Overview of Radiographic Imaging Techniques

Radiography
- **radiography** – use of ionizing radiation to produce a recorded image
- radiography can be described as an art and as a science
    - the **art** of radiography requires specific skills in performance
    - as a **science**, radiography requires study of natural phenomena

Radiology
- **radiology** – the full name of the medical specialty
- two groups of professionals
    - **radiologists** – board certified physicians who practice radiology
    - **radiologic technologists** – professionals who are skilled in the use of x-rays and radiation for the production of high quality images of the human body

Radiograph
- **radiograph** – image produced using x-radiation, it is the end product of radiography
- **characteristics of a radiograph**
    a. **exposure factors** are adequate
    b. there has been **adequate penetration** of the part of interest
    c. sufficient radiographic **density and contrast** are present
    d. **field size** selection is appropriate
    e. **motion** is eliminated during exposure
    f. the anatomic part is **properly positioned**
    g. proper **accessories** have been selected

Technical competencies of the radiographer
1. operation of the control panel
2. selection of appropriate accessories
3. selection of correct factors to make exposures
4. use of terminology in the evaluation of radiographs
5. measurement
6. evaluation of results (poor, fair and good)

The X-ray tube

Tube housing
- heavy and **lead**-lined
- support for the x-ray tube and protection from electrical hazards
- when **x-rays** are produced, they are **emitted in all directions**
- the housing serves as a protective device, preventing x-rays from "**leaking**"
- has several openings for electrical cable connections and the port or window

Glass envelope
- the x-ray tube is located in the tube housing, enclosed in a glass envelope
- material – **Pyrex glass**, heat and chemical resistant to withstand tremendous heat produced in x-ray production
- **window** of the glass envelope – small area in the Pyrex glass which is made thinner so x-ray photons can pass easily

X-ray tube
- a **diode tube** – has two electrodes
- special **vacuum tube** – air interferes with x-ray production
- consist of two electrodes inside a glass envelope
    - positive anode
    - negative cathode

The cathode (–)
- negatively charged electrode
- three parts – large and small filament, and focusing cup
- **filament**
    - source of electrons
    - small coils of **tungsten** wire about **1 to 2 cm** in length
        - tungsten can withstand tremendous heat
        - provides a good source of electrons through **thermionic emission**
    - 2 types
        - **small filament** or small focus directs electrons to a smaller area on the target
        - **large filament** or large focus directs electrons to a larger area on the target
    - **thermionic emission** – occurs when the negatively charged electrons break away from the hot filament to form a space charge
    - **space charge** – a cloud of electrons around the filament which becomes the source of electrons in x-ray production
    - **space charge effect** – phenomena where further thermionic emission is halted by the space charge itself
- **focusing cup**
    - filament cup, encases the two filaments
    - **focuses** the space charge on a target area on the anode
    - the focusing cup is **negatively charged**, thus repelling electrons and focusing them

The anode (+)
- positively charged electrode
- two types – **rotating** (mostly) and **stationary** (outdated technology)
- three parts – rotating target, stem and rotor
- **rotor**
    - shaft-like structure made of copper
    - rotation device that turns the stem and target area
- **stem**
    - attaches rotating target area to rotor
    - **copper** – excellent conductor, dissipates heat away from the target area
- **rotating target**
    - circular, disk-like structure with a beveled edge
    - receives electrons as they move from cathode to anode
    - **tungsten** – can withstand tremendous heat
    - angles on the edge of the anode – **8 to 20°/ 9 to 15°**
    - rotations – **3000 to 10,000 rpm**
    - the rotation distributes heat to a larger area
    - **focal spot** – area of focal track that is struck by electrons
    - **focal track** – runs the circumference of the anode disk

Line-focus principle
- design of the angled anode target area
- the angle makes the actual physical target area appear smaller resulting in a smaller effective focal spot size
- **actual focal spot** – area being struck by electrons
- **effective focal spot** – area directly below the target projected towards the window
- this angle also allows a greater **surface area** for **heat dissipation**

Stationary anode
- designed similarly to rotating anode but without rotating capacity and reduced output
- long shaft of **copper** with **tungsten** target embedded in the slanted surface
- usually found in **dental x-ray units** and some mobile radiographic units

X-ray Production

Control panel (old x-ray generator units)
- part of the radiographic equipment that is **very familiar** to the radiographer
- the controls are the on/off switch, exposure timer, milliampere selector, mA/mAs meter, kilovoltage selector, kV meter, rotor switch, accessory controls for the use of Potter-Bucky diaphragm, and with some units, automated exposure controls

The on/off switch
- main purpose – to connect the electrical power to the x-ray generator
- turned on early in the morning to **warm up** the generator
- **main power box** – turned off with on/off switch in an emergency

Exposure timer
- determine the length of time that x-rays will be produced
- types
    - **mechanical timers** – similar to spring-set dial, shortest setting is **1/10 s**
    - **synchronous timers** – motor driven, utilizes the 60-Hz AC, has intervals related to **1/60 s**, shortest setting is **1/120 s**
    - **electronic timers**– most common, accurate, and reliable, designed with complex circuitry, shortest setting is **less than 120 s**
- **evaluation of timers** – done periodically to guarantee accuracy
    1. **spinning top test**
        - used in evaluation for **1-ø, full-wave rectified x-ray generators**
        - consists of 2 metal parts,
            - **top part** – ~3" round disk with a small hole near the edge
            - **circular pedestal** – where the top part rests and rotates freely
        - **steps**
            a. place the spinning top on top of the cassette with film
            b. the top is set by spinning with a flip of the fingers and exposures are made while the top is spinning
            c. exposures – factors beginning with 1/60, 1/30 or 1/10 sec
        - the timer is normal if there is:
            - **1 dot** per 1/120 sec exposure
            - **2 dots** per 1/60 sec exposure
            - **4 dots** per 1/30 sec exposure
            - **12 dots** per 1/10 sec exposure
    2. **calibrated oscilloscope**
        - for testing a **3-ø x-ray generator**
        - measures actual time of exposure which is compared to the selected time to verify accuracy
        - connected into the circuit to the primary voltage going to the step-up transformer
    3. **pulse-counter device**
        - for **both 1-ø and 3-ø x-ray generator**
        - placed in the primary x-ray beam, where pulses are counted and evaluated

Milliampere selector
- mA selector counts the **amount of electrical current** flowing through the cathode filament
- ranges from **25 to 2000 mA**
- selection of mA determines focal spot sizes
    - **low current** for **small** focal spot
    - **high current** for **large** focal spot

Milliampere second meter
- provide info to the RT by indicating the **total current** passing through the x-ray tube **during the exposure**
- located in the high-voltage section of the x-ray circuit
- **mAs** – total amount of tube current
    - milliampere × time (**seconds**) = milliampere seconds (**mAs**)

Kilovoltage selection
- permits **↑ or ↓** in the voltage across the x-ray tube during the exposure
- determine the specific **tap** on the **autotransformer**
- selection of kV determines the energy of the x-rays produced **during exposure**
- 2 control selectors for easy specific kV setting
    - **kV major** – changes of ~10 kV per turn
    - **kV minor** – changes of 1 to 2 kV per turn

Kilovoltage meter
- "**prereading**" volt meter
    - the meter gives reading during selection for the amount of voltage **expected** to pass across the x-ray tube **as the exposure is made**
- the **meter** indicates voltage selection
- **position** of meter indicates the **amount of PD or voltage** that will move across the x-ray tube **during exposure**

Rotor and exposure switch
- **rotor switch**
    - initiates the rotation of the anode in preparation for the exposure
    - maximum anode rotation is accomplished in **~1 sec**
    - **activation of rotor** permits full current to flow to the cathode, causing it to become **very hot** and turn bright red
- **exposure switch**
    - activated when the maximum RPM of the anode is reached
    - results in the production of x-rays
- both switches are **activated only when necessary**, to permit a **longer life** for the x-ray tube

Accessory controls
- may include
    - Potter-Bucky diaphragm selection
    - vertical or horizontal devices
    - line voltage adjustor

Automated exposure controls
- **AECs** are designed to **terminate the x-ray exposure automatically**
    - termination occurs when desired amount of **exposure** reaches the film
- assist the RT in producing **high quality** and consistent radiographs
- requires **no** direct operation of the RT
- either phototimer or ionization chamber, based on design
    - **phototimer**
        - location – **behind the cassette**
        - faces a fluoroscopic screen that glows during exposure
        - terminates exposure when a proper amount of light reaches the photomultiplier tube
    - **ionization chamber**
        - location – **b/w the cassette holder and patient** (radiolucent)
        - the chamber is ionized during exposure
        - terminates exposure once a preset charge is accumulated and detected

- **back-up timer selection** – a manual timer switch (ex: **1 sec**) that will terminate exposure if the AEC failed, thus protecting the patient and the x-ray tube from continuous exposure
- **radiographer** sets optimal kVp – **machine** controls mAs
    - AEC use a preselected **fixed kVp** while machine controls mAs
    - **varying kVp** when using AEC does not alter density, although **contrast changes**
    - varying kVp serves to alter **penetrating ability** of the beam, resulting in faster or shorter exposure time
- changing **density controls** on AEC allows density to be **↑ or ↓**; each **step** represents a change of **25%** in density
- **image quality in AEC** – consistent from examination to examination
- requirements – **proper chambers selected**; **exact positioning** over the chambers
    - **overexposure or underexposure in AECs**– caused by improper chamber selection and/or patient positioning errors

Selection of exposure factors

- factors selected by the RT to produce high quality radiographs:
    1. kilovoltage
    2. milliamperes
    3. exposure time
    4. table-top vs. Potter-Bucky diaphragm

X-ray production

- **before exposure**
    - patient is ready and in proper position
    - equipment must be in place
    - appropriate factors are selected on the control panel
- **sequence of events when making an exposure**
    1. activation of the **rotor switch**
    2. **anode** begins rotating as it reaches the **proper RPM**
    3. meanwhile, the **cathode filament** gets very hot, resulting in **thermionic emission**
    4. electrons are "boiled off" the filament, creating a **space charge**
    5. with the filament hot, the space charge ready, and the anode rotating at peak RPM, the next step is activating the **exposure switch**
    6. as the exposure switch is activated, the **current will flow** from the (–) cathode to the (+) anode target
    7. **electrons** move at a **very high speed** as a result of the **PD**, amounting to thousands of volts (kilovolts) applied to the 2 electrodes during the exposure
    8. electrons **strike** the anode **target** (focal spot) with great force, resulting in many diff types of interactions
        - production of **heat** (~99%)
        - production of **x-rays** (~1%)
    9. **x-rays are produced** travelling in **all directions**, then **absorbed** mostly by the lead **tube housing**
    10. useful rays are those that pass through the tube **window** and **housing port** (**primary** x-ray beam) strike the patient and produce a radiograph (**remnant** beam)

Proper care of radiographic equipment

- **life** of the x-ray tube = **action** of the radiographer
- x-ray equipment is very expensive
- the RT is **accountable** for proper use of equipment to prevent damage
- focal track **pitting** – occurs from continuous bombardment of the electrons on the focal track, rhenium is added to the **tungsten** target to prevent pitting

1. **warm up procedures**
    - tube should be preheated before use
    - **anode target area** – preheated each morning before use
    - exposures are made using **low mA** (50-100 mA), **large focal spot**, low to **moderate kVp** (65 to 70 kV), **long exposure time** of 2 to 3 seconds
    - 3 or 4 exposures are made, several seconds between each exposure
    - warm up again if tube is not used for several hours before using again
2. **switch precaution**
    - **use** only **as needed**, prolonged rotation with the presence of a "hot" filament will shorten the life of the anode and the cathode filament

Characteristics of x-radiation

Key Points

- use of x-rays is **vital** in assisting physicians with the diagnosis of diseases and disorders
- x-rays are a form of **electromagnetic radiation**
- radiographers must observe the rules for **time**, **distance** and **shielding**
- **image forming x-rays** – those that exit the patient and interact with the image receptor
- **exit beam** – the x-rays that remain as the useful beam exits the patient

Characteristics of x-ray photons

1. cannot be focused by lens as in photography
2. travel in **straight lines** and **diverge** from the point of origin
3. **cannot be deflected** by mirrors or other devices
4. when x-ray photons strike certain substances, visible light is emitted – **luminescence**
5. causes the changes that occurs in the sensitive emulsion of the film
6. when interacting with matter, secondary and **scatter radiation** are produced

Imaging system: X-ray film

Image receptor

- **radiographic film** – the film records the image based on the pattern of transmitted x-rays and light produced by the intensifying screens.
- a **supercoat** or protective coating is then used to protect the sensitive emulsion surface, essential at the time of use in the film holder
- basic parts – **base** & **emulsion**
- other parts – **adhesive layer** & **overcoat**
- thickness – **150 to 300 µm**
- biggest size – **35 × 43 cm.** or **14 × 17 in.**
- smallest size – **20 × 25 cm.** or **8 × 10 in.**

Film composition

1. **Base**
    - the film base is the support that allows the film to maintain its shape, prevent bending and provide **support** for the emulsion
    - foundation and skeletal framework of the film
    - x-ray film is made of flexible thin transparent **base** coated on both sides with a sensitive **emulsion**
    - the base does not affect basic fog level on the radiographic film
    - **characteristics**
        1. **lucency** – must be nearly transparent to white light
        2. **dimensional stability** – maintain size and shape to prevent distortion of image
        3. **superior physical stability** – flexible and sturdy to prevent damage when handling and processing

4. **blue tint** – decrease eye strain, decrease parallax effect, improve contrast, contributes to **0.15 OD**
   - composition
     - ***polyester*** – a polymer matrix
       - ***ethylene glycol***
       - ***dimethyl terephthalate***
   - history – glass plate → ***cellulose acetate*** → ***cellulose triacetate*** → ***polyester***

2. **adhesive layer**
   - **substratum** layer
   - coated on the base before adding the emulsion
   - simply adheres the base to emulsion
   - provides maximum contact b/w the base and emulsion
3. **emulsion**
   - the emulsion is the radiation sensitive and light sensitive layer of the film
   - coated on both sides of the base (duplitized)
   - the **spectral response** of an emulsion is the **absorption of visible light** emitted by the phosphors
   - ↑ **contrast emulsion** = small, uniform grain size
   - composed of silver halide crystals suspended in gelatin
   - **gelatin**
     - a **colloid** extracted from cattle hooves and hide, then rendered into a very pure, uncontaminated state
     - an ideal suspension medium for the silver halide crystals
     - **swells** during processing so that chemicals can penetrate the silver halide crystals
     - **rehardens** after the invisible image becomes visible
   - **silver halide crystals**
     - size – **1.0 to 1.5 µm**
     - active ingredient
     - the material sensitive to radiation and light
     - functions as **energy detectors**
     - **sensitivity specks** – imperfections in the crystal structure
     - ***silver bromide*** – ~98%
     - ***silver iodide*** – ~2%
     - $\mathbf{AgNO_3}$ (*silver nitrate*) + **KBr** (*potassium bromide*) = **AgBr** (*silver bromide*) + $\mathbf{KNO_3}$ (*potassium nitrate*)
     - $\mathbf{AgNO_3}$ = $\mathbf{NO_3}$ (*nitric acid*) + **Ag** (*metallic silver*)
4. **supercoat**
   - **topcoat** or **overcoat**
   - a durable protective layer that is intended to prevent damage to the sensitive emulsion layer underneath it

layer	*thickness*	*material*
base	200 µm	polyester ethylene glycol dimethyl terephthalate
adhesive layer	3 – 5 µm	
emulsion	150 – 300 µm	gelatin silver halide crystals silver bromide silver iodide
supercoat	10 – 20 µm	hard gelatin

Characteristics of x-ray film

- **film speed**
  - speed point
  - speed is the **degree** to which the emulsion is **sensitive** to x-rays or to light
  - ↑ speed = ↑ sensitivity = ↓ exposure necessary to produce a specific density
  - 2 primary factors that affect the speed point
    1. the **number** of silver halide crystals
    2. the **size** of silver halide crystals
  - film speed is given an arbitrary number
    a. 200, 300, etc. – **fast**
    b. 100 – **average**
    c. >50 – **slow**
  - **imaging system** – the combination of a particular film and screen type
  - **IR speed formula**
    - $\frac{1}{\text{exposure}}$ in R to produce an **OD** of **1.0 ↑ b+f**
    - ex: how much **exposure** is required to produce an OD of 1.0 above base plus fog density on a 600-speed image receptor?
    - speed = $\frac{1}{\text{exposure}}$
    - exposure = $\frac{1}{\text{speed}} = \frac{1}{600}$ = 0.00167 R
    - exposure = 1.67 mR
  - **density maintenance** (speed vs. mAs)
    - $\frac{\text{old speed}}{\text{new speed}} = \frac{\text{new mAs}}{\text{old mAs}}$
    - ex: a PA chest examination requires 120 kVp and **8 mAs** with a **250-speed** image receptor. what radiographic technique should be used with a **400-speed** image receptor?
    - $\frac{\text{old speed}}{\text{new speed}} = \frac{\text{new mAs}}{\text{old mAs}}$
    - new mAs = $\frac{\text{old mAs (old speed)}}{\text{new speed}}$
    - new mAs = $\frac{\text{8 mAs (250)}}{400}$ = 5 mAs
- **film latitude**
  - **margin** of errors in technical factors that the film allows that will still produce an acceptable range of densities
  - **inherent characteristic** of the film emulsion that allow a moderate or acceptable range of densities to be recorded
  - **range** of exposures that produce OD within **straight line region** or diagnostic range of sensitometric curve
  - inversely proportional to contrast
    - **↑ latitude = ↓ contrast**
  - **film latitude** – ability of film to record an acceptable range of densities
    - **narrow** film latitude = high contrast emulsion, "**short**" **gray scale**
    - **wide** film latitude = low contrast emulsion, "**long**" **gray scale**
  - **exposure latitude** – ability of exposure factors to record an image with an appropriate range of densities on the film
    - **narrow** exposure latitude – **few factors** can be applied to produce acceptable OD
    - **wide** exposure latitude – **many factors** can be applied to produce acceptable OD (more "forgiving")
- **film contrast**
  - **inherent** ability to record minute differences in densities across the film
  - ability of the radiographic film to provide a certain level of image contrast
  - **high** contrast emulsions – provide **good quality** image
  - **low** contrast emulsions – provide **poor quality** image

Brief history

date	*innovations*
1895	photographic glass plates
1914	cellulose nitrate film base (highly flammable)
1918	duplitized films, exposure is reduced to half
1933	tinted film base
1936	direct exposure film
1940	film suitable for direct and indirect exposure

1958	fast light-sensitive film
1960's	polyester film base and film for rapid processing

Types of x-ray film

1. **screen-type film**
    - the most **widely used** radiographic film, general choice for diagnostic radiology
    - made to be used with one or two **intensifying screens**
    - more **sensitive to light** than x-rays
        - light – 98%
        - x-ray – 2%
    - require **less x-ray exposure**, can be either manually or automatically processed and can have either a single or double emulsion coating (duplitized)
    - **parallax effect** – **crossover**, **crosstalk** or **print-through**, occurs when light forms an angle affecting a spot in the emulsion and travels through the other side striking a spot not exactly corresponding to the opposite layer, producing an effect similar to penumbra
        - **ways of reducing parallax effect**
            1. tinting the film with **blue dye**
            2. using a **monochromatic film** – blue light cannot **crossover** blue dye, orthochromatic films will always have parallax as green light can crossover the blue dye
            3. adding an **anti-crossover layer**
            4. using a **thinner base**
    - **advantages** of screen-type film
        - ↓ emulsion thickness = ↓ developing time
        - ↓ patient dose
    - **disadvantages** of screen-type film
        - ↑ parallax effect = ↓ decreased resolution
        - ↑ quantum mottle
2. **direct-exposure film**
    - designed for use without the need of an intensifying screen
    - also erroneously called a **non-screen film**
    - uses **thicker emulsion** = so processing time is ↑
    - intended to be used in a **cardboard holder**
    - **x-ray sensitivity** must be accurately matched with the proper **kV range**
    - compared with screen film, it requires considerably **more exposure** and may necessitate **manual** processing
    - commonly used for
        1. low-risk or low-exposure examinations of thin areas of the body
        2. intraoral dental radiography
    - **advantages**
        - ↓ parallax effect/crossover/**blur**
        - ↓ quantum mottle = ↑ image quality
    - **disadvantages**
        - ↑ patient dose
        - ↑ emulsion thickness = ↑ development time
3. **single-emulsion film**
    - has emulsion coated on one side of the base only
    - **no** parallax effect
    - manufacturers may add a light-absorbing dye to the emulsion which prevent photons from striking adjacent silver halide crystals
    - **anti-halation backing** – prevents halation of light as the screens fluoresce, ↑ sharpness of image
    - requires ↑ exposure

Types of film according to spectral sensitivity

- **monochromatic film**
    - **blue sensitive**, sensitive to wavelength <
    - globular grains
    - ***calcium tungstate*** phosphor (broad band emission)
    - insensitive to red, orange, and yellow
- **orthochromatic film**
    - **green sensitive**, sensitive to wavelength **<620 nm**
    - tabular grains
    - ***rare earth*** phosphor (specific or line emission)
    - insensitive to red
- **panchromatic film**
    - sensitive to **all visible light**
    - mainly used in photography
    - sensitive to all visible light spectrum
    - no insensitivity

Classification of films according to use

1. **mammographic film**
    - fine grain, single emulsion film
    - for breast examination
    - ↑ exposure = ↑ detail
    - has a special anti-halation layer
    - ↑ resolution = ↓ speed = ↓ OD = needs to ↑ mAs
2. **therapy localization film**
    - fine grain, direct exposure film
    - it serves as a guideline in therapy
    - wide range of exposures
    - advantage –↑ resolution
    - disadvantage – radiation is continuously emitted
3. **dental x-ray film**
    - **intraoral film** – direct exposure, duplex film
        - size – **1¼ × 1⅝ in**
        1. **periapical film** – to image the root of the teeth
        2. **bitewing/interproximal** – localize cavities between the teeth
        3. **occlusal film** – largest, used when periapical film cannot visualize the entire tooth
    - **extraoral film** – screen-film
        - size – **5 × 12 in** or **12.5 × 30 cm**
        1. **panoramic** – used to visualize the entire mouth
4. **video film**
    - single emulsion
    - used in barium swallow
    - exposed in a device called multiformat camera and laser camera, records images on a VHS
5. **photofluorographic**
    - single emulsion
    - for photography of the image on the fluorescent screen by a camera in area chest x-ray examination
    - **abreugraphy** – introduced by Manuel Diaz Abreu
        - for mass chest x-ray examination to monitor PTB
        - miniature fluorography – fluorospot film
    - sizes – **70mm**, **90mm**, **100mm** (pre-cut), **105mm**
    - available in **rolls** similar to cine films
    - the viewer has a frame rate of 10 frames/second
    - LogEtronics printer – uses a reducer device
    - filter – dark green
6. **cine or roll film**
    - single emulsion film w/ sprocket holes
    - a reversal film – uses a positive image, utilizing the reversal effect
    - also known as the **movie film**
    - insensitive to green light
    - angiographic film – used in **cardiac catheterization**
    - uses a **Tagarno viewer** with a frame rate of 30 to 60 frames/sec
    - width – **16 mm** & **35 mm**
    - image – **7.33 × 9.7 mm** & **24 × 35 mm**
    - 100 to 300 rolls, **150 feet** long

  - images recorded represent 35% actual images
  - black and white images
  - filter – **dark green**
7. **duplicating film**
    - single emulsion
    - also called **copy film**
    - responds differently to light photons, density decreases as it is being exposed
    - used to produce an exact copy of a radiograph
    - uses the principle of **solarization**
    - companies
        - Blu-ray copier – can create a copy within 6 seconds
        - DuPont Cronex printer – can create a copy within 15 seconds
        - LogEtronics
8. **subtraction film**
    - single emulsion
    - also called reversal film
    - used in digital subtraction angiography and facial profile views to show the relationship of soft tissue with bony structures
    - designed to produce a copy that is the exact opposite of the original radiograph
9. **dosimeter or personnel monitoring film**
    - measures radiation absorbed dose
    - sensitive to x-ray, gamma, beta and low energy neutrons (**13 mR to 18 mR**)
    - usually uses **2 films** to measure both low energy & high energy radiation, 1 single emulsion and 1 double emulsion
    - same size a dental film
    - **thermoluminiscent dosimeter (TLD)**
        - frequently used
        - monitors monthly exposure
        - ***lithium fluoride***
        - no dosimeter film
    - **optically-stimulated luminescent dosimeter (OSL)**
        - monitors monthly exposure
        - ***aluminum oxide***
        - no dosimeter film
    - **film badge**
        - uses the **dosimeter film**
        - worn inside the apron
    - **pen dosimeter**
        - used for daily exposures and is reset
10. **automatic serial changer**
    - used in **serial radiography** such as angiography
    - used for special procedures
    - also called Elema Zchonander & Franklin changer
    - films have a **special protective coating** to prevent scratches
    - uses 90 seconds automatic processor or processed manually
11. **industrial film**
    - uses mega-electron volts
    - high energy/radiation radiography
    - can also be used in **mammography**
    - uses 90 seconds automatic processing or processed manually
12. **polaroid radiographic film**
    - paper-based
    - thermal paper
    - DSA and UTZ
13. **laser film**
    - laser printing in MRI, CT Scan, Digital Radiography, DSA
    - no darkroom, fixer and developing solution
    - sensitive to **red/infrared light**
    - artifacts include white line mark from resulting from dirt in the crystal that focuses the laser

The latent image

- **photographic effect** – production of latent image
- **latent image** is produced by the **invisible change** that take place when the film emulsion is exposed light or x-radiation
- **sequence of events**
    1. silver halide crystals have a **negative surface**
    2. when the emulsion is **exposed** to light or x-rays, the **crystals absorb the energy**
    3. this causes the negative electrons in the surface to migrate to the **sensitivity speck**
    4. the **positive silver ions** are the attracted to the sensitivity speck (they lack electrons)
    5. interaction occurs, atoms of **atoms of metallic silver** are formed
    6. amount of metallic silver deposits = amount of exposure to the halide crystals
    7. this occurs on the entire surface of the emulsion, forming the **latent image**
    8. during processing, **chemicals** penetrate the gelatin and **react** with the metallic silver
    9. the **metallic silver blackens**, resulting in blackened areas on the radiograph
    10. amount if blackening = amount of exposure the halide crystal received
- **Gurney-Mott theory** – the only accepted theory in the explanation of photographic effect
- **Mitchell theory** – modern theory
- **sensitivity center** – physical imperfection in the lattice of the emulsion layer that occurs during the film manufacturing process, also called the latent image center or the focal point
- ***silver sulfide*** – a chemical contaminant responsible for the physical imperfection of the silver halide crystal
- **imperfections**
    1. **point defect –** occur when silver ions moves out from the normal position in the crystal lattice
    2. **discoloration defect –** a line fault exists, causing a strain on the lattice
    3. **sensitivity speck/center –** occurs when silver ions are trapped because of chemical impurities, secondary electrons are trapped here
    4. **latent image center –** clumping of silver atoms, latent image centers form at the sensitivity speck
    5. **Frankel defect –** physical imperfection, consists of interstitial silver ions and silver ion vacancies

Care of the X-ray film

- **handling**
    - hands must be clean and dry
    - use no lotions or creams on the hand
        - may cause fingerprint marks
    - rubber gloves are avoided, use cotton gloves when necessary
        - may cause static artifacts
    - films should not be bent, buckled or pinched
    - films should not be laid on cabinet or benches
    - film should not be dropped or slid on a surface
    - care must be taken when handling film to prevent pressure marks and static artifacts
    - film should be opened in a darkened room using recommended safelight system
- **storage**
    - **protect from heat and moisture**
        - store in a cool, dry place
        - **20°C or 70°F** – fresh films storage temperature
        - **40% to 60%** – fresh films storage humidity
        - **60 to 80°F** – storage temperature after
        - the usual storage for original radiographs is **5 to 7 years**

            - ↑ temperature = ↑ fog
            - ↓ temperature = ↑ static discharge
            - ↑ humidity = ↑ fog
            - ↓ humidity = ↑ static discharge
    - **prevent fresh films from outdating**
        - **21°C or 70°F** –storage temperature if storing films for **30 to 45 days**
        - **10°C or 50°F** – storage temperature if storing films **>1 year**
        - **0°C** – storage temperature to store at to stop aging process
            - film should be warmed up to room temperature at **35°C or 85°F** before using again
        - ↑ temperature = ↑ aging process
        - store film in original packaging to **note** the **expiration date**, which is located on the top of the box or at the side
        - adhere to "**first in, first out**" or "last in, last out" system
        - expired films are discarded
            - *can be returned to the manufacturer for silver recovery
    - **prevent pressure**
        - films are stored **vertically**, **at edge**, **straight** or **upright**
        - film sheets may or may not be separated by photo-inert leaves of paper that prevent films from sticking to one another or to prevent pressure artifacts
    - **protect from radiation**
        - films are packed in a **photo-inert polyethylene bag** or in a **metal foil** to protect them from light/radiation and moisture
        - store away films from radiation areas or use protective barriers
        - **12 µR limit**
            - store chemicals away from the films
            - a box of ***potassium bromide*** with traces of radioactive ^{40}**K** emits **7 µR** because of decay, two boxes will emit **14 µR**
    - **protect from chemicals**
        - chemical fumes
        - **chemical fog** – contamination of developer solution with **0.1% of fixer**
        - a splash guard is placed to cover the developer tank when the fixing tank must be removed
        - **development fog** – restrainer prevents chemical fog by regulating development
    - **use recommended safelight**
        - **safelight fog** – most common form of film fogging

Film holders

- the cassette is the rigid, light-tight container that holds the screens and film in close contact
- cassettes are film holders used to transport film for use without exposing the film to room light
- **2 to 3 inches** – when loading, the top should not be fully opened in order to prevent dust and formation of artifacts
- **cassette front**
    - metal frame with low Z and radiolucent front
    - composition – ***magnesium***, ***Bakelite*** or ***carbon fiber***
- **contact felt**
    - compression layer
    - maintains proper film-screen contact
- **hinges**
    - light-tight seal is completed by a snap or latch hinges
    - black felt is used in older styles
- **cassette back**
    - **lead foil** – absorbs backscatter
    - composition – ***manganese*** and ***lead***
    - phototiming and AEC cassettes use thinner backsides
        - has a radiolucent back to permit the radiation reaching the film to continue in the AEC
        - has no lead foil

Imaging system – intensifying screen

Intensifying Screens

- used since the 1900s
- acts as a **transducer** – **converts x-ray energy to light** which exposes the radiographic film
- intensifies the action of x-rays
- intensifying screens fluoresce but not phosphoresce
- made of **polyester base** with an active layer containing **phosphors** that produce visible light when struck by x-rays
- normally mounted inside the cassette in **pairs** for use with double-emulsion film
- **contact** between the screens and the film must be perfect; poor contact results in:
    - localized loss of recorded detail
    - localized blurring on the image
- poor film-screen contact may be verified by radiographing a **wire-mesh test**
- allows **15 to 20 times less** radiation exposure
- advantages
    - ↓ radiation dose, ↓ technical factors, ↑ tube life
- disadvantages
    - ↑ quantum mottle, ↓ image quality

Layers of the intensifying screen

1. **base**
    - thickest part – **1 mm** or **1000µm**
    - provides support to the phosphor layer
    - made of high grade cardboard, plastic or polyester
    - **characteristics**
        - resilient & moisture resistant
        - does not suffer radiation damage or discoloration
        - chemically inert & not interact with the phosphor layer
        - flexible but not elastic
        - must not contain impurities
2. **reflective layer**
    - thickness – **25 µm**
    - serves to redirect light toward the film
    - intercepts light photons headed in other direction & redirects them to the film
    - ↑ film efficiency
    - very thin layer of white shiny substance made of ***magnesium oxide*** & ***titanium dioxide***
    - use of reflective layer = 2x film speed = 2x density = ↓ mAs by ½ to maintain density
    - screens may have a crossover effect of 30% or more
    - **anti-crossover layer** – also called crossover control layer, is designed for rare-earth screens and green-sensitive films
    - **anti-halation layer** – designed for single-emulsion films such as mammographic films
3. **phosphor layer**
    - thickness – **150 to 300 µm** or **60 mg/cm²**
    - crystal size **– 5 to 15 µm**
    - active and most important layer of intensifying screen

- emits light during stimulation by x-ray
- **luminescence** – ability to give off visible light
- **fluorescence –** ability of phosphor to give off light only while exposed to x-ray
  - light emission during x-ray exposure or while/promptly emitted or **within 10^{-8} seconds**
  - important to radiography
- **phosphorescence** – continue to emit light even after x-ray exposure has ceased or stopped
  - produces afterglow or screen lag
  - somewhat **after 10^{-8} seconds**
  - important to fluoroscopy
- **characteristics of a good phosphor**
  - **detective quantum efficiency** – the ability of the phosphor to interact with x-ray
    - **↑ Z = ↑ DQE**
  - **conversion efficiency** – the ability of the phosphor to convert x-ray into light
    - rare earth phosphors = ↑ **CE**
  - **spectral matching** – specific color that the phosphors emit must match with the spectral sensitivity of the film
  - **minimum afterglow/lag** – lag is insignificant in radiography but is used in fluoroscopy

4. **protective coating**
   - thickness **– 10 to 20 µm**
   - gives physical protection to the delicate phosphor layer
   - provides a surface which can be handled and cleaned without damaging the phosphor
   - prevents static build up
   - transparent to x-ray

layer	*thickness*	*material*
base	1000 µm	high grade cardboard plastic or polyester
reflective layer	25 µm	magnesium oxide titanium dioxide
phosphor layer	150–300 µm	calcium tungstate lead barium sulfate barium fluorochloride zinc sulfide rare earth lanthanum oxybromide gadolinium oxysulfide yttrium tantalite
protective coating	10–20 µm	

Phosphor materials

- ***calcium tungstate***
  - introduced by Thomas A. Edison
  - responds well to x-rays
  - manufactured in different speeds
    - slow
    - medium or par
    - high speed
  - **5%** x-ray to light conversion
  - used with blue-sensitive films, has globular grains
  - broad band emissions – blue, indigo, violet
  - ***scheelite*** – blue
- ***barium lead sulfate*** or ***barium fluorochloride***
  - used to produce high-speed screens
  - for **high kVp** techniques
  - It was used to ↓ patient dose
  - ↓ mAs = ↑ quantum mottle
- **zinc sulfide**
  - used in **fluoroscopic screens**
  - responds well with **low intensity** radiation
  - for ↓ kVp techniques
  - for high resolution imaging
  - ↑ mAs = ↓ quantum mottle
- ***rare earth***
  - speed – 1000 to 1200
  - more **efficient** in converting x-rays to light
  - needs less x-ray energy to provide the same energy conversion as calcium tungstate
  - ↑ conversion efficiency = no ↑ in crossover = ↑ image sharpness
  - **18 to 25%** x-ray to light conversion
  - only efficient in 40 to 75 kV range
  - too ↑ or ↓ kV = ↑ quantum mottle
  - for green-sensitive film, has tabular grains
  - specific emissions – only one color
  - ***lanthanum oxybromide*** – blue
  - ***gadolinium oxysulfide –*** green
  - ***yttrium tantalite*** – ultraviolet, violet, blue, green

Selection of radiographic imaging system

- **spectral sensitivity** – refers color of light to which particular film is most sensitive
- **spectral emission –** color of light produced by a particular intensifying screen
- **spectral matching –** matching the sensitivity of the film to the color of emission of intensifying screen

Comparison of screen speed

- **screen speed** – the capacity of the screen to produce visible light
- ↑ screen speed = ↑ light emission = ↑ density = ↓ quality
- **screen factors**
  - **type of phosphor used**
  - **thickness of phosphor**
    - ↑thickness/size = ↑ screen speed = ↑ quantum mottle = ↓ recorded detail
    - ↑ light emission = ↑ density = ↓ mAs = ↓ patient dose
  - **crystal size**
    - same as thickness
  - **reflective layer**
    - use = 2x screen speed = ↑ quantum mottle = ↓ recorded detail
    - 2x light emission = 2x density = ↓ mAs = ↓ patient dose
  - **absorbing layer and dye in phosphor**
    - use = ↓ screen speed = ↓ quantum mottle = ↑ recorded detail
    - ↓ light emission = ↓ density = ↑ mAs = ↑ patient dose

Screen factors	*speed*	*detail*	*dose*	*mottle*
↑ phosphor layer thickness	↑	↓	↓	↑
↑ size of crystals	↑	↓	↓	↑
reflective layer	2x	↓	½	↑
absorbing layer	↓	↑	↑	↓
dye in phosphor	↓	↑	↑	↓

Screen speed measurements

- **screen speed** – capability of the screen to produce light
- **tfilm speed** – capability of the film to absorb light
- **intensification factor**
  - intensifying action of the screen
  - standard intensification factor – 30 to 50
  - formula
    - $\text{IF} = \frac{\text{exposure w/o screens}}{\text{exposure w/ screens}}$
    - intensification factor = ↑ intensifying action
- **relative speed value**
  - most common method of designating screen speed
  - the ability of the screen to produce light and density

- **200** – RSV that requires **5 μR** to produce speed point density
- formula
  - $\frac{mAs_1}{mAs_2} = \frac{\text{relative speed}_2}{\text{relative speed}_1}$
  - $mAs_2 = \frac{mAs_1 \times \text{relative speed}_1}{\text{relative speed}_2}$
- values
  - **25** – ultra detail
  - **50** – slow/high resolution/detailed
  - **100** – standard/medium/par
  - **200** – fast/high speed
  - **300** – ultrafast/hi-plus
  - **1200** – rare earth
- RSVs of screens
  - calcium tungstate (slow–detail) – **30 to 50**
  - calcium tungstate (medium–par) – **100**
  - calcium tungstate (high-speed) – **200**
  - rare earth (slow–detail) – **100**
  - rare earth (medium) – **300 to 500**
  - rare earth (fast) – **800 to 1200**

Screen-Film contact

- the screen and the intensifying screen must be in complete contact across the entire surface to achieve maximum image sharpness
- **wire mesh test** – test for screen-film contact
  - **150 kV**, **100 mA**, **50 ms**, **36 in SID**
- **poor screen-film contact** will result in a loss of image sharpness
- causes of poor screen-film contact
  - worn contact felt
  - loose, bent or broken latches (lock)
  - loose, bent or broken hinges
  - warped screen caused by excessive moisture
  - warped cassette front
  - sprung or cracked cassette frame
  - foreign matter under the screen (most common cause)
  - air trapping – transitory poor screen-film contact, more obvious in the serial changing film cassette, a curved back or curved front cassette will prevent air trapping

Care of screens

- care must be taken to avoid abrasions or scratches on the surface while loading the screen with film
- regular visual examinations must be made to reveal any dirt or specks
  - **UV light** – to identify stain
- cleaned on a regular basis
  - **antistatic** cleaner
  - **70% isopropyl alcohol** or **95% alcohol** to shorten the drying time
  - mild soap and water
  - cotton balls – for even cleaning

Processing the Radiograph

The Radiographic Darkroom

- a laboratory where radiography starts and ends
- has controlled environment, designed to be functional and convenient
- designed for handling and storage of x-ray film
- the Occupational Safety and Health Agency requires the RT to wear **face mask** in the darkroom as fumes are carcinogenic
- darkroom disease – hypersensitivity to fumes
- main function of darkroom – to prevent/protect film from exposure to white light and ionizing radiation during handling and processing
- **latensification** – an **exposed film** is **2-8 times more sensitive** to subsequent exposure than unexposed film as it contains a latent image

Factors to Consider in the Processing Room

1. **location**
   - in proximity/near to exposure room
   - placed in the department that requires the RT to walk as few steps as possible
2. **size**
   - **15 ft. × 9.5 ft.** or greater for 200 radiographs/day
   - **wet and dry section**
     - **4 ft.** away from each other to prevent contamination of the dry section
     - a negathoscope can be located on the wet section
3. **protects against radiation**
   - darkroom can be adjacent to exposure room only if the wall is:
     - **concrete –** greater than 6 inches
     - **hollow blocks –** filled with cement
     - **wood –** with 1.5 mm Pb
4. **ventilation**
   - ventilation in the darkroom is designed to eliminate heat and fumes
   - ventilation system must be **light-tight**
   - air changes **– 8-10** room changes of air per hour, exhaust fan
   - air movement **– 15-25 ft/min**, fan
   - storage room temperature – **10-21°C** or **50-70°F**
   - dark room temperature:
     - **20°C** or **67-83°F** (old)
     - **18-24°C** or **65-85°F** (new)
   - humidity for storage room and darkroom:
     - **40-60%** for storage room, not less than **45%**
     - too low humidity will cause static artifacts
     - darkroom – **30-60%**
   - air from the dryer of the automatic processor must be vented to the outside or to the ceiling
   - **psychrometer** – a device used to measure humidity or moisture
   - **hygrometer**– a device used to measure environmental moisture
5. **cleanliness**
   - a darkroom's efficiency pertains to its cleanliness
     - uncluttered countertops
6. **light-tight entrance**
   - **single door**
     - simplest type, a **passbox** is required to allow films to be transferred without entering the darkroom
     - **interlocking system** – prevents opening of the passbox when one side is open
     - the door should be weatherized
     - the door **must be light**, not heavy
     - locking mechanism
       - when the lock is engaged, it will prevent the door from opening when the storage bin is open
     - disadvantage – accidental film exposure
   - **light-lock door or double door**
     - used only when there is darkroom personnel exclusive in the darkroom
     - if door 1 is open, door 2 is automatically locks
     - fresh films are located on the left side, exposed films are located on the right
   - **labyrinth or maze**
     - easy access, zigzag type, doesn't use a door
     - used only when the darkroom is large as it requires more space
   - **revolving door**

- type with fastest access as RTs can enter and exit at the same time

7. **illumination**
   - **white light illumination** – overhead light, **2 to 4** fluorescent lamps, covering **48 in of lamp per 8 m²** of ceiling, for the purpose of maintenance, emergency use and cleaning, white light switch is located **4 m** off the floor at eye level
   - **safelight illumination –** also called safelight system, provides adequate illumination without detriment to film, film is most sensitive after exposure and before processing
   - **distance** – **3 to 4 ft** from the workbench, **4 ft** from the feedtray of the automatic processor
   - **wattage** – **7.5 watts** tungsten bulb at **3 ft** distance, **15 watts** at **4 ft** distance
   - **filters** – filters out intensity and energy/color
     - **amber filter –** filters out red, orange and yellow colors, used in blue-sensitive film appears brownish
     - **Kodak Wratten 6B filter – >550 nm**, filters only the intensity, used for monochromatic film, alternatives include an amber filter & Kodak Morlite
     - **Kodak GBX-2 filter– >600 to 620 nm**, multi-purpose, filters out yellow and orange, for both blue/green sensitive film, appears dark red
8. **color of walls**
   - **pastel and light colors –** ↑ reflectance of safelight, ivory or light gray color
   - **matte finish not glossy** – ↓ reflectance of white light
   - **enamel & epoxy** – easy to clean and durable, dries quickly
   - **neon color** – prohibited
   - **bright color –** chosen over dark colors
9. **electric wiring**
   - should be appropriately installed
10. **safelight**
    - **direct safelight** – fixture type safelight, light is distributed directly, most common in the hospital
    - **indirect safelight** – ceiling type safelight, light goes up first before being reflected, uses **sodium vapor bulb,** distance from the workbench must be **6 ft**, the only disadvantage is that it takes time to warm-up before use

Darkroom and automatic processor quality control

1. **darkroom environment**
   - daily
   - maintained clean, well ventilated, organized and safe
2. **safelight test**
   - semi-annual
   - **safelight fog**
     - contributes to greater than **0.05 OD**
     - always check the **distance**, **wattage** and **filters** used
   - **steps**
     - load a cassette with film with all lights off
     - expose it with a small amount of radiation
     - return to the darkroom and lay the film with all lights off on the area of the work counter
     - cover ¾ of the film
     - turn on the safelight
     - expose the film for 1 minute, then uncover another ¼ of the film
     - continue the procedure, until the entire film is exposed in **4 minutes**
     - turn off the safelight and process the film
   - the film is evaluated using a densitometer
   - acceptable safelight fog – **0.04 OD**
   - if fog is present and increases with continues exposure to safelight, the safelight is considered **unsafe**
3. **automatic processor temperature**
   - weekly
   - must be within **±0.3°C** or **0.5°F**
4. **replenishment rate**
   - weekly
   - must be within **±5%**
   - **oxidized developer**
     - old or exhausted developer
   - **contaminated solution**
     - entire solution is ineffective
     - can't be replenished and should be replaced
   - **function of replenishment**
     - maintain or bring back the activity of chemical on its original activity or composition
   - **fixer tank** – should always be filled first when cleaning a processor
   - an advisable period of changing processing solutions in an automatic processor is **every 6 months**
5. **solution pH**
   - quarterly, every 3 months
   - **pH range** – qualitative method of measuring the alkalinity or acidity of a solution
     - **7 to 14 –** base, alkaline chemical
     - **7 –** neutral
     - **0 to 7 –** acid, acidic chemical
   - developer **– pH of 9.6 to 10.6**
   - fixer**– pH of 4.2 to 4.9**
6. **developer specific gravity**
   - quarterly, every 3 months
   - must not greater than **0.004**
   - **specific gravity** is the amount of water versus chemical
   - **hydrometer** – a device that measures specific gravity
7. **processor control chart monitoring**
   - daily, early in the morning
   - done after the automatic processor reached its maximum capacity or has been warmed up
   - not greater than **0.15 OD** from baseline measurements
   - speed and contrast indication
8. **film sensitometry**
   - quantitative measurement of response of film to exposure and development
   - measures
     - film speed
     - film contrast
     - film latitude
     - contrast using hydroquinone
   - **devices used**
     - **sensitometer** – optical step wedge
     - **penetrometer** – aluminum step wedge, used in step-wedge exposure, alternative for sensitometer
     - **sensitometric strips or step tablet** – made by exposing successive areas on a film and progressively making larger exposure until maximum density on the film is reached
     - **densitometer** – measures the density of exposed film by measuring the percentage of light transmittance
       - 0 OD – 100%
       - 1 OD – 10%
       - 2 OD – 1%
       - 3 OD – 0.1%

Quality Control test	***Schedule***	***Standard***
Darkroom environment	daily	Maintained can, well ventilated,

		organized and safe
Safelight test	semi-annually	Must not contribute to 0.05 OD added as fog
Automatic processor temperature	weekly	Should vary more then ±0.5°F (0.3°C)
Replenishment rates	weekly	Should fall within ±5% of manufacturer's specification
Development time	daily	Maintained within ±2 to 3% of manufacturer's specification
Developer specific gravity	quarterly	Should not vary more than ±0.004 from manufacturer's specifications
Developer solution pH	quarterly	Maintained b/w 10 to 11.5
Fixer solution pH	quarterly	Maintained b/w 4 to 4.5
Processor cotrol chart monitoring	daily	Speed and contrast indicators should not vary more than ±0.15 OD from baseline measurements

Processing System

- processing the x-ray image changes the latent image to a visible image that is made permanent for handling, viewing and storage
- to process a film, one must **develop**, **fix**, **wash**, and **dry** it
  - **latent/potential image** – refers to the image that exists on film after it has been exposed but before it has been processed
  - **visible/manifest image** – black metallic silver image
- **developer solution** in developer tank converts exposed silver bromide crystals (latent image) to black metallic silver (visible image)
- **fixer solution** in fixer tank clears and removes unexposed silver bromide crystals, stops development, and hardens the emulsion
- **water** in the wash tank removes chemicals remaining on film; film is dried in dryer system
- the **overflow** solution is carried over the top of the tanks into the water drain
- **manual processing system**
  - **70°F**
- **processing system tanks**
  - cascade compartment type
    - has a developer tank, fixer tank, and 2 wash tanks
      - for initial and final washing
      - uses hyponeutralizer
  - master tank and insert tank type

Automatic processors

- a device that has roller transport system, comprised of chemical tanks and a dryer system for processing of radiographic film
- dry to dry systems
- standardize the processing of radiographs with consistency and efficiency
- **processing cycle**
  - dry-to-drop time
  - the time to process a single piece of film
  - usually **45 seconds to 3.5 minutes**
- **processing capacity**
  - number of film that can be processed per hour
- standard size of automatic processors – **24 inches/corner**
- **90 secs automatic processor**
  - **33.8 to 35°C** or **90 to 95°F**
  - clear time – **15 to 20 seconds**
    - **5 to 2** seconds before clearing agent begins to function
- **double capacity processor**
  - can process a film in **3 minutes**
- **brief history**
  - **1942** – Pako, 1st automatic processor, moves films on hangers from tank to tank
  - **1956** – Eastman Kodak, 1st roller transport system
  - **1965** – Eastman Kodak, 1st rapid processing at **90 s**
  - **1987** – Konica, rapid processing at **45 s** using special chemicals
- **automatic processor installment types**
  - **totally inside**
    - all automatic processor are located inside
    - advantage – jammed films can be retrieved without exposure to white light
    - disadvantages – ↑ heat, noise and humidity inside the darkroom
  - **bulk inside**
    - more advisable as all automatic processor are located inside but the drop tray is located outside
    - advantages – easy retrieval of films, ↓ heat, noise and humidity
  - **bulk outside**
    - only the feed tray is located inside
    - used only when the darkroom is small
    - advantages – almost no heat, noise and humidity
    - disadvantages **–** jammed films can't be retrieved through white light

Requirements for a processing room

	requirement	*comment*
1.	control of temperature	helps maintain adequate density and contrast
2.	agitation of chemical solutions	provides thorough mixing of chemical solutions
3.	replenishment	maintains volume and strength of solution
4.	minimum spilling of chemicals as film moves from tank to tank	reduces contamination of chemicals
5.	transportation of film through system remains constant	controls length of time film is in developer and fixer
6.	time-temperature relationship	maintains consistency with all processing systems
7.	compact in size	requires very little space to operate
8.	strategic placement	reduces the time spent by radiographers traveling to and from darkroom area

Automatic processor systems

- **processing systems**
  - **transport system –** moves film through the processor and agitates the chemistry
  - **replenishment system** – adds fresh developer and fixer solution for each film as it is fed into the processor
  - **recirculation system** – agitates and filters developer solution; stabilizes solution temperature; prevents stratification of chemicals in the tank
  - **dryer system** – dries film at approximately **120°F** after it leaves wash tank
- **transport system**
  - **advances** the film through the processor
  - the speed the film is moved throughout the processor must **remain constant**
  - the transport system also agitates the solution and helps maintain the temperature
  - **overlapping of film** could occur when film is prematurely fed into the processor because of the rollers
  - the transport system moves film from the feed tray into developer, fixer, wash tank, dryer, and finally out of the processor to the receiving tray
  - **entrance roller –** grabs the film, covered with corrugated rubber, made up or either Plexiglas or

acrylic plastic, polyester plastic, phenolic resin (water absorbent), **rubberized** plastic or stainless steel
        - a **visual signal** is emitted when the film completely passes over the entrance roller
    - **transport or planetary roller** – vehicle transport, moves the film through the chemical tanks and dryer, distributed throughout the processor, **1 in** in diameter
    - **turnaround, solar or master roller** – bottom of the roller assembly, turns the film from moving down the transport assembly to moving up the assembly, some processors have a **semi-master roller**, **2 in** in diameter
    - **crossover roller** – moves the film from one tank to another
        - **squeegee roller** – removes excess moisture from film surfaces using a specialized rubber area to prevent carryover of chemicals as film is moved from tank to tank
    - **guide plates** – found in turnaround and crossover rollers, slightly curved metal plates, properly guide the leading edge of the moving film through the processor
    - **motor drive** – an electric motor, provides power for the roller assembly to transport the film through the processor
        - **on/off switch** – connects the processor to the electric power
        - **standby power** – electric circuit that shuts the power off the roller assemblies when processor is not in use
        - **belt and pulley, chains and sprocket, gears** – connects the motor to the rollers
- **recirculation system**
    - the purpose of the recirculation system is to provide continuous mixing of chemicals
    - acts to circulate the solutions in each of these tanks by **pumping** solution out of one portion of the tank and returning it to a different location in the same tank from which it was removed
    - it **keeps the chemicals mixed**, which helps maintain solution activity and provides agitation of the chemicals around the film to facilitate fast processing
    - helps maintain the proper temperature of the developer solution
    - the **developer recirculation system** includes an **in-line filter** that removes impurities as the developer solution is being recirculated
- **replenishment system**
    - **replenishment**
        - keeps solution at proper strength and extends solution life
        - adds solution to the developer and fixer as each film is processed
        - the physical and chemical means of maintaining the volume and strength of the solutions
    - in departments without central processing facilities, up to **50 gallons** of developer and fixer replenishment tanks are used
    - replenishment system **includes** strainers, devices to control backflow, and instrumentation to measure replenishment
    - automatic processor solutions **last longer** than manual because of constant replenishment
    - the action of the replenishment is controlled by the **microswitch**
    - **high-volume processors** – up to 50,000 films of mixed sizes can be developed before changing the entire solution as long as there is adequate and consistent replenishment
    - **replenishing pumps**
        - diaphragm-type pump
        - bellows-type pump – most recommended
        - magnetic-drive centrifugal pump – used by Kodak processor
        - percentage time pump – Sonics or Litton
        - piston-type pump – the principle is like a syringe
    - **volume replenishment**
        - for processors with **25-50 pcs** of **14×14** or **14×17** films developed **per day**
        - utilizes a **microswitch** located at the entrance of the automatic processor which controls the replenishment rate of processing chemicals
        - replenishment rate are normally established on the basis how much chemistry is required **per 14 in** of film travel
            - developer
                - **60-70 cc/film**
                - **4-5 mL/in**
            - fixer
                - **100-110 cc/film**
                - **6-8 mL/in**
        - replenishment occurs only if **14×14 or 14×17** film is sensed by the microswitch
        - **8×10 in** – no replenishment occurs unless two films are fed together, side by side
    - **flood replenishment** (very rare)
        - timed or standby
        - introduced by Donald Titus of Kodak
        - for processors with **<25-50 14×14** or **14×17** films developed **per day**
        - no microswitch but with timer
        - many films are replenished
        - replenishes the solution every 10 minutes or 1 hour, 65 ml for both the developer and fixer
- **temperature control system**
    - **tempering system**
    - time-temperature relationship is important for the consistency in the processing of radiographs
    - in most **90-second** automatic processors, developer temperature must be maintained at **33.8 to 35°C** or **93 to 95°F**
    - **gross control** (old units)
        - warm water temperature processor
        - uses hot water
        - controlled by a water-mixing valve, a device that interconnects the incoming hot and cold water
    - **fine control**
        - thermostatically-controlled temperature processor
        - uses cold water
        - occurs within the developer tank itself through a thermostatically-controlled heating element by means of heat exchanger
        - the **thermostat**, a heating element or metal tube**,** controls the temperature
        - more advisable than gross control temperature processor
- **wash system**
    - necessary to remove excess chemicals, to prevent deterioration of the film after it is stored away
    - **purposes of washing**
        - remove the silver complexes from the film
        - remove the other salts from the film
        - remove the thiosulfate fixing agent from the film

        - important to **archival quality** as it prevents hyporetention
    - **water** is used as the wash agent, **5% bleach** can be added to prevent microorganism proliferation
    - temperature – **2.8°C or 5°F lower** than developer temperature to help stabilize developer temperature
    - **water filters** – at least two filters are used, a **30 µm** filter to remove iron , a 40 µm filter, or a 1 µm filter to filter microorganisms, water supply filters are replaced annually
    - about **20 minutes** immersion time in manual processing is recommended to remove residual fixer in the washing stage
    - **factors affecting the washing rate**
        - temperature of the wash bath
        - agitation
        - concentration of fixer in the emulsion and wash bath
- **drying**
    - completes the process
    - the dryer blows hot air across the surface of the film
    - removes **85-90% of moisture** from the film so that it can be handled easily and stored while maintaining the quality of the diagnostic image, **10 to 15% moisture** will still be remaining
    - temperature of air = **110 to 120 °F** to remove surface moisture
    - the **air is continually dried** by a dehumidifier
    - the dryer must be **vented** to release built-up air as new air is pulled into the system
    - consist of a **blower**, **ventilation ducts**, **drying tubes**, and an **exhaust system**
    - it completely extracts all residual moisture from the processed radiograph so that it drops into the receiving bin dry
    - drying consumes most of the electricity – **60 to 80% electrical consumption**
        - drying filament = 1500 to 2500 W
        - air blower = 100 to 300 ft^3/min
    - **factors affecting the drying process**
        - temperature
        - humidity
        - flow of the air into the emulsion

Maintaining the processing unit

- regular maintenance are required for consistency in the performance of the processors
- **maintenance procedures include**
    - routine checks and cleaning of the transport rollers by lifting of the racks out of the tank
    - careful examination and adjustment of guideshoes
    - cleaning and replacement of filters throughout the processor unit
    - failure of system or subsystem will result in **non-scheduled maintenance**
    - a **scheduled maintenance** does not include replacement of parts
- **start-up procedure**
    1. close wash tank valve
    2. turn on water source
    3. turn on processor
    4. wash crossover racks
    5. put lid in place
    6. run several 14×17 films through processor
    7. check **replenishment rates** (also check several times throughout the day)
    8. check developer **temperature** after warm-up
- **shutdown procedure**
    1. turn off water source
    2. turn off processor
    3. open wash tank valve and **drain tank**
    4. **wash crossover** racks
    5. **leave lid ajar** several inches to prevent contamination of solutions resulting from condensation or algae formation
- **cleaning and maintenance** (recommended)
    - **daily** – wash crossover racks twice daily (startup and shutdown or morning and evening); drain wash tank
    - **weekly** – clean deep racks
    - **monthly** – drain and clean by hand all tanks and dryer; put in fresh developer and fixer; change developer halter; change water filters
- **processor and handling malfunctions and artifacts**
    - **artifacts** – unwanted, irregular mark or density on the radiograph; may be caused by improper handling, pressure, or static discharge
    - **temperature fluctuations** – ↑ developer temperature causes chemical fog and ↑ density
    - **contamination** – fixer solution splashing into developer tank, (1 ml) causes contamination with odor of **ammonia**; causes ↑ density on films known as chemical fog
    - **jamming** – films caught during transport owing to rollers out of alignment or inadequate replenishment rate, depriving the film of hardener, which allows the emulsion to swell to the point at which it cannot pass between the rollers

Chemistry overview – Development

- **function**
    - convert latent image to manifest image
    - to amplify the amount of metallic silver on the film by increasing the number of silver
    - to reduce the exposed silver halide crystals into metallic silver
- the developer provides electrons for the reduction of the silver halide crystals
    - by giving up electrons, the developer is **oxidized**
    - by gaining electrons, the silver halide crystals are **reduced**
    - **redox** – **red**uction-**ox**idation
    - **europe** – **e**lectrons are **u**sed in **r**eduction; **o**xidation **p**roduces **e**lectrons
- **superadditivity** or **synegism** – activity of each individual component of reducing agent in solution is less that the activity when two components are combined
- developer contamination
    - a small amount of fixer (**0.1 ml**) carried over to the developer will render it **ineffective**
- **20°C or 68°F** for **5 minutes** (**4 to 8 minutes**) processing
- **oxidized developer**
    - can be caused by **evaporation**
    - old or exhausted developer
    - ↓ reducing property
    - ↑ monosulfates
    - ↓ all agents' activity **except for restraining agent**
    - has a strong **ammonia** odor
- **factors that may affect the finished radiograph** (Bushong)
    - concentration of processing chemicals
    - degree of chemistry agitation during development
        - circulation system ↑ the probability of interaction of chemicals with the film
    - development time
        - ↑ development time if:
            - ↑ film size
            - ↑ SHC size
            - ↓ developer activity
        - ↓ development time if:
            - ↓ emulsion thickness

- ↑ agitation (circulation system) = ↑ interaction
- ↑activity
    - ↑ temperature
    - ↑ specific gravity
    - ↓ pH (more alkaline)
- development temperature
    - ↑ development temperature above recommended = ↓ contrast, ↑ relative speed, ↑ fog

Developer chemistry overview

chemical	*function*
phenidone	**reducer** – build grays tones, D_{min} = 1.2, provides intermediate density, principal component, sensitive to light and temperature
hydroquinone	**reducer** – builds blacks, D_{max}, provides upper scale density, sensitive to oxygen
elon/metol	**reducer** – added to hydroquinone in manual processing
PQ	**reducer** – for automatic processing, 15x superadditivity than MQ
MQ	**reducer** – for manual processing
carbonate *boric acid*	**buffer** – maintain pH, source of alkali
Na or K carbonate *Na or K hydroxide*	**accelerator** – speeds up the development process, allows the reducers to attack the AgBr crystals after swelling **activator** – facilitate swelling of gelatin **alkalinizer** – decrease and maintain level of pH, provides the necessary alkaline medium owing to the hydroxide **wetting agent** – stimulate uniform development by reducing surface tension
K or Na bromide *K or Na iodide*	**restrainer** – prevent overdevelopment **regulator** – controls the activity of the reducers **anti-foggant** – prevents chemical fog **starter solution** – added only to a fresh developer solution
benzothiosulfate	**organic restrainer** – added only to PQ developer
Na sulfite *cycon*	**preservative** – prevent rapid aerial oxidation **stabilizer** – promote equilibrium of chemicals **anti-oxidant** – prevents rapid chemical oxidation, reacts with quinone, forming hydroquinone monosulfate
glutaraldehyde *dialdehyde*	**hardener** – tanning agent – a weak hardener, prevents damage to emulsion during transport
distilled water	**solvent** – dilutes and concentrates the chemicals for proper strength
EDTA *chelates/borate salts* *calgon*	**anti-sequestering agent** – an oily substance that prevents precipitation of aluminum and calcium, forms a sludge in the bottom of the tank
bleach 5%	**fungicides** – inhibit growth of fungi
	anti-frothant – anti-foaming, prevent bubble formation and aerial oxidation
	replenisher – high in reducers, activator and preservative but w/o restrainer, can return the chemical activity to the original
bleach 6 ounces	**algaecide** – added to the wash tank

Chemistry overview – Fixing

- **primary function**
    - **removes**, **dissolves** & **clears away** undeveloped silver halide crystals from the film, forming a silver complex of thiosulfate called **monoargento-dithiosulfuric acid**
    - to **permanent** the latent image – the exposed and already developed crystals
- **secondary function**
    - to stop development process
    - to harden the emulsion further
- **fixing time** = clearing time + hardening time
- fixing process is approximately **twice** the development process
- after a predetermined processing period, **development** is halted when the film is placed in the fixer
- **overreplenishment of the fixer** does not greatly affect film quality but is expensive
- **oxidized fixer**
    - ↑ sulfurization
- **factors that affect the use of the fixer**
    1. fixing agent used
    2. concentration of the fixing agent
    3. temperature of the solution
    4. presence of hardener
    5. film material used
    6. agitation of the film
    7. exhaustion of the fixing bath
- **cause of exhaustion of fixers**
    - dilution of water being carried into the tank from the second stage
    - increasing alkalinity brought by the carry over the alkaline developed
    - accumulation of the silver complexes which retard the clearing action of the thiosulfates
    - decreasing acidity
    - loss of hardening power
    - oxidation of the sodium sulfite

Fixer chemicals overview

chemical	*function*
acetic acid 1%	**stop bath** – acid rinse bath, recommended to neutralize the alkaline developer but is rarely used
boric acid *acetic acid* *sulfuric acid*	**buffer** – maintains pH
acetic acid	**acidifier** – provides the necessary acid medium **neutralizer** – neutralizes the developer and stops the development action
ammonium thiosulfate *Na thiosulfate*	**clearing agent** – dissolves and clears away unexposed silver halide crystals (pH 4.2 to 4.9) **fixing agent** – permanents the image
K alum *chrome alum* *Al Chloride*	**hardener** – shrinks and hardens the emulsion **tanning agent** – increases temperature at which the gelatin softens **permanenting agent** – permanents the image
Na or K sulfite *cycon*	**preservative** – prevents deterioration of chemicals and helps maintain chemical balance **anti-oxidant** – prevent internal and external oxidation **stabilizer** – maintains the equilibrium of the chemical in the solution
distilled water	**solvent**
borate salts	**sequestering agent** – an anti-sludging agent which delay precipitation of Al hydroxide (alkaline) by ↑ pH
	hyponeutralizer – solution used between fixing stage and the final washing cycle to ↓ the washing time of the film to prevent hyporetention
acetic acid, silver nitrate and solvent	**hypokit** – a chemical used to determine the presence of thiosulfate on processed films

Indicators of Inadequate Processing

- **dark films and fogged films** – may be caused by developer temperature too high, developer overreplenishment, fixer contamination of developer; white light leak; crack in safelight filter; outdated film, processor improperly mixed

- **light films** – may be caused by developer temperature too low; developer underreplenishment, processor running too fast, exhausted developer, developer improperly mixed
- **pinkish/dichroic stain** – contamination of developer by fixer (chemical fog), developer or fixer underreplenishment
- **brown stain/thiosulfate** – inadequate washing
- **emulsion removed by developer** – insufficient hardener in developer
- **streaks** – dirty processor rollers, inadequate washing and drying
- **water spots** – inadequate drying
- **films appear milky** – may be caused by poor fixer replenishment or inadequate washing
- **films appear greasy** – may be caused by inadequate washing
- **dark flakes** – may be caused by algae in wash water

Alternative processing methods

- **rapid processing**
  - as fast as **30 s**
  - useful for angiography, special procedures, surgery & emergency room procedures
  - uses more concentrated chemicals at higher temperatures
  - disadvantage – increased oxidation rate
- **extended processing**
  - as long as **3 min**, time is allowed to develop the film longer
  - common for mammography
  - used for single emulsion only
  - advantages – greater image contrast & lower patient dose
  - disadvantage – longer dry-to-drop time
- **daylight processing**
  - **2 minutes** load, unload and process time
  - **15 seconds** to insert exposed cassette and retrieve a new cassette
  - uses microprocessor
  - advantages – **no darkroom required**
  - multiple films are automatically accommodated

Silver recovery

- silver is a polluting agent
- the recovery of silver from the fixer solution makes it available for recycling – there is a dwindling supply of silver worldwide
- a **silver recovery unit** attached to the processor can help **conserve money**
- silver sources – photography: 30%, electronics: 20%, sterling: 15%
- classes of films
  - **archival film** – 5 years/10 years, can be sold
  - **scrap film/spoilage** – 50% Ag recovery
  - **green film** – most precious in terms of Ag recovery, 100% Ag recovery, all Ag remain intact
- **electrolytic recovery units**
  - **most common**, an electric current is passed through an ionized solution
  - uses a cathode (stainless steel) immersed in a canister with a positive charge
  - positive Ag accumulates in the cathode and must be frequently "chipped" off
- **chemical replacement**
  - **precipitation of the silver**
    - oldest form of silver recovery
    - Ag in fixer solution is precipitated as silver sulfide by adding sodium sulfide to the solution
  - **metallic replacement of silver**
    - most economic and simplest
    - uses a cartridge filtration system, a very fine aluminum steel wool or a very fine steel mesh
    - silver is attracted to the iron in the metal and forms a sludge that falls in the bottom of the tank

Technical Factors in Radiography

Technique

- technique is the systematic procedure

Kilovoltage

- force that accelerates the electrons from the cathode to the anode
- directly controls the **energy or quality** of the x-ray beam
  - ↑ kVp
  - ↑ pd between the anode and cathode
  - ↑ no. of electrons striking the anode
  - ↑ production of ↓ wavelength photons
  - ↑ production of ↑ energy photons
- the kilovoltage peak is the **crest of the waveform** that represents photon energy
- controls the energy of x-rays produced; also has a direct impact on density, although not proportional; governed by the 15% rule
- **15% rule**
  - ↑ kilovoltage by 15% = 2× density
  - ↓ kilovoltage by 15% = ½ density
- **penetration of the part**
  - penetration of the part means the x-ray photons have sufficient energy to pass through the part and emerge as remnant radiation
  - ↑ kilovoltage = x-ray photon penetrability
- **density maintenance** (**kVp and mAs**)
  - 15% ↓ in kVp = mAs ÷2
  - 15% ↑ in kVp = mAs ×2
- **scatter radiation**
  - exits the body and travels in different directions with many energy levels
  - danger to the patient and radiographer, detriment to image quality
  - the characteristic radiation produced by the **photoelectric effect** is mostly absorbed by the patient
  - ↑ kV = ↓ radiation absorbed by the patient
- **film quality**
  - kilovoltage is the controlling factor of **radiographic contrast**

Milliamperes

- milliamperes represent the current flow through the cathode filament at the time of exposure
  - ↑ mAs
  - ↑ no. of electrons passing from cathode to anode
  - ↑ no. of x-rays produced at the anode
  - ↑ no. of radiation exiting the x-ray tube
    - ↑ mAs = ↑ radiation = ↑ density
    - ↓ mAs = ↓ radiation = ↓ density
  - ↑ no. of x-ray photons absorbed by the patient and no. of remnant x-ray photons exiting the patient
  - ↑ no. of x-rays that eventually strike the IR as remnant rays
- **focal spot blooming**
  - ↑ tube current (mA) = ↑focal spot size
- **quantum mottle or image noise**
  - statistical fluctuation in the quantity of x-ray photons that contributes to image per mm^2
  - ↓ mAs = few x-ray photons – ↑ mottled, splotchy or salt-and-pepper appearance

Time

- factor that sets the length of exposure
- milliamperes × time = milliamperes seconds

- $mAs = mA \times s$
- the **reciprocity law** indicates that blackening in the film remains constant as long as the total energy exposing the film is constant
  - fails at screen-film exposures if time is **less than ~10 ms** (angiography) and **longer than 2 s** (mammography)
  - **mAs = mAs**

Distance

- SID or FFD – length of space from the focal spot to the recording medium
- if SID is ↑ 2×, the same number of photons is spread out over an area 4× the original area, intensity of the beam is ¼ of the original intensity
- **inverse square law**
  - $\frac{\text{intensity}_1}{\text{intensity}_2} = \frac{\text{distance}_2^2}{\text{distance}_1^2}$
  - if distance ↑, the mAs must also ↑ to maintain density

Overview of Radiographic Quality

Radiographic quality (Burns)

- a **high quality radiograph** must have a **sharp image** with adequate density and contrast
- radiographic image **quality** is the exactness of representation of the patient's anatomy on a radiographic image
- **photographic aspect**
  - **density –** overall blackening of the film
  - **contrast –** variation in the density level that makes detail visible
- **geometric aspect**
  - **definition –** clarity and sharpness of structural lines
  - **distortion –** undesired change in the size and shape of the anatomic part

Characteristics of image quality (Bushong)

1. **resolution**
   - **resolution** – ability to image two separate objects and visually distinguish one from the other
   - **spatial resolution** – ability to image small objects that have a high subject contrast
     - film-screen imaging have a high spatial resolution
     - ↓ screen blur + ↓ motion blur + ↓ geometric blur = ↑ spatial resolution
   - **contrast resolution** – ability to image anatomic structures of similar subject contrast
     - ↓ noise = ↑ contrast resolution
   - **detail and recorded detail** – degree of sharpness of structural lines of a radiograph
   - **visibility of detail** – ability to visualize recorded detail when image contrast and optical density (OD) are optimized
2. **radiographic noise**
   - random fluctuations in the optical density of the radiograph
   - speckled background on image
   - caused by ↑ screen speed and ↑ kV techniques
   - **4 components of radiographic noise**
     1. **film graininess** – distribution and size of silver halide crystals in the emulsion, inherent to film
     2. **structure mottle** – speed of the intensifying screens, determined by phosphor size and DQE/CE, inherent to IS, uncontrolled by the RT
     3. **quantum mottle** – an image produced with just a few x-ray photons will have more quantum mottle
        - ↑ mAs + ↓ kVp + slow screen speed = ↓ quantum mottle
     4. **scatter radiation** – main source
3. **speed**
   - speed interconnects resolution and noise
   - each of the three factors influences others

IR speed	***noise***	***spatial resolution***	***contrast resolution***
fast	↑ noise	↓ spatial resolution	↓ contrast resolution
slow	↓ noise	↑ spatial resolution	↑ contrast resolution

Tools for increasing radiographic quality (Bushong)

- **patient positioning**
  - ↓ OID – part must be as close to IR as possible
  - CR must be incident on the center of the structure
  - patient is immobilized to avoid motion blur
- **image receptors**
  - use of intensifying screens decrease patient dose by a factor of at least **20**
  - ↑ image receptor speed = ↑ noise = ↓ spatial resolution
  - low contrast emulsions have wide latitude or margin of error, in producing an acceptable radiograph
- **selection of exposure factors**
  - choose the shortest possible exposure time
  - kVp controls contrast
    - kVp also affects density
  - mAs controls density
    - too much mAs will degrade contrast

Photographic quality factor – Radiographic Density

- opacity of the radiograph, overall blackening/darkness of the film
- without density, all other factors lose significance
- amount of blackness on a given area of a radiograph
- described as **brightness** (digital imaging)
  - **too dark** = high density = overexposed
  - **too light** = low density = underexposed
- controlled by
  - no. of remnant rays striking the image receptor
  - window level
  - amount of exposure = amount of density
  - **mAs**
  - kVp, distance, grids, film screen speed, collimation, anatomic part, anode heel effect, reciprocity law, generator output, filtration & film processing
- acceptable range – **0.25 to 2.0 density units**
- **60-80%** of density is from **fog**
- visible change in density = ↑ density by **30 to 35%**
- **tissue density** – aerated tissue, fatty tissue, water, bone and teeth
- **densitometer** – instrument used to measure density
- for measurement purpose, density is the logarithm of the ratio of the light hitting the film and the light transmitted through the film
  - $\text{density} = \log_{10} \frac{\text{light}_I}{\text{light}_T}$

Photographic quality factor – Radiographic Contrast

- **contrast**
  - makes details visible
  - a psychovisual perception
  - the variation in density levels that makes detail visible
  - caused by attenuation and differential absorption
  - variation, changes or differentiation of adjacent densities on the radiograph
  - produced by photoelectric effect
  - primary function – **make detail visible**
  -
- **satisfactory contrast** – differentiations between densities or details be readily made
- controlled by
  - **kVp**

        - kVp controls differential absorption of the x-ray beam by the body because of its control of x-ray beam energy
    - grids, collimation, OID, CM, processing & air-gap technique
    - ultimately controlled by window width and bit depth
- **radiographic contrast** = IR contrast × subject contrast
    - **image receptor contrast**
        - inherent in the screen-film combination
        - influenced somewhat by processing of the film
        - affected by film (IR), film type & direct/IS exposure
        - affected by range of ODs and film processing technique
            - film-screen images have higher contrasts than direct film exposure images
    - **subject contrast**
        - controlled by anatomy and pathology; affects contrast through variations of Z, tissue thickness, and tissue density
        - differential absorption of adjacent structures
        - **tissue thickness** – thick body sections attenuate more x-rays than thin body sections
        - **tissue mass density** – thickness may be the same but mass density are different: variation in tissue mass density contribute to subject contrast
        - **effective atomic number** – photoelectric effect varies in proportion to the cube of Z
            - contrast media – enhances contrast by enhancing photoelectric absorption
        - **object shape** – objects that coincide with the x-ray beam have high subject contrast
            - absorption blur – caused by the shape of the structure
        - **kVp** – most important factor in controlling subject contrast; ↓ kVp = ↑ contrast
- **high contrast**
    - ↑ contrast = ↓ gray tones / short-scale contrast
    - produced by low kVp
    - few no. of useful densities on the radiograph
        - abrupt change from one density to another
        - high contrast, more contrast & narrow latitude
- **low contrast**
    - ↓ contrast = ↑ gray tones / long-scale contrast
    - produced by high kVp
    - large no. of useful densities on the radiograph
        - little change from one density to another
        - low contrast, less contrast & wider latitude
- **contrast scale**
    - **short scale**
        - ↓ # of useful densities on the radiograph
        - abrupt change from one density to another
        - ↑ contrast, more contrast & narrow latitude
        - ↓ kVp technique
    - **long scale**
        - ↑ # of useful densities on the radiograph
        - little change from one density to another
        - ↓ contrast, less contrast & wider latitude
        - ↑ kVp technique

Contrast terminology

	higher contrast is	*lower contrast is*
	short-scale contrast	long-scale contrast
it shows:	few, very different, image/tissue densities	many similar image/tissue densities
a product of:	lower kV few, dissimilar tissue densities more, "tighter" collimation	higher kV many similar tissue densities larger field sizes

Factors affecting attenuation (Fauber)

factor	*Beam attenuation*	*absorption*	*transmission*
↑ *thickness*	↑	↑	↓
↓ *thickness*	↓	↓	↑
↑ *tissue Z*	↑	↑	↓
↓ *tissue Z*	↓	↓	↑
↑ *tissue density*	↑	↑	↓
↓ *tissue density*	↓	↓	↑
↑ *beam quality*	↓	↓	↑
↓ *beam quality*	↑	↑	↓

Geometric quality factor – Definition

- **clarity** of the **sharpness** of the structural lines of the anatomic parts
- **recorded detail** – sharpness with which anatomical structures are displayed on an image receptor
- other terms:
    - detail sharpness
    - abruptness of borders
    - clarity
    - definition
    - image resolution
    - **spatial resolution** (digital imaging)
- measured with a **resolution test pattern** and expressed in **lp/mm**
    - 1 line pair refers to 1 line and the 1 space adjacent to it
    - ↑ lp/mm = ↓ blur = ↑ recorded detail
    - resolution test tools
        - **star pattern** – focal spot size evaluation
        - **parallel line type** – intensifying screen evaluation
- **visibility of detail** – how well the recorded detail can be seen
    - density has no effect on recorded detail
    - density has effect on visibility of detail because it obscures detail
    - termed as **contrast resolution** (digital imaging)
- **umbra** – true image
- **penumbra** – geometric unsharpness; the blurred areas around the umbra
- affected both by the geometric and photographic aspects
- primarily controlled by SID, OID, and focal-spot size
- **magnification** – inversely related to recorded detail
    - ↑ magnification = ↓ recorded detail
    - SID and OID regulate magnification and image blur
- **focal spot size** – controls image blur
    - focal spot blur occurs because the focal spot is not a point source
    - focal spot – a roughly **rectangular** source, **~0.1 to 0.5 mm** on a side
    - focal spot blur is the most important factor in determining spatial resolution
    - $\frac{\text{SOD}}{\text{OID}} = \frac{\text{effective focal spot}}{\text{focal spot blur}}$
    - focal spot blur = $\frac{\text{(effective focal spot) OID}}{\text{SOD}}$
    - focal spot blur is **small** on the anode side and **large** on the cathode side
- **motion**
    - tube/patient motion causes image blur
    - patient motion is the usual cause
        - either voluntary or involuntary
    - procedures for reducing motion blur
        - shortest possible exposure time

- restrict patient motion by giving instruction or using restraining device
- ↑ SID
- ↓ OID

Definition

recorded detail	*distortion*	*visibility of detail*
focal spot size	alignment of tube,	density (mAs)
SID	part, or film	contrast (kVp)
OID	SID	scatter radiation
motion	OID	grids
screens		beam restriction

Geometric quality factor – Distortion

- distortion is the misrepresentation of the size and/or shape of the anatomic part of interest
- any geometric misrepresentation of an anatomical structure on an image receptor that **alters** its true size and/or shape
- 2 types of distortion
  - **size distortion**
    - magnification
  - **shape distortion**
    - elongation
    - foreshortening
- **magnification**
  - occurs whenever the **OID** is **greater than 0**
  - all images on a radiograph has magnification
  - smallest possible magnification is maintained
  - **magnification radiography** – uses magnification as an advantage
  - **magnification factor**
    - $M = \frac{\text{SID}}{\text{SID-OID}}$
    - $M = \frac{\text{image size}}{\text{object size}} = \frac{\text{SID}}{\text{SOD}}$
    - ex: ano ang magnification factor ng inex-ray na utong na 6 inches ang layo sa film kapag ang SID ay 40 inches?
      - $M = \frac{40}{40-6} = \frac{40}{36}$
      - M = 1.11
      - ibig sabihin, kung ang utong ay **0.5 inches** sa totoong buhay, kung and magnification factor ay 1.11, ang sukat ng utong sa ating radiograph ay magiging 0.5 × 1.11 or **0.55 inches**
  - **minimizing magnification**
    - **large SID** – use as large SID as possible
    - **small OID** – place the part as close to the IR as possible
    - **compression** – ↓ part thickness = ↓ OID = ↓ magnification
  - **SID standards**
    - **180 cm or 72"** – chest radiography
    - **100 cm or 40"** – routine examinations
    - **90 cm or 35"** – special studies
    - **50-70 cm** – general mammography
- **distortion**
  - unequal magnification of different portions of the same object
  - distortion depends on object thickness, object position, object shape
    1. object **thickness** – thick objects are more distorted than thin objects
    2. object **position** – if the object plane and the IR plane are not parallel, distortion occurs
    3. object **shape** – only irregular anatomy shows distinct distortion
  - **foreshortening** – ↑ inclination = ↑ foreshortening
  - **elongation** – an inclined object positioned lateral to the central ray may either be foreshortened or elongated
  - **spatial distortion** – occurs when multiple objects are positioned in various OIDs, each object will have varying degrees of distortion
- projection nature of x-rays
  - a single projection is not enough to describe the 3D configuration of an object
  - reason why most radiographic examinations require 2 or more projections

film factors	*geometric factors*	*subject factors*
characteristic curve	*distortion*	*Contrast*
1. density	1. elongation	1. thickness
2. contrast	2. foreshortening	2. density
3. speed		3. atomic number
4. latitude		
processing	*magnification*	*motion*
1. time		1. voluntary
2. temperature		2. involuntary
	blur	

Quality factor	*Related technical factor*	
	control	***influence***
Density	mAs	kVp distance
Contrast	kVp	
Definition	distance	kVp mAs
Distortion	distance	

Radiographic Density

Factors Affecting Density

- mAs
- kVp, distance (SID), grids, film/screen speed, beam restriction, filtration, anatomy and pathology, generator output, anode heel effect, processing

mAs

- density is **directly controlled** by mAs
- density or blackening is also controlled by **window level**
- ↑ mAs = ↑ exposure = ↑ density
- mAs is governed by the **reciprocity law**
  - any combinations of mA and time that produce the same mAs value will produce the same density
  - overall density on a radiograph is proportional only to the total energy imparted to the radiographic film
  - sometimes expressed by the equation:
    - **mAs = mAs**
    - accurate only on direct exposure
    - fails in screen-film – **<~10 ms & >2 s**
- mAs influences **focal spot blooming**
  - ↑ tube current = ↑ actual focal spot size

kVp

- **fog** – directly affects density through production of fog
  - not directly proportional
    - ↑ kVp = ↑ supplemental density
    - ↓ kVp = ↓ supplemental density
- **15% rule** – an ↑ in kVp of 15% **doubles density**; a ↓ in kVp of 15% **halves density** (only true for **60 to 100 kVp**)
  - density maintenance (kVp and mAs)
    - ↑ kVp 15%, ↓ mAs ½
    - ↓ kVp 15%, ↑ mAs 2×
  - can be used as an advantage
    - lower patient dose = original kVp + 15%, then ↓ mAs ½

- improve image quality = original kVp – 15%, then ↑ mAs 2×
- **penetrating ability**
  - ↑ kVp = ↓ wavelength = ↑ penetrability
  - ↓ kVp = ↑ wavelength = ↓ penetrability
  - affects the production of scattered radiation
  - affects exposure to patient
  - affects no. of remnant x-rays exiting the patient to strike the image receptor

Distance

- **inverse square law**
  - density = function of beam intensity = governed by the inverse square law
  - inverse square law – intensity of the x-ray beam is inversely proportional to the square of the distance between the source of x-rays and the image receptor
    - intensity is measured in **roentgens** (traditional) or **Coulombs/kilogram** (SI)
  - expressed as:
    - $\frac{\text{intensity}_1}{\text{intensity}_2} = \frac{\text{distance}_2^2}{\text{distance}_1^2}$
    - for this to apply, there must be no change in exposure technique
    - if SID is ↑ 2x = intensity/density ↓4x
    - if SID is ↓ ½ = intensity/density ↑4x
  - variation in intensity is the result of the **divergence** of the x-ray beam as it travels through space
- **density maintenance formula**
  - (mAs vs. distance)
    - $\frac{\text{mAs}_{\text{old}}}{\text{mAs}_{\text{new}}} = \frac{D_{\text{old}}^2}{D_{\text{new}}^2}$
  - used to maintain the old density by changing mAs after change in distance
    - if SID ↑**2x** = mAs ↑**4x**
    - if SID ↓ **½** = mAs ↓**4x**

Grids

- ↓ scatter radiation striking the image receptor
- ↓ grid ratio = ↑ density
- ↑ grid ratio = ↓ density
- generally, use of grids = ↓ fog = ↓ density
  - unless mAs is ↑ to compensate for the loss of scatter fog

Film/Screen Speeds

- faster screen/film combination = ↑ density
- direct exposure technique = ↓ density

Beam restriction

- ↓ field size = ↓ area of production of scatter fog = ↓ density
  - unless mAs is ↑ to compensate
- beam restriction will ↓ density by limiting the area of the patient being struck by x-rays
- ↑ beam restriction = ↓ scatter radiation = ↓ fog = ↓ = density
  - fog is **necessary** for proper image processing with digital imaging

Filtration

- negligible effect on density; its purpose is primarily for radiation protection
- radiation protection is due to the reduction in the no. of soft, long-wavelength rays being absorbed in the patient
- has an impact on contrast because the average wavelength of the filtered beam is shorter than the nonfiltered beam
- **compensating filters** even out density of irregular anatomy

Anatomy and pathology

- anatomy affects density through:
  - variation of Z
  - variation of tissue density and thickness
- normal **tissue density differences** exist as a result of:
  - body habitus (asthenic, hyposthenic, sthenic, hypersthenic), age, gender & level of activity
- **pathologic changes** affect density by either altering the **Z** or altering the tissue **integrity**, **density** and **thickness**
- **additive pathologies** = ↑ x-ray absorption in tissue = needs ↑ in kVp
  - abdomen – aortic aneurysm, aortic acne, ascites, cirrhosis, hypertrophy
  - chest – atelectasis, CHF, osteoblastic metastases, pleural effusion, pneumonia
  - skeleton – hydrocephalus, osteochondroma, late stage Paget's disease
  - non-specific – abscess, edema, sclerosis
- **destructive pathologies =** ↓ x-ray absorption in tissue = needs ↓ in kVp
  - abdomen – bowel obstruction, free air
  - chest – emphysema, pneumothorax, active TB
  - skeleton – gout, osteolytic metastases, multiple myeloma, early stage Paget's disease, osteoporosis, degenerative arthritis, osteoporosis
  - non-specific – atrophy, necrosis, emaciation, malnutrition (ma'am alerna)

Generator output

- **3-ø x-ray generation** is much more efficient than 1-ø because the voltage **never drops to zero**
- 3ø equipment = ↓ voltage ripple = ↑ high energy x-ray photons
- mAs is usually adjusted to compensate for differences between 1ø and 3ø waveform equipment

single phase	***three phase***
X mAs	⅔ *X* for 3-ø (6p)
X mAs	½ *X* for 3-ø (12p)
X kVp	*X* – 12% for 3-ø

Anode heel effect

- the anode heel effect is emphasized under the following conditions:
  - at ↓ SIDs
  - with ↑ cassette size
  - with ↓ anode angle x-ray tubes
- x-ray intensity varies along the longitudinal axis of the x-ray beam
  - cathode end = ↑ density
  - anode end = ↓ density
  - x-rays are absorbed by the "heel" of the anode
    - anode side – 75%
    - cathode side – 120%
    - difference – 45%
- **thicker anatomy** should be placed **under the cathode** side of the x-ray tube to take advantage of the anode heel effect
  - ↑ SID = ↓ anode heel effect
  - ↓ field size = ↓ anode heel effect
  - ↑ anode angle = ↓ anode heel effect

examination	***position toward the cathode (–)***	***position toward the anode (+)***
PA chest	abdomen	neck
abdomen	abdomen	pelvis
femur	hip	knee
humerus	shoulder	elbow
AP T-spine	abdomen	neck
AP L-spine	abdomen	pelvis

Processing

- ↑ developer temperature (2-3°F) = ↑ density
- ↑ development time = ↑ density
- ↑ replenishment rate = ↑ density

Contrast

Factors affecting contrast

- kVp
- OID, grid, beam restriction, filtration, anatomy and pathology, processing, casts and splints

kVp

- **directly controls contrast**
  - controls the differential absorption of the x-ray beam in the body
  - contrast is also controlled by window width and bit depth (digital)
- controls **differential absorption** of the x-ray beam by the body because of its control of x-ray beam energy
  - ↑ kVp = ↓ wavelength rays = ↑penetrability = ↓ absorption/photoelectric interaction = ↑ gray tones = longer contrast scale
  - ↓ kVp = ↑ wavelength rays = ↓penetrability = ↑ absorption/photoelectric interaction = ↓ gray tones = shorter contrast scale

OID

- ↑ OID (**15 to 25 cm**) = **air gap** technique= ↑ scatter **cleanup** (equivalent to 8:1 grid ratio) = ↑ contrast
- air gap technique disadvantage – ↑ magnification, ↑ SID,↑ mAs to maintain density

Grids

- ↓ scatter reaching the image receptor = ↓ scatter fog = ↓ gray tones = ↑ contrast

Beam restriction

- limits area being irradiated
- ↓ field size = ↓ number of Compton interactions = ↓ scatter = ↓ patent dose = ↓ gray tones = ↑ contrast

Filtration

- as filtration is ↑, beam becomes **harder** (average photon striking the patient has shorter wavelength)
- ↑ filtration = harder photons = ↑ Compton scatter = ↓ contrast
- air-gap technique = ↓ contrast (owing to **air filtration**)

Anatomy and pathology

- a.k.a. **subject contrast**
- cause differential absorption of x-ray photons, which results in contrast
- control contrast with variations in the following
  - ↑ **atomic number** = ↑ contrast (owing to photoelectric effect)
  - ↑ **tissue density** = ↓ contrast (owing to Compton scattering)
  - ↑ **tissue thickness** = ↓ contrast (owing to Compton scattering)
  - **use of a contrast agent** = ↑ contrast (owing to photoelectric effect)

Processing

- ↑ processing **time** = ↑ chemical fog = ↓ contrast
- ↑ chemical **temperature** = ↑ chemical fog = ↓ contrast
- alternative – extended processing (3 minutes) for radiograph obtained from very low kV = ↑ contrast

Casts and Splints

- **casts**
  - fiber– no change in exposure factor
  - fiberglass + plaster – mAs +50% or +8% kVp
  - fiberglass + solid plastic – mAs +50% or +8% kVp
  - ¾ inch wood – mAs +50% or +8% kVp
  - dry plaster – ↑mAs 2x of +15% kVp
  - large dry plaster ↑ mAs 3× or +22% kVp
  - medium wet plaster –↑ mAs 3x or +22% kVp
  - large wet plaster – ↑ mAs 4× or +30% kVp
- **splints**
  - fiber glass – no ↑ in factor
  - inflatable (air) – no ↑ in factor
  - wood, aluminum & plastic – ↑ exposure only if they are in the path of primary beam

Recorded Detail

Factors affecting detail

- OID
- SID, patient factors, focal-spot size, motion, intensifying screens

OID

- OID – distance from the anatomical part being imaged to the image receptor
- because divergence ↑ as the x-ray beam leaves the source, an ↑ in OID will ↑ magnification
- ↓ OID = ↓ magnification = ↓ image blur = ↑ recorded detail
- ↑ OID = ↑ magnification = ↑ image blur = ↓ recorded detail

SID

- SID – distance from the source of radiation (usually anode in the x-ray tube) to the image receptor
- ↑ SID = ↓ magnification = ↓ image blur = ↑ recorded detail
- ↓ SID = ↑ magnification = ↑ image blur = ↓ recorded detail

Anatomy and pathology

- a certain amount of object unsharpness is an **inherent** part of every radiographic image because of the **position and shape** of anatomic structures within the body

Focal-spot size

- ↑ focal spot size = ↑ unsharpness
- affects border of unsharpness around image details
  - focal spot blur
  - geometric unsharpness
  - edge gradient
- **line focus principle** – effective or projected focal spot size is always smaller than the actual focal spot
  - **effective focal spot size** varies along the longitudinal axis of the image receptor
    - ↑ at the **cathode end** of the x-ray beam
    - ↓ at the **anode end** of the x-ray beam
  - use of **small** focal spot = ↑ recorded detail = ↑ heat at the anode
  - ↓ anode angles
    - ↑ actual focal spot sizes while maintaining ↓ effective focal spot sizes = cost: ↑ **anode heel effect**
    - use of a small anode angle can limit image receptor coverage at traditional and short SIDs
  - ↓ FSS = ↓ area of x-ray production = ↓ image blur = ↑ recorded detail
  - ↑ FSS = ↑ area of x-ray production = ↑ image blur = ↓ recorded detail

Motion

- ↑ motion = ↑ blur = ↓ recorded detail
- motion is the **greatest adversary** of recorded detail
- **patient motion**
  - **voluntary patient motion =** ↓ by good communication
  - **involuntary patient motion** = ↓ by using the shortest possible exposure time

- various **radiographic accessories** are available to help minimize both voluntary and involuntary patient motion

- **equipment motion**
  - can also result in loss of recorded detail in the form of image blur
- special techniques that introduce motion are sometimes employed to see some structures particularly well
- motion causes:
  1. patient motion (voluntary and involuntary)
  2. x-ray tube motion
  3. excessive motion from reciprocating grid

Intensifying Screens

- ↑ IS speed = ↓ patient dose = ↑ tube life
- Intensifying screen phosphors **absorb x-ray photons** → emit a large quantity of fluorescent light
- **fluorescent light** is responsible for **>98%** of film emulsion exposure
- **spectral matching** – the color light emitted by the phosphors must be correctly matched with the film emulsion sensitivity
- **rare earth phosphors** = ↑ conversion efficiency
- **calcium tungstate phosphors** = ↓ conversion efficiency
- ↑ conversion efficiency & speed of screens = ↑ fluorescent light **diffusion** = ↓ recorded detail
- **IS speed** is influenced by
  - type and size of phosphor used
  - thickness of the active/phosphor layer
  - degree of reflectance, given the screen base
- fast screens + ↓ mAs & ↑ kV factors = **↑ quantum mottle**
- **lag** or **afterglow** – phosphor fluorescence after the x-ray source has terminated
- **phosphorescence** – associated with fluoroscopic screens
- **perfect screen-film contact**– required to maintain recorded detail
  - screen–film contact is measured using **wire mesh test**

Distortion

Factors Affecting Distortion

- distance
- size, shape, patient factors

Size

- **magnification** – causes anatomical structure to appear larger on the image than in reality
- SID and OID regulate magnification
  - ↓ SID = ↑ magnification
  - ↑ OID = ↑ magnification

Shape

- **elongation**
  - causes anatomic structure to **appear longer** than in reality
  - caused by angulation **along the long axis** of the part
  - ↑ tube/part/film angulation = ↑ elongation
  - ↑ tube/part/film alignment = ↓ elongation
- **foreshortening**
  - causes anatomic structure to **appear shorter** than in reality
  - caused by angulation **against the main axis** of the part
  - ↑ tube/part/film angulation = ↑ foreshortening
  - ↑ tube/part/film alignment = ↓ foreshortening

Patient factors

- **structural position**
  - structures within the body lie at varying distances from the x-ray image receptor, producing varying degrees of magnification
  - organs **farther** from IR = ↑ magnification
- **structural shape**
  - **structures not parallel** to the x-ray tube and image receptor and/or that **lie outside the central axis** of the x-ray beam will be foreshortened or elongated
  - misrepresentation can be exaggerated when the **part is away from the central axis** of the x-ray beam.
  - distortion can be used to improve visualization of some structures
  - **blur** is accompanied by changes in image density as a result of differing thicknesses traversed by the x-ray beam

Variables	***Photographic Properties***		***Geometric Properties***	
	Density	***Contrast***	***Detail***	***Distortion***
malakas *mAs*	↑			
mahina *mAs*	↓			
malakas *kVp*	↑	↓		
mahina *kVp*	↓	↑		
malayo *SID*	↓		↑	↓
malapit *SID*	↑		↓	↑
malayo *OID*	↓	↑	↓	↑
malapit OID	↑	↓	↑	↓
makapal *grid ratio*	↓	↑		
manipis *grid ratio*	↑	↓		
mabilis *film-screen*	↑		↓	
mabagal *film-screen*	↓		↑	
sinikipan *collimation*	↓	↑		
binuka *collimation*	↑	↓		
malaki *focal spot size*			↓	
maliit *focal spot size*			↑	
mayroong *CR angle*	↓		↓	↑

Principal factors that may affect the making of a radiograph

increase in	***dose***	***M***	***FS****	***M****	***A****	***OD***	***C***
film speed	–			–		+	
screen speed	–			–		+	
grid ratio	+					–	+
dev. time/temp						+	–
pt. thickness	+	+	+	+	+	–	–
field size	+					+	–
use of CM						–	+
focal spot size			+				
SID	–	–	–	–		–	
OID		+	+	+			+
screen-film contact							–
mAs	+					+	±
time	+		+			+	±
voltage	+					+	–
voltage ripple	+		+			–	+
total filtration	–					–	–

Control of Scatter Radiation – Beam restriction

Beam Restriction

- beam restriction is the most effective method for reducing the amount of scatter
  - this will also limit patient exposure
- the purpose of beam restriction is to limit the size of the primary x-ray beam
- ↑ beam restriction
  - ↓ field size

- ↓ scatter radiation
- ↓ density
- ↑ contrast
- ↓ patient dose

- beam restriction directly controls field size
- **field size** is the size and shape of primary beam to the size and shape of the IR
- approximately 1% of the x-rays incident on the patient reaches the image receptor

Types of beam restriction

- **Aperture diaphragm**
  - poor beam restrictors
  - simple flat sheets of lead with a hole in the iddle
  - **size of the hole** in the diaphragm **determines** field size
  - disadvantages
    1. opening is not adjustable, only one field size can be obtained per SID
    2. increase in penumbra caused by undercutting
  - **undercutting** – occurs when x-rays from different points on the target undercut or pass by the aperture diaphragm and the upper lip of a flared cone, and pass tangentially across the edge of a part
  - **calculation of field size**
    - A opening= $\frac{\text{field diameter} \times \text{FS to A distance}}{\text{SID}}$
- **cone/cylinder**
  - heavy metal devices attached to the housing
  - 8 to 10 in. in length
  - shapes – flared circular, rectangular, or cylindrical
  - cylinder cone is the most effective
  - disadvantages
    1. fixed field size
    2. no advantage over aperture diaphragms
    3. undercutting
- **collimator**
  - best type
  - collimation = ↓ patient dose , ↑ contrast resolution
  - box-like structure attached to the port of the x-ray tube
  - useful and accepted type of beam-restricting device
  - has 2 sets of shutters, upper/entrance and lower
    1. entrance shutters nearest the port are fixed
    2. lower shutters adjust longitudinal and transverse borders of the beam
  - mirror – resting 45° along the beam, reflects light to the open shutters
    1. distance from the bulb to the mirror must be equal to the distance of the focal spot and the mirror
- **automatic collimators**
  - positive beam limiting devices (PBLD)
  - automatically limits the size of the beam, accompanied with electric motors
  - accurate within 2 to 3%

Beam alignment test for collimators

- 14 × 17 IR, leave 2 in. unexposed border, mark the corners and the center of light beam with metal, 2.5 mAs, 55 kVp
- check if the light beam is identical to the primary beam, acceptable deviation is **2%**

Control of Scatter Radiation – Grids and Air Gap

Screens and Grids: Selection and Use

- device used to reduce the intensity of scatter radiation in the remnant x-ray beam
- use of grids = ↓scatter radiation reaching the film = ↑ exposure factors to maintain density = ↑ patient dose
- produce higher contrast by absorbing Compton scatter rays, which produce fog if they strike the image receptor
- principal function **–** to **improve image contrast**
- secondary function **–** to absorb scatter radiation
- position – between the patient & IR
- **grid frequency –** number of lead strips per inch (or centimeter)
- **grid cutoff**
  - ↓ density along the periphery of the film caused by absorption of image-forming rays
  - the undesirable absorption of primary x-ray by the grid
  - cause – improper grid position
  - primary radiographic effects:
    - ↓ in the no. of photons reaching the IR
    - ↓ in radiographic density
  - most common in **parallel grids**
  - distance to grid cutoff: **SID ÷ grid ratio**
- **grid pattern** – refers to the linear pattern of the lead lines of a grid
- **grid surface x-ray absorption**
  - **% of x-ray absorption** = [width of grid strip / (width of grid strip + width of interspace)]
- **grid focus** – refers to the orientation of the lead lines to one another

Use of Grids

- reduce the amount of scatter radiation reaching the image receptor
  - scatter travels in divergent paths compared with image-producing rays
  - scatter is more likely to be absorbed in the grid
- used when
  - anatomical part >10 cm
  - >60 kVp is used

Grid Construction

- lead strips separated by aluminum interspaces
  - three important grid dimensions
    1. grid strip thickness (T)
    2. interspace material width (D)
    3. grid height (h)
- **grid strips**
  - size – ~**50 µm wide**
  - characteristics – thin & high absorption properties
  - radiopaque material
  - composition – **lead** (**Pb**)
  - advantages – easy to shape, inexpensive, ↑ Z, high mass density
  - visibility of grid lines is directly related to the width of lead strips, ↑ width = ↑ visibility
  - **grid lines** are the images made when primary x-rays are absorbed within the grid strips
- **interspace material**
  - size – ~**350 µm wide**
  - radiolucent material
  - purpose – to maintain a precise separation between the delicate lead strip of the grid
  - can either be made of fiber, plastic, or aluminum
  - **fiber, paper, or cardboard**
    - allows more remnant radiation to pass through the grid
    - more likely to absorb moisture, resulting to possible warping of the grid
  - **plastic fiber**
    - more preferred than Al
  - **aluminum (Al)**
    - advantages over fiber
      - high Z
      - produces less visible grid lines

            - non-hygroscopic – does not absorb moisture
            - easier to manufacture
        - disadvantages over fiber
            - ↑ absorption of primary beam
            - need for ↑ mAs &↑ patient dose

Grid forms
- **wafer grid**
    - matches the size of cassette
    - used by placing on top of the image receptor
- **grid cassette**
    - an image receptor that has a grid permanently mounted to its front surface
- **grid cap**
    - it contains a permanently mounted grid
    - it allows the image receptor to slide behind it

Grid pattern types
- **linear**
    - **lead strips are parallel** to one another
    - x-ray tube may be angled along the length of the grid without cutoff
    - used primarily with **large SID** and/or **small field**
    - simplest type
    - it has lead lines that run into one direction
    - it cleans up scatter radiation in one direction
    - most popular in terms of grid pattern as it allows angulation of the x-ray tube
    - advantage – **easiest to manufacture**
    - disadvantage – **cutoff** occur at short SID & large area IR, ↓ density along the periphery of the image
    - optical density – ↓ toward the edge of IR
- **focused grids**
    - **lead strips are angled** (has **canting**) to coincide with divergence of x-ray beam
    - used within specific ranges of SID (38–42°)
    - grid radius – distance at which focused grid maybe used (also called focal distance or focal range)
        - wide for low-ratio grids
        - narrow for high-ratio grids
        - stated on the front of the grid
    - focus line – point where all the grid strip angles meet
- **crossed grids**
    - also called crosshatch grids
    - consist of **two linear grids placed perpendicular to each other**
    - superior scatter cleanup
    - allow no angulation of x-ray beam
    - require perfect positioning and centering
    - it is fabricated by sandwiching two parallel grids together
    - it has lead lines that run at right angle to one another
    - advantages – not too difficult to manufacture, not excessively expensive
    - disadvantages
        - grid cutoff
        - requires critical grid positioning
        - tilt table techniques
            - possible only if x-ray tube & the table are properly aligned
        - ↑ exposure technique resulting to higher patient dose
    - advantages over parallel grid
        - more efficient in cleaning up scatter radiation
        - higher contrast improvement factor than parallel grid with twice grid ratio
        - advantage ↑ with increasing kVp

Stationary grids vs. moving grids
- **stationary grids**
    - do not move during the exposure
    - grid lines may be seen
    - **Gustav Bucky** (*1913*) first demonstrated this technique of reducing the amount of scatter reaching the IR
- **moving grids**
    - reciprocate (move back and forth) during exposure
    - eliminate the visibility of grid lines
    - **Hollis Potter** (*1920*) invented the moving grid
        - Potter-Bucky diaphragm or Bucky
    - grid must begin moving just before the exposure and continue until just after the exposure to blur grid lines
    - 2 basic types of moving grids
        - **reciprocating**
            - motor-driven back and forth several times during x-ray exposure
            - total drive distance = ~**2 cm**
        - **oscillating**
            - the grid oscillates in a circular fashion around grid frame
            - coming to **rest** after **20-30 seconds**
    - grid used – **focused grids**
    - advantage – minimize grid lines
    - disadvantages
        - **requires bulky mechanism** – subject to failure
        - **↑ distance between the patient & IR** – ↑ in magnification & image blur (undetectable)
        - introduce **motion** into cassette-holding device – additional image blur (undetectable)
- **patient dose**
    - moving grid – 15% more radiation to patient than stationary grid
    - ↑ kVp & ↑ ratio grid = ↓ patient dose than ↓ kVp & ↓ ratio grid

Grid selection
- depends of 3 interrelated factors
    - kVp
    - degree of cleanup
    - patient dose
- focused grid – most commonly used
    - considerations – must have properly adjusted:
        - SID indicator
        - STD indicator
        - Collimators
- higher ratio grid
    - for ↑ kVp technique
    - ↑ cleanup
    - ↑ patient dose
- **8:1** grid ratio – used when **kVp is <90**
- **above 8:1** grid ratio – used when **kVp is >90**

Grid characteristics
- grid ratio, grid frequency and focal range are **intrinsic or structural factors** associated with construction of grids
- contrast improvement factor, selectivity, and Bucky factor are applied to determine the effectiveness of a particular grid, and are known as **extrinsic or procedural factors**

Grid ratio (gR)
- grid ratio is the height of the lead strips divided by the distance between the lead strips
- ratios range from **4:1 to 16:1**

- formula – **grid ratio = h/D**
  - **h** = the height of the lead strips
  - **D** = the distance between lead strips
- **high ratio grid**
  - advantage over low ratio grid – more effective in scatter clean-up
  - disadvantage – ↑ patient dose, angle of deviation is smaller
- **general radiography –** 8:1 to 10:1
- **mammography –** 4:1 to 5:1

Grid frequency (gF)

- no. of grid strips per centimeter or inches
- range – **25-45 lines/cm** or **60-110 lines/inch**
- ↑ grid frequency = ↓ lead strip thickness = ↓ visibility on radiograph
- formula
  - $gF = \frac{10{,}000\ \mu m/cm}{(T+D)\ \mu m/linepair}$
  - T = grid strips thickness/width
  - D = interspace width
- **high frequency grids**
  - requires ↑ exposure technique
  - ↑ patient radiation dose

Focal range

- the recommended SID for the best use of grid
- determines the distance the focal spot may be placed from the center of the grid to prevent significant grid cutoff
- cross-focused grids have a focal point
- linear-focused grids have a focal line

Contrast improvement factor (gK)

- measure of ability of a grid to ↑ contrast
- expressed as the ratio of the contrast with a grid to the contrast without a grid
- best measure of how well a grid performs
- purpose – measures improvement in image quality when grids are used
- formula – **gK = image contrast w/ grid ÷ image contrast w/o grid**
- most grids – **gK = 1.5 to 2.5**, if less than 1, there is no improvement
- gK factor depends on kVp, field size, part thickness, amount of scatter, grid ratio, and grid frequency
- ↑gF and gR = ↑ gK = ↑ scatter cleanup efficiency

Grid selectivity (gß)

- grid selectivity describes how well the grid differentiates primary radiation from remnant radiation
- generally, **60 to 80%** of the amount of remnant is transmitted through the grid
- grid selectivity describes a grid's efficiency
- formula – **gß = transmitted primary ÷ transmitted scatter**

Bucky Factor (bF)

- also called **grid conversion factor (GCF)**
- determines amount of mAs ↑ necessary to compensate for the absorption of image-forming rays and scatter in the cleanup process
  - ratio of incident radiation to transmitted radiation through a grid
  - ratio of patient dose with & without a grid
- purpose
  1. to measure how much of an ↑ in technique will be required compared with nongrid exposure
  2. indicates how large an ↑ in patient dose will accompany the use of a particular grid
- formula
  - **bF = incident x-rays ÷ transmitted x-rays**
  - **bF = patient dose w/ grid ÷ patient dose w/o grid**
- ↑ grid ratio = ↑ Bucky factor
  - penetration of scatter radiation becomes less likely
- ↑ kVp = requires ↑ Bucky factor
  - more scatter radiation is produced & more are being filtered by the grid
- ↑ Bucky factor = ↑ radiographic technique = ↑ patient dose
- ↑ in mAs needed if non-grid → grid (multiply mAs by GCF)
- ↓ in mAs needed if grid → non-grid (divide mAs by GCF)

Grid conversion formula

- factors used at 120 kVp

grid ratio	*conversion factor*	*kVp increase*
no grid	1	0
5:1	2	+ 8–10
6:1	3	
8:1	4	+ 13–15
10:1 or 12:1	5	+ 20–25
16:1	6	+ 30–40

- $\frac{mAs_1}{mAs_2} = \frac{\text{grid factor}_1}{\text{grid factor}_2}$
  - ex: a radiograph of the abdomen is obtained using an **8:1 grid**, **35 mAs** and 85 kVp. another radiograph is requested using **12:1 grid**, **what is the new mAs** to produce a satisfactory radiograph?
    - $\frac{35}{x} = \frac{4}{5}$
    - 4x = 175
    - x = 43.75

Grid errors – focused grids

- **upside down**
  - result is **normal density in the middle** of the radiograph with **↓ density on the sides**
  - solution – focused grid must be placed with labeled **tube side** facing x-ray tube
- **off-level**
  - result is image-forming rays absorbed all across the radiographic field, with cutoff or **↓ density visible over the entire radiograph**
  - solution – grid must be perpendicular to the central ray
- **lateral decentering**
  - cause – central ray does not strike the grid in the center
  - **cutoff visible, more to one side** of the radiograph
  - solution – center the CR on the center of the grid
- **grid-focus decentering**
  - cause – violation of the grid radius when a focused grid is used
  - **normal density in the middle** of the radiograph with **cutoff visible on the sides**
  - solution – use recommended SID

Air-gap technique

- alternative to the use of radiographic grids
- uses ↑ OID (**10-15 cm**)
- ↑ OID allows scatter (which travels in widely divergent paths) to exit the patient and miss the image receptor
  - scatter radiation is like white light, the closer to the source (the patient) the greater the intensity
- the cleanup of a **6 in air gap** is similar to **8:1 grid**
  - example: lateral cervical spine
  - distance from spine to shoulder causes gap
  - gap is similar to using a 10:1 grid
  - no more grid needed
  - use of grid with air gap will just ↑ patient dose and is unnecessary
- advantages
  - ↓ scatter radiation

- ↑ image contrast
- disadvantages
  - image magnification
  - focal-spot blur
- applications
  - chest radiography
    - from 180 to 300 cm SID
    - effects – little magnification & sharper image
  - cerebral angiography

Scatter Radiation, Filtration, and Patient Exposure

Filtration
- filters serve to reduce low-energy radiation absorbed by **patient**
- **National Council on Radiation Protection (NCRP)** – govern the use of filtration in general diagnostic x-ray equipment
- **inherent filtration**
  - x-ray tube structure, housing and collimator
  - glass envelope – **0.5 mm Al** equivalence
  - window and collimator – **1.0 mm Al** equivalence
- **added filtration**
  - placed between tube and beam restrictor device
  - **aluminum** – most common
  - **copper** – if used, must be with aluminum, and **placed farthest** from the patient as copper can also produce characteristic radiation in the energy range of 8 kVp
- range – 1 to 3 mm Al equivalence

filtration (Al equivalence)	***kV***
0.1 mm	30 kV mammography
0.5 mm	↓ than 50 kV
1.5 mm	50 to 70 kV
2.5 mm	70+ kV

- exposure factors are **↑ slightly** because of filtration
- **compensating filters**
  - added to accommodate variation in tissue thickness
  - **wedge** – most common type
    - **thick anatomy** under the **thin part** of the wedge filter

Scatter radiation
- ↓ image quality and must be controlled by the RT
- scatter contributes to the overall density (**50 to 90%**) of the radiograph but decreases film quality
- 3 factors that contribute to ↑ scatter radiation
  - kVp
  - field size
  - patient thickness

Factors affecting scatter
- **kVp**
  - ↑ kVp = ↑ scatter = ↓ contrast = but ↓ patient dose because of ↑ penetrability
  - the relative no. of x-rays that undergo Compton interaction ↑ as kVp ↑
- **field size**
  - control of field size is the most important factor in controlling scatter radiation
- **patient thickness**
  - ↑ thickness = ↑ scattered radiation
  - a **compression band** can be used to ↓ thickness, thereby reducing scatter
  - **compression of anatomy**
    - improves spatial resolution & contrast resolution
    - ↓ patient dose
    - important to mammography (iipitin suso)
    - **changes in position** – from upright to prone = ↓ thickness of part

Scatter radiation vs. contrast
- **high contrast** – created mostly by transmitted & unattenuated x-rays; appears sharp
- **no contrast** – created mostly by scattered x-rays; appears dull gray
- **moderate contrast** – created by both transmitted & scattered x-rays

Evaluation of radiographs – Characteristic curve

Film appearance (Bushong)
- unexposed processed film – **lucent**
- exposed processed film – **opaque**
- properly exposed processed film – **shades of gray**
- heavily exposed processed film – **black**

Characteristic curve
- the characteristic (**sensitometric**) curve represents the photocharacteristics and sensitivity of x-ray film
- also called sensitometric curve as it measures film sensitivity
- used to:
  1. understand principles of radiographic exposure
  2. compare density, contrast, speed and latitude
  3. evaluate processing methods
     - evaluate consistency of automatic processing systems
- **Hurter** & **Driffield** (*1890*) first used the characteristic curve as a tool in analyzing photographs
- obtained by exposing x-ray film to a series of exposures and plotting the density measurements on a graph
- the curve becomes a graphic representation of the density of the film
- used to compare and evaluate exposure and identify problems before they become severe

Sensitometry
- sensitometry is the process used to create a characteristic curve
- done by exposing film to light or x-rays
- **sensitometric test** is done **daily**, early morning when the processor reached its maximum capacity or has been warmed up
- **densitometer** is used to measure the amount of density on target areas, used to evaluate sensitometric readings from the processed image

Nomenclature for characteristic curves
- **vertical axis** (**Y**)
  - represents **density reading** obtained by the use of a densitometer
- **horizontal axis** (**X**)
  - represents the **amount of exposure** to film received to produce a certain density, exposure is represented in logarithms
  - **use of logarithms** to describe relative exposure and density is **very efficient** because a broad range of numbers can be expressed by a few small numbers
  - **human eye** – has a logarithmic response to OD
- **base + fog**
  - a key factor in sensitometry
  - total amount of exposure present on film before exposure to x-rays or light
  - limit – **0.25 OD**
  - range
    - **0.18** to **0.23 OD** (Burns)
    - **0.1** to **0.3 OD** (Bushong)
  - **base density 0.1 OD** – inherent in the film base, composition and tint

    - **fog density 0.1 OD** – development of silver grains that do not contain latent image centers
- **minimum density or D_{min}**
    - 1st measurement made **after** base plus fog
    - **toe** of the curve, lower left
    - represents an area of **underexposure**
        - too low density to be perceived
    - also called – **low** density & **midpoint** density
    - *controlled by the action of **phenidone**
- **maximum density or D_{max}**
    - highest point on the curve
    - **shoulder** of the curve, upper right
    - represents an area of **overexposure**
        - too much density to be perceived
    - also called – **higher** density & **darkroom** density
    - * controlled by the action of **hydroquinone**
- **straight-line portion**
    - normally to the right and lies between the toe and the shoulder regions
    - **most important area** of measurement of film photocharacteristics
    - **slant line** – indicates that density increases as exposure increases
    - **slope will vary** with changes in exposure conditions such as exposure factors, processing and film-screen systems
    - **linear response** – formation of a straight line as an increase occurs
    - begins at **~0.4 OD above B+F to ~2.5 above B+F**
- **film gamma** (part of straight-line portion)
    - maximum slope of the curve, where **density is greatest**
    - **steepest point** on the straight-line portion
    - used to measure gradient
    - **gradient**
        - curve at any point
        - represents the contrast of a film at a specific density level
    - film exposed to IS – **2.0 to 3.5 OD** – **average film gamma**
    - not included in calculations as it does not reflect overall sensitivity of film
- **average gradient** (part of straight line portion)
    - portion of the curve between **0.25 to 2.0 OD**
    - commonly the **useful density range**
    - average gradient is a **measure of contrast on the film**
    - straight-line portion becomes vertical, contrast ↑
    - straight-line portion becomes horizontal, contrast ↓
    - always calculated with consideration to base plus fog
        - if base plus fog = 0.18
        - add to 0.25 = 0.43
        - add to 2.00 = 2.18
    - average gradient is measured between these two points
    - $average\ gradient\ = \frac{OD_2}{OD_1} \div \frac{LRE_2}{LRE_1}$
    - ↑ average gradient = ↑ contrast

Optical density

- has a logarithmic function
- radiographic films have ODs ranging from 0 to near 4
    - OD of 4 = 1/10,000 photons can penetrate the film
- OD = $\log_{10} I_o/I_t$

Logarithms in sensitometry

- it is not necessary for RT to have extensive knowledge on logarithms, but some understanding is required
- in sensitometry, it is important to know that the logarithm of 2 is 0.3
- a smaller number is used to indicate a larger number

Constructing characteristic curves (Bushong + Burns)

- 2 apparatus
    1. either sensitometer or penetrometer
    2. densitometer
- **sensitometer**
    - optical step-wedge
    - exposes film strips with a calculated amount of light
    - flashes the film with light so that when processed, the film will have areas of increasing OD corresponding to optical wedge steps
    - recommended for daily evaluation of processing systems
- **penetrometer**
    - calibrated **aluminum step-wedge**
    - designed so that each step of the apparatus is exactly twice the absorption thickness of the preceding step
    - x-ray film with IS is utilized
        - **control films** are used (stored separately)
    - penetrometer is centered to cassette, field is collimated **0.5 inch around** and exposure is made using **70 to 75 kVp**
- ***sensitometric strip or step tablet**
    - alternative to sensitometer and penetrometer
    - made by exposing successive areas on a film with one exposure instead of using a penetrometer
    - 11 or 24 strips, image created with decreasing density
- **densitometer**
    - parts
        - **pinhole** – where the light source is focused
        - **light sensor** – positioned on the opposite the film
    - film is placed b/w pinhole and light sensor, then the densitometer measures the amount of transmitted light
    - base + fog is measured, then each step is measured
    - points are plotted to a graph, the line should represent a slanted s-shaped curve, this is the **characteristic curve**

Light transmission

- ↑ density = ↓ light transmission
- base plus fog prevents 100% light transmittance
    - **0.2 OD, 80%** transmittance
- doubling film exposure will ↓ light transmittance by 50% or ½

Evaluation of contrast

- contrast is difference is density values of relative structures
- film gamma, gradient, and average gradient are used to describe contrast
- average gradient is the most suitable in evaluating as contrast is measured within **0.25 to 2.0 above base + fog**
- ex: evaluate the contrast using the following variables:
    - base + fog = 0.20
    - OD_2 (higher density) = 0.2 + 2.0 = **2.20**
    - OD_1 (lower density) = 0.20 + 0.25 = **0.45**
    - LRE_2 = 1.50
    - LRE_1 = 0.80
        - $\text{average gradient} = \frac{\text{OD}_2}{\text{OD}_1} \div \frac{\text{LRE}_2}{\text{LRE}_1}$
        - $= \frac{2.20}{0.45} \div \frac{1.50}{0.80}$
        - = 1.75 ÷ 0.70
        - = 2.5
- If average gradient is more than 1, contrast is enhanced or increased
- ↑ average gradient = ↓ scale of contrast = ↑ contrast

Relationship of density to light transmission

***density** (log)*	***light transmittance***
0.0	100%

0.2	80%
0.3	50%
0.6	25%
0.9	12.5%
1.2	6.2%
1.5	3.1%
1.8	1.5%

for each 0.3↑ in logarithm, light transmission halves and density doubles

Latitude
- range of exposures that will produce densities between 0.25 to 2.0 above the base plus fog density
- sensitometrically, latitude is determined by the range of a given exposure
- ↑ latitude = ↑ scale of contrast = ↓ contrast

Film speed
- speed is the **relative exposure needed** to produce a **density of 1.0 above the base plus fog**
- film speed is calculated on the characteristic curve at the density level of 1.0
- when one compares two or more curves, the **curve nearest the vertical axis** at the density level of 1.0 will be the fastest exposure

Processing system
- sensitometer is the best instrument for preparing **curves for automatic processing monitoring**
- **direct x-ray exposure** is used in evaluating processing conditions
- the slope of the curve may be influenced by aging chemicals, poor replenishment rates, etc. resulting in decrease in contrast and speed

Critique of the Radiographic Image

Critique
- to **critique** the image, the radiographer should be able to assess density, contrast, and overall image definition to include recorded detail and visibility of detail
- density – adequate density is present **if object of interest is visible**
- contrast – a **moderate scale of contrast** must be achieved
- definition and visibility of detail
  - blackening at **appropriate level**
  - sufficient contrast for visibility
  - acceptable amount of **scatter**
    - **adequate cleanup** of scatter by the grid
    - border of **beam restrictor visible**
  - best film-screen combination used
- **tube, film, and part alignment** – evaluate image for magnification, elongation and foreshortening
- **evidence** of beam restrictors – limited to the actual part being examined
- **markers** – must be visible, adhere to standards required by the department

Radiographic artifacts
- extraneous agent that changes the character of an object
- unwanted or undesirable information that limits the interpretation of the image
- **film handling artifacts**
  - **static electricity artifacts** (+) – caused by sliding of the film on the cassette across a surface, static buildup is released, producing a spark that exposes the emulsion, common in low humidity
    - **tree** – static from sudden separation of dry surfaces when there is low humidity
    - **crown** – ground static
    - **smudge** – static from friction with a dirty surface, through dust or lint
  - **dirt and smudge marks** (+) – film dropped in a wet and dirty floor
  - **crescent marks** (+) – bending & kinking of film
  - **scratching/abrasion** (–) – fingernail/scratch
  - **fingerprint** (–) – moisture on finger transferred to the film before exposure
- **darkroom and processing artifacts**
  - **pi lines** (+) – fine lines that occur at **right angles to film travel**, occurs just after thorough cleaning of the rollers and addition of fresh chemicals, can also be caused by a **raised nick** in the roller that scratches the film as it passes by
  - **hesitation marks** (+) – also **right angles to film travel**, results from improper or **uneven travel speed** of the processor transport system
  - **hyporetention/thiosulfate retention** – silver sulfide stain, pale yellow or brown colored stain
  - **wet pressure sensitation** (+) – occurs in the development tank
  - **foreign objects** (+) – some unintended object in the imaging chain
  - **fogging** (+) – exposure to white light, ionizing radiation, heat, safelight fog & use of expired film
  - **density outside collimation area** (+) – off-focused/off-skin radiation
  - **non-specific↓ in density** (–) – dirty screens or cassette
- **artifacts from the patient**
  - pacemaker, nasogastric tubes, IV tubes, metal implants, safety pins, etc. are opaque devices that become artifacts in radiography

Preparation of Radiographic Exposure Guides

Exposure guide
- group of recommended exposure factors and accessories to be used for specific radiographic procedures

Function of exposure guides
- primary purpose – radiation protection by ↓ repeat exposures; for more consistent image quality
- part thickness should always be measured using **calipers**
- **types of technique charts**
  - fixed kVp – variable mAs
  - variable kVp – fixed mAs
  - variable kVp – variable mAs

Standardization of exposure guides
- exposure guides ↑ radiographer accuracy
- still requires skill, judgement and knowledge as exposure guides are not absolute
- ↓ number of repeat exposures

Measurement
- part thickness should always be measured with **calipers**
- **caliper measurement** is used to consult the technique chart

Types of technique charts
1. **high-kilovoltage guide***
   - offers settings of **100 to 130 kV**
   - ↓ contrast, longer scale radiographs
   - ↓ exposure time, reducing motion
   - recommended with **barium studies** because of the increased penetrating ability of the x-ray photons
2. **automated exposure guides***
   - contains a **timer** designed to terminate the exposure automatically when the desired amount of exposure reaches the film
   - anatomic exposure controls – **control panel has anatomic parts** to select from

  - automated exposure guides must include recommended kV level, density selection and back-up timer selection

3. **variable kVp – fixed mAs charts***
    - **kVp is varied according to part thickness** as measured with the calipers
    - based on the assumption that thicker parts require a beam with shorter wavelength rays that are more penetrating
    - requires↑ mAs settings, can be compensated by using **800 to 1200 speed systems**
4. **Fixed kVp (optimal kVp) – variable mAs charts**
    - **mAs is varied according to the part thickness** as measured with the calipers
    - assumes optimal kVp for the part being radiographed
    - except for exceptionally large patients, **kVp never changes** for a given projection
    - based on the assumption that thicker parts require a beam with shorter wavelength rays that are more penetrating
5. **Variable technique (vary both mAs and kVp)**
    - provides for **alteration of routine techniques** because of pathological conditions, patient age and ability to cooperate, casts, or contrast media

Exposure guides

type	***kV***	***mAs***	***characteristics***
high kVp	100–130	low (adjust to patient)	↑ latitude ↓ patient exposure longer contrast scale less contrast
automated exposure	70–90	set by density control	moderate contrast scale
variable kVp	45–75	higher	↓ latitude ↓ patient exposure shorter contrast scale higher contrast
optimal kVp	75–90	varies for patient size	↑ latitude ↑ patient exposure longer contrast scale lower contrast

Requirements for the preparation of exposure guides

1. agree on the characteristics of film quality
2. test and calibrate equipment
3. review tube rating and heating charts
4. standardize the processing system
5. place calipers in every radiographic room
6. make grid selection
7. select film-screen system
8. use body phantoms to rest reliability of guide

Comparison of Exposure guides

- **Variable kVp** – ↓ scale of contrast, ↑ degree on contrast, too low kVp may cause underpenetration, ↓ exposure latitude requires extreme accuracy, uses ↑ mA, ↑ patient dose
- **Fixed kVp or Optimal kVp** – ↑ scale of contrast, ↓ degree of contrast, all anatomic parts penetrated, tissue contrast and visibility of detail are present, ↑ exposure latitude, ↓ mAs, ↓ patient dose
- **Automated** – requires positioning accuracy, ↑ exposure when sensing device is not achieved, moderate scale of contrast
- **High-Kilovoltage** – maximum exposure latitude achieved using guide, ↑ scale of contrast, ↓ degree of contrast, ↓ patient dose, always adequate penetration

"If you want to be the very best at what you do, obsession is a necessity"