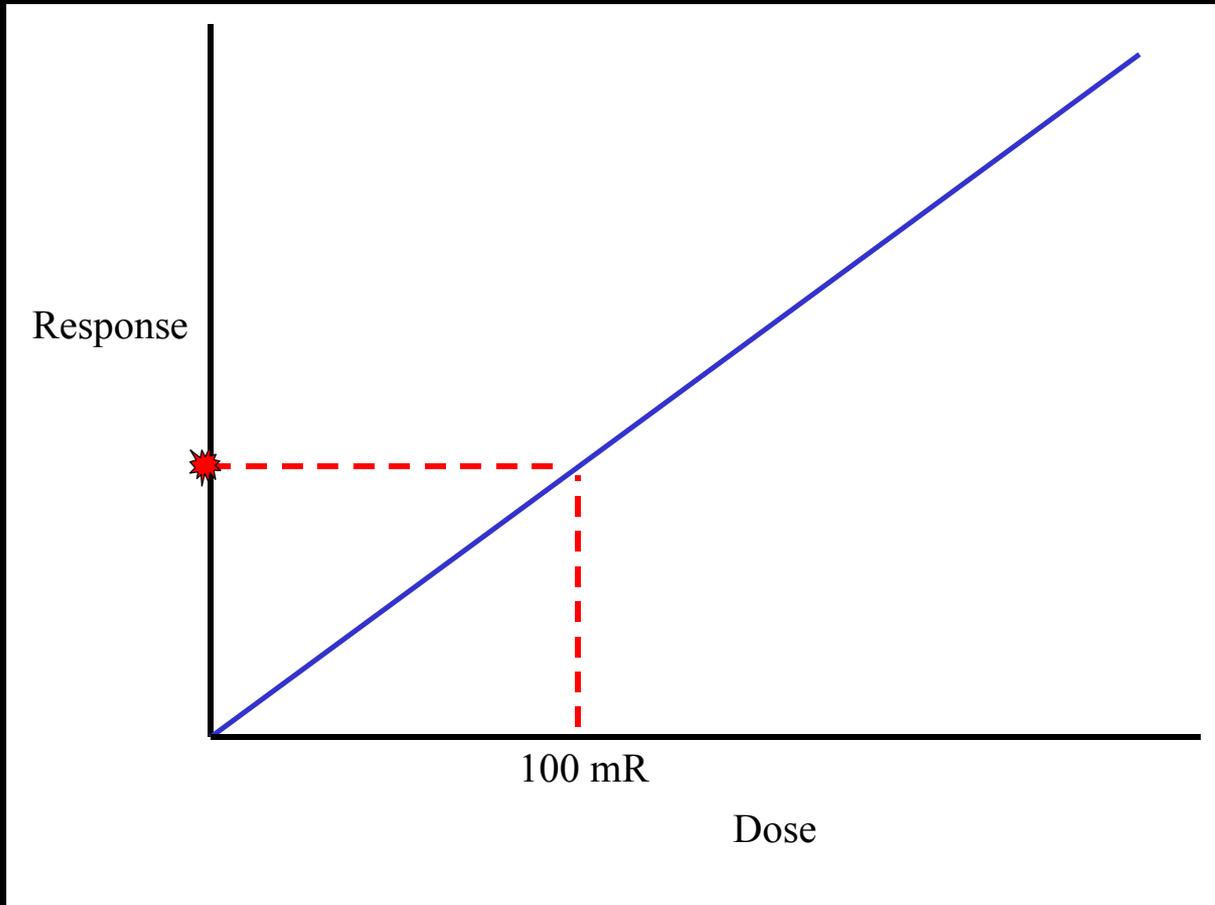
Linear, Nonthreshold Dose-Response Curve:



This dose-response curve illustrates that any dose, regardless of size, will induce a response.

It must be emphasized that this is a hypothetical example of dose-response relationships.

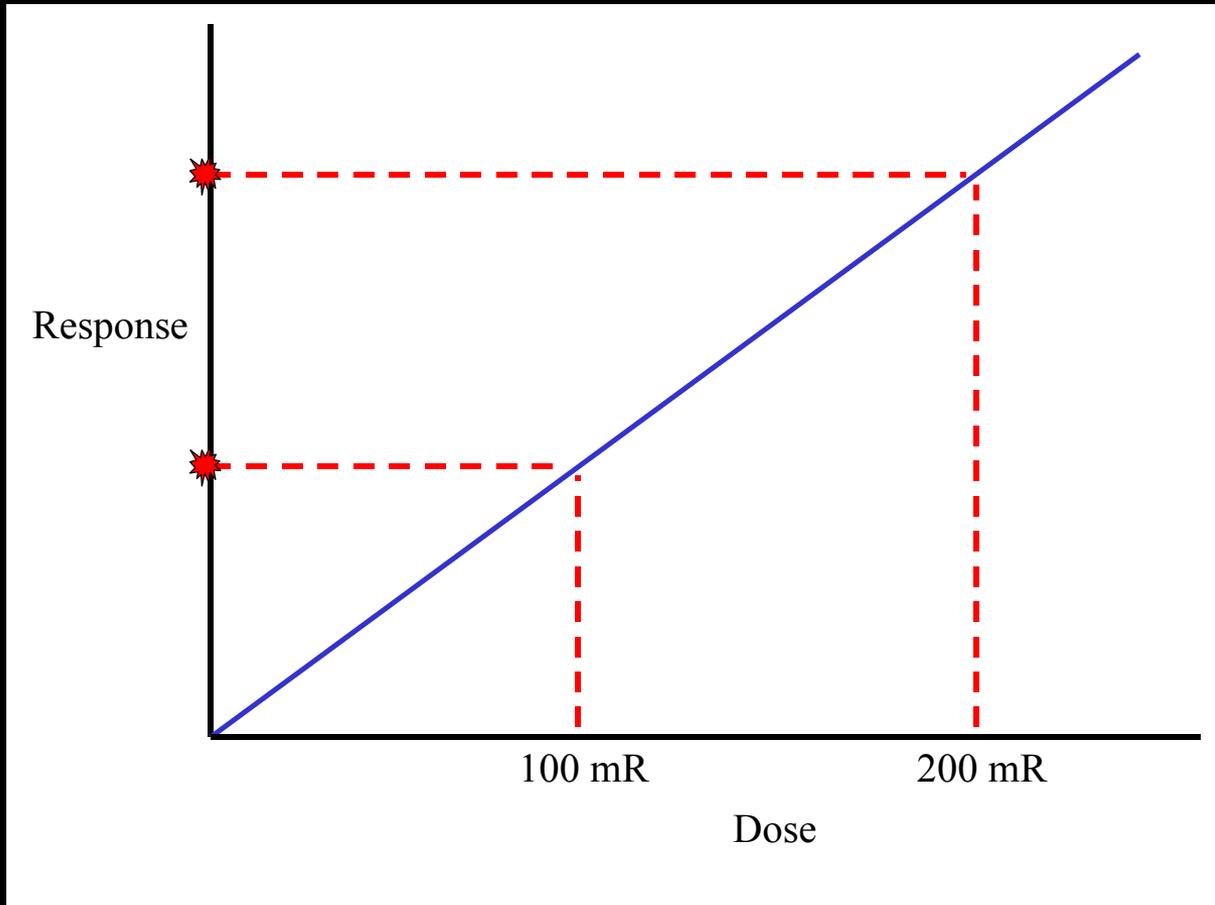
Linear, Nonthreshold Dose-Response Curve:



If the dose is exactly doubled, the response will also be exactly doubled.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Linear, Nonthreshold Dose-Response Curve:



If the dose is exactly doubled, the response will also be exactly doubled.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Nonlinear, Nonthreshold Dose-Response Curve:

- This dose-response curve is based on clinical data and is considered to be more accurate than the linear, nonthreshold model.
- The following is a list of characteristics of the **nonlinear, non-threshold dose-response curve**:

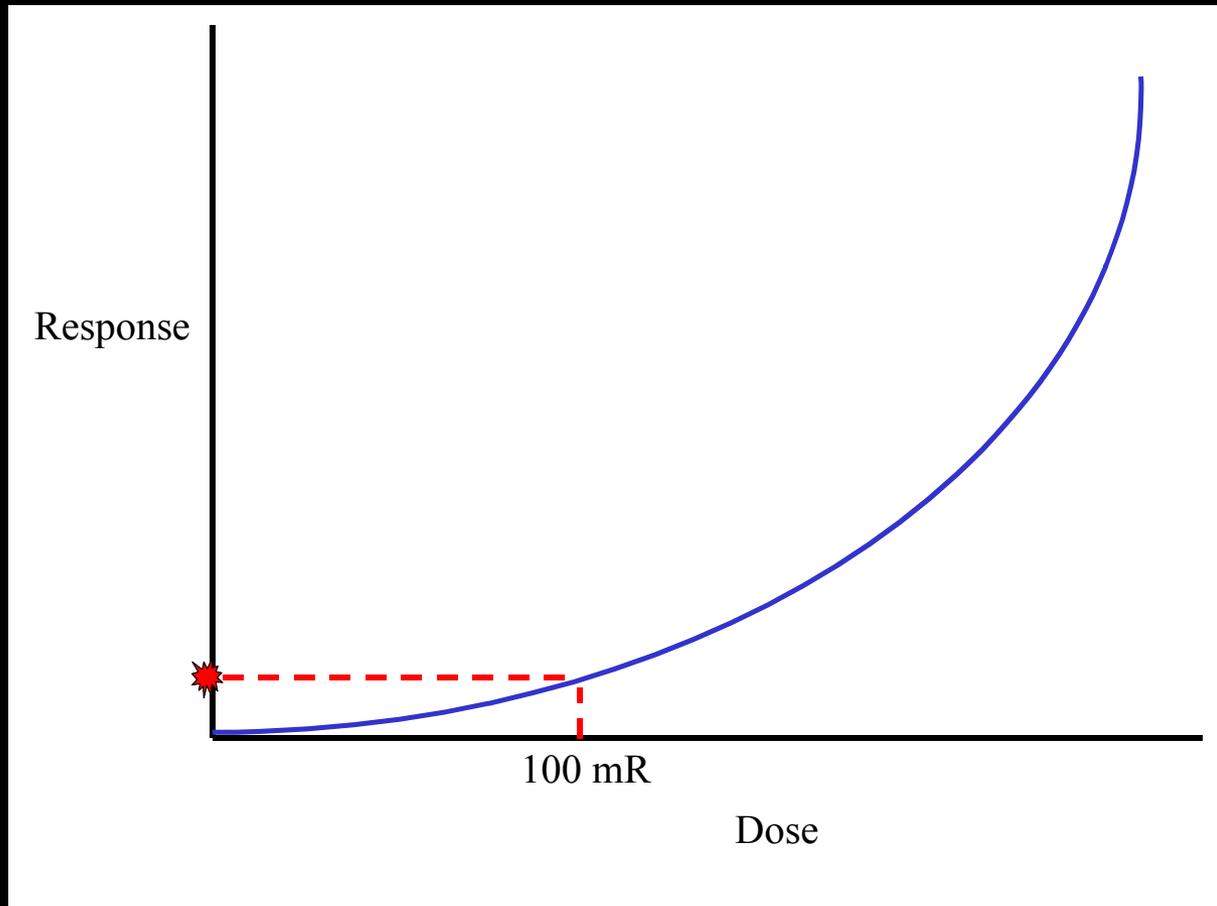
Since it consists of a curve that leaves from the origin, it is sometimes referred to by its mathematical moniker and called the linear-quadratic model.

Any dose, regardless of size will induce a response.

At low doses, a low response is induced but as the dose increases, so does the response.

The following slide illustrates this concept.

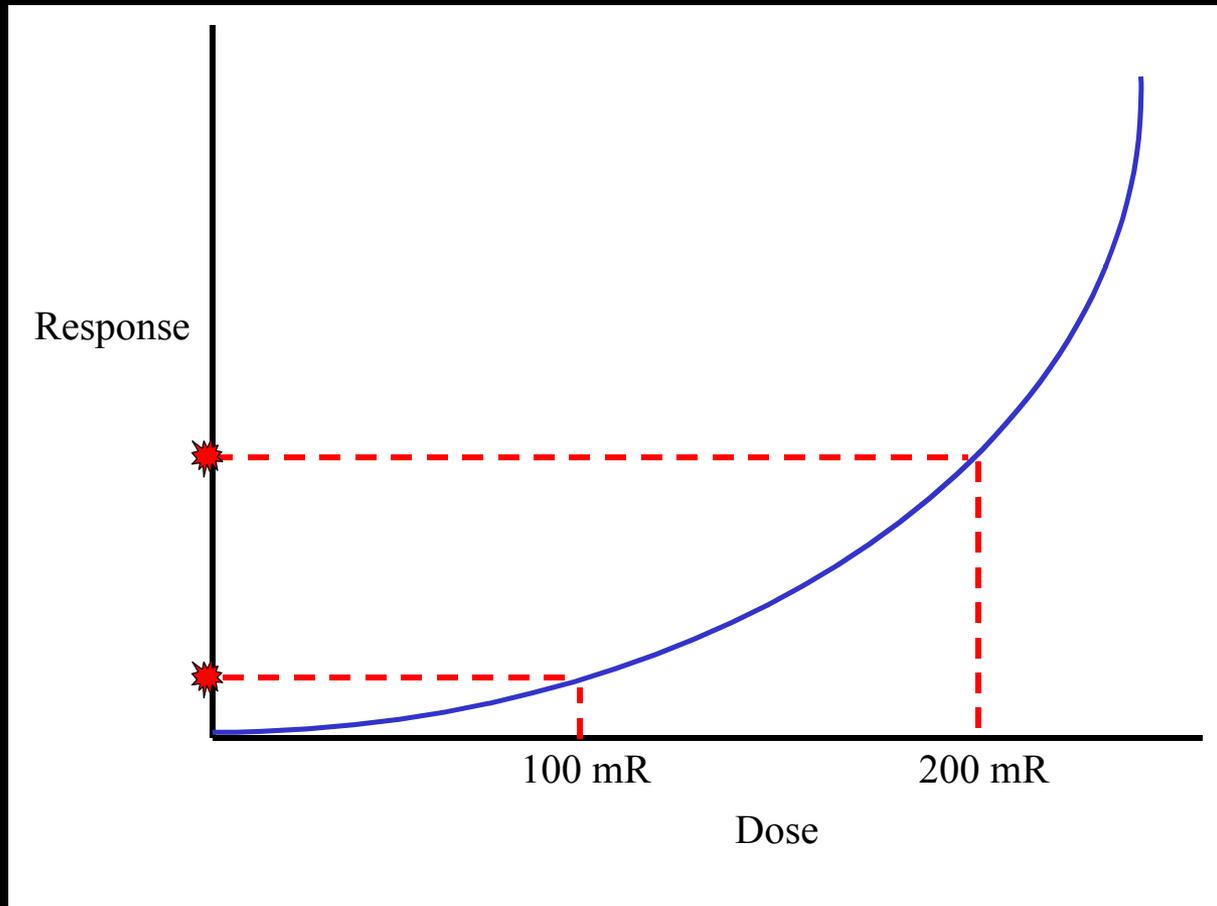
Nonlinear, Nonthreshold Dose-Response Curve:



This dose-response curve illustrates that any dose, regardless of size, will induce a response.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Nonlinear, Nonthreshold Dose-Response Curve:



However, if the dose is exactly doubled, the response will **not** be doubled.

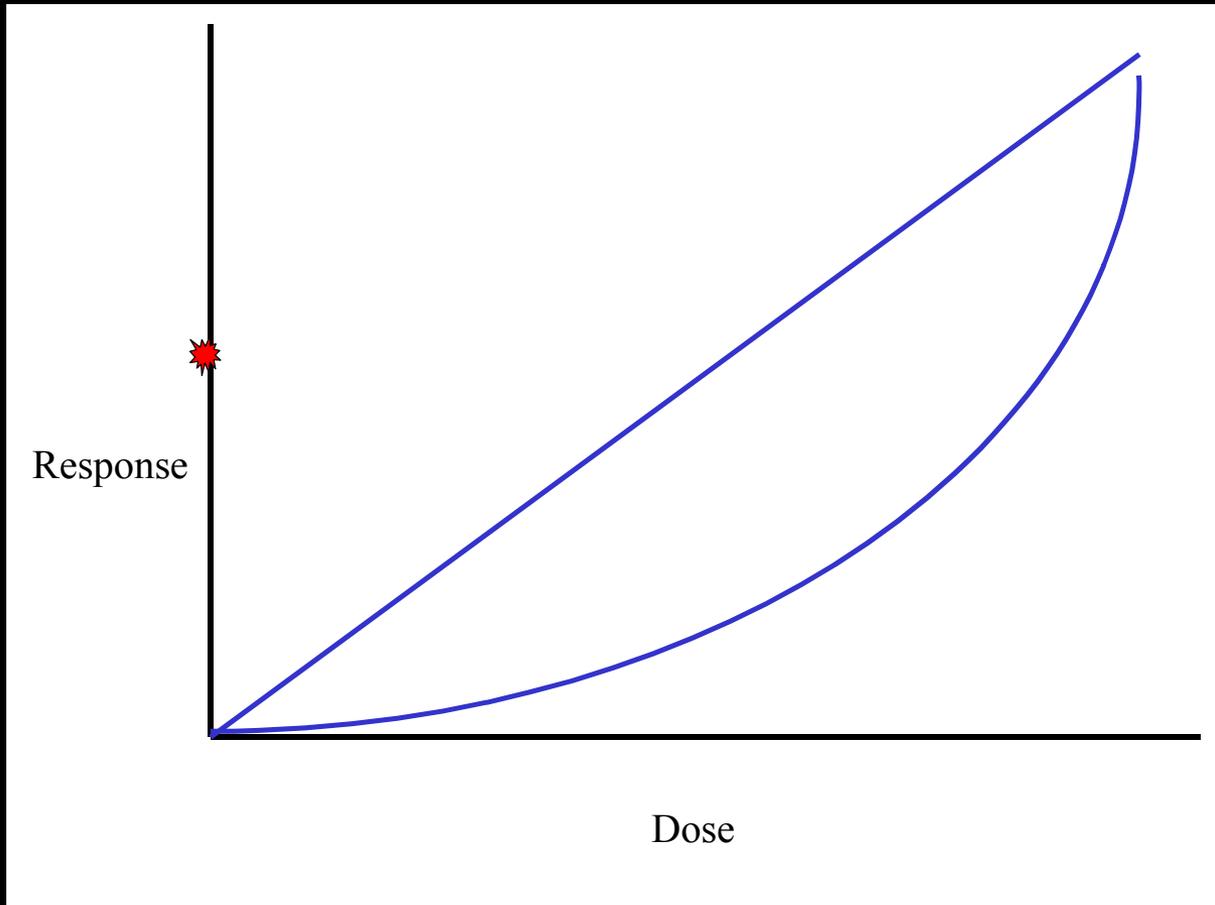
Additionally, at lower doses, you will induce a low response but as the dose increases, the response increases dramatically as in this example.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Dose-Response Curve Comparison:

- The NCRP employs the linear-nonthreshold model to set dose limits for occupationally exposed individuals at 5 rem or 50 mSv per year.
- It is accepted that it is less accurate than the nonlinear, nonthreshold model but, it does provide the means to keep the dose limits at a lower level as illustrated on the next slide.

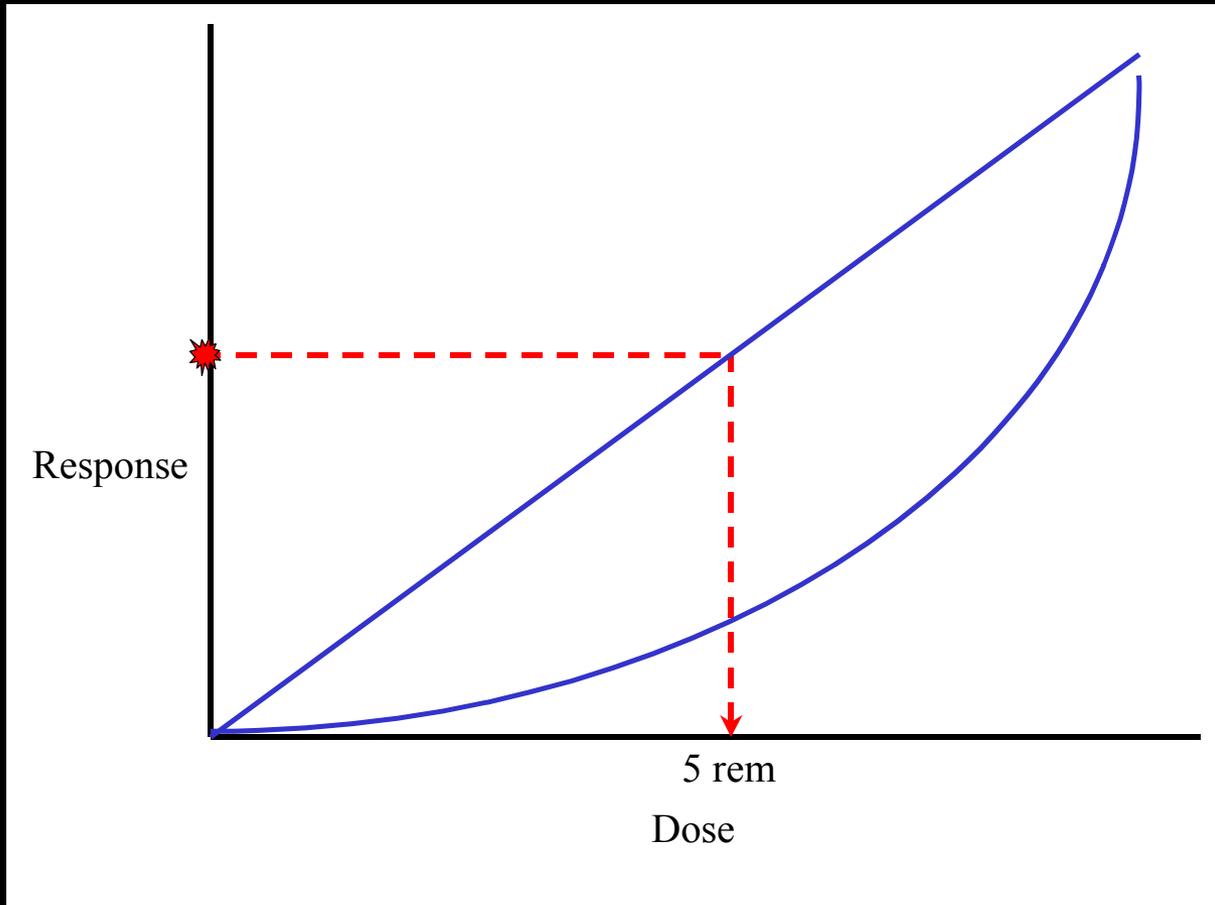
Dose-Response Curve Comparison:



The NCRP created dose limits by first determining an acceptable level of risk as indicated by the red star on the response axis. Next, they had to determine the dose below which this risk would **not** be demonstrated.

It must be emphasized that this is a hypothetical example of dose-response relationships.

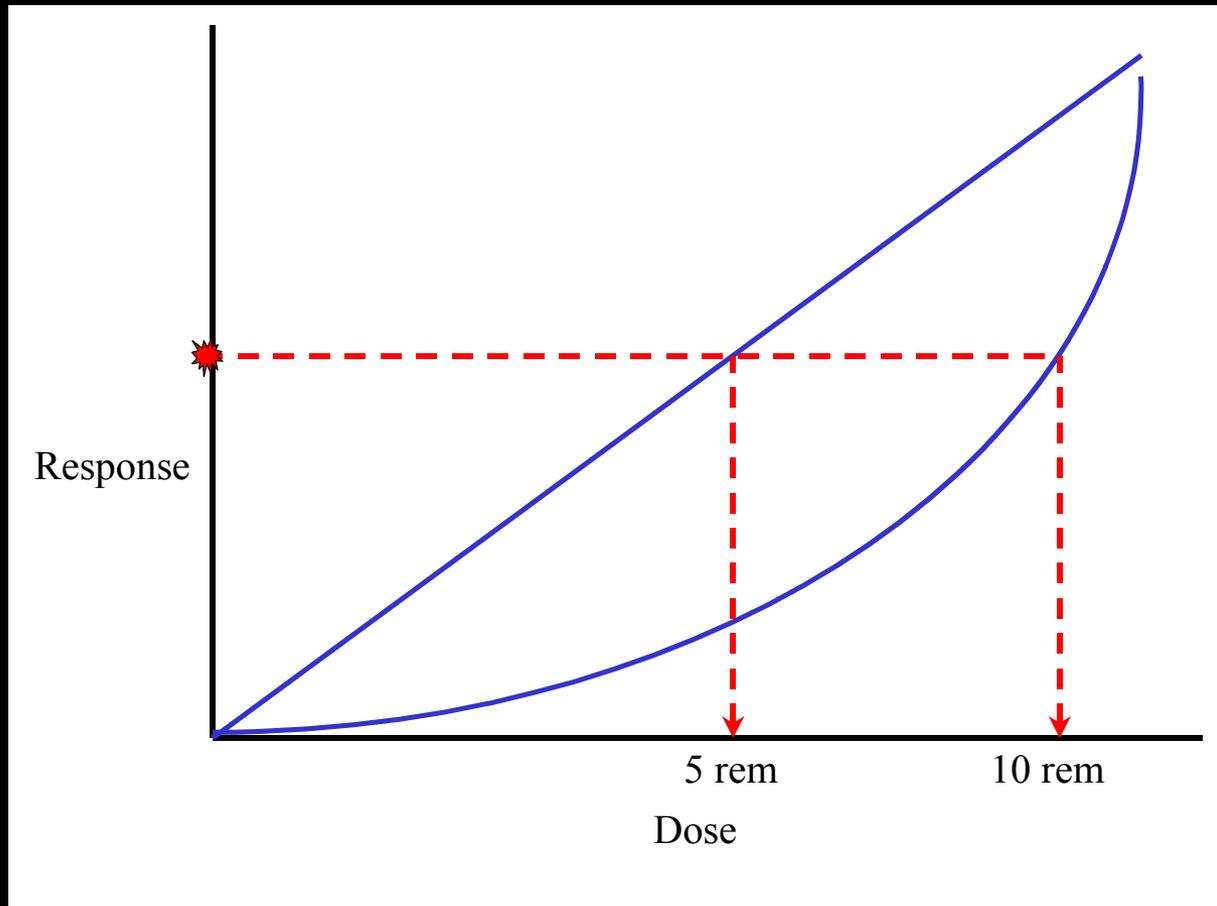
Dose-Response Curve Comparison:



By drawing a line from the response axis to the linear dose-response curve, it was determined that 5 rem per year would be the dose limit for occupational exposures.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Dose-Response Curve Comparison:



If they had chosen to use the more accurate, nonlinear curve, the dose limit would have been much higher. In summary, the use of the linear dose-response curve is less accurate but, it provides for a lower overall dose limit.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Stochastic vs. Nonstochastic Effects:

- **Stochastic effects** are considered to be a nonthreshold type of response of cells to ionizing radiation.
- These are randomly occurring somatic changes such as cancer formation.
- In essence, as the dose increases, the likelihood of the individual acquiring a cancer increases.
- It is imperative to note that the severity of the cancer will not be affected, only the likelihood of acquiring the cancer.

It is an **all-or-none** type of a response.

- Additionally, the notion of this effect being nonthreshold refers to the fact that any dose may cause this effect (cancer formation) to occur.
- Stochastic effects are considered the primary health risk for occupational exposures.

Stochastic vs. Nonstochastic Effects:

- **Nonstochastic or deterministic effects** differ from stochastic effects because as you increase dose, the severity of the effect changes but not the effect itself.
- Nonstochastic effects are considered to be a **threshold** type of response of cells to ionizing radiation.

This refers to the fact that a minimum dose or *threshold* dose is required before the effect is demonstrated.

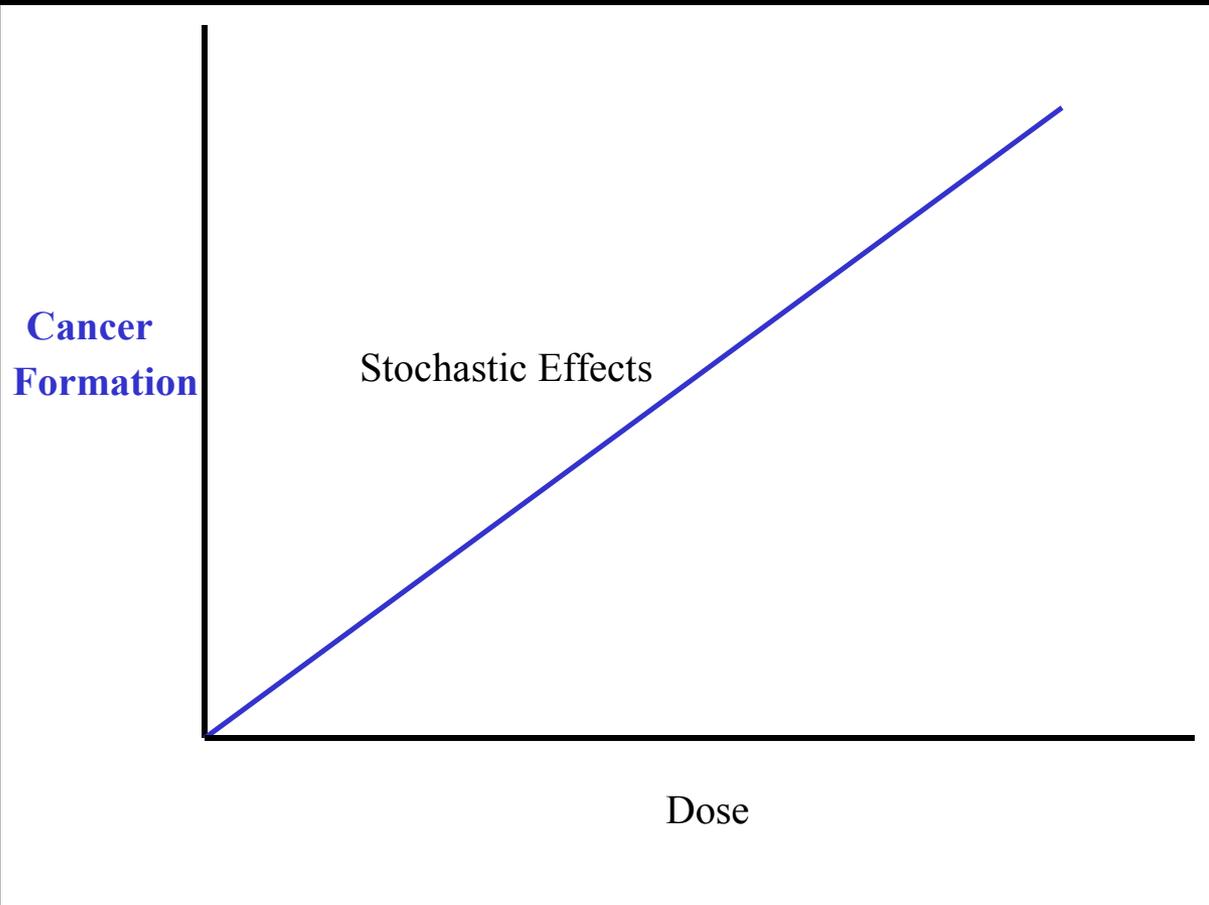
In other words, these effects are not seen until a minimum dose has been delivered.

Additionally, after the threshold dose has been achieved, any dose above that will result in an increase in the severity of the response.

Stochastic vs. Nonstochastic Effects:

- The following is a partial list of nonstochastic effects.
 - Skin erythema** or reddening
 - Epilation** or loss of hair
 - Decrease in the number of **mature lymphocytes**
 - Lymphocytes are white blood cells and they are the most radiosensitive cells found in the body.
 - Cataract formation**
- The following slides illustrate the differences between stochastic and nonstochastic effects.

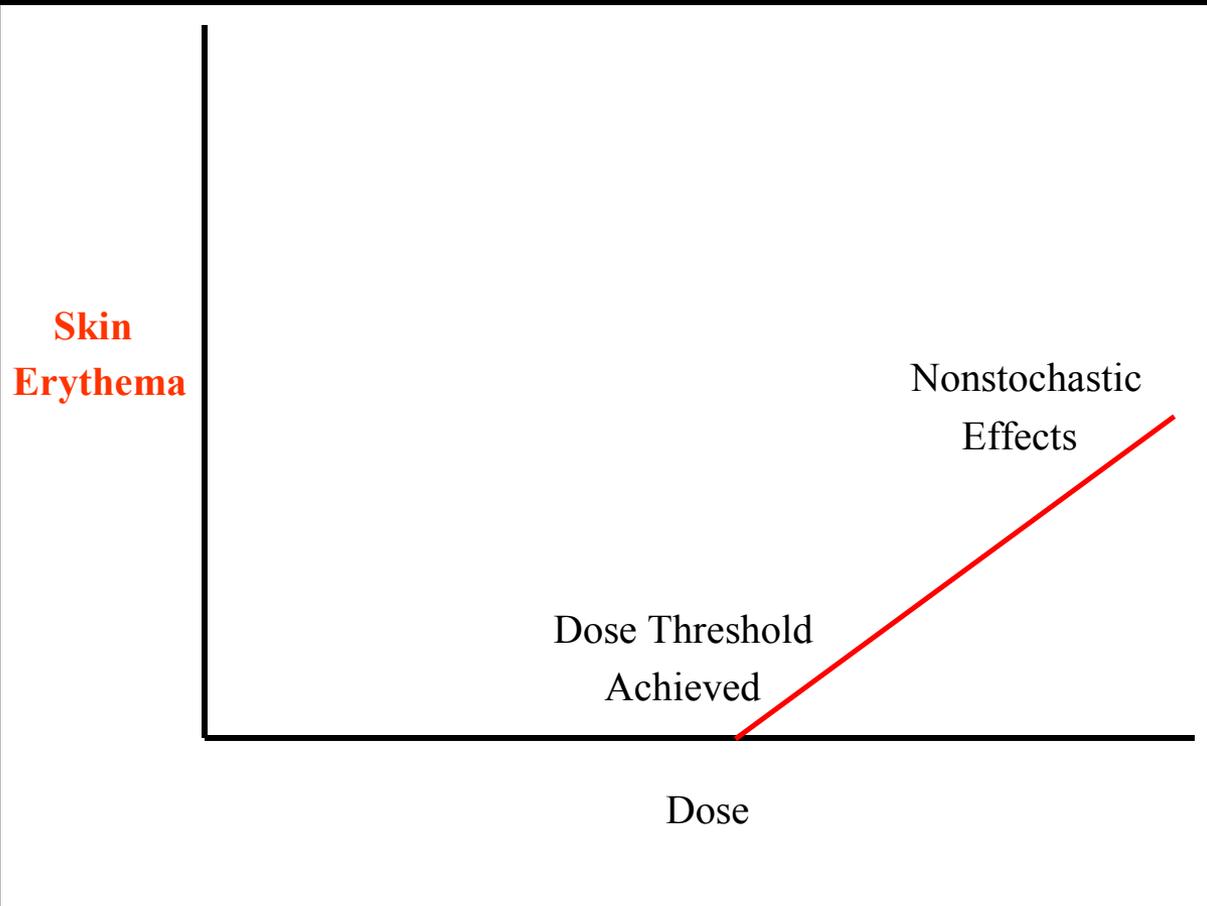
Stochastic Effects:



Stochastic effects are nonthreshold (begin at the origin) in that any dose will increase the likelihood of inducing a response. Also, the severity of the response will not vary, only the probability of seeing the response.

It must be emphasized that this is a hypothetical example of dose-response relationships.

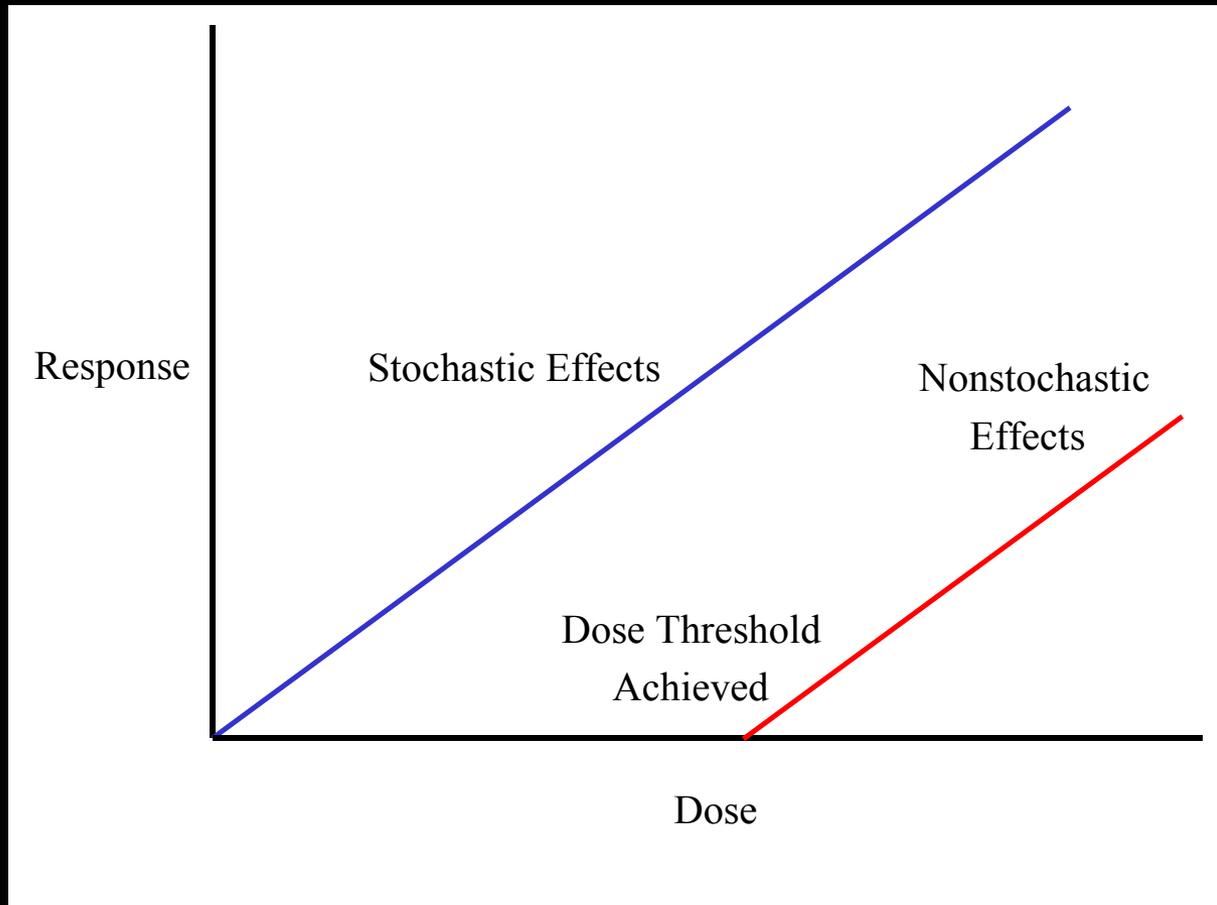
Nonstochastic (Deterministic) Effects:



Nonstochastic effects require a minimum dose (threshold) before they are demonstrated and the effect will increase in severity as the dose increases. Examples include cataract formation and hair loss or epilation.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Stochastic vs. Nonstochastic Effects:



A direct comparison illustrates how a dose threshold is required before a nonstochastic effect is achieved.

It must be emphasized that this is a hypothetical example of dose-response relationships.

Additional Dose Limits Set by the NCRP:

- The following is a non comprehensive list of dose limits set by the NCRP for both occupationally exposed individuals and for the general public:

The annual whole body dose limits for occupationally exposed personnel is as follows:

- Entire Body:** 5 rem/year or 50 mSv/year
- Lens of the Eye:** 15 rem/year or 150 mSv/year
- All other individual organs** (liver, hands, skin etc.) of the body: 50 rem/year or 500 mSv/year

The maximum occupational **lifetime dose** is determined by multiplying your age in years by 1 rem or 10 mSv.

- For example, a 30 year old radiographer is allowed to have a total lifetime dose of no more than 30 rem (30 years old x 1 rem).

Additional Dose Limits Set by the NCRP:

Pregnant radiographers and students must keep their dose limits below the following:

0.05 rem/month or 0.5 mSv/month

0.5 rem/year or 5 mSv/year

There are two categories for annual whole body dose limits for the **general population** and they are as follows:

-Frequent Exposures: this group includes individuals that work in the hospital other than radiographers and their dose limit must be below 0.1 rem/year.

This guideline is meant to ensure that x-ray rooms are properly designed to prevent radiation leakage.

-Infrequent Exposures: this group includes the general population and their dose limit must be below 0.5 rem/year or 5 mSv/year.

Genetically Significant Dose (GSD):

- **Mutagens** are any agent that may cause some type of a mutation. Examples include but are not limited to viruses, drugs, and exposure to ionizing radiation.
- **Spontaneous mutations** are naturally occurring changes to DNA that result in mutations.
- The **mutation frequency** is the number of naturally occurring spontaneous mutations that occur per generation.
- The **doubling dose** is that dose of ionizing radiation that is required to double the mutation frequency.

The doubling dose is thought to be between 50 and 250 rad in humans.

This wide range of values is due to the fact that there are some individuals that are naturally more radioresistant or radiosensitive than others.

Genetically Significant Dose (GSD):

- The **GSD** is a figure that is used to estimate the impact of low level exposure to ionizing radiation on the entire population.
- The GSD is estimated at 20 to 30 mrem per person in the general population per year for exposure to diagnostic levels of radiation.
- As you can see, since the doubling dose is estimated at 50 to 250 rad per year, the GSD will have little impact on the incidence of genetic mutations.
- However, even the smallest dose **may** have some impact on genetic mutations.

This is due to the notion that there is no known level of ionizing radiation exposure that is considered to be safe.

How to Combat the GSD:

- The following is a partial list of methods that radiographers could employ to help reduce the GSD.

Proper shielding could reduce gonadal doses by up to 90%.

Proper collimation could reduce the GSD by 30 to 60%.

Avoiding unnecessary repeats could reduce it by 10%.

Improving exposure factors could reduce the GSD by 30%.

-This could be achieved by using the **15% Rule** which states that you will maintain film density if you increase the kVp by 15% and cut the mAs in half.

-Therefore, if you went from a technique of 100 kVp at 10 mAs to 115 kVp at 5 mAs, the same film density would be achieved and the patient would receive a lower dose thus reducing the GSD.

How to Combat the GSD:

- Other methods to reduce the GSD would be by employing the following strategies or concepts:

The notion of keeping exposures **as low as reasonably achievable** or **ALARA** is endorsed by the NCRP as a strategy to reduce the GSD.

-Radiographers achieve the concept of ALARA by using technical factors, positioning methods, and shielding techniques based on sound educational theory.

The **Risk vs. Benefit Analysis** is another important concept.

-For every procedure that is ordered, it must be determined that the benefits of helping to restore the patient back to good health outweigh the risks of exposing a patient to the potentially harmful effects of ionizing radiation.

How to Combat the GSD:

- In regards to pregnancy and exposure to ionizing radiation, it is recommended that the following concepts be followed:

The notion of the **10-Day Rule** is ultimately to guard against irradiating unsuspecting pregnant patients.

- This rule states that nonemergency radiographic procedures on women in the child-bearing years (ages 11 to 50) should be performed within the first 10 days following the onset of menstruation.
- It is unlikely that a women would be pregnant during this period of time.

Elective Booking is a similar concept that states that elective examinations of the abdomen on women in the child-bearing years should be scheduled during the first 10 days following the onset of menses.

Guidelines for Dose Reduction:

- The following is a compilation of guidelines that are recommended to reduce radiation exposure to the patient and the radiographer.
- Many of these guidelines are a product of NCRP recommendations.
- **Fluoroscopy Guidelines:**

A **cumulative timer** set with a 5 minute alarm must be part of every fluoroscopic unit.

-The idea is to make the radiologist aware of how much fluoroscopic time has elapsed during the procedure.

A **dead-man type** of fluoroscopic exposure control must be employed.

-In other words, radiation will only be emitted when the exposure pedal is depressed.

-A “light switch” type of exposure switch that can be “flipped on” is not permitted.

Guidelines for Dose Reduction:

The **bucky slot** is the opening where the bucky moves up and down below the tabletop and it must be covered with a shielding device that is equal to 0.25 mm of lead or its equivalent.

- The bucky slot is directly at the reproductive organ level of the radiologist and the radiographer and this is a means to reduce their exposure.

A **protective lead curtain** of at least 0.25 mm of lead or its equivalent must be positioned between the image intensifier and the radiologist and/or radiographer.

Patient dose is increased when the radiation **source-to-skin distance (SSD)** is reduced.

- Therefore, the SSD should not be less than 38 cm (15") on stationary fluoroscopic units or less than 30 cm (12") on mobile fluoroscopic units.

Guidelines for Dose Reduction:

- **General Radiography Guidelines:**

The **protective tube housing** must be designed to ensure that tube leakage is kept below 100 mR/hour at a distance of 1 meter

Collimator light field accuracy must be accurate to within +/-2% of the SID that is set.

- For example, at a 40" SID the light field may be off by as much as 0.8" in either direction ($40" \times 2\% = 0.8"$).

- As a rule of thumb, when collimating try not to place body parts of interest within 0.8" of the edge of your light field.

It is recommended that the **central ray alignment** must be accurate within +/- 1 degree of perfect vertical.

Guidelines for Dose Reduction:

Aluminum filtration of the primary beam is employed to remove low energy x-rays before they can exit the x-ray tube housing.

- They do not have any diagnostic value and would normally be absorbed by the patient's skin.
- The amount of aluminum filtration required is dictated by the maximum kVp that the tube can produce.

Greater than 70 kVp requires 2.5 mm of Al

50 to 70 kVp requires 1.5 mm of Al

Less than 50 requires 0.5 mm of Al

The **source-to-image receptor distance (SID)** indicator or dial must be accurate to within 2% of the SID that is set.

- This is to ensure that your “tape measure” is accurate.

Guidelines for Dose Reduction:

X-ray generator reproducibility refers to the ability of the machine to produce the same beam intensity with repeated exposures.

- It must not vary more than $\pm 5\%$.
- For example, if the first exposure produced 100 mR, then the next exposure must produce between 95 to 105 mR to be within the 5% allowable variance.

mA station linearity refers to ensuring that adjacent mA stations are calibrated properly.

- They must not vary more than $\pm 10\%$.
- For example, if a constant time station is employed and the 200 mA station produced 100 mR then the 400 mA station should produce 200 mR.

Guidelines for Dose Reduction:

The **exposure switch cord** on mobile units (portables machines) must be at least 2 meters or 6 feet in length.

- This simply allows the means for the radiographer to stand a safe distance from source.

Protective apparel such as lead aprons, gloves, and thyroid shields must contain a certain thickness of lead as follows:

- The most common thickness is 0.5 mm of lead and it will absorb 88% of the primary beam at 75 kVp.
- Protective apparel made of 1.0 mm of lead will absorb approximately 99% of the primary beam at 75 kVp.

There are **100** questions on this test. All answers can be found within the context of this program. The “hint” button located next to each question will provide you the information needed to answer the question. At any time during the test you may skip a question and return to it later. You must successfully answer 70% of the questions in order to receive credit for the course. To access the test, please close out of this course by clicking the “x” in the top right corner.

About the Author:

I graduated from the St. Petersburg College (SPC) Radiography Program in Pinellas Park, Florida in December of 1985. I have been employed by SPC since May of 1987 and I am currently the Radiography Program Director.

I completed a Master of Education Degree from the University of South Florida in December of 1998 and I have also passed the American Registry of Radiologic Technology's Computed Tomography and Magnetic Resonance Imaging certificate examinations.

Three Phase CEUs has been in existence since December of 2001. The motivation for establishing my company was in response to my graduates having to pay up to \$10 and sometimes more per hour of continuing education. My research indicated that most companies consistently charged top dollar for CEUs and that there were not many options for radiographers to choose from. I knew that there had to be a way to produce quality educational materials at a reasonable price and hence the creation of Three Phase CEUs. With your continued support, it is my intention to continue to provide radiographers with an affordable option to satisfy their continuing educational needs.



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