APPH 226:
Sampling, Histograms, LUT, and Exposure Indicators

Objectives: 4.1, 6.1, 6.4

MRT Program

Digital Imaging

- Digital image receptors capture a wide range of exposures
- If the entire range were digitized, the values at the extreme high and low ends would also be digitized, resulting in an extremely low contrast image
  - Too many shades of grey
- With the CR system
  - To prevent this, only the optimal density exposure range is processed by the data recognition program

Data Recognition Program

- Works by finding the collimation edges and eliminating the scatter outside the collimation
- If the system fails to correctly locate the collimation edges, this can result in incorrect data collection and images may appear too bright or too dark
- Anatomy needs to be centered to the imaging plate to help ensure the appropriate densities are located
  - Failure to center properly may result in images that are too bright/dark

Image Sampling

- Image sampling – the plate is scanned and determines:
  - the image's location
  - the size of the signal
- Values are assigned to each pixel

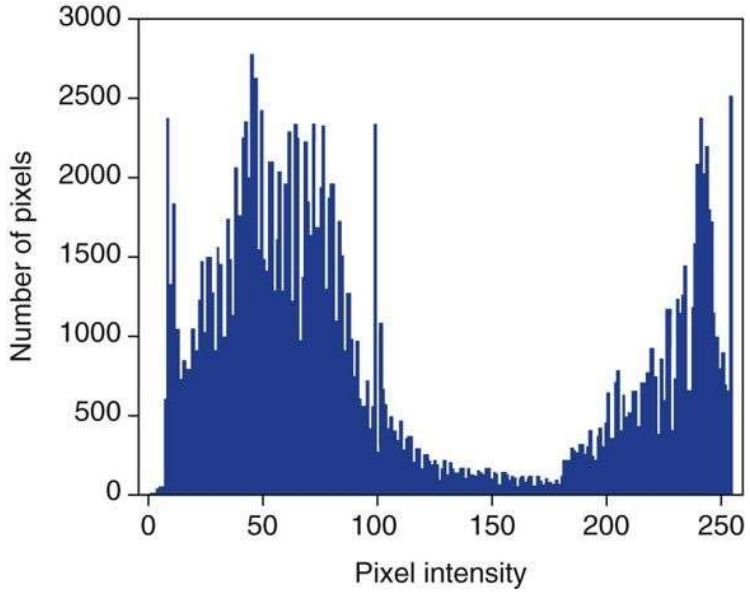
- Histogram is then generated from the information gathered from the sampling

Histogram

- Takes the image data from sampling, and a histogram is generated
- System finds the useful signal by locating the minimum and maximum signal within the anatomic regions of interest on the image
- All intensities of the signal are then plotted on the histogram
- Shows the distribution of pixel values for any given exposure

Histogram

- Is a graphical representation of the optimal densities within the collimated area
- Horizontal axis
  - Amount of exposure
- Vertical axis
  - Number of pixels for each exposure
  - Values at the left represent black
  - Values at the right represent white
    - ***This can vary between systems and textbooks
  - Values in the middle are the medium tones



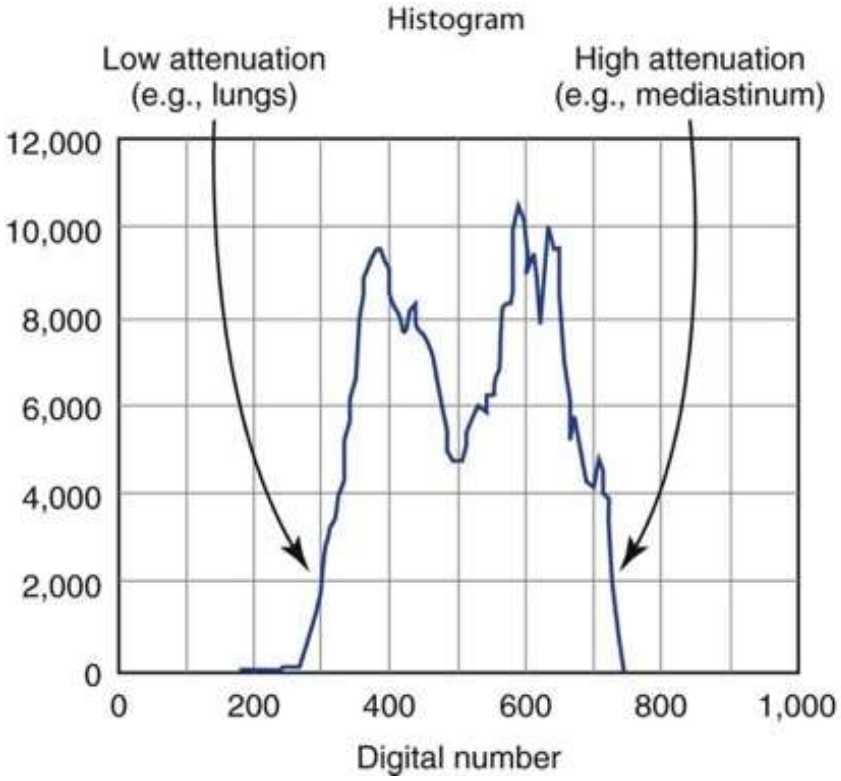
Histogram

- How will a dark image appear?
  - Most of the data points will be on the left
- How will a light image appear?
  - Majority of data points will be on the right

- The information collected within the collimated area is the signal used for image data
  - This is the source of information for the exposure data indicators

Histogram Analysis

- Before displaying the image, the computer creates a histogram of the data set and then it is compared to a stored histogram
- Shape of histogram is anatomy specific
  - Should be fairly constant for each body part
    - I.e. histogram of a knee image should look similar to another knee image of a different patient
- Technologist responsibility – important to select the correct 'body part'
- Raw data (from IR) is compared with a 'normal' histogram of the same body part, and image correction will occur as needed
  - Automatic rescaling also occurs during this process


Histogram
Low attenuation
(e.g., lungs)
High attenuation
(e.g., mediastinum)
12,000
10,000
8,000
6,000
4,000
2,000
0
0
200
400
600
800
1,000
Digital number



Histogram

Knee
Histogram



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Skull
Histogram

Automatic Rescaling

- Used for high or low exposures
- Attempts to correct pixel display
- The computer rescales the image based on the comparison of the histograms – maps the greyscale and presents a specific display of brightness
  - Produces images with uniform density and contrast – regardless of exposure
    - Dose creep
- Exposure is too small
  - Quantum mottle will occur
- Exposure is too large
  - Loss of contrast and edge sharpness due to increased scatter

Nyquist Theorum

- States that:
  - When sampling a signal, the sampling frequency must be greater than twice the frequency of the input signal so that the reconstruction of the original image will be as accurate as possible
- What does that mean for us?
  - In digital imaging, at least twice the number of pixels needed to form the image must be sampled
  - If there are too few sampled, there will be a loss of resolution
  - If oversampling occurs, there will not be an additional useful information gained – no need

Nyquist Theorum

- PSP imaging – many conversions, with every conversion, detail is lost
- Also, imaging plate stores electrons for a while, but the longer they are stored, they start to lose energy
  - Cassettes should be read as soon as possible to prevent signal loss
- FPD systems have less signal loss to light spread vs PSP systems, but the Nyquist theorem still applies to ensure that sufficient signal is sampled

Aliasing

- When the spatial frequency is greater than the Nyquist frequency – sampling occurring less than twice per cycle or exactly at the Nyquist frequency
  - Information is lost and a fluctuating signal is produced
- Aliasing – produces an image that looks like two superimposed images just slightly misaligned
  - Moiré effect
  - Can get a similar effect with grid errors, tech needs to investigate



(From Cesar LJ, Schueler BA, Zink FE, et al.: Artefacts found in computed radiography, Br J Radiol 74:195–202, 2001.)

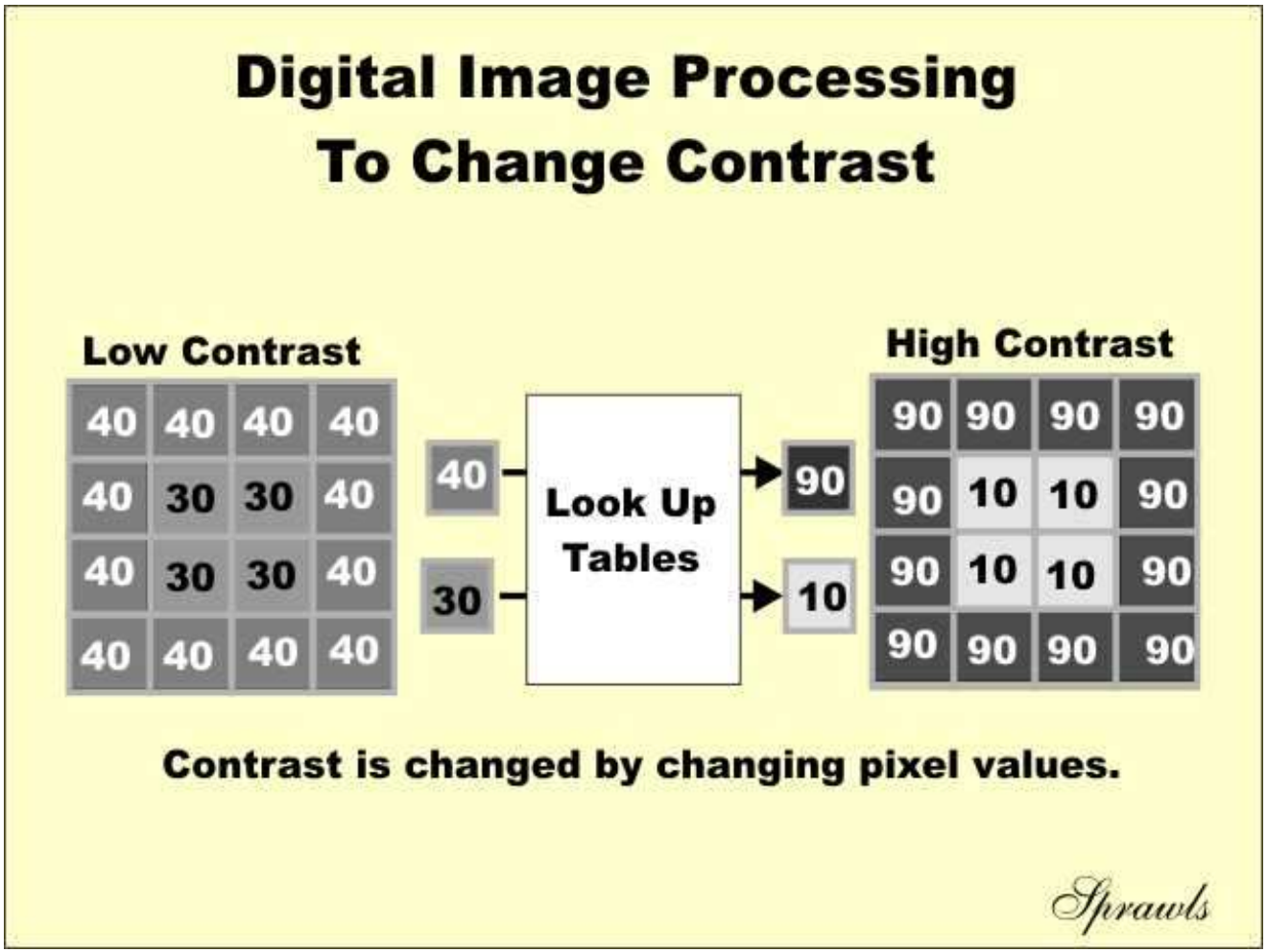
Look Up Tables



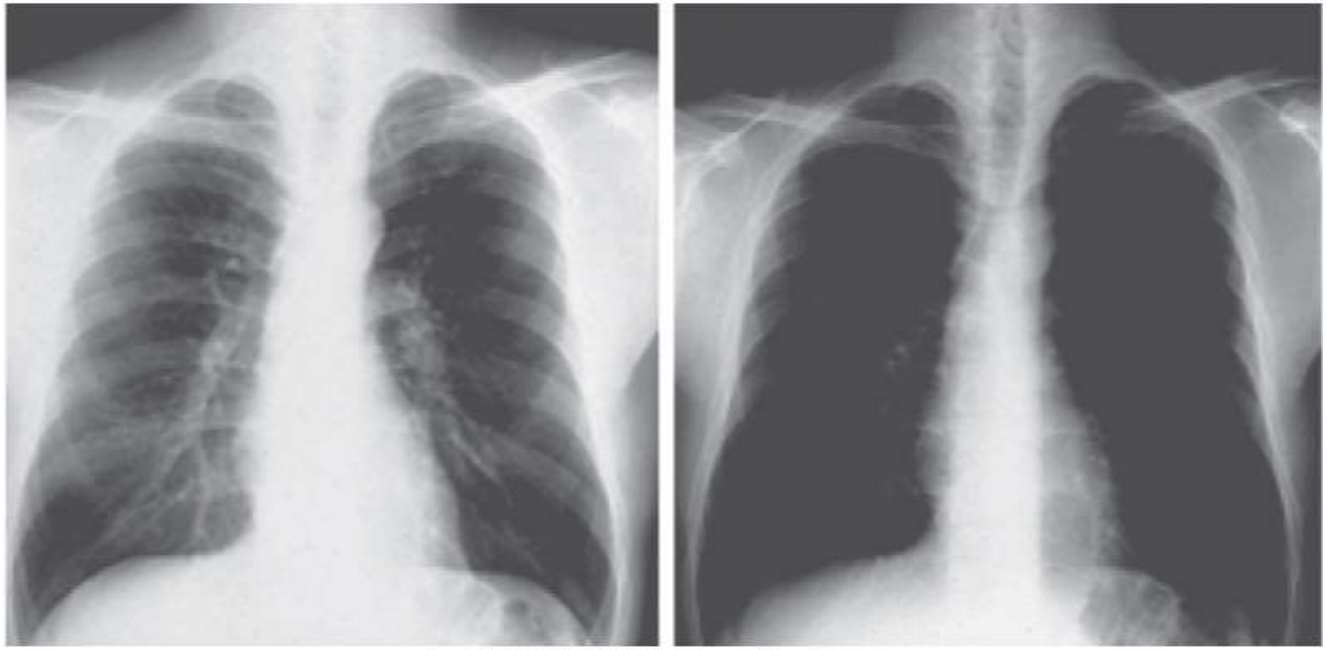
- Used as a reference to evaluate the raw information and correct the pixel values during processing
- Mapping function, in which pixels are changed to a new gray value
  - Tells us what new value to 'substitute' in for each pixel value
- Results in an image that will have the 'appropriate' look for the anatomic part
- Appearance of the image is modified

Look Up Tables

- Raw data does not change
- Values are manipulated to change what the 'output' values are going to be displayed as
- There is an LUT for **every anatomic part**
- Contrast can be increased/decreased
  - changing the slope of the graph
- Brightness (density) can be increased/decreased
  - moving the line along the y-axis


Digital Image Processing
To Change Contrast
Low Contrast
40 40 40 40
40 30 30 40
40 30 30 40
40 40 40 40
40
30
Look Up
Tables
90
10
High Contrast
90 90 90 90
90 10 10 90
90 10 10 90
90 90 90 90
Contrast is changed by changing pixel values.
Sprawls

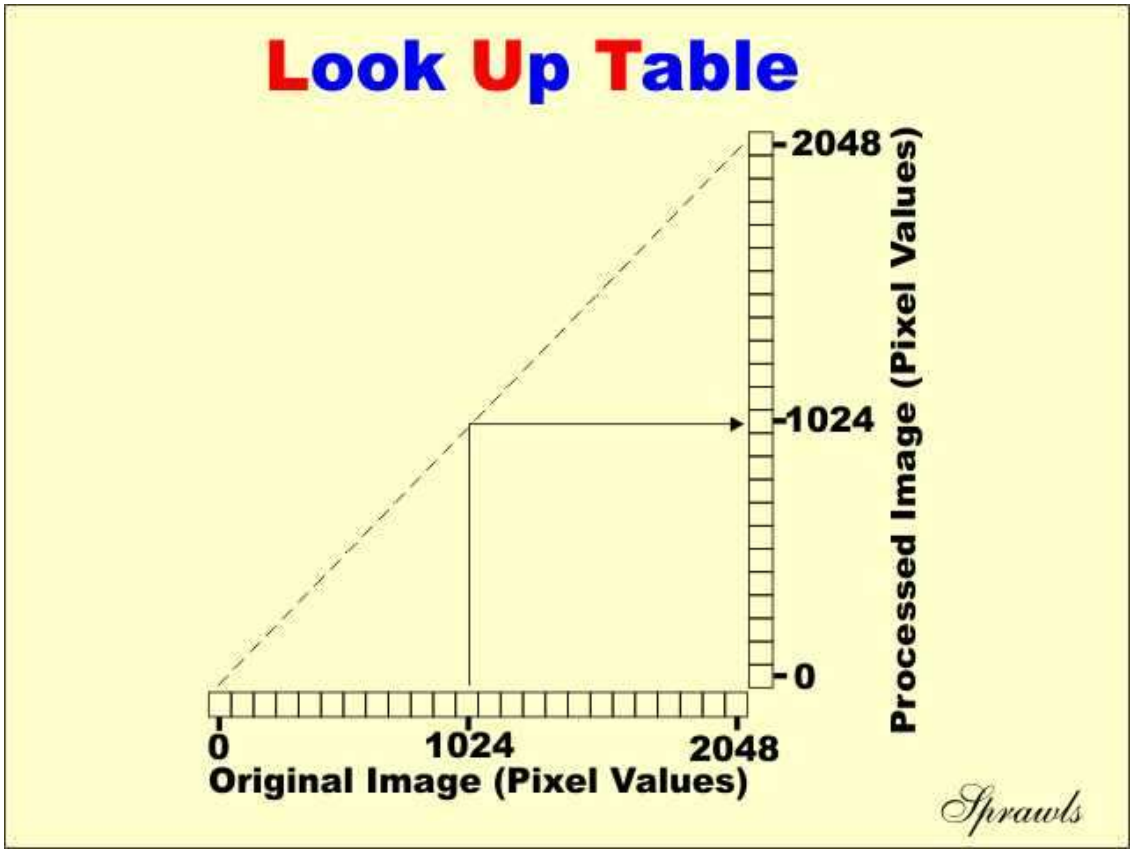
Contrast Enhancement

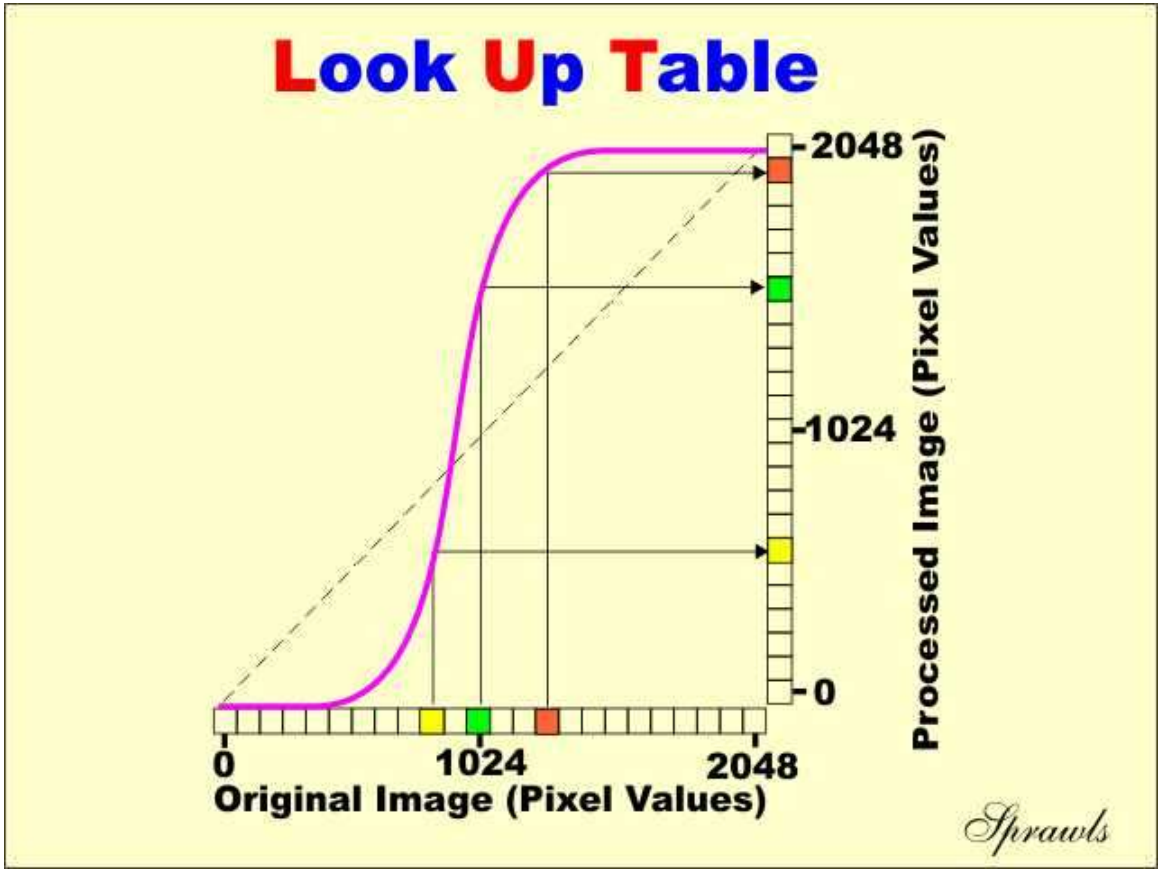


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LUT

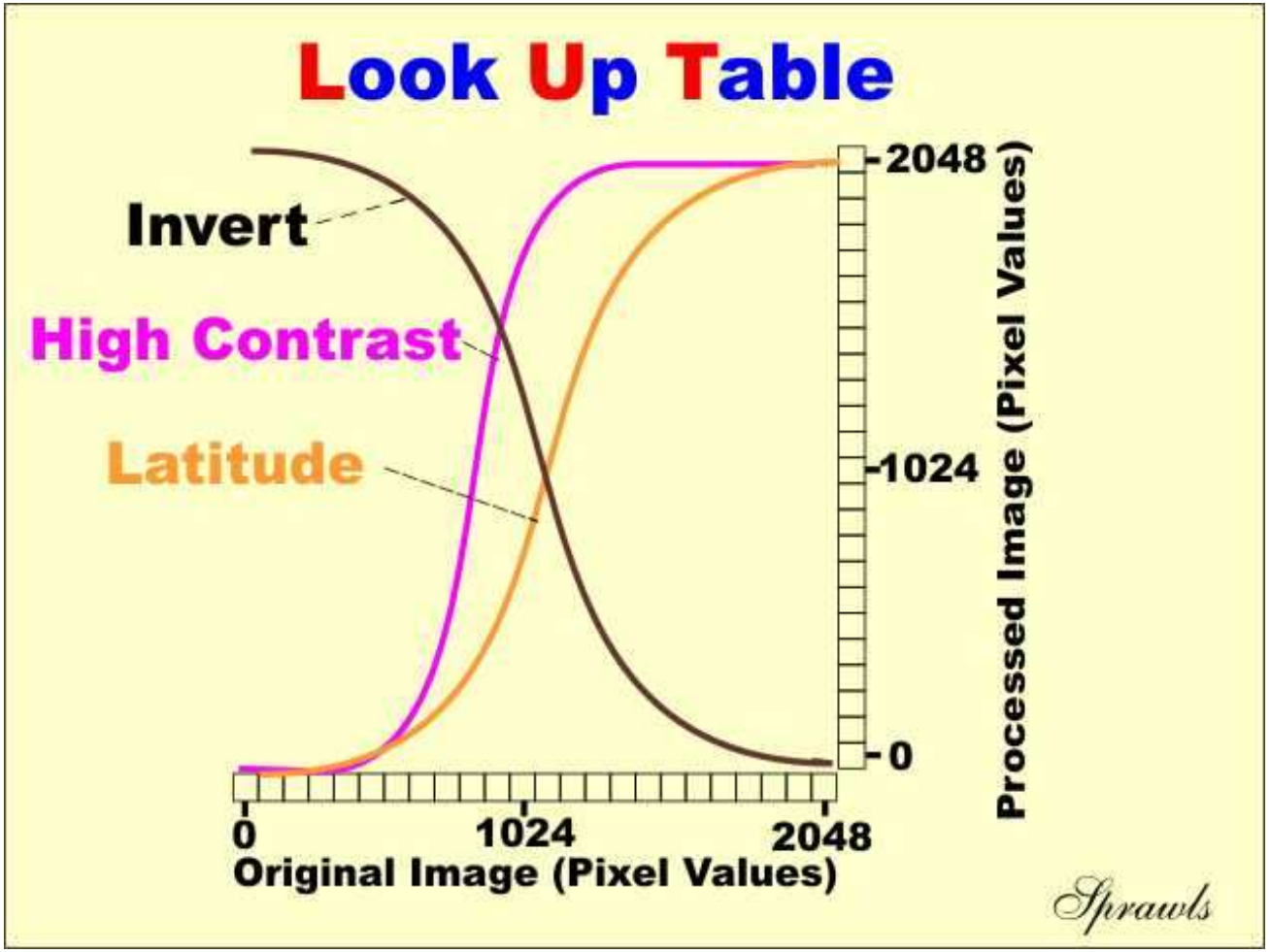
- Indicates what number is to be substituted for each pixel value after applied to the image (processing)
- Straight line LUT does not change the image
  - Shows the substituted number is the same as the original value


Look Up Table
2048
1024
0
Processed Image (Pixel Values)
0
1024
2048
Original Image (Pixel Values)
Sprawls


Look Up Table
2048
1024
0
Processed Image (Pixel Values)
0
1024
2048
Original Image (Pixel Values)
Sprawls

LUT

- In order for the display characteristic to change, the LUT needs to substitute numbers that are different than the original values
- Shape of the curve is similar to a characteristic curve
  - Intentional
  - After processing with this LUT, the image takes on a similar appearance as a radiograph on film


Look Up Table
Invert
High Contrast
Latitude
2048
1024
0
Processed Image (Pixel Values)
0
1024
2048
Original Image (Pixel Values)
Sprawls

Advantages of LUT

- Can produce images with different contrast characteristics
  - Slope of the curve represents contrast
    - Greater slope = high contrast
    - Less slope = low contrast
    - Inverted = black bone

LUT

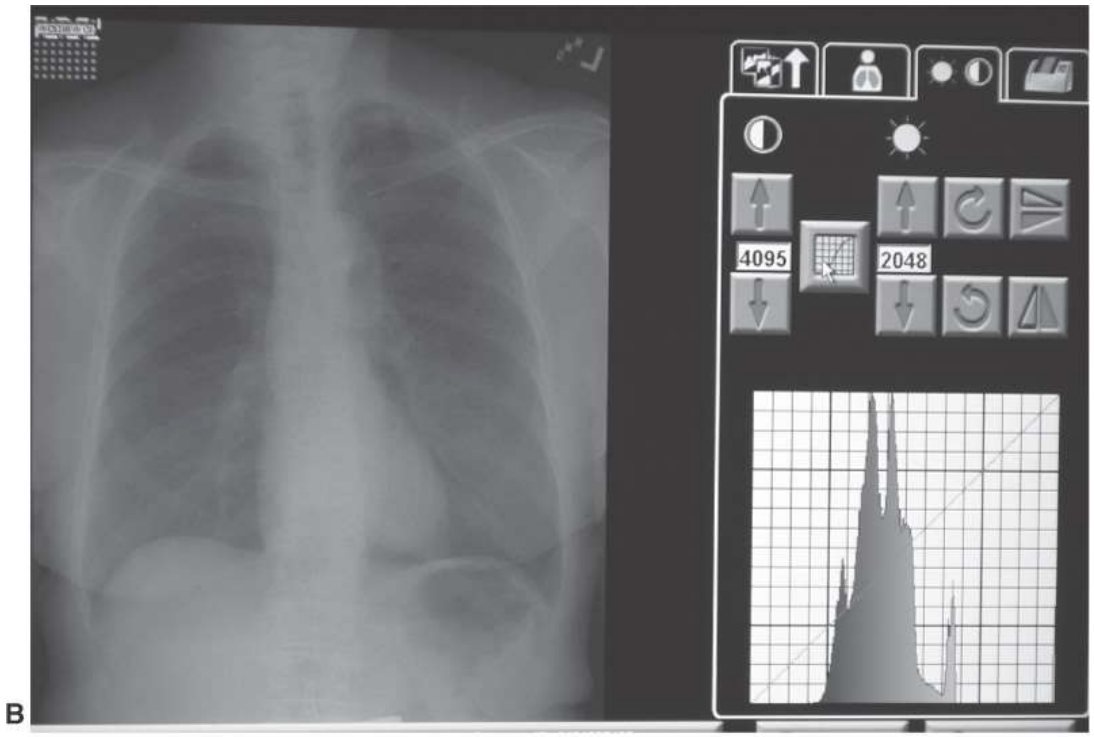
- General radiography rooms have a variety of LUTs installed
- Technologist must select the appropriate procedure (algorithm), and then there will be an LUT automatically selected
  - Ideal contrast characteristics for the procedure/part



Why do we need LUTs?

- Original images recorded with digital systems are usually very low contrast
  - Due to the wide dynamic range and response of the digital receptors
    - Digital doesn't suppress any of the contrast in the exposure range
- Every density is displayed
- Use LUT to increase contrast for some section of the exposure range

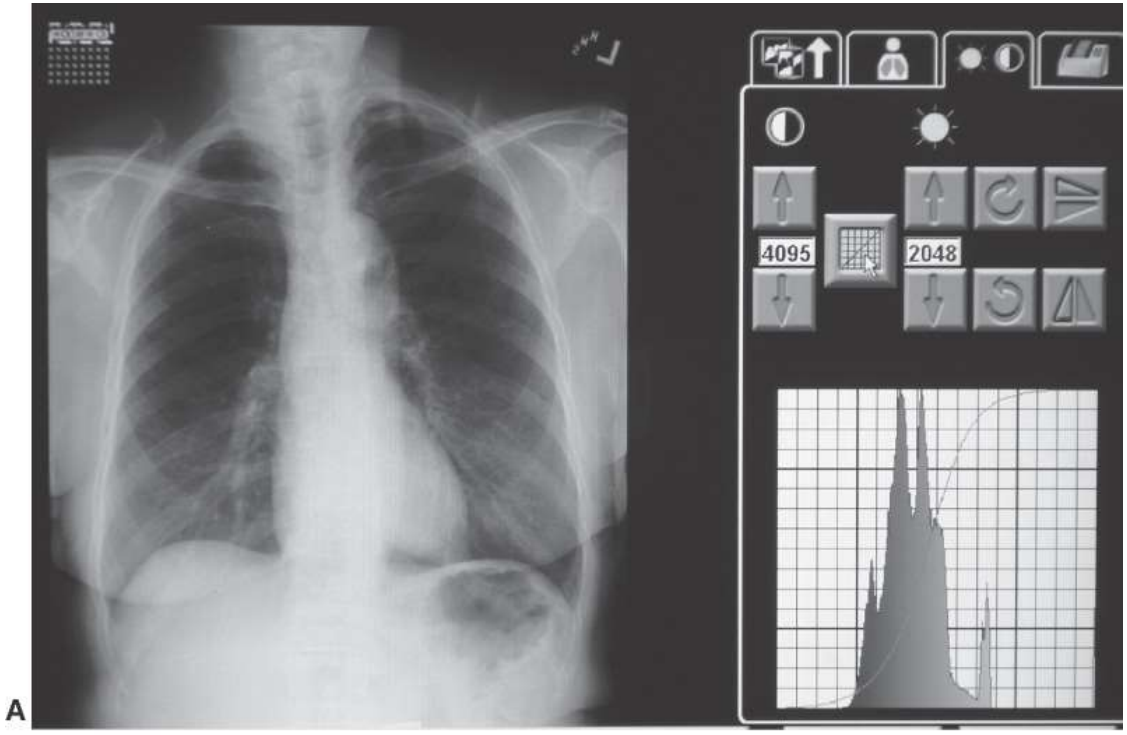
Raw Data Image



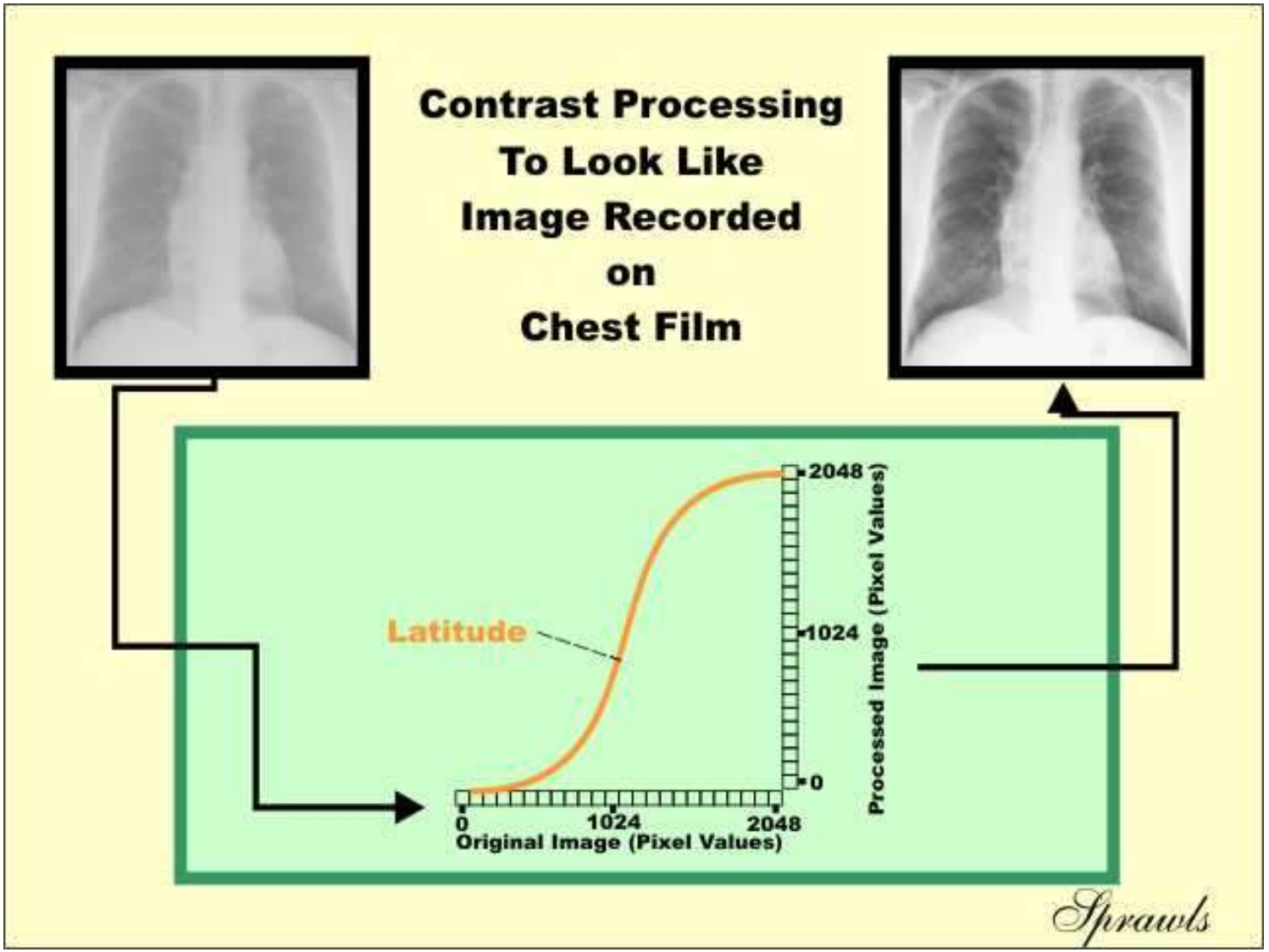
B

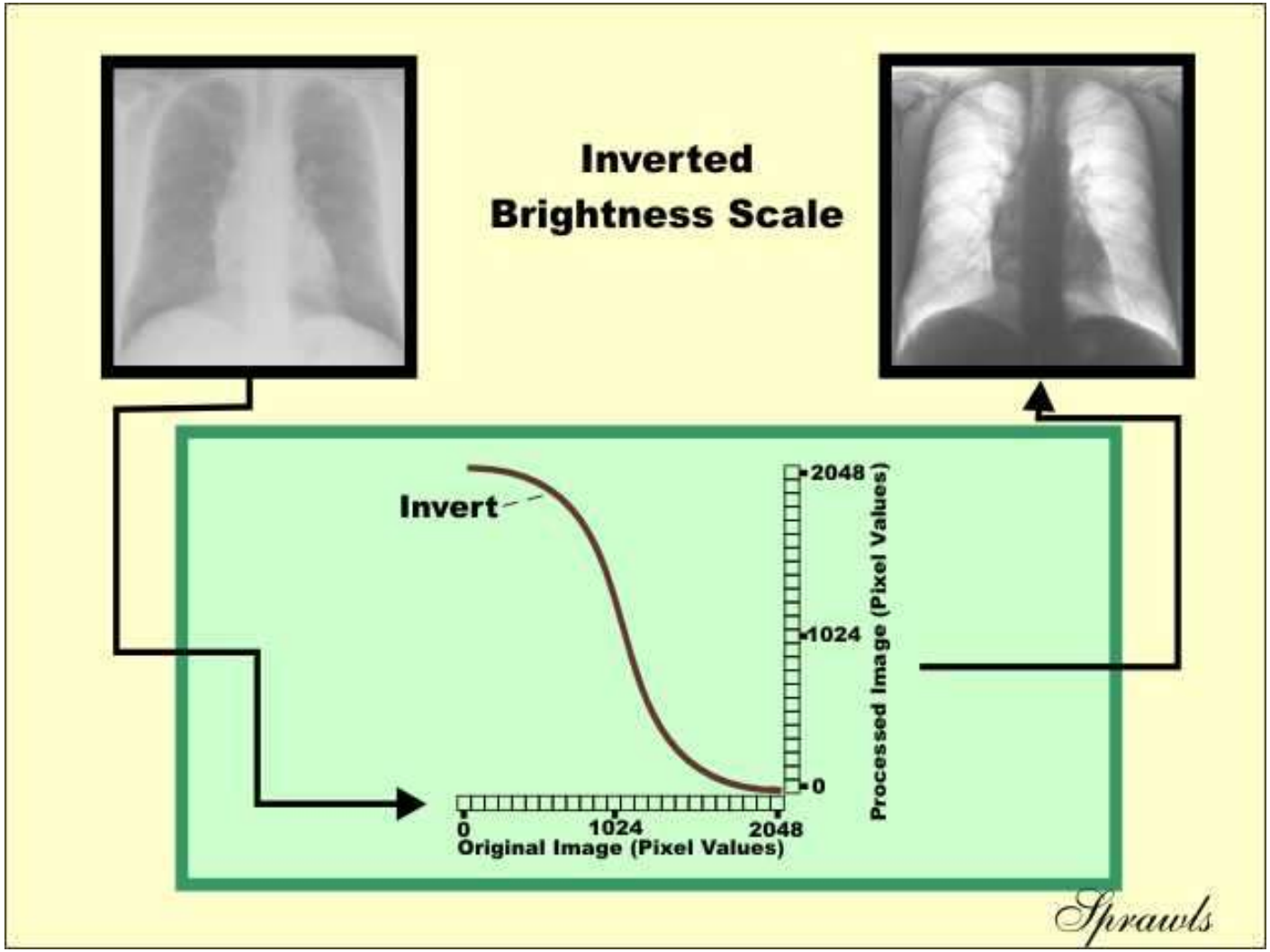
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Chest LUT applied



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Contrast Processing
To Look Like
Image Recorded
on
Chest Film
Latitude
2048
1024
0
Processed Image (Pixel Values)
0
1024
2048
Original Image (Pixel Values)
Sprawls


Inverted
Brightness Scale
Invert
2048
1024
0
Processed Image (Pixel Values)
0
1024
2048
Original Image (Pixel Values)
Sprawls

Exposure Indicators (EI)

- Refers to the amount of exposure received by the IR
- Can be used as a guide to monitor the dose to the patient while maintaining acceptable image quality
- Knowledge of how exposure factors affect the exposure index is key to minimizing patient dose and providing enough exposure to the image receptor.

Exposure Indicators

- Affected by many factors:
  - Technical factors
  - Histogram analysis error
  - Patient positioning
  - Image processing algorithms
  - SID
  - Collimation
  - Beam Centering
  - Artifacts

Exposure Indicators

- Following an exposure:
  - The IR is read and a **histogram** is formed
    - "Counts & plots" all the densities from the exposure into a graph
  - Exposure Indicators represent the average gray shade value of the image
    - Value found by identifying the most exposed vs. the least exposed area detected over the ROI (region of interest)
    - *Based on collimated boundaries*
  - Compared to a pre-programmed histogram of the same anatomical part.
    - Histograms are matched/combined (histogram analysis)

Exposure Indicators

- Manufacturer/Vendor specific values:
  - **EI** numbers (exposure index)
  - **S** numbers (sensitivity numbers)
  - **EI_s** numbers (Exposure index sensitivity)
  - **LGM** (log numbers)
- Values can be calculated by different relationships:
  - Direct
  - Indirect
  - Linear

Exposure Indicators

- EI_s numbers:
    - As the exposure increases, the EI_s value increases
- Acceptable limits are set by the manufacturers recommendations, and radiologist preferences
    - 100-300
    - CXR 450
    - *High value = overexposed*
    - *Low value = underexposed*

Direct relationship

Exposure Indicators

- EI numbers:
  - **Direct relationship** is vendor specific
  - *Carestream/Kodak* (CR Reader):
    - Double the exposure = the EI value increases by 300
    - Half the exposure = the EI value decreases by 300

Exposure Indicators

200-800

CXR 250-320

High value = underexposed

Low value = overexposed

100-300

CXR 450

High value = overexposed

Low value = underexposed

Exposure Indicators

- LGM (log) numbers:
  - **Direct relationship**
    - When the exposure is doubled, the LGM value increases by a factor of 0.3
    - When the exposure is halved, the LGM value decreases by a factor of 0.3
- Agfa CR acceptable limits:
  - 1.90-2.50 (all exams)
  - *High value = overexposed*
  - *Low value = underexposed*

Direct relationship

Exposure Indicators

- S numbers:
  - **Indirect relationship**
    - When the exposure is doubled, the S value decreases by a value of 200
    - When the exposure is halved, the S value increases by a value of 200
- Konica-Minolta acceptable limits:
    - 100-400
    - *High value = underexposed*
    - *Low value = overexposed*

Indirect relationship

Exposure Indicators

- Ideal Exposure Indicator value:
  - Typically the “halfway” value
  - The point between the maximum and minimum exposure value limits (unless specified by the manufacturer)
    - Example: Ideal range = 200-800
      Ideal value = 500
    - Provides the most diagnostic data for the least amount of patient exposure. (aka. perfect balance)

Exposure Indicators

- With DR systems:
  - The ideal exposure indicator value for the ***patient*** is the lowest possible technical factor selection that will enable the closest value to underexposure, without being outside the recommended limits.
    - Example: ideal range = 200-800 (below 200 = underexposed)

      ideal value = 500

      ideal value for the patient = 200

Corrupt EI Numbers

- Exposure Indicator numbers are easily corrupted
- Images need to be critiqued for quality
  - Collimation
  - Positioning
  - Field size/IR size
- Do not repeat on the Exposure Indicator alone

SNR (Signal to Noise Ratio)

- Images consist of two components:
  - Signal - Meaningful pattern carrying information about the subject
  - Noise - Chaotic pattern, carrying no information about the subject
    - “Fuzzy, static, snowstorm effect”
    - Quantum noise = quantum mottle
    - Electronic noise is created during amplification of the signal
- Both of these components make up the image



SNR

- High signal to noise ratio:
  - Signal is higher than the noise
- Low signal to noise ratio:
  - Signal is lower than the noise
  - Information is lost

Critiquing Images

- Techs need to magnify the image to check for noise (quantum mottle) or overexposure (burnout/saturation)
- **Techs need to be able to post-process the image as needed **
- If positioning and centering are accurate, the Exposure Indicator is a great tool for image assessment
- *Can no longer visualize the level of image quality on digital systems*

Latitude in Digital Imaging

- Refers to the amount of error that can be made and still maintain a quality image
- In digital the exposure can be up to:
  - 200% above the ideal exposure
  - 50% below the ideal exposure

Readings

- Radiologic Science for Technologists 10th Ed
  - Pg 306-312 (SNR)
  - Pg 357 (Image Histogram)

- Digital Radiography and PACS 3rd Ed
  - Pg 28-30, 32